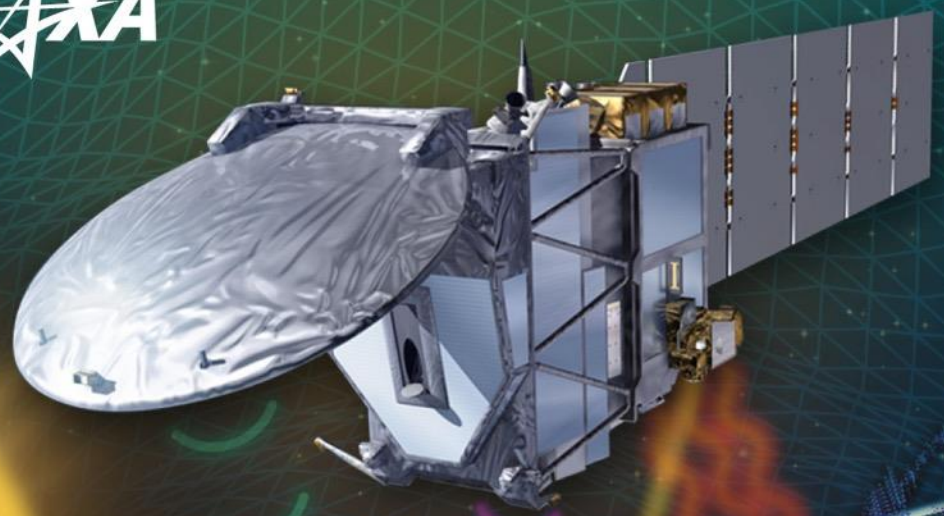


ESA-JAXA Pre-Launch EarthCARE Science and Validation Workshop

13 – 17 November 2023 | ESA-ESRIN, Frascati (Rome), Italy

Aerosol observation using ATLID and CALIOP and its application

Nishizawa, T.[1], Kudo R.[2], Oikawa E.[2], Higurashi A.[1], Jin Y.[1], and Okamoto H.[3]

(1) NIES, Japan, (2) JMA/MRI, Japan, (3) Kyushu University, Japan

EarthCARE
(Earth Clouds, Aerosols and Radiation Explorer)

✓ Joint Japanese (JAXA)-European (ESA) satellite mission
✓ Improve the understanding of cloud-aerosol-radiation interactions
✓ Four sensors:

ATLID (Atmospheric Lidar: 355nm HSRL with dep. Measurement function)
MSI (Multi-spectral imager: 0.66, 0.865, 1.61, 2.2, 8.8, 10.8, 12.0 um)
CPR (Cloud Profiling Radar: 94GHz)
BBR (Broad-band radiometer: SW (0.2-4um), Total (0.2-50um)

=> Observe Global / 3D distribution of clouds and aerosols and Radiation
=> Provide information on Cloud and Aerosol effects on atmospheric radiation

