On the Use of Multiple Planetary Boundary Layer Parameterization Schemes for Forecasting Temperature and Precipitation in Complex Terrain

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INTRODUCTION

Turbulent exchanges of heat and moisture between the Earth and atmosphere are approximated in modern numerical weather prediction (NWP) models by planetary boundary layer (PBL) parameterizations (Stull 1988). These parameterizations were originally formulated in flat terrain, even though they are used in weather models that can be applied to anywhere in the world. In particular, a comparison of the deterministic forecast performance of different parameterizations has not been conducted in the complex, mountainous terrain of western Canada. Given the impact that the parameterization of turbulent exchanges has on the behavior of a weather model, it is important that forecasters choose the best scheme for the right atmospheric and terrain conditions (Hu et al. 2010). An alternative to choosing a single best scheme for forecasting would be to run multiple numerical weather prediction models with different PBL parameterizations, making an ensemble (Du and Zhou 2011).

Objectives:

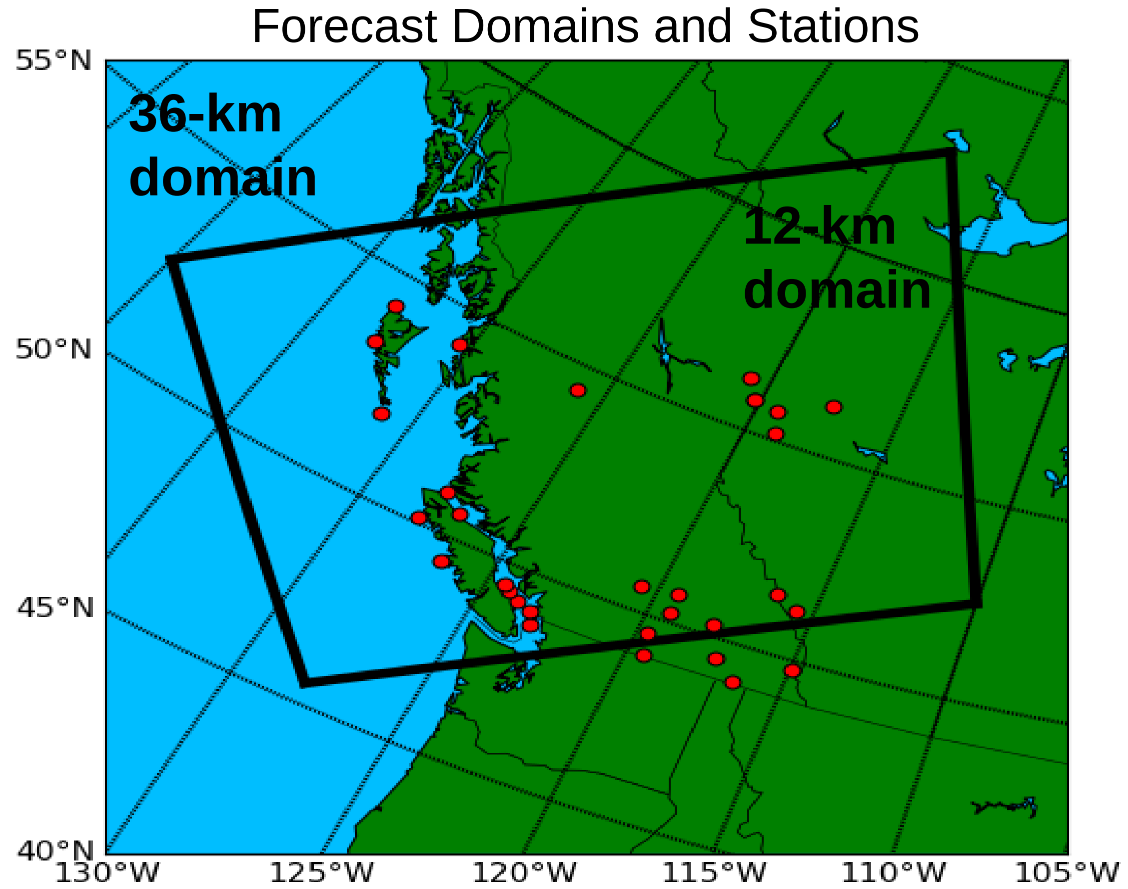
1.) To verify the deterministic forecast performance of 8 PBL schemes for forecasting hourly temperature and daily accumulated precipitation in western Canada

