Evaluation of the Simulated Planetary Boundary Layer in Eastern Texas

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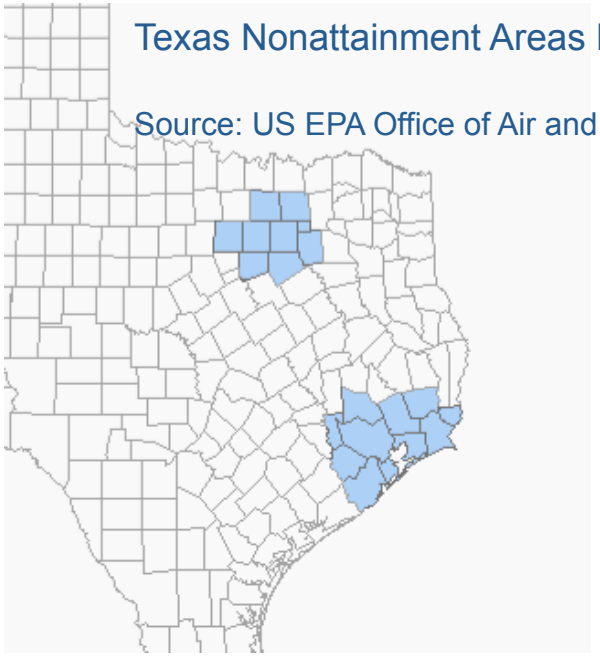
Research Objectives

- Evaluate two different methods for determining the height of the planetary boundary layer (PBL) in meteorological models.
- Test the Asymmetric Convective Model, Version 2 (ACM2) PBL parameterization scheme to see if it can represent convective conditions more accurately than the Eta TKE scheme.



Texas Nonattainment Areas Map – Ozone (8-hour)

Source: US EPA Office of Air and Radiation

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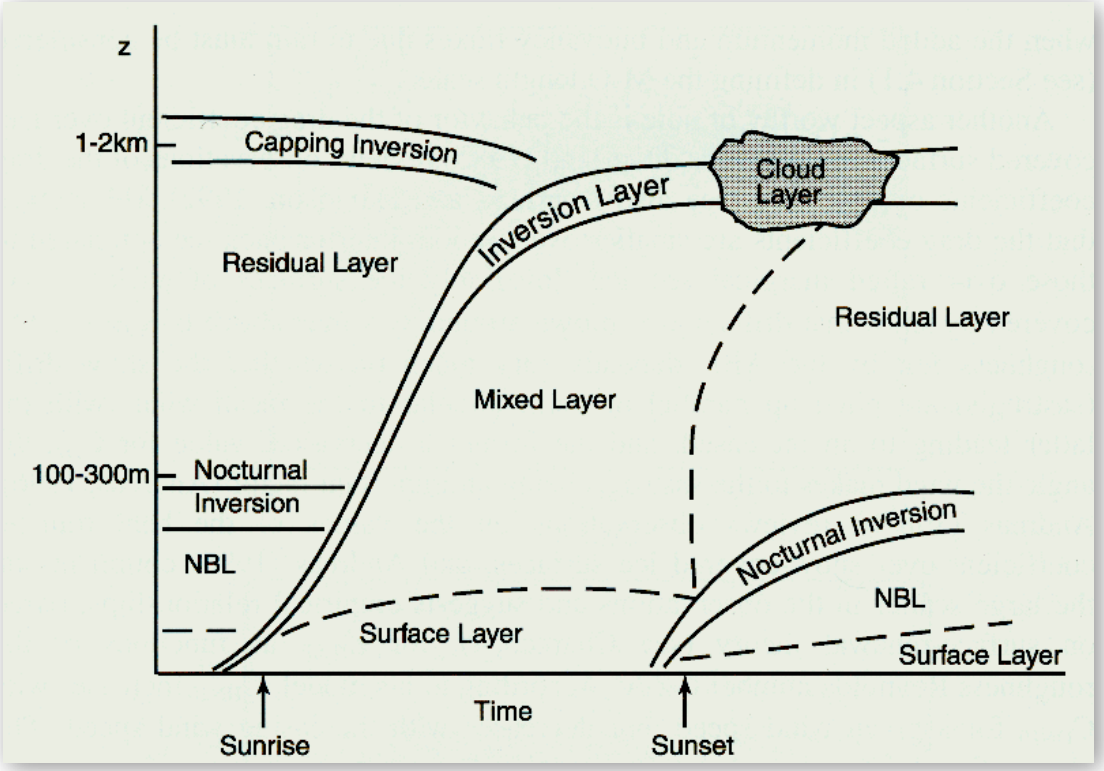
The Planetary Boundary Layer (PBL)

- Directly influenced by Earth's surface
- Thickness is variable in time and space, ranging from a few hundred meters to a few kilometers.



