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Advancing Ocean and Land Surface Remote Sensing with EarthCARE's lidar ATLID

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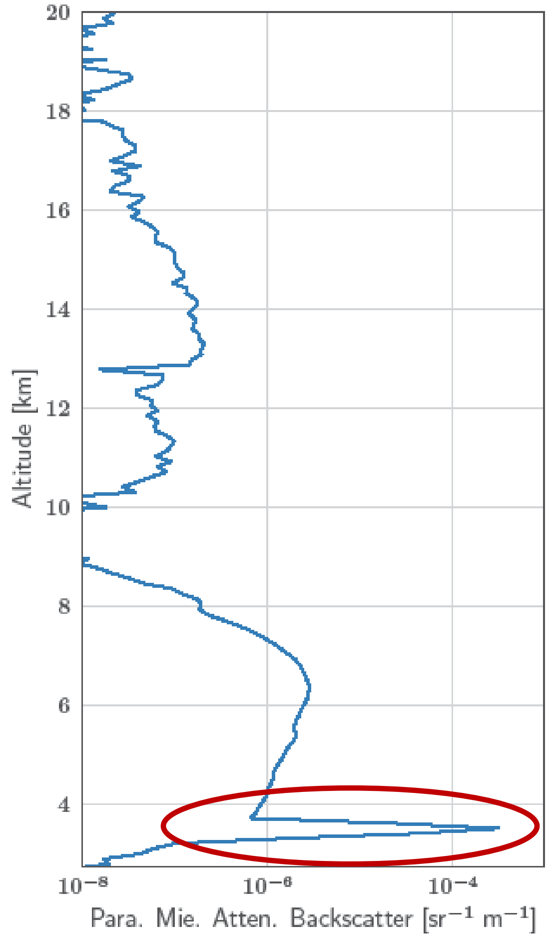
EarthCARE ATLID surface returns

- The lidar surface returns are in general much larger than the atmospheric returns above, resulting in high SNR when used for retrievals.
- The co-polar Mie integrated attenuated surface returns combined with the ECMWF wind information are compared to ocean surface BRDF/reflectance models (e.g. Cox-Munk, Hu 2008) to retrieve the atmospheric Optical Thickness



Frame 7000G (Antarctica)
500 km averaged signals

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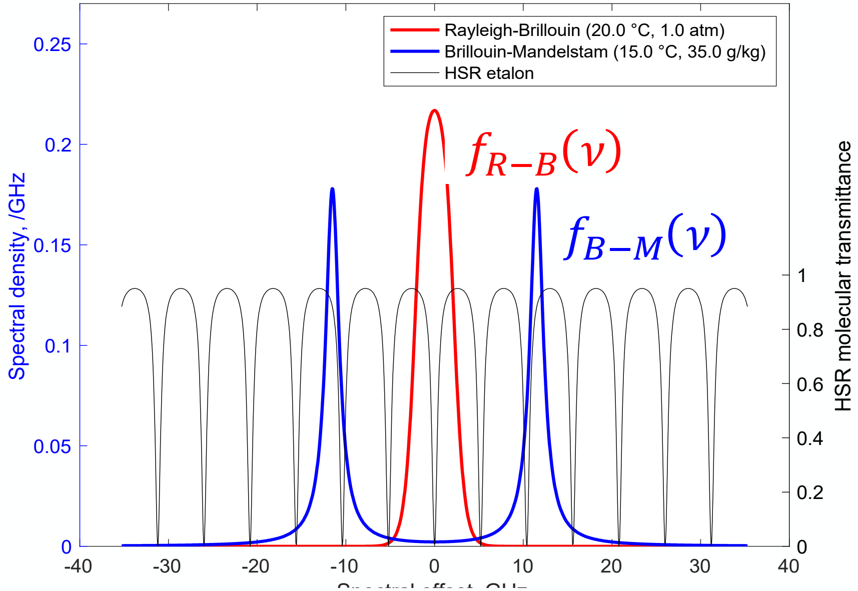
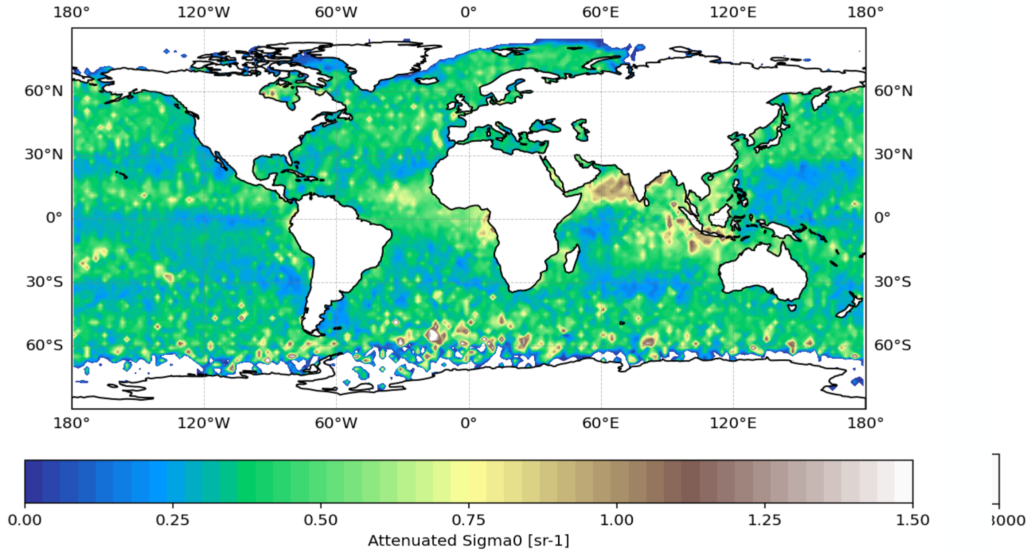
- The co-polar Mie integrated attenuated surface returns combined with the ECMWF wind information are compared to ocean surface BRDF/reflectance models (e.g. Cox-Munk, Hu 2008) to retrieve the atmospheric Optical Thickness
- Part of the lidar backscatter is through Brillouin scattering which arises from the interaction of light with acoustic (density) waves. For air this ‘overlaps’ with the lidar direct backscatter. In water the frequency shift is a lot larger and signal shifts to the Rayleigh channel.
- The ATLID Rayleigh channel design makes it (fortunately) a sub-surface water detector which is sensitive to the extinction within the water.
- Using the Optical Thickness the unattenuated surface returns can be retrieved.