2.) To compare the performance of those individual schemes with ensembles constructed from those schemes

FORECAST DESCRIPTION

- Produced point forecasts from Weather Research and Forecasting model (WRF-ARW) output for a year-long study at stations in BC and AB (red dots)
- 16 daily forecasts produced from 8 PBL schemes and 2 domains (36- and 12-km), using the Global Forecast System (GFS) as source of initial conditions

Forecast Domains and Stations



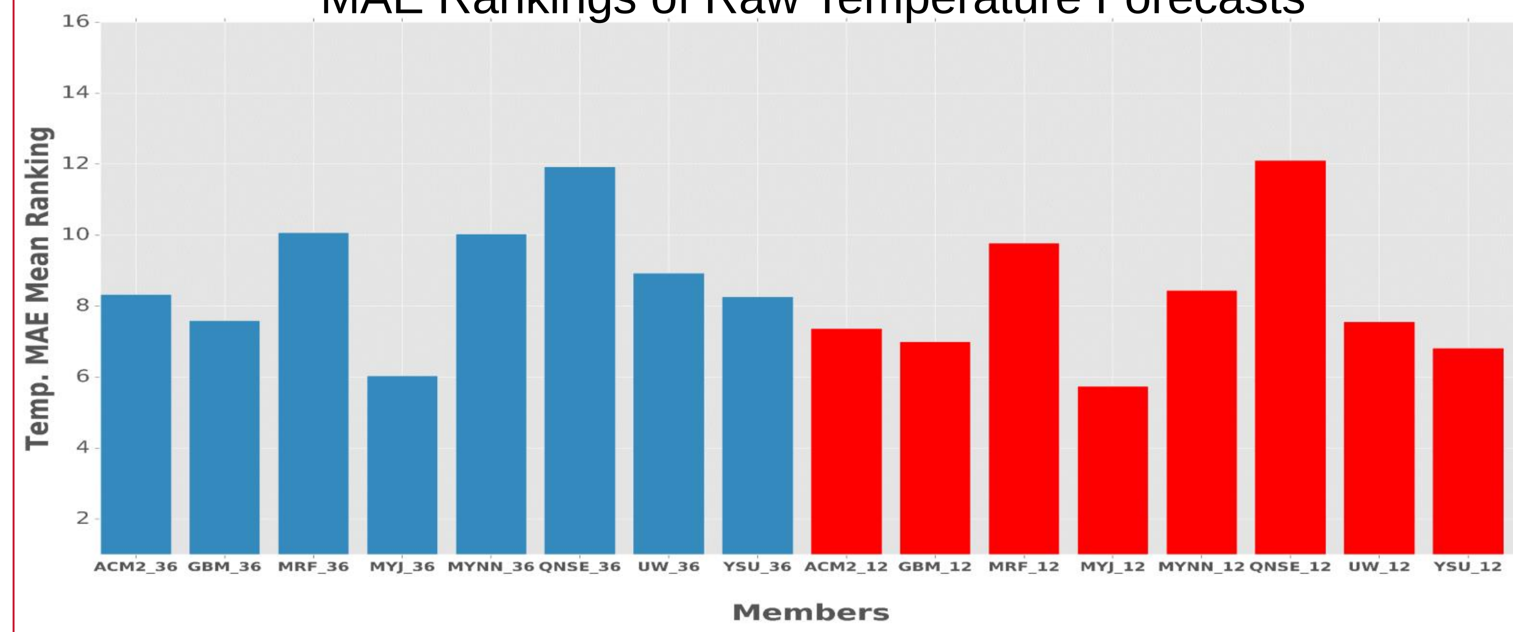
ENSEMBLE CONSTRUCTION METHODS

- **Equal weighting method (EW):** arithmetic mean of raw forecasts (EW-Raw) and bias-corrected forecasts using a simple linear regression (EW-SLR)
- **Inverse-error weighting method (IEW):** weighted linear combination of raw forecasts (IEW-RAW) and bias-corrected forecasts (IEW-SLR) based on previous error (lower previous error = higher weights in the ensemble)
- **Multiple linear regression method (MLR):** selection of best schemes based on previous error for use in a multiple linear regression; only include enough schemes for error in the training set to reach a minimum value, to prevent overfitting

