Research Scanning Polarimeter (RSP) Level 2 cloud files

Document version: 1
Data version: R2
Date: 8 July, 2020

Contributors: Bastiaan van Diedenhoven, Mikhail Alexandrov, Brian Cairns, Kenneth Sinclair, Andrzej Wasilewski

Table of Contents

1. Introduction

These files contain cloud products derived from RSP's level 1C data files. Primary derived cloud parameters are

- Cloud flag/test
- Cloud top altitude
- Cloud top phase index
- Cloud optical thickness
- Cloud droplet size distribution effective radius
- Cloud droplet size distribution effective variance

Note that measurements are not corrected or filtered for contamination of clouds or aerosols above the aircraft. Please use the CAMP2Ex-RSP1-SPNCirrusMask_P3B_ files to screen the data for cirrus contamination.

2. Data contents and usage

Files are compatible with CAMP2EX-RSP1-L1C_P3B files. The GEOMETRY folder is identical and the file structure is similar.

The hdf file contents is organized in 3 folders ('groups'), namely

- DATA: Cloud retrieval products and time
- GEOMETRY: Solar and viewing geometries, target height and location
- PLATFORM: Aircraft and flight path information, land/water mask, solar distance

The data structure and variables are listed in the appendix. Generally users only need parameters from the DATA folder and location information from the GEOMETRY folder.

3. Variables and methods

Variable name	Variable	Method	Reference
Cloud_Test_Passed	Cloud detection flag indicating cloud detected by test (1) or not (0)	Threshold tests. 410 and 670 nm (land) or 865 and 2260 nm (ocean). Observation is considered cloudy if test in both bands pass. Additional 1880 nm band test is performed for detecting cirrus.	None
Cloud_Test_Performed	Cloud detection flag (which test are applied)	See above	None
Cloud_Top_Altitude	Cloud Top Altitude	Multi-angle parallax method applied to 865 nm (1st element) and 1880 nm (2nd element)	Sinclair et al. (2017)
Cloud_Liquid_Index	Index indicating presence of liquid at cloud top	Index derived from multi-angle polarization near cloudbow applied to 865 nm (1st element) and 1880 nm (2nd element). Values >0.3 indicate liquid present at cloud top.	van Diedenhoven et al. (2012)
Cloud_Bow_Optical_Thickness	Cloud Optical Thickness	From nadir 865 nm reflectance using polarimetric drop effective radius retrieval	cf. Nakajima and King (1990)
Cloud_Bi_Spec_Optical_Thickness	Cloud Optical Thickness	From bi-spectral retrieval of effective radius and optical thickness using nadir reflectance at 865 nm and 1590 nm (1st element) or 2250 nm (2nd element)	Nakajima and King (1990)
Cloud_Default_Size_Optical_Thickness	Cloud Optical Thickness	From nadir 865 nm reflectance using default 10 micron drop effective radius	cf. Nakajima and King (1990)
Cloud_Bow_Droplet_Effective_Radius	Drop size distribution effective radius	From multi-angle polarimetry at 865 nm	Alexandrov et al. (2012)

Cloud_Bow_Droplet_Effective_Radius_Bands	Drop size distribution effective radius	From multi-angle polarimetry at all RSP bands separately	Alexandrov et al. (2012)
Cloud_Bow_Droplet_Effective_Radius_Bands_Stddev	Drop size distribution effective radius	Standard deviation between results for all bands (indication of uncertainty)	Alexandrov et al. (2012)
Cloud_Bow_Droplet_Effective_Variance	Drop size distribution effective variance	From multi-angle polarimetry at 865 nm	Alexandrov et al. (2012)
Cloud_Bow_Droplet_Effective_Variance_Bands	Drop size distribution effective variance	From multi-angle polarimetry at all RSP bands separately	Alexandrov et al. (2012)
Cloud_Bow_Droplet_Effective_Variance_Bands_Stddev	Drop size distribution effective variance	Standard deviation between results for all bands (indication of uncertainty)	Alexandrov et al. (2012)
Cloud_Bow_Auxiliary_Fit	Auxiliary parameters fitted along effective radius and variance	Parameters A, B, C of Eq. 3 in Alexandrov et al. (2012)	Alexandrov et al. (2012)
Cloud_Bi_Spec_Particle_Effective_Radius	Drop size distribution effective radius	From bi-spectral retrieval of effective radius and optical thickness using nadir reflectance at 865 nm and 1590 nm (1st element) or 2250 nm (2nd element)	Nakajima and King (1990)
Water_Vapor_Total	Total water vapor column above surface or cloud	Inferred from ratio of 960 nm band and 865 nm nadir reflectance	Sinclair et al. (2019)
Water_Vapor_Pol	Total water vapor column above surface or cloud	Inferred from ratio of polarized reflectance at 960 nm and 865 nm near the cloudbow	Sinclair et al. (2019)

4. Notes on availability, biases and uncertainty

For optical thickness and bi-spectral effective radius retrievals, land surface reflectance is not accounted for at the moment. This mainly affects retrievals over land for cloud with optical depths smaller than about 5.

