The OCEAN (Ocean Color EarthCARE Analysis) Project: Preliminary Results

*D.Dionisi[1], C.Cesarini[2], S.Colella[1], D.D'Alimonte[3], P.Di Girolamo[4], M.Di Paolantonio[1], G.Giuliano[1], C.Jamet[5], T.Kajiyama[3], G. La Forgia[1], M. Li[1], **G. L. Liberti[1]**, L. Masi[1], E. Organelli[1]*

[1] *Consiglio Nazionale delle Ricerche, Istituto di Scienze Marine, Rome, Italy*
[2] *INNUERE Consulting, Italy*
[3] *AEQUORA, Lisbon, Portugal*
[4] *Università degli Studi della Basilicata, Potenza, Italy*
[5] *Laboratoire d'Océanologie et de Géosciences, Université du Littoral-Côte d'Opale, France*

OCEAN

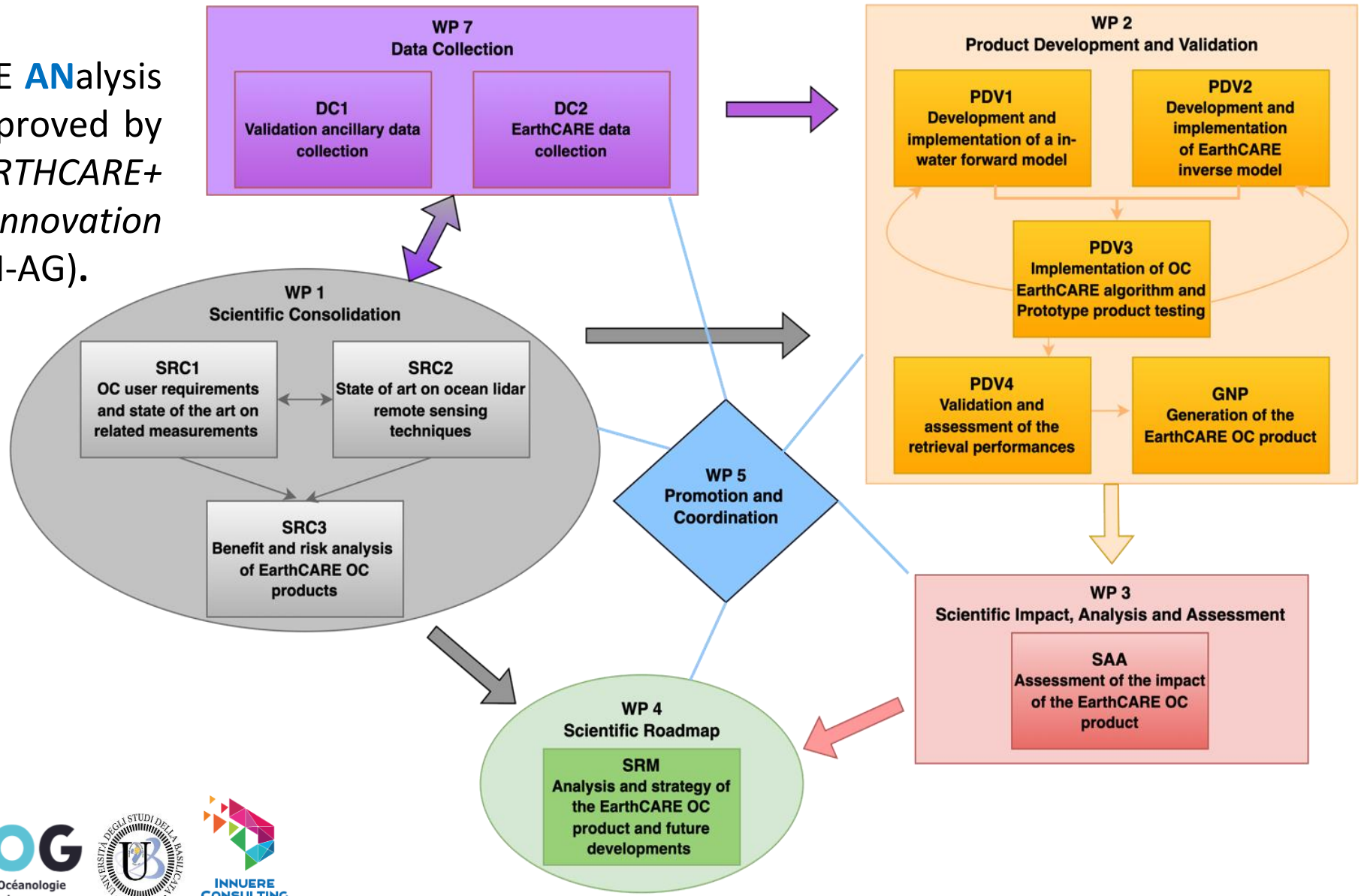
OCEAN

EarthCARE Science and Validation Workshop 2025
1-5 December 2025 | The University of Tokyo | Tokyo, Japan

JAXA esa

Objectives & Approach

OCEAN: **O**cean **C**olor **E**arthCARE **AN**alysis 24 months feasibility study approved by **ESA** within *the EARTHCARE+ INNOVATION - EXPRO+ Innovation program* (ESA 4000147849/25/I-AG)**.**
Kick-off: June 2025.

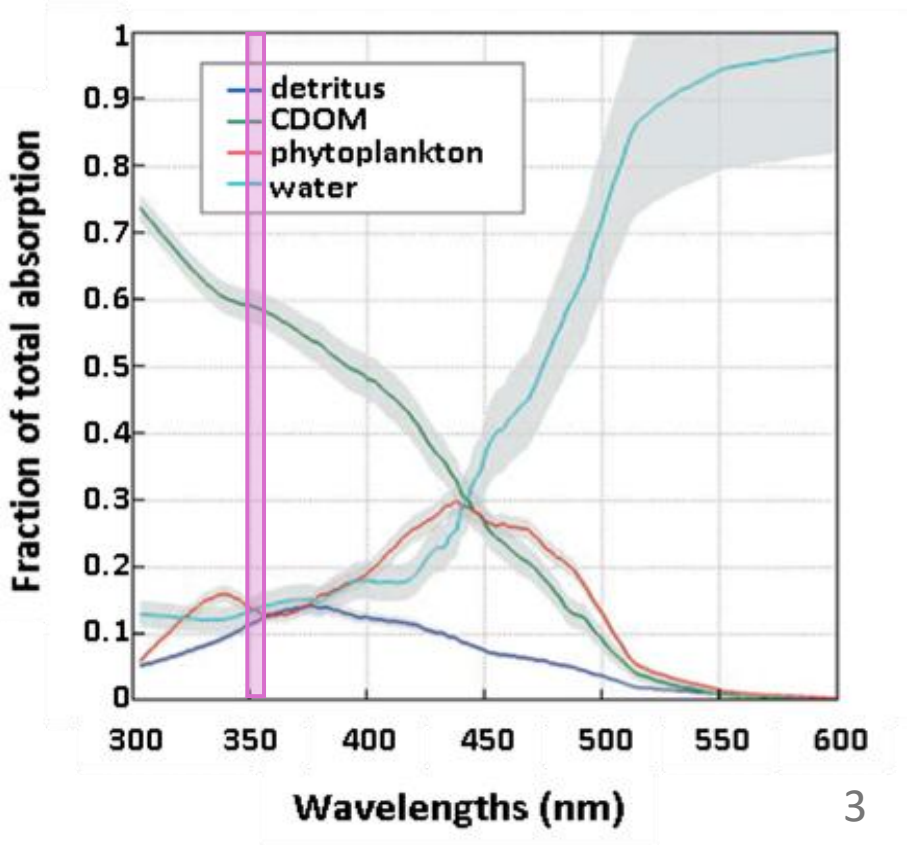


Objectives & Approach

OCEAN proposes to evaluate and document the feasibility of deriving an in-water EarthCARE products from the analysis of the ocean sub-surface backscattered components of the 355 nm signal acquired by ATLID.
The project focuses on the potential retrieval of the ocean optical properties at 355 nm:

- lidar attenuation coefficient ($\mathbf{K_L}$) and the in-water backscattering ($\boldsymbol{\beta}_{wat}^{par}$)
- Ocean Colour parameters $\mathbf{K_d}$ and $\mathbf{b_{bp}}$
- Bio-geochemical parameter **CDOM**

*Chromophoric Dissolved Organic Matter (**CDOM**) is the most relevant contributor to the light absorption at 355 nm. In the UV, $\boldsymbol{K_d}$ is used as a proxy of CDOM light absorption.*



Objectives & Approach

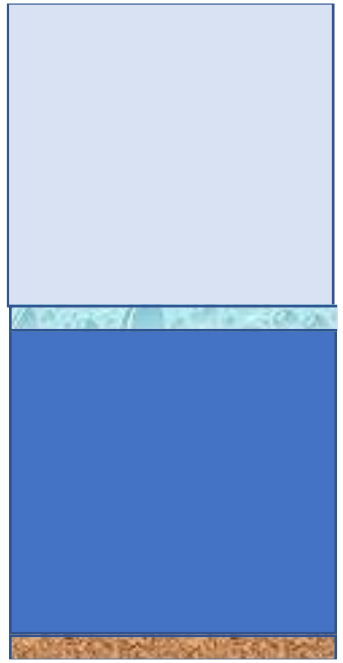
The potential information on ocean subsurface optical properties is contained in the ATLID ground bin volume (Δr_{grd}):

$$S_X\left(r_{grd}\right) = C_X\left[\frac{A}{\left(r_{atm} + \frac{\Delta r_{wat}}{n}\right)^2}\right] B_{grd} T_A^2\left(r_{atm}\right) + S_{bkg}$$

X= $\text{Ray}_{\text{co-polar}}$
X= $\text{Mie}_{\text{co-polar}}$
X= $\text{Ray+Mie}_{\text{crs-polar}}$

$$\boldsymbol{B_{grd}} = B_{atm} + B_{srf} + \boldsymbol{B_{wat}} + B_{sfl}$$

Generic ATLID Ground bin volume contributions



To evaluate B_{grd} and estimate $\boldsymbol{B_{wat}}$ OCEAN set up two parallel and strongly interacting activities:

- *Radiative transfer modeling* (essential tool to interpret the information contained in the ATLID measurements and to develop a physically based inversion model).

