WRF Simulation, Model Sensitivity, and Analysis of the December 2013 New England Ice Storm

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Introduction

In an effort to improve storm response and minimize costs, energy companies have supported the development of ice accretion forecasting techniques utilizing meteorological output from numerical weather prediction (NWP) models. However, few studies consider the sensitivity of the downscaling model, and in turn the ice forecast, to model configuration. As variations in temperature as low as 0.5°C can alter precipitation type (Thériault et al. 2010)], it is crucial to quantify the variability of near-surface variables within the model itself. This study examines the sensitivity of near-surface and tropospheric variables to model configuration using the Weather Research and Forecasting (WRF) model (Skamarock et al. 2008).

Methods

Simulations of the December 2013 New England ice storm were conducted using WRF version 3.9. Two one-way nested domains were used with grid spacings of 9 km and 3 km. The simulations were initialized at 0000 UTC 20 December 2013 and ended at 0000 UTC 25 December 2013, with the first 24 hours used for model spinup. The experiments test the sensitivity of modeled temperature, wind speed, wind direction, and precipitation to the choice of planetary boundary layer (PBL) physics parameterization, reanalysis forcing [ECMWF ERA-Interim (ERAI), ECMWF ERA5, and NCEP North American Regional Reanalysis (NARR)], the use of grid nudging, and the number of vertical levels. The model sensitivity tests consist of two groups with the configurations listed in Table 1. WRF model output was validated against surface station observations and tropospheric sounding data over 21-23 December.

Table 1. Summary of model simulations used in this study.

Short Name	Reanalysis	PBL Scheme	Surface Layer	Nudging (Y/N)	Vertical Levels
YSU	ERAI	Yonsei University	Revised MM5 similarity	Y	36
ACM2	ERAI	Asymmetric Convective Model Version 2	Revised MM5 similarity	Y	36
MYJ	ERAI	Mellor-Yamada-Janjic	Eta similarity	Y	36
QNSE	ERAI	Quasi-Normal Scale Elimination	QNSE	Y	36
MYNN2	ERAI	Mellor-Yamada-Nakanishi-Niino Level 2.5	MYNN	Y	36
BouLac	ERAI	Bougeault-Lacarrere	Revised MM5 similarity	Y	36
UW	ERAI	University of Washington	Revised MM5 similarity	Y	36
TEMF	ERAI	Total Energy-Mass Flux	TEMF	Y	36
ERAI 36	ERAI	Mellor-Yamada-Janjic	Eta similarity	N	36
ERAI 46N	ERAI	Mellor-Yamada-Janjic	Eta similarity	Y	46
ERAI 46	ERAI	Mellor-Yamada-Janjic	Eta similarity	N	46
ERA5 36N	ERA5	Mellor-Yamada-Janjic	Eta similarity	Y	36
ERA5 36	ERA5	Mellor-Yamada-Janjic	Eta similarity	N	36
NARR 36N	NARR	Mellor-Yamada-Janjic	Eta similarity	Y	36
NARR 36	NARR	Mellor-Yamada-Janjic	Eta similarity	N	36

Scan the code for more information about this study.

Results

Near-surface variables are more sensitive to model configuration than tropospheric variables, particularly temperature (Fig. 1). Error values for 2-meter temperatures are generally 0.75°C higher compared to sounding temperatures.

