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METEOROLOGICAL SATELLITE LABORATORY
REPORT NO. 29

Tropospheric Conditions over the Tropical Atlantic as Observed by Two Tiros Satellites and Research Aircraft During 22 September 1962

WASHINGTON, D. C.
JUNE 1964

National Oceanic and Atmospheric Administration
TIROS Satellites and Satellite Meteorology

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U. S. DEPARTMENT OF COMMERCE

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U. S. WEATHER BUREAU

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METEOROLOGICAL SATELLITE LABORATORY

REPORT NO. 29

TROPOSPHERIC CONDITIONS OVER THE TROPICAL ATLANTIC AS OBSERVED BY TWO TIROS SATELLITES AND RESEARCH AIRCRAFT DURING 22 SEPTEMBER 1962

H. McClure Johnson

and

Captain Robert W. Fett
A.W.S. Member

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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PREFACE

This report presents research findings which were obtained during the fall of 1962. The concepts presented and utilized in this report were developed during the fall months of 1962, and are presented here in the form that they had at that time. They represent what was known, discussed, and written at that time. Thus, although the material presented here has well withstood the test of time, and has undergone little refinement during the past year and a half, it is, in fact, dated. The correct, and best, date for these findings and concepts is September-October 1962.

As originally planned this report was to be one part of a more comprehensive report which was to summarize and compare results obtained during the four days of the second set of flights of the MSL-RFF Cape Verde Operation.

The tasks of data reduction and summarization of the findings proved to be so large that it was necessary to reduce the immediate scope of the project and concentrate on the processing of the information obtained during a single day, the day with the best aircraft and satellite coverage, which was September 22, 1962. Shorter related summaries are planned for the other days of this set.

During the preparation of this report several problems arose concerning procedures for the presentation of the information of the report and their improvement. Some experimentation was necessary, and a few innovations were tried. Although the procedures adopted reflect their experimental origins, and are capable of further refinement, they have proved to be useful and effective.

Selected specific cloud formations, atmospheric conditions, and atmospheric systems have been given designator numbers. The numbers are presented in figure 12. Each number refers also to the same condition as shown in <u>all</u> other pictures that include the condition. A specific condition is usually best seen in a particular TIROS picture, which is generally specified, but it is usually also shown (often informatively) in other pictures. The specific conditions are easily located in the unlabeled pictures by appearance and by position relative to the other details shown. Thus a reference to formation (11) in figure 14D refers to the formation labeled 11 in figure 12 but as shown in figure 14D. A specific condition to which reference is made, but which has no designator number, is usually referred to by means of latitude and longitude coordinates. More designator numbers could have been used to advantage.

The observation scale of certain conditions, often of critical importance, is indicated by the designators TOS, AOS, GOS (respectively: TIROS observation scale, aircraft observation scale, and ground observation scale) in this report. These designators, and scale, are further discussed in the glossary. These designators could have been used to advantage more often.

The mosaics are numberd in the order in which they are discussed, which is from east to west on this day. For convenience of reference and comparison they were grouped together to form the set of figures 6-11. They provide an integrated, large-scale, over-all view.

The individual TIROS pictures follow; figure 12, providing the designators, being first, and figure 14 last having been prepared much later than any of the other figures. These figures provide the best available TIROS detailed views.

The picture identifier letters of figures 12, 13 and 14 are presented in the usual conventional order. Thus the pictures form a series which runs from left to right in the upper row and continues from left to right in the lower row. Consequently west is to the left and east is to the right as it is also on maps. However, as the flights on this day went from east to west, these pictures are discussed in the reverse order. This plan clearly would be better for eastward flights, such as those to the Cape Verde Islands on 21 Sept. 1962.

The aircraft pictures of section 4 may be related to the flight tracks and TIROS picture details of figure 14 relatively easily be means of tables II and III. Table III presents longitudes and times in decimal form, and also picture azimuths. Interpolation along the flight tracks by means of longitudes easily locates the place from which each picture was taken. The listed azimuth provides the approximate direction toward which the picture was taken. Alternately, and at times more quickly, the picture positions may be obtained by interpolation along the tracks using times. The times for each flight track dot are listed in Table II. Thus table II provides the time scale associated with the flight track dots, and the interpolation follows easily using the picture times in Table III especially when many pictures are being located during a short period of time. It proved to be not feasible to enter the picture positions, with or without azimuth indications, directly on the TIROS pictures. A suitable overlay was also not feasible in this case. Thus the reader is asked to make these interpolations and locate the pictures himself. We believe the reader will find the effort to be a relatively small one and the result to be rewarding.

The synoptic conditions are discussed first because much of what follows is dependent upon this information. The discussion of the mosaics and related TIROS pictures follows naturally, and amplifies the more conventional discussion of synoptic conditions. The information in the aircraft pictures, and the related discussion, then amplify further the earlier discussions.

A major problem arises from the numerous interrelationships that are a part of this presentation. A strictly linear discussion is not feasible, and the non-linear or reticular discussion that is developed is not as easily followed as might be desired. Although an effort was made to limit cross-references to a practical minimum, a good many are included. More could easily have been used to advantage.

The information summarization was prepared in response to a special request, and was placed before the main body of the report as requested. It replaces the more conventional discussion and summary section that according to the original plan was to follow section 4.

This preface, the information summarization, the main body of the text, the presentation of the information obtained on the southern flight track, the glossary, and the appendices represent primarily the thinking and concepts of the senior author, who prepared these sections, who had a primary interest in "the ITC", and who flew on the southern aircraft. He was ably assisted in important aspects of the preparation of this report by Captain Robert W. Fett, who prepared the discussion of the conditions observed on the northern flight track, and who flew on the northern aircraft.

H. M. Johnson

Suitland, 1964

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TROPOSPHERIC CONDITIONS OVER THE TROPICAL ATLANTIC AS OBSERVED BY TWO TIROS SATELLITES AND RESEARCH AIRCRAFT DURING 22 SEPTEMBER 1962

INFORMATION SUMMARIZATION

This summarization outlines briefly some of the more important observational and interpretive information which is summarized in considerably more detail and somewhat differently in the main body of this report.

The report summarizes a major part of the information obtained by the meteorological satellites TIROS V and VI and that obtained concurrently or approximately concurrently from two Research Flight Facility well-instrumented research aircraft during 22 September 1962. The aircraft flew westward from Sal, Cape Verde Is. to Barbados, B.W.I. on approximately parallel tracks as shown in figure 1. Each aircraft twice obtained photographs and measurements which were simultaneous with the satellite observations, and each obtained many other observations differing in time by small amounts from the corresponding satellite observations. The satellite coverage, the most complete obtained to this date, is shown in figure 1.

A primary concern during these flights was the detection, from the aircraft and from the satellites, of significant atmospheric systems and of details of their structure, clouds, and motions. A closely related primary concern was the determination of the relationships of conditions, phenomena, and clouds as seen from the aircraft (i.e., AOS [aircraft observation scale] conditions) to the same conditions, phenomena, and clouds as observed by the satellites (i.e., to TOS [TIROS observation scale] conditions).

The importance of the AOS-TOS relationships derives from, among others, the facts that: 1) An improved understanding of these relationships makes possible an improved ability to detect atmospheric systems, and details of their structure, clouds, and motions, in satellite pictures taken at other times, both at the Atlantic region and at comparable regions, and to do it both with and without the aid of conventional synoptic information; 2) These relationships represent a body of information necessary for the successful meteorological interpretation of meteorological satellite pictures; 3) These relationships make it possible to relate the new satellite information more certainly to the older concepts and information of meteorology.

Primary objectives during the flights were:

1. To observe, if possible, <u>ea</u>rly* stages of tropical cyclones; and to determine the AOS-TOS relationships of these systems.

---

*See glossary for the meaning intended for terms used in a specialized sense. The first two letters of such terms are underlined where the terms are first used in this summarization.

2. To observe, if possible, "the ITC" and associated phenomena; and to determine AOS-TOS relationships of these phenomena. This was the reason why the southern aircraft flew as far south as its range would permit.

3. To observe, if possible, other synoptic scale atmospheric systems, component subsystems, and synoptic conditions generally, including both disturbances and undisturbed conditions, and including the conditions characteristic of the northeasterly trade flow; and to determine the AOS-TOS relationships of these systems and conditions.

4. To observe cloud units, cloud groups, cloud formations, and cloud systems; to determine the AOS-TOS relationships of these cloud conditions; and to determine so far as possible the synoptic meteorological significance of these cloud conditions.

5. To observe, if possible, characteristic states of the atmosphere and their associated cloud patterns; to determine their AOS-TOS relationships; and to obtain information on their synoptic significance.

6. To observe small-scale (AOS) conditions at areas with trade cumulus lines and bands, to obtain, if possible, information on the small-scale motions, operative mechanisms, and time-variability; and to relate these phenomena to phenomena which are resolved by the TIROS satellites (i.e., to the associated TOS lines, bands, and other phenomena).

The flights represented an unusual opportunity to advance the scientific process of meteorological satellite information interpretation in terms of atmospheric systems and their structure, clouds, and motions by: 1) providing detailed aircraft-obtained information on the tropical atmospheric systems also observed by the satellites during the flights; by 2) establishing relationships in detail between the AOS conditions and the TOS conditions observed at these systems; and by 3) providing needed information on tropical clouds, cloud formations, and cloud distributions and on the AOS-TOS relationships of these cloud conditions. An analysis of the synoptic conditions determinable from the aircraft was developed during the flights as an important aid in the process of interpretive observation.

Among the more significant findings made during these flights, including findings based on related satellite and aircraft observations, are the following:

1. Early stages of tropical cyclones:

A disturbance was observed distantly to the south from the southern aircraft, and was well observed from the satellite TIROS V, which appears to have been an early stage of a system that later developed into a tropical storm [2] that caused damage in Guatemala.

2. "The ITC" and associated phenomena:

The aircraft on the southern track was almost continuously within sight of "the ITC", and obtained a continuous photographic record of the sequence of systems of "the ITC" which extended eastward and westward to the south. This sequence of systems was well observed by the satellites, as is shown well in the TIROS pictures of figures 12 to 14, and is also shown in the mosaics of figures 6-9. The main systems observed were systems (6), (9), (20), (22), (32), (34), (40), and (39), shown in this order westward in figure 12.**

Aircraft views of these systems, as revealed by their associated cloud systems, are: for system (6)-No. 7; for system (9)-Nos. 12, 16, 18, 21, and 22; for system (20)-Nos. 22, 31, 33, and 34; for system (22)-Nos. 34, 36, 39, 41, and 42. Systems (32) and (34) were not observed from the aircraft. The northern part of system (40) was observed from the southern aircraft. Associated disturbed conditions to the north of the flight track are shown in Nos. 56-60. System (39) was penetrated by the southern aircraft and is shown in Nos. 61-64, and in picture U.

All of these systems included extensive cirrus formations. Cirrus, at least in part of systems (6) and (9), extended far to the north of the southern flight track as is shown in Nos. 1, 4, 6, 8, 9, 11, 14, and in pictures A and B. Active cumulonimbus clouds were well seen from the aircraft in systems (20), (22), (39) and (40), and presumably generated much if not all of the cirrus of the other systems. The TIROS pictures indicate active cumulonimbus clouds in all of these systems.

A major gap to the west terminates this sequence, as is well shown in figure 14B.

3. Other atmospheric systems and synoptic conditions:

A. The trade flow conditions of the southern side of the semipermanent subtropical anticyclone of the North Atlantic Ocean (the Bermuda High) were observed almost continuously during the flights. Along the southern track the low level northeasterly trade flow was traced across almost all of the Atlantic by means of cloud lines,* cloud lean,* sea surface whitecap and "white horse" conditions, foam and film streaks, and cloud shadows. Examples of trade flow cloud lean are shown in Nos. 3, 4, 12, 15, 24, 25, 26, 29, 35, 37, 47, 49, 50, 51, 55, 57, 59, and 65, and in pictures J, L, M. and U. Cloud lines are shown in Nos. 24, 34, 35, 40, 41, 44, 47, 48, 50, and 65.

** See figure 12 for designator numbers, and figure 14 for latitudes and longitudes, of conditions referred to by number in this summarization.

* See glossary.

TOS indications of the trade flow were relatively few in the TIROS pictures on this day, but were present, as at bands (1), (2), and (3) in figures 12D and 14H; at group (25) shown best in figure 14F and shown in No. 35; presumably also at group (24); at the long bands shown in figures 9 and 13B (near 9°N as shown by figure 14A); less clearly at the relatively large bands near 16°N, 51°W in figure 14C; and at a downstream cumulus band west of Guadaloupe (G) in figures 9 and 12A.

B. Two upper level subtropical anticyclones, and the col between them, were fairly well defined, as shown in figure 3, by cirrus plumes and bands. TIROS views of dense cirrus formations with axes approximately paralleling the upper flow and with asymmetry indicating flow direction are shown at a number of areas in figures 6-11 and 12-14. Conditions (7), (15), (19), (23), (41), the plume in picture P, and the fine plume group near 15°N, 70°W. in figure 11, represent cirrus of this type. Condition (15) is shown in No. 12, cirrus band (19) is shown in No. 30, and plume (23) is shown in No. 39. The TIROS observations, being more extensive, were more helpful in defining the upper flow pattern than were the more limited aircraft observations.

C. At least one easterly wave was observed by the satellites. The cloud system of one is shown near 20-25°N. and 60°W. in figures 8-10, and figures 12A, 14A and 14C. Associated cloudiness was distantly observed from the aircraft. This system was observed again by satellites and was observed and penetrated by aircraft on 23 September. It is also detectible in the surface chart, figure 2, and in the time sections of appendix 6.

D. A small disturbance, system (42), was crossed by the northern aircraft, as shown in figure 14B. This system had radar rain bands in the form of a numeral 6, curved major cloud bands as shown in figure 12B, Cb activity, relatively high surface winds, and a sharp western edge as shown in pictures S and T.

E. Extensive areas relatively free of low clouds, or with highly suppressed low clouds and cloud fields, and generally with marked haze layers, indicated appreciable low tropospheric subsidence at a number of areas during these satellite and aircraft observations. Examples of such areas are shown south of formation (16) in figure 12C and in Nos. 18 and 22; north and northwest of system (22) in figure 12C and in Nos. 32, 34, 39, 44; and elsewhere in figures 12 to 14.

Smaller or local areas with suppressed low clouds or no low clouds were commonly observed at both disturbed and undisturbed areas. Examples of such areas are shown: north of condition (12) and west of the Sc band in No. 5; east of (10) in figure 12D and in No. 9; north of band (11) in figures 12C, 12D, 13E, 14F, and 14G and in Nos. 15, 17, and 20; west of the band group (25) in figures 12C and 14F and in Nos. 38 and 40; at the westernmost corner in figure 14E and in No. 44; in No. 58, but obscured by higher cloudiness in figure 14D; in pictures B, C, and N and south of formation (28) in figures 12B and 14D; in picture S and at the west edge of system (42) and north of edge (43) in figures 12A and 14B; and at numerous other areas in figures 12 to 14.

4. AOS-TOS relationships of cloud units, groups, formations and systems:

One consequence of the intensive cloud observation and cloud recording program carried out during these flights was that much detailed information on AOS-TOS relationships was obtained. Highlights and examples of these findings fall into four categories, those of: 1] phenomena which are well observed from research aircraft, but which cannot be resolved or observed by the satellites; 2] conditions and details which are at times observable both from aircraft and by satellites, but which are frequently missed by satellite observations; 3] conditions which are well observed from aircraft, but which are often ambiguously, marginally, or otherwise poorly observed by satellites; and 4] conditions which are well observed by satellites, whether well observed from aircraft or not.

Category 1:

A large number of conditions and phenomena are in this category. All small-scale structure, evidence of motions, and cloud elements, units, and groups with dimensions of about 1 1/2 miles or less (with the exception of certain cloud lines) cannot be resolved even with good light and small object nadir angles. Thus most details in the hand-held camera picture sequences are not resolved.

Examples of such details are: a) The small cumulus clouds in Nos. 4, 22 and picture G; b) The small cloud lines in Nos. 24 and 44; c) the nearby cumulus clouds in Nos. 64 and 65; d) The altocumulus details in Nos. 23, 24, and 26; d) The altocumulus waves in No. 47; f) The cirrus details in Nos. 3, 17, and 43, and in pictures C and I; and g) the cirrus shown in Nos. 65 and 66. Many other examples can be seen in the aircraft pictures. The presence of fields of cumulus, such as those shown in Nos. 64-66, may be detectible as faint variations in shades of gray, as along the southern flight track in figure 14B, when the individual clouds are too small to be resolved. Thin formations, such as the altocumulus in Nos. 23, 24, and 27 and the cirrus of Nos. 15, 17, 65 and picture I, may be detectible as faint or very faint gray areas, but are, in general, virtually unobservable.

Category 2:

More important, in the satellite information interpretation process, than what cannot be seen in satellites pictures is what can be seen and how well such details can be seen.

Many details can be clearly detected, at times even well observed, when the lighting conditions and object nadir angles are most favorable, yet not be clearly detected, or even detected at all, when the viewing conditions become less favorable. Such details are sometimes visible in a particular frame of a TIROS picture sequence but not in any other frame. Marginally observed conditions of these types are those of category 2.

Examples of details in this category are:

a) The cumulus bands (25) in figures 12C and 14F and in Nos. 35 and 37.

b) The larger more distant cumulus groups shown in No. 64, but not shown west of edge (43) in figure 14B (very likely because of the 4 hour time difference, and growth leading to what is shown in No. 64).

c) The larger distant cumulus bands shown in No. 65, and shown indistinctly, if at all, in figures 12A and 14B.

d) The larger cirrus lateral filaments or minor bands shown well in Nos. 16 and 18 but shown relatively indistinctly south of band (11) in figures 12C, 13E, 13F and 14F. The major cirrus bands are distinctly shown in figure 14F, and the presence of much cirrus is indicated near 12°N and 28° to 30°W.

e) Much of the cirrus, particularly the smaller scale, thinner details shown in Nos. 1, 5, 6, 8, 9, 15, 21, 22, 43, 64, and pictures B and C. The presence of cirrus is shown in the corresponding TIROS pictures but the structural detail is mostly missing.

f) The long cirrus bands shown best in figure 14G (frame #9) near 18°N, 23°W, which are not well shown in any other frame. Some of these bands can be seen distinctly only in this frame.

Many other examples can be found in the aircraft pictures by comparing them in detail to the corresponding TIROS pictures. Such relatively poorly observed details can be important in the interpretative process, as in the cases of the smaller cirrus plumes, cirrus major bands, and low level cumulus bands, which provide information on upper and lower tropospheric flow.

Category 3:

Many conditions are in this category, for many details are not well observed by the satellites, and ambiguity remains a real problem. The following examples, in this category, reveal more concerning what is observed and what is missed in the TIROS pictures:

a) The cirrus of Nos. 4, 5, and 6 represents an essentially overcast condition. The thinnest cirrus of this overcast is not even clearly evident in the aircraft pictures. The thicker cirrus is distinctly if faintly visible in figure 14H near this position. Cirrus of the type and amount shown in this figure when seen in other TIROS pictures commonly implies the presence of cirrus overcast conditions. Thus, in the tropics at least, the presence of a cirrus overcast condition is commonly indicated even though the overcast can not be clearly detected. Cirrus which is even more dense, as at (7) in figure 12D, is easily seen and clearly indicates a cirrus overcast condition.

b) The major bands of the cirrus formations shown in Nos. 16, 18, 21, and 22 are shown relatively distinctly in figures 12C, 14E, and 14F, but only these larger, more dense details are distinctly shown. Much other cirrus is indicated at this area, but the details are shown indistinctly or not at all. Cirrus formations frequently have details, which, as is the case here, range from category 4 to category 1 conditions.

c) The stratocumulus formation (11) and (16) shown in Nos. 15, 17, 19 and 21 is fairly well shown in figures 12D, 13G, 14G, and 14H, but is better shown about 1 hour later in figures 12C, 13E, 13F, 14E and 14F. The stratocumulus band as seen in the TIROS pictures is clearly cumuliform, relatively sharp-edged, relatively wide, and quite gray, yet relatively reflective. These criteria, among others, distinguish it from cirrus, towering cumulus bands, and most if not all altocumulus of this region and season. The smaller scale details of the western end (16) of formation (11) as shown in figure 13E correspond well to those shown in No. 21, which also shows well what details are not revealed in the TIROS pictures.

d) The row of cloud units (TOS) at (21) in figure 12C, is what it appears to be, namely, a row of higher build-ups, as is shown in Nos. 31, 33, and 34. Although the vertical extent of such clouds may not be determinable with certainty from TIROS pictures alone, the grayness of these units suggests relatively low and spreading build-ups, which was the type observed from the aircraft. The types of details not resolved in the TIROS pictures are also well revealed in these aircraft pictures.

e) At condition (14) shown in Nos. 9 to 14 and in figures 12C, 12D, 14G, and 14F, so much cirrus occurs over stratocumulus that it is difficult to see either the cirrus or the stratocumulus well in the TIROS pictures. The combination of cirrus and stratocumulus is revealed by the many indications of the presence of cirrus shown at and near the area of (14) and by the more reflective, cumuliform structure of the stratocumulus. The distinctly grayer cirrus appears to be significantly more extensive than the underlying stratocumulus.

f) At condition (18) shown in figures 12C and 14F and in Nos. 28 to 31, which represents another area with cirrus over cumulus, the cumulus groups are much more clearly seen in the TIROS pictures than is the cirrus. The cirrus band (19), shown in No. 30, which extends northward from the extensive cirrus of system (20), shown in No. 31, is difficult to identify as cirrus without the aid of the aircraft picture.

Many other conditions in this category can be found in the aircraft pictures. Although the most informative are those which involve small observational time differences, such as those just listed, many of the others are also revealing and informative.

Category 4:

Many conditions are also in this important category, for many details are well observed by the satellites. Some conditions in this category are better revealed by the satellites than by any other routinely available observation procedure. The following examples present details and organization which are unusually well revealed by the satellites.

a) Cloud details (TOS) of the cirrus formations of system (6) which are well shown in figures 13H and 14H include: the extent of the relatively dense cirrus, the positions of the major component formations and their shapes and densities, the relations of the component formations to each other and to the cirrus generating cumulonimbus clouds, and indications of upper tropospheric flow. The dense cirrus major lateral bands are well shown. The extensive very open areas adjacent to, and related to, system (6) are also well shown.

b) Details of the cirrus of system (9) which are well shown in figures 12C, 12D, 13H, 14E, 14F, 14G, and 14H include many long bands extending from the south which have a diagnostic wispy, filamentous, diffuse-edged, almost opalescent appearance. The filaments often curve, tend to fade out at one end in a characteristic way, and sometimes appear branched. It is notable that on all scales (GOS, AOS, TOS) cirrus commonly appears filamentous or fibrous. The cirrus generating cumulus of this system is well shown in figure 13F, as are associated banded cumulus formations to the southwest. Stratocumulus under system (9) cirrus is relatively clearly shown in figures 12C, 14F, and 14H near 13°N to 16°N. The contrasting cumuliform appearance of the underlying stratocumulus is well shown in figure 14H between 15°N and 16°N.

c) A formation of stratocumulus groups under extensive cirrus is well shown at and near area (12) in figures 12D and 14H. Some of the cirrus, especially the nearer cirrus and the cirrus major lateral band, is relatively well shown in No. 7. The stratocumulus, being too low and too distant, is very poorly shown in No. 7. The major cirrus band shown in No. 7 is well shown in figures 12D and 14H, and the lateral band is marginally shown in these figures. The relationship of this major band to the rest of system (6) is very well shown in figure 12D. This notable TIROS picture shows well: 1) the southeastern part of the low level subtropical anticyclone (Bermuda High) with its northeasterly trade flow, inversion controlled conditions, effects of local subsidence, and other conditions, under 2) the western part of the upper tropospheric African subtropical anticyclone with its southerly flow indicated by the extensive cirrus formations.

d) Island cumulus cloud lines are well shown at (1) and (2) in figures 12D and 14H; and just west of D in figure 12A. Although island cloud lines are often well observed from aircraft, the lines (1) and (2) were not well seen from the aircraft on this day.

e) Details of the active cumulonimbus group (22) which are well shown in figures 12C and 13E include: a sharp northwestern edge, a northward extending anvil (23); the very limited southern and zonal extent, a long curved band to the south, the related very open areas to the south, and other conditions not observable from the aircraft.

f) Many details of the larger cumulonimbus system (20) are well shown in figures 13E, 13F, and 14F, including the dense cirrus formations, much low cumulus, and the related very open conditions. The cumulus field (18), well shown in figure 13E, is a field of trade cumulus bands which provides good indications of the low level trade flow. It could be seen from the aircraft, as shown in No. 29, but was relatively poorly seen from the aircraft.

g) The group of large cumulus bands shown near 16°N, 50° to 52°W, are well shown in figure 14C. This group, or a group of this type, is not clearly revealed in picture Q which shows conditions at the eastern part of this area (and at a later time). Extensive groups of large bands of this type are generally not easy to see well from aircraft. Thus the organization in such groups and other details (TOS) may be better observed, in general, by the satellites.

h) Many details of the easterly wave discussed above are in this category.

