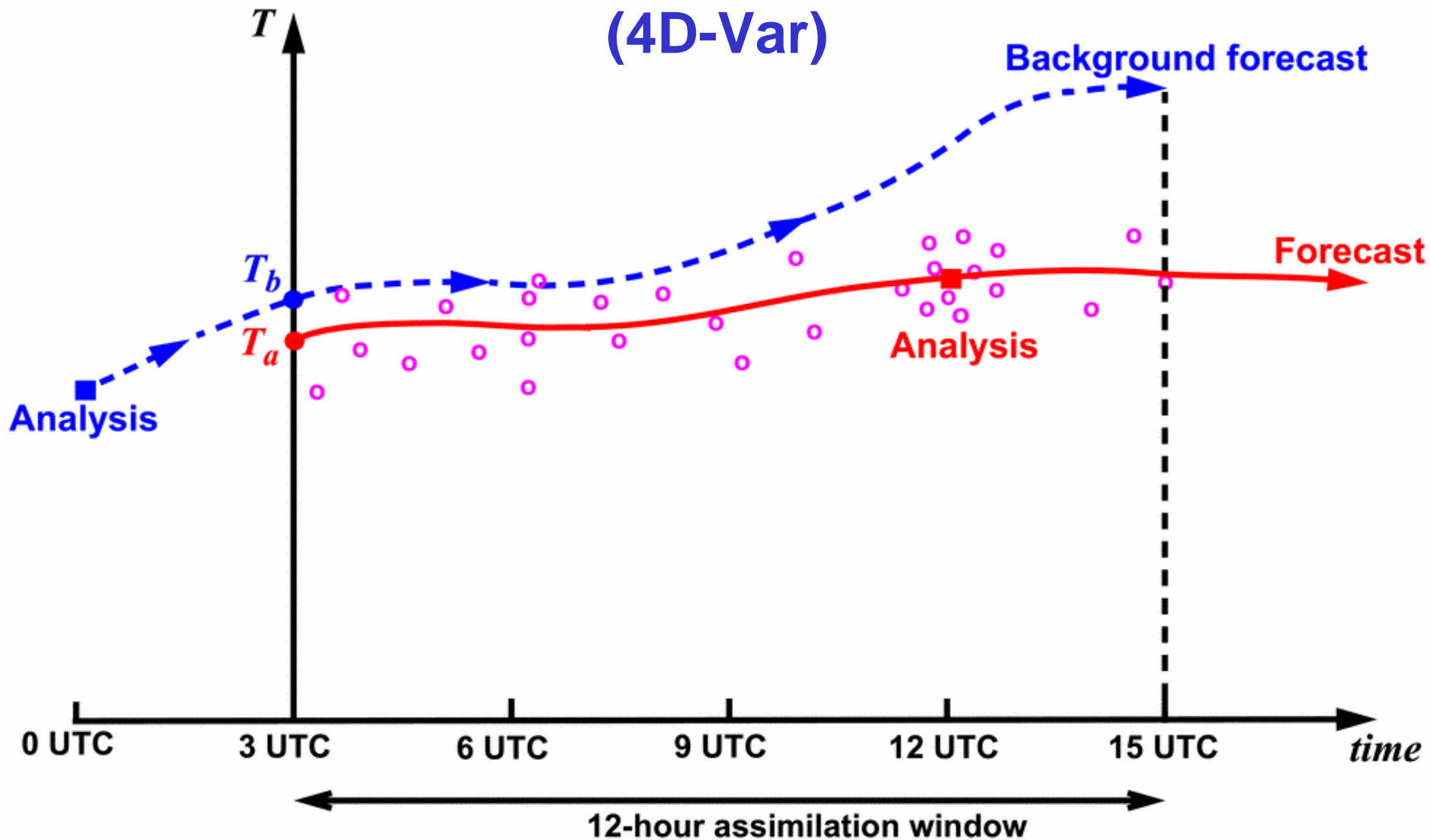


# Use of satellite radiances in the ECMWF system

Graeme Kelly, Eric Anderson, Peter  
Bauer, Marco Matricardi, Tony  
McNally, Jean-Noël Thépaut, Mat  
Szyndel, Phil Watts & many others.

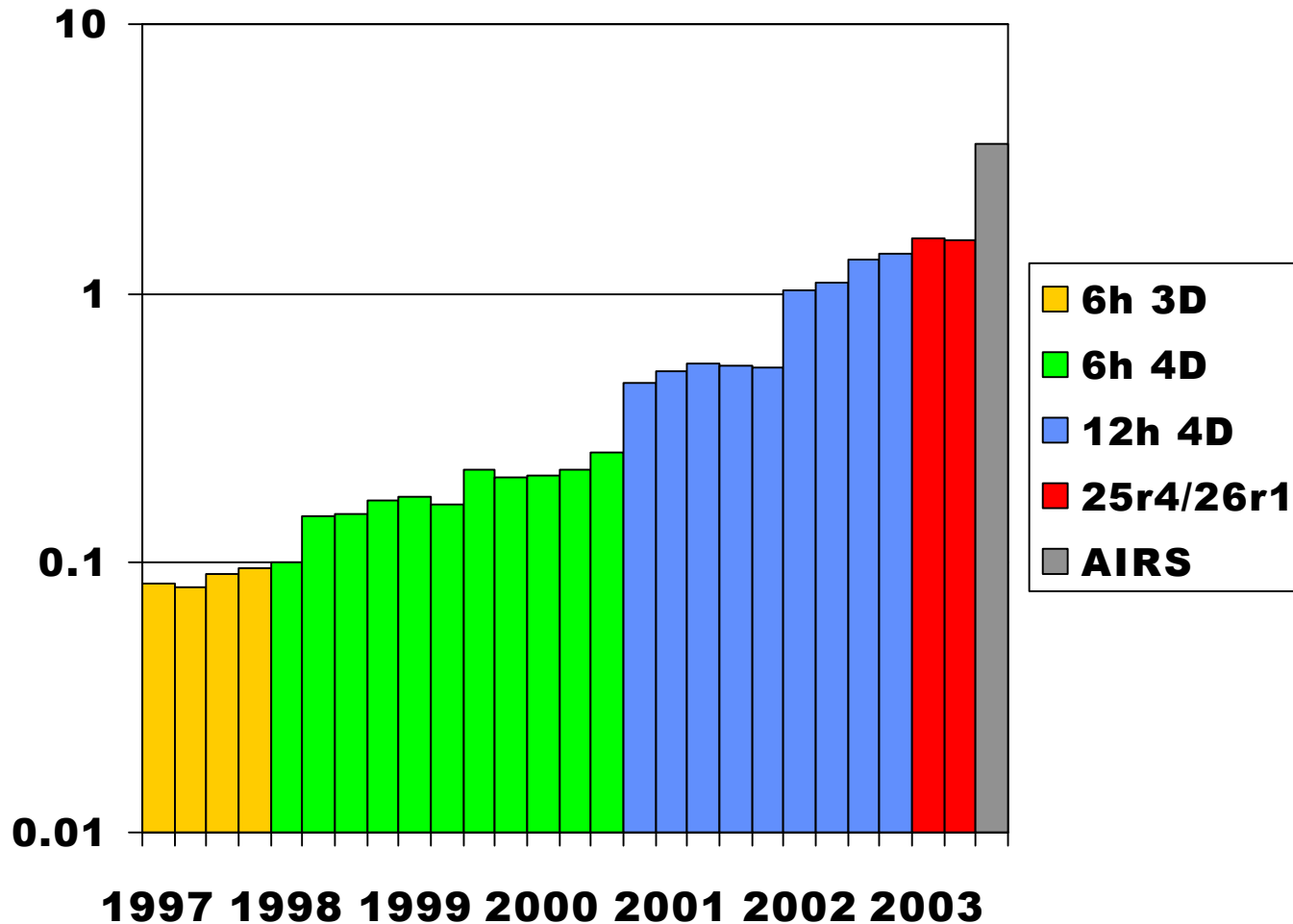
# Four Dimensional variational data assimilation (4D-Var)



# ECMWF operations October 2003

- **AQUA AIRS**
- 3xAMSUA (NOAA-15/16/17) + **AQUA AMSUA**
- 3 SSMI (F-13/14/15)
- 2xHIRS (NOAA-16/17)
- **2xAMSU-B (NOAA-16/17)**
- Radiances from 5xGEOS (Met-5/7 GOES-9/10/12)
- Winds from 4xGEOS (Met-5/7 GOES-10/12)and  
MODIS/TERRA
- SeaWinds from QuiKSCAT
- ERS-2 Altimeter / SAR (limited coverage)
- SBUV (NOAA 16)
- **ENVISAT OZONE (MIPAS)**

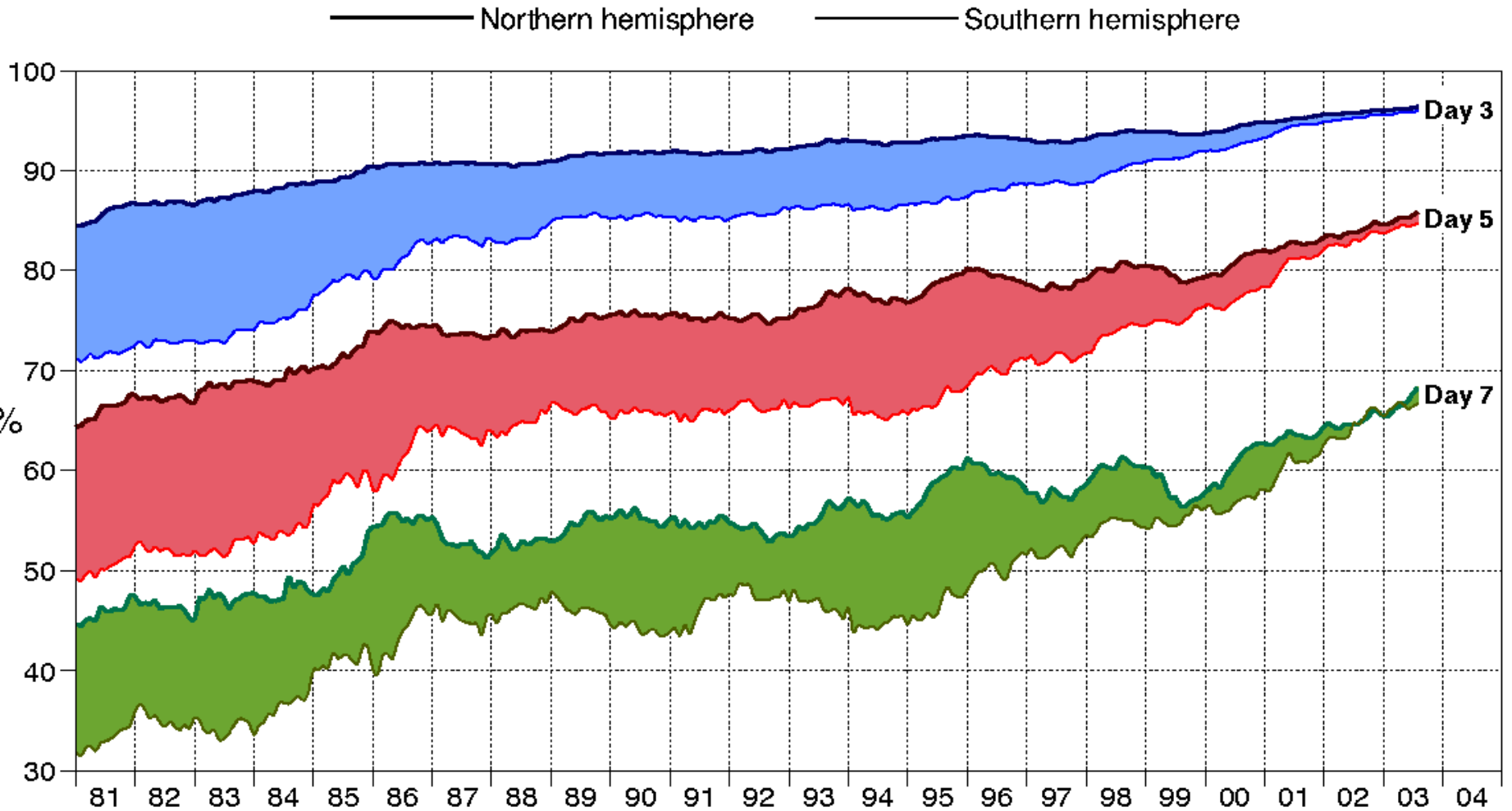
# Number of observational data used in the ECMWF assimilation system (with AIRS)



millions

# ECMWF forecasts 1981-2003

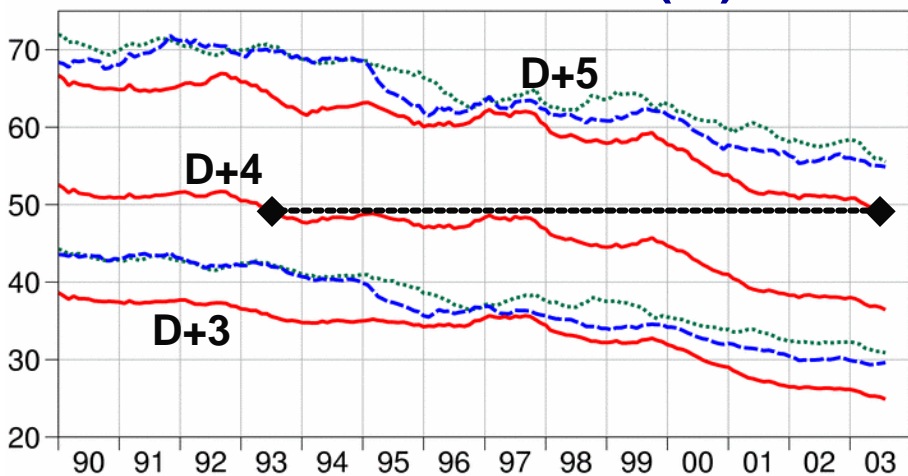
## Anomaly correlation of 500hPa height forecasts



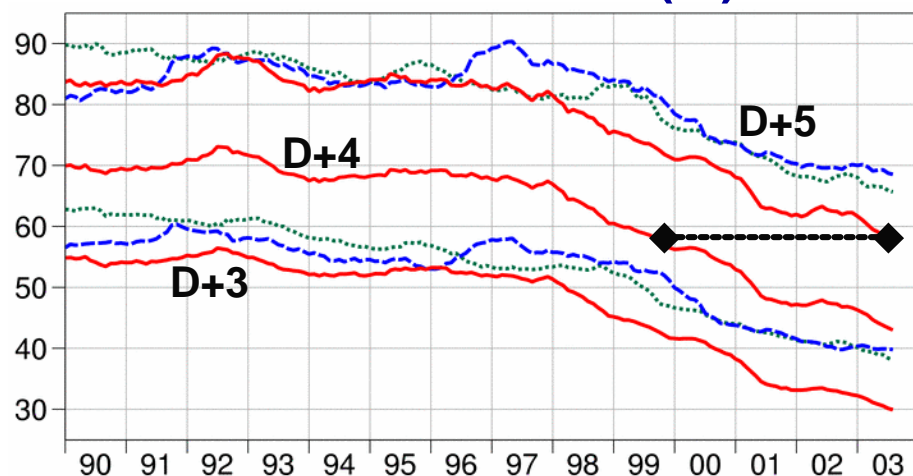
# Annual-mean r.m.s. errors against analyses from WMO

— ECMWF    - - - MET OFFICE    ..... NCEP

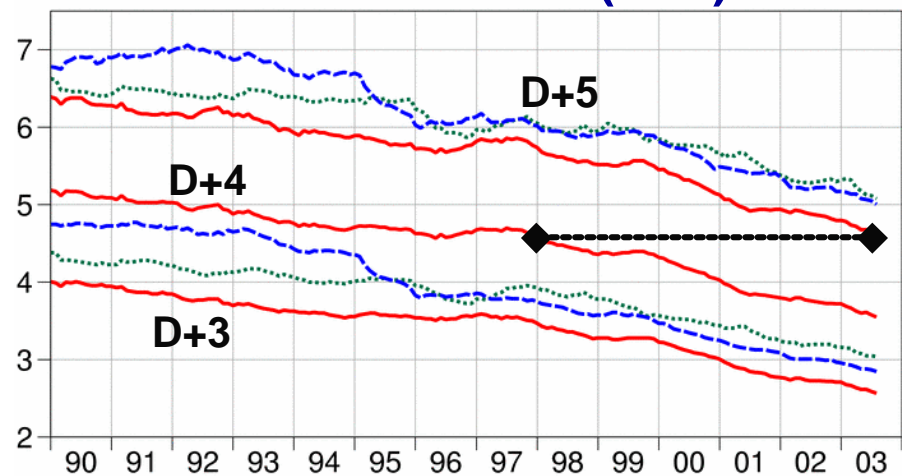
## N Hem 500hPa (m)



