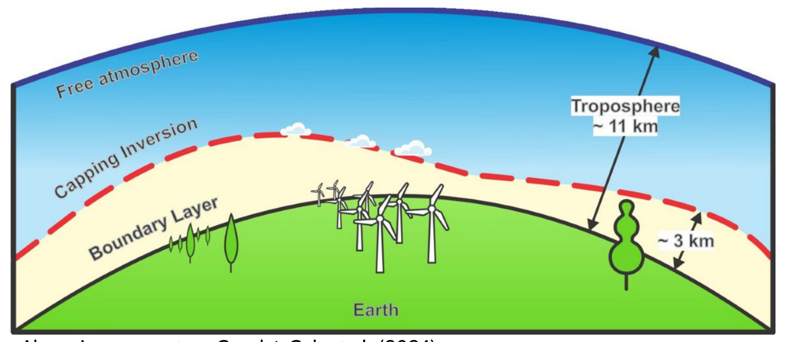

Above image courtesy Canché-Cab et al. (2024).

Daytime Boundary Layer Heights, Tonopah, Nevada from M²HATS

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Objective:

To determine the daily 10 AM and 3 PM boundary layer height (BLH) 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:

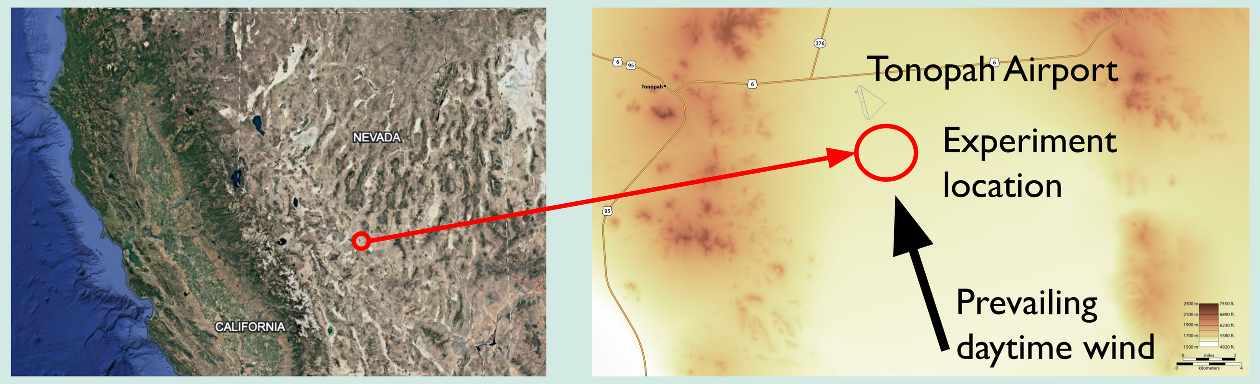
- Slopes in virtual potential temperature (static stability and mixing potential)
- Vertical velocity variance (actual mixing)
- Aerosol backscatter (recent mixing history)
- Bragg scattering peaks (entrainment zone detection)

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 10 AM and 3 PM each day because that is when the two daily radiosonde soundings were made.

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 height including:

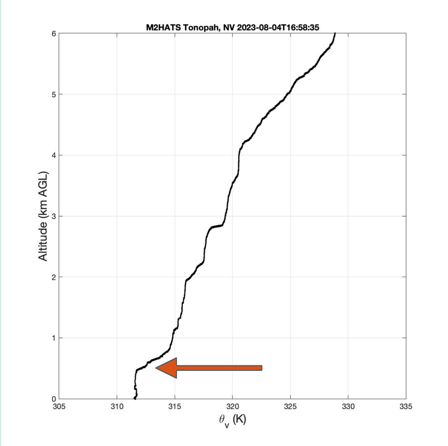
1. Radiosondes: Vaisala MW41 / RS4
   a. Identification of the base of the capping inversion in the virtual potential temperature profile
2. NCAR Micropulse DIAL (Spuler et al. 2021)
   a. Identification of the top edge of aerosol scattering in the 770 nm aerosol backscatter profiles (Colberg et al. 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)

