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SYNOPTIC APPLICATION OF SATELLITE CLOUD PICTURES OVER THE FAR EAST

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Weather Wing (1st)
San Francisco, California

October 1969

AD 697792

TECHNICAL STUDY 19

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BY

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FIRST WEATHER WING

OCTOBER 1969

SCIENTIFIC SERVICES

HQ 1st WEATHER WING

APO SAN FRANCISCO 96553

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ACKNOWLEDGMENTS

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A. Introduction

Satellite cloud observations have proven to be a powerful tool for the meteorologist in describing current states of the atmosphere. This study describes the application of satellite data in daily synoptic analysis and forecasts. General characteristics of the appearance of clouds in satellite pictures are discussed briefly (Reference: WMO Technical Note No. 75, "The Use of Satellite Pictures in Weather Analysis and Forecasting"). Rules which are directly useful for daily forecasting are itemized and divided into various terrain effects and synoptic patterns. Selected examples are photographs from ESSA 2, 4 and Nimbus 2 taken over the Far East, west of 180° longitude from March 1966 to March 1968, and received by the Fuchu TVGS.

B. Characteristics of Clouds in Satellite Pictures

1. Brightness: Generally increased brightness is associated with thicker clouds, especially in cloud systems associated with cyclones. Water-droplet clouds always appear brighter than ice clouds of the same thickness. Tone of high clouds are light gray or white. Brightness of the cloud is dependent on the sun angle and vertical extent. The brightest layers are often associated with nimbostratus, thick stratus or fog and clouds producing precipitation. The results from Conover's study, arranged in order of decreasing brightness, are shown in Table 1.

2. Patterns: The smallest cloud elements visible in a satellite picture are either randomly distributed or are organized into mesoscale cloud formations which form a pattern. One of the most striking patterns is the one produced in cumulus clouds by mesoscale cellular convection (see Fig 1). This pattern occurs in great variety, especially over the oceanic areas of the world. Clouds are also commonly observed as small lines or bands (see Fig 2) which have their own distinct pattern. Gravity waves near a jet stream, or mountain lee waves, produce patterns of banded clouds which are easily recognized in the satellite pictures.

3. Structures: Shadows and highlights are often quite helpful in identifying cloud structures; that is, the relative heights of the different clouds viewed (see Fig 3-1 and 3-2). Shadows can be used to identify the edges of cirrus and high-level altostratus cloud sheets. The structure of clouds is also revealed when low cloud formation can be detected beneath a higher layer of translucent middle or high cloud. Both of these indications of structure are important in identifying certain cloud types and in making synoptic assessments of large-scale cloud formations.

4. Texture: Cloud surfaces, when viewed from above, often vary in degree of apparent smoothness. This characteristic is referred to as the texture of the clouds. Cloud masses which have smooth appearing surfaces are usually quite flat on top and have little variation in their thickness (see Fig 4-1 and 4-2).

5. Shape and Size: All cloud forms vary in shape and size. The edges of cloud formations can be rounded, straight, serrated, scalloped, jagged, or diffuse. The patterns can be arrayed in straight or curbed band intersecting or isolated from other patterns. These characteristics also are important for identifying cloud types.

6. Cumuliform Clouds: Cumuliform groups can either be organized into patterns of cells, bands or lines (see Fig 5), or be randomly distributed (see Fig 6). However, some convective type clouds do not have these characteristics. For example, the area where fair weather cumulus clouds are present may appear only as a light shade of gray in a picture; the cumuliform characteristics mentioned above are therefore lacking. Cumulonimbus clouds are very bright masses which are fully developed and are indicative of squall lines or thunderstorms. They are usually of medium size, unbroken, and of uniform appearance; are often separated or completely isolated from other cloud covers; and range from 100-200 miles in length. When not deeply imbedded in other clouds, these clouds appear as bright blobs 5-20 miles in diameter, or in patches up to 50 miles or more across (see Fig 4-1 and 4-2).

7. Stratiform Clouds: Stratiform cloud areas normally lack organized pattern and texture (see Fig 3-1 and 3-2). Clouds which are identified in pictures as stratiform generally occur under stable conditions. Cloud types which have a stratiform appearance from above are thick stratus or fog, thick alto-stratus or nimbostratus, and thick cirro-stratus; the latter especially when it occurs above another cloud layer.

8. Cirriform Clouds: Cirriform clouds when viewed from above have a distinct fibrous appearance (see Fig 7). A cloud layer thin enough to allow lower clouds or landmarks to be detected beneath it is usually cirrostratus. Cirriform cloud formations can also be recognized by their association with other cloud types such as cumulonimbus.

9. Other Characteristics: Cumuliform clouds less than a mile in diameter resemble stratiform clouds on satellite cloud pictures (see Fig 8), as the camera is unable to resolve the clouds as individual elements. The whitest clouds in the Tiros picture are usually the coldest.

C. Topographical Effects on Cloud Formations

1. Local Characteristics:

a. Parallel lines of low cumuliform clouds tend to form along long, deep valleys, rugged mountains and narrow straits adjacent to shore-lines, and are found in association with circulation about extratropical cyclones or northwest monsoonal flow (see Fig 9). Large scale parallel lines of cumuliform clouds are usually observed downstream east of Japan.

b. Clouds formed in areas of weak pressure gradient are influenced by topography, and considerably affected by the monsoon wind and sea breeze.

c. Locally formed clouds along coast lines are caused by differential heating, differential friction, orographic lifting, or any combination of these (see Fig 9). Clouds caused by only one of these normally do not persist as long as frontal clouds.

d. Hills, mountains and islands often provide clues in identifying clouds as low stratus and fog (see Fig 7). The shadows cast by higher clouds on top of the fog or stratus also provide an additional clue that a cloud layer is relatively low.

e. Orographic effects due to mountains on low clouds are easily recognizable on satellite photos. Effects on high clouds are more difficult to detect. Upslope cloudiness and clearing in areas of strong downslope motions on the leeward side are discernible in satellite photographs. Lee wave clouds are normally parallel bands of straight or curved stratocumulus and/or cumulus clouds downwind from hills or ridges, at altitudes not significantly greater than 10,000 feet (see Fig 9).

2. Frictional Effects with Pressure Patterns:

a. Most patterns in low-level clouds are determined by the condition of the underlying surface and are produced by a combination of differential heating and differential friction. Consider a wind flow parallel to the east coast of a land mass in the northern hemisphere, with the flow from the south (see Fig 10A), and low pressure to the west. Since the reduction in wind speed due to friction is greater over land than over water, the retarded southerly flow over land is deflected to the west by pressure forces while the winds over the water continue to flow swiftly parallel to the coast. The result is a zone of divergence along the coastline. Conversely, if the low-level flow is from the north (see Fig 10B), with low pressure to the east, the slower winds over the land are diverted toward the east and produce a zone of convergence along the coast where the winds are turning cyclonically and meet the stronger northerly flow.

D. Similar Reflectivity from the Surface

1. In case of strong reflectivity, it is often difficult to distinguish clouds over extensive areas of snow and ice from the equally white surface below. Therefore, users should be aware of areas of icy surfaces and snow-covered terrain. Fig 11 is an example of frozen LAKE BAIKAL.

2. Cumuliform clouds and small isolated areas of snow such as the snow-covered tops of mountains appear much the same when viewed from above (see Fig 12).

3. The tops of mountain ranges form a white dendritic pattern, and snow-covered grassland appears much whiter than forestland covered with an equal amount of snow.

4. In the dryer climates of the world (deserts, bare hill, etc.), sparse vegetation combined with red and yellow soils and rocks make the earth's surface highly reflective. These conditions produce the brightest terrain seen in satellite pictures (see Fig 13). The alkaline and saline materials that form the bottoms of dry lake beds are particularly reflective and have been mistaken for cloud formations.

5. From continual satellite cloud pictures, we can spot areas with different sea surface temperatures. Advection of warm air over cool sea surface will cause clouds or fog to form over this surface.

E. Clouds Associated with Fronts and Waves

1. With Cold Fronts:

a. Clouds associated with a cold front form mostly to the rear of the front, and those associated with a warm front form in front of it (see Fig 14).

b. Clouds associated with an active cold front are generally a combination of both stable and unstable cloud types. These frontal bands average three degrees of latitude in width and have a clear-cut edge on one or both sides where cloud type, and often cloud amount change abruptly. Fig 15 illustrates clouds associated with an active cold front over the ocean. Fig 16 is an example of this over the China mainland. A widening of the frontal band with a bulge toward the warm air side usually indicates that a jet axis is crossing the front at this point (see Fig 17).

c. Post-frontal instability line or secondary frontal cloud bands are generally parallel with a cold frontal band and are located behind it; that is, it is the western most cloud band or one of several such bands. The bands may be separated by an area of striated clouds, or by a completely clear area. Fig 18 shows the clouds associated with the beginning stage of secondary cold front, and Fig 19 is an example of the clouds for a topographically decayed secondary cold front.

d. The weak cold frontal band located in the rear of the upper trough line is much narrower and sometimes appears ragged and full of breaks. This portion of the air aloft is sinking, and this area is composed mostly of cumuliform cloud (see Fig 20).

2. With Warm Fronts:

a. Generally, clouds associated with a warm front form over a wider area than those associated with a cold front, and stratus clouds forms at the low level (see Fig 21). However, hardly any clouds are associated with a warm front in the interior of the dry continent over Mongolia and Manchuria, especially during frontogenesis (see Fig 22).

b. The warm frontal cloud bands are associated with a zone of maximum baroclinity (see Fig 23), the area where the front is steepest.

3. With Stationary and Occluded Fronts:

a. As shown in Fig 24, clouds associated with stationary fronts form over a comparatively wide area along the front (300-600 nautical miles wide in the case of a Baiu front). However, there are crevices and broken clouds along the south side of the front, and also to the rear of waves.

b. Generally, clouds associated with a stationary front are more extensive than in the case of a moving cold front. However, when a wave or small cyclone forms on the stationary front, the cloud area increases, but becomes broken near the center of the small cyclone (see Fig 24).

c. The width of the cloud associated with the stationary polar front (including the case with wave formation) located just to the south of Japan and in the vicinity of Okinawa is usually 280-330 nautical miles.

d. Fig 25 shows clouds, usually spiral or circular shaped, associated with an occluded front.

4. Others:

a. An instability line ahead of a frontal band is often differentiated from the band by the scalloped edges of the instability clouds, and by the presence of massive clouds with a curved alignment. In Fig 14, the squall line is clearly delineated as a long, narrow band of cloudiness ahead of the frontal band.

b. The formation of a wave on a frontal cloud band is indicated in satellite pictures by a widening of the frontal cloud band toward the cold side (see Fig 26). In the early stages of wave development, no recognizable circulation center is visible in frontal clouds.

c. Once in a while, a shadowlike line is seen to the rear of an active cold front (see Fig 27). It can extend 1500 nautical miles or more parallel to the front.

F. Clouds Associated with Extratropical Cyclones and Anticyclones

1. Cloud patterns of the beginning state of an occlusion or the regenerating stage of a cyclone are crescent or comma shaped with bright, heavy overcast, middle and/or high clouds having either an amorphous or "pebbled" appearance. These patterns are usually without low and/or middle level clouds spiraling into the central region of the pattern from the northwest. The center of the circular cloud patterns are normally vertical to the cyclone center of the surface chart (see Fig 28).

2. Cloud patterns associated with occluded cyclones are hook shaped, bright, heavy overcast of middle and/or high clouds with spiraling low and/or middle clouds inside the hook. This pattern differs from the crescent shaped pattern by the presence of spiraling low to middle level clouds inside the hook. The low level clouds are usually cumuliform and, at this stage, the clouds are still nearly vertical over the cyclone center on the surface chart (see Fig 29).

3. Fully occluded mature stages of cyclones are cyclonically curved middle and/or high cloud bands, with a heavy overcast area in the northeastern quadrant and striated, broken areas in the southwestern quadrant, usually with low to middle level spiral clouds. Spiral low and middle cloud patterns may appear near the circulation center. The center cloud system is usually located 100 to 300 nautical miles to the rear (west or south) of the cyclone center on the surface chart (see Fig 2).

4. A decaying cyclone is depicted by spiraling low and/or middle clouds, with an appearance of decreasing organization. Such a cyclone may or may not be associated with an active frontal system. Fig 30 is an example of the decaying stage of an Aleutian low which normally has a vertical axis.

5. In most cases, clouds are not observed with non-persisting, weak lows which form over the Sea of Japan. Even if clouds are formed, these are limited to only scattered lower clouds.

6. The spiral cloud bands which form the cloud wall in a well-developed cyclone are shaped like a funnel near the center (see Fig 27).

7. Clouds associated with cold fronts move toward the center of the cyclone (see Fig 31), and form a circular shape. In this stage, south-north oriented and well developed convective cloud can be seen to the rear of the circular-shaped cloud pattern. The cyclonic circulation forming on the top of the cloud can be seen from the movement of the cloud situation.

8. A well developed cyclone with a warm front parallel and to the south of Japan will have an extensive cloud cover extending toward the mountain range. The cloud cover will persist until the cyclone and the associated upper trough moves off toward the east (see Fig 32).

9. As shown in Fig 7, comparatively thick (2,000 feet over Okhotsk Sea) fog or stratus clouds are associated with a maritime cold anticyclone (e.g., Okhotsk high). Due to topographical effects, drizzle is also common.

10. It appears that there is no relationship between cloud patterns and topographically formed cyclones and anticyclones (e.g., formed over mountains area of the central Japan), especially with respect to the time of formation (see Fig 33).

11. With the formation of a Shanghai low, extensive cloud formation can be seen over land and sea (see Fig 34).

12. When cold air is advected over warmer ocean, cumuliform clouds are widespread over the ocean, and snow or rain showers occur along the wind-ward side of coast lines (see Fig 35) in winter.

13. Small-scale vortices related to flow of air over and around islands are sometimes observed in satellite pictures. These cloud features appear as arcs, eddies, or complete spiraling patterns downward from islands. The cloud features can frequently be seen as a broken area and are associated with a layer of stratocumulus or stratus below an inversion, with low wind speeds and ceilings (see Fig 36).

14. Advection fog or stratus often forms to the rear of migratory highs (see Fig 37).

G. Clouds Associated with Jet Stream

1. Cloud formation associated with the jet stream can be correctly identified from satellite photos eight out of ten times. This makes it possible to locate the jet stream axis quite accurately from the pictures (see Fig 36). These clouds extend over 300 to 1200 nautical miles.

2. In most cases, jet streams can be expected with cirriform clouds to the east of the trough line and on the tropical side of the jet axis. This cloudiness occurs either in the form of an extensive cirrus shield that ends abruptly along the jet axis or in the form of long narrow-bands (see Fig 38).

H. Cloud Formation in the Tropics

1. A crescent or comma shaped cloud forms with an intensifying tropical storm (see Fig 39).

2. Tropical cyclones tend to occur in the intertropical convergence zone (transition area from cloudless to cloudy conditions) (see Fig 40). With strong equatorial westerlies, tropical cyclones may occur simultaneously in both hemispheres.

3. Convergence lines or zones of heavy bands of cloudiness are seen to occur over ocean areas where tropical cyclones are likely to develop. These clouds normally move east-northeastward and appear to persist (see Fig 40). These clouds are formed by the warming of the cold air over the warm sea. A one to two degree (°C) temperature difference is all that is needed for the cloud formation.

4. From satellite cloud pictures taken during summer, movements of thin clouds from the southern to the northern hemisphere, near the Caroline and Marshall Islands can be seen (see Fig 40).

5. Frontal cloud bands become narrow with the approach of a typhoon (see Fig 41).

6. During early summer, tropical cyclones do not accompany any frontal clouds (see Fig 42) until they move over land and take on the characteristics of an extratropical cyclone (see Fig 43).

7. During autumn, a tropical cyclone which has moved into mid-latitude regions, usually merges with a frontal cloud system (see Fig 44).

8. With strong equatorial westerlies, tropical cyclones occur with a high frequency (see Fig 45).

I. Cloud Formation over the Plateau Area of Tibet

1. Cloud distribution over the plateau area is frequently observed to be about 120-300 nautical miles to the rear of the surface low pressure center (see Fig 46), e.g., the spiral cloud associated with a cyclone is preceded about 150 miles by the surface low center.

2. The occluding cyclone over the plateau or desert area is very hard to detect from surface and upper air charts, but is readily discernible from the satellite cloud picture (see Fig 47).

3. Generally clear skies are associated with stationary or early stages of cyclones over the plateau area (see Fig 48). On the other hand, comparatively thick cloud layers are seen with migratory cyclones (see Fig 49).