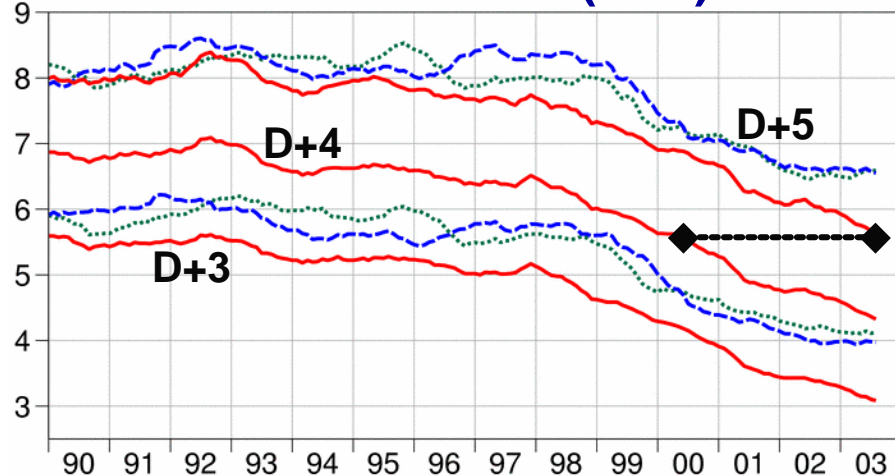
## S Hem 500hPa (m)



## N Hem Pmsl (hPa)



## S Hem Pmsl (hPa)



# Satellite radiance bias correction

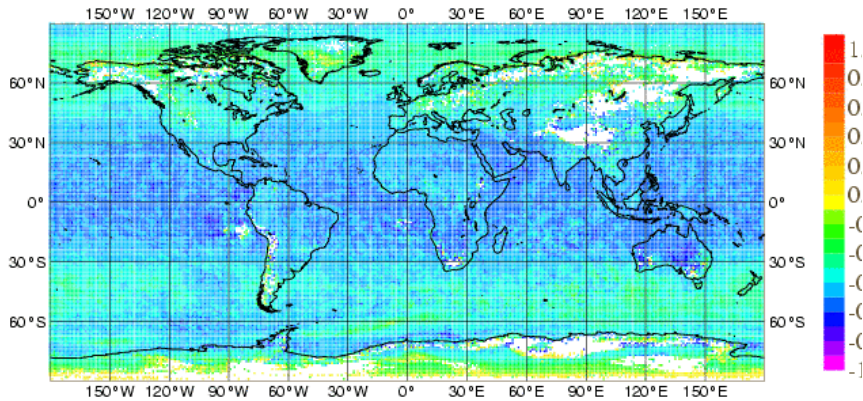
Polar satellites ~50 sensors ~19 e-suite 15 active

Geostationary ~10 sensors ~5 e-suite 5 active

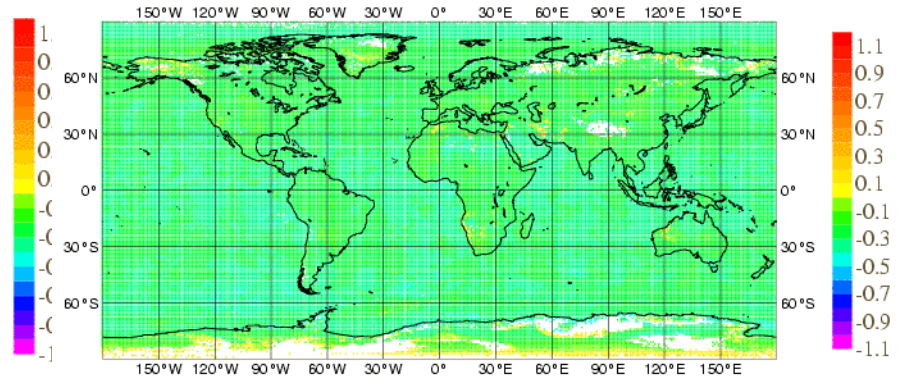
1. Time to retune all sensors
2. Separation of scan correction and first guess predictors
3. Predictors coefficients moved to the assimilation control variable
4. New Data Base for management & time averaging of bias predictors

# AMSUA channel 6 observed-first guess (6 day sample with no bias correction)

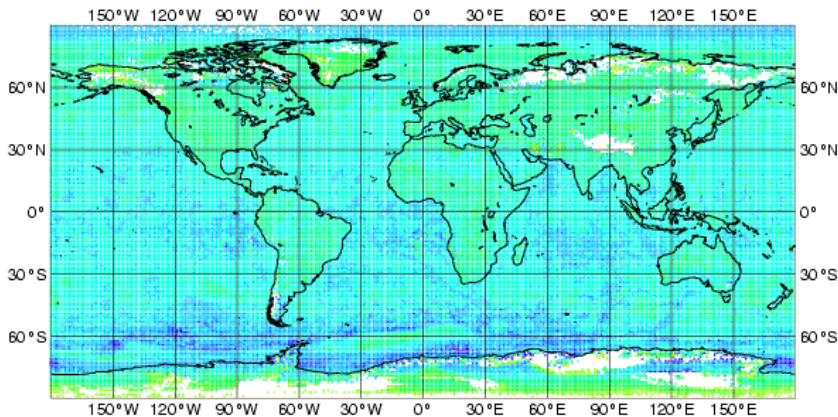
**N15**



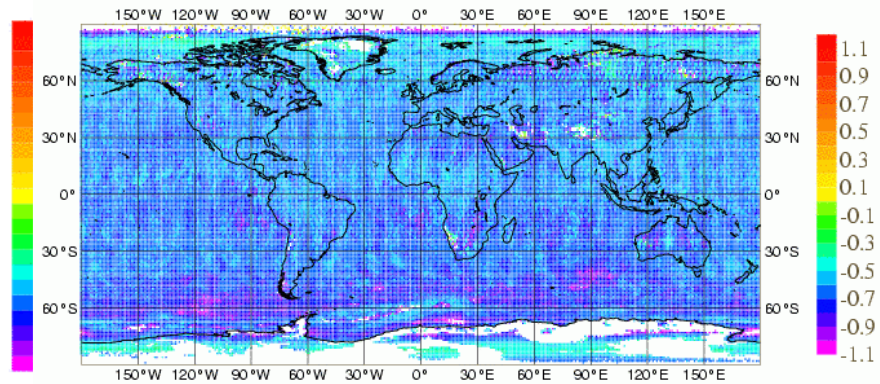
**N16**



**N17**



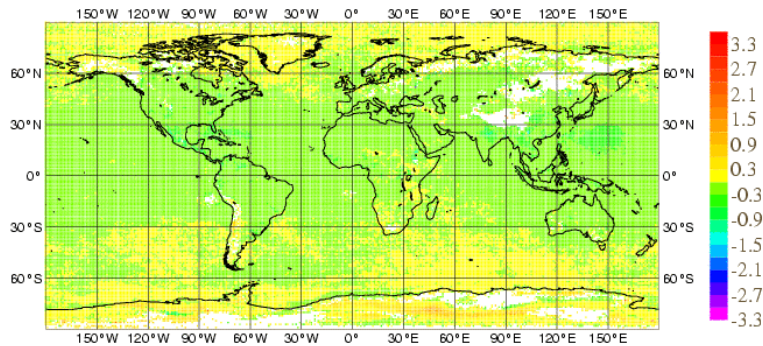
**AQUA**



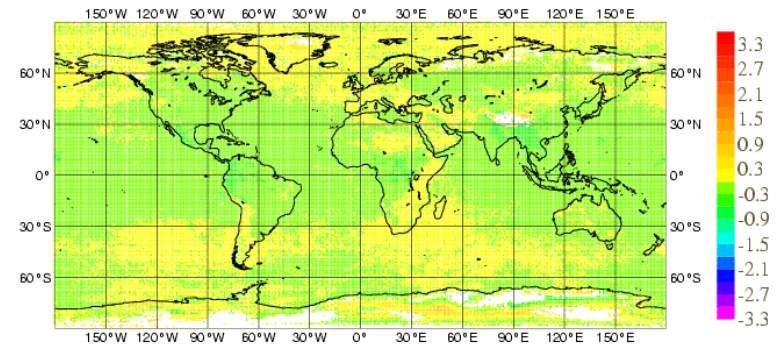


# AMSUA channel 6 observed-first guess (6 day sample with bias correction)

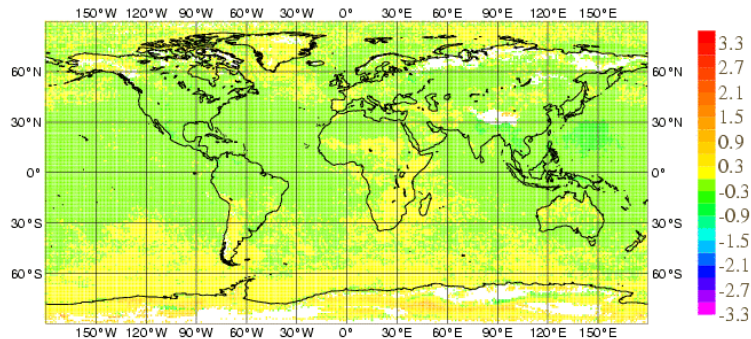
n15



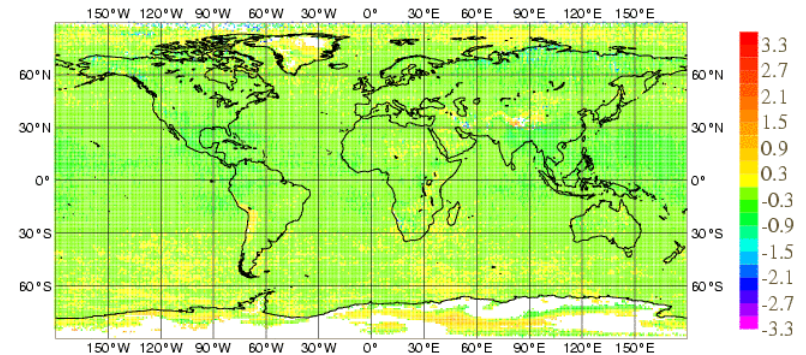
n16



n17

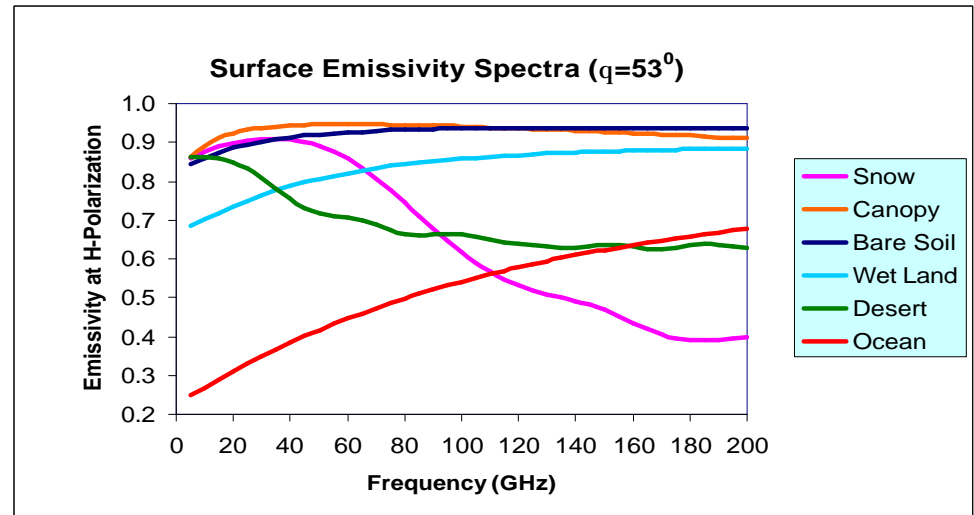
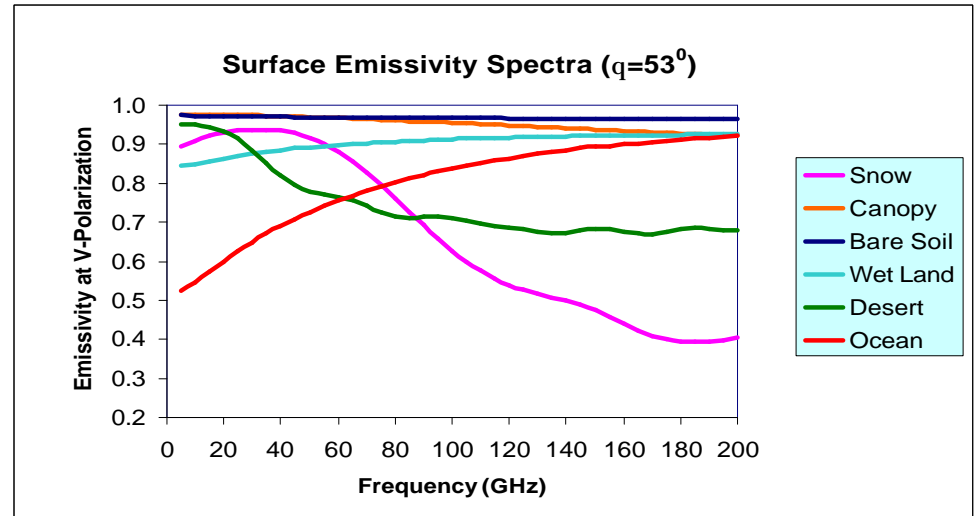


