Chapter 2　Cloud type identification by satellites

2.1　Features of cloud type identification

Unlike ground observation, which visually observes the cloud forms from the earth's surface, the satellites observe the behavior of the cloud tops far from above the earth. The resolution of sensors on board the satellites (with the GMS-5, about 1 km in the visible imagery and about 5 km in the infrared imagery on sub-satellite point) are coarser than the human eye, and cloud form classification as detailed as surface observation is impossible. Thus, we must understand that the cloud types identified by the satellites are basically different from the cloud forms identified by surface observation. We merely use the cloud type names that is similar to origin or structure of the cloud forms determined by surface observation. We call hereafter the cloud types judged from satellite observation "cloud types" as distinguished from the cloud types determined by visual surface observation, which are called "cloud forms".

2.2　Classification of cloud types

In cloud type identification by satellites, the cloud types are classified into 7 groups: Ci (high level clouds), Cm (middle level clouds), St (stratus/fog), Cb (cumulonimbus), Cg (cumulus congestus), Cu (cumulus), and Sc (stratocumulus) (see Table 2.2.1).

Table 2-2-1.　Cloud type classification by satellite imagery

<table>
<tr><th colspan="2">Cloud type</th><th colspan="2">Classification</th></tr>
<tr><td>High level cloud</td><td>Ci</td><td rowspan="3">Stratiform clouds</td><td>High level clouds</td></tr>
<tr><td>Middle level cloud</td><td>Cm</td><td>Middle level clouds</td></tr>
<tr><td>Stratus/fog</td><td>St</td><td rowspan="3">Low level clouds</td></tr>
<tr><td>Stratocumulus</td><td>Sc</td><td>———</td></tr>
<tr><td>Cumulus</td><td>Cu</td><td rowspan="3">Convective clouds</td></tr>
<tr><td>Cumulus congestus</td><td>Cg</td><td rowspan="2">———</td></tr>
<tr><td>Cumulonimbus</td><td>Cb</td></tr>
</table>

These cloud types are characterized as stratiform clouds (Ci, Cm, St) or convective clouds (Cb, Cg, Cu). Sc has an intermediate character between stratiform and convective clouds.

The stratiform clouds have a horizontal extent that is far larger than the vertical extent (cloud thickness). They are characterized as "recognized as a cloud area that has a coherent extent" and "having a smooth cloud surface and an even cloud top height". On the other hand, the convective clouds have a larger thickness and smaller area than the stratiform clouds. They have characteristics such as "readily recognizable as independent cellular cloud areas" and "having an uneven cloud surface".

The clouds as seen from the satellite may be classified into high, middle and low level clouds. We should take note that of the classification into high, middle and low level clouds by satellite observation is based on cloud top height because the classification by surface meteorological observation is based on cloud base height. If classified by cloud top height, the high level clouds are 400 hPa or over, the middle level clouds 400 to 600 hPa, and the low level clouds 600 hPa or less as in a rough standard. Besides the high level clouds (Ci) and middle level clouds (Cm), the low level clouds include Cu, St and Sc. In general, Cg and Cb are not included in such classifications.

2.3 Identification of cloud types

For cloud types identification by human eyes, the visible and infrared imagery have been used generally since the first launch of a meteorological satellite. On the other hand, with the computer, the cloud type identification uses water vapor and the infrared split window channel imagery besides the visible and infrared imagery. Tokuno and Kumabe (1996) developed an algorithm that produce cloud type data automatically for a cloud information chart by a computer. This algorithm identifies the cloud type from the histogram's distribution and temperature differential characteristics obtained from each imagery of 0.25 × 0.25 degree grids. With the computer, objective cloud type identification is possible, however, identification considering meteorological conditions and cloud patterns is difficult. On the contrary, cloud type identification by the human eye has the merit of being able to use meteorological conditions, cloud patterns, changes with time, and other comprehensive meteorological knowledge. For cloud type identification in the future, it is necessary to take in the respective advantage points of the computer and man. This chapter describes cloud type identification by the human eye.

2.3.1 Identification by visible and infrared imageries

The visible imagery represents the intensity of reflected sunlight. A cloud that has larger water content and is thicker reflects more. The convective clouds look brighter than the stratiform clouds because they contain more water droplets and are thicker. Though equally being convective clouds, the cloud becomes thicker and reflects more if developed. That is, Cg is brighter than Cu, and Cb is still brighter than Cg. Therefore, a cloud formed in the low level is brighter than a cloud formed in the high level in most cases. That is, St is brighter than Ci. However, because the very dense Ci that appears frequently in early spring in the Eurasia continent looks bright, we must take care in distinguishing it from other clouds. With a thin Ci, the middle or low clouds underlying it may be seen through. In such a case, the reflection from the underlying cloud is added and the Ci looks brighter than when it is by itself.

In the infrared imagery, a cloud of high cloud top height looks bright and a cloud of low cloud top height looks dark. Of the stratiform clouds, Ci is the brightest, followed by Cm and St in the order of brightness. On a thin cloud, however, radiations from below the cloud are also observed through the cloud layers besides the radiations from the cloud itself. This results in a higher cloud top temperature than actual and may lead to a mistake in judging the cloud top height. For example, Ci frequently consists of a thin cloud layer and it is apt to be mistaken for Cm with the infrared imagery alone. On the contrary, a very dense Ci has about the same cloud top temperature as Cb, and distinction from Cb is frequently difficult. St has a low cloud top temperature that is scarcely different from the surface temperature, and its detection is difficult with the infrared imagery alone. For the convective clouds, their degree of development can be classified by cloud top height. That is, the cloud top height of a developed convective cloud is the highest for Cb, followed by Cg, and a least developed Cu is the lowest.

