The City College of New York

NOAA CREST

New York Metro-Area Boundary Layer Catalogue: Boundary Layer Height and Stability Conditions from Long-Term Observations

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**The City College of New York, New York, NY*

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Introduction

- **Motivation:** A great need in Numerical Weather Prediction to obtain an extensive database of observations of the boundary layer turbulence (Backlanov et al. 2011).

- At CCNY, we have access to boundary layer data (i.e. radiometers & wind profilers), and from these we can start building a **Catalog of BL observations**.

- Temperature profiles from the radiometer may present a unique opportunity to explore vertical structures in the urban BL given that such observations are less frequently found (Barlow 2014).

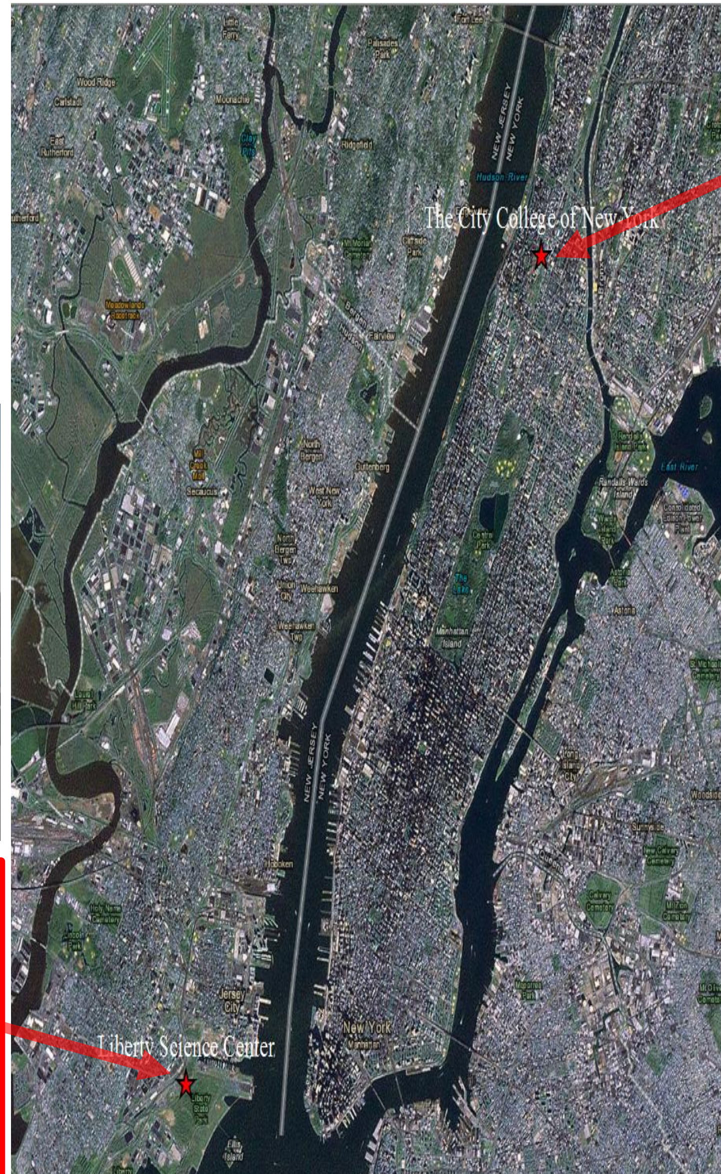
- Here we focus on the variability of the **local gradient of the virtual potential temperature, θ_v**.

- In general, the stability of a flow is characterized by its ability restrict the growth of small perturbations. **Static stability** in particular focuses on the effect of the buoyancy to encourage/inhibit motion after a parcel of air has been perturbed (Stull, 1991).

Instrumentation

Vaisala LAP-3000 Wind Profiler at the **Liberty Science Center**: wind speed, wind direction, and signal-to-noise ratio.

- Measurement every 30 min.
- 100m resolution
- Range: ~250 m to ~2100m

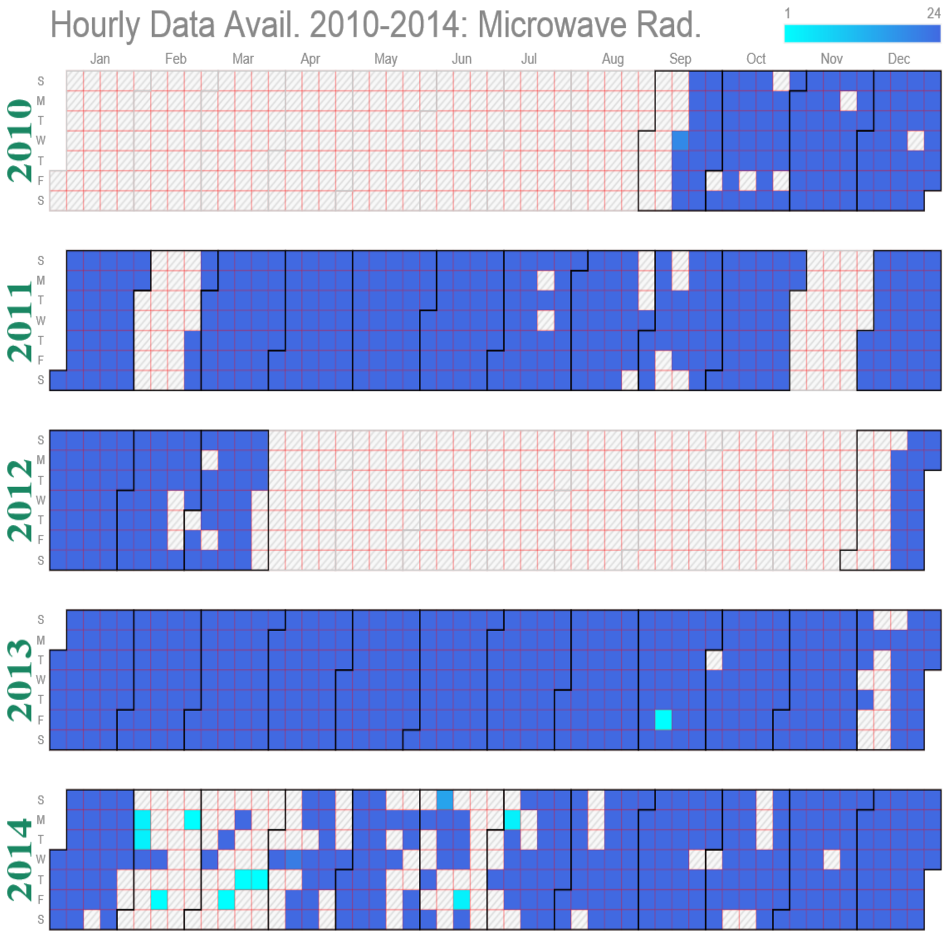


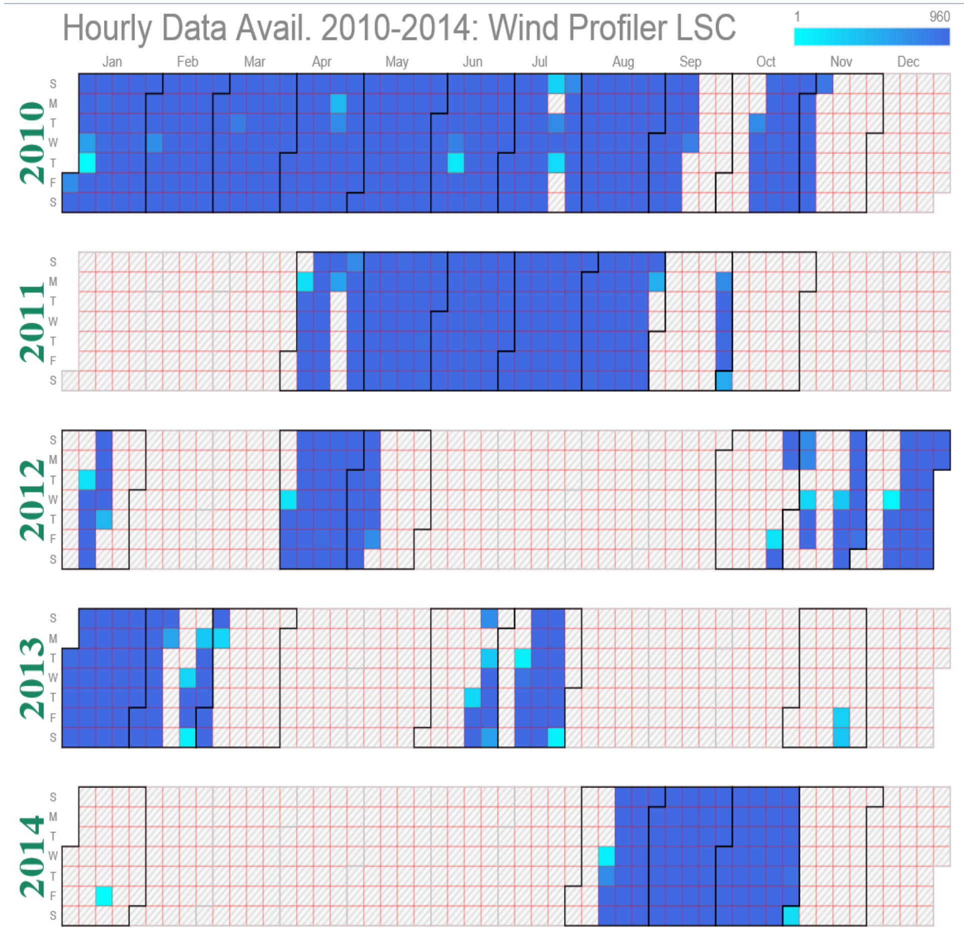
Radiometrics Profiling Radiometer model MP-3000A at the **City College of New York**: temperature, relative humidity, water vapor density, liquid water density.

