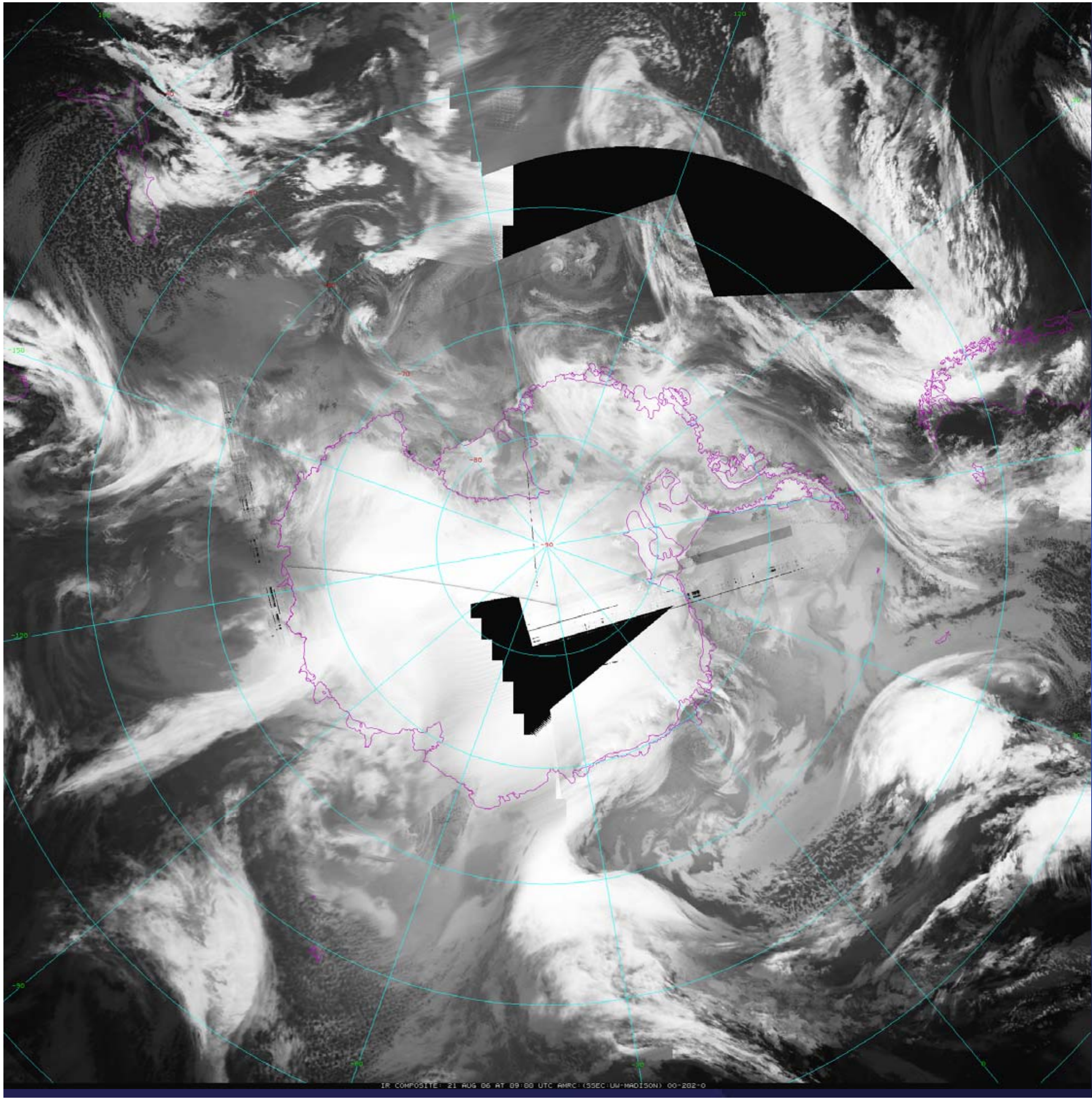
Polar Lows and other High Latitude Weather Systems

John Turner and Tom Bracegirdle

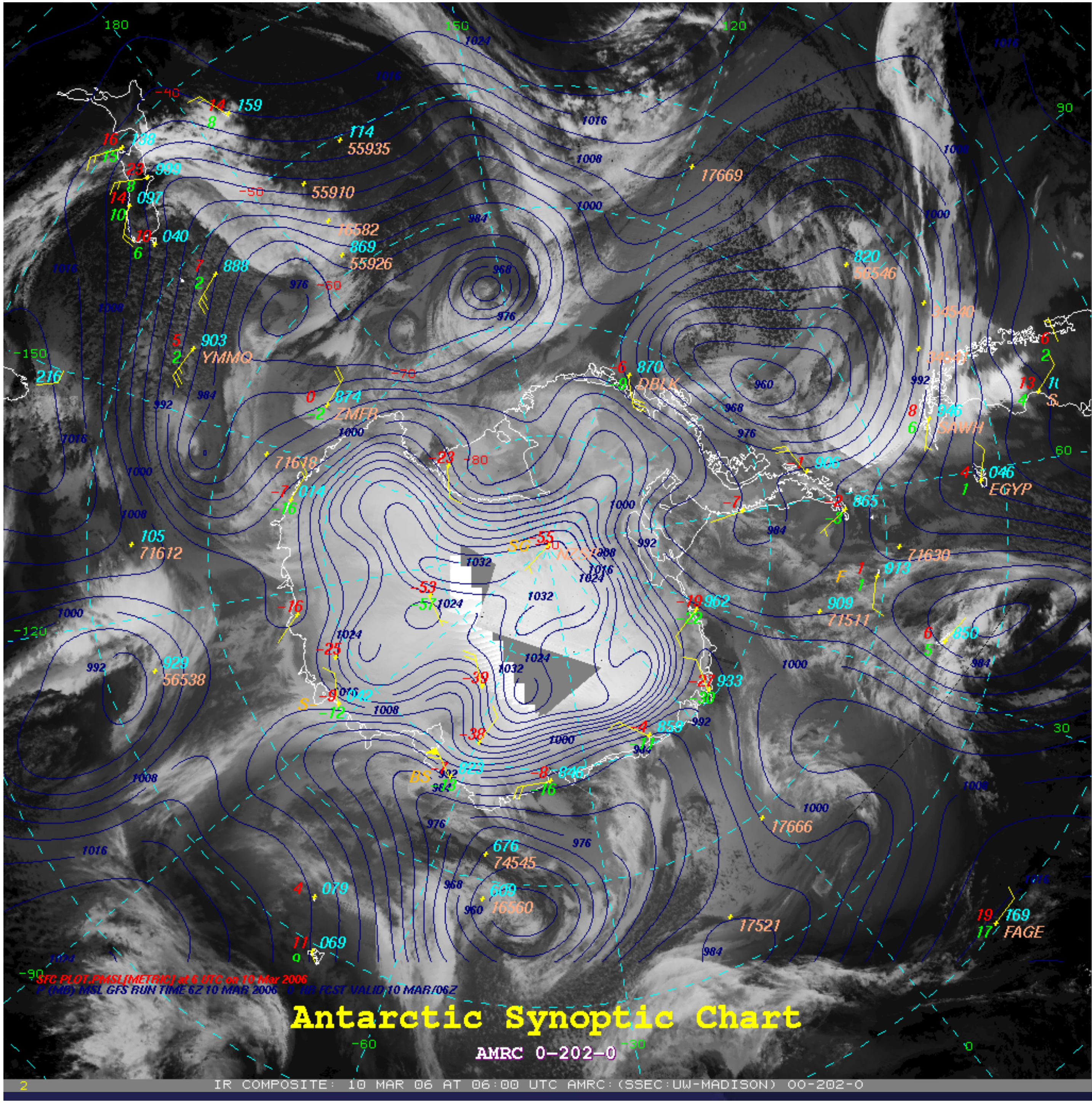
British Antarctic Survey

Cambridge, UK



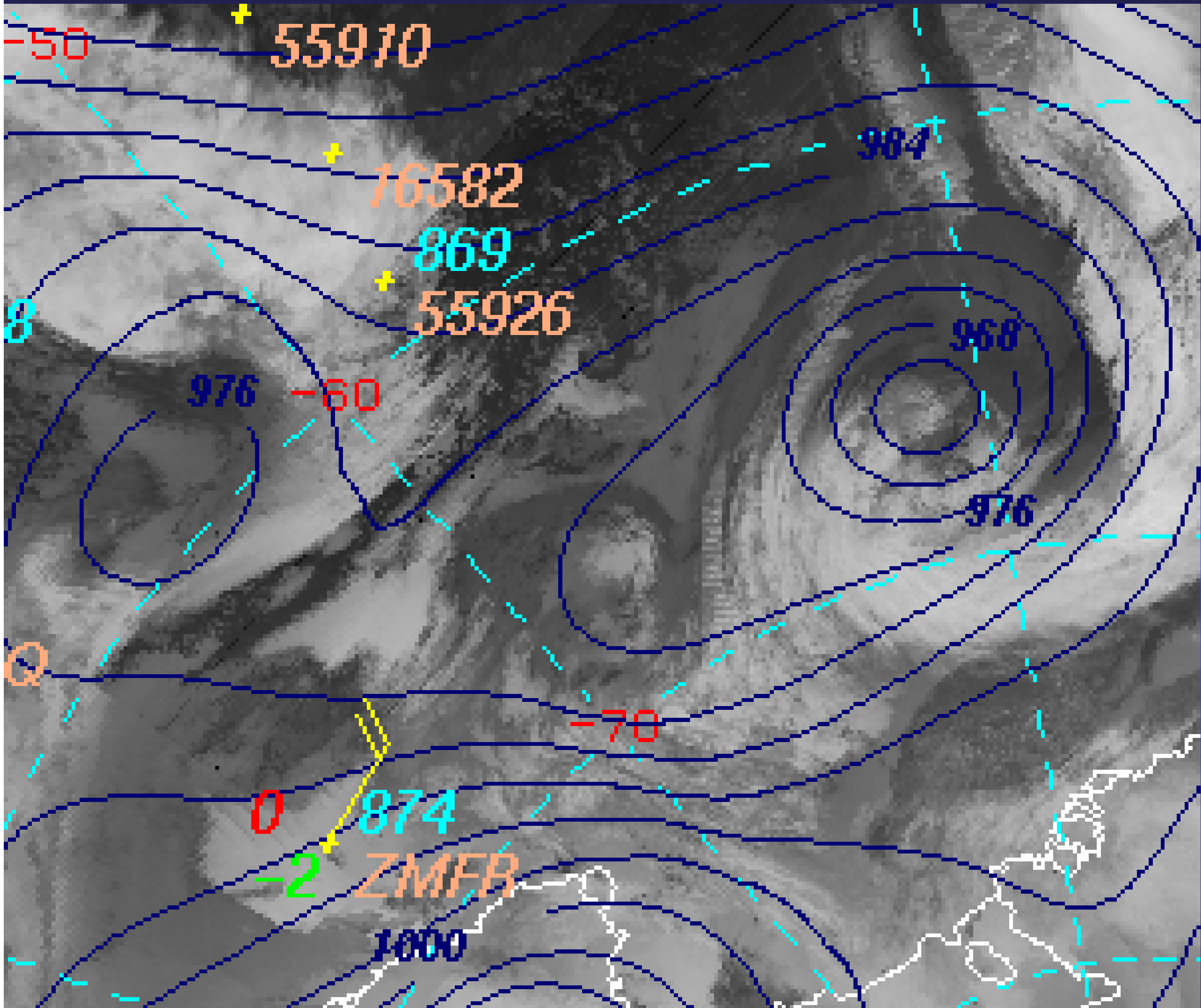
A mosaic of infra-red satellite imagery of the Antarctic and Southern Ocean on 21 August 2006.

University of Wisconsin-Madison



Overlaid satellite imagery and GFS model (NCEP) analysis.

University of Wisconsin-Madison



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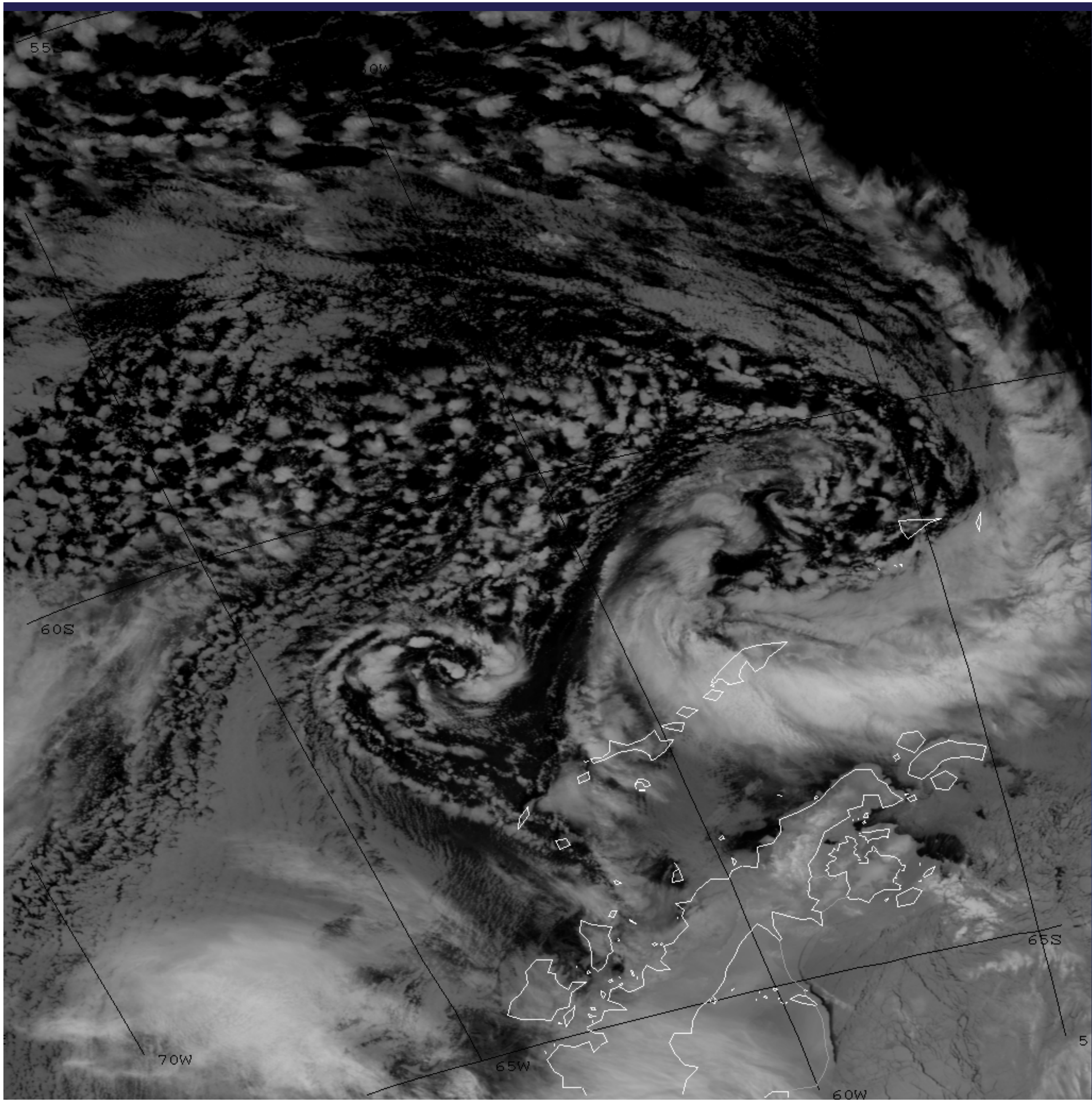
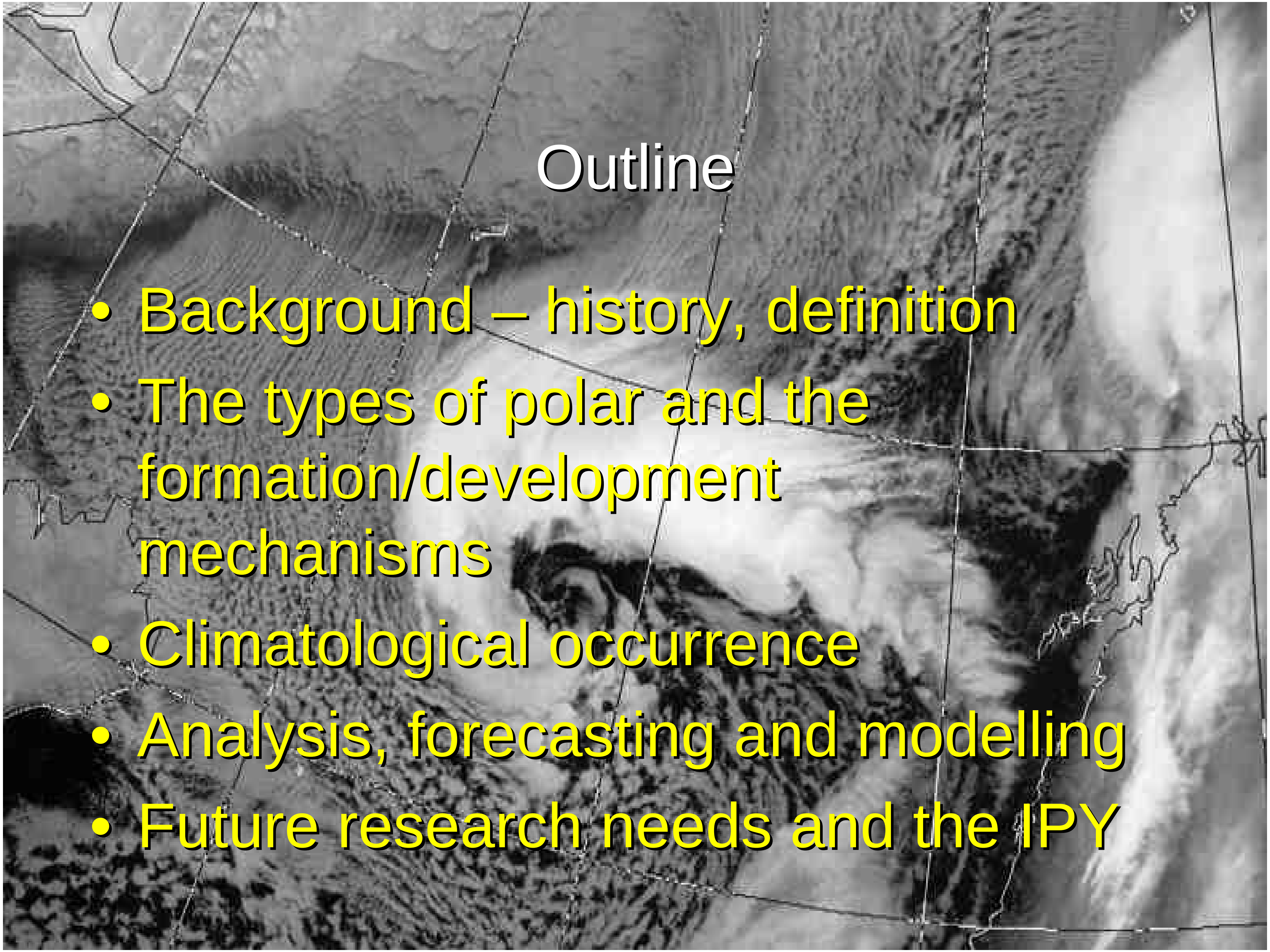


Synoptic and mesoscale weather systems near the tip of the Antarctic Peninsula



Outline

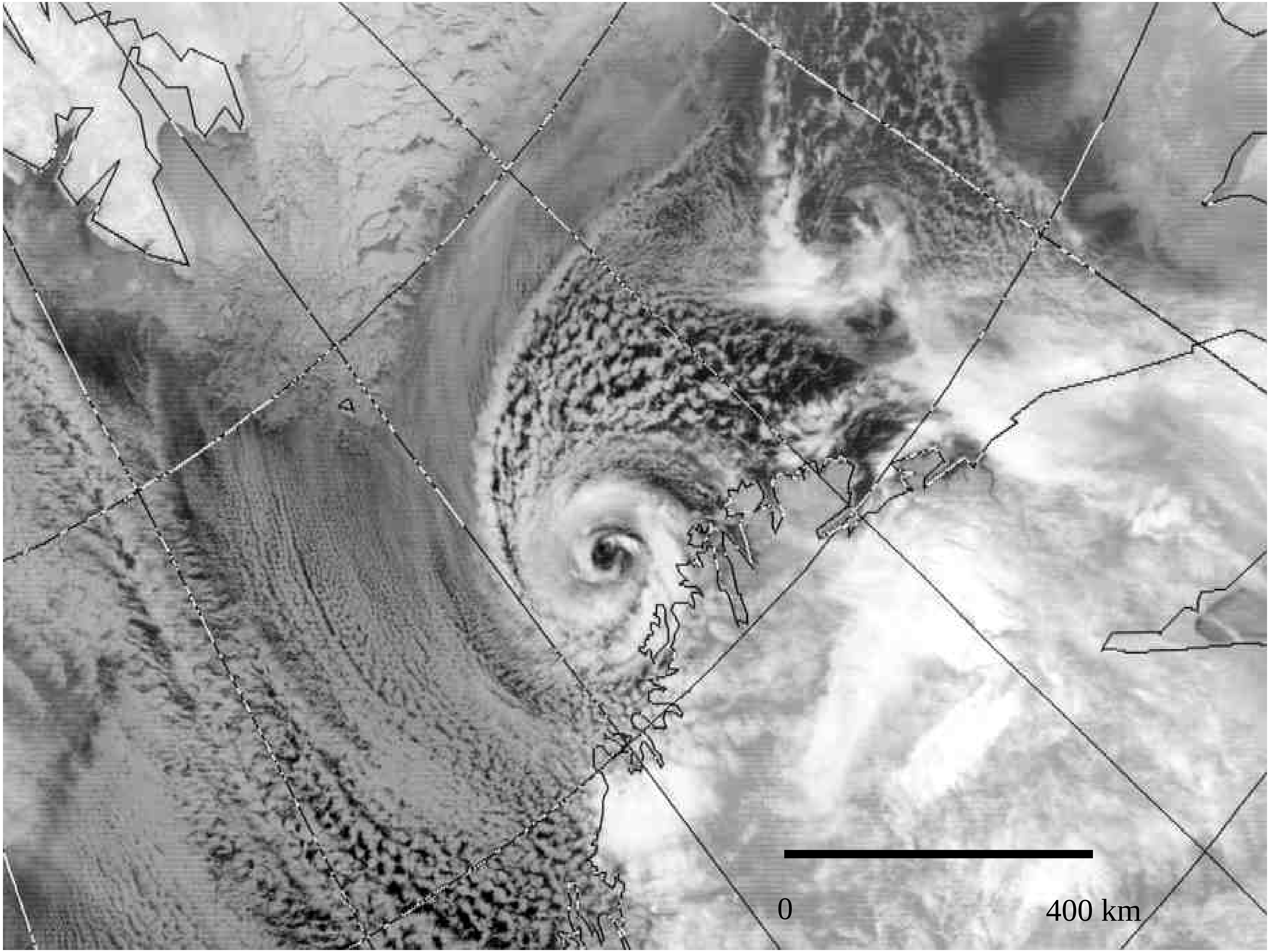
- Background – history, definition
- The types of polar and the formation/development mechanisms
- Climatological occurrence
- Analysis, forecasting and modelling
- Future research needs and the IPY

The Nature of Polar Lows

- Occur poleward of the Polar Front
- Mesoscale <1,000 km diameter, <24 h lifetime
- A maritime phenomenon, declining rapidly over land
- Have winds in excess of gale force
- Usually occur during winter season
- The Arctic systems are more vigorous than their Antarctic counterparts because of the larger fluxes of heat and moisture from the ocean

Possible Climatological Importance

- Individual polar lows can have fluxes of heat of up to 1,000 Wm**2
- The loss of heat from the ocean could trigger downward convection in the ocean
- But the frequent occurrence of polar lows would be needed in an area for this to be of climatological importance
- Modelling studies are needed to assess their importance

