Monitoring and assimilation of the ATLID level 2 aerosol products in ECMWF's IFS-COMPO

Will McLean, ECMWF

With thanks to Mike Rennie, Mark Fielding, Angela Benedetti, and many other colleagues in ECMWF, Aeolus DISC, and the EarthCARE DISC.

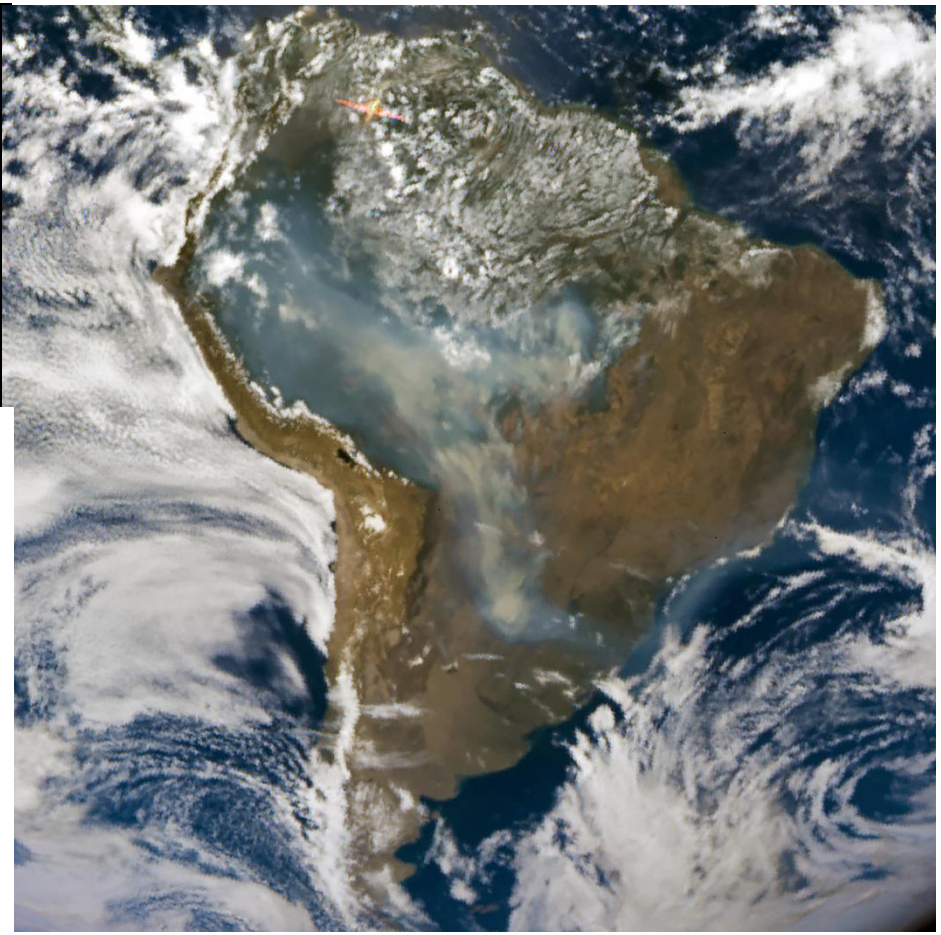
1st ESA-JAXA EarthCARE In-Orbit Validation Workshop

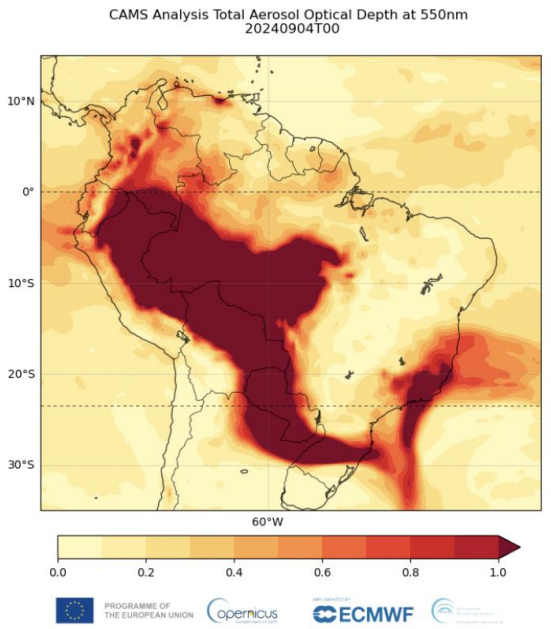
14 – 17 January 2025 | VIRTUAL EVENT

Why are we interested in using lidar aerosol products at ECMWF?

- IFS-COMPO is the system used by the Copernicus Atmosphere Monitoring Service (CAMS), assimilating satellite-retrieved Aerosol Optical Depth (AOD) datasets, reactive trace gases, and greenhouse gases. It has been used operationally since 2014 giving daily forecasts on air quality, and is used to produce multi-decadal reanalysis datasets.

- AOD is a column-integrated quantity, therefore does not yield a constraint on the altitude of an aerosol layer; this is why we need ATLID.





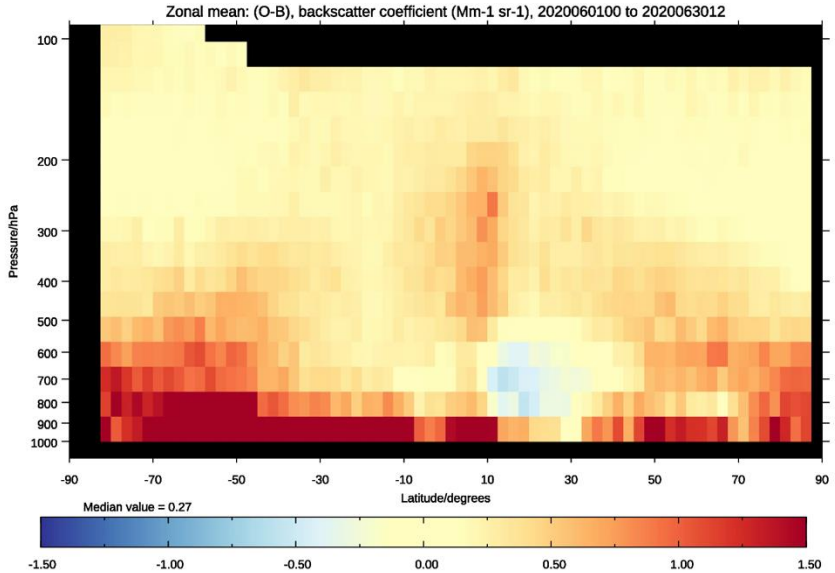
ECMWF

Smoke over South America, from NASA's DSCVR EPIC on 3 September 2024, and CAMS total AOD analysis, thanks to Mark Parrington's CAMS weather room analysis. https://earthobservatory.nasa.gov/images/153295/smoke-fills-south-american-skies

