Satellite Photography — What the Depression looks like from Space.

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Concern about the proper use of satellite imagery in schools has led to this article in the hope that it will raise awareness of this important area in teaching.

Criteria for the analysis of satellite imagery to allow the recognition of cloud types, patterns and systems were developed in the 1960s but are still not in common use in schools. The Editor would be pleased to have articles for Teaching File which develop the use of these or similar materials in the classroom.

In recent years we have been able to view the structure of large-scale weather systems in total using satellites. Since satellite photographs of cloud patterns are now in common use there is a case for the increased use of them in the teaching of meteorology and climatology.

Accepted criteria have been established in order to recognise and classify observed cloud patterns, and a system of cloud analysis (the nephanalysis) has been developed. Some of the most distinctive patterns which have been viewed from space are tropical cyclones, the ITCZ, cellular convective cloud developing in unstable air, and the mid-latitude frontal depression. A model showing the development of depressions using satellite imagery has been produced, and it is accepted that the old polar front model may need to be modified particularly with reference to post-occlusion events.

It is only since the 1960s that we have been able to study satellite photographs of the weather. What was immediately apparent was that the patterns of clouds around the earth appeared to be organised in scales from the cellular structure of large cumulonimbus clouds to the massive travelling low pressure systems. Another major feature is the banded or streaky nature of the clouds and the linear arrangement of some clouds in so called "streets".

Criteria for recognising and classifying clouds through satellite photography

Three broad categories of clouds can be recognised from space: Cumuliform, Stratiform and Cirriform.

1. Cloud texture.
The texture of clouds can be used to recognise the three main cloud types.

a) Cirriform. This cloud appears smooth and fibrous in appearance, with smooth translucent areas and cloud blown out in feathery form at the margins. Some high altitude cloud has to be deduced from a loss of definition of ground features. This translucency allows the upper cloud to be distinguished from low level stratus, or sea fog.

b) Stratiform. Low stratus cloud is seen as a smooth, white, opaque sheet. Fog is very similar, although sea fog will often follow the coast-line. Frontal stratus cloud is often banded in tone, with broad streaks of white embedded in grey. The edges of this cloud often have a ragged appearance.

c) Cumuliform. This cloud is often mottled in appearance, bright and white with fibrous edges.

2. Cloud brightness.
There appears to be a simple relationship between cloud brightness and cloud depth. Deeper, thicker clouds are brighter on satellite photographs than thin clouds. A relationship also seems to exist between cloud brightness and precipitation, with brighter clouds being more likely to produce precipitation. It is likely, however, that only a small area of a bright cloud may be producing precipitation at any one time, although over a longer time period the two patterns, precipitation and cloud brightness, will correlate well. The composition of cloud also affects brightness, water cloud being brighter than ice cloud.

3. The form and size of cloud elements.
Cumuliform cloud is best seen as individual cells or masses of cloud. Cumulonimbus cloud has a bright disk of thick cloud with a tail of dull grey or fine translucent cloud. Cumulus cloud often grows in size during the day, developing into cumulonimbus by late afternoon and sometimes dissipating in the evening.

4. Cloud Patterns.
A surprising degree of organisation of clouds from micro to macro scales is seen on satellite photographs of clouds. The cellular pattern of cumulus cloud in unstable maritime Polar air to the rear of a depression is a typical pattern. Seen particularly over ocean areas in winter the pattern of clouds becomes more dense the further the air travels over the sea, since the lower air layers are warmed giving increased instability. The pattern of these cellular clouds may also be dependent upon wind speed, the clouds becoming more elliptical in shape with increased wind speed. Another typical pattern is the broad streaky band of frontal cloud.