Retrievals are not filtered for contamination of clouds or aerosols above the aircraft. Bi-spectral effective radius retrievals are generally biased high when substantial cirrus (optical depth above ~0.1) is overhead. Cloud optical thickness retrievals may be expected to be biased low by a few percent. Cloud top height and polarimetry cloud retrievals are generally not affected by cirrus or clouds above the aircraft up to a few units of optical depth. Please use the compatible CAMP2Ex-RSP1-SPNCirrusMask_P3B_ files to screen the data for cirrus contamination.

Cloud optical thickness and, especially, bi-spectral effective radius retrievals are substantially affected by cloud complexity, inhomogeneity and 3D radiative transfer effects (Miller et al. 2018). Most of the bi-spectral effective radius retrievals during CAMP2Ex may be expected to be biased high because of these effects. Polarimetry cloud retrievals are much less affected by 3D effects (Alexandrov et al. 2012, Miller et al. 2018).

Bi-spectral effective radius retrievals generally pertain to the top of the cloud down to about 5 optical depth units (cf. Platnick 2000). Polarimetry effective radius and variance pertain to the top of the cloud down to about 1-2 optical depth units (similarly to 3.7 micron retrievals of MODIS) (Alexandrov et al. 2018).

Uncertainties in bi-spectral effective radius retrievals mostly depend on cloud structure (Platnick et al. 2017, Miller et al. 2018). Uncertainties in polarimetry effective radius are estimated to be about 5-10% and about 5-30% for effective variances (Alexandrov et al. 2012, 2018, Shang et al. 2015).

Uncertainties in cloud optical thickness retrievals are generally below 15%, but may exceed 100% for optical thickness values greater than about 40 (Platnick et al 2017). Over land optical thickness values lower than 5 are expected to be biased high.

Uncertainties in cloud top height are estimated to be within 100-500m (Sinclair et al. (2017).

Polarimetric drop effective radius and variance need a specific scattering angle range to be sampled, namely at least 135˚-155˚. The sampled scattering angle range mainly depends and aircraft heading, date and time of day. If this scattering angle range is not sampled, no polarimetric size retrievals or liquid index are available. Bi-spectral retrievals do not require a specific scattering angle range and are available for all cloudy pixels, although they may be particularly biased for low sun conditions. For more notes on data quality, please see the CAMP2Ex-RSP1-L1C_P3B_2019_R3_QuickStart document.

5. References

Alexandrov, M.D., B. Cairns, C. Emde, A.S. Ackerman, and B. van Diedenhoven, 2012: Accuracy assessments of cloud droplet size retrievals from polarized reflectance measurements by the research scanning polarimeter. Remote Sens. Environ., 125, 92-111, doi:10.1016/j.rse.2012.07.012.

Nakajima, T., and M. D. King, 1990: Determination of the optical thickness and effective particle radius of clouds from reflected solar radiation measurements. I: Theory. J. Atmos. Sci., 47, 1878–1893, doi:10.1175/1520-0469(1990)047<1878:DOTOTA>2.0.CO;2.

Miller, Daniel J., Zhibo Zhang, Steven Platnick, Andrew S. Ackerman, Frank Werner, Celine Cornet, and Kirk Knobelspiesse. 2018: Comparisons of Bispectral and Polarimetric Retrievals of Marine Boundary Layer Cloud Microphysics: Case Studies Using a LES–Satellite Retrieval Simulator., Atmospheric Measurement Techniques 11 (6). doi:10.5194/amt-11-3689-2018.

Platnick, S., 2000: Vertical photon transport in cloud remote sensing problems, J. Geophys. Res., 105 (2000), pp. 22919-22935

Platnick, S., Meyer, K. G., King, M. D., Wind, G., Amarasinghe, N., Marchant, B., et al., 2017: The MODIS cloud optical and microphysical products: Collection 6 updates and examples from Terra and Aqua. IEEE Transactions on Geoscience and Remote Sensing, 55(1), 502–525. https://doi.org/10.1109/TGRS.2016.2610522

Shang, H., Chen, L., Bréon, F. M., Letu, H., Li, S., Wang, Z., and Su, L., 2015: Impact of cloud horizontal inhomogeneity and directional sampling on the retrieval of cloud droplet size by the POLDER instrument. Atmos. Meas. Tech., 8, 4931-4945, https://doi.org/10.5194/amt-8-4931-2015.