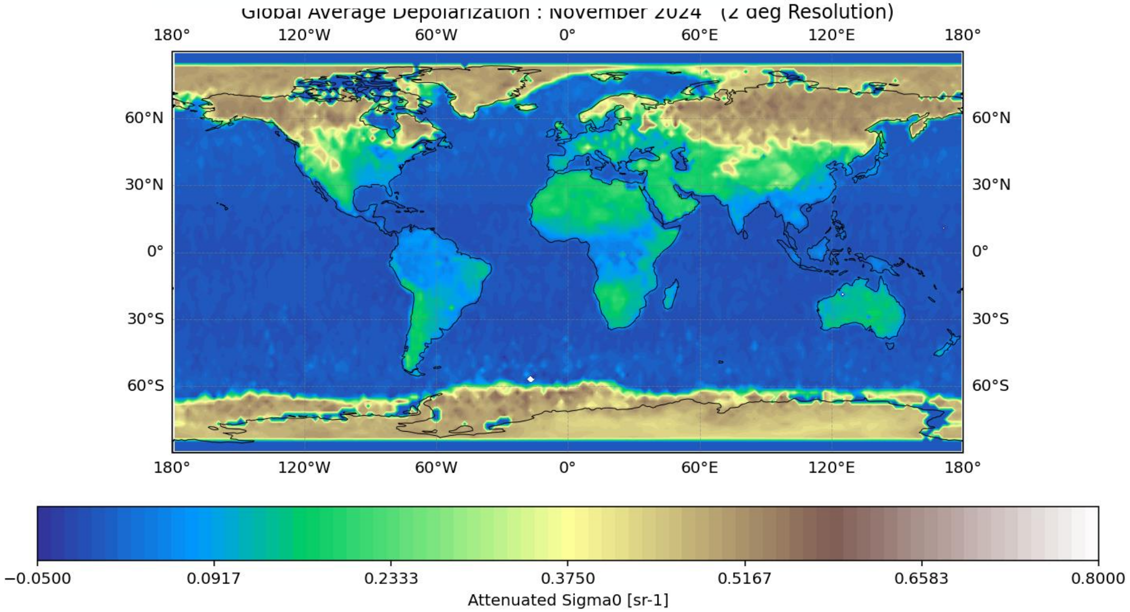
R-B: Rayleigh-Brillouin (air molecule scatter)
B-M: Brillouin-Mandelstam (water molecule scatter)

Surface returns November 2024:
(median in 2x2 deg grid)

