Tellus (1987), *39A*, 326–333

A polar low over the Norwegian Sea 29 February–1 March 1984

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(Manuscript received 24 June; in final form 30 October 1986)

ABSTRACT

A polar low development is described. The development started in a low-level shear zone in the Norwegian Sea on 29 February 1984. A large cloud cluster was built up. It broke up into several pieces. Two of these minor clusters moved closely together in the low-level wind field towards the south. When they reached a strong upper level shear zone near the Norwegian coast, they suddenly developed into a mature polar low.

1. Introduction

In this note, we present a case study of a polar low that developed in a low-level shear zone in the Norwegian Sea near 70°N and 1°E. The development is typical for strong cold air outbreaks. The cold air outbreak was noted in the satellite images as long and very regular cloud-streets which ended up in a shear zone where a large cluster of cumulus and stratocumulus were built up. We will show that the main cloud cluster broke up into several pieces during the night of 1 March 1984. Two of these minor clusters moved closely together towards the south. When they approached the coast of Norway at 63°N and 5°E, one of the clusters started to rotate and merged with the other. There is a good data coverage of the vortex, especially when it passed the coastline, both from satellite pictures, hourly observations from the airports in the area, and in addition two complete pilot reports. This note is a short version of a more detailed report (Rabbe, 1985).

2. Polar low development

Fig. 1 shows the area where the polar low developed and decayed. The names in the map

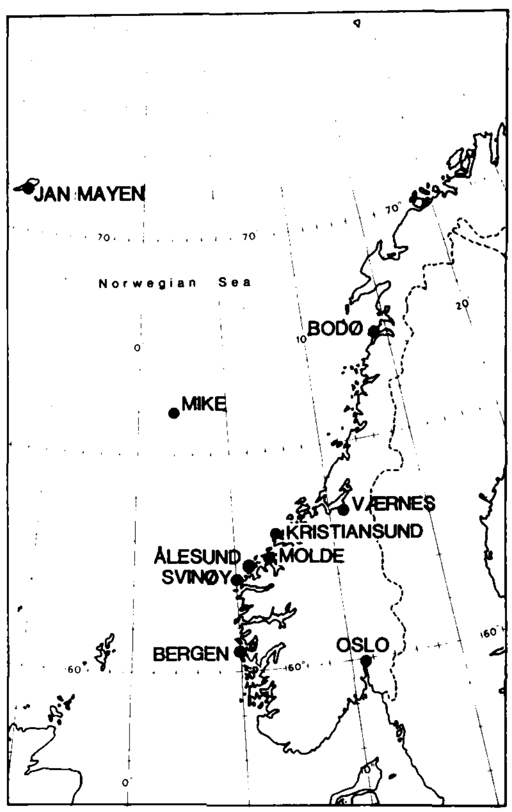

Fig. 1. Map over the area investigated.