Sinclair, K., B. van Diedenhoven, B. Cairns, J. Yorks, A. Wasilewski, and M. McGill, 2017: Remote sensing of multiple cloud layer heights using multi-angular measurements. Atmos. Meas. Tech., 10, 2361-2375, doi:10.5194/amt-10-2361-2017.

Sinclair, K., B. van Diedenhoven, B. Cairns, M. Alexandrov, R. Moore, E. Crosbie, and L. Ziemba, 2019: Polarimetric retrievals of cloud droplet number concentrations. Remote Sens. Environ., 228, 227-240, doi:10.1016/j.rse.2019.04.008.

Van Diedenhoven, B., A.M. Fridlind, A.S. Ackerman, and B. Cairns, 2012: Evaluation of hydrometeor phase and ice properties in cloud-resolving model simulations of tropical deep convection using radiance and polarization measurements. J. Atmos. Sci., 69, 3290-3314, doi:10.1175/JAS-D-11-0314.1.

Appendix: data structure and variables

group /
group /Data
dataset /Data/Cloud_Bi_Spec_Optical_Thickness
dataset /Data/Cloud_Bi_Spec_Particle_Effective_Radius
dataset /Data/Cloud_Bow_Auxiliary_Fit
dataset /Data/Cloud_Bow_Droplet_Effective_Radius
dataset /Data/Cloud_Bow_Droplet_Effective_Radius_Bands
dataset /Data/Cloud_Bow_Droplet_Effective_Radius_Bands_Stddev
dataset /Data/Cloud_Bow_Droplet_Effective_Radius_Stddev
dataset /Data/Cloud_Bow_Droplet_Effective_Variance
dataset /Data/Cloud_Bow_Droplet_Effective_Variance_Bands
dataset /Data/Cloud_Bow_Droplet_Effective_Variance_Bands_Stddev
dataset /Data/Cloud_Bow_Droplet_Effective_Variance_Stddev
dataset /Data/Cloud_Bow_Optical_Thickness
dataset /Data/Cloud_Bow_RMS
dataset /Data/Cloud_Default_Size_Optical_Thickness
dataset /Data/Cloud_Liquid_Index
dataset /Data/Cloud_Quality
dataset /Data/Cloud_Test_Passed
dataset /Data/Cloud_Test_Performed
dataset /Data/Cloud_Top_Altitude
dataset /Data/Data_Quality_Flags
dataset /Data/Product_Time
dataset /Data/Product_Time_Seconds
dataset /Data/Water_Vapor_Pol
dataset /Data/Water_Vapor_Total
dataset /Data/Wavelength
group /Geometry
dataset /Geometry/Collocated_Altitude
dataset /Geometry/Collocated_Latitude
dataset /Geometry/Collocated_Longitude
dataset /Geometry/Distance_To_Mapped_Sector_Statistics
dataset /Geometry/Glint_Angle
dataset /Geometry/Ground_Latitude
dataset /Geometry/Ground_Longitude
dataset /Geometry/Land_Water_Flag
dataset /Geometry/Measurement_Time
dataset /Geometry/Nadir_Deviation
dataset /Geometry/Nadir_Index
dataset /Geometry/Scattering_Angle
dataset /Geometry/Solar_Azimuth
dataset /Geometry/Solar_Zenith
dataset /Geometry/Terrain_Height
dataset /Geometry/Viewing_Azimuth
dataset /Geometry/Viewing_Zenith
group /Platform
dataset /Platform/Day_of_Year
dataset /Platform/Fraction_of_Day

dataset /Platform/GPS_Quality
dataset /Platform/Ground_Elevation_At_Nadir
dataset /Platform/Land_Water_Mask_At_Nadir
dataset /Platform/Platform_Altitude
dataset /Platform/Platform_Latitude
dataset /Platform/Platform_Longitude
dataset /Platform/Pressure
dataset /Platform/Relative_Humidity
dataset /Platform/Seconds
dataset /Platform/Speed
dataset /Platform/Temperature
dataset /Platform/Wingflex
dataset /Platform/Year
dataset /dim_Band_Maps
dataset /dim_Bands
dataset /dim_Bi_Spec_Result_Bands
dataset /dim_Cloud_Bow_Bands
dataset /dim_Cloud_Bow_Retrieval_Params
dataset /dim_Cloud_Quality_Flags
dataset /dim_Cloud_Tests
dataset /dim_Collocation_Stats
dataset /dim_Quality_Flags
dataset /dim_Scans
dataset /dim_Scene_Sectors