Near real-time validation of EarthCARE observations through monitoring within a data assimilation system

Mark Fielding
Marta Janisková

ECMWF

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ECMWF
EUROPEAN CENTRE FOR MEDIUM RANGE WEATHER FORECASTS

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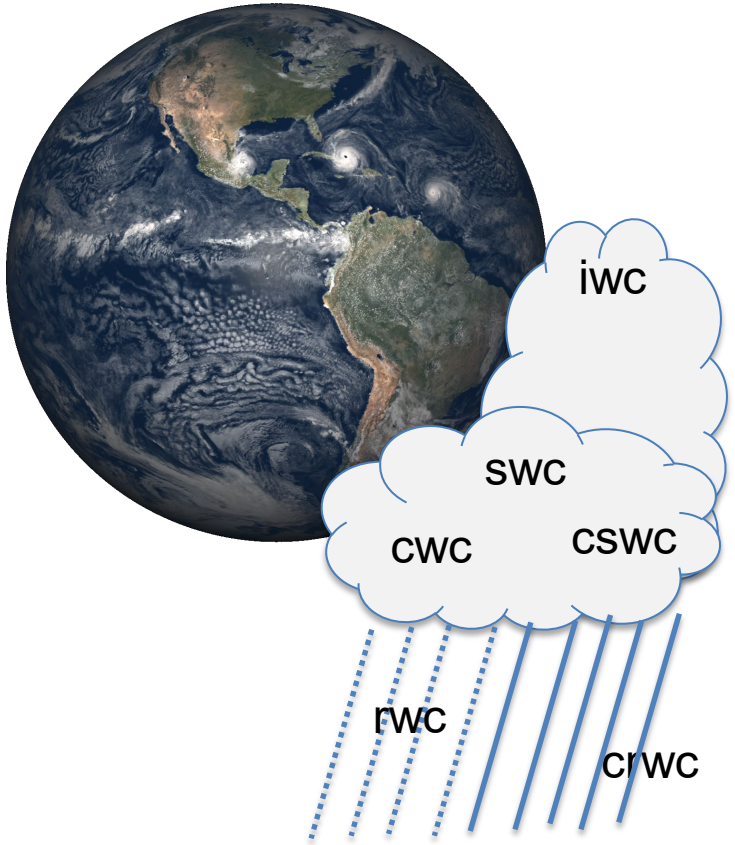
Towards a suite of observation operators for EarthCARE within the IFS

ECMWF IFS (Integrated Forecast System) model cloud fields



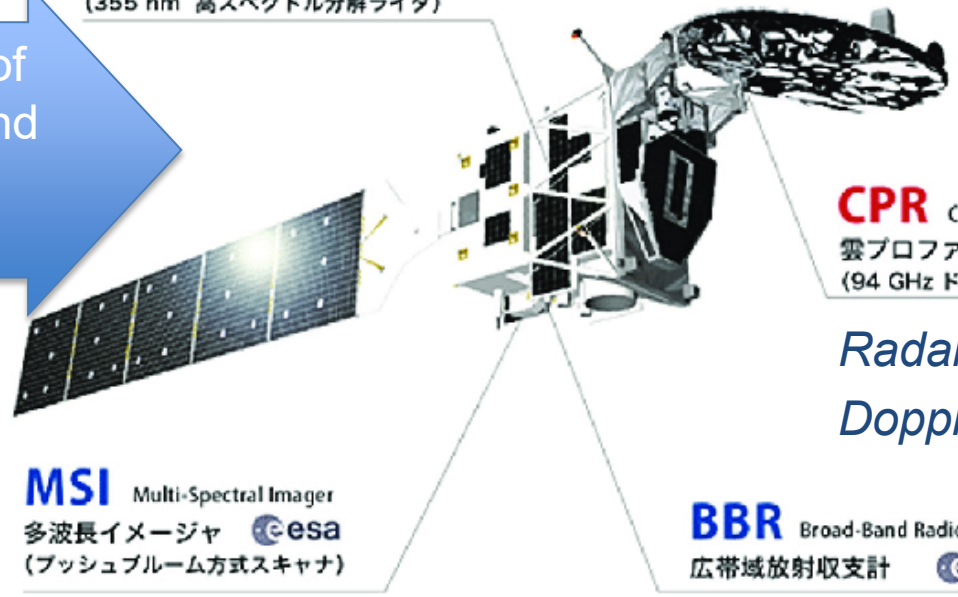
Consistent set of Microphysical and radiative assumptions

Mie backscatter

Rayleigh backscatter → *ZmVar (Di Michele et al., 2012; Fielding and Janisková, 2020)*

Mie extinction

EarthCARE



Radar reflectivity

Doppler velocity

Visible and NIR radiances

Broadband fluxes

MFASIS (Sheck et al., 2016 JSQRT)

FLOTSAM (Hogan, in prep.)

ecRad (Hogan and Bozzo, 2017)

Observation data monitoring is a key component of data assimilation

All observations that are assimilated at ECMWF to produce the model initial conditions also enter quality data monitoring system:

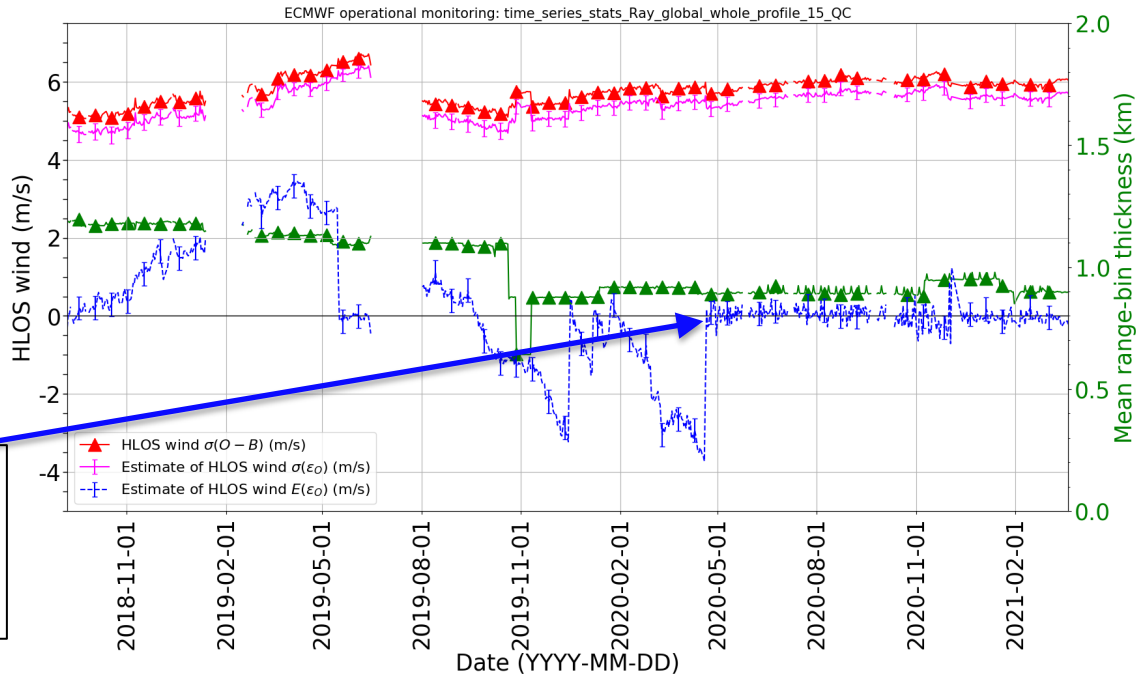
- Assesses the availability and **quality of observations** by comparing them against NWP model in near real-time.
- Uses in-house instrument simulators to monitor biases and variability within 12-hour data assimilation.
- **Rapidly detects instrument issues** that could affect model analysis.

Thanks: Michael Rennie

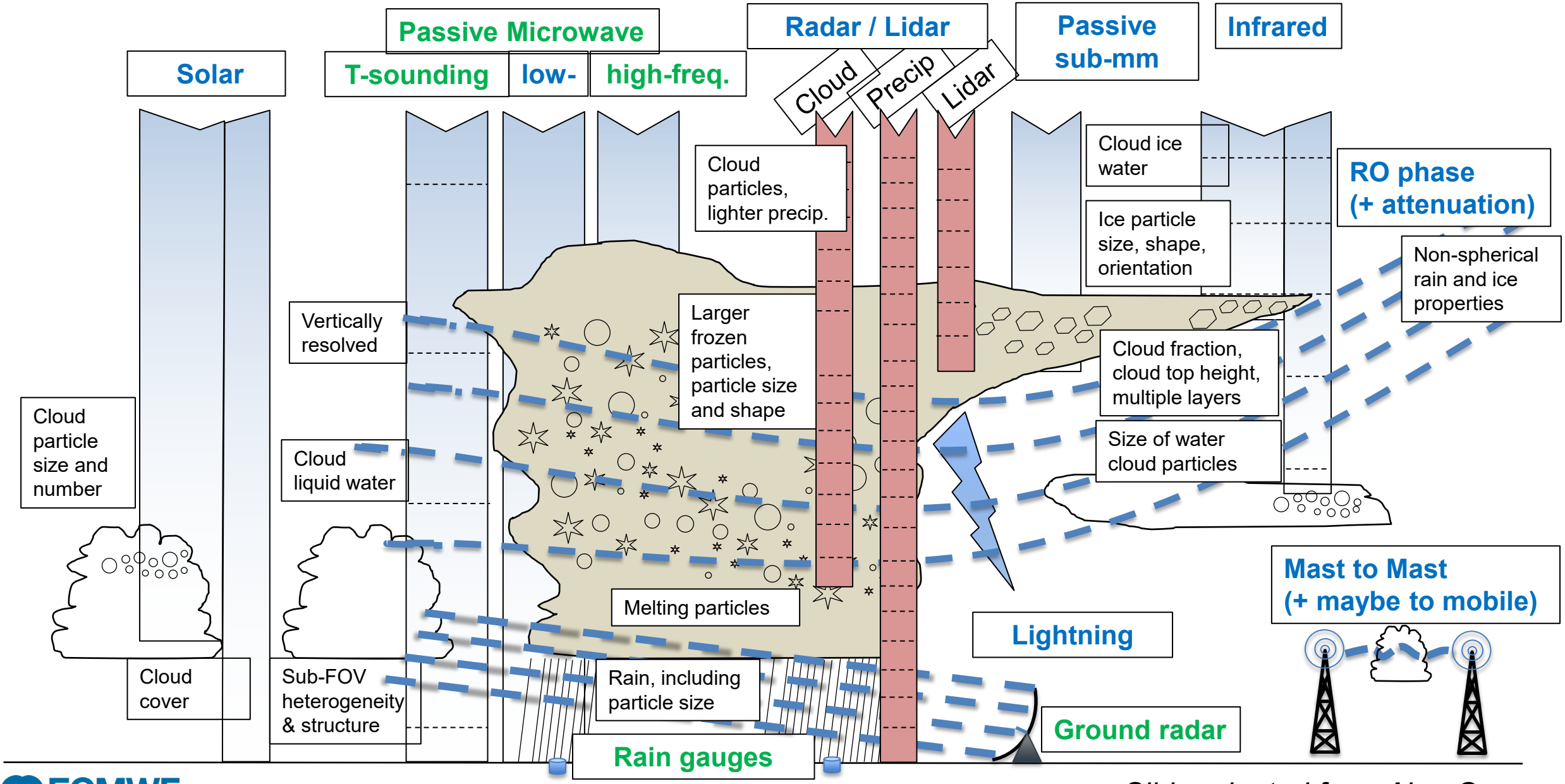
Example: Long-term Aeolus L2B HLOS wind quality monitoring

- Monitoring and correction of Aeolus horizontal line of sight (HLOS) winds against ECMWF model was pivotal to mission success!