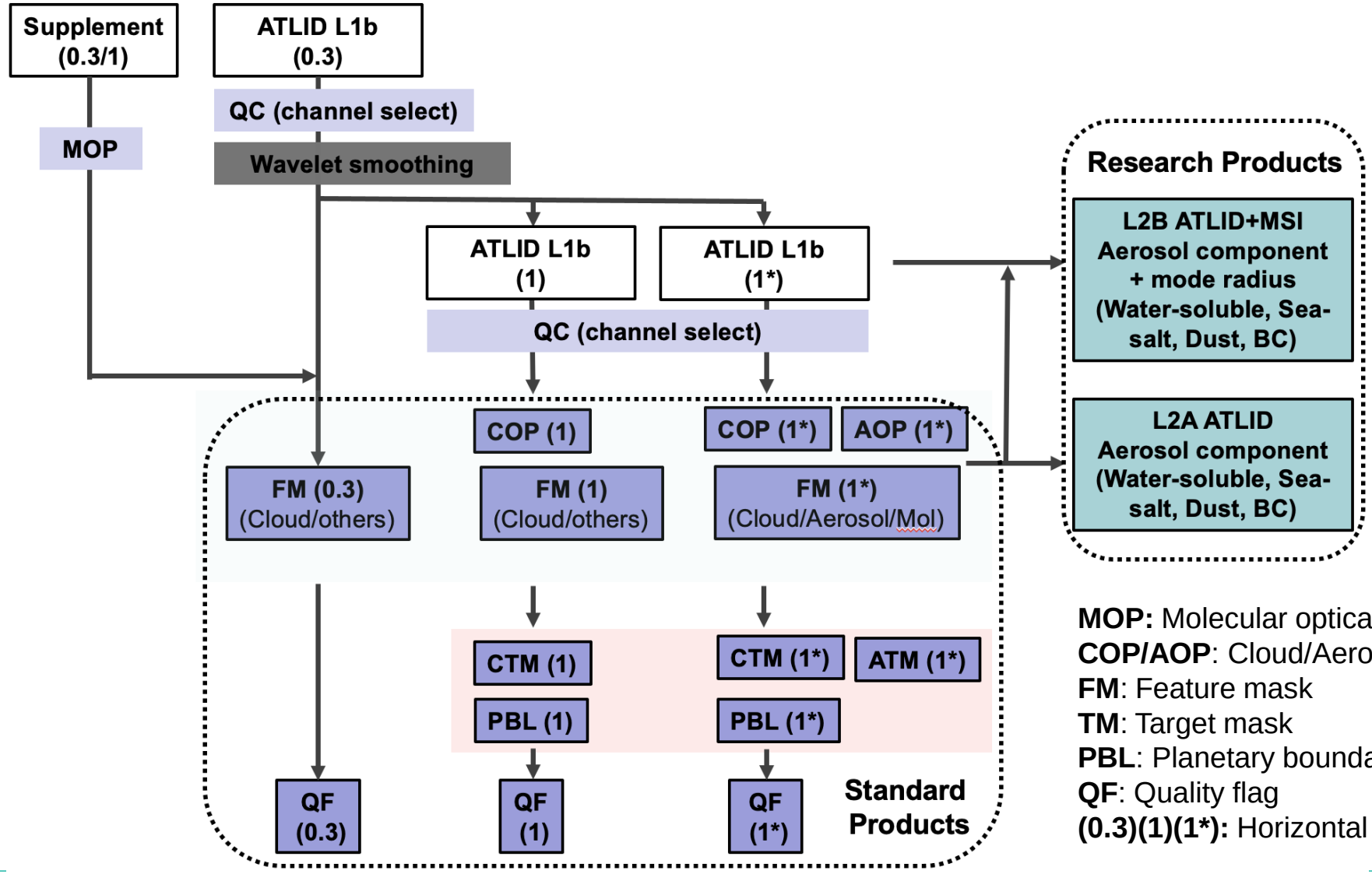
Cloud and precipitation

- Optical / Microphysical / Radiative properties : Extinction, Size distribution, Single scattering albedo, etc…
- Particle type: Water, Ice, Mixed, snow, drizzle, etc…

Aerosols

- Optical / Microphysical / Radiative properties
- Particle type: CALIOP / AERONET / EARLINET: Biomass burning, Marine, Smoke, etc…
- Component: Aerosol transport model / NIES: Dust, Sea-salt, black carbon, Water soluble, etc…

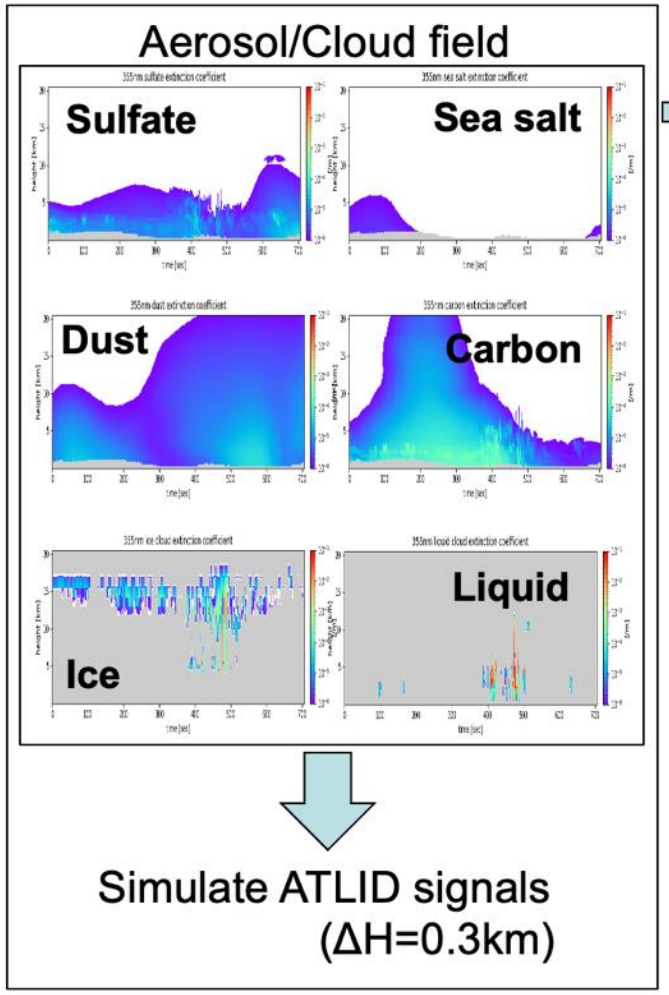
JAXA L2 ATLID & ATLID-MSI algorithm flow



