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U. S. DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

Instructions to Marine Meteorological Observers

CIRCULAR M - ~~MARINE DIVISION~~

Sixth Edition

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1938

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National Oceanic and Atmospheric Administration

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AN APPRECIATION

With the development of navigation of the sea and air, the need of weather observations from the oceans is constantly increasing. Immediate communication of the observations by radio to meteorological centers has opened a vast field of daily service. For ocean weather studies and summaries, the more detailed reports which are forwarded by mail at the end of the voyage are becoming increasingly important. In all of this work the mariner is giving full cooperation to the meteorologist.

Having these greater opportunities for service in mind, the Weather Bureau issues this sixth edition of Instructions to Marine Meteorological Observers.

In issuing this new edition, the Weather Bureau extends its sincere thanks to the masters and officers who contribute so effectively to the maintenance of the ocean weather service.

W. R. Gregg, *Chief of Bureau.*

NOTICE

(To accompany "Instructions to Marine Meteorological Observers", sixth edition, January 1938.)

Attention of observers is especially invited to the following sections, which differ materially from previous editions:

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Aneroid barometers	16–24
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In previous editions of codes, the numbers 18 and 19 for "present weather" were assigned to indications of a tropical storm. Also, on the inside front cover of some editions of Form 1210A, under "present weather," there appears the sentence "Preference should be given to numbers 18 and 19 when they apply." In the International Code, as revised in 1937, the number 18 is used for "dust storm", hence only the number 19 should be used for signs of a tropical storm. (See pages 39 and 42.)

Also, it was formerly specified that 08 be used for "mist". Since this resulted in much confusion, some observers having used 08 for light fog and others having used 08 for fine rain, it is now specified that 08 be used only for "light fog", that is, fog in which visibility is between about 0.5 and 1 nautical mile. (See page 39.)

On the inside front cover of some editions of Form 1210A the instructions state that temperatures should be entered on the form in *whole* degrees, Fahrenheit. It will be appreciated, however, if observers will enter temperatures to fractions of a degree. For transmission in coded radio messages, temperatures must be reported to the nearest whole degree. (See page 49.)

ERRATA

Page 27.—The first sentence of the second paragraph should read as follows:

It is highly desirable that ships carry some form of portable, ventilated psychrometer as part of their regular meteorological equipment.

Page 57.—In the code table for "a" there should be a semicolon (instead of a comma) after the word "steady" in the description opposite code figure 1.

Page 67.—Legend (fig. 17) should be: Cirrostratus, below; with cirrus above.

Page 72.—The photograph is upside down with respect to the legend.

Page 74.—In the legend (fig. 24), stratocumulus should be fractocumulus.

Page 85.—The paragraph heading "Circumzenithal and circumsorigontal arcs" should read as follows:

"Circumzenithal and circumhorizontal arcs."

Page 114.—In table 3, the third number in the fifth column should be 55 instead of 35.

PART I. THE OCEAN WEATHER SERVICE

The ocean meteorological program of the Weather Bureau has two separate and distinct parts. First, there is the daily service by radio. Owing to the need for brevity, the radio reports contain a limited amount of essential information. The daily weather reports from ships and islands reveal the conditions over the ocean; when assembled on a map, including continental reports, they give a picture of weather conditions existing momentarily over a large region. A collection of observations is immediately returned to the mariner by radio broadcast so that he may draw his own weather map on shipboard. By this process, the weather at the earth's surface is mapped and much can be inferred as to conditions above the surface. Formation and movement of storms are revealed; advices and warnings of storms and forecasts of wind and weather are included in the broadcasts for the benefit of the mariner. For this first part of the Weather Bureau's program, observations are secured by radio from certain areas of the Pacific and Atlantic (including the Gulf of Mexico and the Caribbean Sea). This service is of great value to agriculture and commerce as well as navigation; the daily weather forecasts for land areas depend to a considerable extent upon the ocean weather observations. To a very large degree ships' weather reports form the basis of warnings of the destructive storms that sometimes move from the ocean into coastal areas.

As the second part of the program, the Weather Bureau uses more complete reports, forwarded by mail at the end of the voyage, in order that the weather of the oceans may be studied in greater detail. Results of these studies are the wind roses and weather data in other forms, as they appear on the pilot charts, also weather summaries for all parts of the oceans published for the information of the navigator. The life histories of important storms at sea are determined and recorded from ships' weather observations. Information regarding weather conditions at sea is furnished for use in admiralty cases. Observations are used in connection with land data for the construction of weather maps of world areas. Since the oceans influence the weather of the continents, the study of ocean temperatures is one of the important lines of work of the Bureau.

For these purposes the detailed entries of the mail report are of great value. It is a world-wide problem, hence mail reports are desired from every part of the oceans. While radio reports of the weather are required twice or even four times daily, the observations that are sent only by mail are required once each day at Greenwich mean noon, with appropriate notes in the Daily Journal as to conditions between observations.

Since the last edition of this manual was published (1929), the meteorological services of maritime nations have made much progress in standardizing their methods of reporting ocean weather, particularly by radio. The International Figure Code is used in radio weather messages that are easily understood by seamen of all nationalities. These developments have facilitated the preparation of weather maps on shipboard and have been helpful to the mariner in applying a foreknowledge of the weather to the problems of navigation.

It is inevitable that developments of this nature cause some increase in the demands upon the mariner for weather observations, both as to quantity and detail. However, it is the aim of the national weather services of the world to keep the mariner's meteorological work at a minimum consistent with the requirements of navigation and general weather service and to return to him, in publications and in weather broadcasts, a service that fully justifies his cooperation.

The ship's officer who avails himself of the radio weather broadcasts, and constructs and studies weather maps as a regular feature of his work, will find that the science of meteorology is not dull, but on the contrary, full of interest. His meteorological work will cease to be a routine duty; his own observations will fit into the picture that comes to him on the weather map; the weather map will fit into the momentary picture of the circulation of the earth's atmosphere and its attendant phenomena.

In order that the marine weather observer may make a beginning in the serious study of meteorology, if indeed he has not already done so, a description of methods of preparing weather maps is included with these instructions, together with a list of publications that will be helpful in decoding radio weather broadcasts, analyzing the map, drawing inferences as to the weather of the future, and gaining a more thorough knowledge of world meteorology.

PART II. GENERAL INFORMATION FOR THE MARINE OBSERVER

Arrangements for reporting.—Any master or officer will be welcomed as a weather reporter. He may write to the Weather Bureau Office at Washington or he may visit, or write to, any of the port offices of the Bureau in the list given on page 4. Forms, charts, envelopes, and other material will be furnished to him. Thereafter, he may secure additional forms, publications, and supplies by writing his request on the reports sent in, or he may call for them in person. On visiting one of the port offices of the Bureau he is invited to discuss any features of his meteorological work in which he may need advice or assistance.

When the shipmaster or one of the officers begins reporting to the Weather Bureau, immediate action is taken to secure a comparison of the ship's barometer, which is used for records of atmospheric pressure. The procedure necessary to insure accurate barometer readings is described in the section beginning on page 9.

No charge is made for any of the services rendered by the Bureau to ships' officers in testing meteorological instruments or in supplying forms, publications, and supplies. Franked envelopes are provided so that it will not be necessary to pay postage if the reports are mailed in accordance with instructions contained in this manual.

If the shipmaster wishes to send observations also by radio, he should so state when visiting, or writing to, the Weather Bureau

Office. The number of ships that are authorized to send daily reports by radio is limited by the funds available for payment of radio and telegraph tolls, because the observations are sent at Government expense. The chief considerations in selecting a ship for radio reporting are, first, whether the ship's usual route is likely to result in reports from areas where observations are needed; second, whether the ship has long-range radio equipment that will insure transmission to shore radio stations from the distant and less traveled areas where there is often a scarcity of radio reports. For these reasons, the shipmaster should not begin forwarding daily reports by radio until he has first consulted the Weather Bureau. However, radio reports are desired from any ship when an intense storm, particularly one of tropical origin, is encountered.

Instruments.—Since the essential meteorological instruments, the barometer and thermometer, form a part of the equipment of every well-found vessel, the Weather Bureau does not, as a regular program, provide marine observers with instruments. It does recommend, however, that instruments recognized to be of reliable manufacture be used, that they be properly exposed on shipboard, and that barometers, in particular, be regularly compared with standard instruments of the Weather Bureau or some other national meteorological organization. Advice regarding the specifications for instruments to be purchased will be gladly furnished by Weather Bureau officials, and instruments will be tested at time of purchase if desired.

Forwarding reports by mail.—It is highly desirable that reports be forwarded promptly by mail at the end of each voyage, or upon arrival at a port of call if the voyage be a long one. The mail reports are used in writing monthly summaries of weather conditions over the oceans and in preparing accounts, including tracks, of unusual storms for publication. The material goes to press regularly at the close of the month following that in which the weather conditions are experienced and recorded, hence early receipt of the reports is very helpful. This applies also to ships that report by radio. The observations on forms sent by mail contain more detailed information than the radio messages; furthermore, mistakes sometimes occur in transmission by radio and telegraph; hence the mail forms make corrections possible.

Mail reports should be inclosed in envelopes provided by the Weather Bureau. In a foreign port, the envelopes should be addressed to the United States Weather Bureau, Washington, D. C., and handed to the United States Consul, who is under instructions to forward them with his official mail, free of expense. If the reports are put directly in the mail at any port outside of the United States and its possessions, postage is necessary at regular letter rates. Franked envelopes do not require postage when mailed in the United States, Hawaii, the Philippines, Puerto Rico, Panama (Canal Zone), Virgin Islands, Guam Island, Tutuila Island, or Midway Island.

Pilot charts.—Monthly pilot charts of the North Atlantic, North Pacific, and Indian Oceans, and Central American waters, and quarterly charts of the South Atlantic and South Pacific Oceans are sent free to shipmasters who regularly contribute data to the Weather Bureau. The data appearing on the pilot charts are furnished jointly by the United States Weather Bureau and the United

States Hydrographic Office; the charts are printed and distributed by the Hydrographic Office.

"*Weather on the Oceans.*"—The Monthly Weather Review issued by the Weather Bureau contains weather summaries for the Atlantic and Pacific Oceans, including selected maps for the Atlantic Ocean, also accounts of tropical storms and other articles of interest to the mariner. This material is reprinted as a monthly separate entitled "Weather on the Oceans", which is distributed free to shipmasters cooperating with the Weather Bureau.

Location of Weather Bureau offices:

Portland, Maine, First National Bank Building, 57 Exchange Street.
Boston, Mass., Post Office Building, Post Office Square and Milk Street.
New York, N. Y., Whitehall Building, 17 Battery Place.
Philadelphia, Pa., Customhouse Building, Second and Chestnut Streets.
Baltimore, Md., Customhouse Building, Gay and Water Streets.
Norfolk, Va., Post Office Building, 600 Granby Street.
Wilmington, N. C., Customhouse Building, Water Street, between Market and Princess Streets.
Charleston, S. C., Customhouse Building, 200 E. Bay Street.
Savannah, Ga., Post Office Building, Bull, State, and York Streets.
Jacksonville, Fla., Post Office Building, Julia, Monroe, Pearl, and Duval Streets.
Key West, Fla., Weather Bureau Building, Eaton and Front Streets.
San Juan, P. R., Weather Bureau Building, Stop 4, Puerta de Tierra.
Tampa, Fla., Post Office Building, Florida Avenue and Zack Street.
Pensacola, Fla., American National Bank Building, Palafox and Government Streets.
Mobile, Ala., United States Court House and Customhouse, corner of St. Joseph and St. Louis Streets.
New Orleans, La., Post Office Building, Camp and Lafayette Streets.
Port Arthur, Tex., Post Office Building, Austin Avenue and Fifth Street.
Galveston, Tex., Trust Building, 23d Street and Avenue E.
Houston, Tex., Shell Building, Texas Avenue and Fannin Street.
Corpus Christi, Tex., Post Office Building, Broadway and Starr Street.
Seattle, Wash., Federal Office Building, First Avenue and Marion Street.
Portland, Oreg., Customhouse Building, Eighth and Broadway Streets.
San Francisco, Calif., Federal Office Building, Market and Fulton Streets.
Los Angeles, Calif., Central Building, Sixth and Main Streets.
San Diego, Calif., Post Office Building, F Street, between Union and State Streets.
Honolulu, Hawaii, Post Office Building, King, Mililani, and Richards Streets.

Condensed instructions for taking and recording observations.—On the inside of the front cover of the observation form, 1210A, there are condensed instructions for recording weather observations. The experienced marine meteorological observer will find these condensed instructions adequate for entering daily weather reports on the forms. Parts III, IV, and V of this manual are designed to furnish information in detail regarding the most modern and desirable methods of taking weather observations on shipboard. The instructions and explanations therein are based upon the specifications laid down by the International Meteorological Organization and should eventually become universal. The general use of the International Code in ships' weather reports sent by radio makes it necessary that the international methods of recording observations be followed.

When questions arise in connection with any phases of the observational work, the observer should consult the appropriate sections of parts III, IV or V; however, the experienced observer, as well as the beginner, should read through them carefully at his leisure in order that he may be familiar with their contents.

The condensed instructions which follow, in French, German, Italian, Dutch, and Japanese, are intended for observers who cannot read the English text.

INSTRUCTIONS AUX OBSERVATEURS

1. Prendre les observations journalières du temps selon le temps local correspondant à midi moyen Greenwich.

2. Registrer la direction vraie du vent, pas la direction magnetique. Quand votre navire s'est mis en route, se rendre compte de sa course et vitesse. Se servir des tables à la page 116.

3. Registrer le baromètre et le thermomètre exactement comme lus; quand les rapports seront reçus, le Weather Bureau appliquera les corrections nécessaires. Si le Weather Bureau n'aura pas avis sur la correction pour le baromètre, le maître de navire sera assez bon de transmettre une série d'indications pour la comparaison. Trois indications en port se désirent, de préférence aux Etats-Unis. Pour telles comparaisons, formule No. 1202 sera fournie sur demande.

4. Les températures inserées dans les colonnes pour temperature d'air (bulbe sec) et pour température de bulbe mouillé devraient être obtenues de préférence à l'aide d'un psychromètre portatif.

5. Les colonnes réglées appellent un exposé précis des conditions météorologiques qui règnent au temps d'observation vrai. Les conditions qui précèdent et qui suivent l'heure d'observation, le caractère général du temps, changements de vent, rafales, etc., devraient être tous notés dans le "Daily Journal."

6. Se servir des "Gale or Storm Reports" et des "Fog Reports", copiant du livre de loch s'il le faut.

7. Commencer une feuille d'observations nouvelle quand le navire passe d'une mer à une autre, comme aussi au début d'un mois nouveau.

8. Les feuilles d'observations complétées devraient être expédiées sans retard. Des enveloppes, sur lesquelles est imprimée une liste de locaux du Weather Bureau, seront fournies à cet effet; elles devraient être addressées au plus prochain bureau de poste ou au local à Washington, D. C. Dan les ports étrangers, la poste peut être expédiée franche de port en la donnant au Consul américain.

ANWEISUNGEN FÜR BEOBACHTER

1. Tägliche Wetterbeobachtungen zu der mittleren Mittagshöhe von Greenwich entsprechenden Ortszeit.

2. Aufnahme der wirklichen, nicht der magnetischen Windrichtung. Bei fahrenden Schiffen sind Kurs und Geschwindigkeit in Betracht zu ziehen Heranziehung der Tafeln auf Seite 116.

3. Genaue Aufnahme des wirklichen Barometer-und Thermometerstandes; die Weather Bureau nimmt selbst die nötigen Korrekturen nach Eingang des Berichts vor. Falls der Weather Bureau keine Korrekturen für den Barometer-stand vorliegen, wird der Kapitän des Fahrzeugs freundlichst ersucht, eine Gruppe von Lesungen zum Vergleich einzusenden. Es werden drei Hafenlesungen gewünscht, vorzugsweise in den Vereinigten Staaten. Formular No. 1202, steht für dergleichen Vergleiche auf Wunsch zur Verfügung.

4. Die in die Spalten für Lufttemperatur eingetragenen Temperaturen-werte (trockne Kugel) und feuchte Kugel Temperatur sind, wenn möglich, mit einem tragbaren Psychrometer zu erlaugen.

5. Die linierten Spaltan verlangen genaue Angaben der zur Beobachtungszeit wirklich herrschenden Wetterzustände. Der Beobachtungsstunde voraufgehende oder folgende Wetterzustände, der allgemeine Charakter des Wetters Windveränderungen Böen u. s. w. sind in dem "Daily Journal" zu verzeichnen.

6. Heranziehung der "Gale or Storm Reports" und "Fog Reports", wenn nötig, mit Hilfe des Schiffslogbuches.

7. Gebrauch eines neuen unbenutzten Beobachtungsbogens, wenn das Fahrzeug einen andern Ozean berührt; desgleichen zu Beginn eines neuen Monats.

8. Die ausgefüllten Beobachtungsbogen sind unverzüglich einzusenden. Briefumschläge mit einer gedruckten Liste der Zweigstellen der Weather Bureau stehen auf Wunsch zur Verfügung; dieselben sind an die nächste Zweigstelle oder an die Weather Bureau zu Washington, D. C., zu addressieren. In ausländischen Häfen können dieselben franko durch das amerikanische Konsulat besorgt werden.

DIREZIONI PER OSSERVATORI

1. Prendete le osservazioni giornalieri dell'ora locale correspondente a Greenwich mezzogiorno medio.
2. Registrate la direzione vera del vento e non del magnetico. Quando la vostra nave è in cammino, la corsa e velocità di lei devono essere considerate. Usate le tavole a pagina 116.
3. Registrate il barometro e il termometro esattamente come letto; il Servizio Presagi (U. S. Weather Bureau) applicherà le correzioni necessarie quando i rapporti sono ricevuti. Nel caso che il Servizio Presagi non è stato avvertito in quanto a la correzione pel barometro, il capitano di nave piacerà spedire una serie di letture a proposito di comparazione. Tre letture in porto sono considerate, a preferenza negli Stati Uniti. La forma numero 1202 per tali comparazioni sarà fornita per richiesta.
4. Le letture inscritte nelle colonne per la temperatura dell'aria (termometro asciutto e termometro bagnato) devono essere ottenute a preferenza con un psicrometro portabile.
5. Le colonne lineate richiedono un'esposizione precisa delle condizioni meteorologiche prevalenti al tempo attuale di osservazione. Le condizioni, precedenti e seguenti l'ora di osservazione, il carattere generale del tempo, i salti del vento, le raffiche del vento, etc., tutte queste condizioni devono essere notate nel "Daily Journal."
6. Usate i rapporti di temporale e di burrasca e i rapporti di nebbia, copiando dal libro di bordo quando necessario.
7. Incominciate un nuovo foglio di osservazione quando la nave passerà da un oceano al altro; anche al primo giorno d'un mese nuovo.
8. I fogli di osservazione, quando finiti, senza ritardo devono essere spediti per posta. Le buste, sopra le quali è impressa una lista di uffici di Servizio Presagi (U. S. Weather Bureau), saranno fornite a proposito di spedizione per posta. Le buste, sopra le quali è impressa una lista di uffici di Servizio Washington, D. C. Quando nei porti stranieri, il corriere postale può essere mandato franco di posta, nel caso che è dato nelle mani del console degli Stati Uniti.

AANWIJZIGINGEN VOOR OPMERKERS

1. Neem de dagelijksche opmerkingen op den plaatselijken tijd overeenkomstig met greenwich gemiddelde maan.
2. Verhaal de ware richting van den wind en niet de magneetische. Als uw schip onderweg is, moet haar koers en snelheid in aanmerking genomen worden. Gebruik de tafels op bladzijde 116.
3. Verhaal den barometer en thermometer precies als gelezen; het Weather Bureau zal de noodige wijzigingen aanbrengen wanneer de verslagen ontvangen zijn. Als het Weather Bureau niet ingelicht geworden in aangaande de wijziging voor den barometer, zal de schipper gelieve een gevolg van lezingen inzenden voor vergelijking. Drie lezingen in haven zijn gewenscht, liefst in de Vereenigde Staten. Formulier nummer 1202 voor zulke vergelijkingen wordt op verzoek geleverd.
4. De temperaturen opgegeven in de afdeelingen voor lucht temperatuur (drooge bulb) en natte bulb temperatuur zullen liefst met eenen psychrometer verkregen moeten worden.
5. De beregelde afdeelingen zijn bestemd voor eene juiste opgave van de meteorologische toestanden aanwezig op den werkelijken tijd van opmerking. Toestanden voor—en naloopend van het tijdstip van opmerking, algemeen karakter van weder, keeringen van wind, windvlagen, enz., moeten allen aangeduidt worden in het "Daily Journal."
6. Gebruik de "Gale or Storm Reports" en "Fog Reports", overschrijvende van het schip's log wanneer noodzakelijk.
7. Begin een nieuw opmerkingsblad als het schip van eenen oceaan tot eenen anderen overgaat; ook bij het begin van eene nieuwe maand.
8. Opmerkingsbladen, zoodra ingevuld, moeten zonder oponthoud worden verzonden. Envelopen, waarop eene lijst van Weather Bureau kantooren gedrukt is, zullen geleverd worden voor verzending; deze moeten aan het naaste kantoor gericht worden of aan het kantoor te Washington, D. C. In buitenlandsche havens mag post vrij van postzegels gezonden worden als het den konsul der Vereenigde Staten ter hand gesteld wordt.

天候観測ニ関スル注意書

一、グリニッヂ標準時正午ニヨリ日々處在地ニ於テ天候ノ観測ヲナスベシ。

二、風ノ方向ハ磁氣ニヨラズシテ眞ノ方向ニヨルベシ。航海中ニ於テハ、船ノ行路、速度ヲ116頁ノ表ニヨリテ加算スベシ。

三、報告書ノ必要ナル修正ハ観測所ニテ加入スルヲ要セズ。晴雨計ト寒暖計ノ表示ハ、ソノママ記載スベシ。但シ寒暖計ノ正誤表ヲアラカジメ測候所ニ通知シアラザル場合ハ所員ノ比較資料トシテ各種ノ表示ヲ同封スベシ。

港一（コトニ合衆國内）ニ碇泊中ハ三回観測ヲナスベシ。

比較ニ必要ナル一二〇二号形式ハ申込次第郵送ス。

四、濕度ト表記セル欄ニハ、空氣ノ乾濕両温度ノ測定ヲ要シ、出来得ベクンバ両者トモ携帯用ノ温度計ヲ用フルヲ可トス。

五、罫線ノ部ハ觀測時刻ニ於ケル氣象ノ狀態ヲ詳細ニ記載スベシ。日報ニハ觀測時ノ前後ニ於ケル天候ノ概要、風ノ變換、疾風其他ヲ明記スベシ。

六、疾風、暴風雨、雲霧ニ關スル報告ハ茲ニ準ジテ航海日記ヨリ轉載スルモ可ナリ。

七、船ガ別ノ海洋ニ入ル每ニ新シキ觀測表ヲ使用スベシ。每月初モ亦タ之ト同ジ。

八、觀測報告書ハ終了次第速カニ測候所ニ郵送スベシ。各地方測候所ノ所在地ヲ印刷セル封筒ハ申込次第本部ヨリ供給ス。報告書ハ碇泊地ニ最モ近キ測候所或ハワシントンノ測候所ニ送ルベシ。外國ノ港ニ在ル時ハ領事ニ依賴スレバ郵税ハ無料ナリトス。

PART III. INSTRUMENTS AND INSTRUMENTAL OBSERVATIONS

Few ships carry meteorological instruments other than barometers and thermometers. Readings of the barometer, showing the atmospheric pressure and its changes, are of the highest importance. Readings of thermometers, showing the air and water temperatures, and also the depression of the "wet bulb", from which the humidity is determined, are of great value.

The following instructions relate to the care, exposure, and reading of barometers and thermometers and their comparison with standard instruments. Additional information regarding the proper methods of making weather observations on shipboard with instruments will be found in part IV, where the preparation of the complete weather report, including noninstrumental observations, is explained in detail.

MERCURIAL BAROMETERS

Mercurial barometer of marine type.—The difficulties encountered in the use of the ordinary type of mercurial barometer on shipboard, owing to motions of the ship, have been overcome in a form of instrument known as the Kew, or marine, barometer. Its distinguishing characteristics consist in substituting for the simple straight tube of uniform bore commonly employed in land barometers, a tube having a wide bore for 6 or 8 inches of the upper portion only. Below this the tube has thick walls with a small capillary bore only a few hundredths inch in diameter. Near the bottom end the bore of the tube is again enlarged to form an air trap, all as shown in figure 1. If small quantities of air chance to enter the open end of the tube they are not likely to enter the small point of the inner tube, but lodge instead in the surrounding space, as indicated, where the air must remain and does not affect the barometric readings. It may even be removed from the trap when the barometer is undergoing repairs.

The flow of mercury through the capillary bore takes place so slowly that the column cannot surge up and down the tube seriously with the relatively quick motions of the ship. At the same time the height of the column adjusts itself to the slow changes of atmospheric pressure, and thus more or less perfectly answers the desired objects.

Figure 2 shows a high-grade mercurial barometer adapted to all the requirements of marine use, together with a special gimbal supporting bracket and wooden box, into which the barometer and bracket are folded and thoroughly protected and secured when not in use.

The glass tube and boxwood cistern, all as shown in figure 2, are secured inside the bronze-metal jacket provided at the top with a long, slotted opening through which the top of the glass tube and mercurial column can be seen. A scale of graduations is fixed beside the opening and a vernier is arranged to slide up and down so as to enable accurate measurements of the height of the mercurial column to be made.

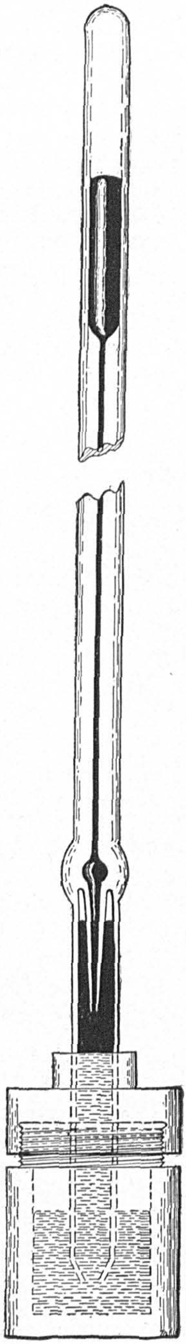


FIGURE 1.—*Tube and cistern of marine barometer.*

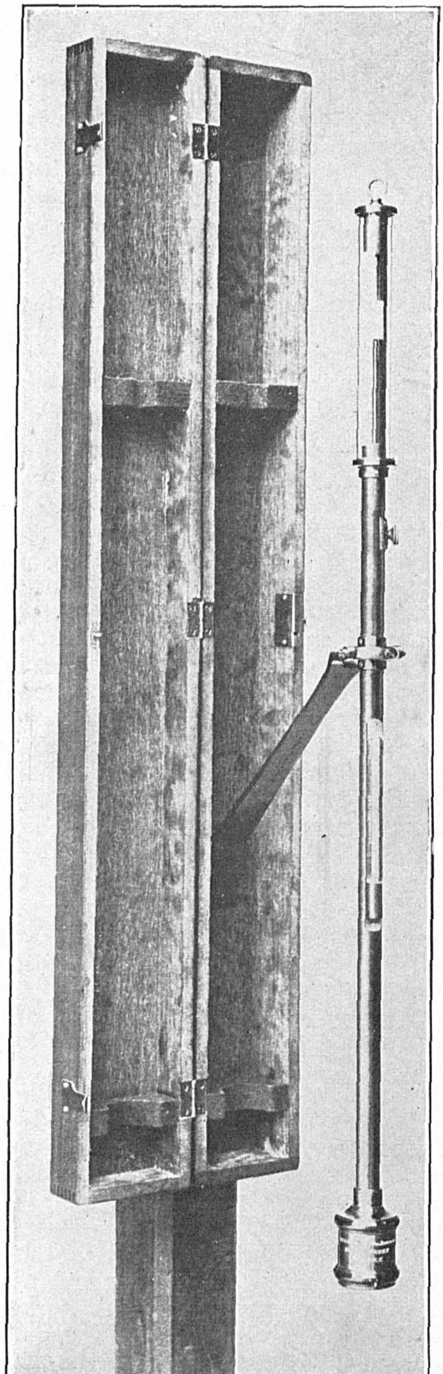


FIGURE 2.—Marine barometer and box.

For marine use it is necessary that the barometer be free to hang in a vertical line despite the rolling and pitching of the vessel. For this purpose the well-known arrangement of gimbal rings is formed upon the outer extremity of a hinged bracket and secured to the barometer at a point some inches above the middle.

In the position shown in the picture the barometer is ready for reading, and the tube will swing on the gimbals so as to remain nearly or quite vertical. After a reading has been taken the barometer must not be left exposed, as it is very liable to injury by violent oscillations in heavy weather. In the equipment of the standard Weather Bureau design the whole bracket, barometer, and all are arranged to fold up compactly within the small mahogany case, the lid of which closes with a spring clasp, and not only secures the barometer from accidental damage but from undue exposure to atmospheric influences as well.

Standard types of both land and marine mercurial barometers are found in offices of the Weather Bureau at the principal United States ports, and seamen are invited to visit such offices for the purpose of familiarizing themselves with these and other meteorological instruments.

Explanation of scale of marine barometer.—All marine barometers are of the fixed-cistern type, as it is called, and the only setting required is to bring the lower edge of the vernier accurately to the level of the top of the mercurial column, whereupon the scale reading gives directly the observed or uncorrected air pressure. This result is realized by shortening the graduations on the scale so that instead of representing true standard inches, millimeters, or millibars, as the case may be, the graduations have such a value as to eliminate or take account of the slight rise and fall of the level of the mercury in the cistern as the column rises or falls.

If, for example, the column of mercury in the tube falls, say, 1 inch, there will be a rise of the mercury in the cistern, but the amount will be small because the area of the cistern is so much greater than that of the tube. For example, in the barometer from which the illustration in figure 1 was prepared, the rise of the mercury in the cistern for a fall of 1 inch in the tube amounts to only about three-hundredths of an inch (0.03). Consequently, in this barometer, an observed fall of 1 inch in the tube means a fall of 1.03 inches in the pressure. If, now, we prepare a special scale for this barometer so that each true inch of space on the scale represents 1.03 inches of the arbitrary scale values, and, if we set this scale so that the barometer reading at any one point of the scale agrees exactly with the reading of a standard barometer alongside of it, then the readings should agree closely at all other points of the scale. Slight irregularities in the bore of the tube and diameter of the cistern may introduce small errors; otherwise, the contracted-scale barometer, with settings made only at the top of the mercurial column, is capable of yielding pressure readings of great accuracy, and this artifice is universally employed in the ordinary marine barometer.

Errors of mercurial barometers.—No matter how carefully a barometer may be made, certain errors due to various causes can hardly be eliminated. In the first place, if any air or other gaseous matter remains in the top of the barometer tube, the column of mercury will be prevented from rising as high as it should. It is known, likewise, from physical laws, that the capillary forces acting between the free surface of mercury and the glass walls at the top of the column also operate to prevent the mercury from rising as high as it should in the tube. Still other errors arise from faults in the graduation of the scale and from failure to place the scale and vernier at exactly the positions they should occupy.

It is not practicable, nor is it necessary, as a rule, to determine these errors separately. When an instrument is completed, its readings are carefully compared with those of a standard barometer. The difference found in this way represents the combined effect of the several errors mentioned and is commonly called the "correction for instrumental error and capillarity."

Another source of considerable variation in the readings of mercurial barometers is the influence of temperature, a rise of temperature expanding both the metal scale and the mercurial column. If both mercury and scale expanded the same amount, no correction would be necessary, but the mercury expands much more than the metal scale, so that a large correction is required, as will be explained more fully on page 15.

Location of the mercurial barometer.—If the ship carries a mercurial barometer, it should invariably be employed in the meteorological work of the Weather Bureau. It should, therefore, be so located as to be readily accessible.

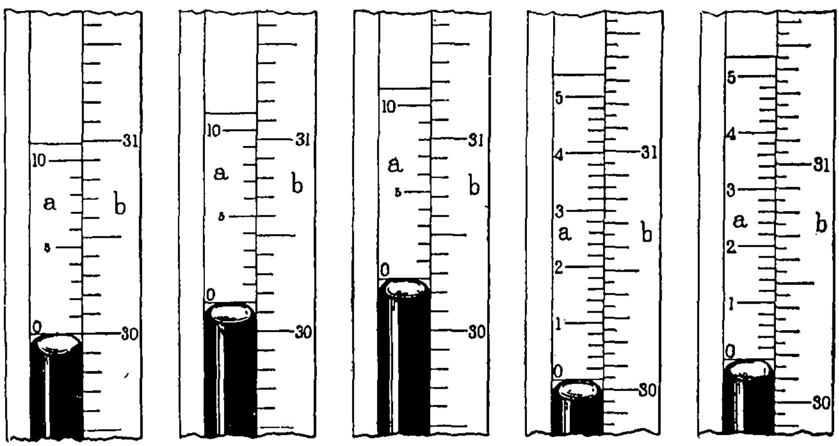
It should be hung in a place where the temperature is fairly uniform; that is, at some distance from any source of heat, such as steam pipes, stove, or lamp, and where there is a good light. It should be at such a height from the deck as to admit of the observer's eye being brought opposite the level of the mercury in the tube. It should also be free, so far as possible, from the jar of the machinery.

Any simple method of suspension may be employed, so long as the instrument is secure. An excellent device is a stout bracket 10 or 12 inches in length, firmly attached to the bulkhead, at the outer extremity of which is a ring swung on gimbals, in which ring the barometer is clamped at about one-half of its length from the top. (Figure 2.) A spiral check spring or a strong rubber band, carried from the grommet at the top of the barometer to the deck above, serves to prevent the cistern from collision with the bulkhead or other object during heavy weather. At the moment of observation it is absolutely essential that the barometer be vertical, as any deviation from the plumb line will make the reading too high. At this moment, therefore, and only at this moment, the check spring should be detached, and the tube allowed to swing freely, not even being steadied by the hand. In order that this interval be as brief as possible, the following method of procedure should be followed:

1. Read and record the temperature of the attached thermometer.
2. Bring the lower edge of the vernier to coincide with the top of the arched surface of the mercury, as nearly as the pumping will permit.
3. As the ship is approaching an even keel, release the check spring from the grommet at the top of the tube; with a touch of the set screw once more bring the edge of the vernier to the top of the mercurial surface, and immediately attach the check spring.
4. Read and record the position of the vernier.

In setting the vernier, the eye of the observer should be brought to the same level as the top of the mercury. A piece of clean white paper placed immediately behind the tube will be found of great assistance in the final adjustment. When observing at night, a strong light should be thrown on this paper.

The principle of the vernier and the method of reading it.—The vernier is a device by which one is able to ascertain accurately much smaller fractional subdivisions of a graduated scale than could otherwise be observed by the eye without the aid of a microscope. For example, with a scale having only 20 subdivisions to the inch a vernier enables us to ascertain accurately the one-thousandth part of an inch. The name of the device is derived from its inventor, Pierre Vernier.



30.00 FIGURE 3. — 30.15 FIGURE 4. — 30.277 FIGURE 5. — 30.034 FIGURE 6. — 30.177 FIGURE 7.

VERNIERS

A vernier consists, essentially, of a small graduated scale, the spaces upon which are just a certain amount smaller or larger than those on the main scale. When two such scales are placed together some particular line of the one will always be coincident, or very nearly so, with a line on the other, and from this circumstance the position of the zero line of the vernier in reference to the scale can be very accurately determined, as will be readily understood from a study of the following figures and explanation:

Figure 3 exhibits the manner of graduating a vernier so as to subdivide the spaces upon the scale into tenths. In the figure, *b* is the scale and *a* is the vernier. The lower edge of the vernier, which in this case is also the zero line, is exactly opposite to or coincident with 30 on the scale. The tenth line on the vernier is coincident with the ninth line above 30—that is, a space of 9 divisions on the scale is divided into 10 spaces on the vernier, so that each space on the latter is one-tenth part shorter than a space on the scale. In the present case the spaces on the scale represent inches and tenths; hence the difference between the length of a space on the vernier and one on the scale is $\frac{1}{10}$ of $\frac{1}{10}=\frac{1}{100}$ of an inch. This principle of matching two scales having spaces of slightly different magnitude is always followed in the construction of verniers, though, of course, the number of spaces embraced by the vernier is varied to suit the circumstances and the degree of minuteness desired. Moreover, in some instances, the vernier embraces one more space on the scale, instead of one less, than the number of its own subdivisions—that is, 10 spaces on the vernier may be made to correspond to 11 spaces on the scale.

If, as we have seen, the spaces on the vernier are one-tenth smaller than on the scale, then, in the adjustment shown in figure 3, the first line above the zero on the vernier is one-tenth part of the space, the next line two-tenths, the next three-tenths, etc., distant from the line next above on the scale. When, therefore, we find the vernier in such a position as shown in figure 4, where the fifth line on the vernier is coincident with a scale line, it is very clear that the zero line of the vernier must be just five-tenths above the scale line next below. Now, since we imagine these scales to represent inches and tenths, then figure 4 will read, 30.15 inches.

In many cases it will happen that no single line on the vernier will be exactly coincident with a scale line, but that one line will be a little above while the next line on the vernier will be a little below the corresponding scale lines.

In the case shown in figure 5 the seventh and the eighth lines on the vernier are each nearly in coincidence, but neither one is exactly so. This indicates that the reading is somewhere between 30.27 and 30.28. Moreover, we can clearly see that the eighth line is nearer coincidence than the seventh. We, therefore, estimate that the true reading is about 30.277. We might, probably, with as great accuracy have selected 30.278.

If the scale and vernier are accurately graduated, such readings by a practical observer will rarely be in error by more than 0.002 inch. It is important in estimating the fractions that the eye be exactly in front of the lines being studied.

In figures 6 and 7 are shown verniers applied to a barometer scale having 20 parts to the inch. In this case 24 parts on the scale are divided into 25 parts on the vernier. By the principle which has already been explained, the value of the subdivisions affected by such a vernier, or, as it is mostly frequently expressed, the least count of the vernier, will be $\frac{1}{25}$ of $\frac{1}{20}=\frac{1}{500}$ of an inch. In reading the vernier, therefore, each line will represent 0.002 inch, so that the fifth, tenth, fifteenth, twentieth, and twenty-fifth lines will represent one, two, three, four, and five hundredths of an inch, respectively, and are so numbered.

As already stated, the lines in this kind of vernier also may not be exactly in coincidence; but in such a case, owing to the smallness of the spaces, it is not of any special advantage in making our estimate to consider whether coincidence is nearer one line than the other. In ordinary practice we simply take midway between. Thus in figure 7 the reading is between 30.176 and 30.178; we therefore adopt 30.177 as the proper reading.

When the zero line of this style of vernier is next above one of the shortest lines on the scale, as was the case in the example above, some attention is necessary in order to take off the correct reading. For example, in figure 7 we find that coincidence on the vernier is between lines designated 26 and 28, which corresponds to a reading of 0.026 or 0.028, or, taking midway between, 0.027. On the scale itself, however, we see the graduation next below the first line of the vernier is 30.150. The complete reading is found by adding the parts thus: 30.150+0.027=30.177. It frequently happens with beginners that the 0.050 represented by the short line on the scale is overlooked and omitted entirely—that is, the above reading might be called 30.127. Whenever readings are made with a scale and vernier of this character special pains must be taken not to omit adding 0.050 to the vernier reading when the first line below the zero of the vernier is a short one.

In recording the height of the mercury always use two whole numbers and two decimals, even though the final is zero. Thus, 30 inches should be recorded 30.00.

Correction and reduction of barometer readings.—The readings of a mercurial barometer are affected by four conditions—temperature, gravity, elevation, or height above sea level, and imperfections in the instrument. The last two of these influences are more or less constant as affecting barometers on board vessels and corrections therefor are embodied in a so-called barometer correction, obtained in the manner described on pages 22 to 24.