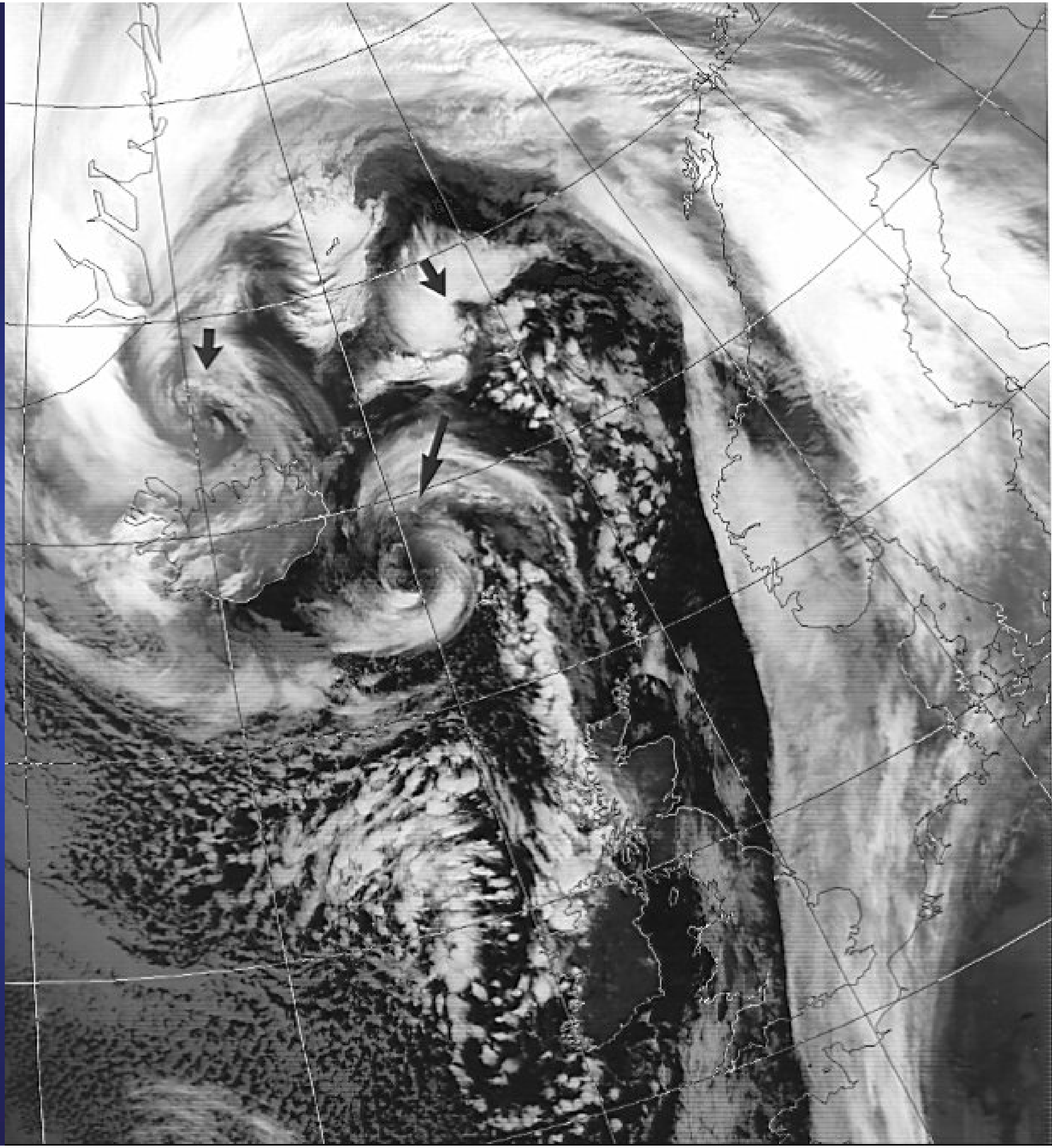

0
400 km

Nomenclature

- Polar lows have also been called:
  - Arctic hurricane
  - Arctic bomb
  - Arctic instability lows
  - Cold air depressions
  - Comma clouds
  - Mesocyclones
- My preferred choice:
  - Polar lows for systems with winds > gale force
  - Polar mesocyclones for weaker systems

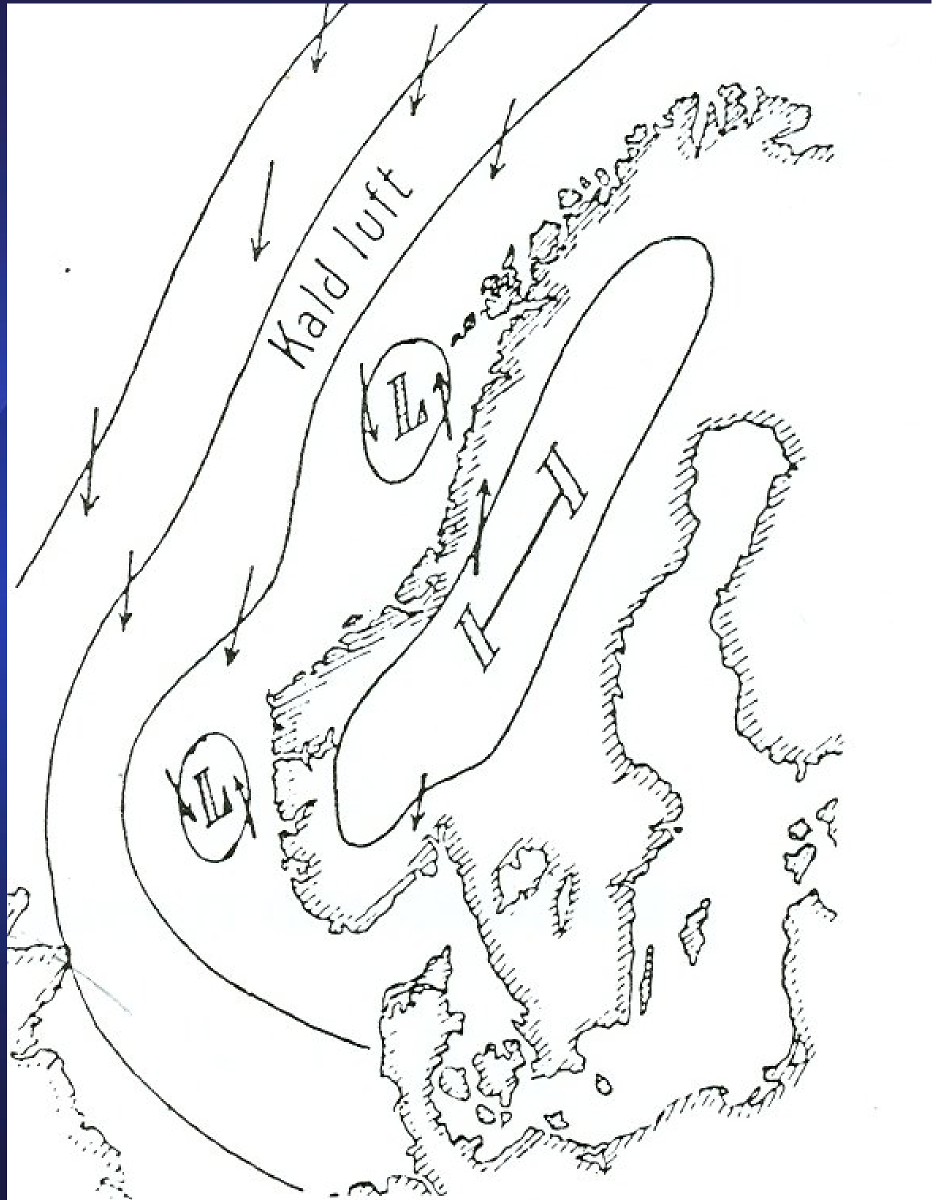
Early references

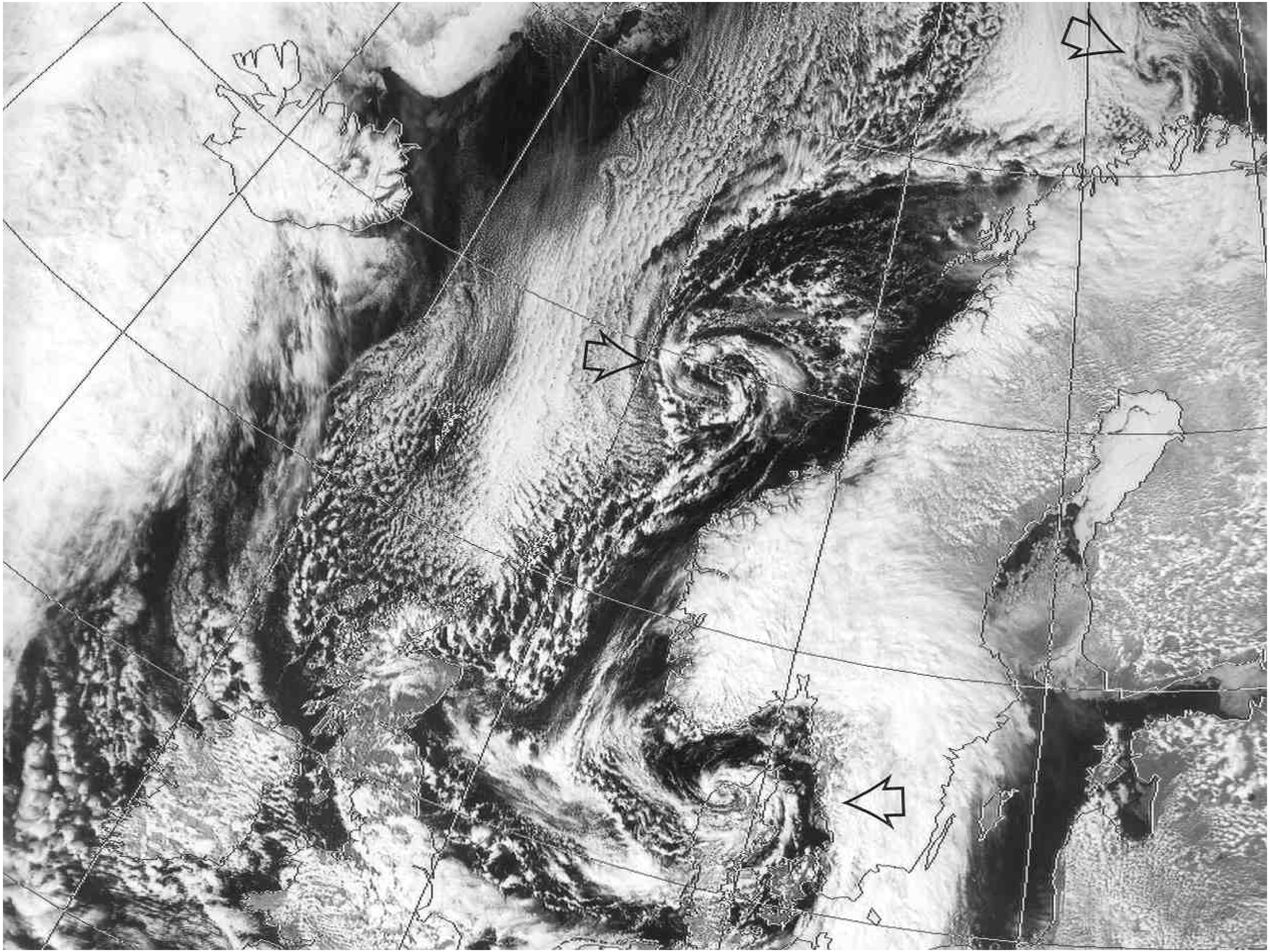
- During the Second World War – the conveys to Russia via the Barents Sea reported very vigorous small weather systems
- Sumner (1950) reported ‘hurricane-like centres within high latitude, synoptic-scale lows’.



Peter Dannevig

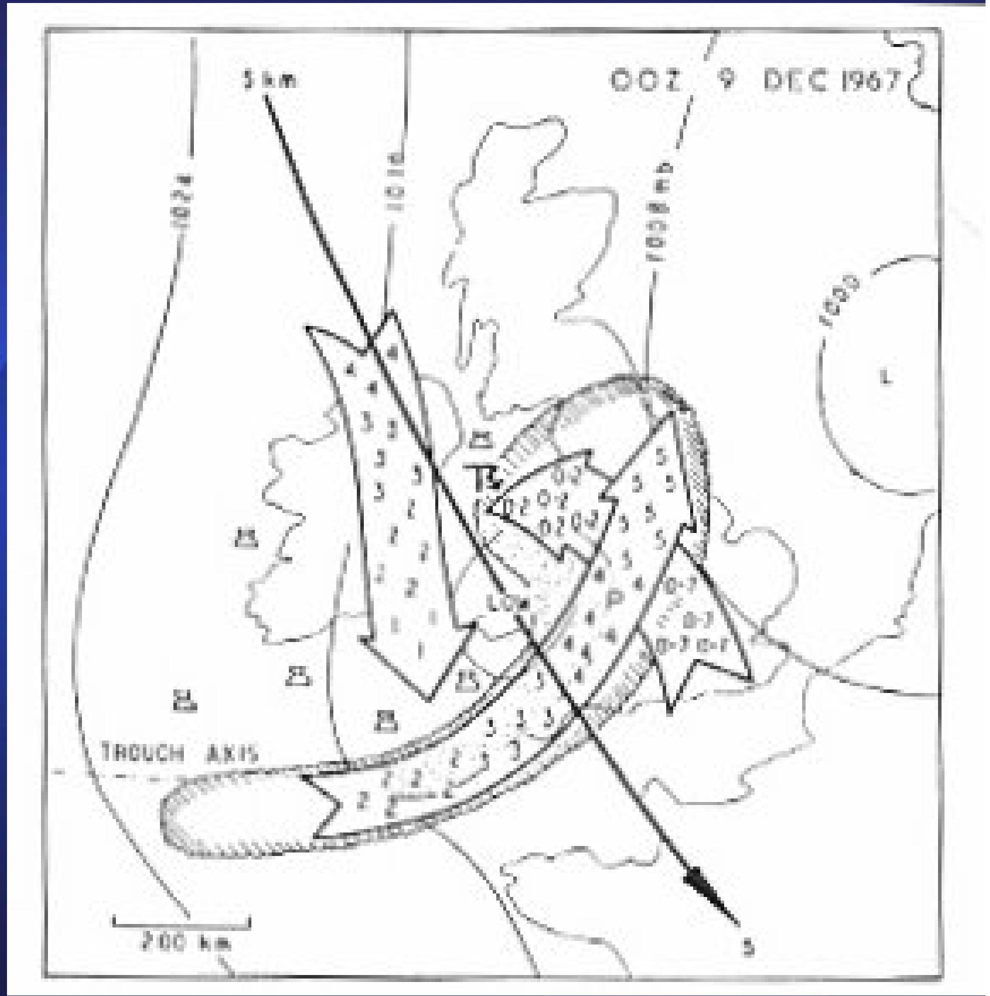
- In 1954 wrote about 'instability lows' over the sea areas around Norway in a book for pilots
- Produced a schematic weather chart showing the relationship between these vortices and the airflow around Norway





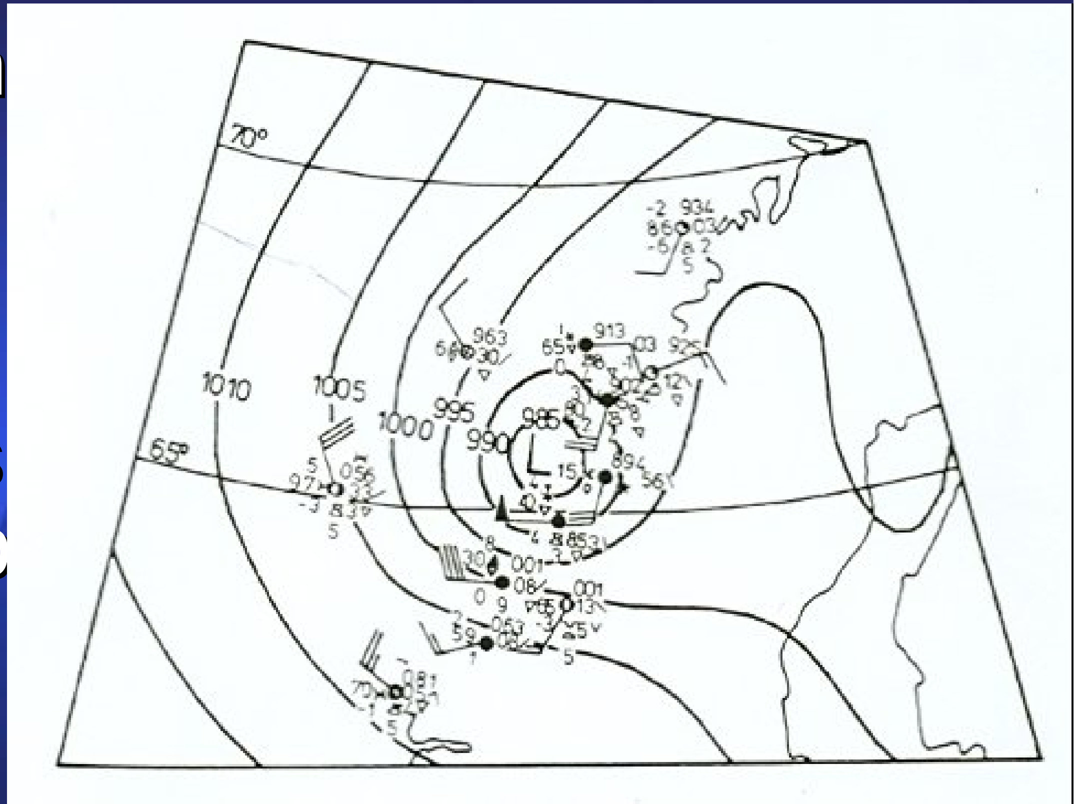
The Harrold and Browning Case (1969 QJ)

- 'The polar low as a baroclinic disturbance'
- Developed a conceptual model for the low that crossed the UK on 9 December 1967

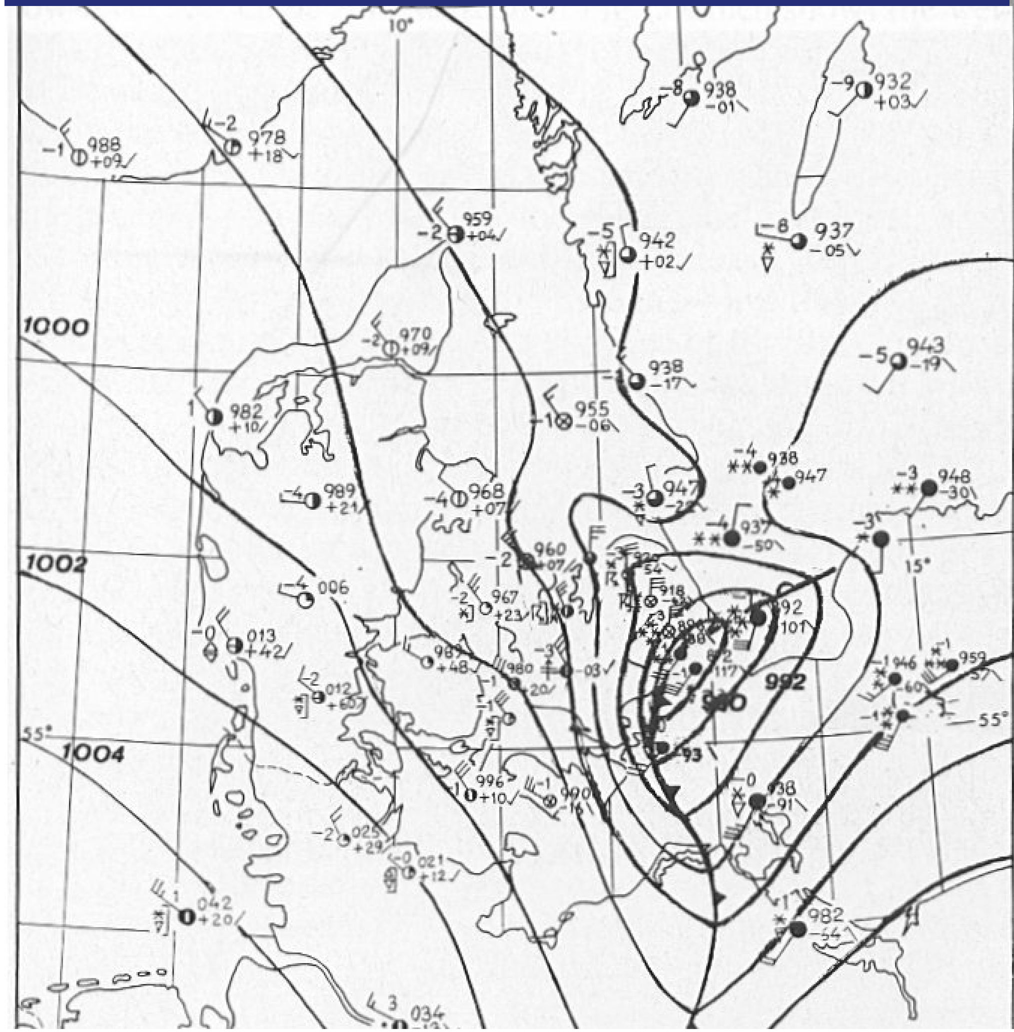


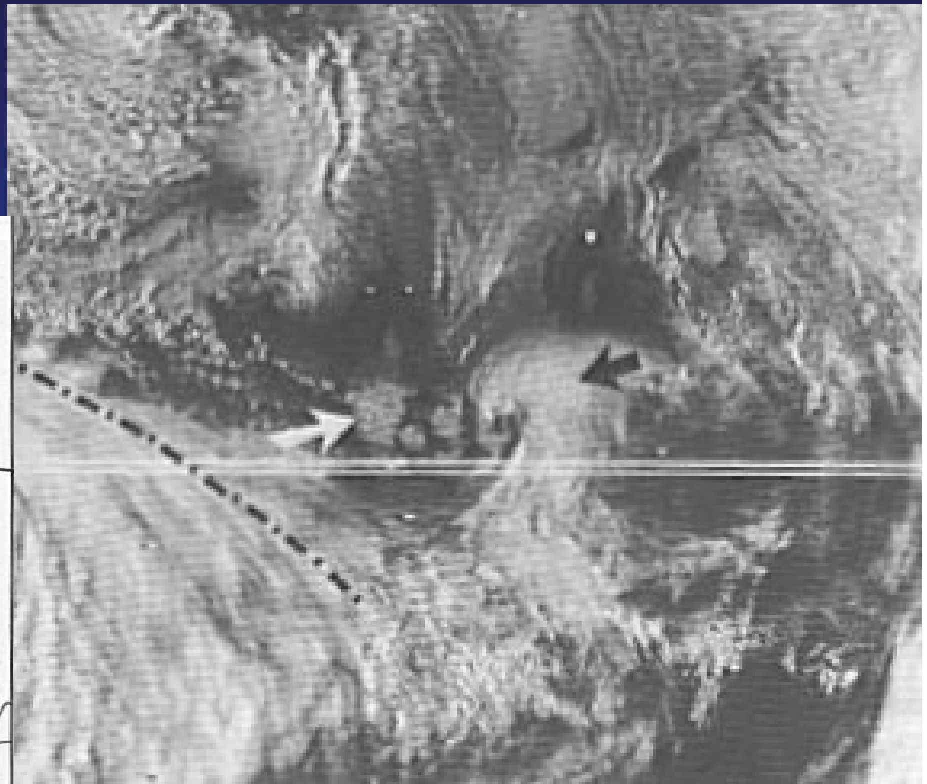
The Rasmussen Paper (1979 QJ)

- ‘The polar low as an extratropical CISK disturbance’
- Supported the old idea that polar lows were driven by deep convection and baroclinicity played only a small role