A cloud type identification diagram using visible and infrared imageries is shown in Figure 2-3-1. This diagram shows the above-stated relationships in a qualitative way.

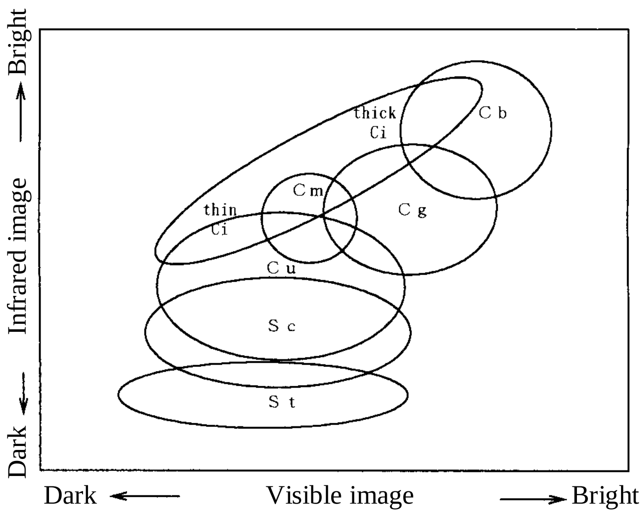


Figure 2-3-1. Cloud type identification diagram

2.3.2 Identification by forms

A stratiform cloud is apt to exist as a cloud area that has an even cloud top height and a fairly large extent. For example, because St has a constant cloud top height, the cloud edge frequently assumes a form along an orographical contour. Ci shows characteristic forms, such as streaks (Ci streak), featherlike cloud blowing out of Cb (anvil cirrus), and a small cloud line perpendicular to the current (transverse line).

The convective cloud exists as a relatively small cloud cluster in most cases. As convective clouds develop further, they increase in thickness and merge together, and the area of the cloud area increases if seen from the satellite. Therefore, in the descending order of size as an individual cloud, they take the order of Cb, Cg and Cu. The convective clouds shows characteristic patterns such as linear, taper, and cellular.

The cloud edge of a convective or low cloud is distinctive and clear. On the other hand, the cloud edge of a high cloud is fluffy or frayed under the influence of the strong wind in the upper level and is not clear.

2.3.3 Identification by texture

With a visible imagery, the fine texture of the cloud surface can be known because of a finer spacial resolution than other imageries. The cloud surface conditions are easily known if irradiated obliquely by sunlight because shadows appear due to unevenness.

A stratiform cloud has a smooth and an even cloud surface. On the other hand, a convective cloud has an uneven and ragged cloud surface.

2.3.4 Identification by movement

Because, in the atmosphere, the wind is generally stronger in the upper level, the upper level clouds move fast and the low level clouds move slowly. Therefore, St, Sc, Cu and other low level clouds are slower movement than Ci. Tall, thick clouds such as Cb and Cg move with the average wind speed of the cloud level, and therefore they move slower than Ci.

2.3.5 Identification by changes with time

Because the convective cloud has a short lifetime, its form and cloud top height change for a short time. On the other hand, the stratiform clouds show little changes in cloud form and cloud top height. In comparison of Cb with Ci, for example, it is Ci that shows less change with time when their forms and patterns are observed.

2.4 Case study of cloud type identification

Figures 2-4-1 a and b show examples of cloud type identification. The cloud area A that extends from North China to the Yellow Sea and the sea east of Kyushu is Ci. In the infrared, it appears as a white and a wide band of clouds and its moving direction is along the wind direction in the upper level. In the visible image, a low level cloud that underlies the Ci is seen through. Therefore, the cloud on the north side is Ci.

The cloud area B that can be seen in Central China in the continent is Cm. In the infrared image, it looks light gray because the temperature is higher than the cloud area A and it has an uniform extention. It looks white in the visible image.

The cloud area C that extends from Sakishima Islands to Taiwan is St. In the infrared image, it is still darker than the surrounding cloud areas and it is at about the same temperature as the sea surface, so distinction is hardly possible. In the visible image, it looks light gray and its surface looks smooth.

The cloud area D that appears to the east side of Korean Peninsula is Sc. It looks dark gray in the infrared image. In the visible image, it looks light gray and it has a more ragged surface and a clearer boundary than C.

The cloud area E that covers the northern part of the Sea of Japan and around the Maritime Territory is Cu. In the infrared image, it looks lighter gray than the Sc in the cloud area D. In the visible image, it looks light white and it forms a cluster and the cloud edge is clear.

The cloud area F (marked by a triangle) to the east of Japan is Cb. In the infrared image, its western cloud edge is clear but it is indistinct on the eastern side because it is swept away by the upper flow. In the visible image, it looks most white and it forms a cluster. To the southeast of this Cb, the cloud area G (representative parts marked by triangles) is seen where Cg clouds range in linear form. In the infrared image, the low temperature areas corresponding to these Cg clouds are appeared in a cluster of form with space. In the visible image, they look as light white clusters with space on the Cu line.

How to distinguish Cb from Ci is described below. They both look white in the infrared image.

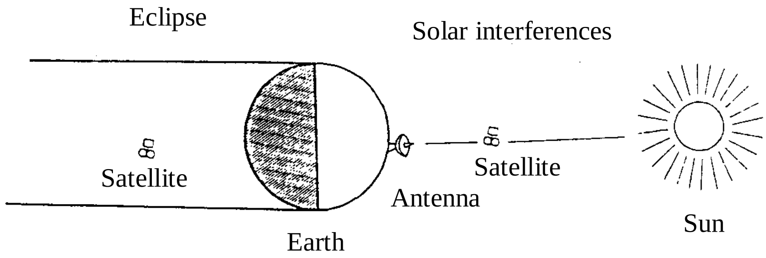
Distinction between Cb and Ci is accomplished considering the differences in form and moving speed of the two clouds and the synoptic field.

