Variations of Ozone in the Atmospheric Boundary Layer

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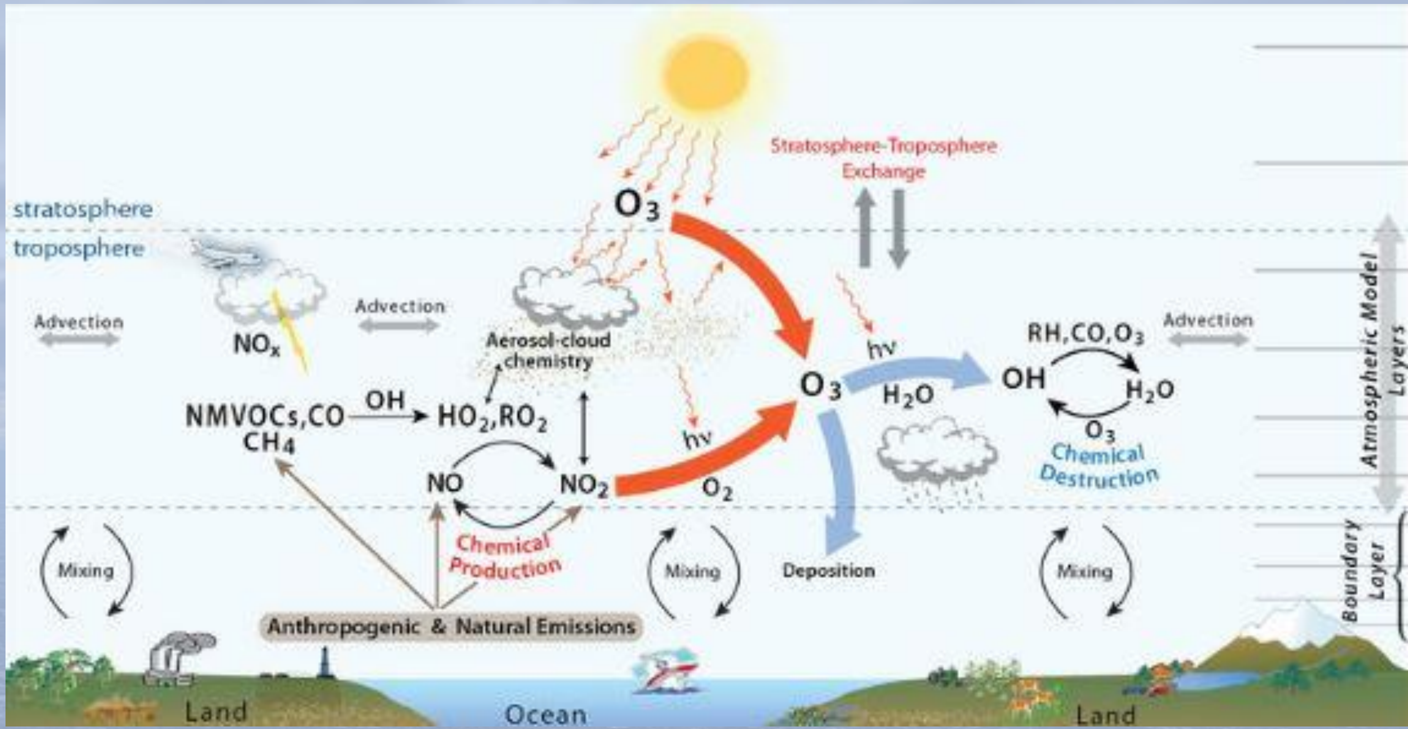
METEO 455

