Observing System Experiments (OSE) to estimate the impact of observations in NWP

Peter Bauer

Acknowledgements:
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ECMWF

Satellite observing system: Status June 2009

Radiances:

- AMSU-A on NOAA-15/16/17/18/19, AQUA, Metop
- AMSU-B/MHS on NOAA-16/17/18/19, Metop
- SSM/I on F-13/15, AMSR-E on Aqua, TMI on TRMM
- HIRS on NOAA-17, Metop
- AIRS on AQUA, IASI from Metop
- MVIRI on Meteosat-7, SEVIRI on Meteosat-9, GOES-11/12, MTSAT-1R imagers

Ozone:

- Total column ozone from SBUV on NOAA-17/18, SCIAMACHY on Envisat, OMI on Aura, GOME-2 on Metop

Bending angles:

- COSMIC (6 satellites), GRAS on Metop, GRACE-A

Atmospheric Motion Vectors:

- Meteosat-7/9, GOES-11/12, MTSAT-1R, FY-2C, MODIS on Terra/Aqua

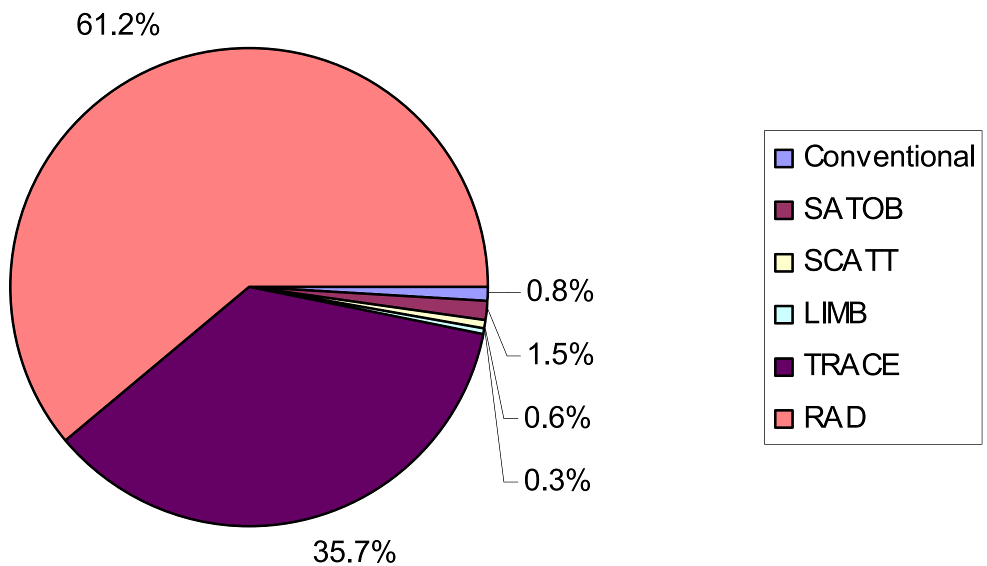
Sea surface parameters:

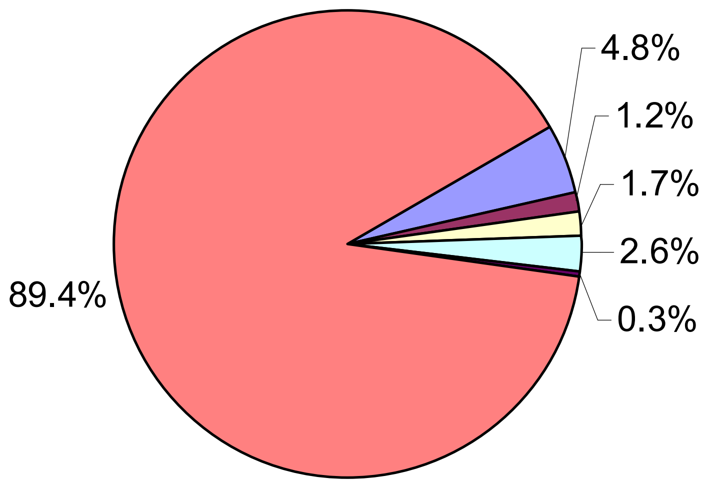
- Significant wave height from Seawinds on QuikSCAT, Scatterometer on ERS-2, ASCAT on Metop
- Near-surface wind speed from RA-2/ASAR on Envisat, Jason altimeter

Data types

Screening
24/04/2008 00UTC

Assimilation
24/04/2008 00UTC





- Satellite data amounts to 99% in screening and 95% in assimilation.
- Radiance data dominates assimilation with 90%.
- Relative GPSRO (limb) data amount strongly increases between screening and assimilation while ozone data is largely reduced.

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Observing System Experiments

Investigating fundamental observation impact:

- Comparison between instruments that constrain similar variables (e.g. AIRS vs IASI, clear vs cloud/rain-affected microwave radiances, GPSRO and VarBC)
- Evaluation of specific operator sensitivity & 4D-Var mechanisms (e.g. geostationary CSR impact on wind analysis, single observation experiments)

→ OSEs with single observation type in addition to poor observing system (e.g. conventional + AMVs + 1 sounder) and operational model version

Adding (improving) a new observation type:

- Introduction of new observation types (e.g. in 2009 all-sky microwave, cloud-affected infrared radiances, NOAA-19)
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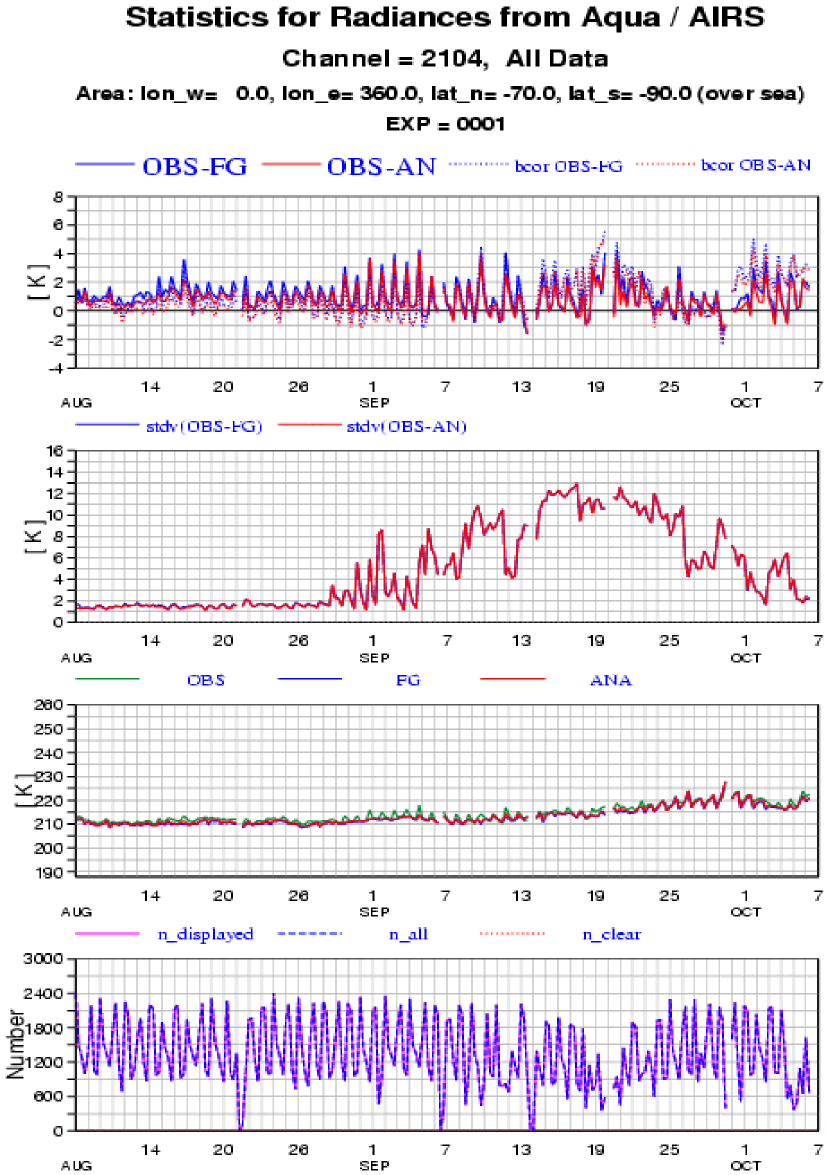
'Continuous' observation impact assessment:

- Assessment of all individual and combined components of observing system

→ OSEs denying types from operational model/observing system, adding types to baseline system.

⇒ The continued assessment is currently only performed through operational radiance monitoring (departures, biases) and irregular (costly) OS experimentation!

Data monitoring – time series



Time evolution of statistics over predefined areas/surfaces/flags

(M. Dahoui)

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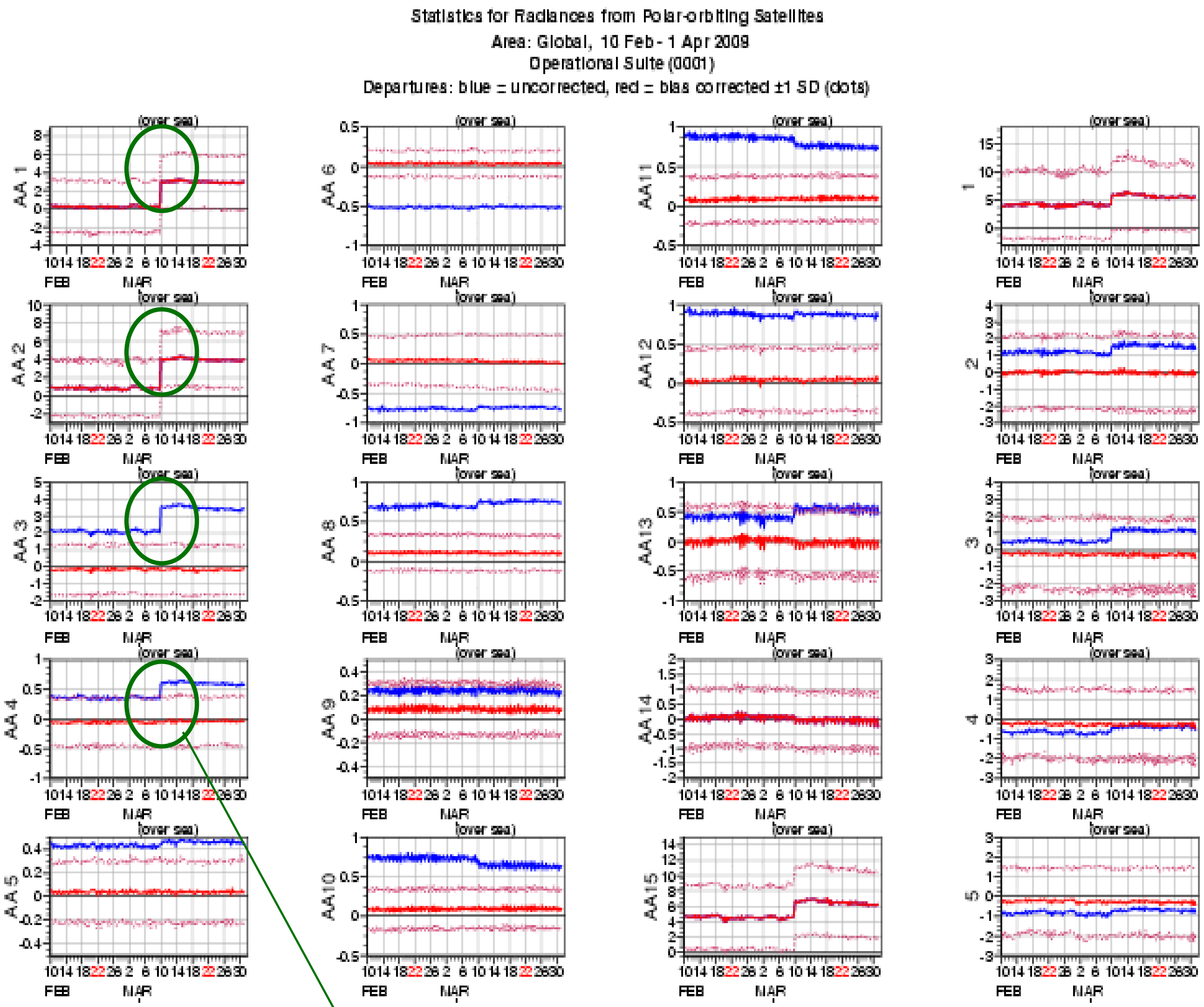
Data monitoring – overview plots