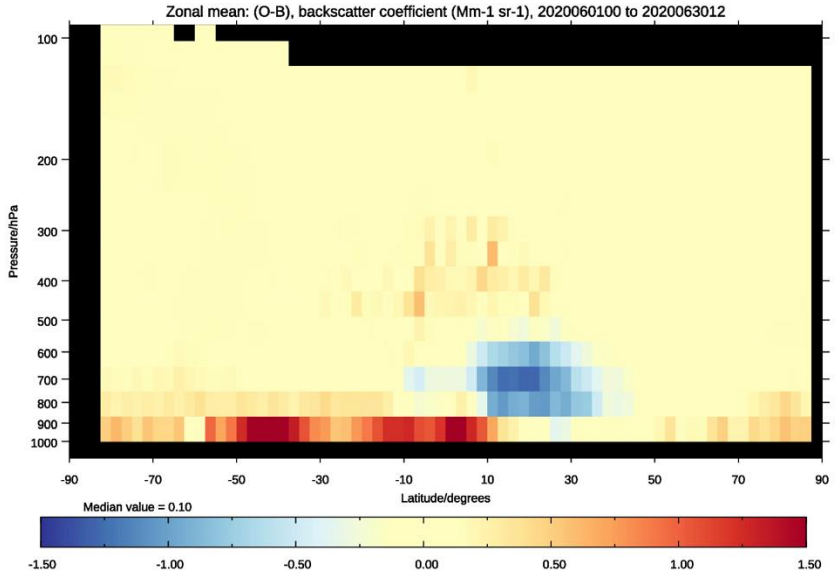
Heritage from Aeolus DISC activities

- During the last 18 months of the operational mission, ECMWF carried out assimilation of Aeolus level 2A particle backscatter, i.e. the total backscatter from the combination of cloud and aerosol.
- Even with a model-level cloud screening applied, the SCA mid-bin product was still significantly populated with cloud signal.
- Following the satellite re-entry, this work continued, with assessment of AEL-PRO retrieval created from the ATLID A-PRO algorithm adapted to work on Aeolus's ALADIN measurements.
- This work continues today, in phase F of the mission, with assessment of the AEL-PRO aerosol extinction and backscatter products and their impact in IFS-COMPO underway.

Zonal mean O-B for 1-30 June 2020



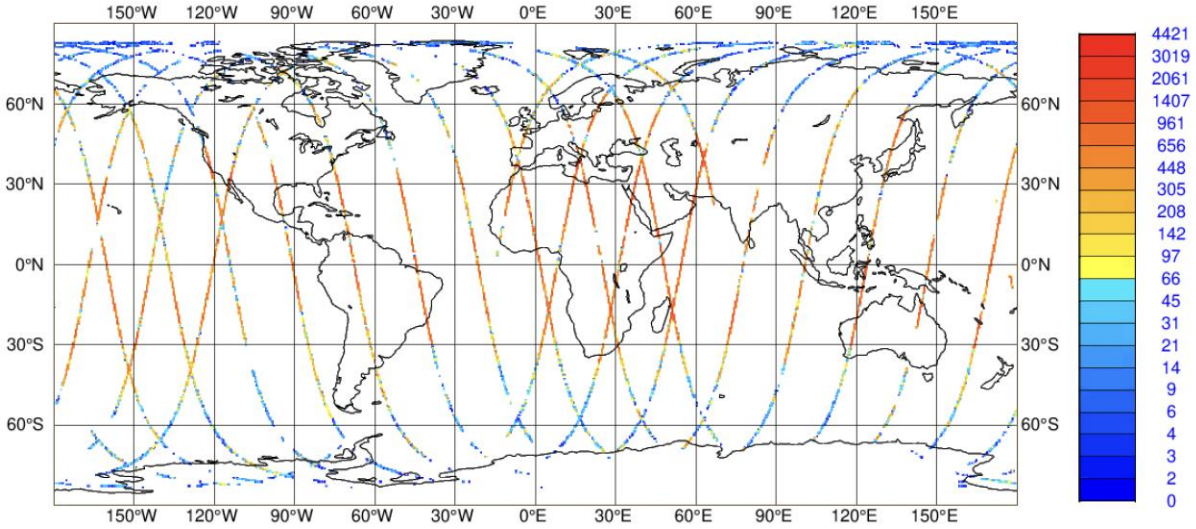
SCA mid-bin total backscatter



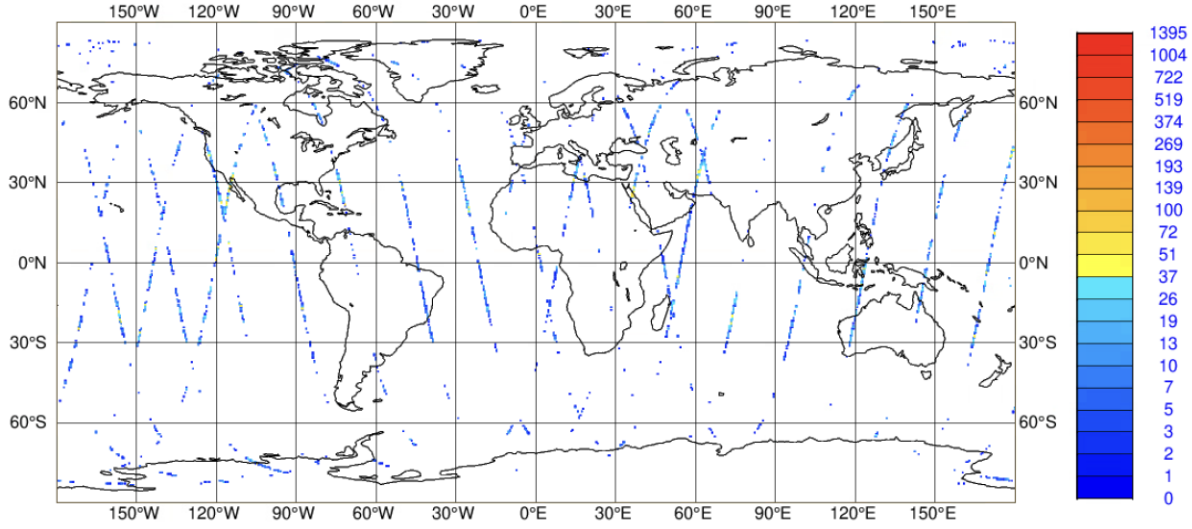
AEL-PRO total backscatter (aerosol classification only)

24 September 2024, first full day of monitoring and assimilation: data coverage in lower troposphere

ATLID EBD WITH CLOUD SCREENING
NUMBER OF OBSERVATIONS (ALL)
DATA PERIOD = 2024-09-23 00 - 2024-09-24 00
EXP =, LEVEL = 700.00 - 1013.25 HPA
Min: 0 Max: 2943 Mean: 793.0 Total: 2457920.0
GRID: 0.50x 0.50



ATLID EBD WITH CLOUD SCREENING
NUMBER OF OBSERVATIONS (USED)
DATA PERIOD = 2024-09-23 00 - 2024-09-24 00
EXP =, LEVEL = 700.00 - 1013.25 HPA
Min: 0 Max: 96 Mean: 23.1 Total: 17766.0
GRID: 0.50x 0.50



