Regional Climate Downscaling Study in Eastern United States

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1. INTRODUCTION

Global climate simulations are commonly conducted with spatial resolutions of a few hundred kilometers. Under this resolution, the integrity of studying local climate change impacts is lost. Thus, dynamical downscaling is applied to these global climate outputs in order to achieve a higher resolution and better accuracy through regional simulation. The earliest case of downscaling was described by Dickinson *et al.* [1989] who applied a horizontal resolution of 60 km to a regional climate model. Subsequently, a series of studies on regional climate downscaling have been performed with resolutions of 50-60 km [*Giorgi*, 1990; *Giorgi et al.*, 1994; *Hostetler et al.*, 1994; *Leung et al.*, 1996; *Podzun et al.*, 1995]. Recently, finer spatial resolutions of 40 km or less have been tested [*Bell et al.*, 2004; *Snyder et al.*, 2002] using Goddard Institute for Space Studies (GISS)/Mesoscale Modeling System Version 5 (MM5) or Community Climate System Model 3 (CCSM3)/Weather Research and Forecasting (WRF) under IPCC AR4 scenarios.

In this study, a newly developed Community Earth System Model (CESM) version 1.0 was used to simulate future climate change under new IPCC Representative Community Pathway (RCP) 8.5. The base period (2001-2004) and future period (2005-2099) were chosen as present climate and future climate, respectively. The outputs of CESM were used as initial and boundary conditions for a downscaling process with WRF. Constrained by computational resources, only seven years of data were simulated by WRF, in which four years (2001-2004) from present climate and three years (2057-2059) from future climate were included.

Considering the importance of high spatial resolution in climate study for public health and policy makers, an ultra-fine resolution of 4 km by 4 km in the Eastern US domain is tested in this study.

2. METHODOLOGY

CESM was conducted on a 0.9 by 1.25 degree resolution from 2001 to 2099, and data was archived for downscaling purposes every three hours. The dynamical downscaling technique was then applied to CESM outputs, and the downscaled outputs were used as initial and boundary conditions for WRF. After WRF simulations, the outputs compared with CESM results to verify the downscaled methodology.

2.1 Downscaled domains

Three downscaled domains were defined (Fig. 1): a 36 km by 36 km North America domain (D1), a 12 km by 12 km continental US domain (D2) and a 4 km by 4 km Eastern US domain (D3). Analysis will mainly focus on domains D2 and D3.

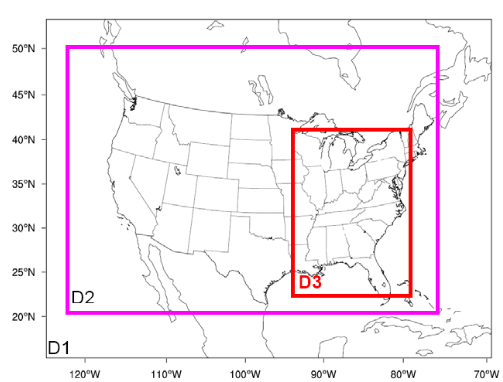

Fig. 1. Three WRF simulation domains

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2.2 Comparison between CESM and WRF Preprocessing System (WPS)

After downscaling, the WRF Preprocessing System (WPS) was used to process the downscaled CESM outputs and prepare the initial and boundary conditions for WRF. In this step, simulation of physics within the system is not involved, so the spatial pattern should be similar between CESM and WPS outputs. The first hour of spatial temperature (2 meter) distributions from CESM and WPS for the 36 km domain are compared in Fig. 2. The distributions of temperature show a high level of agreement across the entire domain between CESM and WPS. In addition, other variables within both surface and vertical layers for the three domains also show consistent patterns between CESM and WPS (not shown here).

