Assimilating EarthCARE ATLID cloud observations in global NWP: progress in optimising the impact

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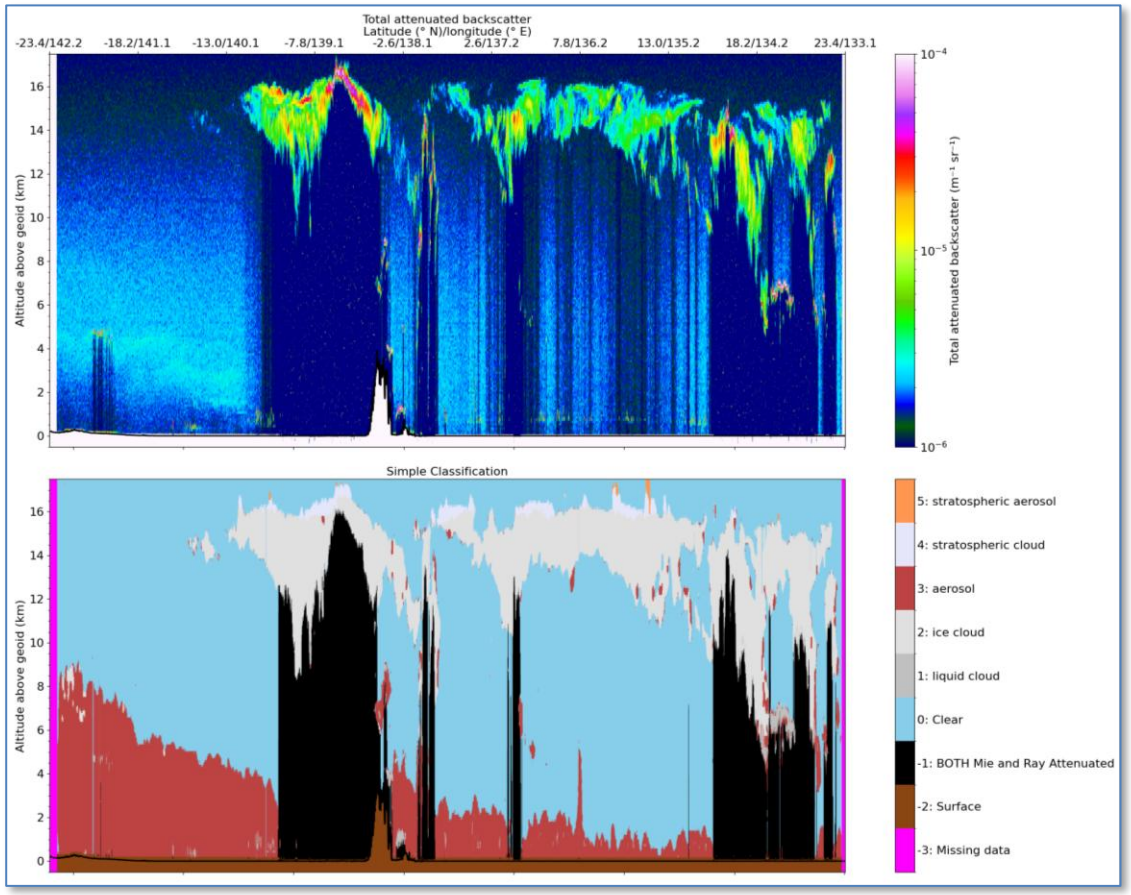


Aim: Improve initial conditions by data assimilation of **ATLID cloud-sensitive observations**

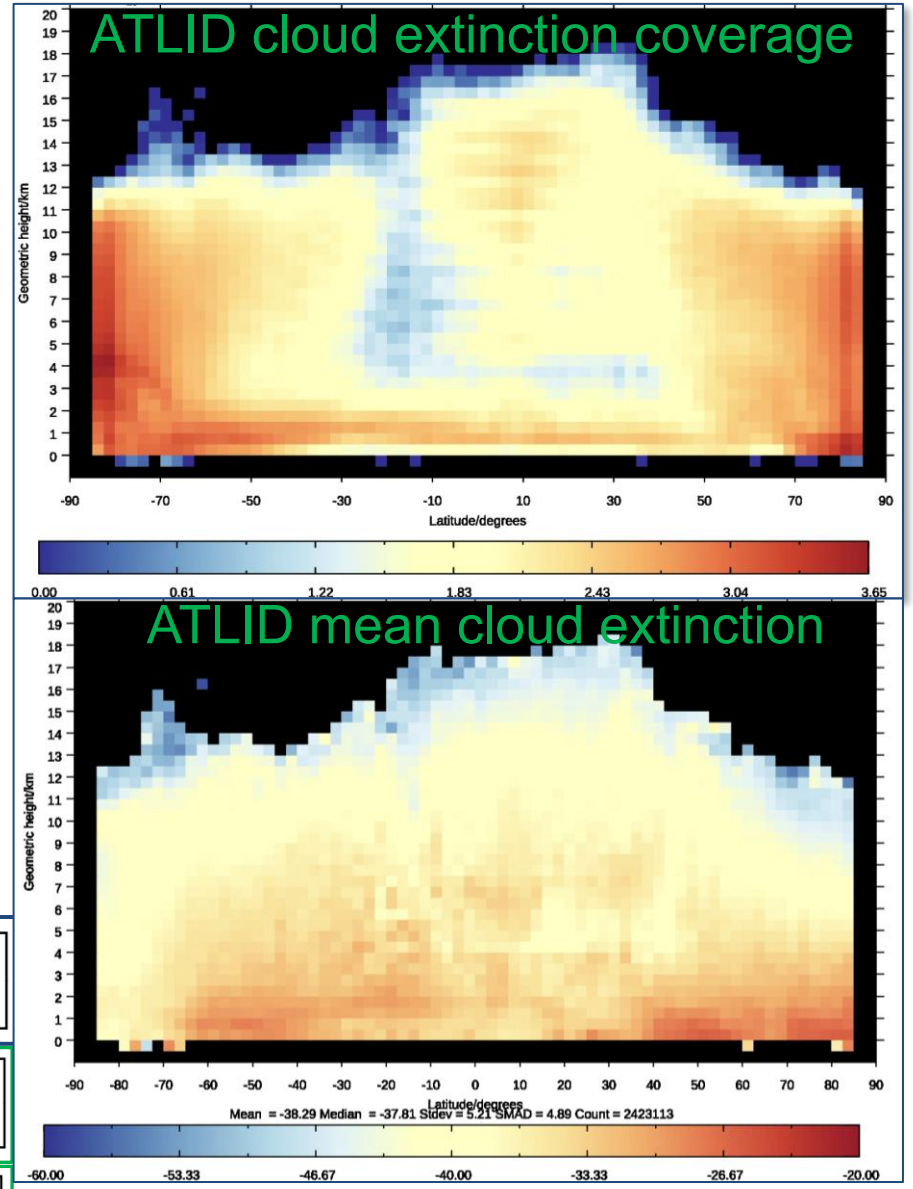
- **Vertically-resolved cloud observations lacking** – ATLID helps with optical properties in **optically thin clouds** and **optically thick cloud tops**

- **O**bserving **S**ystem **E**xperiments:
  - Use **L2a EBD** product – NRT data baselines
    - **Cloudy and clear sky** (simple classification)
    - Use full operational observing system
    - CPR reflectivity not assimilated
  - Test three different data types:
    - b_R, Rayleigh attenuated backscatter (ATB)
    - $b_T = b_R + b_{M,\parallel} + b_{M,\perp}$, total ATB
    - $\alpha_{M,cloud}$, extinction

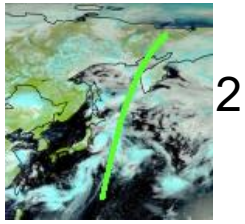
$$b_{\mathrm{R}}(z) = \beta_{\mathrm{R}}(z)\exp\left[-2\int_{z_{\mathrm{lid}}}^{z}\left(\alpha_{\mathrm{M}}(z') + \alpha_{\mathrm{R}}(z')\right)\mathrm{d}r(z')\right]$$

$$b_{\mathrm{M},\parallel}(z) = \beta_{\mathrm{M},\parallel}(z)\exp\left[-2\int_{z_{\mathrm{lid}}}^{z}\left(\alpha_{\mathrm{M}}(z') + \alpha_{\mathrm{R}}(z')\right)\mathrm{d}r(z')\right]$$

$$b_{\mathrm{M},\perp}(z) = \beta_{\mathrm{M},\perp}\exp\left[-2\int_{z_{\mathrm{lid}}}^{z}\left(\alpha_{\mathrm{M}}(z') + \alpha_{\mathrm{R}}(z')\right)\mathrm{d}r(z')\right]$$



