AGRICULTURAL METEOROLOGY

The first meeting of the International Commission on Agricultural Meteorology was held at Danzig on the afternoon of August 28. It was occupied largely with a consideration and review of different solar radiation instruments suitable for making observations in agricultural meteorological work.

At the second meeting, held on the afternoon of August 29, several reviews of recent investigations and researches in the field of agricultural meteorology were presented and extensively discussed.

Before leaving Washington, Dr. H. C. Taylor, the American representative to the International Institute of Agriculture at Rome, called on Mr. Gregg, Chief of the United States Weather Bureau, and explained that the Institute is now engaged in preliminary work on the preparation of a series of soil maps for the entire world; and, upon their completion, it is proposed to prepare climatic maps of a similar character, to accompany the soil maps. He requested that the matter be presented to the International Commission on Agricultural Meteorology at the Danzig meeting, with a view to obtaining its cooperation in the preparation of the proposed agricultural climatological maps. The matter was presented to the Commission and was favorably received. A joint subcommission was set up to cooperate with the Institute, composed of the chairman, Dr. Schmidt, of Austria, and Messrs. Braak (Netherlands), Knoch (Germany), and Kincer (U. S. A.). The International Institute was requested to appoint a representative to serve on this committee.

MEXICAN WEST COAST CYCLONES

By DEAN BLAKE

[Weather Bureau, San Diego, Calif., November 1935]

In this paper, two classes of storms that form on the west coast of Mexico are discussed: The first class consists of tropical hurricanes that originate in low latitudes over the Pacific Ocean during summer and fall. Instances are cited in which they have penetrated into southwestern United States. It is shown that they travel with the air masses in which they originate; and that when these move in a northerly direction, the cyclones occasionally penetrate well into the Temperate Zone, and produce rains out of season in the Southwest. Unquestionably, their paths are contingent upon the development of the semipermanent thermal low area over our Southwest, and the position of the attendant upper-level anticyclone.

The second class comprises storms that develop off the coast of Lower California. Frequently during autumn and winter, when an unusually deep high-pressure area is crested over the far western regions of our country, strong easterly winds of föhn nature prevail at the surface in southern California, with a pronounced wind movement aloft from a southerly direction—part of the clockwise circulation aloft around an upper-level anticyclone usually centered somewhere over the Plateau region. Increasing cloudiness and light rains often result in California. It is demonstrated that this current aloft is at times equatorial in its make-up; that its origin may be on either side of Mexico or Central America, in quite low latitudes; that convective instability is realized when it cools sufficiently in its northward journey to permit of penetrative convection, or when it overruns a colder mass below. Where this equatorial current enters the Temperate Zone, extratropical cyclones often form; the hypothesis is advanced that these disturbances sometimes first develop at high levels, and later appear at the surface. Examples are presented of storms formed in this way, notably those of December 6–15, 1934, and February 2–10, 1935, which caused abnormally heavy rains.

The conviction that the waters off the coast of Lower California are a prolific source region for extratropical storms has been growing ever since weather reports became available from stations in Mexico and ships at sea, and aerological observations began to be made regularly at points along the Pacific coast; particularly during the last season, this conviction has become a certainty. In this period disturbances were observed to appear and develop over the Pacific Ocean southwest of southern California, and it now is certain that this must be a region where cyclogenesis frequently takes place.

It has long been known that the ocean west of Mexico and Central America is the breeding place of tropical hurricanes. Hurd (1) places the region of occurrence from the middle section of Lower California at Point Eugenia to latitude 10° N. in longitude 125° to 130° W., and thence eastward to Costa Rica. He states that this is the scene of more than nine-tenths of the Mexican-Pacific group, and that here conditions are ideal for the development of storms of this type.

Like other tropical storms, they form where there are conflicting air currents; in regions where, in the late summer and autumn, the northeast trades encounter the deflected southeast trades. Werenskiold brings this out convincingly in his charts of the mean monthly air transport over the North Pacific (2), which show a marked line of discontinuity over west coast tropical waters that coincides closely with the area where these cyclones make their appearance.