- Measurement every hour.
- 100m resolution
- Range: 100m to 9800m

More information on the methods used by the particular instruments can be found in Cimini, et al. 2011.

Data Availability





Static Stability Calculation

The static stability of the atmosphere an evaluation can be based solely on the profile of the **virtual potential temperature**, θ_v (Kelvin) ,

$$\theta_v = \theta\,(1 + 0.61 r_v\; - r_l)$$

where θ is the potential temperature, r_v is the water vapor mixing ratio and r_L is the liquid water mixing ratio. At each height of a given hour the vertical gradient of $\theta_v(z)$is calculated using a numerical difference,

$$\frac{\partial\theta_v(z_1)}{\partial z} \approx \frac{\Delta\theta_v(z_1)}{\Delta z} = \frac{\theta(z_2) - \theta(z_1)}{z_2 - z_1}$$

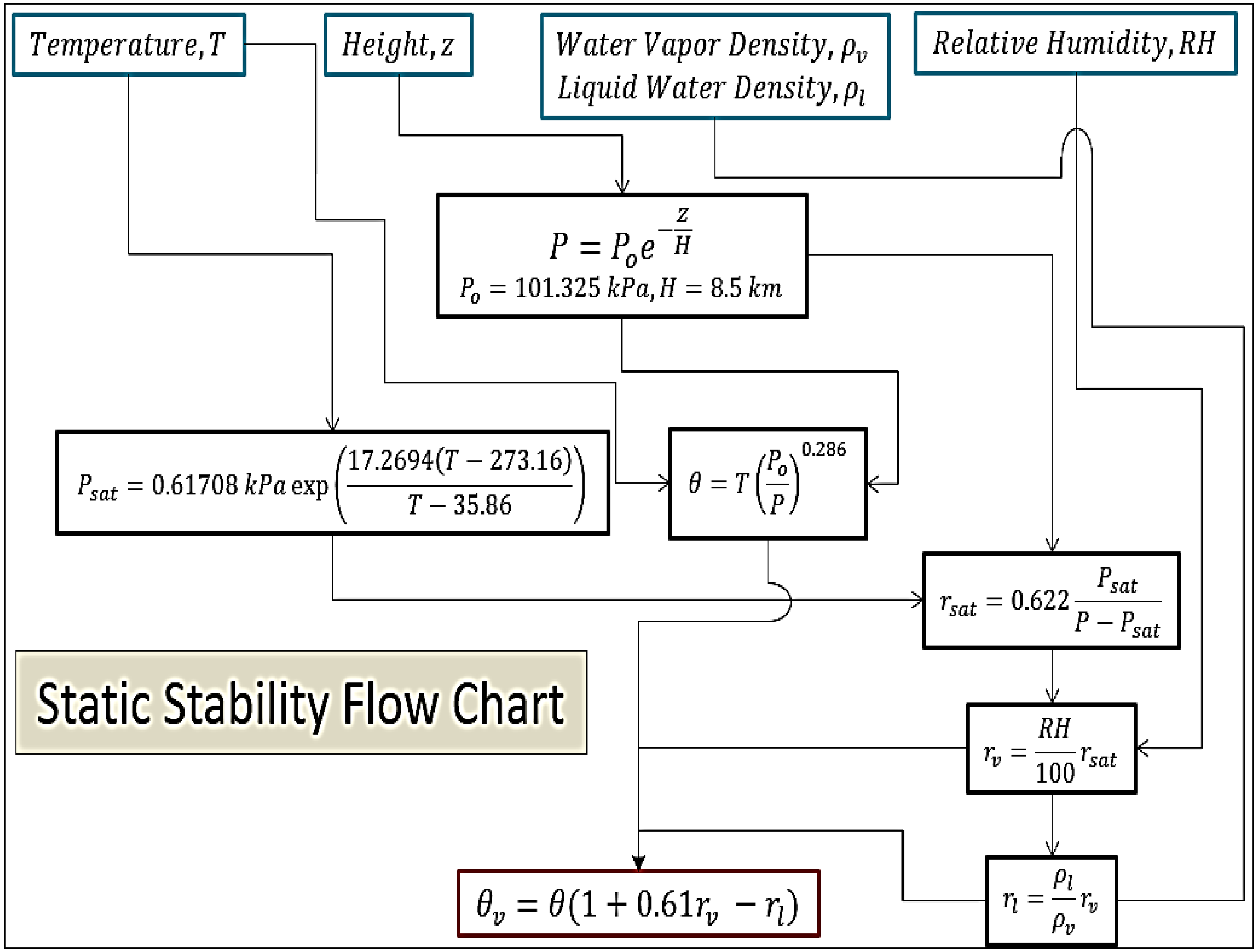
where $z_2 > z_1$. The criteria for static stability is then,

$\frac{\partial\theta_v}{\partial z} > 0$ Stable

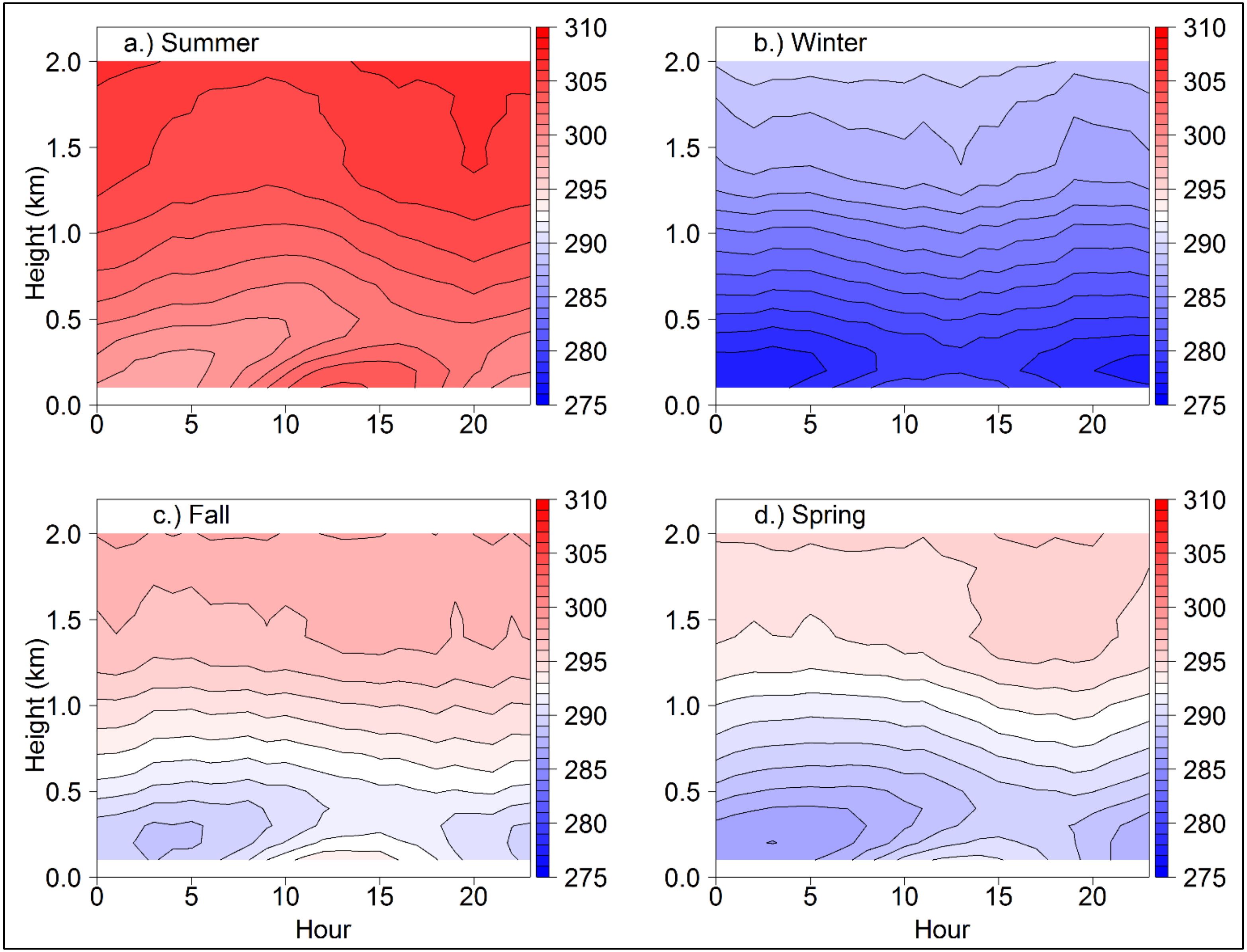
$\frac{\partial\theta_v}{\partial z} = 0$ Neutral

