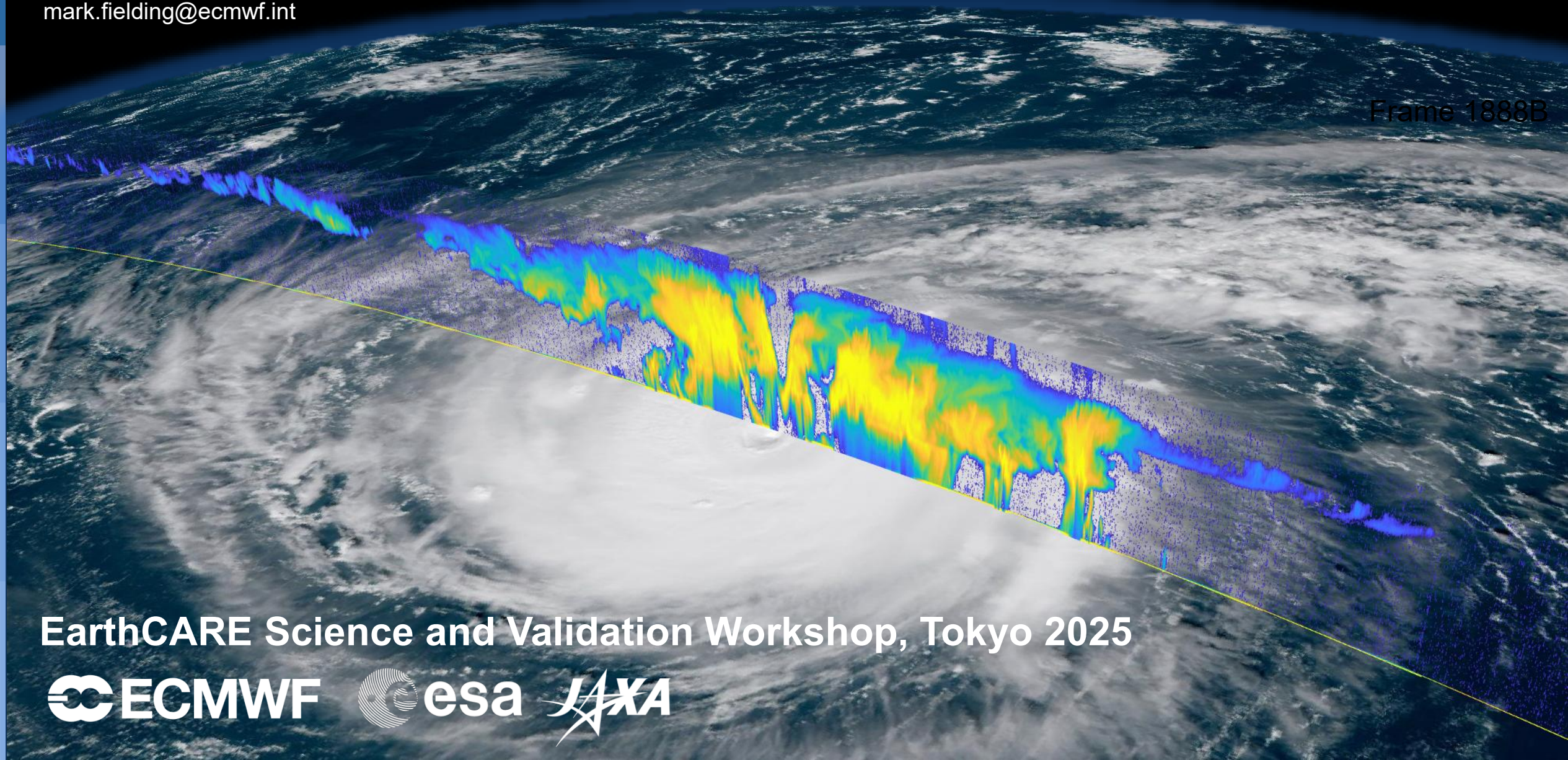
Towards operational assimilation of EarthCARE at ECMWF

Mark Fielding, Kamil Mroz, Michael Rennie, Marijana Crepulja, Mohamed Dahoui

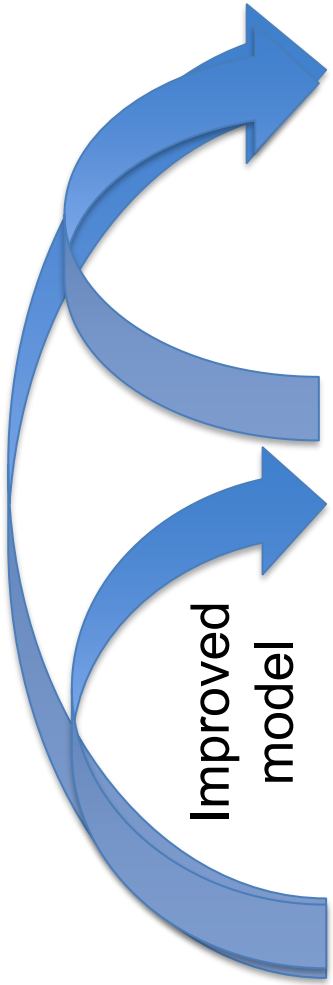
mark.fielding@ecmwf.int



EarthCARE Science and Validation Workshop, Tokyo 2025

ECMWF esa JAXA

Why assimilate EarthCARE observations into global NWP?



1. Near-real time observation quality monitoring

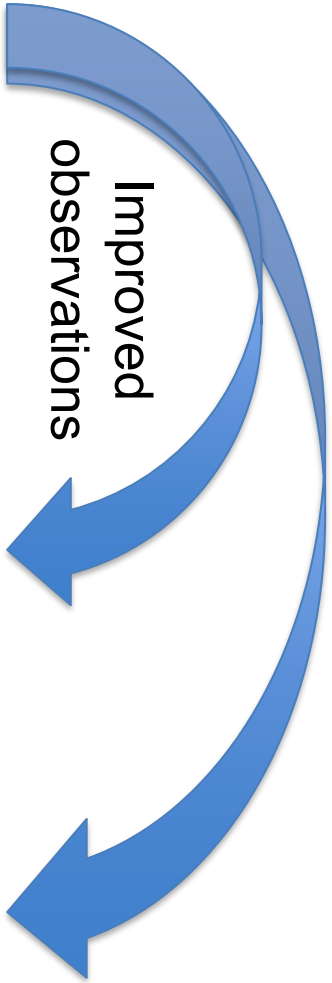
- Quickly diagnose instrument issues
- Assess long-term instrument stability

2. Improved analysis and subsequent forecast

- Profiling observations provide additional information
- Cloudy areas are often meteorologically sensitive areas (reduce error growth)