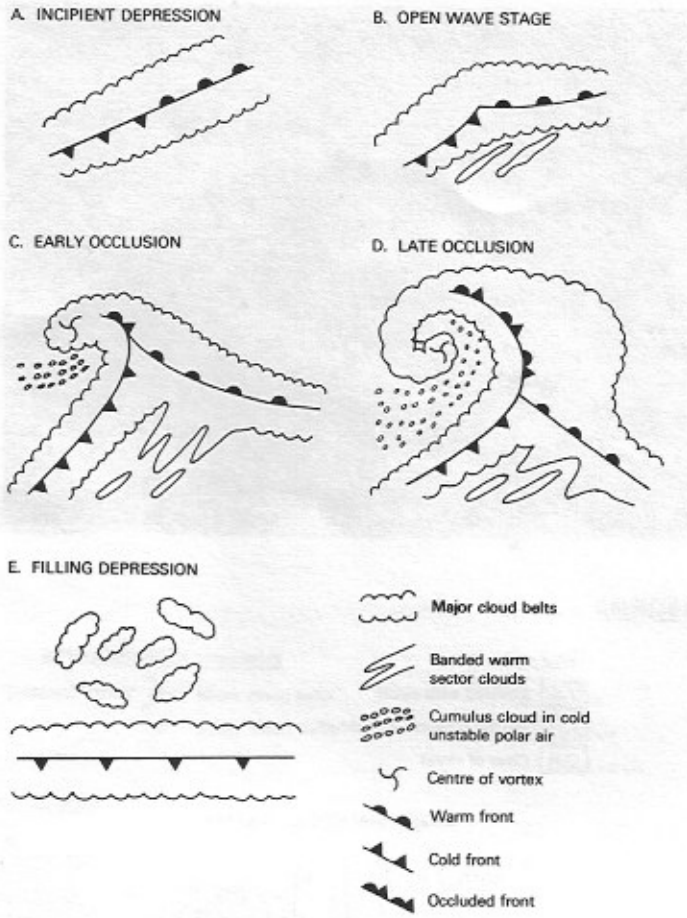


Figure 1. The life cycle of a depression as viewed from space.

The analysis of satellite photographs

Plates 1-4 show approximately one quarter of the northern hemisphere from about 120°W to 10°E. They show a daily sequence from 7th May to 10th May 1968. Using the criteria for the identification of cloud types and patterns it is possible to analyse the photographs and recognise several interesting features.

The following are examples of some of the patterns which can be seen on these photographs.

Plate 1. ITCZ cloud just north of the Equator. This is particularly prominent over the Atlantic Ocean and over the Pacific Ocean to the west of 80°W.

Frontal cloud running south west to north east parallel to the east coast of North America.

Cellular cumulus cloud off the north west coast of Africa around 30°N, 20°W, associated with the northerly airstream in this area. The pattern of cells becomes more dense to the south as the air crosses the progressively warmer sea surface and greater instability is released.

Plate 3. A depressional vortex centred around 40°N 50°W, with cellular cumulus cloud in the clearer maritime polar air beginning to spiral into the centre of the low.

The standard symbols used on synoptic charts are of little use for satellite photographs. A new system of cloud analysis, Nephanalysis, has been developed to analyse the satellite photograph. A nephanalysis is included for each of the satellite photographs, plates 1-4.

The frontal depression from Space

A model (Figure 1) showing the usual development of a depression as viewed from satellites has been developed. The main points illustrated by this model are:

1. the concentric organisation of spiral bands of cloud around the central vortex of the fully occluded depression;

2. the clear or partly clear slot of cold maritime polar air which spirals into the system behind the cold front as the depression begins to occlude;

3. the development of convective cumulus cloud within this generally clearer, unstable, maritime polar air; this cellular cloud is often linear in arrangement;

4. the need to focus much more attention on occlusion and post-occlusion events which are neglected to some extent by the Norwegian polar front model;

5. the streakiness of frontal clouds and the bands of cloud which develop at right angles to the warm front within the warm sector air;

6. the gradual break up of the organised, concentric arrangement of cloud as the system becomes a frontless, filling cyclone. Temperature differences become less distinct and it is easier to see how heat has been transferred polewards as an important part of the general circulation.

A selected depression sequence

The following analysis of a sequence of four satellite photographs with surface weather maps illustrates how interested teachers can use satellite imagery in their teaching. They also show some of the main ideas developed by researchers about how frontal depressions develop, which were noted in the last section.

1. 7TH MAY (Plate 1. Nephanalysis 1. Surface chart 1.)

The main frontal cloud band shows up well on this day, stretching north east to south west off the east coast of North America. This coincides with the polar front on the surface synoptic chart. Around 35°N 60°W along this front the synoptic chart shows a very weak low with one closed isobar of 1020 mb. Surface winds also indicate that a weak anti-clockwise circulation has developed.