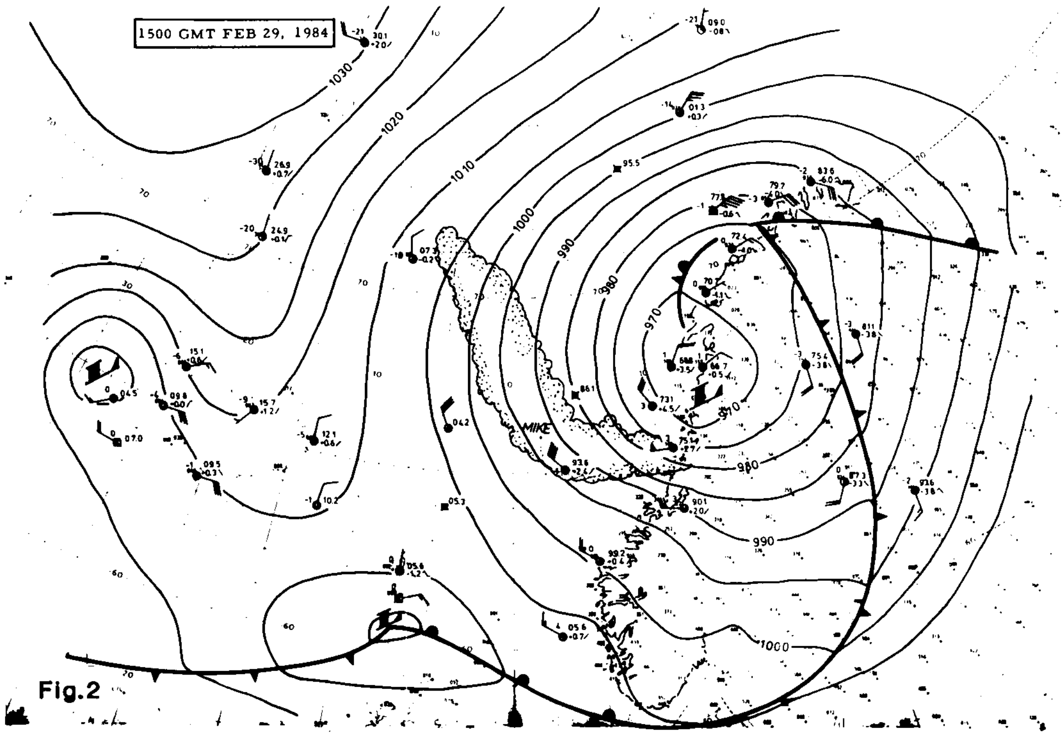

Fig. 2. Surface map at 15.00 GMT 29 February 1984.

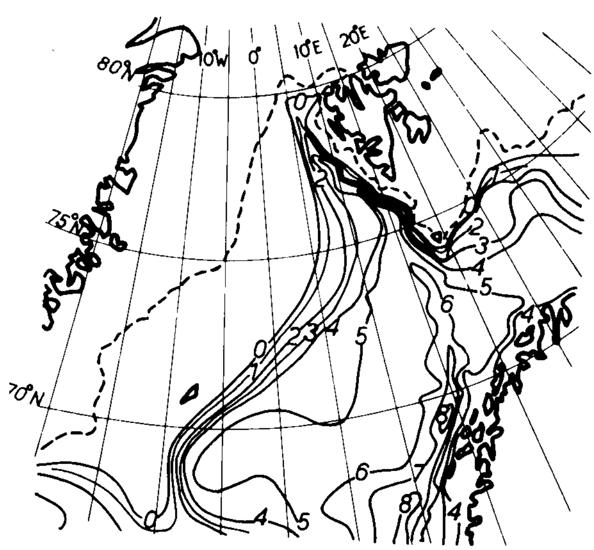

Fig. 3. Sea surface temperatures (units: °C), 3 March 1984. The iceborder is indicated with a dashed line.

are referred to in the text below. Fig. 2 shows the surface weather map at 15.00 GMT on 29 February 1984. A low centre is found at the coast of Northern Norway, at 67°N and 13°E. The fronts are located well to the east of the low centre. A strong and cold northeasterly air current penetrates into the Norwegian Sea from the ice- and snow-covered area around Spitsbergen. In the satellite image at 14.59 GMT (not shown here), an extensive area over the Norwegian Sea southwest of Spitsbergen was covered by cloud streets. They ended up in a large and solid cloud cluster of stratocumulus and cumulus clouds in the sea between Jan Mayen and Norway. The area where the cloud cluster was built up coincides rather well with the maximum sea surface temperatures in the Norwegian Sea (see Fig. 3). In Fig. 3, the actual iceborder is also indicated.