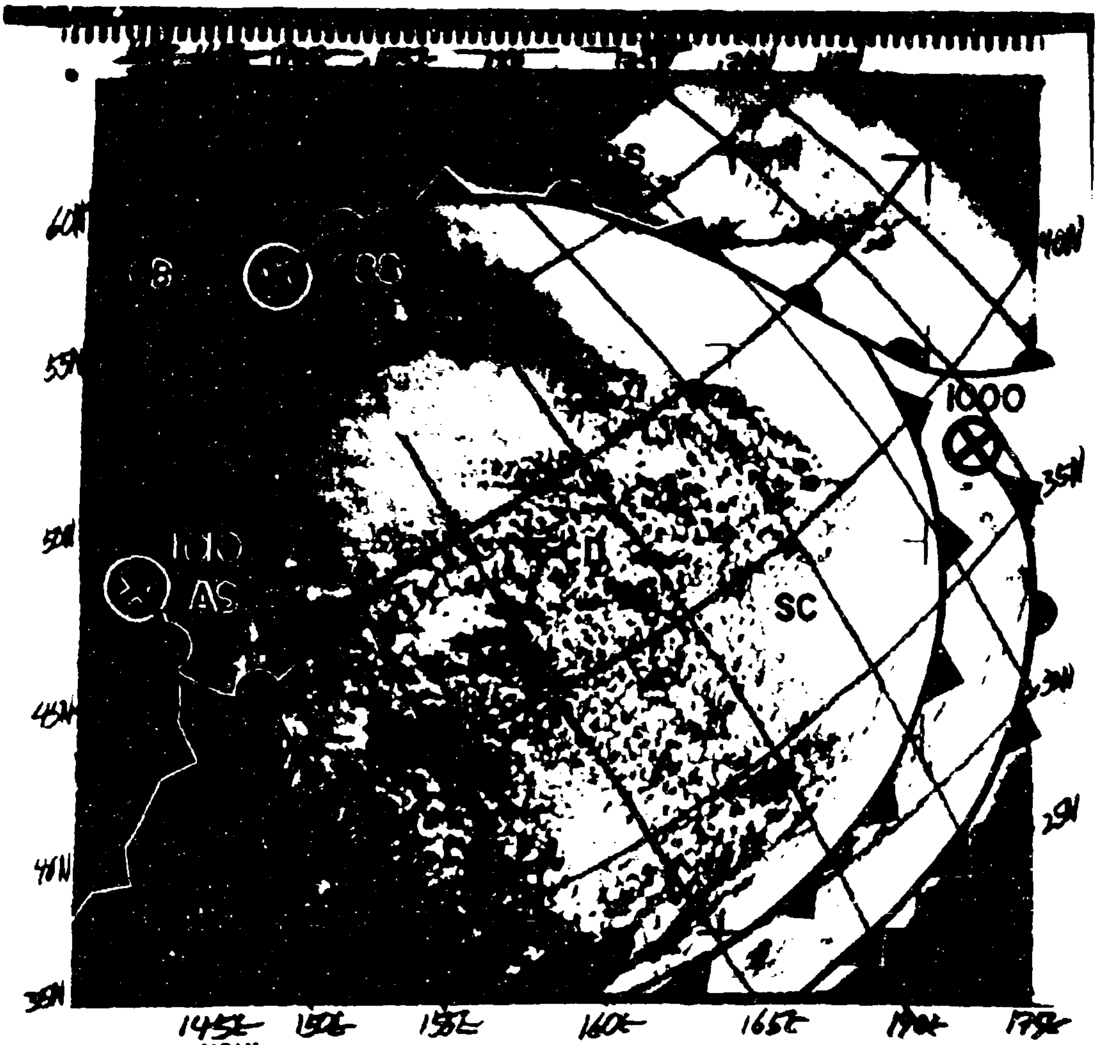

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FIG. 1

FIG. 2

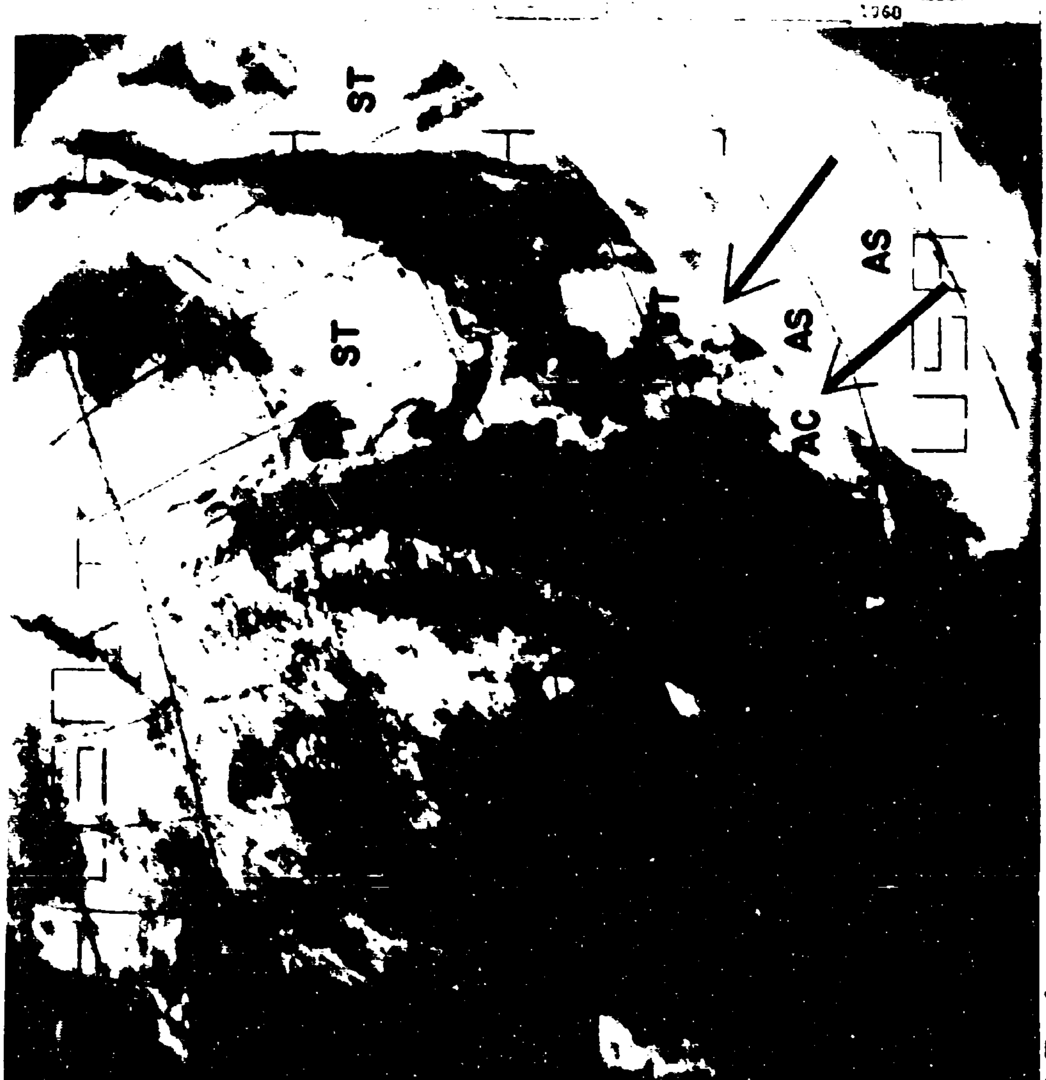

FIG. 3-1

FIG. 3-2

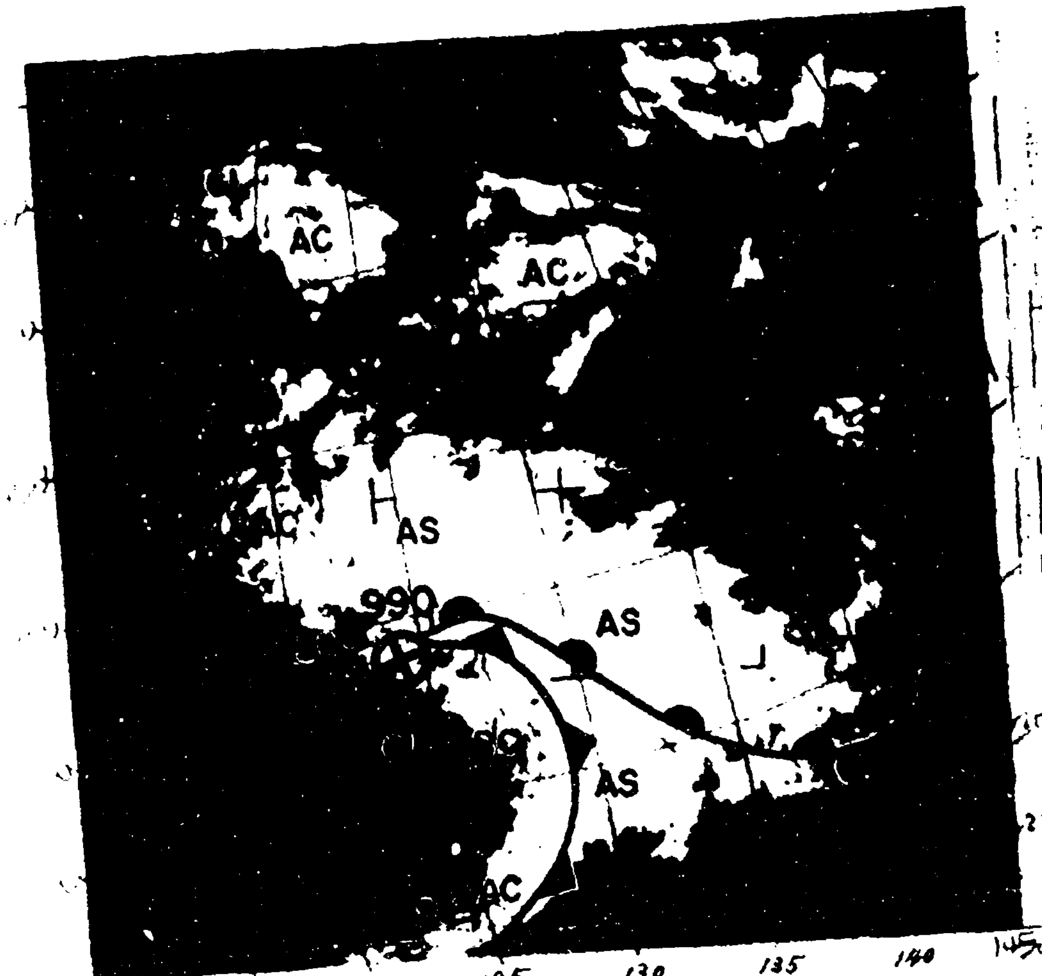

FIG.4-1…

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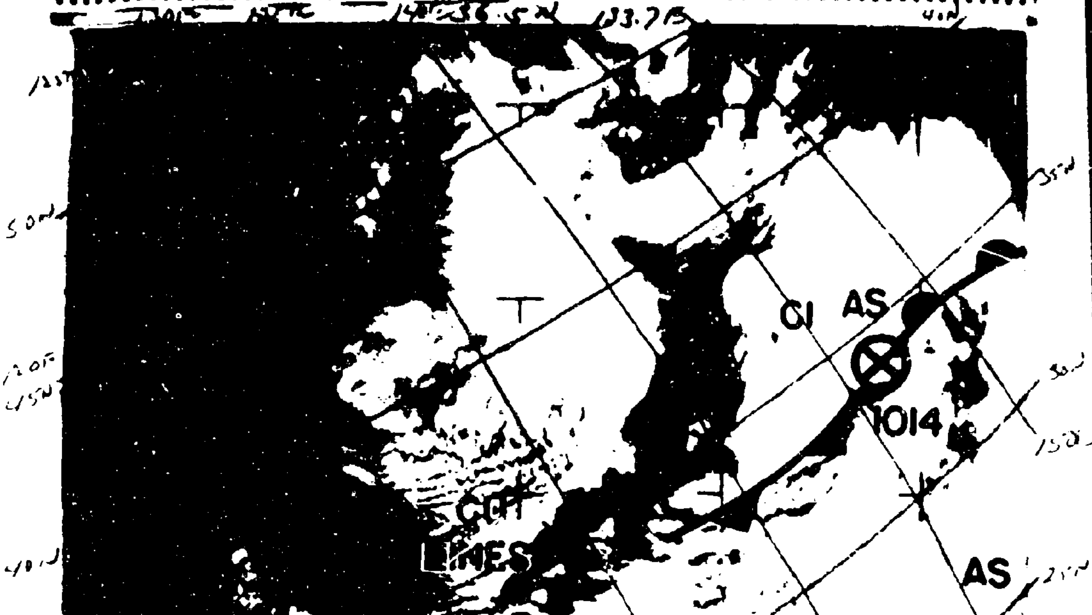

FIG. 5

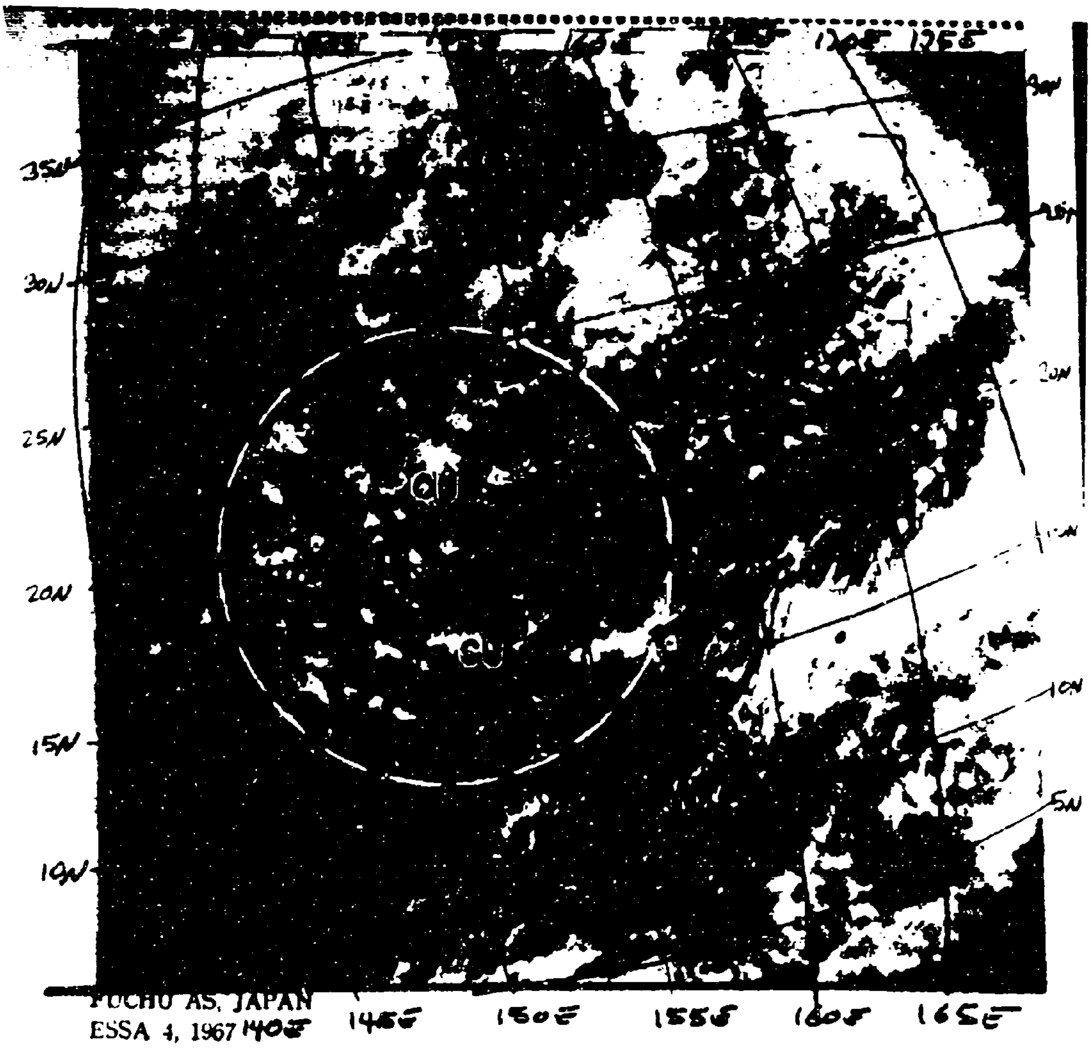
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FIG. 6

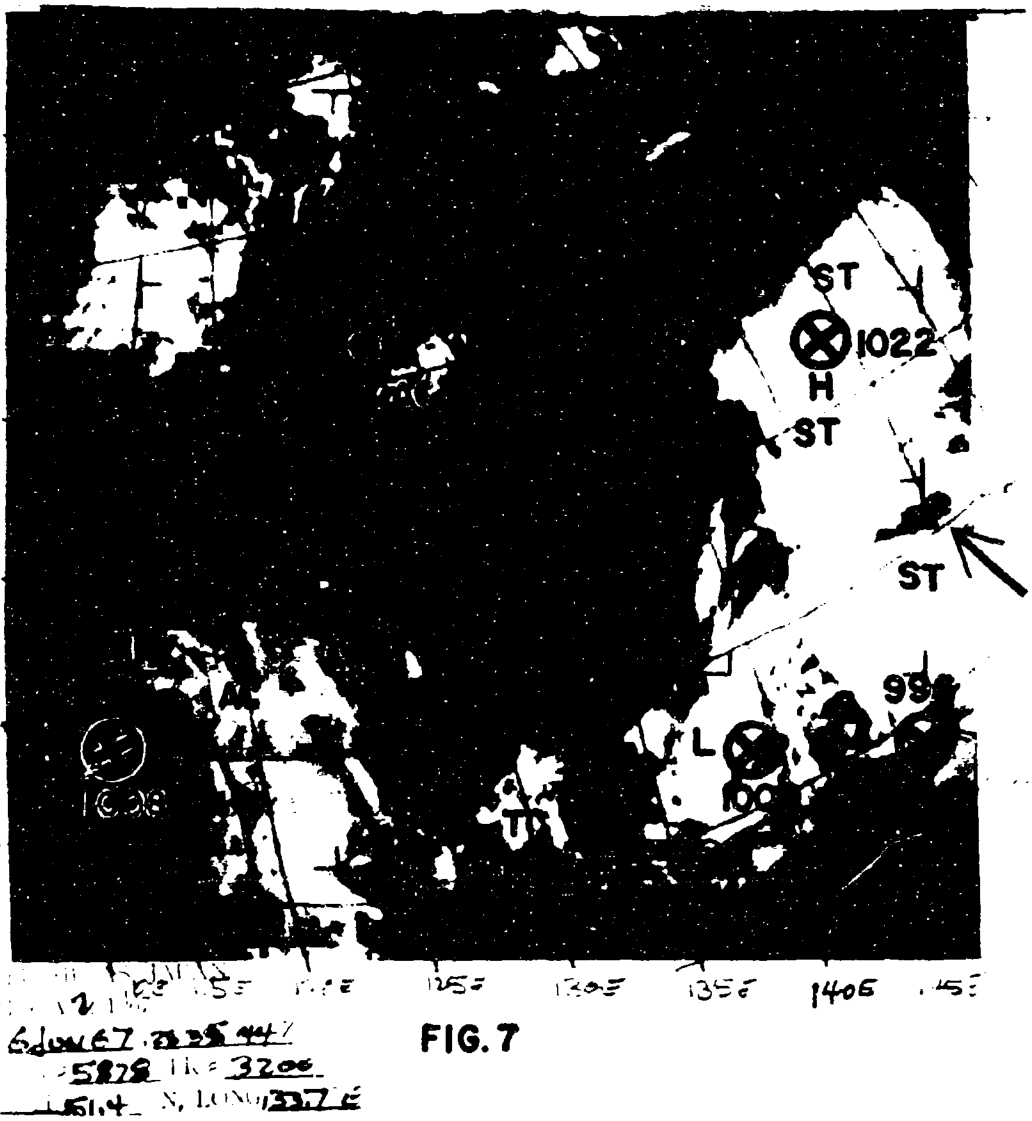


FIG. 7

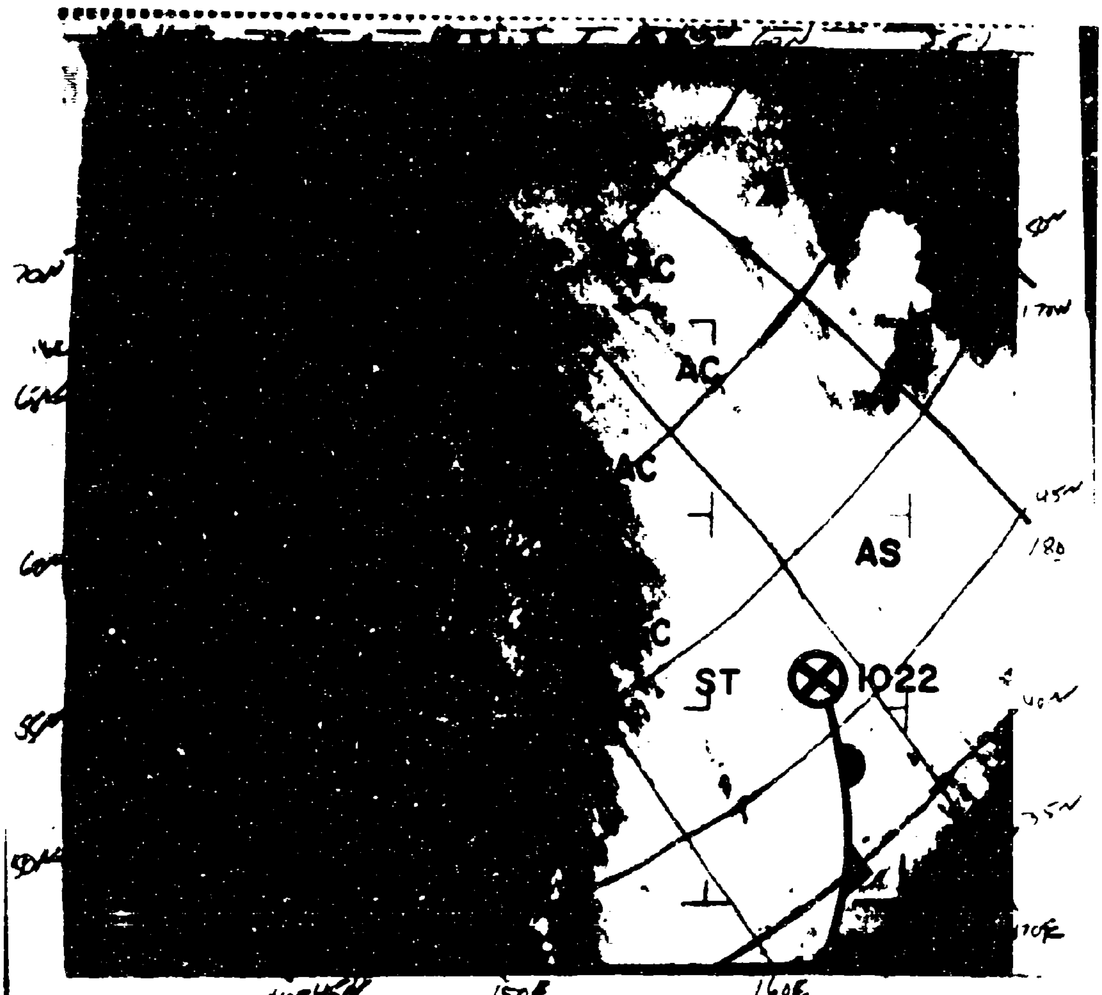
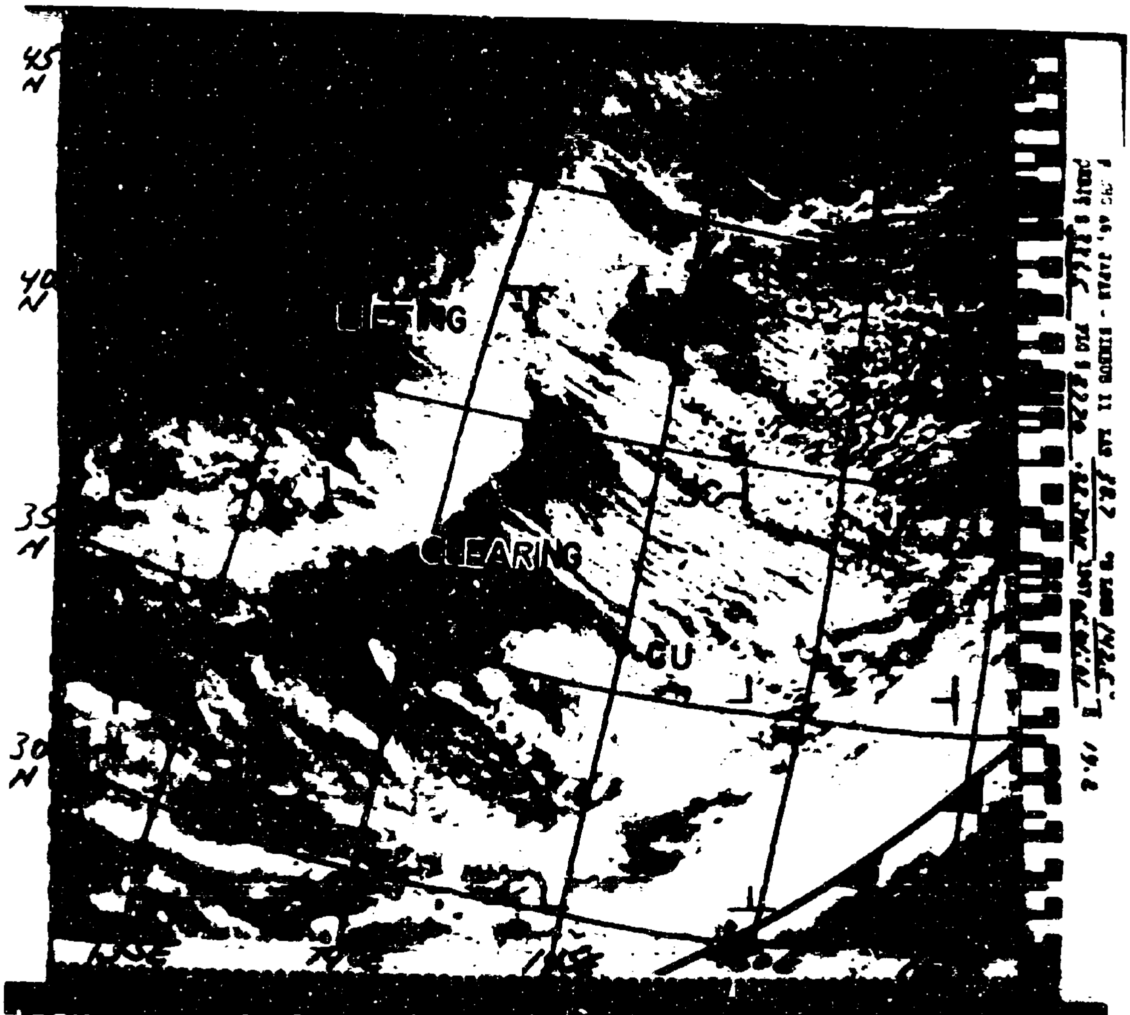


