MPD RELAMPAGO data
Version 1.0

This dataset contains MicroPulse Differential Absorption Lidar (MPD) data collected during RELAMPAGO (Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations). The data was collected between October 25 and December 15, 2018, in Argentina. For more information on RELAMPAGO, see www.eol.ucar.edu/field_projects/relampago.

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]. 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. (2015) and https://www.eol.ucar.edu/mpd.

MPD Specifications	
Parameter	**Specification**
Wavelength	828.2 nm
Pulse length	1 μs
Pulse repetition rate	7 kHz
Vertical resolution	150 m
Vertical range	300-4000 m
Temporal resolution	1 minute sample resolution 5 minute actual resolution

Data description

Data profiles (containing time and range axes) are stored with a variety of ancillary variables where the ancillary variable would be specified
AncillaryName_ProfileName
For example each profile has a time axis associated with it and for the absolute humidity profile this is named
time_Absolute_Humidity

The key data products from this instrument are:
Absolute_Humidity [g/m^3] - estimate of the water vapor density in a parcel of air
Attenuated_Backscatter [arbitrary units] - qualitative image of the backscatter light corrected for range-squared loss and geometric overlap

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
Surface_Temperature_WV
Surface_Pressure_WV

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).

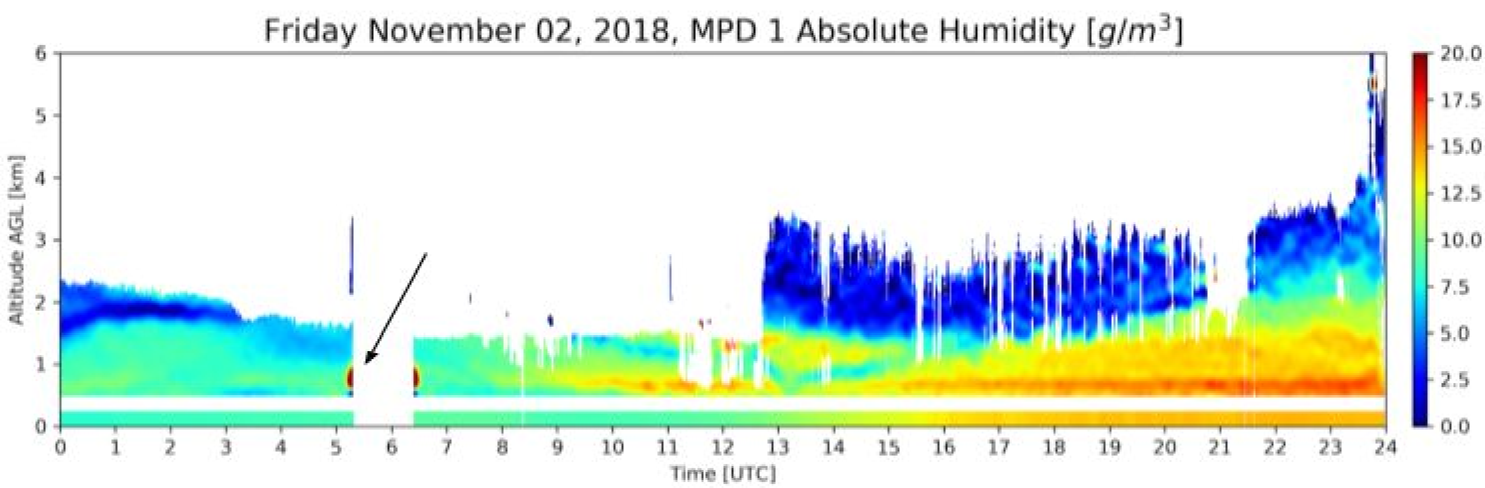
Once the water vapor is calculated using the above equation, clouds are masked due to large biases that occur due to detector nonlinearity and poorly resolved gradients in the backscatter in and near clouds. A Gaussian smoothing kernel of 125 m and 5 minutes is applied to the masked field to provide the final product.

Known problems

Regions of high backscatter gradients can induce biases in water vapor estimates. Regions in and near clouds are particularly prone to this effect.

There are occasional wet and dry bands below 1 km that are the result of slight biases in the instrument. They are constant in altitude and therefore generally easy to distinguish from normal atmospheric variability.

There are some transition regions between valid and invalid lidar signals where biases are induced. “Bubbles” of high and low water vapor can occur in these regions and should not be regarded as valid data. For an example, see below where the arrow is pointing.



References

1. Spuler et al., Field-deployable diode-laser-based differential absorption lidar (DIAL) for profiling water vapor, Atmos. Meas. Tech., 8, 1073-1087, 2015.
2. Kalnay et al.,The NCEP/NCAR 40-year reanalysis project, Bull. Amer. Meteor. Soc., 77, 437-470, 1996.

