Test of revised YSU PBL model within WRF-Chem model

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Outline

1. Introduction of revised YSU stable BL

2. Difference between YSU-STBL and YSU-CTRL model simulations (27 km x 27km horizontal resolution & RACM-ESRL chemistry) : horizontal distribution

3. Ron Brown ship measurements v.s. model simulations (NEAQS04)

4. NOAA P3 aircraft, surface network O_3 and PM2.5 observations v.s. model simulations (NEAQS04)

5. Summary

Revised YSU stable BL model (YSU-STBL)

YSU-CTRL: Old YSU stable model

Hong et al., 2006, MWR

Available up to WRFV2.2

Diffusivity for free atmosphere (Louis, 1979) is used for stable BL.

$$K_m = l^2 f_{m,t}(Rig)\left(\frac{\partial U}{\partial z}\right)$$

$$l : mixing\ length, f_{m,t}(Rig) : stability\ function, \left(\frac{\partial U}{\partial z}\right) : vertical\ wind\ shear$$

$$\frac{1}{l} = \frac{1}{kz} + \frac{1}{\lambda_0}$$

$$k : von\ karman\ constant, z : height, \lambda_0 : asymptotic\ lengths\ cale\ (= 30m)$$

No definition of stable BL height h

Revised YSU stable BL model (YSU-STBL)

YSU-STBL: New YSU stable model

Paper in preparation

Available starting from WRFV3

Once stable BL height is determined, prescribed parabolic function for diffusivity is used as in unstable BL.

Stable BL height is determined based on critical Richardson number (Rib_{cr}) partly similar to Vickers and Mahrt, 2004, JAM.

Over the ocean, $Rib_{cr} = 0.16(10^{-7} R_0)^{-0.18}, R_0 : surface\ Rossby\ number$
Over the land, $Rib_{cr} = 0.25$

Here, PBL height h is defined as

$$h = Rib_{cr} \frac{\theta_{va} |U(h)|^2}{g(\theta_v(h) - \theta_s)}, \theta_{va} : virtual\ potential\ temperature\ at\ the\ lowest\ \mathrm{model}\ level,$$

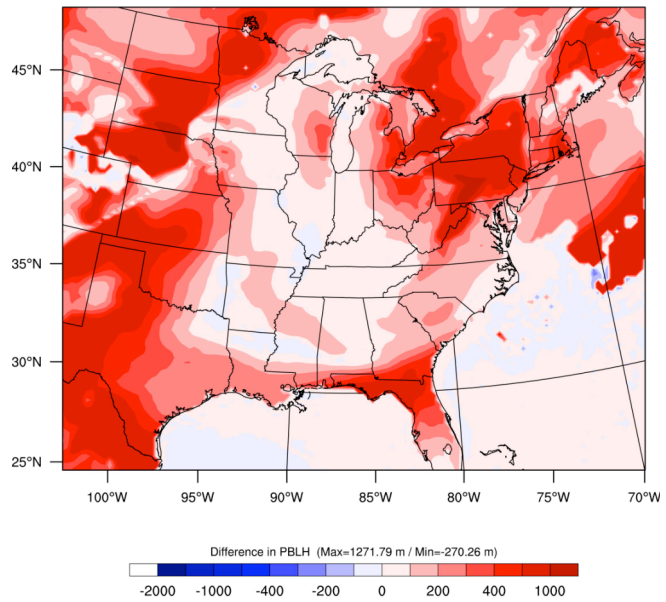
$U(h) : horizontal\ wind\ speed\ at\ h, \theta_v(h) : virtual\ potential\ temperature\ at\ h,$

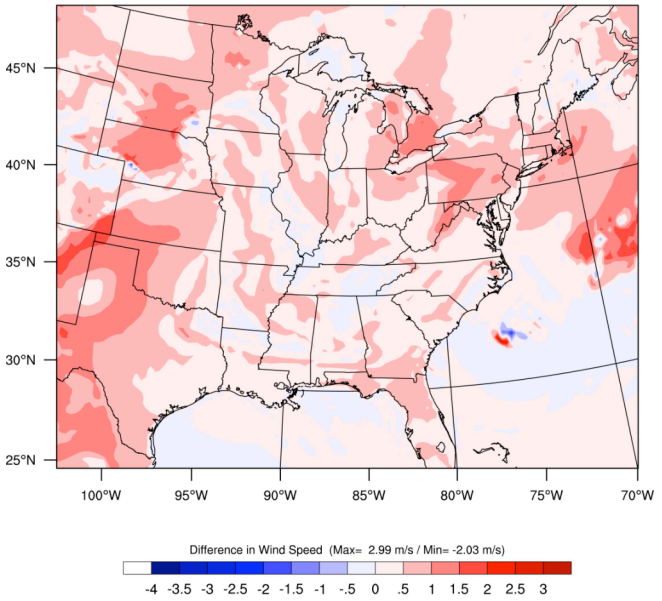
$\theta_s : appropriate\ temperature\ at\ surface.$

