An overview of the assimilation of IASI Radiances at operational NWP Centres

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Thank you to the co-authors!

- This is a huge joint-effort. My co-authors have spent a lot of time contributing material and answering numerous questions about their assimilation schemes
  - Met Office – me, Ed Pavelin, Graeme Kelly, James Cameron, Andrew Collard
  - Météo-France – Vincent Guidard
  - Deutsher Wetterdienst – Marc Schwaerz
  - met.no – Roger Randriamampianina
  - ECMWF – Tony McNally, Andrew Collard
  - NCEP – James Jung, Andrew Collard
  - NRL – Nancy Baker, Ben Ruston
  - Environment Canada – Sylvain Heilliette, Louis Garand

Overview

- Attempt to summarise status of IASI assimilation at operational NWP centres
- What do we do in common?
- What do we do that is different?
- What impact are we seeing from IASI?
- What are we working on at the moment?
- What do we think the major issues are regarding the use of IASI data?

How are IASI radiances used at operational NWP Centres?

Summary of models and data usage (1)

Testing Operational

	Model	Domain	Model Top/ N Levels	Horiz. Resn.	Assimilation System	Bias Correction
Met Office	Global	Global	80km/L70	~60km	4D-Var	Harris&Kelly
	NAE	N Atlantic & Europe	39km/L38	~12km	4D-Var	Harris&Kelly
	UK4/UKVD	UK	40km/L70	4/1.5km	3D(or4D)-Var	Harris&Kelly
Météo-France	ARPEGE	Global	0.1hPa/L60	10-60km	4D-Var	VarBC
	ALADIN	W Europe	0.1hPa/L70	7.5km	3D-Var	VarBC
	AROME	France	1hPa/L60	2.5km	3D-Var	VarBC
ECMWF	Global	Global	80km/L91	~25km	4D-Var	VarBC
DWD	GME	Global	10hPa/L60	40km	3D-Var	Harris&Kelly
	COSMO-EU	Europe	20hPa/L40	7km	Nudging	Harris&Kelly
met.no	HARMONIE	N Pole & Europe	0.2hPa/L60	11-16km	3D-Var	VarBC

Summary of models and data usage (2)

Testing Operational

	Model	Domain	Model Top/ N Levels	Horiz. Resn.	Assimilation System	Bias Correction
NCEP	GFS NAM	Global Regional	0.27hPa/L64 2hPa/L60	~35km 12km	3D-Var 3D-Var	VarBC VarBC
Env. Canada	GEM	Global	0.1hPa/L80	~33km	4D-Var	Dynamic, self-updating "H&K-like"
NRL	NAVDAS-AR	Global	0.4hPa/L42	~55km	4D-Var	Harris&Kelly

- Mostly variational assimilation techniques
- Model top issues for LAM
- Division between Var-BC and Harris&Kelly

Data selection and thinning (1)

	Data Usage	Thinning
Met Office	Clear spots only (limited channels above MW cloud). Moving to channels above cloud Sea and Land	1 pixel in 4 then 154km/80km
Météo-France	Above cloud Sea, Land and Sea-ice	1 pixel in 4 then 125km
ECMWF	Above cloud, all channels for homogeneous cloud Sea and Sea-ice	1 pixel in 4 then 120km
DWD	Above cloud Sea only	1 pixel in 4 then 1 ob in 2
met.no	Above cloud Sea and Land	1 pixel in 4 80km/120km

Data selection and thinning (2)

	Data Usage	Thinning
NCEP	Above cloud Sea, Land and Sea-ice	180km
Environment Canada	Above cloud (Cloud-affected under test) Sea, Land and Sea-ice	1 pixel in 4 then 125km
NRL	Above cloud Sea	1 pixel in 4 then 120km

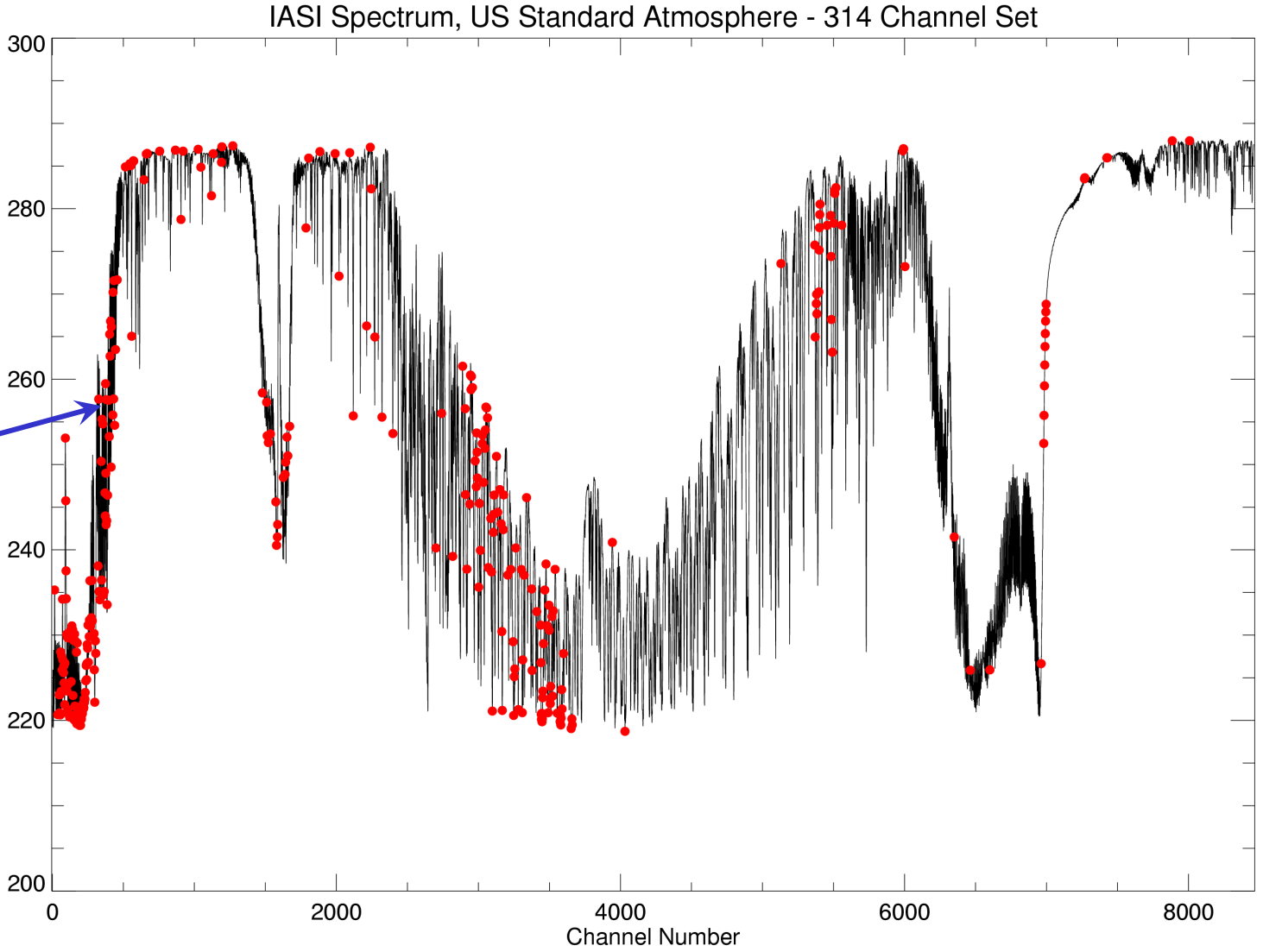
- Different strategies for determining what is “above cloud” at different centres
- General move to assimilating “cloud-affected channels” rather than “clear channels”

Channel selection

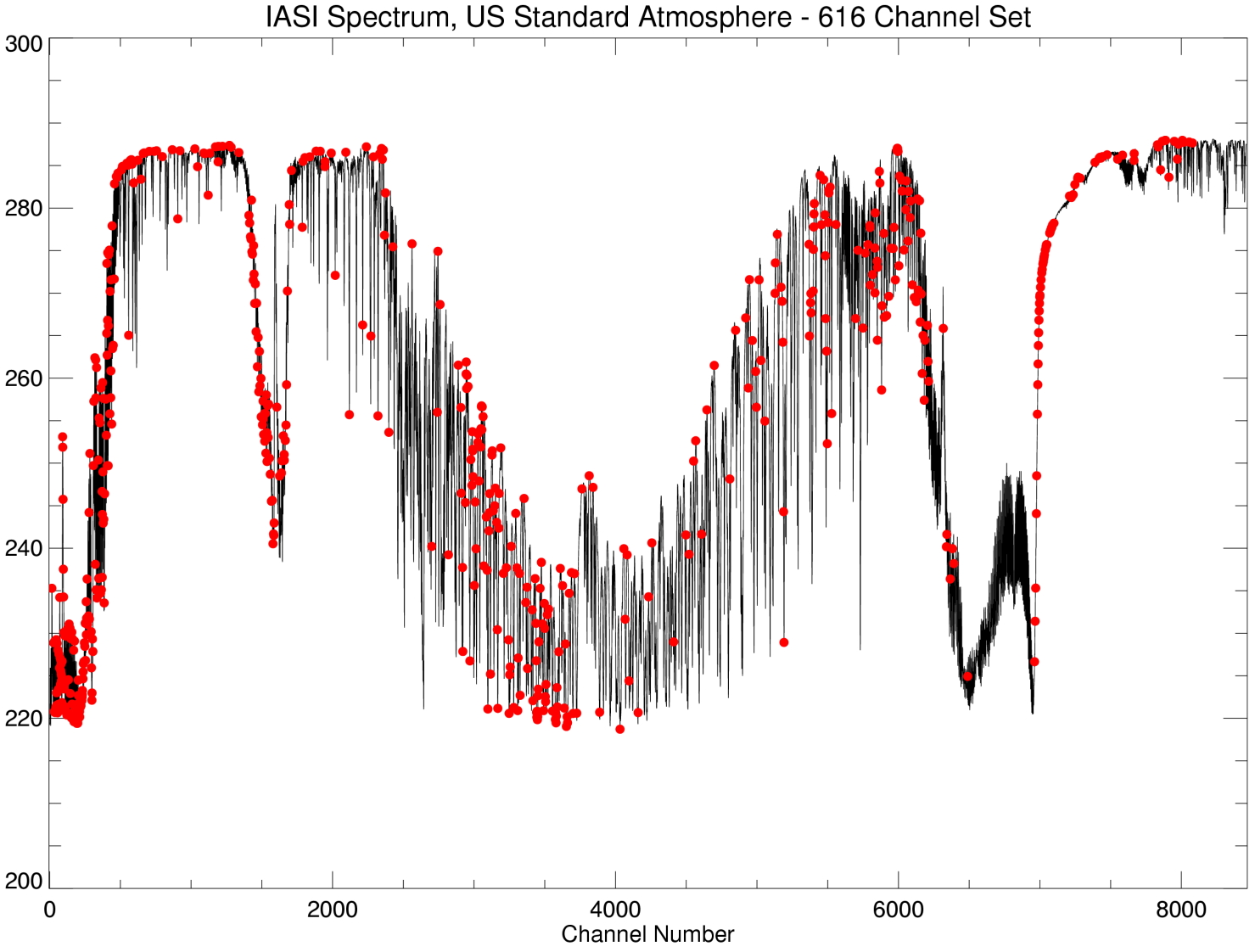
- All centres use a restricted channel set for assimilation
- Based on 314 channel set from Collard (2007)
  - ECMWF add 52 more T sounding channels to base set
  - N American centres have access to 616 channels from NOAA
- General principles
  - Use channels in long-wave CO_2 band
  - Use as many of these as possible!
  - Generally restrict usage of stratospheric channels
  - Generally, restrict usage of surface-viewing channels
  - Some centres already use some water vapour channels, but most are working on this
  - More conservative channel selection over land and ice

314/366 Channel set

366 channel set has more LW CO2 channels



616 Channel set



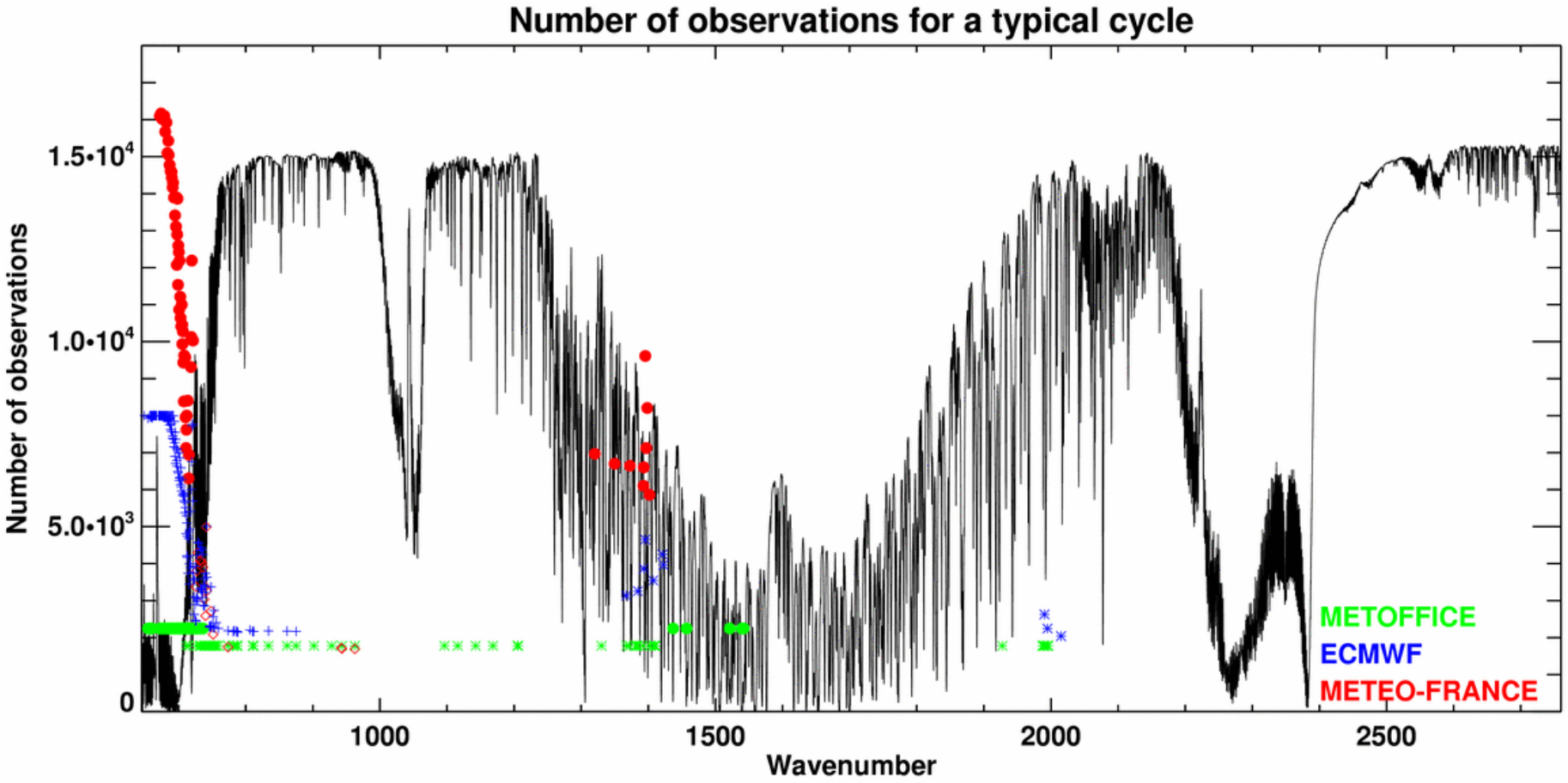
Channel selection

	Sea	Land	Sea-ice
Met Office	151 T/surf 32 WV (for MW cloud same channels as land)	57 T 6 with WV sensitivity	
Météo-France	Up to 68 T Up to 9 WV	Up to 50 T Up to 9 WV	Up to 32 T Up to 9 WV
ECMWF	Up to 165 T Up to 10 WV		Up to 165 T
DWD	Up to 122 T Perhaps up to 93 WV	New results to come ITSC!	
met.no	Up to 41 T	Up to 9 T	

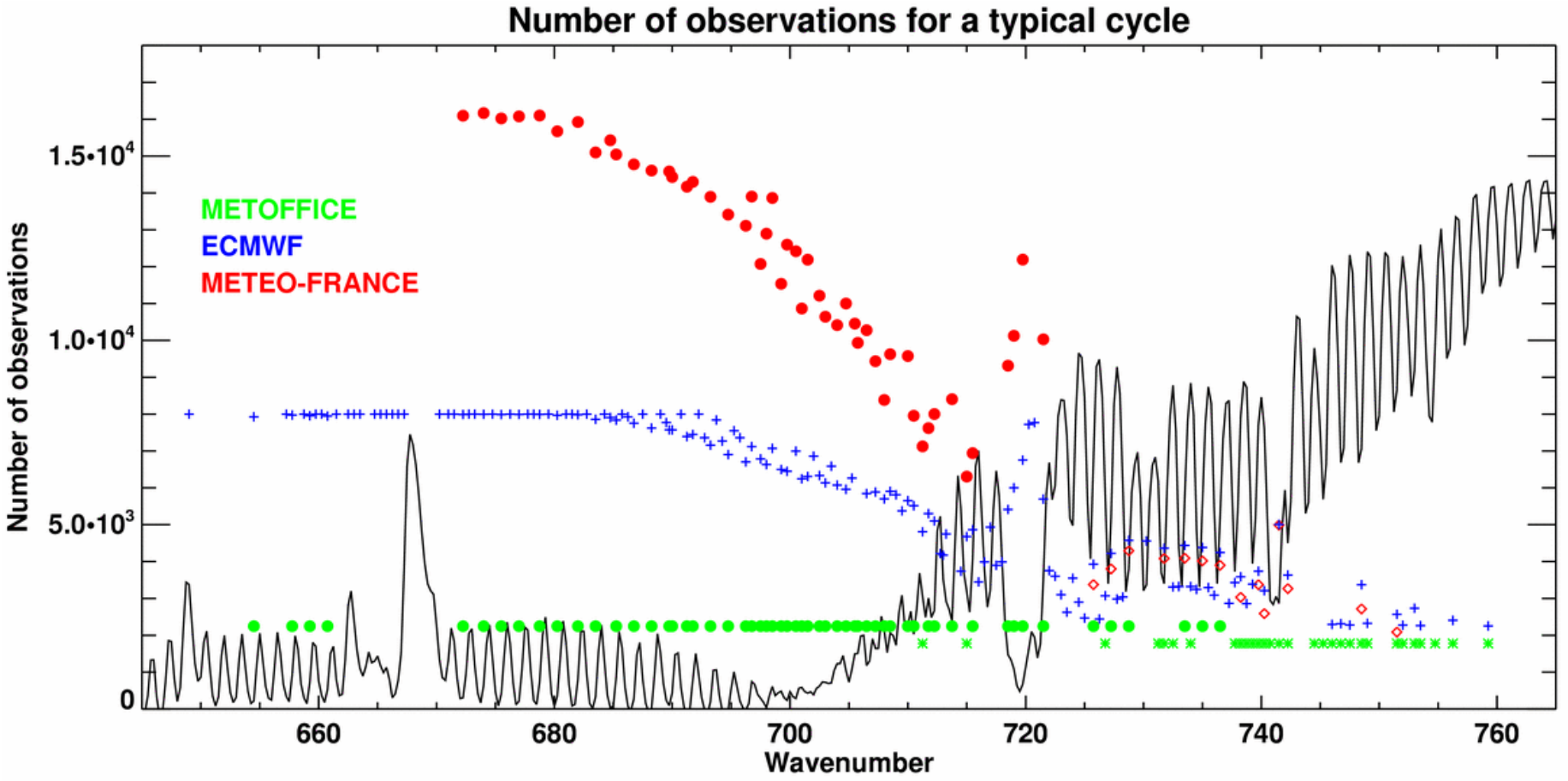
Channel selection

	Sea	Land	Sea-ice
NCEP	Up to 165 T	Up to 165 T	Up to 165 T
Environment Canada	65 T 66 WV 19 surface Planned O_3	?	?
NRL	Up to 41 T		