A P-3 Orion aircraft, from the NOAA Arctic Cyclone Expedition flew through the cloud cluster at different levels in the middle of the day

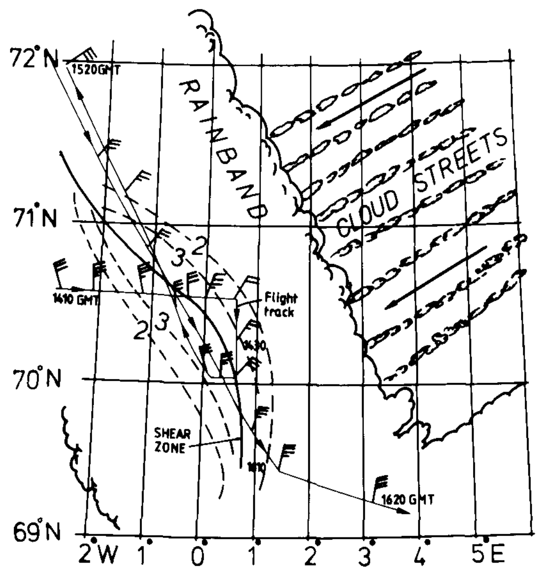

Fig. 4. ORION-P-3 measurements on 29 February 1984. The observations were made at the constant pressure level 961 mb. The dashed lines show the relative vorticity (units: 10^{-4} s^{-1}).

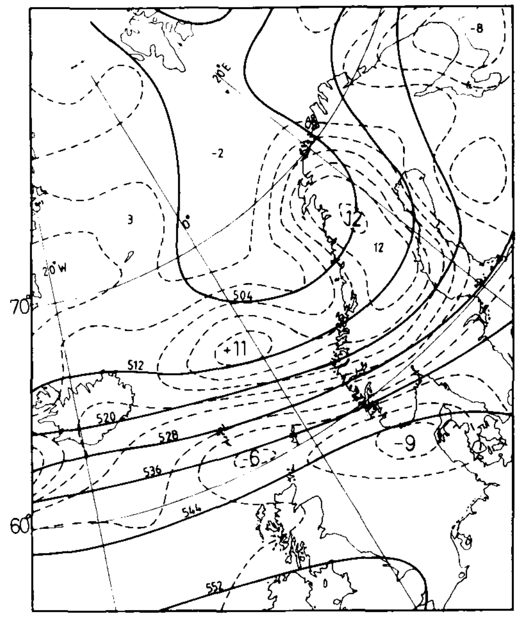

Fig. 5. 500 mb geopotential height at 12.00 GMT 29 February 1984. The full lines are isohypses (units: gpdam) and the dashed lines relative vorticity (units: 10^{-5} s^{-1}).

on 29 February. The flight track at pressure level 961 mb is shown in Fig. 4. To the east of the shear zone, the wind direction was 030–040° and to the west of it 340°. The wind speed was strongest on the western side. We have also calculated the vorticity from the measured wind along the shear zone. There was a rather strong cyclonic vorticity along the shear zone. This is indicated in the figure.

The surface map 12 hours later (not shown here) showed that a trough line had developed to the east of the weathership Mike (66° N, 2° E). The satellite picture at 03.16 GMT (not shown here) showed that the cloud cluster mentioned above had broken up into several pieces. No cyclonic circulation was noted in any of the clusters.

The 500 mb map at 12.00 GMT 29 February is shown in Fig. 5. The full lines are isohypses and we can see that there is a strong jet stream over southern Norway with a horizontal windshear at approximately 63° N. The dashed lines show the relative vorticity at the same level. There is an area of maximum positive vorticity to the west of weathership Mike. This is mainly shear vorticity. 12 hours later at 00.00 GMT 1 March, the area of maximum vorticity had moved towards the southeast and it had increased in strength. Also at this time there was a strong horizontal shear in the same area.