Time evolution of statistics for several channels

Useful for quick and routine verifications

Can not be used for high spectral resolution sounders



RTTOV version upgrade

(M. Dahoui)

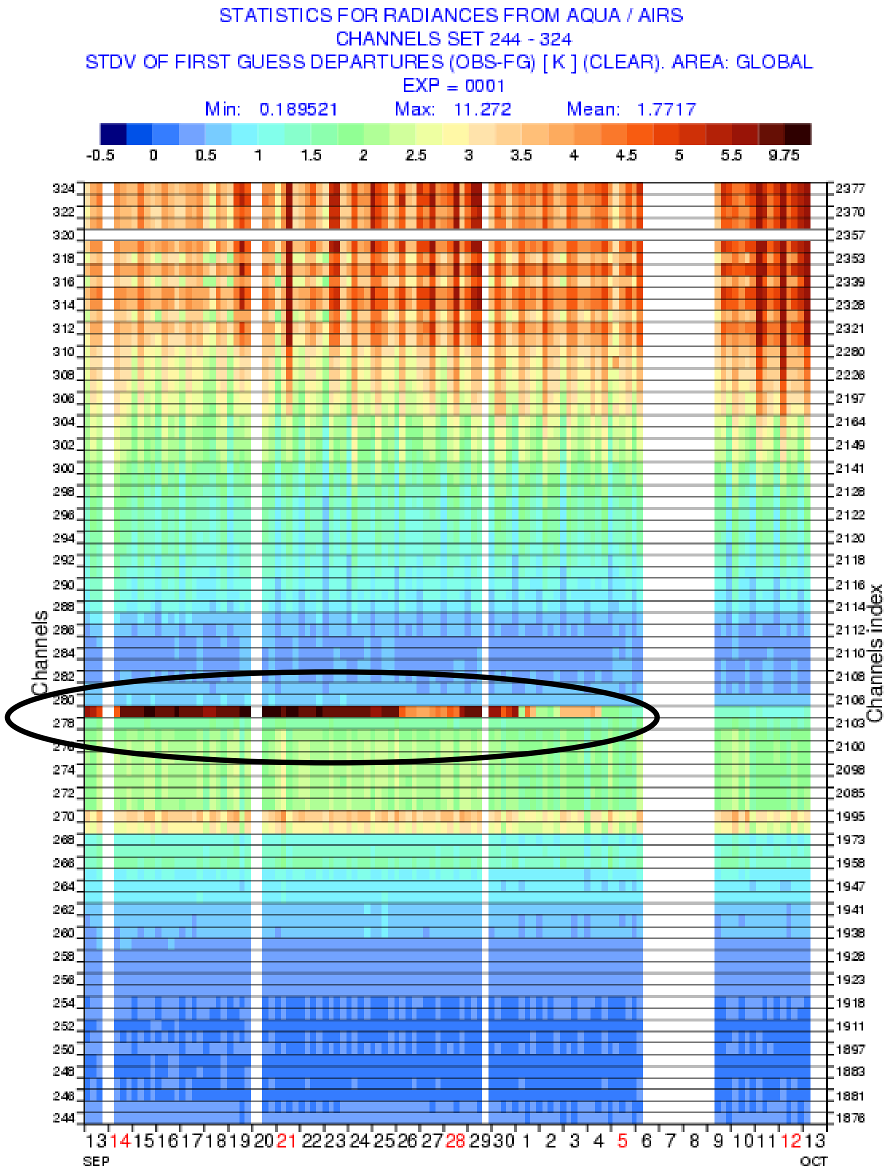
Data monitoring – overview plots, advanced sounders

Time series compact product for high spectral resolution sounders

Increase of the noise of AIRS channel 2104

When a problem is spotted, individual time series and Hovmöller diagrams can be checked.

(M. Dahoui)

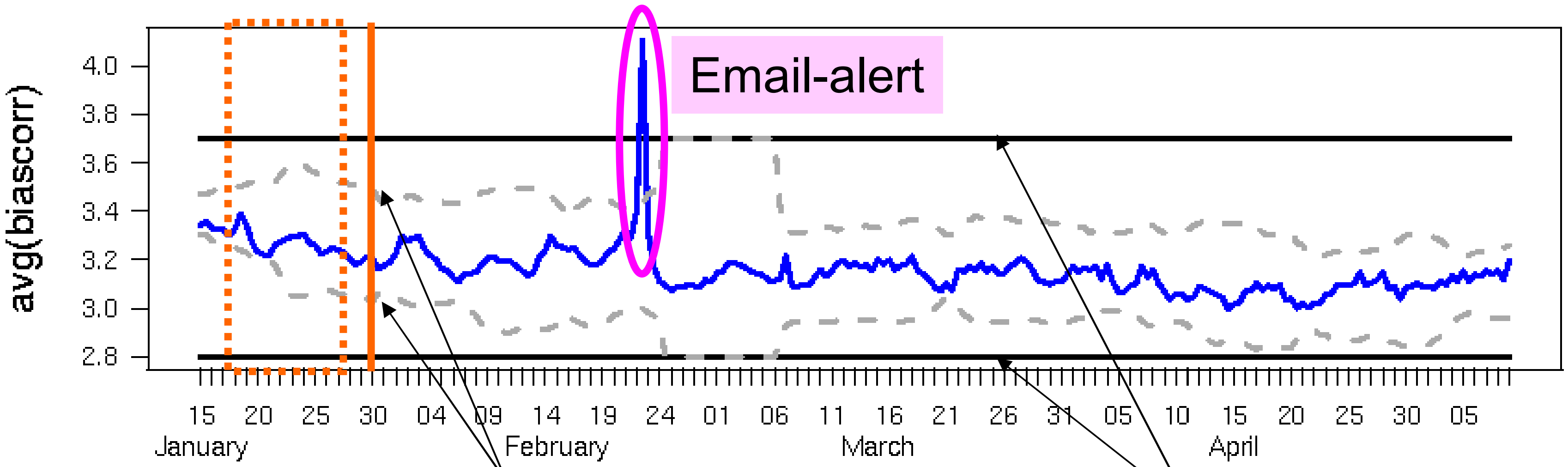


Data monitoring – automated warnings

http://www.ecmwf.int/products/forecasts/satellite_check/

Selected statistics are checked against an expected range.

E.g., global mean bias correction for GOES-12 (in blue):



Soft limits (mean ± 5 stdev being checked, calculated from past statistics over a period of 20 days ending 2 days earlier)

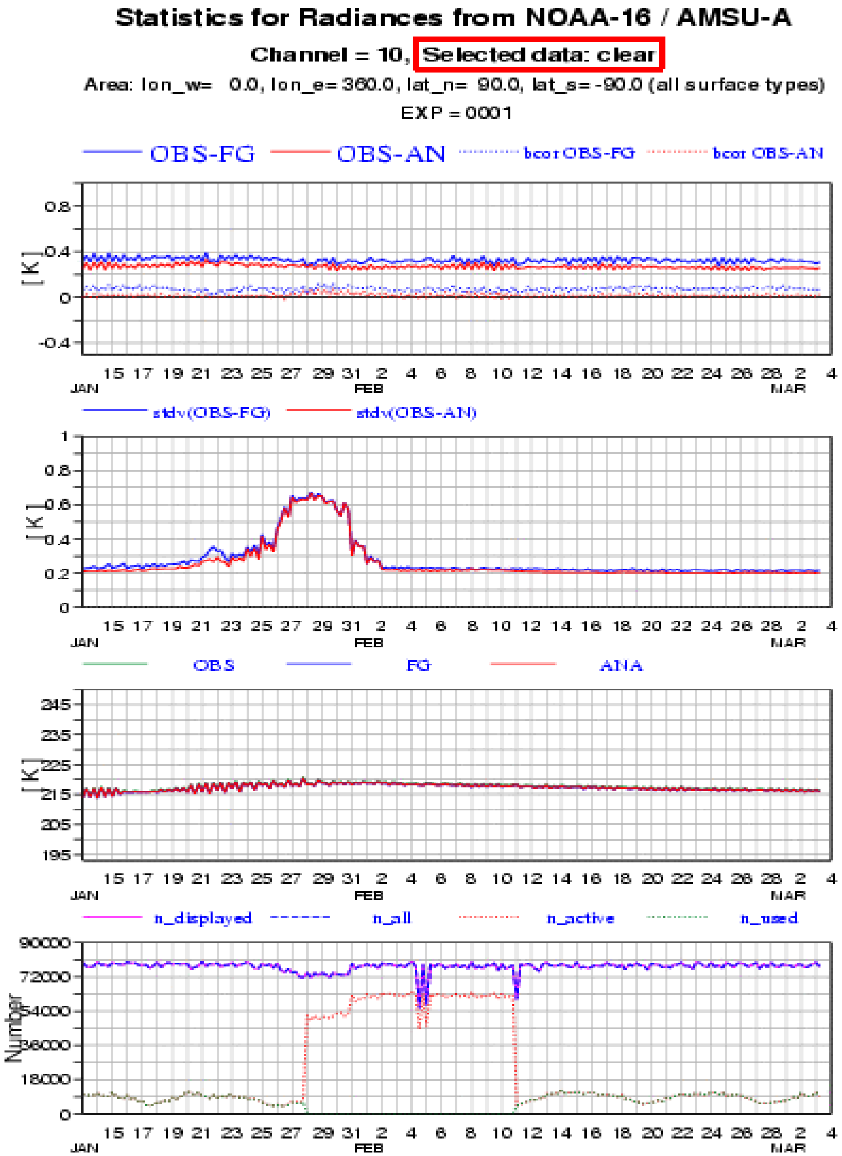
Hard limits (fixed)

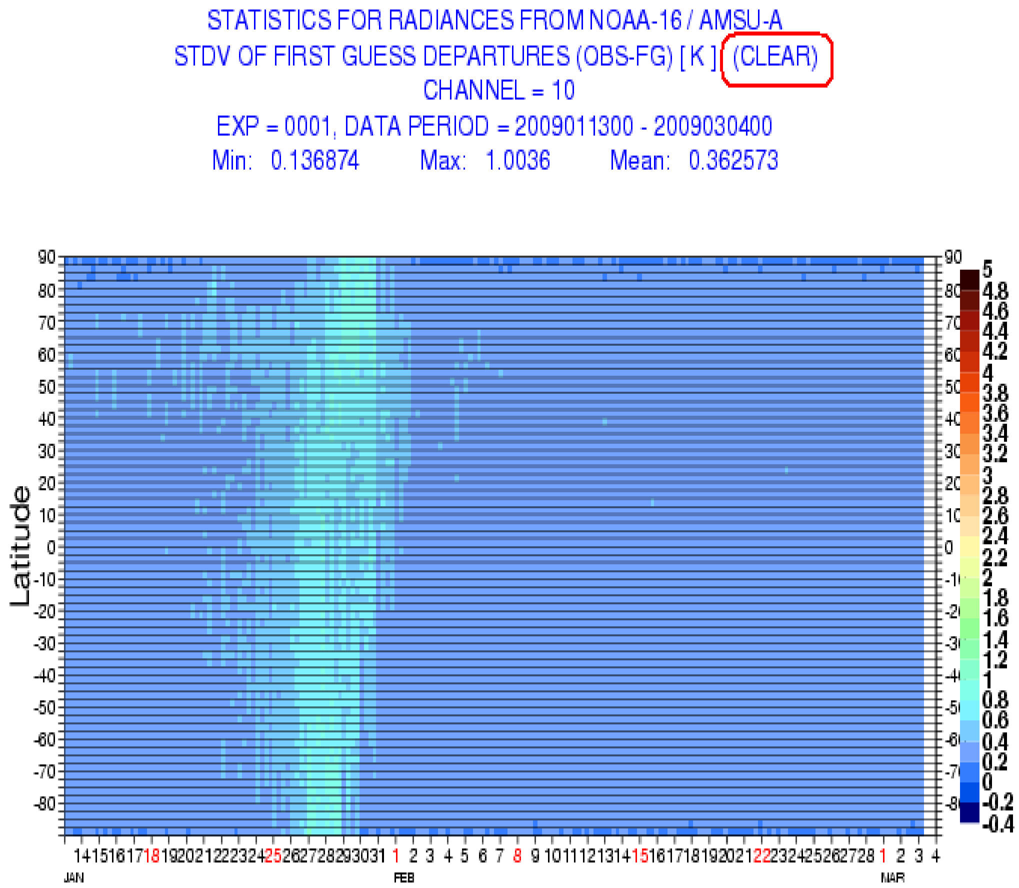
Email alert:

```
GOES-12 GOESIMG 2 clear radiances : out of range:
    avg(fg_depar)=1.34775547847879,  expected range: -0.38 0.47
    avg(biascorr)=4.10498646958382,  expected range: 3.0 3.4
```