Contact

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Appendix A
Variables likely to be of greatest interest are in **red**

Variable	**Unit**	**Description**
time_Absolute_Humidity	s since start of day	
range_Absolute_Humidity	m	
Absolute_Humidity	g/m^3	
Absolute_Humidity_variance	g^2/m^6	
Absolute_Humidity_mask	1 = Masked, 0 = Not Masked	
Absolute_Humidity_ProfileCount	Count	Number profiles 2 second integrated to obtain the estimate
time_WV_Online_Backscatter_Channel	s since start of day	
range_WV_Online_Backscatter_Channel	m	
WV_Online_Backscatter_Channel	Counts	Online backscatter signal used to estimate absolute humidity
WV_Online_Backscatter_Channel_variance		
WV_Online_Backscatter_Channel_mask	1 = Masked, 0 = Not Masked	
WV_Online_Backscatter_Channel_ProfileCount	Count	
time_WV_Offline_Backscatter_Channel	s since start of day	

range_WV_Offline_Backscatter_Channel	m	
WV_Offline_Backscatter_Channel	Counts	Offline backscatter signal used to estimate absolute humidity
WV_Offline_Backscatter_Channel_variance		
WV_Offline_Backscatter_Channel_mask	1 = Masked, 0 = Not Masked	
WV_Offline_Backscatter_Channel_ProfileCount	Count	
time_Temperature	s since start of day	
range_Temperature	m	
Temperature	K	Temperature profile estimated from NCEP reanalysis or the weather station at the lidar location with an assumed lapse rate. See the description in the netcdf for this variable to determine the source.
Temperature_variance	K^2	Not trusted
Temperature_ProfileCount	Count	
time_Pressure	s since start of day	
range_Pressure	m	
Pressure	atm.	Pressure profile estimated from NCEP reanalysis or the weather station at the lidar location with an assumed lapse rate. See the description in the netcdf for this variable to determine the source.
Pressure_variance		Not trusted

Pressure_ProfileCount	Count	
time_Surface_Temperature_WV	s since start of day	
range_Surface_Temperature_WV	m	
Surface_Temperature_WV	K	Temperature measured by the weather station on the lidar
Surface_Temperature_WV_variance		Not trusted
Surface_Temperature_WV_ProfileCount	Count	
time_Surface_Pressure_WV	s since start of day	
range_Surface_Pressure_WV	m	
Surface_Pressure_WV	atm.	Pressure measured by the weather station on the lidar
Surface_Pressure_WV_variance		Not trusted
Surface_Pressure_WV_ProfileCount	Count	
time_Surface_Absolute_Humidity	s since start of day	
range_Surface_Absolute_Humidity	m	
Surface_Absolute_Humidity	g/m^3	Absolute Humidity measured by the weather station on the lidar
Surface_Absolute_Humidity_variance		Not trusted
Surface_Absolute_Humidity_mask	1 = Masked, 0 = Not Masked	
Surface_Absolute_Humidity_ProfileCount	Count	
WVOnline_wavelength	m	Wavelength of the water vapor online laser
WVOffline_wavelength	m	Wavelength of the water vapor offline laser

WVOnline_wavelength_diff	nm	Difference between water vapor online laser set point and actual wavelength (actual - set point)
WVOffline_wavelength_diff	nm	Difference between water vapor offline laser set point and actual wavelength (actual - set point)
WVOnline_wavelength_spread	nm	Water vapor online laser spread in measured wavelengths for a given time bin.
time_WV_Online_Backscatter_Channel_Raw_Data	s since start of day	
range_WV_Online_Backscatter_Channel_Raw_Data	m	
WV_Online_Backscatter_Channel_Raw_Data	Counts	Raw unprocessed photon counts from the online observations
WV_Online_Backscatter_Channel_Raw_Data_variance		
WV_Online_Backscatter_Channel_Raw_Data_ProfileCount	Count	
time_WV_Offline_Backscatter_Channel_Raw_Data	s since start of day	
range_WV_Offline_Backscatter_Channel_Raw_Data	m	
WV_Offline_Backscatter_Channel_Raw_Data	Counts	Raw unprocessed photon counts from the offline observations
WV_Offline_Backscatter_Channel_Raw_Data_variance		
WV_Offline_Backscatter_Channel_Raw_Data_ProfileCount	Count	
time_Attenuated_Backscatter	s since start of	

	day	
range_Attenuated_Backscatter	m	
Attenuated_Backscatter	Counts s^{-1} ns^{-1} m^{2}	Qualitative capture of the backscatter scene observed by the lidar. Includes effects of atmospheric backscatter and attenuation.
Attenuated_Backscatter_variance		
Attenuated_Backscatter_mask	1 = Masked, 0 = Not Masked	
Attenuated_Backscatter_ProfileCount	Count	
offline_std_range	pixel	Gaussian smoothing kernel width applied along the range axis of the water vapor offline channel. Specified in units of range bins. Multiply by the range bin resolution to obtain the temporal resolution
molecular_gain		HSRL Variable only used in systems that have the HSRL channel. Multiplier applied to molecular channel to account for difference in efficiency between the combined and molecular channels
lidar_longitude	deg	GPS longitude location of lidar
online_std_range	pixel	Gaussian smoothing kernel width applied along the range axis of the water vapor online channel. Specified in units of range bins. Multiply by the range bin resolution to obtain the temporal resolution

online_std_time	pixel	Gaussian smoothing kernel width applied along the time axis of the water vapor online channel. Specified in units of time bins. Multiply by the time bin resolution to obtain the temporal resolution
lidar_elevation	m	Lidar elevation above sea level
offline_std_time	pixel	Gaussian smoothing kernel width applied along the time axis of the water vapor offline channel. Specified in units of time bins. Multiply by the time bin resolution to obtain the temporal resolution
time_offset	s	Small offset in the profile timing used for ranging due to relative delays between the counter start, the laser firing and the laser pulse width
lidar_latitude	degrees	GPS latitude location of lidar