$\frac{\partial\theta_v}{\partial z} < 0$ Unstable

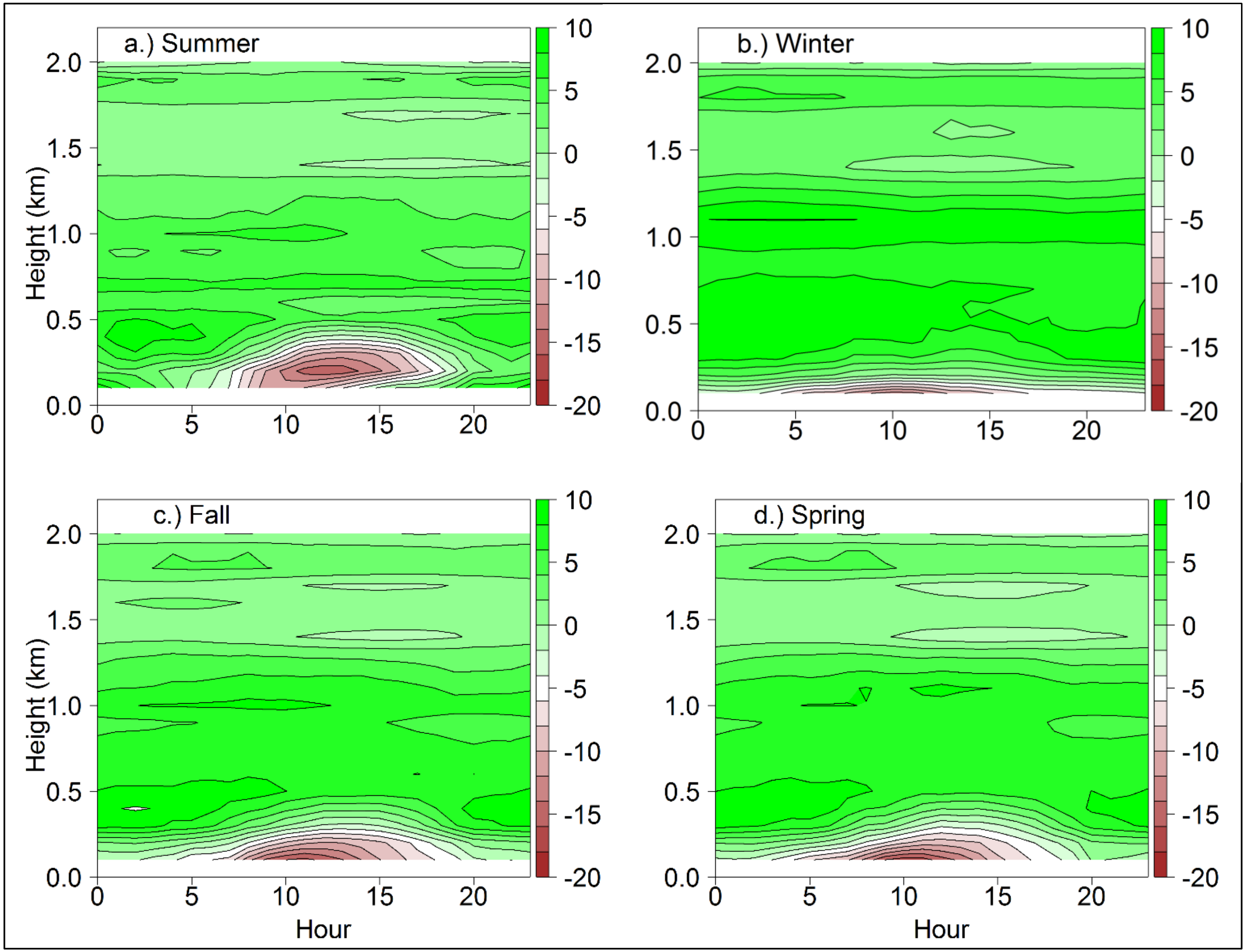
(Stull, 1988), (Wallace & Hobbs, 2006)



