Assimilation of IASI Radiances at European 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
- This talk will cover IASI radiance assimilation from a European perspective
  - Met Office – me!
  - Météo-France – Vincent Guidard
  - Deutsher Wetterdienst – Marc Schwaerz
  - met.no – Roger Randriamampianina
  - ECMWF – Andrew Collard

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 European NWP Centres?

Summary of models and data usage (1)

	Model	Domain	Model Top/ N Levels	Horiz. Resn.	Assimilation System	Bias Correction
Met Office	Global	Global	63km/L50	~60km	4D-Var	Harris&Kelly
	NAE	N Atlantic & Europe	39km/L38	~12km	4D-Var	Harris&Kelly
Météo-France	ARPEGE	Global	0.1hPa/L60	30-70km	4D-Var	VarBC
	ALADIN	W Europe	0.1hPa/L60	10km	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)

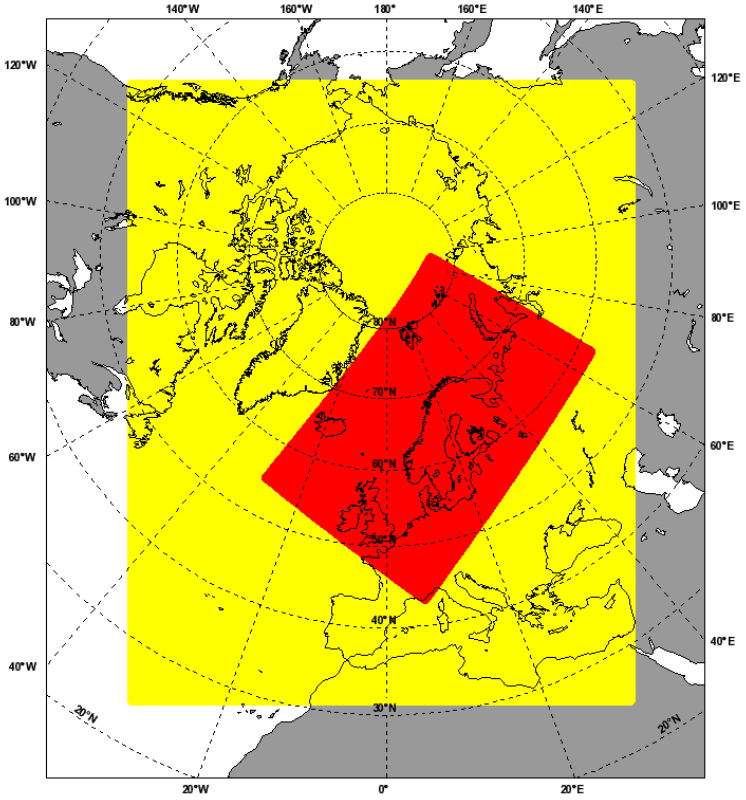
	Model	IASI Status
Met Office	Global	Operational
	NAE	Operational
Météo-France	ARPEGE	Operational
	ALADIN	Operational
ECMWF	Global	Operational
DWD	GME	Testing
	COSMO-EU	Testing
met.no	HARMONIE	Testing

4D- or 3D-Var Nudging

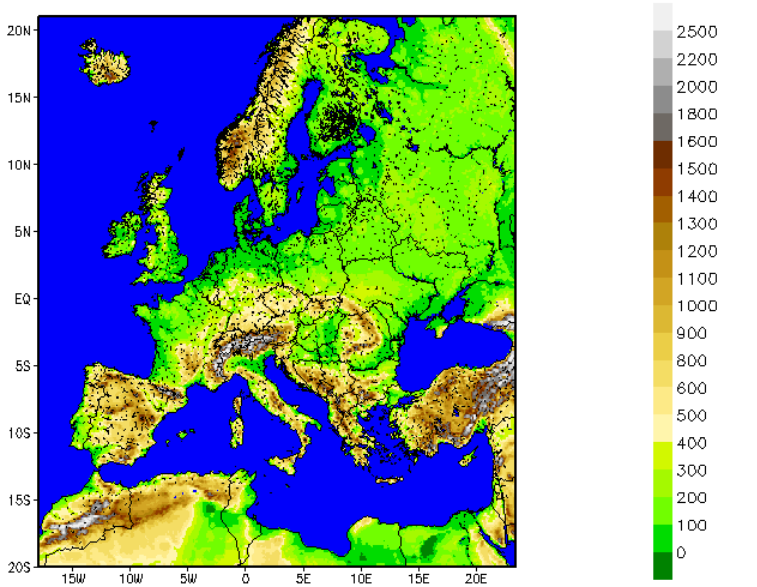
- Centres which have 4D- or 3D-Var all assimilate radiances directly into the model
  - Influence of radiances depends on model errors and observation errors
- DWD has a 3D-Var system for its global model but uses a nudging scheme for COSMO-EU
  - Nudging must be done in model space
  - IASI observations are pre-processed with a 1D-Var to generate retrievals which are then used in the nudging scheme
  - The model trajectory is nudged towards the retrievals (and conventional observations)
  - Nudging weights depend on spatial distance and temporal distance from successive timesteps of the model and must be tuned

LAM domains

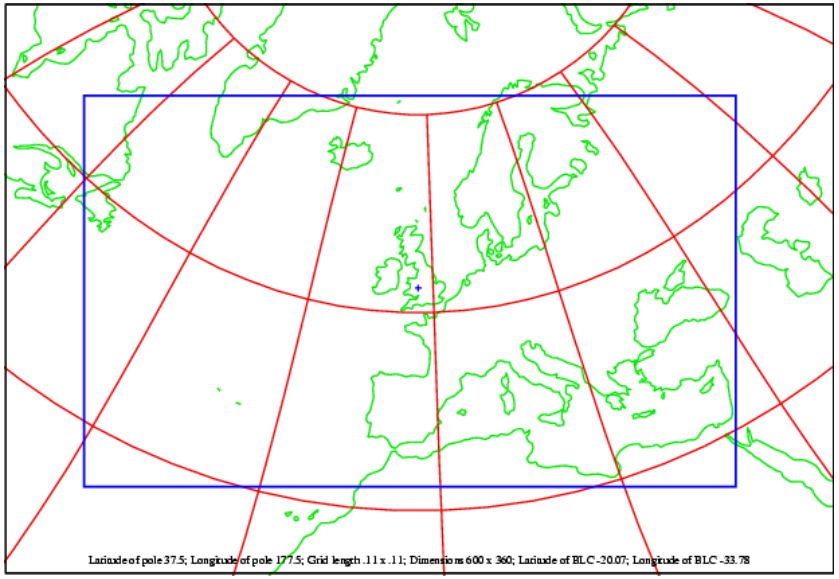
met.no
HARMONIE



DWD
COSMO-EU



Met Office NAE



Data quality monitoring

- All centres actively monitor IASI data
- Monitoring restricted to a subset of channels
  - Generally start from 314 channel set of Collard (2007)
- Operational radiance monitoring statistics are available from
  - Met Office (please register for username/password – very quick!) http://www.metoffice.gov.uk/research/nwp/satellite/infrared/sounders/iasi/index.html
  - ECMWF http://www.ecmwf.int/products/forecasts/d/charts/monitoring/satellite/hsris/iasi/
  - Meteo-France http://www.meteo.fr/special/minisites/monitoring/menu.html

Data selection and thinning

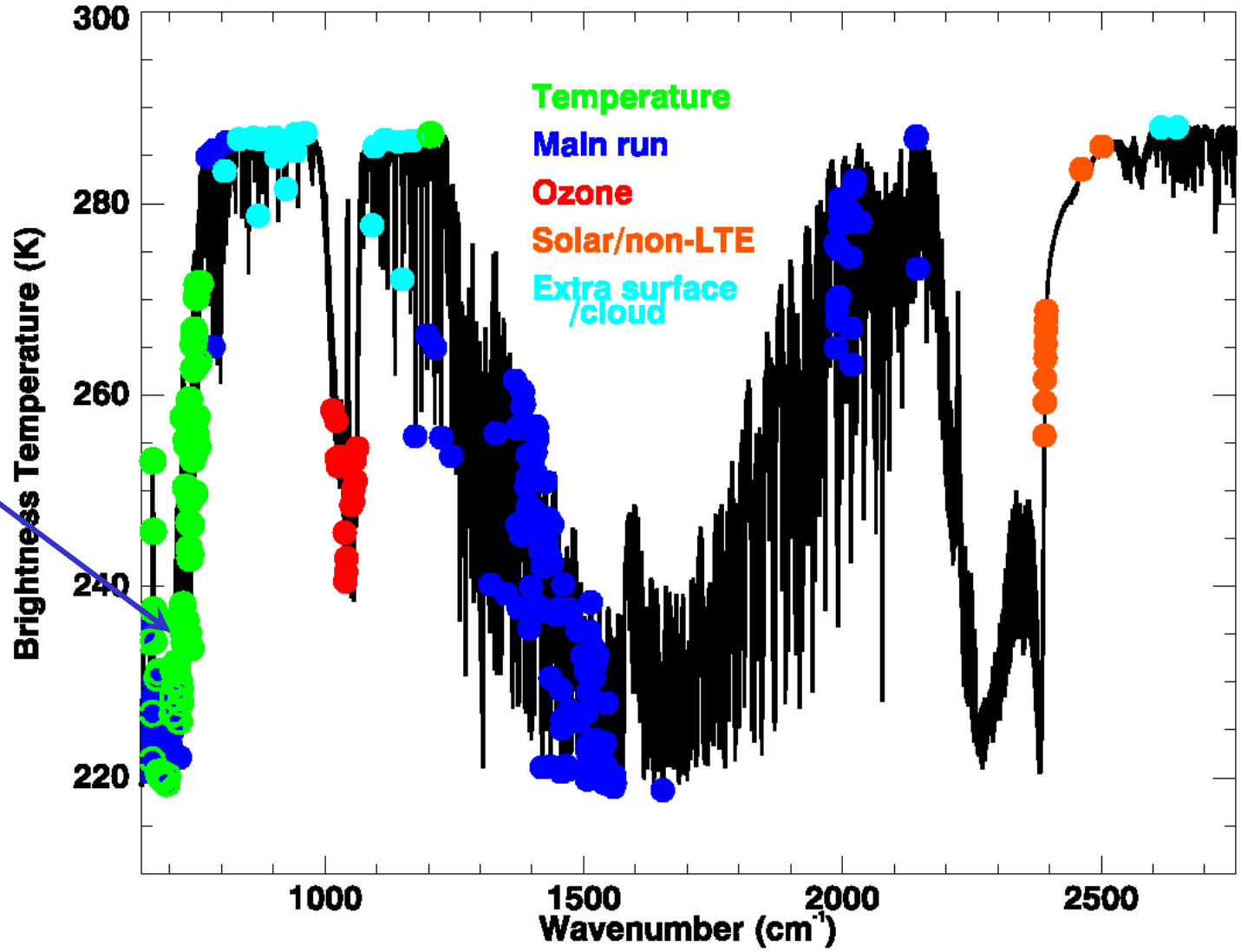
	Data Usage	Thinning
Met Office	IR Clear spots only, limited channels above MW cloud Sea and Land	1 pixel in 4 then 154km
Météo-France	Above cloud Sea, Land and Sea-ice	1 pixel in 4 then 250km
ECMWF	Above cloud Sea and Sea-ice	1 pixel in 4 then 120km
DWD	Subject to experimnetation, Clear spots or Above cloud Sea only	? ?
met.no	Above cloud Sea and Land	1 pixel in 4 Subject to experimentation, 80km

Channel selection (1)

- 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
- General principles
  - Use channels in long-wave CO_2 band
  - Use as many of these as possible!
  - Restrict usage of stratospheric channels
  - Generally, restrict usage of surface-viewing channels
  - Some centres use or are working on water vapour channels
  - More conservative channel selection over land and ice

314/366 Channel set

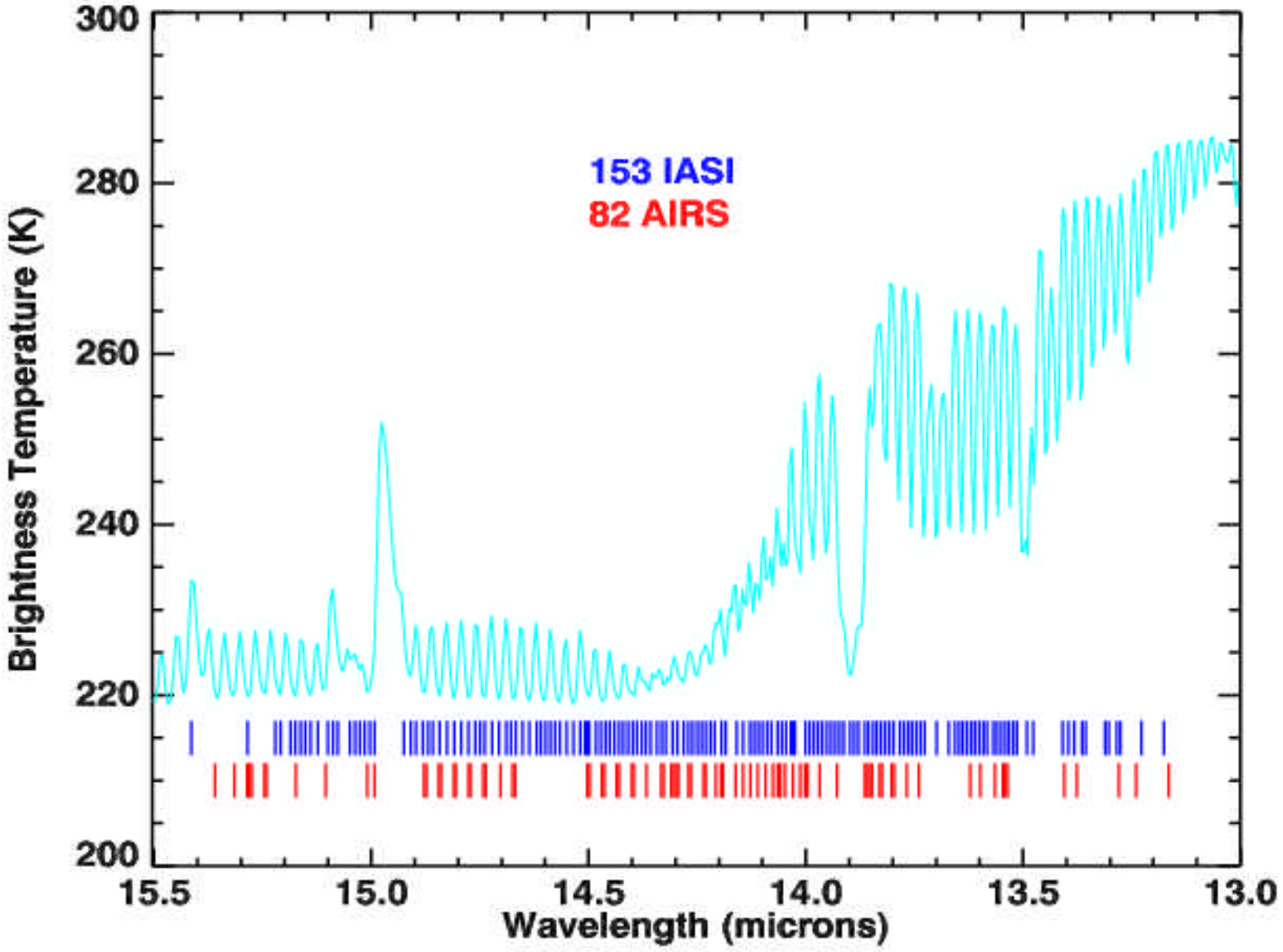
366 channel set has more LW CO2 channels



Channel selection (2)

	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 64 T	Up to 50 T	Up to 32 T
ECMWF	Up to 165 T Up to 10 WV		Up to 165 T
DWD	Up to 122 T Perhaps up to 93 WV		
met.no	Up to 41 T	Up to 9 T	

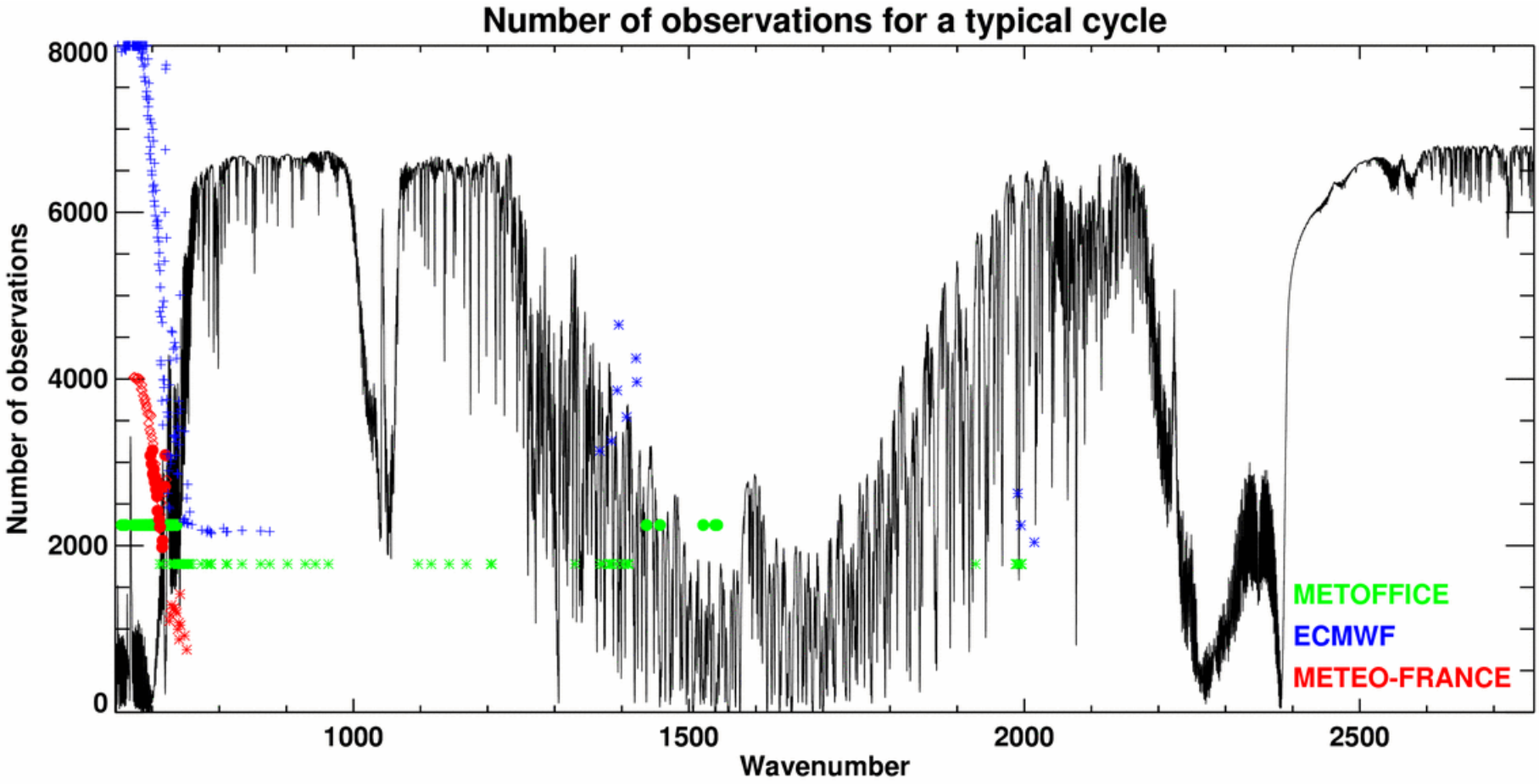
Denser use of LW Co2 compared with AIRS (especially ECMWF 366)



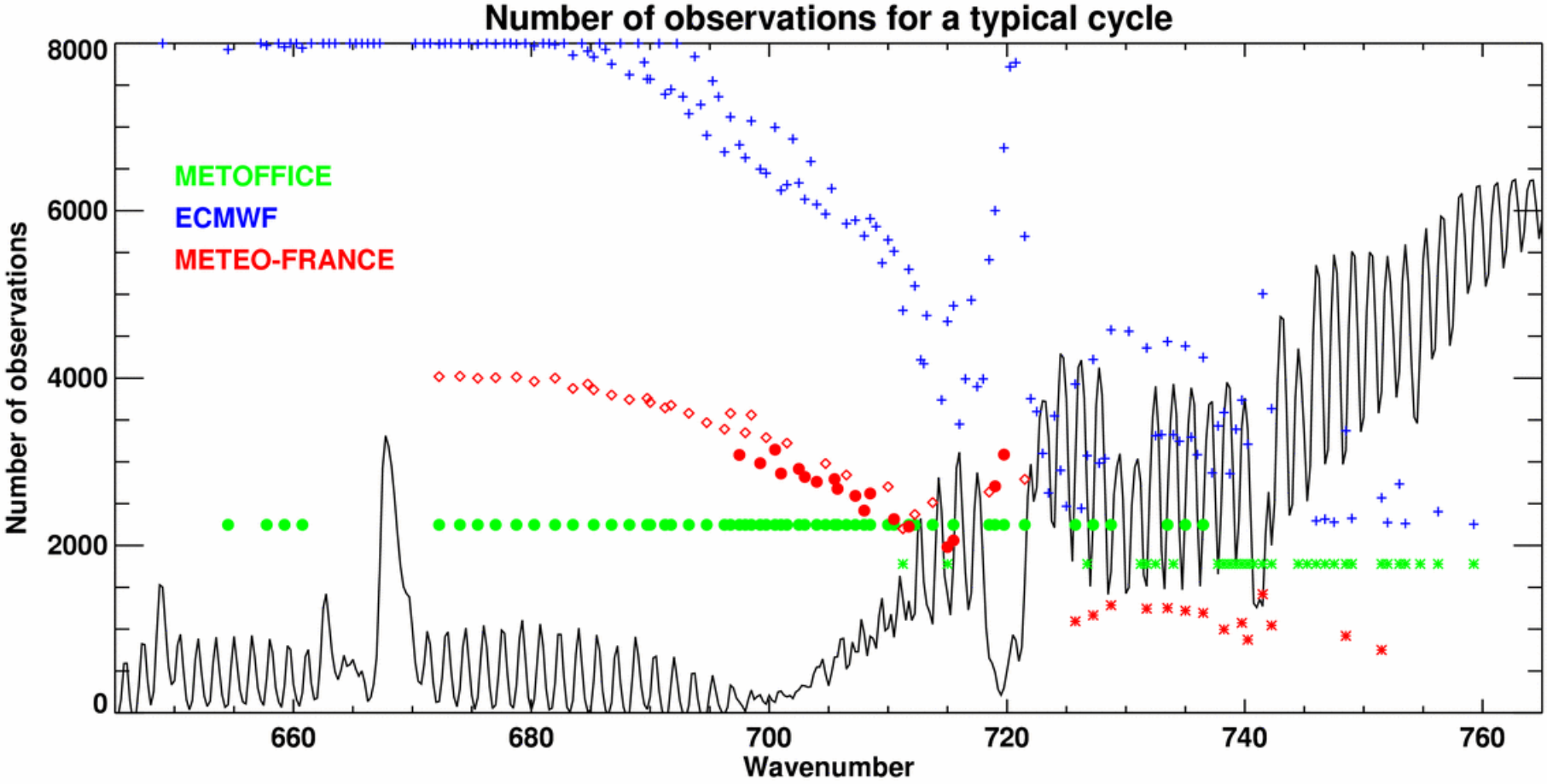
Cloud detection

	Method
Met Office	Two Pre-processor screening checks on SD between FOV and AMSU/IASI consistency Bayesian detection of clear scenes (English et al, 1999) Additional use of AMSU cloud flag to restrict channel usage
Météo-France	McNally & Watts (2003)
ECMWF	McNally & Watts (2003) with cross-band cloud detection for WV channels Some changes coming up this year (cirrus detection + see Tony McNally's talk later)
DWD	McNally & Watts (2003)
met.no	McNally & Watts (2003)