24 September 2024, first full day of monitoring and assimilation: data coverage at mid-tropospheric levels

ATLID EBD WITH CLOUD SCREENING
NUMBER OF OBSERVATIONS (ALL)
DATA PERIOD = 2024-09-23 00 - 2024-09-24 00
EXP =, LEVEL = 400.00 - 700.00 HPA
Min: 0 Max: 3518 Mean: 1110.8 Total: 1825039.0
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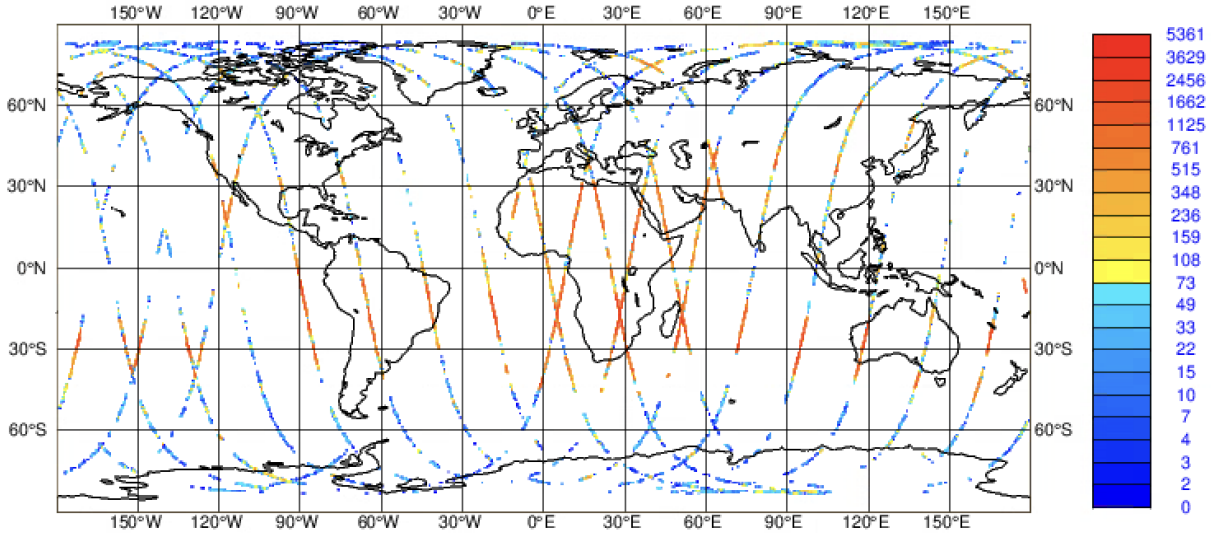
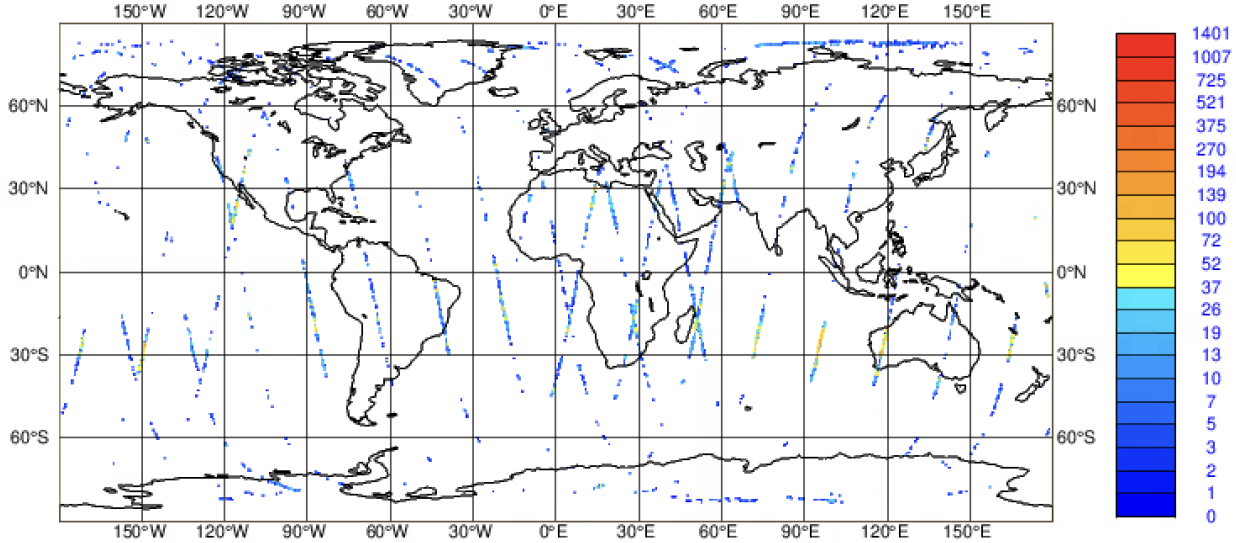


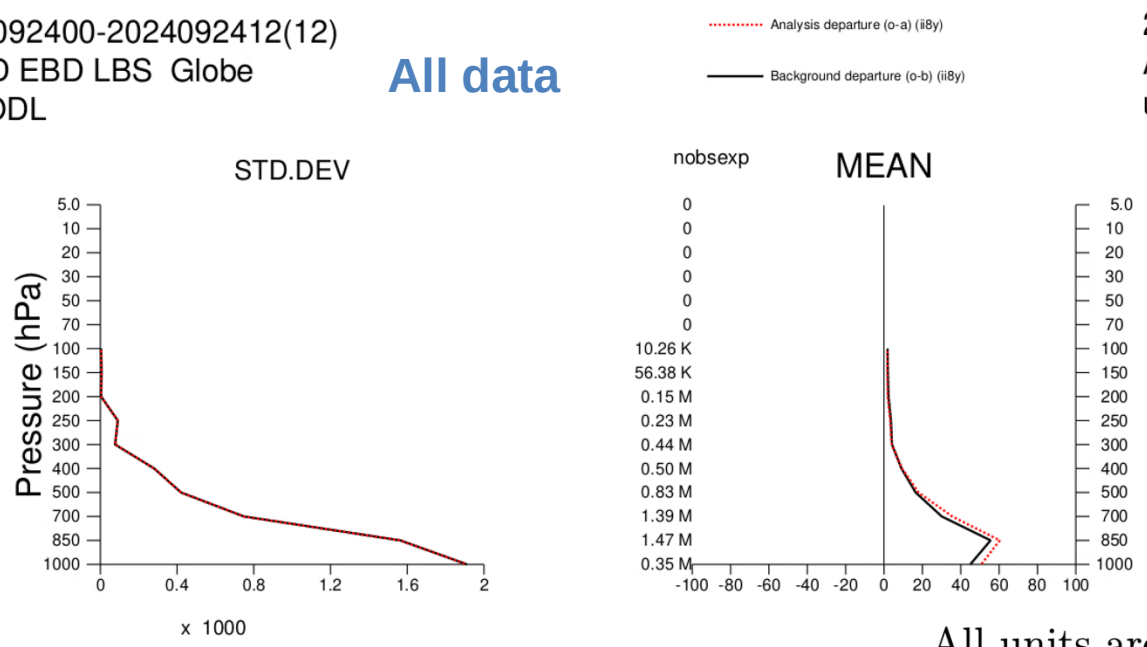
ATLID EBD WITH CLOUD SCREENING
NUMBER OF OBSERVATIONS (USED)
DATA PERIOD = 2024-09-23 00 - 2024-09-24 00
EXP =, LEVEL = 400.00 - 700.00 HPA
Min: 0 Max: 231 Mean: 43.3 Total: 26494.0
GRID: 0.50x 0.50



