An Evaluation of FY-3C MWHS-2 and its potential to improve forecast accuracy at ECMWF

Heather Lawrence, final-year EUMETSAT fellow, ECMWF

Supervised by: **Niels Bormann** & **Stephen English**

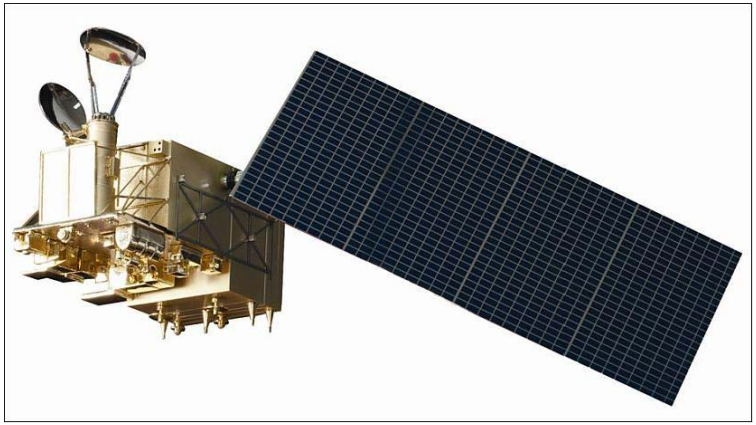
ECMWF

China's FY-3C polar orbiting satellite

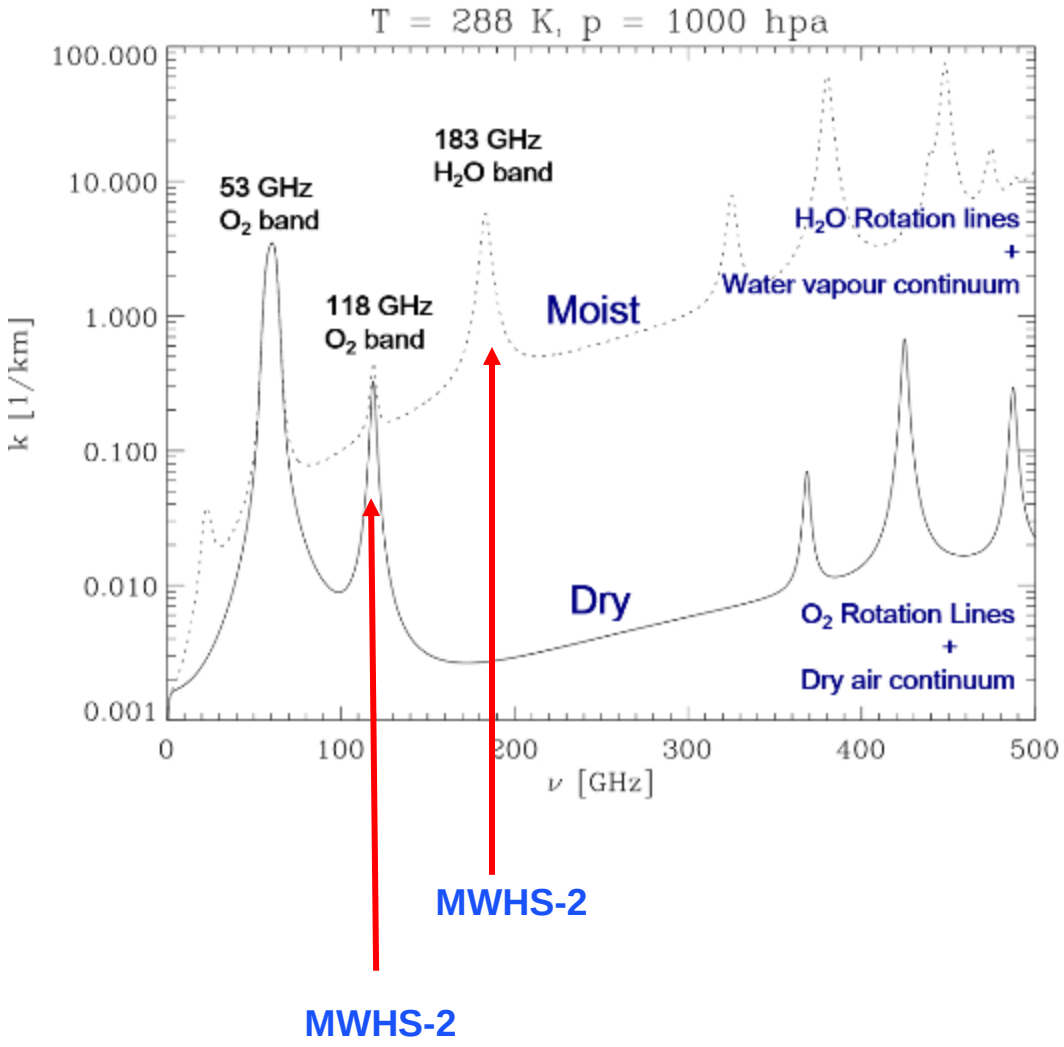
FY-3C: launched Sep 2013, 10am morning orbit

First FY-3 satellite with new instrument designs

- **MWTS-2** Micro-Wave Temperature Sounder – 2 (AMSU-A like)
- **MWHS-2** Micro-Wave Humidity Sounder -2 (MHS-like + new channels)
- **IRAS** Infra-Red Atmospheric Sounder (HIRS-like)
- **MWRI** Micro-Wave Radiation Imager
- **GNOS** GNSS Radio Occultation Sounder



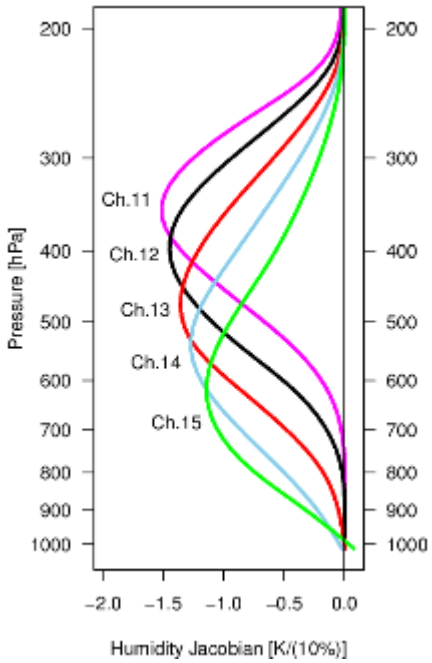
FY-3C Microwave Humidity Sounder MWHS-2



- 5 channels around the 183 GHz water vapour line
- 8 channels around the 118 GHz oxygen line
- 2 window channels (89 GHz, 150 GHz)

