A43A-0228: Daily Evolution of Boundary Layer Properties based on NASA DISCOVER-AQ Airborne Profiles over the California San Joaquin Valley

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Introduction and Overview of D-AQ CA

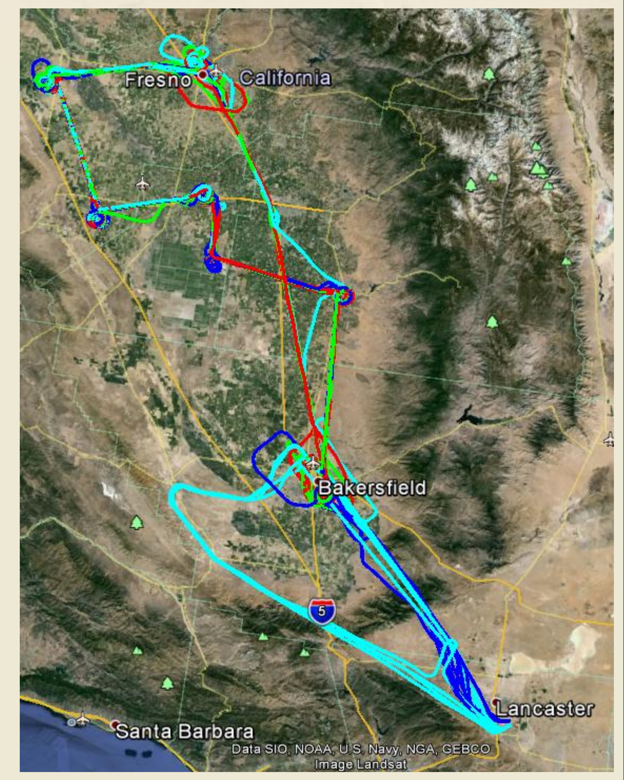
The DISCOVER-AQ (Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality) mission conducted its second field deployment in the California San Joaquin Valley region during January and February 2013. The mission's overarching goal is to better understand how remotely-sensed column measurements can be used to diagnose near-surface air quality. To achieve this objective, the DISCOVER-AQ sampling strategy requires extensive probing of the vertical structure of the lower troposphere as it relates to both trace gases and aerosols. This strategy was implemented by using the NASA P-3B aircraft to perform three circuits of spirals from 0.3 to ~3 km over 6 air quality monitoring ground sites at three different times of the day (mid-morning, midday, and mid-afternoon local time). In addition, missed approach maneuvers were performed at 7 airports along the flight path (5 of which were located near profile sites), which provided profile data from as low as 25 m up through the 0.3 km bottom limit of the spirals. A total of 170 spirals and 157 missed approaches were flown, which generated detailed vertical distributions for a large variety of trace gases, aerosol properties, and meteorological variables.

Goals of this poster:

- Identify evolution of the height of the boundary layer (BLHT) from day to day across the campaign
- Evaluate variability and trends in boundary layer concentrations and vertical gradients of trace gas concentrations and aerosol parameters

Site	Co-located Missed Approach Sites	Profiles Performed	Missed Approaches Performed
Bakersfield	2	28	38
Porterville	1	29	23
Hanford	1	28	20
Huron	0	28	0
Tranquility	0	29	0
Fresno	1	28	29
Total	5	170	110

Breakdown of profiles and missed approaches by site location. The 170 profiles performed were split evenly among the 6 sites. Of the 157 missed approaches performed along the nominal flight path, 110 were at airports in the vicinity of a profile spiral.



Example daily flight track showing the path of the P-3B and the repeated spirals at each of the six profile sites. The aircraft flew from Bakersfield to Porterville and continued around the circuit clockwise back to Bakersfield. Each flight day usually included three such circuits.

Summary and Future Directions

Conclusions:

- In addition to boundary layer heights increasing throughout the day, afternoon boundary layer heights were also higher in the second half of the campaign than they were in the first half.
- For many constituents, profile fluctuations (i.e. BL standard deviation-to-average ratio) decreased throughout the day, probably due to increased mixing and decreased stability in the BL.
- Only H_2O and aerosol scattering appeared to have a consistent non-zero vertical gradient. CO_2 consistently had zero vertical gradient, and the other constituents had too much variability to define a consistent gradient. However, for all other parameters besides O_3, median trends were usually negative, and by the afternoon almost 75% of trends were negative. These results suggest that the BL was not always well-mixed.