STBL-CTRL: Met. Variables at 04 UTC (00 EDT)

Jul/16/2004

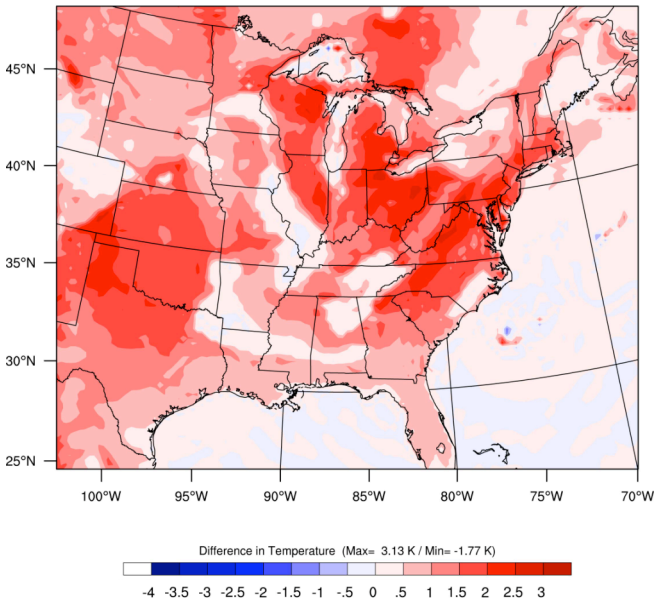
PBL Height

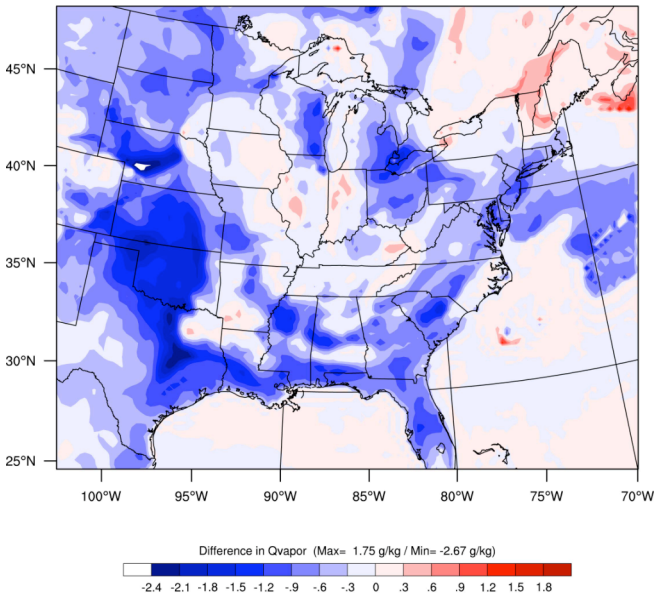




Surface Wind speed

Surface Temp.



