The Global Observing System

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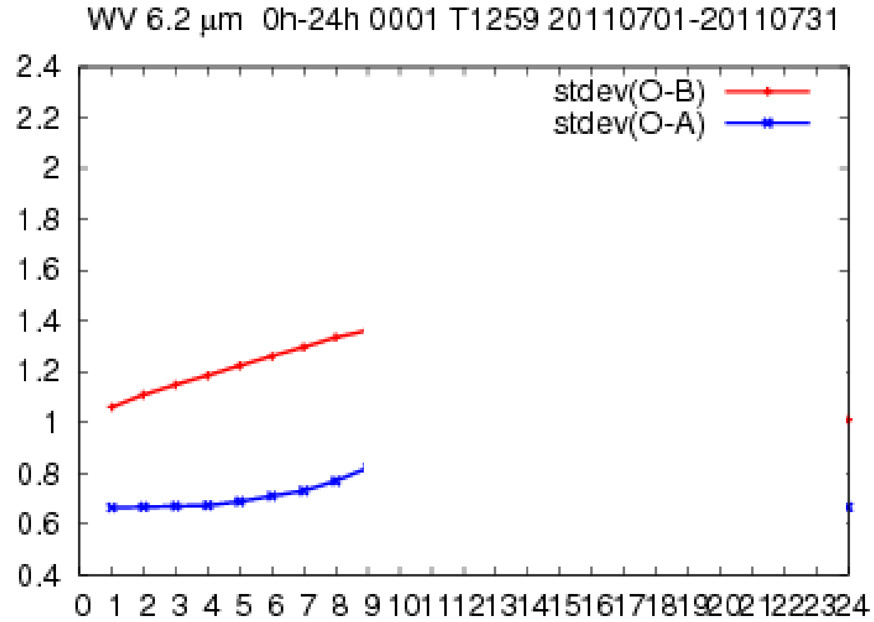
Role of observations

Every 12 hours we assimilate ~20,000,000 observations to correct the model's variables….

The model has many more variables than we have observations.

SEVIRI 6.2 µm



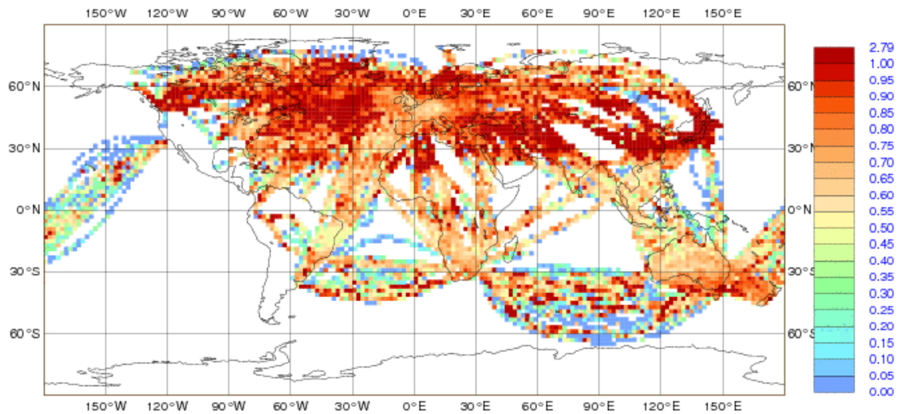
Time (hours)

Observations limit error growth and make forecasting possible….

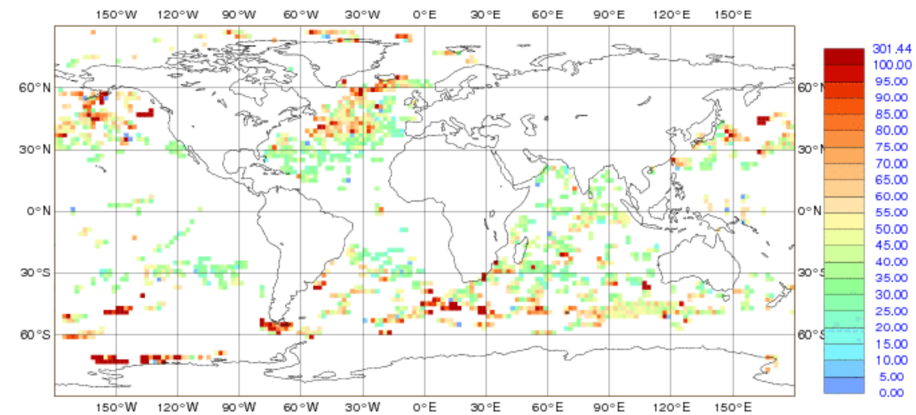
Data sources: Conventional

Instrument	Parameters	Height
SYNOP **SHIP** **METAR**	temperature, dew-point temperature, wind	Land: 2m, ships: 25m
BUOYS	temperature, pressure, wind	2m
TEMP **TEMPSHIP** **DROPSONDES**	temperature, humidity, pressure, wind	Profiles
PROFILERS	wind	Profiles
Aircraft	temperature, pressure wind	Profiles Flight level data

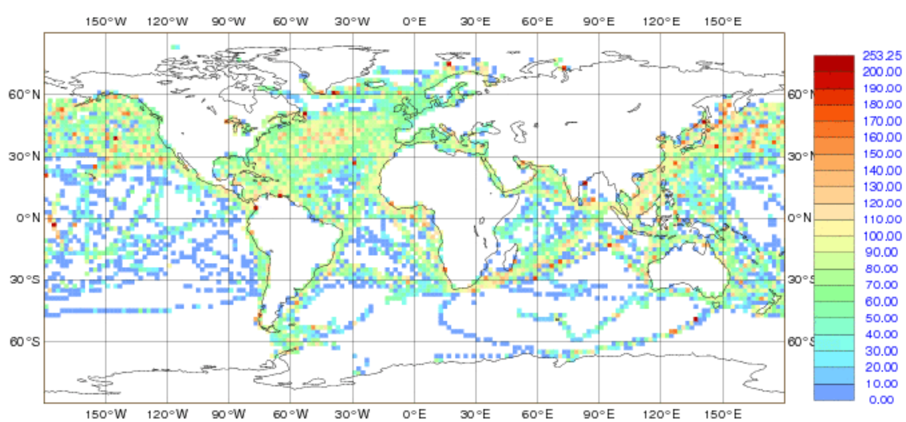
Example of conventional data coverage



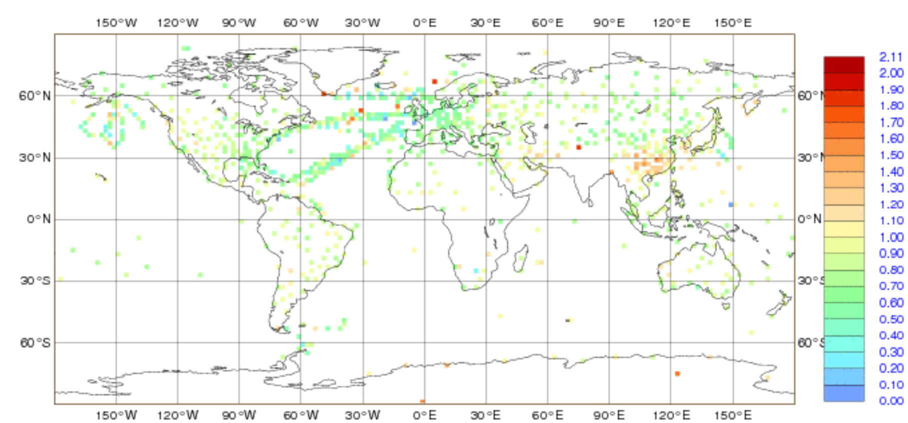
Aircraft – AMDAR (note also have Airep and ACARs)



