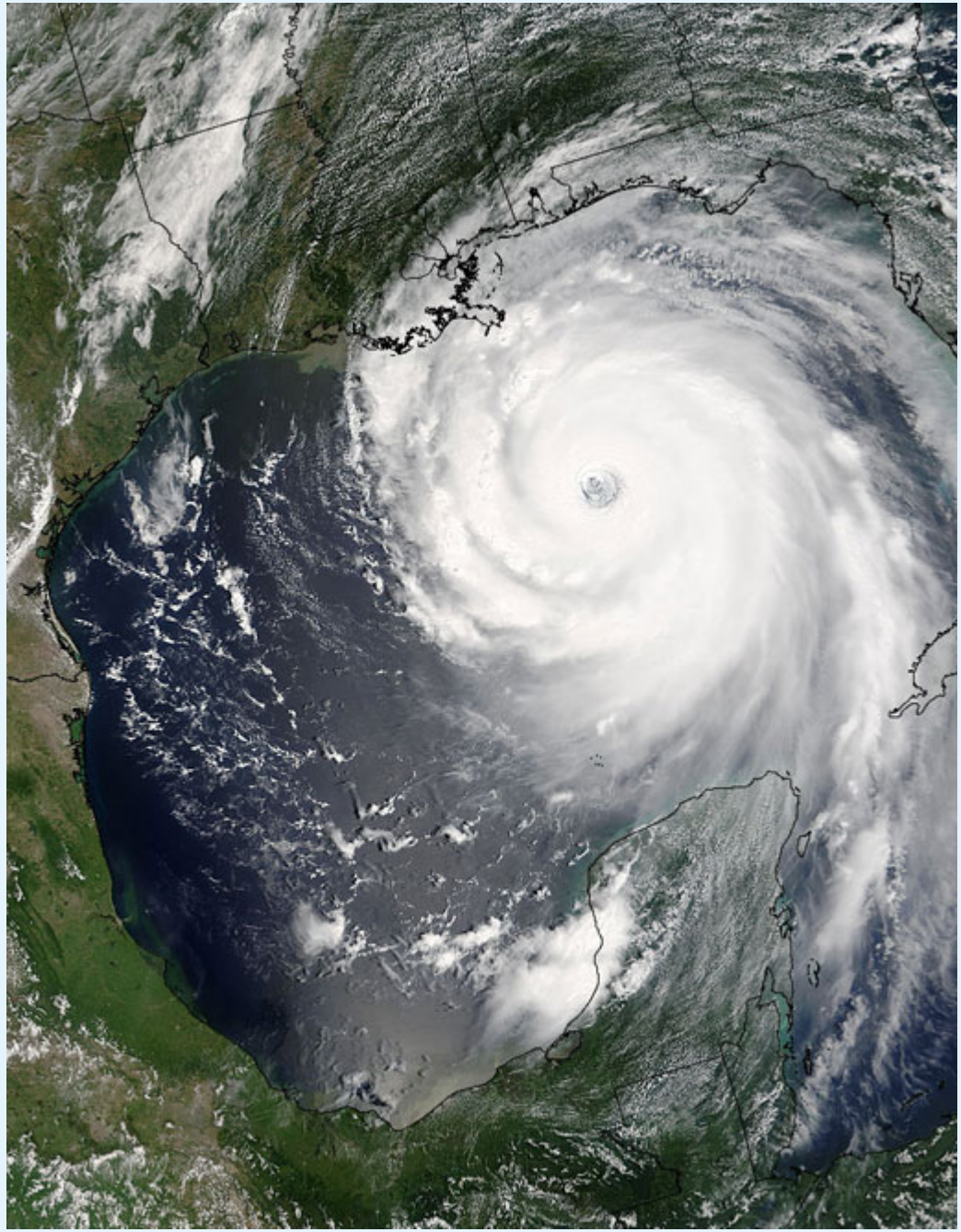
The Exploitation of Satellite Data at the U.K. Met Office



Roger Saunders

with the help of Steve English

Bill Bell, Mary Forsythe,

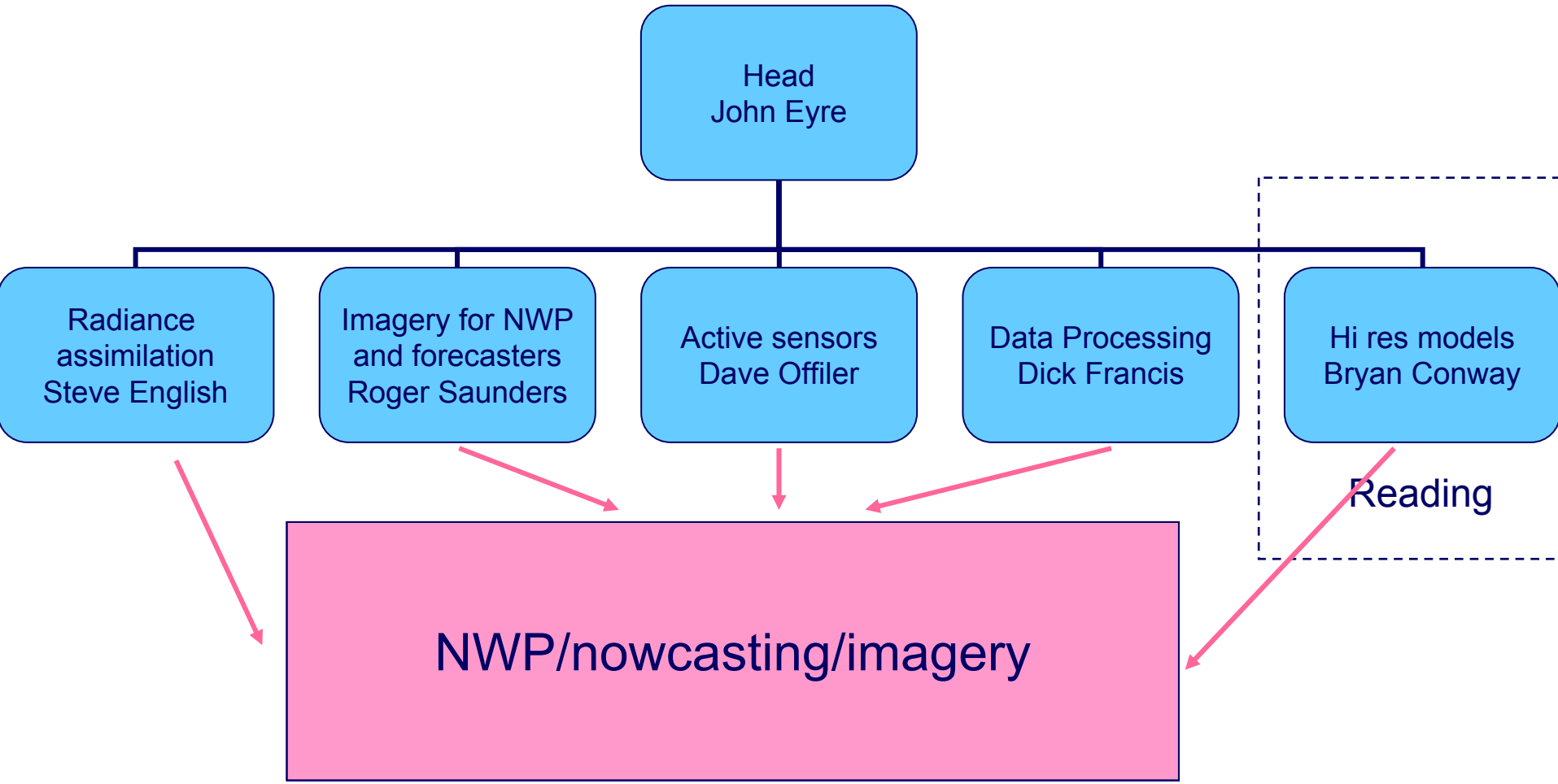
Brett Candy, James Cameron

and many others

Talk topics

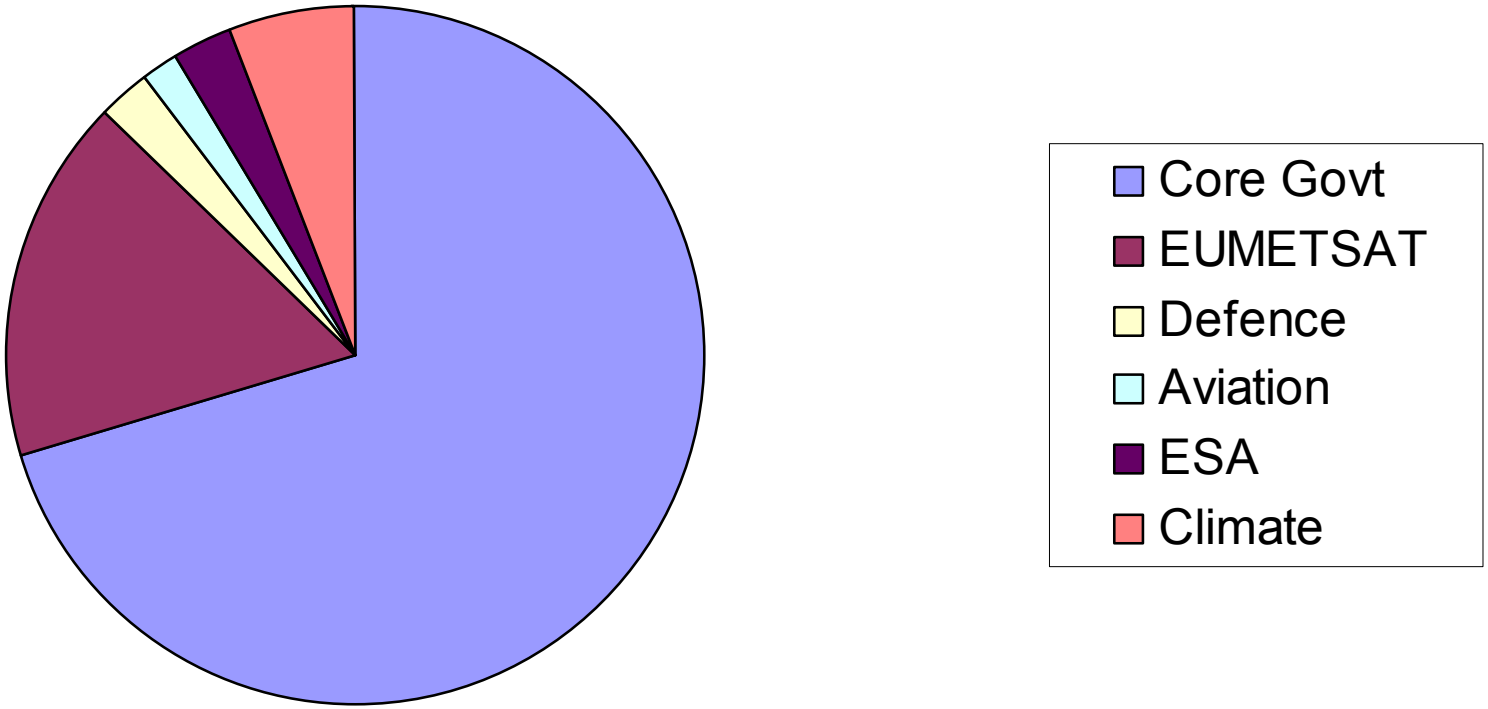
- The Met Office satellite group and NWP SAF
- Current status of models and observation use
- Recent upgrades to use of satellite data
- Satellite data impacts
- Research into use of new data types
- Meteosat Second Generation
- METOP

Satellite Group



Satellite Group Funding

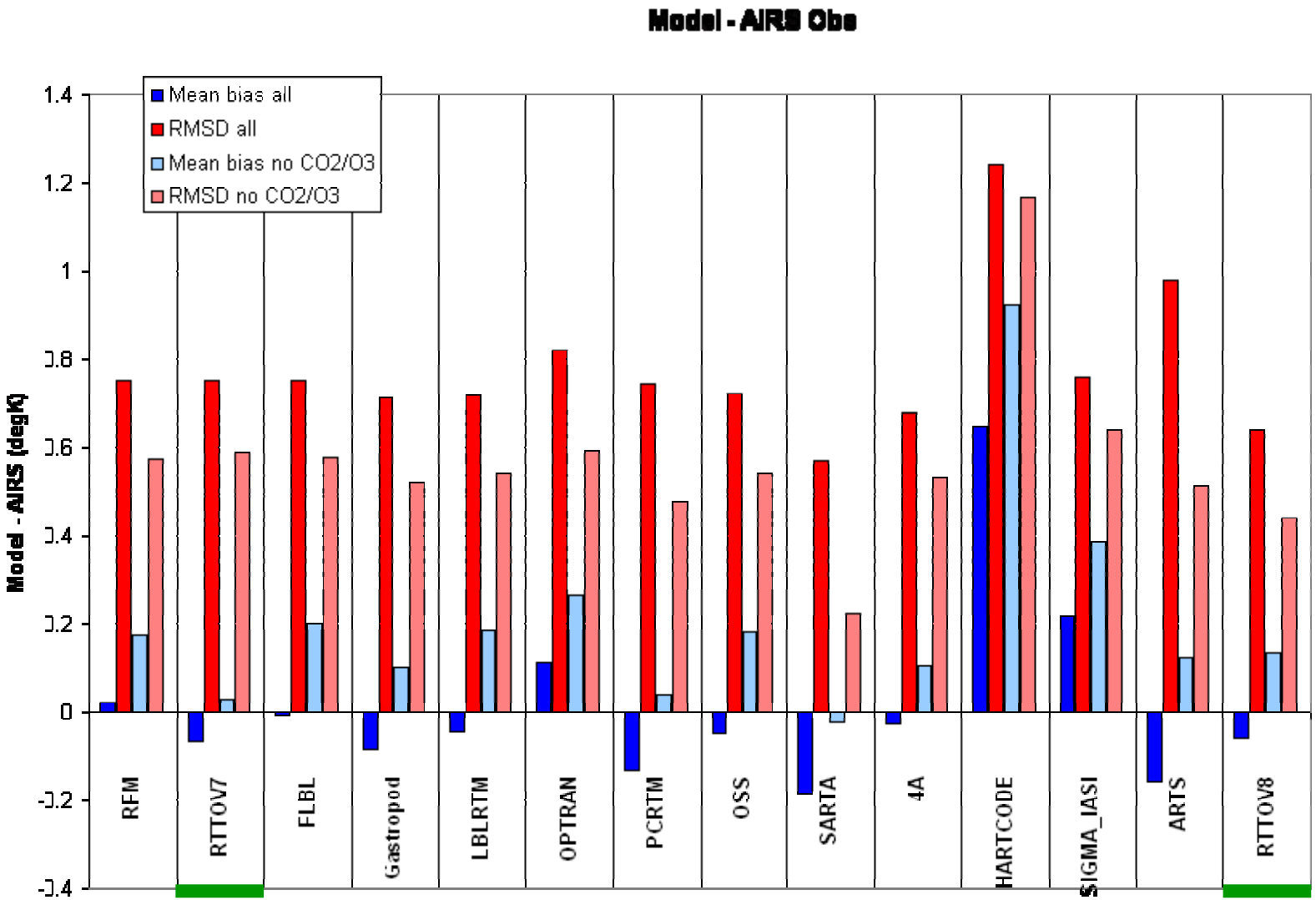
SA Funding 2006/07 31 Staff in total



NWP Satellite Application Facility

- The Met Office leads the NWP SAF
- In final year of initial operational phase
- Preparing proposal for follow-on operational phase (5 years) to start in March 2007.
- Major deliverables are:
  - AAPP (ATOVS/AVHRR direct readout software)
  - RTTOV (Fast radiative transfer model)
  - 1DVAR (Met Office and ECMWF versions)
  - Satellite data monitoring (Radiance, AMVs, O_3)
  - Scatterometer processor
  - Reports on many aspects of satellite data
- Also involved in GRAS (GPS RO) SAF

Summary of model –AIRS observations



Talk topics

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- Current status of models and observation use
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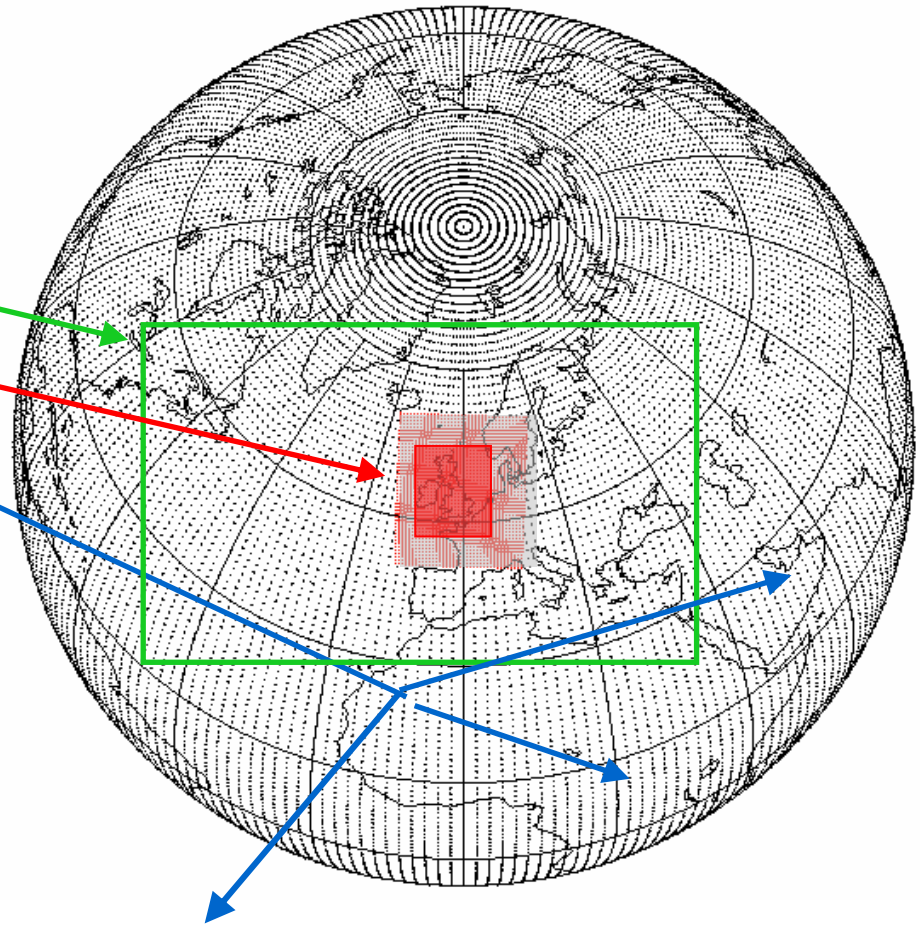
- METOP

Met Office Operational Models : 2006

- Global ~40km ~50Level
- North Atlantic/Europe 12km ~30level
- UK 4km ~30Level
- Re-locatable Defence and Civilian
- *Trial Ensemble (global & regional) at half horizontal resolution*



- *Data assimilation 4DVar 6 hour window for global and regional models*

Operational data usage (Apr 2006)

Observation group	Observation Sub-group	Items used	Daily extracted	% used in assimilation
Ground-based vertical profiles	TEMP PILOT PROFILER	T, V, RH processed to model layer average As TEMP, but V only As TEMP, but V only	1250 850 6500	87,92,50 92 40
Satellite-based vertical profiles	AMSU-A/B NOAA-15/16/18 Aqua AIRS	Radiances directly assimilated with channel selection dependent on surface instrument and cloudiness	430000	3
Aircraft	*Manual* AIREPS *Automated* AMDARS	T, V as reported with duplicate checking and blacklist	24000 185000	14 28
Satellite atmospheric motion vectors	GOES 10,12 BUFR Meteosat 5, 8 BUFR MTSAT SATOB Aqua/Terra MODIS	High resolution IR winds IR, VIS and WV winds IR and VIS winds IR and WV	110000 190000 4000	10 5 55
Satellite-based surface winds	SSMI-13,15 Seawinds, ERS-2	In-house 1DVAR wind-speed retrieval NESDIS retrieval of ambiguous winds. Ambiguity removal in 4DVAR.	3000000 1800000	1 1.5
Ground-based surface	Land SYNOP SHIP, Fixed Buoy Drifting BUOY	Pressure only (processed to model surface) Pressure and wind Pressure	28000 6700 10000	75 94, 92 76

Talk topics

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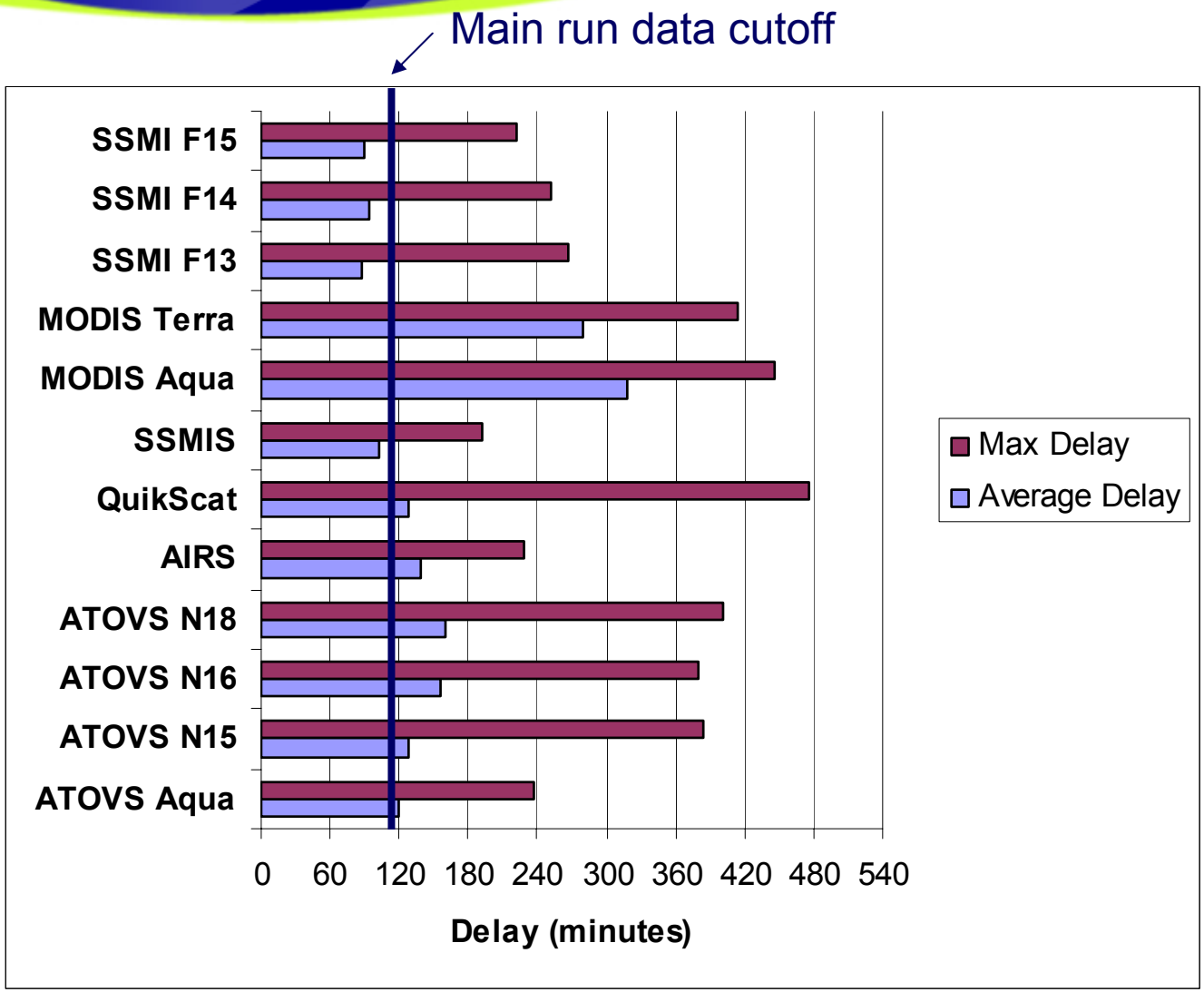
Recent changes to use of satellite data