In Figures 2-4-1 a and b, Cb appears over the sea to the east of Japan (F – marked by an triangle). In the infrared image, it forms a cluster and its western cloud edge is clear. On the east side, it is swept away by the upper flow to become indistinct. It is confirmed from the animation film that the speed is slower than the surrounding cloud areas. Because Cb is affected by the average wind speed in the middle and lower air, its movement is slower than Ci but it changes its form faster. A cloud area H, which is similar to this, covers the Japanese Islands, and it is Ci. This can be judged from the fast movement of the cloud area. A granular cloud I is seen in North China in the infrared image, and it is also Ci. This is also the case where the Ci is apt to be mistaken for Cb from its form and cloud top temperature. In this case, it can be identified as Ci from the facts: "there is an upper trough over Korean Peninsula and a Cb cloud appears hardly in the rear of a trough", "the speed of the cloud area is fairly fast", and "there is little change in form with time".

Solar interference avoiding operation

When the sun, Himawari (GMS) and the ground station antenna are located in a line, that is, when the sun and Himawari are in the same direction as seen from the ground station, the radio waves from Himawari are interfered with noises emitted from the sun and normal signal reception becomes impossible (Attached Figure 1). This phenomenon occurs for about 6 days around the vernal and autumnal equinox. In such cases, observation at 03UTC is suspended as the solar interference avoiding operation. (Kazufumi Suzuki)

References: Seiichiro Kigawa (1989): Prediction of solar interference, Meteorological Satellite Center Technical Note, Vol. 19, 37-42



Attached Figure 1. Positional relation of the earth, satellite and the sun during solar interference and eclipse.

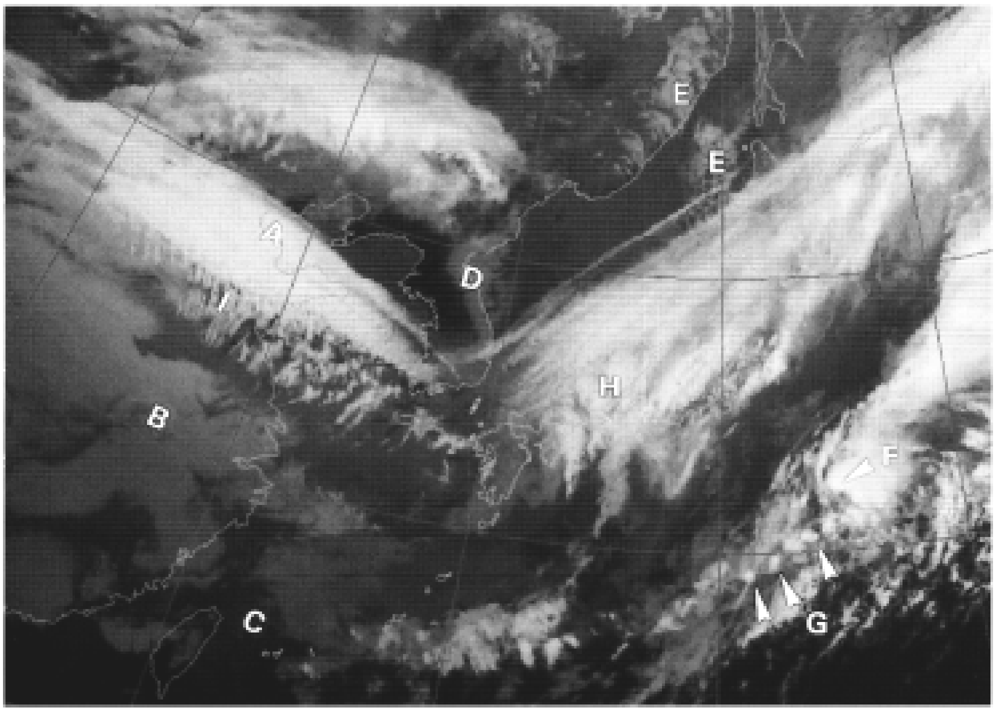


Figure 2-4-1 a. Infrared image for cloud type identification taken at 03UTC, March 20, 1999.

