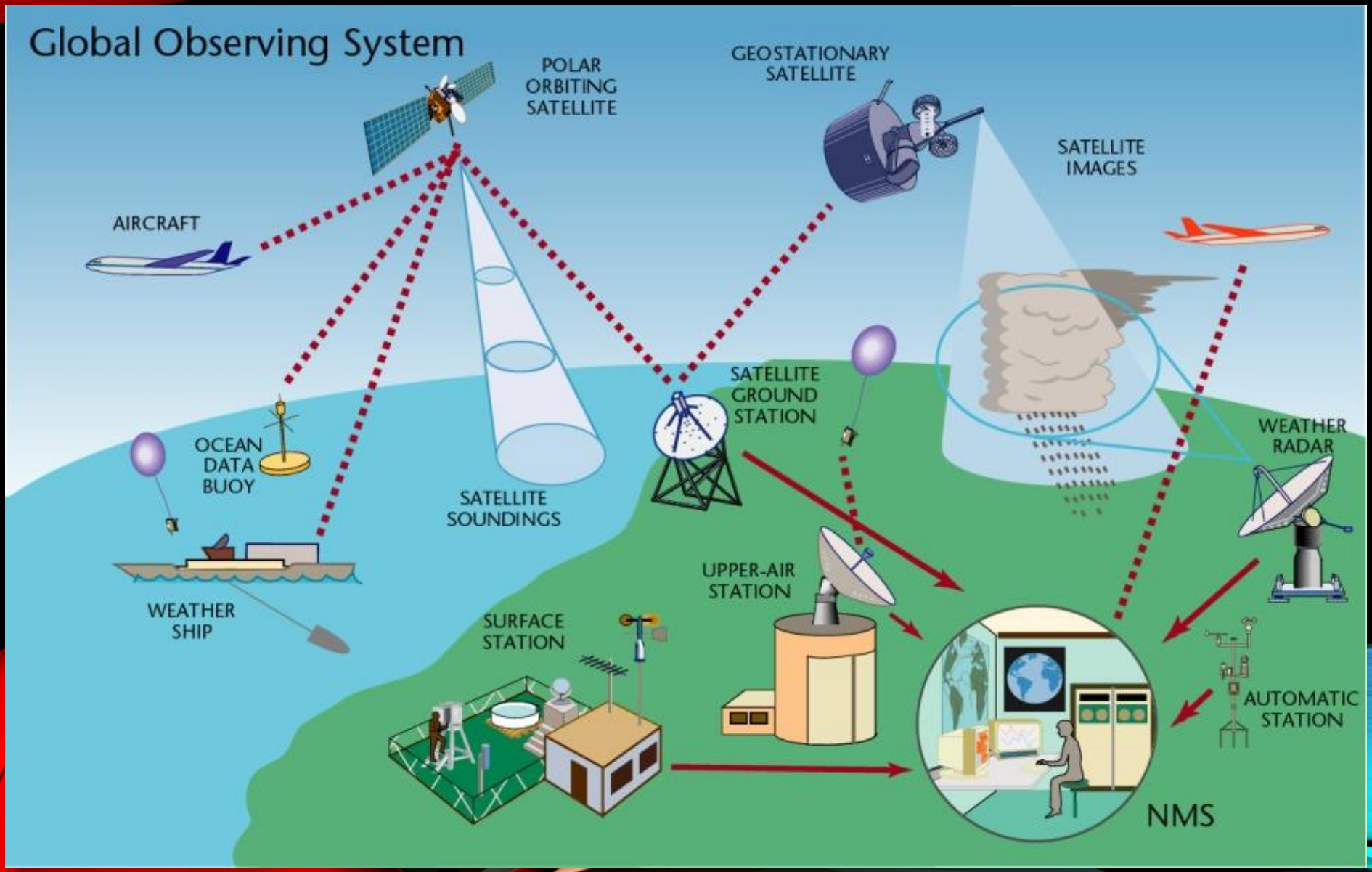
Understanding weather and the weather forecast

Week 15 Fronts, Troughs and Lows

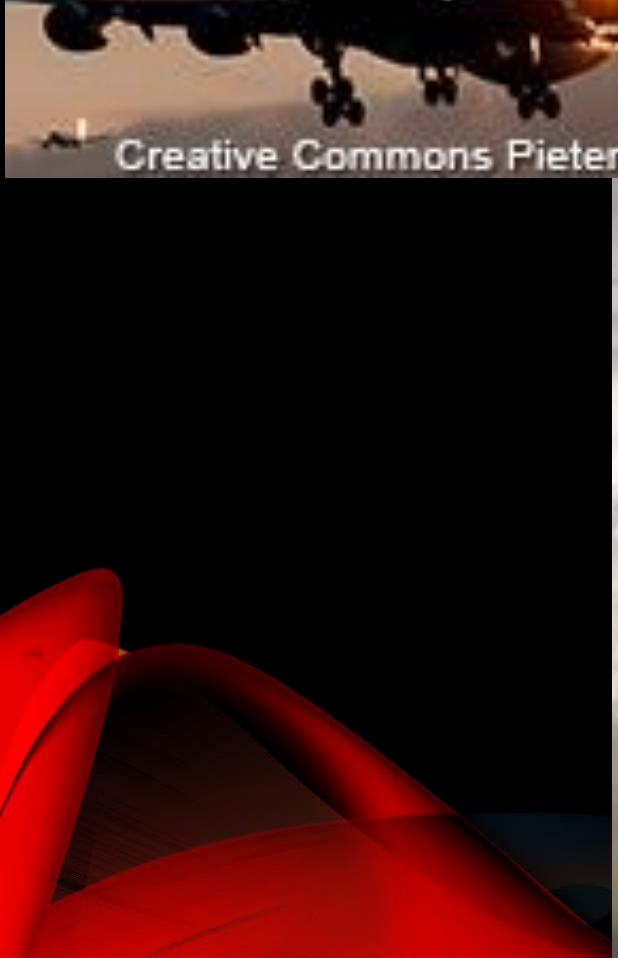
Terry Hart

Observing the atmosphere uses many different types of systems and measurements



Introduction to Aircraft Meteorological Data Relay (AMDAR)

Creative Commons Pieter van Marion



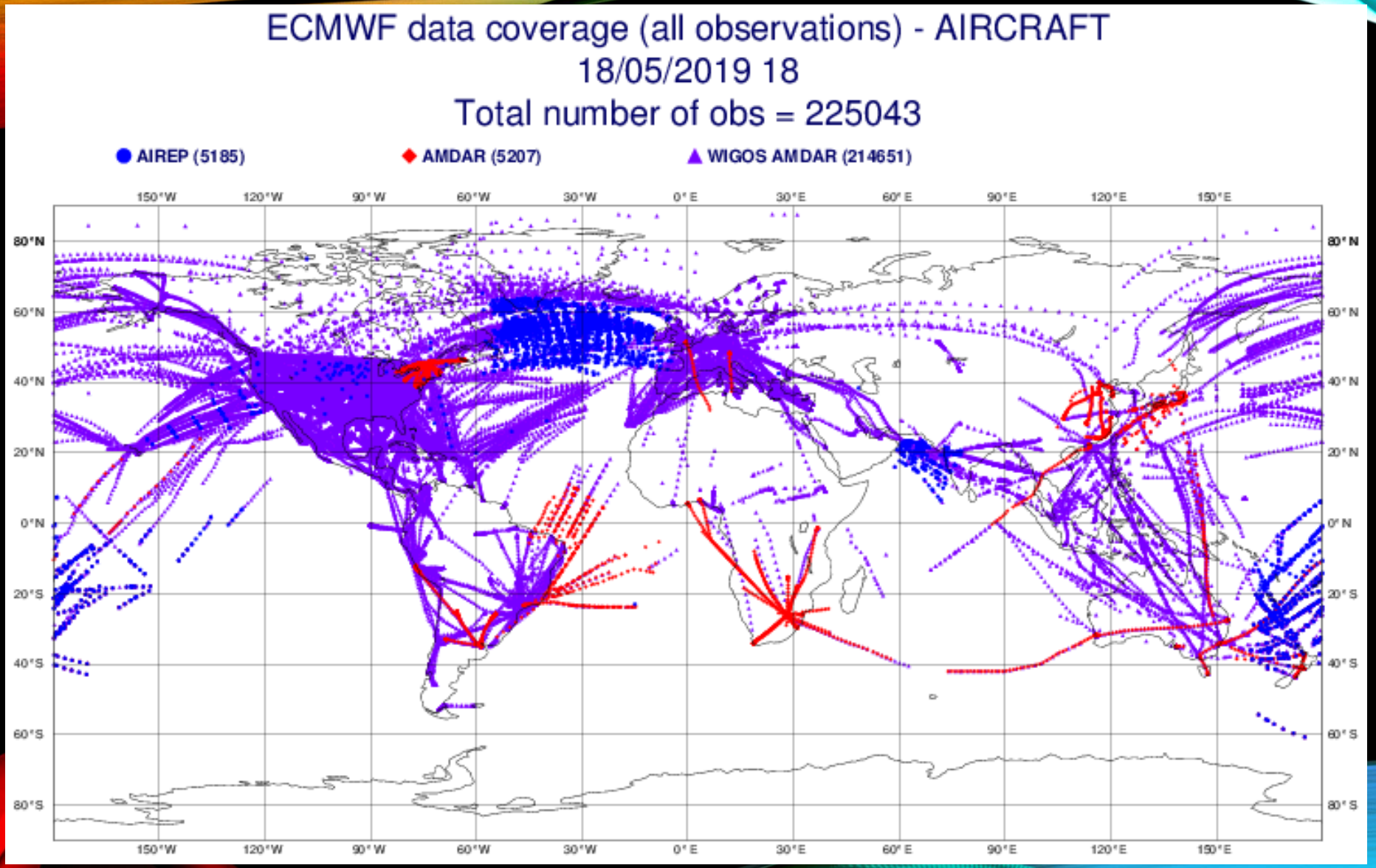
Creative Commons D'Arcy Norman

AMDAR can measure or derive the following meteorological parameters with very accurate time, pressure altitude, and latitude and longitude coordinates:

- Air temperature
- Wind speed and direction
- Pressure altitude (barometric pressure)
- Turbulence
- Water vapour

While in flight, an AMDAR-equipped aircraft reports the real-time meteorological variables above every 3-10 minutes.

This AMDAR animation illustrates how frequently AMDAR instruments transmit data during the various stages of flight.



