

# Research Scanning Polarimeter (RSP) Level 2 aerosol files

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## 1. Introduction

Aerosol properties are inferred from RSP's measurements of multi-angle total radiances and polarized radiances. Details of the retrieval approach are described by Stamnes et al. (2018; Appl. Opt., doi:10.1364/AO.57.002394.). A notable update to the algorithm is that aerosol layer height is now also retrieved from the RSP data.

## 2. Data contents and usage

The data structure and variables are listed in the appendix. Note that the aerosol files are *not* compatible with CAMP2EX-RSP1-L1B\_P3B, CAMP2EX-RSP1-L1C\_P3B or CAMP2Ex-RSP1-SPNCirrusMask\_P3B files.

The variable `rsp_time` contains the times in UTC decimal hours of the day of acquisition (i.e., between 0 and 24). Note that is different from the CAMP2Ex convention (which is UTC decimal hours starting at the day of take-off, running past 24h).

The algorithm infers aerosol optical properties at 555 nm (assuming spectrally invariant refractive indices). However, for the relevant variables, results are calculated and reported at other wavelength of RSP, namely 410, 469, 555, 670, 864, 1594, 2264 nm, in addition to common lidar wavelength, namely 355, 532 and 1064 nm.

Properties of both a fine mode and a coarse mode aerosol are retrieved (or assumed) and reported in the file. For relevant parameters, the values corresponding to the total particle size distribution (PSD) is (also) reported.

In addition to aerosol properties, ocean surface properties are retrieved and reported in the files using the ocean model from Chowdhary et al. (2006; Appl. Opt., doi:10.1364/AO.45.005542).

Aerosol parameters are listed in the table below:

| <b>Aerosol variable name prefix</b> | <b>description</b>            | <b>Units</b> | <b>Fine mode</b> | <b>Coarse mode</b> | <b>Total PSD</b> | <b>555 nm</b> | <b>All wls</b> |
|-------------------------------------|-------------------------------|--------------|------------------|--------------------|------------------|---------------|----------------|
| <code>aerosol_tau</code>            | Total column optical depth    | None         | √                | √                  | √                | √             | √              |
| <code>aerosol_reff</code>           | Effective radius              | μm           | √                | √                  | √                | n/a           | n/a            |
| <code>aerosol_veff</code>           | Effective variance            | None         | √                | √                  | √                | n/a           | n/a            |
| <code>aerosol_ssa</code>            | Single scattering albedo      | None         | √                | √*                 | √                | √             | √              |
| <code>aerosol_real</code>           | Real part of refractive index | None         | √                | √*                 |                  | √             |                |

|                    |                                    |                  |   |    |   |     |     |
|--------------------|------------------------------------|------------------|---|----|---|-----|-----|
| aerosol_imag       | imaginary part of refractive index | None             | √ | √* |   | √   |     |
| aerosol_top_height | Top height of aerosol layer        | m                |   |    | √ | n/a | n/a |
| aerosol_N          | Number concentration               | cm <sup>-3</sup> | √ | √  |   | n/a | n/a |
| aerosol_ext        | Extinction cross section           | μm <sup>2</sup>  | √ | √  |   |     | √   |
| aerosol_p180       | Phase function at 180°             | /sr              | √ | √  |   |     | √   |

\* coarse mode refractive indices are not retrieved, but assumed to be 1.01 times that of water to represent hydrated sea salt (marine) aerosols.

Surface parameters are listed in the table below:

| Surface variable name prefix | description                                 | Units             | 555 nm | 532 nm |
|------------------------------|---------------------------------------------|-------------------|--------|--------|
| surface_kd                   | Ocean diffuse attenuation coefficient       | m <sup>-1</sup>   | √      | √      |
| surface_bbp                  | Ocean hemispherical backscatter coefficient | m <sup>-1</sup>   | √      | √      |
| surface_chlorophyll          | Chlorophyll-a concentration                 | mg/m <sup>3</sup> | n/a    | n/a    |
| surface_windspeed            | Surface windspeed (Cox-Munk)                | m/s               | n/a    | n/a    |

### 3. Notes on availability, biases and uncertainty

The RSP measurements were horizontally averaged over 20 scans or ~17 seconds.

Only data that is cloud free over 40 scans or ~33 seconds is accepted.

Only retrievals for which the final normalized cost function is below 0.15 are accepted. This normalized cost function threshold filters out data where the forward model simulations are not able to represent the observations, for example in situations with substantial non-spherical particles present and data substantially affected by clouds above and below the aircraft.

Any influence of clouds (or aerosols) above the aircraft cannot be excluded, although the cost function filter is expected to filter out most of the affected observations. Use of an above-aircraft cloud flag may be advisable.

