The power of monitoring EarthCARE observations at ECMWF and preparations towards their assimilation.

2nd ESA EarthCARE Validation Workshop

25th May 2021

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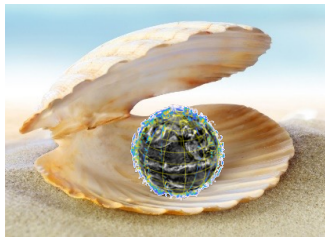
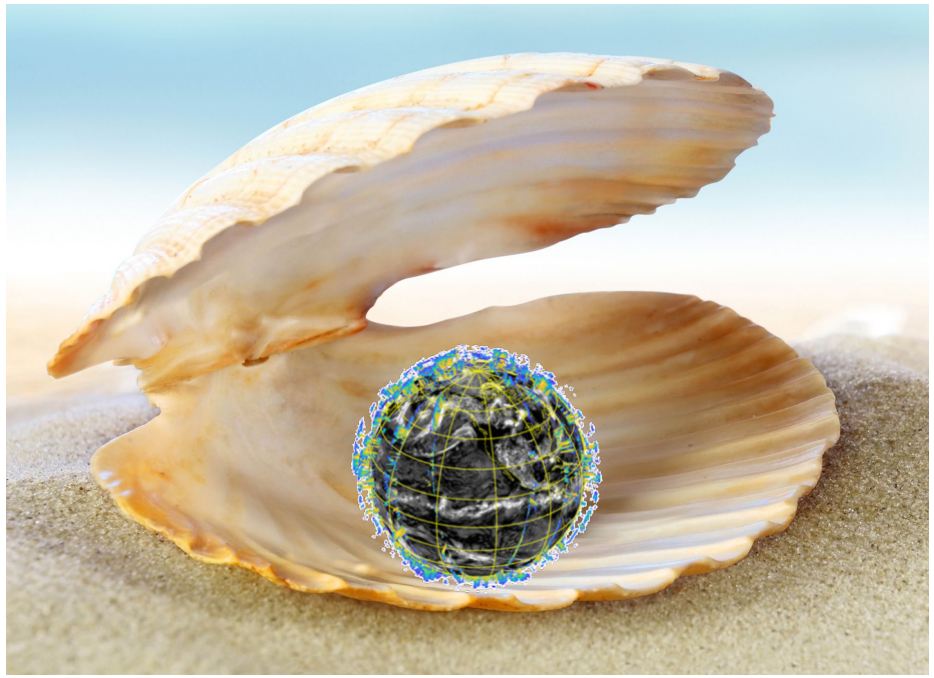
Thanks: Michael Rennie, Mohamed Dahoui



Preparations for EarthCARE assimilation – Radar and Lidar (PEARL)

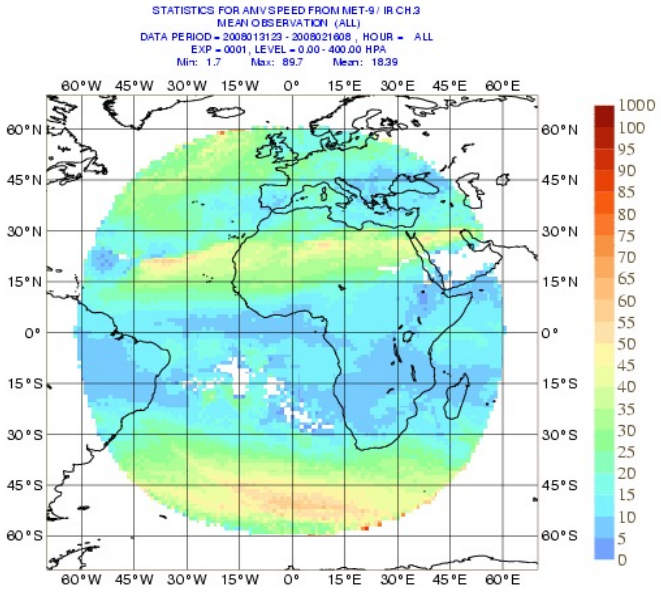
Joint ECMWF-ESA project to maintain and improve developments for monitoring and potential assimilation of EarthCARE cloud radar and lidar observations.

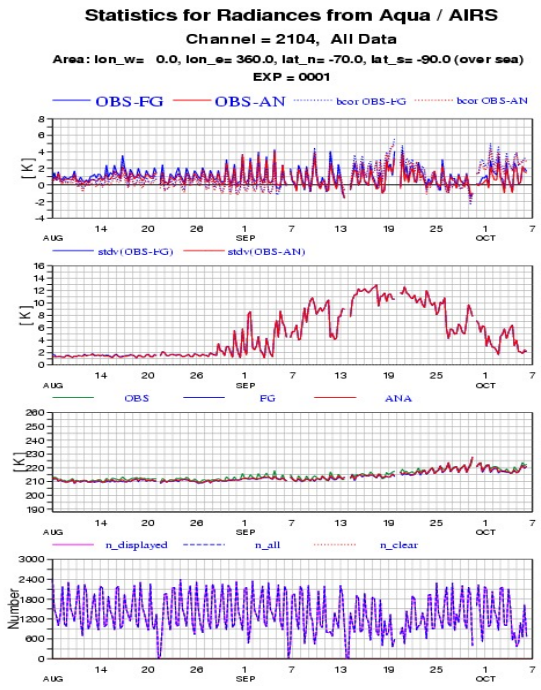
1. Port assimilation developments to latest model cycle and maintain.
2. Optimise observation impact through improvements of observation operator, bias correction, observation error.
3. Explore synergies with other on-board sensors
4. Prepare observation processing so monitoring can begin as soon as possible after satellite launch.