Benjamin Yang

Introduction

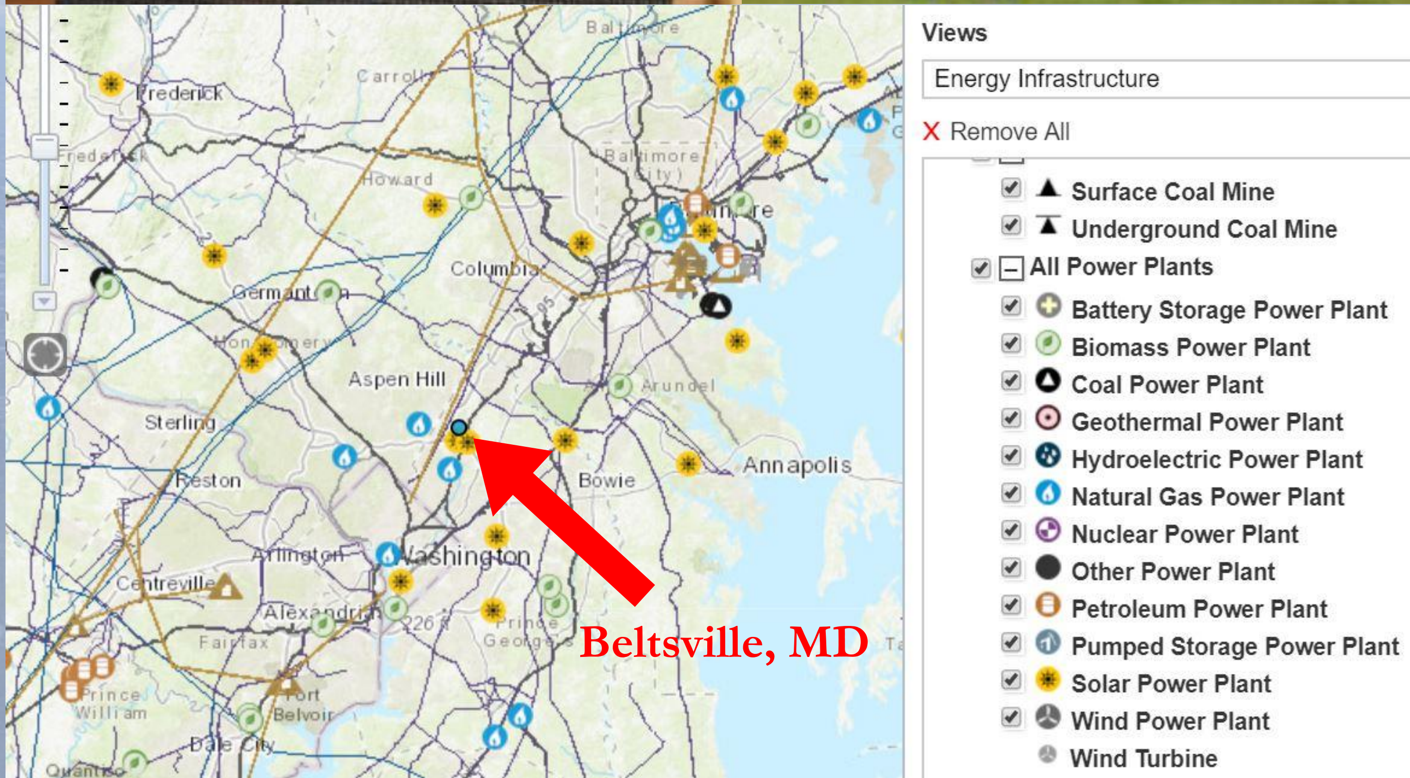
- Tropospheric ozone is an air pollutant and greenhouse gas
- Main factors:
  - Horizonal advection
  - Emission rates
  - Chemical reaction rates
  - Deposition rates
  - Vertical transport