In the reference given above, Hurd discusses at considerable length what he terms "coastwise cyclones", those disturbances that first appear "over and somewhat to the southward of the Gulf of Tehuantepec." He states that this group is the most numerous of all tropical storms found in the eastern Pacific; and, unless short-lived, they usually follow a course to the westward of the entrance to the Gulf of California.

Several in their northwestward journey have actually entered southwestern United States, where, by the unusual and, at the time, unexplainable weather phenomena that attended them, they left an indelible impression. It is true they were no longer of hurricane force, and were in the dying stages of tropical cyclones that pass over land surfaces in the temperate zones, but the attendant high temperatures and unseasonable rains made their incursions long to be remembered.

Three such memorable storms were those of September 24-October 8, 1921; September 10–18, 1929; and September 27–29, 1932. The first originated in the Gulf of Tehuantepec, moved northwestward along the coast of Lower California, and recurved eastward near San Diego. It continued its phenomenal journey over the United States; left the continent in the vicinity of the Gulf of St. Lawrence; and finally disappeared near the British Isles on October 8. At many stations in southern California and Arizona it produced the greatest rainfall ever recorded in September, and, since its arrival was wholly unexpected, caused much damage to crops and drying fruits.

The cyclone of September 10–18, 1929, also entered via southern California. At San Diego it established the maximum wind velocity for September, and its passage was attended by extraordinarily high temperatures and rains. An account of this unique visitation is found in the MONTHLY WEATHER REVIEW for November 1929 (**3**).

The third appeared on September 27, 1932, off Manzanillo, and before its final disappearance over southwestern United States, resulted in excessive rains in places. According to Sprague (**4**) the downpour was particularly destructive in the Tehachapi Mountains, where, owing to forced convergence of the rain-bearing southeast winds by topography, heavy loss of life and property resulted.

During each of these storms, available weather maps show a well marked anticyclone overspreading the far West and Rocky Mountains, and relatively low pressure over the interior of California and the Colorado Valley, a typically summer distribution except, perhaps, that the high area was more intense and extended farther southward over Mexico and the Gulf of Mexico than is usual in summer and early autumn.

There can be little doubt that these disturbances were transported into our territory by an abnormal and unusual drift of the air in which they originated. That they do not cross the southwestern regions of our country more often is largely because air movement aloft is more toward the northwest than the north. This is brought out in the charts accompanying Hurd's article printed on the Pilot Chart for the North Pacific Ocean for November 1929; they show that the cyclones of July and August move in a general northwesterly direction, while those that form in September and October, after the breakdown of the summer thermal low area and its attendant anticyclone aloft over western United States, have a tendency to recurve eastward. Unquestionably, the forecasting of their paths is a matter of correctly anticipating upper air directions in the area which they are likely to traverse.

Reed's investigations (**5**) lead him to believe that even when the center itself has disappeared from the weather map, subsequent rains over the far Southwest often can be attributed to an overrunning tropical air mass.

Northward invasions by these tropical cyclones is not confined to the warmer months alone, for two have actually reached the United States during the winter season; one crossed the coast of southern California on November 2, 1920, and one disappeared in southern Arizona on December 10, 1930.

Data are not at hand for the November storm, except that it appeared on the coast of Mexico on October 29, 1920, and later died out as a weak depression over Arizona and New Mexico.

The December storm, though, because of its intensity was the subject of advisory notices from the district forecasters at San Francisco from the time of its first appearance near latitude 20° N. and longitude 110° W. to its disappearance in Arizona 4 days later. Cloudy, unsettled weather and local rains continued in the Southwest for some time after it was possible to locate the center at the surface, presumably owing to a continued northward movement aloft of unstable air.

Obviously, this disturbance was a tropical hurricane out of season; one that formed when conditions were favorable for a northward advance of equatorial air. No upper air soundings are available, but the high cloud movement over the greater part of the Southwest was from the south. As these cyclones offer visible indications of air mass movement aloft, there are times, then, in the cold as well as the warm season when equatorial air masses from the west coast of Mexico invade the Temperate Zone.