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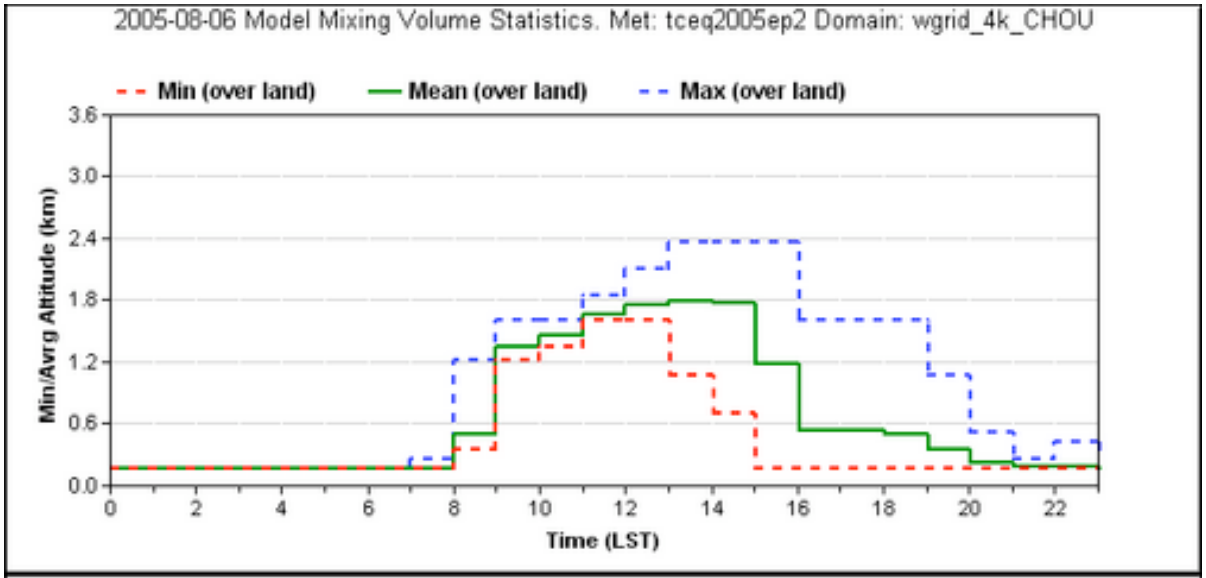
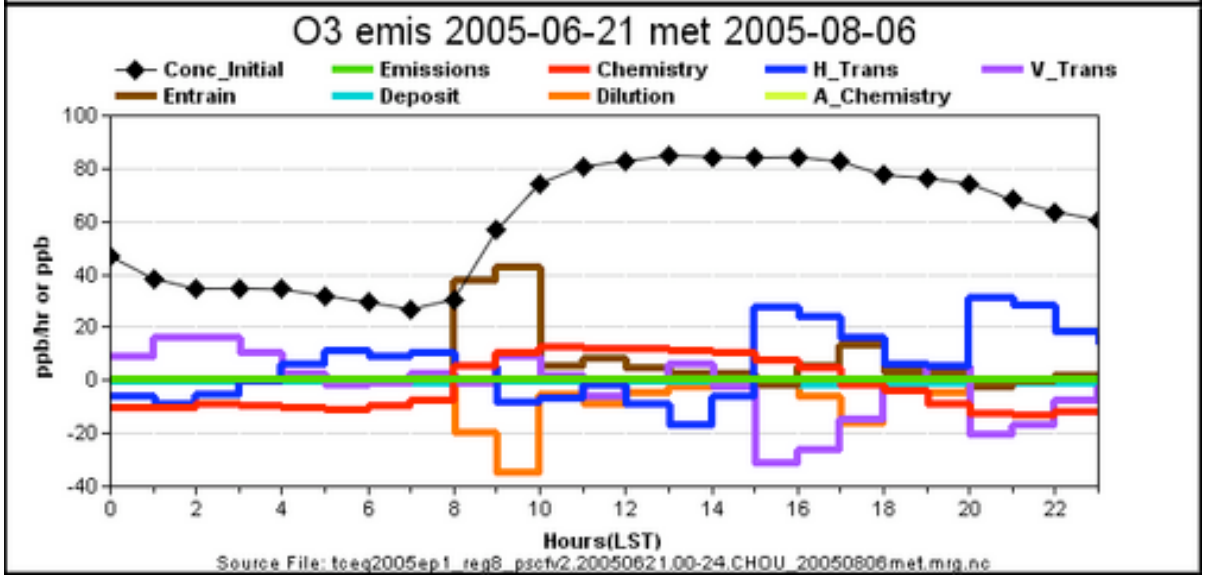
Influence of the PBL on Ozone

- PBL height defines the volume of air into which pollution from surface sources is well mixed.
- Vertical mixing within the PBL during the morning and early afternoon hours can have a variety of effects on ground level ozone concentrations.
- Rapid growth of the morning PBL:
  - dilutes freshly emitted precursors at the ground level.
  - leads to entrainment of aged pollutants from the free troposphere.

PBL Effects on Ozone Modeling in Eastern Texas



MMV Height



[O_3] and Production Pathways

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Modeling the PBL

- The PBL height is computed in the meteorology model by the PBL parameterization scheme, which determines the vertical structure of winds, temperature, and humidity.
- The large range of atmospheric turbulence scales present during convective conditions makes it difficult to accurately predict the timing and magnitude of the rise of the PBL.
- Previous PBL schemes are unable to resolve these turbulent scales of motion, e.g.:
  - Local eddy diffusion schemes assume that all of the turbulence is sub-grid.
  - Simple non-local closure models, represent only large-scale transport driven by convective plumes.

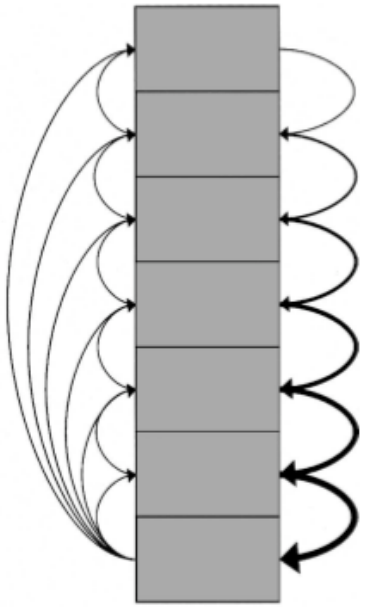
PBL Parameterization Schemes

Eta

- Turbulent kinetic energy scheme with local vertical mixing.
- Previous tests have shown insufficient mixing in the convective boundary layer.

ACM2

- Combines both the local eddy diffusion and nonlocal closure components.
- Should be able to represent convective conditions more accurately and thus more accurately predict the rise of the PBL.