aqua

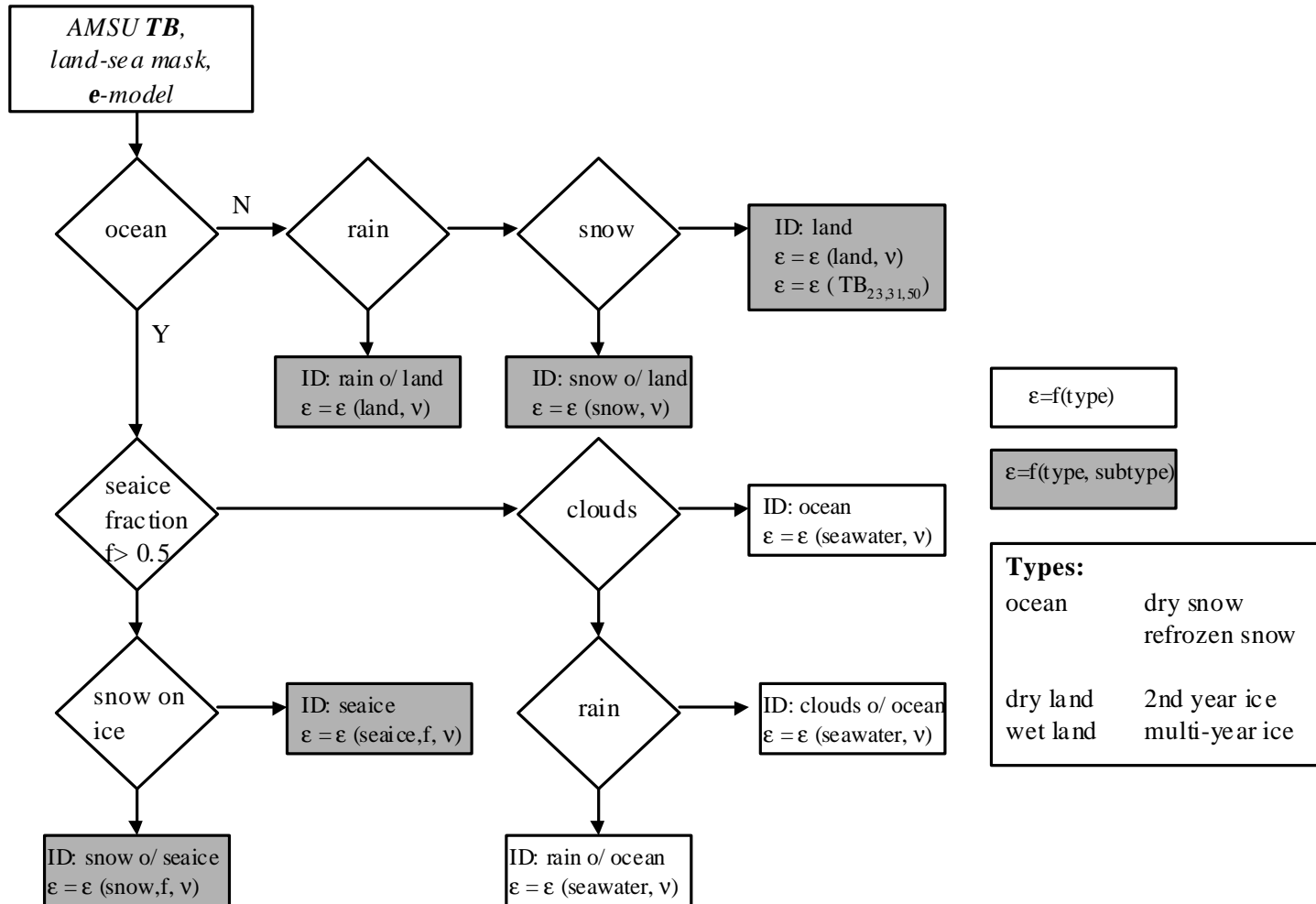


# Surface Emissivity Spectra

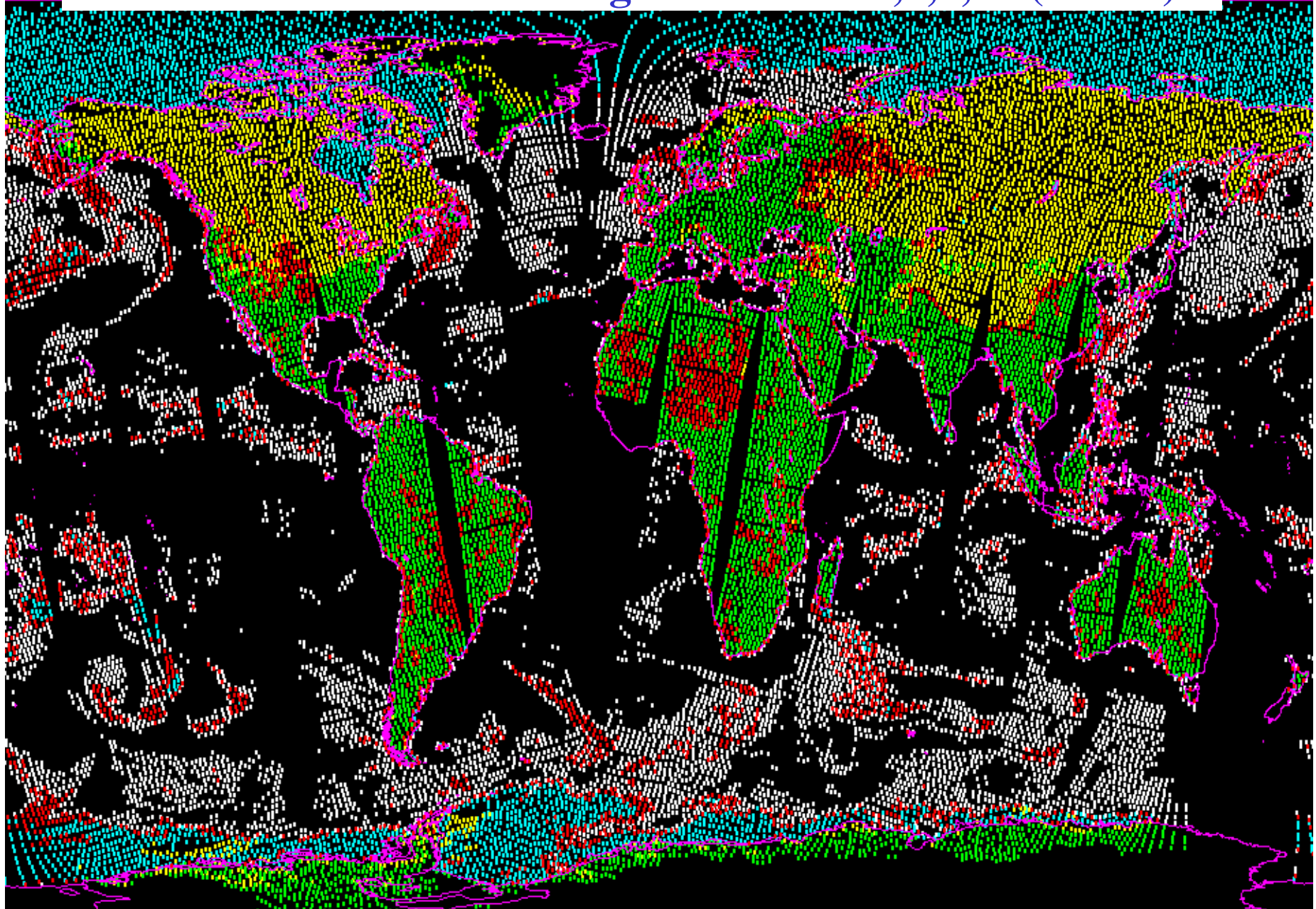
- **Sea ice** – Coherent reflection
- **Canopy** – Four layer clustering scattering
- **Bare soil** – Coherent reflection and surface roughness
- **Open water** – two-scale roughness theory
- **Snow/desert** – Random



# Surface Classification Method (NESDIS)



# Surface classification using AMSU/1 ch1,2,3,15 (nesdis)



Blue sea-ice green land yellow snow white cloud red rain and failed

# 3 (AMSU-A) instruments

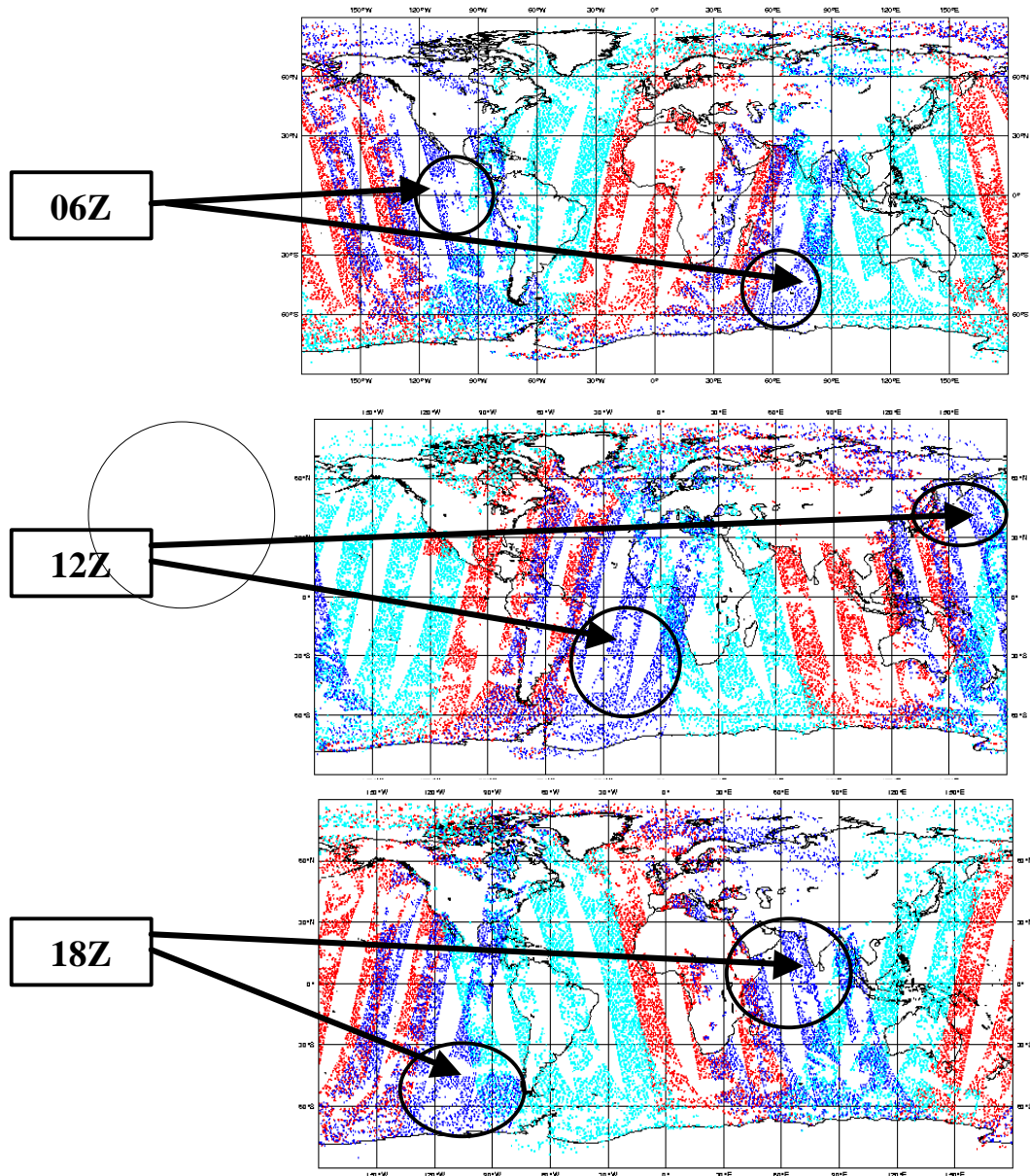
NOAA-15 (07:30 am)

NOAA-16 (13:30 pm)

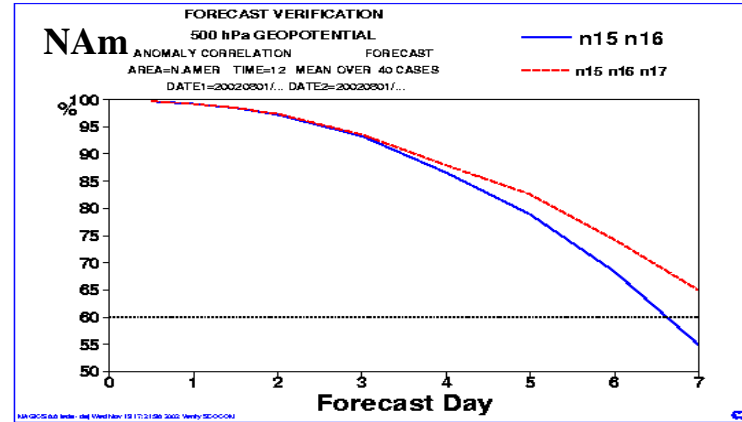
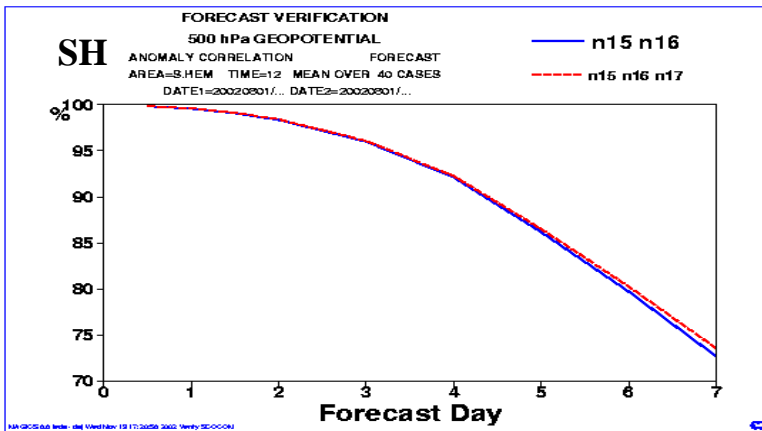
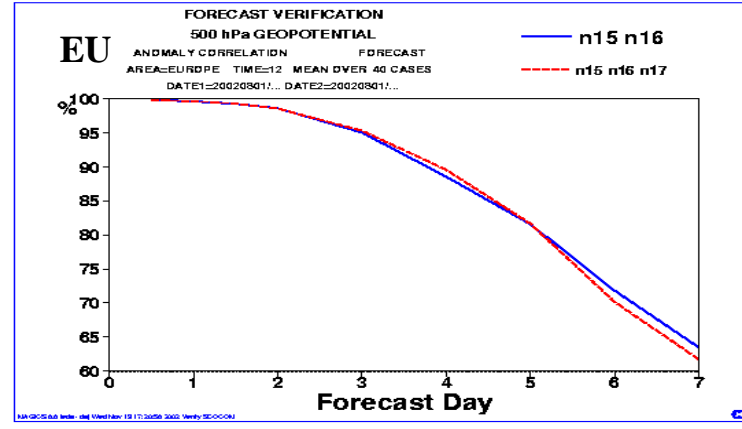
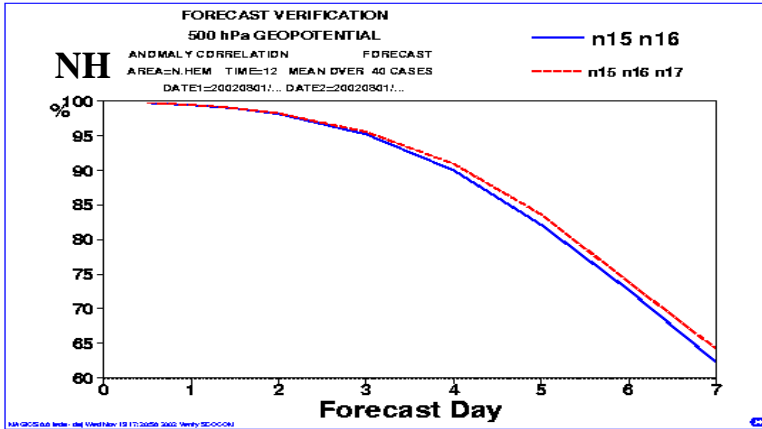
NOAA-17 (10:00 am)

• At any time, NOAA-17 covers large oceanic areas crucial for global NWP forecasts and insufficiently observed by the NOAA-15-16 baseline (e.g. Pacific Ocean at 06 and 12Z)

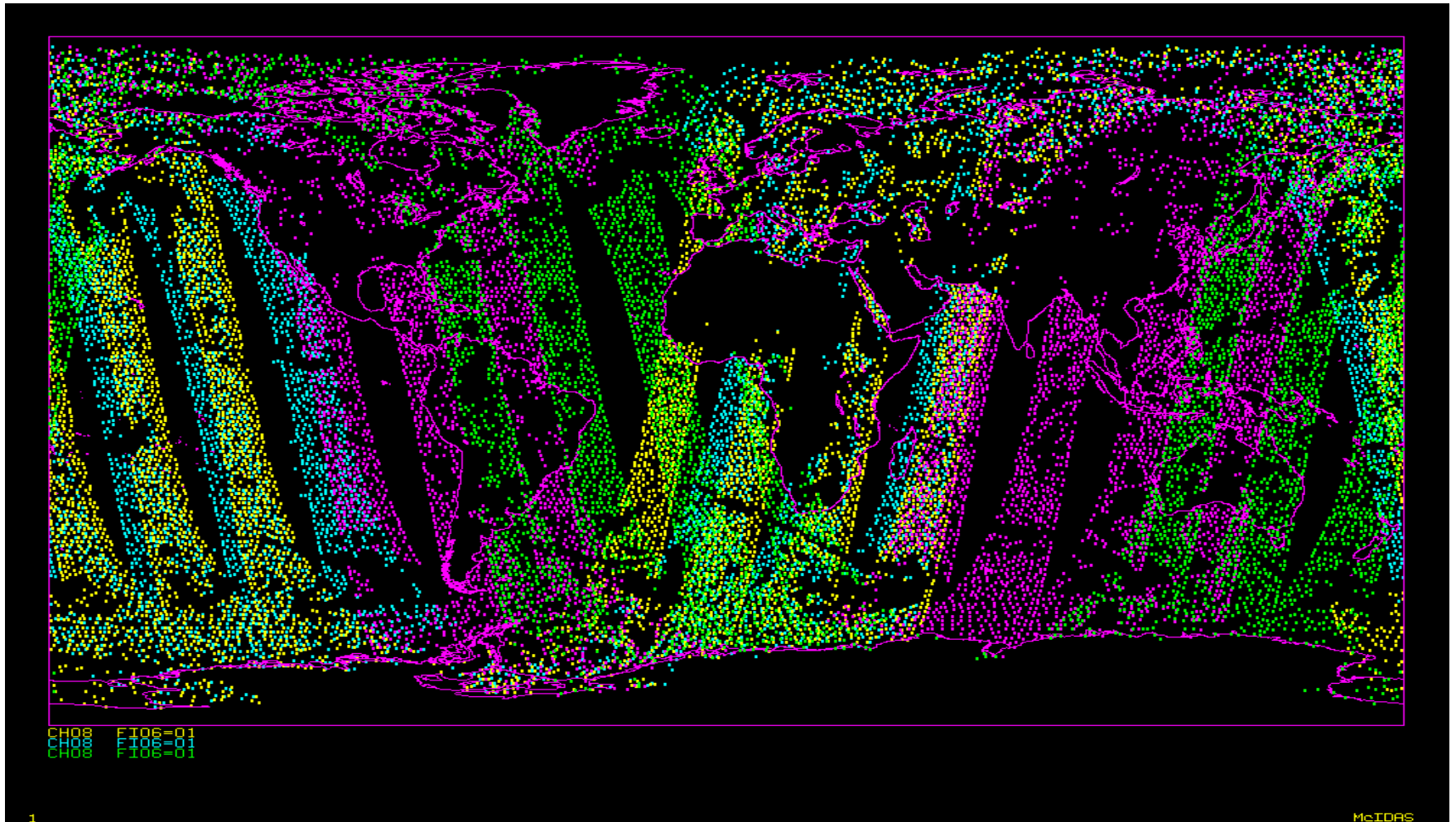
• A time/space uniform coverage can be fully exploited by the ECMWF 4D-VAR system



