NASA/GSFC ALVICE Raman Lidar Products

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1. Data Set Overview

This data set contains images of water vapor data mixing ratio data measured by the NASA Goddard Space Flight Center (GSFC) Atmospheric Laboratory for Validation, Interagency Collaboration and Education (ALVICE) Raman lidar. ALVICE was located at the PECAN FP-2 site in Greensburg, KS (37.60695°N, -99.27606°E, 681 meters above sea level). Figure 1 shows the ALVICE trailer as it was positioned during PECAN operations. Data collection began on 01 June and ended on 16 July 2015.

Figure 1. NASA/GSFC ALVICE Raman lidar at FP-2 during PECAN.

2. Instrument Description

The ALVICE mobile laboratory of NASA/GSFC contains a high-performance Raman lidar based on a Nd:YAG laser, 0.6 m telescope, wavelength selection optics, photon detectors and

signal acquisition electronics. Please see references for more details. The ALVICE lidar measures water vapor mixing ratio, aerosol backscatter, extinction and depolarization, cloud liquid and ice water, and rotational temperature. For the PECAN campaign we are providing data files and images for the water vapor measurements and images of backscatter and depolarization. If data files of aerosol backscatter or depolarization are needed for a particular case, please contact us. The instrument has been involved in numerous field campaigns and is an updated version of the Scanning Raman Lidar instrument that participated in IHOP in 2002.

Accuracy: Calibration accuracy is approximately 5%. Random uncertainty varies as a function of photon count statistics.

Precision: Random uncertainty ranges from less than 1% to 100% at the upper limits of the profiling capability. Random uncertainties are reported in the data files.

Resolution: Atmospheric profiles were acquired 50 times each second and these profiles were summed to report profiles at 30 second resolution. Therefore, 30 seconds is the minimum temporal resolution for data recorded during PECAN.

3. Data Collection and Processing

Water vapor mixing ratio, aerosol scattering ratio, and aerosol depolarization ratio were derived using custom software developed at NASA/GSFC. Currently, quality assurance/control is performed manually, especially at times when issues were known to exist.

4.0 Data Format

The water vapor data are currently released as PNG images and netCDF files.

4.1 Water Vapor netCDF Files

Water vapor timeseries data are contained in files with the name ALV_yyyymmdd_Image_H2O.nc. Below is the file header:

```
netcdf ALV_20150601_Image_H2O {
dimensions:
      time = UNLIMITED ; // (149 currently)
      height = 311 ;
variables:
      double base_time ;
            base_time:long_name = "base time" ;
            base_time:units = "Seconds since 1970-01-01 0000 UTC to 2015-06-
01 0000 UTC" ;
      double time_offset(time) ;
            time_offset:long_name = "Profile time of the beginning of the 30-
second profile that is at the center of the time averaging window" ;
            time_offset:units = "Number of hours from base_time" ;
      float height(height) ;
            height:long_name = "Height of center of vertical averaging
window" ;
            height:units = "km above mean sea level" ;
      float H2O_mixing_ratio(time, height) ;
            H2O_mixing_ratio:long_name = "water vapor mixing ratio" ;
            H2O_mixing_ratio:units = "g/kg" ;
```

```
      float H2O_mixing_ratio_unc(time, height) ;
            H2O_mixing_ratio_unc:long_name = "water vapor mixing ratio
uncertainty" ;
            H2O_mixing_ratio_unc:units = "g/kg" ;
      byte qc_flag(time, height) ;
            qc_flag:long_name = "quality flag" ;
            qc_flag:units = "unitless" ;
            qc_flag:value_0 = "Good" ;
            qc_flag:value_1 = "Questionable based on overlap" ;
      float alt ;
            alt:long_name = "site altitude" ;
            alt:units = "km above mean sea level" ;
      float lat ;
            lat:long_name = "site latitude" ;
            lat:units = "degrees_north" ;
      float lon ;
            lon:long_name = "site longitude" ;
            lon:units = "degrees_east" ;

// global attributes:
            :PI = "David Whiteman, NASA/GSFC, david.n.whiteman@nasa.gov" ;
            :mission = "PECAN" ;
            :creating_program = "ALVtext_convert.py/HDF4_to_netCDF" ;
}
```