ACM2

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Model Configuration

Episode Period: August 13, 2006 – October 11, 2006

Location: Eastern Texas

4 km horizontal grid resolution

Hourly PBL heights

Model Types

- Weather Research and Forecasting Model (WRF) - V3.1
  - PBL Scheme: ACM2
- Fifth-Generation NCAR Mesoscale Model (MM5) – V3
  - PBL Scheme: Eta
  - Used for Houston Ozone Attainment SIP

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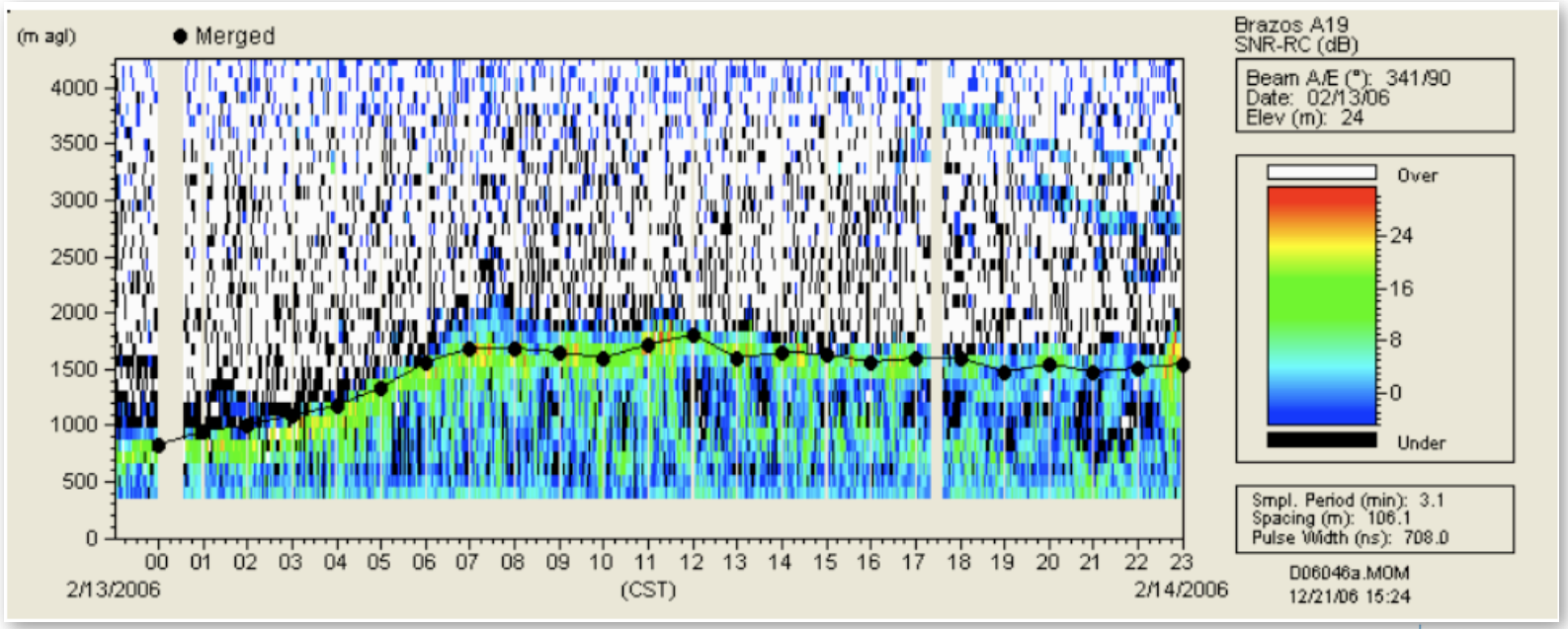
PBL Scheme Evaluation

- Radar Wind Profilers (RWPs)
  - Time-height signal-to-noise ratio data from the radar wind profilers were used to estimate the hourly height of the daytime surface-based mixed layer.



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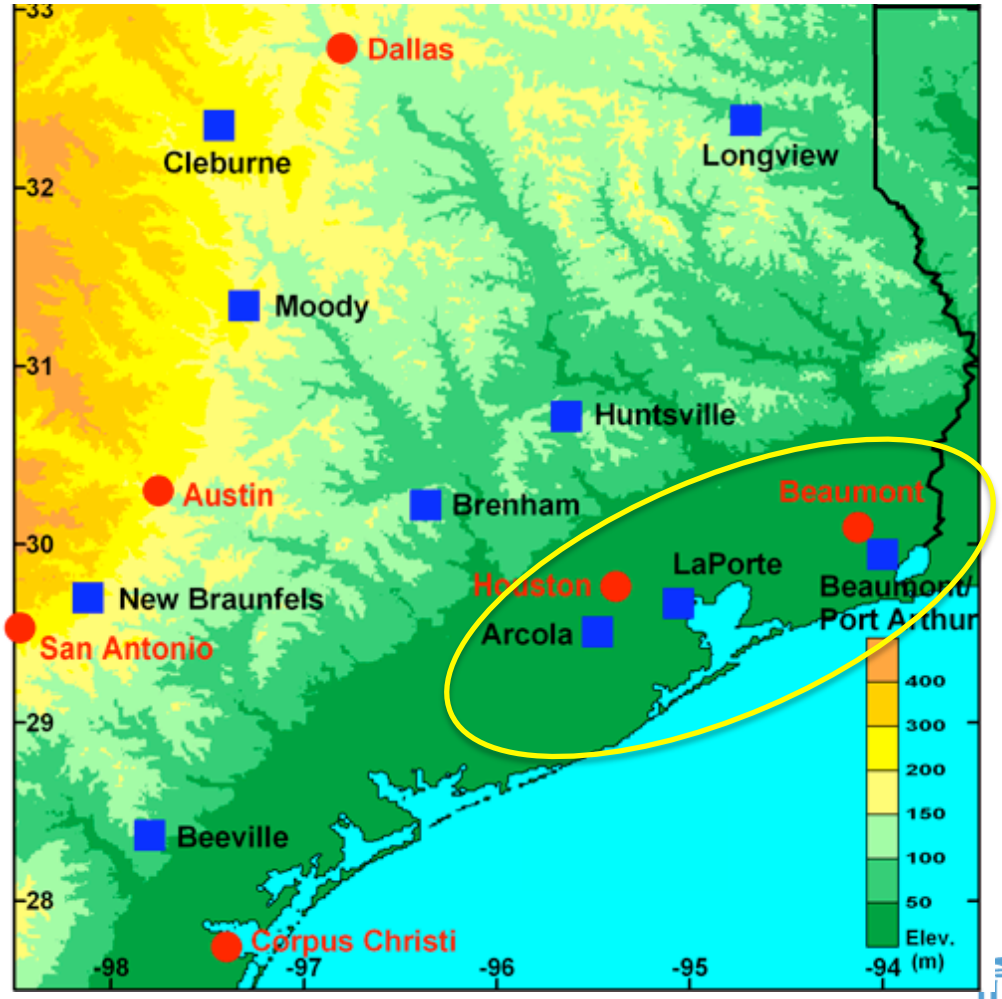
Results