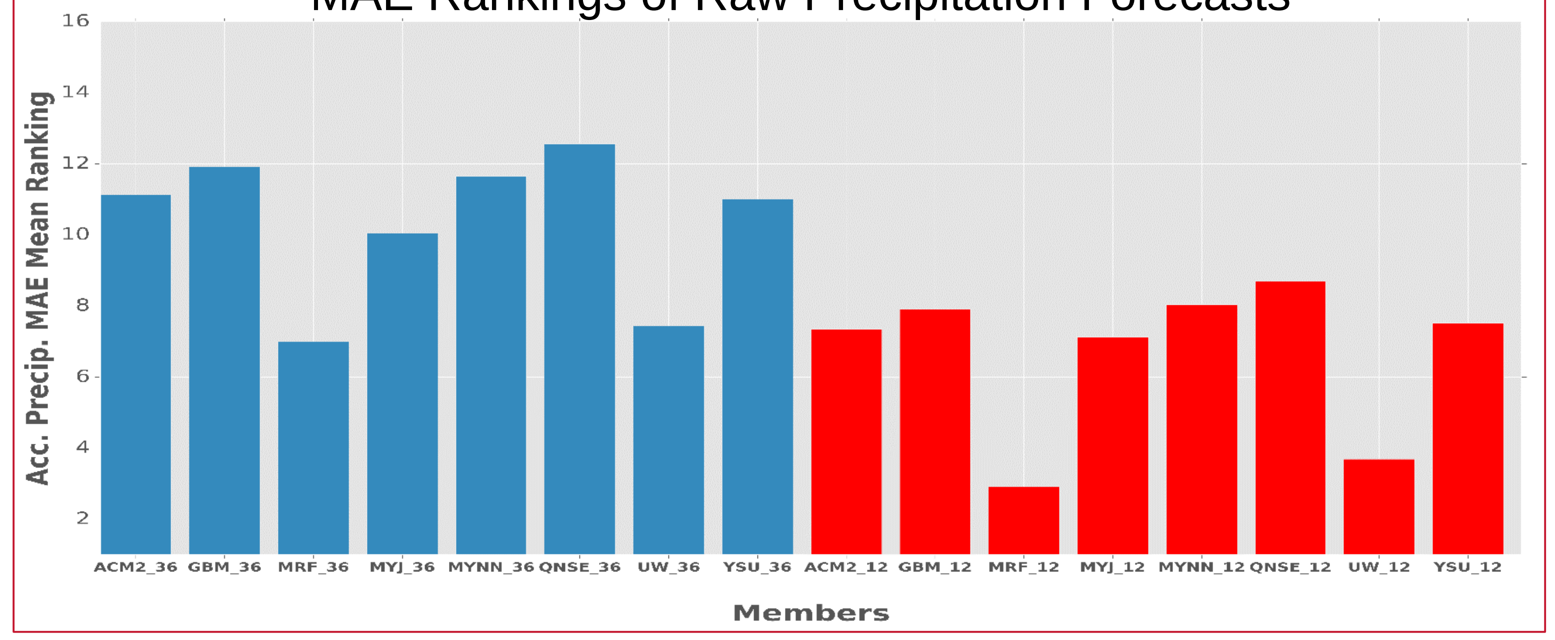
VERIFICATION OF PBL SCHEMES

- Mean absolute error (MAE) rankings of the PBL schemes averaged across all stations **(lower bars are better);** 36-km forecasts are in blue, 12-km forecasts are in red