24 September 2024: first look at departure statistics for L2A EBD backscatter

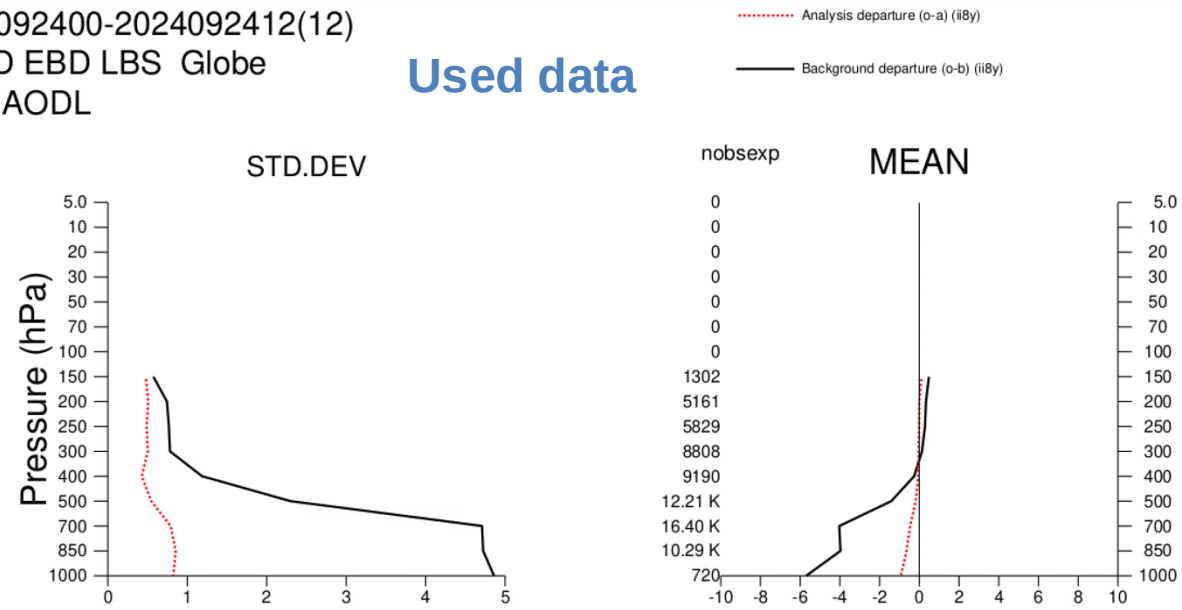
2024092400-2024092412(12)
ATLID EBD LBS Globe
all AODL

All data



2024092400-2024092412(12)
ATLID EBD LBS Globe
used AODL

Used data

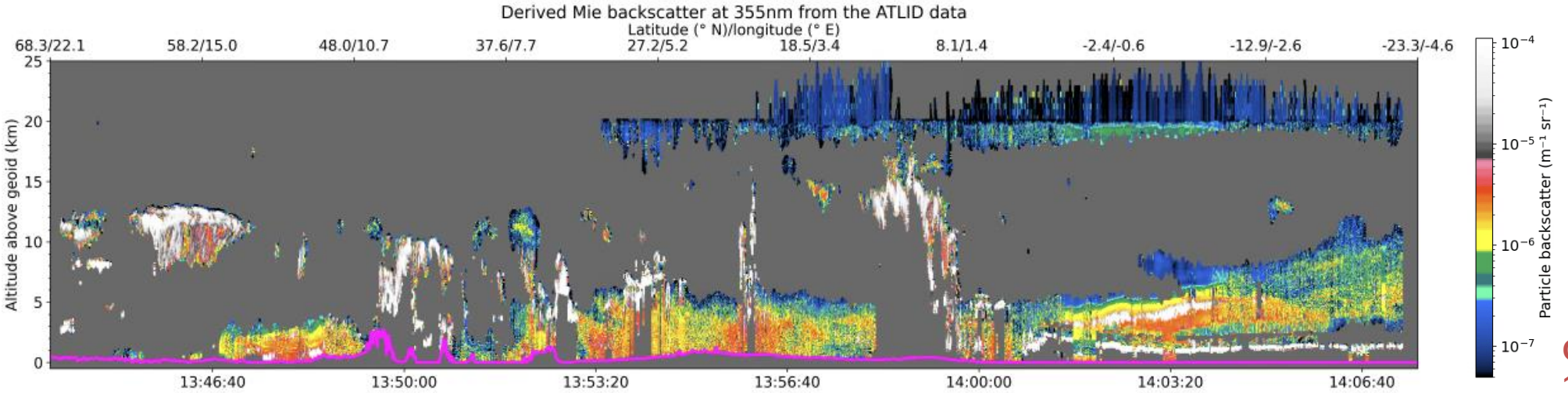


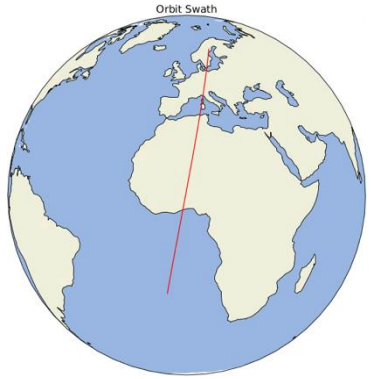
All units are in $10^{-7}\,\mathrm{m}^{-1}\mathrm{sr}^{-1}$.

Black shows the first-guess departures, O-B.
Red lines show the analysis departures, O-A.

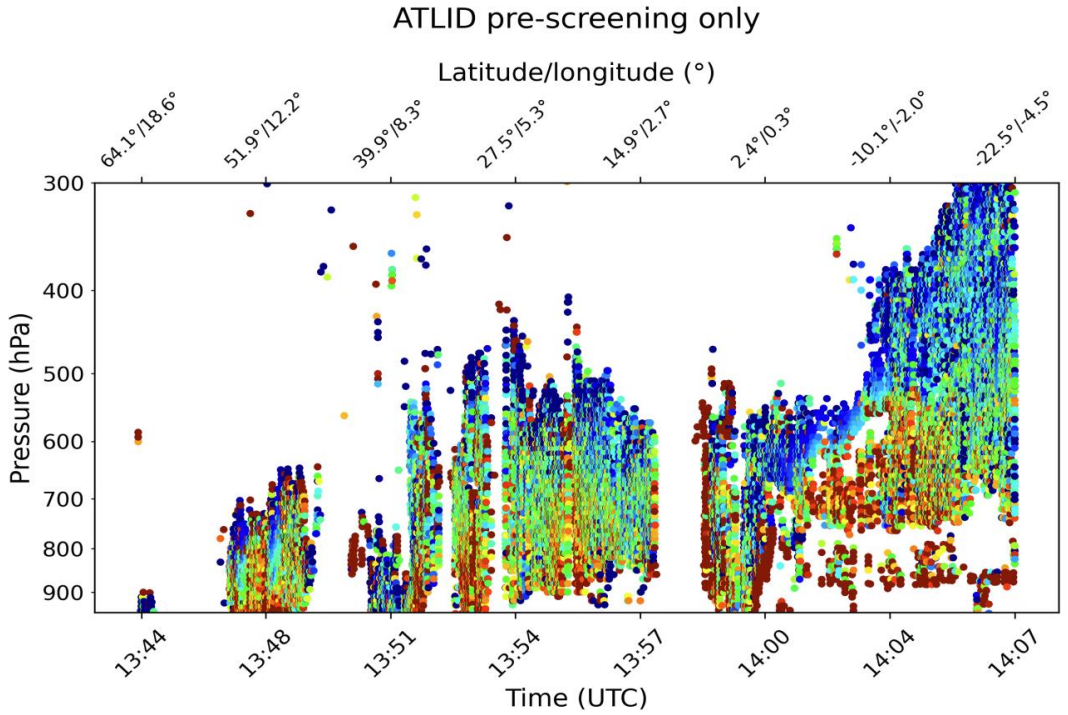
This experiment uses a fixed, constant error of 5E-8, i.e. the analysis is purposefully overweighted.