Radar Wind Profiler Sites



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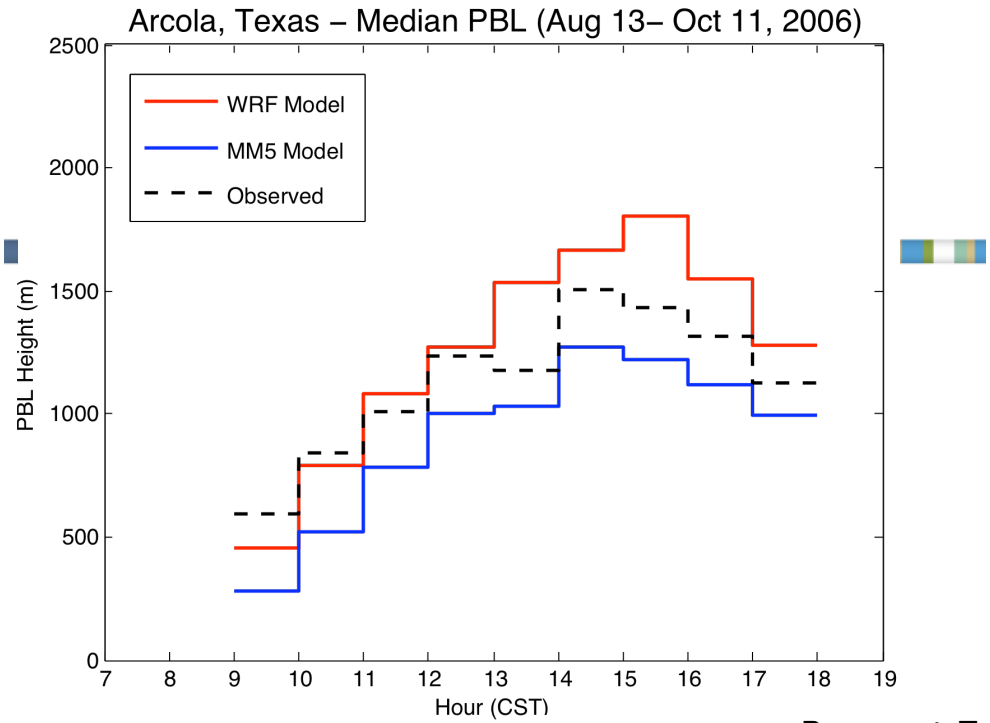