FY-3C MWHS-2: MHS-like 183 GHz channels

183 GHz Channels

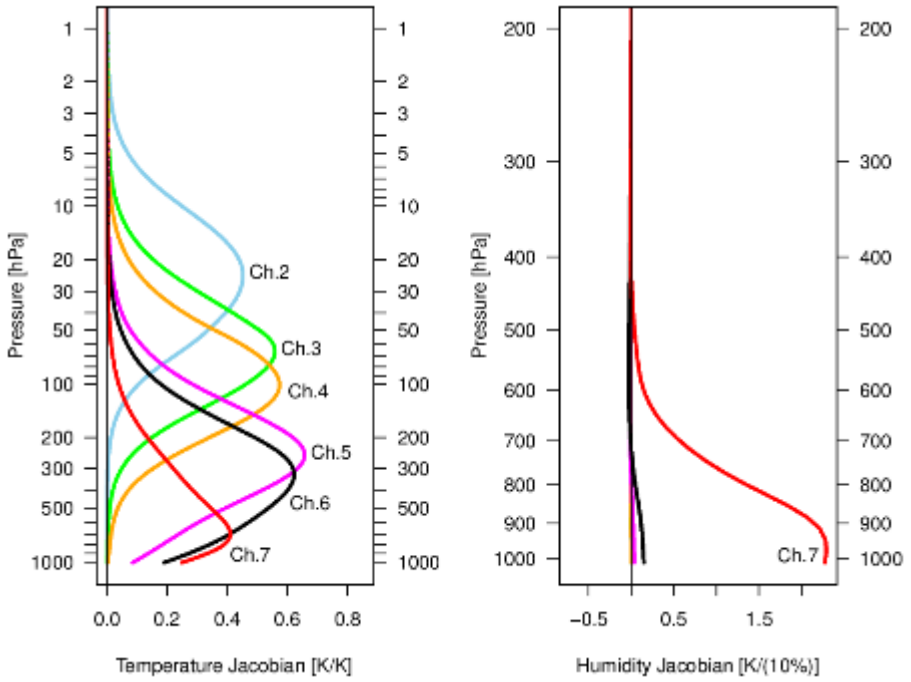


MHS-like Channels

- Sensitive to relative humidity and cloud
- Same channels at ATMS, different orbit
- 2 extra channels compared to MHS
- Expected to bring down noise in areas of overlap and add new information due to 2 new channels

FY-3C MWHS-2: New 118 GHz channels

118 GHz Channels



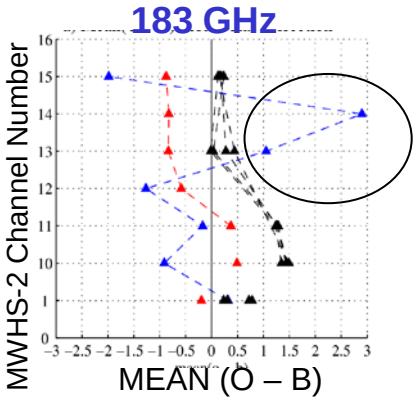
118 GHz: temperature, cloud (ch 5 – 7), humidity(ch7)

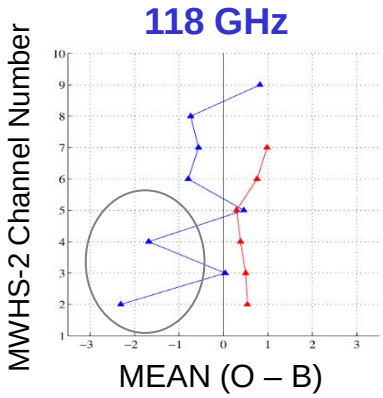
- Higher peaking channels sensitive to temperature
- Lower peaking channels sensitive to temperature, cloud
- Channel 7 sensitive to humidity
- Higher noise specification than AMSU-A

MWHS-2: Data Quality

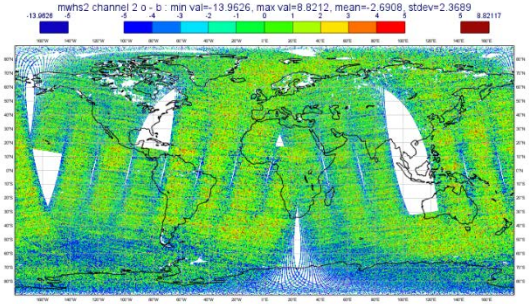
Previously (last year) checked O – B statistics…

Biases mostly ok:

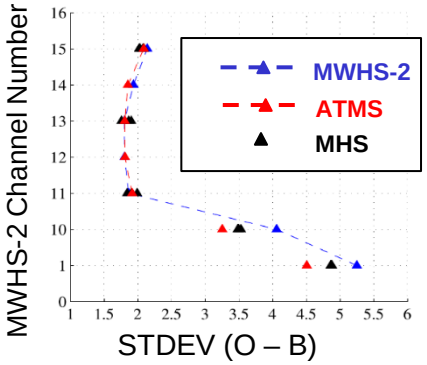




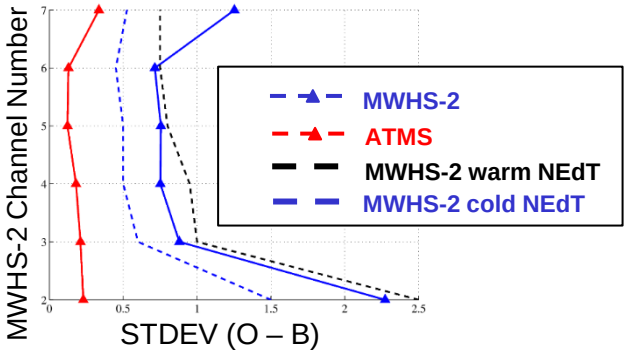
Striping for 118 GHz channels:



Noise equivalent to ATMS/MHS at 183 GHz:



Noise as expected at 118 GHz:



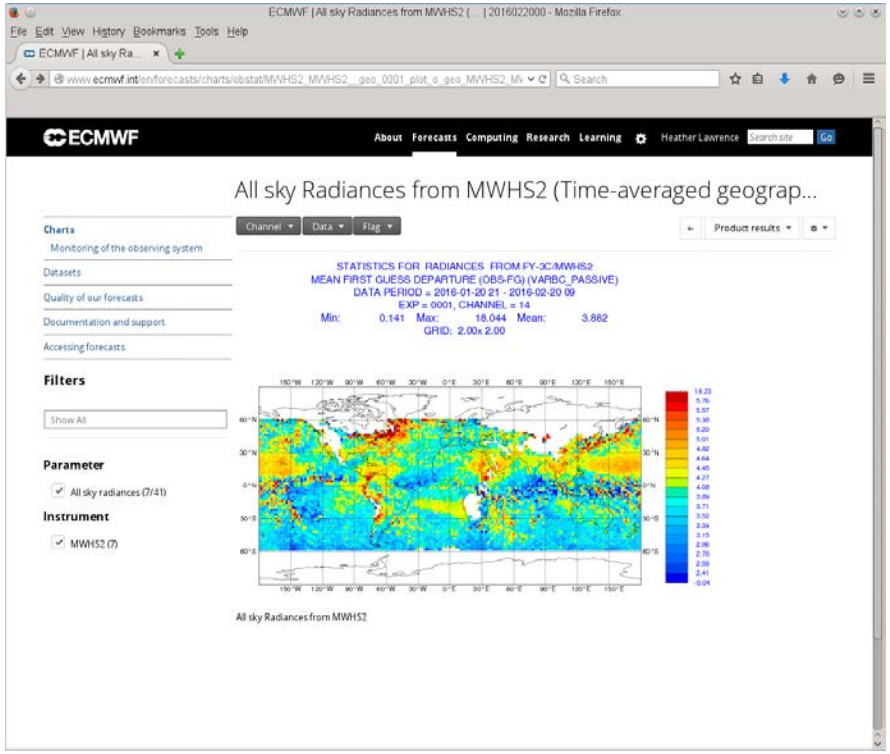
Post-launch NEdT Estimates courtesy of Nigel Atkinson