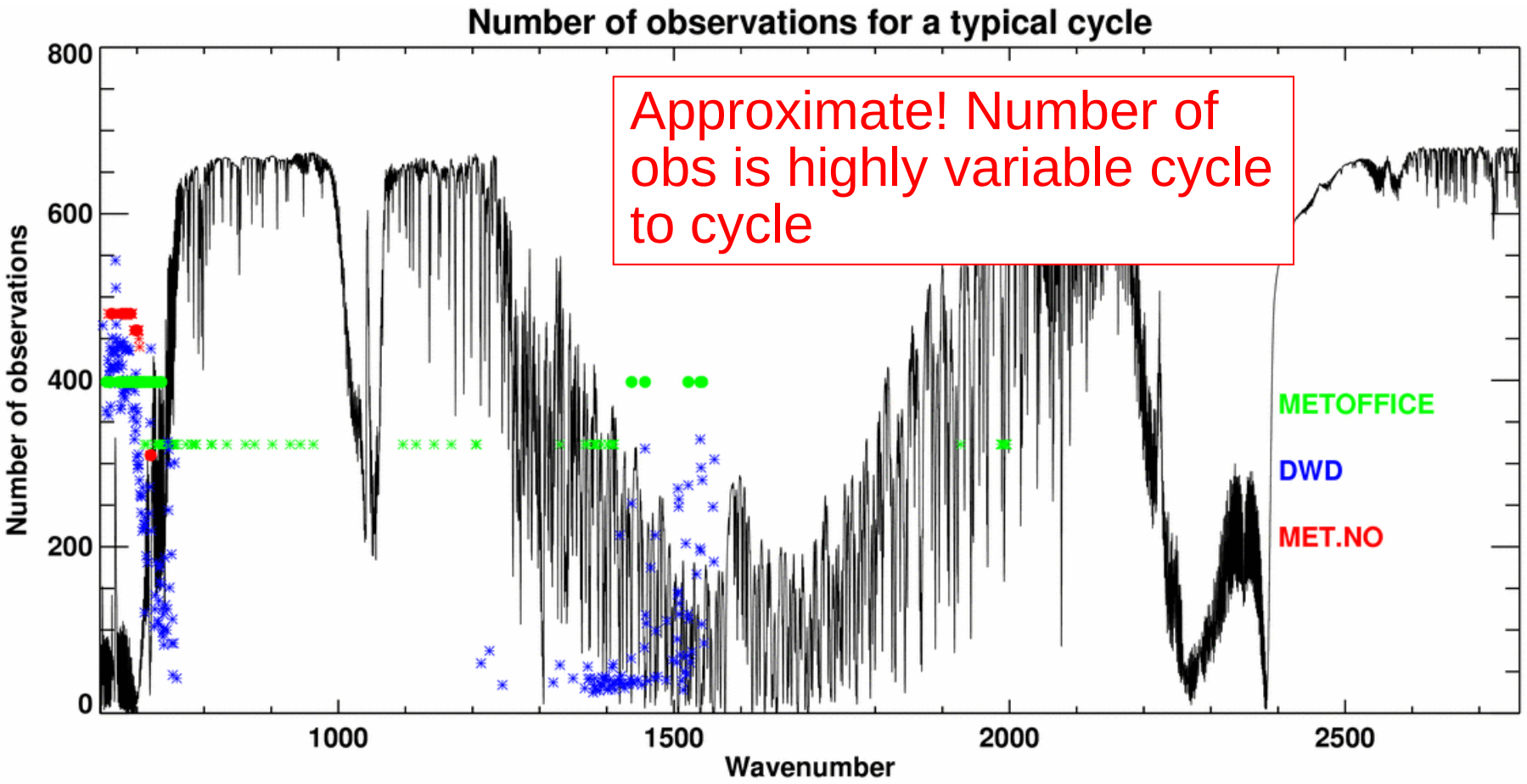
Example Number of obs per cycle – Global Models (Europe)



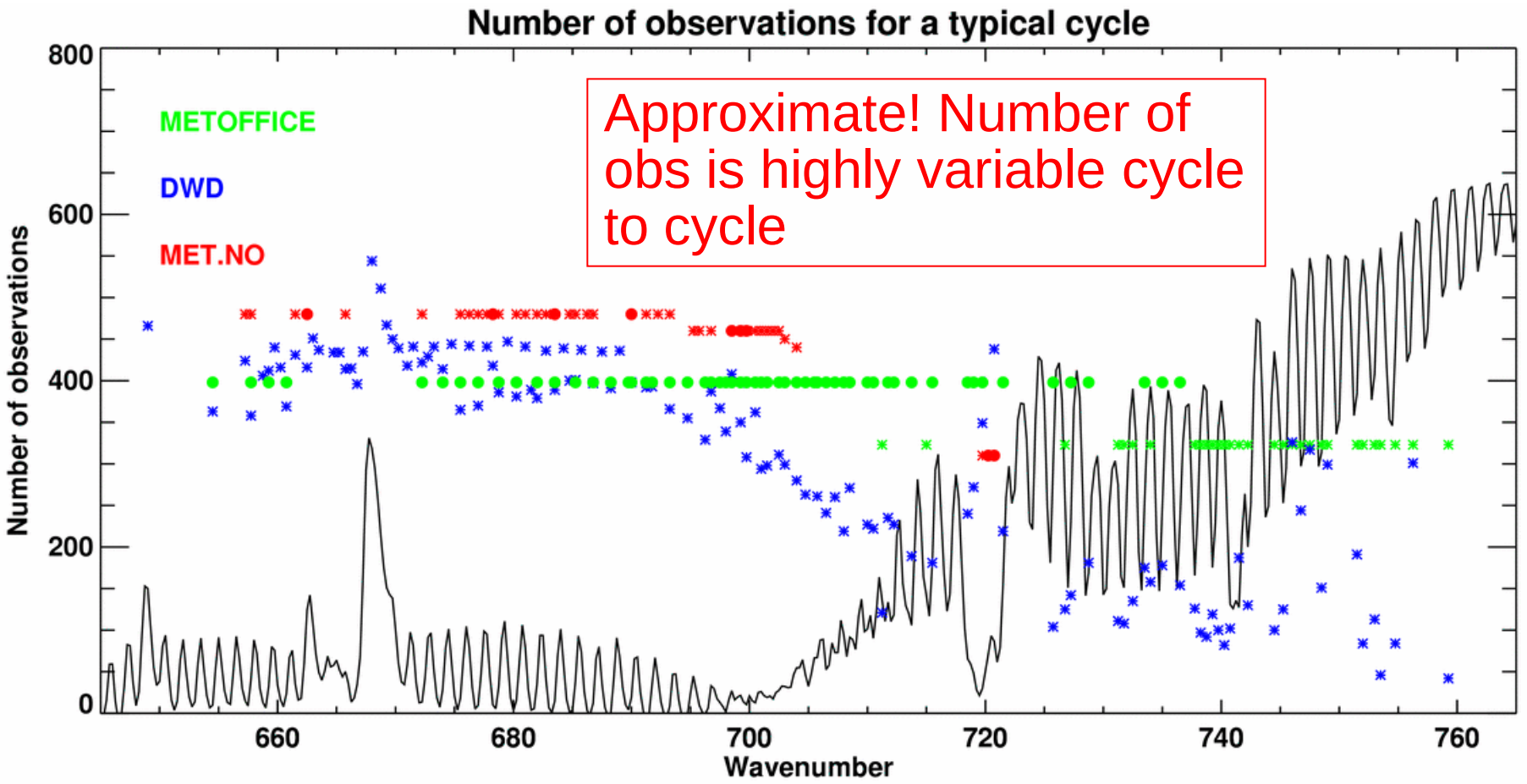
Example Number of obs per cycle – Global Models – Europe (Band 1)



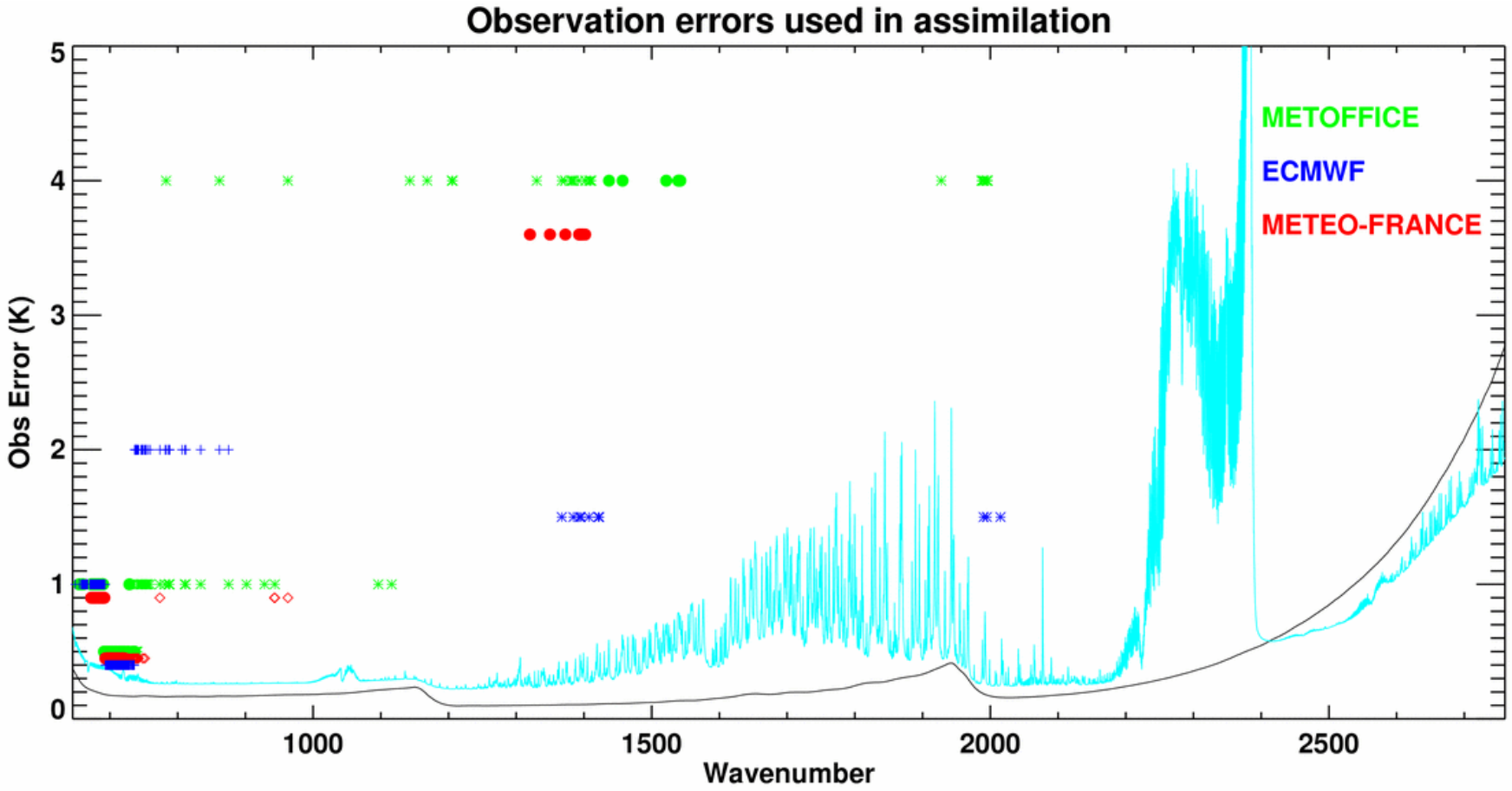
Example Number of obs per cycle – Limited Area Models (May 2009)



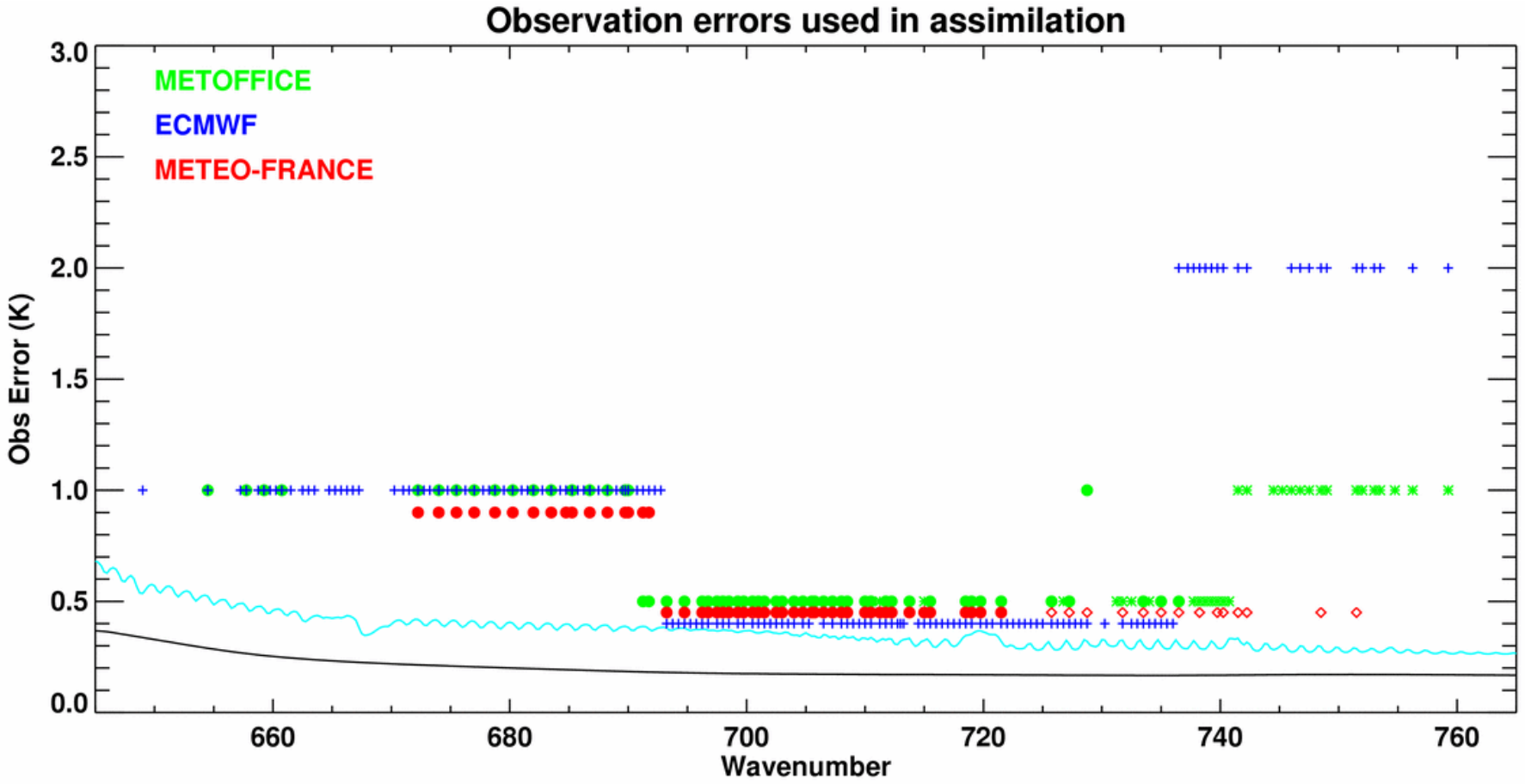
Example Number of obs per cycle – Limited Area Models (May 2009)



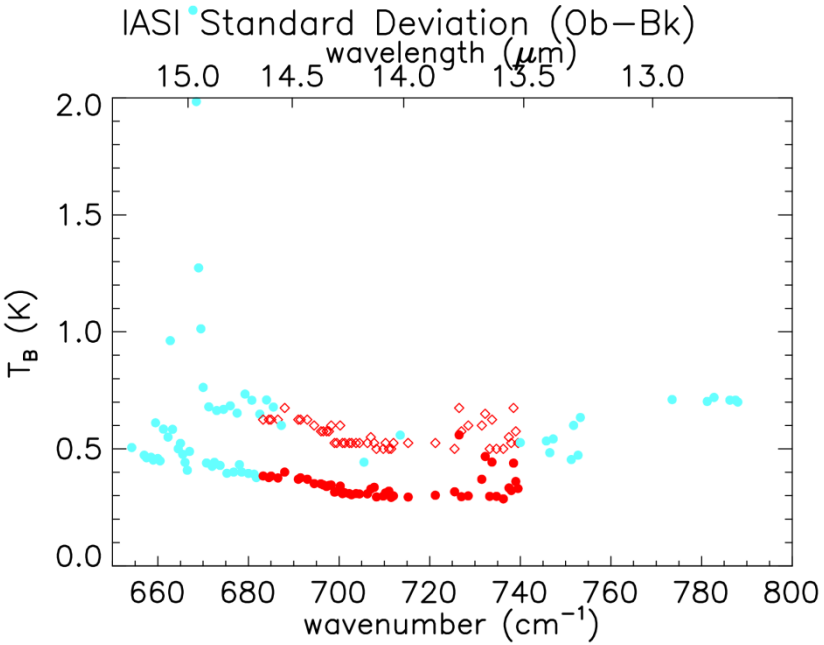
Observation Errors – Global Models (Europe)

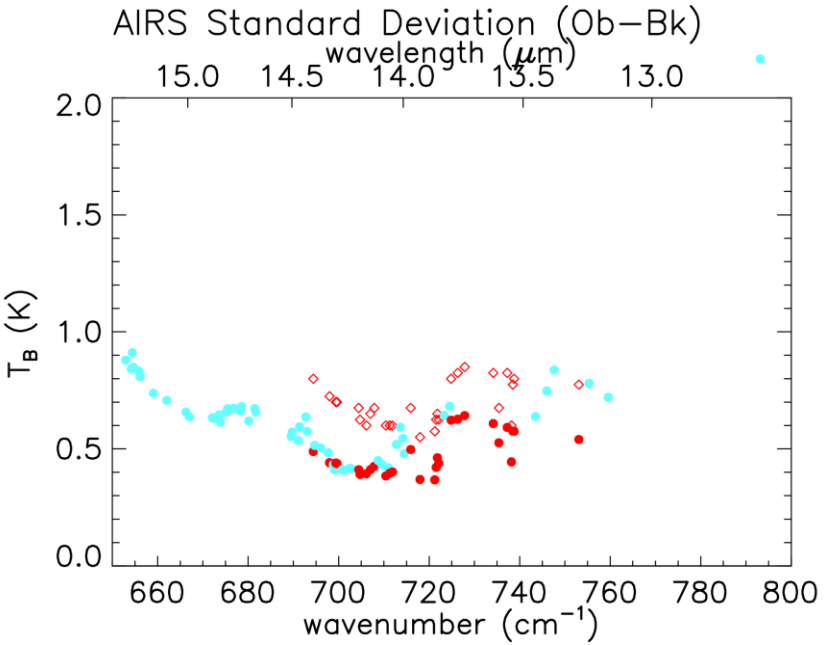


Observation Errors – Global Models (Europe)