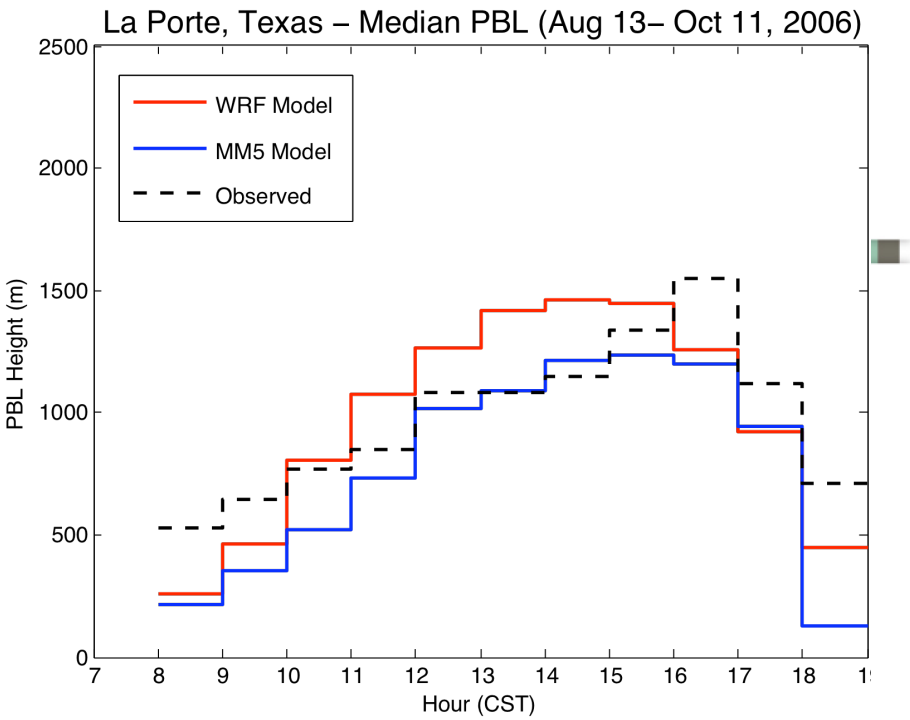

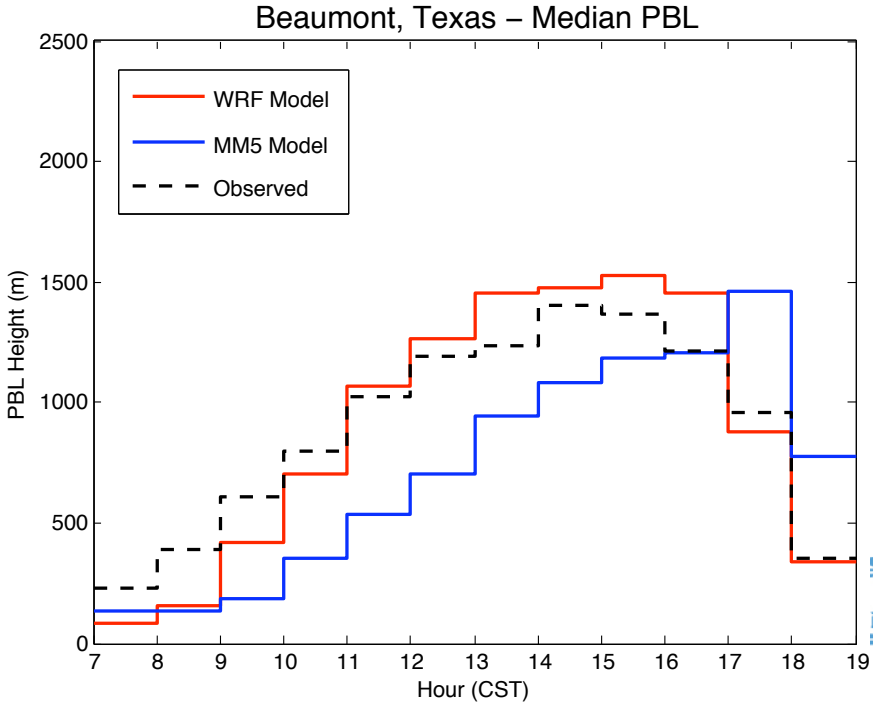

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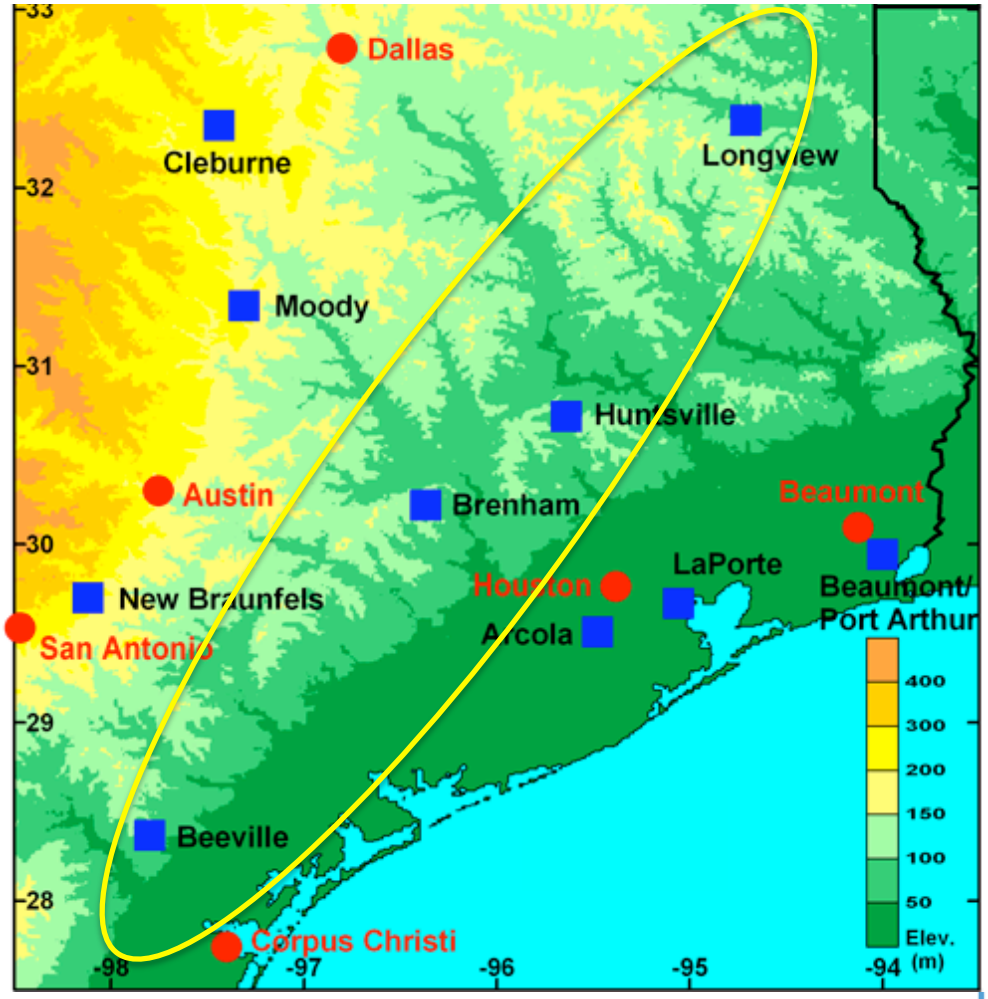
Radar Wind Profiler Sites