Degradations in HLOS winds improved due to telescope-mirror temperature dependent bias correction.



Cloud and precipitation sensitive satellite observations: now and near future

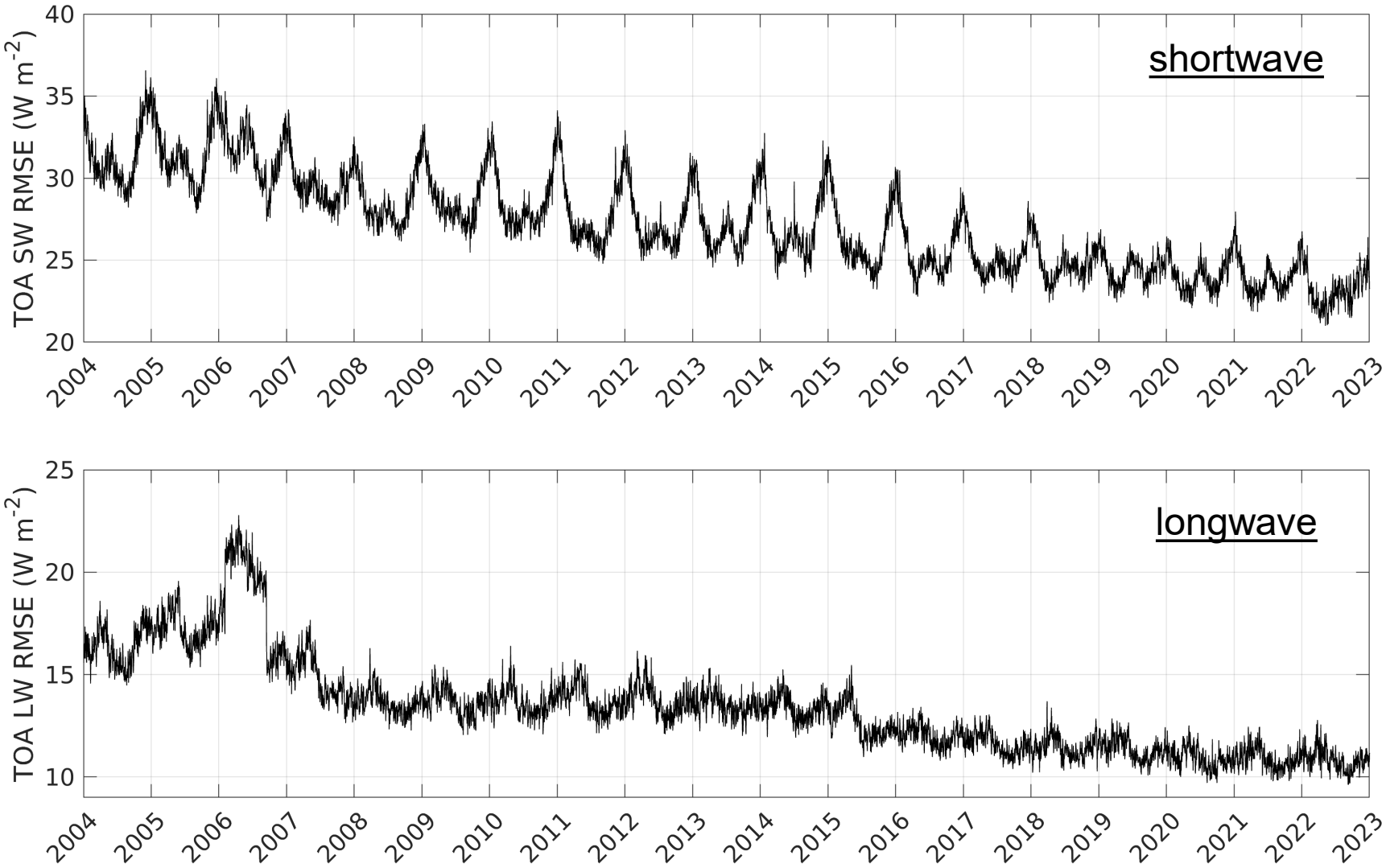


Slide adapted from Alan Geer

Representation of clouds in model is getting better and better!

RMSE in 1x1 deg daily mean

comparison of day 1 forecasts with CERES SYN 1 degree daily mean TOA fluxes



Statistical basis of monitoring

- Monitoring observations against NWP analyses allows faster detection of instrument issues by removing day-to-day variability from observations.