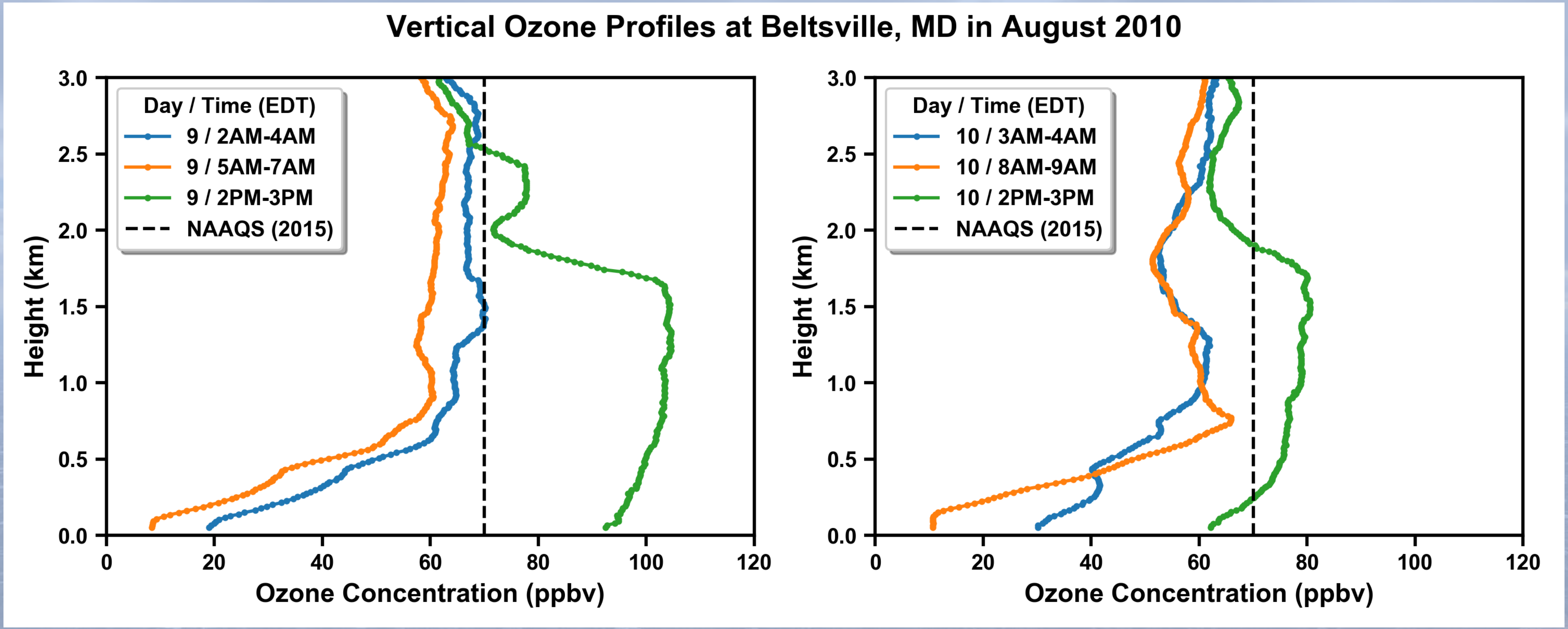
- Improvement in the simulation of nocturnal atmospheric boundary layer (ABL) processes is still needed
- **<u>Objective</u>** is to investigate how/why ozone levels in the ABL vary with height and time of day

Methods

- Used ozone sonde measurements from a summer 2010 field campaign conducted in Beltsville, MD
- Focused on Aug. 9-10 because of elevated ozone levels
- Relied on established methods – creating vertical profiles of variables in the ABL:
  - Ozone concentration
  - Air temperature
  - Virtual potential temperature
  - Wind speed & direction
  - Dry deposition velocity