Examples of the L2a EBD data options for assimilation

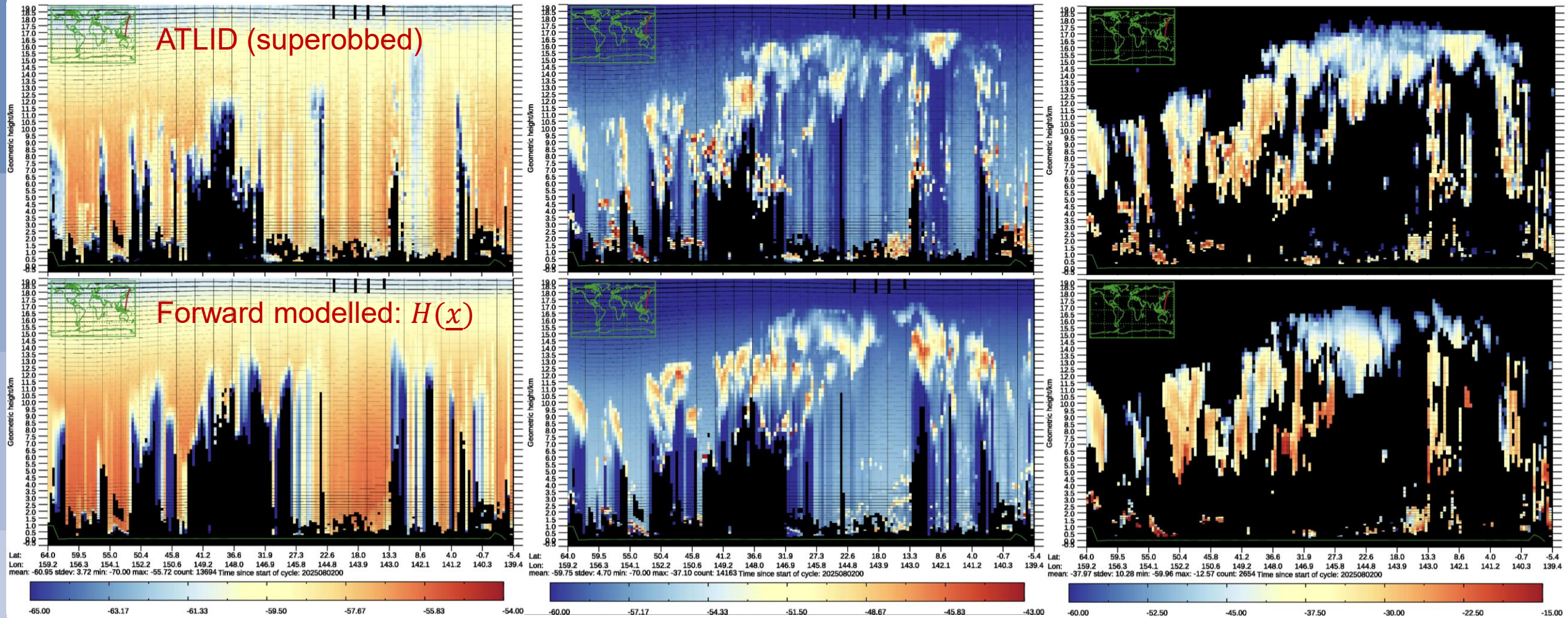


2 Aug 2025

Rayleigh ATB (cloudy + ***clear***), $dB(b_R)$

Total ATB (cloudy + ***clear***), $dB(b_T)$

Extinction (cloud-only), $dB(\alpha_{M,cloud})$



ECMWF

Observation minus short-range (background) forecast departures, zonal averages

August 2025

Rayleigh ATB (cloudy + ***clear***), $dB(b_R)$

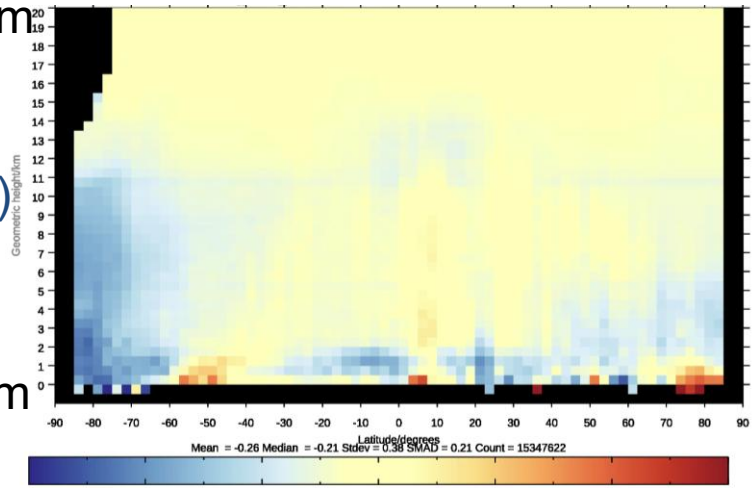
Total ATB (cloudy + ***clear***), $dB(b_T)$