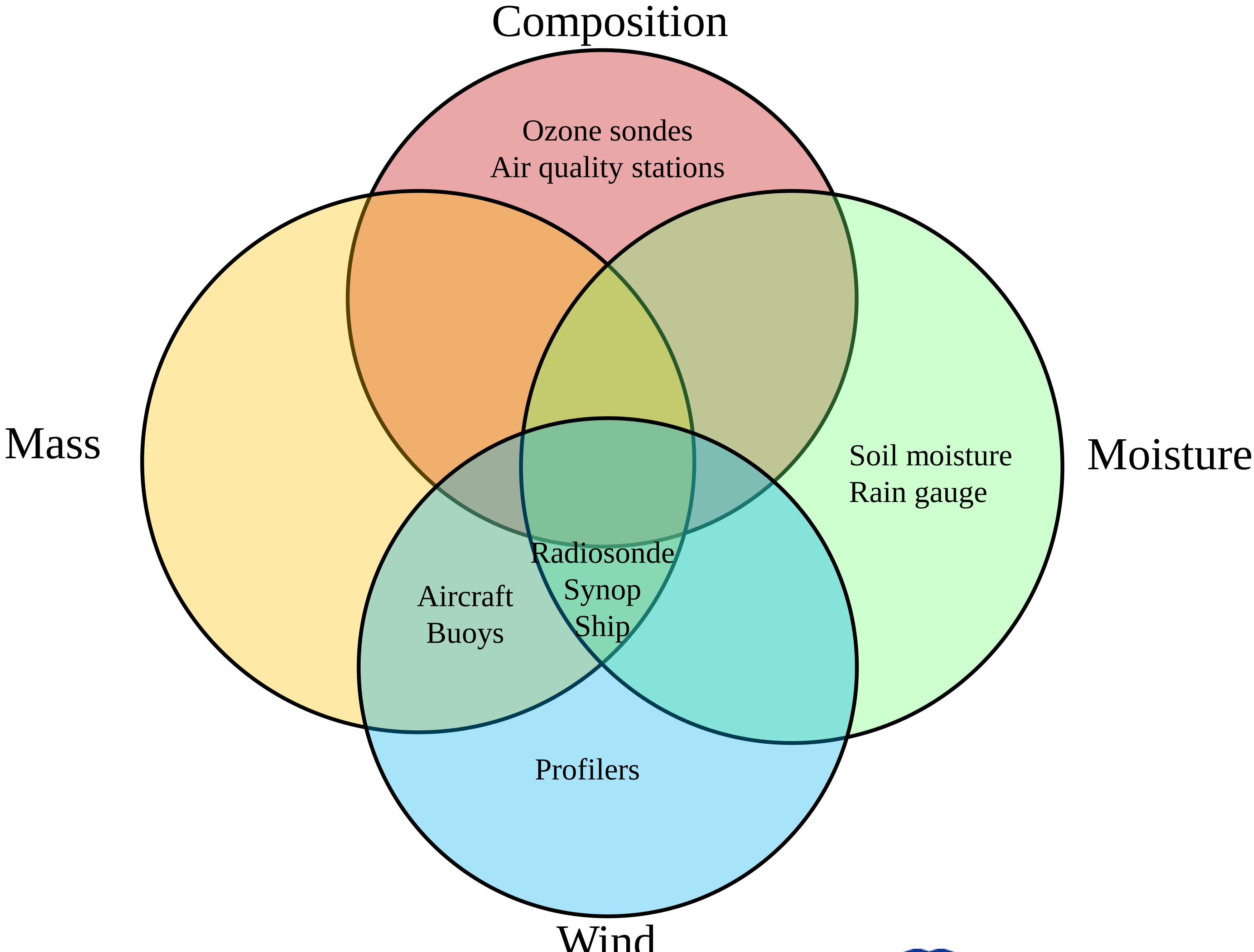
Buoy



Surface (synop) - ship



Balloon profiles e.g. radiosondes


Composition
Ozone sondes
Air quality stations
Mass
Moisture
Soil moisture
Rain gauge
Radiosonde
Synop
Ship
Aircraft
Buoys
Profilers
Wind

In situ data issues

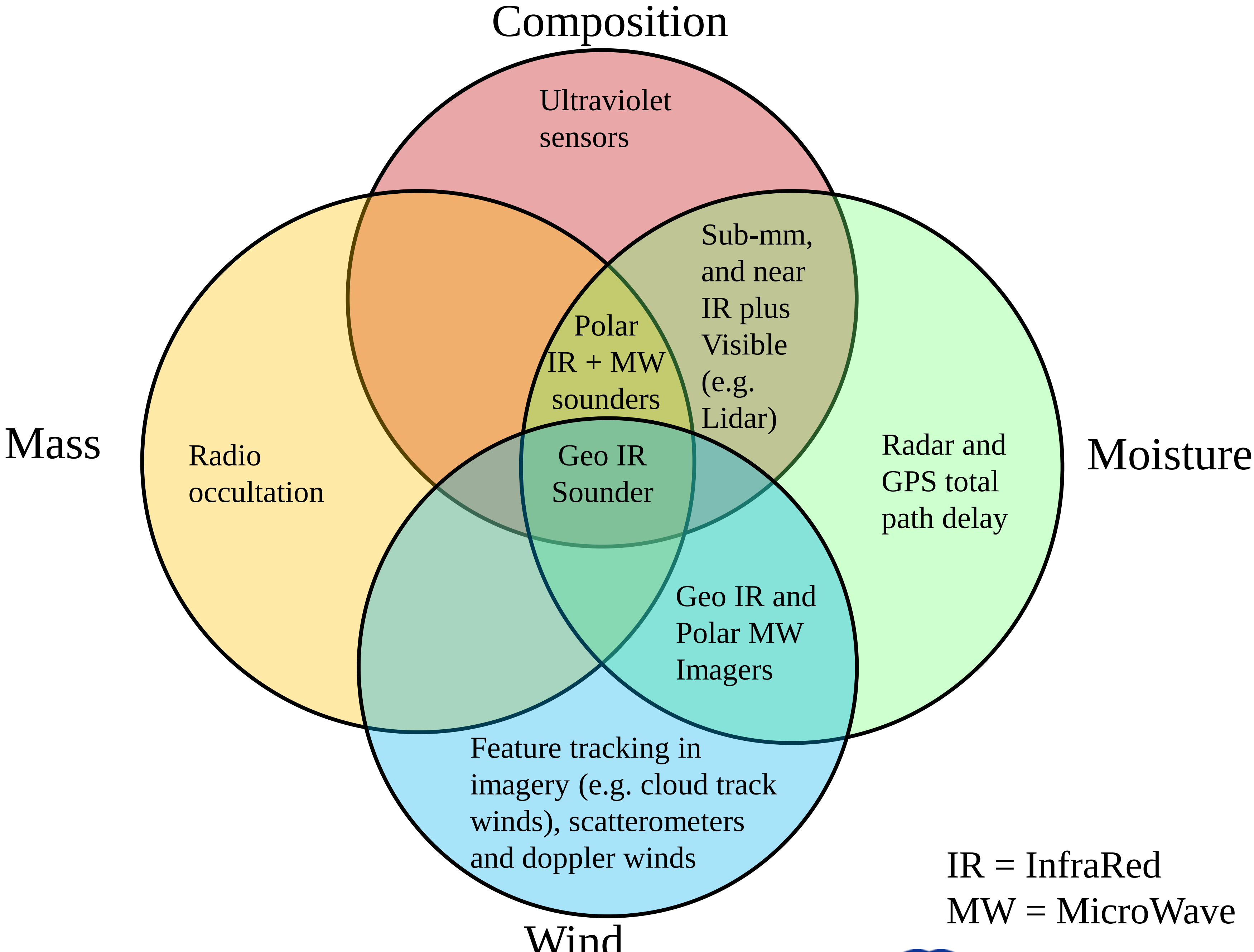
- Biases, duplicates, incorrect locations
- Representivity error….if we measure temperature here at ECMWF is it representative of model grid resolution?
- Data voids
- Data quality – some radiosondes are good quality, others less so; absolute calibration can vary with age
- Old alphanumeric codes -> BUFR
- Sampling e.g. significant levels in radiosonde vs full resolution data

