Remote Sensing Measurements of the Diurnal Structure of the Mixed Layer over the SGP

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Background

The thermodynamic structure and evolution of the Mixed Layer (ML) must be accurately represented in numerical models, as errors can lead to significant biases in many atmospheric processes, including the radiative fluxes, cloud properties and processes, precipitation processes, aerosol and chemical processes, and dispersion. We explore the ability of the SGP remote sensing instruments to capture the diurnal behavior of the ML and determine the ML height. The instruments and measurements include:

- Raman lidar (RLID) measurements of aerosol backscatter, water vapor mixing ratio, and temperature
- University of Wisconsin High Spectral Resolution Lidar (HSRL) measurements of aerosol backscatter and aerosol depolarization
- Doppler lidar (DL) measurements of wind velocity
- AERI (AERI) retrievals of temperature

We examine the measurements acquired during the Combined HSRL And Raman lidar Measurement Study (CHARMS) (mid-July through September 2015).

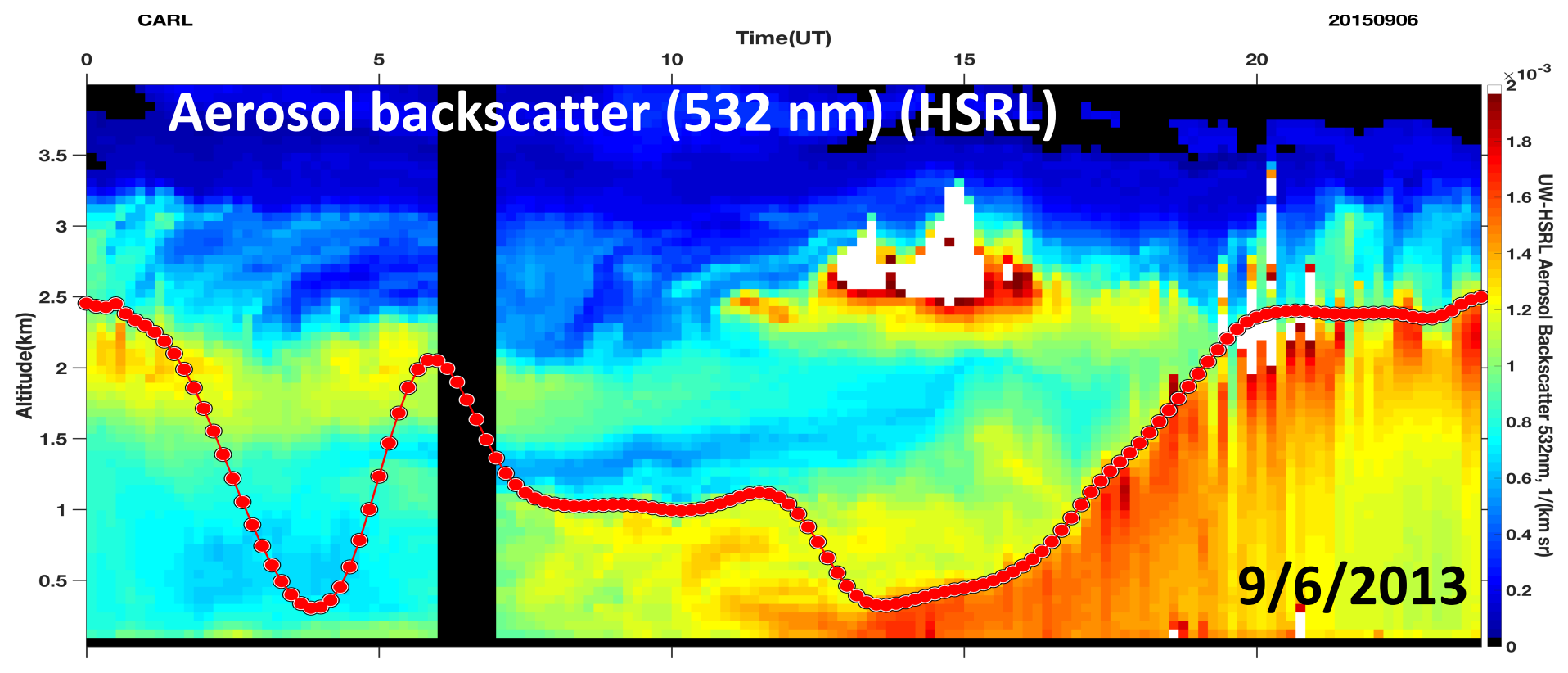
Findings

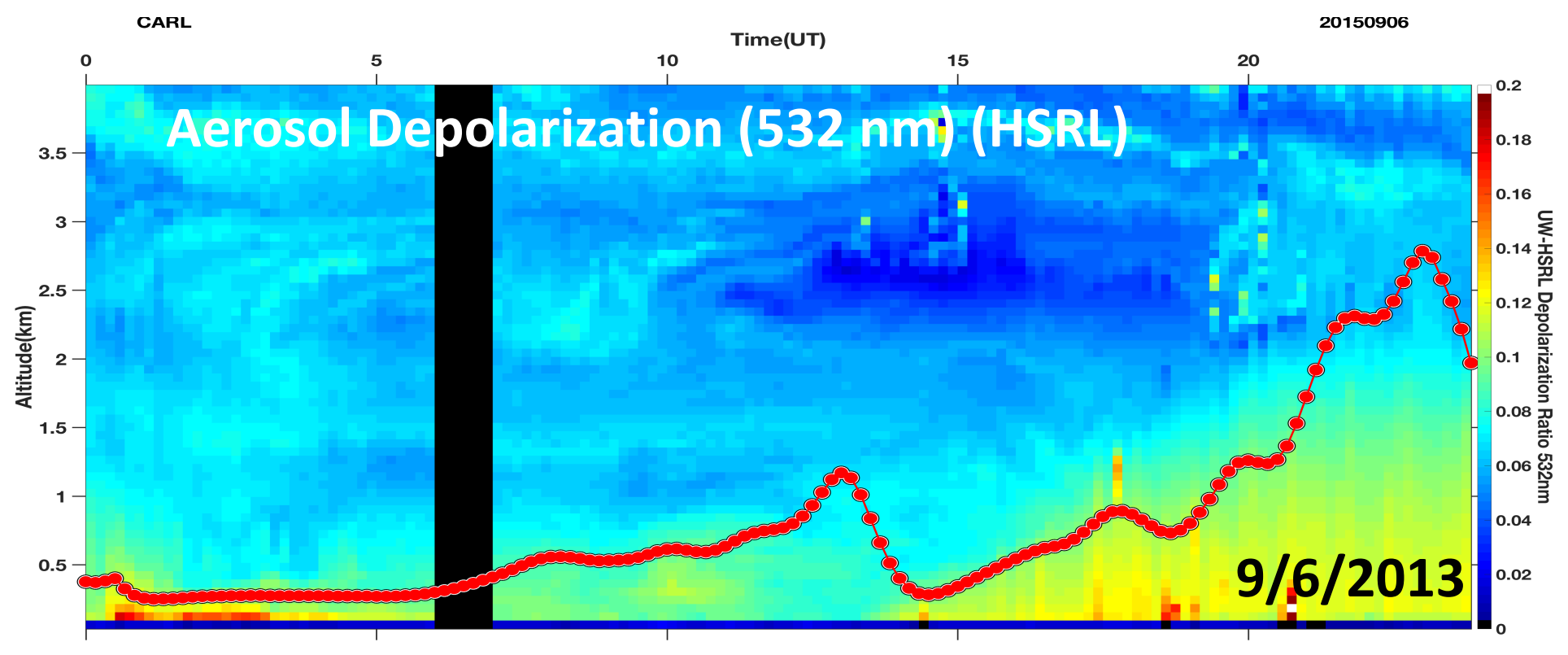
1. Obtaining ML height from aerosol and water vapor gradients worked well during morning through late afternoon but did not work well at night due to the presence of elevated aerosol and water vapor layers. This is a common situation when trying to use these parameters to derive ML height.
2. ML height from RL+AERI potential temperature files provide a more consistent representation of the diurnal behavior of the ML height.
3. At night, ML heights derived from RL+AERI potential temperature files using the Heffter and Liu-Liang algorithms compare well with ML heights derived from radiosonde potential temperature profiles in a similar manner. During the day, ML heights derived from RL+AERI potential temperature files using the Heffter and Liu-Liang methods are slightly lower, due possibly to some difficulty in calibrating the RL temperature profiles in cloudy conditions.
4. ML heights derived from DL vertical velocity variance measurements during the day compare well with ML heights derived from aerosol and water vapor gradients.
5. During the day, ML heights derived from bulk Richardson number thresholds do not match well with ML heights derived from gradients in aerosols, water vapor, or potential temperature. At night, ML heights from bulk Richardson number compare better with those derived from potential temperature gradients.