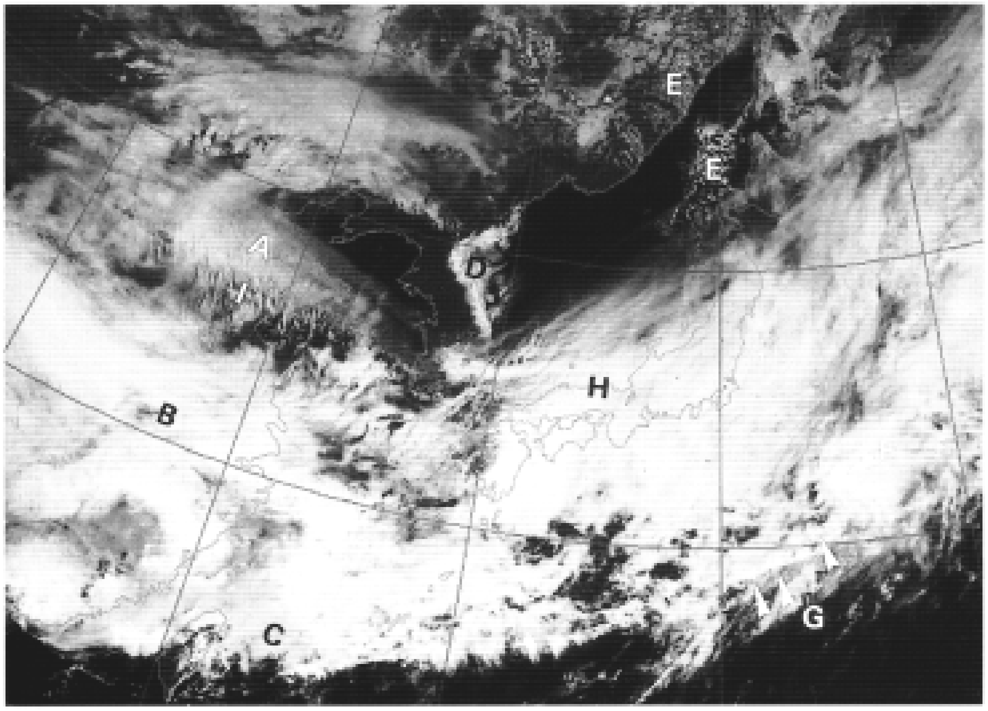


Figure 2-4-1 b. Visible image for cloud type identification taken at 03UTC, March 20, 1999.

2.5 Cloud types identified by meteorological satellite observation and cloud forms observed from ground

This section describes the cloud types that can be identified from a satellite in comparison with their cloud forms as observed from the ground.

In the surface meteorological observation method, the cloud forms are classified into 10 types based on their base height and texture. On the other hand, because the satellite observes clouds from a great distance above the earth, the cloud types are identified by the cloud top temperature and texture as observed in the infrared imagery and the sun's reflection brightness and the cloud's texture as observed in the visible imagery. Of these, because the cloud cells of a cirrocumulus or altocumulus cloud observed from the ground are smaller than the resolution of the sensors on board the satellite, distinction between cirrocumulus and cirrus and between altocumulus and nimbostratus are impossible with the satellite imagery.

The correspondence is shown in Table 2-5-1.

The cloud types seen in the satellite imagery (infrared and visible imageries) and representative cloud forms as seen from the ground are given and compared below.

Table 2-5-1. Cloud types identified by meteorological satellite and cloud forms observed from ground.

Cloud types that can be identified from meteorological satellite and their symbol

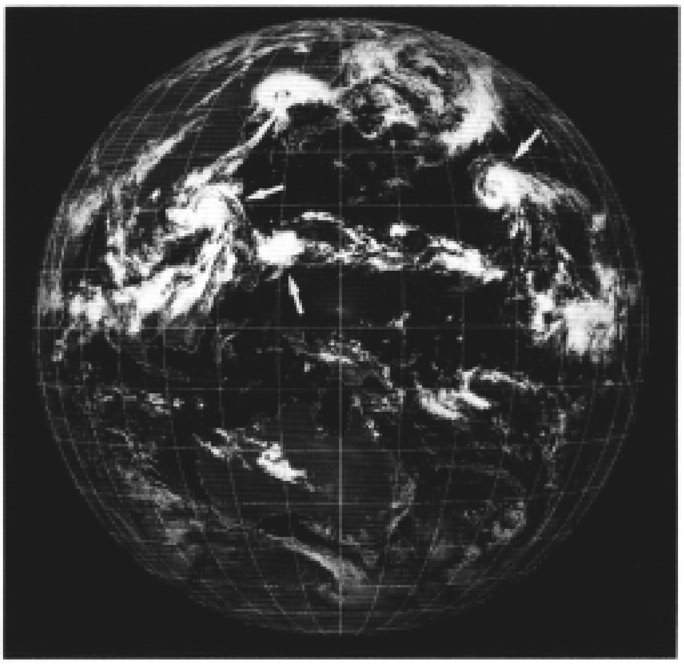
Cloud type identified	Symbols used
High level cloud	Ci
Middle level cloud	Cm
Stratocumulus	Sc
Stratus/fog	St
Cumulus	Cu
Cumulus congestus	Cg
Cumulonimbus	Cb

Cloud forms observed from ground and their symbol

Level	Cloud forms observed from ground	Symbol
High	Cirrus	Ci
	Cirrocumulus	Cc
	Cirrostratus	Cs
Middle	Altocumulus	Ac
	Altostratus	As
	Nimbostratus	Ns
Low	Stratocumulus	Sc
	Stratus	St
	Cumulus	Cu
	Cumulonimbus	Cb

ITCZ (Intertropical Convergence Zone)

The ITCZ is a lower air convergence zone that exists between latitude 5 and 15 degrees north where there are a lot of clouds and a lot of rainfall. From the satellite, it appears as a band of ranging active convective clouds. It contains active areas at intervals of 1000 or 2000 km and some of them can develop into a typhoon. In Attached Figure 1, the clouds corresponding to the ITCZ extend from the east of the International Date Line to the Philippines. Clusters of active clouds are seen here and there, and the typhoon and tropical cyclones marked by an arrow have generated and developed from such a cluster of cloud and have gone up north. The clouds accompanying the ITCZ extend further westward and connect to the band of clouds accompanying the monsoon in the Bay of Bengal. In the satellite imagery, the ITCZ is not always exist as a band of clouds but it becomes clear sometimes and is interrupted at other times, so the amount of clouds varies a lot. (Kazufumi Suzuki)



Attached Figure 1. ITCZ (visible image taken at 03UTC, August 21, 1997).

