The Global Observing System

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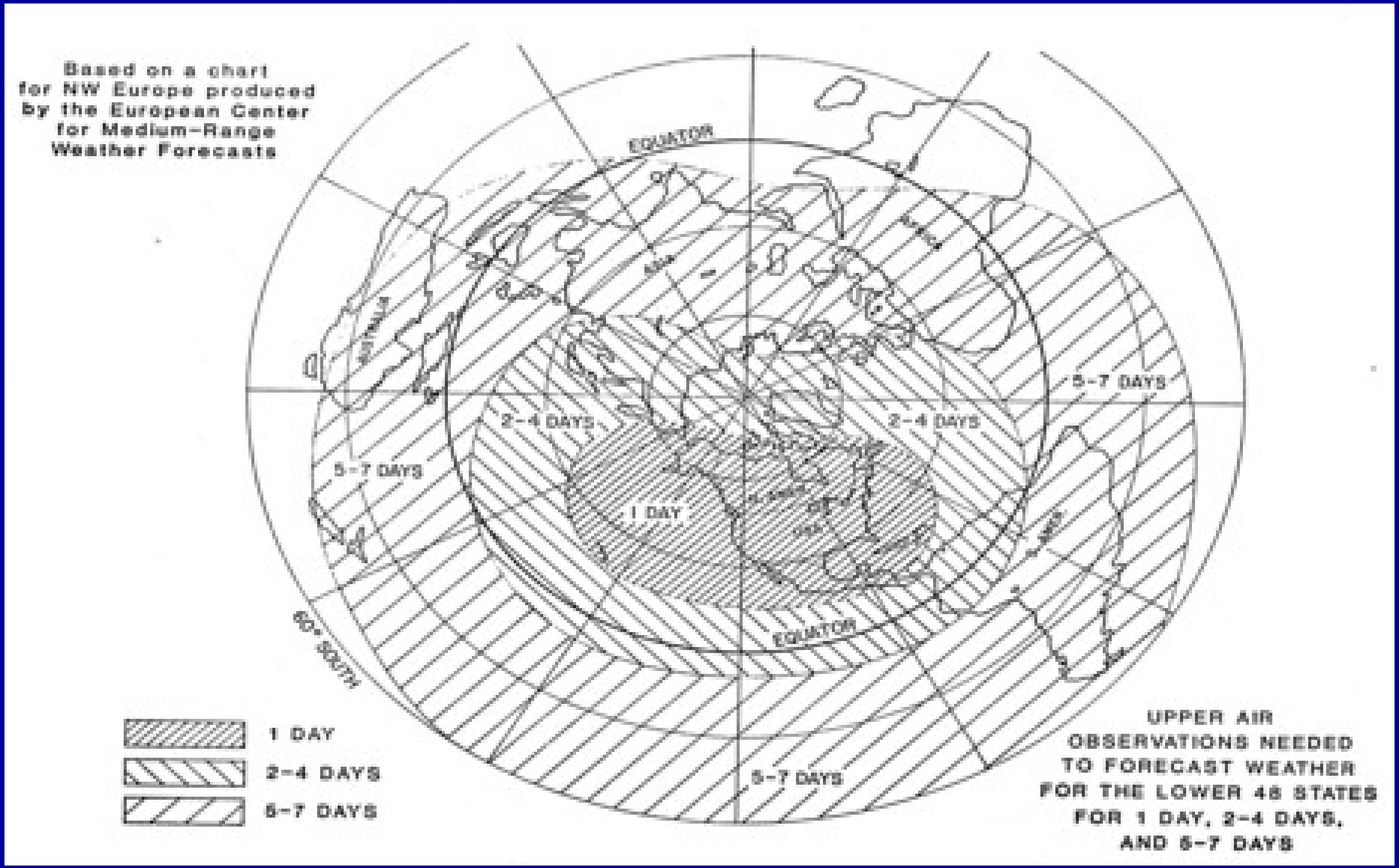
Overview

- What is the GOS and why do we need it?
  - Who owns it?
- Main GOS components
  - Surface-based
  - In-situ
    - RAOBS
    - Aircraft
  - Satellites

Ground rules (assumptions)

- Numerical Weather Prediction is predominantly an *Initial Value Problem*
  - Motion and physics of the atmosphere can be adequately described by known partial differential equations, discretized versions of which are solved on powerful computers
  - Initial conditions are established using <u>observations</u> (among other things ...)

NWP requirements for upper-air data coverage



What is the observational data requirement for NWP?

- Regularly spaced observations covering the full global domain at close to model resolution and taken at regular intervals in time of
  - Temperature (3D)
  - Horizontal winds (3D)
  - Humidity (3D)
  - Secondary constituents - e.g. ozone (3D)
  - Surface pressure (2D)
  - Lower boundary conditions; sea ice, sea surface temperature, soil moisture, ... (2D)

What do we actually get?

- Something quite different
  - ... herein lies part the challenge in data assimilation!