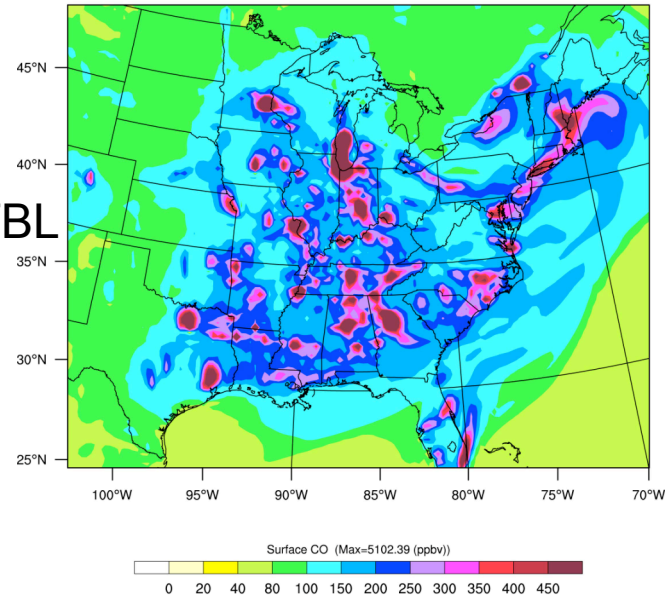


Surface Qvapor

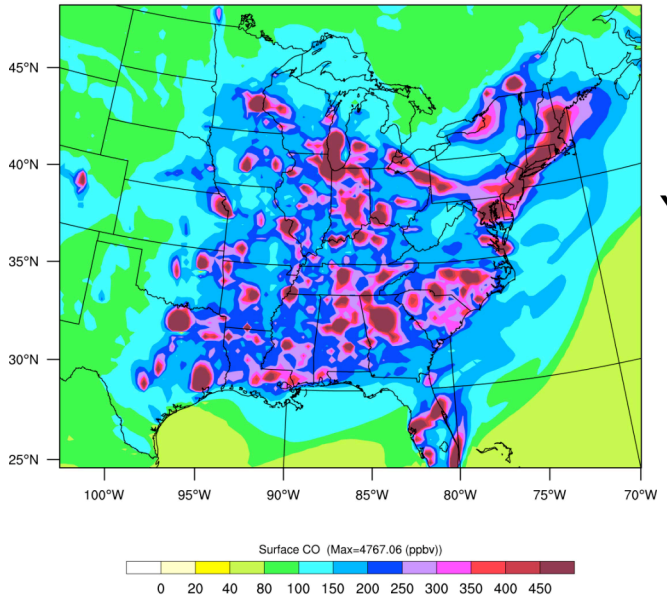
STBL-CTRL: CO at 04 UTC (00 EDT)

Jul/16/2004

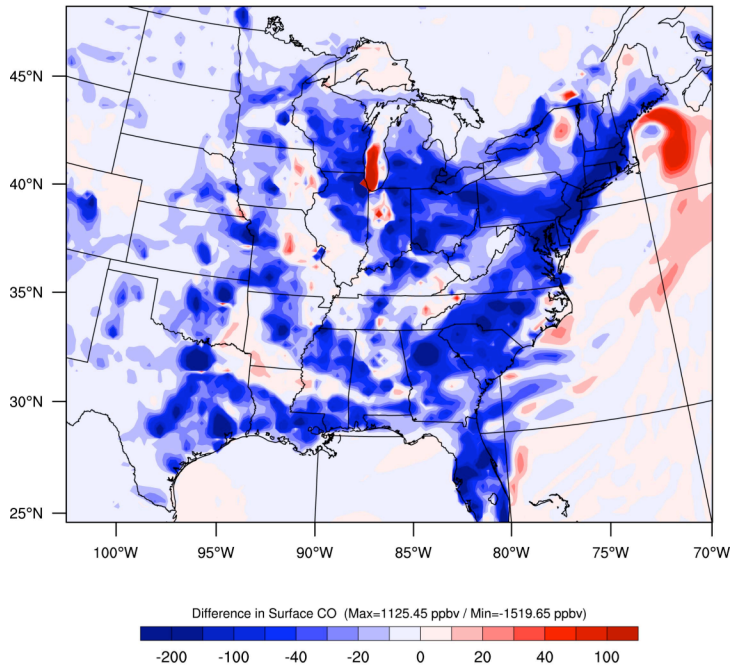
YSU-STBL



YSU-CTRL



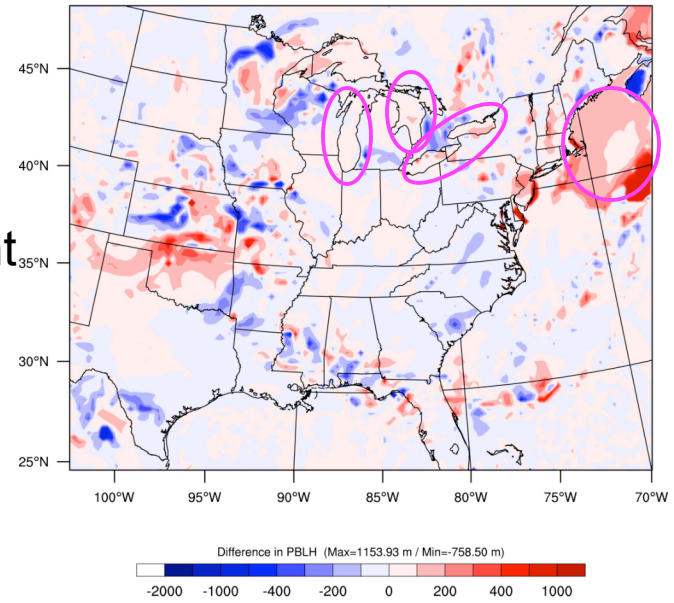
Difference
= STBL-CTRL

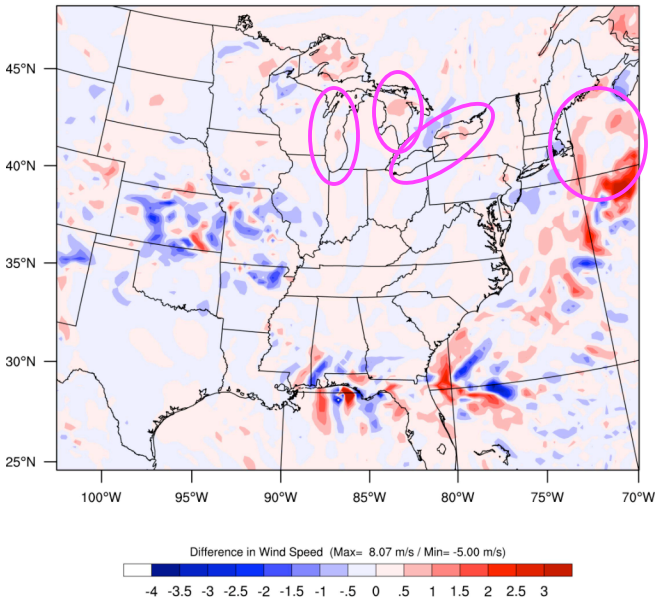


STBL-CTRL: Met. Variables at 16 UTC (12 EDT)