- *ATLID Signal Analyses* (essential to consolidate the ATLID lidar equation, to justify assumptions and to define requirements).

Scientific background and approach

ATLID ground bin volume (no shallow waters)

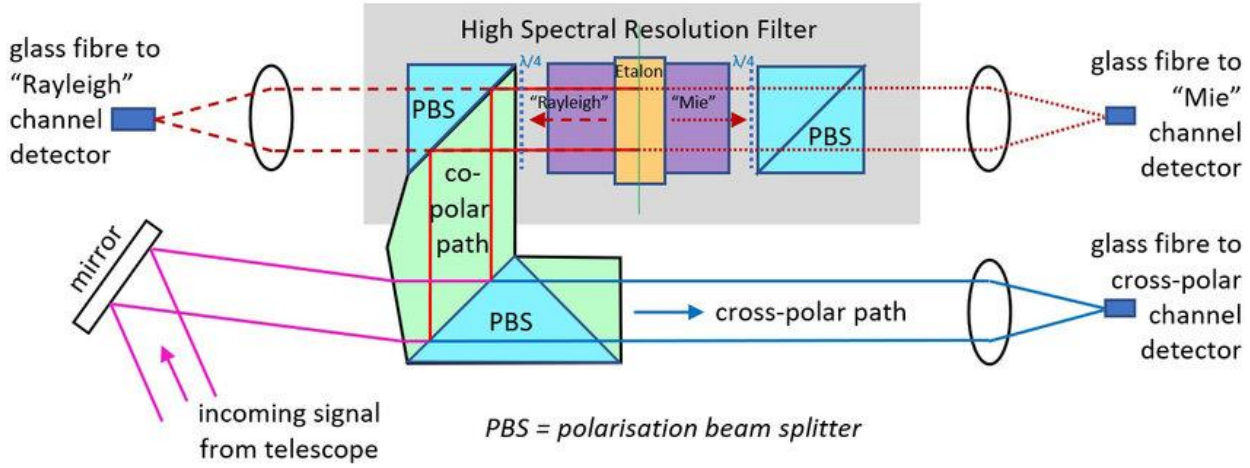
Attenuated Rayleigh copolar backscatter signal $A_R(r_{grd}) = \{B_{atmR} + B_{srfR} + \boldsymbol{B_{watM}}\} T^2_{AR}(r_{atm})$ (1a)

Attenuated Mie copolar backscatter signal $A_M(r_{grd}) = \{B_{atmM} + B_{srfM} + \boldsymbol{B_{watM}}\} T^2_{AM}(r_{atm})$ (1b)

Attenuated Mie+Rayleigh crosspolar backscatter signal $A_X(r_{grd}) = \{B_{atmX} + B_{srfX} + \boldsymbol{B_{watX}}\} T^2_{AX}(r_{atm})$ (1c)

Correcting for atmospheric extinction and assuming that:

- $T_{AX} = T_{AR} = T_{AM} = T_A$
- $B_{srfR} = 0$ and $B_{srfX} = 0$
- $B_{atmi} << B_{srfi} + B_{wati}$
- Deep water ($B_{sfl} = 0$)
- $T^{dn}_{srf} = T^{up}_{srf} = \mathrm{T}_{srf}$



Scientific background and approach

ATLID ground bin channels equations

a) $$B_{watR} = \left[\frac{\Delta r_{wat}}{n(T,S)}\right] \cdot \beta_{wat}^{mol} \cdot f_{co}(r,\pi) T_{srf}^2 \cdot T_{wat}^2(\Delta r_{wat}/n)$$

where: $T_{wat} = \exp\left[-\int_0^r \boldsymbol{K_L}(\boldsymbol{r'})dr'\right]$

$\boldsymbol{K_L}$

b) $$B_{watM} = \left[\frac{\Delta r_{wat}}{n(T,S)}\right] \cdot f_{co}(r,\pi) \cdot (\beta_{wat}^{par} + \beta_{wat}^{mol}) \cdot T_{srf}^2 \cdot T_{wat}^2(\Delta r_{wat}/n)$$

$\boldsymbol{\beta_{war}^{par}}$

c) $$B_{watX} = \left[\frac{\Delta r_{wat}}{n(T,S)}\right] \left[f_{crs}(r,\pi) \cdot (\beta_{wat}^{par} + \beta_{wat}^{mol}) + 2 f_{co}(\pi,r) \cdot (\beta_{wat}^{par} + \beta_{wat}^{mol}) \int_0^r \gamma(r')dr'\right] \cdot T_{srf}^2 \cdot T_{wat}^2(\Delta r_{wat}/n)$$

$\boldsymbol{\delta}$

$$\boldsymbol{\delta} = \frac{A_X^{2a}}{A_M^{2a}(r_{grd}) - B_{srfM}} - 2 f_{co}(r,\pi) \int_0^r \gamma(r')dr'$$ *Churnside et al., 2014*

Useful information is potentially contained in all ATLID received signals

Temptative Flowchart

- **Estimate observation/illumination angular geometry**
- **Screening**
- ***Integration***
- **Estimate Sea (surface) refractive index**
- **Estimate ground-bin in-water volume**
- ***Remove Ground Bin atmospheric contribution***
- **Estimate Sea Surface Transmittance, Reflectance**
- **Correct for Sea Surface contributions: Transmittance, Reflectance**
- **Estimate pure sea water optical properties of the in-water portion of the ground-bin**
- **Estimate total in-water extinction (From Rayleigh channel)**
- **Estimate single components of the total extinction**
- **Estimate single components of backscattering**
- **Estimate uncertainties associated to each retrieved variable**
- **Write prototype product**

Radiative Transfer Model

- Main features
  - 3D Monte Carlo ray tracing
  - Surface reflection, bottom effect
  - IOPs, multiple scattering
- **Input:** wind, T, Chl, a_{ys}, emitter and receiver properties
- **Output:** Backscattered Signal, Single photons history, polarization state
- Application within the project
  - Understand signal propagation details across the surface and in the water column: (e.g., identify / discriminate the signal back-scattered by the sea-surface and from the water column based on polarization)
  - Verify/define validity of adopted assumptions
  - Generate Look-up tables (LUT) for data products retrieval from backscattered signal

- Dionisi et al (2024) Exploring the potential of Aeolus lidar mission for ocean color applications. Remote Sensing of Environment 313:114341
- D'Alimonte et al (2024) In-water lidar simulations: the ALADIN ADM-Aeolus backscattered signal at 355 nm. Opt Express 32:22781

Radiative Transfer Model

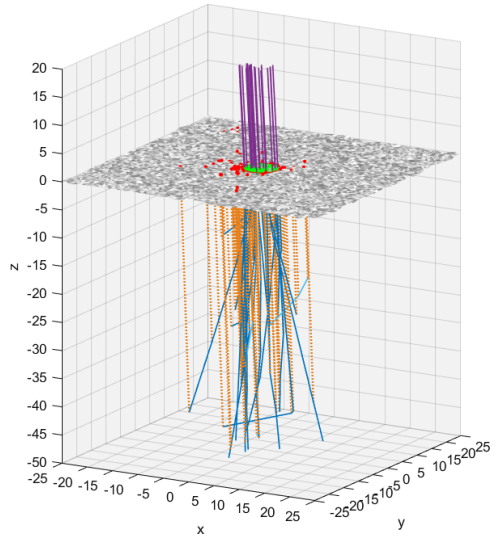


Fig. 1 Ray tracing based on EarthCARE geometry

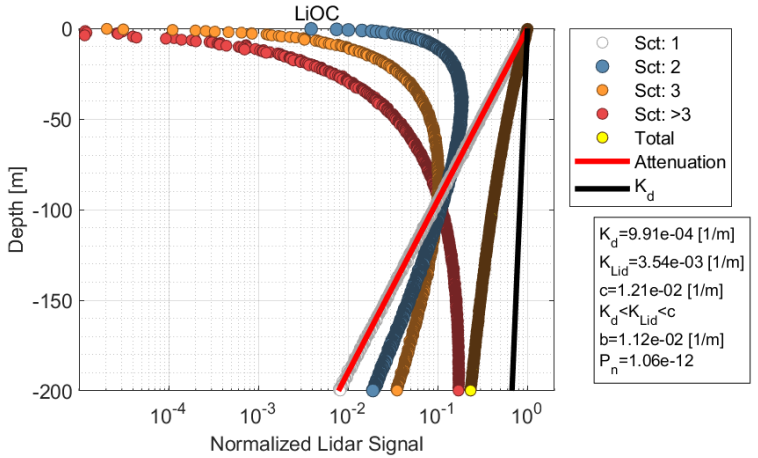


Fig. 2 Profiles in pure sea water as a benchmark

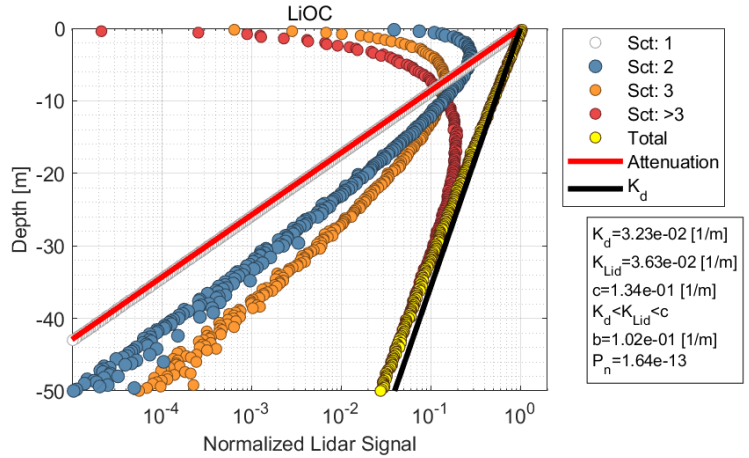
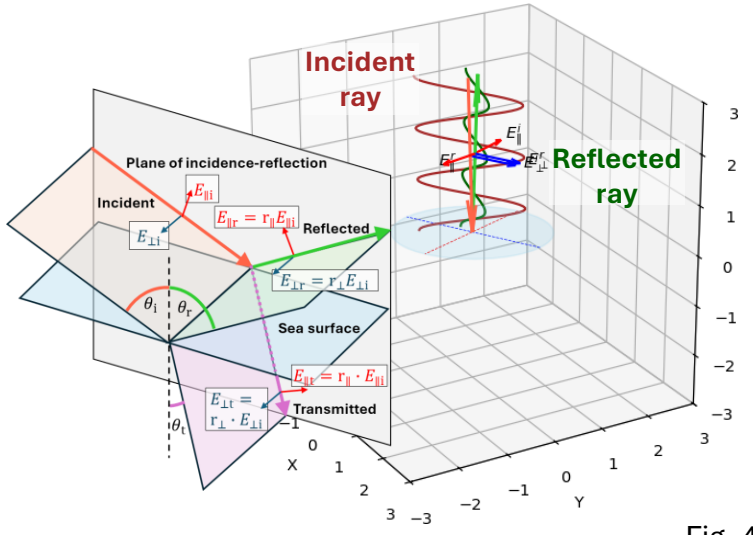