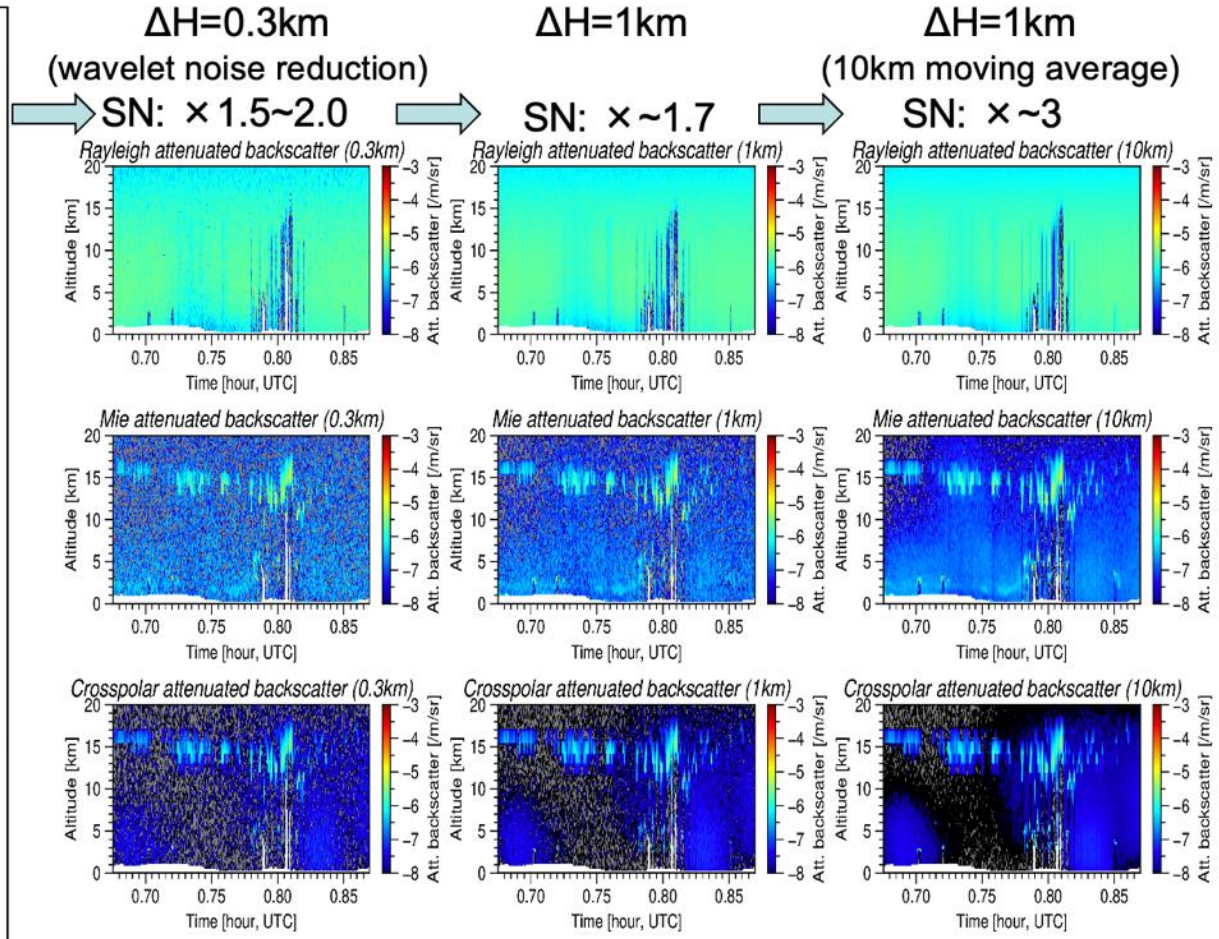
MOP: Molecular optical property
COP/AOP: Cloud/Aerosol optical property
FM: Feature mask
TM: Target mask
PBL: Planetary boundary layer
QF: Quality flag
(0.3)(1)(1*): Horizontal resolution [km]

Application to Joint-Simulator data (Signal)

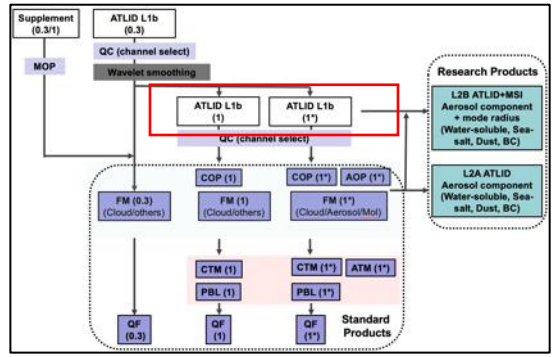
J-Simulator



Integration and smoothing



Algorithm flow



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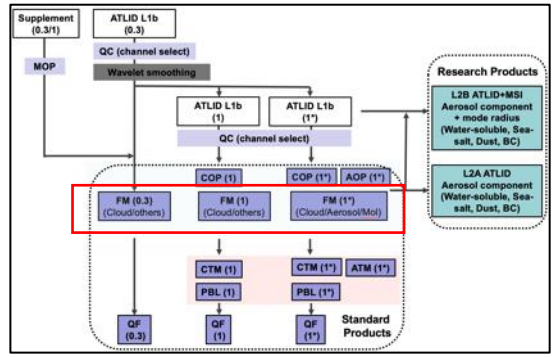
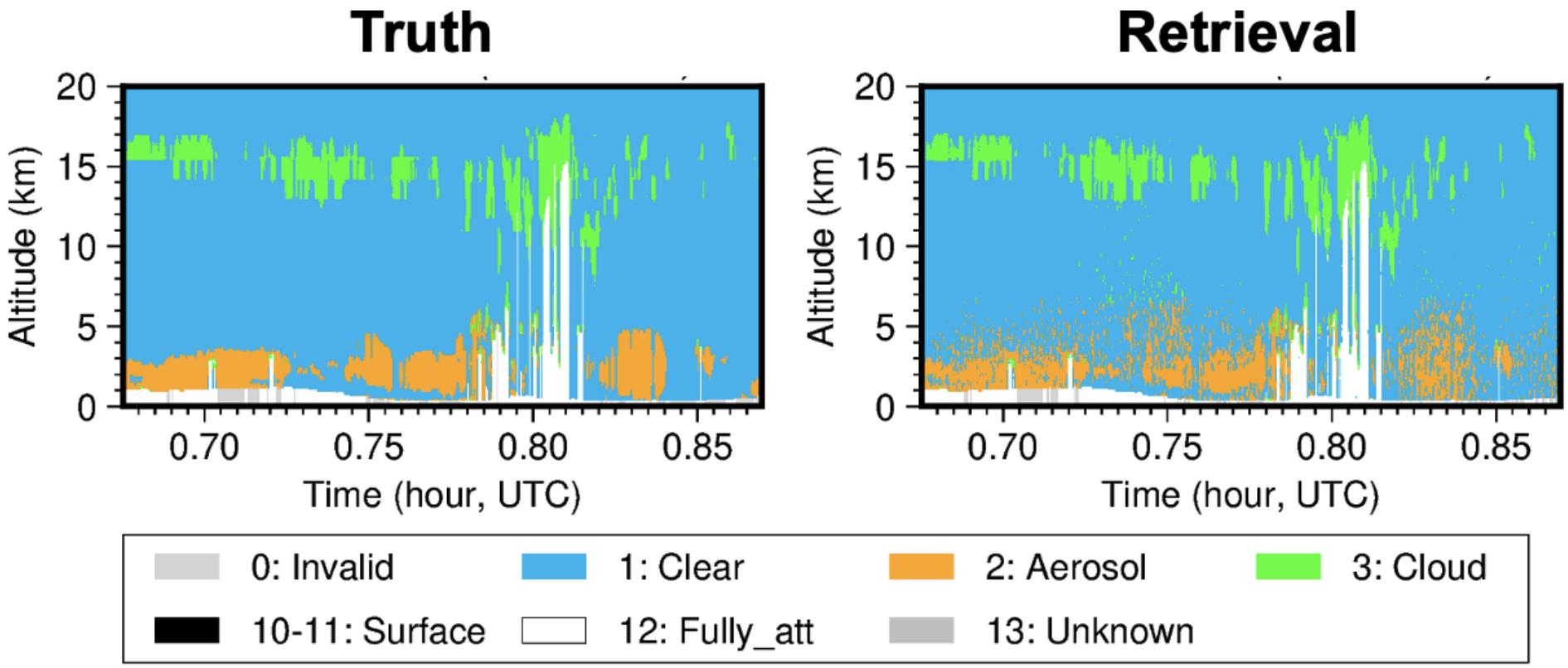
Application to Joint-Simulator data (FM)