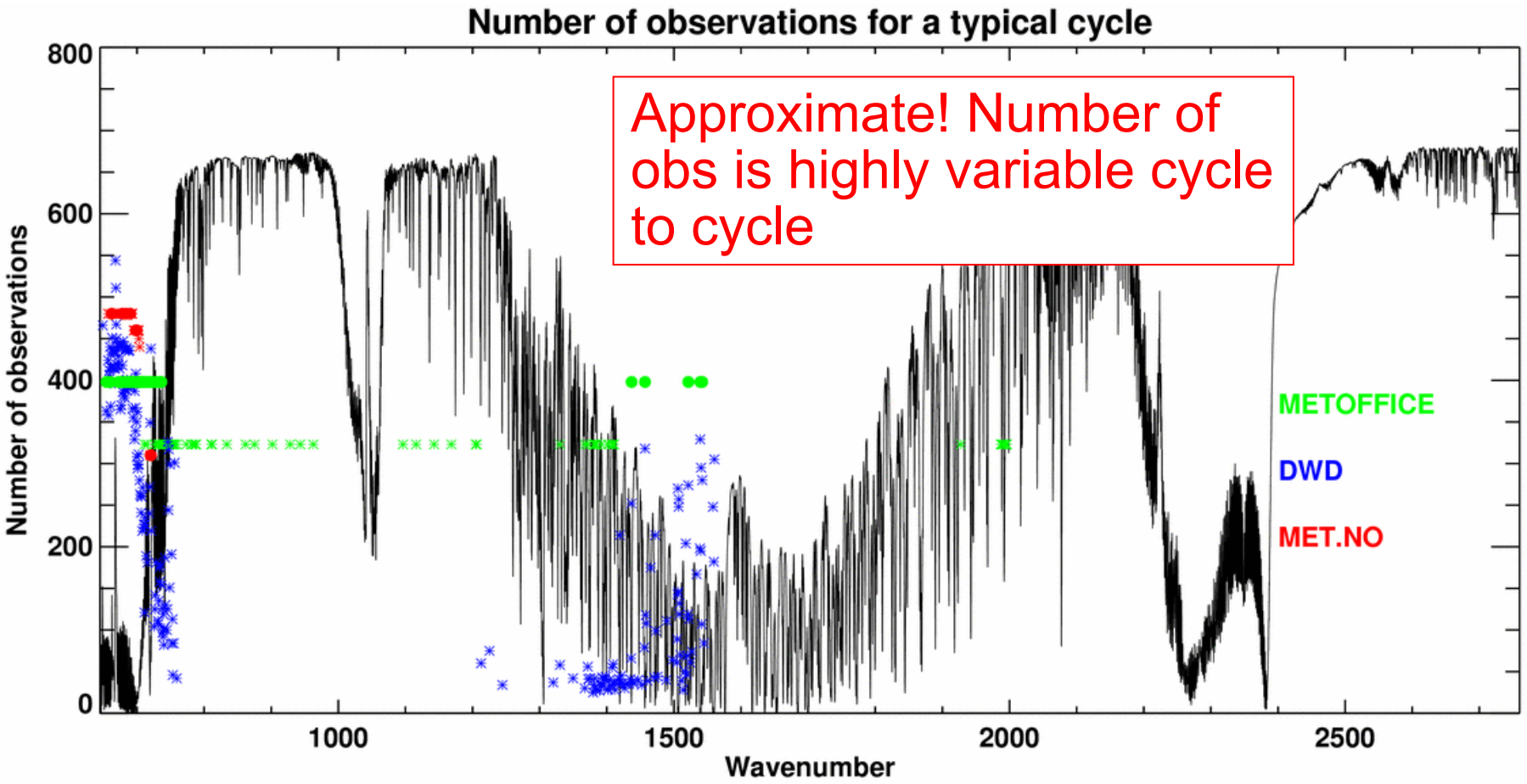
Number of observations per cycle – Global Models



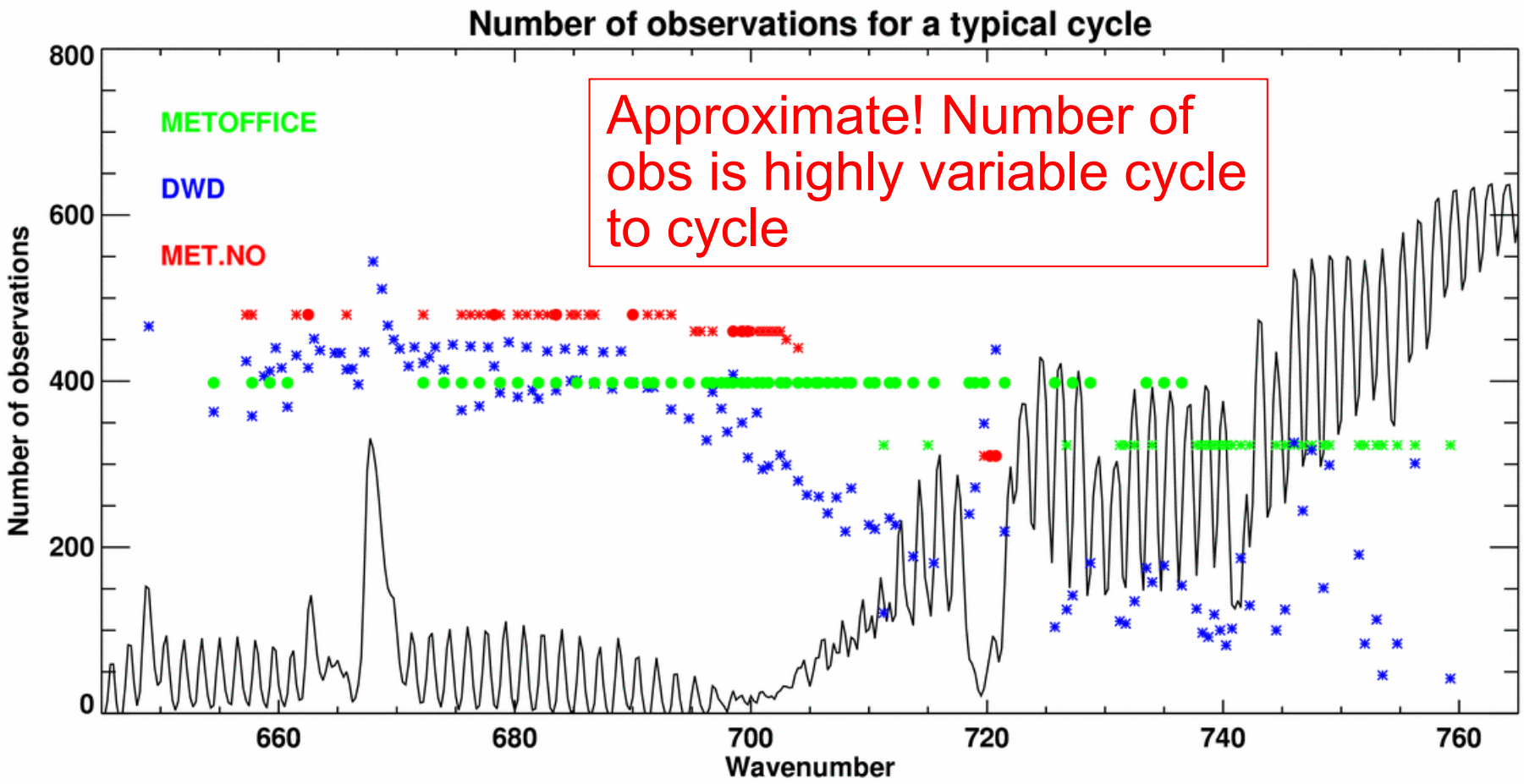
Number of observations per cycle – Global Models



Number of observations per cycle – Limited Area Models



Number of observations per cycle – Limited Area Models



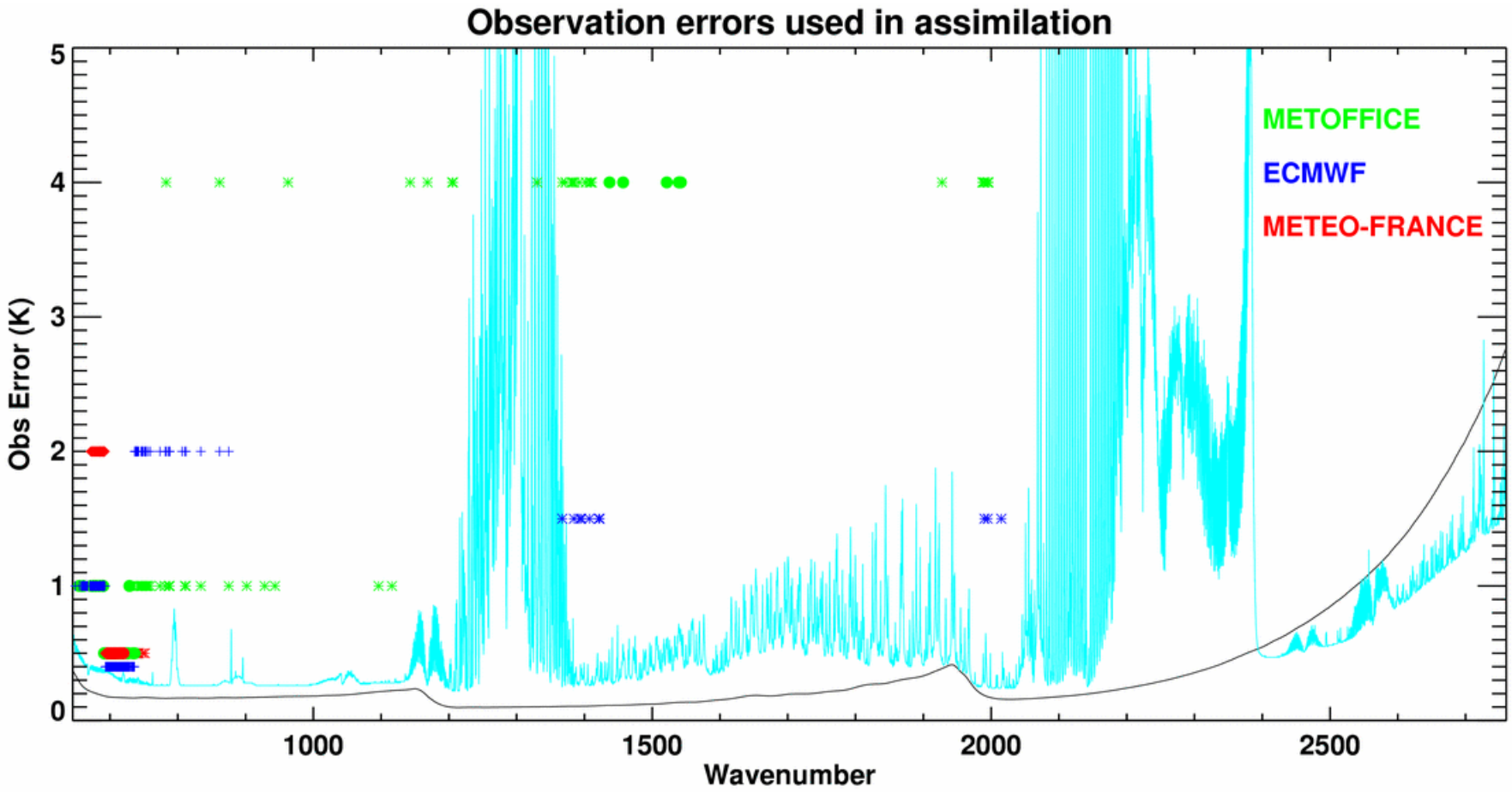
Bias correction (1)

- Met Office and DWD employ the Harris & Kelly method
  - Met Office predictors
    - constant offset
    - scan angle
    - 850-300hPa and 200-50hPa thickness
    - NB I am not that happy with the residual biases but believe they are mostly model bias
  - DWD predictors
    - constant offset
    - scan angle
    - 1000-300hPa and 200-50hPa thickness
    - Tsurf
    - TCWV

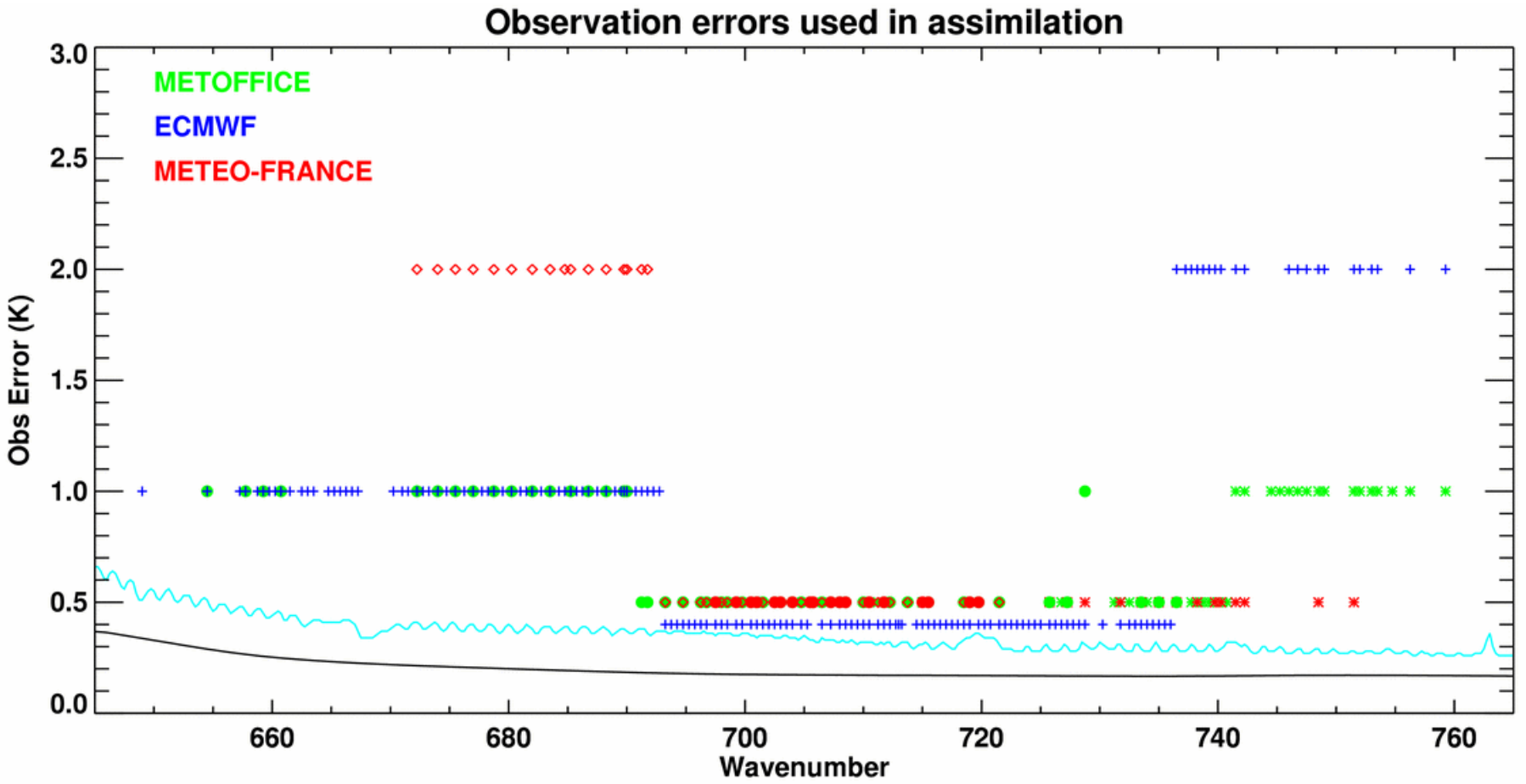
Bias correction (2)

- ECMWF, Meteo-France and met.no all use the same predictors
  - global offset
  - 1000-300hPa, 200-50hPa, 10-1hPa and 50-5hPa thicknesses;
  - nadir view angle **1, **2, **3
- No thickness predictors for LW window channels to restrict aliasing of residual cloud into erroneous bias corrections