Fig. 3 Profiles accounting for Chl-a = 0.1 mg m^{-3}



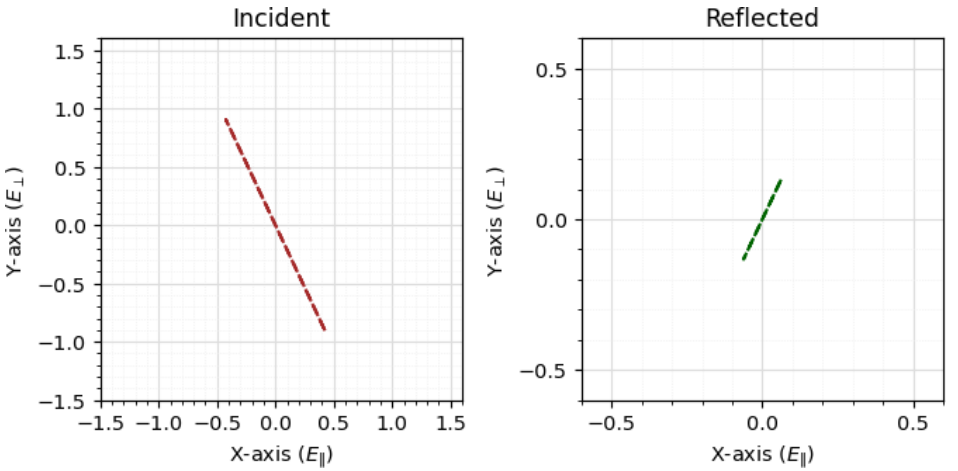


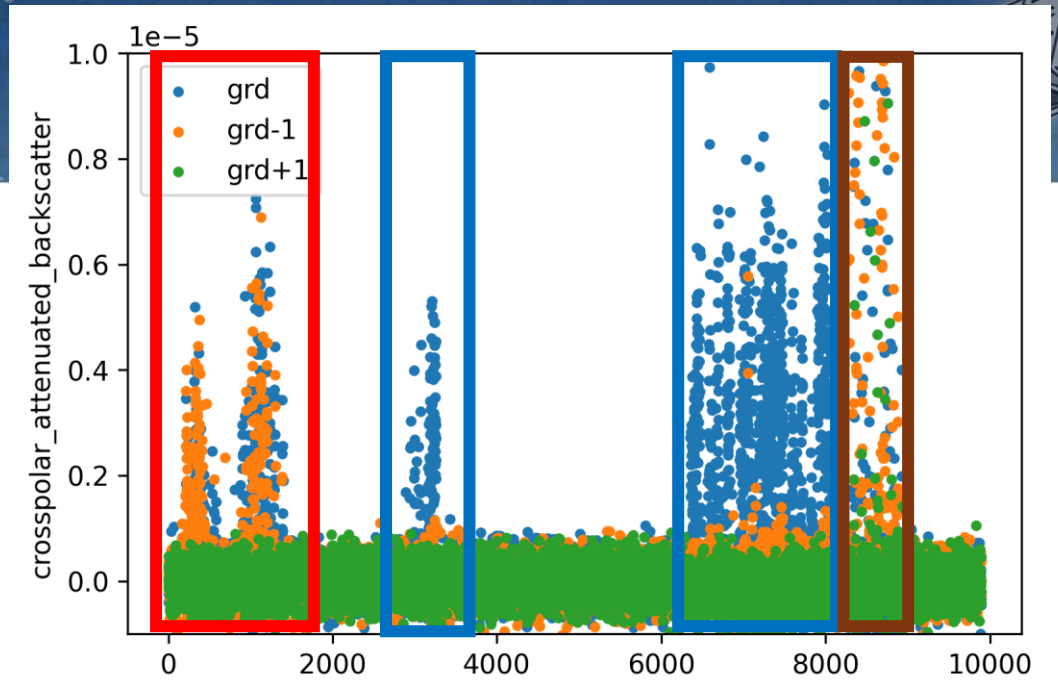
Fig. 4 Ray tracing based on polarization

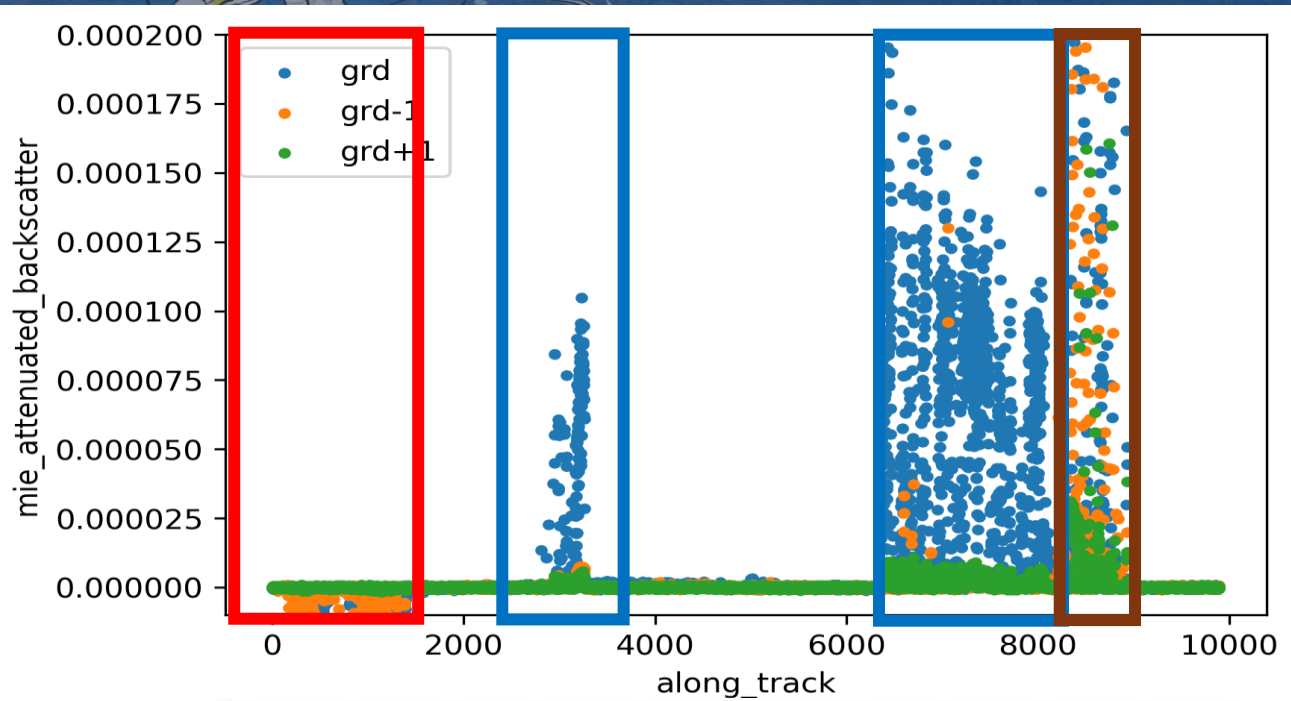
```
# From ray tracing log ...
# Observation direction:
obs_zth_ang=+3.0
obs_azi_ang=+180.0
# Propagation direction of the incident beam.
inc_zth_ang=+177.0
inc_azi_ang=+360.0
# Mueller matrix for reflection.
rfl_mat_mlr=...
  [[+2.1325e-02 +8.2887e-05 +0.0000e+00 +0.0000e+00]
   [+8.2887e-05 +2.1325e-02 +0.0000e+00 +0.0000e+00]
   [+0.0000e+00 +0.0000e+00 -2.1324e-02 +0.0000e+00]
   [+0.0000e+00 +0.0000e+00 +0.0000e+00 -2.1324e-02]]
rfl_stk_mlr[0]=+2.1272e-02
# Fresnel theoretical values
rfl_teo_prl=+1.4575e-01
rfl_teo_prp=-1.4631e-01
E0x**2+E0y**2= +2.1272e-02
```

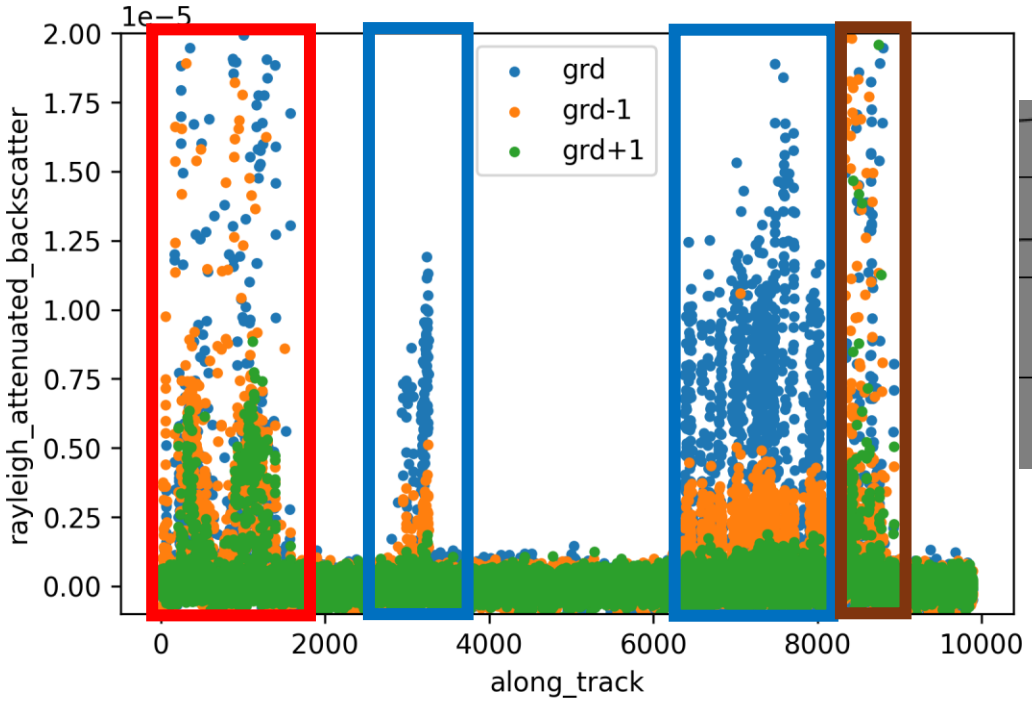
Fig. 5 Benchmark between **Stokes-Mueller** and **Fresnel** formalism at the air-water interface