(M. Dahoui & N. Bormann)

Data monitoring – automated warnings





(M. Dahoui & N. Bormann)

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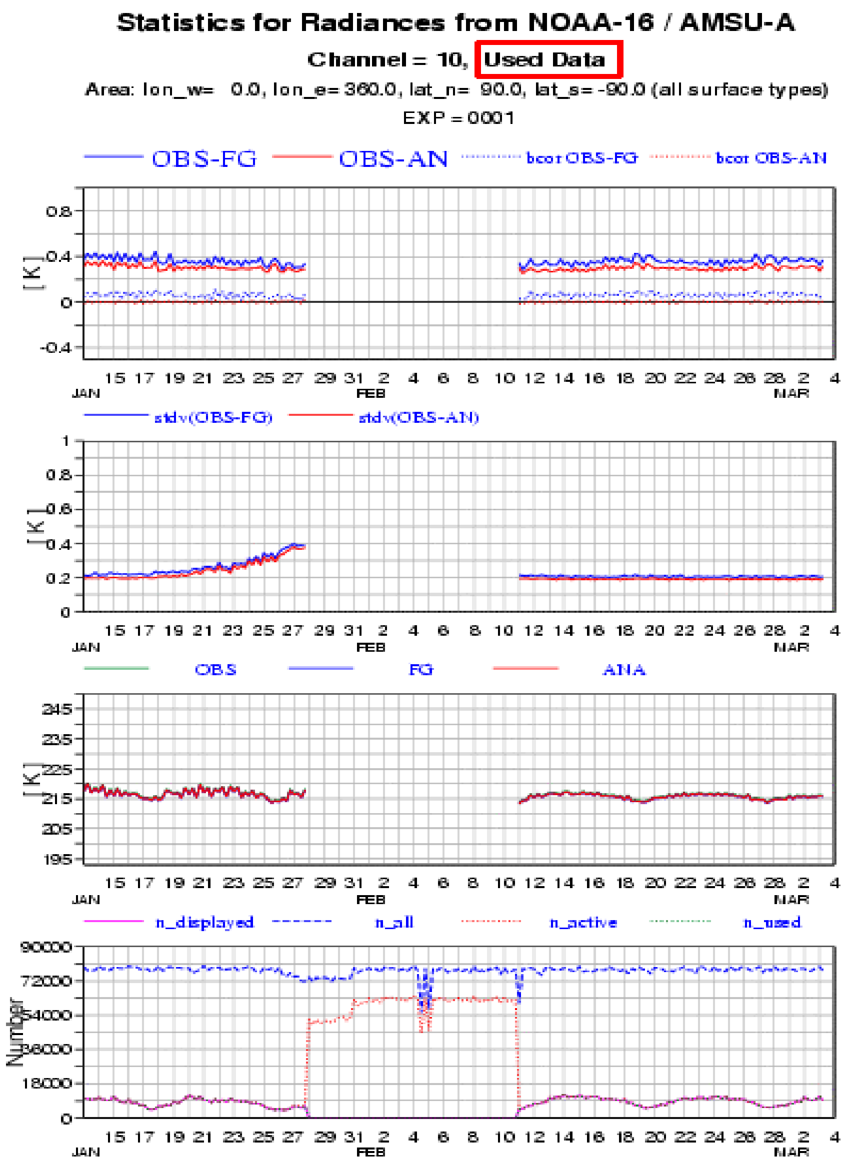

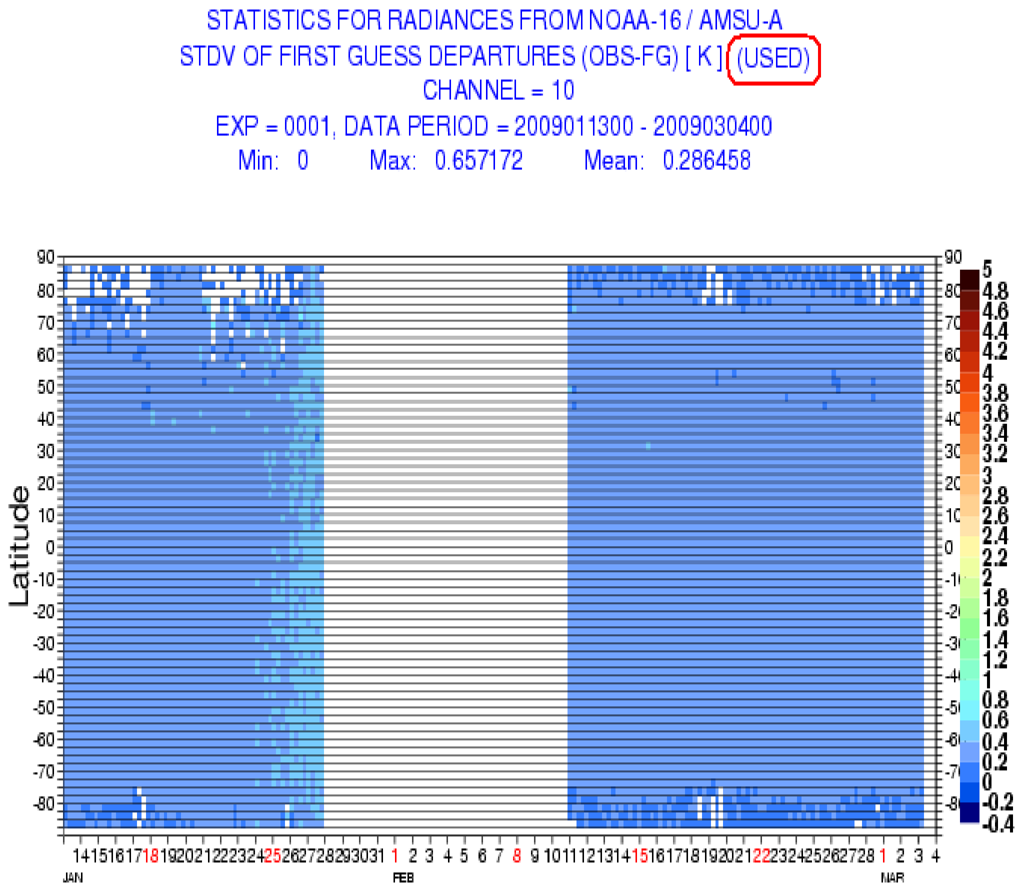

(M. Dahoui & N. Bormann)

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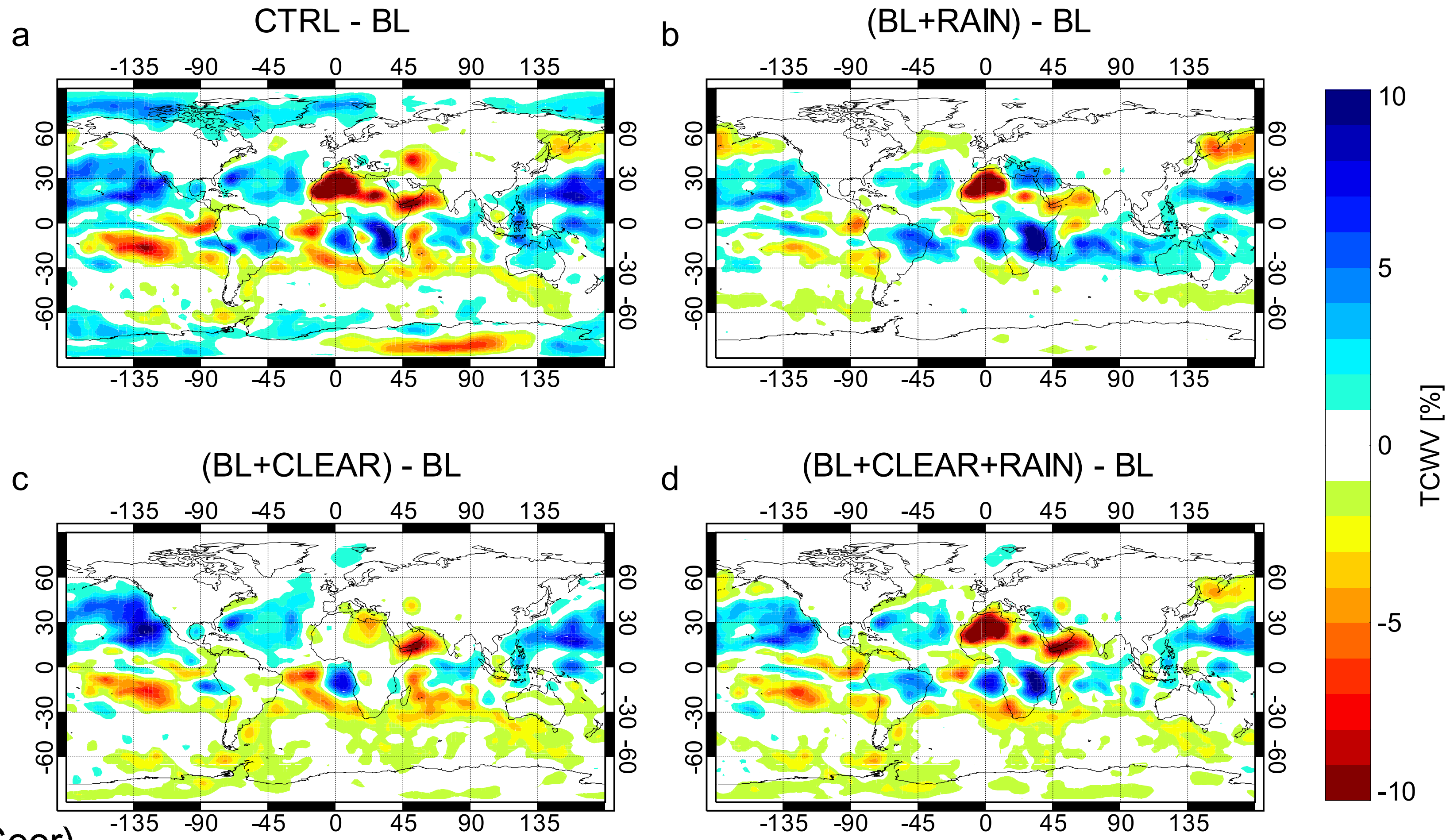
Investigating fundamental observation impact: TCWV

Example: How much of the mean TCWV analysis is driven by clear and cloud/rain-affected microwave observations and are they complementary?

(CTRL: full OS, BL = conventional + AMV + 1 AMSU-A, CLEAR/RAIN: BL + CLEAR/RAIN PMW)



(A. Geer)

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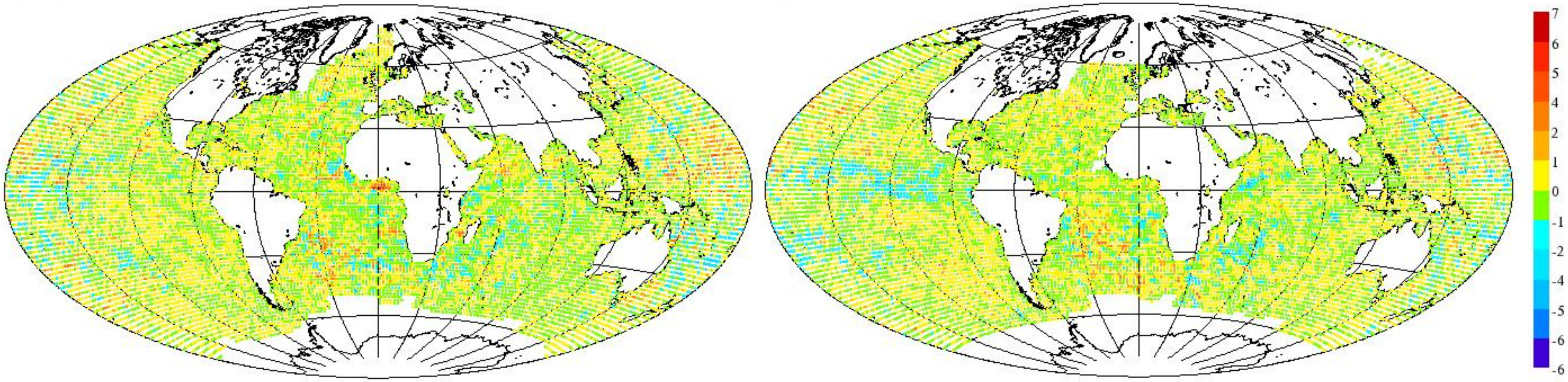
Investigating fundamental observation impact: TCWV