The water vapor best estimate profiles are processed at times of most of the radiosonde launches at FP2. These files contain single profiles of lidar and sonde data and have the name ALV_yyyymmdd_HHMMSS_WV_BestEstimate_v0.9.nc. The best estimate product combines ground values taken from surface meteorology sensors and lidar data above. The lidar data have been processed with an adaptive algorithm that varies the temporal and spatial resolution as a function of altitude so as to achieve a random uncertainty of 10% or less at each altitude range. The corresponding temporal and spatial resolutions are reported in the data files. The sonde data were interpolated to the lidar height levels. Below is the file header:

```
netcdf ALV_20150601_032900_WV_BestEstimate_v0.9 {
dimensions:
      height = 579 ;
variables:
      float alt(height) ;
            alt:long_name = "lidar height levels" ;
            alt:units = "km above sea level" ;
      float mr_best_est(height) ;
            mr_best_est:_FillValue = 9.96921e+36f ;
            mr_best_est:long_name = "water vapor mixing ratio best estimate"
;
            mr_best_est:units = "ppmv" ;
      float mr_best_est_rand_unc(height) ;
            mr_best_est_rand_unc:_FillValue = 9.96921e+36f ;
            mr_best_est_rand_unc:long_name = "water vapor mixing ratio best
estimate random uncertainty" ;
            mr_best_est_rand_unc:units = "ppmv" ;
      float mr_best_est_tot_unc(height) ;
            mr_best_est_tot_unc:_FillValue = 9.96921e+36f ;
            mr_best_est_tot_unc:long_name = "water vapor mixing ratio best
estimate total uncertainty" ;
```

```
            mr_best_est_tot_unc:units = "ppmv" ;
      float mr_best_est_time_res(height) ;
            mr_best_est_time_res:_FillValue = 9.96921e+36f ;
            mr_best_est_time_res:long_name = "water vapor mixing ratio best
estimate time averaging resolution" ;
            mr_best_est_time_res:units = "minutes" ;
      float mr_best_est_vert_res(height) ;
            mr_best_est_vert_res:_FillValue = 9.96921e+36f ;
            mr_best_est_vert_res:long_name = "water vapor mixing ratio best
estimate vertical averaging resolution" ;
            mr_best_est_vert_res:units = "km" ;
      float sonde_mr(height) ;
            sonde_mr:_FillValue = 9.96921e+36f ;
            sonde_mr:long_name = "radiosonde water vapor mixing ratio" ;
            sonde_mr:units = "ppmv" ;
      float sonde_rh(height) ;
            sonde_rh:_FillValue = 9.96921e+36f ;
            sonde_rh:long_name = "radiosonde relative humidity" ;
            sonde_rh:units = "percent" ;
      float sonde_T(height) ;
            sonde_T:_FillValue = 9.96921e+36f ;
            sonde_T:long_name = "radiosonde temperature" ;
            sonde_T:units = "C" ;
      float sonde_P(height) ;
            sonde_P:_FillValue = 9.96921e+36f ;
            sonde_P:long_name = "radiosonde pressure" ;
            sonde_P:units = "hPa" ;
      float lidar_cal_value ;
            lidar_cal_value:long_name = "lidar calibration value" ;
            lidar_cal_value:units = " " ;
      float sonde_launch_time_doy ;
            sonde_launch_time_doy:long_name = "time of sonde launch" ;
            sonde_launch_time_doy:units = "day of year" ;
      double sonde_launch_time ;
            sonde_launch_time:long_name = "time of sonde launch" ;
            sonde_launch_time:units = "number of seconds since 1970-01-01
00:00:00 UTC" ;
      float sonde_ipw ;
            sonde_ipw:_FillValue = 9.96921e+36f ;
            sonde_ipw:long_name = "radiosonde integrated precipitable water"
;
            sonde_ipw:units = "mm" ;
      float UMBCmwr_ipw ;
            UMBCmwr_ipw:_FillValue = 9.96921e+36f ;
            UMBCmwr_ipw:long_name = "UMBC microwave radiometer integrated
precipitable water" ;
            UMBCmwr_ipw:units = "mm" ;
      float ALVICE_ipw ;
            ALVICE_ipw:_FillValue = 9.96921e+36f ;
            ALVICE_ipw:long_name = "ALVICE integrated precipitable water" ;
            ALVICE_ipw:units = "mm" ;
      float all_night_lidar_minutes ;
            all_night_lidar_minutes:long_name = "number of minutes of all
night lidar" ;
            all_night_lidar_minutes:units = "minutes" ;
      float sfc_rh ;
            sfc_rh:_FillValue = 9.96921e+36f ;
```

```
            sfc_rh:long_name = "surface relative humidity" ;
            sfc_rh:units = "percent" ;
      float sfc_T ;
            sfc_T:_FillValue = 9.96921e+36f ;
            sfc_T:long_name = "surface temperature" ;
            sfc_T:units = "C" ;
      float sfc_P ;
            sfc_P:_FillValue = 9.96921e+36f ;
            sfc_P:long_name = "surface pressure" ;
            sfc_P:units = "hPa" ;
      float site_lat ;
            site_lat:long_name = "site latitude" ;
            site_lat:units = "degrees_N" ;
      float site_lon ;
            site_lon:long_name = "site longitude" ;
            site_lon:units = "degrees_E" ;
      float site_elev ;
            site_elev:long_name = "site elevation" ;
            site_elev:units = "km above sea level" ;

// global attributes:
            :radiosonde_file = "UMBC_RS41X.20150601_032900UT.nc" ;
            :source_file_version = "v0.9" ;
            :notes = "Surface data from UMBC Vaisala surface weather station
at FP2" ;
            :file_description = "ALVICE Water Vapor Mixing Ratio Measurements
from the PECAN2015 campaign. Best Estimate File." ;
            :source_file = "ALV_20150601_032900_WV_BestEstimate_v0.9.dat" ;
            :creating_program =
"ALVtext_convert.py/read_convert_WV_BestEstimate_v09" ;
            :processing_status = "Includes overlap and temperature
corrections." ;
            :file_information = "" ;
            :source_file_creation_date = "Tue 6 Sep 2016 21:26:21" ;
            :file_creation_date = "28 Sep 2016 14:24:08 UTC" ;
}
```