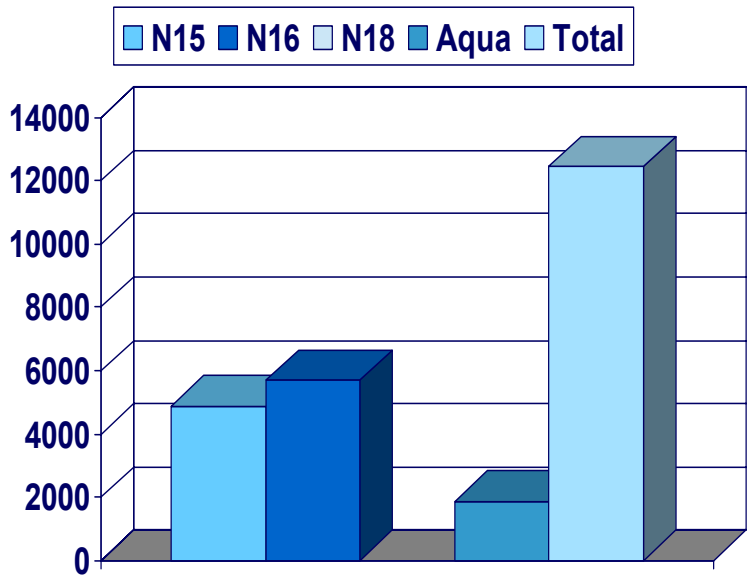
- Aqua AMSU-A replaced by NOAA-18 AMSU
  - Better coverage with NOAA-18
  - Issue of Aqua AMSU-A antenna correction
- AIRS central fov replaced by AIRS warmest fov
- Reintroduction of ERS-2 scatterometer winds
- Meteosat-7 AMVs replaced by Meteosat-8 AMVs

Satellite data delays

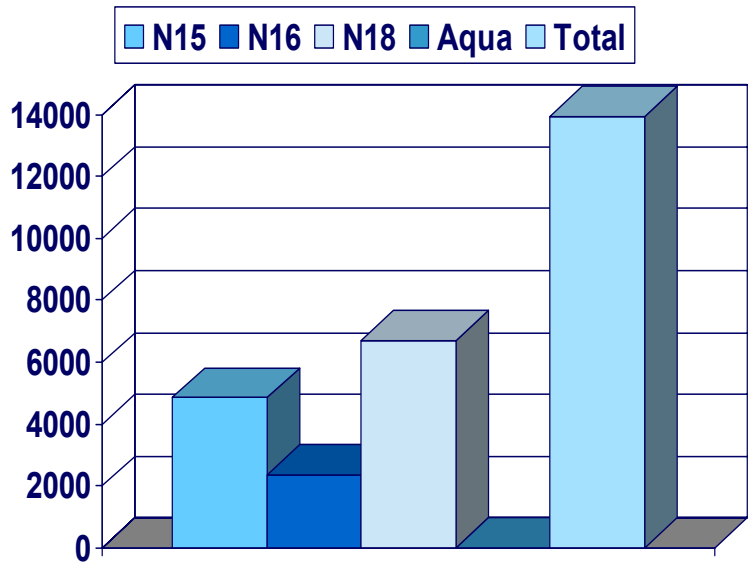


Average AMSU Data Assimilated for a Main forecast Run

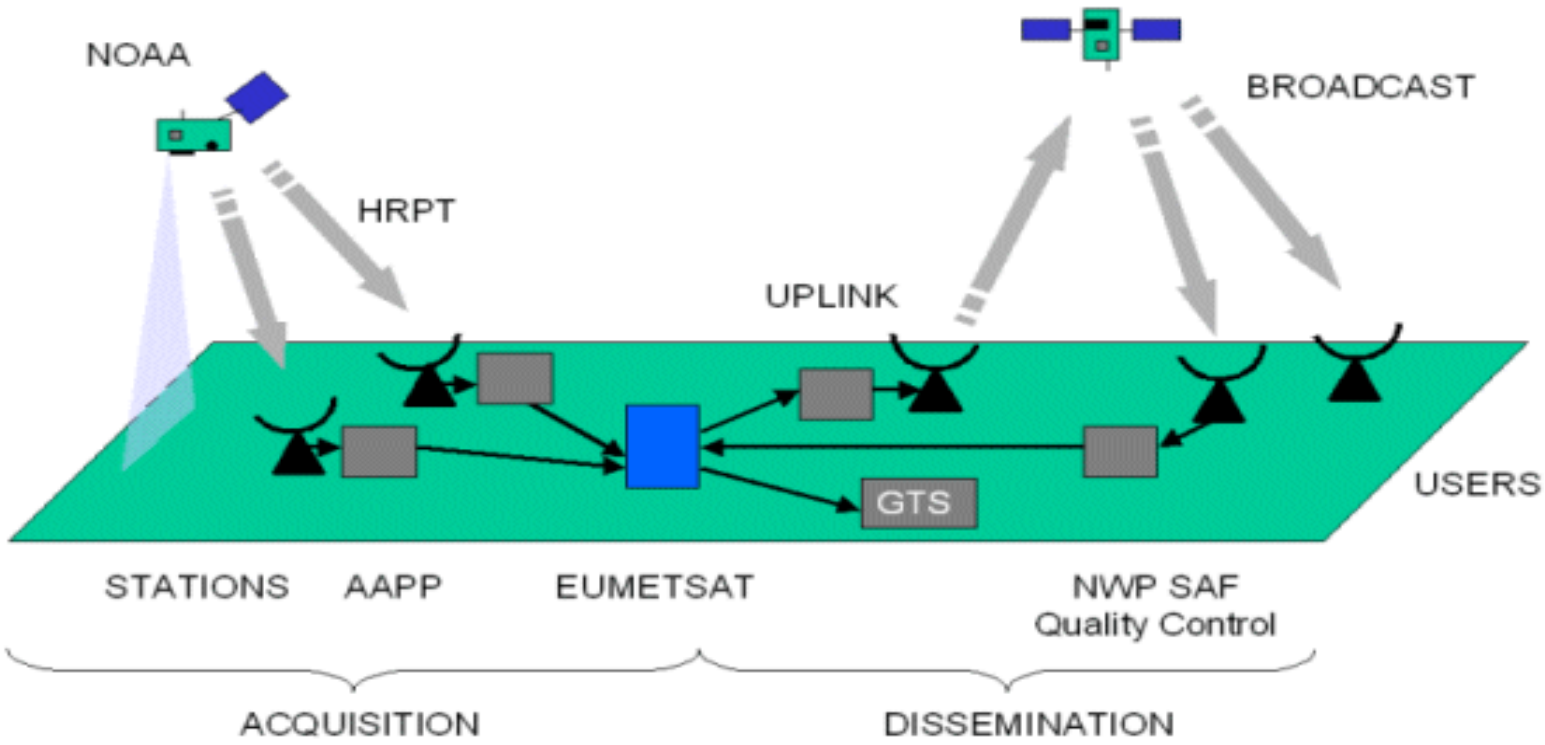
Control



Experiment

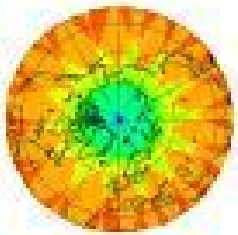
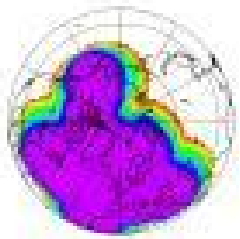
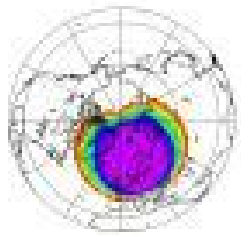


EARS-Mitigating Data Delay



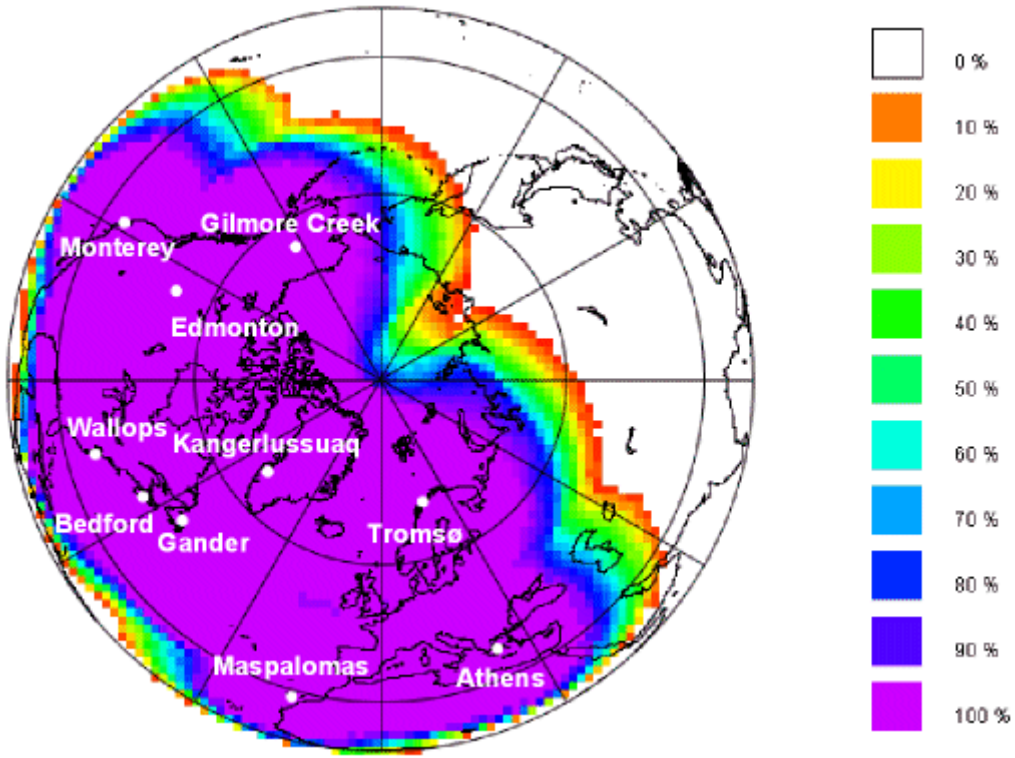
EARS System Overview

EARS (2)

Global Data Dump	EUMETSAT ATOVS Retransmission Service	HRPT Reception
		
Global	Regional	Local
3-6 hours	30 minutes	Immediate

EARS timeliness

EARS (3)



EARS coverage

There are plans to:

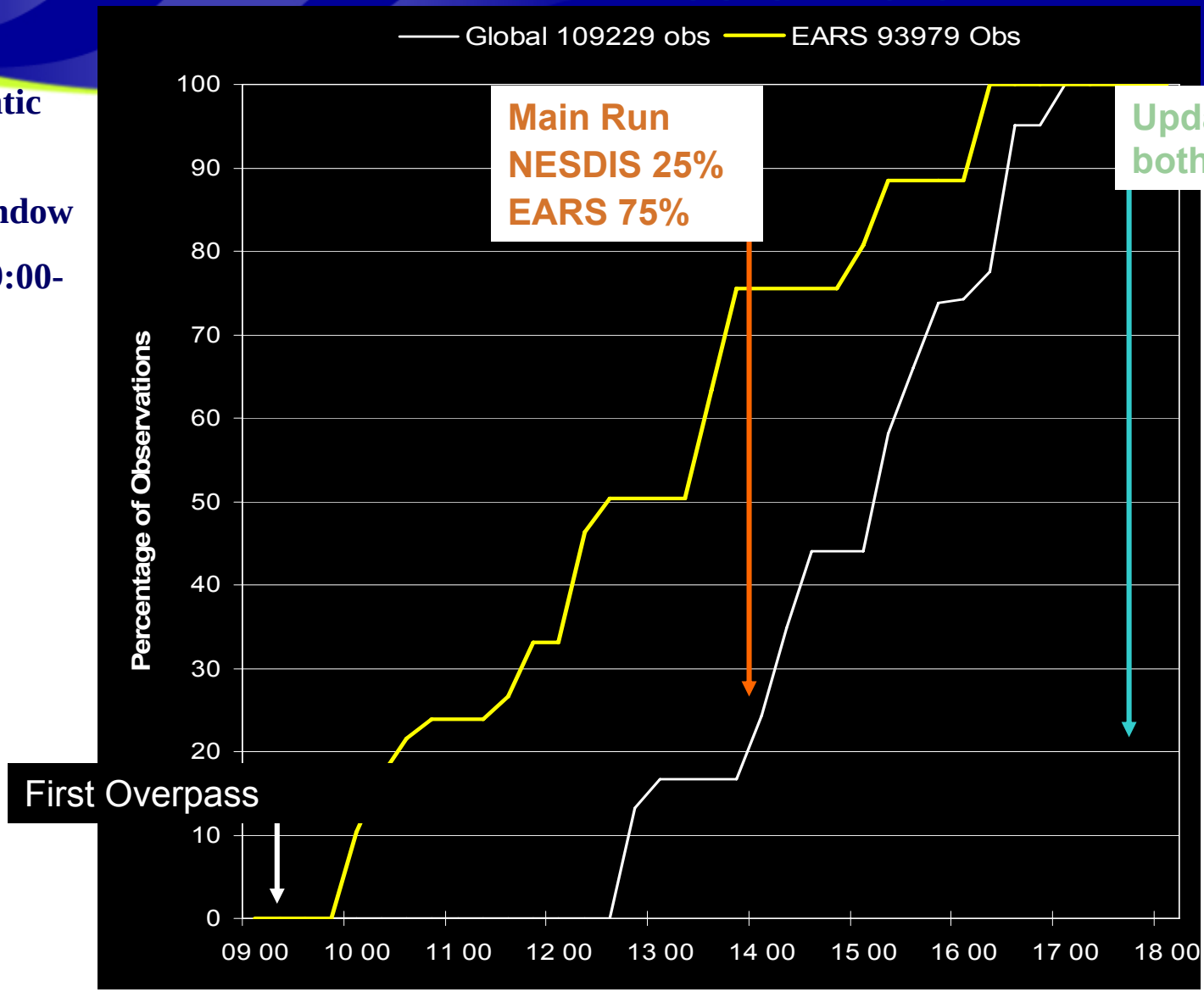
- *extend coverage of EARS to the whole extra-tropical NH*
- *develop other regional systems*

(e.g. S. America, Australia / NZ)

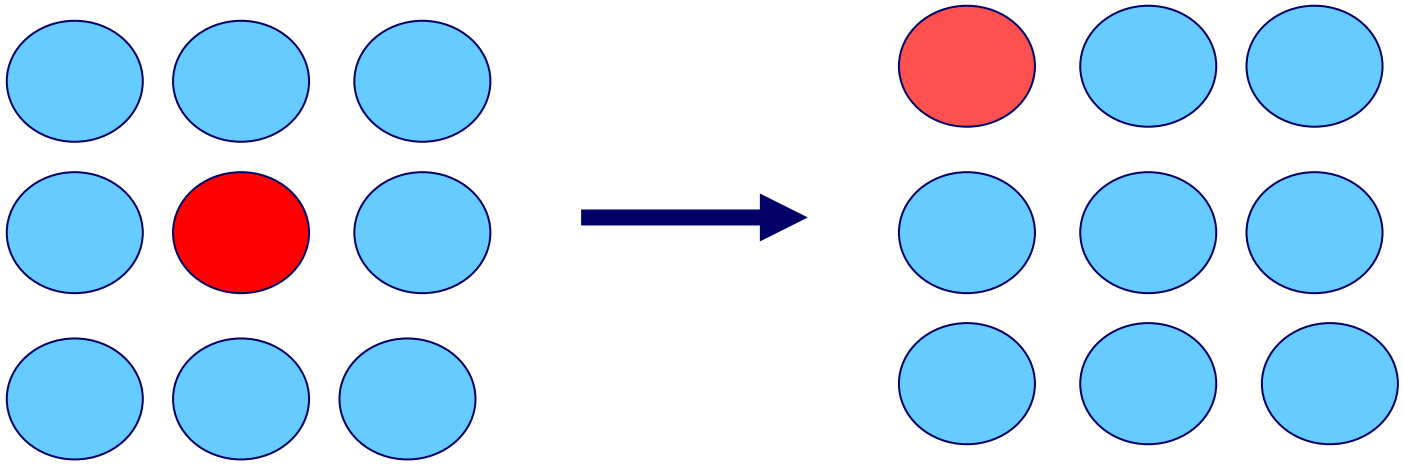
Arrival Times of Data

- **North Atlantic Region**
- **six-hour window**

09/09/2003 09:00-15:00



Moved to use AIRS warmest FOV



Centre FOV

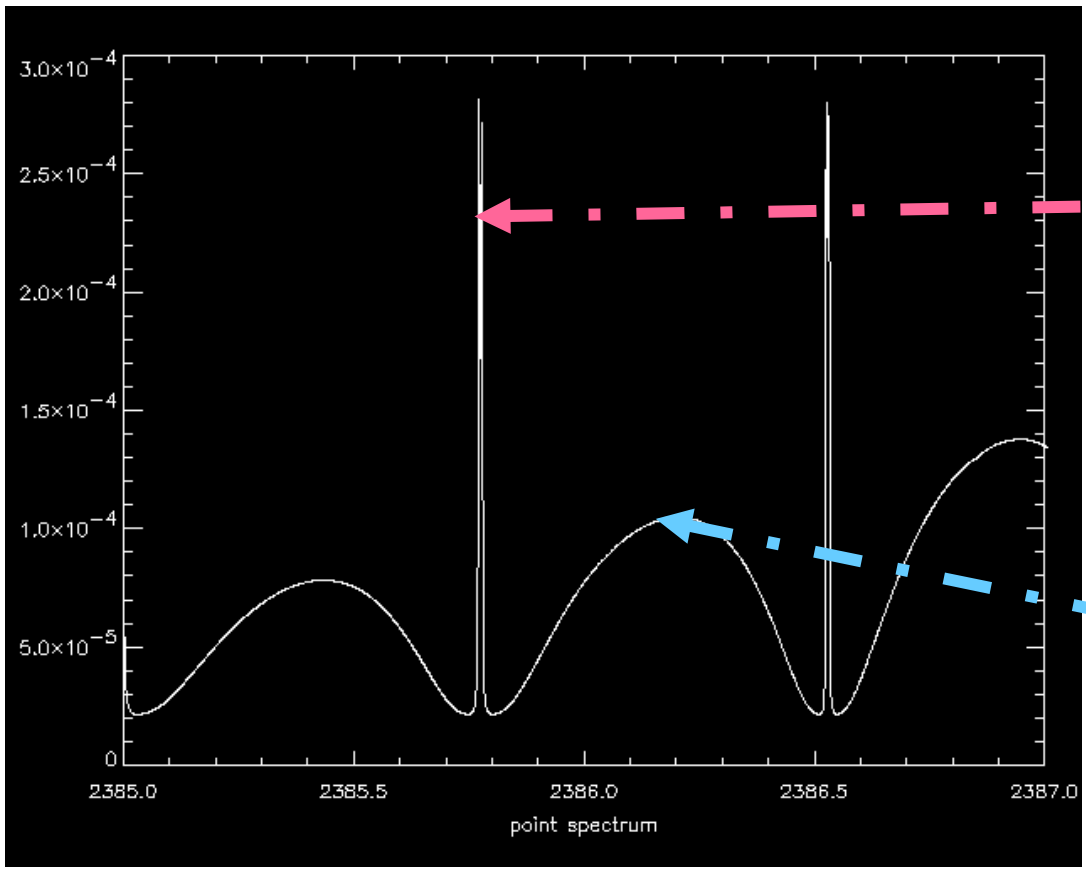
Warmest FOV
any of 9

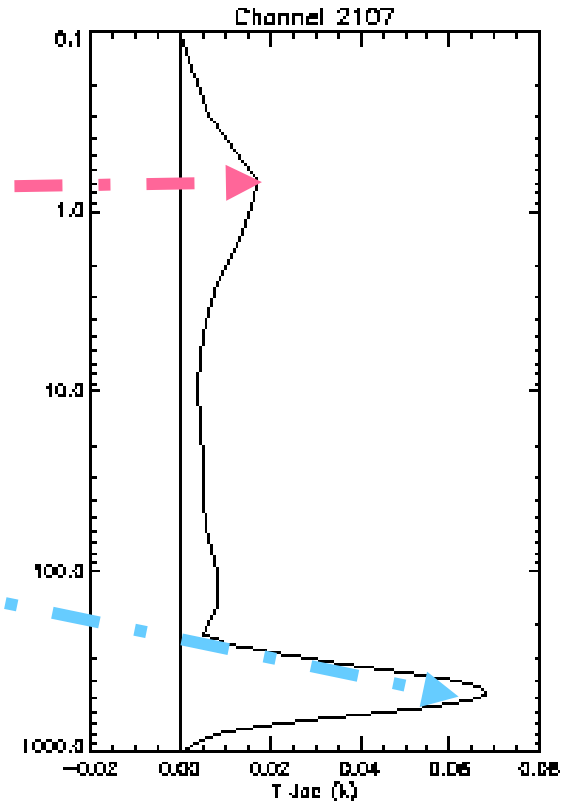
This results in an increased coverage of AIRS clear sky radiances

Removed Double Peaked AIRS Channels

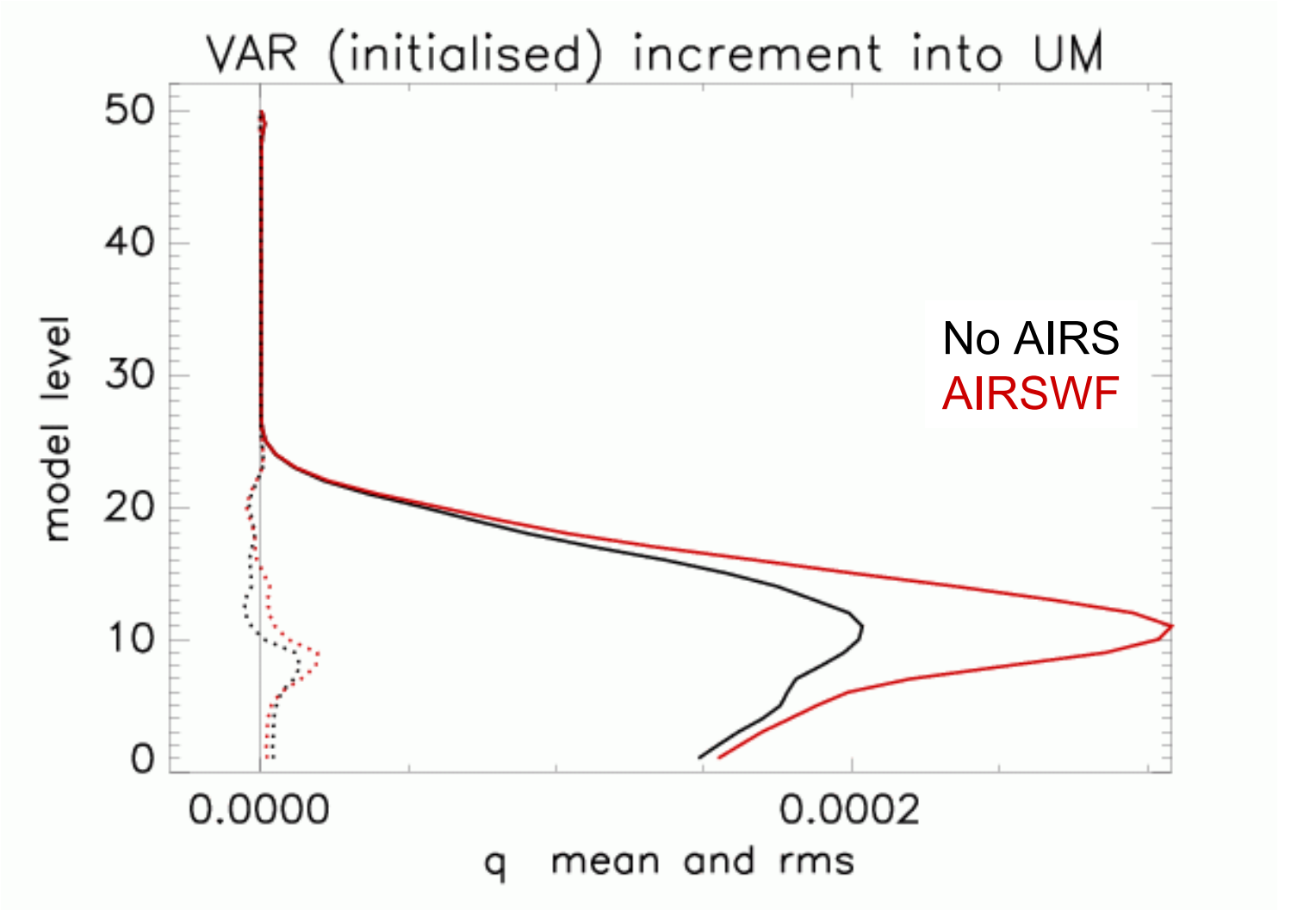
Channel 2107 at 2386cm^{-1} (4.19 microns), FWHM 1.880cm^{-1}

The sharp, strong absorption CO_2 lines cause a double peak in the Jacobian.