World Weather Watch (WWW)

“ To predict the weather, modern meteorology depends upon near instantaneous exchange of weather information across the entire globe. Established in 1963, the World Weather Watch -the core of the WMO Programmes- combines observing systems, telecommunication facilities, and data-processing and forecasting centres - operated by Members - to make available meteorological and related environmental information needed to provide efficient services in all countries”

Main components of WWW

- ***Global Observing System (GOS)***
- Global Telecommunication System (GTS) and
- Radio Frequency Coordination (RFC)
- Global Data-processing and Forecasting System (GDPFS)
- WMO Data Management,
- including WMO Codes
- Instruments and Methods of Observation Programme (IMOP)
- Emergency Response Activities (ERA)
- Tropical Cyclone Programme (TCP)
- WMO Antarctic Activities

The Global Observing System

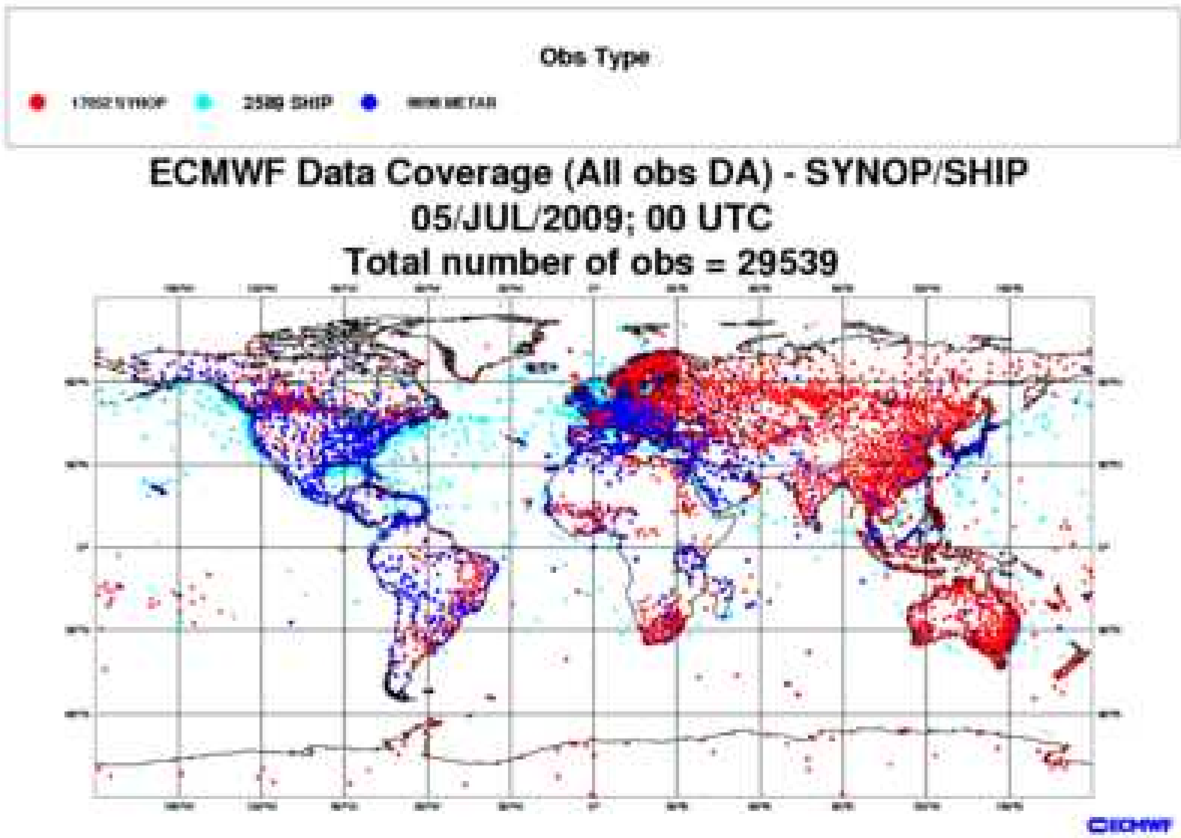
- A global network of observatories taking routine weather-related observations that are processed and disseminated to all WMO member states in real time
  - Observatories are operated by WMO members (and international organizations)
  - WMO coordinates, regulates and issues guidelines and standards

Surface-based observations

- SYNOPs (Z,u,v,t,q, cloud base, visibility, etc., reported every 6 h)
- Ships, buoys (similar to SYNOPS, at sea)

- Wind profilers - regional, over the US, Europe
- Radars - precip, wind, regional, essential for nowcasting
- Lidars - limited range, useful for clear air wind measurements
- SODARs
- ...