The conditions listed here represent conditions which are, in general, better revealed by the TIROS pictures than by the aircraft pictures. This is so despite the fact that much important detail is missing in the TIROS pictures. Numerous other conditions in this category can be found in the TIROS pictures.

5. Characteristic states:

The primary condition which can be considered to be a state of this type was the inversion dominated convective condition observed at the eastern Atlantic and near the Cape Verde Islands. This condition included extensive areas of stratocumulus groups of a characteristic appearance (AOS, TOS). The groups form at a strong low inversion by the lateral spreading of a thin layer of derived stratocumulus (or altocumulus, if sufficiently high) which forms a grayish fringe or layer (a "water anvil" [8]) at or over generating, smaller, more reflective, more or less central, swelling cumulus or stratocumulus clouds or groups. This condition was better developed late in the day during 21 Sept. 1962, than it was during the morning of 22 Sept. 1962, but is shown in figure 14H near 16°N, 24°W and in No. 2 (also less well in No. 1).

Another condition which may be considered to be a state of this type, although not a very good example of a characteristic state, is that shown in Nos. 64 and 66. This represents a type of extensive field of towering cumulus which is very frequently observed at western tropical Atlantic areas. It is not shown in the TIROS pictures on this day. The area of larger convective units and groups shown at and south of condition (46) in figure 12A represents a related but distinctly different condition.

6. Small-scale conditions at areas with trade cumulus lines and bands:

Many observations were obtained at such areas. This information revealed, among other things, that:

1) Conditions favorable for the development of one line usually lead to the development of a group of lines of limited areal extent.

2) Changes in the cloud components of such lines are usually quite rapid, and specific details in such lines are often highly transient.

3) The smaller lines have a relatively complex organized internal structure, and include both ascent and descent within the lines.

4) Most such lines are parallel or very nearly parallel to the low level trade flow. The trade flow characteristically had little change of direction with height through the cloud layer.

5) The cloud lean of the towers of the smaller lines can be relied upon to provide useful information on the direction of the low level flow, and on the vertical gradients of the horizontal component of velocity.

6) The larger lines or bands may be approximately parallel to the smaller lines, and thus may also indicate the direction of the low level flow in TIROS pictures. However, they may also have other axis directions relative to the smaller lines. They commonly show a major tendency to be approximately parallel to the smaller lines; but commonly have at the same time other axis direction tendencies, and branch where differing axes meet.

7) Much of the information on low level flow conditions provided by small cloud lines is also provided by arrays of small cloud units whether in lines, or rows, or in indistinct lines, or not.

8) If any small cumulus clouds are present in the trade flow, almost invariably some will indicate, by their asymmetry, the direction of the low level flow.

This brief summarization presents only a few examples to indicate what can be seen in the TIROS pictures, what is missing in these pictures, and what sense and what use can be made of what is seen. Other significant and revealing examples can be found in the photographs. Other examples are also discussed in the report. Among the most important examples are those which illustrate information on atmospheric systems, and on synoptic conditions, which is contained in the TIROS pictures.

Only systematic comparative study of the aircraft and satellites pictures can provide a clear and detailed understanding of the matters illustrated by the examples presented in this summarization. This is notably so in the cases of the AOS-TOS relationships.

The report that follows provides an opportunity for the interested reader to develop such an understanding by means of careful comparative study of the information presented.

1. INTRODUCTION

During the autumn of 1962 two sets of flights to the Cape Verde Islands off the western tip of Africa were carried out under the sponsorship of the Meteorological Satellite Laboratory (MSL) and the Research Flight Facility (RFF) of the United States Weather Bureau. For convenience this project has been designated the MSL-RFF Cape Verde Operation. This report is a summary of some of the results obtained during one day, 22 September, of the second set of flights. The four flights of this set were: (1) Miami, Florida, to Antigua, B.W.I., on 20 Sept., (2) Antigua to Sal, Cape Verde Islands, on 21 Sept.; (3) Sal to Barbados, B.W.I., on 22 Sept., and (4) Barbados to Miami on 23 Sept. This set of flights was similar to the first set, made during the period 17 to 22 August, except that the earlier set of flights included an exploratory leg to the south of Antigua and a return from the Cape Verde Islands to Miami via Antigua.

The second set of flights was made shortly after the successful launching of the meteorological satellite TIROS VI. During this period the satellite coverage was excellent. Both TIROS V and TIROS VI were obtaining observations over the tropical Atlantic in good light and at good viewing angles. The total coverage of this area during this period was much better than that obtained during any previous period, and was very nearly complete (see figure 1). To take advantage of the unusual opportunity represented by such good coverage, and to maximize related aircraft coverage, two well-instrumented RFF DC-6 aircraft were utilized and flown on approximately parallel courses separated by about 2° to 3° of latitude. The Atlantic crossings were made at an altitude of roughly 12,000 feet not far from latitude 15°N (as indicated by the broken lines in figure 1). The authors, one on each aircraft, occupied the visiting scientist positions and collected important supplementary information in the form of interpretive notes and hand-held camera pictures.

Primary objectives during the second set of flights were:

1. To fly into and observe in detail early* stages of tropical cyclones, particularly those that might later develop into tropical storms or hurricanes.

2. To observe phenomena associated with "the ITC", and, if possible, "the ITC" itself (i.e., systems of the zone of "the ITC"), within the limits imposed by the range of the aircraft.

3. To observe other tropical atmospheric systems, disturbances, and extensive areas of intense convective activity that might be well observed from the aircraft and by the satellites.

4. To observe and determine the common clouds, cloud formations, and cloud systems at cloudy areas and at the relatively inactive and relatively open (TOS-TIROS observation scale) areas observed.

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*See glossary for the meaning intended for terms used in a specialized way. The more important terms of this type are indicated, where first used in this report, by lines under their first two letters.

5. To observe in detail large-scale (TOS) characteristic states of the lower atmosphere at the regions traversed by the aircraft. Of particular interest were states representing relatively undisturbed but generally convective conditions which had been observed previously by the TIROS satellites and were revealed as recurring distinctively organized cloud patterns.

6. To relate in detail the clouds and systems observed from the aircraft to the cloud and system details observed by the satellites, including not only cloud conditions but also very open and apparently cloud-free (or "non-cloud") conditions.

7. To observe in detail from the aircraft the small-scale conditions at areas having trade wind cumulus cloud lines, cloud bands, or approximately linear cloud formations.

An attempt was made continuously to determine at least approximately the nature of the major synoptic systems at both low and high tropospheric levels at the data-gap areas of the regions observed from the air and by the satellites, and the synoptic conditions generally.

The sections of this report which follow present: 1) the satellite observation coverage during 22 September, and the flight tracks; 2) the synoptic conditions of the tropical North Atlantic area on the basis of the information provided by the Miami District Meteorological Office operational charts, the TIROS observations, and the aircraft and supplementary observations; 3) a selection of hand-held camera photographs with related observations, comments, and conclusions; 4) a short bibliography; 5) a glossary; and 6) several appendices.

2. SATELLITE OBSERVATION COVERAGE DURING THE 22 SEPTEMBER FLIGHTS

The TIROS satellite coverage during 22 September is shown in figure 1 (see also figure 11 for pass T5 P64(63), which is not included in figure 1).[1] Four TIROS observation passes occurred over the flight area and at times close to the times of the flights. These primary passes (each listed with the time of the central part of the pass) were: (a) T6 W62(61) 1350GMT (b) T5 W1364 (1363) 1458GMT; (c) T6 W63(62) 1535GMT; (d) T5 P1365(1364) 1644GMT;The aircraft flight tracks crossed the primary pass areas as shown in figure 1. An adjoining pass: T5 W1363(1362) is shown to the east; a continuation: T5 W1364D is shown to the north; and a pass over the Gulf of Mexico: T5 P1366(1365) is shown to the west.

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[1]The designation T5 P64(63) means: TIROS V, Point Mugu readout station, picture-taking pass (63) read out on pass 64. A "W" preceding a readout pass number signifies that that pass was read out at the Wallops Island, Va., readout station. According to this convention a plain number, such as 64, always refers to a readout pass. A picture-taking pass is always referred to with parentheses, and all ambiguity is thus eliminated. Figures 1 and 6 to 11, showing standard TIROS nephanalyses, show also the standard operational convention. Figures 12 to 14 utilize an abbreviated form of the operational convention. These latter conventions require the use of both readout and picture-taking pass numbers to avoid ambiguity.

The aircraft flights commenced at about 1200GMT and terminated at about 2100GMT. The passes designated (a) and (b) above crossed over the flights, thus providing four points with time differences of zero. Passes designated (c) and (d) above occurred before the flights reached these areas. For these areas the time differences were generally 1 to 3 hours, but at the west ends of the tracks they were as great as 5 hours. Figure 1 reveals a gap in the TIROS coverage between passes (b) and (c) with a width generally of 2° to 3° of longitude.[2]

3. THE SYNOPTIC SITUATION DURING THE 22 SEPTEMBER FLIGHTS

The aircraft flew westward along the southern side of the large semi-permanent North Atlantic subtropical anticyclone (Bermuda High), well south of the low level anticyclone center, and just north of the generally east-west zone of enhanced convective activity here termed the zone of "the ITC".

Most of the areas observed from the research aircraft were areas which have been poorly or infrequently observed in the past. Thus, in general, they represent truly sparse-data areas and data gap areas. The main exception is the western area near the Lesser Antilles. Much of this total area, though still sparse-data area in the conventional sense, has been frequently and well observed by the meteorological satellites. As was pointed out above, it was very well observed by satellites on 22 September 1962.

The Surface Chart:

The conventional data coverage shown in the surface chart for 1800GMT (figure 2) is representative, or perhaps somewhat better than average. This chart shows:

(1) the southern and southeastern portion of the Bermuda High with characteristic low level northeasterly winds, revealed by data or implied by the analysis (and confirmed near the flight paths by information obtained during the flights), from the Cape Verde Islands to the central part of the Atlantic;

(2) generally east winds west of the central part of the tropical Atlantic and northwest of the Antilles, becoming generally southeast winds toward Florida and north of Cuba;

(3) a weak trough and wind shift north of the Lesser Antilles, with a trough line near longitude 62°W and cumulonimbus activity east of the trough line, associated with the easterly wave shown near 20°N and 60°W in figures 8, 9, and 10;

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[2] The true size of the gap is somewhat less than that shown, but because the viewing angles were not favorable near the gap on both sides and the coverage was of poor quality in the few pictures that provided it, the effective width of the gap is approximately as shown.

(4) an extensive trough east of the Lesser Antilles, associated with the extensive disturbance shown near 10°N and 50°W in figures 8 and 9;

(5) a small circulation with a surface low pressure center near 14°N and 56°W;

(6) little evidence of "the ITC" (note the two reports near 42°W).

The large low south and west of Spain is the near surface extension of a persistent deep cold low which is well developed at the 200 mb. level (see also figure 3, and the nephanalysis T5 W1363 of figure 1). The presence of this low represents a departure from the conditions of flow more frequently observed at the southeastern portion of the Bermuda High but appears not to have affected the low level flow much, if at all, as far south as 15°N.

The information and continuity of the preceding and subsequent charts confirm most of these conditions.

The TIROS and aircraft observations, discussed below, also confirm most of these conditions, but reveal much additional complexity, and show much intense convective activity in the zone of "the ITC".

The 200 mb level:

The conventional data coverage at the 200 mb level is just good enough to permit an analysis (figure 3) which is a reasonable first approximation. The conditions to the west are relatively well defined on this chart, which shows there: (1) an anticyclone east of the Lesser Antilles with a ridge-line at about 10°N; (2) generally southwest winds along the northwest side of the anticyclone; (3) two small low centers, one north of Puerto Rico and one west of the Lesser Antilles; (4) a cyclonic shear line or zone between 20°N and 25°N which extends from about 45°W to about 60°W. The several earlier and later 0000GMT and 1200GMT charts for this level, particularly the 21 September 1200GMT chart (not shown), provide data and continuity which confirm the main features of this analysis. They also show that the small low north of Puerto Rico persisted and moved slowly westward near latitude 20°N. The time-section analyses for San Juan, Puerto Rico and Antigua, B.W.I. (see Appendix 6) confirm this and reveal that this low was not directly associated with the major cloud system shown to the south in figure 10. These time-sections show that this cloud system was associated with an easterly wave.

The original operational analysis shown near the eastern part of the flight area is less realistic. The center of the major low is placed too far south, and the area of strong gradients is too extensive and too far south. This comment is based on continuity, the data of this chart, and the TIROS and aircraft observations. An improved analysis which is consistent with earlier 200 mb analyses, and which agrees with the upper flow indicated by many cirrus plumes, would place a second anticyclone to the east, with a ridge-line near 15°N at 20°W and extending west-southwestward from the African Coast to beyond 30°W, and would place a col at about 35 to 40°W. This anticyclone may be considered to be a westward extension of the persistent upper level African Subtropical Anticyclone [3]. The reality of this westward extension is nicely revealed in the TIROS pictures of figures 6, 13H, and 14H by the cirrus lines, plumes, and bands which stream northward in the upper

level flow. From the col a trough would extend northeastward to the deep low. (See the schematic analysis indicated by the dashed lines in figure 3). The schematic analysis shows two long-dashed 070 lines, and four short-dashed lines which indicate the trough, the ridge, and the col. Nine cirrus plume directions are also indicated.

The greater complexity of the operational analysis in the region with the larger amount of data is noteworthy.

The 700 mb level:

Although the data coverage at the 700 mb level is much better than that at the 200 mb level, largely because of the wind data provided by the aircraft, the pattern of flow at this level is not entirely clear. Figure 4 shows the conditions at or near 1200GMT on 22 September, and figure 5 shows the conditions at or near 0000GMT on 23 September. Winds determined by the aircraft doppler radar instrumentation are included in these figures (see Appendix 1).

The winds at specific longitudes along the two tracks generally differ, but are similar in a few areas (as at E1N and E2S; G3N and G3S).[3] They can be analyzed, however, in a manner consistent with a concept of an east-west series of weak atmospheric systems. The veering of the winds westward at B on the southern track is a real effect, and considering also the winds on the northern track suggests the presence of a weak convergent zone or possibly an eddy near 25°W. Light south winds were encountered for a distance of at least 2° of longitude at the western part of B on the northern track, and for about 7° in C and D on the southern track, and appear to represent a real zone of southerly flow. A shift to about 9° of longitude of northerly winds at D and E on the northern track, and about 5° of northerlies at D and E on the southern track, indicates a shear line and weak trough near 35°W, which is near and northwest of the area of intense convective activity designated as system (20)[4] in figure 12C. A change to stronger southeast winds which shifted to light easterly winds near 49°W on the southern track, and the stronger winds on the northern track which backed slightly westward, were associated with the disturbances designated as systems (39-40) in figures 12A and 12B. Light easterly winds, over low level easterlies, were observed along the southern track at G and H, and stronger easterlies were observed along the northern track at G and H.

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[3] In figures 4 and 5 intervals of 5° of longitude westward from 20°W have been labeled by means of the letters A to E (figure 4) and E to H (figure 5). The smoothed wind values have been designated by track (N for northern track and S for southern track), by lettered interval (A to H), and by position within the interval (numbered from right to left). For example, D1S refers to the south wind plotted near 14°N, 36°W on the southern track. This scheme permits easy reference to the position of each plotted point and its immediate vicinity.

[4] The identifier numbers and letters used in this section and in section 4 refer to the details labeled in figure 12. The identifier numbers are indicated by parentheses in the text, as in the designations: line (3), and system (20). Certain details, mainly the smaller ones, are located by means of asterisks in figure 12. Others are located directly by identifier numbers. Islands are located by dots and associated letters. These details are also shown, and should be noted (by using figure 12 for identification and location) in the figures 6-11, 13, and 14 (see also Appendix 2).

Also shown on the 700 mb charts are:

1) A trough extending far southwestward from the deep low off Spain and continuing to the shear line shown from about 18°N, 31°W to about 12°N, 38°W.

2) A large anticyclone over North Africa which has a ridge extending over the tropical Atlantic (see also [3]).

3) The Bermuda High, which extends over much of the North Atlantic.

These charts include no evidence of the upper low which lies just north of Puerto Rico (shown in figure 3) nor any evidence of the small disturbance which is placed near 14°N and 54°W in the surface analysis shown in figure 2 and which is designated as system (42) in figure 12A.

The general impression given by the 700 mb data and analysis, and one consistent with the information of the surface and 200 mb analyses, is one of a sequence of weak tropical systems of varying type and intensity extending from east to west in and near the area traversed by the two aircraft.

Another east-west sequence of more intensive systems farther to the south, a sequence of the zone of "the ITC", was observed from the aircraft and was clearly revealed by the TIROS observations. This southern sequence extended westward and then northwestward near its western limit and into the subtropical far western North Atlantic. It was crossed by the aircraft as shown in figures 1 and 14.

The TIROS pictures and mosaics:

The TIROS pictures provide a substantial amount of additional information on the synoptic conditions encountered during the 22 September flights. Reference to some of this information has already been made in the discussion of the synoptic charts above. Just as synoptic charts are when available very important aids in the detailed interpretation of TIROS information, so are TIROS pictures when available very important aids in the development of a detailed understanding of the synoptic conditions indicated by or implied by the charts. Consequently it was difficult to avoid using some TIROS information in the discussion above of synoptic charts. A more detailed discussion of the TIROS information is presented here.

The more highly developed atmospheric and cloud systems, particularly the sequence of systems in the zone of "the ITC" (as referred to above), and many lesser systems, formations, and conditions, are well revealed in the TIROS picture mosaics of figures 6 to 11 and in the related TIROS picture sequences of figures 12 to 14.

The far eastern tropical Atlantic:

Figure 6, and the related figures 13G, 13H, 14G, and 14H (see also figure 12D), show the Cape Verde Islands and adjacent area, and several types of TIROS scale cloud systems and details. The islands are not clearly seen in these pictures, largely because of the presence and complexity of the cloud pattern in their immediate vicinity. Consequently, some of the island boundaries could not be determined exactly. These islands have, however, been seen clearly in pictures obtained during other TIROS passes. Being arid islands extensive enough to be resolved, and with relatively large albedos, they are usually not difficult to see during relatively cloud-free conditions. A good estimate of their positions is indicated by the labels in figure 12D as follows:

SA	Santo Antão
SV	São Vicente
SN	São Nicolau
S	Sal
BV	Boa Vista
M	Maio
ST	São Tiago
F	Fogo

As the uncertainty of the position of the central part of most of these islands is less than ± 1/10° of longitude the configuration of island center position estimates has been used as a "landmark" reference for the refinement of the placement of the grids of figures 14G and 14H (see also Appendix 5).

Each island, except possibly São Vicente, appears to have island controlled cloud formations. Sal and Boa Vista appear to have downstream cumulus cloud lines, the lines (1)* and (2) respectively. A third line (3) is not directly associated with an island. These approximately NE-SW lines are approximately parallel to the low level northeasterly trade flow known to be present in this area (see figure 2). Small (TOS) cumulus groups, such as (4) and (5), which are relatively large groups of a characteristic stratocumulus, have a scattered distribution in this area.[5] Thin cirrus formations lie extensively over the island area, but are not well seen this far north in the T6 W62(61) pictures.[5] They extend from cirrus generating systems to the south, notably the conspicuous system (6) which has generally northward extending cirrus plumes (7) to the north, and has lateral plumes (8) further south. System (6) is an "ITC" system or disturbance in the zone of "the ITC". Another, more extensive, system in the zone of "the ITC" (9) lies to the west. Cirrus associated with this clearly extends northward across the southern flight track, as at (10), and less evident cirrus extends also over the northern track. The ⌐ shaped formation (11) was crossed by the

*See footnote 4 for an explanation of identifier numbers.

[5]The aircraft pictures of these conditions and others discussed in this section are discussed in section 4 below.

aircraft on the southern track and proved to be a stratocumulus formation (see section 4 for details). A third cirrus generating system of "the ITC" lies to the east of the system (6) (see especially figure 13H). Relatively open conditions south of "the ITC" are shown far to the south (see especially figure 6).

Figure 6 also shows to the north of the island area, successively:

1) A very open area (TOS) north of the evident cirrus and near latitude 20°N.
2) An extensive area of stratocumulus groups, generally of relatively large size on the TIROS scale, to about 30°N. This area continues into the circulation of the cold-core cyclone off Spain to the east and north.
3) A variety of mid-latitude conditions to the north including a cold front and probable squall line at about 35° to 40°N.

The central tropical Atlantic-eastern part:

Figure 7, and the related figures 13E, 13F, 14E and 14F (see also figure 12C), show the conditions generally to the west of those just discussed. System (9) is shown with its northward extending cirrus. Banded cumulus extending to the west near the southern limit of this system, and a part of the southern limit are also shown. Formation (11) is shown again but about one hour later. An extensive disturbance (20), also in the zone of "the ITC", and just east of an upper level trough and under upper level anticyclonic flow (see figures 3 and 4), is shown to the west of the system (9). This disturbed area represents a group of actively growing cumulonimbi, and lacks the extensive cirrus formations of the three systems in the zone of "the ITC" to the east. A smaller group of actively growing cumulonimbus clouds (22) lies just to the west of the system (20). To the north of the cumulonimbus groups is a very extensive area of very open conditions and a low level northeasterly trade flow. An extensive area of very open conditions lies under the upper col. A few cumulus groups, such as (24), and bands occur in a scattered distribution to beyond 20°N. The relatively open conditions which are characteristic of the zone to the south of the zone of "the ITC" are well shown in figure 7.

Figure 7 also shows:

(1) An extensive area of cellular stratocumulus and cumulus south of the relatively open area which lies to the south of "the ITC". These formations are considered to be in the easterly flow of the northern margin of the southern hemisphere Atlantic subtropical anticyclone.

(2) Generally open conditions with cumulus groups and bands from about 20°N to almost 40°N, representing the central part of the Bermuda High, with trade easterlies in the southern part and westerlies across a ridge line at about 33°N and in the northern part.

(3) Mid-latitude conditions, including the cold front and squall line of figure 6 which is shown here from 35° to 40°N about one hour later.

The central tropical Atlantic-western part:

Figure 8, and the related figures 13C, 13D, 14C, and 14D (see also 12B), show the conditions to the west of the TIROS coverage gap. An extensive area of disturbed conditions (39-40) between about 5°N and 15°N, and from east of 45°W to 52°W at the southern part (but to at least 56°W at the northern part) is well shown. This disturbance lies under the 200 mb anticyclone shown in figure 3 - an anticyclone well confirmed by the cirrus plumes shown in figures 8 and 13D. This disturbance included internal banding, many cumulonimbus clouds, cyclonic curvature of the flow at flight level, and a marked wind shift. It appears to represent a relatively well defined easterly wave. It may also be considered to be a system in the zone of "the ITC". It has a sharply marked western edge, which can be seen in figure 8 but is much better seen in figure 9. A band of intense convective activity which includes cloud formations (28-31) and extends to formation (32) lies to the north and east. The band is best seen in the mosaic of figure 8, and is designated as a "line of Cb's" on the nephanalysis of this figure. A small but intense banded system (42) lies near 15°N and 54°W, and is close to the position of the small low pressure system shown in figure 2. This system can be seen in figure 8, but is also better seen in figure 9. It is surprisingly inconspicuous. The aircraft on the northern track passed through this system as shown in figure 14B. The surface winds near the center, estimated from ocean surface and white cap conditions, had speeds of 25 to 30 knots. Spiral banding observed by means of radar was extensive and of a form suggesting the numeral "6", a pattern similar to that revealed by the TIROS pictures. As indicated in figure 5, no marked wind shift was apparent in the winds at flight level along the northern track. Another more extensive disturbance is shown to the northwest. The northern and eastern edges of this can be seen fairly well in figure 8, and details near the southern limit of it can be seen in figure 9, but most of it can be seen best in figure 10. This system appears to be a fairly well defined slowly moving easterly wave (see also the discussion of figure 10). It may be considered to be a system which is not in the zone of "the ITC". A disturbed region (32 to 34 and southward) with groups of intense convective activity, and some curved banding to the north, (34), is shown between about 5°N and 10°N and about 40°W and 45°W. This is a system of the zone of "the ITC", the system to the west of groups (20) and (22). Relatively open conditions are shown to the south of the disturbed regions (40) and (32 to 34 and southward).