MWHS-2: Operational Monitoring

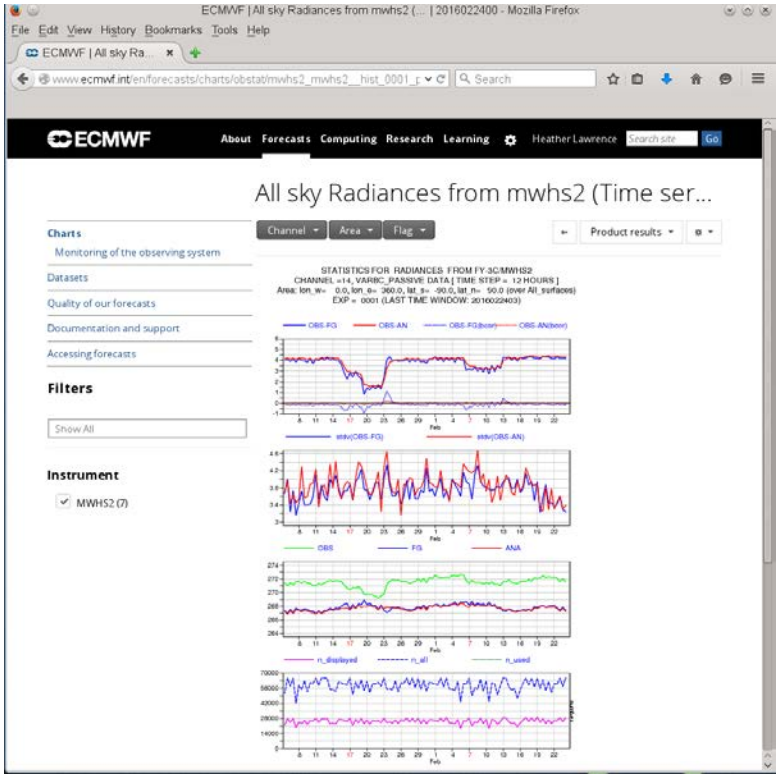
December 2015: Operational Monitoring of FY-3C MWHS-2 (and IRAS, MWRI)

e.g.:

Maps…



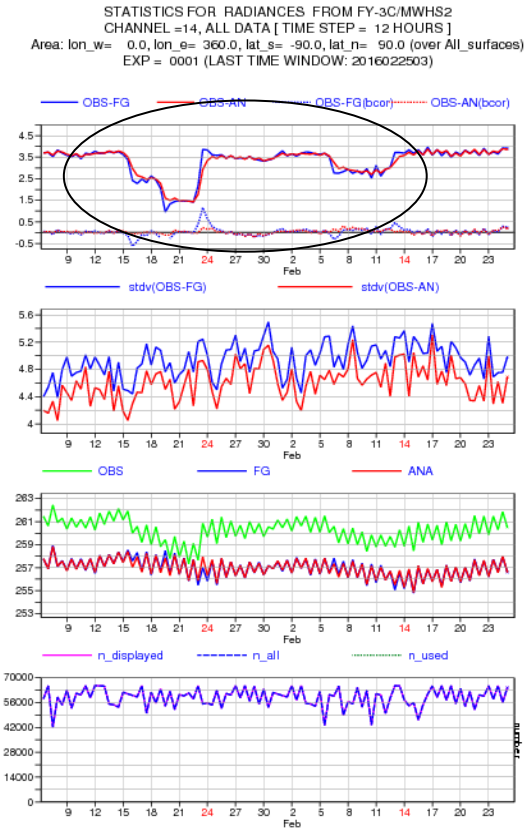
time series..



MWHS-2: Operational Monitoring

Some channels have had some bias changes…:

e.g. channel 14:

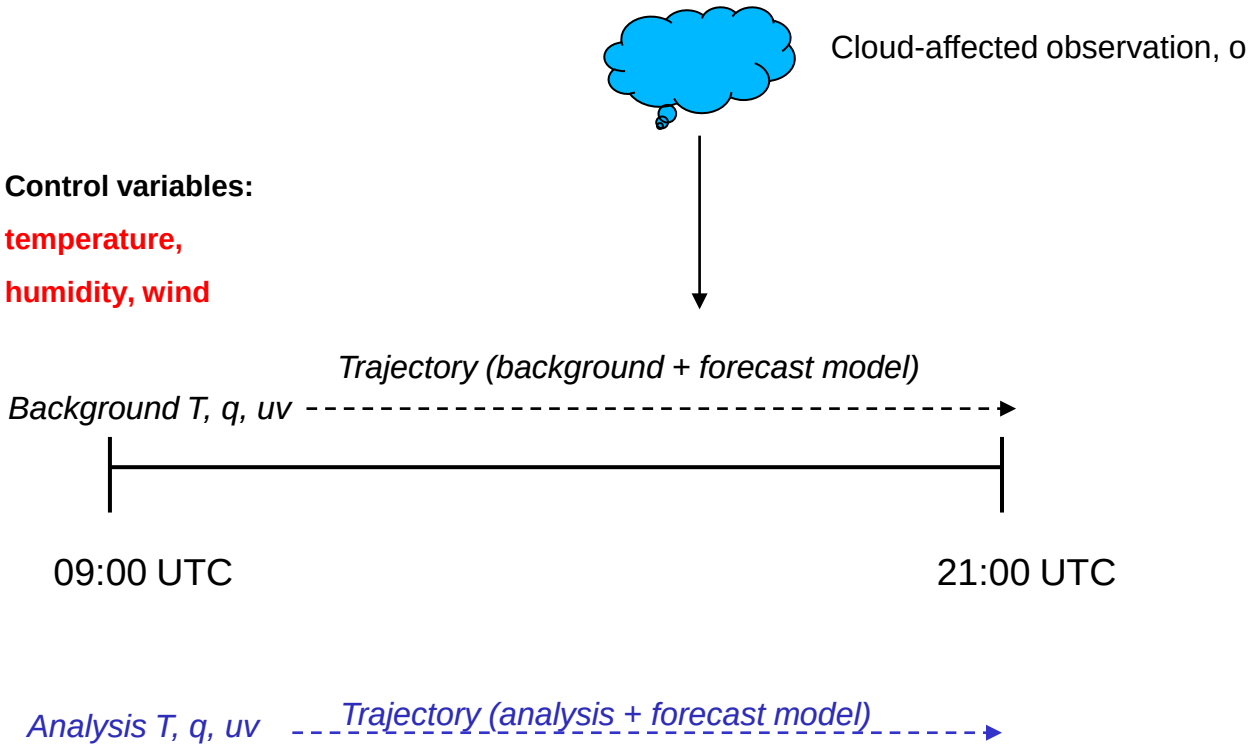


All sky Radiances from MWHS2

Third-year Focus: Assimilation of MWHS-2 in All-sky Conditions

MWHS-2: All-sky Assimilation

- Use a radiative transfer model with cloud effects (RTTOV-SCATT)
- Allow cloud-affected observations to change the control variables



MWHS-2: All-sky Observation Errors

Higher Observation Errors in cloudy situations

Cloud Predictor:

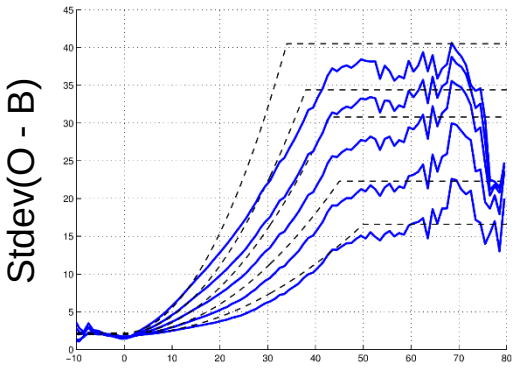
$$SI_{OB} = (TB_{90GHz} - TB_{150GHz}) - (FG^{clr}_{90GHz} - FG^{clr}_{150GHz})$$

$$SI_{FG} = (FG^{cloudy}_{90GHz} - FG^{cloudy}_{150GHz}) - (FG^{clr}_{90GHz} - FG^{clr}_{150GHz})$$

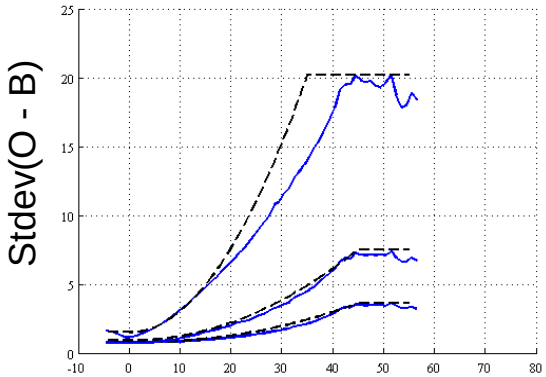
$$C_{sym} = (SI_{FG} + SI_{OB})/2$$

Use a quadratic Model (MHS-like):

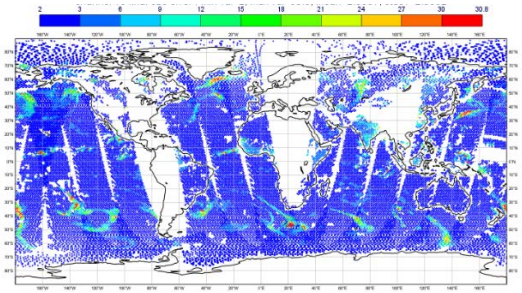
Channels 11 – 15 (183 GHz)

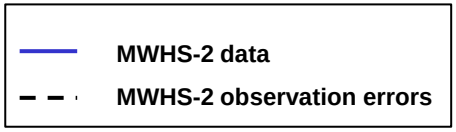


Channels 5 – 7 (118 GHz)



Observation Error Map:





MWHS-2: Full Observing System Assimilation Trials

Assimilate MWHS-2 in all-sky conditions in the **full observing system**:

3 Different trials to assimilate:

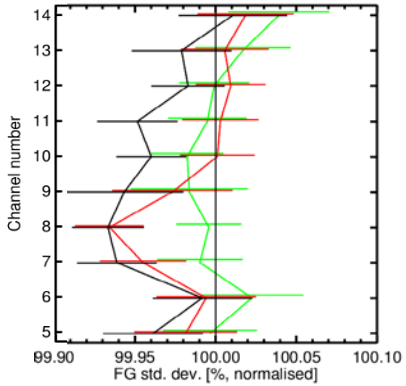
1. 183 GHz channels over all surfaces (ocean, land, sea-ice)
2. 118 GHz channels over ocean
3. 183 GHz channels over all surfaces + 118 GHz channels over ocean

6 months assimilation over 3 different periods

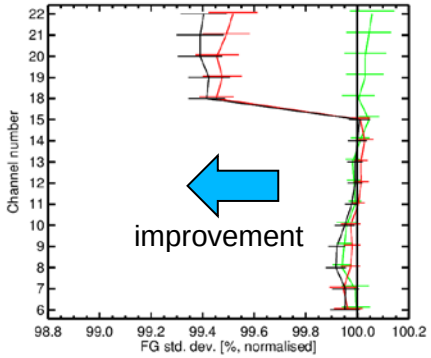
MWHS-2: Full Observing System Assimilation Trials

Impact on Short-Range forecasts (fits to observations):