A Baroclinic Polar Low Over Denmark



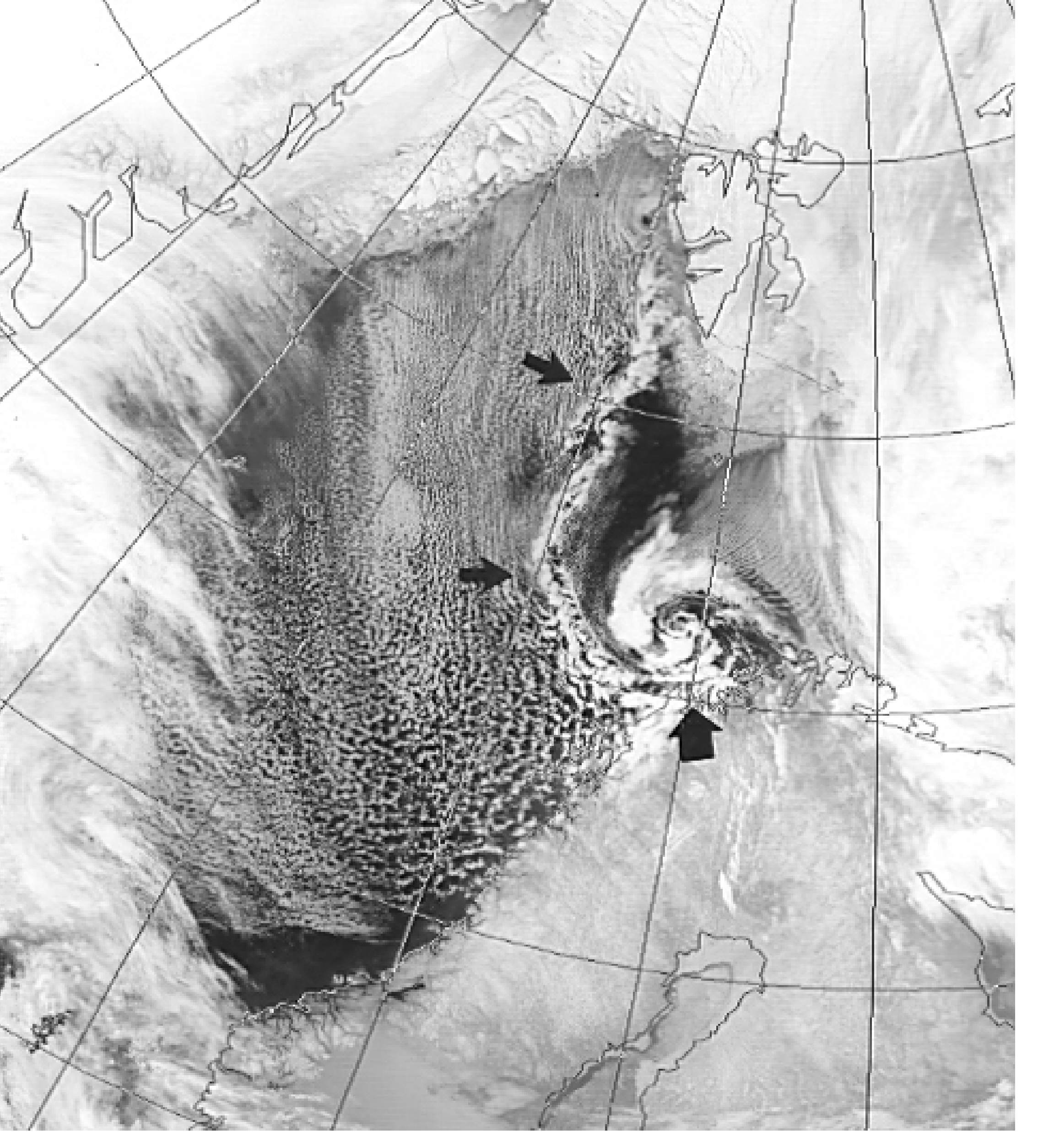


The broken line shows the main baroclinic zone

Snow cover over Jutland is indicated by the white arrow

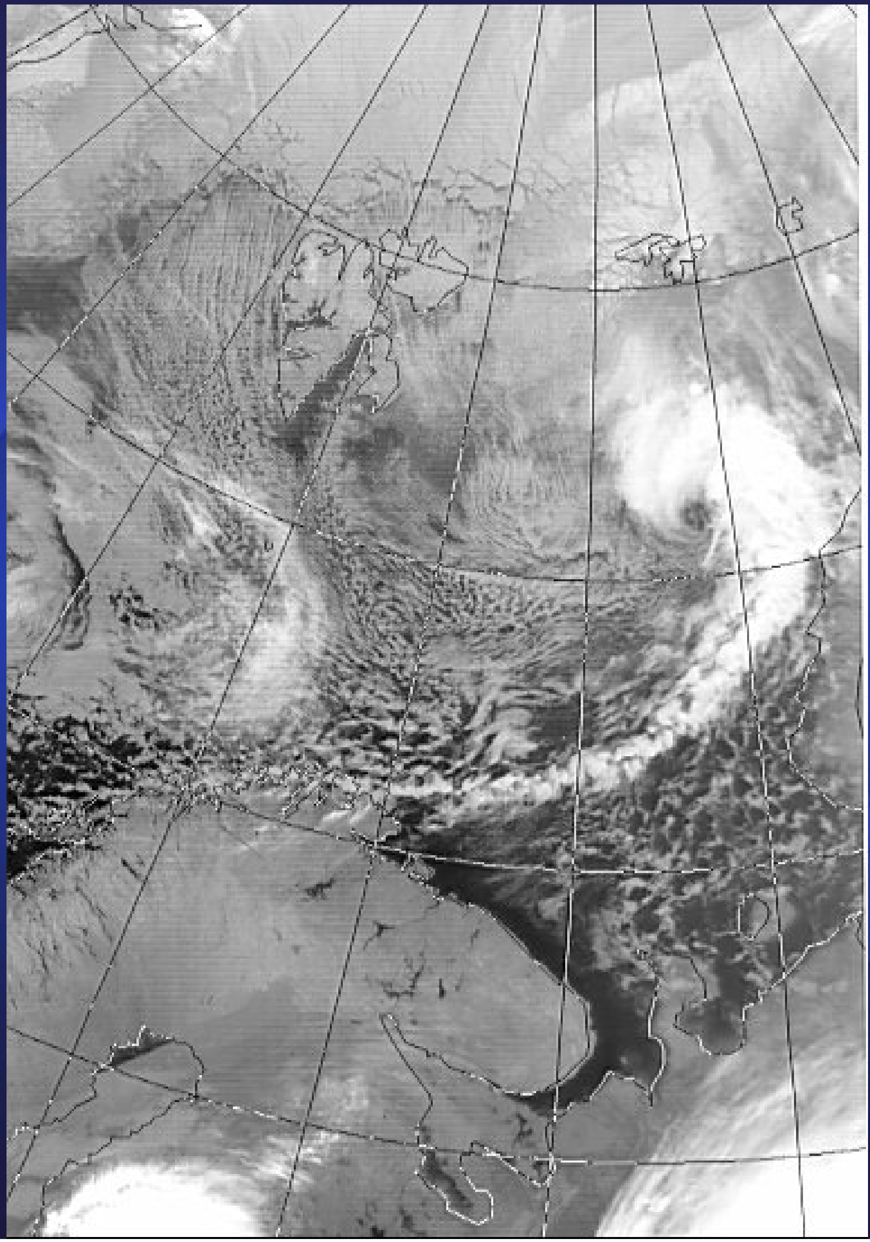
The Spiraliform Cloud Signature

- A polar low with spiraliform cloud signature off the northern coast of Norway
- Also indicated is a boundary layer front



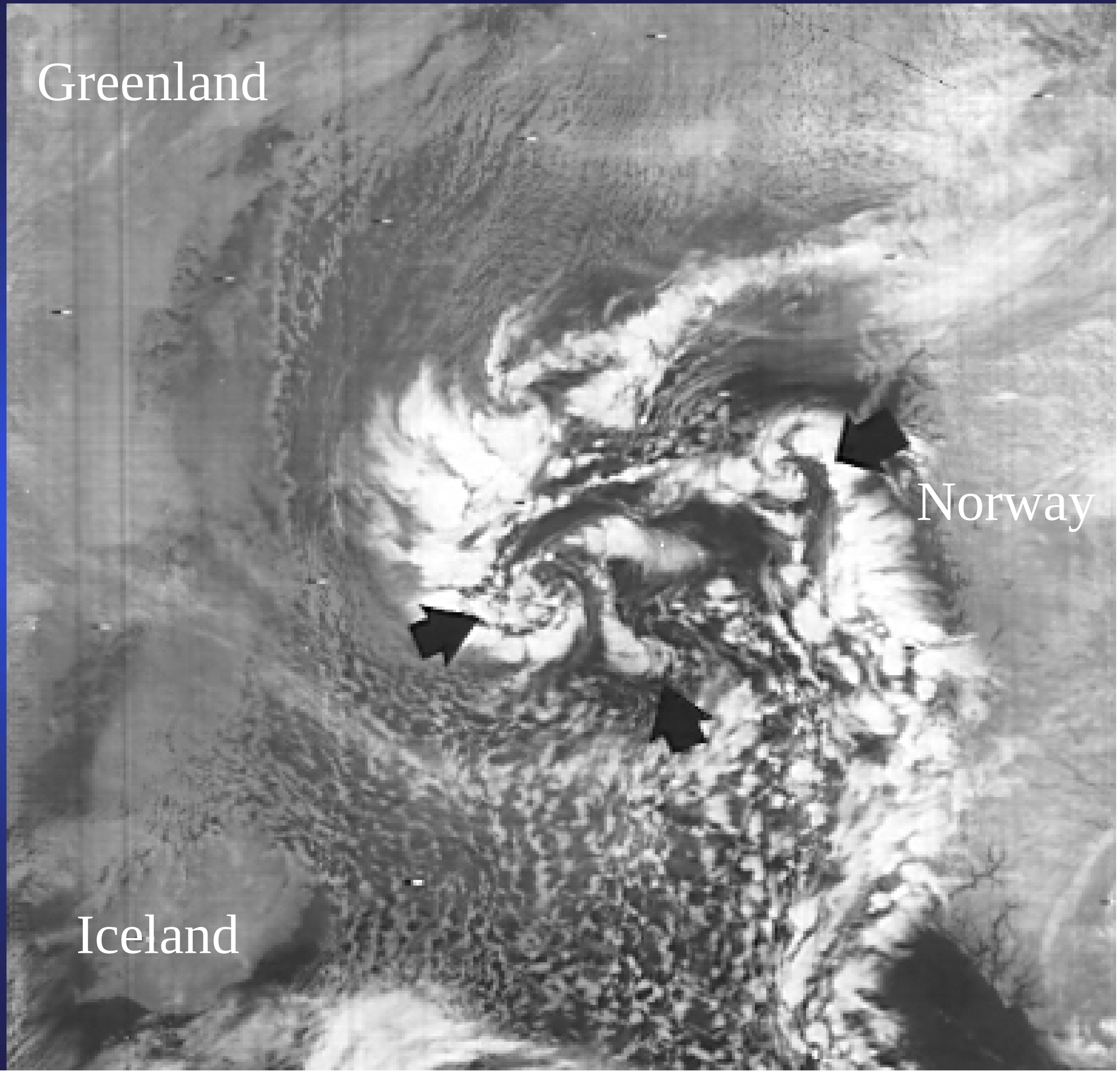
The Comma Cloud Signature

- A rare high latitude comma cloud over the Barents Sea

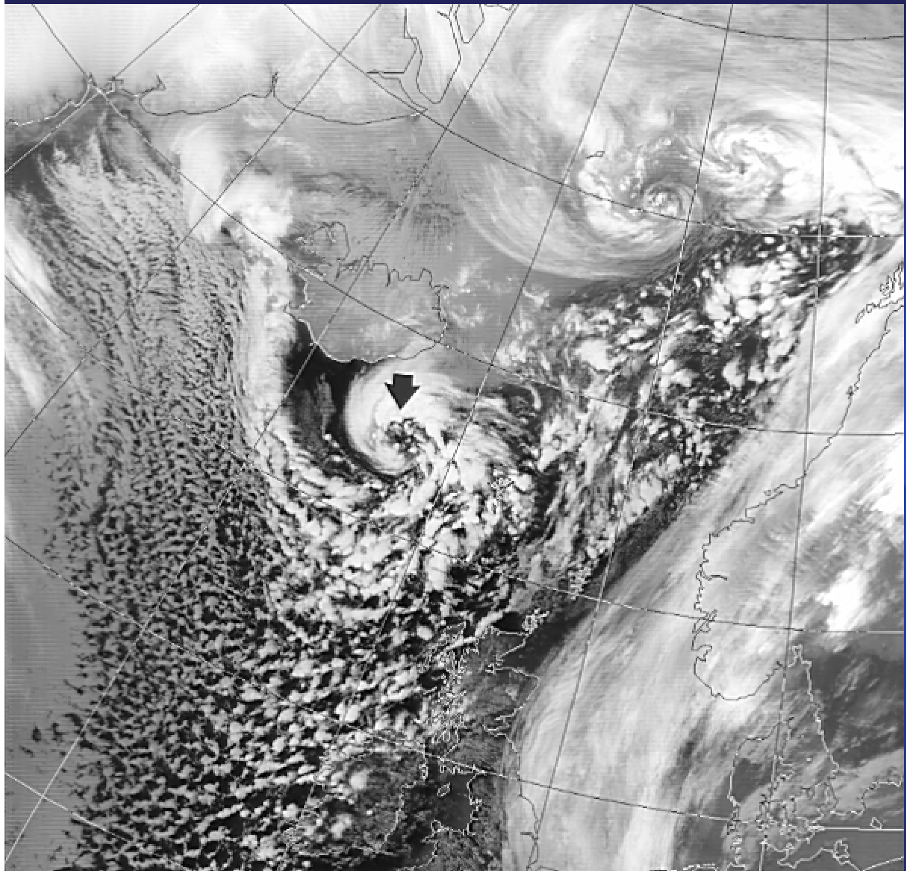


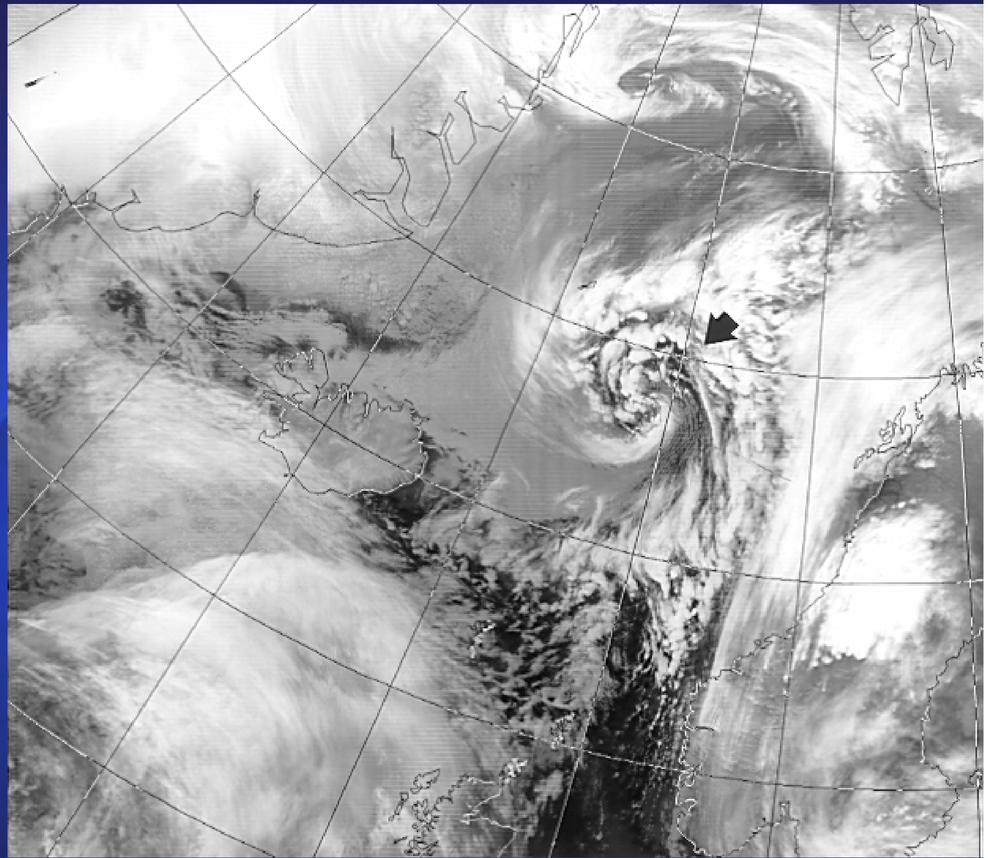
A ‘Merry-Go-Round’ Polar Low

- A polar low with multiple centres over the Greenland / Norwegian Seas.



The Instant Occlusion Process



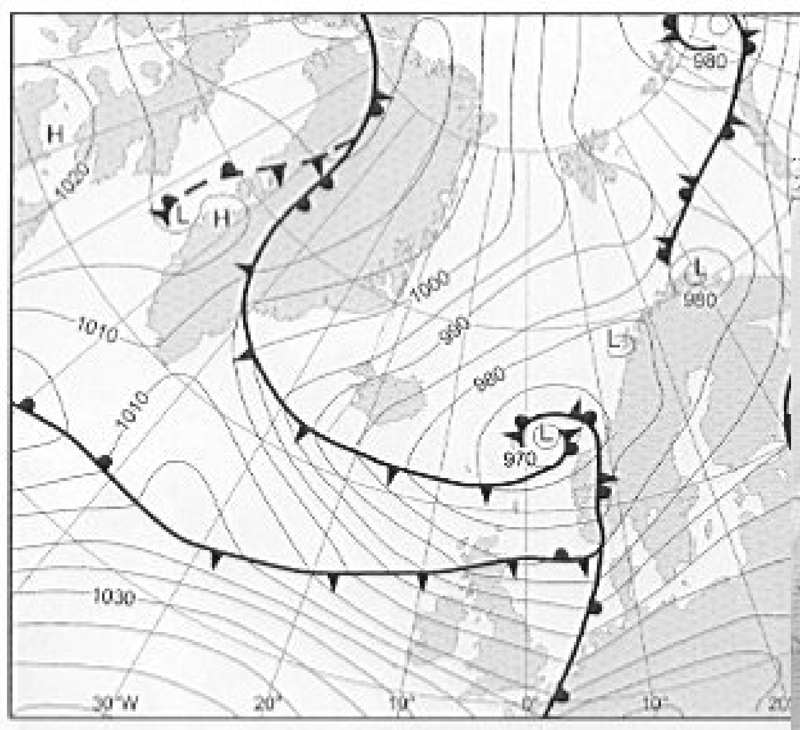


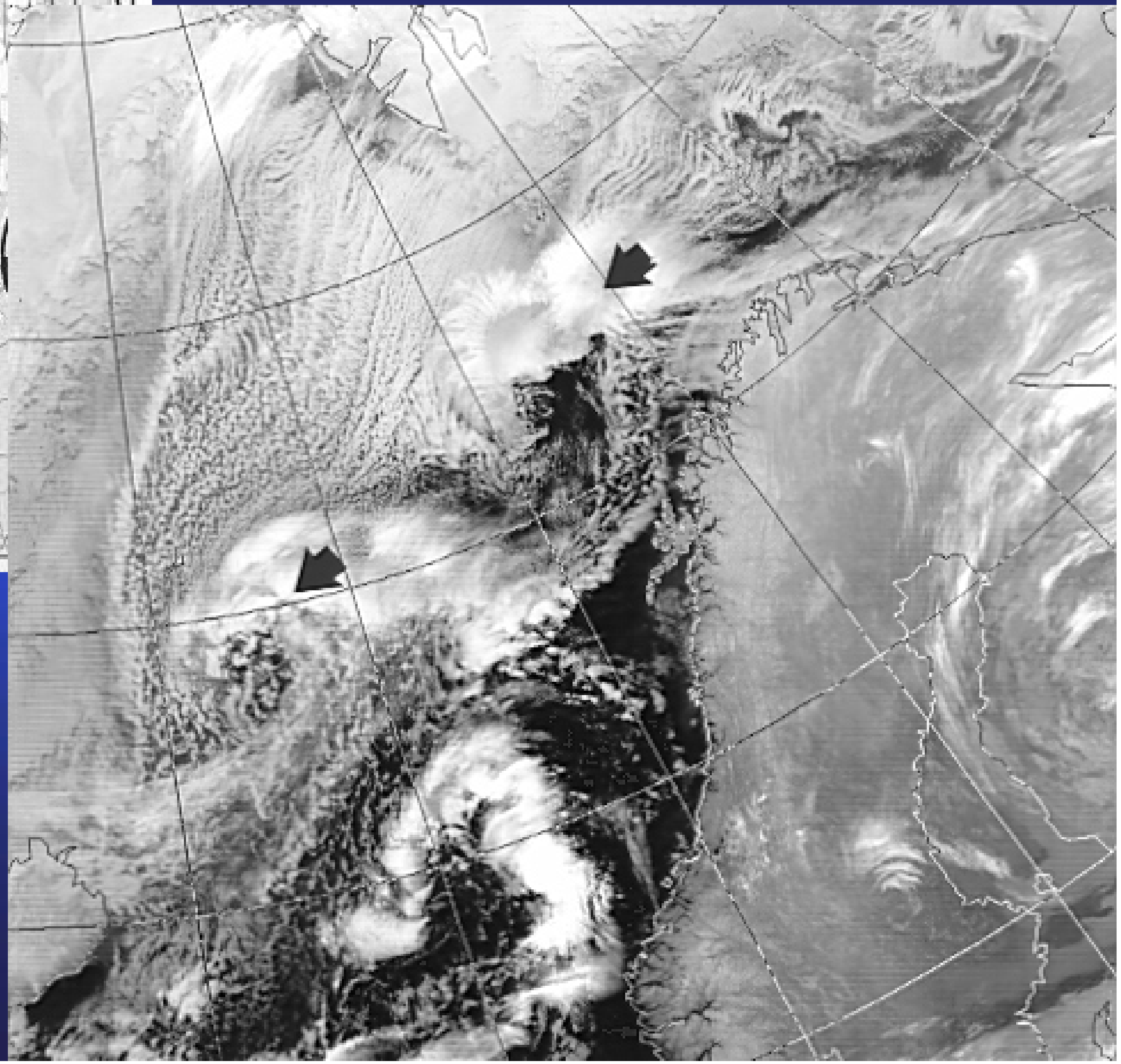
The polar low south of Iceland moves towards the wave on the polar front to form the instant occlusion

One Possible Polar Low Classification System

1. Reverse Shear systems
2. Trough systems
3. Boundary Layer Fronts
4. Cold Lows
5. Comma Clouds
6. Baroclinic-wave Forward Shear
7. Orographic Polar lows

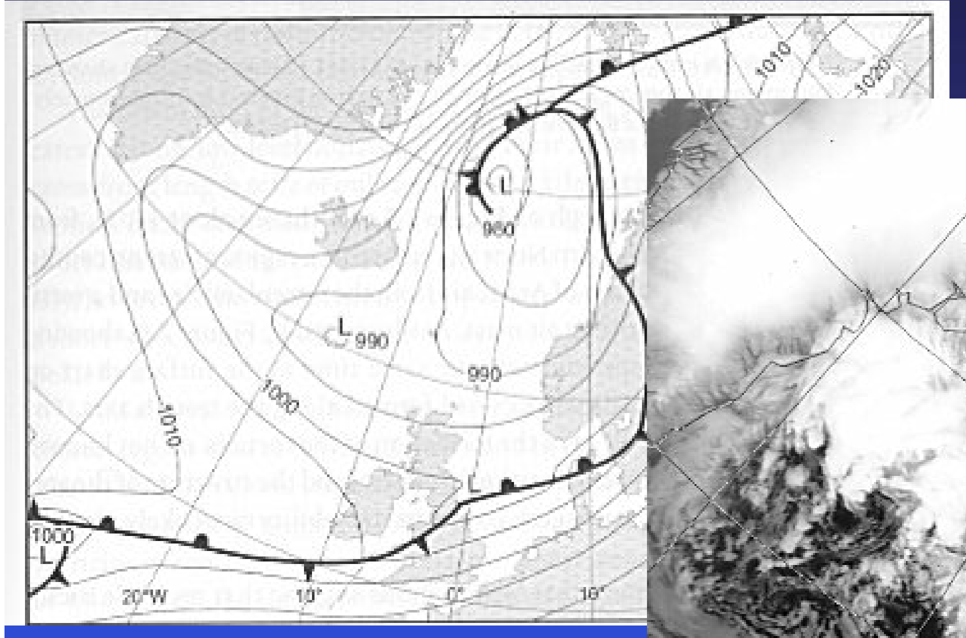
1. Reverse Shear Polar Lows

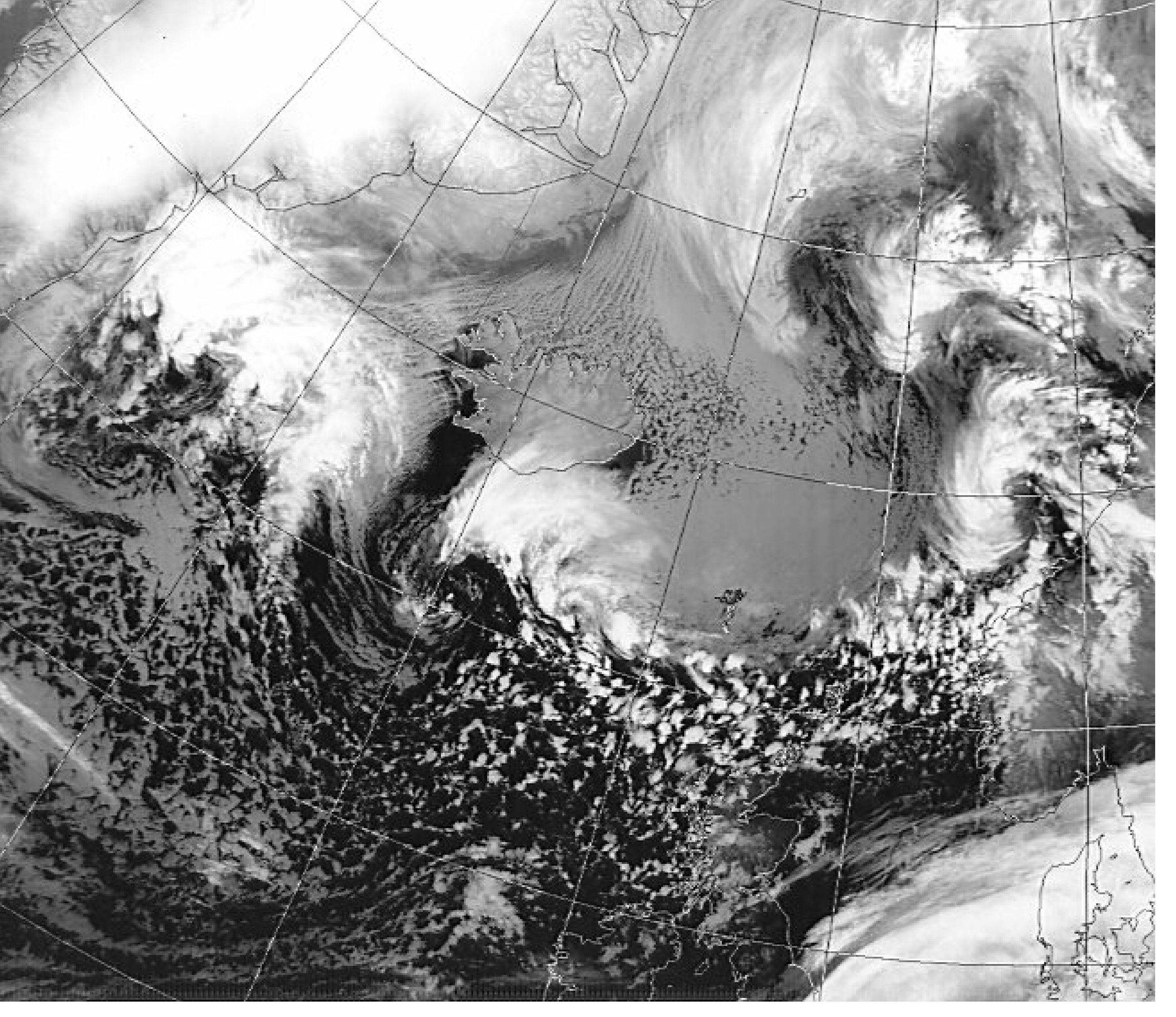




Probably triggered by short-wave, upper trough. Baroclinic instability and deep convection play a part in the developments.