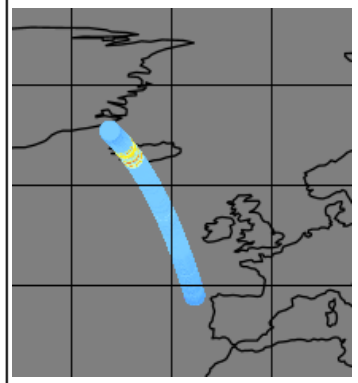
Product	Variable
AUX_MET	eastward_wind_at_10_metres, northward_wind_at_10_metres, Latitude, Longitude, sea_ice_cover, sea_surface_temperature
ATL_NOM	sample_latitude, sample_longitude, sample_altitude, surface_elevation, land_flag, floor_index, time, solar_elevation_angle, rayleigh_attenuated_backscatter, mie_attenuated_backscatter, crosspolar_attenuated_backscatter, rayleigh_attenuated_backscatter_random_error, mie_attenuated_backscatter_random_error, crosspolar_attenuated_backscatter_random_error, rayleigh_attenuated_backscatter_total_error, mie_attenuated_backscatter_total_error, crosspolar_attenuated_backscatter_total_error, hot_pixel_flag_Rayleigh, hot_pixel_flag_mie, hot_pixel_flag_crosspolar
ATL_FM	sigma0_mie, sigma0_crosspolar, sigma0_rayleigh, sigma0_mie_error, sigma0_crosspolar_error, sigma0_rayleigh_error, quality_flag surface_estimation_flag, surface_rayleigh_tau, Featuremask
ATL_EBD	simple_classification particle_extinction_coefficient_355nm particle_backscatter_coefficient_355nm particle_extinction_coefficient_355nm_error particle_backscatter_coefficient_355nm_error particle_optical_depth_355nm particle_extinction_coefficient_355nm_medium_resolution particle_optical_depth_355nm_error particle_extinction_coefficient_355nm_medium_resolution_error particle_backscatter_coefficient_355nm_medium_resolution particle_optical_depth_355nm_medium_resolution particle_backscatter_coefficient_355nm_medium_resolution_error particle_optical_depth_355nm_medium_resolution_error particle_extinction_coefficient_355nm_low_resolution particle_extinction_coefficient_355nm_low_resolution_error particle_backscatter_coefficient_355nm_low_resolution particle_backscatter_coefficient_355nm_low_resolution_error particle_optical_depth_355nm_low_resolution particle_optical_depth_355nm_low_resolution_error rayleigh_backscatter_355nm_model
ATL_AER	simple_classification particle_extinction_coefficient_355nm particle_extinction_coefficient_355nm_error particle_backscatter_coefficient_355nm particle_backscatter_coefficient_355nm_error
ATL_ALD	aerosol_optical_thickness_355nm
GEBCO	bathimetry

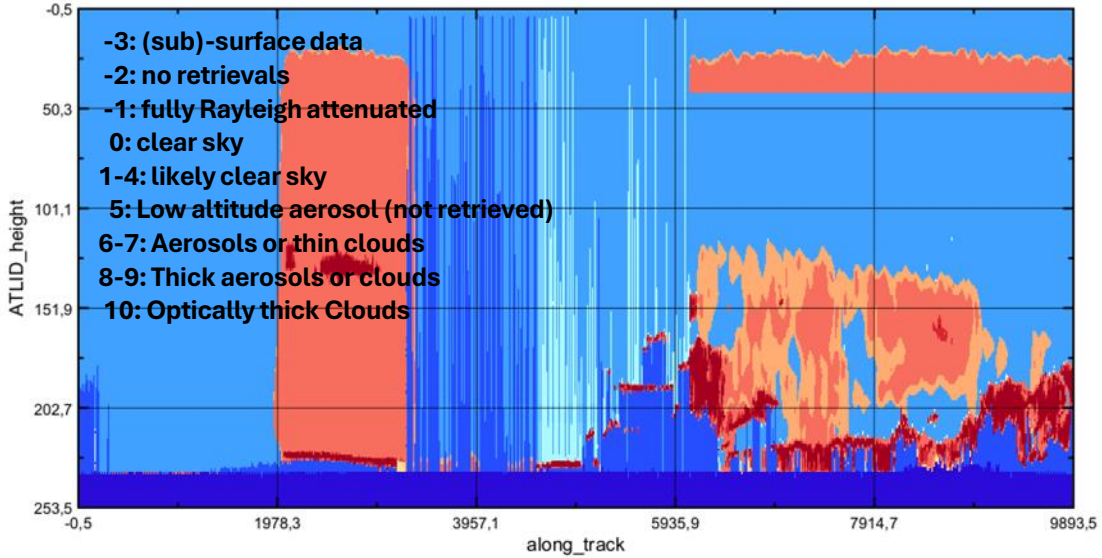
USE:
Surface R/T,
Localization,
Screening,
Interpretation of the results
Retrieval,
Screening and uncertainty estimation,
Screening and refined retrieval


