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.

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

- \( l \): mixing length, \( f_{m,t}(\text{Rig}) \): 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 parabola\( \text{function} \) for diffusivity is used as in unstable BL.

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

\[
\text{Over the ocean, } \text{Rib}_{cr} = 0.16(10^{-7} R_0)^{-0.18}, \quad R_0 : \text{surface Rossby number}
\]
\[
\text{Over the land, } \text{Rib}_{cr} = 0.25
\]

Here, PBL height \( h \) is defined as

\[
h = \text{Rib}_{cr} \frac{\theta_{va} |U(h)|^2}{g(\theta_v(h) - \theta_s)}, \quad \theta_{va} : \text{virtual potential temperature at the lowest model level},
\]

\( U(h) : \text{horizontal wind speed at } h, \theta_v(h) : \text{virtual potential temperature at } h, \)

\( \theta_s : \text{appropriate temperature at surface.} \)
STBL-CTRL: Met. Variables at 04 UTC (00 EDT)

- PBL Height
- Surface Temp.
- Surface Wind speed
- Surface Qvapor
STBL-CTRL: CO at 04 UTC (00 EDT)

YSU-STBL

YSU-CTRL

Difference = STBL-CTRL

Jul/16/2004
STBL-CTRL: Met. Variables at 16 UTC (12 EDT)

Jul/16/2004

Surface
Wind speed

Surface
Temp.

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

YSU-CTRL

YSU-STBL

Jul/16/2004

Difference = STBL-CTRL
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

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<thead>
<tr>
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<th>Original:</th>
<th>New Stable Case:</th>
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<tbody>
<tr>
<td>Mean Bias ($\mu g/m^3$)</td>
<td>-7.8</td>
<td>-6.3</td>
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<tr>
<td>RMSE ($\mu g/m^3$)</td>
<td>11.92</td>
<td>11.32</td>
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New YSU stable case

Original YSU

7/14/04-7/29/04
24-hr average PM2.5
AIRNow surf. monitors
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.