Extinction (cloud-only), $dB(\alpha_{M,cloud})$

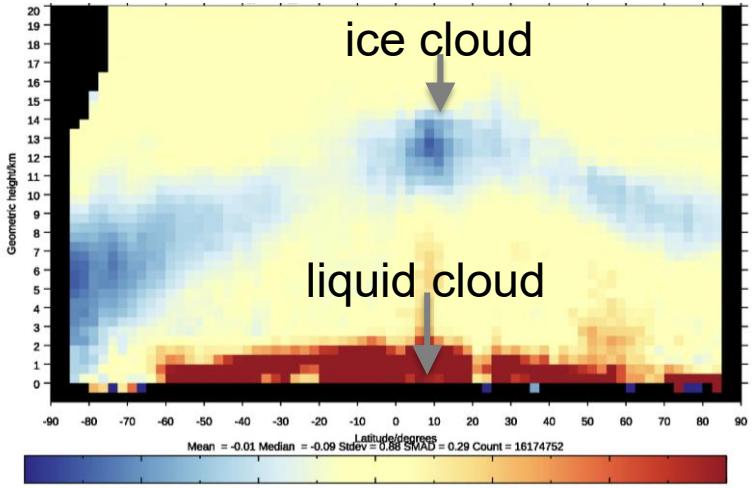
20 km

0 km

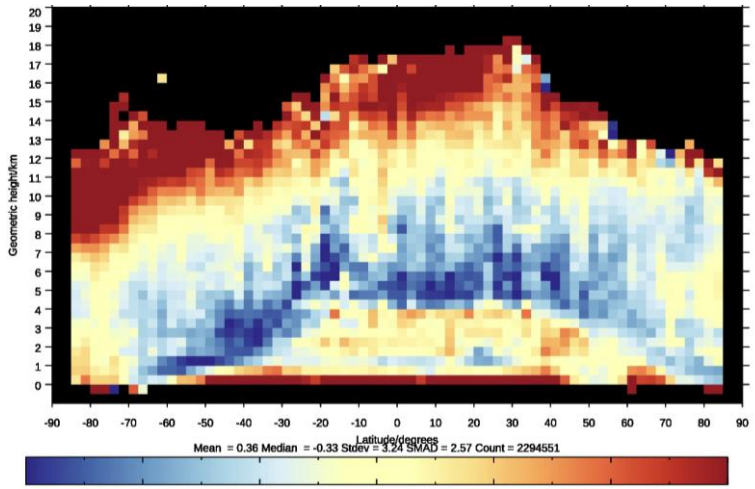
Mean(O-B)
i.e. bias



$-2.5\ dB$ $2.5\ dB$

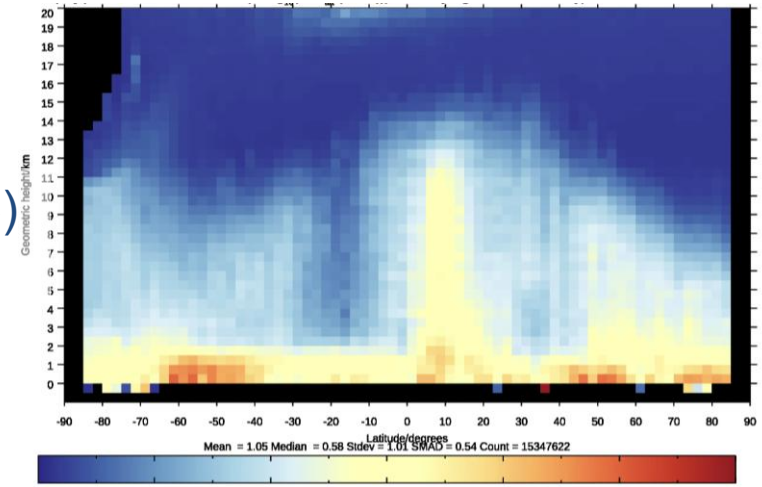


$-2.5\ dB$ $2.5\ dB$

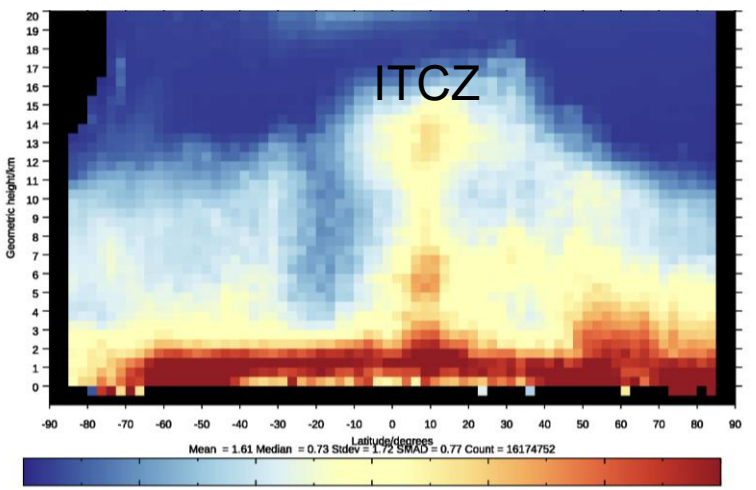


$-5\ dB$ $5\ dB$

Stdev(O-B)
i.e. noise



$0\ dB$ $6.25\ dB$



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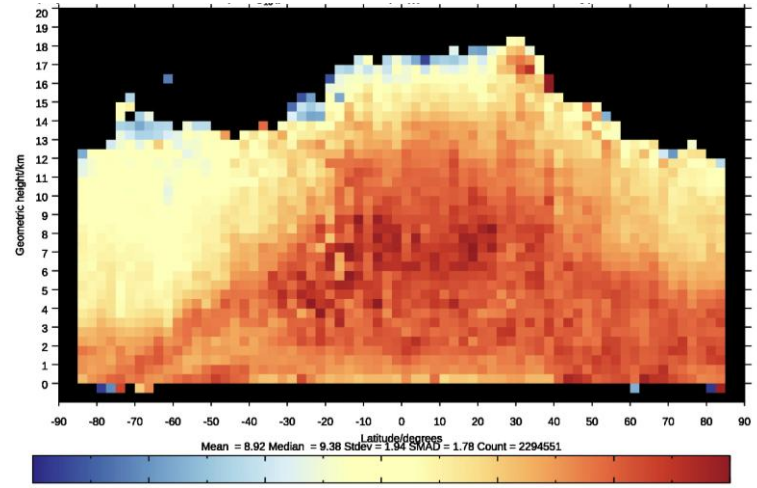


$0\ dB$ $12.5\ dB$

L2a EBD departure time series: observation *minus* short-range forecast, July-Nov 2025

Rayleigh ATB (cloudy + ***clear***), $dB(b_R)$

Total ATB (cloudy + ***clear***), $dB(b_T)$

Extinction (cloud-only), $dB(\alpha_{M,cloud})$

Pressure

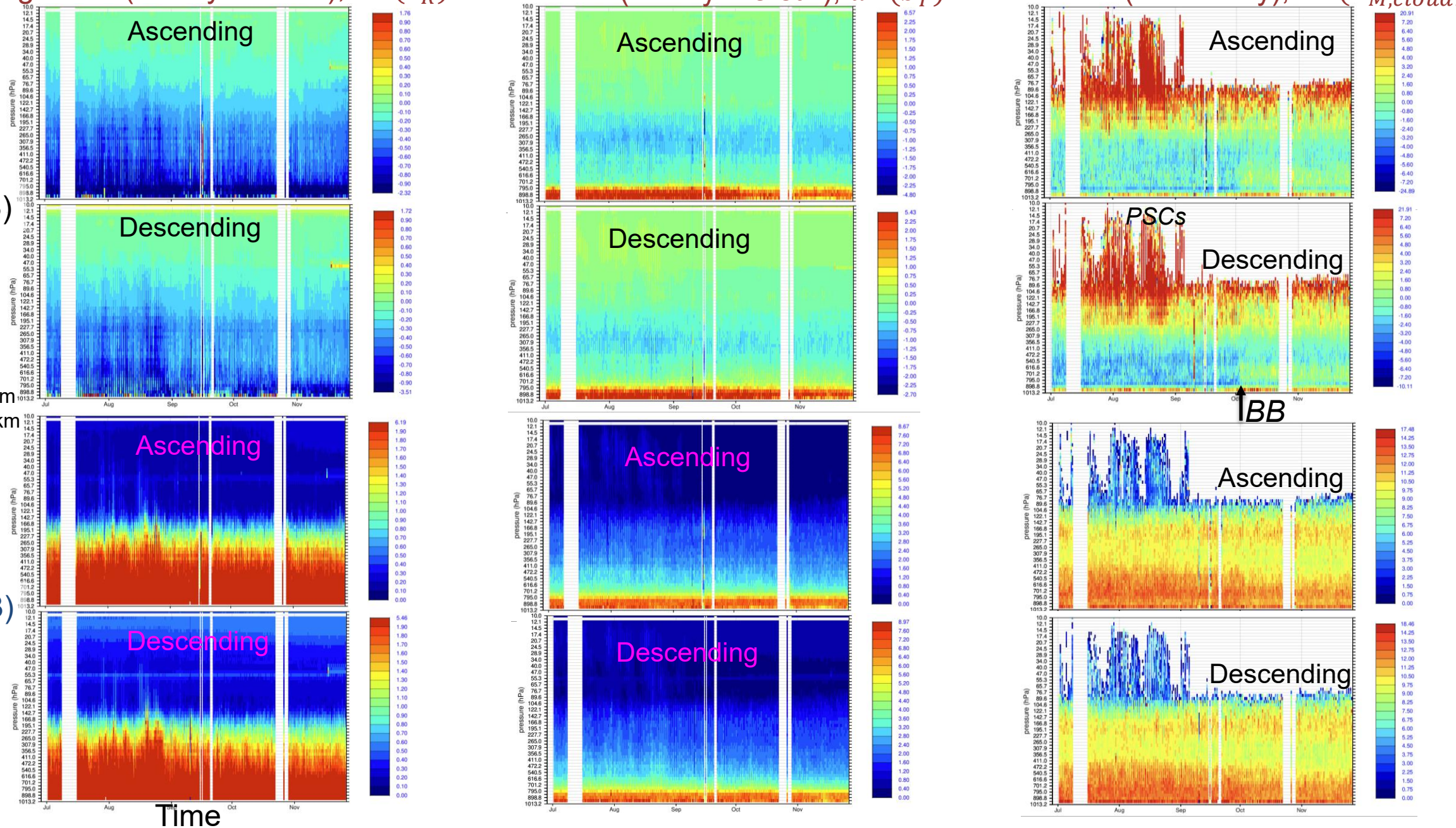
Mean(O-B)

~0 km

~30 km

Stdev(O-B)

Time

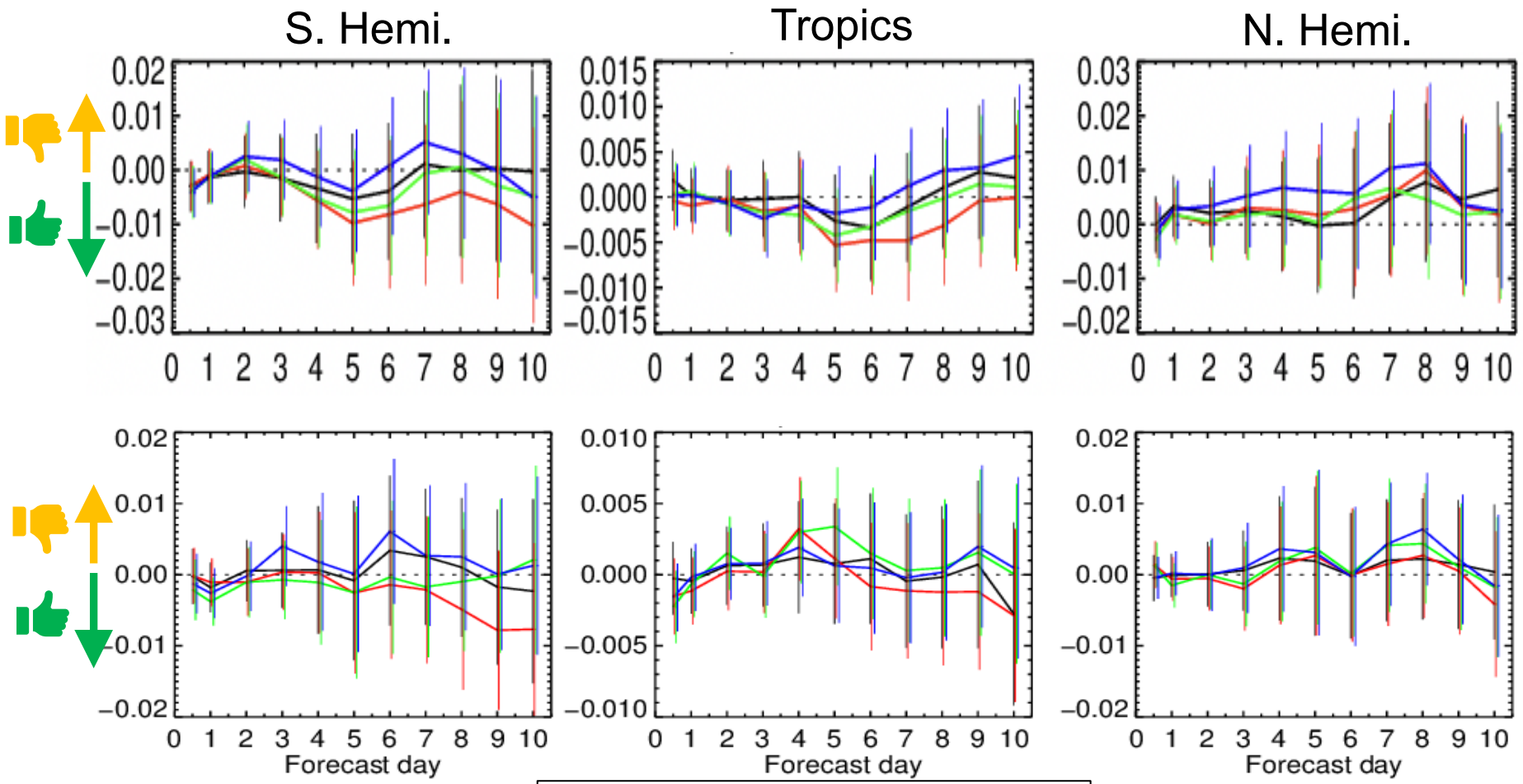


OSE results: Forecast impact of different ATLID data types – total ATB has best impact