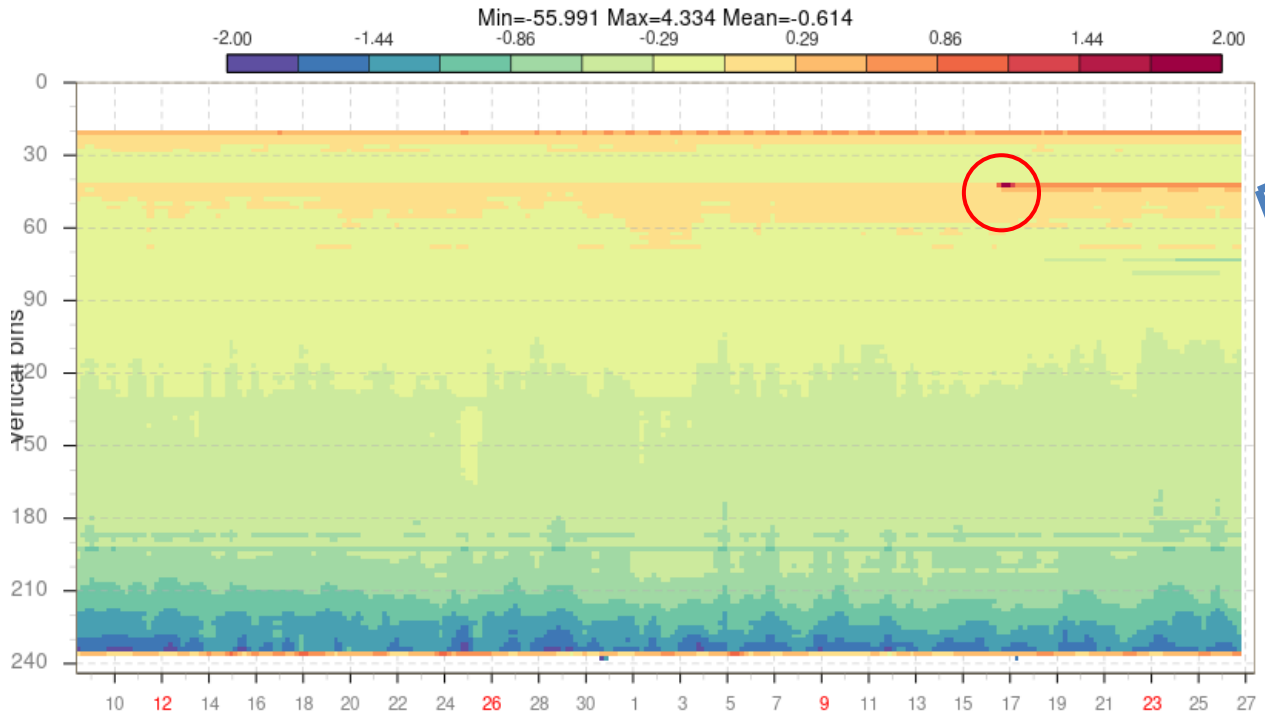
3. Forecast model evaluation and improvement

- Targets regime-dependent systematic errors
- Help constrain higher resolution models – convective storms/high impact weather



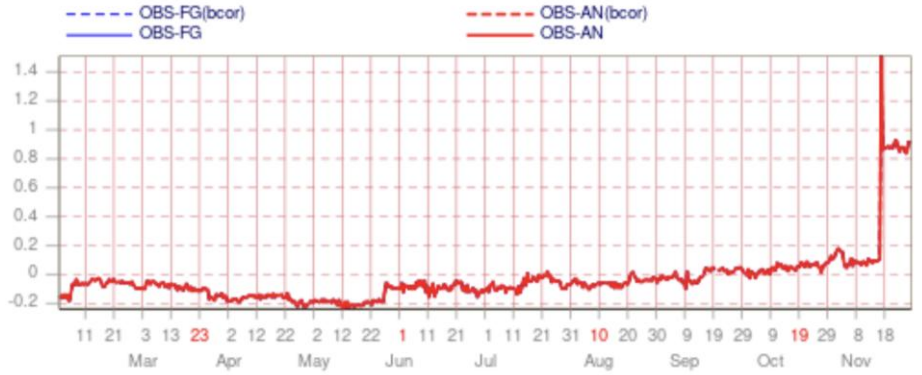
Bin-by-bin monitoring of ATLID L1 for hot pixel detection

- Near-real time monitoring of total attenuated backscatter and Rayleigh backscatter by computing global mean first-guess departures at each native lidar level.

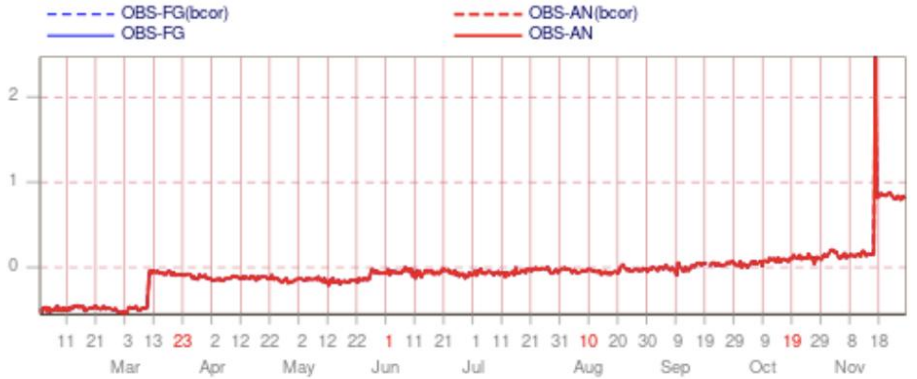


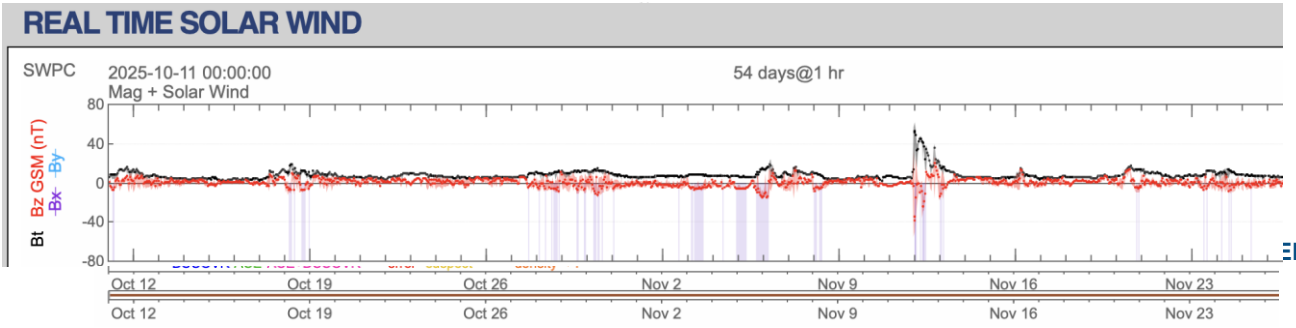
Super-hot pixel!

