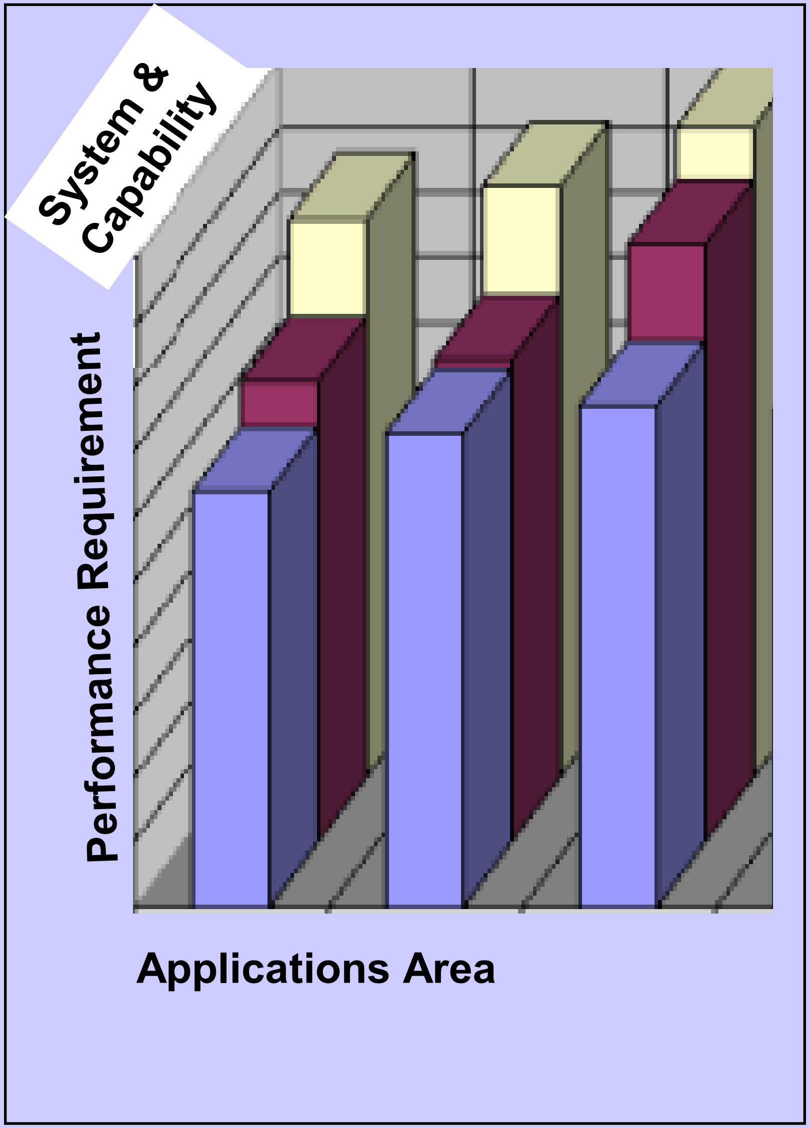
Evolution of the Global Observing System

Lectures in Maratea
22-31 May 2003

Paul Menzel
NOAA/NESDIS/ORA

Observational Data Requirements and Redesign of the Global Observing System



- User requirements and observing system capabilities
- The rolling requirements review (RRR) was readily applied to a diversity of application areas, provided the database of user requirements and observing system capabilities was accurate

Observational Data Requirements and Redesign of the Global Observing System

Wind profile 500-100 hPa (HT)

Analysis for Global NWP (in situ and space-based observing systems)

1. Requirement Summary and assessment key

Colour key	Hor (km)	Vert (km)	Cycle (h)	Delay (h)	Acc (m/s)
Optimum	50.0	1.0	1.0	1.0	1.0
Median	107.7	2.2	2.3	1.6	2.0
	232.1	4.6	5.2	2.5	4.0
Threshold	500.0	10.0	12.0	4.0	8.0

Cycle colour assessment based on a constellation of 2 polar-orbiting satellites (1 geostationary)

2. Instruments for: Wind profile 500-100 hPa (HT)

Showing relevant instruments for which details are available

Instrument	Hor (km)	Vert (km)	Cycle (h)	Delay (h)	Acc (m/s)	Mission name	Mission rating	bit Or
ACARS P RA-VI WE	175.0	0.1	2.0	1.0	2.00	WWW		G
ACARS FL RA-VI WE	38.0	0.6	8.0	1.0	2.00	WWW		G
SEVIRI	100.0	5.0	1.0	1.0	4.00	WWW		G
ACARS FL RA-VI EE	159.0	0.6	8.0	1.0	2.00	WWW		G
ACARS FL RA-V SW	167.0	0.6	12.0	1.0	2.00	WWW		G
IMAGER	150.0	5.0	1.0	1.0	5.00	WWW		G
IMAGER/MTSAT	150.0	5.0	1.0	1.0	5.00	WWW		G
SOUNDER	150.0	5.0	1.0	1.0	5.00	WWW		G
ACARS FL RA-II S	310.0	0.6	12.0	1.0	2.00	WWW		G
ACARS FL RA-IV N	318.0	0.6	12.0	1.0	2.00	WWW		G
ACARS FL RA-IV C	380.0	0.6	12.0	1.0	2.00	WWW		G
ACARS FL RA-II W	429.0	0.6	12.0	1.0	2.00	WWW		G
MVIRI	150.0	5.0	1.0	2.0	5.00	WWW		G
VISSR (GMS-5)	150.0	5.0	1.0	2.0	5.00	WWW		G
VHRR	150.0	5.0	1.0	2.0	6.00	WWW		G
WND P 449 RA-IV C	700.0	0.3	1.0	0.5	1.50	WWW		G
ACARS FL NAO CST	50.0	0.6	24.0	1.0	2.00	WWW		G
WND P 915 RA-IV C	1000.0	0.1	1.0	0.5	2.00	WWW		G
ACARS P RA-VI EE	692.0	0.1	2.0	1.0	2.00	WWW		G
ACARS FL MED	156.0	0.6	24.0	1.0	2.00	WWW		G
ACARS FL NAO OPN	223.0	0.6	24.0	1.0	2.00	WWW		G
ACARS P RA-V NW	3821.0	0.1	6.0	1.0	2.00	WWW		G
ACARS P RA-V SW	644.0	0.1	6.0	1.0	2.00	WWW		G
ACARS FL ARC	270.0	0.6	24.0	1.0	2.00	WWW		G
ACARS FL RA-I S	330.0	0.6	24.0	1.0	2.00	WWW		G

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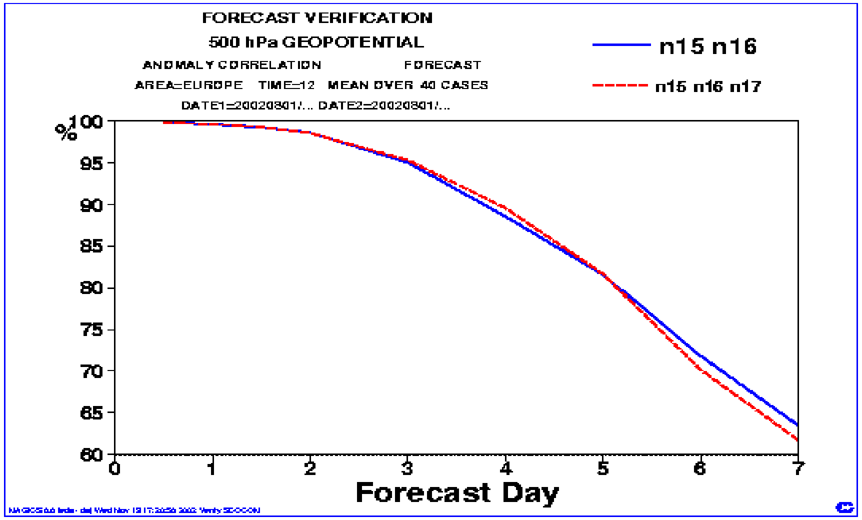
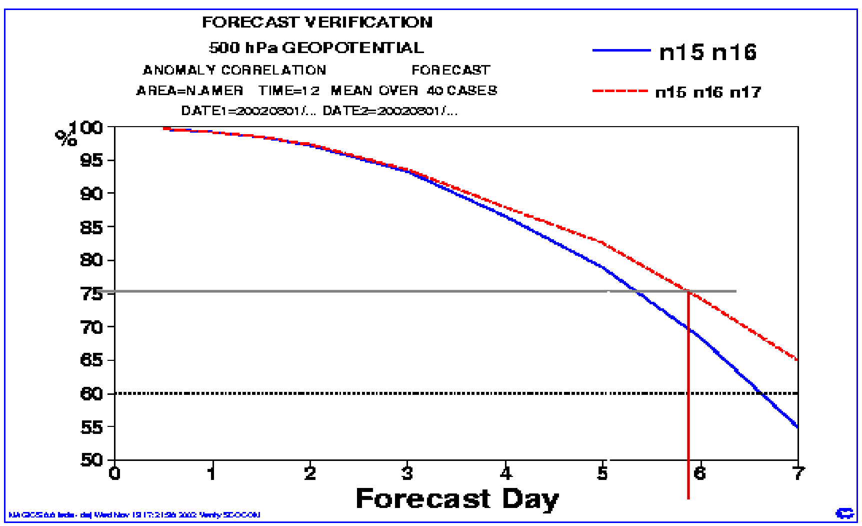
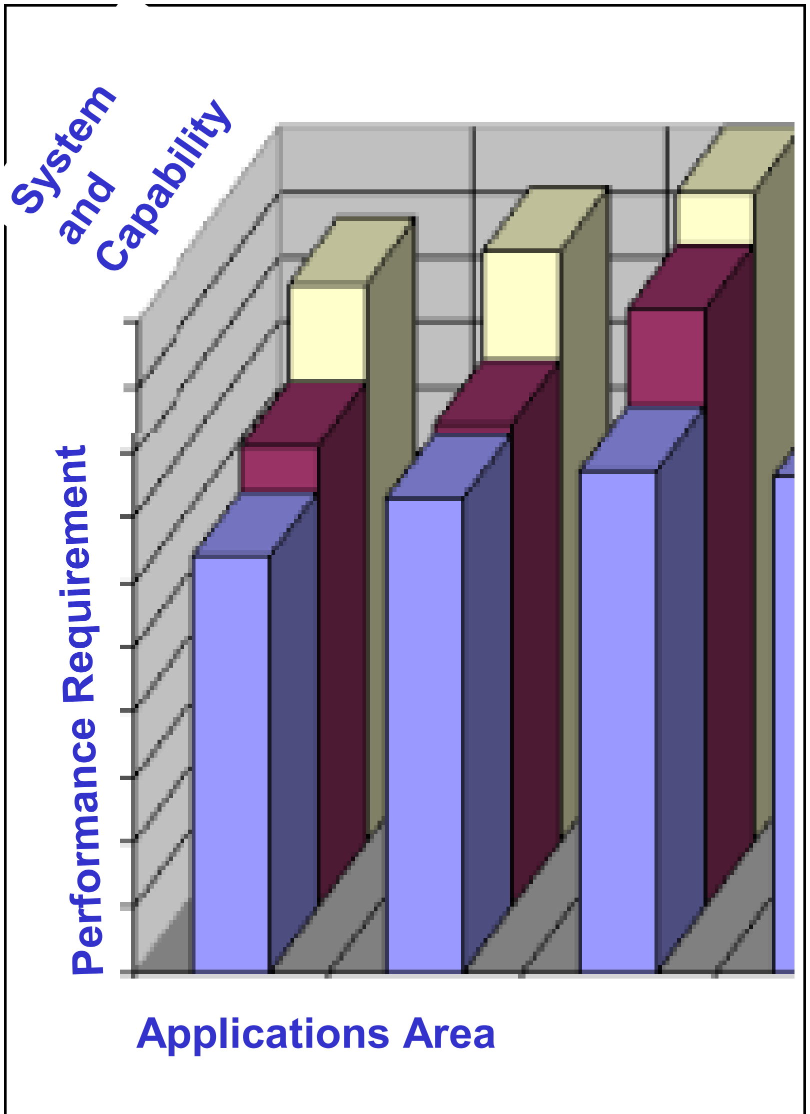
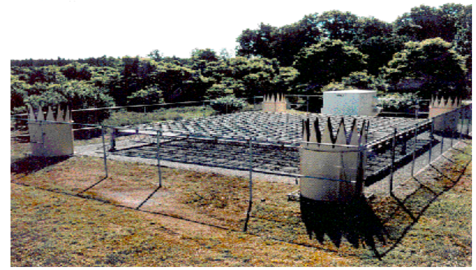


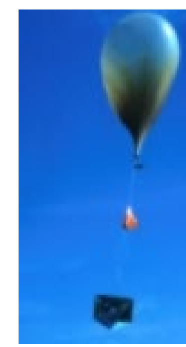


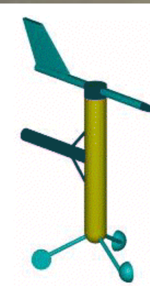
- OSEs test possible GOS re-configurations
- With the Rapporteurs of Regional and Global OSEs: hypothetical changes to the GOS could be explored in OSEs with NWP centre assistance, provided data assimilation procedures were well understood and impact studies were conducted in a statistically significant way.
- OSSEs required huge human and computer resources and were beyond the available resources

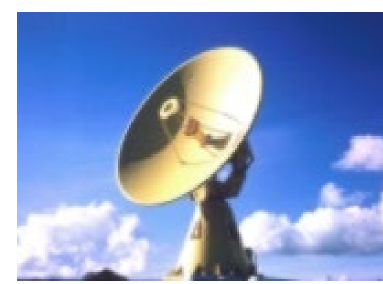
There are many components in the Global Observing System





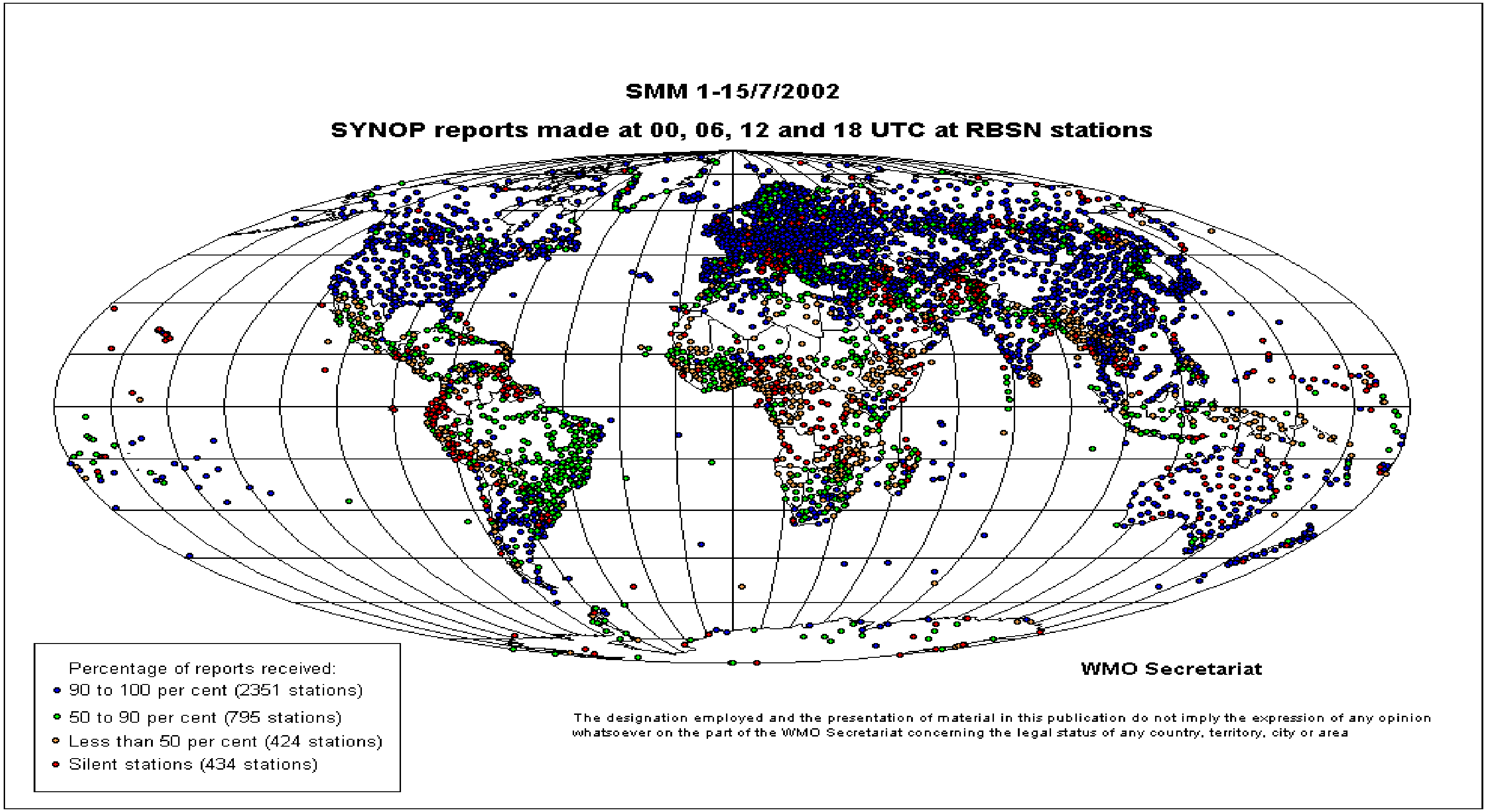




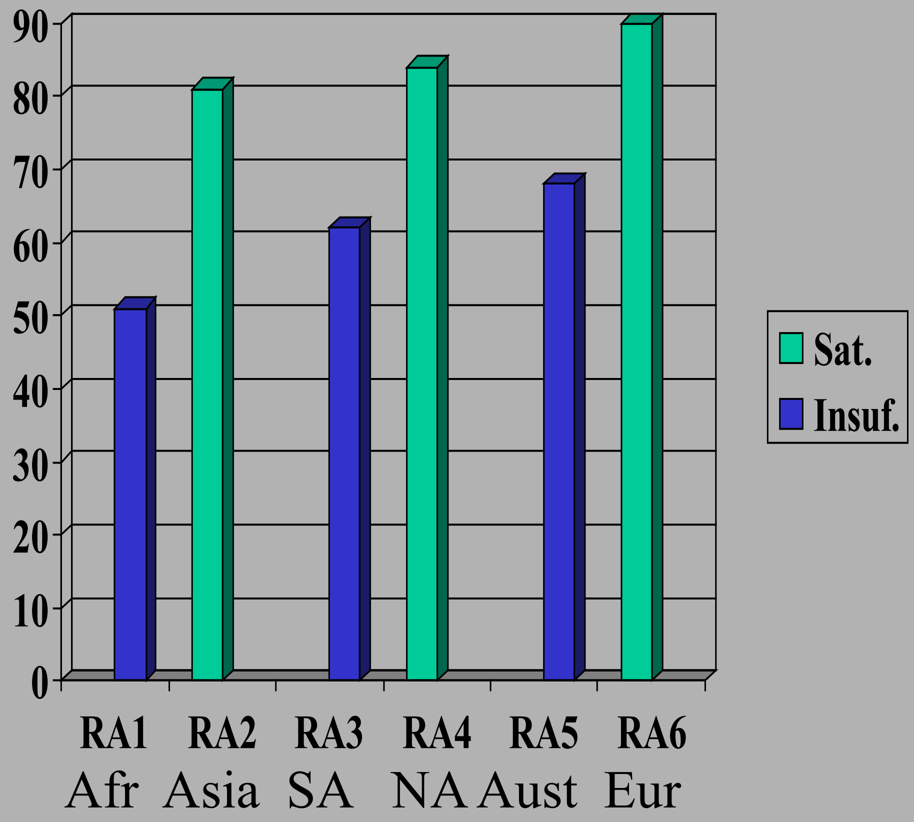


Regional Basic Synoptic Networks (Surface) - GOS

- Jul 2002 monitoring results of overall implementation in Regional Basic Synoptic Networks (RBSNs) of surface and upper-air stations shows increasing stability



SYNOP - GOS

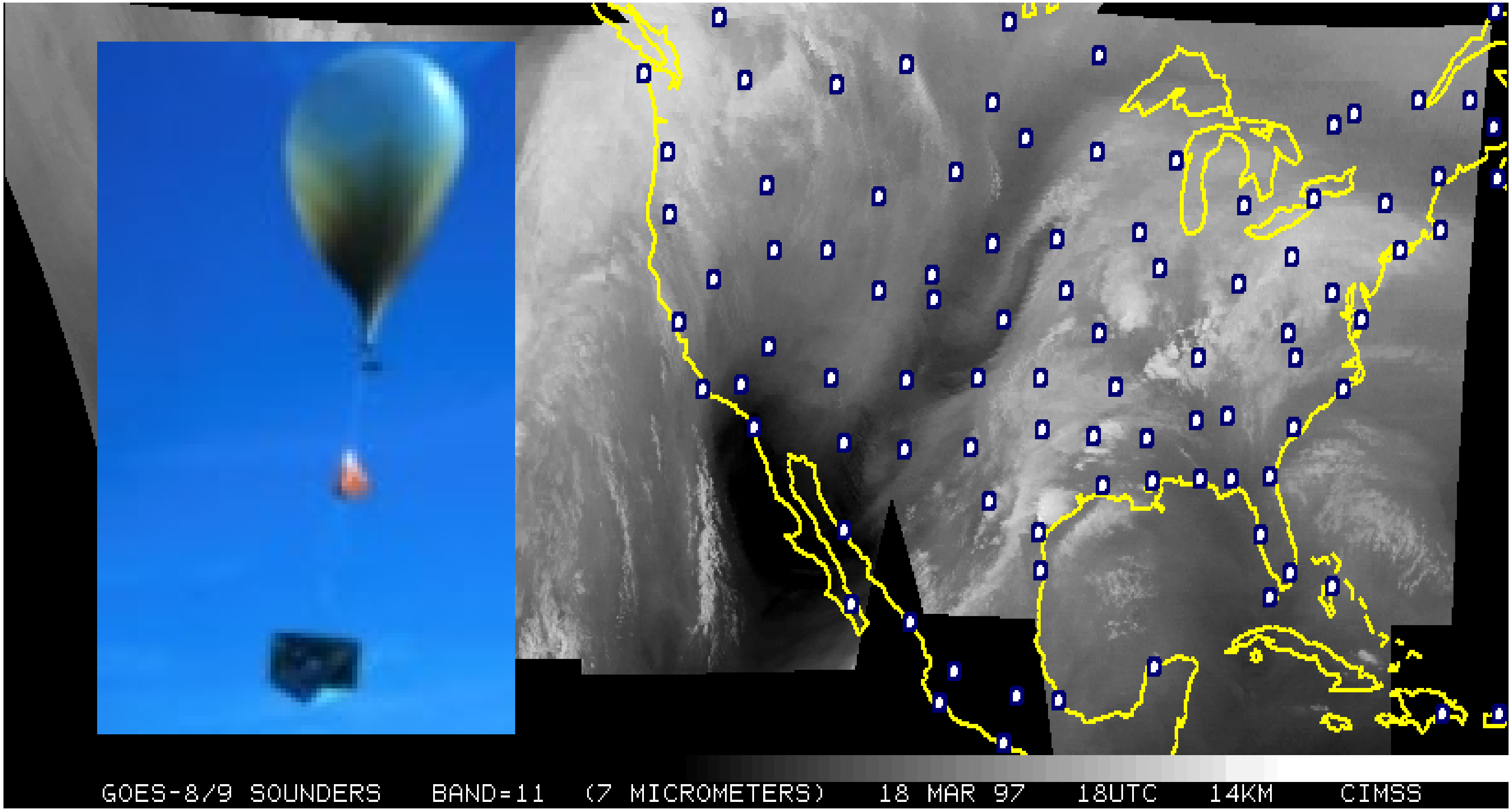


- SYNOP at MTN Centers
  - **2001-2002 remained unchanged globally at 75% from 2000 (up from 72% in 1999 report)**
- Deficiencies in surface data coverage:
  - **Inadequate funds to rehabilitate and operate observational and telecommunications equipment**

