Daytime boundary layer heights at Tonopah, Nevada, from M2HATS

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Objective:

To determine the daily 3 PM boundary layer height over Tonopah, NV, for the Multipoint MOST Horizontal Array Turbulence Study (M2HATS) (23 July - 22 September, 2023). The height of the capping inversion, z_i, is needed as a scaling variable for surface layer turbulence statistics. Boundary layer height may be identified by:

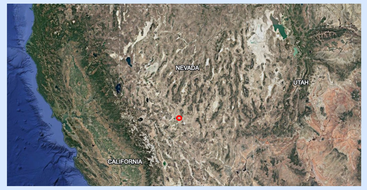
- The slope of virtual potential temperature indicates the static stability which allows or suppresses vertical mixing.
- The actual mixing is indicated in measurements of the velocity variance.
- Tracers such as aerosol scattering may show the history of recent mixing.
- Bragg scattering peaks in the entrainment zone.

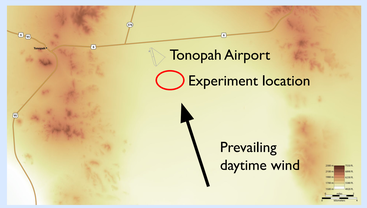
Our objective is not to evaluate the reliability or quality of any particular instrument or method for determining boundary layer depth. Instead, it is to provide the best possible assessment of mixing height given the multiple observing systems available. We limited our work to 3 PM each day because that is when the second of two daily radiosonde soundings were made and likely to be the time when the depth was near maximum.

Location:

The site was located in a broad and almost flat valley, approximately 16 km wide and 20 km in the direction of the prevailing daytime southerly flow. Mountains to the east and west of the valley have ridgeline elevations ranging from approximately 1800 to 2000 m ASL.

The M2HATS experiment took place about 1 km south of the Tonopah, NV, public airport at an elevation of 1655 m ASL. Other observations and modeling studies (such as Ayazpour et al. 2023) show that western Nevada often has some of the deepest planetary boundary layers in the continental United States.





Methods:

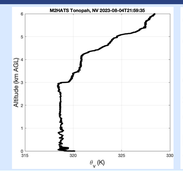
We used data from five observing systems to determine the daytime boundary layer depth including:

1. Radiosondes: Vaisala MW41 / RS4
   a. Identification of the base of the capping inversion in the virtual potential temperature profile
2. NCAR Micropulse DIAL (Spuler et al. 2021)
   a. Identification of the top edge of aerosol scattering in the 770 nm aerosol backscatter profiles (Colberg et al. 2022)
   b. Identification of the base of the capping inversion in virtual potential temperature profiles (using remotely sensed water vapor and temperature)(Hayman et al. 2024)
3. Vertically pointing Doppler lidar
   a. Identification of the top edge of vertical velocity variance field from a vertical staring system (Tucker et al. 2009, Schween et al. 2014)
4. 449 MHz Radar wind profiler
   a. Identification of the maximum in Bragg scattering profiles (Angevine et al. 1994)
5. 915 MHz Radar wind profiler
   a. Identification of the maximum in Bragg scattering profiles (Angevine et al. 1994)

Ideal example: August 4

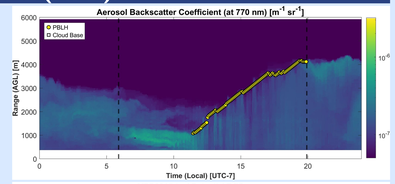
Textbook convective boundary layers (CBLs) feature a sharp capping lid that is easy to identity in data from most observing systems. Of the 64 official days of the experiment, August 4, is a good example of a textbook day. Shown below are 6 ways:

Radiosonde:

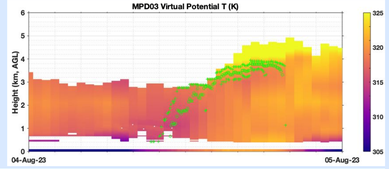


CBL height from radiosonde data can be determined by identifying the base of the capping inversion where θ_v sharply increases. Most of the CBL is neutral, except for perhaps the surface layer where it is unstable.

