

Final Report 2011-2016

In-depth Regional Process-level Analyses of NARCCAP and AR5 simulations over North America: Towards Establishing Differential Credibility of Regional Climate Projections

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NCAR PI's are filing separate report, with coordination.

1 Results and Accomplishments 2011-2016

In this research we are taking an alternative approach to differential evaluation of model credibility by focusing on process-level evaluation rather than on simple metrics. We hypothesize that a consistent set of process-oriented model analyses can be developed and applied in different climate regimes, and that this suite of model analyses will help define credible model members whose future simulated climates will have value for regional climate change assessment. We are focusing on three regions in North America (Southwest, Great Plains, Northeast) with the following objectives: (1) Establish a framework for determining the differential credibility of climate simulations using a process-based methodology for three specified regions; (2) Develop process-level time-series analysis to follow identified mechanistic errors in the evolution (from current period into the future) of warm season precipitation in the regions; (3) Based on the process-level analysis, differentiate the credibility of the models using collective expert evaluation (CEE); (4) Translate the process-level information into quantitative metrics; (5) Compare these metrics with the baseline metrics of ENSEMBLES; (6) Compare credibility rankings based on our process-level collective expert evaluation and developed metrics with rankings based on the ENSEMBLES metrics and diagnose causes of differences. (7) Apply the developed framework to Coupled Model Intercomparison Project (CMIP5) experiments.

This research employs simulation data sets produced through the North American Regional Climate Change Program (NARCCAP) and the global coupled model (50 km) decadal predictions in progress as part of CMIP5 for the present day and near future periods. The process-level investigations will first be conducted for the coupled global models (AOGCMs), atmospheric global models (time-slices), and the regional climate models (RCMs) involved in NARCCAP. Time series of process-level errors are being examined in the reanalysis-driven and AOGCM-driven present day simulations and followed into the future simulations. The importance of the errors as the models respond to the new forcing in the future is being evaluated. In this way, our analysis focuses on the effect of the more consequential errors on the model future response. Our purpose is to perform qualitative process-level collective expert evaluations for each region, which may then be transformed into quantitative indicators.

The ultimate goal of this analysis is to provide meaningful differential weighting of the models using a process-level approach that results in more robust estimates of future climate change. The process-level analyses have value in that, by enhancing our understanding of the evolution of processes under greenhouse gas forcing, uncertainties may be reduced in the sense that better understanding of important mechanisms at work will result. The proposed research directly addresses MAPP FY2011 Priority 1b: 'to evaluate uncertainties in the long-term prediction and projection of twenty-first century climate over North America leveraging NARCCAP and new

CMIP5 projections’.

In years 1-5, we have established a framework for evaluating models on Northeast climate and identified which biases are important (related to circulation and moisture divergence) in determining warm season rainfall. We have applied this framework to a large suite of CMIP5 and NARCCAP models to examine whether differential credibility can be established using expert judgement in addition to more objective metrics. In year 5 we have finalized work with the NCAR team to conduct similar set of analyses for the Great Plains region. This manuscript has been revised and resubmitted to Journal of Climate (Bukovsky et al., 2016). We have also presented this work on the Northeast and Central U.S. at the AMS and AAG meetings this year.

In all, we have examined necessary conditions for reliable climate change projections, considering underlying processes and their biases instead of just precipitation and temperature. This leads to expert judgments about the effects of identified errors on the projections of future precipitation, and the determination of differential model credibility and expected climate changes. The results from this procedure are providing insight into projections with improved understanding of uncertainty.