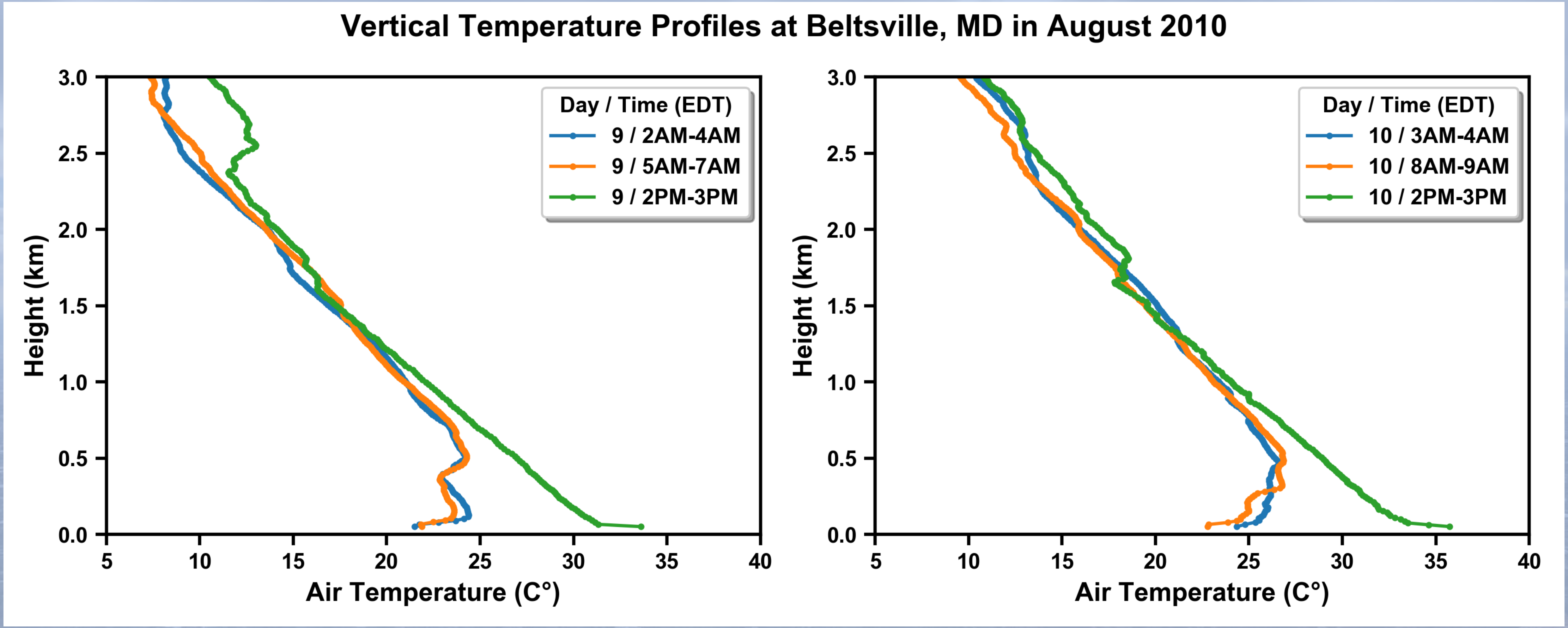


Results



- Ozone levels increase throughout the day; decrease overnight
- Diurnal variations are greatest near ground level; smallest above ABL top

