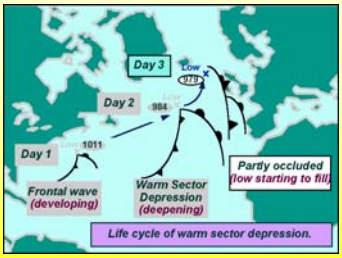
Cyclogenesis

Tor Bergeron lecturing

- Mid latitude cyclones are born on the **Polar Front** as a developing wave
- Theory of cyclogenesis (formation of cyclones) first developed by the Norwegian meteorologists Bjerknes (father and son), Solberg and Bergeron

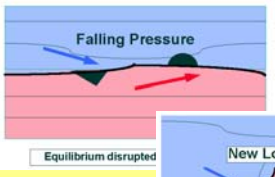
Polar Front Theory

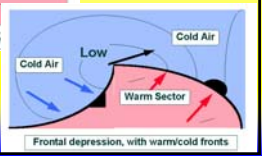
- On a front between cold polar air and warm maritime air a kink will naturally develop into an *incipient cyclone*
- An *open wave* with a well defined warm and cold front deepens
- The cold front catches the warm front and forms an occluded front



- The occluded front finally fills

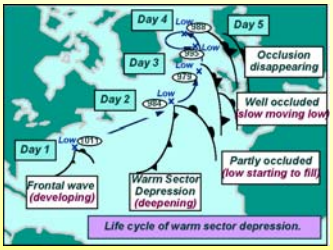
Day 1





- See fig. 13.1/12.1
- A cyclone starts by the development of an open wave

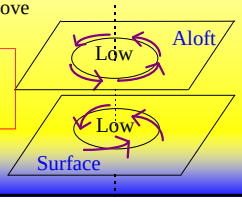
Days 2 - 5



- At the point where the warm, cold and occluded fronts meet, a secondary cyclone can sometimes form
- Why does the cyclone eventually fill?
- Why does the cyclone typically move along a NE track?
- The vertical structure of the cyclone is important

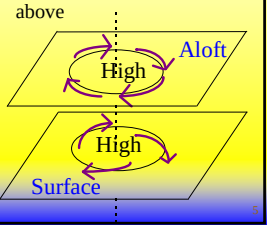
- Surface storms have lows that deepen with height [p. 329/315]
- Surface winds blowing into the cyclone rise vertically
  - this air is **not** removed by a low pressure vertically above

What doesn't happen:



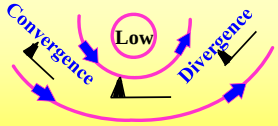
Up Above

- Likewise, surface anticyclones must be fed from wind aloft
  - this can **not** be done by high pressure vertically above



What Happens Aloft

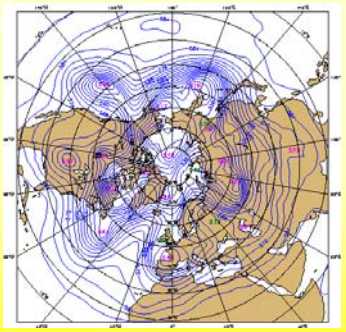
- Up above, there must be an area of **divergence** above a surface cyclone



Pressure aloft

- If upper level divergence exceeds surface convergence, the low deepens
- Up above, there must be a region of **convergence** of air above an anticyclone
  - fig. 13.4/12.7
- If upper level convergence exceeds surface divergence, the anticyclone builds

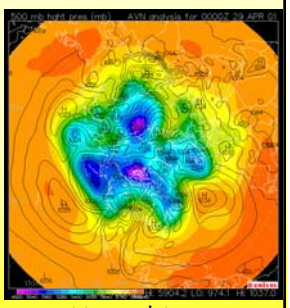
Rossby Waves



- The areas of convergence and divergence aloft are associated with **Rossby waves** that can be seen as ridges and troughs on upper-level charts
  - Rossby waves don't move much around the globe
  - short wave ripples move Eastward around the Rossby waves

7

Cyclone Tracks are Guided by Rossby Waves



- Where the ripples intensify the effect of the Rossby wave, and are well placed with respect to a developing cyclone, the cyclone deepens
- Cyclones need upper-level support to persist
  - cold air comes down the cold front at the 'back' of the cyclone
  - warm air rises up at the front [fig. 13.8/12.8]

