

## ASEN 6519. Lidar Remote Sensing

### HW #7 -- Na Lidar Data Processing (Part II)

This project is to complete the Na lidar data retrieval, built upon HW #6. It gives students quantitative ideas of how to process the entire night of data on April 11, 2002 and distinguish different pointing directions, how to convert line of sight (LOS) wind to zonal, meridional and vertical winds (DBS mode), and how to do error analysis for photon-noise-induced measurement uncertainties of temperature and wind.

**Subproject 1** – Process the entire datasets and plot temperature, wind and Na density results.

- (1) Process the entire datasets for April 11, 2002, using loop and distinguishing different pointing directions of the lidar beam.
- (2) Calculate zonal, meridional and vertical wind from the derived LOS wind.  
*Note: Let's use the notion of LOS wind moving away from the lidar beam is positive, and eastward, northward and upward winds are positive.*
- (3) Plot a contour of temperature versus UT time and altitude.
- (4) Plot a contour of zonal wind versus UT time and altitude.
- (5) Plot a contour of meridional wind versus UT time and altitude.

**Subproject 2** -- Temperature error analysis.

Temperature ratio is defined as

$$R_T = \frac{N_+ + N_-}{N_a} \quad (1), \quad R_T = \frac{\sigma_{eff}(f_+, T, V_R) + \sigma_{eff}(f_-, T, V_R)}{\sigma_{eff}(f_a, T, V_R)} \quad (2)$$

The temperature error caused by photon noise is given by

$$\Delta T = \frac{\partial T}{\partial R_T} \Delta R_T = \frac{R_T}{\partial R_T / \partial T} \frac{\Delta R_T}{R_T} \quad (3)$$

- (6) Derive the temperature error coefficient  $\frac{R_T}{\partial R_T / \partial T}$  using Eq. (2) of  $R_T$ . It is easy to derive this numerically. Plot the temperature error coefficient versus altitude and side-by-side plot the temperature versus altitude (put altitude to y-axis) for profile 001.

*Note: The temperature error coefficient is the reciprocal of temperature sensitivity  $S_T = \frac{\partial R_T / \partial T}{R_T}$ .*

- (7) Derive the following error equation for  $\Delta R_T / R_T$  (i.e., Eq. (5.83) in our textbook), and then calculate and plot  $\Delta R_T / R_T$  versus altitude from “raw photon counts” for profile 001.

$$\frac{\Delta R_T}{R_T} = \frac{\left(1 + \frac{1}{R_T}\right)^{1/2}}{\left(N_{f_a}\right)^{1/2}} \left[ 1 + \frac{B}{N_{f_a}} \frac{\left(1 + \frac{2}{R_T^2}\right)}{\left(1 + \frac{1}{R_T}\right)} \right]^{1/2} \quad (4)$$

- (8) From above steps, calculate the temperature errors caused by photon noise for profile 001. Plot the temperature error  $\Delta T$  vs altitude, and side-by-side plot the Na photon count profile and temperature profile.

- (9) In real data processing, we usually simplify the temperature error coefficient, i.e., do not count in the coefficient variation with operating points (i.e., T and V values) but use a nominal coefficient at T = 200 K and  $V_R = 0$  m/s to estimate the errors. This nominal temperature coefficient is 202.8 for the Na Doppler lidar. Thus, the Na lidar temperature error can be estimated as Eq. (5), where  $\Delta R_T/R_T$  is also given by Eq. (4)

$$\Delta T = 202.8 \times \frac{\Delta R_T}{R_T} \quad (5)$$

Please implement Eq. (5) into your subproject 1 data processing code so that you can calculate the Na temperature error for every profile. (Put altitude to y-axis)

*Note: The photon counts used in the error analysis should be raw photon counts, i.e., photon counts without PMT, chopper, and range corrections.*

**Extra assignments (not required):**

- (1) Wind error can be analyzed in similar way as the temperature errors (see our textbook and lecture notes). You may derive and then add wind error analysis to your Na lidar data processing code.
- (2) You may also add the temperature and wind error analyses to your range-resolved lidar simulation code. Once this is done, you can check how the measurement errors vary with the lidar and atmospheric parameters.

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