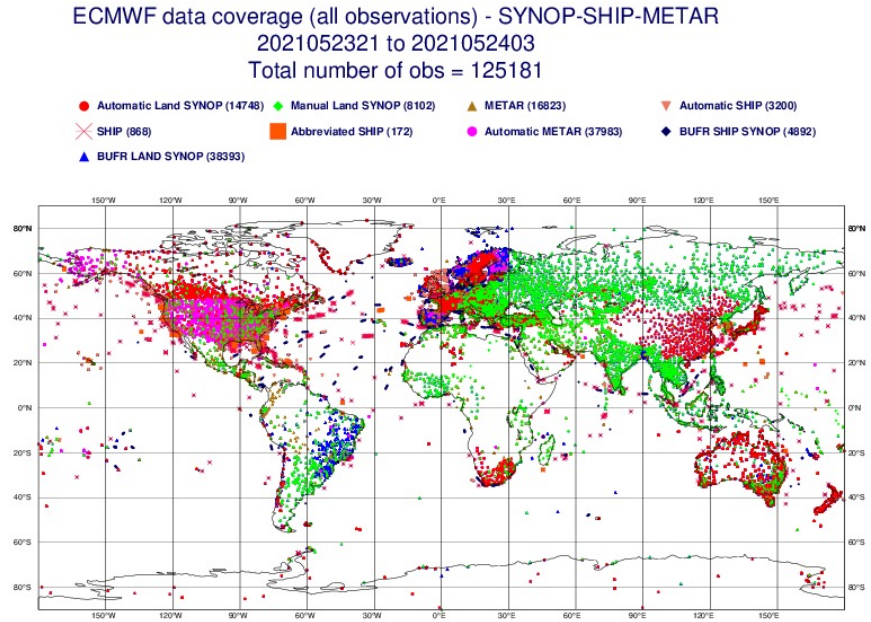


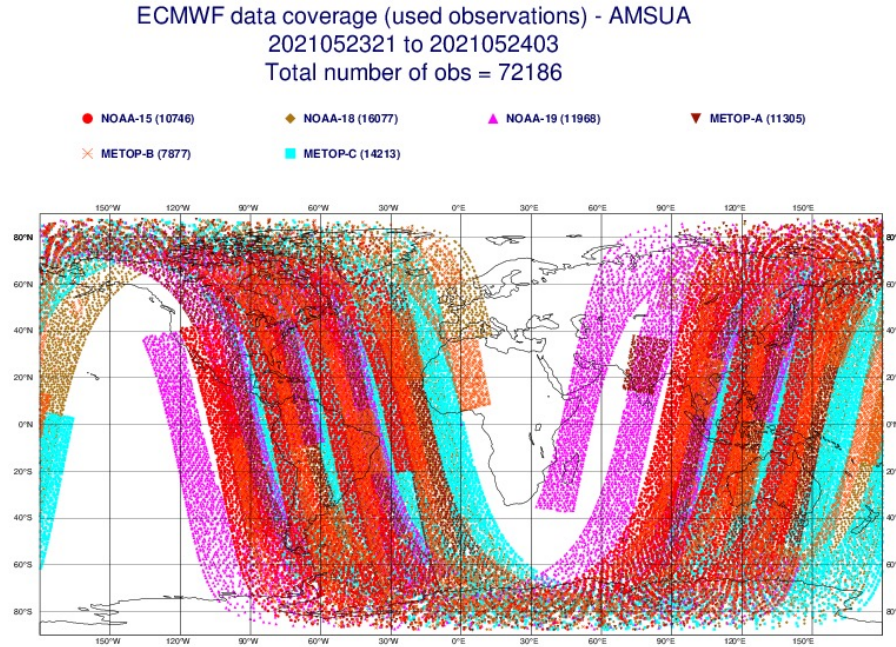
Observation data monitoring at ECMWF

- Observational data monitoring is a key component of the data assimilation system:
  - Assesses the availability and **quality of observations** by comparing them against NWP model.
  - Typically, biases and variability in ‘observation minus background’ (O-B), also known as ‘First Guess’ (FG) departures, are monitored.
  - Detects instrument and model issues that could affect quality of analysis.





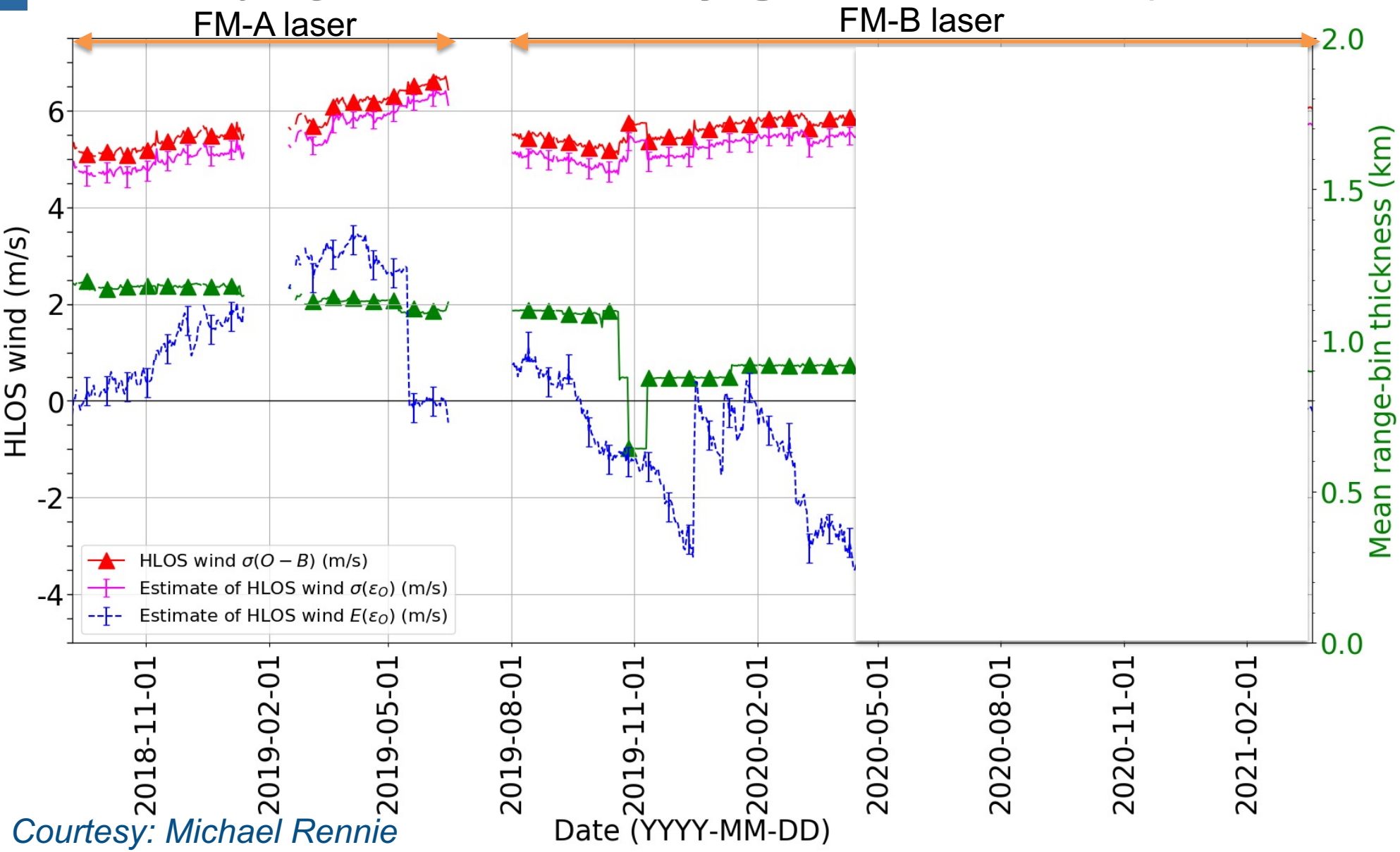




Long-term L2B HLOS wind quality monitoring using background departures (O-B statistics)