This contention has been justified by recent observations in southern California, where it has been noticed in the fall and winter that when a large and intense high barometric area covered the western parts of our country, and persisted without important diminution in intensity, cirrus and cirro-stratus clouds usually made their appearance on the southern horizon. So long as this pressure regime continued and the clouds increased in amount, the ceiling decreased and alto-stratus or alto-cumulus became the predominating kinds. Rain occurred at times; an almost inexplicable phenomenon, as days were unseasonably dry and warm, and frost was often found in sheltered pockets at night. Sometimes strong föhn winds were in evidence. Under these conditions the balloon runs invariably showed a deep current from the southeast or south, coming from the same general direction as the clouds.

In seeking an explanation for these apparently anomalous conditions, and also for some tangible aid in their prediction, the synoptic charts during the last few years have been examined, and from the many instances available, several special cases have been selected.

Invariably, in these examples, when the upper air first became easterly (winds aloft normally are from some westerly point during the colder months), weather charts showed the same general barometric distribution at the surface; namely, an intense high area of great depth over the Pacific Ocean and the far western regions, with crests located several hundred miles at sea and over the Great Basin, respectively. At the same time wind-flow maps at the 10,000-, 12,000-, and 14,000-foot levels, clearly depicted an anticyclonic circulation clockwise around a center over the Plateau region.

It may be interpolated here that it is realized that the classification of American air masses in general use employs the designation "tropical" rather than "equatorial" for air that comes out of the tropics, whether it originates below latitude 20° or not. In this connection Willett (**6**) points out that for central and eastern United States "the predominating source of our tropical air masses is actually equatorial in its characteristics, and nearly so in latitude." He further states, "On the Pacific coast and in the Rocky Mountain region * * * the only tropical maritime air mass which plays any role is the one which comes from the subtropical zone of the north Pacific Ocean (TP). This tropical Pacific air * * * is quite distinct in its properties from the TA and TG air masses." He writes again, "The source of the TP air masses is that portion of the Pacific Ocean lying west and southwest of southern California, roughly between latitudes 25° and 35° N."

Byers (**7**), in his paper on the Air Masses of the North Pacific, does not consider Tropical Gulf (TG) of enough importance in its effects to merit consideration or warrant discussion; and the possibility of an air mass originating at low latitudes along the west coast and often materially affecting the weather over California and the Southwest is not mentioned.

So, to simplify matters, it has been decided to designate the tropical air masses involved in this paper as "equatorial", whether they originated in the Gulf of Mexico or the Pacific Ocean. As the properties of the two are quite similar, their exact source is of no fundamental importance in this discussion. There is good reason, however, for believing that in California, at least, the source of this equatorial air is as often from the west of Mexico as the east, for in the tropical cyclones cited above as moving into our country, it is quite evident that they formed on the Pacific side considerably below latitude 20° N.

But to return to our examples of invasion by equatorial air during the fall and winter months. The first case selected for discussion occurred between November 12 and 16, 1933. On the 12th a high pressure area of extraordinary depth was crested over the Great Basin, and warm, dry weather with northerly or easterly winds prevailed over all of California. Skies were clear except in the extreme south, where high clouds were reported moving northward. Upper air to the highest elevations showed an unmistakably clockwise circulation around an upper level anticyclone over Nevada.

During the days which followed, the upper-level anticyclone drifted southward; and winds aloft, that began in the southeast, veered to the south. As a result, the clouds moved up the coast, and the weather became increasingly unsettled until rains actually began in the Pacific Northwest. The barometric situation, the trajectory of the wind currents along the Pacific coast, and the synoptic situation over Mexico certainly justify an assumption that the mass responsible for the rains was the equatorial air aloft rendered unstable by cooling as it passed northward.

A similar example in which equatorial air undoubtedly figured was found beginning January 27, 1934. On this date northeast gales aloft were reported over southern California with moderate east to south winds over Arizona. At the surface there was a large anticyclone over the Far West, which extended southward over the Gulf of Mexico, and, as should be expected, clear skies obtained at all stations in the district.