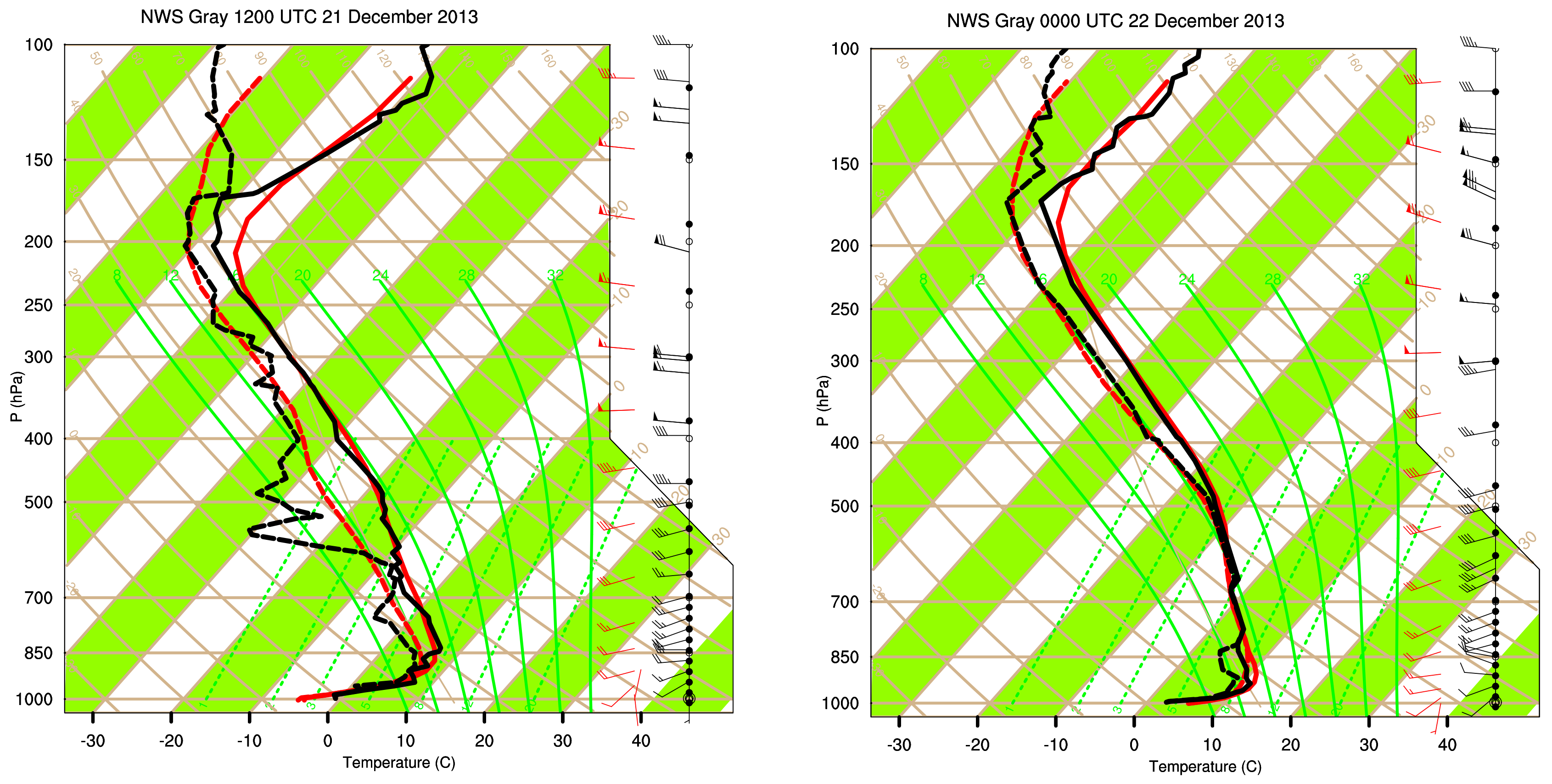

Figure 1. Sounding profiles for Gray, ME comparing the observed (black) and modeled (red) sounding for the MYJ PBL simulation. Temperature profile (solid) is plotted to the right of dewpoint profile (dashed).