Future Investigations:

- Incorporate balloon-borne measurements from Huron and Porterville to refine current BLHTs and potentially to help identify additional BLHTs at those sites
- Find the cause of the higher afternoon boundary layer heights later in the campaign, possibly through back-trajectory analysis, and analyze its effects on BL concentrations
- Evaluate any trends in boundary layer height or vertical gradients among the six profile sites

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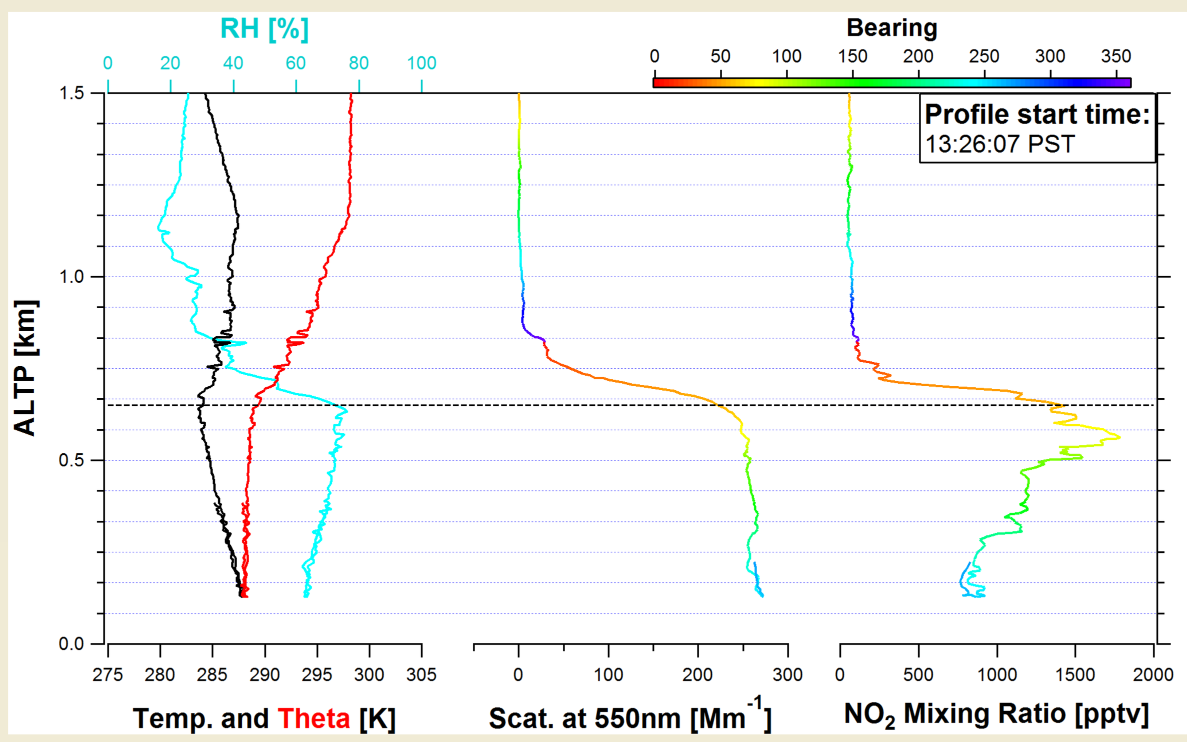
Identification of BLHTs

- BLHT assessment was based on the P-3B aircraft observations, primarily of meteorological parameters
- Primary criteria for BLHT identification include a sharp change from constant to increasing potential temperature (i.e. theta) with increasing height and a distinct trend change in temperature and relative humidity vertical profiles.
- If necessary, BLHTs were refined using vertical profiles of trace gas concentrations and aerosol properties



A vertical profile with a clear BLHT, indicated by the horizontal dashed black line. The profiles of temperature, theta, and relative humidity all have sharp changes at 0.675 km. Profiles of other parameters, such as scattering and NO_2, also had clear transitions at this altitude.