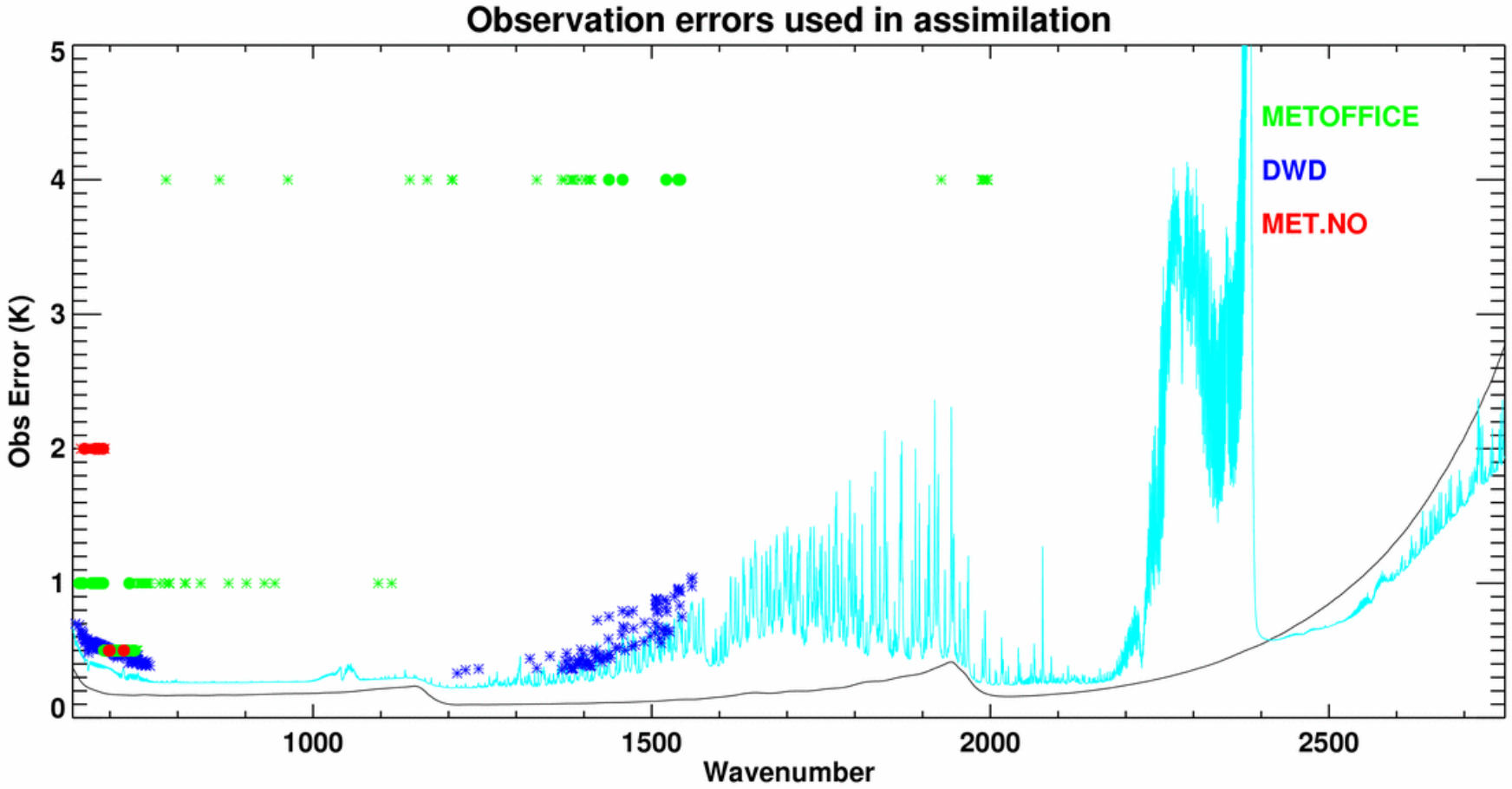


NRL Obs errors NAVDAS-AR

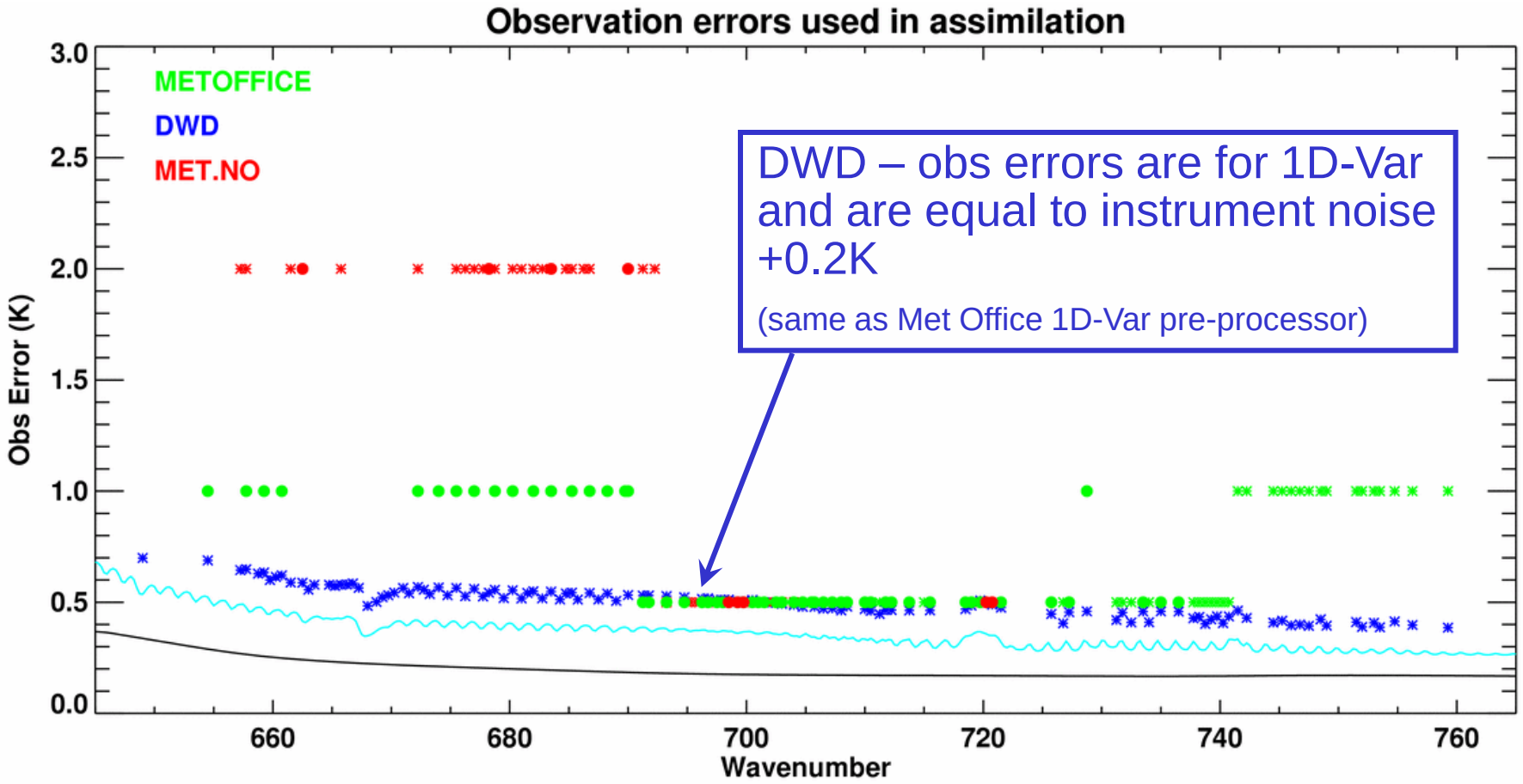




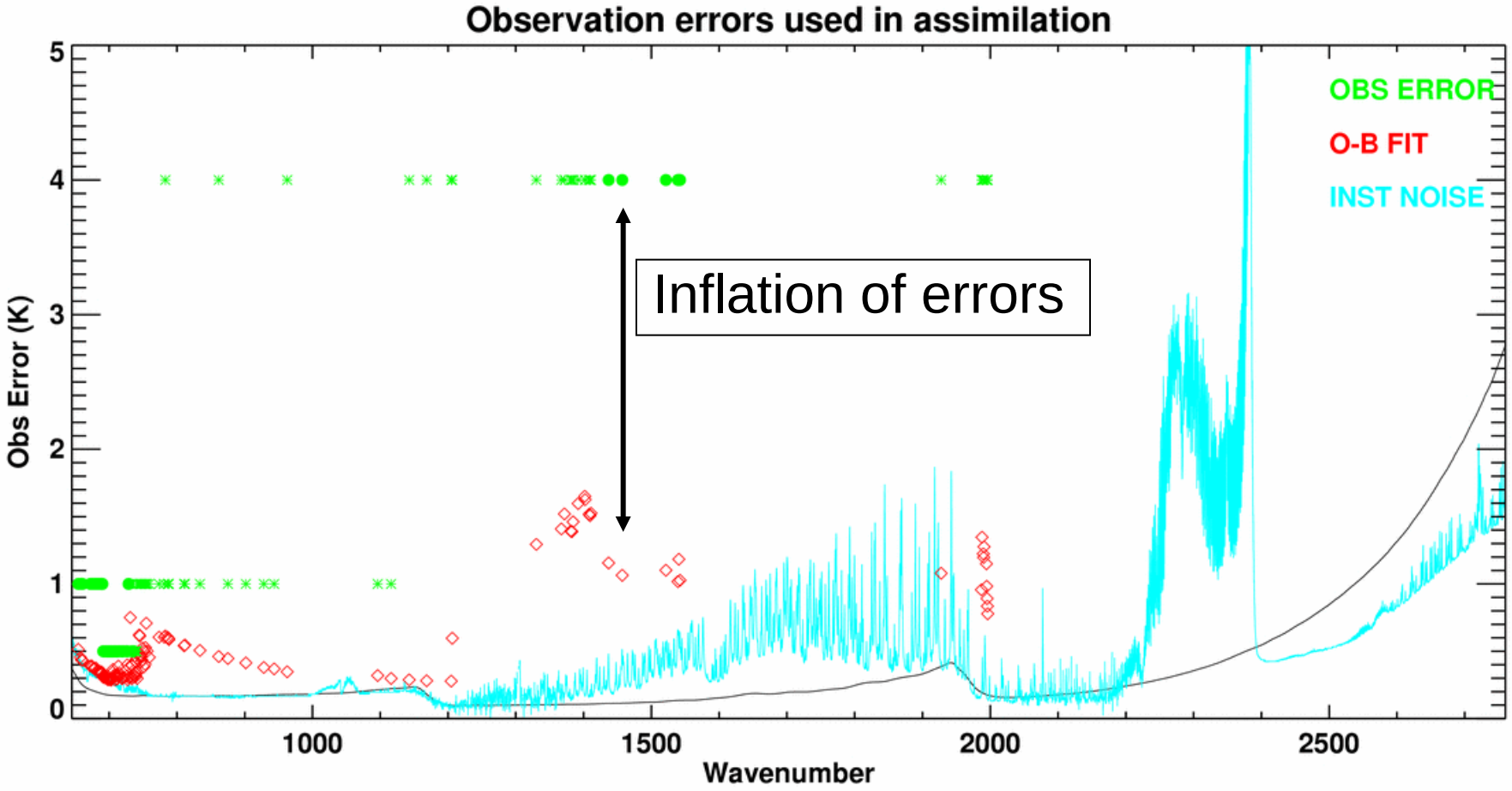
Observation Errors – Limited Area Models



Observation Errors – Limited Area Models



How do observation errors compare to model fit to data? (Met Office May 2009)



Summary of IASI data usage (1)

- All centres are assimilating radiances apart from DWD's LAM which uses a nudging scheme
- All centres heavily thin the data (start with only 1 pixel in 4)
- All centres use a channel selection of at most ~200 channels
- All centres are using predominantly channels in the long-wave CO_2 band
- Some centres are additionally using some water vapour channels, others are working on this also

Summary of IASI data usage (2)

- Channel selection is usually restricted over land and sea-ice, or depends on quality control to reject observations
- Height of model top generally restricts usage of high-peaking channels, particularly in LAM
- Observation errors are inflated significantly over O-B fit
- There are some differences in bias correction scheme, roughly 50:50 divide between VarBC and Harris&Kelly
- European centres + Canada use RTTOV, US use CRTM
- General move towards cloud-affacted radiances

Impact of IASI data assimilation in NWP

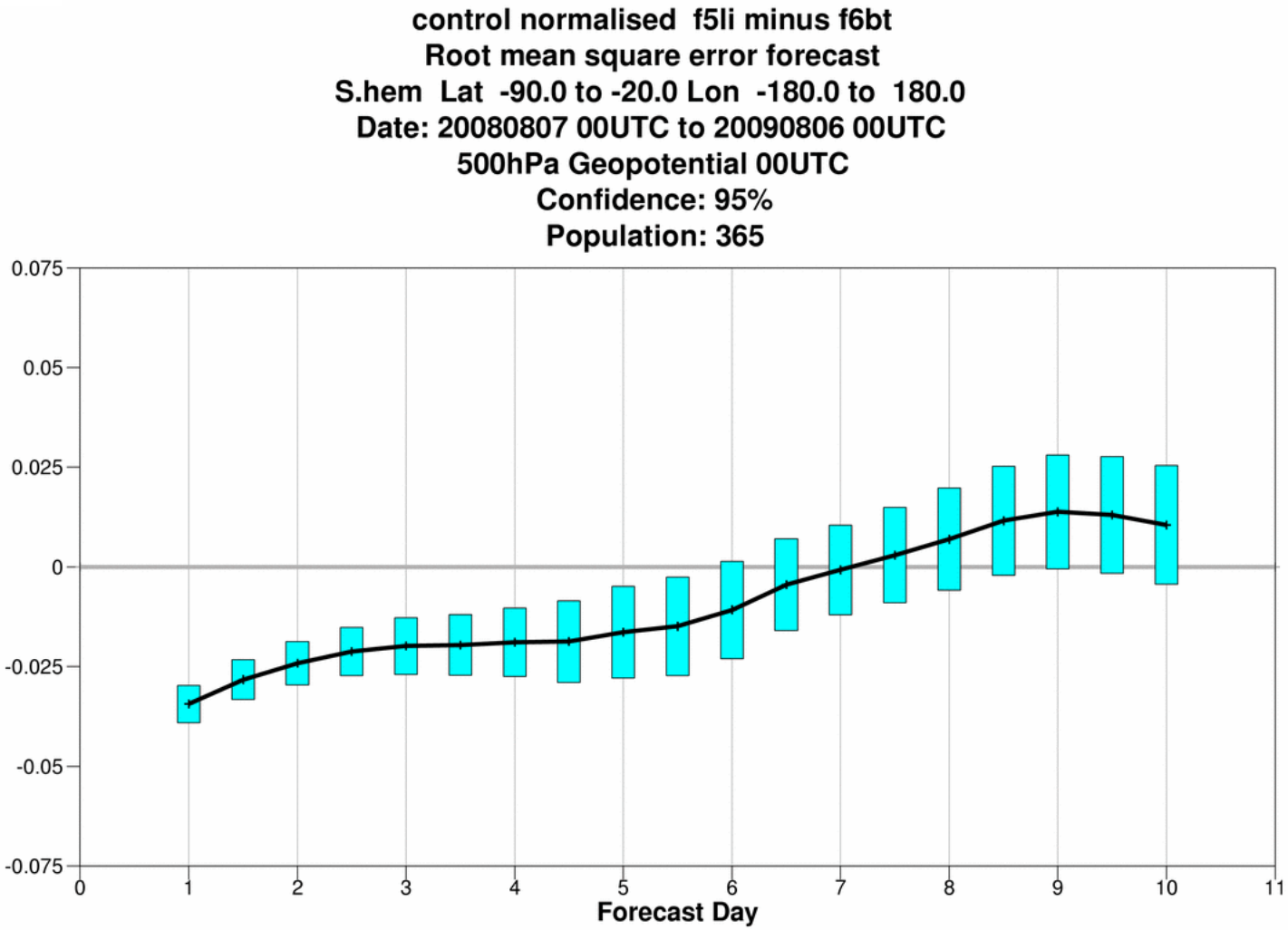
Comparing impacts between centres

- It is quite hard to compare impacts at different centres directly
- All centres use different methods to assess impact
- Everyone produces different types of plots!

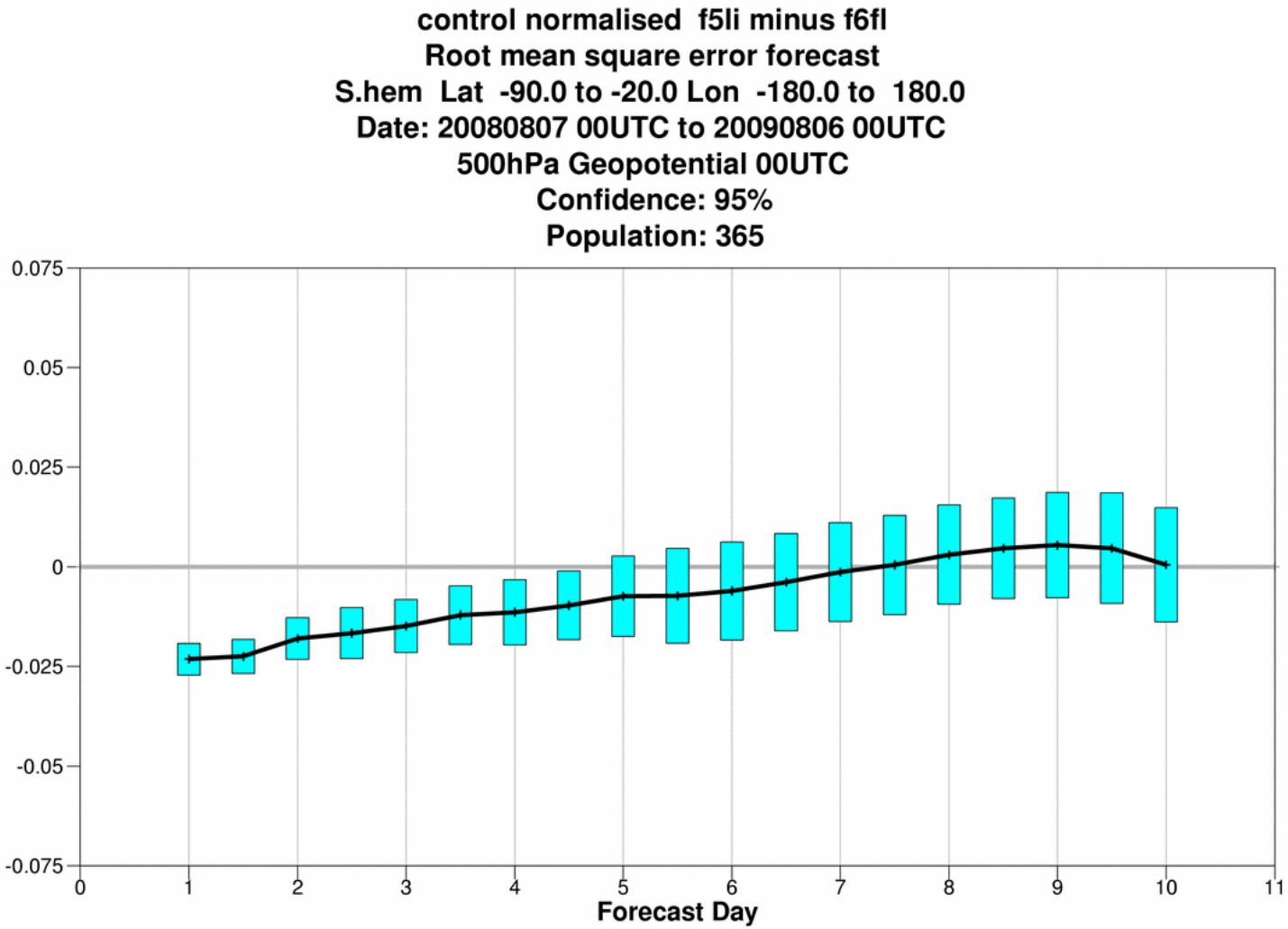
Summary of impacts in Global Models

- All centres see good positive impact with assimilation of IASI data
- Anecdotal evidence (i.e. the plots I have seen) suggests that impact tends to be good at medium forecast ranges (~72 hours plus)
  - Of course this is a hugely generalised conclusion and I'm sure everyone can come up with exceptions
- Impact good in the southern hemisphere as expected
  - Benefit in northern hemisphere also
- General improvements to most fields can be seen
- Impact from IASI tends to be as good as any previously observed impact from satellite data, and probably better