July to November 2025; verified against operational analyses

200 hPa **vector wind**, normalised RMS error change

Total column water vapour, normalised RMS error change

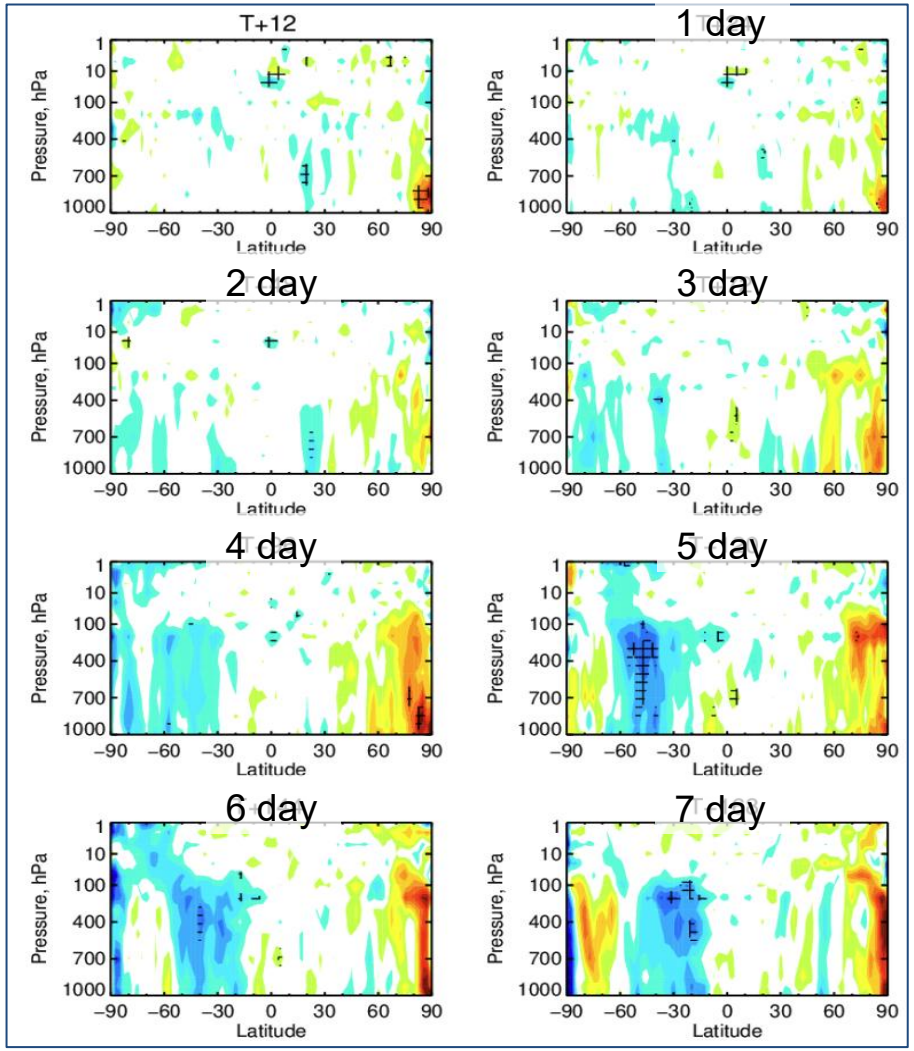


Ray ATB
Total ATB (to higher altitudes)
Total ATB
Extinction

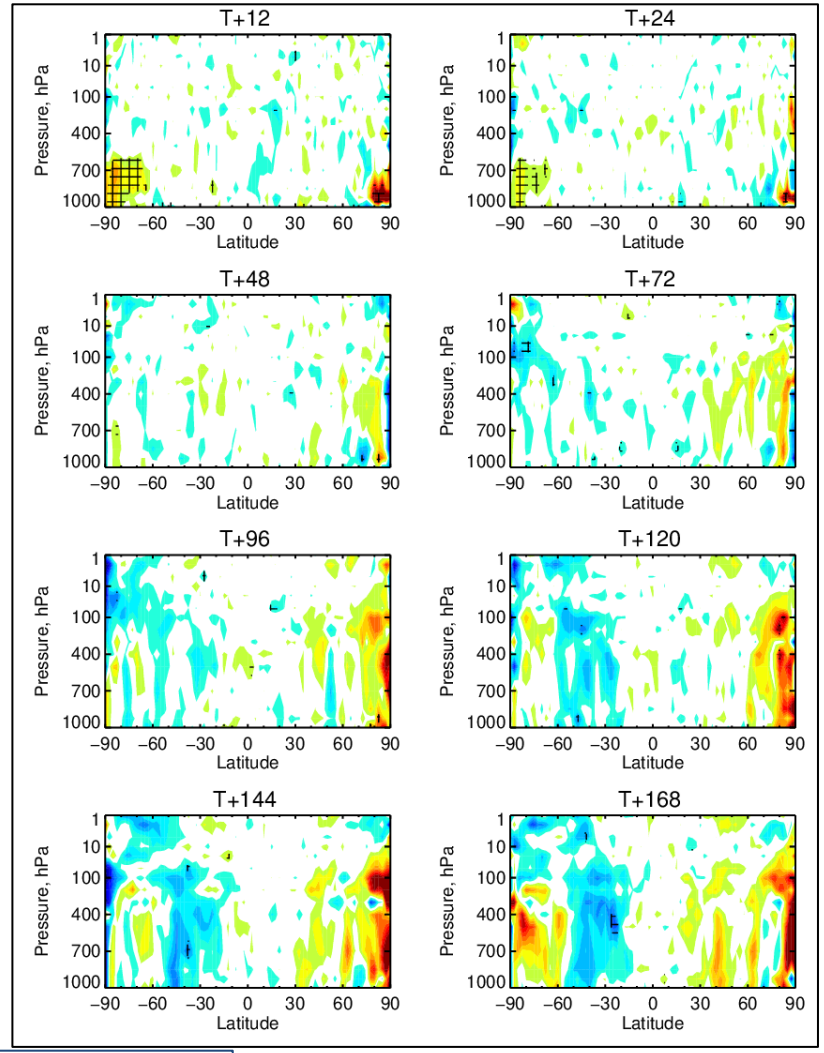
ECMWF

Total attenuated backscatter zonal average impact

Normalised change in wind RMS error of forecasts (±4% scale)



Normalised change in temperature RMS error of forecasts (±4% scale)