4 am Melbourne time

Satellite data:

- Temperature sounding from radiation measurements
- Temperature sounding from occultation of GPS satellites
- Winds in the atmosphere by tracking clouds
- Satellites with radar to measure ocean winds, height of waves and Sea level
- Satellites to measure soil moisture
- Measuring rainfall and water content
- Ozone

At ECMWF – 98 % of data received, and 95% of the data used come from satellites

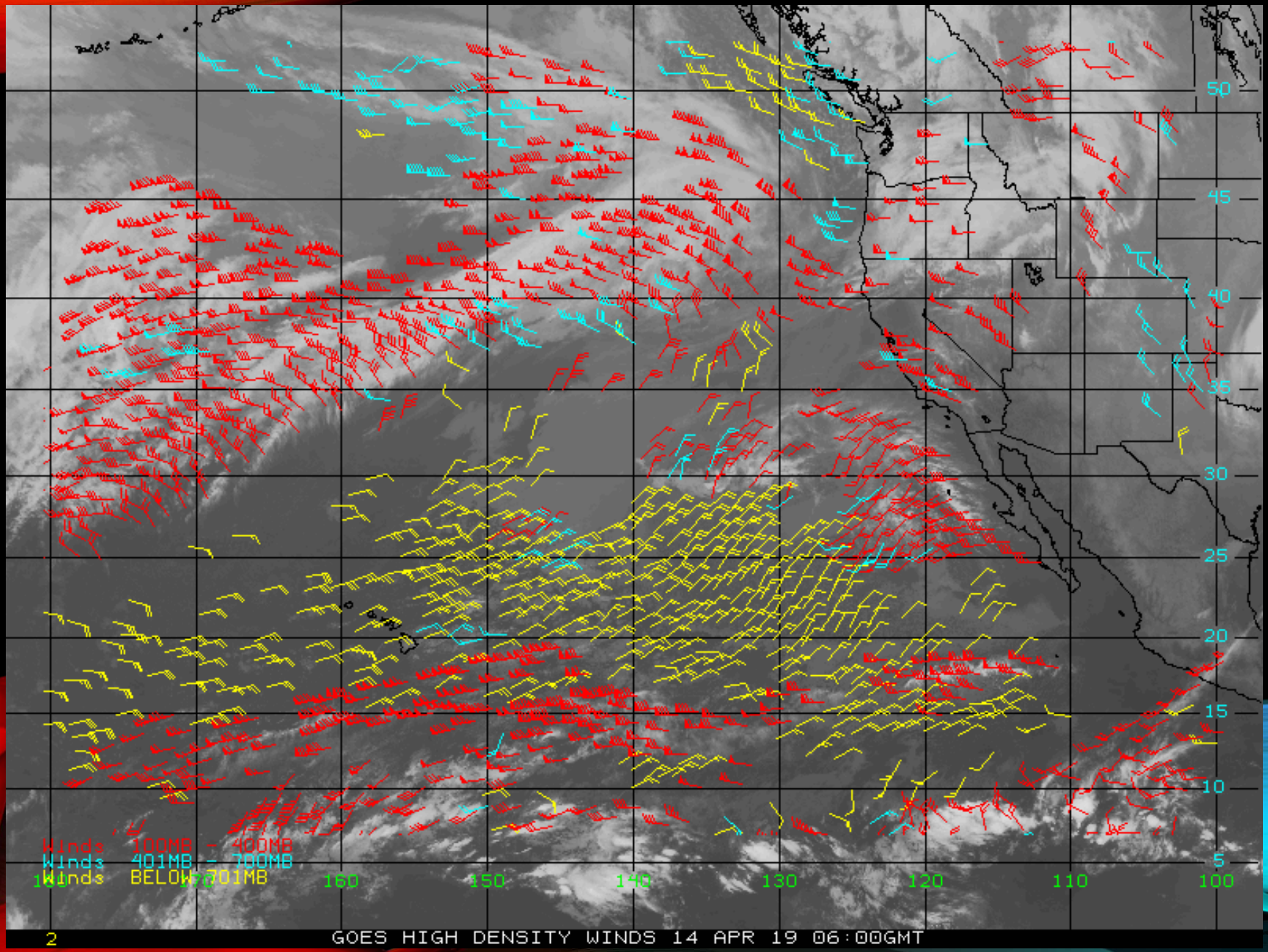
Satellite data have made a big difference to the skill of forecasts, and made the forecasting of the synoptic patterns in the southern hemisphere as accurate as in the north – a major achievement!

Atmospheric Motion Vectors (satellite-derived winds)

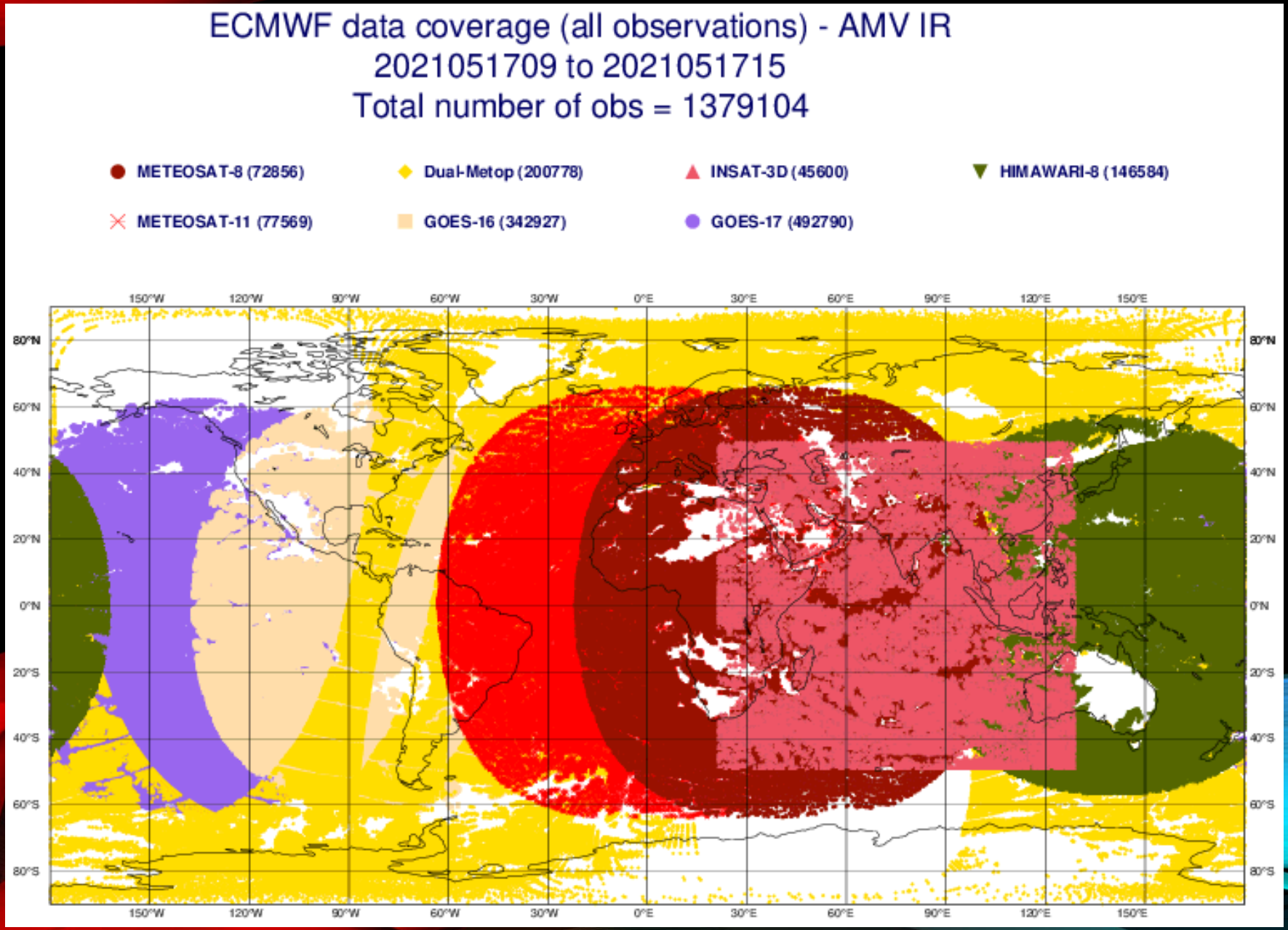
(Infrared, Visible and Water Vapour)

Atmospheric Motion Vectors are derived using a sequence of images. Using 3 images features targeted in the second image (cirrus cloud edges, small cumulus clouds etc.) are tracked in the first and third images, giving two estimates of wind speed. These two are averaged to get a better estimate.

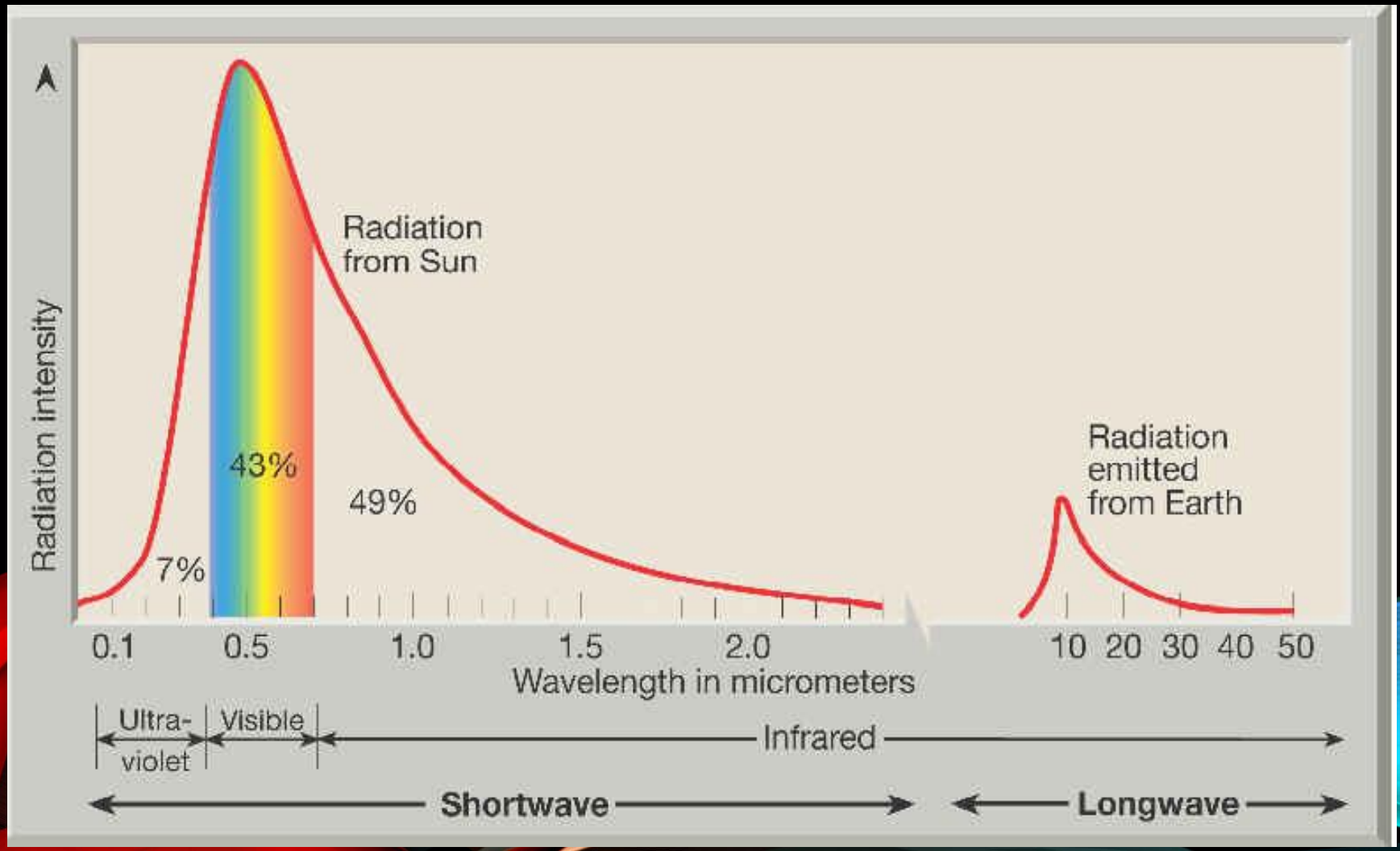
Atmospheric Motion Vectors (satellite-derived winds)