The surface map at 06.00 GMT 1 March is shown in Fig. 6. At this time, the trough or cloud cluster passed very close to the weathership Mike. The surface wind had increased to 26 m/s at the ship. The satellite image at 04.46 GMT (not shown here) indicates that the northernmost of the two clusters, which are moving together towards the south, is the most extensive one. This is also verified by the cloud cluster composite chart in Fig. 7, which shows that the northernmost cluster had much lower cloud top temperatures than the other one. The cloud top temperatures were calculated from the infrared channel 4 in the NOAA satellites. In Fig. 7, it can be seen that the cloud top temperatures were calculated at 4 different times: at 15.05 GMT and 17.44 GMT on 29 February, and at 03.16 GMT and 14.50 GMT on 1 March. The corresponding height of the cloud tops were calculated to 4500 m, 5000 m, 6000 m and 7500 m, respectively.

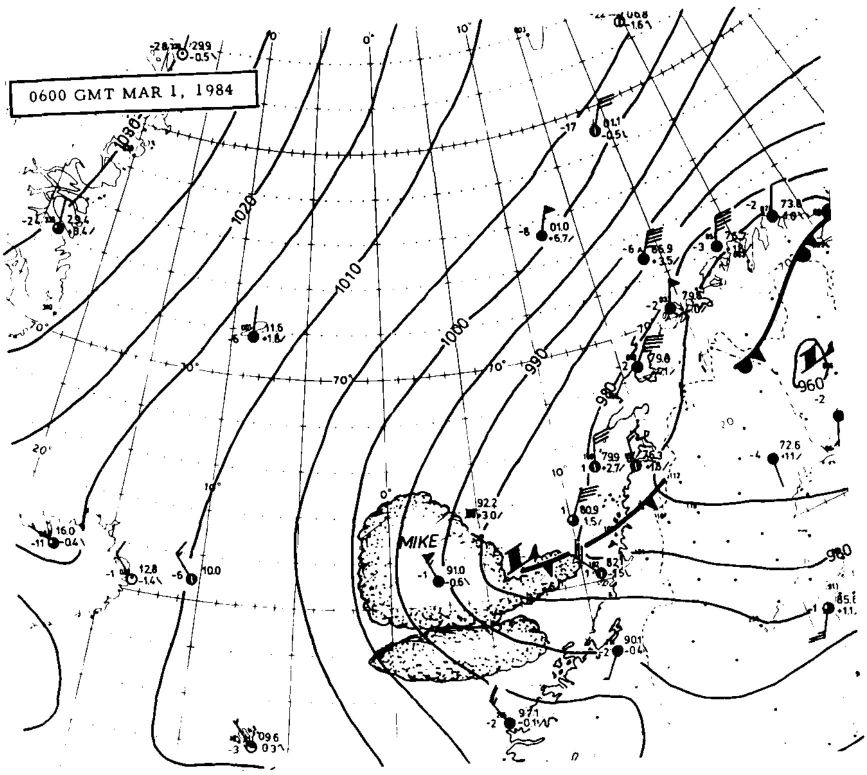

Fig. 6. Surface map at 06.00 GMT 1 March 1984.

The surface map at 09.00 GMT is shown in Fig. 8. The trough had at that time developed into a small low centre, visible in the pressure field, close to the Norwegian coast. The satellite image at 08.57 (not shown here) indicated that the rear of the two clusters had just started to rotate.

At 12.00 GMT the same day, the polar low reached the coast and the wind at one coastal station, Svinøy (see Fig. 1), reached 20 m/s. The 500 mb map at 06.00 GMT (Fig. 9) shows that a trough line was located just outside the coast. The satellite image at 08.57 GMT (not shown here) showed that the rear cluster by this time had developed into a mature polar low. The cloud cluster in front had started to merge with the rear cluster. The polar low had a clearly visible cloud-free eye with a diameter of 50–70 km, whereas the diameter of the whole cloud system was 300–400 km. This can be verified by the image taken at 13.02 GMT (Fig. 10) when the eye of the low was right at the coast. One coastal station (Svinøy lighthouse) reported a wind of 22 m/s at this time. The low continued onshore in the afternoon this day and it died out in the same evening.