1e−5
crosspolar_attenuated_backscatter
grd
grd-1
grd+1

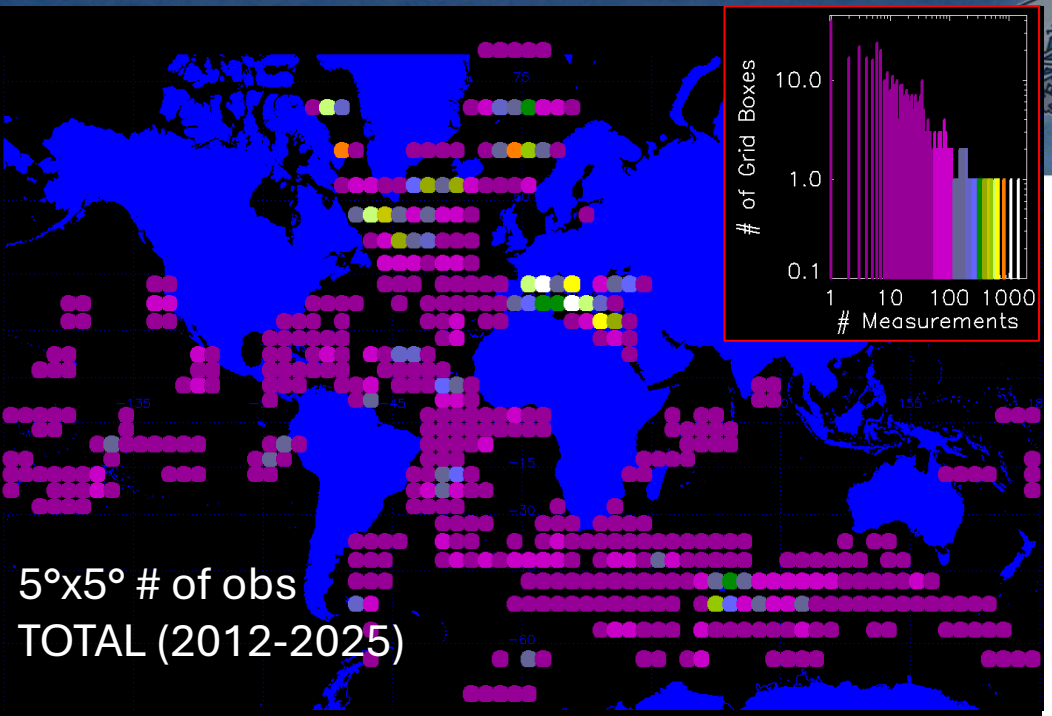

mie_attenuated_backscatter
grd
grd-1
grd+1
along_track

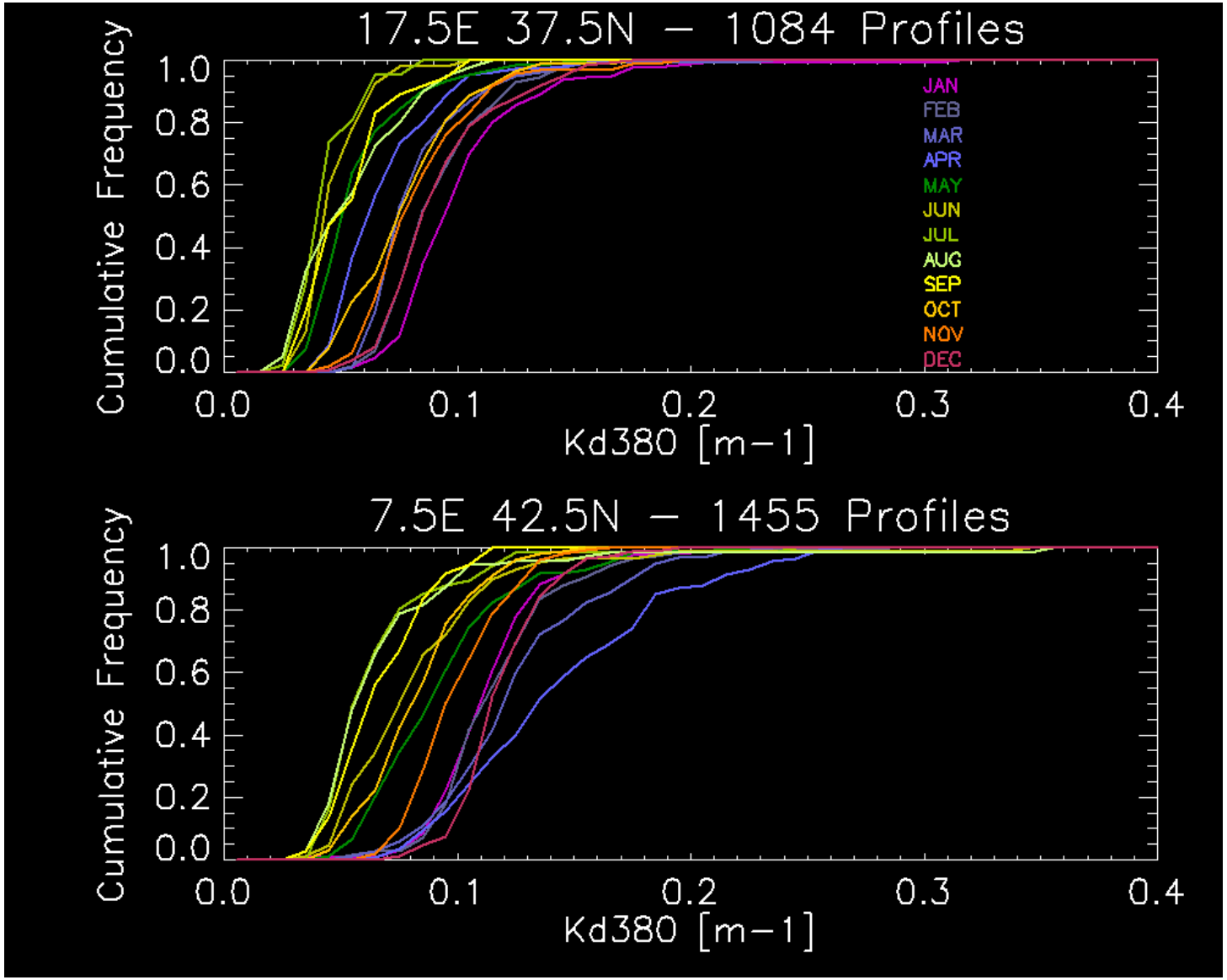

1e−5
rayleigh_attenuated_backscatter
grd
grd-1
grd+1
along_track




-3: (sub)-surface data
-2: no retrievals
-1: fully Rayleigh attenuated
0: clear sky
1-4: likely clear sky
5: Low altitude aerosol (not retrieved)
6-7: Aerosols or thin clouds
8-9: Thick aerosols or clouds
10: Optically thick Clouds
ATLID_height
along_track
Lidar Feature Mask at the merged lidar/radar resolution ()

Validation: BGC ARGO





Validation: Satellite

Dataset	Sensors	Spatial grid	Temporal sampling	Period	Available Bands
a_{cdm}, Kd (CMEMS)	Multi-Sensor: SeaWiFS, MODIS-Aqua, MODIS-Terra, MERIS, VIIRS-SNPP, OLCI-S3A & S3B	4 km	Daily	1998-06/2025	443 nm for a_{cdm} 490 nm for Kd
a_{cdm}, Kd (ESA-OC-CCI)	Multi-Sensor: SeaWiFS, MODIS-Aqua, MERIS, VIIRS-SNPP, OLCI-S3A	4 km	Daily	1998-06/2025	412, 443, 490, 510, 560 and 665 nm for a_{cdm} 490 nm for Kd
Total absorption (a), Kd (OCI-PACE GIOP model)	Ocean Color Instrument (OCI) onboard Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)	4 km	Daily	03/2024-06/2026	400, 413, 425, 442, 460, 475, 490, 510, 532, 555, 583, 618, 640, 655, 665, 678, 701 nm
Kd (Sentinel5p)	Tropospheric Monitoring Instrument (TROPOMI) onboard the Sentinel-5 Precursor (S5p)	5 Km	Daily	05/2018-06/2025	region 390 - 423 nm (blue); region 356.5 - 390 nm (UVA); region 312.5 - 338.5 nm (UVAB)

Critical Issues….on going

Assumption	Issue	Impact	Mitigation
Useful information from all 3 channels is available	Insufficient SNR	Missing information	Horizontal integration
Contribution from Sea Surface negligible in the Rayleigh and Cross Polar Mie	Residual cross talk (in the ocean)	Need to estimate the contribution	Use of the RTM
Contribution from Sea Surface can be removed from Mie copolar	Large contribution of sea surface	Large value of the correction with high probability of generating negative values of water contribution	Discriminate on the basis of wind speed + Horizontal integration
Atmospheric contribution negligible in the ground bin	Atmospheric contribution not-negligible	Need to estimate the contribution	Estimate the atmospheric contribution for the estimated atmospheric portion of the ground-bin assuming the aerosols properties
No contribution from the seafloor	Navigation or grid size issue	Over(Under)estimation of backscattering(Extinction)	Increase the minimum bathimetry threshold value
Ground-bin correctly identified	Problems in interpreting the data	Wrong/missed retrieval	Investigate multisource ground-bin identification

Thank you for your attention

gianluigi.liberti@cnr.it

OCEAN

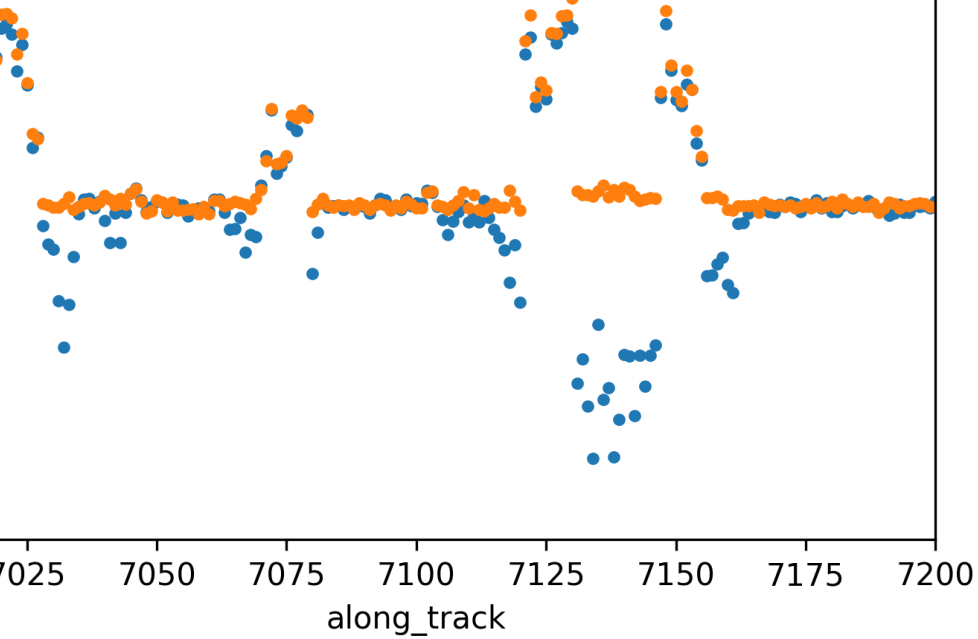
OCEAN

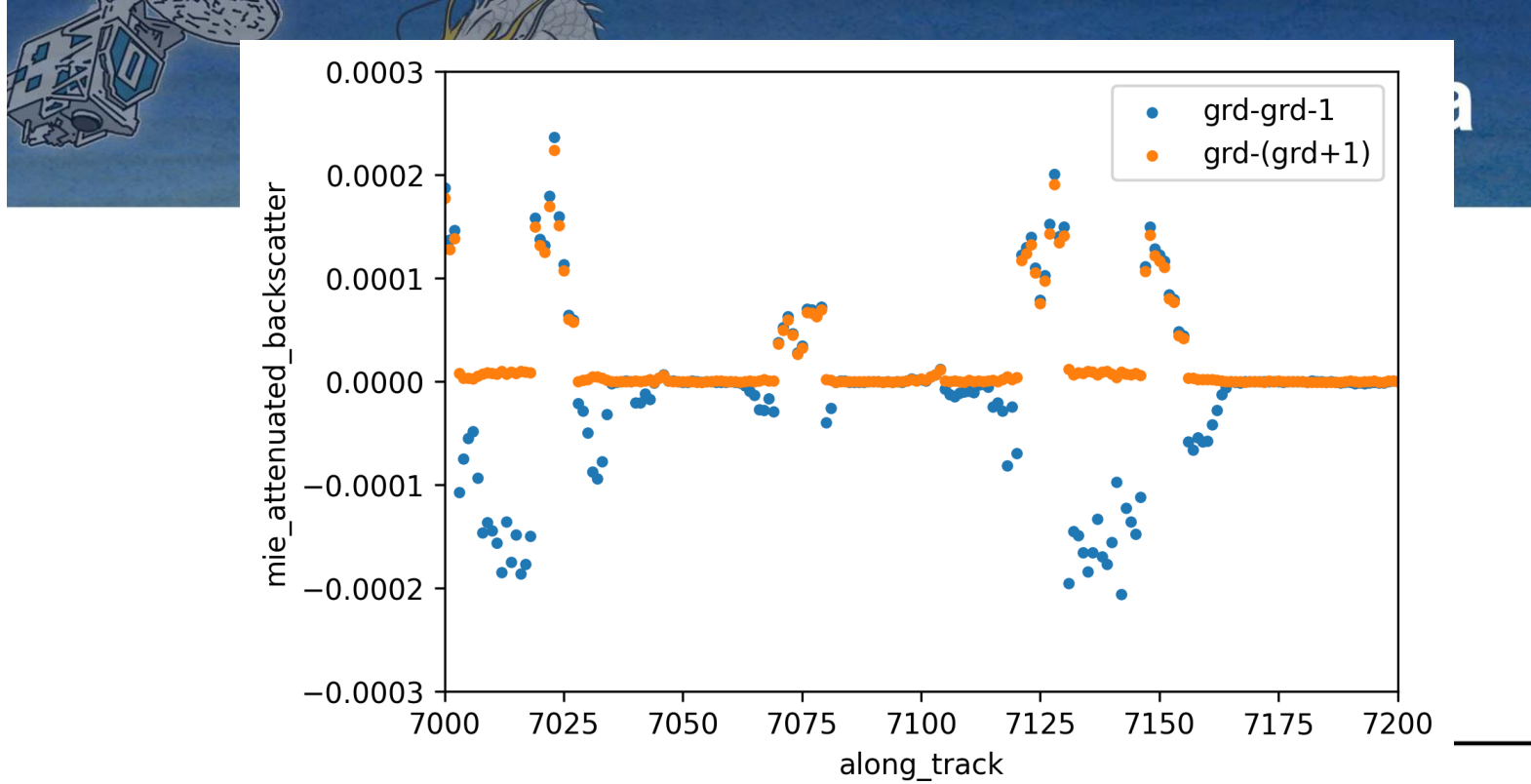
EarthCARE Science and Validation Workshop 2025