Results from monitoring exercise for July 2002

GOS – Radiosonde Observations

Raobs over land every 12 hours are providing
*** all weather temperature and moisture profiles**
*** wind profiles along ascent path**



RBSNs (Upper Air) - GOS

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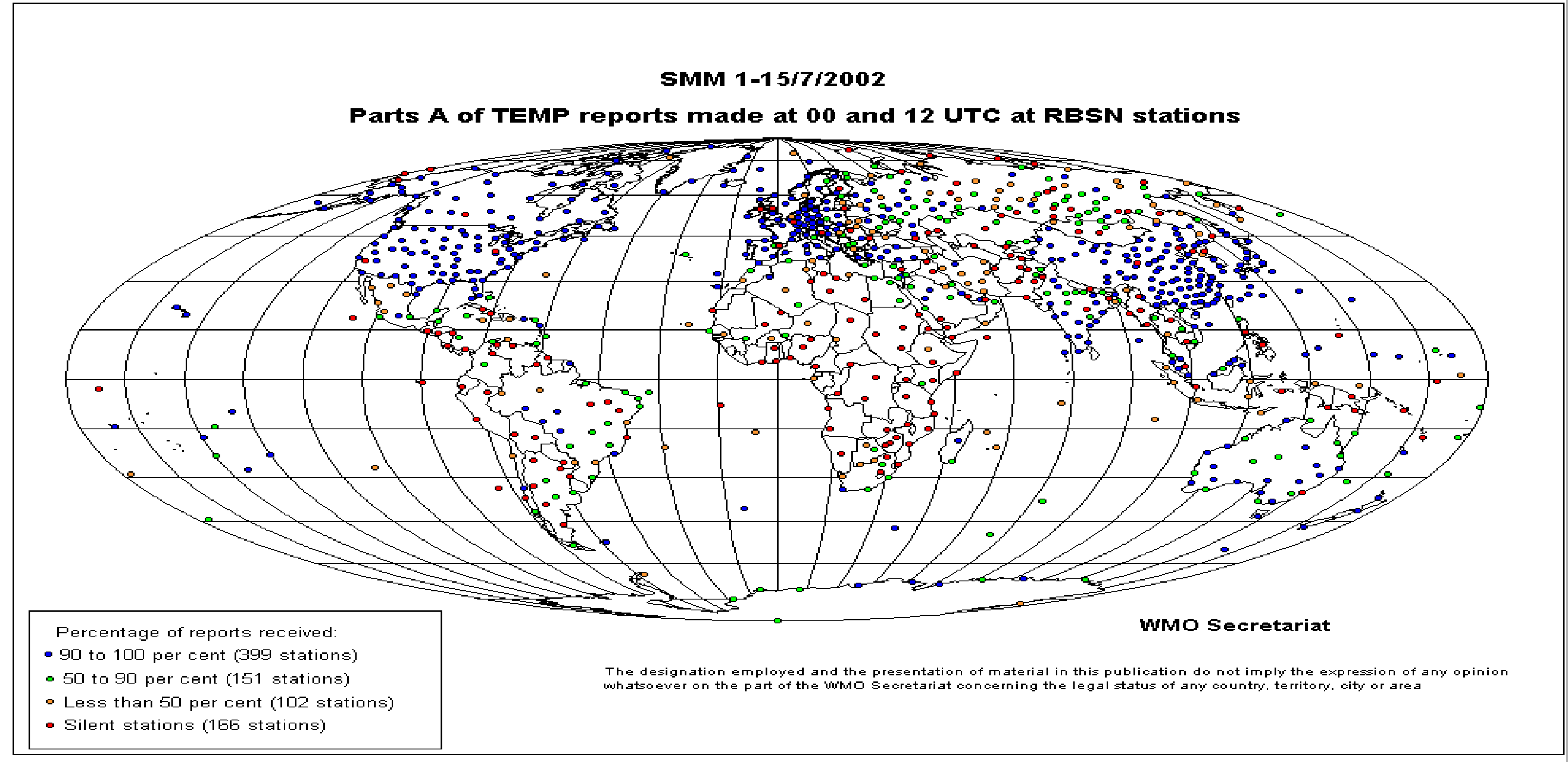
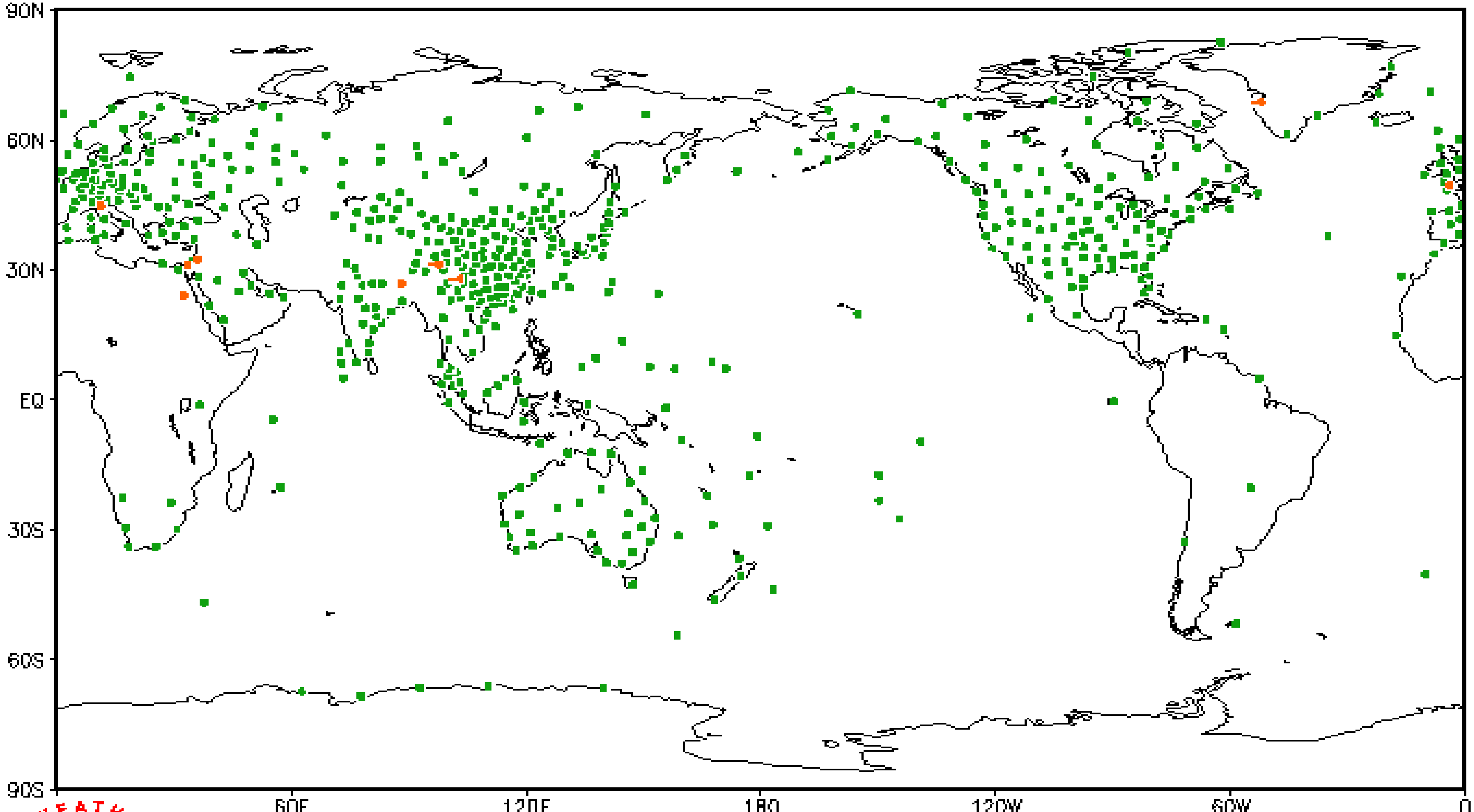


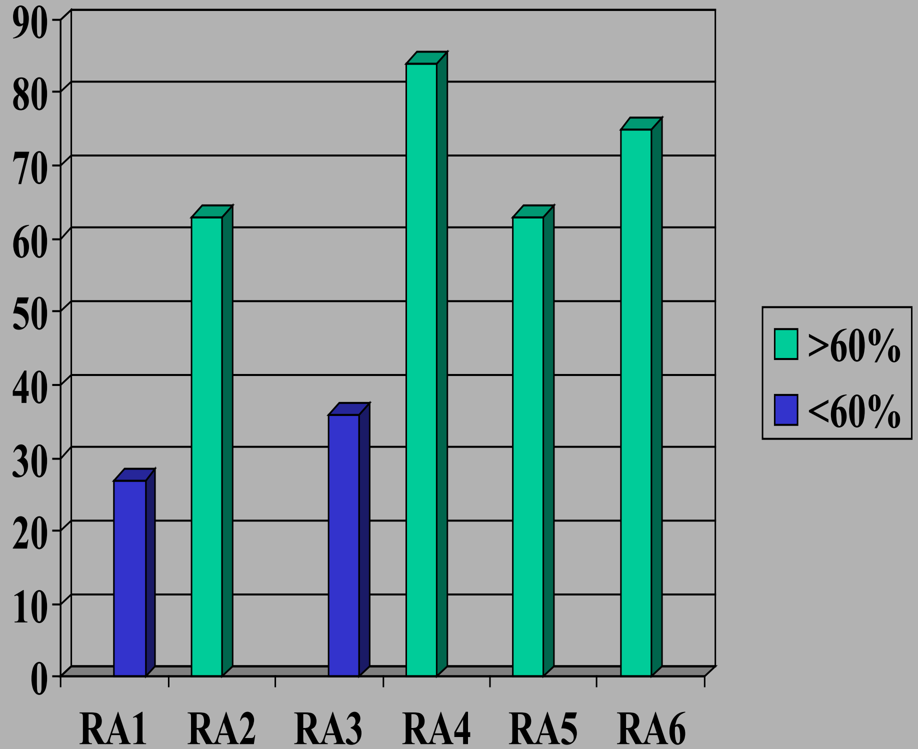
00Z05MAR1999 WIND Coverage from RAWINDSONDES 700–300 mb

Accepted 5192 Rejected 76 Type 220



SURANJANA SAHA, GMB/EMC/NCEP/NWS/NOAA

Upper Air Network - GOS



Afr Asia SA NA Aust Eur

Results from monitoring exercise for July 2002

- Upper Air at MTN Centers
  - **Remained unchanged globally at 61% from 2000 (up from 58% in 1999 report)**
- Deficiencies in coverage:
  - **Lack of trained staff and consumables in countries with financial difficulties**

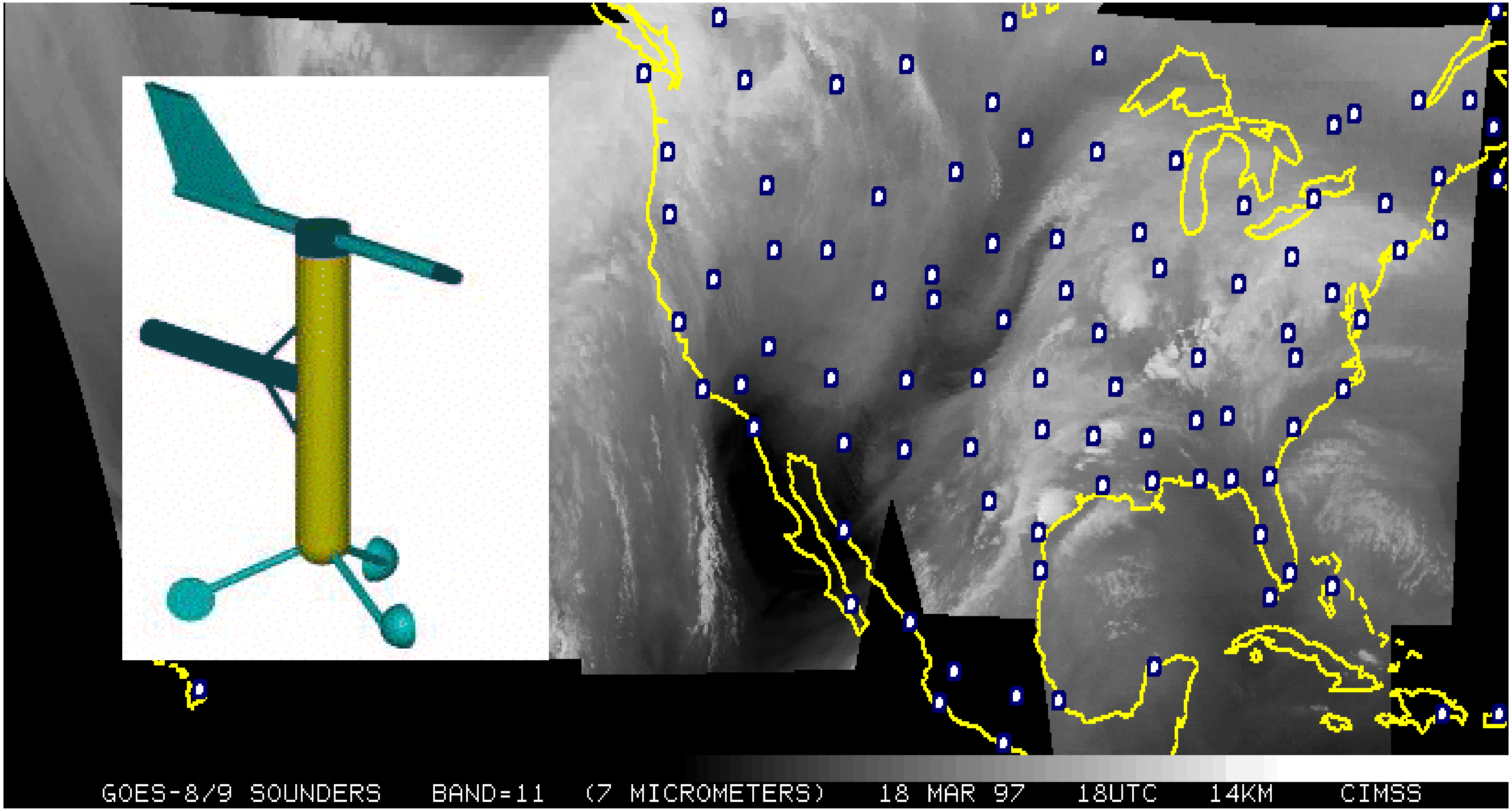
GOS – Automated Surface Observing System

ASOS over land every hour are providing

*** Surface temperature and pressure and wind**

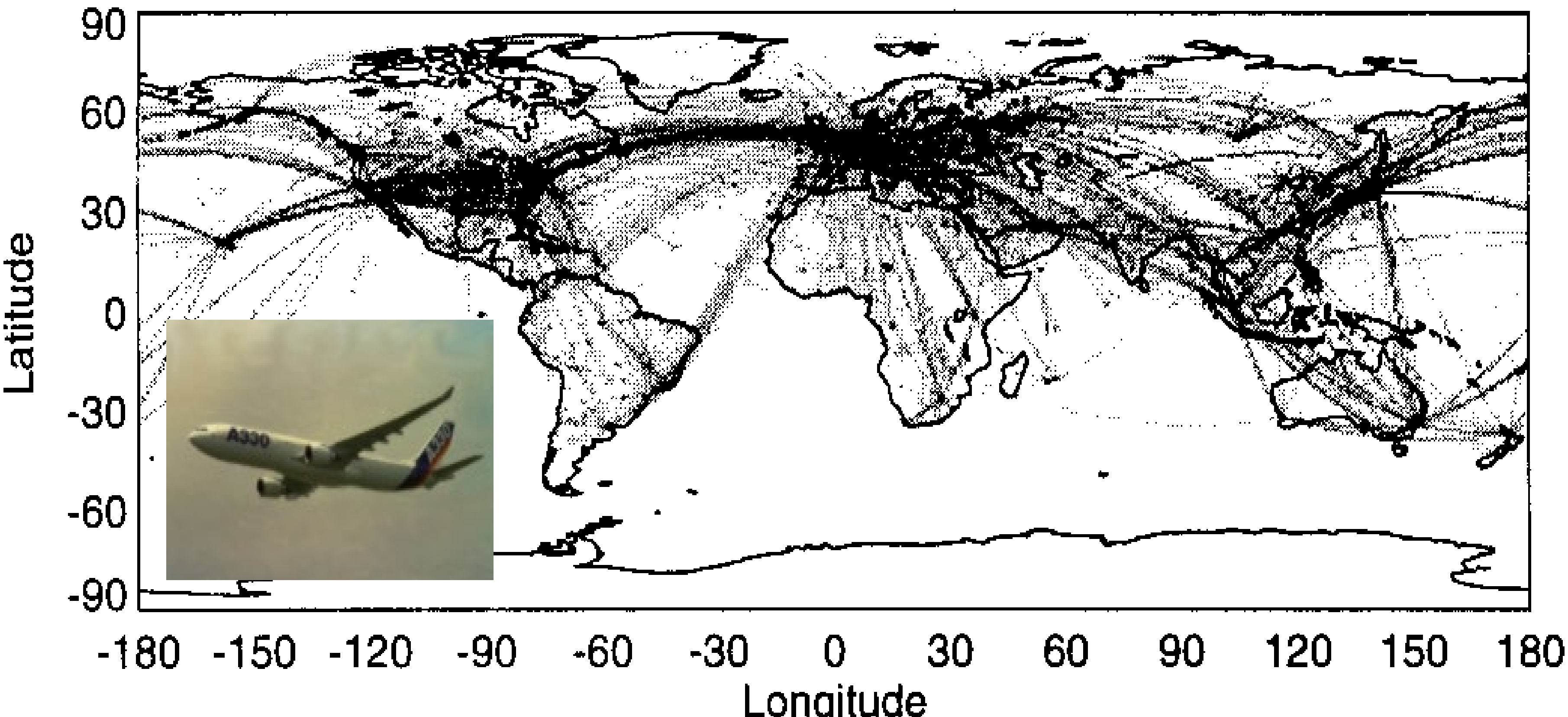
*** Hydrometeor detection**

*** Cloud detection up to 10,000 ft**



GOS – AMDAR

Aircraft Reports along flight tracks every 6 minutes are providing
*** temperature and wind**
*** profiles during landing and takeoffs**
*** moisture sensors are being added to newer systems**



