The Development of Dynamical Downscaling at the Environmental Protection Agency: Developing a Model Framework for WRF

Jared H. Bowden, Tanya L. Otte, Jerold A. Herwehe, Christopher G. Nolte
US EPA National Exposure Research Laboratory; contact: bowden.jared@epa.gov

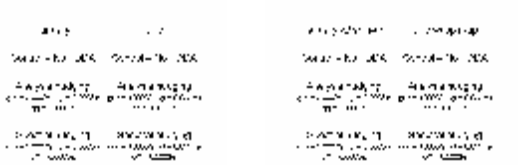
Introduction: The mission of the EPA's Global Change Research Program is to assess the impacts of global change on air and water quality, ecosystems, and human health. The 2009-2014 EPA strategic plan targets the impacts of global climate change as an area of needed improvement. This study aims to provide a model framework for WRF using the most recent advances within the modeling system which will be used for future regional climate change projections.

Background: There is a common problem typical in the mid-latitudes where the atmospheric state simulated By the regional climate model deviates from the driving state at large scales (von Storch et al. 2000). The problem arises from a distortion of the large scale circulation by way of Interaction of the modeled flow with the lateral boundaries of the nested domain as the regional model is forced to satisfy the boundary conditions and the large-scale flow within the modeled domain. Hence, regional climate simulations are sensitive to the domain size and position. Miguez-Macho et al. (2004) attributed the physical mechanisms for the large scale drift within a regional climate model with varying domain sizes and positions to distortions of the large-scale modeled flow with the lateral boundaries. Using spectral nudging in a regional climate model, they were able to eliminate the dependency on domain position by constraining the synoptic-scale flows which helped improve the precipitation results. They further suggest that this technique is necessary for dynamical downscaling with domains of a few thousand kilometers. An additional nudging technique named "analysis" nudging uses gridded analyses of meteorological state variables to help characterize the meteorological conditions. This technique has been applied extensively for creating 4D "retrospective" meteorological data sets for air quality simulations (Stauffer et al. 1993; Otte 2008). This technique may lead to improved "climatological" simulations as it helps to constrain the large-scale circulation.

Objective: The objective of this study is to test the sensitivity of regional climate solutions via testing analysis nudging and spectral nudging techniques. The model sensitivities will help determine the appropriate use of nudging for future climate change downscaling studies.

von Storch H, Langenberg H, Feser F (2000): A spectral nudging technique for dynamical downscaling purposes. *Mon Wea Rev* **128**:3664-3673
Miguez-Macho G, Stenchikov G, Robock A (2004): Spectral nudging to eliminate the effects of domain position and geometry in regional climate model simulations. *J Geophy Res* **109** D13104
Stauffer DR, Seaman NL, Warner TT, Lario AM (1993): Application of an atmospheric simulation to diagnose air-pollution transport in the Grand Canyon region of Arizona. *Chem Eng Com* **121**:9-25
Otte TL (2008): The impact of nudging in meteorological model for retrospective air quality simulations. Part 1: Evaluation against national observation networks. *J App Meteor Climatol* **47**:1853-1867.

Methodology: To test the initial sensitivity of traditional analysis nudging vs. spectral nudging the following set of experiments have been performed for WRF for a 108km-36km two way nest over North America driven by the NCEP-NCAR reanalysis data and OI SST for the year 2001:

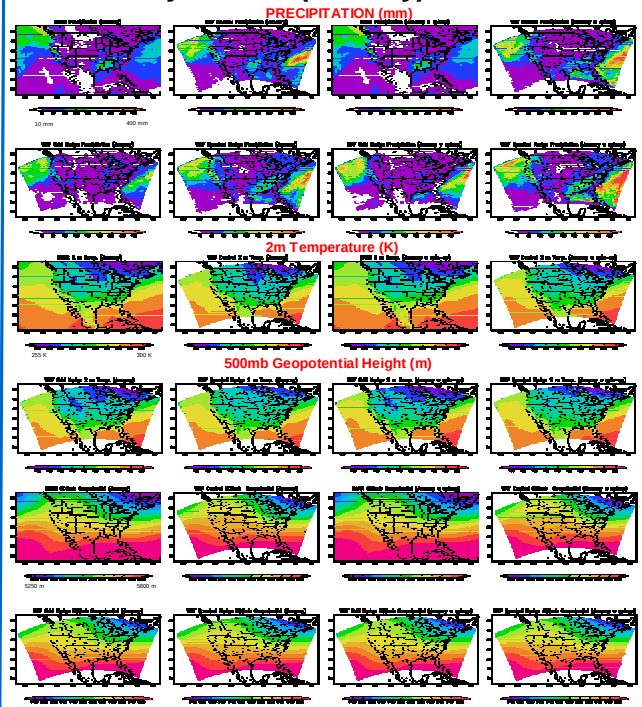


There is no nudging within the boundary layer

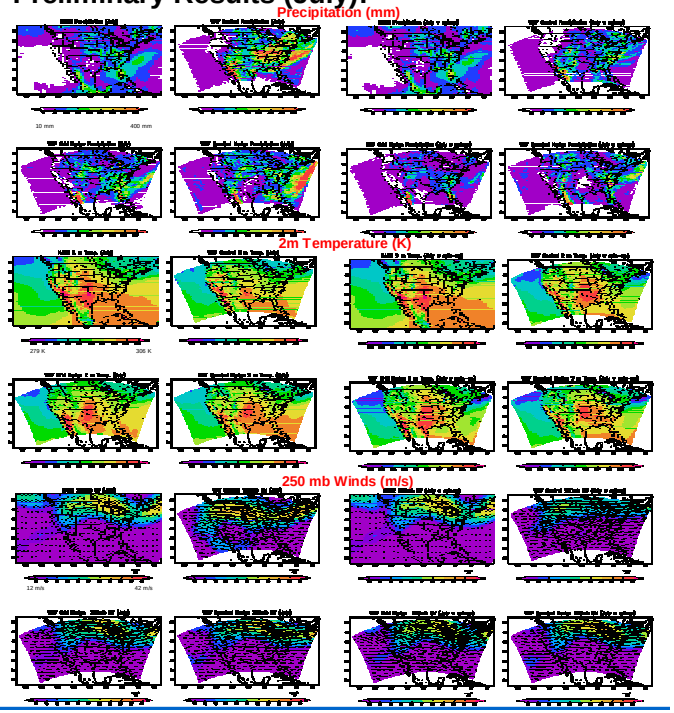
The NCEP-NCAR Reanalysis driving fields was chosen because its resolution is similar to the resolution of "typical" GCMs. The one month spin-up will help illustrate the impact of surface fields such as the soil moisture. We will use the 32km North American Regional Reanalysis for model verification.

Model Options: KF Cumlus, WSM 6, PX LSM, ACM PBL, CAM radiation

Preliminary Results (January):



Preliminary Results (July):



Early Thoughts and Future Research:

- The control simulations illustrate that the amplitude of the ridge is overestimated in January and displaces the synoptic wave in July. Spectral and analysis nudging both correct the large-scale circulation bias, but the nudging simulations do not illustrate superior performance for the surface fields (e.g. precipitation).
- The Rocky Mountain West precipitation is overestimated in the summer despite the choice of the nudging. Local surface processes are hence more important in this region for this simulation than the large circulation bias.
- The precipitation in January over the Gulf States is a good example that the analysis nudging can suppress the development of key fundamental processes for precipitation. However, we caution that more tests need to be performed to determine the use of analysis nudging for climate applications, e.g. moisture nudging coefficient may be too strong.
- The spin-up period is crucial for the success of short-term climate simulations (e.g. seasonal projections) in areas that have large evaporation sources in the absence of large-scale forcing. This suggests that there needs to be a minimum one month spin-up to test the sensitivity of nudging for climate.
- We need to work to understand the over prediction of rainfall in the Rocky Mountain West. Sensitivity studies such as changing LSM and PBL may help determine the source of error.
- There is a need for longer continuous simulations to determine the statistical significance of nudging for climate applications. This will also eliminate problems related to model spin-up.
-The PX LSM was used w/o soil temp. & moisture nudging features. Tests need to be conducted to determine the impacts of those functions for regional climate simulations.