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Refined Dynamical Downscaling from Previous Work at 36-km Resolution

Russ Bullock, Kiran Alapaty, Jerry Herwehe, Megan Mallard, Tanya Otte

National Exposure Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina

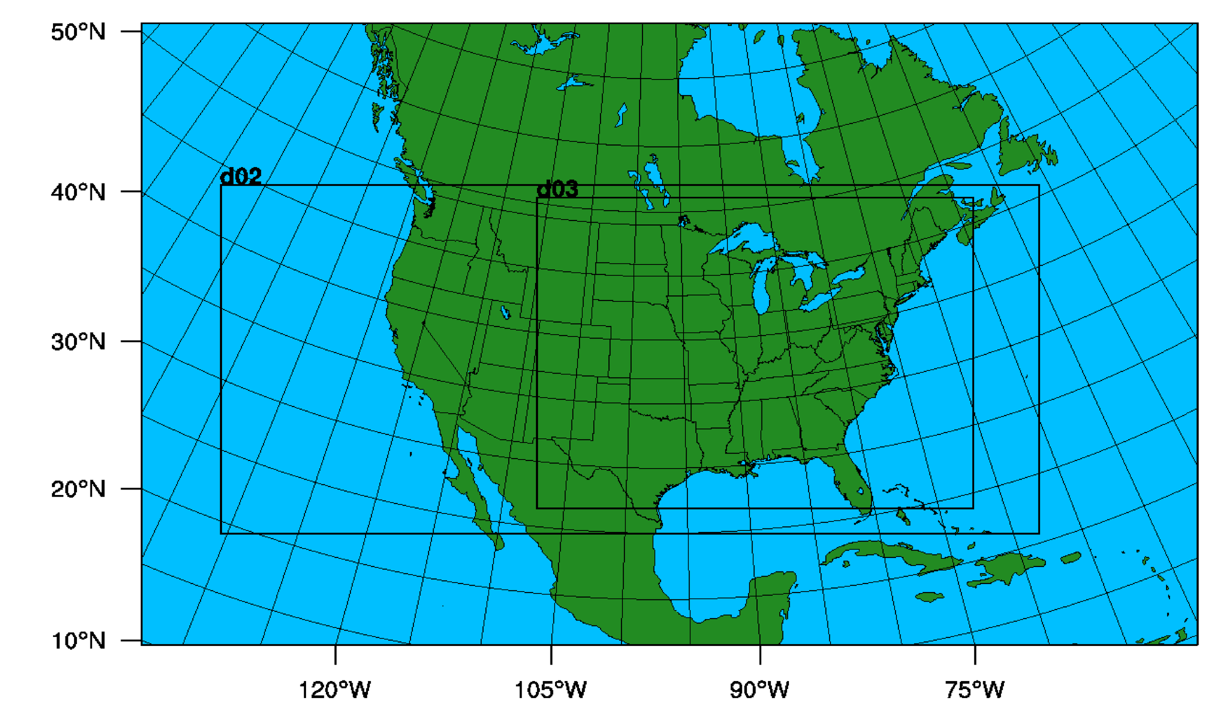
O. Russell Bullock, Jr. | bullock.russell@epa.gov | 919-541-1349

Introduction

Dynamical downscaling techniques were previously developed by the US EPA using a nested WRF at 108- and 36-km resolution (Bowden et al., 2012, *J. Climate*; Otte et al., 2012, *J. Climate*). Hydrologic planning and urban air quality management require finer spatial resolution in future climate projections. In this work, WRF was applied at 12-km resolution (d03 in figure at right) using one-way nesting from the 36-km results. We expected that adjustments to the 36-km downscaling strategy might be required for optimum results at 12-km resolution. Using reduced nudging coefficients from the 36-km work as a basis, we tested one-half and double strength coefficients for both analysis and spectral nudging. We also applied WRF without any interior nudging. An alternate method for setting lake surface temperatures was tested. Two sub-grid cumulus parameterizations and two cloud microphysics schemes were also tested. Simulated 2-meter temperature, water vapor mixing ratio, and 10-meter wind speed were compared to more than 11 million hourly observations from the Meteorological Assimilation Data Ingest System (MADIS) to evaluate all simulations. Comparing simulated 36- and 12-km precipitation fields to Multisensor Precipitation Estimator (MPE) data is also underway.

