

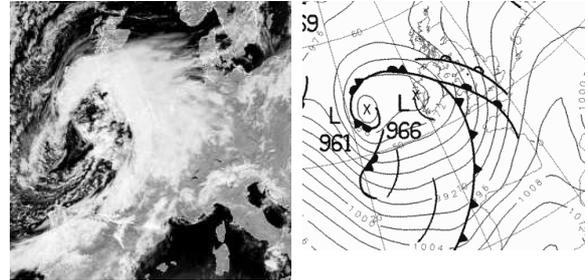
Weather systems

Dr Pete Inness

<http://www.metlink.org/weather-climate-resources-teachers/weather-systems-video.html>

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What are we talking about?



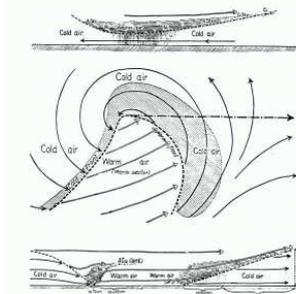
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A bit of history

- The first scientific study and classification of these weather systems was performed by a group of Norwegian meteorologists – *the Bergen School*
- The location was no coincidence – Bergen experiences a *lot* of weather systems
- Working without the benefit of satellite pictures, this group did a remarkable job of describing the nature of weather systems

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A bit of history



This figure from a 1922 paper by Bjerknes and Solberg shows pictures of a typical mid-latitude depression that will be familiar to anyone who has read a modern textbook on weather systems

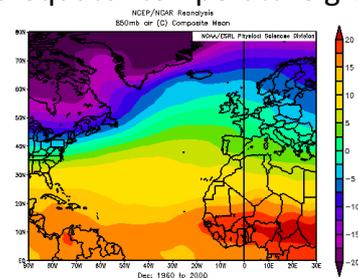
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Why do they occur?

- Depressions occur as a consequence of the pole-to-equator temperature gradient
- The equator is always warmer than the poles, especially in the winter hemisphere
- The atmosphere acts to prevent the equator continually heating up and the poles continually cooling down
- Mid-latitude depressions play a vital role in this process

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Pole-to-equator temperature gradient



The south to north rate of change of temperature is greatest between 30 and 70 degrees north

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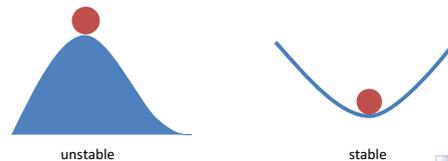
Back to the history books

- The Bergen meteorologists realised that this temperature gradient was a key part of the formation of weather systems
- They referred to the temperature gradient as “the polar front” – a boundary separating warm tropical air from colder air near the pole
- They believed that all depressions formed on this polar front

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Pole-to-equator temperature gradient

- This large temperature gradient is *unstable*
- This means that if a small perturbation is introduced to the gradient, it will grow with time



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Waves on the polar front

- A small perturbation on the polar front can grow, a bit like an ocean wave approaching the shore



Such systems are often called “wave depressions” by meteorologists

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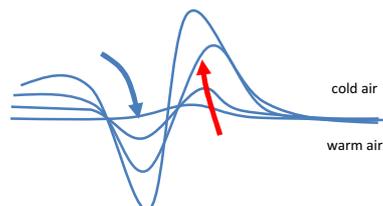


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Waves on the polar front

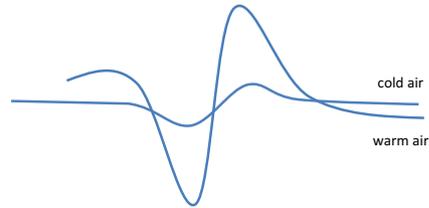
- Eventually the wave “breaks”, stranding warm air on the cold side of the front, and cold air on the warm side



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Waves on the polar front

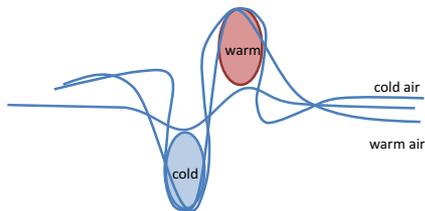
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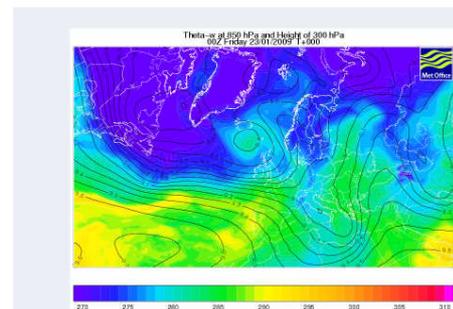
Waves on the polar front

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A sequence of wave depressions



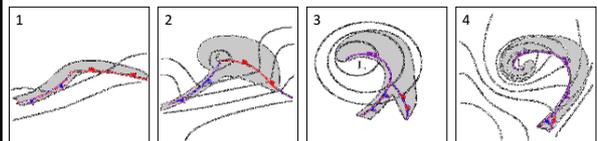
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A more detailed look...

