MPD Pre-CIP_2021 data
Version 1.0

This dataset contains MicroPulse Differential Absorption Lidar (MPD) data in NetCDF format which were collected during the Preparatory Rockies Experiment for the Campaign In the Pacific 2021 (Pre-CIP_2021), a preparatory project for the Prediction of Rainfall Extremes Campaign In the Pacific (PRECIP). The data was collected by three MPD units between June 17 and August 20, 2021, in Ft. Collins, Colorado (MPD 5), at the NCAR Foothills campus in Boulder, Colorado (MPD 2) and the NCAR Marshall Field site near Boulder, Colorado, USA (MPD 3). For more information on Pre-CIP_2021 and PRECIP, see https://data.eol.ucar.edu/project/611 and https://www.eol.ucar.edu/field_projects/precip.

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 (5-10 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” so some type of diffraction grating is used for feedback to the seed laser. 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	0.625 μs
Pulse repetition rate	8 kHz
Vertical resolution	150 m

Vertical range	200-4000 m
Temporal resolution	1 minute sample resolution 5 minute actual resolution

Data description

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
Absolute_Humidity_variance [g^2/m^6] - estimate of the statistical variance of the water vapor density estimate due to shot noise.
Absolute_Humidity_mask - for quality control, indicates if mask (1) or no mask (0) should be applied to Absolute_Humidity field
Relative_Backscatter [Hz] - estimate of mean photon arrival rate after correction for geometric overlap. This field is effectively a qualitative view of the backscatter structure in the atmosphere
Aerosol_Backscatter_Coefficient [m^{-1} sr^{-1}] (only available for MPD 5) - the backscatter coefficient of non-molecular scatterers (e.g. aerosols and clouds)

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]

Data processing

Differential Absorption Lidar (DIAL) measures water vapor by transmitting two closely spaced wavelengths. One is tuned to the absorption line of water vapor while the other is tuned off the line. Observations at these two wavelengths are referred to as "online" and "offline". The two observations have nearly identical backscatter and instrument effects in their signals where the only difference is the difference in water vapor absorption. When the two channels are ratioed, all terms cancel except those relating to water vapor.

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 (Kalnay et al., 2016). 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 1 minute in time. These observations are smoothed using Gaussian kernels in range and time where the kernel size is optimized to minimize the mutual contributions of error due to smearing and random noise. The size of the kernels in range and time are reported in the dataset (e.g. offline_std_range is the kernel standard deviation in the range dimension applied to the offline channel).

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 125 m and 5 minutes 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.

The MPD does experience biases in the water vapor retrievals 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.

MPD 5 experienced a low altitude bias near 500 m AGL which became progressively worse throughout the project. This bias is relatively easy to see when viewing multiple days at a time. This error is *not* captured in the variance estimates. Use low altitude data from MPD 5 with caution.

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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