2. Trough Systems



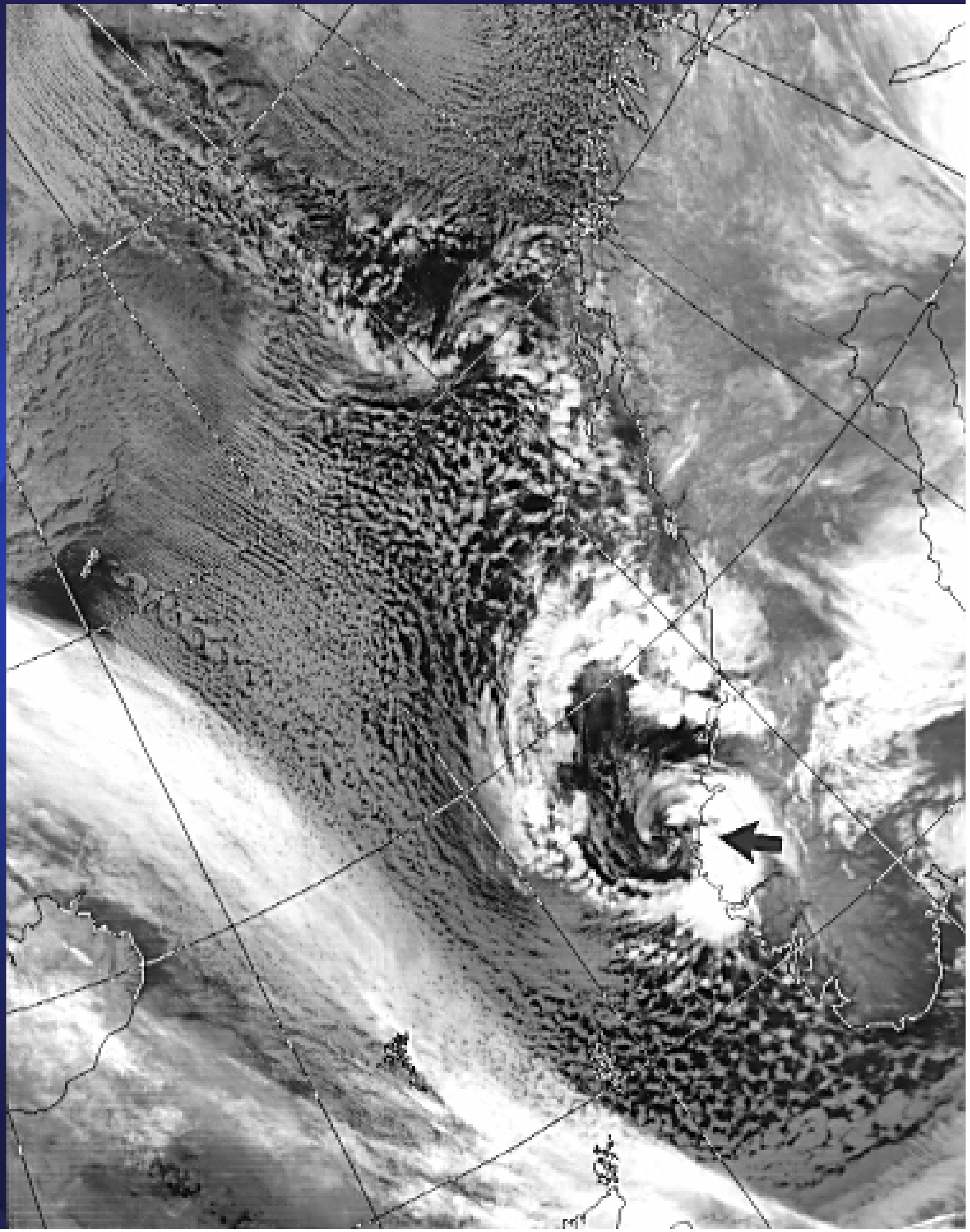


These systems often develop in trailing troughs associated with major synoptic scale lows. Again often triggered by short, UA troughs, or jet streaks. The cold air advection enhances convection.

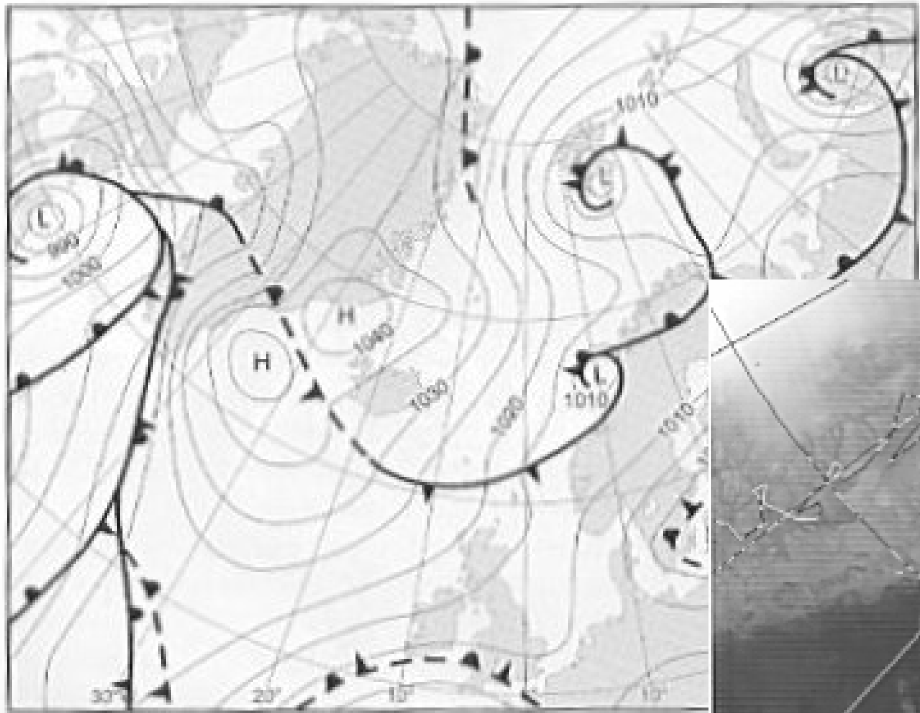
3. Boundary Layer Front Systems

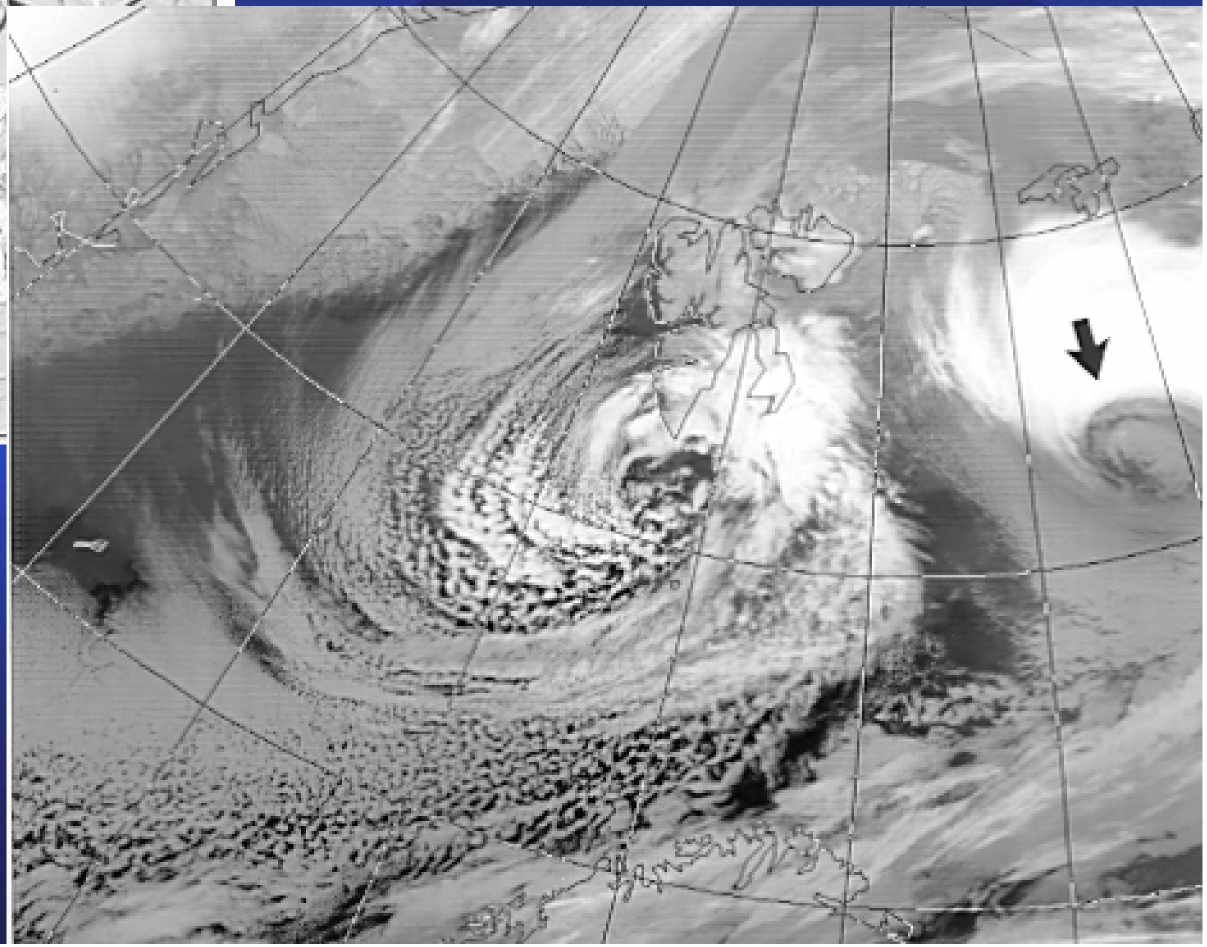
Boundary Layer fronts are frequently found over the Norwegian and Barents Seas, any many polar lows form on these features.

The lows developing in these baroclinic regions are often short-lived.

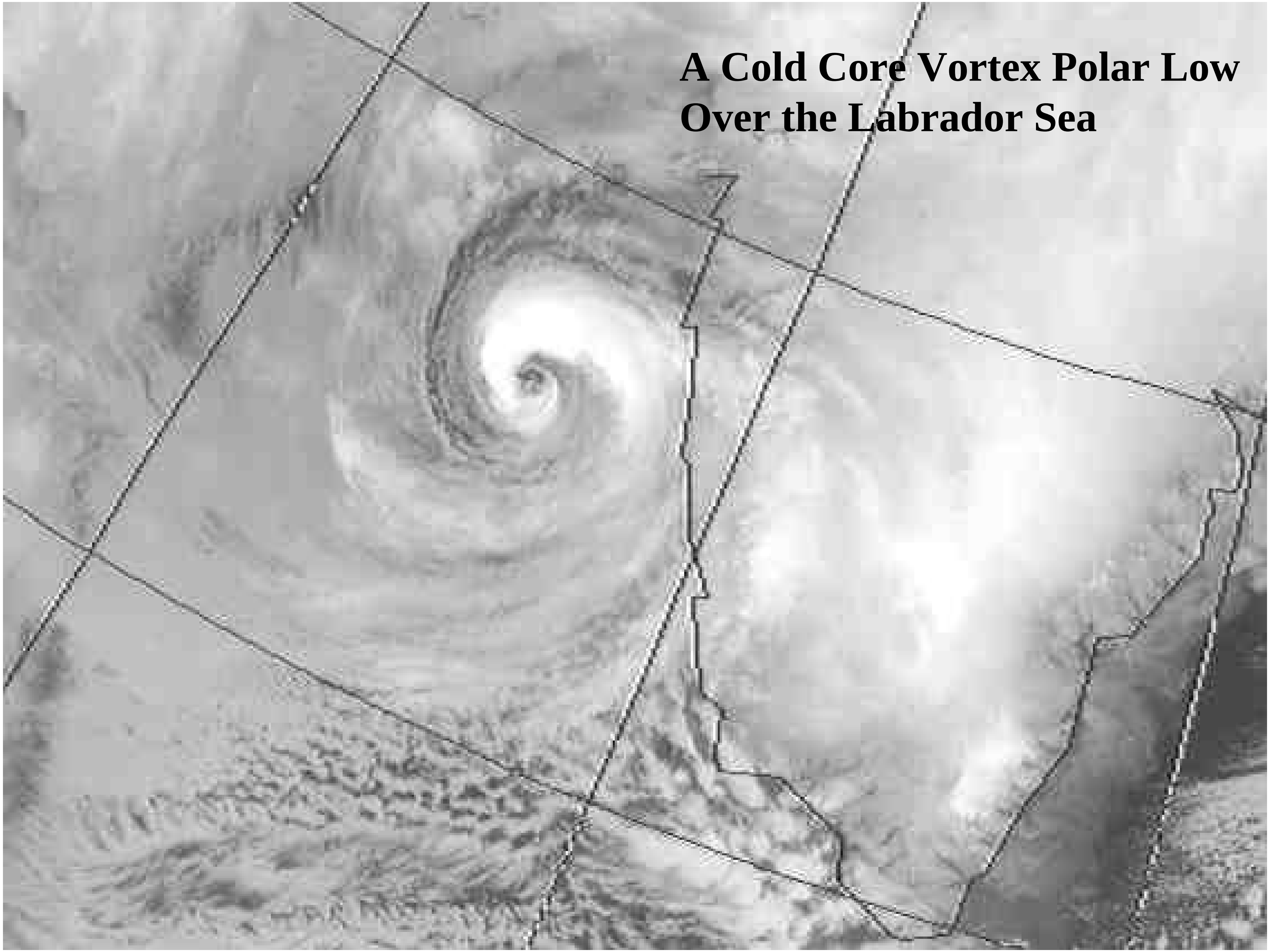


4. Cold Low Types



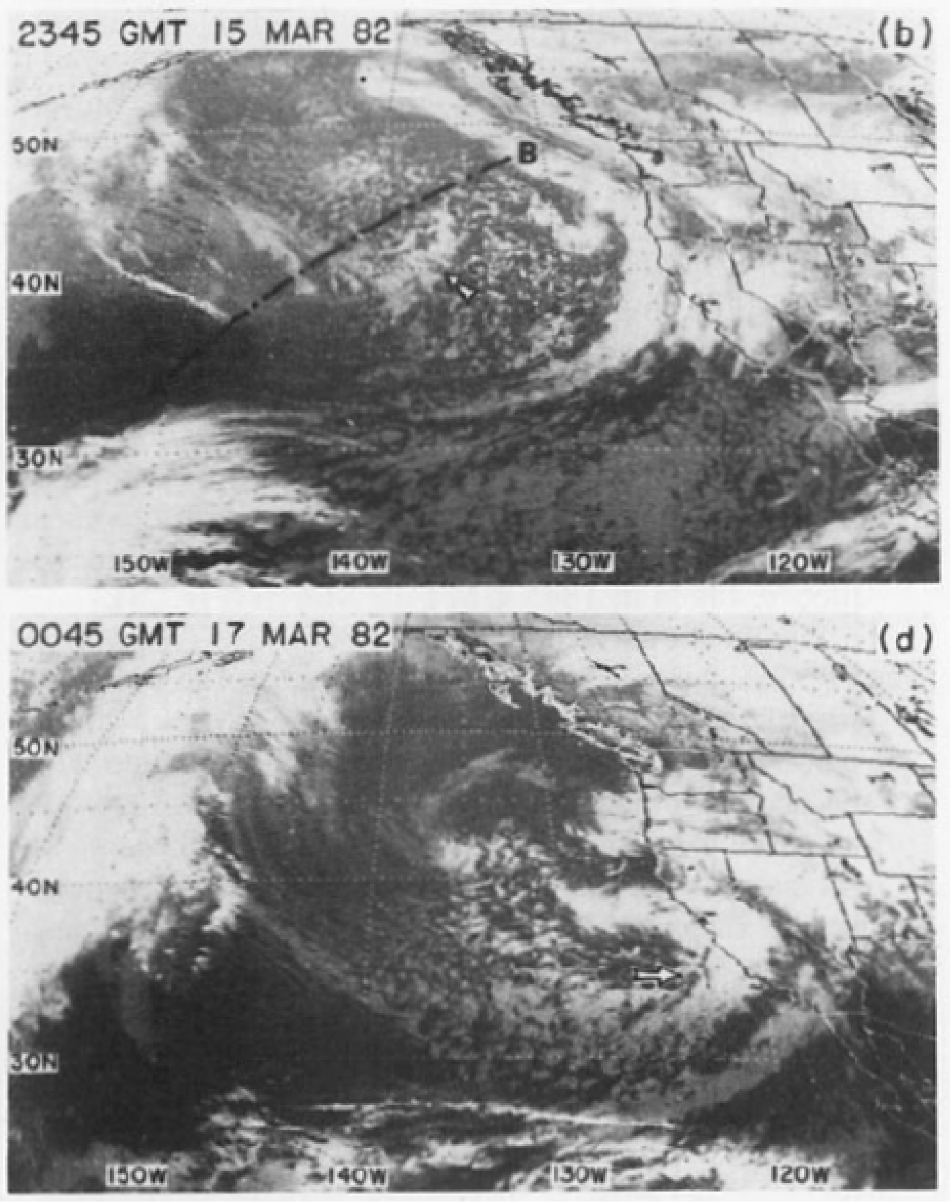


Forming deep in the cold air, these lows often have spiral cloud patterns. They often develop within old cold core lows. They often form when the low moved over water.

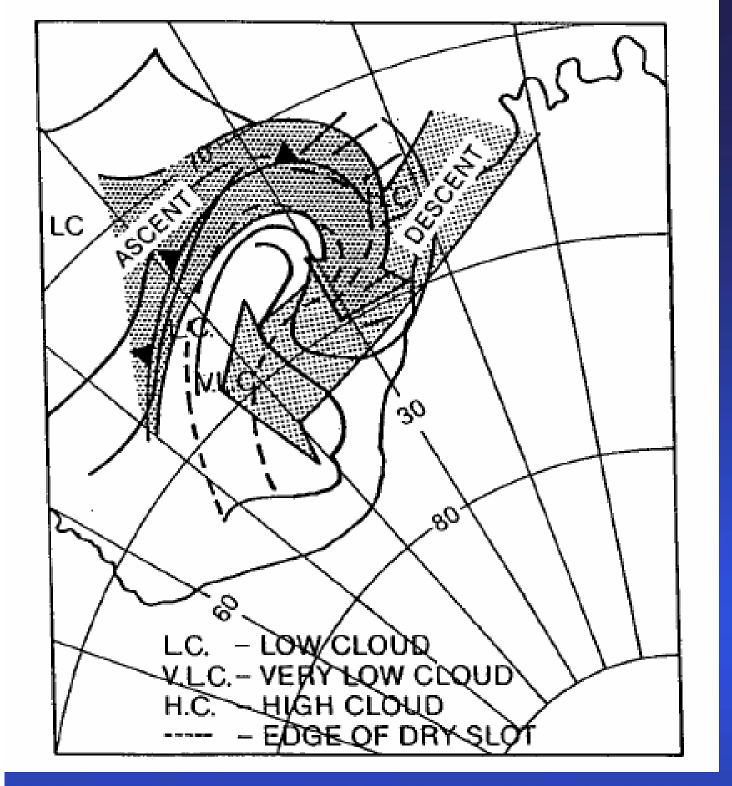

A Cold Core Vortex Polar Low
Over the Labrador Sea

5. Comma clouds

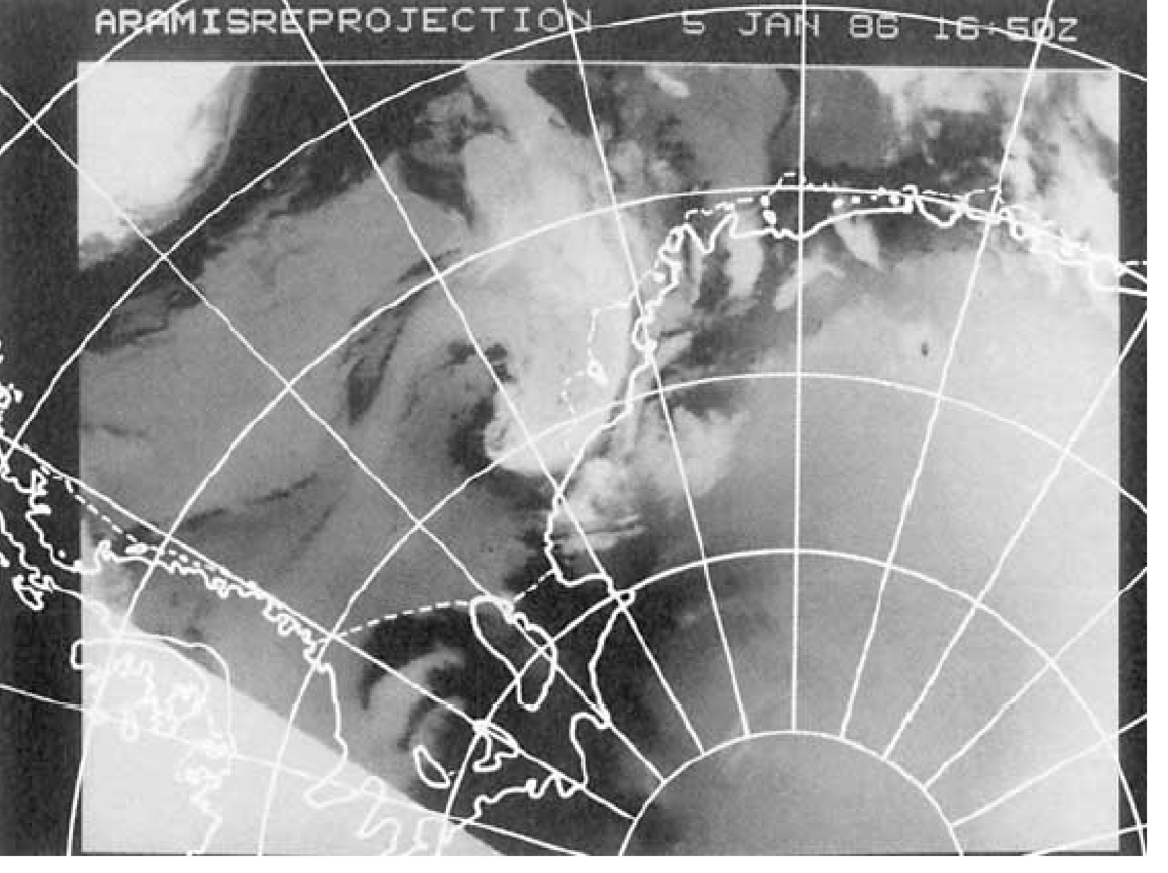
These systems often form at much more southerly latitudes close to the polar front. They can often develop in more baroclinic regions in the cold air to the west of synoptic-scale lows.