Applying the threshold method developed based on the Kyushu University method [Okamoto et al. 2008,2010, Hagihara et al. 2010]

Algorithm flow



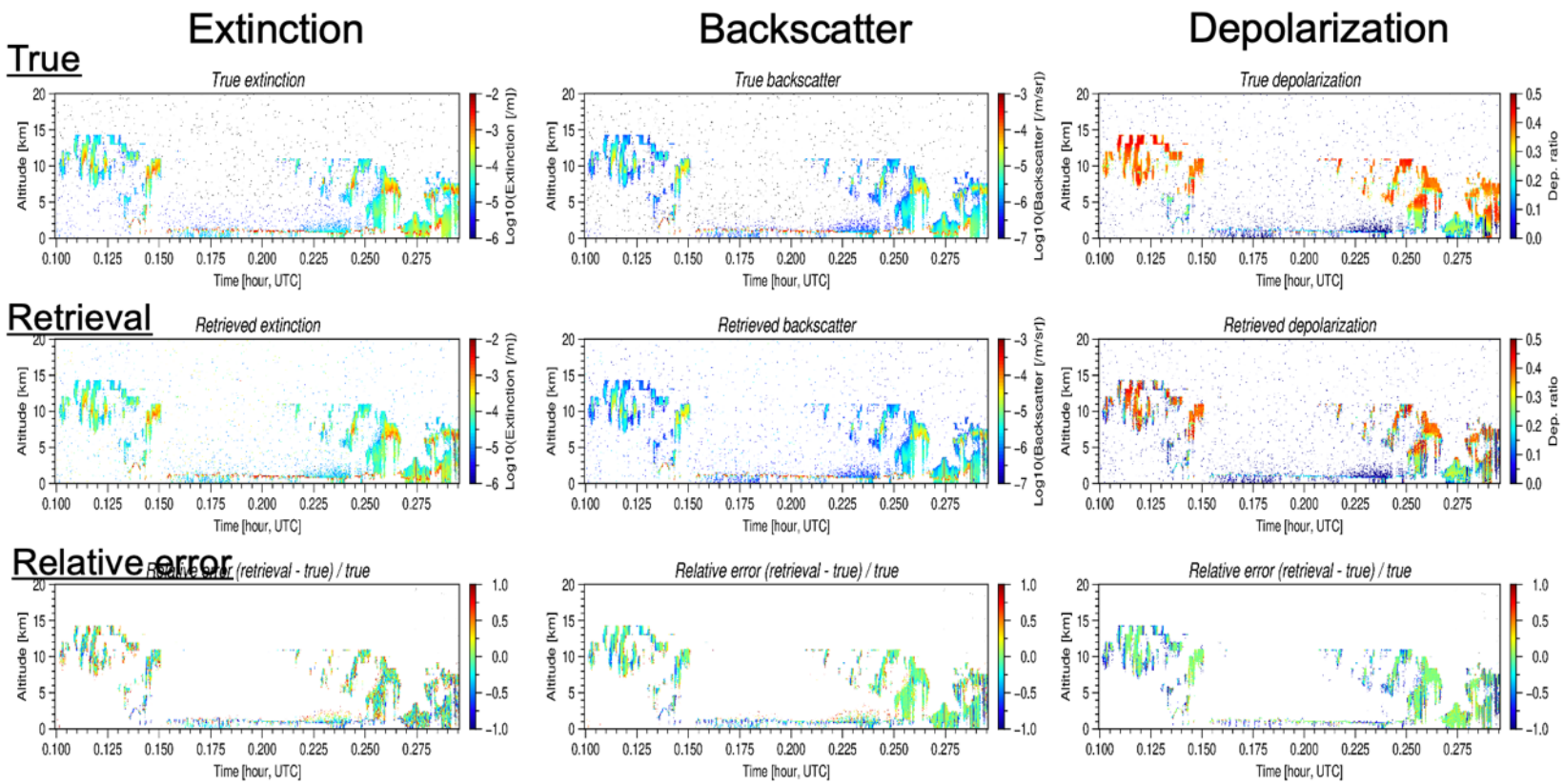


Correct rates for Aerosol, Cloud, Total > 90%

ΔH=10km, ΔZ=0.1km
ECA_J_ATL_CLA_2AS_20080619T0040_20080619T0051_60002A_vAa

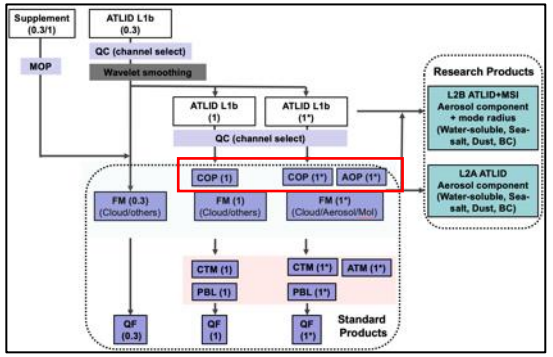
Application to Joint-Simulator data (AOP, COP)

ΔExtinction, ΔBackscatter, ΔDepolarization ~ 30% or less (excluding edge area)



