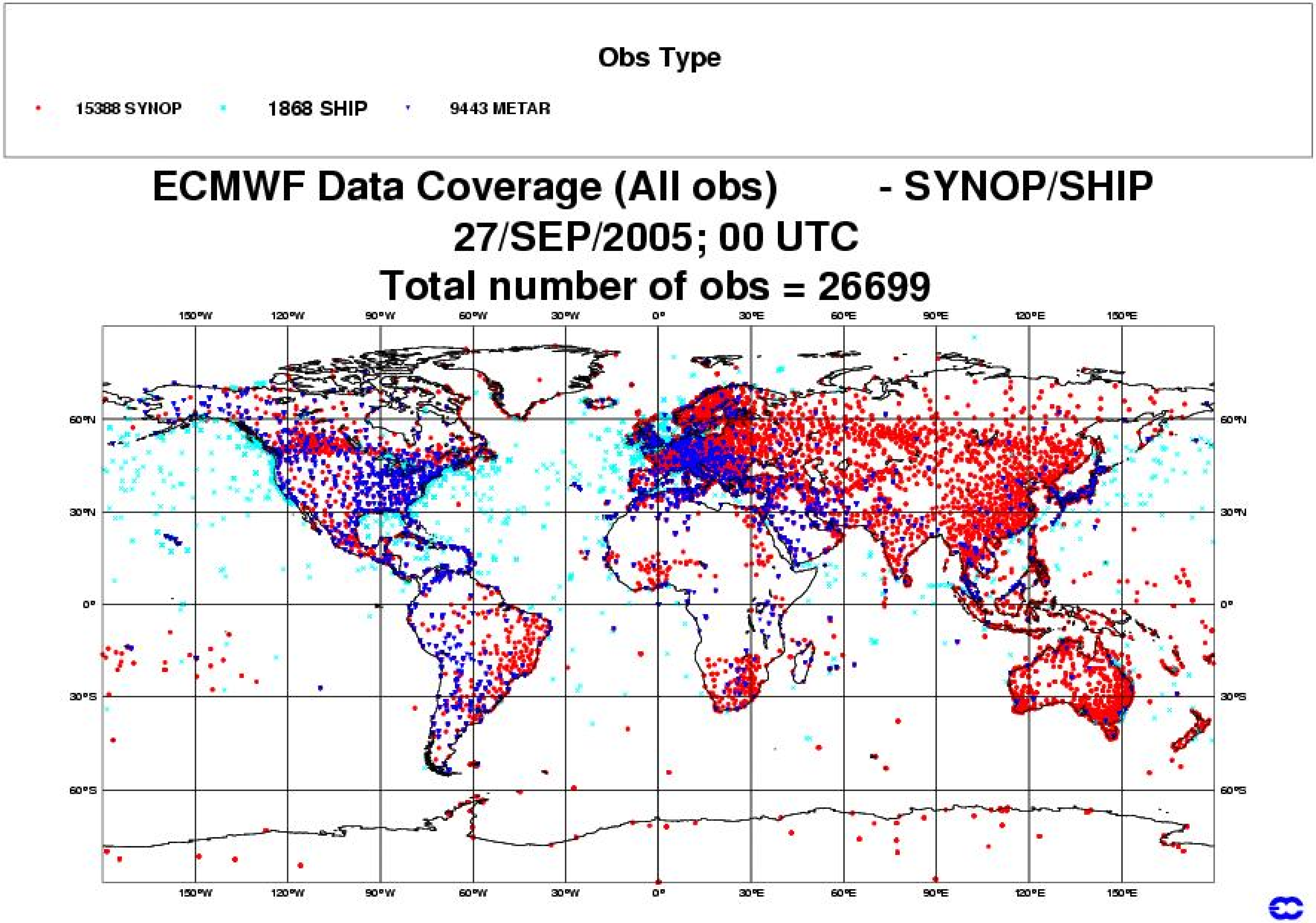
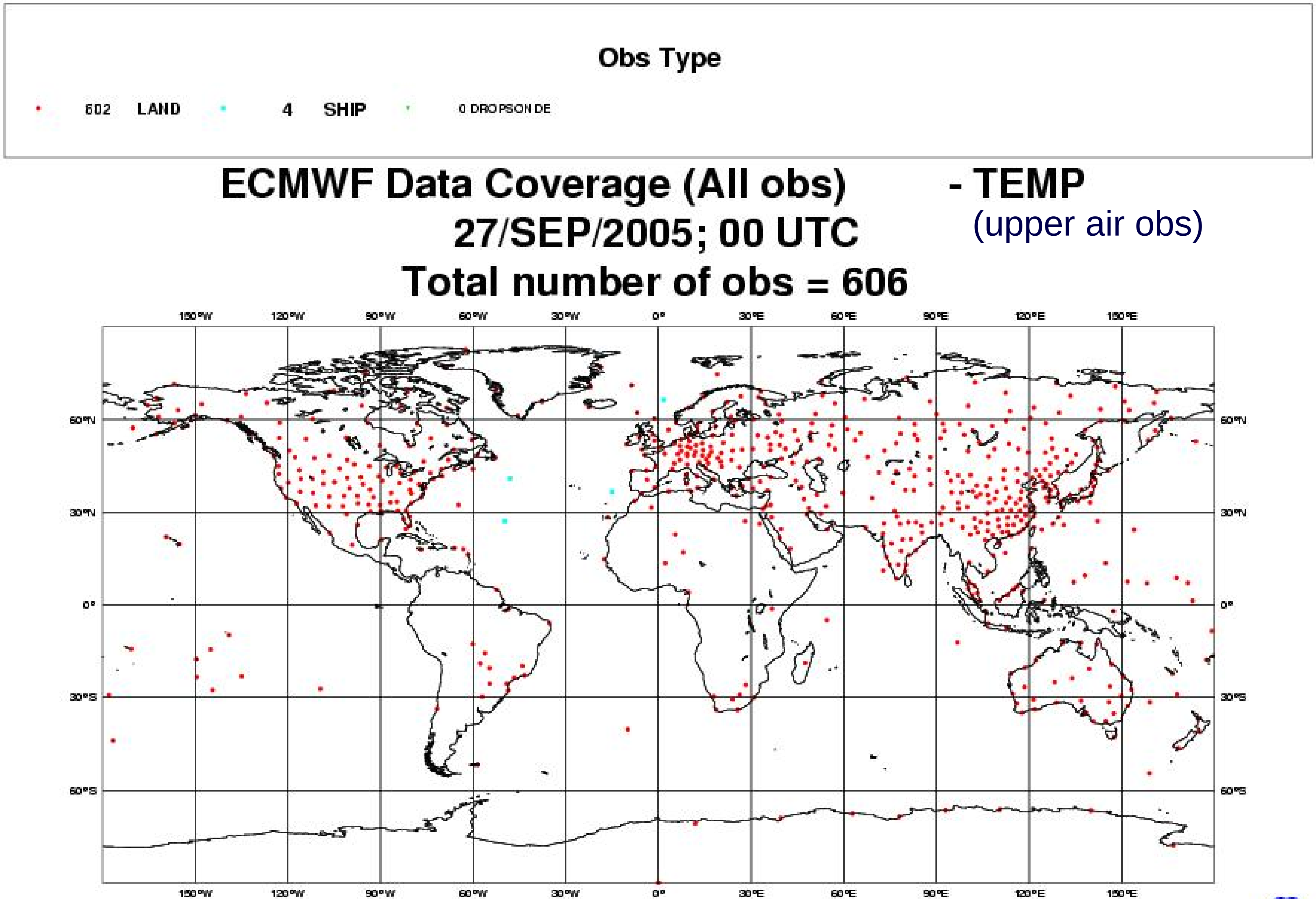
Model and remote-sensing data

SOEE1400 Lecture 5


Obs Type
15388 SYNOP
1868 SHIP
9443 METAR
ECMWF Data Coverage (All obs) - SYNOP/SHIP
27/SEP/2005; 00 UTC
Total number of obs = 26699

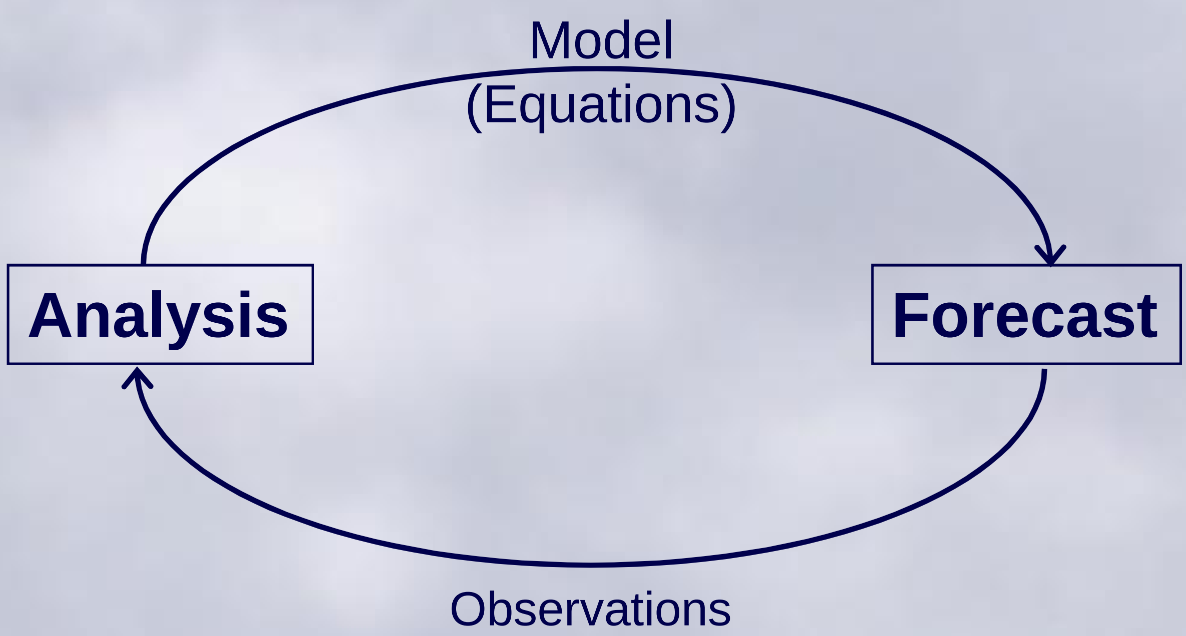

Obs Type
602 LAND
4 SHIP
0 DROPSONDE
ECMWF Data Coverage (All obs) - TEMP
(upper air obs)
27/SEP/2005; 00 UTC
Total number of obs = 606
150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E
60°N 30°N 0° 30°S 60°S