For some profiles, the BLHT could not be identified. These cases usually had one of three problems:

- Suspected BLHT was near or below the bottom of the profile
- Suspected BLHT was between the bottom of a spiral and the top of a missed approach
- Aircraft was not able to complete a spiral due to visibility issues

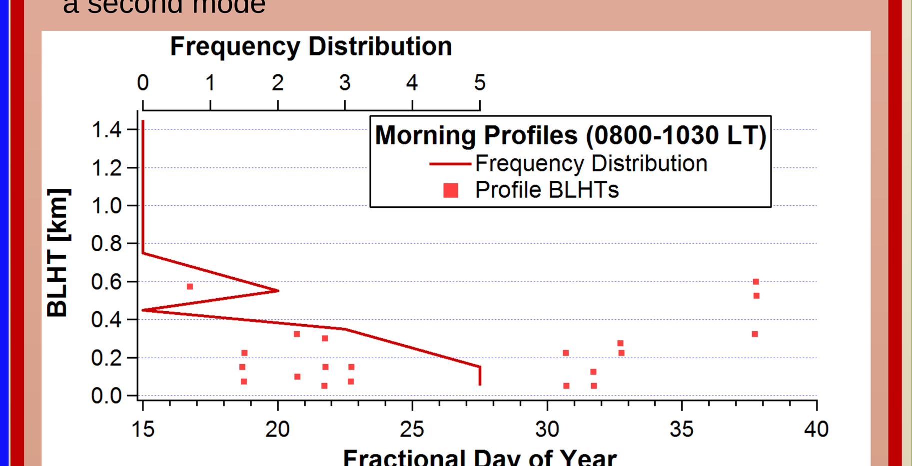
These issues happened most frequently on the first circuit of the day (in the morning when BLHTs are very low) and on the last two days of the mission (when fog or low cloud decks were present). Profiles where the BLHT was not identified were removed from further analysis. In total, 119 of the 170 profiles had clear BLHTs.

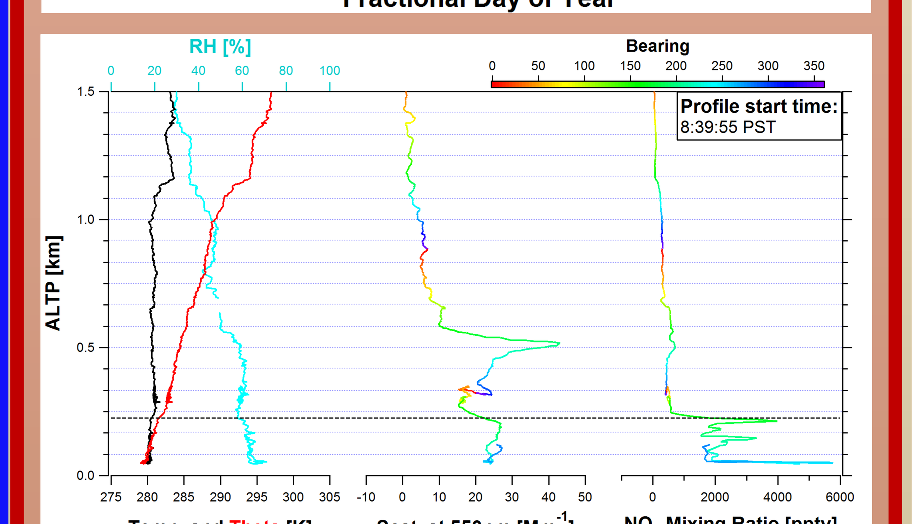
BLHT Evolution across the Campaign

To more clearly identify trends in BLHT from day to day across the campaign, profiles were separated by starting time into three groups: 0800-1030, 1030-1300, and 1300-1600 PST. These times loosely correspond to the start and end times of the three circuits. The distributions of the BLHTs in these time intervals were then analyzed. The distributions and time series of the BLHTs for each interval is shown below, along with an example profile from that interval. Constituent vertical profiles are colored by bearing from center of spiral.