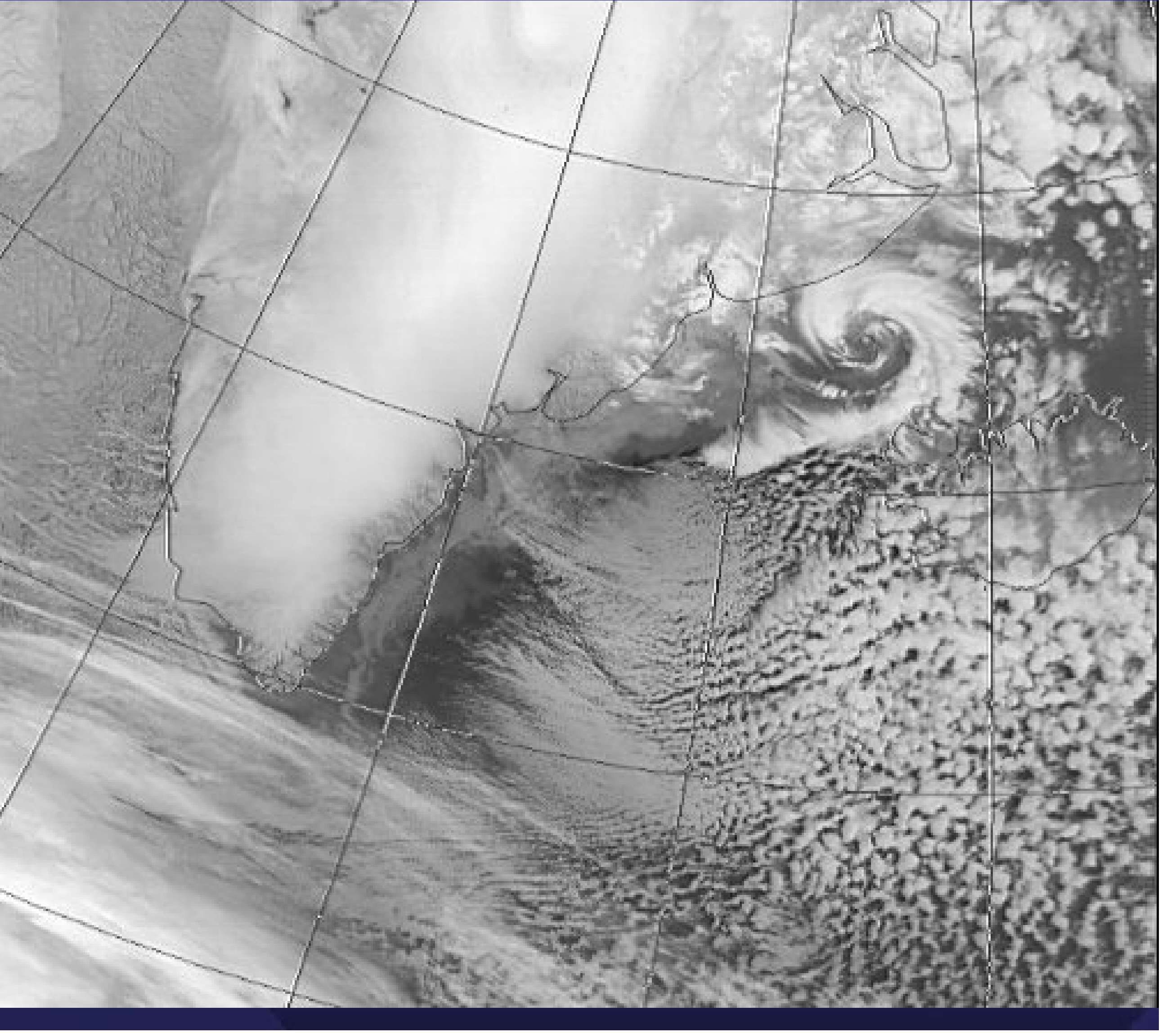
6. Baroclinic Waves



A baroclinic polar low that developed on a strong thermal gradient over the eastern Weddell Sea.



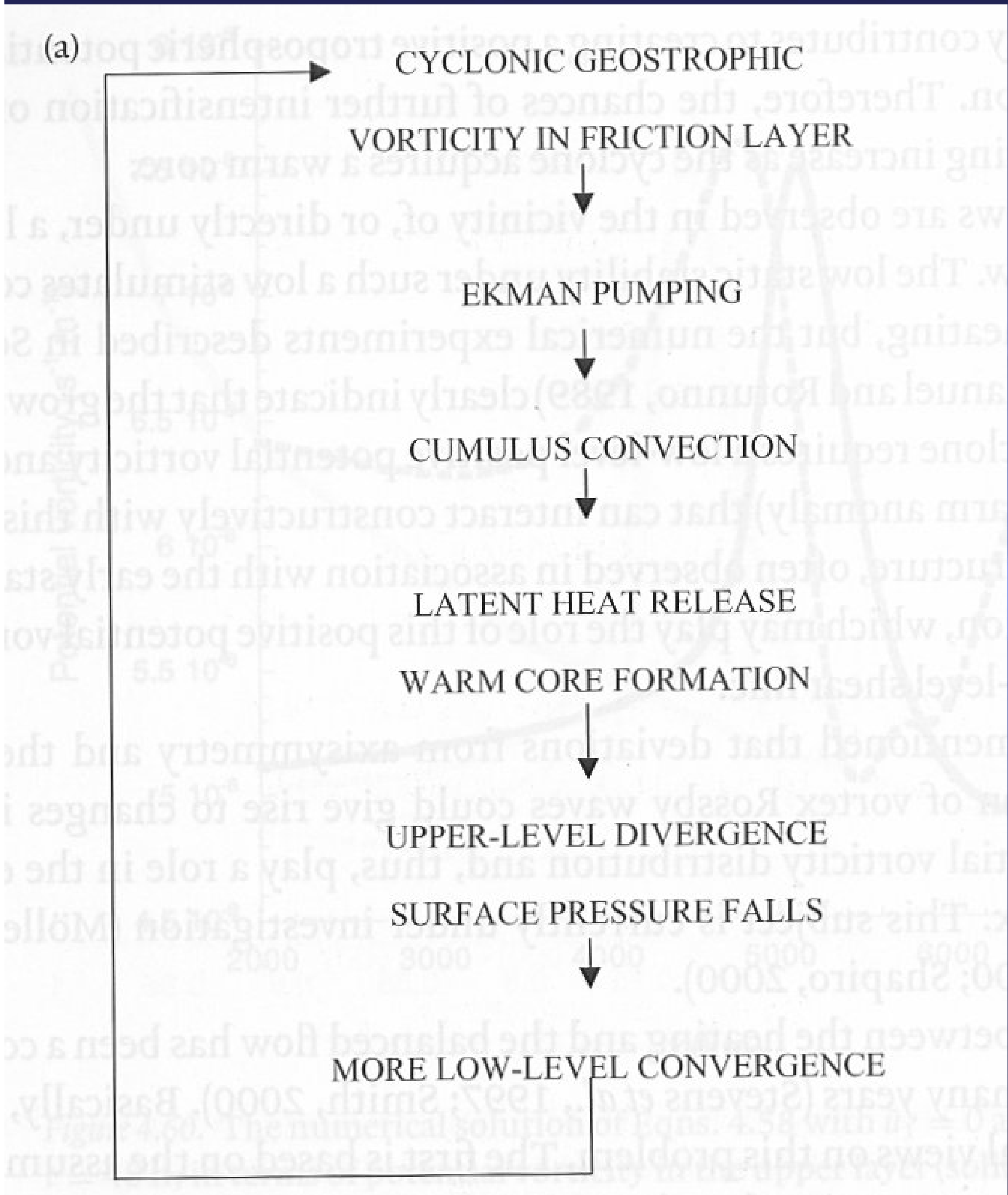
7. Orographic Polar Lows

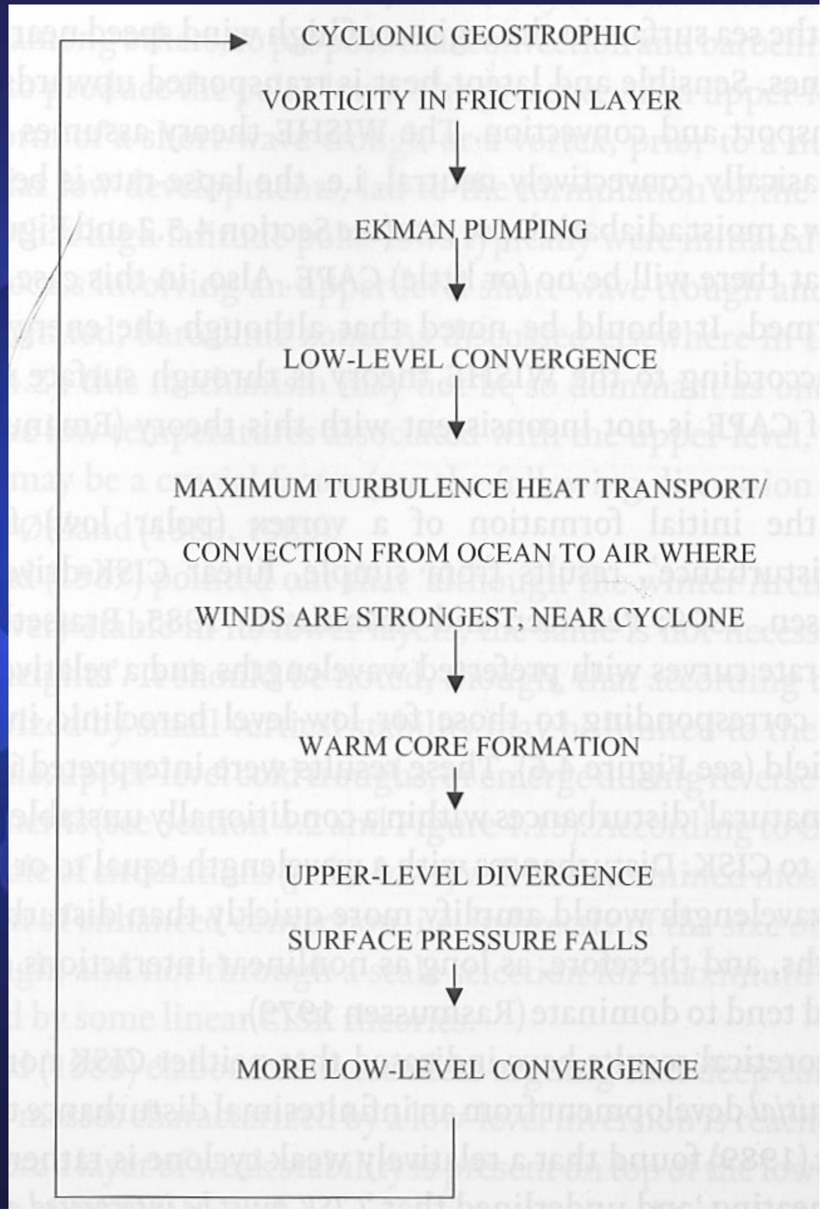


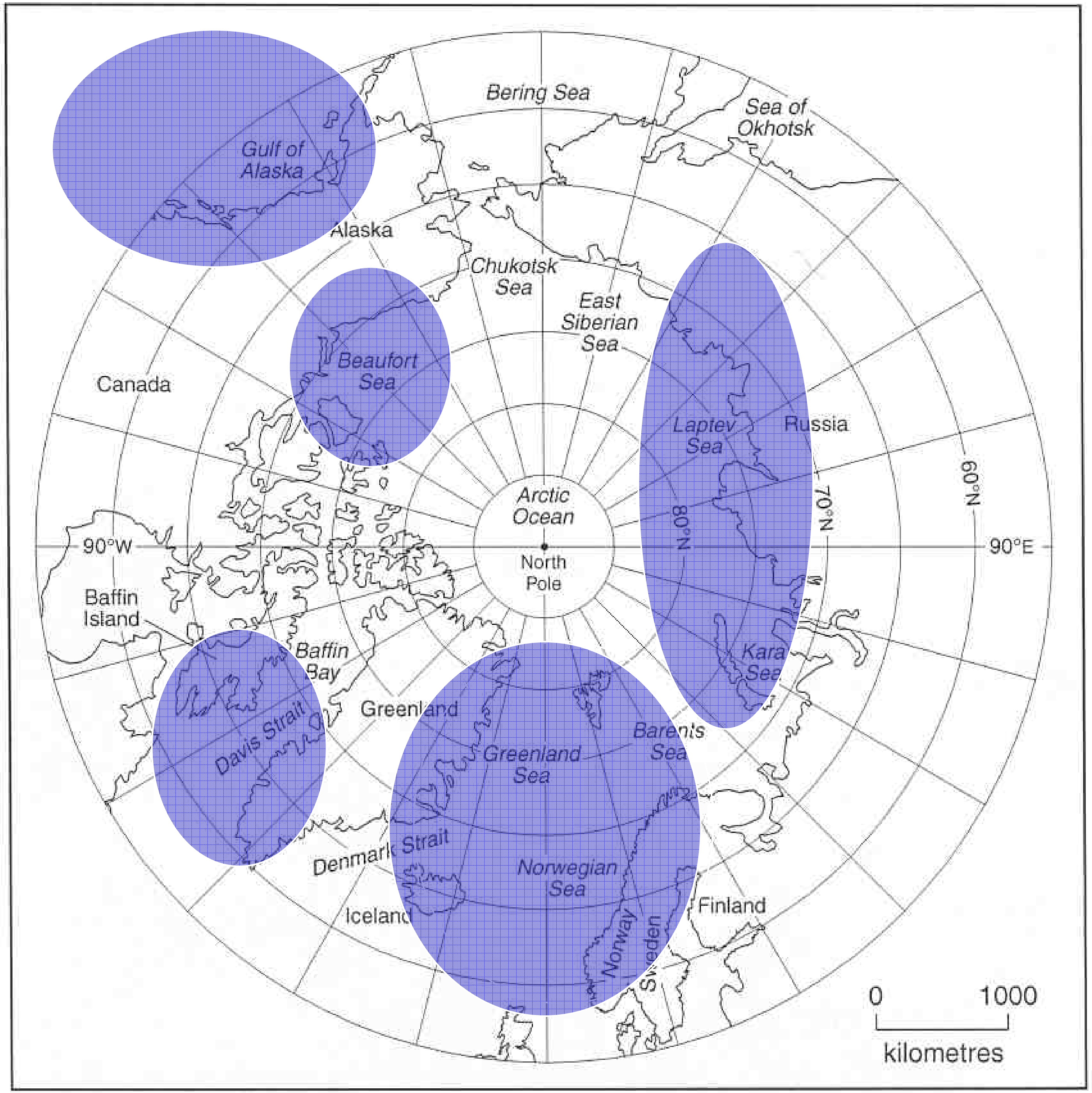
A baroclinic polar low that developed on a strong thermal gradient over the eastern Weddell Sea.

CISK

WISHE

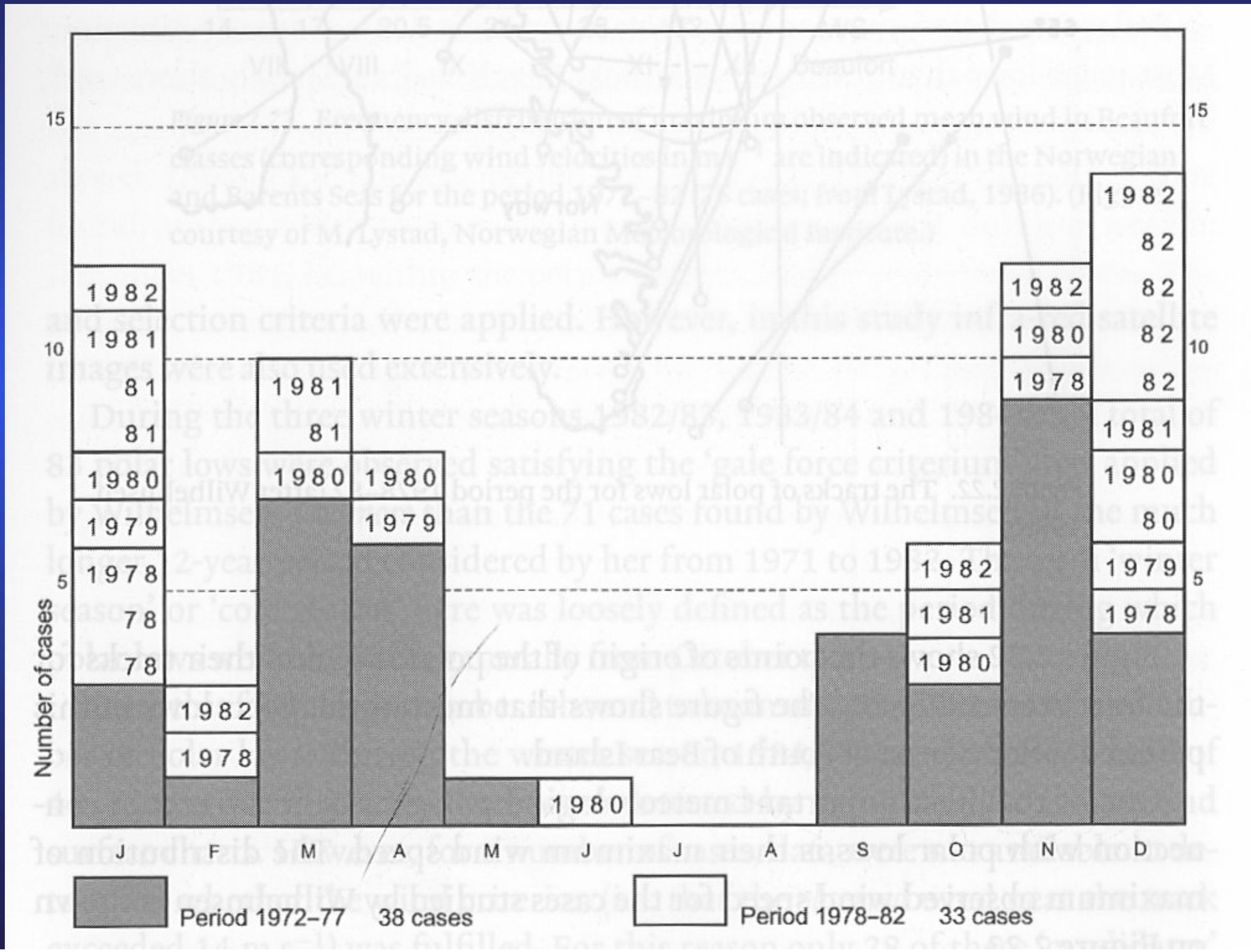

(a)
CYCLONIC GEOSTROPHIC
VORTICITY IN FRICTION LAYER
EKMAN PUMPING
CUMULUS CONVECTION
LATENT HEAT RELEASE
WARM CORE FORMATION
UPPER-LEVEL DIVERGENCE
SURFACE PRESSURE FALLS
MORE LOW-LEVEL CONVERGENCE


CYCLONIC GEOSTROPHIC
VORTICITY IN FRICTION LAYER
EKMAN PUMPING
LOW-LEVEL CONVERGENCE
MAXIMUM TURBULENCE HEAT TRANSPORT/
CONVECTION FROM OCEAN TO AIR WHERE
WINDS ARE STRONGEST, NEAR CYCLONE
WARM CORE FORMATION
UPPER-LEVEL DIVERGENCE
SURFACE PRESSURE FALLS
MORE LOW-LEVEL CONVERGENCE

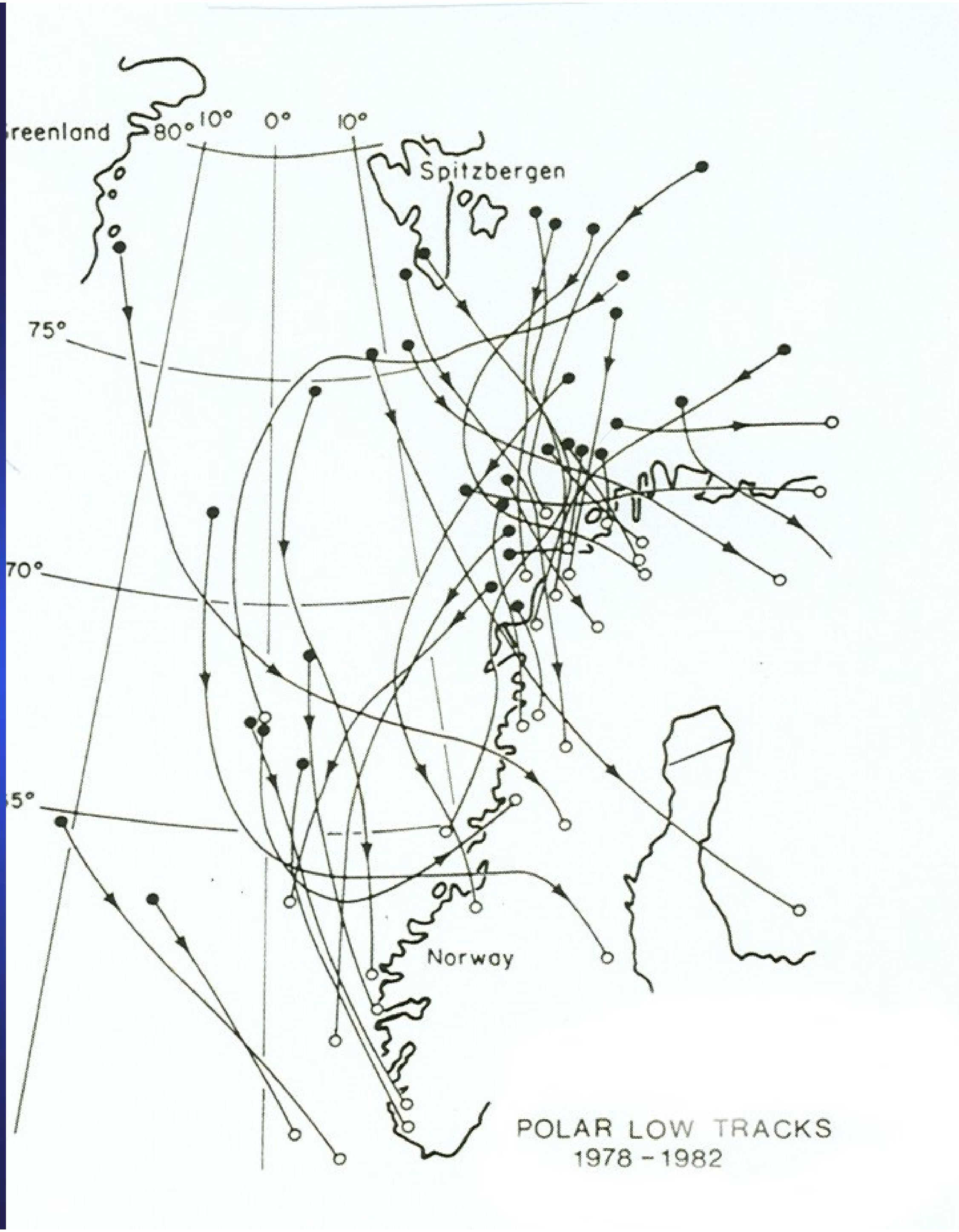


Bering Sea
Sea of Okhotsk
Gulf of Alaska
Alaska
Chukotsk Sea
East Siberian Sea
Canada
Beaufort Sea
Laptev Sea
Russia
Arctic Ocean
North Pole
90°W
90°E
80°N
70°N
60°N
Baffin Island
Baffin Bay
Kara Sea
Greenland
Davis Strait
Greenland Sea
Barents Sea
Denmark Strait
Norwegian Sea
Iceland
Finland
Norway
Sweden
0
1000
kilometres

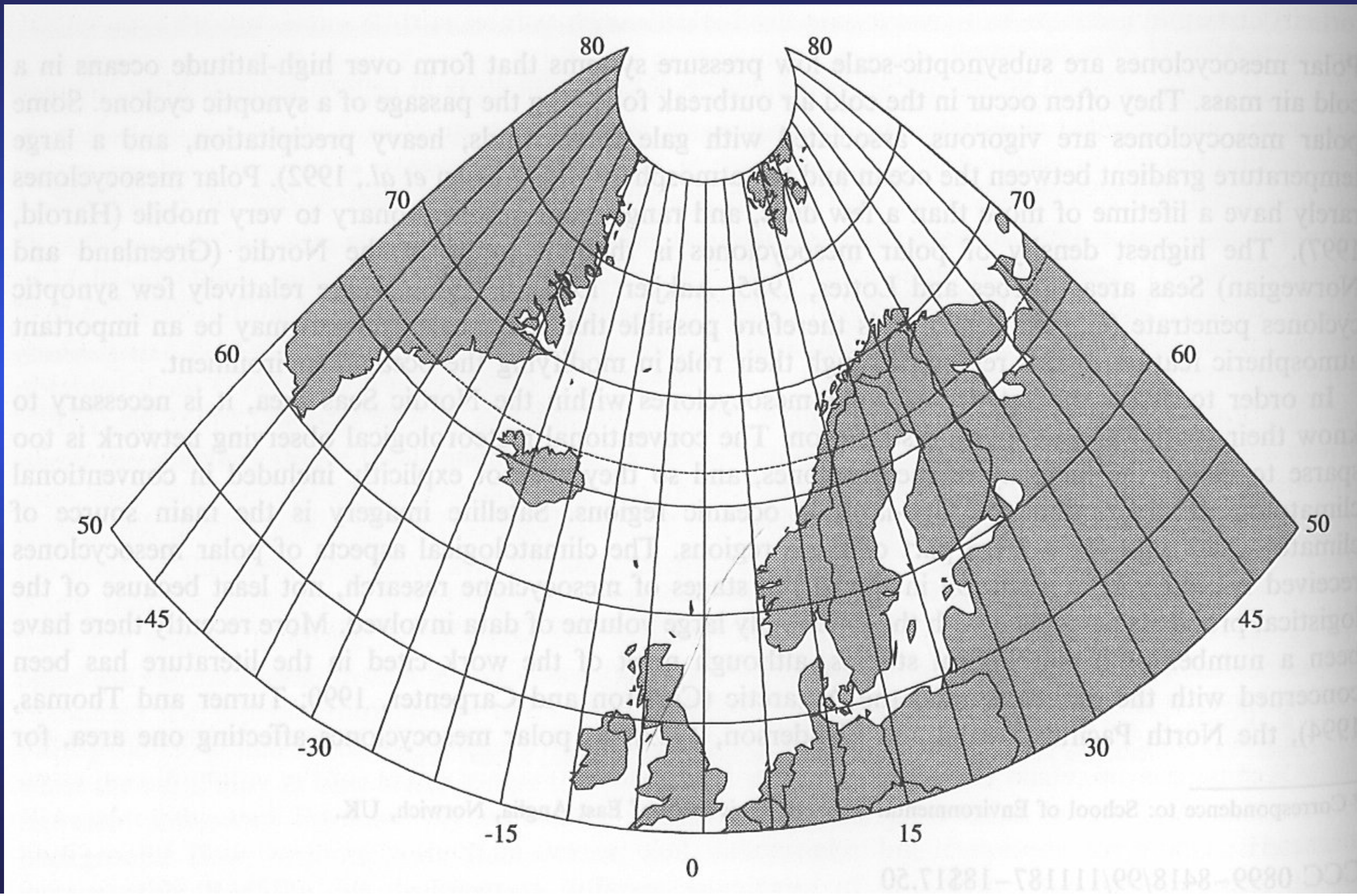
The Seasonal Distribution of Polar Lows in the Norwegian Sea