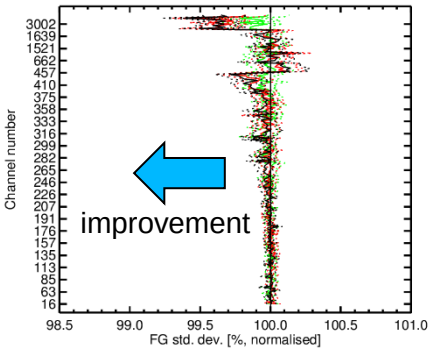
Fit to AMSU-A



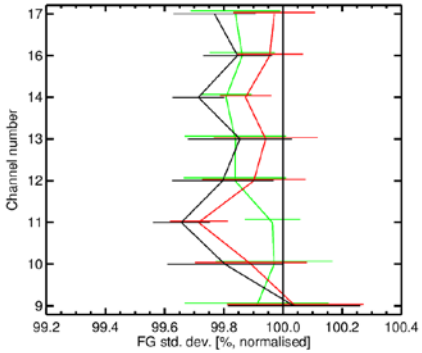
Fit to ATMS



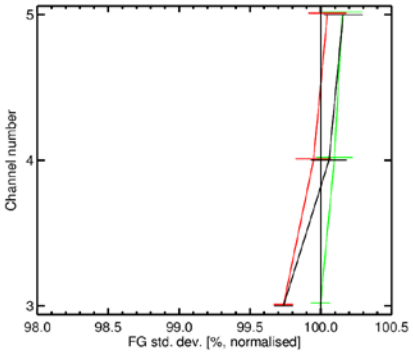
Fit to IASI



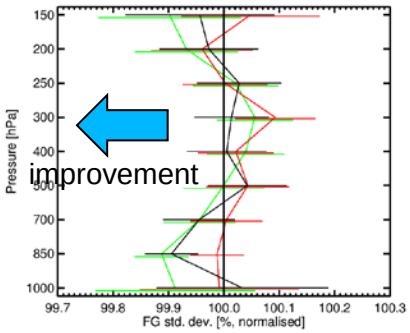
Fit to SSMI/S



Fit to MHS



Fit to AMVs

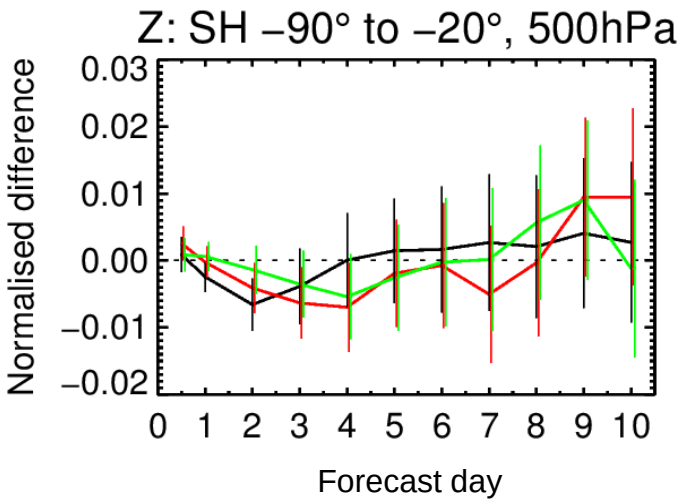


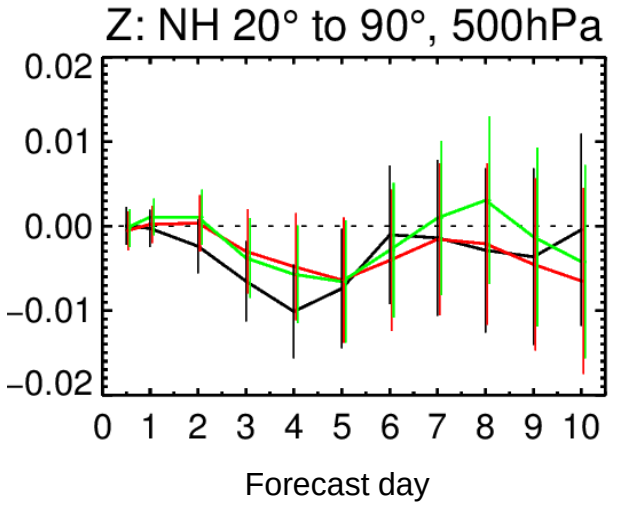
183 + 118 assimilation
183 assimilation
118 assimilation

MWHS-2: Full Observing System Assimilation Trials

Impact on Medium-Range forecasts (forecast scores):

Improvement in forecast accuracy



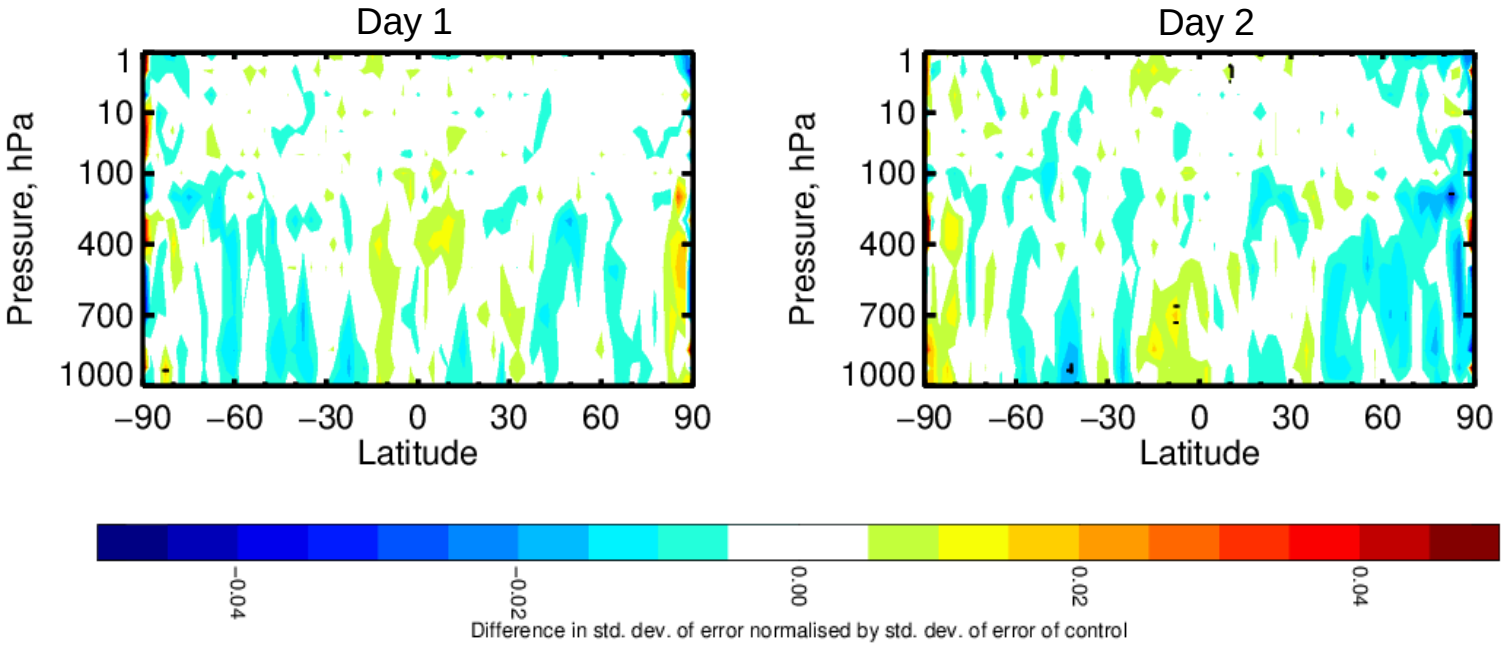


183 + 118 assimilation
183 assimilation
118 assimilation

MWHS-2: Full Observing System Assimilation Trials

Impact on Medium-Range forecasts (forecast scores):

Vector wind forecast scores:



MWHS-2: Full Observing System Assimilation Trials

Summary

- MWHS-2 118 GHz and 183 GHz channels improve forecast accuracy in the full global observing system