FIG. 8



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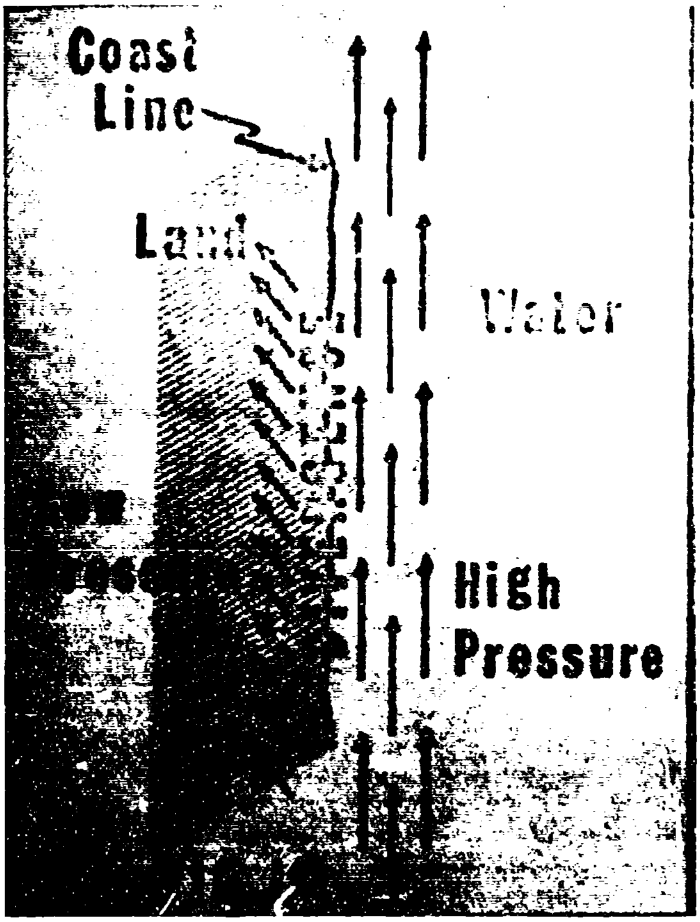
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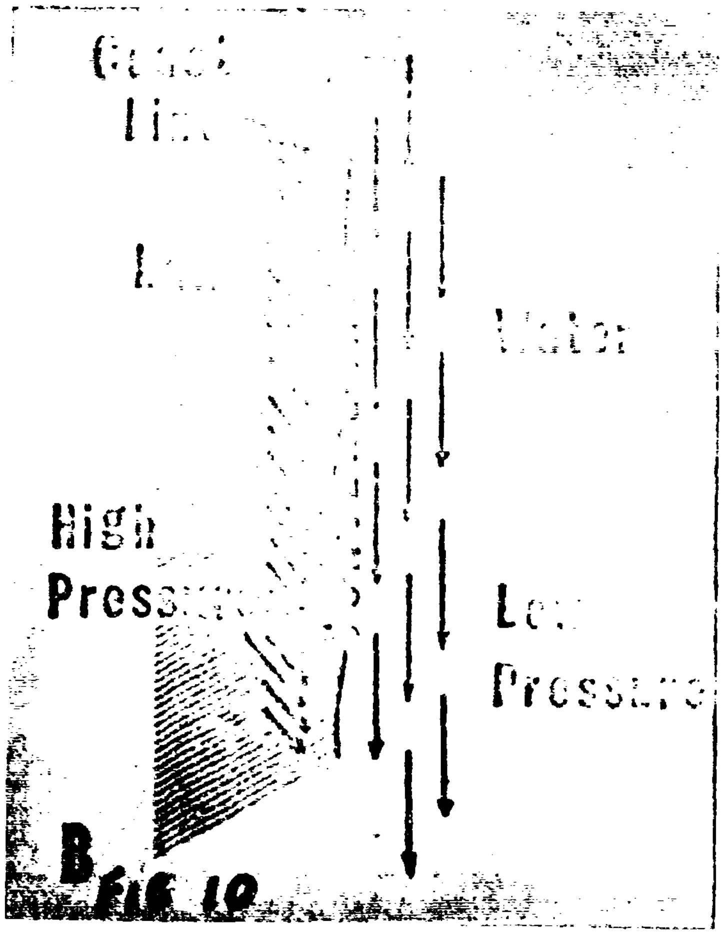

FIG 10

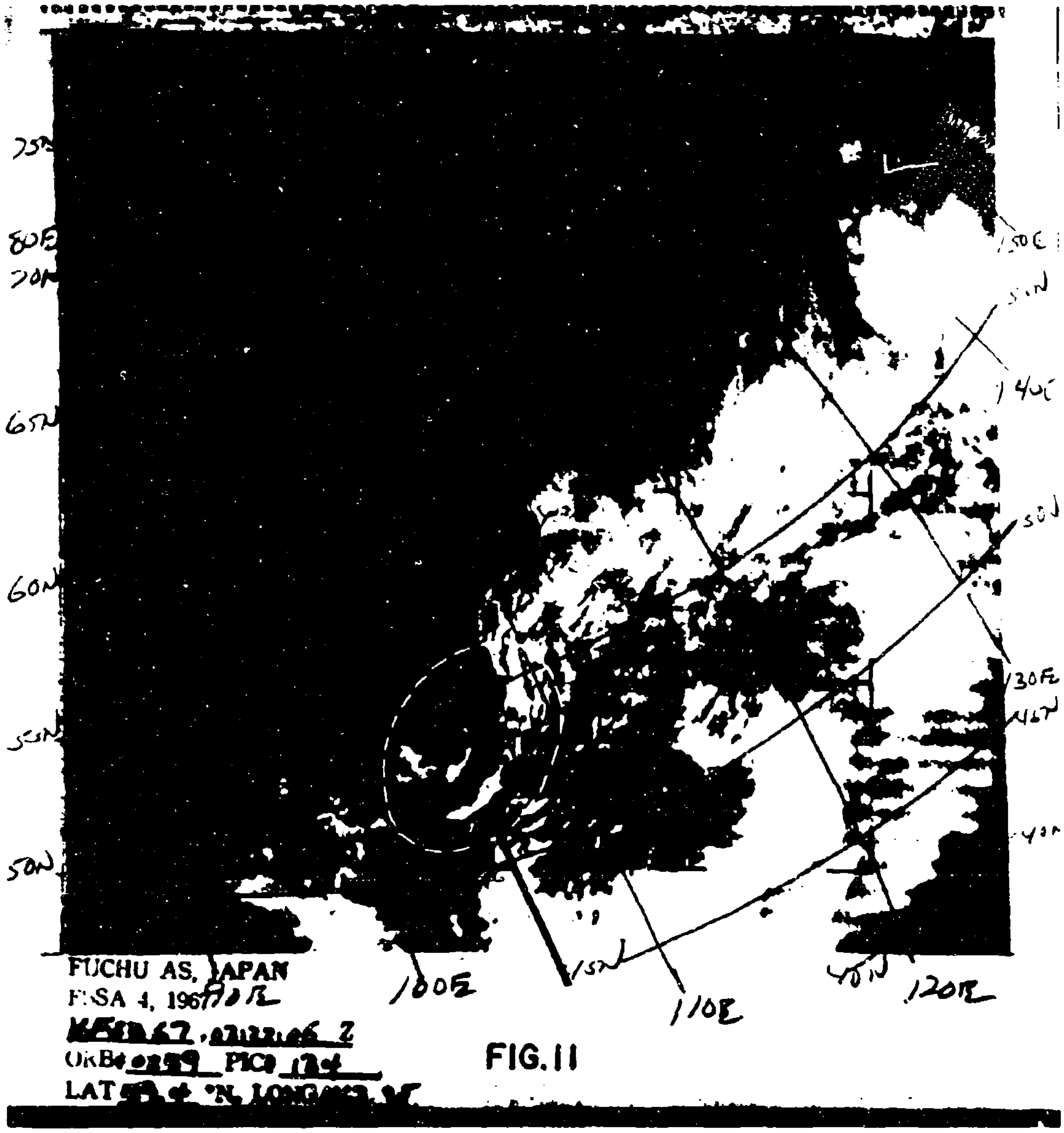
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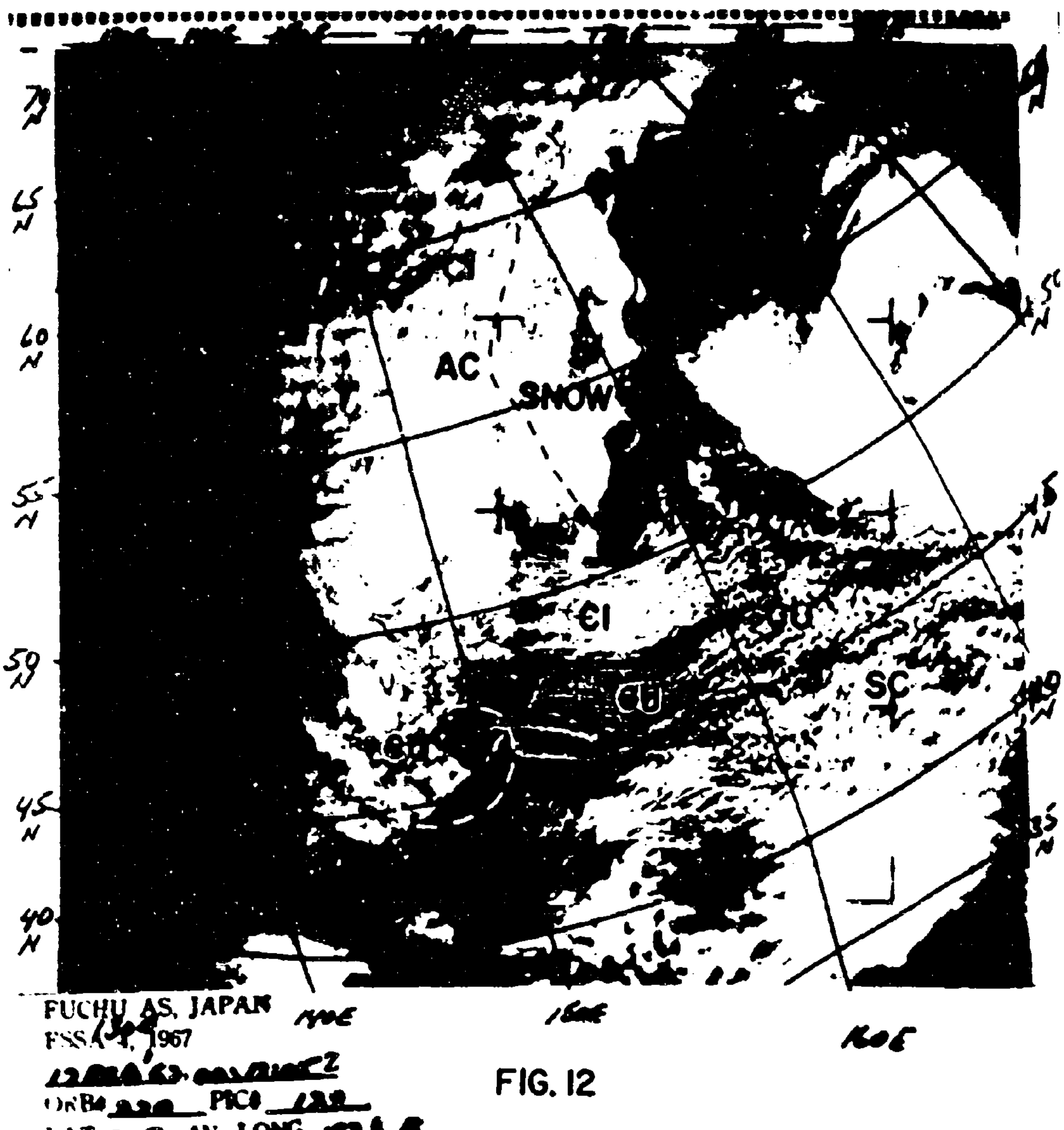
FIG.11



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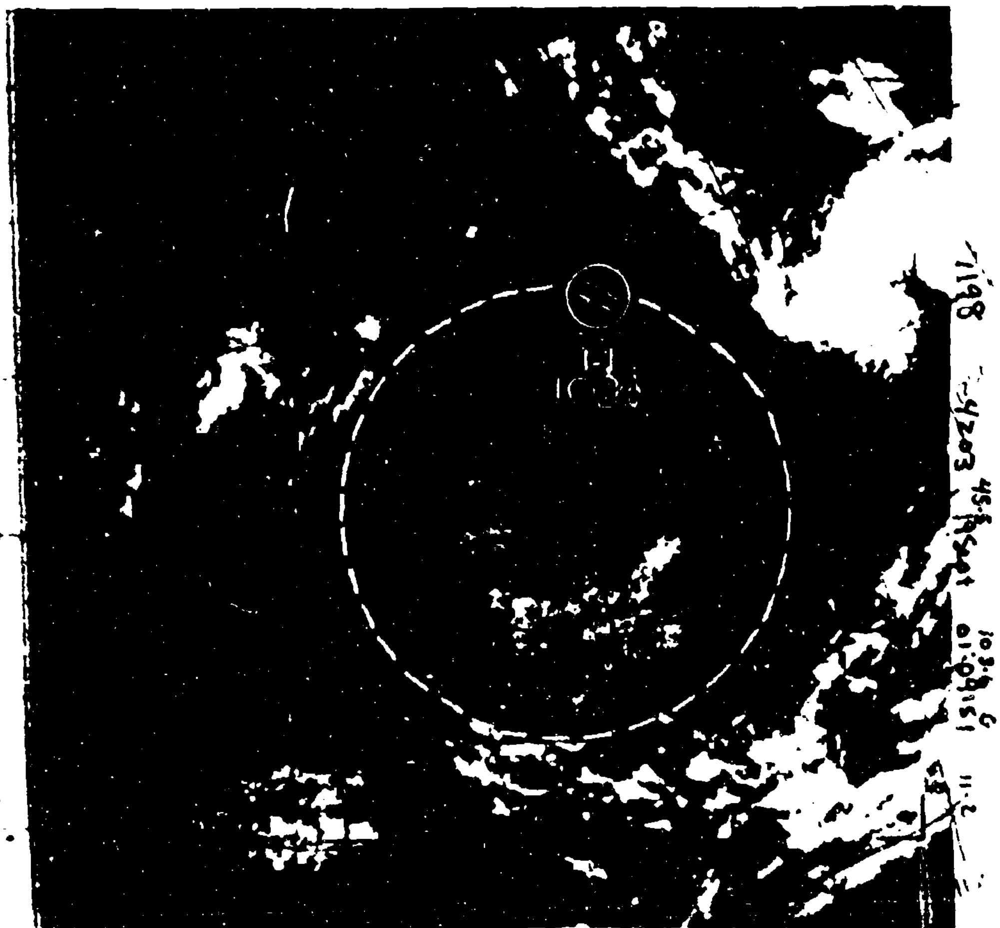