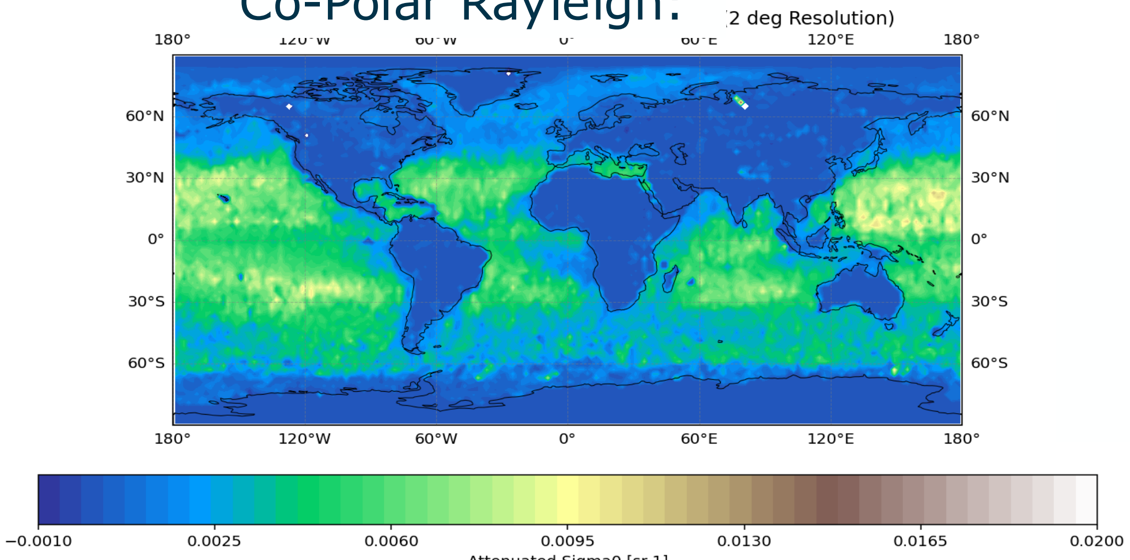
Atmospheric Optical Depth



Surface Depolarization



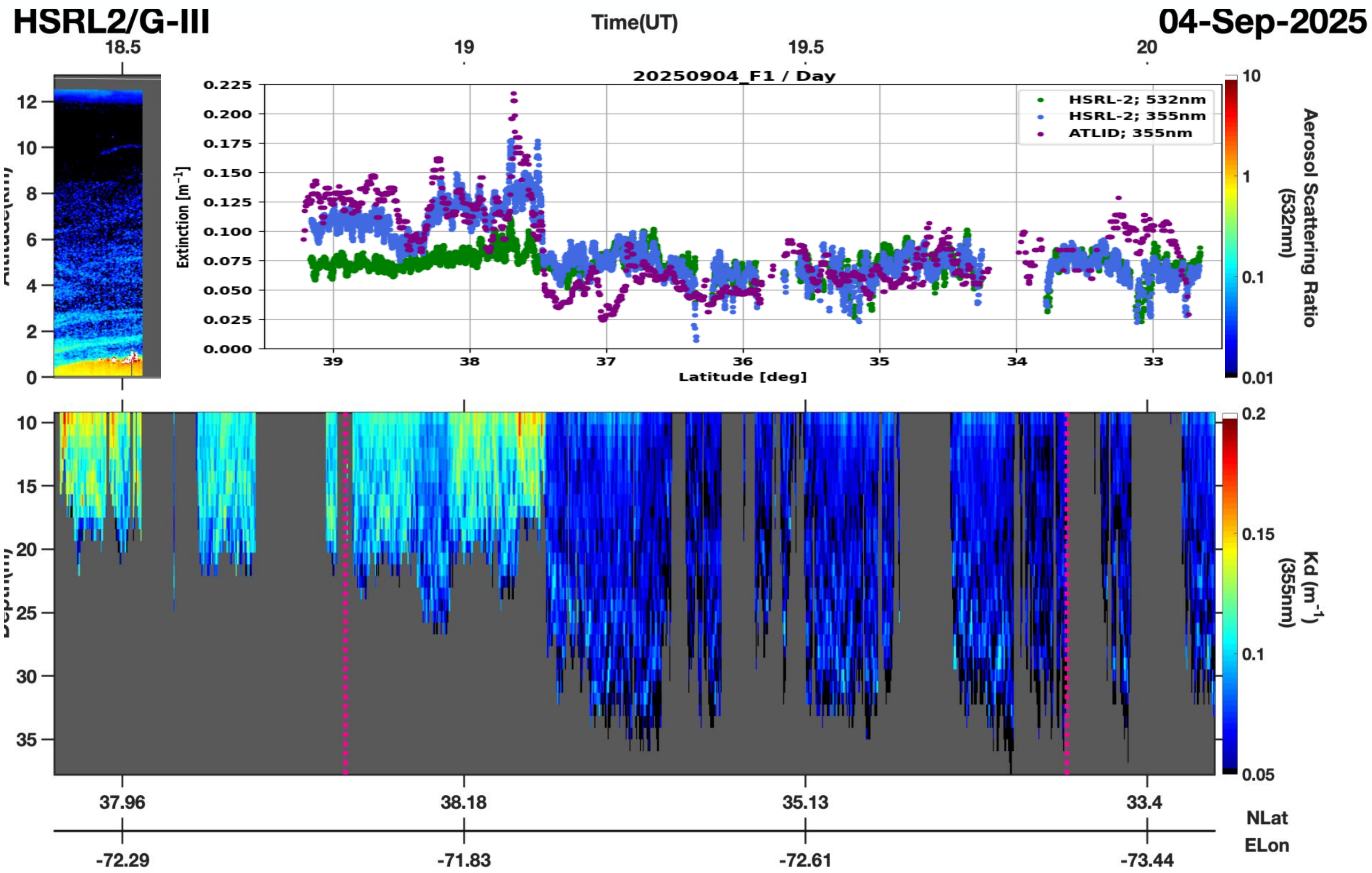
Co-Polar Rayleigh:



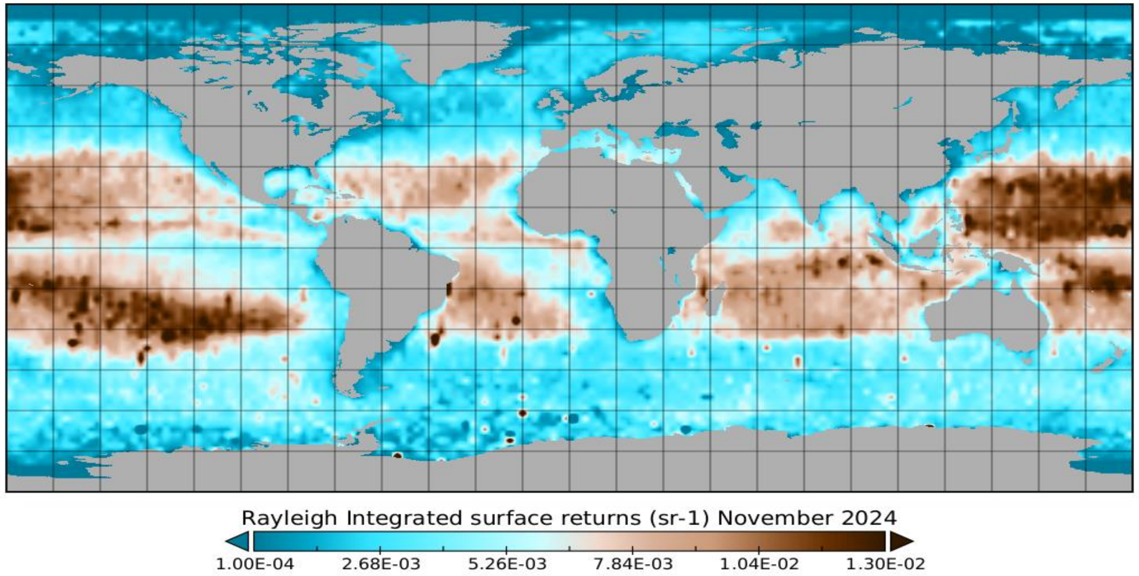
- Co Polar Mie channel → Retrieval of OT
- Rayleigh channel → sub-surface water detection (sensitive to extinction due to e.g., chlorophyll-a, CDOM).
- Cross-Polar / Co-Polar → surface depolarization (separation ice, land(type) & water)

