Measuring atmospheric temperatures with Cabannes scattering at 589 nm with sodium vapor filters

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Realizing that atomic (and molecular iodine) absorption vapor filters can be effective notch filters for blocking aerosol scattering, the group at Colorado State University proposed the use of filtered Cabannes scattering through two filters with different widths, a low-temperature (LT) and a high-temperature (HT) atomic or molecular vapor filter, for atmospheric temperature measurements [Shimizu et al., 1983]. They then succeeded in making atmospheric temperature measurements with barium and iodine filters, respectively, in [She et al., 1992; Alvarez et al., 1993; Krueger et al., 1993] and in [Hair et al., 2001]. Although this elegant temperature measurement technique has not been widely adopted, the use of one iodine absorption filter as an aerosol blocking filter has become a standard for the measurements of aerosol optical properties via high-spectral-resolution lidar [Piironen et al., 1994; Eloranta, 2005; Hair et al., 2008] and atmospheric winds using edge techniques [Friedman et al., 1997; Liu et al., 2002; Wang et al., 2010]. Very recently, She et al. [2021] has revisited the fundamentals of this technique and pointed out the different issues existed in barium and iodine vapors that prevented them from being effective for implementing HT filter, making their performance only comparable to the pure rotation Raman temperature lidar (RRL) at 532 nm (with 78 times weaker in scattering signal). In this analysis, the use of alkali potassium vapor filters as better alternatives for measuring atmospheric temperature with Cabannes scattering at 770 nm was proposed. They showed the temperature uncertainty of the proposed Potassium Cabannes lidar (PCL) to be 5.3 times and 6.1 times smaller than the demonstrated Cabannes Iodine Lidar (CIL) and RRL lidar, respectively. They also pointed out that Alkali sodium could be another candidate vapor for atmospheric temperature measurements, though the larger ground state hyperfine splitting, 1.771 GHz in sodium compared to 0.6418 GHz for potassium may be a concern as it would set a lower bandwidth limit for the LT filter.

Since a successful implementation of Sodium Cabannes lidar (SCL) would allow temperature profiling from ground to the upper mesosphere (~ 105 km), with the existing laser-induced-fluorescence (LIF) lidar, we estimate the figure of merit of SCL for atmospheric temperature measurements in this paper. Preliminary analysis showed when the sodium laser is lock at the NaD_{2a} transition, the temperature uncertainty of SCL utilizing the same lidar transmitter at 589 nm is 2.5 times larger and 2.4 times smaller than that of the PCL and RRL, respectively. When scaled to the 532 nm, the temperature uncertainty of the SCL is 1.7 times larger than the PCL and 2.0 times smaller than the RRL. We will explain our analysis and discuss the way that the SCL may be implemented with a 3-frequency LIF lidar [Krueger et al, 2015] using the same lidar transmitter at 589 nm in practice. We will also compare the proposed method to the existing lidar methods for measuring atmospheric temperatures.