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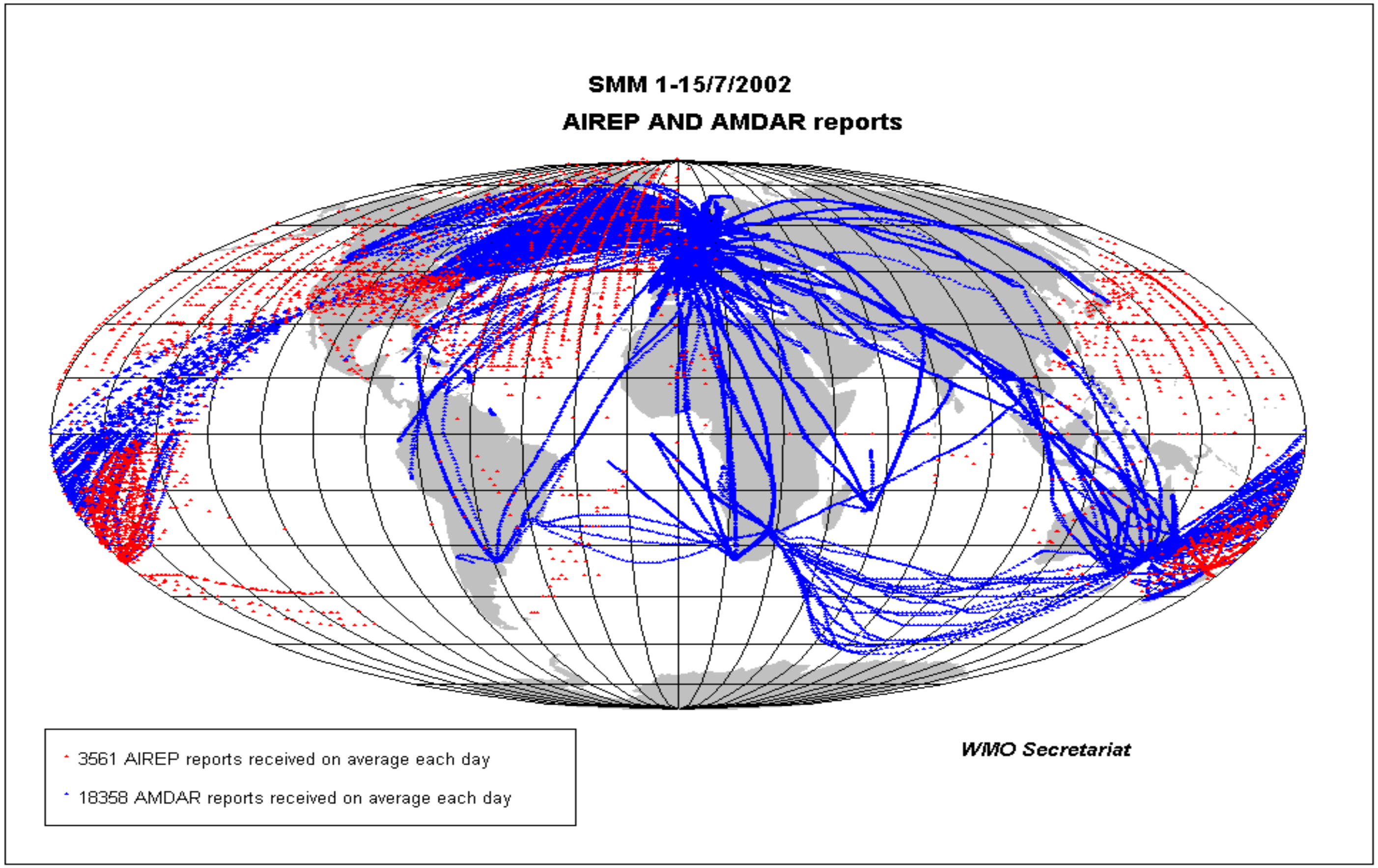
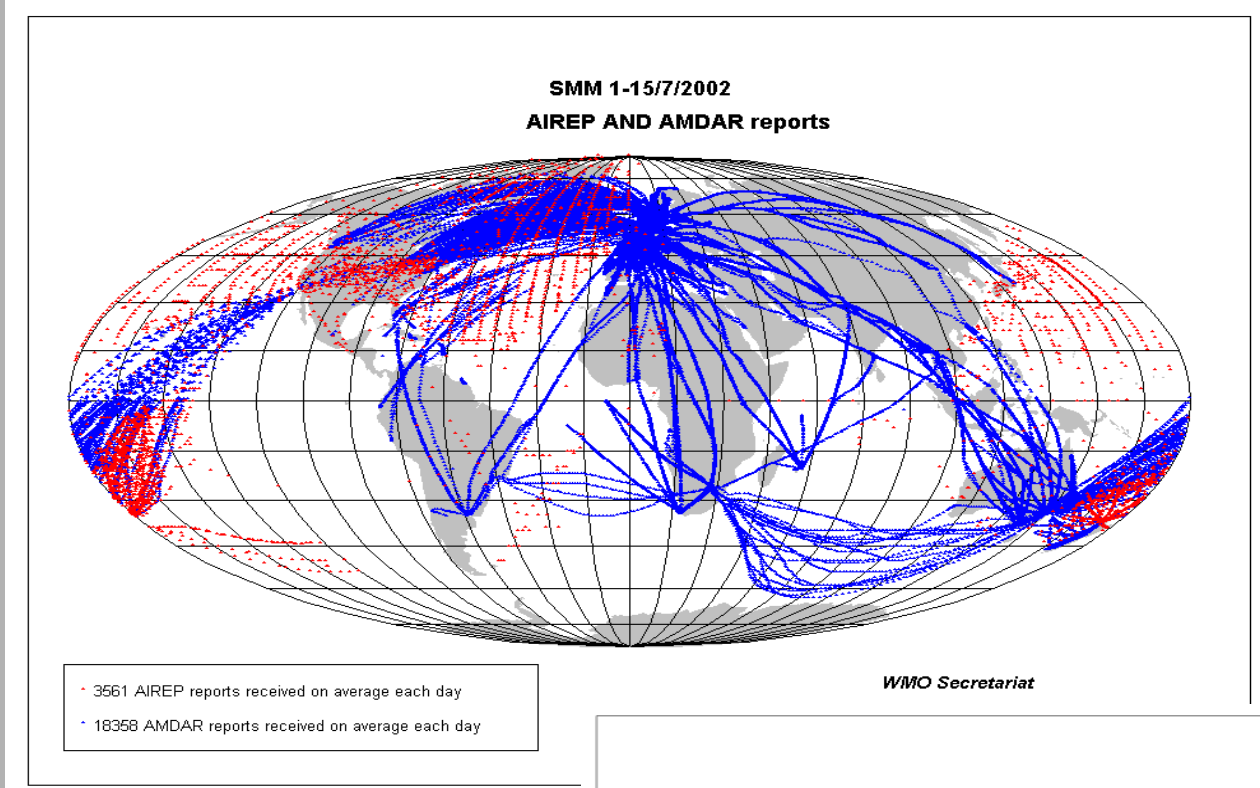
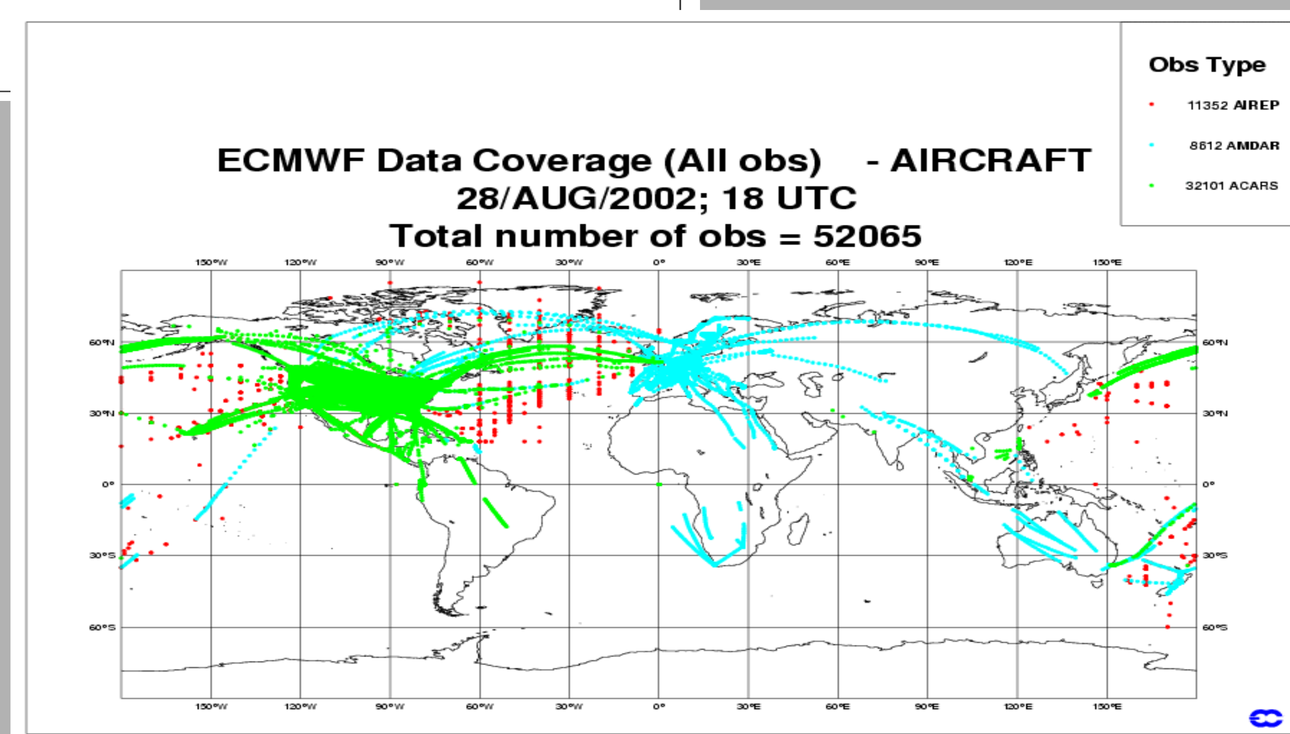


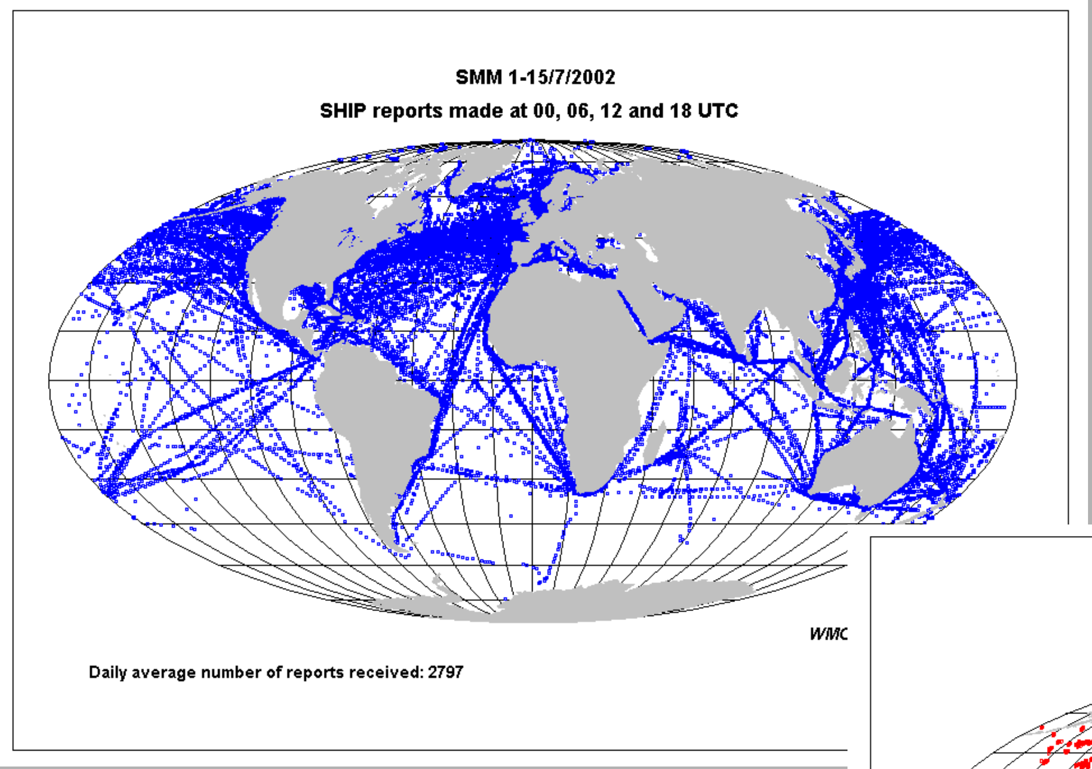


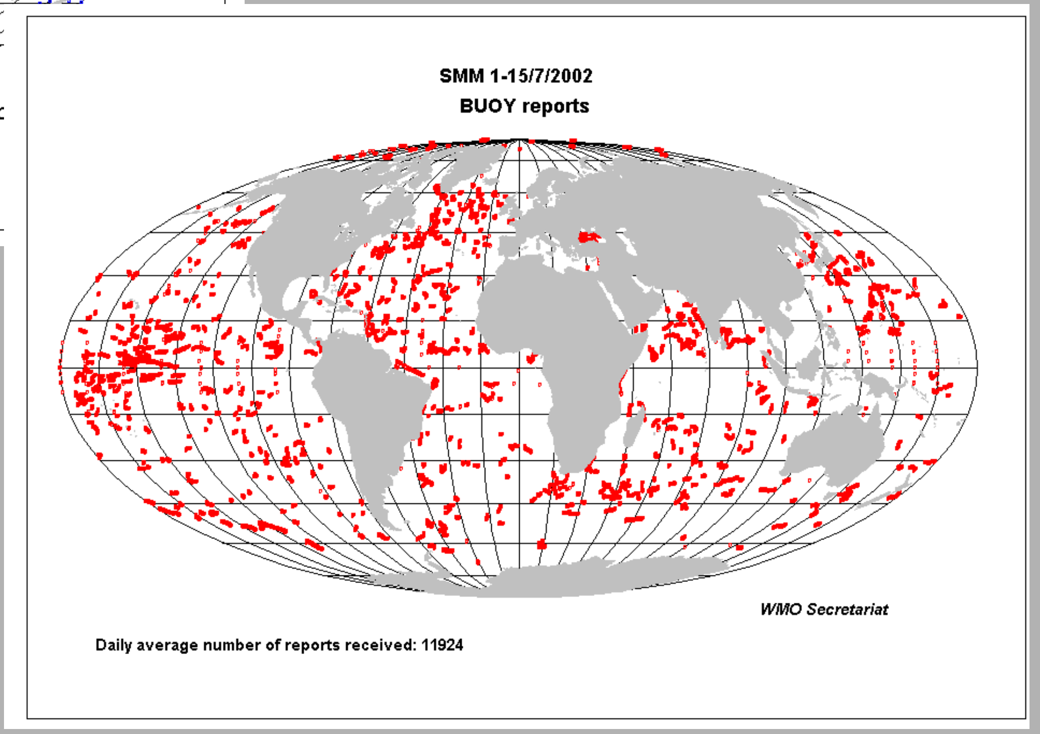
Data taken



Data Received

Ship and Buoy Reports - GOS





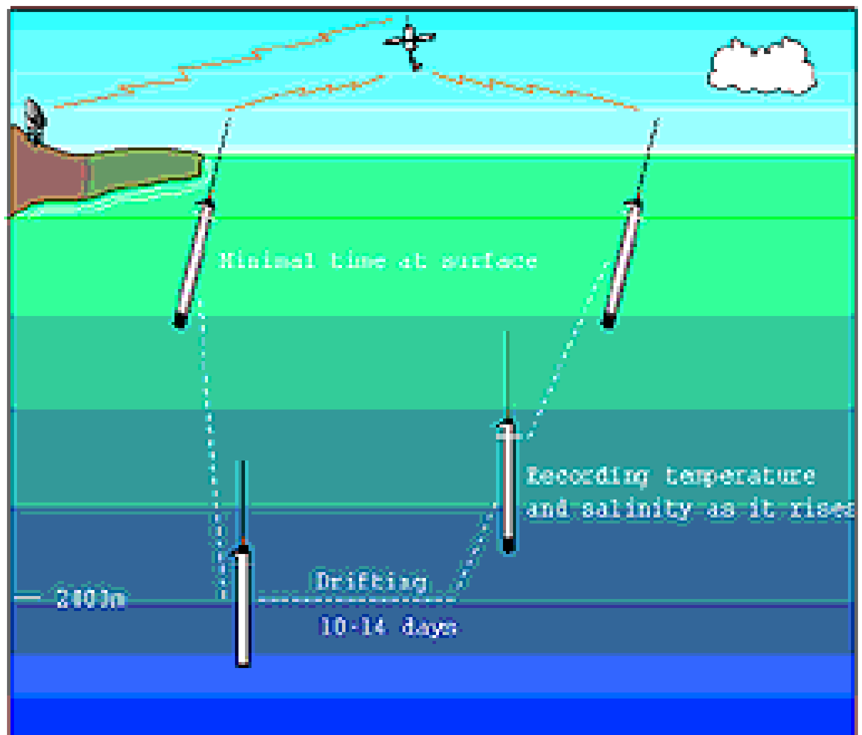
GOS – VOS and Buoys

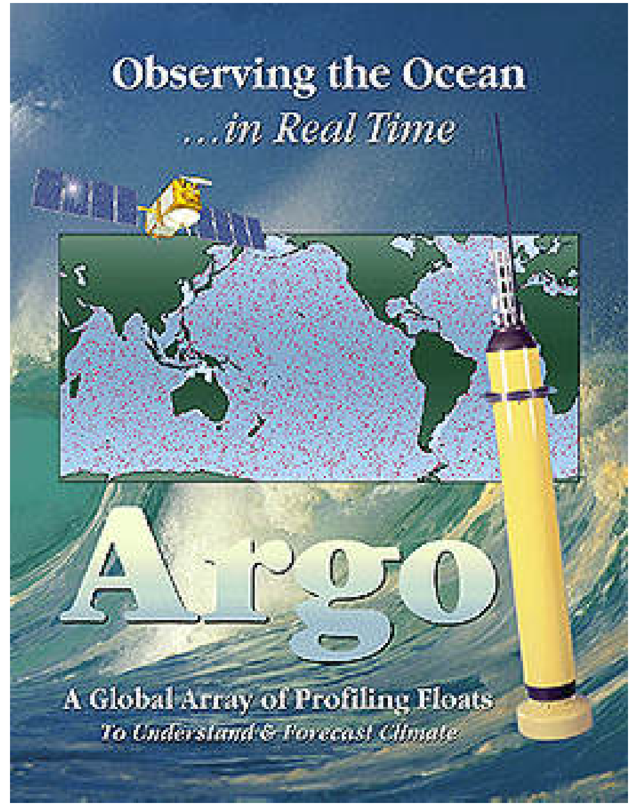
- Voluntary Observing Ships (VOS)
  - **Decline from over 900 in 1999 to around 6000 ships reporting per day**
  - **Quality and total number of reports stable at around 160,000 per month**
- VOS Climate Project being implemented to provide subset of high quality VOS data

- Data buoy program
  - **12% increase in drifting buoys since May 2000**
    - **900 active drifting buoys deployed globally with half providing pressure observations**
  - **Significant impact**
    - **Increase in monthly pressure reports over GTS from 40,000 to 200,000 continues to increase**
    - **Stable moored buoy system continues to provide data over GTS**

GOS - In-situ Ocean Profiles from ARGO

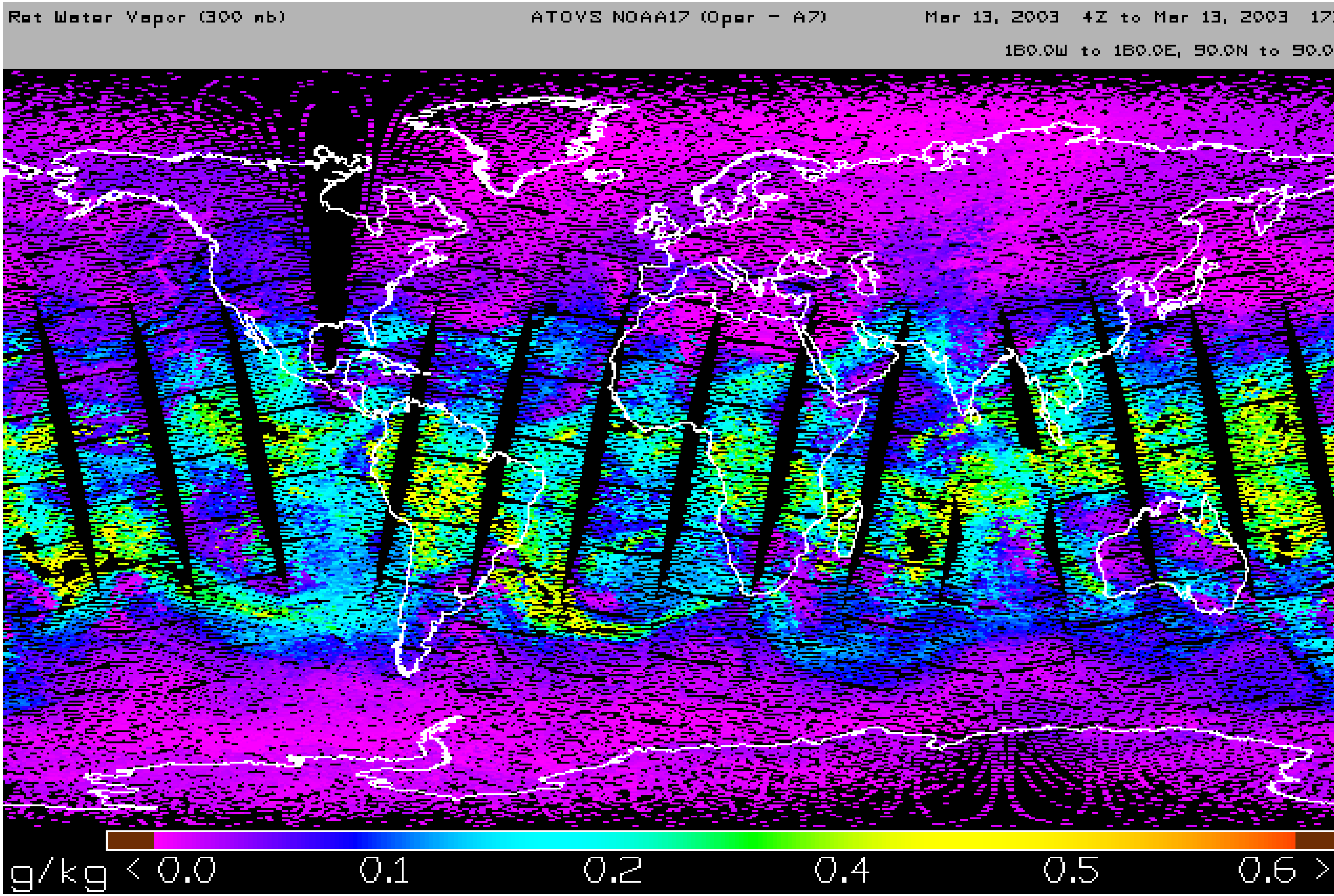
ARGO network of 575 floats deployed as of October 2002 with plans for network of 3000 by end of 2005





GOS - POES global soundings am and pm

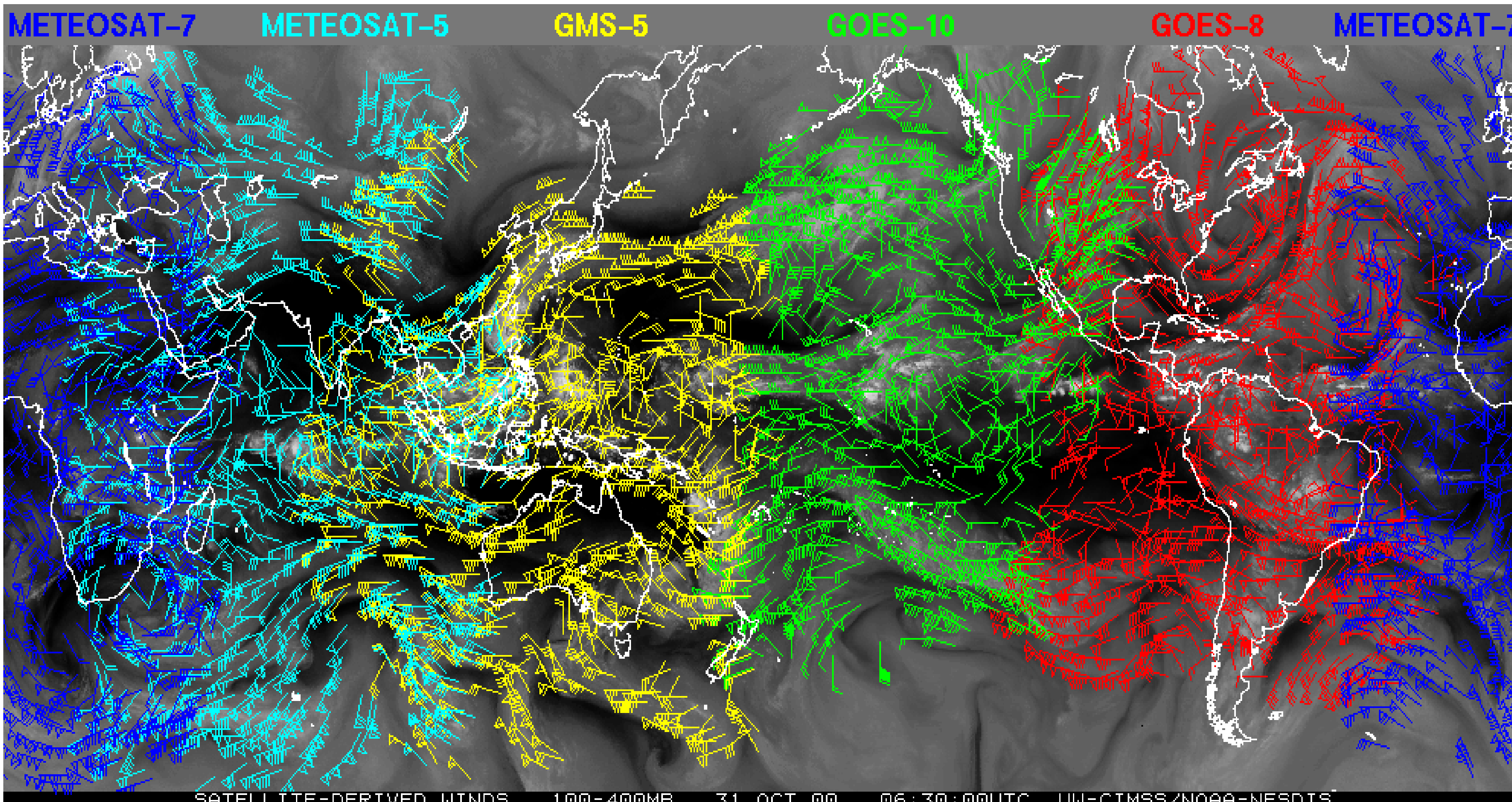
Each ATOVS provides global sounding coverage every 12 hours



