MPD PRECIP data, Version 1.1

Changes from Version 1.0

Improved data quality masking algorithm: The data masking algorithm used to blank regions of high bias and uncertainty in the data has been improved to provide greater data availability without significantly changing the data accuracy. The Absolute_Humidity_mask field should be used to identify regions where data is not reliable.

Added additional post project data: Version 1.1 includes the end-of-project colocated operation of all three MPDs Aug 18-22, 2022 at NCU, Taoyuan, Taiwan.

Overview

This dataset contains MicroPulse Differential Absorption Lidar (MPD) data in NetCDF format which were collected during the Prediction of Rainfall Extremes Campaign In the Pacific (PRECIP). Three MPDs were deployed to Taiwan for this field project. Data was provided over a period from May 28, 2022 - August 10, 2022. The locations of the instruments are listed in the table below. For more information on PRECIP see https://www.eol.ucar.edu/field_projects/precip.

MPD #	Location Description	Elevation [m]	Latitude	Longitude
MPD 2	NCU, Taoyuan, Taiwan	135	24.97 N	121.19 E
MPD 3	Yilan, Taiwan	22	24.76 N	121.76 E
MPD 4	Hsinchu, Taiwan	25	24.83 N	121.01 E

Instrument description

The diode-laser-based (DLB) lidar architecture developed by NCAR in collaboration with Montana State University (MSU) uses continuous wave seed lasers that are amplified into pulses (5-10 μJ/pulse) at high repetition rates (7-10 kHz)[1,2]. For high quality daytime operation, suppression of the solar background is achieved with a narrow receiver field of view (100 μrad) and extremely narrow-band (10-20 pm full width half max) optical filters. The transmitted laser beam is eye-safe and invisible (Class 1M) and the receiver uses single photon counting detectors.

The differential absorption lidar (DIAL) technique uses two separate laser wavelengths: an absorbing wavelength (online) and a non-absorbing wavelength (offline). The ratio of the

range-resolved backscattered signals between the online and offline wavelengths is proportional to the amount of water vapor in the atmosphere. The technique requires knowledge of the absorption feature (obtained from molecular absorption database) and estimates of the atmospheric temperature and pressure (obtained from surface measurements and standard atmosphere models). The technique also requires the laser wavelength to be stable and confined to a narrow band or “single frequency”. For more information, see Spuler et al. (2021) and https://www.eol.ucar.edu/mpd.

MPD Specifications	
Parameter	**Specification**
Wavelength	828.2 nm
Pulse length	0.800 μs (majority)
Pulse repetition rate	8 kHz
Vertical resolution	150 m
Vertical range	200-4000 m
Temporal resolution	10 minute sample resolution 10 minute actual resolution

Data description

The data is provided in NetCDF format. Each data product contains time (seconds) and range (meters) dimensions. The lidar is vertically pointing, so range is the same as altitude above ground level (AGL). The conversion to altitude above mean sea level can be obtained by using the ‘elevation’ field in the dataset attributes.

The key data products from this instrument are:
Absolute_Humidity [g/m^3] - estimate of the water vapor density in a parcel of air. This data has not been masked for noise and biases. Use the **Absolute_Humidity_mask** to avoid using data that has high uncertainty.
Absolute_Humidity_variance [g^2/m^6] - estimate of the statistical variance of the water vapor density estimate due to shot noise. This field also includes an estimate of uncertainty resulting from assumed temperature uncertainty.
Absolute_Humidity_mask - for quality control, indicates if mask (1) or no mask (0) should be applied to the Absolute_Humidity field. *Masked data (1) is not considered accurate or valid.*
Relative_Backscatter [Hz] - estimate of mean photon arrival rate after correction for geometric overlap. This field is effectively a qualitative view of the attenuated backscatter structure in the atmosphere.

In addition a weather station records the temperature, pressure, and absolute humidity at the lidar's location. This data is stored in variables:
Surface_Absolute_Humidity [g/m^3]
Surface_Temperature [K]
Surface_Pressure [atm]

Note that Temperature_model and Pressure_model fields come from NCAR/NCEP Reanalysis[3]. They are not observations. The source of these fields are listed in the attributes of the data variables.

Data processing

Data is processed using the standard DIAL equation where it is assumed all instrument and atmospheric features in the profiles cancel except the difference in absorption. Water vapor is calculated using the formula

$$n_{wv}(r) = \frac{1}{2\Delta\sigma_{wv}} \frac{d}{dr} \ln \frac{N_{on}(r)}{N_{off}(r)}$$

Where $n_{wv}(r)$ is the range resolved water vapor number density (molecules per m^3), $\Delta\sigma_{wv}$ is the difference in absorption cross-section of water vapor between the online and offline wavelengths, $N_{on}(r)$ and $N_{off}(r)$ are the measured signals when transmitting the online and offline wavelengths, respectively.

The absorption cross section of water vapor is pressure and temperature dependent. To approximate the temperature we used NCEP reanalysis data[3]. Note, the water vapor line has been selected for its low temperature dependence so there is relatively little error contributed by uncertainty in the thermodynamic state parameters.

The data is processed at a base resolution of 37.5 m in range and 10 minutes in time.

Once the water vapor is calculated using the above equation, clouds are masked due to large biases that occur due to detector nonlinearity and poorly resolved gradients in the backscatter in and near clouds. A Gaussian smoothing kernel of 170 m in range is applied to the masked field to provide the final product.

Known problems

The MPD retrievals are photon limited in clear atmosphere. In most cases, instances of excessive noise should be reliably flagged by high Absolute_Humidity_variance.

Comparison of MPD PRECIP data to colocated sondes (MPD 3 and 4) show the MPD tends to estimate 0.5 g/m^3 higher absolute humidity than that obtained from the sondes. The source of this difference is not known.

The MPD estimated water vapor has significant biases in clouds and, in some cases, rain and virga. While we have attempted to mask these cases with the Absolute_Humidity_mask, there may be a few instances that remain unmasked. Use caution when analyzing data near high backscatter targets such as clouds.

In general, use caution when interpreting data from the MPD below ~500 m. Based on sonde comparisons, typical uncaptured errors in this region are on the order of 2 g/m^3.

MPD 3 shows a moist bias (~2 g/m^3) compared to sondes below 500 m. Use low altitude data from MPD 3 with caution as the absolute estimates may not be accurate.

MPD 4 shows a moist bias (~3 g/m^3) compared to sondes below 500 m. Use low altitude data from MPD 4 with caution as the absolute estimates may not be accurate.

References

1. S. M. Spuler, M. Hayman, R. A. Stillwell, J. Carnes, T. Bernatsky, K. S. Repasky, “MicroPulse DIAL (MPD)–a diode-laser-based lidar architecture for quantitative atmospheric profiling,” Atmos. Meas. Techniques 14(6), 4593-4616 (2021).
2. Spuler et al., Field-deployable diode-laser-based differential absorption lidar (DIAL) for profiling water vapor, Atmos. Meas. Tech., 8, 1073-1087, 2015.
3. Kalnay et al.,The NCEP/NCAR 40-year reanalysis project, Bull. Amer. Meteor. Soc., 77, 437-470, 1996.

Citation

When using this data set please cite

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