Polar low tracks over the Norwegian and Barents Seas 1978 -82

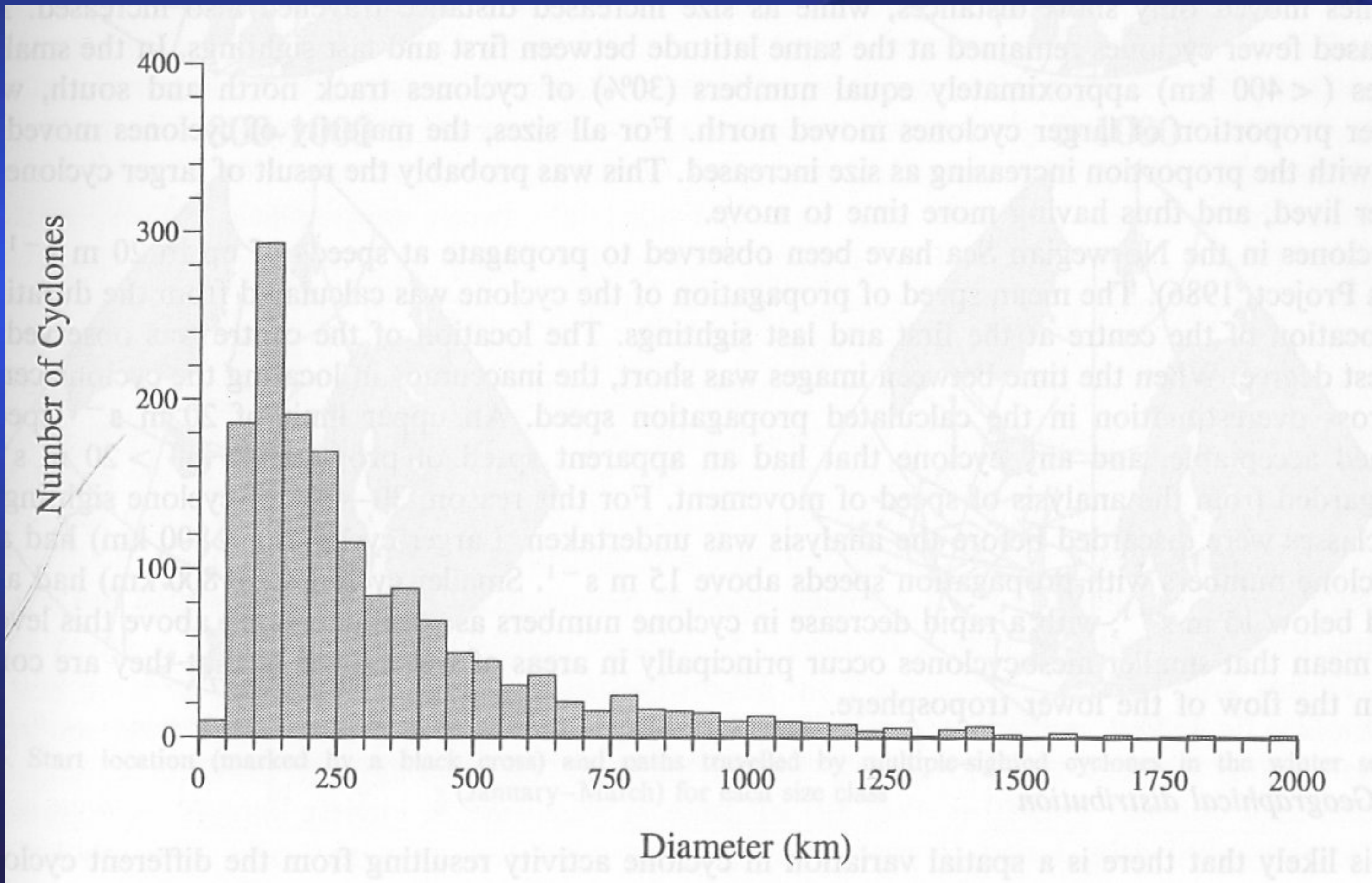


The Harold Study Based on AVHRR Imagery

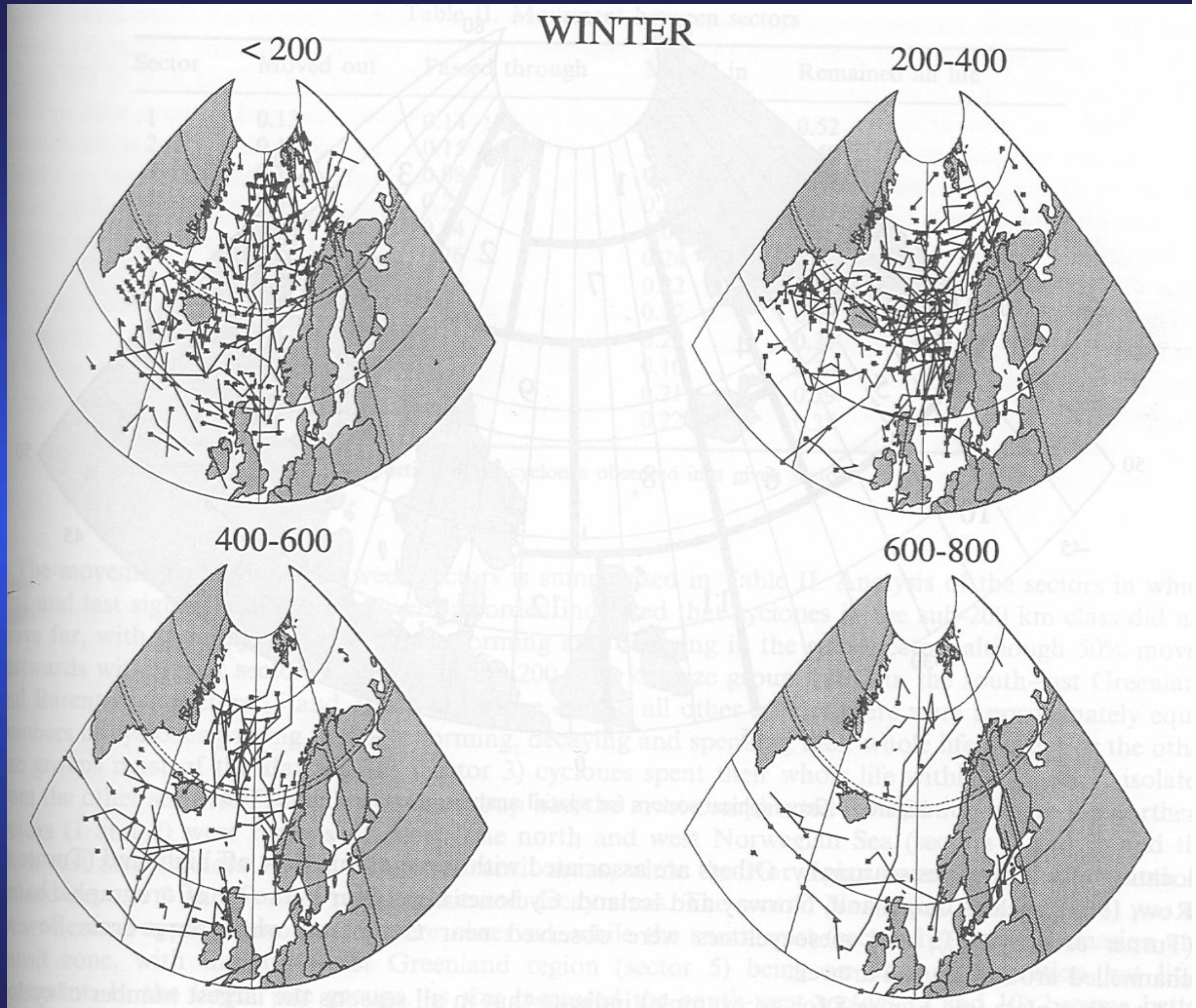


Two years of imagery were analysed and 4054 vortices identified!

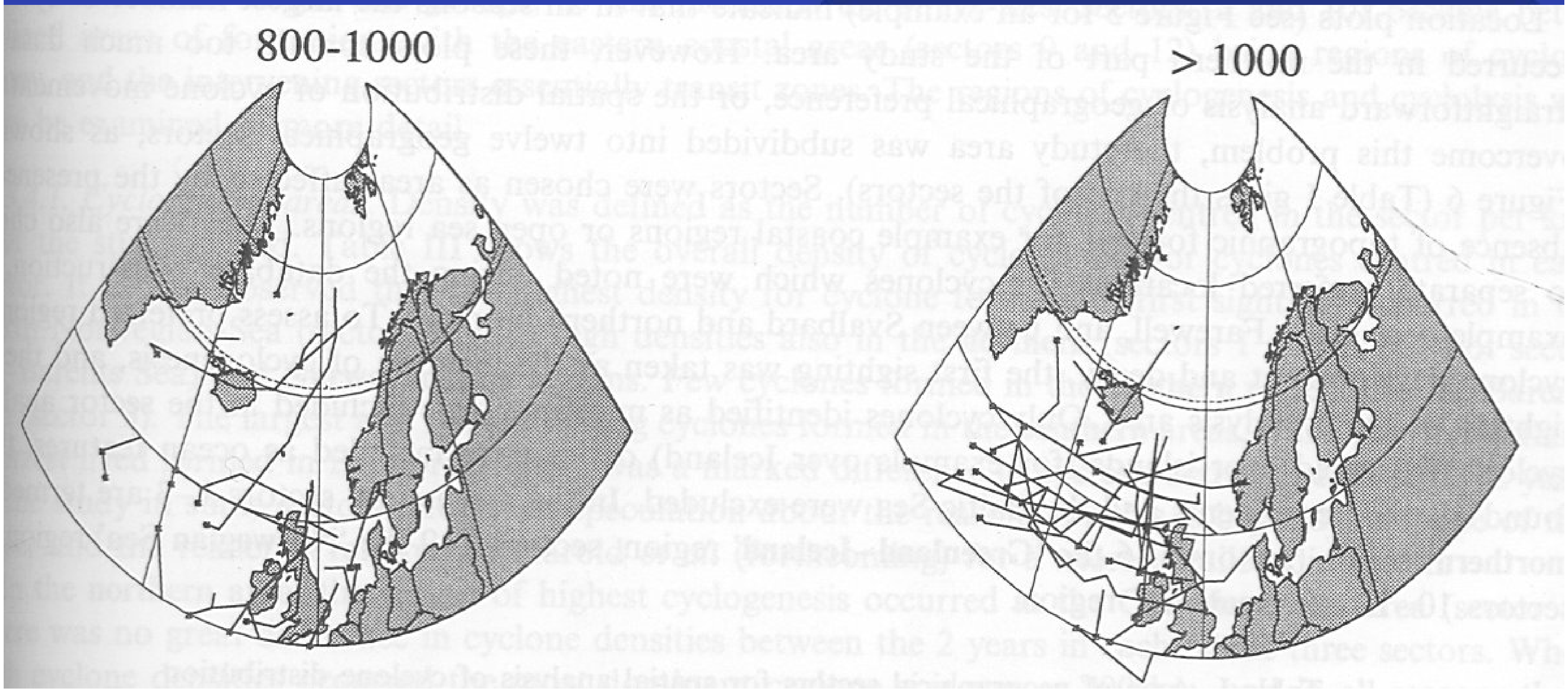
This figure shows the number of systems identified by diameter.



The tracks of systems in four diameter ranges

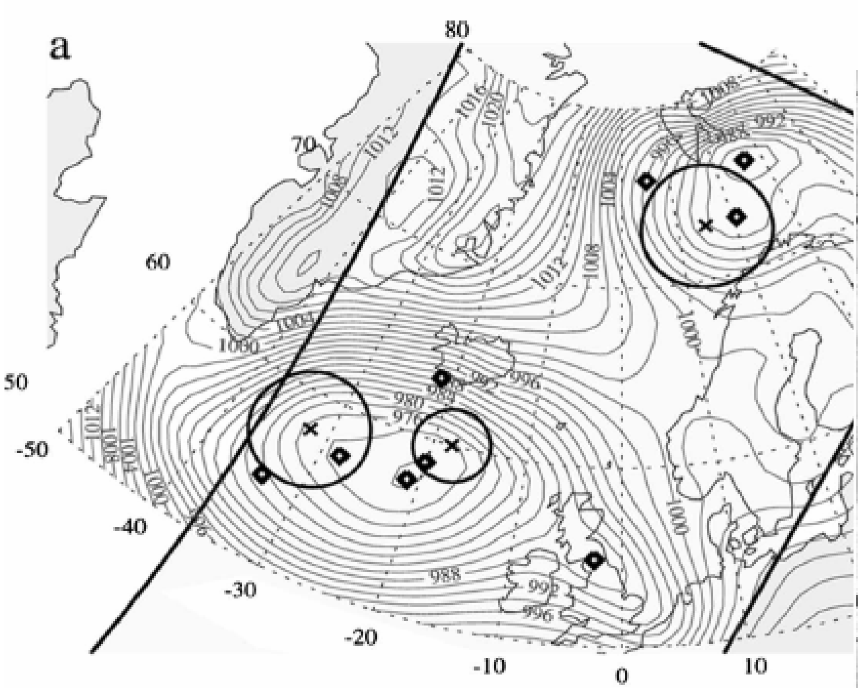


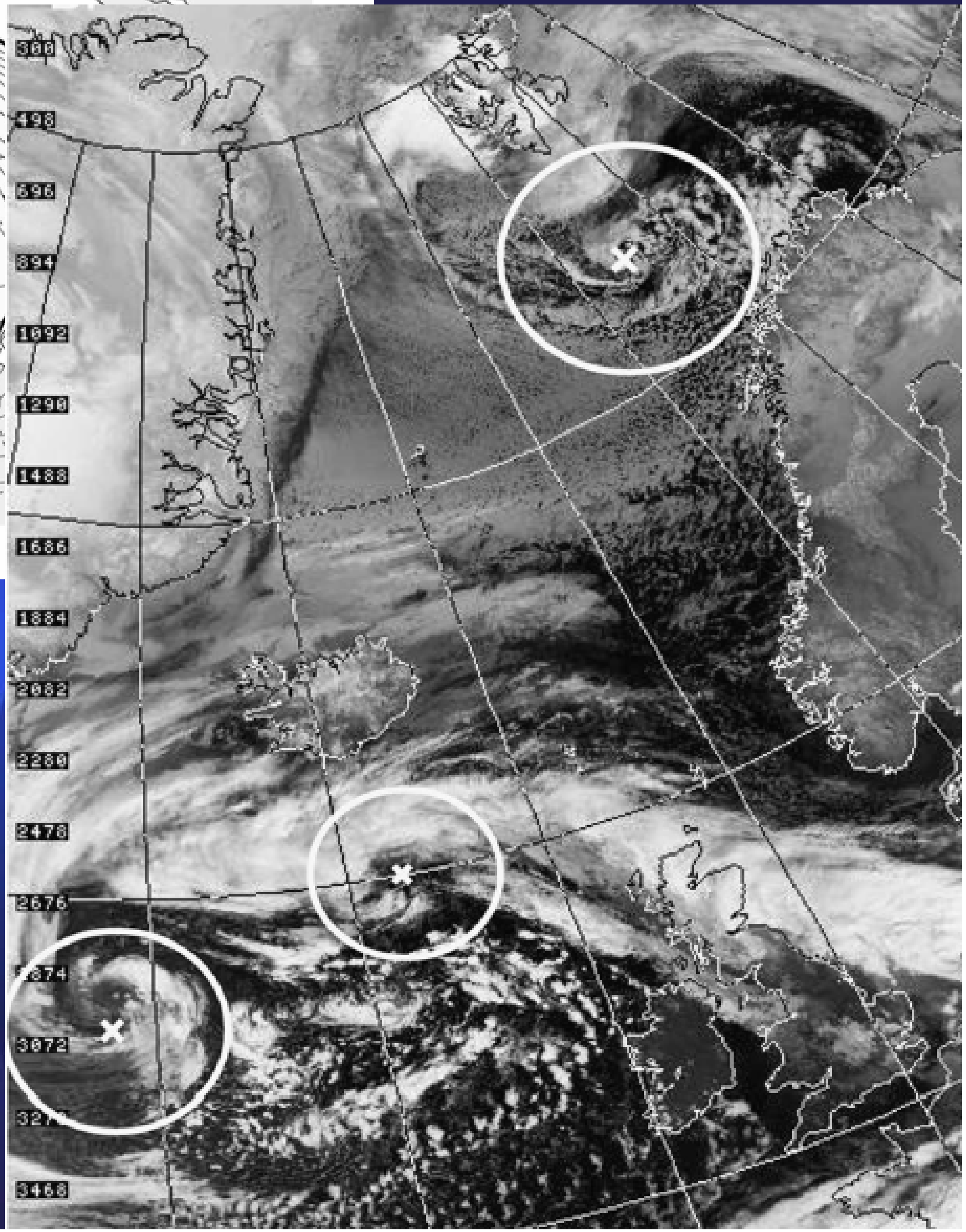
Larger vortices in the Harold study



The Condron and Bigg Study

1. Investigated mesoscale lows in the ERA-40 re-analysis
2. Used the Harold data base as ‘truth’
3. Automatically detected vortices using PMSL and 500 hPa height
4. Oct 1993 – Sep 1995





Automatic detection of polar lows in ERA-40

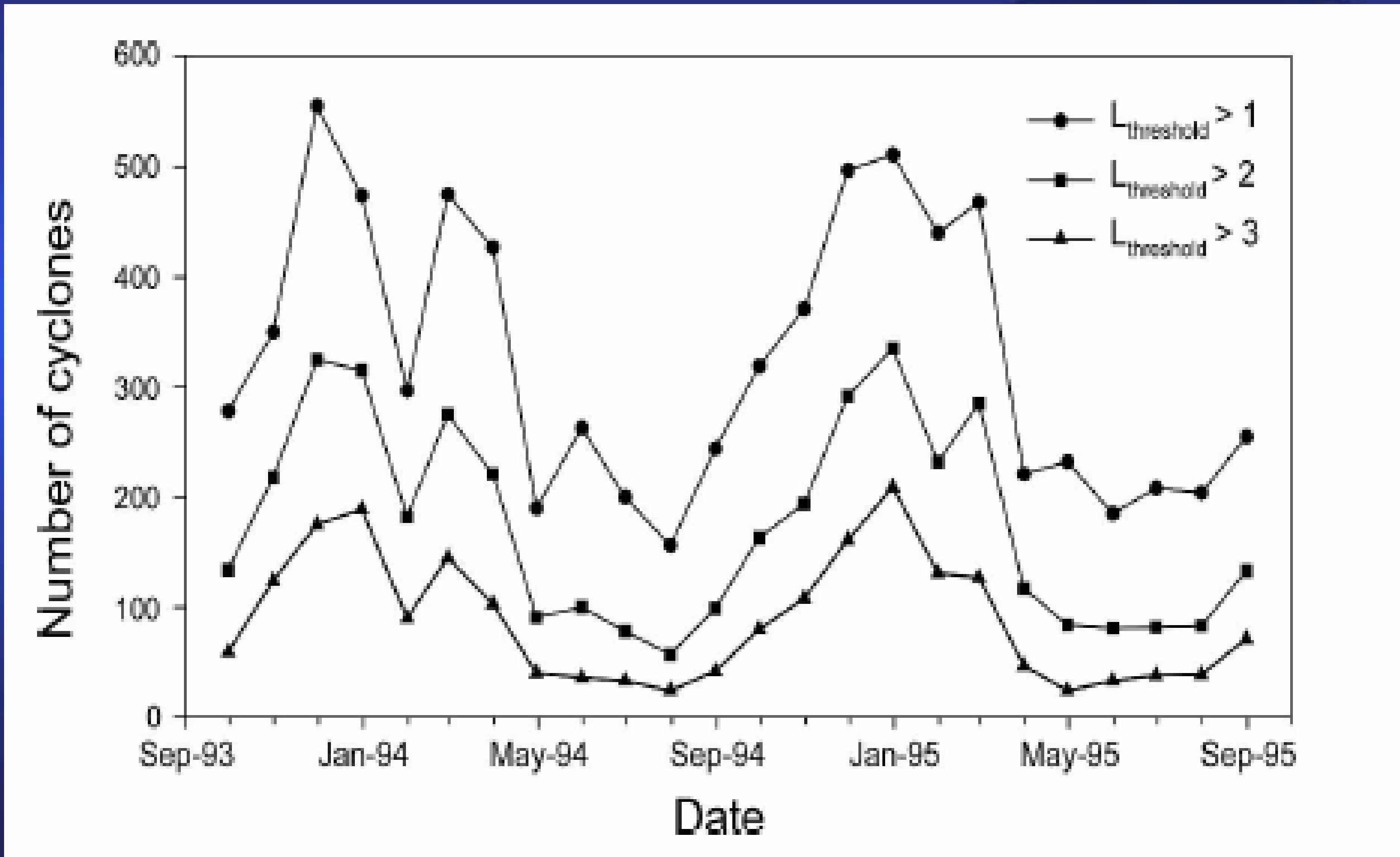
Diamonds – reanalysis (9)

Circles/cross – imagery (3)

The Condron and Bigg Study - Results

1. Up to 80% of cyclones larger than 500 km are detected in the MSLP field
2. This falls to 40% for 250 km vortices
3. Only 20% were detected for 100 km scale systems

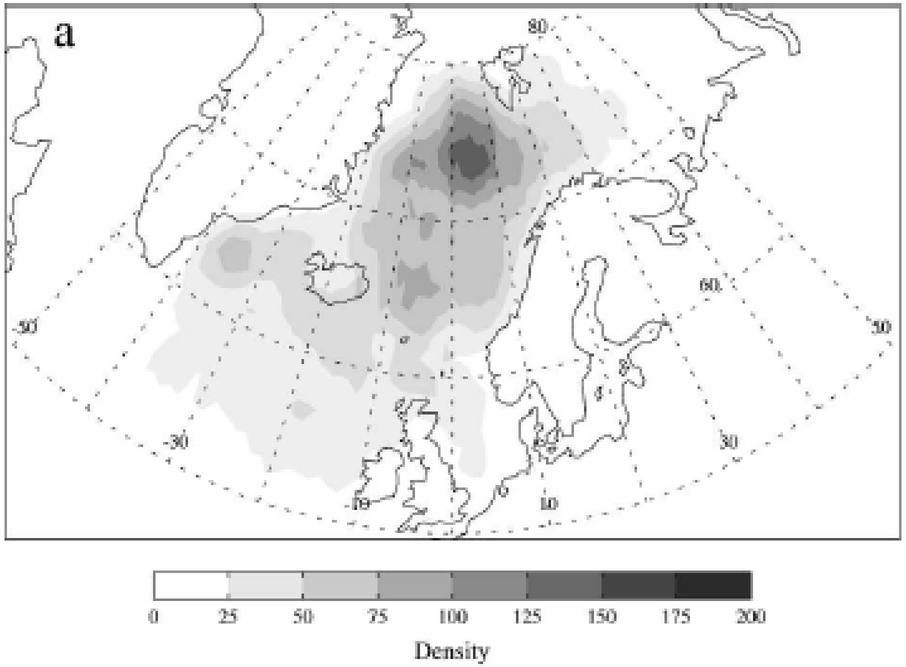
The Monthly Number of Vortices Found in ERA-40

