ASEN 6519. Lidar Remote Sensing

HW Projects #3 – Na Lidar Data Processing (Part I)

This project is to give students quantitative ideas of how lidar raw data look like, how to obtain necessary information (e.g., date, UT time, range bin, base altitude, zenith or off-zenith angle, azimuth, etc) from raw data, and how to convert raw photon counts to meaningful physical quantities (temperature, wind and Na density).

The lidar raw data can be accessed from our class website, named "NaLidar_AR1102". The folder includes many datasets obtained by a Na wind and temperature lidar for an entire night on April 11, 2002 at Maui Haleakala Mountain by Dr. Xinzhao Chu. Note: bin resolution "7" in the data header means 160 ns of bin width. The file "TPNDMauiAR1102.dat" contains the MSIS00 temperature, pressure, and number density data. All data are in ASCII format.

You are required to process "AR1102.001" (zenith pointing) and "AR1102.009" (30 degree off-zenith pointing to East) profiles for this Project #3. Then in Project #4 you will process all profiles, plot the temperature and wind contours through the night, and also calculate the temperature and wind errors.

This Project #3 is divided into three sub-projects:

1) Compute the calibration curve of R_T versus R_W
2) Pre-process and profile-process to obtain normalized photon counts,
3) Main process to obtain temperature, wind and Na density.

Subproject 1: Compute and plot the calibration curves (R_T versus R_W) for the Na Doppler lidar with the following temperature and wind metrics:

1). $$R_T = \frac{\sigma_{eff}(f_+) + \sigma_{eff}(f_-)}{\sigma_{eff}(f_a)}, \quad R_W = \frac{\sigma_{eff}(f_-)}{\sigma_{eff}(f_+)}$$

2). $$R_T = \frac{\sigma_{eff}(f_+) + \sigma_{eff}(f_-)}{\sigma_{eff}(f_a)}, \quad R_W = \frac{\sigma_{eff}(f_+) - \sigma_{eff}(f_-)}{\sigma_{eff}(f_a)}$$

3). $$R_T = \frac{\sigma_{eff}(f_+) + \sigma_{eff}(f_-)}{\sigma_{eff}(f_a)}, \quad R_W = \frac{\ln\left[\sigma_{eff}(f_-)/\sigma_{eff}(f_+)\right]}{\ln\left[\sigma_{eff}(f_-) \times \sigma_{eff}(f_+)/\sigma_{eff}^2(f_a)\right]}$$

where σ_{eff} is the effective cross section of Na D_2 line, frequencies f_a = -651.4 MHz, f_+ = -21.4 MHz, and f_- = -1281.4 MHz (relative to the line center). Assume the laser line shape is a Gaussian with rms width of 60 MHz. The temperature and wind ranges are T = 100 to 300 K and V_R = -100 to +100 m/s at resolutions of 10 K and 10 m/s.

Subproject 2 contains the following assignments –

(1) Draw a flowchart for your data processing code to show the pre-process and profile-process procedures.
Note: you may refer to our lecture notes #17 and 18, but I do want you to write a flowchart for your own code, because it helps you to keep a clear mind in writing such a complicated code.

(2) Read in the lidar raw data and plot raw-data profiles for three frequencies versus bin number and altitude for both .001 and .009 profiles.

Note: pay attention to how to convert bin number to range (the actual distance from lidar to the scatter) and then to altitude (the height above the mean sea level).

(3) Do PMT/discriminator saturation correction and plot the peak-frequency data profiles after this correction. Sample MatLab code is provided at our website.

(4) Do chopper correction and plot the peak-frequency data profiles after this correction. Note: chopper profiles are in the same folder as the data.

(5) Subtract background and plot the peak-frequency data profiles after this step.

(6) Remove range dependence and plot the peak-freq data profiles after this step.

(7) Add base altitude and then take Rayleigh signal @ 40 km as the Rayleigh normalization signal. Plot the Rayleigh fitting and the Rayleigh signal for the peak-frequency data profiles.

(8) Normalize the entire profile by the Rayleigh normalization signal and plot the normalized profiles for all three frequencies.

Subproject 3 contains the following assignments –

(9) Draw a flowchart for your data processing code to show the whole procedure how you process the data. This is to add the main procedure to your previous flowchart.

(10) From the normalized photon count profiles at all three frequencies to derive the temperature and wind ratios R_T and R_W, and then infer temperature and wind from these ratios for each altitude (either by look-up table method or iteration method).

Note: Pay attention to the extinction caused by the Na absorption, and the subtraction of Rayleigh signals from the Na altitude range.

(11) Then derive Na density for each altitude.

Use the following metrics to calculate the ratios

$$R_T = \frac{\sigma_{eff}(f_+) + \sigma_{eff}(f_-)}{\sigma_{eff}(f_a)}, \quad R_W = \frac{\ln\left[\sigma_{eff}(f_-)/\sigma_{eff}(f_+)\right]}{\ln\left[\sigma_{eff}(f_-) \times \sigma_{eff}(f_+)/\sigma_{eff}^2(f_a)\right]}$$

Conditions: Three laser frequencies are f_a = -651.4 MHz, f_+ = -21.4 MHz, and f_- = -1281.4 MHz (relative to the line center), the laser lineshape is a Gaussian with a linewidth (rms) of 60 MHz, and PDA frequency offset is 10.27 MHz for the night of April 11, 2002.

Please show the following plots as the products of your code:

1) Ratio R_T versus altitude for .001 and .009 profiles
2) Ratio R_W versus altitude for .001 and .009 profiles
3) Derived temperature T versus altitude for .001 and .009 profiles
4) Derived radial wind V_R versus altitude for .001 and .009 profiles when PDA frequency offset is 0 MHz.
5) Derived radial wind V_R versus altitude for .001 and .009 profiles when PDA frequency offset is set to 10.27 MHz.
6) Derived zonal wind u versus altitude for .009 profiles when PDA frequency offset is set to 10.27 MHz.
7) Derive Na density versus altitude for .001 and .009 profiles when PDA frequency offset is set to 10.27 MHz.

You are required to show your MatLab or equivalent code with your data processing results.