GOS - The Geo Component

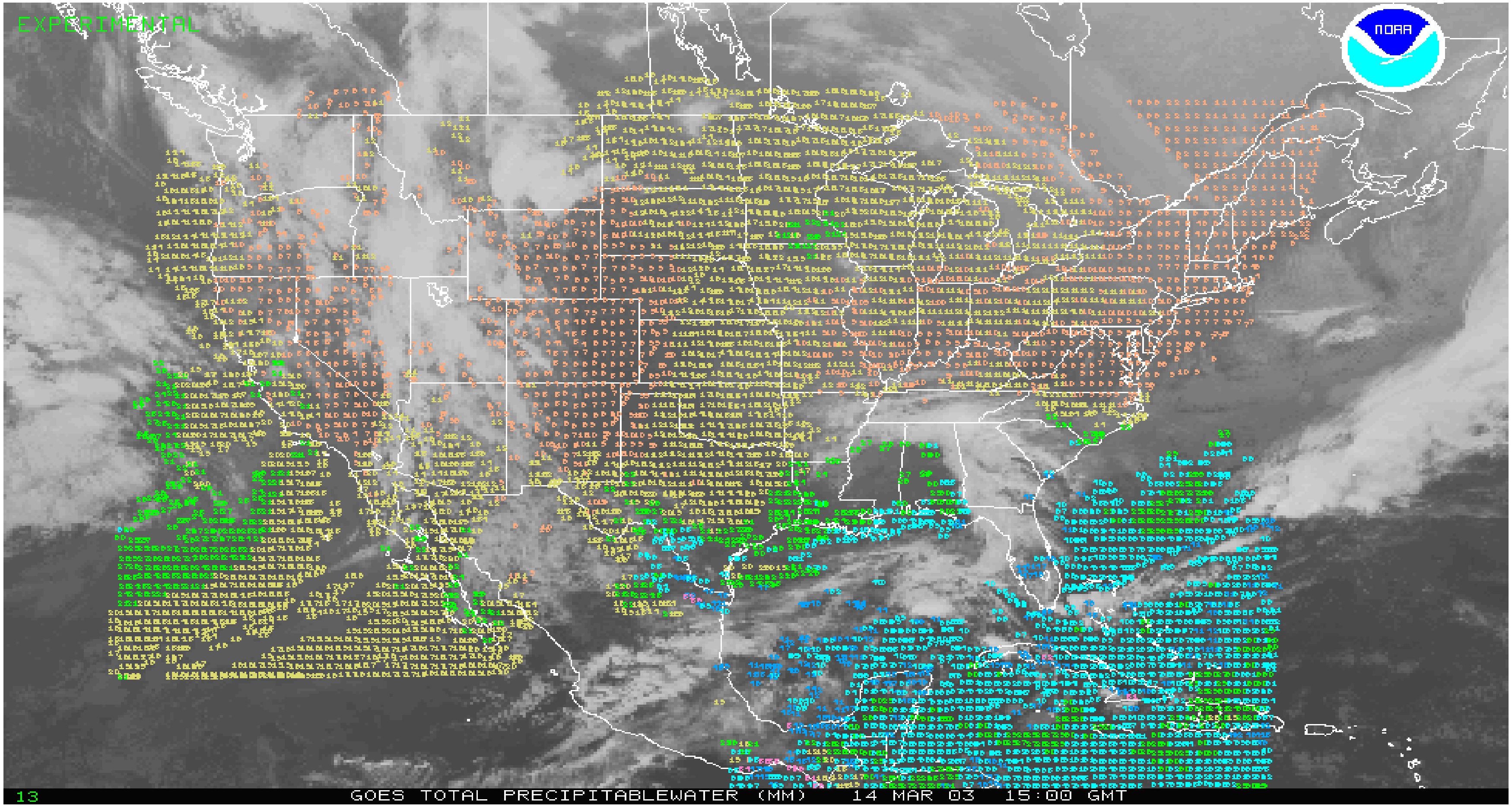
GOS – Geo Cloud Motion Vectors

Five geos are providing global coverage for winds in tropics and mid-lats



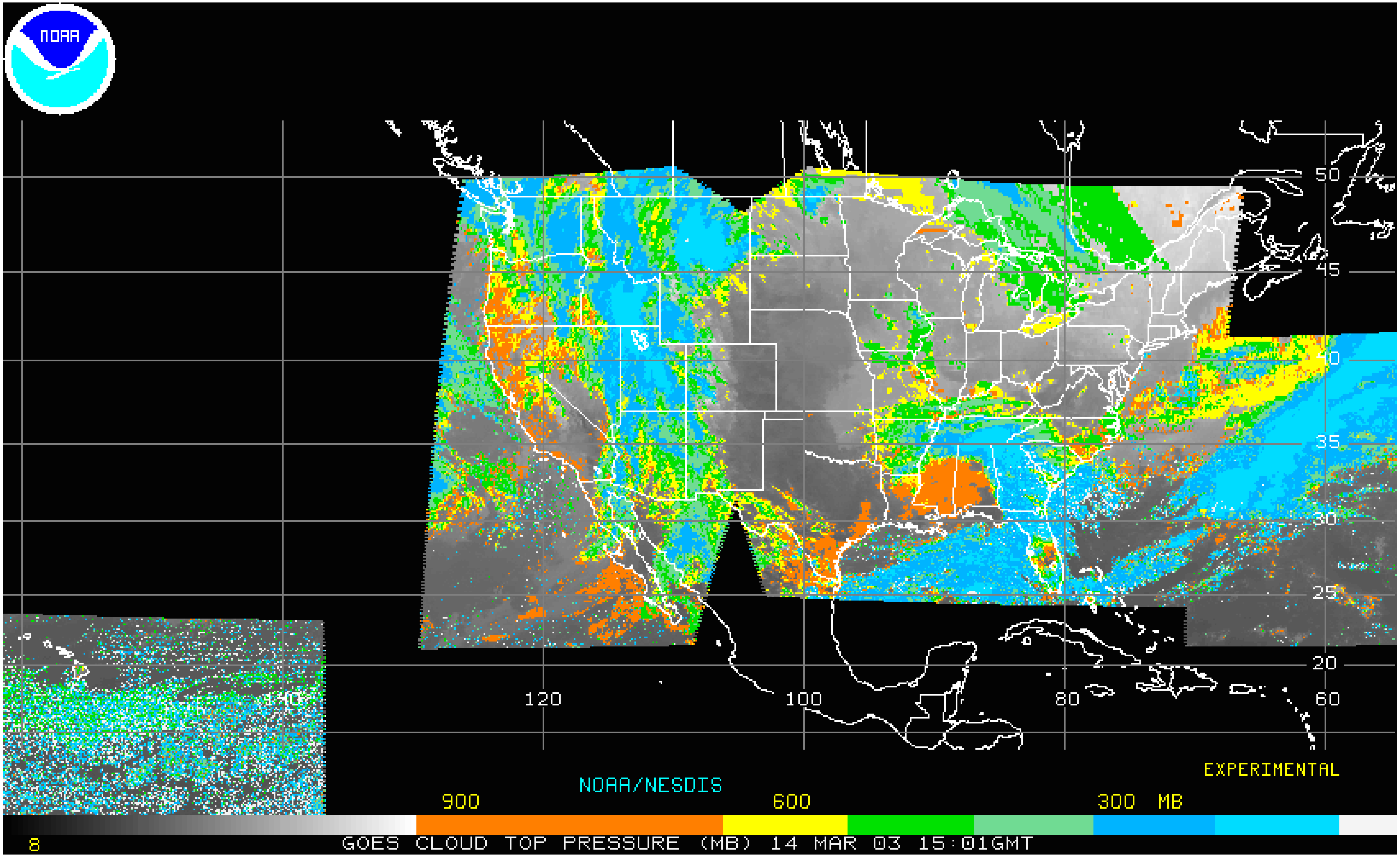
GOS – Geo Soundings

Hourly coverage from two GOES-Sounders is providing
* radiances from 4 to 15 microns
* clear sky temperature and moisture profiles
* cloud amount and height
* motion from moisture and cloud features

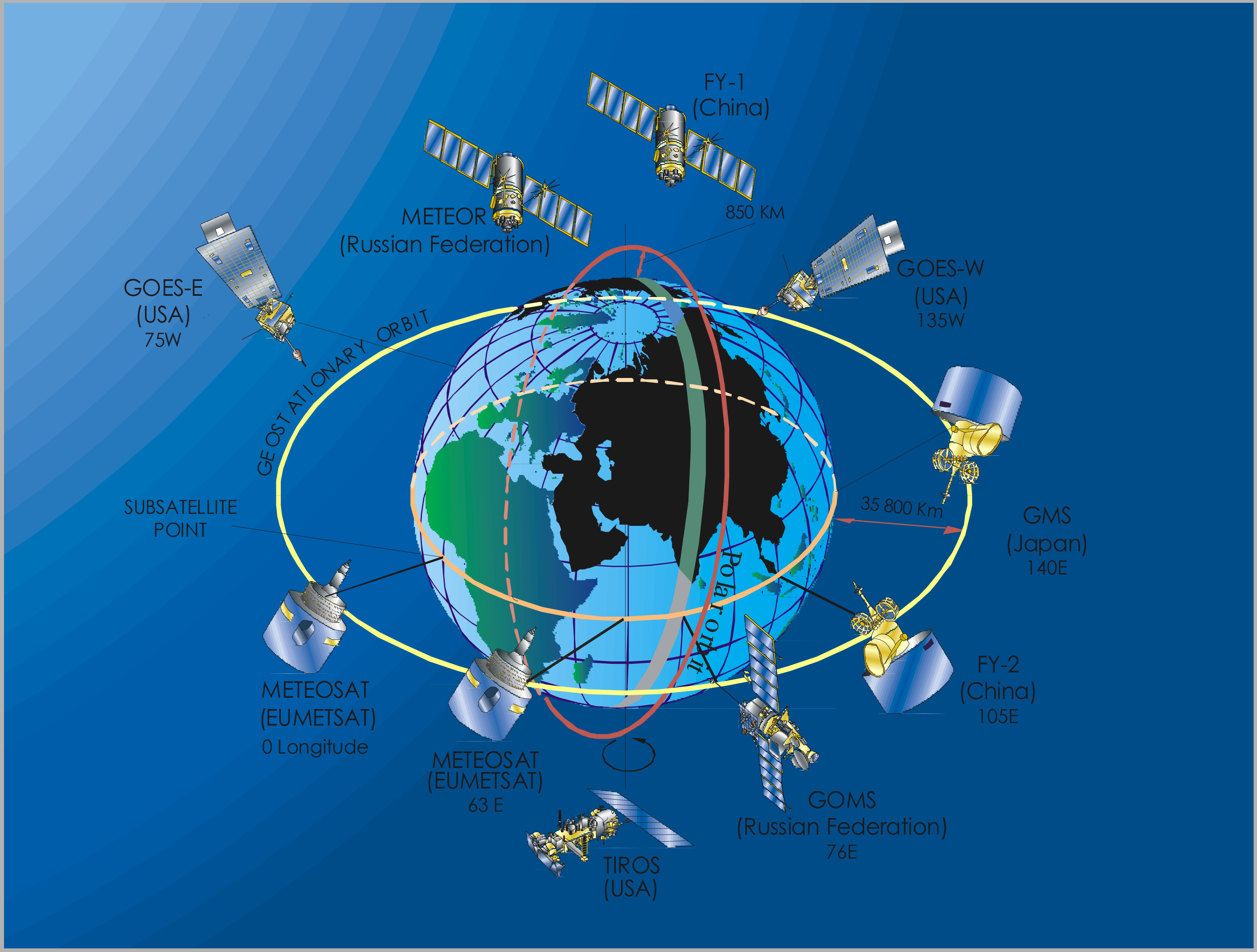


GOS – Cloud Properties

Hourly coverage from two GOES-Sounders is providing cloud amount and height



Space - based GOS



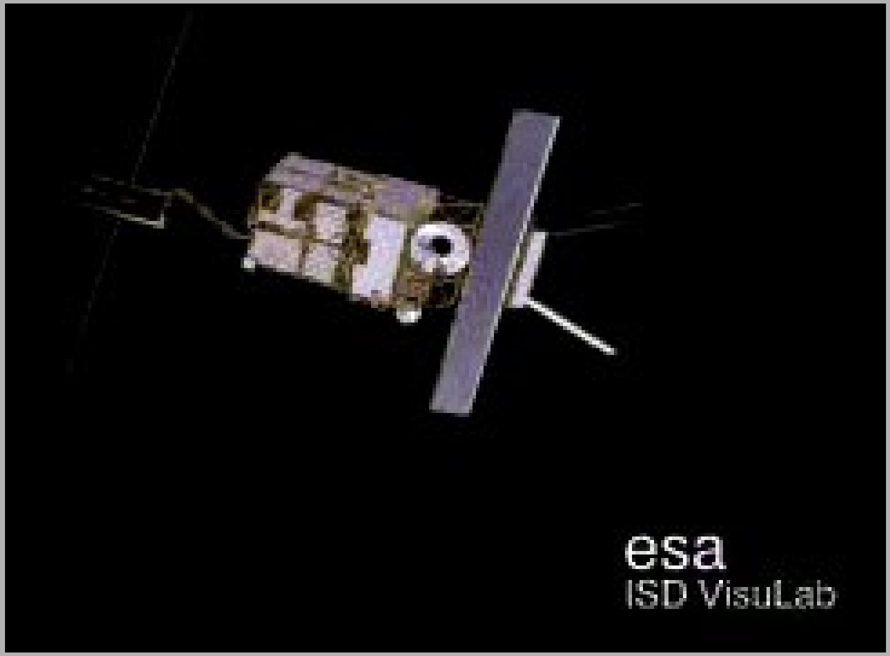
Current operational space- based GOS

- Geostationary
  - EUMETSAT
    - Meteosat-7 at 0°
    - Meteosat-5 at 63°E
    - MSG
  - Russian Federation
    - GOMS-1 at 76°E
  - People's Republic of China
    - FY-2B at 105°E
  - Japan
    - GMS-5 at 140°E
    - GOES-9 at 155°E
  - United States of America
    - GOES-10 at 135°W
    - GOES-12 at 75°W

- Polar Orbiting
  - People's Republic of China
    - FY-1C & 1D
  - Russian Federation
    - METEOR-2 and 3 series
  - United States of America
    - NOAA-15
    - NOAA-16
    - NOAA-17

Research component of space - based GOS

- Research satellite operators providing data for operational utilization
- NASA providing MODIS Direct Readout from Terra and Aqua, Quikscat winds, and AIRS radiances for NWP centres from Aqua
- Altimetry data being provided by NASA/CNES and ESA; ENVISAT data is available also Plans also in place for NASDA and Roshydromet to provide data



ERS from ESA

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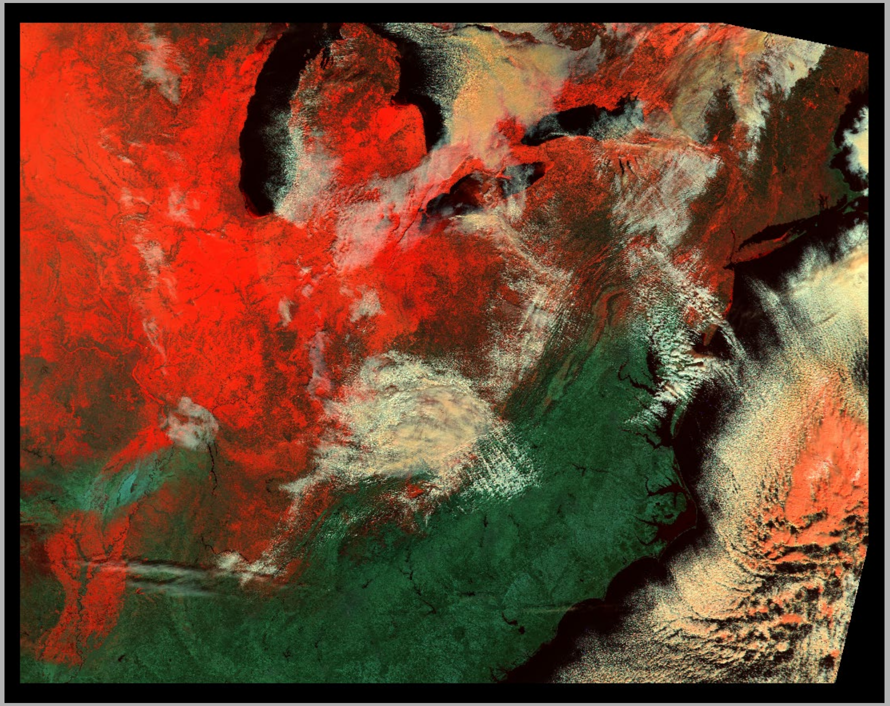

More than 50 MODIS/AIRS direct broadcast reception sites world wide

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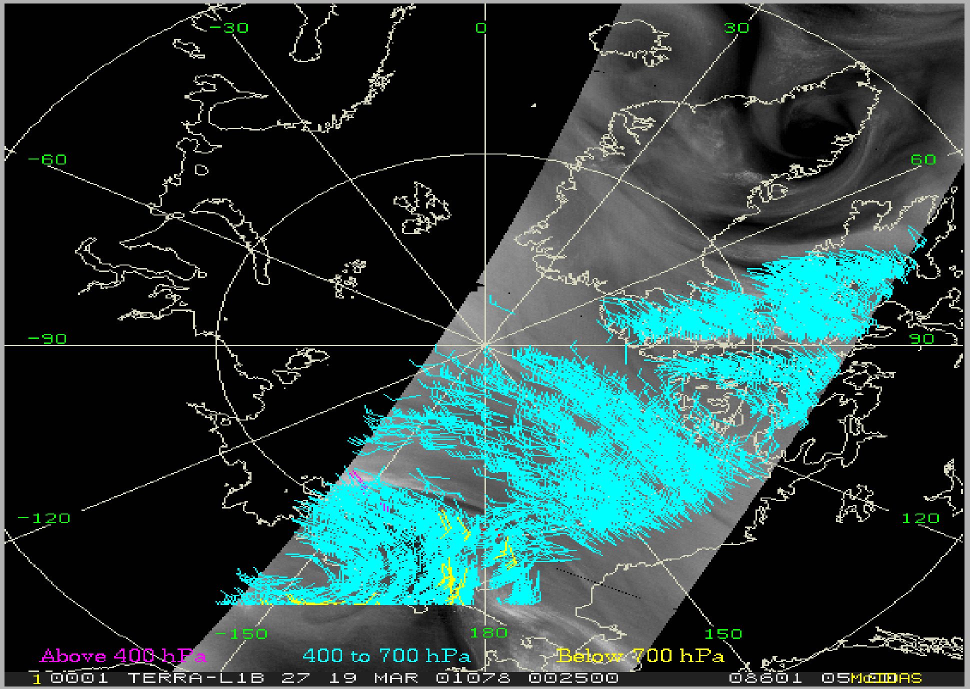

Polar WV winds have significant positive NWP impact

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ENVISAT carries 10 Instruments for different environmental purposes, including MERIS

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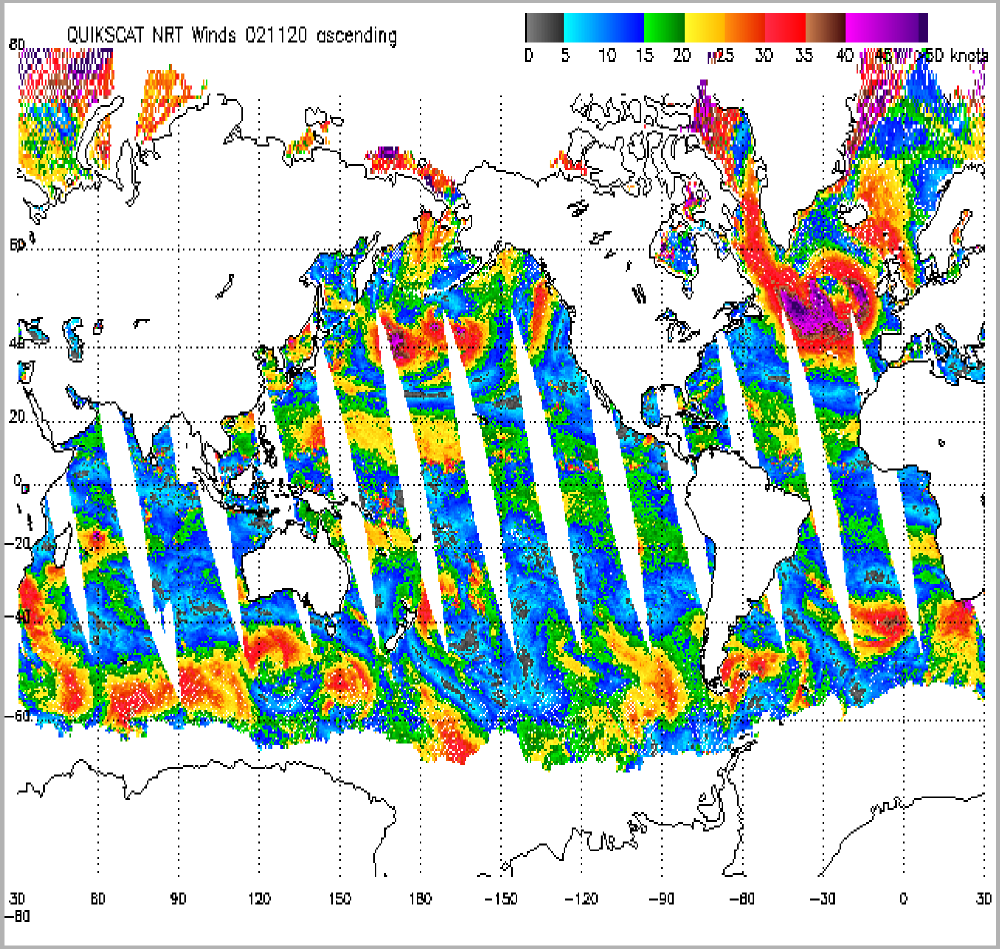

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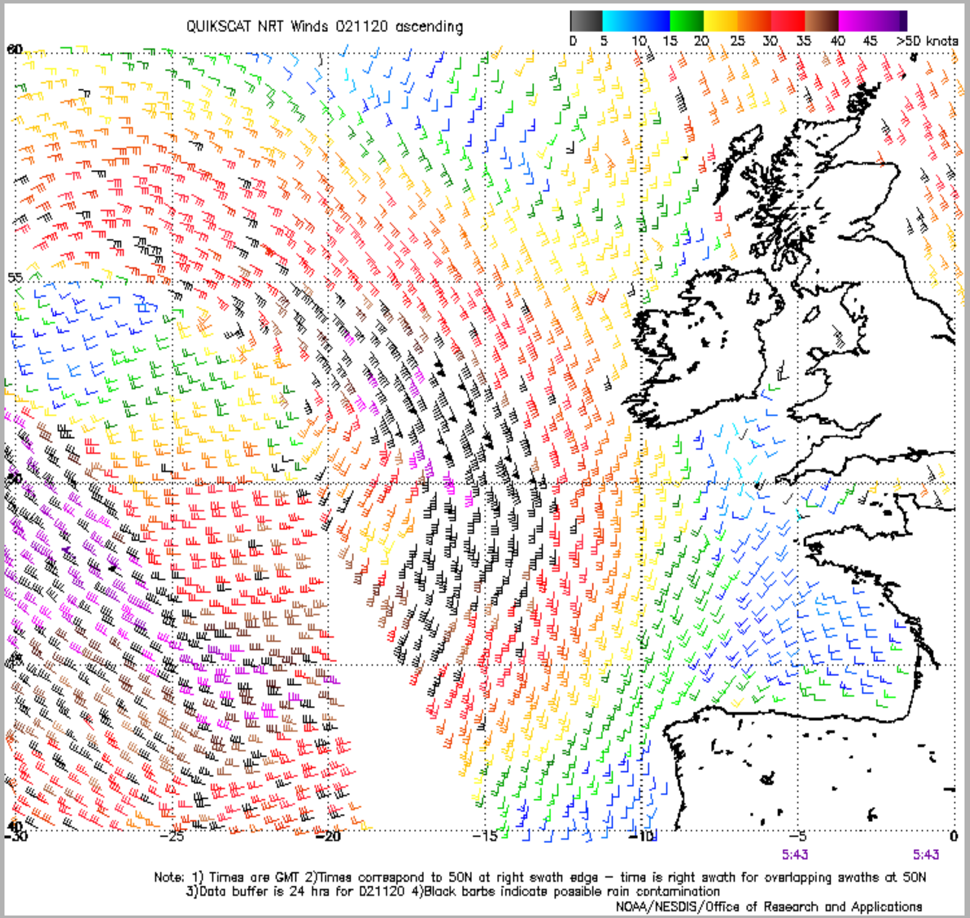

