A Modeling Study of PBL height

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Meteorology 605
Motivation

• PBL parameterization schemes in NWP models need to know the depth through which to mix heat, momentum, moisture, wind etc.

• Many different definitions of PBL height
  – Which is correct?
Experimental setup

- WRF-ARW version 3.1.1
- 16 total simulations
  - Four real-data cases
    - Summer (14 – 16 July 2010)
    - Winter (04 – 06 January 2010)
    - Spring (23 – 25 April 2010)
    - Autumn (19 – 21 October 2010)
  - Four PBL schemes (surface layer scheme)
    - Yonsei University (YSU)
      - Monin-Obukhov
    - Mellor-Yamada-Janji (MYJ)
      - Monin-Obukhov (Janji)
    - Quasi Normal Elimination Scale (QNSE)
      - QNSE
    - Medium Range Forecast (MRF)
      - Monin-Obukhov

- Rapid Update Cycle (RUC) hourly analyses used as “observations”
PBL definitions

- PBL top when the following are exceeded:
  - YSU
    - Critical Bulk Richardson number (Ri): 0.0
  - MRF
    - Critical Ri: 0.5
  - MYJ
    - Minimum of 2*TKE parameter: 0.20
  - QNSE
    - Minimum of 2*TKE parameter: 0.01
  - RUC
    - $T_v > T_{v,sfc} + 0.5 \, K$

\[ Ri = \frac{\Delta \theta_v * \left( \frac{g}{\theta_{vs}} \right) * \Delta z}{\max \{ U^2 + V^2, 1 \}} \]
Experimental setup

• Initialized at 0000 UTC
• Run for 60 hours
• GFS ICs/LBCs

• 325 x 249 x 27 grid points
• dx = dy = 20 km
• dt = 100 s
• Ferrier microphysics
• Kain-Fritsch convection
  – cudt = 5 min
Experimental setup

• Four analysis regions
  – “Southeast”
    • 94°-82° W lon., 31°-38° N lat.
  – “Midwest and Plains”
    • 103°-88° W lon., 34°-46° N lat.
  – “Intermountain West”
    • 118°-105° W lon., 34°-42° N lat.
  – “Gulf”
    • 96°-85° W lon., 22°-28° N lat.
Summer case – water vapor
Winter case – water vapor
Spring case – water vapor
Autumn case – water vapor
Results

- Case
- Region
summer case — PBL height by region

midwest/plains

PBL height (m)

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000

14JUL 2010 16JUL 06Z 12Z 06Z 12Z 06Z 12Z 06Z 12Z

gulf

PBL height (m)

0 500 1000 1500 2000 2500 3000 3500 4000 4500

14JUL 2010 16JUL 06Z 12Z 06Z 12Z 06Z 12Z 06Z 12Z

southeast

PBL height (m)

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000

14JUL 2010 16JUL 06Z 12Z 06Z 12Z 06Z 12Z 06Z 12Z

intermountain west

PBL height (m)

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000

14JUL 2010 16JUL 06Z 12Z 06Z 12Z 06Z 12Z 06Z 12Z

black: YSU   blue: MRF   green: QNSE   red: MYJ   purple: RUC
winter case – PBL height by region

black: YSU | blue: MRF | green: QNSE | red: MYJ | purple: RUC

Midwest/Plains

Culf

Southeast

Intermountain West

PBL height (m)

06Z 12Z 18Z 06Z 12Z 18Z 06Z 06Z 12Z
4JAN 5JAN 6JAN 2010
spring case - PBL height by region

black: YSU | blue: MRF | green: QNSE | red: MYJ | purple: RUC

Midwest/Plains

Culf

Southeast

Intermountain West

PBL height (m)

06Z 12Z 18Z 00Z 06Z 12Z 00Z 06Z 12Z

23APR 2010 24APR 25APR 06Z 06Z 12Z
autumn case - PBL height by region
black: YSU | blue: MRF | green: QNSE | red: MYJ | purple: RUC

Midwest/Plains

Culf

Southeast

Intermountain West
Results

- Region
- Case
Gulf – PBL height by scheme

black: summer | blue: spring | green: autumn | red: winter
Intermountain West – PBL height by scheme

black: summer  |  blue: spring  |  green: autumn  |  red: winter

MYJ

PBL height (m)

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000

01Z 06Z 11Z 16Z 21Z

MRF

PBL height (m)

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000

01Z 06Z 11Z 16Z 21Z

YSU

PBL height (m)

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000

01Z 06Z 11Z 16Z 21Z

QNSE

PBL height (m)

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000

01Z 06Z 11Z 16Z 21Z
Results

Areal, by case
autumn PBL height errors

MYJ

MRF

YSU

QNSE

416.0

-95.0

37.9

719.0
Discussion

• MRF and YSU schemes better overall
    • Not in this study
  • Pleim (2007b): MRF can over mix, resulting in too deep, too dry, too warm BL
  • G. Thompson (2010, personal communication): YSU scheme produces warm and dry BL, MYJ scheme produces cool and wet BL
summer - Midwest & Plains area-averaged RH - RUC vs. PBL scheme
summer - Gulf area-averaged RH - RUC vs. PBL scheme
Future work

• Computation resource limitations on:
  – Horizontal resolution (4 km?)
  – Domain size
  – Length (3, 4, diurnal cycles or more)

• Use other analysis regions

• Use other PBL schemes

• Alter code so that many different definitions of PBL height are used
  – Compare how the different definitions result in different PBL heights
References