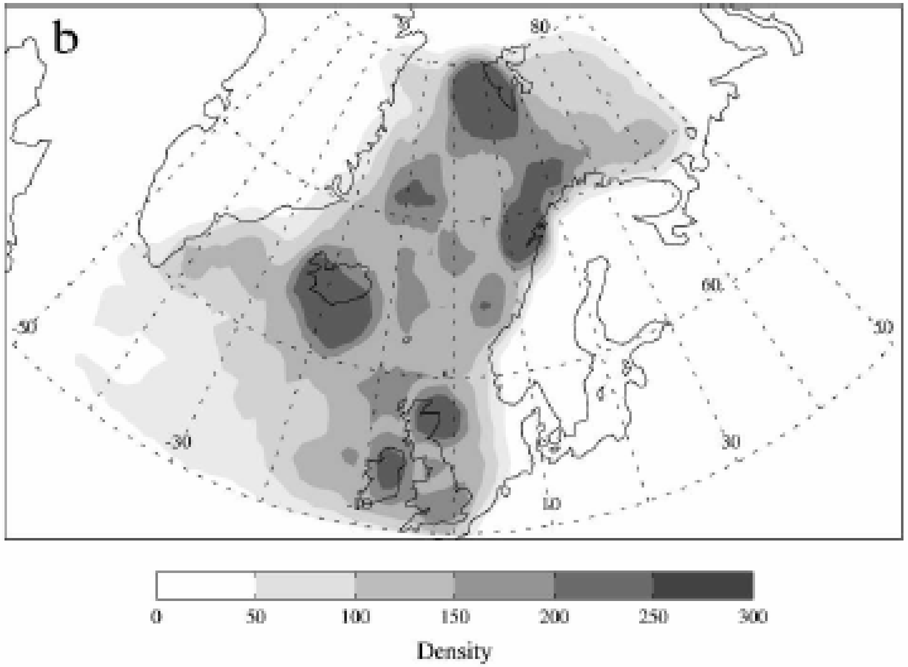


Cyclone Density

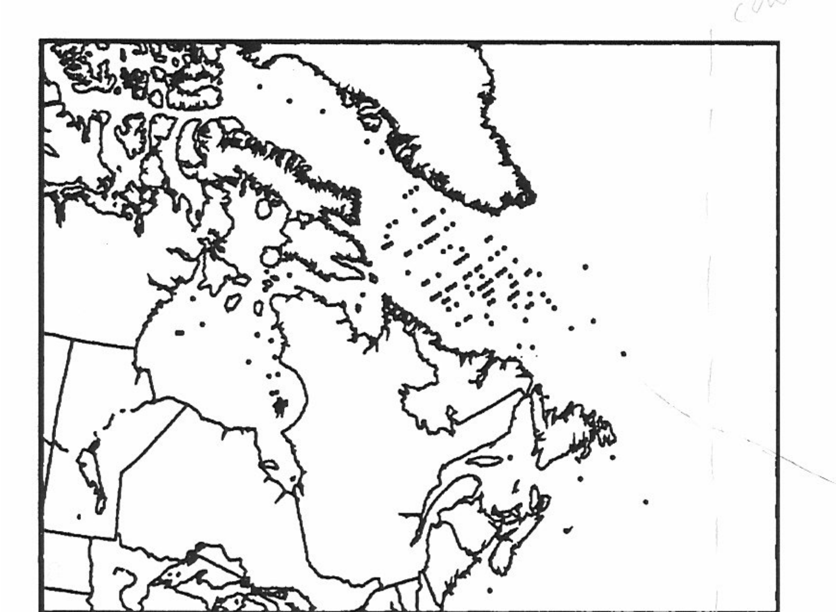
From Imagery

From ERA-40



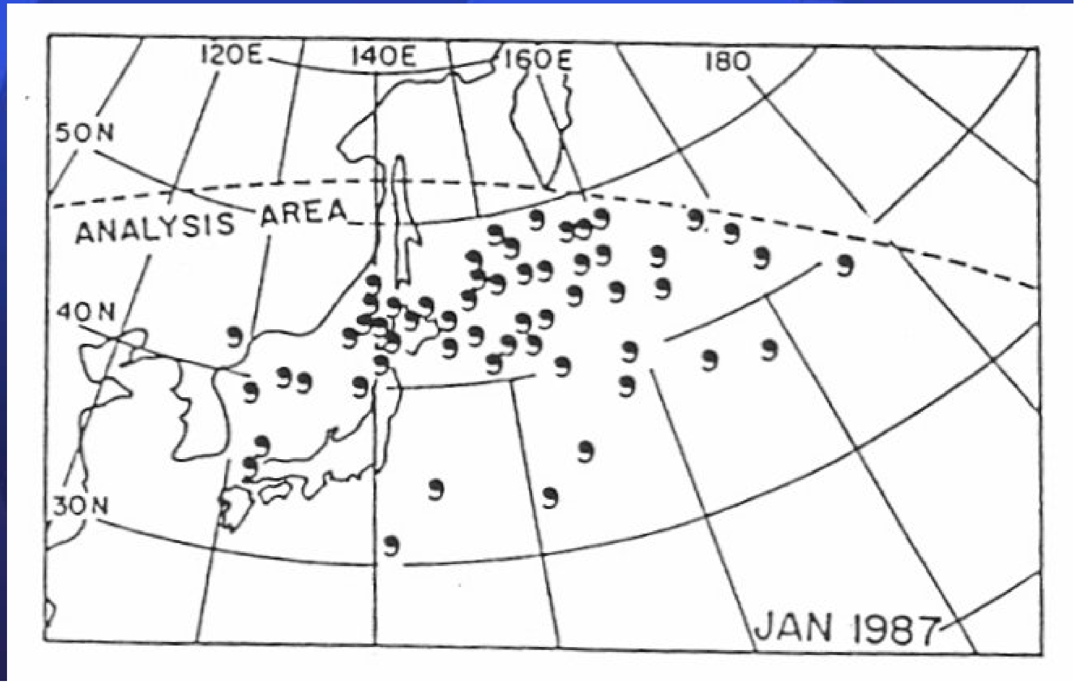


Polar Lows in Other Areas

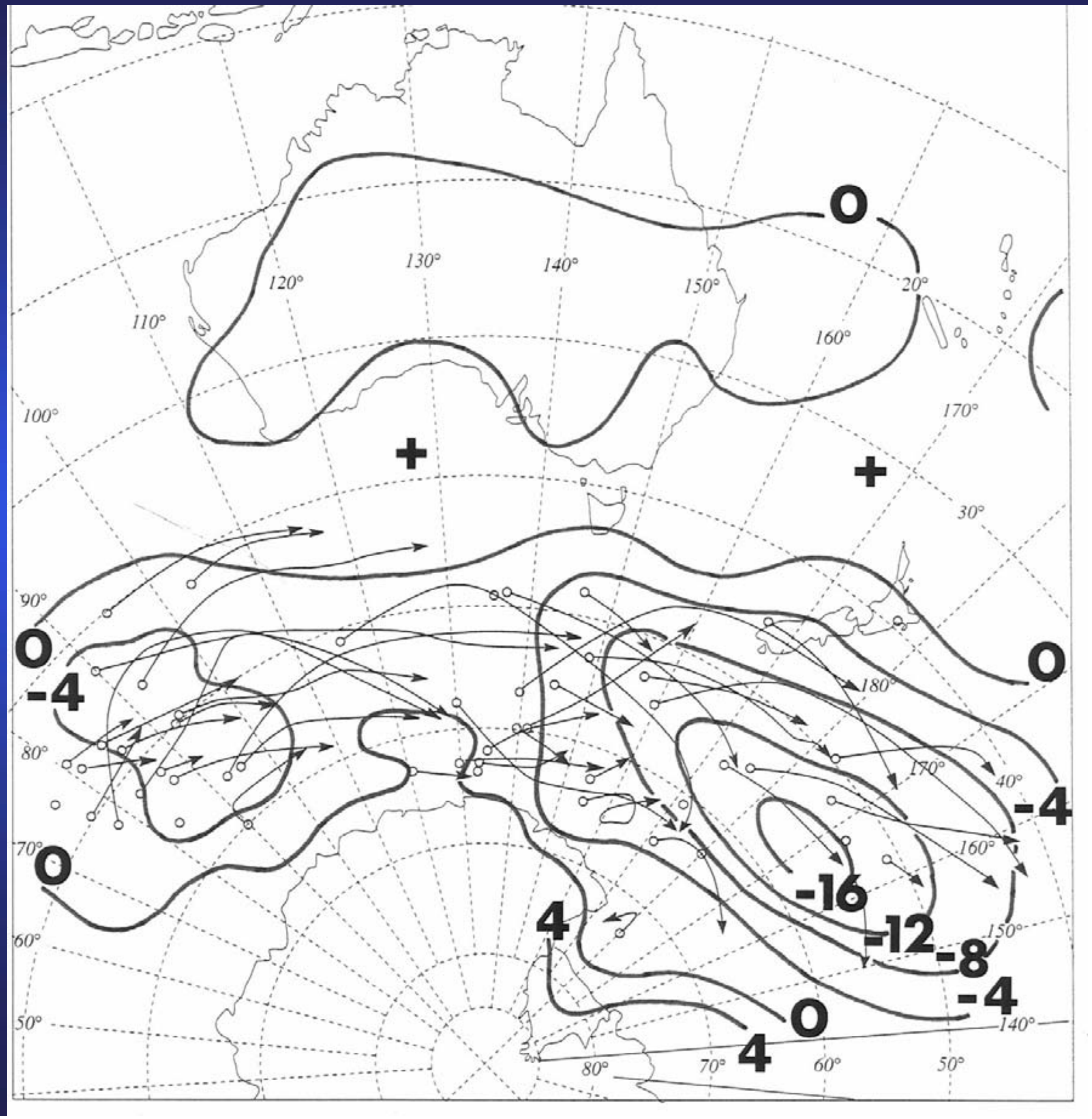


Labrador Sea 1977-93

Japan January 1987



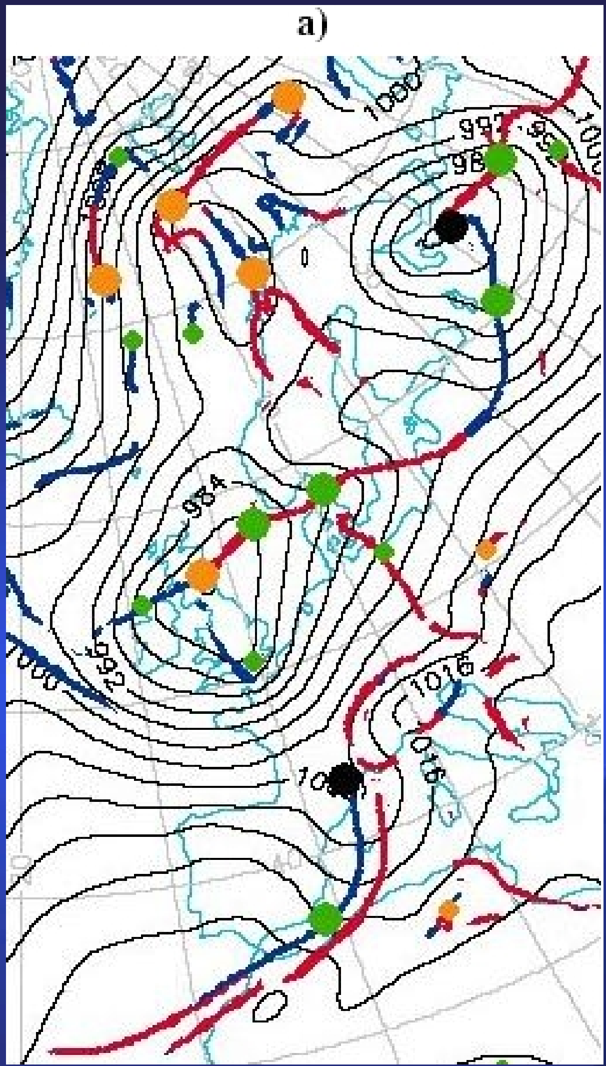
Mesoscale Lows Around the Antarctic

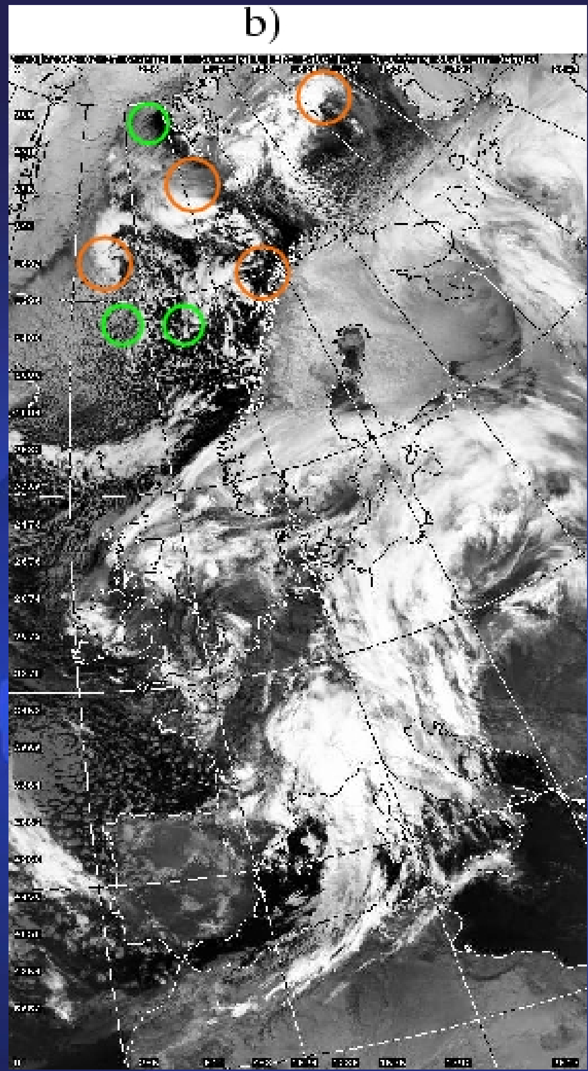


All vortices in March 1992. The contours indicate MSLP anomalies

Use of the UKMO Cyclone Database

- A database of cyclones objectively identified in the Met Office global model. It covers the period from January 2000 to April 2004. Hewson (2001).
- For each cyclone a range of diagnostics and variables are stored.
- Why choose the Cyclone Database to study polar lows?
- High resolution compared to reanalysis datasets.
- Designed to detect many features, including very weak disturbances. Typically 50 at any one time in the North Atlantic / Europe region.

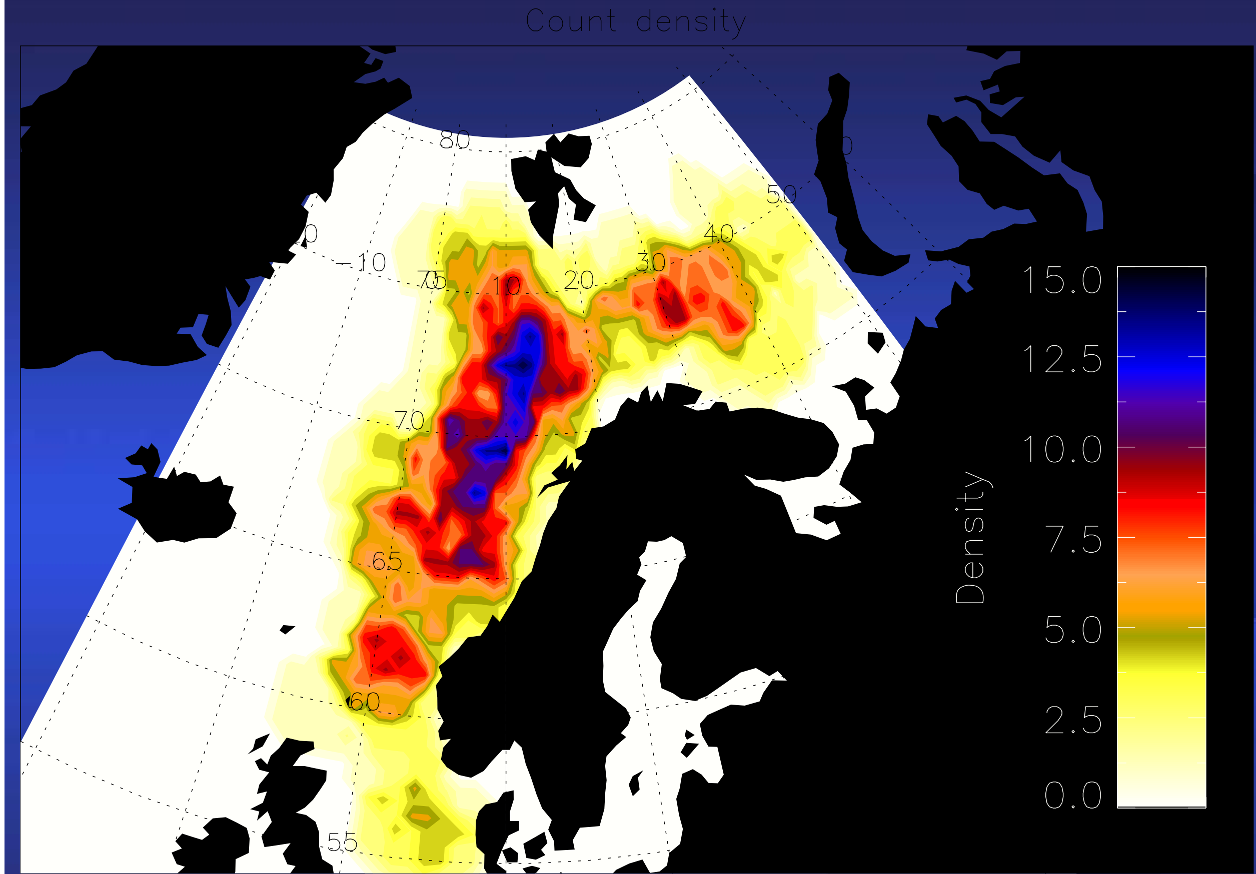




Vortices identified in the UKMO cyclone data base

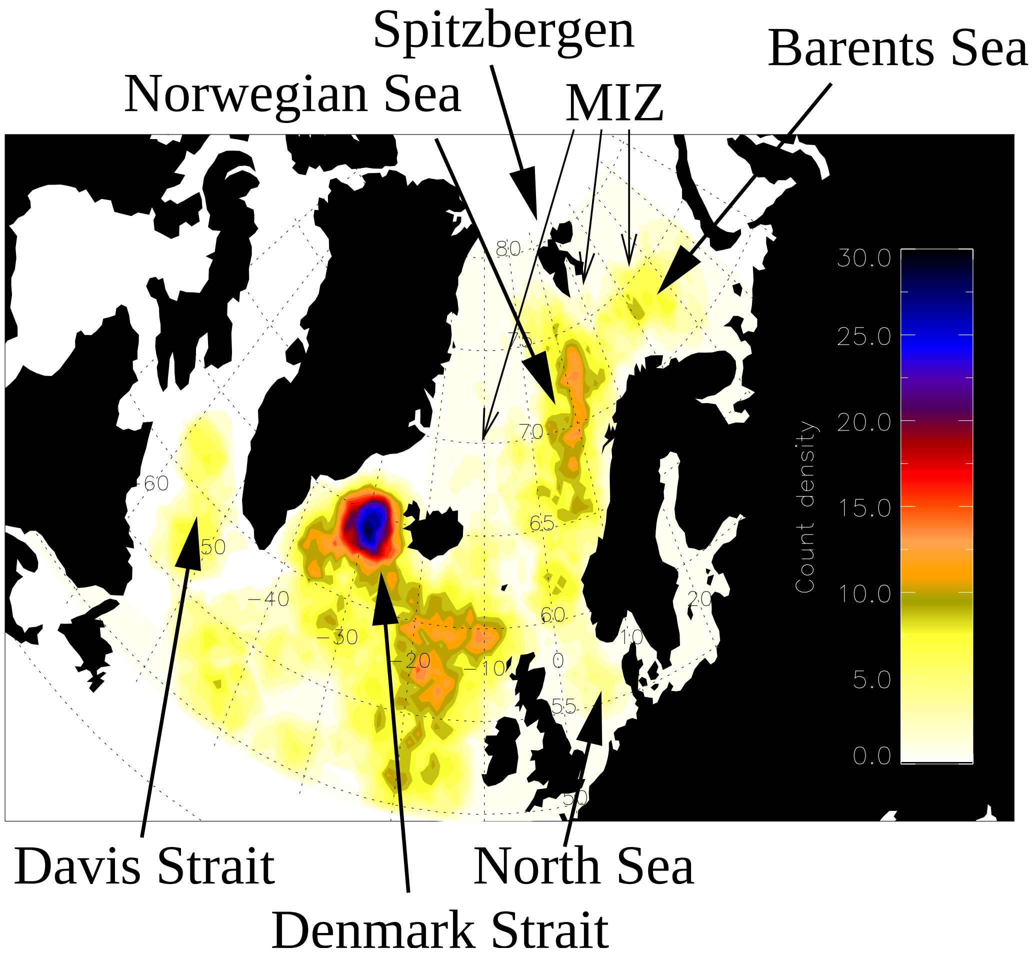
Vortices identified in the AVHRR imagery

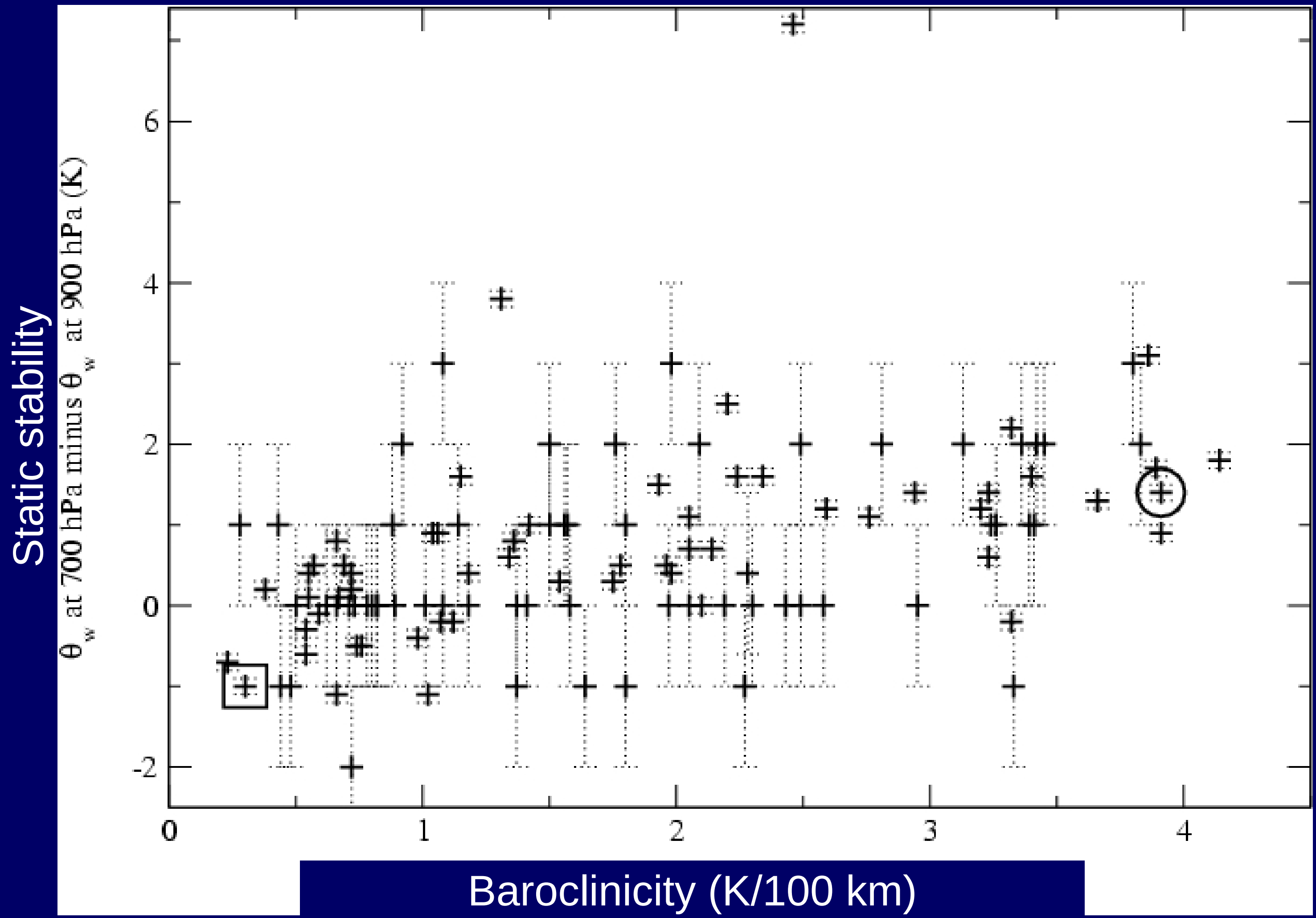
Spatial distribution of polar low activity



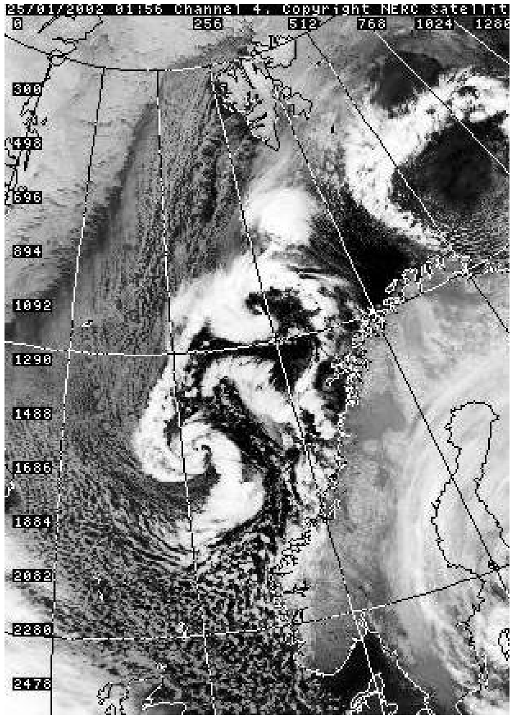
- Polar low **count density** from Jan 2000 to April 2004 calculated for area bins of ~125,000 km2 (200 km radius)

Spatial distribution of polar low activity

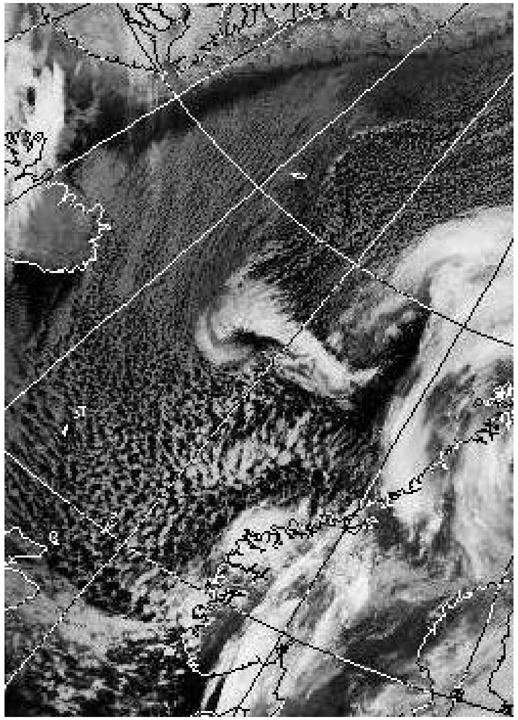



Static stability
θw at 700 hPa minus θw at 900 hPa (K)
6
4
2
0
-2
0
1
2
3
4
Baroclinicity (K/100 km)

Convective (marked by square on previous slide)



Baroclinic (marked by circle on previous slide)



Infrared satellite imagery for (a) 0156 25/1/2002 and (b) 1201 14/12/03. NOAA AVHRR imagery retrieved courtesy of the Dundee Satellite Receiving Station.