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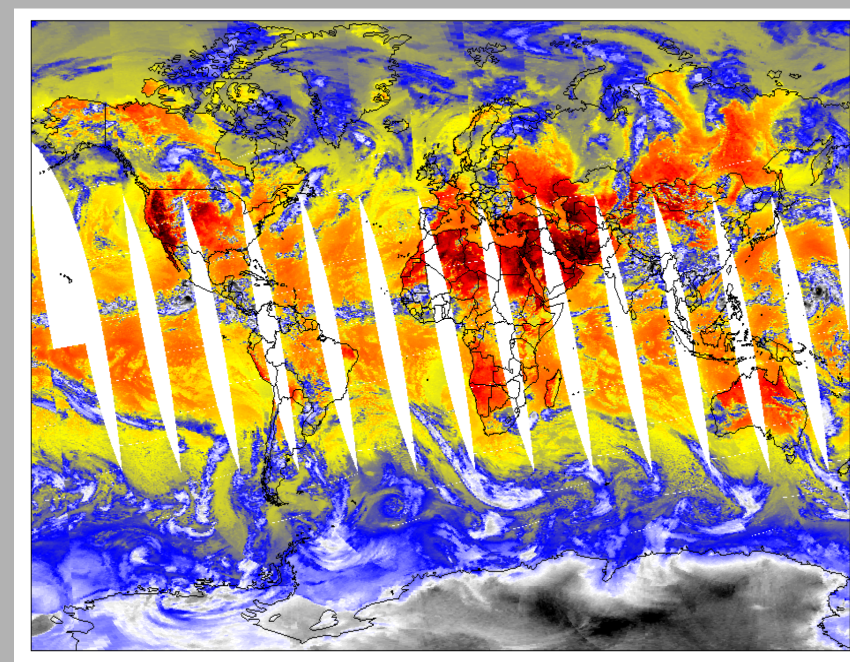

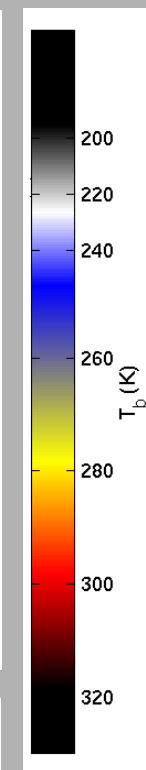

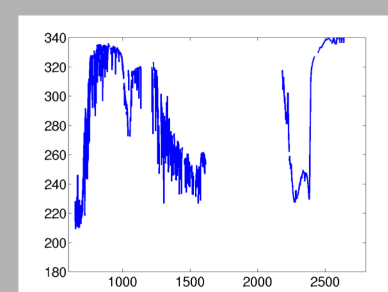

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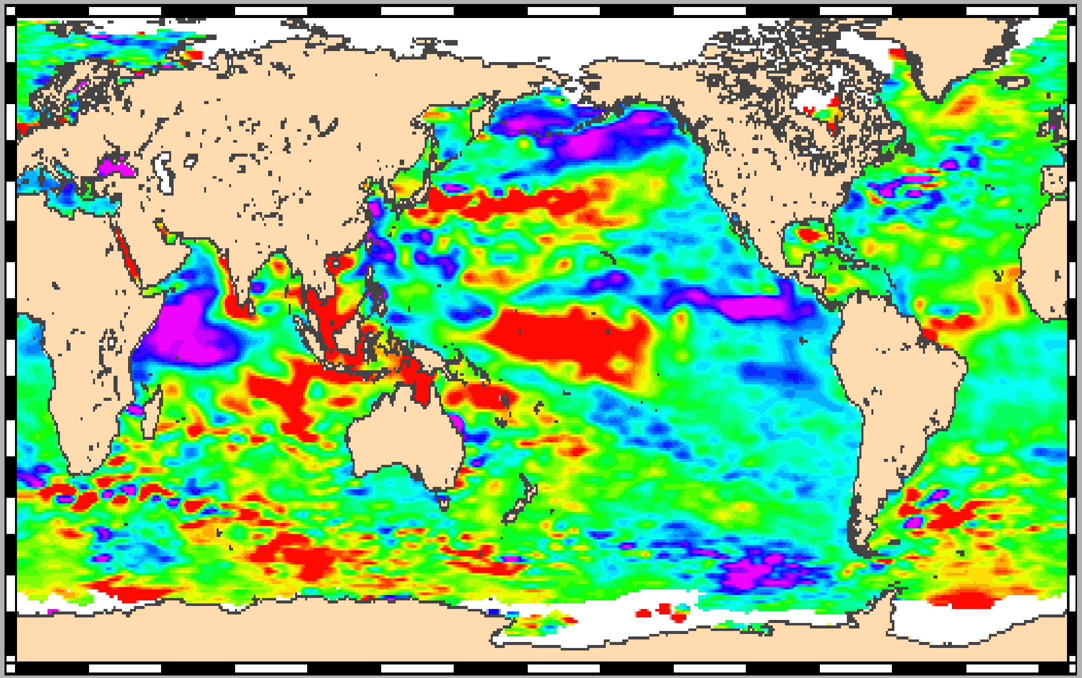

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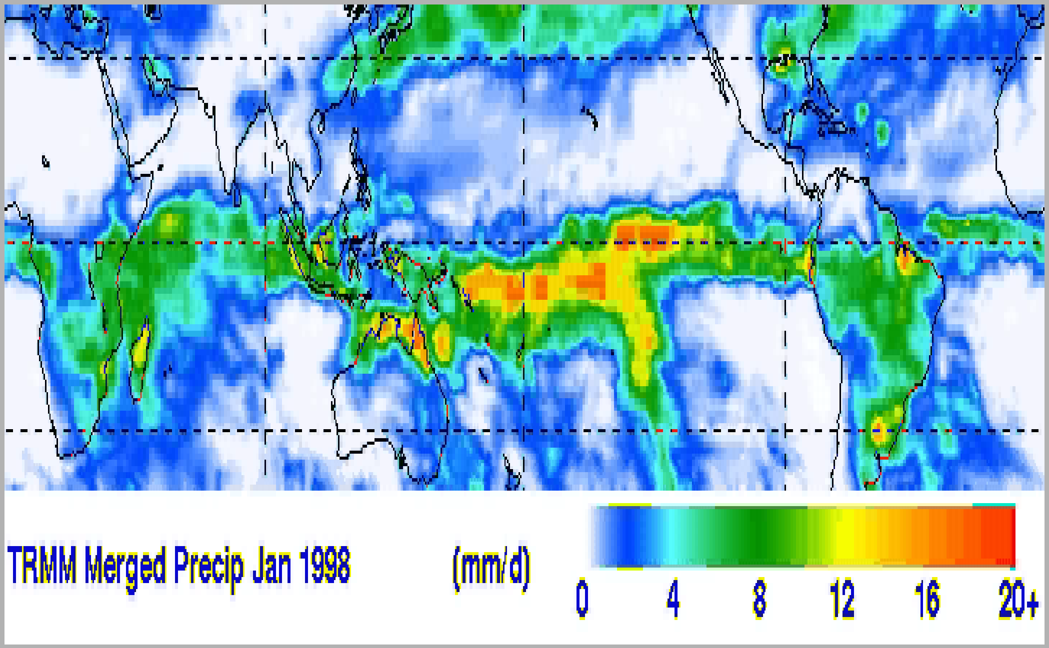
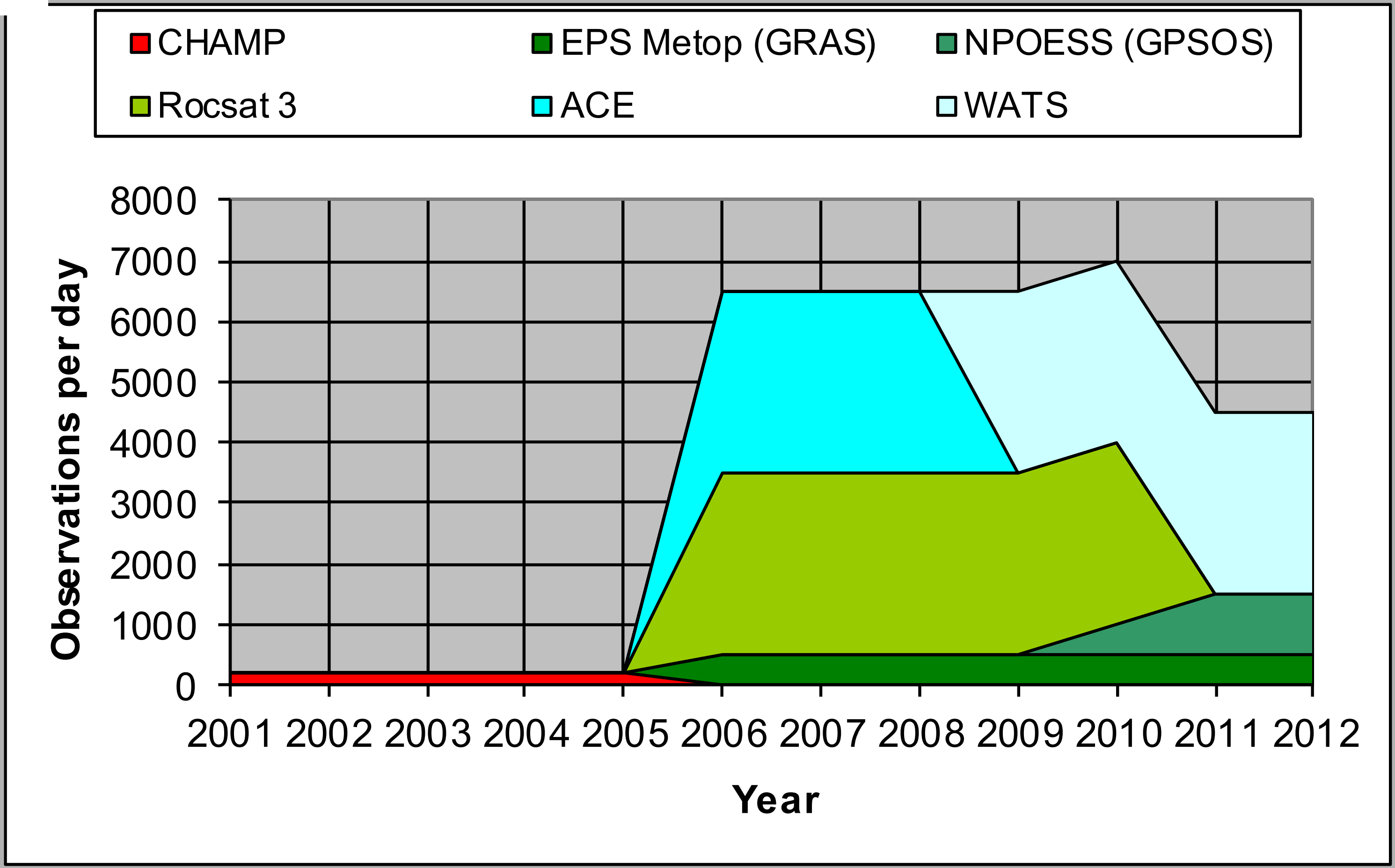


Monthly merged precipitation product based on TRMM data. 3 hourly global precipitation products also available.

Radio occultation - GOS



This is a prediction based on planned and proposed missions

NWP User Requirements vs GOS Provision

priority parameters

temperature, humidity, and wind profiles
total column humidity, cloud top height, and cloud water content.

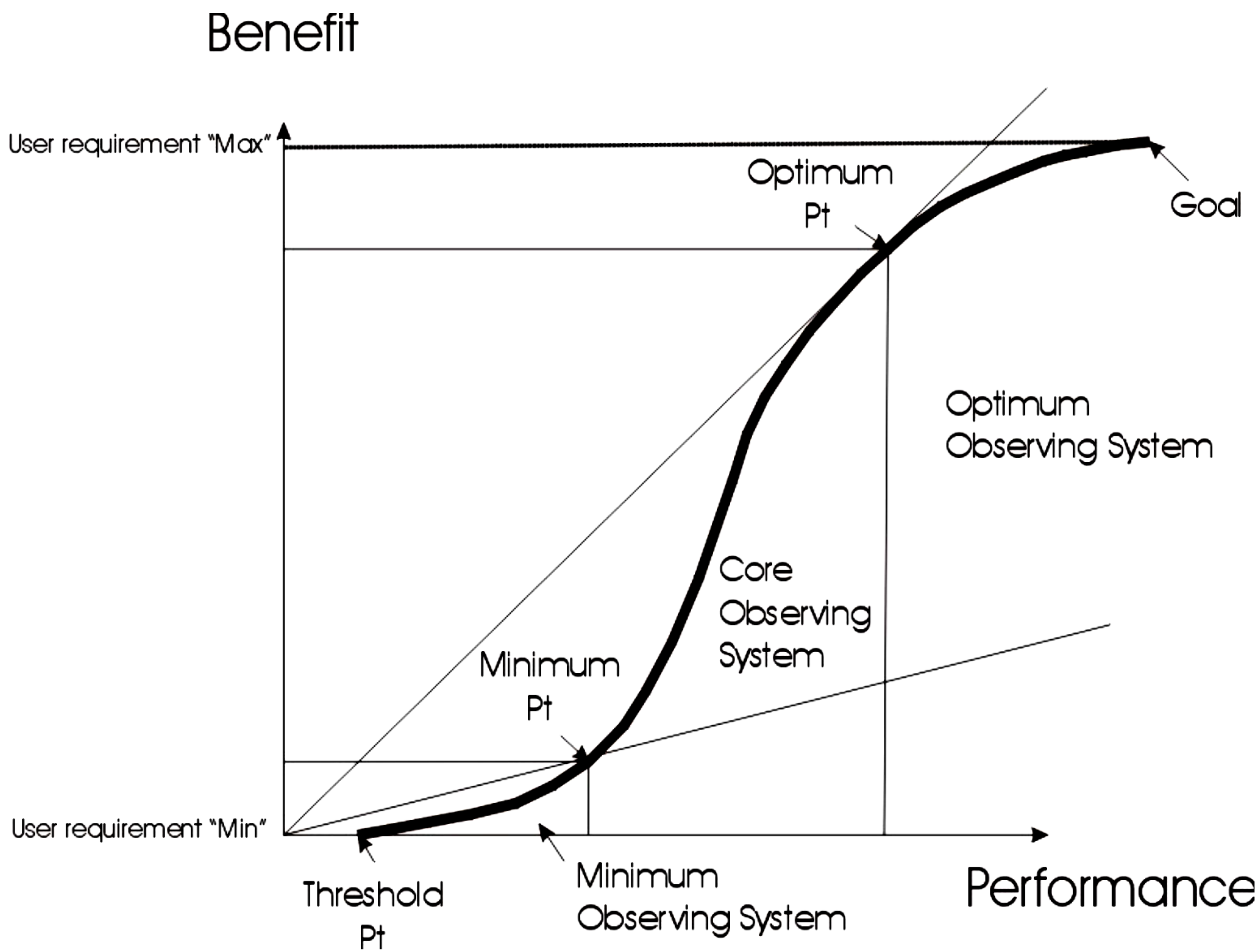
NWP requirements (median to optimum)

Hourly profiles, 10-50 km hor res, 1 km vert res
T(p) to 1 K and Q(p) to 0.5 g/kg, V(p) to 1 m/s accuracy
tot Q to 1000 g/m2
cloud heights to 0.5 km, cloud water content to 20 g/m2.

currently available

winds at 100 km resolution every 3-6 hrs
3 m/s for low and 7.5 m/s for high, speed biases less than 1.0 m/s
aircraft wind reports, ocean sfc scatterometer winds
T & Q profiles at 100 km res 4x daily from leos
T(p) to 2.0-2.5 K rms wrt raobs, RH within 20%, clear sky only

Performance-benefit curve for an observing system



Excerpts from Global NWP SOG

Ongoing need for operational measurements from at least 2 polar orbiting and 5 geostationary platforms.

NWP requires v(p) (especially in tropics) and T(p) and Q(p) with raob type accuracy over land and ocean.

NWP showed positive impact from recent addition of AMSUs (adding stratospheric skill and cloudy sky soundings).

Increased coverage of aircraft data providing benefit, particularly from ascent/descent.

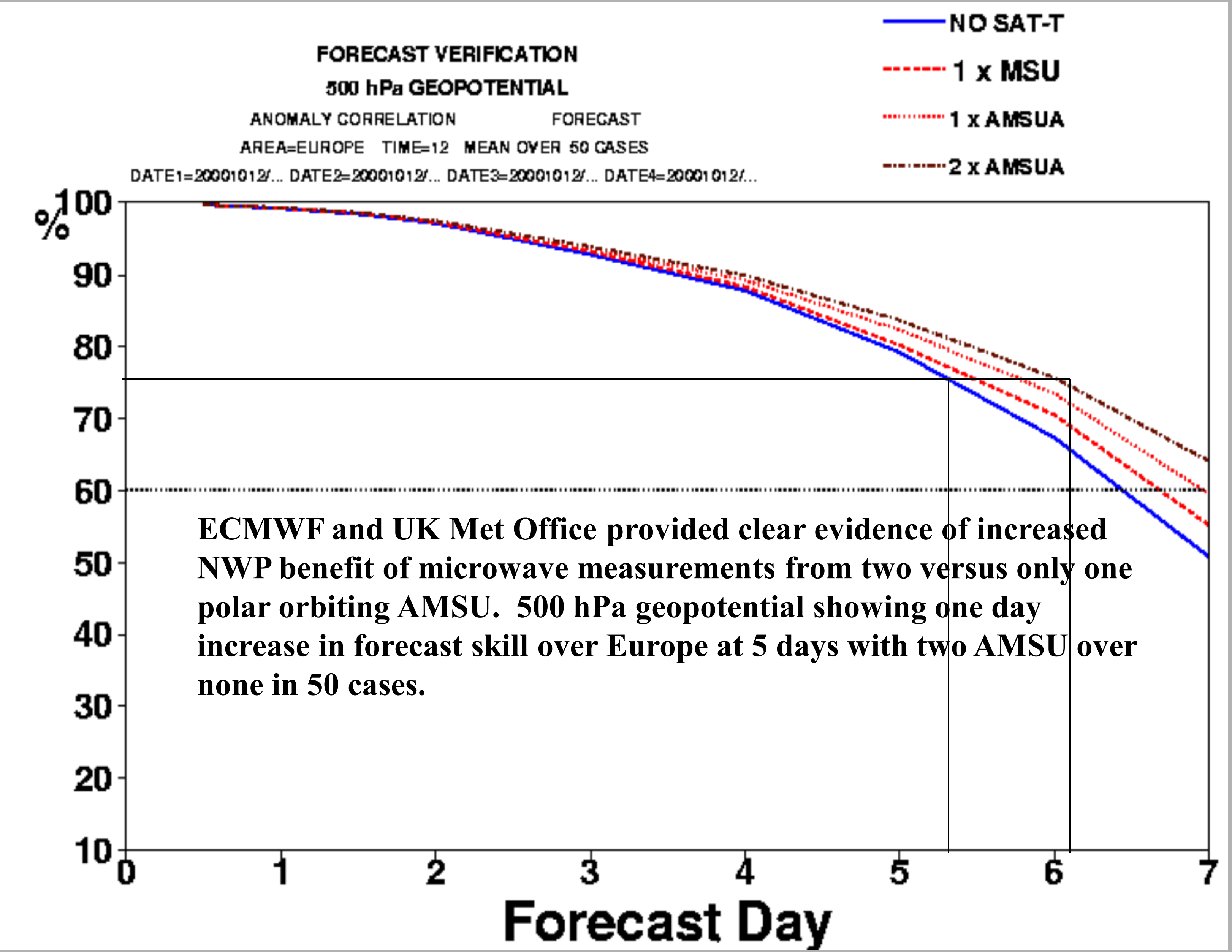
NWP awaiting high spectral resolution measurements from AIRS, IASI, & CrIS (for enhanced vertical resolution clear sky soundings).

Measurement of wind profiles most challenging (remote sensing lidar systems offer promise, but need opportunity to mature).

NWP needs include surface pressure, snow equivalent water content, precipitation, and soil moisture.

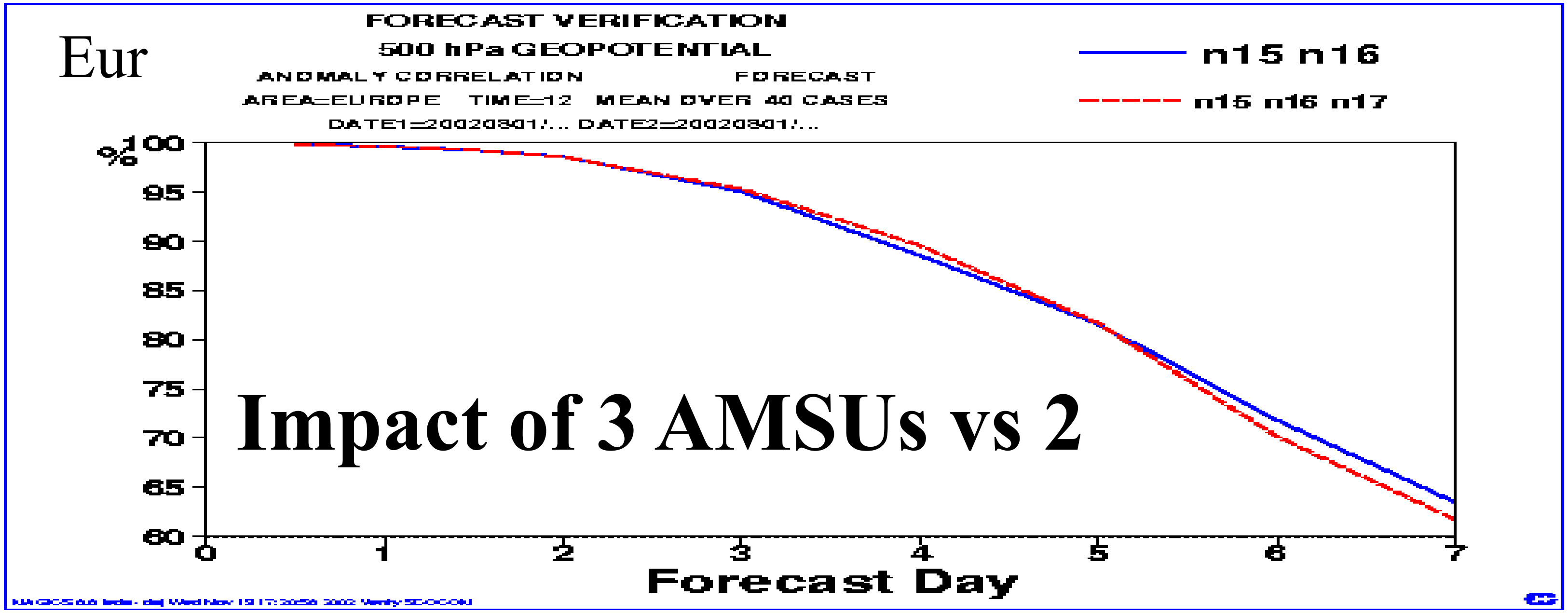
Variational data assimilation techniques offer potential for improved exploitation of observations with high temporal frequency (geo IR interferometer and microwave).