3. The vertical structure of the polar low

The low passed very close to the weathership Mike, where soundings are made every 6 hours. In Fig. 11, we have plotted the temperature curves before and during the passage of the polar low. The sounding to the left shows the situation well before the passage of the polar low: the wind was northwesterly and had decreased after the passage of the major polar front low. In the two next sections at 18.00 GMT and 00.00 GMT, the temperature had decreased in the upper troposphere. The wind had continued to decrease, especially in the middle of the troposphere,

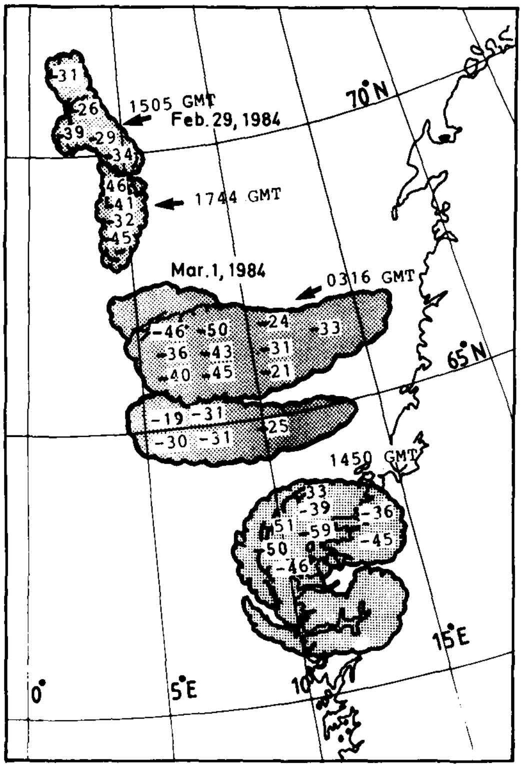

Fig. 7. Cloud composite chart with cloud top temperatures in °C computed from infrared satellite images.

whereas the humidity increased at the same time. At 06.00 GMT, the polar low passed very close to this ship station. The tropopause level had now increased to 350 mb. At the same time, the temperature in the lower part of the troposphere increased, and the air thereby became more unstable throughout the whole troposphere. The wind increased very strongly in the middle of the troposphere and veered towards northeast between 700 mb and 500 mb. This means that the low axis tilted towards the southwest at this time of its life cycle. At 06.00 GMT, the relative humidity was also high throughout the whole troposphere.

4. Observations of wind, pressure and precipitation

The pressure registrations at weathership Mike and at Ålesund airport (62°N, 06°06′E) are shown in Fig. 12 (top panel). The wind registration at Ålesund at the time of the passage of the low is also shown (bottom panel). The low can be traced in the registration from 1 March. It passed the weathership Mike at 05.00 GMT. The pressure decreased rather slowly before the passage, but increased abruptly and strongly afterwards. At Ålesund, the low passed shortly after 13.00 GMT. It can be seen that here, the pressure decreased suddenly before the passage. The pressure rise after the passage was stronger than the pressure fall before. This is a salient feature of polar lows.

The wind registration at Ålesund is also characteristic for polar lows. In this case, the wind increased suddenly from a mean wind of approximately 12 m/s up to almost 25 m/s, with gusts up to near 35 m/s. The wind direction varied almost 180° during the passage. The strong variation in wind direction and in addition the strong wind force might cause moderate to severe turbulence in the actual area. The sudden wind increase in a rather short time is very characteristic for these polar lows.

The precipitation connected with the polar low is presented in Fig. 13. Some of the stations reported every 12 hours, while others reported only every 24 hours. The amount of precipitation at the 24-hour stations has been reduced by 30%. This was made as a rough estimate after comparing the 12 hours recordings during the two 12-hour periods. The isohyetals should then represent the precipitation amount between 06.00 GMT and 18.00 GMT 1 March. The cloud system connected with the low has been indicated in the figure. It was reproduced from the satellite images at 13.02 GMT and 14.45 GMT. The maximum precipitation was concentrated to the south of the center of the cyclone. Orographic uplift might have contributed to the amount. We believe, however, that most of the precipitation resulted from strong convection in the cloud system.