FIG.13 85E 90 95 100 105 110E

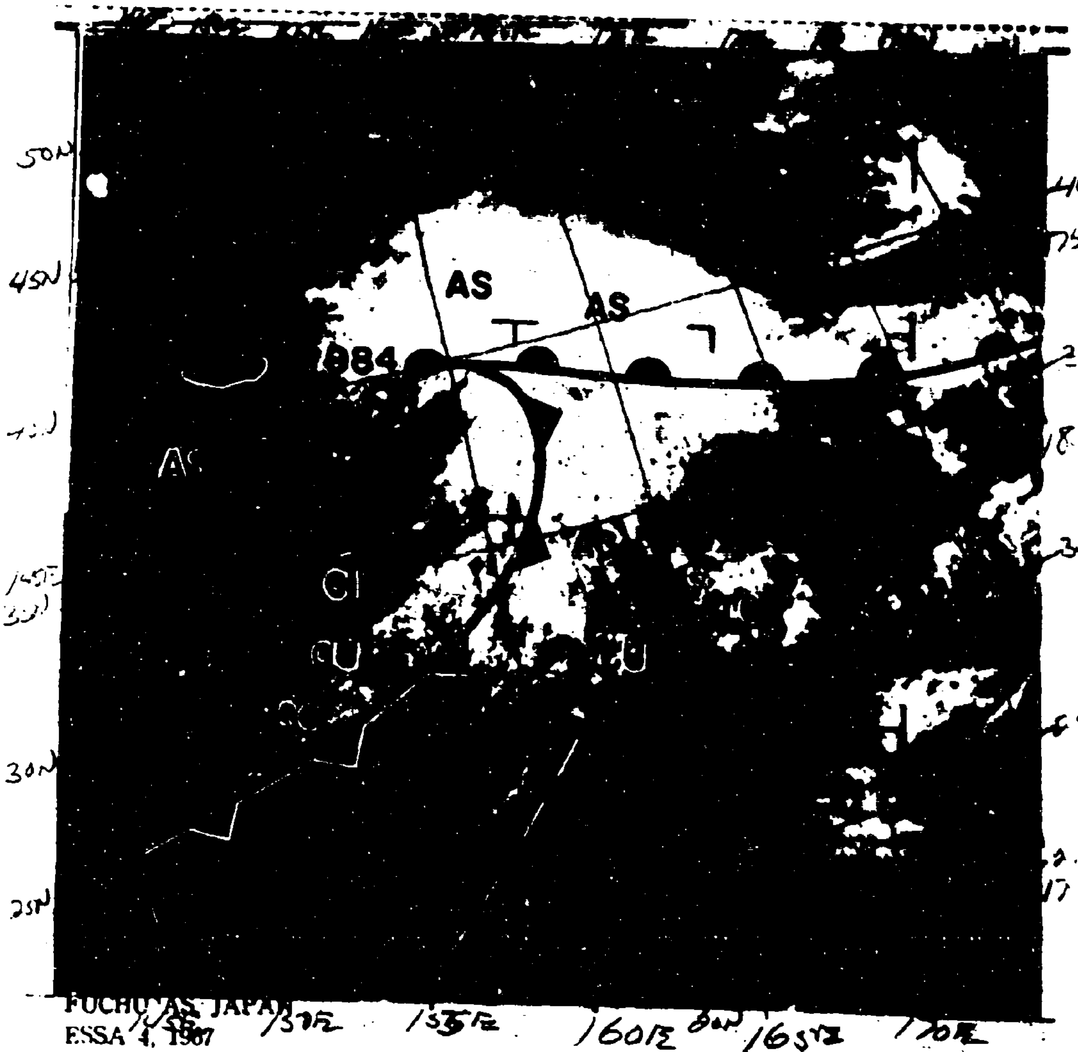

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FIG. 14

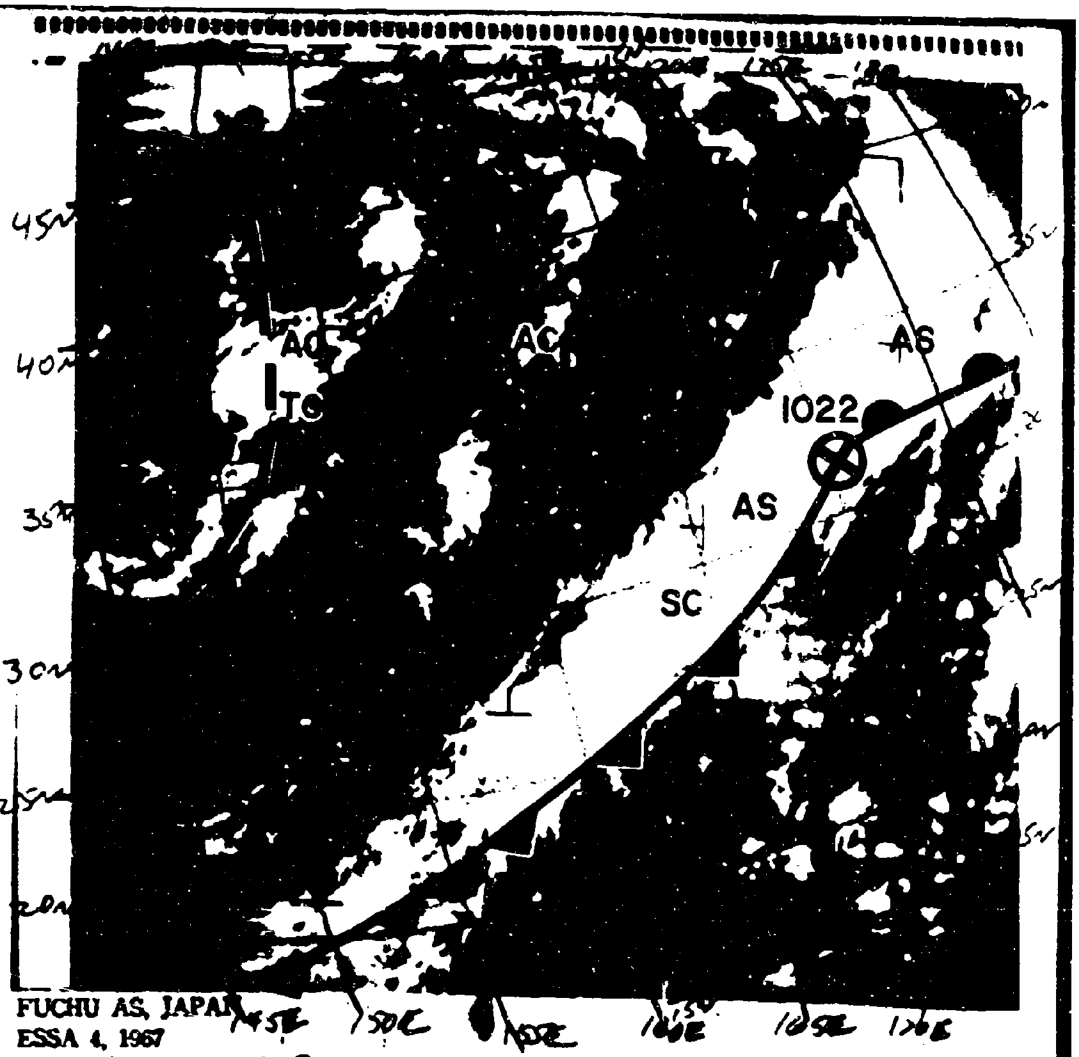

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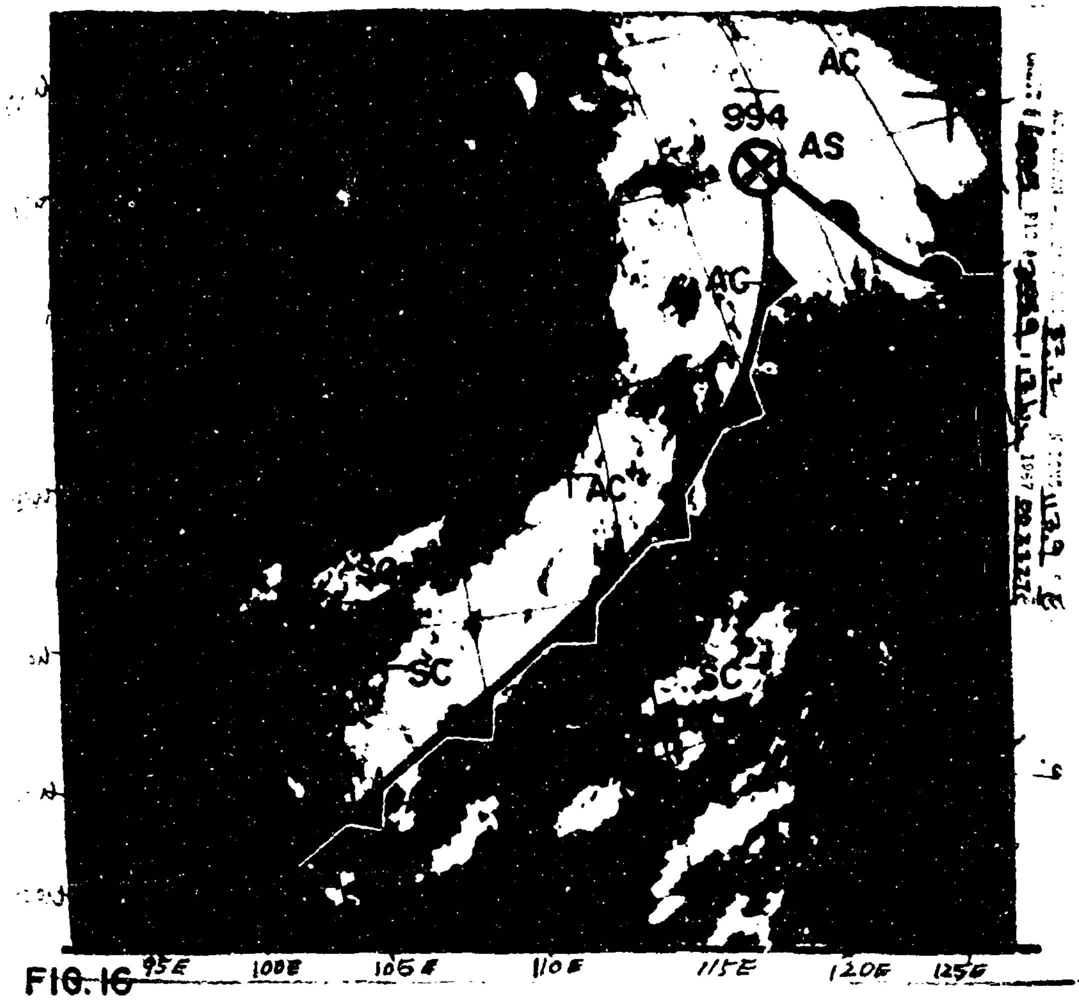
FIG. 15



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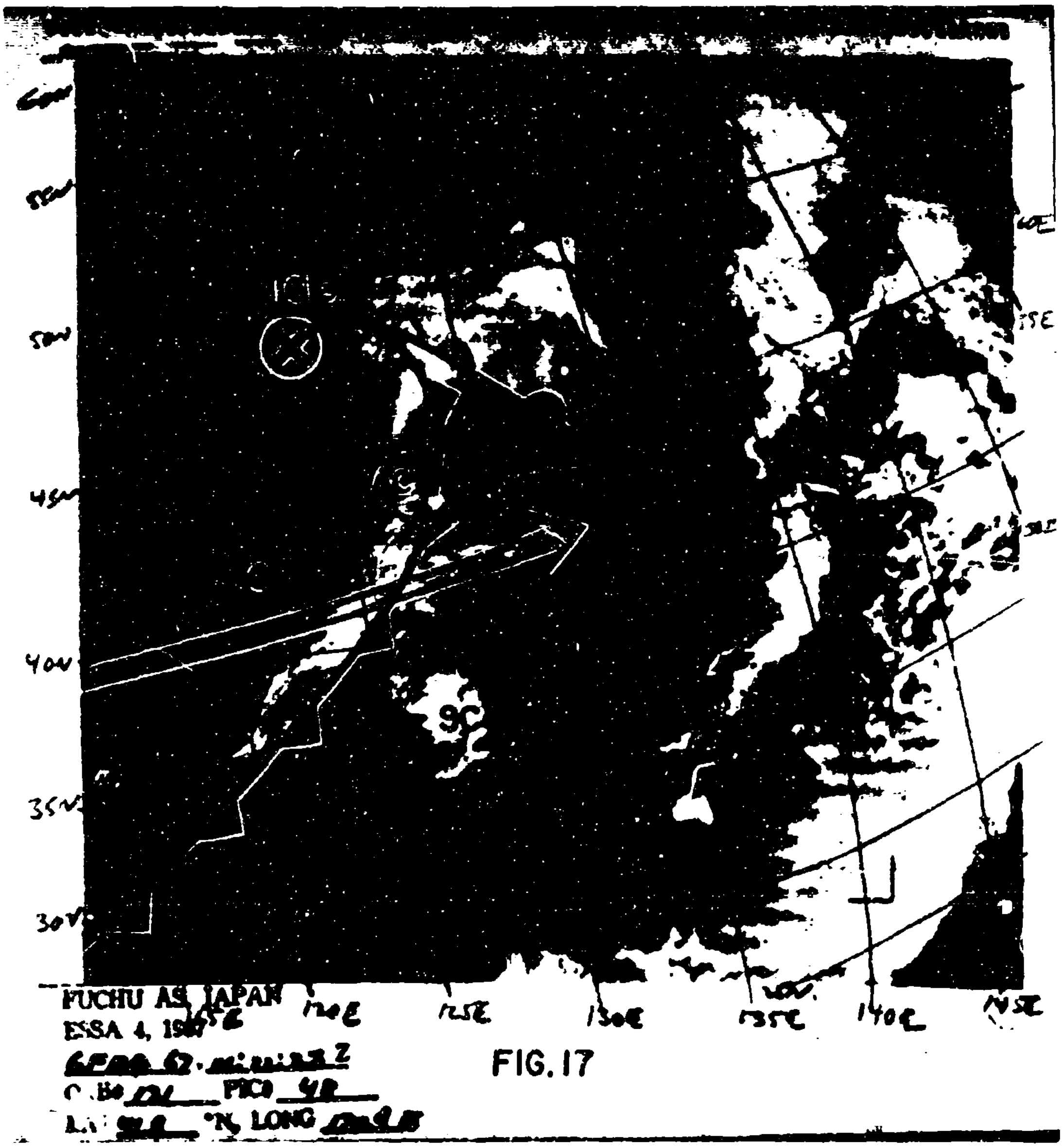
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FIG. 17

FIG. 18

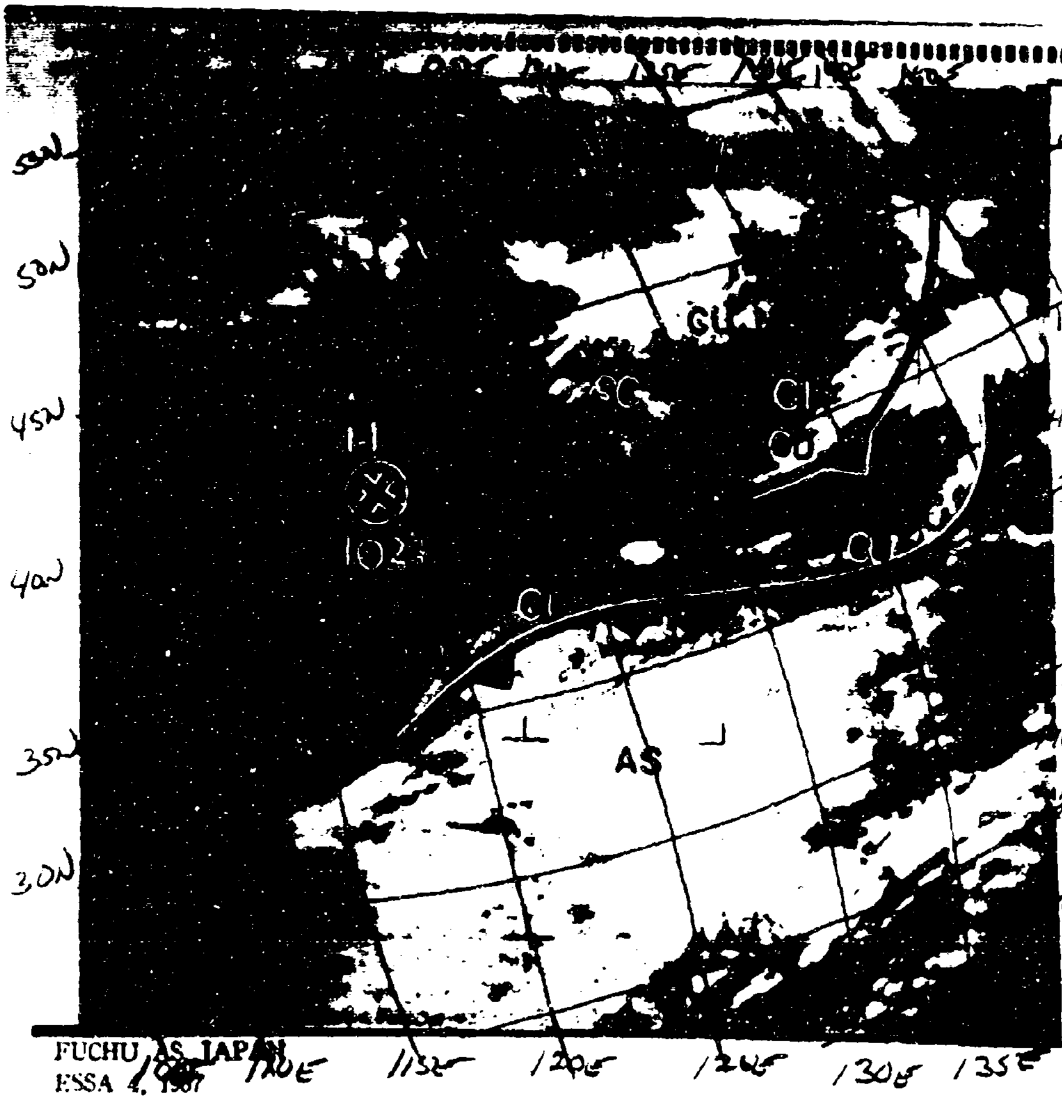

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FIG. 19

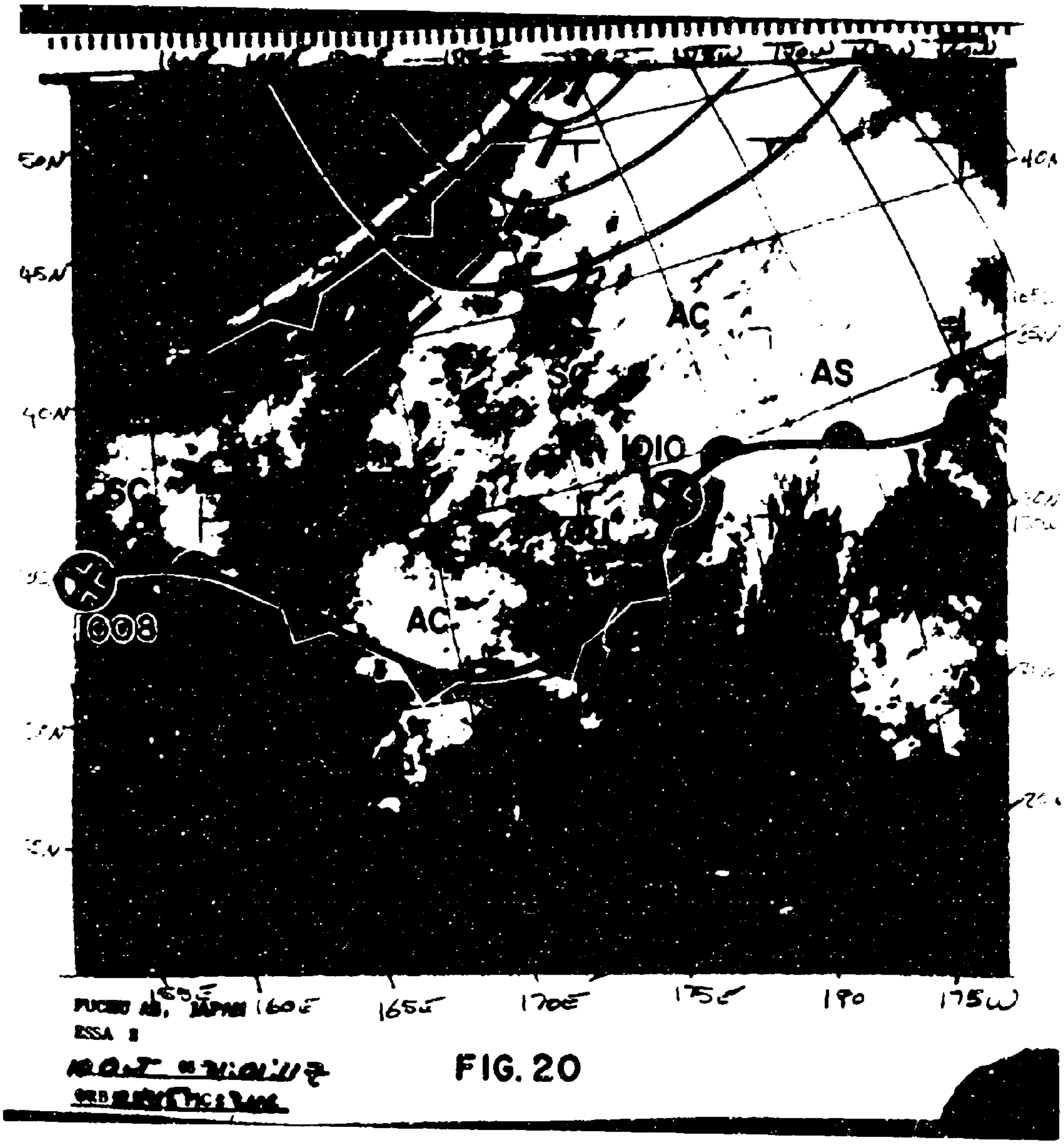
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FIG. 20