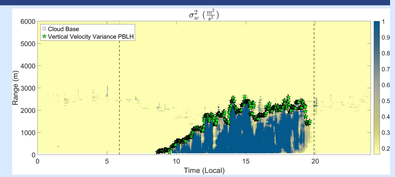
NCAR Micropulse DIAL (MPD):



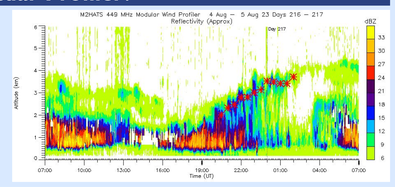
The MPD (above) measures calibrated aerosol backscatter, water vapor, and temperature profiles. Water vapor and temperature are used to calculate virtual potential temperature (right).



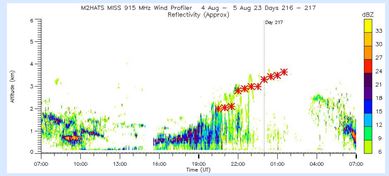
Doppler lidar:



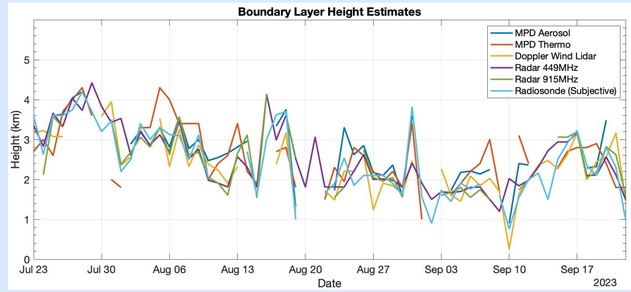
449 MHz Doppler Radar Profiler:

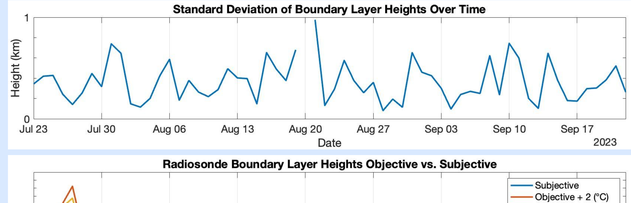


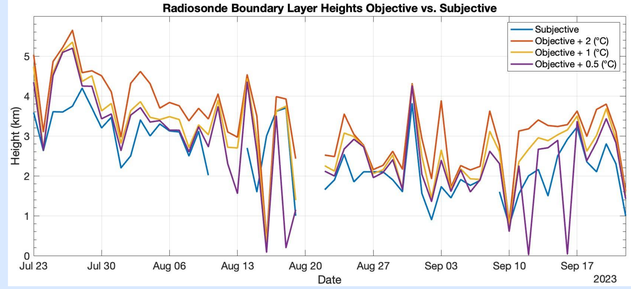
915 MHz Doppler Radar Profiler:

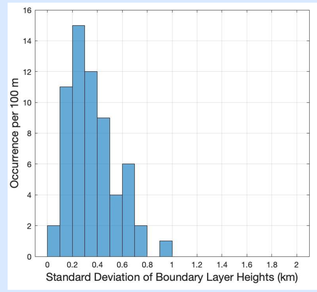


Results:

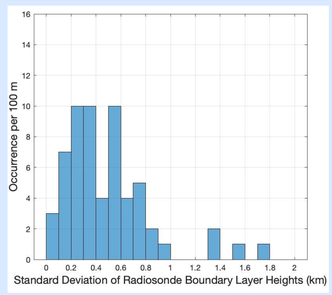








Left: Standard deviation of up to 6 measures of boundary layer height for each day.
Above: Number distribution of the standard deviations for the 62 day experiment.



Conclusions:

We used 5 different instruments and 7 different methods to measure boundary layer height. Each method has strengths and weaknesses and measures a different attribute of the vertical dimension of the boundary layer. Our results show these differences.

References:

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