ASEN 6519. Lidar Remote Sensing

HWK Project #3 – Computation of Calibration Curves and Sensitivities

This project is to compute the calibration curves (R_T versus R_W) for different possible metrics and the temperature and wind sensitivities (S_T and S_W) for Na and K Doppler lidars so that we can compare and assess the performance of different lidars.

This project contains three main aspects plus comment –

(1) Compute and plot the calibration curves (R_T versus R_W) for the Na Doppler lidar (same system parameters as used in HWK Project #2) with the following temperature and wind metrics:

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

2). $R_T = \dfrac{\sigma_{eff}(f_+) + \sigma_{eff}(f_-)}{\sigma_{eff}(f_a)}$, $R_W = \dfrac{\sigma_{eff}(f_+) - \sigma_{eff}(f_-)}{\sigma_{eff}(f_a)}$ (same as Project #2)

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

4). $R_T = \dfrac{\sigma_{eff}(f_+) \times \sigma_{eff}(f_-)}{\sigma_{eff}^2(f_a)}$, $R_W = \dfrac{\sigma_{eff}(f_-)}{\sigma_{eff}(f_+)}$

5). $R_T = \dfrac{\sigma_{eff}(f_+) \times \sigma_{eff}(f_-)}{\sigma_{eff}^2(f_a)}$, $R_W = \dfrac{\sigma_{eff}(f_+) - \sigma_{eff}(f_-)}{\sigma_{eff}(f_a)}$

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

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).
The temperature and wind ranges are T = 100 to 300 K and V_R = -100 to +100 m/s at resolution of 10 K and 10 m/s.

(2) Compute and plot the calibration curves (R_T versus R_W) for the K Doppler lidar (same system parameters as used in HWK Project #2) with the same six pairs of temperature and wind metrics as listed in (1). The temperature and wind ranges are T = 100 to 300 K and V_R = -100 to +100 m/s at resolution of 10 K and 10 m/s.

Here, σ_{eff} is the effective cross section of K D_1 line, frequencies f_a = -180 MHz (relative to the line center), $f_+ = f_a$ + AO_freq_shift, and $f_- = f_a$ - AO_freq_shift where AO_freq_shift = 477.6 MHz. The laser line shape is a Gaussian with a linewidth of 70 MHz (FWHM).

Other related K atomic parameters are (frequency in Hz unit)

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freqiK39(1) = 310.00983e6;
freqiK39(2) = 252.84983e6;
freqiK39(3) = -151.7099e6;
freqiK39(4) = -208.8699e6;
freqiK41(1) = 405e6;
freqiK41(2) = 375e6;
freqiK41(3) = 151e6;
freqiK41(4) = 121e6;
strengthK(1) = 5;
strengthK(2) = 1;
strengthK(3) = 5;
strengthK(4) = 5;
abdnK39=0.932581;
abdnK41=0.067302;
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Note: K has isotopes 39 and 41, while Na has only one isotope 23.

(3) Calculate and plot the temperature sensitivity ($S_T = \frac{\partial R_T / \partial T}{R_T}$) for both Na and K Doppler lidars for two metrics in the temperature range of 100-300 K for V_R = 0 m/s:

$$R_{T1} = \frac{\sigma_{eff}(f_+) + \sigma_{eff}(f_-)}{\sigma_{eff}(f_a)}, \quad R_{T2} = \frac{\sigma_{eff}(f_+) \times \sigma_{eff}(f_-)}{\sigma_{eff}^2(f_a)};$$

Calculate and plot the wind sensitivity ($S_W = \frac{\partial R_W / \partial W}{R_W}$) for both Na and K Doppler lidars for the following wind metrics in the radial wind range of -100 to 100 m/s for T = 200 K:

$$R_W = \frac{\sigma_{eff}(f_-)}{\sigma_{eff}(f_+)}.$$

(4) Please comment on the curvature feature and sensitivity of different metrics and comment on the comparison of Na and K lidar sensitivity.

You are required to show your MatLab or equivalent code with your computation results (numbers or figures).