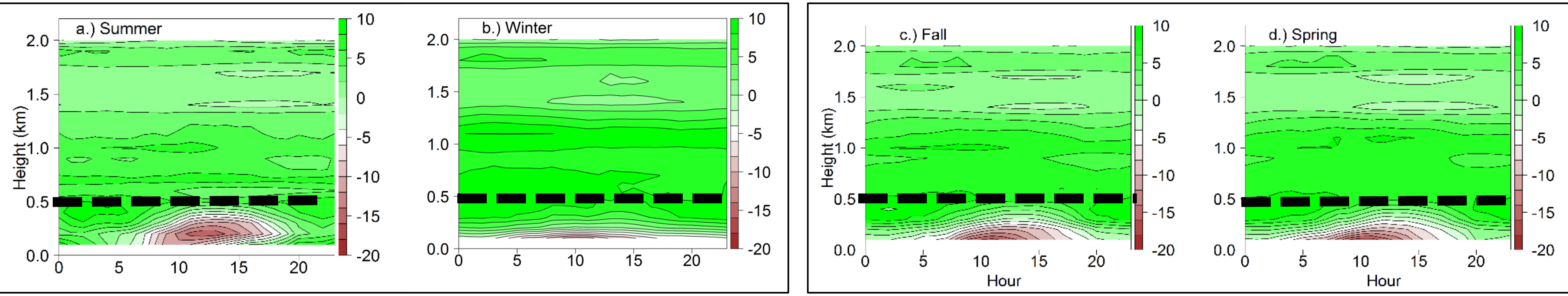
Seasonal Diurnal Cycle of θ_v



Seasonal Diurnal Contours of $\frac{\partial \theta_v}{\partial z}$



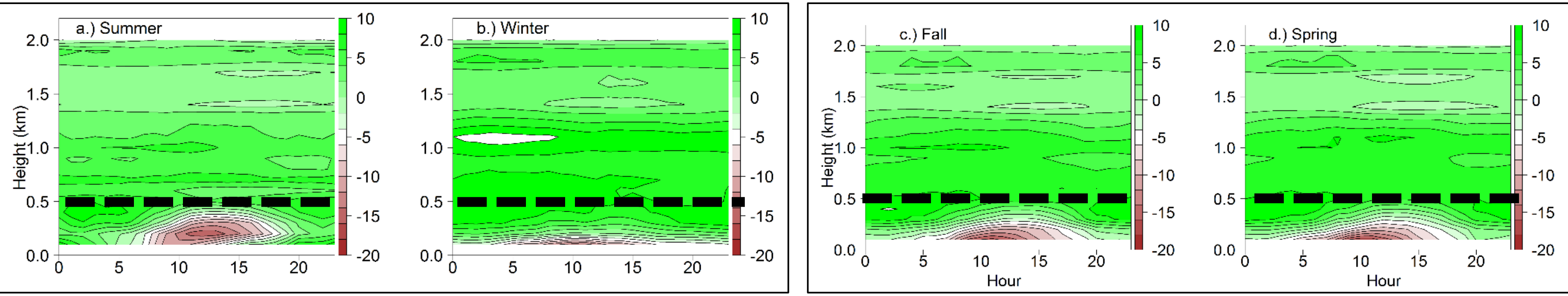
Static Stability: Hourly Catalog

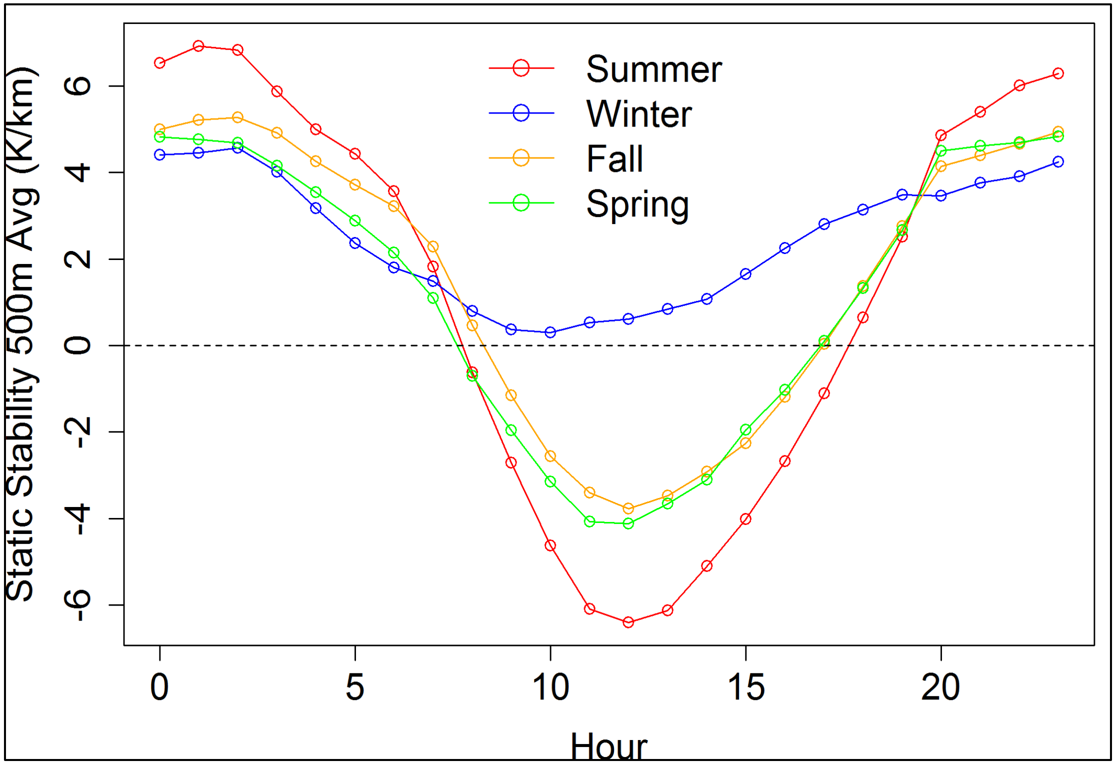


Looking at the diurnal profiles of the static stability, the region that experiences the greatest amount of variability lies between heights of 100m and 500m. These heights will be used as the limits for an averaging process for determining the static stability for the hour.

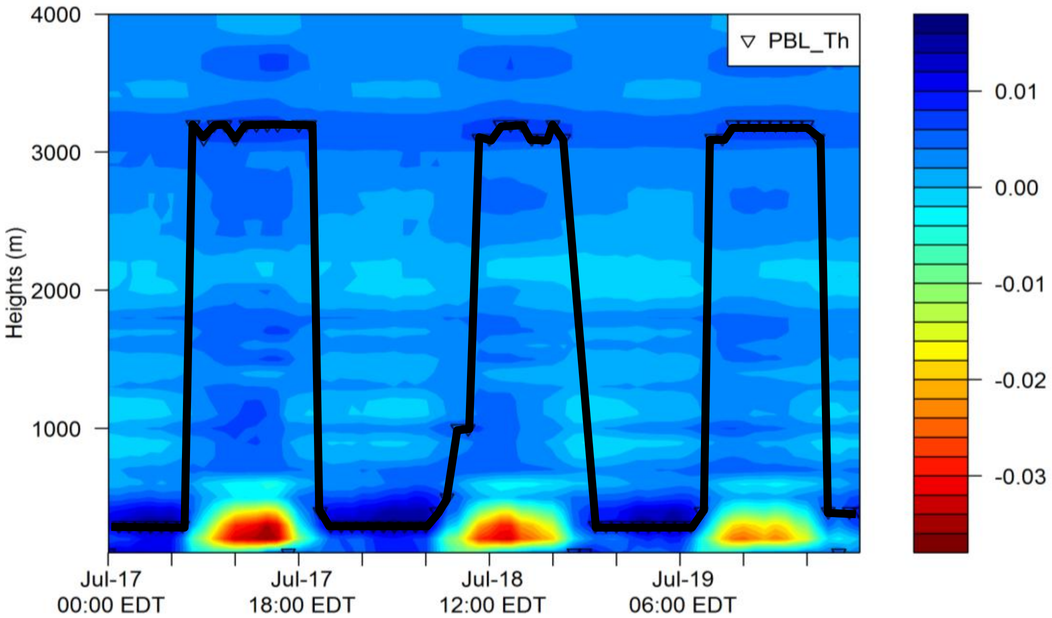
This 'bulk' static stability is what will be used to catalog the static stability of the hour.

Static Stability: Hourly Catalog





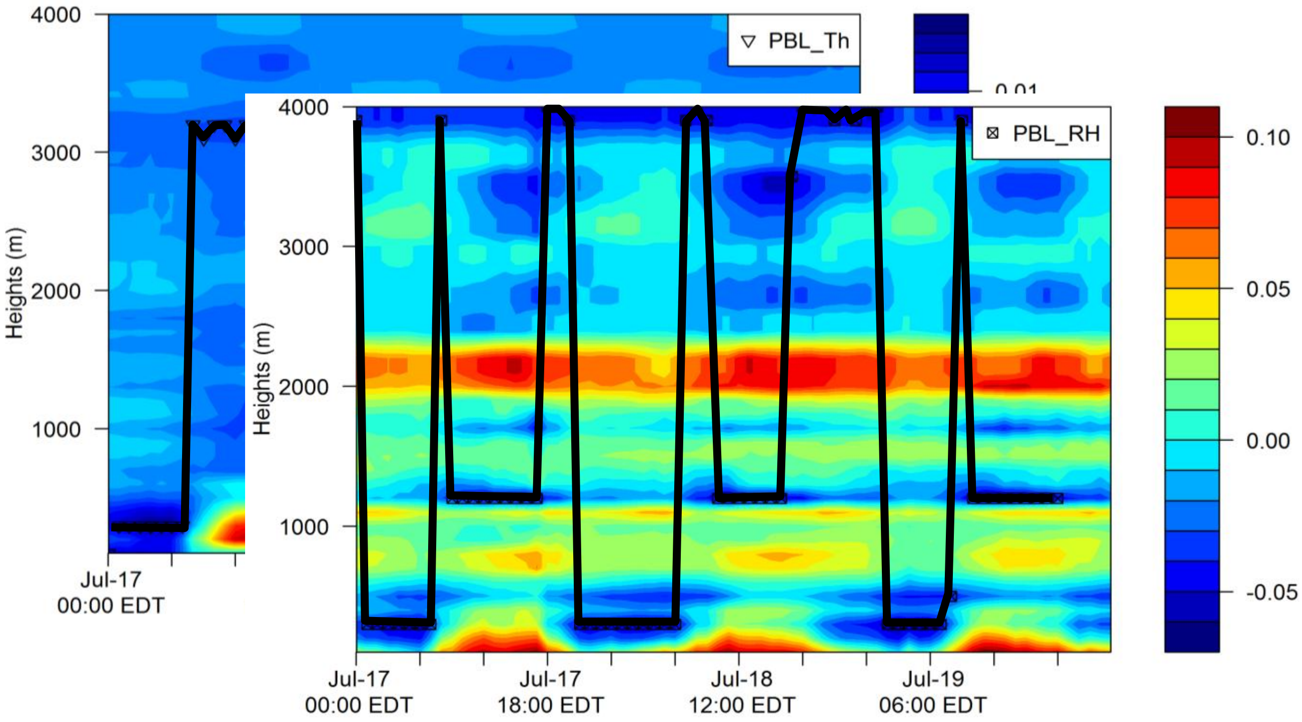
PBLH Determination



1. <u>Potential Temperature Method</u>
The location of the maximum vertical gradient of potential temperature. Uses measurements from the microwave radiometer.

