REGIONAL DYNAMICAL DOWNSCALING OF GISS-ER CLIMATE SIMULATIONS WITH FOCUS ON GULF OF MEXICO STATES

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Dynamical downscaling is considered a generally reliable approach to extract more regional details from climate simulations performed with Global Climate Models (GCM). Recent studies (e.g. Liang et al. 2004, Lynn et al. 2010) show that, regional details in downscaled precipitation and air temperature fields are not noisy (despite the regional biases that may exist); and therefore might be valuable for assessing impacts of climate variability and change. In this study, the state-of-the-art Weather Research and Forecasting (WRF) model (Skamarock et al. 2006) was used as the regional climate model (RCM) to downscale global climate simulations over the southeastern United States, particularly in the northern Gulf of Mexico. WRF Version 3.2.1 was used to downscale the IPCC AR4 simulations from the NASA GISS-ER GCM (Russell et al. 2000, Schmidt et al. 2006). A set of two 11-year periods were used: 1990-2000 (20C3M scenario) and 2050-2060 (selected from the SRESA2 forcing scenario).

The following physical options were used: Kain-Fritsch cumulus parameterization; the WRF single-moment 5-class microphysics scheme; Rapid Radiative Transfer Model (RRTM) for longwave atmospheric radiation; the Goddard scheme for shortwave radiation; the Yonsei University parameterization for the atmospheric boundary layer; and the Noah land surface model with a 2-m deep soil layer. All the WRF-RCM simulations were performed at three nested domains with two-way coupling between the nests with grid spacing of 45-, 15-, and 5 km. The spatial extent of the inner fine-grid domain with 5 km grid spacing is shown in Fig. 1. The vertical levels in WRF were represented by 41 sigma-pressure levels. Initial and boundary data for were pre-processed from the GISS-ER model output (WCRP 2010). This conversion includes the modification of original atmospheric and land surface variables, their spatial interpolation from the GISS 4˚x5˚ latitude-longitude grid to 1˚x1˚ latitude-longitude grid, temporal interpolation, level/time subseting and units conversions. Missing values of air temperature, relative humidity, and wind components at low isobaric levels (1000 hPa, 925 hPa, and 850 hPa) were extrapolated from above.

Each of 11-years downscaling simulations were performed on a month-long basis (e.g. Lynn et al. 2010). Every month-long simulation was started from initial conditions retrieved from the GISS model data. To keep the WRF-based solution close to the GISS large-scale fields, a simple nudging approach was adopted above 700 hPa for the following model variables: air temperature, geopotential, water vapor mixing ratio, and wind components. The sea surface temperature (SST) was represented by the skin temperature field available from the GISS model output.

Three sets of mean 2 m air temperature fields averaged over the years 1990-2000 for the months of July and October are shown in Fig.1. The warmest overland temperatures are observed over the Mississippi Delta (having lower vegetation fraction in comparison with adjacent areas and therefore the higher surface temperature) and over the state of Louisiana. The spatial distribution of this warm bias indicates that it could be associated with a different specification of green vegetation fraction in the WRF-based RCM and in the NARR processing system/model. During July, the Mississippi Delta is clearly observed as a region of elevated surface air temperature both in RCM and in the NARR data, as shown in Fig. 1. Note that a better agreement between the NARR data and RCM simulations over the Delta is due to fine spatial resolution (5 km grid spacing) used in the RCM. During January, the GISS model produces a marked cold bias of about 3 ˚C in the northern part of the domain. In April, the surface air temperature is consistently warmer in the RCM simulations if compared with the corresponding NARR data over the 5 km domain (not shown). Fig. 2 illustrates the mean annual cycle (averaged for 1990-2000) of the surface (at 2 m level above the ground) air temperature. In general, the RCM-downscaled simulations show a closer agreement with the NARR data as compared with the output from the GISS model, except for spring and the northern part of the 5 km domain. Typically, the GISS model shows lower values of surface temperature having negative monthly mean bias of 2-3 ˚C, as compared to temperatures from the NARR data and RCM simulations. Figure 3 shows mean annual cycles (averaged for 1990-2000 and for 2050-2060) of the surface air temperature simulated with the WRF-based

RCM. An overall increase of monthly mean temperatures (a warming trend of the surface air temperature) between 1990-2000 and 2050-2060 is quite clear in Fig. 3. Both the RCM simulations and the GISS model indicate the most substantial increase of surface air temperature, exceeding 3 ˚C during February, September, and October (see left frames in Fig. 3). Finally, the RCM and the GISS model failed to reproduce a correct annual precipitation cycle, especially over northern part of the 5 km domain. Contrary to the NARR data, these two models produced an excessive increase in precipitation amount from April to August.

REFERENCES

Liang, X-Z, Li Li, K.E. Kunkel, M. Ting, and J. X.L. Wang, 2004: Regional climate model simulation of U.S. precipitation during 1982-2002. Part I: Annual cycle. *J. Climate*, **17**, 3510-3529.