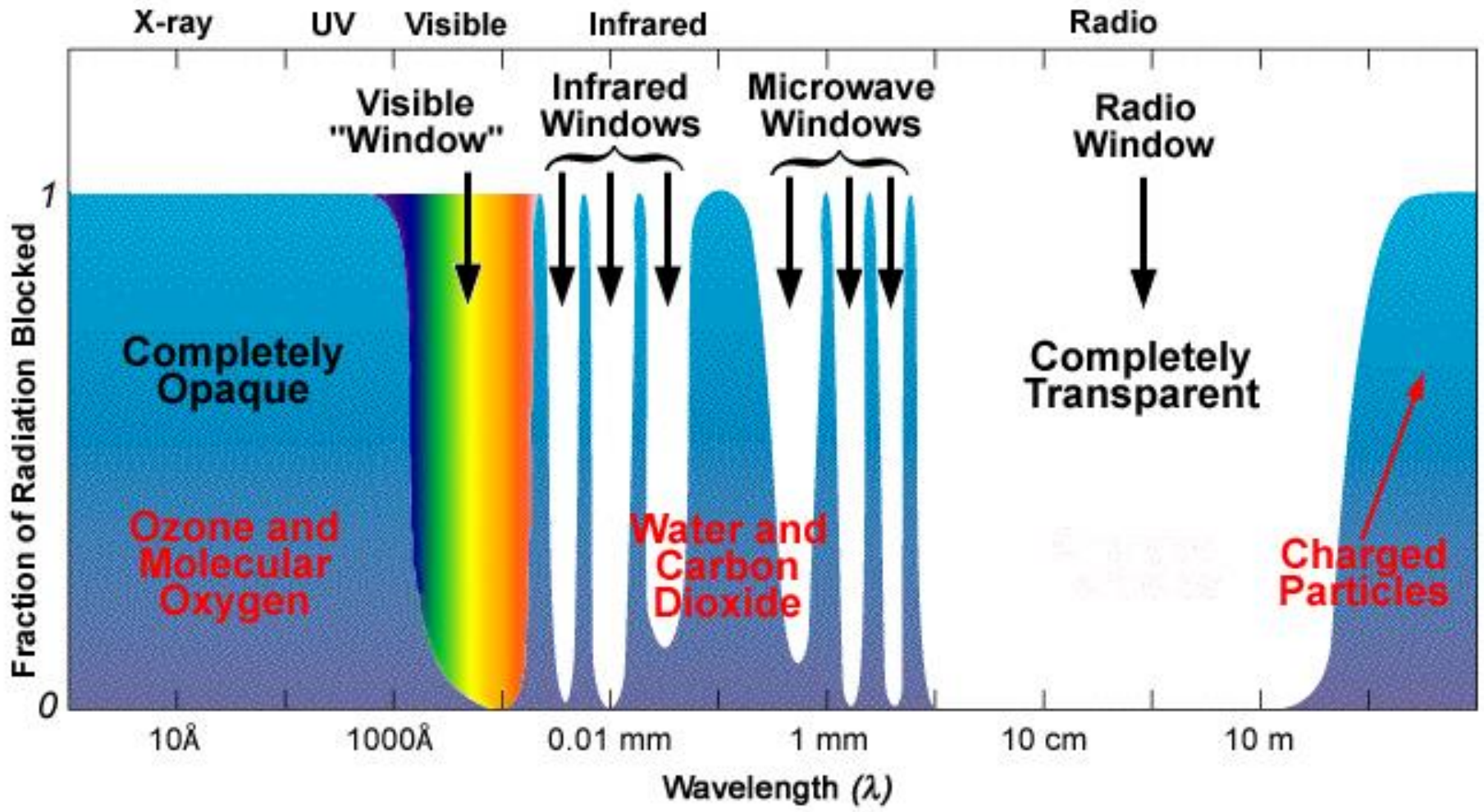


Atmospheric Motion Vectors (satellite-derived winds) - **Infrared**



The Earth's energy budget – inward from the sun and outwards from the Earth





Note: The absorption bands are not as smooth as depicted.

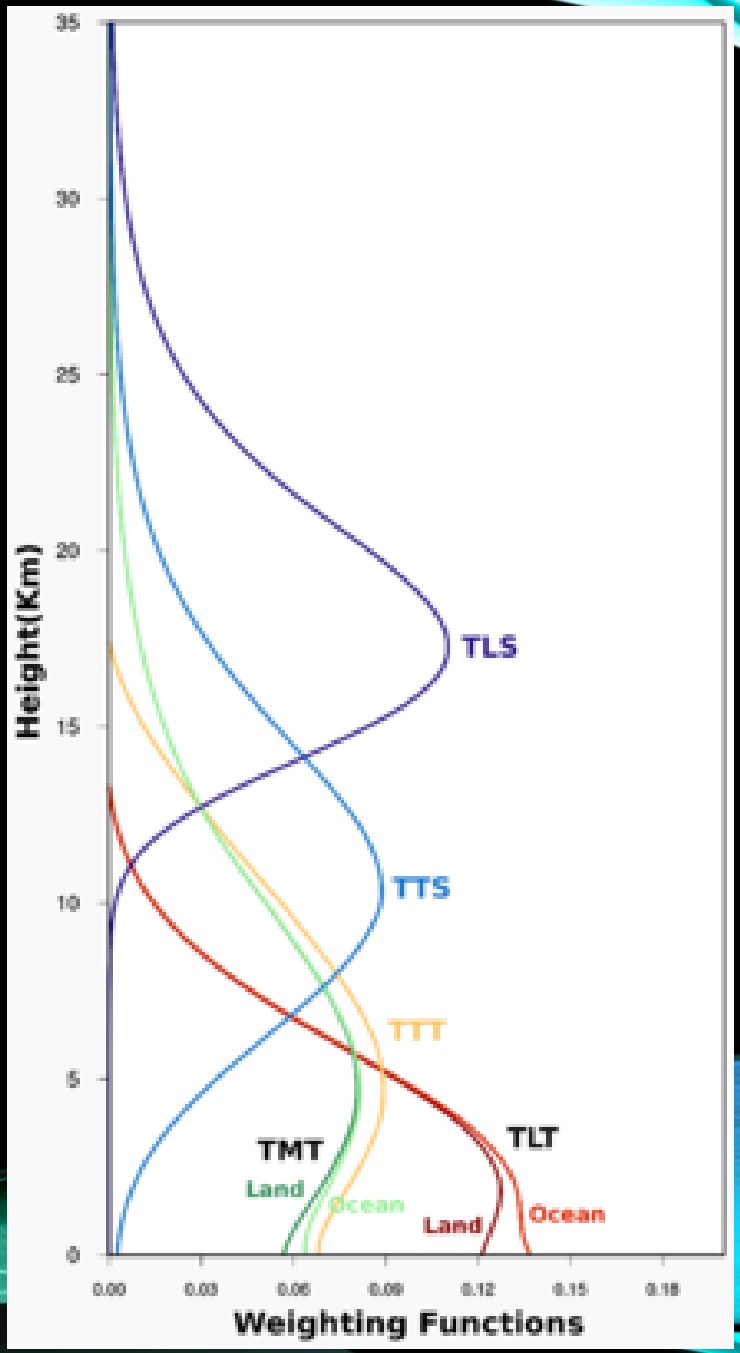
The principle of satellite temperature soundings is to take measurements at several wavelengths through an absorption band.

Where the absorption is strong, the radiation will come from the upper levels. Where the absorption is weak, the radiation will come from nearer the surface.

It needs a gas that is well mixed through the atmosphere and constant in composition.