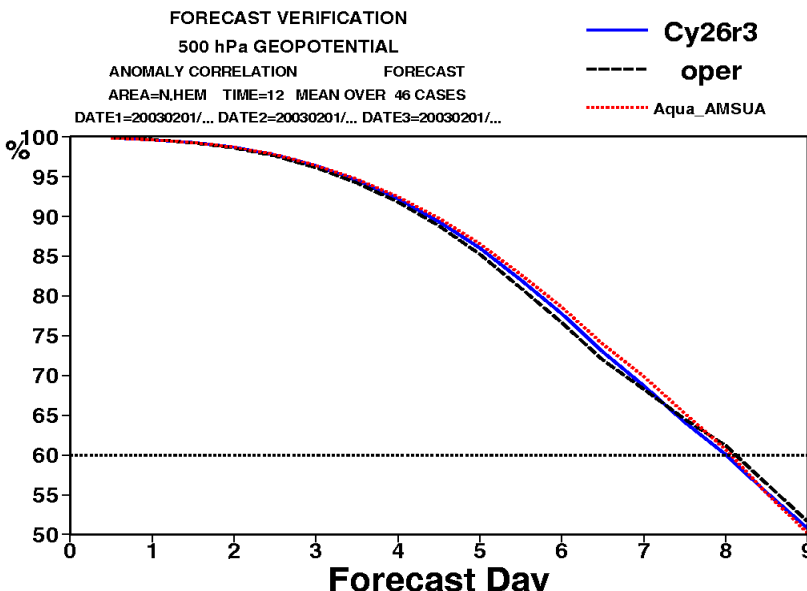
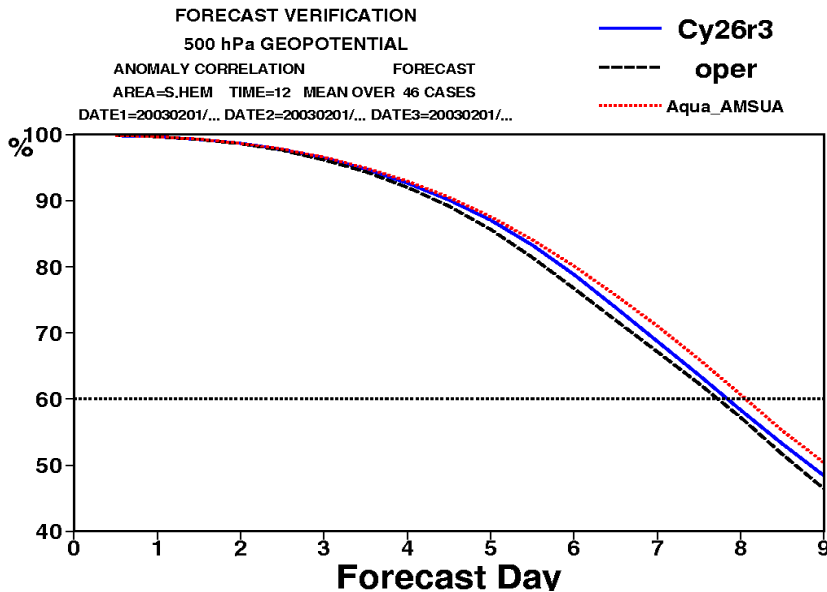
# 500 hPa Z scores averaged over 40 cases



# Data used for AMSU-A channel 6 in 4DVAR minimization for four satellites



# Four satellites/three in new operational cycle





## HIRS cloud detection

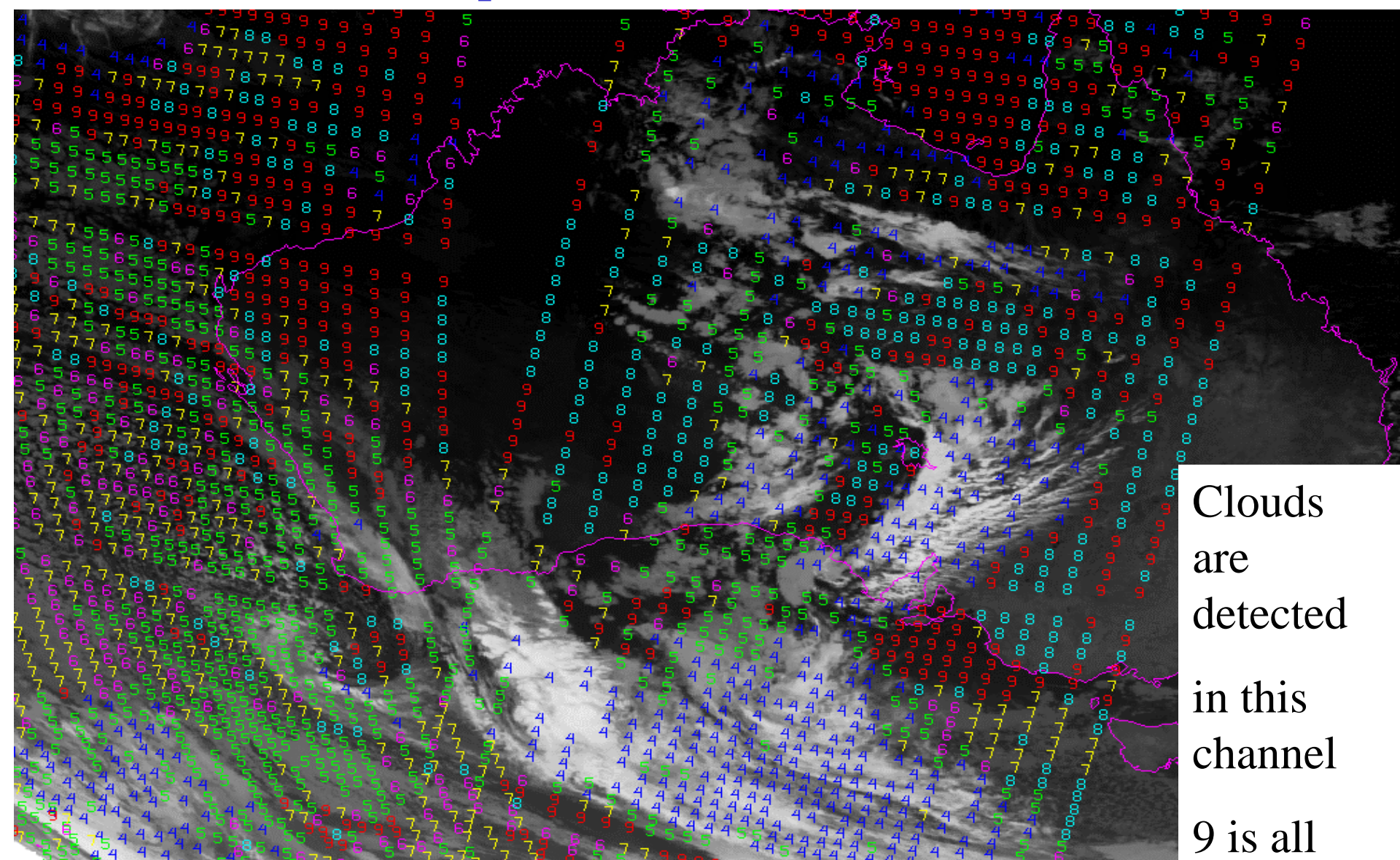
A simple cloud detection is based on the CO<sub>2</sub> slicing ideas and window channel checks. The required clear sky estimate is calculated from the forecast.

Use is made of the 13.4-15micron HIRS channels assuming no cloud effects in HIRS channels 1 and 2.

Starting with channel 2 normalized departures from the first guess are then compared with the channel below. If the departure difference exceeds a threshold then cloud is determined to be in this channel and others below are determined cloudy.

The other channels out of this band are linked to these tests for example if cloud is detected in channel 4 then channel 12 is cloudy.

# Example of HIRS cloud detection

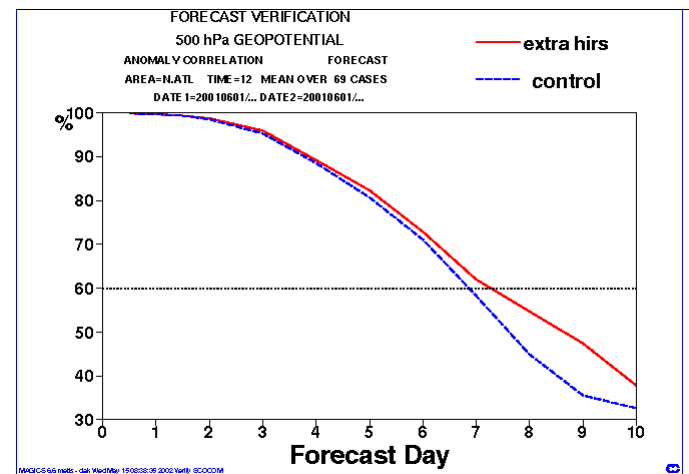
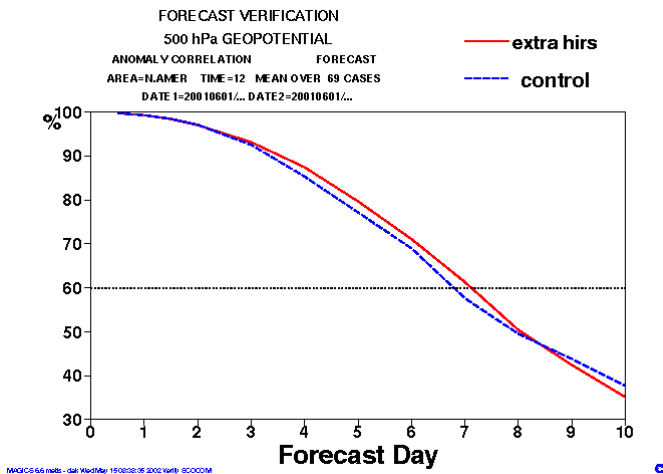
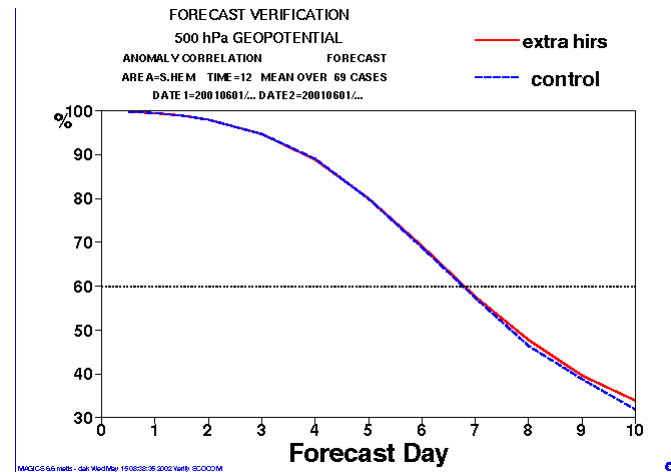
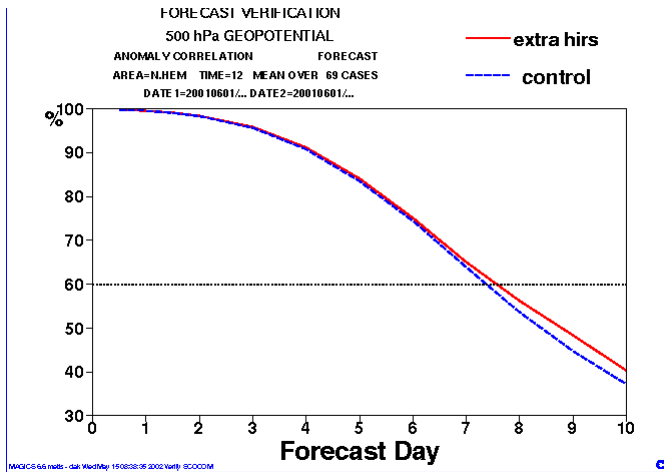


Clouds  
are  
detected  
in this  
channel  
9 is all  
clear

ICCC ICCL=6

30003 GMS-5 02 20 OCT 01293 162500 03072 01088 02.00

# Impact of extra HIRS data (69 cases)



# AMSU B cloud and rain detection

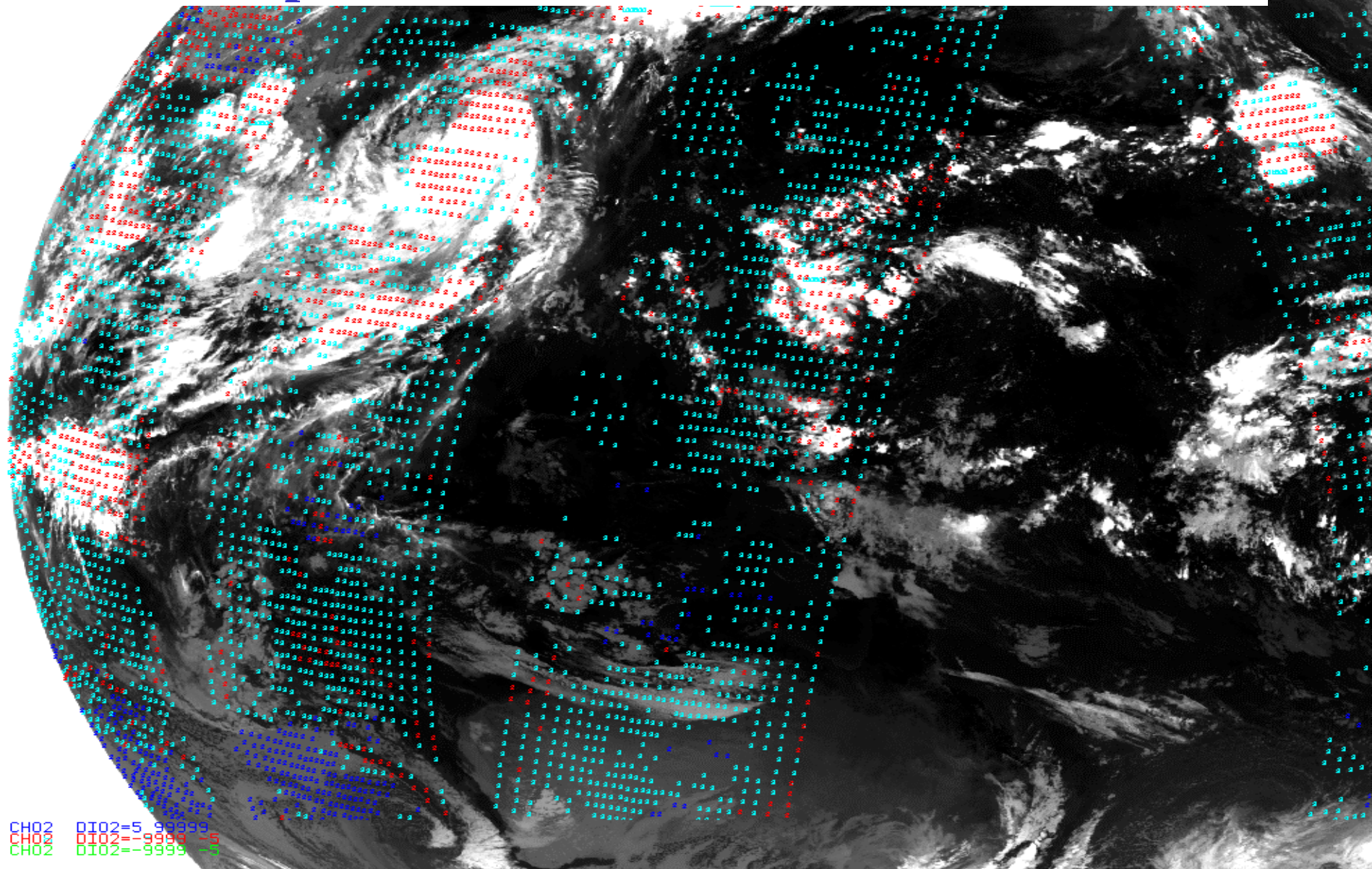
A Q/C for rain and heavy cloud liquid water has been developed for non frozen land and water but some more test are required over frozen land and ice.