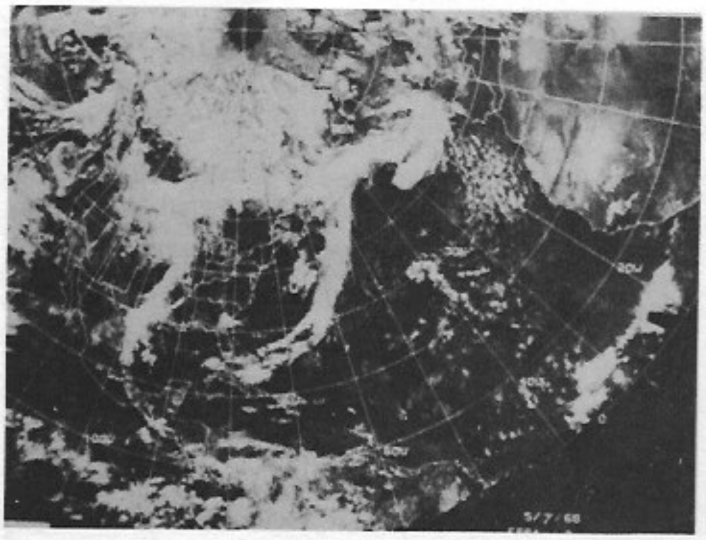
The frontal band of cloud shows no wave form as yet, although there is a slight thickening and some irregularity of the cloud along the band. Immediately to the rear of this is a globular mass of cloud and this appears to be in some way related to the development of the depression, although it does not show up on the surface chart.

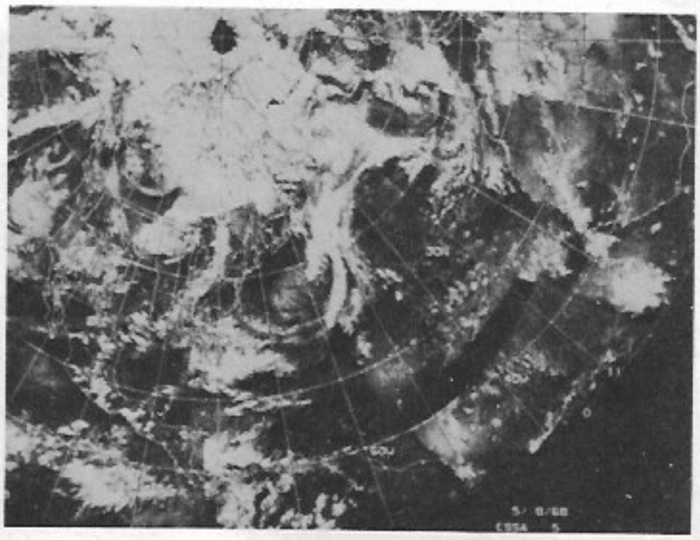
2. 8TH MAY (Plate 2. Nephanalysis 2. Surface chart 2)

The change between the surface chart for the 7th and that for the 8th indicates how quickly the frontal depression develops. The surface chart for 8th May shows that the weak low has deepened to 1000 mb and the system has intensified. The fronts have developed an open wave form and the whole system has moved to the north east.

The satellite photograph shows a distinct change. A comma shaped cloud mass has developed with a curved tail of frontal cloud which mirrors the position of the cold front on the surface synoptic chart. This cloud has a clearly defined rear edge, typical of a cold front and indicating the sudden clearance with the passage of the front.

East of the cold front cloud has developed in the warm sector. This cloud is banded south to north, indicating the wind direction in this area.





NEPHANALYSIS SYMBOLS

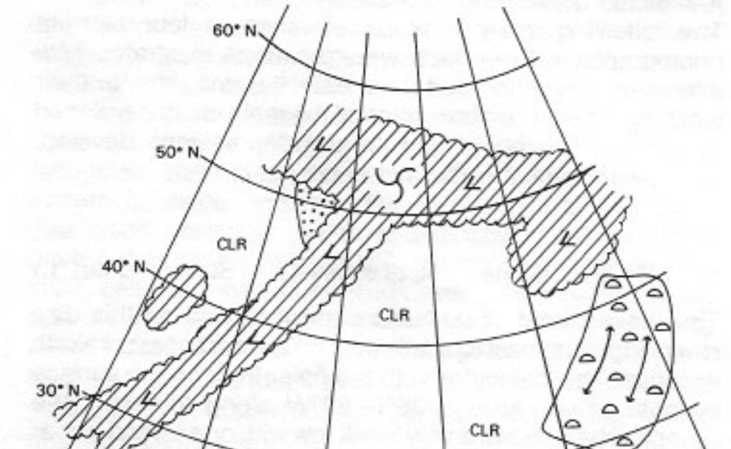
Cloud boundaries
- Major cloud belts
- Minor cloud belts