SYNOPS, SHIPS



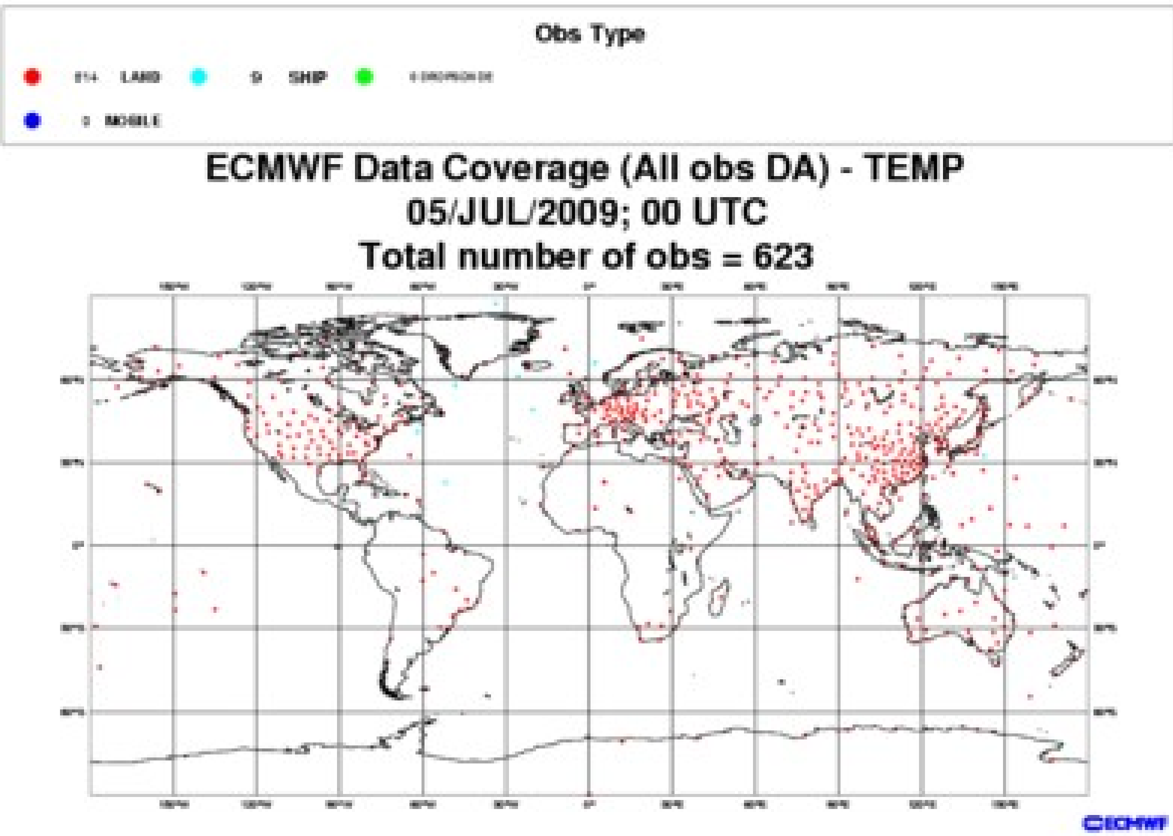
Impact, issues

- Models cannot function without these data
- Highly heterogeneous distribution
- Sparse in the Southern Hemisphere
- Observations over land difficult to use in terrain (mismatch between actual vs. model topography)

In situ measurements

- Ballon-borne radiosondes
  - TEMP - u, v, T, q at synoptic times (00 and 12 Z) at ~600 locations mostly over the densely populated regions in the NH
  - PILOT - u, v at synoptic times (6 and 18Z) at limited number of locations
- Dropsondes (targeted)
- Aircraft measurements
- Research balloons