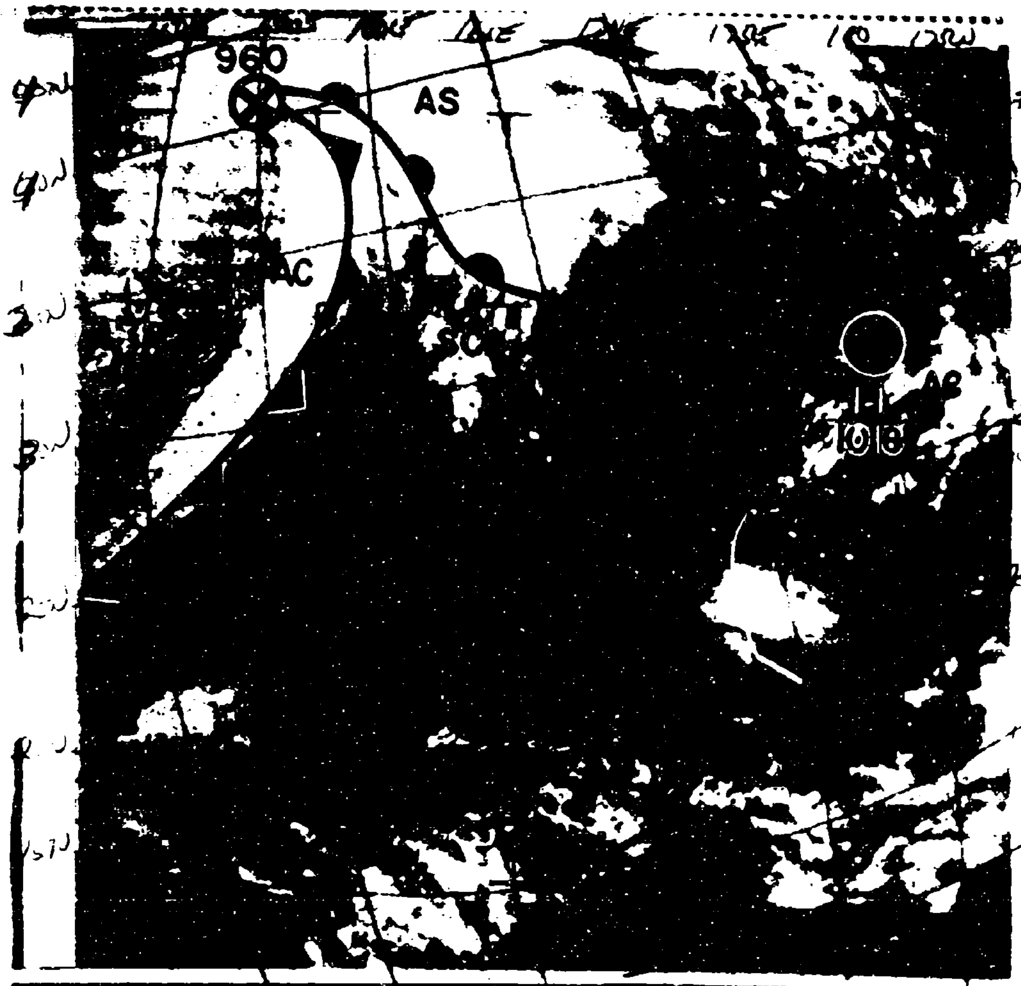

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FIG. 21

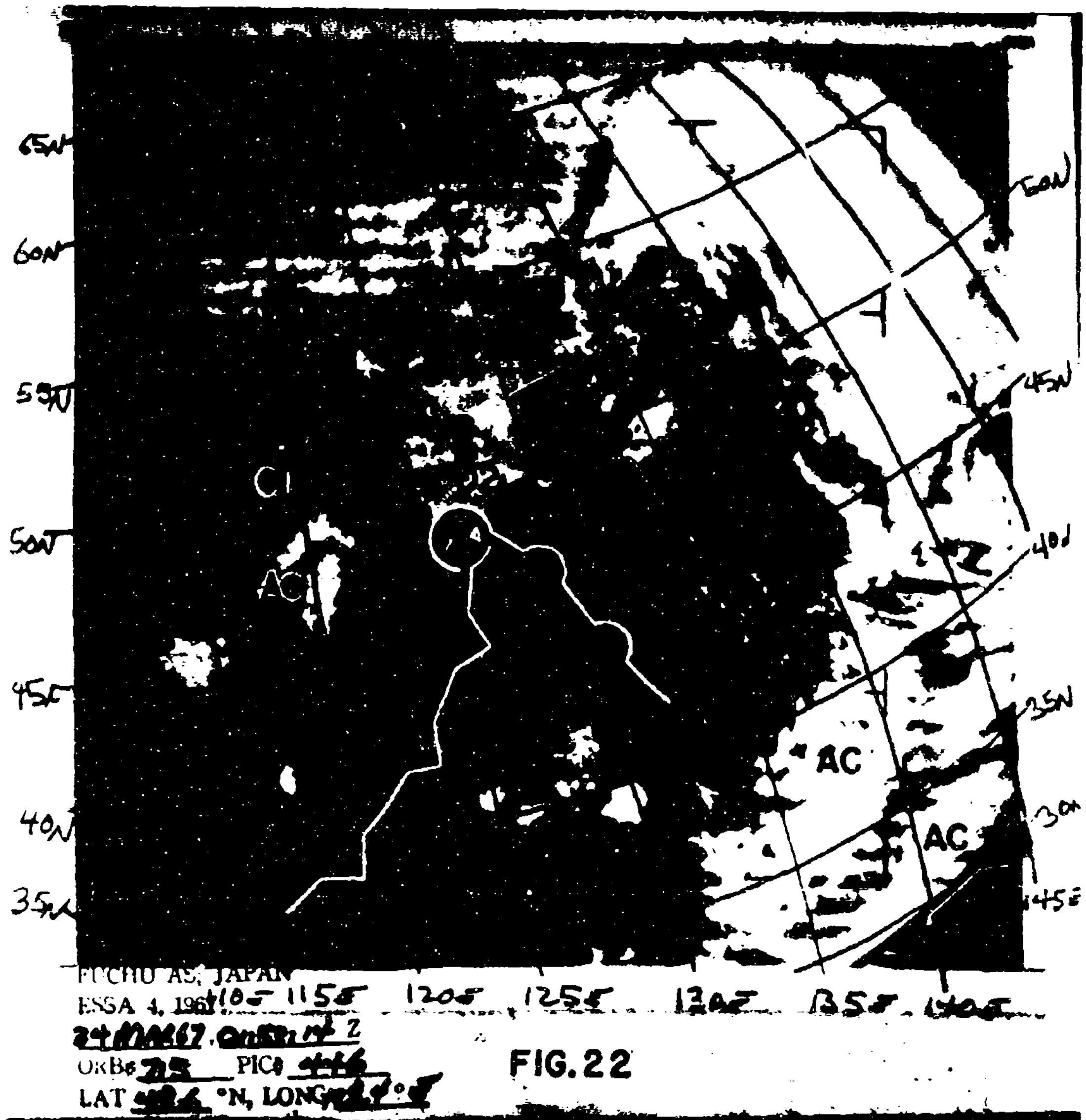
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FIG. 22

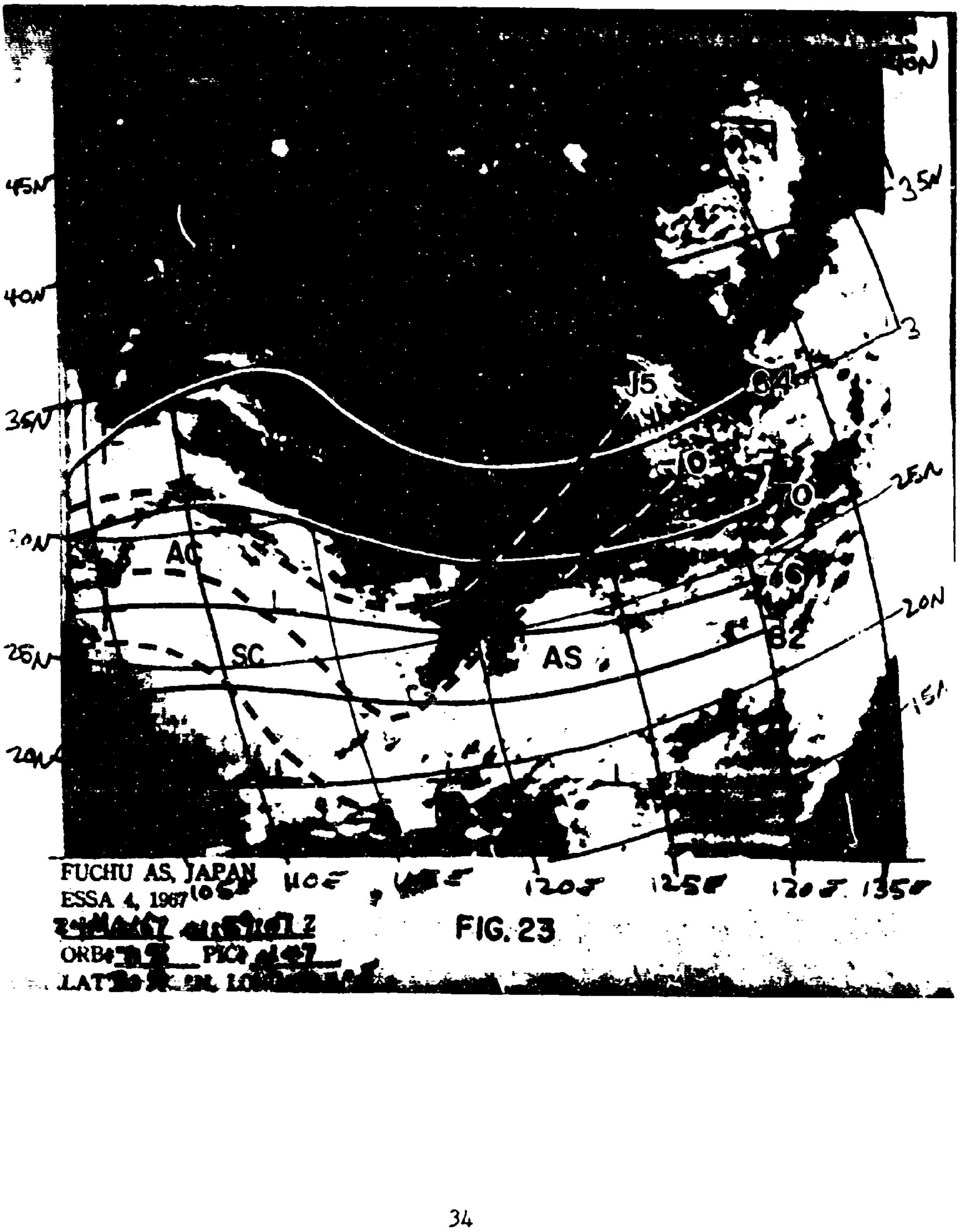
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FIG. 23

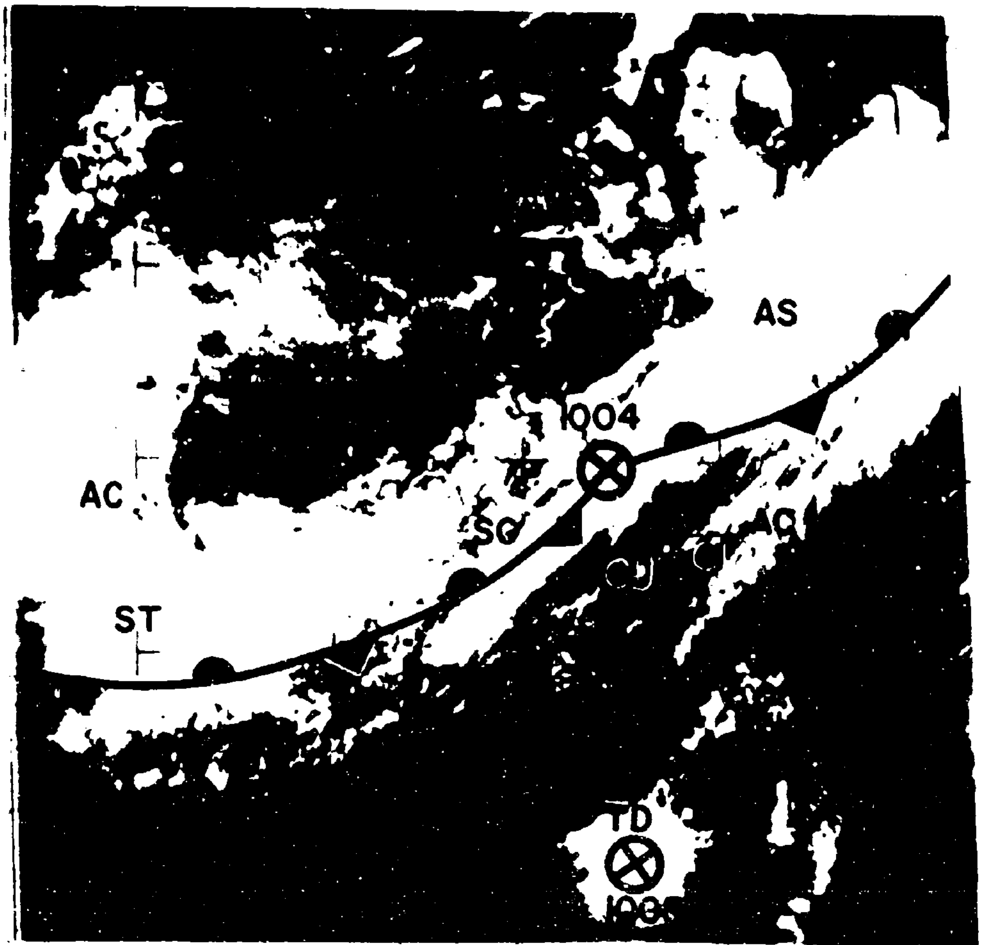

FIG. 24

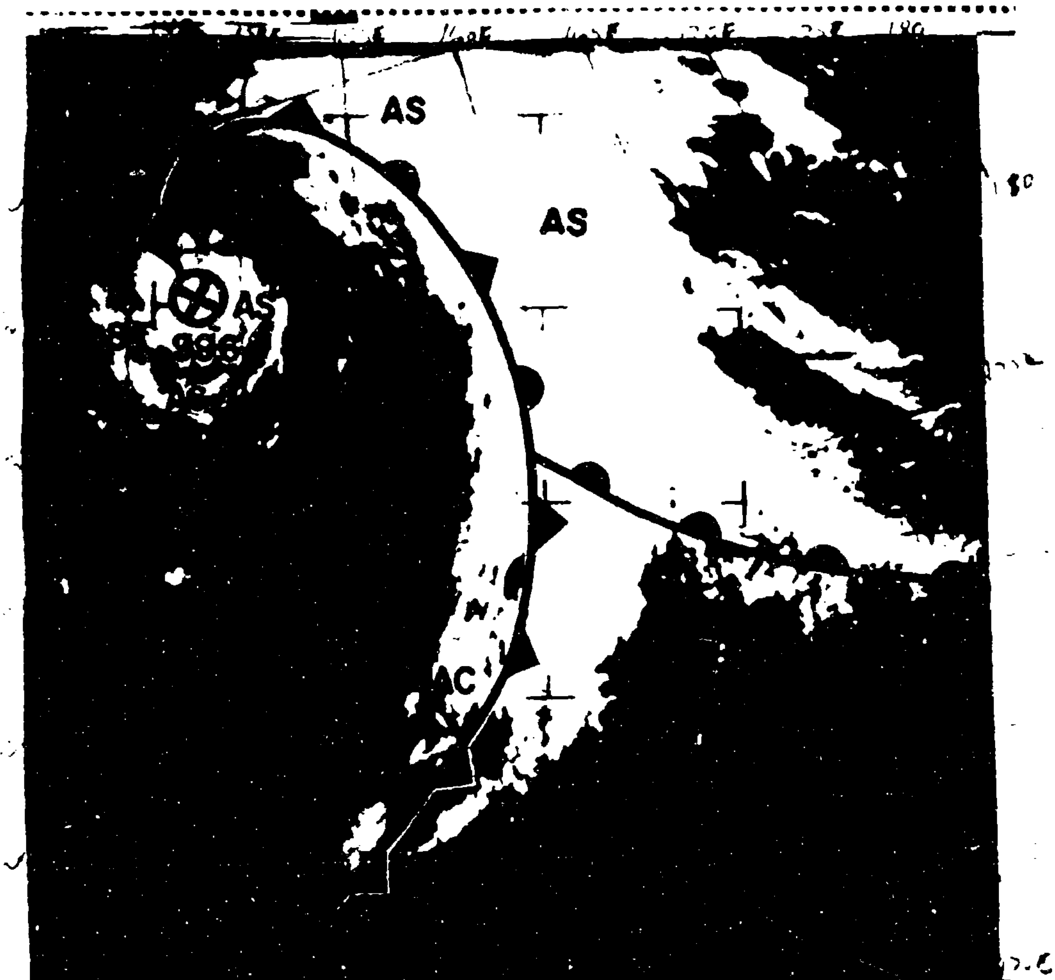

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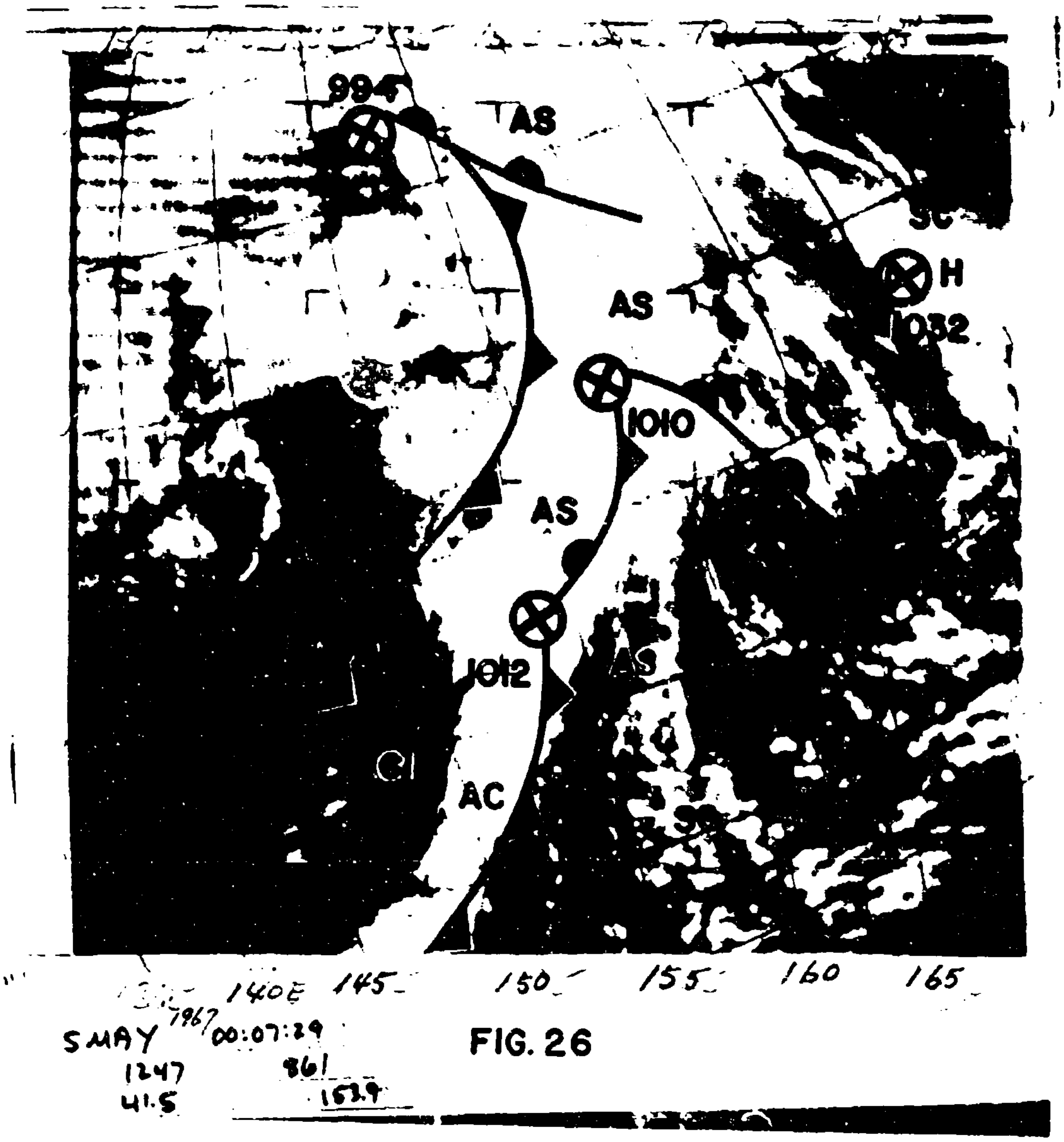
FIG. 25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153.9