Forecast sensitivity to observations in analysis

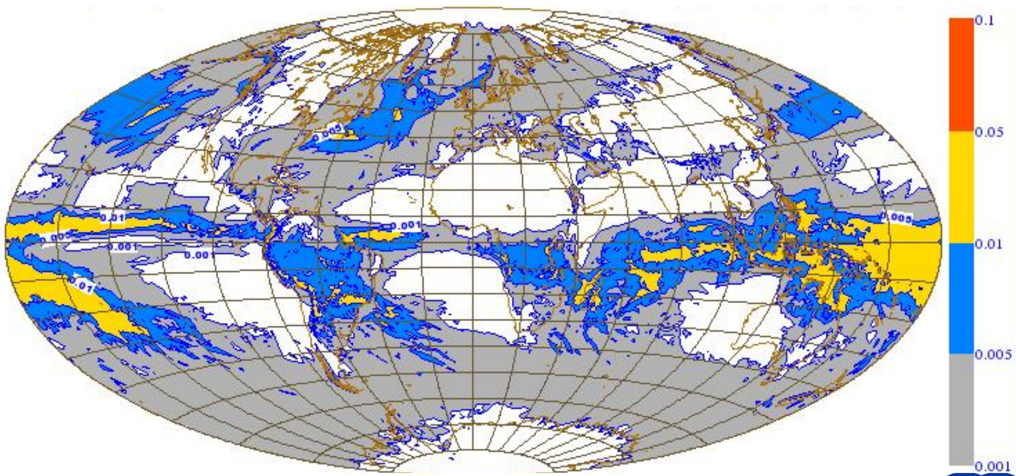
SSM/I clear-sky, winter

SSM/I clouds/rain, winter



[J/kg]

Mean 36-12h precipitation forecast initialized at 12 UTC



[10^{-3} mm]

(C. Cardinali)

Investigating fundamental observation impact: GPSRO

Example: How do GPSRO data (unbiased – not bias corrected) affect variational bias correction of AMSU-A radiance data (at levels where model temperature biases are significant)?

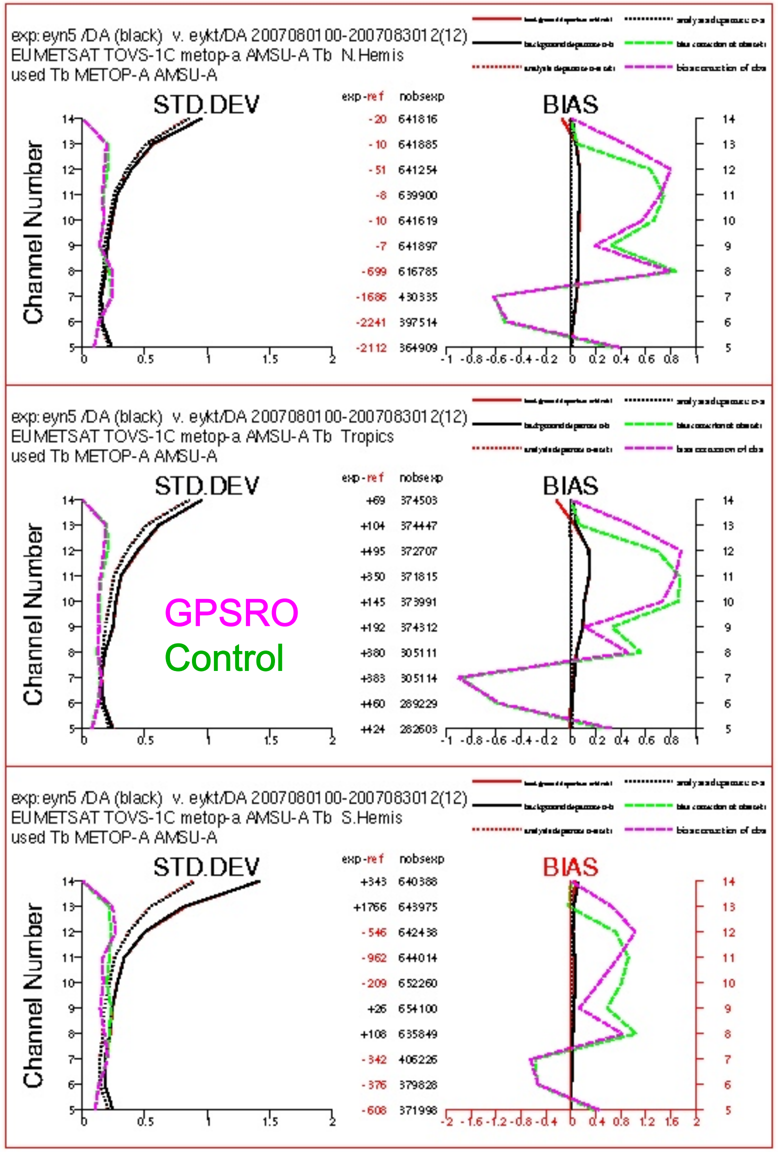
- OSE: only conventional + Metop AMSU-A, MHS, initialized with operational analysis:
  - control
  - control + COSMIC GPSRO
- Variational bias correction active.

→ AMSU-A channel 8-11 bias correction smaller when GPSRO data present (better constraint)

→ AMSU-A channel 12-13 bias correction larger when GPSRO data present (model bias too large?)

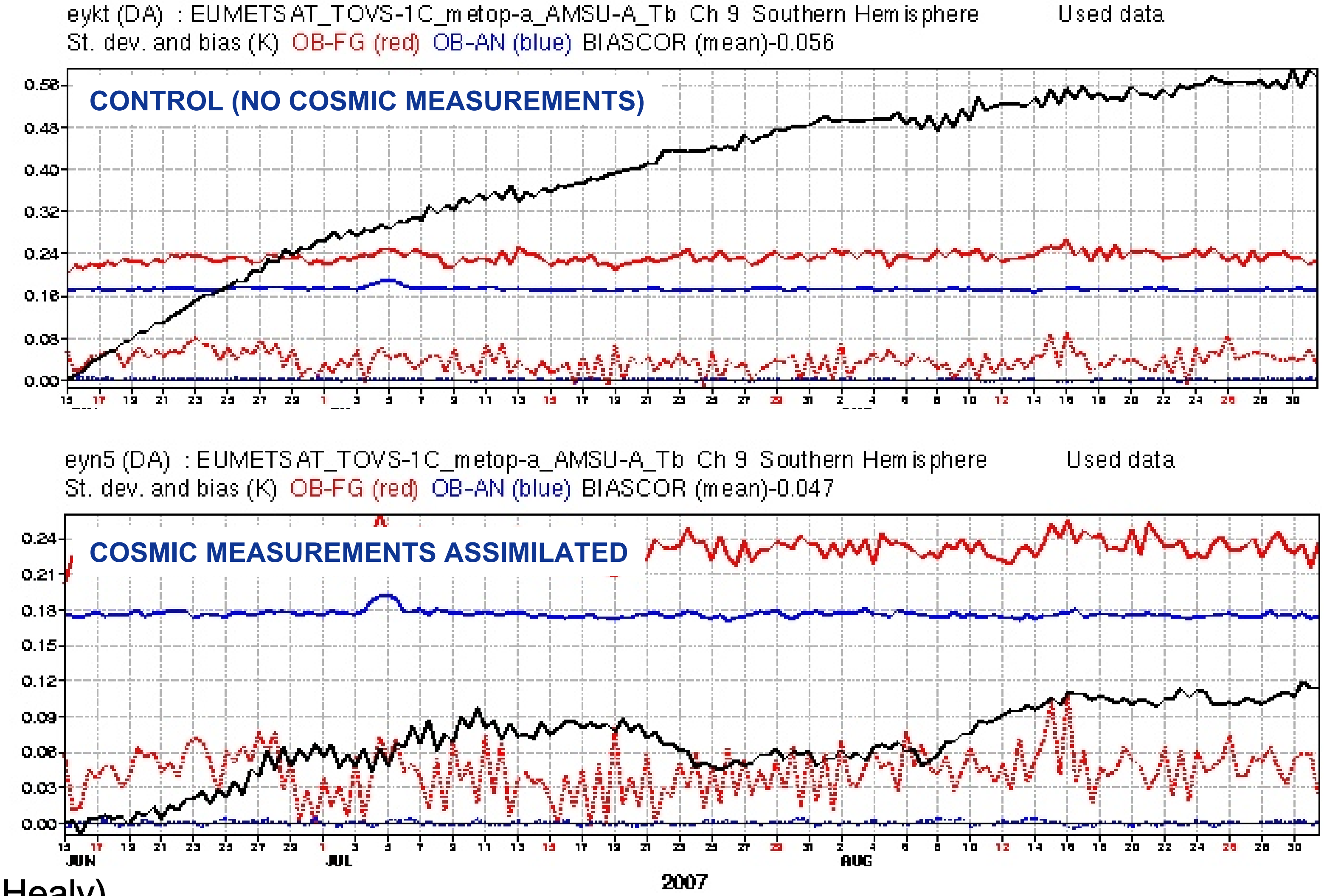
(AMSU-A channel 14 bias frozen)

(S. Healy)



Investigating fundamental observation impact: GPSRO

Metop AMSU-A channel 9 departure & bias correction evolution



(S. Healy)

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Adding a new observation type

Technical implementation:

- BUFR conversion of received format (if necessary)
- BUFR conversion to observational database (ODB) that is used in analysis system
- Management of satellite/instrument IDs in system
- Generation of radiative transfer model coefficients
- Screening (q/c for data problems, clouds, surfaces)
- Management of satellite/instrument in variational bias correction

Monitoring:

- Blacklisting of observations (i.e. data active in screening but not in minimization)
- Monitoring experiments to evaluate data quality and spin up biases

Diagnostics

Analysis impact evaluation:

- Assimilation experiments with data active and evolved biases (plus control)
- Impact on short-range forecast/analysis fit to other observations
- Impact on mean analysis state

Forecast impact evaluation:

- Assimilation experiments with data active and evolved biases (plus control)
- Impact on short-to-medium-range forecasts (statistical significance)

Evaluation for operational implementation with a new cycle:

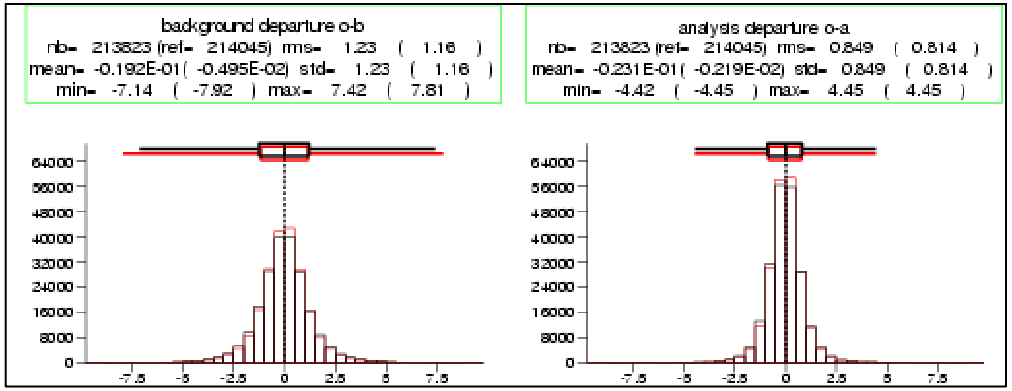
- Repeat previous two steps with other modifications

Experiment verification

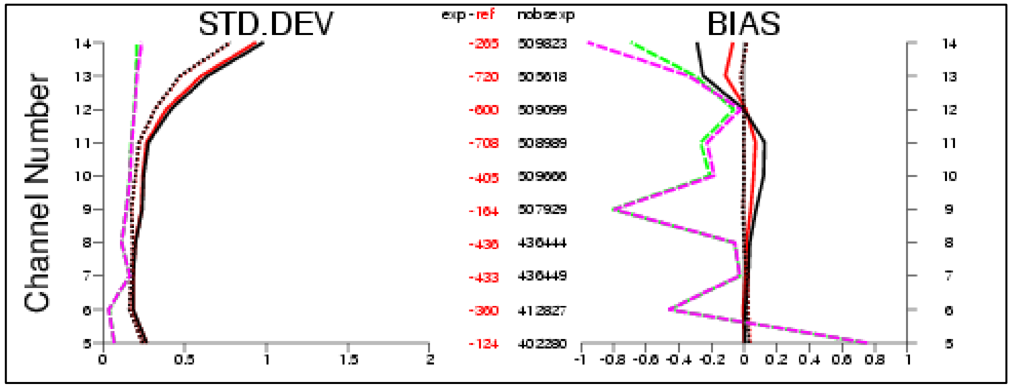
Analyses:

→ Fit (bias and standard deviation) of observations (in-situ and remotely sensed) to model first guess and analysis: Better observing system should improve analysis and short-range forecast, i.e. draw closer to entire observed data set and should reduce bias correction.