Estimated uncertainties are listed in the table below (from Stamnes et al. 2018). For the further discussion on uncertainties we refer to Stamnes et al. (2018). The diagonals of the posterior error covariance matrix represent the uncertainties of each retrieval parameter, and are reported in the variable /Serr\_diag. These uncertainties are currently underestimated because RSP data is hyper-angular and correlated, which is not currently taken in account. This issue will be fixed in a future update.

**Table 2. Aerosol Uncertainty Targets for One Standard Deviation ( $1\sigma$ )<sup>a</sup>**

| Param.        | Description                         | $1\sigma$ Desired Uncertainty | RMSD (Simulated)                |
|---------------|-------------------------------------|-------------------------------|---------------------------------|
| $\tau_{555f}$ | fine-mode optical depth at 555 nm   | 0.02                          | 0.0427<br>(0.0372) <sup>b</sup> |
| $r_{eff,f}$   | fine-mode effective radius          | 0.015 $\mu\text{m}$           | 0.0196 $\mu\text{m}$            |
| $\nu_{eff,f}$ | fine-mode effective variance        | 0.05                          | 0.0487                          |
| $r_{nf}$      | fine-mode real part                 | 0.02                          | 0.0293                          |
| $SSA_f$       | fine-mode SSA                       | 0.02                          | 0.0209                          |
| $\tau_{555c}$ | coarse-mode optical depth at 555 nm | 0.02                          | 0.0132                          |
| $r_{eff,c}$   | coarse-mode radius                  | 0.15 $\mu\text{m}$            | 0.148 $\mu\text{m}$             |
| $\nu_{eff,c}$ | coarse-mode effective variance      | 0.05                          | 0.0669                          |
| CHL           | chlorophyll concentration           | 0.7 mg/m <sup>3</sup>         | 2.59 mg/m <sup>3</sup>          |
| $\nu$         | Wind speed                          | 0.5 m/s                       | 0.501 m/s                       |

<sup>a</sup>Assumption: aerosol optical depth  $\tau_{555f} \geq 0.05$  and  $\tau_{555c} \geq 0.02$ , otherwise uncertainty targets become difficult to meet. The effective radius is a function of the mode radius  $r_n$  and the mode width  $\sigma_g$  [Eq. (9)]. The effective variance is a function of the size distribution mode width  $\sigma_g$  only [Eq. (10)]. The root-mean-square deviation (RMSD) for the simulated retrievals presented in this paper are provided in the fourth column.

<sup>b</sup>RMSD versus HSRL-1 total (fine and coarse) AOD at 532 nm from SABOR. Non-spherical aerosols such as dust are not included in the present retrieval, but can be detected and avoided by using HSRL-1 aerosol depolarization measurements.

## Appendix: data structure and variables

```

group      /
dataset    /000-README
dataset    /Serr_diag
dataset    /Serr_total
dataset    /Serr_total_diag
dataset    /aerosol_N_c
dataset    /aerosol_N_f
dataset    /aerosol_imag_c_555

```

dataset /aerosol\_imag\_f\_555  
dataset /aerosol\_kext\_c  
dataset /aerosol\_kext\_f  
dataset /aerosol\_p180\_c  
dataset /aerosol\_p180\_f  
dataset /aerosol\_real\_c\_555  
dataset /aerosol\_real\_f\_555  
dataset /aerosol\_reff\_c  
dataset /aerosol\_reff\_f  
dataset /aerosol\_reff\_total  
dataset /aerosol\_ssa\_c  
dataset /aerosol\_ssa\_c\_555  
dataset /aerosol\_ssa\_f  
dataset /aerosol\_ssa\_f\_555  
dataset /aerosol\_ssa\_total\_555  
dataset /aerosol\_tau\_c  
dataset /aerosol\_tau\_c\_555  
dataset /aerosol\_tau\_f  
dataset /aerosol\_tau\_f\_555  
dataset /aerosol\_tau\_total\_555  
dataset /aerosol\_top\_height  
dataset /aerosol\_veff\_c  
dataset /aerosol\_veff\_f  
dataset /aircraft\_altitude  
dataset /aircraft\_lat  
dataset /aircraft\_lon  
dataset /aircraft\_pitch  
dataset /aircraft\_roll  
dataset /aircraft\_yaw  
dataset /atmos\_water\_vapor\_column\_amount  
dataset /cloud\_top\_height  
dataset /output\_channels  
dataset /retrieval\_normalized\_cost\_function\_data  
dataset /retrieval\_normalized\_cost\_function\_total  
dataset /rsp\_relative\_azimuth  
dataset /rsp\_solar\_zenith  
dataset /rsp\_time  
dataset /surface\_Kd\_532  
dataset /surface\_Kd\_555  
dataset /surface\_bbp\_532  
dataset /surface\_bbp\_555  
dataset /surface\_chlorophyll  
dataset /surface\_windspeed