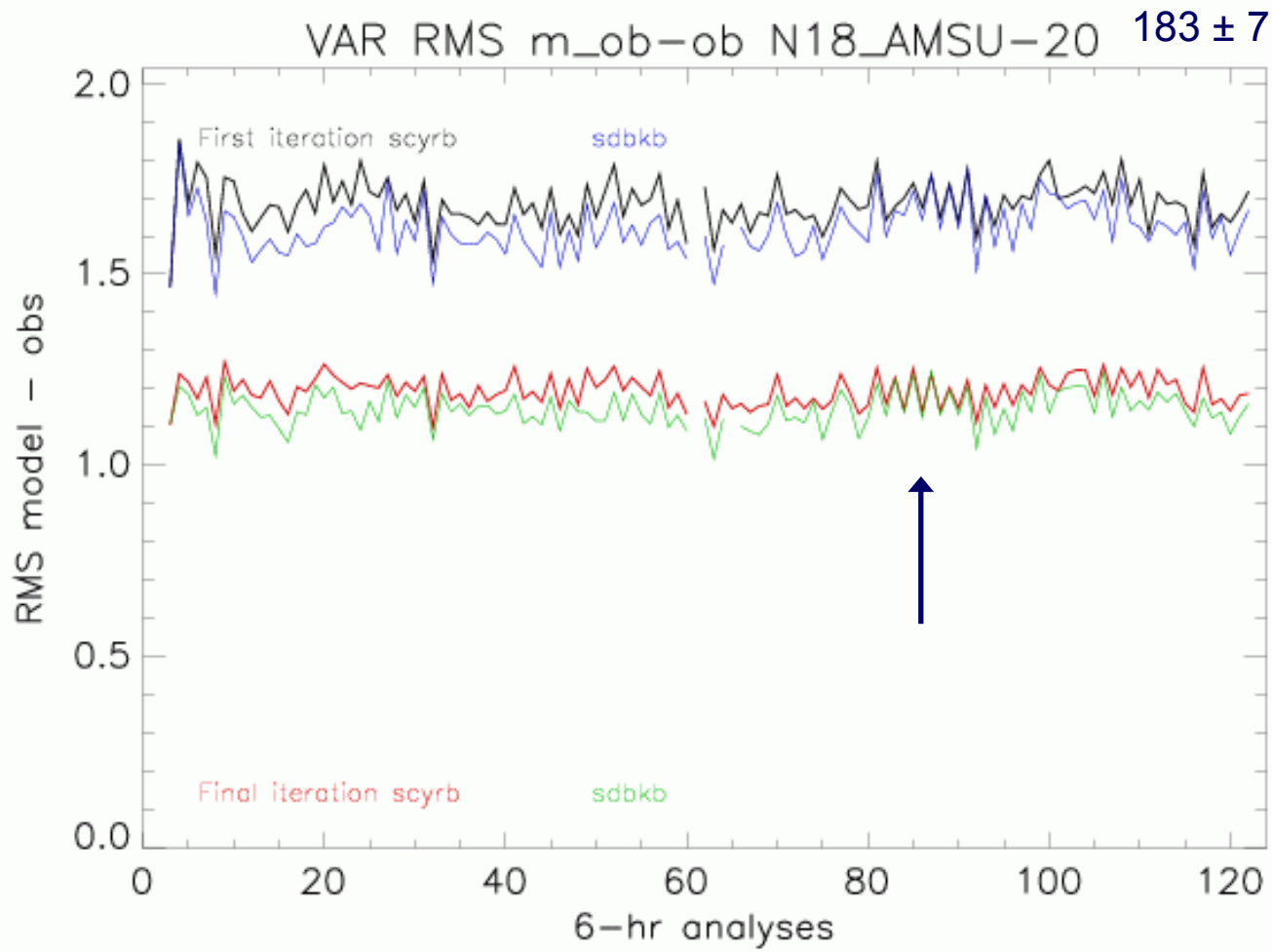




AIRS q increments



Impact on AMSU-B Channels



First Iteration
No AIRS
AIRSWF

Final Iteration
No AIRS
AIRSWF

Summary

- Assimilating AIRS leads to significant humidity changes.
- All AIRS trials show improved fits to SSMI TCWV (not assimilated) and all AMSU-B channels.
- An improvement to RH is not confirmed by sondes, where no particular effect is apparent.
- We have not seen a big improvement in forecasts going from AIRS to AIRSWF.

What is the NWP SAF AMV monitoring?

NWP SAF – Numerical Weather Prediction Satellite Application Facility

A EUMETSAT-funded initiative, led by the Met Office, with partners ECMWF, KNMI and Météo-France

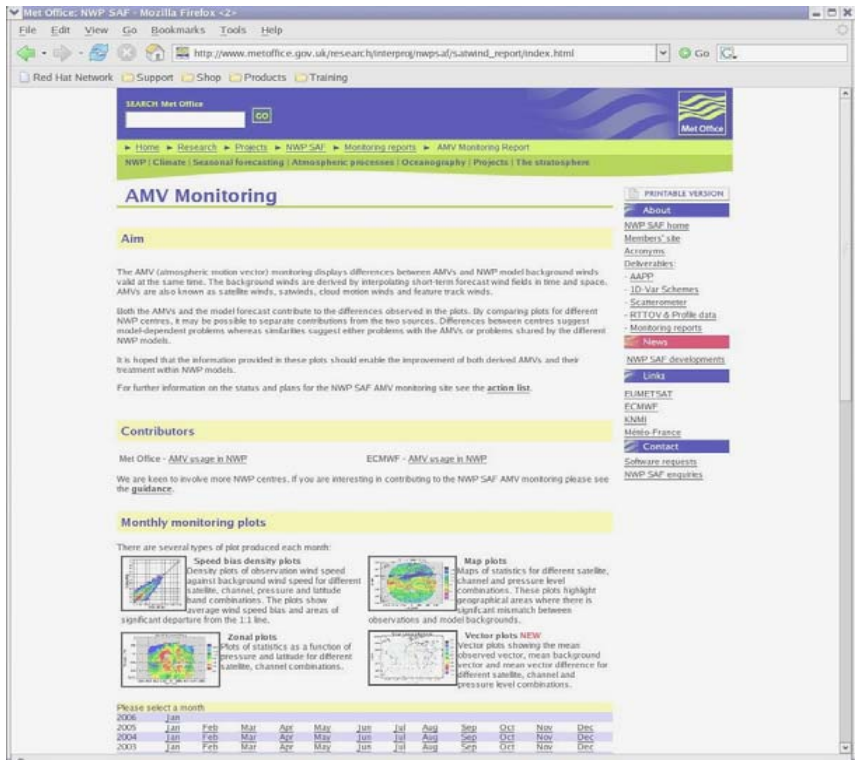
Aim to improve the benefits derived by European National Met. Services from NWP by developing techniques for more effective use of satellite data and to prepare for effective exploitation of new data/products.

AMV Monitoring

Displays comparable AMV monitoring output from different NWP centres in order to help identify and partition error contributions from AMVs and NWP models.

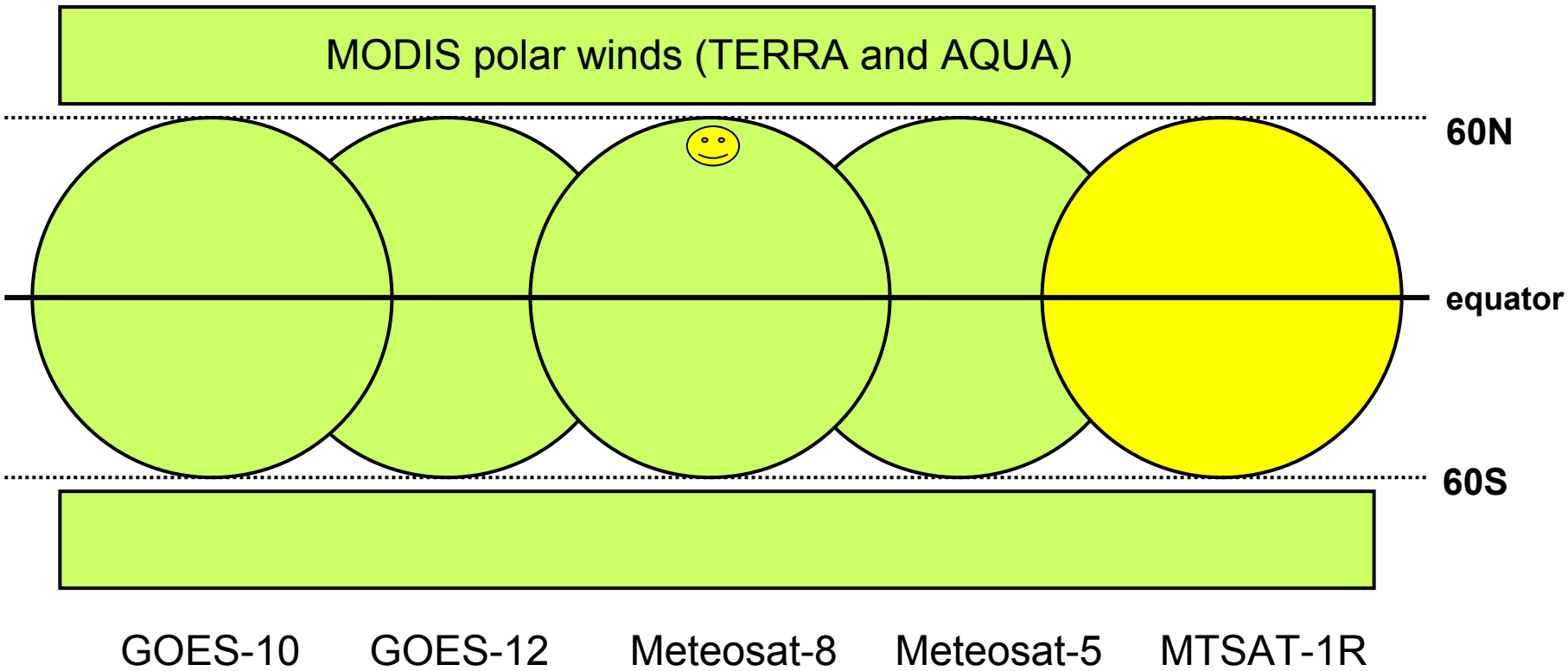
Analysis reports produced periodically (planned every 2 years to coincide with winds workshops).

Intended to stimulate discussion and to lead to improvements in AMV derivation and AMV use in NWP.



http://www.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report

Data used - Mar 2006



SATOB

BUFR

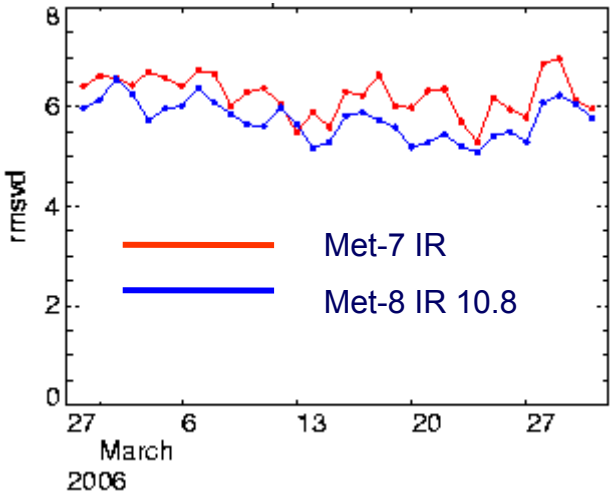
1. 8th Feb 05 - Introduce NESDIS MODIS polar winds
2. 14th Jun 05 – GOES SATOB IR -> GOES BUFR IR and cloudy WV
3. 1st Sep 05 – start using MTSAT-1R SATOB
4. 14th Mar 06 – Meteosat-7 -> Meteosat-8

Meteosat-7→ Meteosat-8

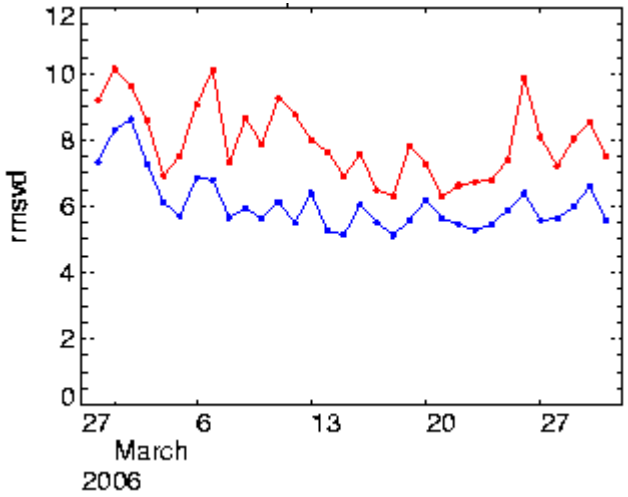
Replace Meteosat-7 IR, WV and VIS with Meteosat-8 IR10.8, WV7.3, HRVIS and VIS0.8 using same QC as applied to Meteosat-7

Root mean square vector difference

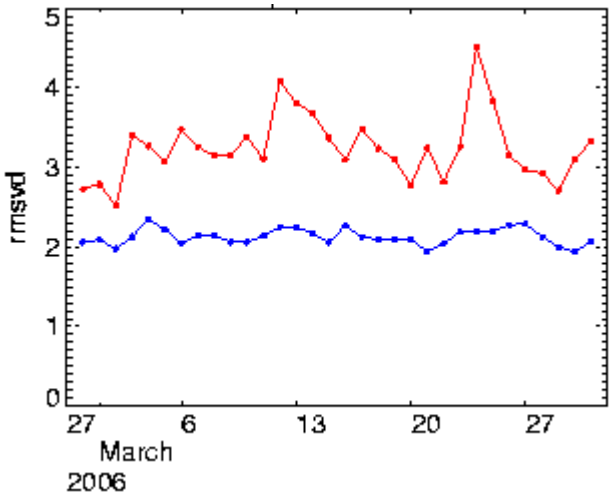
100-400 hPa



400-700 hPa



700-1000 hPa

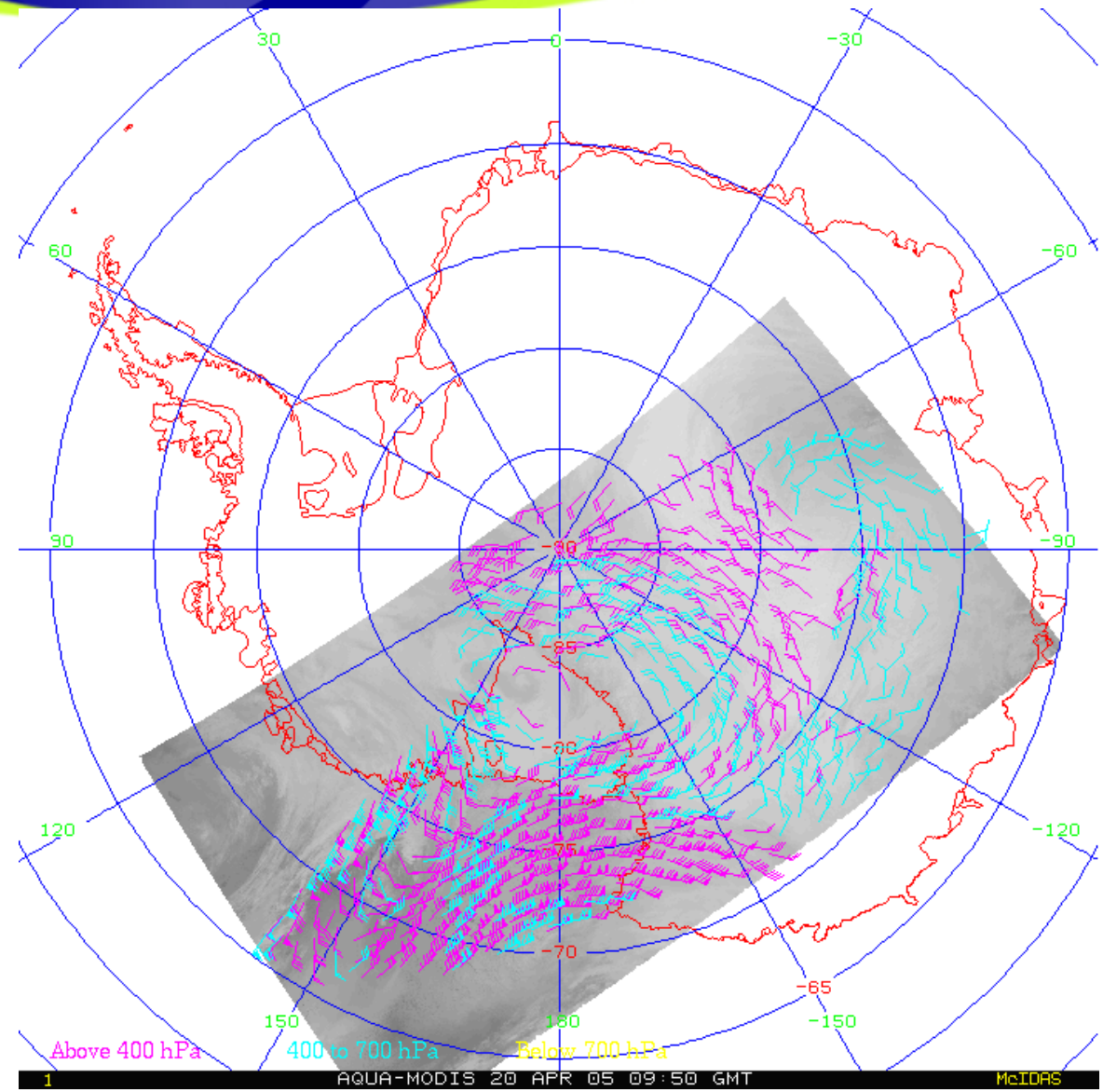


Impact neutral in Jul-Aug and moderately positive in Dec-Jan.

Main benefit from tropical wind fields (W250 and W850) and southern hemisphere PMSL (against both observations and analyses).

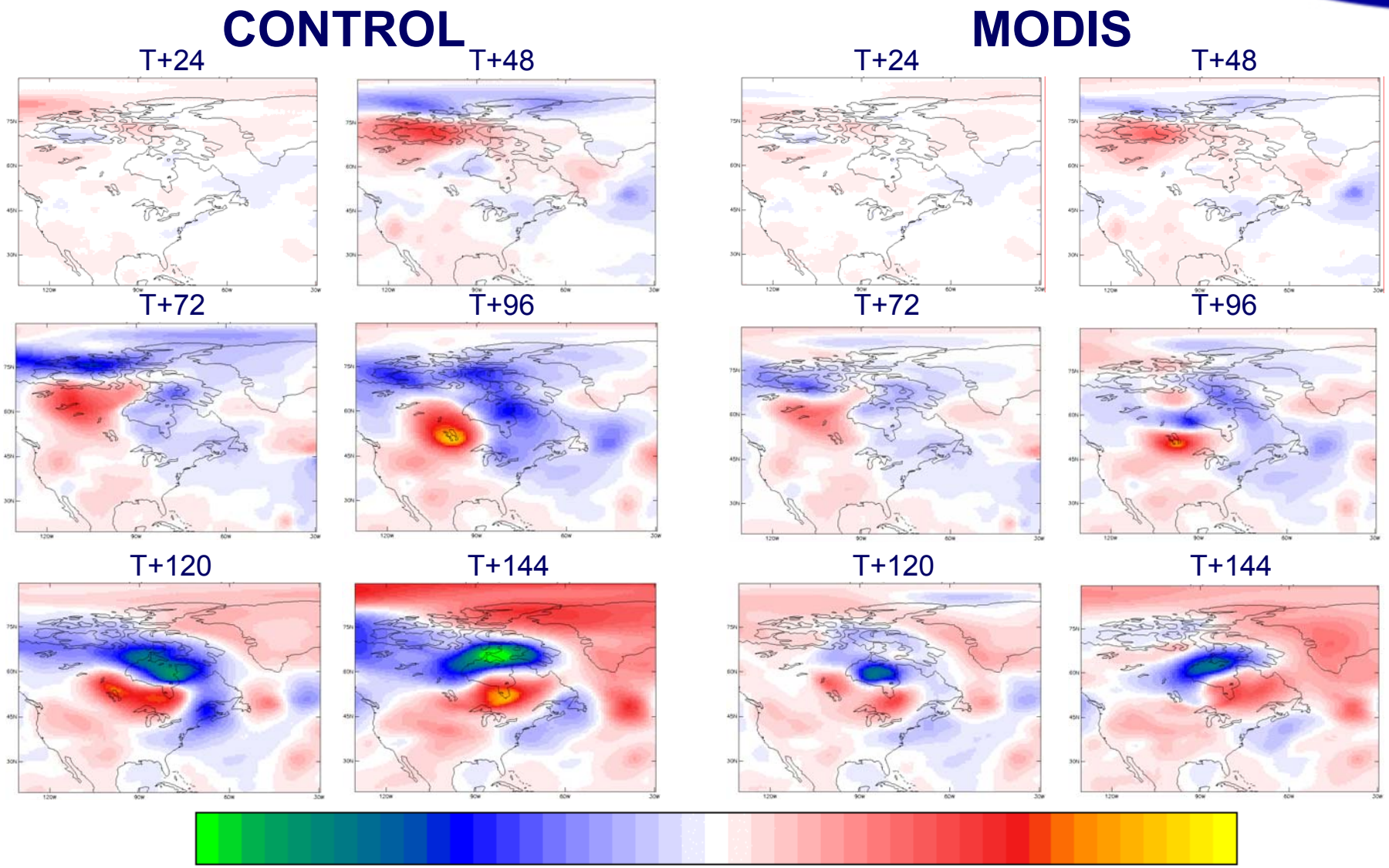
Few forecast parameters improved or degraded by more than 2%.