The threshold test uses AMSU B channel 2

$$|\text{observed} - \text{calculated ( first guess)}| < 5 \text{ deg}$$

AMSU B channels 3,4 and 5 are used in 4D-VAR

# Example of AMSU B cloud and rain detection

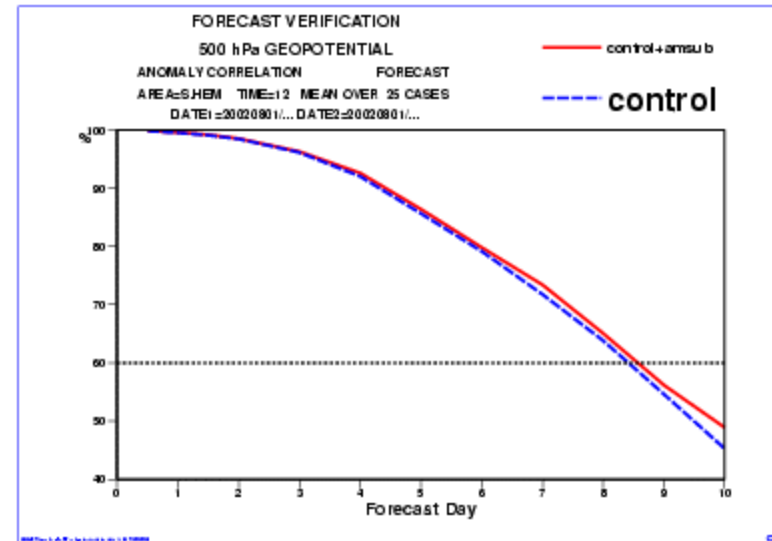
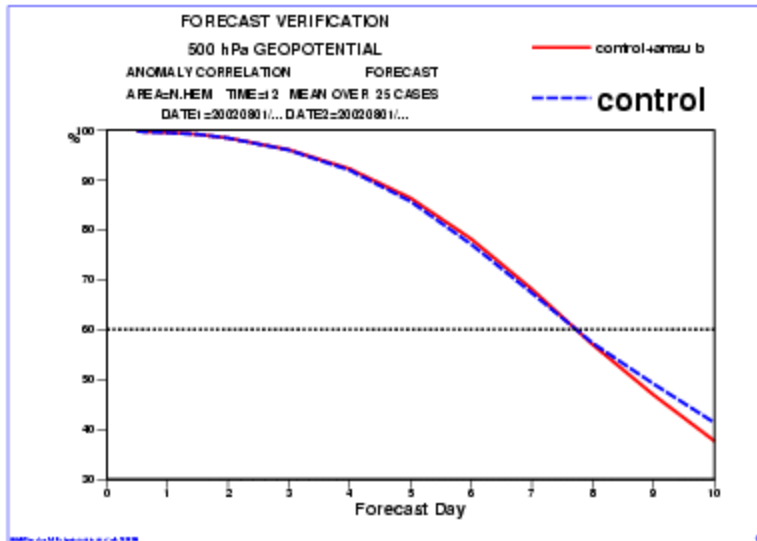
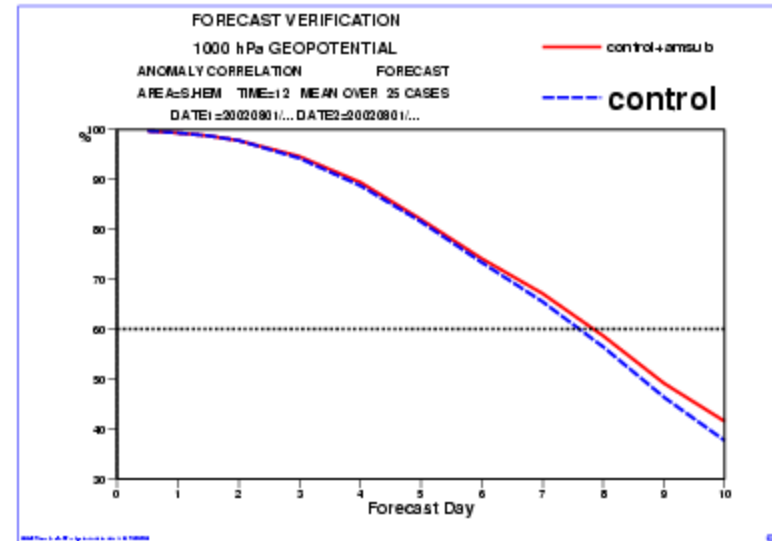
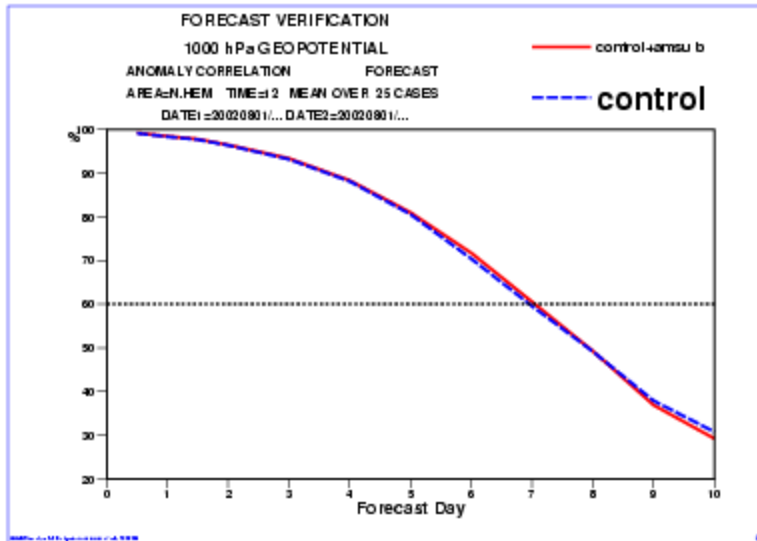


CH02 DI02=5 99999  
CH02 DI02=-99999 5  
CH02 DI02=-99999

7 0007 GMS-5 02 5 JUL 01186 233300 00904 00016 04.00

ITSC 13

# Impact of AMSU B ( 25 cases)



# Clear Sky Radiances (CSR)

- CSR is defined for a group of pixels:
  - GOES Imager: 11 x 17 pixels (typically 45 x 45 km).
  - Meteosat : 16 x 16 pixels (80 x 80 km at nadir).
  - SEVIRI : 16 x 16 pixels (48 x 48 km at nadir).
- Scene is analysed for cloud.
- Radiance is averaged across cloud free pixels.
- Quality flags give percentage of scene clear and standard deviation of radiances.
- Products are disseminated hourly in BUFR format.

# GEOS CSR data coverage (6 hours)

69979 MET5

75328 MET7

107143 GOES9

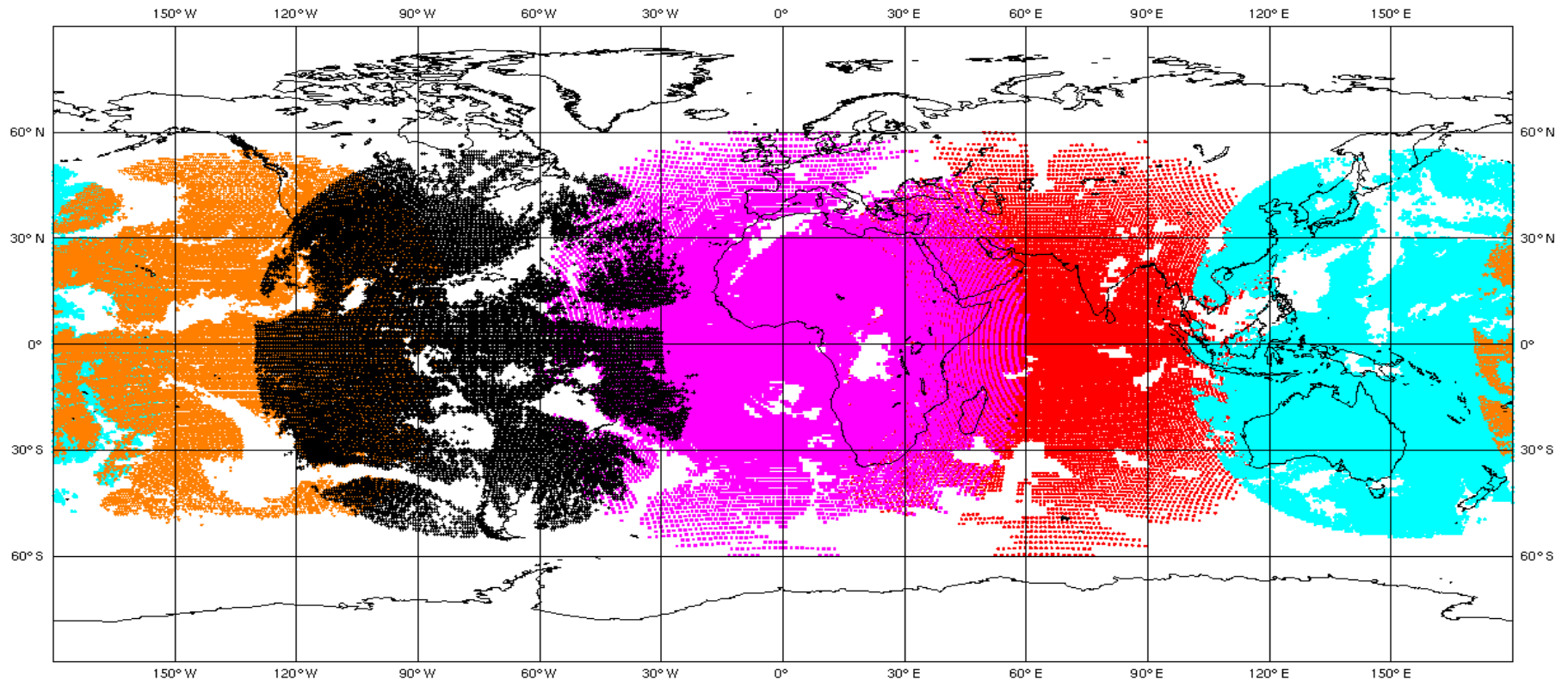
69736 GOES10

68569 GOES12

## ECMWF Data Coverage (All obs) - GRAD

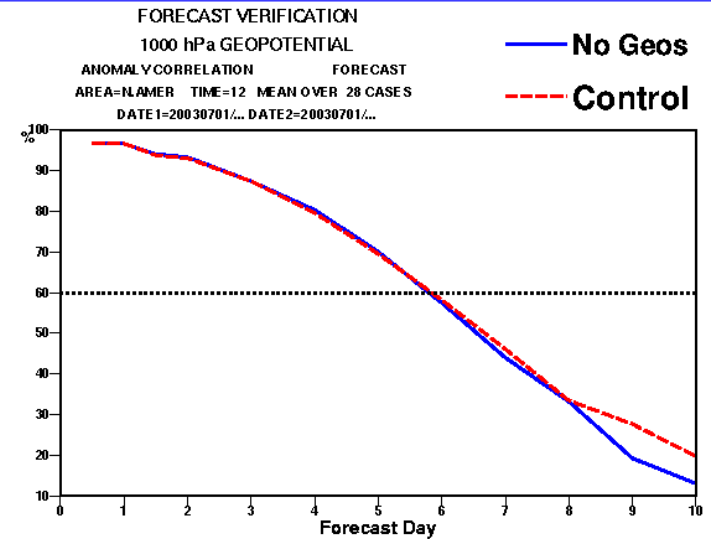
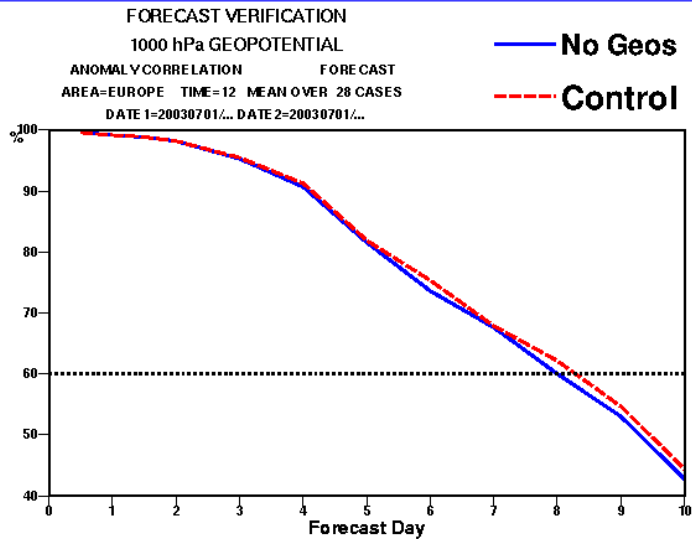
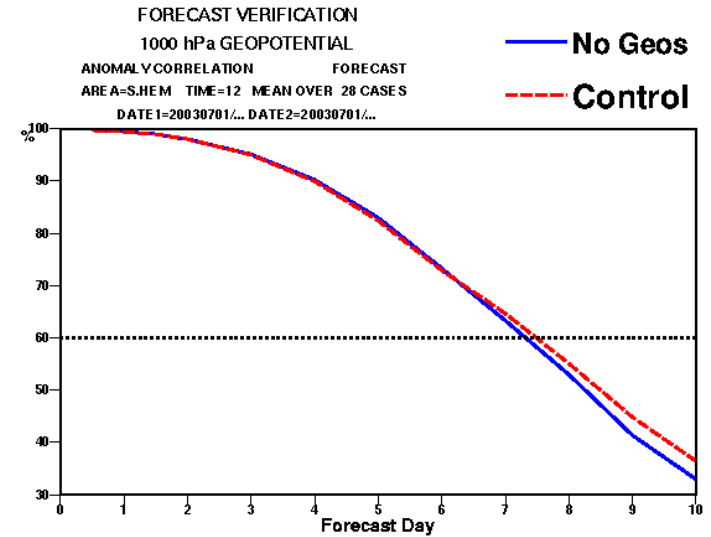
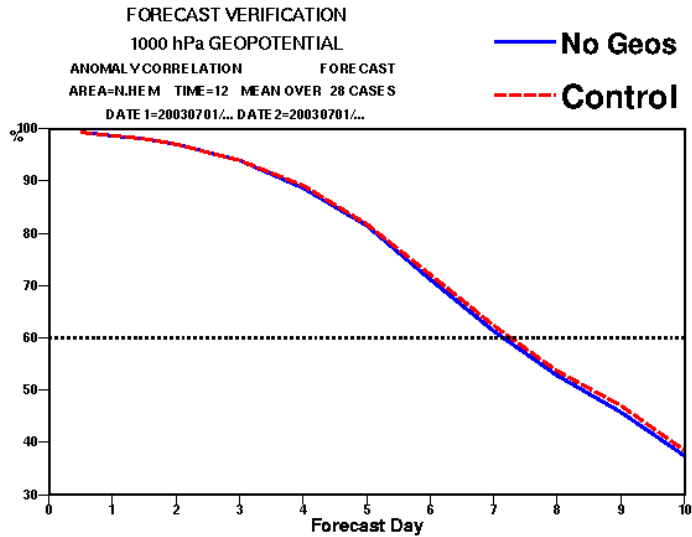
### 23/OCT/2003; 00 UTC