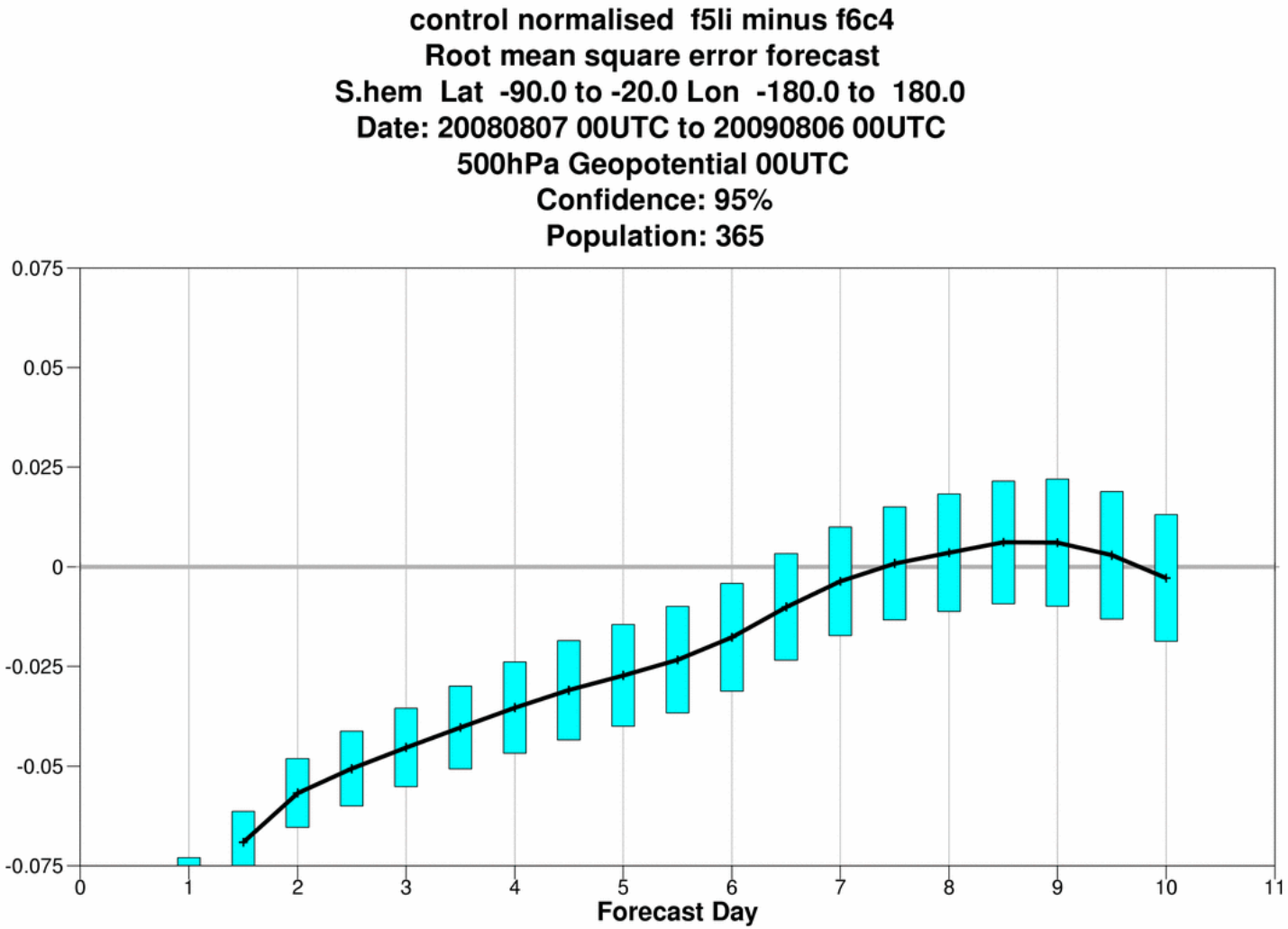
Long period trialling impact ECMWF IASI



Long period trialling impact ECMWF AIRS

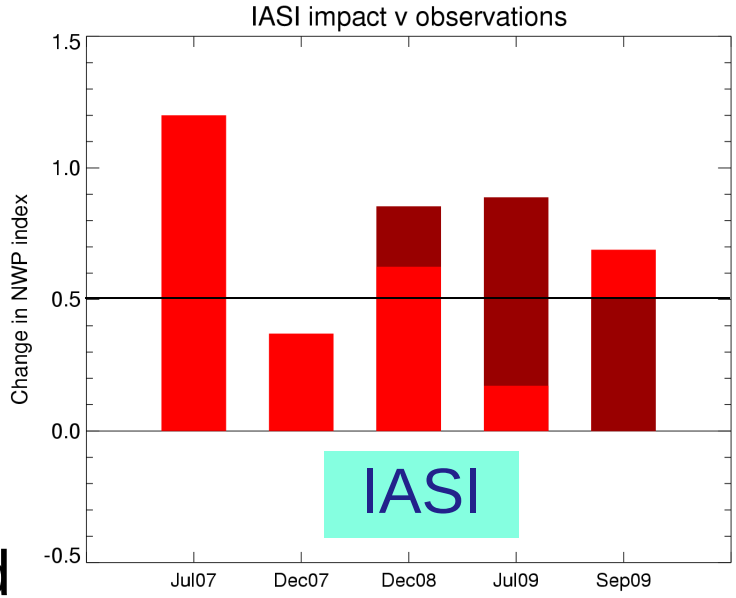


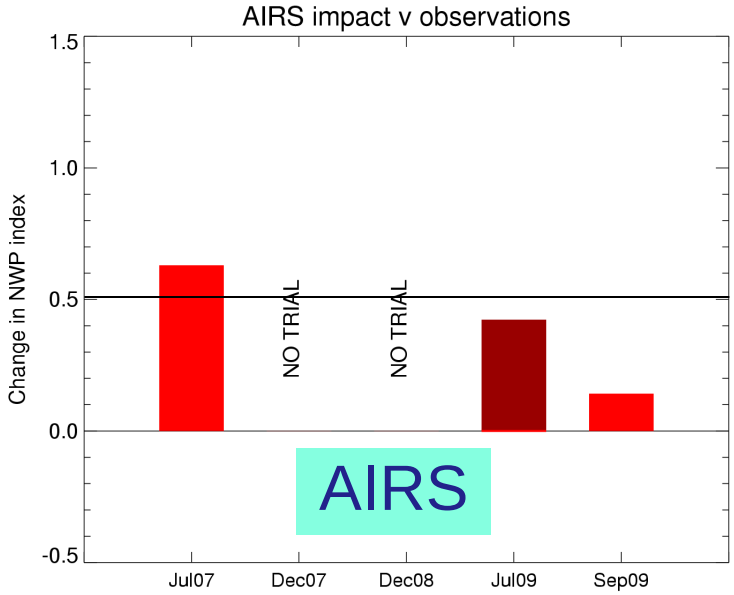
Long period trialling impact ECMWF IASI+AIRS