Conclusions of the Study

- Showed the potential for using operational analyses for investigating polar lows and other high latitude mesoscale vortices
- Over the 3 months from Dec 2001 100% of the polar lows were represented in the UKMO analyses
- 76% of the polar mesocyclones (i.e. not polar lows) were in the cyclone data base
- Allowed the investigation of the processes involved in polar low development

Forecasting of Polar Lows

- Traditionally based on identification in satellite imagery and then a nowcasting approach
  - Monitoring areas know for frequent polar low development during the polar low season
  - Extra vigilance during cold air outbreaks
  - Monitoring troughs behind synoptic scale lows for developments
  - Frequent monitoring of infra-red imagery
  - Predicting the track with the 700/500 hPa winds

Woetman Nielsen's Case 'P' 13-16 October 1993

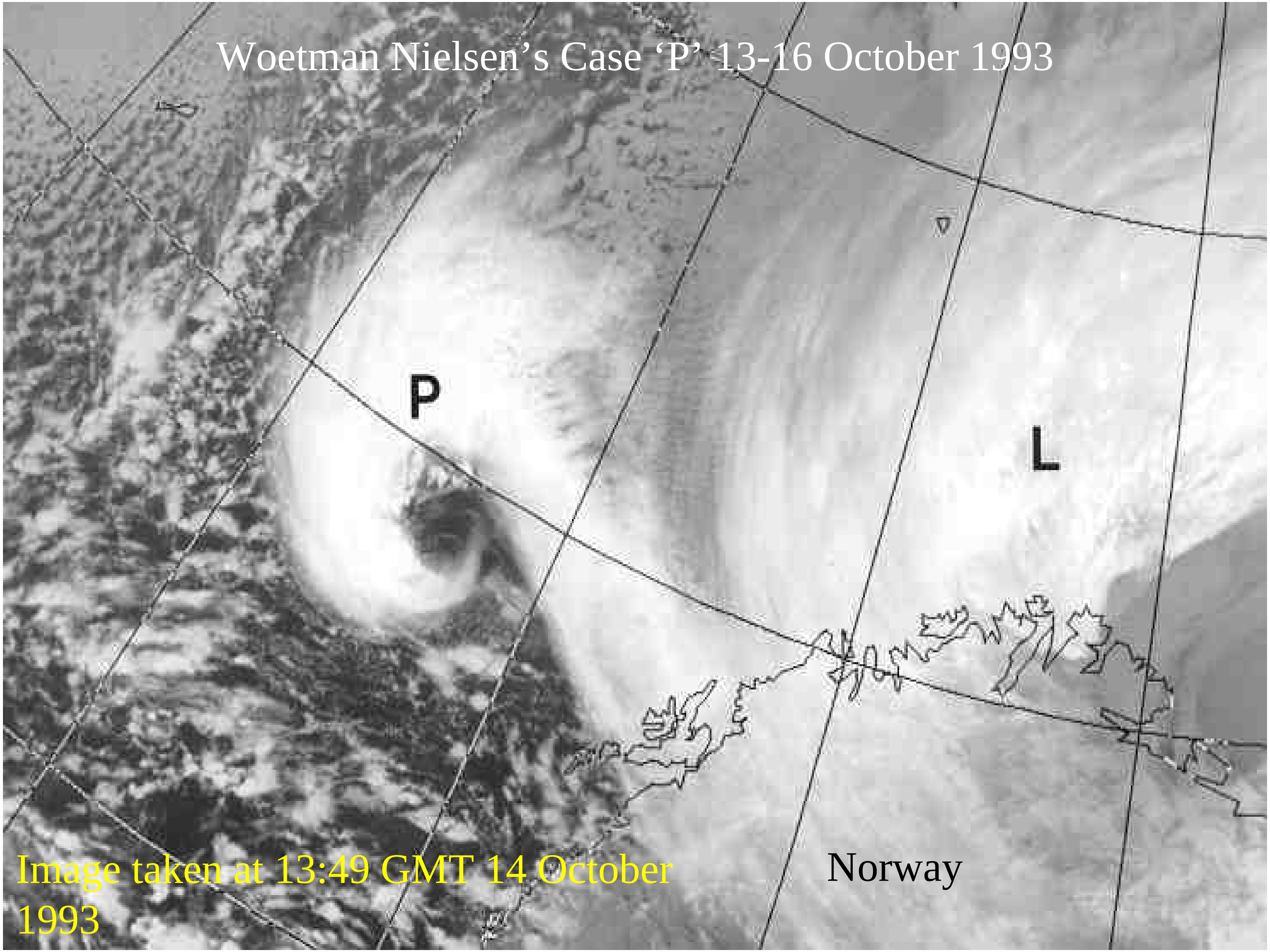
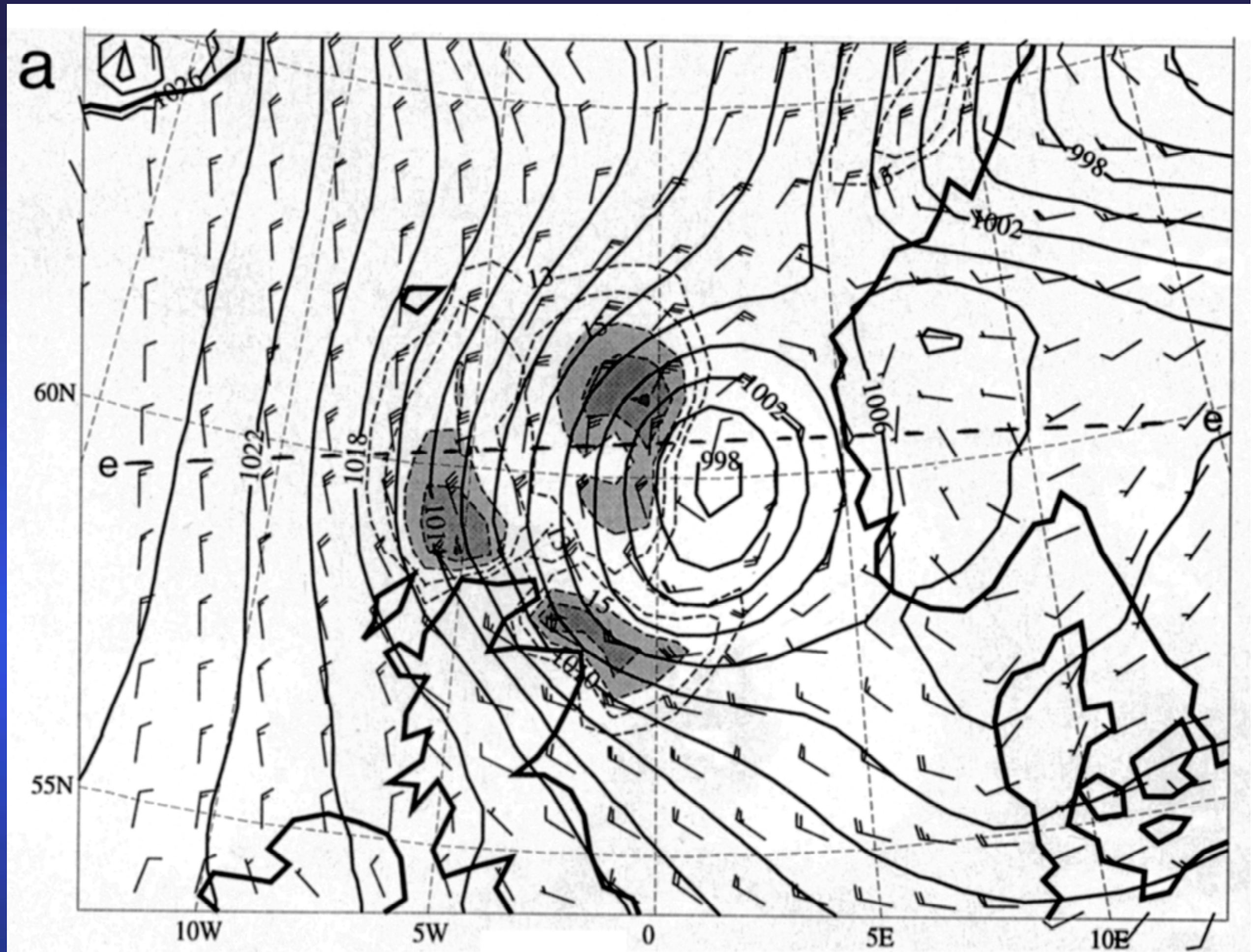


Image taken at 13:49 GMT 14 October 1993

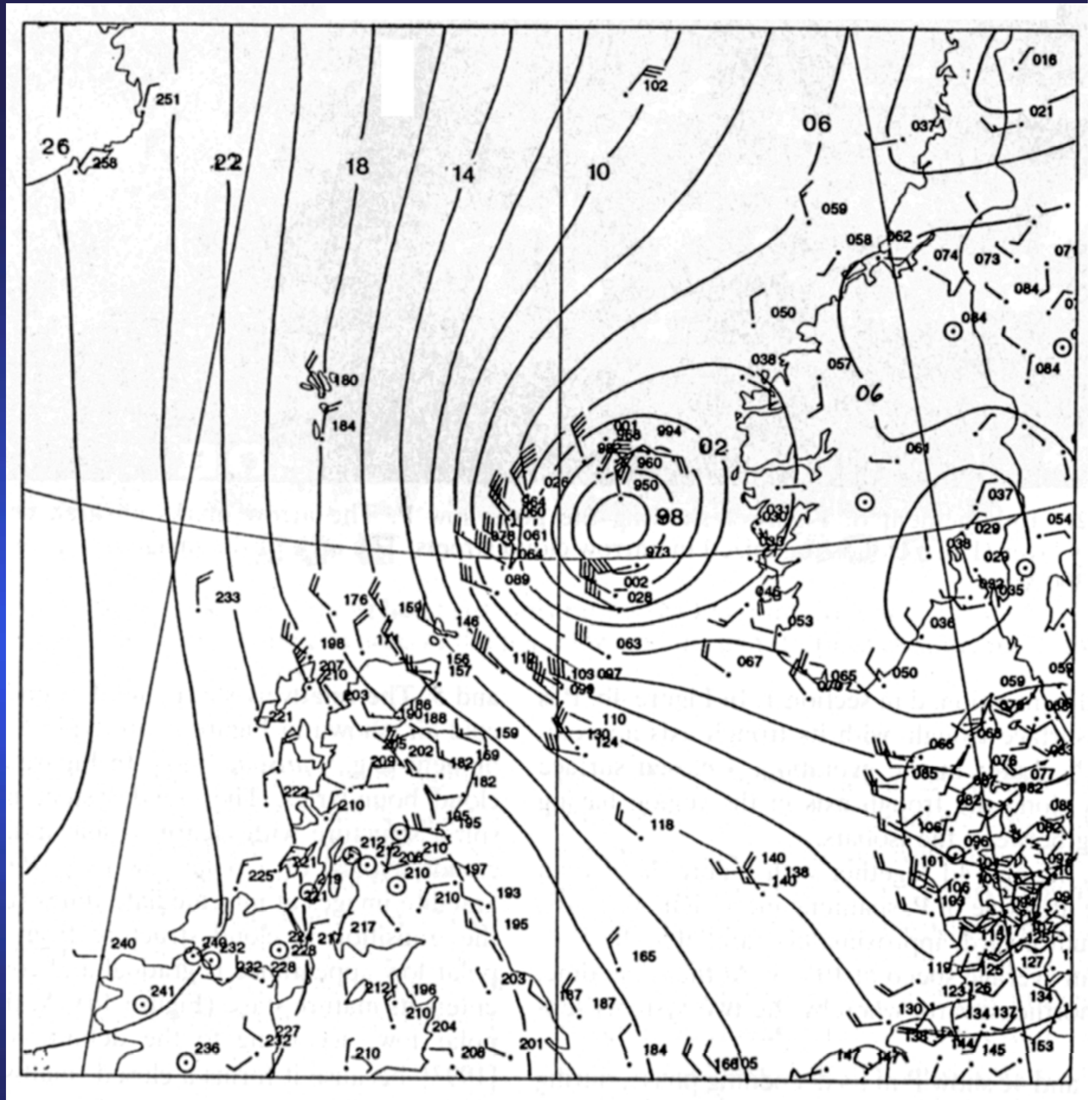
A 48 h forecast of MSLP and 10 m wind vectors using the Danish HIRLAM model.

Data time 00 14 Oct 93

Verifying 00 16 Oct 93



Surface analysis at 00 GMT 16 October 1993



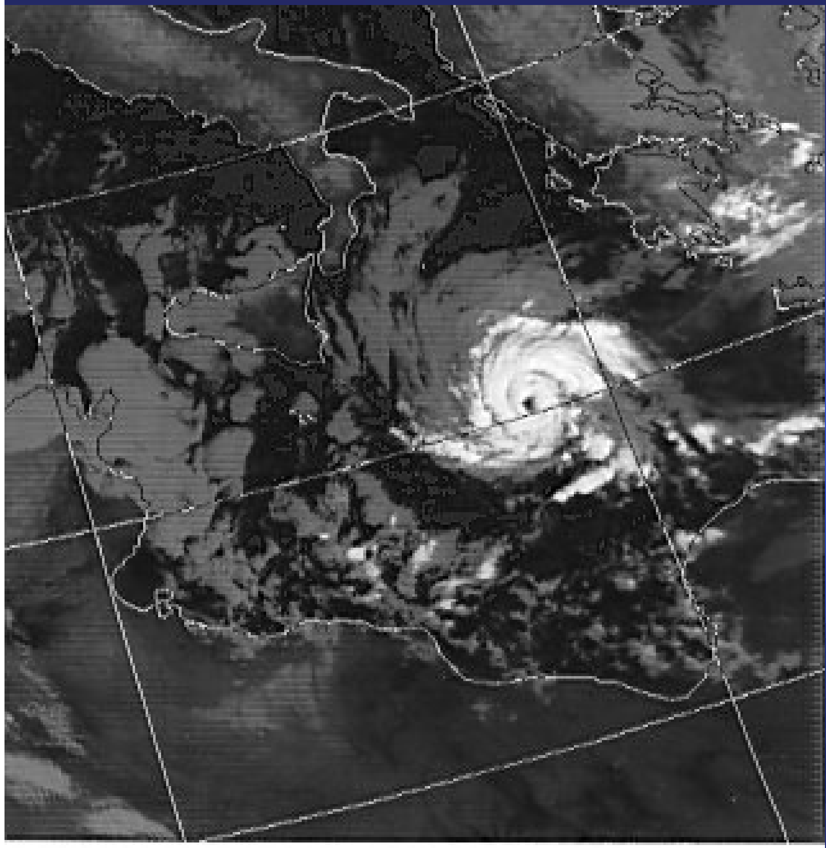
Future Research Needs (1)

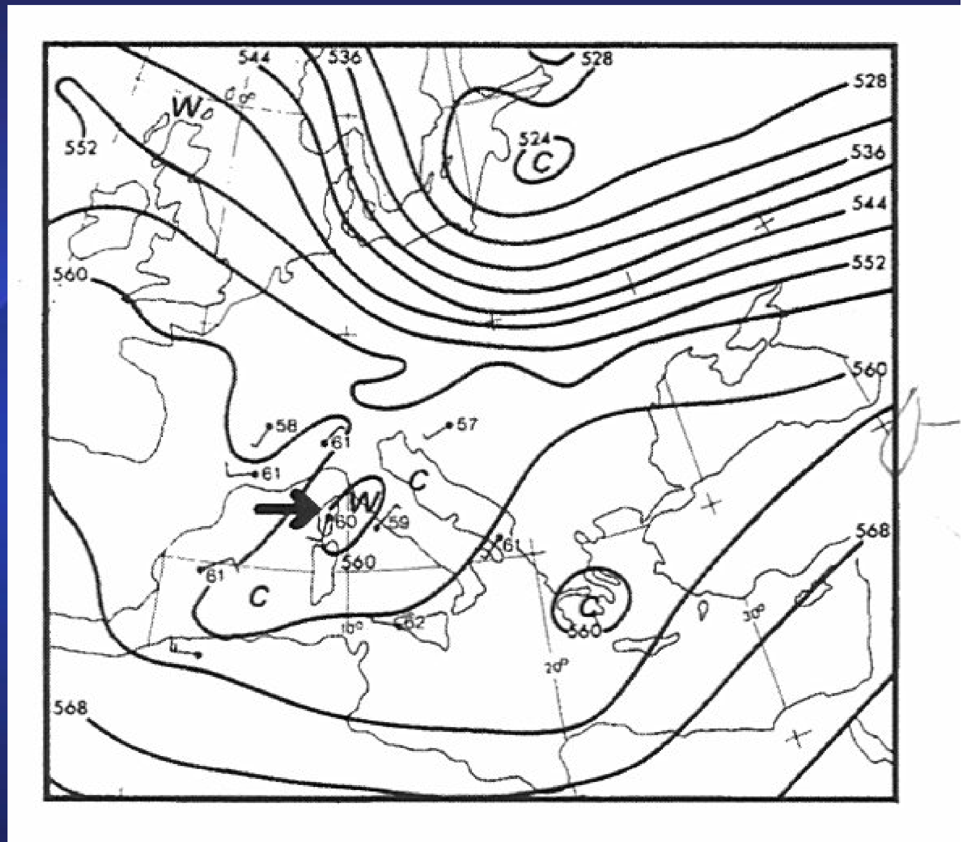
- The fact that modern operational analyses can represent polar lows opens up exciting possibilities
- A bi-polar data base of polar lows could be created
- The variability and trend in polar low occurrence could be investigated
- The Hewson data base of cyclones also contains data on systems in the forecasts – what weight can we put on the forecasts of polar low development?

Future Research Needs

- Still debate over how convection acts to intensify the lows – CISK, WISHE
- The operational analyses can provide insight into the environment of polar low development
- Are polar lows a distinct phenomenon or just part of the family of mesoscale lows?

A ‘Polar Low’ over the Mediterranean

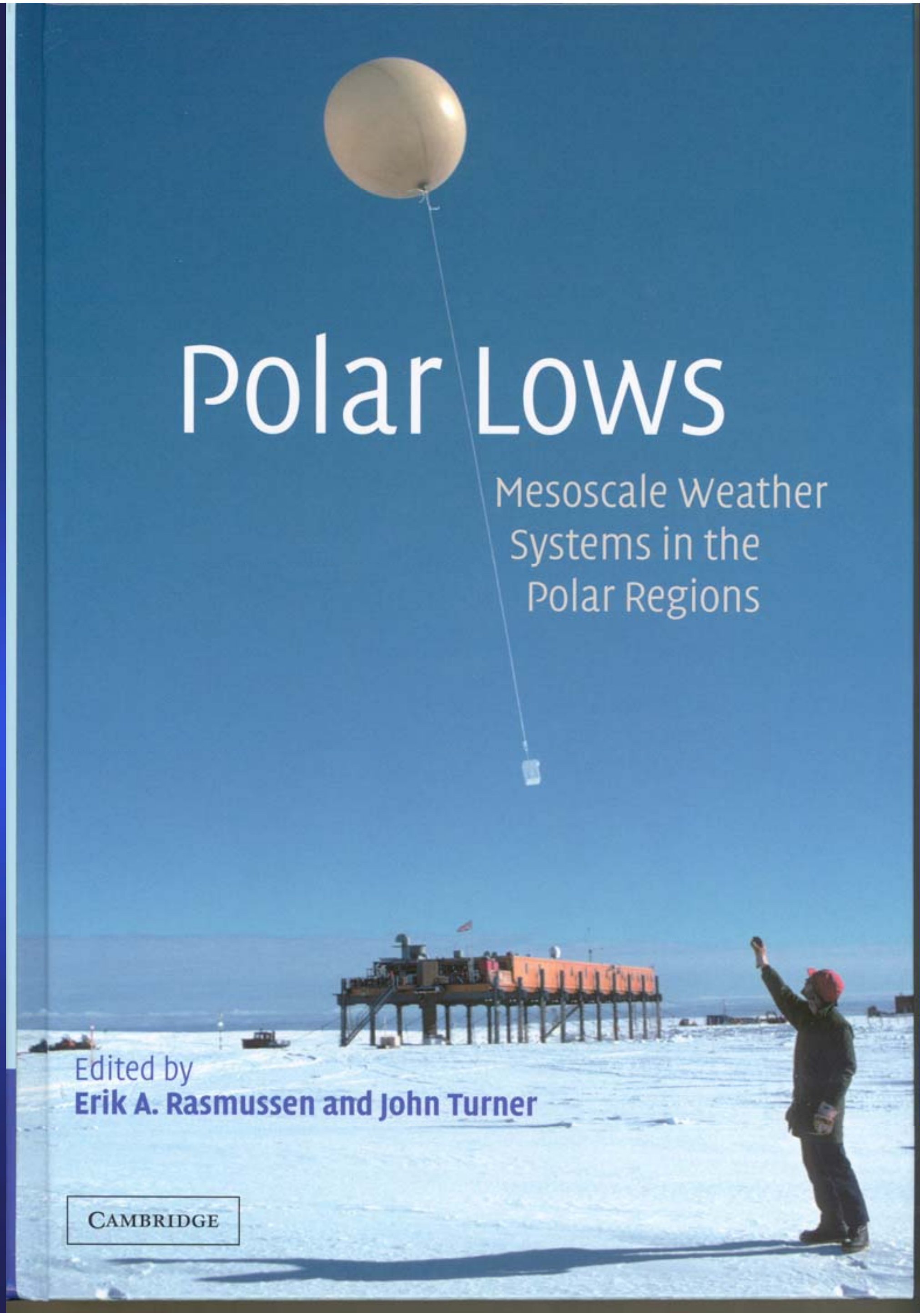




16 January 1995

The International Polar Year

- March 1997 to March 2009
- The additional observations will hopefully results in very high quality analyses
- Provides an excellent opportunity to assess our ability to analyse and forecast polar lows


Polar Lows
Mesoscale Weather Systems in the Polar Regions
Edited by
Erik A. Rasmussen and John Turner
CAMBRIDGE


Thank You