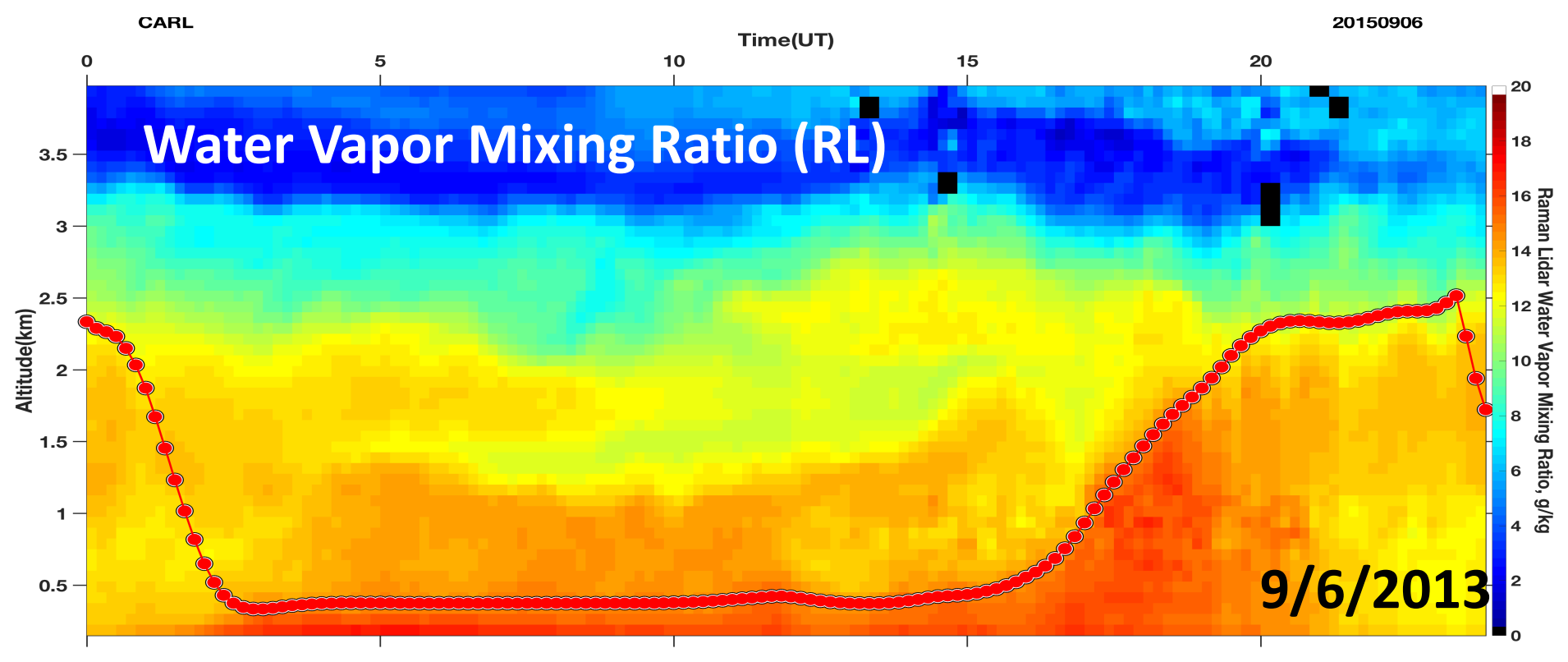
Method 1

Automated technique to identify sharp gradients at the top of the ML using various parameters:

- Aerosol backscatter or extinction (RL-355 nm, UW-HSRL-532 nm)
- Water vapor mixing ratio (RL)
- Aerosol depolarization (UW-HSRL)