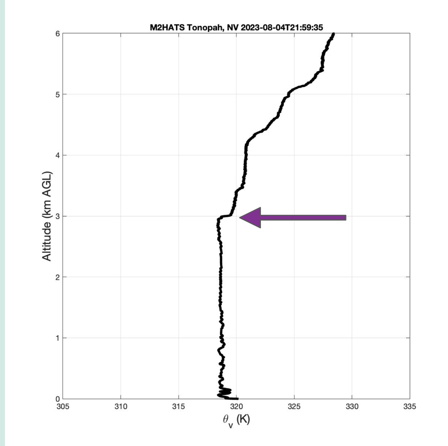
Example Day: August 4

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 we can identify CBL height:

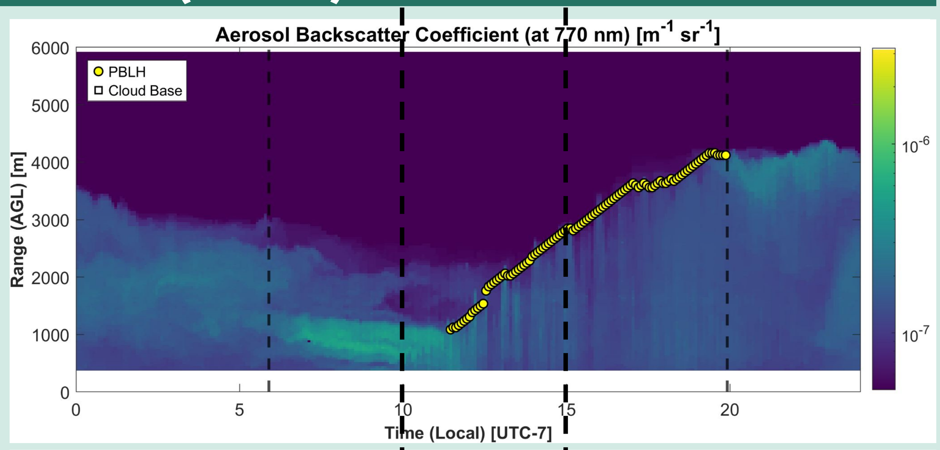
Radiosonde:

17 UTC (10 AM PDT) | 22 UTC (3 PM PDT)

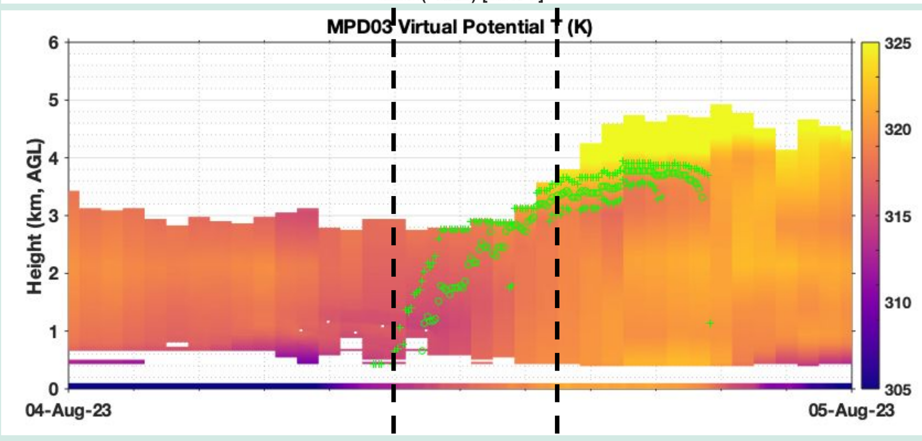




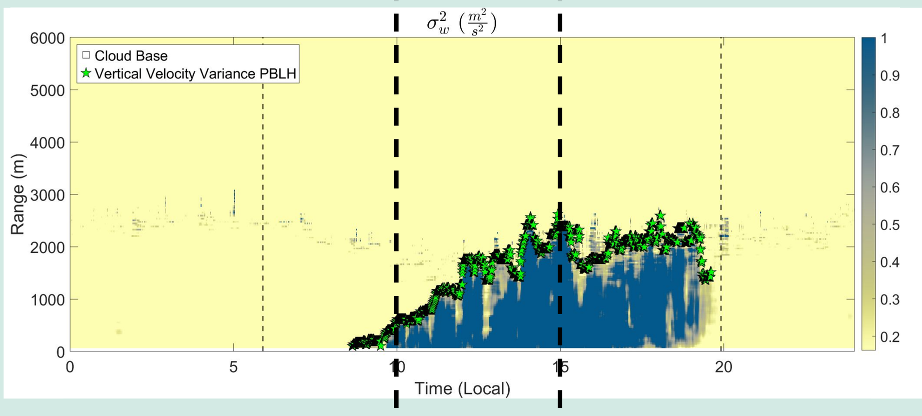
NCAR Micropulse DIAL (MPD):