Observation only

Profiling sensor observation

Systematic error

$$y_o = Y_t + \varepsilon_0,$$

'True' global distribution of clouds

$$\varepsilon_o = \overline{y_o} - \overline{y_t}.$$

Variability in clouds

$$\Delta y_o = \Delta \varepsilon_o = \frac{\sigma_0}{\sqrt{n}},$$

Standard error in mean

Observation minus model

$$y_o - y_b = Y_o - Y_b + \varepsilon_o.$$

simulated profiling observation

Variability in simulated clouds

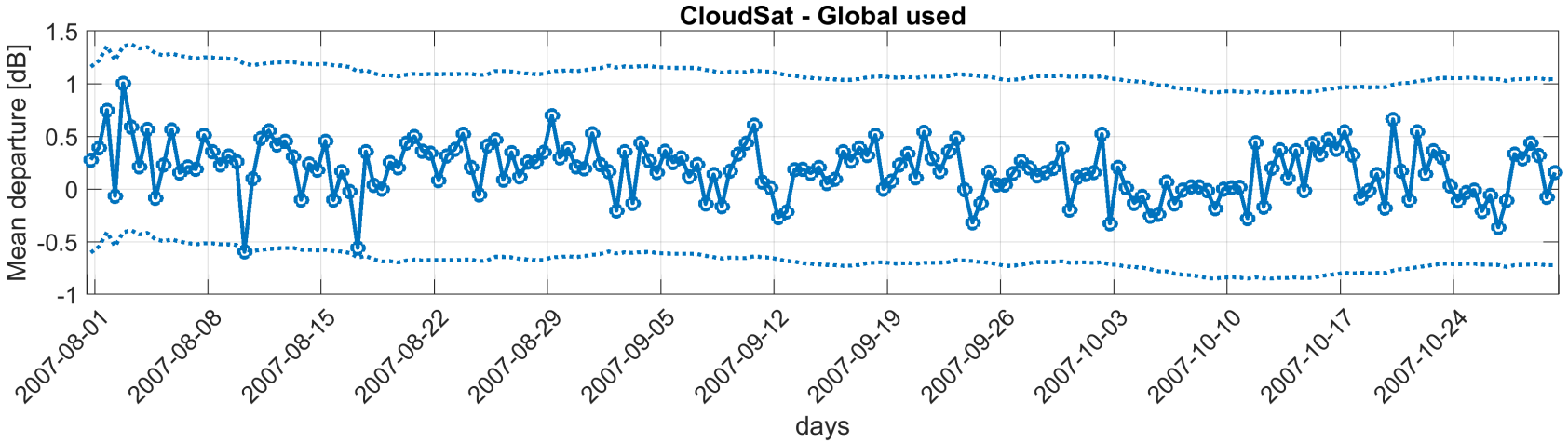
$$\Delta \varepsilon_{o-b} = \sqrt{\frac{\sigma_o^2 + \sigma_b^2 - 2\rho\sigma_o\sigma_b}{n}},$$

Correlation between observations and simulations are key to successful monitoring

Example of monitoring observations from CloudSat against ECMWF model

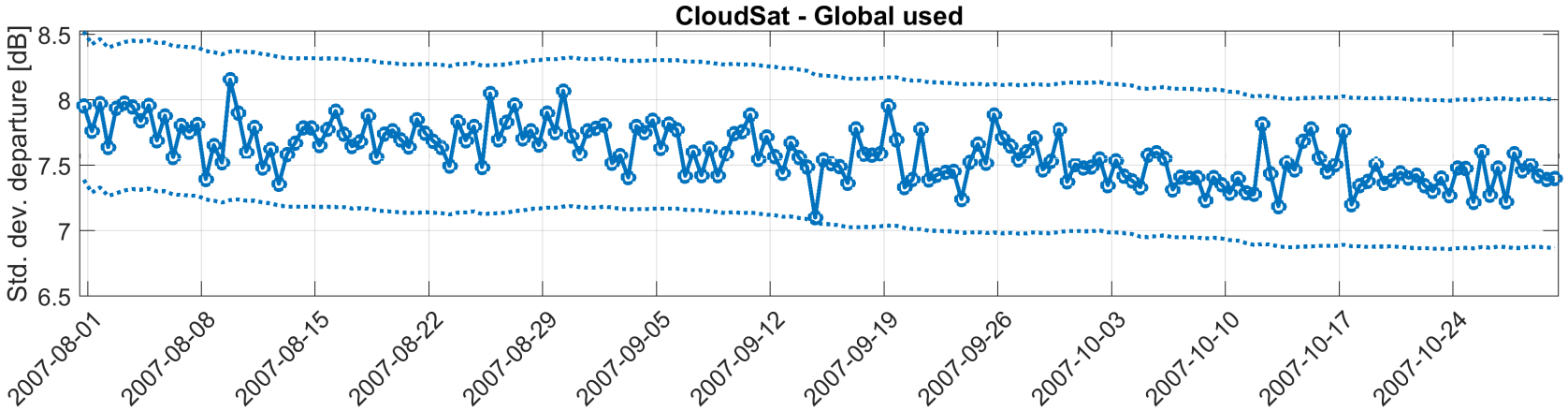
- Small changes in calibration can be detected because of low variability in global mean, e.g., 1 dB drift in radar reflectivity would trigger ‘alarm’ within days.

Global 12 h mean bias



±3 s.d.

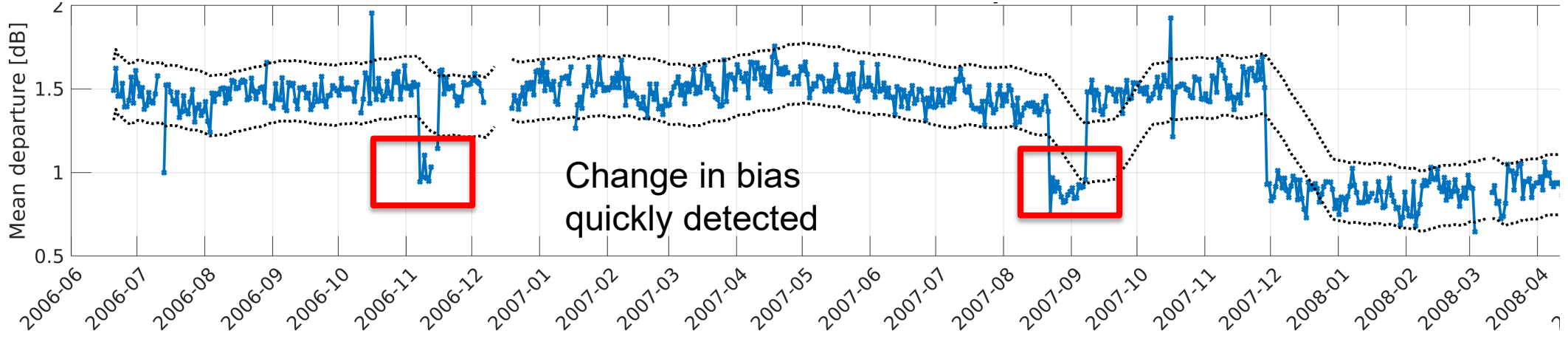
Global 12 h std. dev.