However, subsequent developments were not indicated by the weather map, and therefore were wholly unexpected; for with a rapid change in wind direction aloft from the northeast to the southeast, rapidly increasing cloudiness began. By the 29th the soundings indicated a well-defined high-level cyclone [1] southwest of San Diego, which retained its identity as it travelled eastward, and brought sprinkles over southern California, rising temperatures and widespread rains over most of Arizona. Precipitation occurred in the desert, as well as the mountains, showing a general cooling and unstable condition rather than local convective action. Unquestionably, the high-level cyclone propagated downward, as neither the weather charts for Mexico nor for the United States showed any indications of a disturbance at sea level, and we can be reasonably certain that there was no movement of a depression into this field until some time after precipitation had begun.

Another situation, illustrative of conditions that gave rise to the development of an upper-level cyclone in the same region, is found on the maps for August 1931.[2] On the 25th, after causing east winds aloft for 3 days over southern California, the upper-level anticyclone, then centered over Arizona, began a southeastward movement, and a gradual turning of the upper air to the south resulted. At the time, unsettled weather and local rains were reported from northern Mexico; and, as the unstable mass moved northward, light convectional rains overspread the districts near the border. The persistence of southerly winds aloft resulted in the formation of a high-level cyclone off the coast, and rains began which continued for several days and overspread the area from the Tehachapi Mountains south, a most unusual occurrence for August. Two days later, the storm which had remained aloft reached the surface, and, gaining in intensity, was readily followed on the daily chart as it moved eastward over Arizona, Colorado, and Kansas. Although this example occurred in the late summer, it is used to show that even in the driest time of the year a stream of equatorial air aloft can be instrumental in producing upper-level disturbances and general precipitation over large areas. In this case also the pressure distribution was such that a cyclone could not have moved up from the south.

Emphasis is placed on the fact that the cloudiness and the instability rains were contingent upon the air flow aloft coming from the south. As long as the high-level anticyclone produced easterly winds over southern California, föhn conditions prevailed; but when it moved southward, the upper air shifted to a direction that would bring in equatorial air, the sine qua non of our requirements.

There is no question that the exceptional rains of December 6–15, 1934, and February 2–10, 1935, had their inception under the same general synoptic situation as already described. Although of minor intensity, the disturbances that produced them will go down in the climatological history of southern California, Arizona, and Lower California. At San Diego, nearly 75 percent of the average seasonal precipitation was recorded in the two storms; and in Lower California information has come that the rainfall was the greatest in years. It is of interest, too, that in proportion to the normal seasonal totals, amounts were heavier over the desert than over the mountains. For instance, Needles measured the phenomenal amount for the Colorado Valley of 5.24 inches, or 0.79 inches more than the average seasonal, a greater total than was reported at many of the high mountain stations.

In many respects the two storms were remarkably similar, but that of December was several days longer in its initial stages. Both began with the cloud sequences and instability rains characteristic of the equatorial current; and preceding both, the weather map showed the usual abnormally deep HIGH overlying the western districts of our country.

Any detailed description of the formation of these two storms would merely be a repetition in the main of the events that accompanied the development of those cited above. Certain it is that there were no cyclones in Mexican or American waters at the time the first rains began.