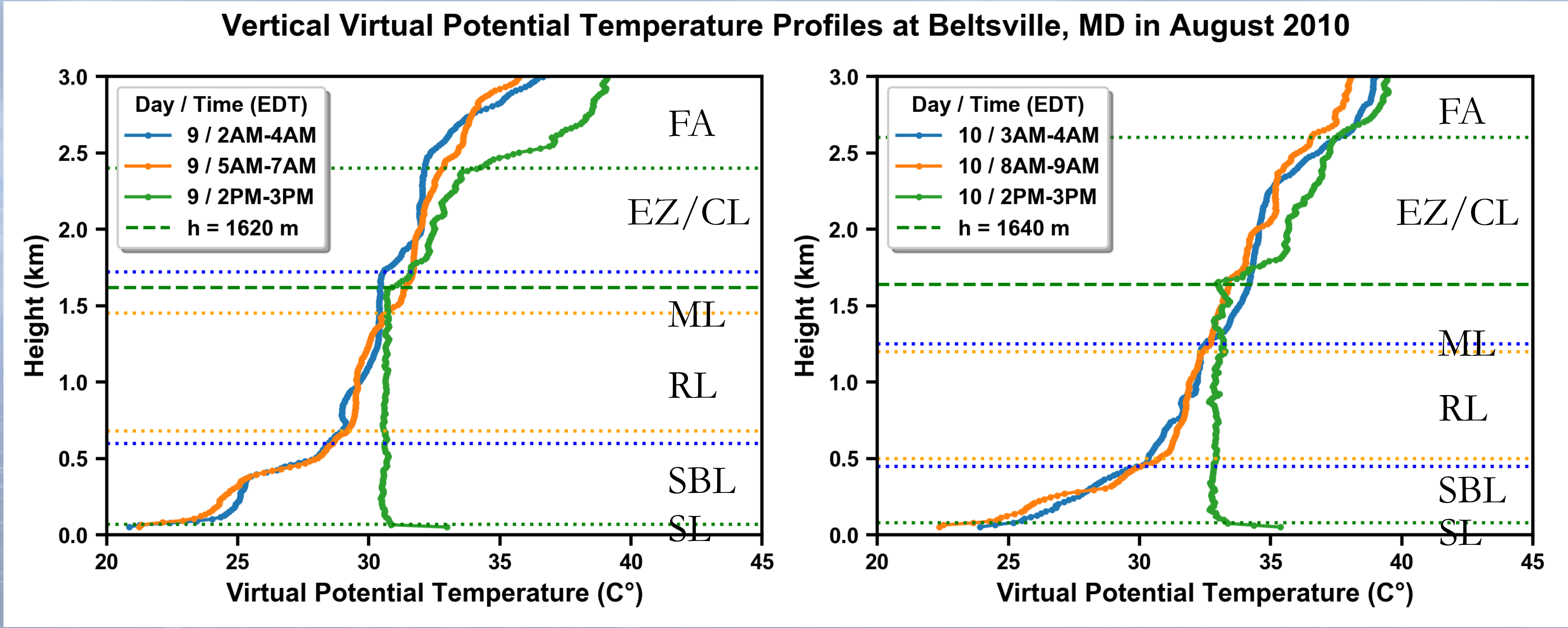
Results



- Steep lapse rates (average is 6.5°C/km) indicate instability & rising air
- Temperature inversion in the lowest ~500 m in the night / early morning