- The wave on the polar front model is a useful concept when understanding the role of depressions in moving warm air polewards
- However, it doesn't describe the detailed structure of depressions such as the winds, cloud and rain associated with them

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Depression life-cycle



This sequence shows the “classical” lifecycle of a depression

The grey shading shows the region of continuous cloud cover

The warm front (red) and cold front (blue) denote the boundaries of the “wave” of warm air – often called the **warm sector**

But what about the purple line?

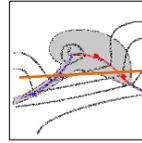
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Looking in 3 dimensions

- At this point its important to remember that weather systems are **3 dimensional**
- In fact the 3rd dimension is crucial – *all* the cloud and rain produced by a depression is caused by **air rising and cooling**
- At this stage we'll look at the vertical structure of a developing depression

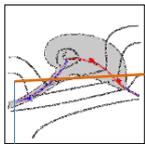
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Looking in 3 dimensions



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Looking in 3 dimensions

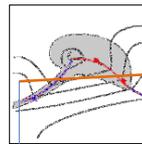


height

Horizontal distance

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Looking in 3 dimensions



System moving this way

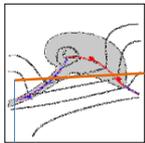
height

WARM
SECTOR

Horizontal distance

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Looking in 3 dimensions



System moving this way

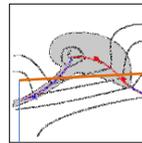
height

WARM
SECTOR

Horizontal distance

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Looking in 3 dimensions



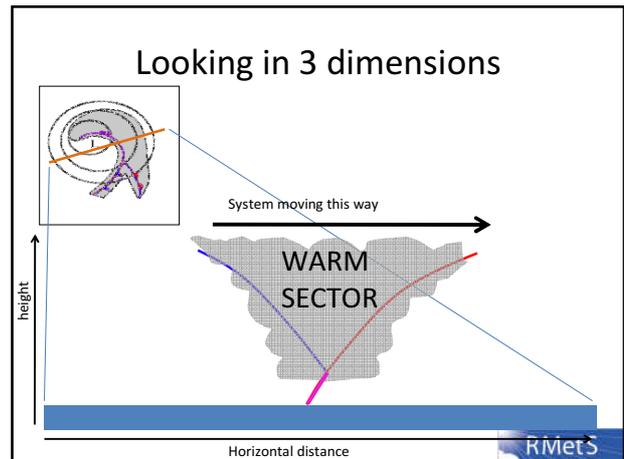
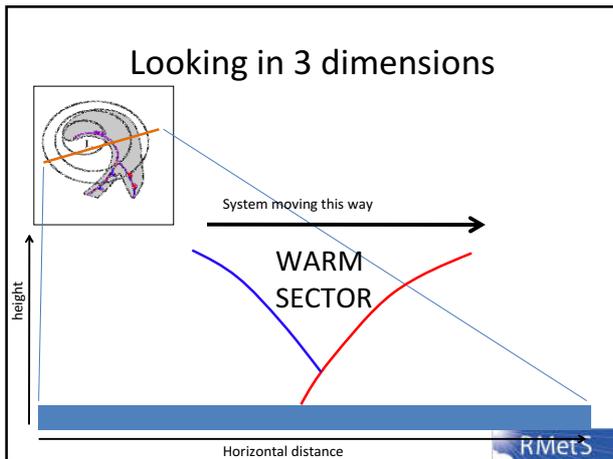
System moving this way

height

WARM
SECTOR

Horizontal distance

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Why does the pressure fall in the middle of a depression?