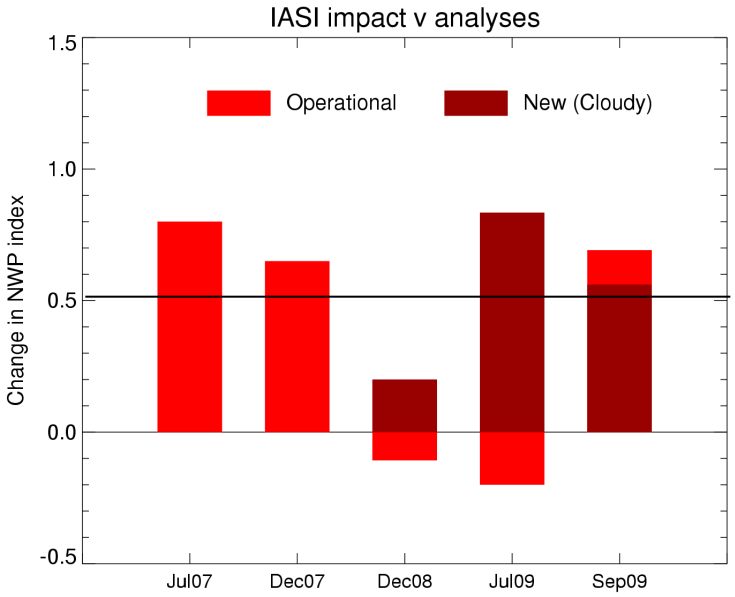


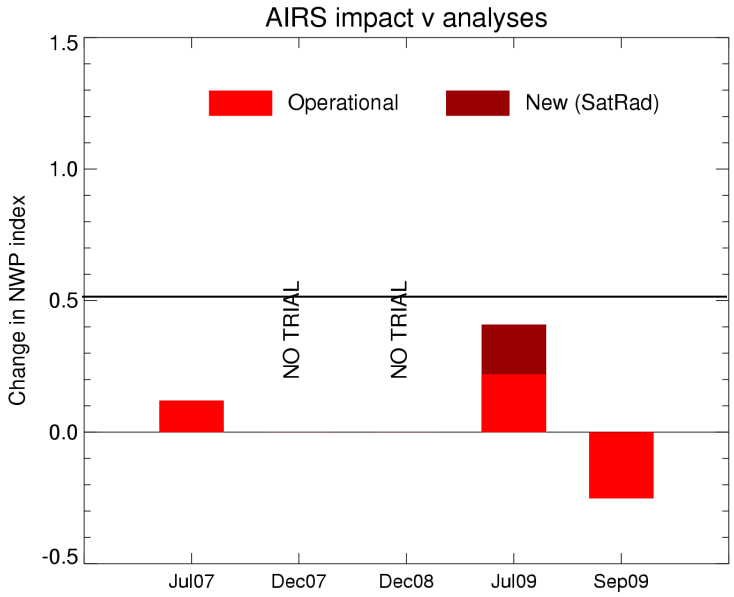
Met Office time series of impact trials

Variations in impact results are not really understood at this time



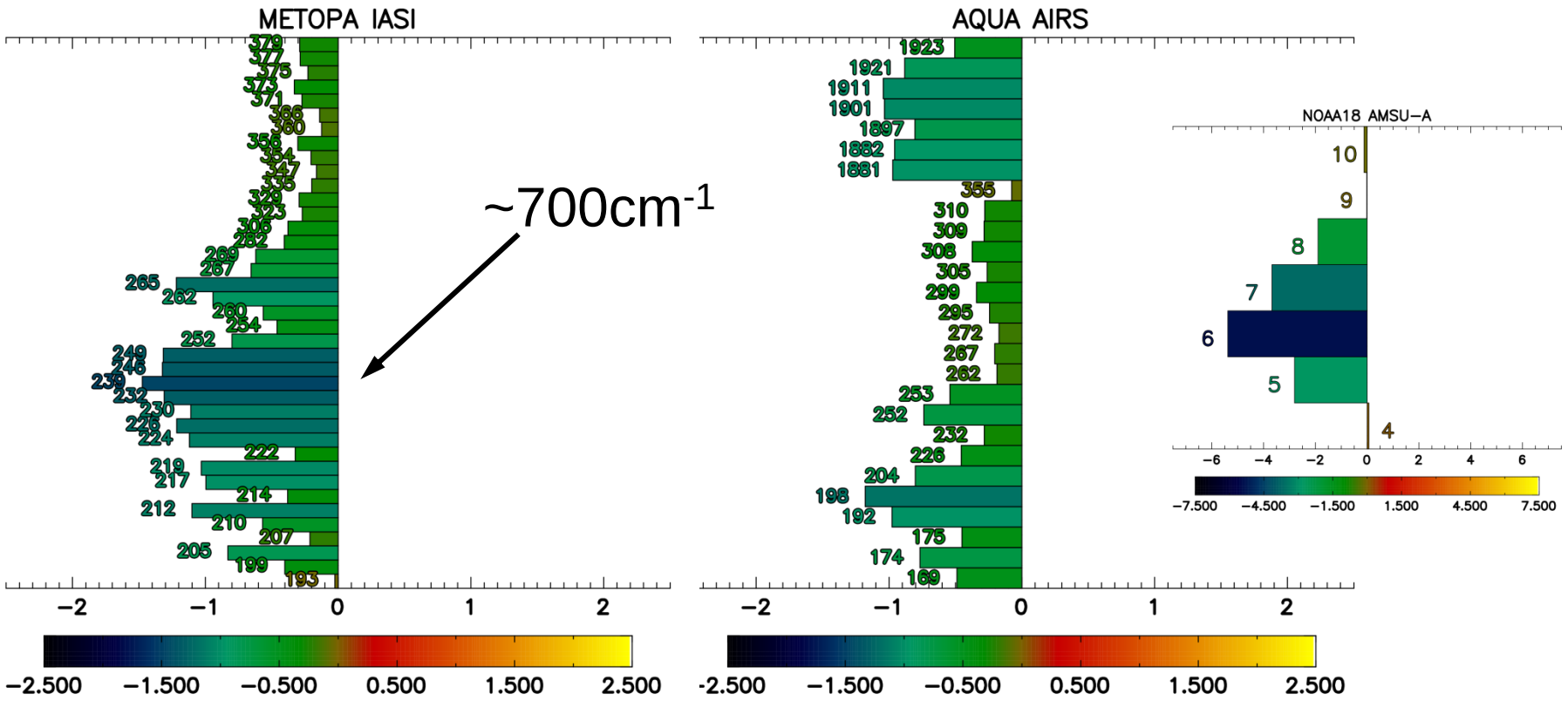






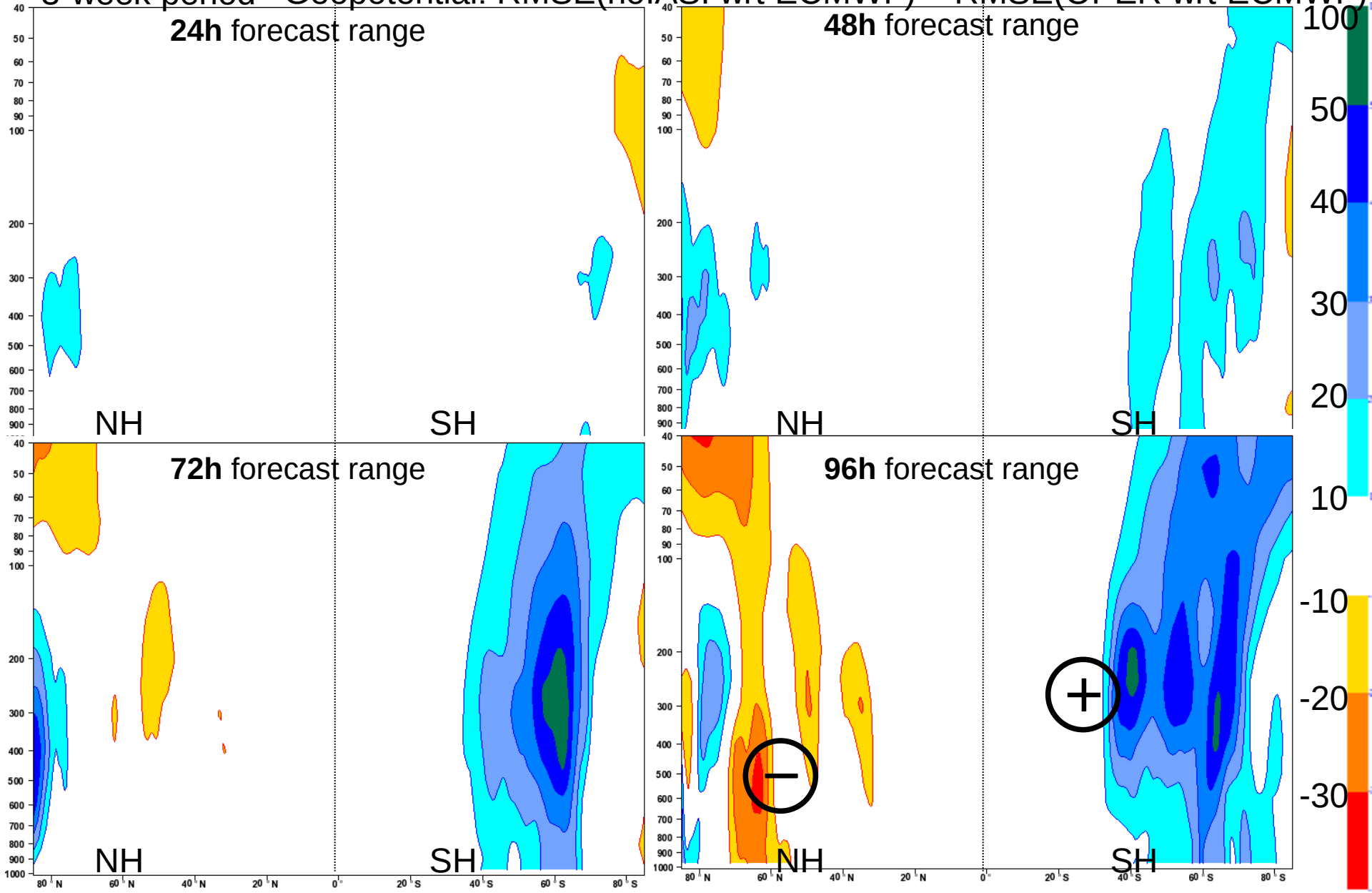
Adjoint technique impact by channel NRL

Individual Channel Impact Summation over time by Sensor

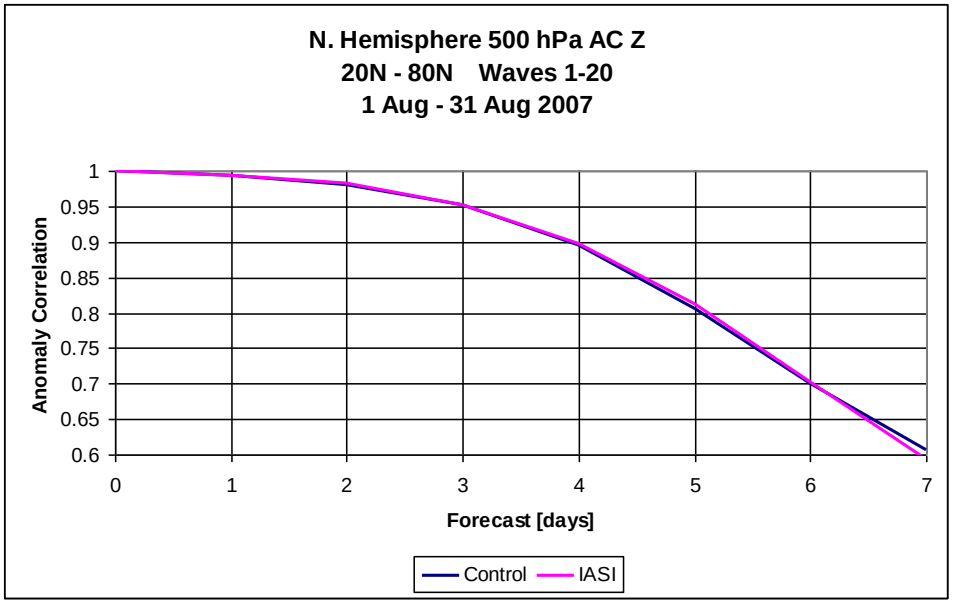


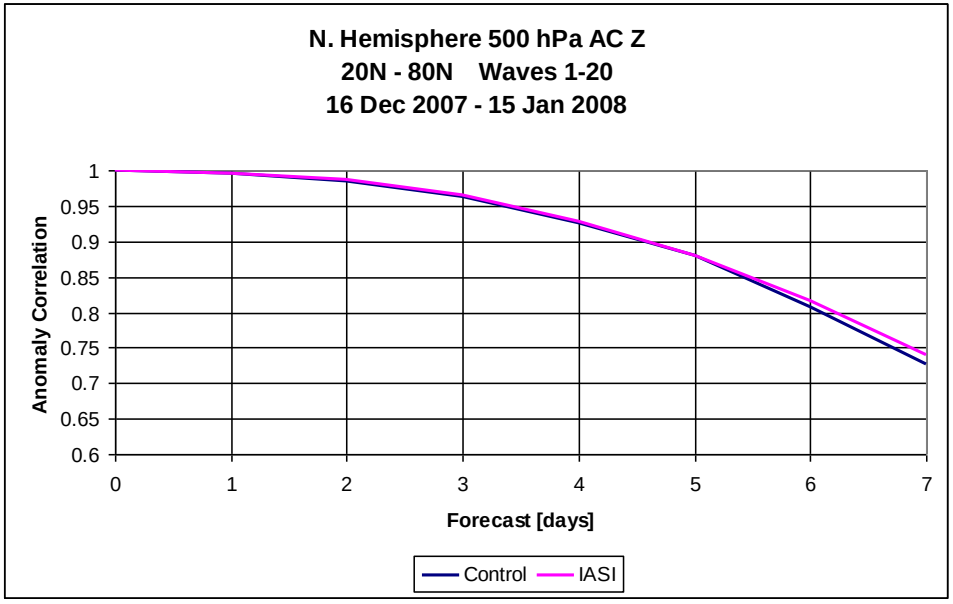
Meteo-France global model impact

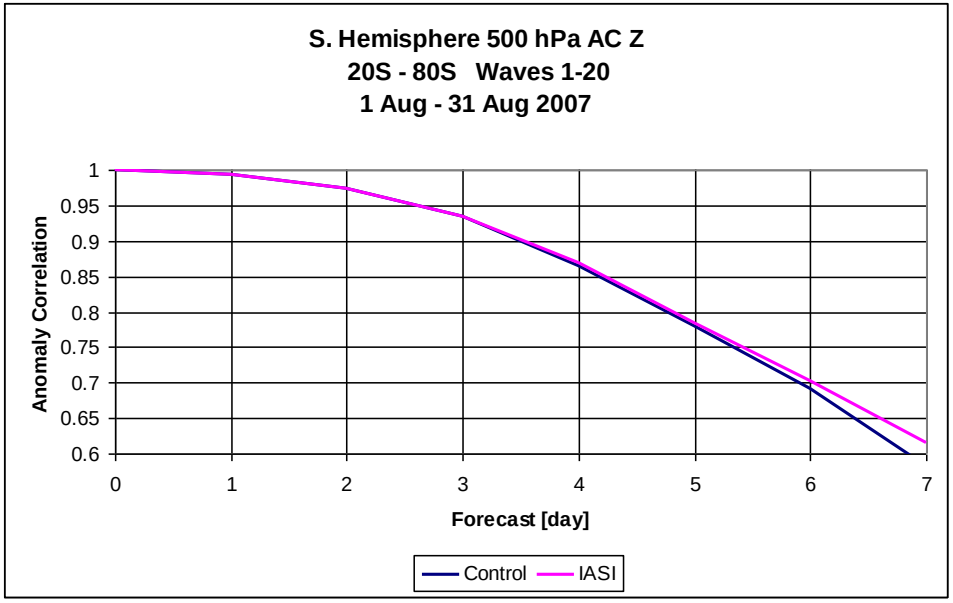
3-week period Geopotential: RMSE(noIASI wrt ECMWF) – RMSE(OPER wrt ECMWF)

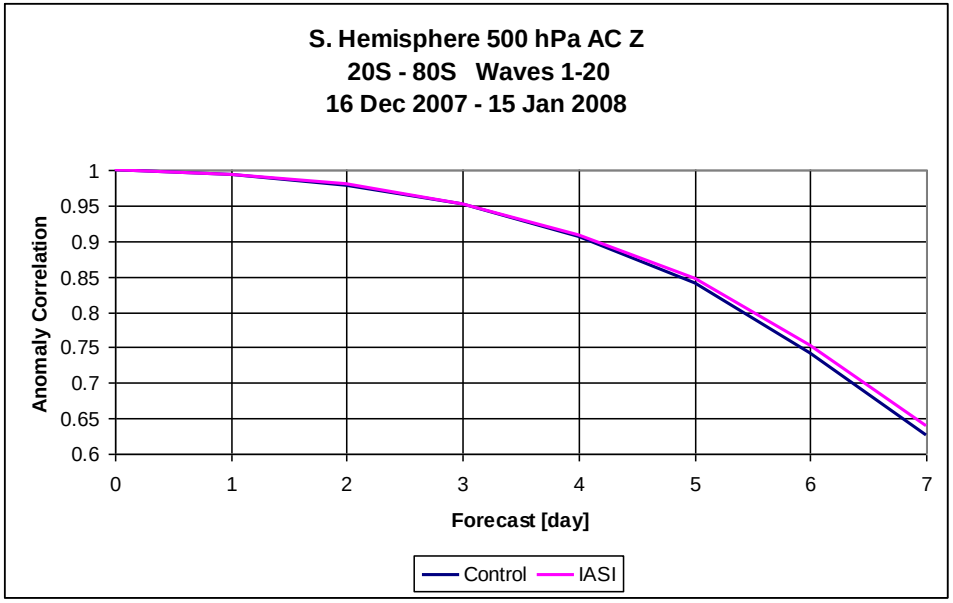


NCEP – 2 season anomaly correlation results





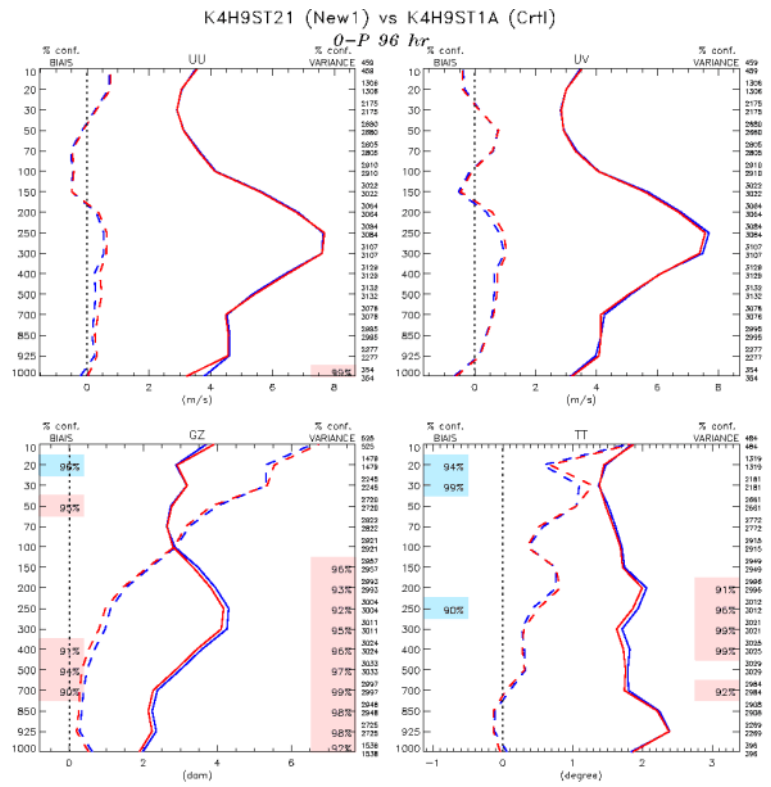




Environment Canada – southern hemisphere impact

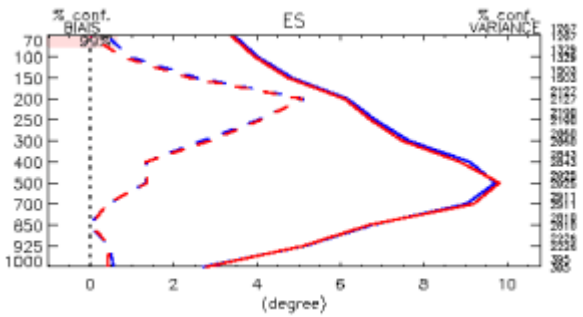
- Validation of forecasts against radiosondes: Southern hemisphere 96 h

Wind



Geopotential height Temperature

Dew point depression



54 cases

Legend:

Control is better

Test is better

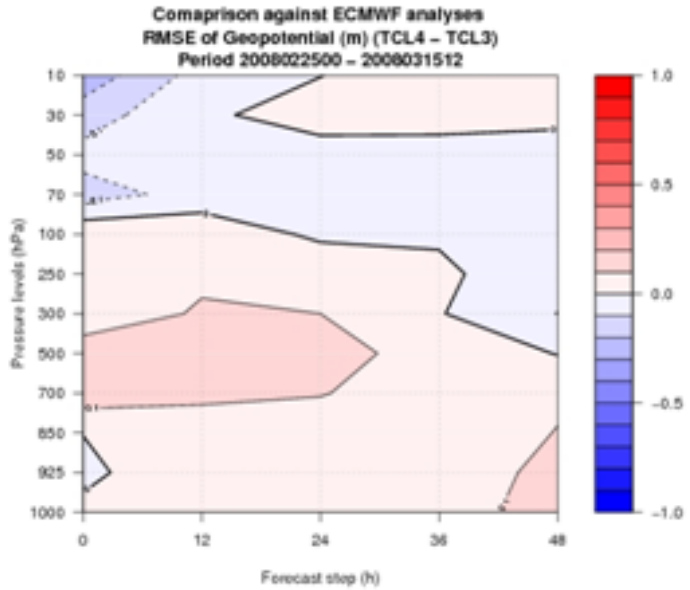
Summary of impacts in Limited Area Models

- Impact in LAMs can be harder to prove
  - Neutral results in Met Office model which uses surface weather variables for impact assessment
- Good improvements of RMS for upper air fields
- In particular geopotential height
- Wind fields are somewhat improved

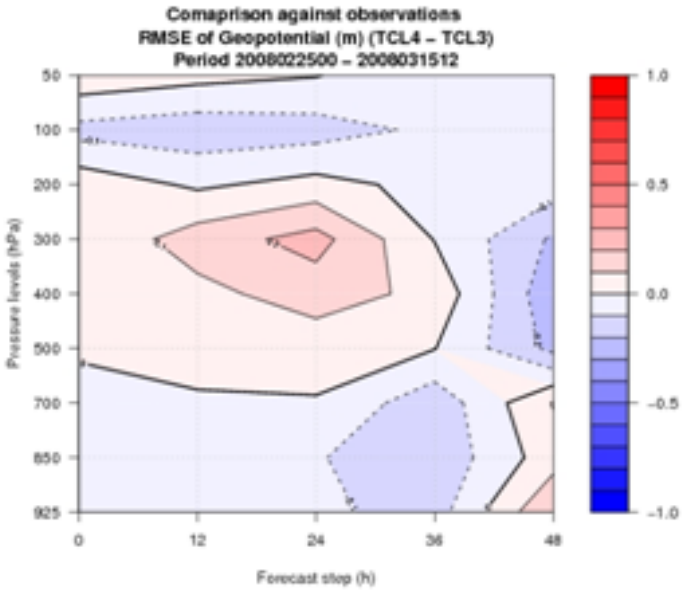
- Improvements in case study forecasts when weather is developing within the region of the LAM itself
- IASI impact best when combined with other observation sources (Randriamampianina poster)

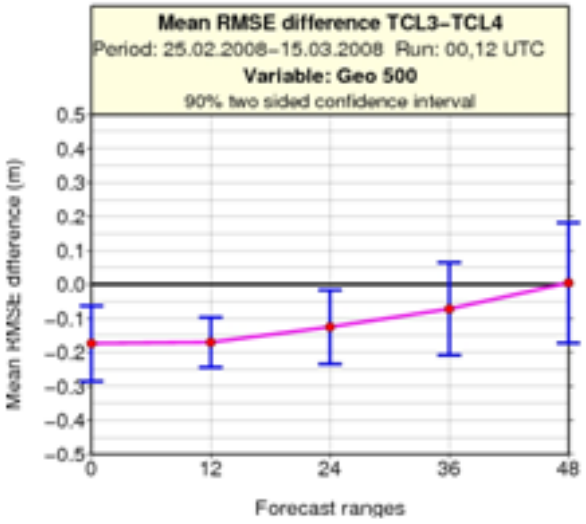
Norwegian Meteorological Institute
met.no

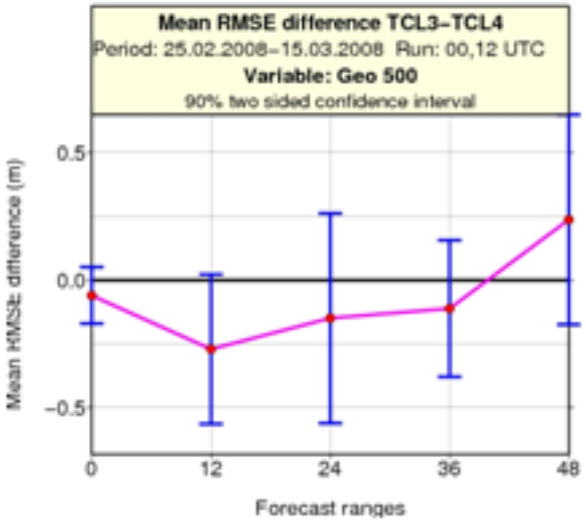
met.no special validation campaign



Impact on Geo exp. without campaign data

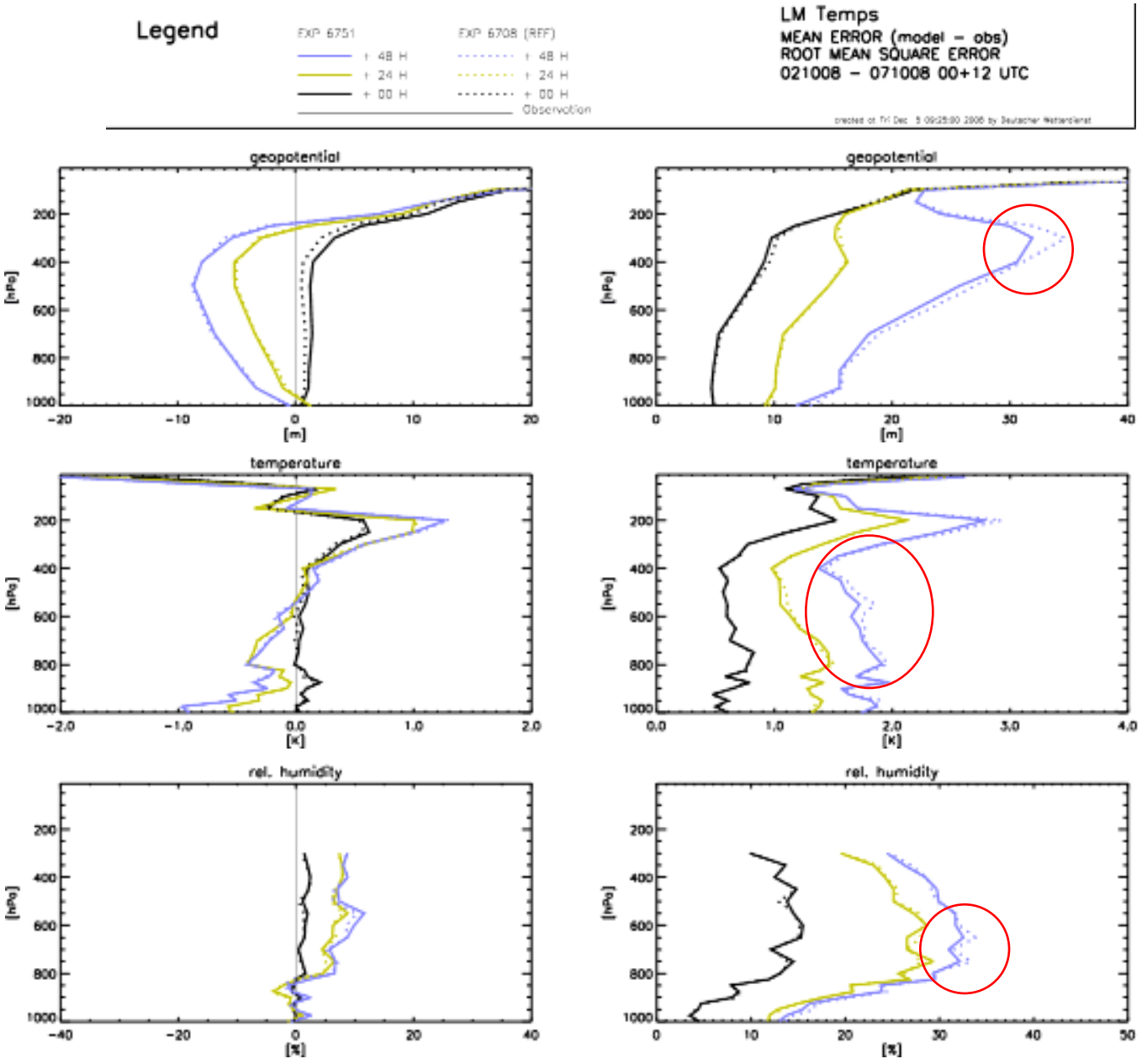






DWD impact in Cosmo-EU

- Solid IASI
- Dashed control
- LH plot Bias
- RH plot RMSE



Current areas of research

Areas of active research

- Assimilation of cloud affected radiances
  - Moving forward to precipitation and aerosol-affected
- Assimilation of water vapour channels
- Assimilation of radiances over land and ice/snow
- Assimilation of aerosols, trace gases and chemical species
- Assimilation in limited area models
- Investigations into observation and background error correlations

- Goal is to increase assimilation of all usable and appropriate satellite data

Humidity assimilation

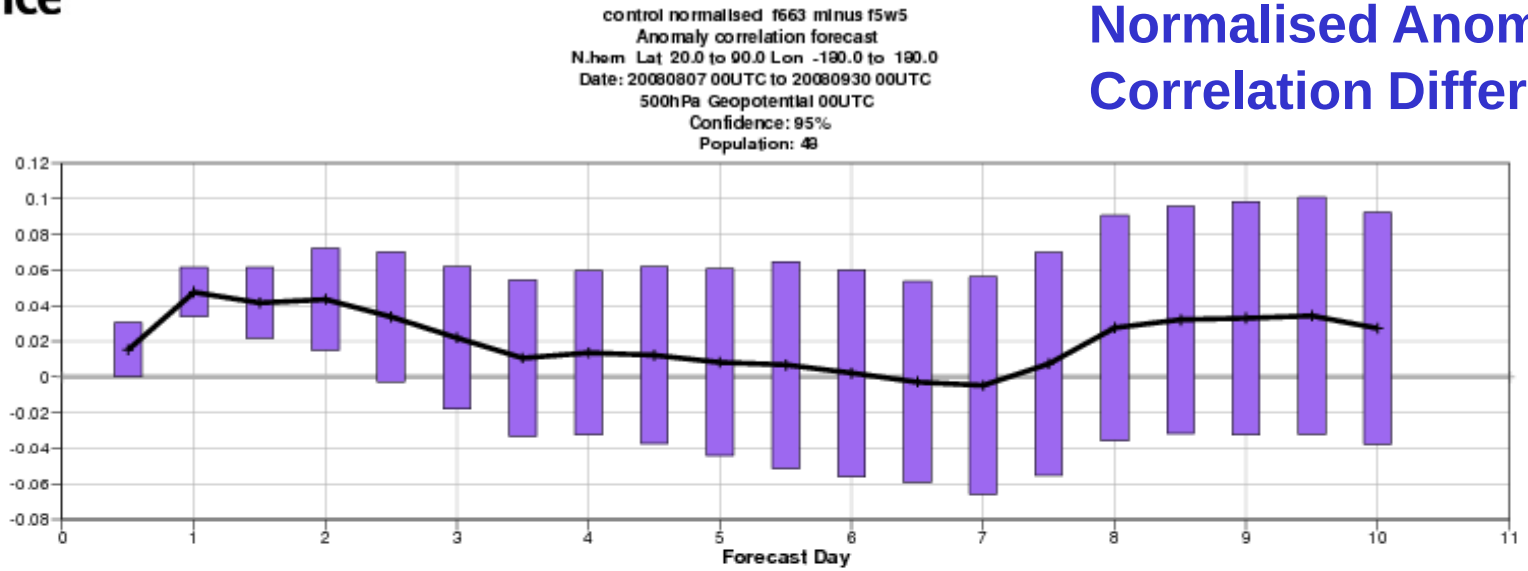
- Problematic *in general*, but especially for fine vertical structures (e.g. IASI and AIRS)
- Ambiguity with humidity Jacobians - the water vapor (WV) channels have strong sensitivity to humidity and temperature
- Humidity Jacobians are non-linear; i.e., the Jacobians themselves are a function of the humidity field
- Large bias relative to NWP model (model bias). Bias correction algorithms remove this bias.
  - RT model errors/biases may contribute as well.
  - Variational bias correction algorithms need to have suitable anchoring observations.
- NWP models have a hard time keeping impact of assimilation after 1-2 days.