Two good candidates are:
Carbon dioxide (Infrared 15 microns)
Oxygen (Microwave – around 55 GHz (5 mm))

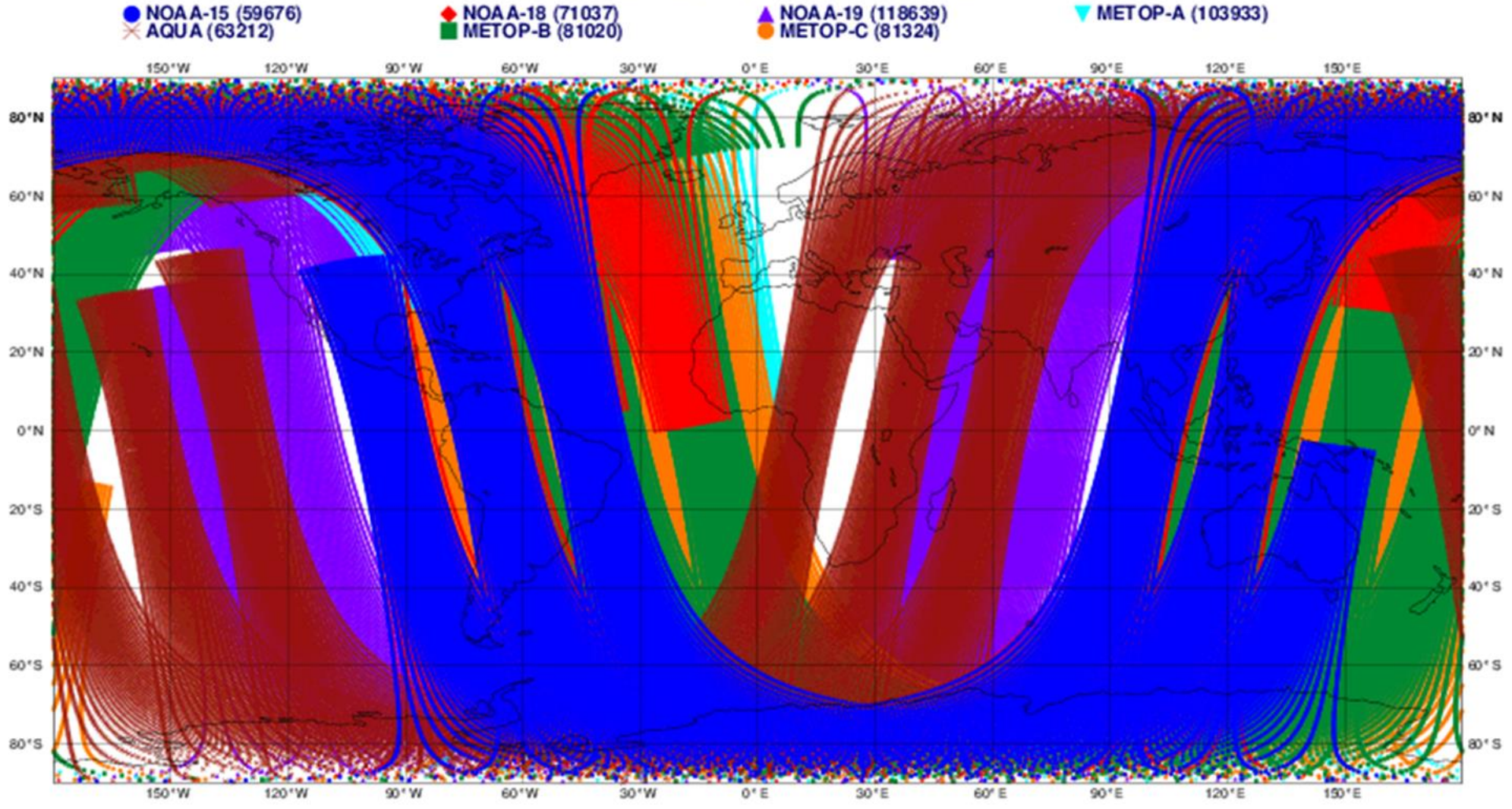
Note: battle to keep the 55 GHz channels clear of human communications traffic.



ECMWF data coverage (all observations) - AMSUA

26/05/2019 00

Total number of obs = 578841



Placing satellite data in the global meteorological record

Satellites

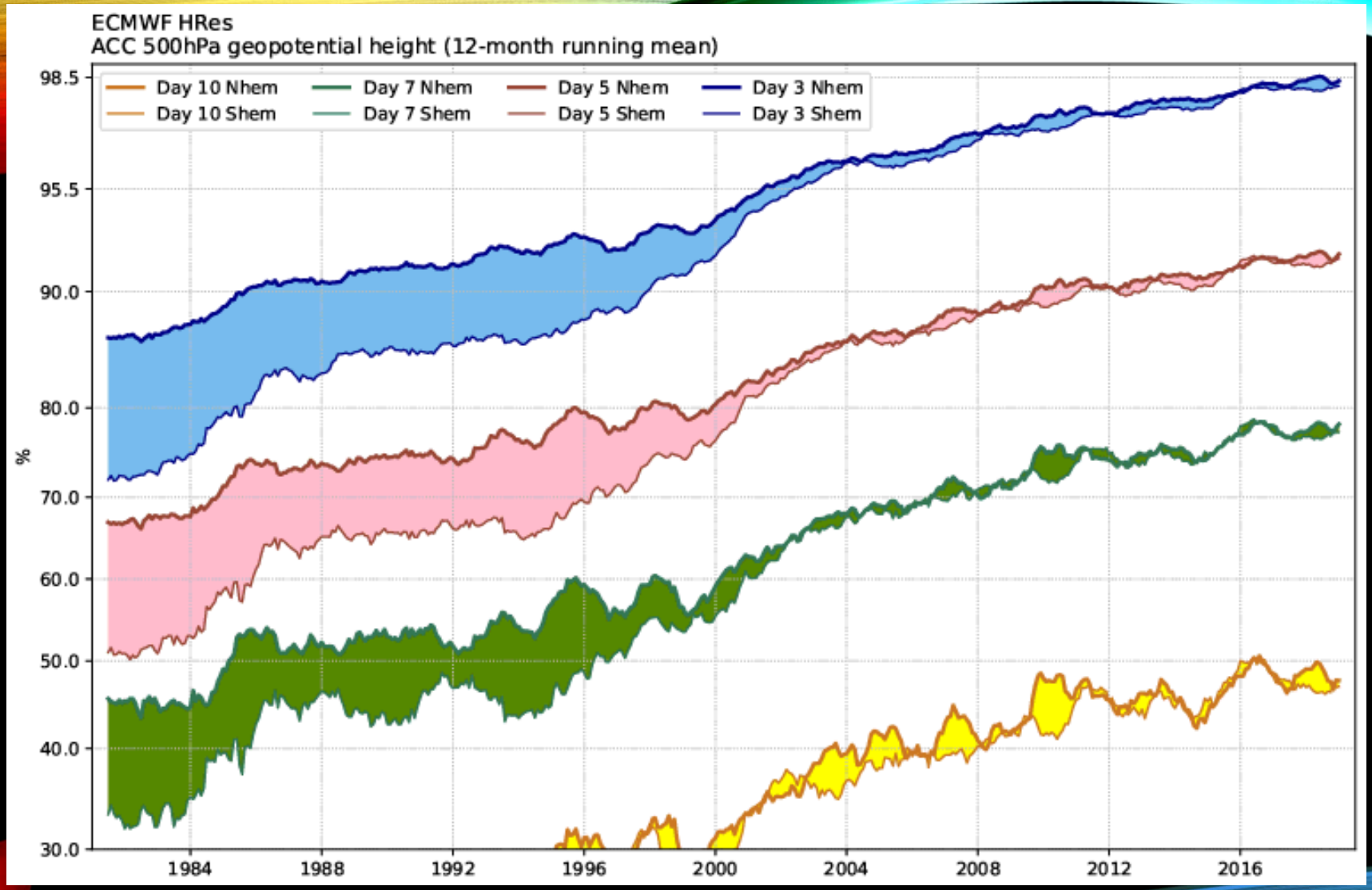
Upper-air soundings

Surface observations

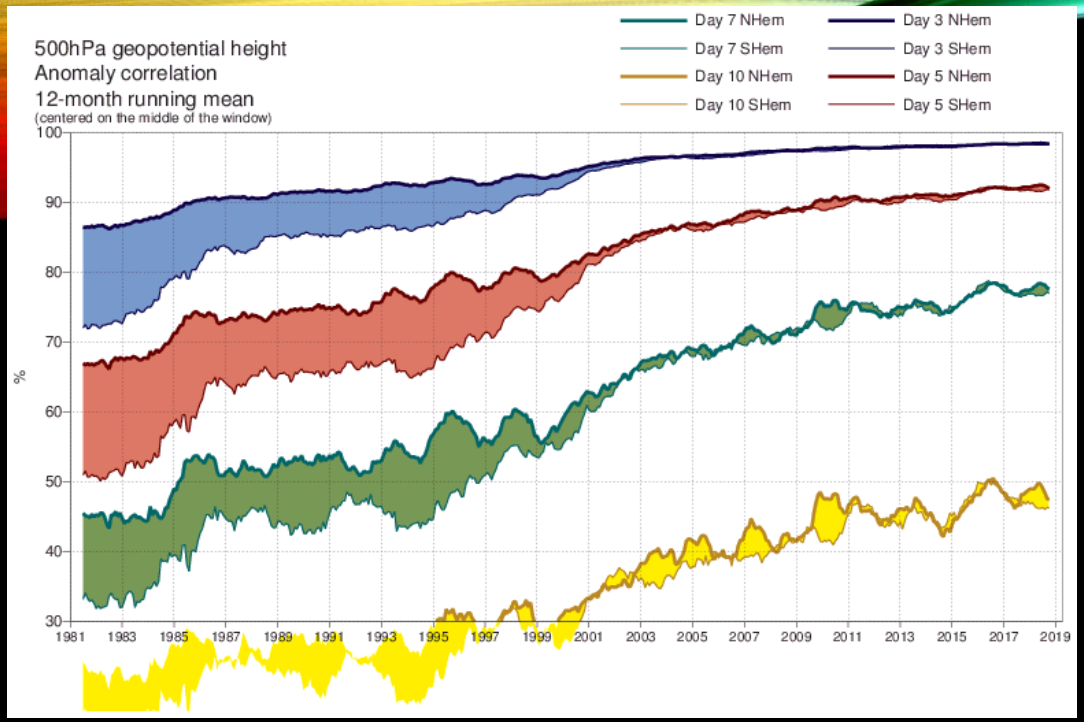
log(number of observations)

D. Dee

1890	1938	1957	1973	1979	Today	2020
Manual observations from stations and ships, limited data exchange	First radiosonde networks, systematic soundings	IGY restored West/ East scientific inter-change. Global data exchange set-up	First operational satellite soundings (NOAA-2)	Improved sounding from polar orbiters; Winds from geostationary orbit; More data from commercial aircraft; First drifting buoys		*Opportunity sensors : cell phones, UAVs, vehicles, rooftops, . . .*