Other things being equal, the mercury will stand higher in the tube when it and the metal scale are warm than when they are cold, owing to expansion. To eliminate this effect, and for the purpose of comparison, all observations of mercurial barometers must ultimately be reduced to a standard temperature. The standard universally adopted is the freezing point of water, corresponding to 32° on the Fahrenheit scale and to 0° on the Centigrade scale. The appropriate corrections to be applied to reduce barometric readings to this standard temperature have been determined and expressed in tabular form. Table 1, pages 112 and 113, gives the value of this correction for each degree Fahrenheit.

The following will elucidate the nature of the gravity correction as applied to barometric observations—an important matter that is often but indifferently considered in the ordinary textbooks of meteorology.

By the well-known principle of hydrostatics, on which the action of the mercurial barometer is based, the pressure of the atmosphere is equal to the pressure of the column of mercury that it will support. But this latter pressure is only another name for the weight of the mercury, and for columns of equal section the weight varies both with the height of the column and with the force of gravity.

The force of gravity varies with latitude and altitude; therefore the height of the barometer, even when corrected for temperature and instrumental error, does not give us a true measure of the atmospheric pressure unless we first eliminate the small variations that are due to gravity; that is, observations taken over a widely extended region to be strictly comparable must be reduced to a standard force of gravity.

The standard gravity adopted by physicists is that at the level of the sea in latitude 45°.

A table of corrections for gravity is given on page 114.

As an example, let the observed reading of the mercurial barometer on board a vessel in the Caribbean Sea, midway between Colon and the Windward Passage, be 29.95 inches and the temperature as given by the attached thermometer, 74° F.

We then have—

	Inches
Observed height of the mercury	29. 95
Correction for temperature, 74° (table 1)	—0. 12
	29. 83
Correction for gravity, latitude 15° (table 3)	—0. 07
	29. 76
Correction for height above sea level and instrumental error, assumed, (Barometer Tag)	+0. 06
Corrected barometer reading	29. 82

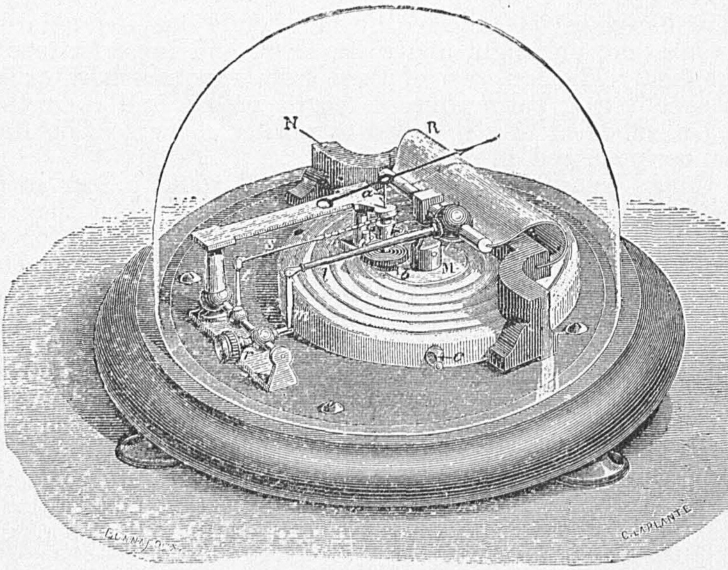


FIGURE 8.—Aneroid barometer.

ANEROID BAROMETERS

Figure 8 represents one of the more important types of aneroid or holosteric barometers, showing, principally, the internal mechanism. The essential feature consists of the small metallic box or cell, *M*, the upper and lower walls of which are made of very thin circular sheets of corrugated German silver, which are soldered together on their outer edges, forming a very short cylinder. The air is thoroughly exhausted from this cell through a tube at one side, which, when the vacuum is as perfect as desired, is pinched tightly together, cut off, and hermetically sealed with solder, producing the projection seen at *c*. The flexible corrugated surfaces, which tend to be collapsed by the pressure of the outside air, are forcibly held apart by the action of a strong steel spring, *R*. As the pressure of the air increases the spring is compressed and the corrugated surfaces approach each other slightly, returning again or separating still farther with diminution of pressure. To measure the changes in atmosphere pressure, it is only necessary to measure the minute movements of this flexible cell.

In the common aneroid a lever, *l*, attached directly to the spring, connects by a link, *m*, with a very short arm of a sort of bell-crank lever, *r*, *t*, having a horizontal axis on pivots at each end.

The longer arm, *t*, of this bell-crank lever is connected by means of a wire, *s*, with a very fine chain, the other end of which winds around a small wheel or drum on the axis, *a*, upon which is mounted the hand as seen. At *b* is shown a small spiral steel spring, like the hairspring of a watch, which serves to take up the slack in the loose connections of the numerous joints, levers, and links.

At *r* is shown, also, a small counterpoise weight attached to the bell-crank lever to aid in securing a more stable position of the index when the barometer is placed in different positions; that is, whether the dial is horizontal, or vertical, or turned to one side or the other.

The point of attachment of the link, *m*, to the bell-crank lever is sometimes adjustable so that the movements of the hand can be made to correspond to the value of the scale graduations.

The steel spring, *R*, is also slightly adjustable by means of a screw from the underside threaded into the part, *N*. This permits adjusting the hand to any particular point of the scale to give correct readings.

Effects of temperature.—The steel spring and the feebler elastic reaction of the composition metal of the vacuum chamber are appreciably weakened by increase of temperature, so that in some cases a rise of the pressure may seem to occur which is really caused by the weakening of the spring. In some cases efforts are made to compensate for this by leaving a small quantity of air in the vacuum chamber, which when heated increases its pressure upward and tends to offset the weakening effect upon the springs. A better plan is to make the lever, *l*, of two different metals, viz, brass and iron, firmly brazed together. The differential expansion of these two metals with temperature changes produces flexure in the lever. By filing and adjusting the bimetallic bar the flexure due to temperature can be made very nearly to balance the effect of temperature on the spring. The aneroid is then said to be "compensated" and this word is often found on the dial. In many cases this word is there when the compensation is very imperfect.

Aneroid barographs.—Extremely simple and portable barographs are constructed upon the aneroid principle, of which that of Richard, being widely used, is here described (fig. 9).

It consists of a cylinder, *A*, on which the recording paper is wound, revolving once a week by means of a clockwork contained inside. A series of corrugated metallic shells, *B*, eight in number, joined one above the other and exhausted of air, forms an aneroid system eight times as sensitive as a single chamber. The movement of the shells is still further greatly magnified and is transmitted to the recording pen, *C*, by a series of connecting levers. The pen may be released from contact with the paper by pushing the lever, *D*, to the right.

The corrugated shells are the same as used in ordinary aneroids, the steel springs for distending the shells being placed inside. The shells are made into a vertical column by screwing one to another. The lower base of the column being fixed, the upper end rises and falls with every variation in the atmospheric pressure, by a quantity which is the sum of the displacements of the elementary shells.

The compensation for temperature is accomplished by leaving a sufficient quantity of air in one of the shells, ascertained by experiment when the instrument is made, so that with a rise of temperature the tendency of the barometer to register too low on account of the weakening of the springs, and the expansion of the levers and other parts is counteracted by the increased pressure of the air in the shell. However, the instrument should be kept at a uniform temperature as far as possible.

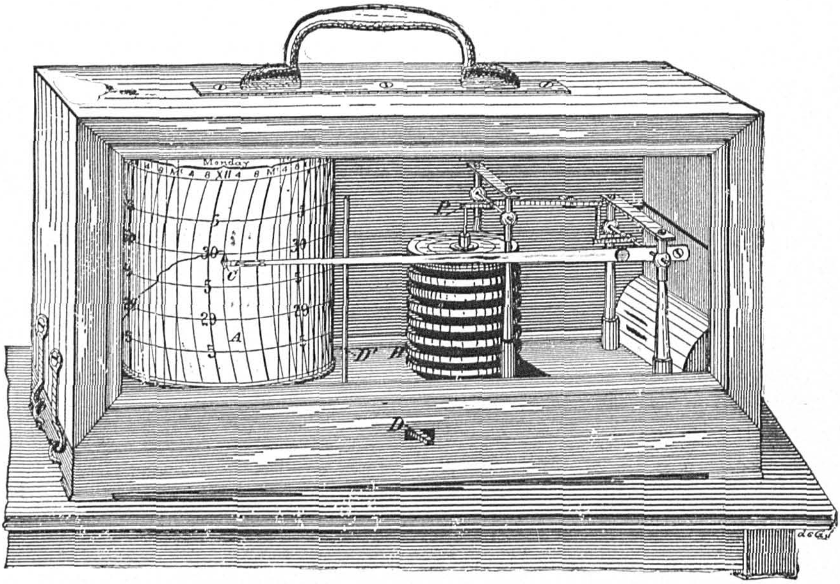


FIGURE 9.—Richard's aneroid barograph.

Reading of aneroid barometers.—These instruments are usually graduated to every two-hundredths of an inch, and reading of them to hundredths is, therefore, easy. Care, however, should be taken not to confuse the tenths divisions with those for hundredths. Figure 10 is a reproduction of a portion of the dial of a common type of aneroid barometer, to which has been affixed a series of imaginary positions of the needle marked "*a*", "*b*", "*c*", etc. The following are the correct readings corresponding to these positions:

(*a*) 28.75 inches.
(*b*) 29.06 inches.
(*c*) 29.20 inches.
(*d*) 29.56 inches.
(*e*) 30.00 inches.
(*f*) 30.10 inches.

Defects in aneroids.—There are many sources of mechanical defects in aneroid barometers. This is especially true of those of inexpensive manufacture, and of those which do not have the dealer's guaranty of good performance. Aside from the defects induced by long usage and stress of weather on shipboard, several may be mentioned. For instance, springs and linkage may be too tight and sluggish, so that response to pressure changes, great or small, is slow or incomplete. In other words, the hand sticks, and if it finally succeeds in pointing to a very low pressure, it may fail to return properly to indicate the following much higher pressure. Likewise, it may fail, except partly, to indicate any change in pressure.

Other aneroids, due to poor construction of adjusting parts, are so erratic in action that, for meteorological purposes, they are practically worthless.

Then there is the "creeping" error, which troubles many aneroids, and produces a gradual increase in the correction until it assumes large proportions. Creeping may be due to one or more causes. There may be porosity in the metal box inside the instrument which admits minute quantities of air into the vacuum space and thus gradually destroys the power to respond to the pressure of the atmosphere; or, the heavy spring which opposes the air pressure may be crystallizing slowly and thus more and more preventing the vacuum element from responding to the outer-air pressure. An aneroid with creeping trouble may become worthless in time, but until that stage occurs, if the change in error is very slow, frequent comparisons will keep pace with it, and the instrument may be serviceable for a considerable period.

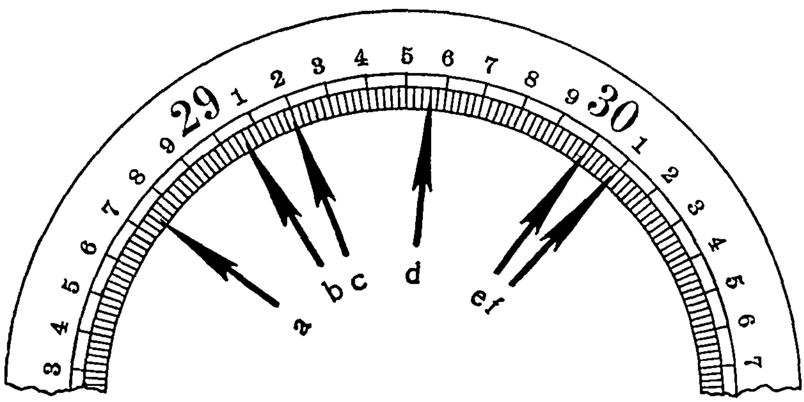


FIGURE 10.—Illustrating six different readings of the aneroid barometer.

Some aneroids do not correctly register considerable changes in pressure, though they may continue reliable under ordinary pressures. Let the pressure fall to a low value, as in a deep cyclonic storm, such instruments either fail to keep pace with the change, or come to a dead stop at some point while the pressure is still falling.

Compensation for temperature.—Another defect, and a very common and important one, is entire lack, or insufficiency, of a temperature-compensating device in the instrument.

All aneroid barometers that are properly manufactured with the purpose of giving correct pressure readings, are fitted with a means in the mechanism which automatically compensates for the effects of temperature changes upon the dimensions and elasticity of the parts of the instruments. This device, therefore, when perfect, not only corrects the errors which would otherwise arise when expansion of the parts occurs during rising temperature, but also those due to the contraction which takes place when the temperature falls. When the device is imperfect, there is only partial compensation for temperature, and the readings of the instrument suffer in accuracy on account of it. The aneroid may continue to be serviceable, however, but its value as a meteorological recorder has been distinctly lessened. When there is no compensating device—and there are many of these instruments which lack it, or have it so inadequately developed that it is useless—readings from such aneroids can never be depended upon for accurate pressure indications.

Measures for remedying defects.—Aneroid barometers that are decidedly erratic, because of one or more of the defects mentioned, are subject to one of two remedies, viz, repair or replacement by a better-performing instrument. This is in justice to the Weather Bureau, in the interest of accurate observations, and of benefit to the ship, in the possession of a satisfactory navigating instrument.

Some aneroids, after becoming disordered, may be satisfactorily repaired. If the trouble is due to gumminess in the works, which condition may occur in the aneroid on a tanker, cleaning will effect the desired result. Tightness or looseness in the springs and linkage may be relieved. When, however, there are defects in manufacture, the results of attempted repairs are doubtful. Much more frequently than otherwise, as shown by actual experience, they are fruitless. Such delicate work as the repair of an aneroid barometer should be entrusted to the makers of the instrument or their representatives, or to a repairman who is fully equipped for such work. This rule applies also to the resetting of an aneroid, since many a barometer has been impaired by resetting and has had to be subsequently recalibrated before its readings could be trusted.

Testing of aneroids.—Some aneroid tests may be made simply and without resort to apparatus. For instance, the freedom of movement of the hand of an aneroid can be quickly tested by tapping the instrument on the side or bottom with the fingers or knuckles, or perhaps better by lifting the instrument about one-fourth of an inch from a table or cane-seated chair and placing it back again somewhat sharply. Under this treatment, if the joints and levers are perfectly free, the hand will jump away and then return quickly with a vibratory movement to its original position. If the instrument is defective, the hand in some cases will not respond to the slight knocks, or will do so without exhibiting any vibratory movement, or upon being disturbed it may move a little, but will not return to its original position.

When aneroids fail, or appear to fail, to register correctly considerable changes in pressure, as in passing through a deep cyclonic storm, they should be tested for the real or apparent defect. The Weather Bureau maintains apparatus in its offices at New York, New Orleans, and San Francisco for this purpose. The instrument to be tested is placed under a bell jar connected to an air pump, and the air is gradually removed from the jar. If the aneroid is a good one, it should register the same falling pressure changes as are indicated by the attached column of mercury, during the period in which the jar is being exhausted of air.

Aneroids suspected of temperature trouble may likewise be tested, and shipmasters are cordially invited to avail themselves of the opportunity of having their barometers given the benefit of this test, which may be had free of charge at the following Weather Bureau port offices:

Boston, New York, Philadelphia, Baltimore, New Orleans, Port Arthur, San Pedro, San Francisco, Portland, and Seattle.

Special temperature-testing boxes have been devised, and are in use at most of the foregoing-named stations. Each box contains a copper tank for holding ice-salt mixture, and is also equipped with a thermometer and with 50-watt and 100-watt electric light bulbs. By means of these cooling and heating arrangements, box temperatures as low as 40° F. and as high as 110° F. may be artificially produced. This assures a good thermal range to which the aneroids may be exposed at 10° to 20° intervals of temperature change during the period of the test.

In cold weather a partial test at high and low temperatures may be secured by obtaining the reaction of the aneroid at the artificially heated room temperature, then, after exposing the instrument to the chilled outer air until thoroughly cooled to this outer air temperature, again comparing the barometer with standard at the same elevation.

If the shipmaster cannot avail himself of the opportunity to have his aneroid tested for temperature at a Weather Bureau office, the instrument division of the Bureau suggests a test method that may be given readily to an aneroid on shipboard. Choosing the early morning of a fair day, simply carry the barometer to the cold-storage room of the ship, being careful to hang it in the same relative position as on the bridge, and allow an hour or more for all parts of the instrument to reach the same temperature. With due regard to the actual change in the barometric pressure, and with allowance for a rise of 0.01 inch for each 10 feet change to a lower level, the effect due to change in temperature of the instrument should not exceed 0.02 to 0.04 inch in a well-compensated aneroid. A similar test for high temperature may be made by carrying the barometer to the engine room. The test as indicated should be made during a period of practically stationary atmospheric pressure, and not during a period of sharp barometer change when the errors, if any, due to temperature would be overshadowed by the natural pressure rise or fall. If a second barometer is available, allowance through comparisons may readily be made for the change in general conditions during the test. This test, it should be understood, is not for the purpose of obtaining a working correction for the instrument, but merely to show if the reading indicated by the aneroid is influenced to any degree by temperature.

Replacement of defective aneroids.—When aneroids are shown to be defective and giving misleading data, it is important to all concerned that they be discarded for better instruments without hesitation.

Many ships' companies have adopted the commendable practice of having their reserve stock of aneroids thoroughly tested at the nearest Weather Bureau office to prevent, so far as possible, the issuance of untrustworthy barometers to ships of their lines. In many instances barometers are now purchased subject to replacement by dealers if found unreliable. The tendency, therefore, is in favor of a stricter attitude toward the replacement of old and erratic or usage-worn barometers by new instruments on shipboard, and toward an insistence that new barometers be proven satisfactory before acceptance for installation.

This action has resulted in a decided betterment in marine barometric equipment and in an equally positive improvement in the accuracy of marine meteorological observations.

BAROMETER COMPARISONS

Notwithstanding that the greatest care may be taken in the construction and handling of barometers certain errors due to various causes can hardly be eliminated. In the case of mercurial barometers the errors are usually small and fairly constant. In aneroids, however, the instrumental error may be quite large and undergo irregular changes.

In order to obtain satisfactory readings of barometers it is necessary to find the error of each instrument and apply a correction of the opposite sign. The errors are determined by comparison with a standard instrument. In order to obtain such a comparison it is only necessary to make and record several readings of the ship's barometer when in some port where a standard instrument is located, the readings being made at the same hours at which the latter is read. In United States ports the barometer is read each day at 7:30 a. m. and 7:30 p. m., 75th meridian time. In European ports observations are made generally at 7 and 18 hours, Greenwich mean time. Such observations ultimately reach the Weather Bureau and are available for use in checking comparative readings.

In making comparisons it is desirable that at least three readings of the ship's barometer should be made at uniform intervals of 12 or 24 hours. During the comparison the instrument should hang in its accustomed place aboard ship. If possible the readings should be made by the officer charged with the duty of making the meteorological observations.

Blank cards, known as barometer comparison cards (Form No. 1202–Marine), for recording comparative readings are supplied by the Weather Bureau. A sample card, filled out and with corrections made, is shown on page 24.

The successive readings of the barometer, at the hours selected by the observer, are entered in column 1 of the barometer comparison card. The readings of the attached thermometer will be entered in the adjacent column. The card should then be dispatched to the nearest office of the Weather Bureau.

At the Weather Bureau office the readings of mercurial barometers are corrected for temperature and reduced to standard gravity (latitude 45°), the results being entered in column 2. In column 3 are given the corresponding readings of the standard Weather Bureau barometer, likewise corrected for temperature and reduced to standard gravity, as well as to sea level.

The differences between the simultaneous readings of the two barometers are entered in column 4, and the mean of these differences, if accepted, is adopted as the instrumental error of the ship's barometer. This is at once inscribed upon a barometer tag (Form No. 1203–Marine or 1203A–Marine), a Weather Bureau identification number is given to the barometer, and the tag mailed to the observer. A sample of the tag used for aneroid barometers, properly filled out, is given below. A similar tag (Form No. 1203A–Marine) is used for mercurial barometers.

Form No. 1203—Marine

U. S. DEPARTMENT OF AGRICULTURE

U. S. WEATHER BUREAU BAROMETER TAG

VESSEL American S. S. QUIRIGUA
(Nationality) (Kind) (Name)

Aneroid Barometer No. 6125 W. B. List

COMPARED

Place New York Date Apr. 12-13, 1937

To determine sea-level (corrected) readings—

Add Subtract .15

(SEE REVERSE SIDE OF THIS TAG)

Lack of agreement in the observations.—In case the range between the largest and the smallest individual corrections in the series of comparative readings is more than 0.10 inch, the card is returned to the observer with the statement that the several observations do not agree sufficiently well among themselves to furnish a reliable correction for the instrument, and with a request for another set of readings.

In some instances differences indicated by comparative readings are due to errors on the part of observers, but more often are occasioned by defects in the instrument. The true source of such differences is generally revealed by a second set of comparative readings, and if these indicate that the instrument is unreliable, it should be repaired or replaced in the interest of safe navigation.

Frequency of comparison.—On account of the severe usage a barometer is subjected to aboard ship its instrumental error is likely to change. Observers should, therefore, take advantage of every opportunity to obtain a comparison with a standard instrument. Aboard steam vessels such a comparison should be made at least once in 3 or 4 months. If the performance of the barometer appears to be questionable, more frequent comparisons are desirable.

No attempt should be made to adjust a barometer. Such attempts are likely to increase the irregularities of the instrument. It is preferable to allow the errors to accumulate, the amount to be determined by frequent comparison, as explained on page 19.

Form No. 1202—Marine.

U. S. WEATHER BUREAU BAROMETER COMPARISON CARD

Vessel, Amer. S. S. *Argonne.* Captain C. P. Snyder.
In port of San Francisco. Observer, G. A. Bryan.
W. B. List Barometer No. 3430. Mercurial or Aneroid? Mercurial.
Address tag to U. S. Transport Service, San Francisco.

The observer is requested to make at least three barometer readings in order that a reliable correction may be obtained. In United States and Canadian ports please make the readings on three successive days, at 7:30 a. m., 75th meridian time, or if in a United States port for a shorter period, make three readings as many hours apart as possible. In European ports make the readings at 7 a. m., Greenwich time.

A tag will be furnished showing the instrumental error of the ship's barometer if the range between the largest and smallest individual corrections in column 4 does not exceed 0.10 inch (2.5 millimeters, or 3 millibars).

Date, 1923	Time (local)	1 Ship's barometer (as read off)	Attached thermometer	Observers will leave these columns blank		
				2 Reduced	3 Standard	4 Correction
Sept. 17	7:30 a. m.	29.83	75	29.68	29.71	+.03
Sept. 18	7:30 a. m.	30.06	67	29.94	30.00	+.06
Sept. 19	7:30 a. m.	30.16	66.5	30.04	30.07	+.03

In United States ports no postage is required; in foreign ports hand to United States consul.

Change in barometers.—Ordinarily only a barometer bearing an identification number assigned by the Weather Bureau should be used in the regular meteorological work for the bureau. This number should be stated in every Weather Report and on every Barometer Comparison Card. If, for any reason, another barometer is used, the fact should be made clear in order that no mistake may be made in applying corrections. If a new barometer is used comparative readings should be furnished with the first report, or as soon thereafter as possible.

THERMOMETERS

Thermometers should be of reliable manufacture and should have the graduations etched upon the glass stem. For some years after a thermometer has been manufactured the glass in the bulb contracts and, notwithstanding that a certain period of "curing" is allowed by good manufacturers, this contraction not infrequently results in appreciable error in the readings. On this account it is necessary to compare the readings of a thermometer with those of a standard instrument to ascertain if any error exists and, if so, the proper correction to be applied to the readings. Ordinarily no thermometer should be employed the indications of which at any point on the scale differ by more than 1° from the true temperature given by a standard instrument.

Use of thermometers in meteorological observations.—The principal use of thermometers in meteorological observations is for the purpose of determining the temperature and humidity of the free air. The actual temperature of the air is obtained from the reading of an ordinary thermometer. The humidity is determined by measuring the so-called temperature of evaporation and comparing this with the temperature of the air. The "temperature of evaporation" is given by the reading of a thermometer whose bulb is covered with thin muslin and moistened with water. If two thermometers, one with its bulb moistened, the other with its bulb completely dry, are exposed to a rapidly moving current of air, the thermometer with moistened bulb (the so-called wet-bulb thermometer) will show a lower temperature than the dry bulb, or ordinary unmoistened thermometer. The difference between the two bears a known relationship to the humidity, the latter being obtained with the aid of appropriate tables.

Thermometers are also employed in obtaining the temperature of the ocean surface. This is an important element in all meteorological observations made at sea.

Exposure of thermometers.—The free air is nearly always in motion and therefore is so thoroughly intermixed locally that within a small area no appreciable temperature differences are likely to exist. When any portion of the air is confined, however, so that it cannot intermingle freely with the general air currents, its temperature will be influenced to a marked extent by the local surroundings and will not be a free-air temperature.

These ideas show us at once that if we aim to make accurate observations of the air temperatures our instruments must, if possible, be placed in an open space where the circulation of the air is entirely unobstructed. It will not do, however, to place the thermometers simply in the open air, exposed freely to the sky and the direct rays of the sun. The sunshine would cause the thermometers to register too high, and even if the instrument were not exposed directly to the sun it could not be depended upon to indicate the true air temperature. To overcome these difficulties, it is customary to employ some sort of shelter. The form adopted by the Weather Bureau for the use of its observers on land is a box with louvered sides and a double roof, made in such a way that the air can move through it with the greatest possible freedom. To minimize the effects of insolation and conduction of heat, shelters should be made of wood and painted white. This is an essential condition for proper exposure. The object of the shelter is simply to screen off the direct and reflected sunshine and the radiation to and from the sky and to keep the instruments dry.

Although a thermometer shelter can easily be set up in a suitable permanent position on land, experience has shown that on shipboard it is virtually impossible to mount a shelter in a convenient, fixed location in such a way that its exposure is not appreciably affected at times (particularly in the case of a following wind) by radiation from the deck or some nearby portion of the ship's superstructure and by currents of warm air issuing from the interior of the vessel. These undesirable effects may be eliminated to a large extent if use is made of a portable shelter, which can be suspended on the weather side before the observation is taken, in a position where it is freely exposed to the wind and unaffected by artificial sources of heat.

However, even a portable shelter has serious draw-backs. In the first place, it possesses the undesirable feature common to all types of shelters, namely, that it affords little, if any, protection from flying spray. If it is allowed to stand continuously out of doors the thermometers inside it, unless they are cleaned from time to time, will become coated with a thin deposit of salt. Thus the wet bulb, though pure water be applied to it, will in reality be moistened by a weak salt solution. Since dissolved salt has the effect of decreasing the rate of evaporation, the temperature indicated by the wet-bulb thermometer will be somewhat higher than the true wet-bulb temperature. Furthermore, the problem of subjecting thermometers that are housed in a shelter (portable or otherwise) to the proper ventilation necessary for accurate humidity measurements presents obvious difficulties. Finally, there is always the danger that the shelter itself may be smashed or carried away in heavy weather, especially if it is mounted (as it ought to be, in order to secure true air temperatures) in an exposed position.

The conclusion is that a thermometer shelter, though it serves its purpose satisfactorily on land, is not well suited for use on shipboard. Therefore, it is desirable, whenever possible, to employ some special type of instrument whose readings of air temperature will not be affected by direct exposure of the thermometers to sunshine and rain.

The aspiration thermometer.—The instrument best adapted to the accurate measurement of air temperatures at sea is the portable aspiration thermometer. Its essential features are (1) protection of the thermometer bulb from radiation (direct sunshine or deck radiation) by means of a tubular shield, made of a good reflecting and insulating substance; (2) artificial ventilation of the thermometer bulb, which is produced by a mechanically driven fan attached to the top of the instrument. The chief advantages of the aspiration thermometer are three-fold. Exposure to direct sunshine will not affect its readings. Consequently there is no necessity for placing it in the shade at the time an observation is made. When not in use it may be hung in the chart room or other convenient place where it will be protected from the effects of fog, rain, and spray. Finally, when an observation is made, the observer can readily select the most suitable exposure under the conditions prevailing at any given hour of observation and make the reading directly at that point.

For the measurement of temperature alone there is available a type of aspiration thermometer (dry bulb only) that is rugged and especially constructed for use at sea. This instrument is comparatively inexpensive.

PSYCHROMETERS

From the foregoing considerations it follows that, purely from the standpoint of accuracy, the ideal method of obtaining simultaneously the true air temperature and humidity on shipboard is the use of an aspirating instrument that is equipped with two thermometers—one a dry bulb, the other a wet bulb. Such an instrument is known as an aspiration psychrometer. However, the type now available is both expensive and delicate. It is also rather heavy and difficult to handle, especially on a ship that is rolling or pitching. Furthermore, to keep it in proper condition requires a great deal of care and attention. From a practical standpoint, therefore, it is not really suitable for making routine observations at sea.

The sling psychrometer.—There is another and well-known type of portable ventilated instrument called the sling psychrometer, with which it is possible to measure both air temperature and humidity at sea with a reasonable degree of accuracy, at least with greater accuracy than can be secured through the use of stationary thermometers in a shelter. The sling psychrometer has the disadvantage that the two thermometer bulbs are not afforded protection from rain and direct sunshine, but errors arising from the latter source are, to a large extent, overcome by the strong ventilation to which the apparatus may be subjected. The instrument is comparatively inexpensive, light, and easy to handle. Although it is designed especially for measuring both dry- and wet-bulb temperatures, it can, of course, be used to measure the air temperature alone, in which case a reading of the wet-bulb thermometer is not necessary. If the ship is equipped with a sling psychrometer, the observer will always be able to measure the air temperature at the point which happens to provide the best "free-air" exposure under the existing conditions. The point of observation should always be on the windward side of the ship and preferably near the bow or the stern, depending upon whether the apparent wind is forward of or abaft the beam. It will usually be most convenient, however, to make the observation on the wing of the bridge. The instrument should then be held outside the rail and on the weather side. But if spray is continually being blown aft from the bows, it will be necessary for the observer to seek a more favorable location.

It is very difficult to describe effectually the movements incident tilated psychrometer as part of their regular meteorological equipment. A comparatively rugged type (Bureau of Mines type) of sling psychrometer, and one that is well fitted for use on shipboard, is shown in figure 11. In this instrument the thermometer bulbs are partially protected by a rectangular frame which encloses the other parts of the apparatus.

It is very difficult to describe effectually the movements incident to skillful whirling and stopping of the sling psychrometer. The arm is held with the forearm about horizontal, and the hand well in front. A peculiar swing starts the thermometers whirling, and afterward the motion is kept up by only a slight but very regular action of the wrist, in harmony with the whirling thermometers. The rate should be a natural one, so as to be easily and regularly maintained. If too fast, or irregular, the thermometers may be jerked about in a violent and dangerous manner.

The stopping of the psychrometer, even at the very highest rates, can be perfectly accomplished in a single revolution, when one has learned the knack. This is only acquired by practice, and consists of a quick swing of the forearm by which the hand also describes a circular path, and, as it were, follows after the thermometers in a peculiar manner that wholly overcomes their circular motion without the slightest shock or jerk. The thermometers may, without very great danger, be allowed simply to stop themselves; the final motion in such a case will generally be quite jerky, but, unless the instrument is allowed to fall on the arm, or strikes some object, no injury should result.

It is important that the muslin covering for the wet bulb be kept in good condition. The evaporation of the water from the muslin always leaves in its meshes a small quantity of solid material, which sooner or later somewhat stiffens the muslin so that it does not readily take up water. On this account it is desirable to use as pure water as possible, and also to renew the muslin from time to time. New muslin should always be washed to remove sizing, etc., before being used. A small rectangular piece wide enough to go about one and one-third times around the bulb, and long enough to cover the bulb and that part of the stem below the metal back, is cut out,

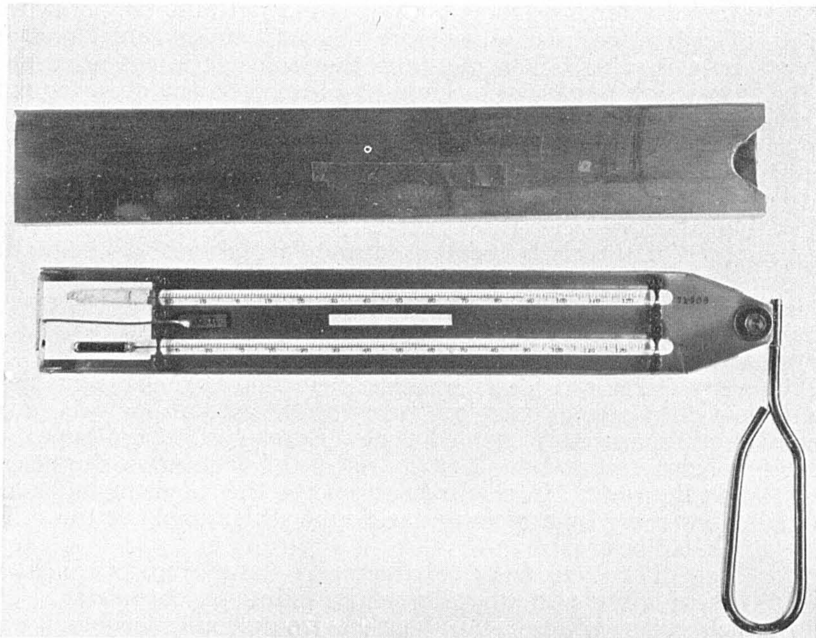


FIGURE 11.—Sling psychrometer (Bureau of Mines type).

thoroughly wetted in clean water, and neatly fitted around the thermometer. It is tied first around the bulb at the top, using a moderately strong thread. A loop of thread to form a knot is next placed around the bottom of the bulb, just where it begins to round off. As this knot is drawn tighter and tighter the thread slips off the rounded end of the bulb and neatly stretches the muslin covering with it, at the same time securing the latter at the bottom.

Certain precautions must be observed in preparing and fitting the muslin covering of the wet bulb as follows:

(1) Fine, preferably loosely woven, muslin is the best, and, if new material is used, it must first be thoroughly washed with water to remove all sizing as far as possible.

(2) The covering must be carried up on the stem of the thermometer above the bulb a distance so that the stem near the bulb, as well as the bulb itself, is cooled by the evaporation.

(3) The muslin must be thoroughly wetted when a new piece is to be applied to the bulb, and fitted in the manner already explained.

The psychrometer should at all times be handled with great care, and when not in use it should always be kept in the case provided by the manufacturer of the instrument. The fact that the thermometer bulbs project below the metal back makes them very susceptible to breakage. Consequently, when the psychrometer is being whirled, the utmost caution should be exerted to make sure that the thermometers have plenty of room in which to swing clear of all obstacles.

BUCKET AND INTAKE METHODS OF OBTAINING OCEAN SURFACE TEMPERATURES

Experience has shown that numerous difficulties exist in the making of accurate observations of the temperature of the sea surface. Both the bucket and intake methods commonly employed on steamships have their own peculiar disadvantages and sources of error. It is the temperature of the sea surface that is desired, but the condenser-intake method gives temperatures at some distance below the surface. This is not objectionable, however, since the water between the surface and intake depth is almost always so well stirred by wave action that its temperature is essentially uniform to that depth.

The bucket method is always a time-consuming operation and is particularly troublesome on large ships. It is not an easy matter to dip out a sizable sample of water with a bucket when the ship is moving rapidly. Often the bucket can be only partially filled, even by the most skillful handling. (Some vertical stiffening of the ordinary canvas bucket and an extra middle ring, to prevent collapse on entering the water, are desirable.) Further difficulty is encountered while the sample is being hauled up to the deck—the force of the wind, which is often considerably augmented by the movement of the ship, may cause the bucket to swing about and strike the side of the vessel, thereby spilling a large part of the water.

In addition to the difficulties of obtaining a satisfactory sample by the bucket method, there exist a number of influences tending to change the original temperature of the sample. These are, notably: (1) The bucket itself is not likely to have the same initial temperature as the sea surface; (2) a small quantity of water left from a previous observation and having a temperature different from that of the sea may be in the bucket when the dip is made; (3) the water sample being hauled up is usually cooled by evaporation, especially in the case of a canvas bucket; (4) the thermometer inserted is seldom at the same temperature as the water in the bucket; (5) while the thermometer is resting in the bucket further cooling, or perhaps heating, of the water may take place, and (6) sometimes the temperature of the water drawn up has been affected by the discharge through ejection pipes. However, it is possible to avoid these undesirable effects to some extent. How this may be accomplished is described on pages 49 and 50.

If observations by the condenser-intake method are carefully made, the only source of error of any consequence arises from imperfect installation of the intake thermometer. If the latter is at a point in the injection pipe where the circulation is locally reduced and where pockets of warmed water can collect, the readings will be higher than the true ocean temperature. However, errors on this score will be avoided if the thermometer is mounted on the centrifugal pump or at some point on the intake pipe between the pump and the ship's side. It has been found by experiment that the best method of installation is to fit the thermometer in a stainless steel tube, the lower end of which is bathed by the incoming sea water. This lower end of the tube should be filled with enough mercury to surround the bulb of the thermometer completely, thus assuring good conduction of heat between the sea water and the bulb.

The practical disadvantages peculiar to the condenser-intake method can be serious. In the first place, there is the difficulty of finding a place of installation for the thermometer which combines the desirable qualities of proper exposure and accessibility. In the second place, there is the ever-present danger of error of parallax in reading the thermometer. It is not often possible to install the thermometer in a place which affords a suitable exposure and at the same time permits the eye to be on a level with the top of the fluid without the observer assuming an awkward or uncomfortable posture. In the third place, there is the necessity of securing the cooperation of the engineer on duty at the time that a meteorological observation is made. The engineer should realize that a greater degree of accuracy is required in obtaining the ocean temperature for the weather report than in noting the approximate temperature of the water circulating through the cooling system.

The condenser-intake method is the simpler and shorter means of obtaining the water temperature. It is the more certain method and the more accurate, where the required standards of installation and of careful observation are met. However, circumstances vary greatly on different ships, and the selection of the method to be used should be left to the judgment of the individual observer. He should make the choice after a careful consideration of the conditions existing on his ship. That method which will consistently give the most satisfactory results should, of course, be employed.

An entry should be made in the appropriate space on Form 1210A to show which method is used in securing sea-water temperatures.

PART IV. INSTRUCTIONS FOR TAKING AND RECORDING WEATHER OBSERVATIONS

For many years, wind and weather and condition of the sea have been subjects of daily entries in the ship's log, hence the taking of systematic observations for the Weather Bureau does not involve much additional time. However, weather conditions are recorded in somewhat more detail than in the ship's log; moreover, the readings of the barometer and thermometer are used in preparing weather maps, hence their errors must be known so that corrections may be applied. The proper methods of installing, reading, and caring for the meteorological instruments are fully described in Part III.

The observations are recorded on special forms (1210A–Marine) provided by the Weather Bureau. Ships reporting by mail enter only one observation a day, at Greenwich mean noon. Also on radio-reporting ships, when outside the areas from which daily radio reports are sent, the observations are entered only once each day at Greenwich mean noon. On all ships cooperating with the Weather Bureau, by radio or mail, it is desired that appropriate entries be made in the spaces for "Daily Journal" and also in the spaces for "Gale or Storm", and "Fog" reports.

The forms provide for 10 observations on each sheet. However, it is requested that the observer begin a new record sheet upon crossing from one ocean to another, and on the first of a new month. The reason for this request is that the forms are filed at the Weather Bureau in separate compartments for the oceans and months, hence special compartments must be provided for forms which contain observations for more than one ocean or more than one month. It is also highly desirable that the forms be mailed at the end of a voyage, even if a sheet is not filled; a new sheet should be started at the beginning of the next voyage.