Lv 42



Lv 43





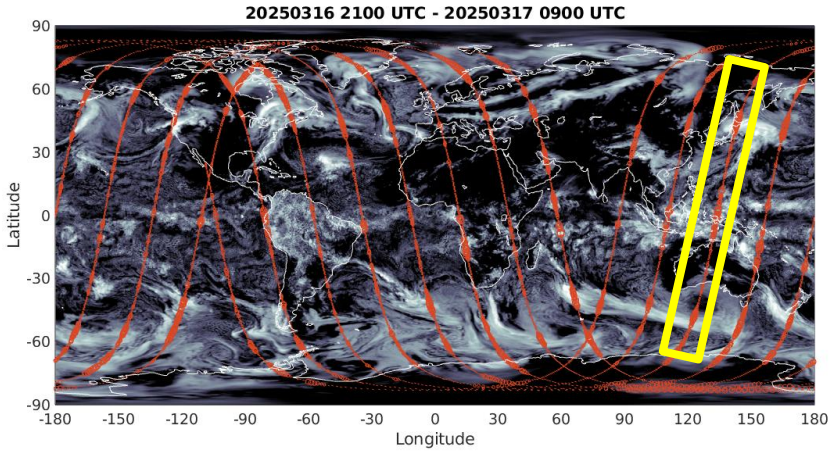
https://charts-test.ecmwf.int/catalogue/packages/obstat/

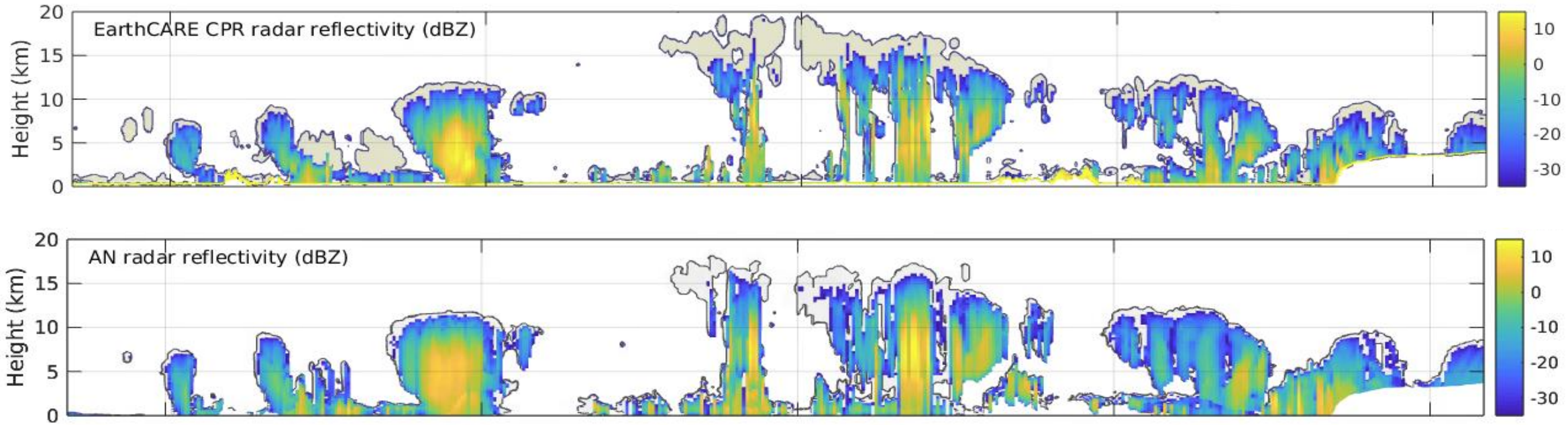
4D-Var observing system experiment setup

- Integrated Forecast System (IFS) CY49R1 4D-Var experimentation with forecasts using TCo639 grid (~18 km) for 5-month period between 01 December 2024 – 06 April 2025.
- Assimilate CPR L1B radar reflectivity and/or ATLID L2 extinction (at 355 nm) superobbed to (O320-> ~38 km) and model vertical levels, in addition to current observing system.
- Verification of **analysis** skill evaluated by comparing:
  - analysis to independent observations (e.g., EarthCARE BBR fluxes).
- Verification of **forecast** skill evaluated by comparing:
  - Short-term forecast fits to other observations in observing system (background departures)
  - Forecasts of model variables (e.g., T, RH, winds) against own analysis at variety of lead times.
  - L3 gridded observational products (e.g., CERES TOA radiative fluxes), to model variables at different lead times.

Single orbit example for Pacific Ocean

- Example single-cycle 4D-Var assimilation experiment using TCo639 grid (~18 km) 17 March 2025.
- 4D-Var control variables (such as temperature and humidity) are adjusted during minimization to improve forward modelled fit to observations.