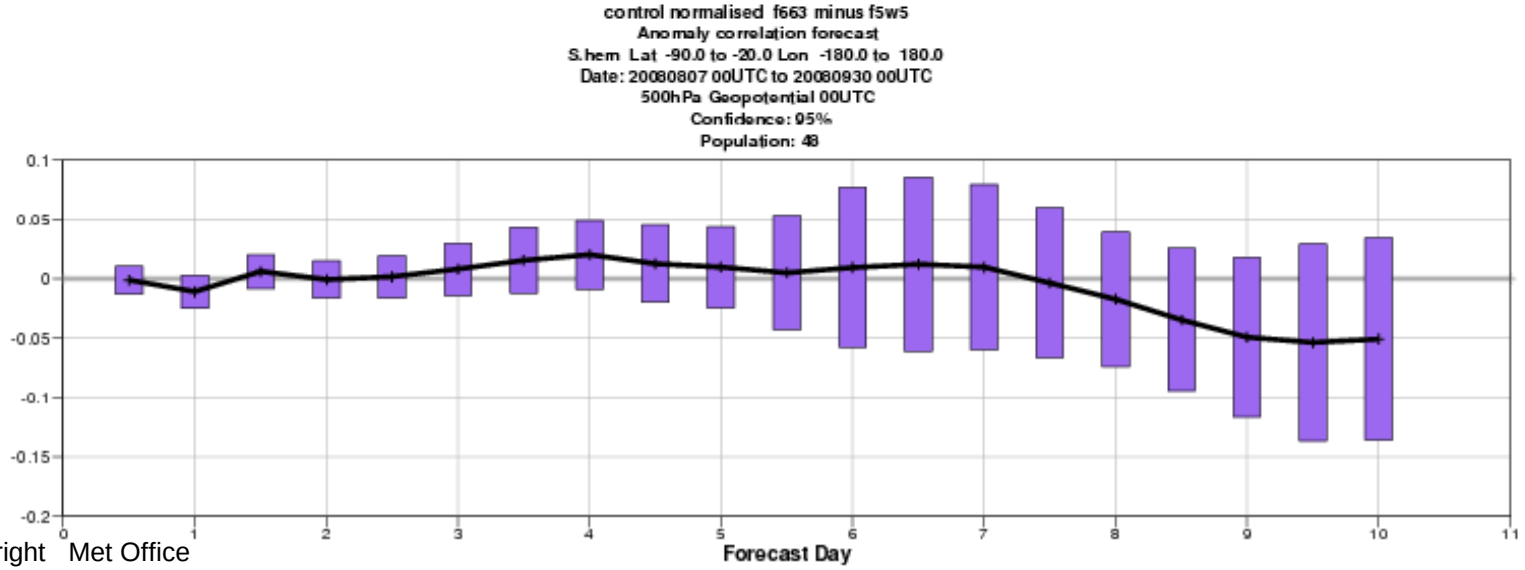
Use of data over land

- Most centres have active projects to improve land surface emissivity and increase usage of channels over land
- Several centres assimilate non-surface-affected channels over land already
- Possible inclusion of PCs of emissivity to the (1D-Var) control vector.
- Interaction with cloud detection schemes over land
  - How to decide whether a scene is cloudy or that the emissivity is wrong?
- Work on improvement of emissivity in early stages
- Land surface much more important in LAMs!!

ECMWF trial of data over land with fixed emissivity

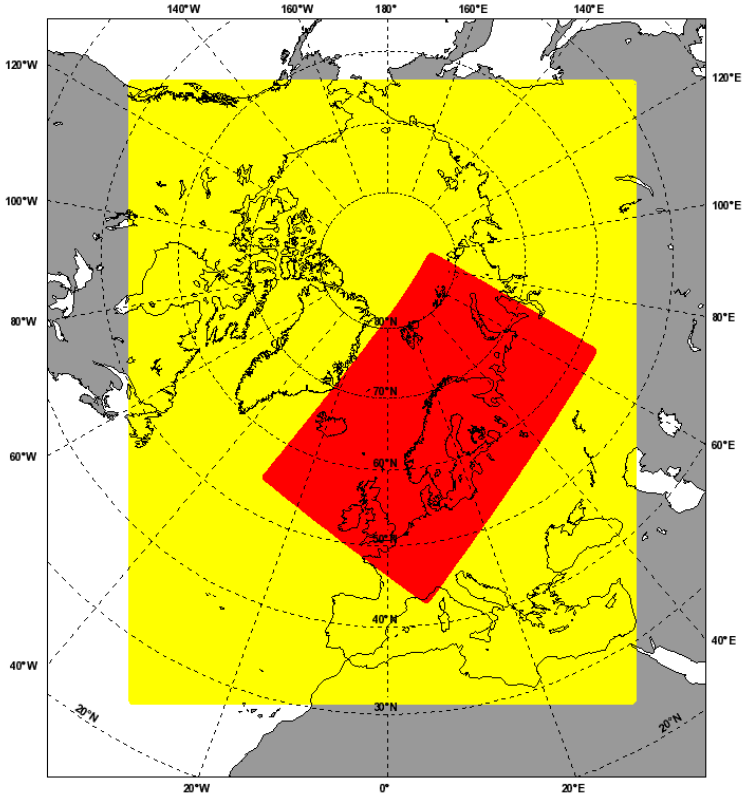
500hPa Geopotential Normalised Anomaly Correlation Difference



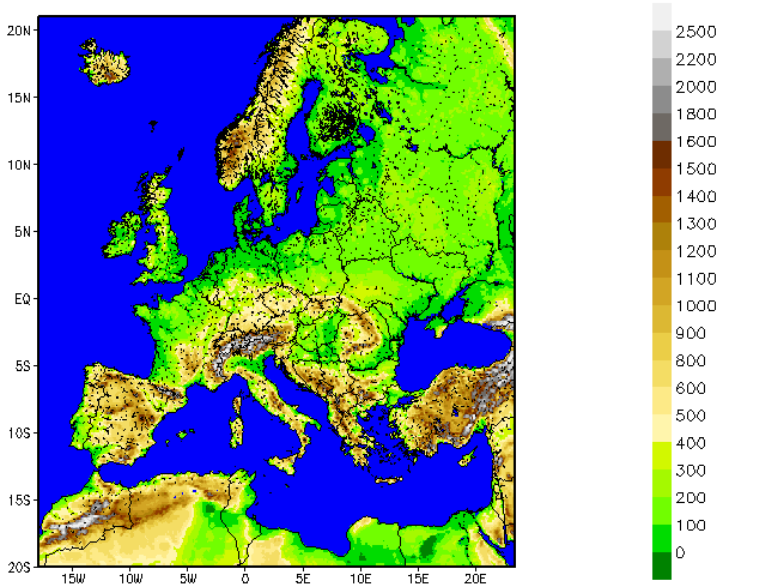


LAM domains

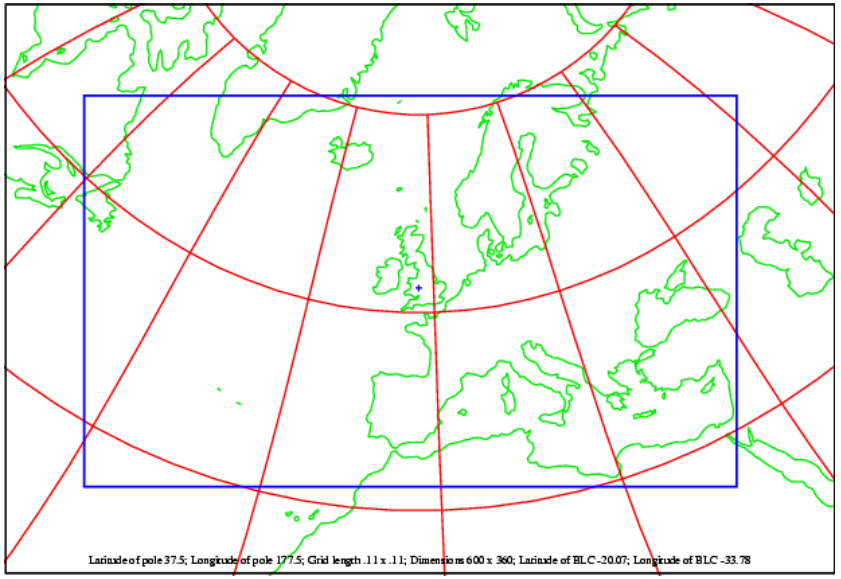
met.no HARMONIE



DWD COSMO-EU



Met Office NAE

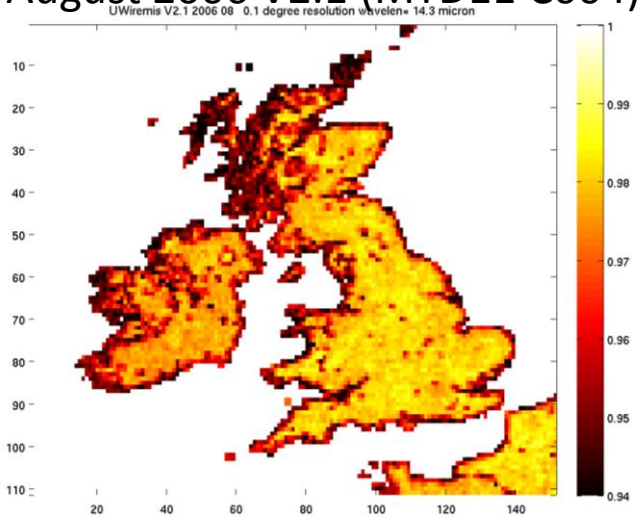


Issues for limited area models

- Land is much more important when there is very little sea!
  - But over a local area, it may be possible to use a constant emissivity
- Bias correction of observations requires careful thought
  - Data coverage is highly variable between cycles
  - Often a global model is not available to provide bias corrections
  - Even if there is a global model, there may be bias differences particularly for high peaking channels
- Strategy for estimating stratospheric temperatures
- Weather systems developing outside the model domain

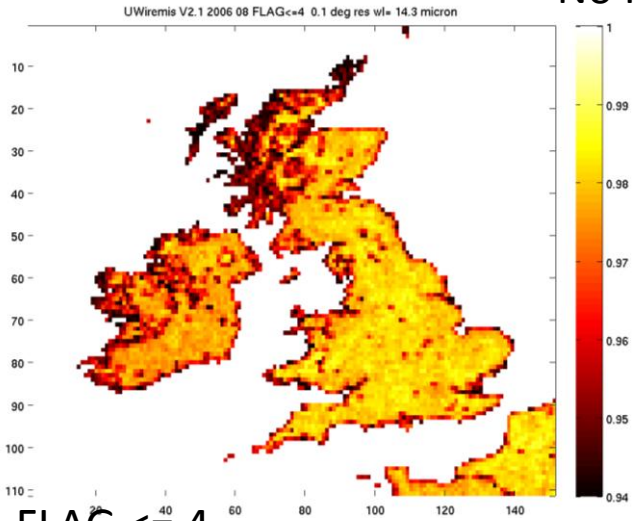
University of Wisconsin Atlas – Emissivity quality control over the British Isles

August 2006 V2.1 (MYD11 C004) 14.3 µm

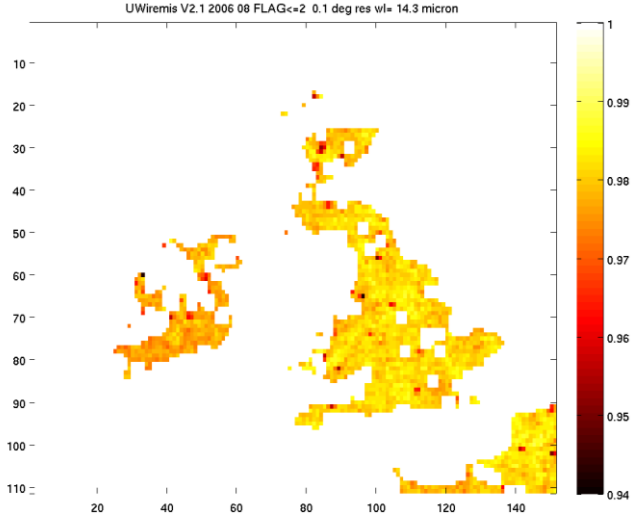


No FLAG

From Eva Borbas,
University of Wisconsin



FLAG <= 4



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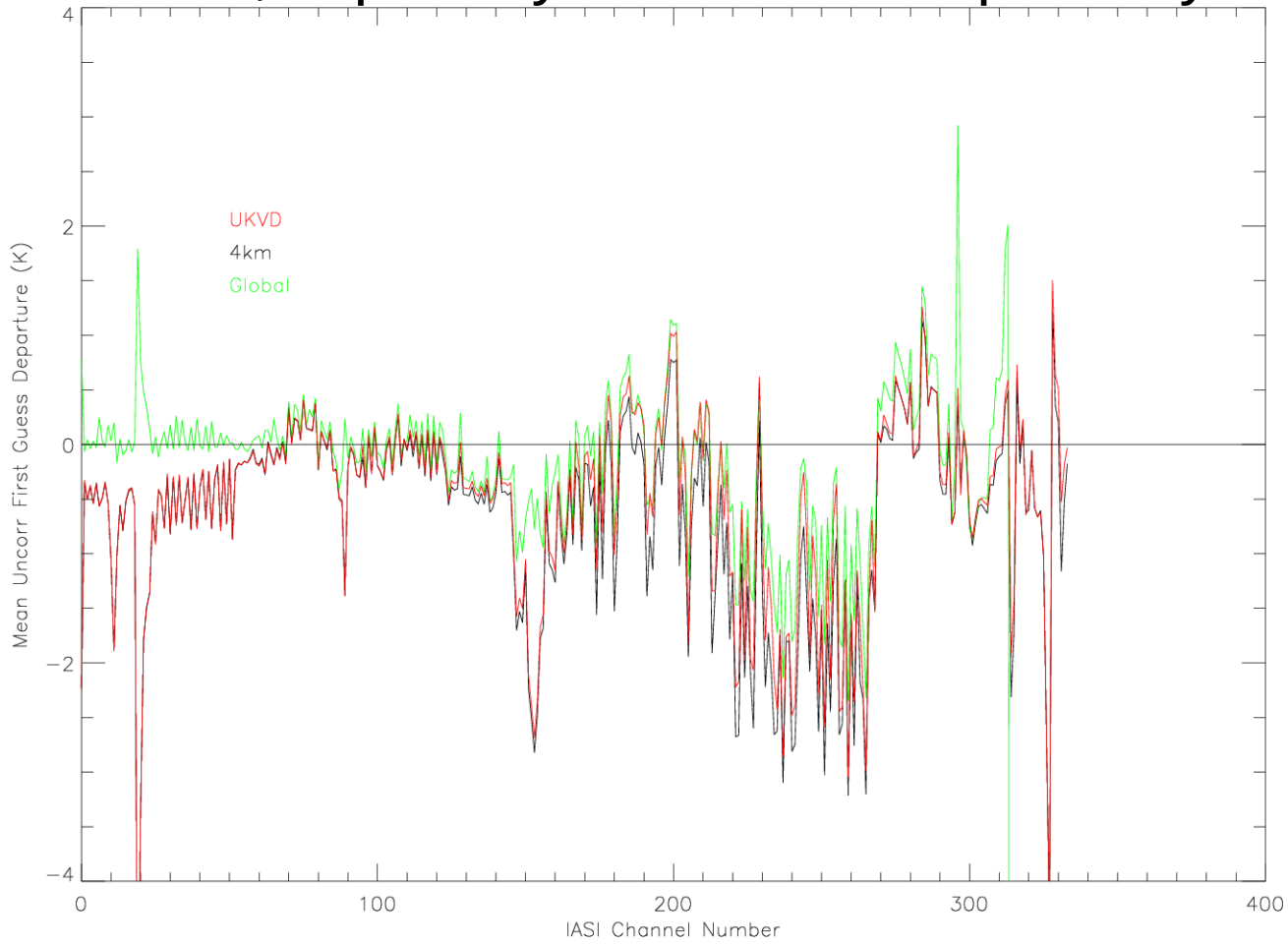
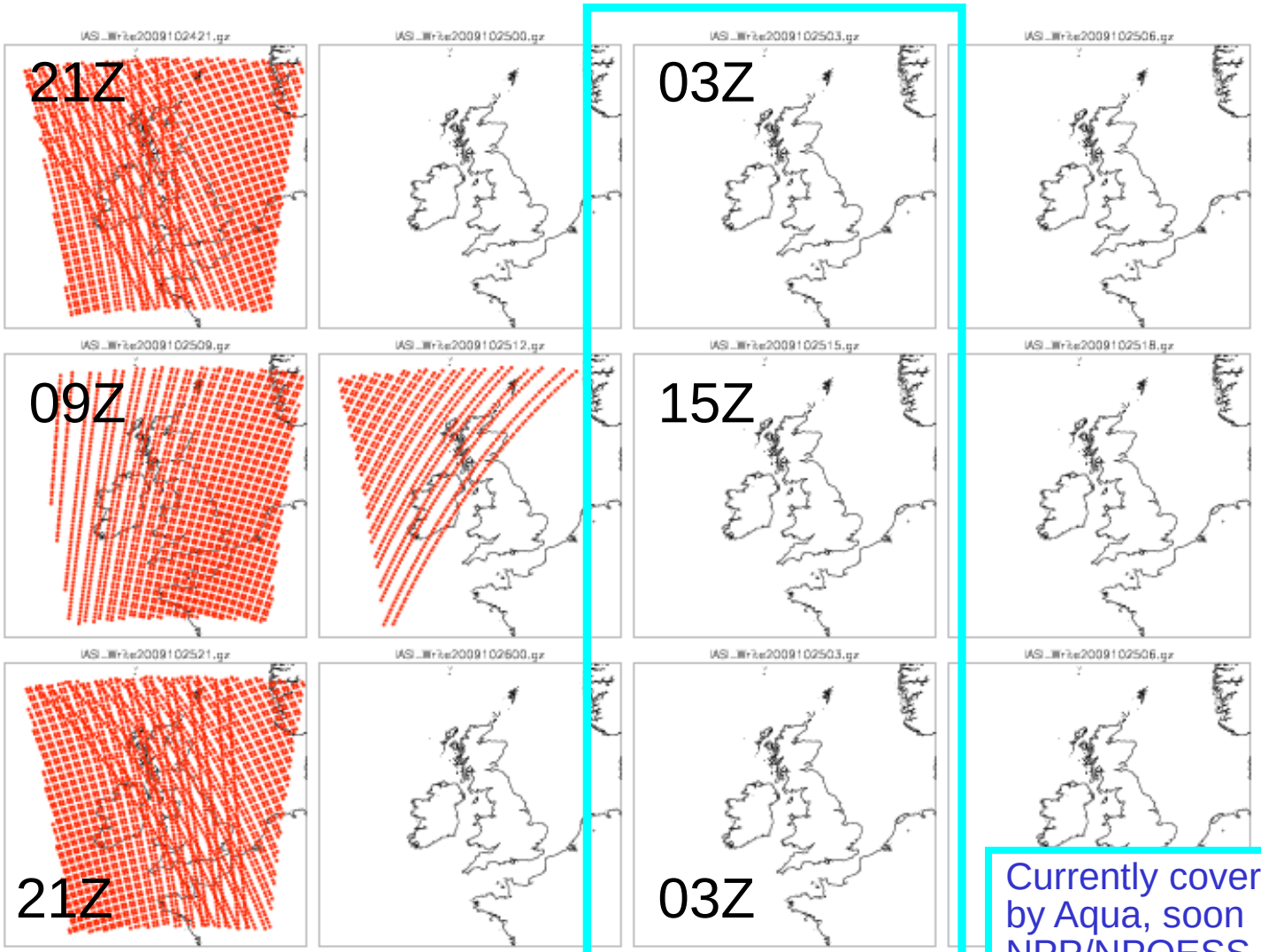
Bias correction issues for LAM