- This is perhaps the most obvious question to ask about depressions
- In order to answer it we must again think about the 3-D structure of the system, and vertical motion
- We also need to consider what atmospheric pressure actually is

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Atmospheric pressure

When we measure atmospheric pressure with a barometer we are simply measuring the **weight of the column of air** above us

If the pressure reduces, it means there must be less air in the column above our heads

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Atmospheric pressure

Near the centre of a depression, air is rising

The tropopause acts as a lid to vertical motion, so the air spreads out horizontally at this level - **divergence**

Near the surface, air **converges** into the column to replace the air being lost through rising motion

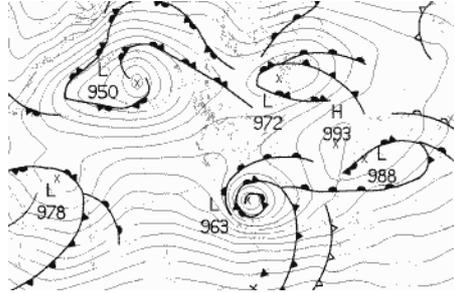
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Atmospheric pressure and winds

- The stronger the **pressure gradient** in a depression, the stronger the winds around it
- The Earth's rotation means that winds don't blow directly into the centre of the low but instead **blow around the low** – in an **anticlockwise** direction in the northern hemisphere
- The absolute value of pressure in the centre of the depression is less important than the difference in pressure between the centre and the edge of the system

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Atmospheric pressure and winds



Surface pressure chart. 0000. 24th Jan. 2009.
The depression in the Bay of Biscay has winds of hurricane force on its western and southern flanks

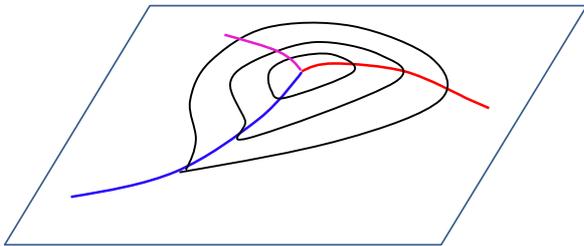
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Airflow through depressions

- The “classical” model of a depression, with its fronts and warm sector doesn’t really describe the flow of air through the system
- Without a constant input of warm moist air, a depression would soon lose energy and start to dissipate
- This feed of warm moist air is provided by an airflow called the **Warm Conveyor Belt**

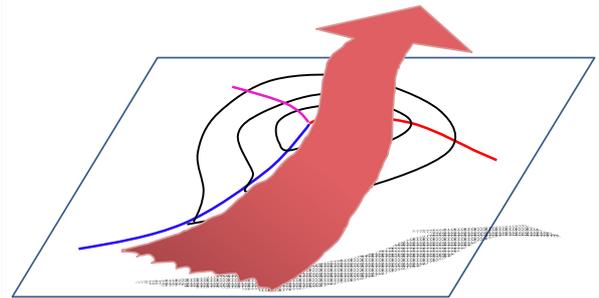
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Conveyor belts



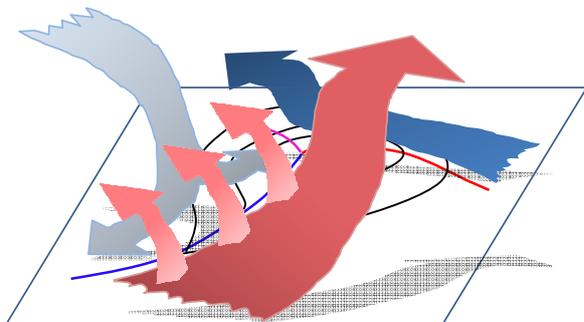
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Conveyor belts



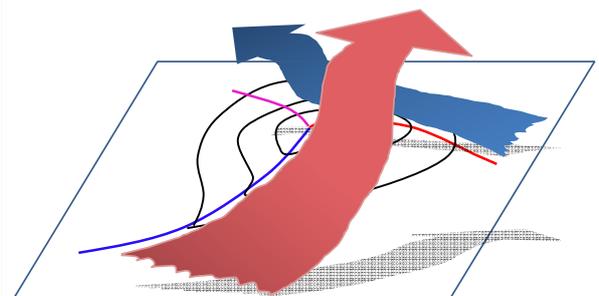
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Conveyor belts



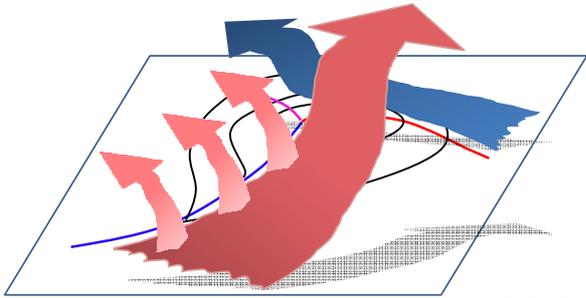
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Conveyor belts