ΔH=10km, ΔZ=0.1km
Data=ECA_J_ATL_CLA_20080619T0005-600001F

Algorithm flow

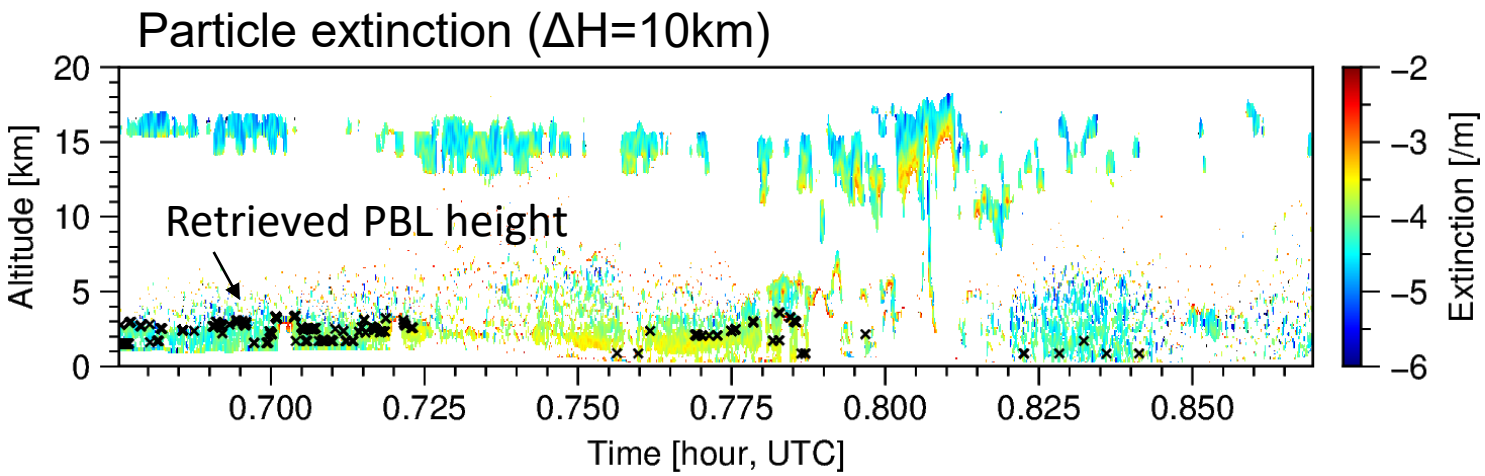


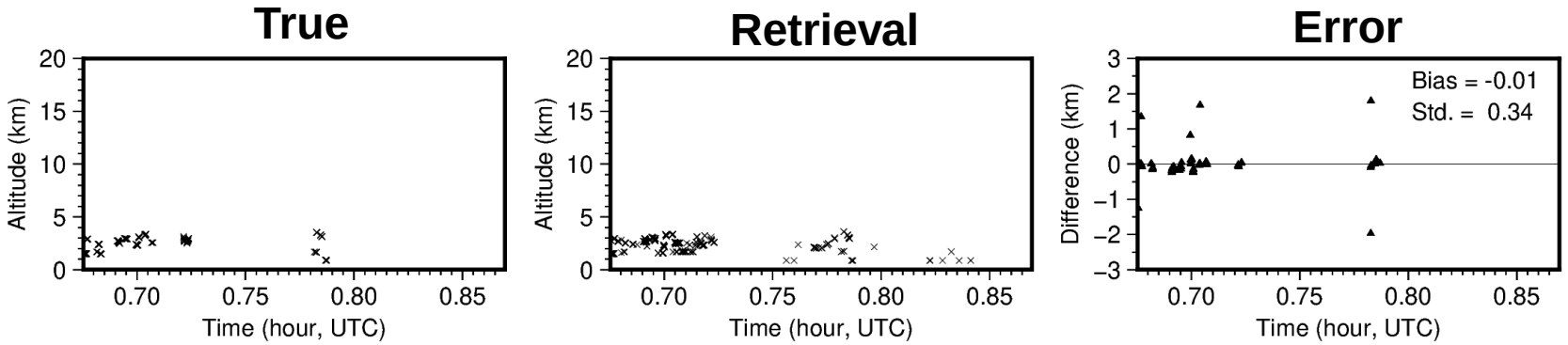
Method
Optimization by using Gauss-Newton method with Biconjugate gradient method [Kudo et al. 2016]

A priori constrains
- Vertical and Horizontal smoothness
- A priori value for lidar ratio with lagrange multiplier depending on the extinction coefficient.