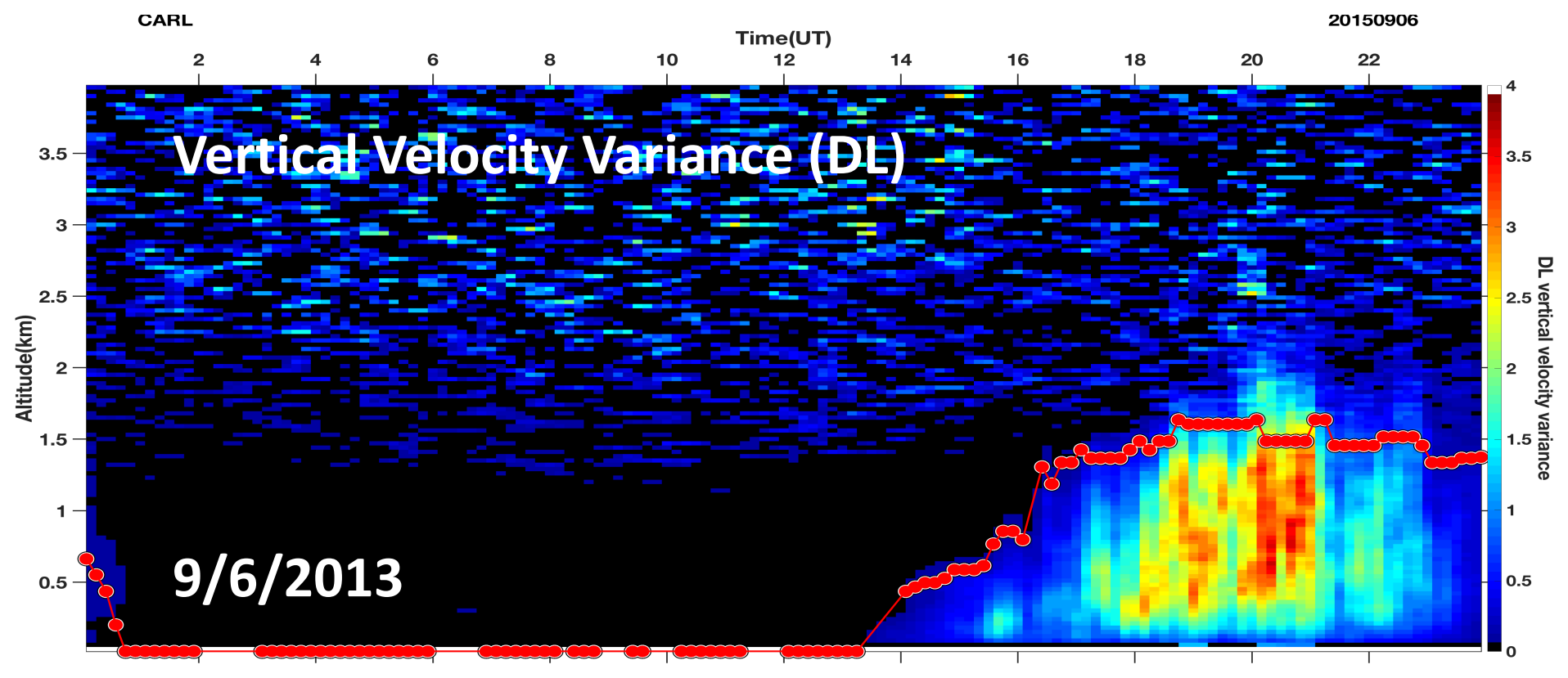




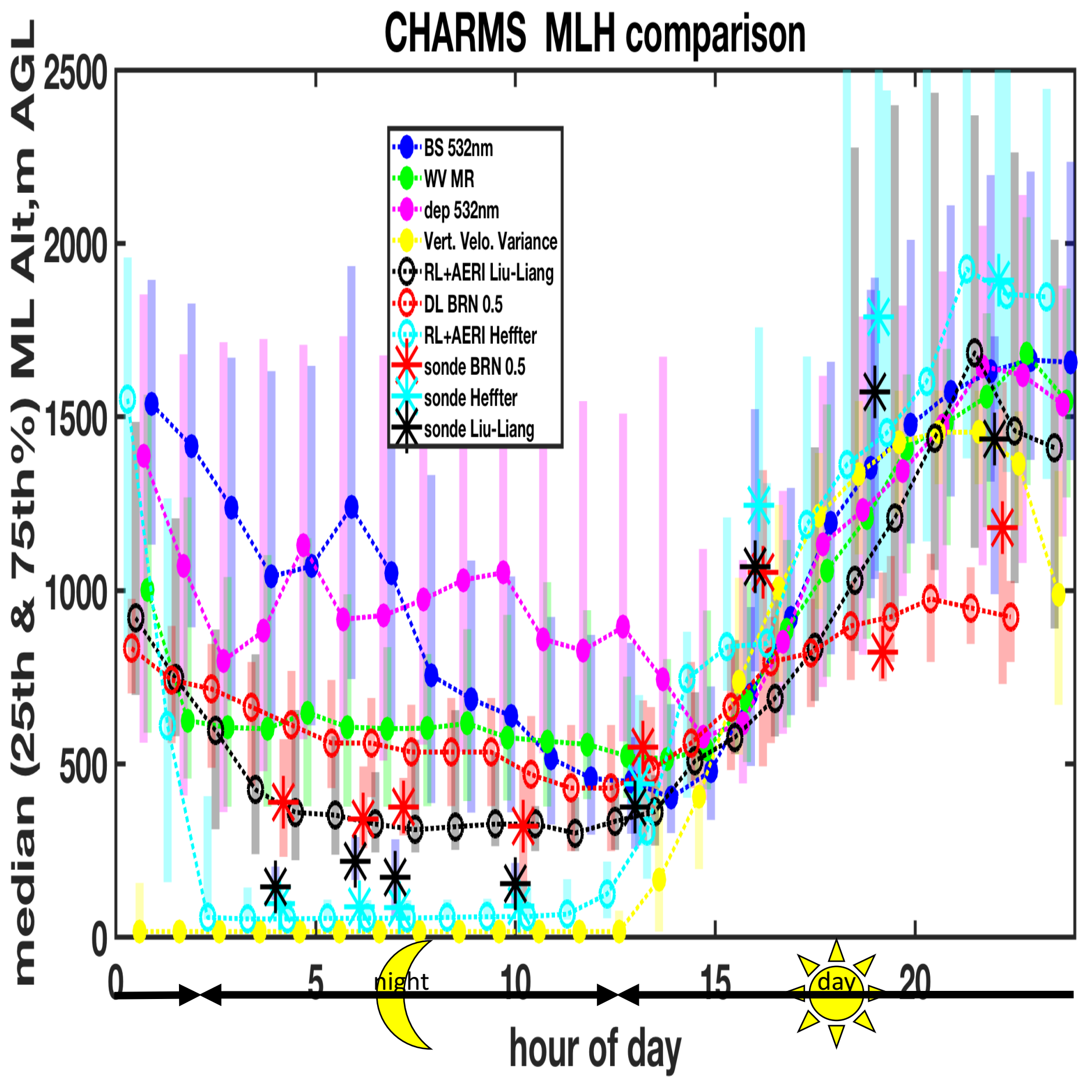


Method 2

This method uses vertical gradients in the vertical velocity variance measured by the Doppler lidar. It may fail to identify near surface ML heights or when the S/N is too low at the ML height.

