How does the WRF model capture the intrinsic features of the evening transition boundary layers?

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What is the evening transition?

Definition: the transition from the unstable PBL mode (CBL) to the stable mode (SBL)

Main feature: absence of steady state conditions (a transient state)
Acevedo and Fitzjarrald, 2001

Profiler data
Day 228, 1996

Grimsdell and Angevine, 2002
How did the WRF model perform?

- Radiation Measurements
- Micro-meteorological Observations
- Scintillometry

Bushland Campaign 2008
DBSAS:

\[ C_n^2 \rightarrow C_T^2 \]

\[ L_0 \rightarrow \mathcal{E} \]

Optical measurement of turbulence with Surface Layer Scintillometer

Courtesy: Scintec
Direct Interactions of Parameterizations

Microphysics

Cloud effects

Radiation

Cloud fraction

Surface fluxes

SW, LW

Surface emission/albedo

Downward

PBL

Surface T, Q_v, wind

Cloud detrainment

Cumulus

Shallow Cu, downdrafts from deep Cu

Courtesy: J. Dudhia
WRFs

- A WRF3.1 multi-scale nesting approach was used to explicitly obtain the ET characterization on July 24th 2008 (Case Study, Bushland Observational Campaign)
- Two initializations at 00:00 UTC July 24th 2008:
  - NAM (North American Mesoscale), NCEP Eta 212 grid (40 km)
  - NARR (North American Regional Reanalysis), NCEP Eta 221 grid (32 km)
WRFs (cont…)

- Six ABL parameterizations: YSU, MYJ, ACM2, QNSE, MYNN2, MYNN3
- 6 ABL parameterizations x 2 data initializations
  - = 12 high resolution simulations

<table>
<thead>
<tr>
<th>Parameterization</th>
<th>Mixing Scheme</th>
<th>Entrainment Treatment</th>
<th>PBL Top</th>
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<tbody>
<tr>
<td>YSU</td>
<td>K profile</td>
<td>Explicit</td>
<td>From critical bulk Ri = 0</td>
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<tr>
<td>MYJ</td>
<td>K from TKE</td>
<td>Part of the mixing scheme</td>
<td>From TKE</td>
</tr>
<tr>
<td>ACM2*</td>
<td>up: transilient, down: local K</td>
<td>Part of the mixing scheme</td>
<td>From thermal profile</td>
</tr>
<tr>
<td>QNSE</td>
<td>scale elimination</td>
<td></td>
<td>No single Ri</td>
</tr>
<tr>
<td>MYNN2</td>
<td></td>
<td>They are modifications of MYJ</td>
<td></td>
</tr>
<tr>
<td>MYNN3</td>
<td></td>
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</tr>
</tbody>
</table>

*ACM2 has its own land surface scheme
Case Study
Evening 2008 07 24

Synoptic Conditions
Low pressure center over Southeastern Colorado, frontal boundary over New Mexico

IR Satellite Picture Loop
Fair weather cumulus over the Texas Panhandle
NARR: The ensemble mostly embedded the observation
NARR: The ensemble failed to embed the obs. between 21:00 and 00:00.

As expected the heat flux followed the net radiation lead!

Energy balance at the Earth's surface:

\[ R_{\text{net}} = H + LE + G \]

- \( R_{\text{net}} \): net radiation
- \( H \): sensible heat flux
- \( LE \): latent heat flux
- \( G \): soil / ground heat flux

Energy balance can be used to estimate \( LE \):

\[ LE = R_{\text{net}} - G - H \]
NAM: YSU indicated a strong peak at 22:00; the ensemble mostly embedded the obs.
As expected the heat flux followed the net radiation lead!

ACM2 being moister seemed to overestimate the latent heat flux

\[ \text{net } R = H + LH + G \]

(?)
BEAREX08 - July 24-25

NARR: The ensemble mostly embedded the observations; warm bias during the late evening (all the parameterizations)
Here the ensemble failed to embed the observations between about 2300-3000 m; AMC2 inversion lower than the others.
NAM: The ensemble embedded the observations better (than with NARR); AMC2 is the coldest
The ensemble embedded the observations
Sunset at 02:00 UTC
NARR: The ensemble embedded the observations
ACM2 moister than the others;

q jump?
NARR: The ensemble failed to embed the observations between ~ 1200 – 2500 m. ACM2 moister than the others at the surface and within the incipient residual layer.
NAM: The ensemble mostly embedded the observations, four parameterizations seemed to capture the increasing q after 01:00.
NAM: The ensemble failed to embed the observations between ~ 1000 – 2500 m
ACM2 moister than the others at the surface and within the incipient residual layer
NARR: The ensemble embedded mostly the observations although with a positive bias. Remember YSU clipping value = 0.1.
NAM: The ensemble mostly missed to embed the observations (clear positive bias)
NARR: Both ensembles have problem embedding the observations
NARR: The ensemble mostly embedded the observations; problems at ~400 m, 3800 m, and 4800 m.
Both captured the evening wind features although MYJ seemed to give stronger speed values.

Sunset at 02:00 UTC
Conclusions:

WRF parameterization ensembles seemed to capture the physics by embedding the observations of the mean variables and illustrating some of the correlations; biases of course were present;

However, the biases were greater when calculating the fluxes, especially heat fluxes (sensible and latent)

Particularly, evening wind features appeared to be well captured

Thanks!
Literature Review

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<th>Modeling-based</th>
<th>Laboratory-based</th>
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<tr>
<td>Richardson (1920): (TKE budget)</td>
<td>Sorbjan (1997): LES (better surface heat flux)</td>
<td></td>
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*LES for Large-Eddy Simulation*