Synoptic Analysis

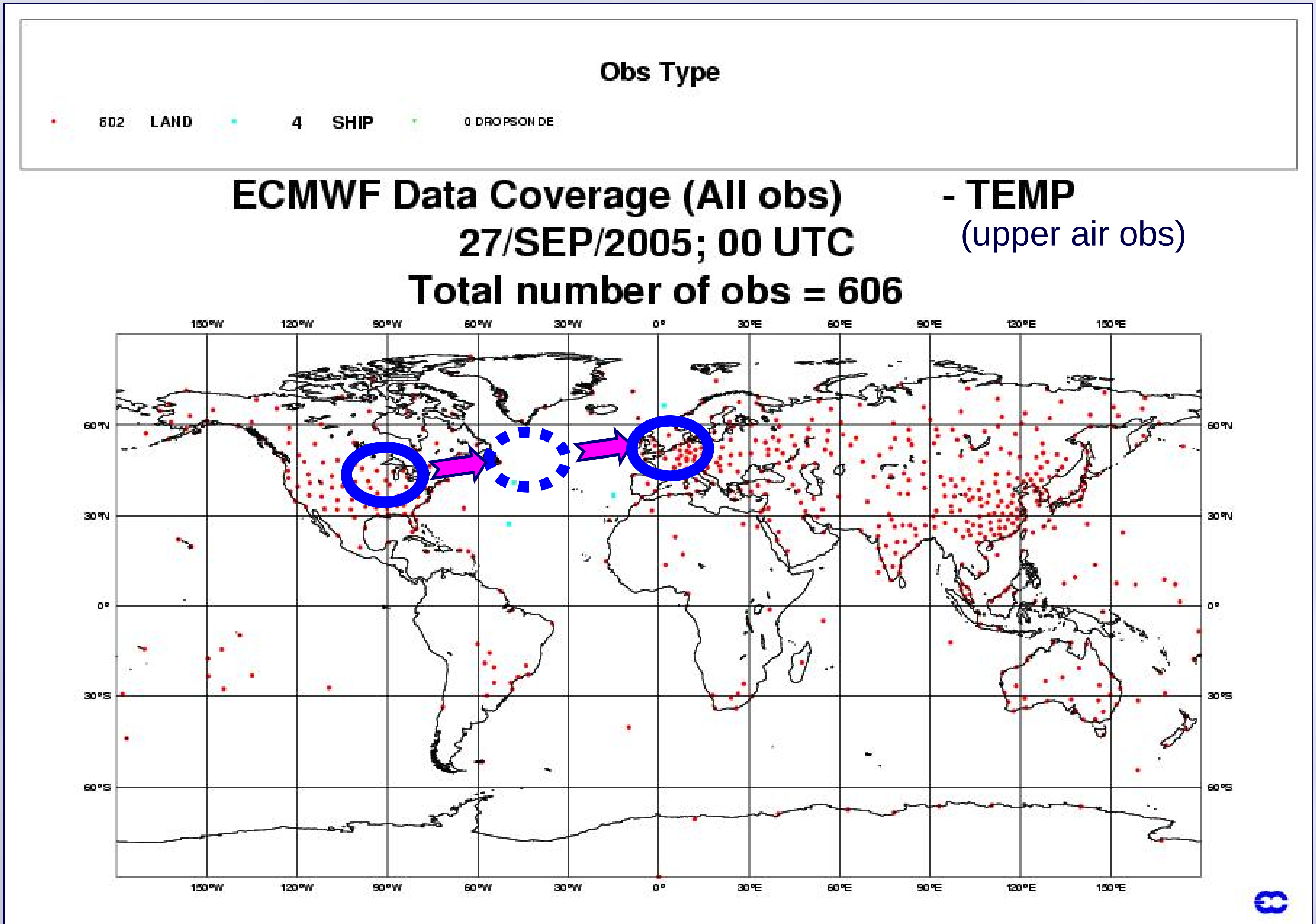
- A simple analysis based on the observed synoptic data provides an instantaneous snapshot of the state of the atmosphere
- Problems:
  - Very scattered observations…excessive interpolation in data sparse regions
  - Bias by individual measurements
    - Instrument error
    - Sample unrepresentative of general conditions

Model Analyses

- The use of numerical models in an analysis-forecast cycle introduces an extra dimension – **time**.



- ADVANTAGES:
  - Data from past observations affects present analysis (4D variable assimilation)
  - Regions without observations are handled more realistically because information from past observation upwind propagates into data-sparse region.
  - Raw observations are smoothed during interpolation onto model grid – helps remove bias from non-representative measurements.
- LIMITATIONS
  - Generally better than just sparse observations, BUT it is not real data – errors are very hard to assess.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REANALYSIS

- ECMWF (and NCEP in USA) conduct **reanalyses** of past $\rightarrow$ forecasts of past weather.
  - Not all observations are available in time to be included in regular forecast cycle
  - Allows time for extra quality control and corrections to be applied
- ECMWF:
  - ERA-15 : 1978-1993
  - ERA-40 : 1958-1997

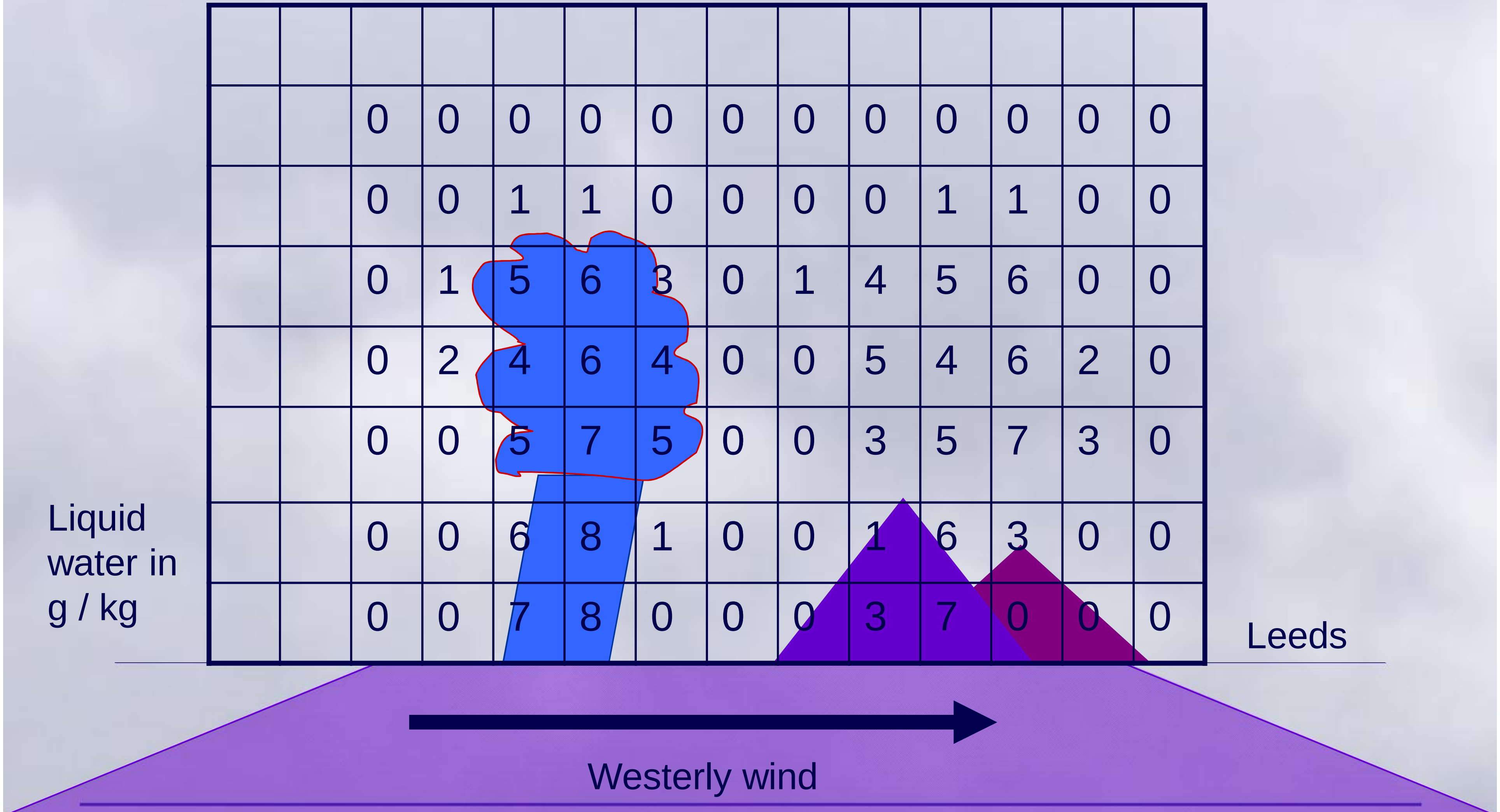
- Reanalysis data are used for:
  - Climatological studies
  - As model initialization fields (for research) in data-sparse regions or upper atmosphere
    - Atmospheric chemistry modelling studies
  - To provide boundary conditions for regional-scale modelling studies (Research)

MODELS

- Global models divide the world into a grid, data is held on the intersections of the grid.
- Figure shows a 10° grid
- MetOffice global model uses a grid of approximately 0.8° longitude by 0.5° latitude
  – UK represented by ~10x20 grid points (~60km spacing)

- MetOffice mesoscale model – higher resolution, limited area model.
- Uses the global model to provide initialization and boundary conditions.
  - 0.11° by 0.11° grid: approximately 11km resolution.
  - 38 vertical levels in both global and mesoscale models, spacing increases with altitude.