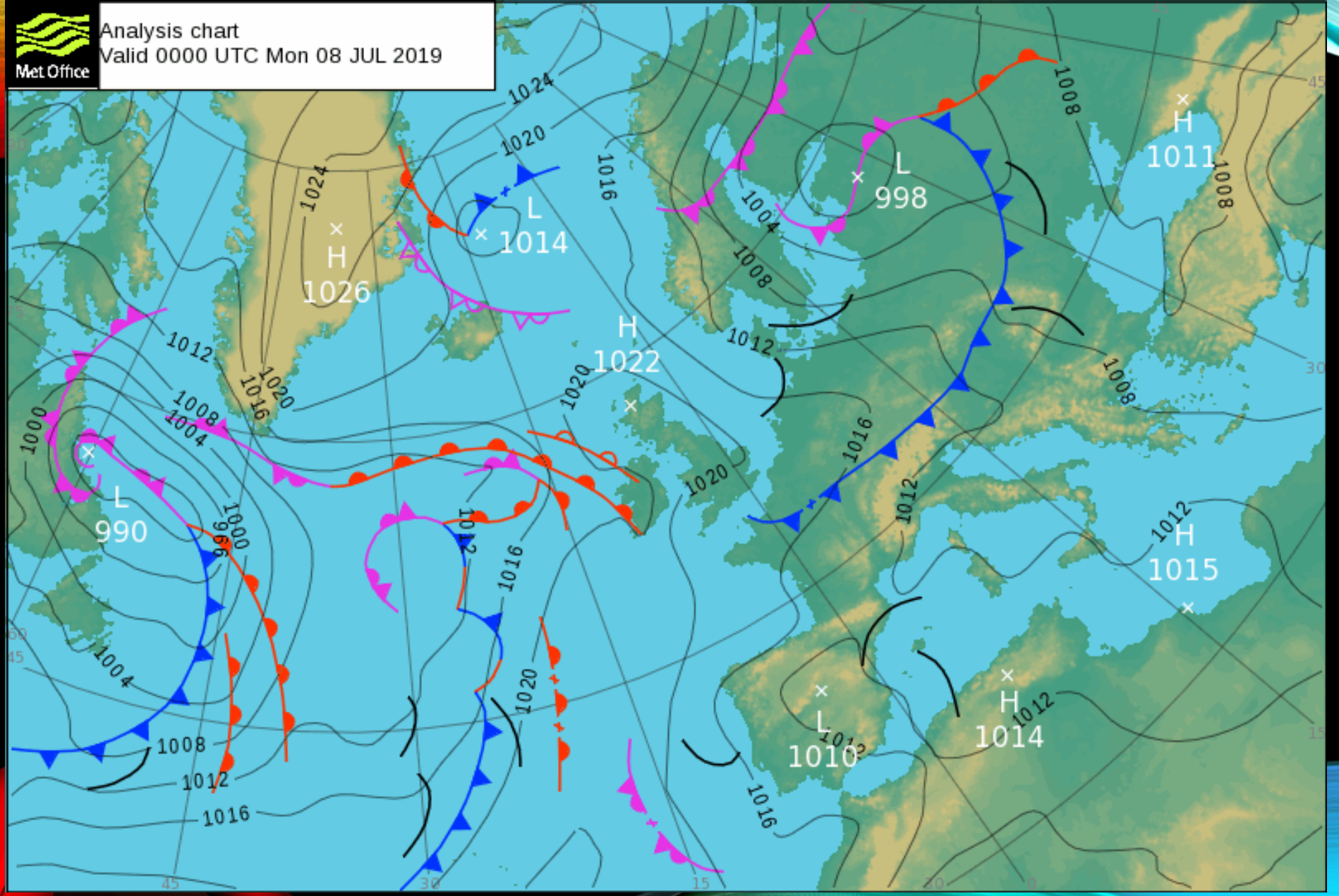


Time series showing the "skill" of the ECMWF computer predictions of the synoptic patterns of weather, at since 1981.
The number shows how well the forecast weather pattern correlates with the observed. So a higher number is good.



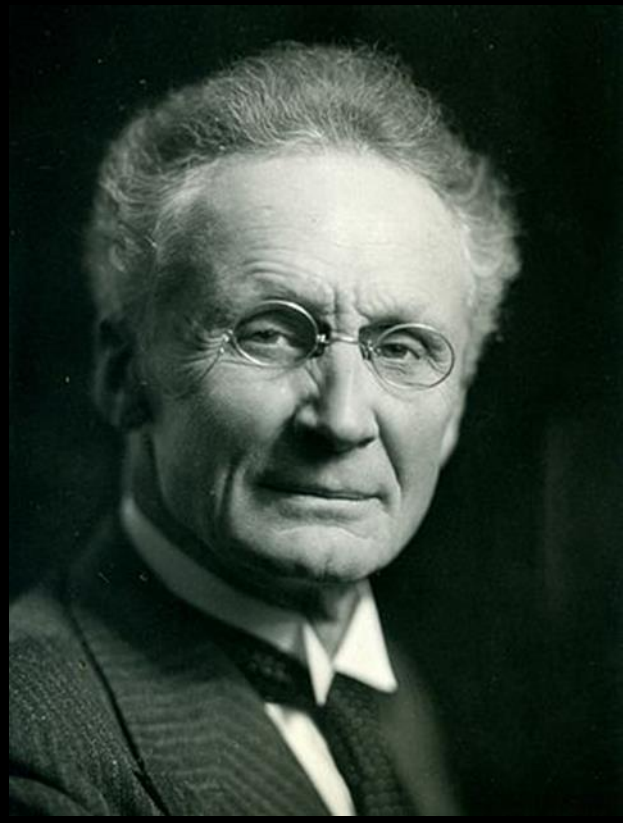
There are two main stories here and a question:

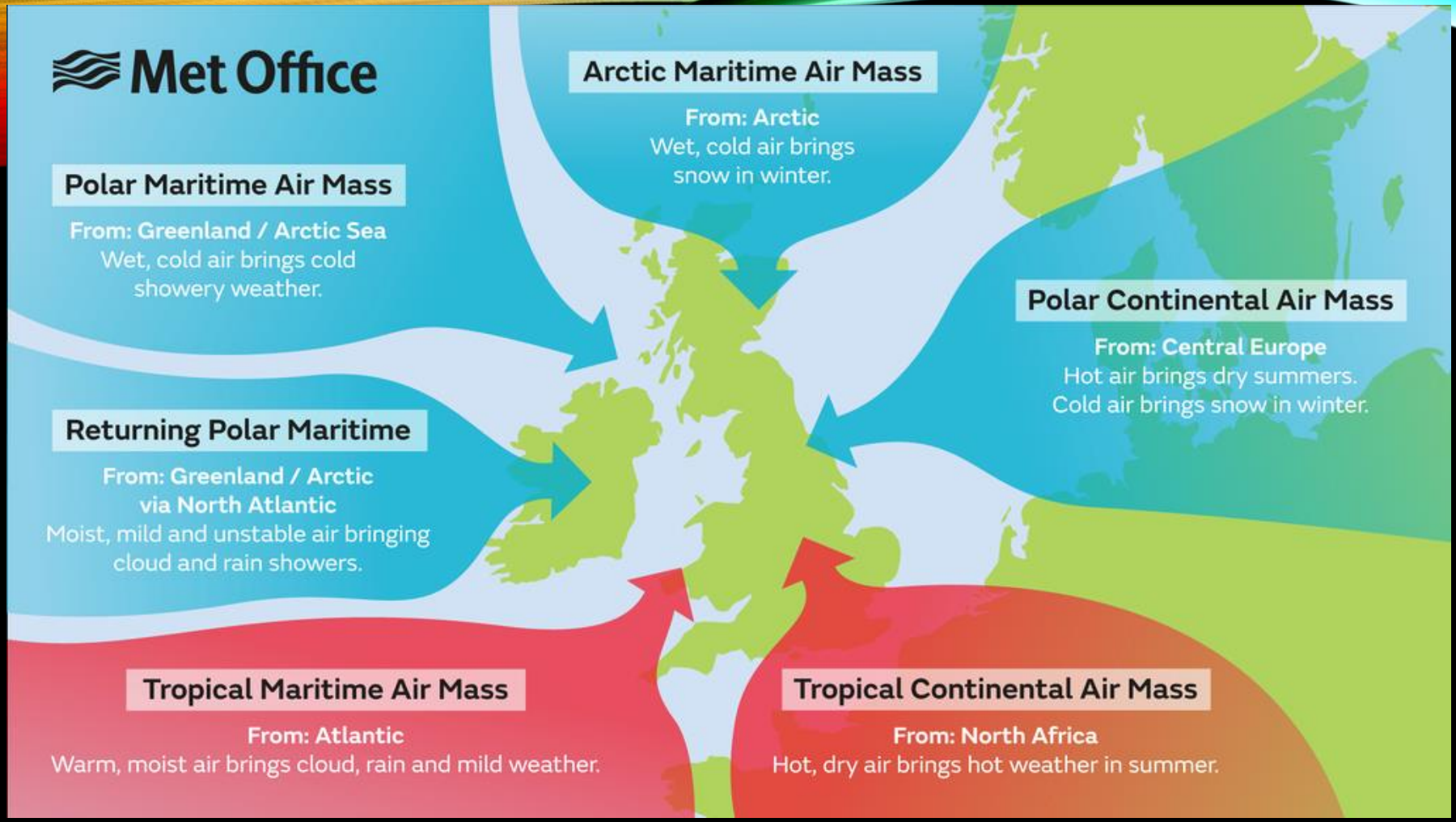
- The great improvement in weather prediction since the 1980s
- The closing of the gap between the skill of forecasts in the northern and southern hemispheres (mainly due to satellite data)
- Question: why does the forecast skill deteriorate at longer range?