L2B Rayleigh-clear winds; **daily**, **global** data, **whole** profile

Relaxed QC: $|O-B| > 15\ m/s$ rejected



- Random error fairly stable recently; ~5.5 m/s
- Improvements in ground processing algorithms and settings helped mitigate **signal losses**

Due to radiometric performance issues the Rayleigh winds as ~twice as noisy as expected pre-launch

Courtesy: Michael Rennie

In late 2019, an explanation for the largest source of Rayleigh wind bias was found

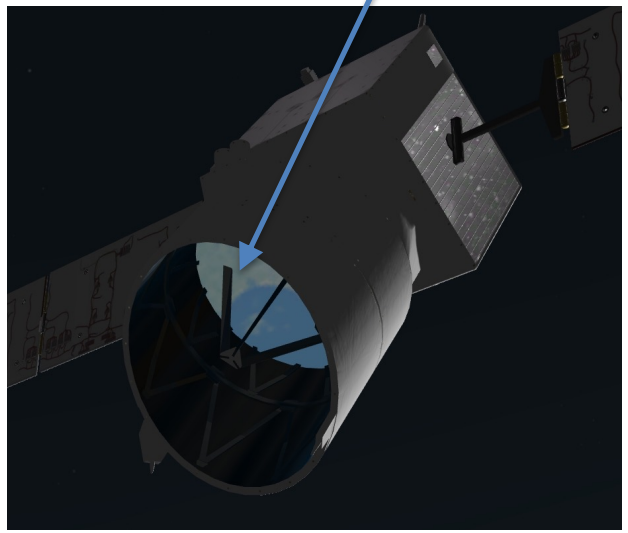
- Using **ECMWF departures** and satellite house-keeping data it was identified Rayleigh wind bias depends linearly on the telescope primary mirror's (M1) temperature readings (particularly outer minus inner gradients)

- M1 temperature varies with Earthshine (short and long-wave radiation) and onboard thermal control

- ***Physical mechanism for bias:*** temperature changes affect mirror shape and focus, causing angular changes of atmospheric path (backscattered) light upon the spectrometers
  - Spectrometer response is sensitive to frequency (Doppler shift) and to angle of incidence

- **Bias correction** trained on ECMWF departures, using M1 temperatures as predictors, was **implemented in ground processing chain on 20 April 2020**
  - Required major restructuring of the ground processing software
  - Regression updated every 12 hours with 24 hours of past data (at ECMWF) using DLR's software (multiple linear regression)
  - Regular updates required primarily to correct for a global bias drift (internal path laser pointing drift)
  - The method works very well

Primary (M1) mirror



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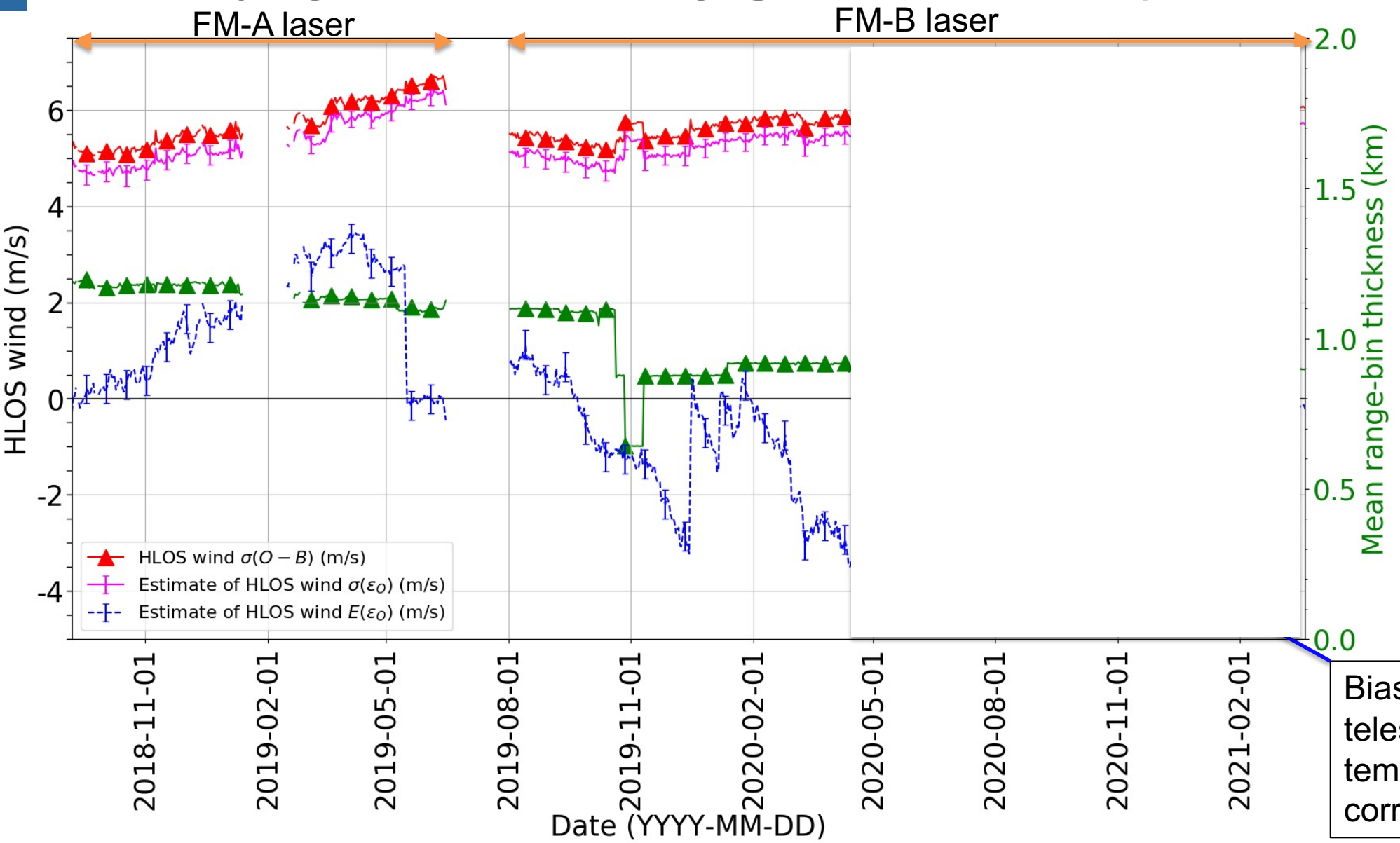