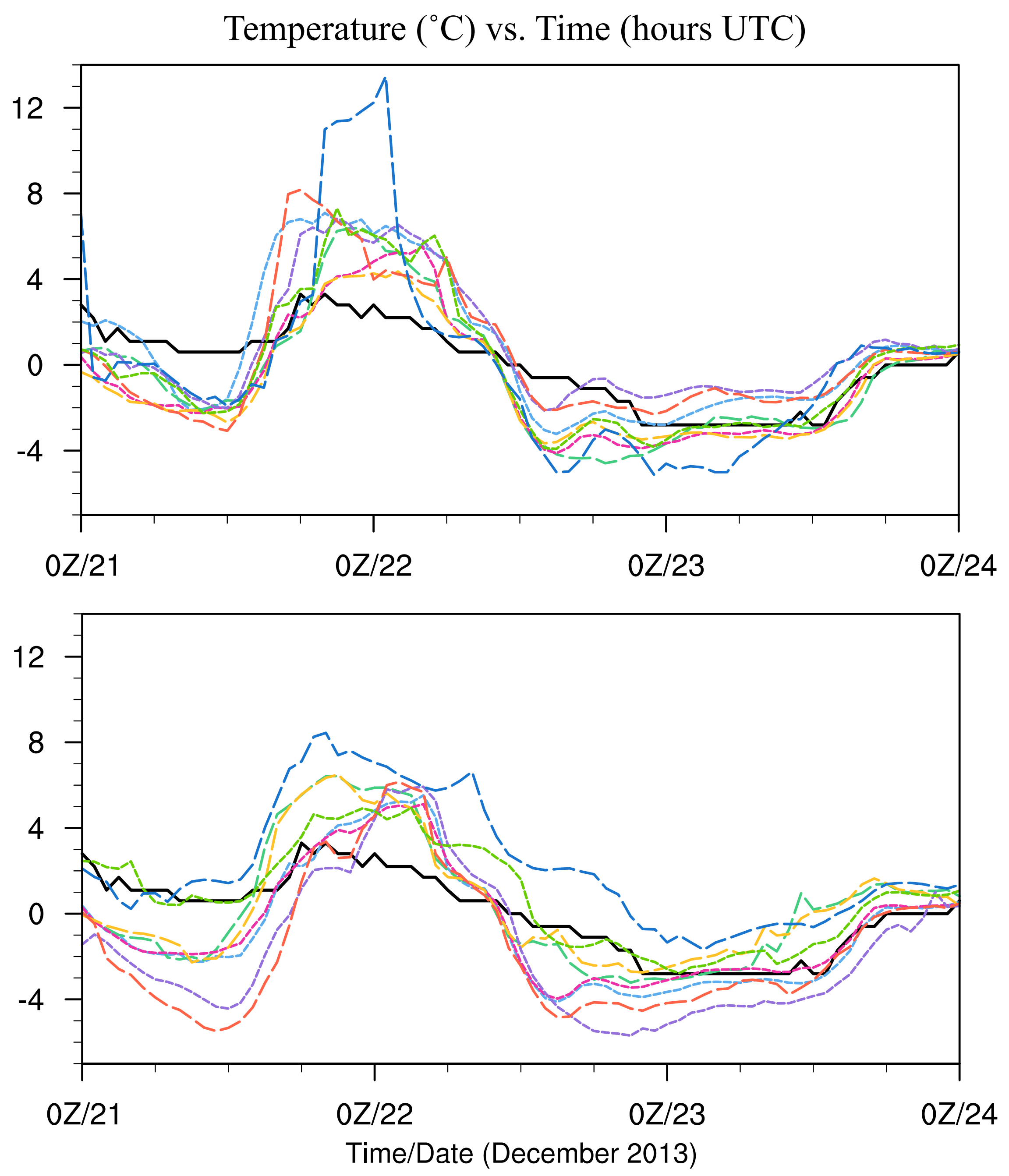

Figure 2. Observed and modeled 2-meter temperature time series at Portland, ME for the simulations testing PBL schemes (top) and other model configuration choices (bottom).

Although the storm progression is similar among simulations, there is considerable spread in modeled values of near-surface variables (Fig. 2).

When compared to surface and radiosonde observations, the mean average errors are:

- 1-2°C for temperature
- 1-3 ms^{-1} for wind speed
- 20-30 degrees for wind direction
- 1.0-1.5 mm for precipitation

There are also substantial spatial differences in modeled temperature fields, particularly between simulations forced with different reanalysis datasets (Fig. 3).