FIG. 26


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AC
SC

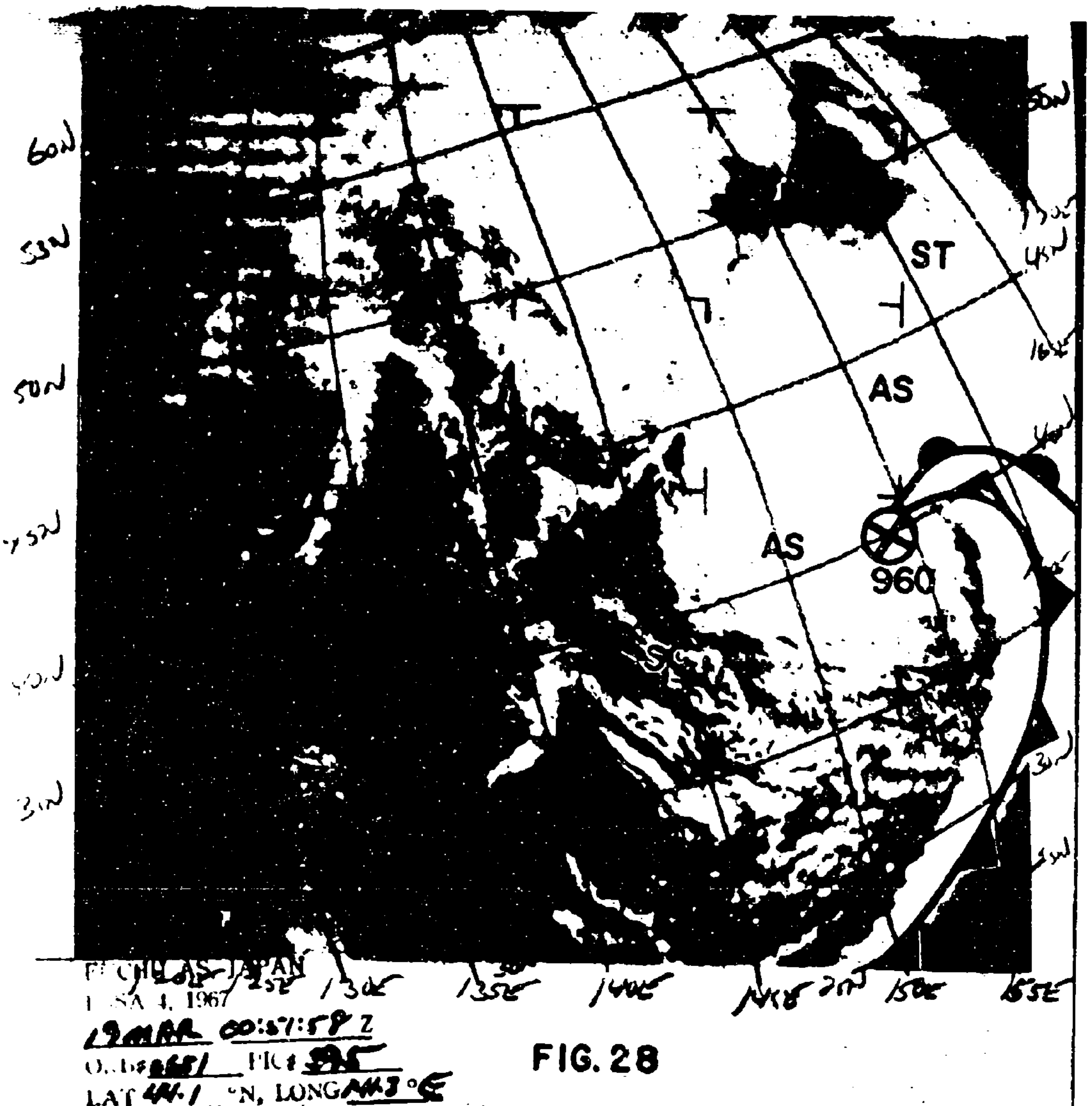
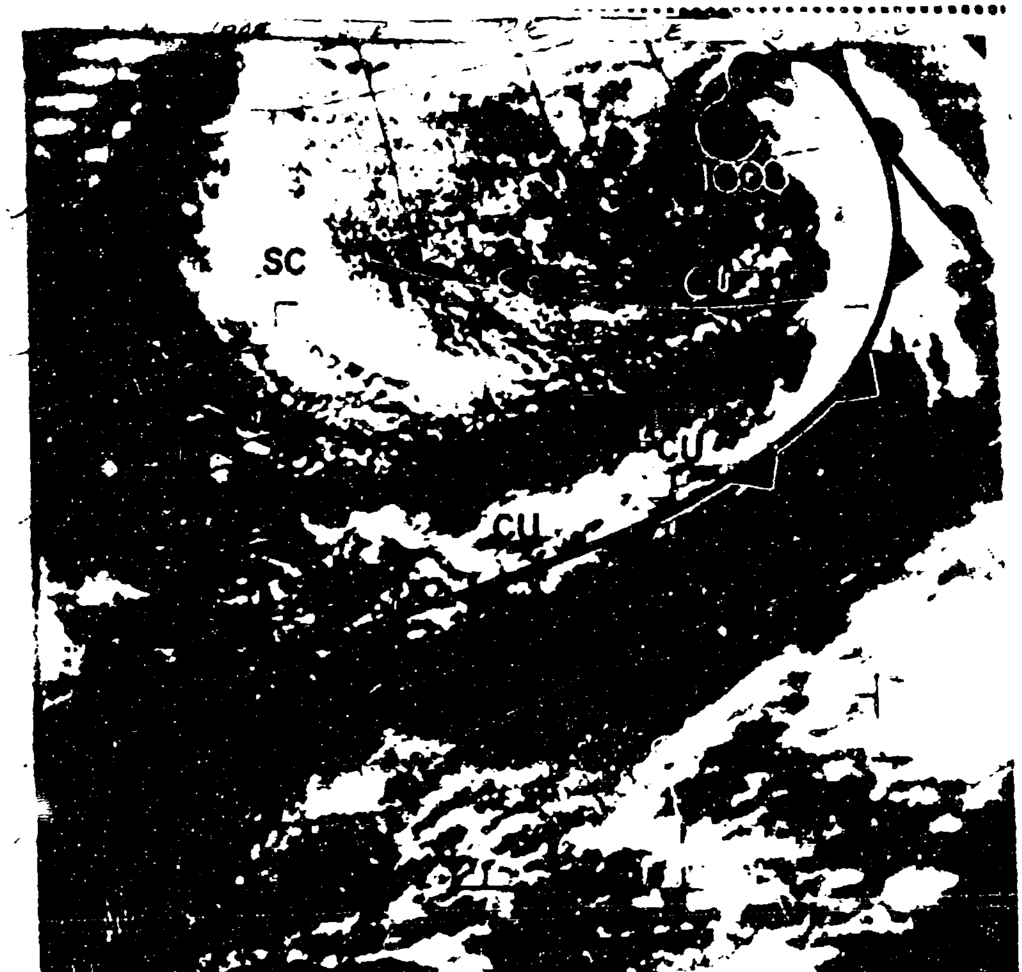

60N
55N
50N
30N
ST
AS
AS
960
ESSA 4, 1967
19 MAR 00:57:58 Z
LAT 44.1 °N, LONG
135E
140E
150E
155E

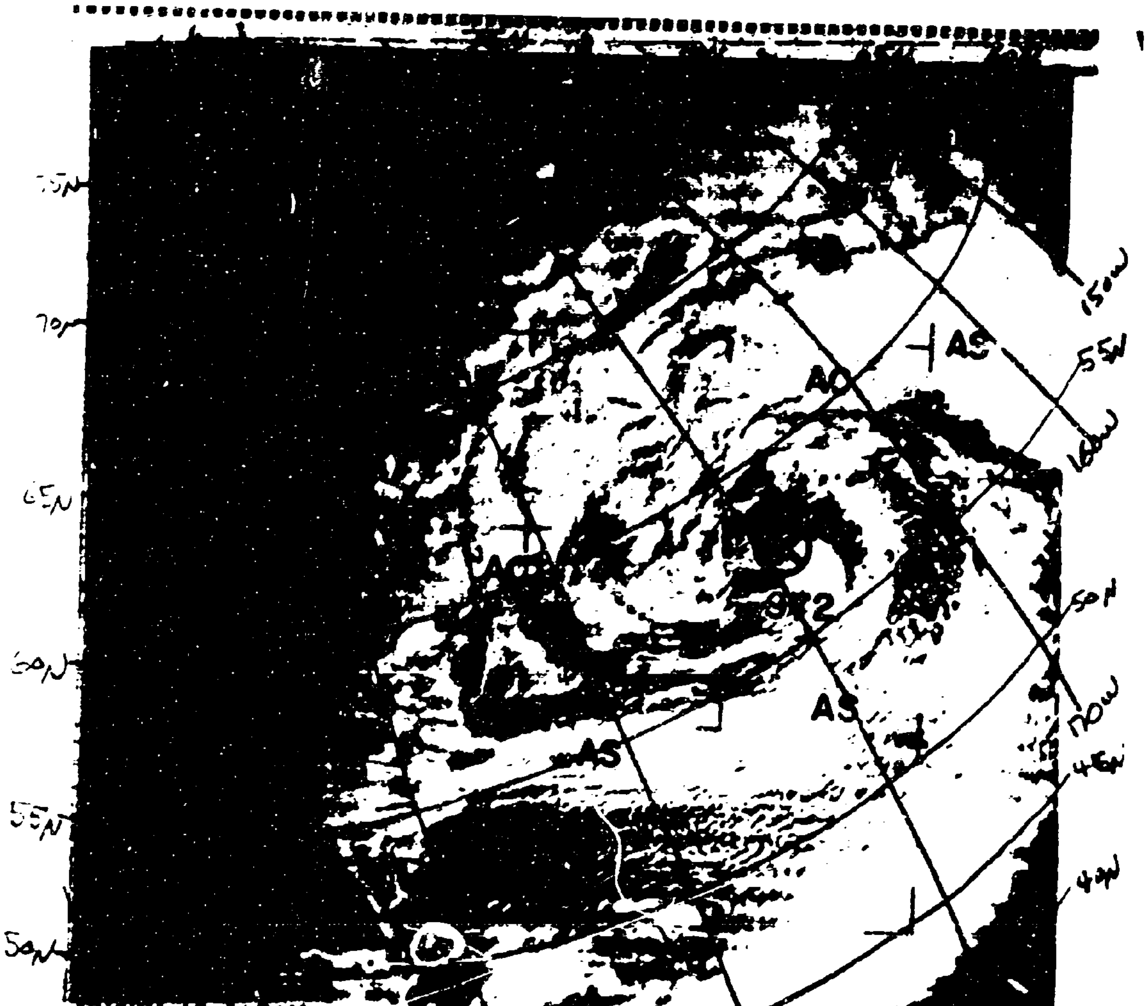
FIG. 28



AS, JAPAN
155E 160E 165E 170E 175E

ORB# PIC# 845
LAT °N. LONG

FIG. 29



FUCHU AS, JAPAN
ESSA 3, 1967
16 FEB 67, 23:24:14 Z
ORB# 0257 PIC# 127
LAT 60.6 °N, LONG 169.2° E

FIG. 30

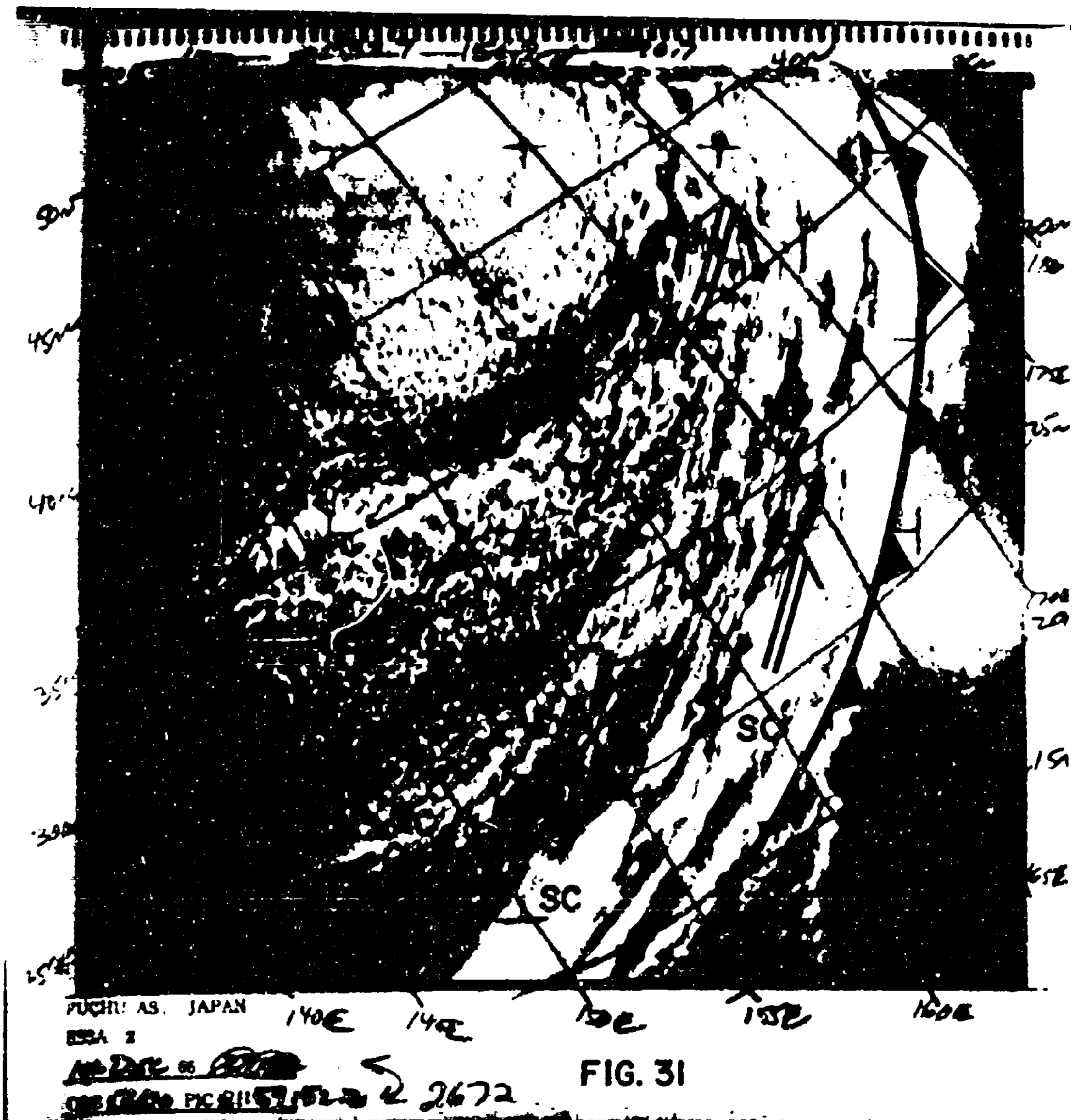
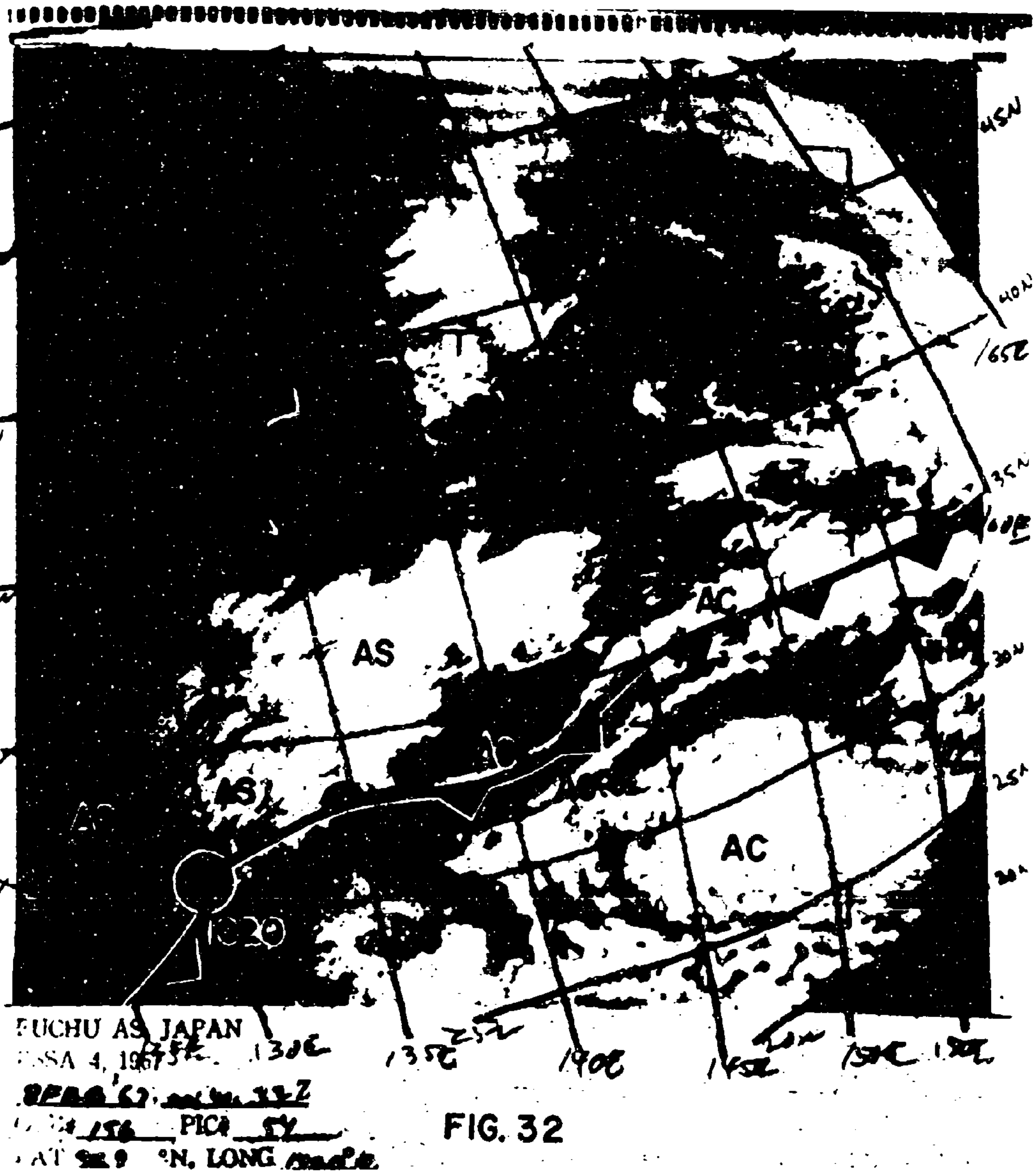