Jul/16/2004

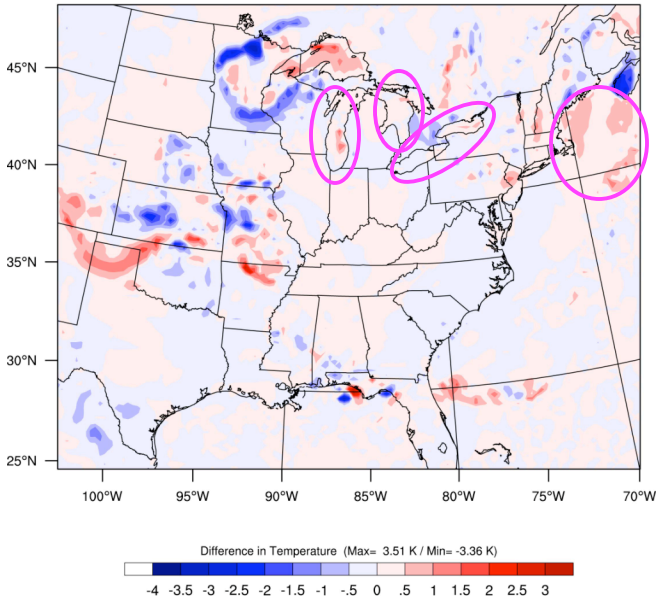
PBL Height

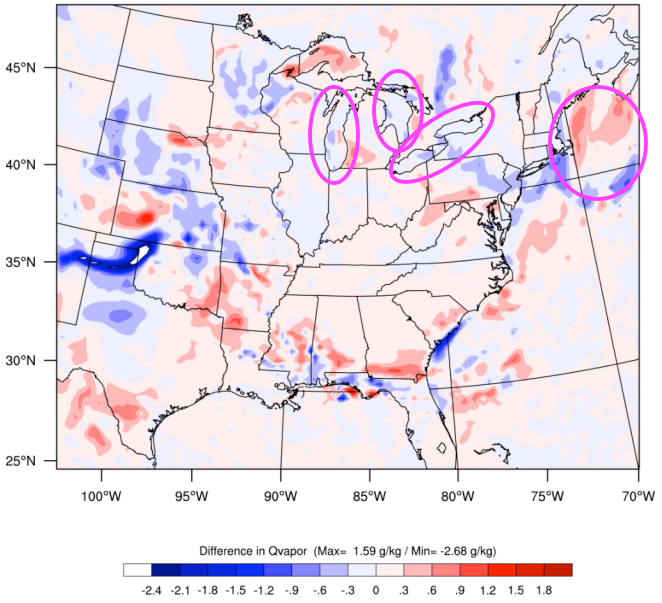




Surface Wind speed

Surface Temp.