Numerical weather prediction.

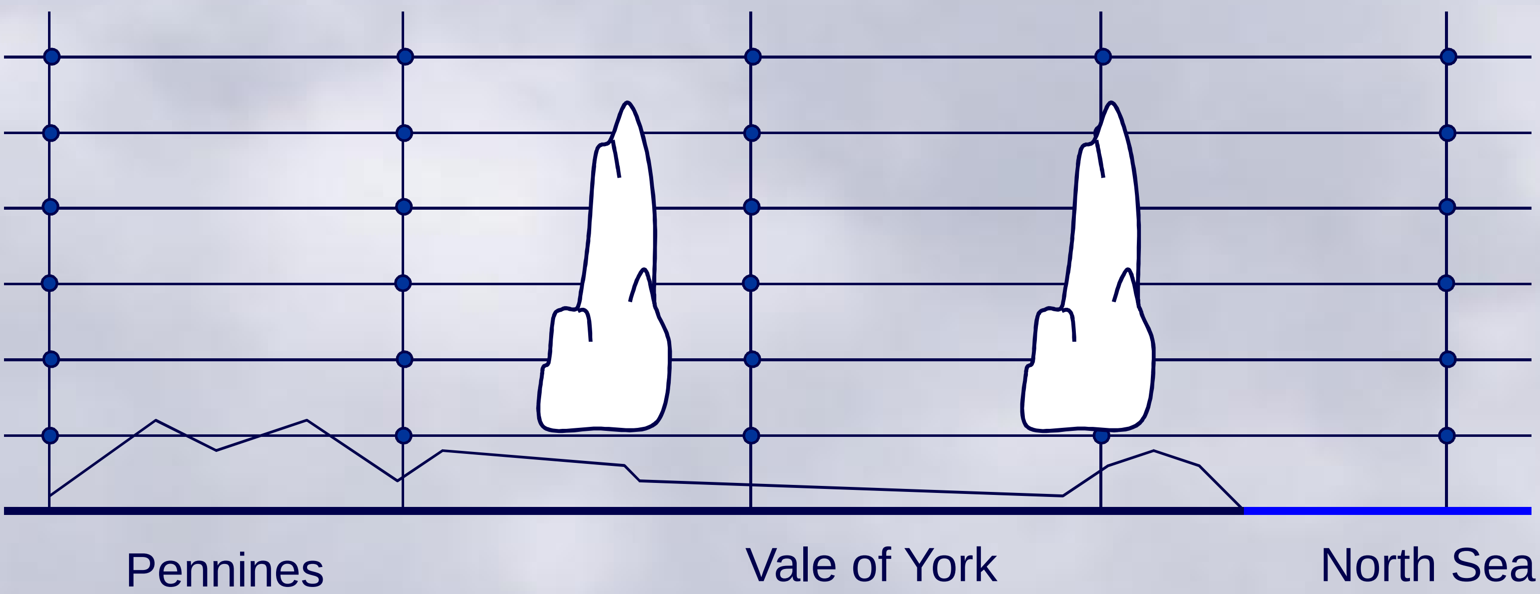


		0	0	0	0	0	0	0	0	0	0	0	0
		0	0	1	1	0	0	0	0	1	1	0	0
		0	1	5	6	3	0	1	4	5	6	0	0
		0	2	4	6	4	0	0	5	4	6	2	0
		0	0	5	7	5	0	0	3	5	7	3	0
		0	0	6	8	1	0	0	1	6	3	0	0
		0	0	7	8	0	0	0	3	7	0	0	0

Model resolution is too low to resolve:

- Individual clouds, even large thunderstorms.
- Full details of topography
- Details of changes of surface type

Processes on scales smaller than the grid must be **parameterized**.

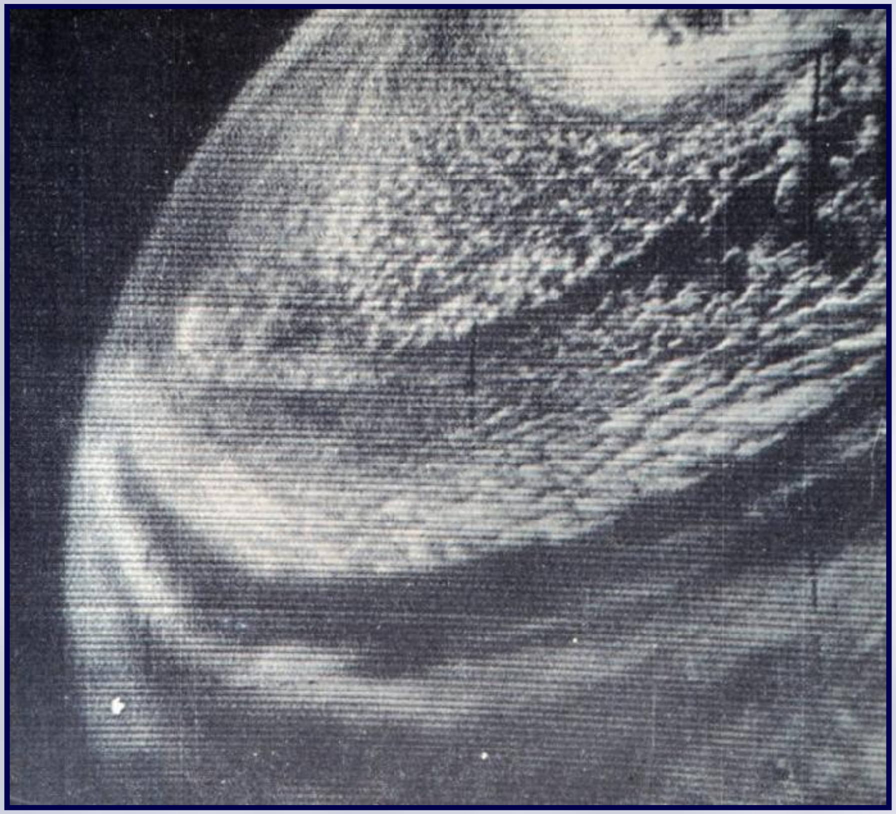


Parameterization

- **Parameterization** is the simplification of a complex physical process in terms of **parameters** that are available to the model, or readily measured.
- Models must use parameterizations of processes that :
  - Take place on scales smaller than the model grid
  - Involve parameters that are not explicitly defined in the model

Satellite Data

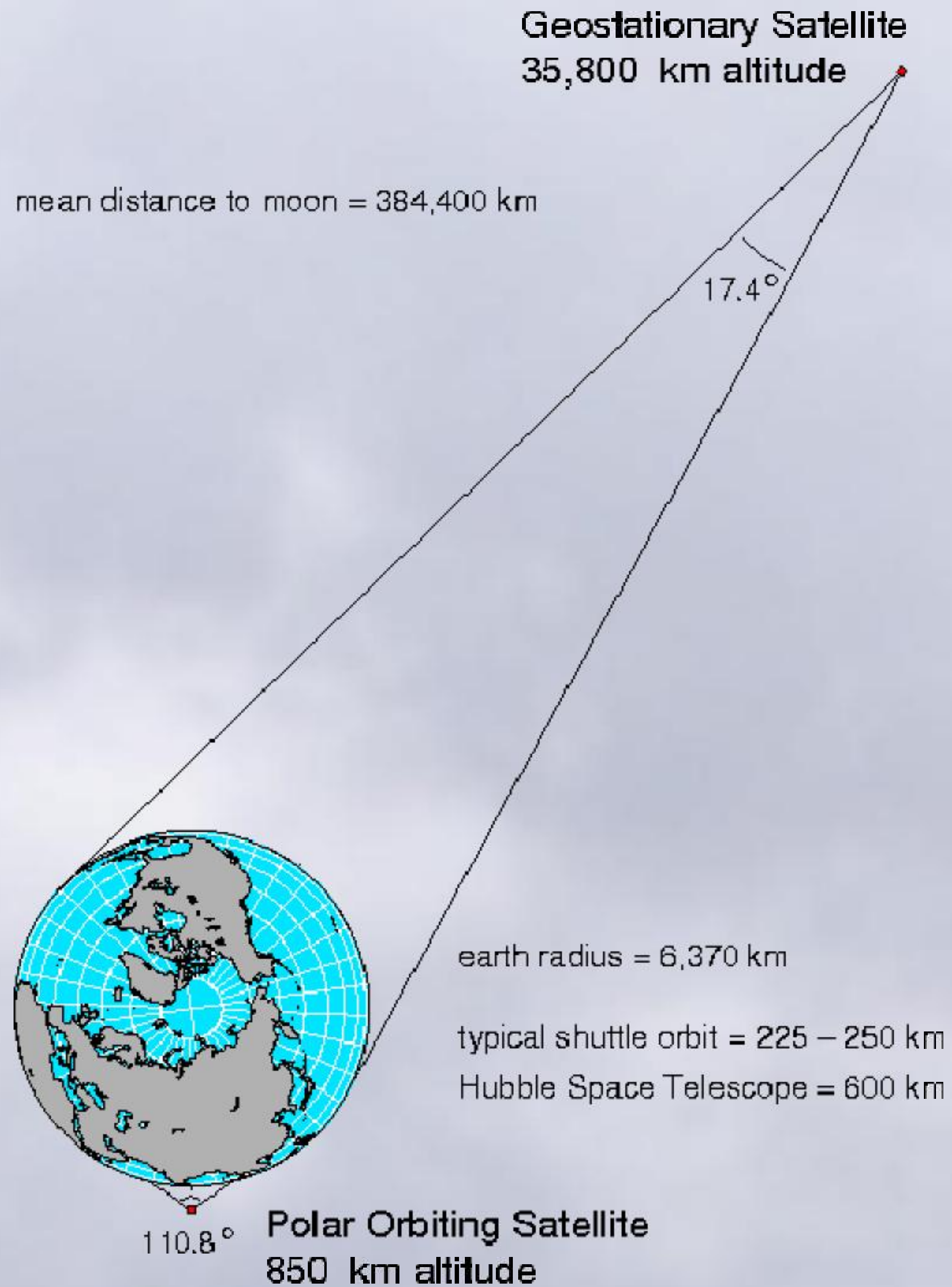
- First meteorological satellite: TIROS-1 (Television Infrared Observation Satellite), launched April 1, 1960.