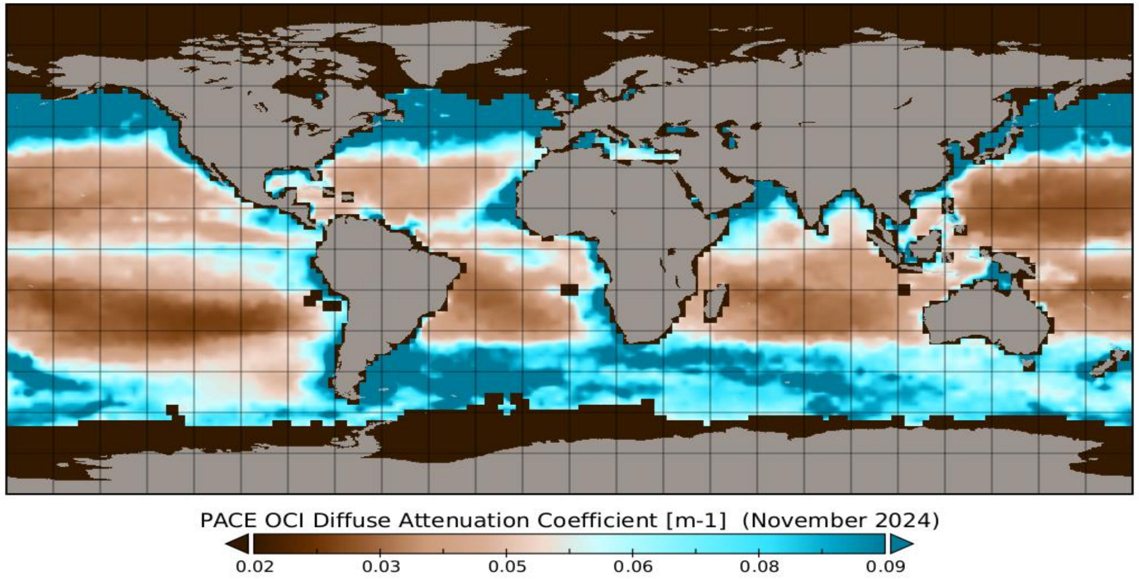
Subsurface return evaluation from the NASA NightBLUE Campaign using the HSRL-2 (04-09-2025)

- HSRL-2 retrievals of ocean extinction (532 and 355 nm) at 10 m depth
- ATLID retrievals of ocean extinction (355 nm) from the integrated molecular backscatter channel.
- North of 37.5 degrees latitude 355 nm extinction increased independently of 532 nm extinction in a region of coastal water high in UV absorbing Colored Dissolved Organic Matter (CDOM) advected offshore by the Gulf Stream.

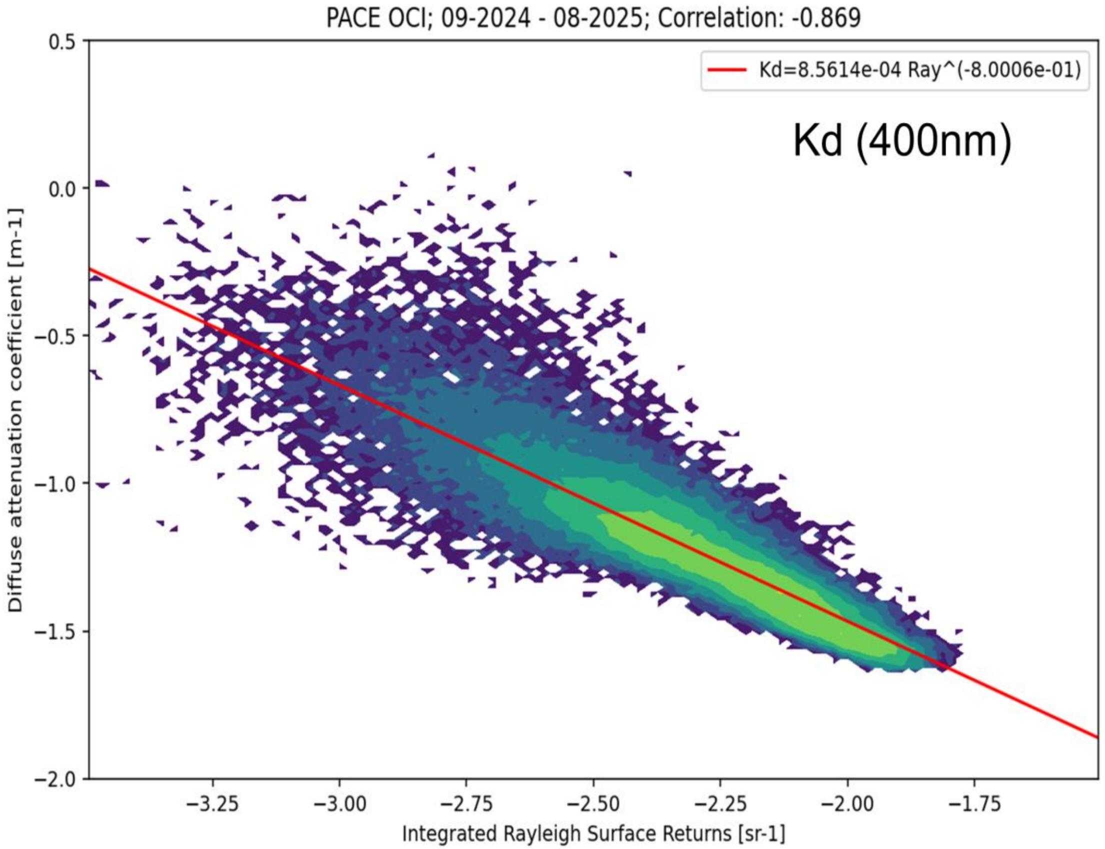


Comparing unattenuated Rayleigh signals to Chlorophyll-a and Diffuse Attenuation Coefficient





Histogram of all 12 months



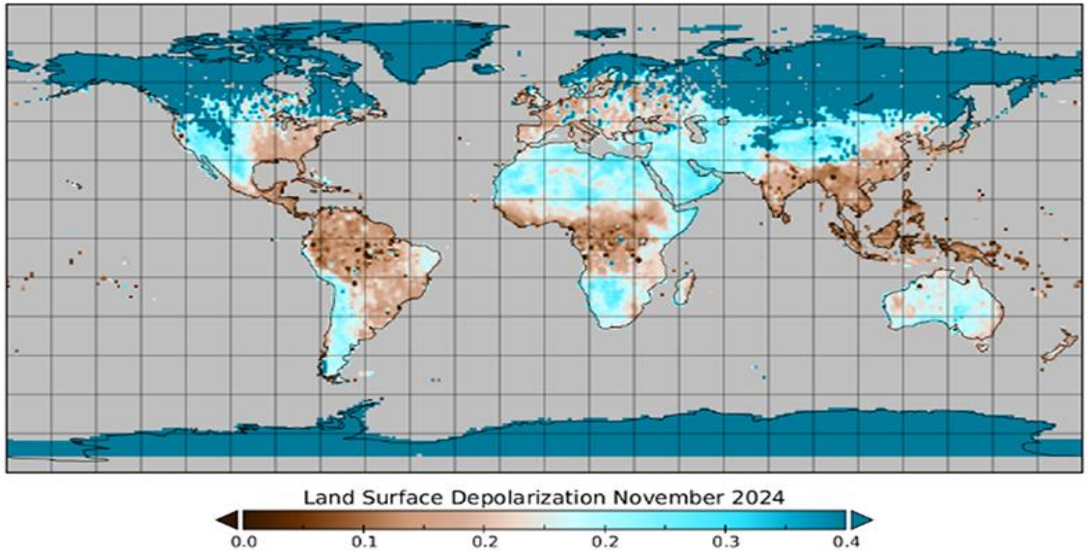
For a well mixed ocean surface with near constant chlorophyll concentration in the first ~1 optical depths