Single-level observation



Multiple level/channel observation



Experiment verification

Forecasts:

• Verification against experiment's own analyses,

• Verification against operational analyses,

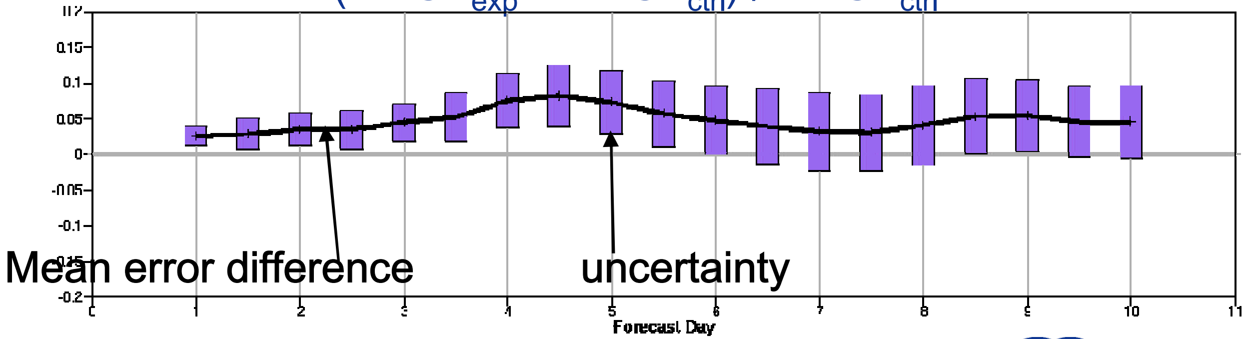
• Verification against observations,

incl. information on statistical significance.

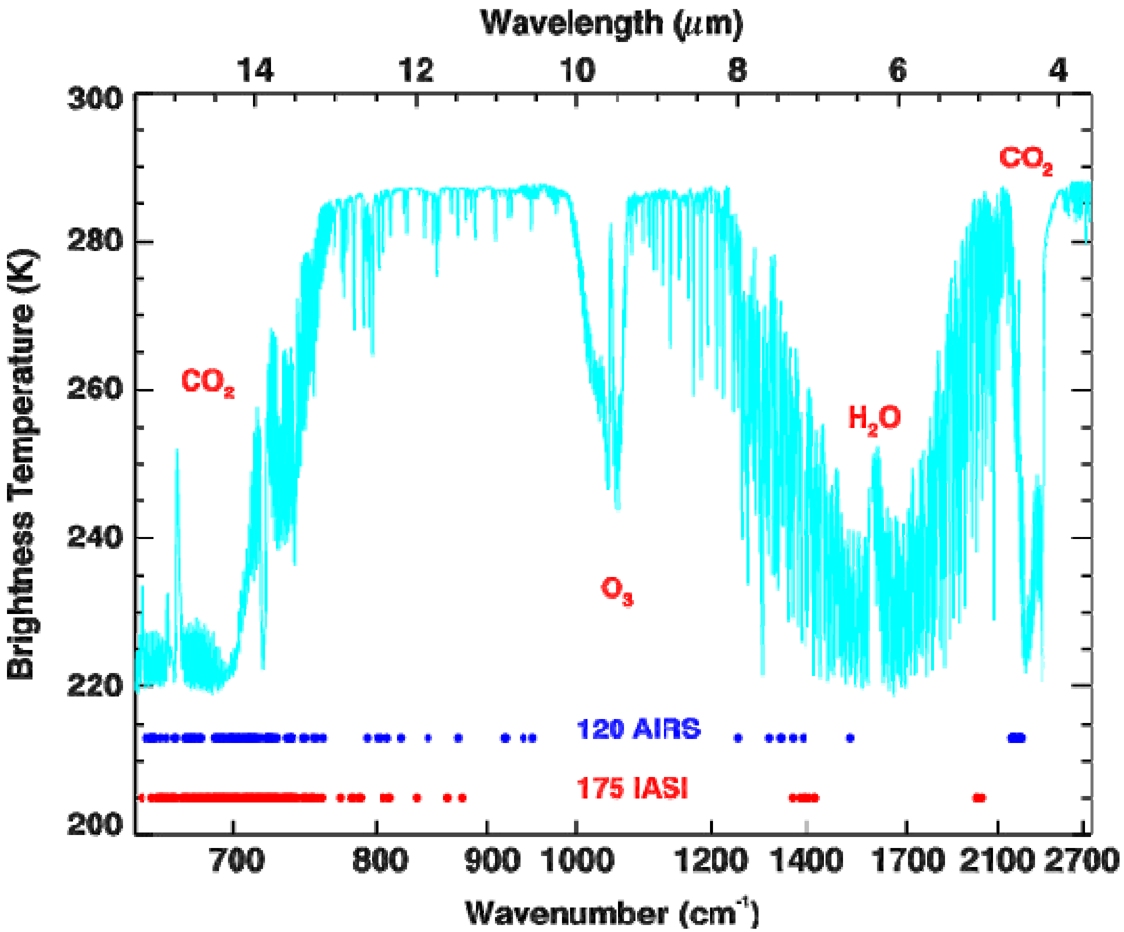
→ Accuracy (anomaly correlation, root-mean-square error) of selected meterological parameter (T, q, z, R) forecasts at significant model heights (1000, 750, 500, 200 hPa): Better observing system should improve analysis and medium-range forecast, i.e. produce larger anomaly correlations and smaller errors.

Normalized RMSE difference:

$(RMSE_{exp} – RMSE_{ctrl}) / RMSE_{ctrl}$



Example – Advanced IR sounders

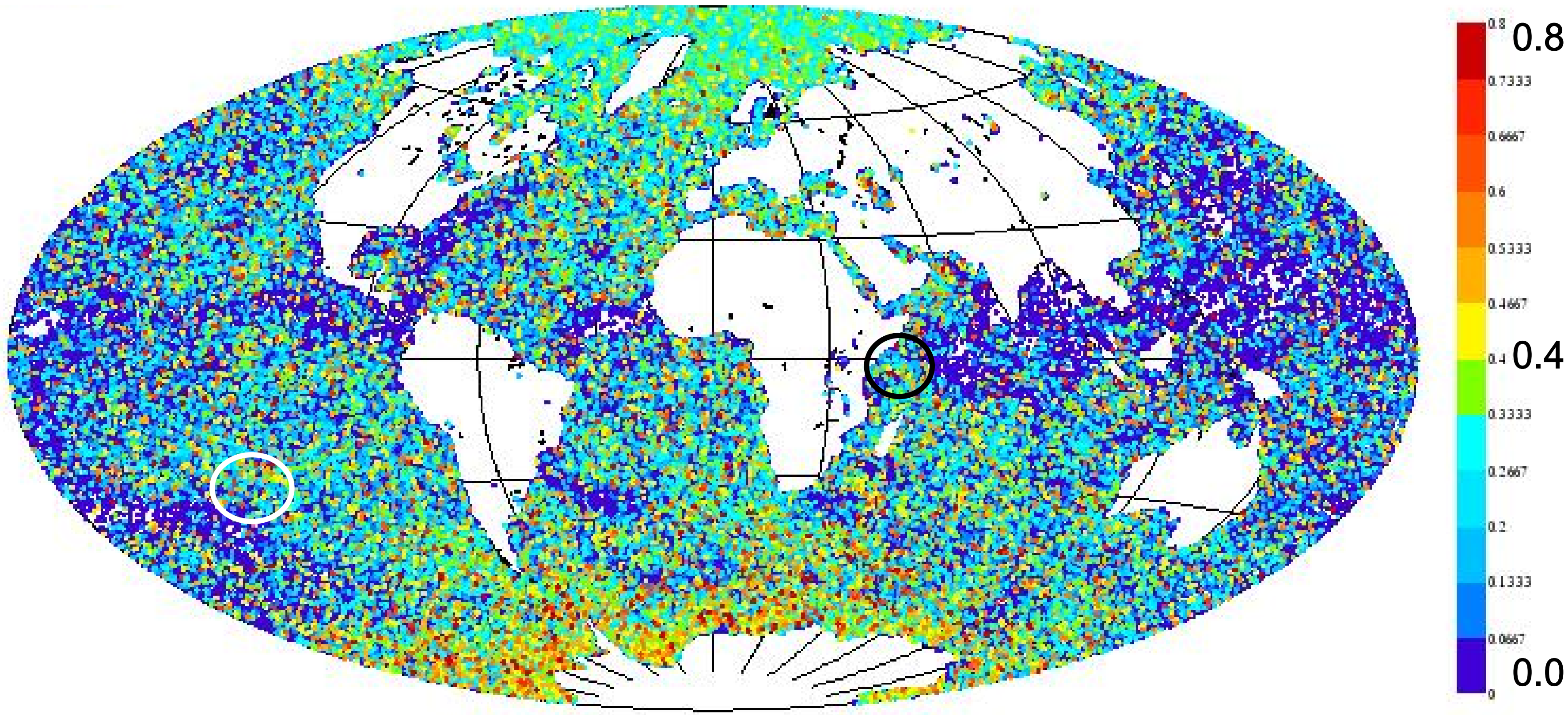


- AIRS CO_2 and H_2O channels assimilated since October 2003.
- IASI CO_2/H_2O channels assimilated since June 2007/March 2009.
- Assimilated in clear-sky areas and above clouds , since March 2009 in fully overcast situations, AIRS (IASI not) over land surfaces/sea-ice.
- Continuous revision of channel usage, quality control.

(A. Collard)

IASI – channel 212 (250 hPa)

First-guess departure standard deviation (K; 7 days)
Assimilation over sea-ice but not over land

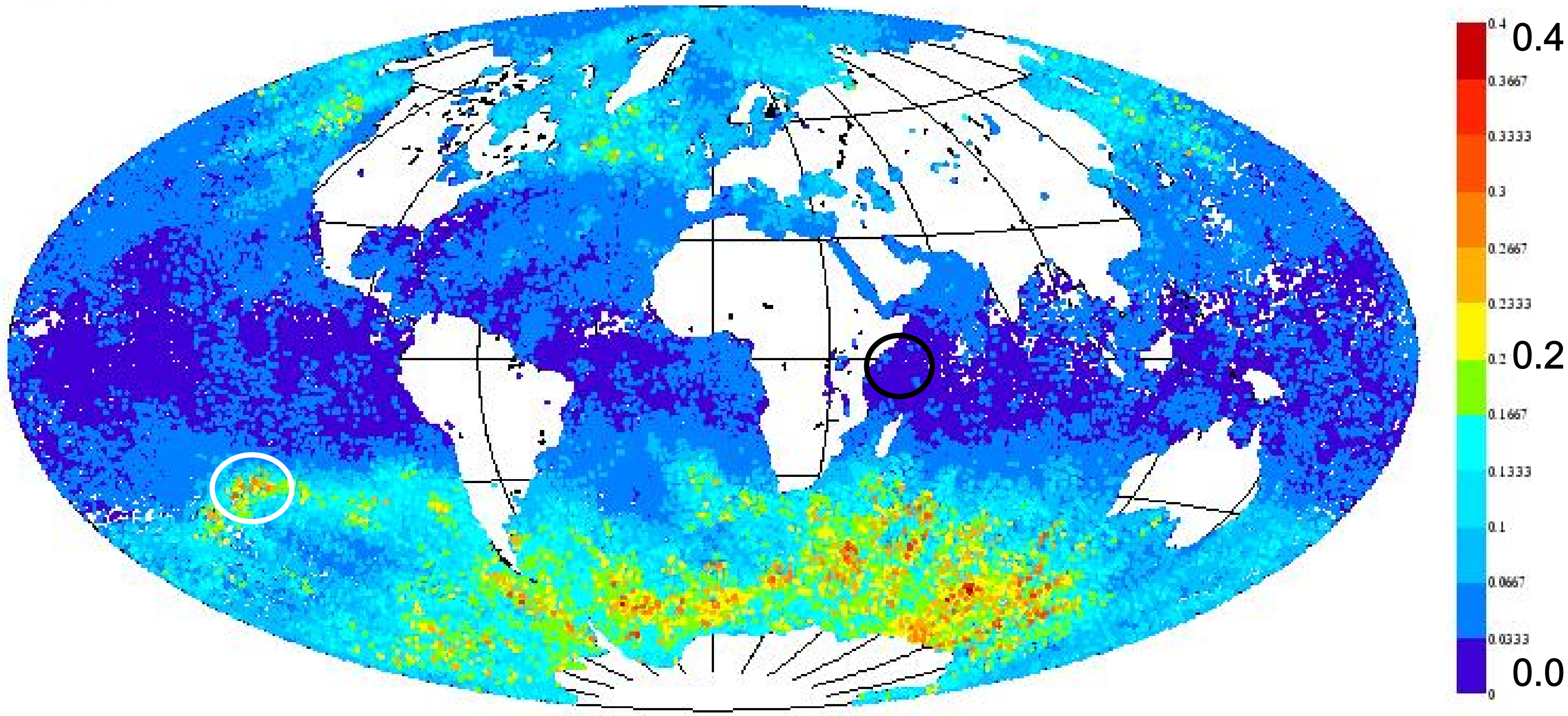


⇒ Information available for analysis from observations (= innovation)