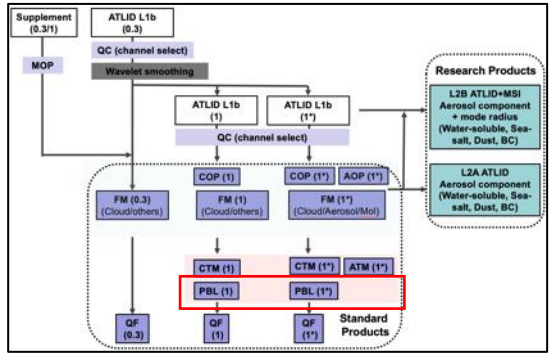
Application to Joint-Simulator data (PBLH)

✓ Retrieve PBLH using Wavelet Covariance Transform (WCT)
✓ Bias = -0.01 km, RMSE = 0.34 km





Algorithm flow

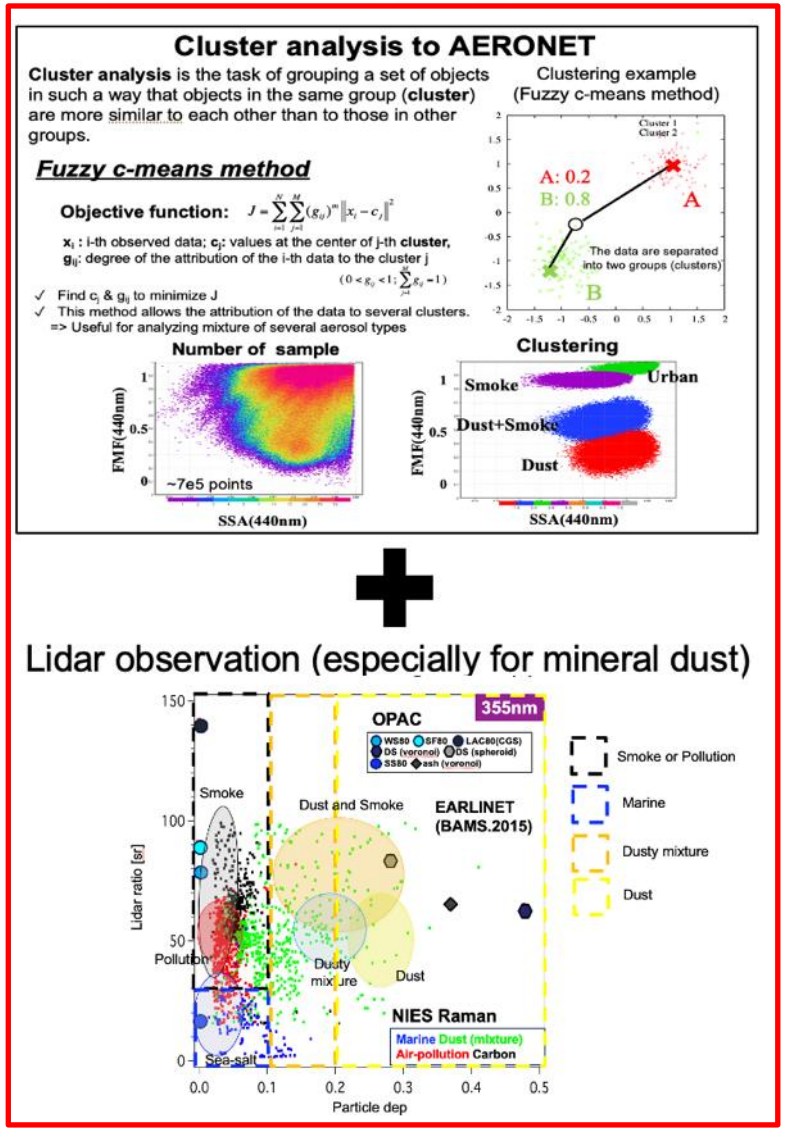


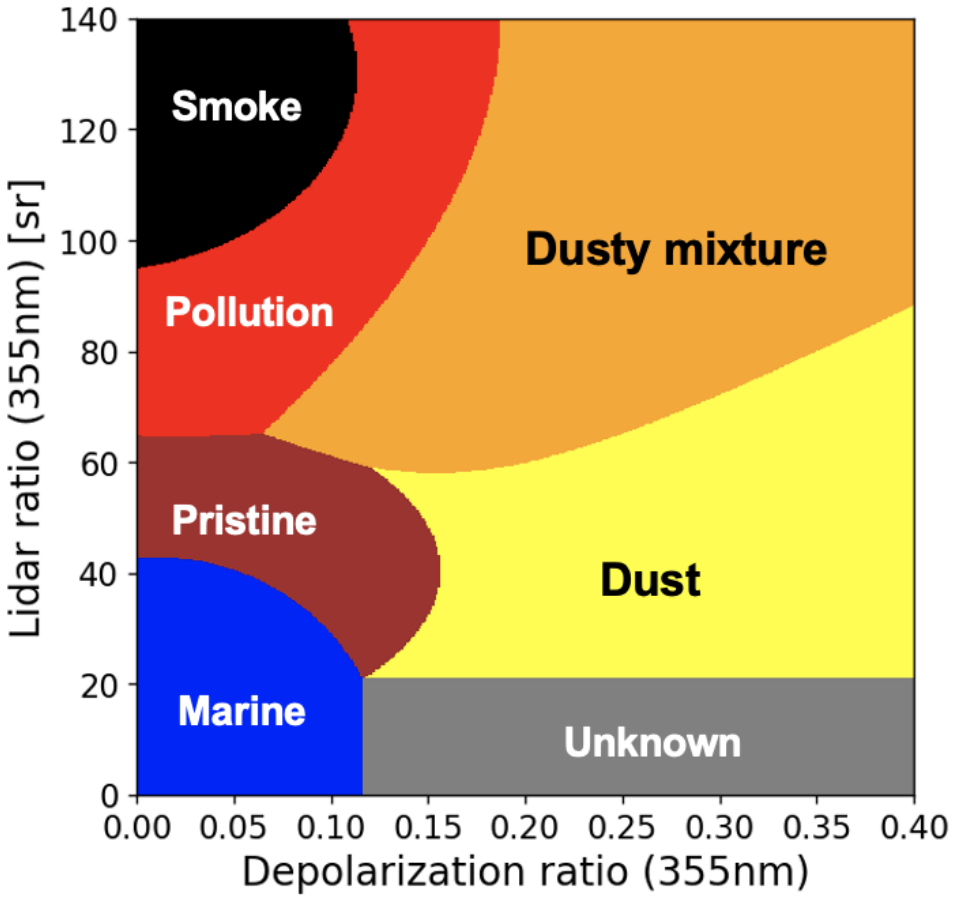
Retrieval Procedure

1. Calculate backscattering ratio – 1 by Mie att. backscatter / Rayleigh att. backscatter from L1b data
2. Normalize BR – 1 to 1.0 for the first 1 km height from the surface elevation
3. Calculate wavelet covariance transform (WCT) for the normalized BR – 1 with Haar function (1 km window)
4. PBL height is determined when exceeding a threshold (0.2) and having the maximum WCT

ΔH=10km, ΔZ=0.1km
ECA_J_ATL_CLA_2AS_20080619T0040_20080619T0051_60002A_vAa

Application to Joint-Simulator data (TM/aerosol)





The algorithm performance is being investigated.

Research Products
-- Aerosol retrieval using CALIOP+MODIS --

State vector x
- Dry volume concentrations of WS, LA, DS, SS
- Dry median radii of fine (WS, LA) and coarse (DS) particles

Forward models $y(x)$
- Aerosol optical property
- CALIOP observations
- MODIS observations

A priori constraints $y_a(x)$
- Smoothness of vertical profiles of WS, LA, DS, SS
- Similarity of vertical profiles of WS and LA