Northern Hemisphere – Fronts are very complex and systems tend to stay around longer

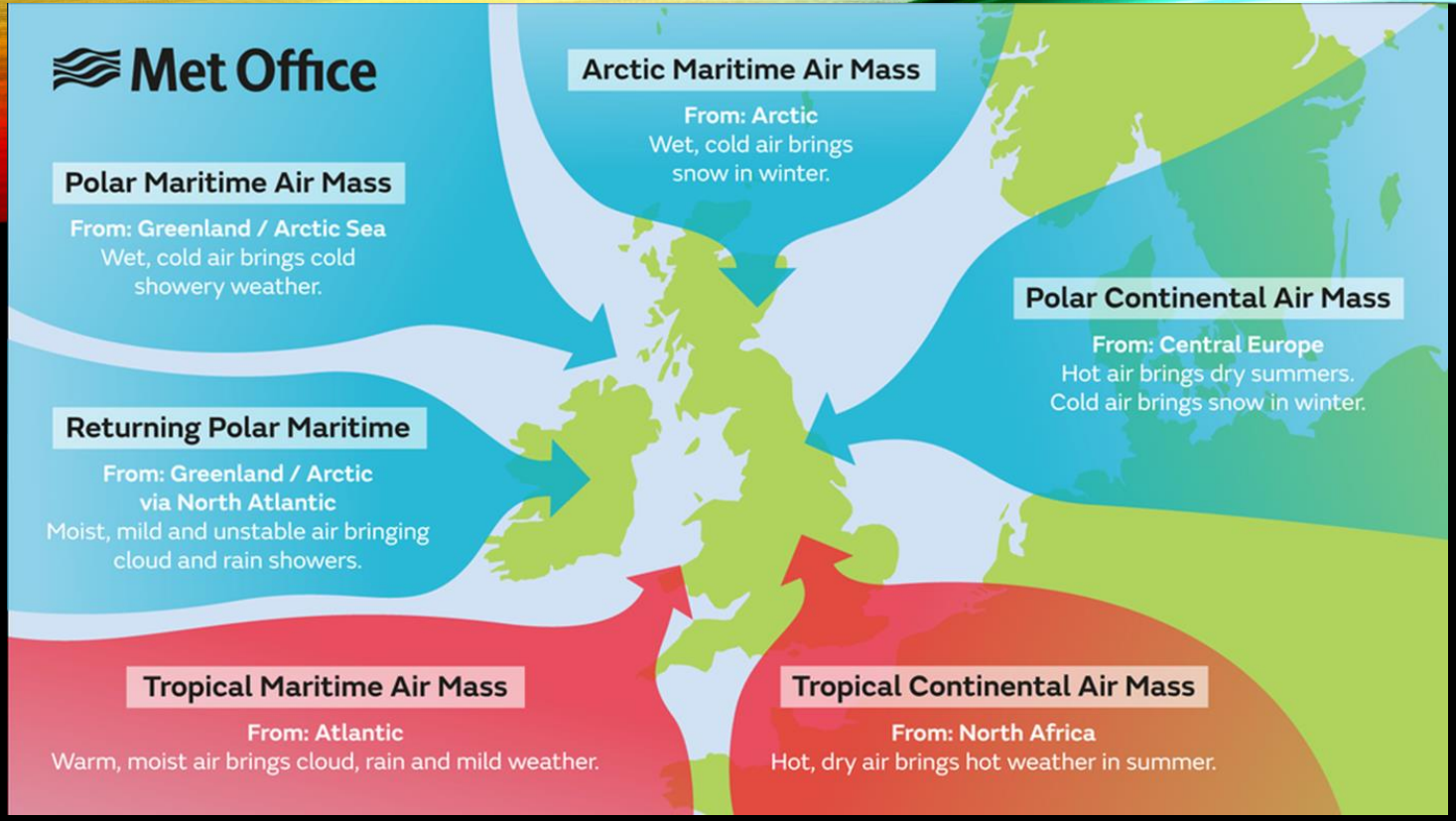
- From the late 1800s routine weather reports were transmitted by telegraph.
- A major organisation studying weather was the Bergen School of Meteorology in Norway, founded by Vilhelm Bjerknes (1862-1951). His son Jacob (1897-1975) was part of the team.
- Very influential in establishing the modern practice of weather forecasting.
- Their aim was to define the motion of the atmosphere by means of **fluid dynamics** and **thermodynamics**, and make mathematical predictions regarding the weather possible based on systematic data analysis.
- Bjerknes established the equations that are now used in computer weather prediction but, before computers, he had no way of applying these equations
- So their work remained **qualitative and conceptual.** They worked out that rain and thunderstorms tended to form in lines. **Remember –** there were no satellite images so their work was based on weather maps.





The Bergen School introduced the idea of **air mass** - a large volume of air in the atmosphere that is *mostly* uniform in temperature and moisture, with character determined by its origin.

https://www.youtube.com/watch?v=kvk-hBFnBTI

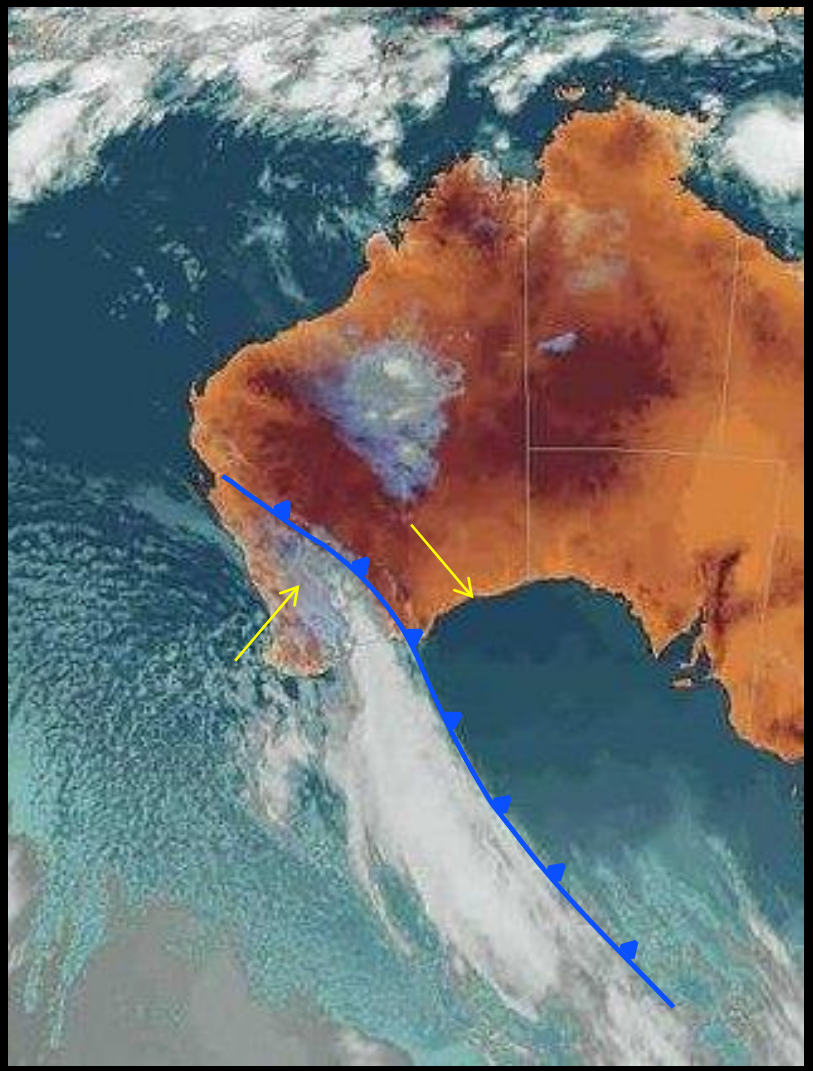


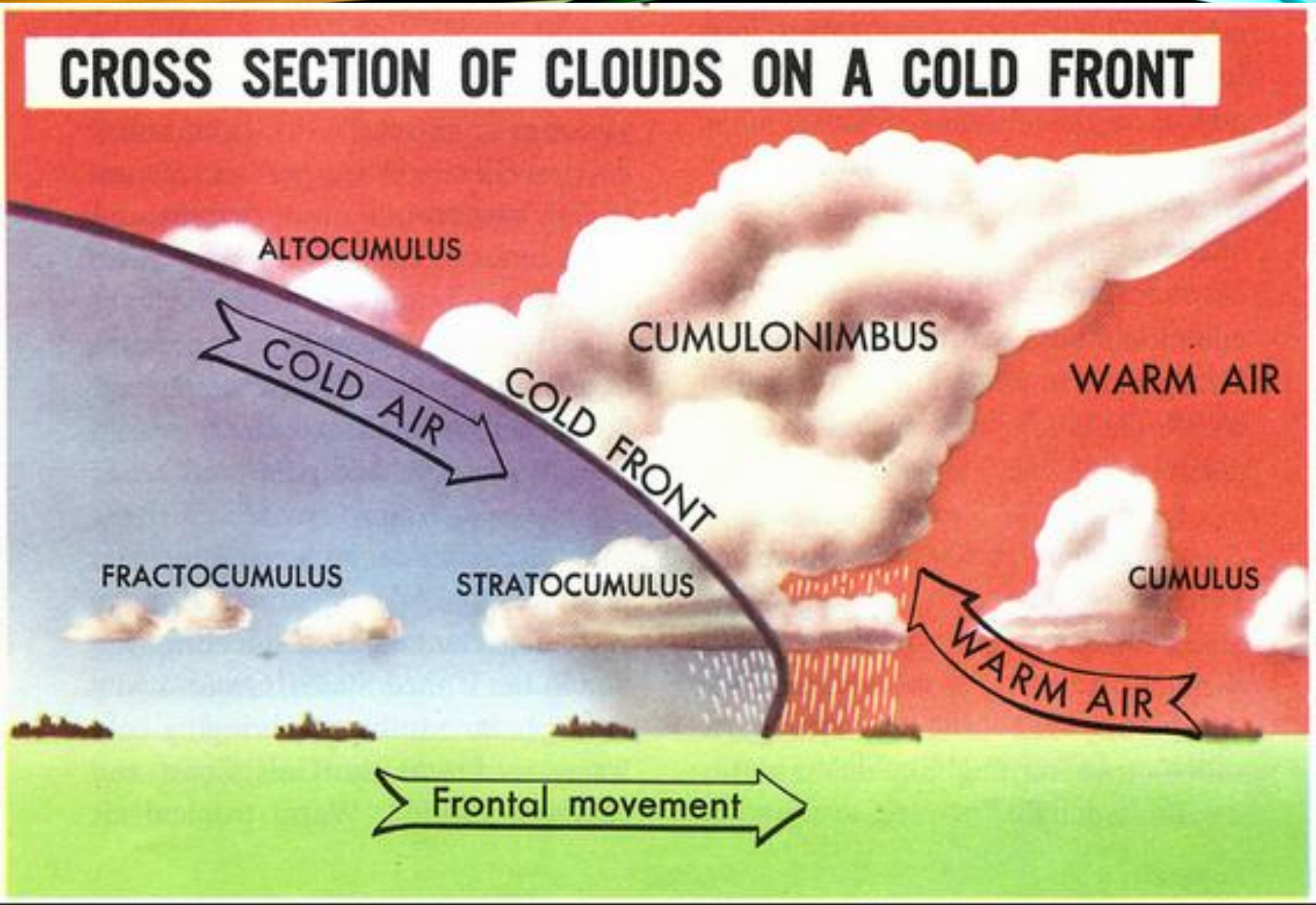
Based on their experience in Europe they realised that much of the rain occurred at the boundaries between air masses.

Given that they were developing their ideas during the First World War, the concept of a front arose.
https://www.youtube.com/watch?v=BLIZT2MuV_c

Cold front

- Leading edge of cooler air mass replacing warmer air mass
- Accompanied by temperature drop (20°C common), wind veers from NW to SW in southern hemisphere
- cumuliform clouds (including cumulonimbus) may form along fronts




CROSS SECTION OF CLOUDS ON A COLD FRONT
ALTOCUMULUS
COLD AIR
COLD FRONT
CUMULONIMBUS
WARM AIR
FRACTOCUMULUS
STRATOCUMULUS
CUMULUS
WARM AIR
Frontal movement

Frontal systems

A front is a boundary between two air masses of different density, temperature and humidity.