Figure 8 also shows:

1) An extensive very open area to the north of the major disturbed areas, the southern part of which is in the zone of low level easterlies and includes bands of towering cumulus.

2) Frontal clouds to the far north, which are better shown in figure 10.

3) The eastern tip of the "bulge" of Brazil with diurnal terrestrial cumulus fields, and a NW-SE banded formation of cumulus build-ups off the coast to the east and northeast, the northern part of which indicates the presence of the normal easterly trade flow.

4) Relatively open conditions to the south of the tip of Brazil.

5) Mid-latitude conditions, and probable frontal cloudiness, far to the south.

The western tropical Atlantic:

Figure 9, and the related figures 13A, 13B, 14A, and 14B (see also figure 12A), show the conditions to the west of those just discussed and in the vicinity of the Lesser Antilles. The western limits of the three major systems referred to in the discussion of figure 8 are shown, as is the southern limit of system (40). A vast area of apparently very open conditions, as at (45), is shown to the west and south. These conditions are not as open as they appear here (see section 4 below). West of the edge of system (39-40) several long roughly E-W bands of larger towering cumulus (44) are evident in the low level easterly trade flow (see especially figure 13B). Scattered groups of small (TOS) cumulus are visible to the north of the bands, and shades of gray reveal the presence of other less well resolved small groups. An area of larger, and therefore apparently more numerous, towering cumulus groups (46) is shown to the north, mainly north of 15°N. The islands are mostly clearly visible and are indicated by the labels in figure 12A as follows:

A	Antigua
G	Guadeloupe
D	Dominica
M	Martinique
SL	St. Lucia
B	Barbados
SV	St. Vincent
GR	Grenada
TO	Tobago
T	Trinidad

Island orographic cloudiness and a few downstream cumulus lines in the low level easterlies are shown.

Figure 9 also shows:

1) Thin cirrus formations to the far north and west.
2) The Guiana coast of South America, the Amazon drainage and Amazon River from Belterra to the mouth of the Amazon and Marajo Island, and other areas of northern Brazil, all with vast fields of diurnal tropical terrestrial cumulus and towering cumulus. Areas of more intense convection are shown to the south and west, and an extensive area of very open conditions is visible over central and southern Brazil far to the south.
3) Mid-latitude conditions, including presumed frontal cloudiness, south of 20°S (see also figure 8).

Figure 10 shows well, between the latitudes 20°N and 28°N, the major system referred to as an easterly wave in the discussion of figure 8. The time-sections for Antigua and San Juan, Puerto Rico, support this interpretation, as do the synoptic charts preceding and following those of figures 2 to 5. The small upper low north of Puerto Rico shown in figure 3 lies to the west of the extensive cloud system associated with this easterly wave. This low appears to lie mainly over weakly organized, generally open, low level conditions, although it should be noted that several oceanic cumulonimbus clouds lie below it, and that its eastern margin lies over or at least very

close to the western edge of the extensive cloud system (as is indicated by the 200 mb wind report at 23°N, 63°W). The 200 mb wind report is reasonable, and is taken to be essentially correct. The cirrus plume indications in the vicinity of 23°N, 63°W have approximately north-south axes and extend generally northward. Furthermore, several cirrus plumes on the northern edge of the extensive cloud system also extend northward and have axes approximately parallel to the direction of the wind of the 200 mb report (see also figure 8). The upper low moved westward away from this position for several days after the time of figure 3, and existed near or southwest of this position during the preceding several days (see also the discussion of the 200 mb level).

Also shown in figure 10 in the relatively open area west of the extensive cloud system are:

1) Small (TOS) bands of large towering cumulus between 20°N and 25°N, and near 65°W, or just west of the easterly wave extensive cloud system.

2) Dense, long, cirrus plumes streaming east-northeastward from the vicinity of Puerto Rico and in the southwesterly upper flow shown in figure 3.

These cirrus plumes are approximately parallel to the 50 knot 200 mb wind report at San Juan and suggest the presence of a restricted relatively high velocity upper current or local speed maximum zone extending from near San Juan to at least 20°N and 60°W. The zone of diverging flow (difluence) which lies north of this westerly current and southeast of the southerly current near 63°W (see figure 3) appears to be one characterized by strong directional divergence. If the associated and implied speed convergence field does not dominate, as seems likely in view of the strength of the directional divergence, this zone of difluence may well be a zone of significant divergence. It is notable that the zone of difluence lies over the extensive cloud system of the easterly wave. Significant upper level divergence would, presumably, favor intensification of the easterly wave and its cloudiness. Furthermore, since the cloud system is extensive and includes intense convective activity with many large and active cumulonimbi, as near 21°N, 62°W, the system as shown may well imply significant upper divergence. Although the condition of upper divergence cannot be considered to be firmly established, the agreement of the several indications is noteworthy.

Figure 10 also shows:

1) An extensive cloud formation associated with a weakening frontal system to the north.

2) An extensive area of relatively open conditions south of the frontal cloud formation. The open conditions extend eastward and then far southward as is shown to the north in figure 8, and also extend westward and southward to the area which lies west of the extensive cloud system of the easterly wave as is shown in figure 10.

3) Long generally NE-SW bands of towering cumulus which are conspicuous in the relatively open area just south of the frontal cloud formation.

Figure 11 shows to the north apparently open conditions in the Caribbean area, with some intense convective activity over eastern Cuba, Jamaica, western Hispaniola, and other areas. The notable group of cumulonimbus clouds near 15°N and 70°W reveals clearly, by its array of dense cirrus plumes all streaming east-northeastward, the west-southwesterly upper level flow north of Venezuela, which is also indicated in figure 3.

Also shown, to the south, are the terrestrial diurnal cumulus fields of the Amazon drainage area, with increasingly intense convective activity northward, and several relatively large groups of intense convective activity near the coast of western Venezuela and Colombia. These areas of increased convective activity near 10°N are near the zone of relatively low pressures (and pressure minima) shown near 10°N in figure 1. Such areas of convective activity have been considered to be systems of "the ITC". Although this interpretation may be realistic for many of the observed cases it is important to keep in mind a fundamental distinction between systems of this kind which are affected by strong continental heating and the oceanic systems of "the ITC" which are not directly affected by strong surface heating.

4. THE HAND-HELD CAMERA AIRCRAFT PHOTOGRAPHS

Procedure:

A substantial number of photographs were taken from the aircraft by means of the hand-held still and motion picture cameras. Most of these pictures were taken from the visiting scientist position which was near the nose section and on the right side of the aircraft. Each picture was an interpretive picture taken to record some specific phenomenon or particular combination of conditions. The pictures were not taken routinely, as for example every ten minutes, a rate which would have provided fairly good coverage. Consequently, the coverage from the right side was somewhat spotty, although for certain periods the coverage was relatively complete. An automatic motion picture camera mounted on the aircraft provided generally good coverage from the left side in a direction normal to the longitudinal axis of the aircraft and at a rate of one picture every second. Another automatic camera recorded the conditions forward and slightly to the right at a rate of one frame every two seconds (see Appendix 4). The only coverage obtained normal to the longitudinal axis of the aircraft from the right side was that provided by the hand-held cameras. Much of the coverage obtained from the right side was at angles of from 20 to 60° from the normal. A relatively small number of pictures were taken from the left side of the aircraft by means of the hand-held cameras. To obtain the pictures from the left side, because of the instrumentation forward on the left side, it was necessary to move to the tail section of the aircraft and return along the narrow, crowded, and busy central aisle of the aircraft. The difficulties of this procedure and the fact that this side was rather well covered by the automatic camera were the main factors accounting for the relatively small number of pictures obtained from the left side.

The photographs were taken with at least 6 objectives in mind:

1) to record quickly significant situations involving much detail, as a memory aid and as an integral part of the interpretive analytic supplementary note taking process;

2) to obtain a detailed photographic record of selected phenomena, or important choice combinations of phenomena, seeking superior illustrations and crucial combinations, in an attempt to gain and record answers to primary and secondary research questions at the time of the flights;

3) to obtain additional or better views of details and systems presumed to be resolved or well observed or significant in TIROS pictures;

4) to obtain partial photographic coverage for the otherwise generally not covered right side of the aircraft;

5) to provide backup coverage, so that at least some side coverage would be obtained if the automatic side camera failed; and

6) to obtain photographic coverage which could be used and reviewed very soon after the aircraft returned to Miami.

The picture sequences:

The following sequences of photographs, each ordered chronologically, represents a selection made from the hand-held camera pictures taken from both aircraft during 22 September 1962. Frames from the 16 mm. motion picture camera footage are not included in this section. The first sequence, numbered by successive integers, presents information obtained during the flight made on the southern track. The second, labeled by successive letters, presents similar information for the flight made on the northern track. The selection has been made carefully to illustrate a variety of conditions, and to reduce the number of pictures requiring reproduction as well as to minimize duplication. In a few cases pictures were selected to provide an east-west continuity of observed conditions.

The selected brief comments following the numerical information for each picture are based to a large extent on notes taken during the flights. They are intended to clarify; to be descriptive, interpretive, and integrative; and to provide additional revealing information. A few comments refer to conditions which cannot be seen in the associated pictures. Some comments in the second sequence refer to conditions for which no associated pictures were or could be obtained; these comments are presented in the sequence in chronological order but without identifier letters. The detailed notes made on the southern flight which were not associated with specific pictures are not presented or discussed here.

The flight tracks are shown in figures 1, 4, 5, and 14. The positions shown in figure 14 are the same as those shown in figures 4 and 5. Figure 14 should be referred to frequently when this section is read. It provides the location and orientation necessary for a real appreciation of what each picture reveals. The position from which each picture was taken is easily and quickly determined by interpolating along the appropriate flight track using the picture longitude listed in Table III (Appendix 7). The approximate direction toward which the picture was taken is also provided by Table III. Alternately the times of the position dots of figure 14 (i.e. the time scale) may be obtained from Table II (Appendix 7), and the interpolation may be made using the picture times provided by Table III.

The southern track sequence:

Picture
No. 1 115705/1631/2318//NW/luc//186/8/19.6[6]

This view, taken soon after departure from the island of Sal, at an altitude of about 5170 feet, shows a banded cirrus overcast (with band axes roughly NW-SE) of the type that is also visible in figure 14G north and south of this position. Groups of inversion suppressed swelling cumulus, with tops near 4000 feet and with thin layers of derived Sc spreading from the tops of the groups, of various sizes and separated by gaps of various sizes, are scattered over an extensive area. Large groups or clusters of this type of cloud formation are resolved in figures 14G and 13G near this position.

No. 2 120636/1618/2344//W/2uc//210/6/8.1

A view of a larger group of swelling Cu and thin fringing layer of derived Sc seen from an altitude of about 8150 feet near the large group (5) of figure 12D. Cumulus formations of this type are very common at, and are characteristic of, this area and adjoining areas of the eastern tropical Atlantic. Also shown are other cumulus groups and gaps to the west, and much thin cirrus above.

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[6]The first line after each picture number contains numerical information according to the following plan: Time (GMT)/Latitude (deg., min.)/ Longitude (deg., min.)// Azimuth/ Tropical Sky Code// Wind Direction (deg.)/ Wind Speed (kt.)/ Temperature (deg.C.). Thus picture No. 1 was taken at 1157:05 GMT at the position 16°31'N, 23°18'W. The picture center was approximately northwest of the aircraft. The sky code value was luc. The wind direction and speed were 186° and 8kt. The temperature at or near flight level was approximately 19.6°C. (See Appendix 2 for details concerning numerical information, and Appendix 3 for information on the Tropical Sky Code.)

No. 3 121554/1604/2410//NW/1uc,o//185/11/4.9

This view shows a long relatively narrow approximately NE-SW Sc band, one of several similar parallel bands observed at and near this area, seen from an altitude of about 11,130 feet. A similar formation can be seen in figure 14H near this position. Very open conditions exist to the northwest. Similar open conditions can be seen northwest of the flight track near this position in figure 14H. As picture No. 3 was taken about $1^h\ 40^m$ before figure 14H, an exact correspondence of details in these pictures is not revealed. A banded thin cirrus overcast represents a northward extension of the cirrus of system (6), figure 12D. Very few white caps were present on the ocean surface.

No. 4 122345/1553/2432//W/7ss//167/13/3.5

A view of a field of a common type of small cumulus (or fractocumulus), seen from a altitude of about 12,800 feet. This type of cumulus, and the common open and small groups of this type, are not resolved in TIROS pictures and would generally appear as a "clear" condition. Larger fields and fields of larger and more dense cloud units or groups may be revealed indistinctly as variations in the shades of gray of the "clear" condition. Note the relatively open conditions that can be seen in figure 14H west of this position. Cumulus elements leaning northeastward confirm the presence of the low level northeasterly trade flow.* West of the cumulus field is an extensive area with few or no low clouds.

A series of parallel, approximately N-S, relatively dense cirrus bands extends to the horizon and represents a northward extension of the plumes (7) of the "ITC" system (6) shown in figure 12D, and indicates southerly flow at the cirrus level. The cloudiness shown west of and near this position in figure 14H is primarily this cirrus. South of this position cumulus and stratocumulus formations can be seen below the cirrus. Cirrus of the types resolved in the TIROS pictures, such as the relatively dense cirrus shown here and in No. 1, is generally relatively persistent. Even minor bands and minor relatively dense cirrus units have been observed to maintain their identity for periods of 2 to 3 hours or more. Such cirrus may reveal a relatively good correspondence of details even when the observation time differences are as large as 1^h30^m or more as is the case here.

No. 5 122714/1547/2443//WNW/7o,v//166/8/4.4

This shows again the cirrus bands shown in No. 4. An isolated derived Sc band lies across but not perpendicular to the low level flow. This band is too small to be clearly detected in the wide angle camera TIROS pictures. Very open conditions are shown to the west and were also observed north and south of the aircraft. A haze layer was thick and conspicuous and had a sharply defined top. The relatively indistinct cloudiness shown in figure 14H near this position is evidently mainly the cirrus shown here.

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*See cloud lean in glossary

No. 6 123802/1526/2518//W//7v//202/8/3.3

A view of relatively dense cirrus bands with major axes oriented approximately north-south, and associated minor bands and lateral bands. Small fields of small cumulus cloud units are visible, but otherwise the conditions are very open at low levels in all directions. Figure 14H shows the very open conditions to the west from this position, and also shows, indistinctly, the cirrus shown in this picture. The larger cumulus field may be detectible near this position in figure 14H but is not clearly shown. Similar but more dense and extensive cumulus formations (12) are clearly shown to the south near this position in figures 12D, 14G and 14H.

No. 7 124159/1518/2531//S/7dc//202/6/3.1

A view of cirrus bands associated with system (6), the cirrus becoming less dense to the west, especially northward, toward the zone (gap) between systems (6) and (9). To the south haze was conspicuous. Conditions in the near distance are very open at low levels, with a few small cumulus groups visible. Figure 14H shows that extensive groups (12) of low cumulus and stratocumulus lie farther to the south. These groups are mostly too low and too distant to be visible in No. 7, although the edge of one distant and extensive group can be detected near the center of the picture. These groups represent a condition which when sufficiently distant is better seen from the satellite than from the aircraft. Figure 14H shows that these groups extend eastward and under the dense cirrus formation that is clearly shown also in No. 7. Lesser lateral cirrus bands are shown in No. 7 and in figures 14G and 14H.

No. 8 125111/1501/2559//NW/7v//229/6/3.3

A view of the cirrus which extends to the north near the gap area referred to at No. 7 above. Conditions are very open at low levels to the north, northwest, and west, with only a few small cumulus units and groups visible. Figures 12D, 13G, 13H, 14G and 14H also show open conditions in these directions, and reveal that cirrus is present in and near this area. The low cumulus groups shown not far to the northwest from this position in figure 14H are not visible in No. 8

No. 9 130634/1430/2646//NW/7v//293/12/1.8

This shows a relatively dense cirrus formation to the west which extends northward from system (9). It is also shown in the TIROS pictures of figures 14G and 14H (and also near (10) in figure 12D). A field of cumulus with small (AOS) units becoming stratocumulus westward lies to the west, northwest, and south. Cumulus of this type is shown, relatively indistinctly, near this position in figures 14G and 14H. Somewhat more dense extensive cumulus and stratocumulus is more clearly shown farther to the north and northwest. Southward much dense cirrus was visible.

No. 10 131026/1422/2657//W/7//299/13/1.5

A view of the relatively dense cirrus bands shown also in No. 9, and an underlying extensive cumulus field. In the foreground small cumulus clouds lean*southwestward, indicating a) the presence of the northeasterly trade flow and b) a speed maximum near or above the cloud tops. The direction of cloud lean, determined during the flight in each case, is often not clearly shown in a single picture. It is evident but not well shown in this picture. The cumulus field is shown, under cirrus, in figures 12D, 14G and 14H.

No. 11 131416/1414/2708//W/7o//280/8/1.4

A view of the relatively dense cirrus also shown in Nos. 9 and 10 over a banded stratocumulus field which has band axes tending to be approximately normal to the low level northeasterly flow. Reflective cumulus fields of the types shown in Nos. 10 and 11 are evident under the cirrus at condition (14) which lies just west of this position as shown in figures 12D and 14H. The cumuliform nature of this stratocumulus is masked by the cirrus and not clearly evident in the TIROS pictures. The presence of the cumulus is indicated by the relatively high reflectivity of the cirrus and cumulus combination. A few seconds after this observation a turn was commenced which changed the heading from about 237° to (a minute later) about 270°.

No. 12 131805/1412.5/2722//SE/7dc//298/7/1.6

A view of the banded dense cirrus shield to the southeast which extends northward from system (9) as between (10) and (15) in figure 12D. Low level conditions southward are very open. Small cumulus towers of the cumulus group in the foreground lean* northeastward indicating the presence of the northeast trade flow and a wind speed maximum below the tower tops.

No. 13 132026/1412.5/2731//N/7//295/6/1.6

A view of the cumulus field to the north showing inversion suppressed swelling cumulus, which is fringed at the top by thin derived stratocumulus, in groups of various sizes and separated by gaps of various sizes. A part of the northwestern edge of the cirrus of system (9) is visible to the north. The cumulus and cirrus, representing condition (14) and conditions to the north and northwest of (14), are shown also in figures 12D, 13G, 14G, and 14H.

No. 14 132327/1412.7/2741//NNW/7c//298/7/2.0

This shows the swelling cumulus groups, with derived thin stratocumulus, and relatively large open areas of condition (14). A small build-up is visible to the north. The northwestern edge of the cirrus formation shown in No. 13 is better shown here. The cirrus extends far to the north. The deep haze layer had a diffuse upper limit. The clouds shown in figures 12D, 14G and 14H near and north of this position are mainly cumulus groups of the type shown here. The cumulus, being more reflective, sharp-edged, and cumuliform, is more clearly shown than the cirrus; but the cirrus is also shown, as a gray, diffuse-edged, wispy formation, in these figures.

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*See cloud lean in glossary.

No. 15 132841/1412.8/2800//NW/7o,v//308/7/2.7

This shows a long generally E-W band (11) of swelling cumulus north of an open area in which are a few small cumulus towers leaning southwestward. Also shown are the northern ends of cirrus "filaments" which are the northernmost extensions of the western edge of the system (9) cirrus. The atmosphere was very hazy westward. Conditions are very open to the north of the band. These conditions, which are just west of the condition (14), are also well shown in figures 12D, 14G and 14H.

No. 16 133541/1413.1/2827//S/7dc,v//306/5/2.3

A view south and somewhat eastward toward system (9) showing a large rather dense cirrus band which extends to the south horizon and showing associated lesser lateral bands (or "filaments") which extend generally westward. Conditions at low levels to the south are very open as far as can be seen clearly. The more dense cirrus is well shown in the TIROS pictures near this position and further south near and west of condition (15) in figures 12D and 14H. The major band shown here is indistinctly shown in figure 12D. The major bands, and lesser lateral bands, are more clearly shown, for a time about 1^h30^m later, in figures 13E, 13F and 14F.

No. 17 133731/1413.2/2833//N/7o,v//286/4/2.0

A view of the long generally E-W swelling cumulus band (11) which extends across this picture and is a continuation of the band shown in No. 15. It is resolved in the TIROS pictures of two passes, as is shown in figures 12C, 12D, 14F, and 14H. The somewhat open structure of this band is well shown, at a later time, in figures 13E, 13F and 14F. Note the scales of the details which are, and which are not, resolved in the TIROS pictures. Extensive areas of very open conditions lie north and south of this band. These are also well shown inthe TIROS pictures. Cirrus associated with system (9) is still present but is thin in this view. The cirrus is too thin to be clearly detected in the TIROS pictures.

No. 18 134444/1413.5/2900//SE/7dc,v//277/4/1.8

A view southeastward of the cirrus band formation west and north of condition (15) of the "ITC" system (9). This cirrus formation is the southern part of the cirrus system shown in No. 16. Note the lesser lateral bands shown in both pictures. Bands of this type are not clearly shown in the TIROS VI pictures, but are distinctly shown in the somewhat later TIROS V pictures. The major band is well shown in both TIROS V and TIROS VI pictures. No low clouds are visible over almost all of the area of this view. Band (11) continues westward to the north.

No. 19 135215/1414.3/2928//N/7v//261/4/2.0

A view of the southwestward extending western end (16) of the swelling cumulus band (11) showing inversion suppressed convective activity with some derived thin stratocumulus near the tops of the swelling cumulus groups. The cumuliform nature of this band is clearly evident in the TIROS pictures, as in figures 13G, 14G and 14H, and more clearly but for a later time in figures 12C, 13E, 13F, and 14F. Very open conditions exist north, west, and south of this low cloud group. The open conditions are also well shown in the TIROS pictures. The haze layer was deep and conspicuous. The few cirrus wisps present represent a northwesternmost extremity of the system (9) cirrus. Much cirrus is still visible to the south. TIROS VI passed over the aircraft flight tracks at about this time.

No. 20 135746/1414.7/2948//N/7v//261/5/2.3

This shows a NNE-SSW cumulus band near the western limit of formation (16), and another, smaller, band to the northwest. Other conditions are as described for No. 19.

No. 21 140456/1415.2/3014//SE/7dc//246/6/3.0

A view of the southwestern limit of the cumulus group (16) (see also figures 12C, 13E, and 14F). Note the relatively close relationship of the larger details shown here to those shown in the TIROS V pictures, as in figures 13E and 13F, despite the time difference of about 55 minutes. The conditions were very open south of this group, and also very open (essentially clear) north of the aircraft. Apparently radiating long relatively dense cirrus bands extending from a more continuous and dense cirrus shield of system (9) are conspicuous far to the southeast. Most of the lesser bands (or "filaments") are not clearly resolved in the TIROS pictures, although some may be detected, and several major bands are clearly resolved as is shown in figures 13E, 13F and 14F. These cirrus bands appear to be similar to the bands of the cirrus of system (6) which are well revealed in the TIROS pictures (as in figure 14H). Edges of thin altocumulus formations are also visible far to the southeast.

No. 22 141008/1415.6/3034//S/7dc,v//229/5/2.5

A view southward of the distant cirrus of system (9) and the adjoining eastern extension of system (20) showing also some distant altocumulus as relatively dark gray thin formations against a background of very white cirrus (see also figures 13F and 14F). Cloud details to the left are the same as those to the right in No. 21. An open field of very small cumulus clouds is visible in the foreground. This field, and such fields, are not resolved in the TIROS pictures. The TIROS pictures show that very open low level conditions extend south and southeast of this position for 2° to 3° of latitude and that cirrus lies over much of the area of open conditions.

No. 23 141910/1415.5/3108//NW/7v//211/4/2.6

This shows generally very open conditions at low levels, and an open field of small cumulus towers with tower tops leaning northeastward, indicating the continued presence of low level northeasterlies. A thin altocumulus formation is visible above and near the aircraft. Against the dark sky background this appears to be a relatively white cloud formation. A formation in this position relative to the aircraft but of varying form was visible close to the north a few minutes earlier, and continued to be visible in or near this position for a total period of about one hour. None of these clouds can be seen in the TIROS pictures. The haze layer was conspicuous. White caps were numerous, indicating a stronger low level flow. The formation shown just northeast of condition (17) in figure 12C was not seen from the aircraft on the southern track hence cannot be detected in Nos. 19, 20, and 23. This formation was undoubtedly a low cumulus formation which was too low and too distant to be seen from the aircraft. It represents another example of a condition which although relatively close to the aircraft was not seen from the aircraft but which was relatively well observed by a satellite.