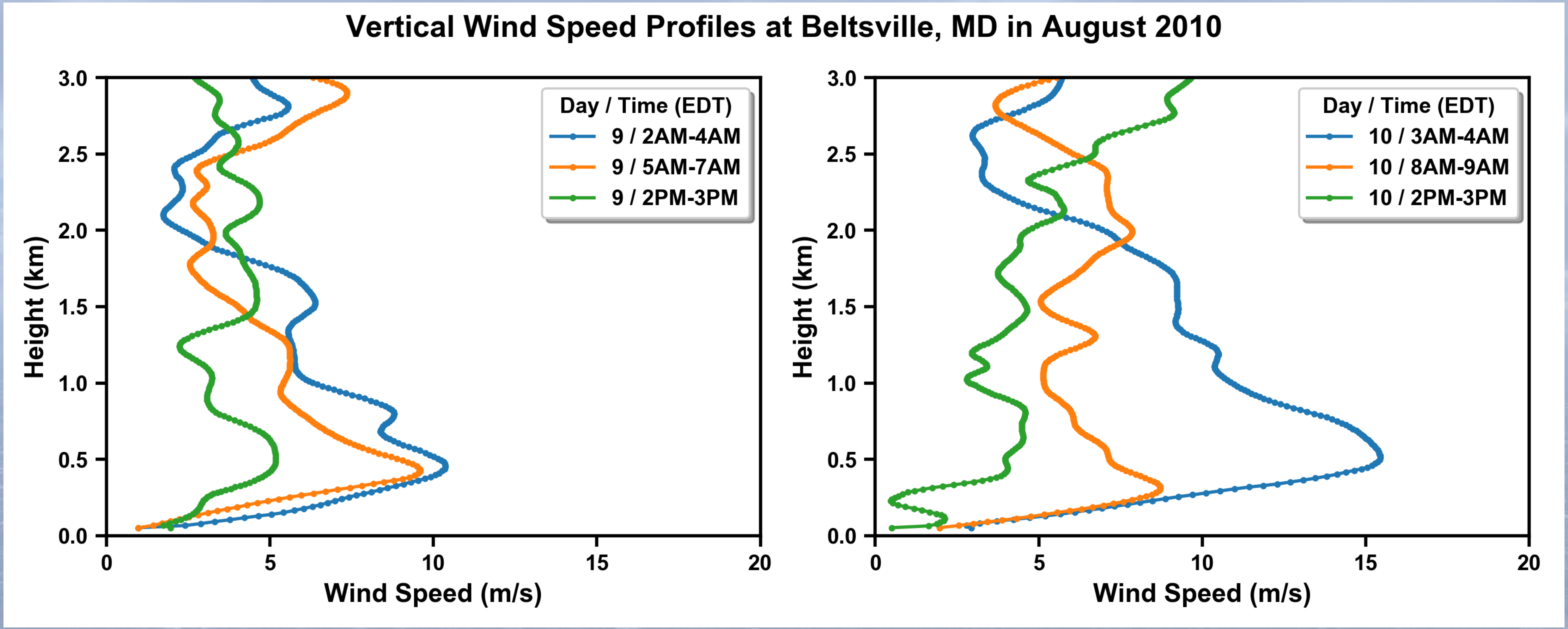
Results

$$\theta = T\left(\frac{P_0}{P}\right)^{R/c_p} \qquad q = \frac{w}{1+w} \qquad \theta_v = \theta(1 + 0.61q)$$