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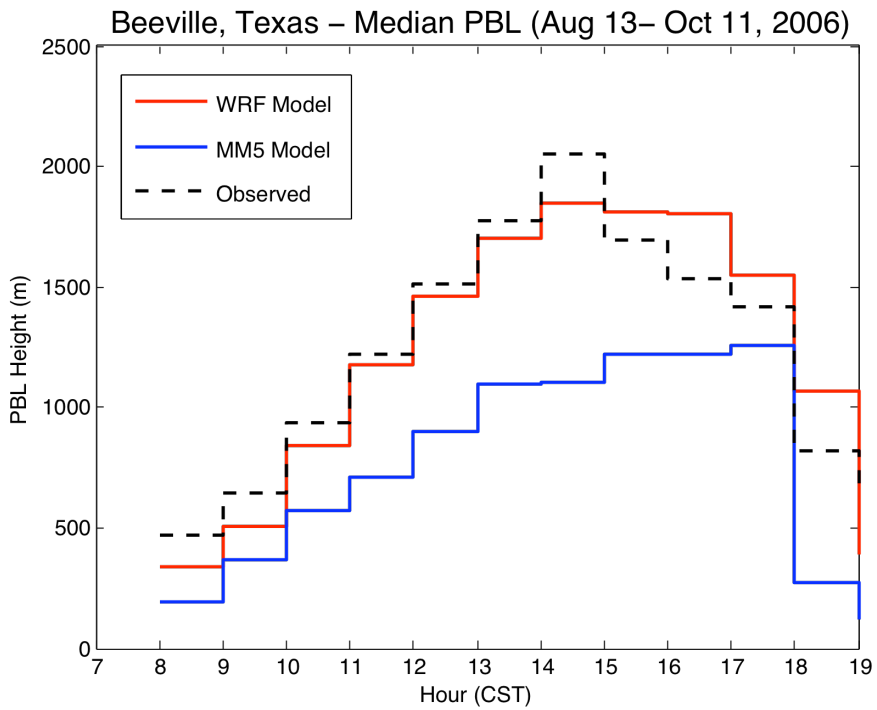
Beeville, Texas – Median PBL (Aug 13– Oct 11, 2006)
WRF Model
MM5 Model
Observed
PBL Height (m)
Hour (CST)
0
500
1000
1500
2000
2500
7
8
9
10
11
12
13
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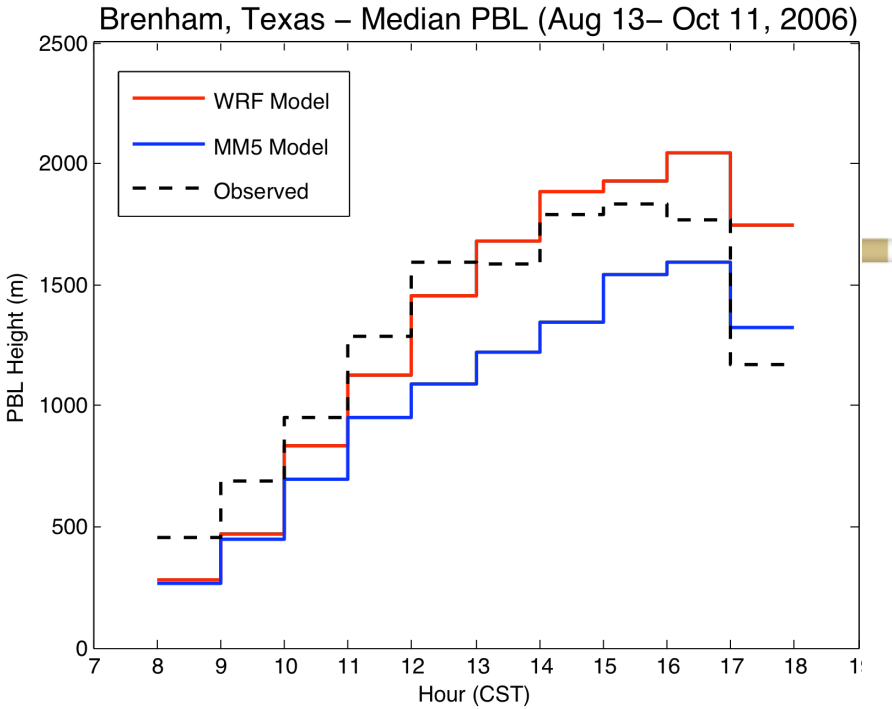
Brenham, Texas – Median PBL (Aug 13– Oct 11, 2006)
WRF Model
MM5 Model
Observed
PBL Height (m)
Hour (CST)
0
500
1000
1500
2000
2500
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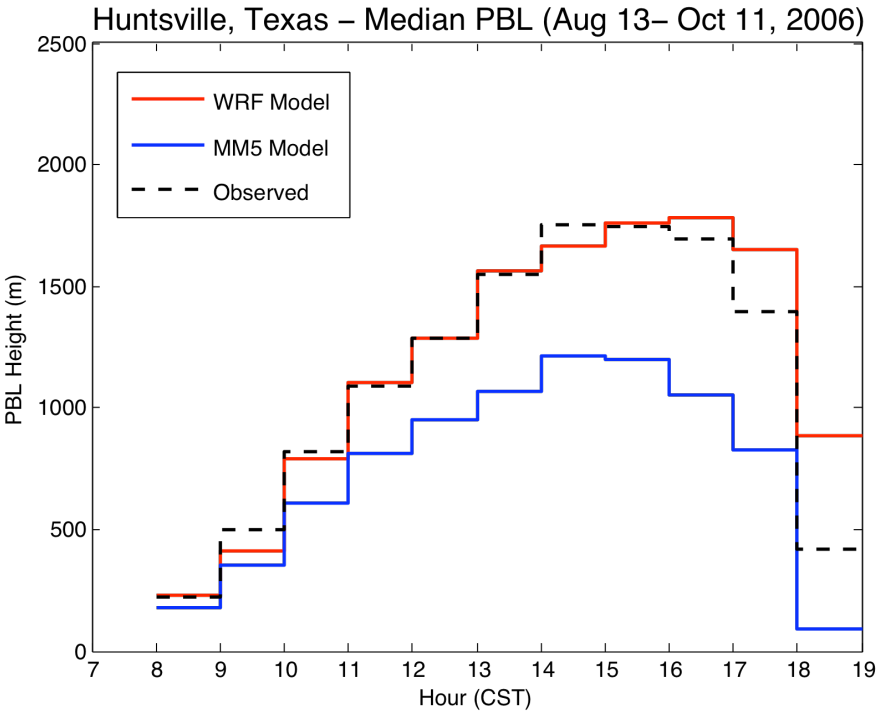
Huntsville, Texas – Median PBL (Aug 13– Oct 11, 2006)
WRF Model
MM5 Model
Observed
PBL Height (m)
Hour (CST)
0
500
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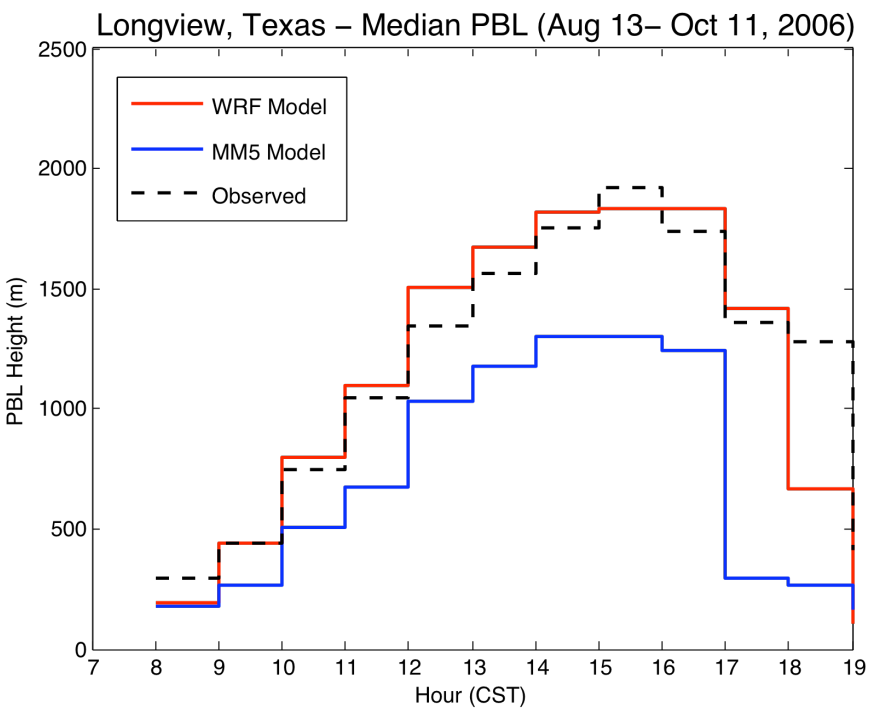
Longview, Texas – Median PBL (Aug 13– Oct 11, 2006)
WRF Model
MM5 Model
Observed
PBL Height (m)
Hour (CST)
0
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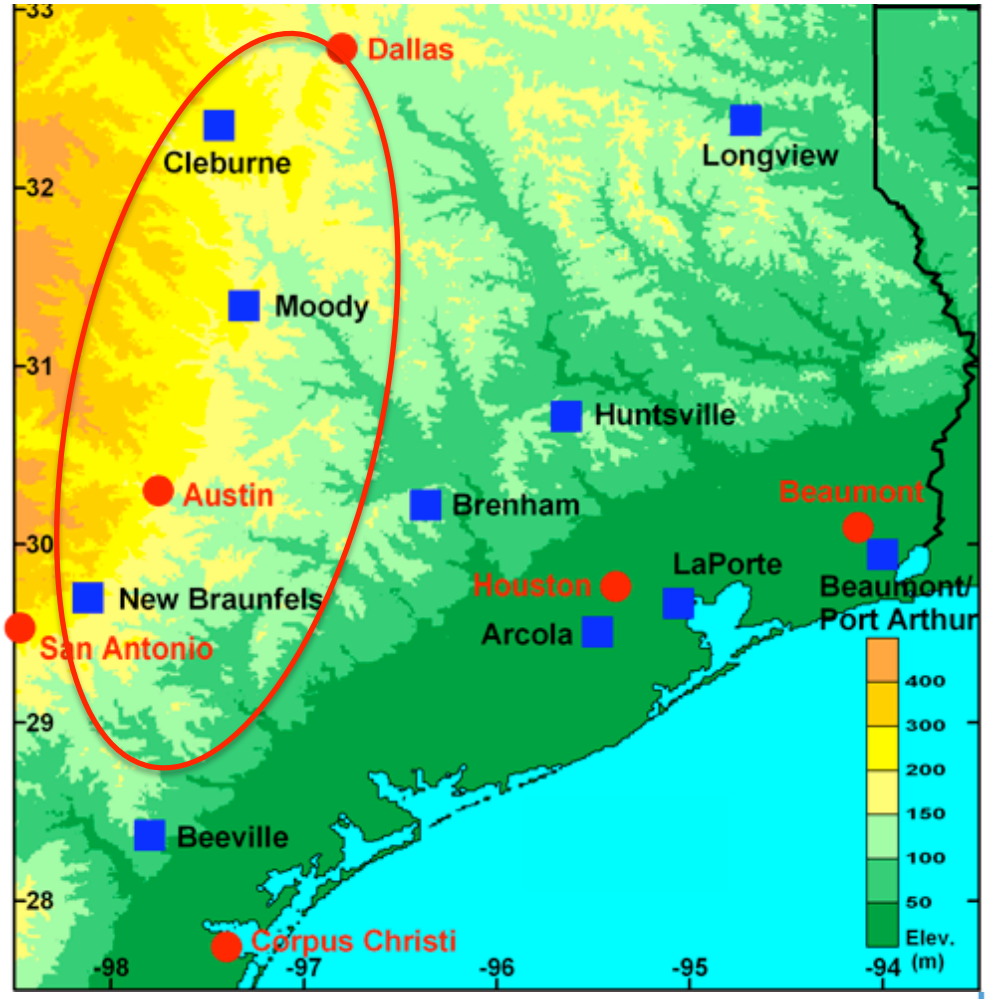
Radar Wind Profiler Sites