### Total number of obs = 390755





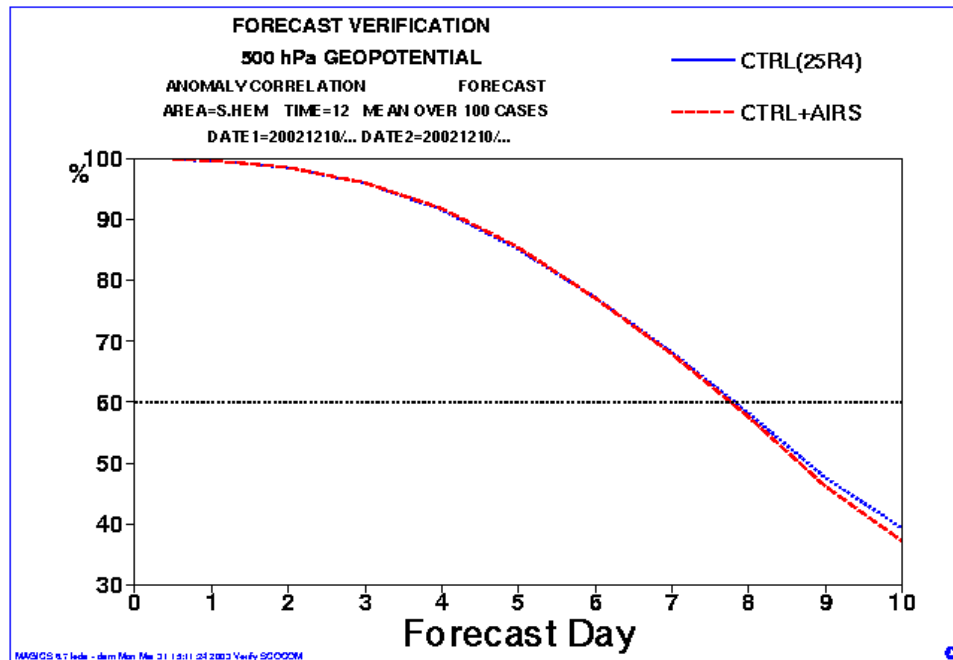
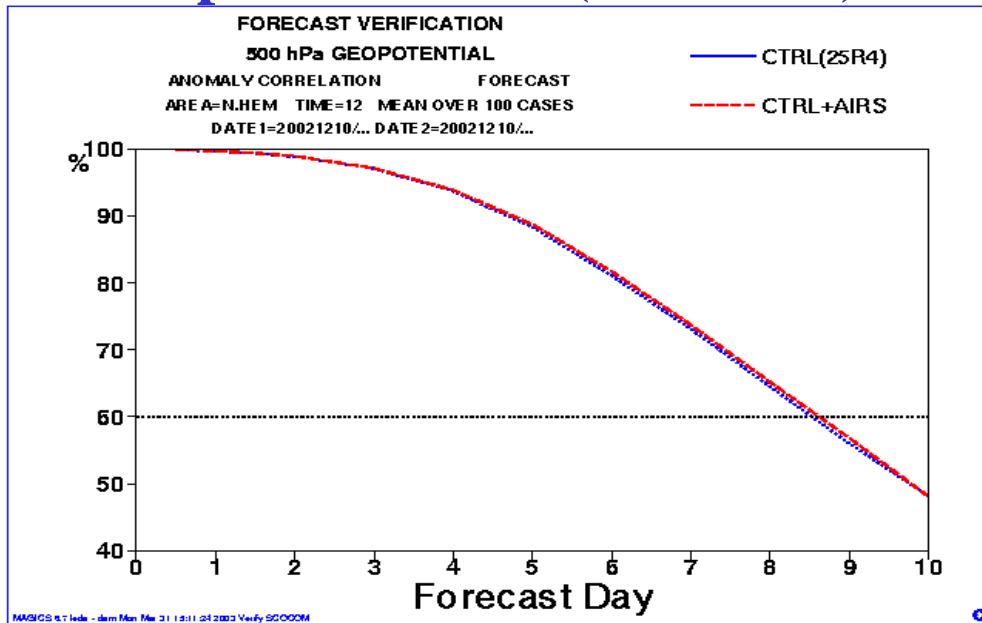
# Impact of GEOS rads



# AIRS data usage in 4DVAR

- Input radiance data consists of sampled **324 channels** from NASA / NESDIS-ORA
- All channels **flagged clear** at a location are assimilated (subject to blacklist)
- After cloud screening ‘good’ data are **thinned** to a horizontal spacing of 120Km
- Currently we do not attempt to assimilate channels in the **O3 band or 4.2** micron band
- Currently we do not attempt to assimilate **low level channels over land**
- **Flat** (single global number rather than varying) **bias correction** used for each channel
- Very simple (and conservative) observation error assigned to each channel (**0.6 / 1.0 / 2.0K**)

# Impact of AIRS (100 cases)

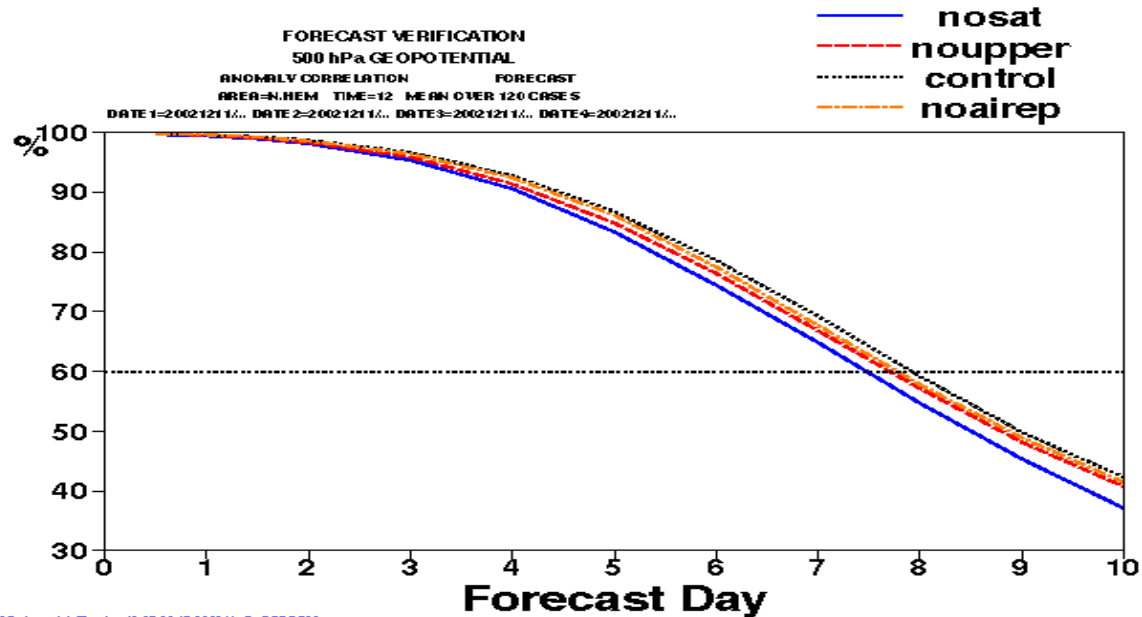


# There are three OSE experiments (two summer and two winter months)

1. **CONTROL** the current operational system at ecmwf  
3 AMSUs, 2 HIRS, 5 GEOS winds 3 GEOS radiances, 3 SSMI, Quikscat radiosondes temps and pilots, profiles, aireps, synops, bouys and paobs.
2. **NOSAT** -- all satellite removed ie only radiosondes temps and pilots, profiles, aireps, synops, bouys and paobs.
3. **NO AIREP** -- no airep winds and temperatures.
- 4 **NO UPPER** -- no radiosondes temps and pilots and profiles.

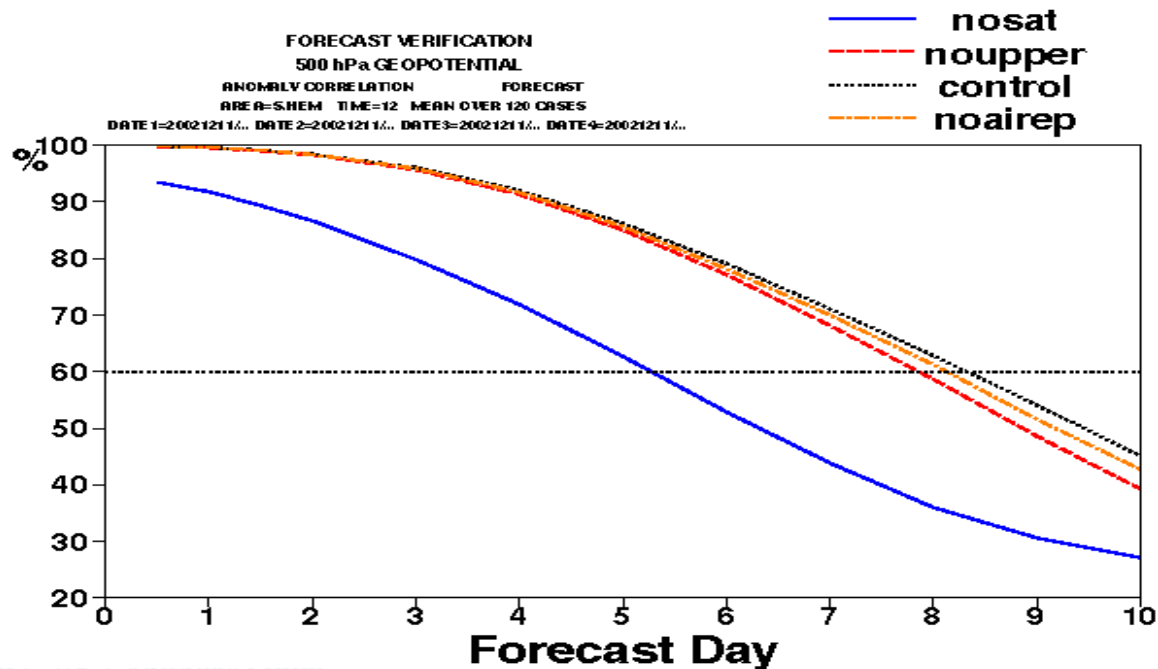
# OSE EXPERIMENTS

NH



MAGICS 6.7 styx - dsk Thu Apr 10 07:39:47 2003 Verity SDCOM

0

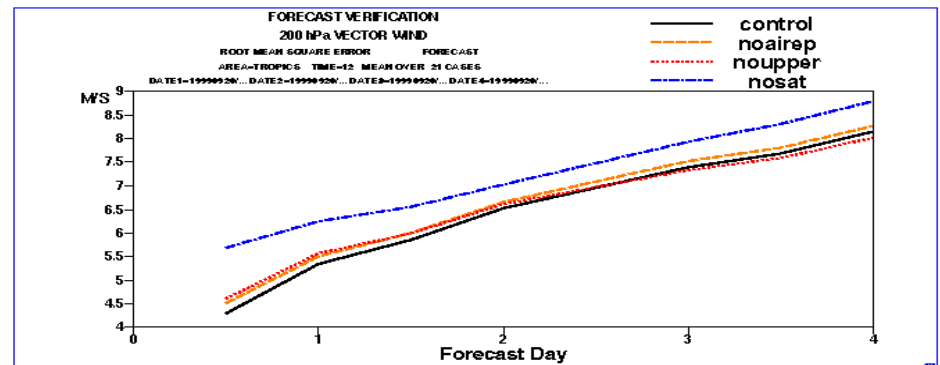
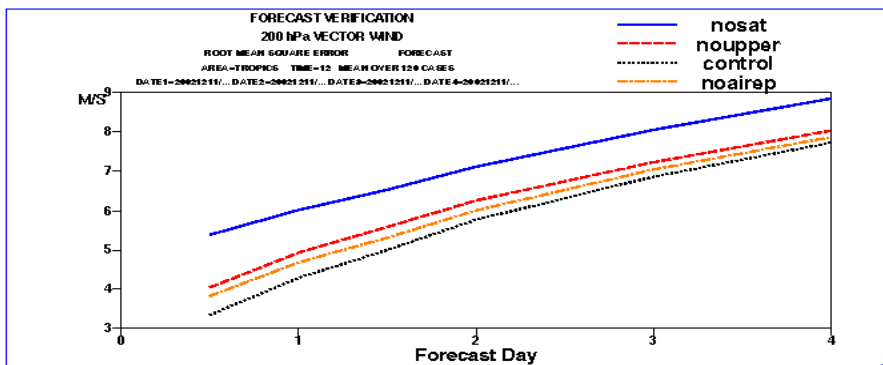
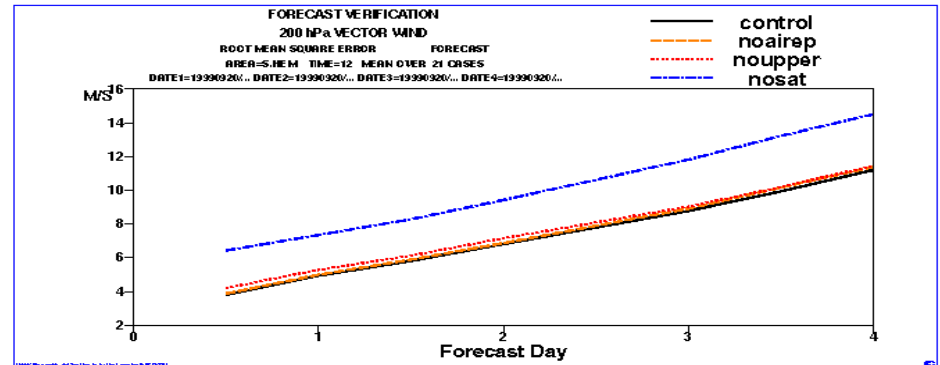
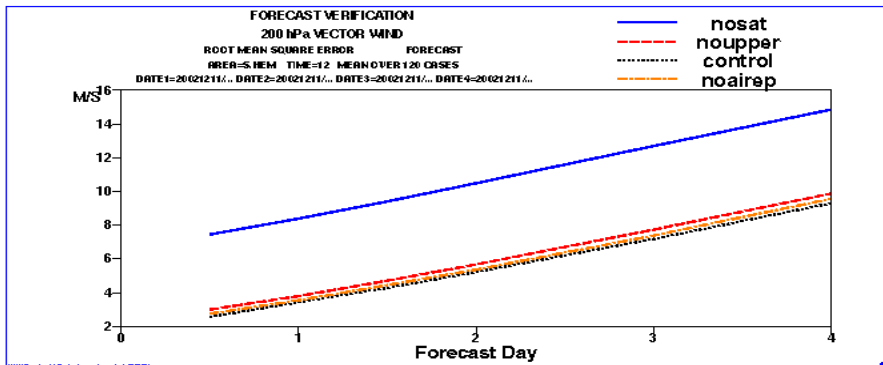
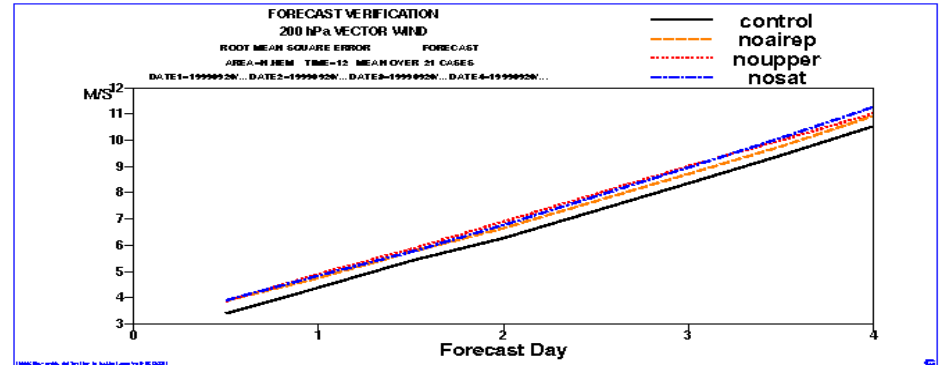
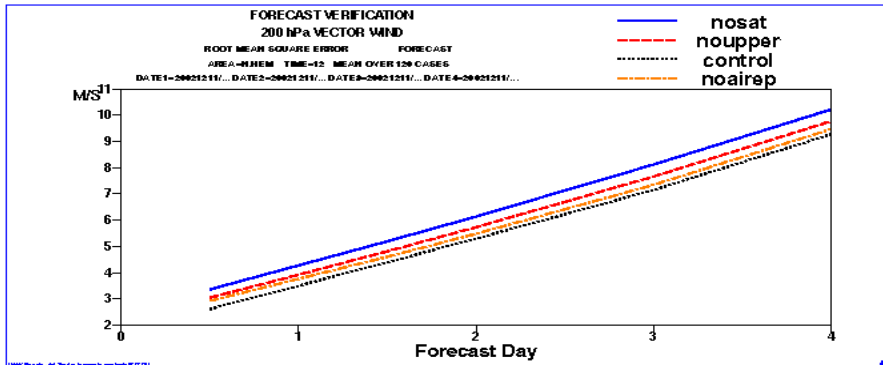