(Seidel, Ao, & Li, 2010)

PBLH Determination



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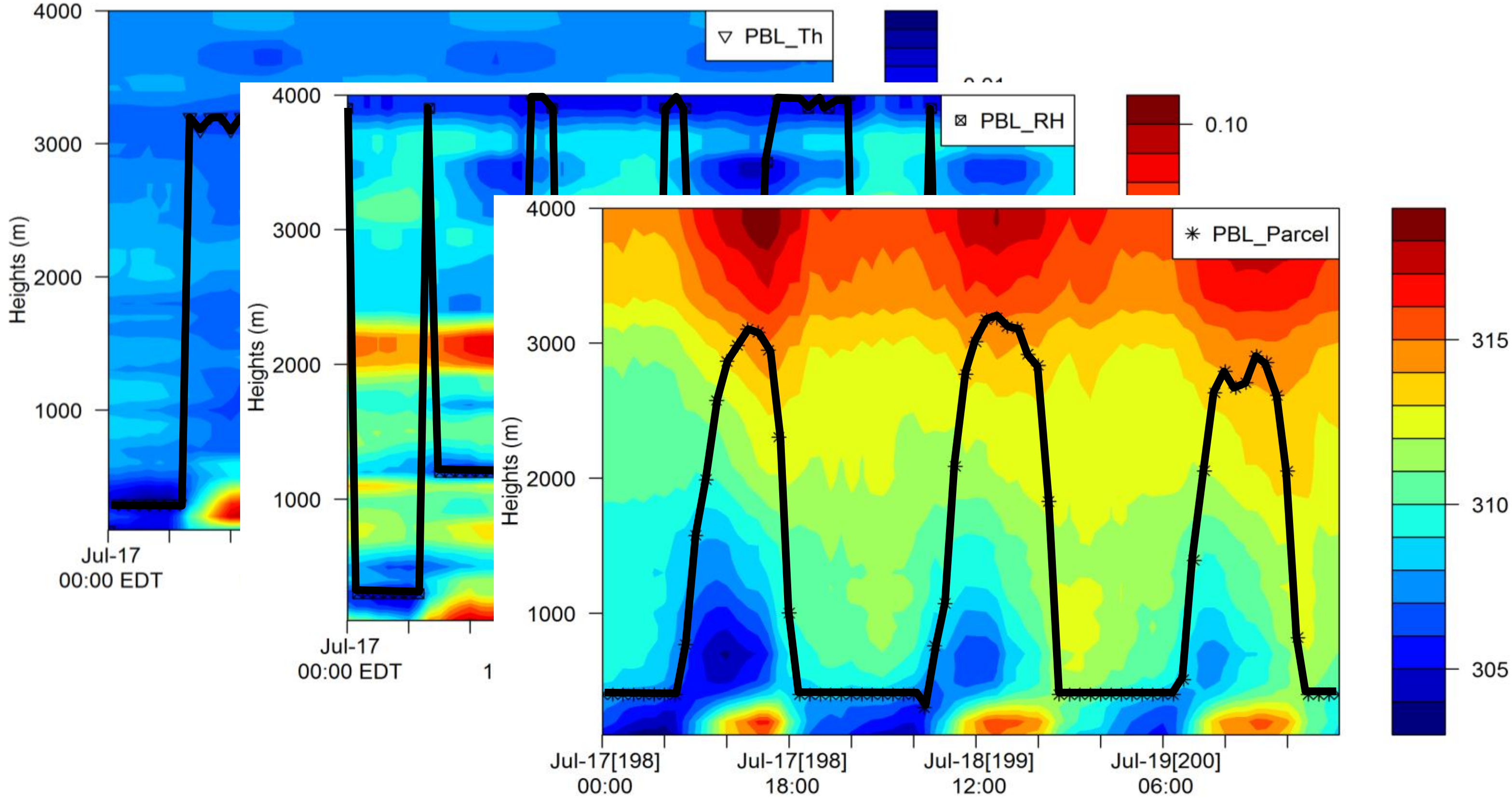
PBLH Determination



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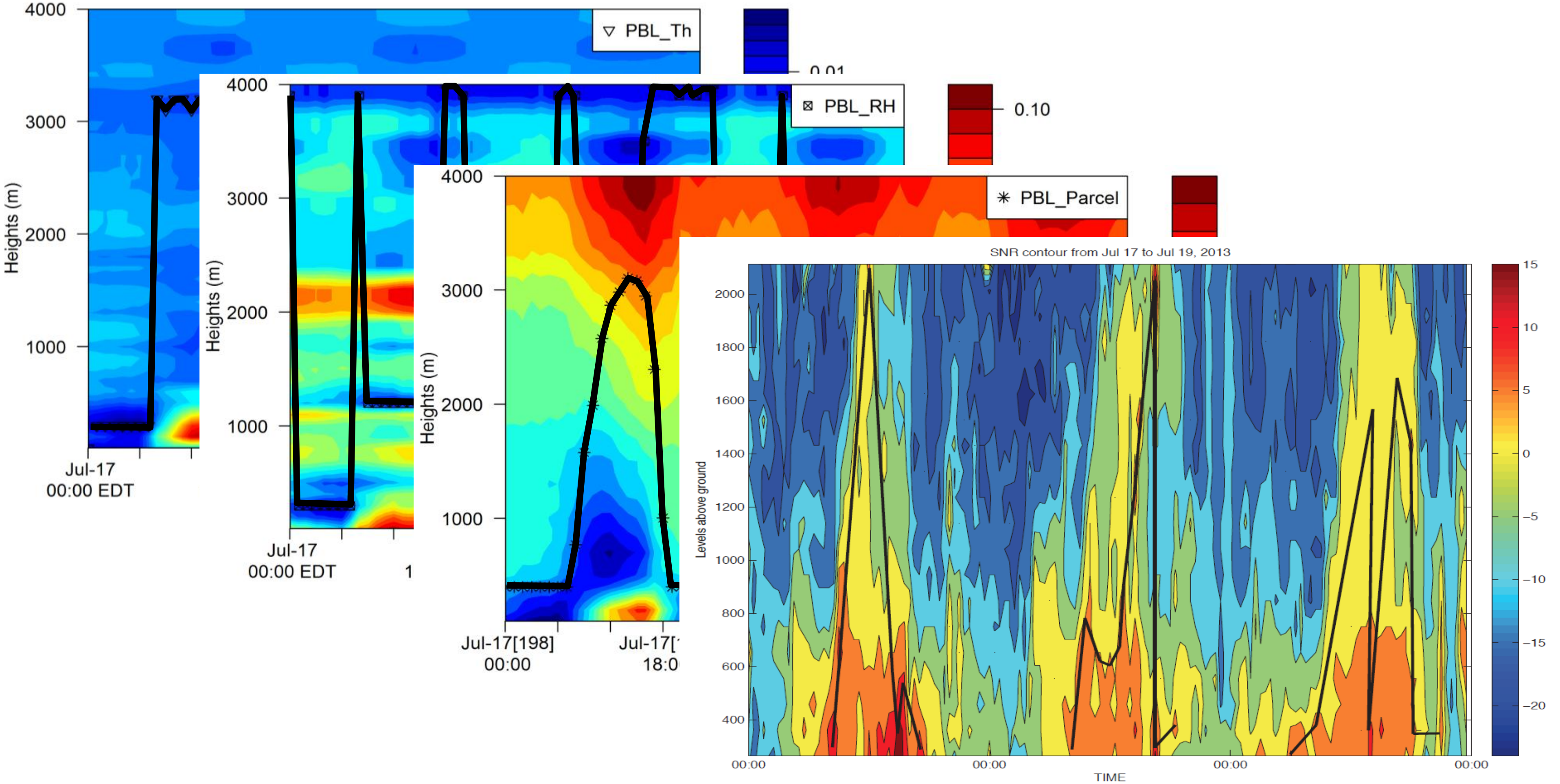
3. <u>The Parcel Method</u>
The location where θ_v is equal to its surface value. Uses measurements from the microwave radiometer.

(Seidel, Ao, & Li, 2010), (LeMone et al. 2013)