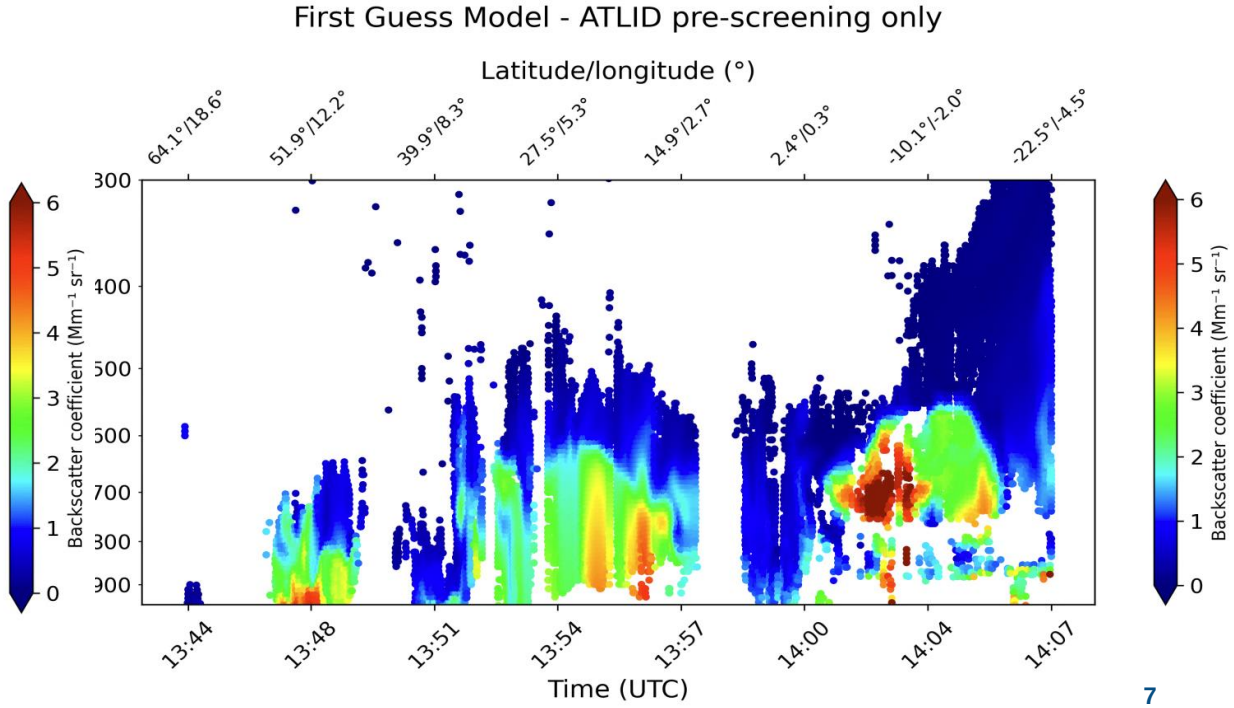
Monitoring and assimilation of ATLID L2A aerosol backscatter in IFS-COMPO: 18 September 2024