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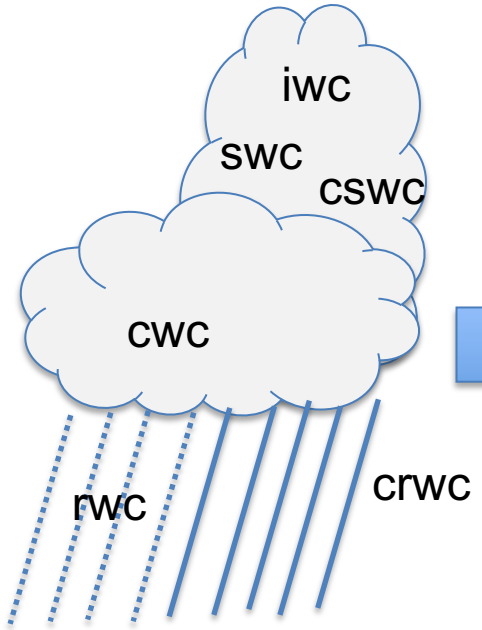
Due to radiometric performance issues the Rayleigh winds as ~twice as noisy as expected pre-launch

Bias improved due to telescope-mirror temperature dependent bias correction

Monitoring EarthCARE observations requires sophisticated operator



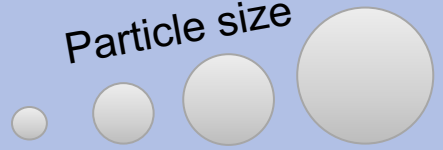
+cc, pfra

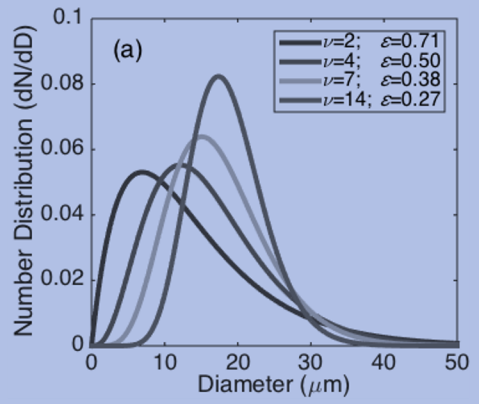
Model space

Particle habit

Scattering properties

Particle size



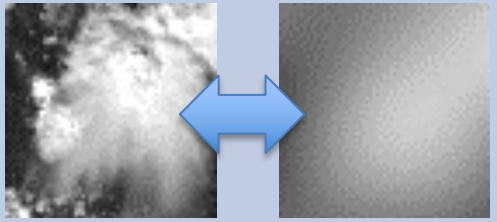


Particle size distribution

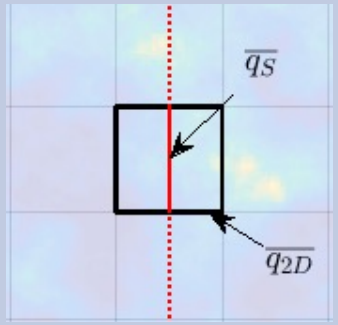
Microphysical

Scale invariant

Cloud overlap



Subgrid scale condensate variability



Representativity

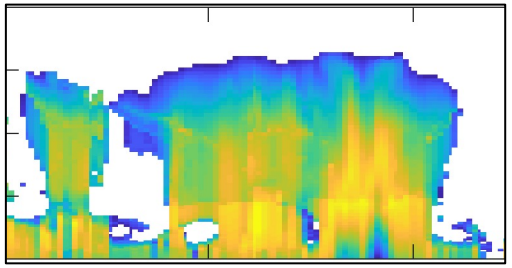
Macrophysical

Scale dependent

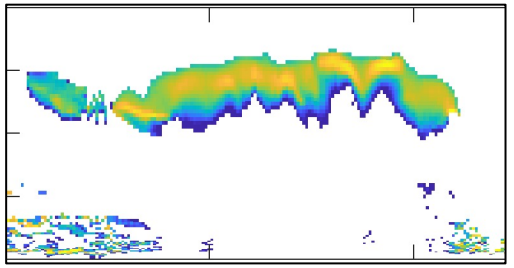
see *Fielding and Janisková, 2020*
doi:10.1002/qj.3878