2.5.1 Cloud area of Ci only

Figure 2-5-1 a. Photograph of clouds taken from the ground (Tottori City, Tottori Prefecture) at 0801 JST, July 9, 1984.
<Cloud forms observed from ground>
Surface Meteorological Observation Methods (supplement volume): 1989
High level clouds Cirrus and cirrostratus clouds (Ci and Cs) CL = 0, CM = 3, CH = 5

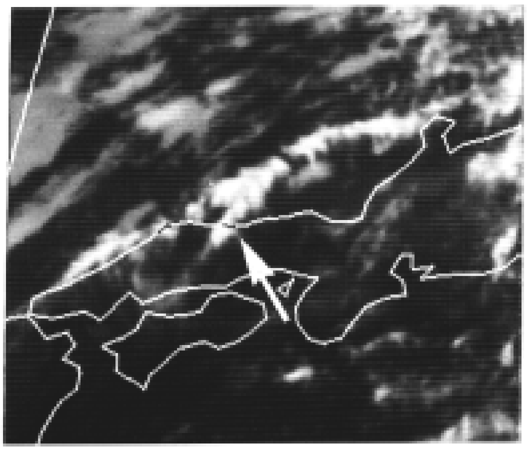


Figure 2-5-1 b. Infrared image

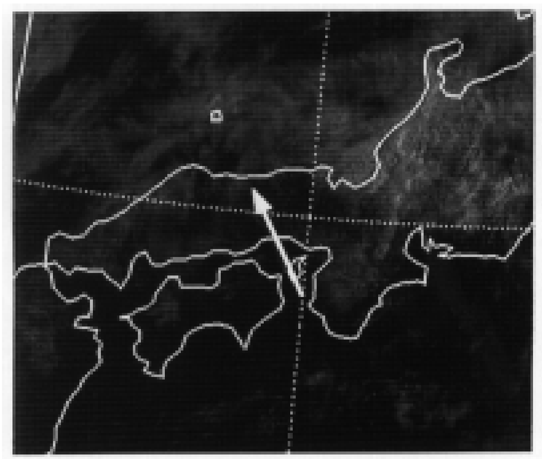


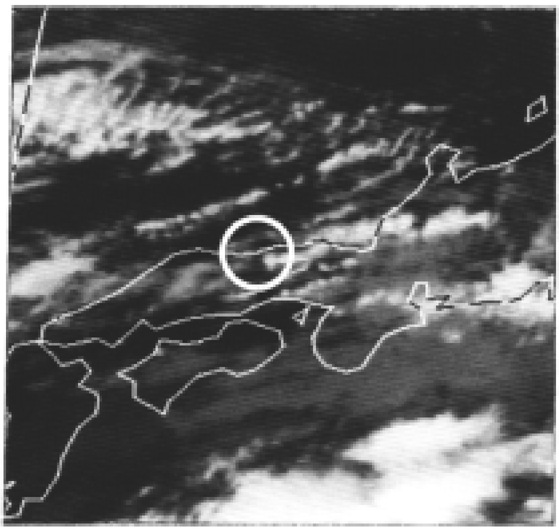
Figure 2-5-1 c. Visible image

Both taken at 0900 JST, July 9, 1984 (Arrow pointing at the vicinity of Tottori City, Tottori Prefecture).
<Cloud types observed from satellite> Cloud area of Ci only

Here, pay attention to Tottori City, Tottori Prefecture (marked by an arrow). In the infrared image, a streak of Ci clouds extends from San’in District to Noto Peninsula. Only the west end of this Ci streak covers the vicinity of Tottori City, and no other cloud can be observed. In the visible image as well, the land can be seen transparently. In this case, both surface and satellite observation judge the cloud as a high level cloud in the same manner.

2.5.2 Cloud area of Ci and Cm superposed

Figure 2-5-2 a. Photograph of clouds taken from the ground (Tottori City, Tottori Prefecture) at 1111 JST, September 22, 1978.
<Cloud forms observed from ground>
Surface Meteorological Observation Methods (supplement volume)] 1989
Translucent altocumulus (Ac) CL = 0, CM = 3, CH = 0



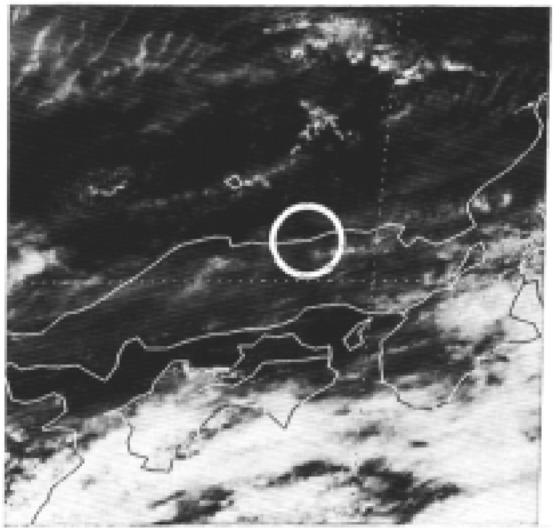


Figure 2-5-2 b. Infrared image Figure 2-5-2 c. Visible image
Both taken at 1200 JST, September 22, 1978.
(Circle indicating the vicinity of Tottori City, Tottori Prefecture)
<Cloud types observed from satellite> Cloud area of Ci and Cm superposed

Here, pay attention to the vicinity of Tottori City, Tottori Prefecture (marked by a circle). Ci and Cm clouds, which have come from the East China Sea, cover the vicinity of Tottori City. It is found from the visible image that this cloud area is not thick. No low level cloud can be observed.