- Using the 118 + 183 GHz channels together is better than using them separately

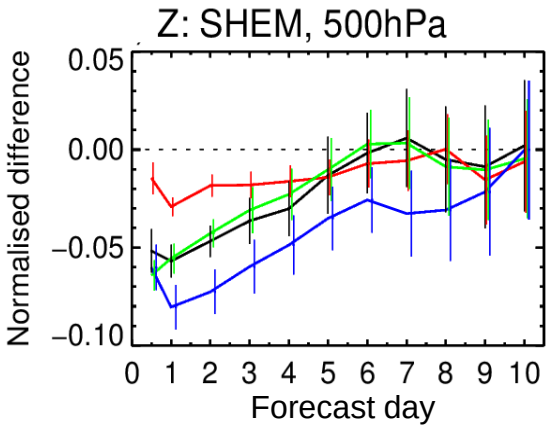
MWHS-2 Assimilation: Compare to MHS and AMSU-A

Compare MWHS-2 to AMSU-A and MHS using Re-initialised Depleted Observing System Experiments:

- Assimilate an instrument without other atmospheric data
- At each cycle take the background fields from a full observing system experiment
- Compare one AMSU-A, one MHS, MWHS-2 183 GHz channels, MWHS-2 118 GHz channels

MWHS-2 Assimilation: Compare to AMSU-A/MHS

AMSU-A the best overall:

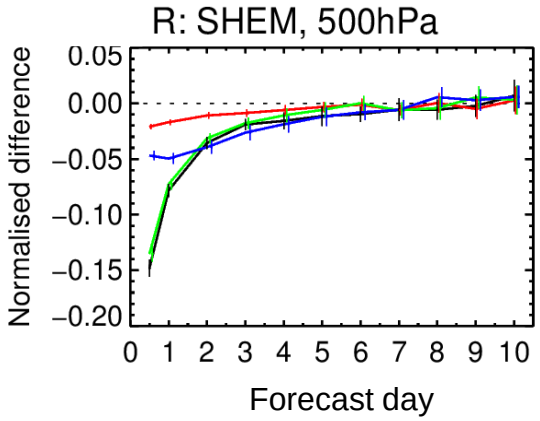


-ve values

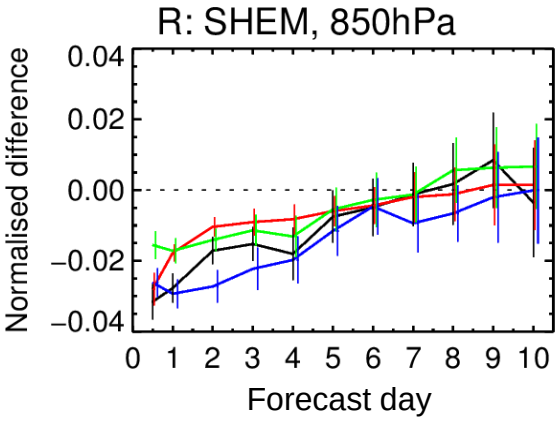
Better than

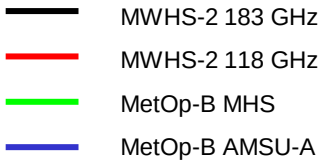
No Data

MHS/MWHS-2 183 GHz the best for humidity:

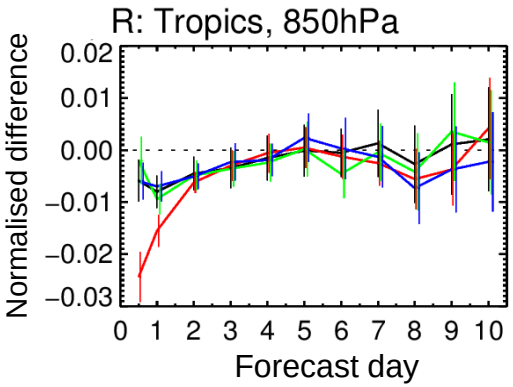


MWHS-2 183 GHz extra channels help short-range humidity at 850 hPa in SHEM:





MWHS-2 118 GHz channels are the best for low level humidity in the Tropics:



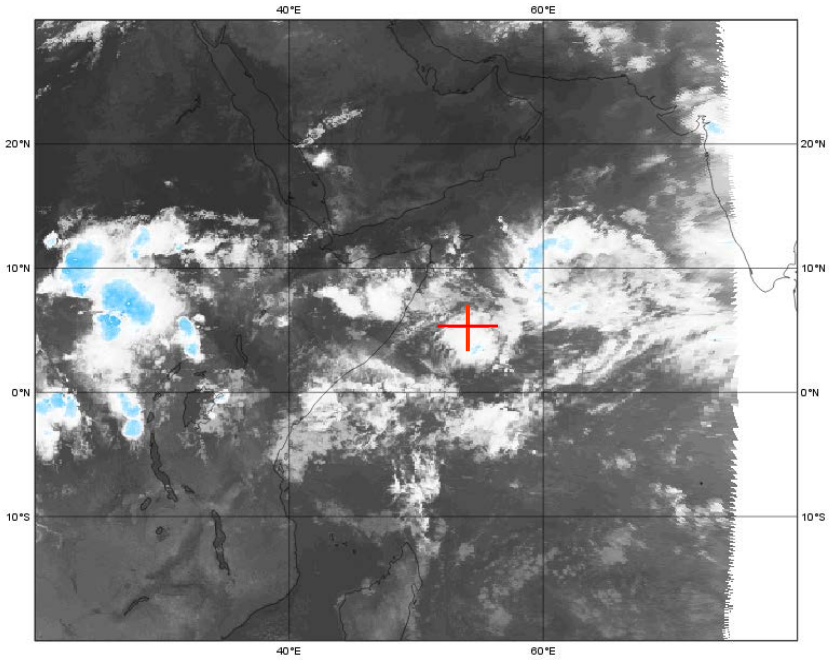
1 month's assimilation

MWHS-2: Single Observation Experiment

How does the cloudy 118 GHz information affect the analysis? What is the mechanism?

Single Observation Experiment:

Met-10 image 03/06/2014 18:45 from EUMETSAT



Observation in the Tropics, at the end of the assimilation window

Cloudy Observation (scatter index = 51.9 K)

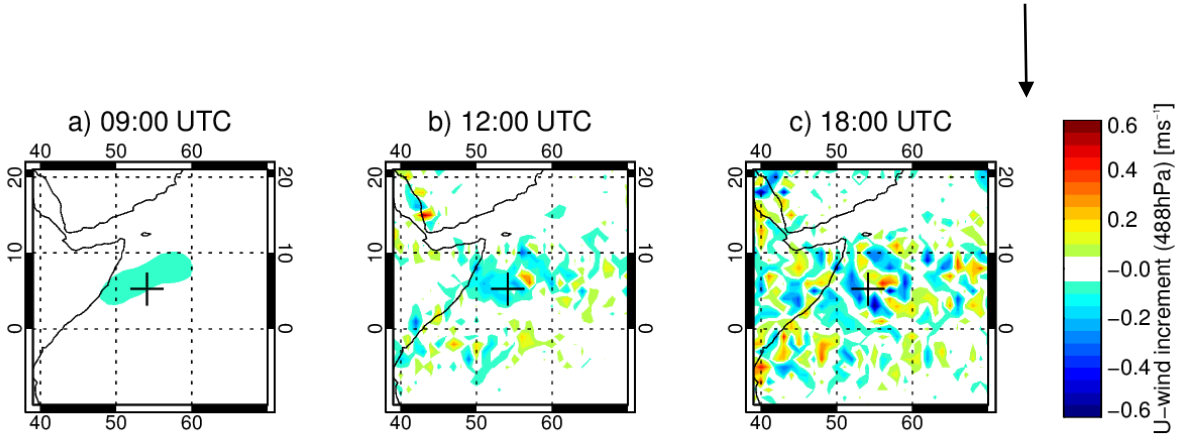
Clear(er) Background (scatter index = 4.3 K)

MWHS-2: Single Observation Experiment

How did the cloudy observation affect the analysis?