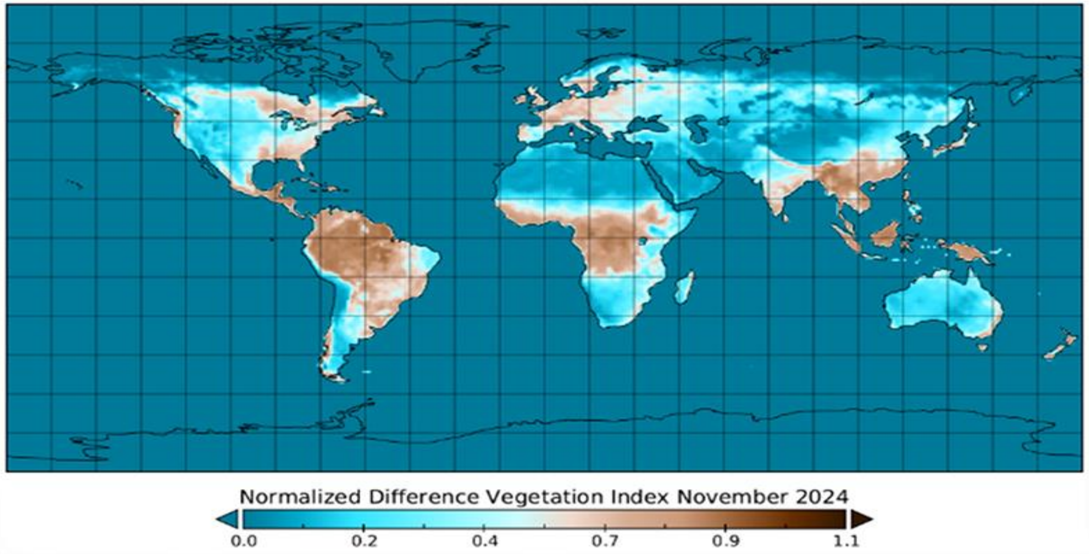
$$chl \cong 11.93\left(\frac{T_S{}^2}{n^2 FR}\frac{\beta_{B-M}}{2\gamma_{R-B}} - 0.0239\right)^{1.303} \quad [\mathrm{mg/m^3}]$$

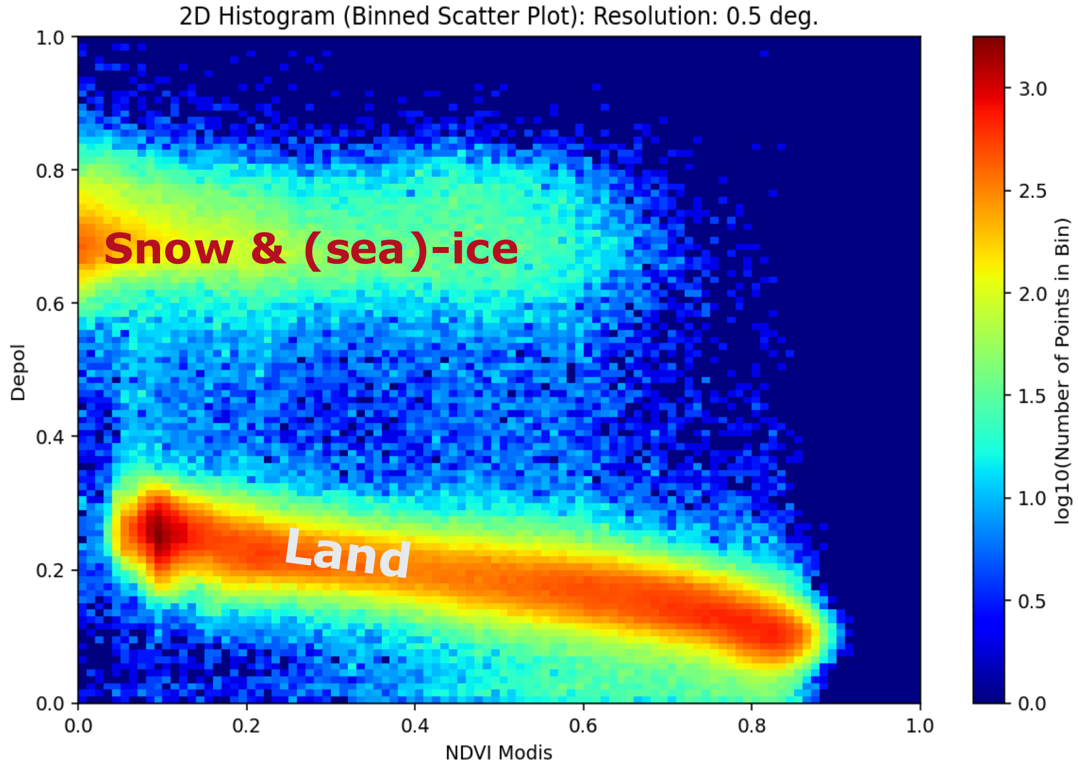
(dashed line uses 1.2 instead of 1.303)

Use of surface depolarization returns

- OD can not be directly retrieved over land using Mie signals
- For Depolarization signals however all OT effect fall away and can be directly used to separate snow/ice from land & ocean
- Well correlated with the vegetation index NDVI over land