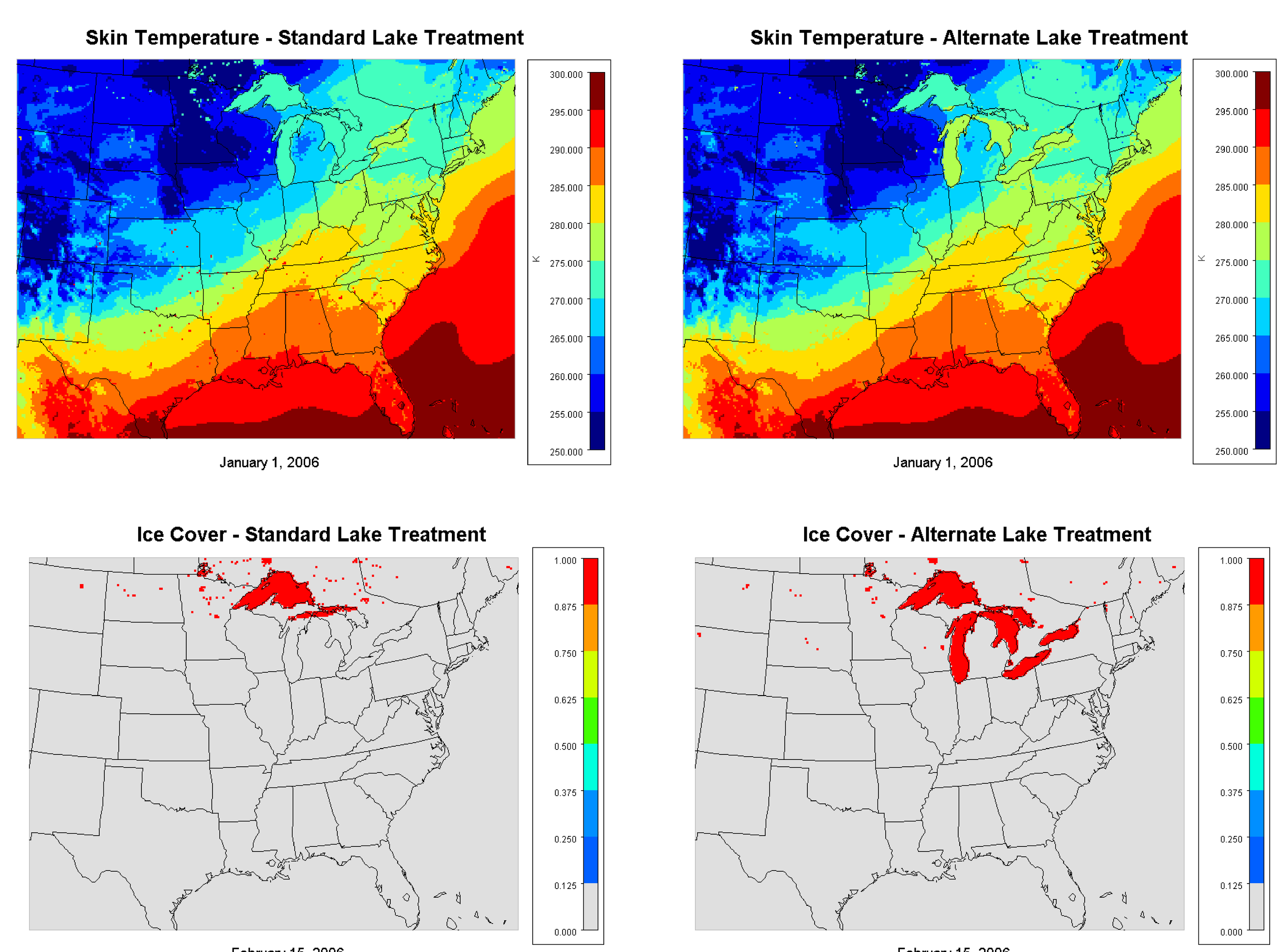
Modeling Configuration

WRF 3.3.1 was used for 13 test simulations of the year 2006 at 12-km resolution. Outputs from the previous 36-km downscaling with analysis nudging based on NCEP-DOE Reanalysis 2 (R-2) data were used to define the parent domain for one-way nesting. R-2 data were also used for all analysis and spectral nudging tests at 12-km resolution. Simulations were started at 0000 UTC 2 December 2005 to provide a 30-day spin-up and were calculated continuously to 0000 UTC 1 January 2007 with no restarts. WRF was run on the 12-km domain with the same 34-layer configuration and 50 hPa model top used in the previous 36-km work. Input data for the lower boundary and for interior nudging above the PBL (when applied) were the 2.5° × 2.5° analyses from the R-2 data. Physics options used include RRTMG for longwave and shortwave radiation, the Yonsei University PBL scheme and the Noah land-surface model. The WRF single-moment 6-class microphysics scheme was used in most of the 12-km simulations, but we tested the Morrison double-moment scheme with no nudging and with spectral nudging. Most 12-km simulations used the Grell-Devenyi ensemble cumulus parameterization scheme, but we also tested the Kain-Fritsch scheme with no nudging and with spectral nudging.