MAE Rankings of Raw Temperature Forecasts

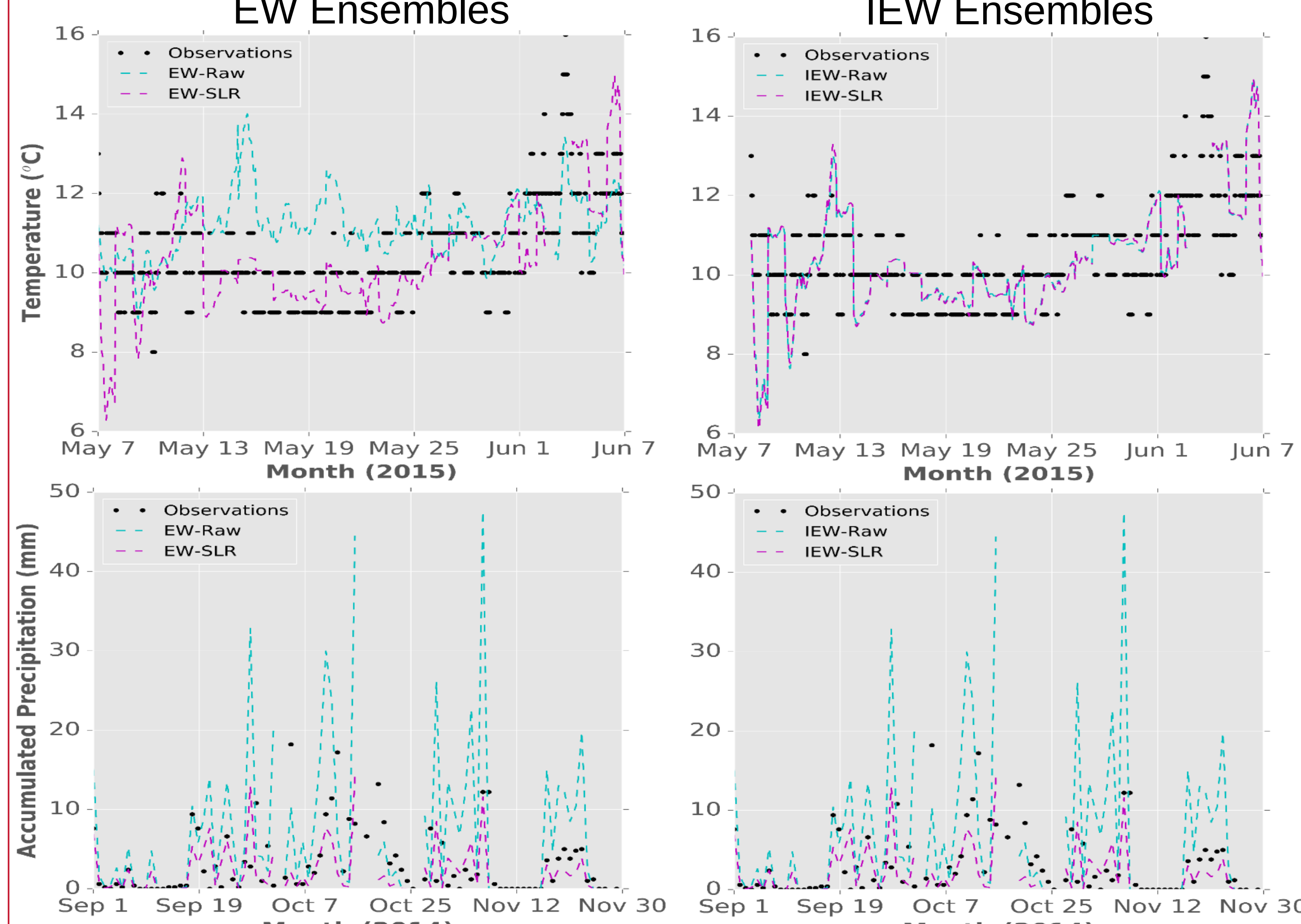


MAE Rankings of Raw Precipitation Forecasts



ENSEMBLE FORECASTS

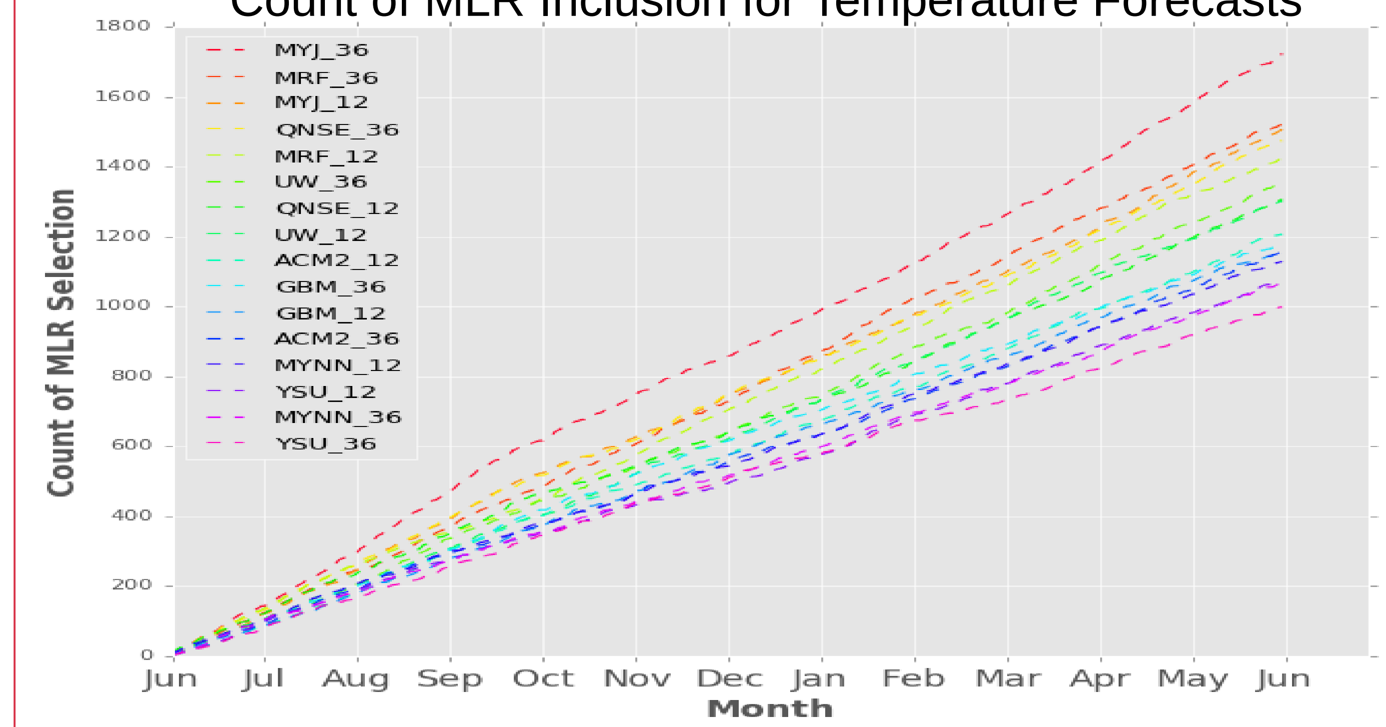
- Temperature (1st row) and precipitation (2nd row) ensemble forecasts at Holland Rock, BC
- Clear difference between SLR and raw ensemble forecasts except for the IEW temperature forecasts; raw ensemble performed as if it was bias corrected