In this case, an altocumulus cloud of a single layer is observed from the ground, however, no high level clouds are observed because altocumulus extends over the entire sky.

2.5.3 Cloud area of coexisting Cu and Sc

Figure 2-5-3 a. Photograph of clouds taken from the ground (Kiyose City, Tokyo) at 1740 JST, August 19, 1983.
<Cloud forms observed from ground>
Surface Meteorological Observation Method (supplement volume): 1989
Middle and low level clouds (Ac and Cu)
Translucent altocumulus (lenticular) CL = 2, CM = 4, CH = 0

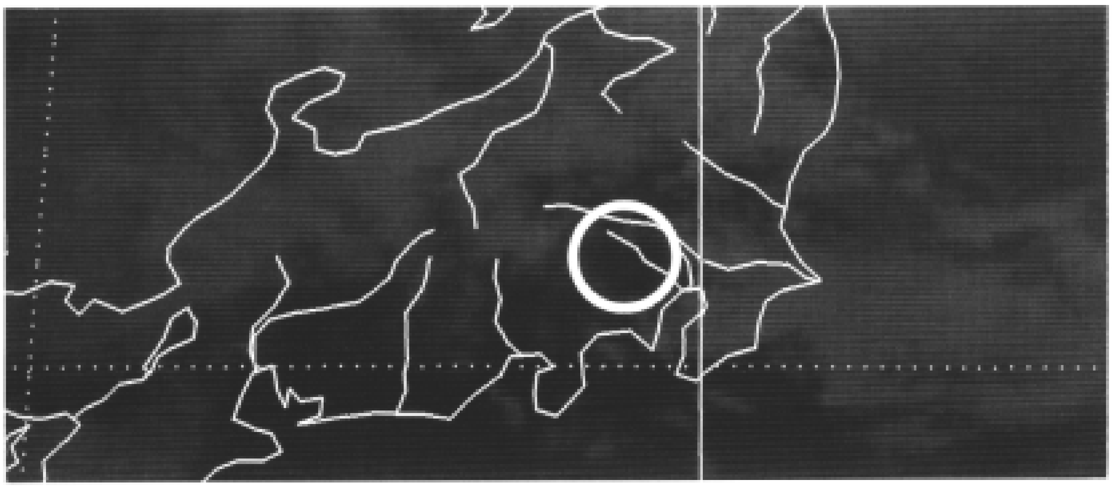


Figure 2-5-3 b. Infrared image taken at 1800 JST, August 19, 1983.
(Circle indicating the vicinity of Kiyose City, Tokyo)
<Cloud types observed from satellite> Cloud area of coexisting Cu and Sc

Here, pay attention to the vicinity of Kiyose City, Tokyo (marked by a circle). In the satellite image, a cloud area of coexisting Cu and Sc covers the vicinity of Tokyo, however, it is not thick. From the ground, altocumulus clouds are observed indeed. However, their amount is sparse and they have many openings. For such a sparse cloud area that is smaller than the resolution of the radiometer on the satellite, the cloud top height is estimated lower because the radiations coming from the ground through the openings between the clouds are added.

2.5.4 Cloud area of Ci only

Figure 2-5-4 a. Photograph of clouds taken from the ground (Sendai City, Miyagi Prefecture) at 1710 JST, September 6, 1981.
<Cloud forms observed from ground>
Ground Meteorological Observation Methods (supplement volume): 1989
Middle level cloud, Ac, translucent altocumulus CL = 0, CM = 5, CH = 0

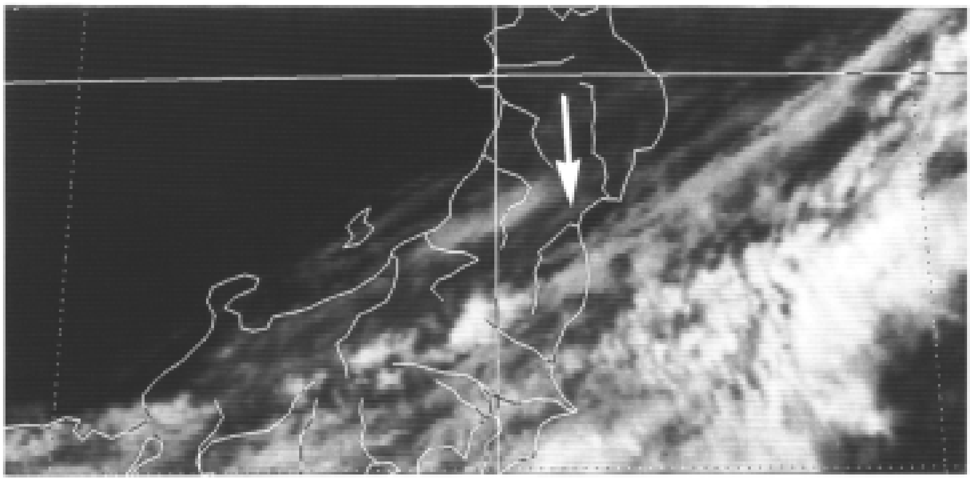
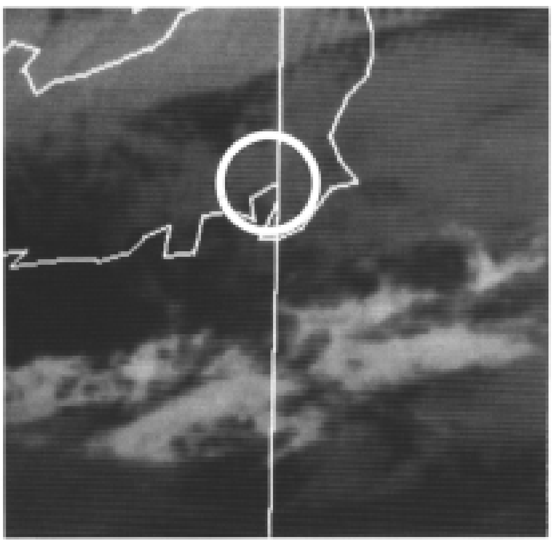