Cloud
- Stratus
- Cumulus
- Cloud bands

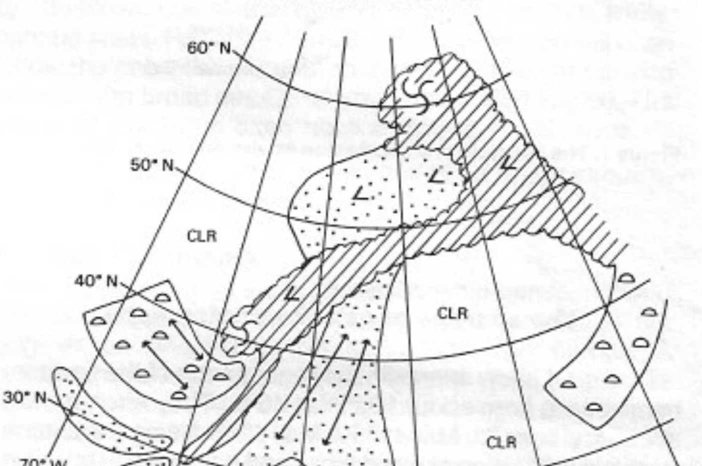
Cloud areas
- Covered with cloud
- Mostly covered with cloud
- CLR Clear of cloud

Weather system
- Vortex (cyclone)