The various columns on Form 1210A are grouped in such a way that all the so-called Universal Data will be recorded exactly in the order specified by the International Radio Weather Code. The columns for these data are boxed off from the other columns on the form by heavy black lines. However, in obtaining and entering the data at the time of an observation the observer does not necessarily proceed across the sheet from left to right. It is most natural to enter simultaneously the data relating to the day, the hour, and the ship's geographical position. The actual weather observations, likewise, are entered in a group. Therefore, in the following paragraphs detailed instructions for the taking and recording of a complete observation will be given as nearly as possible in the order usually followed, and not strictly in order from left to right on the form.

When a new form is begun the first step is to fill in the blank spaces at the top of the sheet. This entails the entry of the vessel's name, etc., and of details relating to the character of the instrumental equipment.

Notes on instruments used.—The kind of barometer, whether aneroid or mercurial, should be given, with the identification number furnished by the Weather Bureau.

The same barometer should be employed continuously. If for any reason it becomes necessary to use another instrument, the fact should be stated, the reasons given, and the second instrument fully described, in order that the readings of the latter may not be confused with the readings of the barometer listed by the Weather Bureau.

The error of the barometer should be entered as determined by the last comparison with a standard instrument; also the place and date of this last comparison in the space provided.

If it is a mercurial barometer, the scale of the attached thermometer employed, whether Fahrenheit, Centigrade, or Absolute, should be stated.

Space is provided at the top of the form for indicating how the sea-surface temperature is measured. It is desirable to know this, because the temperature of a sample of sea water obtained by means of a bucket is, within a very few minutes, apt to become somewhat different from the true temperature of the ocean surface, and a thermometer installed in the condenser intake may be affected by the heat of the engine room.

It is important also to state whether the temperature of the air and also the wet-bulb temperature are measured with stationary thermometers or with a psychrometer (i. e., a pair of ventilated thermometers), because stationary thermometers, as pointed out in Part III, give much less accurate results than the psychrometer. Furthermore, the formula employed for determining the relative humidity from the readings of a psychrometer is not applicable to the readings of a stationary wet-bulb thermometer.

TIME AND POSITION

Day of month.—The date given in the column at the left of each page should be the civil day, beginning at a given midnight and ending at the following midnight.

In crossing the 180th meridian, observers aboard westward-bound vessels sometimes make the mistake of dropping a day from the record of the Greenwich mean noon observations, and conversely of using the same date twice when eastward bound. This is incorrect. In crossing the date line, 24 hours are dropped or repeated as the case may be, in local time reckoning, but not, of course, in the dates of the Greenwich noon observations, which should run consecutively. To avoid any confusion regarding the dates of observations, the observer should remember that when Greenwich noon observations are taken regularly there should never be two of the same date and never any date without an observation.

When radio observations are taken regularly at Greenwich midnight there may be two midnight observations on the same local date, or none at all, depending on the vessel's course, whether eastward or westward when crossing the 180th meridian. The Greenwich date of the midnight observations is always the *day just beginning at Greenwich.*

Local ship's time.—The small chart given on page 120 shows the local time corresponding to Greenwich mean noon for each 15° of longitude east and west, i. e., the local (ship's) time at which the daily observation should be taken to the nearest hour. The exact local time at which the observation in any longitude, east or west, should be taken may easily be found from the table of longitude and time (table 9). In east longitude, the Greenwich noon observation should always be taken during the afternoon hours, local time; in west longitude, during the forenoon hours.

Day of week ($\bar{Y}$).—One figure only should be entered in this column to indicate the day. The appropriate code figures for each day of the week are given in the table for Y. The observer should be careful to record the day of the week at Greenwich and not that at the ship, unless the Greenwich day and local day happen to be the same. When an observation is taken at 0000 G. C. T. (Greenwich midnight), the day of the week should be coded as the day just beginning and not the day just ended.

Code table for Y (day of the week)

Day	Code figures
Sunday	1
Monday	2
Tuesday	3
Wednesday	4
Thursday	5
Friday	6
Saturday	7

Octant of globe (Q).—The correct entry in this column is determined by the position of the ship with respect to the equator and to the meridian of Greenwich. The proper code figure is obtained from the accompanying table.

Code table for Q (octant of the globe)

Longitude	Code figures
North latitude:	
0° W. to 90° W.	0
90° W. to 180° W.	1
180° E. to 90° E.	2
90° E. to 0° E.	3
South latitude:	
0° W. to 90° W.	5
90° W. to 180° W.	6
180° E. to 90° E.	7
90° E. to 0° E.	8

Latitude (LLL) and longitude (lll).—In these columns should be recorded the latitude and longitude of the vessel at the actual time of the meteorological observation. Three figures should always be entered in each column. No code table is necessary for these entries.

In the LLL column the first two figures to be recorded are the latitude in whole degrees. If the latitude is less than 10°, a 0 (zero) should be entered as the first figure. The third figure is the fraction of a degree of latitude, which is recorded in tenths of a degree, and not in minutes of arc. The tenths are obtained by dividing the minutes of arc by 6 and neglecting the remainder. (Examples: (a) latitude 42°38′ N. is coded 426; (b) latitude 10°20′ N. is coded 103.) The differentiation between north and south latitude is shown by the figure for Q in the preceding column.

In the lll column the longitude is recorded in degrees and tenths in the same manner as for the latitude. If the longitude is 100°, or more, the first figure, 1, should be dropped. (Examples: (a) longitude 46°22′ W. is coded 463; (b) longitude 123°41′ W. is coded 236.) The differentiation between longitudes less than 100° and greater than 100° and also between east and west longitude is shown by the figure entered in the Q column.

The columns for latitude and longitude should always be filled out to the best of the observer's ability, even though astronomical observations or radiocompass bearings have not been obtained.

When the position is doubtful, a note should be made to that effect.

Greenwich civil time (GG). In this column the Greenwich time of the observation should be recorded to the nearest whole hour. Two figures should be entered, according to the scale 00 to 24. When observations are reported by mail only they are entered once daily at 12 hours G. C. T. Observations to be sent by radio are entered twice daily at 00 and 12 hours, G. C. T. Intermediate observations for radio messages are sent in certain seasons from ships specially designated for that purpose, the hours being 06 and 18, G. C. T.

WIND

Wind direction (DD).—The direction of the wind to be recorded is the *true* direction, not the magnetic. Its direction as given by the compass should, therefore, be corrected for the magnetic variation and for the deviation, if this is large, as is sometimes the case.

The direction of the wind is best ascertained by making use of the fact that the crest lines of the smallest ripples on the sea surface are perpendicular to the direction of the wind. These ripples, as every seaman knows, are very sensitive to sudden changes in the character of the wind. Accentuation of them by a localized increase in wind velocity produces an apparent darkening of the sea surface, which serves to show the rate of travel of individual gusts or puffs. With wind forces of 6 (Beaufort) or more the wind direction may also be correctly estimated from the direction of the streaks of foam which are then formed. At night, however, the observer may not be able to distinguish the ripples on the surface, or, if it is raining very hard, the pattern of the wind ripples may be obliterated. In these circumstances use may be made of the "apparent" wind (see p. 37) properly corrected for the movement of the ship.

The direction of the wind may be entered in the appropriate column on Form 1210A either directly in terms of compass points or in code, according to the scale 01—32, in which 08=E, 16=S, etc. However, inasmuch as the wind direction must be coded in figures whenever an observation is transmitted by radio, it is customary for most observers to enter the code number, and this procedure is preferred by the Weather Bureau. Therefore, observers who have been accustomed to recording the wind direction directly in terms of compass points are urged to make a practice of using the numerical scale instead. This scale is given in the code table for DD shown on the following page.

Occasionally the observer is confronted by a peculiar problem when making an observation. If a squall happens to pass over the ship just at the time of observation the direction of the wind may suddenly change by an appreciable amount. The observer may not be able to tell whether the change represents a definite and widespread shift or simply a local disturbance, after the passage of which the wind will revert to the direction it had maintained prior to the squall. If he believes that it represents a local and temporary condition, he may think it proper to record the wind direction which had prevailed before the squall. The correct procedure in such a case is as follows: *Record the wind direction that happens to be prevailing at the moment of observation, even if it may appear to* *be only temporary; in coding the radio message, add the number 67 to the code number appropriate to the observed wind direction.* This will indicate to the person receiving the message that a squall is occurring at the time of observation or has occurred during the preceding hour, and that any apparent peculiarity in the wind direction is to be regarded as having purely local significance. As a matter of fact, the number 67 should be added to the number for the wind direction whenever squalls have occurred during the hour preceding the observation, even if these squalls did not appreciably change the wind direction. More details in this connection are given in the section containing instructions for recording "present weather."

Code table for DD (wind direction)

[Direction from which wind is blowing]

Code figures	True directions	Code figures	True directions
00	Calm.	17	S. by W.
01	N. by E.	18	SSW.
02	NNE.	19	SW. by S.
03	NE. by N.	20	SW.
04	NE.	21	SW. by W.
05	NE. by E.	22	WSW.
06	ENE.	23	W. by S.
07	E. by N.	24	W.
08	E.	25	W. by N.
09	E. by S.	26	WNW.
10	ESE.	27	NW. by W.
11	SE. by E.	28	NW.
12	SE.	29	NW. by N.
13	SE. by S.	30	NNW.
14	SSE.	31	N. by W.
15	S. by E.	32	N.
16	S.		

Rapid and pronounced changes of the wind should be noted under the heading "Daily Journal" on Form 1210A. In recording any large change the observer should specify the time at which it occurred, the direction of the change, and the force on the Beaufort scale; for example, "at 10 a. m. wind veered from SE, 3, through S, to W, 8."

Observers sometimes fail to distinguish between shifting winds and variable winds. The term "shifting" applies to winds whose direction is changing in accordance with the movement or development of some well-marked cyclonic or anticyclonic system. The term "variable" applies to weak winds (force 3 or less) whose direction is indefinite, coming in feeble puffs, first from one point, then from another. The term "variable" should be applied also to the strong but short-lived winds which are associated with local squalls.

Wind force (F).—To an experienced observer the appearance of the sea surface serves as the best means of estimating the true wind force, just as it affords the best means of ascertaining correctly the wind direction. However, the appearance and the roughness of the sea obviously depend upon a number of factors, and not solely on the strength of the wind locally. The length of time the wind has been blowing and the rate at which it is changing its direction and velocity are some of the more important influences. Consequently it is virtually impossible to lay down reliable criteria which will be valid at all times; a precise knowledge of the relation of wind force to the appearance of the sea must be gained by experience.

In recording the force of the wind, the scale devised by Admiral Sir Francis Beaufort is employed. According to this scale, which is contained in the code table for F below, the wind varies from 0, a calm, to 12, a hurricane, rated as the highest force ever attained. When a weather report is to be transmitted by radio, the proper code number for the wind force in the radio message is the same as the Beaufort number on the form, provided that the wind force is not greater than 9. Since the International Radio Weather Code permits the sending of but one figure for the wind force, winds of greater strength than force 9 must be reported by radio in a special manner. The procedure in such cases is as follows: *If the wind force is 10, 11, or 12, Beaufort, the force should be reported in the radio message as 9, but at the end of the report a word, "gale", "storm", or "hurricane", respectively, should be added in plain language.* However, the figure 9 should not be entered on the observation form for forces of 10, 11, or 12. The higher force should be recorded there exactly as observed.

Code table for F (wind force, Beaufort scale)

Beaufort number		Code figures
Zero	Calm	0
One	Light airs	1
Two	Light breeze	2
Three	Gentle breeze	3
Four	Moderate breeze	4
Five	Fresh breeze	5
Six	Strong breeze	6
Seven	High wind (moderate gale)	7
Eight	Gale (fresh gale)	8
Nine	Strong gale	9
Ten	Whole gale [1]	9
Eleven	Storm [1]	9
Twelve	Hurricane [1]	9

[1] When force is in excess of strong gale the observer uses code figure 9 and adds word "gale", "storm", or "hurricane" (as the case may be) to the end of the message.

Assuming that the ship is in the open sea where there is an absence of appreciable current, and that the wind direction and force have remained essentially constant for a sufficient length of time so that the sea surface is in equilbrium, so to speak, with the wind, the following conditions usually are observed. With force 0 (calm) the surface of the sea is glassy; with force 1 the sea tends to be rippled in patches. With force 2 the entire surface of the sea is rippled and miniature waves several inches in height are formed. One of the principal distinctions between force 1 and force 2 is afforded by the distinctness with which the sea horizon may be seen on clear days. With force 1 the horizon presents an indefinite line, whereas with force 2 the horizon is quite sharply delineated. A wind force of 3 produces a definite wave formation with scattered incipient whitecaps making their appearance. Force 4 is characterized by numerous well-developed whitecaps, which give the ocean a spotted appearance. Force 4 produces a distinct sea which is easily distinguished from any swell that may be prevailing. The difference in the appearance of the ocean surface between forces 4 and 5 is principally one of degree. However, with force 5 spume tends to be blown from the breaking wave crests, whereas no such tendency is noticeable with force 4. No attempt will be made here to describe the appearance of the sea surface with winds of greater strength, because these occur usually in the neighborhood of cyclonic storm centers where the rapid changes of direction and velocity do not permit the sea to reach a state of equilibrium with respect to the wind at any given time.

The motion of the air is never perfectly uniform, but is subject to incessant variations in direction and velocity. These variations are designated as "turbulence" or "gustiness." The occurrence of *unusual* gustiness should always be noted in the weather report. Unusual gustiness is reported in the radio message by adding 33 to the appropriate code number for the wind *direction*. It should not be reported by describing or coding the state of weather as "squally." Gusts are distinguished from squalls by their brief duration, by the absence of any special accompanying cloud formation and by the fact that the wind does not vary appreciably from its average direction. Unusual gustiness may be defined as the condition prevailing when the wind temporarily exceeds its average force by a full figure or more on the Beaufort scale but continues essentially (i. e., to within two points) from the same direction. Care should be taken that the average force of the wind is recorded, and not its force during the gusts.

The apparent and the true direction and force of the wind.—The apparent direction and velocity of the wind is the resultant of two motions, that of the vessel and that of the air. As an example of this, take the case of a vessel steaming westward 20 knots, and let the true direction of the wind be due north, or 8 points off the starboard bow, its true velocity 20 knots. Let *A D* (fig. 12), represent the true direction and velocity of the wind; *B D* the direction (west) and the velocity (20 knots) of the wind created by the motion of the steamer. Then *C D*, the resultant of *A D* and *B D*, will be the apparent direction and velocity of the wind as observed aboard the steamer; i. e., the wind, while its true direction is due north (8 points off the starboard bow), and its true velocity 20 knots, will apparently be NW. (4 points off the starboard bow), and will have an apparent velocity of 28 knots.

The true direction of the wind is thus always farther from the bow than the apparent direction.

The true velocity of the wind is greater than the apparent as long as the apparent direction is aft of the beam.

The true velocity of the wind is less than the apparent as long as the true direction is forward of the beam.

Having observed the apparent force and direction of the wind, in points off the bow, the true force and direction may be taken from the table on pages 116 and 117.

The following examples will serve to illustrate the manner of using the table:

1. Let the true course and speed of the vessel be SSW., 20 knots, the apparent force of the wind, 0 (dead calm). The true direction of the wind is NNE. (16 points off the bow); its true force is 5.

2. Let the true course and speed be WSW., 15 knots, and let the apparent wind be NW. (6 points off the bow), force 1; referring to the table we see that the true direction of the wind in this case is 15 points off the bow (NE. by E.), and that its true force is 4.

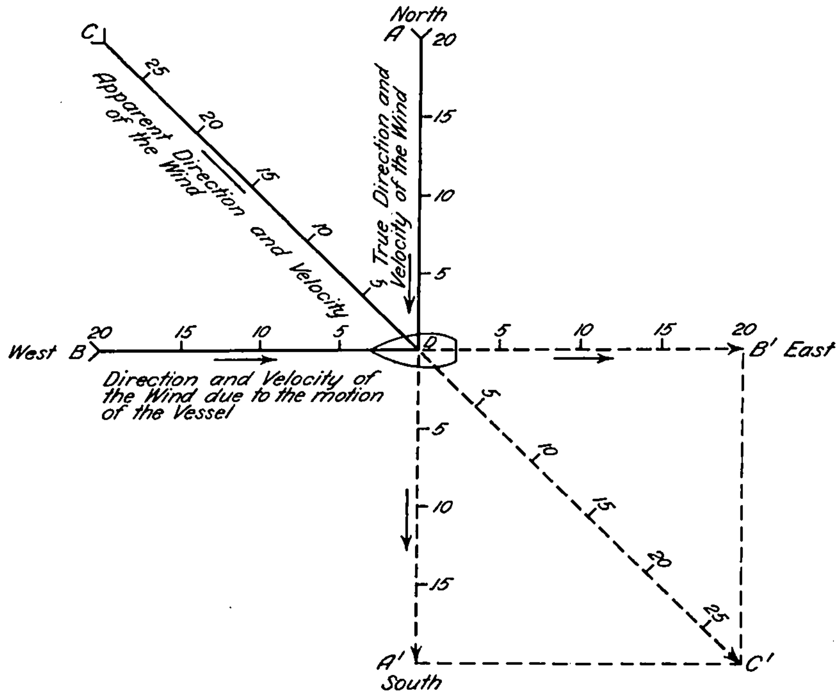


FIGURE 12.—True direction and velocity of the wind determined from the apparent wind and motion of vessel.

3. Let the true course and speed be E., 10 knots, the apparent wind SW. (12 points off the bow), force 3. The true direction of the wind is 14 points off the bow (WSW.), the true force is 5.

4. Let the true course and speed be NE., 20 knots, the apparent wind SW. (16 points of the bow), force 6, the true direction is still SW.; the true force, however, is 9.

WEATHER

In the column headed "Present weather" (ww) on Form 1210A, the state of the weather must be indicated by entry of one of the numbers (00 to 99) in the following code table for *ww*. Figures are necessary in preparing the radio messages. Only one number (two figures) can be sent, but more than one number for weather may be entered on the form, if appropriate. If two or more numbers are entered, they should be separated by dashes or written one above the other.

When two or more numbers are entered to describe the state of the weather, the observer should be guided by the instructions which follow in the next section as to which number is the more important for the radio message; provided, of course, that the vessel is scheduled to send a report by radio.

Code table for ww (present weather)

ABBREVIATED DESCRIPTION OF SKY AND SPECIAL PHENOMENA

00 Cloudless.
01 Partly cloudy.
02 Cloudy.
03 Overcast.
04 Low fog, on ground or over sea.
05 Haze (but visibility greater than 2,000 m., 2,200 yds).
06 Dust devils seen.
07 Distant lightning.
08 Light fog (visibility between 1,000 and 2,000 m., 1,100 and 2,200 yds).
09 Fog at a distance, but not at the ship.
10 Precipitation within sight.
11 Thunder, without precipitation at the ship.
12 Dust storm within sight, but not at the ship.
13 Ugly, threatening sky.
14 Squally weather.
15 Heavy squalls } in last 3 hours
16 Waterspouts seen } in last 3 hours
17 Visibility reduced by smoke (industrial, grass or forest fires), or volcanic ashes.
18 Dust storm (visibility greater than 1,100 yards).
19 Signs of tropical storm (hurricane).

PRECIPITATION IN LAST HOUR BUT NOT AT TIME OF OBSERVATION

(20–29: In last hour but not at time of observation.)

20 Precipitation (rain, drizzle, hail, snow, or sleet)
21 Drizzle } other than showers
22 Rain } other than showers
23 Snow } other than showers
24 Rain and snow, mixed } other than showers
25 Rain shower (s).
26 Snow shower (s).
27 Hail or rain and hail shower (s).
28 Slight thunderstorm.
29 Heavy thunderstorm.

DUST STORMS AND STORMS OF DRIFTING SNOW

(Visibility less than 1,000 m., 1,100 yards)

30 Dust or sand storm.
31 Dust or sand storm has decreased.
32 Dust or sand storm, no appreciable change.
33 Dust or sand storm has increased.
34 Line of dust storms.
35 Storm of drifting snow.
36 Slight storm of drifting snow } generally low.
37 Heavy storm of drifting snow } generally low.
38 Slight storm of drifting snow } generally high.
39 Heavy storm of drifting snow } generally high.

FOG

(Visibility less than 1,000 m., 1,100 yards)

40 Fog.
41 Moderate fog in last hour } but not at time of observation.
42 Thick fog in last hour } but not at time of observation.
43 Fog, sky discernible } has become thinner during last hour.
44 Fog, sky not discernible } has become thinner during last hour.
45 Fog, sky discernible } no appreciable change during last hour.
46 Fog, sky not discernible } no appreciable change during last hour.
47 Fog, sky discernible } has begun or become thicker during last hour.
48 Fog, sky not discernible } has begun or become thicker during last hour.
49 Fog in patches.

DRIZZLE

(Precipitation consisting of numerous minute drops)

50	Drizzle.
51	Intermittent } slight drizzle.
52	Continuous } slight drizzle.
53	Intermittent } moderate drizzle.
54	Continuous } moderate drizzle.
55	Intermittent } thick drizzle.
56	Continuous } thick drizzle.
57	Drizzle and fog.
58	Slight or moderate } drizzle and rain.
59	Thick } drizzle and rain.

RAIN

60	Rain.
61	Intermittent } slight rain.
62	Continuous } slight rain.
63	Intermittent } moderate rain.
64	Continuous } moderate rain.
65	Intermittent } heavy rain.
66	Continuous } heavy rain.
67	Rain and fog.
68	Slight or moderate } rain and snow, mixed.
69	Heavy } rain and snow, mixed.

SNOW

70	Snow (or snow and rain, mixed).
71	Intermittent } slight snow in flakes.
72	Continuous } slight snow in flakes.
73	Intermittent } moderate snow in flakes.
74	Continuous } moderate snow in flakes.
75	Intermittent } heavy snow in flakes.
76	Continuous } heavy snow in flakes.
77	Snow and fog.
78	Grains of snow (frozen drizzle).
79	Ice crystals; or frozen raindrops (sleet—U. S. definition).

SHOWER (S)

80	Shower (s).
81	Shower (s) of slight or moderate } rain.
82	Shower (s) of heavy } rain.
83	Shower (s) of slight or moderate } snow.
84	Shower (s) of heavy } snow.
85	Shower (s) of slight or moderate } rain and snow.
86	Shower (s) of heavy } rain and snow.
87	Shower (s) of snow pellets (soft hail).
88	Shower (s) of slight or moderate } hail, or rain and hail.
89	Shower (s) of heavy } hail, or rain and hail.

THUNDERSTORM

90	Thunderstorm.
91	Rain at time } thunderstorm during last hour, but not at time of observation.
92	Snow, or rain and snow, mixed, at time } thunderstorm during last hour, but not at time of observation.
93	Thunderstorm, slight without hail or soft hail, but with rain (or snow) } at time of observation.
94	Thunderstorm slight with soft hail } at time of observation.
95	Thunderstorm moderate without hail, but with rain (or snow) } at time of observation.
96	Thunderstorm moderate with soft hail } at time of observation.
97	Thunderstorm heavy without hail, but with rain (or snow) } at time of observation.
98	Thunderstorm combined with dust storm } at time of observation.
99	Thunderstorm heavy with hail } at time of observation.

Situations may occur, however, in which it is especially difficult to decide what is the proper number for the radio message. If the observer has entered more than one number for present weather and, after referring to the instructions, is still in doubt as to which one to send in the radio message, he should send the highest number entered.[1] For example, with entries of 02, 10, 25 (cloudy, precipitation within sight, rain showers in last hour) he should send the number 25 by radio.

In the Daily Journal the weather may be described briefly in plain language, abbreviations, Beaufort notation, or by numbers preceded by "weather" or "wea." For example, "wea 03, 10, 14, 19" would indicate "overcast, precipitation within sight, squally weather, signs of a tropical storm".

Explanatory remarks on the code table for "Present weather" and instructions as to its use.—Since the publication of the previous edition of this manual, the application of new methods of analyzing weather reports for purposes of forecasting and making meteorological studies has served to emphasize the great value of accurate "present weather" observations from ships. This applies particularly to the correct identification of the various precipitation forms. Provision has been made in the International Code for a large number of "present weather" descriptions, as is obvious from a glance at the code table.

The table is divided into 10 "decades", i. e., into 10 groups, each of which contains 10 numbers. These decades, which correspond to 10 main types of weather, are numbered 0 to 9. The first digit of any number in the table indicates the decade to which that particular number belongs.

After the observer has selected the decade which best applies to the prevailing weather conditions, he should pick out from that particular decade the number which most correctly describes the weather at the time of observation or during the hour preceding. Neither when selecting the decade nor in the determination of the complete number must account be taken of weather phenomena which occurred more than 1 hour prior to the time of observation (except in cases ww=15 or 16). Occasionally it will be appropriate to select numbers from two or more different decades for entry on the observation form, as illustrated above. However, in selecting the proper decade and number for transmission in the radio message, the observer should remember that correct and explicit information regarding types of precipitation is of the most value, both to the Government forecaster and to the mariner who is constructing his own weather chart. An accurate report of hydrometeors (i. e., precipitation forms) not only tells what kind of air mass is present but also what kind of thermodynamic process is taking place aloft, the knowledge of both of which is of great assistance in drawing an inference as to the weather of the future. Therefore, *as far as the radio message is concerned, numbers 00–18 should be used only when no precipitation has occurred during the preceding hour, and also no precipitation at the time of observation.*

[1] Exceptional cases in which this rule does not hold will be noted later.

It is *most important* that the number 19 be sent when it applies. When the ship is in tropical or subtropical waters of the North Atlantic Ocean, the Caribbean Sea, the Gulf of Mexico, or the Pacific Ocean off the coast of Mexico or Central America, and there is evidence of the formation of a tropical disturbance, the number 19 from the "present weather" table should be sent in the radio message. Even if the ship is not scheduled to send daily radio reports, a special observation should be sent by radio to "Observer, Jacksonville" when on the Atlantic side and to "Observer, San Francisco" when on the Pacific side. The Government will pay the toll charges on the message.

In selecting the proper number from the table for "Present weather" the following will be of assistance:

(a) A number from decade 2 (numbers 20–29) may be used in combination with a number from some other decade for entry in the observation form, but a number from 20 to 29 should be included in the radio message only in the case of *precipitation during the last hour;* never when precipitation is occurring at the time of observation.

(b) Decade 3 (numbers 30–39) will apply only very rarely, since the numbers contained in it refer to phenomena that occur primarily over land.

(c) Decade 4 (numbers 40–49) should be recorded only in the case of moderate, thick, or dense fog without actual precipitation. The horizontal visibility must be less than 1 kilometer (1,100 yds). Fog, together with actual precipitation, should be reported by one of the numbers 57, 67, or 77.

(d) Decade 5 (numbers 50–59) should be recorded only in the case of drizzle, i. e., fairly uniform precipitation (with or without fog) consisting of tiny and extremely numerous droplets which appear almost to float in the air. Drizzle usually falls out of a continuous, dense and low layer of stratus cloud. It should always be carefully distinguished from fine rain. Small rain drops falling from broken shower-type clouds should never be classified as drizzle. Two criteria which may be helpful in distinguishing drizzle from light rain are: (1) Drizzle droplets falling on absolutely calm water do not produce noticeable ripples when they strike the surface; (2) drizzle is characteristically accompanied by a horizontal visibility of less than 2 nautical miles.

If precipitation is not occuring at the time of observation but there has been drizzle in the preceding hour, one of the numbers in decade 2 should be used. If ordinary rain falls simultaneously with drizzle at the time of observation, one of the numbers 58 or 59 should be used. If fog occurs simultaneously with drizzle, the number 57 should be used.

(e) Decade 6 (numbers 60–69) should be used only in the case of fairly continuous precipitation of ordinary rain drops from a continuous cloud sheet. The sky in this case is, as a rule, covered with a layer of rain clouds forming from an altostratus system, or with a uniformly gray but relatively high canopy of clouds, generally with formless masses of cloud below (which may even be present in such quantity that the upper clouds are completely hidden).

If no rain is falling at the time of observation, but has fallen during the preceding hour, one of the numbers in decade 2 should be used. If, in addition to the ordinary or large rain drops, there are also considerable amounts of very small drops, one of the numbers 58 or 59 of the preceding decade should be used.

(f) Decade 7 (numbers 70–79) should be used only in the case of ordinary snow, grains of snow, or ice particles; that is, fairly continuous precipitation in solid form from a continuous cloud sheet. The sky in this case is generally covered with a layer of snow clouds forming from an altostratus system, or with a uniformly gray but relatively high canopy of clouds, generally with formless masses of cloud below (which may even be present in such quantities that the upper clouds are completely hidden). Sometimes, however, as when isolated snow crystals or small snowflakes fall, the sky may be covered with a layer of stratus or stratocumulus.

Numbers 71 or 72 should be used only when isolated snow crystals fall without causing the horizontal visibility to become less than 4 kilometers (2½ miles). Numbers 73 to 77 should be used in the case of ordinary snowfall. The number 78 should be reserved for granular snow (see Glossary).

The number 79 should be used for ice crystals or for frozen raindrops (grains of ice). These two phenomena, which are rarely, if ever, observed at sea, are quite unlike in character. Furthermore, they do not occur simultaneously. The recipient of the message will be able to judge which one is meant.

If no snow is falling at the time of observation, but has fallen during the preceding hour, one of the numbers in decade 2 should be used. If, in addition to the precipitation in solid form, ordinary rain also falls, the numbers 68 or 69 of the preceding decade should be used.

(g) Decade 8 (numbers 80–89) should be used only in the case of precipitation of a *showery* character, but no thunderstorm, at the time of observation. The showery character is distinguished not only by the rapid beginning and cessation of the precipitation, and by its widely varying intensity, but also, and primarily, by the appearance of the sky—rapid alternation between dark threatening shower clouds and short bright periods, often with deep blue sky. Sometimes there is no definite bright period between showers, which is due either to a layer of high cloud (often the forerunner of a new rain area) or to the spaces between the shower clouds being filled up with low but lighter clouds. It may also happen that the precipitation never completely ceases between the showers; the arrival of a shower cloud is then manifested by a sudden darkening of the sky and by a sudden increase in the intensity of the precipitation.

(h) Decade 9 (numbers 90–99) should be used only in the case of a thunderstorm; that is, precipitation at the time of observation with thunder at the same time or during the preceding hour.

(i) When precipitation has been going on for a long time, the observer has no difficulty in deciding whether it is of the shower type, continuous type, or intermittent type, but when the precipitation has only recently begun the observer may often find it difficult to decide to which type the precipitation belongs.

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Recommendations regarding the procedure for reporting precipitation that has recently begun are as follows: If the precipitation is not clearly of the "shower" type, the observer should report it by one of the numbers of the appropriate decades, according as it is "drizzle", "rain", or "snow." In determining whether the precipitation is of the "continuous" or "intermittent" type, the observer should be guided by the character of the precipitation during the period since it began and by his experience of the weather of the last three hours.

(j) Use of the numbers 20, 30, 40, 50, 60, 70, 80, 90 must be avoided if possible. The descriptions accompanying these numbers are not specific enough to be of any great value. The numbers have been introduced in the table solely to meet certain exceptional cases, such as when the observer is unable, because of darkness, to determine which number in the complete scale should be used. It is desirable that their use be strictly confined to unusual circumstances of this sort.

(k) When the choice of a number for the radio message is definitely limited to the selection of either 02 or 03, it is important to make a careful distinction between a sky that is 10/10 covered with clouds (overcast) and one more than 9/10 covered but less than overcast. Therefore, 03 (overcast) should be reported only when an *unbroken* cloud sheet covers the sky; that is, a cloud layer without any openings.

(l) Observers should not send the number 14 (squally weather) for "present weather" in the radio message.[1] "Squally weather" has too general a meaning; it does not give a sufficiently accurate description of the state of the weather. Close examination of vessel weather reports indicates that observers sometimes describe the state of weather as "squally" if the wind is unusually gusty (as is frequently the case when it is blowing hard). At other times "squally" is used to describe the occurrence of isolated, definite squalls or heavy showers associated with cumulonimbus (Cunb) clouds, which pass over the ship at most once or twice an hour.

The two phenomena are quite different and should not be confused. A distinction between them is incorporated in the International Code for recording wind direction (DD). The phenomenon of unusual gustiness is indicated by the addition of 33 to the appropriate number for the true wind direction. That of isolated squalls is indicated by the addition of 67 to the appropriate number for the true wind direction, if the squalls have occurred at the time of observation or during the hour preceding it. To illustrate, for a west-southwest wind the observer will use the number 22 in the wind direction code table, but if the wind is unusually gusty he will add 33; consequently he should use the number 55 for the wind direction. Another example: For a north-northwest wind the observer will use the number 30 in the table, but if a squall is occurring at the time of observation, or has occurred during the preceding hour, he will add 67; consequently, he should use the number 97 for the wind direction.

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[1] With this exception: In the tropics during the hurricane season the number 14 may be used when the weather appears to be abnormally squally. Such a condition may indicate that a tropical storm is forming.

BAROMETRIC PRESSURE

In the column headed "Barometer as read", which is found near the left margin of Form 1210A, the observer should record the barometer *exactly as read* (i. e., without application of any corrections whatever) to the nearest hundredth of an inch, tenth of a millimeter, or tenth of a millibar. Particular care must be taken to make certain that the reading obtained is correct, as even the most conscientious observer is prone on occasions to misread the barometer by 0.10 inch or 10 millibars (depending upon the scale of the barometer) or multiples thereof. Errors of this sort, usually committed when a hurried observation is made, can be eliminated if the observer will make it a practice to verify the original observation by taking a check reading. Since the accurate reading of the barometer depends largely upon a familiarity with the construction and adjustment of the instrument, detailed instructions for its reading have been included in Part III.

When the barometer is pumping the observer should take two or three *pairs* of readings. Each pair should contain one of the highest and one of the lowest readings obtainable. The reading to be recorded is that which is obtained from averaging the whole set.

Attached thermometer.—If the reading is obtained from a mercurial barometer the temperature indicated by the small thermometer that is affixed to the barometer must be entered in the adjacent column to the left, headed "Attached thermometer"; this is necessary in order that the height of the mercury in the barometer tube may be properly corrected for temperature. The reading shown by the attached thermometer represents the temperature which the instrument, as a whole, has assumed. It should be obtained before the actual barometer reading is made, because heat from the observer's body may, after a moment or two, cause the attached thermometer to rise slightly and to indicate a temperature somewhat higher than that of the mercury in the barometer.

If the barometer is an aneroid, with attached thermometer, the temperature should be entered. If there is no attached thermometer it is desired, when practicable, to make an entry in the "Attached thermometer" column, of the reading of a thermometer in the same room.

Barometer corrected.—A third column is provided near the left margin in which should be entered the reading of the barometer after all necessary corrections have been applied, including the correction for instrumental error furnished by the Weather Bureau. This last correction includes reduction to sea level when the barometer employed is an aneroid. The observer need not make an entry in this column, unless the observation is to be transmitted by radio, in which case he must, of course, apply the corrections himself. However, when a mercurial barometer equipped with a Gold scale is used in taking the observations, the corrected as well as the uncorrected readings of the instrument should *always* be entered in the spaces provided on Form 1210A, as the Weather Bureau does not attempt to establish individual corrections for mercurial barometers with Gold scales.

Barometer as coded (PP).—When the barometer reading is to be reported by radio, the observer must use the code table for PP below if the scale of his barometer is graduated in inches. This table enables one to convert inches to millibars. The proper way to use the table is as follows: Find in the table (in one of the columns headed inches) the value which is closest to the corrected barometer reading. In the column just to the *right* will be found the equivalent value in millibars. In the column just to the *left* will be found the proper code number. This number should be entered on Form 1210A under the heading "PP, Barometer as coded." It will be seen that the code number always consists of the last two figures of the reading as expressed in millibars. Consequently, observers who have barometers with the millibar scale do not need to refer to the code table for PP. In this case the last two figures of the corrected barometer reading to the nearest whole millibar are entered directly in the "Barometer as coded" column on Form 1210A.

Code table for PP (Corrected barometer reading)

[In millibars and inches]

Code figures	Inches	Millibars	Code figures	Inches	Millibars	Code figures	Inches	Millibars
25	27.32	925	70	28.65	970	15	29.97	1,015
26	27.35	926	71	28.67	971	16	30.00	1,016
27	27.38	927	72	28.70	972	17	30.03	1,017
28	27.41	928	73	28.73	973	18	30.06	1,018
29	27.44	929	74	28.76	974	19	30.09	1,019
30	27.46	930	75	28.79	975	20	30.12	1,020
31	27.49	931	76	28.82	976	21	30.15	1,021
32	27.52	932	77	28.85	977	22	30.18	1,022
33	27.55	933	78	28.88	978	23	30.21	1,023
34	27.58	934	79	28.91	979	24	30.24	1,024
35	27.61	935	80	28.94	980	25	30.27	1,025
36	27.64	936	81	28.97	981	26	30.30	1,026
37	27.67	937	82	29.00	982	27	30.33	1,027
38	27.70	938	83	29.03	983	28	30.36	1,028
39	27.73	939	84	29.06	984	29	30.39	1,029
40	27.76	940	85	29.09	985	30	30.42	1,030
41	27.79	941	86	29.12	986	31	30.45	1,031
42	27.82	942	87	29.15	987	32	30.48	1,032
43	27.85	943	88	29.18	988	33	30.51	1,033
44	27.88	944	89	29.21	989	34	30.53	1,034
45	27.91	945	90	29.24	990	35	30.56	1,035
46	27.94	946	91	29.26	991	36	30.59	1,036
47	27.97	947	92	29.29	992	37	30.62	1,037
48	28.00	948	93	29.32	993	38	30.65	1,038
49	28.03	949	94	29.35	994	39	30.68	1,039
50	28.05	950	95	29.38	995	40	30.71	1,040
51	28.08	951	96	29.41	996	41	30.74	1,041
52	28.11	952	97	29.44	997	42	30.77	1,042
53	28.14	953	98	29.47	998	43	30.80	1,043
54	28.17	954	99	29.50	999	44	30.83	1,044
55	28.20	955	00	29.53	1,000	45	30.86	1,045
56	28.23	956	01	29.56	1,001	46	30.89	1,046
57	28.26	957	02	29.59	1,002	47	30.92	1,047
58	28.29	958	03	29.62	1,003	48	30.95	1,048
59	28.32	959	04	29.65	1,004	49	30.98	1,049
60	28.35	960	05	29.68	1,005	50	31.01	1,050
61	28.38	961	06	29.71	1,006	51	31.04	1,051
62	28.41	962	07	29.74	1,007	52	31.07	1,052
63	28.44	963	08	29.77	1,008	53	31.10	1,053
64	28.47	964	09	29.80	1,009	54	31.13	1,054
65	28.50	965	10	29.83	1,010			
66	28.53	966	11	29.86	1,011			
67	28.56	967	12	29.89	1,012			
68	28.59	968	13	29.92	1,013			
69	28.62	969	14	29.94	1,014			

It will be seen also that the code figures may represent two values of barometric pressure, but this is true only with a very high or very low barometer reading. For example, the code figures 48 may be used for barometer readings of 28.00 and 30.95. In such cases the recipient of the radio message will be able to decide which value is intended.

If the observer's barometer is graduated according to the millimeter scale it will be necessary for him to refer to the table, "Conversion of millimeters to millibars", on page 115 of this manual.

Observers who are not scheduled to transmit weather reports by radio need not enter any figures in the "Barometer as coded" column.

VISIBILITY

Observations of visibility (V) should be made in accordance with the international scale, which is given in the code table for V, below. One code figure from this table should be entered in the "Visibility" column on Form 1210A. When it is not possible to determine precisely what figure in the scale most accurately describes the condition, the entry should be made according to the best judgment of the observer.