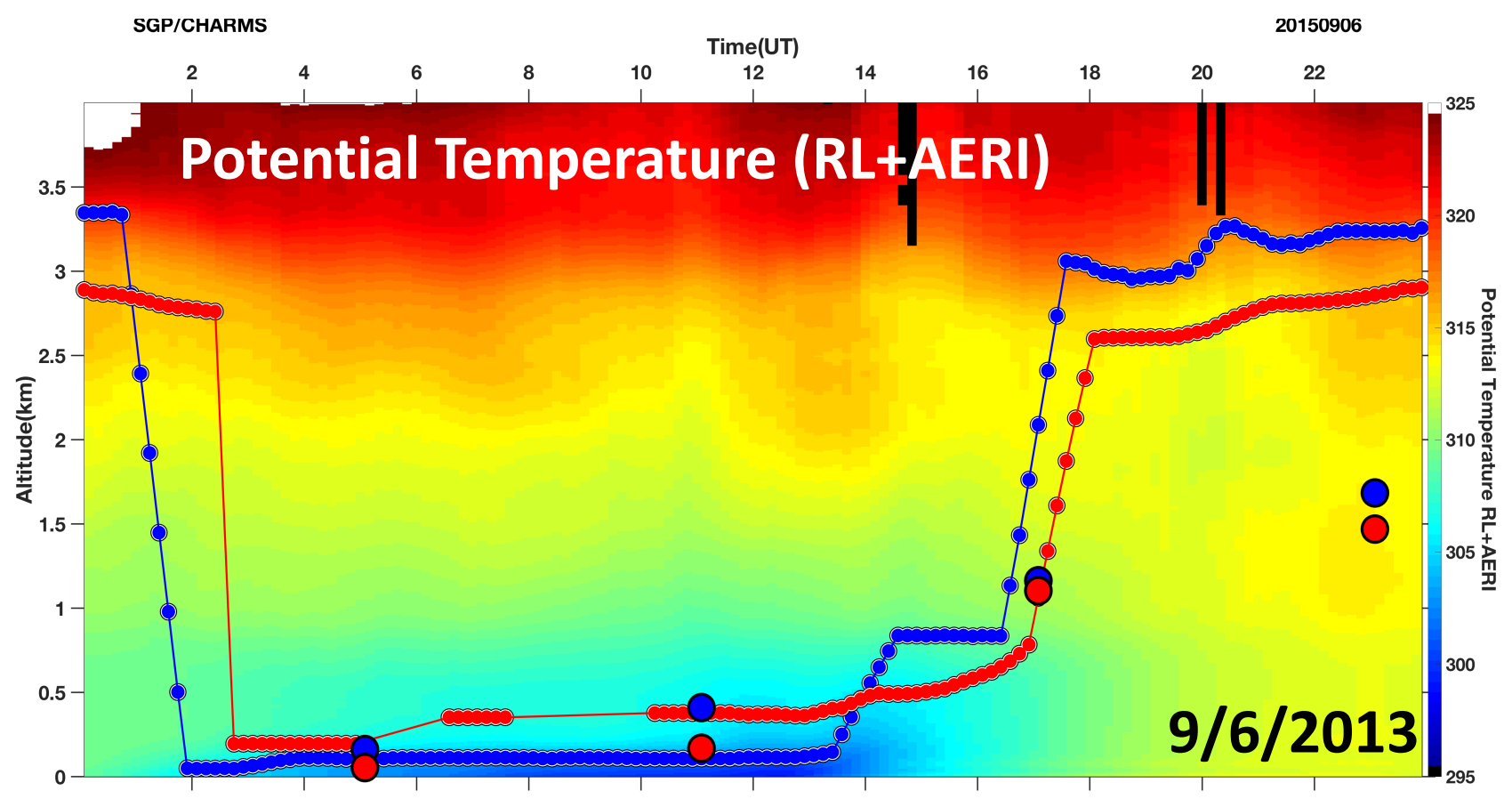


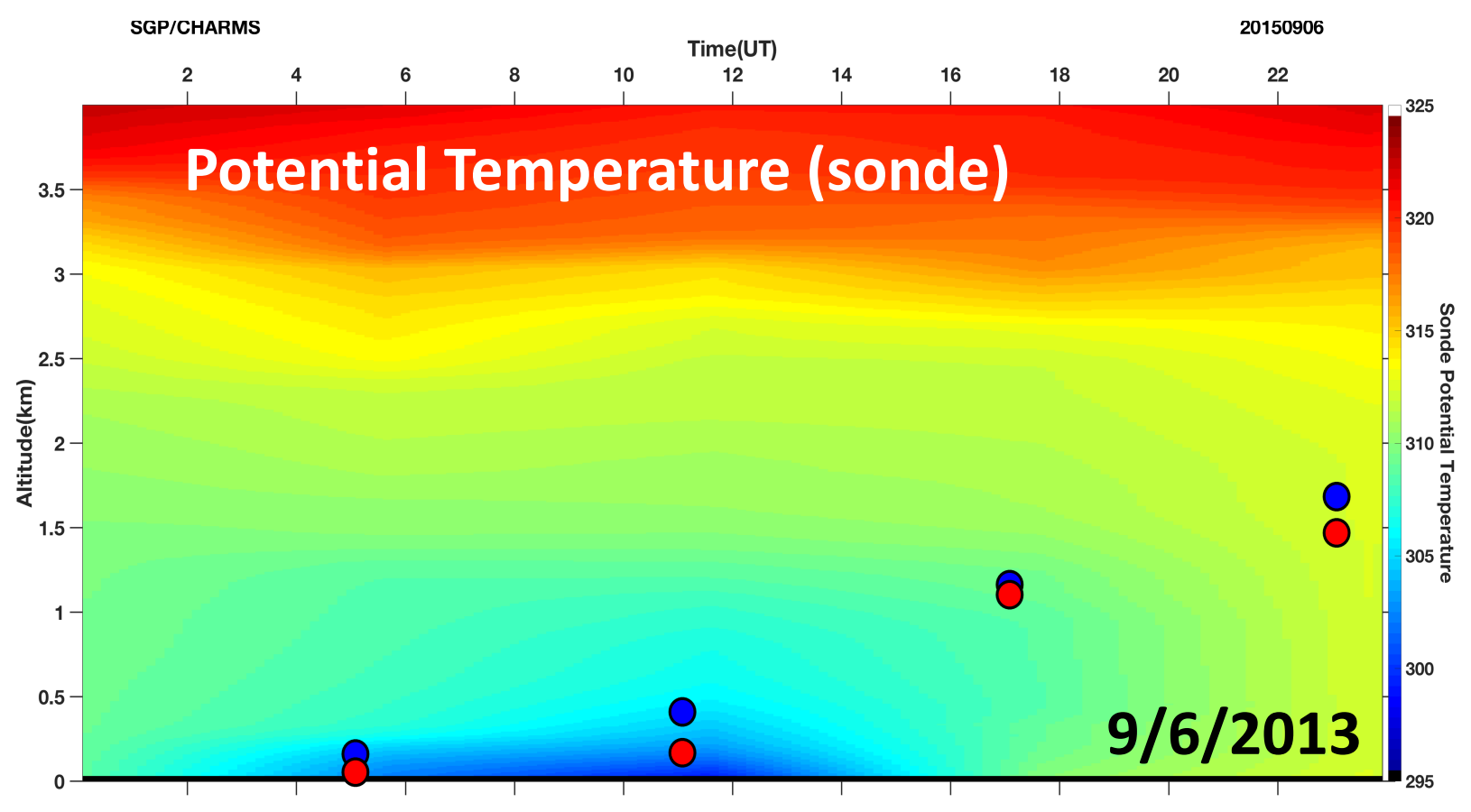
CHARMS comprehensive plot

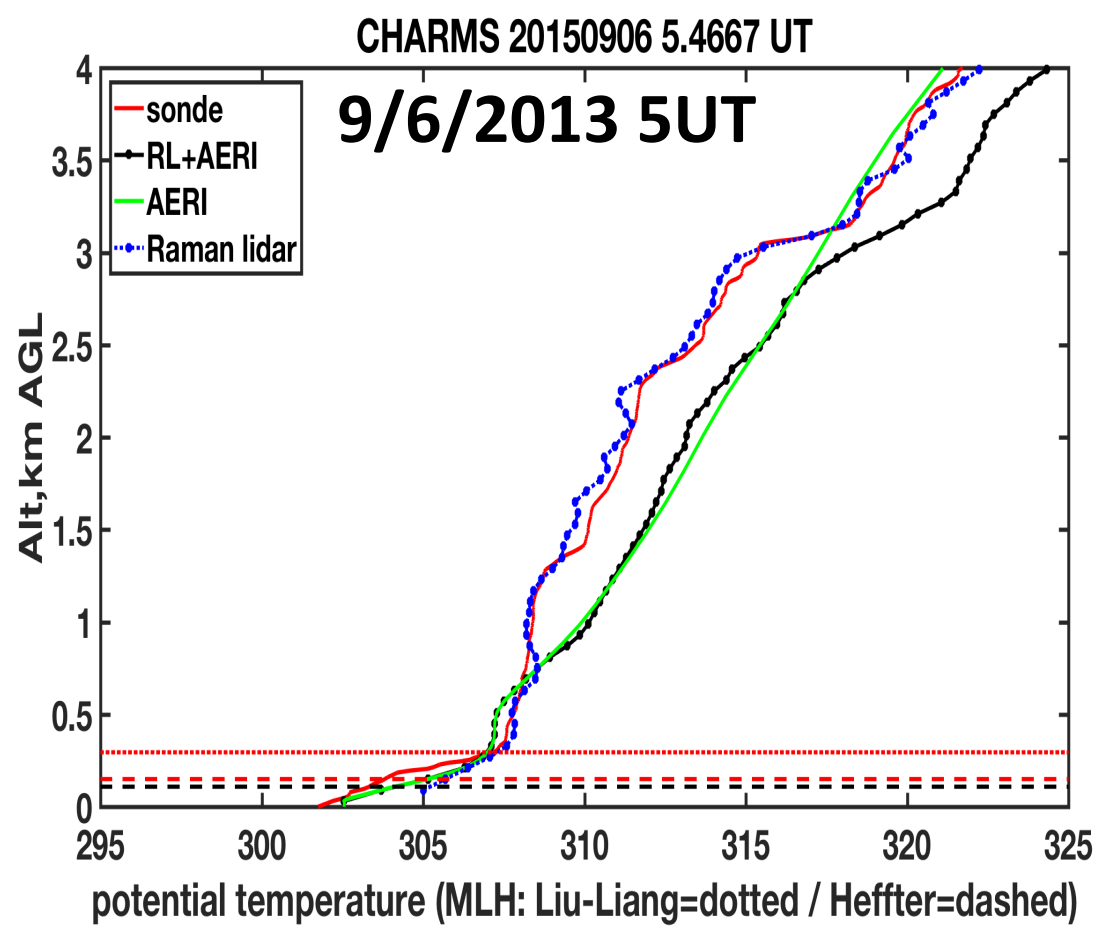


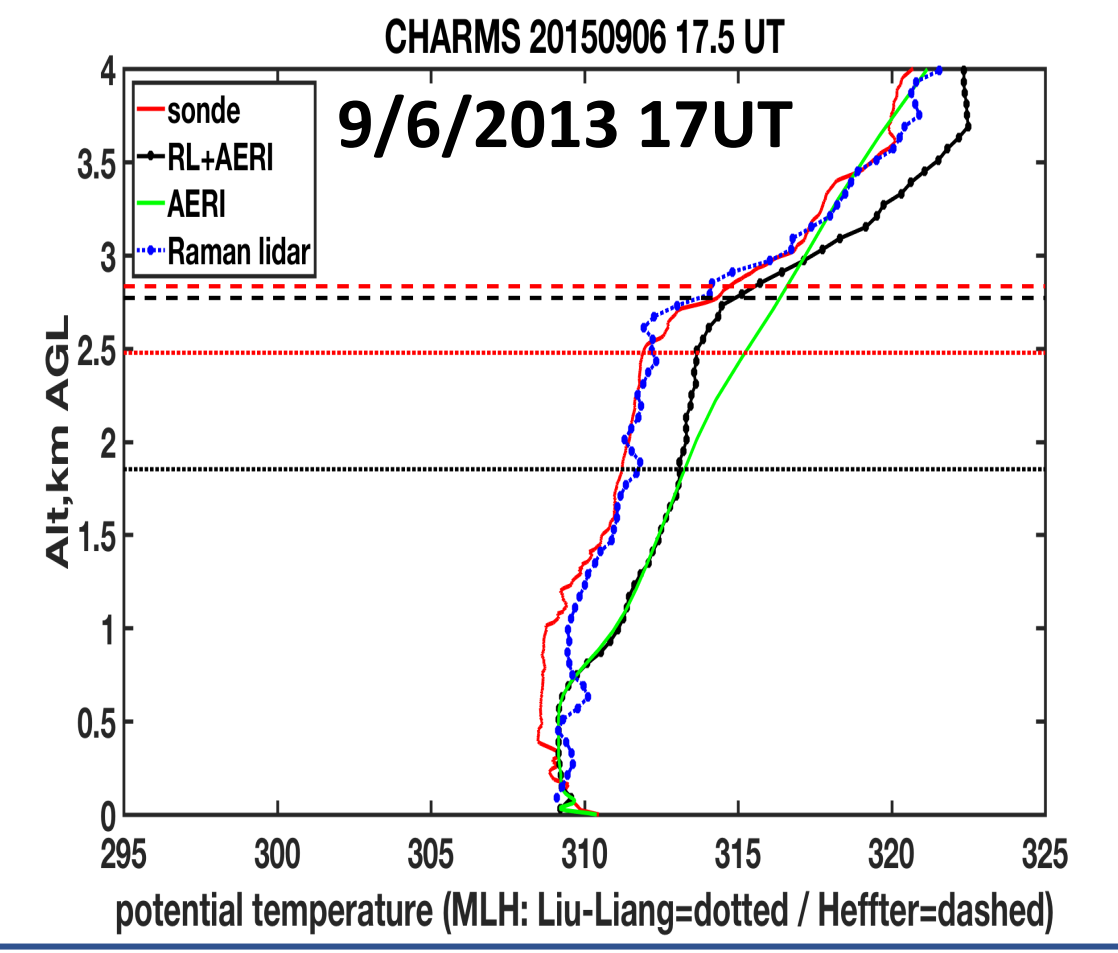
Method 3

- Potential Temperature (RL, AERI)
  - ML heights were derived from potential temperature profiles derived from a combination of AERI+RL temperature profiles. AERI temperature profiles are used below about 1 km and RL temperature profiles are used above 1 km. This takes advantage of better AERI performance near the surface and the higher resolution RL profiles farther away from the surface. ML heights are derived using two techniques:
  - 1) **Heffter** technique (Heffter, 1980; Della Monache et al., 2004) seeks the lowest height where the potential temperature lapse rate exceeds 5°K/km and the inversion strength exceeds 2 K.
  - 2) **Liu-Liang** technique (Liu and Liang 2010) uses potential temperature differences and gradients, somewhat similar to the Heffter technique, for convective and neutral layers. For stable layers, the ML is the top of the lowest stable layer or the level of the low level jet.









Method 4

The bulk Richardson number (Ri_b) represents the ratio of thermally produced turbulence to mechanically produced turbulence. ML heights were derived at the height at where ($Ri_b > 0.5$). Ri_b is computed using RL+AERI potential temperature profiles, RL water vapor mixing ratio profiles, and DL wind profiles