MAGICS 6.7 styx - dsk Thu Apr 10 07:39:47 2003 Verity SDCOM

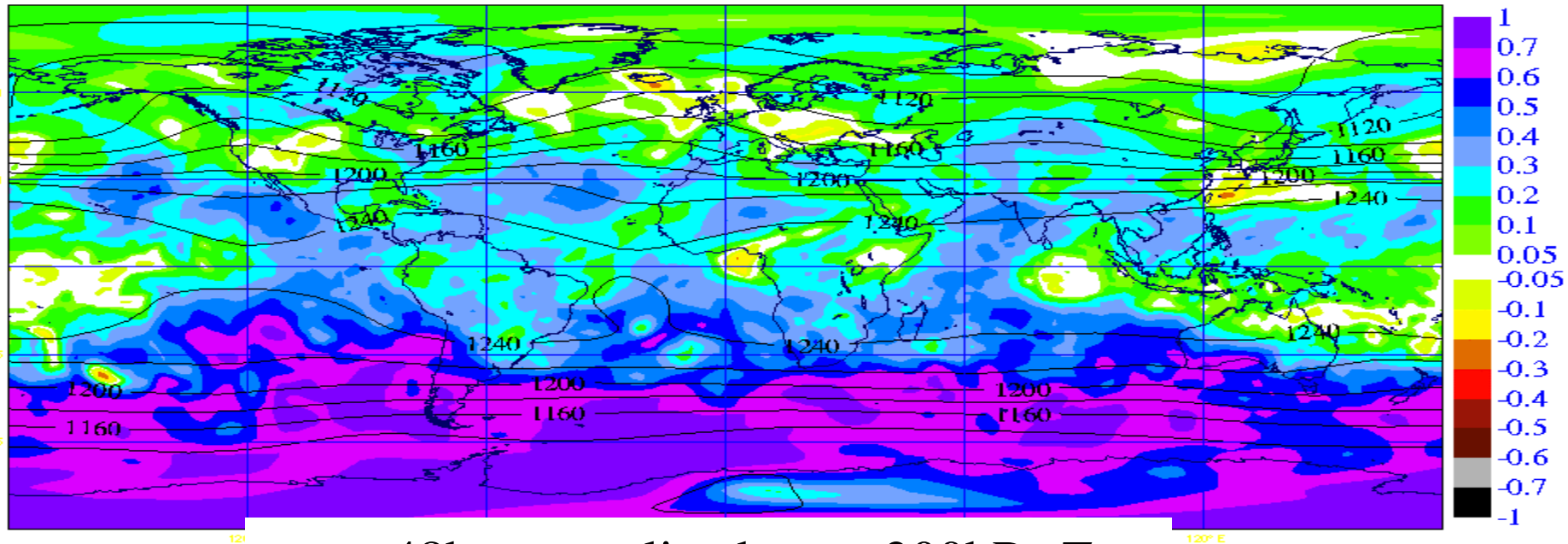
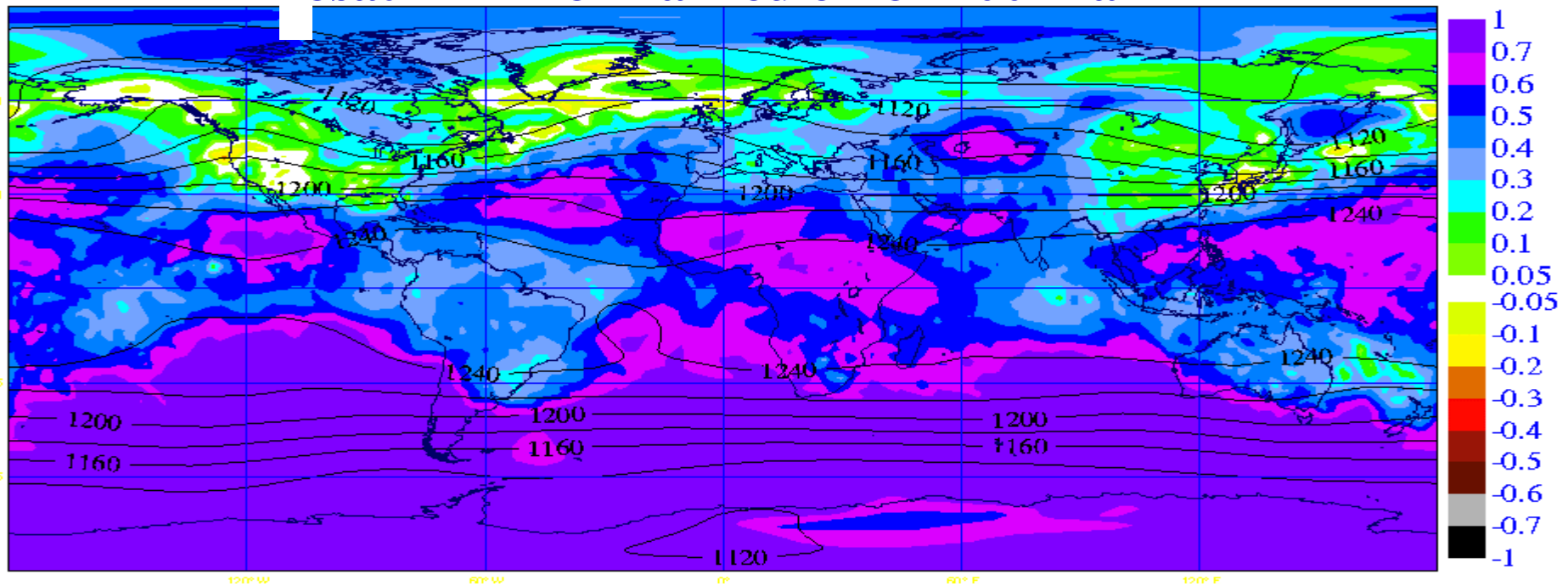
SH

0

# COMPARISON OF OSE 2003 AND 1999

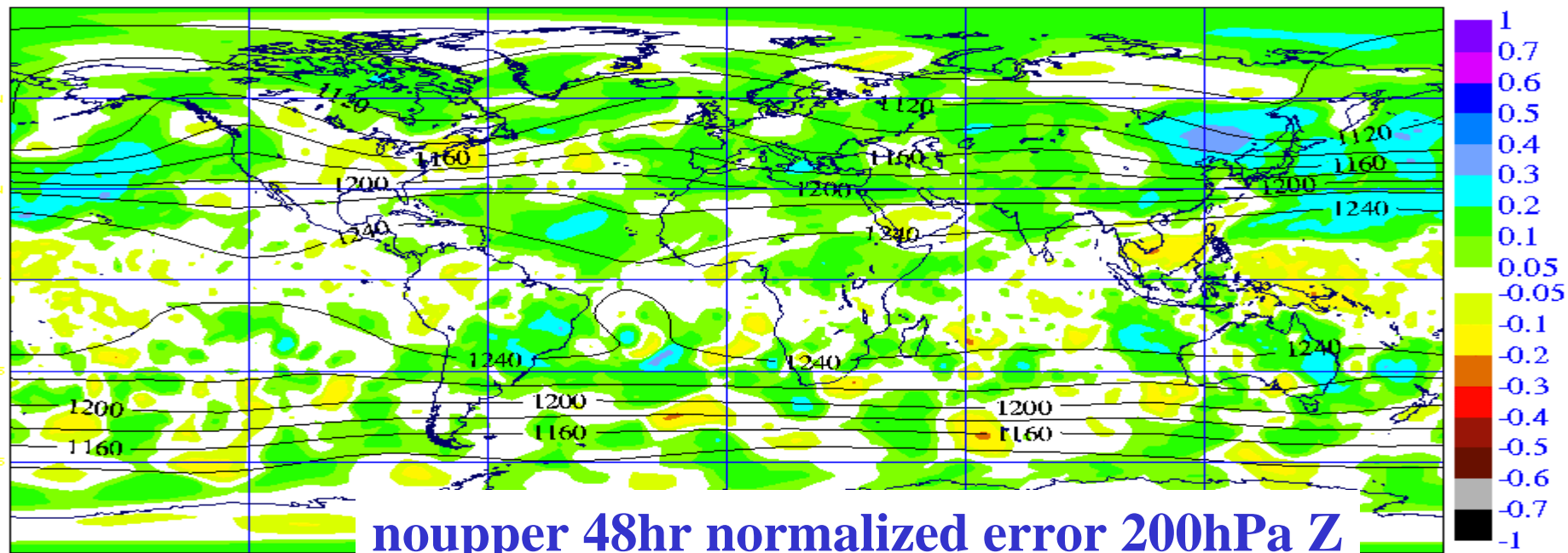
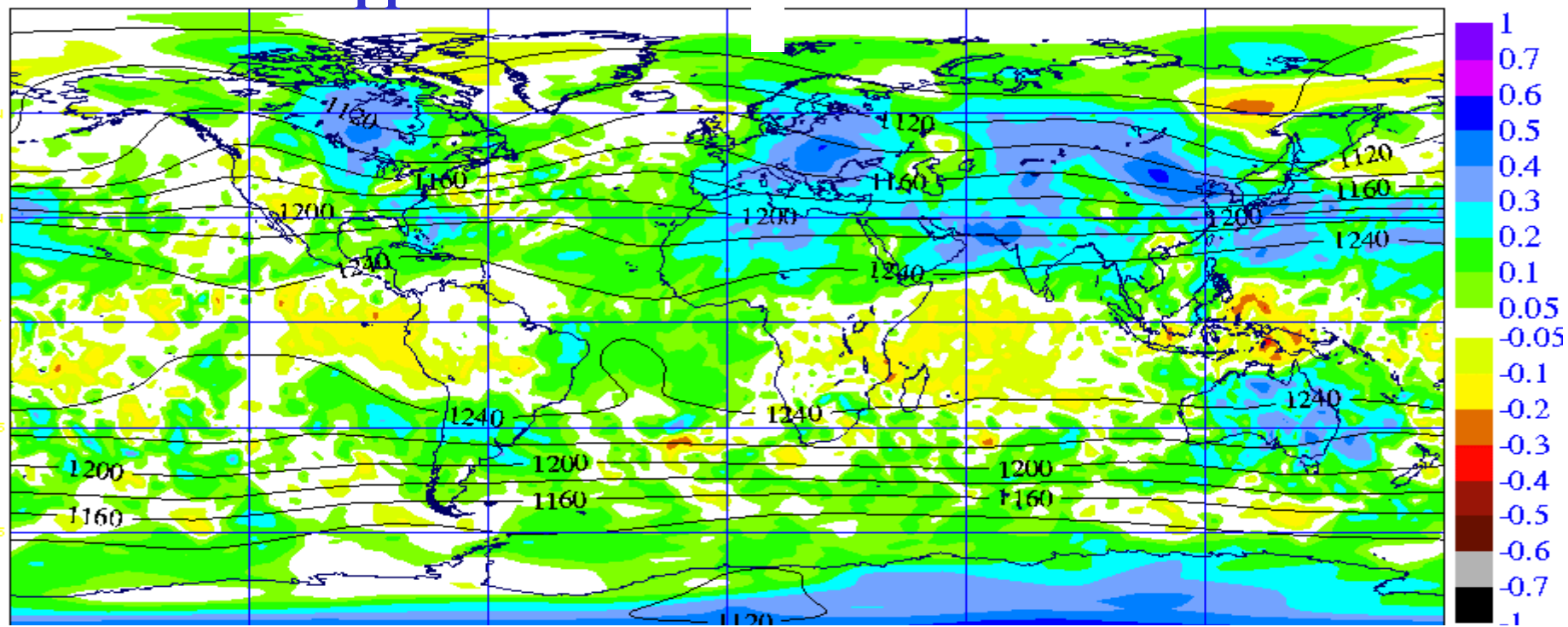


nosat 12hr normalized error 200hPa Z



nosat 48hr normalized error 200hPa Z

# noupper 12hr normalized error 200hPa Z

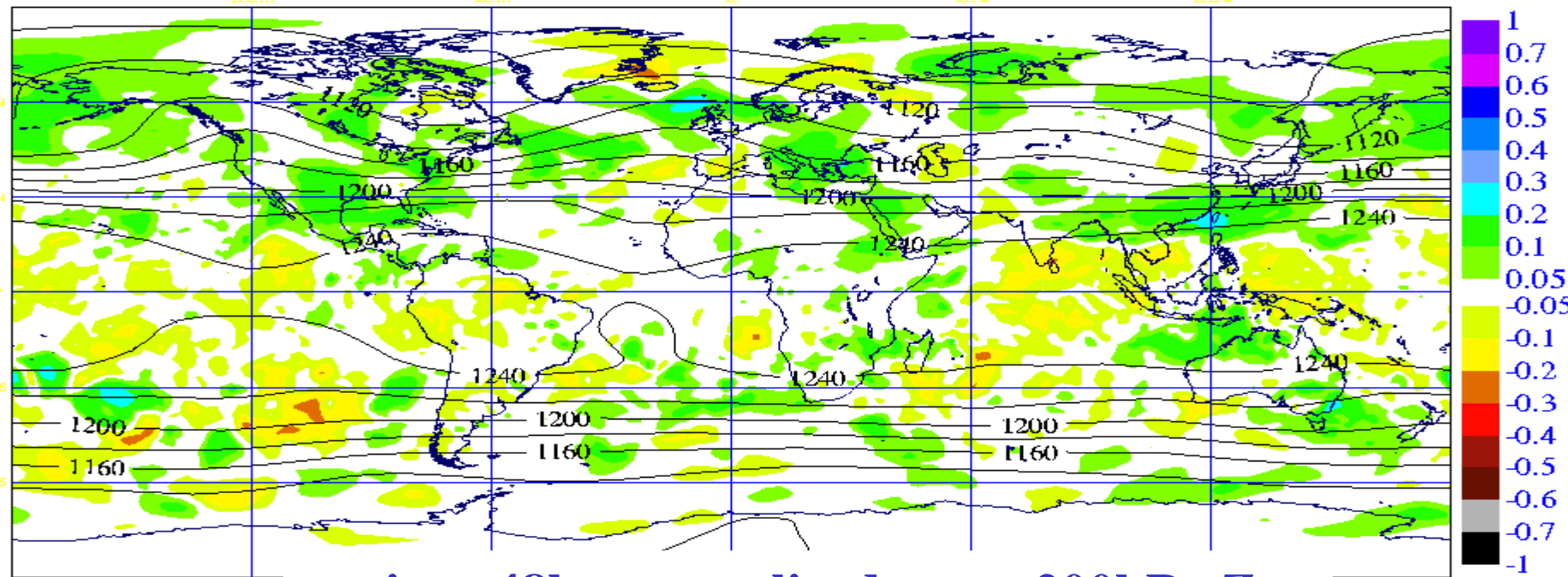
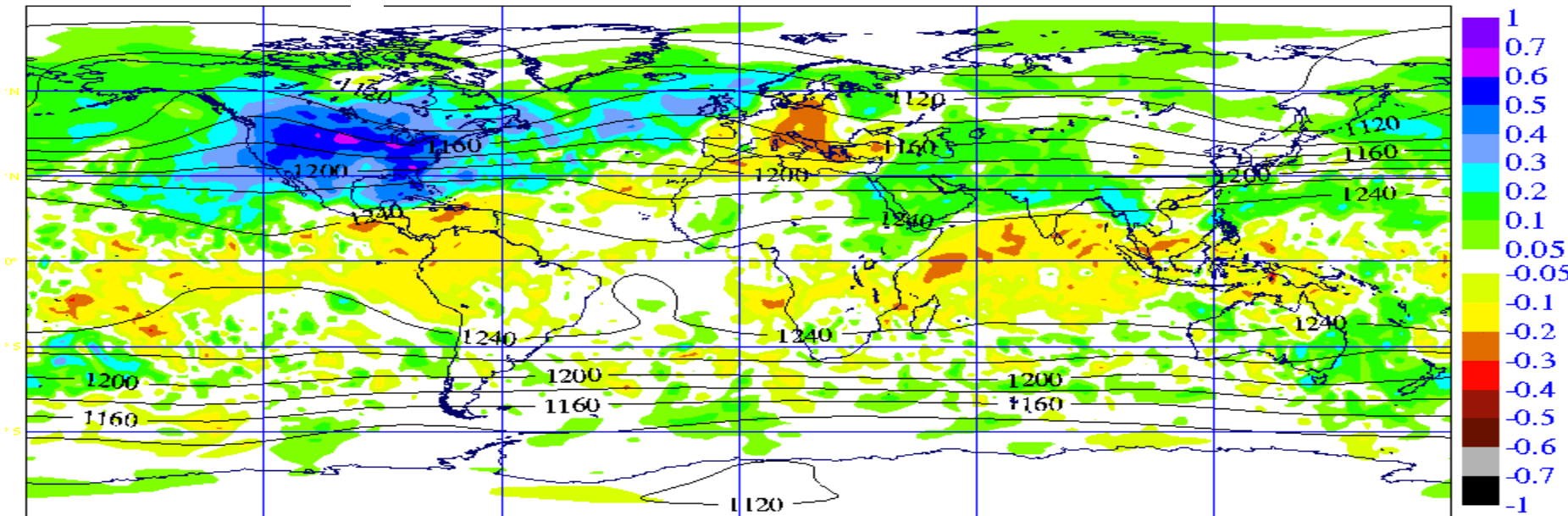