2 Highlights of Accomplishments in Years 1–5

- Process based-evaluation of NARCCAP and CMIP5 models has been completed for the Northeast, Southwest Monsoon and Southern Great Plains regions of the U.S., and examination of model credibility based on expert judgement is complete for each of these regions.
- This research has collectively resulted in 10 publications emphasizing aspects of the process-based methodology, and each of the three regions of interest.
- Results of this research have been disseminated via 23 presentations/posters given at national and international conferences, including 3 that were invited.
- For the North American monsoon region, the NARCCAP RCMs and their driving GCMs showed strong consensus on how precipitation was going to change, but our analysis showed that few of the simulations were credible. In fact, the less credible the simulation/projection was, the greater the projected decrease in precipitation was. Here, inherited GCM bias played a very strong role in the simulation credibility.
- In the southern Great Plains, we found that most of the NARCCAP simulations and projections were credible, showed strong consensus on projections of precipitation, and the changes in precipitation were being forced by physically plausible changes in the larger-scale drivers of precipitation in the region in a warming climate. Here, it is clear that, in better simulating regional precipitation, and responding to changes in forcing in a more plausible way, the RCMs are adding value to the simulations/projections from their GCM-drivers.
- In the Northeast U.S., a process based analysis of CMIP and NARCCAP projections for warm-season precipitation was able to identify the poorest model performers, but not the best. Our analysis also demonstrated little consensus on the sign of precipitation change, even among the more credible simulations.
- Overall summary of differential credibility and expert judgement methodology: Overall, we find in-depth process-level evaluation of the simulations to be a worthwhile endeavor, even if more time-consuming than other methods. Analysis needs to vary by region, although we

believe that systematic methods could be developed for specific regions. In assessing simulations in this manner, one can identify factors that are most important to simulate well, and identify how biases are affecting projections. In some cases, establishing differential credibility is less informative regarding the end ensemble projections, particularly when the models perform similarly, or the differential credibility makes no difference on the end ensemble mean projection. In other cases, it becomes very clear that some simulations are much less credible, and in throwing them out the ensemble mean projection changes significantly. Simple metrics do not produce the same results.

- The UConn team contributed to the MAPP CMIP5 Task Force publications and special issue of *Journal of Climate*.
- A post-doctoral researcher (Jeanne Thibeault) was mentored during this research.

3 Publications from Project

Bukovsky, M.S., J. Thompson, L.O. Mearns, 2017: The effect of weighting on the NAR-CCAP ensemble mean: Does it make a difference? *Clim. Res.*, to be submitted (draft complete, submission pending completion of a complementary manuscript).

Bukovsky, M., McCrary, R., Seth, A. and Mearns, L. O. (2016). A Credible, Poleward Shift in Warm-Season Precipitation Projected for the U.S. Southern Great Plains. *Journal of Climate*, accepted, pending revision.

Thibeault, J., and A. Seth (2015), Toward the Credibility of Northeast United States Summer Precipitation Projections in CMIP5 and NARCCAP Simulations, *Journal of Geophysical Research- Atmospheres*, 120(19), doi:10.1002/2015JD023177.

Bukovsky, M.S., C.M. Carrillo, D.J. Gochis, D.M. Hammerling, R.R. McCrary, and L.O. Mearns, 2015: Towards assessing NARCCAP regional climate model credibility for the North American Monsoon: Future climate simulations. *Journal of Climate* 28(17), 6707-6728. doi: 10.1175/JCLI-D-14-00695.1.

Thibeault, J. and A. Seth, 2014: A Framework for Evaluating Model Credibility for Warm Season Precipitation in Eastern North America: A Case Study of CMIP5 Simulations and Projections, *Journal of Climate*, **27**, 2, 493–510, doi:10.1175/JCLI-D-12-00846.1. (MAPP/CMIP5 Special Issue on North American Climate Change)

Eric Maloney, Ph.D; Suzana J Camargo; Edmund Chang; Brian Colle; Rong Fu; Kerrie Geil; Qi Hu; Xianan Jiang; Nathaniel Johnson; Kristopher Karnauskas; James Kinter; Benjamin Kirtman; Sanjiv Kumar; Baird Langenbrunner; Kelly Lombardo; Lindsey Long; Annarita Mariotti; Joyce Meyerson; Kingtse Mo; David Neelin; Zaitao Pan; Richard Seager; Yolande Serra; Anji Seth; Justin Sheffield; Julianne Stroeve; Jeanne Thibeault; Shang-Ping Xie; Chunzai Wang; Bruce Wyman; Ming Zhao, 2014: North American Climate in CMIP5 Experiments: Part III: Assessment of 21st Century Projections, *Journal of Climate*, **27**, 6, 2230–2270, doi:10.1175/JCLI-D-13-00273.1.