- Often, bias from the LAM does not match that of the global model, especially if the model top is very different

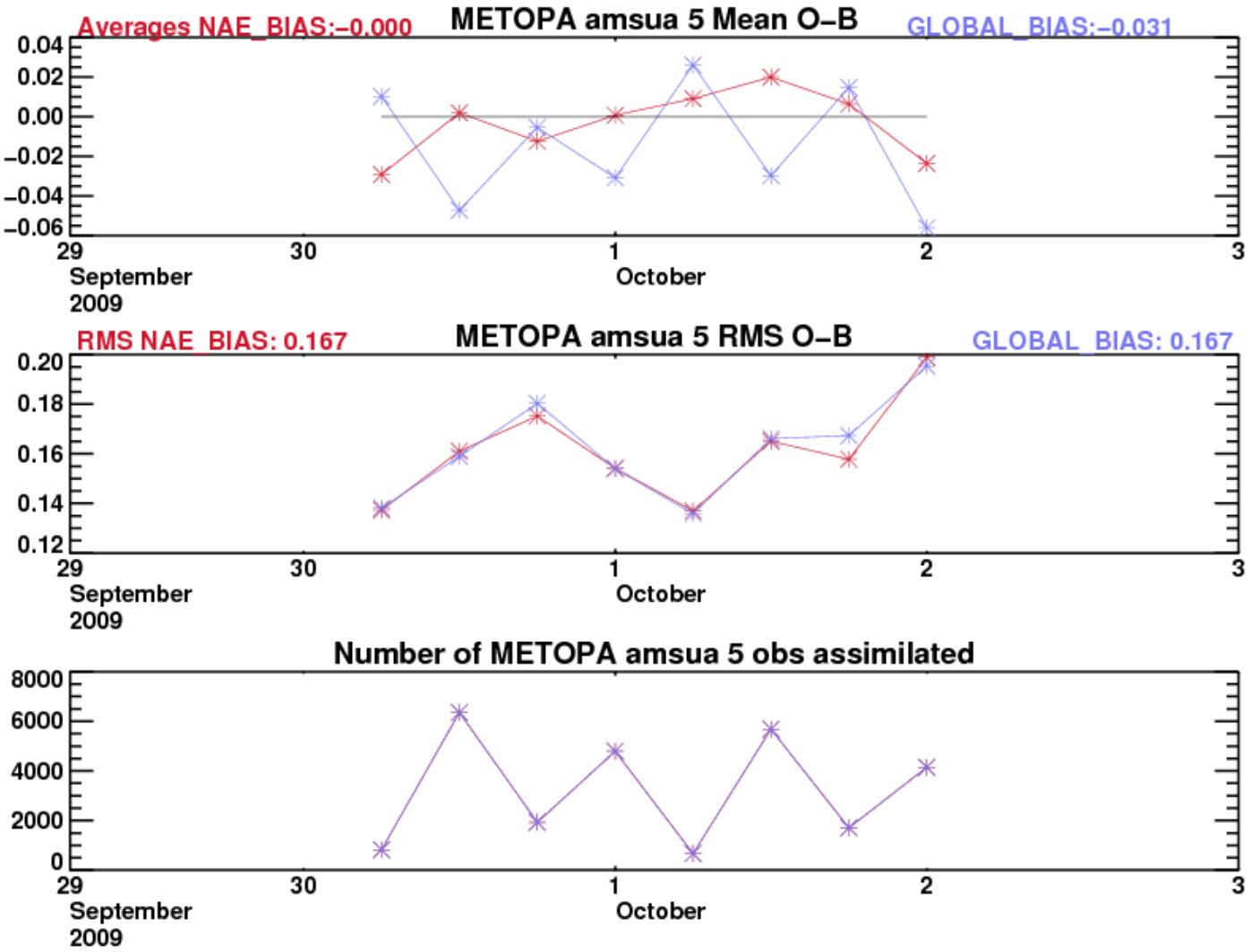


Data coverage may make it hard to calculate bias corrections from the model itself

This assumes all obs from ±1.5 hr window are available



LAM-derived bias corrections (AMSU)

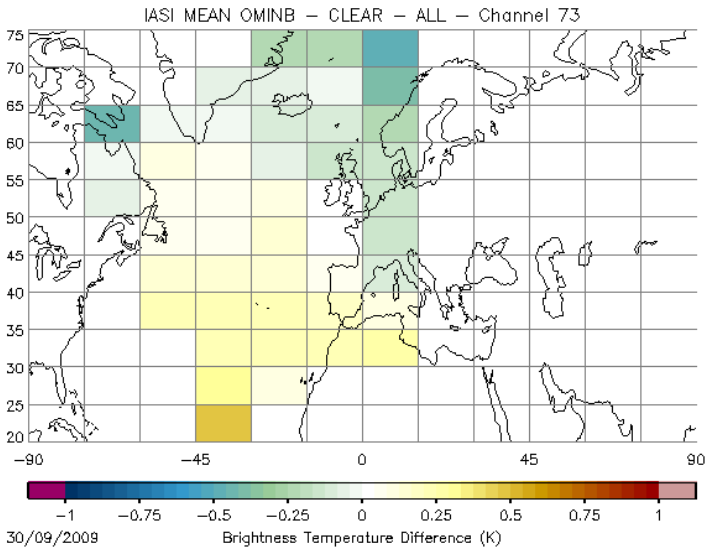


Biases cycle by cycle?

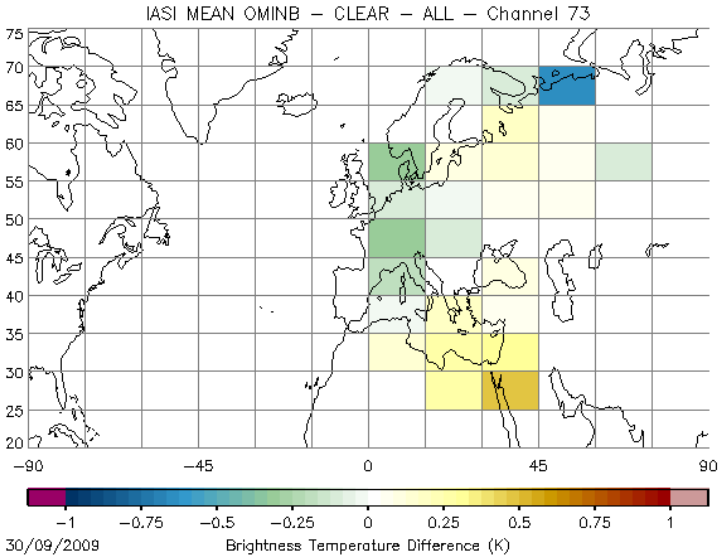
- Testing at met.no suggested that calculating new bias corrections for each cycle gave better forecast impact
  - No evidence at Met Office that bias significantly different for most channels (see next slide)
- With a domain as small as the UKV, one must take extreme care with bias corrections derived from the LAM itself
  - High seasonal dependency of biases
  - Need to ensure all scan positions are covered

