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

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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, $\theta_v$.

- 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 ~2100 m

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

Hourly Data Avail. 2010-2014: Microwave Rad.

Hourly Data Avail. 2010-2014: Wind Profiler LSC
The static stability of the atmosphere an evaluation can be based solely on the profile of the virtual potential temperature, \( \theta_v \) (Kelvin),

\[
\theta_v = \theta (1 + 0.61r_v - r_l)
\]

where \( \theta \) 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,

\[
\frac{\partial \theta_v}{\partial z} > 0 \quad \text{Stable} \\
\frac{\partial \theta_v}{\partial z} = 0 \quad \text{Neutral} \\
\frac{\partial \theta_v}{\partial z} < 0 \quad \text{Unstable}
\]

(Stull, 1988), (Wallace & Hobbs, 2006)
Seasonal Diurnal Cycle of $\theta_v$

- **a.) Summer**
- **b.) Winter**
- **c.) Fall**
- **d.) Spring**
Seasonal Diurnal Contours of $\frac{\partial \theta_v}{\partial z}$
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

[Graphs showing static stability for different seasons: Summer, Winter, Fall, Spring]
1. Potential Temperature Method
The location of the maximum vertical gradient of potential temperature. Uses measurements from the microwave radiometer.

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2. Relative Humidity Method
The location of the minimum vertical gradient of relative humidity. Uses measurements from the microwave radiometer.

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3. The Parcel Method
The location where $\theta_v$ is equal to its surface value. Uses measurements from the microwave radiometer.
(Seidel, Ao, & Li, 2010),
(LeMone et al. 2013)
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4. Signal-to-Noise Ratio Method
The location of the peak of the range-corrected SNR. Uses measurements from the RADAR wind profiler.
(Angevine, White, & Avery, 1994)
PBLH Diurnal Cycles

1. Potential Temperature Method

2. Relative Humidity Method

3. The Parcel Method

4. Signal-to-Noise Ratio Method
Static Stability: July 2013 Heat Wave

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 $\theta_v$ (K)

Summer Avg. of $\theta_v$

Observations July 17 $\theta_v$

July 17, Urbanized-WRF

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

Summer Avg. of $\theta_v$

Observations July 17 $\theta_v$

July 17, Urbanized-WRF
# Conclusions

## Static Stability in an Urban Environment

<table>
<thead>
<tr>
<th>Methods</th>
<th>Seasonal Diurnal Variability</th>
<th>Comments</th>
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</table>
| ‘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

<table>
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<th>Methods (instrument used)</th>
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| 1. $\theta$-method (MWR)  
2. RH-method (MWR)  
3. Parcel method (MWR)  
4. SNR-method (RWP) | • 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. |

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| MWR – microwave radiometer  
RWP – radar wind profiler | | |

## Future Work

<table>
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<tr>
<th>Measurement Evaluation</th>
<th>uWRF Evaluation</th>
<th>Elevated Superadiabatic Layers</th>
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<td>Combine results with measurements from other instruments available at City College.</td>
<td>Evaluate the vertical structure of the boundary layer as calculated by uWRF.</td>
<td>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).</td>
</tr>
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References


References


References for urbanized-WRF

• For similar physics options used in the July 2013 case go to:


Acknowledgements

NYCMetNet Stations: Future Work

a) Hyper spectral radiometer
b) Sodar to 300 m
c) Radar Wind Profiler to 2 km
d) Backscatter aerosol Lidar
e) Building top Met Tower
f) Sodar to 400 m
NYC MetNet Stations: Future Work

a) Hyper spectral radiometer
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e) Building top Met Tower
f) Sodar to 400 m

Thank you. Any Questions?
Wind Speed Diurnal Avg.s.

a.) Summer

b.) Winter

c.) Fall

d.) Spring
Wind Direction Diurnal Avgs.

(a) Summer

(b) Winter

(c) Fall

(d) Spring