Figure 2-5-4 b. Infrared image taken at 1800 JST, September 6, 1981.
(Arrow pointing at Sendai City, Miyagi Prefecture)
<Cloud types observed from satellite> Cloud area of Ci only

Here, pay attention to the vicinity of Sendai City, Miyagi Prefecture (marked by an arrow). In the satellite image, a cloud band consisting mainly of high and middle level clouds extends from over the sea area east of Japan to Boso Peninsula and the offshore area of Tokaido. Ci clouds accompanied the upper level jet stream flowing on the north side of this cloud band and part of these clouds covers the vicinity of Sendai City. In this case, the surface observation judges the cloud as a middle level cloud, which differs from the judgment by the satellite observation. Such cases can occur because of the difference in observation method between visual and satellite observation. In particular, discrimination between Ci and Cm is difficult also for the satellite.

2.5.5 Cloud area of Sc only

Figure 2-5-5 a. Photograph of clouds taken from the ground (Chiyoda-ku, Tokyo) in November 12, 1984.
<Cloud forms observed from ground>
Surface Meteorological Observation Methods (supplement volume): 1989
Stratocumulus clouds (Sc) other than stratocumulus as the result of transformation of cumulus
CL = 5, CM = /, CH = /



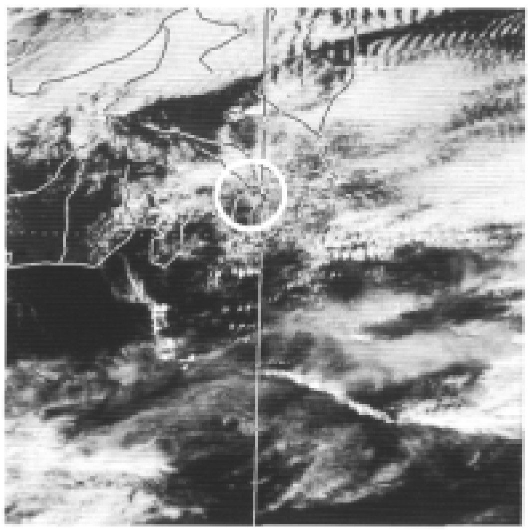


Figure 2-5-5 b. Infrared image Figure 2-5-5 c. Visible image
Both taken at 1200 JST, November 12, 1984 (Circle indicating the vicinity of Tokyo).
<Cloud types observed from satellite> Cloud area of Sc only

Here, pay attention to the vicinity of Tokyo (marked by a circle). In the satellite image, the vicinity of Tokyo is covered by Sc clouds. For the low level clouds, cloud form identification by surface observation applies relatively well to cloud type identification by satellite observation.

2.5.6 Cloud area of coexisting Cb, Cg and Cu

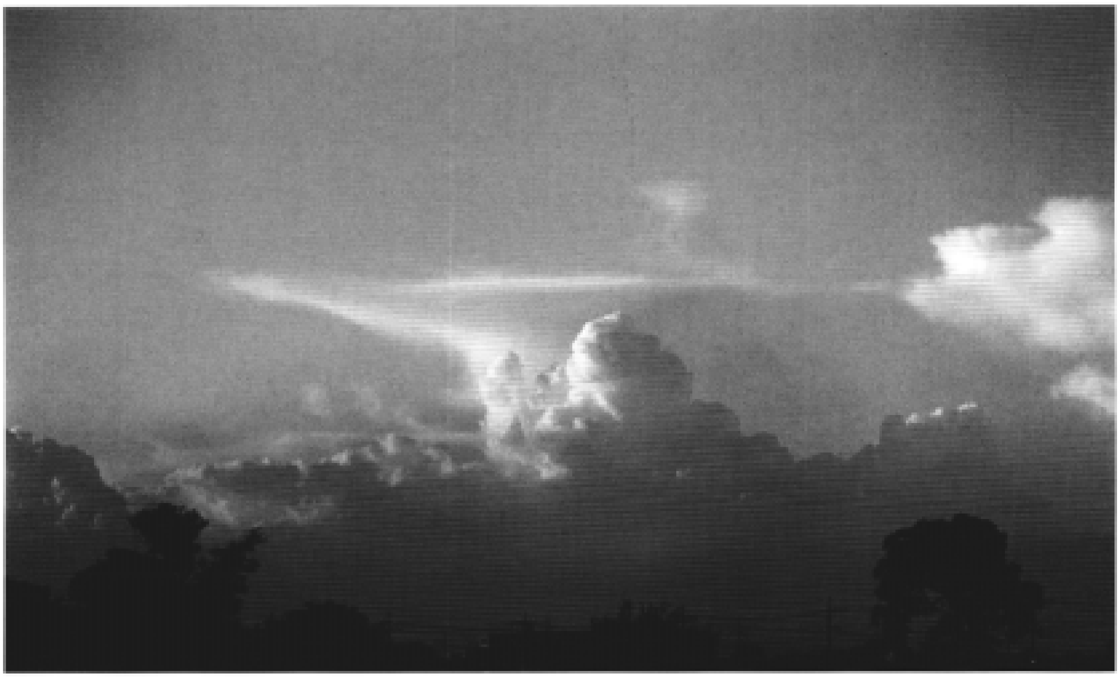


Figure 2-5-6 a. Photograph of clouds taken from the ground (Kiyose City, Tokyo) at 1810 JST, August 10, 1985.
<Cloud forms observed from ground>
Surface Meteorological Observation Methods (supplement volume): 1989
Capillary cumulonimbus cloud (Cb) CL = 9, CM = 0, CH = 3