MODIS winds



Forecast error evolution Aug 14th, 2004

500 hPa geopotential height

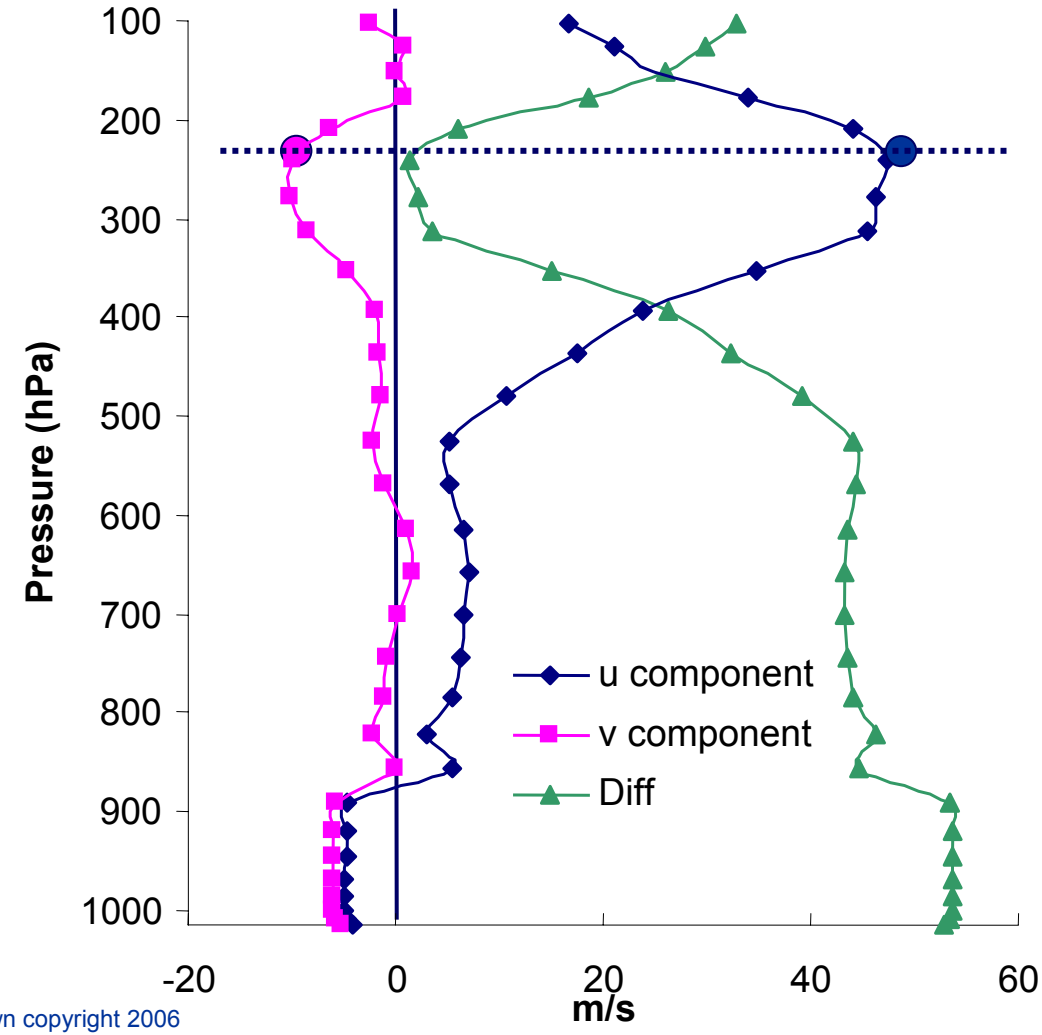


AMVs

- Why do we struggle to see impact from AMVs?
- Is it poor height assignment of some winds?
- We are starting to investigate this
- Discussed at IWW in Beijing

Comparison to model best-fit pressure

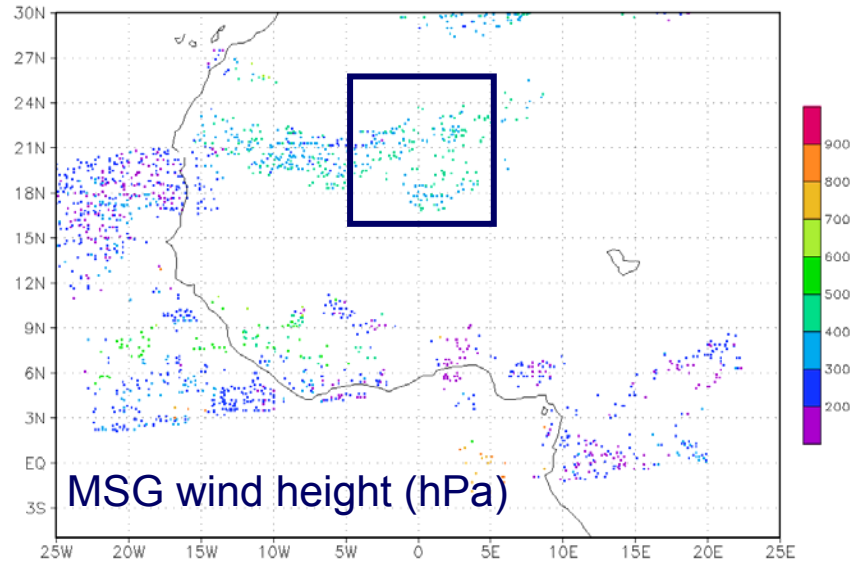
$$\text{Vector Difference}_i = \sqrt{((\text{ObU} - \text{BgU}_i)^2 + (\text{ObV} - \text{BgV}_i)^2)}$$

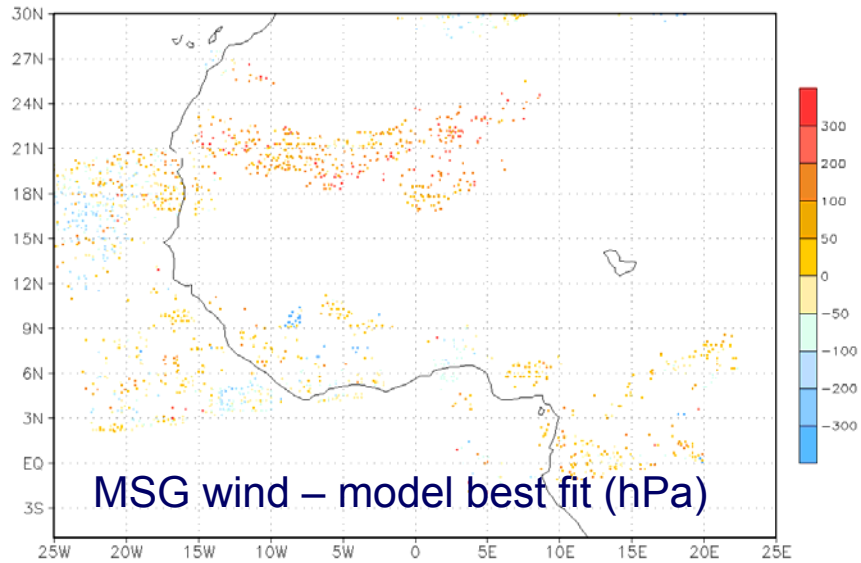


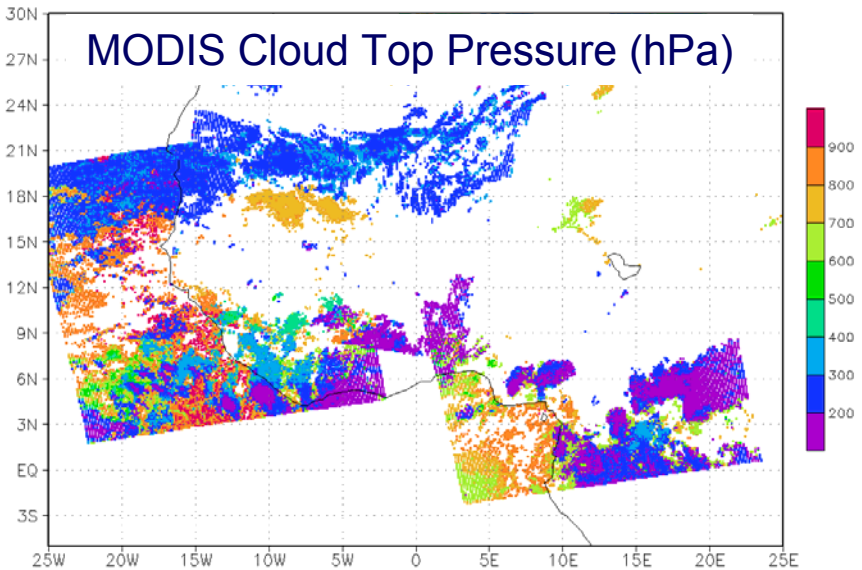
Model best-fit at minimum in vector difference profile.

AMV pressure and model best-fit pressure agree well in this case.

Case studies – Sahara 8th Dec







From 7th December 21:00 UTC to 8th December 2005 3:00UTC (night time)

Can also compare to other cloud top pressure products

Talk topics

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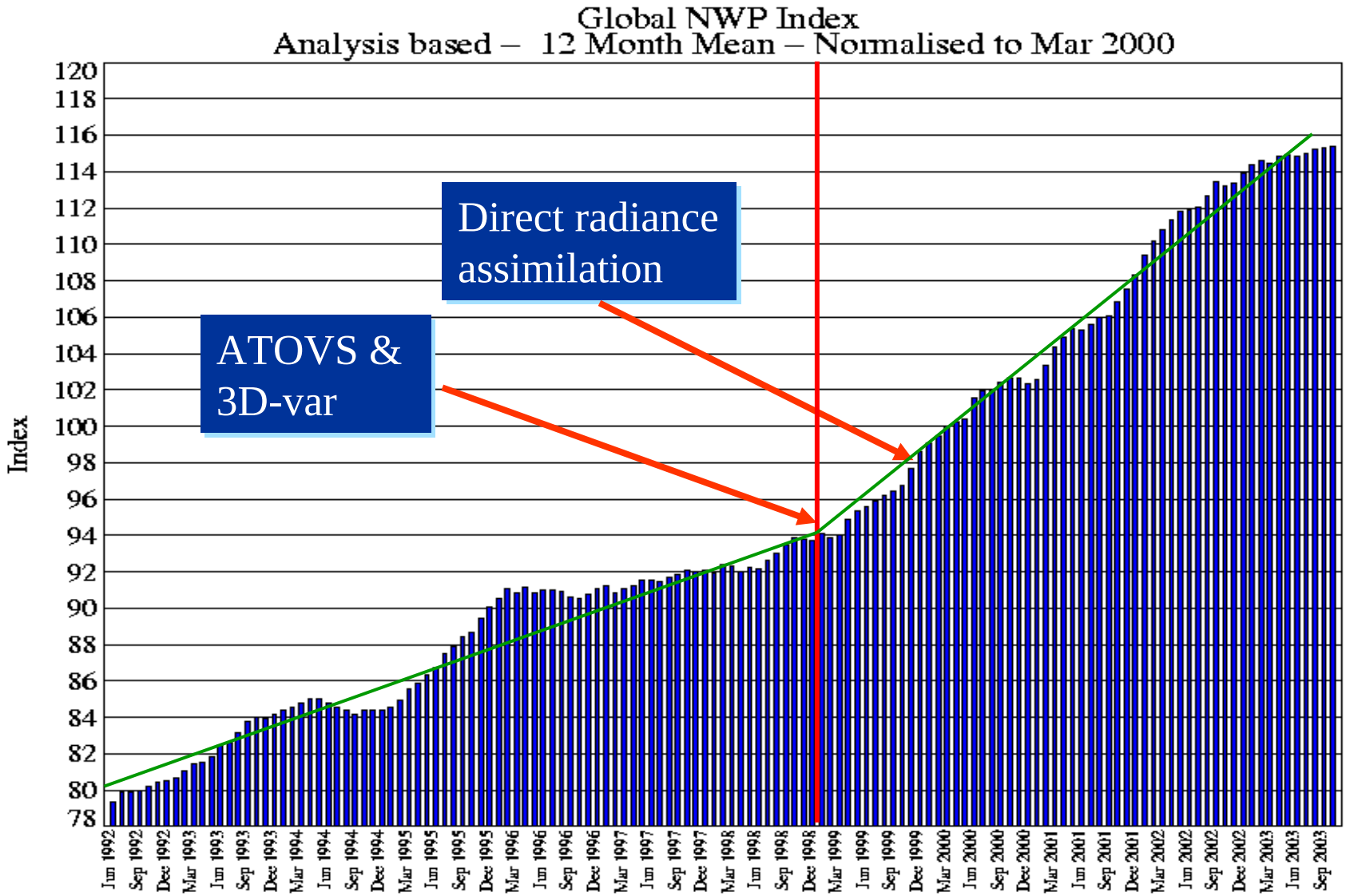
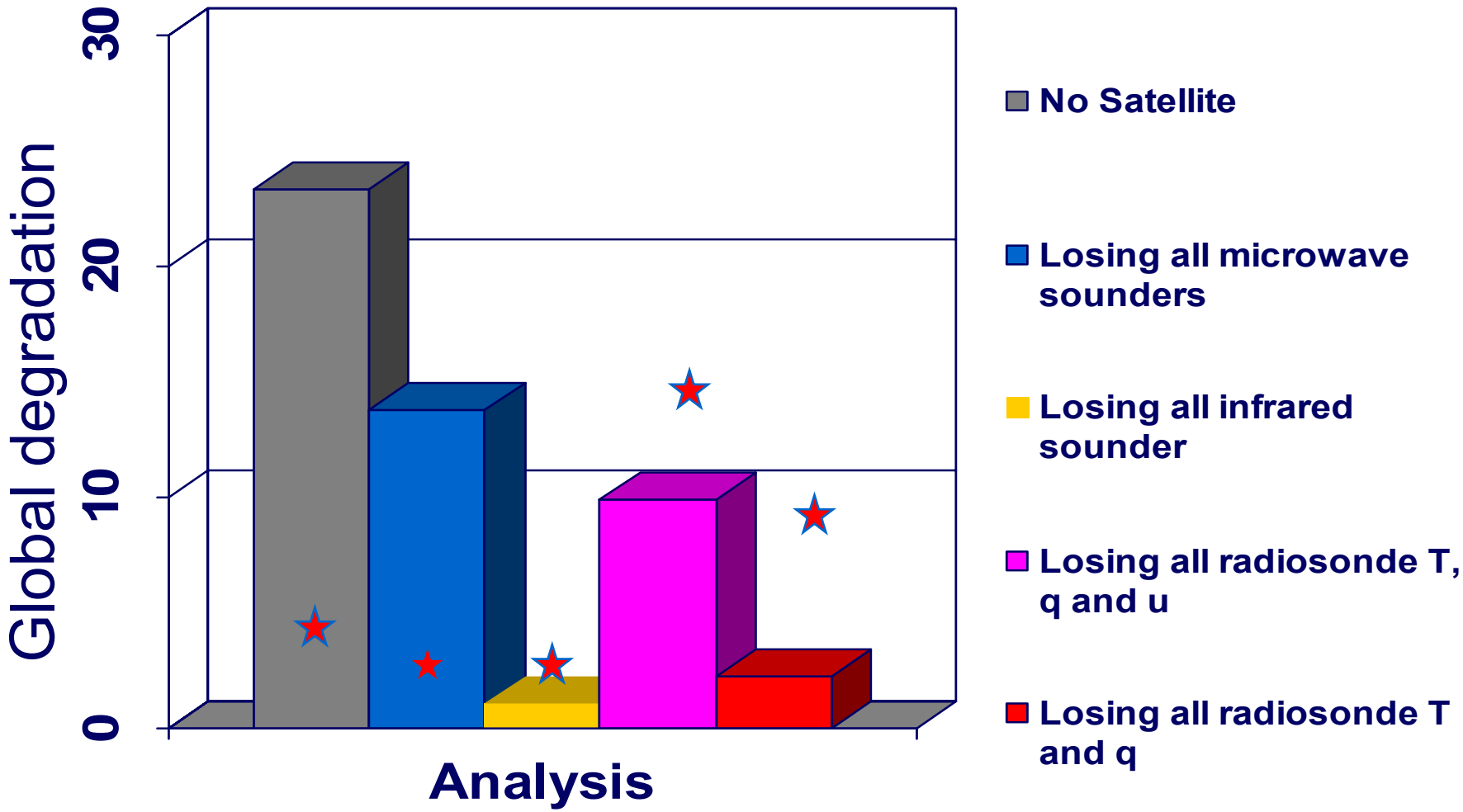
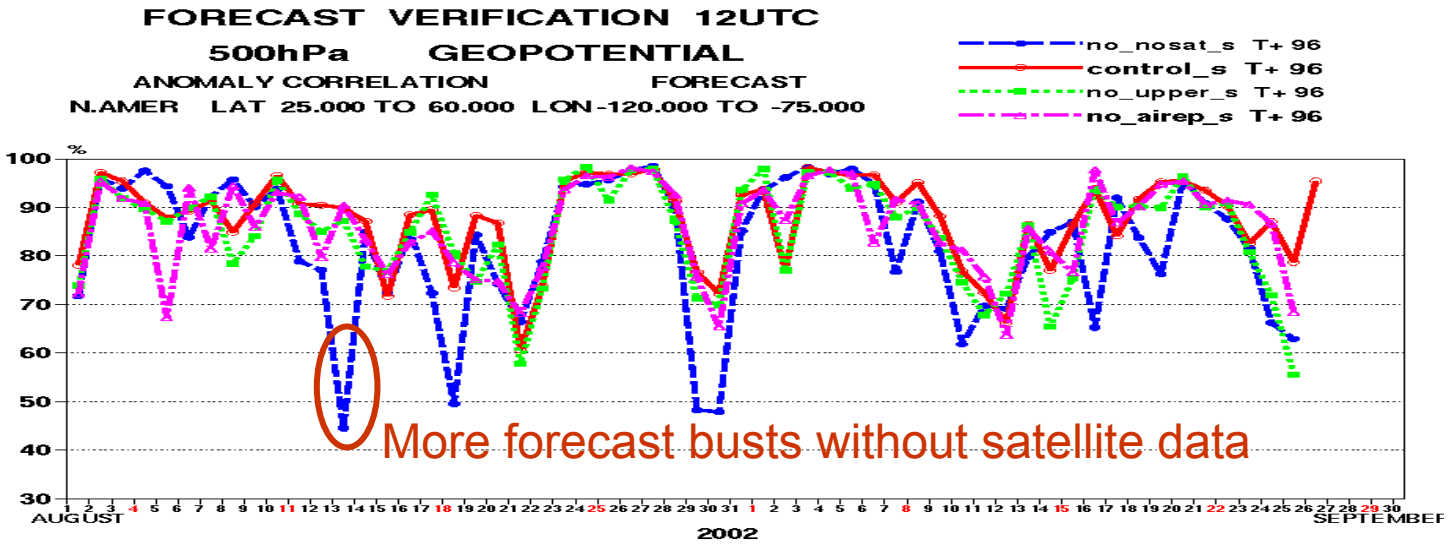


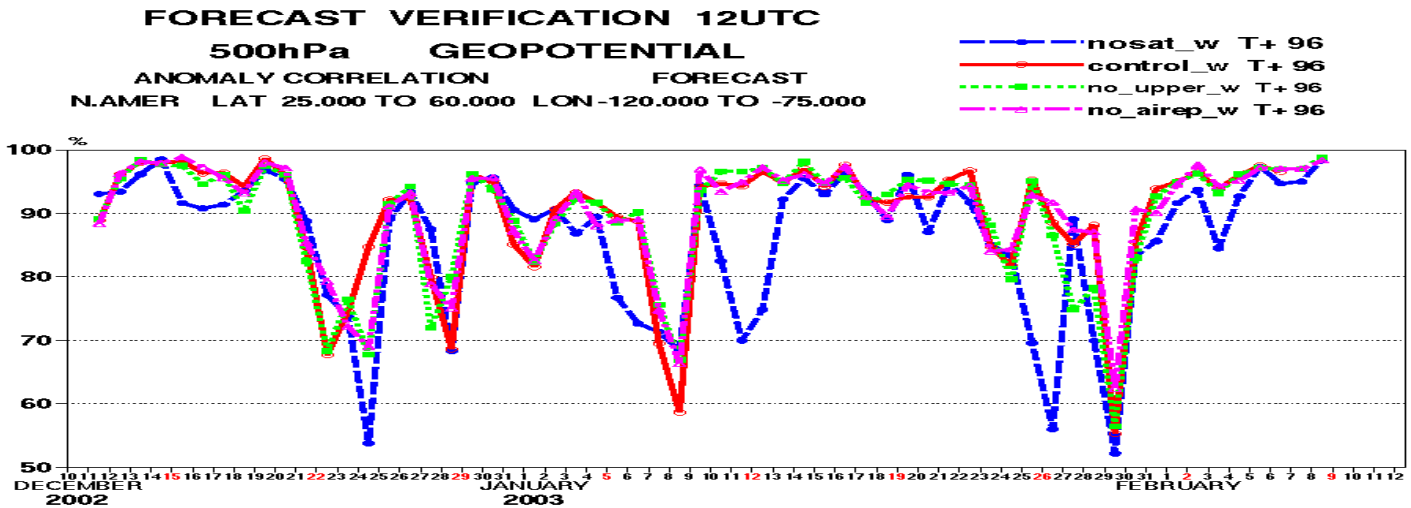
Comparison of impact of observing sounding data



★ Ten years ago? TOVS NESDIS retrievals, AMV, more but lower quality radiosondes

Forecast skill vs time





Talk topics

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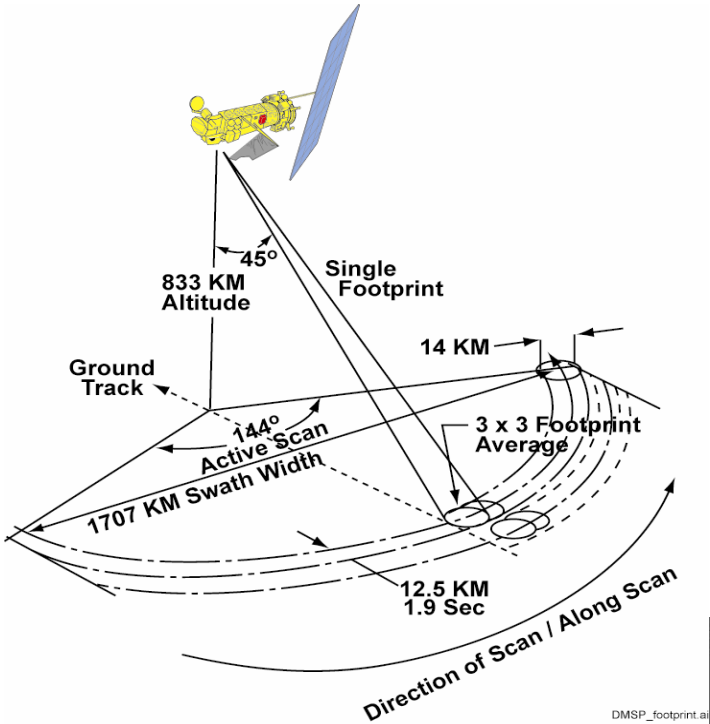
Work in progress…..