- Better in tropics and SH
- Some issues in polar regions

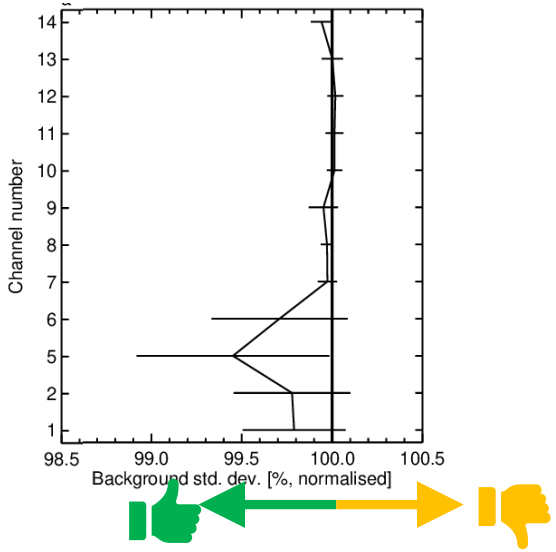
July – Nov 2025

Total attenuated backscatter impact, short-range forecast fit to observations

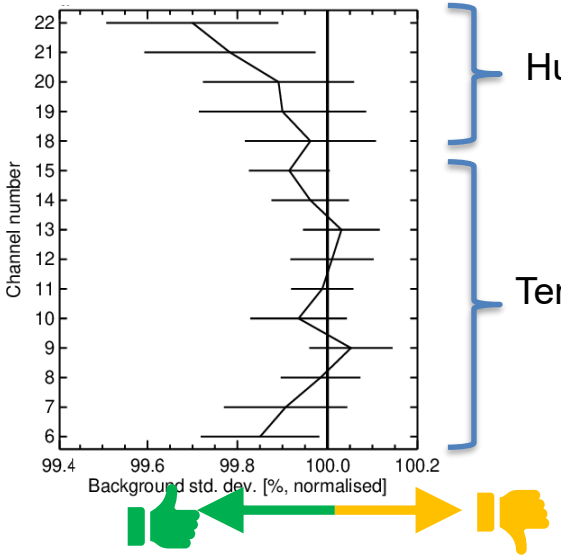
August 2025

Microwave sounders

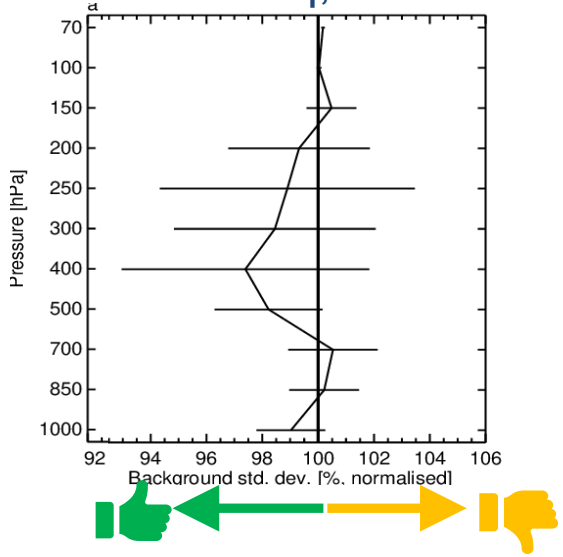
All sky, global



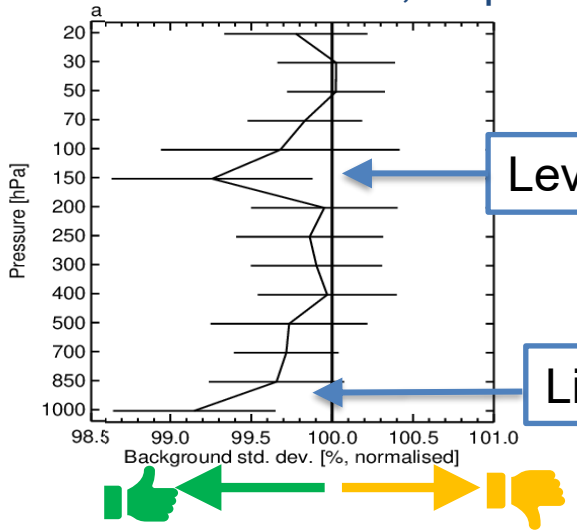
Clear sky, global



Radiosonde q, S. Hem



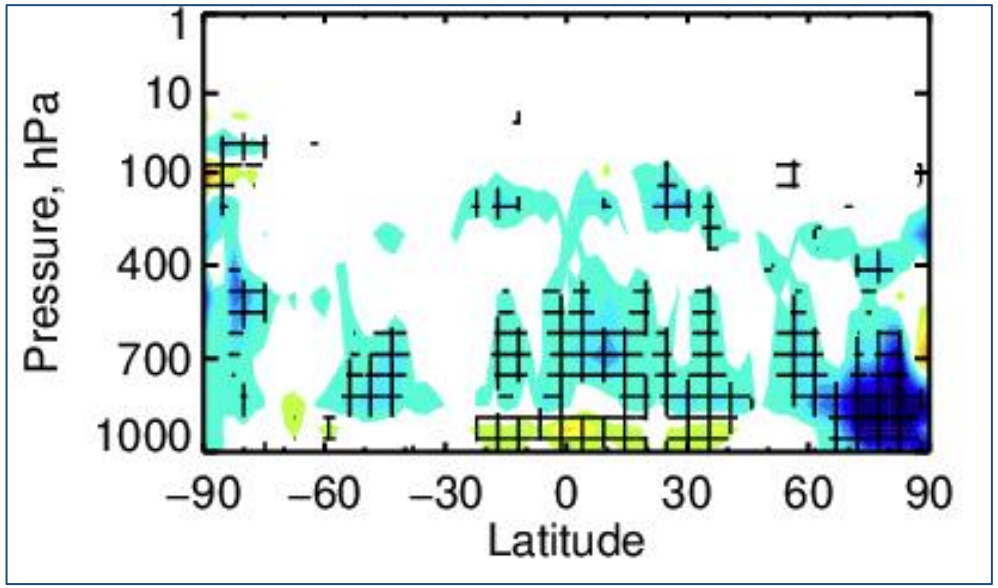
Conventional wind, tropics



Positive impact w.r.t. humidity-sensitive observations and winds

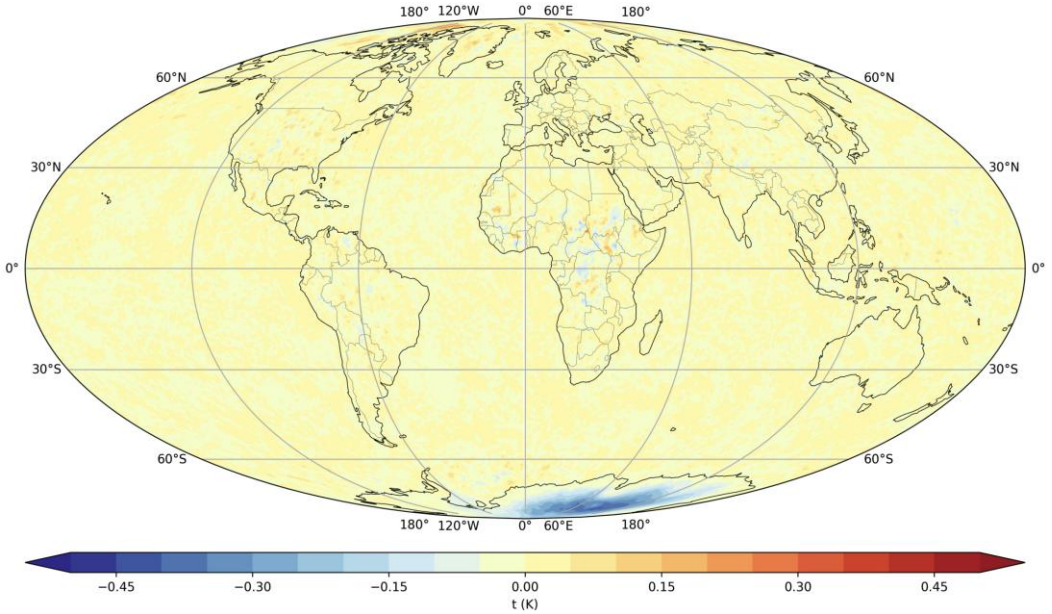
Systematic changes to analysis over polar regions

Total ATB:
Relative humidity ($\pm 0.3\%$ scale)



Slightly drying analysis

Extinction:
Temperature (± 0.5 K scale)



Cooling near surface in Antarctica

Many possible reasons:

- IFS model systematic errors in clouds
- Forward model systematic errors e.g. liquid cloud multiple scattering
- ATLID systematic errors + *aerosol misclassification*
- Lots of data over poles