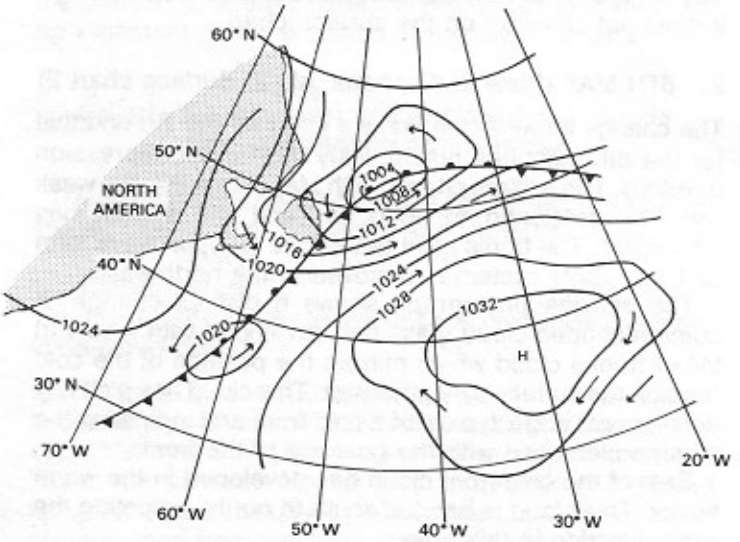
NEPHANALYSIS 1 - 7th MAY



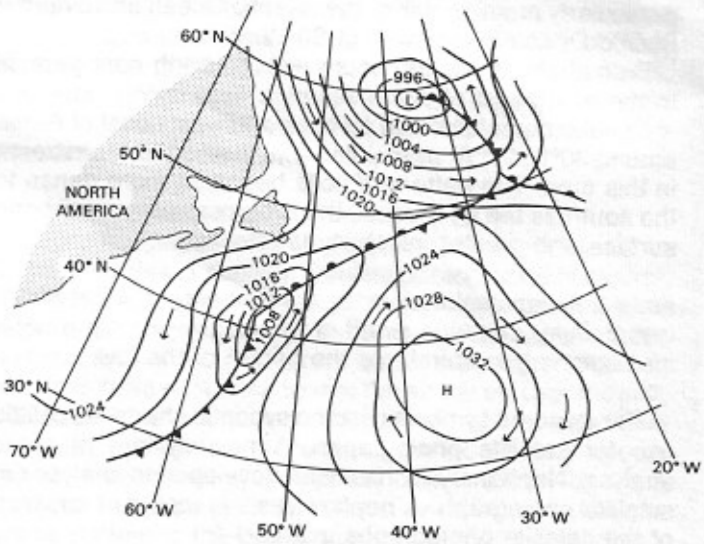
NEPHANALYSIS 2 - 8th MAY

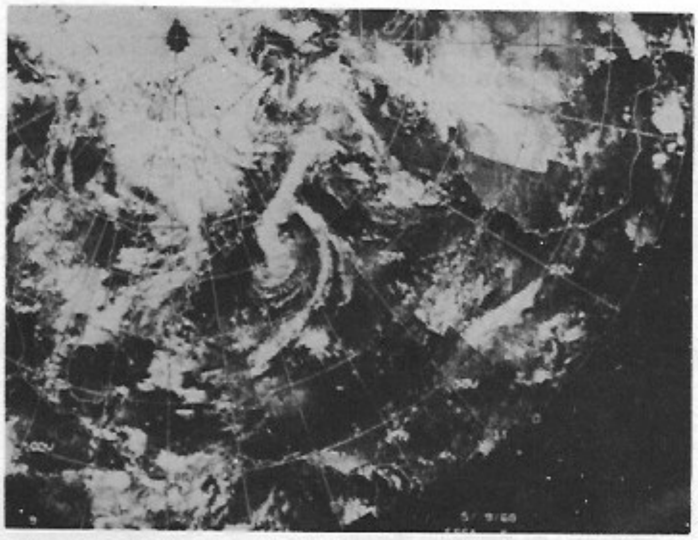


SURFACE SYNOPTIC CHART 1 - 7th MAY



SURFACE SYNOPTIC CHART 2 - 8th MAY





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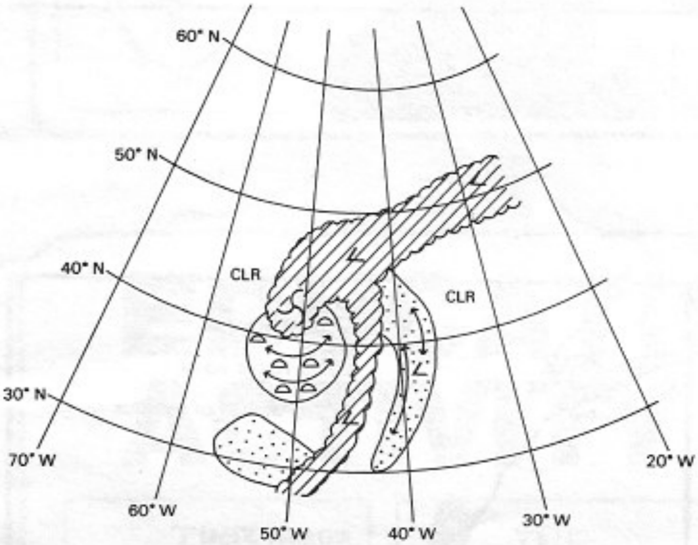
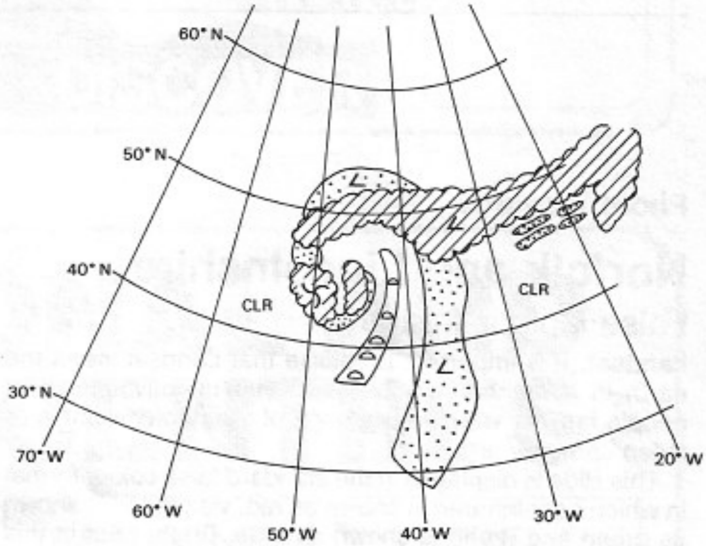
Mostly covered with cloud
CLR Clear of cloud

Weather system
Vortex (cyclone)