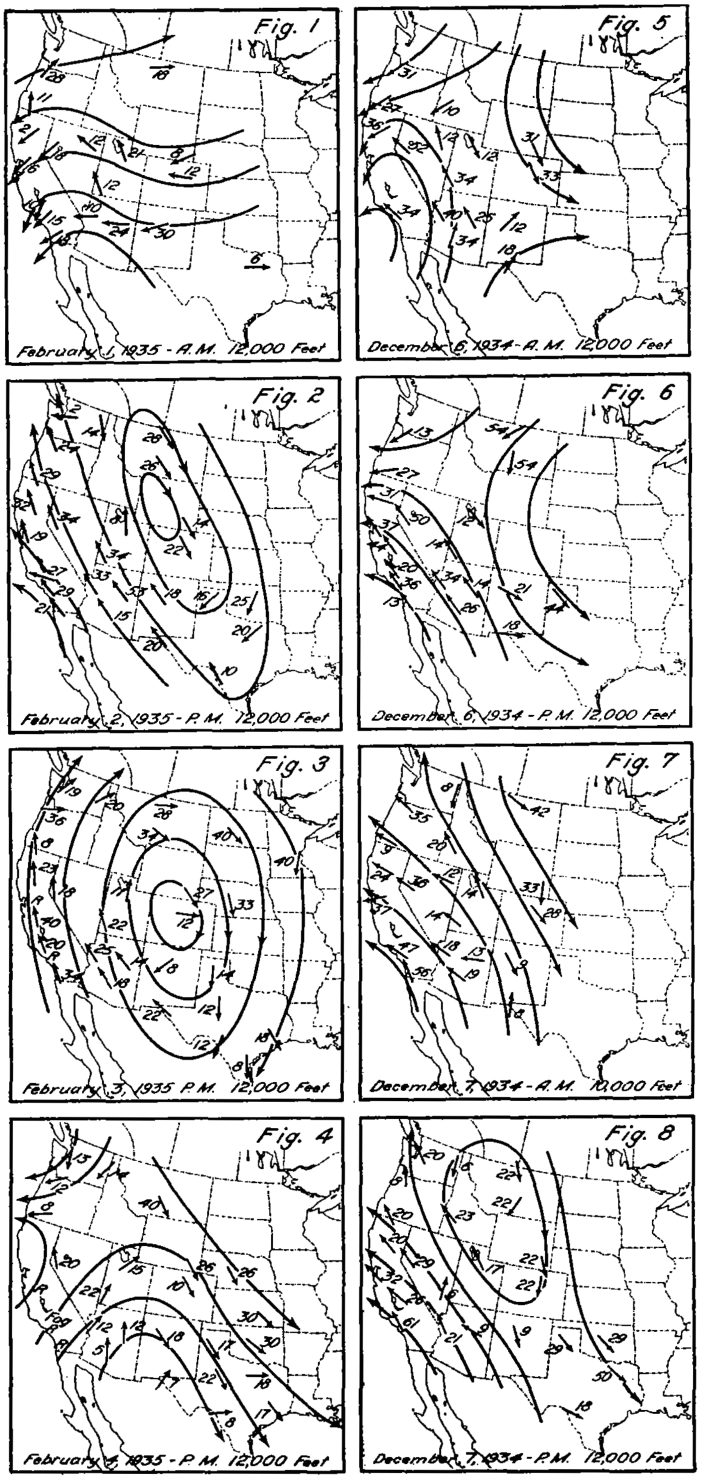
It must not be inferred, though, that it is assumed that all of the precipitation produced by these disturbances resulted from a situation that merely permitted penetrative convection. "Fronts" most assuredly did appear later; but in the early stages of development the conditions were very similar to those of the typical summer situation, seldom found in winter, discussed by Reed (5).

The observation that the rainfall remained negligible, so long as the upper air winds continued from the east, was demonstrated forcibly in the December storm, when for one whole week accurate precipitation forecasts proved impossible. Subsequently it was learned that winds aloft contained the correct interpretation of the situation, for the rainfall invariably increased when they veered to the south, and decreased when they backed toward the east.

[1] Reed, in the paper cited above, defines a high-level cyclone thus: "By a high-level cyclone is meant a system of counterclockwise winds aloft, a phenomenon, as has already been said, which is not uncommon over the far western United States, and which sometimes seems to originate in upper air which has been transported into those regions by the agency of the high-level anticyclone. Such developments are not necessarily indigenous to that air, but in the warm season it is their likeliest source."

[2] The relationship that exists between Far Western weather in the warmer months of the year and the position of the high-level thermal anticyclone is clearly shown by Reed, and he offers many charts in support of his theories. A careful reading of his paper will be profitable to all interested in the meteorology of the Southwest.