Wind at 500 hPa:

Cloudy 118 GHz observation 18:53



Cloudy information acting as a tracer for wind

MWHS-2: Summary

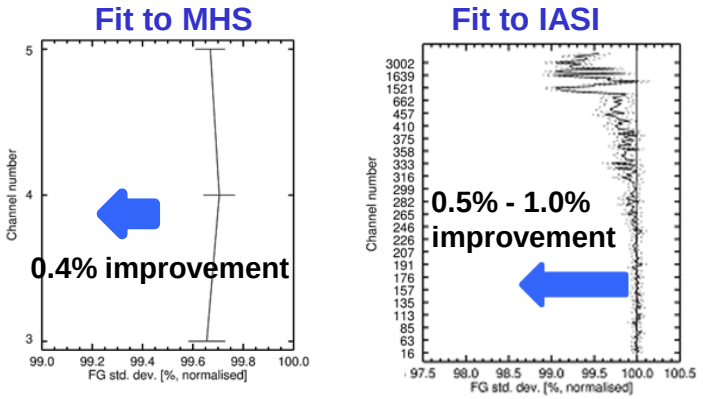
- MWHS-2 118 GHz and 183 GHz channels improve short-range forecasts when assimilated in all-sky conditions in the full observing system (improved fits to other observations)

- 118 GHz channels improve forecast accuracy in a depleted observing system, though not as much as clear-sky AMSU-A or all-sky MHS

- Cloudy information seems to act as a tracer to improve the analysis wind

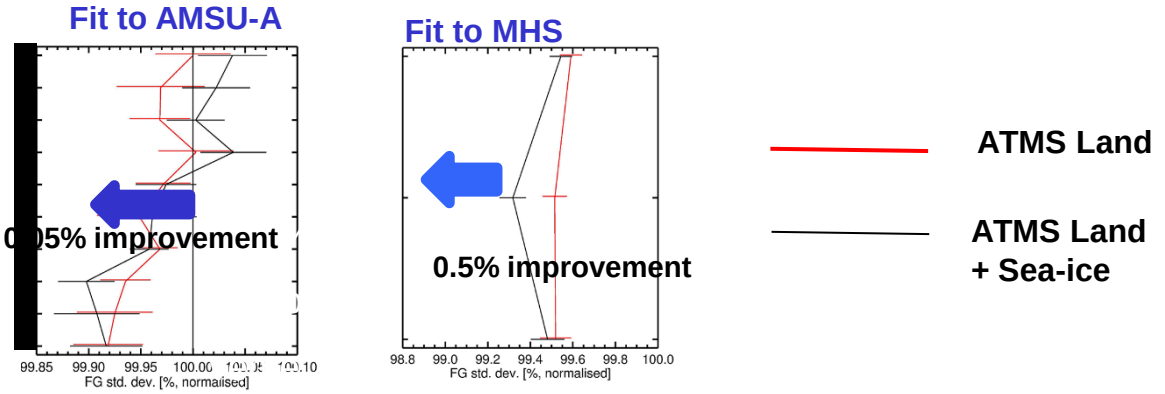
Summary of 3-year EUMETSAT fellowship at ECMWF

- Tested the impact of HIRS (3 instruments) at ECMWF



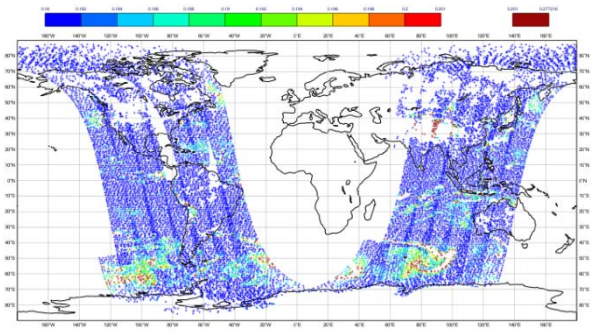
Improvements to short-range humidity

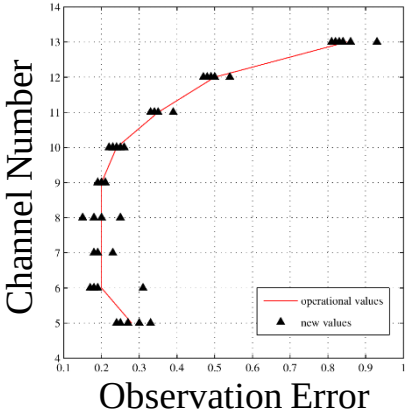
- Tested the introduction of ATMS over land and sea-ice: operationally added ATMS over land



Summary of 3-year EUMETSAT fellowship at ECMWF

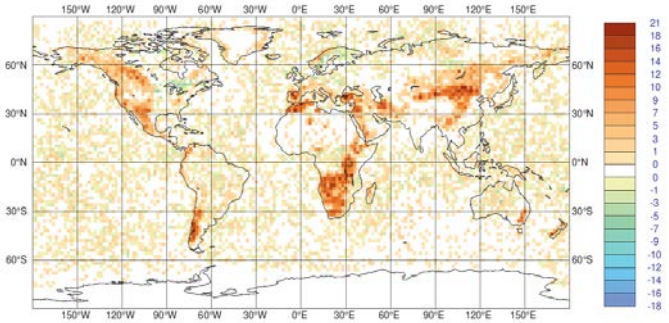
- Developed Scene-dependent Observation Errors for AMSU-A