No. 24 142729/1414.8/3140//NNW/7o,ss//200/8/2.7

A view of cloud lines of generally small cumulus units and towers aligned approximately ENE-WSW, showing a number of towers leaning east-northeastward. The lines and towers indicate well the presence of the low level northeast trade flow. The altocumulus formation continues nearby to the north. Other thin altocumulus formations can be seen in the distance to the northwest. Most of these cloud formations are not resolved in the TIROS pictures. A field of larger bands is shown to the northwest in the TIROS V pictures, and shades of gray can be detected just north of this position, as in figure 14F.

No. 25 143036/1414.5/3152//NW/7ss//196/8/2.9

A view of a field of small towering cumulus units and groups with towers leaning east-northeastward. Altocumulus is still present to the north, and the edge of a more extensive and complex altocumulus formation is visible to the west. At this time the aircraft was approaching the edge (17) of the condition (18) which was resolved by TIROS V as shown in figures 12C, 13E and 14F. Condition (18) represents an extensive field of low cumulus towers, groups, and bands under some thin altocumulus, as shown here, and also shown in subsequent pictures (as in Nos. 26, 28, and 29). White caps were numerous, indicating the presence of a moderate low level trade flow.

No. 26 143325/1414.4/3202//NNW/7ss//208/5/3.3

A view of a field of small towering cumulus units showing aligned groups, open bands, and towers leaning east-northeastward. Thin altocumulus formations are also visible. Much of this trade cumulus is not clearly resolved in the TIROS pictures. However, some of this cumulus, and more cumulus of this type, appear in the TIROS V pictures as a set of small, relatively short bands near and north and northwest of this position, as in figures 13E and 14F. These bands indicate directly and well the presence of the low level northeasterly trade flow. The larger cumulus groups are well resolved, as is shown in figures 13E and 14F.

No. 27 143616/1414.1/3213//N/7//236V/3/3.4

This shows banded structure, waves, and other details of the thin altocumulus to the north near and above the aircraft. Light southerly winds were measured at the flight level (about 12,700 feet) on the southern track from about 30°W to 36°W, which is from a point near formation (16), over condition (18), and to a point west of formation (25) where the flight level wind shear line was crossed (near 37°W) as is shown in figure 4.

No. 28 143822/1413.9/3221//NW/7o,ss/192/9/3.1

A view of trade cumulus in approximately NE-SW lines and small bands showing towers leaning northeastward. Altocumulus formations are visible to the north. The satellite-observed pattern of the clouds of condition (18), shown in figures 12C, 13E and 14F, represents mainly the field of trade cumulus lines, bands, and groups. In the TIROS V pictures the larger trade cumulus bands and the larger groups are relatively clearly resolved, smaller groups and lines contribute to the rather indistinct gray areas, some of the altocumulus probably also contributes to the gray areas, and open fields and groups of small trade cumulus and much of the thin altocumulus are apparently not resolved at all. The compact larger cumulus group shown to the right of the center of this picture appears to be that shown near 14.5°N, 32.5°W in figures 13E and 14F. The area of significantly more open conditions shown to the west of this group is well shown in figures 13E and 14F (as near 14.3°N, 32.8°W). A number of other details of this trade cumulus field are also shown in figures 13E and 14F as well as in this picture. Cirrus appears to be absent over much, but not all, of the area of condition (18).

No. 29 144549/1413.2/3250//NNW/7s//190/5/3.0

A view of a field of trade cumulus aligned and leaning as in picture No. 28 and showing a relatively extensive and densely cloudy group to the west. This larger group is resolved in the TIROS pictures and is the relatively bright group shown in figures 12C and 14F just west of the 14.3°N, 32.8°W open area and north of and at the flight track near 33°W, and extending west and south from 14.2°N, 33°W. The areas of relatively open conditions east of this group are well shown in these figures. Thin altocumulus formations are also shown in this picture.

No. 30 145234/1412.4/3317//NW/7v,ss//186/7/2.9

This shows the northern part of a dense relatively wide NE-SW cirrus band which is apparent as band (19) in figures 12C, 13E and 14F. This band, being over and near other clouds, could easily have been misidentified in the TIROS pictures and not recognized to be a cirrus formation. It should be noted that in the TIROS pictures it differs in appearance from the formations of the underlying and nearby cumulus field, and does show cirrus characteristics although relatively poorly. A field of small trade cumulus cloud units with towers leaning generally northeastward is visible in the foreground. Thin altocumulus is also visible. TIROS V passed over the aircraft flight tracks a few minutes after this time.

No. 31 150648/1411.5/3413//S/7dc//179/8/1.6

A view to the south showing the southern extension of the cirrus band (19) to the southeast, and an extensive system including much cirrus which extends far southward. Much thin altocumulus is also shown. These formations represent the northern part of the northern part of the western edge of the large "ITC" system (20) which extends over 3 degrees to the south. This system appears to be an early stage of the system which later became a tropical storm and caused damage in Guatemala. A field of trade cumulus clouds, groups, and NW-SE lines with towers leaning generally northeastward is visible in the foreground. Although most of these cumulus formations are not resolved in the TIROS pictures, the larger bands and groups, such as those shown near the left edge of this picture, may be detectible, as in figure 13E near and south of this position. A larger group of swelling cumulus is shown farther south. The line of four cumulus grops (21) consists of such larger cumulus formations. This group appears to be present, but obscured by higher clouds, south of this position (near 34.3°W) in figures 13E and 14F. Conditions were very open to the north and very hazy. Altocumulus was still present nearby to the north (see also No. 32). Figures 13E and 14F show well the open conditions to the north, and gray formations south of this position which represent mainly the trade cumulus groups but which may also represent a contribution from the generally poorly resolved overlying altocumulus formations.

No. 32 151045/1411.3/3429//NW/7ʹv//170/7/0.9

A view showing almost no cirrus, and the edge of a thin altocumulus formation. Very open conditions were observed nearly everywhere to the north, and much of the area was truly clear. The lower atmosphere was very hazy. Figure 14F shows well these very open conditions, but shows shades of gray not far to the north and northwest and a sizable cluster of large towering cumulus groups and bands (24) farther to the north and northwest, clouds which were not seen from the aircraft at this position. The nearer gray bands and groups, and the large and highly reflective group (24), represent good examples of conditions which were relatively well observed by a satellite but which, though relatively close, were too far from the aircraft and too low to be visible from the aircraft.

No. 33 151505/1411.1/3446//SE/7ʹdw//166/10/0.6

A view of the extensive cirrus and thin altocumulus formations of system (20). Also shown are very open low level conditions nearby to the south, and scattered groups of cumulus and swelling cumulus farther south. Some of the cumulus groups are resolved in the TIROS pictures, as is shown in figures 13E and 14F. The larger cumulus group at the right edge of this picture is the group of the set (21) which is near longitude 34.7°W. The less distinct more distant groups near the picture center, at least partly under thin altocumulus formations, are also shown in figures 13E and 14F. The gray formations shown to the south near longitude 34.5°W in figures 13E and 14F appear to represent mainly cumulus clouds and groups but appear to include also some thin altocumulus. The northwestern edge of the higher dense cirrus formation of system (20) lies still farther to the southeast as is shown in figures 13E and 14F and also in picture no. 31.

No. 34 152045/1410.7/3509//S/7df//165/6/1.2

This shows the generally very open conditions which extend to the distant systems (20) to the left and (22) to the right. The dark edge of an altocumulus formation is conspicuous to the left. Scattered cumulus small lines and groups, including two larger groups of the line (21), are visible to the south. The group left of the picture center is the group near 35°W in in figure 14F (and under the star of the label (21) in figure 12C) and the group shown under the aircraft wing is the smaller group shown to the west (near 35.2°W) in figures 12C and 14F. Thin altocumulus formations were still present near the aircraft to the north. For the first time at flight level turbulence was appreciable (for a short period of time). The haze was unusually dense to the north and to the south. The anvil (23) of the cumulonimbus group (22) is well shown far to the south.

No. 35 152746/1410.3/3538//NW/4ss//178/8/1.6

A view of a restricted field of generally NE-SW lines and bands of trade cumulus. The larger bands are visible in the TIROS V pictures, as shown at (25) in figures 12C, 13E and 14F. The towers lean northeastward. Thin altocumulus is still present nearby to the north. Very open conditions extend to the far distance northwest of the cumulus field. A long high dense cirrus apparent band is shown near the horizon. During the flight it appeared to be a far distant long cirrus plume or band with its western end somewhat closer to the aircraft than the eastern end. The eastern end is evidently wider than the western end, is apparently somewhat lower, and may well be a fairly extensive layer or shield rather than a narrow band. Parts of this formation are evidently relatively thin and much of it may be relatively thin. This formation lies at the eastern end of the group (26) shown in figures 12C and 14F. It is not clearly revealed in these pictures. It appears to be an extensive but poorly resolved cirrus formation associated with the easternmost subgroup near 15.5°N and 36.7°W. Inconspicuous indications of rather thin cirrus can be seen in the TIROS pictures at and near this subgroup. This formation is not associated with the group (24) or with the conspicuous long east-west band near the center of the group (26), groups which were not seen from the aircraft on the southern track. Although the presence of cirrus of this or a similar type was suspected at these groups, because of the presence of this cirrus formation and because of possible indications of cirrus in the TIROS pictures, it was not clearly observed at these groups. This formation represents a good example of a major and distant cloud band or shield which was relatively well observed from the aircraft but was, unexpectedly, very poorly observed by the satellite. This cirrus formation implies the presence, possibly earlier, of at least a small cirrus-generating cumulonimbus cloud. The bright largest cloud unit of the subgroup near 15.5°N and 36.7°W may well be the cirrus-generating cumulonimbus cloud. However it should be noted that during the flight the band appeared to be detached, a condition which could not be clearly verified, and the generating cloud may have changed greatly or partly dissipated and may not be recognizable in figures 12C and 14F. The flight level shear line extends over the group (24), over the cluster of bands to the northeast, over the point 30°W and 18.5°N, and farther northeastward. It should be noted that the trough which includes the flight level shear line is associated with very open low level conditions, the two minor exceptions being these rather open groups of towering cumulus bands.

No. 36 153008/1410.0/3547//S/Ódf//191/2/2.3

A view of convective system (22) showing active cumulonimbus clouds with cirrus tops spreading laterally, and the short cirrus plume (23) extending northward. A rapidly growing tower is visible near the west end of this group just below the western edge of the cirrus (see also Nos. 39, 41, and 42). The northern edge of system (22) lies about 2 degrees of latitude south of the aircraft. Very open conditions extend south to this system and also to system (20) to the east. Widely scattered small cumulus clouds and lines and a larger trade cumulus group are visible in the foreground. The larger trade cumulus group is the westernmost group (near longitude 35.5°W) of the line (21). (The other groups of the line of groups (21) are shown in Nos. 33 and 34). These conditions are well shown in figures 13E and 14F.

No. 37 153151/1409.7/3554//NNW/4-ss//178/5/2.6

A better view of the cirrus band shown also in No. 35, which shows that it is west of the group (24) and is as far west as the subgroup of (26) at 15.5°N and 36.7°W. The western tip of a second apparently even more distant cirrus formation can be seen at the extreme right in this picture. The indistinct formation near 16.2°N and 36.2°W in figure 14F is in the right direction and at a reasonable distance (see also Nos. 42 and 39) and may possibly be this cirrus formation. Both of these band-like cirrus formations appear to be somewhat anomalous. Trade cumulus lines and bands, including a branched band, are shown in the foreground. The curved towers with bases leaning southwestward and tops leaning northeastward indicate the presence of the northeasterly trades and a speed maximum near the middle level of the more distant towers. The small cumulus lines, and the ENE-WSW band axis tendency shown here and in figure 14F, also indicate the presence of the northeasterly trade flow. Thin altocumulus is still present nearby to the north. The branched cumulus band, the eastern part of which is the band shown in the left half of No. 35, appears to be visible near 14.4°N, 35.8°W in figure 14F, which shows conditions about 30 minutes before the time of this picture. Other cumulus bands including one crossed by the aircraft are also shown in figure 14F.

No. 38 153728/1409.1/3616//NNW+/Ov//173/3/2.5

This shows the cirrus band also shown in Nos. 35 and 37 in the distance, thin altocumulus nearby, and very open low level conditions over most of the area. A few small trade cumulus lines are shown, with tower tops leaning northeastward. The haze layer was deep and conspicuous. Most of the clouds shown in this picture are not resolved in the TIROS pictures. The larger cumulus group to the right in this picture is apparently revealed (near longitude 36.1°W), and the cirrus band appears to be poorly resolved as was discussed under No. 35 above.

No. 39 154924/1406.8/3704//SE/Ov,df//5V/3/3.4

A view of the northwestern edge of system (22), showing the tower referred to at No. 36 distinctly larger. This tower was determined from the side camera 16 mm film to be about 130 n.mi. from the aircraft when near this position and to have a top altitude of about 56,500 feet. The easternmost anvil of system (22) reached a height of about 50,500 feet and was about 100 n.mi. distant. Very open conditions are shown over an extensive area in this view and in figure 14F. Approximately NE-SW lines of very small cumulus cloud units are visible in the foreground. Details along the northwestern edge of system (22) are also well shown in figures 13E and 14F.

No. 40 155444/1405.4/3725//NW/Oo//14V/5/3.0

A view of small cumulus lines with axes approximately NE-SW, and very open conditions over a very extensive area. A thin cirrus formation is visible. Haze was conspicuous. These clouds are not resolved in the TIROS pictures. The open conditions, however, are well shown in figure 14F.

No. 41 155702/1404.8/3735//SE/Oo,df//20V/2/2.5

A view of system (22) showing further growth of the western tower and a lateral spreading of its upper part. Very open conditions extend far to the south. A field of approximately NE-SW small cumulus lines is visible in the foreground. The open conditions just west of those shown here, including those far to the south, lie in the TIROS coverage gap and are not shown in figures 12B, 12C, 14D, 14E or 14F. These extensive open conditions are mainly under the col shown in figure 3 and under the trough shown in figure 4. The trade cumulus lines are not resolved in the TIROS pictures. The open conditions shown here, and details of the distant system (22), are also well shown in figures 13E and 14F.

No. 42 160715/1402.8/3816//SE/4-df//117/3/3.2

A final view of system (22) showing the western tower, further developed, a far distant western cirrus plume (also shown in Nos. 31 and 41), and the very open conditions to the west. Trade cumulus cloud units, approximately NE-SW lines, and groups are shown in the foreground. Haze was conspicuous. Cirrus formations were visible to the north. A field of cumulus groups, probably similar to the larger groups shown in this picture, is shown in figure 14F south of this position near 13°N. The cumulus at the base of the western cirrus plume, which is well shown in No. 39, is almost not visible in this picture because of the increased distance and the curvature of the surface of the Earth (see also No. 41).

No. 43 161327/1401.6/3842//NW/7-,v//112V/2/3.2

This shows a cirrus formation extending westward. Very open (apparently clear) conditions extend to the horizon. The low cumulus formations shown in figure 14E north of 15°N in this direction are not shown here and were not visible from the aircraft. The deep haze layer had a conspicuous sharply marked upper limit. The aircraft passed under a relatively dense NE-SW cirrus band at 1622. Much cirrus was visible to the south at 1633. Because of the satellite coverage gap most of the resolvable features of these conditions are not shown in the TIROS pictures. Some of the cirrus observed near this time can be detected near 14.2°N and 39.2°W in figure 14E.

No. 44 163943/1354.6/4027//NW/7o,df//12/7/3.6

A view showing very open conditions to the north, and a field of approximately ENE-WSW small trade cumulus lines which reveal the continued presence of the northeasterly trade flow. The irregular eastern edge and part of the overcast shield of an extensive high altocumulus formation is shown to the west. Haze was conspicuous to the west. The altocumulus represents the eastern edge of the band of extensive altocumulus formations, some extending from large towering cumulus groups, which lies to the east of the similar formations (30) and (31), and which is indicated at (33) in figure 12B and north of (33) in figure 14D.

No. 45 164312/1353.8/4041//SE/7-//6/9/3.7

A view of a relatively dense cirrus band which includes several dense cirrus masses and which extends eastward to the south. At low levels very open conditions extend far to the southeast. These represent the western side of the area of open conditions referred to at No. 42. Low trade cumulus lines with approximately ENE-WSW axes and groups are visible to the south.

No. 46 (Data the same as those for No. 45 except that the azimuth is south)

This shows the western end of the cirrus band shown in No. 45. An extensive high level cloud system which includes much altocumulus is visible to the west. This is the southern part of the eastern edge of the band of altocumulus formations referred to at No. 44 and is the eastern edge of formation (33). A band of larger swelling cumulus is shown to the west. Much distant cumulus is also shown to the west. The cumulus lines shown in No. 45 are better shown here. The larger cloud formations shown in this picture are large enough to be resolved in the TIROS pictures, but are not shown in the TIROS pictures because of the coverage gap.

No. 47 164903/1352.5/4105//NNW/7o,ss//12/8/4.1

A view of the southern part of the altocumulus formation shown to the west in No. 44 showing thinness, banding, and wave structure. An ENE-WSW band of trade cumulus, and other trade cumulus groups and cloud units, with towers leaning east-northeastward indicate the continued presence of the low level northeasterly trade winds. A somewhat more distant larger band is also shown. The top of the haze layer was marked to the east but diffuse to the west. This picture shows well the conditions to the north of the aircraft at the satellite coverage gap area.

No. 48 170027/1350.5/4151//SE/7v,dn//7/3/3.5

A view of an extensive shield of altostratus associated with a penetrating large towering cumulus central mass. This shield appears to be the central part of formation (33), which lies to the east of formation (31). The western edge of formation (33) can be detected but is not well shown in figures 12B and 14D. The eastern edge of this formation is shown in picture No. 46. It should be noted that most of the formations and formation details seen from the aircraft near and after this time do not correlate as well with the smaller details shown in the TIROS pictures as did the formations and formation details seen earlier. This is primarily due to the larger observational time differences. Pictures No. 48 and No. 49 were taken about 1.5 hours after the time of figures 12B and 14D. Significant translation, development, dissipation, and other changes may occur when the time differences are as large as this or larger. It was found, however, that the correlation is usually improved when it is possible to make a reasonable allowance for lateral displacement. Generally open conditions continue beneath the altostratus. A few ENE-WSW small cumulus lines are shown. A towering cumulus build-up is clearly visible in the distance. At this time the aircraft was still in the weak northerly current west of the 700 mb shear line.

No. 49 170209/1350.3/4158//NW/7ss//14/6/3.5

A view of a thin altostratus shield, almost an overcast, which is a northward continuation of the altostratus shown in No. 48, which is a formation of a later stage of the roughly NW-SE curved and relatively wide complex band that lies northwest of formation (33) as shown in figures 8, 12B and 14D, and which appears to extend into altostratus associated with a later stage of formation (30). Much of this altostratus, being relatively thin, may not be clearly shown in the TIROS pictures, as when over areas of few or small low cumulus clouds. The cloudiness shown between formations (30) and (33), notably that shown just east of formation (30) in figure 14D, appears to be indistinctly shown altostratus over some low cumulus. That shown between formations (31) and (33) appears to be indistinctly shown thin altostratus over very little if any low cumulus. An extensive field of trade cumulus with towers leaning approximately east-northeastward is shown below the altostratus shield. This field is less well developed to the east. Dense cirrus is visible far to the northwest. White caps were present but few in number.

No. 50 171159/1348.9/4238//N/7v,os//16V/4/3.8

A view of conditions similar to those shown in No. 49. The altostratus is thicker and forms an overcast. The field of trade cumulus is more open, and becomes very open to the west. The part of total field shown here consists mainly of scattered approximately ENE-WSW small suppressed trade cumulus lines, with towers leaning west-southwestward. The distant dense cirrus is still visible. These conditions occur between the positions of formations (30) and (33) shown in figures 12B and 14D.

No. 51 172354/1347.3/4326//NW/14ss//29V/2/2.4

A view taken when the aircraft was approaching a formation which had considerable vertical development and extended into a high altostratus overcast and extensive and dense cirrus shield. Several layers of middle level altostratus are visible. Relatively tall trade cumulus towers leaning east-northeastward are clearly shown east of the apparent "wall" of the large formation. Lower trade cumulus towers, similar to those shown in No. 50, lean west-southwestward. The large formation is evidently a later stage of formation (30). Shortly after this time the aircraft passed from the weak northerly current to a southerly flow which increased westward to the wind shift zone near 50°W (as shown in figure 5) and which extended over a wide area northeast of system (40) and east of system (39).

No. 52 173337/1345.8/4405//NW/13p//134/4/2.4

A view of a large band, apparent band, or second "wall" of convective build-ups, to the west of the formation shown in No. 51. This band is bounded on the west by an approximately N-S long and relatively broad zone, or corridor, which lacks large towering cumulus clouds and is in general relatively open at the lower levels. The lower portions of the cumulus towers lean generally eastward, and extend from low level easterlies through mid-level southerlies into upper level northwesterlies. Much altostratus, and some cirrus, are visible above. This band, apparent band, or corridor "wall" appeared from the aircraft to be a type of convective band. It appeared to be a distinct band or elongate quasi-linear group of large towering cumulus cloud systems, a band of intense convective activity. It appears to represent a major part, the northern part, of formation (35) which is well shown in figures 12B and 14D, but appears to include also some of the towering cumulus clouds of the western side of formation (30) which lies to the north. This generally N-S band, or apparent band, of parts of formations (35) and (30), and with a major open corridor to the west, is relatively well shown in figures 12B and 14D. As No. 52 was taken about 2 hours after figures 12B and 14D the details shown in this picture represent later stages and a detailed one-to-one correspondence of cloud formation features can no longer be determined with certainty. Formation (35) may have moved significantly, perhaps even somewhat eastward, and certainly changed or developed during this interval.

No. 53 173836/1345.4/4425//W/13p//148V/2/2.3

A view forward showing an extensive stratiform cumulus layer below the aircraft, high thin cirrus to the south, and a dense cirrus band associated with a group of cumulonimbus clouds to the north. The dense cirrus band is probably part of a later stage of formation (36). This formation is evidently a cumulonimbus cloud system. The low stratiform clouds appear to be too thick and extensive to be the same in type as the gray formations shown in figures 12B and 14D near this position but may be later stages of such formations. The details shown in this picture correspond in a general way only with those shown in figures 12B, 13C and 14D. The differences are doubtless due to rapid changes, growth, and displacement during the 2 hour interval between the times of the aircraft and the TIROS pictures. For example, the dense cirrus may have increased in amount and very likely moved southeastward appreciably in the upper level northwesterlies during this period. The conditions shown in this picture, when compared with those of figure 14D, suggest such changes. White caps were almost absent below.

No. 54 175007/1344.0/4510//N/13p//152V/1/2.9

This shows an extensive approximately N-S band or apparent band of towering cumulus to the east, and a broad corridor with small suppressed cumulus clouds to the west. The corridor to the east of this band is the one west of the formation shown in No. 52. Much cirrus, dense to the east but thinner to the west, and some altostratus and altocumulus, are shown at the higher levels. The dense cirrus shown to the north and east appears to be cirrus of a later stage of formation (36). The band of towering cumulus appears to be part of the western side of a later stage of formation (36). A generally NW-SE zone of relatively open low level conditions is shown near and west of this position in figures 12B and 14D (see also No. 55). Generally NW-SE cumulus small bands are also shown in figures 12B and 14D, and better in figure 13C; over a relatively extensive area near and south of this position and elsewhere in these TIROS pictures. A variety of other details are well shown in the TIROS pictures in and near the flight track area at this region. These were, in general, not observed or not clearly observed from the aircraft.

No. 55 (Data essentially the same as those for No. 54, except that the azimuth is NW)

A view of the field of small trade cumulus cloud units, lines, and groups in the broad corridor. The curved towers reveal the presence of a low level approximately east-northeasterly flow (in a manner similar to that shown in No. 37). The smaller cumulus towers lean approximately west-southwestward as did the smaller towers observed to the east in this region. The larger towers though curved, and unlike those shown in No. 51, are nearly vertical, indicating reduced vertical gradients in the wind field of the trade flow. Increased cloudiness is also shown west of the NW-SE relatively open zone or corridor, and west of this position, in figures 12B and 14D. This cloudiness includes cirrus and several layers of altocumulus and altostratus as is well shown in this picture.