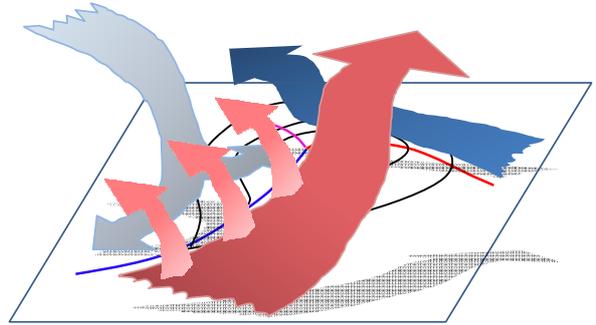
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Conveyor belts



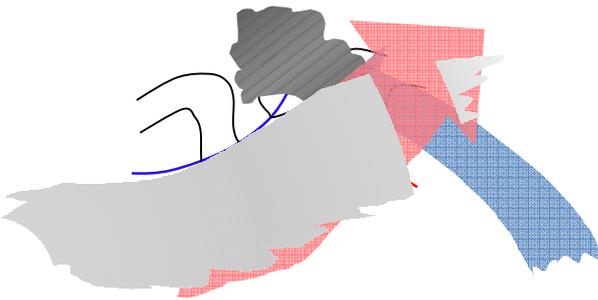
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Conveyor belts



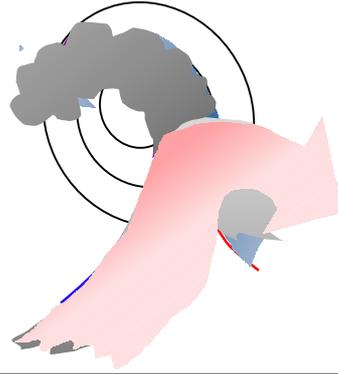
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Conveyor belts and clouds (1)



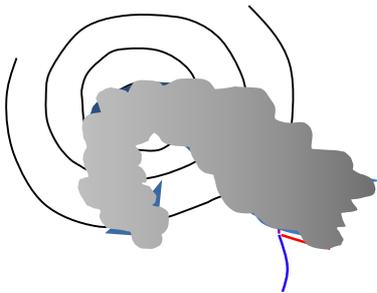
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Conveyor belts and clouds (2)



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Conveyor belts and clouds (3)



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Case study. Jan 24th, 2009



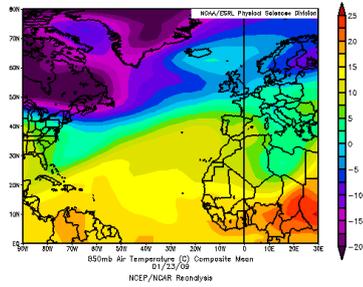
27 DIE AS WINDS LASH FRANCE AND SPAIN



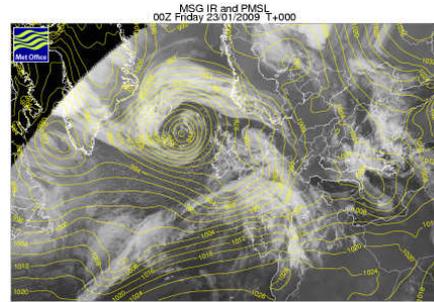
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Pole-to-equator temperature gradient

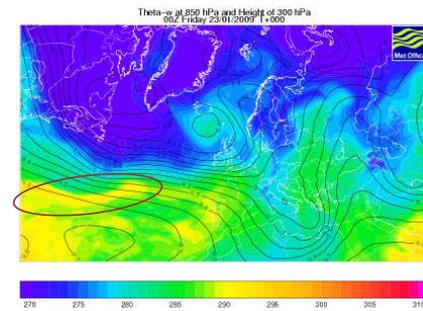
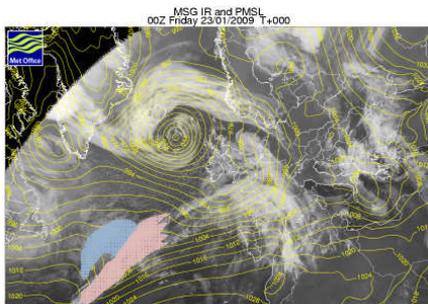
- On the 23rd of January, there was a strong temperature gradient across the Atlantic



