Evaluation of WRF Model's Physical Parameterizations for Regional Climate Studies Over Southern Ontario

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Abstract

The Weather Research and Forecasting (WRF) Model is used to investigate the sensitivity of total precipitation (RAINC + RAINNC) and daily temperatures in physical parameterization schemes for Southern Ontario, Canada. Simulations overestimated precipitation in July but underestimated it in January, and were more sensitive to convective and PBL parameterizations. WRF performed poorly in simulating summer extreme precipitation. For surface air temperature, the model captured spatial heterogeneity well; however, the magnitude is systematically underestimated, being higher in January and lower in July. Model underestimates daily minimum temperature but overestimates maximum temperature. Temperature is most sensitive to PBL schemes, followed by Microphysics. Taylor diagram analysis indicates that modeled precipitation and temperature agree well with DAYMET observations with correlation coefficient of 0.6~0.8 and >0.9, respectively. Thus, optimum selection of parameterization combinations is indispensable in configuring WRF for regional climate change assessment.

Objective of the study

We used WRF version 3.3 as nested regional climate model mode. Model grids were configured so innermost domain covers Southern Ontario and outermost covers entire Great Lakes basin (Figure 1). **Main objective**: Identify optimal physical parameterizations for model of region undergoing rapid population growth/urbanization, and simulate land-use/land-cover conversion impacts.

Experimental Configuration

Simulation Period: January and July, 2002
Horizontal Resolution: 8 km, 2.67km, and 0.9km
Vertical layer: 28 (Sigma)
ILBC: NARR reanalysis data updated by every three hour
Cumulus Scheme: Kain-Fritsch, Betts-Miller-Janjic, Grell-Devenyi, Simplified Arakawa Schubert, and Tiedtke
PBL Physics: YSU, MYJ, MYNN2, and MRF
Microphysics Scheme: Lin, Eta, WSM6, Thompson, and Goddard
Relaxation Zone width: (4+1) and (9+1)

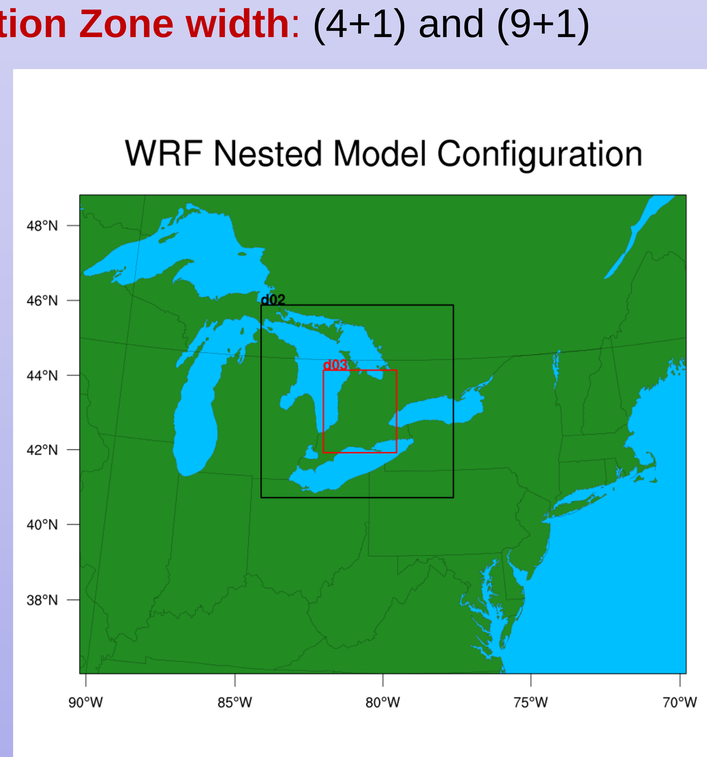

Figure 1: Model domain for simulations

WRF Simulation Comparison

- WRF model output was compared against DAYMET observations;
- DAYMET: a very high-resolution (1km horizontal) gridded climate dataset by Thornton *et al.* (2012) re-gridded to match the given WRF domain size and resolution.
- In all simulations: MP stands for microphysics, CU for cumulus parameterizations, PBL for planetary boundary layer schemes, and RZ stands for relaxation zone width.

Precipitation

- WRF realistically reproduces January precipitation patterns and magnitude and captured extreme precipitation pattern very well.
- However, poor performance were observed for July precipitation.
- Precipitation was very sensitive to cumulus and PBL parameterization, which is quite the reverse of Mooney *et al.* (2013) results over European domain.