No. 56 1757/1341.0/4538//N/13//167V/3/2.3

A view of the band of towering cumulus clouds which bounded to the west the corridor shown in No. 54. Another corridor is shown to the west of this band. Also shown are a thin cirrus overcast above, some altocumulus at middle levels, and suppressed cumulus in the corridor. A relatively small cumulus band with a small relatively open zone to the west is shown near this position, especially to the south of the flight track, in figure 14D. Other bands and open areas and zones are also shown southwest of formation (36). The major band shown in this picture may well be a later stage of one of these satellite-observed bands. A larger relatively open zone is present near longitude 46°W. Many of the bands and open zones shown near this area in figure 14D reveal a tendency toward orientation along NW-SE axes; others indicate a weak but real tendency toward an approximately NNE-SSW axis orientation (see also No. 57). The former are approximately normal to the trade flow; the latter appear to be approximately parallel to the estimated wind difference (approximate mean shear) between the trade and mid-tropospheric flows, and could conceivably be used to improve the estimate of this difference.

No. 57 180236/1338.2/4559//NW/15v//159/7/2.4

A view showing the westward extension of the corridor shown to the west in No. 56. This is near the position of the open zone shown near longitude 46°W in figure 14D. This picture shows very open areas to the east and west and an open low approximately NNE-SSW band of curved trade cumulus towers, which (as in Nos. 37 and 55) indicate the level of the speed maximum of the low level generally easterly trade flow. A southeasterly flow is still present at the flight level. A relatively dense cirrus overcast, which appears to be an extension from formation (37), is well shown above. It should be noted that much cirrus, in general a cirrus overcast, is shown in the aircraft pictures west of about 42°W, and that relatively little cirrus is clearly revealed in the TIROS picture near the flight track from about 42°W to about 46°W.

No. 58 180823/1335.2/4623//N/15v//168/13/2.2

A view of an extensive area clear of low cumulus clouds, which extends west of the area of open conditions shown in No. 57, and a relatively dense cirrostratus overcast. Almost no whitecaps were visible. This area was under the cirrus shield of formation (37) (see figures 12B and 14D). Some cumulus is shown to the northeast in this picture, and may represent the edge of a cumulus formation of the type which causes the cumuliform inhomogenity apparent north of the flight track near this position in figure 14D. The southern part of formation (37) is more homogeneous and apparently includes less low cumulus cloudiness.

No. 59 182109/1328.7/4714/NNW/15ss/165/13/3.0

This shows the conditions at the western side of the area of low level open conditions shown in Nos. 57 and 58. Cumulus towers lean somewhat north of eastward under a dense cirrus overcast. Altocumulus formations are shown to the west and in the distance to the east. Over this area the winds at flight level were significantly stronger than they were to the east. Many white caps were present at this time. Rain areas were also visible to the west. This area was near the position of the western limit of the more reflective clouds of formation (37) shown in figures 12B and 14D. More open conditions are indicated to the west in these figures, but are not shown in this picture. About 10 minutes after this time the aircraft passed the position shown in figures 12B and 14D of the northeastern margin of the relatively dense cirrus of the systems (39) and (40). In fact, by then, as the aircraft pictures show, the aircraft had been flying under dense cirrus for over 30 minutes. The observation time difference at the time of this picture was almost 3 hours. Clearly major changes had occurred since the time of these TIROS pictures.

No. 60 184258/1318.5/4841//NNE/14-//164/13/3.3

A view of the western side of the band of precipitating towers which lay to the west of the open conditions shown in No. 59. This major band is not clearly shown in figures 12B and 14D near this position, but may be a later stage of the formation shown extending to the north near 48.5°N, or may be a formation that developed after the time of the TIROS picture. Also shown are a relatively dense cirrus overcast above, and much altocumulus. An extensive zone of solid cloudiness at flight level and rain lay to the west. The major generally N-S band shown under cirrus near longitude 49.2°N in figure 14D may represent an earlier stage of this solidly cloudy condition. The stronger southerly flow at flight level was still present over this area.

No. 61 190946/1303.6/5030//N/14s//74/4/4.1

A view about 1 minute after flight out of the cloud and rain area referred to at No. 60, and about 15 minutes after the change in the wind direction, showing a relatively dense cirrostratus overcast, build-ups and cumulonimbus clouds to the north, and indications of the high level westerly flow. Much altostratus is also shown. A more open condition is shown near and north of this position in figure 14D. This figure also shows that this position is at the northeastern margin of the extensive very dense cloud system of system (39) which lies to the west and southwest. The northern aircraft did not encounter a marked wind shift near this area, but did encounter a slight wind shift and markedly stronger winds north of this area. These strong easterly winds at flight level along the northern track occurred at the area from about 48°W to 52°W which has, as is well shown in figure 14C, well-defined sizable east-west bands of towering cumulus and cumulonimbus clouds. These easterlies continued westward to about 56°W, or through and past the organized intense convective activity of the system (42) shown in figures 12A and 14C.

No. 62 191829/1257.5/5106//NNW/14s//85/4/3.7

A view showing a dense cirrus overcast, approximately E-W bands of stratocumulus to the north (which were also present to the south), a distant cumulonimbus cloud (also shown in No. 61), and more indications of the high level westerly flow. Another solid cloud and rain area with turbulence at flight level lay to the west. The aircraft was under the very dense cirrus shield of system (39), and was about to enter a major rain area of this system. The aircraft crossed the northern part of this highly reflective system as shown in figures 14B and 14D.

No. 63 194231/1240.8/5247//NNW/15//14/8/4.2

A view of a dense turbulent overcast of cirrus, which had a mammatus structure over this area, showing also some altocumulus, at and within the northern part of system (39). Many conspicuous white caps were present. An area of solid cloud and rain lay to the west. It included active cumulonimbus clouds both north and south of the aircraft. The last rain area was passed at about 2005. System (39) included so much solid cloudiness and rain that few pictures could be obtained during the crossing of this system. This was in sharp contrast to the conditions observed nearly every where else during this flight.

No. 64 201656/1222.5/5508//NNW/5dn//93/1/3.4

A view about 5 minutes after the aircraft left the western edge (43), also well shown in figures 12A and 14B, of system (39). It shows altocumulus formations, dense cirrus, and cumulonimbus clouds to the east. It shows also the extensive field of trade cumulus (45) with a few large cumulus towers, small towers leaning generally eastward, and approximately E-W small lines, which lay to the north, west, and south. Almost no white caps were present. Much cirrus is shown to the north and far to the north. This cirrus is not clearly shown in the TIROS pictures. Most of the trade cumulus is too small to be resolved in the TIROS pictures.

No. 65 203145/1230.7/5608//S/5-o,ss//126/2/4.5

A view to the south showing an open field of trade cumulus groups and long roughly east-west bands, comparable to those marked (44) and well shown in figure 13B, in the trade cumulus field far to the south. Towers in the foreground leaning approximately eastward reveal the presence of the low level easterly trade flow. Most of the trade cumulus of fields of this type is not resolved in the TIROS pictures. It is not shown in figures 12A, 13A, 13B, and 14B, although shades of gray mark the areas of increased cloudiness near this position in these figures and indicate the presence of fields of trade cumulus. Bands of the scale of those shown in the distance here are well resolved when the TIROS observing conditions are most favorable, that is, when the object nadir angles are small and angles between the raster lines and the band axes are relatively small. Such bands are not shown near this position in figures 13B and 14B, probably mainly because of the observation time difference (this picture representing conditions about 4 hours later than those of the TIROS pictures). The bands shown farther to the south in figure 13B are

comparable but are considerably larger. The low level conditions shown here are generally very open. It should be noted that the TIROS pictures do indicate an extensive area of very open low level conditions near this position. Much cirrus is also shown in this picture. This cirrus is not resolved in the TIROS pictures. It is not distinctly shown in the TIROS pictures. Few, if any, indications of it can be detected over most of this and the adjacent very open area. It is, in effect, not shown in these TIROS pictures.

No. 66 205140/1241.1/5728//NW/5uc//67/2/4.8

A view of towering cumulus groups showing extended gaps, other details of the distribution of these groups, and indications of the low level easterlies. A thin cirrus overcast is present to the north. The TIROS pictures show only indistinct shades of gray near this position. Neither the cirrus nor the cumulus present at the time of the satellite crossing were resolved. As the cumulus groups shown here represent conditions about 4 hours later than those shown in figures 13B and 14B, and as the larger cumulus groups are large enough to be resolved in the TIROS pictures, some intensification and growth is indicated. The amount of the growth was probably relatively small, however, as the cumulus clouds shown here and in the TIROS pictures are relatively strongly suppressed. The larger cumulus groups shown here may well represent conditions more like those shown south of the label at condition (46) than those shown at condition (45) in figures 12A and 13B. It should be noted, however, that condition (46) includes many cumulus groups that are substantially larger than any shown here. The very open relatively strongly suppressed conditions shown in pictures Nos. 64-66 and at the corresponding and adjacent areas in the TIROS pictures imply the presence of a subsidence inversion and extensive subsidence. At least along the eastern margin of this extensive open area this subsidence is associated with the extensive disturbances which lie to the east as is well shown in figures 13A, 13B, 14A and 14B.

The northern track sequence:

Picture A 1223/1630/2400//NE/7v//135/20/M*

Ci and Cs, visible in this picture, was broken variable to overcast and quite dense. It appeared streaked with apparent alignment NW-SE. This cloudiness is also apparent in the TIROS view 1 1/2 hours later (figure 14G) north of the first position dot between latitudes 17°-20°N. The alignment of streaks in the TIROS view agrees precisely with that determined from the aircraft. Note, however, that the Cs viewed from the aircraft was more abundant and more dense than that apparent in the TIROS view (it was even more dense in the view to the south). In fact, it was so inconspicuous to the analyst at the read-out station that the area in question was analyzed as containing only scattered cumuliform clouds (figure 6). The picture also shows scattered, very suppressed Cu or Fc which had been much heavier and appeared in broken amounts over Sal.

*See footnote 6. "M" indicates report omitted or missing.

Picture B 1239/1630/2510//NW/7v//150/11/M

A very few small Cu appear in this area with scattered variable to broken Ci streaks above aligned ENE-WSW. The Ci in this area appear derived from system (6) shown in figure 12D. The time-lapse movie film shows quite dense cirrus extending southward in broken to overcast amounts to the area of the Island of Fogo (figure 12D). The aircraft on the southern track also photographed these cirrus near Fofo and noted their southward extension to system (6). [See discussion of picture 3 on S. sequence]. Figure 12D also reveals the broken Sc, noted over Santo Antoa Island (SA) and clear conditions over St. Vincente (SV).

Picture C 1300/1630/2620//N/7v//130/8/M

Scattered Fc in this area with broken Cs in patches and streaks above. This Cs was positively identified through the time lapse photos as part of the long plume visible in the TIROS picture 50 minutes later, extending northward in figure 14G along longitude 26°20'W. between latitudes 16 to 18N. The broader part of the plume near 16N has underlying areas of scattered to broken elements of Cu and Fc. These elements give a brighter "speckled" appearance to the base of the plume, apparent in the TIROS views. Surface wind at this time was estimated 060°/10kt.

1308/1625/2640//M/M//135/5/M

The edge of the Cs plume was reached at this point though more Ci were visible to the south in what appeared to be a least broken amounts. These were determined photogrammetrically, to be at a distance of 34 n.mi. and at a height of 30,800 feet.[7] This is in excellent agreement with the cloud patch visible in figure 14G just south of position dot number 4 (counting from right to left) along 16N latitude. The "speckled" appearance of this cloudy patch, however, supports the aircraft observation that it was made up of underlying areas of broken Fc and Sc elements. The cirrus appears to have been derived from system (9), figure 12D. It was clear of cirrus ahead and to the north, for the next 3 degrees.

1317/1625/2720//M/M//196/10/5

Clear above, scattered Fc below. Broken to overcast Ci visible on south horizon, with underlying areas of scattered to broken Cu and Fc.

1327/1620/2820//M/M//184/11/5.1

Clear above, scattered Fc below. Broken Ci on south horizon in streaks. Edge of patch referred to at 1308 reached. Ci now viewed to the south are over area of a hook pattern [Feature (11) figures 12C and D]. The "hook" itself was identified by the aircraft on the southern track as an E-W band of swelling Cu. Picture 15 shows the northern limit of Ci derived from system (9), figure 12D, over this "hook".

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[7] Photogrammetry measurements were made by Dr. Paul McClain, NWSC.

1337/1620/2830//M/M//190/10/4.8

Scattered rows Fc, several thin bands of Ac oriented NNE-SSW on NW horizon. These are not apparent in the TIROS photos.

1351/1630/3030//M/M//M/M/M

Scattered Fc Clear above.

Picture D 1410/1630/3120//SW/0d//240/8/4

Scattered Fc below are more dense ahead. Ac or dense Ci and Sc appear on SW horizon. Aircraft picture shows cloudiness near 16°N, 30°31'W best seen in the TIROS view in the form of a flying gull in figure 14F near 16°10'N, 30°20'W. This feature was determined to be 36 n.mi. from the aircraft at a height of 29,700 ft. The cloud patch south of this feature, near 15°N, 31°W. (figure 14H) has the characteristic brighter speckled appearance of low Cu or Sc and was seen from neither aircraft because of its low elevation and distance.

Picture E 1416/1650/3110//NW/2//M/M/M

Approaching area of broken Sc intercepted by aircraft track in figure 14E at approximately 17°N., 32°W. Note the bright speckled appearance of this cloud group. Tops were estimated at 6000 feet. Alignment of rows appeared to be generally E-W in good agreement with the alignment suggested in the TIROS pictures taken 40 minutes later (figures 7 and 14E).

Picture F 1431/1650/3215//NW/4//211/9/4

This pictures shows rows of scattered to broken Sc forming group referred to at 1416. From this position, looking to the south, the northern extensions of system (20) in figure 12C, could be seen. These were determined to be Ci at a distance of 102 n.mi. with tops to 40,300 ft.

1442/1648/3350//M/M//M/M/M

Ac streaks are visible SW. Some of the horizon cloudiness appeared to have considerable vertical development.

Picture G, H 1500/1645/3400//NW/0//165/5/4

The picture shows Ci streaks visible to the west. Scattered Fc appears below. Picture G shows Ci streaks aligned N-S. Picture H shows long Ci band. This cirrus was apparently derived from cloudiness to the south, implying southerly flow at the Ci level (see figure 3). The long plume nearest the horizon in picture H was calculated to be over 100 n.mi. distant (see further comments at 1532).

1513/1645/3430//M/M//215/2/4.2

Ci streak ahead is aligned NE-SW. Surface wind estimated at 215°/10 kt.

Picture I 1523/1655/3534//NW/2//025/1/4.9

Broken Sc appears below the long Ci streak noted earlier. The Sc patch which measured about 2 miles in diameter cannot be seen in the TIROS views. Portions of the Ci band may also have been observed from the aircraft flying the southern track (See discussion of picture 35). TIROS evidence of this Ci band is very indistinct. However, some evidence may appear in figure 14E. A long wisp of grey can be detected extending NE from feature (26) [figure 12C] between position dots 7 and 8 on figure 14E. The wisp extends over the group of Sc near 18°N, 35°W. The alignment of this Ci band parallels the flight level shear line and may be associated with similar shear producing a wind maximum at the Ci level. The importance of similar Ci bands in relation to jet streams suggests the importance of obtaining better resolution in future satellites so that such bands can be more readily detected. It is clear that this band would not have been found in the TIROS pictures without the supplementary aircraft observations, and, even then, the evidence is admittedly weak. Group (24), [figure 12C], consisted of low Cu, Fc and Sc which extended up to the aircraft track. Much of this cloudiness was unresolved by TIROS because of the small size of the individual elements. Note the bright speckled appearance of this group.

1532/1652/3610//M/M//M/M/M

The Ci streak, referred to at 1523 was directly above the aircraft at this time.

1539/1648/3639//M/M//340/6/4.0

No middle or high clouds were visible to the north and west. Only a few Fc and the first Cu projecting above the inversion appeared ahead. To the south low cloudiness surrounding feature (26) in figure 12C was visible in broken amounts.

Picture J 1551/1642/3727//NW/10c//M/M/M

A scattered variable to broken field of small Cu were visible aligned NE-SW. Some Ac and As aligned in a similar manner were visible near the tops of the Cu. These clouds were apparently formed by the spreading out of the tops of the Cu against the inversion. Cloudiness in this picture appears north of, but associated with, feature (26) in figure 12C. Nearly all of the small Cu elements were unresolved in the TIROS photograph.

1607/1634/3831//M/M//008/12/4.5

Cs was visible on the SW horizon over the west end of feature (26) in figure 12C. A check on the height and distance of these clouds using the time lapse pictures showed them to be approximately 58 n.mi. distant and at a height of 32,500 feet. Conditions were clear overhead, however, with scattered variable to broken Fc and Sc below. The low clouds leaned northeastward indicating a decrease in the speed of the easterlies with height. Cu appeared aligned in rows rather than cellular groups.

1631/1626/4008//M/M//014/9/5.0

In the "gap" area of no TIROS coverage (see figure 1) scattered variable to broken Fc were still present. No upper clouds were present in the area of the aircraft. However, a major area of upper clouds appeared over the western and southwestern horizon. TIROS views of this cloudiness appear in figures 8, 12A, 12B, 13C and 13D.

1648/1620/4118//M/M//M/M/M

Ci streaks ahead appeared aligned NE-SW. Virga trailed from the Ci. The haze layer appeared to deepen over this area with top approximately 11,000 ft. Low Cu appeared aligned with the surface wind which was estimated at 025°/12 kt.

Picture K 1710/1613/4247//NW/7o//050/4/6.0

In the Gap area, picture shows broken Ac as the aircraft passed under the edge of this cloudiness. These clouds formed the eastern extension of cloudiness off the band of Cb's extending northwestward in figures C and D from 16N; 44W to approximately 19°N,52°W. Rows of Fc are also visible in the aircraft picture, reflecting the northeasterly low level flow.

1722/1606/4336//M/M//100/5/5.5

Aircraft was still under a broken Ac layer at this time. Scattered lines of cumulus appeared below. A few build-ups were indicated on the radar bearing 240°, range 50 n.mi. These build-ups were apparently associated with the "line of Cb's" shown on the nephanlysis of figure 8 and seen most clearly also along the right edge of figures 13C and 14D.

Picture L 1728/1603/4401//NW/5ss//085/8/5.2

The cumulus clouds changed markedly in appearance, becoming much larger, in this area, as the aircraft flew into the band apparent at the top of figure 14D. The northern edge of this band can be seen in the aircraft photo and also at the top of figure 14D. The individual cumulus towers in this view still leaned toward the NE.

1734/1600/4427//M/M//110/14/+6.0

Multiple layers appeared in the band area with scattered cumulus build-ups.

1746/1554/4518//M/M//120/16/5.6

Winds at flight level during the preceding hour shifted from northerly to easterly or southeasterly with the most rapid change occurring as the aircraft passed from the suppressed area, described at 1631, to the multiple layer cloudiness in the more disturbed region.

1751/1552/4539//M/M//110/18/5.2

The aircraft had passed through the Cb band, indicated on figure 8, at about this time, and entered a relatively clear area, which extended northwestward. This area can be seen just west of the three bright Cb clouds visible in the upper right hand corner of figure 13C. These are numbered (27), (28) and (29) in figure 12B. Note that the band had moved westward by about 1/2 degree from the time of the TIROS view (1535) until aircraft penetration (1751).

Picture M 1802/1543/4638//NW/9s//110/17/4.3

Picture shows broken patches of Ac and curved Cu streets as the circulation appeared to intensify. The grey area to the south of the flight track near 15°40'N., 46°40'W. in figure 14C consists of the Ac and underlying Cu which made up this cloudiness. The brighter flecks of grey represent the Cu groups. They had apparently developed considerably in the 2 1/2 hr. time lapse from TIROS to aircraft view. Cloudiness such as this was nephed as only scattered cumuliform by the read-out analyst.

Picture N 1819/1529/4738//N/6s//120/19/4.6

The aircraft passed under dense Cs, apparently derived from Cb's, visible in a line curving northwestward in figure 14D from 13°30'N., 46°20'W. to 15°20'N., 51°W. The line must have expanded northward during the time lapse from TIROS to aircraft view since figure 14D appears clear of cloudiness at the aircraft position. The picture shows Cb's leaning eastward reflecting the upper westerlies over this area (see figure 3). The sea became more choppy in this area. Surface winds were estimated 090°/15 kt.

1828/1522/4816//M/M//110/24/4.8

Note wind increase to 24 kt.

Picture O 1834/1518/4841//NW/12s1//120/28/5.2

Picture shows overcast St patch to west of aircraft. Broken Fc were below with scattered variable to broken Cs above. Some of the Cs appeared banded. Figure 14C shows the band of Cb's extending westward from this position. The Ci cloudiness and most of the smaller Fc and Sc elements and patches were unresolved or appear only as a faint grey over this area.

1843/1511/4920//M/M//M/M/M

Aircraft was over the broken variable to overcast Sc referred to at 1834. The Cs layer ended above as the aircraft flew in and out along the edge of the overcast system (figure 14C).

Picture P 1846/1508/4933//NW/12s1//110/22/5.2

Picture shows pronounced easterly shear to Cb on horizon. Note banded Cb cloudiness aligned E-W in figure 14C between 15°-17°N, and 48°-52°W. The Miami 200 mb analyses for 1200GMT, 22 Sept. 62 and 63 Sept. 62 verify upper level westerly flow over the Antilles in excess of 30 knots (figure 3). Easterly low-level winds coupled with the upper level westerlies combine to cause the extreme E-W elongation visible in picture P and the banded structure apparent in the TIROS view. Antigua's PIBAL for 1800GMT, 22 Sept. 62 shows that light easterly winds changed very sharply to strong westerlies at upper levels in agreement with these other observations.

Picture Q, R 1854/1501/4956//N/12s//088/20/5.2

Pictures show another view of the Cb to the north. A major wall of Cb's can also be seen in the path of the aircraft, with Cs emanating from these clouds. Very suppressed low cloudiness conditions existed prior to penetrating the Cb's. These pictures cannot easily be related to specific cloud masses appearing in the TIROS view although a general correspondence of cloudiness conditions is quite apparent. The 3 1/2 hour time lapse between aircraft observation and TIROS view during which development and translation of features occurred appears to be an important factor in this respect, as well as the disturbed and complex nature of the cloudiness conditions over this area (Not true of the western edge. See remark at 2008, picture S).

1908/1446/5151//M/M//080/27/6.0

A long band of build-ups was visible to the NE (See discussion 1846). Dense overcast Cs shield was above with a broken multiple cloud layer below. Cs was streaked along the direction NE-SW. This Cs was apparently derived from the extensive dense area to the south of track, visible in figure 14C, which now completely covered the flight track area. The aircraft flew under this shield until 2008.

1918/1436/5151//M/M/086/25/+6.0

The Cb band to the northeast was still visible extending westward. (See discussion at 1846) Dense overcast above.

1926/1428/5225//M/M//080/22/6.2

An extensive area of build-ups was apparent to the west. The radar pattern showed spiral bands winding around a center approximately 40 n.mi. west. A distinct cloud mass in the form of the cypher 6 was visible in the TIROS and radar view of this area and is labelled feature (42) in figure 12A. The aircraft was embedded in cloudiness throughout this area so no pictures are available. See also surface analysis (figure 2) which shows a surface pressure center in this area.

1949/1424/5302//M/M//090/15/5.8

Sea suddenly became calm over this area near the apparent center of circulation inculation as determined by radar and TIROS. Note, however, that little or no shift in winds could be detected from the winds at flight level determined from the aircraft flying the north track. A weak wave over this area may have possibly been indicated by the shift in winds shown by the aircraft flying the south track (figure 5).

1959/1416/5444//M/M/075/24/7.0

Sky was still overcast with Cs at this time. Build-ups were apparent to the north and southwest. Figure 14B shows the best view at this time and indicates that the circulation, centered near 15°0'N, 53°30'W. at time of TIROS pass (1644, figure 9) had moved westward by about one degree during the 3-hour lapse until the aircraft traversed the same area.

Picture S 2008/1410/5523//N/13//095/22/6.0

Picture shows conditions "breaking out" of the disturbed area. A pronounced clear channel is visible extending north along the edge of the major cloud mass. (See also picture T).