5. Concluding remarks

The development of the polar low described here took place at a low-level shear zone in the Norwegian Sea. The shear zone coincided well with an area of maximum sea surface tempera-

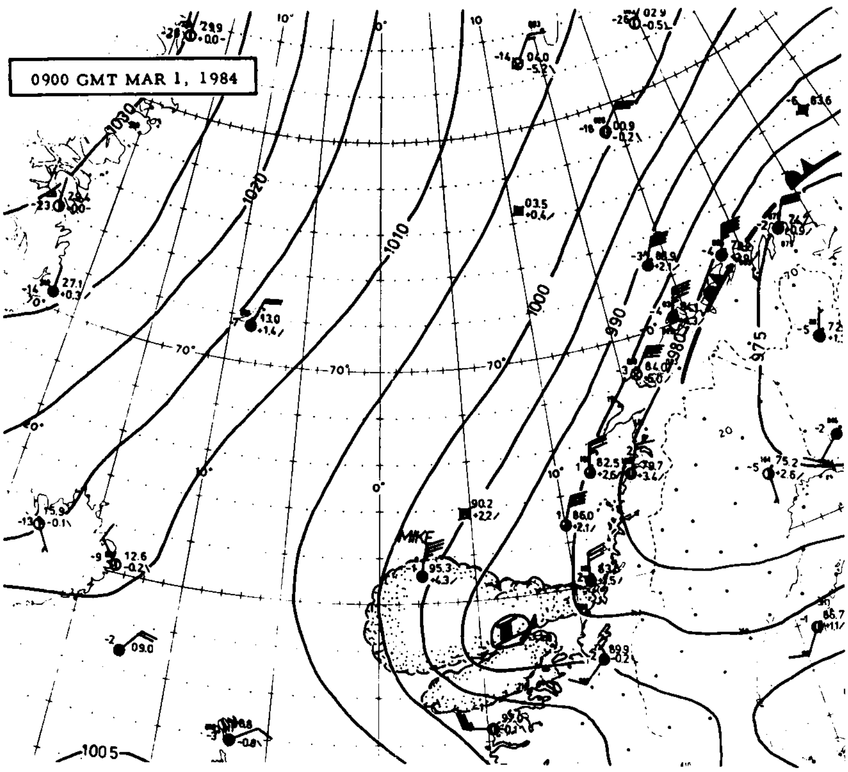

Fig. 8. Surface map at 09.00 GMT 1 March 1984.

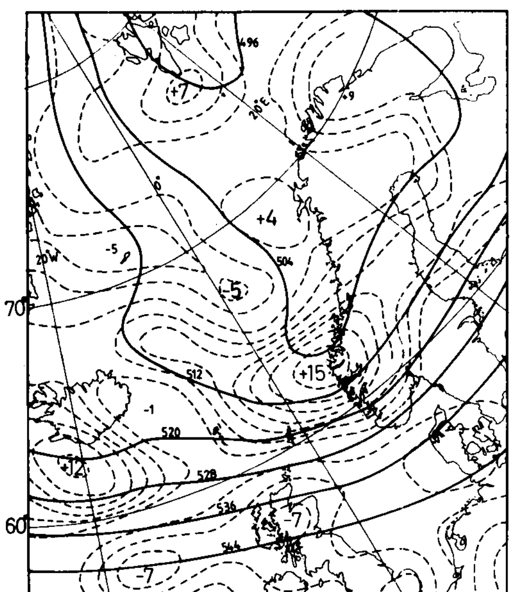

Fig. 9. 500 mb geopotential height at 06.00 GMT 1 March 1984. The full lines are isohypses (units: gpdam) and the dashed lines relative vorticity (units: $10^{-5}\ s^{-1}$).

ture. In the shear zone, a rather large cloud cluster was built up. Low-level vorticity was created in this shear zone. The large cluster broke up into several pieces during the night of 1 March. Two of these minor clusters moved closely together towards the south in the low-level windfield. When the two clusters reached an upper level strong shear zone, they were supplied with additional cyclonic vorticity. This new cyclonic vorticity source made the two clusters merge and develop into a mature polar low.