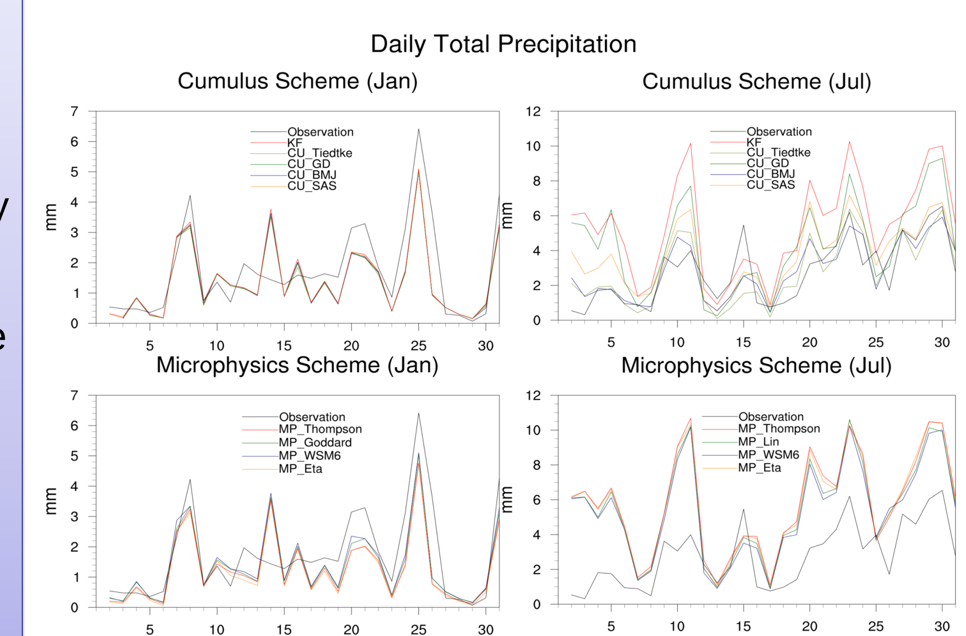

Figure 2: Temporal characteristics of simulated and observed precipitation: sensitivity to cumulus and microphysics parameterization

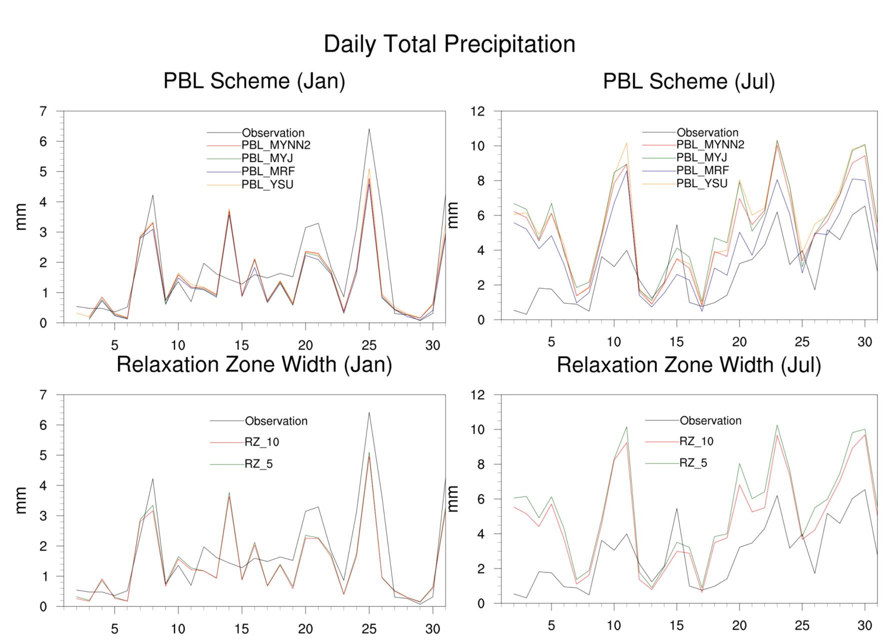

Figure 3: Temporal characteristics of simulated and observed precipitation: sensitivity to PBL parameterization and relaxation zone width

- Taylor diagram indicates that simulated precipitation is nearly independent of choice of physical parameterizations. However, contrasting behaviour was found in July.
- In general, simulated precipitation and temperature agree well with the DAYMET observations (correlation coefficient of 0.6~0.8 and >0.9, respectively).
- Root mean square difference (RMSD) is higher for precipitation and lower for temperature (not shown).