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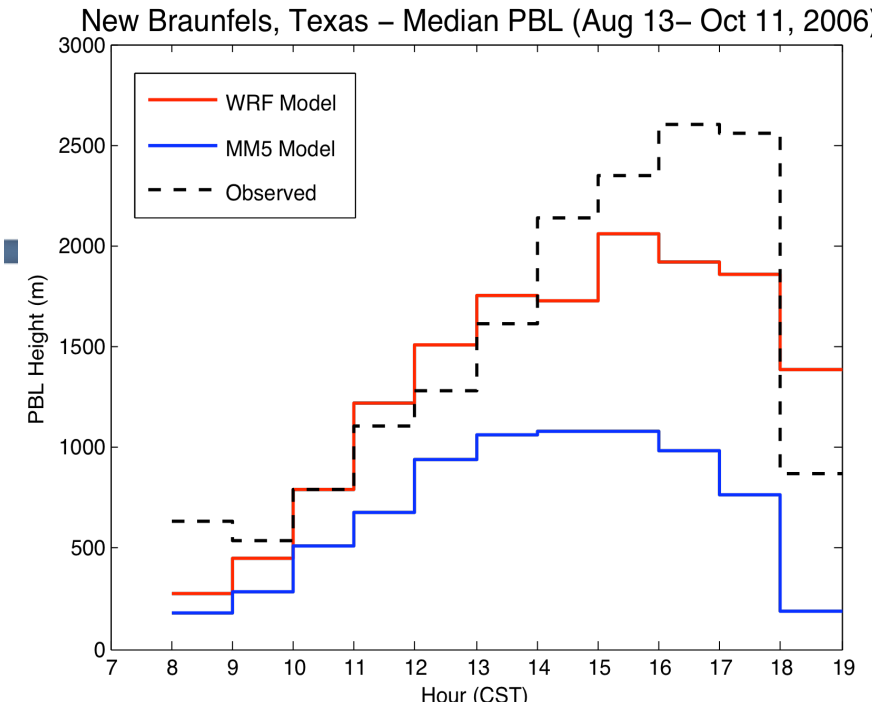