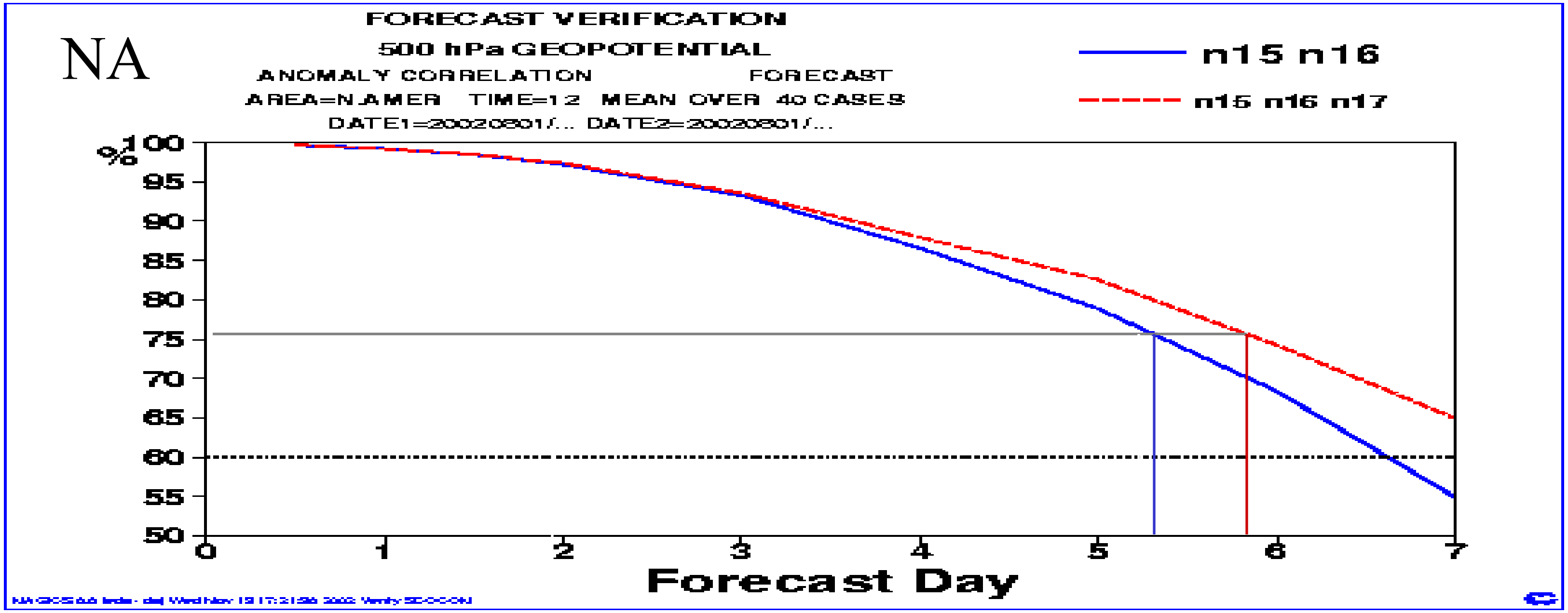
OSE shows Impact of two AMSUs



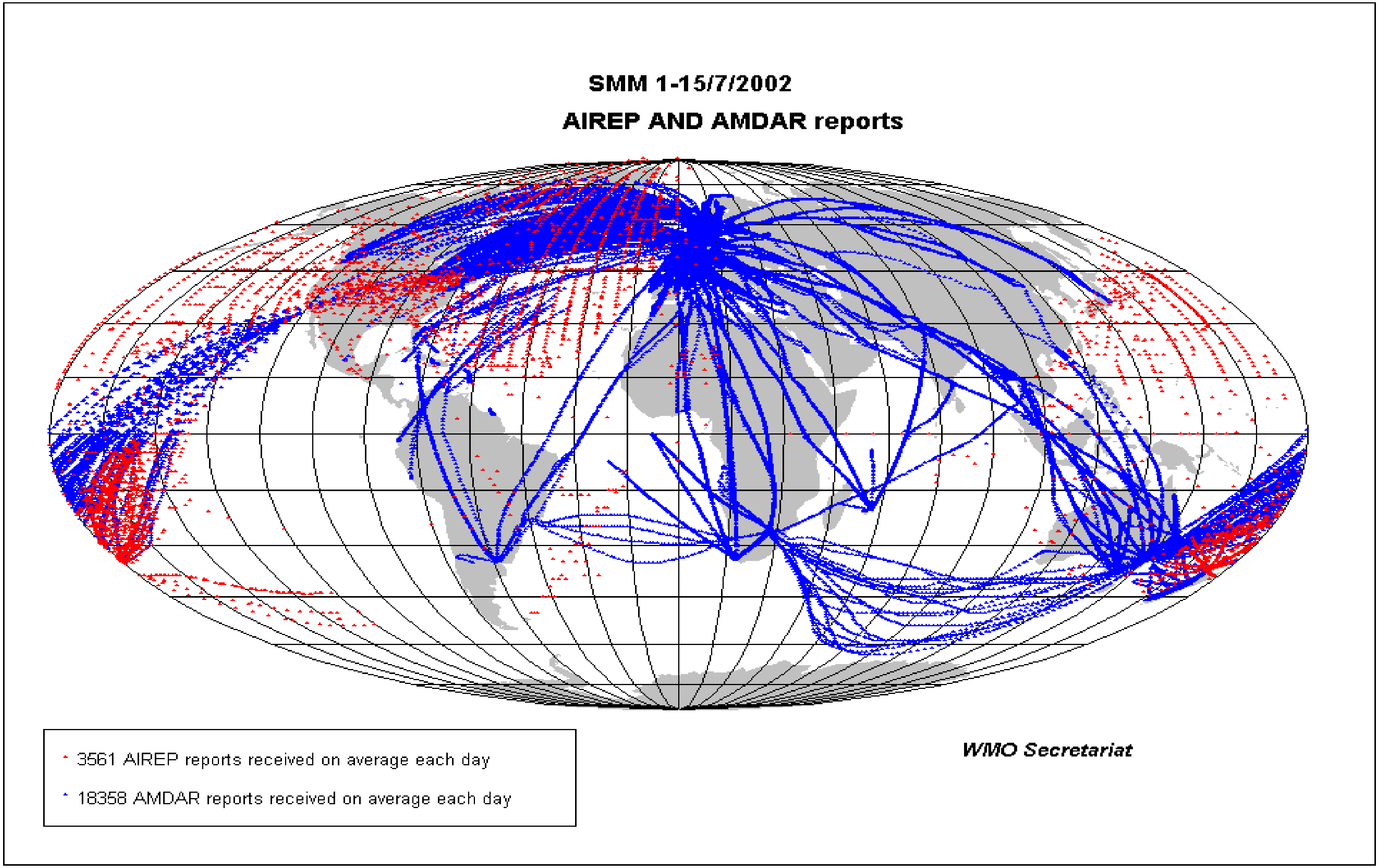
ECMWF and UK Met Office provided clear evidence of increased NWP benefit of microwave measurements from two versus only one polar orbiting AMSU. 500 hPa geopotential showing one day increase in forecast skill over Europe at 5 days with two AMSU over none in 50 cases.

Impact of 3 AMSUs vs 2

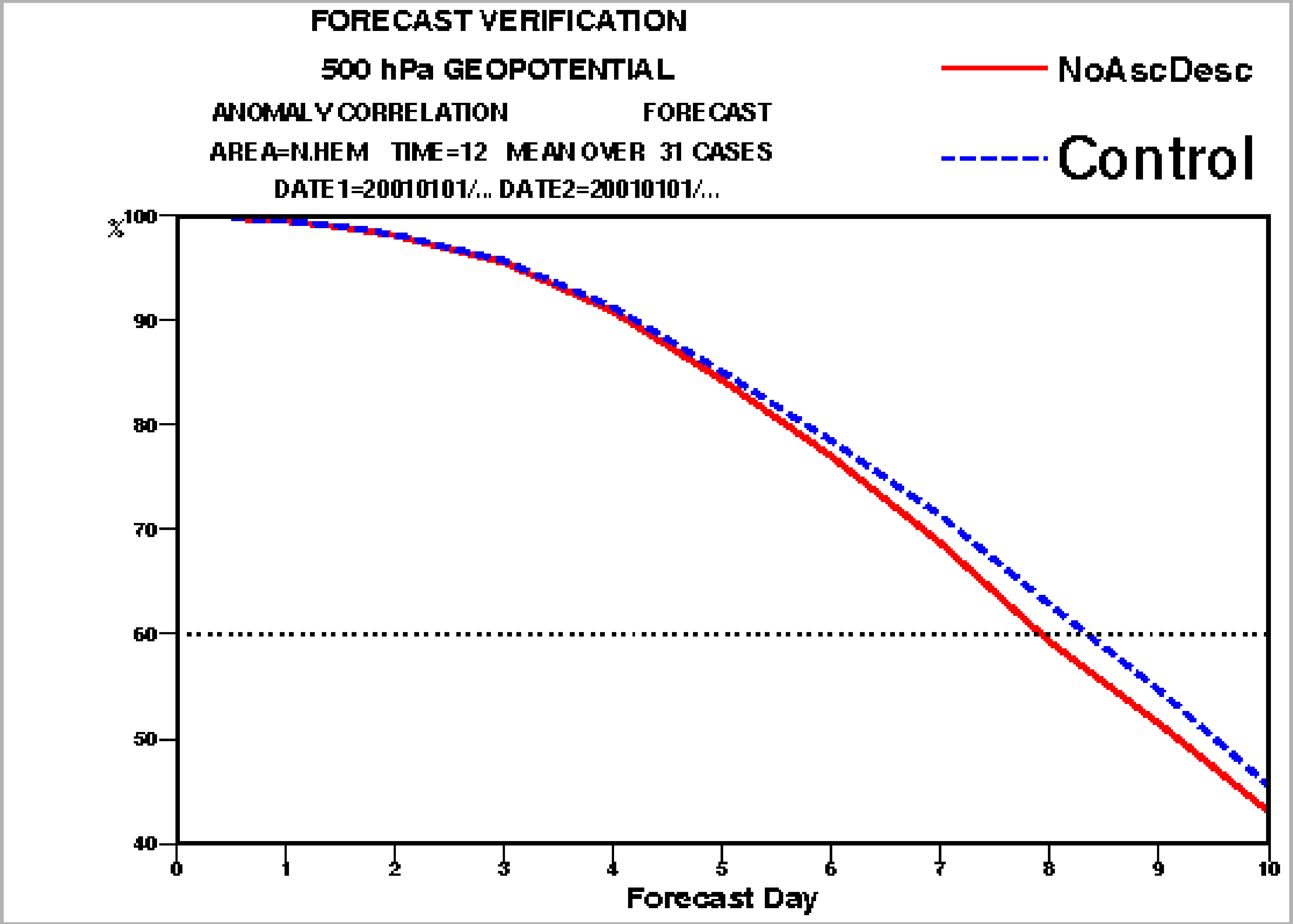




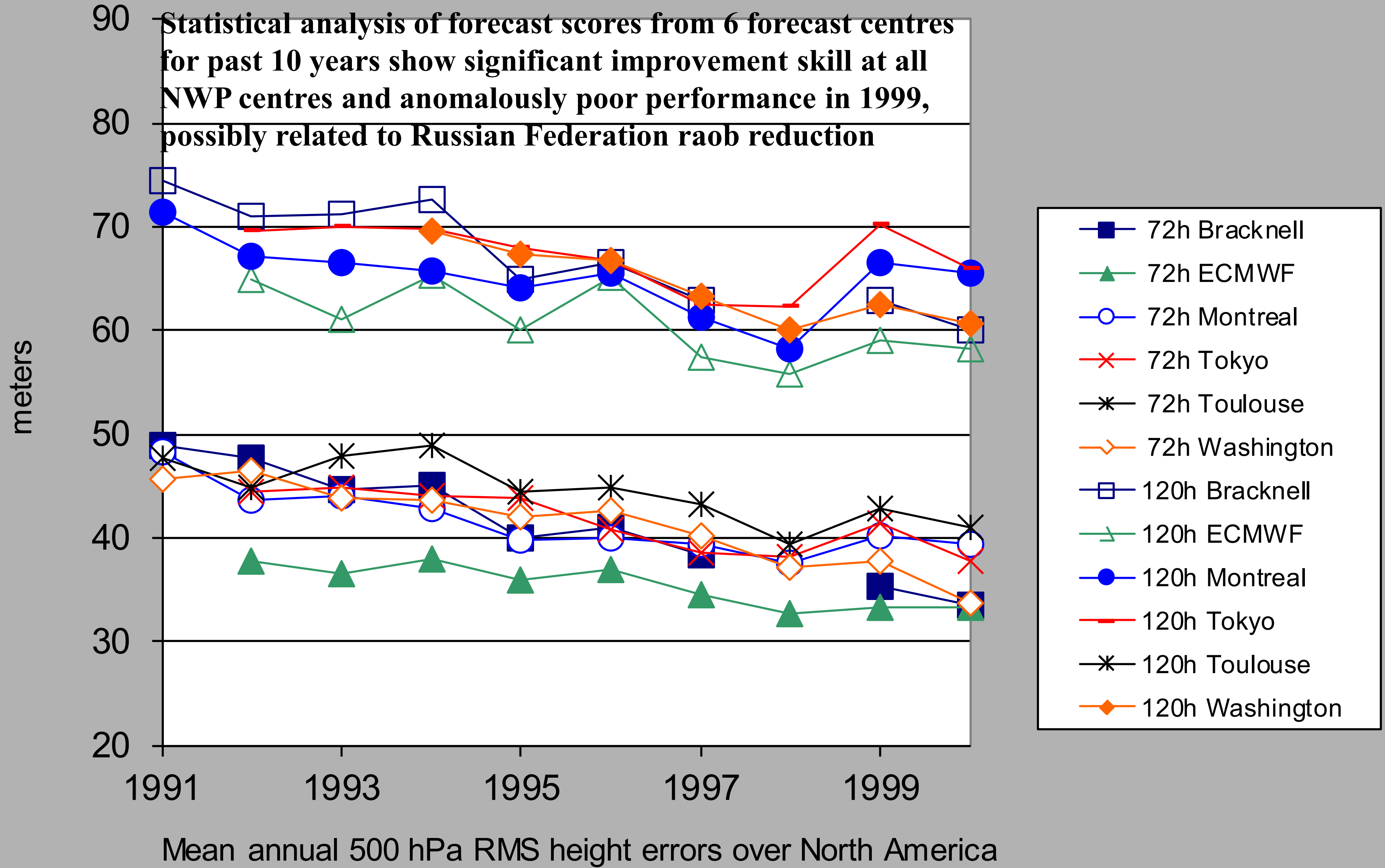
Aircraft reports starting over poles and southern oceans



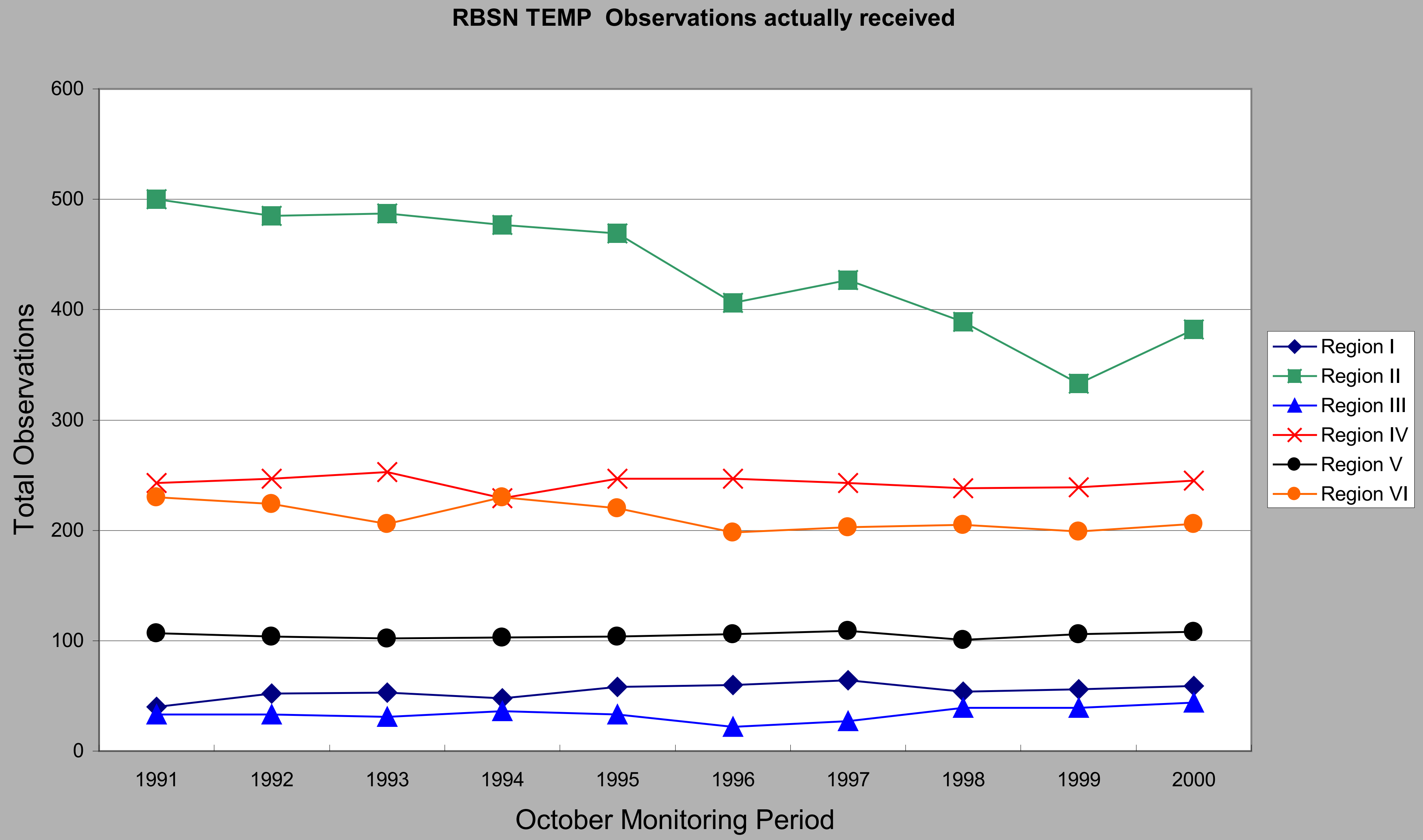
OSE shows Impact of NH Ascent and Descent AMDAR



Forecast error for North America at six forecast centers since 1991

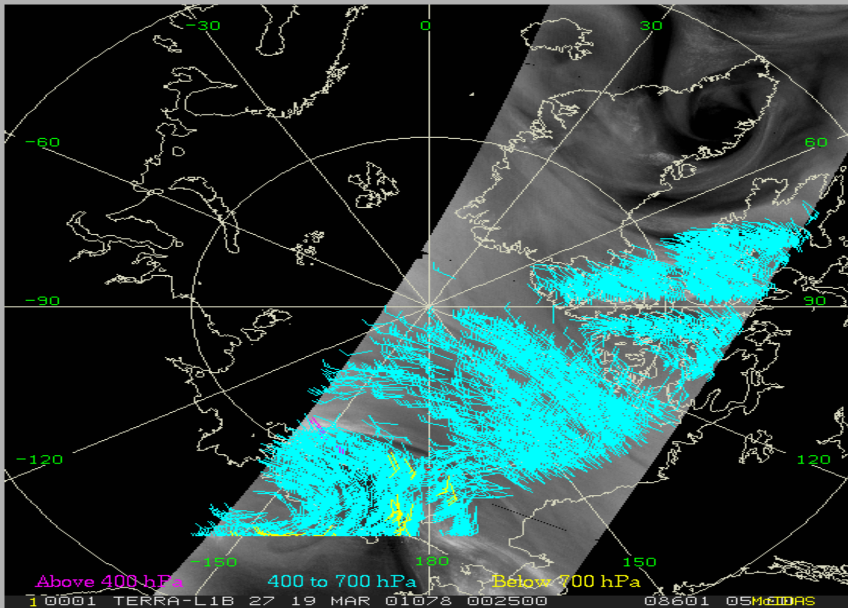


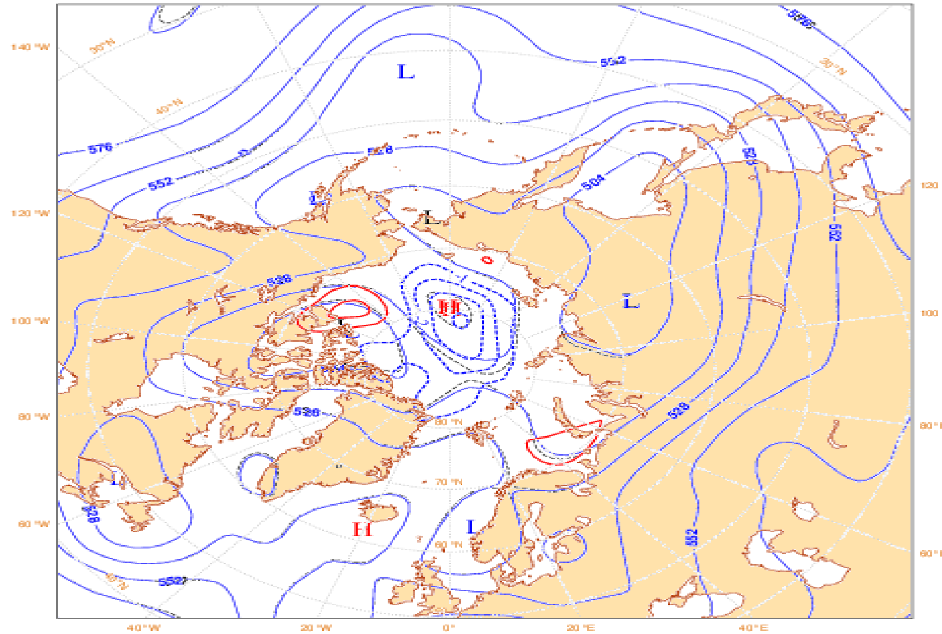
Raobs decreased in from 1996 to 1999 in Region II



1-Afr 2-Asia 3-SA 4-NA 5-Aust 6-Eur

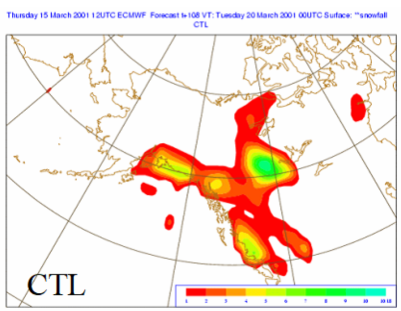
Polar Winds OSE

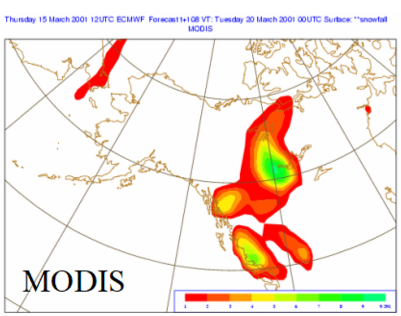


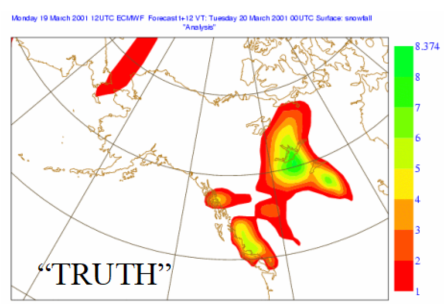


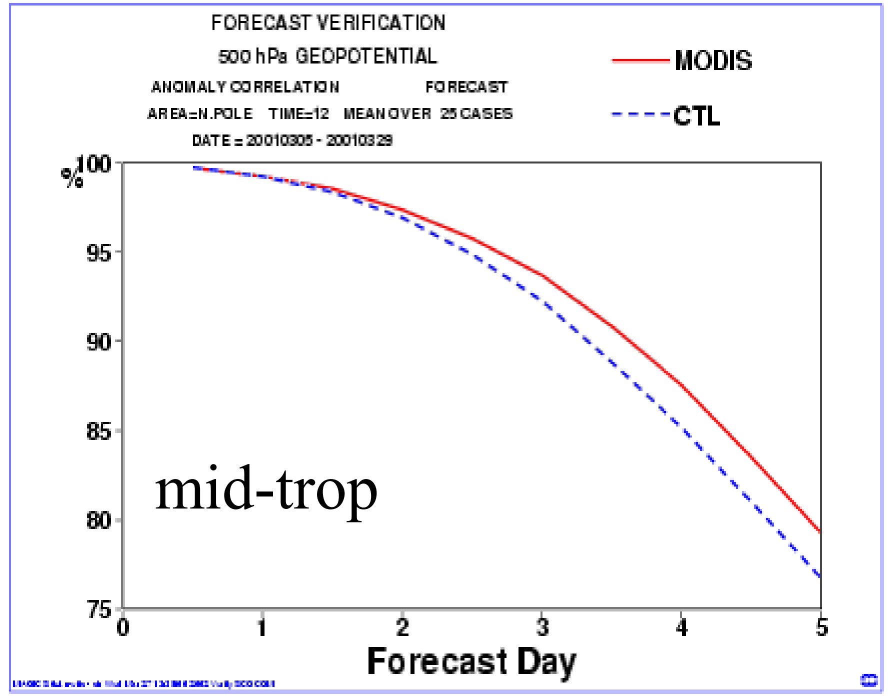
Error Propagation to the Midlatitudes: Snowfall

Accumulated snowfall forecasts, in mm water equivalent, over Alaska on 03/20/02 (end of animation period). At right is the snowfall from the 5-day CTL forecast, below left is the snowfall from the 5-day MODIS forecast, below right is the snowfall from a 12-hr forecast for verification. The CTL run produced spurious snowfall in southern Alaska.