- But, they are a direct, in situ measurement
- Interpretation is usually more straightforward than remotely sensed data

Remotely sensed data issues

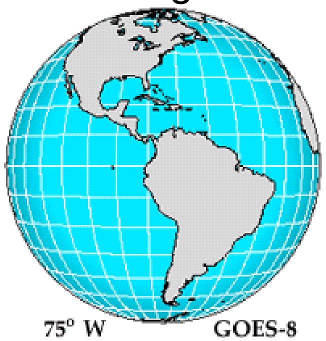
- **Poor vertical resolution (in general)**
- **Rarely an absolute measurement – long term drifts, observation biases**
- **Data voids: less of a problem than for in situ, but there are areas where data is hard to interpret**
- **Data quality – whilst most remotely sensed observations are of very high quality, this can change suddenly.**
- **An indirect measurement – we need complex observation operators**

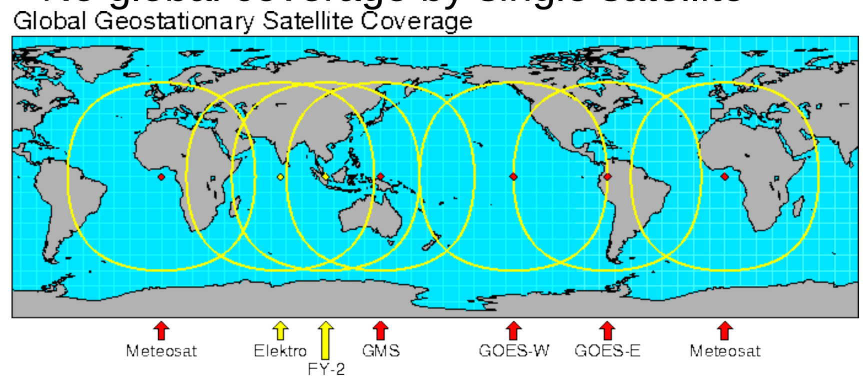
- **But, they measure on a global or regional scale**
- **Representivity error is lower – large volumes are more representative of what the model is trying to represent**


Composition
Ultraviolet sensors
Mass
Radio occultation
Moisture
Radar and GPS total path delay
Wind
Feature tracking in imagery (e.g. cloud track winds), scatterometers and doppler winds
Polar IR + MW sounders
Sub-mm, and near IR plus Visible (e.g. Lidar)
Geo IR Sounder
Geo IR and Polar MW Imagers
IR = InfraRed
MW = MicroWave

What types of satellites are used in NWP?

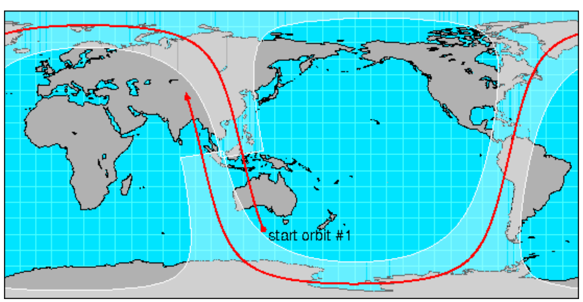
	Advantages	Disadvantages
GEO	- Regional coverage	No global coverage by single satellite