- $AOD_{LA} < AOD_{WS}$
- A priori distributions of fine (WS, LA) and coarse (DS) median radii

Iteration by Gauss-Newton method and a line search with Armijo rule (Kudo 2016)

$$x_{k+1} = x_k + \alpha d$$

Objective function

Observations y^{obs}
- CALIOP observations
- MODIS observations

Convergence

Optimized x

$$f(x) = \frac{1}{2}\left(y^{obs} - y(x)\right)^T (W^2)^{-1}\left(y^{obs} - y(x)\right) + \frac{1}{2} y_a(x)^T (W_a^2)^{-1} y_a(x)$$

Output
- AOD, SSA, etc. of total aerosols
- AOD and extinction coefficients of WS, LA, DS, SS

Aerosol optical property
- Lognormal size distribution.
- Median radii of WS and LA is same.
- Median radius of SS is estimated by the parameterization using ocean surface wind speed (Erickson 1988)
- Hygroscopic growth depending on relative humidity for WS, Shell of LA, and SS (Hess 1998)
- WS, LA, DS over land. WS, LA, DS, SS over ocean.

CALIOP
- Lidar equation

MODIS
- Vector RTM, PSTAR (Ota 2010)

- Smoothness of vertical profile

$$y_a(x) = \ln\left(V_{dry}(z_{i-1})\right) - 2\ln\left(V_{dry}(z_i)\right) + \ln\left(V_{dry}(z_{i+1})\right)$$

- Similarity of vertical profiles of WS, LA

$$y_a(x) = \ln\left(V_{dry,LA}(z_i)/V_{dry,LA}(z_{i+1})\right) - \ln\left(V_{dry,WS}(z_i)/V_{dry,WS}(z_{i+1})\right)$$