Picture T 2010/1410/5525//N/13//M/M/M

A picture of the edge of the disturbance. The build-ups in this picture correspond to a portion of the band of clouds, visible in figure 14B extending diagonally from 14°N, 54°W to 16°N, 56°W. Note the sudden transition from the very suppressed cloudy conditions to the west, and in fact a probable downdraft condition extending northward along the edge of the band, to the intense upward vertical motion in the band and in the disturbance itself. The clear area corresponds to the downdraft area, which otherwise would have consisted of the low cloudiness shown to the west in Picture T. The thin Cs layer visible to the east in the picture was almost entirely unresolved by the TIROS camera. The clear cut transition in "breaking out" of the western edge versus the much more complex transition on entry to the east (near 16°N, 44°W) was a major and possibly fundamentally important characteristic of this disturbance.

Picture U 2011/1410/5525//S/13//M/M/M

This picture shows conditions to the south in the direction of feature (43), figure 12A and shown most clearly in figure 14B.

2018/1404/5606//M/M//095/18/+6.0

Very thin overcast Cs clouds were above streaked NE-SW. A scattered variable to broken Cu field appeared below. The Cu were aligned NW-SE. There is some suggestion of this alignment in the TIROS picture (figure 14A) in the area from 14-18°N and 56-60°W. The many small Cu elements were unresolved by the TIROS cameras. Streaks in the thicker cirrus cloudiness, visible in the TIROS pictures in the vicinity of Trinidad (figure 14A and 14B near 11°N,61°W) suggest a southwest flow aloft, verified by Trinidad's PIBAL for 1200GMT on 22 Sept 62. This indicated a 200 mb wind of 250°/25 knots. This relates well to the alignment of the thinner Cs located over the flight area and also verified by the 200 mb analysis of figure 3.

2034/1341/5711//M/M//085/11/6.0

Thin overcast Cs sheet was still overhead, with a field of small scattered, variable broken Cu below. A haze layer appeared to the west.

2046/1328/5801//M/M//095/11/6.8

The Cu became very suppressed in this area. TIROS view in figure 14B shows no detectable cloudiness in this area.

2106/Barbados//M/M//M/M/M

Sky condition was clear above with a broken Cu field over the island. The island of Barbados is visible because of this cloudiness in figure 14A.

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GLOSSARY

This list of terms is an annotated partial list of terms used in this report. The purpose of the list is to clarify the meaning intended when a term is used in a specialized or restricted way in this report. Although a few conventional terms are included, most of the terms represent relatively new refinements and usages. The set of newer terms represents a statement of a set of working definitions which have been developed, refined, and tested by use during a period of several years. Although the definitions are in a sense preliminary, as the process of refinement is a continuing one, most of them have reached a relatively stable status based on need, usefulness, and the natural limits involved. Most of the terms retain a more or less close relationship to earlier terms or earlier usages, that is, to the earlier terminology of meteorology and science generally. Other objectives were to avoid ambiguities and to meet the considerable need for improved terms which was made evident by the new meteorological satellite information. Increased precision was sought, both for general categories and for specific conditions and phenomena. Few of the terms are included in the Glossary of Meteorology [4]. These terms generally have a different or more limited meaning in that glossary.

Since the scale referred to matters very much, at times critically, when such relative terms as "long", "large", and "distinct" are used, an attempt has been made to specify the scale in a general way by the use of the designators GOS, AOS, and TOS (see also Scale below). As a realistic "rule of thumb" approximation the ground observer scale (GOS) is generally (frequently, if not usually) an order of magnitude (about 10 times) smaller than the air observer scale (AOS), which in turn is about an order of magnitude smaller than the TIROS observation scale (TOS). Because the TOS is about two orders of magnitude larger than the GOS, and because of the TIROS resolution limits, much that is clearly visible on the GOS can not be seen at all on the TOS. Conversely, the TOS can reveal patterns, relations, and details which can not be seen effectively or can not be detected at all on the GOS. The AOS observations represent an important link or key which can very effectively reveal the relationships between the TOS conditions and the GOS conditions. Thus AOS pictures can provide a useful connection between GOS and TOS observations, as did also the narrow angle TIROS pictures. Although some of the terms have been generalized to apply on all three scales, others apply mainly or only on one or two scales as noted below.

AOS -
See scale.

Apparently cloud-free -
A very open RO (q.v.) condition (mainly TOS, but also AOS). See also "non-cloud".

Atmospheric regime -

A general term for atmospheric conditions which represent, generally over a limited area but at times over an extensive area, essentially a single type of condition. Such types may be quite simple or relatively complex. The most complex are not as complex as the more complex atmospheric systems (q.v.).

Thus atmospheric regimes are, in general, not the same as atmospheric systems, although atmospheric regimes may at times be considered to be atmospheric systems. Complex atmospheric systems commonly have atmospheric regimes as component subsystems.

This term refers to a particular condition or set of component conditions which is:

1) relatively distinct, hence relatively sharply separated from different conditions of adjacent areas,
2) relatively homogeneous horizontally, although some horizontal variation is usual,
3) in general, a recurring condition, often of frequent occurrence, although rare conditions are not necessarily excluded.

Such regimes occur in a wide variety of types. Major and minor regimes are distinguished. Some regimes have highly distinctive associated cloud patterns. Some represent characteristic states (q.v.). Many represent relatively undisturbed conditions. Each distinct type representing a particular type of atmospheric condition is necessarily indicative of the state of a component, generally a lower tropospheric component, of the controlling synoptic system. Thus, each is intimately related to, and contains information regarding, components of the regional synoptic systems.

Atmospheric systems -

A very general term which refers to thermodynamic and hydrodynamic (hydro-thermodynamic) components of the atmosphere of varying degree or organization, complexity, and scale, which for certain purposes can be usefully considered to be distinct entities. They are generally relatively highly organized, and are usually relatively distinct with relatively sharp natural boundaries. Many are disturbances (q.v.). They are often revealed, more or less clearly, by their associated clouds, but are not, in general, the same as cloud systems (q.v.). Many have associated cloud systems, which are often composed of a variety of cloud formations (q.v.). In general, they consist of more than their component cloud systems. At times, however, a cloud system may usefully be considered to be a lesser atmospheric system or subsystem.

Atmospheric systems of the tropics include: the tropical cyclones (q.v.); systems or disturbances of the zone of "the ITC" (q.v.); other disturbances (q.v.); mesoscale eddies, eddy groups, and vortical cloud systems; extensive convective regimes (q.v.); isolated cumulonimbus groups and lines; shear line subsystems; small upper level cyclones and anticyclones; and many other atmospheric conditions. Major and minor systems are distinguished. Distinct atmospheric regimes (q.v.), some representing relatively undisturbed conditions, such as the undisturbed trade flow regimes, are included. The larger mesoscale, synoptic scale, and more significant systems are implied, unless otherwise indicated, when this term is used in a general sense.

Cellular field -
See cloud field.

Characteristic states -
A rather specific term, based primarily on meteorological satellite information (TOS), which refers to atmospheric states, atmospheric regimes (q.v.), or atmosphere subsystems, which have associated cloud patterns which are distinctive, often highly distinctive, in a variety of respects; which are presumably to some degree diagnostic; and which recur relatively frequently. Such states are commonly characteristic at specific regions, and may be characteristic of specific synoptic conditions. Each is presumed to represent a limited range of atmospheric states or a particular type of synoptic condition. Both undisturbed and disturbed states of the atmosphere are included. A relatively high degree of organization and of organization and of homogeneity (TOS) is implied.

Clear -
Cloud free over the area considered (GOS, AOS). In the case of TOS conditions it is best to avoid the use of this term, for a truly cloud-free condition cannot be determined with certainty without the use of supplementary information.

Cloud band -
A very general term which refers to a cloud formation or cloud group (GOS, AOS, TOS) which has a distinct long axis and is significantly longer than wide. The length is generally more than 2 or 3 times the width, and is commonly much greater than the width. Bands may be hundreds even thousands of miles long. Bands are generally considered to be more than one basic cloud unit (q.v.) wide, and may be many cloud units wide. They may also be a continuous cloud layer equivalent in width to many basic cumulus cloud units. Bands may be very large (GOS, AOS, TOS), or may be small (GOS, AOS). They are generally larger than cloud lines (q.v.). Bands may include component bands, and thus show more or less marked subbanding, or multiple banding. Bands may be of many types including: cumuliform bands, trade cumulus bands, cellular bands, stratiform bands, cirrus bands, cumulonimbus bands, frontal bands, and others. They occur frequently in the atmosphere and on all scales (GOS, AOS, TOS).
See also: cloud lines.

Cloud condition -
The most general term referring to the state or condition of the atmosphere with respect to its clouds and cloud free areas.

Cloud details -
A very general term which refers to any details, subdivisions, or structure of clouds as seen on several scales (GOS, AOS, TOS). The smaller details are often, but not necessarily, implied.

Cloud element -
See cloud unit.

Cloud field -

A type of cloud group (GOS, AOS, TOS) which: (1) consists of individual clouds, cloud units, or small cloud subgroups that are generally distinctly separated and are often relatively widely separated (the group then including much cloud-free area); and (2) represents a significant degree of order (i.e. non-randomness of distribution). Cloud fields may consist of very small units, or large units; may be very open, or consist of units which are quite closely spaced; and may be very extensive or of very limited extent. Many types of fields are clearly cumuliform in nature. Others consist of units which are essentially stratiform in nature. Although some cloud fields are cellular, hence may be termed cellular fields, other cellular formations are not cloud fields according to this usage. Thus, in general, cellular cloud fields represent a special type of cloud field as well as a special type of cellular formation. Fields of cloud lines and of small (AOS, TOS) bands, occur commonly in the tropical trade wind zones. In general, cloud fields have distinctive, often highly distinctive, associated cloud patterns (q.v.).

Cloud formation -

A very general term which refers variously to a cloud unit (GOS, AOS, TOS) (q.v.), an extensive cloud layer or cloud shield (q.v.), or a large or small cloud group (q.v.); which represents a relatively continuous, and homogeneous cloud condition (q.v.); and which has a relatively well-marked and continuous boundary so that it can be reasonably considered to be a distinct and separate entity. Cloud formations may be very extensive, but usually do not cover a major region, and if they do, usually do not do so for long. They are normally not sufficiently extensive to cover a major land mass or most of an ocean. Cloud formations may also be of very limited extent (GOS, AOS, TOS). Cloud formations may show much structure, pattern, and evidence of organization or order, or may have no evident structure, pattern or indication or organization. They may be persistent or highly transient.

Larger cloud systems (q.v.) generally consist of several cloud formations, as in strong cold front cloud systems, extratropical cyclone cloud systems, and tropical cyclone cloud systems.

Cloud group -

A very general term which refers to aggregations of clouds or small cloud formations (GOS, AOS, TOS) which consist of 2 or more separated, discrete cloud units (q.v.) or elements (GOS). As most cumuliform formations seen in TIROS pictures, particularly if they are at all sizable (TOS), are groups in this sense, the term may be used to refer to small (TOS) isolated clouds, cloud formations or cloud "units". A variety of distinctive types of groups have been observed, including cloud lines, bands, fields, cellular arrays, and others with distinctive patterns. Groups may be of very limited extent (GOS, AOS, TOS) or may be extensive. They often represent a significant degree of organization or order.

Cloud lean -

A cloud condition observed when clouds have sufficient vertical development through atmospheric layers with appreciable vertical gradients of the horizontal velocity component. It occurs very frequently in trade cumulus formations. In trade flow with little variation of wind direction with height, and a speed maximum at an intermediate level, cloud towers below the speed maximum level often have tops that lean downstream conspicuously. Towers with bases near the speed maximum level have tops that lean upstream, at times conspicuously. Towers or turrets which extend from below the speed maximum level to well above it have lower portions that lean downstream, and upper portions that lean upstream, so that the towers are ⟨ -shaped or (-shaped, and the speed maximum level is indicated by the downstream-most part of the tower. These effects may be weak or they may be strongly marked. In more complexly varying fields of flow, turrets may lean in different directions at different levels, and may even appear to spiral upward. Useful information concerning relative motions in the lower troposphere may be obtained, at times almost continuously, from observations (GOS, AOS) of the cloud lean conditions of the more informative cloud towers (notably the tall narrow ones).

The direction of the cloud lean is not always clear in a single aircraft picture. Most direction determinations were made during the flights by means of 3-dimensional vision and perspective changes observed as the aircraft passed leaning clouds.

Cloud line -

A general term referring to those ordered cloud groups (q.v.) which are at least several basic cloud units (GOS, AOS) long, but are, in general, only one cloud unit wide. They are frequently many cloud units long. The cloud units referred to here are a particular type of cloud unit. They are the generally distinct basic individual clouds of which the lines are composed. These components are, in general, distinct basic entities even when they subdivide more or less distinctly laterally or vertically into lesser components (as they frequently do) to become, in fact, small groups. Cloud lines may consist of very small (GOS, AOS) basic units, such as those which are small fair weather cumulus or fractocumulus clouds. Trade cumulus cloud lines occur frequently over extensive areas of the tropical oceans, and commonly occur at or near islands. They are usually very much longer than wide, and may be over 100 miles long. Some cloud lines, including some squall lines, consist of quite large (GOS, AOS) units, the largest being active cumulonimbus clouds.

The larger cumulus lines, of cumulus congestus or cumulonimbus basic units, are at times referred to as bands (GOS, AOS) (see cloud band), and grade into bands as they become distinctly more than one basic unit wide.

Cloud lines may be considered to be a particular type of band, an extreme or limit in the continuum of band types. However, when a cloud group is known to be line, that term is normally used to designate the group, and the term band is generally used to refer to the other types of bands. Very long and narrow (TOS) cloud formations, of basic units that are not resolved, or which are apparently generally wider than one basic unit, are properly referred to as long, narrow bands. Lines (TOS) of cloud units which are larger than the individual basic units, such as certain stratocumulus small groups, are properly referred to as bands, or alternately, as cloud unit rows, or cloud rows. Cloud streets, according to the early, restricted, specialized (and preferred) meaning of the term, are a particular type of cloud line.

Cloud pattern -

A general term which refers to evident structure (GOS, AOS, TOS) of cloud formations or of distributions of cloud units (q.v.), cloud formations (q.v.), and RO (q.v.) units or areas, which reveals a significant degree of order (or non-randomness) or organization. The order may be distinctive and characteristic. It may be complex or relatively simple. It may occur frequently or rarely. It may be relatively indistinct. Related patterns may vary greatly in degree of development, hence in detail and in evident pattern. Distinctive patterns are associated with the ordered types of cloud groups, such as cloud lines and cloud line arrays, certain cloud bands, open cloud fields, cellular arrays, and others. Distinctive patterns are also associated with many cloud systems, notably vortex cloud systems. Characteristic states (q.v.) of the atmosphere have associated cloud patterns which are characteristic in a variety of respects and are presumed to be diagnostic. Truly random conditions are normally excluded, so that it is normally improper to refer to a "random pattern", although it is reasonable to refer to the degree of randomness of a pattern.

Cloud plume -

A cloud formation (GOS, AOS, TOS) which extends mainly downstream and thus asymmetrically from its generating source cloud. Important and very effective plume generators are large active cumulonimbus clouds, which during favorable conditions characteristically produce anvil top plumes and frequently produce very prolonged plumes. These are widely distributed over land and ocean areas of the warmer regions of the earth. The cirrus plumes produced may taper to an apparent point downstream, or may be bandlike and not taper appreciably, or may spread laterally downstream to form a small cirrus fan or a small cirrus shield. Adjoining plumes may merge to form an extensive and dense cirrus shield.

Cloud row -

See cloud line.

Cloud shield -

A cloud formation (GOS, AOS, TOS) which is generally relatively extensive and continuous, hence represents an overcast condition over a substantial area; and which is relatively sharply bounded, commonly having a long, very distinct edge. A shield may be very thick, or optically dense, or may be very thin. A shield is characteristically a product of a relatively large scale cloud generating process. Thus shields, of some degree of development, are characteristic of developing extratropical cyclones, distinct warm fronts, major tropical cyclones and certain active cumulonimbus clouds and groups.

Cloud street -

See cloud line.

Cloud system -

A general term which refers to an individual cloud, or a group of clouds, or other cloud formations (q.v.), or a complex combination of several cloud formations or types of cloud formations, viewed as an organized physical system (i.e. as a hydro-thermodynamic system). In contrast, cloud formations are defined solely by geometrical considerations. Many cloud formations are also cloud systems. However, cloud systems need not qualify as cloud formations, and often have formations as components or subsystems. A cloud system, whether simple or complex, is, in general, a distinct entity with relatively sharp natural boundaries. The term generally implies relatively complex major systems, with distinct and significant component subsystems, unless otherwise indicated. Some systems recur relatively frequently; others may be rare or represent an infrequent extreme degree of development.

Well known cloud systems are: well developed squall lines, cold front cloud systems, and the complex cloud systems of extratropical and tropical cyclones. A cloud system is, in general, a component or subsystem of a more inclusive atmospheric system (such as the typhoon cloud system of the atmospheric system which is the typhoon). When convenient a cloud system may also be considered to be a type of atmospheric system.

Cloud unit -

A general term, used for convenience, which refers variously to: 1) an individual cloud (GOS, AOS), such as a fair weather cumulus cloud or a cumulus congestus cloud; 2) a small, usually sharply bounded, cloud formation (GOS, AOS, TOS) or group (mainly TOS); or 3) any apparent (TOS) unit, or TIROS picture "small white spot" or cloud "bit".

A cloud unit is not clearly subdivided into distinctly separated comparable subunits or components. Cloud units may be isolated or they may be closely spaced. Cloud units are the evident unitary components of cloud groups.

Cloud lines (q.v.) are composed of a particular type of cloud unit.

The term is, in certain respects, an alternative to the ambiguous and unrealistic "cloud element" when used as a general term. The term "cloud element" (AOS, TOS) is to be avoided. As usually used it refers to cloud formations which are rarely true elements in any logical or natural sense. In general, better alternative terms are available. The term "element" as used in GOS and AOS research can have a precise and realistic application, but is then necessarily a highly technical and specialized term.

Data gap area -

An area with no conventional meteorological data on a particular day or during a succession of days. Satellite information may be available, however. (compare with sparse-data area [q.v.]).

Disturbances -

A very general term, not synonymous with "tropical disturbances" (q.v.), which refers to a variety of atmospheric conditions which may be considered to be developments in, major alterations of, or departures from normal "undisturbed" conditions. In general, significant or relatively large deviations from the prevailing condition or set of conditions are implied. Such developments include: systems of enhanced convective activity, cumulonimbus groups, extensive unusual cloud systems (as in the upper troposphere), upper (distal) cyclones and associated activity, tropical disturbances and tropical cyclones generally, systems in the zone of "the ITC", and many other conditions. In general, disturbances represent types of atmospheric systems. As disturbances occur on a wide variety of scales, and may represent a rather wide range of degree of development, it is necessary to indicate what is being referred to when this term is used in a restricted sense; otherwise full generality is implied.

Early stages of tropical cyclones -

This refers to all early stages which have a detectible cyclonic circulation (with respect to the basic flow within which they occur), whether they develop further or not, and whether they are detectible by conventional means or not. This category is intended to be more general and more inclusive than that of "tropical disturbances" as conventionally defined.

Easterly wave -

A term for a particular type of atmospheric system which resembles more or less closely the "classical" model developed by H. Riehl [7], and which is normally detected by means of conventional synoptic charts and time-sections.

Such a wave is a disturbance in an easterly trade current which has characteristically; a generally north-south axis; a very cloudy, often showery, part which is generally east of the axis; a weak surface pressure trough; a wind shift which is generally more marked aloft in the lower troposphere than at the surface; and a generally westward movement. Such waves vary rather widely in degree of development and distinctness. They often form an east-west sequence of waves, some very weak and indistinct, others quite distinct. Some, perhaps many, include a distinct closed circulation aloft. Others apparently lack any appreciable horizontal circulation. They may represent more than one type of atmospheric system. Such waves are of a scale that is relatively well observed by the TIROS satellites. A variety of distinct densely cloudy cloud systems, rather different in extent and appearance, but clearly associated with easterly waves, have been recorded in the satellite pictures. Other similar cloud systems observed by the satellites may well represent atmospheric systems of this general type or of closely related types.

Extensive convective regime -

A type of atmospheric regime (q.v.) which is both extensive and characterized by convective activity. Such a regime may represent weak or strongly suppressed convective activity, as at an open field (q.v.) of small trade cumulus cloud units, or may represent intense convective activity (q.v.), as at an extended group of cumulonimbus clouds in the zone of "the ITC". Such regimes generally have cloud units which are distinctly (GOS, AOS, TOS), cumuliform in type, but regimes characterized by stratiform cloud units also occur commonly. Such regimes generally have highly distinctive associated cloud patterns (q.v.).

Flight area -

See flight track area.

Flight track area -

The total surface area which was visible from the research aircraft, or would have been visible during good viewing conditions. This area may be extended to include areas which could not be seen because they were beyond the apparent horizon, but which were under clouds which were observed from the aircraft.

GOS -

See scale.

Intense convective activity -

A general term which refers to cumulus convection ranging in intensity from: 1) conditions characterized by groups, generally relatively extensive, of large towering cumulus clouds, such as large trade cumulus and cumulus congestus clouds; through 2) conditions with glaciating trade cumulus and cumulus calvus clouds or groups; to 3) conditions with cumulonimbus clouds and cloud groups, including cloud and atmospheric systems which have cumulonimbus clouds and groups. Marked organization may be present, but is not necessarily implied. Atmospheric conditions of these types occur frequently at many tropical areas. Conditions of these types occur characteristically in the zone of "the ITC". Conditions of these types are commonly considered to be disturbed conditions or disturbances (q.v.). Many are strongly controlled by terrestrial topographic and surface conditions. Some of these convective conditions are types of atmospheric regimes (q.v.). Others occur in, and often are characteristic of, well organized systems such as tropical cyclones.

"ITC" system -

Here the same as: system of "the ITC" (q.v.). See also "the ITC".

ITCZ -

The intertropical convergence zone as conventionally defined [4]. See zone of "the ITC".

Mosaic -

A composite of TIROS pictures formed by matching cloud details seen in successive pictures (as opposed to one formed by matching longitude and latitude lines of gridded pictures). This process gives a good integrated view, but commonly introduces a significant distortion which causes the mosaic to be curved, sometimes markedly.

Non-cloud -

A term (mainly TOS) which refers to a clear area or volume, or "space", between clouds; or, in the case of "apparently non-cloud", a very open RO (q.v.) condition.

Terrain features and snow and ice are not referred to by this term in this report.

Northeasterly wind -

See winds.

Object nadir angle -

The angle at the satellite between the local vertical passing through the satellite and the line from the satellite to the cloud unit or other object specifically referred to.

Observation pass -

A pass (q.v.) during which a satellite obtained a picture, pictures, or a picture sequence. An observation pass is usually, but not always, an earlier pass than the corresponding readout pass (q.v.), and may be over 10 passes earlier. The same as picture-taking pass.

Pass -

A portion of a satellite "orbit" during which a satellite was read out by a ground station (readout pass) or during which a satellite obtained observations (observation pass). An orbit here refers to one complete circuit of the earth by a satellite, considered to begin as the satellite crosses the equator going northward (i.e. at an ascending node) and to end when the satellite next crosses the equator going northward (i.e. at the next ascending node). Orbits are numbered by successive integers, orbit 1 commencing when the satellite first crosses the equator going northward.

A readout pass takes the number of the orbit of which it was a part. An observation pass takes the number of the orbit of which it was a part, or of the orbit the satellite was completing when the observations began. Thus when observations continue as a satellite begins the next orbit an observation pass consists of adjoining portions of two orbits.

Pass number -

See pass.

Picture taking pass -

The same as observation pass (q.v.).

Primary pass -

An observation pass (q.v.) which was made at a time when a research aircraft was flying over the area observed. Thus during a primary pass some part of the total area observed by the satellite was observed simultaneously from an aircraft, while contiguous parts were also observed from the aircraft and by the satellite but with time differences which increase with distance from the point of simultaneity.

Readout pass -

A pass (q.v.) during which a satellite was "read out" and the satellite observation information acquired at a ground station.

RO -

See relatively open.

Relatively open (RO) -

A general basic category of "sky condition" [4] or cloud condition (TOS, AOS, GOS) which includes those characterized by areas having a small fraction covered by clouds (AOS) or by areas which appear to have a small fraction covered by clouds (TOS). Areas having these conditions are better considered to have large fractions which are cloud free (AOS) or apparently cloud free (TOS). Clear areas are included.

