Description of SODA (Synergized Optical Depth of Aerosols)
A new multi-instrument Aerosol Optical Depth retrieval product
based on CALIOP-CPR-AMSRE

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Aerosol optical depth retrieval approach :

The atmospheric optical depth is retrieved at lidar wavelength through 3 steps corresponding to 3 modules.

Data profiles are analyzed only if the maximum of the lidar signal is situated at ocean level. This allow to remove profiles with low level dense clouds and profiles totally attenuated. Only profile over the ocean surface are treated. This correspond to an IGBP value of 17. Profiles with other IGBP values are excluded from the treatment.

Module 1) Monthly global calibration (nighttime)

The radar normalized scattering cross section $\sigma_{SR,att}$ for the ocean is first corrected from gaseous water vapor attenuation (τ_{AR}) and corrected from ocean refractive index ρ_{0R} variations with temperature [Meissner and Wentz, 2004]. Water vapor gaseous attenuation is retrieved from AMSR-E integrated water vapor content using the expression of [Tanelli et al. 2008].

This procedure allows to obtain the reduced radar scattering cross section σ'_{SR}.

$$\sigma'_{SR} = \frac{0,4\sigma_{SR,att}\exp(2\tau_{AR})}{\rho_{0R}}$$

The same procedure can be performed with the lidar ocean scattering cross section, however it is not necessary, as the refractive index is relatively constant with temperature (its value being slightly different at 532 and 1064 nm) so it is enough to correct it from atmospheric molecular attenuation (molecular rayleigh scattering and ozone absorption).

The relationship between σ'_{SR} ans $\gamma_{SL,att}$ is determined on a monthly basis from collocated data during nighttime for clearest lidar profiles (integrated backscatter coefficient < 0.01 sr^{-1}) and can be expressed as.

$$\gamma_{SL,att} = f(\sigma'_{SR})$$

The first module allows to determine the value to be used for A, B, C, D, E, the 4th order polynomial coefficients linking σ'_{SR} and $\gamma_{SL,att}$ data that is

$$\gamma_{SL,att} = A\sigma'^{4}_{SR} + B\sigma'^{3}_{SR} + C\sigma'^{2}_{SR} + D\sigma'_{SR} + E$$

This procedure allow to calibrate the method and through a lidar-radar cross calibration, to correct any monthly calibration bias coming from the lidar or radar. As it is based only on observations, it does not rely on any underlying assumption of surface roughness behavior.

Module 2) Latitudinal day and night calibration

On the base of the relationship determined by module 1, the latitudinal calibration bias is determined on clear air (integrated backscatter coefficient < 0.01 sr^{-1}) for day and night observations. More specifically, this module determines the ratio

$$\frac{\gamma_{SL,att}}{A\sigma_{SR}^{'4} + B\sigma_{SR}^{'3} + C\sigma_{SR}^{'2} + D\sigma_{SR}^{'} + E} = f(\text{latitude})$$

This ratio should be equal to 1 and its determination allow to correct any latitudinal bias present in the data, day or night.

Module 3) Aerosol Optical Depth retrieval

Lidar observations are corrected from calibration variations determined by module 2.

Aerosol attenuation induces a deviation from the relationship determined in module 1. The determination of atmospheric optical depth τ_{AL} (subscript A for atmosphere, L for lidar) is performed by module 3 at lidar wavelength. The link between τ_{AL} and oceanic scattering cross section of the radar σ'_{SR} and lidar $\gamma_{SL,att}$ is determined using the following relationship

$$\tau_{AL} = \frac{1}{2}\ln\left(\frac{A\sigma_{SR}^{'4} + B\sigma_{SR}^{'3} + C\sigma_{SR}^{'2} + D\sigma_{SR}^{'} + E}{\gamma_{SL,att}}\right)$$

This value is determined on a shot to shot basis and stored into hdf files.

Data input:

CALIPSO L1
- 532 nm total
- 1064 nm total

IGBP
- GMAO pression, temperature, humidity

CLOUDSAT L1
- Normalized scattering cross section

AMSR-E
- sea surface temperature
- Integrated water vapor path
- Surface wind speed

Output
- Total column Aerosol Optical Depth

[1] T. Meissner and F. J. Wentz (2004), The complex dielectric constant of pure and sea water from microwave satellite observations. IEEE Trans. Geosc. Rem. Sens., 42 (9), 1836-1849

[2] S. Tanelli, S. L. Durden, E. Im, K. S. Pak, D. G. Reinke, P. Partain, J. M. Haynes and R. T. Marchand (2008), Cloudsat's Cloud Profiling Radar after two years in Orbit: Performance, Calibration and Processing, IEEE Trans. Geosc. Rem. Sens., 46 (11), 3560-3573