NH mid-latitudes

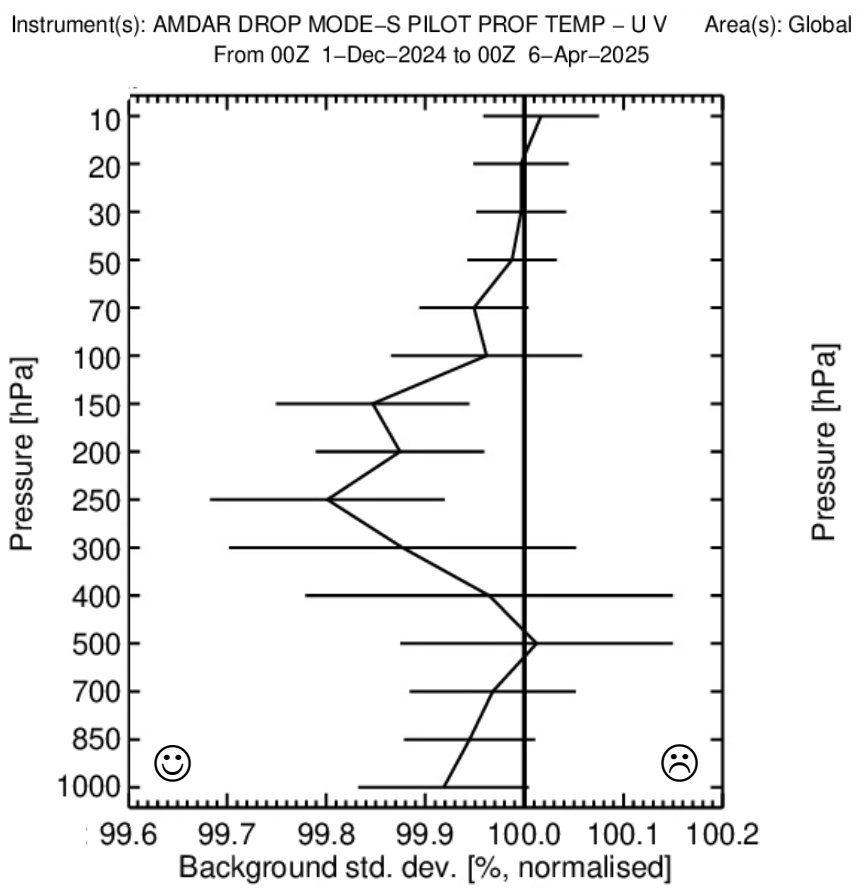
Tropical deep convection

Southern ocean

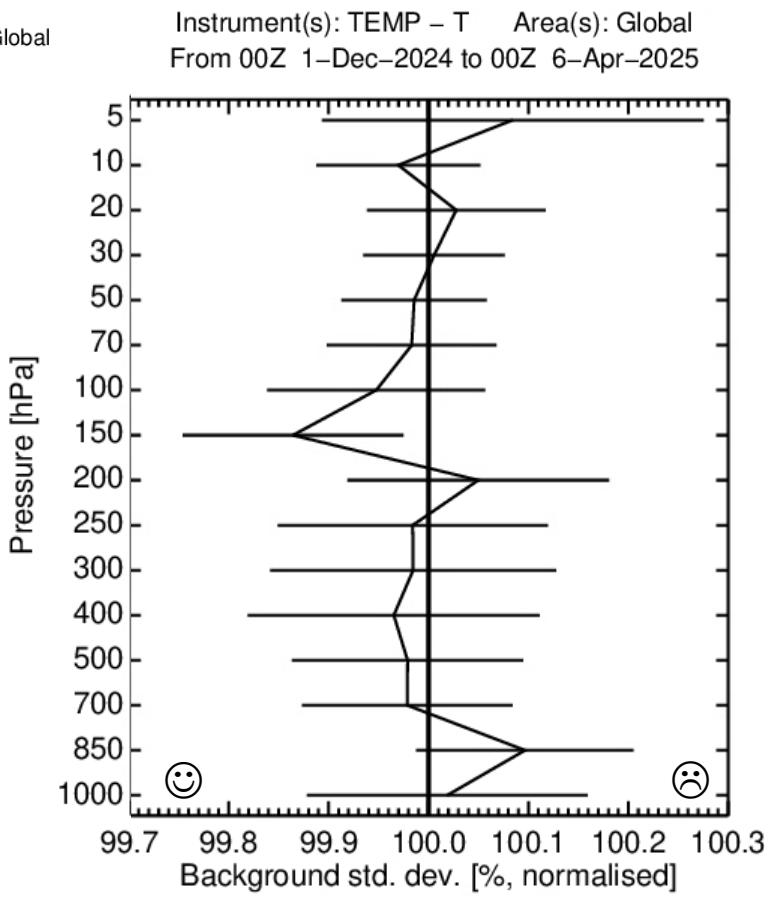
Verification against conventional observations – CPR only

- Assimilating radar reflectivity improves short-term forecasts (background departures) of wind and humidity