It might be an important point that convective instability at low levels is a necessary, but not a sufficient condition for a polar low to develop into a real storm. Another releasing or triggering effect has to be present. We do believe that the upper level vorticity near the shear zone aloft was the triggering effect in this particular case.

6. Acknowledgements

The author wishes to thank the crew and the scientists on board the NOAA research aircraft,

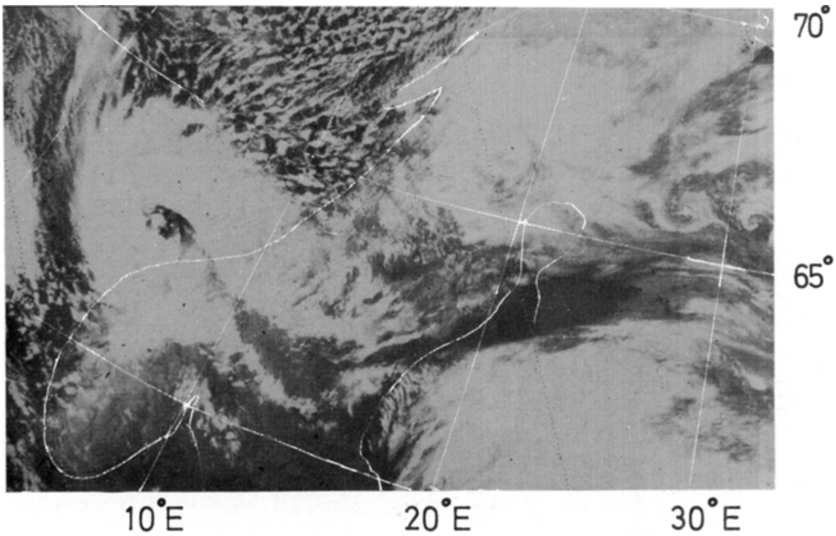

Fig. 10. Infrared NOAA 7 satellite image, 13.02 GMT 1 March 1984.