(G. Radnoti)

IASI – channel 212 (250 hPa)

Mean analysis sensitivity to observations* (7 days)
Assimilation over sea-ice but not over land

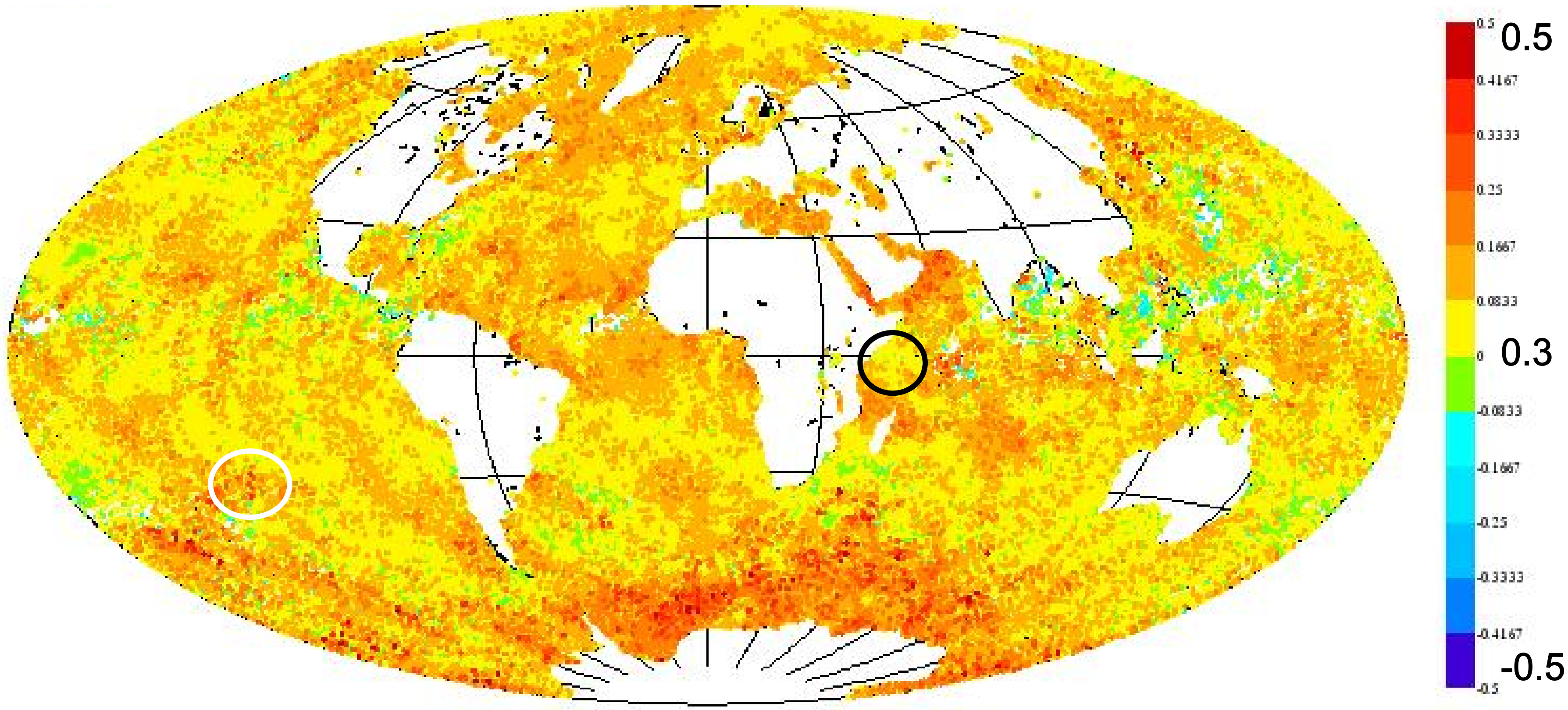


⇒ Sensitivity of the analysis to those observations
(* or self-sensitivity, see Cardinali et al. (2004))

(G. Radnoti)

IASI – channel 212 (250 hPa)

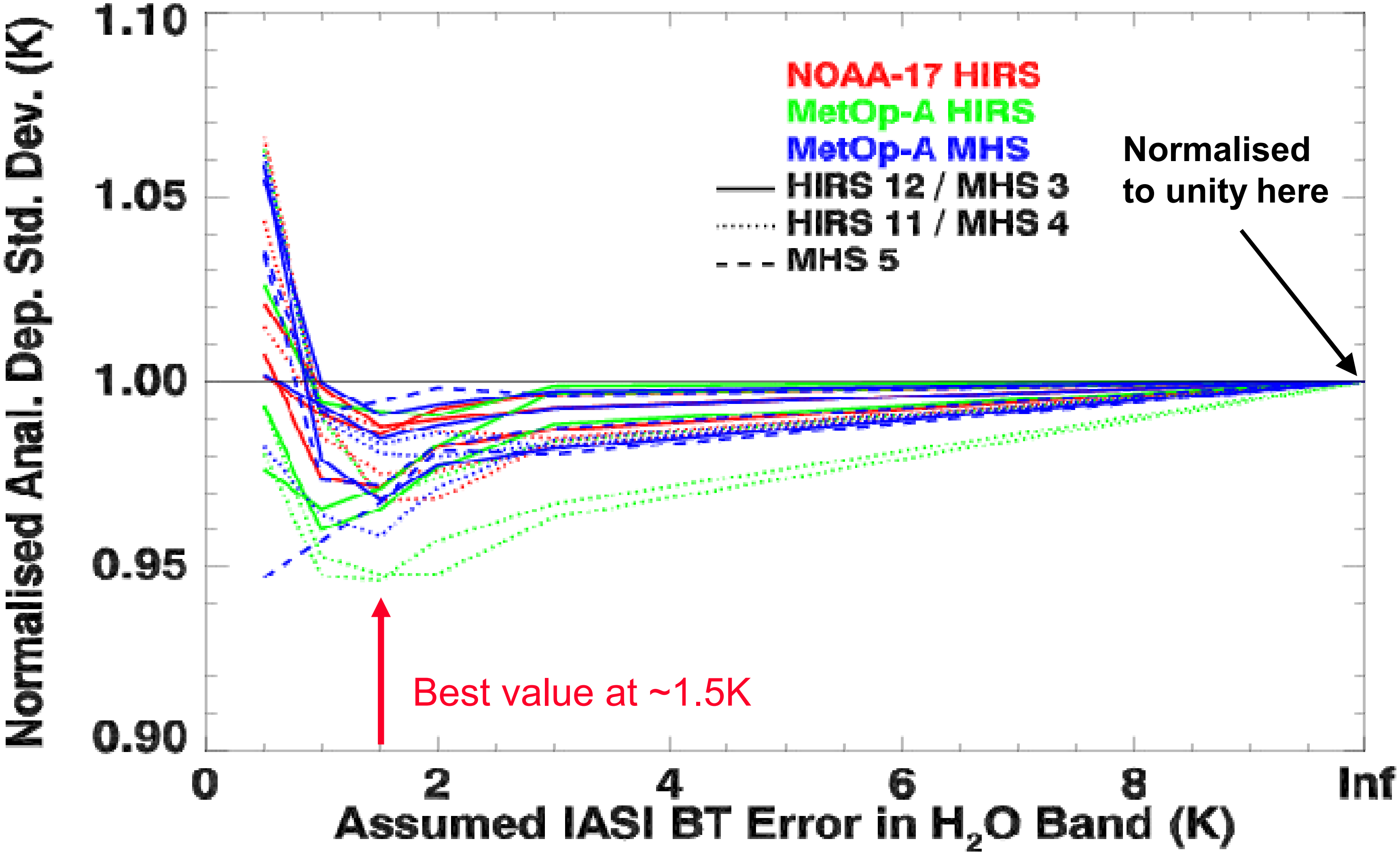
Mean analysis increment (K; 7 days)
Assimilation over sea-ice but not over land



⇒ Work performed by the analysis in observation space

(G. Radnoti)

Adding 10 IASI water vapour channels



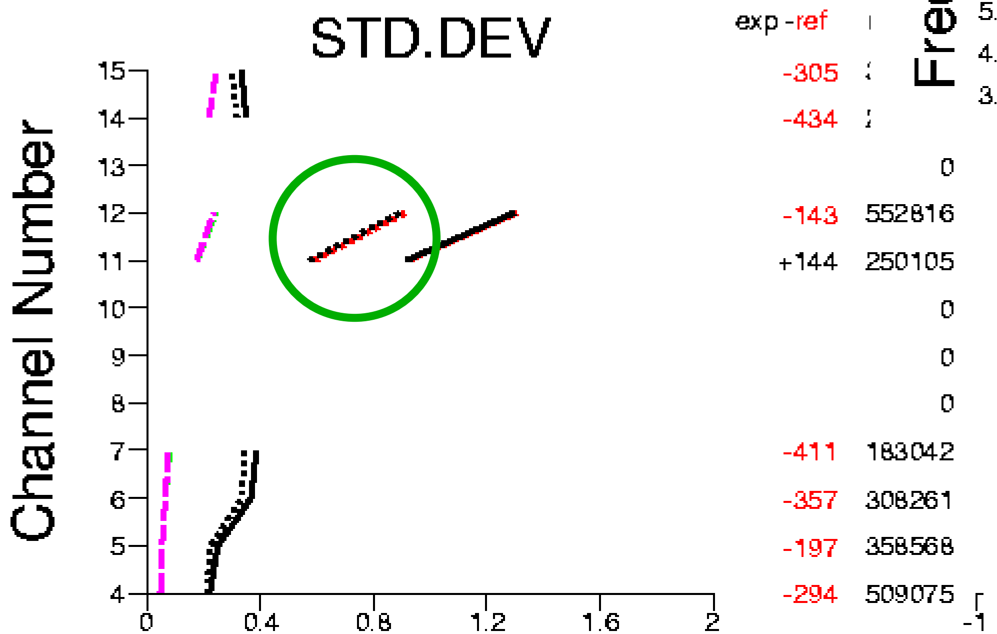
(A. Collard)

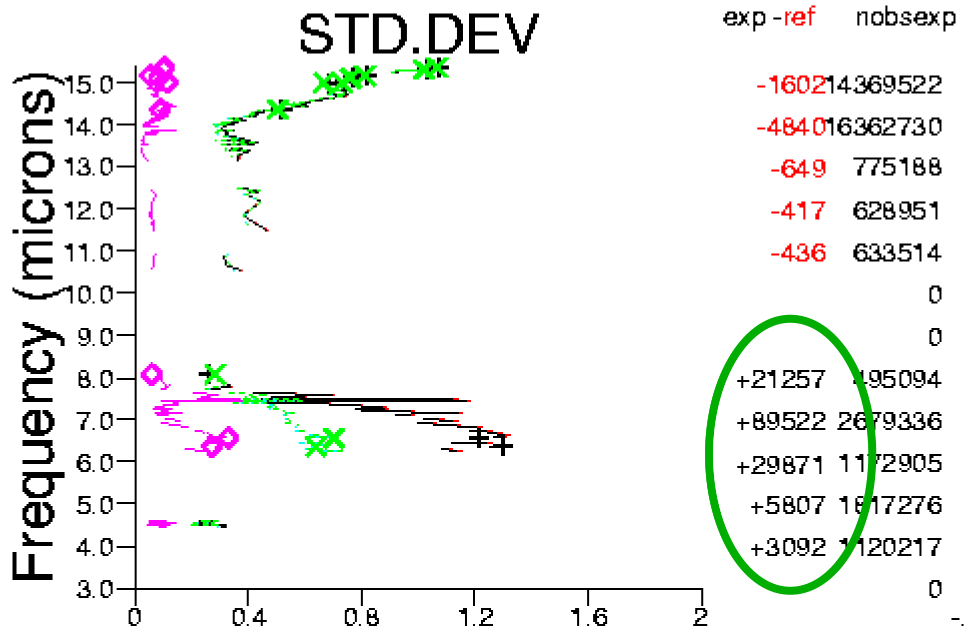
Fit to other observations: NOAA-17 HIRS, Aqua AIRS

Black: IASI w/ humidity channels

Red: Control

NOAA-17 HIRS S. Hemis.