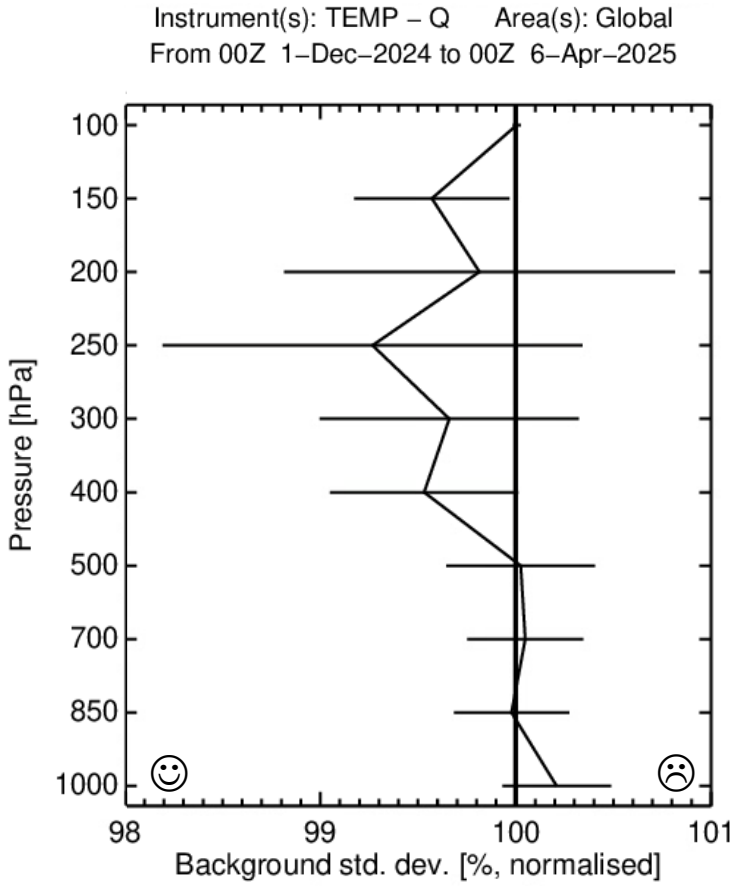
Profiler and radiosonde **Wind**



Radiosonde **Temperature**



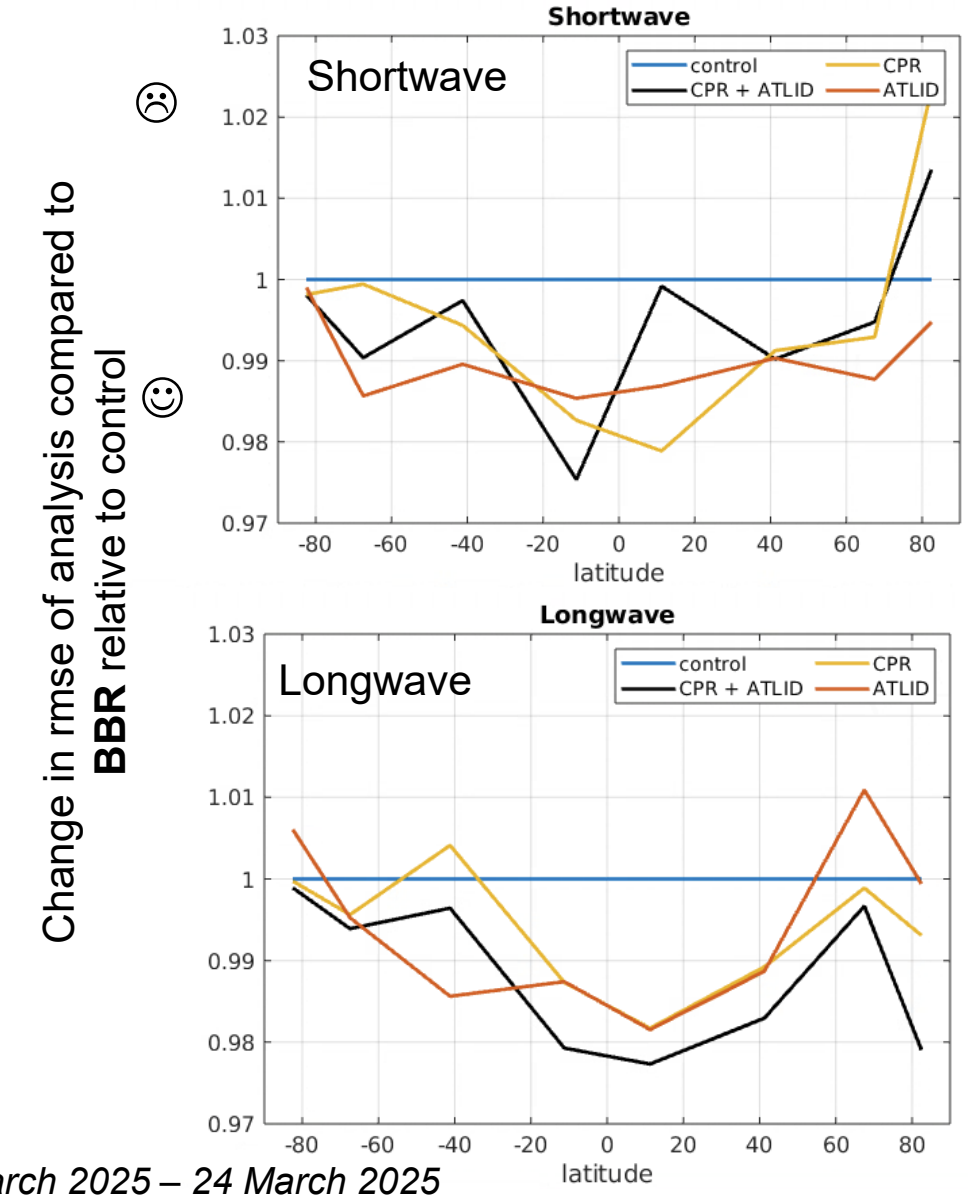
Radiosonde **Humidity**



ECMWF

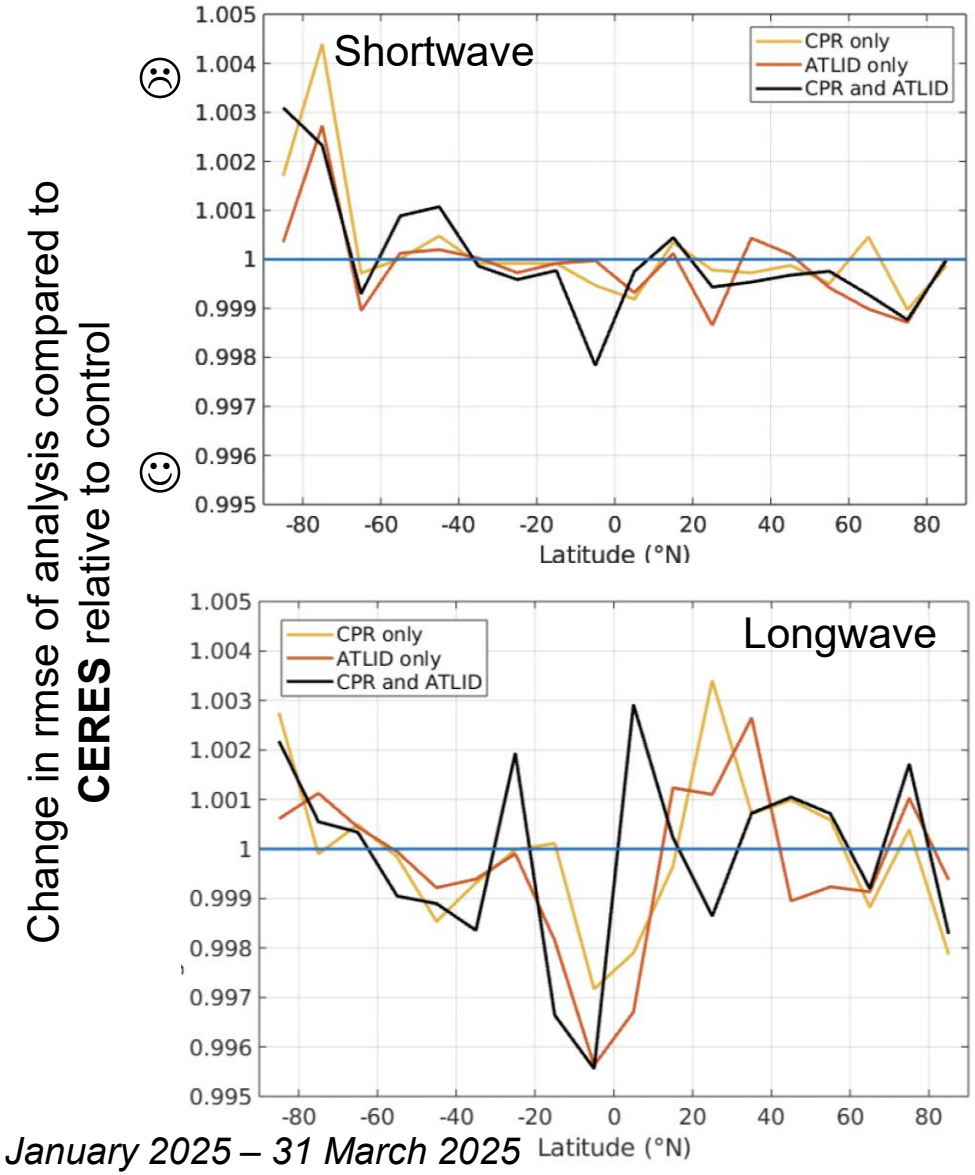
Assimilating EarthCARE improves fit to TOA radiation observations