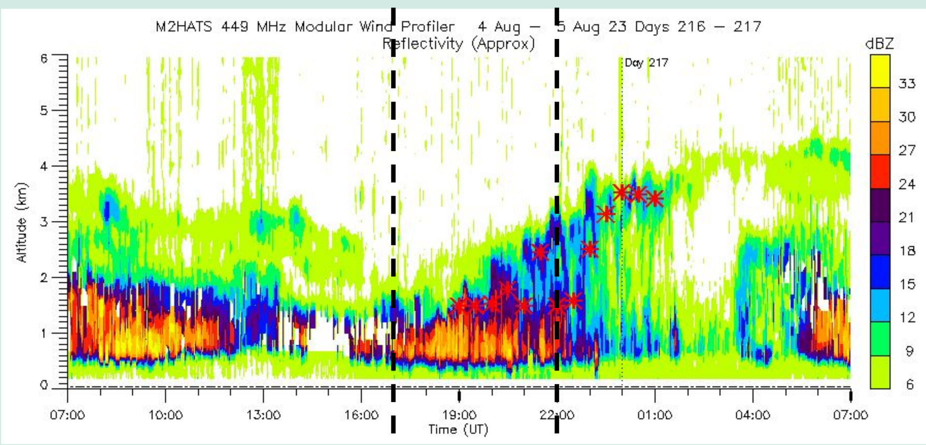
The MPD (above) measures calibrated aerosol backscatter, water vapor, and temperature profiles. Water vapor and temperature are used to calculate virtual potential temperature (right).



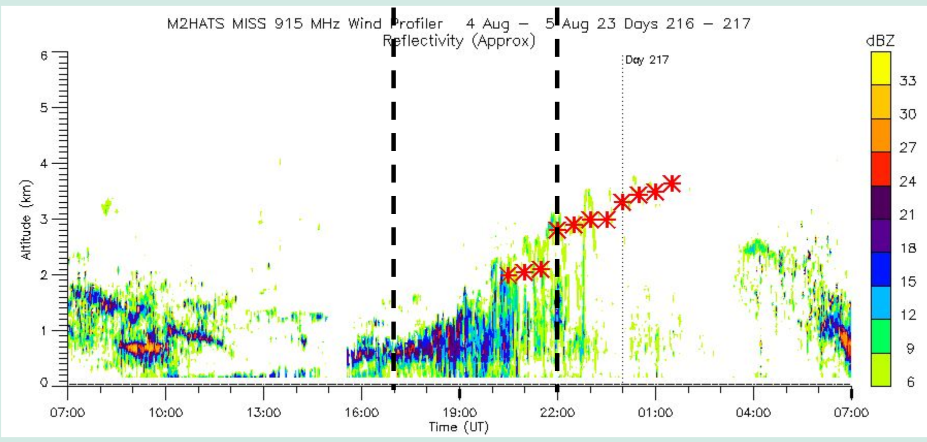
Doppler lidar:

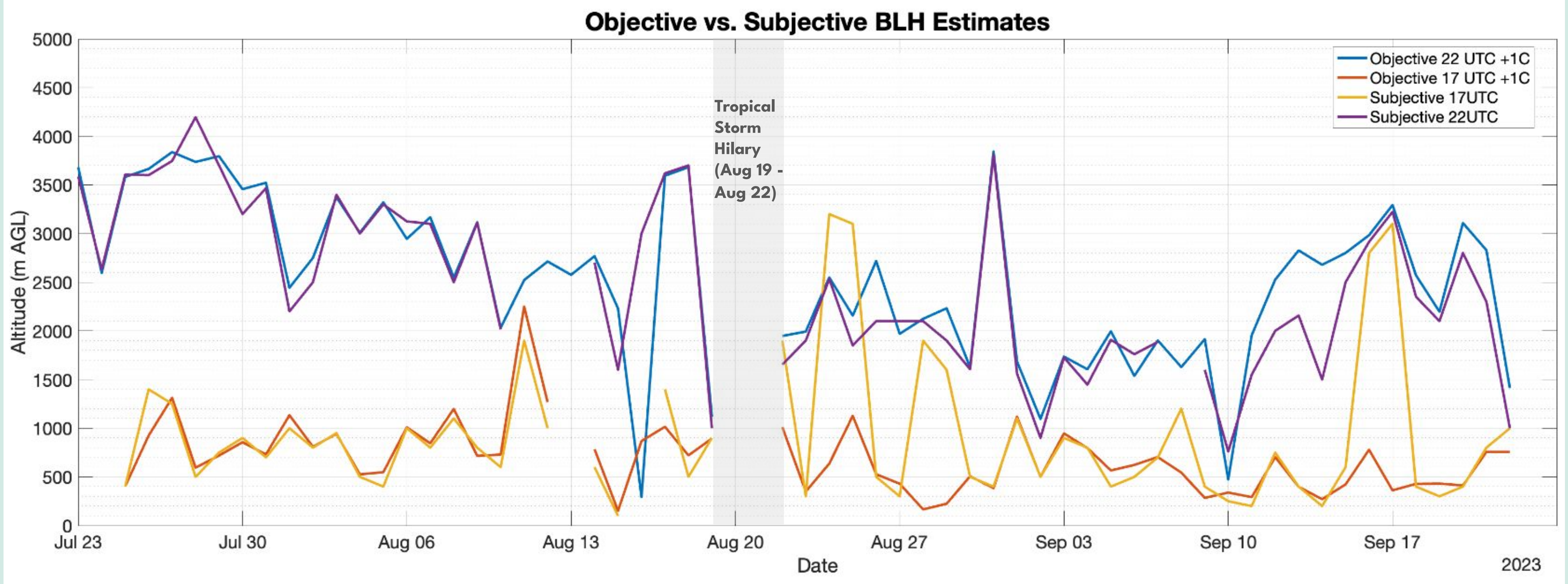


449 MHz Doppler Radar Profiler:

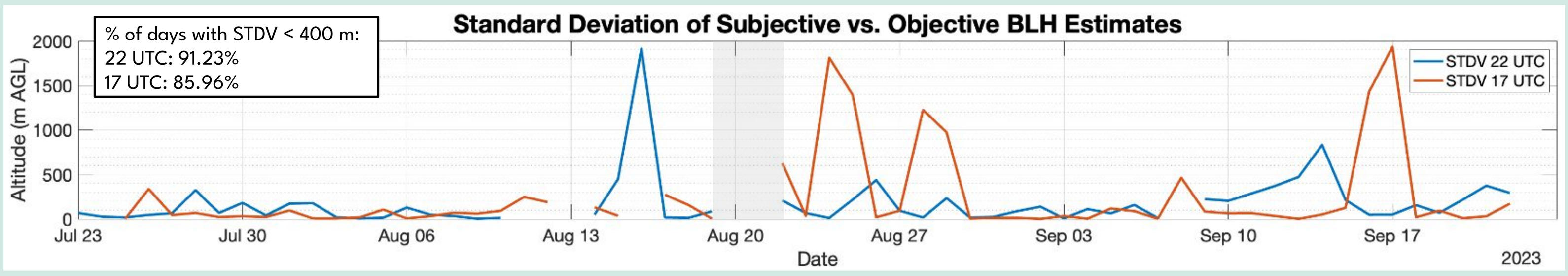