Radiosonde coverage, 00Z

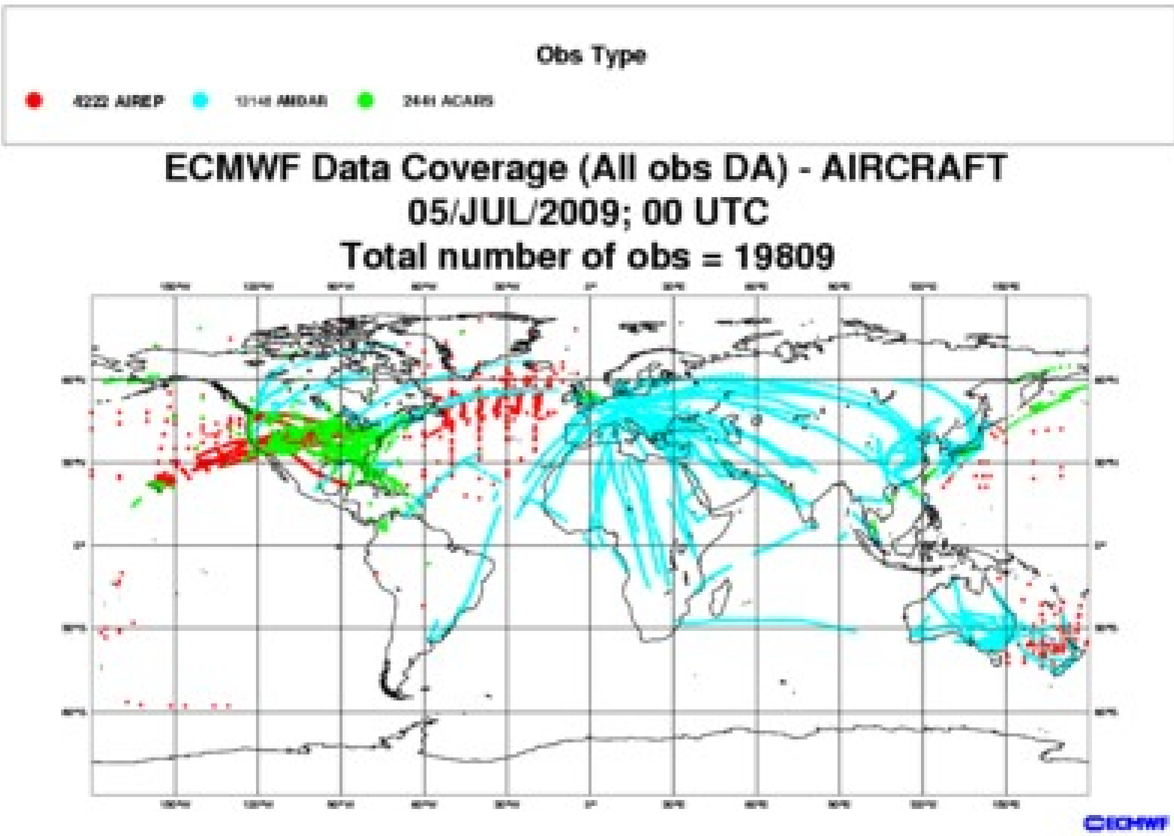


- **Essential for NWP skill (Top 2 observing system by impact)**
- Time sampling is problematic
  - Different parts of the globe systematically sampled at different local times
- Horizontal sampling is inadequate (minimal SH coverage)
- Little or no stratospheric penetration
- Quality control is very difficult
  - Different operating practices
  - Different models and manufacturers of on-board sensors
- Operating costs (~$4B/year)

Aircraft observations

- PIREP - human report, provided by both general and commercial aviation; no longer widely used for NWP
- AIREP - human report, regular lat/lon intervals, disseminated on WMO GTS
- AMDAR ("ACARS") - automated observations of u,v,T transmitted to ground via terrestrial or satellite radio, disseminated on GTS
  - Both ascent/descent profiles and flight level information widely used for NWP
  - Pilot programs with on-board humidity sensors both in Europe and the US (primarily for profiling)

Aircraft data coverage



- **Medium to high NWP impact**
- Anisotropic sampling both horizontally and vertically
- Flight level winds represent a biased sampling (routing driven by fuel savings)
- Difficult QC problem
  - E.g. record does not include aircraft tail number

Satellite observations

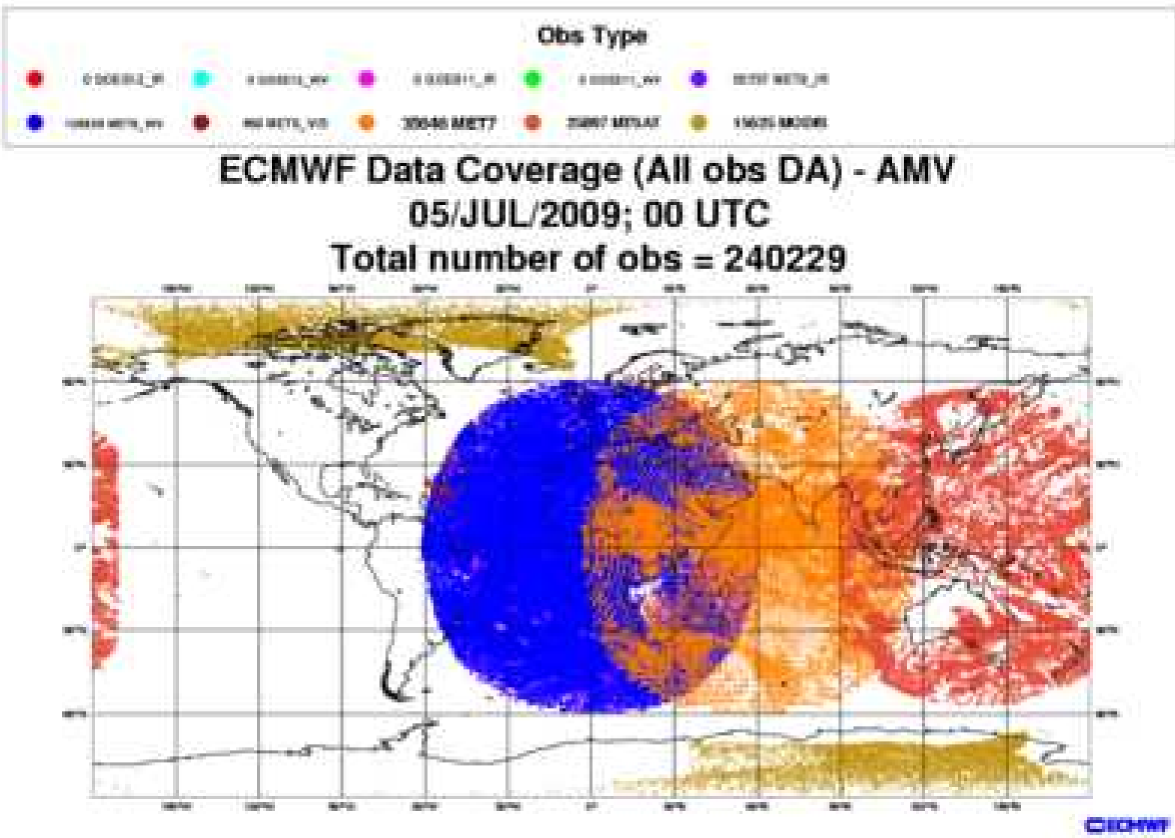
- Geostationary orbit
- Polar orbit
  - Sun-synchronous
  - Other
- MEO