Along track impact on analysis



17 March 2025 – 24 March 2025

Global impact on day 1 forecast

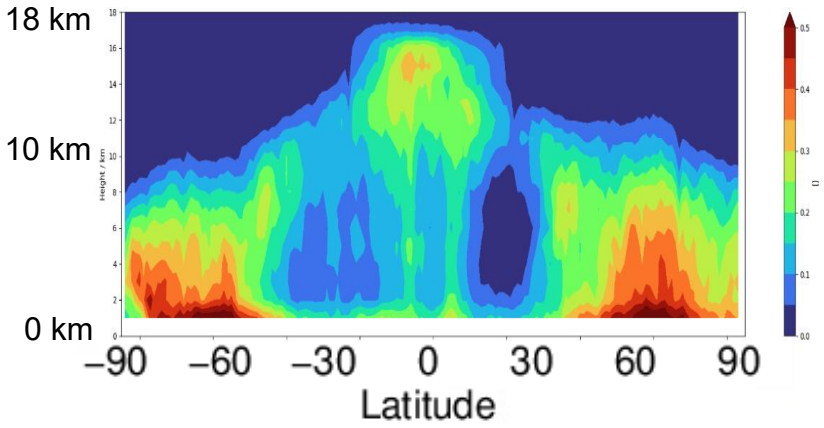


1 January 2025 – 31 March 2025

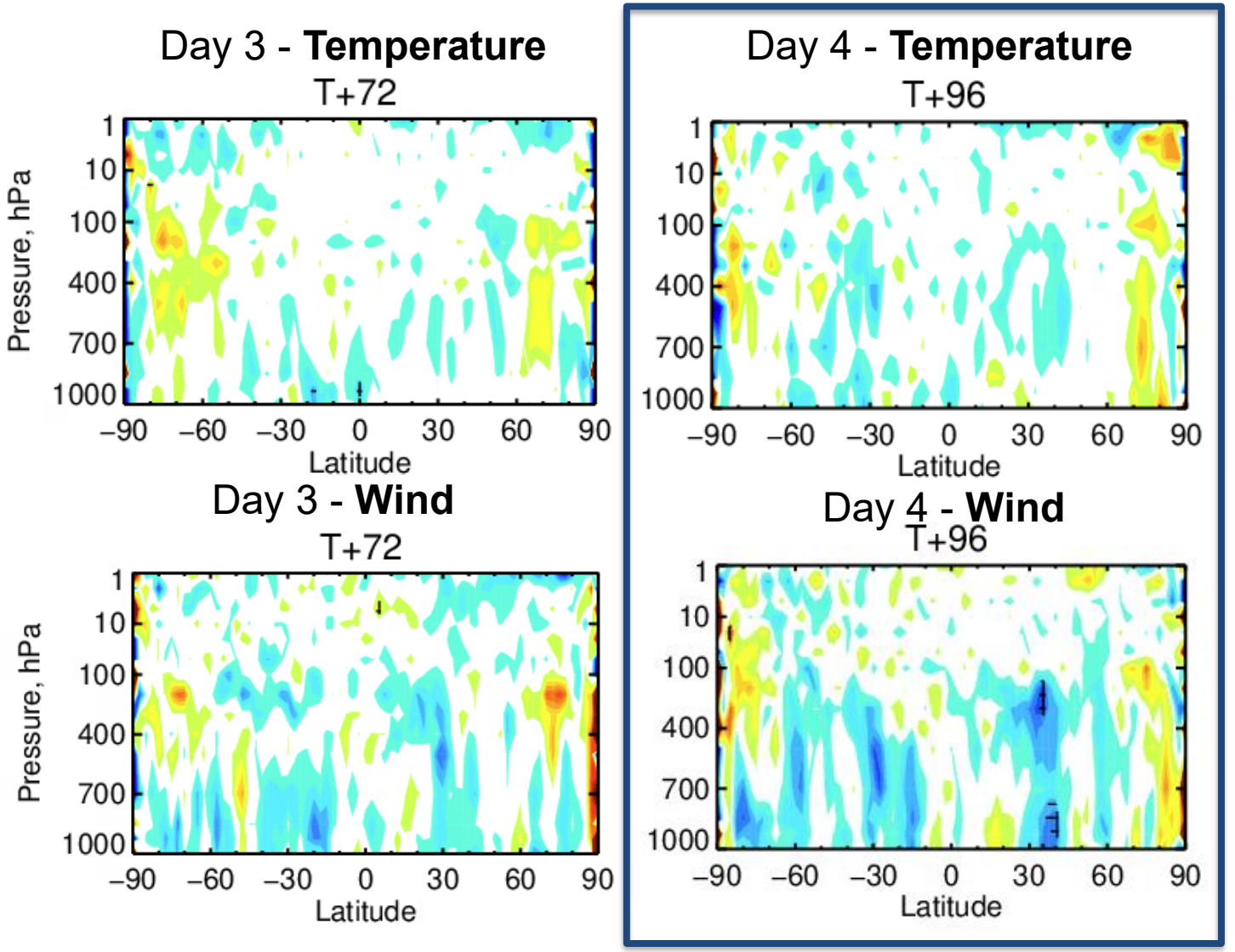
Assimilating radar reflectivity improves medium-range forecasts of winds in the extra-tropics

- Improvements of 0.5 - 1 % at day 3-4 in cloudy regions, consistent with CloudSat assimilation experiments.
- Smaller, positive impact on temperature scores.