FIG. 31



AS
AS
AC
AC
AC
1020
45N
40N
165E
35N
30N
25N
20N
130E
135E
140E
145E
150E
FUCHU AS JAPAN
ESSA 4, 1967
PIC#
°N, LONG

FIG. 32

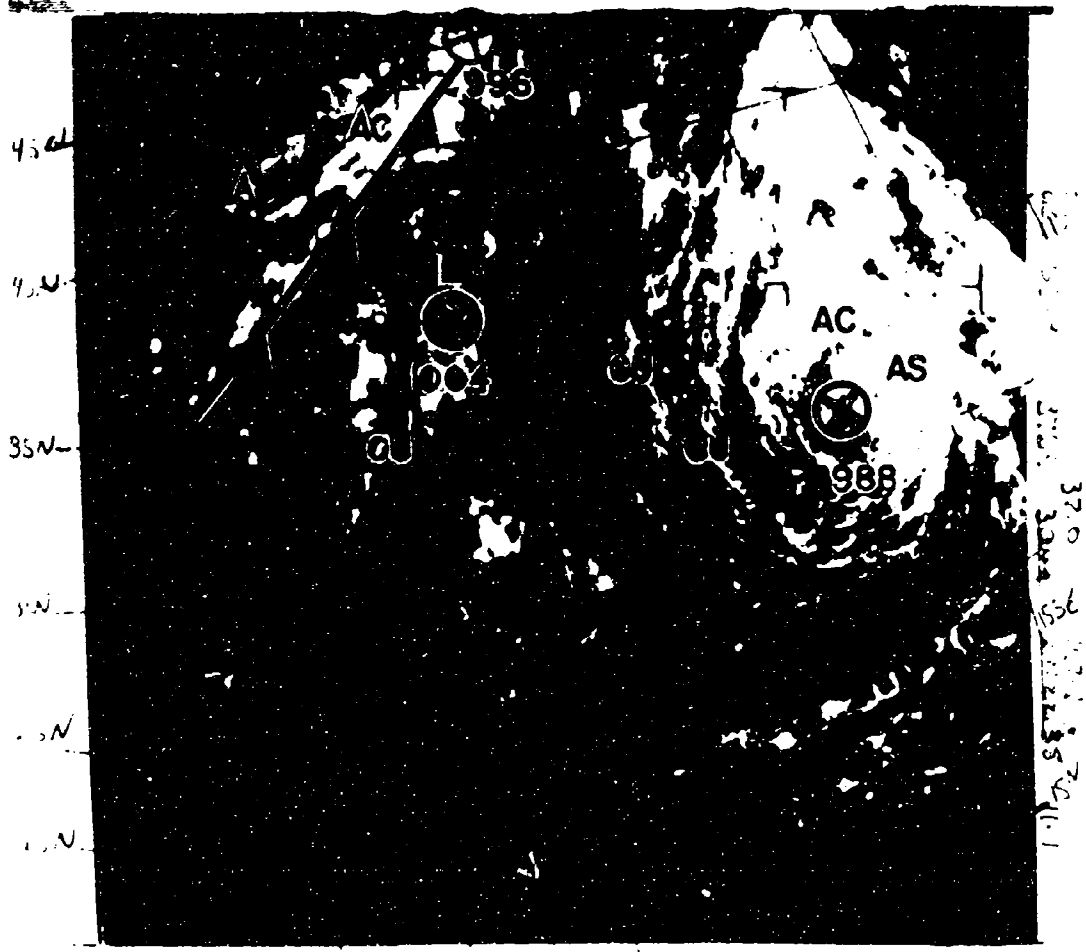


FIG. 33 125E 130 135 140 145 150E

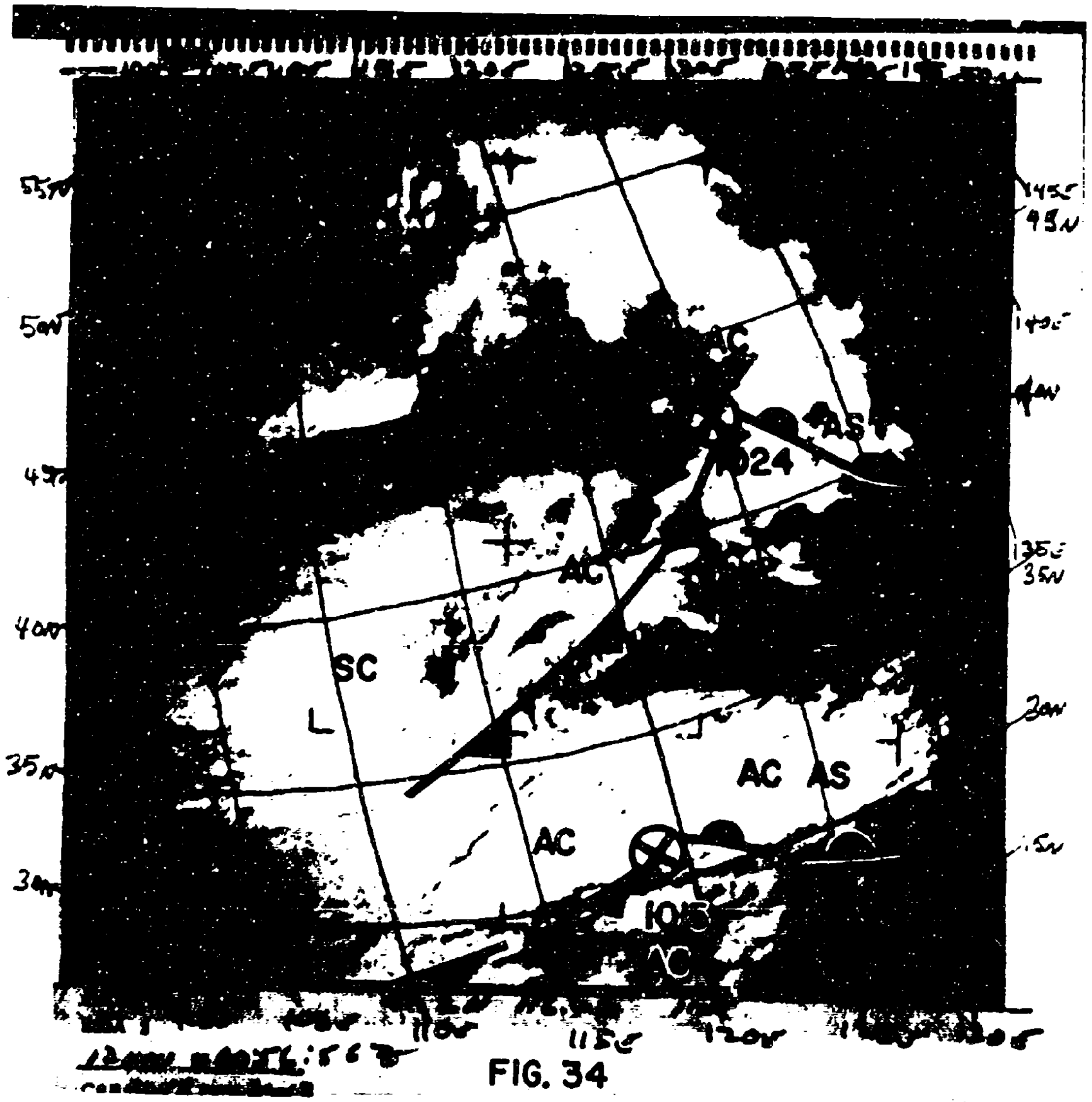


FIG. 34

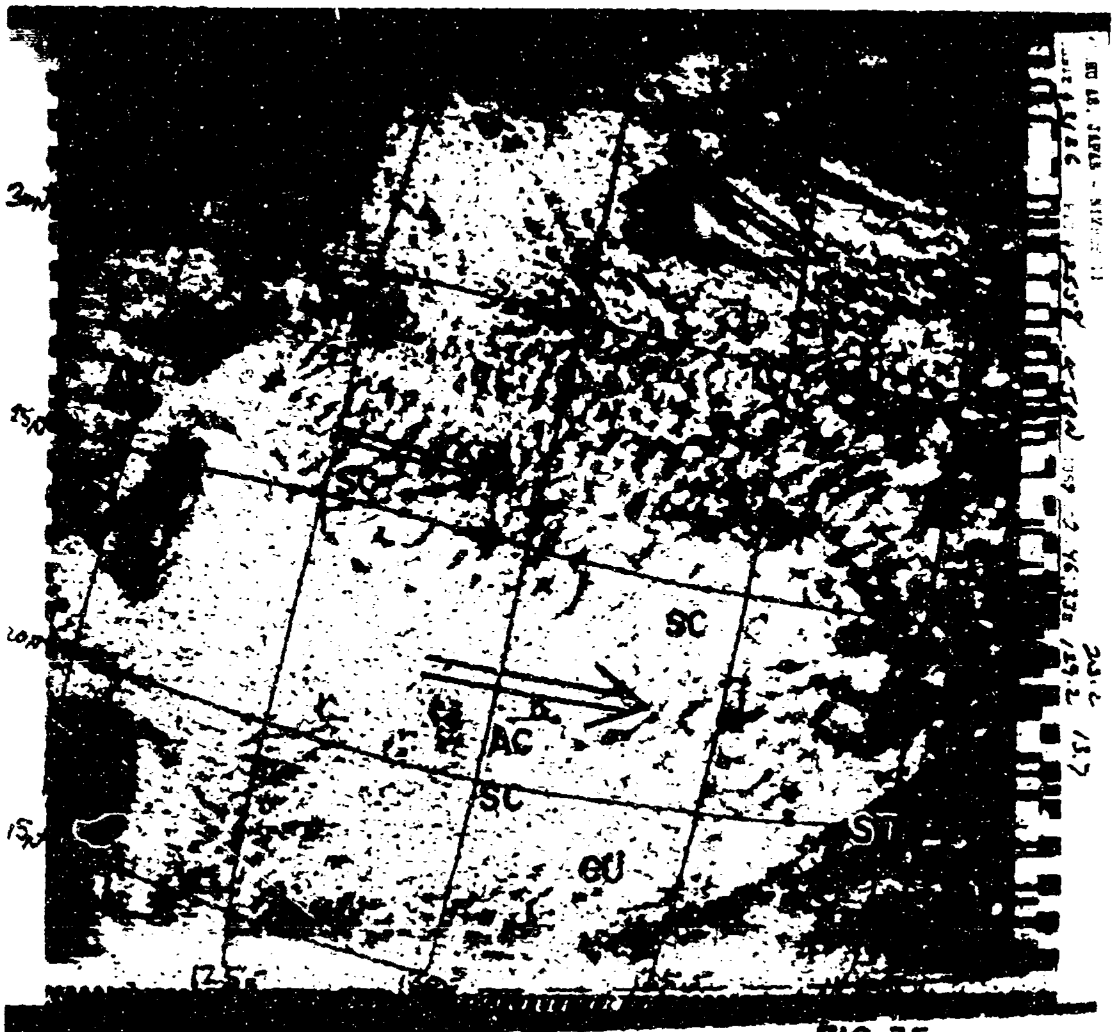


FIG. 35

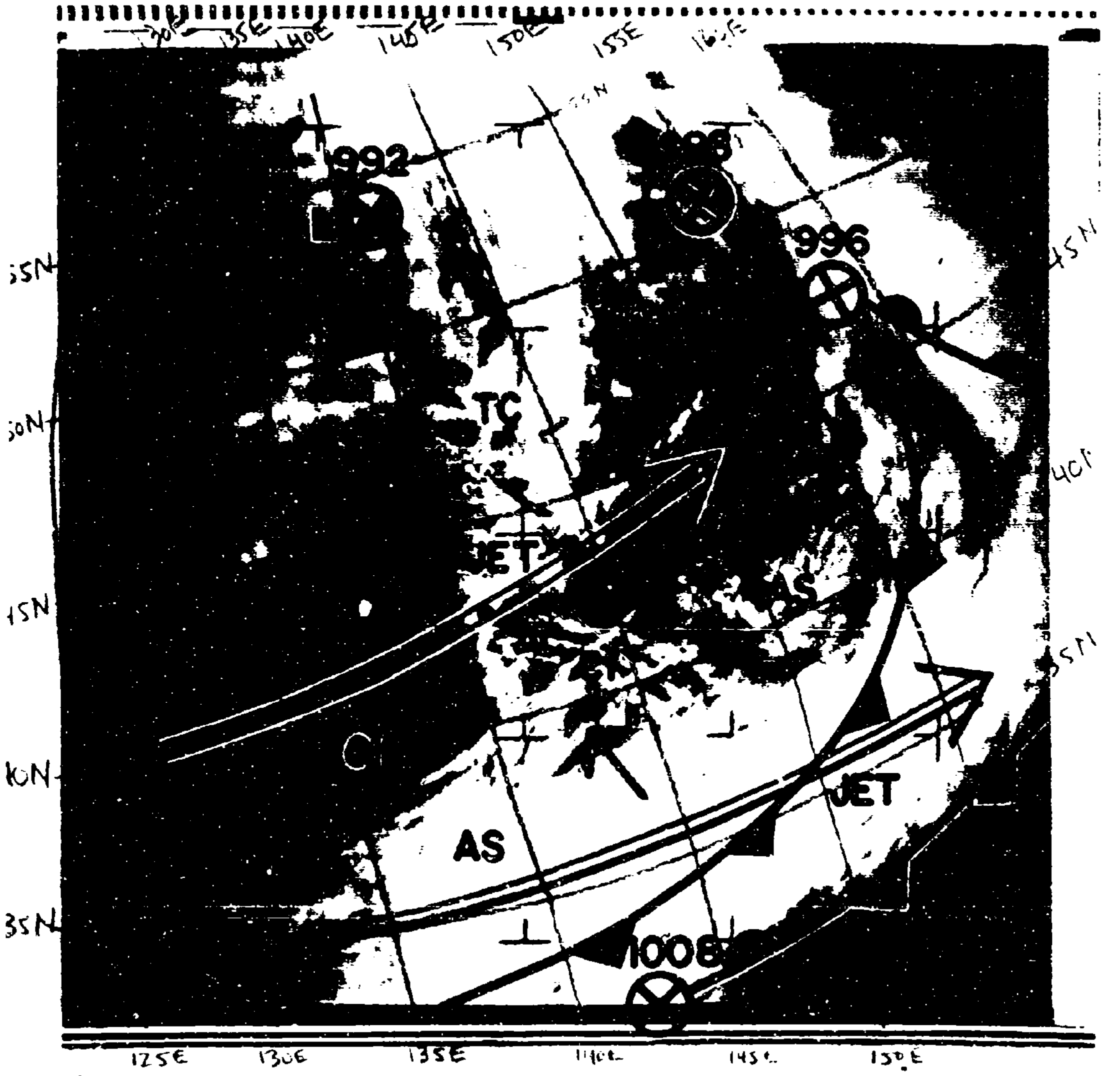
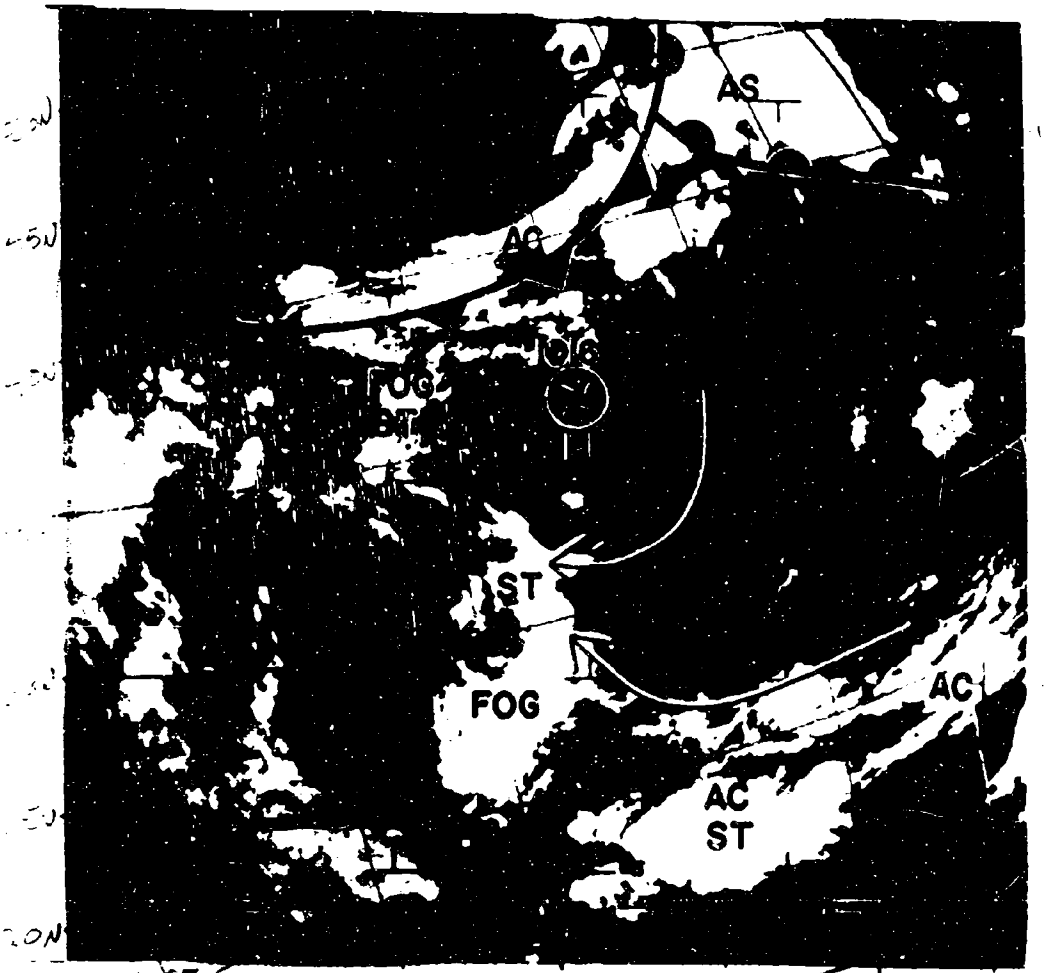