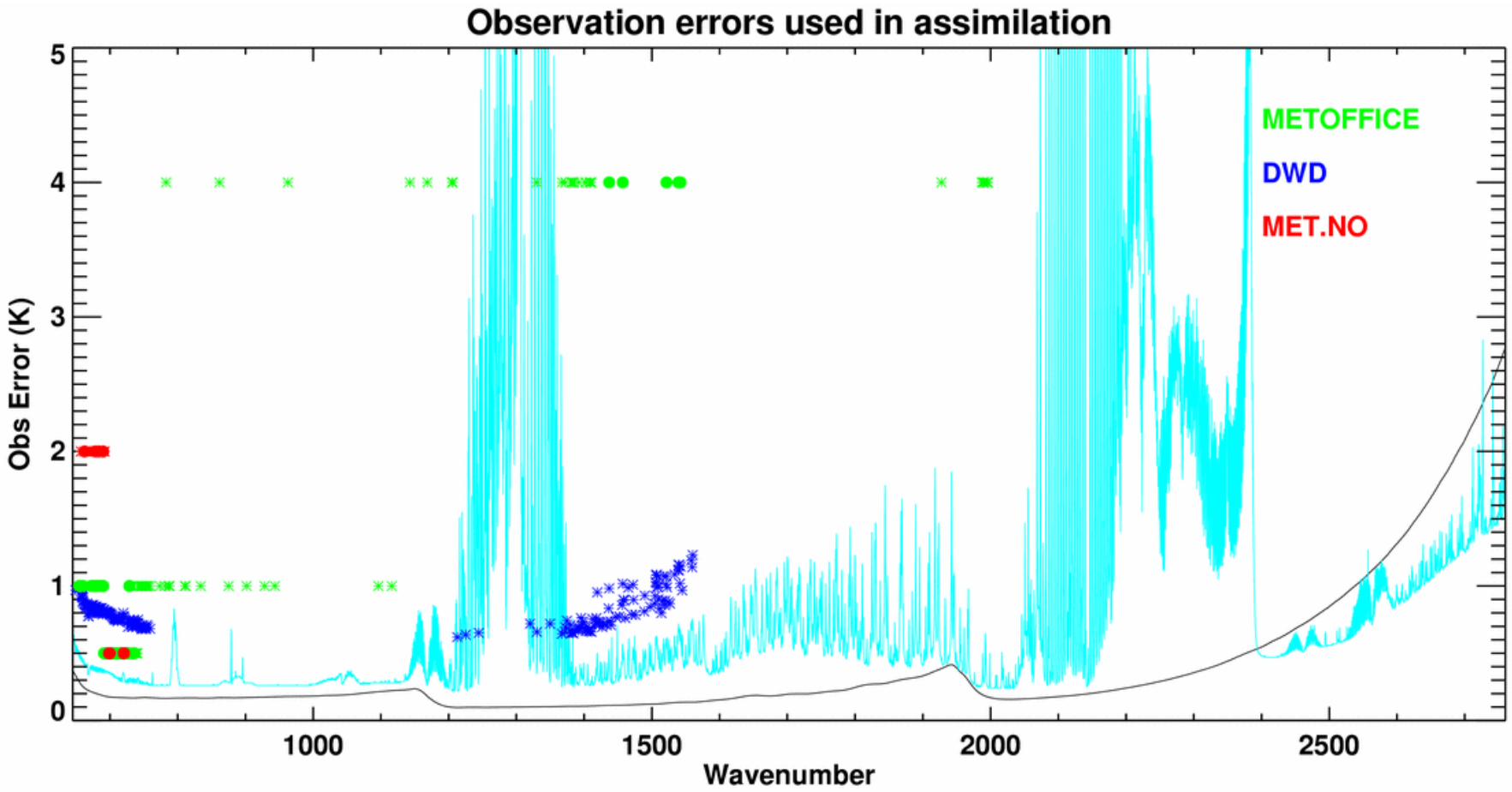
Observation Errors – Global Models



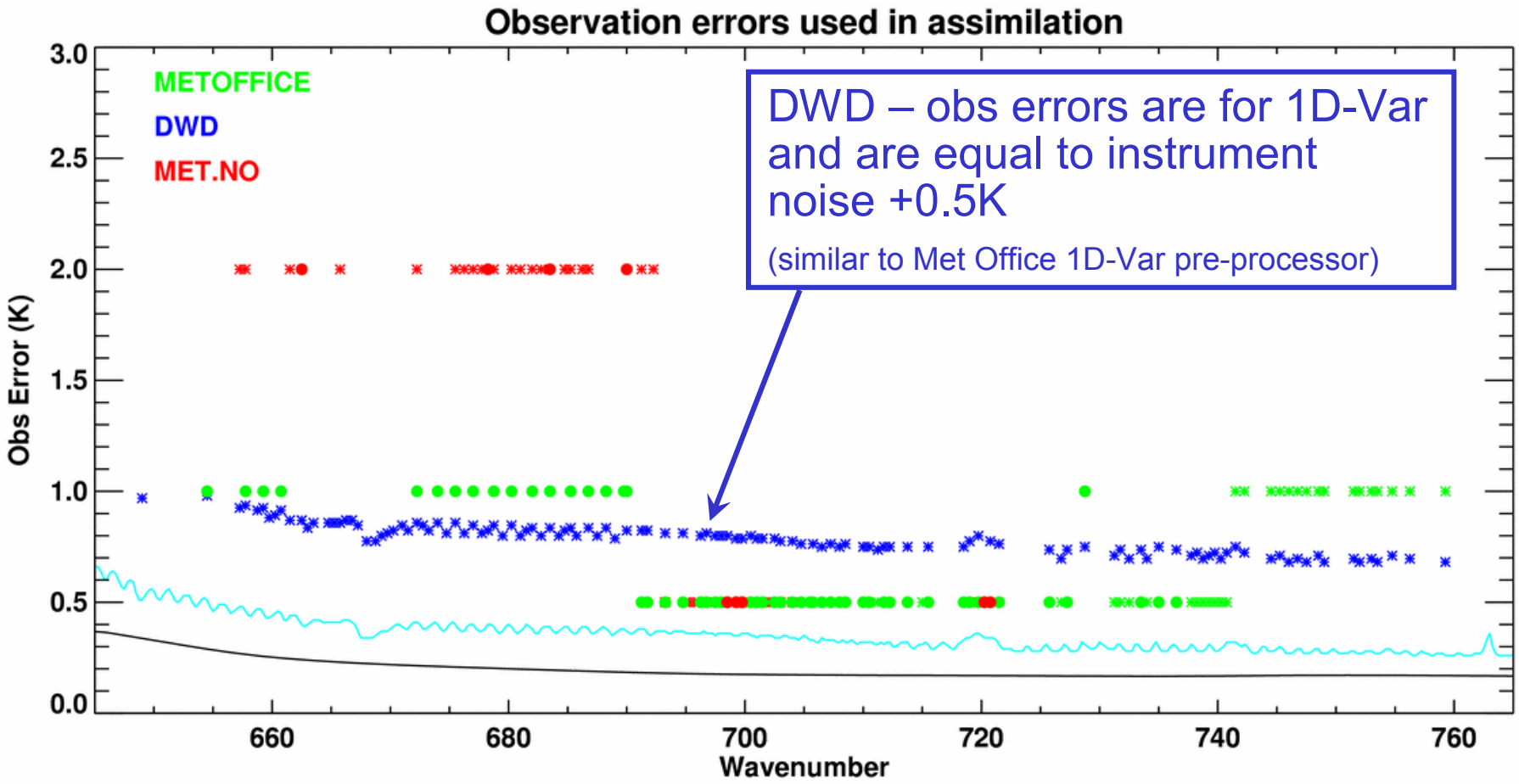
Observation Errors – Global Models



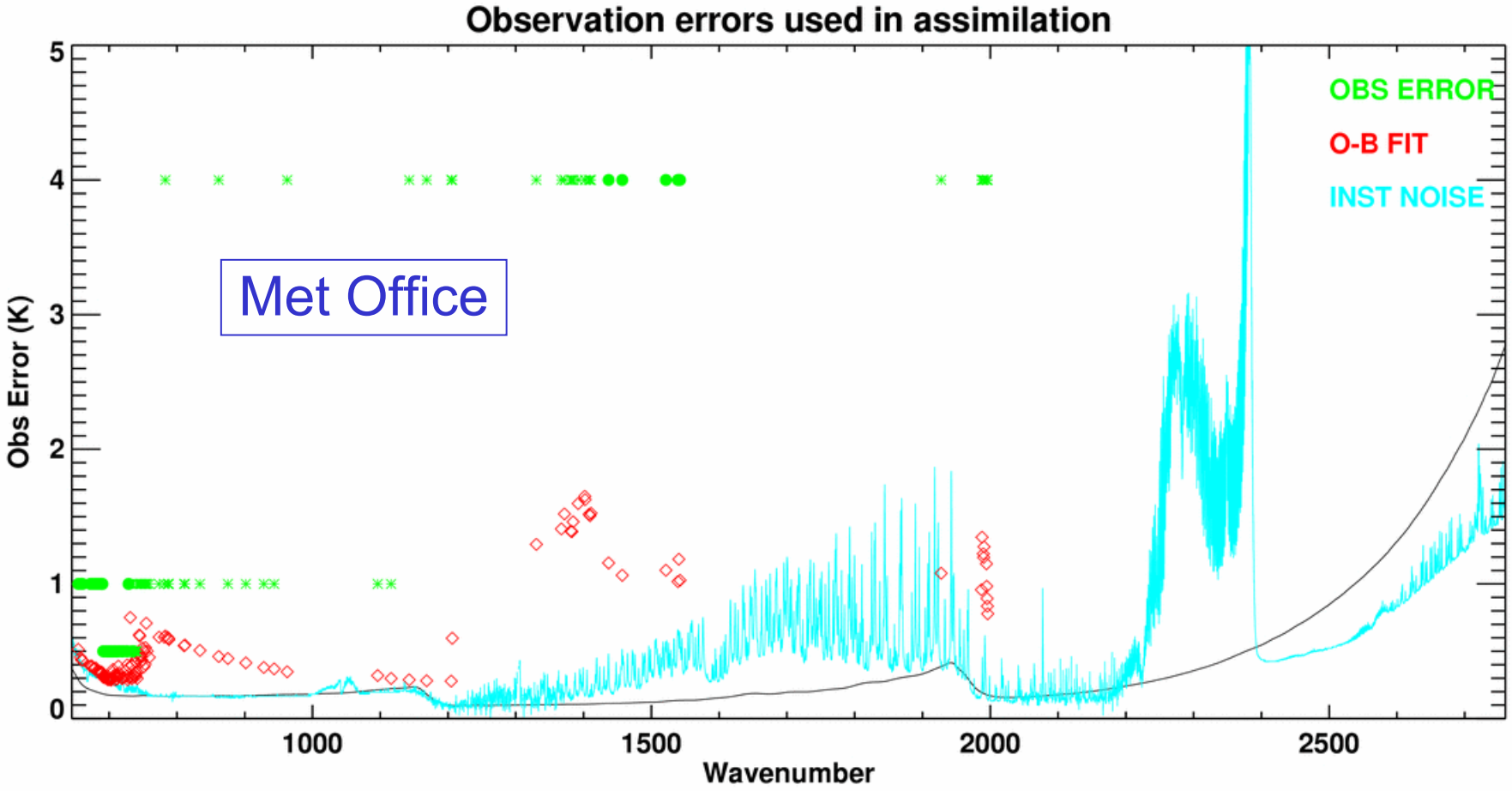
Observation Errors – Limited Area Models



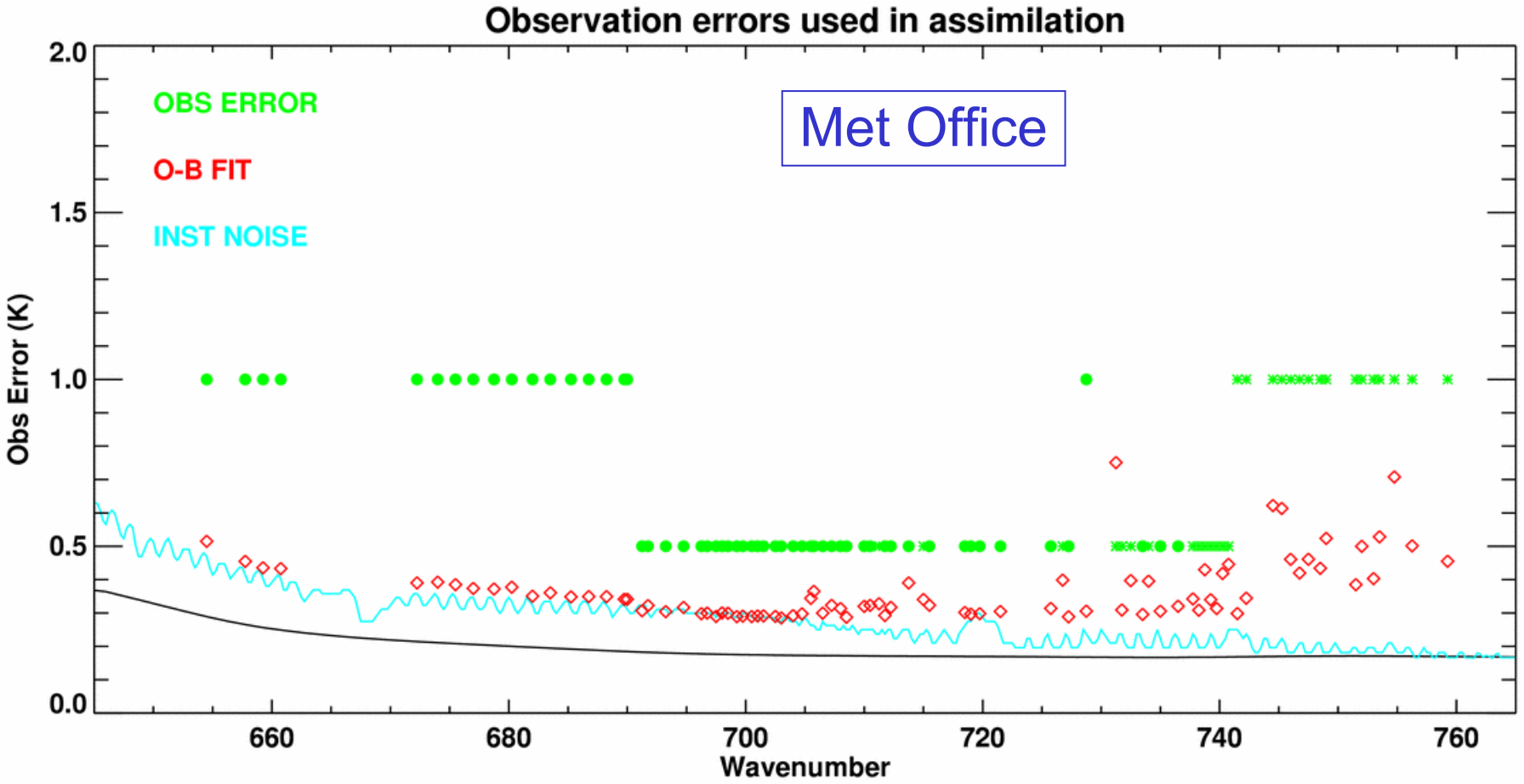
Observation Errors – Limited Area Models



How do observation errors compare to model fit to data? (1)



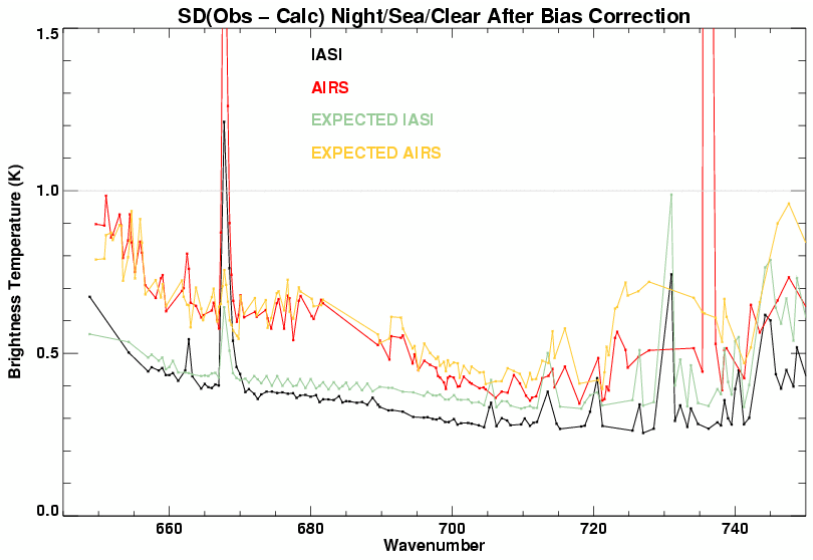
How do observation errors compare to model fit to data? (2)



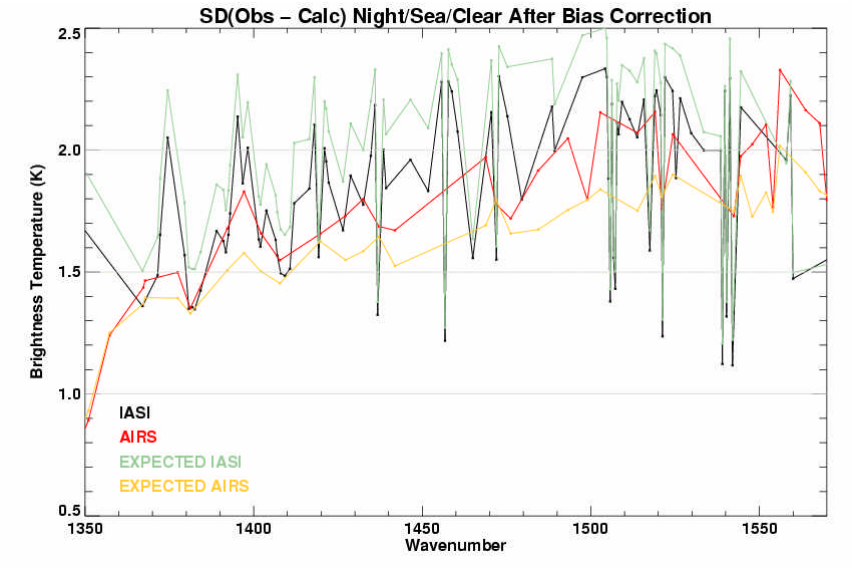
How do observation errors compare to model fit to data? (3)

- SD(O-B) compared to HBH^T+R

Met Office



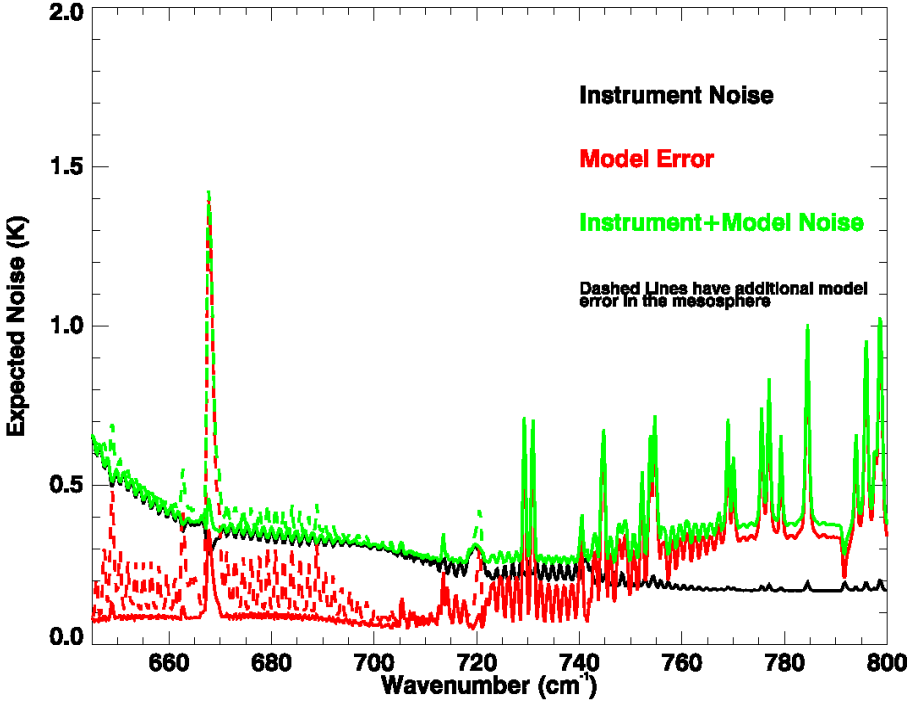
LW CO2



Water Vapour

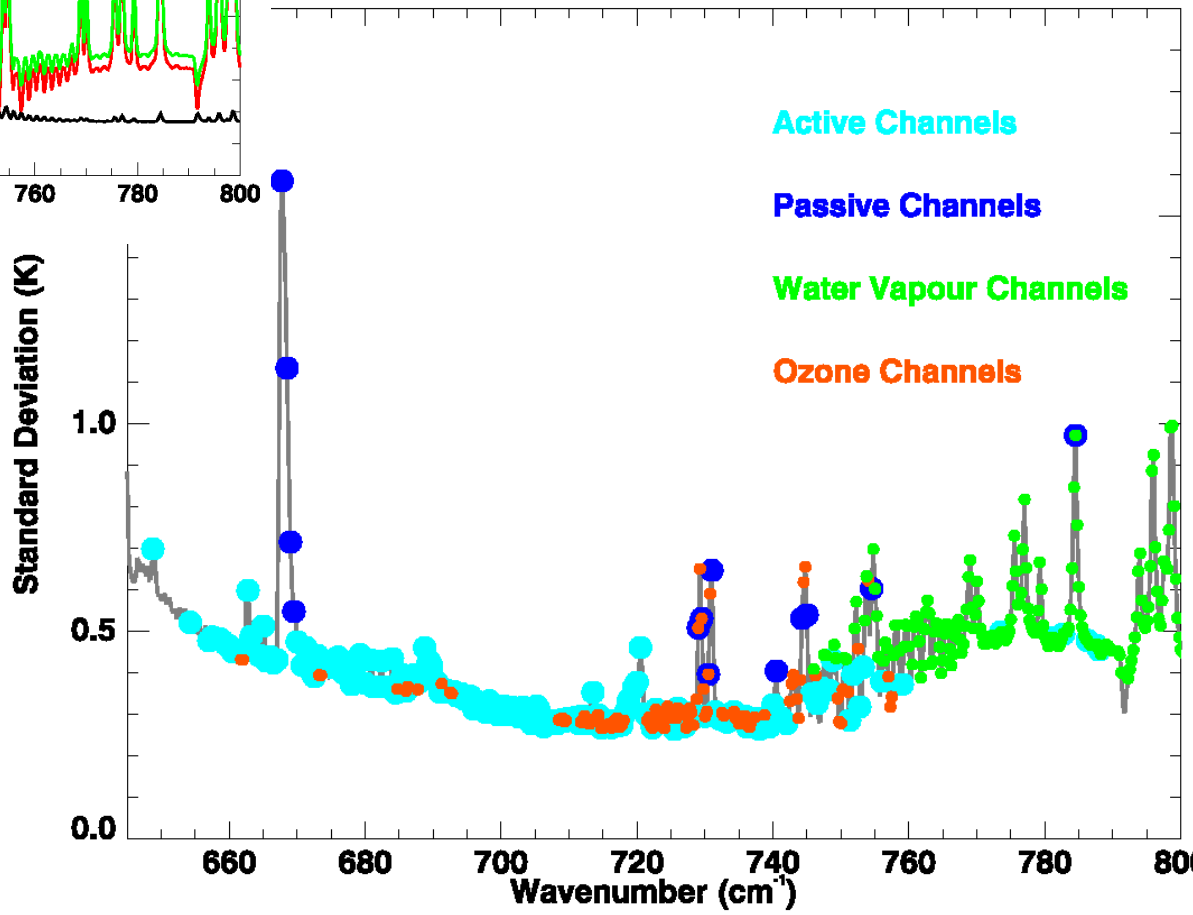
How do observation errors compare to model fit to data? (4)

ECMWF



Calculated Std. Dev.

Observed Std. Dev.



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 restricted over land and sea-ice
- Height of model top generally restricts usage of high-peaking channels
- Observation errors are inflated significantly over O-B fit
- There are some differences in bias correction scheme
- We all use RTTOV! (though the version varies)

Impact of IASI data assimilation in NWP

Comparing impacts between centres

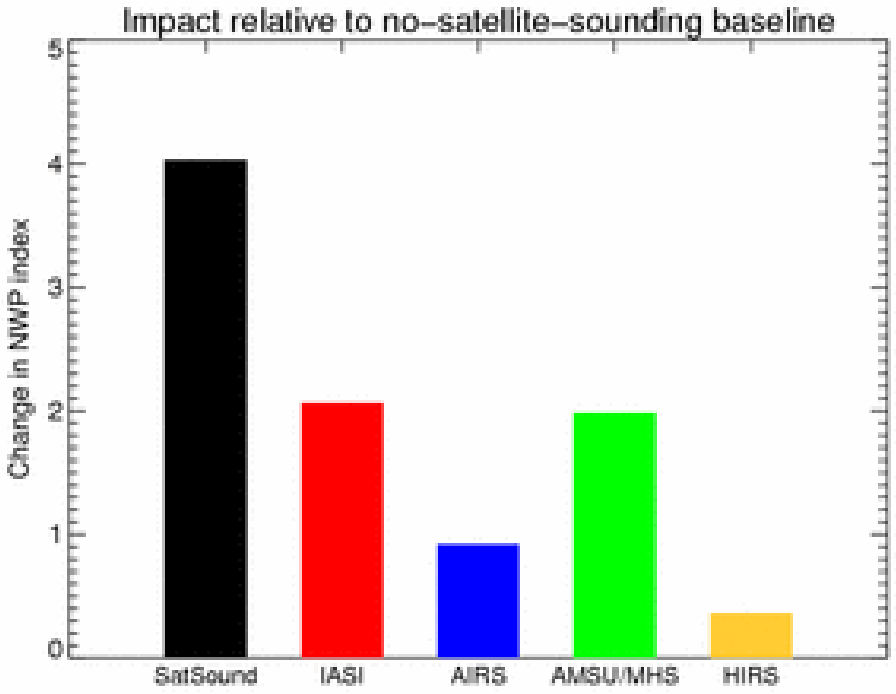
- It is quite hard to compare impacts at different centres directly
- All centres use different methods to assess impact
- Everyone produces different types of plots!