An example of misclassification of aerosol/cloud in EBD simple-classification

Aerosol-classified backscatter

Cloud-classified extinction

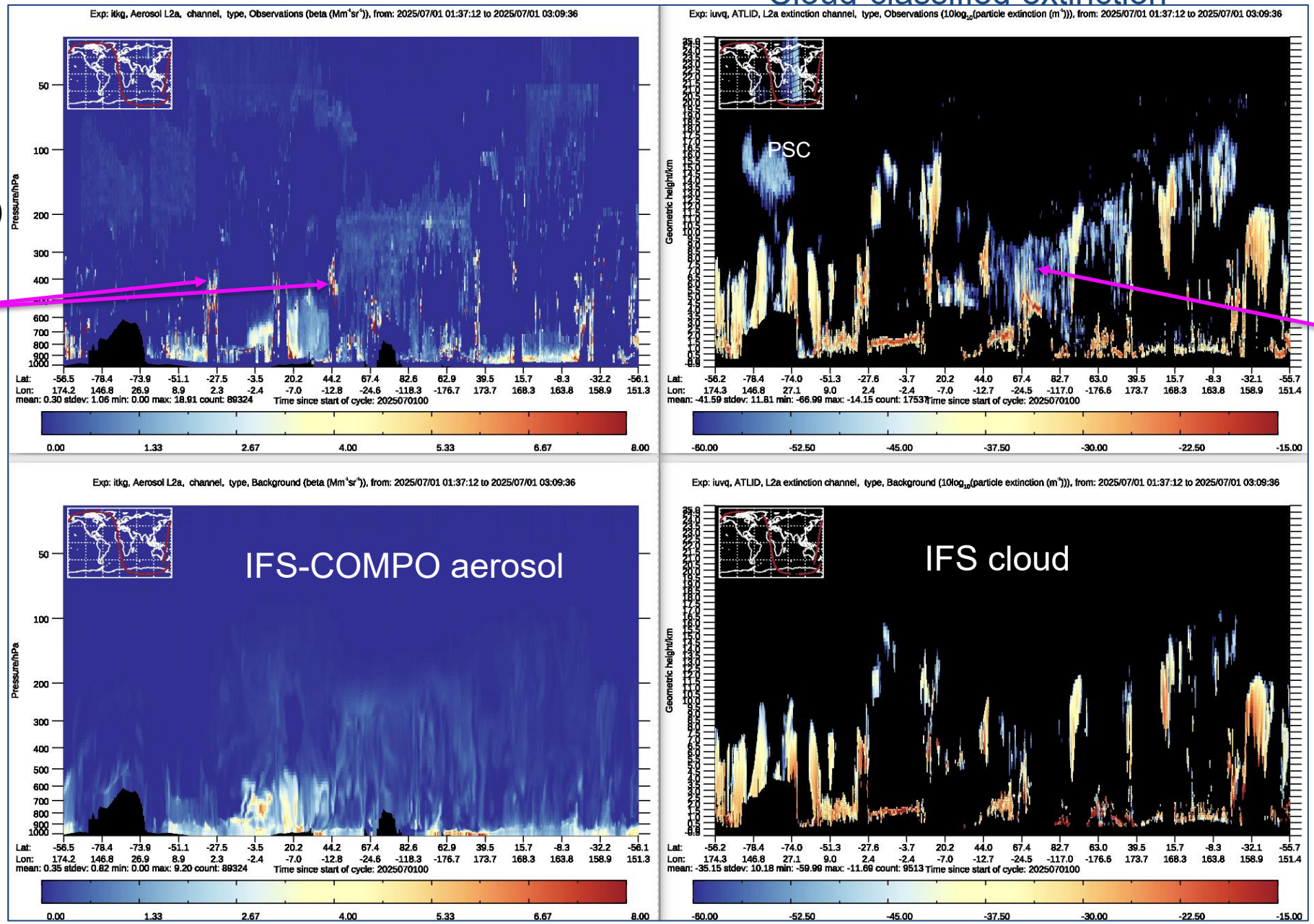
1 July 2025

ATLID (superobbed)

IFS (COMPO) model equivalent

Some cloud contamination of “aerosol”

Some aerosol contamination of “cloud”



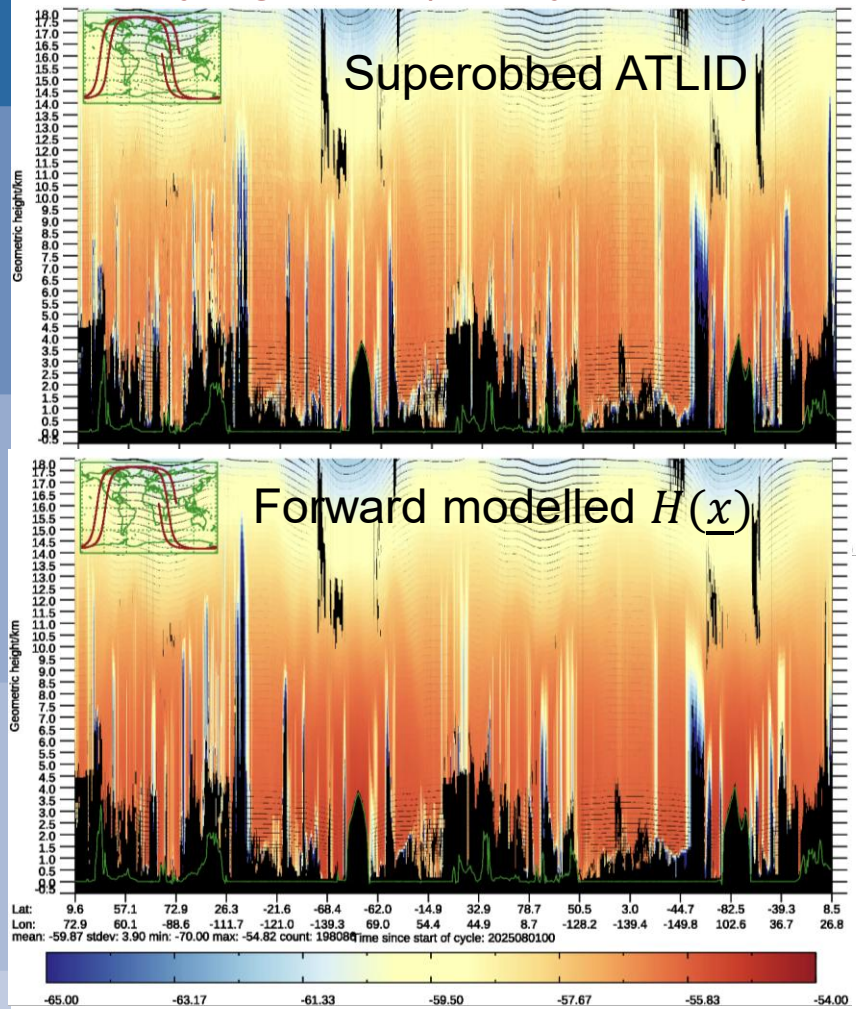
Conclusions and plans

- **ATLID improves humidity and wind in tropics and SH** by useful amount (0.5-1% at day 5)
  - But some degradations in polar regions
- **Total attenuated backscatter** tends to have better impact than Ray ATB and extinction
- Next steps:
  - Try lower obs weighting towards polar regions
  - Improve *multiple scattering* forward modelling for liquid cloud (common in Arctic)
  - Quality Control to reject data ATB below PSCs
  - Try to screen-out aerosol incorrectly classified as cloud
- Continue testing with aim to switch “on” ATLID in operations in early Q2 2026
- **Longer term:** IFS parameterisation improvements should reduce bias w.r.t. ATLID – and hopefully allow better impact

The end – thanks for listening

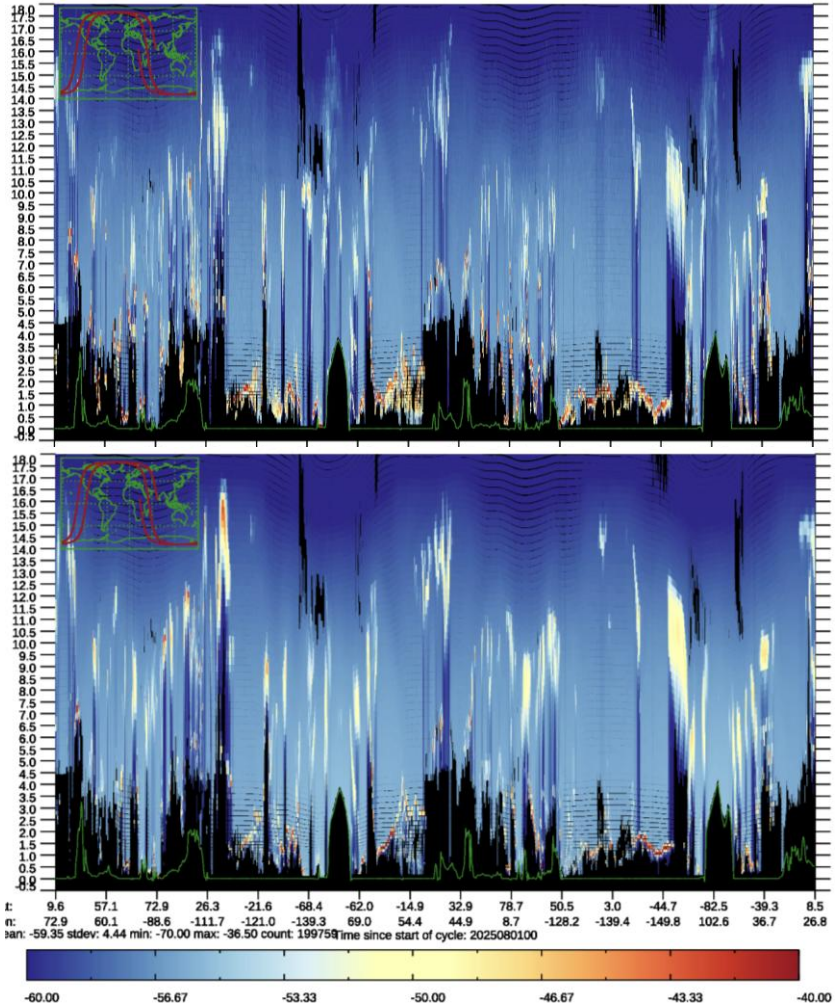
Three types of observation from L2a EBD product were tested

Rayleigh ATB (cloudy + ***clear***)