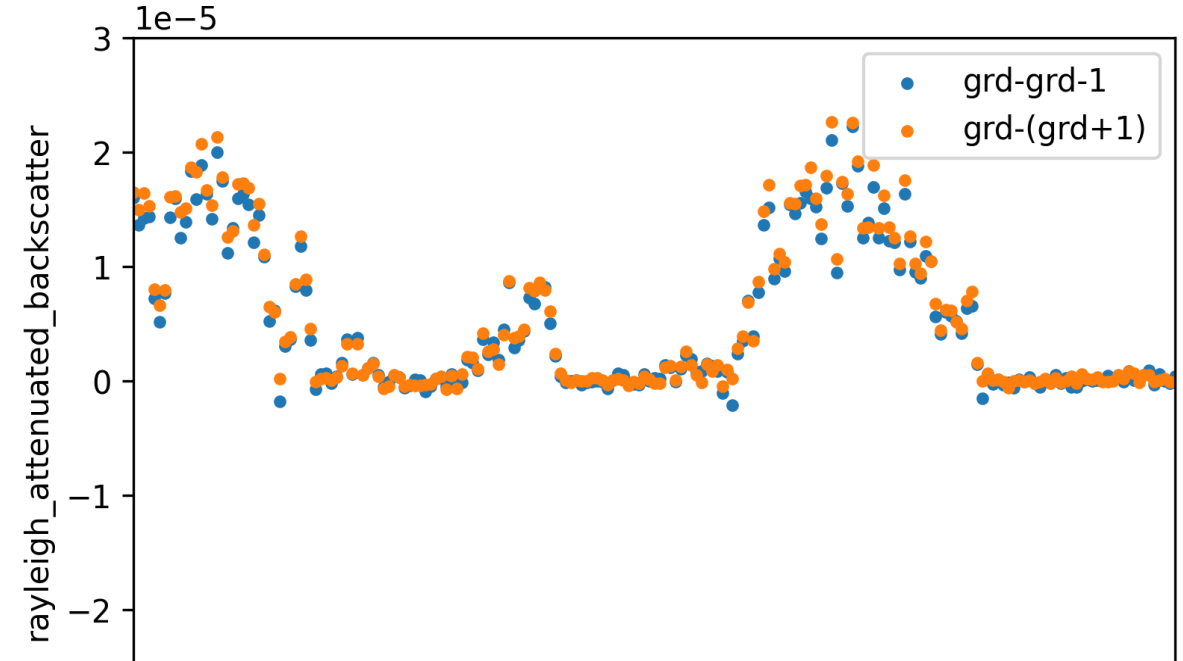
1-5 December 2025 | The University of Tokyo | Tokyo, Japan

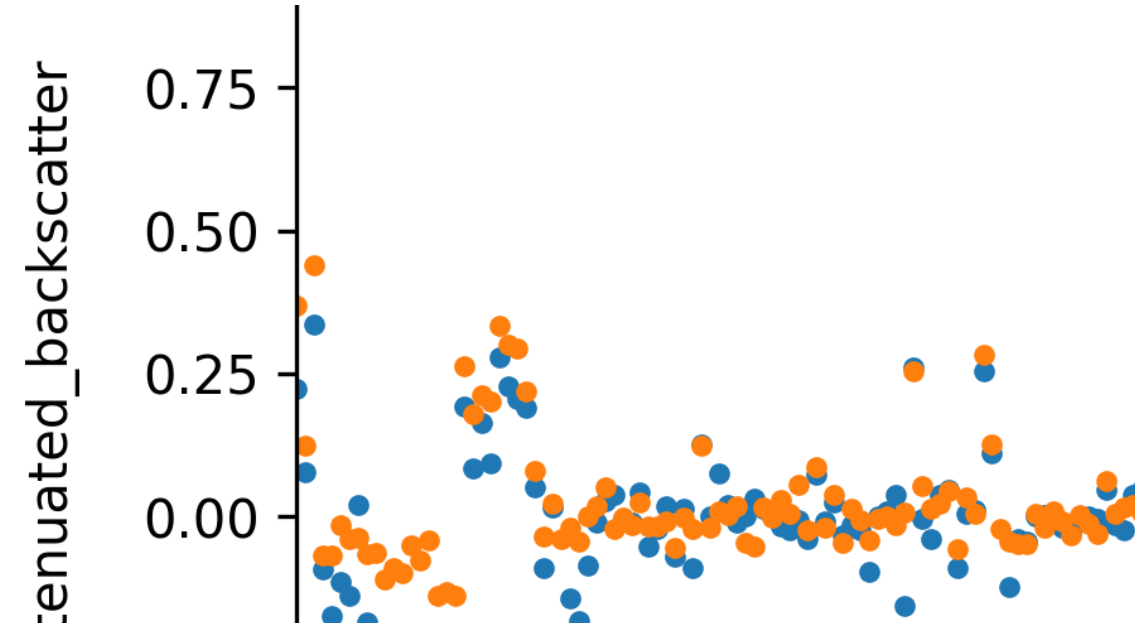
JAXA

esa


7025
7050
7075
7100
7125
7150
7175
7200
along_track


0.0003
0.0002
0.0001
0.0000
−0.0001
−0.0002
−0.0003
mie_attenuated_backscatter
grd-grd-1
grd-(grd+1)
7000
7025
7050
7075
7100
7125
7150
7175
7200
along_track


1e−5
3
2
1
0
−1
−2
rayleigh_attenuated_backscatter
grd-grd-1
grd-(grd+1)


0.75
0.50
0.25
0.00

Satellite

Dataset	Sensors	Spatial grid	Temporal sampling	Period	Available Bands	Uncertainties	Volume per year
a_{cdm}, Kd (CMEMS)	Multi-Sensor: SeaWiFS, MODIS-Aqua, MODIS-Terra, MERIS, VIIRS-SNPP, OLCI-S3A & S3B	4 km	Daily	1998-06/2025	443 nm for a_{cdm} 490 nm for Kd	N/A	50 Gb
a_{cdm}, Kd (ESA-OC-CCI)	Multi-Sensor: SeaWiFS, MODIS-Aqua, MERIS, VIIRS-SNPP, OLCI-S3A	4 km	Daily	1998-06/2025	412, 443, 490, 510, 560 and 665 nm for a_{cdm} 490 nm for Kd	N/A	250 Gb
Total absorption (a), Kd (OCI-PACE GIOP model)	Ocean Color Instrument (OCI) onboard Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)	4 km	Daily	03/2024-06/2026	400, 413, 425, 442, 460, 475, 490, 510, 532, 555, 583, 618, 640, 655, 665, 678, 701 nm	N/A	50 Gb
Kd (Sentinel5p)	Tropospheric Monitoring Instrument (TROPOMI) onboard the Sentinel-5 Precursor (S5p)	5 Km	Daily	05/2018-06/2025	region 390 - 423 nm (blue); region 356.5 - 390 nm (UVA); region 312.5 - 338.5 nm (UVAB)	N/A	80 Gb

EarthCARE datasets and OCEAN Archive generation

Product	Variable
AUX_MET	eastward_wind_at_10_metres, northward_wind_at_10_metres, Latitude, Longitude, sea_ice_cover, sea_surface_temperature
ATL_NOM	mie_background_signal, rayleigh_background_signal, crosspolar_background_signal, sample_latitude, sample_longitude, sample_altitude, surface_elevation, land_flag, floor_index, time, solar_elevation_angle, rayleigh_attenuated_backscatter, mie_attenuated_backscatter, crosspolar_attenuated_backscatter, rayleigh_attenuated_backscatter_random_error, mie_attenuated_backscatter_random_error, crosspolar_attenuated_backscatter_random_error, rayleigh_attenuated_backscatter_total_error, mie_attenuated_backscatter_total_error, crosspolar_attenuated_backscatter_total_error, rayleigh_lidar_constant_monitoring_value, mie_lidar_constant_monitoring_value, crosspolar_lidar_constant_monitoring_value, hot_pixel_flag_Rayleigh, hot_pixel_flag_mie, hot_pixel_flag_crosspolar
ATL_FM	sigma0_mie, sigma0_crosspolar, sigma0_rayleigh, sigma0_mie_error, sigma0_crosspolar_error, sigma0_rayleigh_error, quality_flag, surface_estimation_flag, surface_rayleigh_tau, Featuremask
ATL_EBD	latitude longitude height simple_classification particle_extinction_coefficient_355nm particle_extinction_coefficient_355nm_error particle_backscatter_coefficient_355nm particle_backscatter_coefficient_355nm_error particle_optical_depth_355nm particle_optical_depth_355nm_error particle_extinction_coefficient_355nm_medium_resolution particle_extinction_coefficient_355nm_medium_resolution_error particle_backscatter_coefficient_355nm_medium_resolution particle_backscatter_coefficient_355nm_medium_resolution_error particle_optical_depth_355nm_medium_resolution particle_optical_depth_355nm_medium_resolution_error particle_extinction_coefficient_355nm_low_resolution particle_extinction_coefficient_355nm_low_resolution_error particle_backscatter_coefficient_355nm_low_resolution particle_backscatter_coefficient_355nm_low_resolution_error particle_optical_depth_355nm_low_resolution particle_optical_depth_355nm_low_resolution_error rayleigh_backscatter_355nm_model
ATL_AER	latitude longitude height simple_classification particle_extinction_coefficient_355nm particle_extinction_coefficient_355nm_error particle_backscatter_coefficient_355nm particle_backscatter_coefficient_355nm_error
ATL_ALD	latitude longitude aerosol_optical_thickness_355nm

USE: Surface R/T, Localization, Screening, Daytime passive retrieval/closure, Retrieval, Screening and uncertainty evaluation, KNMI-NASA comparison, Screening and refined retrieval