Radiative transfer

Radar reflectivity

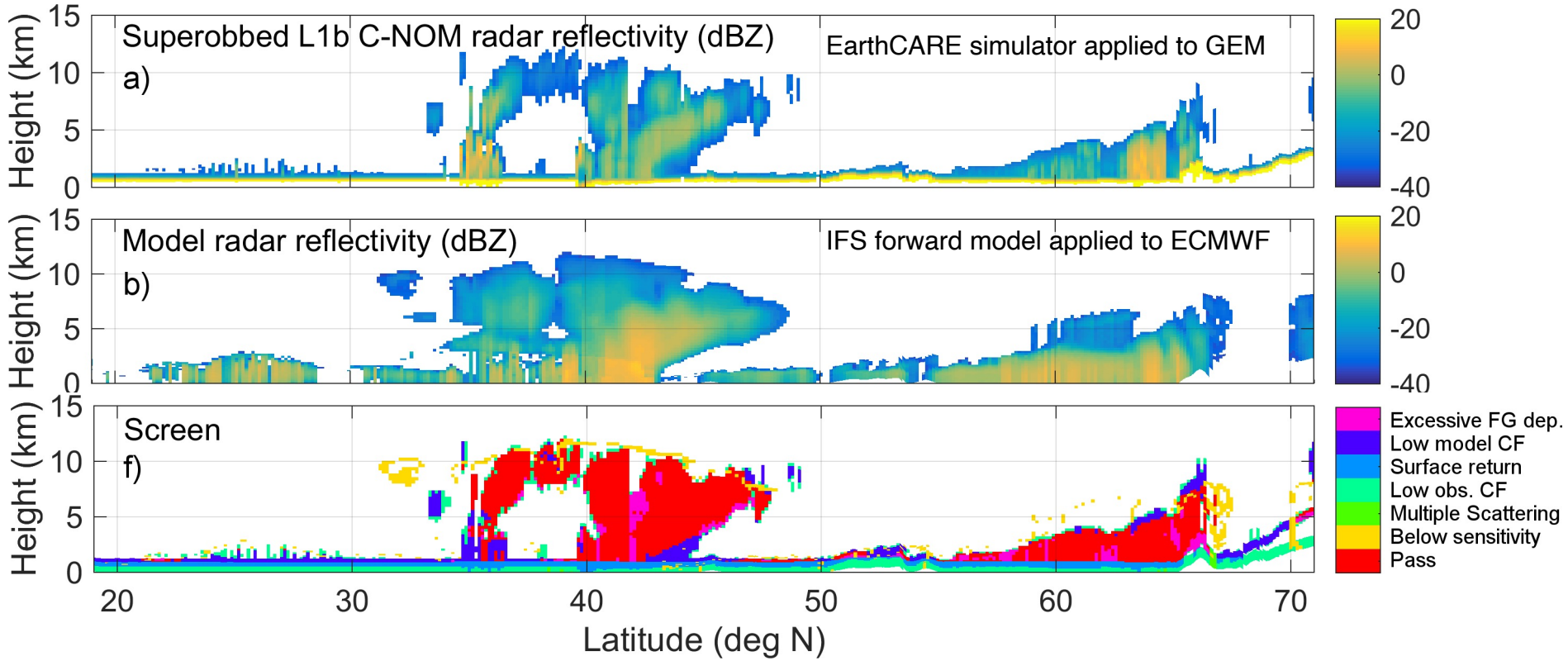


Lidar backscatter



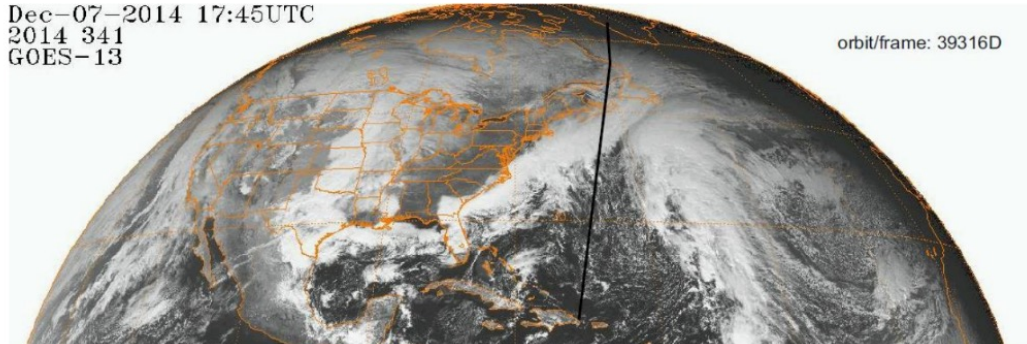
Observation space

Observation operators (and pre-processing) tested using EarthCARE test data



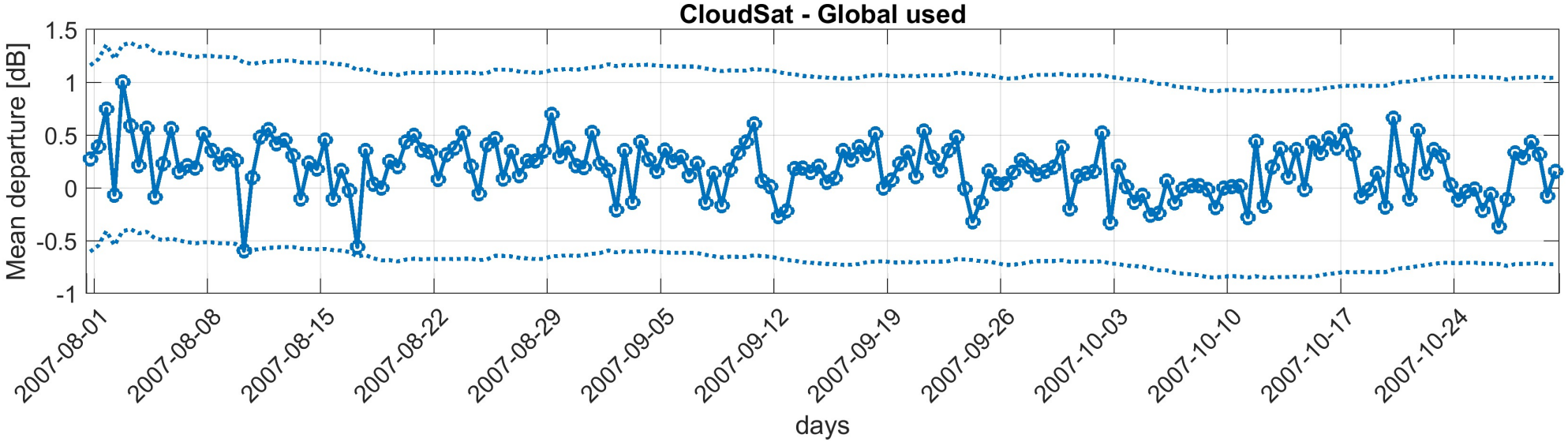
➢ Screening helps to improve quality of monitoring and assimilation

- Screening example based on C-NOM test data from ‘Halifax scene’ (courtesy of Aleksandra Tatarevic, Zhipeng Qu)
- C-NOM data was also used to test obs. Pre-processing (e.g., conversion to BUFR and ODB)



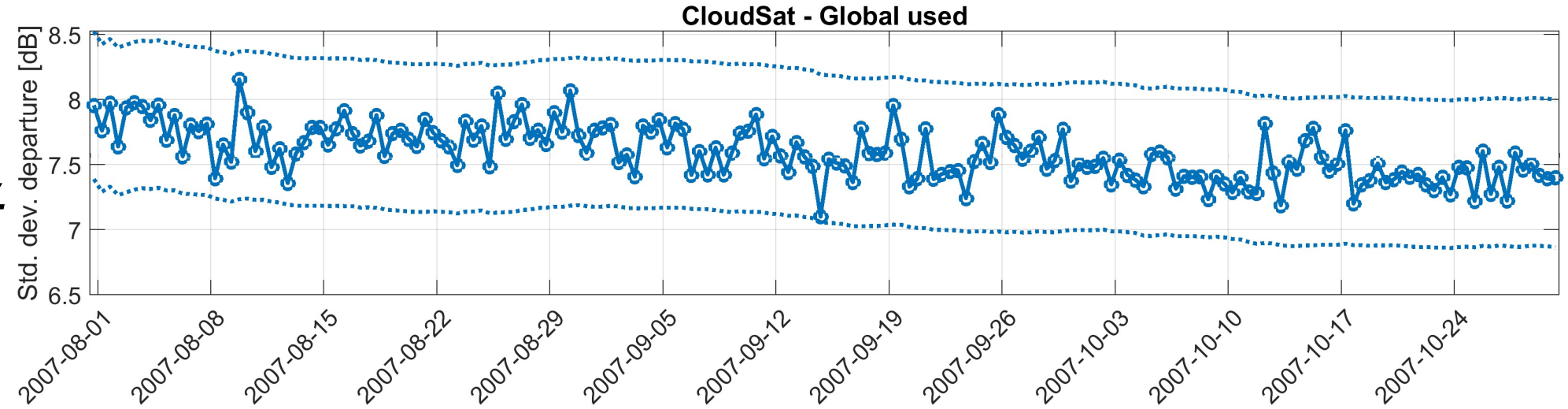
Monitoring cloud radar reflectivity from CloudSat against ECMWF model

Global mean



±3 s.d.

Global Std. dev.