FIG. 36



FUCHU AS, JAPAN
ESSA 4 1967
15 MAR 67 . 23:48:23Z
ORB 5599 PIC 2989
LAT 32.7 N, LONG 134.4 E

FIG. 37


FIG 38

FIG. 39

FIG. 40 115E 120 125 130 135

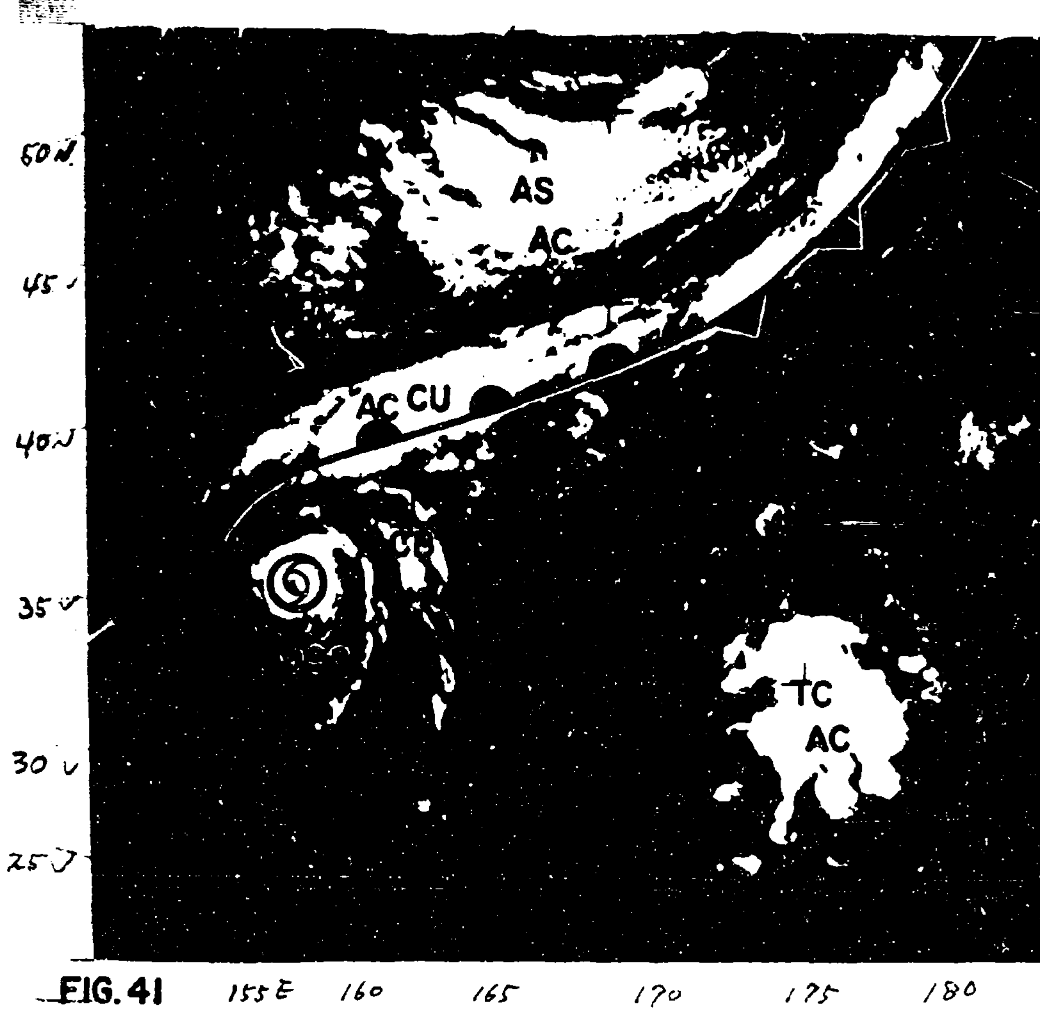


FIG. 41

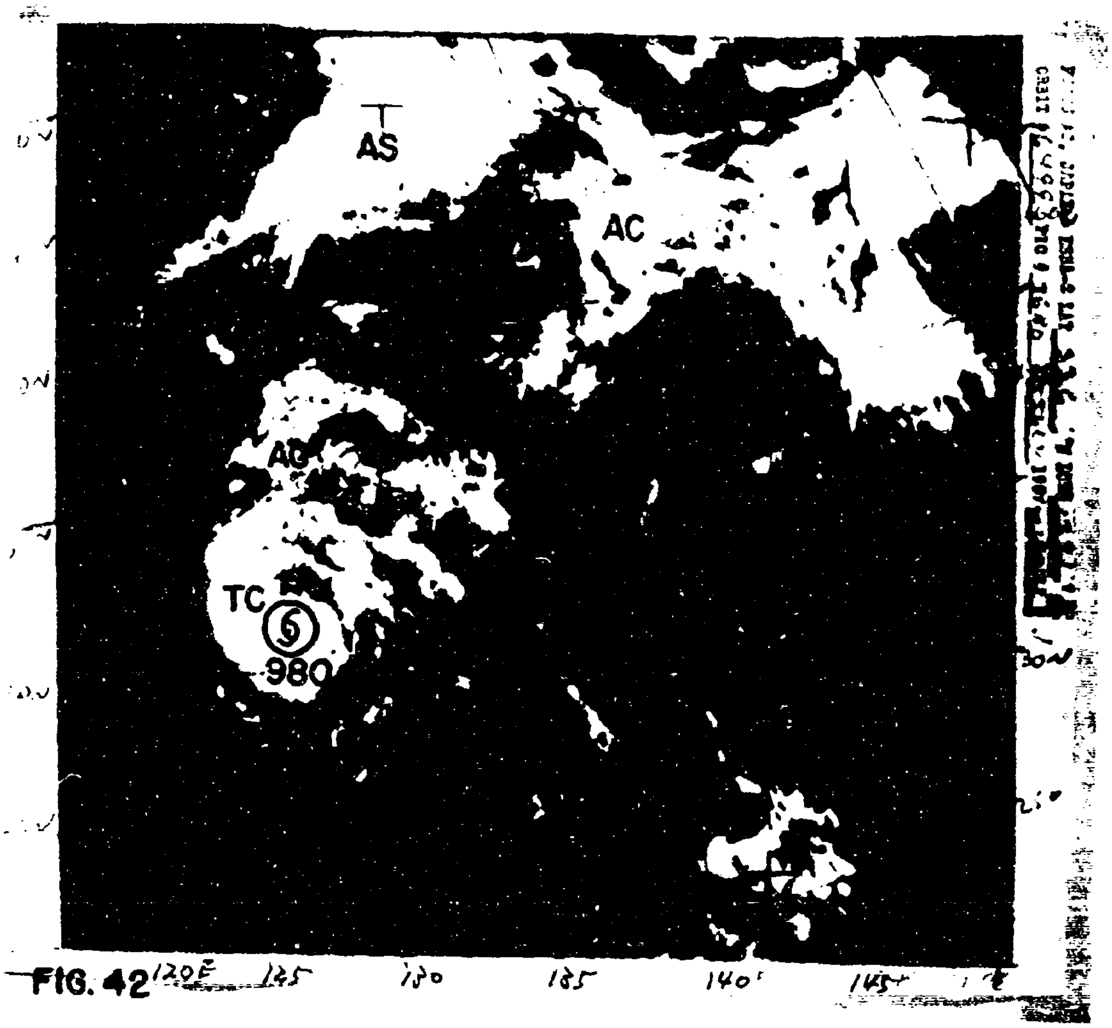


FIG. 42

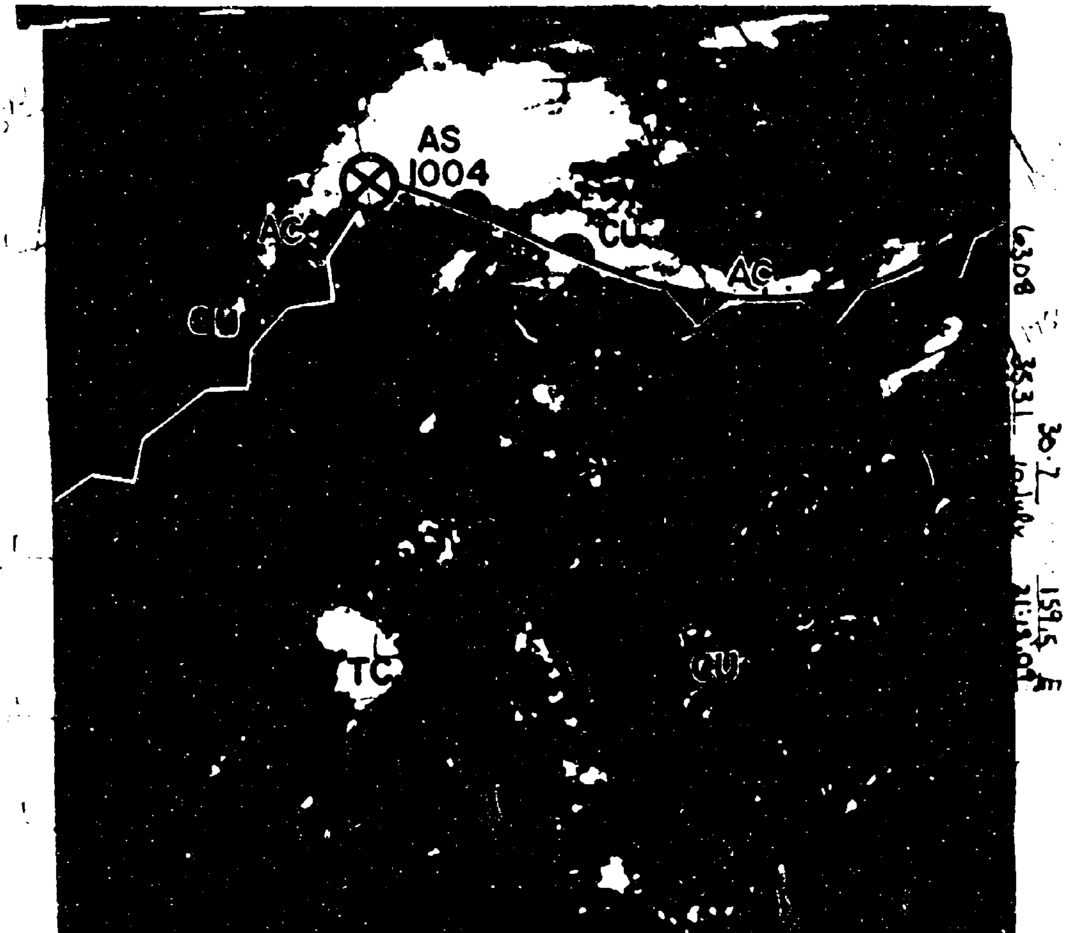


FIG. 43 140E 145 150 155 160 165

FIG. 44 140 145 150 155 160E.

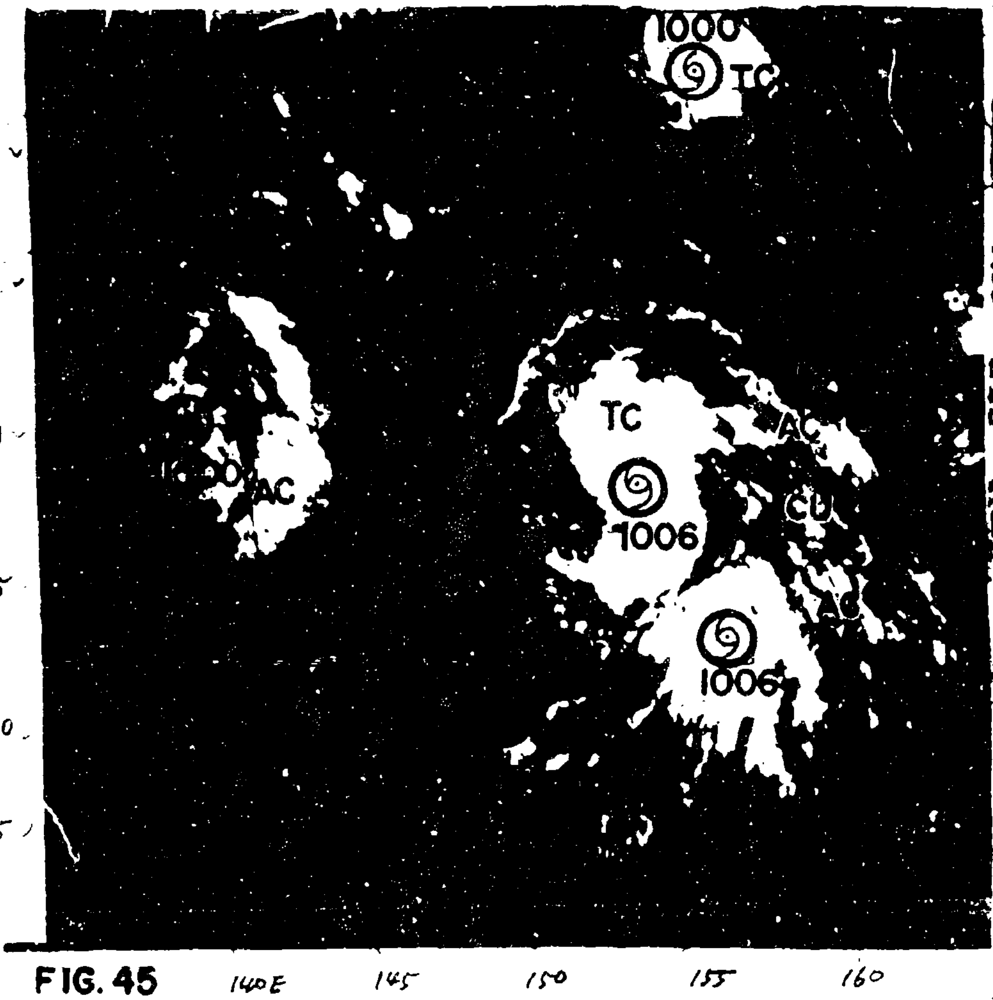


FIG. 45

FIG. 46

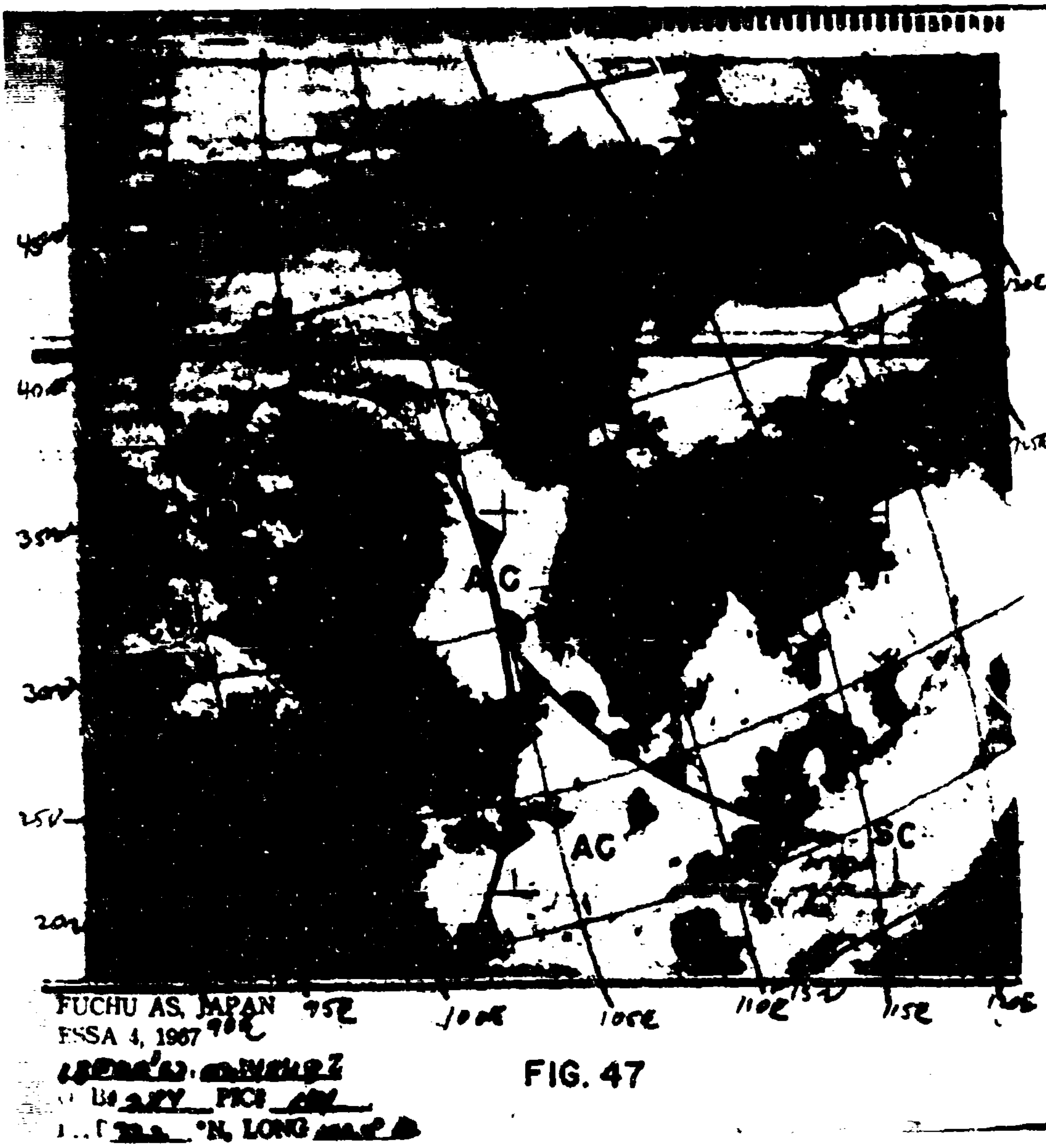


FIG. 47

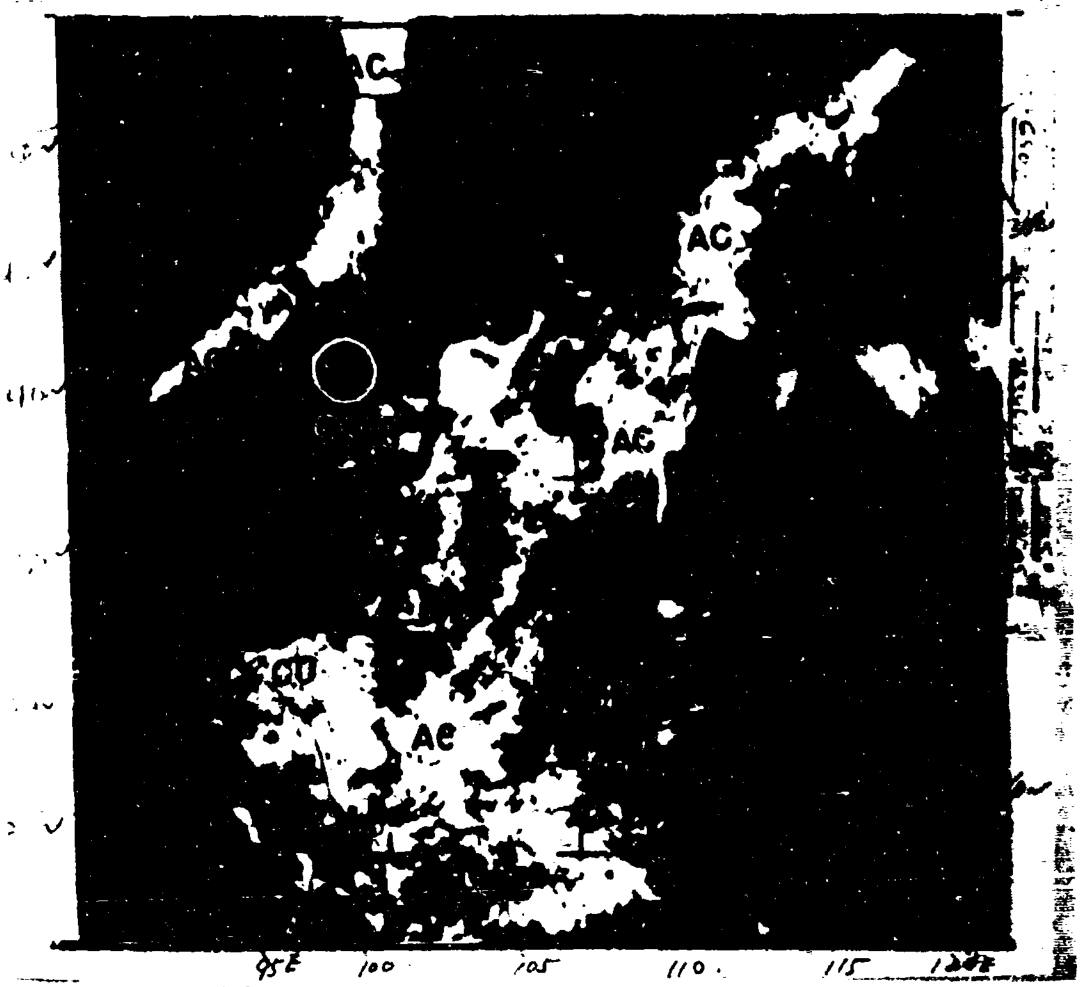


FIG. 48

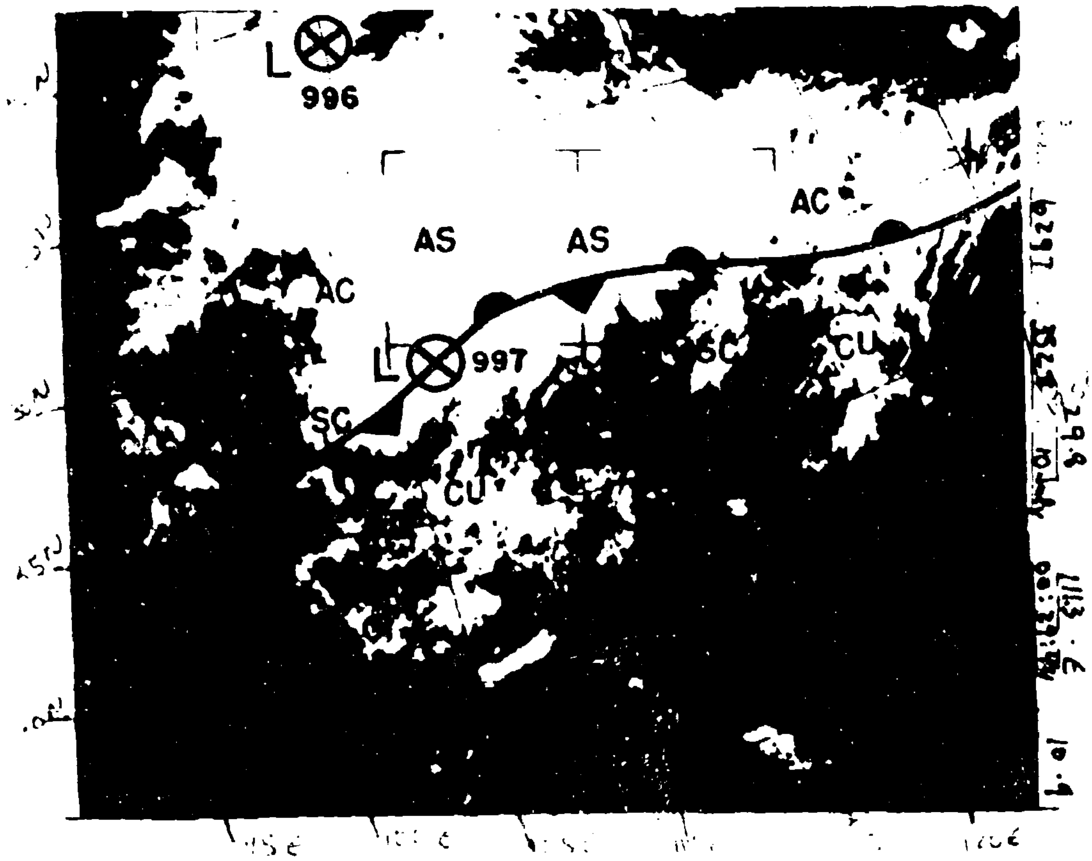


FIG. 49

Table 1*. Average albedos (A) in percent for various cloud and terrestrial surfaces as measured from satellite pictures

(MCO - Cloud Cover greater than 80 percent)

		(A)
(1)	Cumulonimbus - large and thick	92
(2)	Cumulonimbus - [illegible], top estimated 6 km	86
(3)	Cirrostratus - thick, with lower clouds and precipitation	74
(4)	Cumulus and Stratocumulus - MCO, over land	69
(5)	Stratocumulus - MCO, over land	68
(6)	Stratus - Approximately 0.5 km thick over ocean	64
(7)	Sand - White Sands, New Mexico, USA	60
(8)	Stratocumulus masses within cloud sheet over ocean	60
(9)	Snow, 3-7 days old covering mountain above timber	59
(10)	Stratus - thin, over ocean	42
(11)	Cirrus - over land	36
(12)	Cirrostratus - over land	32
(13)	Cumulus of fair weather - MCO, over land	29
(14)	Sand, Valleys, plains and slopes	27
(15)	Sand and brushwood	17
(16)	Coniferous forest	12
(17)	Lake - Great Salt Lake, USA	9
(18)	Ocean - Gulf of Mexico	9
(19)	Ocean - Pacific	7

* After Conover (1965)

J. REFERENCES

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This study describes the application of satellite data in daily synoptic analysis and forecasts. General characteristics of the appearance of clouds in satellite pictures are briefly discussed. Rules which are directly useful for daily forecasting are itemized and divided into various terrain effects and synoptic patterns. Selected examples of photographs from ESSA 2 and 4 and Nimbus 2 are discussed.

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