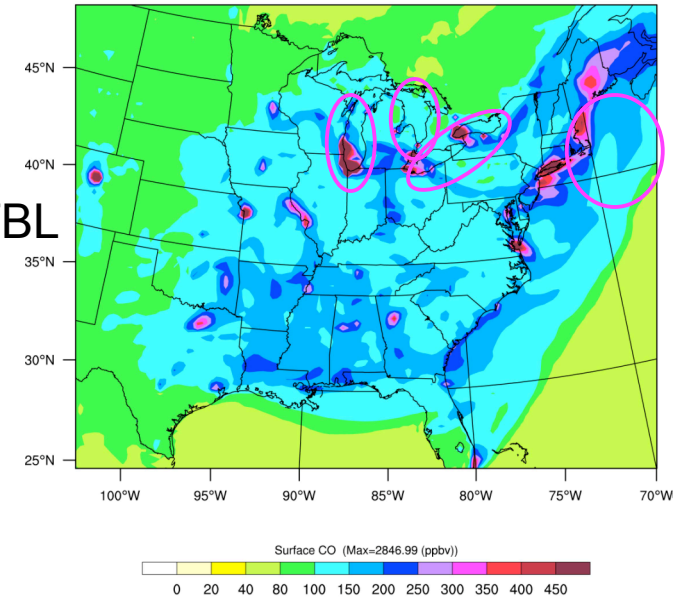


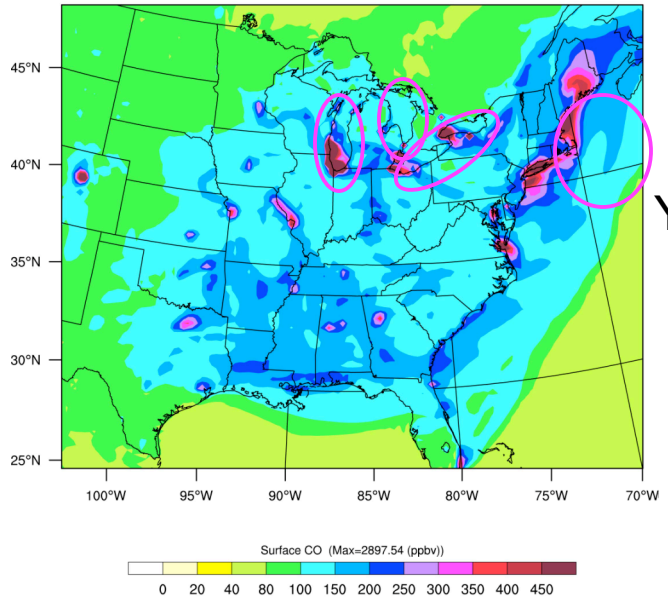
Surface Qvapor

STBL-CTRL: CO at 16 UTC (12 EDT)