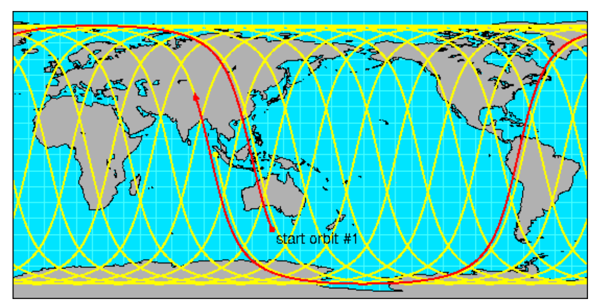




- Temporal coverage

LEO - Global coverage with single satellite



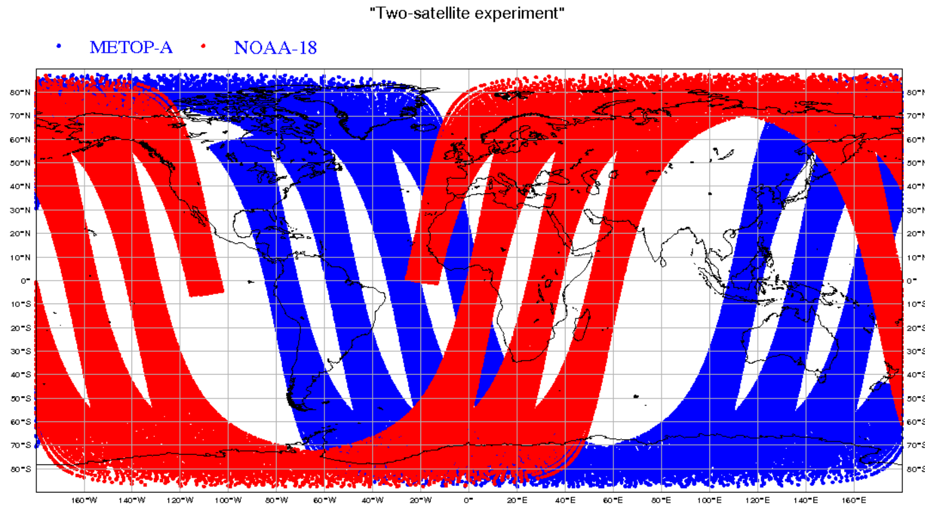


ECMWF

Satellite orbits

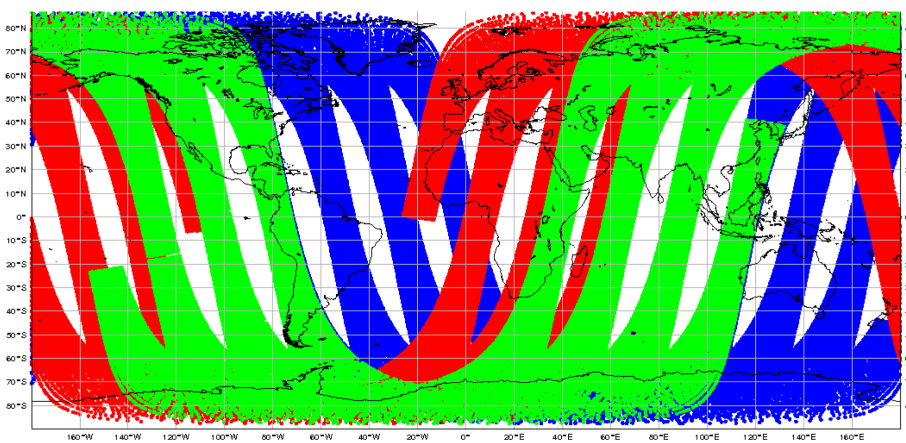
AM + PM

* MetOp-A   * NOAA-18