PBLH Determination



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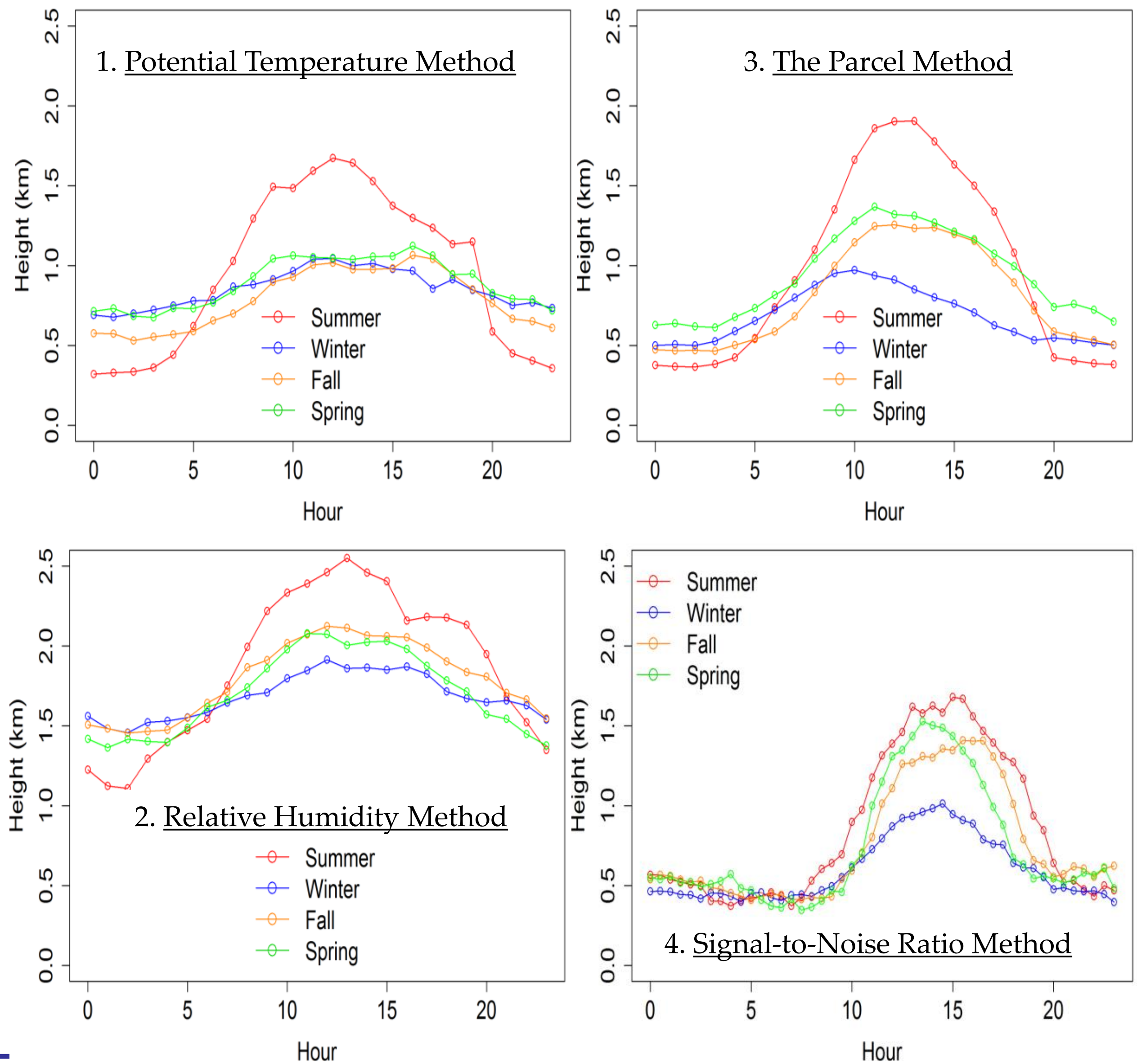
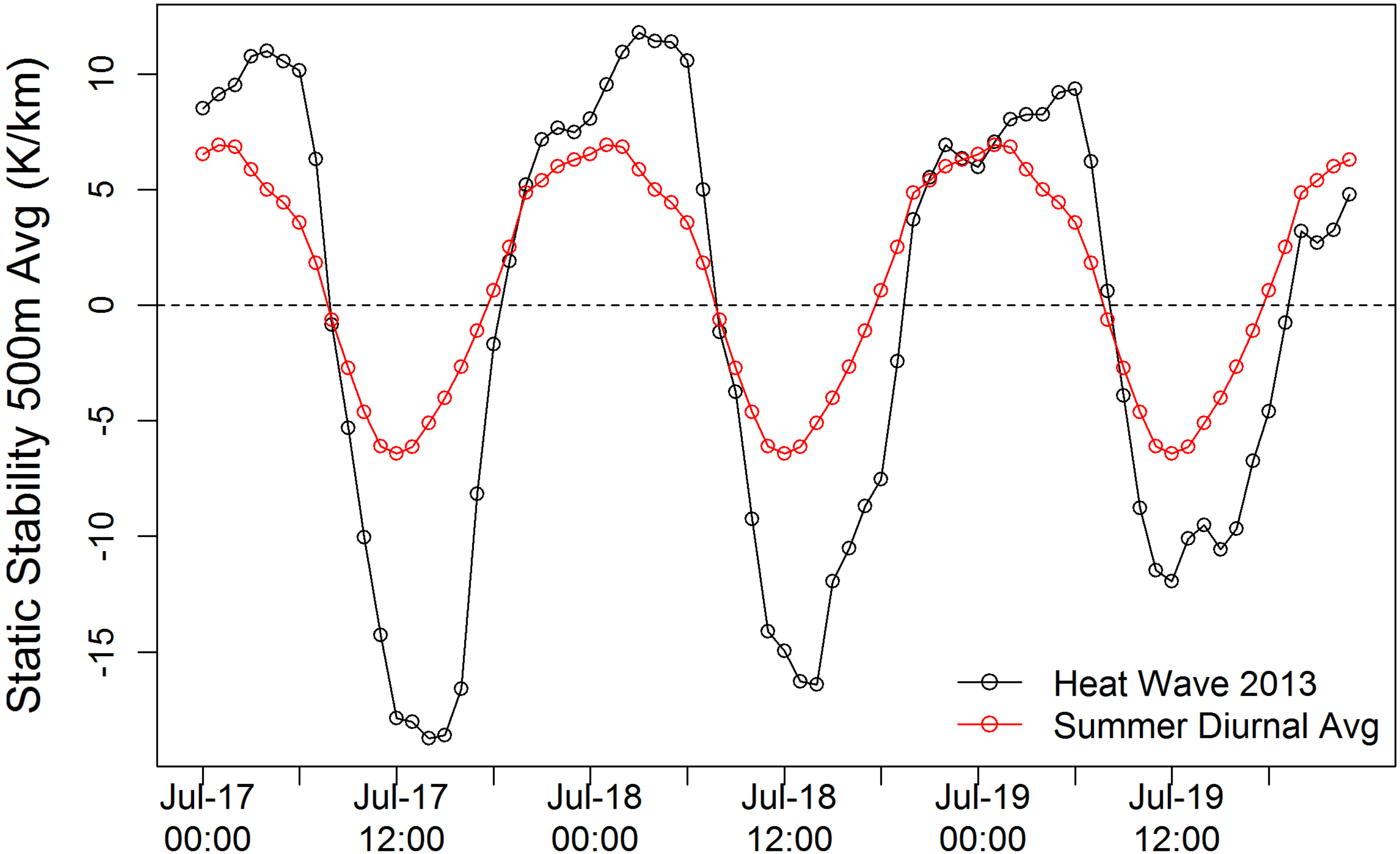
4. <u>Signal-to-Noise Ratio Method</u>
The location of the peak of the range-corrected SNR. Uses measurements from the RADAR wind profiler.

(Angevine, White, & Avery, 1994)

PBLH Diurnal Cycles



Static Stability: July 2013 Heat Wave



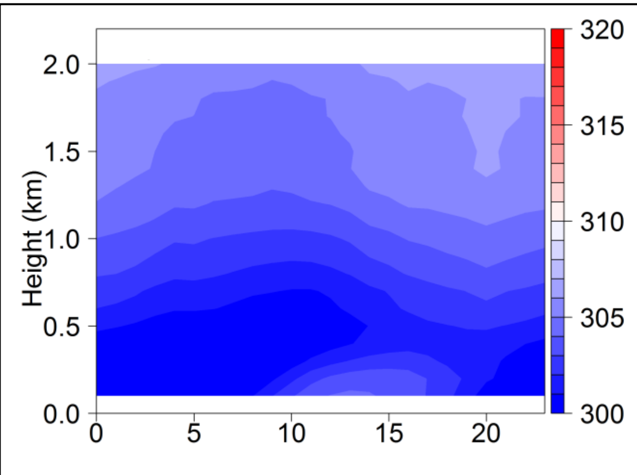
July 17-19 2013

More details on the heat wave event can be found from a presentation at AMS 2014 in Atlanta, GA by Gutierrez et al., presented by J. Gonzalez.

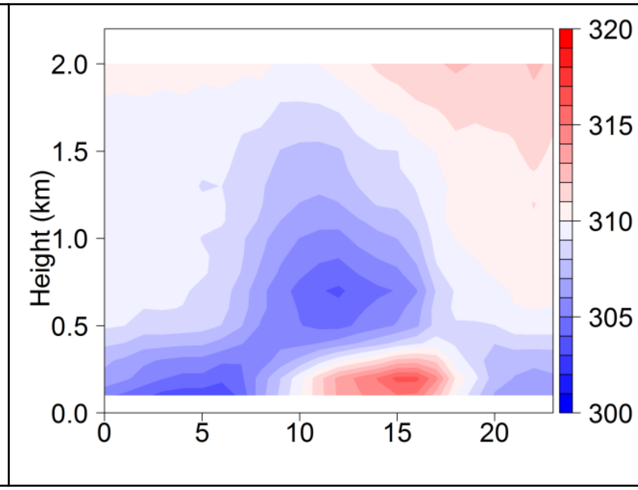
Diurnal Avg -- Observations -- urbanized-WRF

Contours of θ_v (K)