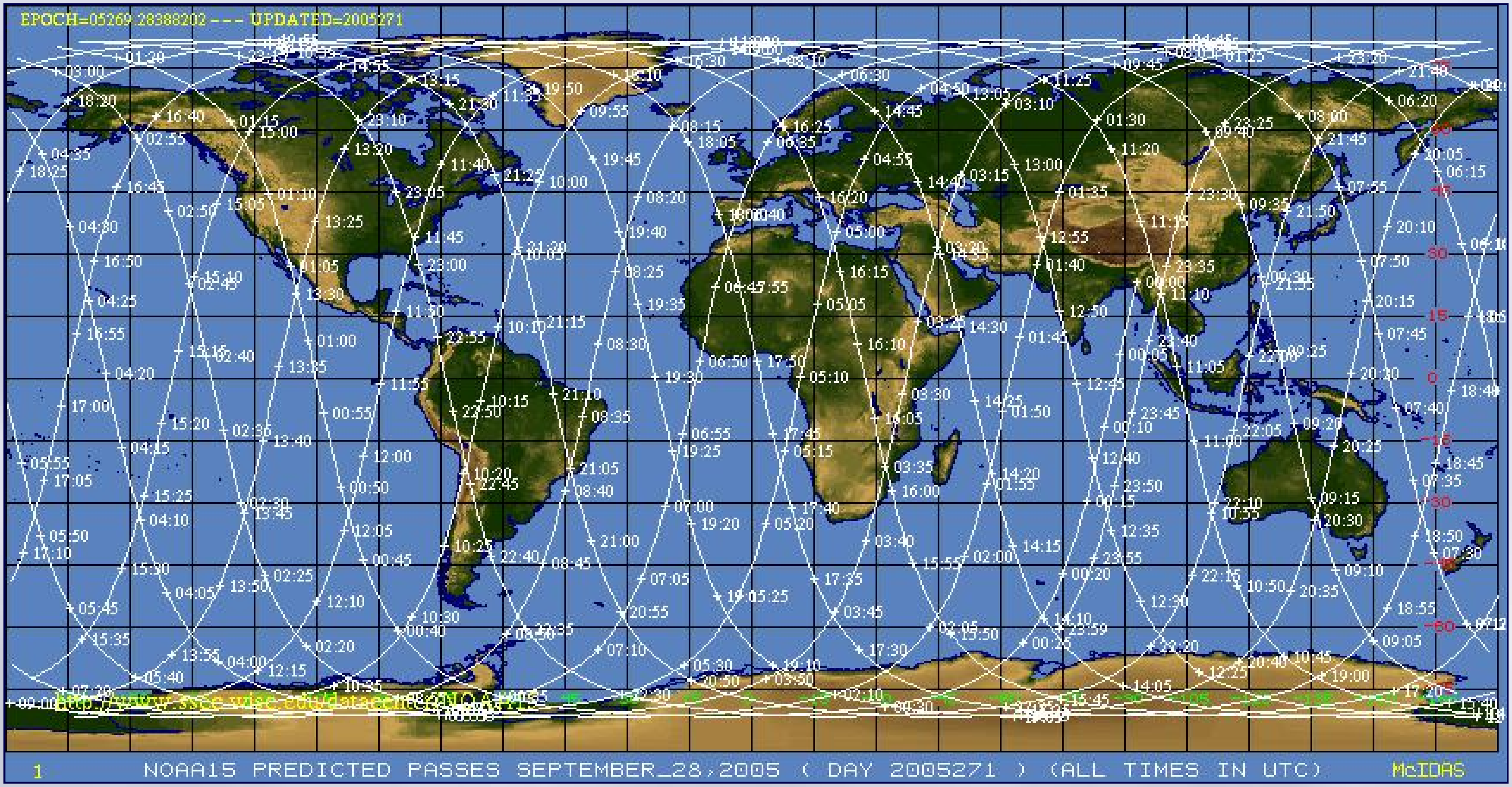


TIROS-1 image of tropical storm in Pacific, April 1960.

- **Geostationary satellites**:
  - remain above the same spot on the Earth’s surface – orbital period = period of rotation of earth.
  - Approximately 36000km above surface.
  - 5 or 6 satellites spaced to give coverage of whole earth.
  - e.g: METEOSAT (EU), GOES series (USA)
- **Polar Orbiting**:
  - Orbit is oriented north-south (inclined slightly). Often sun-synchronous.
  - Orbital period ~100 minutes.
  - Pass over different part of surface on every orbit – passes over same spot at irregular intervals.
  - Low-altitude (700-800km) allows much higher resolution imagery than geostationary satellites.

See: http://www.sat.dundee.ac.uk, http://www.goes.noaa.gov/


Geostationary Satellite
35,800 km altitude
mean distance to moon = 384,400 km
17.4°
earth radius = 6,370 km
typical shuttle orbit = 225 – 250 km
Hubble Space Telescope = 600 km
110.8°
Polar Orbiting Satellite
850 km altitude



NOAA-15 polar orbiter ground track for September 28 2005.

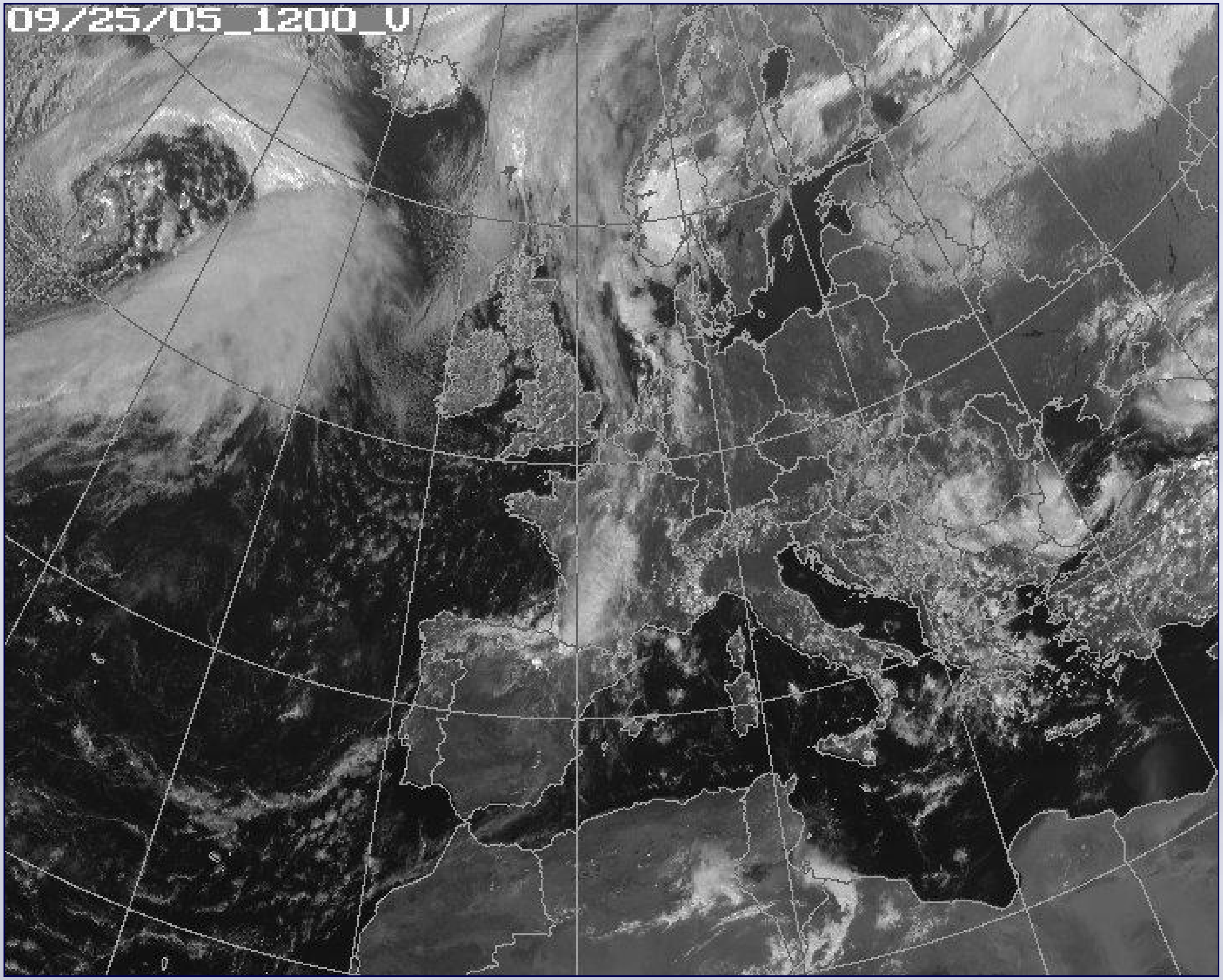
Satellite data … main channels

- Visible imagery (B/W and true colour):
  - “like a photograph from space” – interpretation is intuitive.
  - Thin cloud (particularly cirrus) can be transparent.
  - No use at night.
- Infrared imagery (multiple wavelengths in IR)
  - AVHRR imagery from Dundee archive: CH2 = visible, CH4 = thermal infrared.
- Water vapour concentration (integrated through full depth of atmosphere)