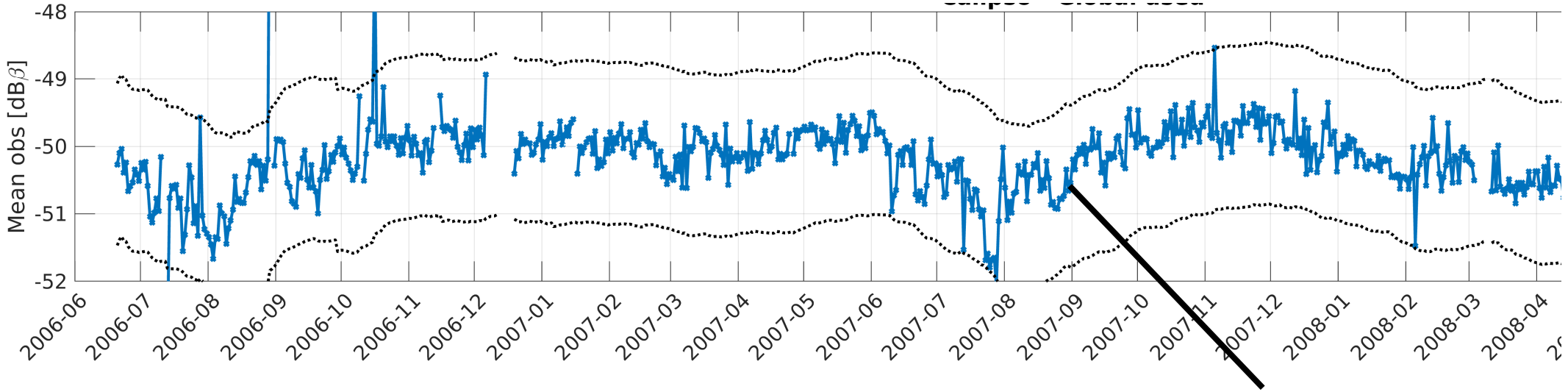
Statistics can be generated for many other indicators based on model or satellite