Donald Wuebbles, Gerald Meehl, Katharine Hayhoe, Thomas R. Karl, Kenneth Kunkel, Benjamin Santer, Michael Wehner, Brian Colle, Erich M. Fischer, Rong Fu, Alex Goodman, Emily Janssen,

Viatcheslav Kharin, Huikyo Lee, Wenhong Li, Lindsey N. Long, Seth C. Olsen, Zaitao Pan, Anji Seth, Justin Sheffield, Liqiang Sun, 2014: CMIP5 Climate Model Analyses: Climate Extremes in the United States, *Bulletin of the American Meteorological Society*, doi:10.1175/BAMS-D-12-00172.1.

Bukovsky, M.S., D.J. Gochis, and L.O. Mearns, 2013: Towards assessing NARCCAP regional climate model credibility for the North American Monsoon: Current climate simulations. *J. Climate*, 26, 8802-8826, doi: <http://dx.doi.org/10.1175/JCLI-D-12-00538.1>.

Seth, A., S. Rauscher, M. Biasutti, A. Giannini, S. Camargo, M. Rojas, 2013: CMIP5 Projected Changes in the Annual Cycle of Precipitation in Monsoon Regions, *Journal of Climate*, **26**, 19, 7328-7351, doi:10.1175/JCLI-D-12-00726.1. (MAPP/CMIP5 Special Issue on North American Climate Change)

Justin Sheffield; Andrew Barrett; Brian Colle; Rong Fu; Kerrie L Geil; Qi Hu; Jim Kinter; Sanjiv Kumar; Baird Langenbrunner; Kelly Lombardo; Lindsey N Long; Eric Maloney; Annarita Mariotti; Joyce E Meyerson; Kingtse C Mo; David Neelin; Zaitao Pan; Alfredo Ruiz-Barradas; Yolande L Serra; Anji Seth; Jeanne M Thibeault; Julienne C Stroeve, 2013: North American Climate in CMIP5 Experiments. Part I: Evaluation of 20th Century Continental and Regional Climatology, *Journal of Climate*, **26**, 23, 9209-9245, 10.1175/JCLI-D-12-00592.1.

4 Conference Presentations

- Invited presentation: Bukovsky, M.S., 2016: North American CORDEX. 8th ICTP Workshop on the Theory and Use of Regional Climate Models, Trieste, Italy. 25 May 2016.
- Presentation: Bukovsky, M.S., 2016: NA-CORDEX Simulations of the North American Monsoon. International Conference on Regional Climate-CORDEX. Stockholm, Sweden, WCRP. 18 May 2016.
- Presentation: Bukovsky, M.S., A. Seth, R.R. McCrary, L.O. Mearns, 2016: Regional climate model precipitation projections for the Southern Great Plains. 28th Conf. on Climate Variability and Change, New Orleans, LA. Amer. Meteor. Soc., 13B.5.
- Invited Presentation: Bukovsky, M.S., C.M. Carrillo, D.J. Gochis, L.O. Mearns, 2015: Assessing regional climate model simulation credibility for the North American Monsoon. Reunin Annual 2015, Puerto Vallarta, Jalisco, Mexico. Unin Geofisica Mexicana, SE15-4.
- Presentation: Seth, A., M. Bukovsky, R. McCrary, and L. O. Mearns, 2016: Credibility of Climate Projections in the U.S. Southern Great Plains, AAG Annual Meeting, 29 Mar - 2 Apr, San Francisco, CA.
- Presentation: Bukovsky, M.S., C. Carrillo, D.J. Gochis, L.O. Mearns, 2015: Regional climate model projection credibility for the North American Monsoon. AMS Annual Meeting, 4-8 January 2015, Phoenix, AZ.