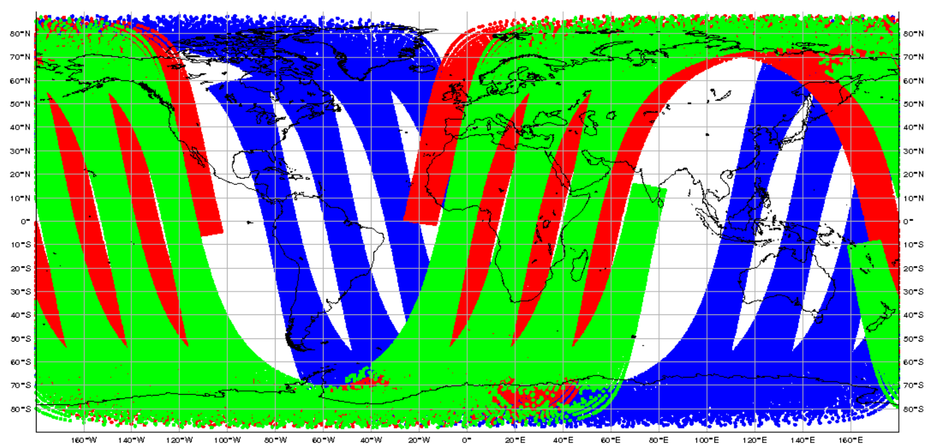
E-AM + AM + PM

* MetOp-A   * NOAA-18   * NOAA-15

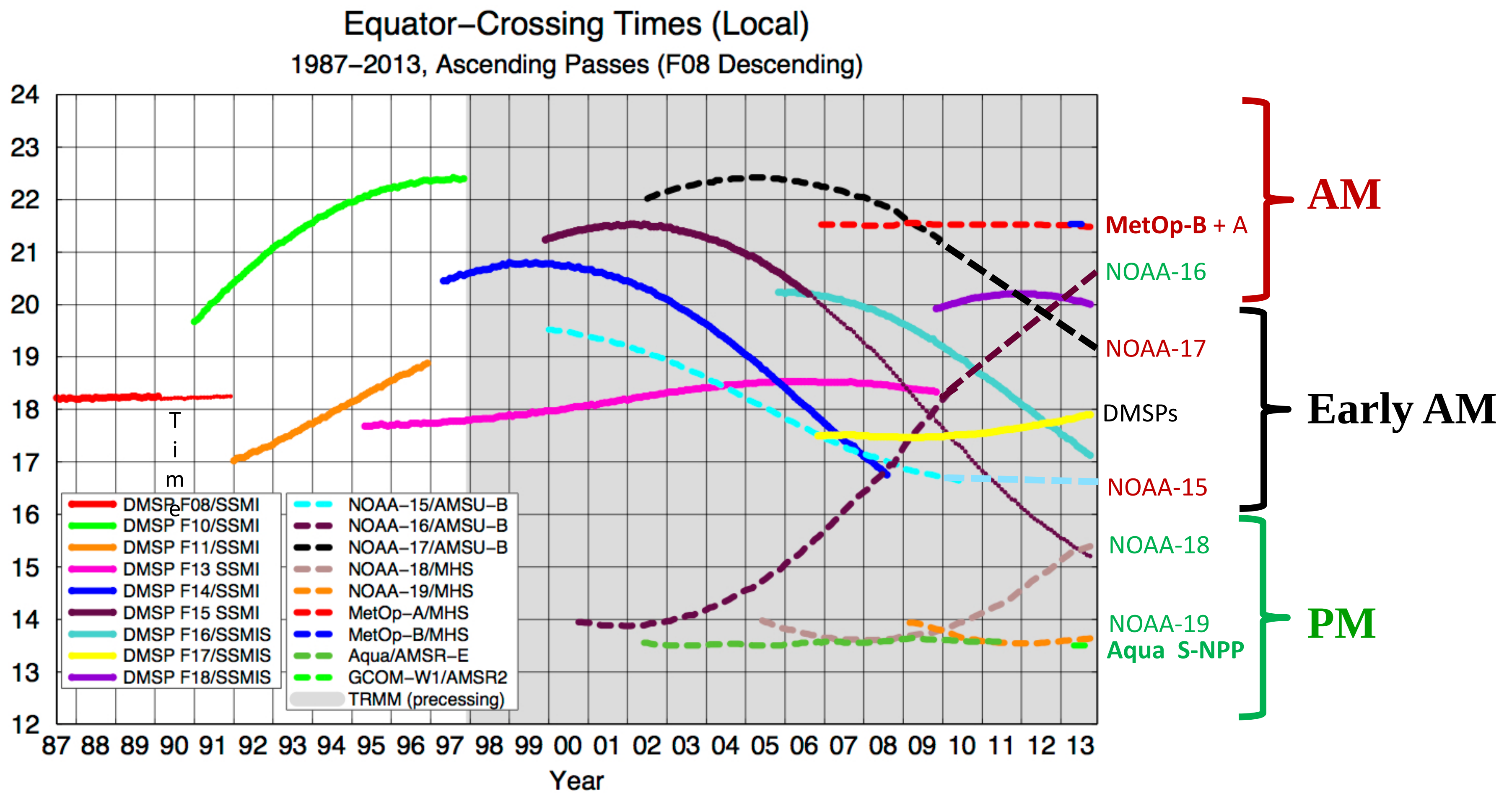


AM + 2 x PM

* MetOp-A   * NOAA-18   * NOAA-19

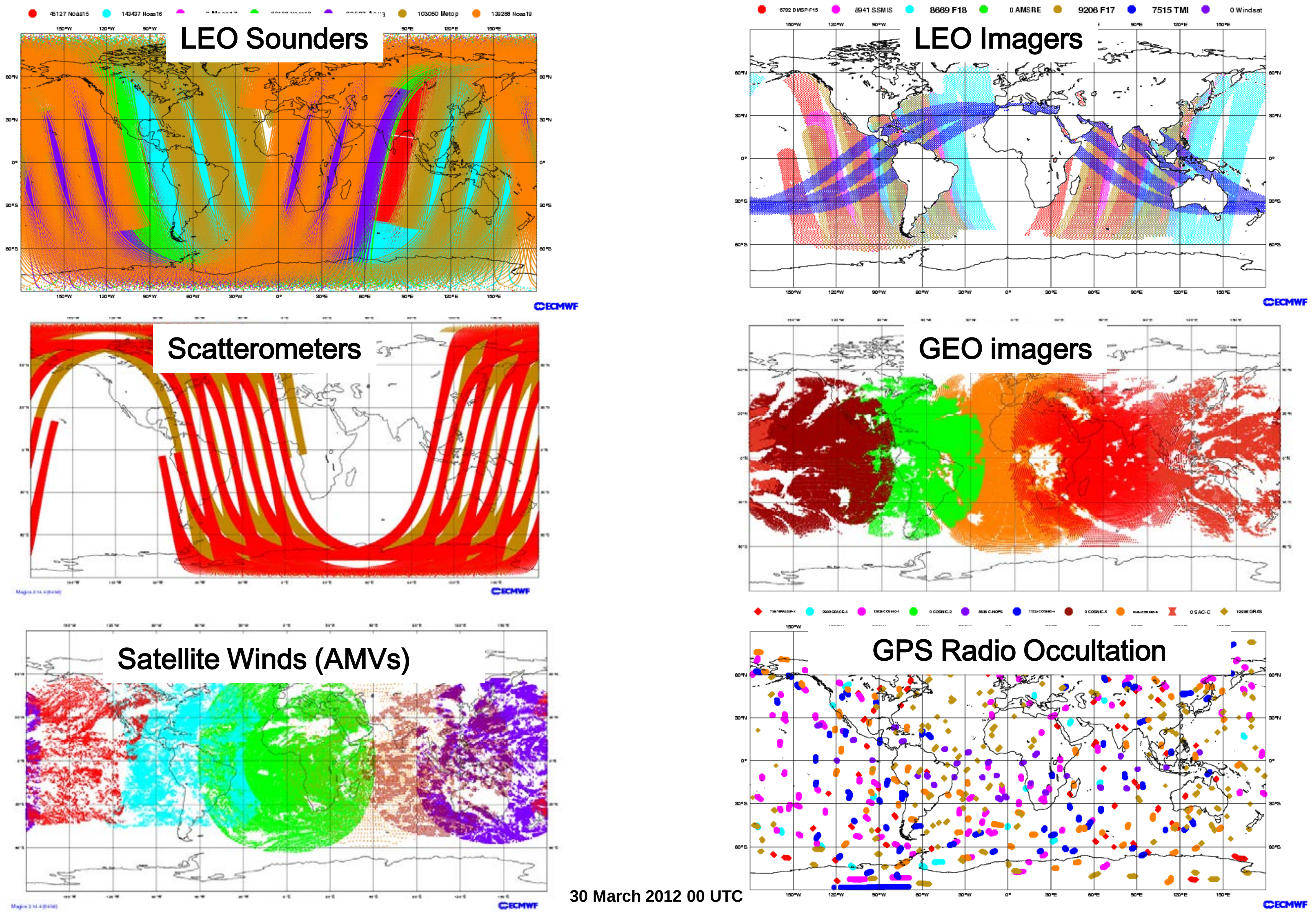


Satellite orbits