Morning Profiles (0800-1030 LT)

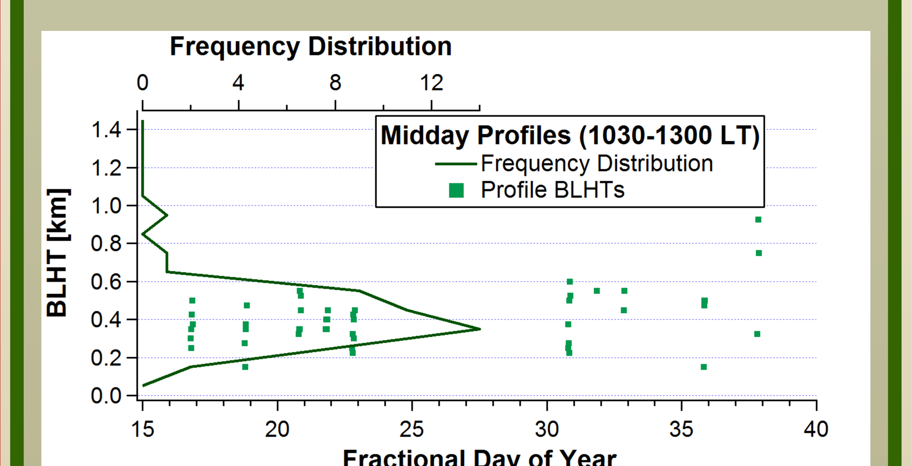
- Morning BLHTs were consistently low (about 0.35 km or less)
- Aircraft was often unable to get low enough to see a clear transition into the boundary layer; only 20 of 61 morning profiles had clear BLHTs
- Not enough sample points to know if high outliers were part of a second mode

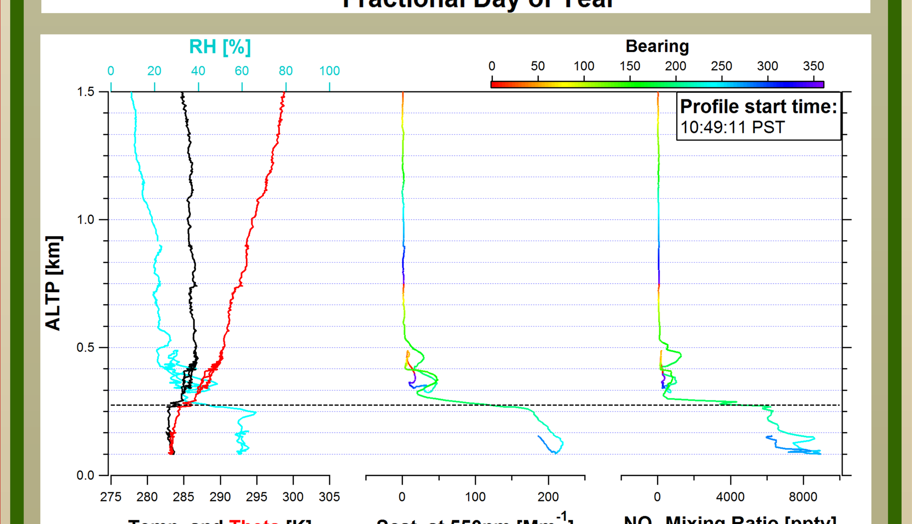




Midday Profiles (1030-1300 LT)

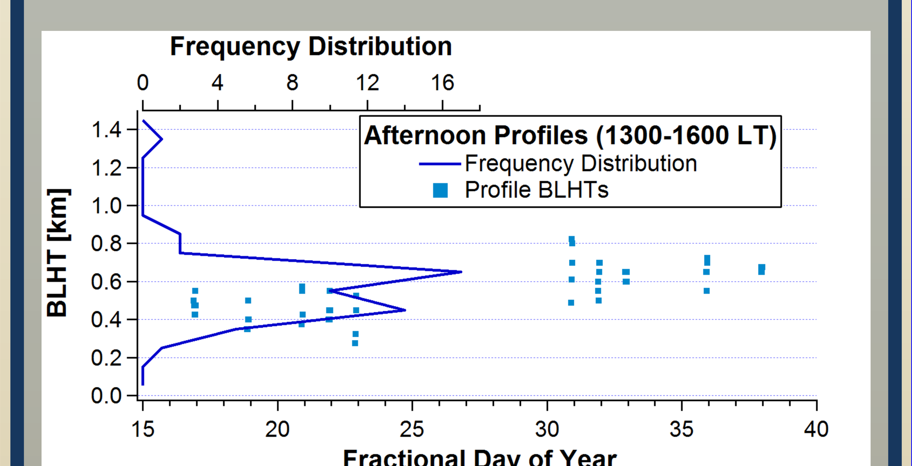
- Midday BLHTs were consistently between 0.2 and 0.6 km
- 47 of 53 midday profiles had clear BLHTs