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
  - Met Office impact surprisingly good in the northern hemisphere
- 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

Impact relative to other instruments

- Verification v observations
- HIRS and AMSU/MHS MetOp only
- Same cloud detection methodology for IASI/AIRS/HIRS

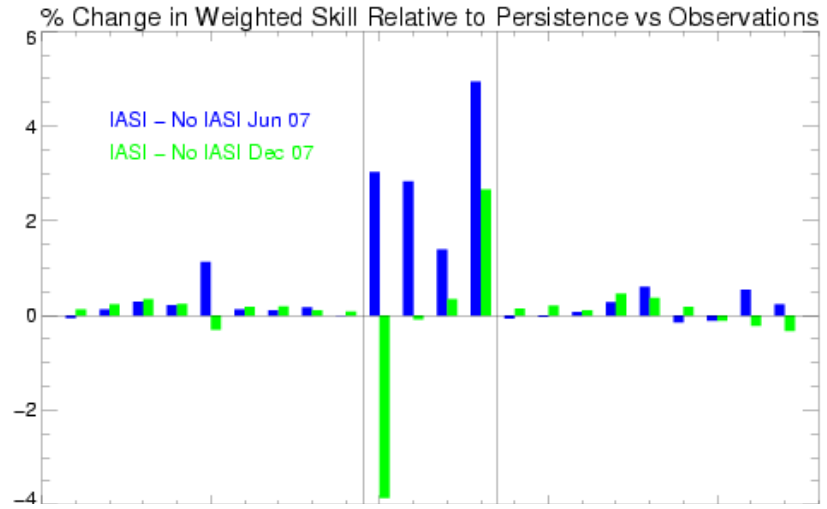


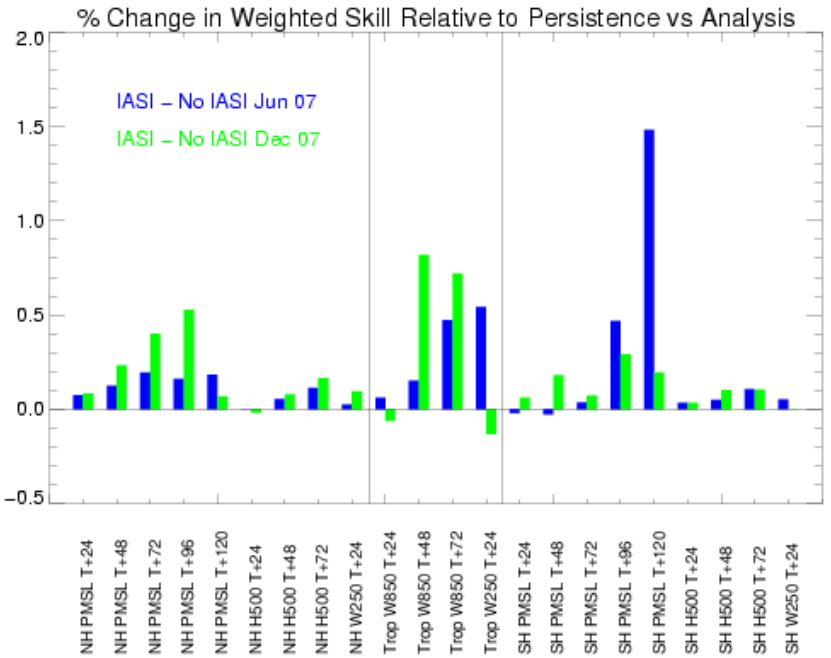
Summary of impacts in Limited Area Models

- 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
- DWD find improvement in 2m temperature when using McNally&Watts instead of IASI L2 cloud flags to determine observation usage

Met Office impact

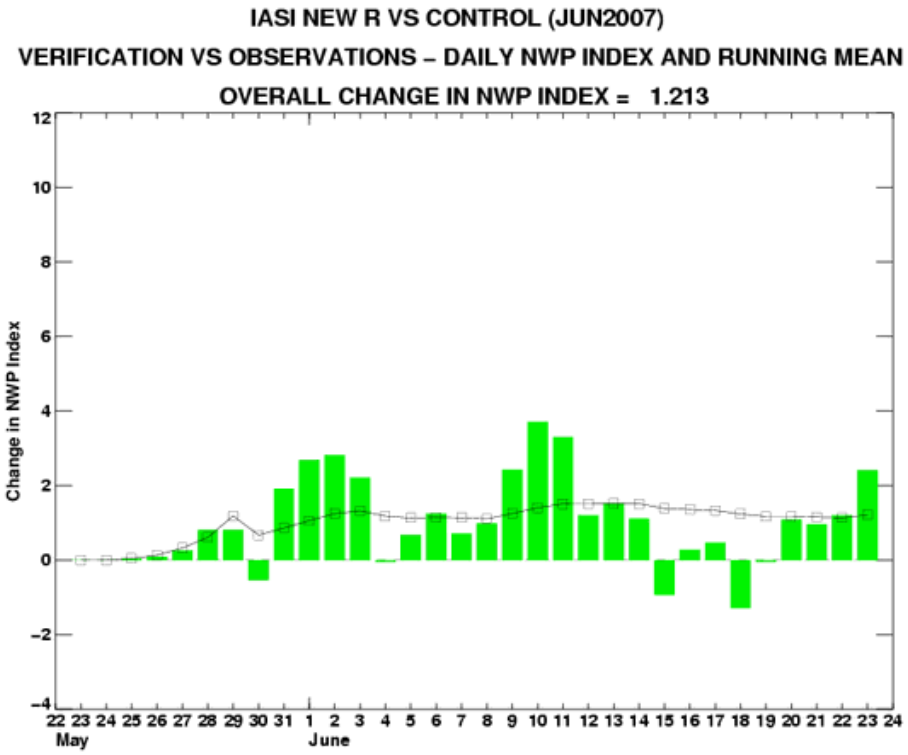
- Verified v Obs, positive impact:
  - H500 in tropics and SH
  - Winds in tropics and SH
  - Strat T in SH
  - PMSL in NH
- Verified v Obs, negative impact:
  - Strat Height
- Verified v Anl, positive impact:
  - Heights in NH and Tropics
  - Most variables in SH
- Verified v Anl, negative impact:
  - Strat T in Tropics