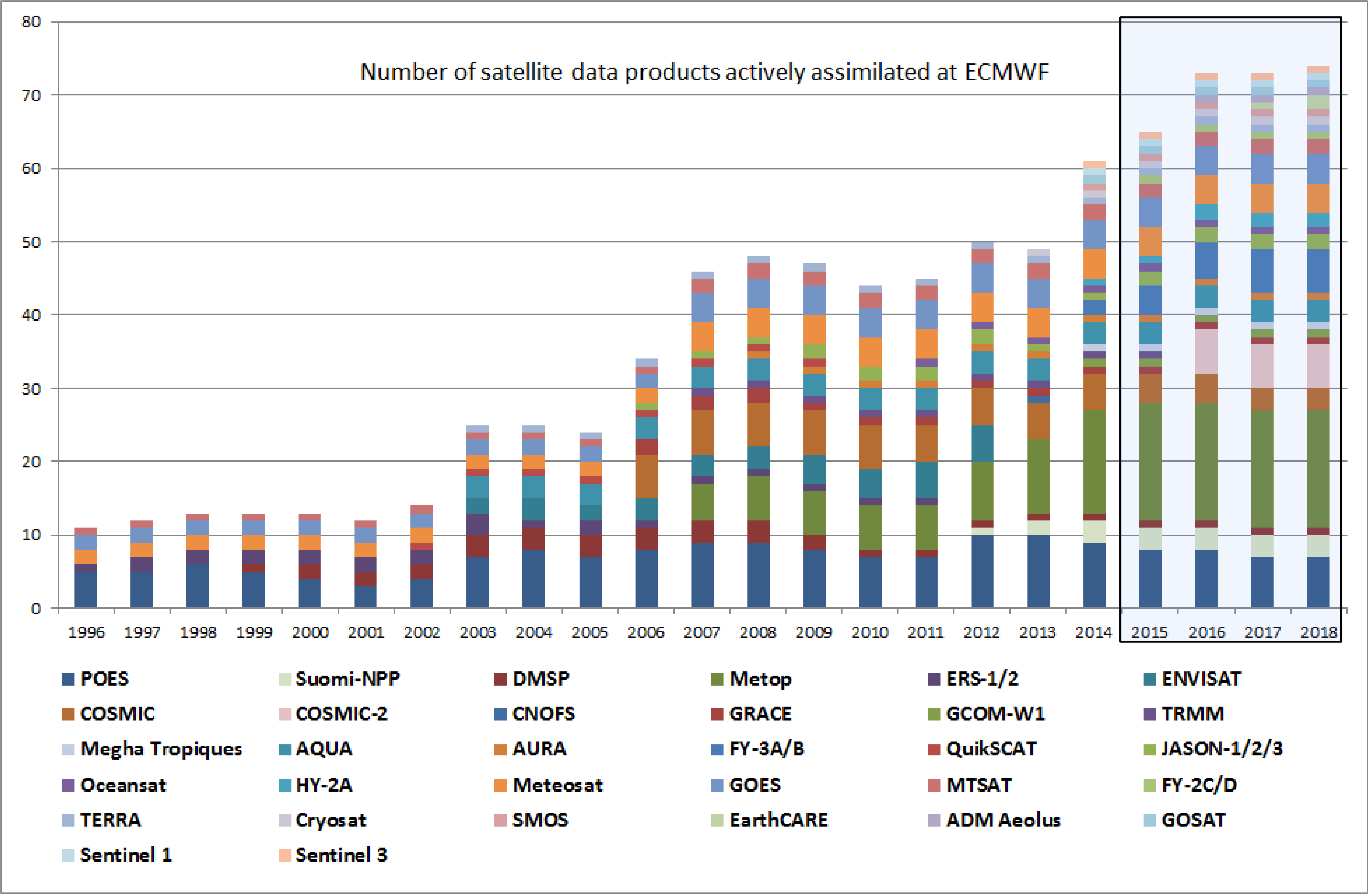


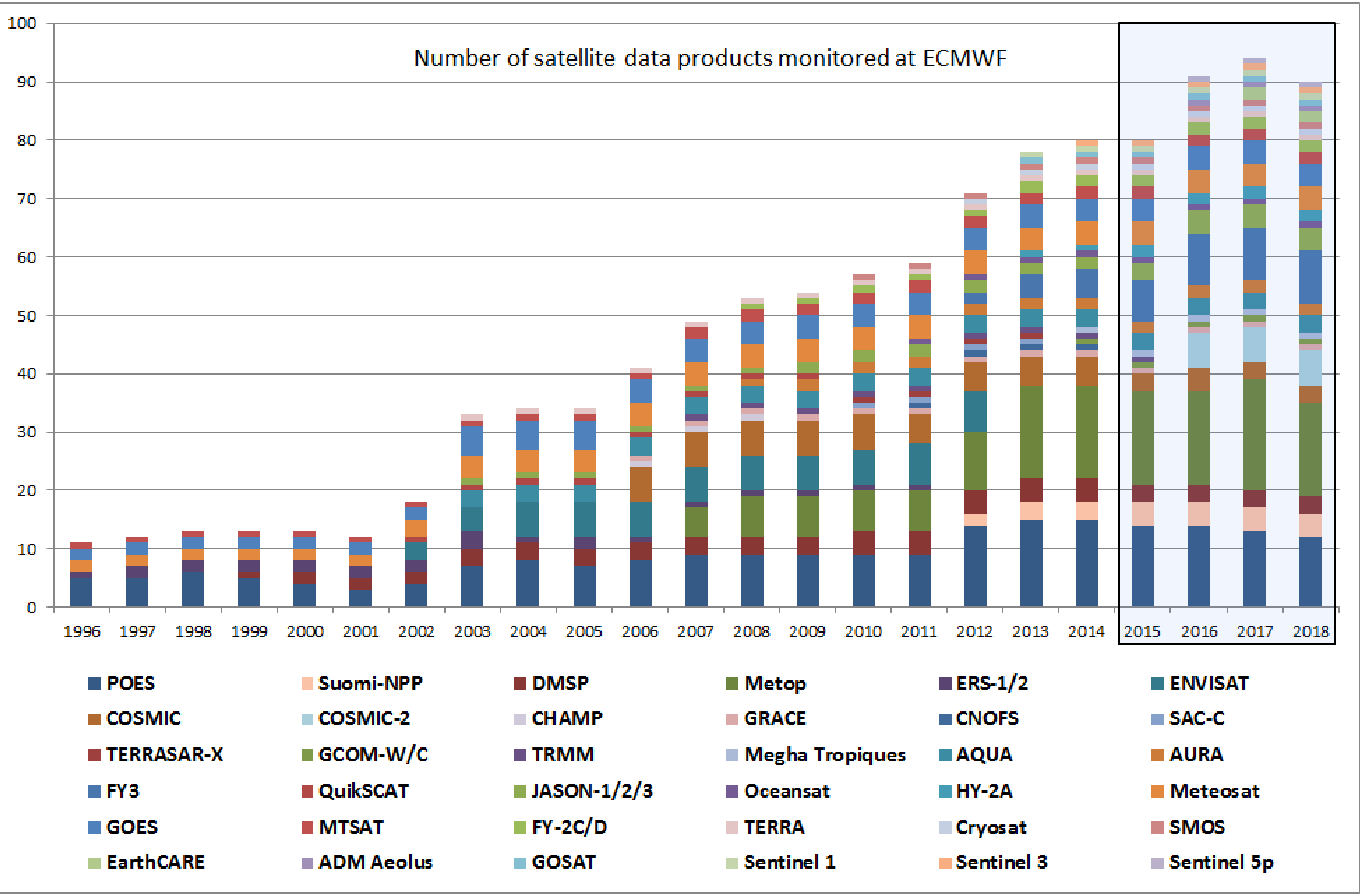
Adapted from
Image by Eric Nelkin (SSAI), 23 October 2013, NASA/Goddard Space Flight Center, Greenbelt, MD.

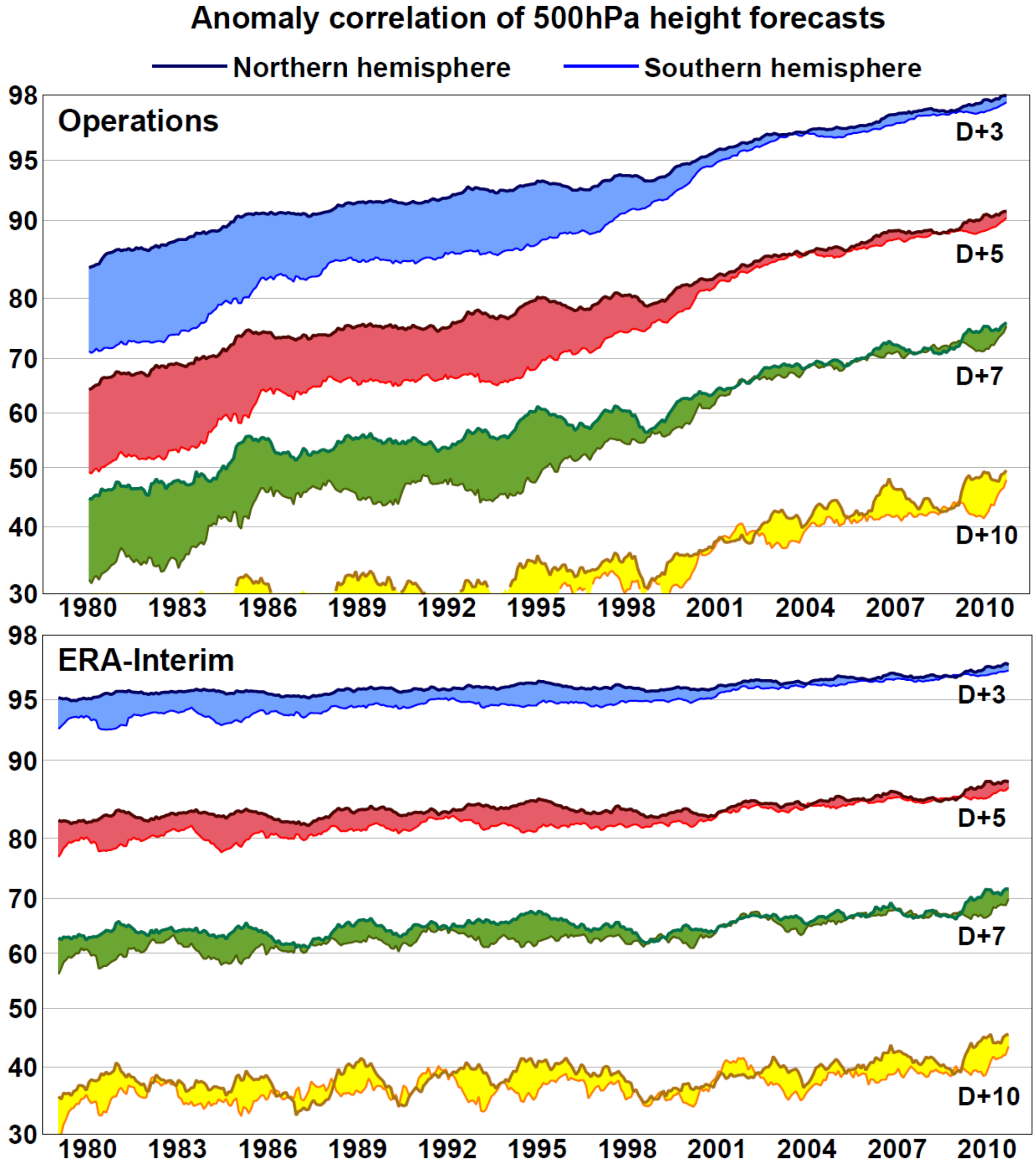
Example of 6-hourly satellite data coverage