Geostationary satellites

- Five (or six) operational satellites in fixed equatorial orbits at 35,800 km altitude
  - High temporal resolution imaging from a ‘staring’ perspective
  - Extremely valuable for monitoring and nowcasting
  - Up until now data assimilation considered a secondary application

QuickTime™ and a
Video decompressor
are needed to see this picture.

Geostationary derived product (SATWIND) coverage

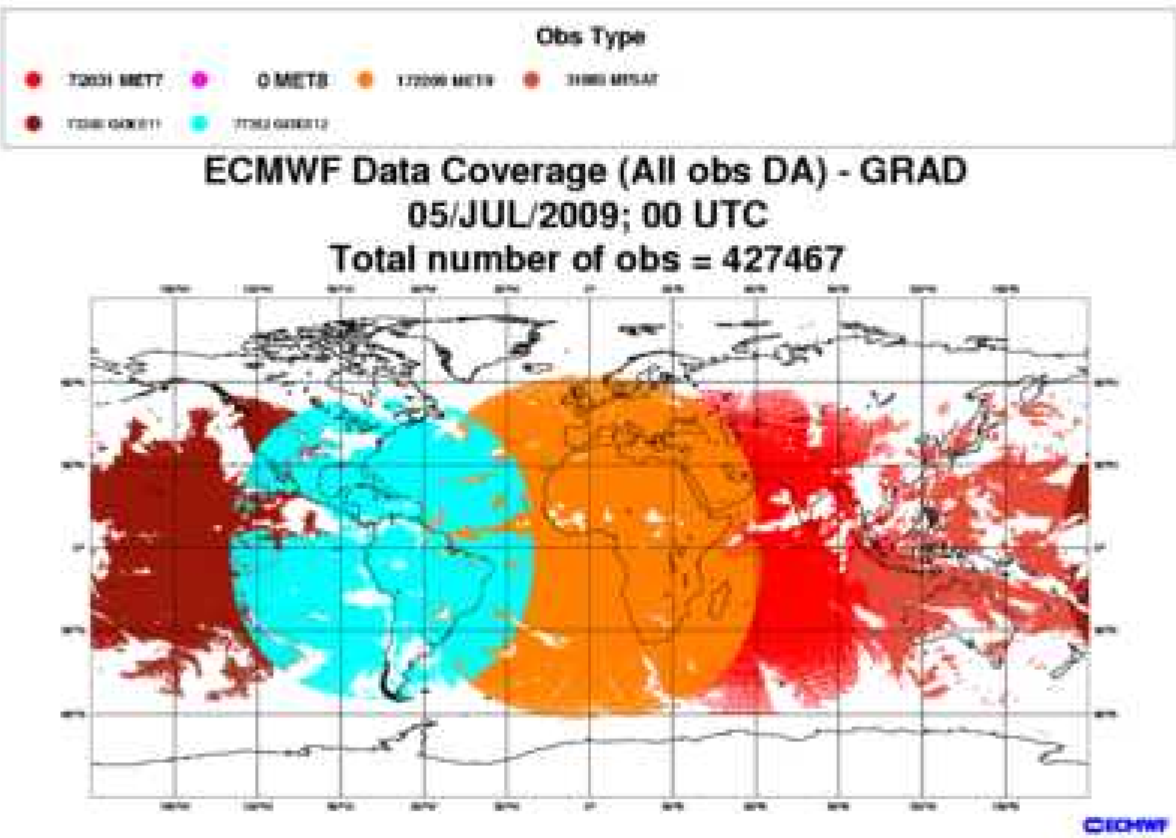


- **Medium impact on NWP skill**
- Winds derived from tracking of features in clouds (or WV) field
- Single level coverage
- No high-latitude coverage
  - Experimental dataset available from MODIS
- Difficult quality control problem
  - Errors in assigned height can lead to negative impact
  - Errors in tracking can lead to gross errors

Meteosat-7 RGB March 2-3 2004

QuickTime™ and a
decompressor
are needed to see this picture.

