Cloud and Precipitation Properties Value-Added-Product (CPP-VAP) version 1.6

User's Guide

Dr. Roger Marchand, University of Washington

1.0 Introduction

This value added dataset has been developed to advance scientific studies associated with the Department of Energy supported Measurements of Aerosols, Radiation and CloUds over the Southern Ocean (MARCUS) field campaign and the Macquarie Island Cloud and Radiation Experiment (MICRE).

This product (CPP-VAP) contains a variety of retrieved cloud and precipitation variables (such as, cloud liquid water path and surface precipitation rate) derived from a combination of cloud-radar, lidar, passive microwave radiometer, and surface disdrometer. Also include are measurement from some instruments, specifically, cloud radar reflectivity and Doppler velocity, microwave radiometer brightness temperatures, surface broadband radiometer fluxes, PARSIVEL disdrometer size-velocity spectra, and surface meterological fields. The data are stored in NetCDF format, with one file per day.

<u>Work on the CPP-VAP is not complete.</u> In particular, the intent is to include cloud-based and sub-cloud precipitation phase (liquid vs. ice) based on lidar-depolarization measurements, and day-time cloud microphysics based on microwave radiometer and broadband SW fluxes. We hope to have the depolarization based phase, soon.

The contents of the VAP are listed in Table #1. The data is organized by **DATA_SOURCE** (defined as an instrument or retrieval) where the data source is in capital letters and the associated variables are in small letters. So for example the data file contains the variable "RADAR_time_gmt" which is the time of day (in gmt hours) associated with all the RADAR variables. Many but not all of the variables are tied to the radar time-grid.

Please note that **most of DATA_SOURCE categories have a data_quality field**. This is a bit-packed variable, where a value of 0 mean "no known problems or concerns" and all other values mean there is a problem or concern. The problem or concern may or may not matter to you and the file metadata explains what each bit in the data_quality fields means.

Additional details on the retrievals are given in section 2.

<u>*Table #1 – Contents of CP-VAP file.*</u> Units and other metadata are included in the NetCDF file.

DATA SOURCE	Variables	Notes:
RADAR Radar Measurements	time_gmt data_quality_flag height reflectivity_masked mean_Doppler_velocity	Radar data has been processed to remove coupling artifacts and clutter.
RADAR_LIDAR_BOUNDARIES Boundaries from combination of radar, ARM ceilometer and UC ceilometer	time_gmt data_qualtity_flag n_layers (number of layers) layer_type (radar only, lidar only, both) layer_radar_base layer_radar_top layer_median_lidar_base n_ceilometer_columns n_ceilometer_columns_obsercured	Time sampling matches radar (~12s) when radar was running, otherwise 60s. Lidar boundaries are smoothed to 1 minute scale.
ZV_PRECIP_RETRIEVAL Near surface precipitation based on radar reflectivity (Z) and mean Doppler velocity (V)	time_gmt near_surface_data_quality_flag near_surface_max_reflecitity near_surface_max_precip_rate near_surface_max_precip_effective_radius	Near surface mean 250 to 500 m above the surface but also below cloud base. Retrieval is not undertaken when cloud-base is below 350m (see quality flag)
MWR_RETRIEVAL Retrieval uses radiosondes profiles and radar-lidar-boundaries, in addition to MWR brightness temperatures.	time_gmt data_quality_flag liquid_water_path (LWP) precipitable_water_vapor (PWV) hours_to_sonde n_layers tb23 (measured value) tb31 (measured value) calculated_tb23 (retrieved value) calculated_tb31 (retrieved value)	Based on an iterative technique that tries to adjust LWP and PWV so forward calculated value of brightness temperatures (tb) matches observed values.
Z_LWP_CLOUD_RETRIEVAL Retrieved cloud microphysics for ***non-precipitation*** liquid clouds ONLY.	time_gmt data_quality_flag droplet_number_concentration column_effective_radius (LWC-weighted)	
SURFACE_MET Automated surface meteorological station data	time_gmt temperature pressure relative_humidity wind_speed wind_direction accumulated_rainfall	accumulated_rainfall is based on tipping bucket, since the start of the UTC day.
PARSIVEL Parsivel surface disdrometer VENDOR retrievals (not	time_gmt vendor_precip_rate vendor_precip_effective_radius	Neither the Parsivel's measurements nor vendor's retrievals