ECMWF

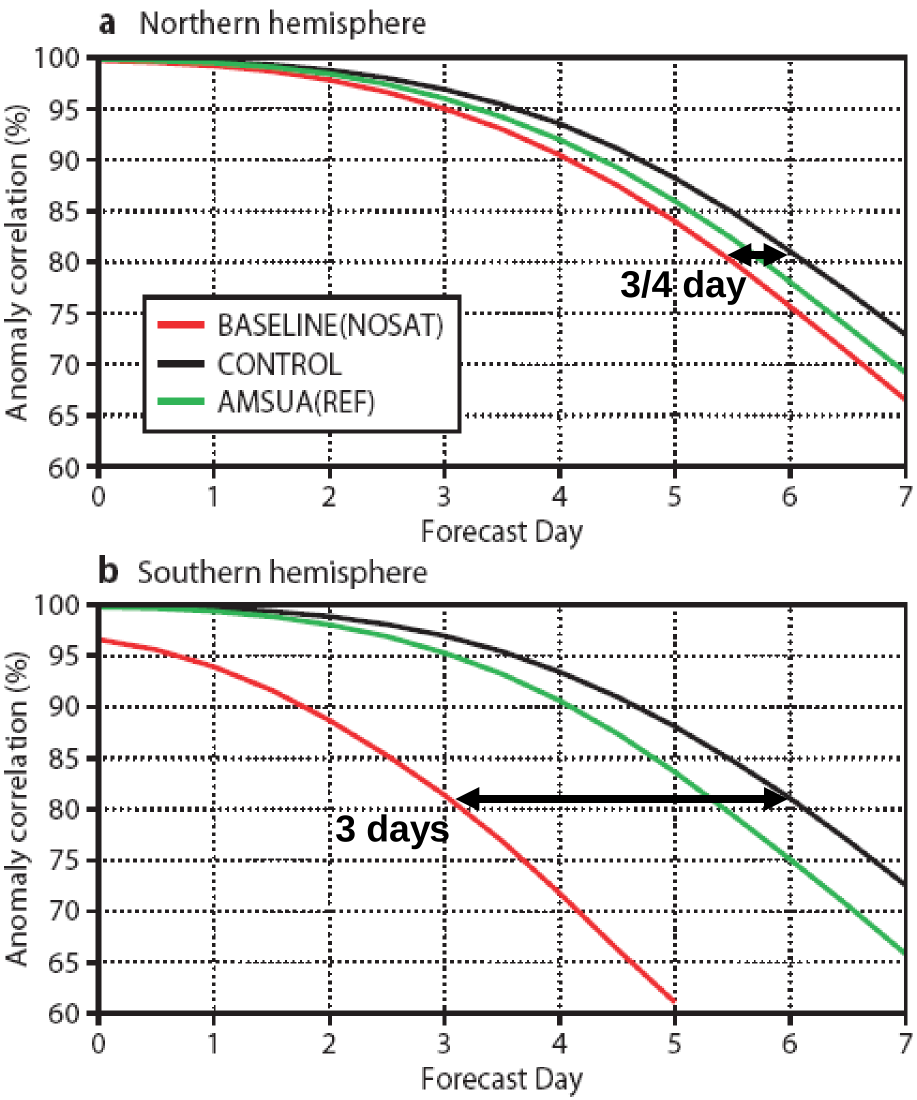

Number of satellite data products actively assimilated at ECMWF
0
10
20
30
40
50
60
70
80
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
POES
Suomi-NPP
DMSP
Metop
ERS-1/2
ENVISAT
COSMIC
COSMIC-2
CNOFS
GRACE
GCOM-W1
TRMM
Megha Tropiques
AQUA
AURA
FY-3A/B
QuikSCAT
JASON-1/2/3
Oceansat
HY-2A
Meteosat
GOES
MTSAT
FY-2C/D
TERRA
Cryosat
SMOS
EarthCARE
ADM Aeolus
GOSAT
Sentinel 1
Sentinel 3


Number of satellite data products monitored at ECMWF
100
90
80
70
60
50
40
30
20
10
0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
POES
Suomi-NPP
DMSP
Metop
ERS-1/2
ENVISAT
COSMIC
COSMIC-2
CHAMP
GRACE
CNOFS
SAC-C
TERRASAR-X
GCOM-W/C
TRMM
Megha Tropiques
AQUA
AURA
FY3
QuikSCAT
JASON-1/2/3
Oceansat
HY-2A
Meteosat
GOES
MTSAT
FY-2C/D
TERRA
Cryosat
SMOS
EarthCARE
ADM Aeolus
GOSAT
Sentinel 1
Sentinel 3
Sentinel 5p



Anomaly correlation of 500hPa height forecasts
Northern hemisphere
Southern hemisphere
Operations
ERA-Interim
D+3
D+5
D+7
D+10
98
95
90
80
70
60
50
40
30
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010

Combined impact of all satellite data



EUCOS Observing System Experiments (OSEs):

- 2007 ECMWF forecasting system,
- winter & summer season,
- different baseline systems:
  - no satellite data (NOSAT),
  - NOSAT + AMVs,
  - NOSAT + 1 AMSU-A,
- general impact of satellites,
- impact of individual systems,
- all conventional observations.

← 500 hPa *geopotential height* anomaly correlation

Using DA to help design and make best use of the Global Observing System

Examples questions we use Data Assimilation techniques to study:

- Very specific questions e.g. Would it be beneficial for the Chinese FY3 program to move to the "early morning orbit" with the Europeans occupying the "morning orbit" and the Americans the "afternoon orbit"?

- Preparation for future instruments such as lidar and radar (EarthCARE) – will these observations make a difference?

- Which observations were vital to key high profile events such as the Sandy forecast – guiding future investment.

- Monitoring the quality of observations – protecting the operational system

Global Observing System is essential to weather forecasting

Technology driven….a more integrated approach now?