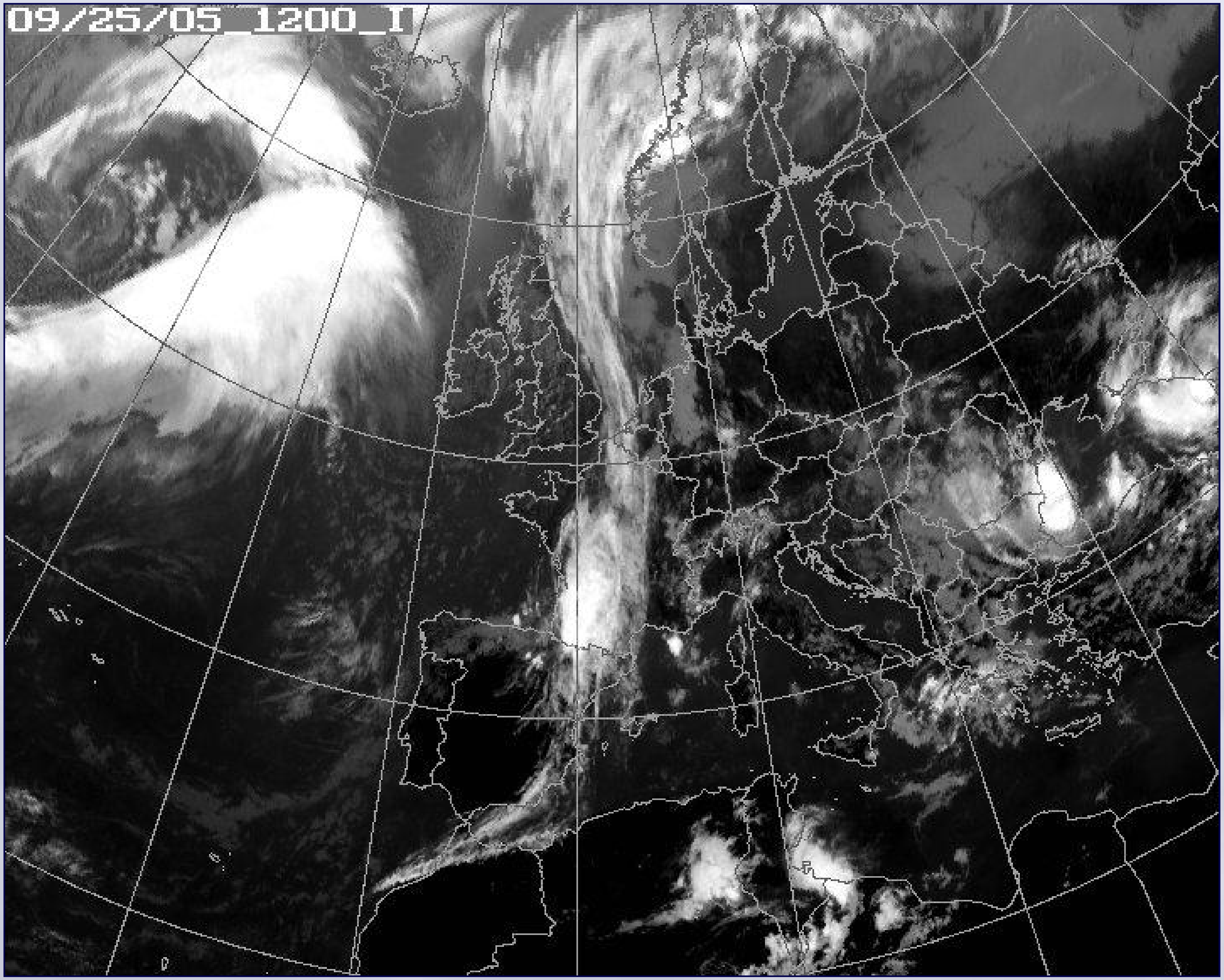
Examples …

Satellite data … others …

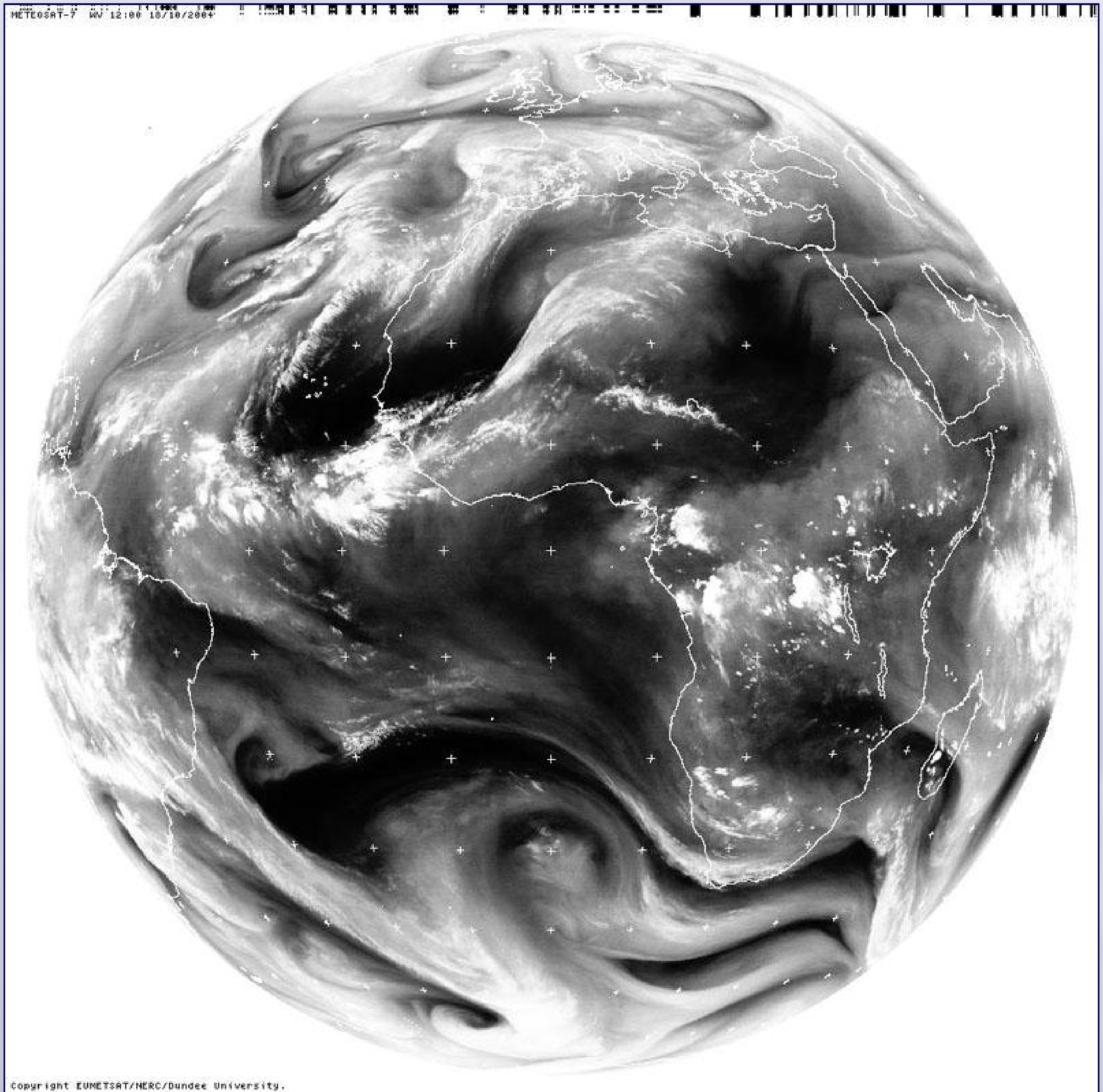
- Sea Surface Temperature
- Ocean Chlorophyll content
- Land use
- Wind speed over ocean from synthetic aperture radar (SAR)
- Chemistry (O_3, NO_2,…)