While it is not possible to prove beyond question that these cyclones have their inception aloft, yet there is strong evidence in favor of such a hypothesis. For how else can we logically explain the winds of gale force from

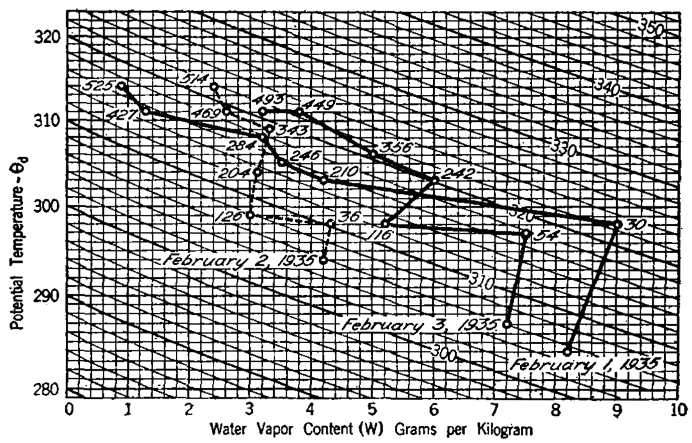


the southeast found in the soundings over southern California at the time the rains first began, and prior to the appearance of a low area at sea level southwest of San Diego?

In support of our contention, figures 5–8, that depict the upper air streams on December 6 and 7, 1934, a. m. and p. m., over the western section of the country, are presented. They offer graphical evidence of the counterclockwise circulation referred to above. It is not illogical to predicate that cyclones of this type would find conditions for their genesis most favorable at higher elevations, for that is where the greatest contrasts in temperature and moisture content of the contiguous air currents are found.

Naturally, the question is asked "if the instability rains are from free air cooling, how is this cooling brought about?" Probably an effective way is by radiation from the upper part of the moist equatorial current. This is offered by Reed as an important underlying cause of the summer rains over the Southwest, supplying the necessary requirements for precipitation, viz, a radiating mass that cools sufficiently to permit and sustain penetrative convection.

Another way in which convective instability and rains may be realized under these conditions is by the overrunning of the relatively colder air mass by warmer air above. In both December and February the equatorial air arrived after several days of outflow of transitional polar Pacific (NPP) air from the continent, and, assuredly, there must have been a decided up-glide as it moved



farther and farther north over this denser air. Only surface data are available on the west coast of Mexico, but reports on the mornings of February 2 and 3, 1935, showed low clouds and rain in the area around Cape San Lucas, and high or intermediate clouds solely at San Diego and points to the north. This would seem to indicate either a slope of sufficient steepness to produce the drizzle that ensued, or instability produced by a gradual lifting. In any event, the fact remains that the advent of the equatorial air aloft was followed by typically warm front cloud sequences and warm front precipitation.

It may be argued, on the other hand, that positive proof of the southern origin of the air mass aloft has not been established. Through the courtesy and kindness of H. C. Willett we are able to include not only his interpretation, but also a Rossby diagram of the three aerographical soundings made at San Diego the mornings of February 1, 2, 3, 1935. Owing to the rain that began the morning of the 4th and continued during the day no airplane flight was made on that date.

Willett writes:

Considering the soundings individually, I would make the following interpretation:

February 1. This sounding shows a shallow layer of moist transitional air near the ground (probably old NPP which has picked up moisture in its lower strata along the coast) and above that the warm dry air, of föhn nature, which might be either subsiding dynamically heated NPP or the sinking dry air of tropical origin which we are now indicating as Ts (Tropical Superior). There is no evidence of any other air to the top of the ascent, as the moisture content w continues to decrease steadily with elevation.

February 2. This sounding shows marked changes both at the top and bottom from that of the day before. The surface layer has become much warmer and much drier, showing that the shallow layer of moist NPP at the ground on the preceding day has been displaced by the warm dry outflowing föhn NPP or Ts current aloft. But now, instead of steadily decreasing moisture with elevation, as on the preceding day, we find a deep layer, from 1,260 to 3,430 m, in which w increases slightly, and at upper levels it is uniformly much higher than on the previous day. There is no doubt that from 3,430 m to the top we are in Tropical maritime air, either TG or TP from quite low latitudes. The temperature is very little different from that of the Ts current which prevailed there on the preceding day, as shoud be the case. The contrast lies in the moisture difference.