Code table for V (visibility)

Code figures	Visibility
0	Dense fog. (Objects not visible at 50 yards.)
1	Thick fog. (Objects not visible at 200 yards.)
2	Fog. (Objects not visible at 500 yards.)
3	Moderate fog. (Objects not visible at ½ nautical mile.)
4	Thin fog. (Objects not visible at 1 nautical mile.)
5	Poor visibility. (Objects not visible at 2 nautical miles.)
6	Moderate visibility. (Objects not visible at 5 nautical miles.)
7	Good visibility. (Objects not visible at 10 nautical miles.)
8	Very good visibility. (Objects not visible at 30 nautical miles.)
9	Excellent visibility. (Objects visible at more than 30 nautical miles.)

Horizontal visibility is often very useful as an indicator of the thermal structure of the lower atmosphere. As a general rule, the visibility is good when the air temperature is lower than the sea temperature and very poor when the reverse holds true. The reason for this is that when the air temperature is lower than the sea temperature there is a transfer of heat from the sea to the lowest layers of the atmosphere. This will tend to make the atmosphere thermally unstable and favor active vertical mixing, which in turn tends to disperse haze or fog particles that may have accumulated at low levels. An unstable atmosphere is characterized by cumuliform clouds and a showery type of weather.

On the other hand, when the sea temperature is lower than the air temperature it follows that there is a transfer of heat from the lowest layers of the atmosphere to the sea. This will tend to make the atmosphere thermally stable and prevent active vertical mixing, which in turn favors the accumulation of haze at low levels. The cooling of the surface air also favors the production of fog. A stable atmosphere is, therefore, characterized by poor visibility and, if it is sufficiently moist, by fog, low stratus clouds, and drizzle.

This shows that an accurate report of visibility may often serve to supplement the description of the character of the weather as reported in the "present weather" column.

Islands or mountains, whose distance from the observer is known, should be used whenever possible as objects on which the estimate of visibility may be based. Otherwise, use may be made of another ship or the horizon. The latter, when viewed from the level of the bridge (30 to 40 feet above sea level), appears at a distance of 6 to 7 nautical miles.

Table 10 on page 119 gives the distance of visibility of objects at sea.

When isolated showers are within sight, but are not occurring at the ship, the observation of visibility should be made in a direction where the horizon is not obscured by falling precipitation.

TEMPERATURES

Temperature of the air (TT).—Air temperatures prevailing at sea are far more representative of the general thermal conditions in the lower layers of the atmosphere than the temperatures observed at land stations, where local influences must be taken into account. Accurate reports of air temperature from ships are a valuable aid in forecasting, especially when they are used in conjunction with observations of water temperature. Because of their representativeness, they are indispensable to all studies of large-scale fluctuations of climate. For these reasons it is most important, when taking an observation, to make sure that the true value of the air temperature is obtained.

In order to obtain the true temperature of the air, it is necessary that reliable thermometers be employed and that they be properly exposed and accurately read. When practicable, thermometers should be compared with a standard instrument, and if an appreciable error is shown to exist a correction should be applied to the readings. Comparisons may be made at any Weather Bureau office. The Weather Bureau will gladly furnish information regarding the purchase of reliable thermometers.

Proper exposure of thermometers is *absolutely essential.* If a thermometer is simply fastened to the deck house or to a bulkhead it will rarely, if ever, register the true air temperature. In this position the instrument may give readings that are 20° F. or more too high in the presence of sunshine and absence of wind. It is, therefore, strongly recommended that a portable thermometer be used. It will then always be possible to measure the air temperature on the weather side of the ship, where the thermometer will be freely exposed to the wind and unaffected by artificial sources of heat. A detailed treatment of the problem of thermometer exposure on board ship is contained on pages 25 to 27, which observers are asked to read carefully.

Care must be taken to read the thermometer correctly. It may happen that the observer glances at the instrument rather hastily and fails to make an accurate mental note of the positions of the numbers opposite the graduations of the scale. This sometimes leads to an error of an even 5° or 10° in recording the temperature.

The air temperature should be read and entered on the form to the nearest tenth of a degree, Fahrenheit (or Centigrade), if possible. When the ship is scheduled to send a meteorological observation by radio to the Weather Bureau, the air temperature should be reported *in whole degrees*, Fahrenheit, according to the scale 00 to 99. Temperatures below 0° F. or above 100° F. may be encountered on very rare occasions, but only when the ship is extremely close to the land, in which case it is not necessary to send a radio report. Consequently, no provision is made herein for the reporting of temperatures outside these limits.

If temperatures on the Centigrade scale are converted to readings in degrees Fahrenheit for entry on Form 1210A, care should be taken in the use of the conversion table. Observers sometimes take temperatures from the wrong line, thus obtaining Fahrenheit readings that are in error by the equivalent of 1°, 5°, or even 10° Centigrade; for example, the reading 15.6 is by mistake converted to degrees Fahrenheit when the actual reading is 5.6 C.

Temperature of the ocean surface.—The temperature of the ocean surface has a more or less marked effect upon the weather and the climate of adjacent land areas, depending upon the relative position of water and land with respect to the prevailing winds. It exerts, also, a considerable influence upon the character of the weather experienced at sea. The general and accurate observance of the temperature of the surface water of the oceans, particularly of the principal currents, is, therefore, a matter of *greatest* importance. In order to obtain the true temperature of the sea surface it is necessary, just as in measuring the temperature of the air, that a reliable thermometer be employed and that it be properly exposed and accurately read.

The sea-surface temperature may be obtained either by measuring the temperature of a sample of water hauled up from the sea in a bucket or by measuring the temperature of the water that flows through the injection pipe to the cooling system in the engine room. When the bucket method is used, the observer should follow the instructions given below in order to attain the greatest possible accuracy.

1. Use a dry bucket, or at least empty all residual water before a throw.

2. From as far forward as possible, heave the bucket overboard; if the bucket is warm from exposure to sunshine or contact with steam pipes, give it time to cool off before hauling it up.

3. Haul up the bucket as quickly as is consistent with getting most of its contents safely on deck without spilling.

4. Carry the bucket immediately to a sheltered place where wind or sunshine cannot affect the original temperature of the sample.

5. Plunge the thermometer into the bucket and stir the water with it until the thermometer has taken on the temperature of the water. This will be indicated when the instrument shows a constant temperature. A thermometer with a cylindrical bulb responds more readily to temperature changes than one with a spherical bulb.

6. Read the thermometer, but in so doing do *not* remove it from the bucket. Tilt it within the bucket so that the scale can be viewed squarely, but make sure that the bulb of the thermometer remains

under water. At night the *entire bucket* should be carried to the nearest deck light (unless the observer has provided himself with a flashlight); the thermometer should be read there while its bulb is still in the water.

7. After every observation, leave the bucket upside down in order that all the water may drain out.

When the condenser-intake method is employed, the observer will be obliged to secure the reading by telephoning to the engine room. In this case he should make sure that the reading reported to him by the engineer on duty is the temperature of the water flowing through the injection pipe at the time of the meteorological observation and not the last entry made in the engine room log. He should satisfy himself, also, that the engineers are sufficiently interested in the meteorological work to realize the importance of reading the intake thermometer accurately to a fraction of a degree, if possible.

In the column on Form 1210A, headed "Temperature of water", the reading obtained *must* be entered to the nearest whole degree Fahrenheit or half degree Centigrade as a minimum standard of precision. Better still, if circumstances assure the possibility of securing greater accuracy, the reading to the nearest tenth of a degree Fahrenheit or Centigrade should be entered. A common practice has been to read the thermometer to the nearest even-numbered Fahrenheit degree or nearest whole Centigrade degree. Such readings are practically useless.

If the severity of the weather is such as to exclude the possibility of making a bucket observation on any particular day, observers in the habit of using the bucket method should leave the space for water temperature blank. A condenser-intake reading should not be recorded as a substitute unless it is so labeled.

The various problems and difficulties connected with the taking of sea-surface temperatures are outlined in more detail on pages 29 to 30. Observers are urgently requested to study those paragraphs in order that they may acquire a full appreciation of the care which must be exercised if the desired standards of accuracy in the making of ocean-temperature measurements are to be attained.

Temperature of the wet bulb.—The temperature of the so-called "wet-bulb" thermometer is necessary in determining the amount of moisture present in the atmosphere, as previously indicated. Just as in the case of the air temperature, the wet-bulb temperature should be obtained correctly to the nearest tenth of a degree Fahrenheit, if possible, and so entered in the column headed "Temperature of wet bulb" on Form 1210A. Such exactness is necessary because the *difference* between the air and wet-bulb temperatures must be determined as accurately as possible. An error of 1° F. in recording the true depression of the wet bulb results, at ordinary temperatures, in an error of from 5 to 10 percent in the computation of the humidity.

In the past the wet-bulb temperature has usually been obtained on shipboard from the reading of a stationary thermometer whose bulb is tightly fitted with a piece of muslin, to which one end of a cotton wick is attached. The other end of the wick is allowed to stand in a reservoir of water. This arrangement keeps the muslin moist, with the result that evaporation is continually taking place around the thermometer bulb.

In order to obtain the most nearly correct results, the muslin should be thoroughly saturated, but not coated with a superfluous film of water. If too much water surrounds the thermometer bulb, the indicated wet-bulb temperature will be too high. Similarly, if the muslin is only partially moistened, the reading will again be too high. Trouble of either sort can usually be remedied by adjusting the wick. The water that is supplied to the muslin must at all times be pure and free from dissolved substances, such as sea salt; otherwise, incorrect wet-bulb temperatures will be indicated. To this end it is necessary that the water supply be renewed and the wick washed at frequent intervals.

The results obtained through the use of stationary thermometers are unsatisfactory, and to meet the needs of modern weather science it is advisable to employ a more reliable type of apparatus. An alternative and more accurate method of measuring wet-bulb temperatures on shipboard is afforded through the use of the sling psychrometer, a full description of which is given on pages 27 to 29.

In making an observation with the psychrometer the first step is to saturate the muslin-covered wet bulb with pure water. This is most easily accomplished with the aid of an eye-dropper or small syringe. When this operation has been completed, the observer should take up his station at some well-exposed point on the weather side of the ship and hold the psychrometer at arm's length, outside the rail whenever possible. If the apparent wind at the point of observation is force 4, or greater, the natural ventilation thereby produced is ample and the instrument need not be whirled. It may simply be held stationary and freely exposed to the wind. However, when the apparent wind is less than force 4, artificial ventilation is required. The thermometers are then whirled rapidly for at least 30 seconds; stopped and quickly read, the wet bulb first. This reading is kept in mind, the psychrometer immediately whirled again, and a second reading taken. This is repeated three or four times, or more if necessary, until at least two successive readings of the wet bulb are found to agree closely, thereby showing that it has reached its lowest temperature. Two minutes or more is generally required to secure the correct temperature.

When the air temperature is at or below the freezing point, or even slightly above it, it very often happens that the wet-bulb temperature will fall below the freezing point before the water actually freezes. This phenomenon of supercooled water may always be recognized when it occurs, since the sinking mercury does not stop at the freezing point but falls rapidly below it. No error results on this account, provided the minimum temperature is reached. However, after a longer or shorter interval the water suddenly begins to freeze, heat is liberated, and the temperature of the wet bulb instantly rises to 32° F. (0° C.). It will remain at this value until all the water that covers the wet bulb has frozen. Subsequently it will begin to fall again. In such cases it is necessary to continue the ventilation until the ice-covered bulb has reached a minimum temperature.

While the psychrometer will give quite accurate indications, even in bright sunshine, yet observations so made are not without some error. Therefore, it is desirable to hold or whirl the psychrometer in the shade, provided that this can be done without sacrificing the essential requirement of a good windward exposure. The observer should also remember that the instrument is quite sensitive to slight variations in temperature, such as those resulting from the proximity of the observer's body or of some object which has been strongly heated by sunshine. The observer should, therefore, face the wind, holding or whirling the psychrometer in front of his body, and should also stand to windward of any overheated objects whose presence might cause the thermometers to indicate false values.

CLOUDS

Amount of clouds.—The proportion of the sky covered by clouds, irrespective of type, should be recorded on Form 1210A in the space for total amount according to the scale 0 to 10. In this scale 0 represents a sky that is cloudless at the time of observation, 1 a sky that is one-tenth covered, and so on to 10, which represents a sky completely overcast. The amount of clouds should agree in general with the state of weather; that is, a sky with less than one-tenth of cloud covering is clear, 1 to 5 tenths is partly cloudy, 6 to 9 tenths is cloudy, 10 tenths is overcast.

In the thin types of "mackerel" clouds there are almost always gaps or spaces through which clear sky can be seen. When these conditions prevail, therefore, the amount of cloud should never be recorded as greater than 9, even though such clouds are spread all over the sky.

In case the sky is completely obscured by dense fog, it should be described as overcast, and ten-tenths of dense fog, without direction of movement, should be entered in the space for cloud amount. However, should the ship be enveloped in fog (or haze) which allows blue sky, sun, moon, or stars to appear through and there is no trace of cloud above the fog (or haze), the cloud amount should be recorded as 0. On the other hand, if clouds are visible above the fog, an attempt should be made to estimate the total amount of cloud, and this should be recorded as though no fog were present.

Kind of clouds.—In recording the kind of clouds, observers should conform strictly to the international system of classification, a full description of which will be found, commencing on page 63, accompanied by illustrations to aid observers in identifying the various cloud forms.

In determining the kind of cloud, attention should be directed mainly to the neighborhood of the zenith. Near the horizon the appearance of the clouds is much affected by perspective.

Names of clouds should be entered on the observation form by abbreviations, for example, Ci. for Cirrus, Cu. for Cumulus. The proper abbreviations are shown in the condensed instructions on the inside front cover of Form 1210A.

Direction of cloud movement.—The direction of cloud movement is always the direction *from which* the clouds are moving. This is frequently very difficult to determine on shipboard. Observers should be guided by the remarks contained in the following paragraphs:

1. The direction of cloud motion should be determined by using some heavenly body as a reference point. If the sky is completely covered with thick clouds, it is best not to attempt to ascertain the direction of cloud motion.

2. When there are two or more cloud sheets with openings so that cloud movement at more than one level is visible, the absolute movement of each layer should be ascertained, if possible. This can be done only when the cloud layers are so thin or broken that the sun (or moon) is plainly visible from time to time. The mistake should not be made of determining the direction of motion of one cloud layer with reference to another.

3. In estimating the true (not the magnetic) direction from which the clouds proceed, the course and speed of the vessel should be taken into account, precisely as in the case of the wind. This applies especially to the determination of the motions of low clouds, because their rate of movement is usually less than that of high clouds. The following example shows how wide, in the case of slowly moving clouds, the variation between apparent and true cloud direction can be: If the clouds are *actually* moving from NE. at a speed of 12 knots and the ship is steaming due W. at 20 knots, the clouds will *appear* to be moving from about NW. by W. The slower the actual rate of cloud movement the more the apparent direction will differ from the true direction, except when the true direction is from dead ahead.

Since the observer ordinarily has no way of knowing the exact velocity of the clouds, it is quite impossible to make a really accurate allowance for the movement of the ship. However, it should be remembered that the lower clouds usually are floating within the same air current as prevails at the sea surface. Therefore, in most cases the true speed and direction of the lower clouds will be roughly the same as those of the wind at sea level. In the case of upper clouds, this is seldom true. However, if the upper clouds display a clearly noticeable motion, their actual speed must be large compared with that of the ship. It is then unnecessary to make much allowance for the ship's movement. On the other hand, if the upper clouds appear to be almost motionless, it is advisable not to attempt to ascertain the true direction of their movement.

4. Finally, and in general, when there is any doubt about the direction of cloud movement, it is better to enter a question mark or a dash, since no observation at all is preferable to an incorrect one.

Cloud notes in Daily Journal.—In addition to the records of clouds as a part of regular observations, notes in the Daily Journal should briefly describe important changes in the amount and kind of clouds between observations.

SEA AND SWELL

When a light wind blows over a water surface it produces at first a series of ripples, moving with the wind. As the ripples move forward with the wind they increase in size. A strong wind produces larger waves and, if it continues, a heavy sea results.

After a wave moves beyond the influence of the winds which caused it there is a change in its form. The most rapid change at first is a decrease in height. Finally the wave becomes a relatively low, undulating movement of the sea surface, known as a swell. In recording observations in accordance with the following scales, swell is wave motion produced by winds at some distance from the point of observation.

The swell is distinguished by two features; first, its relatively smooth, undulating form, without the steep and ragged crests characteristic of waves actively driven by local winds and, second, the movement of winds and waves in different directions, indicating that the waves have been formed elsewhere by winds from another quarter. Ordinarily, then, waves which are moving with the wind constitute the "sea", while a relatively low, undulating sea surface, with motion in a direction different from the local wind, is the "swell."

These definitions are not entirely satisfactory. Usually, the ocean surface is disturbed by both forms of wave motion, with the swell from distant winds crossing the local sea. The combined effect is the "sea", while the well-defined ridges of waves moving in a different direction from the local wind are the "swells."

State of sea.—The following scale should be used in classifying the character of the sea disturbance. In recording observations in accordance with this scale, "sea" may be considered to be composed of swells, combined with waves produced by the winds at the place of observation.

State of sea

Scale	Description	Height of wave crest to trough	Abbreviation
0	Calm	0	Calm.
1	Smooth	Less than 1 foot	Sm.
2	Slight	1 to 3 feet	Sl.
3	Moderate	3 to 5 feet	M.
4	Rough	5 to 8 feet	R.
5	Very rough	8 to 12 feet	VR.
6	High	12 to 20 feet	H.
7	Very high	20 to 40 feet	VH.
8	Precipitous	Over 40 feet	P.
9	Confused		Con.

The scale of sea disturbance is approximate, based roughly on the observer's judgment as to the height of waves. Accurate estimates of wave height are not easily made on shipboard. For large waves, with the ship on an even keel in the trough of the wave, the observer's height above the water line where he sees the crest of the wave coincide with the horizon, is taken as the height of the wave.

Character and direction of swell.—The character and direction of the swell should be entered in the appropriate columns of Form 1210A according to the following scales:

Character of swell

Scale	Description	Scale	Description
0	No swell.	5	Moderate swell, long.
1	Low swell, short or average length.	6	Heavy swell, short.
2	Low swell, long.	7	Heavy swell, average length.
3	Moderate swell, short.	8	Heavy swell, long.
4	Moderate swell, average length.	9	Confused swell.

Direction of swell

[Direction *from which* swell is moving]

True direction	Scale	True direction	Scale
No sea or swell	0	SW	5
NE	1	W	6
E	2	NW	7
SE	3	N	8
S	4		

Period of swells.—Observations of length and height of the swell are not so valuable as the period. The number of swells that pass a given point in one minute may be taken as the period. On shipboard this may be calculated by watching the rise and fall of a patch of foam and noting the time interval.

In so doing, rise and fall due to the true swell, and not the smaller waves, should be noted. A series of such observations will give a good approximation of the time interval in seconds or the period expressed in number of swells in a minute.

Observations of swell period, especially in connection with tropical storms, will be appreciated. They should be written in the "Daily Journal" or under "Remarks." The entries should show clearly whether they give the average interval in seconds or the number of waves per minute.

GALE, STORM, AND FOG REPORTS

Gales and storms.—A summary of every gale encountered should be entered in the spaces provided on the form. Gale, or storm, reports are desired for winds reaching force 8, Beaufort scale, except that in tropical seas reports for winds of force 6 or higher are requested. Special accounts of storms may be prepared on a separate sheet and attached to the form. The report should especially include shifts of wind, lowest barometer, highest wind force, and also the time and ship's position and course when each occurred. Reports of this character are very useful in determining the intensity of the storm and the exact course of the center, and particularly valuable for storms of tropical origin.

Fogs.—The local date and hour of entering and emerging from fog should be given in the Fog Report, together with other special information, as indicated by the headings. Under the heading "General character of fog" should be entered a word, or words, to indicate character, whether dry, wet, light, dense, low, spotted, or in banks. In case no fog is observed during the period covered by the report, a statement should be made to that effect. Negative information is sometimes of much value.

SUPPLEMENTAL DATA FOR RADIO MESSAGES

All observations sent by radio contain the four Universal groups, the symbols for which are—

YQLLL   lllGG   DDFww   PPVTT

Under certain conditions supplemental data are also required. They may be sent in any one of three forms, as indicated by the first figure of the first group. The first form, which has only two groups, is sometimes used by ships reporting to the Weather Bureau; the first figure of the first group in this case is always 6. The order of symbols [2] is as follows:

$6KD_KCN \quad T_dd_sAWC_H$

The second form, with three groups, is quite generally used in sending radio reports to the meteorological services of certain other nations. Here the first figure of the first group is always 3. The order of symbols [2] is as follows:

$3C_LC_MC_HN \quad T_dKD_KWN_h \quad d_sv_sapp$

A third form is occasionally required, the first figure of the first group of which is always 9. The order of symbols [2] is as follows:

$9SKD_KW \quad CNN_hAT_d$

No matter what form of supplemental data is used, it is always preceded by the four Universal Groups.

If one or more figures of a group cannot be given, owing to lack of observation, or to failure of, or damage to, instruments, each missing figure should be replaced by the letter X.

The following information will serve as a guide to the obtaining and reporting of supplemental data:

Barometric tendency (A).—This quantity, representing the approximate amount and general character of the change of the barometer in the 3 hours prior to the observation, is expressed in the radio message by a single figure, in accordance with the table given below. It is obtained either from the record traced out by a barograph or from two readings of a barometer made at the hour of observation and 3 hours prior to it, respectively. The amount of the tendency is simply the difference between the barometric readings observed at these two instants of time. The character of the tendency is described as "steady", "rising", or "falling", depending upon whether the net change is zero, positive, or negative.

Symbol A—Barometric tendency

Code figures	Barometric tendency
0	Barometer steady. (Has not fallen or risen more than 0.01 inch (½ millibar) in last 3 hours.)
1	Barometer rising slowly; (Has risen 0.03 to 0.04 inch (1 to 1½ millibars) in last 3 hours.)
2	Barometer rising. (Has risen 0.06 to 0.10 inch (2 to 3½ millibars) in last 3 hours.)
3	Barometer rising quickly. (Has risen 0.12 to 0.18 inch (4 to 6 millibars) in last 3 hours.)
4	Barometer rising very rapidly. (Has risen more than 0.18 inch (6 millibars) in last 3 hours.)
5	Barometer falling slowly. (Has fallen 0.03 to 0.04 inch (1 to 1½ millibars) in last 3 hours.)
6	Barometer falling. (Has fallen 0.06 to 0.10 inch (2 to 3½ millibars) in last 3 hours.)
7	Barometer falling quickly. (Has fallen 0.12 to 0.18 inch (4 to 6 millibars) in last 3 hours.)
8	Barometer falling very rapidly. (Has fallen more than 0.18 inch (6 millibars) in last 3 hours.)

[2] For meaning of these symbols, see headings of sections which follow.

Characteristic of changes of the barometer in the last 3 hours (a).—The character of the variation of pressure during the 3-hour period preceding the observation is expressed by a single figure in the radio message. It must be determined from a barograph that is properly compensated for temperature. The barograph should be elastically suspended in order that it may not be affected by shocks and vibration incident to the motion of the ship. Singularities in the run of the curve, obviously due to defects in the instrument (friction, backlash, etc.) or to external effects other than rapid changes in atmospheric pressure, should be disregarded.

The use of barograph sheets with 3-hour divisions is recommended.

The character of the 3-hour pressure change is described in the table below, and graphically illustrated in figure 13. The appropriate code number for each distinctive type of curve is also given.

Symbol a—Characteristic of changes of barometer in the last 3 hours

Code figures	Description	
0	Rising, then falling	Barometer now higher than or the same as 3 hours ago.
1	Rising, then steady, *or rising, then rising more slowly*	
2	Unsteady	
3	Steady or rising	
4	Falling or steady, then rising; *or rising, then rising more quickly*	
5	Falling, then rising	Barometer now lower than 3 hours ago.
6	Falling, then steady; *or falling, then falling more slowly*	
7	Unsteady	
8	Falling	
9	Steady or rising, then falling; *or falling, then falling more quickly*	

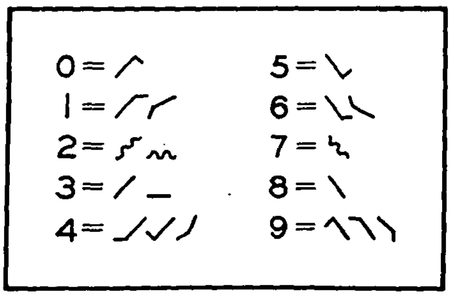

FIGURE 13.—Characteristics of changes of the barometer in the last three hours.

In regions where there is a marked regular diurnal variation of the barometer the figures 2 and 7 may be used when the regular diurnal variation is interrupted in such a way that the term "unsteady" gives the best description of the character of the curve.

When unusually rapid changes of the barometer occur between regular Greenwich noon observations, a note is desired in the Daily Journal describing the changes. If an unusual barometric change is accompanied by winds of force 8 or higher (force 6 or higher in tropical seas), the facts should be incorporated in the space headed "Gale or Storm Reports."

Barometer change (pp).—This quantity, which represents the *exact* amount of the variation of pressure during the 3-hour period preceding the observation, is expressed *in fifths of a millibar* according to the scale 00 to 99. Thus, if the pressure variation were 3.4 millibars, "pp" would be coded as 17; if it were 11.6 millibars, "pp" would be coded as 58. The conversion table, giving the code numbers for different values of pressure variation, follows.

Symbols pp—Barometer change

[Amount of rise or fall of the barometer in the last three hours]

Code figure	Amount of rise or fall		Code figure	Amount of rise or fall		Code figure	Amount of rise or fall	
	Millibars	Inch		Millibars	Inch		Millibars	Inch
01	0.2	0.01	36	7.2	0.22	71	14.2	0.43
02	.4	.01	37	7.4	.22	72	14.4	.43
03	.6	.02	38	7.6	.23	73	14.6	.44
04	.8	.02	39	7.8	.23	74	14.8	.44
05	1.0	.03	40	8.0	.24	75	15.0	.45
06	1.2	.04	41	8.2	.25	76	15.2	.46
07	1.4	.04	42	8.4	.25	77	15.4	.46
08	1.6	.05	43	8.6	.26	78	15.6	.47
09	1.8	.05	44	8.8	.26	79	15.8	.47
10	2.0	.06	45	9.0	.27	80	16.0	.48
11	2.2	.07	46	9.2	.28	81	16.2	.49
12	2.4	.07	47	9.4	.28	82	16.4	.49
13	2.6	.08	48	9.6	.29	83	16.6	.50
14	2.8	.08	49	9.8	.29	84	16.8	.50
15	3.0	.09	50	10.0	.30	85	17.0	.51
16	3.2	.10	51	10.2	.31	86	17.2	.52
17	3.4	.10	52	10.4	.31	87	17.4	.52
18	3.6	.11	53	10.6	.32	88	17.6	.53
19	3.8	.11	54	10.8	.32	89	17.8	.53
20	4.0	.12	55	11.0	.33	90	18.0	.54
21	4.2	.13	56	11.2	.34	91	18.2	.55
22	4.4	.13	57	11.4	.34	92	18.4	.55
23	4.6	.14	58	11.6	.35	93	18.6	.56
24	4.8	.14	59	11.8	.35	94	18.8	.56
25	5.0	.15	60	12.0	.36	95	19.0	.57
26	5.2	.16	61	12.2	.37	96	19.2	.58
27	5.4	.16	62	12.4	.37	97	19.4	.58
28	5.6	.17	36	12.6	.38	98	19.6	.59
29	5.8	.17	64	12.8	.38	99	19.8	.59
30	6.0	.18	65	13.0	.39			
31	6.2	.19	66	13.2	.40			
32	6.4	.19	67	13.4	.40			
33	6.6	.20	68	13.6	.41			
34	6.8	.20	69	13.8	.41			
35	7.0	.21	70	14.0	.42			

Should the value of the variation be 20.0 millibars or more, "pp" should be reported as 99, and the actual amount of the tendency, without regard to sign, should be given at the end of the report in plain language, e. g., "Tendency 23.8 millibars."

Form of predominating cloud (C).—When two or more layers of clouds are visible, the predominating clouds are those which cover the largest proportion of the sky. Their form is to be determined by referring to the descriptions and photographs in Part V. The table below, which is to be used when this information is transmitted by radio, gives the code numbers corresponding to the various forms of clouds.

Symbol C—Form of predominating cloud

Code figures	Form of cloud	Code figures	Form of cloud
1	Cirrus.	6	Stratocumulus.
2	Cirrostratus.	7	Nimbostratus.
3	Cirrocumulus.	8	Cumulus or fractocumulus.
4	Altocumulus.	9	Cumulonimbus.
5	Altostratus.	0	Stratus or fractostratus.

Form of lower clouds (C_L).—The form of the lower clouds is entered in the appropriate space on Form 1210A. The table below gives the radio code numbers corresponding to the various forms of lower clouds.

Symbol C_L—Form of lower clouds

Code figures	Form of clouds
0	No lower clouds.
1	Cumulus of fair weather.
2	Cumulus (large, without anvil).
3	Cumulonimbus.
4	Stratocumulus (spread from cumulus).
5	Stratus or stratocumulus (in layer).
6	Ragged low clouds of bad weather.
7	Cumulus *and* stratocumulus of fair weather.
8	Cumulus, large (or cumulonimbus) *and* stratocumulus.
9	Cumulus, large (or cumulonimbus) *and* ragged low clouds of bad weather.

Form of middle clouds (C_M).—The form of the middle clouds is entered in the appropriate space on Form 1210A. The table below gives the radio code numbers corresponding to the various forms of middle clouds.

Symbol C_M—Form of middle clouds

Code figures	Form of clouds
0	No middle clouds.
1	Altostratus, typical thin.
2	Altostratus, typical thick (sun or moon invisible), or nimbostratus.
3	*Altocumulus or high stratocumulus, single layer.*
4	Altocumulus, in bands, decreasing.
5	Altocumulus, in bands, increasing.
6	Altocumulus, spread out from cumulus.
7	Altocumulus, with altostratus; or altostratus with parts resembling altocumulus.
8	Altocumulus castellatus (altocumulus in ragged fragments).
9	Altocumulus in several layers, generally with fibrous veils and chaotic appearance of sky.

Form of upper clouds (C_H).—The form of the upper clouds is entered in the appropriate space on Form 1210A. The table below gives the radio code numbers corresponding to the various forms of upper clouds.

Symbol C_H—Form of upper clouds

Code figures	Form of clouds
0	No upper clouds (cirrus type).
1	Cirrus, fine, not increasing; scarce.
2	Cirrus, fine, not increasing, plentiful but not a continuous layer.
3	Cirrus, anvil.
4	Cirrus, fine, increasing.
5	Cirrus or cirrostratus increasing, below 45° altitude.
6	Cirrus or cirrostratus increasing, and reaching above 45° altitude
7	Cirrostratus, veil covering entire sky.
8	Cirrostratus, not increasing, and not covering whole sky.
9	Cirrocumulus predominating, and a little cirrus.

Total amount of all clouds (N).—In coding total amount of clouds for the radio message, use the code figure (see table below) which corresponds to the entry in the column for total amount of cloud on Form 1210A; instructions for this entry appear on page 52.

Symbol N—Total amount of all clouds

[Regardless of kind of clouds]

Code figures	Proportion of sky covered (in tenths)
0	0.
1	Less than 0.1.
2	0.1.
3	0.2 to 0.3
4	0.4 to 0.6.
5	0.7 to 0.8.
6	0.9.
7	More than 0.9 but with openings.
8	Sky completely covered with clouds.
9	Sky obscured by fog, duststorm, or other phenomenon.

Code figure 0 is to be used only when the sky is completely free from clouds.

Code figure 8 is to be used only when the sky is completely covered with clouds, so that no blue sky is visible.

Code figure 9 should be reported only if the sky is invisible, owing to fog.

Amount of lower clouds (N_h).—The total amount of lower clouds is coded according to the scale and table used in reporting the total amount of all clouds (N).

Temperature difference between air and water (T_d).—This quantity is the decisive factor in the stratification of temperature and humidity in the lower layers of the atmosphere over the sea, and hence, to a large degree, for the state of the weather and the visibility. Since the difference between air and sea temperatures rarely amounts to more than 10° F. over the open ocean, the utmost care must, therefore, be taken to obtain accurate values of these quantities, from which "T_d" is calculated. This is especially important when the air and sea have nearly the same temperature.

The table below gives the code numbers to be used in reporting various values of "T_d."

Symbol T_d—Temperature difference (air and water)

[Difference between temperature of air and temperature of water at or near surface]

Code figures		
0	More than 9° F.	Air temperature same as or higher than sea temperature.
1	6° to 9°	
2	3° to 6°	
3	1° to 3°	
4	No difference or less than 1° F. higher	
5	Less than 1° F.	Air temperature lower than sea temperature.
6	1° to 3°	
7	3° to 6°	
8	6° to 9°	
9	More than 9°	

Past weather (W).—This part of the message calls for a description of the state of the weather during the 6 hours preceding the observation. The code table to be used in reporting "W" is given below.

Symbol W—Past weather

Weather	Code figures
Fair (clear or slightly clouded)	0
Variable sky	1
Mainly overcast	2
Sandstorm or duststorm, or storm of drifting snow	3
Fog or thick dust haze (visibility less than 1,000 meters [1,100 yards])	4
Drizzle	5
Rain	6
Snow or sleet	7
Showers	8
Thunderstorm	9

Should the type of weather undergo a complete change during the interval in question, the figure chosen should be the one which describes the weather conditions existing *before* the change to the type of weather that prevails at the hour of observation, so that "W" and "ww" together give as complete a description as possible of the weather in the time interval concerned.

Should more than one figure of the "W" scale be applicable to the past weather, the higher figure should be selected. When the past weather has been characterized chiefly by the presence of broken clouds, with showers occurring within sight of the ship, it is important that the figure 8 (showers) be sent in the message rather than 1 (variable sky), even if no showers have passed directly over the ship. In general, the occurrence of any form of precipitation should be given preference in the report of past weather.

State of sea (S).—Instructions for the recording and coding of observations of the state of the sea have been given on page 54.

Character of swell (K).—Instructions for the recording and coding of the character of the swell have been given on page 54.

Direction from which swell is moving (D_K).—Instructions for the recording and coding of the direction of the swell have been given on page 55.

Ship's course (d_S).—The direction toward which the ship is moving is recorded and coded according to the scale 0–8, in which 1=NE., 2=E., etc.

Symbol d_s—Direction toward which ship is moving

True direction	Code figures
Ship at anchor or hove to	0
NE	1
E	2
SE	3
S	4
SW	5
W	6
NW	7
N	8

Ship's speed (v_s).—This part of the message calls for the average speed of the ship during the 3-hour period preceding the observation. The table below gives the radio code numbers corresponding to various speeds.

Symbol v_s—Ship's speed

Code figures	Speed	Code figures	Speed
0	Ship stopped.	5	13 to 15 knots.
1	1 to 3 knots.	6	16 to 18 knots.
2	4 to 6 knots.	7	19 to 21 knots.
3	7 to 9 knots.	8	22 to 24 knots.
4	10 to 12 knots.	9	More than 24 knots.

MISCELLANEOUS PHENOMENA

The occurrence of such phenomena as halos, coronas, waterspouts, mirages, and meteors should be recorded on separate sheets if there is insufficient space on the forms.

Observation of meteors.—Owing to the exceptional opportunities afforded for the purpose at sea, it would be of great scientific value if the officers of ships would record the paths of brilliant and exceptional meteors and fireballs seen by them. The data needed include the approximate position of the ship at the time the object appeared and the civil Greenwich mean time of its appearance, certainly to the nearest five minutes. If any other time than Greenwich mean time is used, it should be so specified. For the object itself the angular coordinates of its points of appearance and disappearance are desired. These are preferably expressed in right ascension and declination, which can readily be read off from a star map if the path is plotted thereon, or by the altitudes and azimuths if more convenient. Notes giving the brightness, color, character of train, and particularly the estimated number of seconds the object was visible are desired. If an explosion is either seen or heard, it should be recorded, especially the time interval between these features if both are observed.

Records of brilliant objects, regularly made, would in a short time furnish data for the calculation of many real heights and orbits for such bodies—data which possess definite meteorological as well as astronomical value, since they aid in the determination of the height of the atmosphere.

In addition to the foregoing, which it is desirable that all should be willing to cooperate in securing, it is hoped that a few persons, especially interested in astronomy, will wish to make regular observations at certain periods of the year when meteors are most abundant.[3] These are:

[3] To anyone who cares to make observations of some of these showers, regular charts, blanks, and full instructions for making the observations will be furnished on application to Chas. P. Olivier, Director Flower Observatory of University of Pennsylvania, Upper Darby, Pa., who has charge of this work for the American Meteor Society. Other observations should be entered in the Weather Report.

Radiant in—	Epoch	Maximum
Ursa Major	Jan. 1-3	Jan. 2.
Lyra	Apr. 17-22	Apr. 20.
Aquarius	May 1-8	May 4.
Aquarius	July 27-31	July 28,
Perseus	Aug. 8-14	Aug. 11, 12.
Orion	Oct. 14-27	Oct. 19-22.
Leo	Nov. 13-16	Nov. 14.
Gemini	Dec. 8-15	Dec. 12.

PART V. CLOUDS

In general, a cloud differs from fog only in its location. Both result from the cooling of air to a temperature below its dew point, but in the case of the cloud, this cooling usually results from upward movement of the air, and hence the cloud is nearly always separated from the earth, except on mountain tops. Fog, on the other hand, is induced by cooling of the air at and near the surface, and commonly extends quite to the surface, at least during the stage of its development. In short, fog consists of water droplets or ice spicules condensed from and floating in the air near the surface; cloud, of water droplets or ice spicules condensed from and floating in the air well above the surface. Fog is a cloud on the earth; cloud a fog in the sky.

Classification of clouds.—The classification of clouds is based upon their form and appearance. However, there is a general relationship between the form of clouds and their height, as shown by actual measurements, so that a classification according to form and appearance is also, in effect, one according to height.

The classification and descriptions which follow are taken from the abridged edition of the International Cloud Atlas, published in 1930.

The heights given are for temperate latitudes, and refer not to sea level but to the general level of the land in the region. It should be noted that, in certain cases, there may be large departures from the given mean heights, especially as regards cirrus, which may be found as low as 3,000 meters (10,000 feet) in temperate latitudes, and in polar regions even almost as low as the surface.

CLASSIFICATION OF CLOUDS [4]

HIGH CLOUDS

(Mean lower level, 6,000 meters, 20,000 feet.)
Cirrus.
Cirrocumulus.
Cirrostratus.

MIDDLE CLOUDS

(Mean upper level, 6,000 meters, 20,000 feet; mean lower level, 2,000 meters, 6,500 feet.)
Altocumulus.
Altostratus.

[4] Abbreviations for entry of cloud names on weather reports will be found in the condensed instructions on the inside of the front cover of Form 1210A.

LOW CLOUDS

(Mean upper level, 2,000 meters, 6,500 feet; mean lower level, close to the surface.)

Stratocumulus.
Stratus.
Nimbostratus.

CLOUDS WITH VERTICAL DEVELOPMENT

(Mean upper level, that of the cirrus; mean lower level, 500 meters, 1,600 feet.)

Cumulus.
Cumulonimbus.

DEFINITIONS AND DESCRIPTIONS OF THE FORMS OF CLOUDS

Cirrus.—Detached clouds of delicate and fibrous appearance, without shading, generally white in color, often of a silky appearance.