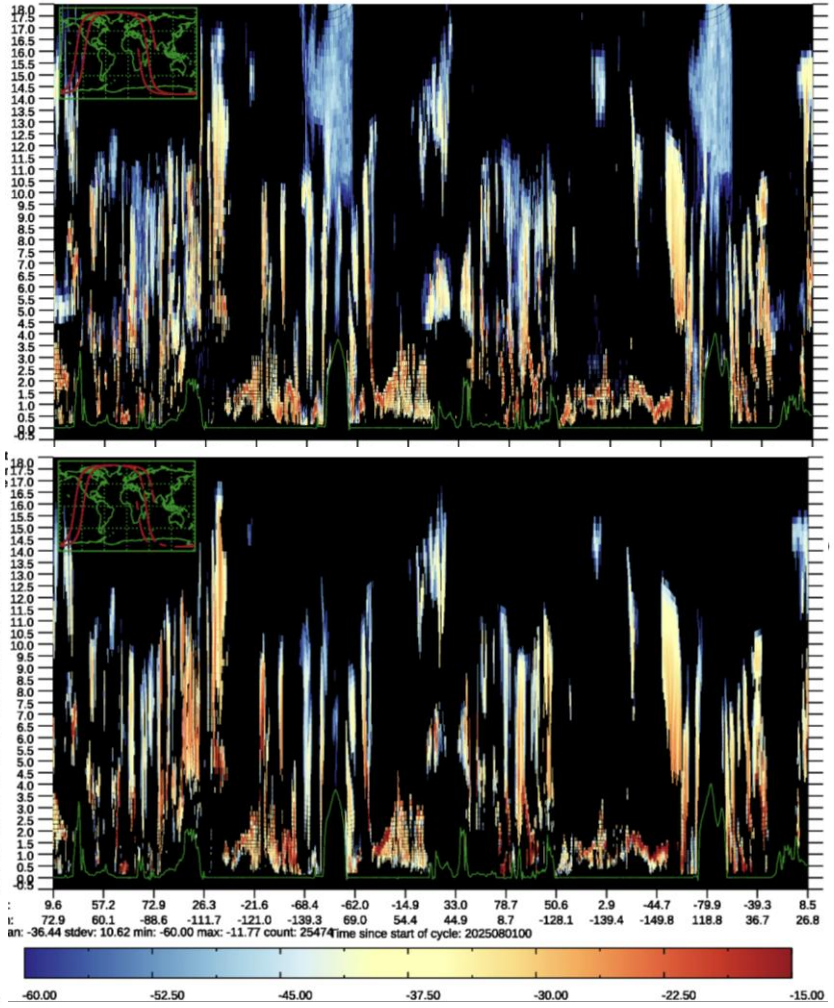
$10\log_{10}(b_R)$

Total ATB (cloudy + ***clear***)



$10\log_{10}(b_T) = 10\log_{10}(b_R + b_{M,\parallel} + b_{M,\perp})$

Extinction (cloud-only)



$10\log_{10}(\alpha_{M,cloud})$

$$b_{\mathrm{R}}(z) = \beta_{\mathrm{R}}(z)\exp\left[-2\int_{z_{\mathrm{lid}}}^{z}\left(\alpha_{\mathrm{M}}(z') + \alpha_{\mathrm{R}}(z')\right)\mathrm{d}r(z')\right]$$

$$b_{\mathrm{M},\parallel}(z) = \beta_{\mathrm{M},\parallel}(z)\exp\left[-2\int_{z_{\mathrm{lid}}}^{z}\left(\alpha_{\mathrm{M}}(z') + \alpha_{\mathrm{R}}(z')\right)\mathrm{d}r(z')\right]$$

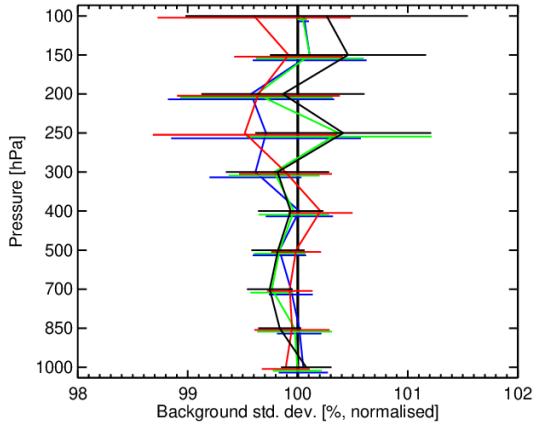
$$b_{\mathrm{M},\perp}(z) = \beta_{\mathrm{M},\perp}\exp\left[-2\int_{z_{\mathrm{lid}}}^{z}\left(\alpha_{\mathrm{M}}(z') + \alpha_{\mathrm{R}}(z')\right)\mathrm{d}r(z')\right]$$

ATLID **O**bserving **S**ystem **E**xperiments results

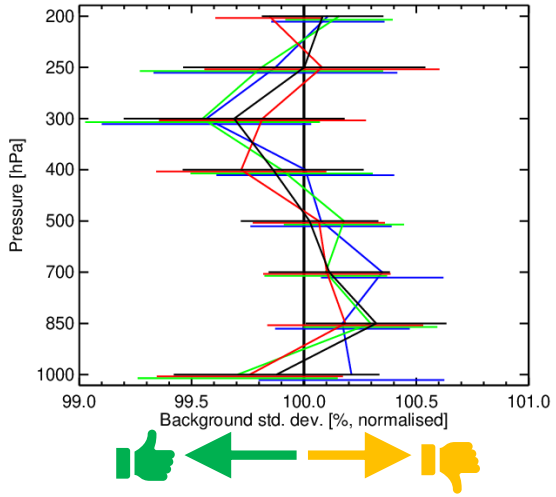
- Found several small improvements e.g. in superobbing, forward model, QC
- Observation error ~10 dB (quite large!) tends to give best results – dominance of representativeness error

July to Nov 2025, 49R1 fit to other observation types

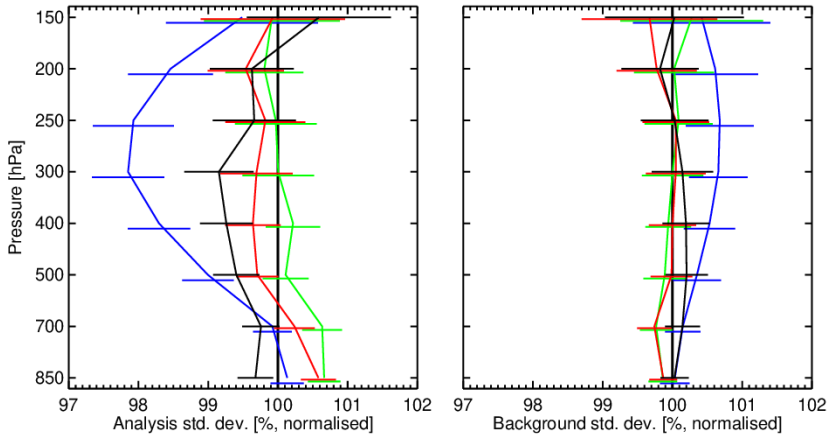
Radiosonde q, global



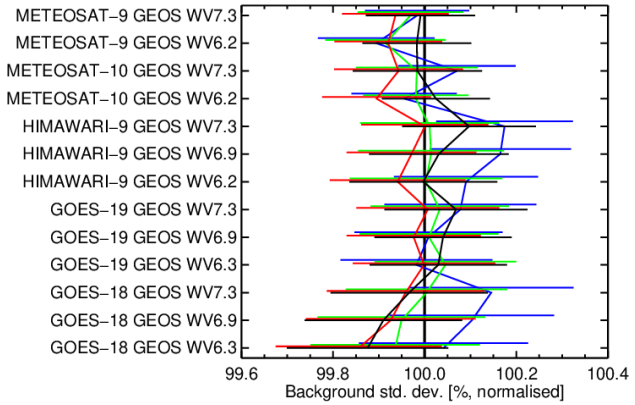
Aircraft q, NH



CPR dBZ, global



Geostationary IR, global



Ray ATB
Total ATB (to higher altitudes)
Total ATB
Extinction

Strongest influence with respect to humidity ~200-300 hPa (8-10 km)