There are four main types of front:

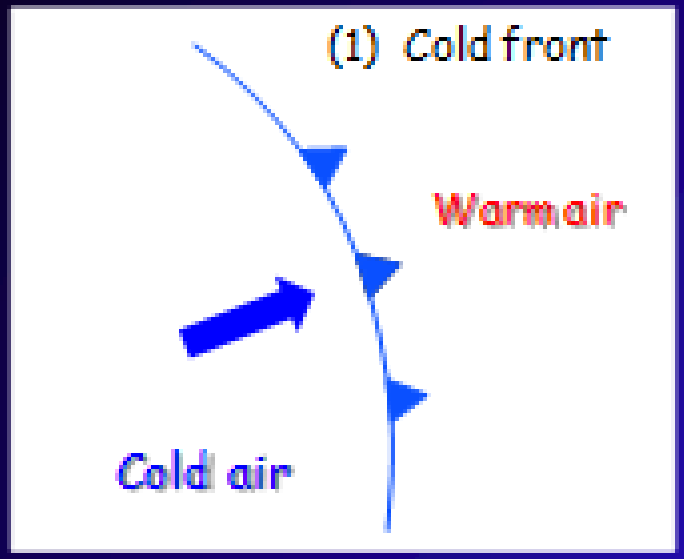
(1) Cold front
Boundary between a cooler air mass and the warmer air mass that it is undercutting and replacing

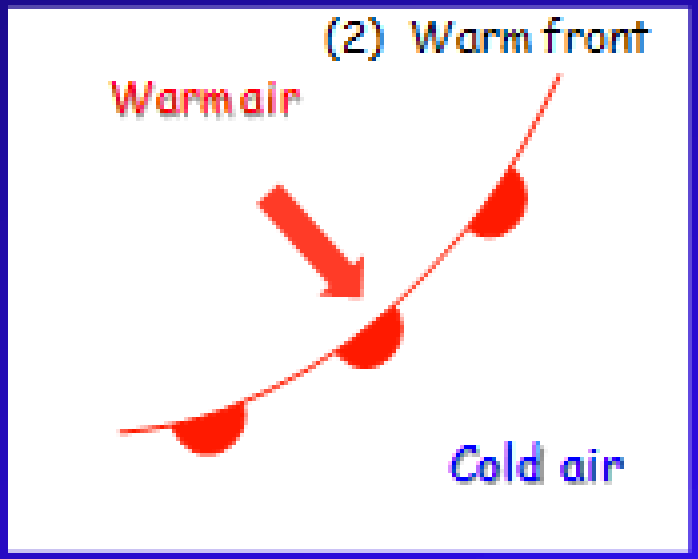
(2) Warm front
Boundary between warm air that is replacing cooler air

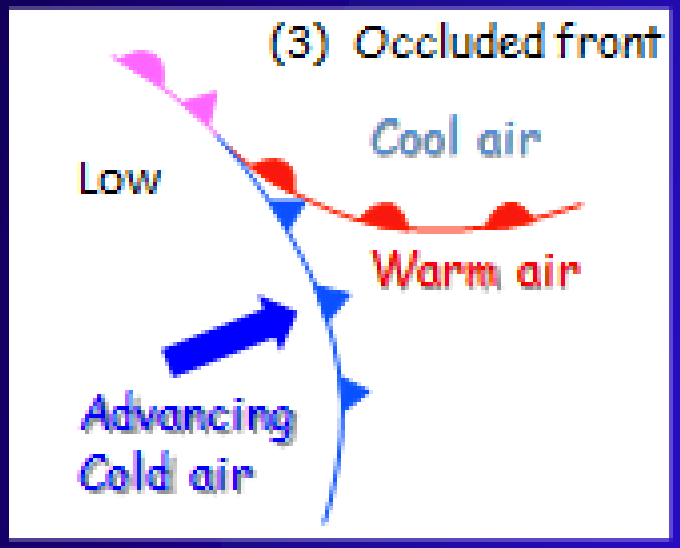
(3) Occluded front
Occurs when warm air overtakes cold air or vice versa

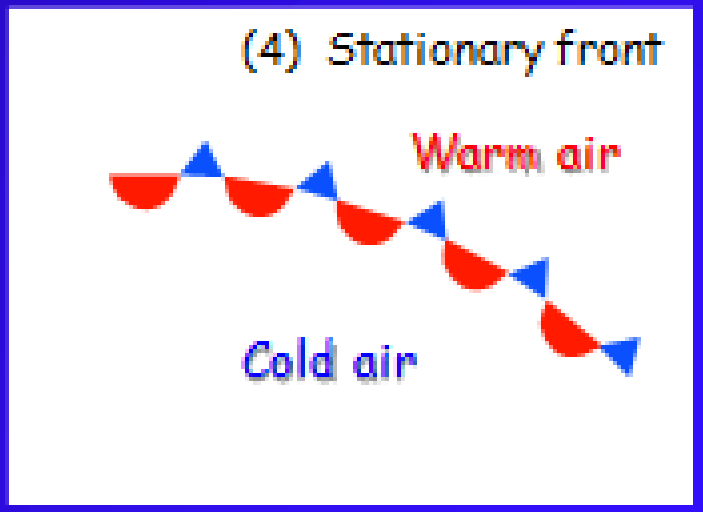
(4) Stationary front
Forms when cold front or warm front stops moving and neither is strong enough to replace the other