February 3. This sounding shows the almost complete disappearance of the warm dry air mass. It has been replaced at the ground again by somewhat moister and cooler air, probably old NPP from off the water, and at upper levels the Tropical maritime current has become lower and deeper. The transition zone, which on the previous day extended from 1,260 to 3,430 m, now lies between 1,160 and 2,420 m, and above 2,420 to the top of the ascent we find a typical Tropical maritime curve, slightly moister at all levels than on the preceding day.

To help in elucidating these summaries, maps of the air flow at 12,000 feet for the first 4 days of February are submitted. It will be noticed that the increase in moisture in the deep layer aloft occurred when winds aloft changed from northeast to south, and it was not until then that the layer was classified as "tropical maritime air from quite low latitudes". This substantiates the assumption that the southerly current originated in the Tropics, and removes all question as to its source on these dates as well as on the other dates specified.

The area several hundred miles off the coast between Point Eugenia and Point Conception is undoubtedly a source region for these storms; meteorologists who are following weather sequences in southern California must admit that numerous depressions, unheralded and unpredicted, have appeared first in this general vicinity. Why is this a zone of cyclogenesis?

It is to be regretted that the region is more or less remote from the main-traveled steamship routes; the development of these frontal disturbances is often unknown until a full-fledged extratropical cyclone moves into the scene of ocean commerce, or reaches the Pacific coast. This lack of definite reports makes it impossible to ascertain the true situation until they appear within our field of observation.

Nevertheless, it is certain these storms often originate near the southern boundary of the temperate zone, in the so-called calms of Cancer, just north of the trade-wind belt; and it is a matter of observation that they occur at a time and in the season of the year when an enormous outflow of air has been possible over that region from the American continent. Maps and ship reports from Mexican waters prove conclusively that they are not cyclones that form along the southern coast and move northward into this area.

Clearly, then, this must be a region of converging currents, warm, moist southerly air in conflict with colder, drier northerly air. Winds over this part of the Pacific Ocean are largely the outflow from the subtropical high pressure belt, and, as has been emphasized before, during the periods of frontogenesis, widespread anticyclones invariably cover both the western continental areas and the ocean to the west. In the case of the storms of December 6–15, 1934, and February 2–10, 1935, the frontal system did not develop until there was a marked barometric rise to the west. Whether the colder mass is tropical maritime (for tropical may act as a cold mass to equatorial), or transitional polar Pacific can be determined only by a qualitative analysis of the vertical structure of the air involved.

In conclusion, the writer wishes to acknowledge his indebtedness to his associates at San Diego, and to T. R. Reed, in particular, whose interest stimulated the study, and whose advice and help were largely responsible for its completion.

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UNUSUAL THUNDERSTORM ACTIVITY IN THE MOUNTAINS OF OREGON AND WASHINGTON IN 1935

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Thunderstorm frequency in the Oregon Cascade Range and northeastern part of the State was greater in 1935 than in any year since 1930; the storms were likewise numerous in the Cascade Range of Washington, but less so than in 1932. This was shown by an analysis of the records kept annually by fire lookouts on the national forests, describing all thunderstorms seen during the summer. The lookouts selected for the analysis were distributed about 25 miles apart in a network covering nearly all of the mountainous territory of Oregon and Washington, the principal areas of thunderstorm occurrence in these States.

As compared with the 10 previous years of record, 1935 differed by having the preponderance of its lightning-storm days in July instead of either in August or more equally divided between July and August.

On July 23, thunderstorms were more widespread than on any other day since 1930. They were reported from each of the 10 national forests that make a continuous 500-mile chain along the Cascade Range north and south through Oregon and Washington, and from each of 5 forests in a 200-mile chain through the Blue Mountains of northeastern Oregon. Thunderstorms were extensive in the mountains of Oregon and Washington on several other days in the last decade of July, and from July 21 to 31 caused a total of 407 forest fires on the national forests of the region.