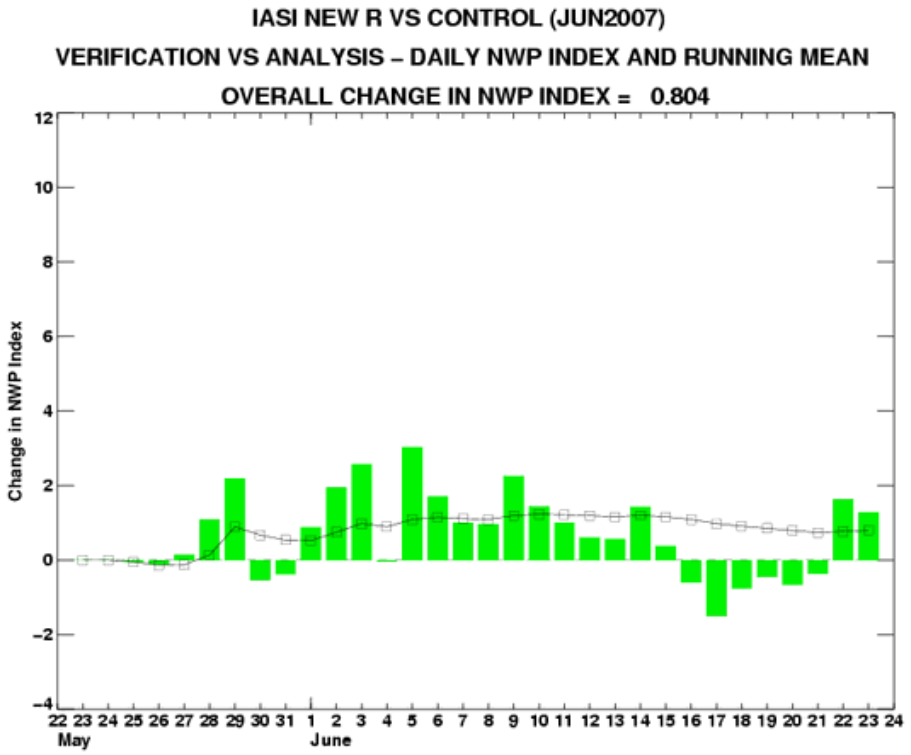




Met office impact

- Results good for most days of the trial period May 24-June 24 2007



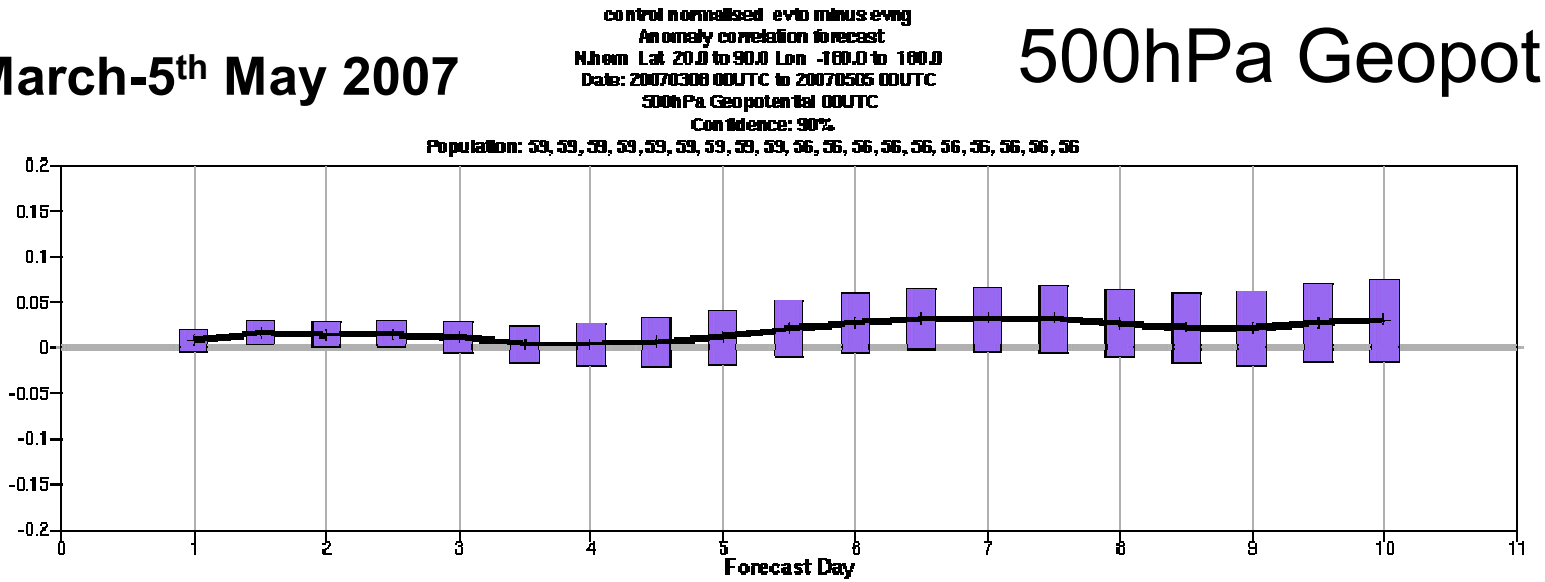


ECMWF impact

8th March-5th May 2007

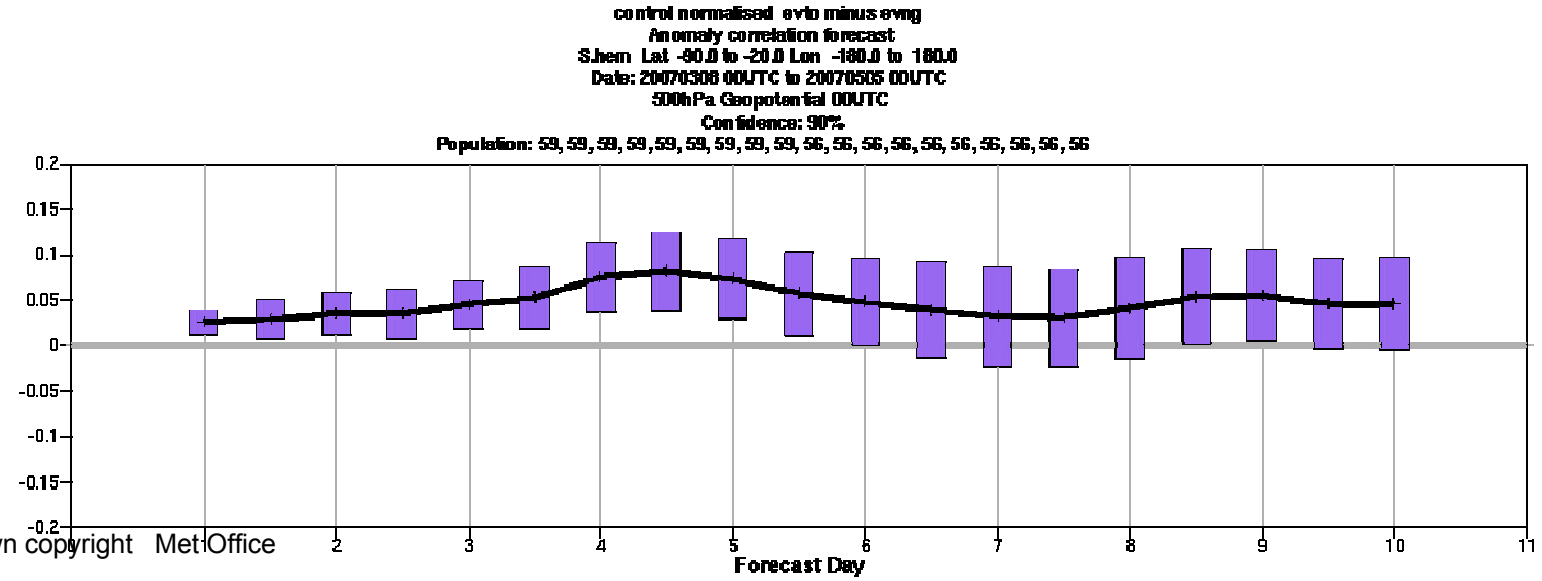
500hPa Geopot. AC

NH



IASI Better

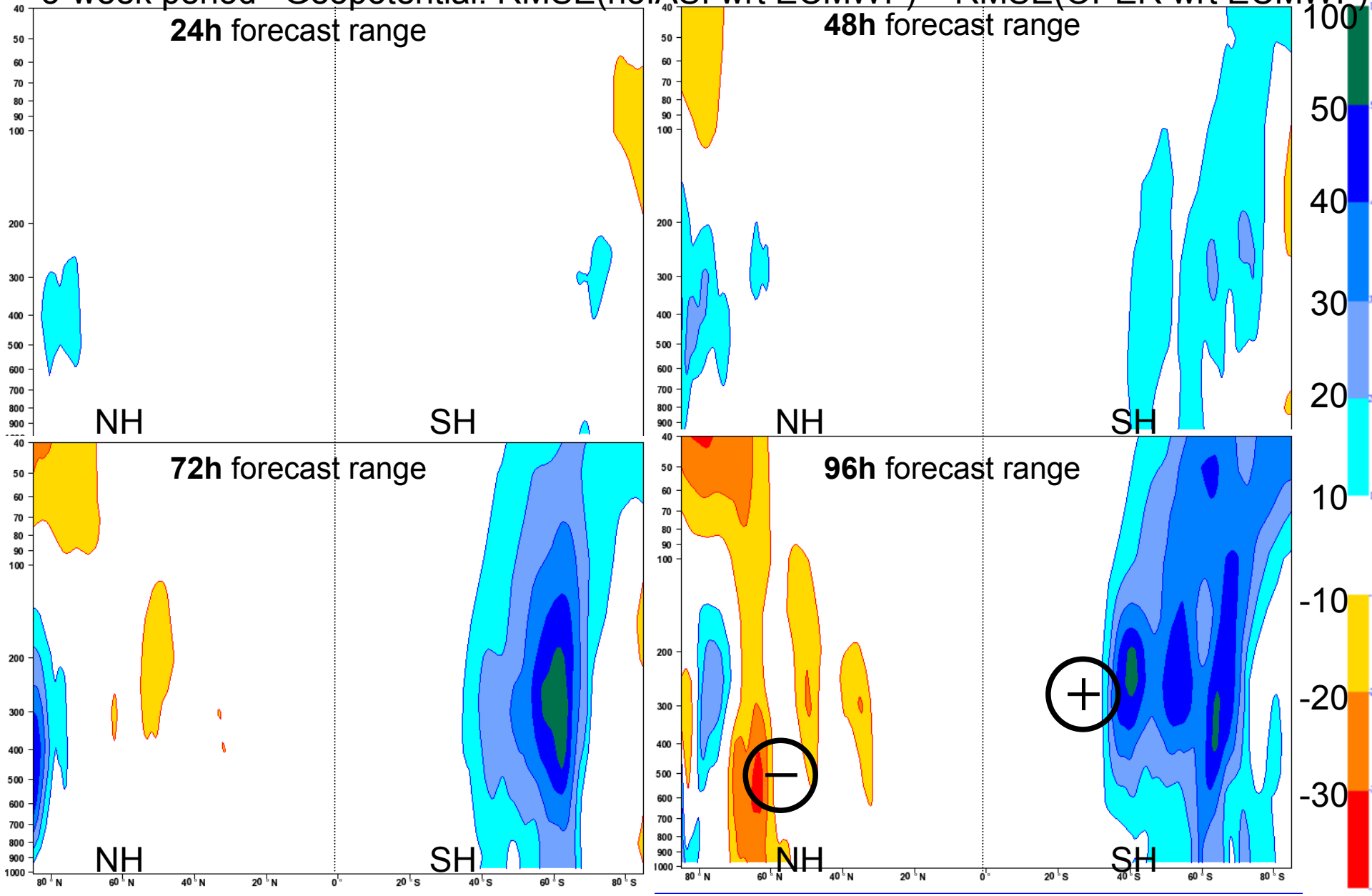
SH



IASI Worse

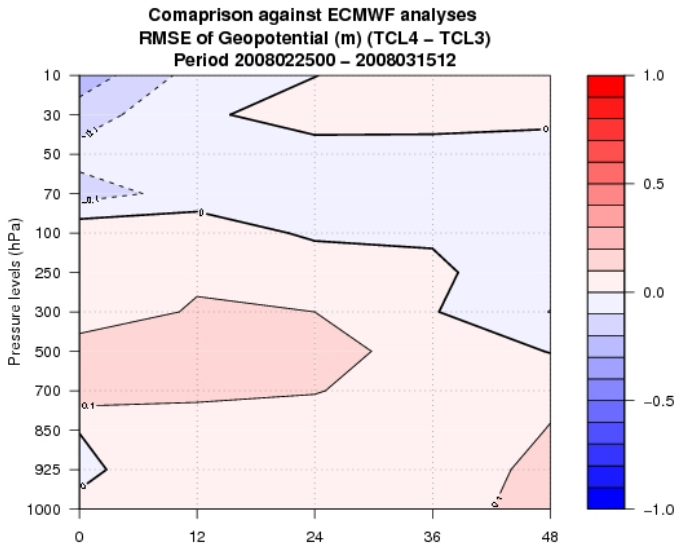
Meteo-France impact

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



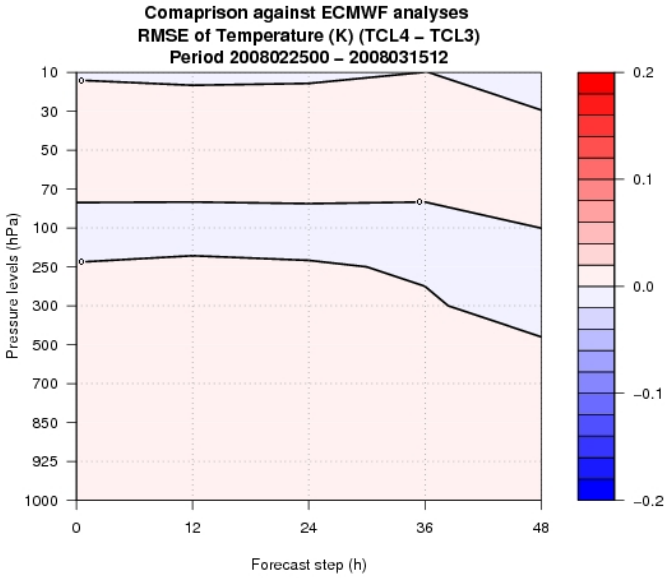
met.no Impact

Comparison against analyses



Impact on Geopotential

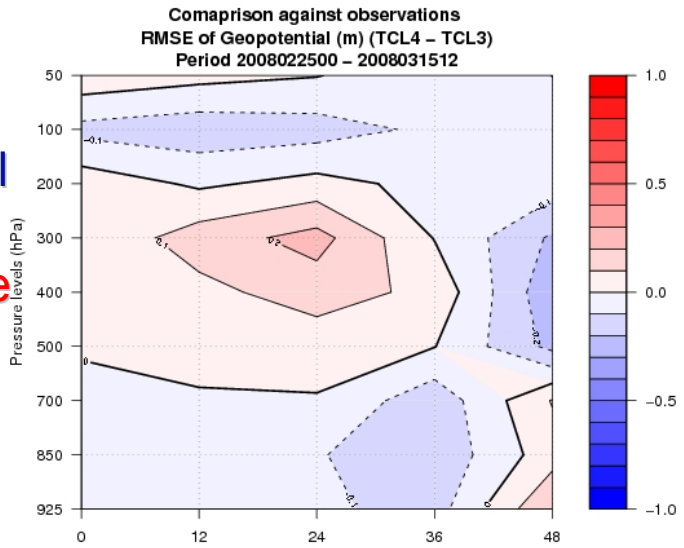
Red: positive impact

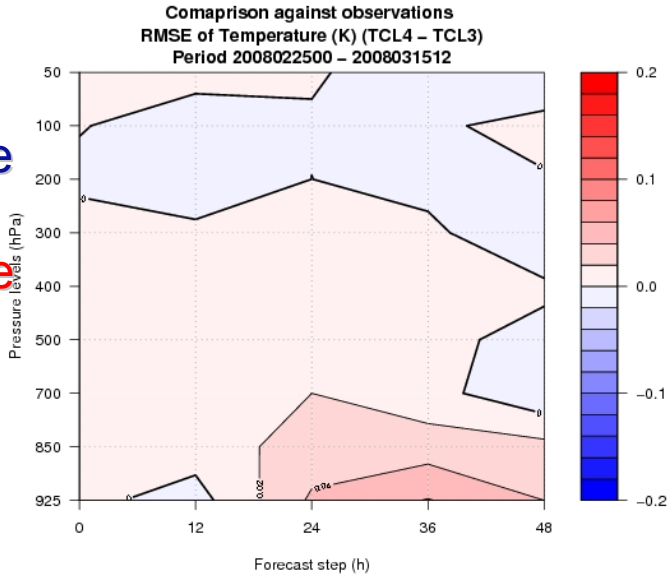


Impact on Temperature

Red: positive impact

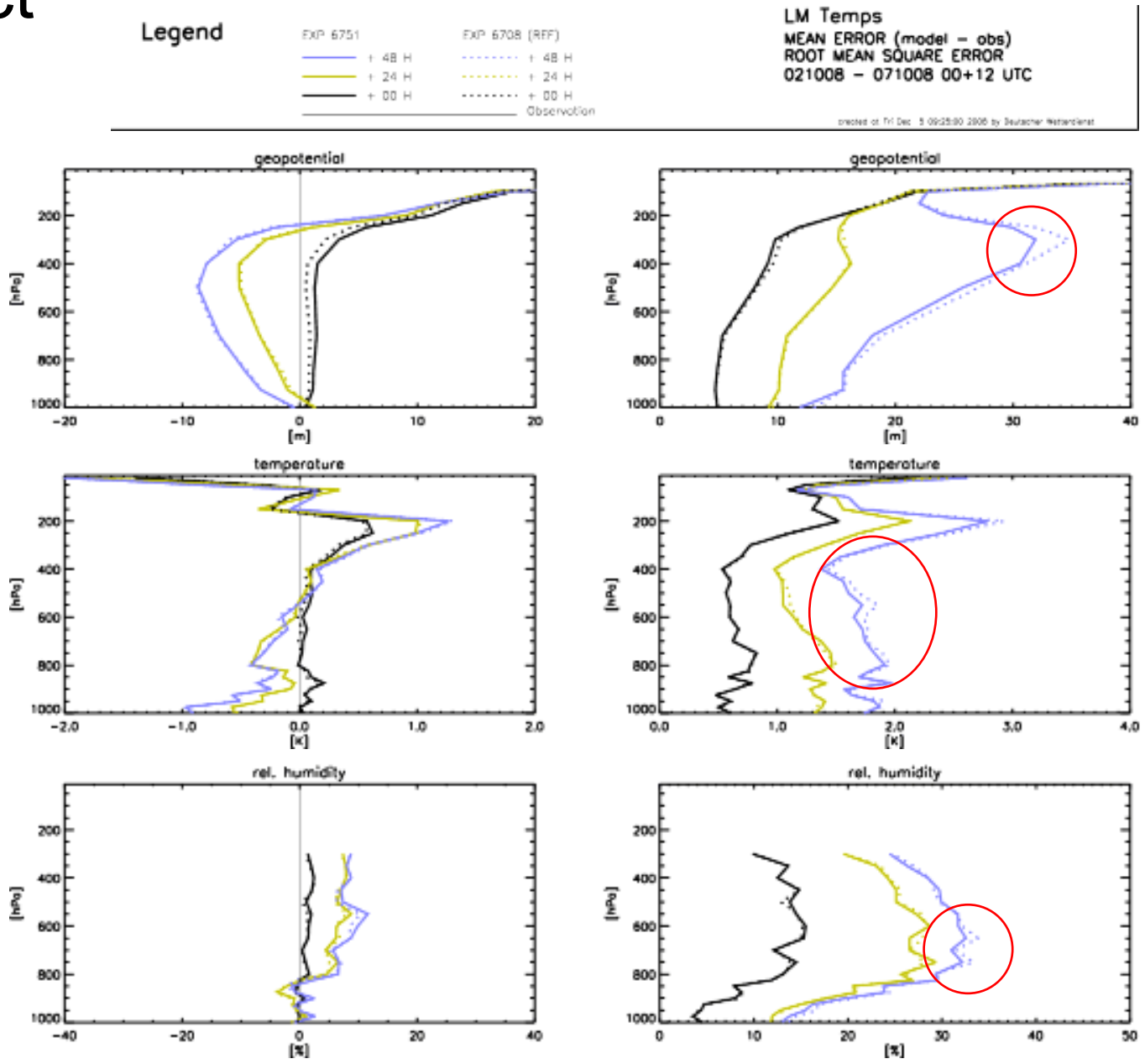
Comparison against observations





DWD impact

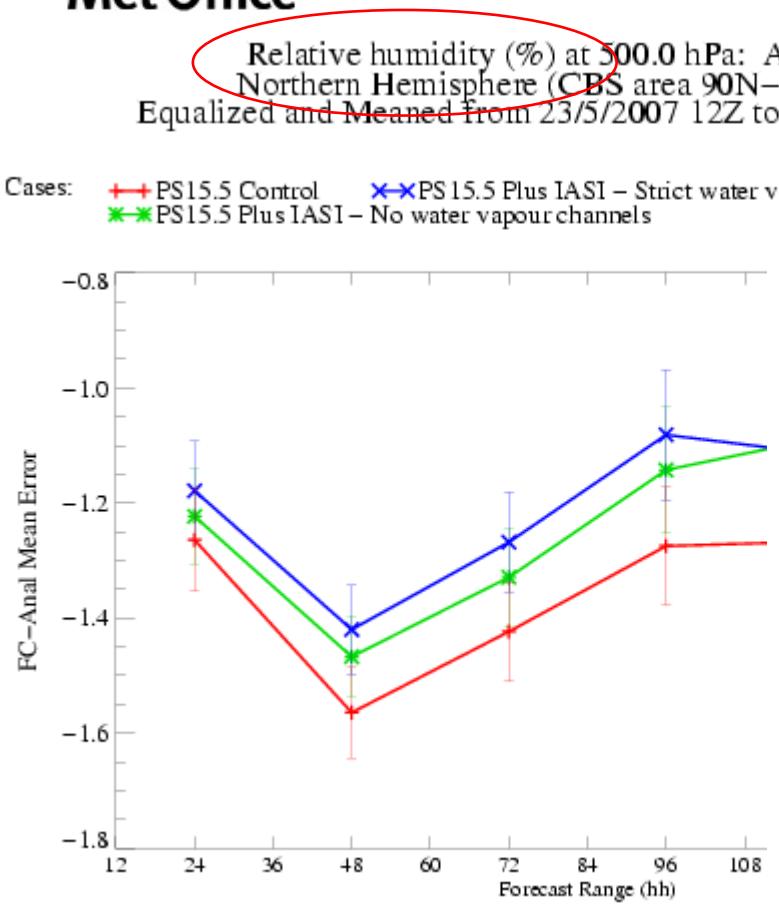
- Solid IASI
- Dashed control
- LH plot Bias
- RH plot RMSE

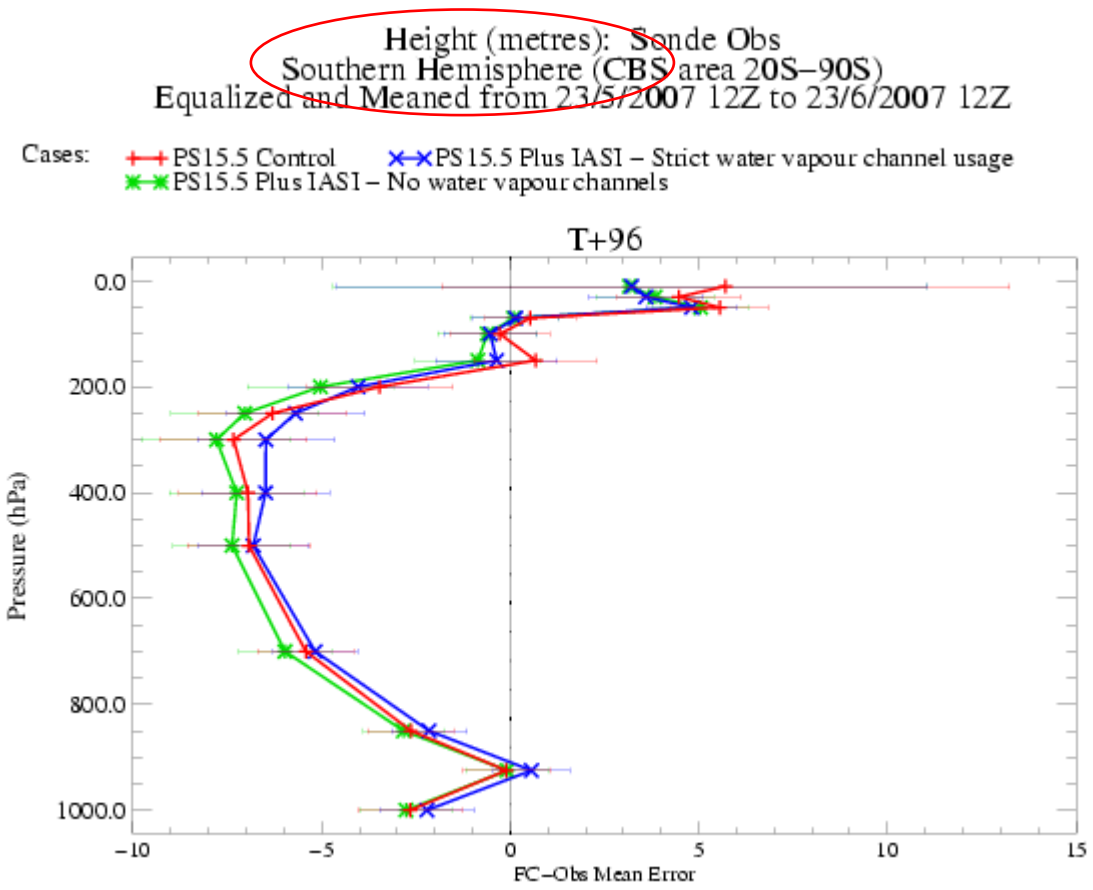


Impact of water vapour channels

- Generally a rather weak impact is observed from assimilation of water vapour channels
- Observation errors greatly inflated to prevent damage to the model
  - Error correlations between channels are not taken account of during assimilation
- Only slight evidence that RH is improved directly
- Met Office impact mostly on tropical winds

Impact of water vapour channels – Met Office

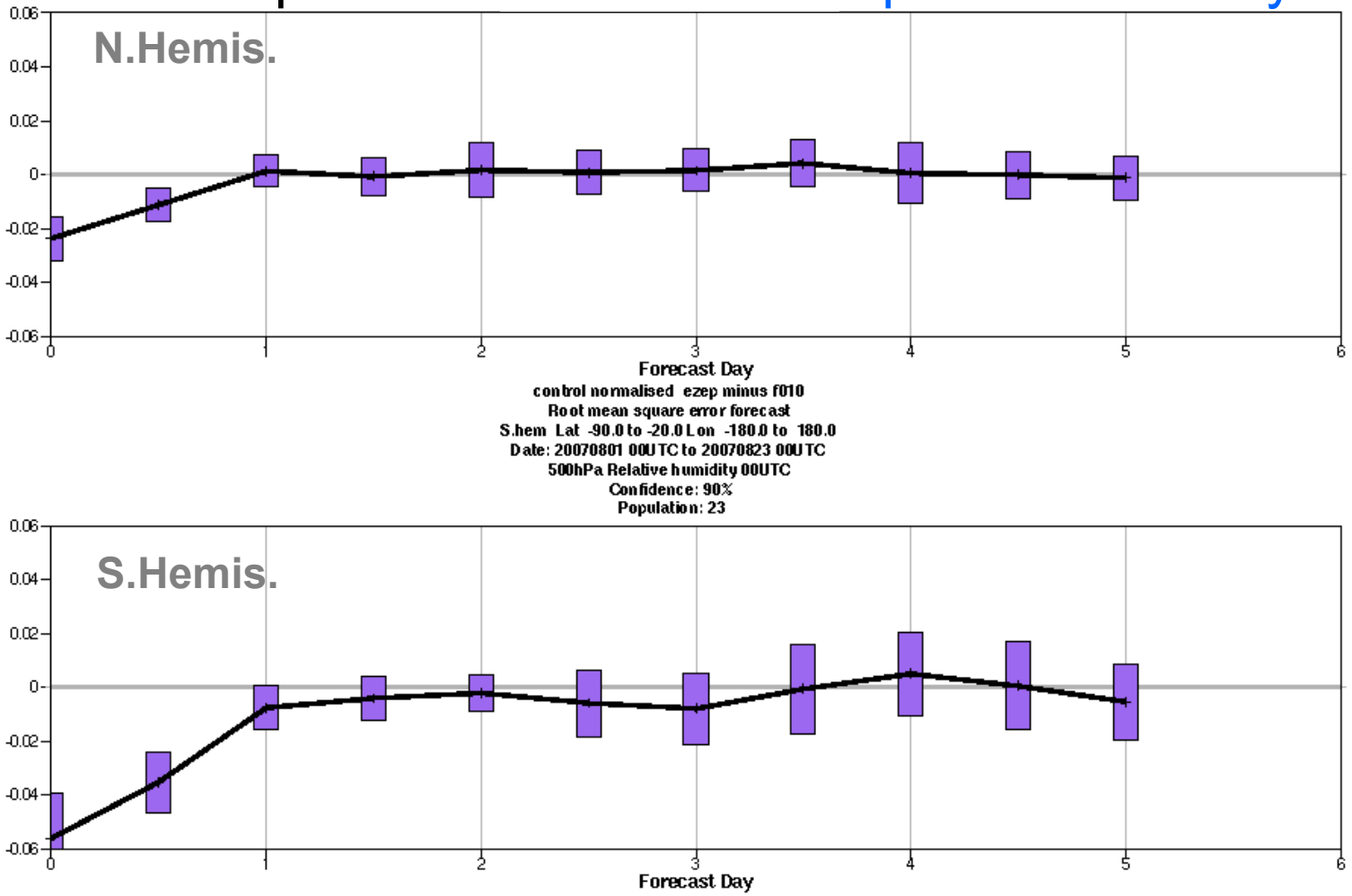




Impact of water vapour channels – ECMWF

1st-23rd August 2007

RH500 Forecast Impact
Root Mean Square Error verified vs Operational Analysis



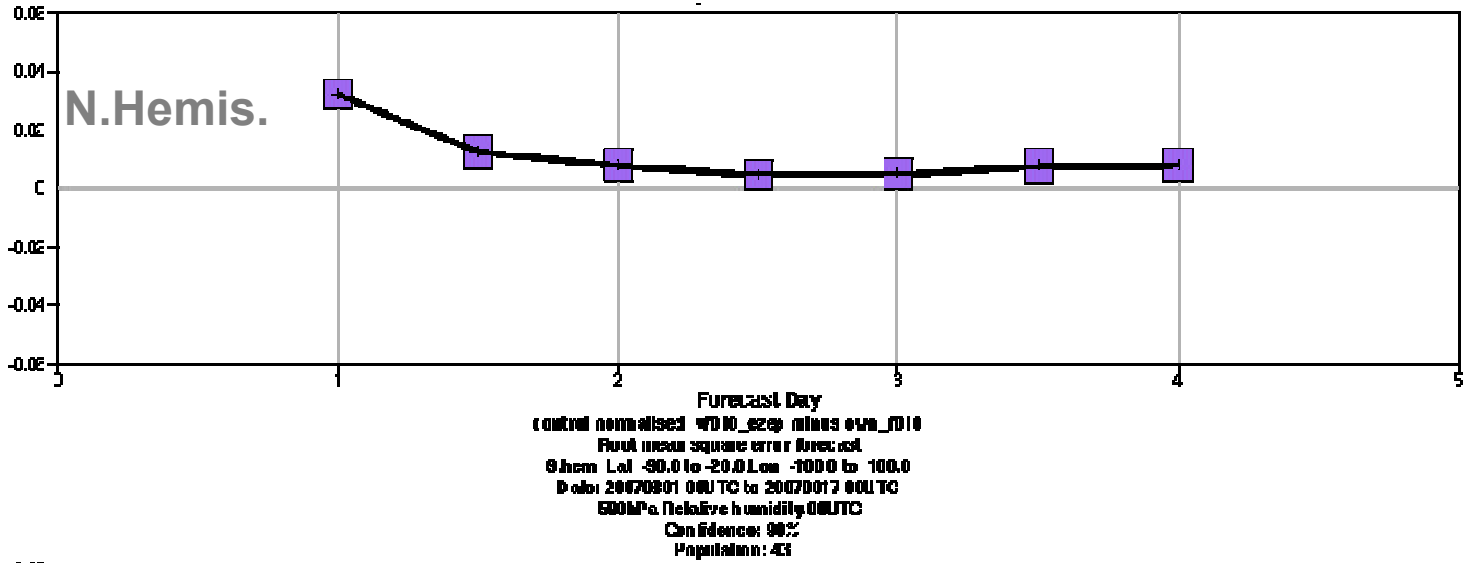
Expt Better

Cntrl Better

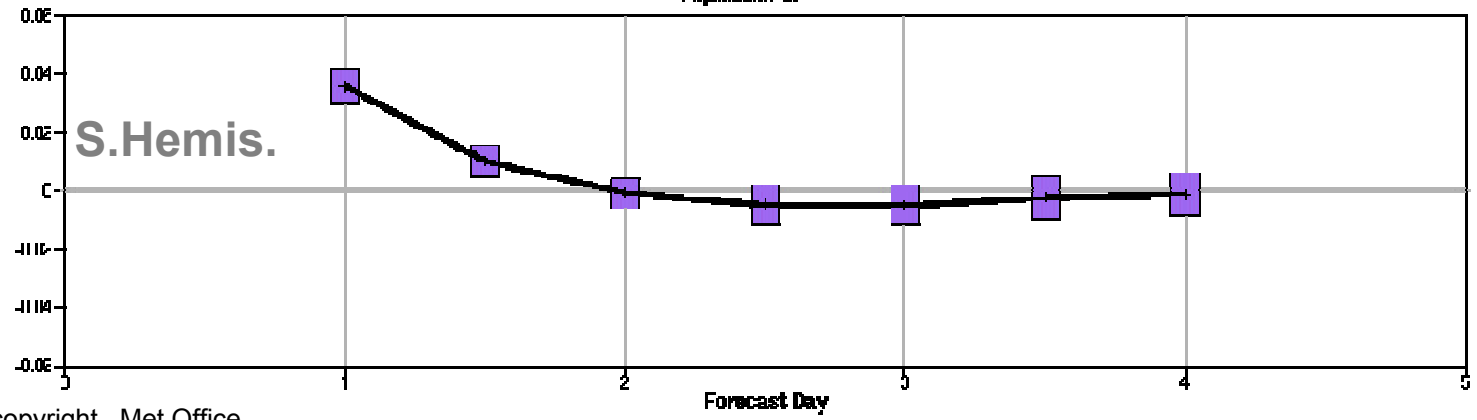
Impact of water vapour channels – ECMWF

RH500 Forecast Impact: RMS Error verified vs Experiment's Analysis

1st Aug.-9th Sept. 2007



Expt Better

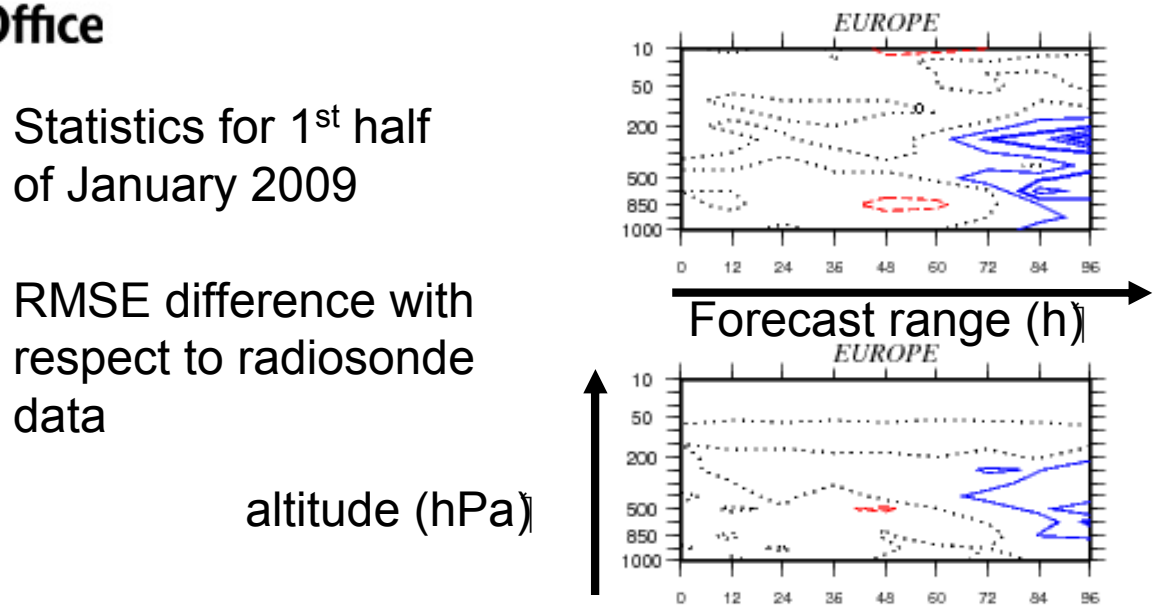


Cntrl Better

Impact of water vapour channels – Meteo-France

Statistics for 1st half of January 2009

RMSE difference with respect to radiosonde data



Temperature,
1 isoline every 0.05 K

Humidity,
1 isoline every 1%

Impact of assimilating WV channels:
blue: positive = reduction of RMSE
red : negative = increase of RMSE