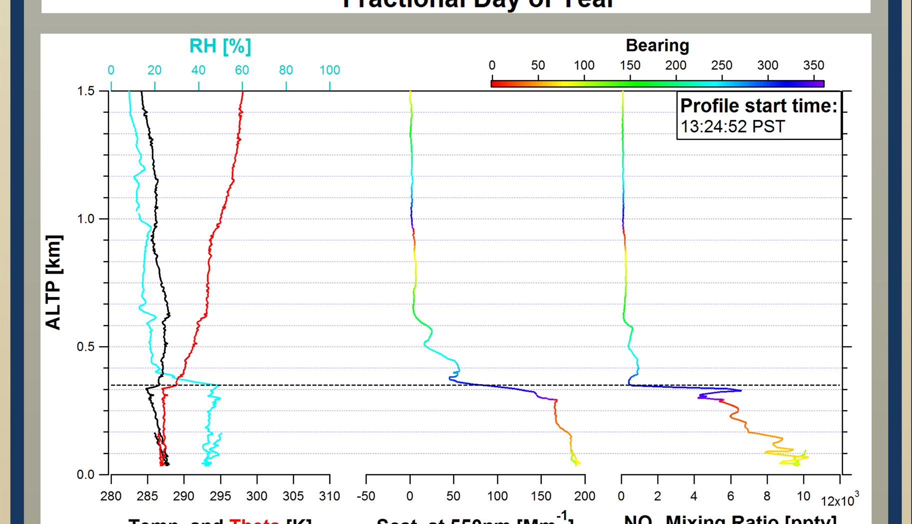




Afternoon Profiles (1300-1600 LT)