EOS-Aqua AIRS S. Hemis.

The addition of the IASI water band improves the analysis fit to HIRS on NOAA-17 and increases usage of AIRS data.

(A. Collard)

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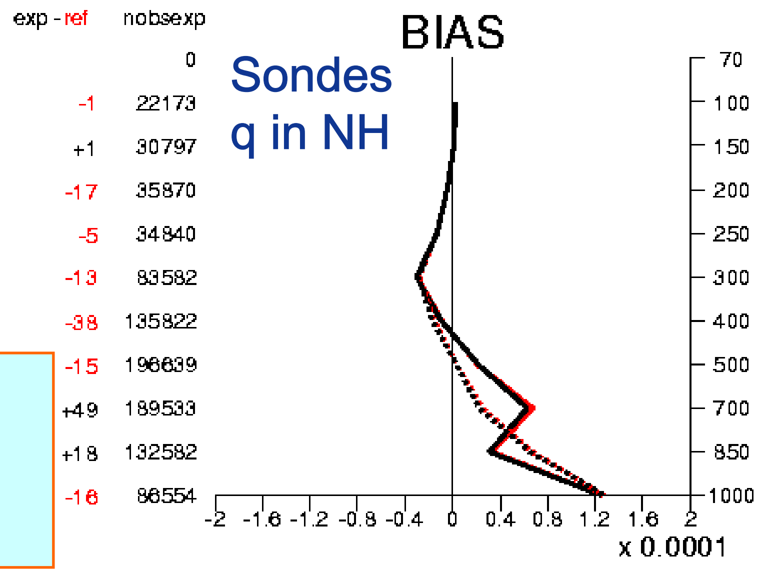
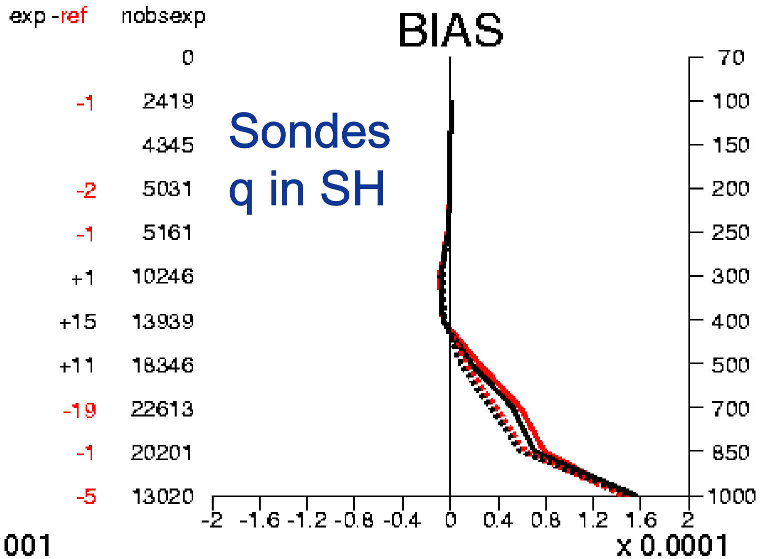
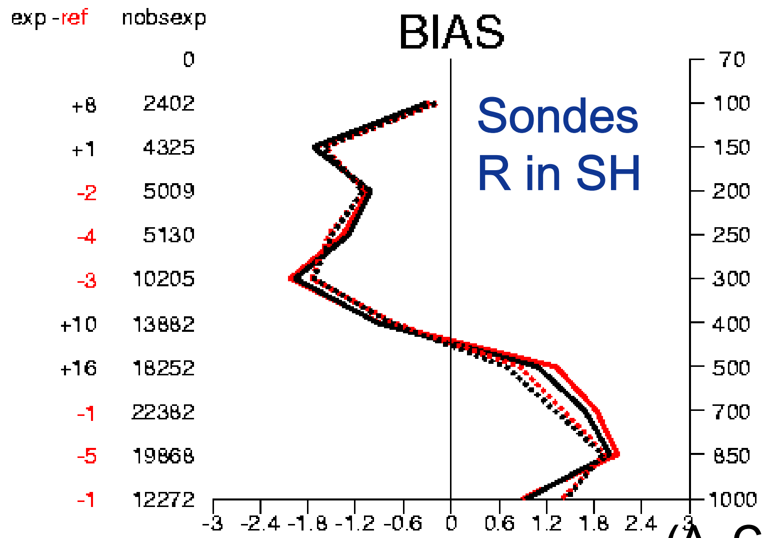
Fit to other observations: Radiosondes

Black: IASI w/ humidity channels
Red: Control



The addition of the IASI water band improves the analysis fit to radiosondes





(A. Collard)

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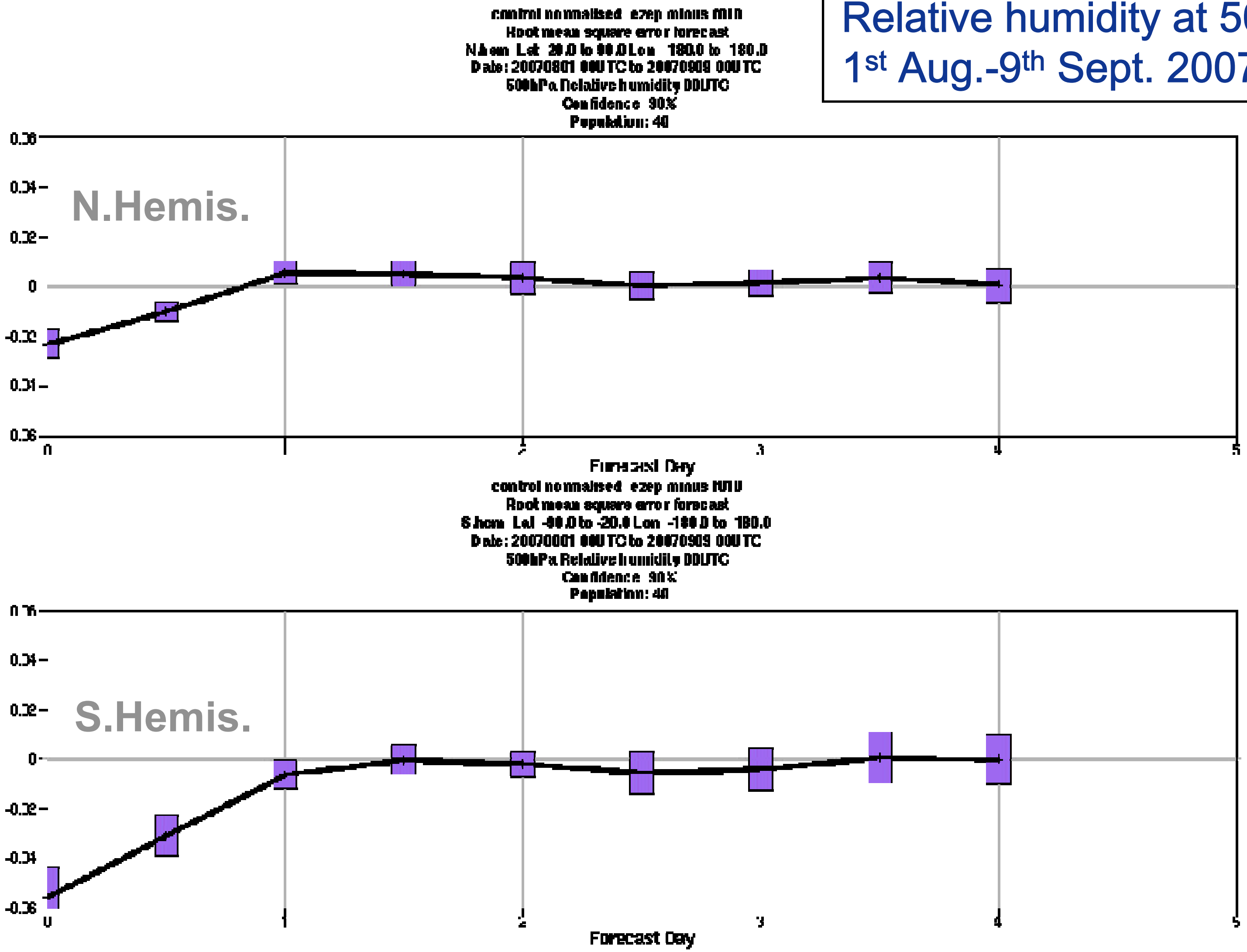
Forecast skill: Verified with operational analysis

Relative humidity at 500 hPa
1st Aug.-9th Sept. 2007



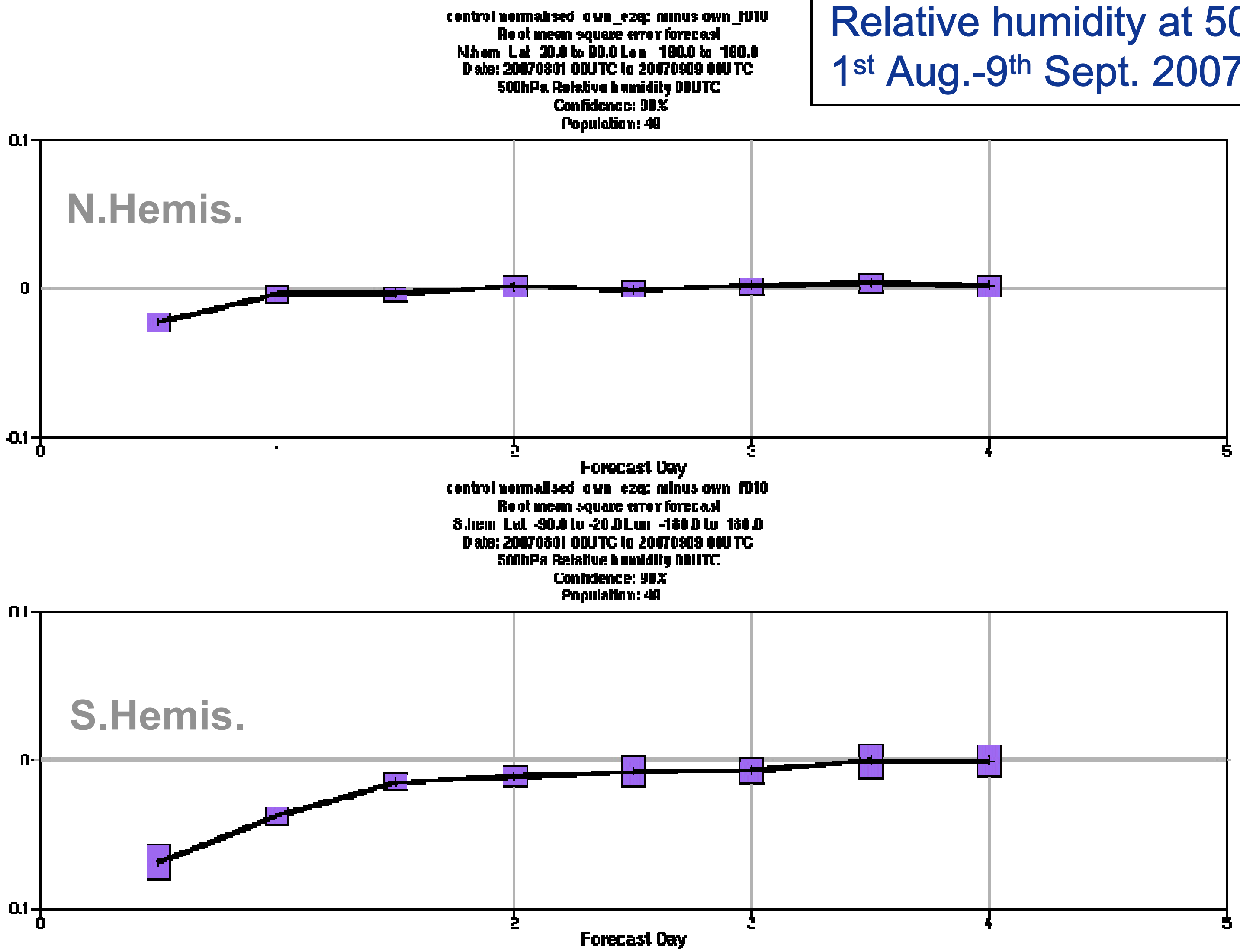
Expt Better

Cntrl Better

(A. Collard)

