# Regional Climate Model Downscaling in Eastern United States

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## Abstract

One of the commonly used global climate models Community Earth System Model (CESM) version1.0 was used to conduct present climate (2001-2010) and Intergovernmental Panel on Climate Change (IPCC) Representative Community Pathways (RCP) 4.5 (2011-2059) climate simulations. NCEP/NCAR Reanalysis data (2001-2010) was used to evaluate CESM present climate and the overall bias for temperature is from -1.0 to 1.0 K and the correlation coefficient is 0.8-0.9 in majority of the areas. Heat waves were also determined in present climate (2001-2010) and future climate (2050-2059) simulations, and the average duration of heat waves increases by a factor of 1.0 to 2.0 in future in US and Europe. Dynamical downscaling was applied to CESM by driving regional climate model Weather Research and Forecasting (WRF), for further studying local climate impact. CESM outputs were used to provide initial and boundary conditions for WRF. We downscaled CESM outputs (0.9 by 1.25 degree resolution) to 36 km by 36 km continental United States (CONUS) domain, and further down to 12 km by 12 km CONUS and 4 km by 4 km Eastern US. Base year (2001) WRF simulation was evaluated with both CESM and Meteorological Assimilation Data Ingest System (MADIS) observational data. Temperature was used to compare between CESM and WRF outputs and the bias is ranging from -1.0 to 1.0 K. The bias between MADIS and WRF is from -1.5 to 1.5 K. Small bias illustrates successful regional climate downscaling technique has been applied to CESM.

## Evaluations of CESM Simulations

After simulations, CESM outputs were compared with NCEP/NCAR Reanalysis data for the period of 2001-2010 (Present Climate). Fig. 1 shows the bias and correlations between these two model outputs for temperature at 2 meter. The overall bias is within -1.0 to 1.0 K in majority of the areas. It shows warming bias (positive values) in Midwest and Eastern US, Europe, while cold bias exists in north and south poles, partial of Asia and Africa. The average bias in four continents of Europe, South Asia, East Asia and North America (shown in Fig. 1 a, with white squares from left to right) is 0.12, -0.48, -0.07 and 0.98 K, respectively. High correlation coefficients (0.8 to 0.9) in most of the areas show good correlations between CESM and NCEP data while relative poor correlations exist in the tropical ocean areas. The average correlations for the four continents are 0.80, 0.69, 0.84 and 0.76, respectively.

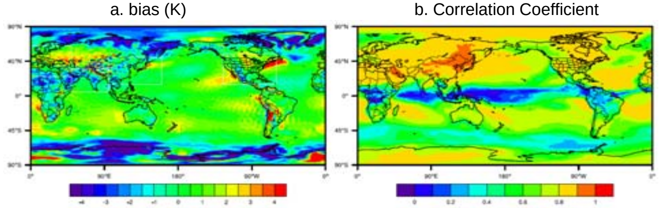


**Fig. 1. Bias and correlations between CESM outputs and NCEP/NCAR Reanalysis data for temperature at 2 meter from 2001 to 2010**

## Duration/Frequency of Heat Waves

There are a few ways for defining heat waves and one way is to define the duration and frequency (number of events) of a heat wave. This definition is based upon two thresholds (T1 and T2). T1 and T2 were defined as 97.5th and 81st percentile of a given period of time. Then the heat wave was defined as the longest continuous period during which (1) the maximum daily temperature reach T1 for at least 3 days (2) the mean daily maximum temperature can not be less than T1 and the daily maximum temperature must reach T2 every day [Huth et al., 2000; Meehl and Tebaldi, 2004]. The duration and frequency of heat waves were examined and shown in Fig. 2. The top panel shows average heat wave duration and number of heat wave events for present climate. The bottom panel shows similar information but for future climate. Large increasing of the average heat waves duration and frequency was found in future climate and it increases by a factor of 1.0 to 2.0 in US and Europe.

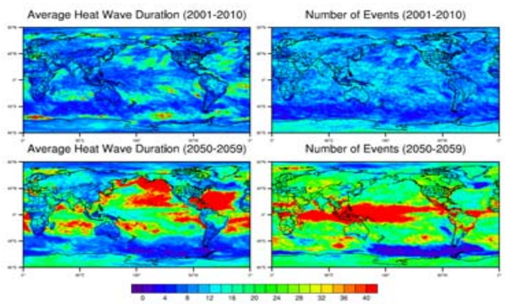


**Fig. 2. Duration (left) and number of events (right) of heat waves**

## Downscale Methodology and Evaluation of WRF Simulations

We implemented dynamical downscaling technique and applied to CESM. The downscaled CESM output was processed by WRF Preprocessing System (WPS), which provides initial and boundary conditions for WRF simulations. In order to verify the correctness of the downscaling methodology, we compared the spatial distribution between CESM and WPS in terms of all downscaling variables such as temperature, specific humidity, wind vector, etc. The distributions of all these variables in both surface and vertical layers show good agreement between CESM and WPS (not shown).

Three domains were chosen for WRF simulations, shown in Fig. 3 marked in white square. The outer domain has a horizontal resolution of 36 km by 36 km, the second one has a resolution of 12 by 12 km and the inner domain covers 4 km by 4 km Eastern US. The 4 km by 4 km domain contains three sub-regions: Midwest (MW), Northeast (NE) and Southeast (SE). We have chosen 2001 as the base WRF simulation year for the evaluations.

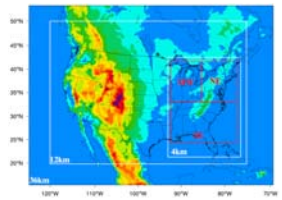

**Fig. 3. Three regional climate domains with three sub-regions inside the 4 km domain**

The WRF outputs from downscaling were used to compare with CESM outputs and observational data for investigating the effects of downscaling. Fig. 4 shows the temperature bias between CESM and WRF (left) and MADIS and WRF (right). The bias is ranging from -1.0 to 1.0 K between CESM and WRF and -1.5 to 1.5 K between MADIS and WRF for the three sub-regions shown in Fig. 3. The small bias shows good downscaling implementation from CESM to WRF.

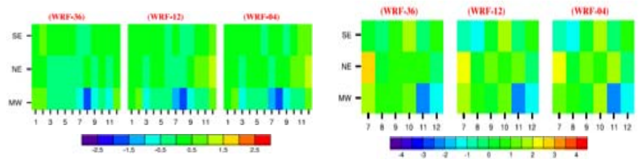


**Fig. 4. Bias of temperature at 2 meter from CESM/WRF and MADIS/WRF**

## Summay

We have successfully simulated present and future global climate using CESM. The results of heat waves from CESM demonstrated dramatic increase in future climate in terms of both duration and frequency. We also implemented dynamical downscaling technique for finer regional climate simulations. The evaluations between CESM and WRF in 2001 prove WRF is capable of predicting present climate conditions with suitable downscaling methodology. In future, we will downscale 2050s RCP 4.5/8.5 CESM outputs to 4 km by 4 km Eastern US WRF simulations for studying regional heat wave impact in a local higher resolution scale.

## References

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## Acknowledgements

This research was supported in part by the National Science Foundation through TeraGrid resources provided by National Institute for Computational Sciences (NICS) under grant number [TG-ATM110009].