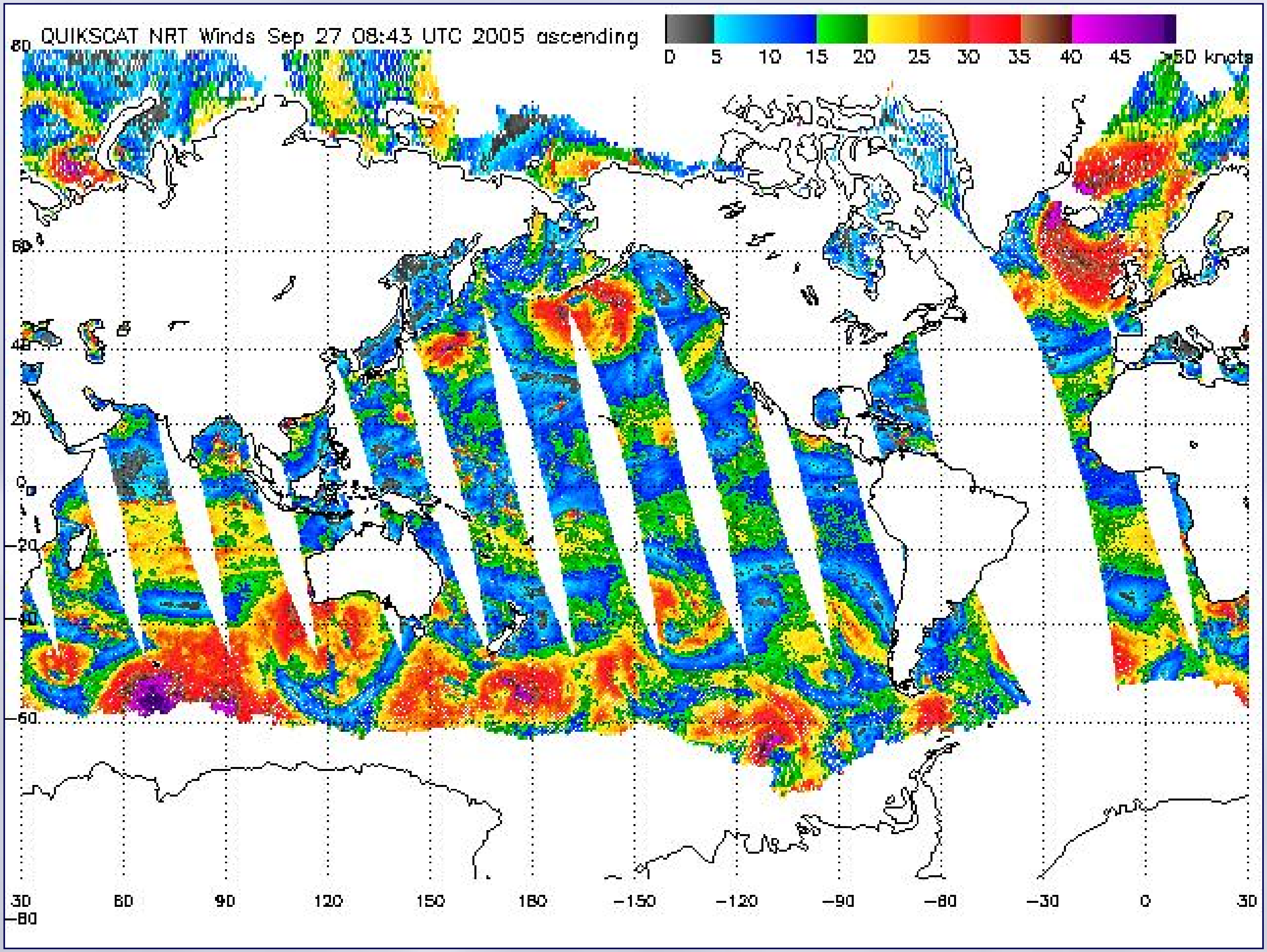


Visible imagery from METEOSAT

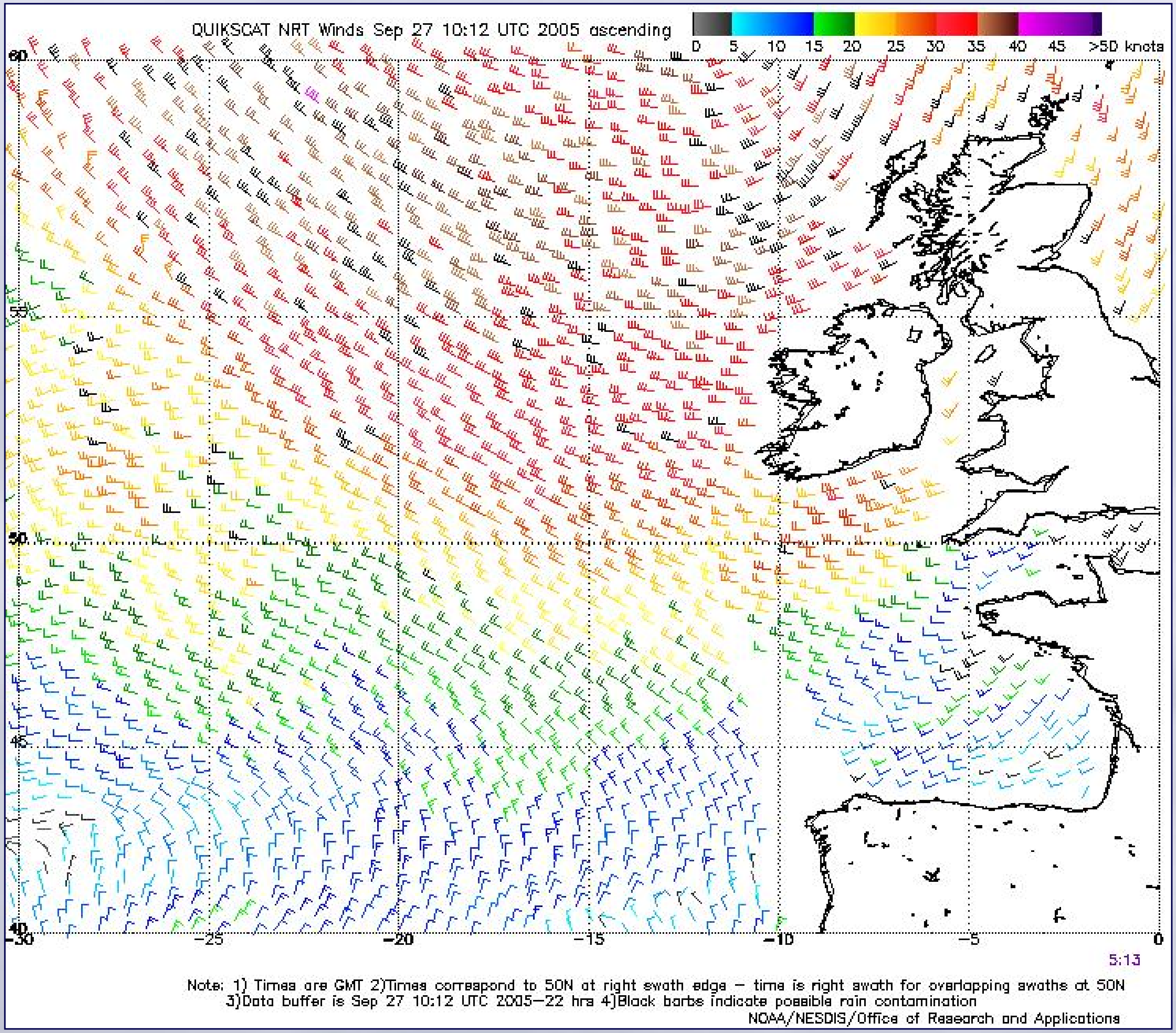


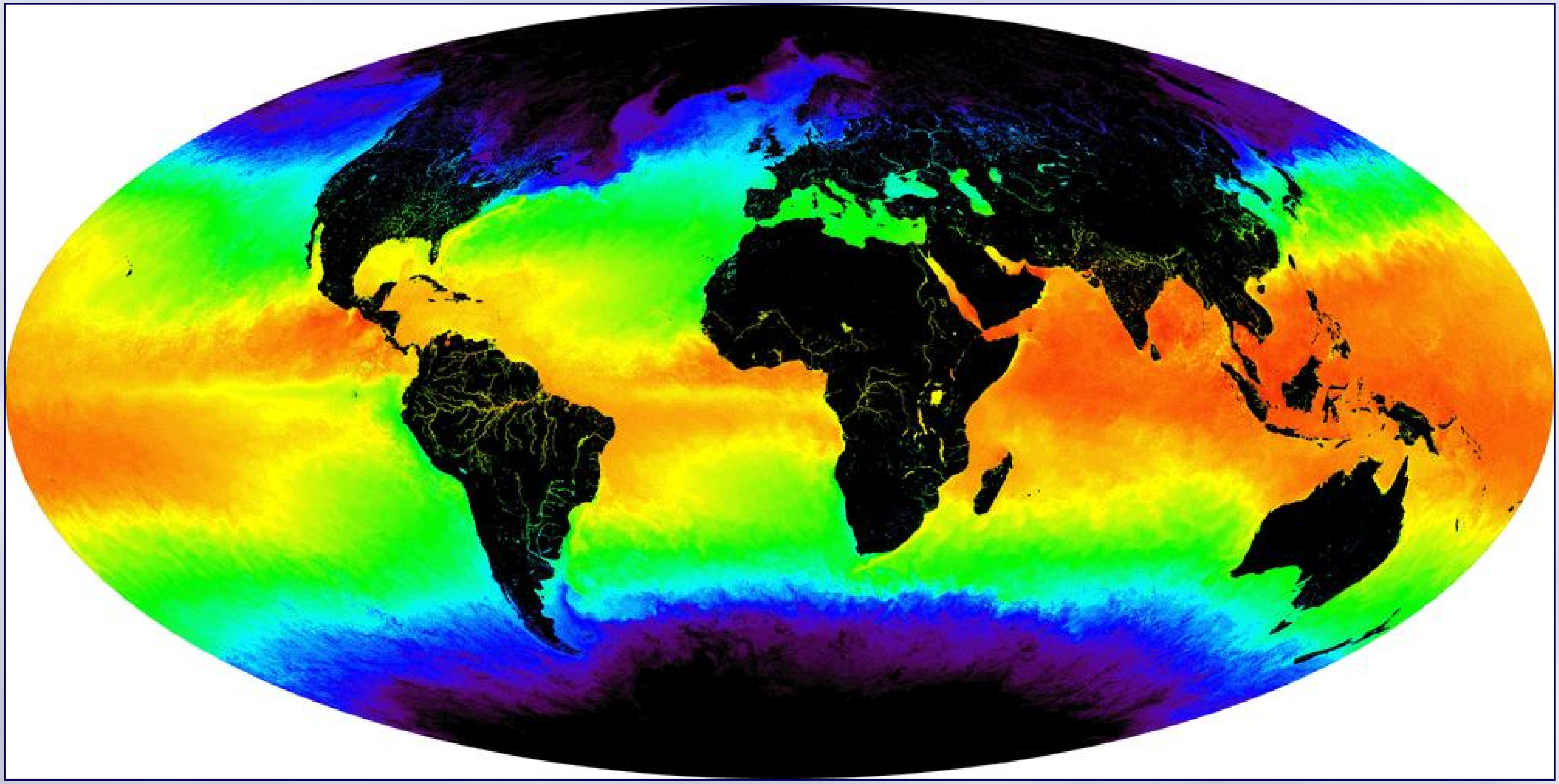
Infra red imagery from METEOSAT


METEOSAT-7 WV 12:00 10/10/2004
Copyright EUMETSAT/NERC/Dundee University.

