Improving Boundary Layer Representation for Air Quality Modeling

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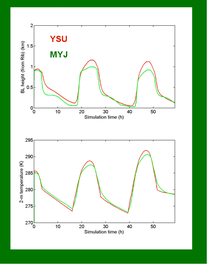
What are we doing?

- Evaluating existing BL parameterizations with field data and community intercomparisons
- Developing a new BL scheme (TEMF) that includes shallow cumulus and a well-designed stable BL representation

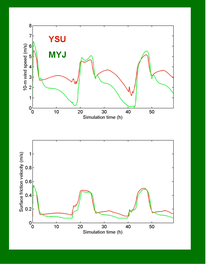
GABLS2
BL height and 2m temperature

- Moderate resolution (40 levels, 1st level = 25 m)
- YSU BL is deeper day and night
- Other models are all over the map at night
- Using Ri_c=0.25 in YSU makes nocturnal BL even deeper at moderate resolution



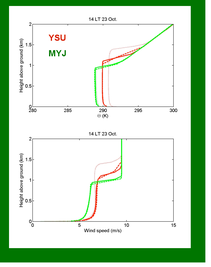
Wind speed and friction velocity
(moderate resolution)

- YSU wind speeds are higher at night
- MYJ winds at night are weaker than other models in comparison



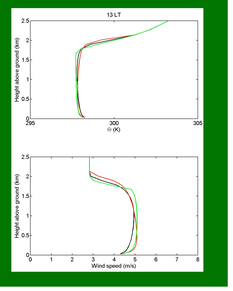
Daytime theta and U profiles

- YSU BL deeper, depends strongly on resolution
- MYJ not resolution dependent at this time
- MYJ in range of others in comparison



GABLS3

- Comparing potential temperature and wind speed profiles from 3 BL schemes
- Early afternoon
- Differences are much smaller than in GABLS2



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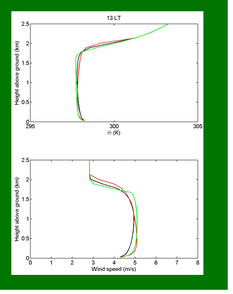
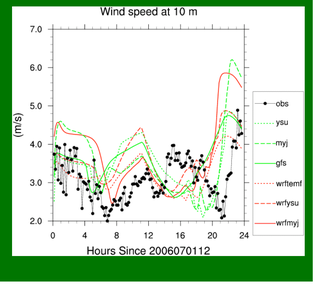


GABLS3 10-m wind

- Wind speed does not go to zero at night (as it did in GABLS2)
- Both MYJ versions have high speeds on second morning

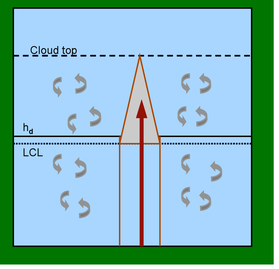


Why a new scheme?

- Existing schemes in WRF have known deficiencies in stable conditions
  - too little mixing or too much
- Fair-weather cumulus "fall in the crack" between BL schemes and cumulus schemes
- Non-local component of convective BL transport is still an issue
- Many groups are moving toward a convective BL scheme incorporating eddy diffusion and mass flux -- "EDMF"

Concept diagram

- Updraft-environment decomposition
- One updraft
- Dry thermal top above or below LCL determines whether cloud forms
- Eddy diffusion in subcloud and cloud layer



Status and plans

- TEMF implemented in Matlab, 1D
- Implemented in WRF (not released)
- Known deficiencies:
  - needs subgrid condensation
  - numerical stability questionable
  - no ice phase
- Need to test and evaluate:
  - converging parameters with other EDMF schemes
  - effect on various applications (offsetting errors)
  - more shallow cumulus cases
  - interface to cumulus scheme(s)
  - interface to radiation schemes
  - time delay for updraft growth?
- Will put into KNMI testbed "soon"

Acknowledgements:

Thorsten Mauritsen, MPI Hamburg

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The stable side
(Mauritsen et al. 2007 JAS)

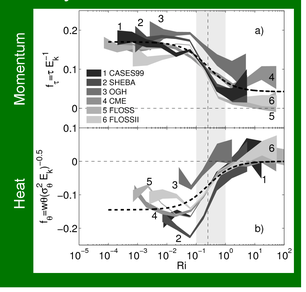
- Use of total turbulent energy in stable stratification (potential + kinetic energy)
  - therefore no implicit critical Ri
- Use of local gradient Ri stability functions
  - does not assume a single surface-based BL
  - "sharp tails"
- A length-scale incorporating z, f and N
- Avoids self-correlation in selection of empirical coefficients
- Tested in almost 100 LES cases

The GOMACCS cases

- Gulf of Mexico Atmospheric Composition and Climate Study
- September 2006
- LES simulations with RAMS/LES
- Shallow cumulus over land
- TEMF 1D / SCM in Matlab
- Boundary conditions from LES

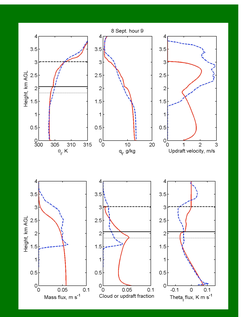
Stability functions

- Dashed lines show empirical fits used in the scheme
- (Normalized) momentum transport continues at high Ri
- "Sharp tails"



TEMF vs. LES
8 September

- Profiles at 1500 LST as labeled
- Red = TEMF, blue = LES
- Good correspondence in theta and q
- Reasonable correspondence in cloud parameters (note these are snapshots)

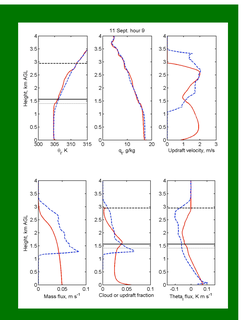


The convective side
(Angevine 2004 JAM)

- Eddy diffusion – Mass flux (EDMF) scheme
- Patterned after work by Siebesma, Teixeira, and others
- Diffusion coeffs. based on total energy (TE)
- Mass flux transports all quantities, including TE, U, V
- Length scale based on distance from surface and inversion

TEMF vs. LES
11 September

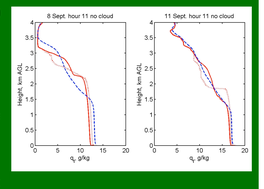
- Profiles at 1500 LST as labeled
- Red = TEMF, blue = LES
- Good correspondence in theta and q
- Reasonable correspondence in cloud parameters (note these are snapshots)



The bottom line:
Better vertical transport of constituents

TEMF vs. LES

- Final q profiles at 1700 LST with and without cloud
- Red = TEMF, blue = LES, dashed = TEMF with cloud turned off
- Cloud base in TEMF is higher early
- Too little moisture above cloud base without cloud transport



TEMF vs. LES

- Final q profiles at 1700 LST
- q (moisture) is a proxy for surface-emitted pollutants
- Red = TEMF, blue = LES
- Cloud base in TEMF is higher early
- Cloud top is never as high as in LES
- Small tendency to move too much moisture from lower to upper layer
- Much better than any scheme lacking cloud