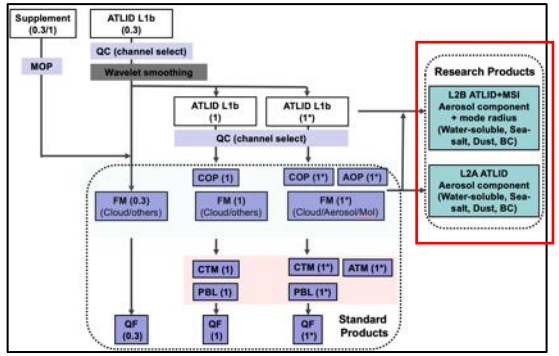
- $\tau_{LA} < \tau_{WS}$

$$y_a(x) = -\ln(1 - \tau_{LA}/\tau_{WS})$$

- A priori values of median radii

$$y_a(x) = \ln(r_{fine/coarse}) - \ln\left(r_{fine/coarse}^{a\ priori}\right)$$

Algorithm flow

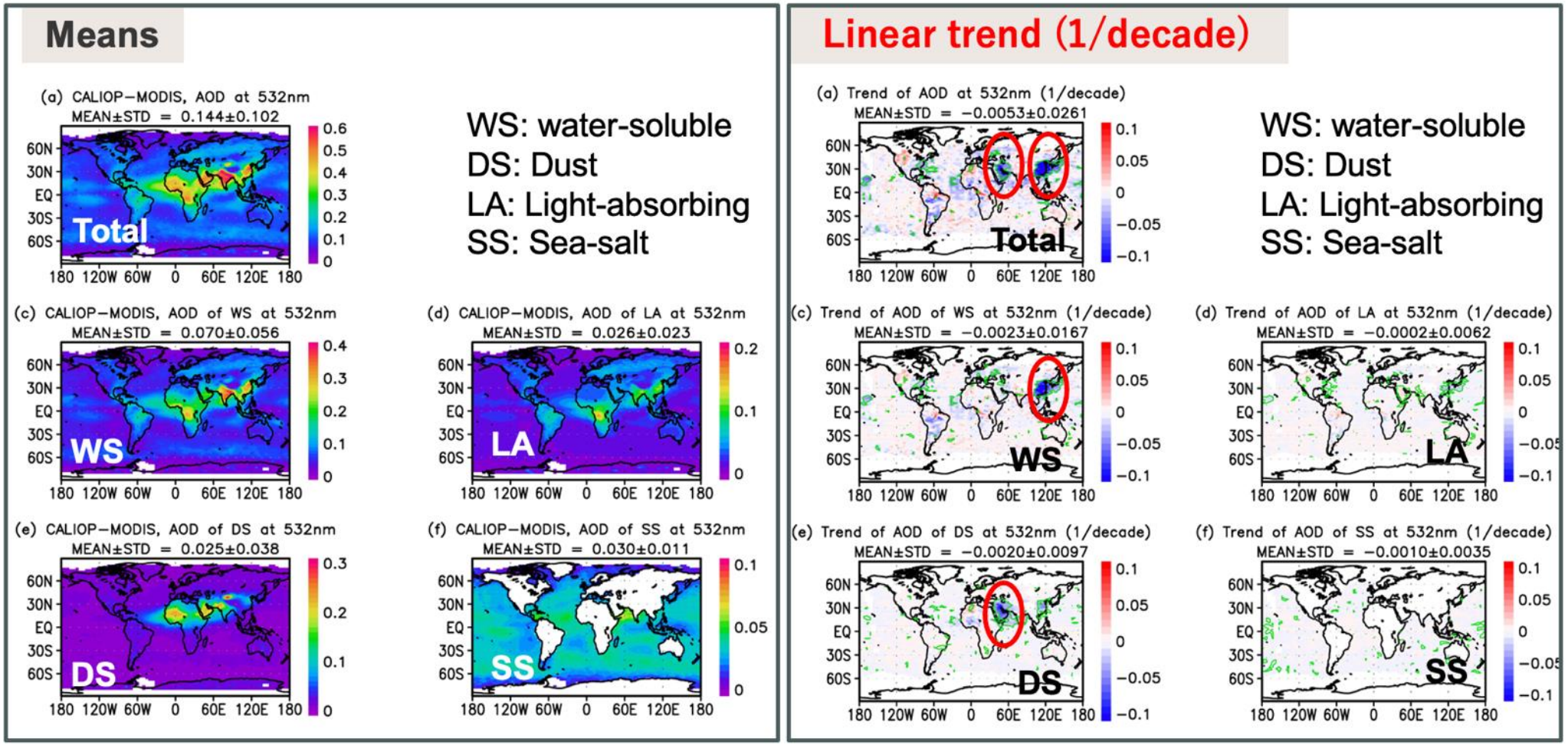


Details are in
Kudo et al. AMT, 2023

Retrieved parameters
- ✓ Extinction coefficients for water-soluble, Sea-salt, Dust, Light-absorbing particle
- ✓ Columnar-mean fine-mode and coarse-mode radii

Research Products
-- Long term trend in 2007-2021--

Remarkably decreasing trend of AOD was found in East and West Asia,
which is consistent with the other studies (e.g., Pollutant emission data and dust observation date by meteorological observation).



*Green contour indicates statistically significant trend determined by t-test.

Summary

We have developed aerosol and cloud retrieval algorithms using the EarthCARE satellite onboard lidar and imager.

1) Apply the algorithm to Joint-simulator and evaluating its overall performance.

2) Feature mask
Introduce the threshold method based on the Kyushu University method
(discrimination of noise, atmospheric molecules, aerosols, and clouds).

3) Particle optical properties (POP product)
Retrieve extinction/backscatter/dep by Maximum Likelihood Estimation (MLE).

4) Aerosol type identification (target mask)
Develop the threshold values and models using ground-based lidar + passive sensor data.
The algorithm performance is under investigation.

5) Aerosol component analysis (CALIOP/MODIS analysis)
・Long-term data analysis from 2007 to 2021 was conducted, and we found the remarkable trend in East Asia and West Asia.
・Data assimilation experiments using the NICAM-Chem model are underway.
=> These studies can be extended to EarthCARE data.