Lynn, B.H., and Coauthors, 2010: Testing GISS-MM5 physics configurations for use in regional impact studies. *Clim. Change*, **99**, 567-587.

Russell, G.L., J.R. Miller, D. Rind, R.A. Ruedy, G.A. Schmidt, and S. Sheth. 2000: Comparison of model and observed regional temperature changes during the past 40 years. *J. Geophys. Res.*, **105**, 14891-14898.

Schmidt, G.A., and Coauthors, 2006: Present-day atmospheric simulations using GISS ModelE: Comparison to in situ, satellite, and reanalysis data. *J. Climate*, **19**, 153-192.

Skamarock, W.C., J.B. Klemp, J. Dudhia, D.O Grell, D.O. Gill, D.M. Barker, W. Wang, and J.G. Powers, 2006: A description of the advanced research WRF. *NCAR Technical Note*, NCAR/TD-468+STR, 88pp.

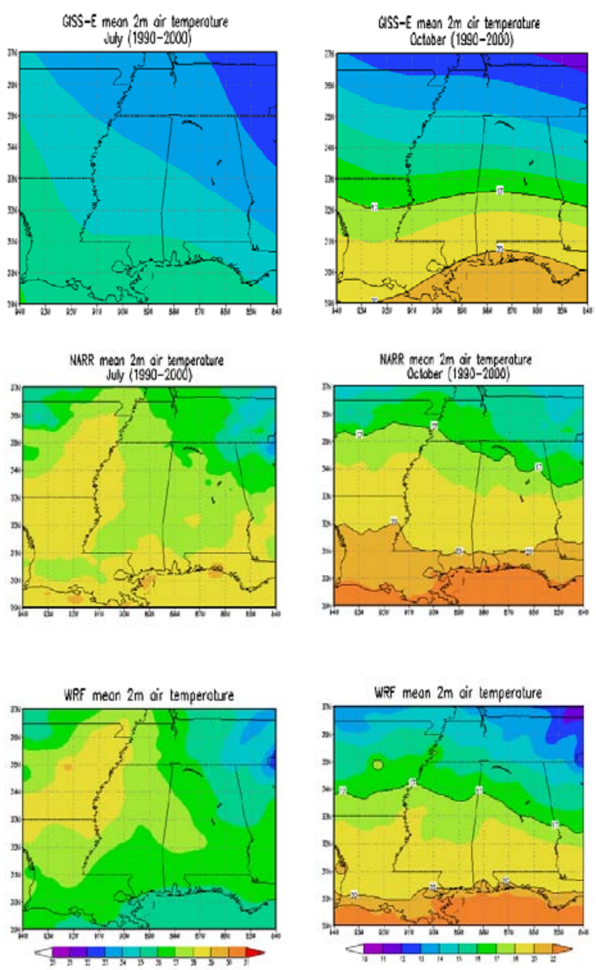

Figure 1. Distribution of air temperature at 2m for July (left frames) and October (right) from NARR data (middle frames) and from GISS-E model (upper frames) and WRF-based downscaling (lower frames) averaged for 11 years (1990-2000).

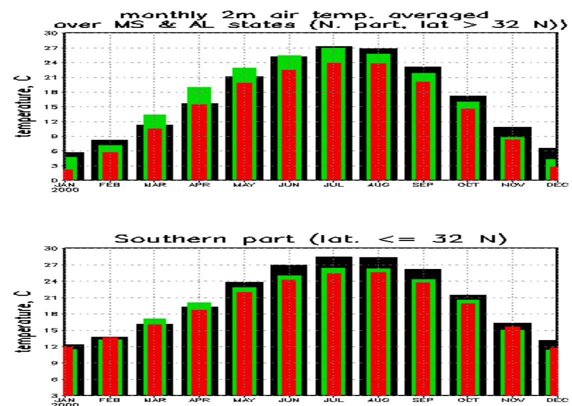

Figure 2. Comparisons of monthly mean 2 m air temperature (averaged for 5-km domain) between NARR data (black bars) and WRF-based RCM (green) for 1990-2000. Red bars stands for temperature from GISS model. Northern part of the domain (upper frame) and southern part (lower).

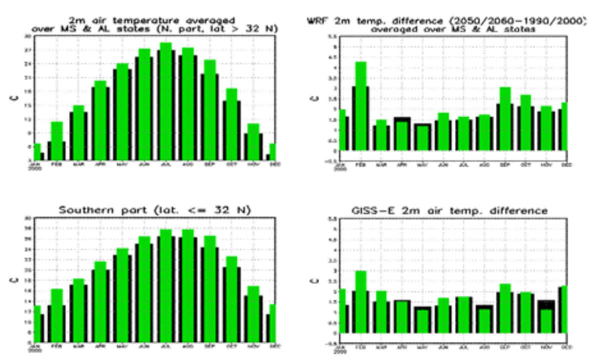

Figure 3. Monthly mean 2 m air temperature (left frames) for 1990-2000 (black bars) and 2050-2060 (green) and their difference (right frames) from WRF-based RCM simulations. Right frames: black bars indicate northern part of the domain and green – southern part.