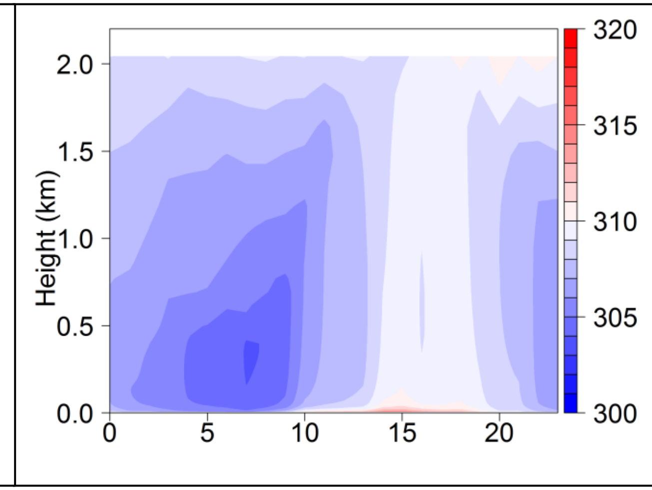
Summer Avg. of θ_v



Observations July 17 θ_v

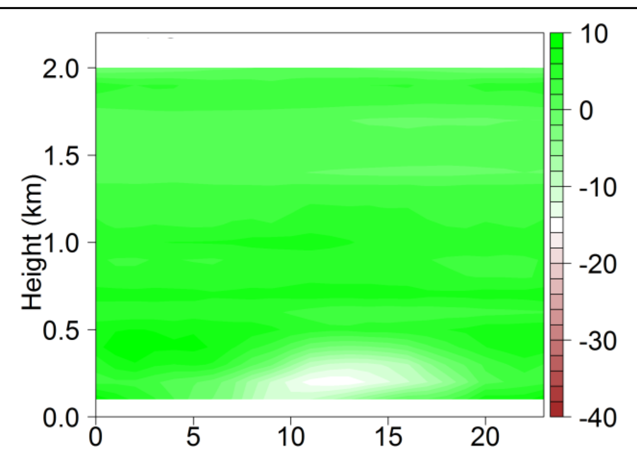


July 17, Urbanized-WRF

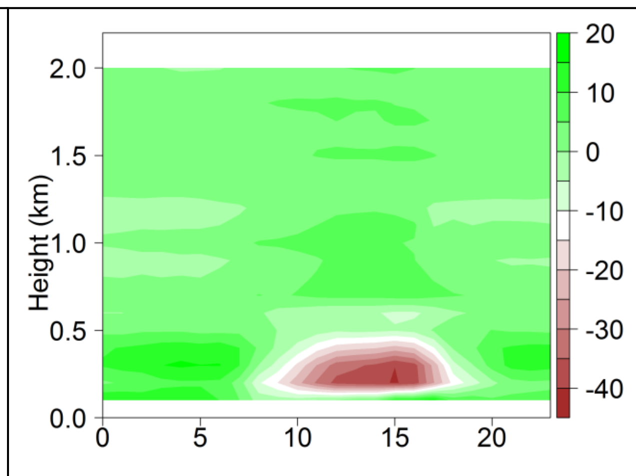


Contours of Static Stability ($\partial\theta_v/\partial z$; K/km)

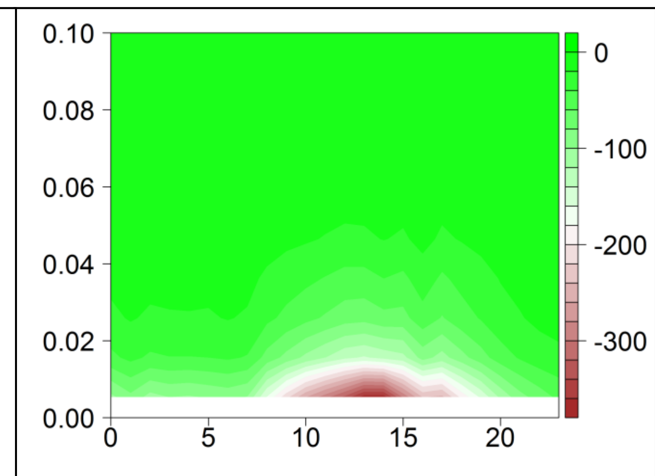
Summer Avg. of θ_v



Observations July 17 θ_v



July 17, Urbanized-WRF



Conclusions

Static Stability in an Urban Environment

Methods	Seasonal Diurnal Variability	Comments
'Bulk' static stability from using region of greatest variability in $\partial\theta_v/\partial z$.	• Summer: -6 to 6 K/km • Fall & Spring: -4 to 5 K/km • Winter: ~ 0 to 5 K/km	Most of the variability: below 500m in MWR measurement.

Planetary Boundary Layer Heights in an Urban Environment

Methods (instrument used)	Seasonal Diurnal Variability	Comments
1. θ-method (MWR) 2. RH-method (MWR) 3. Parcel method (MWR) 4. SNR-method (RWP) MWR – microwave radiometer RWP – radar wind profiler	• RH-method consistently produces high values. • Summer: highest PBLH with large variability throughout the day. • Winter: lowest PBLH and shallow throughout day	Nighttime PBLH may not be well represented but Pal et al., 2012 was able to measure nighttime PBLH of 330m in urban areas of Paris, which may indicate that similar elevated levels may be present in NY.

Future Work

Measurement Evaluation	uWRF Evaluation	Elevated Superadiabatic Layers
Combine results with measurements from other instruments available at City College.	Evaluate the vertical structure of the boundary layer as calculated by uWRF.	Czarnetzki, 2012 shows similar elevated superadiabatic layers using the same MWR. Further investigation is still needed as these results may not be believed by forecasters (Hodges, 1956).

References

- Angevine, W. M., White, A. B., & Avery, S. K. (1994). Boundary-layer depth and entrainment zone characterization with a boundary-layer profiler. *Boundary Layer Meterology*, *68*(4), 375-385.
- Baklanov, A. A., Grisogono, B., Bornstein, R., Mahrt, L., Zilitinkevich, S. S., Taylor, P., . . . Fernando, H. J. (2011). The Nature, Theory, and Modeling of Atmospheric Boundary Layers. *Bulletin of the American Meteorological Society*, *92*(2), 123-128. doi:10.1175/2010BAMS2797.1
- Barlow Janet F., 2014: Progress in Observing and Modelling the Urban Boundary Layer. *Urban Climate*, 10 (December), 216–40.
- Cimini Domenico, Visconti Guido, and Marzano Frank S., eds., 2011: *Integrated Ground-Based Observing Systems*. Berlin, Heidelberg: Springer Berlin Heidelberg.
- Czarnetzki, A. C., 2012: Persistent daytime superadiabatic surface layers observed by a microwave temperature profiler. Preprints, 37th Natl. Wea. Assoc. Annual Meeting, Madison, WI, Natl. Wea. Assoc., P2.55.
- Gutierrez, E., Gonzalez, J., Melecio, D., Arend, M., Bornstein, R., Martilli, A. On the Genesis and Evolution of the Summer 2013 Heat Wave Event in New York City: Observations and Modelling. American Meteorological Society National Conference 2014. Atlanta, GA.
- Hodge Mary W., 1956: SUPERADIABATIC LAPSE RATES OF TEMPERATURE IN RADIOSONDE OBSERVATIONS. *Monthly Weather Review*, **84 (3)**, 103–6.
- LeMone Margaret A., Tewari Mukul, Chen Fei, and Dudhia Jimy, 2013: Objectively Determined Fair-Weather CBL Depths in the ARW-WRF Model and Their Comparison to CASES-97 Observations. *Monthly Weather Review*, **141 (1)**, 30–54.
- Seidel, D. J., Ao, C. O., & Li, K. (2010). Estimating climatological planetary boundary layer heights from radiosonde observations: Comparison of methods and uncertainty analysis. *Journal of Geophysical Research*, *115*(D16). doi:10.1029/2009JD013680

References

- Stull, R. (1988). *An Introduction to Boundary Layer Meteorology*. Dordrecht: Kluwer Academic Publishers.
- Stull, Roland B. (1991). Static Stability—An Update. *Bulletin of the American Meteorological Society* 72, no. 10: 1521–29. doi:10.1175/1520-0477(1991)072<1521:SSU>2.0.CO;2.
- Wallace, J. M., & Hobbs, P. V. (2006). *Atmospheric Science: An Introductory Survey* (2nd ed.). Elsevier, Inc.
- Wu, X., Fuentes J. D. (2013). Temporal Changes in Static Stability in Arctic Boundary Layer. Poster. American Meteorological Society National Conference 2013. Austin, TX.