Geostationary radiance coverage



- **Modest impact on NWP skill**

- Satellite measured radiances targeted at direct assimilation, similar to methodology for polar orbiters
- High temporal and spatial resolution
- Coverage limited to viewing disk
- Low spectral resolution (~10 channels compared to ~1000 for polar IR instruments)

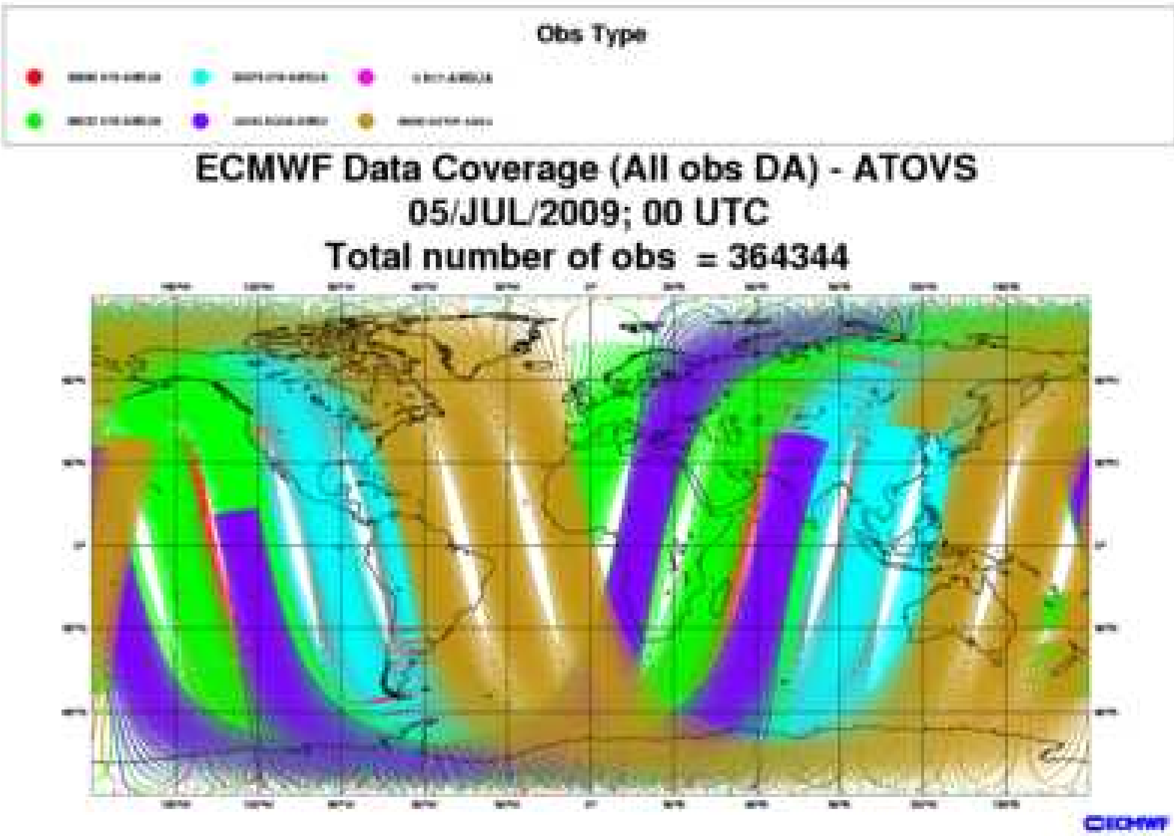
Polar orbiters

- Large fleet of research and operational satellites in a variety of “polar” orbits (sun-synchronous or otherwise)
  - NOAA - POES => NPOESS
  - EUMETSAT - EPS (MetOp)
  - US DoD - DMSP => NPOESS
  - NASA - Terra, Aqua, Aura, Cloudsat, CALIPSO, Jason-2...
  - ESA - ERS-1/2, Envisat
  - CNES, CSA, JAXA, ISRO ...

Polar orbiters (II)