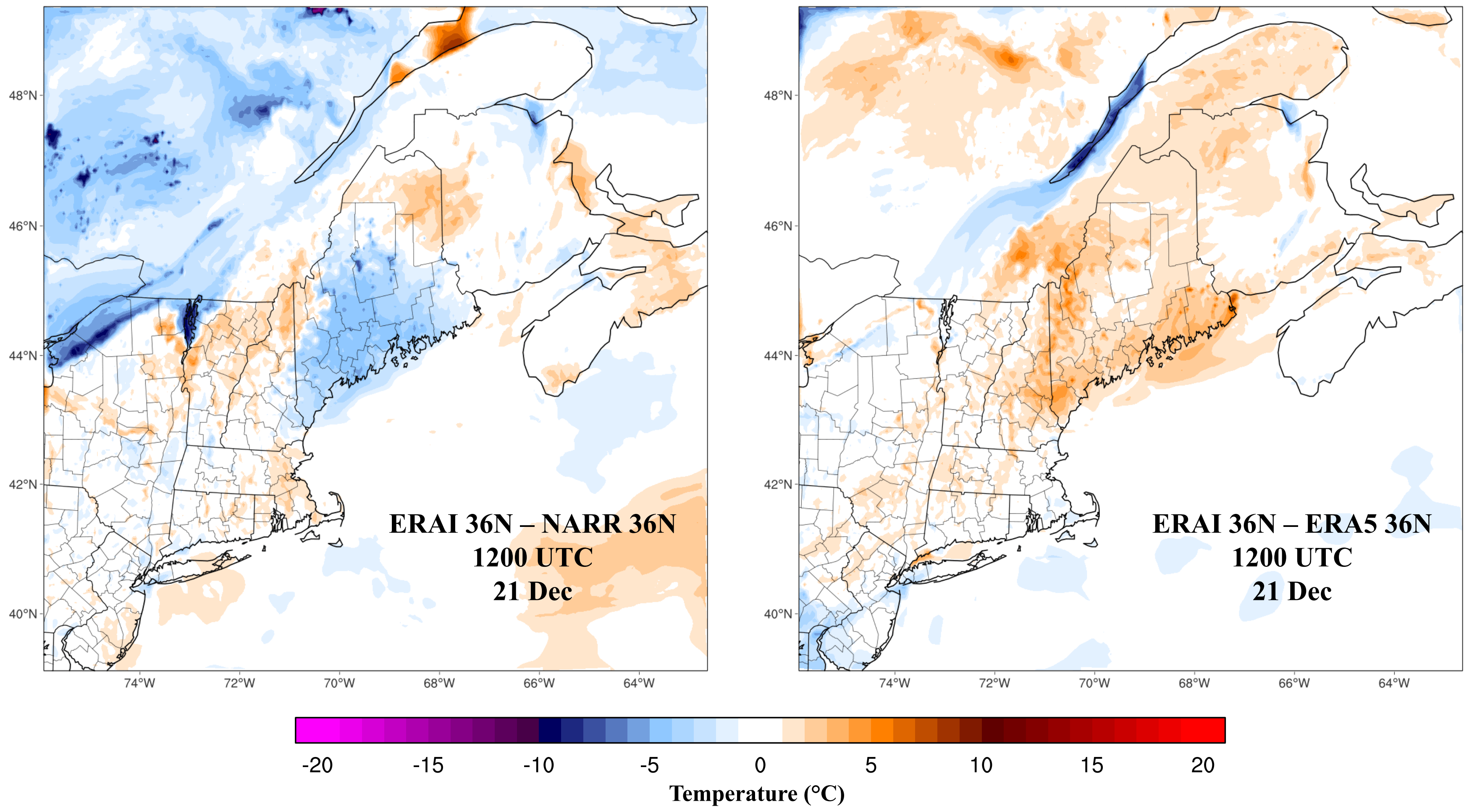

Figure 3. Difference in WRF 2-meter temperatures (°C) between the ERAI 36N and NARR 36N (left) simulations, and the ERAI 36N and ERA5 36N simulations.

Conclusions

The WRF model is able to reproduce the overall meteorological conditions associated with the case study storm. However, the variability of modeled conditions are sufficiently large enough to potentially alter the precipitation type identified. The choice of the "best" configuration is less one of which simulation was the most realistic, but the one which minimizes biases at specific locations. This study underscores the importance of extensive validation of model output to assess the accuracy and realism of the WRF model solution in comparison to observational data, particularly for case studies of weather events as impactful to civil infrastructure as ice storms.

Acknowledgements

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