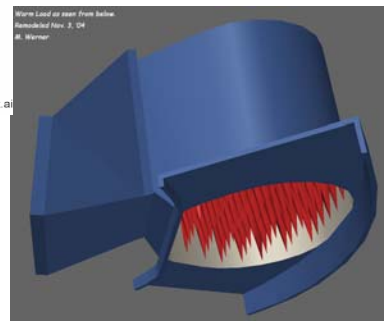
- Use of SSMIS
- GPS radio occultation
- GPS total column water vapour
- Meteosat precipitation

Longer term….

- NPP
- AMSR-E precip
- WINDSAT
- Scatterometer soil moisture
- ADM

SSMIS: Instrument and scan geometry



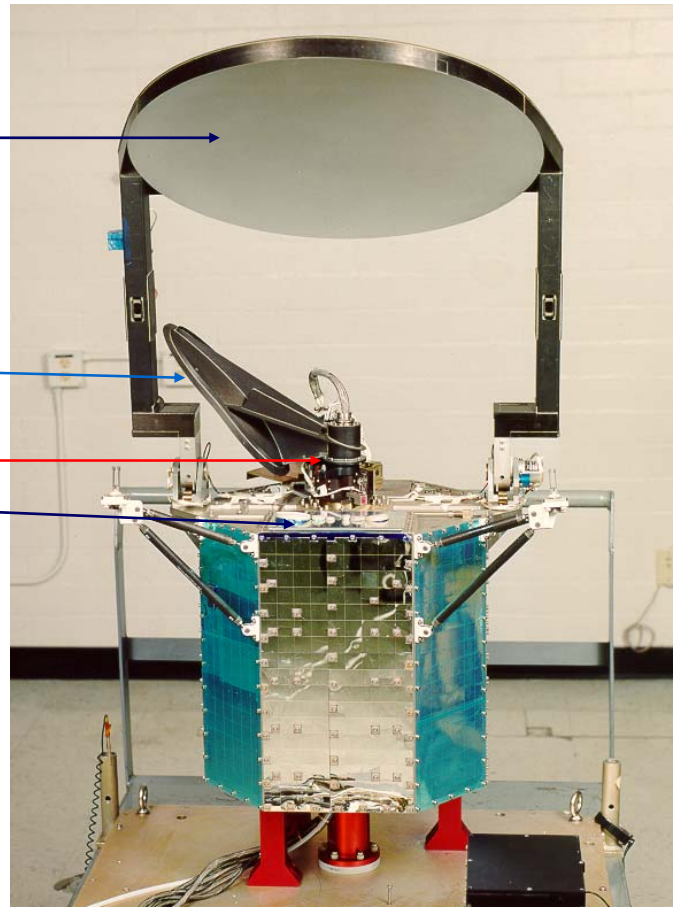


Main Reflector

Cold Calibration Reflector

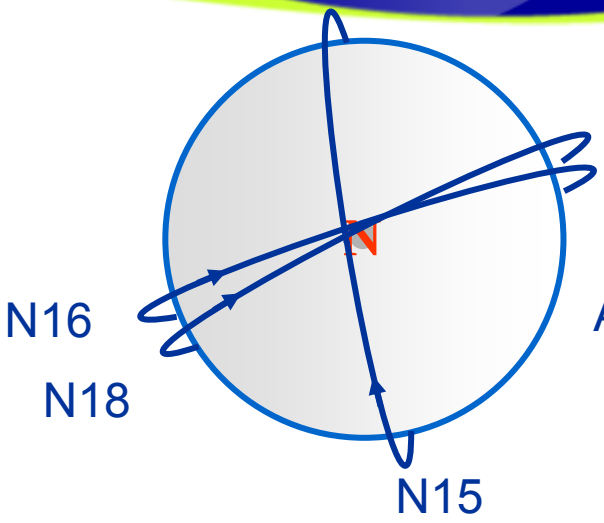
Warm Load

Feedhorns

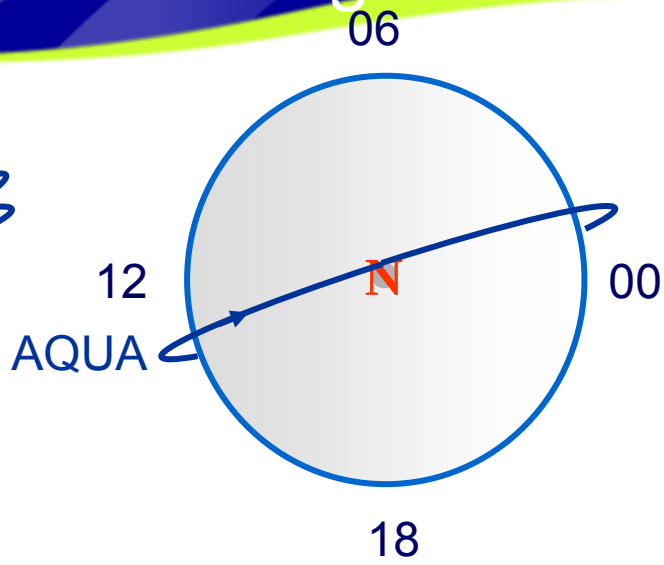


Special Sensor Microwave Imager/Sounder (SSMIS)

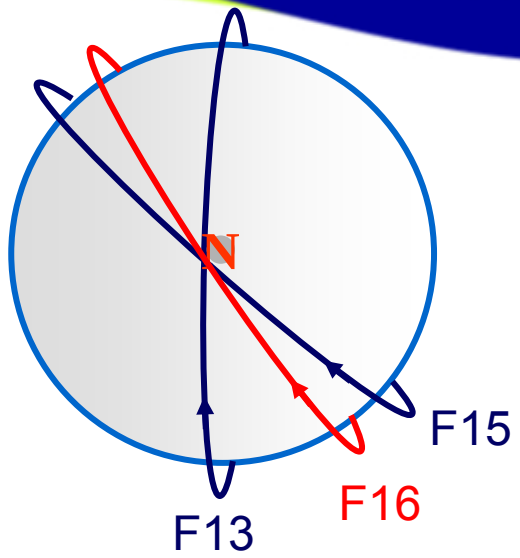
Orbit coverage of operationally assimilated sounders / imagers



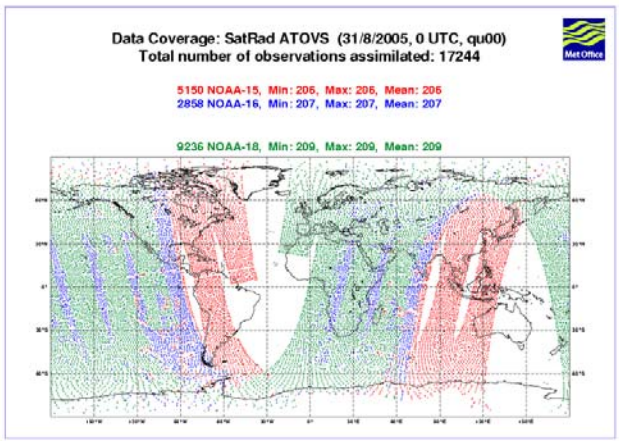
ATOVS (T & q)

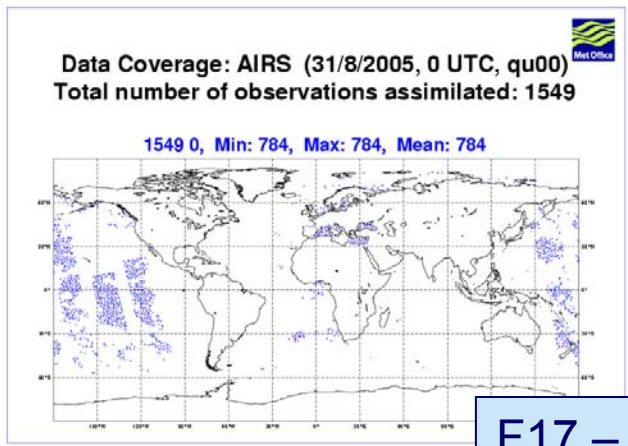


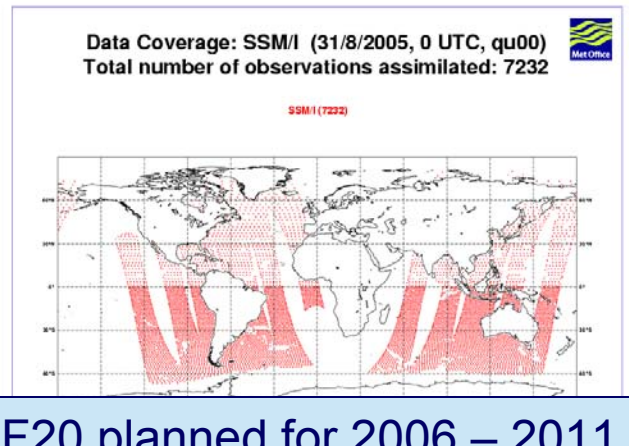
AIRS (T & q)



SSMI (WS)
SSMIS (T, q, WS)

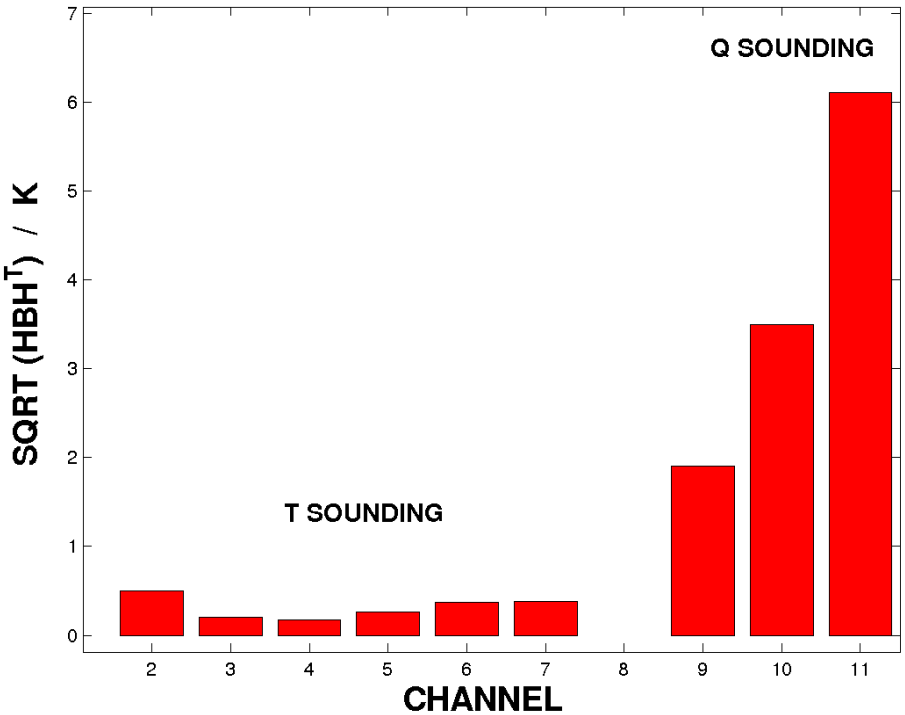




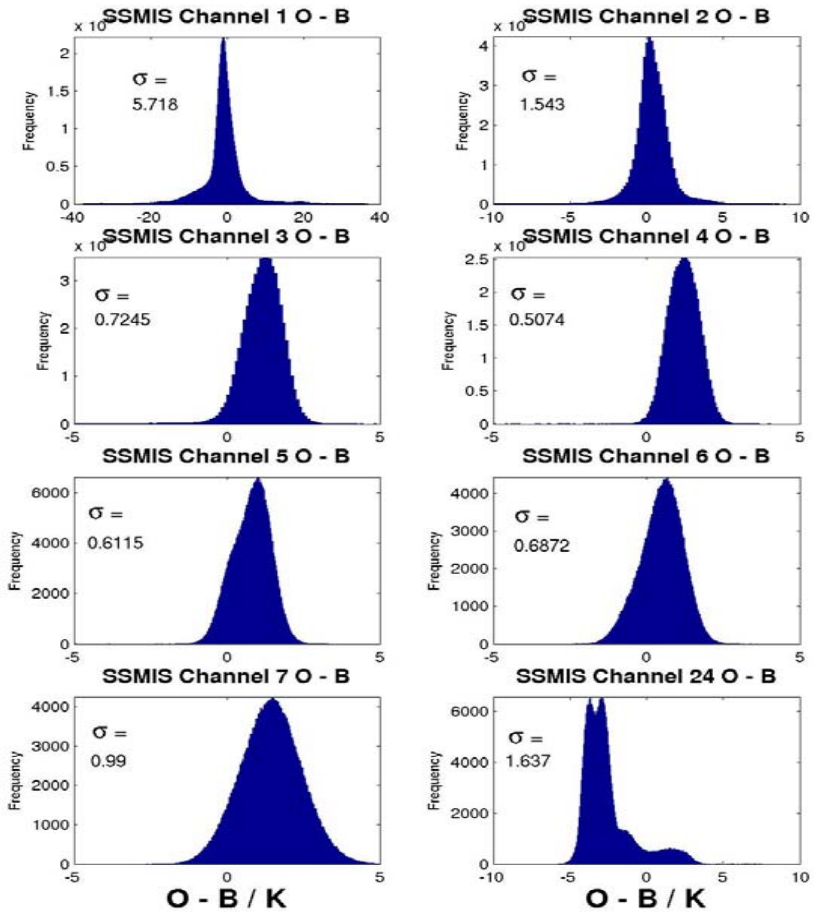


F17 – F20 planned for 2006 – 2011

Background: Accuracy Requirements and Initial Performance

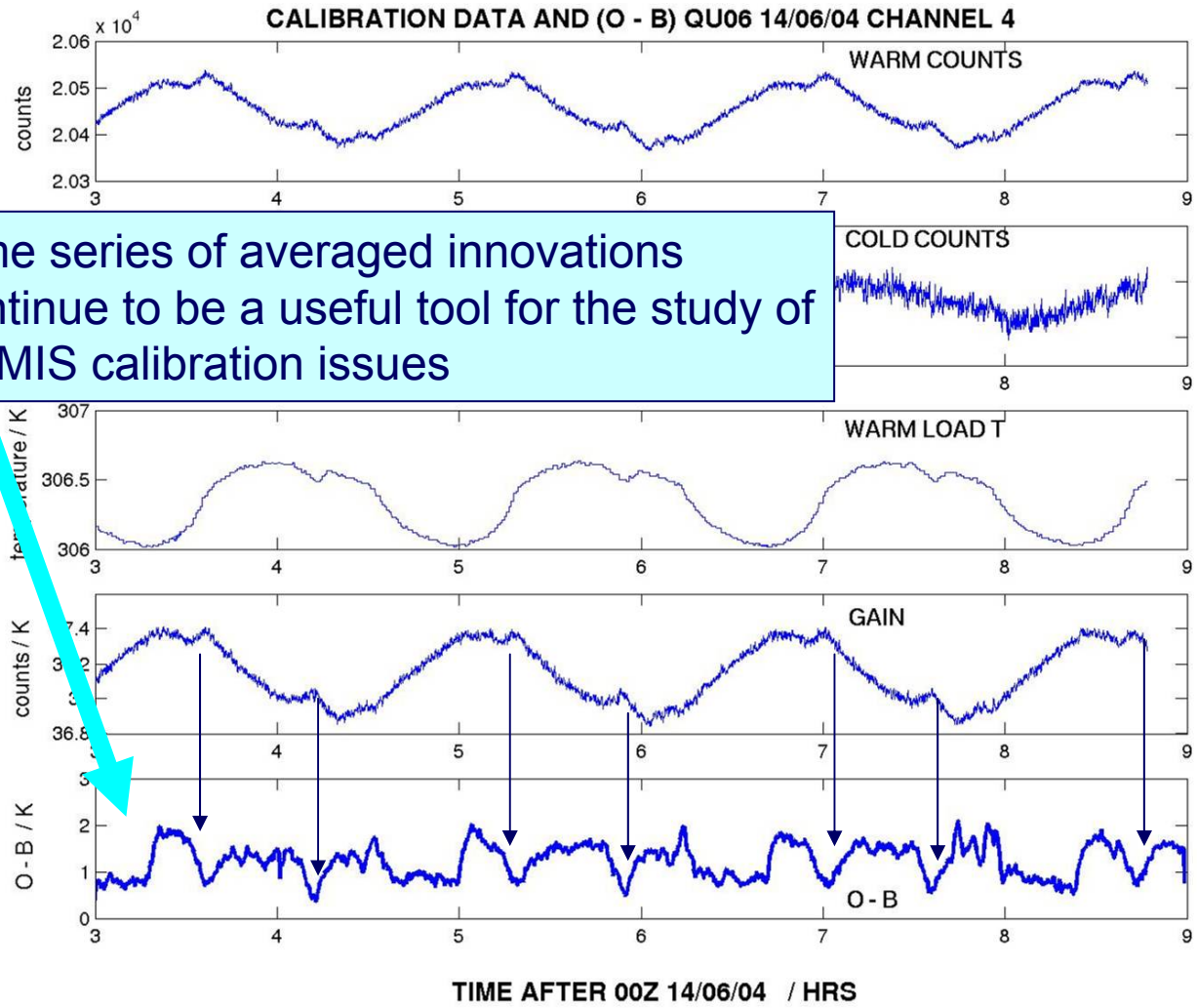


Require $U(T_B) \sim 0.2K$

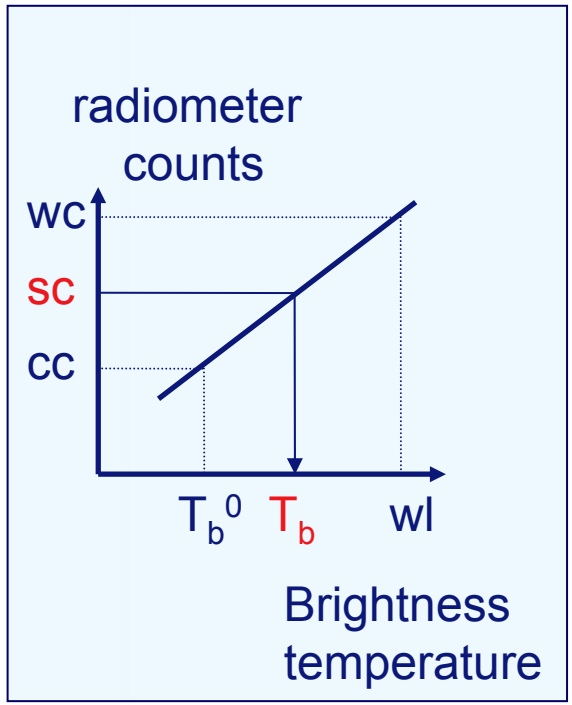


Initial evaluation indicated $U(T_B) \sim 0.5$ K

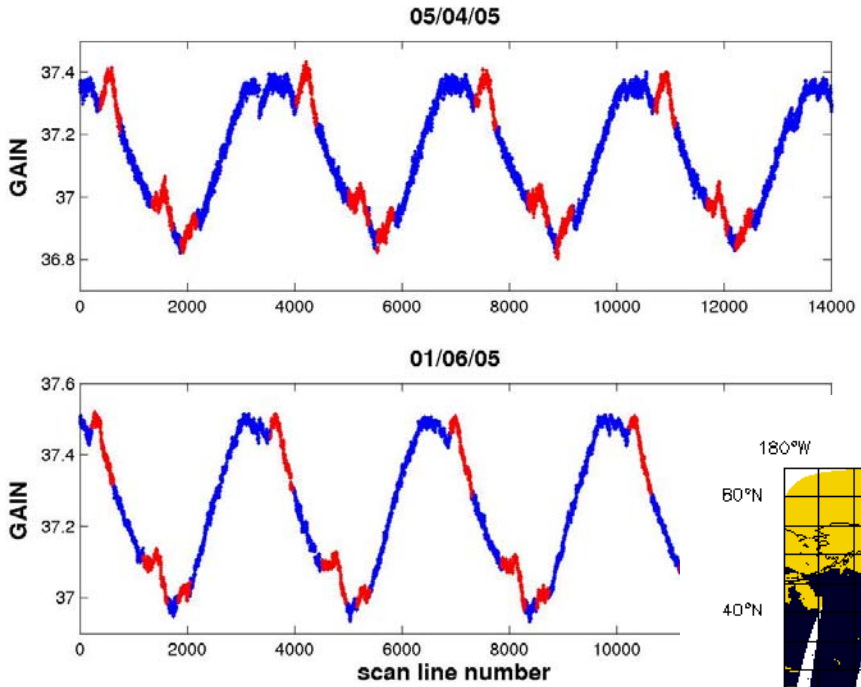
Instrumental Biases: warm load solar intrusions



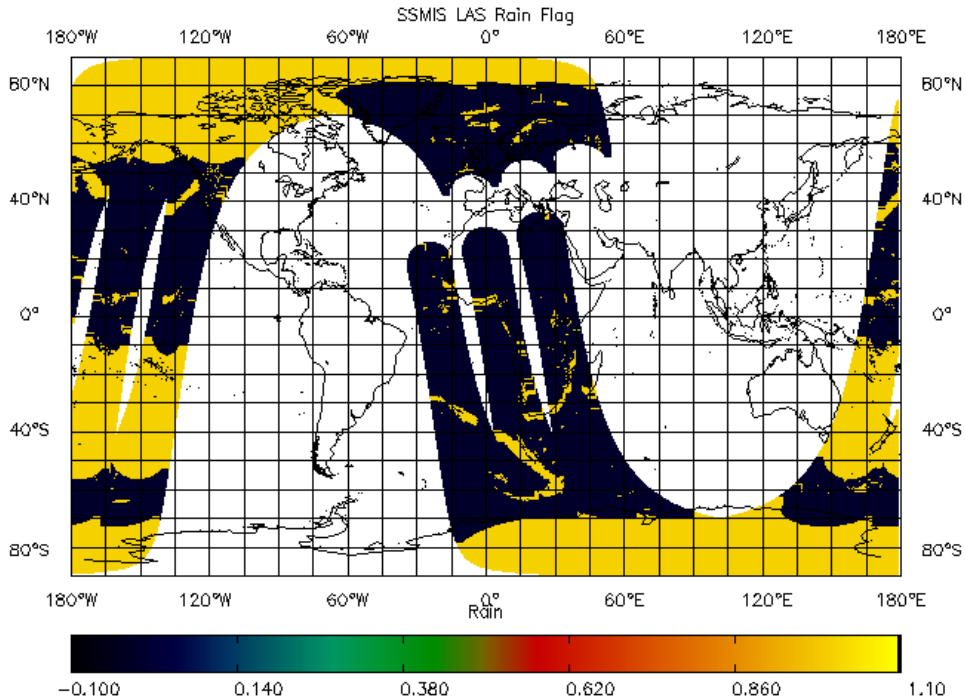
Time series of averaged innovations continue to be a useful tool for the study of SSMIS calibration issues