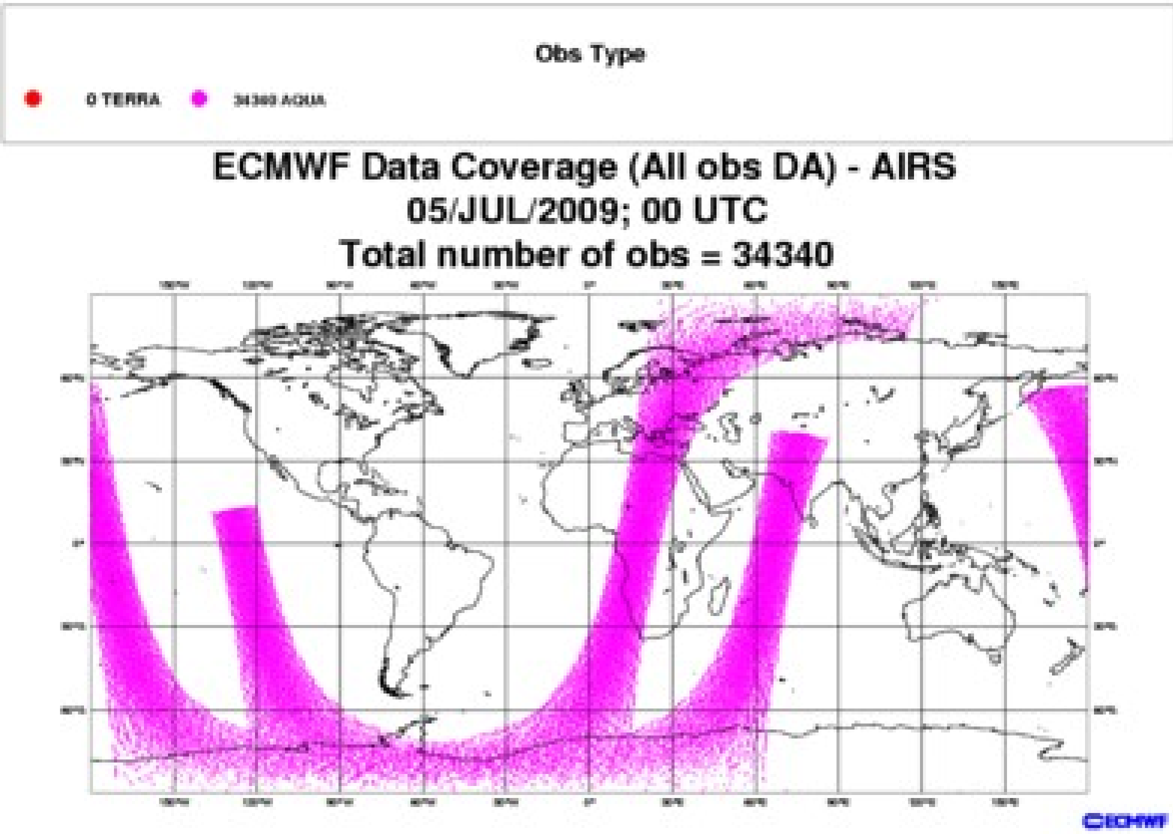
- Observations are asynoptic by nature
  - Typical orbit height between 350 and 850 km; velocity relative to ground ~7 km/s
  - Global coverage is “patched” together over a period of 12 or 24 hours or longer
  - Data assimilation is primary application for several polar orbiting sensors

Example of data coverage from polar orbiters (AMSU-A)



- **Essential for NWP (AMSU-A ranked #1 in terms of impact on skill)**
- Best global coverage of any observing system
- Requires observation operators (radiative transfer modeling)
- Use of surface sensing channels problematic; emissivity of snow, ice, land, and to some extent sea
- Clouds, precipitation affected many locations
- Inter-instrument biases

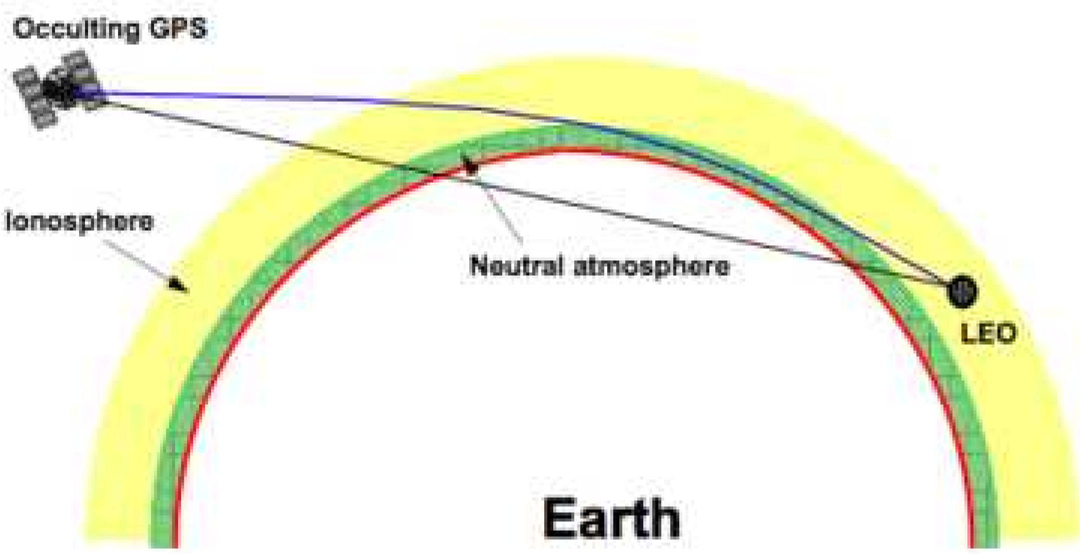
Hyperspectral IR coverage (AIRS)