Orbit swath from 13.45 - 14.07, 18 September 2024

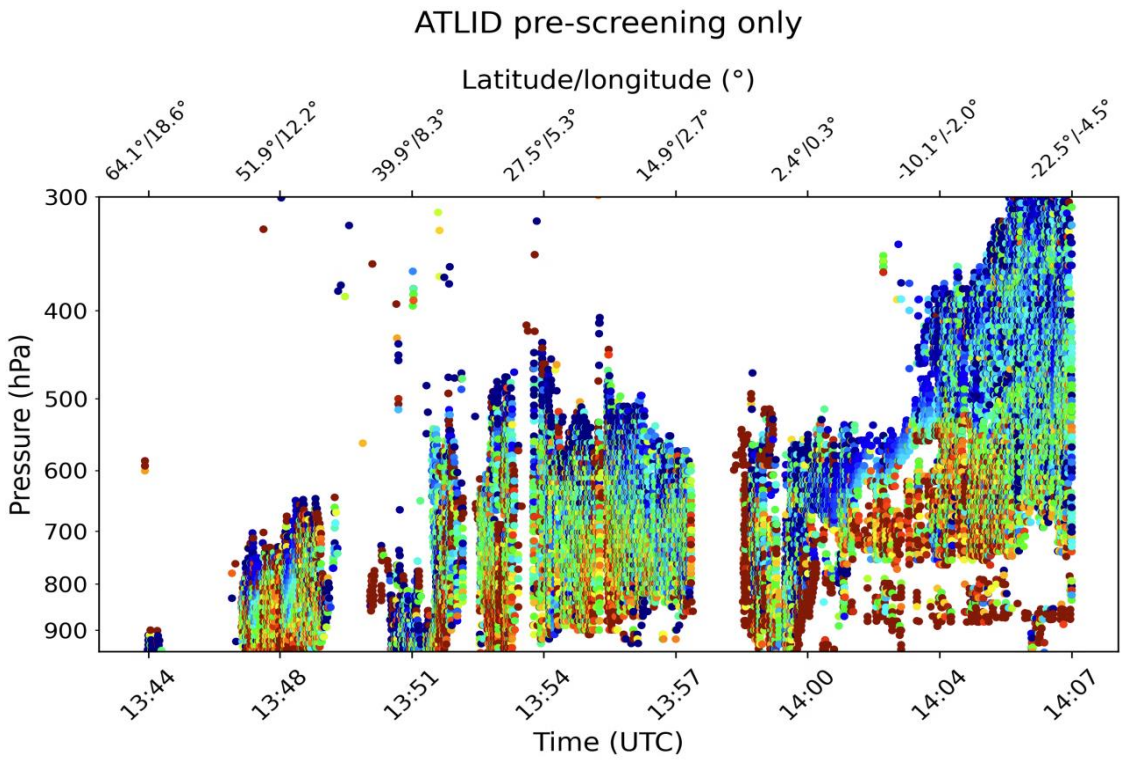


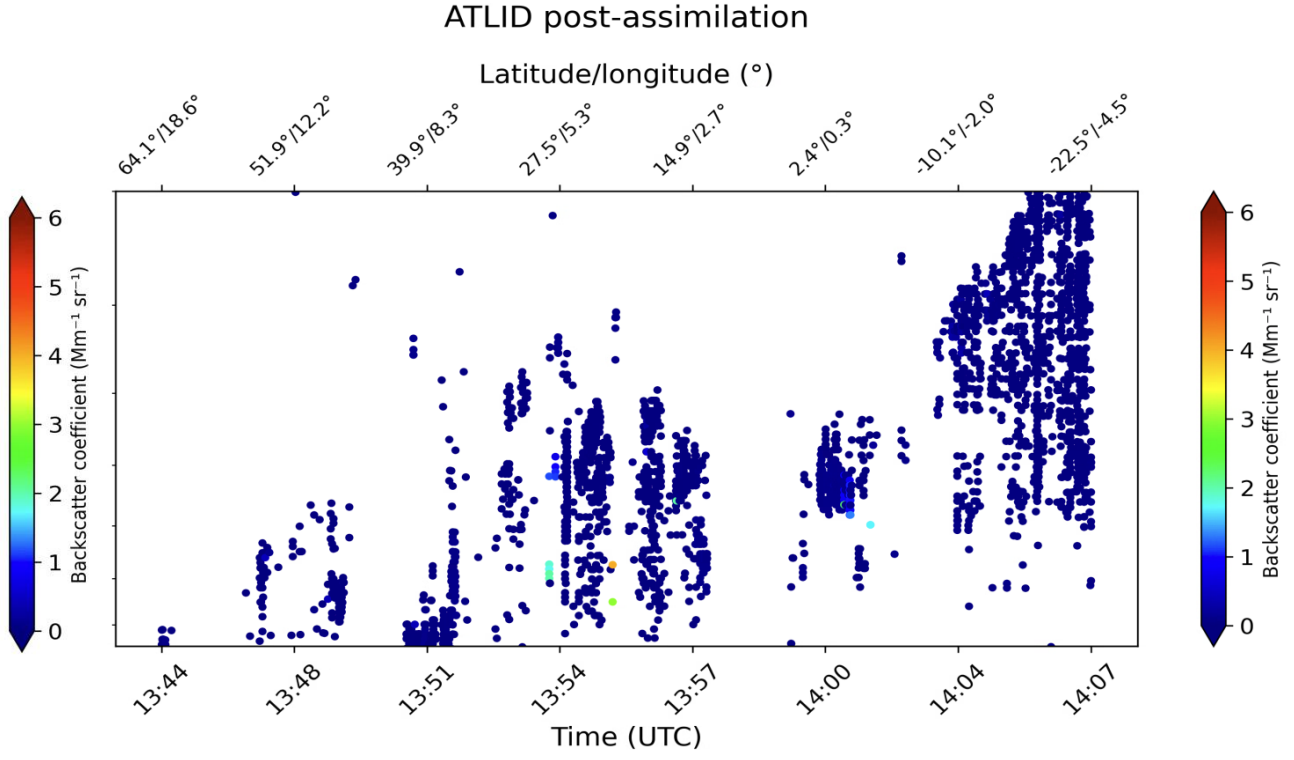


Assimilation test 1: small, fixed observation error (giving a high weighting to the ATLID data in the IFS)

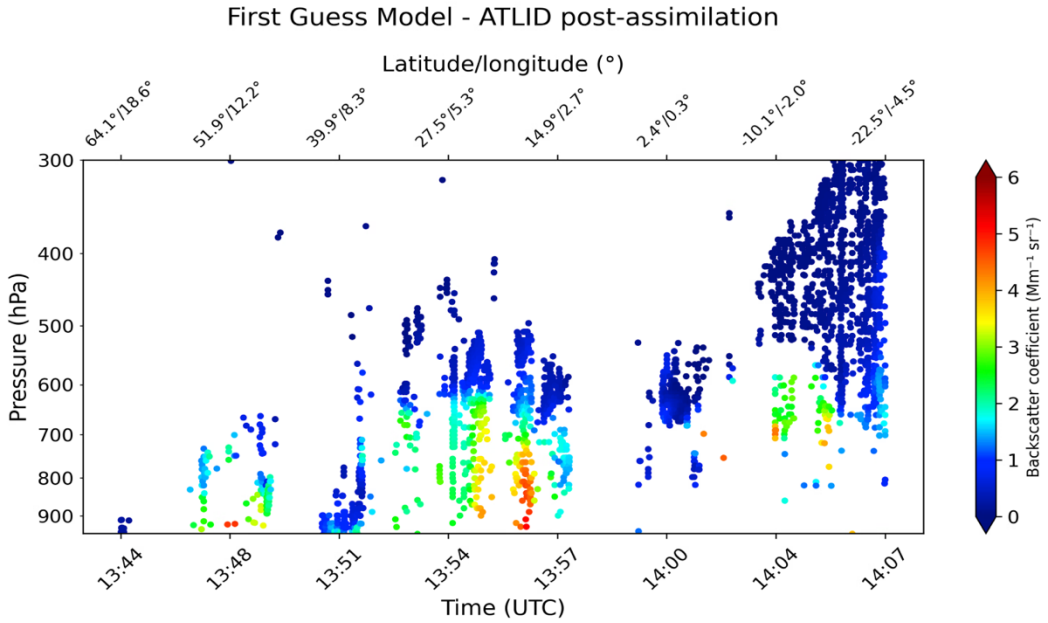
- Left: ATLID L2 EBD aerosol backscatter, along the swath with pressure in hPa (capped at 300hPa; ~9km). Units are $(\mathrm{Mm\ sr})^{-1}$, with only pre-screening carried out in the offline data grouping.

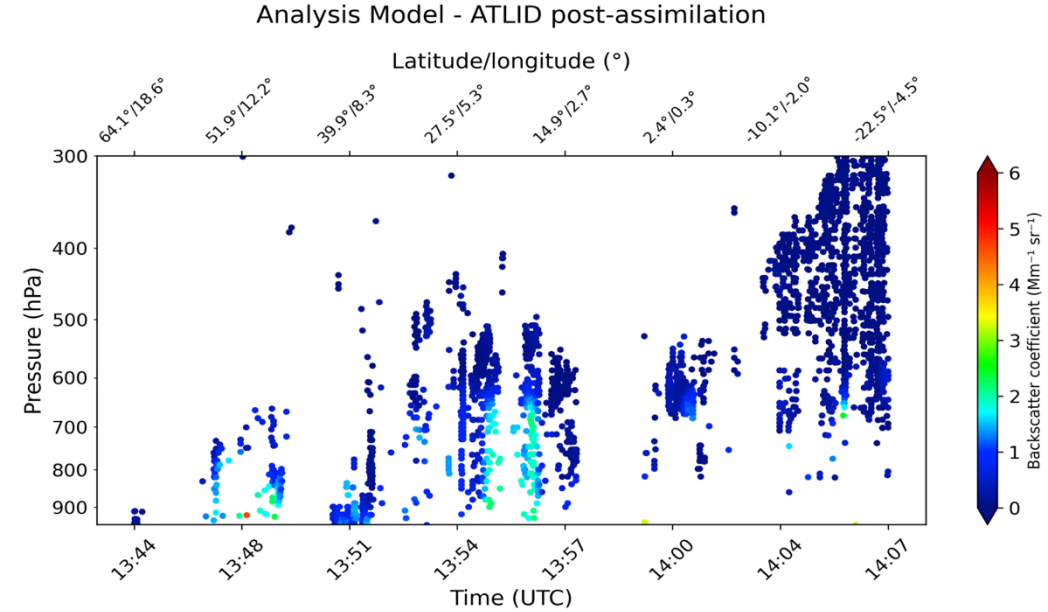
- Right: remaining data following assimilation in IFS-COMPO. Here we are overweighting the data, which heavily draws the analysis to ATLID, with the large reduction of data resulting from how the observations are handled in the IFS; a high weighting reduces the observation counts until the analysis is sufficiently close to ATLID.