Flagging solar intrusions



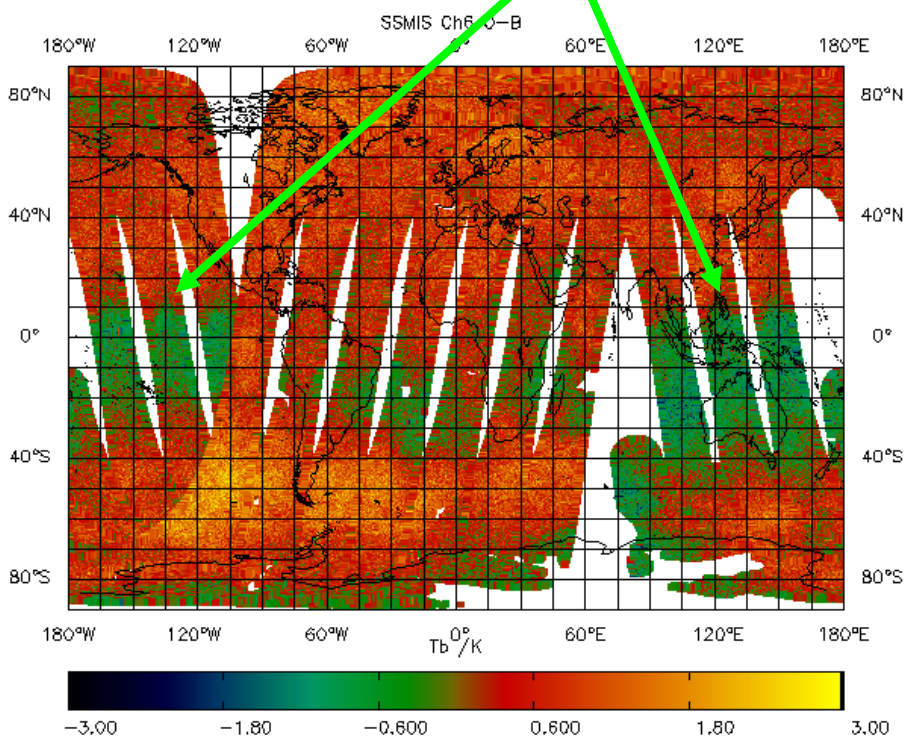
Yellow : rejected
Black: OK
(30 - 40% data flagged)

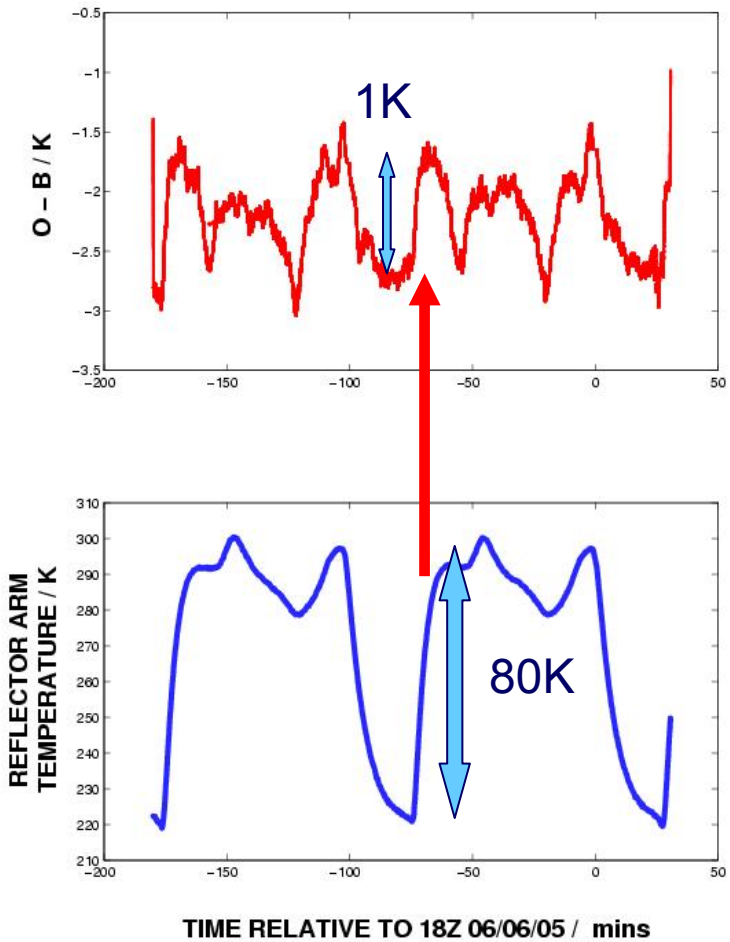


Improved corrections under test
At NRL/ NESDIS – will allow recovery of this data

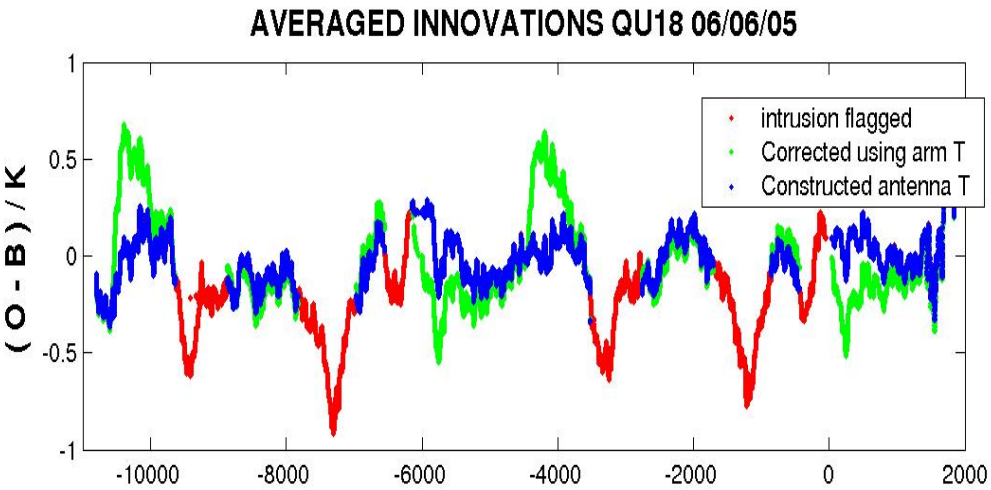
Reflector emission

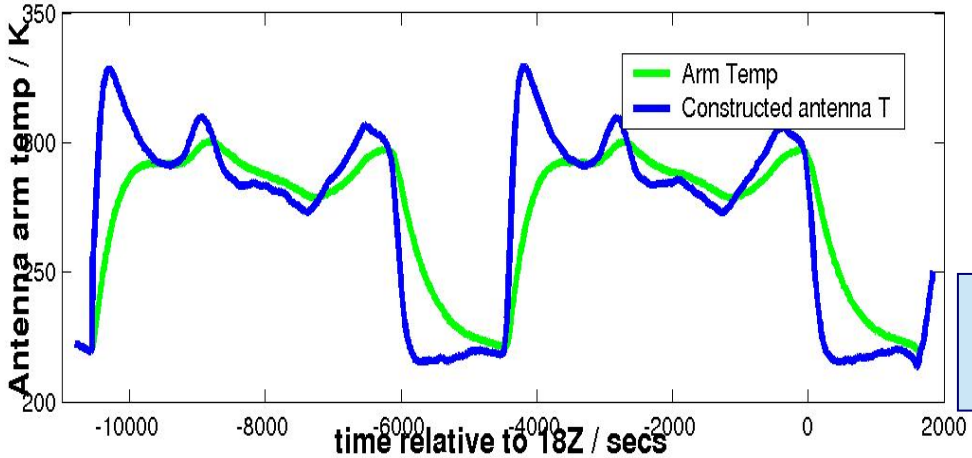
Problems in ascending node not evident in descending node





SSMIS – reflector emission correction using constructed antenna T

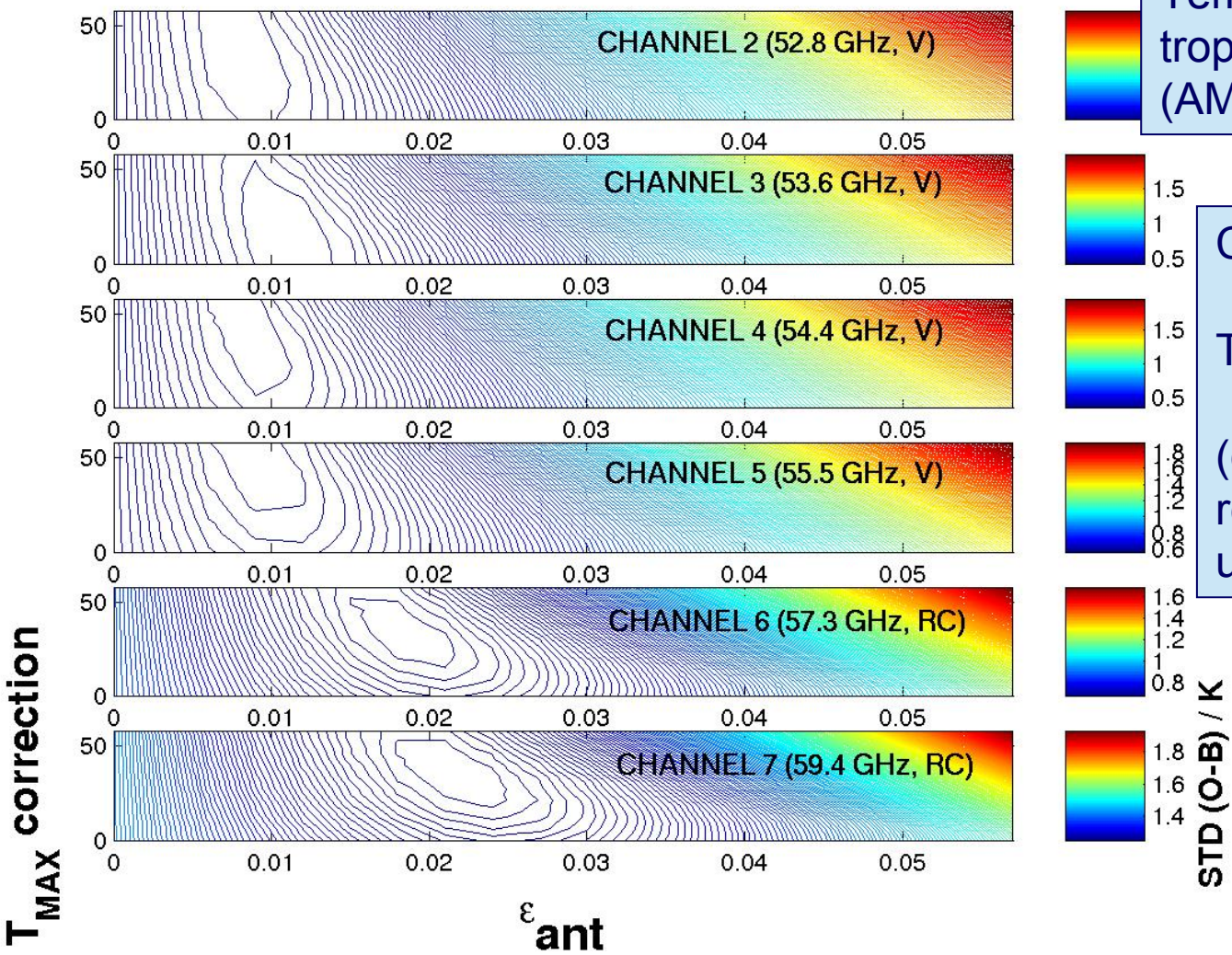




$$T_{ant}(t) = T_{arm}(t) + c_1 \int_0^T c_2 e^{-\tau/\sigma} \frac{dT_{arm}}{dt}(t-\tau)\,d\tau$$

Consistent with solution of heat transfer equation, assuming conductive cooling

Characterising T_{ANT} & ε : Chs 2 – 7



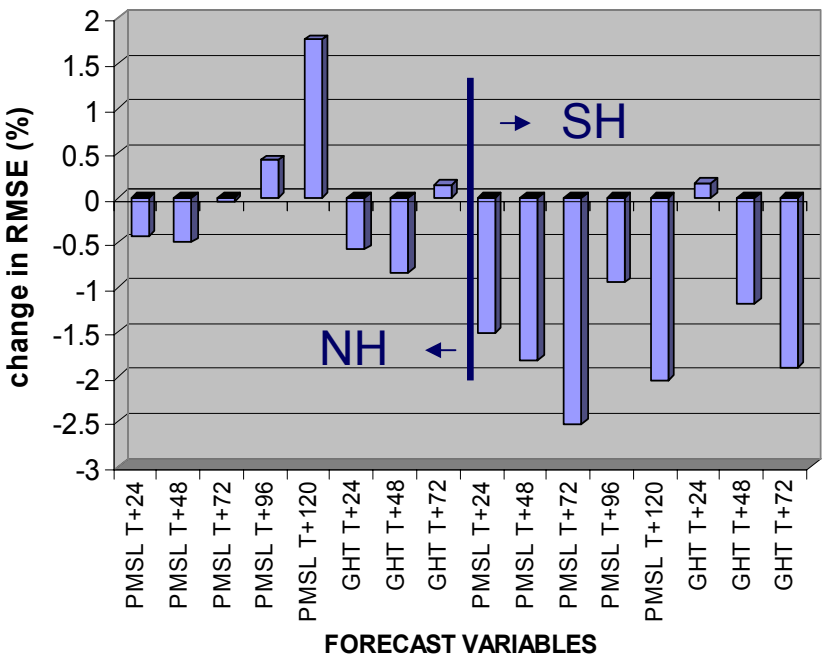
Temp sounding channels trop – lower strat (AMSUA like)

Ch 1 - 5 : ε = 0.01
6,7 : ε = 0.02
T corr = 30 – 40 K

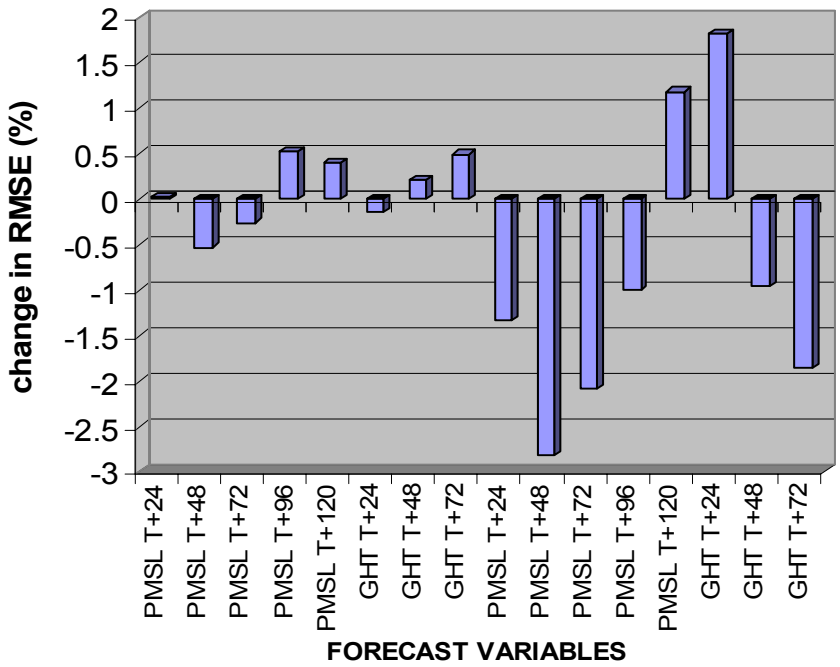
(effectively calibrating reflector emissivity using NWP T fields!?)

SSMIS Assimilation trials at the Met Office

OPNS vs OPNS +SSMIS



(OPNS – N15 ATOVS)
vs
(OPNS – N15 ATOVS) + SSMIS

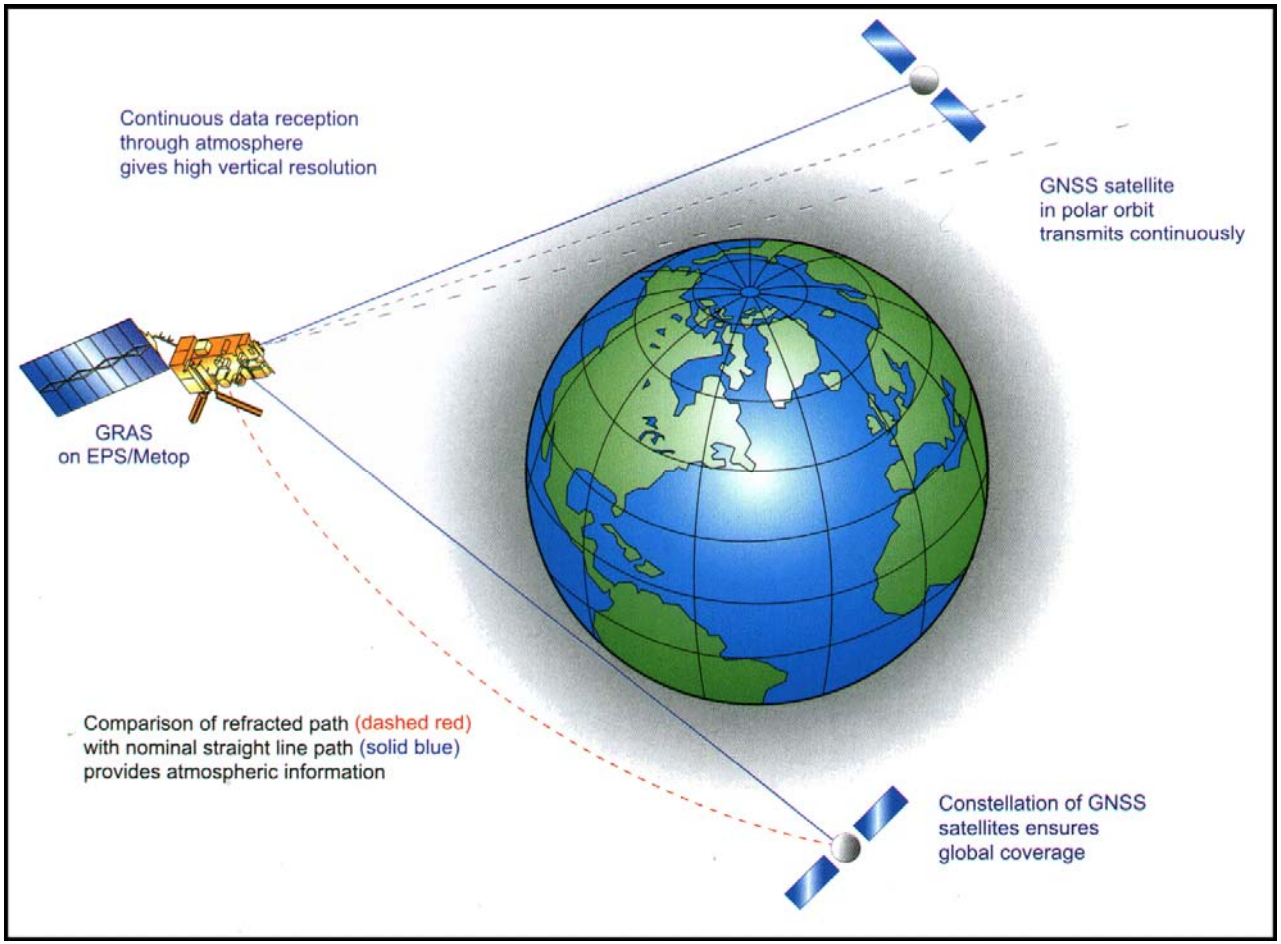


Conservative use of SSMIS gives significant improvement in SH forecasts of PMSL for forecast days 1 - 4 on top of 2 and 3 satellite systems

Summary

- NWP DA systems require high quality radiances ($U(T_B) \sim 0.2K$) in temperature sounding channels to deliver improvements to forecast accuracy
- Post launch Cal/Val program has identified two sources of significant bias associated with solar intrusions into cal warm load and thermal emission from the main reflector.
- Correction strategies have been developed to deal with both effects and the resulting radiances are of comparable quality to those from AMSU-A for the tropospheric T sounding channels
- Assimilation experiments at the Met Office show significant benefit from assimilating T sounding channels for SSMIS in SH verified against baseline configurations with 2 and 3 AMSU's.
- Assimilation experiments at ECMWF show SSMIS delivers > 50% the benefit of N15 AMSU against NOSAT controls.
- Further improvements are expected as correction algorithms are refined.