Most frequently the conditions referred to are at the low cloud level, although the term applies to all levels. If the cloud units are small (GOS, AOS, TOS) the open fraction may be as small as 6/10, but is generally larger (GOS, AOS). The apparently open fraction (TOS) may have a cover which is broken or even a thin overcast (GOS, AOS). If a large cloud formation (GOS, AOS, TOS) occurs in or near the area considered, the open condition extends up to but does not include the extensive and relatively cloudy or overcast condition. Thus, in general, large cloud formations are excluded, even if widely scattered in distribution. The white spots or areas in TIROS pictures are cloud units or formations; the dark spots or areas are RO units or areas (which, in general, are <u>not</u> cloud-free areas). RO areas may be small or extensive, and may take the form of lines, bands, "spiral arms", fields and other namable forms.

In general, cloud patterns (TOS) consist of an organized, often characteristic, distribution of white (cloud formations) and dark (RO areas).

Scale -

Three scale sizes are distinguished: 1) TOS, the TIROS observation scale (wide angle camera picture scale); 2) AOS, the air observation scale (referring mainly to aircraft flying about 10,000 feet or higher); 3) GOS, the ground observer or ground observation scale. The TOS is about two orders or magnitude greater than, and the AOS is about one order of magnitude greater than, the GOS.

See also glossary introduction.

Sparse-data area -

Any relatively extensive area for which very little conventional atmospheric data were obtained during the course of a season, year, or period of years in the recent past, or are being obtained at present. The same as data-sparse area.

System of "the ITC" -

A significant atmospheric system (q.v.) or major cloud system (q.v.) occurring in the zone of "the ITC". Many of these systems are characteristic of the zone of "the ITC".

See also: "the ITC", and: zone of "the ITC".

"The ITC" -

The term ITC (for intertropical convergence) as it has been used and is still used conventionally refers loosely to a variety of concepts and a variety of tropical conditions which occur in or near the equatorial trough zone. It is often viewed as a narrow zone where the northeast trades and southeast trades meet or "intersect". It is perhaps more often viewed as a very long narrow zone, or band, of intense convective activity and stormy weather, which is about 1° of latitude wide and extends essentially continuously for thousands of miles zonally. It is still viewed by some as a frontal condition. These and other concepts are unrealistic as generally applied, although they have some validity at specific places and times. They are generally based on very little or no (i.e. inadequate) data and on questionably interpreted climatic data.

The term "the ITC" has been introduced here in a transitional attempt to avoid using ITC simply, with its ambiguous meanings, fuzzy concepts, and generally unrealistic implications, but to stay close to the older terminology so that any reader may recognize immediately what is being referred to. The term "the ITC" thus is not the same as the term ITC, and does not refer to any previous concept.

The term "the ITC" refers to the real atmosphere; and refers collectively to the variety of conditions, phenomena, and cloud and atmospheric systems which occur in the near-equatorial active zone (here termed the zone of "the ITC") and many of which are characteristic of this distinct zone. Thus this term refers to the real entities, observed or understood or not, which correspond to the conditions which were encountered in the past and which have been described in terms of the various earlier concepts. The distinction is a practical and realistic one made possible by the abundance of information on the real conditions occurring in the zone of "the ITC" provided by the TIROS meteorological satellites. If "the ITC" is to be considered a single entity it must be considered to be a zonal sequence of generally distinct atmospheric and cloud systems which extends along the length of the zone of "the ITC", or along the lengths of its segments. Thus to see "the ITC" is really to see one or more of these systems, systems generally well observed by the TIROS satellites. In this usage local convergence is common, but not necessarily implied, and extensive RO (q.v.) areas, subsidence, and divergence may be present.

The term "the ITC" as used in this specialized sense is considered to be a temporary convenience term which refers to a particular set of real atmospheric conditions. The set doubtless merits a better term. One alternative is to focus on the zone in which the activity occurs, the zone of "the ITC" or ZITC, and refer to sequences of systems in the ZITC, or to individual systems of the ZITC.

See also: zone of "the ITC".

TOS -

See scale.

Tropical cyclones -

A very general term for tropical cyclonic systems of synoptic scale, whether weak or strong, or whether early, mature, or dissipating stages.

Tropical disturbance -

A conventional term [1] for a tropical cyclone having "no closed surface isobars and no strong winds", and a rotary circulation which is slight or absent at the surface but which may be better developed aloft.

Tropical storms -

The conventional term [4] for tropical cyclones having maximum winds stronger than 27 knots, but less than 66 knots.

Very open -

A RO (q.v.) condition (mainly TOS, AOS) with or apparently with very few or virtually no clouds. Clear (q.v.) conditions are included.

Winds -

The approximate direction designations: easterly, northerly, northeasterly, etc., indicate approximations of a specialized type. Thus easterly implies mainly close to from the east, generally inside the limits ENE and ESE, and not (or rarely) outside the limits NE and SE. Similar restrictions apply to the other directions. If a wind is mainly close to from the northeast, then northeasterly is used. If a wind is mainly close to an ENE wind, "easterly" may be used, or if emphasis on the north component is desired "northeasterly" may be used. Occasionally a term such as "east-northeasterly" is used, but this implies a smaller range of directions, so that, in this case, the winds would be generally very close to ENE, and not (or rarely) outside the limits NE and E.

ZITC -

See: zone of "the ITC

Zone of "the ITC" -

A generalized term used here to refer to that generally near-equatorial zone of the atmosphere in which occur the conditions, phenomena, and systems which correspond to what is usually referred to by the conventional term ITC (and related terms). It refers to the real atmosphere, and is the zone in which the real phenomena and systems occur whether they are observed or understood or not. This zone is not the same as the intertropical convergence zone (ITCZ) as conventionally defined [4, 6]. It may be reasonably designated the ZITC, to distinguish it from the ITCZ.

The ZITC is a restricted zone, generally of the order of 5° latitude in width, which may be very extensive zonally but may be subdivided into segments, hence is not necessarily continuous around the earth. It has generally sharp natural boundaries, and is a distinct zone over much of the earth. It has marked seasonal variations in position and extent and in the degree of development of the included systems. The conditions within it also vary significantly from region to region. It is, relative to the adjoining zones, a highly active zone. However, its presence does not invariably imply low level convergence, or relatively intense convective activity (q.v.). Extensive RO (q.v.) areas may be present within it, and appreciable subsidence and divergence may also be present. Thus the word "convergence" in the term may be considered to be a general term which includes divergence as negative convergence, the converse of common usage, but mathematically correct. It is, notably, the zone in or near the equatorial trough zone in which marked low level convergence and associated phenomena and systems characteristically do occur. Its position and extent are defined by the occurrence of its convective activity and component atmospheric systems, particularly as determined from the satellite information. This position and extent is related to, but not the same as, that of the ITCZ as determined by conventional means.

See also: "the ITC".

APPENDIX 1 - The doppler radar winds.

The winds along the southern track in figures 4 and 5 are shown for times separated by 20 minute intervals (with a few exceptions), starting at 1215GMT in figure 4 and at 1640GMT in figure 5. Those along the northern track are for times separated by the same intervals, but starting at 1225GMT in figure 4 and at 1650 GMT in figure 5 (see also Tables I and II). These winds are representative smoothed winds. They were obtained by averaging ten consecutive final print-out values approximately centered on (5 before and 4 after) the listed times and separated by ten-second intervals. Since in most of the sets of ten values the variability was relatively small, apparently random, and contained a large component of instrumental error this smoothing process was considered to be appropriate as well as convenient. For most, if not all, of these sets of wind values the corresponding vectorial means would not be significantly better or more meaningful. Plotted points which lack wind information, as at H2S and H4S (see footnote 3), have wind values which are considered to be seriously in error (see also table 1). Light and variable winds, which are not well determined by the doppler radar equipment, occurred at D3S and E1S. As the tabulated values for these times are considered to be nonrepresentative, other values which are considered to be representative and are based on determinations for slightly different times are plotted at D3S and E1S. The wind values at G2S, H1S, H2S, H3S, H4S, and H4N were also not representative, because of doppler radar difficulties and descent. The light easterlies observed along the southern track at these longitudes and reported in the half-hourly reconnaissance reports have not been plotted in figure 5. Ascent affected only two plotted values. On the southern track the aircraft was approaching the 11,000 foot level at A1, but by B1 was at the 12,700 foot flight level. On the northern track the aircraft was approaching the 12,000 foot level at A1, but was at the 12,800 foot flight level at B1.

APPENDIX 2 - Numerical and other information provided in the comments of Section 4.

The latitude, longitude, wind, and temperature values are corrected values taken from the RFF "NHRP 1" final printout. The wind and temperature values are spot values for the second indicated at the listed time. Such wind values are not necessarily the most representative values available. More representative mean winds are shown in Figures 4 and 5. The temperatures are highly representative, and have been adjusted to a common reference level, the 12,000 foot level. The flight altitude, determined by radar, was generally near 12,500 feet. Altitudes significantly different from this are specifically noted.

The azimuth listed is a good approximation, refers to the picture center, and represents a 16 point compass direction. The sky code referred to is a slightly modified version of the tropical whole sky code developed by Dr. Joanne Malkus and others (Reference 5). The code text (not illustrated) and modifications are presented in Appendix 3.

Standard abbreviations are used to denote cloud types. A letter V after a wind direction marks a highly variable apparent wind direction, as occurred when the wind speed was too low for the doppler radar system to function effectively. A letter M indicates missing numerical information.

The identifier numbers and letters, shown in Figure 12, are used to refer to cloud formations, atmospheric systems, and other specific conditions and details which can be seen in the TIROS pictures. Figure 12 is intended to be mainly a means of labeling and locating these details. The same details are shown, in many cases better shown, in the other TIROS pictures including the unmarked pictures of Figure 13, the gridded pictures of Figure 14, and the mosaics of Figures 7 to 11. In certain cases these details are also shown in the hand-held camera pictures. The identifier numbers are used to refer to these details wherever they are shown. Many details (for example the numerous very open areas) are not labeled in Figure 12 nor referred to by number in this report. Most such details can easily be located in the TIROS pictures by using as reference points the details which are labeled. Identifier letters are used for the labeled islands.

APPENDIX 3a - Tropical Whole Sky Code

This code is for use primarily in coding aerial photographs (or visual observations) over the open seas in the tropics far from land masses. Categories 0-4 denote undisturbed trade-wind skies. Categories 5-9 cover weak or trade-wind type disturbances, while categories 10-16 relate to strong disturbances (deep easterly waves, equatorial trough disturbances or convergence, through typhoons). The letters (to be placed after the appropriate numbers) permit some further refinements or sub-specifications.

Trade-Wind Skies

0 No clouds at all, or a few suppressed, or small numbers of very suppressed cumulus. Upper cloud 1/10 or less.

1 Inversion-dominated: trade cumulus spreading out into stratocumulus, definite signs of stratiform but total sky cover less than about one-half.

2 Extensive strato-cumulus decks, more than about one-half total sky cover.

3 Average trade cumulus sky, no particular organization into lines. No significant upper clouds. No marked shear. Tops 8,000-10,000 or less, precipitation unlikely.

4 Average trade cumulus sky, but with marked organization into rows or lines. No significant upper clouds. No marked shear. Tops 8,000-10,000 or less. Precipitation unlikely.

5 Average trade cumulus sky with upper sheet clouds up to broken. No marked organization or shear. No precipitation.

6 Marked organization of convection, rather large convection clouds (not cumulonimbus) in view, with extensive clear or almost clear areas. Upper sheets to broken may be present.

7 Suppressed trade cumulus sky with upper sheets broken or overcast but not precipitating. No marked shear or organization in cumulus.

8 Above average cumulus activity, high tops, occasional cumulus congestus. Showers suspected or seen. Upper cloudiness less than broken. No marked shear or organization of cumulus.

9 Above average cumulus activity, high tops, occasional cumulus congestus. Showers suspected or seen. Upper cloudiness broken to overcast. No marked shear or organization.

10 Occasional cumulonimbus, no obvious organization, no significant or extensive independent upper sheet clouds. Indicate component of shear in plane of film.

11 Rows or suspected organization of cumulonimbus, no extensive or significant independent upper clouds. Indicate component of shear in plane of film.

12 Cumulonimbus and partial coverage of independent upper sheet clouds. Cirrus, altostratus and/or altocumulus.

13 Substantial upper cloud coverage, suppressed convection over wide clear areas, except some cumulonimbus visible. Precipitation from upper clouds absent or unlikely.

14 Rain from upper sheets (overcast or almost overcast) cumulonimbus indistinct, picture dark.

15 Rain from upper overcast, cumulonimbus still suspected but not clearly visible, picture dark and disturbed.

16 Upper overcast raining, no cumulonimbus seen or suspected, suppressed low convective activity; picture dark and disturbed.

Postscripts (primarily for trade-wind skies)

o Marked organization into rows or line.

s Shear obvious; indicate component in plane of film.

c Apply to 1 or 2 if cumulus tops are seen poking through the stratus.

d Distant disturbance - evident from high clouds low on horizon.

- Weaker, more suppressed or less development than normal for category.

(From J. S. Malkus et.al. [Reference 5])

APPENDIX 3b - The Modified Tropical Whole Sky Code

The tropical whole sky code as presented in Appendix 3a, was developed to describe aircraft-observed oceanic conditions in the trade wind regions of the North Atlantic and Pacific, with an emphasis on conditions observed at the central and western parts of the subtropical anticyclones which control the trade winds of these regions. For conditions in these regions the code has proved to be effective, revealing, and useful. TIROS pictures suggest, and flight experience confirms, that the code applies less well for: 1) the very different conditions of the far eastern parts of the tropical North Pacific and Atlantic, and 2) flights in one regime which are near and approximately parallel to the boundary of another regime, such as was the case during the 22 September 1962 Cape Verde flights which were to the north of and roughly parallel to the ITC. The code was not developed to cope with tropical coastal and continental conditions.

The basic categories of this code specify particular conditions, such as "no marked shear" and "no marked...organization of cumulus", usually in characteristic combination. A postscript is used to indicate presence of a condition which is otherwise specified to be absent. Other postscripts provide additional information.

In applying the code in this work a modification has been utilized which preserves the basic categories and postscripts (hereafter referred to as "first position postscripts") but includes more first position postscripts to indicate the presence of additional conditions and includes a preliminary set of second position postscripts to provide additional information. This scheme permits a better correspondence between code category and observed condition, and permits a useful increased flexibility. Refinement of the postscripting system, and inclusion of a few more basic categories, may well be all that is needed for this code to apply generally throughout the tropics and at continental as well as at oceanic areas.

The modification used in this report consists of additions as follows:

A) first position postscripts:

1) p for "precipitation present"
(precipitation from cumulus in #3-6, 8, 9 and from upper clouds in #13)

2) u for "broken, overcast, or significant upper clouds"

3) v for "low cumulus very suppressed, or generally absent"

4) c (can be used with numbers other than 1 or 2)

B) second position postscripts:

1) with u:
   uc for "broken or overcast cirrus"

2) with o:
   os for "small scale organization"
   ol for "large scale organization"
   ob for "both large and small scale organization"

3) with s:
   ss for "marked shear on small scale"
   sl for "marked shear on large scale"
   sc for "marked shear indicated by cirrus"

4) with d:
   df for "distant disturbance, in far distance"
   dn for "distant disturbance, in near distance"
   dc for "distant disturbance, evident from cirrus which is in near distance or overhead"
   dw for "distant disturbance, evident from high clouds low on horizon" (which is the original definition of d)

C) other modifiers:

A ' indicates that the code, even as modified, does not fit the observed situation very well.

A comma followed by another letter indicates that this letter is another first position postscript (which may also be the first letter of a postscript pair).

These modifications should be considered to be preliminary and tentative and subject to further change and refinement.

Although illustrated by single photographs, the conditions coded refer to the whole sky, hence may take into account information not contained within the single photographs.

APPENDIX 4 - Camera Information

1. Crown Graphic Camera:

focal length:	65 mm.
lens:	F 6.8
angle of view:	height 23.9°, width 32.5°
negative size:	2 1/4 x 3 1/4

2. Cine Kodak Royal 16 mm. hand camera:

focal length:	15 mm.
lens:	F 2.5
angle of view:	(unknown)

3. DC-6 16 mm. nose and side cameras:

focal length:	9.5 mm. (nominal)
lens:	F 2.2 Angenieux
Side camera axis:	90° to aircraft axis, on left side only, up 2 1/2° from horizontal.
Nose camera axis:	17 1/2° to right of aircraft axis, up 5 1/2° from horizontal.
angle of view:	58° (nominal)
model:	Flight Research Inc. No. 3B

APPENDIX 5 - The Grids of Figure 14

The grids were fitted to the corresponding pictures with great care using the following primary constraints:

1) Positions of islands, particularly those of island groups.

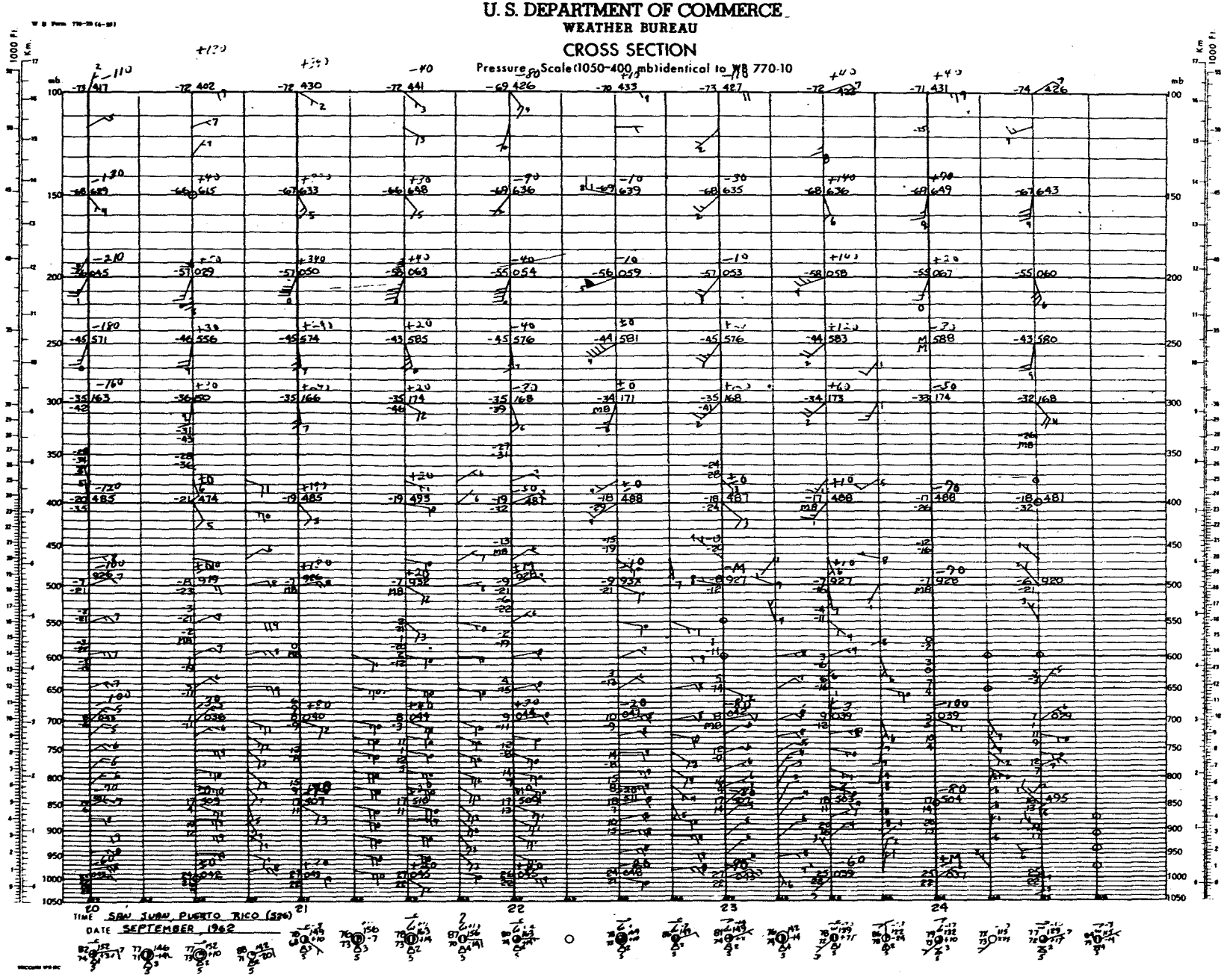
2) Consistency of coordinates of most if not all cloud details and configurations in gridded frames of a single pass.

3) Consistency of coordinates of corresponding cloud details seen more or less clearly in adjacent passes.

4) Consistency of plotted flight track and known position of track relative to cloud formations observed both from the aircraft and by the TIROS satellites.

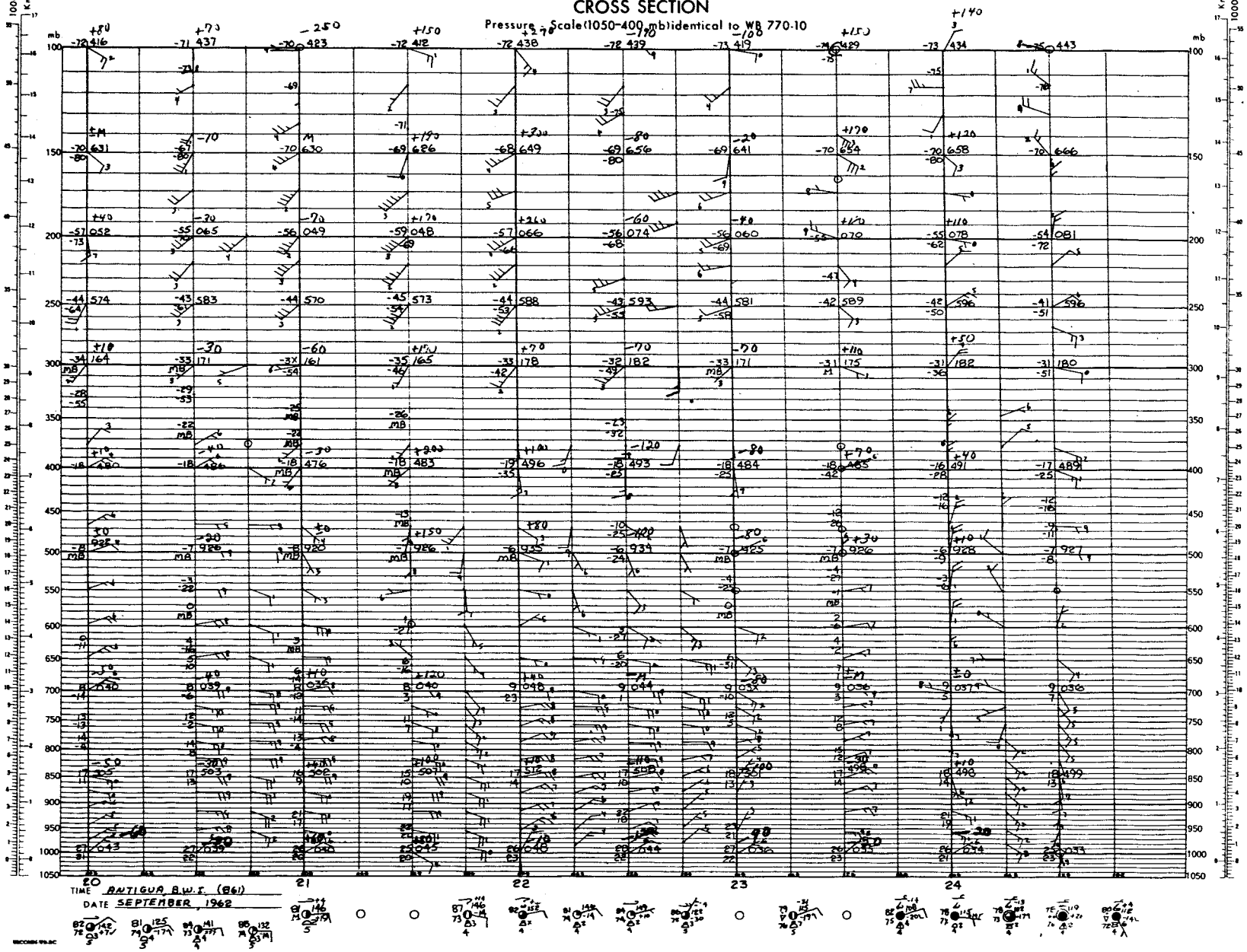
As all four constraints applied well in the cases of passes T6 W62(61) and T5 P1365(1364) the grids for the pictures of these passes could be fitted with almost no residual uncertainty. Constraints 2) to 4) applied well in the case of pass T5 W1364(1363), consequently the grids for the pictures of this pass could be fitted with a very small residual uncertainty. In the case of pass T6 W63(62) the constraint 2) applied well but the constraints 3) and 4) were less binding because of the time differences between the pass time and flight times, because of the difference between the time of this pass and the time of the adjacent pass to the east, and because of rapid changes in cloud conditions. In this case the three constraints were applied as carefully as was possible, but more weight was given to the positions of the corner fiducial marks. The final fitting agreed well with the independent G-15 indications and very well with the aircraft observations.