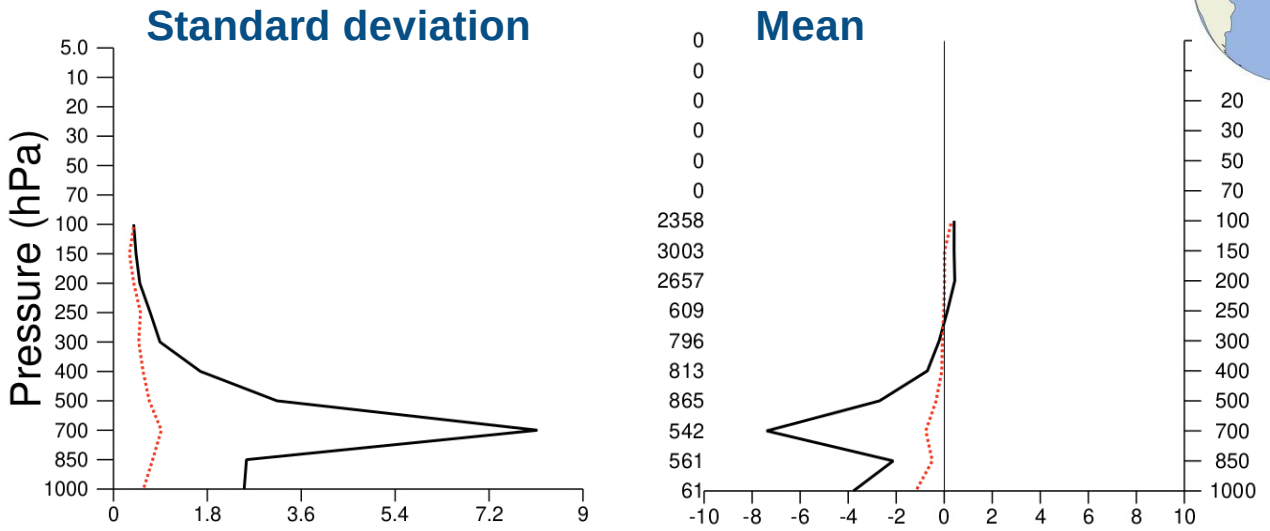




Assimilation test 1, small observation error (continued)





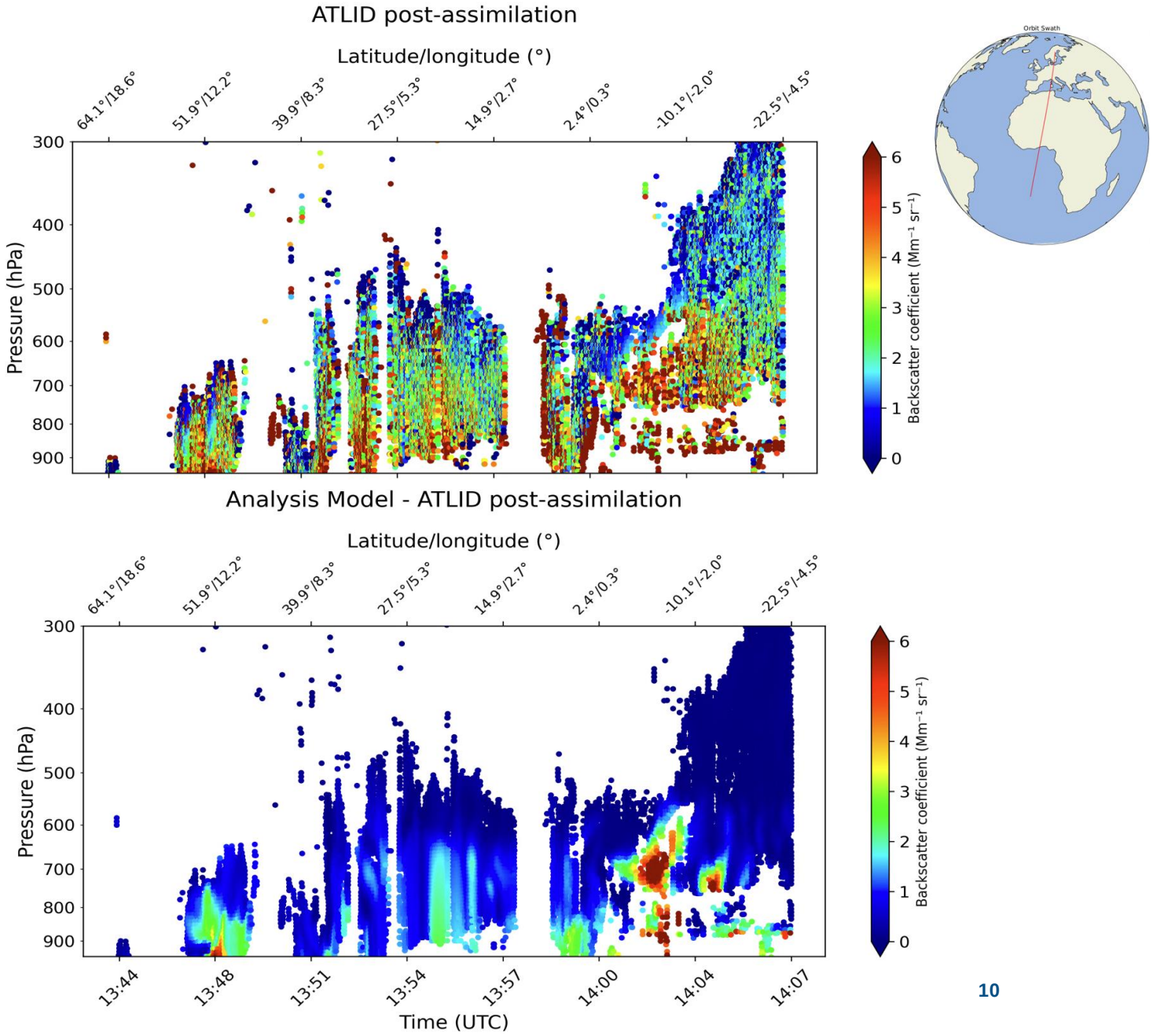


O-B and O-A; units are $10^{-7}(\mathrm{m\ sr})^{-1}$.