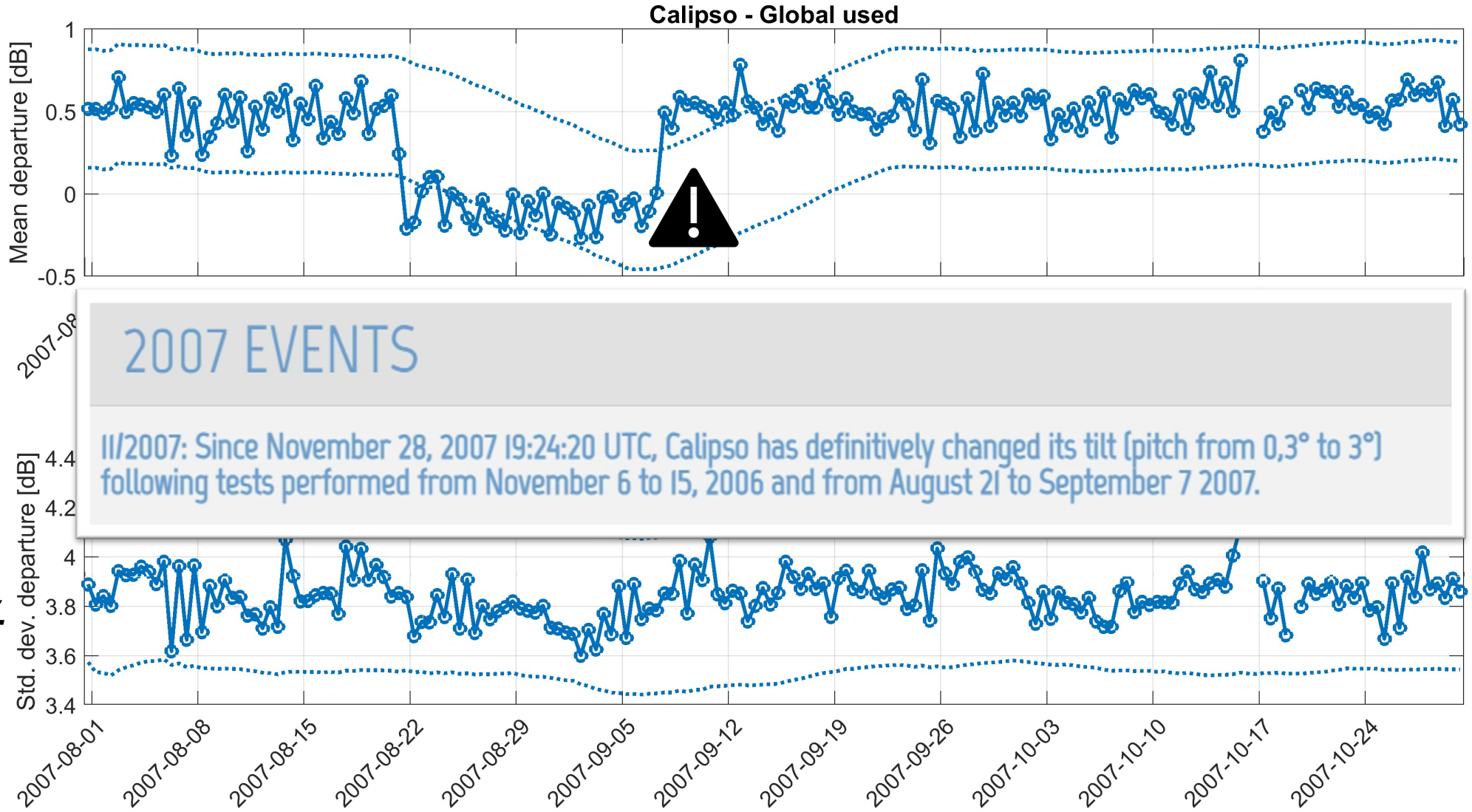


12-hour global statistics for all observations passing screening

Monitoring cloud lidar backscatter from CALIPSO against ECMWF model

Global mean

Global Std. dev.



12-hour global statistics for all observations passing screening

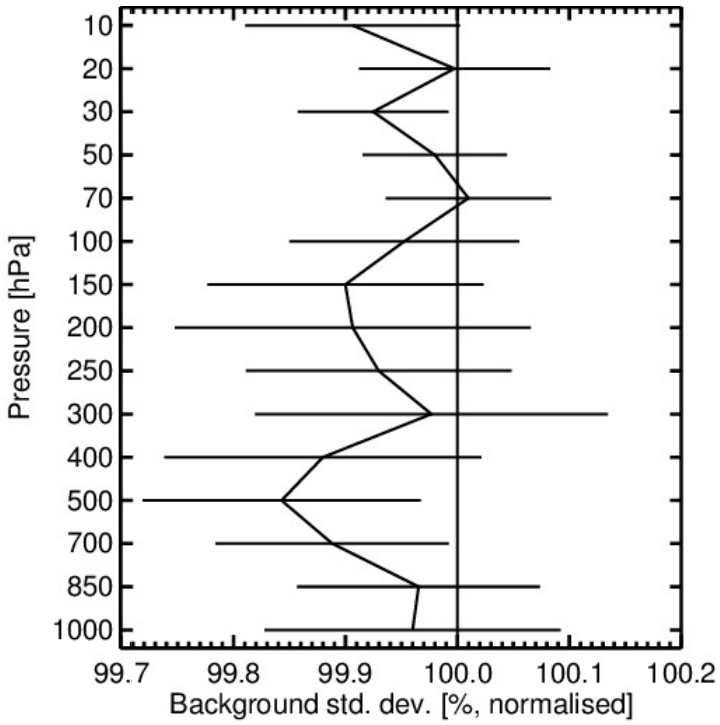
Benefits of monitoring EarthCARE observations at ECMWF

- Rapid feedback on changes of calibration or drifts
- Indications of regional variations of calibration that would be difficult to detect otherwise (e.g., ECMWF pivotal in detecting and correcting Aeolus wind biases)
- Offer a sanity check on absolute calibration