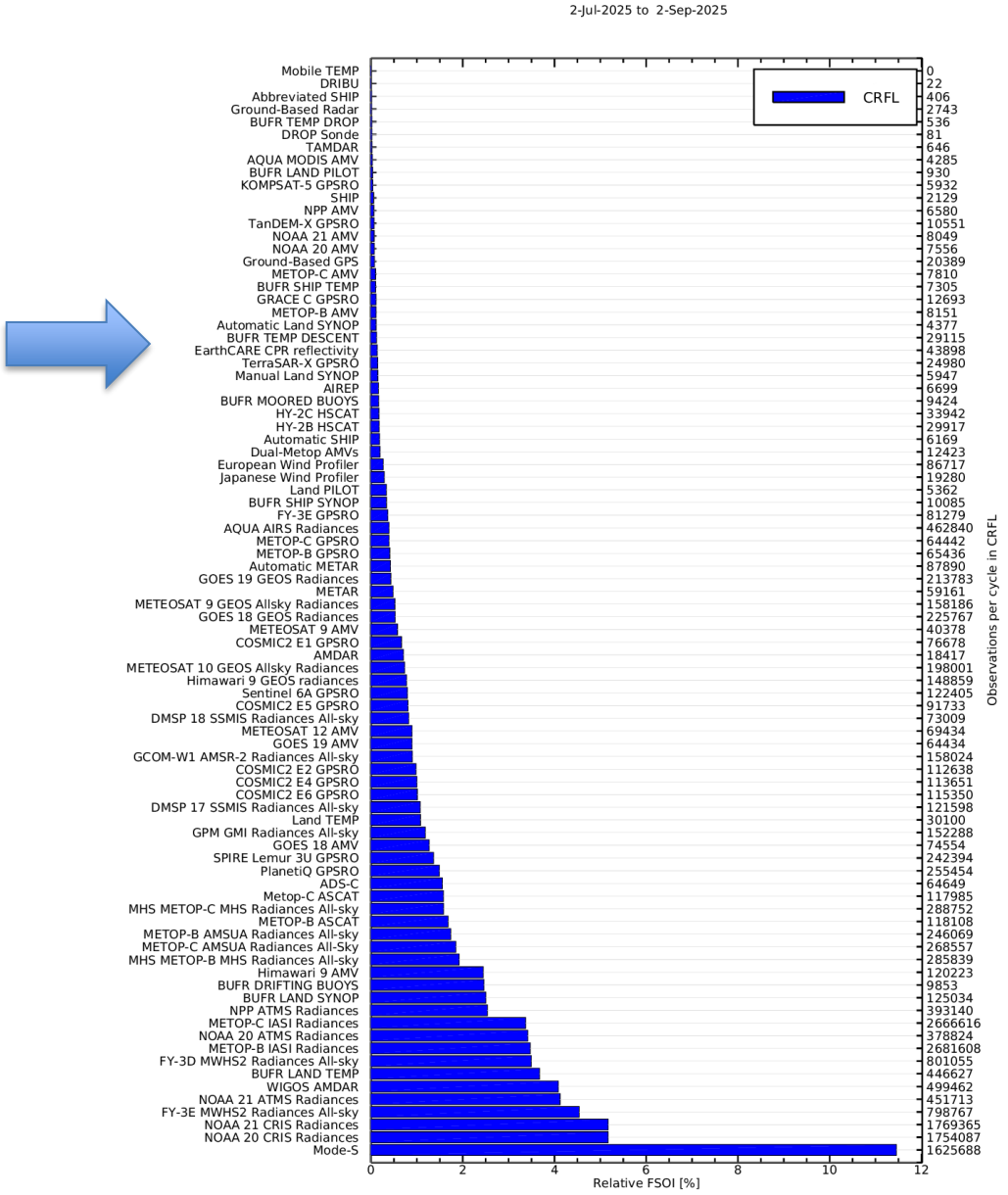
EarthCARE hydrometeor fraction



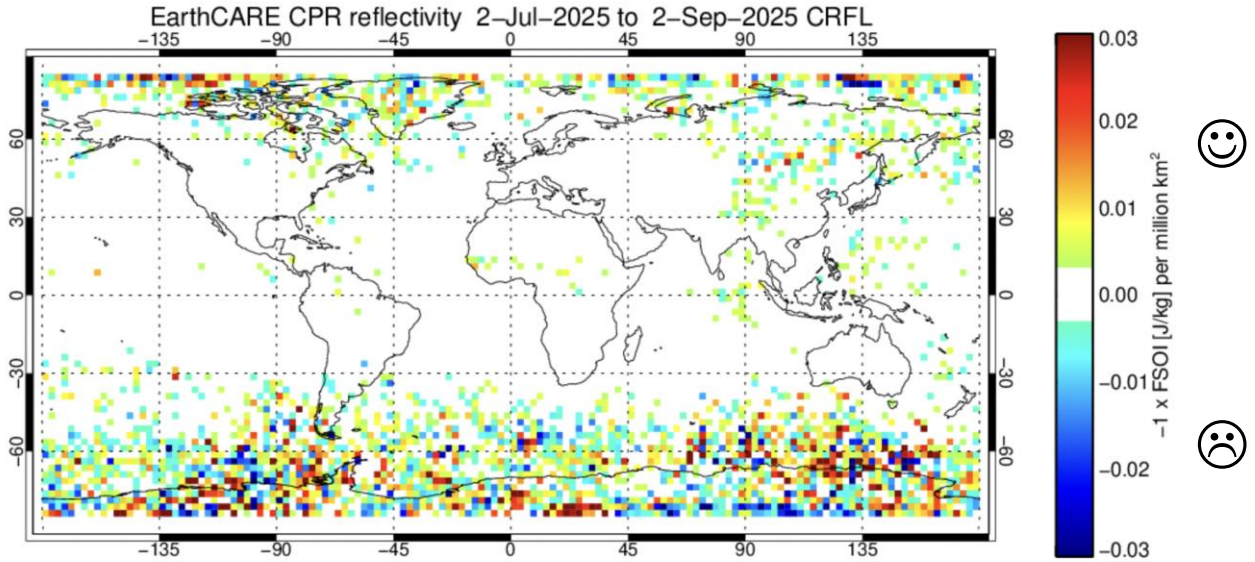
CPR-only OSE (20241201 to 20250406)



EarthCARE CPR impact relative to other observations (Kamil Mroz)