Cirrus appears in the most varied forms, such as isolated tufts, lines drawn across a blue sky, branching feather-like plumes (fig. 14),

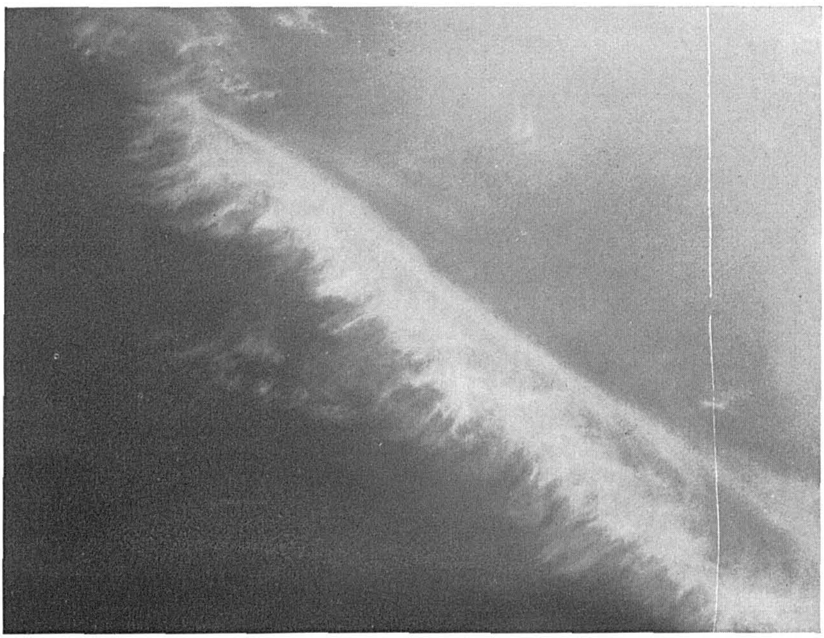

FIGURE 14. Cirrus, plume-like form.

curved lines ending in tufts (fig. 15), etc.; they are often arranged in bands which cross the sky like meridian lines, and which, owing to the effects of perspective, converge to a point on the horizon, or to two opposite points (cirrostratus and cirrocumulus often take part in the formation of these bands).

Cirrus clouds are always composed of ice crystals, and their transparent character is due to the state of division of the crystals.

As a rule, these clouds cross the sun's disc without dimming its light. But when they are exceptionally thick they may veil its light and obliterate its contour. This would also be the case with patches of altostratus, but cirrus is distinguished by its dazzling whiteness and silky edges.

Halos are rather rare in cirrus.

FIGURE 15.—Cirrus, tufted form. (F. Ellerman.)

Cirrocumulus.—A cirriform layer, or patch composed of small white flakes or of very small globular masses, without shadows, which are arranged in groups or lines, or more often in ripples resembling those of the sand on the seashore (fig. 16).

In general, cirrocumulus represents a degraded state of cirrus and cirrostratus, both of which may change into it. In this case the changing patches often retain some fibrous structure in places.

Real cirrocumulus is uncommon. It must not be confused with small altocumulus patches on the edges of altocumulus sheets.

Cirrostratus.—A thin, whitish veil, which does not blur the outlines of the sun or moon, but gives rise to halos. Sometimes it is quite diffuse and merely gives the sky a milky look; sometimes it more or less distinctly shows a fibrous structure with disordered filaments (fig. 17).

FIGURE 16.—Cirrocumulus, undulated form. (E. E. Barnard.)

A milky veil of fog is distinguished from a veil of cirrostratus of a similar appearance by the halo phenomena, which the sun or the moon nearly always produce in a layer of cirrostratus.

Altocumulus.—A layer, or patches, composed of lamina or rather flattened globular masses (fig. 18), the smallest elements of the regularly arranged layer being fairly small and thin, with or without shading. These elements are arranged in groups, in lines, or waves (fig. 19), following one or two directions, and are sometimes so close together that their edges join.

The thin and semitransparent edges of the elements often show irisations, which are rather characteristic of this class of cloud.

At the lower levels, where altocumulus may be derived from a spreading out of the tops of cumulus clouds, it may easily be mistaken for stratocumulus; the convention is that the cloud is altocumulus if the smallest well-defined and regularly arranged elements which

FIGURE 17.—Cirrostratus, fibrous type. (A. J. Weed.)

are observed in the layer (leaving out the detached elements which are generally seen on the edges) are not greater than 10 solar diameters in their smallest diameters.

When the edge of a thin semitransparent patch of altocumulus passes in front of the sun or moon a corona appears close up to them;

this is a colored ring, with red outside and blue inside; the colors may be repeated more than once. This phenomenon is infrequent in the case of cirrocumulus, and only the higher forms of stratocumulus can show it.

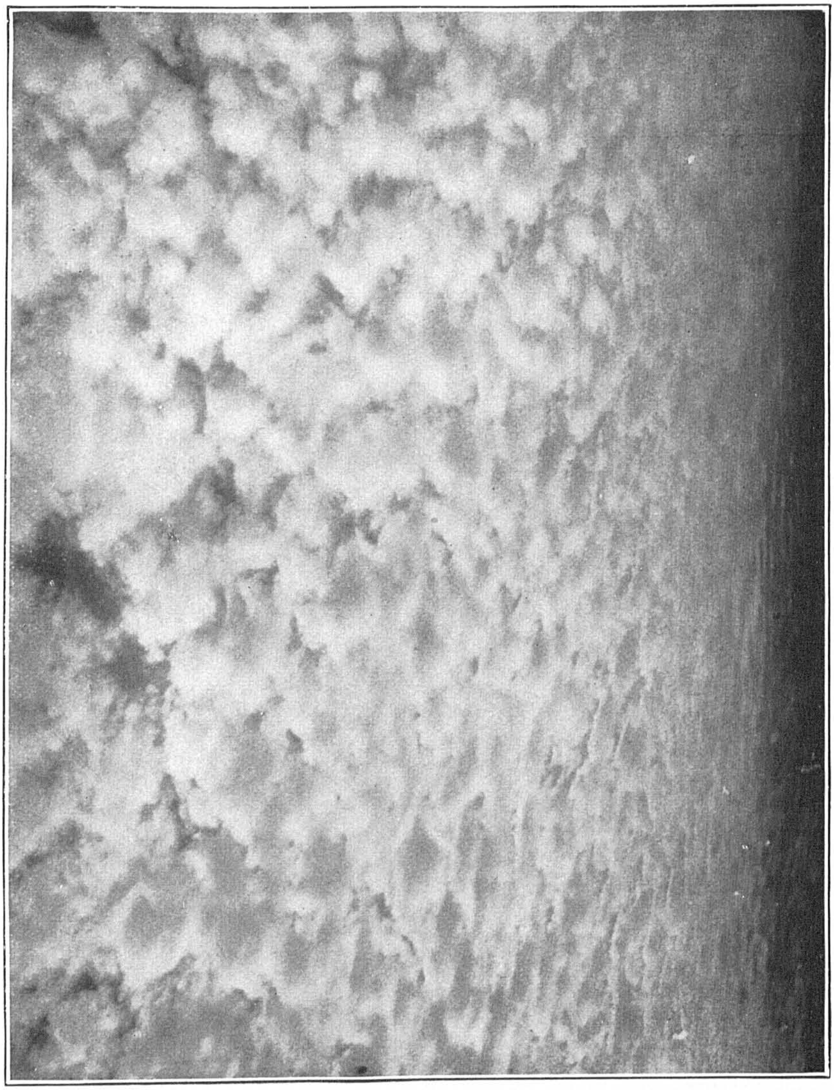

FIGURE 18.—Altocumulus. (A. J. Weed.)

Irisation, mentioned above, is a phenomenon of the same type as the corona; it is a sure mark of altocumulus as distinguished from cirrocumulus or stratocumulus.

Altostratus.—Striated or fibrous veil, more or less grey or bluish in color. This cloud is like thick cirrostratus but without halo phenomena; the sun or moon shows vaguely, with a faint gleam, as though through ground glass (fig. 20). Sometimes the sheet is thin, with forms intermediate with cirrostratus. Sometimes it is very thick and dark, sometimes even completely hiding the sun or moon. In this case differences of thickness may cause relatively light patches between very dark parts; but the surface never shows relief, and the striated or fibrous structure is always seen in places in the body of the cloud.

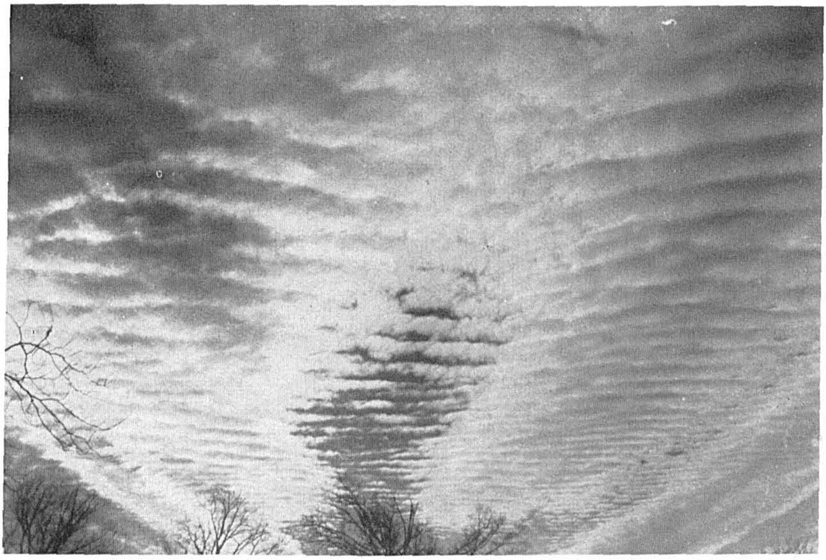

FIGURE 19.—Altocumulus, undulated form.

Every form is observed between high altostratus and cirrostratus on the one hand and low altostratus and nimbostratus on the other.

Rain or snow may fall from altostratus, but when the rain is heavy the cloud layer will have grown thicker and lower, becoming nimbostratus; but heavy snow may fall from a layer that is definitely altostratus.

The limits between which altostratus may be met with are fairly wide (about 5,000 to 2,000 meters).

A sheet of high altostratus is distinguished from a rather similar sheet of cirrostratus by the convention that halo phenomena are not seen in altostratus.

A sheet of low altostratus may be distinguished from a somewhat similar sheet of nimbostratus by the following characters: Nimbostratus is of a much darker and more uniform gray and shows nowhere any whitish gleam or fibrous structure; one cannot definitely see the limit of its undersurface, which has a "soft" look, due to the rain, which may not reach the ground.

The convention is also made that nimbostratus always hides the sun and moon in every part of it, while altostratus only hides them in places behind its darker portions, but they reappear through the lighter parts.

Stratocumulus.—A layer or patches composed of lamina, or globular masses; the smallest of the regularly arranged elements are fairly large; they are soft and gray, with darker parts (fig. 21).

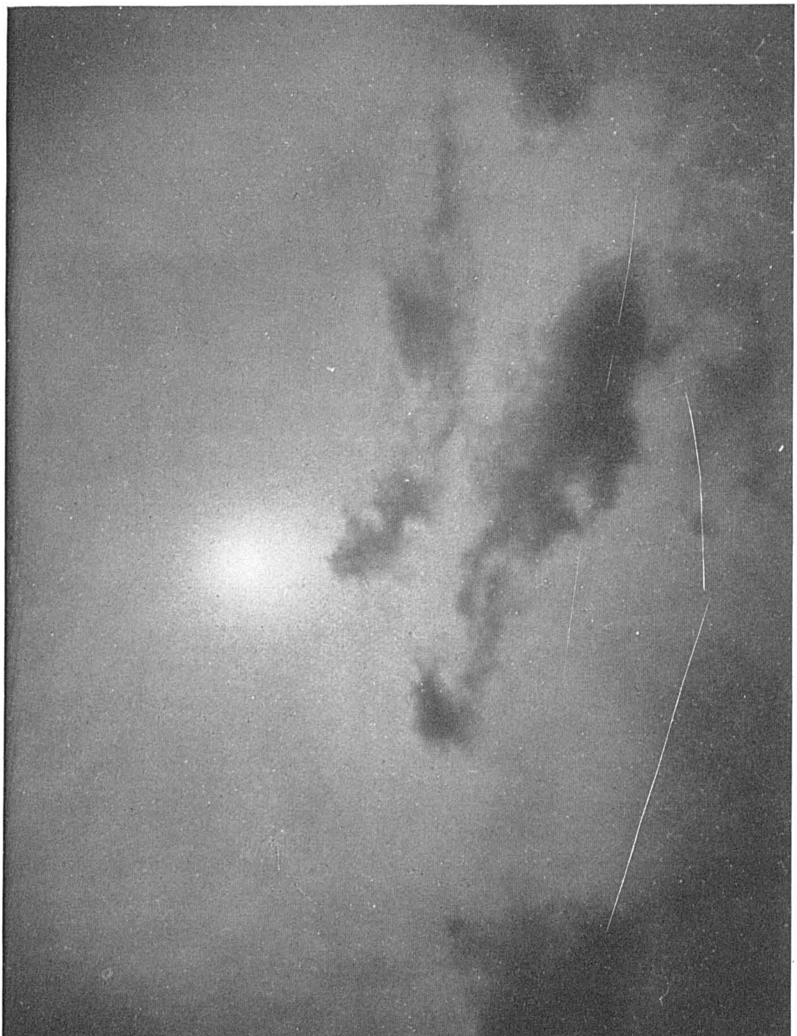

FIGURE 20.—Thin altostratus with fractostratus below. (G. A. Clarke.)

These elements are arranged in groups, in lines, or in waves, aligned in one or two directions. Very often the rolls are so close that their edges join together (fig 22); when they cover the whole sky, as on the continent, especially in winter, they have a wavy appearance.

The elements of thick stratocumulus often tend to fuse together completely, and the layer can, in certain cases, change into nimbostratus. The cloud is called nimbostratus when the cloud elements of

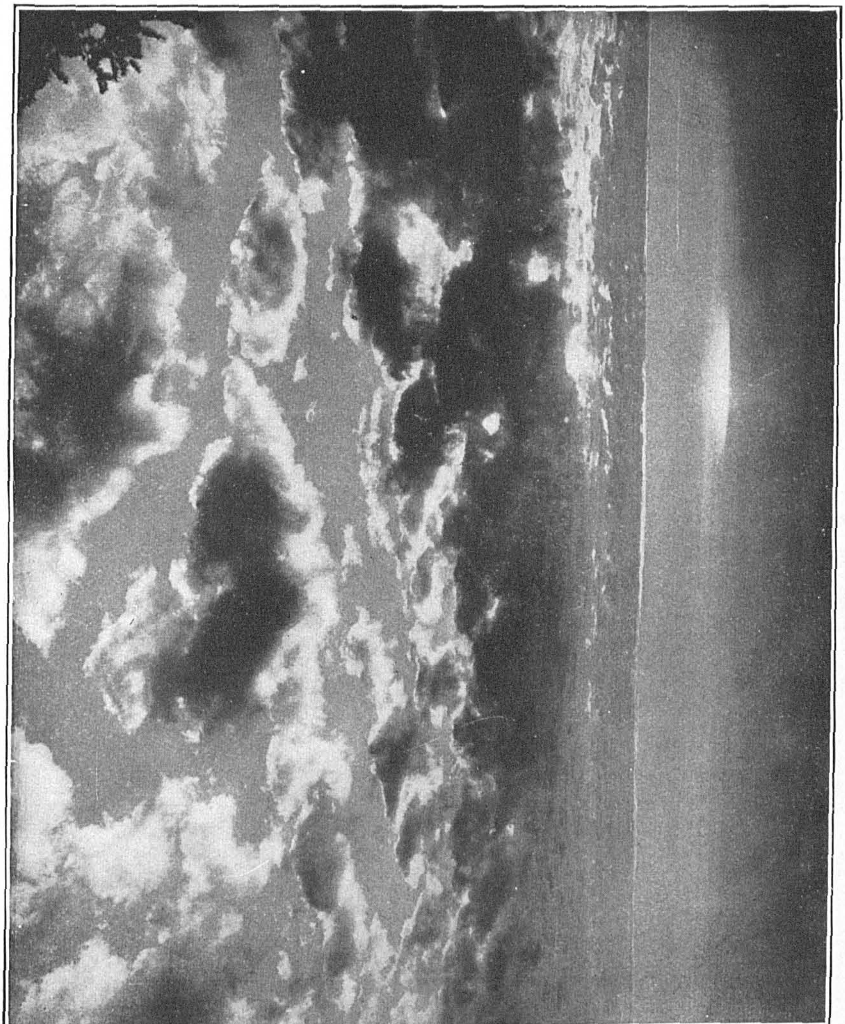

FIGURE 21.—Stratocumulus. (F. Ellerman.)

stratocumulus have completely disappeared and when, owing to the trails of falling precipitation, the lower surface has no longer a clear-cut boundary.

Stratocumulus can change into stratus, and vice versa. The stratus being lower, the elements appear very large and very soft, so that the structure of regularly arranged globular masses and waves disappears as far as the observer can see. The cloud will be called stratocumulus as long as the structure remains visible.

Stratus.—A uniform layer of cloud, resembling fog, but not resting on the ground (fig. 23).

When this very low layer is broken up into irregular shreds it is designated fractostratus.

FIGURE 22.—Stratocumulus, roll type. (W. S. Davis.)

A veil of true stratus generally gives the sky a hazy appearance, which is very characteristic but which, in certain cases, may cause confusion with nimbostratus. When there is precipitation, the difference is manifest—nimbostratus gives continuous rain (sometimes snow), precipitation composed of drops which may be small and sparse, or else large (at least some of them) and close together, while stratus only gives a drizzle, that is to say, small drops, very close together.

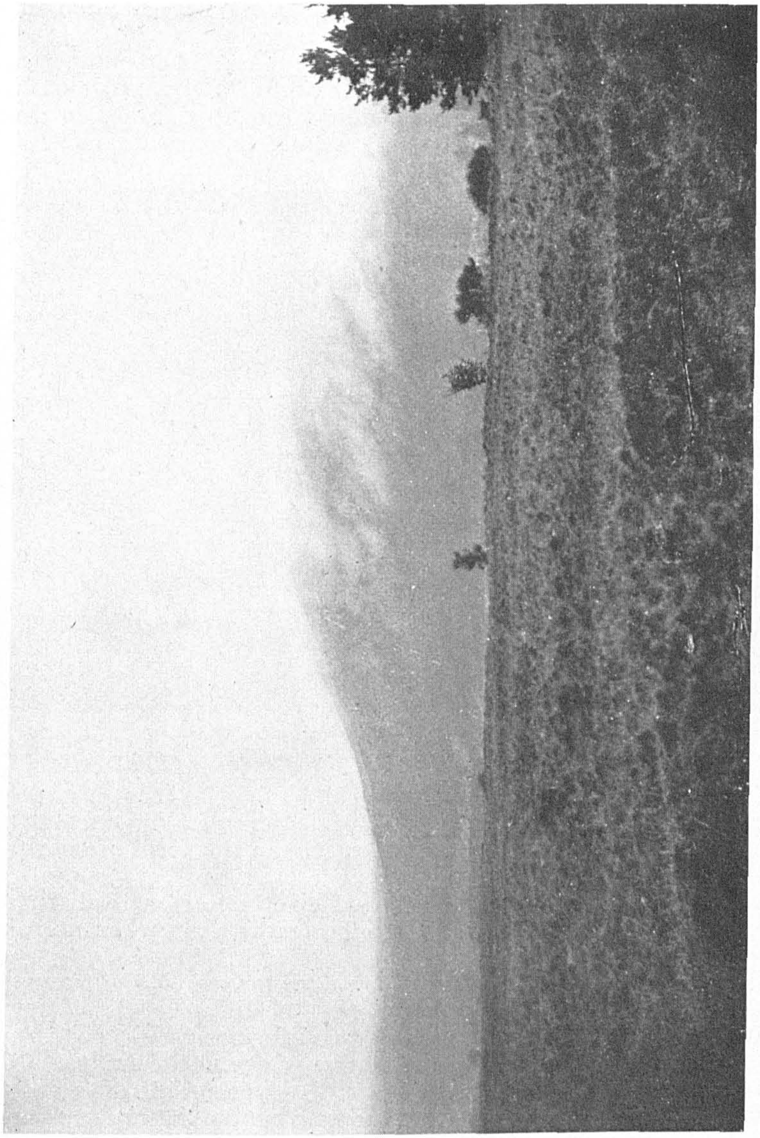

FIGURE 23.—Stratus, with shreds of fractostratus below. (G. A. Clarke.)

When there is no precipitation, a dark and uniform layer of stratus can easily be mistaken for nimbostratus. The lower surface of nimbostratus, however, has always a soft appearance (widespread, trailing precipitation, "virga"); it is quite uniform and it is not possible to make out definite detail; stratus, on the other hand, has a "drier" appearance, and however uniform it may be, it shows some contrasts and some lighter transparent parts.

Fractostratus sometimes originates from the breaking up of a layer of stratus; sometimes it forms independently and develops till it forms a layer below nimbostratus, which latter may be seen in the interstices.

A layer of fractostratus may be distinguished from nimbostratus by its darker appearance, and by being broken up into cloud elements. If these elements have a cumuliform appearance in places, the cloud layer is called fractocumulus and not fractostratus.

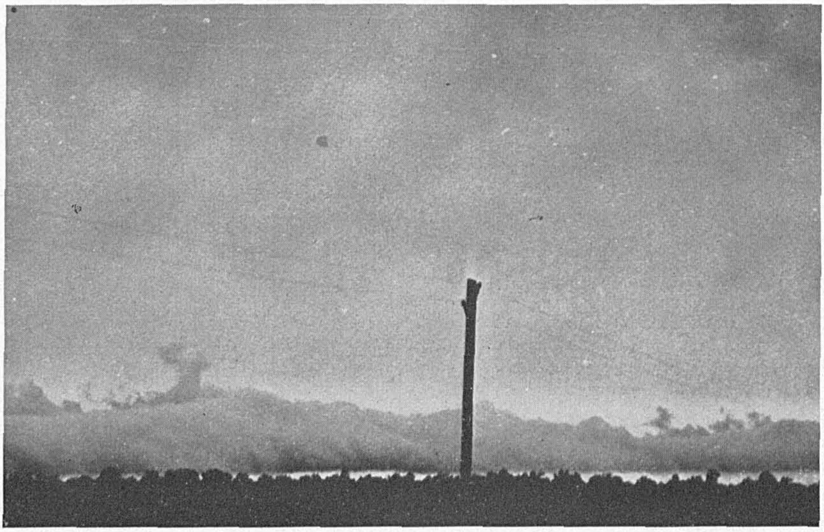

FIGURE 24.—Nimbostratus (above) with stratocumulus roll along horizon. (John C. Hagan.)

Nimbostratus.—A low, amorphous, and rainy layer, of a dark grey color and nearly uniform; feebly illuminated, seemingly from inside (fig. 24). When it gives precipitation it is in the form of continuous rain or snow.

But precipitation alone is not a sufficient criterion to distinguish the cloud which should be called nimbostratus, even when no rain or snow falls from it.

There is often precipitation which does not reach the ground; in this case the base of the cloud is always diffuse and looks "wet" on account of the general trailing precipitation ("virga"), so that it is not possible to determine the limit of its lower surface.

The usual evolution is as follows: A layer of altostratus grows thicker and lower until it becomes a layer of nimbostratus. Beneath the latter there is generally a progressive development of very low, ragged clouds, isolated at first, then fusing together into an almost continuous layer, in the interstices of which, however, the nimbostratus can generally be seen. These very low clouds are called fractocumulus or fractostratus, according as to whether they appear more or less cumuliform or stratiform.

Cumulus.—Thick clouds with vertical development; the upper surface is dome shaped and exhibits protuberances, while the base is nearly horizontal (fig. 25).

When the cloud is opposite to the sun the surfaces normal to the observer are brighter than the edges of the protuberances. When the light comes from the side, the clouds exhibit strong contrasts of light and shade; against the sun, on the other hand, they look dark with a bright edge.

True cumulus is definitely limited above and below; its surface often appears hard and clear cut. But one may also observe a cloud resembling ragged cumulus in which the different parts show constant change. This cloud is designated fractocumulus.

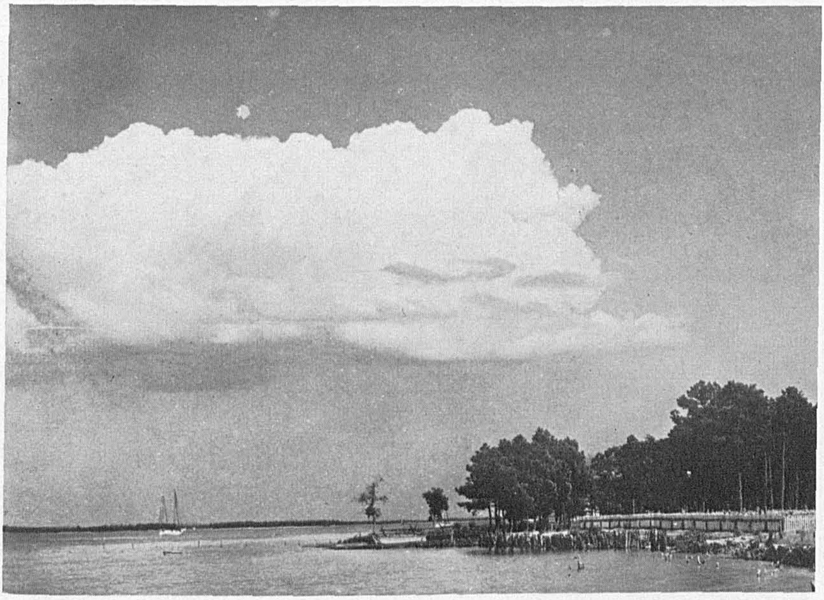

FIGURE 25.—Cumulus. (A. J. Henry.)

Cumulus, whose base is generally of a grey color, has a uniform structure; that is to say, it is composed of rounded parts right up to its summit with no fibrous structure. Even when highly developed, cumulus can only produce light precipitation.

Cumulus, when it reaches the altocumulus level, is sometimes capped with a light, diffuse, and white veil of more or less lenticular shape, with a delicate striated or flaky structure on its edges; it is generally shaped like a bow, which may cover several domes of the cumulus and finally be pierced by them.

Cumulonimbus.—Heavy masses of cloud, with great vertical development, whose cumuliform summits rise in the form of mountains or towers, the upper parts having a fibrous texture and often spreading out in the shape of an anvil (fig. 26).

The base resembles nimbostratus, and one generally notices virga. This base has often a layer of very low ragged clouds below it.

Cumulonimbus clouds generally produce showers of rain or snow and sometimes of hail or soft hail, and often thunderstorms as well.

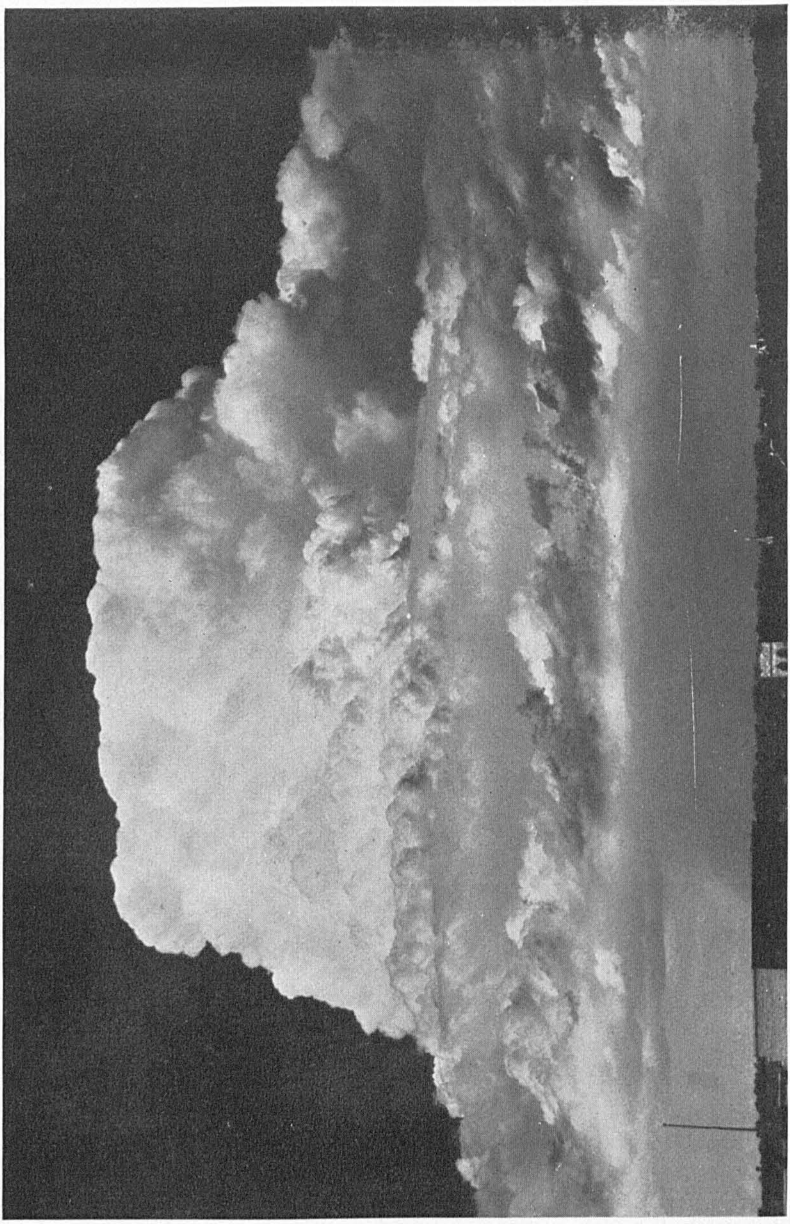

FIGURE 26.—Cumulonimbus.

If the whole of the cloud cannot be seen, the fall of a real shower is enough to characterize the cloud as a cumulonimbus (fig. 27).

Even if a cumulonimbus were not distinguished by its shape from a strongly developed cumulus, its essential character is evident in the difference of structure of its upper parts, when these are visible (fibrous structure and cumuliform structure). Masses of cumulus, however heavy they may be and however great their vertical devel-

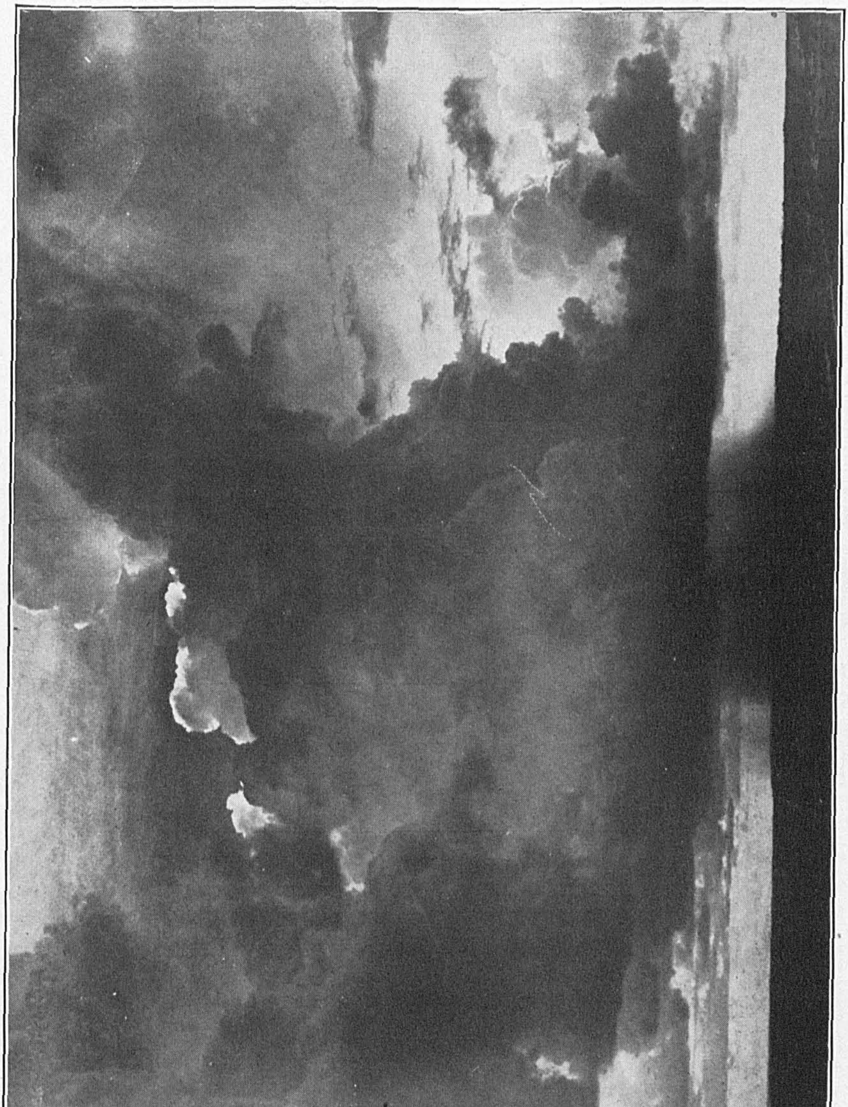

FIGURE 27.—Cumulonimbus. (Air Service, U. S. N.)

opment, should never be classed as cumulonimbus unless the whole, or a part of their tops, is transformed or is in process of transformation into a cirrus mass.

When a cumulonimbus covers nearly all the sky the base alone is visible and resembles nimbostratus, with or without fractostratus or fractocumulus below. The difference between the base of a cumulonimbus and a nimbostratus is often rather difficult to make out. If the cloud mass does not cover all the sky, or if even small portions of the upper parts of the cumulonimbus appear, the difference is evident. If not, it can only be made out if the preceding evolution of the clouds has been followed, or if precipitation occurs; its character is violent and intermittent (showers) in the case of cumulonimbus, as opposed to the relatively gentle and continuous precipitation of a nimbostratus.

The front of a thunder cloud of great extent is sometimes accompanied by a roll cloud of a dark color in the shape of an arch, of a frayed-out appearance, and circumscribing a part of the sky of a lighter grey. This cloud is named "arcus" and is nothing more or less than a particular case of fractocumulus or fractostratus.

DEFINITIONS OF IMPORTANT HYDROMETEORS

[Adapted from the International Atlas of Clouds and of States of the Sky. Paris, 1932]

Rain.—More or less continuous precipitation consisting of fairly large drops falling from an unbroken deck of clouds. The sky is covered either with a layer of so-called rain clouds that has formed from an altostratus system, or with a uniformly gray, but relatively high, canopy of clouds, generally with shapeless masses of cloud below. The latter may even be present in such quantities that the upper clouds are completely hidden.

Snow.—More or less continuous precipitation consisting of solid particles mainly in the form of hexagonal crystals falling from an unbroken deck of clouds. The appearance of the sky is the same as in the case of rain.

Soft hail.—White, opaque, round pellets of snow-like structure and about 2–5 mm in diameter. The pellets are crisp and easily compressible; they rebound when falling on hard surfaces, and thereby often burst. Soft hail occurs mainly at temperatures near the freezing point and mostly on land, often before or together with ordinary snow.

Hail.—Irregular lumps of ice varying in size from that of peas to that of a man's fist. They are either completely transparent or formed of alternating clear and opaque, or snow-like, layers. Hail falls almost exclusively during severe or protracted thunderstorms and never with temperatures below the freezing point.

Drizzle.—More or less uniform precipitation consisting of numerous tiny droplets (diameter generally less than ½ mm) which seem almost to hover in the air and share its slightest movements. Drizzle falls from an unbroken, dense, low layer of stratus clouds. Drizzle can sometimes yield considerable amounts of precipitation, even as much as 20 mm (0.80 inches) in 24 hours, particularly along coastlines and on mountain ranges.

Shower.—Of the above mentioned hydrometeors, rain, snow, soft hail, and ordinary hail may fall in showers. A shower is characterized not only by the quick onset and cessation of the precipitation or its rapid changes of intensity but also, and more especially, by the appearance of the sky. Showery weather is characterized by a rapid alternation of dark, threatening shower-clouds and bright periods of short duration. Deep blue skies are often observed to accompany the latter. If there is absence of definite clearing between the showers it is due either to the presence of a layer of high cloud (which is often the forerunner of further precipitation) or to the fact that the spaces between the shower-clouds are filled with low though lighter clouds. It may even happen that the precipitation never completely stops, the arrival of a shower being marked in such cases by a sudden darkening of the sky and by a sudden increase in the intensity of the precipitation.

Fog.—Microscopic droplets of water, which appear to float in the air, and which cause a sensation of cold and dampness. If watched carefully the water droplets may, under certain circumstances, be seen almost to pass in front of one's eyes. On the whole fog appears white, except near industrial regions, where it becomes dirty gray or yellow. During a true fog which is not dispersing the horizontal visibility is less than 1 km (1,100 yds.).

Mist.—Light fog, in which the horizontal visibility is greater than 1 km (1,100 yds.). It does not cause a raw or damp sensation because the water droplets are too small and far apart. Mist often has a grayish appearance in distinction from actual fog.[1]

Haze.—Tiny particles of dust or salt, which are dry and so extraordinarily small that they are neither felt nor perceived by the naked eye, but which give the air a characteristically smoky appearance. Haze casts a completely uniform veil over the landscape and dulls its colors. Against a dark background this veil has a bluish color but against a light background (such as clouds on the horizon, snow-covered mountain tops, or the sun) it has a dirty or reddish yellow color. Haze may be distinguished by this characteristic from grayish mist, which it sometimes equals in intensity.[2]

PART VI. OPTICAL PHENOMENA

The material appearing under this heading has been taken, with some modifications, from the work, Physics of the Air, by W. J. Humphreys, of the Weather Bureau. It is, of necessity, very much abridged from the original and consists principally of definitions and descriptions.

Many curious and beautiful phenomena, of which the mirage, the rainbow, the halo, the azured sky, and the twilight glow are some of the more conspicuous, are due to the optical properties of the air and the foreign substances suspended in or falling through it. All or nearly all, of them have been the objects of innumerable observations and many careful studies, the results of which, fortunately, have been summarized and discussed by various authors, of whom perhaps the best known are Pernter and Exner.

Most optical phenomena attract the attention of observers, some by their beauty, others on account of the rarity of occurrence. Many of them are more or less closely connected with the weather. All are of importance for one reason or another and call for careful observance and accurate description.

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[1] In North America the term "mist" is commonly applied to precipitation of small intensity; hence it is used synonymously with drizzle or fine rain.

[2] In North America the term "haze" refers to a lack of transparency in the atmosphere, the cause of which is not specified.

PERSPECTIVE PHENOMENA

Apparent stair-step ascent of clouds.—The stair-step appearance of the echelon cloud is perhaps the simplest sky phenomenon due to perspective. The clouds producing this effect on the eye of the observer are more or less evenly spaced, flat-bottomed cumuli of the same base elevation—flat-bottomed and of constant level because of the approximately uniform horizontal distribution of moisture.

Since the clouds are at a higher level than the observer, each successive cumulus, as the distance increases, is seen at a lower angle than its predecessor; and the dark bases of any two adjacent clouds appear to be connected by the lighter side of the farther one, thus forming the alternate "tread" and "riser" of the stair-step.

Apparent arching of cloud bands.—The arching of narrow cloud bands, in a curve resembling the conchoid, is an optical illusion due entirely to the projection of the cloud (above the observer's level) upon the sky. The amount of arching increases with the closeness (and elevation) of the cloud.

Apparent divergence and convergence of crepuscular rays, (sunbeams).—Everyone is familiar with the beautiful phenomenon of the "sun drawing water." in which sunbeams, finding their way through rifts in the clouds, are rendered luminous by the dust in their courses, in the same manner as when passing through a window into a room. Equally familiar and equally beautiful are also those streaks and bands of pearly light, (when the lower atmosphere is illuminated), and azure shadows, (where only the upper atmosphere is illuminated), that often at twilight and occasionally at dawn radiate far out from the region of the sun, and at times even converge toward the opposite point of the horizon. These, too, are only beams of sunlight and shadow bands caused by broken clouds or irregular horizon. Coming, as they do, from the sun, some 93,000,000 miles away, necessarily the beams are practically parallel. Their apparent divergence, convergence, and arching are all illusions due to perspective, just as in the case of the seeming convergence of rails on a long straight track.

Other phenomena due to perspective are the apparent divergence of auroral streamers; the apparent flattening of the dome of the sky (more noticeable when the sky is covered with high cirrus clouds); the change, with elevation, of the apparent size of sun and moon, and a similar change in the apparent distance between neighboring stars.