8

Influence of the Rockies

Courtesy NASA

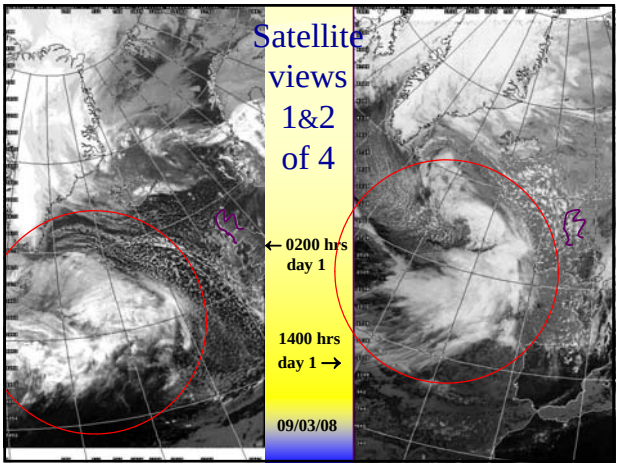
- In the N. hemisphere, the Rocky Mountains disturb the flow aloft up-wind of us. The 'ripples' created have an important influence in nucleating mid-latitude cyclones that affect us
  - flow in the S. hemisphere is more regular, where there are no such mountains at the same latitudes

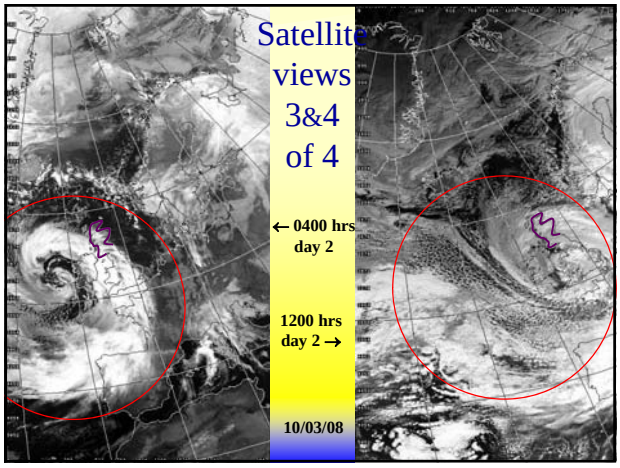
9

Real Examples

- The next few slides show some real examples of mid-Atlantic cyclones forming over the Atlantic and moving across to the UK
  - notice the characteristic cloud swirl visible on satellite images
  - notice the characteristic cyclonic pattern of isobars and fronts on the pressure chart

10

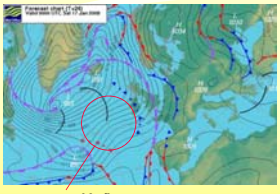




Cyclone over UK with next one building

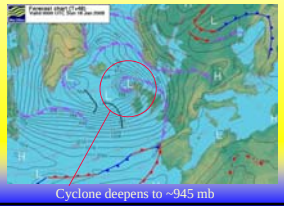
Courtesy:
http://www.sat.dundee.ac.uk/geobrowse/geobrowse.php?sat=0&year=2008&month=3&day=10&slot=1200&ch=1&sat_num=2&grid=1&size=1