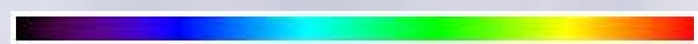


QuikScat winds derived from SAR measurements
(includes 22 hours of data)


QUIKSCAT NRT Winds Sep 27 10:12 UTC 2005 ascending
0 5 10 15 20 25 30 35 40 45 >50 knots
60
55
50
45
40
-30 -25 -20 -15 -10 -5 0
5:13
Note: 1) Times are GMT 2)Times correspond to 50N at right swath edge – time is right swath for overlapping swaths at 50N
3)Data buffer is Sep 27 10:12 UTC 2005–22 hrs 4)Black barbs indicate possible rain contamination
NOAA/NESDIS/Office of Research and Applications



MODIS sea surface temperature



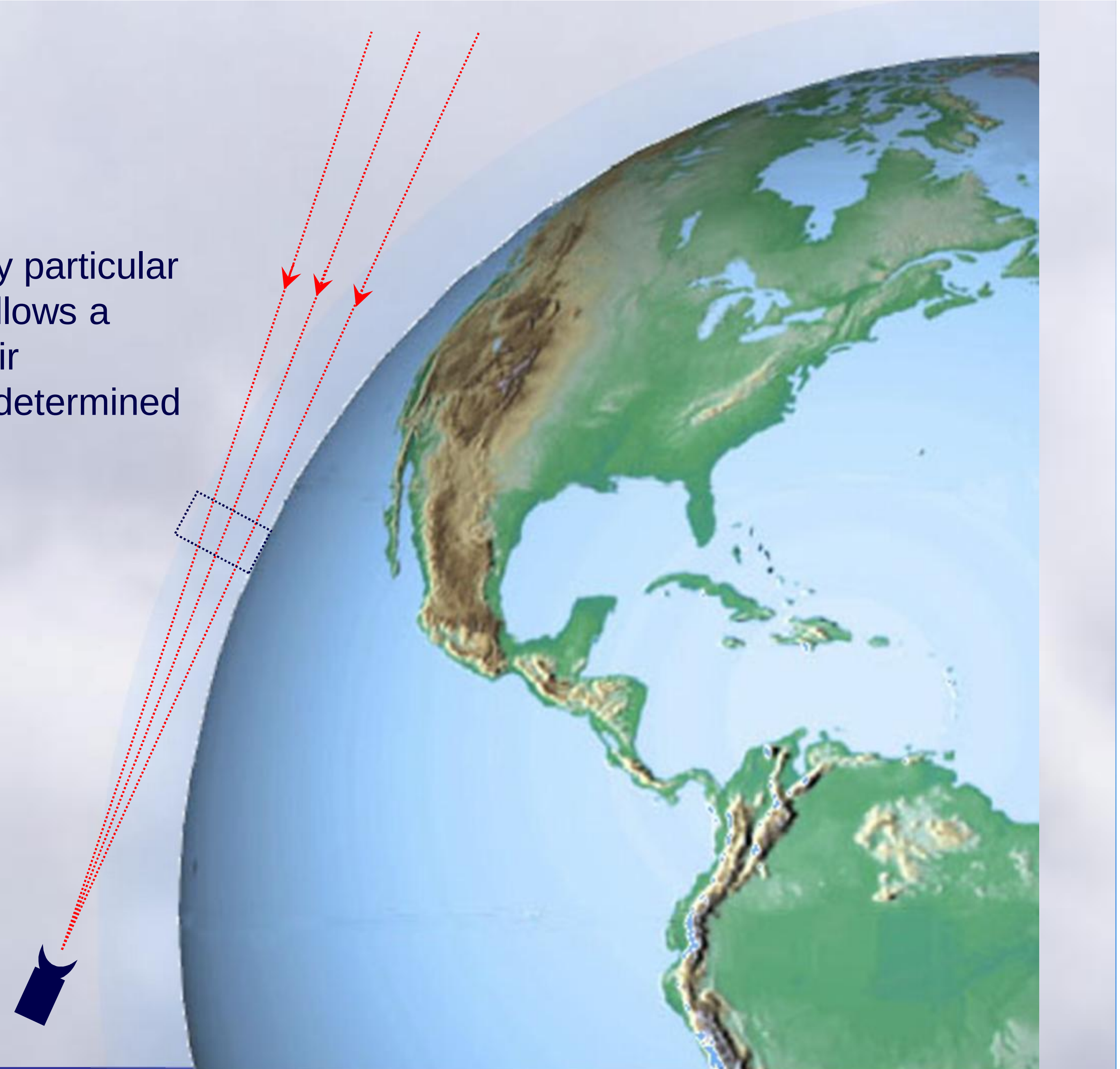
-2 îC **35 îC**

Vertical profiles from satellites

- Most satellites look vertically downwards – data is either:
  - Vertical integral through atmosphere (e.g. water vapour)
  - Represents value at some upper altitude (cloud top)
  - Surface value
- In latter two cases, it can sometimes be difficult to determine vertical location e.g:
  - distinguishing cloud from snow/ice,
  - low cloud temperature from surface temperature.

- Vertical profiles of some quantities can be obtained via limb-sounding – looking at the edge (limb) of the visible disk of earth, i.e. sideways through the atmosphere.
  - Vertical resolution is good
  - Horizontal resolution is poor
- Particularly useful for chemical measurements, where certain wavelengths of light are absorbed by known chemical species.

Absorption of light by particular molecular species allows a vertical profile of their concentration to be determined



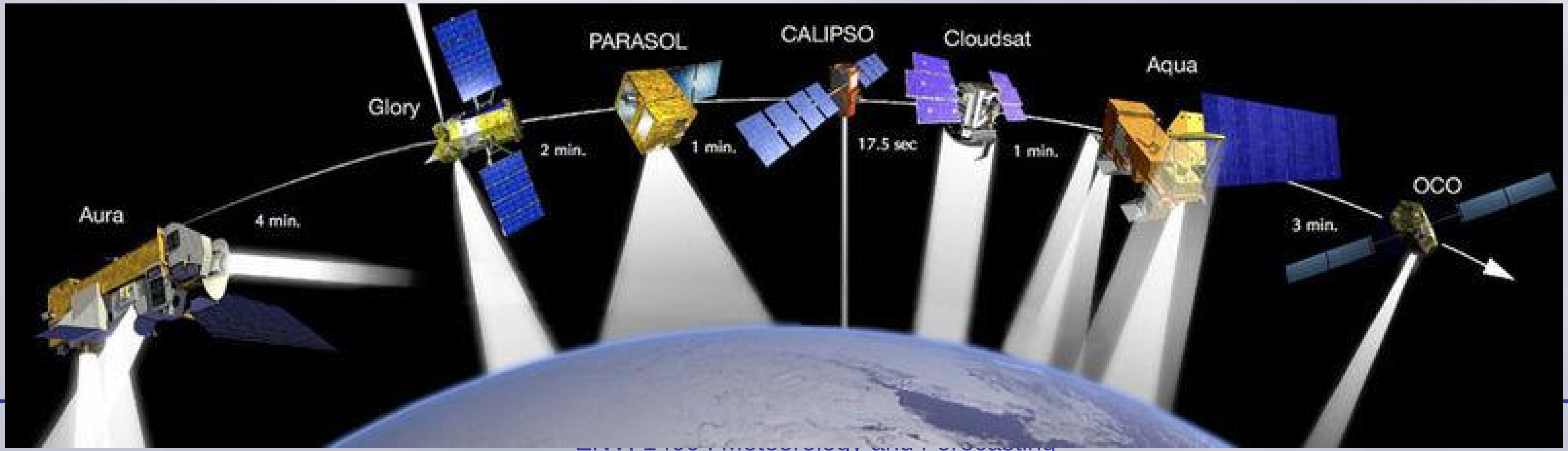
Satellite data: active sensors

- Active sensors transmit a beam of radiation which is reflected from atmospheric constituents (clouds, rainfall, aerosol …) back to a sensor on the satellite.