# noupper 48hr normalized error 200hPa Z

120°W

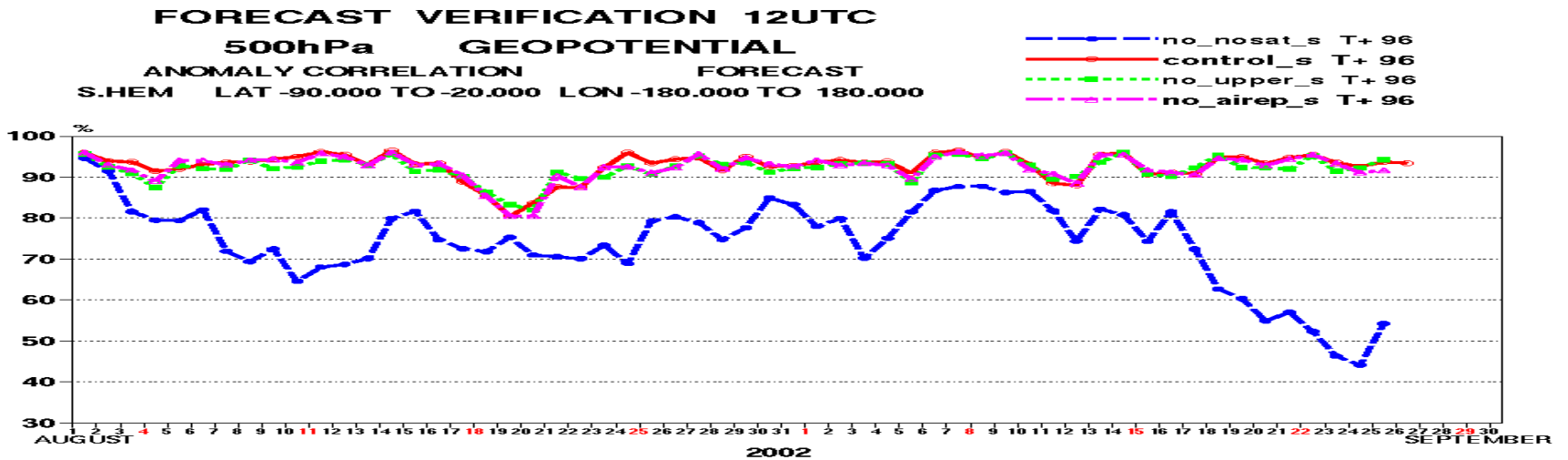
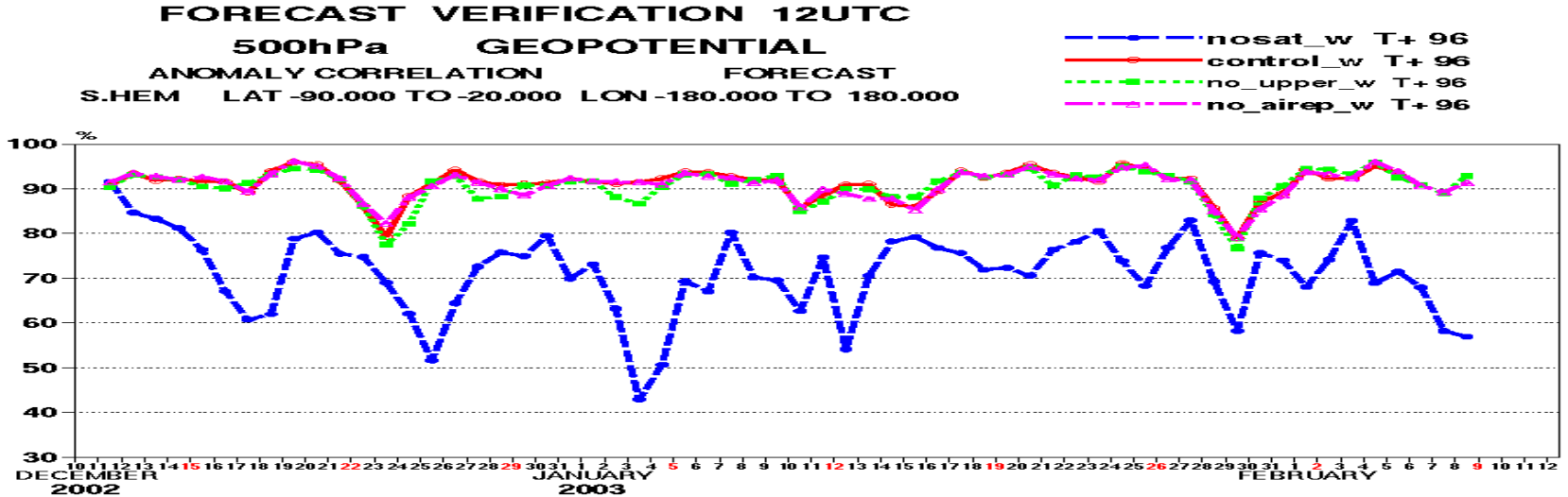


# noairep 12hr normalized error 200hPa Z



# noairep 48hr normalized error 200hPa Z

# TIME SERIES OF 4 DAY FORECST



# TIME SERIES OF 4 DAY FORECST

## FORECAST VERIFICATION 12UTC

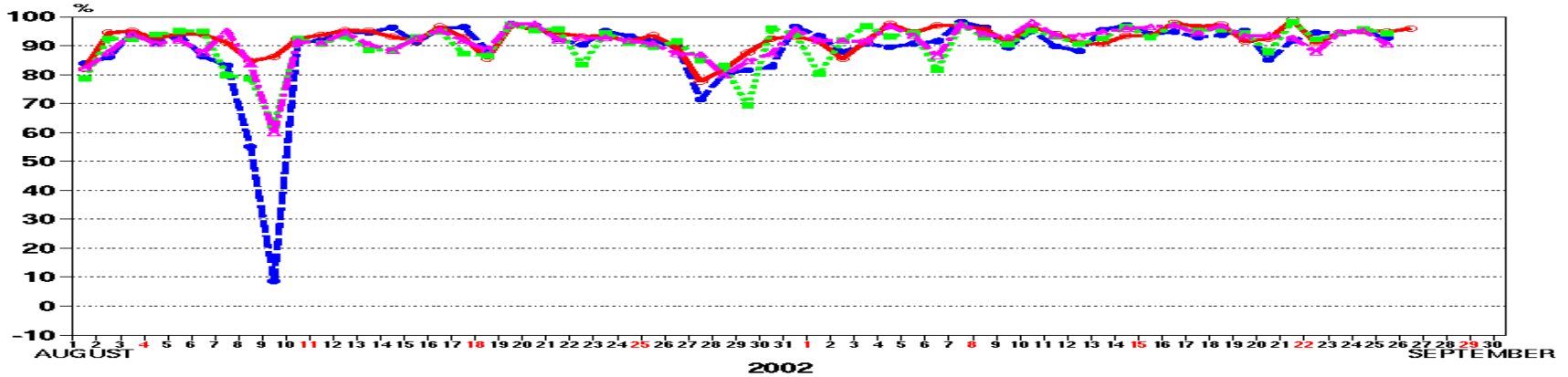
500hPa GEOPOTENTIAL

ANOMALY CORRELATION

FORECAST

EUROPE LAT 35.000 TO 75.000 LON -12.500 TO 42.500

- no\_nosat\_s T+ 96
- control\_s T+ 96
- no\_upper\_s T+ 96
- no\_airep\_s T+ 96



## FORECAST VERIFICATION 12UTC

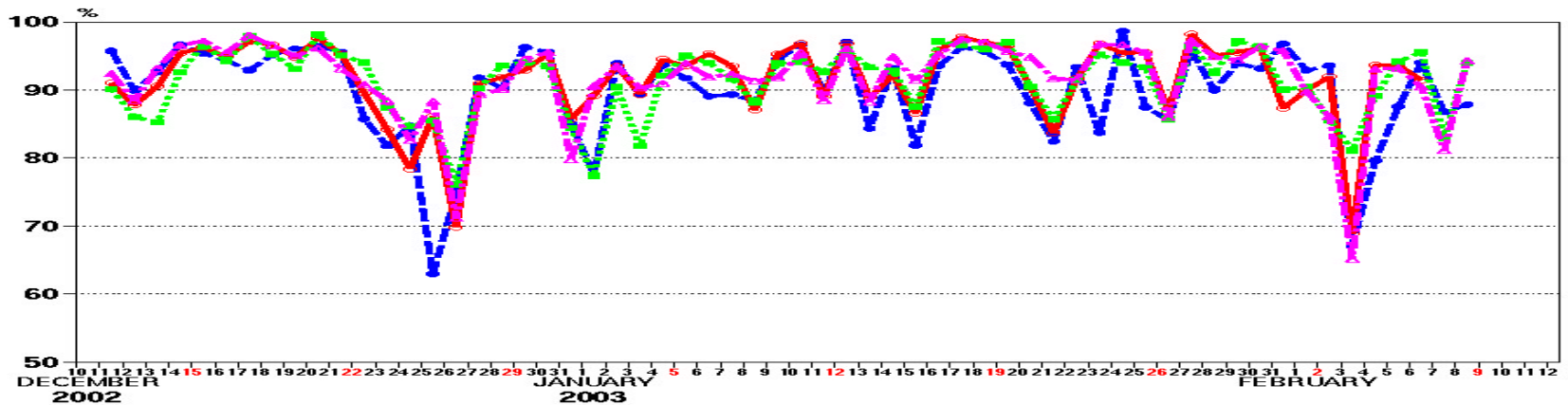
500hPa GEOPOTENTIAL

ANOMALY CORRELATION

FORECAST

EUROPE LAT 35.000 TO 75.000 LON -12.500 TO 42.500

- nosat\_w T+ 96
- control\_w T+ 96
- no\_upper\_w T+ 96
- no\_airep\_w T+ 96



# TIME SERIES OF 4 DAY FORECST

## FORECAST VERIFICATION 12UTC

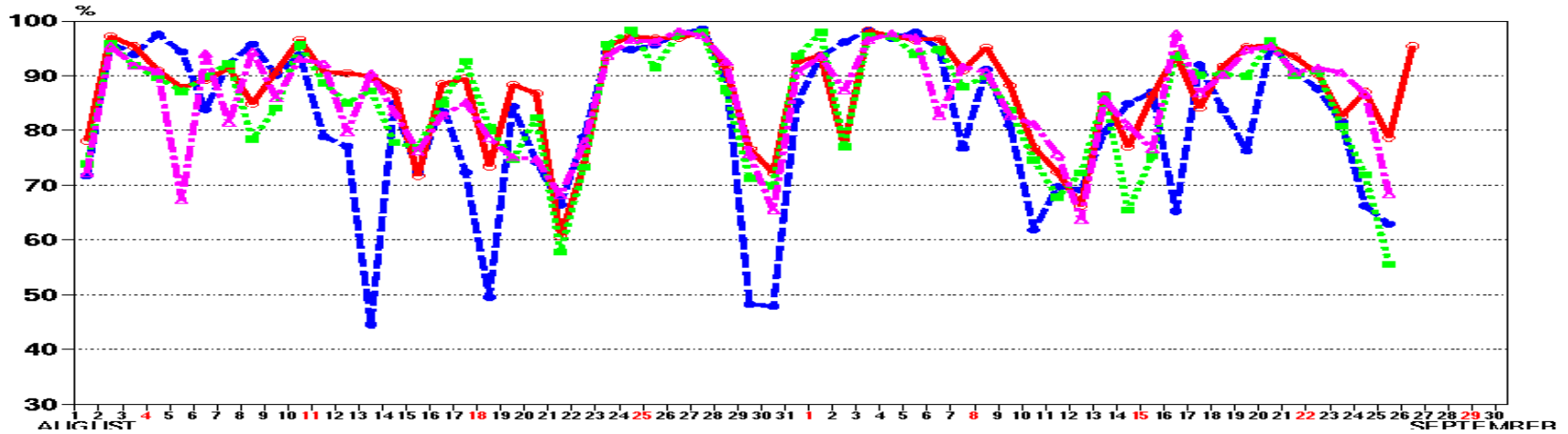
500hPa GEOPOTENTIAL

ANOMALY CORRELATION

FORECAST

N.AMER LAT 25.000 TO 60.000 LON -120.000 TO -75.000

- no\_nosat\_s T+ 96
- control\_s T+ 96
- no\_upper\_s T+ 96
- no\_airep\_s T+ 96



## FORECAST VERIFICATION 12UTC

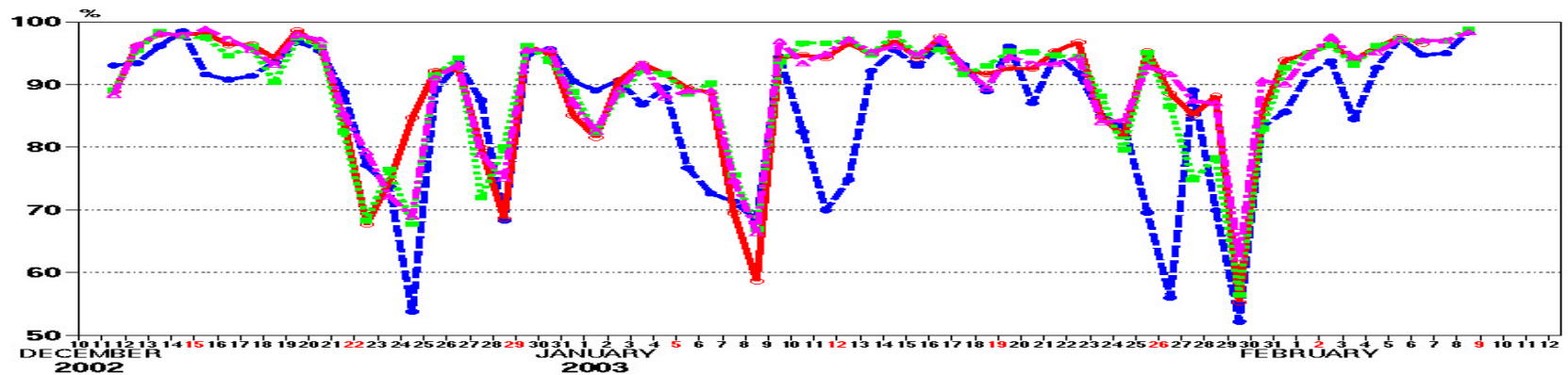
500hPa GEOPOTENTIAL

ANOMALY CORRELATION

FORECAST

N.AMER LAT 25.000 TO 60.000 LON -120.000 TO -75.000

- nosat\_w T+ 96
- control\_w T+ 96
- no\_upper\_w T+ 96
- no\_airep\_w T+ 96



# Discussion

**Some important findings from the 2003 OSE's are:**

The satellite data has more impact in the Northern Hemisphere than in previous OSE's even more than radiosondes and profiles combined.

In the four months of assimilation there are very few busts as defined by the anomaly correlation dropping less than 0.6 at day 4.

The Southern Hemispheric forecasts are as good as the Northern Hemispheric forecasts.

The short range RMS wind and temperature forecasts are of excellent quality and show the importance of satellite data.

## Discussion (continued)

In the late 80's TOVS satellite retrievals were removed from the operational OI system in the Northern Hemisphere due to negative impact.

In the early 90's the use of 1D-VAR TOVS retrievals were re-introduced to the Northern Hemisphere but the impact was very small.

In the mid 90's operations changed to 3-DVAR and direct use of radiances and the TOVS radiances improved the Northern Hemispheric forecasts and their impact was similar the that of radiosondes.

Today the impact of TOVS radiances together with other satellite data is much larger than impact of radiosondes in the Northern Hemisphere.

# Conclusions

The is now a must stronger dependence on satellite data in the ECMWF system and the influence of other data types are becoming less important.

In the future even more use will be made of satellite data with a large research effort being directed towards use of cloud and rain affected radiances.

A research effort is also directed to improving the use of 'clear air' satellite data over land.

New OSE's are required on an on-going basis to understand the relative importance of various components of the current observing system