Product	Variable
AUX_MET	eastward_wind_at_10_metres, northward_wind_at_10_metres, Latitude, Longitude, sea_ice_cover, sea_surface_temperature
ATL_NOM	mie_background_signal, rayleigh_background_signal, crosspolar_background_signal, sample_latitude, sample_longitude, sample_altitude, surface_elevation, land_flag, floor_index, time, solar_elevation_angle, rayleigh_attenuated_backscatter, mie_attenuated_backscatter, crosspolar_attenuated_backscatter, rayleigh_attenuated_backscatter_random_error, mie_attenuated_backscatter_random_error, crosspolar_attenuated_backscatter_random_error, rayleigh_attenuated_backscatter_total_error, mie_attenuated_backscatter_total_error, crosspolar_attenuated_backscatter_total_error, rayleigh_lidar_constant_monitoring_value, mie_lidar_constant_monitoring_value, crosspolar_lidar_constant_monitoring_value, hot_pixel_flag_Rayleigh, hot_pixel_flag_mie, hot_pixel_flag_crosspolar
ATL_FM	sigma0_mie, sigma0_crosspolar, sigma0_rayleigh, sigma0_mie_error, sigma0_crosspolar_error, sigma0_rayleigh_error, quality_flag, surface_estimation_flag, surface_rayleigh_tau, Featuremask
ATL_EBD	simple_classification particle_extinction_coefficient_355nm particle_extinction_coefficient_355nm_error particle_backscatter_coefficient_355nm particle_backscatter_coefficient_355nm_error particle_optical_depth_355nm particle_optical_depth_355nm_error particle_extinction_coefficient_355nm_medium_resolution particle_extinction_coefficient_355nm_medium_resolution_error particle_backscatter_coefficient_355nm_medium_resolution particle_backscatter_coefficient_355nm_medium_resolution_error particle_optical_depth_355nm_medium_resolution particle_optical_depth_355nm_medium_resolution_error particle_extinction_coefficient_355nm_low_resolution particle_extinction_coefficient_355nm_low_resolution_error particle_backscatter_coefficient_355nm_low_resolution particle_backscatter_coefficient_355nm_low_resolution_error particle_optical_depth_355nm_low_resolution particle_optical_depth_355nm_low_resolution_error rayleigh_backscatter_355nm_model
ATL_AER	simple_classification particle_extinction_coefficient_355nm particle_extinction_coefficient_355nm_error particle_backscatter_coefficient_355nm particle_backscatter_coefficient_355nm_error
ATL_ALD	aerosol_optical_thickness_355nm

USE:
Surface R/T,
Localization,
Screening,
Daytime passive retrieval/closure
Retrieval,
Screening and uncertainty evaluation,
KNMI-NASA comparison
Screening and refined retrieval

Validation

Statistical

Match-up

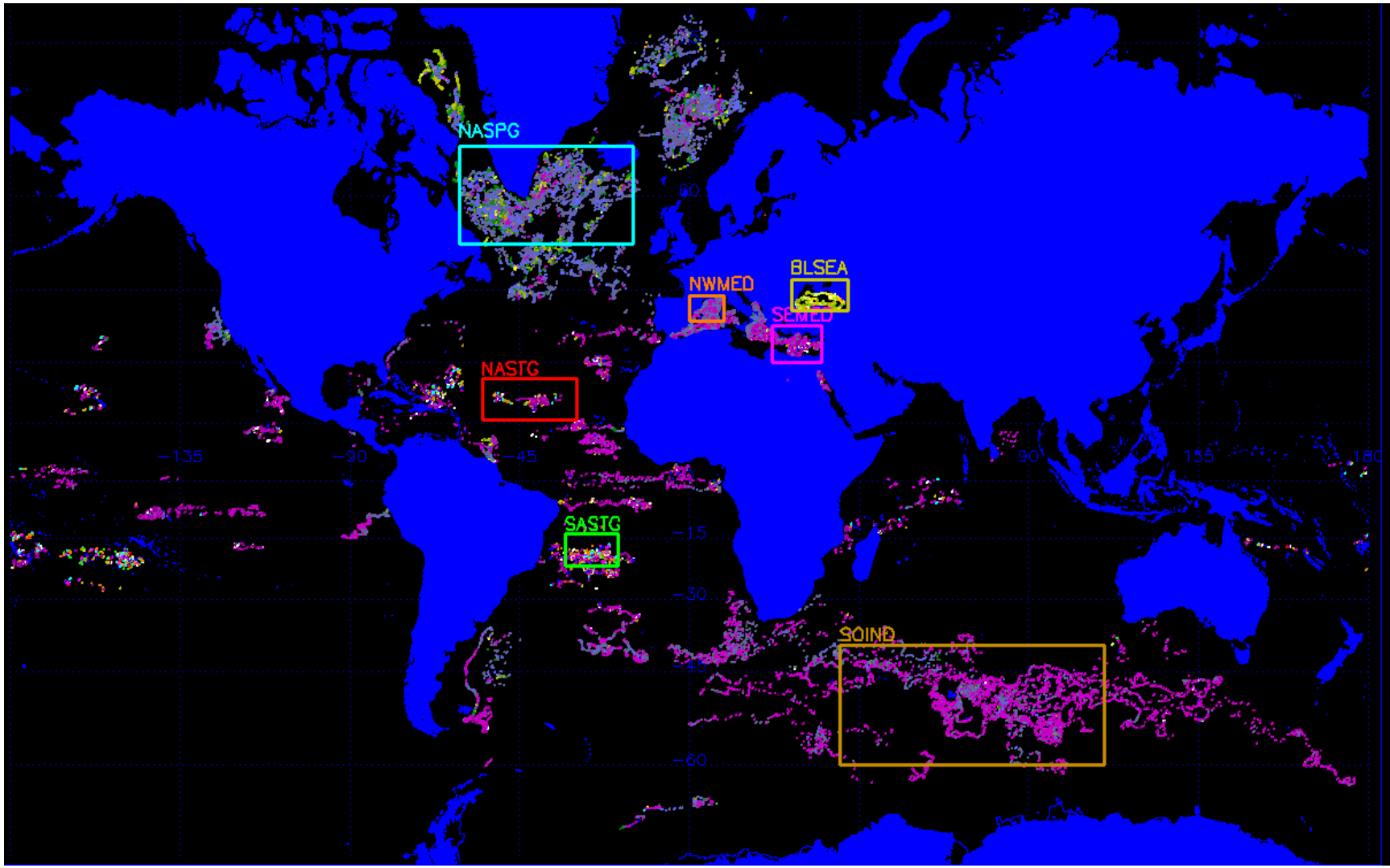
Satellite

In-situ

Map of ARGO site

Cumulative histograms

Table with numbers of data for area



EarthCARE datasets and OCEAN Archive generation

1. Open relevant EC data and ancillary information files and update log wrt to problems in availability of the files.
2. Grid products on the same (L1) horizontal grid