Monitoring detects change in CALIPSO lidar tilting angle immediately

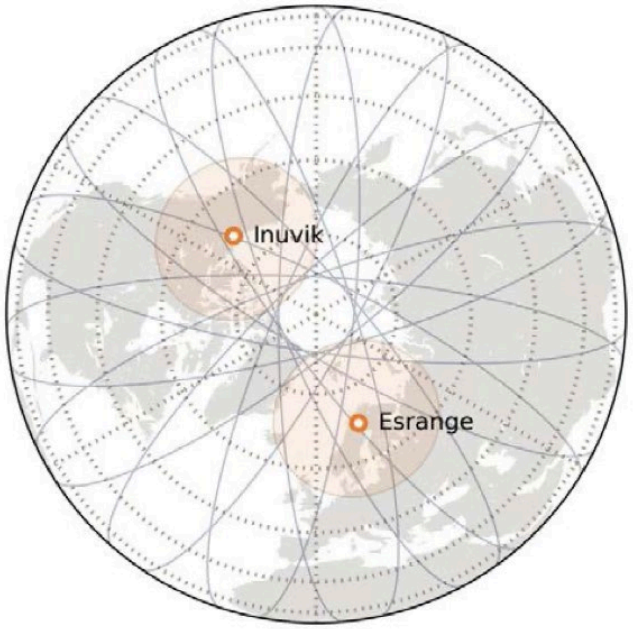
Global 12 h mean bias



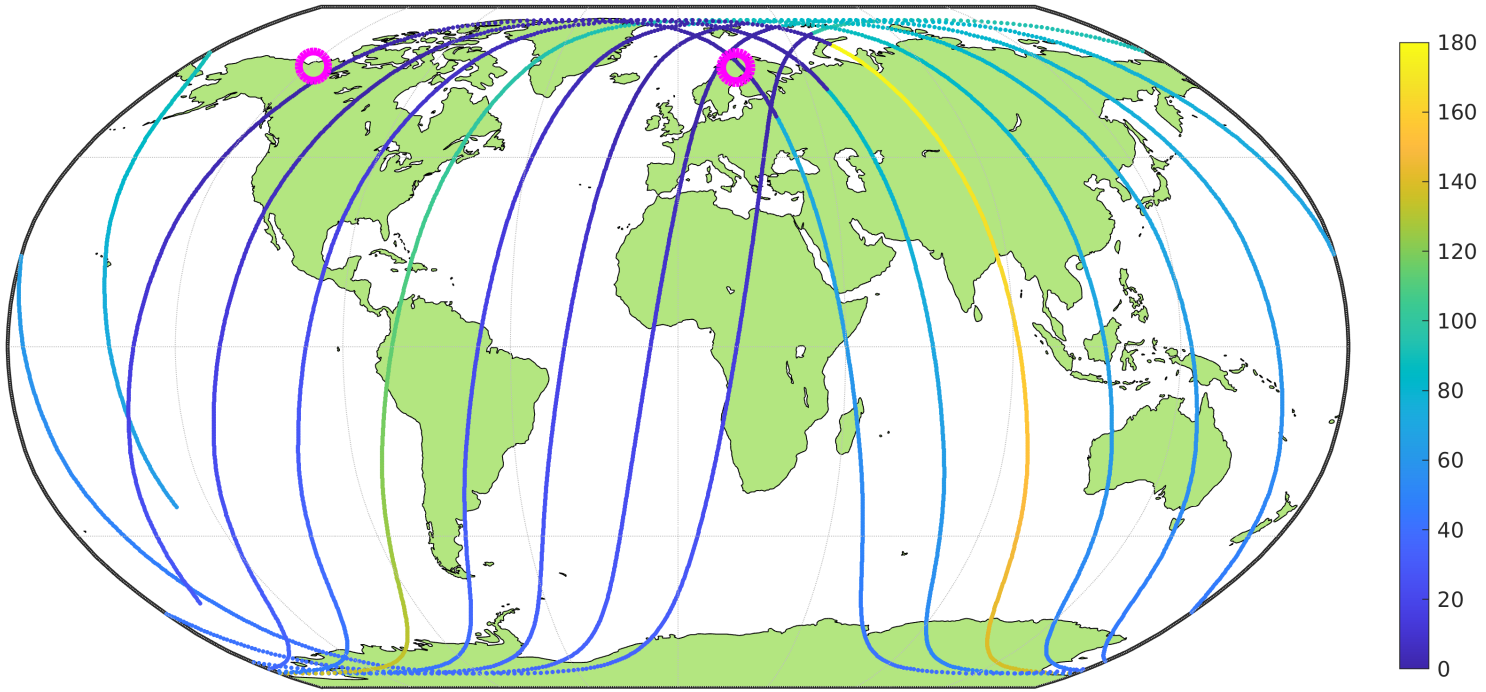
Global 12 h mean obs



Investigation into tolerance for delays

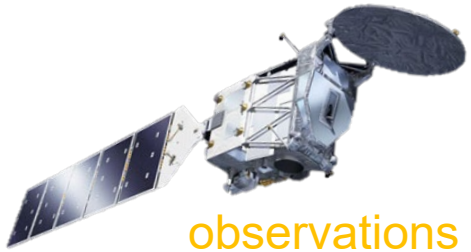


- EarthCARE data will be downlinked to two stations, and, with fast ground segment processing, the data will be available in NRT.
- Using simulated EarthCARE orbit data, we can estimate the expected data latency for a given period.



Example of data latency (minutes) for profiles in a 12-hour window

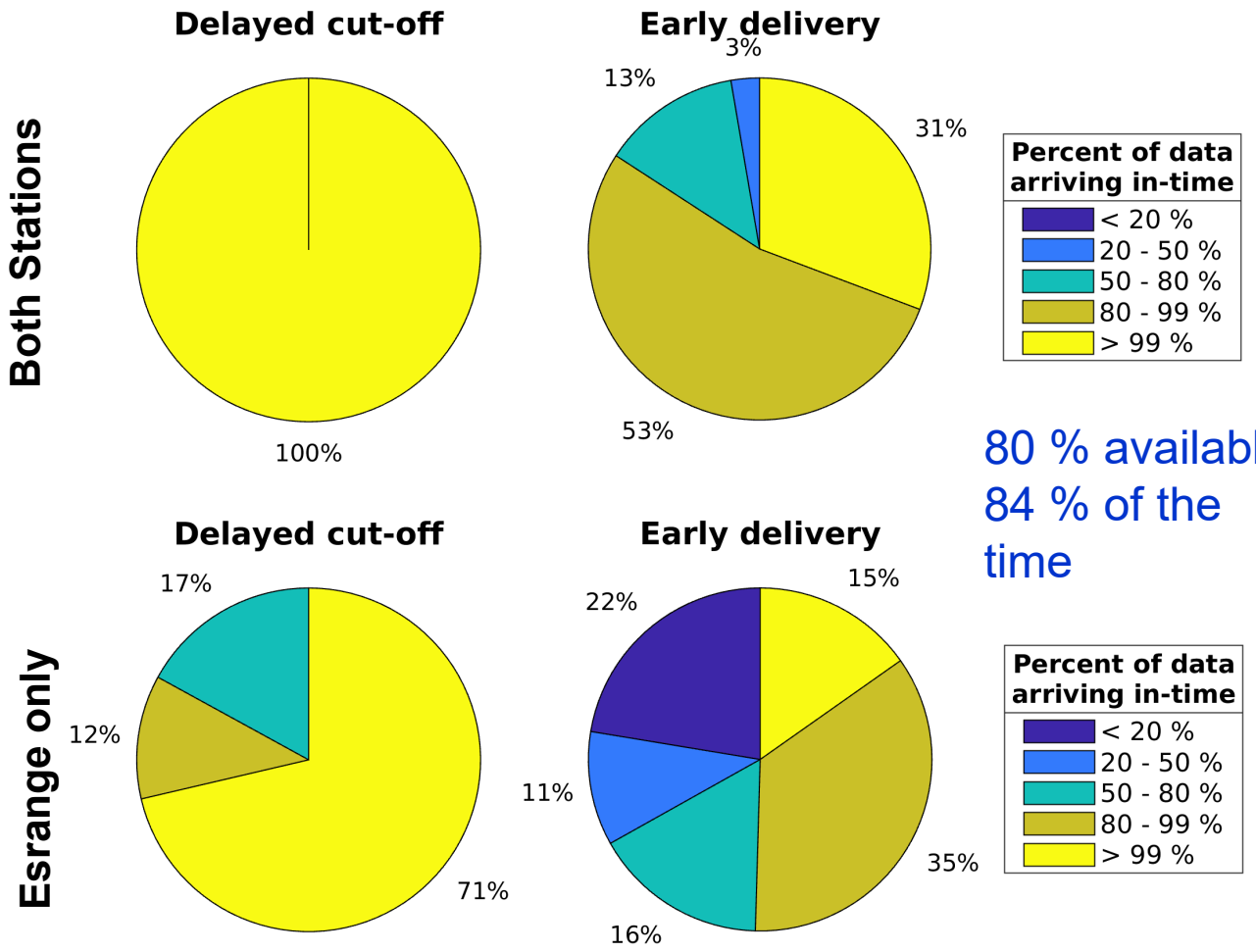
ECMWF data assimilation cut-off times



Cut-off times for 00Z forecast:
0145 UTC for delayed cut-off
0400 UTC for early delivery
-> Forecast dissemination ~ 0800UTC