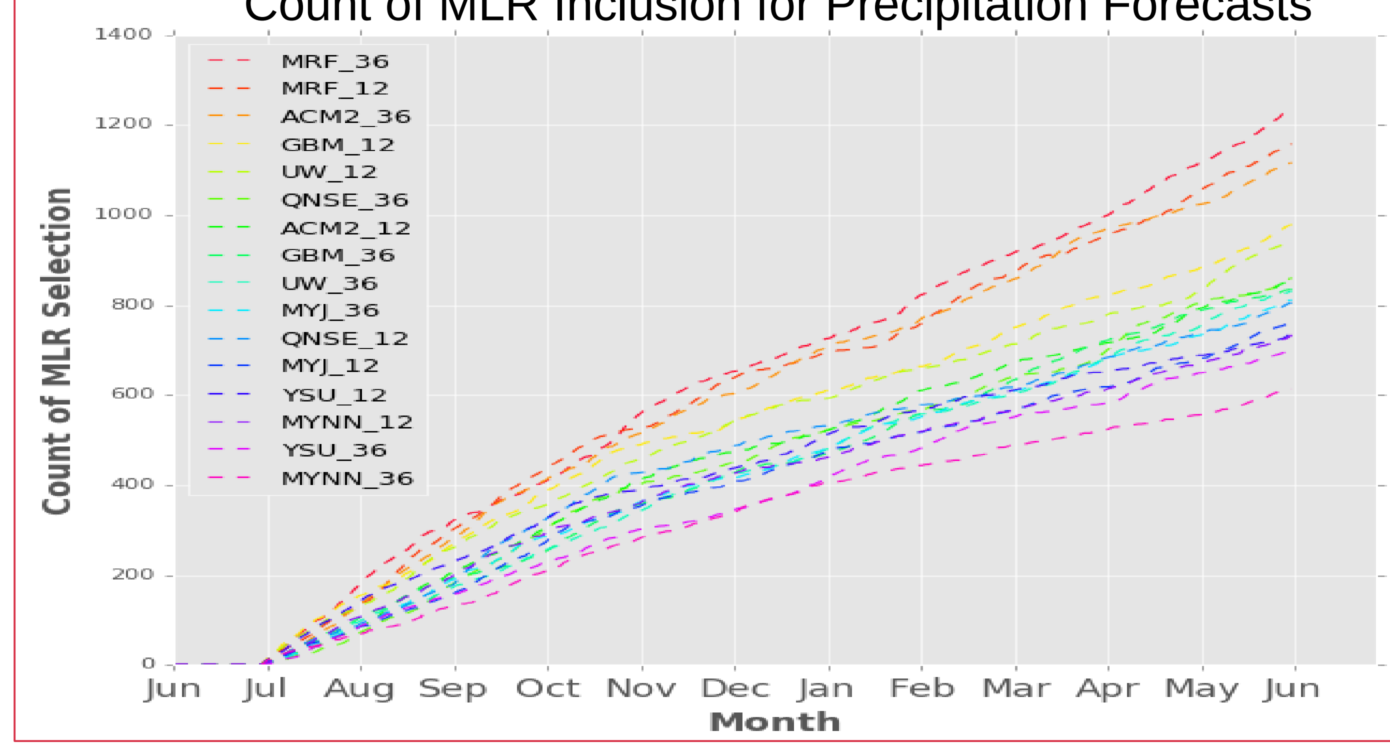
FREQUENCY OF INCLUSION INTO MLR

- Count of inclusion into MLR can give an indication of the forecast error; schemes with higher counts of inclusion have lower error on a daily basis
- MYJ and MRF were included most frequently in the MLR, whereas the YSU and MYNN were often excluded (mediocre schemes that rarely performed best)

Count of MLR Inclusion for Temperature Forecasts



Count of MLR Inclusion for Precipitation Forecasts



CONCLUSIONS

- Bias-corrected forecasts using a simple linear regression produced better deterministic verification statistics than the raw model output
- Preference for certain schemes over others dependent on station and variable
- Calculated average MAE skill scores (SS_{MAE}) for each ensemble, using the best bias-corrected scheme at each station as the reference forecast (+1 is best)

SS_{MAE}	EW-Raw	EW-SLR	IEW-Raw	IEW-SLR	MLR
Temperature	-0.409	-0.004	-0.000	-0.007	-0.174
Precipitation	-18.102	-0.054	-17.962	-0.848	-0.404

- If the best performing member at a station is unknown, then use the **IEW-Raw** ensemble with 16 PBL schemes for hourly **temperature** forecasts, and the **EW-SLR** ensemble for daily accumulated **precipitation** forecasts
- Future work: evaluation of other physics parameterizations, nonlinear weighting methods, and probabilistic verification

REFERENCES

Du, J., and B. Zhou, 2011: A Dynamical Performance-Ranking Method for Predicting Individual Ensemble Member Performance and Its Application to Ensemble Averaging. *Mon. Wea. Rev.*, **139**, 3284-3303.
Hu, X. M, J. W. Nielsen-Gammon, and F. Zhang, 2010: Evaluation of Three Planetary Boundary Layer Schemes in the WRF Model. *J. Appl. Meteorol. Climatol.*, **49**, 1831-1844.
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