- Meteo-France and the Met Office also see curious impact on stratosphere
  - Meteo-France heights especially in Southern Hemisphere (summer hemisphere)
  - Met office temperatures in Northern Hemisphere (summer hemisphere)

Current areas of research

Extending use of channels

- Meteo-France have an active project to add water vapour channels
- Met.no would like to add more tropospheric and surface channels (and in the longer term water vapour channels) but some improvements to surface analysis must be made first
- DWD are investigating use of water vapour channels
- Modest impacts expected from these changes

Use of cloud-affected radiances (1)

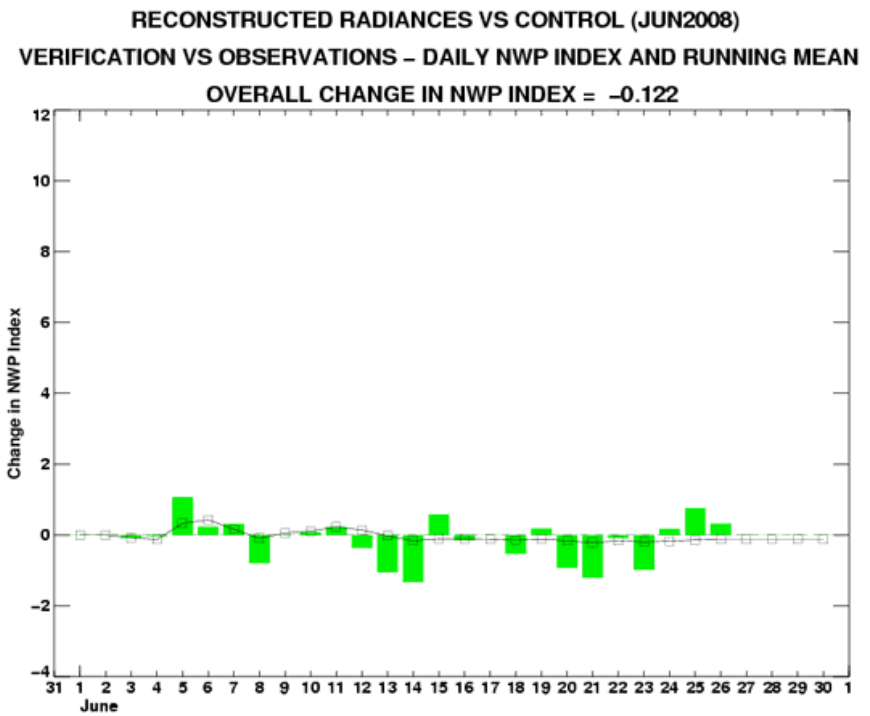
- Meteo-France and ECMWF currently use McNally & Watts scheme to determine clear channels unaffected by cloud
- Met Office currently clear scenes only
- All three plan to implement variations on a theme, assimiliating channels peaking above homogeneous cloud, using an effective cloud emissivity and CTP as fixed constraints.
  - Met Office and Meteo-France currently already use their schemes for AIRS processing
  - See Tony McNally's talk later

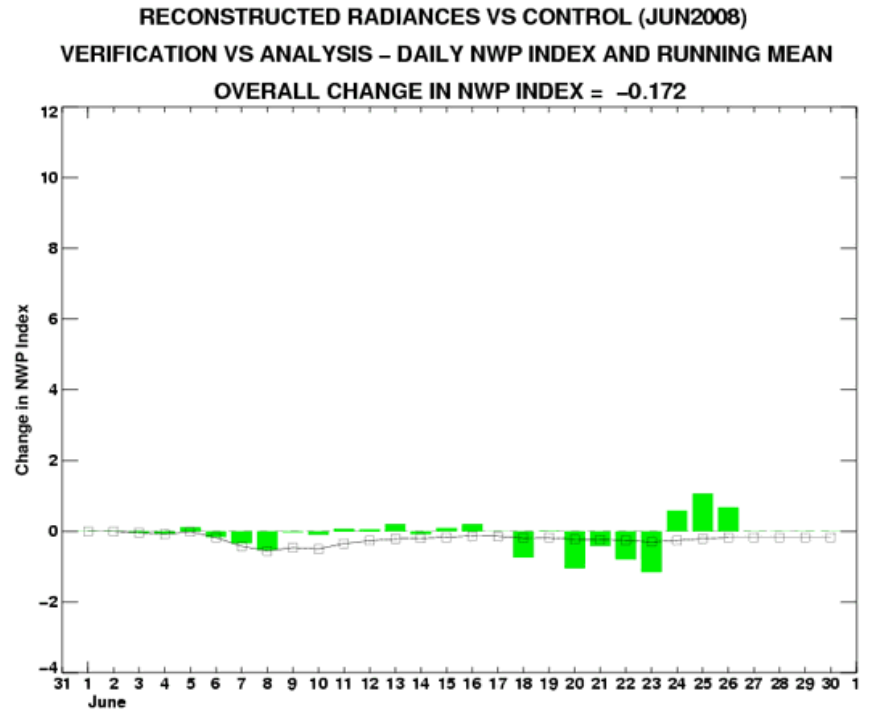
Use of principal component compression (1)

- Operational centres are thinking about the proposed PC-compressed data stream
  - It is possible to switch to reconstructed radiance datastream without damaging impact from IASI obs
  - It is very hard to get extra impact out of PCs (often regarded as “better”/“lower noise”
- Centres are waiting for stabilisation of PC radiative transfer models
  - This is a separate issue, the current idea is that data is disseminated via PC scores based on real data…
  - … but would be assimilated with PCs based on simulated data
  - This would require a transformation which may not be desirable
- See Andrew Collard’s talk later

Use of PC compression (2)

- Radiances reconstructed from 120 PCs based on 6 months of real data
- Otherwise treated exactly as normal IASI obs
- Insignificant impact of -0.147
- Impact mixed day-to-day
- Compare with overall IASI impact of +1.0



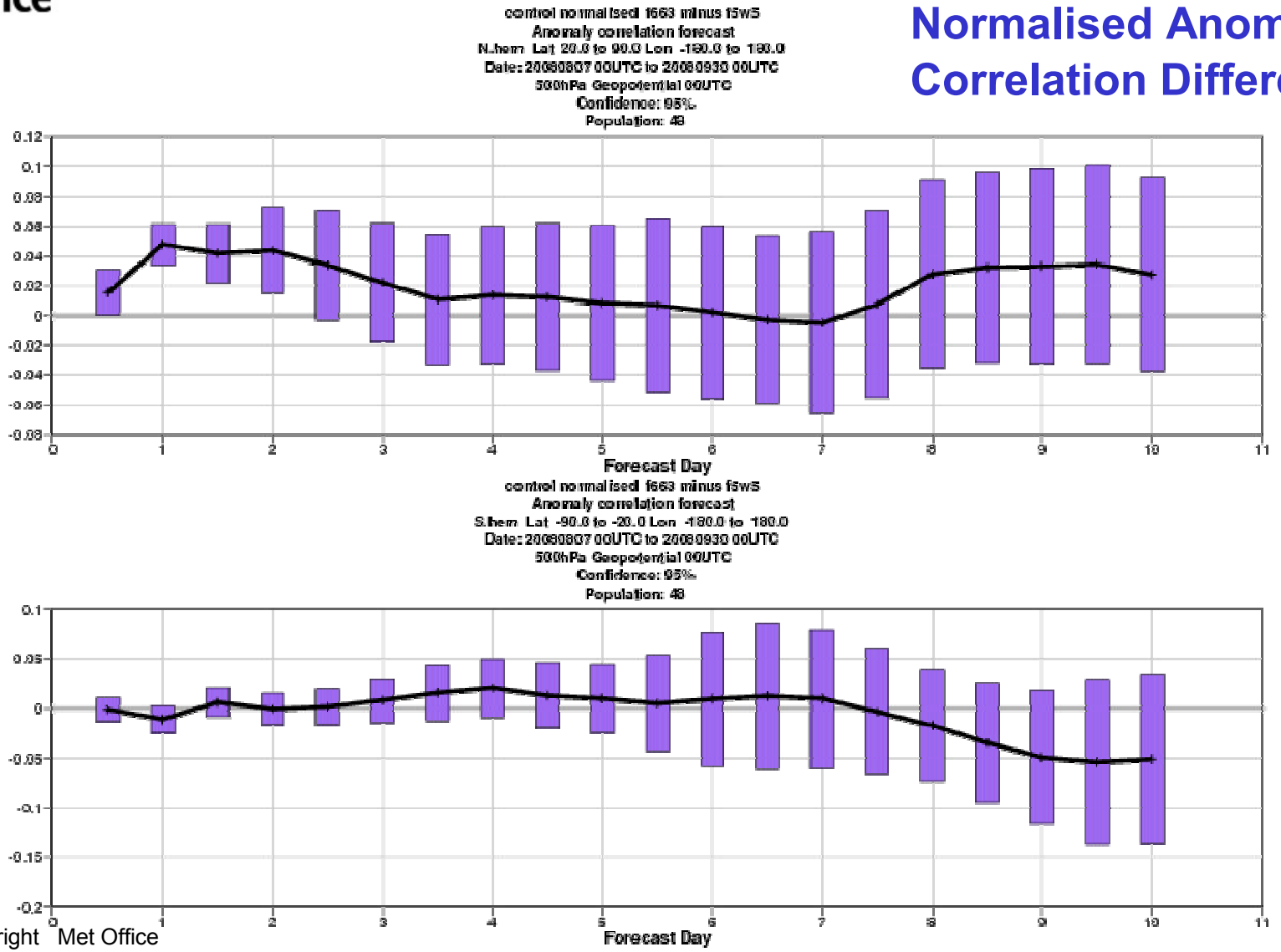


Use of data over land (1)

- ECMWF and Met Office both have active projects to improve land surface emissivity and increase usage of channels over land
- This would possibly include adding 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
- Met Office already use limited IASI data over land but current AIRS implementation does not.
- ECMWF have recently trialled assimilating obs over land with fixed emissivity

Use of data over land (2)

500hPa Geopotential Normalised Anomaly Correlation Difference



Problem errors and concerns for NWP

- Using high-peaking channels
  - Often model tops are not high enough and require filling in for the RT model.
  - Often there are large model biases in the uppermost levels
  - Channels have very long tails
  - Can find very large increments are generated which can propagate down through atmosphere
- Using data in polar regions
  - High snow/ice-covered land over Antarctica
  - Problems with model sea ice analyses around ice edge
  - Problems with cloud detection in polar regions
  - Vincent Guidard's talk

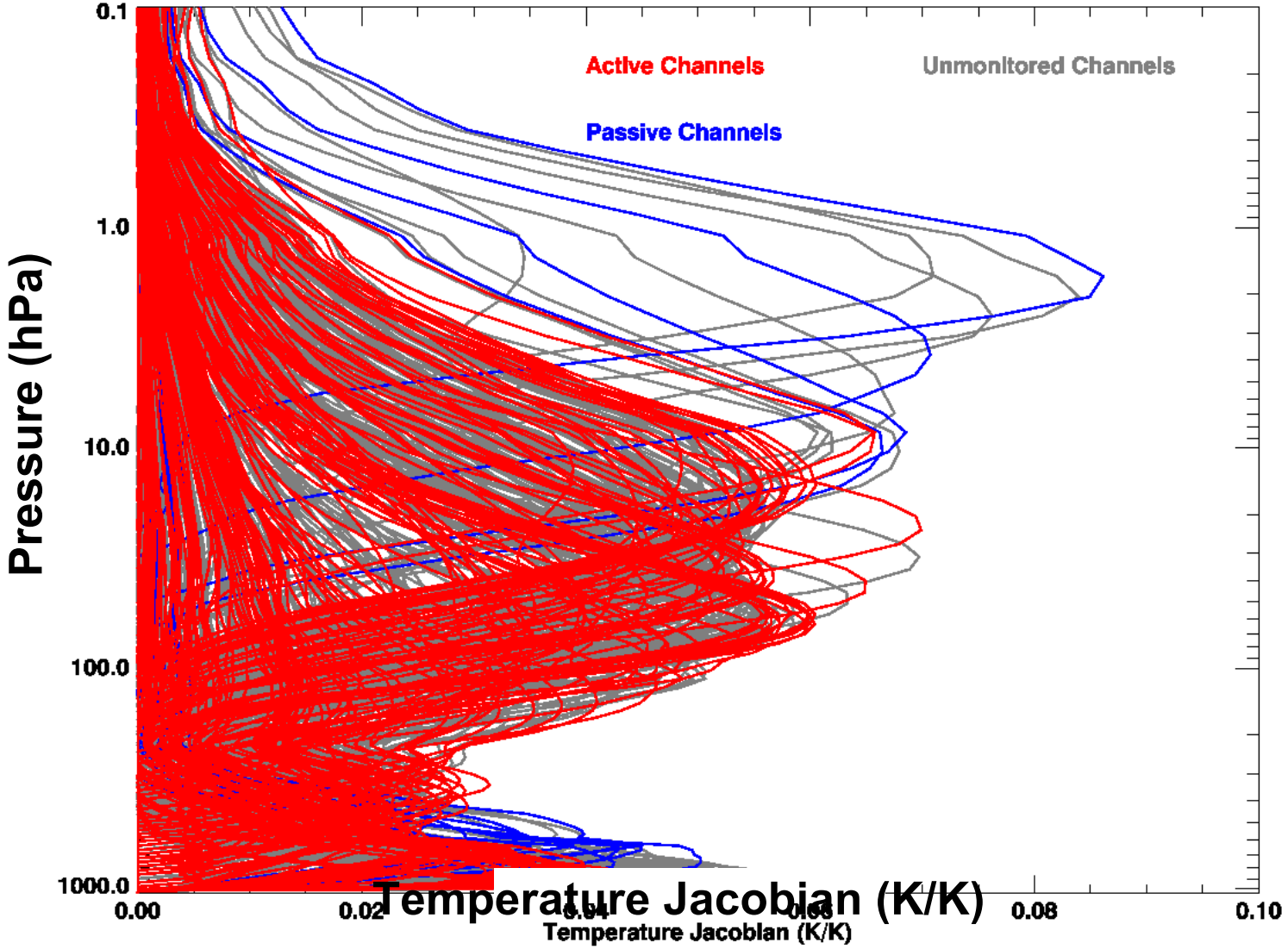
Why is impact from water vapour channels low

- One of the most crucial questions!
- IASI “sold” on its contribution to humidity analysis
- Small impact from water vapour channels rather disappointing…
- Problems especially with upper tropospheric channels
- Correlated observation errors likely to play a large part
- Are there general problems interfacing satellite obs with model?
- Do model biases exacerbate problems?

Thank you for listening! Any questions?