Jul/16/2004

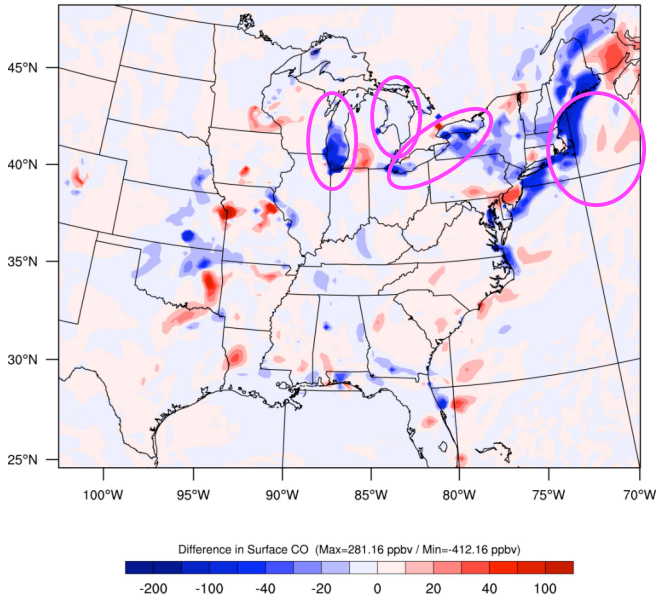
YSU-STBL

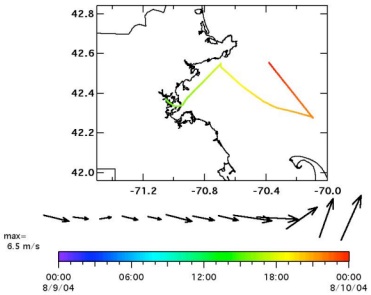




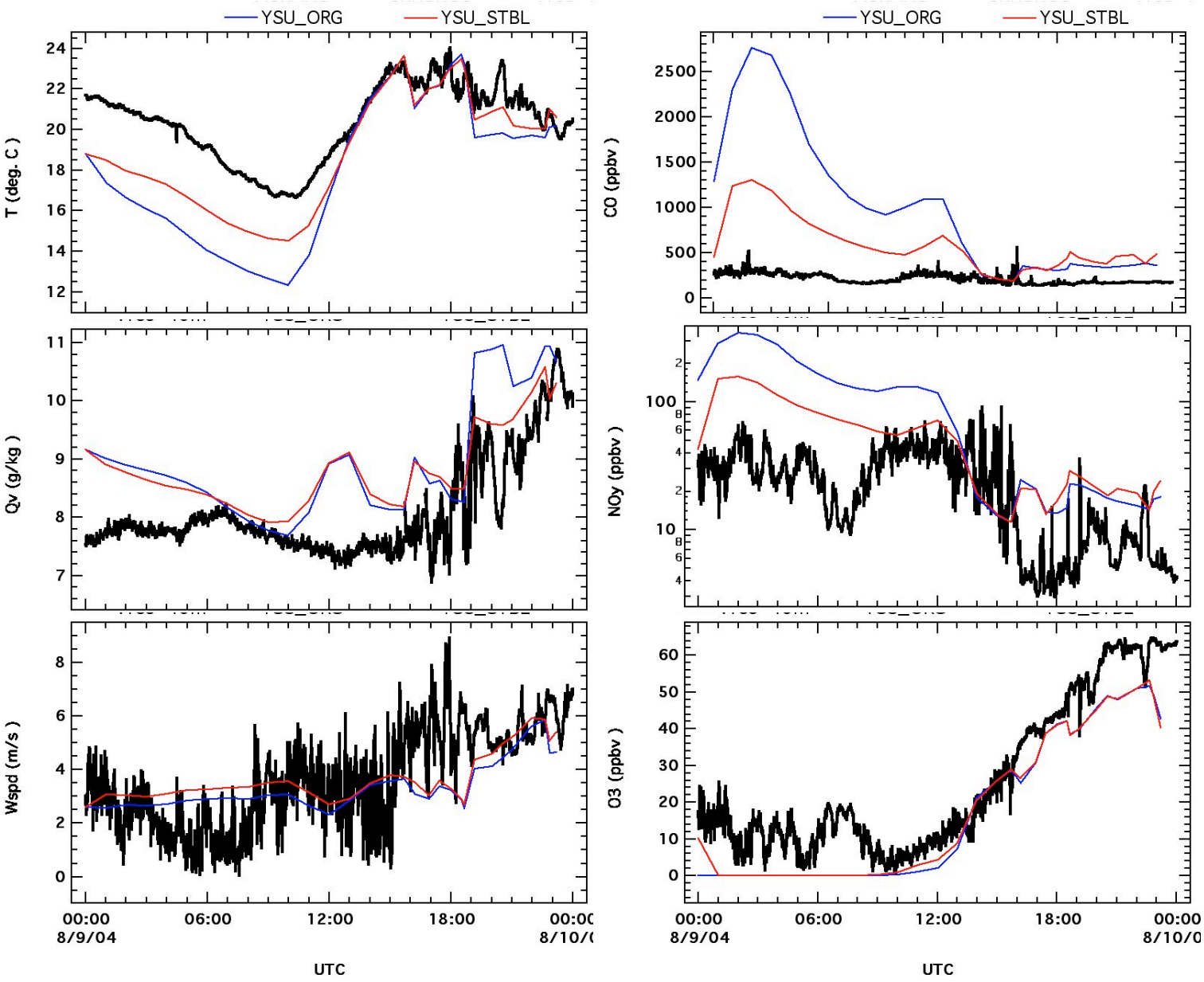
YSU-CTRL

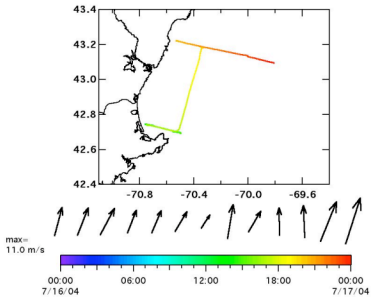
Difference
= STBL-CTRL



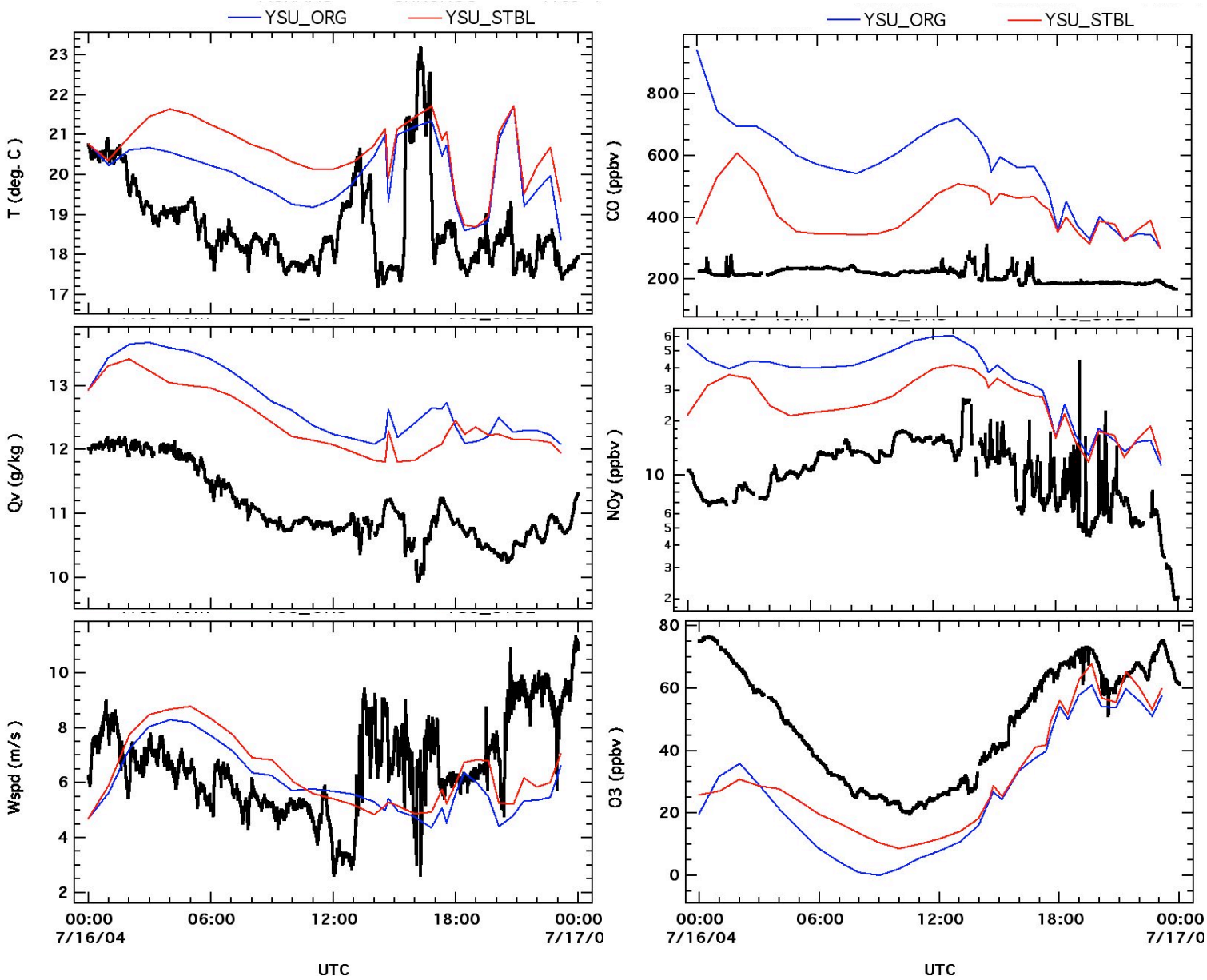


Ron Brown Measurements v.s. Model: Aug./9/2004

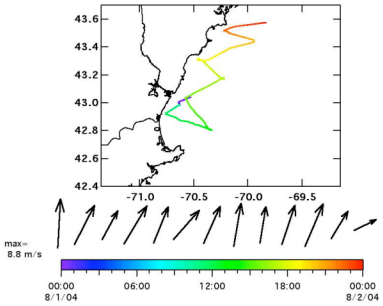


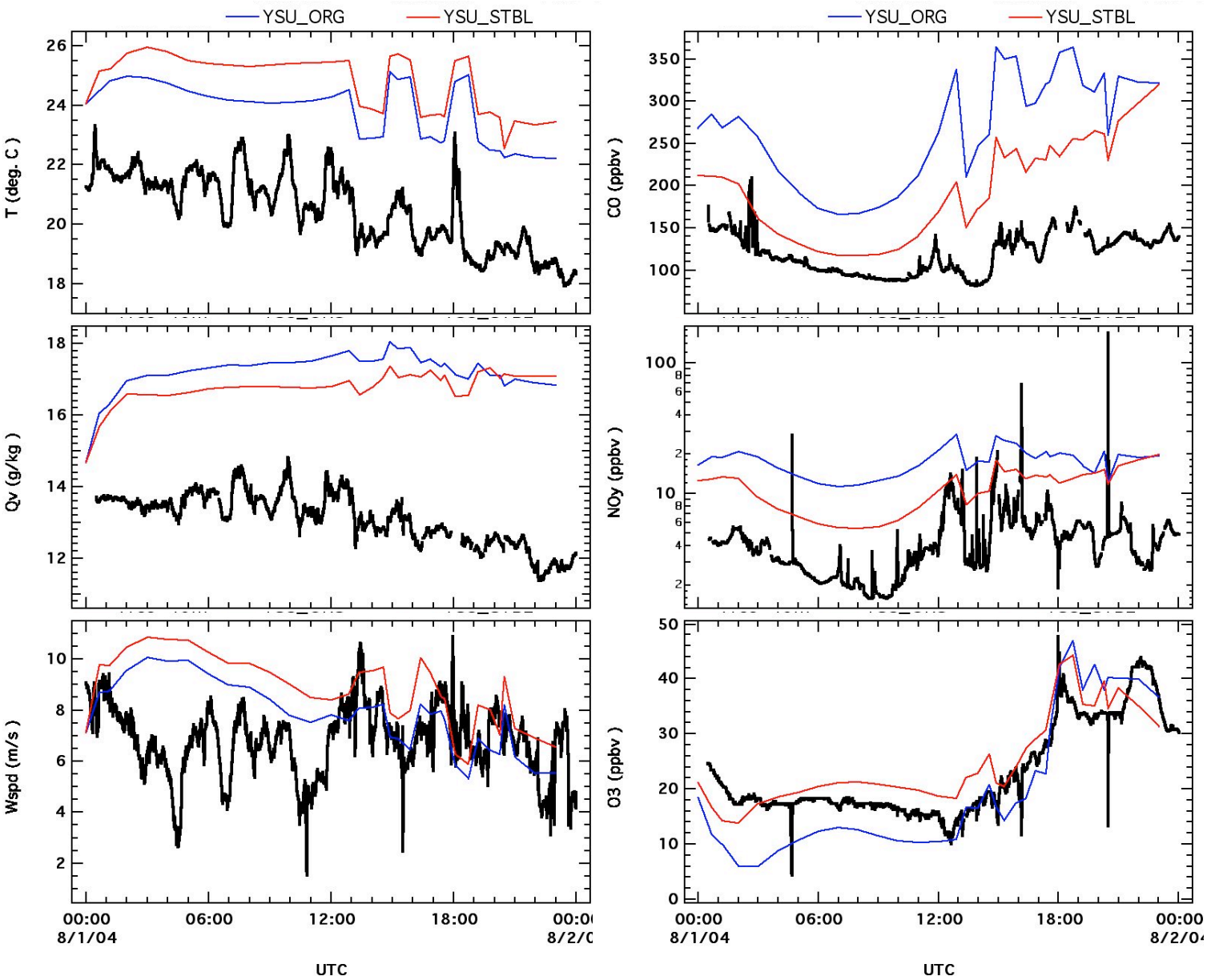


Ron Brown Measurements v.s. Model: July/16/2004



Ron Brown Measurements v.s. Model: Aug./1/2004