recommended)		are optimal for Macquarie. We will likely remove these data in future versions.
PARSIVEL_PIRAT Parsivel Improved Rate and Type (PIRAT) retrieval	time_gmt (fixed five minute grid) precip_type_best precip_type_metrics precip_rate_best precip_rate_by_type precip_effective_radius bin_particle_size bin_velocity spectrum_raw spectrum_corrected	Temporal sampling rate is reduce to 5 minutes to improve S/N, and includes various corrections (see section 2). Data includes raw and corrected Drop Size-Velocity Spectra.
SURF_RAD Surface broadband shortwave and longwave fluxes	time_gmt shortwave_down_total shortwave_down_direct shortwave_down_diffuse shortwave_up_total longwave_down longwave_up	

2.0 Retrieval Details

2.1 Radar-Lidar Boundaries

Boundaries are determined from a combination of cloud radar and ceilometer data. For MARCUS, radar boundaries are obtained via ARSCL processing, while for MICRE it is based on BASTA radar processing following Delanoë et al [2016] but also includes some custom filtering for antenna-coupling and clutter under taken by Alain Protat and Roger Marchand.

Ceilometer boundaries are obtain from the Vaisala ceilometers based on the manufactures algorithms. For MICRE data from both the ARM ceilometer and a second ceilometer deployed by the University of Canterbury (New Zealand, Adrian McDonald) are merged.

In order to obtain a unified set of boundaries, each radar column is divided into a set of up to 5 layers. Layers are defined as contiguous vertical regions in which a significant radar reflectivity (i.e. greater than the background noise) is obtained, with no gap (a vertical region devoid of significant reflectivity) larger than 100 meters. Lidar cloud bases (there can be up to three in each 15 to 20 second lidar sample) are group by the radar-layer in which they occur, or if separated by more than 100m from any radar layer are taken to constitute a separate layer detected by the lidar only. All lidar bases within +/- 30 seconds of a radar column is used in determining the median lidar cloud base. Thus each layer is defined as radar only, lidar only, or both. Each layer (with radar data) has radar base and top and each layer (with lidar data) has an associated median lidar cloud base value. In the rare case where there are more than 5 total layers at any instant, the highest layer base and top are redefined to bound all layers above the 4^{th} layer.

2.2 Radar Reflectivity–Velocity (ZV) Light Precipitation Retrieval

The radar reflectivity (Z) and Doppler velocity (V) retrieval is based on the approach of Frisch et al. [1995] and assumes liquid precipitation. No check is currently being done on the precipitation phase, but the hope is depolarization lidar data will eventually be processes to serve as a check. The retrieval also assumes Rayleigh scattering (particles size < ~500 mm), and the data quality flag denotes times when the retrieval suggests particles are too large, or indeed too small. The limit on small particles derives from the need to specify the mean particle fall velocity.

The mean fall speed is derived from the radar measured mean Doppler velocity following the approach developed by Orr and Kropfli [1999]. The radar measured mean Doppler velocity is the total (reflectivity-weighted) motion of all the particles in the radar volume, which includes motions due to both updrafts and downdrafts (that is air motions) in addition to the fall (sedimentation) speed of individual particles. What Orr and Korpfli did was to assume that (i) air motions average out over time while (ii) for a given value of radar reflectivity at a given altitude, there is a mean fall speed that is not correlated with the air motion. Thus by averaging the mean Doppler velocity (for the given value of reflectivity) one can obtain the mean fall speed. Unfortunately, the assumption that air motions are not correlated with the fall speed is not entirely true, as periods with stronger drizzle tend to be associated with stronger upward air motions. However our experience is that the mean updraft velocities in stratocumulus are not large (typically less than 10 to 20 cm/s). This is smaller than the fall velocity of drizzle as long as the drizzle effective radius is larger than about 50 microns, which is true for most drizzle when the reflectivity is larger than about -30 dBZe. And as noted above the data_quality_flag tracks whenever the mean velocity is too low or too large.

In the present treatment, a spectrum width of 0.3 is assumed, and (following Frisch et al. 1999) when combined with the radar reflectivity and fall velocity provides enables one to determine the precipitation water content, precipitation rate, as well as the particles size which can be expressed in any number of ways such as a mean diameter or effect Diammeter (3 moment/2 moment of the drop size distribution).