The gridding accuracy is believed to be better than ±1/10° generally, and perhaps as poor ±2/10° at the eastern side of the pass T6 W63(62) pictures where the residual uncertainty was greatest (although the accuracy there may well also be better than ±1/10°).


U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU
CROSS SECTION
Pressure Scale (1050-400 mb) identical to WB 770-10
mb
1000 Ft.
Km.
20
21
22
23
24
TIME
SAN JUAN, PUERTO RICO (SJU)
DATE SEPTEMBER, 1962

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU
CROSS SECTION

Pressure Scale (1050-400 mb) identical to WB 770-10



APPENDIX 7

Table Ia (Northern Track) 20922A *

Designator	Time (GMT)	Wind Direction	Wind Speed	Latitude (°N)	Longitude (°W)
	1200:04.1	99.6	010.6	16°41.3'	23°9.4'
	1205:04.1	103.0	013.5	16°40.3'	23°24.8'
	1210:04.1	103.4	014.4	16°40.2'	23°40.2'
	1215:04.1	119.8	014.2	16°40.1'	23°56.1'
	1220:04.1	122.8	018.3	16°40.4'	24°12.4'
A1	1225:04.1	117.6	012.4	16°40.5'	24°28.9'
	1230:04.1	106.3	005.9	16°40.2'	24°46.1'
	1235:04.1	120.6	008.0	16°40.4'	25°5.8'
	1240:04.1	118.2	007.3	16°40.0'	25°26.0'
B1	1245:04.1	120.1	007.8	16°39.3'	25°46.2'
	1250:04.1	106.7	005.5	16°38.6'	26°6.3'
	1255:04.1	110.9	006.2	16°37.7'	26°26.3'
	1300:04.1	93.4	007.6	16°36.8'	26°46.3'
B2	1305:04.1	106.1	006.6	16°35.8'	27°6.4'
	1310:04.1	93.9	004.8	16°34.9'	27°26.2'
	1315:04.1	144.5	005.8	16°34.2'	27°46.0'
	1320:04.1	168.3	006.3	16°33.6'	28°5.8'
B3	1325:04.1	157.0	006.5	16°33.2'	28°25.5'
	1330:04.1	165.6	007.0	16°32.5'	28°45.6'
	1335:04.1	154.7	007.2	16°31.7'	29°5.8'
	1340:04.1	166.9	005.1	16°31.1'	29°25.9'
B4	1345:04.1	245.2	012.4	16°30.2'	29°45.8'
	1350:04.1	248.1	022.4	16°29.3'	30°6.0'
	1355:04.1	130.7	006.9	16°29.2'	30°24.0'
C1	1400:04.1	250.3	019.1	16°29.0'	30°40.1'
	1405:04.1	259.0	042.2	16°28.1'	31°0.2'
	1410:04.1	267.9	033.4	16°32.7'	31°5.3'
	1415:04.1	234.6	002.8	16°32.0'	31°23.7'
C2	1420:04.1	178.9	097.0	16°45.4'	31°30.1'
	1425:04.1	218.3	016.9	16°59.9'	31°43.5'
	1430:04.1	99.5	022.1	17°5.7'	31°56.2'
	1435:04.1	191.2	003.1	17°4.6'	32°16.5'
C3	1440:04.1	283.4	005.6	17°2.8'	32°36.6'
	1445:04.1	268.0	015.0	17°1.2'	32°56.4'
	1450:04.1	268.0	015.0	16°59.0'	33°14.4'
	1455:04.1	115.0	004.7	17°04.2'	33°40.0'
C4	1500:04.1	107.9	003.4	17°2.9'	34°0.4'
	1505:04.1	135.6	004.9	17°1.4'	34°20.8'
	1510:04.1	119.6	003.4	16°59.9'	34°41.4'
	1515:04.1	84.6	002.7	16°58.3'	35°1.7'

*Aircraft number

Table Ia (Northern Track) 20922A-(Cont.)

Designator	Time (GMT)	Wind Direction	Wind Speed	Latitude (°N)	Longitude (°W)
D1	1520:04.1	051.9	003.9	16°56.5'	35°21.8'
	1525:04.1	051.9	004.0	16°54.5'	35°42.1'
	1530:04.1	045.5	004.6	16°52.5'	36°2.4'
	1535:04.1	009.4	007.4	16°50.2'	36°22.7'
D2	1540:04.1	007.2	007.6	16°47.7'	36°42.9'
	1545:04.1	011.0	011.1	16°45.2'	37°3.3'
	1550:04.1	007.4	010.4	16°42.7'	37°22.7'
	1555:04.1	015.3	011.3	16°40.1'	37°42.7'
D3	1600:04.1	012.3	010.9	16°37.5'	38°2.6'
	1605:04.1	019.3	012.9	16°35.1'	38°22.7'
	1610:04.1	017.9	013.1	16°33.4'	38°43.2'
	1615:04.1	015.5	014.6	16°31.6'	39°3.7'
	1620:04.1	014.2	013.9	16°29.9'	39°23.9'
D4	1625:04.1	016.0	012.3	16°28.1'	39°44.9'
	1630:04.1	025.9	011.2	16°26.5'	40°4.5'
	1635:04.1	025.8	011.3	16°24.2'	40°24.6'
	1640:04.1	040.2	009.0	16°22.1'	40°45.1'
E1'	1645:04.1	038.6	007.5	16°20.5'	41°5.8'
E1	1650:04.1	035.9	005.8	16°18.9'	41°26.0'
	1655:04.1	038.7	007.5	16°17.4'	41°46.1'
	1700:04.1	042.4	009.0	16°15.8'	42°6.4'
	1705:04.1	065.4	005.8	16°14.2'	42°27.0'
E2	1710:04.1	058.0	004.7	16°12.9'	42°47.2'
	1715:04.1	052.4	006.4	16°10.1'	43°7.6'
	1720:04.1	054.9	007.6	16°7.2'	43°27.9'
	1725:04.1	061.2	007.8	16°4.4'	43°49.2'
E3	1730:04.1	085.5	011.0	16°1.7'	44°9.9'
	1735:04.1	092.2	013.5	15°59.1'	44°30.8'
	1740:04.1	100.1	013.4	15°56.8'	44°52.2'
	1745:04.1	105.8	013.9	15°54.6'	45°13.4'
F1	1750:04.1	100.3	017.5	15°52.3'	45°34.2'
	1755:04.1	094.3	018.4	15°49.2'	45°56.0'
	1800:04.	093.0	017.0	15°45.0'	46°17.3'
	1805:04.1	100.9	016.5	15°40.8'	46°38.5'
F2	1810:04.1	091.4	017.2	15°36.8'	46°59.4'
	1815:04.1	092.5	019.1	15°32.3'	47°20.6'
	1820:04.1	101.8	018.4	15°28.4'	47°41.8'
	1825:04.1	099.4	020.1	15°24.3	48°2.9'
F3	1830:04.1	103.0	024.1	15°20.5'	48°24.4'
	1835:04.1	111.5	026.8	15°16.8'	48°45.8'
	1840:04.1	110.3	022.8	15°13.6'	49°7.2'
	1845:04.1	107.1	023.6	15°9.1'	49°28.5'

Table Ia (Northern Track) 20922A-(Cont.)

Designator	Time (GMT)	Wind Direction	Wind Speed	Latitude(°N)	Longitude(°W)
F4	1850:04.1	094.6	021.9	15°4.5'	49°49.7'
	1855:04.1	090.7	020.1	14°59.9'	40°10.8'
	1900:04.1	075.4	022.5	14°54.9'	50°32.3'
	1905:04.1	077.2	025.3	14°49.7'	50°53.8'
G1	1910:04.1	076.8	029.6	14°44.5'	51°15.4'
	1915:04.1	074.8	029.5	14°39.0'	51°37.1'
	1920:04.1	075.1	026.4	14°33.8'	51°59.1'
	1925:04.1	073.4	027.7	14°28.6'	52°20.9'
G2	1930:04.1	069.8	023.9	14°24.3'	52°42.7'
	1935:04.1	071.1	026.4	14°19.7'	53°4.3'
	1940:04.1	073.8	023.3	14°18.6'	53°25.5'
	1945:04.1	069.3	016.5	14°22.7'	53°45.5'
G3	1950:04.1	080.5	018.1	14°24.2'	54°6.3'
	1955:04.1	060.9	019.0	14°21.4'	54°27.7'
	2000:04.1	071.0	026.7	14°15.6'	54°48.5'
	2005:04.1	056.2	019.0	14°12.1'	55°9.9'
H1	2010:04.1	079.9	024.6	14°8.7'	55°31.3'
	2015:04.1	083.7	022.8	14°5.9'	55°53.3'
	2020:04.1	079.3	019.0	14°1.2'	56°14.6'
	2025:04.1	084.4	016.7	13°53.4'	56°34.7'
H2	2030:04.1	079.5	015.1	13°46.2'	56°54.9'
	2035:04.1	075.8	013.8	13°40.2'	57°15.3'
	2040:04.1	080.0	014.7	13°34.8'	57°36.4'
	2045:04.1	080.5	013.4	13°29.4'	57°56.6'
H3	2050:04.1	089.3	013.5	13°24.2'	58°17.6'
	2055:04.1	090.8	015.4	13°19.1'	58°39.4'
	2100:04.1	056.1	008.1	13°13.3'	59°1.5'
H4	2105:04.1	063.4	042.0	13°6.0'	59°21.7'

Table Ib (Southern track) 20922B

Designator	Time (GMT)	Wind Direction	Wind Speed	Latitude (°N)	Longitude (°W)
	1155:02.1	241.0	004.8	16°33.6'	23°12.5'
	1200:02.1	191.4	007.9	16°26.6'	23°25.7'
	1205:02.1	192.6	007.2	16°19.5'	23°40.0'
	1210:02.1	208.4	007.2	16°12.7'	23°53.5'
A1	1215:02.1	180.8	012.1	16°05.4'	24°07.4'
	1220:02.1	193.6	011.3	15°58.2'	24°21.1'
	1225:02.1	165.9	011.3	15°50.7'	24°35.7'
	1230:02.1	167.5	007.7	15°41.8'	24°52.6'
B1	1235:02.1	196.4	005.3	15°32.1'	25°8.9'
	1240:02.1	193.4	006.5	15°22.3'	25°24.6'
	1245:02.1	200.1	006.6	15°12.6'	25°40.3'
	1250:02.1	226.2	005.5	15°3.1'	25°55.6'
B2	1255:02.1	229.0	005.9	14°53.4'	26°11.0'
	1300:02.1	271.9	006.8	14°43.5'	26°26.1'
	1305:02.1	294.6	011.7	14°33.3'	26°41.1'
	1310:02.1	296.5	013.3	14°22.7'	26°55.7'
B3	1315:02.1	286.4	007.5	14°28.7'	27°10.6'
	1320:02.1	294.3	006.1	14°12.4'	27°28.7'
	1325:02.1	310.5	006.5	14°12.8'	27°46.9'
	1330:02.1	297.5	005.4	14°12.8'	28°5.3'
B4	1335:02.1	314.5	006.1	14°13.1'	28°24.2'
	1340:02.1	279.1	004.9	14°13.2'	28°42.6'
	1345:02.1	275.6	004.1	14°13.5'	29°00.9'
	1350:02.1	234.0	004.9	14°14.1'	29°19.4'
B5	1355:02.1	272.8	004.1	14°14.5'	29°38.6'
	1400:02.1	269.9	004.0	14°14.9'	29°56.5'
	1405:02.1	249.6	004.8	14°15.2'	30°14.8'
	1410:02.1	205.9	004.1	14°15.5'	30°33.5'
C1	1415:02.1	209.1	005.9	14°15.7'	30°52.2'
	1420:02.1	216.1	004.9	14°15.5'	31°11.1'
	1425:02.1	217.2	004.5	14°15.0'	31°30.0'
	1430:02.1	201.2	006.8	14°14.5'	31°49.5'
C2	1435:02.1	184.2	005.3	14°14.2'	32°8.6'
	1440:02.1	183.5	004.4	14°13.9'	32°27.7'
	1445:02.1	172.4	005.1	14°13.4'	32°47.3'
	1450:02.1	196.0	005.1	14°12.9'	33°6.6'
C3	1455:02.1	186.8	006.2	14°12.2'	33°26.5'
	1500:02.1	184.2	005.6	14°11.9'	33°46.6'
	1505:02.1	178.8	006.0	14°11.6'	34°6.2'
	1510:02.1	171.8	009.0	14°11.3'	34°26.0'
C4	1515:02.1	167.0	008.9	14°11.1'	34°46.3'
	1520:02.1	173.6	005.3	14°10.8'	35°6.2'
	1525:02.1	170.7	008.1	14°10.5'	35°26.5'
	1530:02.1	176.7	003.6	14°10.0'	35°46.6'

Table Ib (Southern track) 20922B-(Contd.)

Designator	Time (GMT)	Wind Direction	Wind Speed	Latitude (°N)	Longitude (°W)
D1	1535:02.1	179.2	002.7	14°9.4'	36°6.6'
	1540:02.1	180.0	004.3	14°8.7'	36°26.3'
	1545:02.1	256.4	001.3	14°7.9'	36°46.2'
	1550:02.1	017.6	003.6	14°6.7'	37°6.2'
D2	1555:02.1	017.2	004.9	14°5.4'	37°26.3'
	1600:02.1	108.9	001.3	14°4.3'	37°46.8'
	1605:02.1	096.9	002.6	14°3.1'	38°7.2'
	1610:02.1	074.1	002.4	14°2.1'	38°27.8'
D3	1615:02.1	084.1	002.4	14°1.2'	38°48.0'
	1620:05.1	032.5	003.6	14°00.0'	39°8.4'
	1625:05.1	012.4	006.0	13°58.7'	39°28.8'
	1630:05.1	009.1	007.3	13°56.9'	39°51.4'
E1'	1635:05.1	008.7	007.2	13°55.7'	40°8.2'
E1	1640:05.1	010.0	005.4	13°54.4'	40°28.6'
	1645:05.1	006.9	009.4	13°53.3'	40°49.0'
	1650:05.1	008.1	009.5	13°52.3'	41°9.3'
	1655:05.1	010.3	007.7	13°51.3'	41°29.7'
E2	1700:05.1	015.0	003.9	13°50.5'	41°50.0'
	1705:05.1	015.3	004.6	13°49.9'	42°10.0'
	1710:05.1	015.9	004.7	13°49.2'	42°30.1'
	1715:05.1	012.9	003.6	13°48.5'	42°50.1'
E3	1720:05.1	018.1	004.4	13°47.9'	43°10.0'
	1725:05.1	126.1	001.7	13°47.3'	43°30.2'
	1730:05.1	065.1	002.3	13°46.4'	43°50.4'
	1735:05.1	127.4	002.5	13°45.7'	44°10.9'
E4	1740:05.1	150.5	002.9	13°45.2'	44°31.1'
	1745:05.1	037.7	008.8	13°45.1'	44°50.8'
	1750:05.1	117.2	001.7	13°44.0'	45°9.7'
	1755:05.1	122.5	002.9	13°42.6'	45°29.4'
F1	1800:05.1	157.5	006.9	13°39.5'	45°49.2'
	1805:05.1	154.7	008.4	13°37.0'	46°9.4'
	1810:05.1	166.5	014.7	13°34.4'	46°30.0'
	1815:05.1	156.8	014.4	13°31.7'	46°49.9'
F2	1820:05.1	165.7	015.9	13°29.2'	47°9.7'
	1825:05.1	164.9	015.8	13°26.9'	47°29.4'
	1830:05.1	169.3	017.0	13°24.4'	47°49.6'
	1835:05.1	167.7	020.7	13°22.4'	48°9.7'
F3	1840:05.1	168.0	016.5	13°20.1'	48°29.6'
	1845:05.1	162.0	013.5	13°17.3'	48°49.1'
	1850:05.1	157.4	012.7	13°14.1'	49°9.2'
	1855:05.1	147.8	007.0	13°11.3'	49°29.3'

Table Ib (Southern track) 20922B-(Contd.)

Designator	Time (GMT)	Wind Direction	Wind Speed	Latitude (°N)	Longitude (°W)
F4	1900:05.1	106.1	004.3	13°8.6'	49°49.7'
	1905:05.1	136.8	007.2	13°6.0'	50°10.3'
	1910:05.1	068.3	004.3	13°3.4'	50°31.5'
	1915:05.1	043.1	005.2	12°59.9'	50°52.2'
G1	1920:05.1	082.4	004.5	12°56.3'	51°13.0'
	1925:05.1	096.5	004.2	12°52.9'	51°33.6'
	1930:05.1	070.4	005.3	12°49.5'	51°54.4'
	1935:05.1	066.9	004.9	12°46.4'	52°15.2'
G2	1940:05.1	036.8	006.8	12°42.6'	52°36.5'
	1945:05.1	019.6	004.3	12°38.9'	52°57.3'
	1950:05.1	040.8	010.8	12°35.1'	53°17.7'
	1955:05.1	040.6	015.4	12°28.5'	53°37.8'
G3	2000:05.1	092.8	014.1	12°22.1'	53°58.8'
	2005:05.1	150.1	008.3	12°19.3'	54°20.5'
	2010:05.1	217.6	001.7	12°19.4'	54°41.1'
	2015:05.1	093.0	001.0	12°21.5'	55°1.1'
H1	2020:05.1	027.1	005.4	12°24.2'	55°21.0'
	2025:05.1	023.2	005.1	12°27.2'	55°41.0'
	2030:05.1	029.0	003.1	12°29.8'	56°1.6'
	2035:05.1	126.0	002.0	12°32.7'	56°21.6'
H2	2040:05.1	126.0	002.0	12°35.5'	56°41.2'
	2045:05.1	048.9	003.7	12°38.5'	57°0.7'
	2050:05.1	062.2	003.0	12°40.4'	57°21.1'
	2055:05.1	010.2	007.9	12°42.4'	57°41.3'
H3	2100:05.1	071.0	002.0	12°44.4'	58°1.8'
	2105:05.1	091.0	003.0	12°47.6'	58°23.8'
	2110:05.1	089.0	003.0	12°52.2'	58°43.9'
	2115:05.1	083.3	002.4	12°56.2'	59°2.7'
H4	2120:05.1	323.5	001.4	13°00.7'	59°20.1'

TABLE II

Figure	Track dot number (counted from right to left)	Time	Designator
SOUTHERN TRACK			
14H	1	- GMT	Sal
	2	1215	A1S
	3	1235	B1S
	4	1255	B2S
	5	1315	B3S
	6	1335	B4S
	7	1355	B5S
14F	1	1335	B4S
	2	1355	B5S
	3	1415	C1S
	4	1435	C2S
	5	1455	C3S
	6	1515	C4S
	7	1535	D1S
	8	1555	D2S
14D	1	1720	E3S
	2	1740	E4S
	3	1800	F1S
	4	1820	F2S
	5	1840	F3S
	6	1900	F4S
	7	1920	G1S
14B	1	1840	F3S
	2	1900	F4S
	3	1920	G1S
	4	1940	G2S
	5	2000	G3S
	6	2020	H1S
	7	2040	H2S
	8	2100	H3S
	9	2120	H4S
	10	-	Barbados
NORTHERN TRACK			
14G	1	-	Sal
	2	1225	A1N
	3	1245	B1N
	4	1305	B2N
	5	1325	B3N
	6	1345	B4N

TABLE II - Northern Track (Continued)

Figure	Track dot number (counted from right to left)	Time	Designator
14E	1	1325 GMT	B3N
	2	1345	B4N
	3	1400	C1N
	4	1420	C2N
	5	1440	C3N
	6	1500	C4N
	7	1520	D1N
	8	1540	D2N
	9	1600	D3N
	10	1625	D4N
14D	1	1730	E3N
	2	1750	F1N
	3	1810	F2N
	4	1830	F3N
	5	1850	F4N
14C	1	1750	F1N
	2	1810	F2N
	3	1830	F3N
	4	1850	F4N
	5	1910	G1N
	6	1930	G2N
	7	1950	G3N
	8	2010	H1N
	9	2030	H2N
14B	1	1830	F3N
	2	1850	F4N
	3	1910	G1N
	4	1930	G2N
	5	1950	G3N
	6	2010	H1N
	7	2030	H2N
	8	2050	H3N
	9	2105	H4N
	10	-	Barbados

TABLE III

Southern Track Picture Sequence

Picture No.	Approximate Longitude	Time	Approximate Azimuth
1	23.3(°W)	1157.1 GMT	NW
2	23.7	1206.6	W
3	24.2	1215.9	NW
4	24.5	1223.75	W
5	24.7	1227.2	WNW
6	25.3	1238.0	W
7	25.5	1242.0	S
8	26.0	1251.2	NW
9	26.8	1306.6	NW
10	26.95	1310.4	W
11	27.1	1314.3	W
12	27.4	1318.1	SE
13	27.5	1320.4	N
14	27.7	1323.45	NNW
15	28.0	1328.7	NW
16	28.45	1335.7	S
17	28.55	1337.5	N
18	29.0	1344.7	SE
19	29.5	1352.25	N
20	29.8	1357.8	N
21	30.2	1404.9	SE
22	30.6	1410.1	S
23	31.1	1419.2	NW
24	31.7	1427.5	NNW
25	31.9	1430.6	NW
26	32.0	1433.4	NNW
27	32.2	1436.3	N
28	32.35	1438.4	NW
29	32.8	1445.8	NNW
30	33.3	1452.6	NW
31	34.2	1506.8	S
32	34.5	1510.75	NW
33	34.8	1515.1	SE
34	35.15	1520.75	S
35	35.6	1527.8	NW

TABLE III - Southern Track Picture Sequence - (Continued)

Picture No.	Approximate Longitude	Time	Approximate Azimuth
36	35.8(°W)	1530.1 GMT	S
37	35.9	1531.85	NNW
38	36.3	1537.5	NNW
39	37.0	1549.4	SE
40	37.4	1554.7	NW
41	37.6	1557.0	SE
42	38.3	1607.25	SE
43	38.7	1613.45	NW
44	40.45	1639.7	NW
45	40.7	1643.2	SE
46	40.7	1643.2	SE
47	41.1	1649.05	NNW
48	41.85	1700.45	SE
49	42.0	1702.15	NW
50	42.6	1712.0	N
.			
51	43.4	1723.9	NW
52	44.1	1733.6	NW
53	44.4	1738.6	W
54	45.2	1750.1	N
55	45.2	1750.1	NW
56	45.6	1757.2	N
57	46.0	1802.6	NW
58	46.4	1808.4	N
59	47.2	1821.15	NNW
60	48.7	1843.0	NNE
61	50.5	1909.8	N
62	51.1	1918.5	NNW
63	52.8	1942.5	NNW
64	55.1	2016.9	NNW
65	56.1	2031.75	S
66	57.5	2051.7	NW

TABLE III - Northern Track Picture Sequence

Picture Letter	Approximate Longitude	Time	Approximate Azimuth
A	24.0 (°W)	1223 GMT	NE
B	25.2	1239	NW
C	26.3	1300	N
D	31.2	1410	SW
E	31.0	1416	NW
F	32.25	1431	NW
G	34.0	1500	NW
H	34.0	1500	NW
I	35.6	1523	NW
J	37.45	1551	NW
K	42.8	1710	NW
L	44.0	1728	NW
M	46.6	1802	NW
N	47.6	1819	N
O	48.7	1834	NW
P	49.55	1846	NW
Q	49.9	1854	N
R	49.9	1854	N
S	55.4	2008	N
T	55.4	2010	N
U	55.4	2011	S

TABLE IV

TIROS Picture Times

Pass	Frame Number	Time (22 Sept. 1962)
T6 W62(61)	9	135400 GMT
	8	135430
	7	135500
	6	135530
T5 W1364(1363)	17	145830
	16	145900
	15	145930
	14	150000
T6 W63(62)	22	153300
	21	153330
	20	153400
	19	153430
T5 P1365(1364)	31	163900
	30	163930
	29	164000
	28	164030

25. Infrared Photography of the Earth from Mercury Spacecraft MA-9, Stanley Soules, (in preparation)
26. Meteorological Products from Digitized Satellite Vidicon Cloud Pictures, C. L. Bristor and W. M. Callicott, (March 1964)
27, 28, In preparation