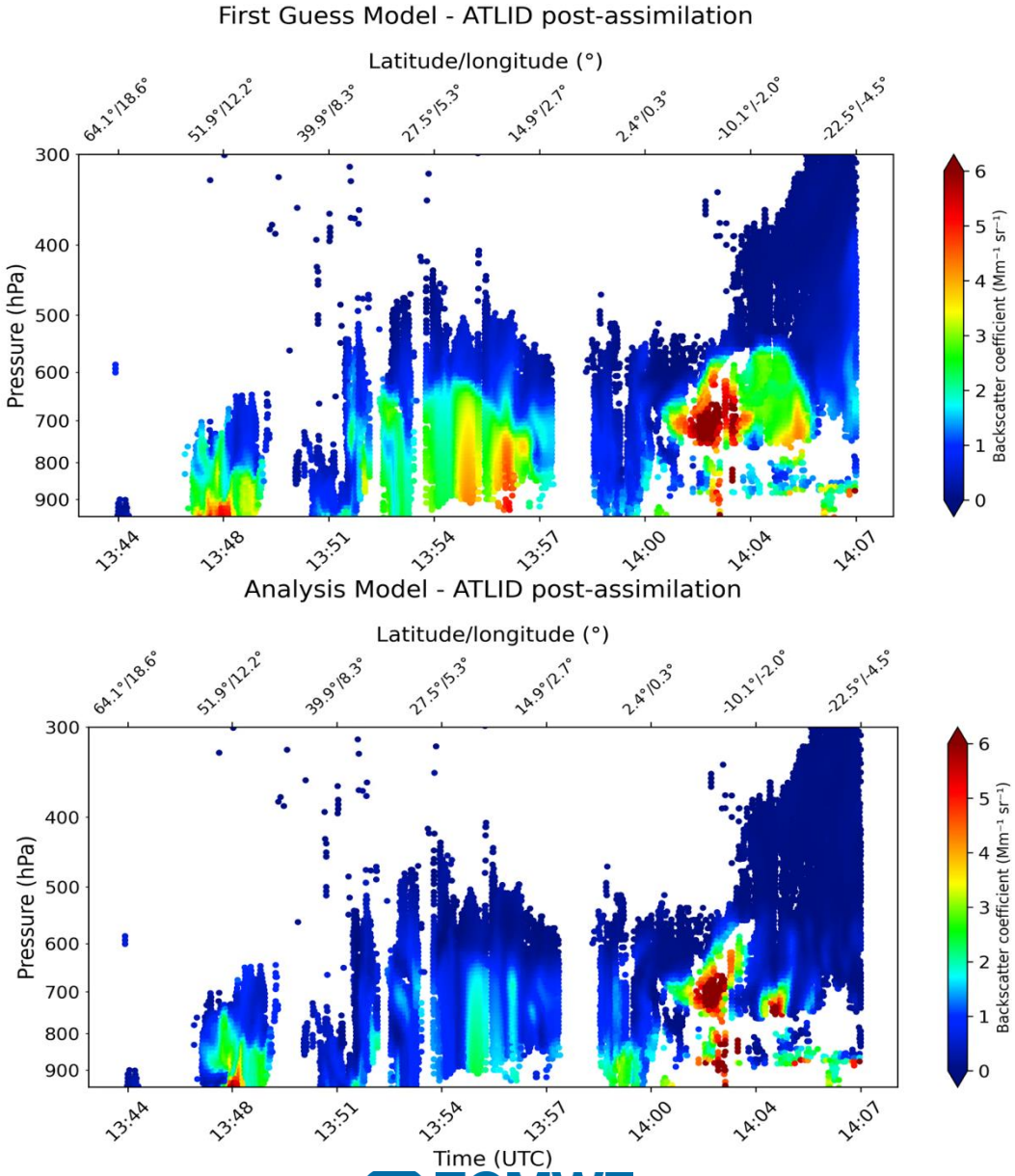
Vertical profiles of the global standard deviation and mean first-guess departures (black) and analysis departures (red), i.e. the difference between ATLID and the IFS-COMPO aerosol backscatter with no ATLID assimilation, and the difference between ATLID and the IFS-COMPO aerosol backscatter with assimilation, respectively.

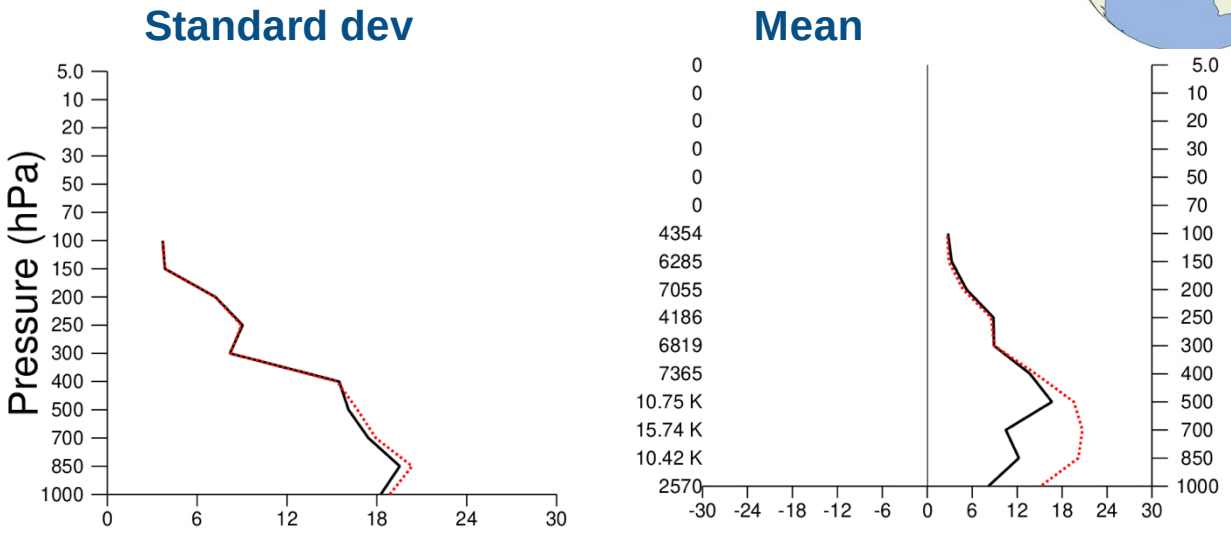
Case 2: assimilation with an inflated observation error, giving a low weighting to the ATLID data

- Top: ATLID L2 EBD aerosol backscatter following assimilation with a large observation error, along the swath with pressure in hPa (capped at 300hPa; ~9km). Units are $(\mathrm{Mm\ sr})^{-1}$.
- Bottom: ECMWF model aerosol backscatter calculated from assimilation of ATLID (the analysis).
- A large observation error results in a degradation of the analysis, as the 4D-Var does not discard the majority of data to overfit the analysis to ATLID as in the low error case.



Assimilation test 2, small observation error (continued)





O-B and O-A; units are $10^{-7}(\mathrm{m\ sr})^{-1}$.

Vertical profiles of the global standard deviation and mean first-guess departures (black) and analysis departures (red), i.e. the difference between ATLID and the IFS-COMPO aerosol backscatter with no ATLID assimilation, and the difference between ATLID and the IFS-COMPO aerosol backscatter with assimilation, respectively.

Summary and outlook

- PEARL cloud and aerosol project**:** focussed on preparing ECMWF's integrated forecasting system in atmospheric composition setup (IFS-COMPO) for monitoring and assimilation of the ATLID level 2 aerosol backscatter and extinction profiles.

- Initial monitoring of the L2 aerosol products has commenced, with pre-operational near-real time monitoring of the products in the framework of the EarthCARE DISC beginning as soon as the code upgrades are finalised, along with porting of these developments to the next (and now current ECMWF operational version) CY49R1.

- Pre-operational assimilation of the L2 aerosol backscatter and extinction will be carried out in parallel with the monitoring, with the impact on the aerosol fields assessed and verified against ground-based AERONET and lidar stations.

Thank you!