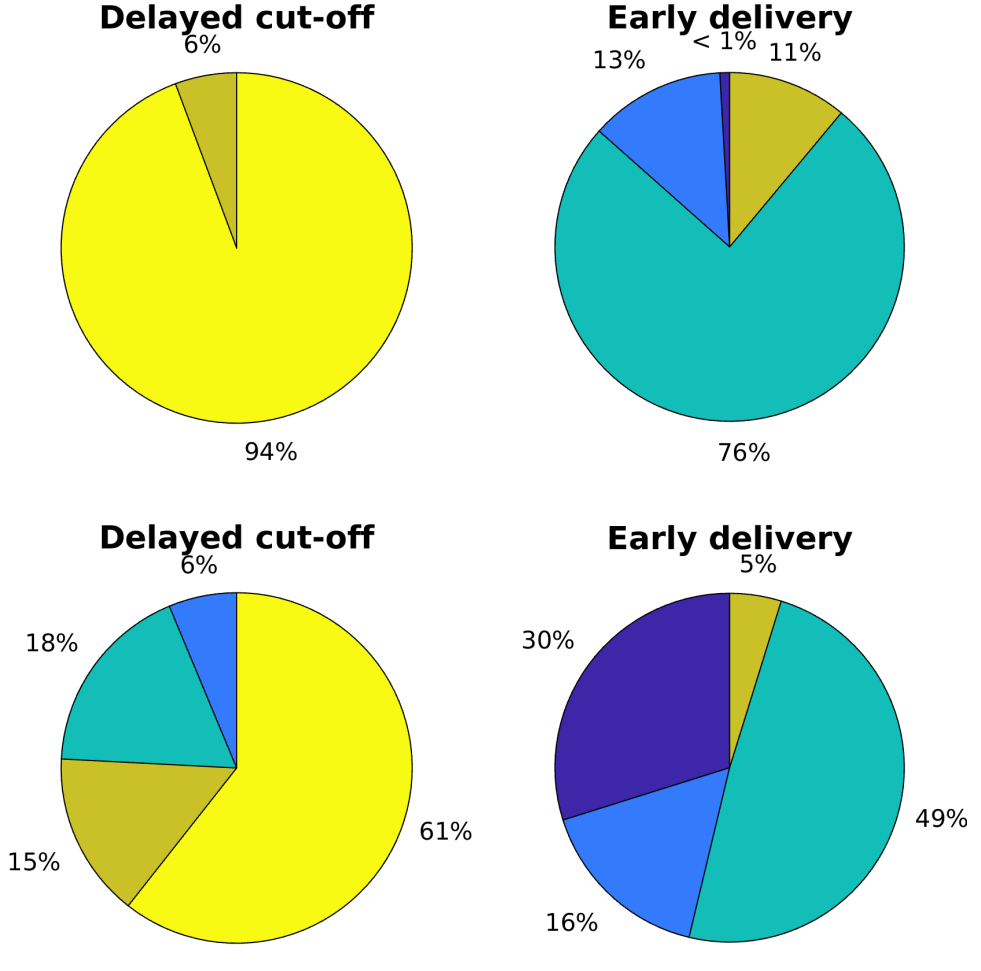
Change of data missing cut-off times

- Including 30-minute data processing time.



80 % available
84 % of the time

- Including 120-minute data processing time.

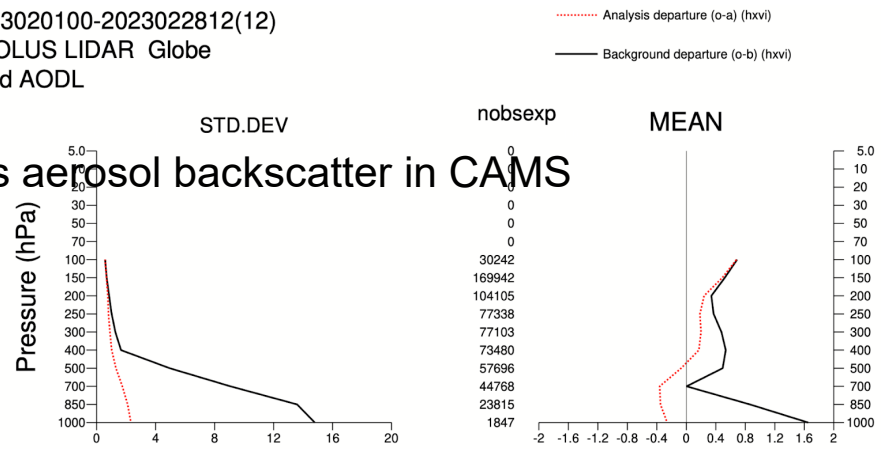


Two downlink stations enables good tolerance to delays in processing chain.

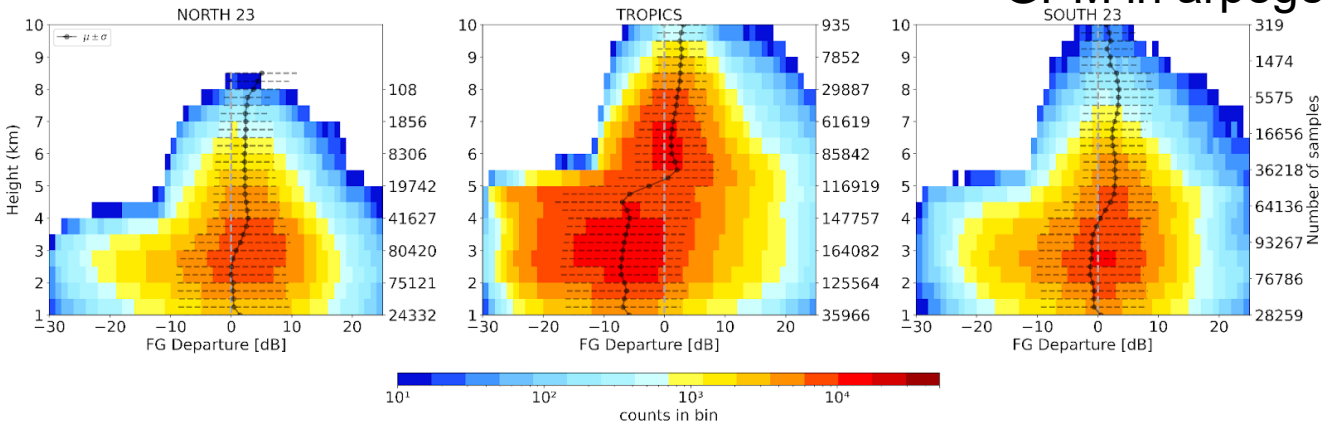
Highlights from Chapter 6: Near-real time validation through data assimilation