Fronts


(1) Cold front
Warm air
Cold air

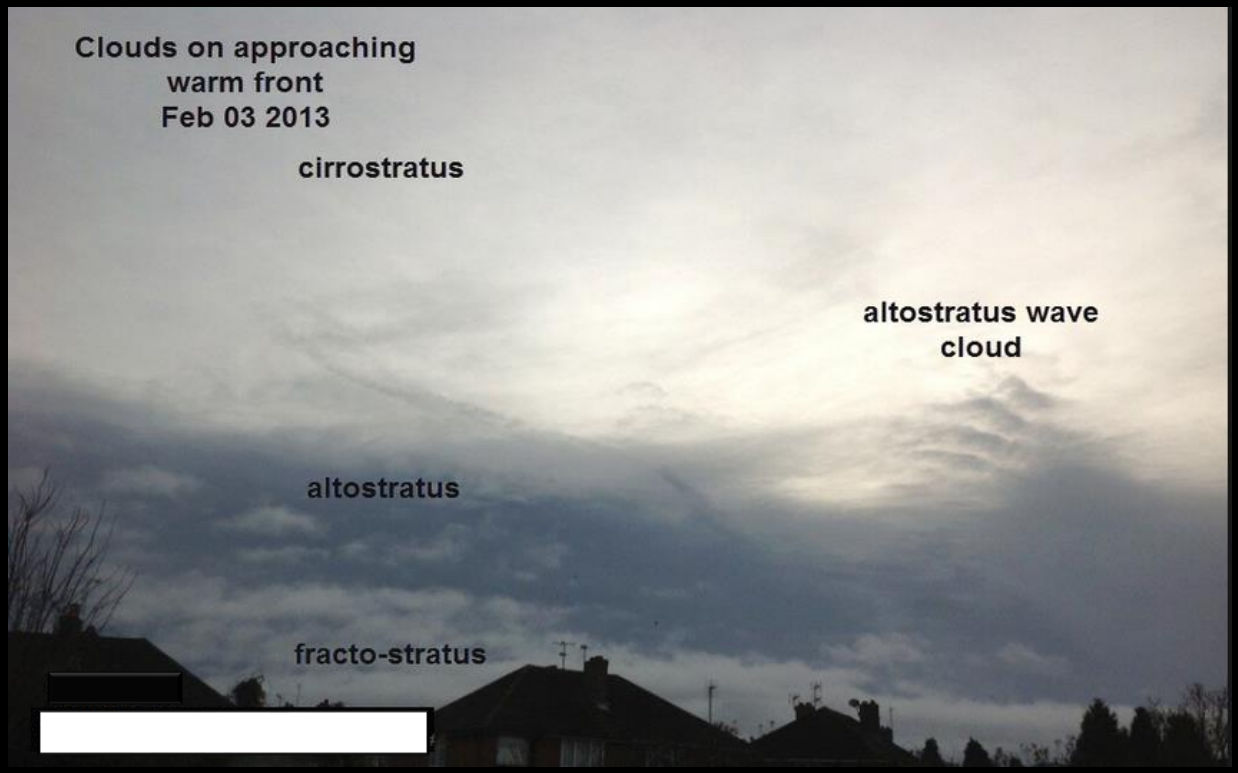

(2) Warm front
Warm air
Cold air


(3) Occluded front
Cool air
Low
Warm air
Advancing
Cold air

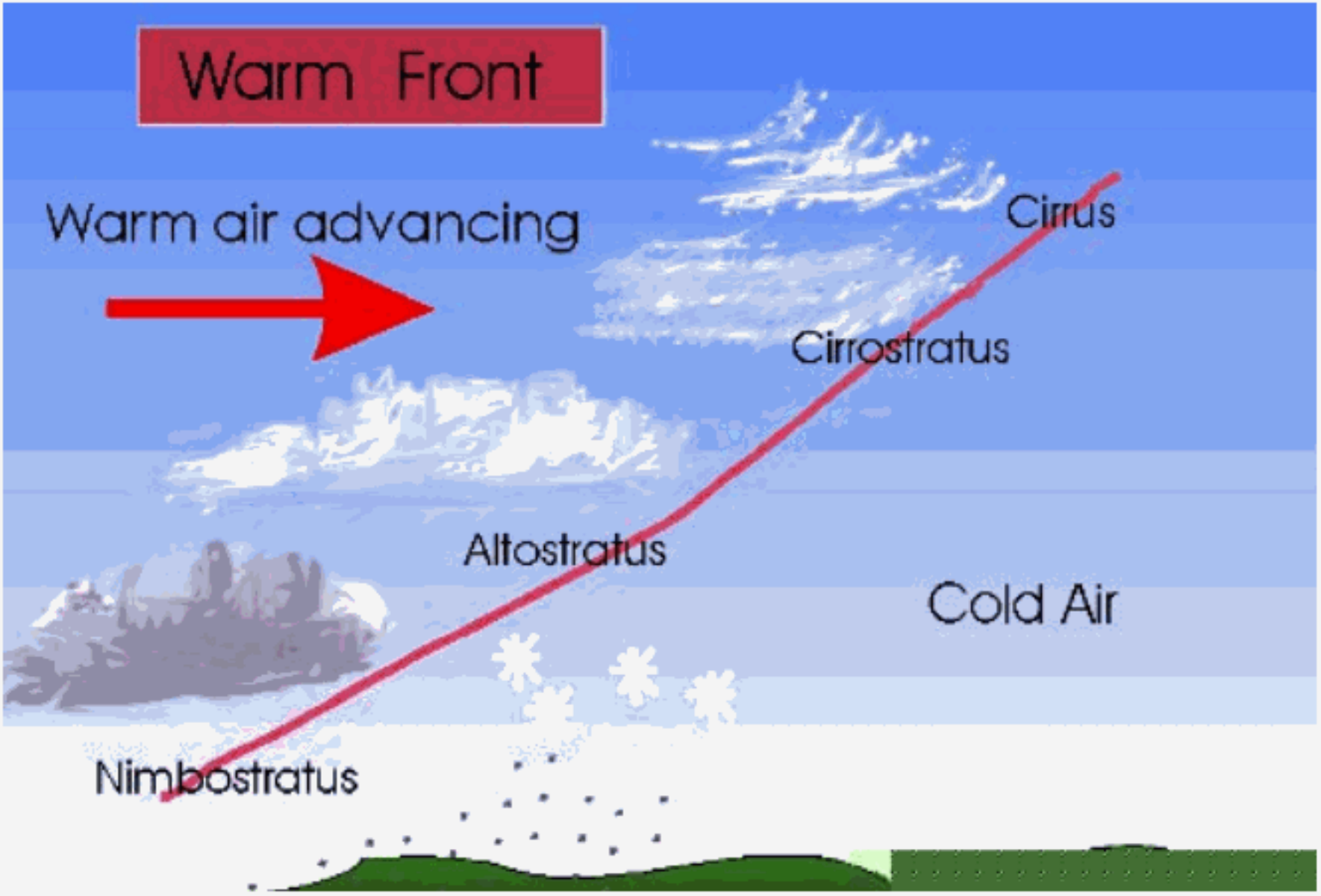

(4) Stationary front
Warm air
Cold air

Warm front

- Transition zone where warm air is progressively replacing cold air
- air behind warm front is warmer (and may be more humid) than the air ahead of it
- clouds ahead of warm front are mostly stratiform with increasing rainfall

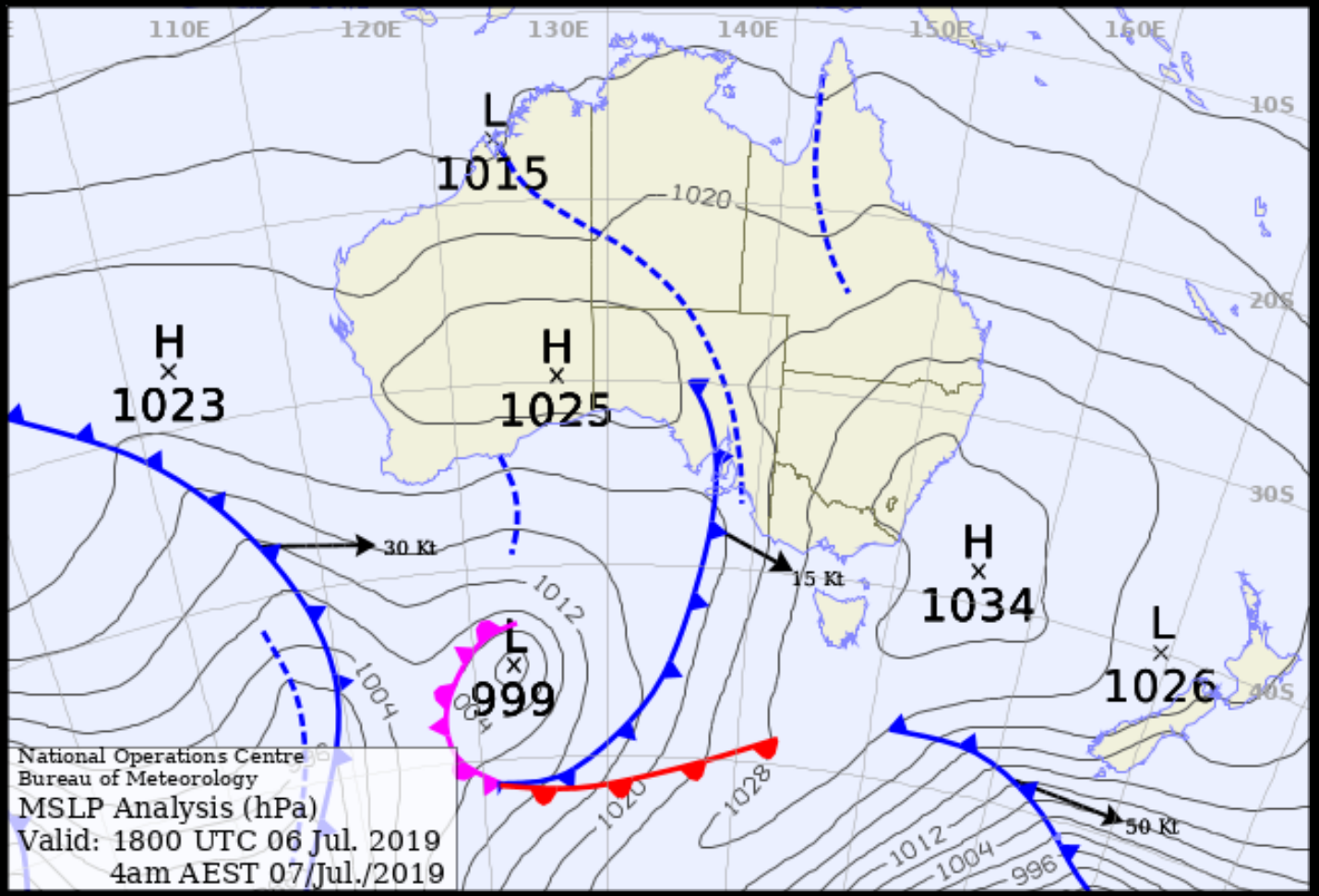


Warm front

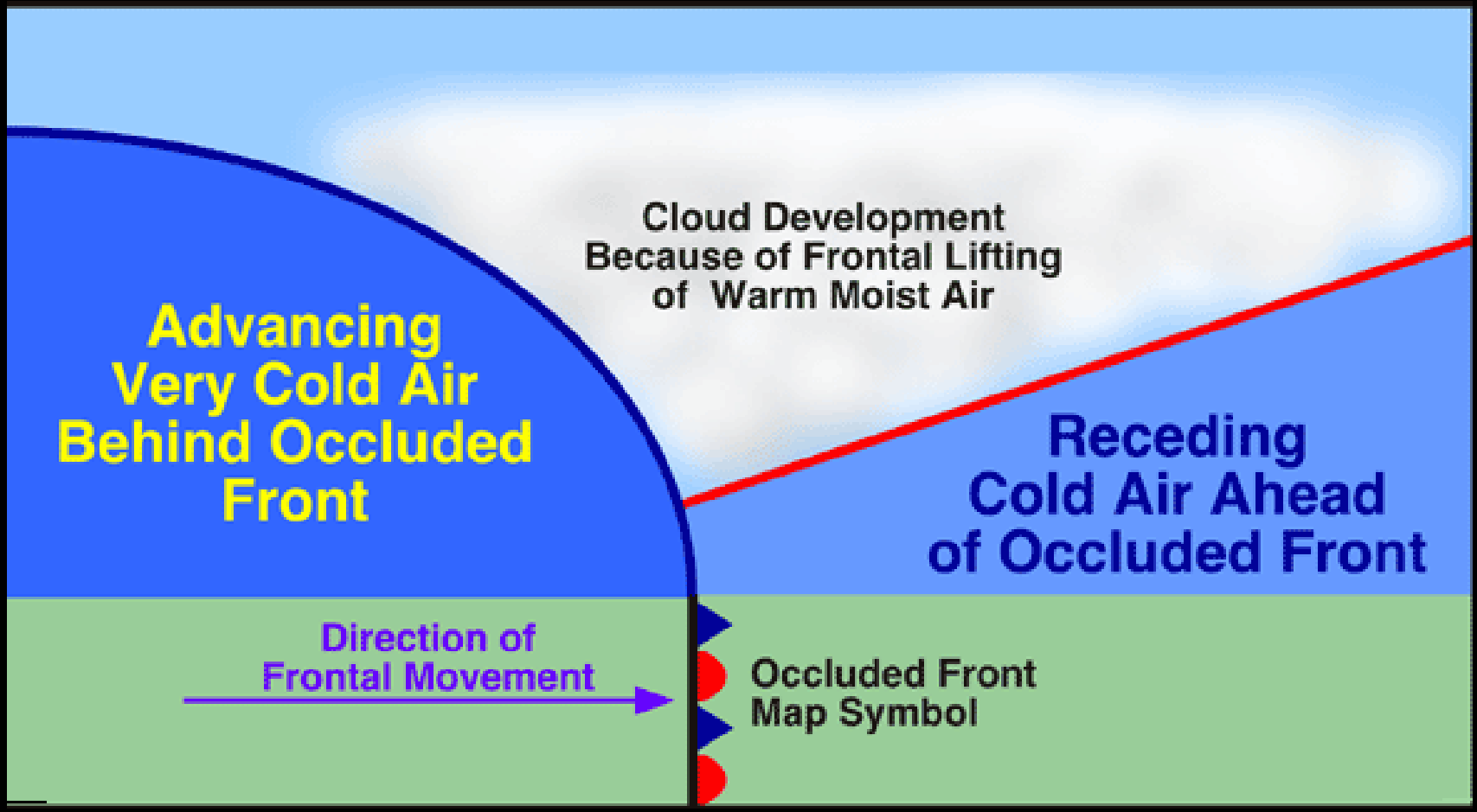

Warm Front
Warm air advancing
Cirrus
Cirrostratus
Altostratus
Cold Air
Nimbostratus

Occluded front

- Form during the intensifying of a low pressure system
- Occluded front occurs where one air mass overtakes another
- Can be heavy rainfall in tis cloud band wrapped around a low ("sting in the tail")



Occluded front



Cold fronts and warm fronts video:

Front as a “wedge”
https://www.youtube.com/watch?v=huKYKykjcm0&t=30s

(Met Office https://www.youtube.com/watch?v=G7Ewqm0YHUI)

BoM https://www.youtube.com/watch?v=OFeN5nMqT7M

https://www.abc.net.au/news/2019-07-12/what-is-a-cold-front/11303562