Mass – is well observed by satellites and conventional observations, albeit only on the large scale.

Moisture – satellite observations are data rich but difficult to exploit to their full potential. Radar and lidar will become more important.

Dynamics – wind observations are scarce. Aeolus may help.

Composition – NWP techniques have been successfully extended to environmental analysis (ozone, aerosol, trace gases…)

Surface – Some "static" fields are needed e.g. vegetation, orography, land:sea, lakes; others are more dynamic e.g. sea ice, snow, soil moisture, surface temperature, flooding

Sun-Synchronous Polar Satellites

Instrument	Early morning orbit	Morning orbit	Afternoon orbit
High spectral resolution IR sounder		IASI	Aqua AIRS NPP CrIS
Microwave T sounder	F16, 17 SSMIS	Metop AMSU-A FY3A MWTS DMSP F18 SSMIS Meteor-M N1 MTVZA	NOAA-15, 18, 19 AMSU-A Aqua AMSU-A FY3B MWTS, NPP ATMS
Microwave Q sounder + imagers	F16, 17 SSMIS	Metop MHS DMSP F18 SSMIS FY3A MWHS	NOAA-18, 19 MHS FY3B MWHS, NPP ATMS
Broadband IR sounder		Metop HIRS FY3A IRAS	NOAA-19 HIRS FY3B IRAS
IR Imagers		Metop AVHRR Meteor-M N1 MSU-MR	Aqua+Terra MODIS NOAA-15, 16, 18, 19 AVHRR
Composition (ozone etc).		NOAA-17 SBUV	NOAA-18, 19 SBUV ENVISAT GOMOS AURA OMI, MLS ENVISAT SCIAMACHY GOSAT

Sun-Synchronous Polar Satellites (2)

Instrument	Early morning orbit	Morning orbit	Afternoon orbit
Scatterometer		Metop ASCAT Coriolis Windsat	Oceansat OSCAT
Radar			CloudSat
Lidar			Calipso
Visible reflectance			Parasol
L-band imagery	SMOS SAC-D/Aquarius		

Non Sun-Synchronous Observations

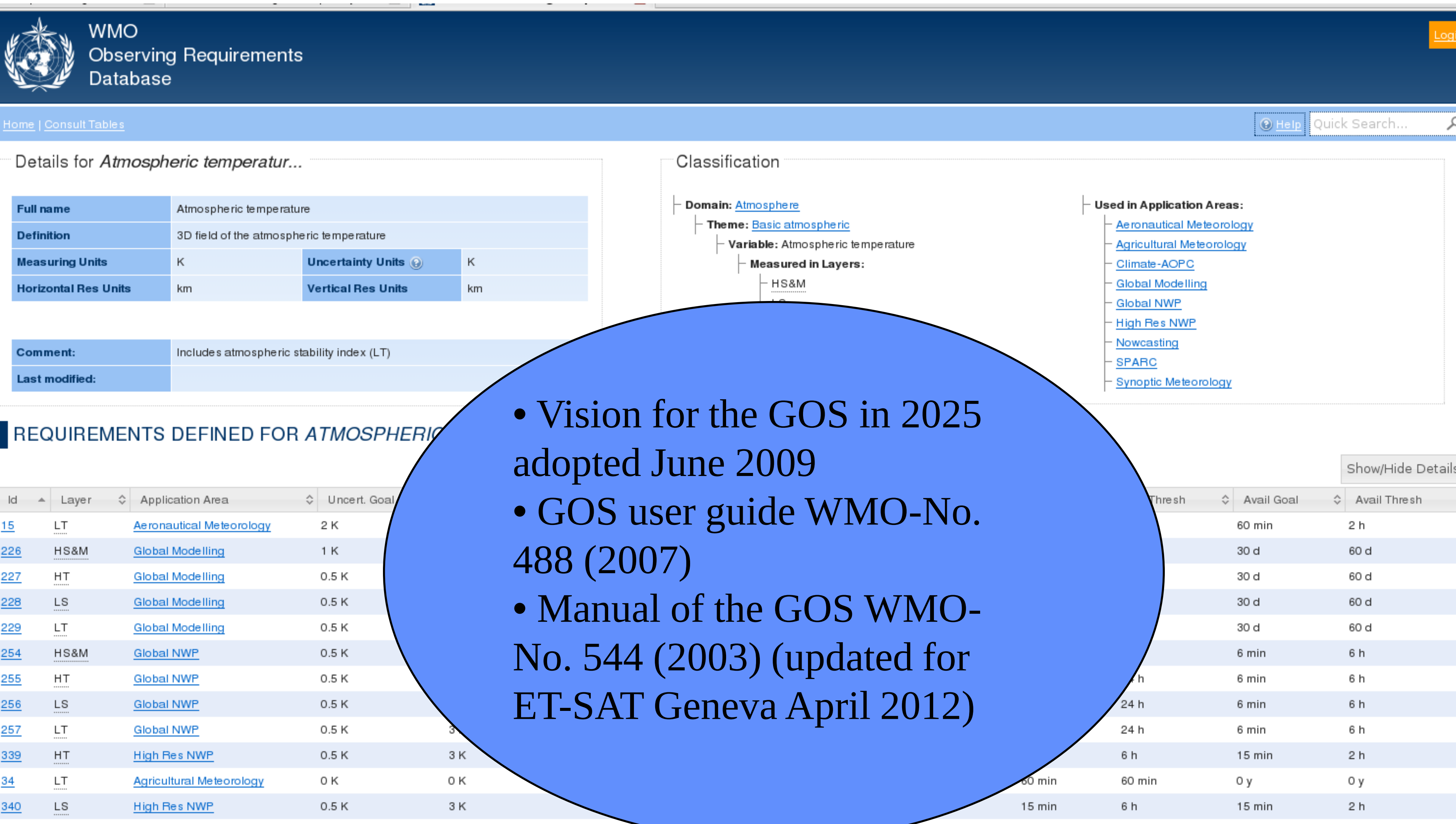
Instrument	High inclination (> 60°)	Low inclination (<60°)
Radio occultation	GRAS, GRACE-A, COSMIC, TerraSarX C-NOFS, (SAC-C), ROSA	
MW Imagers		TRMM TMI Meghatropics SAFIRE MADRAS
Radar Altimeter	ENVISAT RA JASON Cryosat	

Data sources: Geostationary Satellites

Product	Status
SEVIRI Clear sky radiance	Assimilated
SEVIRI All sky radiance	Being tested for overcast radiances, and cloud-free radiances in the ASR dataset
SEVIRI total column ozone	Monitored
SEVIRI AMVs	IR, Vis, WV-cloudy AMVs assimilated
GOES	AMVs, Clear sky radiances assimilated
MTSAT-2	AMVs, Clear sky radiances assimilated

User requirements and satellite data: OSCAR

www.wmo-sat.info/oscar/



- Vision for the GOS in 2025 adopted June 2009
- GOS user guide WMO-No. 488 (2007)
- Manual of the GOS WMO-No. 544 (2003) (updated for ET-SAT Geneva April 2012)

OSCAR demonstration / practical