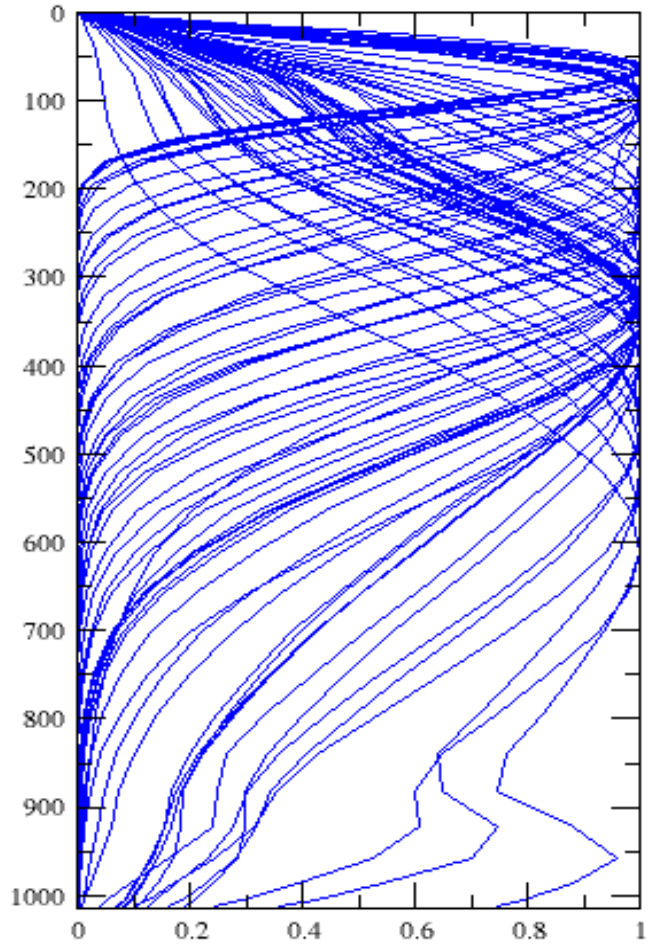
Backup slides

ECMWF
Jacobians of 15μm CO_2 Band

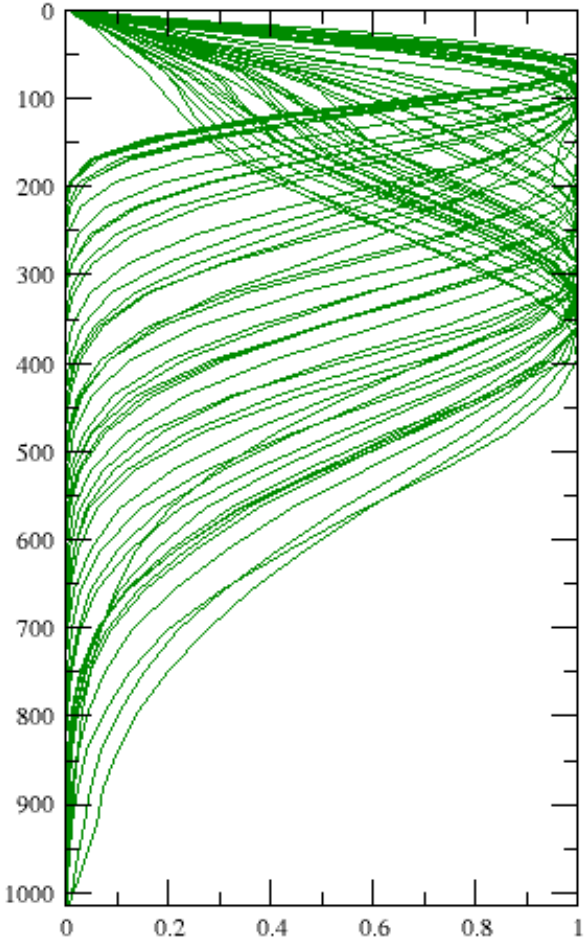


Meteo-France channel selection

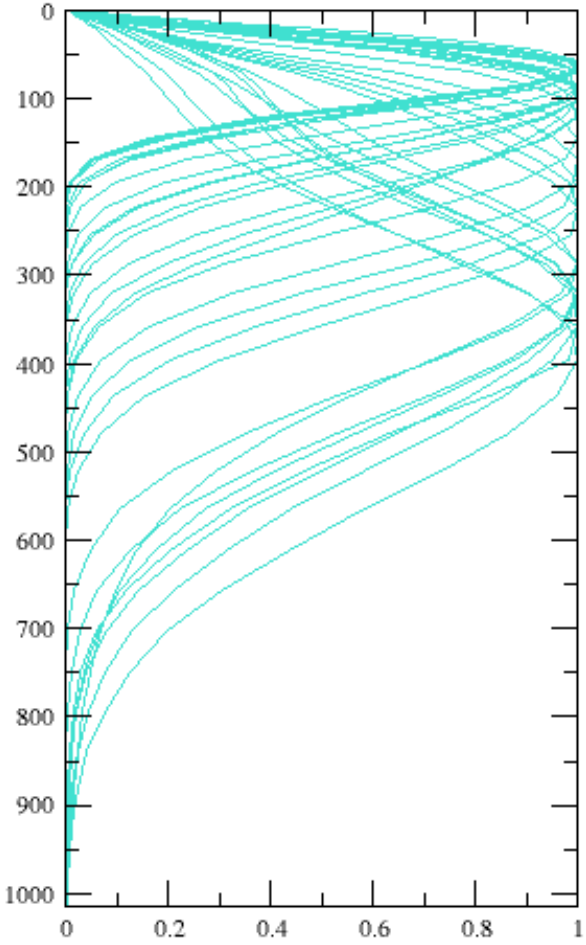
Weighting functions



sea

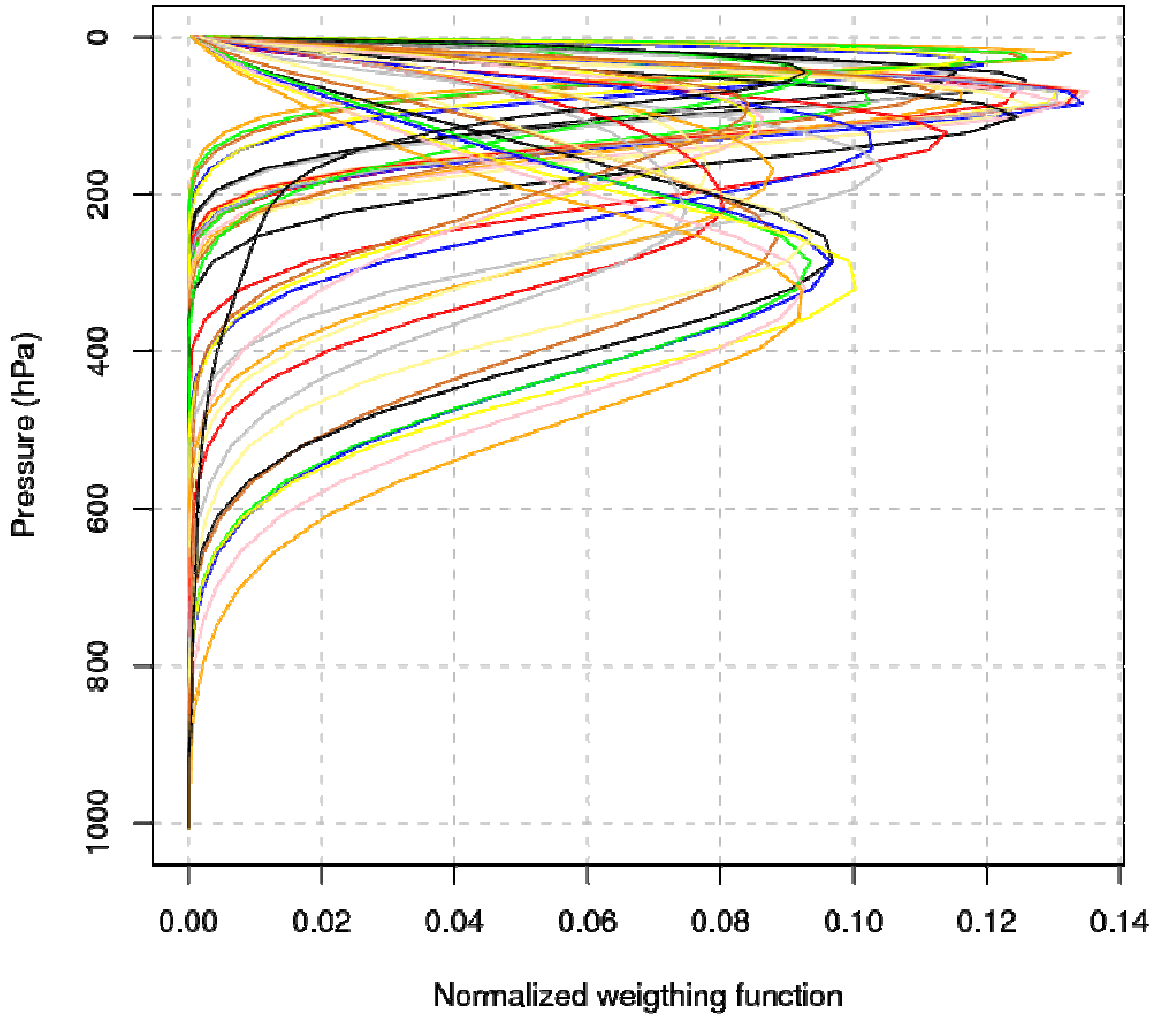


land



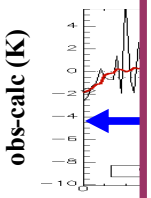
sea-ice

Met.no channel selection



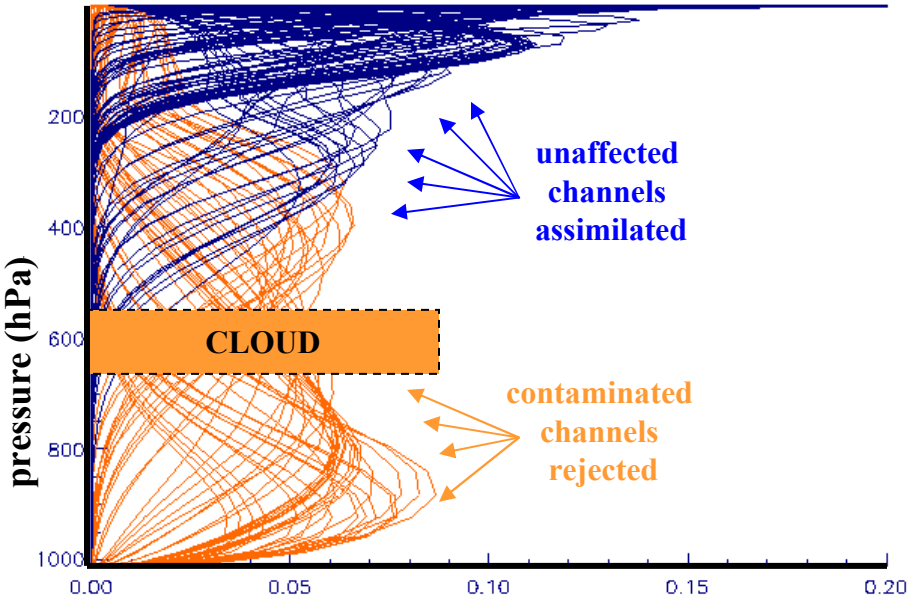
Cloud detection scheme for Advanced Sounders

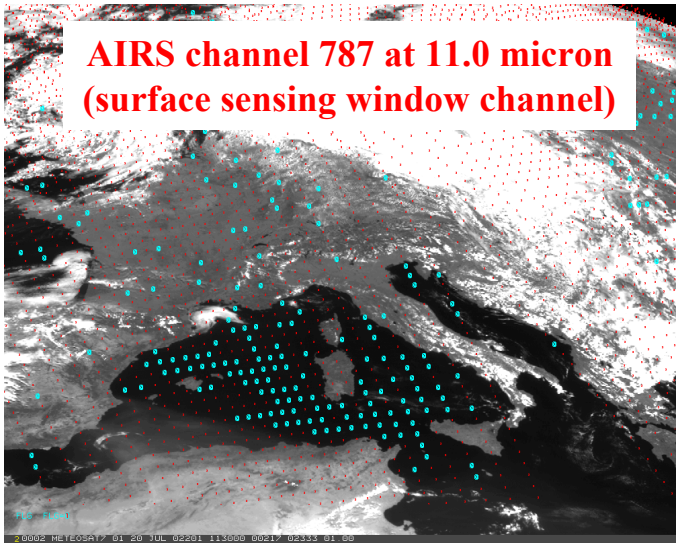
A non-linear pattern recognition algorithm is applied to departures of the observed radiance spectra from a computed clear-sky background spectra.



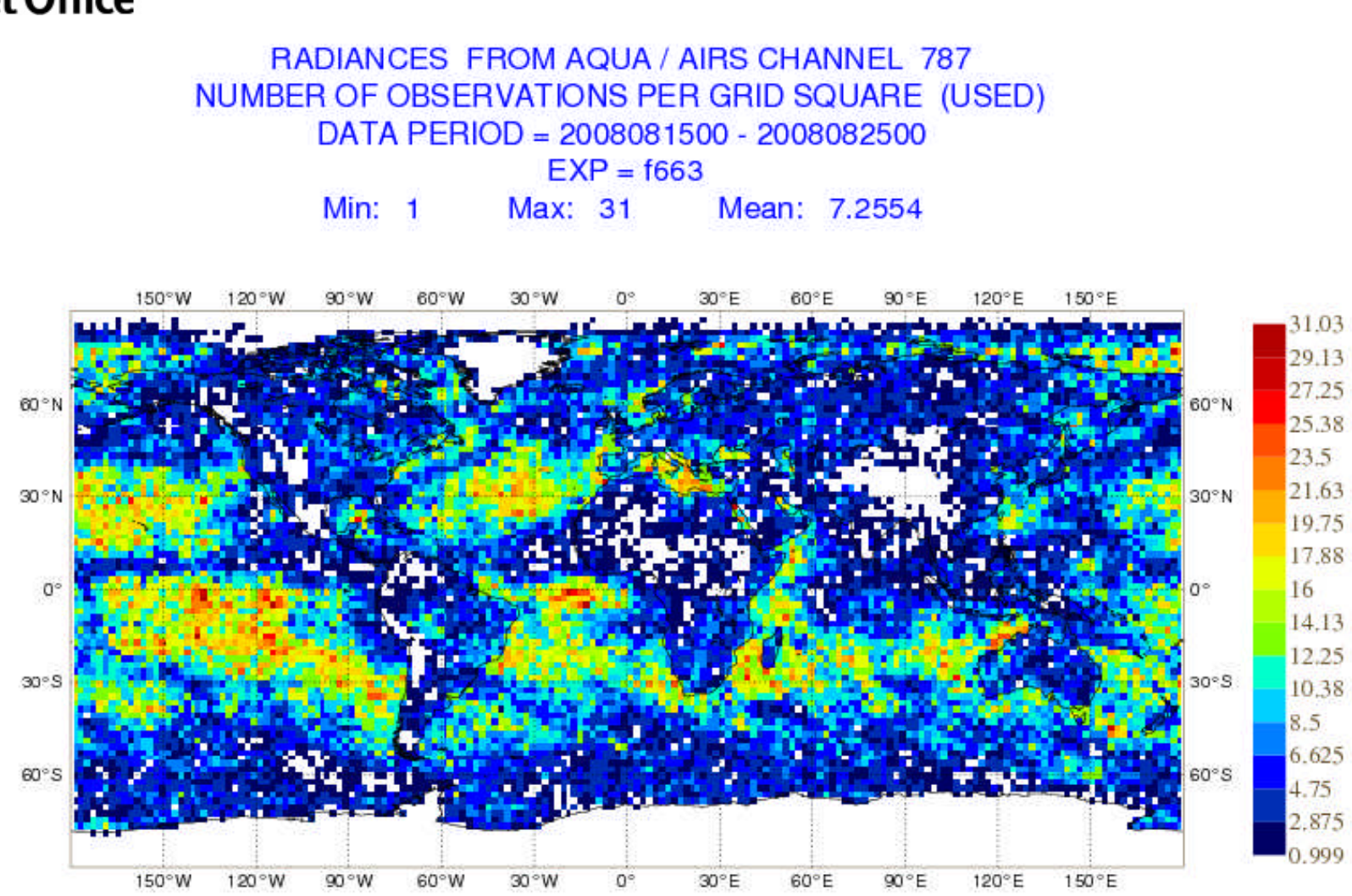
The large number of AIRS or IASI channels allows improved measurement of the cloud-top height compared to HIRS

This identifi
data and allows contaminated channels to be rejected

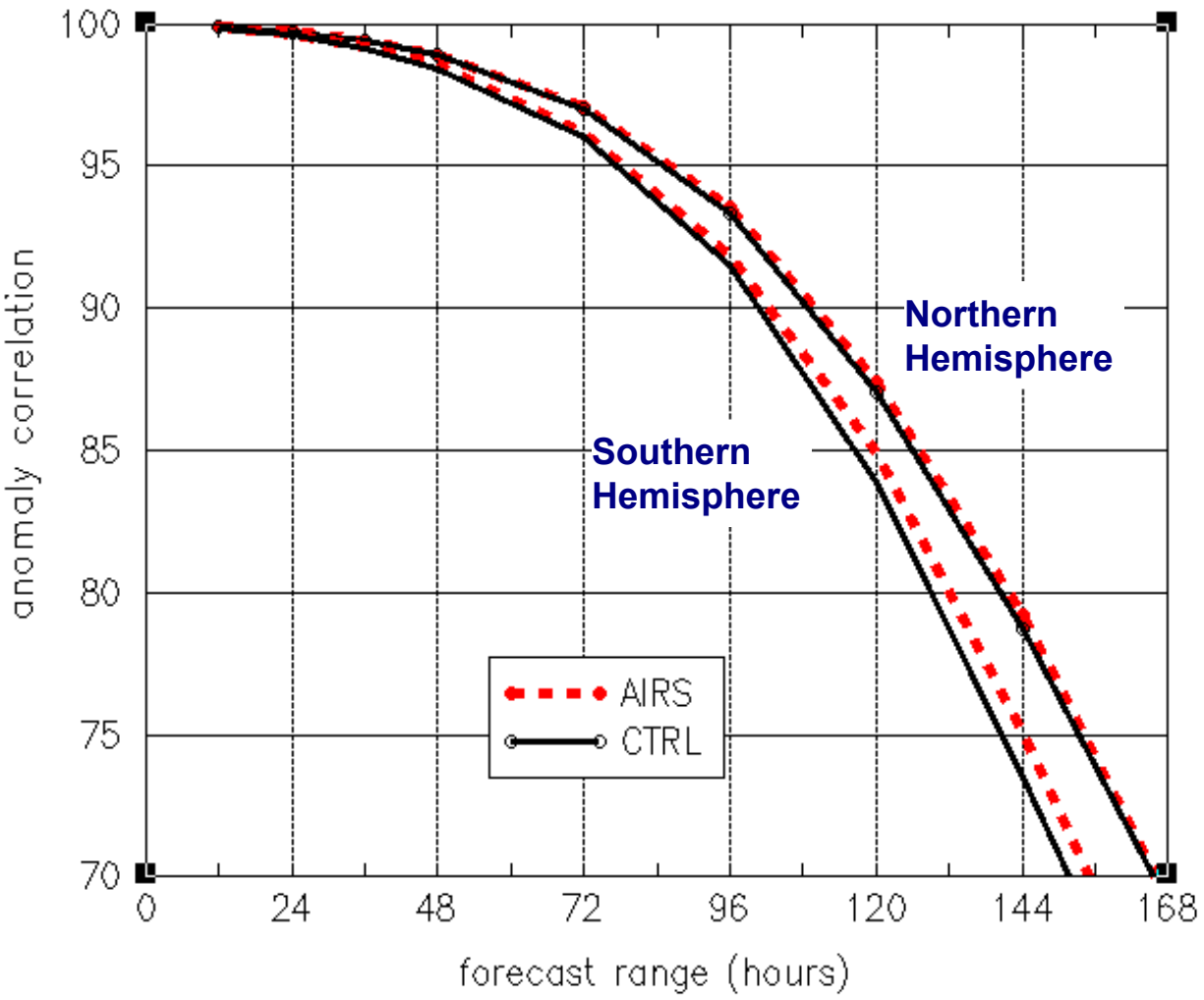




ECMWF Using IASI over land: Data Numbers

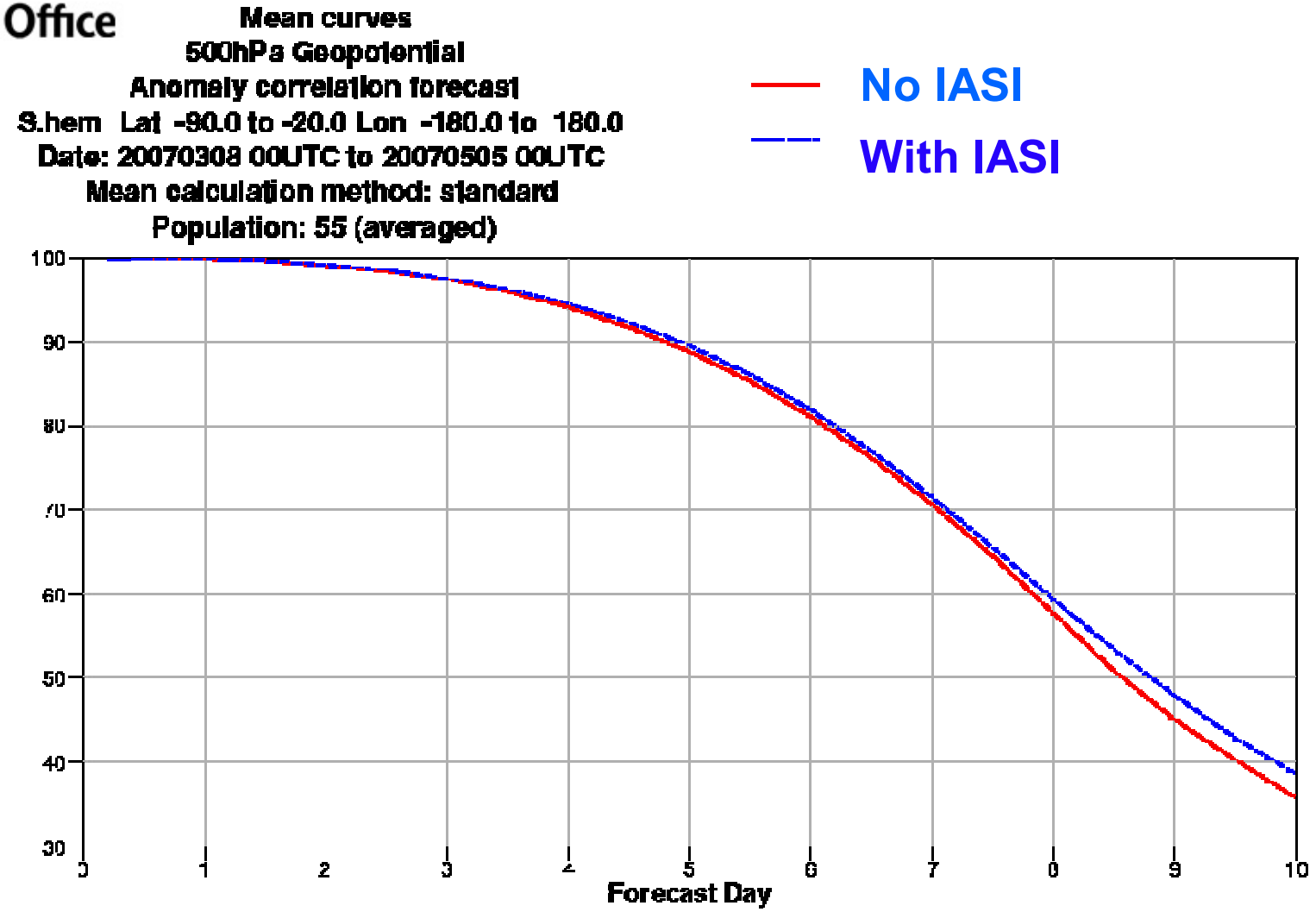


AIRS Impact at ECMWF



500hPa Geopotential Anomaly Correlation

IASI Impact on SH Geopot. AC



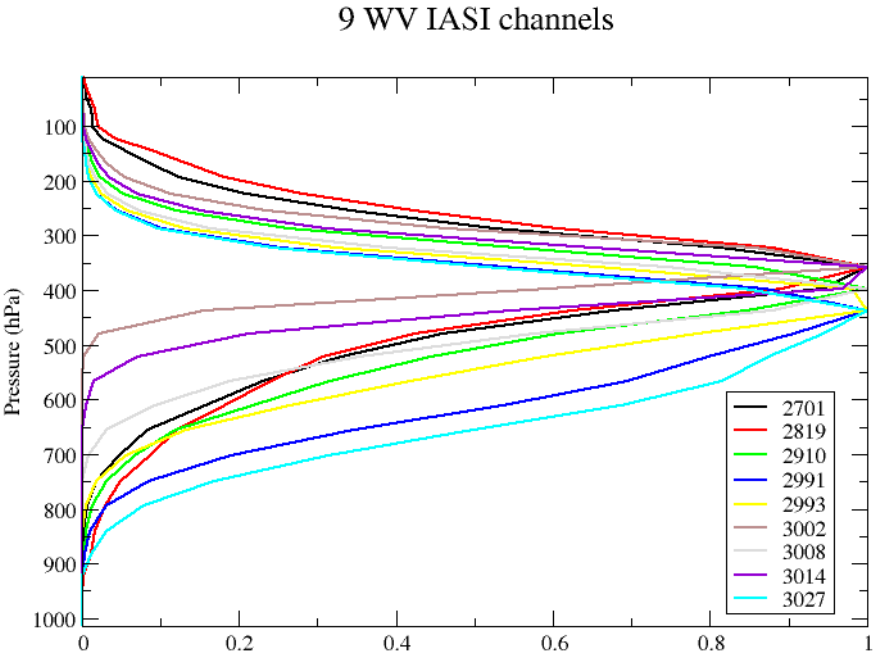
M-F Extension to WV channels

Nadia Fourrié

Add 9 WV channels

only over sea

sigma_o(WV) = 4 K to compare to sigma_o(LW) = 0.5 – 1 K



Reference = OPER

IASI+WV = Reference
+ 9 WV channels over sea

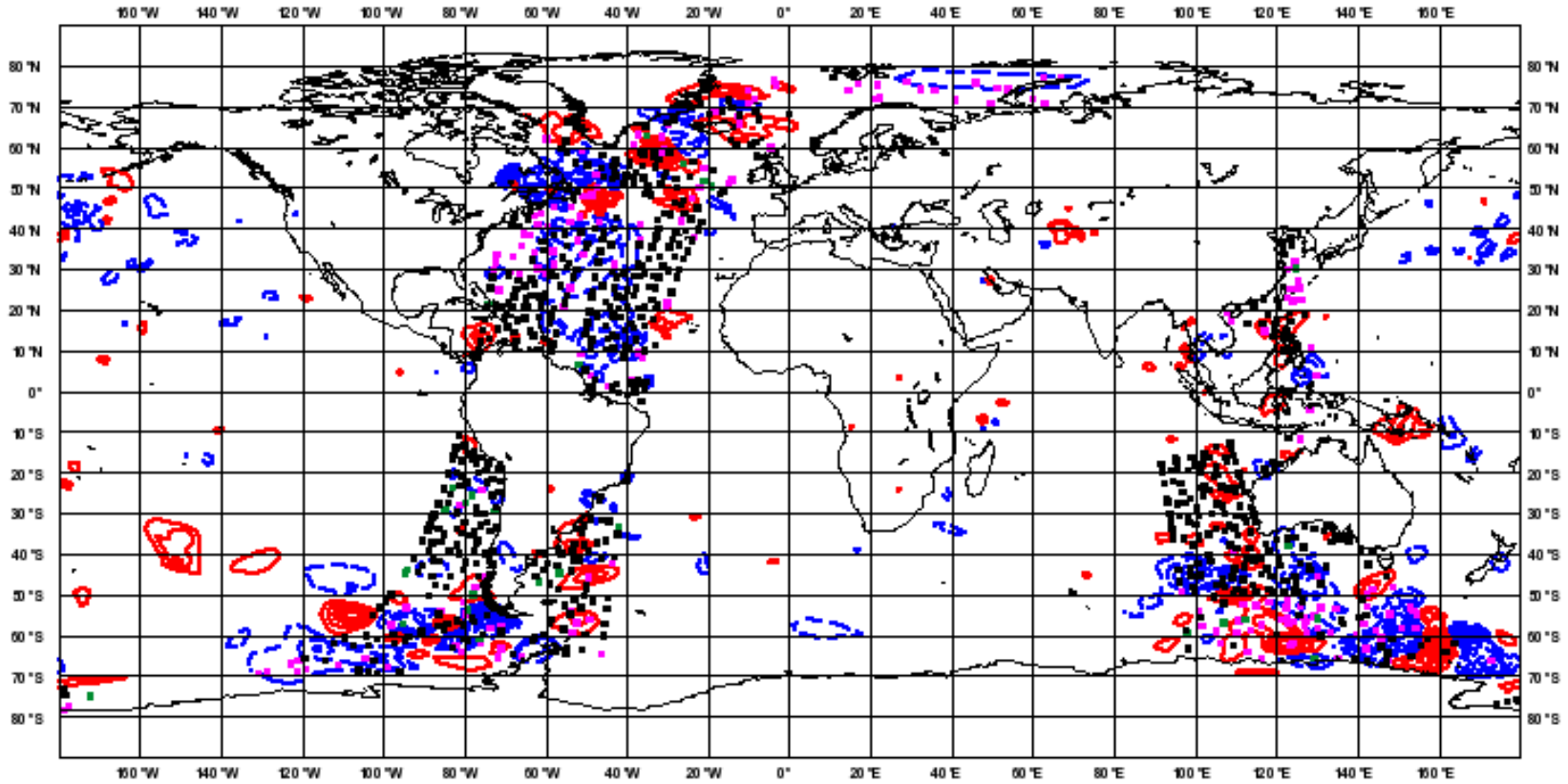
M-F Extension to WV channels

Nadia Fourrié

Analysis difference "IASI+WV – Reference"
for temperature at 400 hPa
blue & red lines, 1 isoline every 0.25 K
Squares indicate WV obs. which are assimilated