	A	B	C	D	E	F	G	H	I
1	File	Field Name	# Dim	Dimensions	Type	Units	Description	Use	Notes
2	AUX_MET	eastward_wind_at_10_metres	1	horizontal_grid	float	m s-1	10 metre U wind component	Surface B/T	
3	AUX_MET	northward_wind_at_10_metres	1	horizontal_grid	float	m s-1	10 metre V wind component	Surface B/T	
4	AUX_MET	latitude	1	horizontal_grid	float	degree_north	Latitude	Localization	needed only for AUX_MET regridding
5	AUX_MET	longitude	1	horizontal_grid	float	degree_east	Longitude	Localization	needed only for AUX_MET regridding
6	AUX_MET	sea_ice_cover	1	horizontal_grid	float	1	Sea ice area fraction	Screening	
7	AUX_MET	sea_surface_temperature	1	horizontal_grid	float	K	Sea surface temperature	Refractive index	
8	ATL_NOM	mie_background_signal	2	along_track, background	float	BU	Mie co-polar channel background signal	Daytime passive retrieval/closure	Needs calibration
9	ATL_NOM	rayleigh_background_signal	2	along_track, background	float	BU	Rayleigh channel background signal	Daytime passive retrieval/closure	Needs calibration
10	ATL_NOM	crosspolar_background_signal	2	along_track, background	float	BU	Mie cross-polar channel background signal	Daytime passive retrieval/closure	Needs calibration
11	ATL_NOM	sample_latitude	2	along_track, height	double	degree_north	Latitude	Localization	Extract only the ground bin value (# 237) and convert to 1D float
12	ATL_NOM	sample_longitude	2	along_track, height	double	degree_east	Longitude	Localization	Extract only the ground bin value (# 237) and convert to 1D float
13	ATL_NOM	sample_altitude	2	along_track, height	float	m	Altitude (WGS84)	Localization	Center of the bin (around bin around # 237)
14	ATL_NOM	surface_elevation	1	along_track	float	m	Surface elevation (WGS84)	Retrieval	
15	ATL_NOM	land_flag	1	along_track	byte		Land flag. 0:water 1:land	Screening	
16	ATL_NOM	floor_index	1	along_track	ubyte		Index of floor sample for Rayleigh cross-talk computation	Screening	This is not the ground bin, can be a cloud
17	ATL_NOM	time	1	along_track	double	s	Time, seconds since 2000-1-1 00:00:00.0 0:00	Localization	Convert to: year, month, day, hours, minutes, seconds
18	ATL_NOM	solar_elevation_angle	1	along_track	float	degree	Solar elevation angle (at line-of-sight/ellipsoid intersection)	Screening, daytime passive retrieval/closure	
19	ATL_NOM	rayleigh_attenuated_backscatter	2	along_track, height	float	m-1 sr-1	Attenuated Rayleigh backscatter signal	Retrieval	
20	ATL_NOM	mie_attenuated_backscatter	2	along_track, height	float	m-1 sr-1	Attenuated Mie copolar backscatter signal	Retrieval	
21	ATL_NOM	crosspolar_attenuated_backscatter	2	along_track, height	float	m-1 sr-1	Attenuated Mie crosspolar backscatter signal	Retrieval	
22	ATL_NOM	rayleigh_attenuated_backscatter_rand	2	along_track, height	float	m-1 sr-1	Random error in the attenuated Rayleigh backscatter signal	Screening and uncertainty evaluation	
23	ATL_NOM	mie_attenuated_backscatter_random	2	along_track, height	float	m-1 sr-1	Random error in the attenuated Mie copolar backscatter signal	Screening and uncertainty evaluation	
24	ATL_NOM	crosspolar_attenuated_backscatter_ra	2	along_track, height	float	m-1 sr-1	Random error in the attenuated Mie crosspolar backscatter signal	Screening and uncertainty evaluation	
25	ATL_NOM	rayleigh_attenuated_backscatter_tota	2	along_track, height	float	m-1 sr-1	Total error in the attenuated Rayleigh backscatter signal	Screening and uncertainty evaluation	
26	ATL_NOM	mie_attenuated_backscatter_total_en	2	along_track, height	float	m-1 sr-1	Total error in the attenuated Mie copolar backscatter signal	Screening and uncertainty evaluation	
27	ATL_NOM	crosspolar_attenuated_backscatter_to	2	along_track, height	float	m-1 sr-1	Total error in the attenuated Mie crosspolar backscatter signal	Screening and uncertainty evaluation	
28	ATL_NOM	rayleigh_lidar_constant_monitoring_v	1	along_track	float	BU m3 sr	Rayleigh lidar constant monitoring value	Daytime passive retrieval/closure	
29	ATL_NOM	mie_lidar_constant_monitoring_value	1	along_track	float	BU m3 sr	Mie lidar constant monitoring value	Daytime passive retrieval/closure	
30	ATL_NOM	crosspolar_lidar_constant_monitoring	1	along_track	float	BU m3 sr	Crosspolar lidar constant monitoring value	Daytime passive retrieval/closure	
31	ATL_NOM	hot_pixel_flag_rayleigh	1	height	byte		Flag for hot pixels in the rayleigh channel	Screening	
32	ATL_NOM	hot_pixel_flag_mie	1	height	byte		Flag for hot pixels in the mie channel	Screening	
33	ATL_NOM	hot_pixel_flag_crosspolar	1	height	byte		Flag for hot pixels in the crosspolar channel	Screening	
34	ATL_FM	sigma0_mie	1	along_track	float	sr-1	Integrated surface return for the Co-Polar Mie channel	KNMI-NASA comparison	
35	ATL_FM	sigma0_crosspolar	1	along_track	float	sr-1	Integrated surface return for the Cross-Polar Mie channel	KNMI-NASA comparison	
36	ATL_FM	sigma0_rayleigh	1	along_track	float	sr-1	Integrated surface return for the Co-Polar Rayleigh channel	KNMI-NASA comparison	
37	ATL_FM	sigma0_mie_error	1	along_track	float	sr-1	Error in the surface return for the Co-Polar Mie channel	KNMI-NASA comparison	
38	ATL_FM	sigma0_crosspolar_error	1	along_track	float	sr-1	Error in the surface return for the Cross-Polar Mie channel	KNMI-NASA comparison	
39	ATL_FM	sigma0_rayleigh_error	1	along_track	float	sr-1	Error in the surface return for the Co-Polar Rayleigh channel	KNMI-NASA comparison	
40	ATL_FM	quality_flag	1	along_track	byte		Quality status of the retrieved profile, 0: Good quality retrieval 1: Good quality for strong scatterers, low SNR for low signal features 2: Only strong features, no smoothed low signal retrievals (close to a gap) 3: Potential bad retrieval of the column due to low energy (energy_ error_flag=1)4: Not retrieved due to L1 problems (e.g. intersection_error_flag=1)	Screening	
41	ATL_FM	surface_estimation_flag	1	along_track	byte		Ocean-based surface bin estimation: 1=DEM-based surface bin estimation	Screening	
42	ATL_FM	surface_rayleigh_tau	1	along_track	float		Rayleight Optical thickness at Surface	Retrieval	
43	ATL_FM	featuremask	2	along_track, height	byte		Lidar Feature Mask at the merged lidar/radar resolution -3: (sub)-surface data -2 : no retrievals -1 : fully Rayleigh attenuated 0 : clear sky 1–4: likely clear sky 5 : Low altitude aerosol (not retrieved) 6-7: Aerosols or thin clouds 8-9: Thick aerosols or clouds 10 : Optically thick Clouds	Screening	
44	ATL_AER_A	latitude	1	JSG_along_track	double	degree_north	Latitudes of the pixel centres [-90,90]	Localization	needed only for ATL_AER, ATL_EBD, and ATL_ALD regridding
45	ATL_AER_A	longitude	1	JSG_along_track	double	degree_east	Longitudes of the pixel centres [-180,180]	Localization	needed only for ATL_AER, ATL_EBD, and ATL_ALD regridding
46	ATL_AER_A	height	2	JSG_along_track, JSG_height	float	m	Altitude of pixel centre in meters above WGS84 ellipsoid	Localization	needed only for ATL_AER and ATL_EBD regridding
47	ATL_EBD	simple_classification	2	JSG_along_track, JSG_height	byte		Simple Classification (used as backup if A-TC class if unknown). -3: Missing data -2: Surface -1: BOTH Mie and Ray Attenuated 0: Clear 1: liquid cloud 2: ice cloud 3: aerosol 4: stratospheric cloud 5: stratospheric aerosol	Screening	
48	ATL_EBD	particle_extinction_coefficient_355nm	2	JSG_along_track, JSG_height	float	m-1	Derived extinction at 355nm from the ATLID data	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM
49	ATL_EBD	particle_extinction_coefficient_355nm	2	JSG_along_track, JSG_height	float	m-1	Estimated 1-sigma derived Extinction error	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM
50	ATL_EBD	particle_backscatter_coefficient_355n	2	JSG_along_track, JSG_height	float	m-1 sr-1	Derived Mie backscatter at 355nm from the ATLID data	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM
51	ATL_EBD	particle_backscatter_coefficient_355n	2	JSG_along_track, JSG_height	float	m-1 sr-1	Estimated 1-sigma derived Backscatter error	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM
52	ATL_EBD	particle_optical_depth_355nm	2	JSG_along_track, JSG_height	float	1	Particle optical depth corrected for lidar tilt i.e. vertical optical depth is reported	Screening and refined retrieval	
53	ATL_EBD	particle_optical_depth_355nm_error	2	JSG_along_track, JSG_height	float	1	Estimated 1-sigma error in Optical Depth	Screening and refined retrieval	
54	ATL_EBD	particle_extinction_coefficient_355nm	2	JSG_along_track, JSG_height	float	m-1	Extinction (medium horizontal resolution version) at 355nm, 11 horizontal JSG pixels	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM
55	ATL_EBD	particle_extinction_coefficient_355nm	2	JSG_along_track, JSG_height	float	m-1	Estimated 1-sigma error in Extinction (medium horizontal resolution version)	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM
56	ATL_EBD	particle_backscatter_coefficient_355n	2	JSG_along_track, JSG_height	float	m-1 sr-1	Backscatter (medium horizontal resolution version) at 355nm, 11 horizontal JSG pixels	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM
57	ATL_EBD	particle_backscatter_coefficient_355n	2	JSG_along_track, JSG_height	float	m-1 sr-1	Estimated 1-sigma error in derived backscatter (medium horizontal resolution version)	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM
58	ATL_EBD	particle_optical_depth_355nm_mediu	2	JSG_along_track, JSG_height	float	1	Optical Depth (medium horizontal resolution version)	Screening and refined retrieval	
59	ATL_EBD	particle_optical_depth_355nm_mediu	2	JSG_along_track, JSG_height	float	1	Estimated 1-sigma error in Optical Depth (medium horizontal resolution version)	Screening and refined retrieval	
60	ATL_EBD	particle_extinction_coefficient_355nm	2	JSG_along_track, JSG_height	float	m-1	Extinction (low horizontal resolution version) at 355nm, 101 horizontal JSG pixels	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM
61	ATL_EBD	particle_extinction_coefficient_355nm	2	JSG_along_track, JSG_height	float	m-1	Estimated 1-sigma error in Extinction (low horizontal resolution version)	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM
62	ATL_EBD	particle_backscatter_coefficient_355n	2	JSG_along_track, JSG_height	float	m-1 sr-1	Backscatter (low horizontal resolution version) at 355nm, 101 horizontal JSG pixels	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM
63	ATL_EBD	particle_backscatter_coefficient_355n	2	JSG_along_track, JSG_height	float	m-1 sr-1	Estimated 1-sigma error in derived backscatter (low horizontal resolution version)	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM
64	ATL_EBD	particle_optical_depth_355nm_low_re	2	JSG_along_track, JSG_height	float	1	Optical Depth (low horizontal resolution version)	Screening and refined retrieval	
65	ATL_EBD	particle_optical_depth_355nm_low_re	2	JSG_along_track, JSG_height	float	1	Estimated 1-sigma error in Optical Depth (low horizontal resolution version)	Screening and refined retrieval	
66	ATL_EBD	rayleigh_backscatter_355nm_model	2	JSG_along_track, JSG_height	float	m-1 sr-1	Rayleigh backscatter from atmospheric density	Retrieval	
67	ATL_ALD	aerosol_optical_thickness_355nm	1	JSG_along_track	float	1	Column aerosol optical thickness at 355 nm	Screening and refined retrieval	
68	ATL_AER	simple_classification	2	JSG_along_track, JSG_height	byte		Simple Classification (used as backup if A-TC class if unknown). -3: Missing data -2: Surface -1: BOTH Mie and Ray Attenuated 0: Clear 1: liquid cloud 2: ice cloud 3: aerosol 4: stratospheric cloud 5: stratospheric aerosol	Screening	rename to simple_classification_aer
69	ATL_AER	particle_extinction_coefficient_355nm	2	JSG_along_track, JSG_height	float	m-1	Derived extinction at 355nm from the ATLID data	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM, rename to particle_extinction_coefficient_355nm_aer
70	ATL_AER	particle_extinction_coefficient_355nm	2	JSG_along_track, JSG_height	float	m-1	Estimated 1-sigma derived Extinction error	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM, rename to particle_extinction_coefficient_355nm_aer_error
71	ATL_AER	particle_backscatter_coefficient_355n	2	JSG_along_track, JSG_height	float	m-1 sr-1	Derived Mie backscatter at 355nm from the ATLID data	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM, rename to particle_backscatter_coefficient_355nm_aer
72	ATL_AER	particle_backscatter_coefficient_355n	2	JSG_along_track, JSG_height	float	m-1 sr-1	Estimated 1-sigma derived Backscatter error	Screening and refined retrieval	save only the values corresponding to bins # 230-239 in ATL_NOM, rename to particle_backscatter_coefficient_355nm_aer_error