Assimilating radar and lidar observations improves NWP analysis…

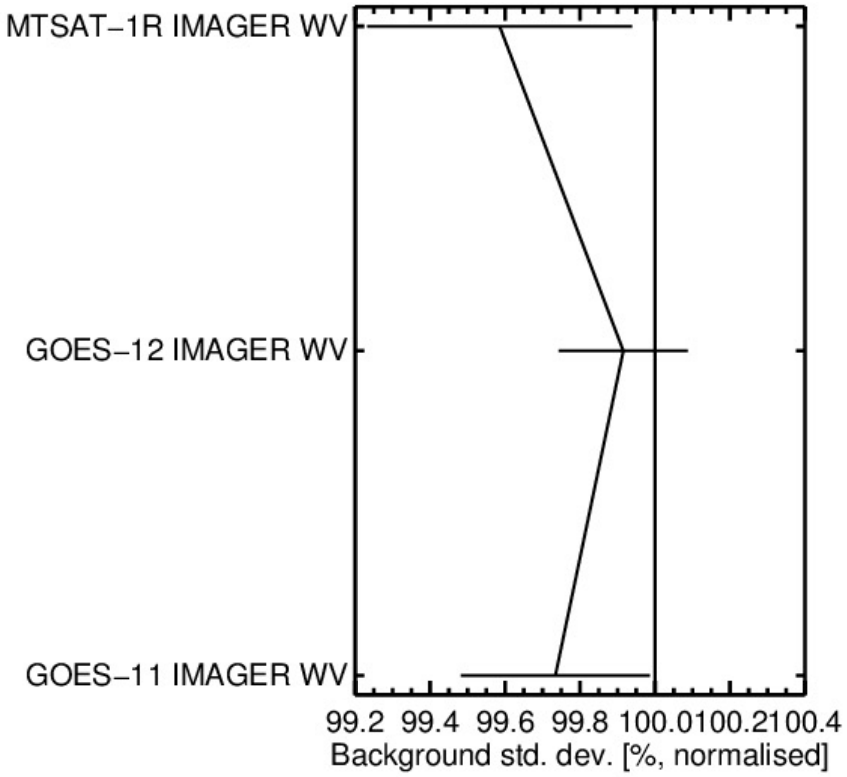
Wind

Sonde wind - Global



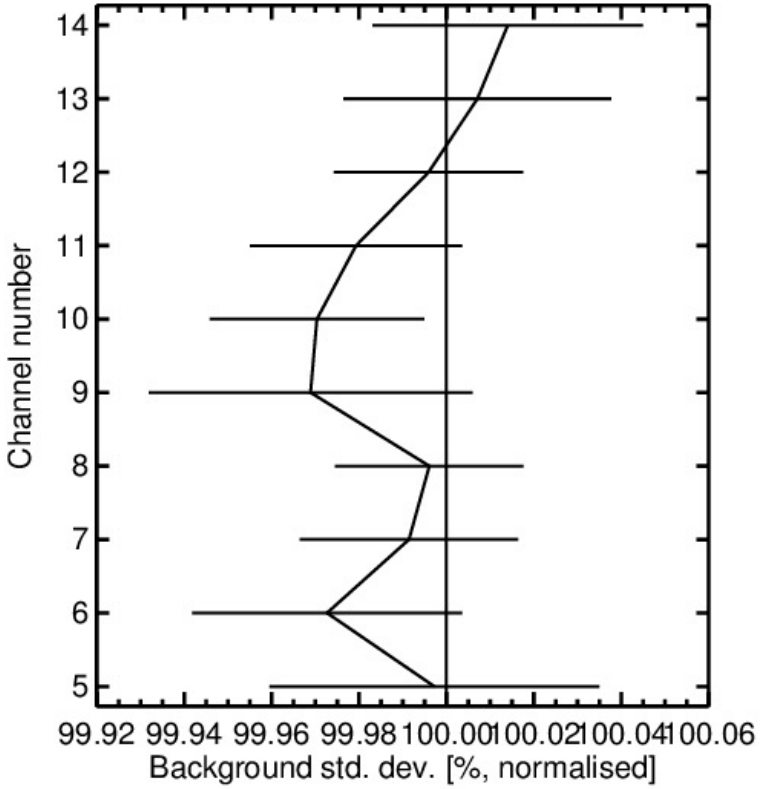
Water vapour

Geostationary IR - Global



Temperature

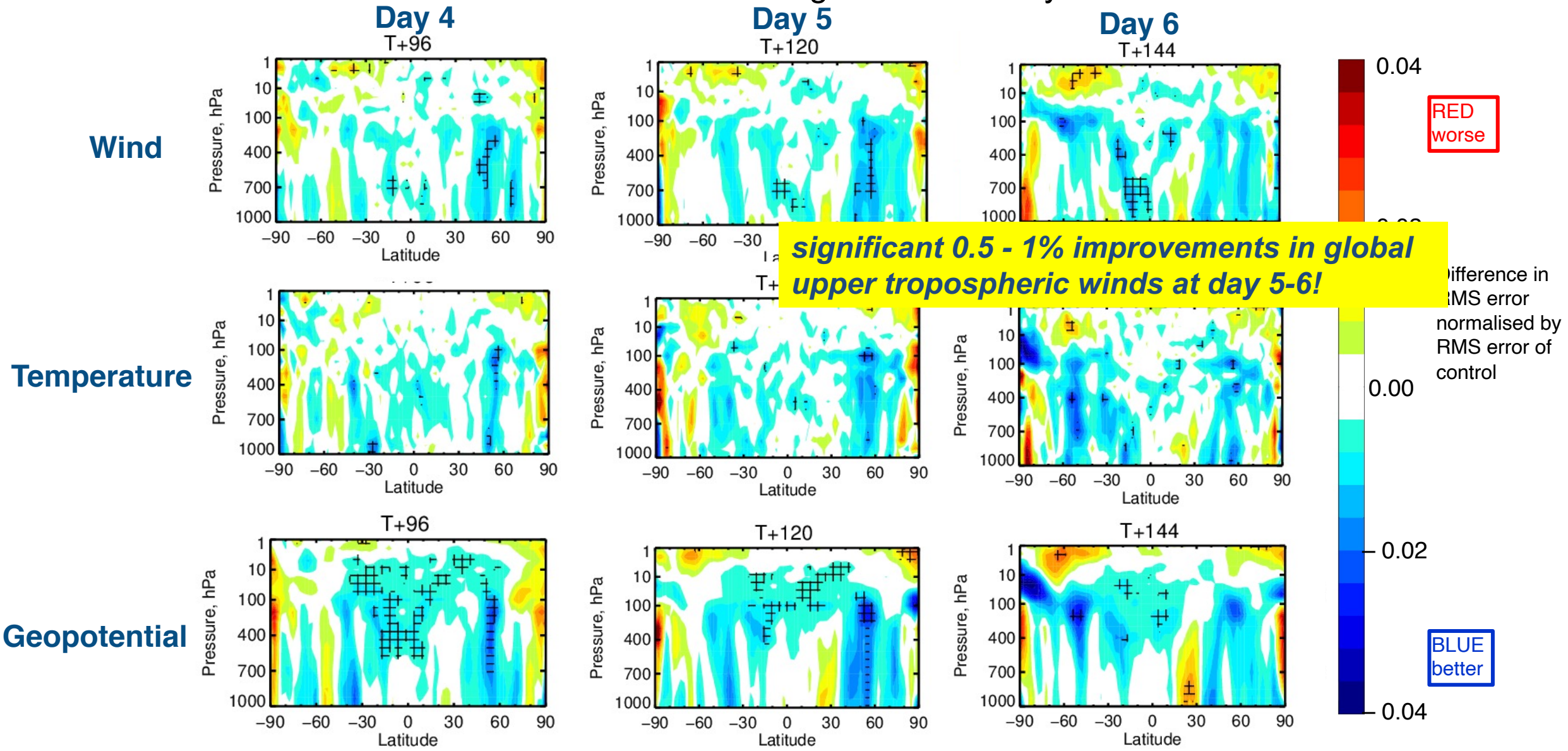
AMSUA - Global



ECMWF

OSE: 6-month (08.-10. 2007 and 02.-04. 2008) CloudSat and CALIPSO observations in addition to regularly assimilated observations vs control