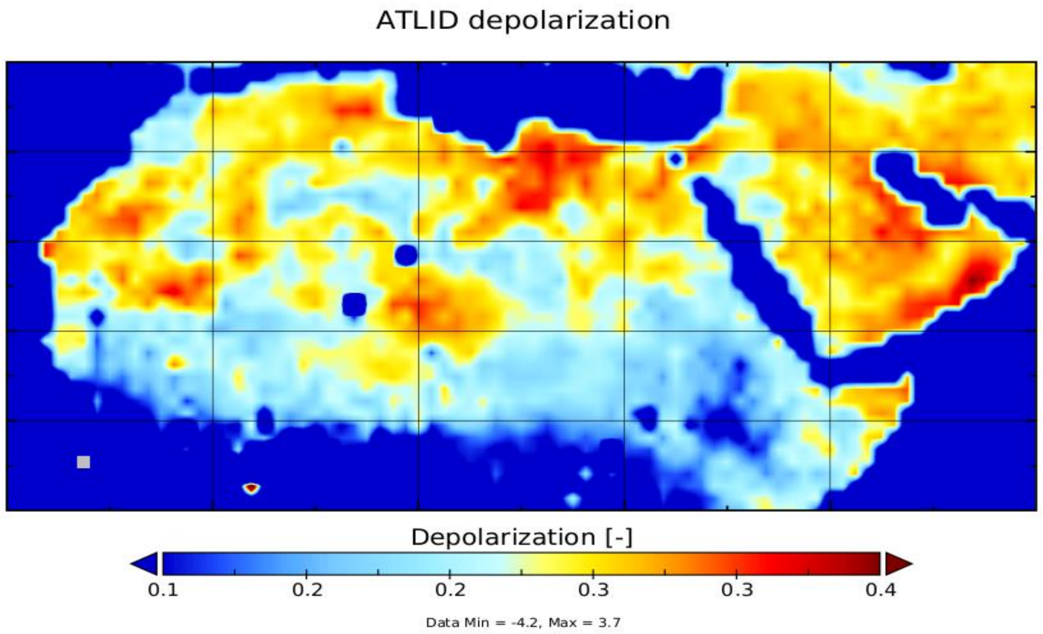


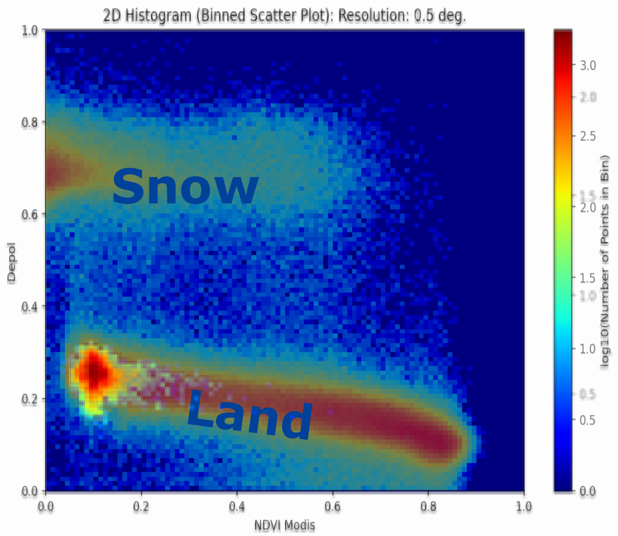


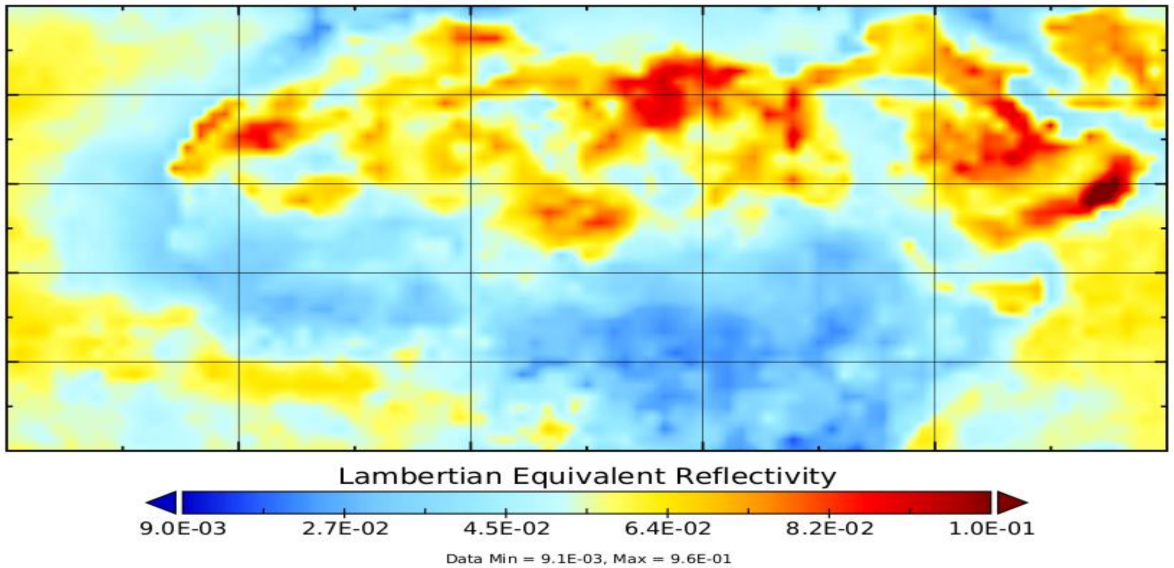


Zooming in on the Sahara (May 2025)

- The Sahara/Middle East regions have the lowest NDVI and high surface depolarization.
- When zooming in, large variations and structures in the depolarization signal can be seen.
- These structures resemble the variations seen in the albedo as shown in the Lambertian Equivalent Reflectivity at 340nm from TropOMI.
- This suggests that ATLID depol. can potentially be used to improve the dessert albedo for the EarthCARE 3D-RT.