Example of mid-Atlantic Cyclogenesis

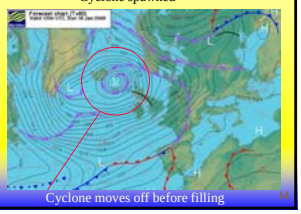


Unstable flow

Cyclone spawned



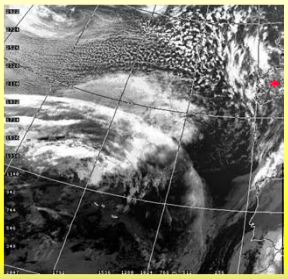
Cyclone deepens to ~945 mb



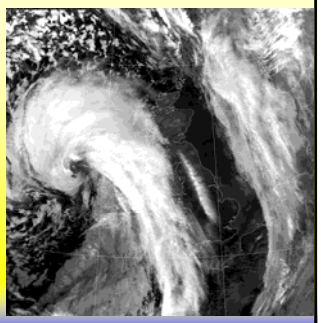
Cyclone moves off before filling

Satellite images for previous charts

West of UK, 1 hr before chart 1



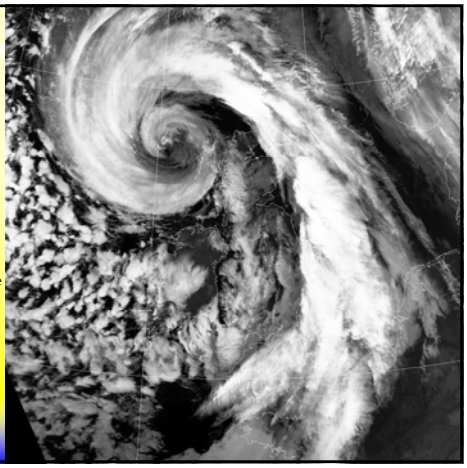
UK, Sat 1300 hrs, 1 hr after chart 2



* Locates Ireland

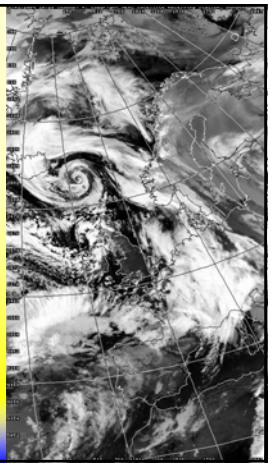
Series continued

UK Sat 2100, 3 hrs before chart 3



Low moving off

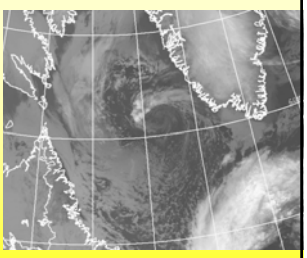
Sun 10.30, 1.5 hrs before chart 4. Low centre is close to the position predicted 80 hrs earlier



Polar Lows

- Polar lows develop on the poleward side of the polar front, usually in winter
- They are typically smaller than mid-latitude lows, but quite intense
- They grow in the right conditions when extremely cold arctic air meets 'warm' ocean air

- IR satellite picture of polar low above 60°N



- Aberdeen (latitude 57°N) is South of the eyes of most polar lows

A Comparative look at Anticyclones

- All anticyclones aren't cloud-free but the descending air within an anticyclone tends to lead to cloud evaporation and hence clear skies

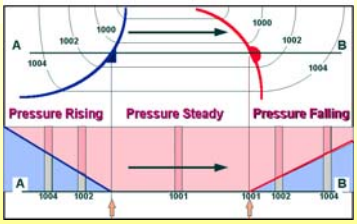
Courtesy: NEODAAS image gallery. 06-Apr-2002

A Final Word on Forecasting

Frankly, I don't like the look of the weather……

Courtesy: Vancouver Sun

Recap of Frontal Weather



- The lower half of the diagram shows the vertical profile
- The warm air is shown pink, the cool air blue
- The cold front slope is typically 4 times warm front slope
- Passage of fronts over an observer
- Remember the typical weather pattern associated with these fronts

Forecasting Strategies

When rain comes before wind, Hallyards, sheets and braces mind

The West wind is a gentleman and goes to bed

Clear Moon, frost soon

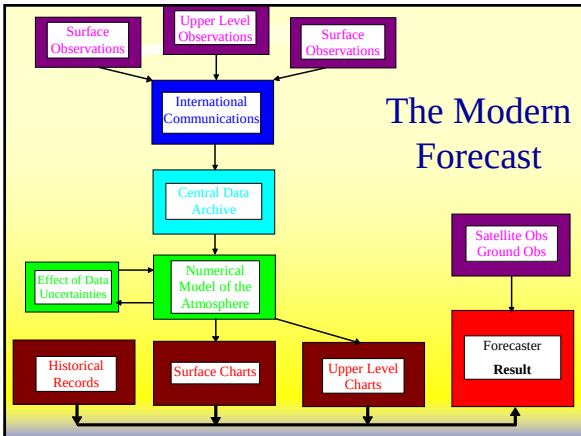
Ne'er trust a July sky

March comes in like a lion and goes out like a lamb

Mackerel skies and mares' tails Gar mony a ship carry furled sails

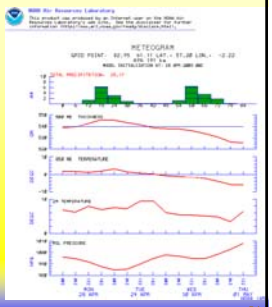
- Observation + old sayings
- Persistence forecast - estimate how long the current weather will last
- Trend forecast - assume that current movement of weather will continue at constant speed and direction
- Analogue forecast - look to see what happened when similar conditions existed before

The Modern Forecast



The Computer Generated Forecast

- Global circulation models using a global mesh
  - e.g. one Met Office global model uses 17 km grid and 70 vertical layers
- Raw model output is the **meteogram**
- Presentational program shows forecast for any point on the globe



Meteogram from AVN model: courtesy NOAA

Increasing sophistication of numerical models

- variable grid resolution
  - Met Office for UK uses 1.5 km grid in inner region, 4 km surrounding grid (UKV model)
    - 36 hr predictions
  - fine detailed region can be transferred to areas of interest anywhere in the world
- Ensemble forecasting perturbing initial conditions and some of embedded processes
  - MOGREPS global ensemble, 33 km grid, 12 variations for 7 days ahead