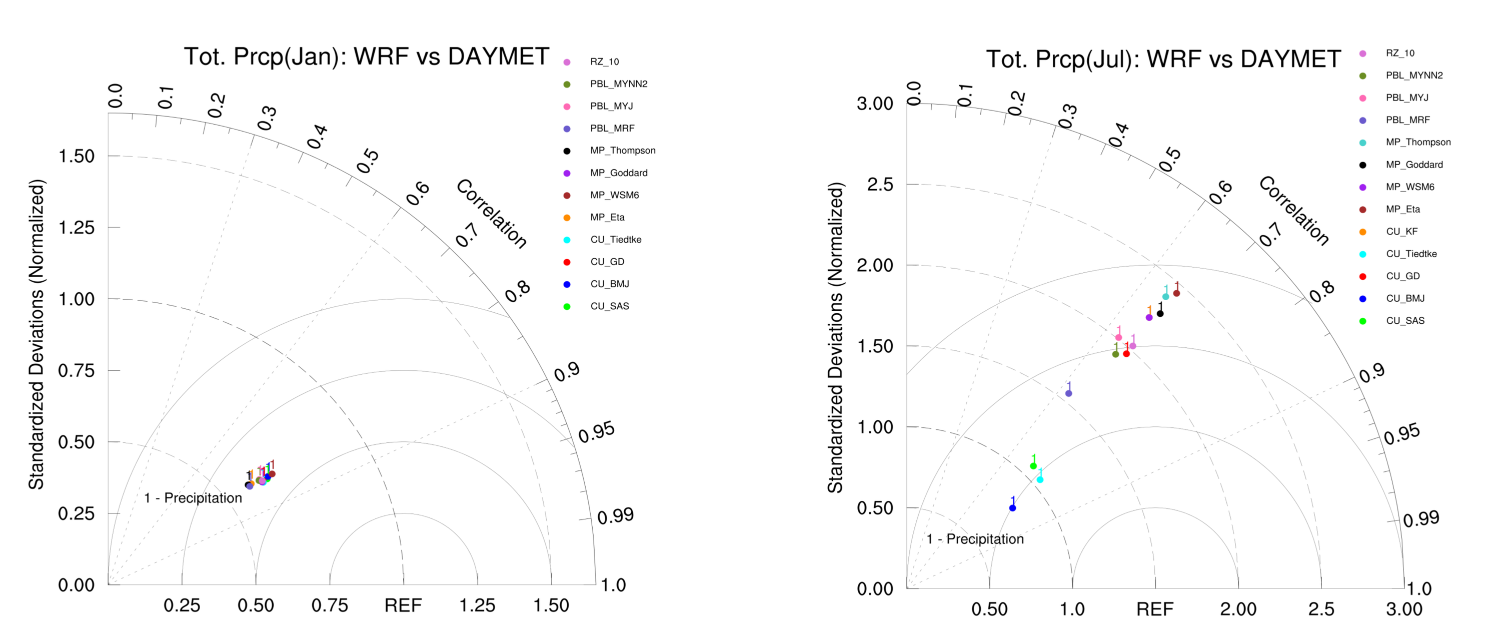

Figure 4: Taylor diagram showing correlation coefficient, and standard deviation and root mean square difference of modeled precipitation relative to DAYMET observation.

Temperature

- Comparison between simulated daily maximum and minimum surface air temperatures with observation showed underestimation and overestimation, respectively. Mean temperature agrees fairly well with observation.
- For all those variable model is most sensitive to PBL parameterizations, also to Microphysics. One more time, our result disagree with Mooney *et al.* (2013).
- Among all PBL schemes, observed temperatures were best reproduces by MRF.