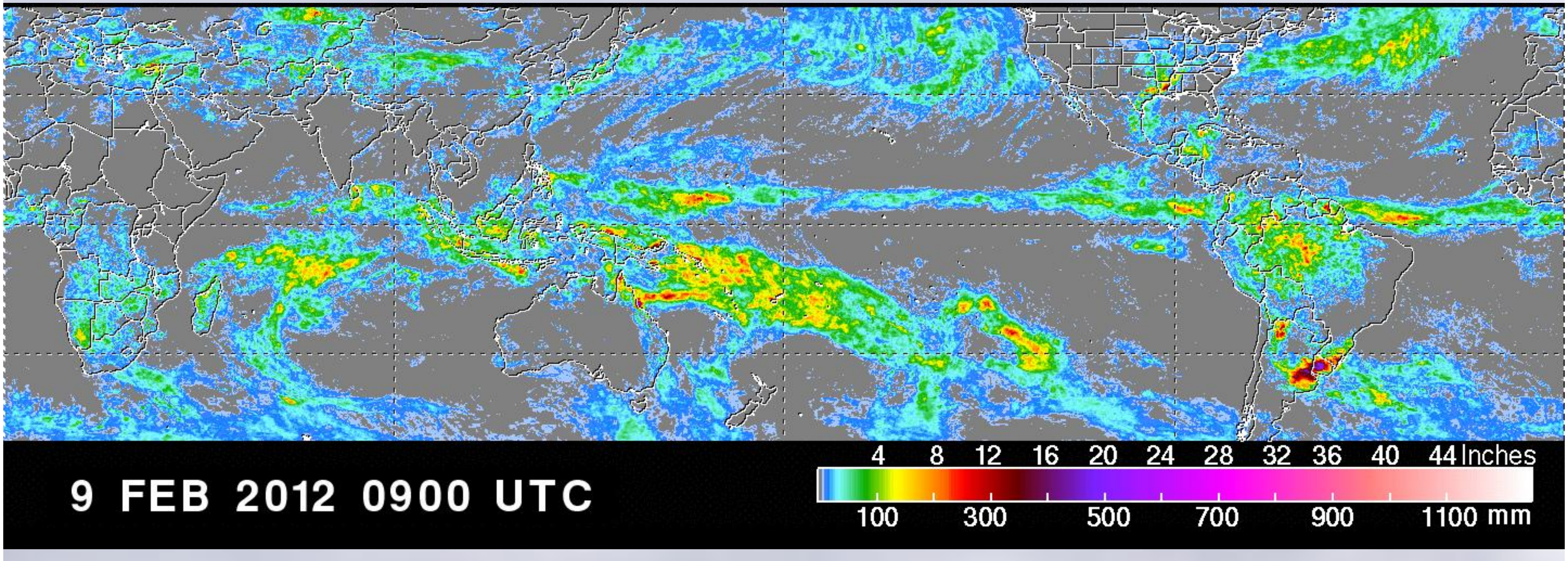
- Examples:
  - TRMM (space-borne rainfall radar) – “sees” rainfall within cloud.

    http://trmm.gsfc.nasa.gov/
  - CloudSat (space-borne cloud and rainfall radar)
  - CALIPSO (space-borne lidar) – sees aerosol, thin cirrus and cloud-top.

The A-train (NASA)



TRMM


9 FEB 2012 0900 UTC
4 8 12 16 20 24 28 32 36 40 44 Inches
100 300 500 700 900 1100 mm

CloudSat

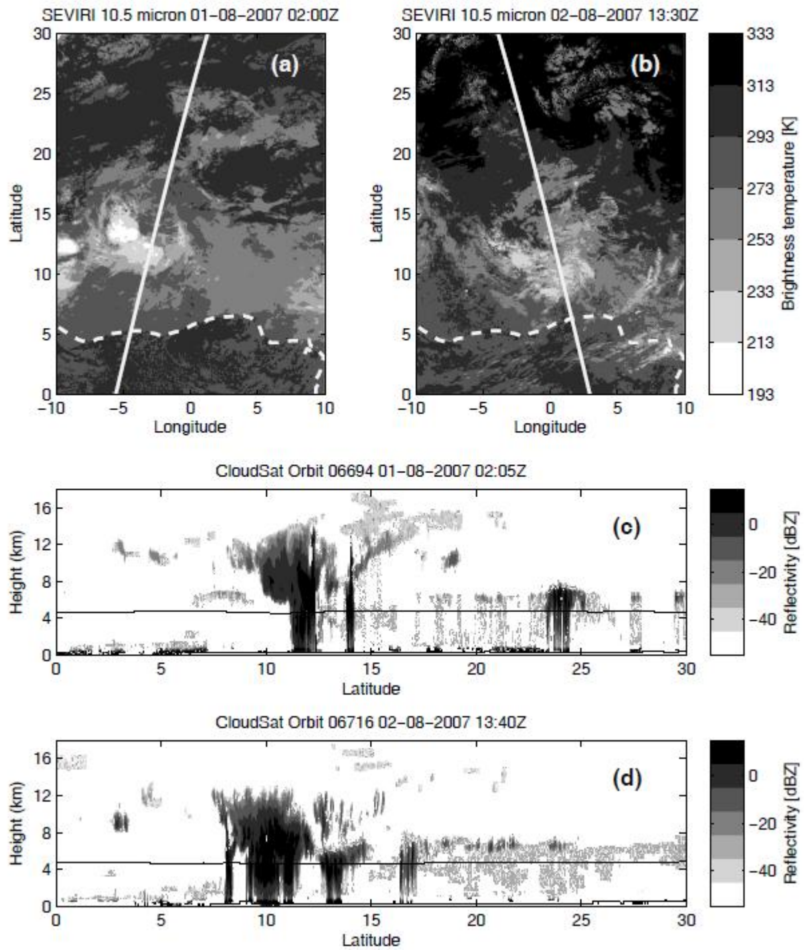


FIG. 2. (a–b) SEVIRI 10.8 micron brightness temperatures for the region of interest, at (a) 1 August 2007, 02:00Z; and (b) 2 August 2007, 13:30Z. A dashed line shows the African coastline, with the solid line showing the near-coincident CloudSat overpass. (c–d) CloudSat radar reflecitivities and CALIPSO cloud from orbits (c) 06694, 1 August 2007, crossing the equator at 02:05Z; and (d) 06716, 2 August 2007, crossing the equator at 13:40Z. CALIPSO cloud observations are shown when CloudSat reflectivities are below its sensitivity threshold of -28dBZ, and are given a value of -40dBZ. A solid line indicates the 0°C temperature contour.

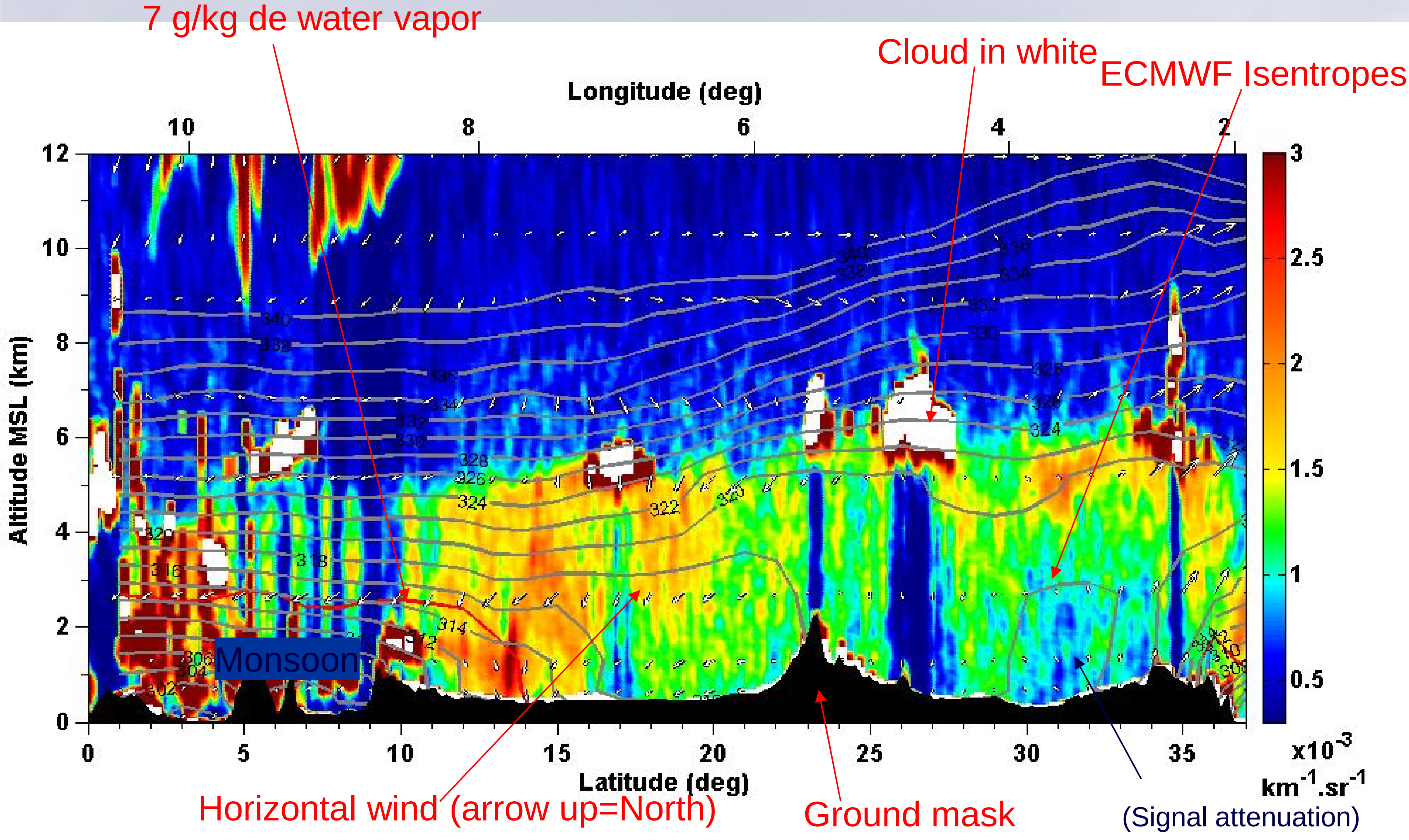
Meteosat

CloudSat

Courtesy of Thorwald Stein, U. Reading

CALIPSO lidar data

1241 UTC 25/06/2006 (from Cuesta et al., JGR)



Summary

- Model analysis-forecast cycle provides a means of smoothing measurements, and interpreting them in a common framework.
- Satellites and radar provide many different measurements – increasing variety and quality with time.