Bias by cycle - Channel 242 at 705.25cm^{-1} peaks at about 300hPa

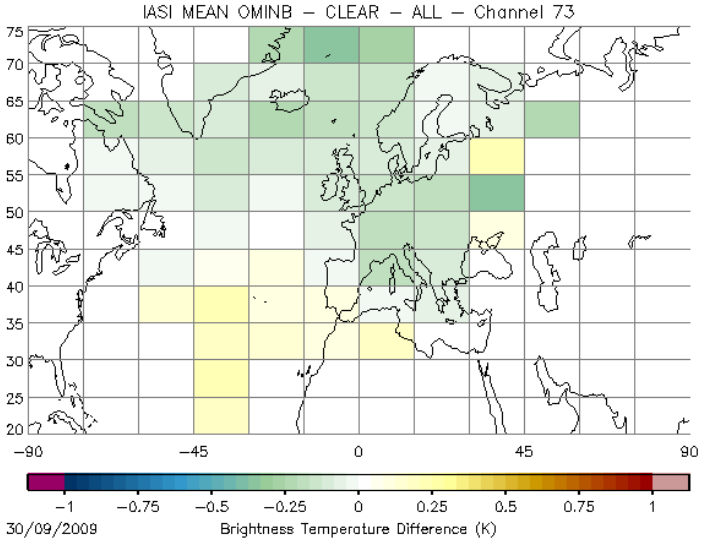
QZ00



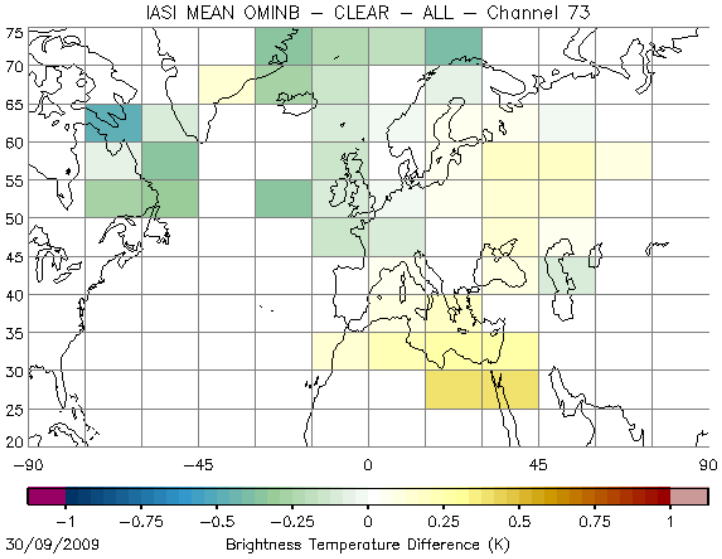
QZ06



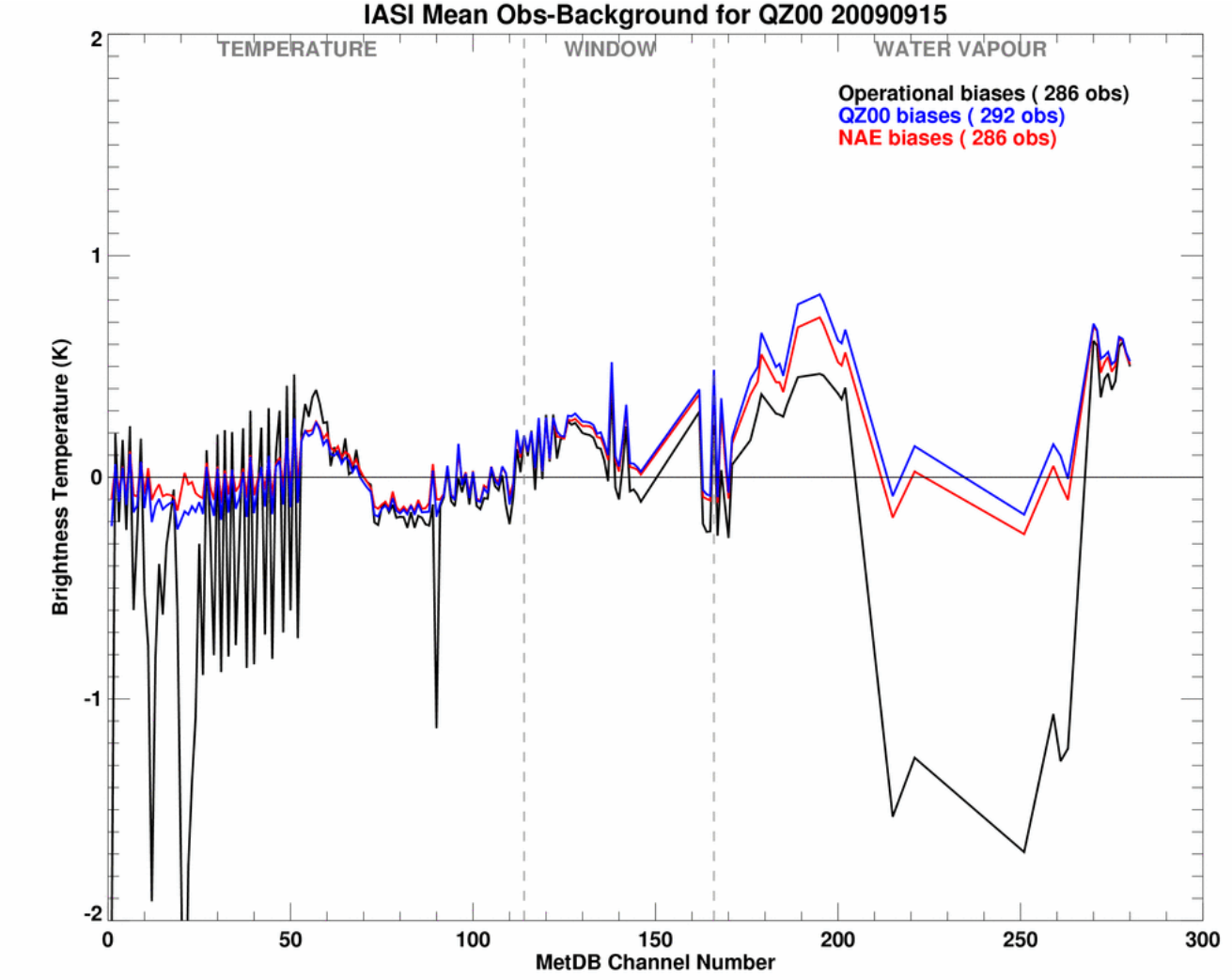
QZ12



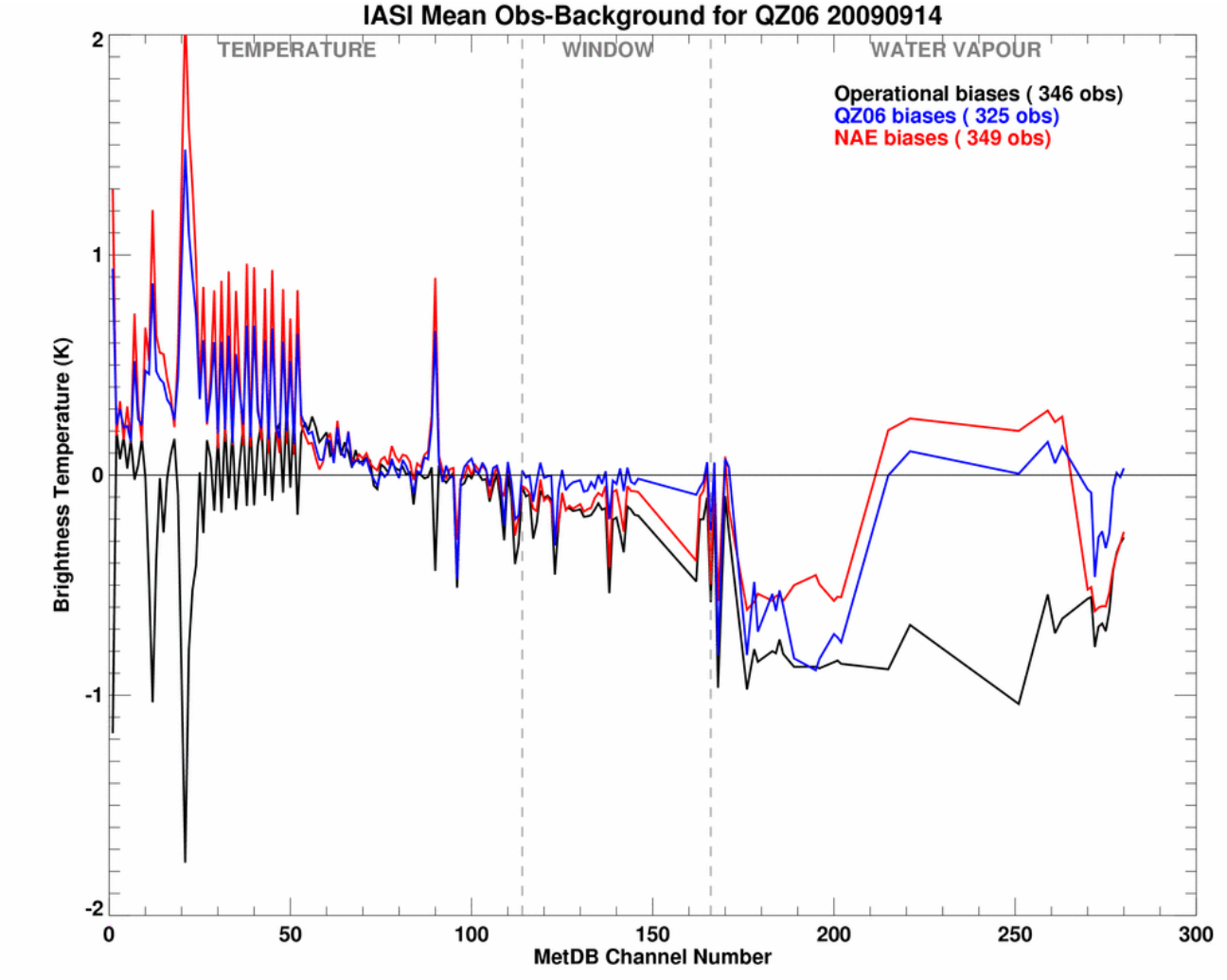
QZ18



Biases from global v biases from NAE – QZ00



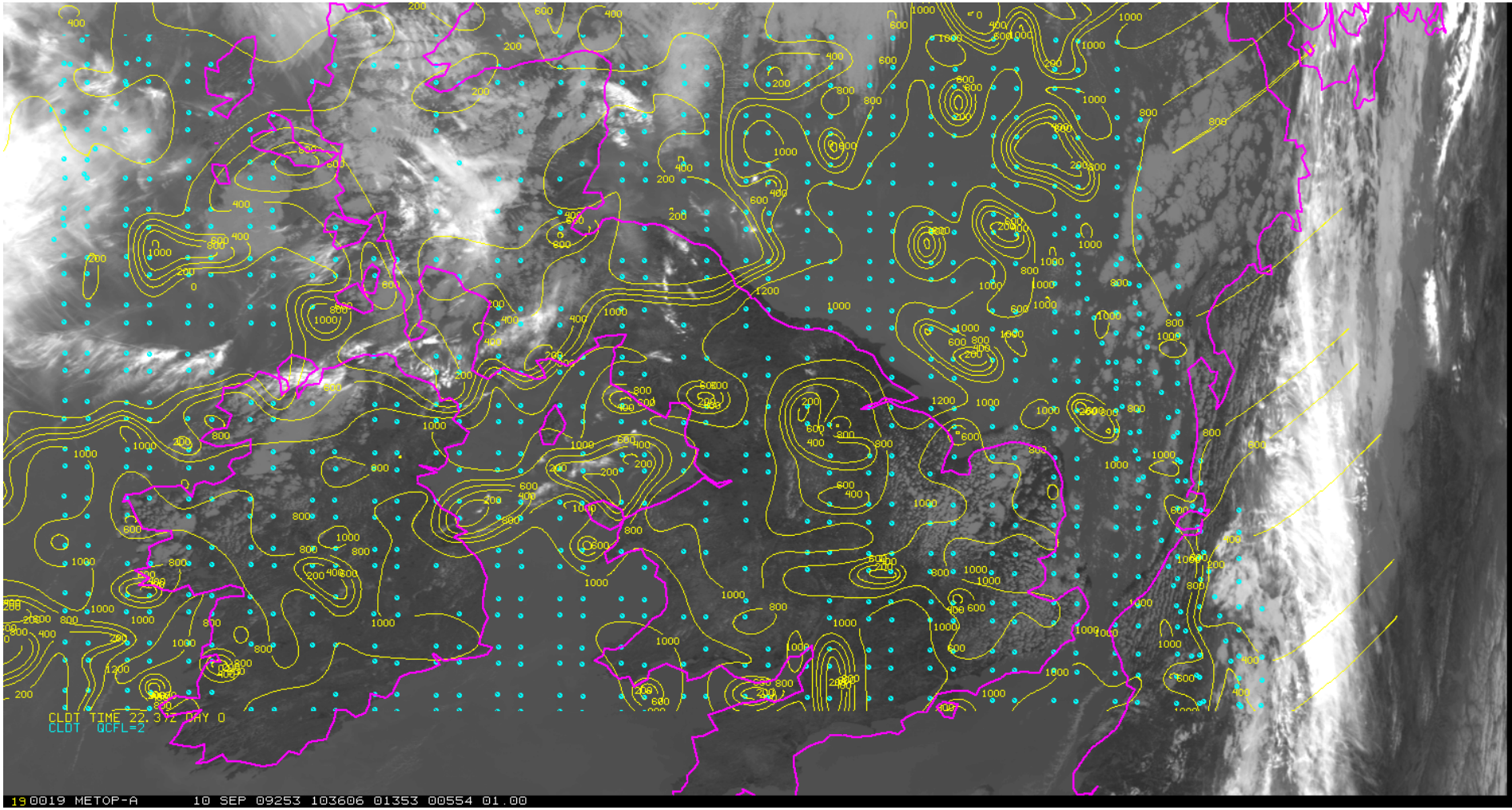
Biases from global v biases from NAE – QZ06



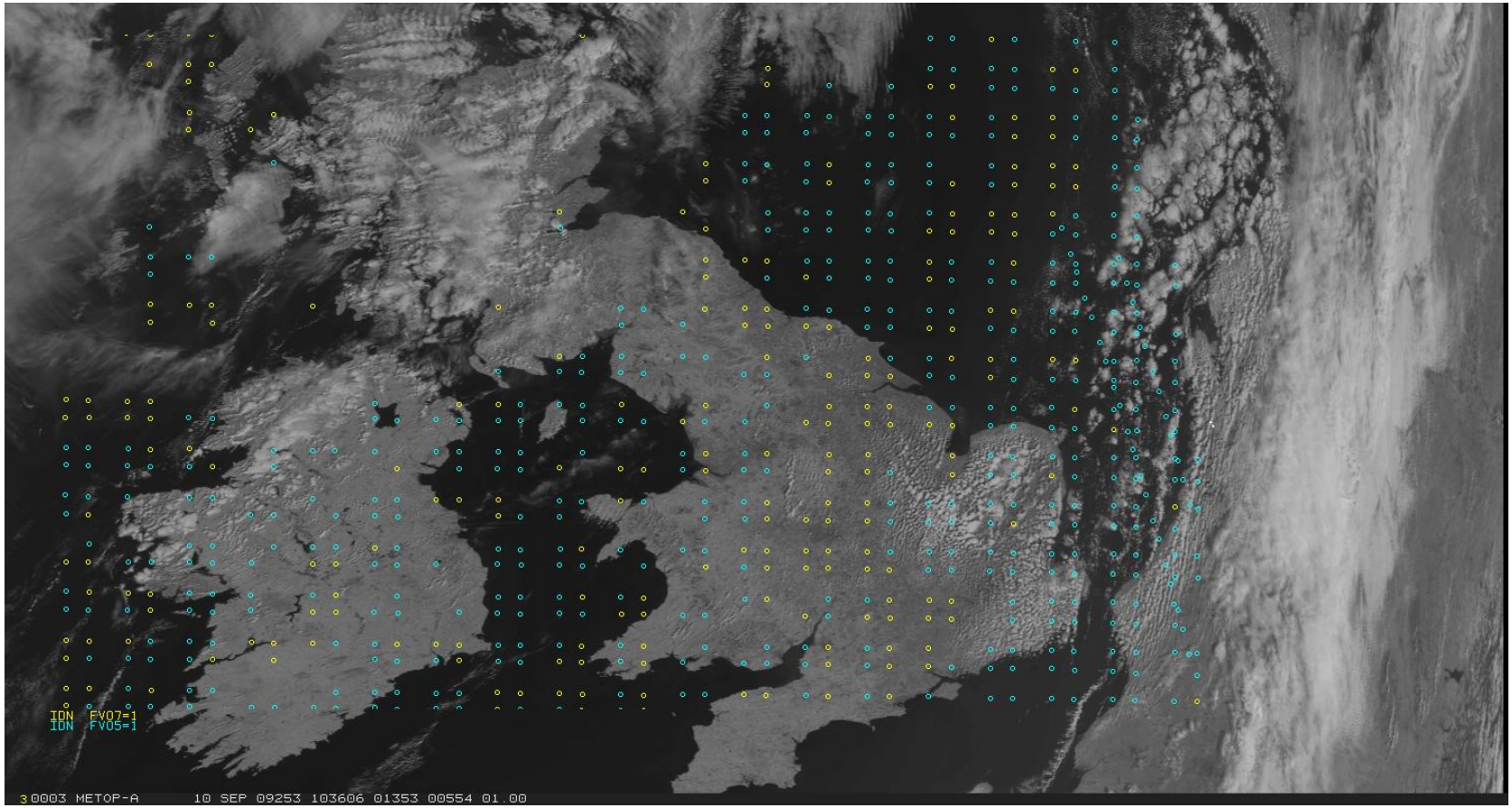
Use of IASI in high-res models is looking promising

- Work at several centres on the use of IASI in regional models shows that positive impact can be seen (as shown previously)
- Testing is underway in several convective-scale models
  - Meteo-France AROME (Guidard)
  - Met Office UKVD
  - More??
- Despite simple treatment of model grid within footprint (no adjoint of averaging model grid points), O-Bs look promising, and plenty of useful data is available
- Proving impact may be more difficult!

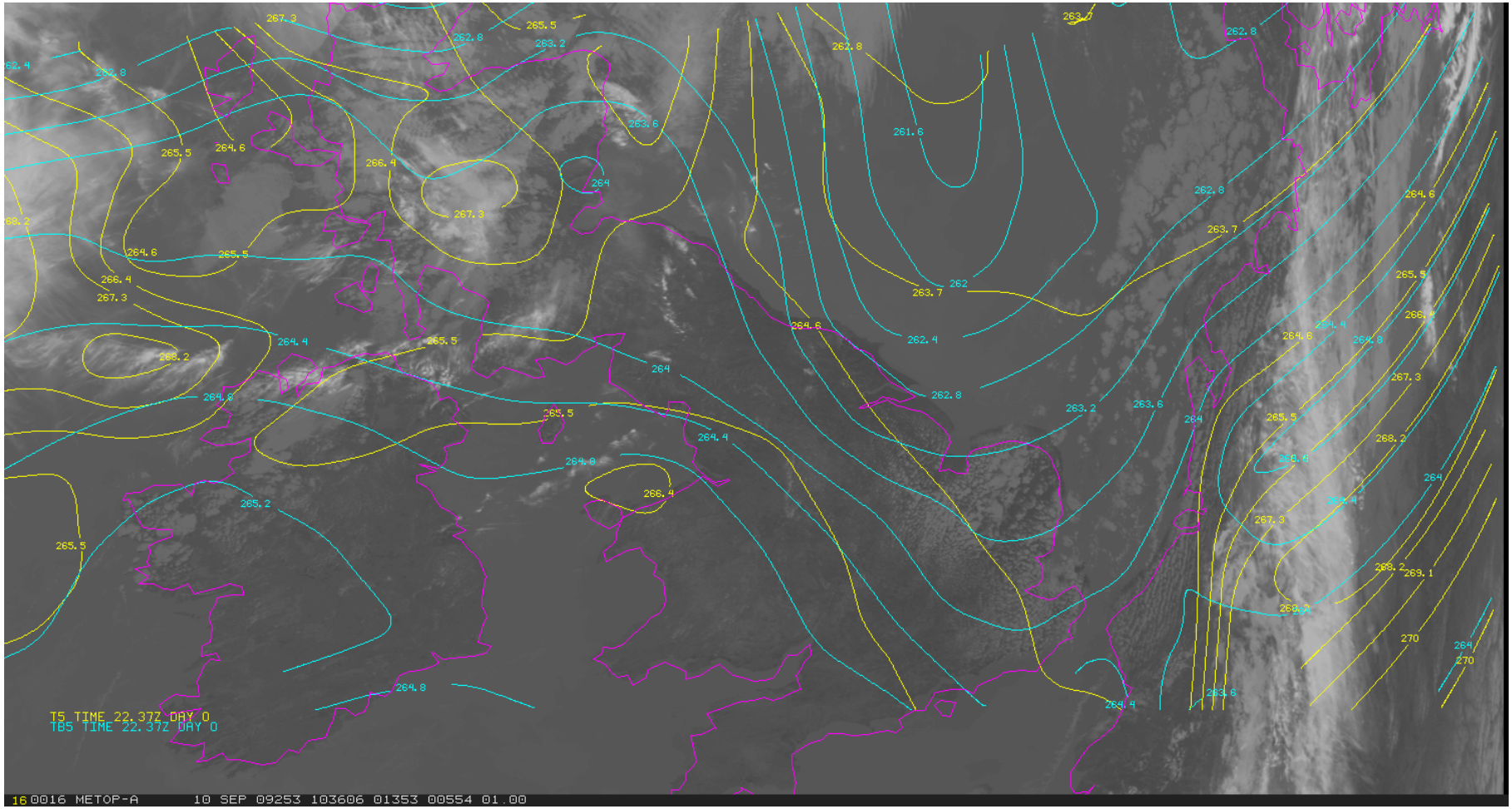
Case study 1
IASI spots passing cloudy 1D-Var Q/C blue
Yellow contours 1D-Var retrieved cloud top height



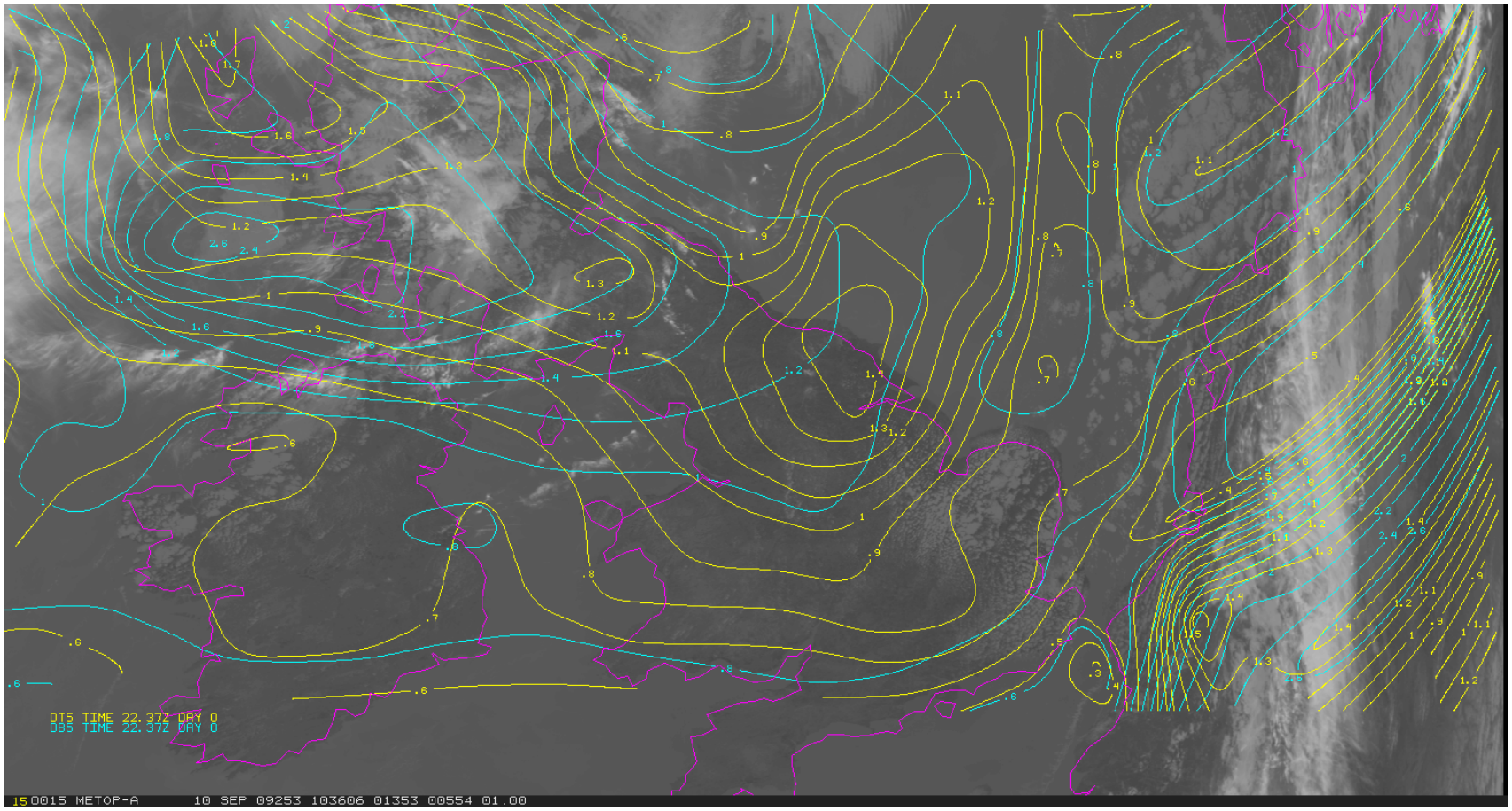
Case study 1
Yellow good IASI (to HIRS 7)
Blue good IASI (to HIRS 5)



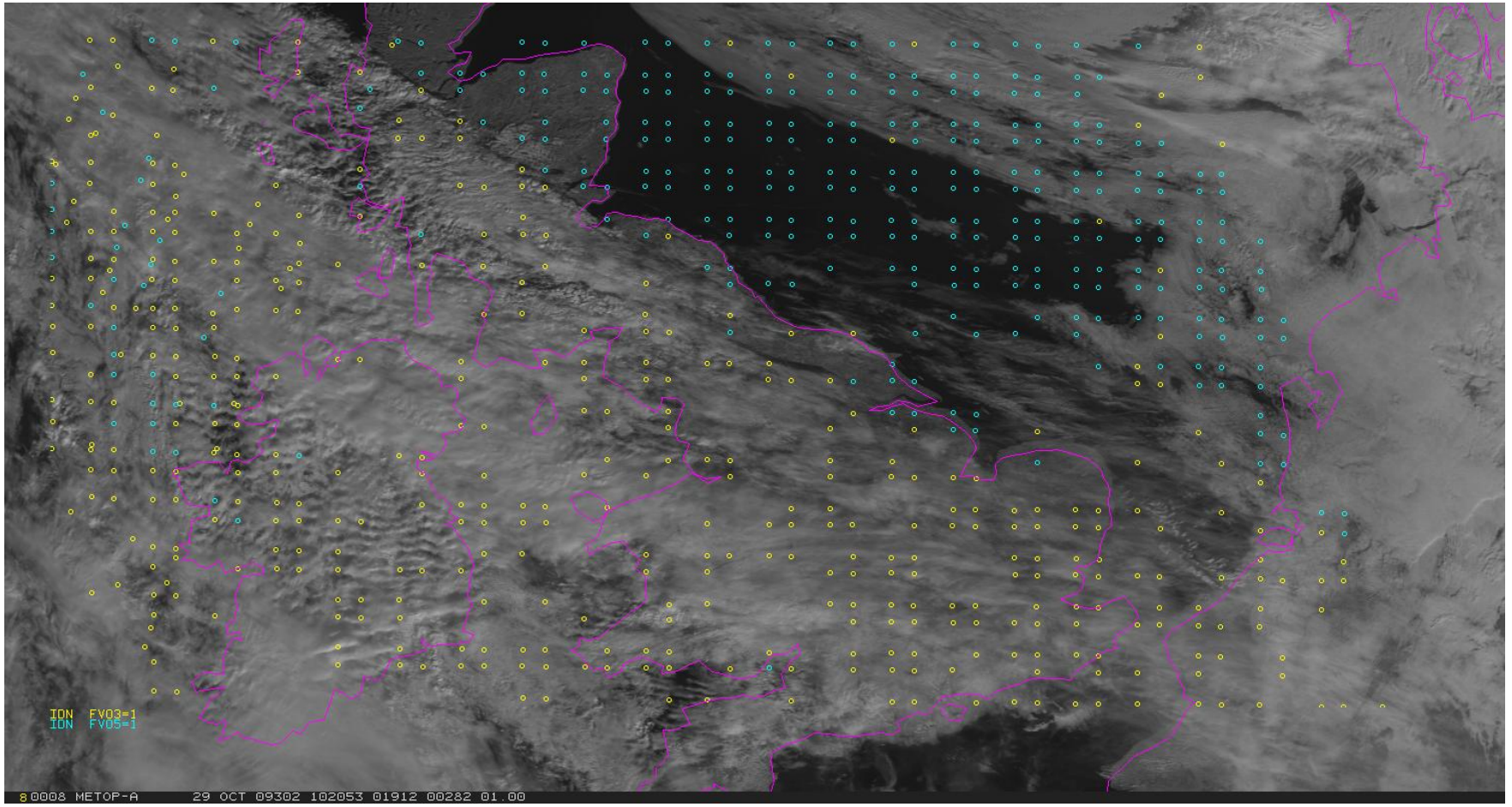
Case study 1
Temperature 565 hPa
yellow - 1dvar analysis; blue - background



Case study 1
Mixing ratio 565 hPa
yellow - 1dvar analysis; blue - background



Case study 2 - Mostly cloudy
Yellow good IASI (to HIRS 3)
Blue good IASI (to HIRS 5)



Take home message from UKVD case studies

- Quality control rather strict
  - Channel usage possibly unnecessarily restricted
- Plenty of observations do pass QC and are available for assimilation
- The observations do have an impact on the analysis

Take home message from this talk

- Good progress has been made with use of IASI
- Still a lot more to do with the data
- Progress depends on a lot of things:
  - New science in assimilation system and data usage
  - Improvements in NWP models themselves
  - Opportunities for operational system upgrades
- IASI provides significant forecast impact in NWP systems

Thank you for listening! Any questions?