REFRACTION PHENOMENA

Refraction phenomena are due to irregularities in the density of the atmosphere. Some, such as the scintillation or twinkling of stars, have been observed and studied since remote times, certainly since the days of Aristotle, (384–322 B. C.), who noted the fact that stars twinkle, while planets shine with comparatively steady light.

It is true that on account of their sensible disks the scintillation of planets is much less than that of fixed stars, but under favorable circumstances it is quite perceptible. Even the rims of the sun and moon boil or "scintillate" while, of course, any fine marking on either or on a planet is quite as unsteady as the image of a fixed star.

It is well known that the atmosphere, generally, is so stratified that with increase of elevation many more or less abrupt changes occur in temperature, composition, density, and therefore, refrangibility. As such layers glide over each other, billows are formed, and the adjacent layers thereby corrugated. The several layers frequently also heat unequally, largely because of disproportionate vapor contents, and thereby develop, both day and night, and at various levels, innumerable vertical convections; each moving mass differing, of course, in density from the surrounding air, and by the changing velocity being drawn out into dissolving filaments. Optically, therefore, the atmosphere is so heterogeneous that a sufficiently bright star shining through it would produce on the earth a somewhat streaky pattern of light and shade.

Shadow bands.—A striking proof of the optical streakiness of the atmosphere is seen in the well-known shadow bands that at the time of a total solar eclipse appear immediately before the second, and after the third, contact.

Terrestrial scintillation.—A bright terrestrial light of small size, such as an open electric arc, scintillates when seen at a great distance, quite as distinctly as do the stars and for substantially the same reason; that is, optical inequalities due to constant and innumerable vertical convections or conflicting winds.

Shimmering.—The tremulous appearance of objects. The common phenomenon of shimmering, seen through the atmosphere immediately over any heated surface, is another manifestation of atmospheric refraction, and is due to the innumerable fibrous convections that always occur over such an area.

Optical haze.—The frequent indistinctness of distant objects on warm days when the atmosphere is comparatively free from dust, and ascribed to optical haze, is due to the same thing, namely, optical heterogeneity of the atmosphere, which causes that unsteadiness or dancing of star images that so often interferes with positional and other exact work of the astronomer. Both are but provoking manifestations of atmospheric refraction.

An interesting and important result of astronomical refraction is the fact that the sun, moon, and stars rise earlier and set later than they otherwise would. For places at sea level the amount of elevation of celestial objects on the horizon averages about 35′, and therefore the entire solar and lunar disks may be seen before (on rising), and after (on setting), even their upper limbs would have appeared, in the first case, or disappeared, in the second, if there had been no refraction. This difference in time of rising, or setting, depends on the angle or inclination of the path to the horizon.

Green flash.—As the upper limb of the sun disappears in a clear sky below a distant horizon its last starlike point often is seen to change rapidly from pale yellow or orange to green and finally blue, or, at least, a bluish green. The vividness of the green, when the sky is exceptionally clear, together with its almost instantaneous appearance, has given rise to the name "green flash" for this phenomenon. The same gamut of colors, only in reverse order, occasionally is seen at sunrise.

Terrestrial refraction.—The curving of rays of light is not confined to those that come from some celestial object, but applies to those that pass between any points within the atmosphere, whether at the same or different levels. This latter phenomenon, known as terrestrial refraction, causes all objects on the earth or in the atmosphere to appear to be at greater altitudes than they actually are, except when the surface air is so strongly heated as to cause an increase of density with elevation.

The distance to the horizon, corresponding to a given altitude, therefore obviously depends upon the rate of vertical density decrease.

Looming.—When there is an increase over the normal rate of vertical density decrease, such as often happens over water in middle to high latitudes, it gives rise to the phenomenon known as looming, or the coming into sight of objects normally below the horizon.

Towering.—This phenomenon is similar to looming, and sometimes is so designated. It occurs, as occasionally happens, when the inversion layer is so located that rays to the observer from the top of an object are more curved than those from the bottom. The effect is to make the top appear more elevated—it will tower and seem to draw near.

Sinking.—A phenomenon, exactly the reverse of looming, also frequently observed at sea. It is caused by a decrease below the normal in the rate of vertical density decrease of the atmosphere.

Stooping.—The reverse of towering. Occasionally rays from the base of an object may be curved downward much more rapidly than those from the top, with the obvious result of apparent vertical contraction, and the production of effects quite as odd and grotesque as those due to towering.

REFRACTION BY WATER DROPS

Rainbow.—The ordinary rainbow, seen on a sheet of water drops—rain or spray—is a group of circular or nearly circular arcs of colors whose common center is on the line connecting the observer's eye with the exciting light, (sun, moon, electric arc, etc.), or rather, except rarely, on that line extended in the direction of the observer's shadow. A very great number of rainbows are theoretically possible and doubtless all actually occur, though only three, (not counting supernumeraries), certainly have been seen on sheets of rain.

Rainbows are produced by a complicated process of refraction of sunlight as it enters and passes out of the raindrops, internal reflection of the light within the drops and interference of the rays after leaving the drops, (Davis).

The records of close observation of rainbows soon show that not even the colors are always the same; neither is the band of any color of constant angular width; nor the total breadth of the several colors at all uniform; similarly the purity and brightness of the different colors are subject to large variations. The greatest contrast, perhaps, is between the sharply-defined brillant rainbow of the retreating thunderstorm and that ill-defined, faintly tinged bow that sometimes appears in a fog—the " white bow " or " fog bow."

All these differences depend essentially upon the size of the drops, and therefore inequalities often exist between even the several portions, especially top and bottom of the same bow, or develop as the rain progresses. Additional complications occasionally result from the reflection of bows and from bows produced by reflected images of the sun, but though unusual and thus likely to excite wonder and comment, such phenomena are easily explained.

Rather narrow bands of color, essentially red, or red and green, often appear parallel to both the primary and the secondary bows, along the inner side of the first and outer of the second. These also differ greatly in purity and color, number visible, width, etc., not only between individual bows but also between the several parts of the same bow. No such colored arcs, however, occur between the principal bows.

REFRACTION BY ICE CRYSTALS

The cirrus clouds and others formed at temperatures considerably below 0° C. usually consist of small but relatively thick snowflakes with flat bases, or ice spicules with flat or, rarely, pyramidal bases, always hexagonal in pattern and detail.

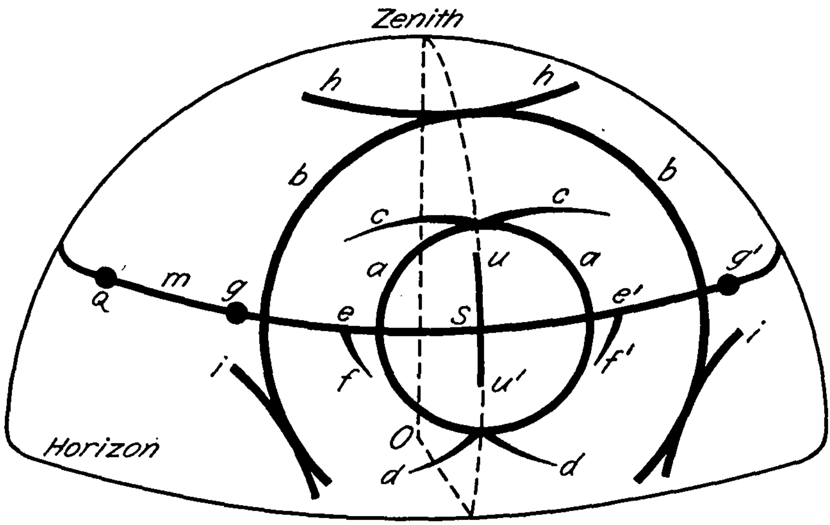

FIGURE 28.—Perspective view of the sky, showing the sun (S); ordinary halo of 22° (a); great halo of 46° (b); upper tangent arc of the halo of 22° (c); lower tangent arc of halo of 22° (d); ordinary parhelia of 22° (e, e′); Lowitz arcs (f, f′); parhelia of 46° (g, g′); circumzenithal arc (h); infralateral tangent arcs of the halo of 46° (i); the parhelic circle (m); a paranthelion of 90° (q); plane of the horizon; the observer (O).

Light from the sun, for instance, obviously takes many paths through such crystals and produces in each case a corresponding and peculiar optical phenomenon. Several of these phenomena, the halo of 22° radius, the halo of 46° radius, the circumzenithal arc, parhelia, etc., are quite familiar and their explanations definitely known. Others, however, have so rarely been seen and measured that the theories of their formation are still somewhat in doubt. Finally, many phenomena, theoretically possible, as results of refraction by ice crystals, appear so far to have escaped notice. The more common forms of halos as well as some phenomena less frequently observed, are illustrated in figures 28 and 29.

The most frequent of the numerous phenomena caused by the passage of light through ice crystals, of which the halo of 22° is an example, are occasioned by prismatic refraction between the sides of the hexagonal spicules, forming angles of 60° with each other. The less numerous phenomena, among which is the halo of 46°, are caused by refraction between the sides and bases of spicules, forming angles of 90° with each other.

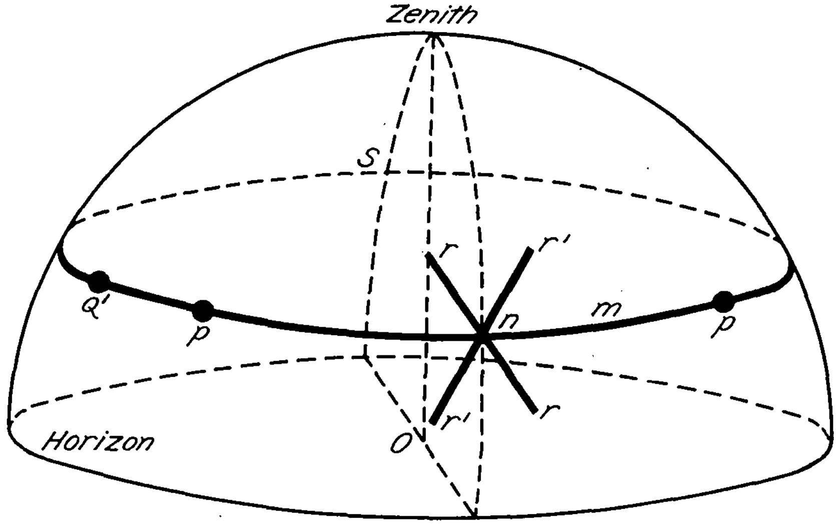

FIGURE 29.—Perspective view of the sky, showing the observer (O); his horizon, and his meridian (O S zenith, n); the parhelic circle (m); ordinary paranthelia of 120° (p); the paranthelion of 90° (q'); the oblique arcs of the anthelion (r, r'); and the anthelion (n).

Parhelia of 22°.—Whenever the air through any depth or at any level contains innumerable hexagonal snow crystals with their sides vertical (the position about which relatively broad crystals oscillate), two colored bright spots, known as parhelia, or sun dogs, appear at 22°, or more, from the sun, one to the right, the other to the left. Each bright spot is in the direction of maximum light or minimum refraction, and has the same altitude as the sun.

Halo of 22°.—When the refracting edges of the ice crystals are vertical, as they tend to be in the case of relatively thin snowflakes falling through still air, parhelia are produced, as just explained. But, in general, these edges lie in all directions, especially at the windy cirrus level and when the crystals are of the short columnar type; and as refracted light reaches an observer in every plane through his eye and the sun, (or moon), to which the refracting edges are approximately normal, it follows that the effect produced by fortuitously directed snow crystals must be more or less symmetrically distributed on all sides of the exciting luminary. There may, however, be a maximum brightness both directly above and directly below the sun, since ice needles tend to settle with their refracting edges horizontal.

This condition gives rise to the halo of 22°, the most frequent and best known of the halo family. Its inner portion is red, because light of that color is least refracted. Other colors follow, with increase of distance, in the regular spectral sequence, but with decrease of wave length they so rapidly fade that even green is indistinct and blue seldom detected.

When the sun is within 10° of the horizon, the halo of 22° and the parhelia of 22° are practically superimposed. At greater altitudes they become distinctly separated.

Tangent arcs of the halo of 22° are the well-known and fairly common arcs that occur above and below the circular halo. These arcs change with the elevation of the sun. Portions below the natural horizon can only be seen from sufficient height. The horizontal tangent arcs are produced by crystals whose principal axes are horizontal, which is the position in which ice spicules or needles tend to float.

Arcs of Lowitz.—On rare occasions oblique extensions of the parhelia of 22°, concave toward the sun and with red inner borders, are seen. These are known as the arcs of Lowitz, after the astronomer who described them as seen in the famous Petersburg halo complex of July 18, 1794.

Produced by crystals whose principal axes oscillate in that particular vertical plane that passes through the sun, they are nearly always too faint to be seen, because, in part, this unique attitude can only rarely be assumed by any considerable proportion of the crystals present.

Parhelia of 46°.—Similar to the parhelia of 22°, but due to refraction between the sides and ends of snow crystals, having an angle of intersection of 90°, when the intersection is vertical.

Halo of 46° and 90°.—The image of the sun produced in the principal plane of a 90° refracting angle of an ice crystal, as seen by the observer, is 45°44′ from the sun itself. Hence it follows that when such crystals are very abundant and set at random in all directions the innumerable images so produced must together assume the shape of a ring about the sun of radius 45° 44′. This is the well-known, though not very common, halo of 46°.

Occasionally a faint white halo, sometimes called the halo of Hevelius, is seen at 90° from the sun.

Circumzenithal and circumsorigontal arcs.—Occasionally, an arc of, perhaps, 90°, having its center at the zenith, and, therefore, known as the circumzenithal arc, is seen some 46°, or a little more, above the sun. It generally lasts only a few minutes, about five on the average, but during that time often is so brilliantly colored, especially along that portion nearest the sun—red on the outside, to violet inclusive—as to be mistaken by persons unfamiliar with it for an exceptionally bright rainbow. It occurs most frequently when the altitude of the sun is about 20° and at times when the parhelia of 22° are conspicuous; presumably, therefore, when the principal axes of a large portion of the crystals are practically vertical.

Kern's arc is so-called from the name of the first person to report it. It occurs exactly opposite the corresponding circumzenithal arc and on the same circle. It might, therefore, also be called the anticircumzenithal arc.

A colored arc, red on the upper side, of perhaps 90° in extent, occasionally seen parallel to the horizon and about 46°, or a little more, below the sun is called a circumhorizontal arc.

Tangent arcs.—Just as flat-topped crystals with vertical sides produce a circumzenithal arc when the altitude of the sun is between 0° and 32°12′, so, too, similar crystals whose axes are horizontal and directed toward any point whose solar distance is between 90° and 57° 48′, or between 0° and 32°12′, produce a colored arc—red next the sun—about this directive point as a center. And as there are two such points corresponding to each solar distance, one to the right, the other to the left, of the solar vertical, it follows that arcs formed in the above manner are symmetrically situated with respect to this vertical. Further, when the solar distance of the directive-points is 67°52′ or 22°8′, the resulting arc is tangent to the halo of 46°, and as always some, at least, of the innumerable crystals are turned toward this point, except when the altitude of the sun is greater than these values, respectively, it follows, with the same exceptions, that the blend of the numerous arcs produced by the various directed crystals is always tangent to the halo of 46°, and also that except near the point of tangency only the red of these blends is reasonably pure.

Infralateral tangent arcs of the halo of 46° are produced when the altitude of the sun is less than 67°52′.

When the altitude of the sun is 57°48′, or a little greater, the two tangent arcs, springing from a common point on the solar vertical, form a wide V.

When the solar altitude equals 67°52′, the two arcs, now merged into a smooth continuous curve, are tangent to the halo at its lowest point.

Finally, for altitudes of the sun greater than 67°52′, the arcs, still appearing as a single curve, are slightly separated from the circular halo even at its lowest and closest point.

When the altitude of the sun is less than 22°8′ superlateral tangent arcs similar to the infralateral are produced.

Unusual halos.—Halos of various radii other than those already given have occasionally been reported. They can readily be accounted for on the assumption that the columnar ice crystals have certain pyramidal bases that afford the appropriate refraction angles.

Obviously, each bright spot of the primary halo phenomena, especially the upper and lower points of the 22° circle and its parhelia, must in turn be the source of secondary halos. Doubtless, the 22° halos of the lateral parhelia contribute much to the flaring vertical column through the sun that occasionally has been seen; and, perhaps, the brilliant upper and lower points of the halo of 22° may produce faint secondary parhelic circles. In general, however, very few of the secondary halos are ever bright enough to be seen even when carefully looked for.

A few halos not included in any of the above classes have been once reported. No satisfactory explanations of them have been offered. Clearly, though, since the ice crystal appears in many modified forms—with flat tabular, and pyramidal ends, for instance—and even in orderly clusters, it is obvious that although only a few halos are well known, a great many are possible.

DIFFRACTION PHENOMENA

Coronas.—Coronas consist of one or more sets of rainbow-colored rings, usually of only a few degrees radius, concentrically surrounding the sun, moon, or other bright objects when covered by a thin cloud veil. They differ from halos in having smaller (except in rare cases), and variable radii, and in having the reverse order of colors; that is, blue near the sun, say, and red farthest away.

Clearly, then, coronas are caused by diffraction or the distribution of effective (nonneutralizing), quantities of light off the primary path, resulting from the action of cloud particles on radiation from a distant source.

When coronas are seen in clouds whose temperature is above 0° C., or in which halos do not form, it is certain that they are due to droplets. The most brilliant coronas, however, are formed by very high clouds, whose temperatures often must be far below freezing, from which it has been assumed that these coronas must be due to the diffractive action of ice needles. There are reasons, however, for believing that they are due instead to very small undercooled water droplets of approximately uniform size.

Iridescent clouds.—Thin and perhaps slowly evaporating cirrostratus and cirrocumulus clouds occasionally develop numerous iridescent borders and patches of irregular shape, especially of red and green, at various distances from the sun up to 30° or more. A brilliantly colored iridescent cloud of considerable area is justly regarded as one of the most beautiful of sky phenomena. Imperfectly explained until recently, it is now believed that these colored patches are only fragments of unusually large and exceptionally brilliant coronas, formed as described in the preceding paragraph.

MIRAGE

The mirage is a refraction phenomenon occasioned when the air is calm and the change of density with increase of height unusual. (It includes looming, towering, sinking, and stooping, previously described under the heading "Refraction phenomena.") When the density of the air decreases from the ground upward more rapidly than the normal rate, as it does when the ground is covered with a layer of very cold air, the rays of light are bent more than normally toward the earth and the mirage is seen raised above the object, which may be below the horizon at the time. This form of the phenomenon, in which the mirage appears as if reflected from an overhead plane mirror, is known as the superior mirage.

If, on the other hand, the density increases from the ground upward, as it does over highly heated deserts, the rays are bent upward and the image appears as if reflected from a plane mirror below the observer. This is the inferior mirage, common in flat desert regions, especially during the warmer hours of the day. The phenomenon closely simulates, even to the quivering of the images, the reflection by a quiet body of water of objects on the distant shore, the "water" being the image of the distant low sky.

In addition to these simpler forms of mirage, there is one of complex displacements and distortions known as the Fata Morgana, which apparently results from the coexistence of the temperature disturbances peculiar to both the superior and inferior mirage. The name Fata Morgana has become generic for all such multiple images, wherever they occur.

AURORA POLARIS

The aurora polaris is a well-known but imperfectly understood luminous phenomenon of the upper atmosphere.

While no two auroras are exactly alike, several types have been recognized, such as arcs, bands, rays, curtains or draperies, coronas, luminous patches, and diffuse glows. The arcs normal to the magnetic meridian, often, but not always, reach the horizon. Their under edge is rather sharply defined, so that by contrast the adjacent portion of the sky appears exceptionally dark. The rays, sometimes extending upward from an arch, at other times isolated, are parallel to the lines of magnetic force. Many auroras are quiescent, others exceedingly changeable, flitting from side to side like wandering searchlights, and in some cases even waving like giant tongues of flame.

The aurora of the Northern Hemisphere occurs most frequently, about 100 per year, at the latitudes 60° (over the North Atlantic and North America) to 70° (off the coast of Siberia). Its frequency appears to be less within this boundary, while with decrease of latitude it falls off so rapidly that even in southern Europe it is a rare phenomenon. At the same latitude it is distinctly more frequent in North America than in either Europe or Asia.

The distribution of auroras in the Southern Hemisphere is not so well known, but it appears to be similar, in general, to that of the Northern.

It is well established that on the average auroras are more numerous during years of sun-spot maxima than during years of spot minima. They also appear to be more numerous before midnight than after. Relations of frequency to phase of the moon, seasons, etc., have also been discussed, but with no conclusive results.

Color.—Many auroras are practically white. Red, yellow, and green are also common auroral colors. Some streaks and bands are reddish through their lower (northern), portion, then yellowish, and finally greenish through the higher portions. Much of the light is due to nitrogen bands, but the source of the prominent green line of the auroral spectrum is oxygen.

There is good evidence that this green light, the light that produces the "auroral line," is always present in the sky, though whether wholly of auroral origin, or due in part to bombardment by meteoric dust, or to some other cause, is not known.

Height.—The problem of the height of auroras has often been investigated, but only recently solved. By simultaneously photographing the same aurora from two stations against a common background of stars, many excellent height measurements have been secured. The upper limits of the auroral light vary from about 100 kilometers to over 500 kilometers; and the lower limits from perhaps 85 kilometers to 170 kilometers, with two well-defined maxima, one at 100 kilometers, the other at 106 kilometers.

Cause.—The fact that brilliant shifting auroras are accompanied by magnetic storms renders it practically certain that they, and presumably therefore all auroras, are due to electrical discharges; and the further fact that they vary in frequency with the sun-spot period indicates that this current either comes from or is induced by the sun.

PART VII. PREPARATION OF WEATHER MAPS ON SHIPBOARD

If the shipmaster desires to have weather maps prepared at sea he must secure observations by radio and, since they are in code, he must have them deciphered before making entries on the map. The observations may be secured by either of two methods. He may exchange weather reports with other ships in the region to be mapped. However, this practice, if followed generally, would result in much confusion by crowding radio communication channels and involving a great deal of unnecessary labor for all concerned. It is the only method possible in regions that are not covered by regular broadcasts of weather data by a national meteorological service; it is very helpful when the ship is in the vicinity of a severe storm, even when regular broadcasts are available, since special reports collected in this manner serve to supplement the broadcast data and also provide information during intervals between the broadcasts.

The practice of copying the daily broadcasts of data arranged especially for preparation of weather maps is recommended, whenever feasible. One transmission by radio then serves all ships in the area with selected reports favorably distributed over the region.

CODE USED

The International Figure Code is now used quite generally in the weather broadcasts, hence the problem of deciphering the observations has been greatly simplified. The reports are considerably abbreviated by use of code, hence much less time is consumed in transmission than in individual exchanges in plain language.

RADIO BROADCASTS

The principal radio bulletins broadcast by the Weather Bureau for the benefit of ships at sea are known as Major Marine Bulletins. Separate bulletins are broadcast for Pacific and Atlantic waters, the latter including the Gulf of Mexico and Caribbean Sea. Both of these bulletins contain forecasts, warnings, and pressure synopses, which are followed by land-station reports and ships' observations suitable for preparing weather maps.

Many other local and special broadcasts are made by the Weather Bureau for the benefit of mariners. A description of the bulletins and local broadcasts, with schedules and explanations of the codes used, is contained in Circular No. 1—Radio, issued by the Weather Bureau. The bulletins are subject to change from time to time, and the revised editions are distributed to mariners and others.

Schedules and frequencies of broadcasts containing forecasts, warnings, and meteorological data from the weather services of other countries and, briefly, the contents of the broadcasts, are given in one or more of the following publications: Radio Aids to Navigation, issued by the Hydrographic Office, United States Navy Department, Washington, D. C.; Wireless Weather Messages, M. O. 252, issued by the Meteorological Office, Air Ministry, London, England; and Les Messages Synoptiques du Temps, issued by the International Meteorological Organization, Utrechtsche weg 194, De Bilt, Netherlands.

PREPARATION OF WEATHER MAPS

After the weather observations from various ships and land stations are secured by radio, they are entered on a skeleton map or a blackboard.

If a blackboard is used, it should provide for at least two maps, of the current and preceding days, or of the current and preceding observations if two or more maps are prepared daily. It is important that the map of the previous day or observation be retained for comparison with the current map to determine the rate of movement of weather conditions shown thereon.

Outline charts or base maps specially designed for drawing weather maps at sea are furnished by the United States Weather Bureau and some other meteorological services to mariners who cooperate in furnishing weather observations by radio or mail. If suitable base maps are not available they may be improvised; a sheet of transparent paper is placed over an appropriate small scale map and the continental outlines are sketched in; the weather observations are then entered, the paper is removed and the map is completed by drawing the lines of equal pressure—the isobars.

A plan which requires less labor is as follows: A suitable map is covered with tracing paper fastened down with pins or thumb tacks. The observations are entered and the map is completed. The tracing paper is left in place with the meteorological data thereon until time to draw another map. After removal, the tracing paper may be filed away. By this method it is not necessary to sketch in the continental outlines. If any particular map is consulted at a later date it may be placed in position over the base map if the reference points have been marked on the tracing.

Some base maps designed for preparing weather charts have small circles at the locations of selected weather stations from which observations are available. The circle is used to show the percentage of the sky covered by clouds at the time of observation. For observations from ships, since they have no fixed reporting position, it is not possible to have fixed circles printed on the base chart. In entering the state of the sky on the map it is, therefore, necessary to draw a small circle at the geographical position from which each ship report originated; this is also done for each land-station location if such circles are not already provided on a printed base.

An abridged list of symbols for entry of state of weather is shown in figure 30.

In ship reports containing only the universal groups, the amount of cloudiness is not always specifically given. In such cases the location of the observing station or ship may be shown by a dot instead of a circle, as in examples "C" and "D" in figure 31. The supplementary groups, when included in the reports, always contain the amount of cloudiness.

The direction of the wind is shown by an arrow drawn through the station circle. The arrow flies with the wind; that is, the head of the arrow points in the direction *toward* which the wind is blowing. A northwest wind, for example, blows from the northwest toward the southeast and the head of the arrow should point toward the southeast. To save time, the head of the arrow is omitted on some maps and only the shaft is drawn, pointing in the direction *from* which the wind blows. When calm, no arrow is drawn.

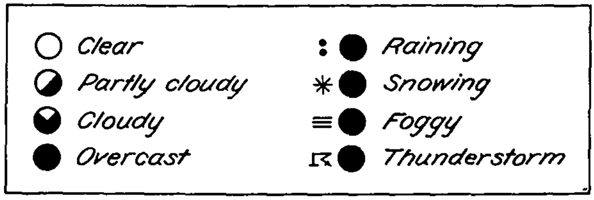

FIGURE 30.—Symbols (abridged) for showing state of weather.

The force of the wind is shown by barbs (or feathers) on the shaft of the arrow, the number of feathers being equal to the number for wind force on the Beaufort scale.

If preferred, wind force to half scale may be indicated by full barbs and half barbs. The full barb represents two units of force on the Beaufort scale and the half barb one unit; for example, two full barbs and one half barb together indicate force 5. If this practice is adopted, the barbs (or feathers) are all drawn on the same side of the arrow shaft, which is the right side when facing in the direction from which the wind is blowing. The use of full- and half-length barbs (Beaufort half scale) was adopted by the United States Weather Bureau, effective January 1, 1937.

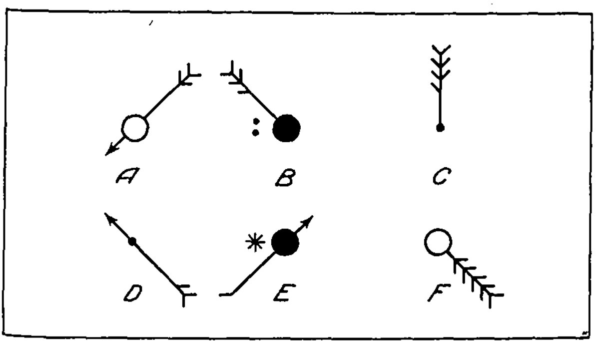

FIGURE 31.—A. Wind northeast, force 4, weather clear (with arrowhead). B. Wind northwest, force 5, raining (arrowhead omitted). C. Wind north, force 7 (state of weather not shown; arrowhead omitted; dot shows location of observing station or ship). D. Wind southeast, force 3. E. Wind southwest, force 1, snowing. F. Wind southeast, force 10, clear.

Examples of different methods of making entries of wind direction and force, with and without station circles and arrowheads, are shown in figure 31.

Various methods of entry (arrowheads, state of weather, etc.) are shown in order that the shipmaster may adopt practices suited to his needs. Whatever practice is adopted should preferably be uniformly used on all his maps.

After the entry of wind direction and force has been made, with state of weather when required, figures are placed in a convenient location at the right of the station position to show barometric pressure at time of observation and, if desirable, temperatures of air and water. In the International Code for ships' weather reports, barometric pressure is given in millibars with the first figure (or figures) omitted. Thus, 998 millbars is coded as 98; 1,021 millibars is given as 21.

Temperatures in reports from land stations and from ships cooperating with the Weather Bureau are given in Fahrenheit degrees. The supplemental groups of the code also contain a figure for the difference between air and water temperatures, from which the water temperature may be computed approximately.

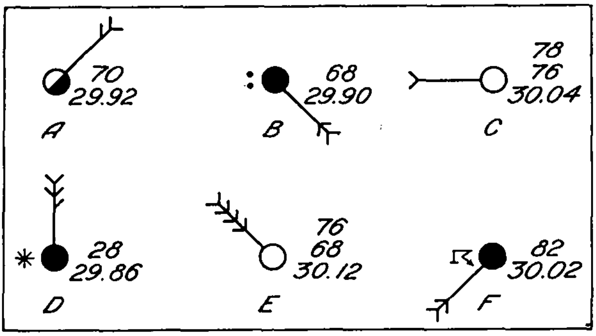

FIGURE 32.—Examples of entry of data on weather maps. A. Wind northeast, force 3, partly cloudy, air temperature 70, pressure 29.92. B. Wind southeast, force 4, raining, air temperature 68, pressure 29.90. C. Wind west, force 2, clear, air temperature 78, water temperature 76, pressure 30.04. D. Wind north, force 5, snowing, air temperature 28, pressure 29.86. E. Wind northwest, force 8, clear, air temperature 76, water temperature 68, pressure 30.12. F. Wind southwest, force 4, overcast, thunderstorm, air temperature 82, pressure 30.02.

If both air temperature and pressure are entered, the figures for temperature are placed above those for pressure. If both air and water temperatures are entered, the first figure is air temperature, the middle figure water temperature, and the last figure barometric pressure. In entering barometric pressure the inches may be omitted and two figures used for hundredths of an inch.

Examples of complete entries, including temperature and pressure, are given in figure 32.

THE ISOBARS

All available weather reports from regions of interest are entered on the chart in standard form in the manner indicated in the foregoing and the map is then ready for drawing of the isobars, or lines joining points of equal pressure.

Atmospheric pressure reduced to sea level, as reported in ships' weather observations and in the radio broadcasts, is used. It is customary to draw isobars for each one-tenth inch of pressure. If millibars are used, lines are drawn at intervals of 4 millibars.

When numerous observations are secured and entered on the chart, the isobars may be drawn satisfactorily by adhering rather closely to the pressures entered. In preparing weather charts at sea, however, the observations are often widely scattered, which makes it necessary to study carefully the wind circulation, as shown by the wind arrows, before drawing the isobars.

In some areas of considerable extent there may be no observations at all. The wind directions at surrounding stations must then serve as a guide in extending the isobars into or through such regions. A study of the wind circulation is useful also in the event that an incorrect pressure reading appears on the map, owing to faulty observation, a defective barometer, or to an error in transmission by radio.

In a convenient place near to the lowest barometer reading on the map, the word LOW is written; near the highest barometer reading the word HIGH is written. If the lowest and highest barometer readings fall well within the field of observations, the words LOW and HIGH will mark the locations of the centers of the principal cyclone and anticyclone, respectively. In many cases, however, the actual center of the principal cyclone will lie outside of the field of observation. In such cases the word LOW merely marks the place of lowest barometric pressure on the map and not the actual center of the cyclonic system.

Frequently there are a numbers of separate and distinct regions of low and high pressure, hence the words LOW and HIGH may each appear in several places on the map.

The weather map of February 27, 1933, with the isobars drawn from data contained in the Major Marine Bulletin broadcast at 10 p. m., 75th meridian time (0300 G. C. T., Feb. 28, 1933), is shown in figure 33.

A deep LOW is centered near Sable Island (fig. 33) with lowest barometer reading 28.74 inches. The wind circulation and barometer readings in the northeastern portion of the map indicate the presence of another LOW center to the eastward. A third LOW center appears in the northwestern Gulf of Mexico, a short distance southeast of Galveston, while a fourth is evident from wind circulation and slightly lower pressure in the extreme northwestern portion of the map. The principal HIGH overlies the lake region and central valleys.

If the barometer readings and wind arrows clearly indicate that the center of the LOW or HIGH is within the field of observations, a circle is drawn to enclose the central region of lowest or highest pressure, as has been done in the case of the LOW centered at Sable Island in figure 33. If it appears that the region of highest or lowest pressure lies beyond the boundaries of the map or outside the field of observations, the isobars are left open as in the case of the LOW in the northeastern corner of the map in figure 33.

After the isobars are drawn to enclose, or partially enclose, all of the separate and distinct regions where pressure is higher or lower than in surrounding areas on the chart, lines for intermediate pressures are drawn for each one-tenth inch. If the highest pressure is 30.46 inches, an isobar is drawn for 30.40 inches and so marked with the word HIGH at the center. If the lowest pressure is 29.23 inches, an isobar for 29.30 inches is drawn with the word LOW at the center. All intermediate lines, 29.40, 29.50, 29.60, etc., up to 30.30 inches, are then drawn in. At the ends of the line, or in a break in the line, the pressure is indicated (fig. 34).

In drawing the lines it should be kept in mind that pressure must be relatively high on one and the same side of a line and relatively low on the other side throughout its course. This requirement is sometimes troublesome for the beginner to satisfy when the isobaric map is "flat", i. e., when there are only slight pressure differences over considerable areas. Practice in preparing weather charts with

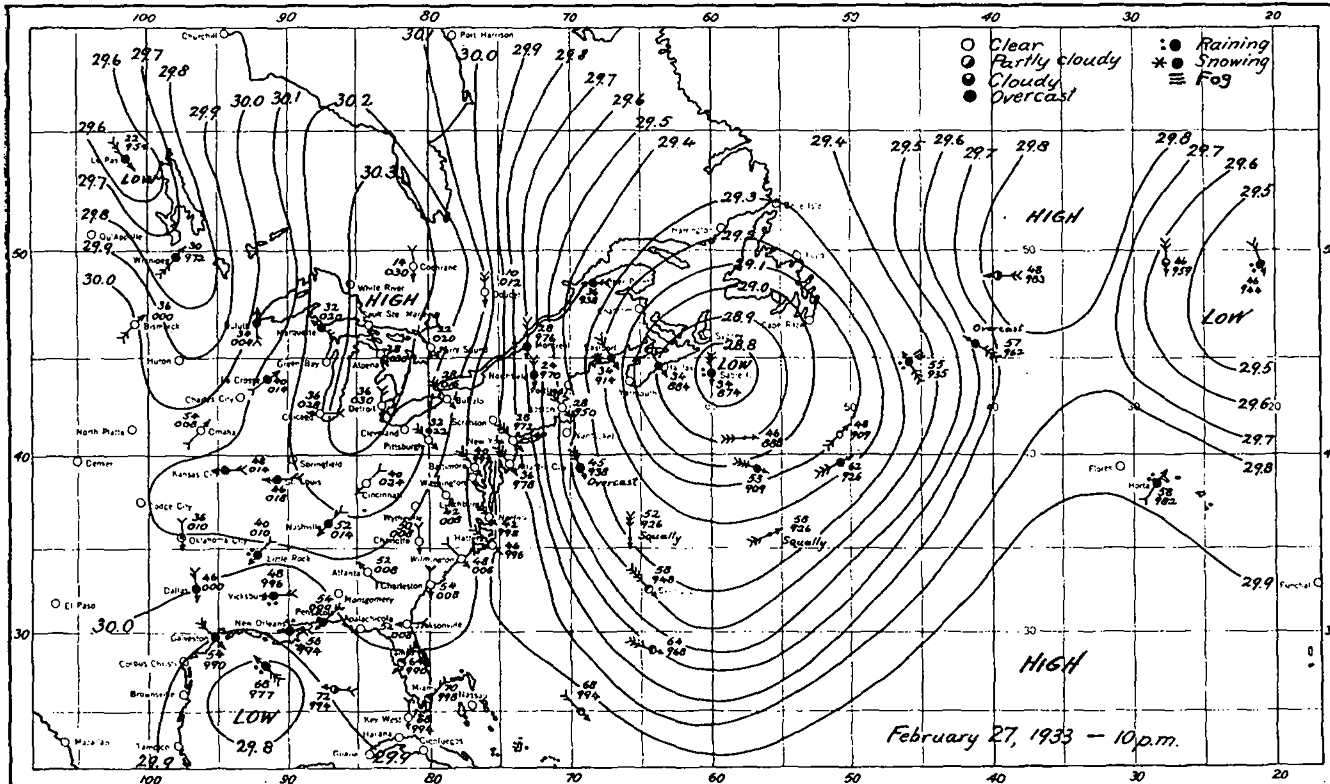

FIGURE 33.—Weather map prepared from Major Marine Bulletin broadcast from Washington (Station NAA) at 10 p. m., 75th meridian time, Feb. 27, 1933 (0300 G. C. T., Feb. 28, 1933).

well-defined pressure areas will be of assistance in dealing with maps of the "flat" type.

When the isobaric line is drawn, say, for 29.90 inches, there may be no observations of pressure exactly 29.90 inches. There may be some readings of 29.86, 29.88, 29.92, etc. The line for 29.90 is always drawn between readings which are below and above 29.90, and never between two readings in the .90's or two in the .80's (see fig. 34). The 29.90 line will be drawn nearer to a location with pressure 29.92 inches than another with 29.84 inches,

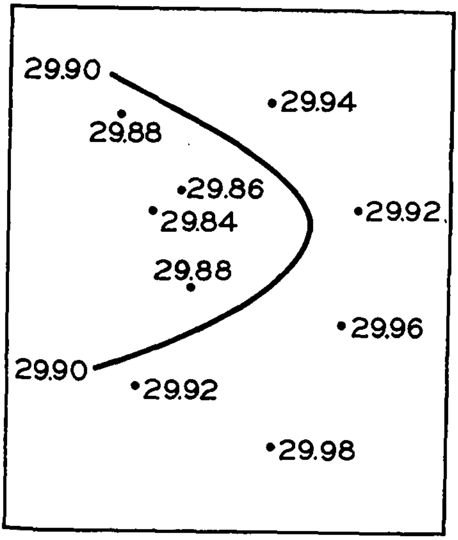

FIGURE 34.—The 29.90 line is shown properly drawn among readings in the .80's and the .90's. The dot (or station circle) showing the location of the ship or land station is the point of reference in drawing the line. The line should not be drawn with reference to the figures for barometric pressure, since they are not placed at the exact location of the observing station or ship, but at a convenient point nearby, usually to the right.

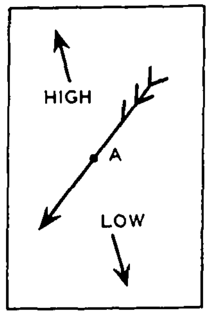

FIGURE 35.—The observer standing with his face to the wind (NE) at the position shown by the dot "A" will have the LOW and HIGH centers in the general directions indicated by the small arrows.

with distances in proportion to the differences between the readings entered and 29.90 inches. In some instances, with well-developed LOWS, there may be differences of 0.20 to 0.30 inch or even more between adjacent observations. In such cases two or more isobars must be drawn between the two observation points.