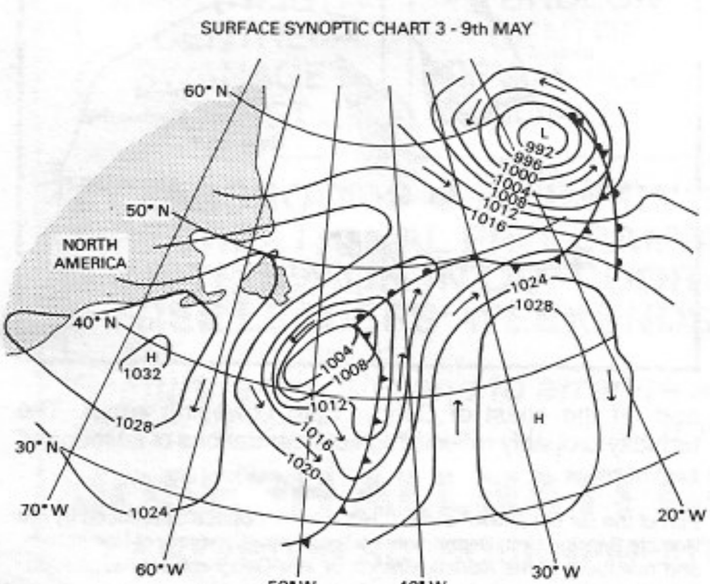
NEPHANALYSIS 3 - 9th MAY



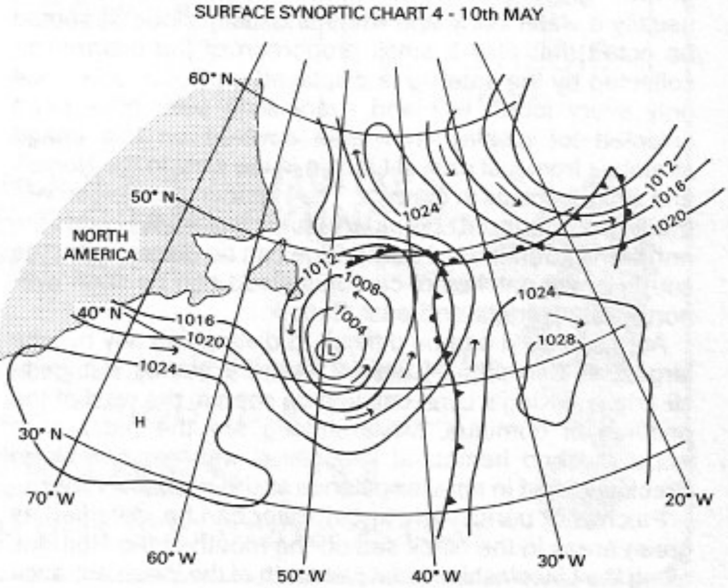
NEPHANALYSIS 4 - 10th MAY



SURFACE SYNOPTIC CHART 3 - 9th MAY



SURFACE SYNOPTIC CHART 4 - 10th MAY



3. 9TH MAY (Plate 3. Nephanalysis 3. Surface synoptic chart 3)

On the surface chart the depression centred near 42°N 50°W appears to be on the point of occlusion. A small secondary low has developed to the south west of the main low. The spiral cloud associated with the depression is well developed at this stage. The slot of clearer air has widened, although within this colder air "streets" of cumulus clouds have developed due to the unstable atmosphere. The frontal cloud bands are still prominent; that associated with the cold front spiralling away to the south west and the warm frontal cloud stretching to the north east.

4. 10TH MAY (Plate 4. Nephanalysis 4. Surface chart 4)

The surface synoptic chart shows an occluded depression, the pressure of the low has not deepened and the circulation is less intense. The occluded front has lost its close association with the position of the surface low. The transition between the open wave stage of a frontal depression and an occluded depression is very rapid. Since most depressions have reached this stage when they approach the British Isles, there is a case for concentrating more on occluded depressions.

The satellite photograph shows a large spiral of cloud positioned over the surface low. This is the typical depression cloud pattern which was first noticed on satellite photographs. The cloud spiral is less distinct than on previous days and the frontal cloud, especially the cold frontal cloud, is beginning to break up.

As the depression begins to fill the circulation will become less organised and less intense, and the spiral pattern of cloud will begin to disintegrate as temperature differences lessen.

References and Suggested Reading

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