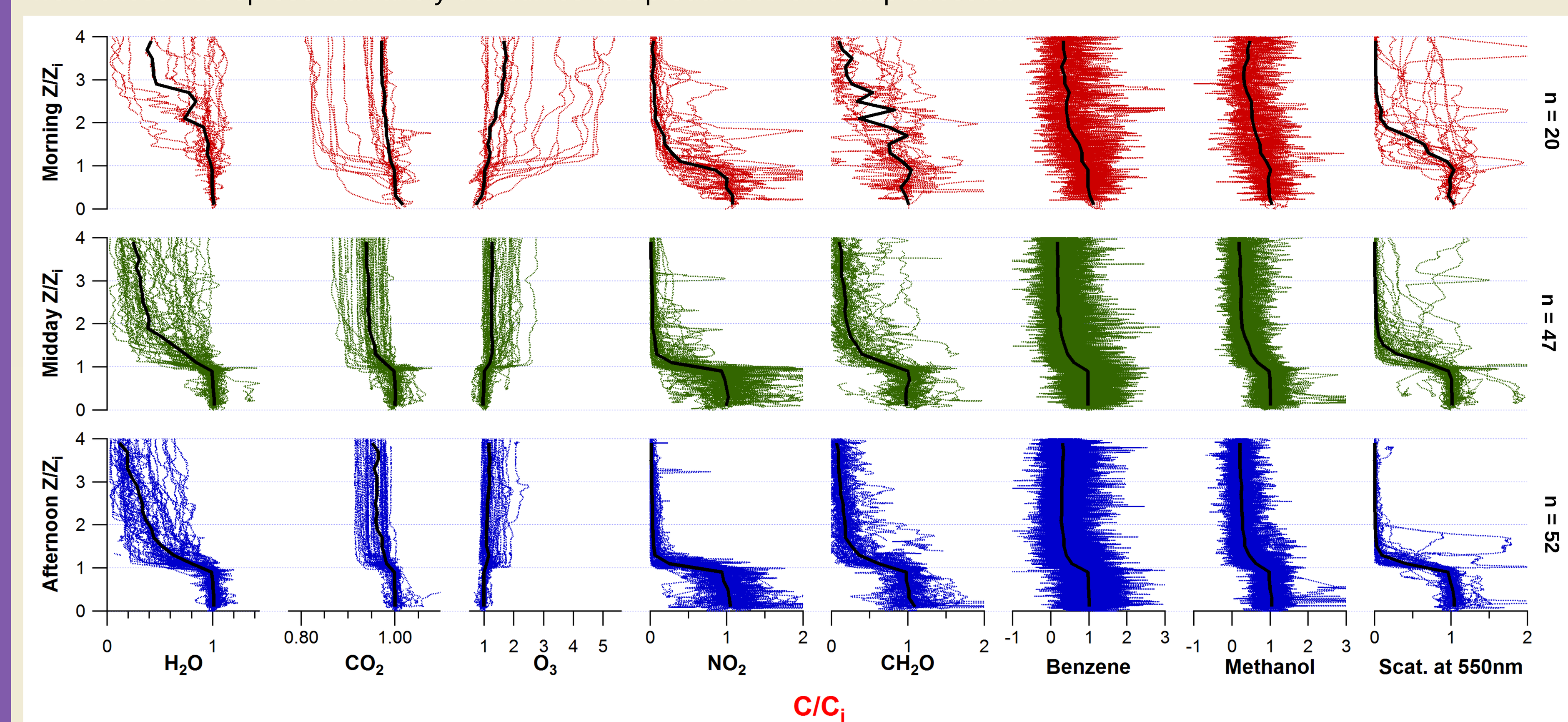
- Afternoon profile BLHTs seem to be bimodal
  - First half of the campaign: BLHTs from 0.3 to 0.6 km
  - Second half of the campaign: BLHTs from 0.5 to 0.7 km
- 52 of 56 afternoon profiles had clear BLHTs