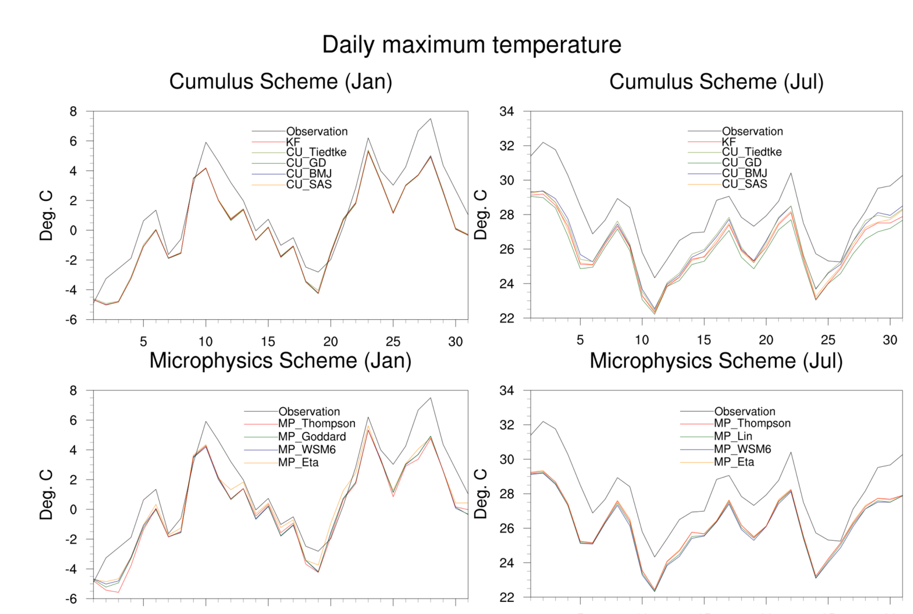

Figure 5: Same as figure 2, but for daily maximum temperature

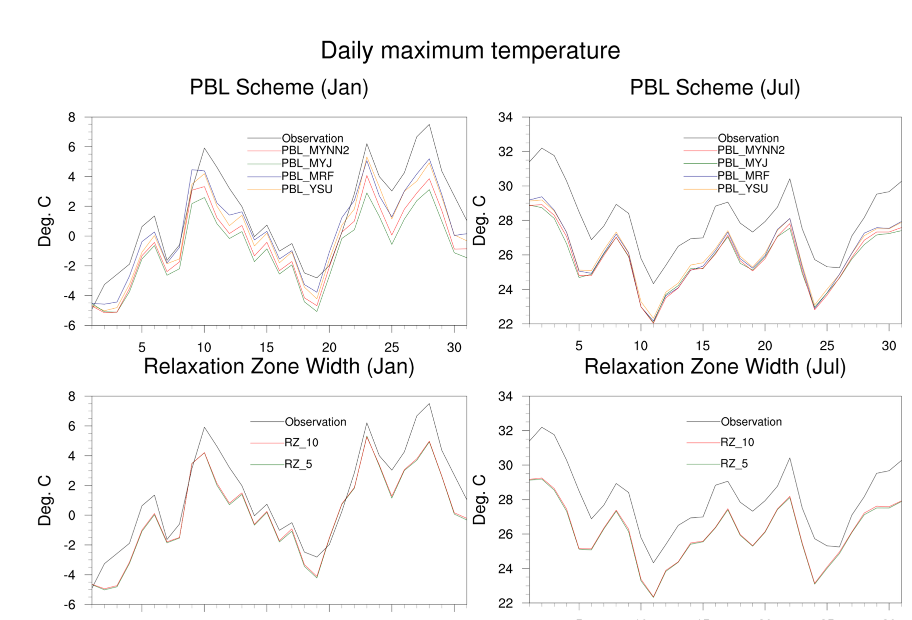

Figure 6: Same as Figure 3, but for daily maximum temperature

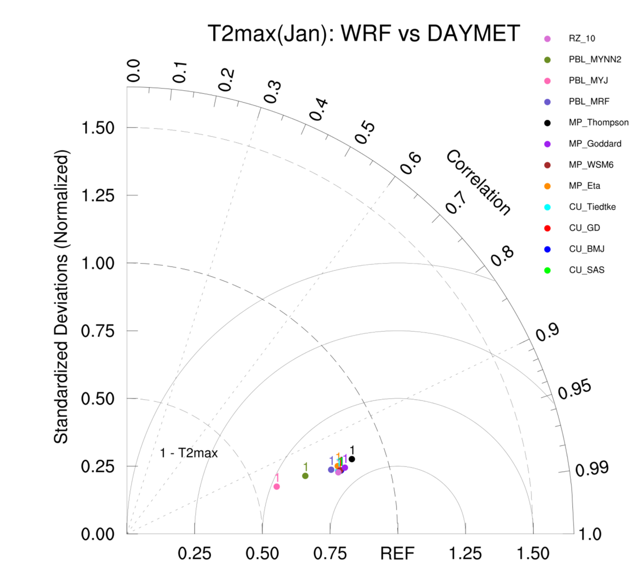

Figure 7: Same as figure 4, but for daily maximum temperature of January

Summary/Future Work

Precipitation

- Simulated precipitation shows overestimation in July but underestimation in January.
- WRF performs poorly in simulating extreme precipitation event in July.
- Precipitation is most sensitive to cumulus and PBL parameterization.

Temperature

- Colder bias in winter and warmer bias in summer.
- Temperature insensitive to convective parameterizations and relaxation zone width but sensitive to PBL and Microphysics schemes.
- Performance of physical parameterizations depends on geographic distribution of the area of interest.

Future Work

- To investigate whether temperature and precipitation converges numerically when regional climate model's horizontal resolution approaches to nearly cloud resolving scale.

References

1. Thornton *et al.*, DAYMET: Daily Surface Weather on a 1 km Grid for North America. 1980—2008, "Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, T, N. doi,10, 2012
2. Mooney *et al.* Evaluation of the Sensitivity of the Weather Research and Forecasting Model to Parameterization Schemes for Regional Climates of Europe over the Period 1990–95. *Journal of Climate* 26.3 (2013): 1002-1017.

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