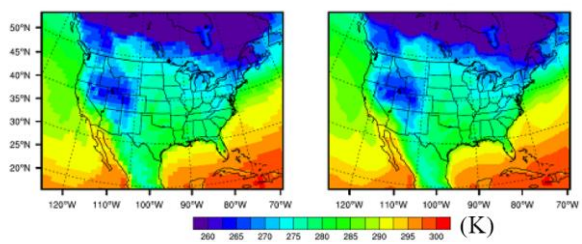

Fig. 2. Spatial patterns comparison of temperature (2m) between CESM and WPS

2.3 Comparison between CESM and WRF outputs

Mean precipitation during 2001-2004 was used to compare model outputs with real observational data. The observational data for precipitation was downloaded from http://www.esrl.noaa.gov/psd/data/gridded/data.UDel_AirT_Precip.html. Overall, the spatial patterns between model outputs (CESM, WRF-D2 and WRF-D3) show consistent patterns with observational data (Fig. 3). However, in the Northwestern US, WRF over predicts the precipitation while CESM slightly under-predicts. In the southeast, WRF captures more precipitation compared with CESM, but shows slightly over prediction compared with observational data.

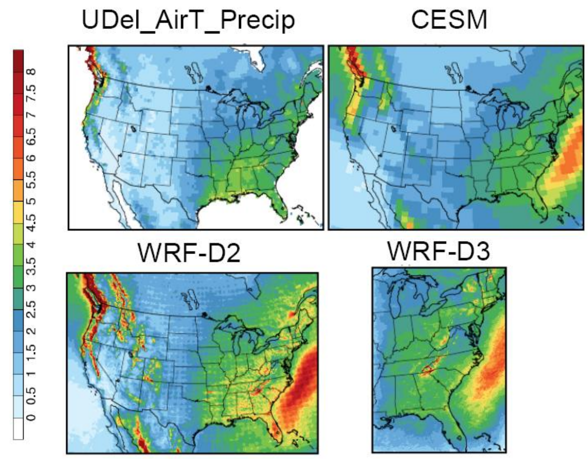

Fig. 3. Spatial patterns of precipitations: the top panel shows the precipitation for observational data and CESM, while the bottom panel shows the precipitation for WRF 12 km and 4 km domains.

3. FUTURE TEMPERATURE ANOMALIES

The mean temperature change from present climate (2001-2004) to future climate (RCP 8.5 2057-2059) in the eastern US is shown in Fig. 4. Significant temperature increases are observed in both model simulations, ranging from 1.5 to 3 ºC in the domain. This increase is slightly larger in the Northeast and upper Midwest US compared with the Southeast. Compared with CESM outputs, the temperature increases in WRF 4 km outputs are slightly lower (about 0.5 ºC) in the Southeast. Also, WRF shows more spatial variation due to higher spatial resolution.

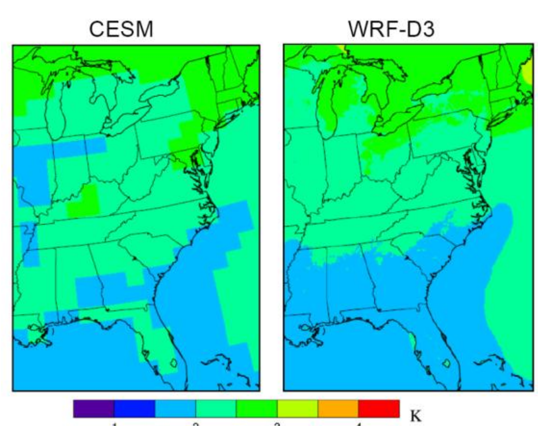

Fig. 4. Temperature change from present climate (2001-2004) to future climate (2057-2059) between CESM and WRF 4 km domain

4. SUMMARY

Dynamical climate downscaling technique has been applied on CESM outputs for simulating regional WRF. Consistent spatial patterns between CESM and WPS have demonstrated the robustness of this downscaled methodology. The evaluations of precipitation between CESM and WRF verify that WRF as capable of predicting present climate when implementing initial and boundary conditions downscaled from CESM. In 2057-2059, significant increases in temperature were observed in both CESM and WRF simulation, indicating an increasing trend in future temperature under the RCP 8.5 scenario.

5. ACKNOWLEDGEMENTS

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