GPS Radio Occultation



RO Missions:

GPS/Met : 1995 – 2000

Ørsted : 1998 –

SunSat : 1999 –

SAC-C : 1999 –

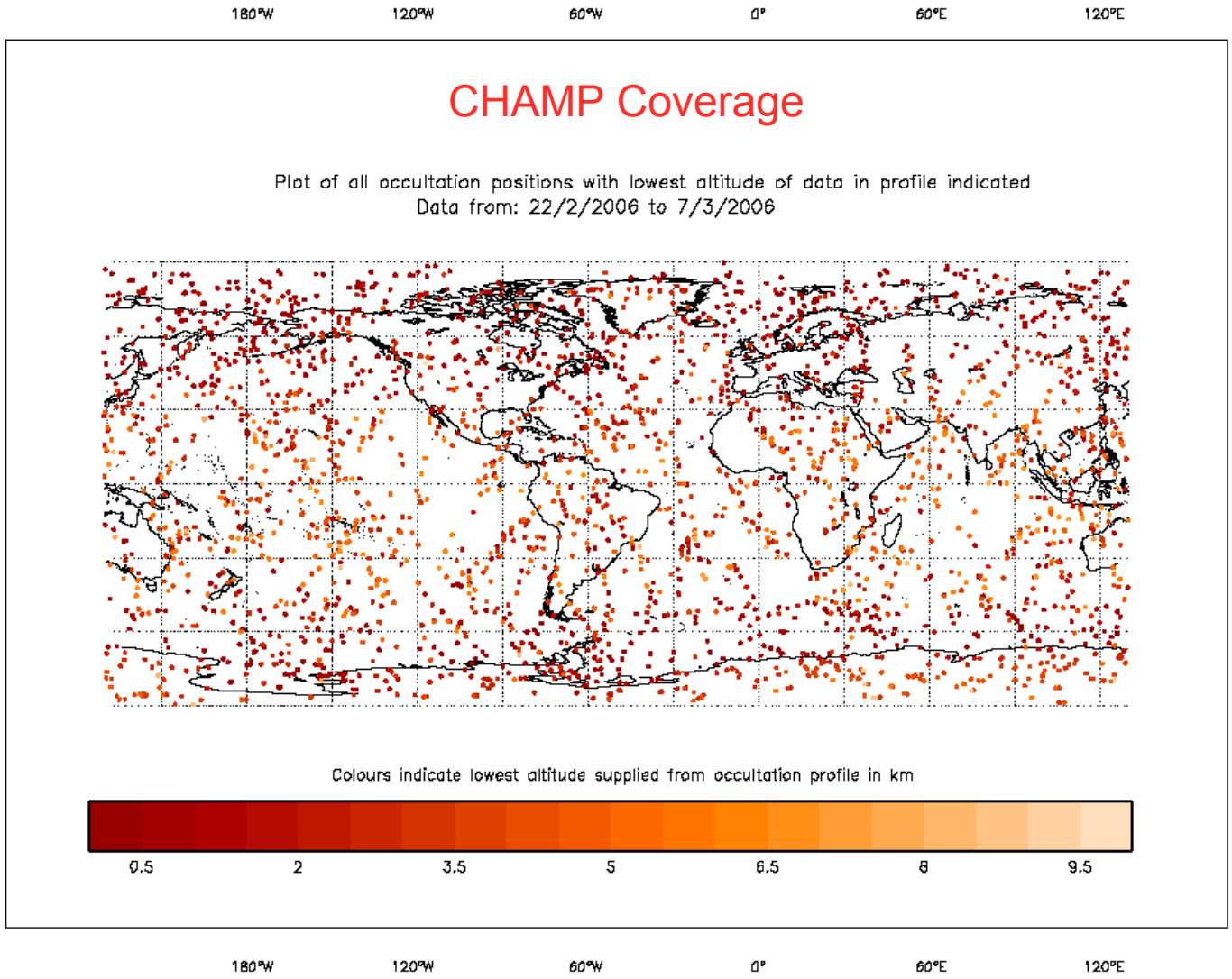
CHAMP: 2000 –

GRACE-A/B : 2002 –

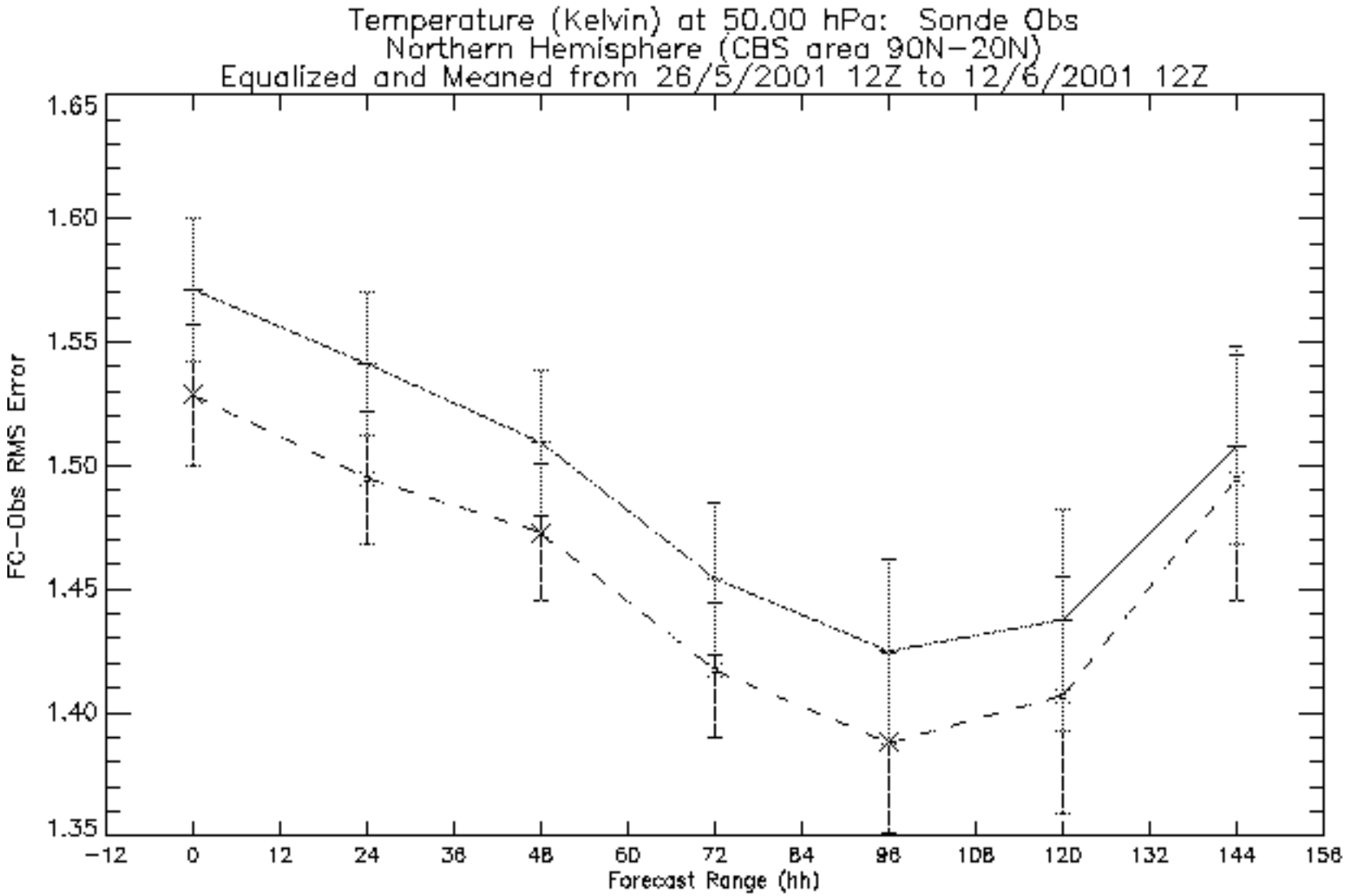
COSMIC : ? Apr 2006

GRAS : 17 Jul 2006

Radio Occultation



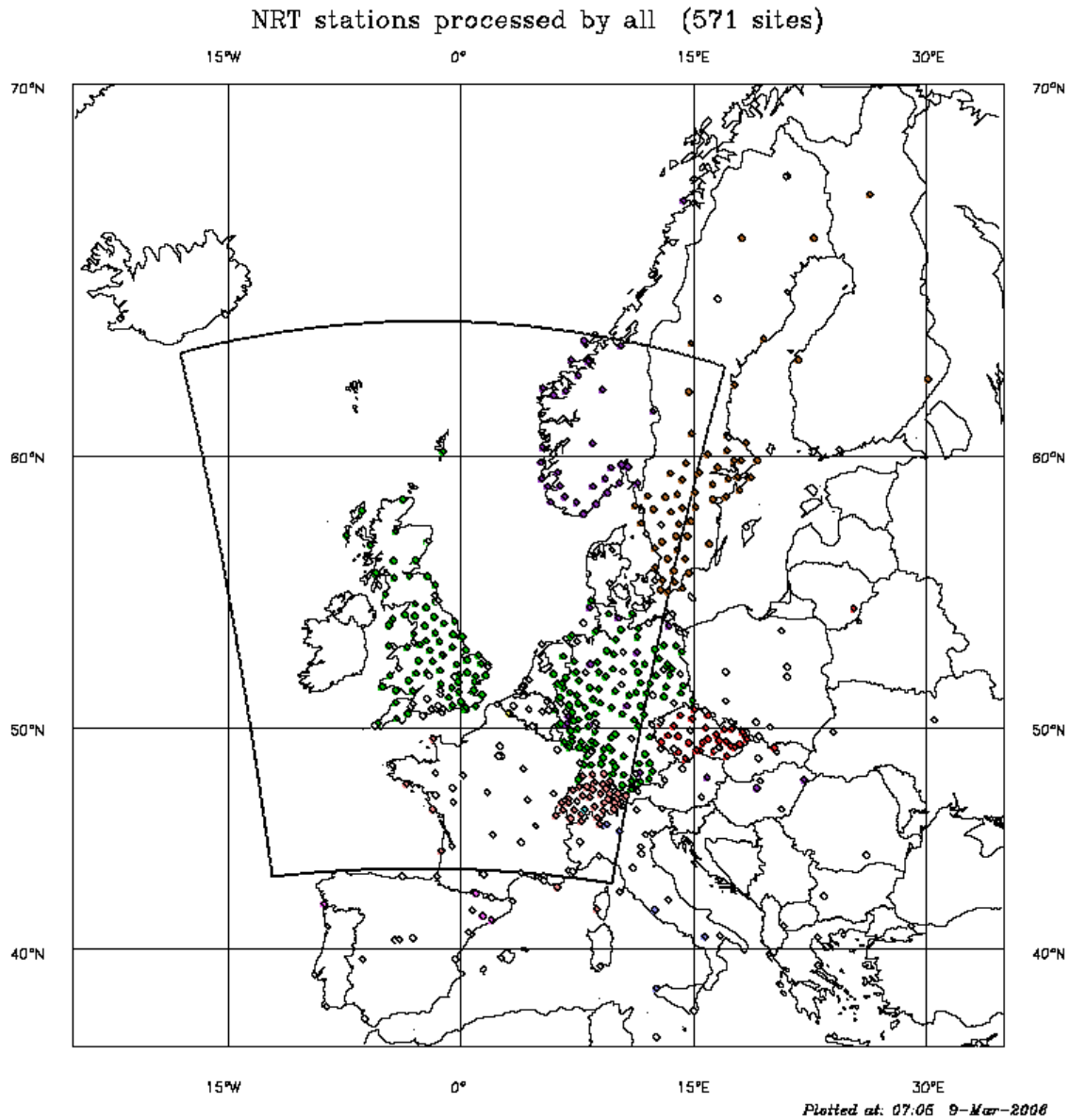
Radio Occultation impacts



Ground-based GPS

- Uses standard GPS navigation signals and standard geodetic-quality receivers
- Atmospheric zenith total delay (ZTD) included in position solution
- Information on ‘dry’ (ZHD) and ‘wet’ (ZWD) components
- IWV = (ZTD-ZHD)/k = ZWD/k (k ~6.5)
- European collaboration via EUMETNET E-GVAP (& previously EU COST-715 & TOUGH)
- Semi-operational hourly data downloads from 500+ stations over Europe
- Processed to Total Zenith Delay in <2 hours

Ground-based GPS over Europe



Talk topics

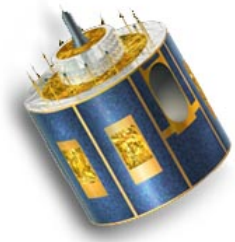
- The Met Office satellite group
- Current status of models and observation use
- Recent upgrades to use of satellite data
- Satellite data impacts
- Research into use of new data types
- Meteosat Second Generation
- METOP

Meteosat vs MSG: Differences

Meteosat 7

- 30 Minutes
- 3 Channels
- 2500 x 2500 pixels
- 5 km at SSP (2.5km)

Meteosat 8

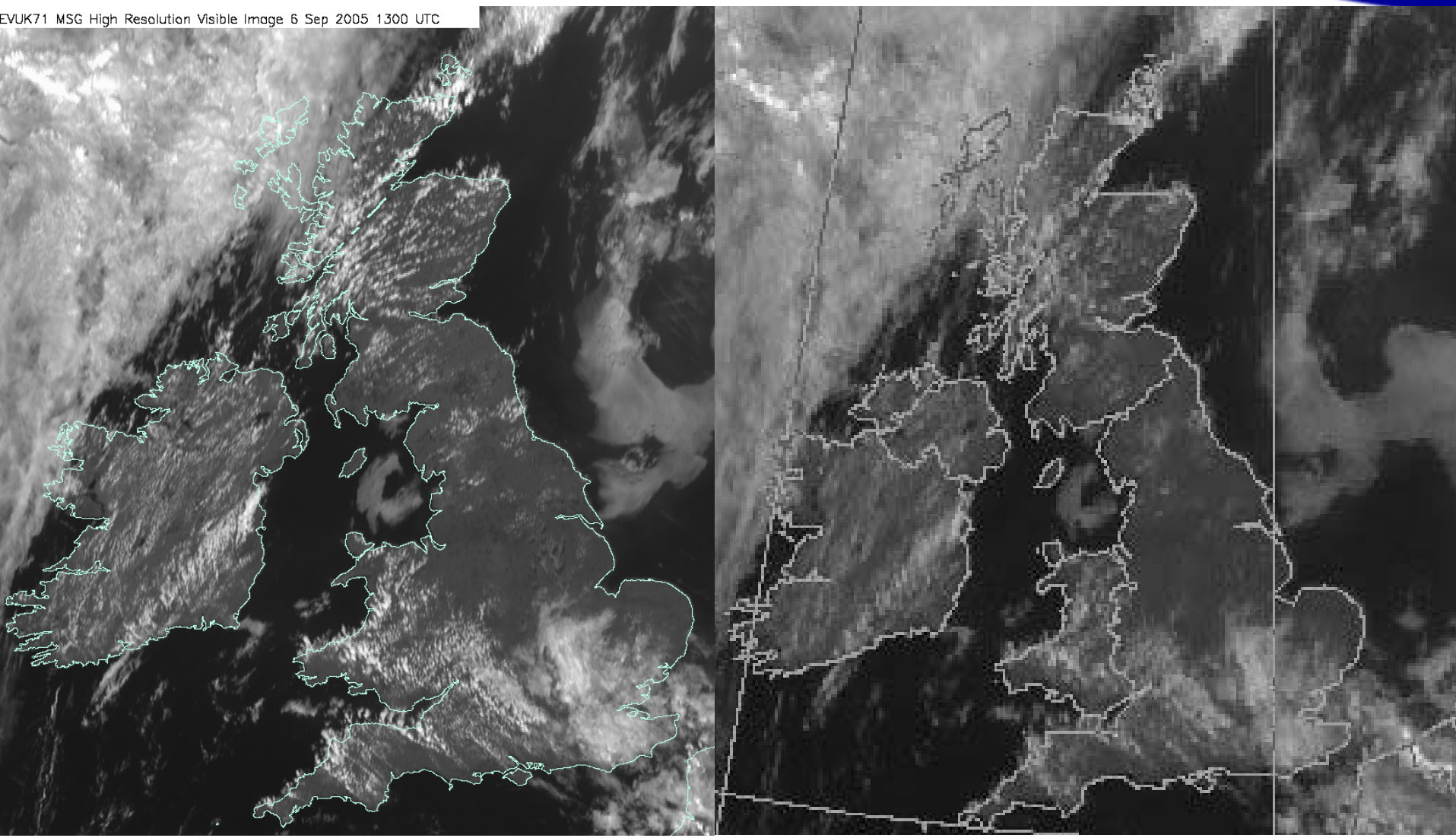


- 15 Minutes
- 12 Channels
- 3712 x 3712 pixels
- 3 km at SSP (1km)