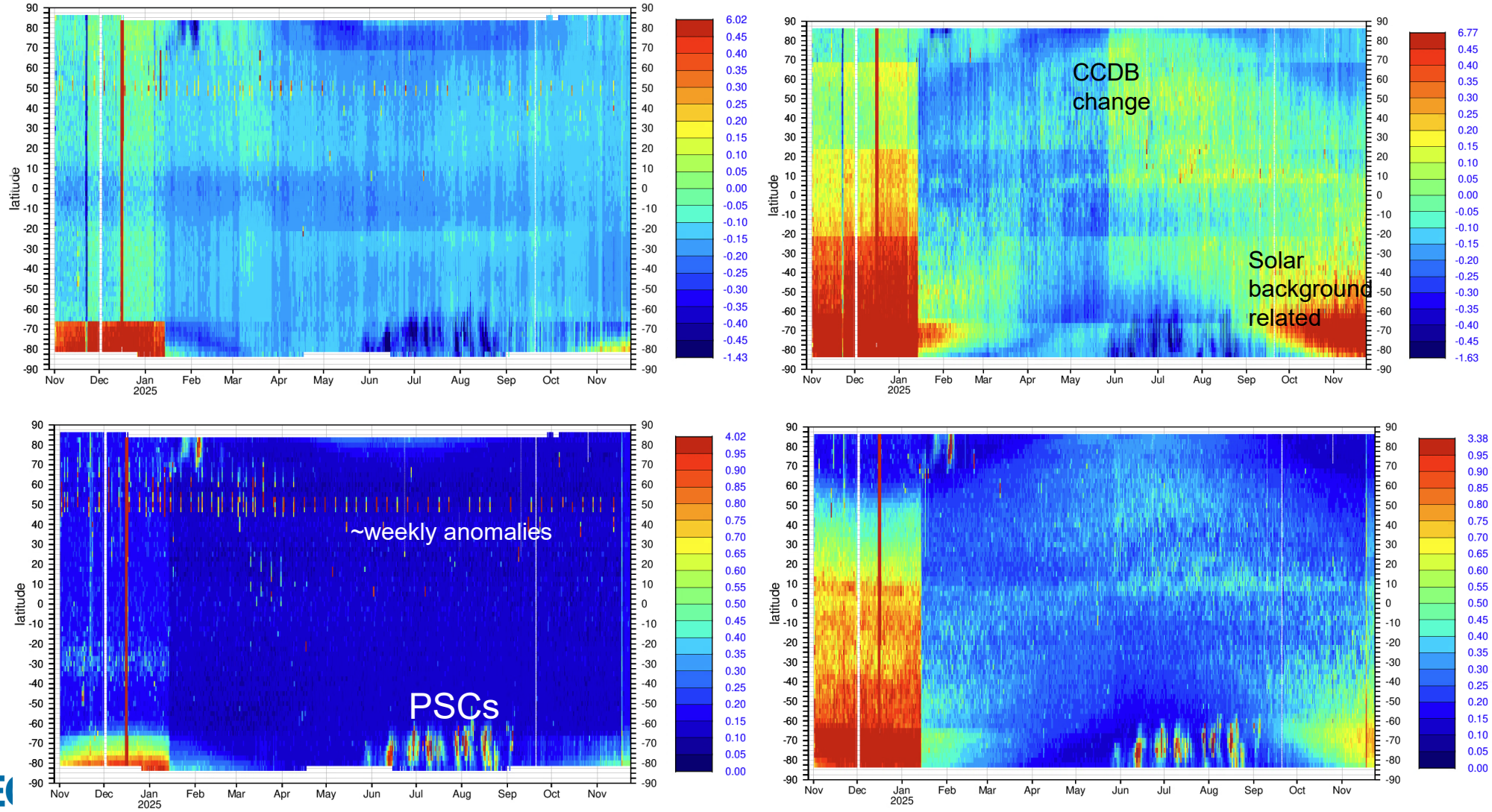
Monitoring data quality via departures: comparing observations to short-range forecasts – over a year of NRT **L1b Rayleigh ATB in stratosphere**

Ascending orbits (~night)

Descending orbits (~day)

Mean(ATLID – ECMWF)

Stdev(ATLID – ECMWF)



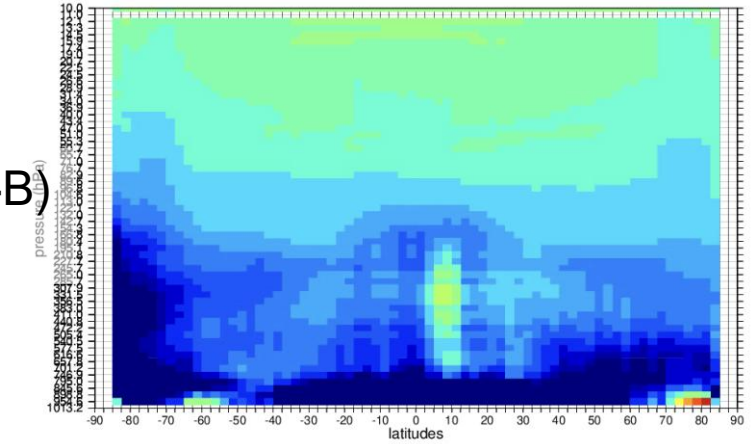
Zonally averaged *observation minus short-range forecast* departures

Rayleigh ATB (cloudy + ***clear***)

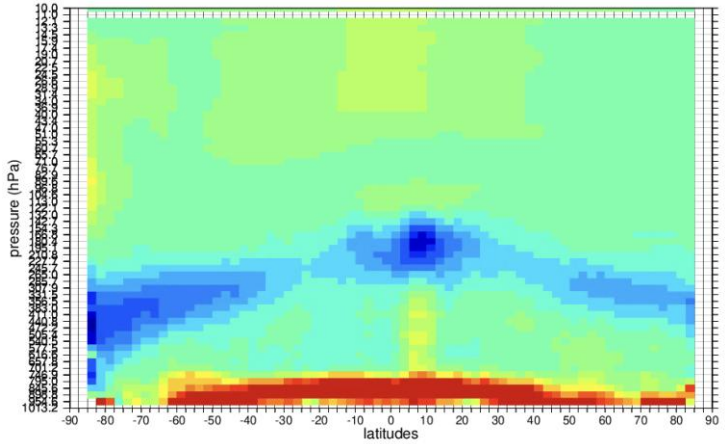
Total ATB (cloudy + ***clear***)

Extinction (cloud-only)

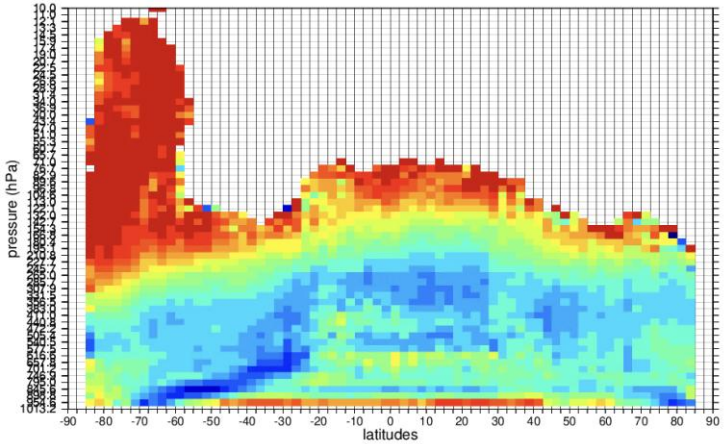
Mean(O-B)
i.e. bias



$\pm 1.0\ dB$

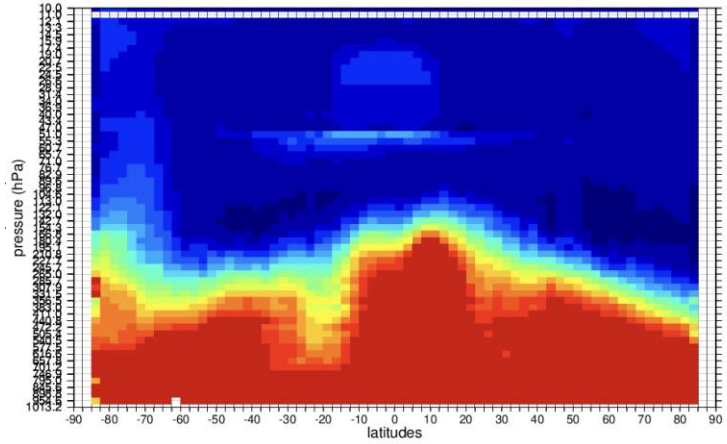


$\pm 2.5\ dB$



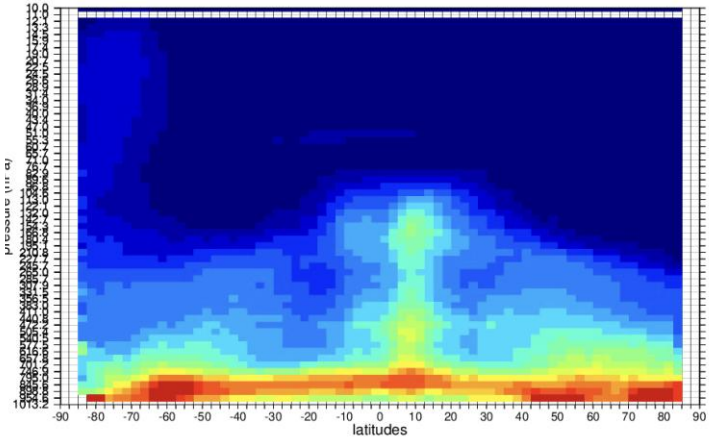
$\pm 8\ dB$

Stdev(O-B)
i.e. noise



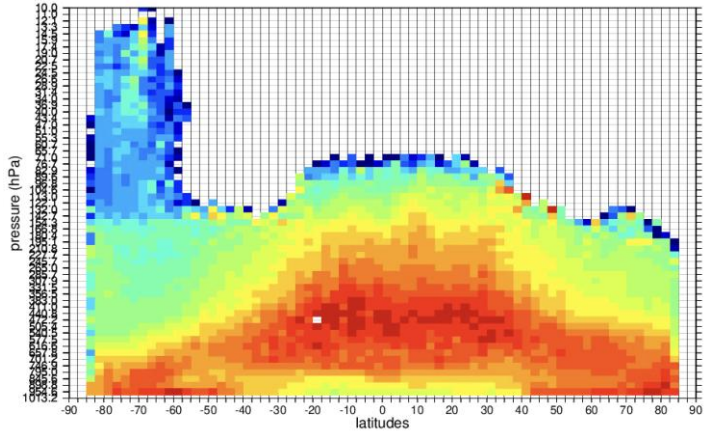
$0 - 2dB$

$dB(b_R)$



$0 - 8dB$

$dB(b_T)$



$0 - 14.5dB$

$dB(\alpha_{M,cloud})$