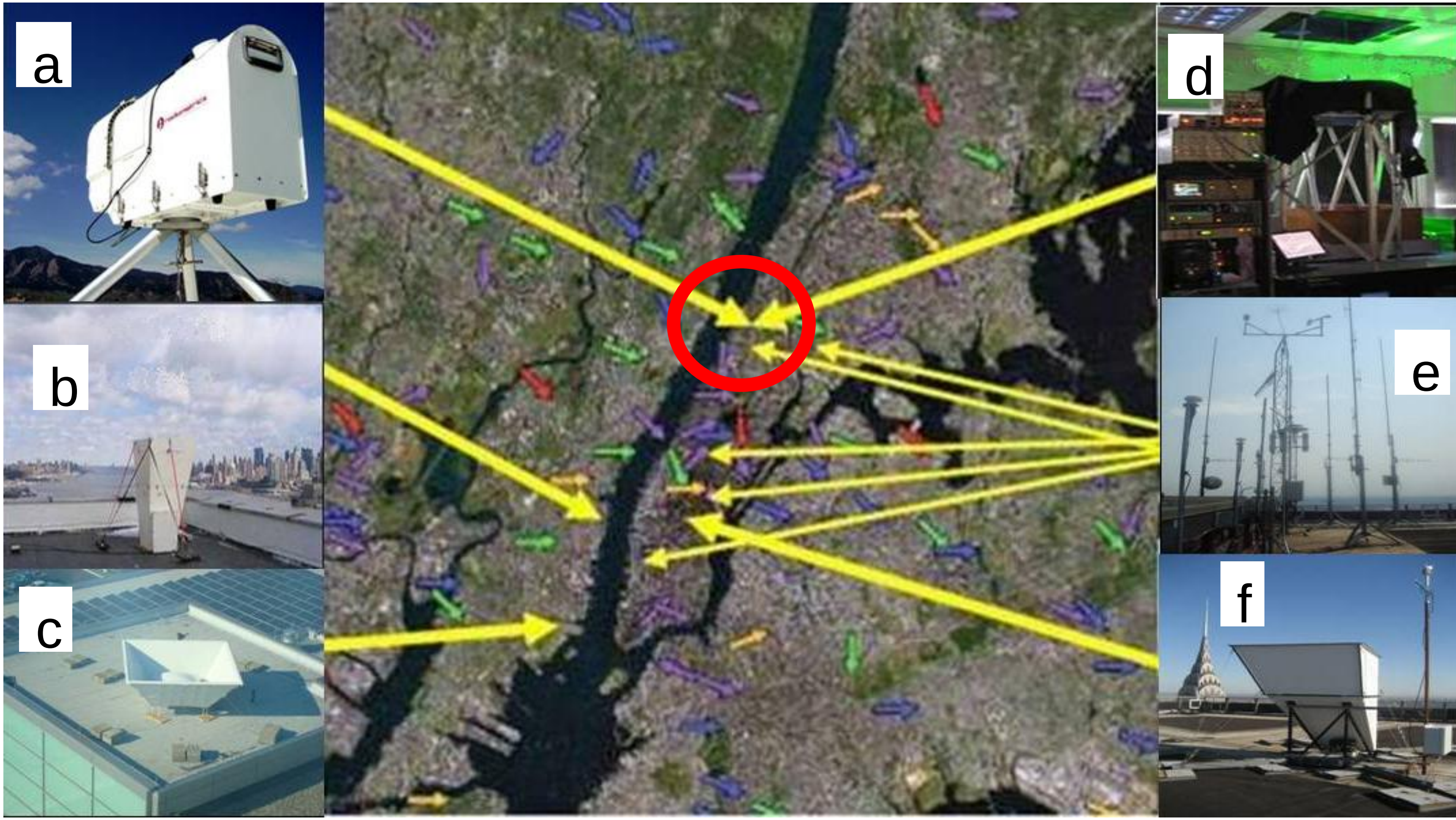
References for urbanized-WRF

- For similar physics options used in the July 2013 case go to:
  Gutiérrez Estatio, González Jorge E., Martilli Alberto, Bornstein Robert, and Arend Mark, 2015: Simulations of a Heat-Wave Event in New York City Using a Multilayer Urban Parameterization. *Journal of Applied Meteorology and Climatology*, 54 (2), 283–301.
- Gutiérrez E., Martilli A., Santiago J. L., and González J. E., 2015: A Mechanical Drag Coefficient Formulation and Urban Canopy Parameter Assimilation Technique for Complex Urban Environments. *Boundary-Layer Meteorology*,**,** June.
- Gutiérrez Estatio, González Jorge E., Martilli Alberto, and Bornstein Robert, 2015: On the Anthropogenic Heat Fluxes Using an Air Conditioning Evaporative Cooling Parameterization for Mesoscale Urban Canopy Models. *Journal of Solar Energy Engineering*, 137 (5), 051005.

Acknowledgements

- The National Oceanic and Atmospheric Administration – Cooperative Remote Sensing Science and Technology Center (NOAA-CREST). NOAA CREST - Cooperative Agreement No: NA11SEC4810004

NYCMetNet Stations: Future Work



a) Hyper spectral radiometer
b) Sodar to 300 m
c) Radar Wind Proifiler to 2 km

d) Backscatter aerosol Lidar
e) Building top Met Tower
f) Sodar to 400 m

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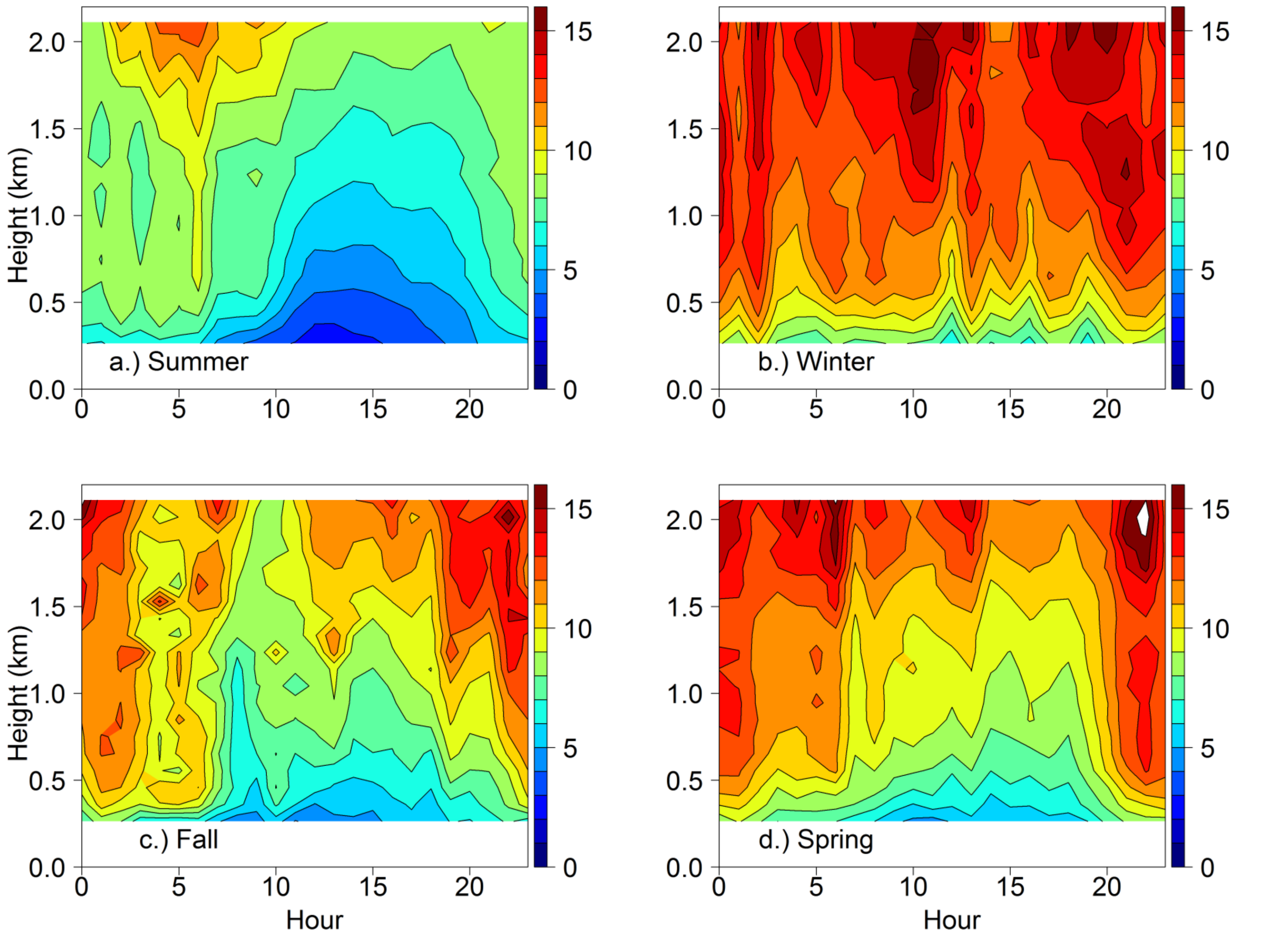
Wind Speed Diurnal Avgs.



Wind Direction Diurnal Avgs.