Forecast skill: Verified with own analysis

Relative humidity at 500 hPa
1st Aug.-9th Sept. 2007



Expt Better

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(A. Collard)

ECMWF

Forecast skill: Verified with experiment's analysis

Relative humidity at 500 hPa
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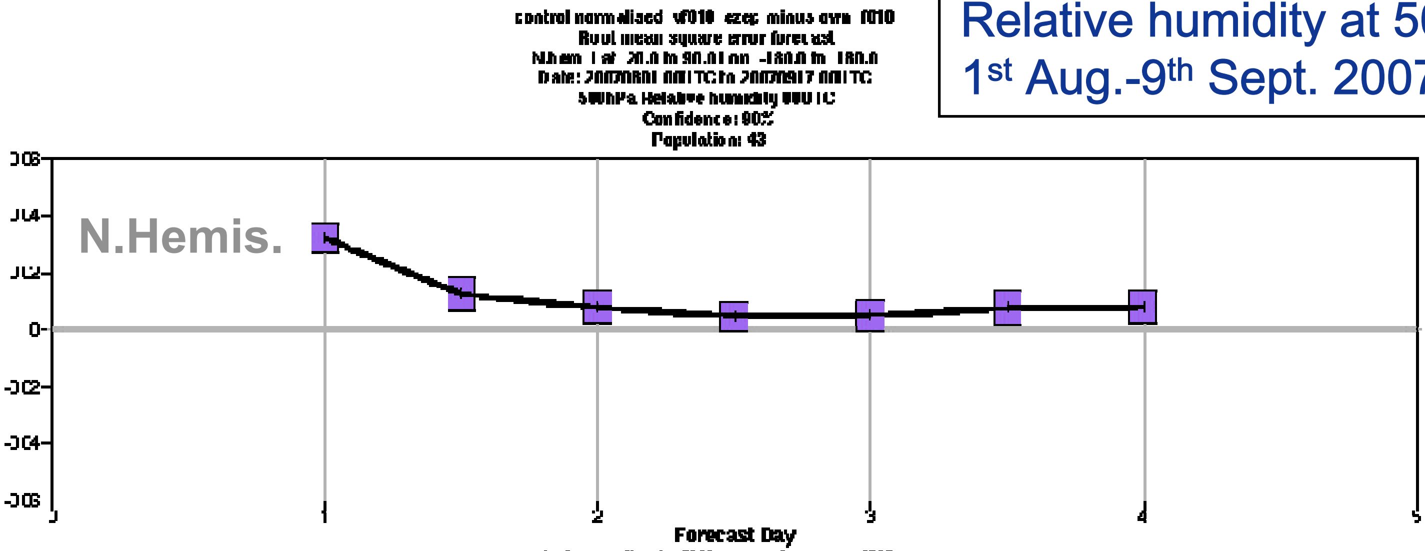

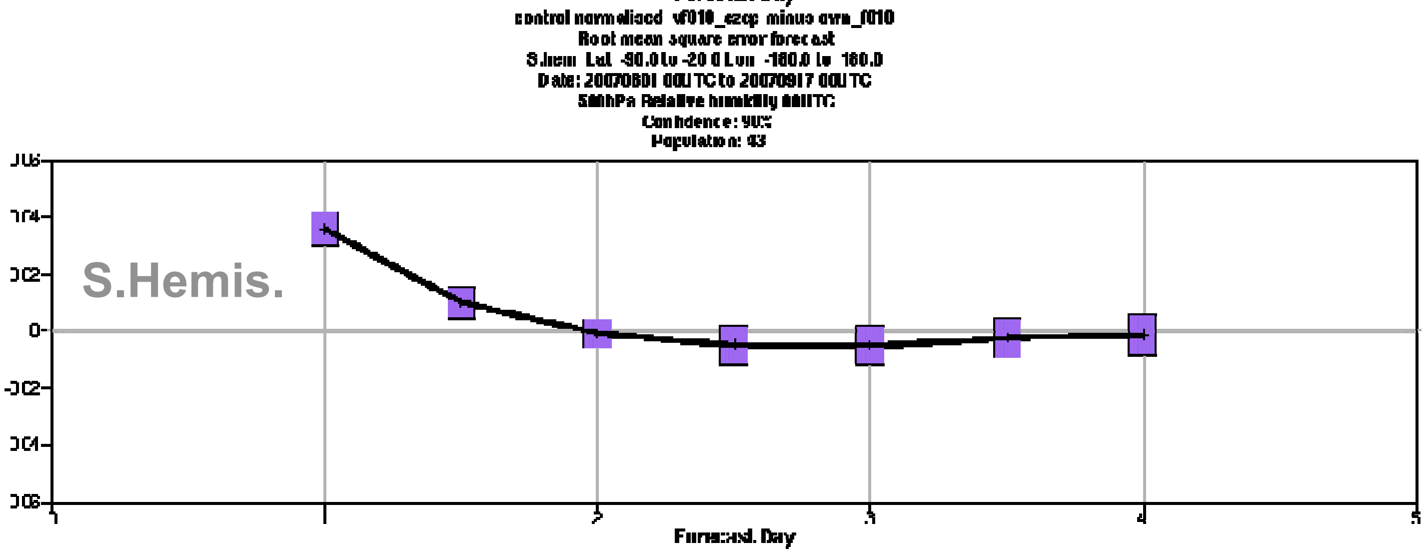

Expt Better

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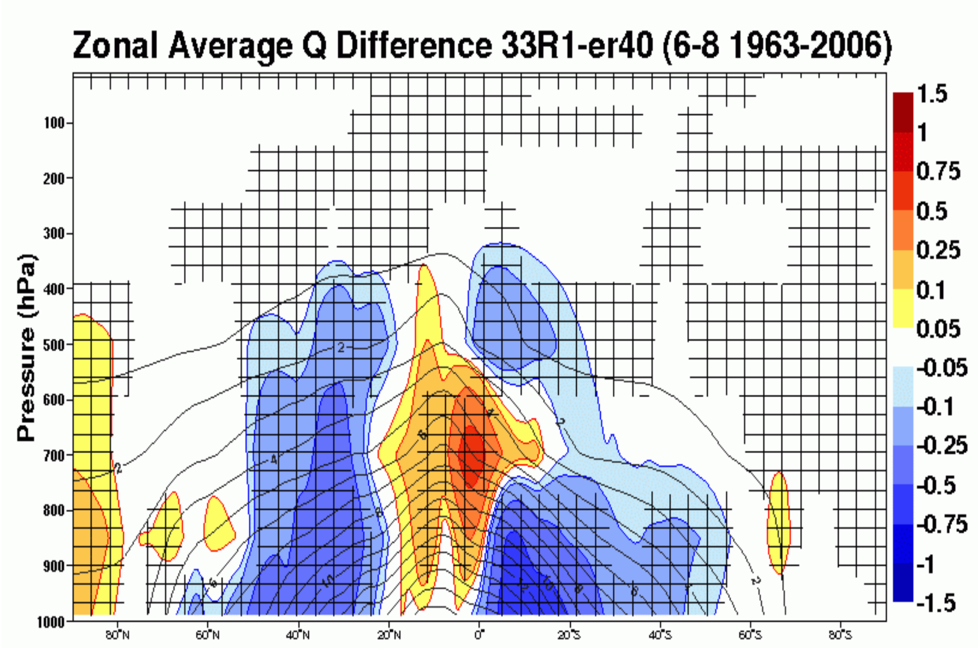
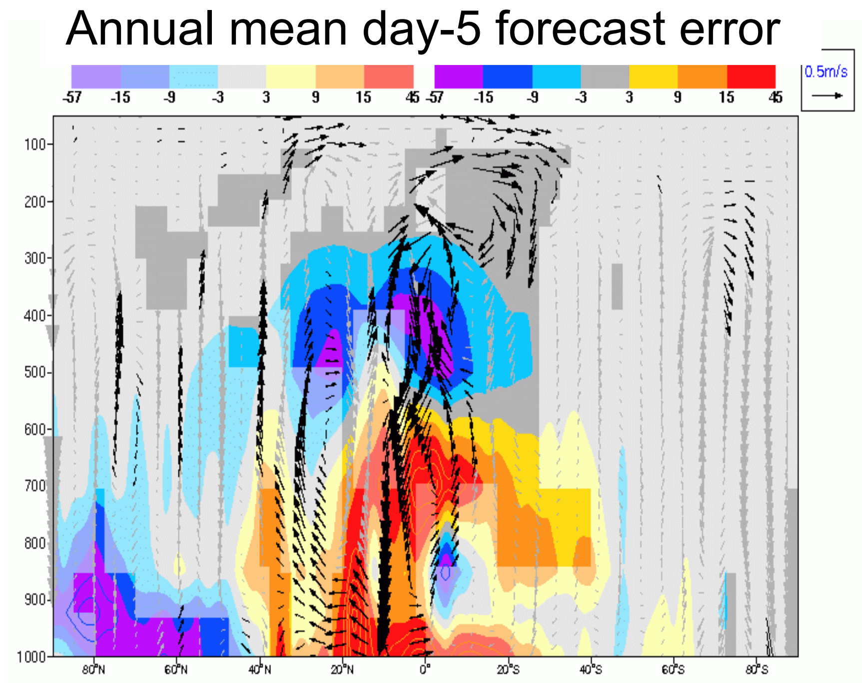
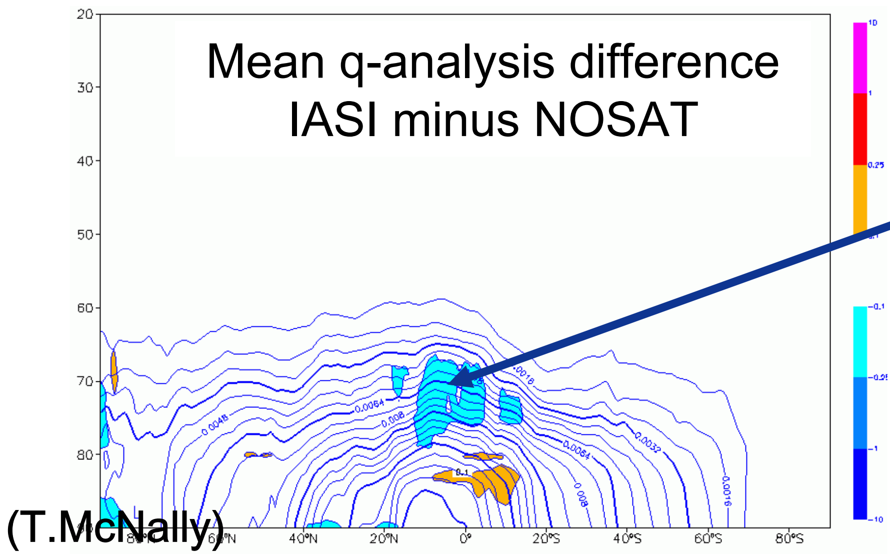
(A. Collard)

Forecast skill and model bias







(T.McNally)

The IASI observations act to dry the NOSAT (and OPS) system which has run to an excessively moist state

→ is consistent with the observed climate bias of the forecast model 700hPa.

→ observations that draw analysis away from model climate will score negatively unless when both experiment and control are verified with improved analysis

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Concluding remarks

- OSEs are continuously performed for:
  - assessment of new (revised) observation impact along model updates;
  - study of basic impact features (poor observing system);
  - assessment of entire observing system components.
- Impact is currently evaluated using:
  - fit to short-range forecast/analysis model fields (consistency, reference observations);
  - model forecast skill using standard scores.
- Shortcomings of current observation impact assessment:
  - evaluation of individual observation type impact on fit of model fields to other observation types is only available for analyses *not* forecasts;
  - diagnostics for tuning/optimization of observing system is not available (thinning, channel selection, observation errors);
  - overview diagnostics require large and costly set of OSEs, no continuous built-in evaluation yet;
  - standard forecast scores often contradict analysis evaluation (new observations add noise and may increase root-mean-square 'error').

Experiment forecast verification - Issues

Forecasts:

- Verification against experiment's own analyses:
  - assumes that observing system in experiment is affecting mean analysis state such that operational analysis is not a good reference,
  - risk of larger variability in analysis due to the additional information introduced by new observation type.

- Verification against operational analyses:
  - justified if experiment configuration obviously inferior compared to operational system (spatial resolution, observing system (baseline experiments)),
  - risk of bias towards operational observing system (e.g. evaluating impact of system A in experiment and control with operational system that contains A).

- Verification against observations:
  - currently only available for radiosonde observations

- Scores:
  - normalized differences are difficult to interpret if forecast errors are small