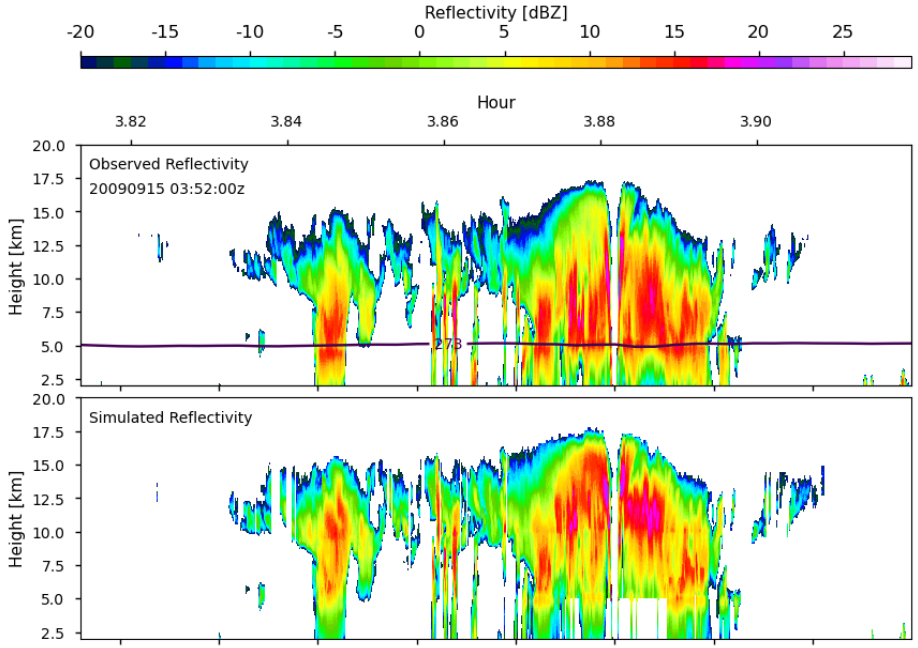
Mark Fielding, Marta Janisková, Angela Benedetti, Will McLean, Michael Rennie – ECMWF, Mary Borderies, Rohit Mangla - Météo-France
Jerónimo Escribano - Barcelona Supercomputing Centre, Yasutaka Ikuta – JMA, Isaac Moradi - NASA, Derek Posselt - JPL-NASA, Jianglong Zhang - UND

Aeolus aerosol backscatter in CAMS

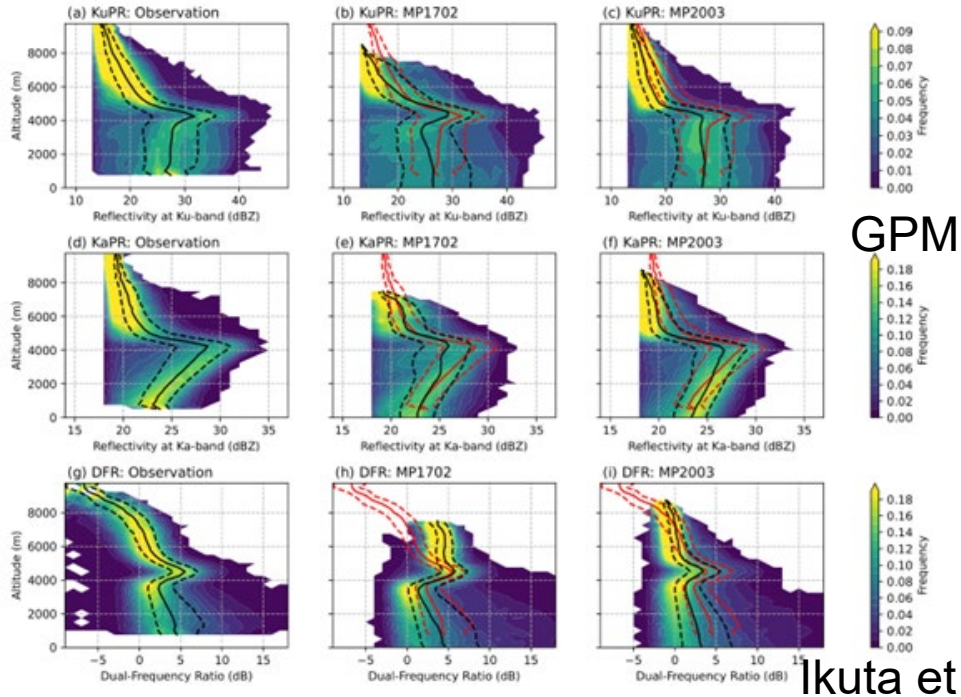


GPM in arpege





GPM at JMA



Community Radiative Transfer Model (CRTM)

Ikuta et al. (2021)

Summary

- Monitoring observations against NWP data is a powerful tool for detecting instrument issues,
- A suite of observation operators for simulating EarthCARE within IFS is now available.
- ECMWF is finalising preparations for near real-time validation of CPR radar reflectivity and ATLID channels during commissioning phase.
- Recent developments in RTTOV and CRTM should allow more operational centres to simulate EarthCARE data.