Effects of Planetary Boundary Layer Parameterizations on CWRF Regional Climate Simulation

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Abstract

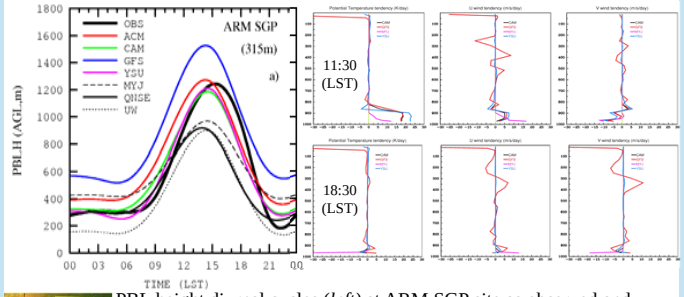
Planetary Boundary Layer (PBL) parameterizations incorporated in CWRF (Climate extension of the Weather Research and Forecasting model) were first evaluated by comparing simulated PBL height diurnal cycles with observation at ARM (Atmospheric Radiation Measurement) SGP (Southern Great Plains) site. Among the seven evaluated PBL schemes, two (CAM, UW) are new in CWRF while the other 5 are original WRF schemes. MYJ, QNSE and UW determine the PBL heights based on turbulent kinetic energy (TKE) profiles, while others (ACM, CAM, GFS, YSU) are from bulk Richardson criteria. Effects of PBL parameterizations on CWRF regional climate simulation were then compared with CAM serving as the control run. QNSE, MYJ and GFS PBL parameterizations were identified as obvious outliers of overall performance in representing precipitation, surface air temperature or PBL height variations.

Related references

Liu S. and X.-Z. Liang, 2010: Observed diurnal cycle climatology of planetary boundary layer height, *Journal of Climate*, **23**, 5790-5809.

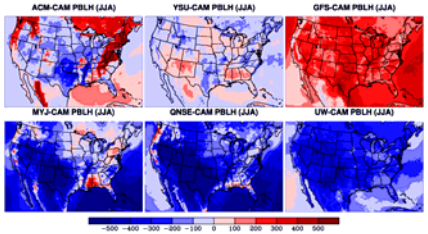
Results

All TKE-based schemes (MYJ, QNSE, UW) substantially underestimate convective or residual PBL heights from noon toward evening, while others (ACM, CAM, YSU) well captured the observed diurnal cycle except for the GFS with systematic overestimation.



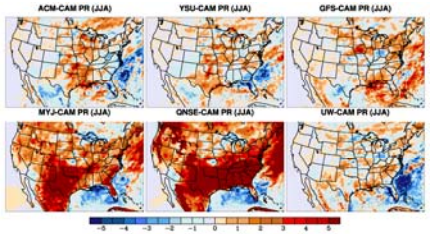
PBL height diurnal cycles (*left*) at ARM SGP site as observed and simulated by CWRF with ACM, CAM, GFS, YSU, MYJ, QNSE and UW and vertical tendencies (*right*) from CAM, GFS, MYJ and YSU

ACM: Asymmetric Convective Model
CAM: Community Atmosphere Model
GFS: Global Forecast System
YSU: Yonsei University
MYJ: Mellor–Yamada–Janjic
QNSE: Quasi-Normal Scale Elimination



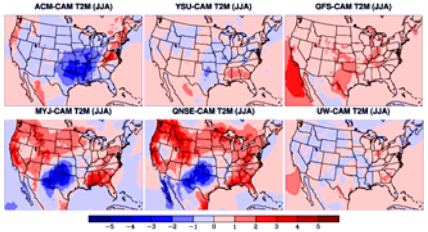
Differences of PBL height between CAM and ACM, YSU, GFS, MYJ, QNSE, UW as simulated by CWRF during summer of 1993

These differences among the schemes are representative over most areas of the simulation domain, suggesting systematic behaviors of the parameterizations. Lower PBL heights simulated by the QNSE and MYJ are consistent with their smaller Bowen ratios and heavier rainfalls, while higher PBL tops by the GFS correspond to warmer surface temperatures.



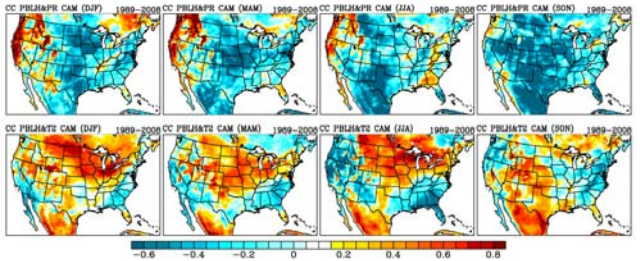
Differences of precipitation between CAM and ACM, YSU, GFS, MYJ, QNSE, UW as simulated by CWRF during summer of 1993

The QNSE PBL scheme yields systematically heavier rainfall almost everywhere and throughout the year; this is identified with a much greater surface Bowen ratio (smaller sensible versus larger latent heating) and wetter soil moisture than other PBL schemes. Its predecessor MYJ scheme shares the same deficiency to a lesser degree.

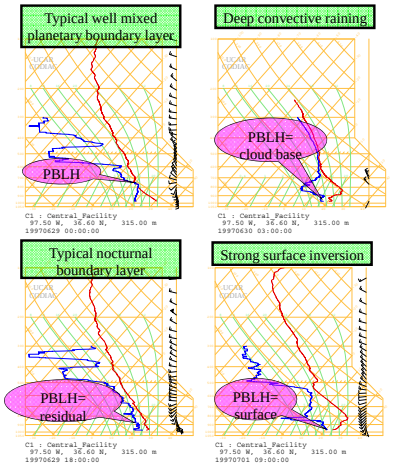


Differences of surface air temperature between CAM and ACM, YSU, GFS, MYJ, QNSE, UW as simulated by CWRF during summer of 1993

For surface aire temperature, the performance of the QNSE and MYJ schemes remains poor, having substantially larger RMS errors in all seasons. GFS PBL scheme also produces large warm biases. Pronounced sensitivities are also found to the PBL schemes in winter and spring over most areas except the southern U.S. (Southeast, Gulf States, NAM); excluding the outliers (QNSE, MYJ, GFS) that cause extreme biases of -6 to +3° C, the differences among the schemes are still visible (±2° C), where the CAM is generally more realistic.



Correlation coefficients between PBL height and precipitation (*upper*), surface air temperature (*lower*) as simulated by CWRF with CAM PBL scheme for DJF, MAM, JJA and SON during 1989-2008.



T-logP for typical PBL structures on ARM SGP site

Simulations of precipitation and surface air temperature are highly correlated with PBL height in CWRF for all the four seasons. Improvement of PBL height simulation will benefit realistic reproduce the observed precipitation and surface air temperature.

Oversimplification regarding PBL regimes classify and PBL height calculation is common in PBL schemes. Every PBL schemes perform good regarding well mixed convective boundary layer, while need to work on the others.

Conclusion

QNSE, MYJ and GFS PBL parameterizations are identified as obvious outliers of overall performance in representing precipitation, surface air temperature or PBL height variations. Their poor performance may result from deficiencies in physical formulations, dependences on applicable scales, or trouble numerical implementations, requiring future detailed investigation to isolate the actual cause.

Acknowledgement

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