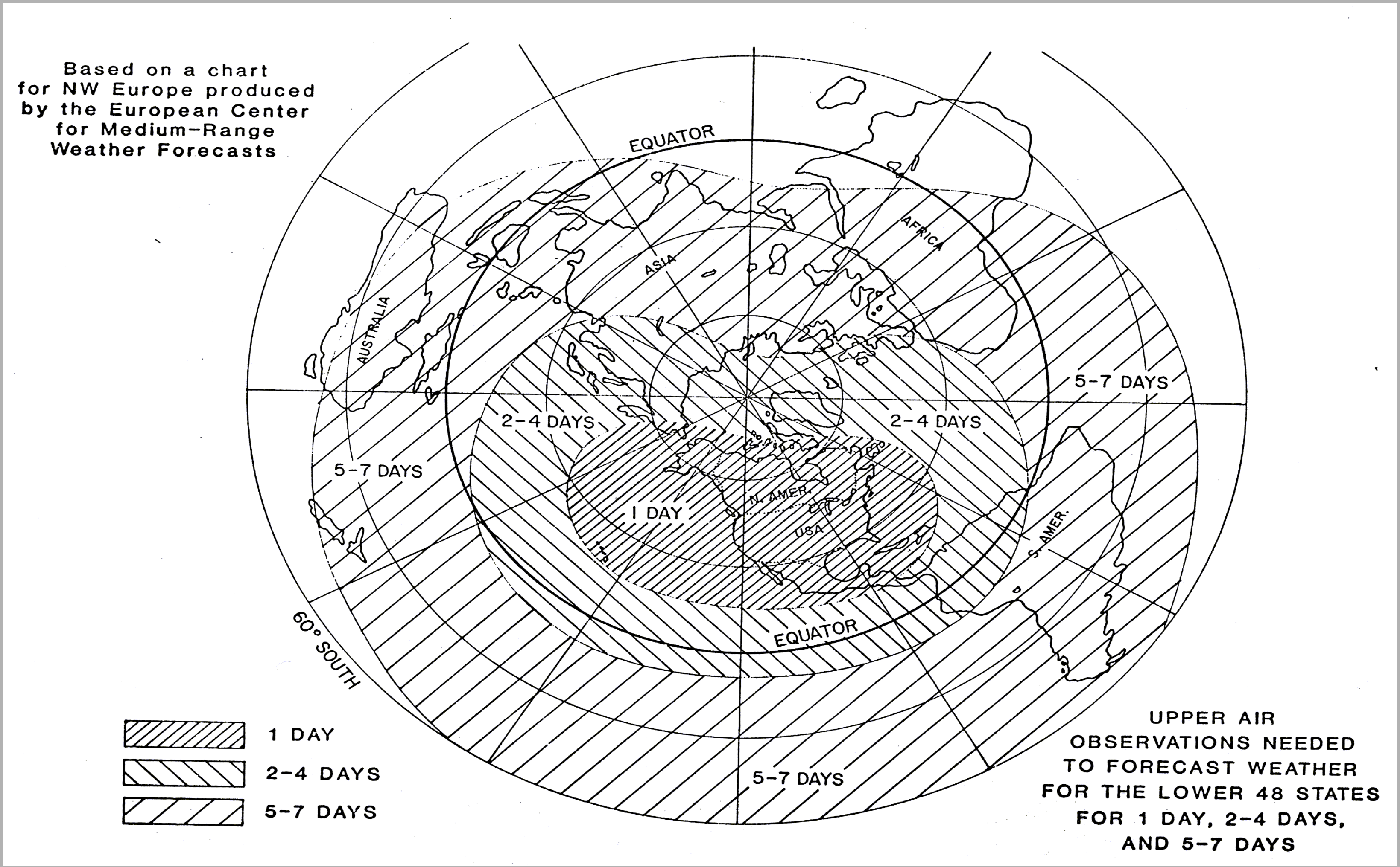






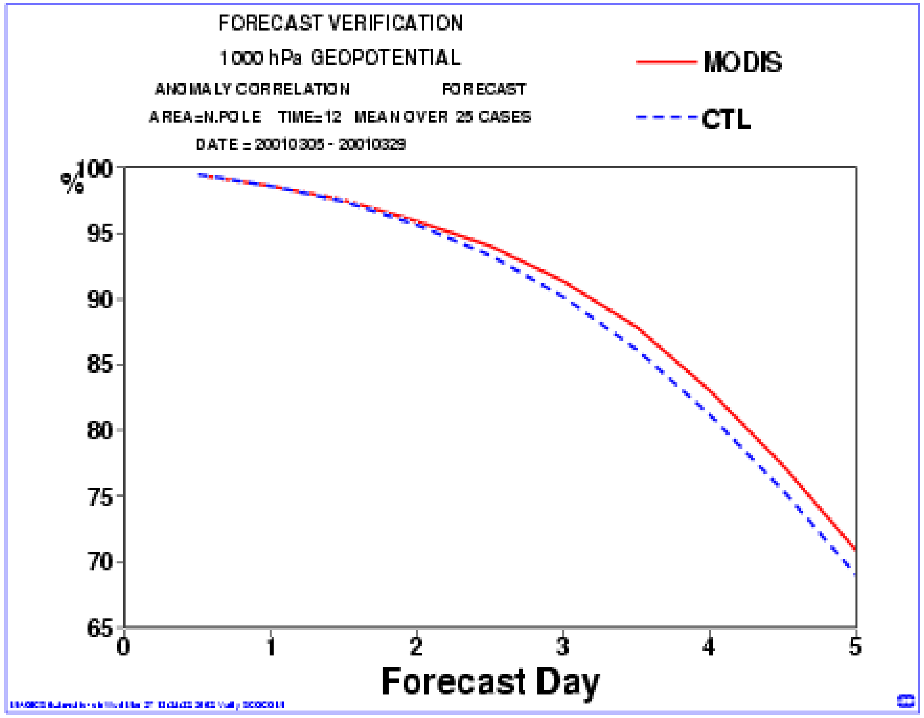


Upper Air Observations Needed To Forecast Weather For The Lower 48 States For 1, 2-4 & 6-7 Days

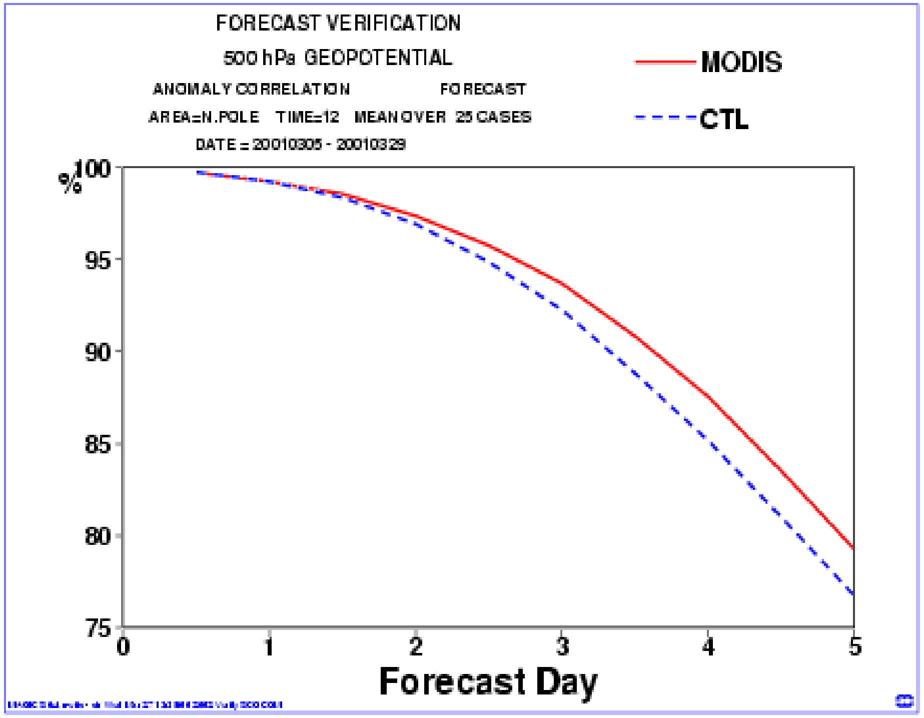


Impact over 25 days of polar WV winds in ECMWF Fcst for Arctic

1000 hPa - sfc



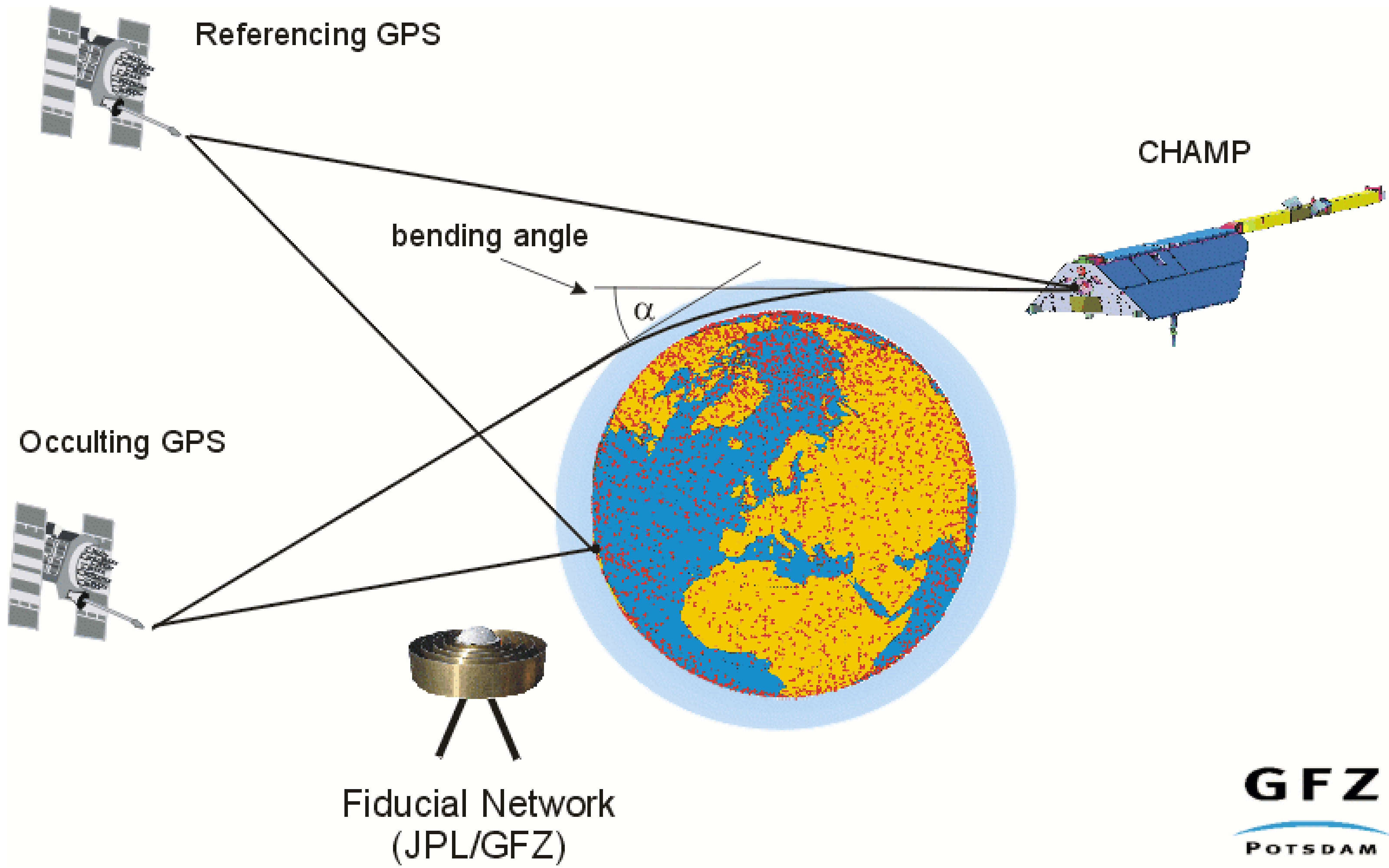
500 hPa - mid trop



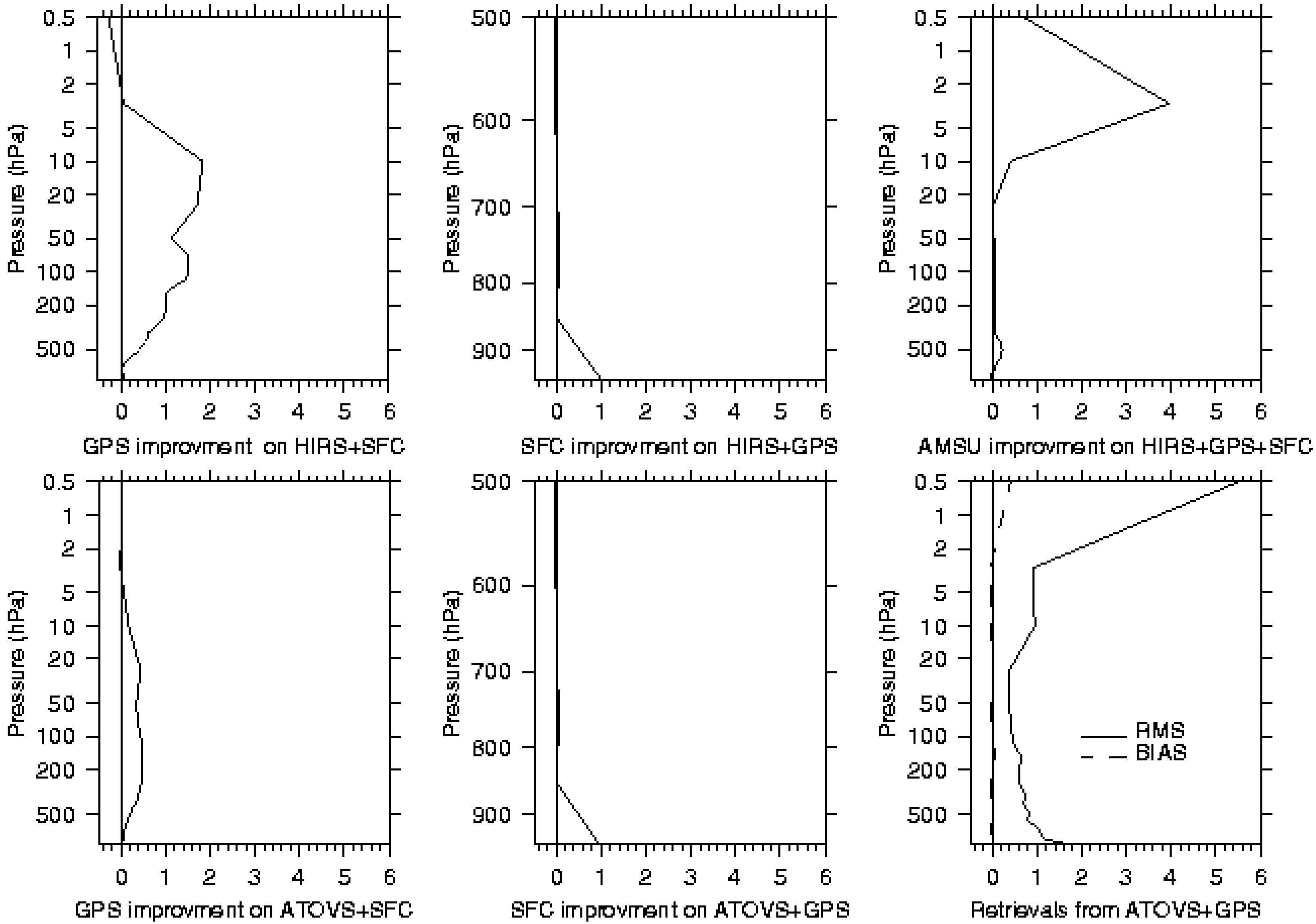
Forecast scores (anomaly correlations) as a function of forecast range for the geopotential at 1000 hPa (left) and 500 hPa (right). Study period is 5-29 March 2001. Forecast scores are the correlation between the forecast geopotential height anomalies, with and without the MODIS winds, and their own analyses. The Arctic ("N. Pole") is defined as north of 65 degrees latitude.

There is a significant positive impact on forecasts of geopotential from assimilation of MODIS WV winds, particularly for Arctic, but also for whole Northern Hemisphere (next slide).

Radio Occultation



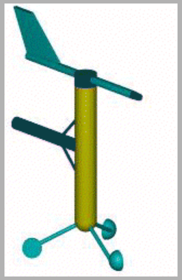
Radiometric temperature profile retrieval improvements (RMS) for different combinations of geometric (GPS), surface (SFC), IR (HIRS), and MW (AMSU) data. ATOVS +GPS bias and RMS errors wrt RAOBS are shown as a reference in bottom right panel.