It is important to keep in mind that the wind directions entered on the chart are closely related to the distribution of pressure. The flow of air is, roughly, inclined at sea 20° to 30° to the isobars. The law of Buys Ballot, to the effect that the observer, standing with his face to the wind in the Northern Hemisphere, will have the center of low pressure on his right, is helpful when observations are scattered. For example (fig. 35), if the wind is from the northeast, the observer, with his face to the northeast will have the low pressure to his right, or to the southeast, and the high pressure to his left, or to the northwest, roughly.

After drawing a few maps, the beginner will become familiar with the clockwise and counterclockwise wind systems of the HIGH and LOW, respectively (in the Northern Hemisphere), and with the conditions which are associated with the development of secondary centers.

Drawing highly irregular isobars, in order to satisfy slight differences in pressure distribution, is a common fault of the beginner. On the other hand, after considerable experience, he is inclined to round out or smooth out the isobars too much in an effort to get symmetrical lines. When irregularities actually exist in the pressure distribution, they are attended by corresponding irregularities or discontinuities in wind direction and in the distribution of other elements—a fact which should be kept in mind.

It is desirable that observations to be entered on any single map be made as nearly as possible at the same moment of time and on successive maps, at uniform intervals. It is then possible, by comparing maps, to learn what changes have taken place in weather conditions over a given area within known periods of time and to draw therefrom inferences as to the character of subsequent changes and the time when they will occur.

USE OF THE WEATHER MAP

The subjects of map analysis and weather forecasting, and their use as an aid to navigation, do not come within the scope of this publication, which is confined in the main to weather observations. However, the Weather Bureau is desirous of assisting the mariner in analyzing the completed weather map and in drawing inferences as to the weather of the future. Meteorologists at port stations of the Bureau will be glad to confer with ships' officers regarding any features of the work. Publications on this subject that are available for distribution will be supplied to cooperating officers on request.

PART VIII. GLOSSARY

A. TECHNICAL TERMS

Absolute temperature.—The temperature of the centigrade thermometer, increased by 273°, more properly called the temperature on the absolute or thermodynamic scale. On the Fahrenheit scale the absolute zero is approximately 459° below the Fahrenheit zero.

Actinometer.—An instrument for measuring the intensity of radiation received from the sun.

Adiabatic.—The word applied in the science of thermodynamics to a process during which no heat is communicated to or withdrawn from the body or system concerned. Adiabatic changes of atmospheric temperature are those that occur only in consequence of compression or expansion accompanying an increase or a decrease of atmospheric pressure. Such changes are also described as dynamic heating and cooling.

Advection.—The process of transfer by horizontal motion, particularly applied to the transfer of heat by horizontal motion of the air. The transfer of heat from low to high latitudes is the most obvious example of advection.

Advection fog.—Fog resulting from the transfer of warm, humid air over a cold surface, especially a cold ocean surface, or (comparatively rarely) from the transport of air that is relatively very cold over an ocean surface that is relatively very warm.

Aerology.—The study of the free atmosphere throughout its vertical extent, as distinguished from investigations confined to the layer of the atmosphere adjacent to the earth's surface. Aerological investigations are made directly with pilot balloons, sounding balloons and by means of airplanes. They are also made indirectly by visual observations from the ground. Included in the latter are observations of clouds, meteor trails, the aurora, etc.

Afterglow.—The glow in the western sky after sunset.

Air mass.—A term applied by meteorologists to an extensive body of air within which the conditions of temperature and moisture in a horizontal plane are essentially uniform.

Air mass property.—Any quality or quantity the nature or value of which can be used in a characterization of the physical state or condition of an air mass.

Altocumulus.—A form of cloud. (See part V.)

Altostratus.—A form of cloud. (See part V.)

Anemogram.—The record traced by a self-registering anemometer.

Anemometer.—An instrument for measuring the force or speed of the wind.

Anemoscope.—An instrument for indicating the existence of wind and showing its direction.

Aneroid barometer. (See part II.)

Anomaly.—The difference between the mean of any meteorological element, or phase of that element, over a given time at a particular place, and the mean of the same element or phase over the same time for all other points on the same parallel of latitude.

Anthelion.—A rare species of halo, consisting of a brilliant, usually white, image of the sun opposite the latter in azimuth. (This term has also been applied to the glory, q. v.).

Anticrepuscular rays.—The continuation of the crepuscular rays, converging toward a point in the sky opposite to the sun.

Anticyclogenesis.—The term applied to the process which creates or develops a new anticyclone. The word is applied also to the process which produces an intensification of a pre-existing anticyclone.

Anticyclone.—An area of high barometric pressure and its attendant system of winds. (Cf. Cyclone.)

Antitrades.—The term applied to the westerly winds which are observed at high elevations above the trade winds.

Antitwilight arch.—The pink or purplish zone of illumination bordering the shadow of the earth (dark segment), in the part of the sky opposite the sun after sunset and before sunrise.

Aqueous vapor.—Water vapor. (Cf. Humidity.)

Arcs of Lowitz.—A pair of rare halo phenomena. These arcs are directed obliquely downward from the parhelia of 22° on either side of the sun toward the halo of 22°.

Arctic front.—The line of discontinuity between very cold air flowing directly from the Arctic regions and polar maritime air that has moved away from its source region in a more or less circuitous path and been warmed through contact with the ocean surface.

Atmosphere.—The whole mass of air surrounding the earth.

Aurora.—A luminous phenomenon due to electrical discharges in the atmosphere; probably confined to the tenuous air of high altitudes. It is most commonly seen in sub-Arctic and sub-Antarctic latitudes. Called aurora borealis or aurora australis, according to the hemisphere in which it occurs. Observations with the spectroscope seem to indicate that a faint "permanent aurora" is a normal feature of the sky in all parts of the world.

Back.—Of the wind, to shift in a counterclockwise direction; opposite of veer. In scientific practice this definition now applies to both hemispheres.

Bar.—A unit of pressure equal to 1,000,000 dynes per square centimeter. A bar=100 centibars=1,000 millibars. A barometric pressure of one bar is sometimes called a "C. G. S. atmosphere," and is equivalent to a pressure of 29.531 inches of mercury at 32° F. and in latitude 45°.

Barocyclonometer.—One of the several instruments that have been devised for locating tropical hurricanes without the aid of a weather map.

Barogram.—The continuous record made by a self-registering barometer.

Barograph.—A self-registering barometer.

Barometer.—An instrument for measuring the pressure of the atmosphere. The two principal types are the mercurial and the aneroid. The microbarometer is used to show very small changes of pressure.

Barometric tendency.—The change of barometric pressure within a specified time (usually three hours), before the observation.

Beaufort scale.—The scale of wind force devised by Admiral Sir Francis Beaufort in 1805.

Bishop's ring.—A large corona due to fine dust in the atmosphere. It has been seen after certain great volcanic eruptions, especially that of Krakatoa, in 1883.

Blizzard.—A violent, intensely cold wind, laden with snow.

Bright segment.—The broad band of golden light that, in clear weather, borders the western horizon just after sunset and the eastern just before sunrise.

Buys Ballot's law.—In the Northern Hemisphere, if you face the wind the atmospheric pressure decreases toward your right and increases toward your left. In the Southern Hemisphere the reverse is true. The law is useful in locating centers of cyclones and anticylones.

Calibration.—The name ordinarily given to the process of ascertaining the corrections to be applied to the indicated readings of an instrument in order to obtain true values.

Calm.—Absence of appreciable wind.

Calms of Cancer; calms of Capricorn.—The belts of high pressure lying north of the northeast trade winds and south of the southeast trade winds, respectively.

Cascade.—The name applied to the mass of spray or dense vapor thrown outward from around the base of a waterspout. Also known as "bush", or "bonfire."

Center of action.—Any one of several large areas of high and low barometric pressure, changing little in location, and persisting through a season or through the whole year; e. g., the Iceland low, the Siberian winter high, etc. Changes in the intensity and positions of these pressure systems are associated with widespread weather changes.

Centibar.—(See Bar.)

Centigrade.—A thermometric scale on which 0° denotes the temperature of melting ice, and 100° the temperature of boiling water, both under standard atmospheric pressure.

Chinook, or chinook wind.—A foehn blowing down the eastern slopes of the Rocky Mountains over the adjacent plains, in the United States and Canada. In winter, this warm, dry wind causes snow to disappear with remarkable rapidity, and hence it has been nicknamed the "snow-eater" (Cf. Foehn).

Circumscribed halo.—A halo formed by the junction of the upper and lower tangent arcs of the halo of 22°, when the luminary is about 40° or more above the horizon. As the altitude of the luminary increases, the circumscribed halo gradually assumes an elliptical form and finally merges into the halo of 22°.

Circumzenithal arc.—A rainbow-tinted halo, often very bright, convex to the luminary, and 46° or a little more above it. It is sometimes called the upper quasi-tangent arc of the halo of 46°, but the circumzenithal arc and the halo of 46° are rarely seen at the same time.

Cirrocumulus.—A form of cloud. (See part V.)

Cirrostratus.—A form of cloud. (See part V.)

Cirrus.—A form of cloud. (See part V.)

Climate.—The prevalent or characteristic meteorological conditions of any place or region.

Climatology.—The study of climate.

Cloud banner.—A banner-like cloud streaming off from a mountain peak.

Cloud-burst.—A sudden and extremely heavy downpour of rain; especially in mountainous regions.

Cloud cap.—A cap-like cloud crowning (1) a mountain summit, or (2) another cloud, especially a mass of cumulonimbus.

Col.—A neck of relatively low pressure between two anticyclones; also called a saddle.

Cold air mass.—Broadly speaking, an air mass that is cold relative to neighboring air masses. The term implies that the air mass originated in higher latitudes than those in which it now finds itself and that it is, therefore, colder that the surface over which it is moving.

Cold front.—The discontinuity at the forward edge of an advancing cold air mass which is displacing warmer air in its path.

Cold wave.—A rapid and marked fall of temperature during the cold season of the year. The United States Weather Bureau applies this term to a fall of temperature in 24 hours equaling or exceeding a specified number of degrees and reaching a specified minimum temperature or lower; the specifications varying for different parts of the country and for different periods of the year.

Conservative property.—Any air mass property the nature or value of which is affected comparatively little by the various modifying influences to which a moving body of air is exposed.

Continental climate.—The type of climate characteristic of the interior of a continent. As compared with a marine climate, a continental climate has a large annual and daily range of temperature.

Convection.—The upward or downward movement, mechanically or thermally produced, of a limited portion of the atmosphere. Convection is essential to the formation of many clouds, especially of the cumulus type.

Convergence.—The condition that exists when the distribution of winds within a given area is such that there is a net horizontal inflow of air into the area. The removal of the resulting excess is accomplished by an upward movement of air; consequently areas of convergent winds are regions favorable to the occurrence of precipitation.

Corona.—(See part VI.)

Corposant.—(See St. Elmo's fire.)

Countertrades.—(See Antitrades.)

Counter sun.—(See Anthelion.)

Crepuscular rays.—(See part VI; see also "Sun drawing water.")

Cumuliform.—A general term applied to all clouds having dome-shaped upper surfaces which exhibit protuberances, the bases of such clouds being generally horizontal. Cumuliform clouds are characteristically distinct and separated from one another by clear spaces.

Cumulonimbus.—A form of cloud. (See part V.)

Cumulus.—A form of cloud. (See part V.)

Cyclogenesis.—The term applied to the process which creates or develops a new cyclone. The word is applied also to the process which produces an intensification of a pre-existing cyclone.

Cyclone.—An area of low barometric pressure with its attendant system of winds. The cyclones occurring within the Tropics (tropical cyclones) are smaller, on an average, than those of higher latitudes and in many cases are the most violent of all storms, except tornadoes. Those occurring in higher latitudes (extra-tropical cyclones) whether originating there or in the Tropics, usually bring about marked changes of weather and temperature during their passage; their winds may be high or otherwise. Tropical cyclones are also called hurricanes (when violent), typhoons, or baguios. Extratropical cyclones are commonly known as lows or barometric depressions.

Dark segment.—The shadow of the earth which, in clear weather, rises from the eastern horizon at sunset and sinks below the western horizon at sunrise.

Débacle.—Breaking up of the ice in the spring in rivers and seas.

Deepening.—The occurrence of decreasing pressure in the center of a moving pressure system.

Depression.—A cyclonic area, or low.

Deviation of the wind.—The angle between the direction of the wind and the direction of the pressure gradient. (Cf. Inclination of the wind.)

Dew.—Atmospheric moisture condensed, in liquid form, upon objects cooler than the air, especially at night.

Dewpoint.—The temperature at which, under ordinary conditions, condensation begins in a cooling mass of air. It varies with the specific humidity. The dewpoint is a conservative air mass property.

Discontinuity.—The term applied in a special sense by meteorologists to a zone within which there is a comparatively rapid transition of the meteorological elements.

Disturbance.—A local departure from the normal or average wind conditions of any part of the world, or, in other words, a feature of what is sometimes called the "secondary" circulation of the atmosphere, as distinguished from the general circulation. In everyday usage *disturbance* has come to be synonymous with *cyclone* and *depression.*

Divergence.—The condition that exists when the distribution of winds within a given area is such that there is a net horizontal flow of air outward from the region. The resulting deficit is compensated by a downward movement of air from aloft; consequently areas of divergent winds are regions unfavorable to the occurrence of precipitation.

Doldrums.—The equatorial belt of calms or light variable winds, lying between the two trade-wind belts.

Drizzle.—Precipitation consisting of numerous tiny droplets. Drizzle originates from stratus clouds. (See also part V.)

Drought.—A protracted period of dry weather.

Dry adiabatic lapse rate.—A rate of decrease of temperature with height approximately equal to 1° C. per 100 meters (1.8° F. per 328 feet.) This is close to the rate at which an ascending body of unsaturated air will cool due to adiabatic expansion.

Dry bulb.—A name given to an ordinary thermometer used to determine the temperature of the air, in order to distinguish it from the wet bulb.

Dry fog.—A haze due to the presence of dust or smoke in the air.

Dust counter.—An instrument for determining approximately the number of dust particles or condensation nuclei per unit volume in a sample of air.

Dynamic meteorology.—The branch of meteorology that treats of the motions of the atmosphere and their relations to other meteorological phenomena.

Eddy.—A more or less fully developed vortex in the atmosphere, constituting a local irregularity in a wind. All winds near the earth's surface contain eddies, which at any given place produce "gusts" and "lulls." Air containing numerous eddies is said to be "turbulent."

Equivalent potential temperature.—The temperature that a given sample of air would have if it were brought adiabatically to the top of the atmosphere (i. e., to zero pressure) so that along its route all the water vapor present were condensed and precipitated, the latent heat of condensation being given to the sample, and then the remaining dry air compressed adiabatically to a pressure of 1,000 millibars. The equivalent potential temperature at any point is therefore determined by the values of absolute temperature, pressure and humidity. It is one of the most conservative of air mass properties.

Evaporimeter.—An instrument for measuring the rate of evaporation of water into the atmosphere.

Exposure.—In meteorology the method of presentation of an instrument to that element which it is destined to measure or record, or the situation of the station with regard to the phenomenon or phenomena there to be observed.

Eye of the storm.—A calm region at the center of a tropical cyclone or a break in the clouds marking its location.

Fahrenheit.—A thermometric scale on which 32° denotes the temperature of melting ice, and 212° the temperature of boiling water, both under standard atmospheric pressure.

Fall-wind.—A wind blowing down a mountainside; or any wind having a strong downward component. Fall-winds include the foehn, mistral, bora, etc.

False cirrus.—Cirruslike clouds at the summit of a thunder cloud; more appropriately called "thunderstorm cirrus."

Fata Morgana.—A complex form of mirage, characterized by marked distortion of images.

Festoon cloud.—Mammatocumulus.

Filling.—The occurrence of increasing pressure in the center of a moving pressure system. *Filling* is the opposite of *deepening.*

Foehn.—A dry wind with strong downward component, warm for the season, characteristic of many mountainous regions. The air is cooled dynamically in ascending the mountains, but this leads to condensation, which checks the fall in temperature through the liberation of latent heat. The wind deposits its moisture as rain or snow. In descending the opposite slope it is strongly heated dynamically and arrives in the valleys beyond as a warm and very dry wind. Some writers apply this term to any wind that is dynamically heated by descent; e. g., the sinking air of an anticyclone.

Fog.—A cloud at the earth's surface. Fog consists of numerous droplets of water, which are so small that they cannot readily be distinguished by the naked eye. In ordinary speech the term "fog" generally implies an obscurity of the atmosphere sufficiently great to interfere with marine and aerial navigation. (See also part V.)

Fogbow.—A rainbow, colorless or nearly so, formed in a fog.

Fog drip.—Moisture that is deposited on terrestrial objects by fog and drips from them to the ground.

Fractocumulus.—A form of cloud. (See part V.)

Fractostratus.—A form of cloud. (See part V.)

Front.—A surface of discontinuity between two juxtaposed currents of air possessing different densities, or, more simply, the boundary between two different air masses.

Frontogenesis.—The term used to describe the process which creates a front i. e., produces a discontinuity in a continuous field of the meteorological elements; also applied to the process which increases the intensity of a preexisting front. Frontogenesis is generally set up by the horizontal convergence of air currents possessing widely different properties.

Frontolysis.—The term used to describe the process which tends to destroy a pre-existing front. Frontolysis is generally brought about by horizontal mixing and divergence of the air within the frontal zone.

Frost.—Atmospheric moisture deposited upon terrestrial objects in the form of ice crystals. Also called hoarfrost.

Frost smoke.—A fog produced by apparent steaming of the sea in the presence of air having a temperature much below freezing. Also called "Arctic sea smoke."

Gale.—Wind with an hourly velocity exceeding some specified value. In American practice a wind of or exceeding force 8 on the Beaufort scale is counted a gale.

Glaze.—Term applied by the United States Weather Bureau to a smooth coating of ice on terrestrial objects due to the freezing of rain; often popularly called sleet. In Great Britain such a deposit is called glazed frost. A deposit of glaze on an extensive scale constitutes an "ice storm."

Glory.—A series of concentric colored rings seen around the shadow of the observer, or of his head only, cast upon a cloud or fog bank. It is due to the diffraction of reflected light.

Gradient.—Change of value of a meteorological element per unit of distance. The gradients commonly discussed in meteorology are the horizontal gradient of pressure, the vertical gradient of temperature, and the vertical gradient of electric potential. Meteorologists now prefer the term "lapse-rate" to "vertical gradient."

Gradient wind.—A wind of the velocity which is necessary to balance the pressure gradient. The direction of the gradient wind is along the isobars, and the velocity is so adjusted that there is equilibrium between the force pressing the air toward the region of low pressure, and the centrifugal action to which the moving air is subject in consequence of its motion.

Granular snow.—A form of precipitation consisting of small nontransparent grains of snow.

Green flash.—A bright green coloration of the upper edge of the sun's disk, sometimes seen when the rest of the disk is below the horizon at sunrise or sunset.

Gust.—A sudden brief increase in the force of the wind. Most winds near the earth's surface display alternate gusts and lulls.

Hail.—Balls or irregular lumps of ice, often of considerable size, having a complex structure; large hailstones generally have a snowlike center, surrounded by layers of ice, which may be alternately clear and cloudy. Hail falls almost exclusively in connection with thunderstorms. (Cf. Sleet.)

Halo.—A generic name for a large group of optical phenomena caused by ice crystals in the atmosphere. The commonest of these phenomena is the halo of 22° (i. e., of 22° radius), surrounding the sun or moon. The halo of 46° and the rare halo of 90°, or halos of Hevelius, also surround the luminary. Other forms of halo are the tangent arcs, parhelia (or paraselenae), parhelic (or paraselenic) circle, anthelion, etc.

Haze.—A lack of transparency in the atmosphere caused by the presence of dust or of salt particles left by evaporated ocean spray. At a certain distance, depending on the density of the haze, all details of landscape and of color disappear. (See also part V.)

High.—An area of high barometric pressure; an anticyclone.

Hoarfrost.—(See Frost.)

Hot wave.—A period of abnormally high temperatures. It has sometimes been defined, in the United States, as a period of three or more consecutive days during each of which the maximum temperature is 90° F. or over.

Humidity.—The degree to which the air is charged with water vapor. This may be expressed in several ways. *Absolute humidity* expresses the weight of water vapor per unit volume of air; *relative humidity* is the ratio of the actual vapor pressure to the vapor pressure corresponding to saturation at the prevailing temperature, or simply the percentage of saturation; *specific humidity* expresses the mass of water vapor contained in a unit mass of moist air. Specific humidity is the only truly conservative air mass property of the three.

Hurricane.—A tropical cyclone; especially one of the West Indian region. (A cyclone originating in this region and passing northward into the Temperate Zone is often called a "West India hurricane", even after it has assumed the character of an extra-tropical cyclone, and if sufficiently severe, justifies the display of "hurricane warnings" at ports of the United States. "Hurricane" is also the designation of the highest wind force on the Beaufort scale.

Hydrometeor.—A generic term for weather phenomena such as rain, cloud, fog, etc., which mostly depend upon modifications in the condition of the water vapor in the atmosphere.

Hygrograph.—A self-recording hygrometer.

Hygrometer.—An instrument for measuring the humidity of the air.

Iceberg.—A large mass of ice that breaks from the tongue of a glacier running into the sea and floats away.

Iceblink.—A white, luminous appearance near the horizon caused by the reflection of light from ice.

Ice needles.—Thin crystals or shafts of ice, so light that they seem to be suspended in the air. (See also part V.)

Ice rain.—1. A rain that causes a deposit of glaze. 2. Falling pellets of clear ice (called sleet by the United States Weather Bureau.)

Ice storm.—(See Glaze.)

Inclination of the wind.—The angle which the wind direction makes with the direction of the isobar at the place of observation. Over the ocean the angle is usually between 20° and 30°. (Cf. Deviation of the wind.)

Insolation.—Solar radiation, as received by the earth or other planets; also, the rate of delivery of the same, per unit of horizontal surface.

Instability.—A state in which the vertical distribution of temperature is such that an air particle, if given either an upward or a downward impulse, will tend to move away with increasing speed from its original level. (In the case of unsaturated air the lapse rate for instability will be greater than the dry adiabatic lapse rate; in that of saturated air greater than the saturated adiabatic lapse rate.)

Instrument shelter.—The American name of the cage or screen in which thermometers and sometimes other instruments are exposed at meteorological stations. Called thermometer screen in Great Britain.

Intertropical front.—The boundary between the trade wind systems of the northern and southern hemispheres. It manifests itself as a fairly broad zone of transition commonly known as the *Doldrums*.

Inversion.—An abbreviation for "inversion of the vertical gradient of temperature." The temperature of the air is ordinarily observed to become lower with increasing height, but occasionally the reverse is the case, and when the temperature increases with height there is said to be an "inversion."

Irisation.—Irregular patches or fringes of iridescence sometimes seen in clouds, (called iridescent clouds), not corresponding in location with the ordinary corona or the known forms of halo (such as parhelia). They are probably fragments of coronas of unusual size, produced by exceedingly fine cloud particles.

Isobar.—A line on a chart or diagram drawn through places or points having the same barometric pressure. (Isobars are customarily drawn on weather charts to show the horizontal distribution of atmospheric pressure reduced to sea level or the pressure at some specified altitude.)

Isogram.—A line drawn on a chart or diagram to show the distribution of some physical condition in space or time (or both), by connecting points corresponding to equal values of the phenomenon represented. Most of the isograms used in meteorology are drawn on geographical charts, and show the distribution of a meteorological element in space only. A special form of isogram, known as the *isopleth*, shows the variation of an element in relation to two coordinates; one of the coordinates representing the time of the year (month), and the other usually the time of the day (hour), but sometimes space (especially altitude). The following list includes the most important meteorological isograms: *Anisallobar*, isogram of rise of barometric pressure in a given time; *isallobar*, isogram of the amount of change in barometric pressure within a specified period; *isanomal*, or *isanomalous line*, isogram of anomaly, i. e., of the departure of the local mean value of an element from the mean pertaining to the latitude; *isobar*, isogram of barometric pressure; *isotherm*, isogram of temperature; *katisallobar*, isogram of fall of barometric pressure in a given time.

Isotherm.—A line on a chart or diagram drawn through places or points having equal temperatures.

Isothermal layer.—(See Stratosphere.)

Land and sea breezes.—The breezes that, on certain coasts and under certain conditions, blow from the land by night and from the water by day.

Lapse rate.—The rate of decrease of temperature in the atmosphere with height.

Lenticular cloud.—A cloud having approximately the form of a double-convex lens. Clouds of this sort may be formed at the crests of standing waves in the atmosphere such as are often induced by mountain ranges; usually they represent a transitional stage in the development or disintegration of one of the more well-known cloud types.

Lightning.—A disruptive electrical discharge in the atmosphere, or, generally, the luminous phenomena attending such a discharge.

Light pillar.—A form of halo, consisting of a column of light, vertical or nearly so, extending from or through the sun or moon. Called a sun pillar, or a moon pillar, as the case may be.

Line squall.—A more or less continuous line of squalls and thunderstorms marking the position of an advancing cold front.

Looming.—An apparent elevation of distant objects by mirage.

Low.—An area of low barometric pressure, with its attendant system of winds. Also called a barometric depression or cyclone.

Mammatocumulus.—A form of cloud showing pendulous sack-like protuberances.

March.—The variation of any meteorological element in the course of a day, year, or other interval of time; e. g., the diurnal march of temperature; the annual march of barometric pressure.

Marine climate.—A type of climate characteristic of the ocean and oceanic islands. Its most prominent feature is equability of temperature.

Maximum.—The highest value of any element occurring during a given period.

Meniscus.—The curved upper surface of a liquid in a tube.

Meteorograph.—A self-registering apparatus which records simultaneously the values of two or more meteorological elements. Certain types of meteorograph are connected, electrically or otherwise, with some of the standard instruments at meteorological stations. These record conditions at the earth's surface only. Other types are carried aloft by airplanes and free balloons.

Meteorology.—The science of the atmosphere.

Microbarograph.—An instrument designed for recording small and rapid variations of atmospheric pressure.

Millibar.—(See Bar.)

Minimum.—The lowest value of any element occurring during a given period.

Mirage.—An apparent displacement or distortion of observed objects by abnormal atmospheric refraction. Sometimes the images of objects are inverted, magnified, multiplied, raised, or brought nearer to the eye than the object. Refraction layers in the atmosphere often assume the appearance of fog. (See Refraction Phenomena, pages 80 to 82.)

Mist.—A very thin fog, in which the horizontal visibility is greater than 1 kilometer, or approximately 1,100 yards. (This is the definition laid down by the International Meteorological Organization.) In North America the word is often used synonymously with drizzle or fine rain. (See also part V.)

Mock fog.—A simulation of true fog by atmospheric refraction.

Mock sun.—(See Parhelion.)

Monsoon.—A wind that reverses its direction with the season, blowing more or less steadily from the interior of a continent toward the sea in winter, and in the opposite direction in the summer.

Nephoscope.—An instrument for measuring the movement of clouds.

Neutral point.—The term applied in a special sense to any point at which the axis of a wedge of high pressure intersects the axis of a trough of low pressure. Also called "saddle point."

Nimbostratus.—A form of cloud. (See part V.)

Noctilucent clouds.—Luminous, cirrus-like clouds sometimes visible throughout the short nights of summer; supposed to be clouds of dust at great altitudes shining with reflected sunlight. Such clouds were observed during several summers after the eruption of Krakatoa (1883), and are still occasionally reported.

Normal.—The average value which in the course of years any meteorological element is found to have on a specified date or during a specified month or other portion of the year, or during the year as a whole. Also used as an adjective in such expressions as "normal temperature", etc. Thus, for any station at which records have been maintained for years, we may compute the normal temperature of January 1, the normal pressure of February, the normal rainfall of the year, etc. The normal serves as a standard with which values occurring in a particular year may be compared in order to determine the departure from normal.

Nucleus.—A particle upon which condensation of water vapor occurs in the free atmosphere in the form of a water drop or an ice crystal.

Oblique arcs of the anthelion.—A rare form of halo, consisting of intersecting arcs, usually white, passing through the anthelion or the place where the anthelion would occur if visible.

Occluded front.—The front that is formed when and where the cold front overtakes the warm front of a cyclone. This front marks the position of an upper trough of warm air, originally from the warm sector, which has been forced aloft by the action of the converging cold and warm fronts.

Occlusion.—The term used to denote the process whereby the air in the warm sector of a cyclone is forced from the surface to higher levels. The process is accompanied by an increase in the intensity of the cyclone.

Ozone.—An allotropic form of oxygen which occurs transiently in small quantities in the lower atmosphere and is supposed to be permanently present and relatively abundant at high atmospheric levels.

Paranthelion.—A halo phenomenon similar to a parhelion, but occurring at a distance of 90° or more in azimuth from the sun. The solar distance of the ordinary paranthelia is 120°. (Analogous phenomena produced by the moon as source of light are called parantiselenæ.)

Paraselene (plural paraselenæ.)—(See Parhelion.)

Paraselenic circle.—(See Parhelic circle.)

Parhelic circle.—A halo consisting of a white circle passing through the sun and parallel to the horizon. A similar phenomenon in connection with the moon is called a paraselenic circle.

Parhelion (plural parhelia).—A mock sun, or sun dog; a form of halo consisting of a more or less distinctly colored image of the sun at the same altitude as the latter above the horizon, and hence lying on the parhelic circle, if present. The ordinary parhelia are 22° from the sun in azimuth, or a little more, according to the altitude of the luminary. Parhelia have occasionally been seen about 46° from the sun. Analogous phenomena seen in connection with the moon are called paraselenæ, mock moons, or moon dogs.

Pilot balloon.—A small free balloon the drift of which, as observed from the ground, indicates the movements of the air aloft.

Polar continental air.—The term used to describe any air mass that originates over land or frozen ocean areas in the polar regions. Polar continental air is characterized by low temperatures, low specific humidity and a high degree of vertical stability.

Polar front.—The surface of discontinuity separating an air mass of polar origin from one of tropical origin.

Polar maritime air.—The term used to describe any air mass that originally came from the polar regions but has since been modified by reason of its passage over a relatively warm ocean surface. Polar maritime air is characterized by moderately low surface temperatures, moderately high surface specific humidity, and a considerable degree of vertical instability.

Potential temperature.—The temperature that a specimen of air or other gas would assume if brought adiabatically to a standard pressure, now usually selected as 1,000 millibars.

Precipitation.—The collective name for deposits of atmospheric moisture in liquid and solid form, including rain, snow, hail, dew, hoarfrost, etc.

Pressure.—An elliptical expression, current in meteorological literature, for atmospheric pressure, or barometric pressure.

Pressure gradient.—The decrease in barometric pressure per unit horizontal distance in the direction in which the pressure decreases most rapidly.

Prevailing westerlies.—The belts of winds lying on the poleward sides of the subtropical high-pressure belts.

Psychrometer.—An instrument for measuring atmospheric humidity, consisting usually of a dry-bulb thermometer and a wet-bulb thermometer. The former is an ordinary mercurial thermometer. The latter has its bulb covered with muslin or other fabric, which is either permanently wet or is wetted before use. In some psychrometers there is only one thermometer, readings being taken both before and after moistening the bulb. In the aspiration psychrometer the air is drawn past the bulb by a revolving fan.

Pumping.—Unsteadiness of the mercury in the barometer caused by fluctuations of the air pressure produced by a gusty wind, or due to the oscillation of a ship.

Purple light.—The purple or rosy glow observed over a large area of the western sky after sunset and the eastern sky before sunrise; it lies above the bright segment that borders the horizon.

Pyrheliometer.—An instrument that measures solar radiation by its heating effects.

Radiation fog.—Fog characteristically resulting from the radiational cooling of air near the surface of the ground on calm clear nights.

Rain.—Drops of water falling from the sky. (See also part V.)

Rainbow.—A luminous arc formed by the refraction and reflection of light in drops of water. (See part VI.)

Rainfall.—A term sometimes synonymous with rain, but most frequently used in reference to amounts of precipitation (including snow, hail, etc.)

Rain gage.—An instrument for measuring rainfall.

Reduction.—As applied to meteorological observations, generally means the substitution for the values directly observed of others which are computed therefrom, and which place the results upon a comparable basis.

Refraction.—Astronomical refraction, change in the apparent position of a heavenly body due to atmospheric refraction; terrestrial refraction, change in the apparent position of distant terrestrial objects due to the same cause.

Relative humidity.—(See Humidity.)

Representative observations.—Those which give the true or typical meteorological conditions prevailing in an air mass; hence they must be relatively uninfluenced by local conditions.

Réseau.—A collection of meteorological stations operating under a common direction or in the same territory. An international réseau is a group of stations in different countries cooperating for any purpose. The réseau mondial is a world-wide system of selected stations, the observations of which may be utilized in studies of the metorology of the globe.

Ridge.—A relatively narrow extension of an anticyclone or high-pressure area as shown on a weather chart.

Rime.—1. Hoarfrost. 2. A rough or feathery coating of ice deposited on terrestrial objects by fog. (The second meaning is the one now used in technical literature).

Saddle.—(See Col.)

St. Elmo's fire.—A luminous brush discharge of electricity from elevated objects, such as the masts and yardarms of ships, lightning rods, steeples, etc., occurring in stormy weather. Also called corposant.

Saturated adiabatic lapse rate.—A rate of decrease of temperature with height equal to the rate at which an ascending body of saturated air will cool during adiabatic expansion. The value of the latter, unlike the case for unsaturated air, is not the same under all conditions. However, under no circumstances is it greater than the dry adiabatic rate. It varies inversely with the temperature.

Saturation.—The condition that exists in the atmosphere when the partial pressure exerted by the water vapor present is equal to the maximum vapor pressure possible at the prevailing temperature.

Scarf cloud.—A thin cirruslike cloud which often drapes the summits of tall cumulonimbus clouds.

Sea breezes.—(See Land and sea breezes.)

Secondary.—A small area of low pressure on the border of a large or "primary" one. The secondary may develop into a vigorous cyclone while the primary center disappears.

Semicircle.—The "dangerous semicircle" of a cyclonic storm at sea is the half of the storm area in which rotary and progressive motions of the storm reinforce each other, and the winds are also directed in such a way as to drive a vessel running before the wind across the storm track ahead of the advancing center. The other half is called the "navigable" semicircle.

Shower.—A fall of rain, of short duration but often of considerable intensity, and usually consisting of relatively large drops. Also a similar fall of snow, sleet, or hail. Showers characteristically fall from isolated clouds separated from one another by clear spaces. They occur typically in air masses that posses a high degree of instability. (See also part V.)

Sleet.—1. Frozen or partly frozen rain; frozen raindrops in the form of particles of clear ice. (The official definition of the United States Weather Bureau.) 2. Snow and rain falling together. (The British use, and the one occurring in publications of the International Meteorological Organization. In popular and engineering use in the United States the word is often applied to a coating of glaze on trees, wires, rails, etc.)

Snow.—Precipitation in the form of small ice crystals, falling either separately or in loosely coherent clusters (snowflakes). (See also part V.)

Soft hail.—White, opaque, round pellets of snow. (See also part V.)

Solar constant of radiation.—The intensity of solar radiation outside the earth's atmosphere at the earth's mean distance from the sun. Recent investigations indicate that this intensity may vary and that its mean value is 1.94 gram-calories per minute per square centimeter of area lying normal to the incident solar ray.

Sounding balloon.—A free, unmanned balloon carrying a set of self-registering meteorological instruments.

Source region.—An extensive area of the earth's surface characterized by essentially uniform surface conditions and which is so placed in respect to the general atmospheric circulation that air masses may remain over it long enough to acquire definite characteristic properties. Examples of source regions are the ice-covered polar regions and the broad expanses of uniformly warm tropical oceans.

Specter of the Brocken.—The shadow of an observer and of objects in his immediate vicinity cast upon a cloud or fog bank; sometimes attended by a series of colored rings, called the glory or Brocken-bow.

Squall.—1. A sudden storm of brief duration; closely akin to a thunderstorm but not necessarily attended by thunder and lightning. 2. A sudden brief blast of wind, of longer duration than a gust.

Stability.—A state in which the vertical distribution of temperature is such that an air particle will resist displacement from its level. In the case of unsaturated air the lapse rate for stability will be less than the dry adiabatic lapse rate; in that of saturated air less than the saturated adiabatic lapse rate.

Static.—(See Stray.)

Storm.—A marked disturbance in the normal state of the atmosphere. The term has various applications, according to the context. It is most often applied to a disturbance in which strong wind is the most prominent characteristic, and sometimes specifically to a wind of force 11 on the Beaufort scale. It is also used for other types of disturbance, including thunderstorms, rainstorms, snowstorms, hailstorms, dust storms, sand storms, magnetic storms, etc.

Stratiform.—A general term applied to all clouds which are arranged in unbroken horizontal layers or sheets.

Stratocumulus.—A form of cloud. (See part V.)

Stratosphere.—The upper region or external layer of the atmosphere, in which the temperature is practically constant in a vertical direction. The stratosphere is free from clouds (except occasional dust clouds) and from strong vertical air currents, in other words, active convection. The height of its base (see Tropopause) varies in regular fashion with latitude and with the seasons over the earth as a whole and fluctuates irregularly from day to day over any particular place.

Stratus.—A form of cloud. (See part V.)

Stray.—A natural electromagnetic wave in the ether. The term is used in reference to the effect of such wave in producing erratic signals in radiotelegraphic receivers. Strays are also known as atmospherics, and collectively, as static.

Subsidence.—The word used to denote a slow downward motion of the air over a large area. Subsidence accompanies divergence in the horizontal motion of the lower layers of the atmosphere.

Sun pillar.—(See Light pillar.)

Sunshine recorder.—An instrument for recording the duration of sunshine; certain types also record the intensity of sunshine.

Surge.—A general change in barometric pressure apparently superposed upon cyclonic and normal diurnal changes.

Synoptic chart.—A chart, such as the ordinary weather map, which shows the distribution of meteorological conditions over an area at a given moment.

Synoptic meteorology.—The branch of meteorology that deals with the analysis of meteorological observations made simultaneously at a number of points in the atmosphere (at the ground or aloft) over the whole or a part of the earth, and the application of the analysis to weather forecasting and other problems.

Tangent arc.—Any halo that occurs as an arc tangent to one of the heliocentric halos.

Thermogram.—The continuous record of temperature made by a thermograph.

Thermograph.—A self-registering thermometer.

Thermometer.—An instrument for measuring temperature; in meteorology, generally the temperature of the air. Maximum and minimum thermometers indicate, respectively, the highest and lowest temperatures occurring between the times of setting the instrument. A wet-bulb thermometer is used in measuring humidity. (See Psychrometer.)

Thermometer screen.—A construction designed to screen a thermometer from the direct rays of the sun and from other conditions that would interfere with the registration of the true air temperature; usually a wooden cage with louvered sides. In the United States commonly called the instrument shelter.

Thunder.—The sound produced by lightning discharge.

Thunderstorm.—A storm attended by thunder and lightning. Thunderstorms are local disturbances, often occurring as episodes of cyclones, and, in common with squalls, are marked by abrupt variations in pressure, temperature, and wind.

Tornado.—1. A violent vortex in the atmosphere, attended by a pendulous, more or less funnel-shaped cloud. 2. In West Africa, a violent thunder-squall.

Trade-winds.—Two belts of winds, one on either side of the equatorial doldrums in which the winds blow almost constantly from easterly quadrants.

Trajectory.—The path traced out by a small volume of air in its movement over the earth's surface.

Transition zone.—The relatively narrow region occupied by a front wherein the meteorological properties exhibit large variations over a short distance and possess values intermediate between those characteristic of the air masses on either side of the zone.

Tropical disturbance.—The name used by the Weather Bureau for a cyclonic wind system of the tropics that is not known to have sufficient force to justify the use of the words "storm" or "hurricane."