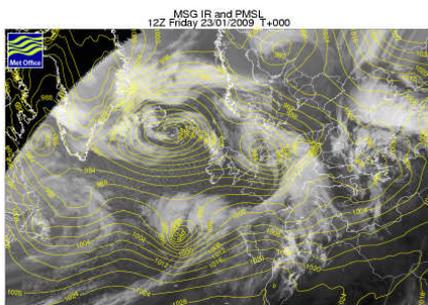
Satellite image and surface pressure



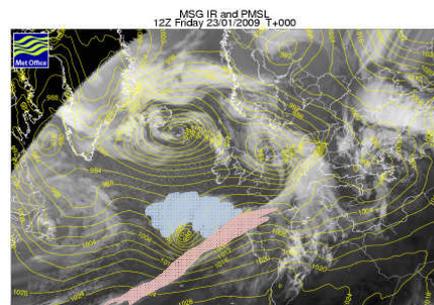
Satellite image and surface pressure



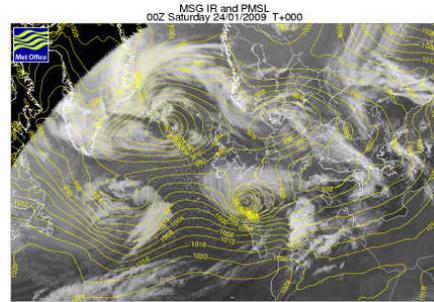
Satellite image and surface pressure



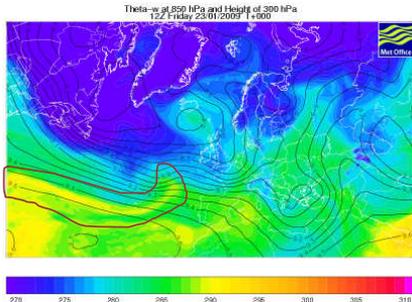
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Satellite image and surface pressure

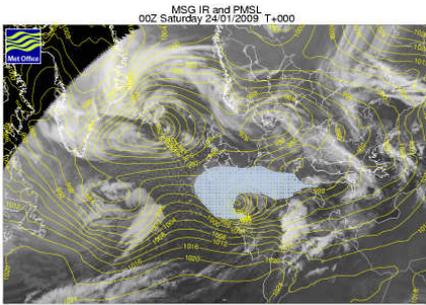


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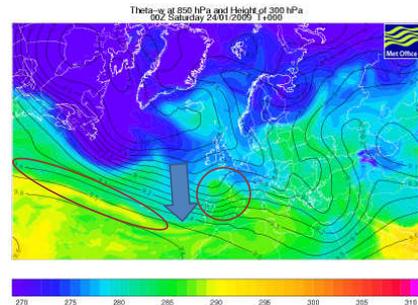


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Satellite image and surface pressure

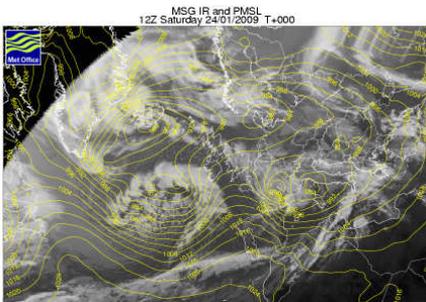


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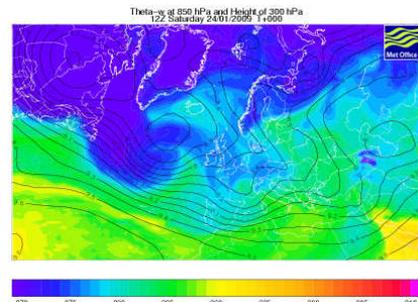


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Satellite image and surface pressure



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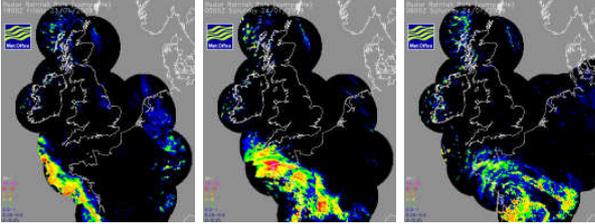
Rainfall Radar

Bright colours show heaviest rain

1900. 23/1/09

0000. 24/1/09

0600. 24/1/09



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Why was this depression so intense?

- The **very strong temperature gradient** across the Atlantic
- Very strong upper level **winds in excess of 200mph at heights of about 9km**
- The storm formed further south than most depressions so the air feeding into the system was **very warm and moist**

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