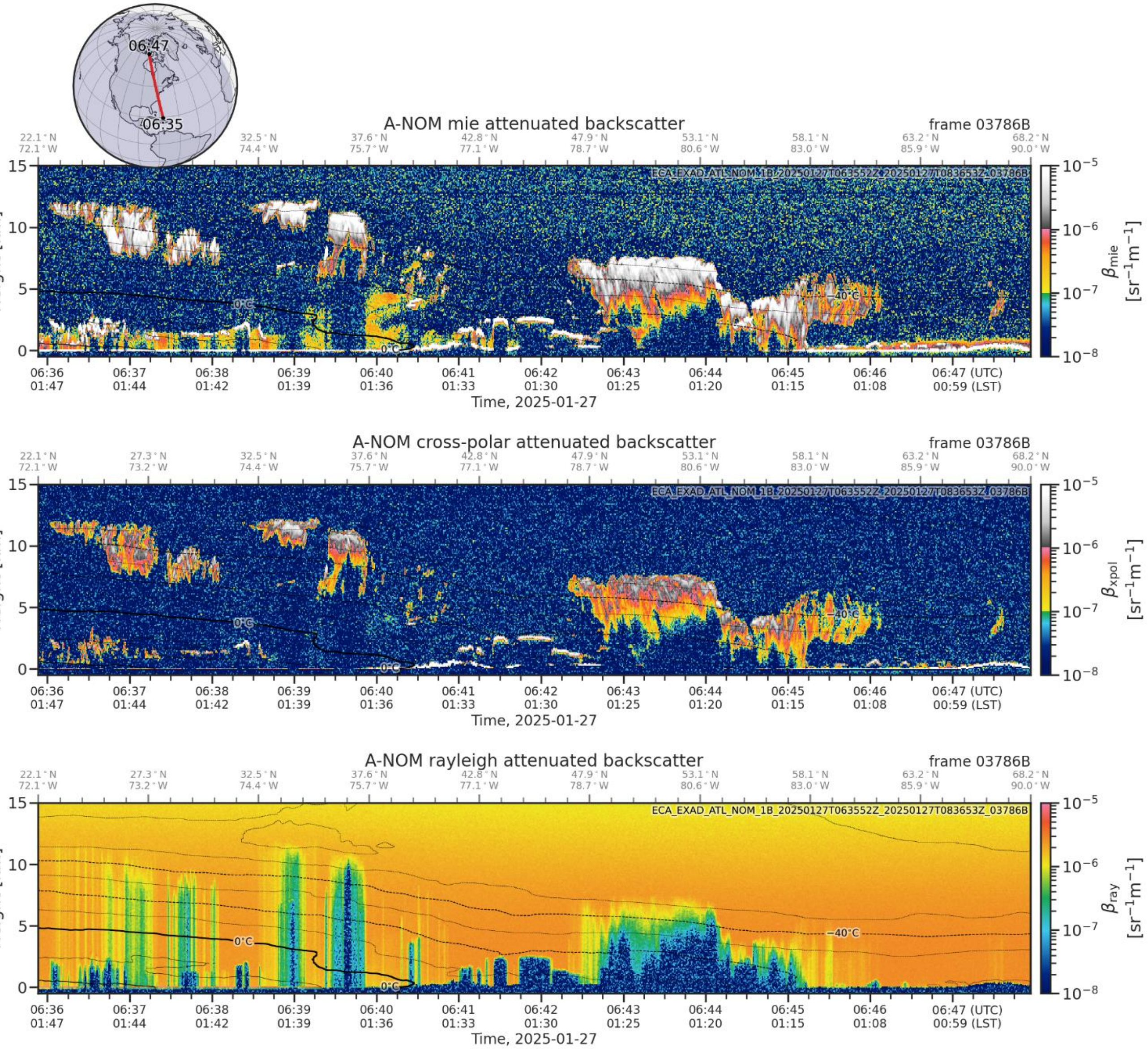


Conclusions EarthCARE ATLID surface returns

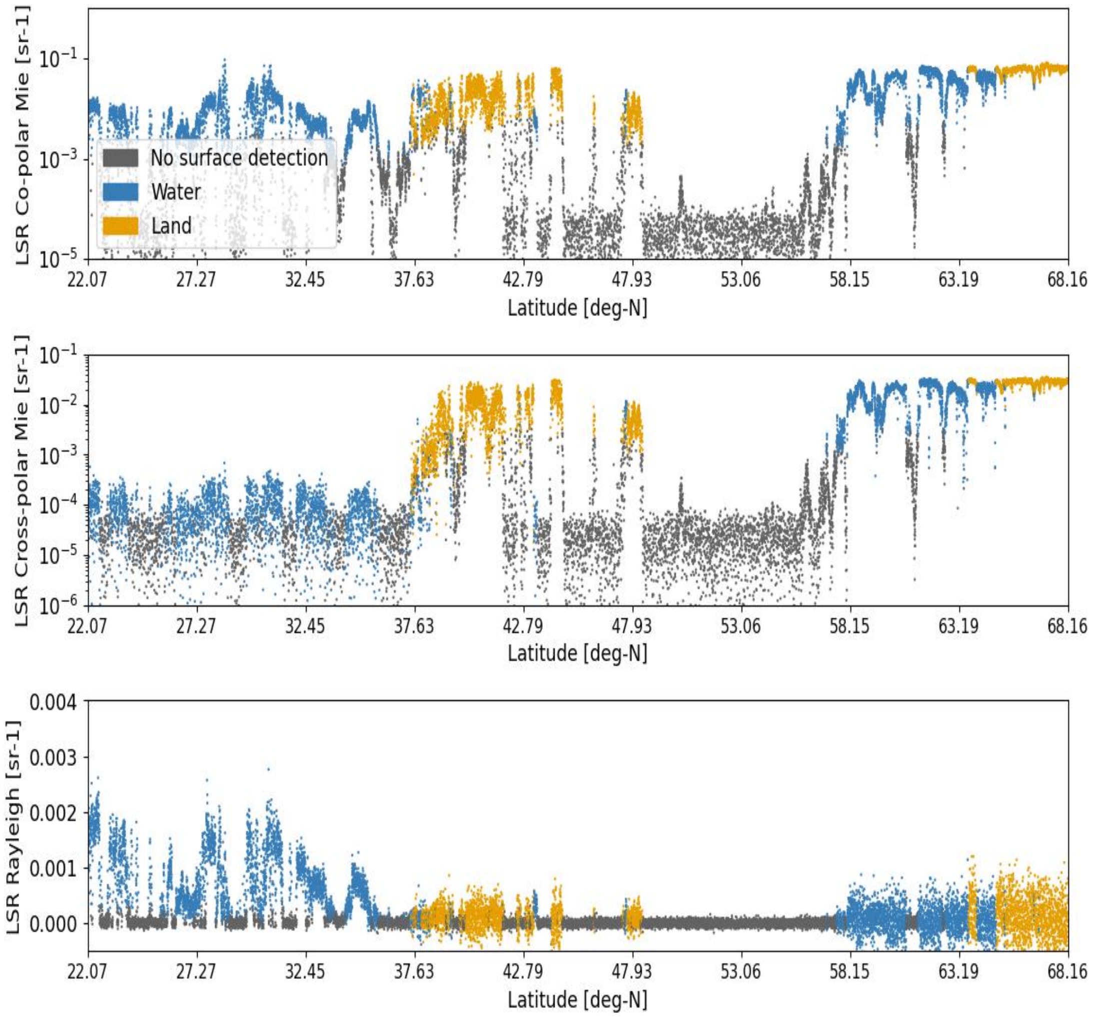
- The use of ATLID surface returns allows for an independent retrieval of optical thickness over ocean (like for Calipso and Aeolus)
- NightBLUE campaign data shows that the integrated Rayleigh returns follow the 10m extinction below the surface and detects sub-surface water reflectance.
- The Rayleigh data is correlated with the Ocean Diffuse attenuation coefficient due to e.g. Chlorophyll-a & Colored Dissolved Organic Matter.
- The ATLID surface depolarization can easily detect snow/land-ice and sea-ice
- Over land the ATLID surface depolarization correlates with the vegetation index (NDVI)
- When zooming in over desserts the depolarization seems to be indicative of the surface albedo (link to minerology).