4.2 Water Vapor PNG Image Files

Images with the name lidar.FP2_ALVICE.yyyymmddHHMM.H2O_Image.png contain time-height water vapor mixing ratio profiles contained in the time series netCDF files. Vertical dashed lines indicate times of radiosonde releases at FP2. Horizontal white lines (when visible, near the bottom of the profiles) indicate the minimum usable range based on overlap function behavior.

Images with the name lidar.FP2_ALVICE.yyyymmddHHMM.H2O_Plot.png contain lidar and radiosonde water vapor mixing ratios of almost all the radiosondes launched at FP2. The orange line is the line from the lidar time series data file. The green line is the best-estimate water vapor product profile and horizontal dashed lines indicate the minimum usable lidar height based on the overlap function behavior.

5. Data Remarks

We have studied misalignment and electronic non-linearity due to overheating of the instrument, which was a persistent problem during PECAN. Data where these issues existed are being further analyzed and corrected prior to release. There were also some low-altitude oscillations in the data acquisition which are evident in some data sets. This README documentation will be updated to reflect the lidar products currently released. The ALVICE integrated precipitable water variable (ALVICE_ipw) in the water vapor best estimate netCDF files has been set to a fill value until the overlap function near the bottom of the profile can be corrected to achieve a more-accurate integrated precipitable water value.

6. References

Whiteman, D. N., K. Rush, S. Rabenhorst, W. Welch, M. Cadirola, G. McIntire, F. Russo, M. Adam, D. Venable, R. Connell, I. Veselovskii, R. Forno, B. Mielke, B. Stein, T. Leblanc, S. McDermid, and H. Vömel, 2010: Airborne and ground-based measurements using a high-performance Raman lidar. *J. Atmospheric and Oceanic Tech.,* **27,** 1781-1801. DOI: 10.1175/2010JTECHA1391.1.

Whiteman, D. N., I. Veselovskii, M. Cadirola, K. Rush, J. Comer, J. R. Potter, and R. Tola, 2007: Demonstration measurements of water vapor, cirrus clouds, and carbon dioxide using a high-performance Raman lidar. *J. Atmospheric and Oceanic Tech.,* **24,** 1377-1388. DOI: 10.1175/JTECH2058.1.

Whiteman, D. N., B. Demoz, P. Di Girolamo, J. Comer, I. Veselovskii, K. Evans, Z. Wang, M. Cadirola, K. Rush, G. Schwemmer, B. Gentry, S. H. Melfi, B. Mielke, D. Venable, and T. Van Hove, 2006: Raman lidar measurements during the International H_2O Project. Part I: Instrumentation and analysis techniques. *J. Atmospheric and Oceanic Tech.,* **23,** 157-169.

Whiteman, D. N., B. Demoz, P. Di Girolamo, J. Comer, I. Veselovskii, K. Evans, Z. Wang, D. Sabatino, G. Schwemmer, B. Gentry, R-F. Lin, A. Behrendt, V. Wulfmeyer, E. Browell, R. Ferrare, S. Ismail, and J. Wang, 2006: Raman lidar measurements during the International H_2O Project. Part II: Case studies. *J. Atmospheric and Oceanic Tech.*, **23,** 170-183.