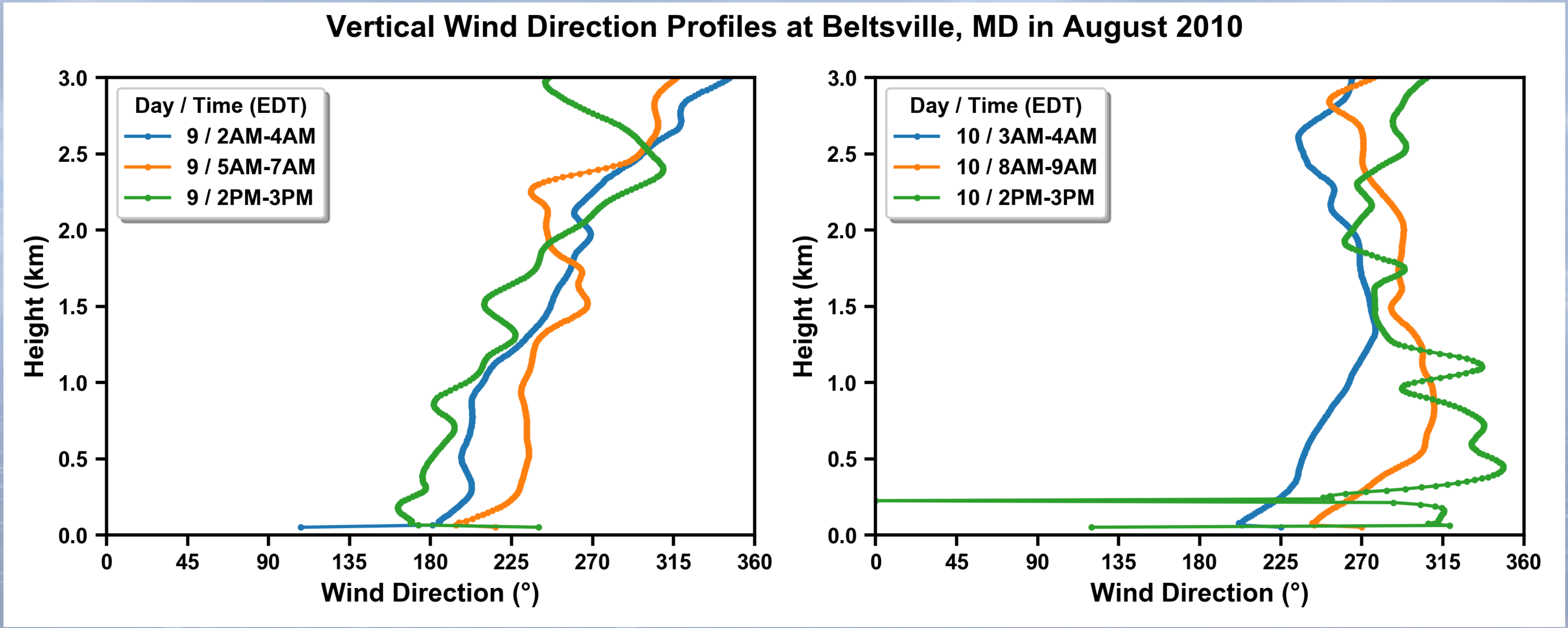
- Unstable in SL & neutral in ML (afternoon); stable otherwise
- Greater ABL depth → more volume for mixing → lower ozone levels