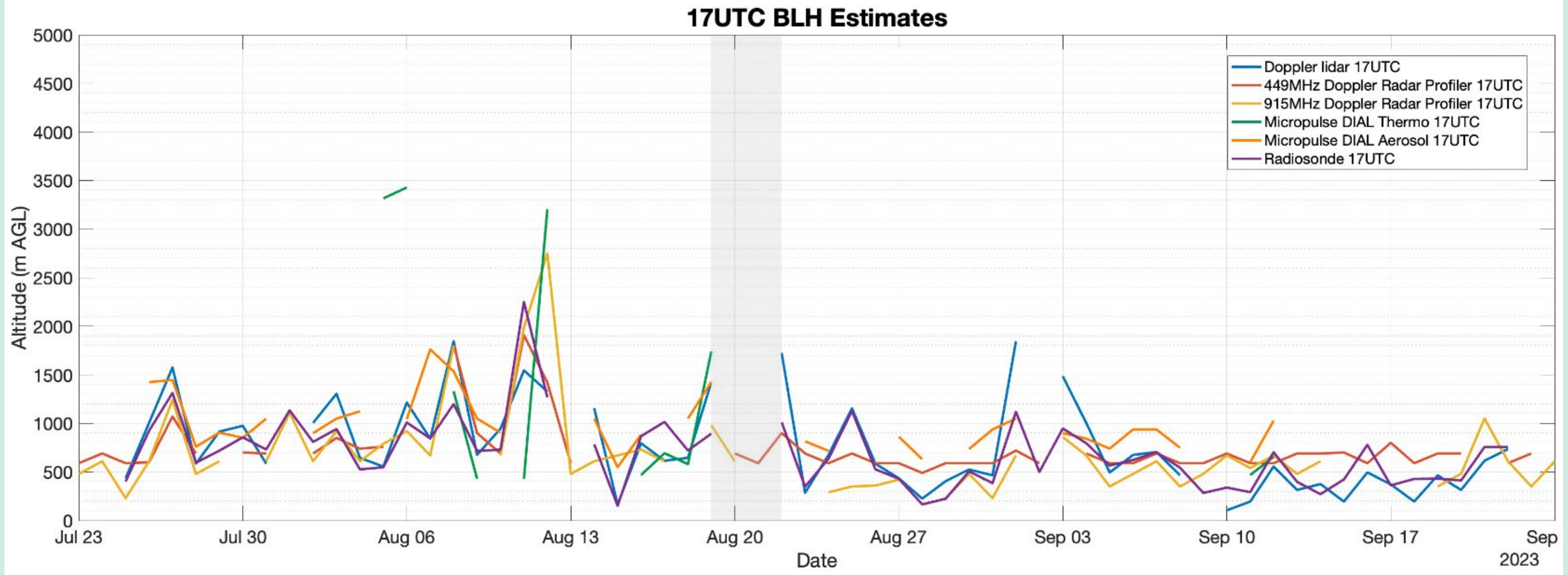
915 MHz Doppler Radar Profiler:



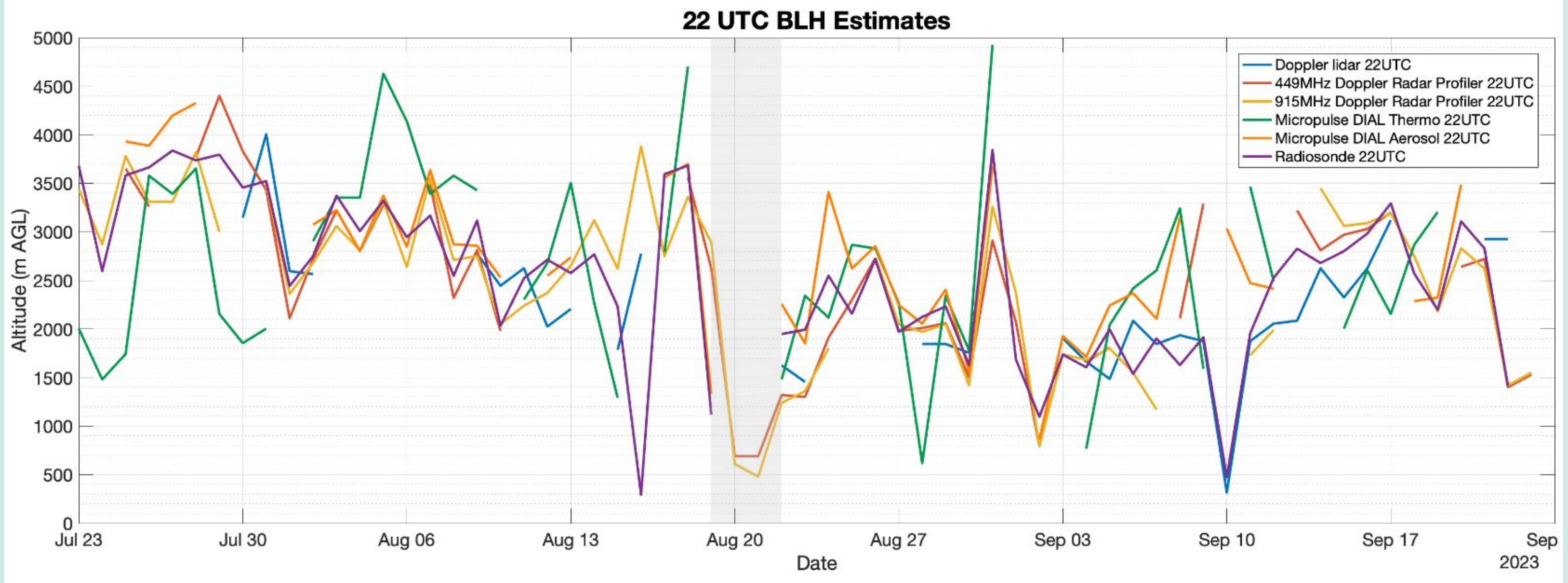


A Matlab program was developed to objectively determine radiosonde BLH for 17 and 22 UTC. The program analyzes each virtual potential temperature profile to find the minimum temperature (K), then identifies where the plot exceeds that temperature by 1˚C and marks the corresponding altitude (m). The choice of a +1˚C increase was made after evaluating 0.5-degree temperature increases between 0.5˚C and 3˚C and comparing them with subjective BLH findings.

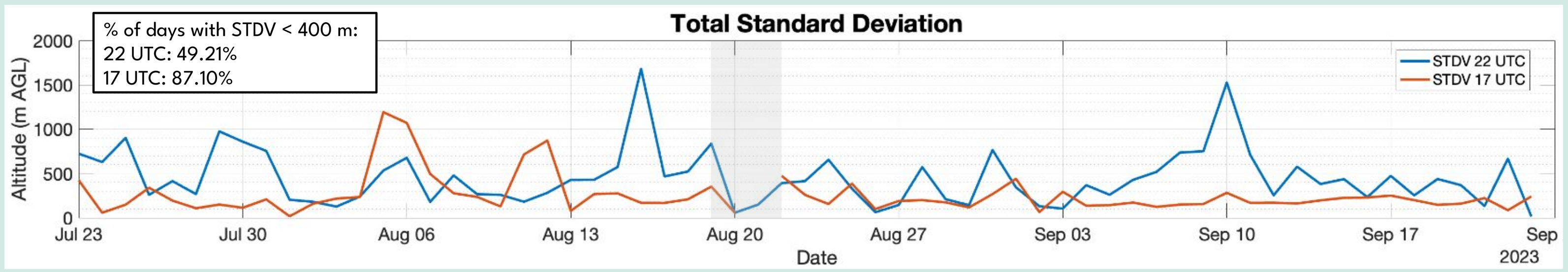


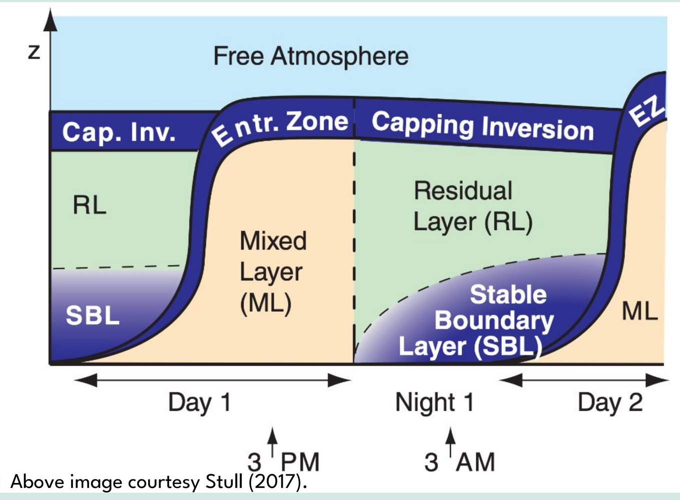


17 UTC BLH estimates averaged 781.5 [762.2 , 800.9] m AGL. The mean height of the CBL at 10 AM local is relatively shallow at this time because it has not had time to grow through surface sensible heat flux.



22 UTC BLH estimates averaged 2529.5 [2496.1 , 2562.9] m AGL. The BLH is very deep due to multiple factors including solar heating of the surface throughout the day.





Above image courtesy Stull (2017).

Conclusions:

We employed five distinct observing systems and utilized seven different analysis methods to measure the boundary layer height every morning and afternoon during the experiment. The measurements tend to agree more at the 10 AM hour than the 3 PM hour. Each method has strengths and weaknesses and measures a different attribute of the vertical dimension of the boundary layer.

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