2.3 Physical-Iterative Microwave Radiometer (MWR) Retrieval

A physical-iterative Microwave Radiometer (MWR) Retrieval for column liquid water path (LWP) and precipitable water vapor (PWV) is applied following the algorithm of Marchand et al. [2003]. Temperature and pressure profiles from nearest in time radiosondes are used (and the time offset to the nearest-in-time sonde data is likewise stored). The liquid water is placed between median-lidar-base for the lowest layer with the top nominally determined by the radar cloud top for that same layer. If no radar top is present the layer is assumed to be 500 m thick, and if no lidar-base is found the retrieval is run assuming a lidar base is at 1000m above the surface.

Thus as designed the retrieval will attempt retrieve a LWP even if no cloud appears to be present according to the lidar or radar. This is useful for gauging a confidence level for the LWP due to errors in the inputs (MWR radiances, sonde profiles).

The most significant limitation associated with this retrieval is simply corruption of the MWR measurements due to rain on the instrument radome. A variety of flags have been put it place (see metadata associated with data_quality_flags) to help users identify when the instrument may be wet. The flags have been set conservatively such that a data_quality_flag value of zero means the LWP and PWV values are good. However, often the PWV and LWP retrievals are good even when one or more positive data flags have been triggered (but it is often difficult to be confident). In particular, flag 4 indicates boundaries were not known. This reduces the accuracy of the LWP but typically this is not a large source of error.

2.4 Radar-MWR (Z-LWP) Retrieval for Cloud Droplet Effect Radius and Number Concentration

Cloud Droplet Effect Radius and Number Concentration for **non-precipitation** liquid clouds and derived following the approach given by Frisch et al. [2002]. This retrieval is extremely sensitivity to (i) the presence of drizzle in cloud, which increases the the radar reflectivity and causes the retrieval to overestimate the effective radius and (ii) cloud that goes undetected by the radar (because small droplets can have a low reflectivity but still have appreciate amounts of water). An longs set of data quality test have been implemented and unfortunately show that this retrieval is rarely useful, because most SO clouds contain enough drizzle to corrupt the retrieval. Thus we advise users to carefully examine the associated data quality flags.

In the near future, we anticipate running a daytime-only retrieval that incorporates SW fluxes rather than relying on the radar reflectivity oe.g., Dong et al. 2016]. However, this retrieval is limited by the need for relatively homogenous conditions and does not work at low solar angles.

References

Delanoë, J., and Coauthors, 2016: BASTA: A 95-GHz FMCW Doppler radar for cloud and fog studies. J. Atmos. Oceanic Technol., 33, 1023–1038, doi: 10.1175/JTECHD-15-0104.1.

Dong, X., B. Xi, S. Qiu, P. Minnis, S. Sun-Mack, and F. Rose (2016), A radiation closure study of Arctic stratus cloud microphysical properties using the collocated satellite-surface data and Fu-Liou radiative transfer model, J. Geophys. Res. Atmos., 121, 10,175–10,198, doi:10.1002/ 2016JD025255.

Frisch, S., M. Shupe, I. Djalalova, G. Feingold, and M. Poellot, 2002: The Retrieval of Stratus Cloud Droplet Effective Radius with Cloud Radars. J. Atmos. Oceanic Technol., 19, 835–842, doi: 10.1175/1520-0426(2002)019<0835:TROSCD>2.0.CO;2

Frisch, A.S., C.W. Fairall, and J.B. Snider, 1995: Measurement of Stratus Cloud and Drizzle Parameters in ASTEX with a Kα-Band Doppler Radar and a Microwave Radiometer. J. Atmos. Sci., 52, 2788–2799, doi:10.1175/1520-0469(1995)052<2788:MOSCAD>2.0.CO;2.

Marchand, R., T. Ackerman, E. R. Westwater, S. A. Clough, K. Cady-Pereira, and J. C. Liljegren, 2003, An assessment of microwave absorption models and retrievals of cloud liquid water using clear-sky data, J. Geophys. Res., 108(D24), 4773, doi:10.1029/ 2003JD003843.

Orr, B.W. and R.A. Kropfli, 1999: A Method for Estimating Particle Fall Velocities from Vertically Pointing Doppler Radar. J. Atmos. Oceanic Technol., 16, 29–37, 10.1175/1520-0426(1999)016<0029:AMFEPF>2.0.CO;2