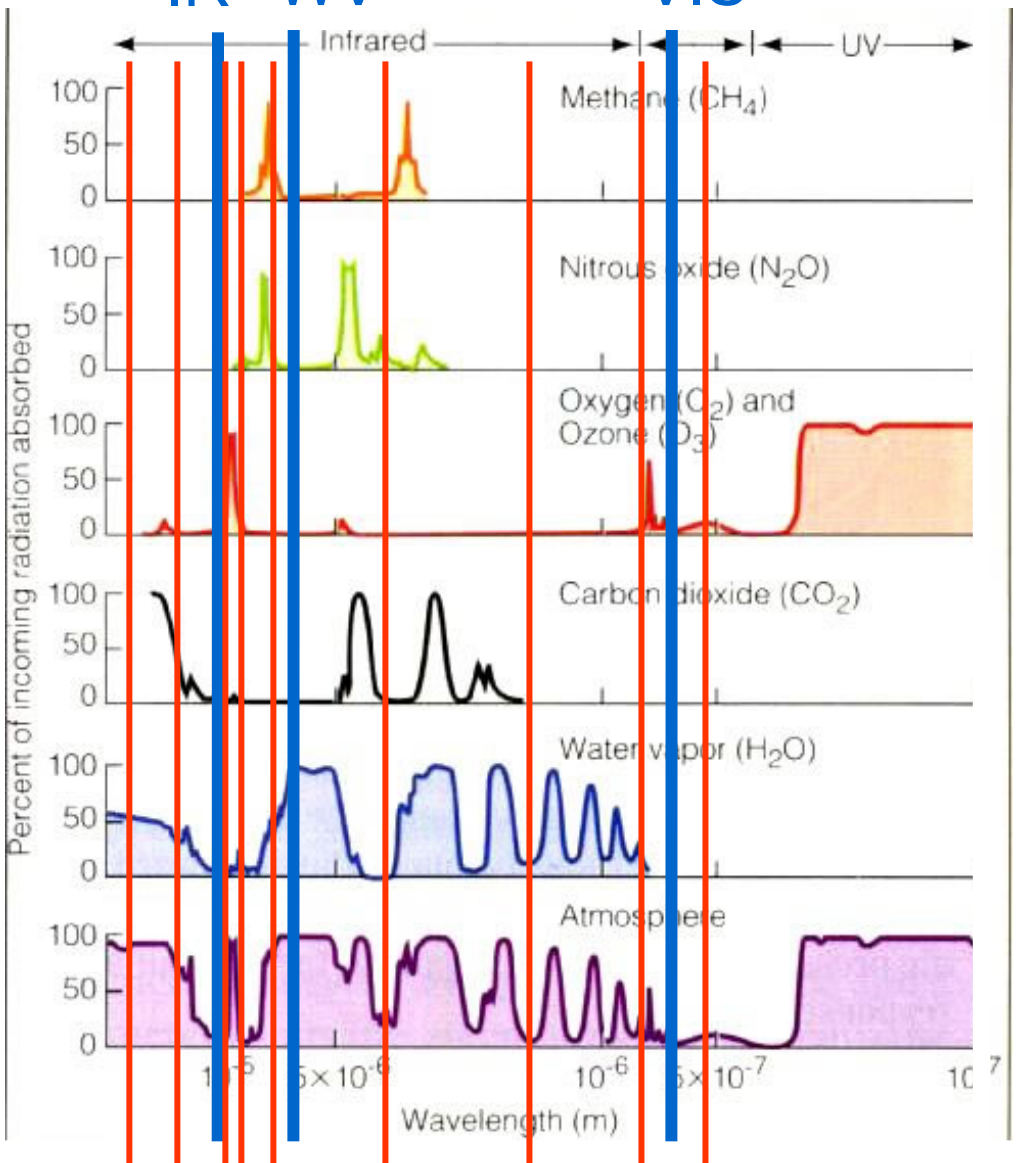
High Res Vis image

Meteosat-8

Meteosat-7

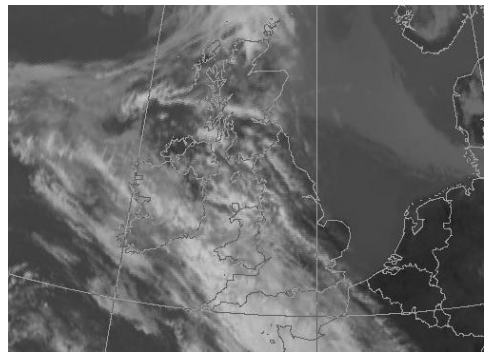


MSG channels

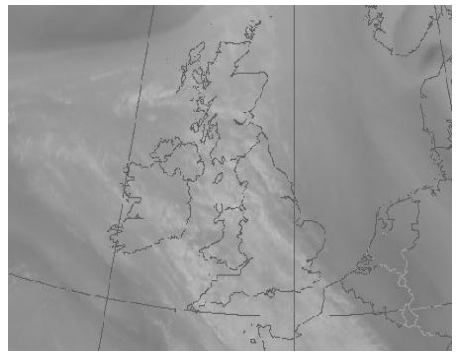


New MSG channels

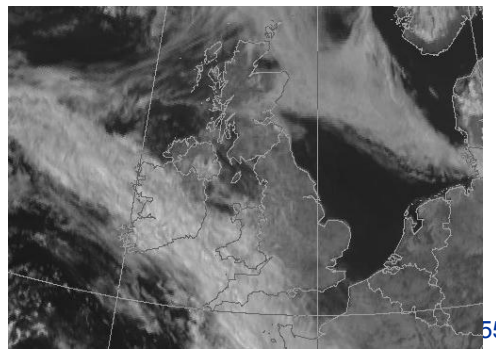
IR window ~ 10.8µm



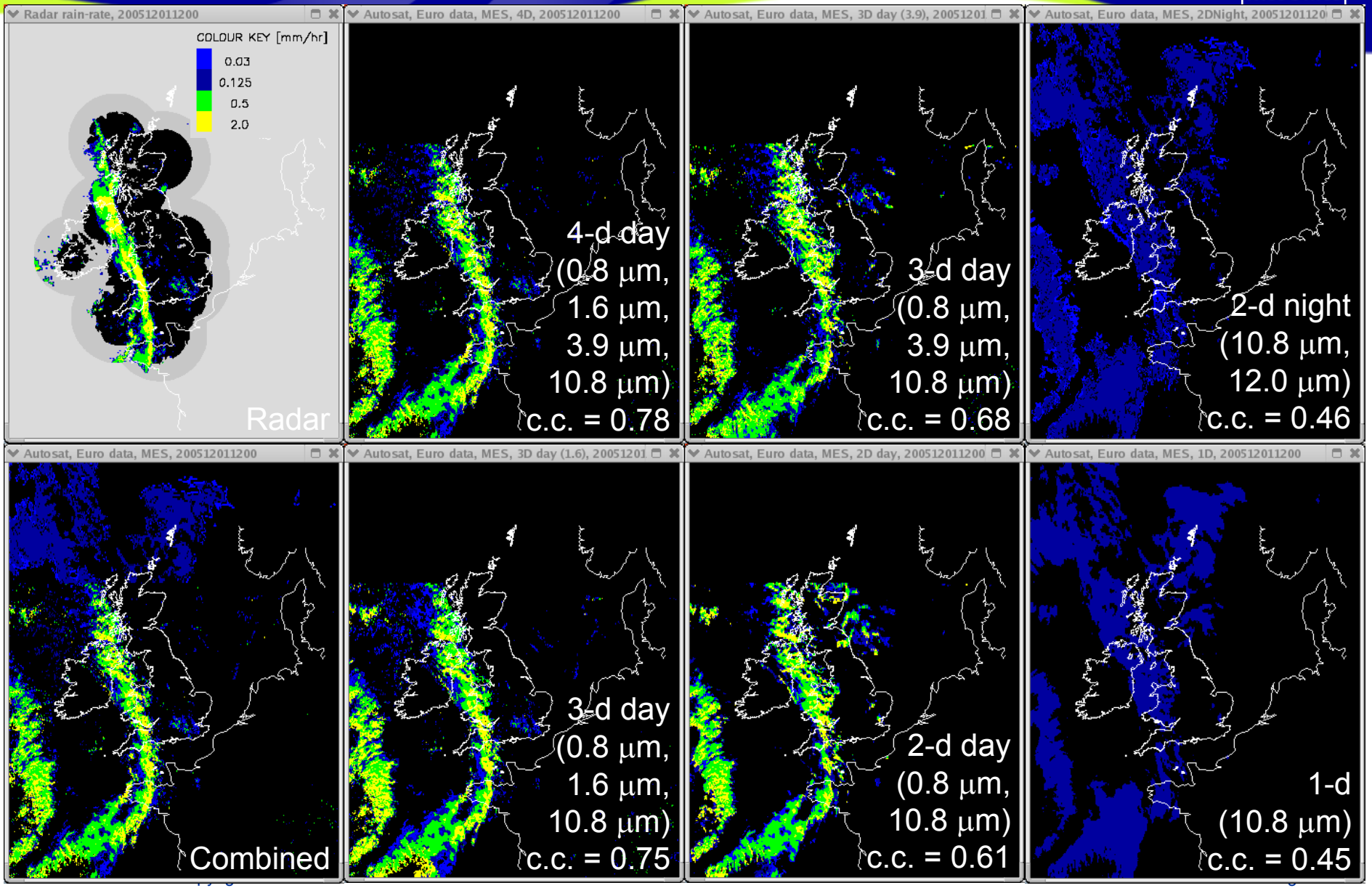
WV absorption ~6.7µm



VIS ~0.6µm



Day-time correlations – 1200Z, 1st December 2005

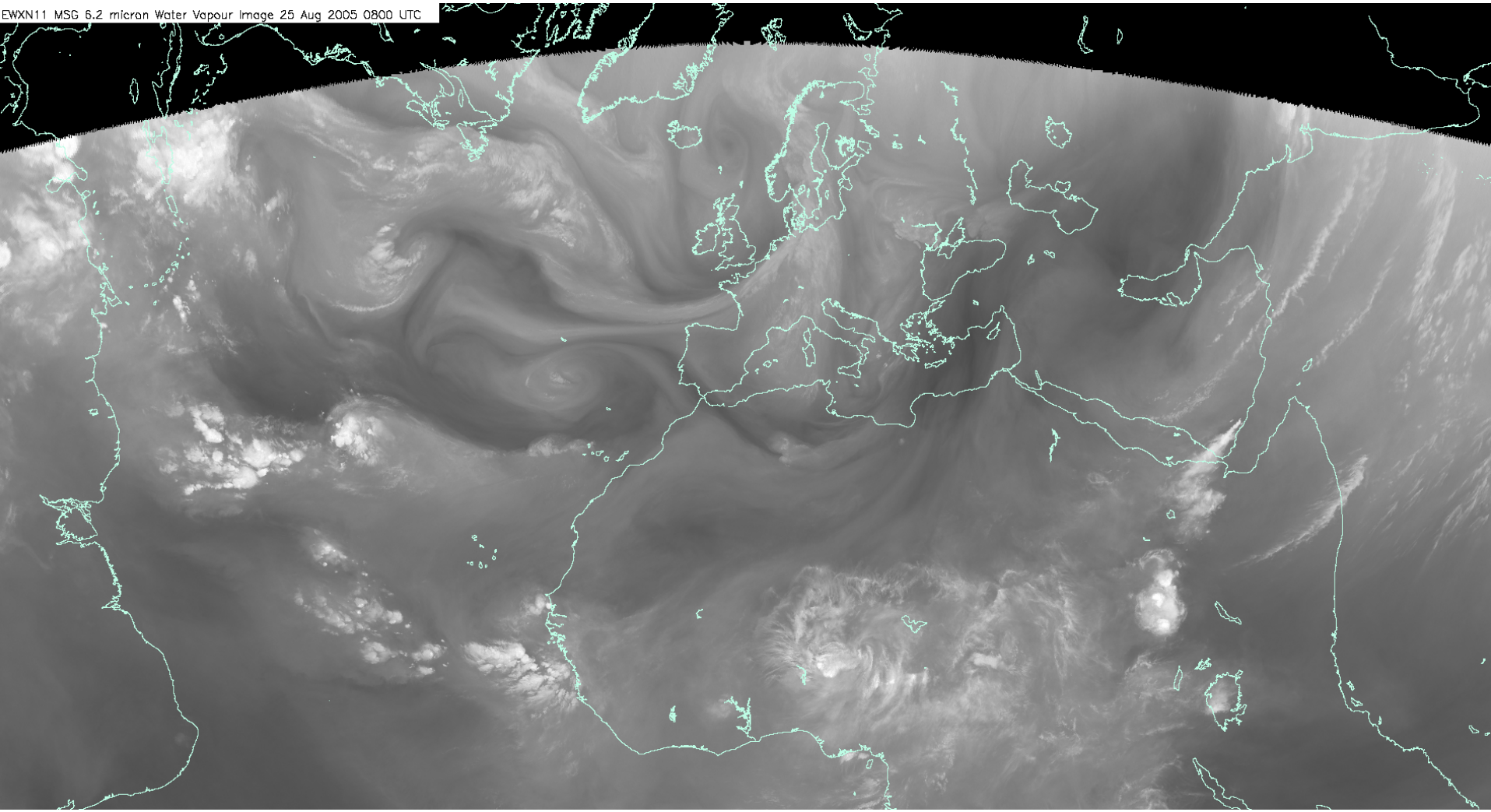


Simulated imagery at Met Office

- Use regional NWP analysed fields of T(p), RH(p), Ts as input to fast RT model (RTTOV-7)
- Estimate cloud at each level from RH (if RH>80% then cloud fraction assigned 0-1)
- Compute cloud overlap (maximal or random)
- Run RTTOV with cloud layers seen by satellite
- All IR channels simulated for each model grid box (clear+cloudy)
- Display alongside measured SEVIRI imagery
- Only 6.2um used at present by forecasters

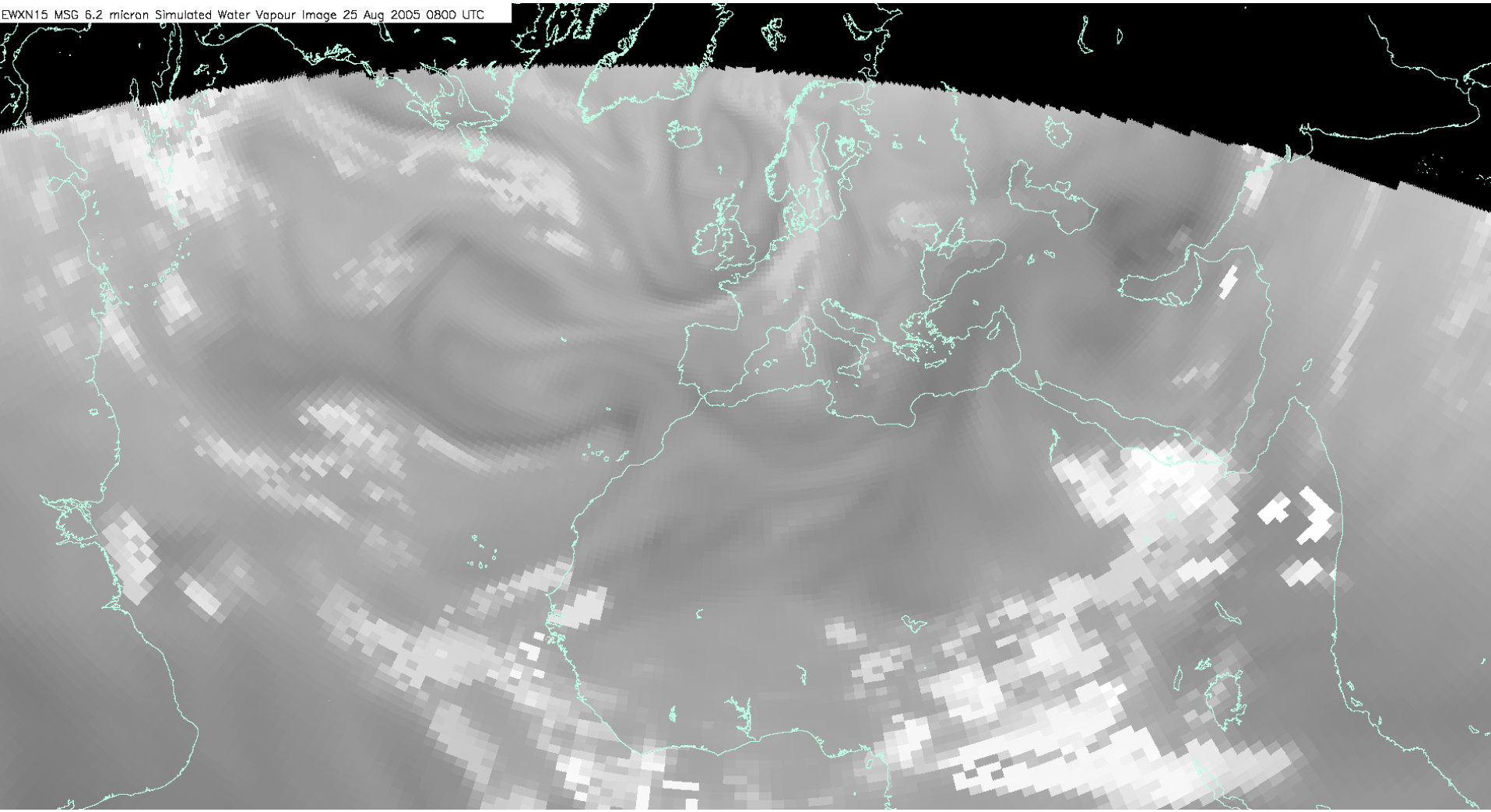
Simulated MSG imagery from NWP

MSG



Simulated MSG imagery from NWP

NWP



Talk topics

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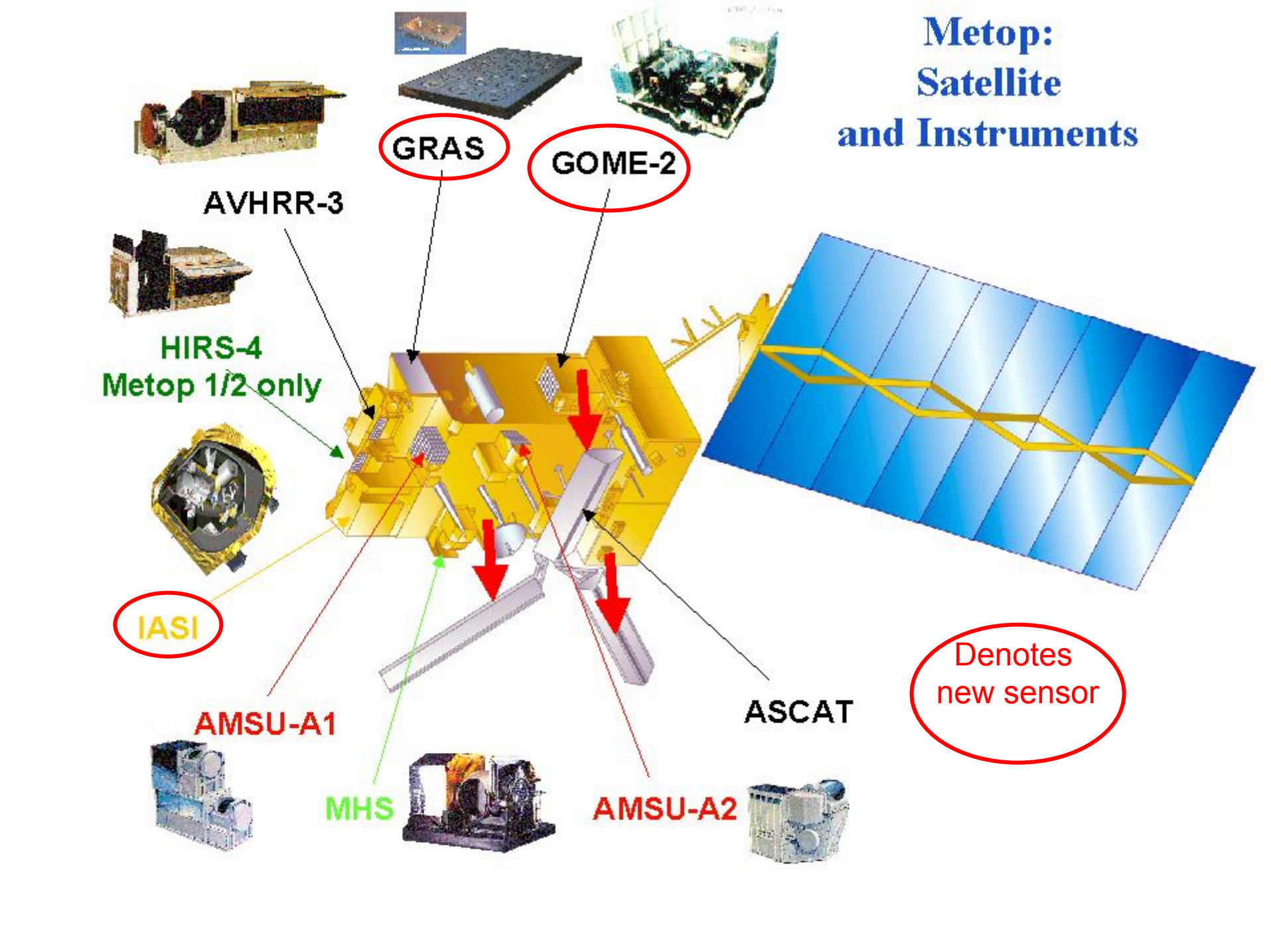
- METOP

Metop: Satellite and Instruments



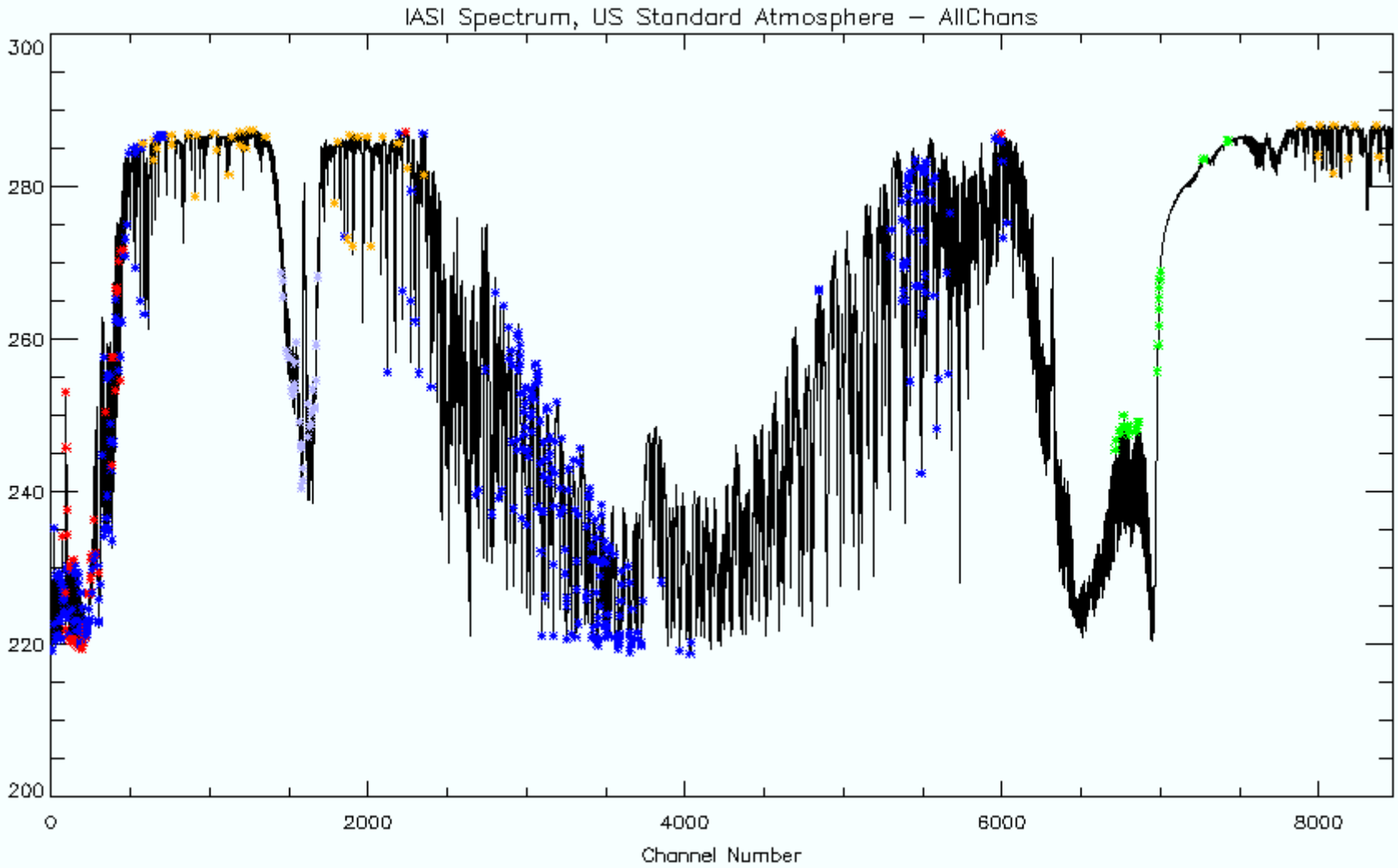
METOP preparations

- Launch on 17 July from Baikonur
- Testing systems using NCEP simulated METOP datasets
- Data reception tests using EUMETCAST
- Use ATOVS within a few months of launch
- Use ASCAT, GRAS and IASI within 18 months of launch

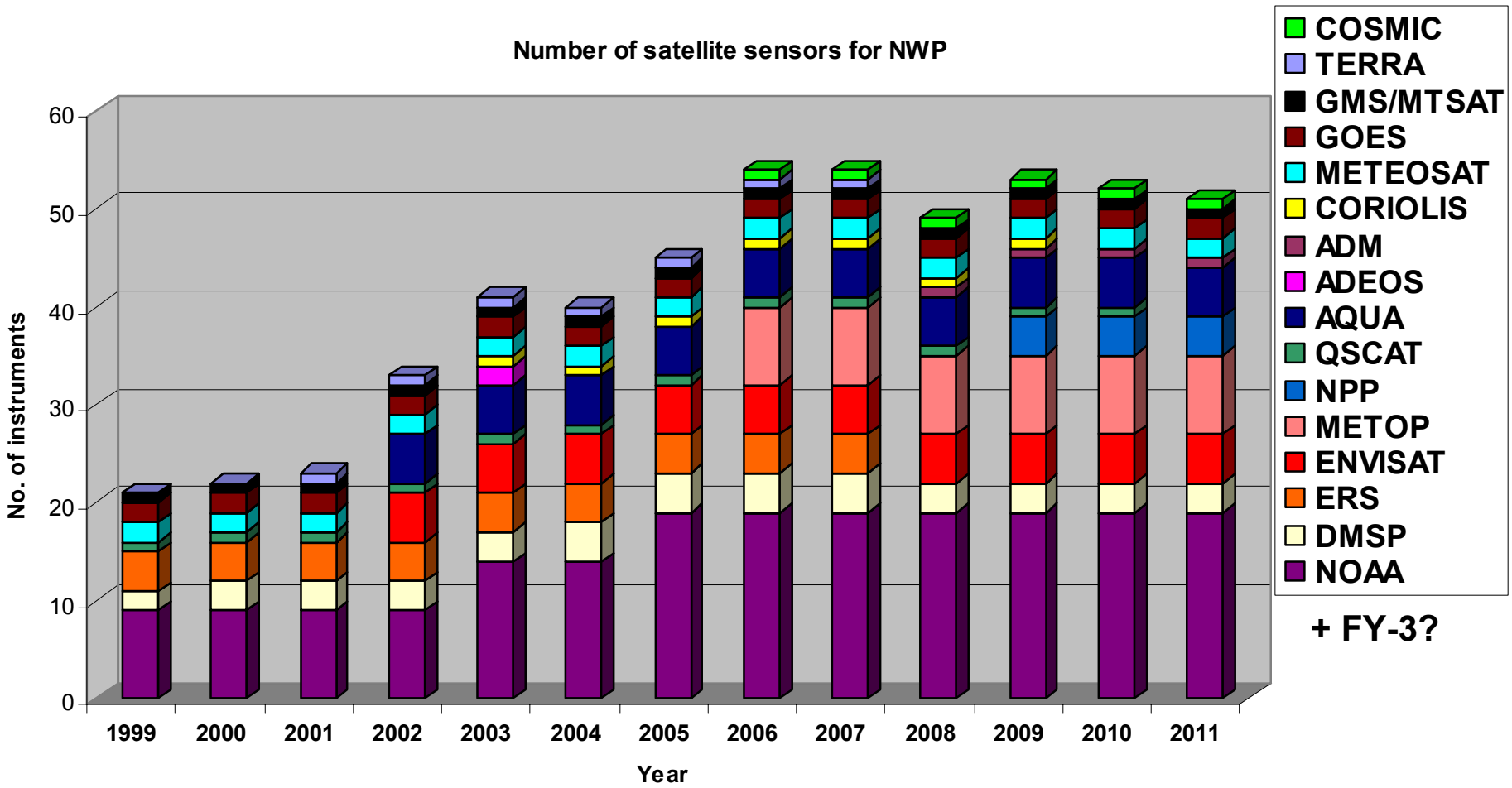
IASI Implementation

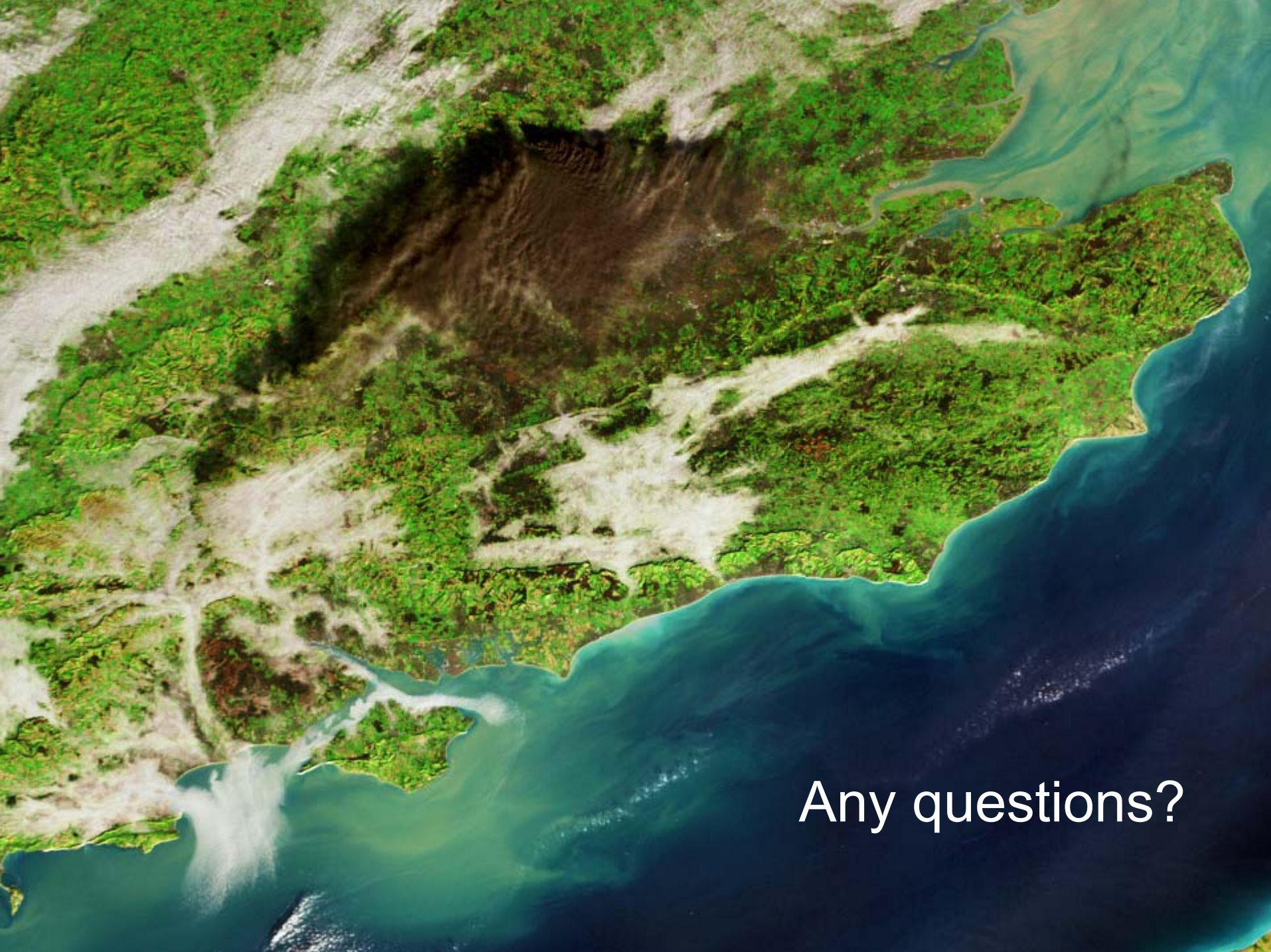
- IASI poses huge challenges because of the volume of data
  - 8461 channels, 120 observations per scan
- We will reduce this data volume by using only 300 channels and one in four observations
  - Channels selected on the basis of information content
  - Reduces data volume of one IASI to about the level of three ATOVS
- Initially, we will use the data in a very similar way to AIRS
  - Sea only
  - Clear only (via 1D-Var cloud detection)

IASI Channel Selection



Satellite data increases




Any questions?