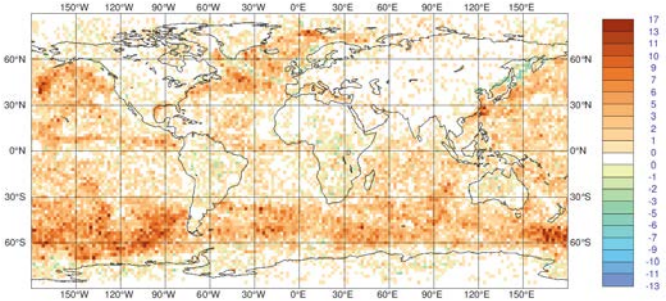


- Increased number of used data for AMSU-A

Ch 5 - 6: orography



Ch 6 – 8: over ocean



ch 5: 6%

ch 6: 11%

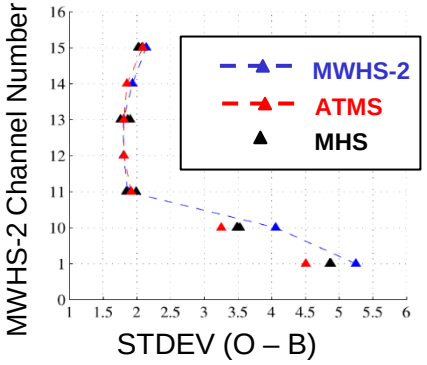
ch 7: 8%

ch 8: 3%

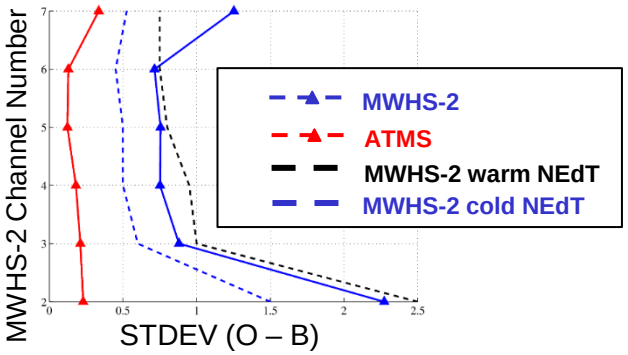
Summary of 3-year EUMETSAT fellowship at ECMWF

- Assessed the quality of FY-3C MWHS-2 in collaboration with CMA and the Met Office

Noise equivalent to ATMS/MHS at 183 GHz:



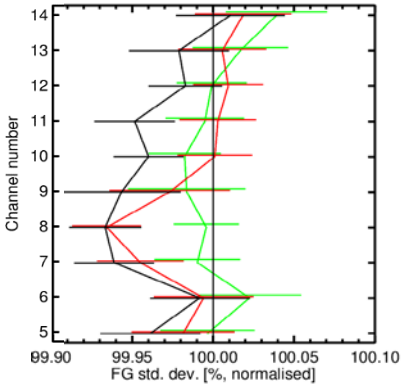
Noise as expected at 118 GHz:



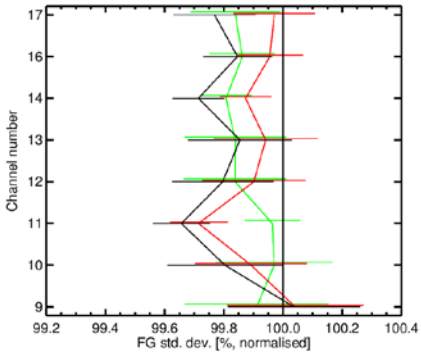
- Assessed the assimilation of FY-3C MWHS-2 in all-sky conditions

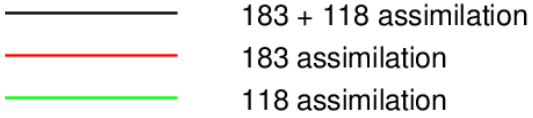
e.g.

Fit to AMSU-A



Fit to SSMI/S

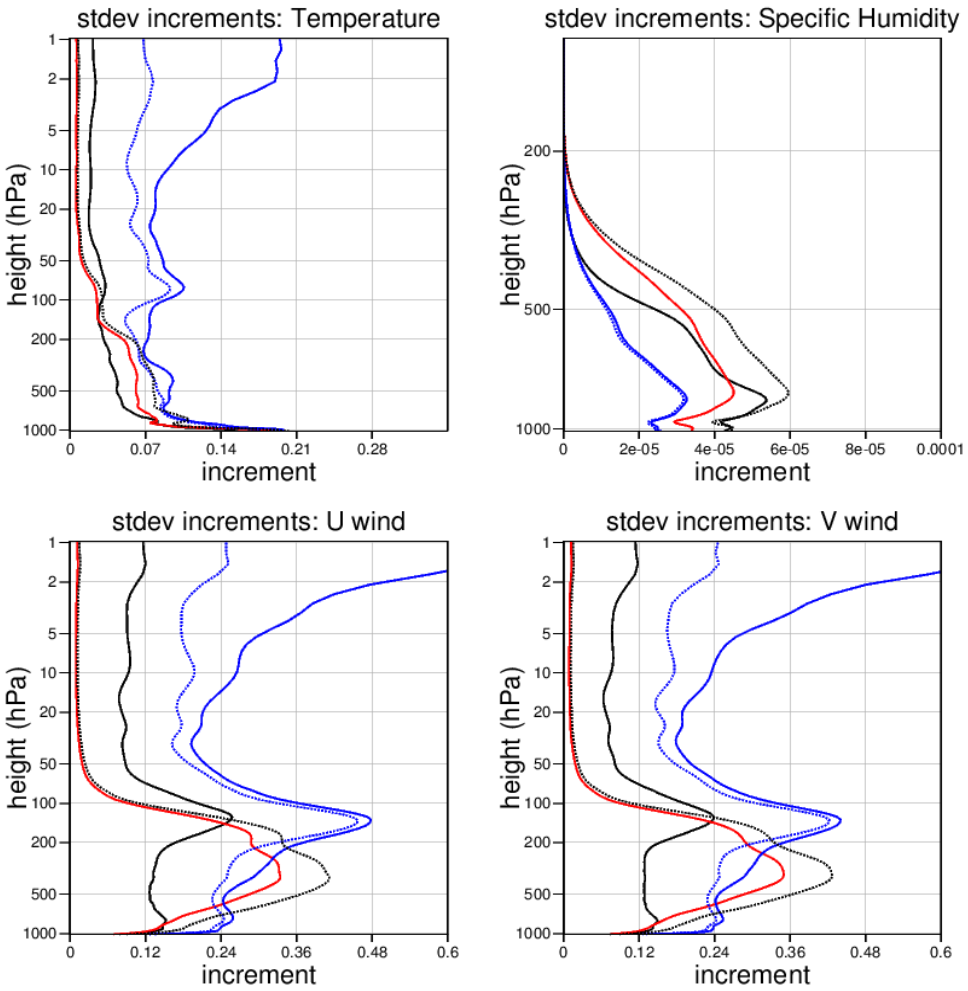




A Big Thank You to EUMETSAT for funding this research and creating this opportunity

MWHS-2 Assimilation: Compare to AMSU-A/MHS

Analysis Increments from MWHS-2, AMSU-A, MHS:



MWHS-2 118 GHz
MWHS-2 183 GHz
MetOp-B AMSU-A
MetOp-B AMSU-A channel subset
MetOp-B MHS

1 month's assimilation