Van Zadelhoff et al. ; in preparation

Example of surface returns



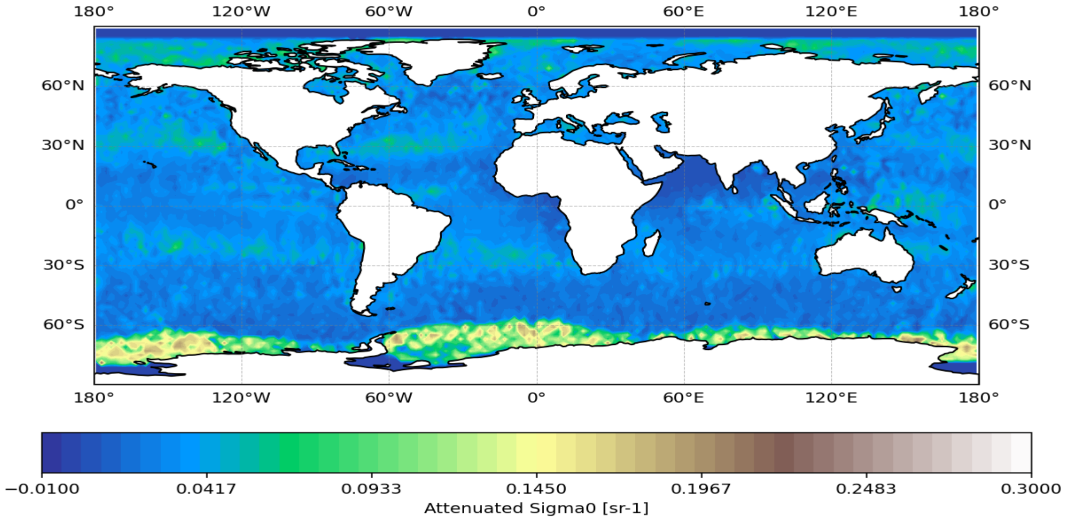
All detected (blue & orange) surfaces for each profile and grey when no surface could be detected for frame 3786B.

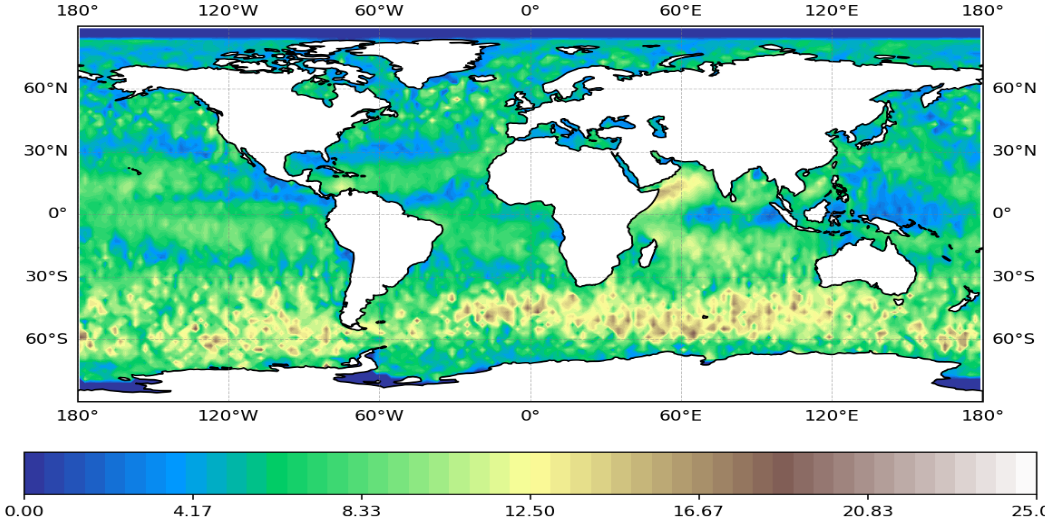


Global AOD based on ATLID LSR & WIND

(2°-by-2° grid)

Co-Polar Mie: July 2025





Wind July 2025

OD July 2025