Reference = OPER

IASI+WV = Reference
+ 9 WV channels over sea



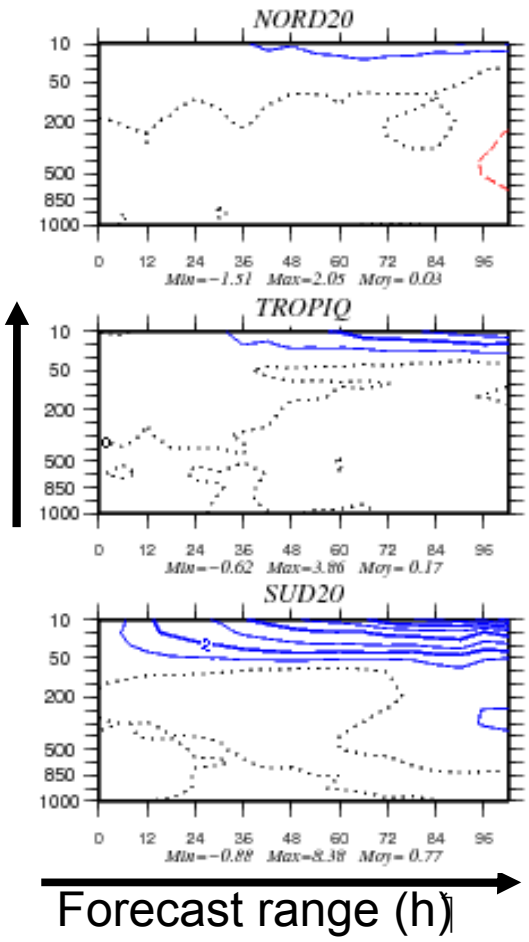
2.b. Extension to WV channels

Reference = OPER *Nadia Fourrié*

IASI+WV = Reference
+ 9 WV channels over sea

Statistics accumulated on the1st half of January 2009

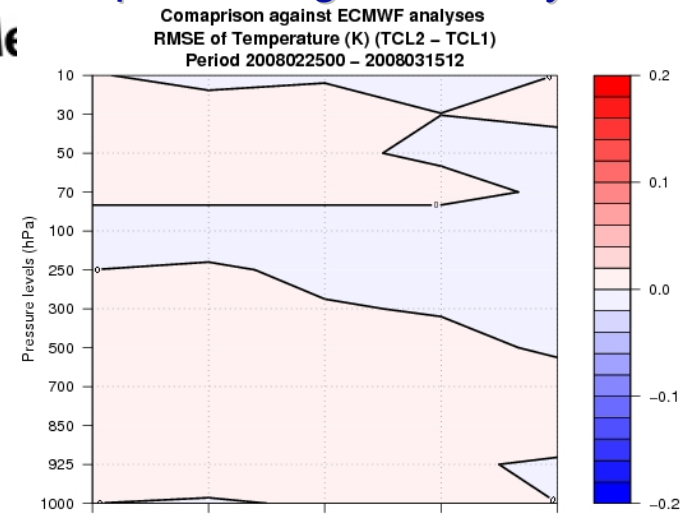
RMSE difference for geopotential height with respect to ECMWF analyses



Impact of assimilating WV channels:
blue: positive = reduction of RMSE
red : negative = increase of RMSE

Impact of IASI data

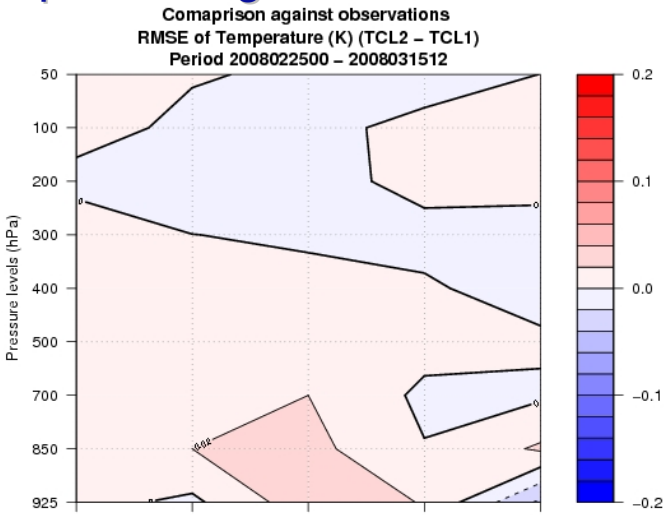
Comparison against analyses

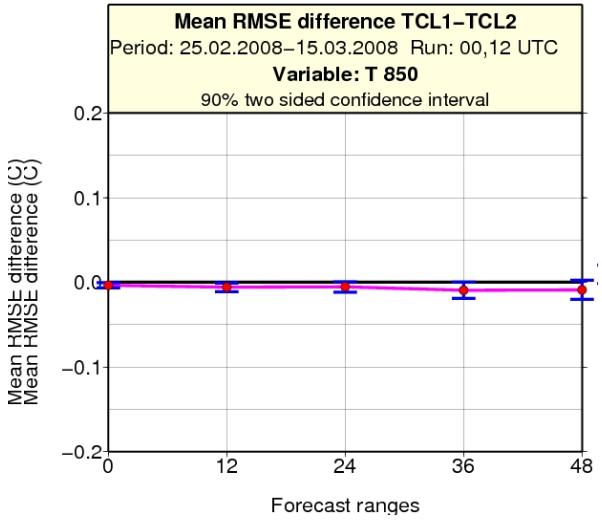


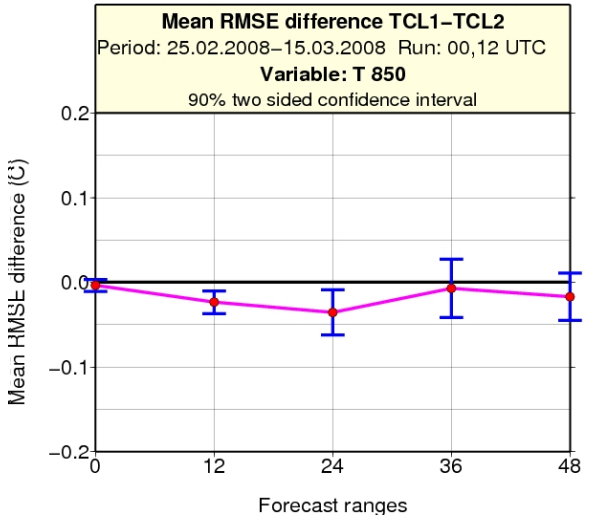
Impact on T exp. with campaign data

Red: positive impact

Comparison against observations

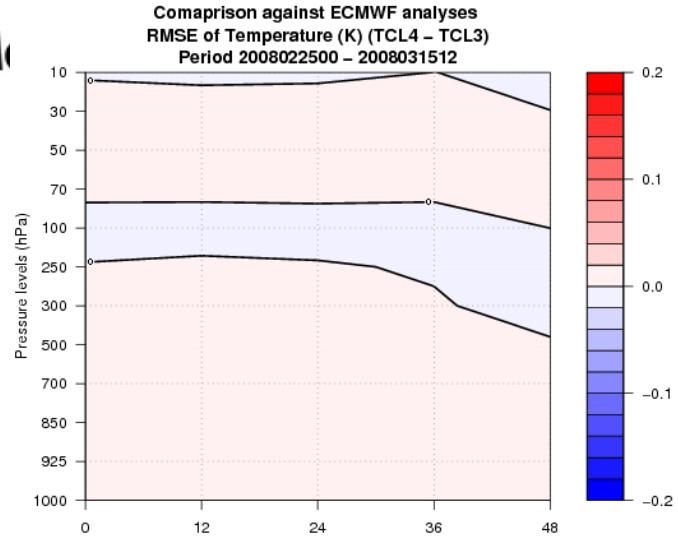




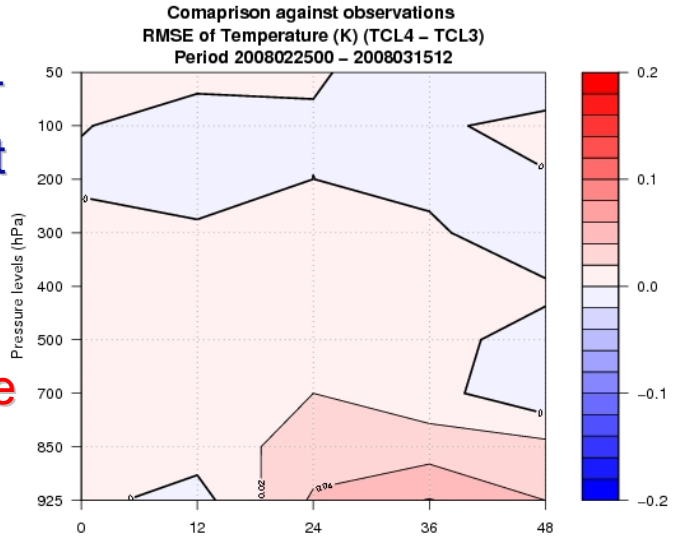


Impact of IASI data

Comparison against analyses

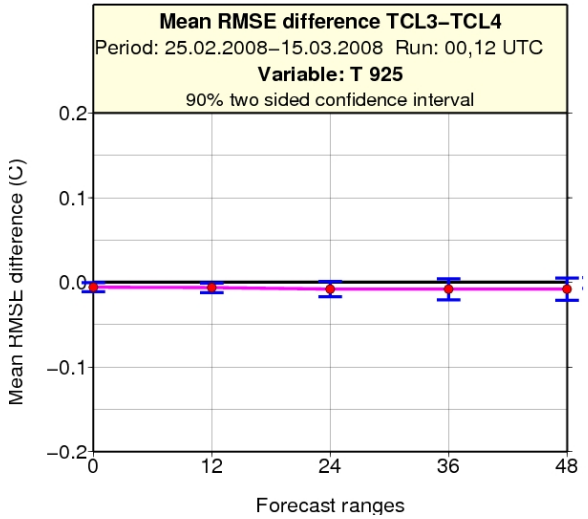


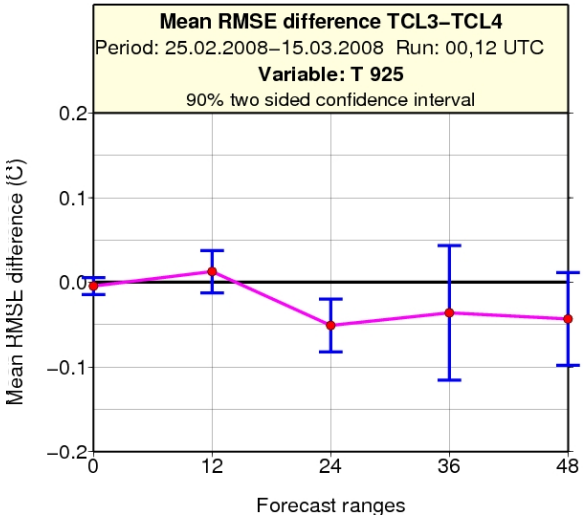
Comparison against observations



Impact on T exp. without campaign data

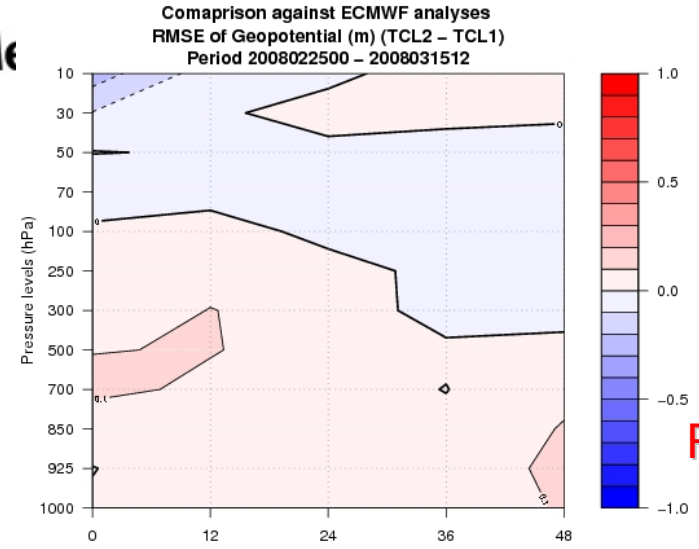
Red: positive impact





Impact of IASI data

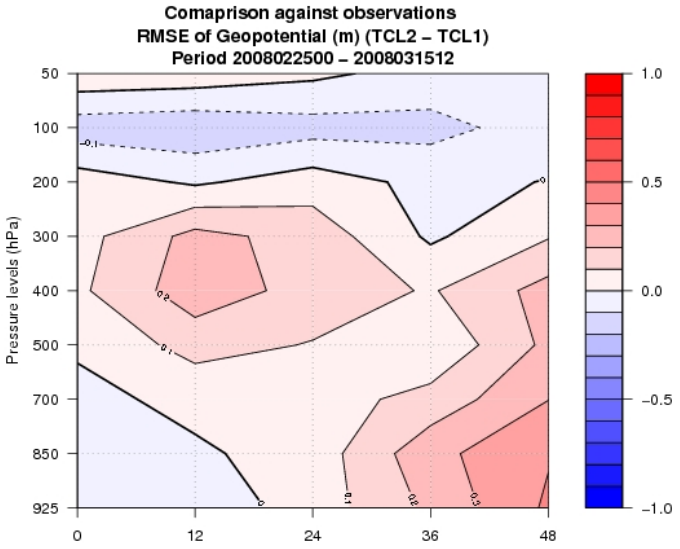
Comparison against analyses

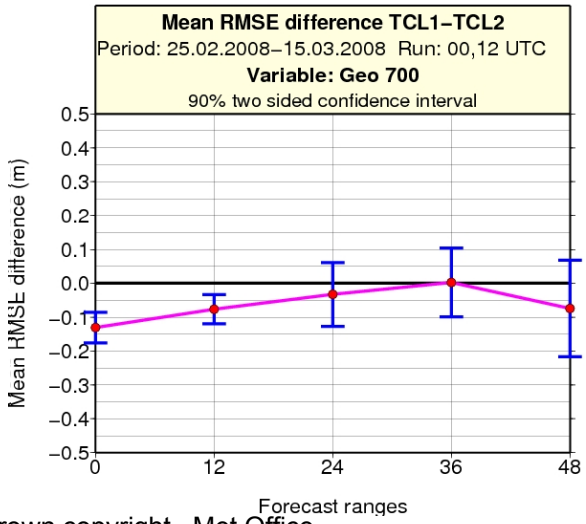


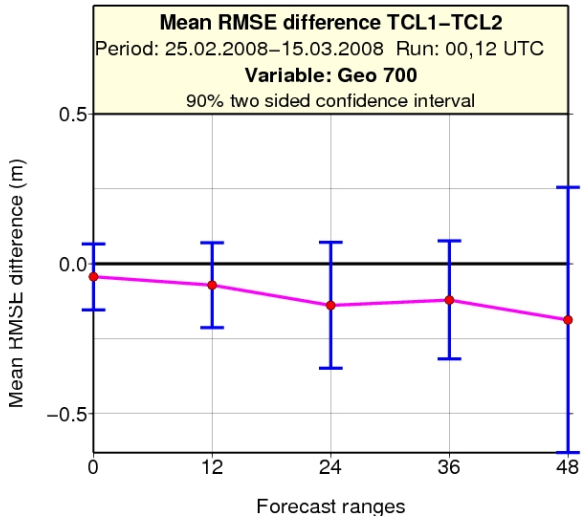
Impact on Geo exp. with campaign data

Red: positive impact

Comparison against observations

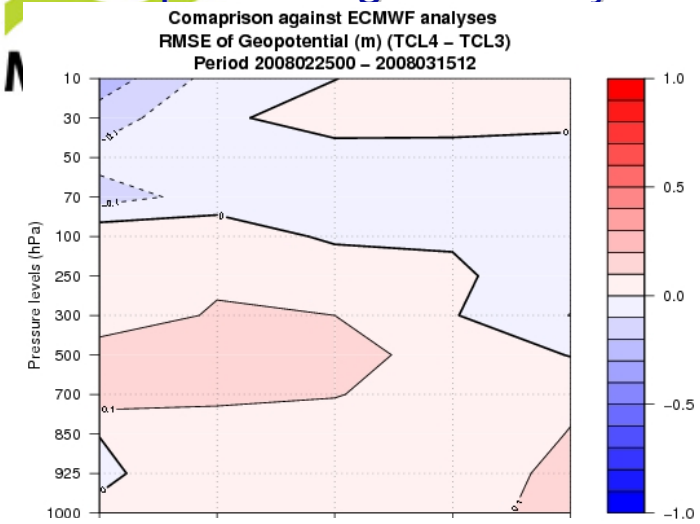




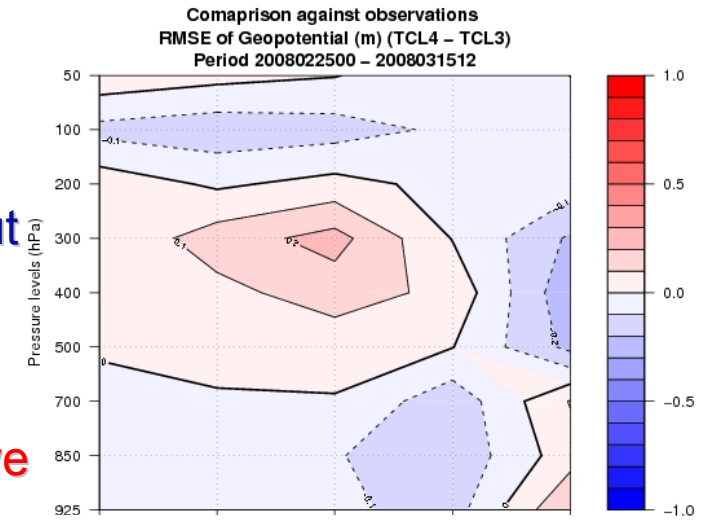


Impact of IASI data

Comparison against analyses

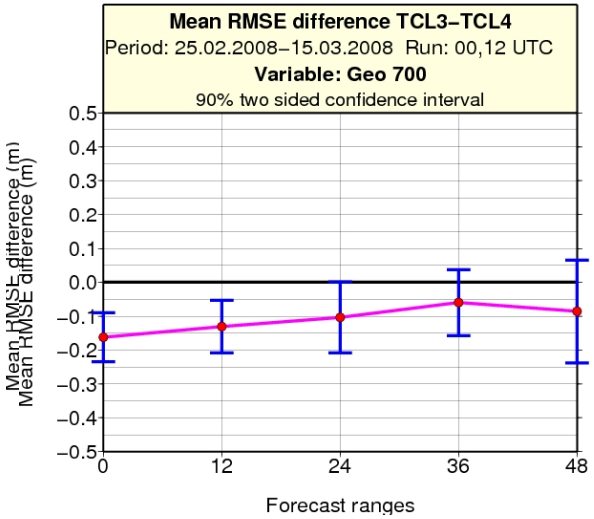


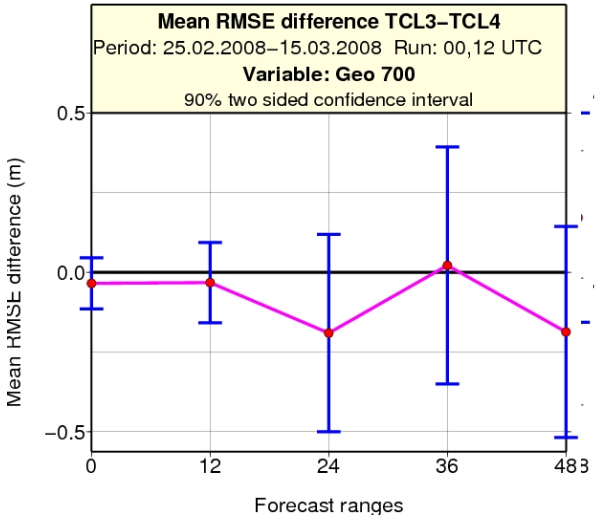
Comparison against observations



Impact on Geo exp. without campaign data

Red: positive impact





DWD – 2m temperature error