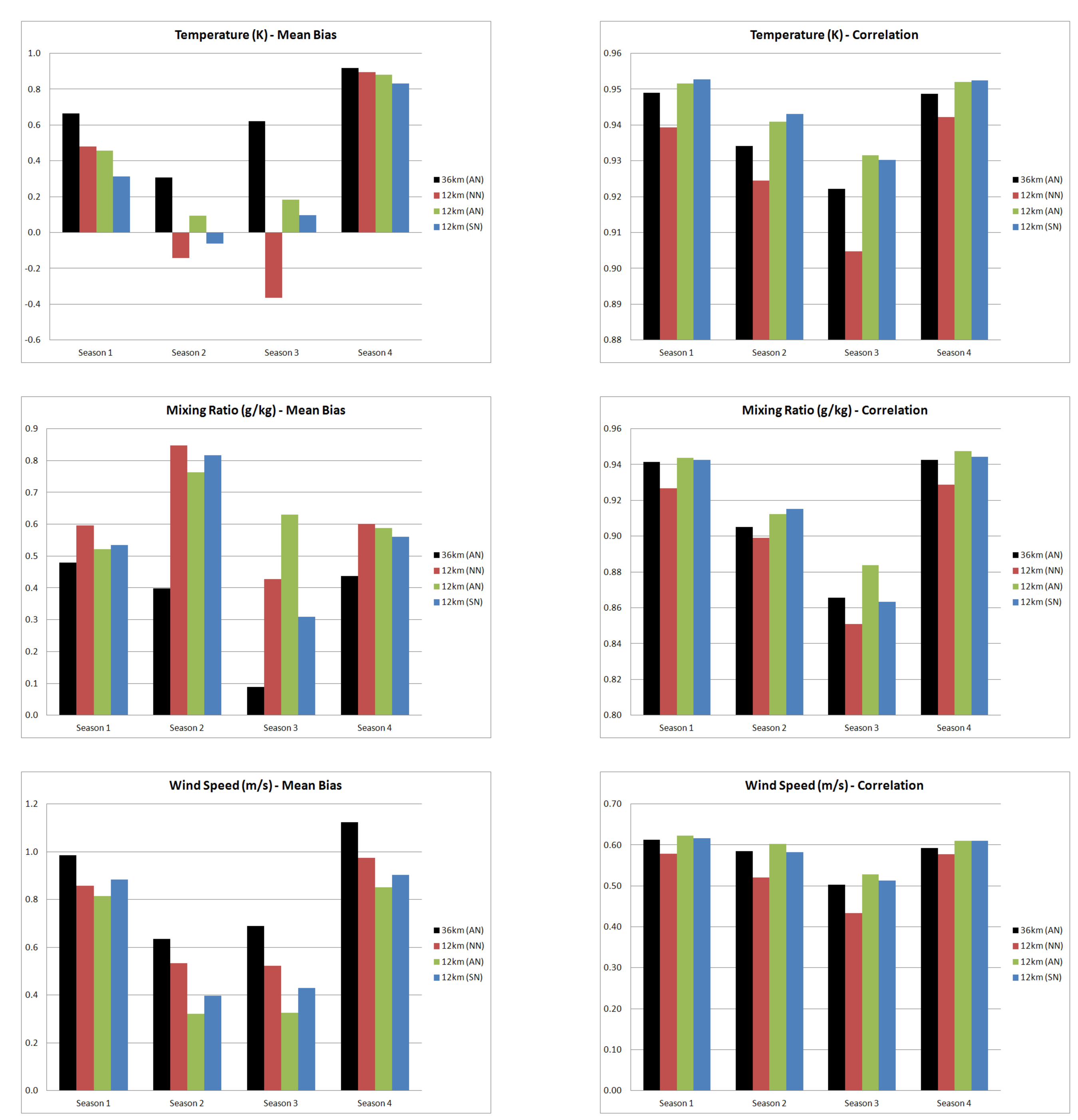
Preliminary Findings

Lake Temperatures and Ice Cover



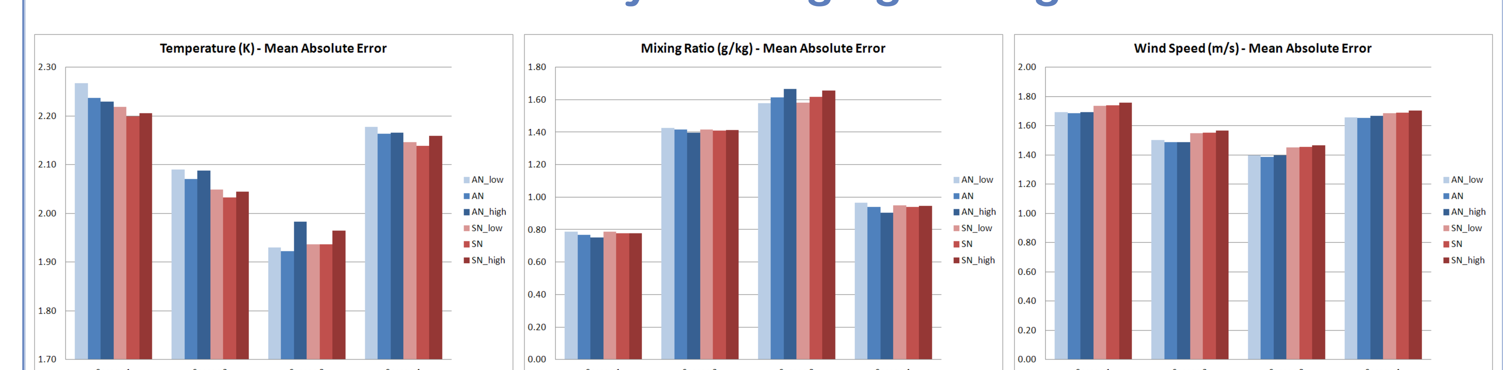
The standard method of setting lake surface temperatures in WRF uses a nearest-neighbor approach and sea-surface temperature data from the lower boundary input data. The graph above at the upper left shows surface skin temperature with the temperature of inland lakes unreasonably warm in the central Great Plains and Lower Ohio Valley due to their proximity to the Gulf of Mexico. Even the Great Lakes are not resolved in the R-2 data used to define lower boundary conditions and their temperature is based on James Bay to the north or, in the case of Lake Ontario, the Atlantic Ocean to the east. Standard WRF preprocessing software provides the ability to set lake temperatures based on average prior surface air temperatures. A one-month prior average results in the lake temperatures shown at the upper right. These do look more reasonable, but further analysis later in the simulation shows this alternate lake temperature method results in a complete freezing of all of the Great Lakes (lower right graph). The standard method does not result in reasonable ice cover either, as it produces complete freezing of Lake Superior which does not happen in reality. We are currently incorporating a fresh-water lake model ("FLake") into our implementation of WRF (Mironov et al., 2010, *Boreal Env. Res.*) and preliminary results show much more reasonable water temperatures and ice cover for all of the Great Lakes.