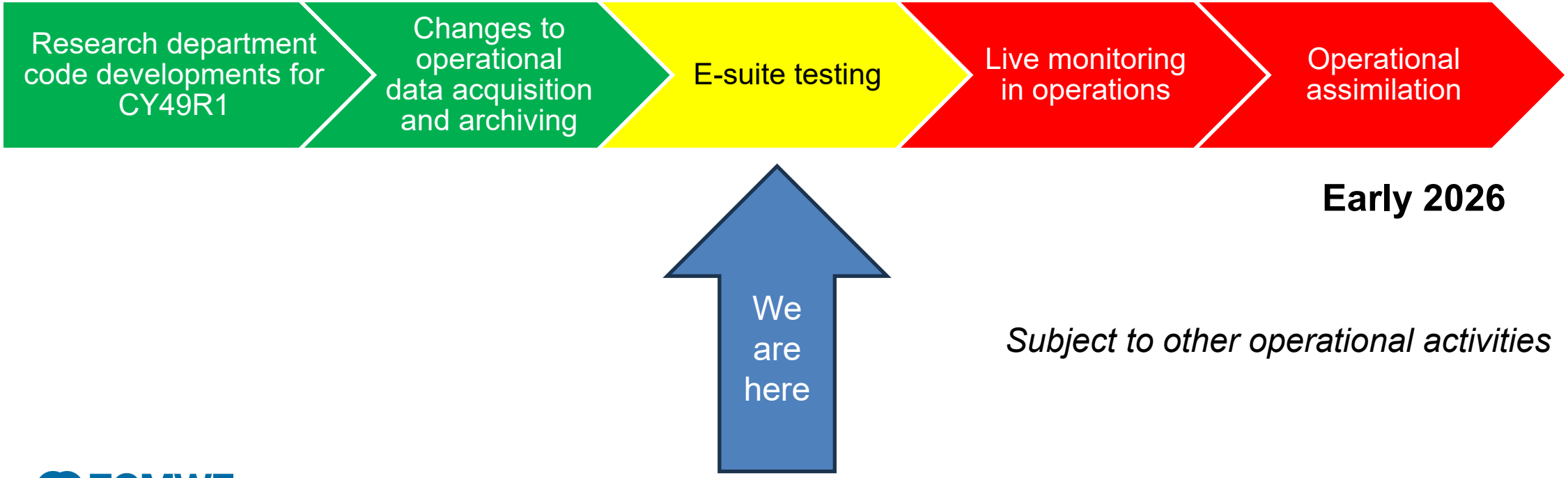


- Forecast sensitivity to observations impact (FSOI) scores use an adjoint technique to assess the impact of different observation types on forecast error.
- Analysis increments from **EarthCARE CPR observations contribute 0.15 %** to the total reduction in 24 hour forecast error for each 4D-Var cycle.
- FSOI scores can be misleading due to correlations between observation types, non-linearities and neglect humidity information (when using dry energy norm).



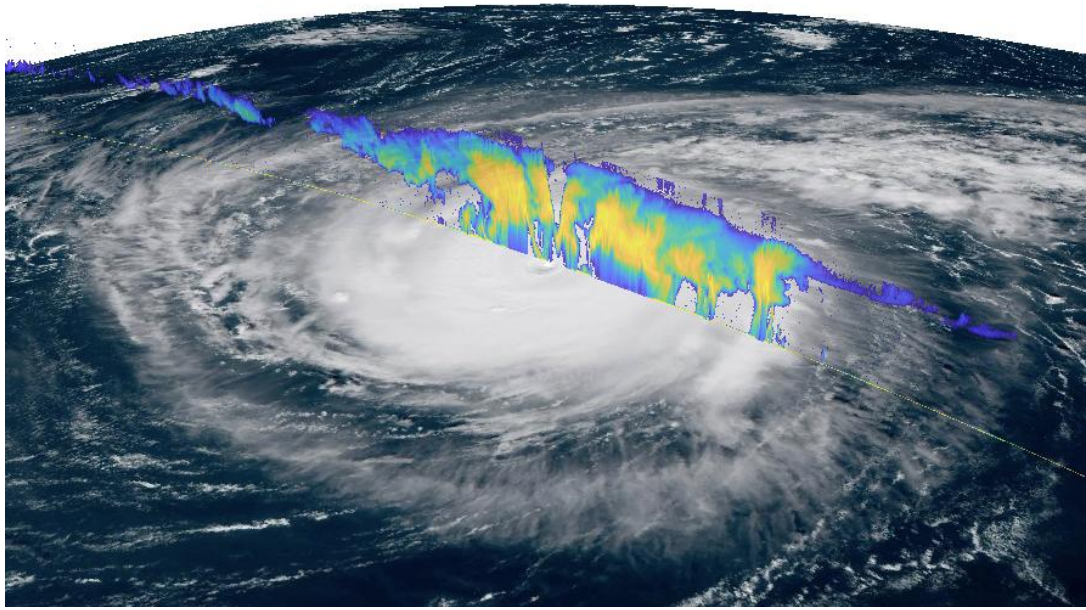
Timeline for EarthCARE operational assimilation at ECMWF

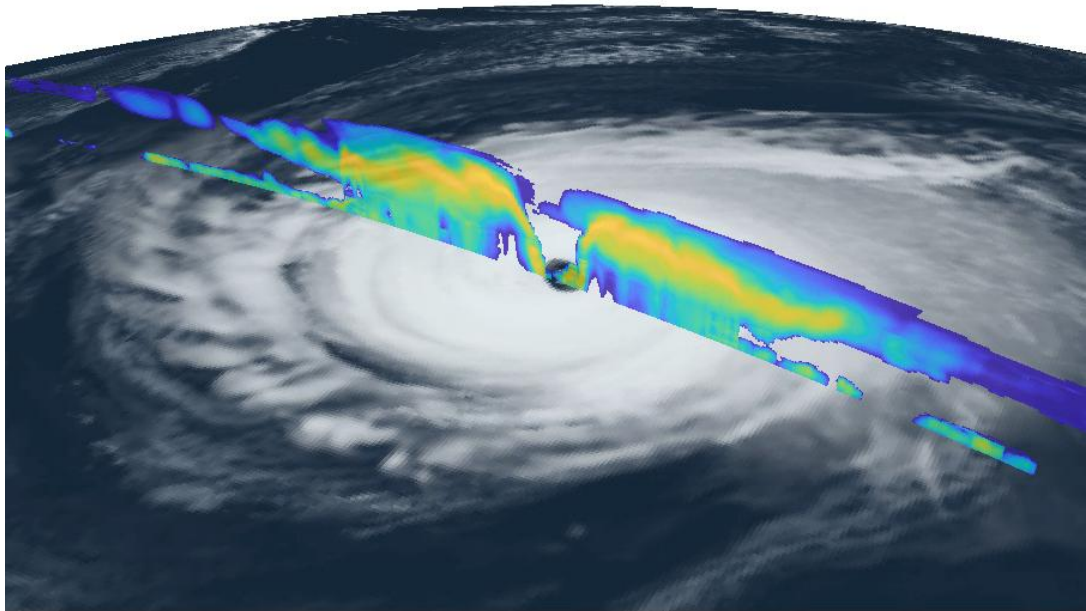
- Operational assimilation of EarthCARE previously planned for CY50R1.
- Due to delays in CY50R1 implementation, EarthCARE now prioritized for inclusion in CY49R1.
- Necessitated further code developments, testing and evaluation in CY49R1, which are now complete.



Conclusions and outlook

- ECMWF ready for operational implementation of EarthCARE CPR data in early 2026.
- Assimilating EarthCARE improves both analysis and medium range forecasts skill scores, shown through a variety of metrics including radiation measurements from BBR and CERES.
- Additional benefit expected through error tuning, correcting model cloud biases and exploiting other EarthCARE observations.
- Including EarthCARE observations in data assimilation system has helped unlock synergies between model evaluation, quality monitoring and data assimilation.





Further reading: Fielding et al., 2025, ECMWF newsletter
https://doi.org/10.21957/65ds8j72mf