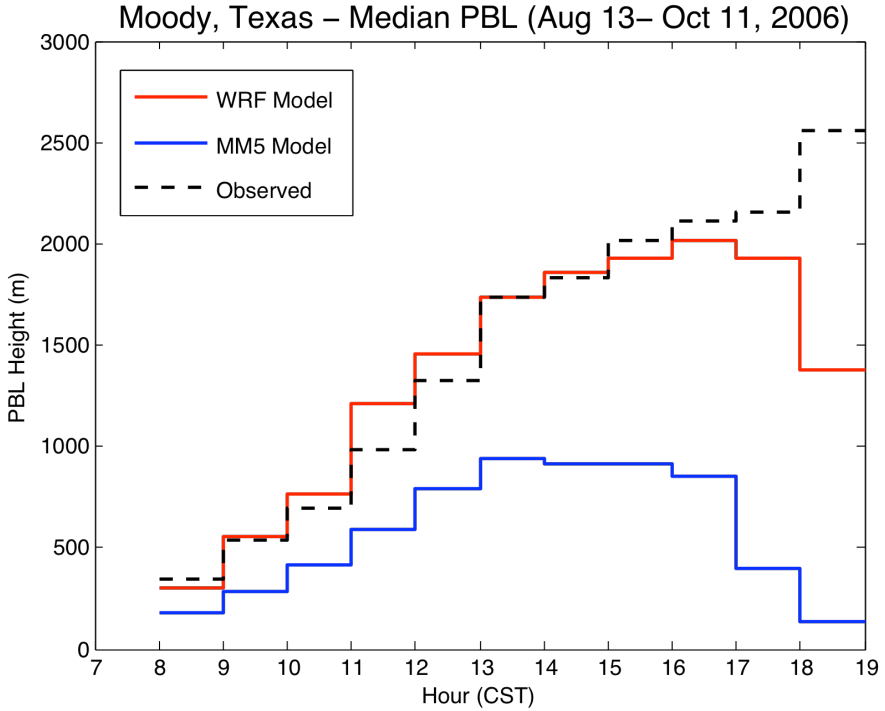

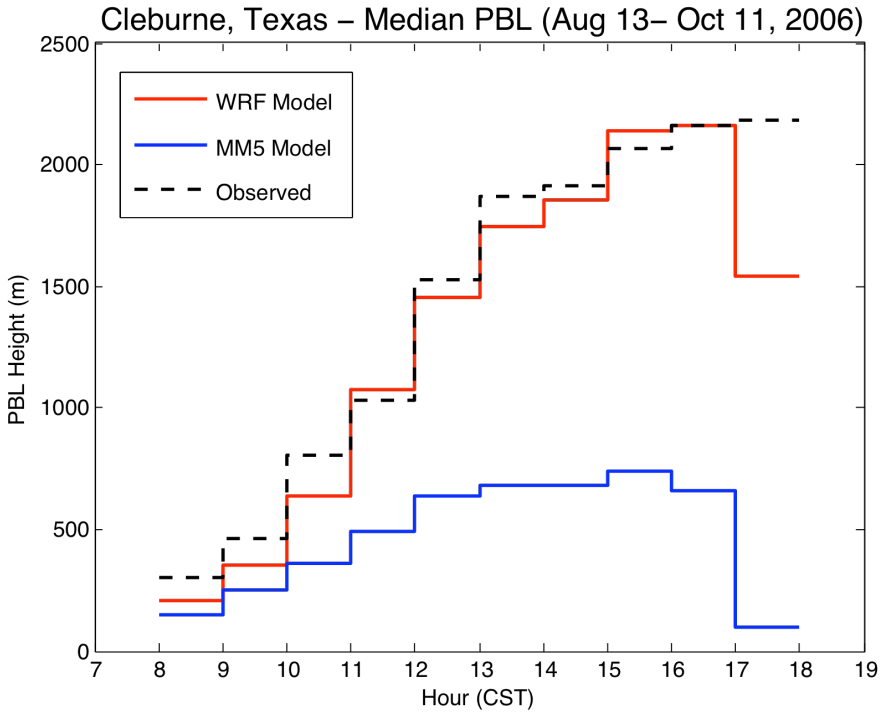

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Preliminary Findings

- For the 4km East Texas domain, WRF/ACM2 is able to predict much more accurate hourly median PBLs when compared to the MM5/Eta combination.
- The WRF/ACM2 model was much more accurate than the MM5/Eta model at predicting the diurnal evolution of the PBL for the 7 inland sites in Eastern Texas.
- For the 3 sites located closest to the Gulf of Mexico, the WRF/ACM2 model was more accurate at predicting the morning rise of the PBL, however it slightly over-predicted the afternoon peak of the PBL.

Future Work

- Calculate the average error and mean bias for both Met/PBL combinations.
- Expand evaluation to include more PBL height observations taken during TexAQSII including PBLs measured from a ground-based Lidar and rawinsonde balloons launched several times a day.
- Look at specific days where PBL rose rapidly to evaluate PBL schemes during convective conditions.
- Evaluate the use of WRF/ACM2 in CMAQ to see how PBL heights translate into MMVs and how ozone concentrations are affected.

Acknowledgements

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Questions?

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