Effects of new YSU stable regime treatment on WRF/Chem chemistry/aerosol (Comparisons made for the ICARTT/NEAQS 2004 field study)

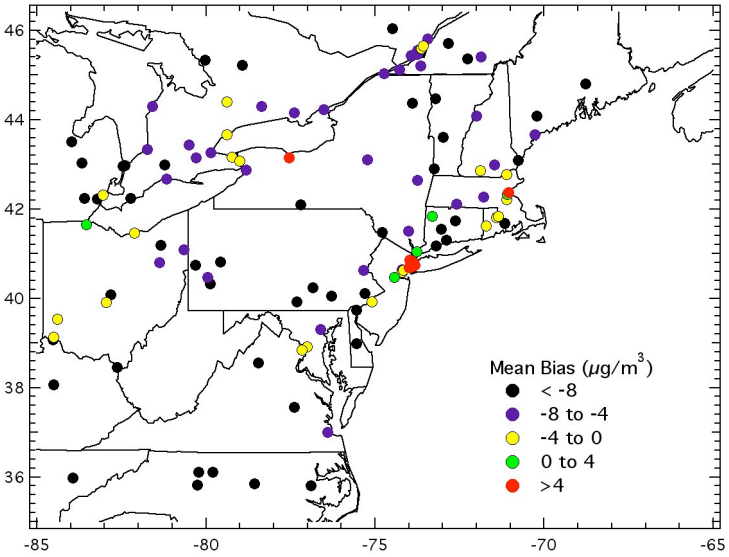
From NOAA P-3 aircraft comparisons:
Daytime, gas-phase, upper-air - **very minor**

From AIRNow surface O3 network:
Max. 8-hr average surface O_3 - **very minor**

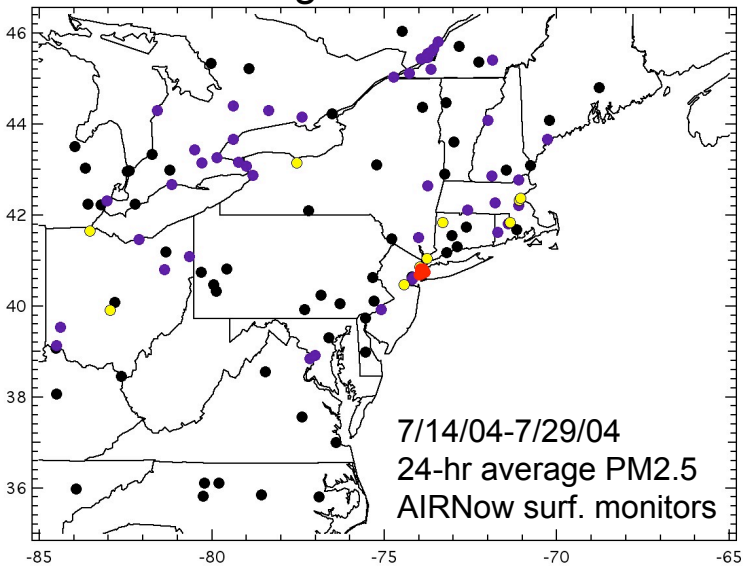
From AIRNow surface PM2.5 monitor network:
24-hr average surface PM2.5 - **significant**

(medians)	Original:	New Stable Case:
Mean Bias (μg/m^3)	-7.8	-6.3
RMSE (μg/m^3)	11.92	11.32

New YSU stable case



Original YSU



Summary

1. Revised YSU stable BL increases stable boundary layer height by introducing different critical Richardson number in stable regime.

2. YSU-STBL gives enhanced mixing compared to YSU-CTRL at nighttime over land and at daytime over lakes or part of ocean: Warmer and drier surface & stronger wind condition in YSU-STBL.

3. Compared to Ron Brown ship measurements, improved model simulations of chemical species with YSU-STBL.

4. No effect on daytime gas-phase chemistry, but significant improvement to 24-hr avg. PM2.5 forecasts

5. Further statistical analysis is planned.