Evaluating 12-km vs. 36-km Resolution



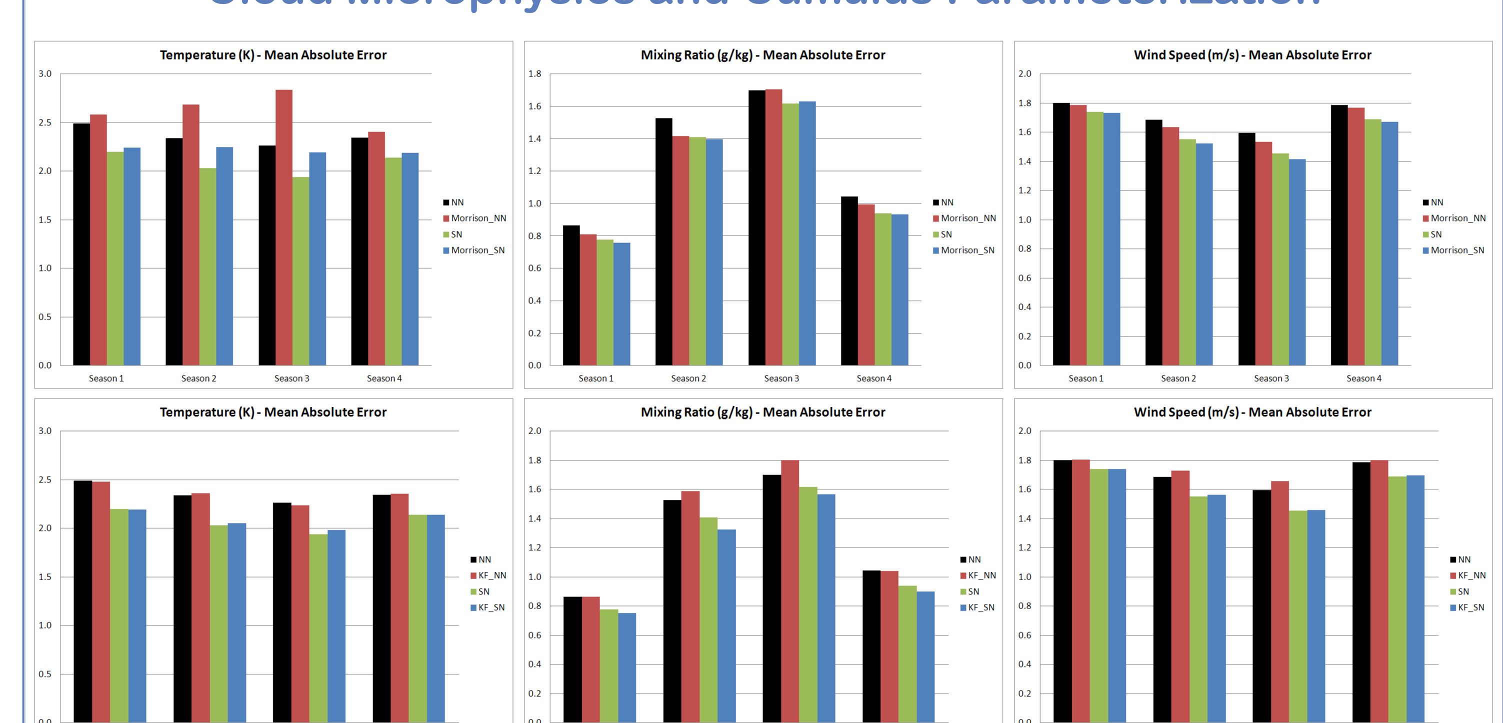
The graphs above show seasonal evaluations of the parent 36-km WRF simulation and our 12-km nested simulations with no interior nudging (NN), with analysis nudging (AN), and with spectral nudging (SN) as compared against hourly surface data from MADIS. Physics options in the 12-km simulations were the same used in the 36-km study. Nudging coefficients for 12-km analysis nudging were 5×10^{-5} s^{-1} for θ and UV and 5×10^{-6} s^{-1} for Q, or one-half the values used in the 36-km simulation. For 12-km spectral nudging, the coefficients were 1×10^{-4} s^{-1} for θ, UV and Φ with a top wave number of 2 in the X and Y dimensions . Three-month seasons are defined as January-March (season 1) to October-December (season 4). In general, the 12-km simulation with no interior nudging is less accurate than the 36-km simulation that was constrained with analysis nudging. However, analysis or spectral nudging at 12-km resolution does increase accuracy for 2-meter temperature and, to a limited degree, 10-meter wind speed. A strong positive bias in water vapor is apparent in all runs and will be investigated.

Sensitivity to Nudging Strength



To test sensitivity to nudging strength, the nudging coefficients for analysis and spectral nudging were all reduced by one-half and increased to twice the base values for 12-km simulations. The results of comparison to hourly surface data for each 3-month season of the 2006 simulation period are shown above. In general, the changes in model accuracy were minor and the base values appear to be appropriate. However, sensitivity to nudging strength did vary depending on the variable and the type of nudging applied. Sensitivity to the wave numbers used for spectral nudging will also be investigated.

Cloud Microphysics and Cumulus Parameterization



The 12-km simulations using no nudging and base-strength spectral nudging were evaluated by varying the cloud microphysics and cumulus parameterization options. The top row shows the mean absolute error when either the WRF single-moment 6-class scheme (NN and SN) or the Morrison double-moment scheme (Morrison_NN and Morrison_SN) is used for cloud microphysics. The bottom row shows the effect of using either the Grell-Devenyi ensemble cumulus scheme (NN and SN) or the Kain-Fritsch scheme (KF_NN and KF_SN). The benefit of using spectral nudging is evident in all simulation cases and for all variables analyzed.