Tropical maritime air.—The term used to describe any air mass that originates over an ocean area in the tropics. Tropical maritime air is characterized by high surface temperatures and high specific humidity.

Tropopause.—The point in the atmosphere at which the fall of temperature with increasing height abruptly ceases. This point marks the base of the stratosphere. Over most of the earth it is located, on the average, at elevations of between 10 and 15 kilometers (6 and 9 miles) above sea level. Its normal level over the polar regions is somewhat below 10 kilometers and over the equator somewhat above 15 kilometers.

Troposphere.—The lower region of the atmosphere from the ground to the tropopause, in which the average condition is typified by a more or less regular decrease of temperature with increasing altitude.

Trough.—An elongated area of low barometric pressure.

Turbulence.—Irregular motion of the atmosphere produced when air flows over a comparatively uneven surface, such as the surface of the earth, or when two currents of air flow past or over each other in different directions or at different speeds. The existence of turbulence in the atmosphere is made apparent by the character of the trail of smoke from a ship's funnel and by gusts and lulls in the wind.

Twilight.—Astronomical twilight is the interval between sunrise or sunset and the total darkness of night. Civil twilight is the period of time before sunrise and after sunset during which there is enough daylight for ordinary outdoor occupations.

Typhoon.—The name applied in the Far East to a tropical cyclone.

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Ulloa's ring.—1. A glory. 2. A halo (also called Bouguer's halo), surrounding a point in the sky diametrically opposite the sun; sometimes described as a "white rainbow."

V-shaped depression.—A trough of low barometric pressure bounded, on the weather map, by V-shaped isobars.

Vane.—A device that shows which way the wind blows; also called weather vane or wind vane.

Vapor pressure.—The pressure exerted by a vapor when it is in a confined space. In meteorology vapor pressure refers exclusively to the pressure of water vapor. When several gases or vapors are mixed together in the same space each one exerts the same pressure as it would if the others were not present; the vapor pressure is that part of the total atmospheric pressure which is due to water vapor.

Variability.—Interdiurnal variability is the mean difference between successive daily means of a meteorological element.

Veer.—Of the wind, to shift in a clockwise direction; opposite of "back." In scientific practice this definition now applies to both hemispheres.

Vernier.—An auxiliary scale for estimating fractions of a scale division when the reading to the nearest whole division on the main scale is not sufficiently accurate.

Visibility.—The transparency and illumination of the atmosphere as affecting the distance at which objects can be seen. It is usually expressed on a numerical scale.

Warm air mass.—Broadly speaking, an air mass that is warm relative to neighboring air masses. The term implies that the air mass originated in latitudes lower than those in which it now finds itself and that it is, therefore, warmer than the surface over which it is moving.

Warm front.—The discontinuity at the forward edge of an advancing current of relatively warm air which is displacing a retreating colder air mass.

Warm sector.—The area bounded by the cold and warm fronts of a cyclone.

Waterspout.—A tornadolike vortex and cloud occurring over a body of water.

Wave disturbance.—A localized deformation of a front, which travels along the front as a wave-shaped formation, and which generally develops into a well-marked cyclone.

Wedge.—1. A wedge-shaped area of high barometric pressure as shown on a weather chart. Synonymous with "ridge". 2. Applied to an air mass whose advancing forward portion, from a three-dimensional standpoint, is shaped like a wedge.

Wet bulb.—(See Psychrometer.)

Williwaw.—A sudden blast of wind descending from a mountainous coast to the sea. (Especially applied to such blasts in the Straits of Magellan.)

Wind.—Moving air, especially a mass of air having a common direction of motion. The term is generally limited to air moving horizontally, or nearly so; vertical streams of air are usually called "currents".

Wind rose.—1. A diagram showing the relative frequency and sometimes also the average strength of the winds blowing from different directions in a specified region. 2. A diagram showing the average relation between winds from different directions and the occurrence of other meterological phenomena.

Zodiacal light.—A cone of faint light in the sky which is seen stretching along the zodiac from the western horizon after the twilight of sunset has faded and from the eastern horizon before the twilight of sunrise has begun.

B. COLLOQUIAL TERMS

"Backstays of the sun."—A sailor's name for crepuscular rays extending downward from the sun.

Baguio.—The name current in the Philippines for a tropical cyclone.

Bora.—A cold wind of the northern Adriatic, blowing down from the high plateaus to the northward. Also, a similar wind on the northeastern coast of the Black Sea.

Brave west winds.—The boisterous westerly winds blowing over the ocean between latitudes 40° and 50° S. This region is known as the "Roaring Forties."

Bull's-eye.—1. A patch of clear sky at the center of a cyclonic storm; the "eye of the storm". 2. A small isolated cloud seen at the beginning of a bull's-eye squall, marking the top of the otherwise invisible vortex of the storm.

Bull's-eye squall.—A squall forming in fair weather, characteristic of the ocean off the coast of South Africa; so called on account of the peculiar appearance of the small isolated cloud that marks the top of the invisible vortex of the storm.

Callina.—A Spanish name for dry fog.

Cat's paw.—A slight and local breeze, which shows itself by rippling the surface of the sea.

Chubasco.—A violent squall on the west coast of tropical and subtropical North America.

Cordonazo; in full, *cordonazo de San Francisco* ("lash of St. Francis").—A hurricane wind blowing from a southerly quadrant on the west coast of Mexico as the result of the passing of a tropical cyclone off the coast.

Devil.—The name applied to a dust whirlwind in India. The term is also current in South Africa.

"Doctor".—A colloquial name for the sea breeze in tropical climates. The name is sometimes applied to other cool, invigorating breezes.

Etesians.—Northerly winds blowing in summer over the eastern Mediterranean.

Garúa.—A wet fog of the west coast of South America.

Gregale.—The northeast wind on the Mediterranean; especially a stormy northeast wind at Malta.

Harmattan.—A dry, dusty wind of the West Coast of Africa, blowing from the deserts.

Horse latitudes.—The regions of calms and variable winds coinciding with the subtropical high-pressure belts lying on the poleward sides of the trade winds. (The term has generally been applied only to the northern of these two regions in the North Atlantic Ocean, or to the portion of it near Bermuda.)

Indian summer.—A period of mild, calm, hazy weather occurring in autumn or early winter, especially in the United States and Canada; popularly regarded as a definite event in the calendar, but weather of this type is really of irregular and intermittent occurrence.

Khamsin.—A hot, dry, southerly wind occurring in Egypt during the spring.

Leste.—A hot dry, easterly wind of the Madeira and Canary Islands.

Levanter.—A strong easterly wind of the Mediterranean, especially in the Straits of Gibraltar, where it is attended by damp or foggy weather.

Mackerel sky.—An area of sky covered with cirrocumulus or altocumulus clouds; especially when the clouds resemble the patterns seen on the backs of mackerel.

Mares' tails.—Cirrus in long slender streaks.

Mistral.—Along the Mediterranean coast, from the mouth of the Ebro to the Gulf of Genoa, a stormy, cold northerly wind, blowing down from the mountains of the interior. (The name is sometimes applied to northerly winds on the Adriatic, in Greece, and in Algeria.)

Moon dog.—A paraselene. (See Parhelion.)

Mountain and valley breezes.—The breezes that in mountainous regions normally blow up the slopes by day (valley breeze), and down the slopes by night.

Norther.—A northerly wind; especially strong northerly winds of sudden onset occurring during the colder half of the year over the region from Texas southward, including the Gulf of Mexico and the western Caribbean.

Pampero.—A southwest squall blowing over or from the pampas of South America. Off the coast of Argentina these squalls are most prevalent from July to September.

Papagayo.—A strong to violent northeasterly wind, somewhat similar to the Tehuantepecer, which blows during the colder months in the Gulf of Papagayo, on the northwest coast of Costa Rica, and in adjacent Pacific coastal waters.

Roaring forties.—(See Brave west winds.)

Scud.—Shreds or small detached masses of cloud moving rapidly below a solid deck of higher clouds. Scud may be composed of either fractocumulus or fractostratus clouds.

Shamal.—A northwesterly wind of Mesopotamia and the Persian Gulf.

Simoom.—An intensely hot and dry wind of Asian and African deserts; often described as a sand storm or dust storm, but certain authorities state that the typical simoom is free from sand and dust.

Sirocco.—A name applied to various types of warm wind in the Mediterranean region. Some of these siroccos are foehns. The term is also used as the generic name for winds blowing from a warm region toward an area of low pressure in a normally colder region.

Sundog.—A mock sun or parhelion.

"*Sun drawing water.*"—The sun is popularly said to be "drawing water" when crepuscular rays extend down from it toward the horizon. The sun's rays, passing through interstices in the clouds, are made visible through illumination of particles of dust in the atmosphere along their paths. (See part VI.)

Tablecloth.—A sheet of cloud that sometimes spreads over the flat top of Table Mountain, near Cape Town.

Tehuantepecer.—A strong to violent northerly wind of Pacific waters off southern Mexico and northern Central America, confined mostly to the Gulf of Tehuantepec, and occurring during the colder months.

Willy-willy.—A violent storm of wind and rain on the northwest coast of Australia. (The name is also applied in some parts of Australia to a local dust whirl.)

Woolpack.—Cumulus.

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PART X. TABLES

TABLE 1.—*Correction of mercurial barometer for temperature (English measures)*

ADD

Temp. ° F.	Observed reading (inches)					Temp. ° F.	Observed reading (inches)				
	28.5	29.0	29.5	30.0	30.5		28.5	29.0	29.5	30.0	30.5
0	0.07	0.08	0.08	0.08	0.08	16	0.03	0.03	0.03	0.03	0.04
1	.07	.07	.07	.08	.08	17	.03	.03	.03	.03	.03
2	.07	.07	.07	.07	.07	18	.03	.03	.03	.03	.03
3	.07	.07	.07	.07	.07	19	.02	.02	.03	.03	.03
4	.06	.06	.07	.07	.07	20	.02	.02	.02	.02	.02
5	.06	.06	.06	.06	.07	21	.02	.02	.02	.02	.02
6	.06	.06	.06	.06	.06	22	.02	.02	.02	.02	.02
7	.06	.06	.06	.06	.06	23	.02	.02	.02	.02	.02
8	.05	.05	.06	.06	.06	24	.01	.01	.01	.01	.01
9	.05	.05	.05	.05	.05	25	.01	.01	.01	.01	.01
10	.05	.05	.05	.05	.05	26	.01	.01	.01	.01	.01
11	.05	.05	.05	.05	.05	27	------	------	------	------	------
12	.04	.04	.04	.04	.05	28	------	------	------	------	------
13	.04	.04	.04	.04	.04	29	------	------	------	------	------
14	.04	.04	.04	.04	.04	30	------	------	------	------	------
15	.04	.04	.04	.04	.04						

TABLE 1.—*Correction of mercurial barometer for temperature (English measures)*—Continued

SUBTRACT

Temp. ° F.	Observed reading (inches)					Temp. ° F.	Observed reading (inches)				
	28.5	29.0	29.5	30.0	30.5		28.5	29.0	29.5	30.0	30.5
31	0.01	0.01	0.01	0.01	0.01	66	0.10	0.10	0.10	0.10	0.10
32	.01	.01	.01	.01	.01	67	.10	.10	.10	.10	.11
33	.01	.01	.01	.01	.01	68	.10	.10	.10	.11	.11
34	.01	.01	.01	.02	.02	69	.10	.11	.11	.11	.11
35	.02	.02	.02	.02	.02	70	.11	.11	.11	.11	.11
36	.02	.02	.02	.02	.02	71	.11	.11	.11	.12	.12
37	.02	.02	.02	.02	.02	72	.11	.11	.12	.12	.12
38	.02	.02	.02	.03	.03	73	.11	.12	.12	.12	.12
39	.03	.03	.03	.03	.03	74	.12	.12	.12	.12	.12
40	.03	.03	.03	.03	.03	75	.12	.12	.12	.13	.13
41	.03	.03	.03	.03	.03	76	.12	.12	.13	.13	.13
42	.04	.04	.04	.04	.04	77	.12	.13	.13	.13	.13
43	.04	.04	.04	.04	.04	78	.13	.13	.13	.13	.14
44	.04	.04	.04	.04	.04	79	.13	.13	.14	.14	.14
45	.04	.04	.04	.04	.04	80	.13	.14	.14	.14	.14
46	.04	.05	.05	.05	.05	81	.14	.14	.14	.14	.14
47	.05	.05	.05	.05	.05	82	.14	.14	.14	.14	.15
48	.05	.05	.05	.05	.05	83	.14	.14	.14	.15	.15
49	.05	.05	.05	.06	.06	84	.14	.14	.15	.15	.15
50	.06	.06	.06	.06	.06	85	.15	.15	.15	.15	.16
51	.06	.06	.06	.06	.06	86	.15	.15	.15	.16	.16
52	.06	.06	.06	.06	.06	87	.15	.15	.16	.16	.16
53	.06	.06	.06	.07	.07	88	.15	.16	.16	.16	.16
54	.06	.07	.07	.07	.07	89	.16	.16	.16	.16	.17
55	.07	.07	.07	.07	.07	90	.16	.16	.16	.17	.17
56	.07	.07	.07	.07	.08	91	.16	.16	.17	.17	.17
57	.07	.08	.08	.08	.08	92	.16	.17	.17	.17	.18
58	.08	.08	.08	.08	.08	93	.17	.17	.17	.17	.18
59	.08	.08	.08	.08	.08	94	.17	.17	.17	.18	.18
60	.08	.08	.08	.08	.09	95	.17	.17	.18	.18	.18
61	.08	.08	.09	.09	.09	96	.17	.18	.18	.18	.19
62	.09	.09	.09	.09	.09	97	.18	.18	.18	.18	.19
63	.09	.09	.09	.09	.10	98	.18	.18	.18	.19	.19
64	.09	.09	.10	.10	.10	99	.18	.18	.19	.19	.19
65	.09	.10	.10	.10	.10	100	.18	.19	.19	.19	.20

TABLE 2.—*Reduction of barometric reading to mean sea level*

[Reading, 30 inches. The correction is always to be added]

Height in feet	Temperature of air (dry bulb)									
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-------	-------	-------
10	.01	.01	.01	.01	.01	.01	.01	0.01	0.01	0.01
15	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
20	.02	.02	.02	.02	.02	.02	.02	.22	.02	.02
25	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
30	.04	.04	.04	.04	.03	.03	.03	.03	.03	.03
35	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04
40	.05	.05	.05	.05	.04	.04	.04	.04	.04	.04
45	.06	.05	.05	.05	.05	.05	.05	.05	.05	.05
50	.06	.06	.06	.06	.06	.06	.05	.05	.05	.05
55	.07	.07	.06	.06	.06	.06	.06	.06	.06	.06
60	.07	.07	.07	.07	.07	.07	.06	.06	.06	.06
65	.08	.08	.08	.08	.07	.07	.07	.07	.07	.07
70	.09	.08	.08	.08	.08	.08	.08	.07	.07	.07
75	.09	.09	.09	.09	.08	.08	.08	.08	.08	.08
80	.10	.10	.09	.09	.09	.09	.09	.08	.08	.08
85	.10	.10	.10	.10	.10	.10	.09	.09	.09	.09
90	.11	.11	.11	.10	.10	.10	.10	.10	.09	.09
95	.12	.11	.11	.11	.11	.11	.10	.10	.10	.10
100	.12	.12	.12	.12	.11	.11	.11	.11	.10	.10

TABLE 3.—*Reduction of the mercurial barometer to standard gravity (45°) (30 inches)*

Lat.	Cor.	Lat.	Cor.	Lat.	Cor.	Lat.	Cor.
°	*Inch*	°	*Inch*	°	*Inch*	°	*Inch*
0	−0.08	25	−0.05	45	0.00	70	+0.06
5	−.08	30	−.04	50	+.01	75	+.07
10	−.08	35	−.03	35	+.03	80	+.08
15	−.07	40	−.01	60	+.04	85	+.08
20	−.06	45	0.00	65	+.05	90	+.08

TABLE 4.—*Equivalent temperature (Centigrade and Fahrenheit)*

[C°=temperature Centigrade; F°=temperature Fahrenheit; F°=$\frac{9}{5}$C°+32°]

C°	F°	C°	F°	C°	F°	C°	F°	C°	F°
−10	14.0	0	32.0	10	50.0	20	68.0	30	86.0
−9	15.8	1	33.8	11	51.8	21	69.8	31	87.8
−8	17.6	2	35.6	12	53.6	22	71.6	32	89.6
−7	19.4	3	37.4	13	55.4	23	73.4	33	91.4
−6	21.2	4	39.2	14	57.2	24	75.2	34	93.2
−5	23.0	5	41.0	15	59.0	25	77.0	35	95.0
−4	24.8	6	42.8	16	60.8	26	78.8	36	96.8
−3	26.6	7	44.6	17	62.6	27	80.6	37	98.6
−2	28.4	8	46.4	18	64.4	28	82.4	38	100.4
−1	30.2	9	48.2	19	66.2	29	84.2	39	102.2

TABLE 5.—*Equivalent lengths (millimeters and inches)*

[1 millimeter=0.0393700 inch]

Mm	0	1	2	3	4	5	6	7	8	9
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
690	[a] 27.16	27.20	27.24	27.28	27.32	27.36	27.40	27.44	27.48	27.52
700	27.56	27.60	27.64	27.68	27.72	27.76	27.80	27.84	27.87	27.91
710	27.95	27.99	28.03	28.07	28.11	28.15	28.19	28.23	28.27	28.31
720	28.35	28.39	28.42	28.46	28.50	28.54	28.58	28.62	28.66	28.70
730	28.74	28.78	28.82	28.86	28.90	28.94	28.98	29.02	29.06	29.09
740	29.13	29.17	29.21	29.25	29.29	29.33	29.37	29.41	29.45	29.49
750	29.53	29.57	29.61	29.65	29.68	29.72	29.76	29.80	29.84	29.88
760	29.92	29.96	30.00	30.04	30.08	30.12	30.16	30.20	30.24	30.28
770	30.32	30.35	30.39	30.43	30.47	30.51	30.55	30.59	30.63	30.67
780	30.71	30.75	30.79	30.83	30.87	30.90	30.94	30.98	31.02	31.06
790	31.10	31.14	31.18	31.22	31.26	31.30	31.34	31.38	31.42	31.46

[a] For example, 690 millimeters=27.16 inches

TABLE 6.—*Conversion of millimeters (mm) to millibars (mb)*

Mm.	Mb.	Mm.	Mb.	Mm.	Mb.
696	927.9	726	967.9	756	1,007.9
697	929.3	727	969.3	757	1,009.3
698	930.6	728	970.6	758	1,010.6
699	931.9	729	971.9	759	1,011.9
700	933.3	730	973.3	760	1,013.3
701	934.6	731	974.6	761	1,014.6
702	935.9	732	975.9	762	1,015.9
703	937.3	733	977.3	763	1,017.2
704	938.6	734	978.6	764	1,018.6
705	939.9	735	979.9	765	1,019.9
706	941.3	736	981.3	766	1,021.2
707	942.6	737	982.6	767	1,022.6
708	943.9	738	983.9	768	1,023.9
709	945.3	739	985.3	769	1,025.2
710	946.6	740	986.6	770	1,026.6
711	947.9	741	987.9	771	1,027.9
712	949.3	742	989.3	772	1,029.2
713	950.6	743	990.6	773	1,030.6
714	951.9	744	991.9	774	1,031.9
715	953.3	745	993.3	775	1,033.2
716	954.6	746	994.6	776	1,034.6
717	955.9	747	995.9	777	1,035.9
718	957.3	748	997.3	778	1,037.2
719	958.6	749	998.6	779	1,038.6
720	959.9	750	999.9	780	1,039.9
721	961.3	751	1,001.3	781	1,041.2
722	962.6	752	1,002.6	782	1,042.6
723	963.9	753	1,003.9	783	1,043.9
724	965.3	754	1,005.3	784	1,045.2
725	966.6	755	1,006.6	785	1,046.6

TABLE 7.—*For obtaining the relative humidity of the air*

Temperature of the air, dry-bulb thermometer	Difference between dry-bulb and wet-bulb readings									
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
°F	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
24	87	75	62	50	38	26	--------	--------	--------	------
26	88	76	65	53	42	30	--------	--------	--------	------
28	89	78	67	56	45	34	24	--------	--------	------
30	90	79	68	58	48	38	28	--------	--------	------
32	90	80	70	61	51	41	32	23	--------	------
34	90	81	72	63	53	44	35	27	--------	------
36	91	82	73	64	55	47	38	30	22	------
38	92	83	75	66	57	50	42	34	26	------
40	92	84	76	68	59	52	44	37	30	22
42	92	84	77	69	61	54	47	40	33	26
44	92	85	78	70	63	56	49	43	36	29
46	93	85	79	72	65	58	51	45	38	32
48	93	86	79	73	66	60	53	47	41	35
50	93	87	80	74	67	61	55	49	43	37
52	94	87	81	75	69	63	57	51	46	40
54	94	88	82	76	70	64	59	53	48	42
56	94	88	82	77	71	65	60	55	50	44
58	94	89	83	78	72	67	61	56	51	46
60	94	89	84	78	73	68	63	58	53	48
62	95	89	84	79	74	69	64	59	54	50
64	95	90	85	79	74	70	65	60	56	51
66	95	90	85	80	75	71	66	61	57	53
68	95	90	85	81	76	71	67	63	58	54
70	95	90	86	81	77	72	68	64	60	55
72	95	91	86	82	77	73	69	65	61	57
74	95	91	86	82	78	74	70	66	62	58
76	95	91	87	82	78	74	70	66	63	59
78	96	91	87	83	79	75	71	67	63	60
80	96	92	87	83	79	75	72	68	64	61
82	96	92	88	84	80	76	72	69	65	62
84	96	92	88	84	80	77	73	69	66	63
86	96	92	88	84	81	77	73	70	67	63
88	96	92	88	85	81	77	74	71	67	64
90	96	92	88	85	81	78	74	71	68	65

The constants of this table were determined for a ventilated psychrometer and are not strictly applicable to the readings of a stationary hygrometer.

TABLE 8.—*Table for obtaining the true direction and force of the wind from the deck of a moving vessel* [1]

Apparent force of the wind (Beaufort scale)	Speed of the vessel, knots	Apparent direction of the wind (points off the bow): 0		1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16	
		True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale	True direction, points off the bow	True force, Beaufort scale
0	10	16	3	16	3	16	3	16	3	16	3	16	3	16	3	16	3	16	3	16	3	16	3	16	3	16	3	16	3	16	3	16	3	16	3
	15	16	4	16	4	16	4	16	4	16	4	16	4	16	4	16	4	16	4	16	4	16	4	16	4	16	4	16	4	16	4	16	4	16	4
	20	16	5	16	5	16	5	16	5	16	5	16	5	16	5	16	5	16	5	16	5	16	5	16	5	16	5	16	5	16	5	16	5	16	5
1	10	16	3	16	3	16	3	15	3	15	3	15	3	15	3	15	3	15	3	15	3	15	3	15	4	15	4	16	4	16	4	16	4	16	4
	15	16	4	16	4	16	4	16	4	15	4	15	4	15	4	15	4	15	4	15	4	15	4	15	4	16	4	16	4	16	5	16	5	16	5
	20	16	5	16	5	16	5	16	5	16	5	16	5	16	5	15	5	15	5	16	5	16	5	16	5	16	5	16	5	16	6	16	6	16	6
2	10	16	2	15	2	14	2	14	2	13	3	13	3	13	3	13	3	14	4	14	4	14	4	14	4	15	4	15	4	15	4	16	4	16	4
	15	16	3	16	3	15	3	15	4	14	4	14	4	14	4	14	4	14	4	14	5	15	5	15	5	15	5	15	5	16	5	16	5	16	5
	20	16	4	16	4	15	4	15	4	15	5	15	5	15	5	15	5	15	5	15	5	15	6	15	6	15	6	15	6	16	6	16	6	16	6
3	10	16	1	12	1	11	2	11	2	11	3	11	3	12	3	12	4	12	4	13	4	13	4	14	4	14	5	15	5	15	5	16	5	16	5
	15	16	2	15	3	14	3	13	3	13	3	13	4	13	4	13	4	13	5	14	5	14	5	14	5	15	6	15	6	15	6	16	6	16	6
	20	16	4	15	4	15	4	14	4	14	4	14	5	14	5	14	5	14	5	14	6	14	6	15	6	15	6	15	6	15	7	16	7	16	7
4	10	0	1	3	2	6	2	7	3	8	3	9	4	10	4	11	4	11	5	12	5	12	5	13	5	14	6	14	6	15	6	15	6	16	6
	15	16	1	11	1	10	2	10	3	11	4	11	4	11	4	12	5	12	5	13	6	13	6	14	6	14	6	15	6	15	7	16	7	16	7
	20	16	2	14	3	13	3	12	4	12	4	12	5	12	5	13	5	13	6	13	6	14	7	14	7	14	7	15	7	15	7	16	7	16	7
5	10	0	3	2	3	4	3	5	4	7	4	8	4	9	5	10	5	10	5	11	6	12	6	13	6	13	6	14	7	15	7	15	7	16	7
	15	0	2	4	2	6	3	8	3	9	4	9	5	10	5	11	5	11	6	12	6	13	7	13	7	14	7	14	7	15	7	15	8	16	8
	20	16	1	10	2	10	3	10	4	10	4	11	5	11	5	12	6	12	6	13	7	13	7	14	8	14	8	15	8	15	8	16	8	16	8

6	10	0	4	2	4	3	4	5	5	6	5	7	5	8	6	9	6	10	6	11	7	12	7	12	7	13	7	14	7	15	8	15	8	16	8
	15	0	3	2	3	5	4	6	4	7	5	8	5	9	6	10	6	11	7	12	7	12	7	13	8	13	8	14	8	15	8	15	8	16	8
	20	0	2	4	2	7	3	8	4	9	5	10	5	10	6	11	7	11	7	12	8	13	8	13	8	14	9	14	9	15	9	15	9	16	9
7	10	0	5	1	5	3	5	4	6	5	6	7	6	8	7	9	7	10	7	11	7	11	8	12	8	13	8	14	8	14	8	15	8	16	8
	15	0	4	2	4	4	5	5	5	6	6	8	6	9	7	9	7	10	7	11	8	12	8	13	8	13	9	14	9	15	9	15	9	16	9
	20	0	3	3	4	5	4	6	5	8	5	9	6	9	7	10	7	11	8	12	8	12	9	13	9	14	9	14	10	15	10	15	10	16	10
8	10	0	6	1	6	3	7	4	7	5	7	6	7	7	8	8	8	9	8	10	8	11	9	12	9	13	9	14	9	14	9	15	9	16	9
	15	0	6	2	6	3	6	5	6	6	7	7	7	8	8	9	8	10	8	11	9	12	9	12	9	13	10	14	10	15	10	15	10	16	10
	20	0	5	2	5	4	5	6	6	7	6	8	7	9	8	10	8	11	9	11	9	12	10	13	10	13	10	14	10	15	11	15	11	16	11
9	10	0	8	1	8	3	8	4	8	5	8	6	8	7	9	8	9	9	9	10	9	11	10	12	10	13	10	14	10	14	10	15	10	16	10
	15	0	7	2	7	3	7	4	7	6	8	7	8	8	8	9	9	10	9	11	10	11	10	12	10	13	11	14	11	14	11	15	11	16	11
	20	0	6	2	6	3	6	5	7	6	7	7	8	8	8	9	9	10	10	11	10	12	10	12	11	13	11	14	11	15	11	15	11	16	11
10	10	0	9	1	9	2	9	4	9	5	9	6	9	7	10	8	10	9	10	10	10	11	11	12	11	13	11	13	11	14	11	15	11	16	11
	15	0	8	1	8	3	8	4	8	5	9	6	9	7	9	8	10	9	10	10	11	11	11	12	11	13	11	14	12	14	12	15	12	16	12
	20	0	7	2	7	3	7	5	8	6	8	7	9	8	9	9	10	10	10	11	11	12	11	12	12	13	12	14	12	15	12	15	12	16	12
11	10	0	10	1	10	2	10	4	10	5	10	6	10	7	11	8	11	9	11	10	11	11	12	12	12	13	12	13	12	14	12	15	12	16	12
	15	0	9	1	9	3	9	4	10	5	10	6	10	7	11	8	11	9	11	10	12	11	12	12	12	13	12	14	12	14	12	15	12	16	12
	20	0	9	1	8	3	9	4	9	6	10	7	10	8	11	9	11	10	11	10	12	11	12	12	12	13	12	14	12	14	12	15	12	16	12
12	10	0	10	1	10	2	10	3	11	5	11	6	11	7	11	8	11	9	12	10	12	11	12	12	12	12	12	13	12	14	12	15	12	16	12
	15	0	10	1	10	3	10	4	10	5	11	6	11	7	11	8	11	9	12	10	12	11	12	12	12	13	12	14	12	14	12	15	12	16	12
	20	0	9	1	9	3	9	4	10	5	10	7	11	8	11	9	11	10	12	10	12	11	12	12	12	13	12	14	12	14	12	15	12	16	12

First figure column indicates speed of the vessel, knots. Second column gives direction, points off the bow. Third column, true force, Beaufort scale. Proper allowance should be made for compass variation.

[1] Including new values determined by the Bureau of Aeronautics, Navy Department, in 1927.

TABLE 9.—*Time of observation*

WEST LONGITUDE, A. M., CIVIL DATE

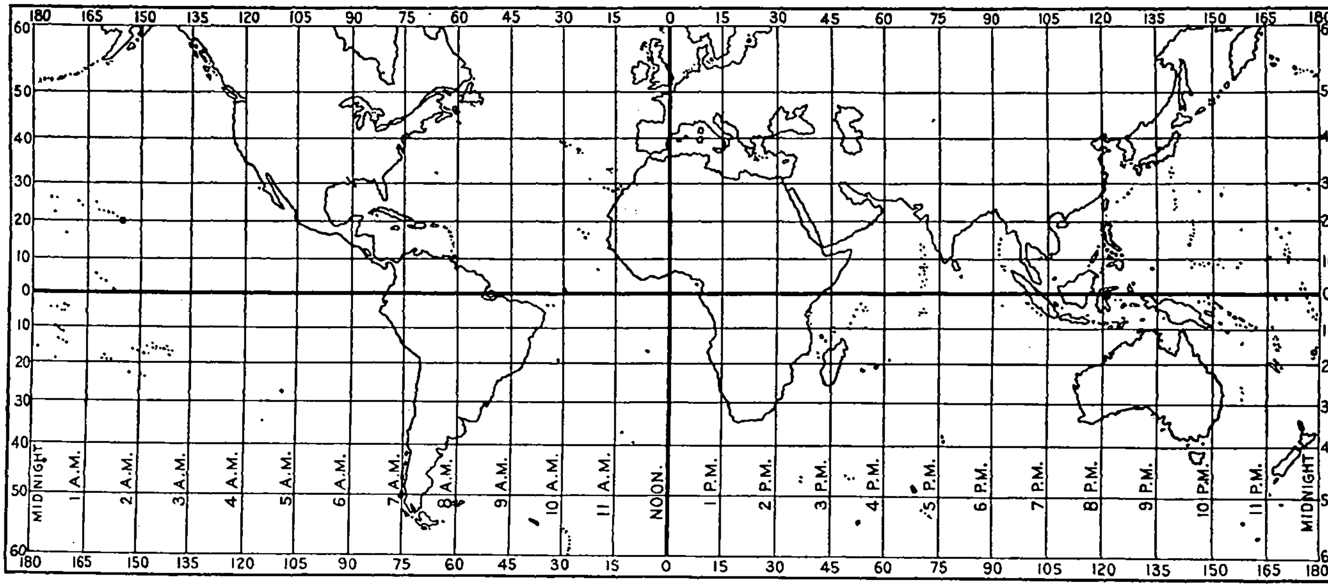
Ship's longitude	Local mean time, a. m.	Ship's longitude	Local mean time, a. m.	Ship's longitude	Local mean time, a. m.	Ship's longitude	Local mean time, a. m.
°*W.*	*h. m.*	°*W.*	*h. m.*	°*W.*	*h. m.*	°*W.*	*h. m.*
0	Noon	45	9 00	90	6 00	135	3 00
1	11 56	46	8 56	91	5 56	136	2 56
2	11 52	47	8 52	92	5 52	137	2 52
3	11 48	48	8 48	93	5 48	138	2 48
4	11 44	49	8 44	94	5 44	139	2 44
5	11 40	50	8 40	95	5 40	140	2 40
6	11 36	51	8 36	96	5 36	141	2 36
7	11 32	52	8 32	97	5 32	142	2 32
8	11 28	53	8 28	98	5 28	143	2 28
9	11 24	54	8 24	99	5 24	144	2 24
10	11 20	55	8 20	100	5 20	145	2 20
11	11 16	56	8 16	101	5 16	146	2 16
12	11 12	57	8 12	102	5 12	147	2 12
13	11 08	58	8 08	103	5 08	148	2 08
14	11 04	59	8 04	104	5 04	149	2 04
15	11 00	60	8 00	105	5 00	150	2 00
16	10 56	61	7 56	106	4 56	151	1 56
17	10 52	62	7 52	107	4 52	152	1 52
18	10 48	63	7 48	108	4 48	153	1 48
19	10 44	64	7 44	109	4 44	154	1 44
20	10 40	65	7 40	110	4 40	155	1 40
21	10 36	66	7 36	111	4 36	156	1 36
22	10 32	67	7 32	112	4 32	157	1 32
23	10 28	68	7 28	113	4 28	158	1 28
24	10 24	69	7 24	114	4 24	159	1 24
25	10 20	70	7 20	115	4 20	160	1 20
26	10 16	71	7 16	116	4 16	161	1 16
27	10 12	72	7 12	117	4 12	162	1 12
28	10 08	73	7 08	118	4 08	163	1 08
29	10 04	74	7 04	119	4 04	164	1 04
30	10 00	75	7 00	120	4 00	165	1 00
31	9 56	76	6 56	121	3 56	166	12 56
32	9 52	77	6 52	122	3 52	167	12 52
33	9 48	78	6 48	123	3 48	168	12 48
34	9 44	79	6 44	124	3 44	169	12 44
35	9 40	80	6 40	125	3 40	170	12 40
36	9 36	81	6 36	126	3 36	171	12 36
37	9 32	82	6 32	127	3 32	172	12 32
38	9 28	83	6 28	128	3 28	173	12 28
39	9 24	84	6 24	129	3 24	174	12 24
40	9 20	85	6 20	130	3 20	175	12 20
41	9 16	86	6 16	131	3 16	176	12 16
42	9 12	87	6 12	132	3 12	177	12 12
43	9 08	88	6 08	133	3 08	178	12 08
44	9 04	89	6 04	134	3 04	179	12 04

EAST LONGITUDE, P. M., CIVIL DATE

Ship's longitude	Local mean time, p. m.	Ship's longitude	Local mean time, p. m.	Ship's longitude	Local mean time, p. m.	Ship's longitude	Local mean time, p. m.
° *E.*	*h. m.*	° *E.*	*h. m.*	° *E.*	*h. m.*	° *E.*	*h. m.*
1	12 04	46	3 04	91	6 04	136	9 04
2	12 08	47	3 08	92	6 08	137	9 08
3	12 12	48	3 12	93	6 12	138	9 12
4	12 16	49	3 16	94	6 16	139	9 16
5	12 20	50	3 20	95	6 20	140	9 20
6	12 24	51	3 24	96	6 24	141	9 24
7	12 28	52	3 28	97	6 28	142	9 28
8	12 32	53	3 32	98	6 32	143	9 32
9	12 36	54	3 36	99	6 36	144	9 36
10	12 40	55	3 40	100	6 40	145	9 40
11	12 44	56	3 44	101	6 44	146	9 44
12	12 48	57	3 48	102	6 48	147	9 48
13	12 52	58	3 52	103	6 52	148	9 52
14	12 56	59	3 56	104	6 56	149	9 56
15	1 00	60	4 00	105	7 00	150	10 00
16	1 04	61	4 04	106	7 04	151	10 04
17	1 08	62	4 08	107	7 08	152	10 08
18	1 12	63	4 12	108	7 12	153	10 12
19	1 16	64	4 16	109	7 16	154	10 16
20	1 20	65	4 20	110	7 20	155	10 20
21	1 24	66	4 24	111	7 24	156	10 24
22	1 28	67	4 28	112	7 28	157	10 28
23	1 32	68	4 32	113	7 32	158	10 32
24	1 36	69	4 36	114	7 36	159	10 36
25	1 40	70	4 40	115	7 40	160	10 40
26	1 44	71	4 44	116	7 44	161	10 44
27	1 48	72	4 48	117	7 48	162	10 48
28	1 52	73	4 52	118	7 52	163	10 52
29	1 56	74	4 56	119	7 56	164	10 56
30	2 00	75	5 00	120	8 00	165	11 00
31	2 04	76	5 04	121	8 04	166	11 04
32	2 08	77	5 08	122	8 08	167	11 08
33	2 12	78	5 12	123	8 12	168	11 12
34	2 16	79	5 16	124	8 16	169	11 16
35	2 20	80	5 20	125	8 20	170	11 20
36	2 24	81	5 24	126	8 24	171	11 24
37	2 28	82	5 28	127	8 28	172	11 28
38	2 32	83	5 32	128	8 32	173	11 32
39	2 36	84	5 36	129	8 36	174	11 36
40	2 40	85	5 40	130	8 40	175	11 40
41	2 44	86	5 44	131	8 44	176	11 44
42	2 48	87	5 48	132	8 48	177	11 48
43	2 52	88	5 52	133	8 52	178	11 52
44	2 56	89	5 56	134	8 56	179	11 56
45	3 00	90	6 00	135	9 00	180	Mid.

TABLE 10.—*Distance of visibility of objects at sea (in nautical miles)*

Height of observer's eye above sea level (in feet)	Height of object above sea level (in feet)													
	10	20	30	40	60	80	100	150	200	300	400	600	800	1,000
10	7.2	8.7	9.9	10.8	12.5	13.9	15.1	17.7	19.8	23.5	26.5	31.6	36.0	39.8
15	8.0	9.5	10.7	11.6	13.3	14.7	15.9	18.5	20.6	24.3	27.3	32.4	36.8	40.6
20	8.7	10.2	11.4	12.3	14.0	15.4	16.6	19.2	21.3	25.0	28.0	33.1	37.5	41.3
25	9.3	10.8	12.0	12.9	14.6	16.0	17.2	19.8	21.9	25.6	28.6	33.7	38.1	41.9
30	9.9	11.4	12.6	13.5	15.2	16.6	17.8	20.4	22.5	26.2	29.2	34.3	38.7	42.5
35	10.4	11.9	13.1	14.0	15.7	17.1	18.3	20.9	23.0	26.7	29.7	34.8	39.2	43.0
40	10.8	12.3	13.5	14.4	16.1	17.5	18.7	21.3	23.4	27.1	30.1	35.2	39.6	43.4
45	11.3	12.8	14.0	14.9	16.6	18.0	19.2	21.8	23.9	27.6	30.6	35.7	40.1	43.9
50	11.7	13.2	14.4	15.3	17.0	18.4	19.6	22.2	24.3	28.0	31.0	36.1	40.5	44.3
60	12.5	14.0	15.2	16.1	17.8	19.2	20.4	23.0	25.1	28.8	31.8	36.9	41.3	45.1
70	13.2	14.7	15.9	16.8	18.5	19.9	21.1	23.7	25.8	29.5	32.5	37.6	42.0	45.8
80	13.9	15.4	16.6	17.5	19.2	20.6	21.8	24.4	26.5	30.2	33.2	38.3	42.7	46.5
90	14.5	16.0	17.2	18.1	19.8	21.2	22.4	25.0	27.1	30.8	33.8	38.9	43.3	47.1
100	15.1	16.6	17.8	18.7	20.4	21.8	23.0	25.6	27.7	31.4	34.4	39.5	43.9	47.7



This chart gives the local time corresponding to Greenwich mean noon.