- **Ranked no. 1 in terms of impact on skill <u>per instrument</u> (only two currently operating)**
- Prolific data source (billions of measurements per day)
- Only on the order of 1% of these used for NWP due to difficulties with
  - Clouds
  - Model prediction (WV)
  - Surface emissivity
  - Correlated information
  - Data volume

Radio Occultation concept

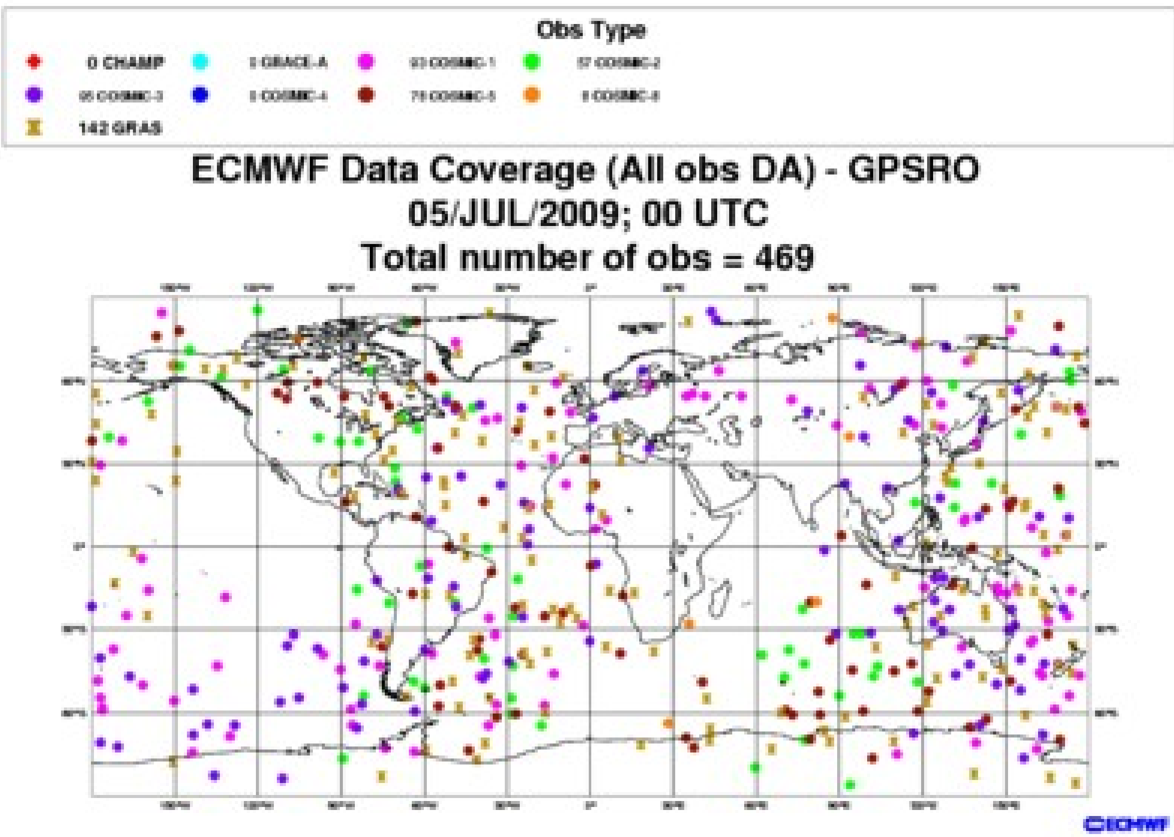
- An occultation occurs when a GPS (GNSS) satellite rises or sets across the limb wrt to a LEO satellite.
- A ray passing through the atmosphere is refracted due to the vertical gradient of refractivity (density).
- During an occultation (~ 3min) the ray path slices through the atmosphere



Raw measurement: change of the delay (phase) of the signal path between the GPS and LEO during the occultation. (It includes the effect of the atmosphere).

GPS transmits at two different frequencies: ~1.6 GHz (L1) and ~1.3 GHz (L2).

MEO (GPSRO)



- **Medium / high impact on NWP skill**
- Large impact especially in the upper tropospere
- Methodology still under development (lecture Thursday July 16)
- Unusual measurement geometry due to limb approach
- Good global coverage can be obtained by constellation approach

Summary and conclusions

- Global (and indirectly also regional) NWP requires global observational data coverage
- The GOS provides the framework for the 188 WMO member states to exchange weather observations across national boundaries routinely in near-real time

Summary and conclusions (II)

- In spite of its successes, the heterogeneity of the GOS poses an enormous challenge to the data assimilation/NWP community
  - Quality control
  - Bias
  - Observation operators (relationship between observed and modeled variables)
  - Data latency
  - ...
- Data assimilation community can help define the GOS of the future (subject of lecture Thursday)