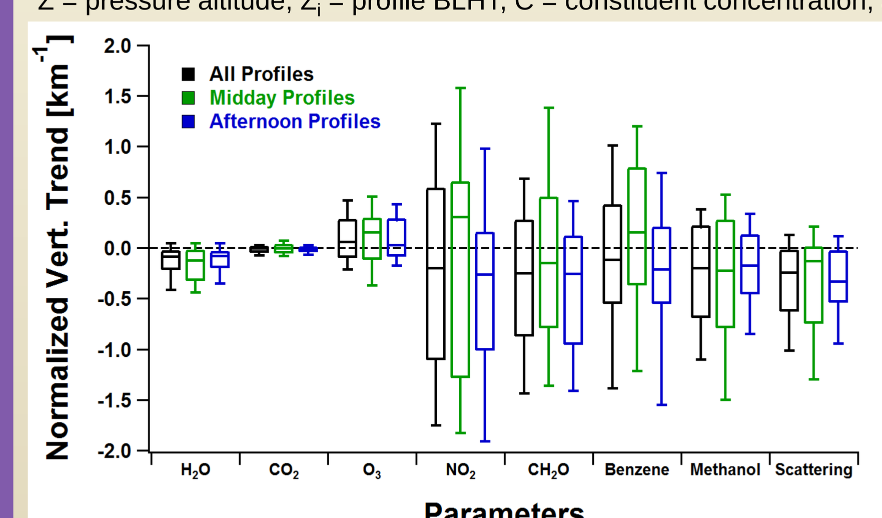


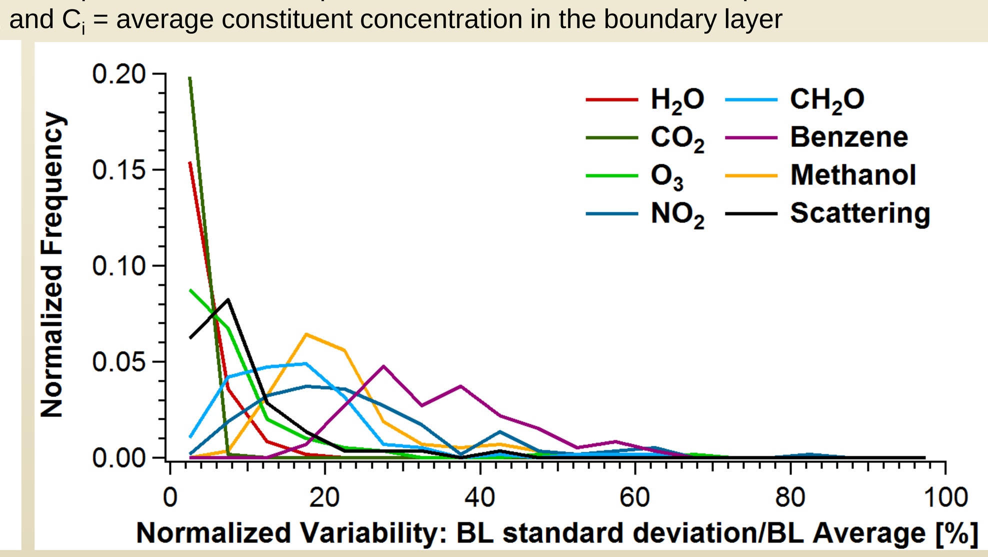
Variability and Trends of BL Concentrations and Vertical Gradients

To visualize BL variability and vertical gradients, composite profiles for eight different constituents were created. Constituents were chosen to represent a variety of lifetimes and production/removal processes.



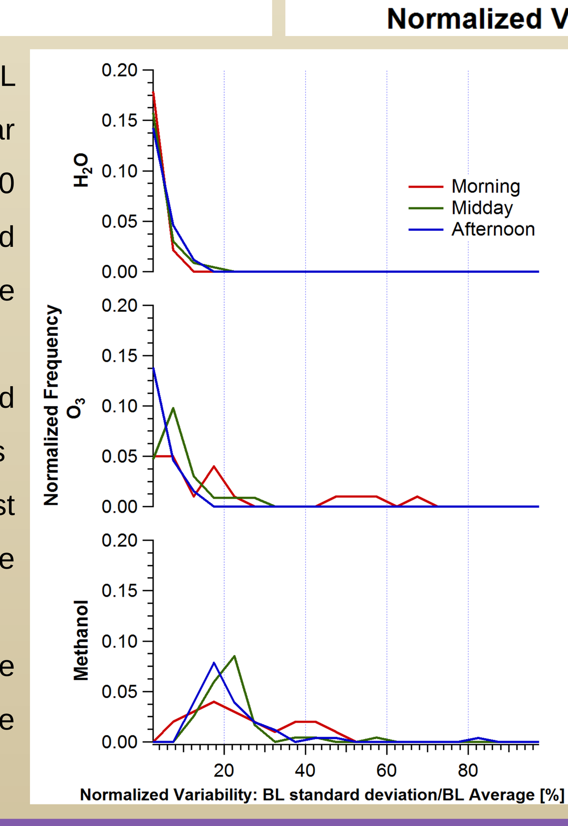
Composite profiles of different constituents scaled by the profile BLHT and the average concentration of the constituent within the boundary layer. The dotted, colored lines represent individual profiles, and the solid black lines represent the median profile for that constituent and time period. Z = pressure altitude, Z_i = profile BLHT, C = constituent concentration, and C_i = average constituent concentration in the boundary layer





The vertical trend of constituents in the BL was calculated by performing linear regression on profiles with at least 100 seconds of sampling within the BL and normalizing the subsequent slopes by the constituent BL average.

- Longer-lived constituents generally had shallower and less variable vertical trends
- Slope variability decreased in almost every case from the midday to the afternoon profiles
- Note that only one morning profile had the required BL sampling time, so separate morning profiles are not shown



To assess BL variability, the ratio of the BL standard deviation to the BL average of each profile and constituent was calculated. Shown are the normalized distributions for all constituents and profiles (above) and for select constituents separated into time intervals (left).

- H_2O, CO_2, benzene, and scattering show little decrease in variability throughout the day
- O_3 variability decreases throughout the day
- Methanol and CH_2O see most of their decrease in variability by midday, while NO_2 variability decreases between midday and afternoon