Verification of forecast against own analysis

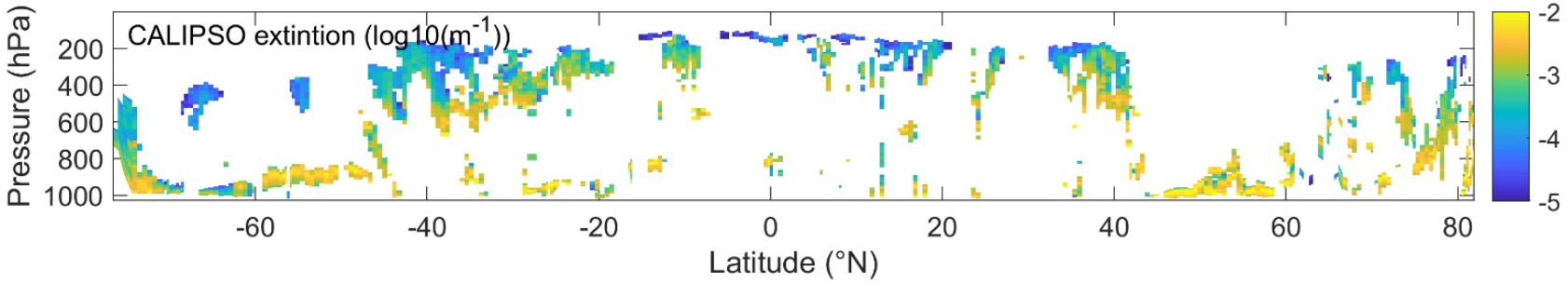


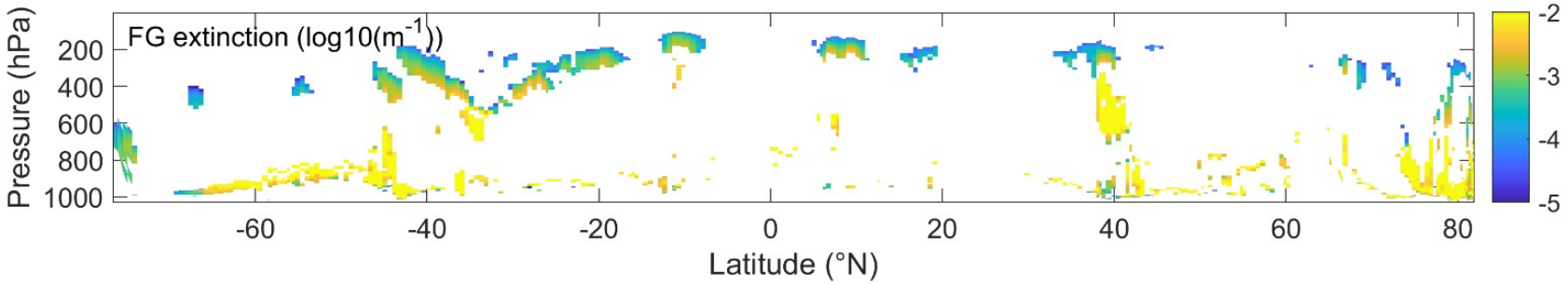
significant 0.5 - 1% improvements in global upper tropospheric winds at day 5-6!

ECMWF

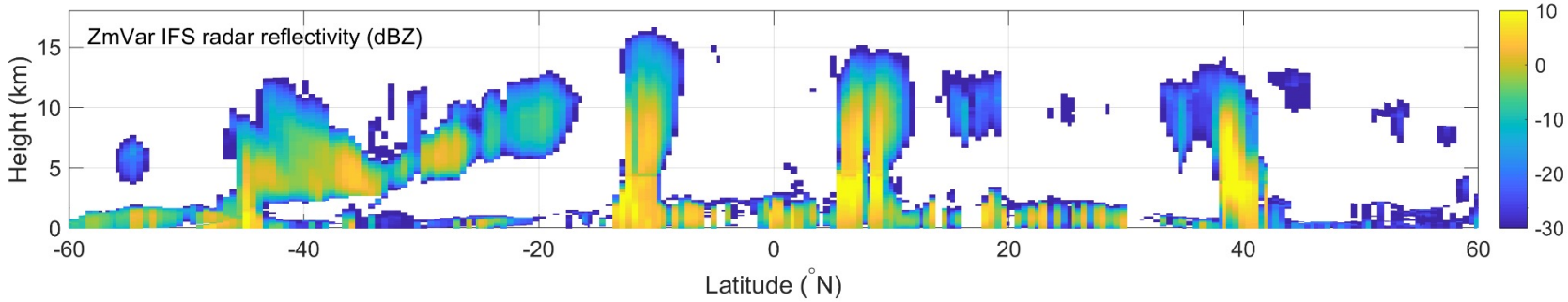
…leading to improvements in medium-range weather forecasts

Preparations for the monitoring of additional EarthCARE observations are underway

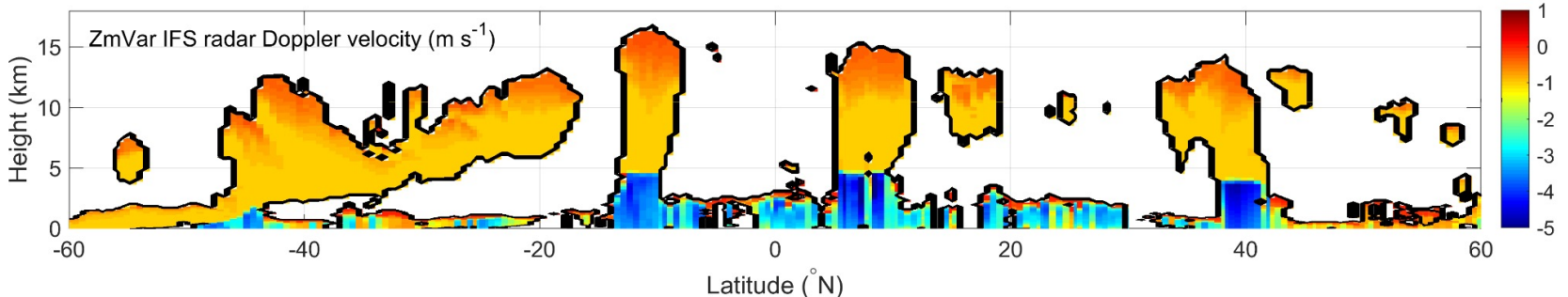




L2 HSRL products



Radar Doppler velocity



ECMWF

Summary

- Monitoring observations against ECMWF forecast data is a tried and tested method for quality control of satellite data.
- ECMWF is preparing for the monitoring of EarthCARE observations as part of the joint ESA-ECMWF project ‘PEARL Cloud’.
- Radar reflectivity and lidar backscatter operators are mature: individual HSRL channels, extinction, Doppler velocity, MSI radiances are under development.
- Assimilation of cloud radar reflectivity and lidar backscatter shows huge promise for improving model cloud analysis AND subsequent forecast.