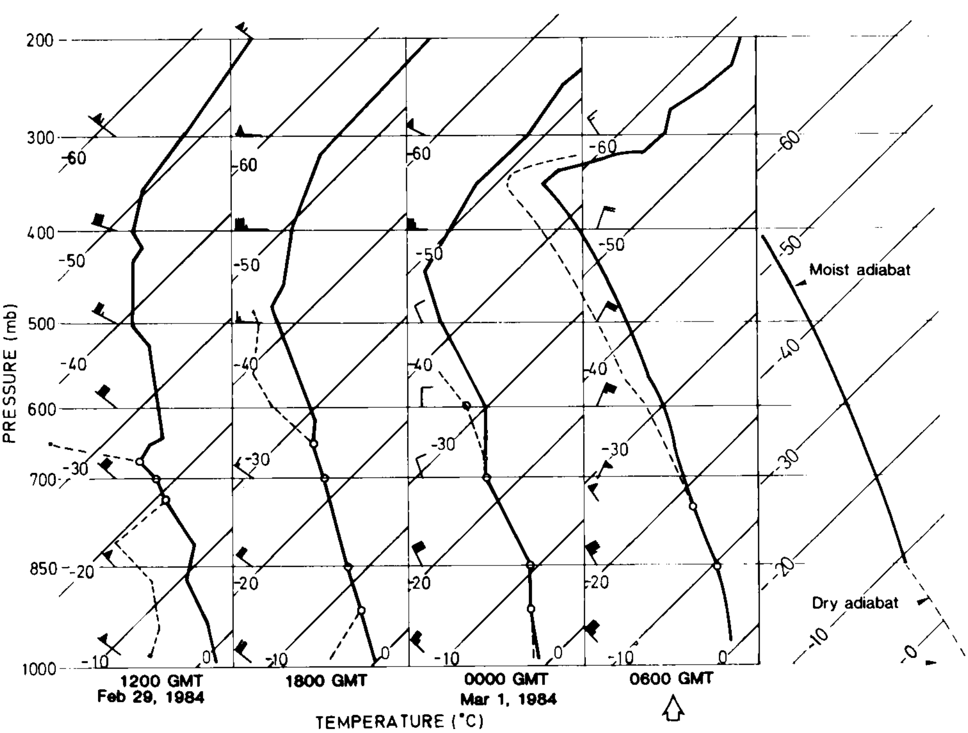

Fig. 11. Soundings taken before and at the passage of the polar low at weathership Mike (66° N, 2° E). The arrow indicates the passage of the low.

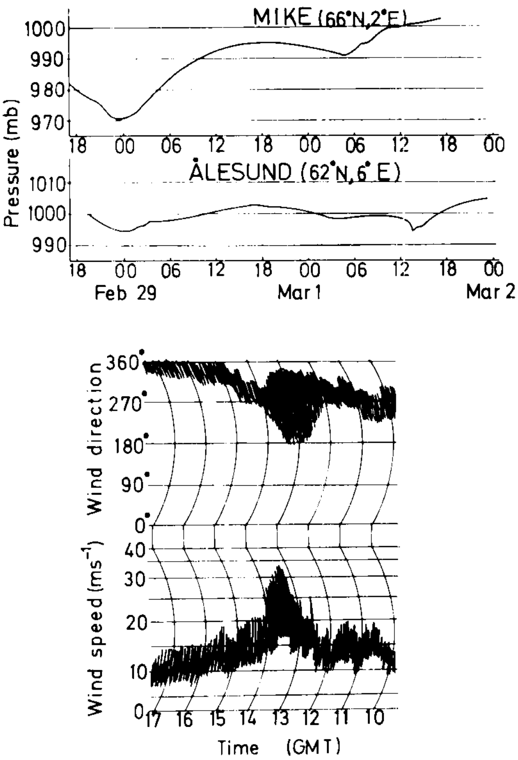

Fig. 12. Top panel: surface pressure registration 29 February through 1 March at weathership Mike and at Ålesund. Bottom panel: wind registration at Ålesund airport 10.00–17.00 GMT 1 March 1984.

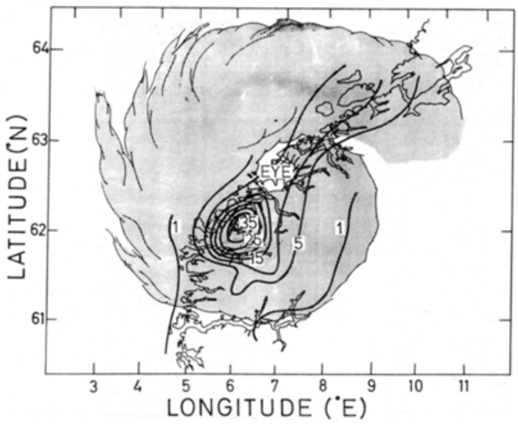

Fig. 13. Precipitation (mm) over southwestern Norway during the period 06.00–18.00 GMT 1 March 1984. The cloud system at approximately 13.00 GMT is stippled.

who supported this research with the most valuable flight data. Special thanks go to Leonard Fedor, Melvyn Shapiro and S. Naegele.

REFERENCE

Rabbe, Å. 1985. Analysis of a polar low in the Norwegian Sea, February 29 to March 1, 1984. Polar lows project, Techn. Rep. No. 14, The Norwegian Meteorological Institute, Oslo, Norway.