- Poster: Bukovsky, M.S., C. Carrillo, D.J. Gochis, L.O. Mearns, 2015: Regional climate model projection credibility for the North American Monsoon. AGU Fall Meeting, 15-19 December 2014, San Francisco, CA.
- Presentation: Seth, A., S. Rauscher, M. Biasutti, A. Giannini, S. Camargo, M. Rojas, 2014: Annual Cycle Changes in Monsoons in a Warming Climate, UCLA Department of Atmospheric Sciences, 10 December, Los Angeles, CA, INVITED.
- Presentation: Seth, A., C. Lynch, and J. M Thibeault, 2014: Seasonal Transitions in the Next Climate Assessments, AGU Fall Meeting, 15-19 Dec, San Francisco, CA.
- Presentation: Seth, A., S. Rauscher, M. Biasutti, A. Giannini, S. Camargo, M. Rojas, 2014: Mechanisms for Annual Cycle Changes in Monsoons in a Warming Climate, European Geosciences Union, 28 Apr - 2 May, Vienna, Austria, INVITED.
- A process based-evaluation of NARCCAP and CMIP5 models has been completed for the Northeast U.S., and examination of model credibility based on expert judgement is complete for this region and the manuscript is now being revised for JGR. item
- Presentation: Thibeault, J. and A. Seth, 2014, Warm Season Precipitation in the Northeast United States: A Process Evaluation of CMIP5 and NARCCAP Experiments, *Association of American Geographers Annual Meeting*, Apr. 8-12, Tampa, FL.
- Poster: Seth, A., J. Thibeault, 2014: Climate Processes in CMIP5: A Process-based Analysis of Warm Season Precipitation for Northeast North America , *AMS Annual Meeting*, 2-6 Feb, Atlanta, GA.
- Presentation: Bukovsky, M.S., D.J. Gochis, and L.O. Mearns, 2014: Assessing the Credibility of the North American Monsoon Projections from the NARCCAP Regional Climate Models. *NCAR/CISL Seminar*, Boulder, CO.
- Presentation: Bukovsky, M.S., D.J. Gochis, and L.O. Mearns, 2014: Assessing the Credibility of the North American Monsoon Projections from the NARCCAP Regional Climate Models. *NCAR/NRCM Seminar*, Boulder, CO.
- Presentation: Bukovsky, M.S., L.O. Mearns, 2014: Dealing with a regional climate model ensemble. *7th ICTP Workshop on the Theory and Use of Regional Climate Models*, Trieste, Italy.
- Presentation: McCrary, R.R., M.S. Bukovsky, J.M. Thibeault, L. O. Mearns, and A. Seth, 2014: Land-Atmosphere interactions in the NARCCAP simulations: A process level approach to understanding model differences. *2014 AMS Annual Meeting*, Atlanta, GA, Amer. Metero. Soc. 28th Conference on Hydrology.
- Presentation: Seth, A., R. McCrary, J. Thibeault, 2014: Climate Model Credibility in Projections of Warm Season Precipitation in the US Central Plains, *AAG Annual Meeting*, 7-12 Apr, Tampa, FL.
- Thibeault, J. and A. Seth, 2013: A Framework for Evaluating Model Credibility for Warm Season Precipitation in Eastern North America: A Case Study of CMIP5 Simulations and Projections, *Journal of Climate*, revised, (MAPP/CMIP5 Special Issue on North American Climate Change)

- Thibeault, J. and A. Seth, 2013, Process Evaluation of Warm Season Precipitation in the Northeast U.S: NARCCAP driving AOGCMs, Timeslice Experiments, and CMIP5 Simulations, 93rd AMS Annual Meeting, Jan. 6-10, Austin, TX, poster
- Bukovsky, M.S., L. Mearns, A. Seth, J. Thibeault, 2012: Towards establishing NARCCAP regional model credibility through process-based analysis. NOAA MAPP webinar, 11 December 2012.
- Seth, A., S. Rauscher, 2012: CMIP5 Projected Changes in the Annual Cycles of Precipitation in Monsoon Regions, AGU Fall Meeting, 3-7 Dec, San Francisco, CA.
- Thibeault, J. and A. Seth, 2011, Regional Evaluation of Global High Resolution Time Slices for the Northeast U.S., American Geophysical Union Fall Meeting, Dec. 5-9, San Francisco, CA, poster.

5 PI Contact Information

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