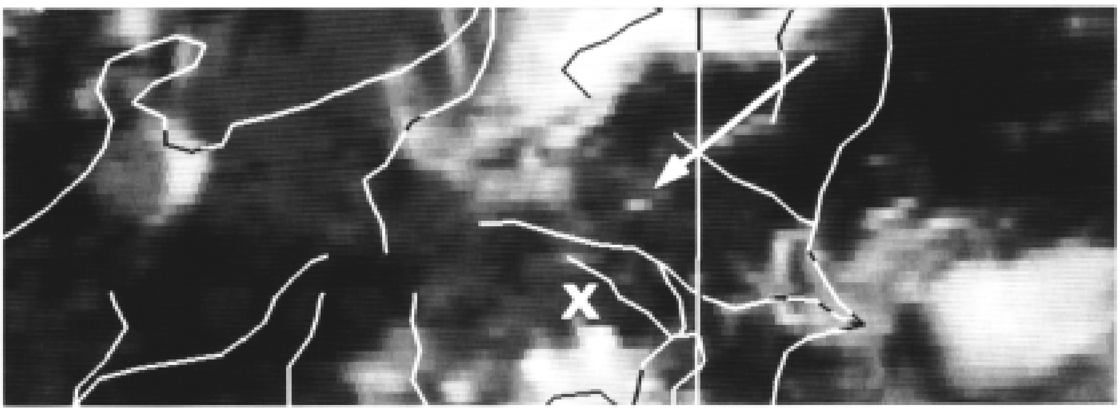


Figure 2-5-6 b. Infrared image taken at 1800 JST, August 10, 1985.
(X mark indicating the vicinity of Kiyose City, Tokyo)
<Cloud types observed from satellite> Cloud area of coexisting Cb, Cg and Cu

Here, pay attention to the vicinity of Kiyose City, Tokyo (marked by X). In the satellite image, Cb clouds appear the inland areas of Tokai and Kanto districts, and a small Cb cluster (marked by an arrow) can also be observed in the southern part of Tochigi Prefecture.

The surface observation looks the Cb clouds in the north-northeast direction from Kiyose City, Tokyo toward Tochigi Prefecture (about 60 km distant). An anvil cirrus cloud extends to on the head of the Cb. Cumulus congestus clouds also extend on this side.

2.5.7 Cloud area of coexisting Cu and Cg

Figure 2-5-7 a. Photograph of clouds taken from the ground (Ohshima Motomachi, Tokyo) in December 19, 1994
<Cloud forms observed from ground> Tokyo District Meteorological Observatory Technical News 1995 (No. 119)
Cumulus (Cu) CL = 2, CM = X, CH = X

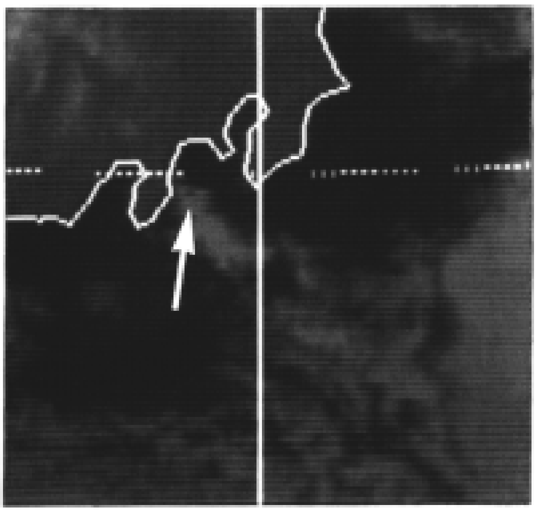


Figure 2-5-7 b. Infrared image

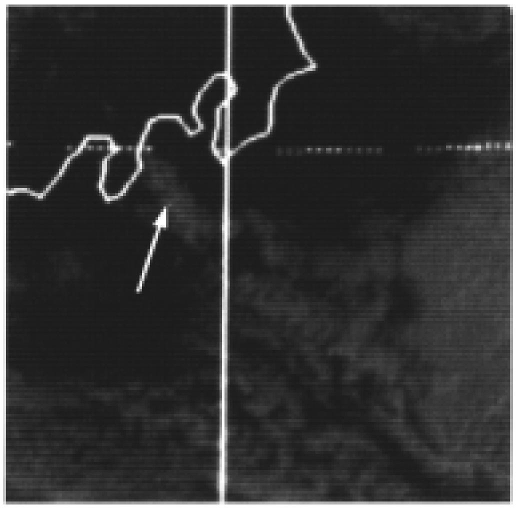


Figure 2-5-7 c. Visible image

Both taken in December 19, 1994 (arrow pointing at Ohshima Motomachi, Tokyo)
<Cloud types observed from satellite> Cloud area of coexisting Cu and Cg

Here, pay attention to the vicinity of Ooshima Island (marked by an arrow) to compare with a photograph of clouds taken from the ground.

In the satellite images, a convective cloud band extends to over the sea east of Izu Peninsula and Ooshima is under the clouds. Judging from the cloud top brightness of this convective cloud band, both clouds coexist not only a cloud band of only Cu but also Cg developed more than Cu. This corresponds with genesis of a tornado which can be observed by a photograph taken from the ground.