Results



- Windiest at night, with low-level jet above SBL; turbulent drag in ML
- Stronger near-surface winds → more dispersion of pollutants

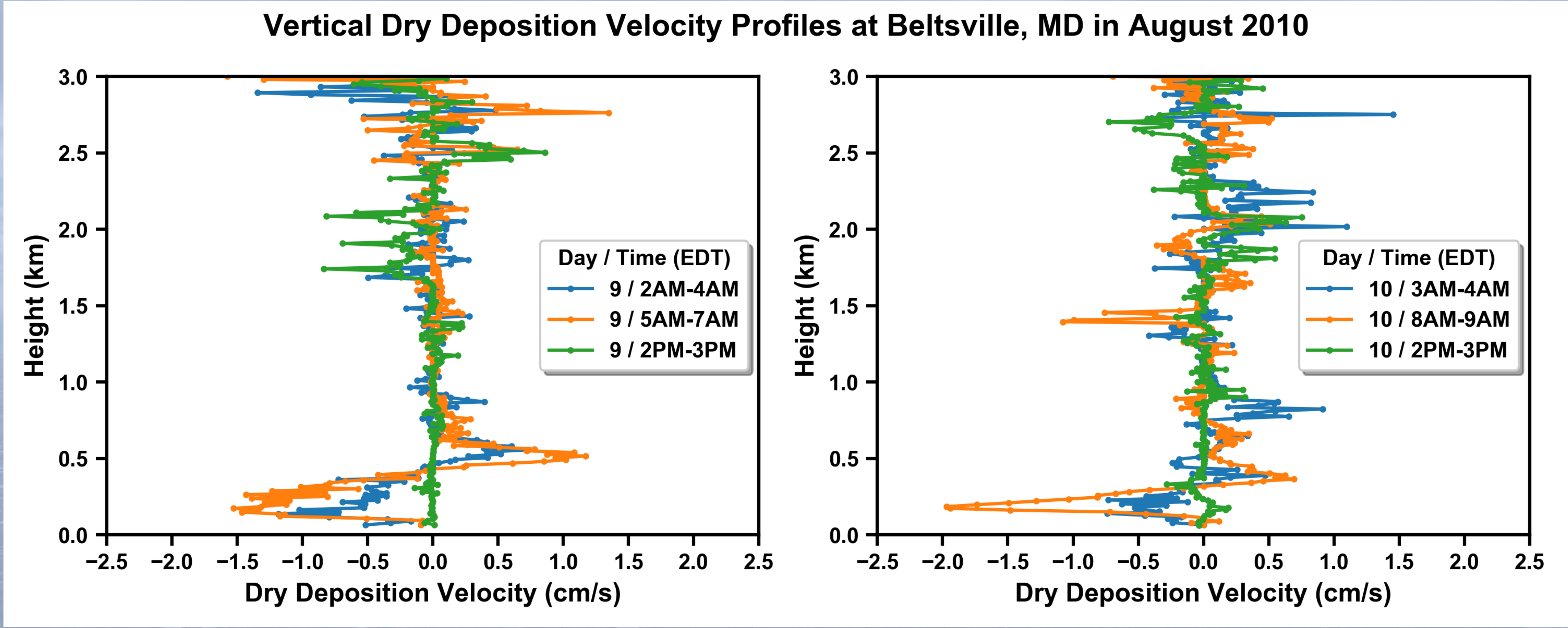
Results



- Wind direction more erratic at ground level due to terrain roughness
- SSE-SW on Aug. 9 (D.C.) vs. SSW-NW on Aug. 10 (suburbs)

Results

$$u_* = \frac{\bar{u}(z_1) - \bar{u}(z_2)}{\ln(z_2/z_1)}\kappa \qquad K_z = u_*\kappa z \qquad F = \overline{(w'\rho')} = -K_z\frac{\partial\bar{\rho}}{\partial z} \qquad v_d = -\frac{F}{\bar{\rho}(z_r)}$$



- Dry deposition velocity is highest in magnitude in the early morning
- Higher dry deposition velocity on Aug. 10 afternoon → reduction in ozone

Summary

- Ozone levels are likely to exceed the NAAQS on hot, humid, & sunny days
- Temperature and wind speed did not sufficiently explain the higher ozone levels (Aug. 9 afternoon)
  - Needed to also analyze ABL depth, wind direction, and dry deposition velocity

- **<u>Note:</u>**
  - Times of day, ABL depths, and wind directions were manually approximated
  - Instrumental errors may be significant
- Understanding all physical processes are important
  - Summertime air quality forecasting in Mid-Atlantic
  - Climate studies on a broader scale

Sources

2015 National Ambient Air Quality Standards (NAAQS) for Ozone. (2018, July 20). Retrieved April 22, 2019, from https://www.epa.gov/ground-level-ozone-pollution/2015-national-ambient-air-quality-standards-naaqs-ozone

Copy of Tropospheric Ozone Assessment Report (TOAR). (2017, August 1). Retrieved April 22, 2019, from https://collections.elementascience.org/tropospheric-ozone-assessment-report-toar

D.C., Baltimore tie for No. 3 spot in smoggiest large metro areas. (2011, September 23). Retrieved April 22, 2019, from https://wjla.com/news/local/d-c-baltimore-tie-for-no-3-spot-in-smoggiest-large-metro-areas-66955

Fuentes, J. D. (2019, April 22). *Ground Observations at Beltsville During July 2011*. Lecture.

Hu, X., Doughty, D. C., Sanchez, K. J., Joseph, E., & Fuentes, J. D. (2012). Ozone variability in the atmospheric boundary layer in Maryland and its implications for vertical transport model. *Atmospheric Environment,46*, 354-364. doi:10.1016/j.atmosenv.2011.09.054

Neu, U., Kunzle, T., & Wanner, H. (1994). On the relation between ozone storage in the residual layer and daily variation in near-surface ozone concentration - a case study. *Boundary-Layer Meteorology,69*(3), 221-247. doi:10.1007/bf00708857

Silva, S. J., & Heald, C. L. (2018). Investigating Dry Deposition of Ozone to Vegetation. *Journal of Geophysical Research: Atmospheres,123*(1), 559-573. doi:10.1002/2017jd027278

U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (n.d.). Retrieved April 22, 2019, from https://www.eia.gov/state/maps.php