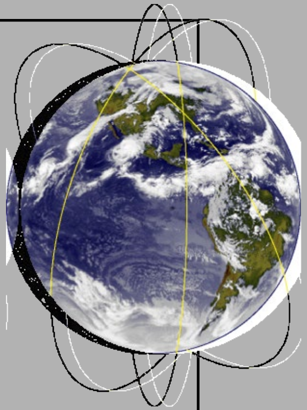


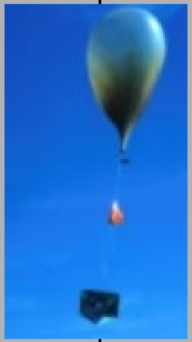
Observational Data Requirements and Redesign of the Global Observing System

Candidate Observing Systems

- The future GOS should build upon existing components, both surface and space based, and capitalize on existing and new observing technologies not presently incorporated or fully exploited
- Each incremental addition to the GOS would be reflected in better data, products and services from the NMHSs







Observational Data Requirements and Redesign of the Global Observing System

Impact of Evolution

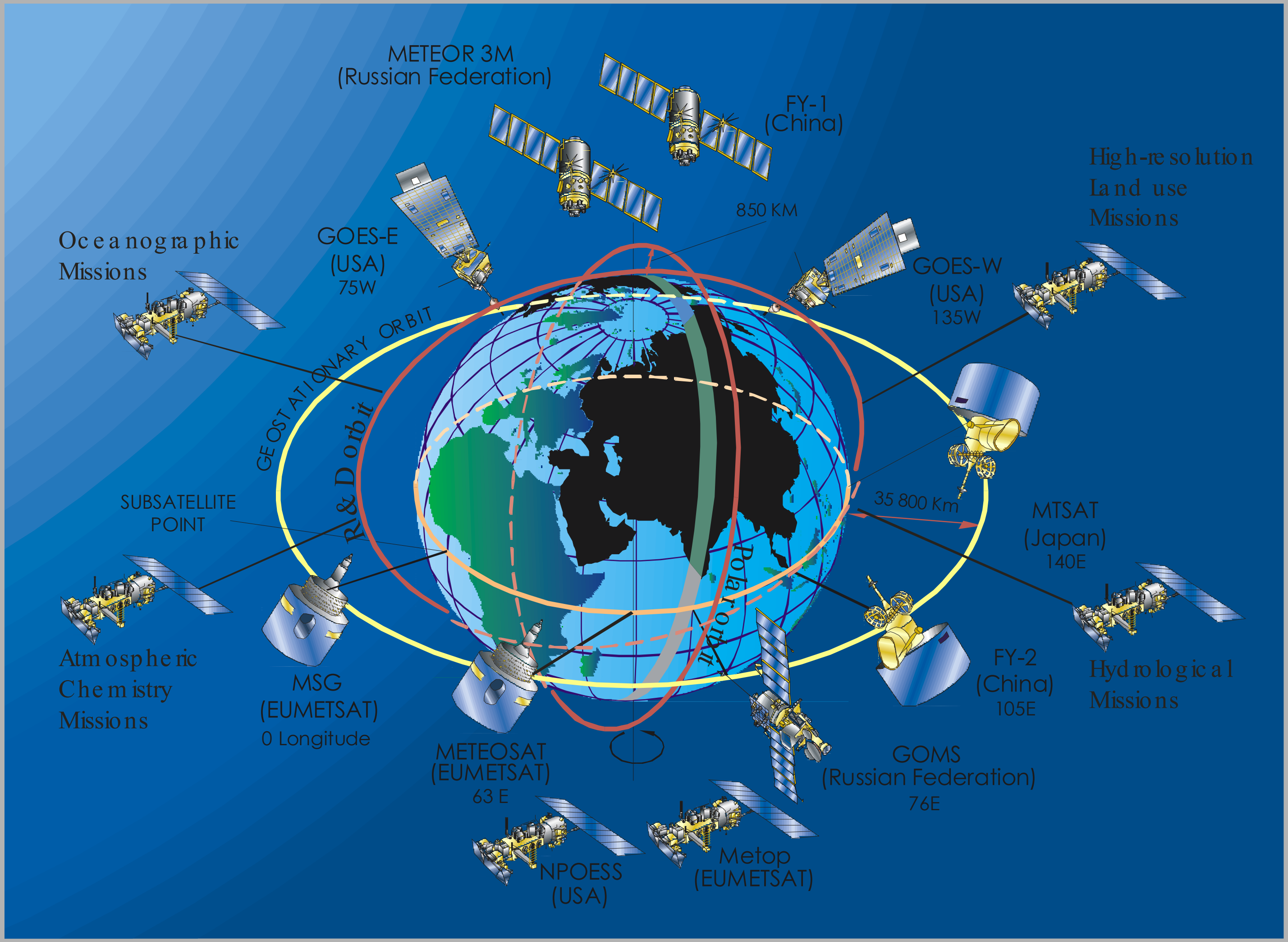
- The impact of the changes to the GOS in the next decades will be so massive that new revolutionary approaches for science, data handling, product development, training, and utilization would be required
- There is an urgent need to study comprehensive strategies for anticipating and evaluating changes to the GOS

Observational Data Requirements and Redesign of the Global Observing System

- Evolution of the GOS
  - **42 recommendations**
    - **final report of CBS/IOS/ICT-2**
      (14-18 October 2002).
- Recommendations reflected:

- Statements of guidance in 11 application areas
  NWP, synoptic met, nowcasting, SIA fcst, marine wx fcst, atm chem, aero met, agro met, hydrology, …
- Results from regional programmes such as COSNA, EUCOS and NAOS
- Conclusions from the March, 2000,Toulouse Workshop on Impact of Various Observing Systems on NWP
- Numerous OSEs

Future Space Based Global Observing System



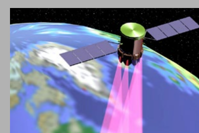
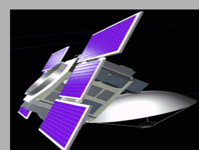
US Missions leading to future GOS

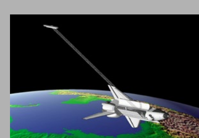
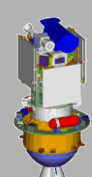
2005 | 2010 | 2020

Current Era | **Near Focus** | **Advanced Concepts**

- POES
- GOES

- TRMM
- TOPEX
- EOS
- QUIKSCAT

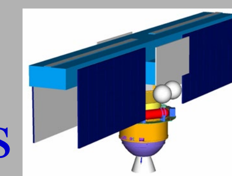
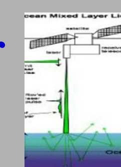
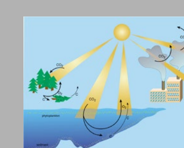



- NPP

- NPOESS
- ABI/HES

- Hyperspectral
- Imaging Lidars
- Geo Soil Moist Sensors
- CO_2 Lidar
- Ocean Mixed Layer Lidar
- Synthetic Aperture Radiometry
- New Initiatives

NOAA lead Missions

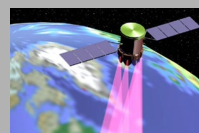
NASA leveraged Missions

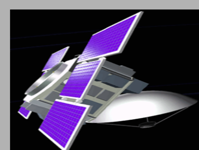
European Missions leading to future GOS

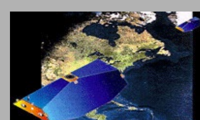
2005 | 2010 | 2020

Current Era | **Near Focus** | **Advanced Concepts**

- MSG





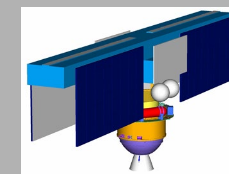


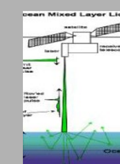
- ERS
- ENVISAT
- EOS
- QUIKSCAT

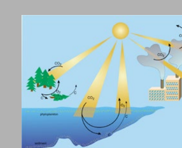
- Earth Watch & Explorer

- METOP
- MTG

- Hyperspectral
- Wind Lidars
- Geo Soil Moist Sensors
- Cloud Lidar
- Broadband Radiation Imager
- New Initiatives



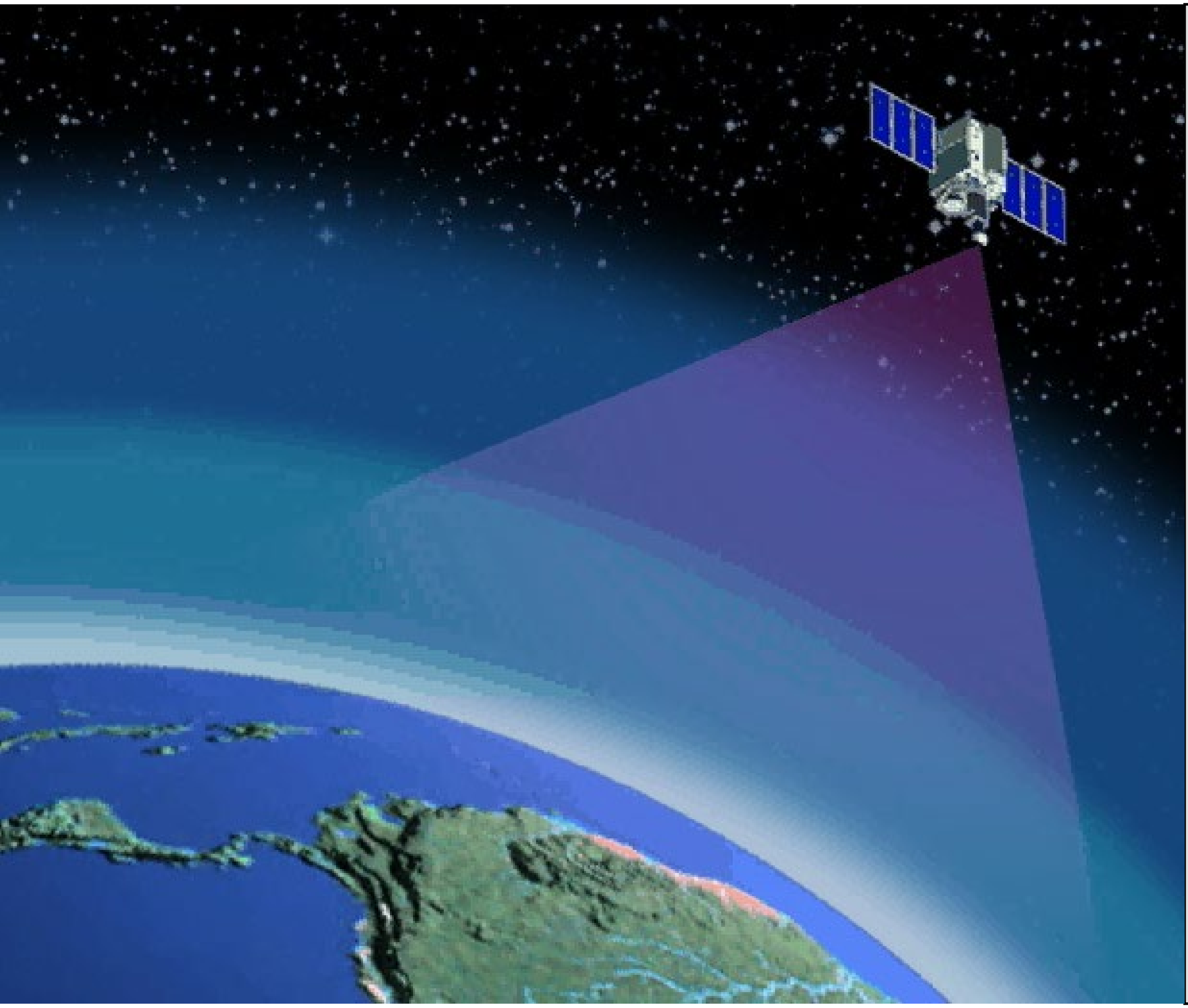




EUMETSAT lead Missions

ESA leveraged Missions

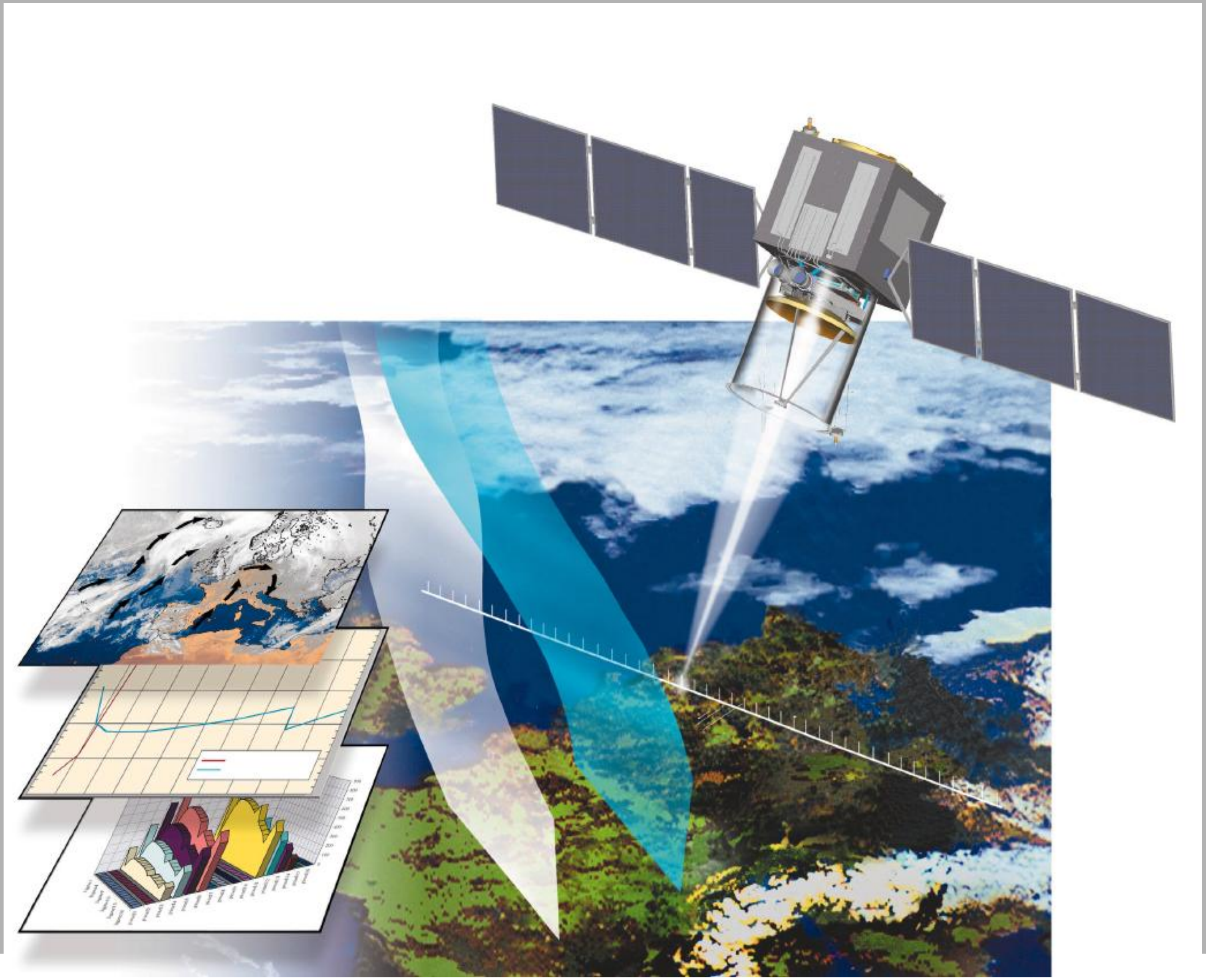
GIFTS Sampling Characteristics



- Two 128x 128 Infrared focal plane detector arrays with 4 km footprint size
- One 512 x 512 Visible focal plane detector array with 1 km footprint size
- Field of Regard 512 km x 512 km at satellite sub-point
- Ten second full spectral resolution integration time per Field of Regard

Lidar Wind Measurements:

The Atmospheric Dynamics Mission (ADM-Aeolus)



Evolving Space based GOS

System	Improved parameters	Instrumentation
GEOs upgraded	Temperature, humidity, ozone profiles, winds at tracer heights Atmospheric instability index, OLR	Frequent-sounding and imaging IR spectrometer
	Cloud pattern, cover, type, top temp and height, low stratus / fog sea-surface temp, land surface temp, fires, volcanic ash	Fast VIS/IR imager
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LEOs upgraded (post-METOP)	Temp, humidity, & ozone profiles; total columns of key trace gases	IR/MW sounder
	Sea/land/ice surface temperatures, sea-ice cover, NDVI, fires, Aerosol size, Cloud pattern, cover, type, top height, cloud optical thickness, drop size, low stratus/fog, high lat winds at tracer heights	Improved VIS/NIR/IR imager
	Short- and long-wave outgoing radiation at TOA	Broadband imager
	Sea-surface wind and temp, sea-ice cover and surface temp snow cover, snow water equivalent, precipitation	MW radiometer with multi-polarisation/viewing
	Water and ice cloud properties, aerosol properties Ozone LAI, PAR, FPAR (large scale). Ocean colour	Imagers covering parts of UV, VIS, NIR, IR, FIR, & Sub-mm, with multi-polarisation
	Wave height, sea level, ocean topography, geoid	Altimeter
----------------------	--	----------------------------
R&D GEO SubMM	Cloud water / ice, precipitation	Sub-mm radiometer
R&D LEO for ocean topography	Significant wave height, sea level, ocean topography, geoid. Polar ice thickness and sheet topography	Medium-class altimeter (follow-on Jason)
R&D LEO for wind Profiles	Wind profile in clear air. Aerosol profile (large scale), cloud top and base height	Doppler lidar (follow-on Aeolus)
R&D LEO for land & ocean ice	Wave spectra, ocean ice. Land snow & ice	SAR
R&D LEO for salinity & moisture	Ocean salinity (large scale). Soil moisture (large scale)	Low-frequency MW radiometer
R&D Constellation of mini-sats	UT/LS temperature profile, height of tropopause., LT moisture profile (with ground GPS)	Radio-occultation sounders

Evolving Surface based GOS

System	Parameter	Action/Development
AMDAR	Vertical profiles of temperature and wind at airports Flight level data Vertical profiles of humidity	Increase coverage, increase vertical resolution Extend programme to short-haul, commuter and freight flights Study feasibility of adaptive use, demonstrate the need for high frequency data, in particular over Africa, South America Develop capability
TAMDAR	Vertical profiles of temperature and wind at regional airports	Develop the programme (currently undertaken by NASA), suitable for expansion to other regions, such as the arctic, Siberia, etc.
Radiosondes	Vertical profiles of temperature wind and humidity	Optimise horizontal spacing of raobs and vertical resolution of reports and operation of sub-system (launch times, adaptive operation) Increase the availability over the oceans (ASAP, dropsondes, etc.)
Ozone soundings	Vertical profile of ozone	Integrate into GOS
UAVs	Spatial coverage and vertical profile of wind, temperature and humidity	Demonstrate feasibility of an operational sub-system; target areas for operation are the ocean storm tracks (planned in THORPEX)
High-altitude balloons deploying sondes	Vertical profile of temp, wind and humidity	Demonstrate feasibility of an operational sub-system
Drifting buoys	Surface measurements of temp, wind and pressure, SST	Extend coverage especially in SH based on SVPB and WOTAN technology
Moored buoys	Surface wind, pressure, sub-surface temp profiles Wave height	Improve timely availability for NWP (monthly & seasonal forecasting) Extend coverage into Indian Ocean Provide data
Ice buoys	Ice temp, air pressure, temp and wind	Increase coverage

Evolving Surface based GOS

VOS	Surface pressure, SST, wind	Maintain their availability to provide complementary mix of observations
Ships of opportunity (SOOP)	Sub-surface temperature profiles (XBT)	Improve timely delivery and distribute high vertical resolution data
Subsurface profiling floats Argo programme	Sub-surface temperature and salinity	Improve timely delivery and distribute high resolution data
Tide gauges (GLOSS)	Sea level observations	Establish timely delivery
SYNOP and METAR data	Surface observations of pressure, wind, temperature, clouds and 'weather' Visibility Precipitation Snow cover and depth Soil moisture	Exchange globally for regional and global NWP at high temporal frequency (at least hourly), develop further automation Ditto Ditto Distribute daily Distribute daily
Wind profiling radar	Vertical profile of wind	Distribute data
Scanning weather radar	Precipitation amount and intensity Radial winds, Velocity Azimuth Display (VAD)	Provide data, demonstrate use in hydrological applications (regional and global NWP) Demonstrate use in regional NWP Ensure compatibility in calibration and data extraction methods
Ground Based GPS	Column Water Vapour	Demonstrate real-time capability
Ground Based Interferometers and other radiometers (e.g. MW)	Time continuous vertical profile of temp/humidity	Demonstrate capability

2015 Vision for GOS

for the Space based component

* 6 operational GEOs all with multispectral imager (IR/VIS); some with hyperspectral sounder (IR)
* 4 operational LEOs optimally spaced in time, all with multispectral imager (MW/IR/VIS/UV), all with sounder (MW), 3 with hyperspectral sounder (IR), all with radio occultation (RO), 2 with altimeter, 3 with conical scan MW or scatterometer
* Several R&D satellites, constellation small satellites for radio occultation (RO), LEO with wind lidar, LEO with active and passive microwave precipitation instruments, LEO and GEO with advanced hyperspectral capabilities, GEO lightning, possibly GEO microwave
* Improved intercalibration and operational continuity

2015 Vision for GOS

for the Surface based component

*** Automation to enable**

- **targeting of observation in data sensitive areas**
- **optimal operation of radiosondes, ASAP systems, aircraft in flight**

*** Rawinsondes**

- **optimized utilization**
- **stable GUAN**
- **supplemented by AMDAR ascent/descent, ground based GPS water vapor, wind profilers, satellite soundings**
- **rawinsondes automatically launched**
- **computerized data processing & real-time transmission**
- **high vertical resolution**

2015 Vision for GOS

for the Surface based component

*** Commercial aircraft observations**

- **of temperature & wind plus humidity on some aircraft**
- **in-flight and ascent/descent data**
- **high temporal resolution**
- **available from most airports including currently data void airports in Asia, Africa and South America.**
- **possibly supplemented with UAVs**

*** Surface observations**

- **automated systems**
- **land sensors at high spatial resolution, supporting local applications such as road weather**
- **ocean platforms (ship, buoys, profiling floats, moorings) in adequate number to complement satellite data**

2015 Vision for GOS

for the Surface based component

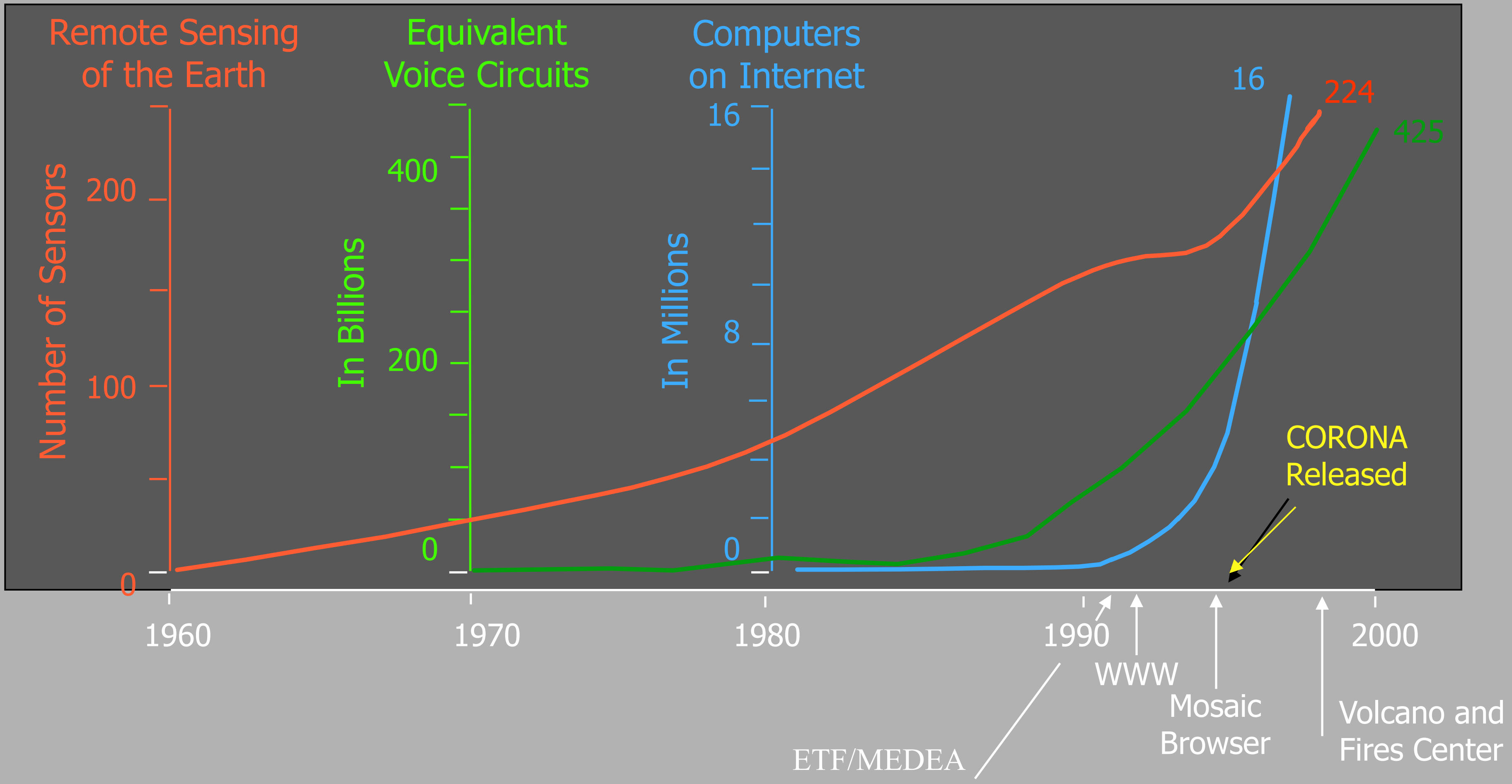
*** Radar observing systems measuring**

- **radial winds**
- **hydrometeor distribution and size**
- **precipitation phase, rate, and accumulation**
- **multiple cloud layers, including base and top height.**

*** Data collection and transmission**

- **digital in a highly compressed form**
- **entirely computerized data processing**
- **role of humans in observing chain reduced to minimum**
- **information technology in all areas of life will provide new opportunities for obtaining and communicating obs**

Sensors, Communications, and Computers



Striving for the Sustainable Society

"A place where humans and their use of the environment are in balance with nature"