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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Development and comparative evaluation of a stochastic analog method to downscale daily GCM precipitation" *by* S. Hwang and W. D. Graham

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——— Comment: what is the basis of selecting the GCMs in the downscaling? This is important so please provide.

Response: Originally 4 different CMIP3 GCMs (BCCR, CCSM3, CGCM, and GFDL) were selected to apply three different statistical downscaling methods (BCSD_daily, SDBC, and BCSA) based on availability and previous use in testing downscaling approaches. The GFDL, CGCM, and CCSM3 models have previously been used to drive a set of regional climate models (RCMs, dynamical downscaling models) over

a domain covering the U.S. and most of Canada for the North American Regional Climate Change Assessment Program (NARCCAP). We selected those because we plan to use NACCAP in future work for comparative investigation of dynamical downscaling and statistical downscaling methods. BCCR was arbitrarily selected is an additional GCM to compare. Subsequently, in addition to the downscaling methods using interpolation (BCSD_daily, SDBC), we compared existing BCCA results, which use historical data to produce constructed analogs, to the new BCSA method because BCSA is also based on an analog approach. Unfortunately BCCA results, available at http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/, are not available for BCCR and CCSM3, so two alternative models (CNRM-CM3 and MIROC3.2) were selected for BCCA instead. Importantly, in this study we found that the differences among the GCMs downscaled with the same technique were not significant in terms of the spatiotemporal statistics reproduced by that method. This is because each method bias-corrected the GCM results using the same observational data so that properties of the downscaled fields fit those of observations (either at the observation or GCM scale), regardless of the GCM. In other words, differences among downscaling techniques were more significant than differences among GCM predictions. Thus use of different/consistent GCMs for each method does not affect the major findings and conclusion derived by the study. We will clarify these issues in the revised data section 2.

——— Comment: All complicated indices are shown but the most important index which is correlation R was not at all shown. This is the most important skill score that shows if you can really use your downscaled data with dynamic hydrologic models. I want to see a correlation (just simple R is enough, no complex indices needed) between monthly and seasonal (exclude ANNUAL!!!) rainfall with GCMs (all used or mentioned) with observed (not the gridded but stations).

Response: We are not sure what the reviewer is asking here. Unlike reanalysis predictions (which assimilate actual observations into the GCM predictions and are intended

to reproduce a particular observed climate sequence), the retrospective GCM simulations used in this study do not provide time series comparable to observed time series at any time scale (daily, monthly, seasonal, or annual). Instead they are intended to provide plausible time series of climatic data that reproduce the climatology of the region (e.g., statistics such as mean, variance, cumulative distribution functions and spatial correlation structures over diurnal/seasonal cycles as evaluated in our study). Therefore evaluating the correlation of a particular retrospective GCM sequence of predictions at a daily, monthly, seasonal or annual time scale with actual observed climate sequences will not be meaningful.

——— Comment on gridded data: I don't know the gridded data how they are developed, their characteristics in terms of biases etc should be also shown and discussed. are these 12-km gridded 'station-scale' data or averaged across 12-km scale? Daily? Also, in addition to the gridded 12-km downscaling application, it would be interesting to see the results at station level. Daily data averaged across domain is not a good benchmark for downscaling - do to the station level. Here, statistics e.g., dry spells, time structure etc will be more meaningful.

Response: The daily gridded observations that we used were derived directly from observations by Maurer et al. (2002) and are available across the entire United States. These data are spatially averaged across each grid cell and were used to derive the BCSD and BCCA downscaling results we compare with (Maurer et al., 2010). Additionally they have been used to assess hydrologic implications of the differences among the downscaling methods (i.e., BCSD, CA (constructed analog), and BCCA) using the Variable Infiltration Capacity (VIC) hydrologic model (Liang et al., 1994). We assessed the Maurer et al (2002) data against locally available gage observations where available (http://gis.tampabaywater.org/rainfall) as well as PRISM (Oregon State University, (http://prism.oregonstate.edu) and NLDAS (NASA GES DISC, (http://mirador.gsfc.nasa.gov/)) data and found them to be unbiased (compared to these other gage and gridded products) in Florida. Furthermore in our study, it was

necessary to use the same observation data for all downscaling methods so that we could consistently evaluate the results across the methods. More explanation regarding the accuracy of the gridded data and reasons for its choice will be included in the revised manuscript. As we discuss in section 5.3 of the present manuscript, the BCSA method can be applied to downscale coarse resolution climate data into any temporal (e.g., monthly, daily, sub-daily) and spatial scale (e.g., gridded or irregularly distributed points) wherever observations are available to estimate the cumulative distribution functions and spatial correlation structure of precipitation. The purpose of this manuscript was to compare the BCSA method to other commonly used downscaling methods consistently over the state of Florida, independent of application. However for any particular application where long term station data are available over the domain of interest these data can be used in BCSA to bias-correct and downscale GCM data directly onto the station data.

——— Comment: For the BCSA, I did not really get how analogs were used in the downscaling as presented in the paper. I have been working with analogs so I understand what and how they are used but as presented here it is not clear. How much more of those laymen who are interested to understanding the method?

Response: The three existing bias-correction and spatial downscaled datasets (i.e., BCSD, SDBC, BCCA) are available for CMIP3 over the entire U.S. from http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html#Welcome). While investigating the usefulness of these data for Florida, we found that none of the existing retrospective bias-corrected, downscaled CMIP3 datasets adequately reproduced the observed spatial variability of daily precipitation which is known to be regionally important for accurately simulating hydrologic behavior. To overcome this problem we developed BCSA which uses the same bias-correction methodology but improves over the spatial interpolation (BCSD and SDBC) and constructed analog (BCCA) methods by synthetically generating a random rainfall field that matches both the mean areal bias-corrected rainfall estimated from the GCM and the small-scale variability exhibited by

historical data. We term this synthetic random rainfall field a “stochastic analog”. This terminology is analogous to that used in the “natural or historical analog” methodology in which an actual historical spatial distribution of daily rainfall that preserved the mean areal bias-corrected rainfall estimated from the GCM would be selected as an analog. The terminology is also analogous to that used in the “constructed analog” methodology in which a deterministic synthetic analog is constructed from a linear combination of several historical analogs that closely resemble the GCM prediction. The differences between the stochastic analogs used in the BCSA method and the natural or historic analogs and constructed analogs used in other methods will be explained more clearly in the revised manuscript.

——— Comment: Suggest that the paper should link the downscaled rainfall data with a hydrologic model to simulate the response of the system. . ...use local station datasets in this addendum.

Response: We are currently conducting a follow-on study to evaluate the importance of spatiotemporal variability of statistically downscaled climate model outputs for a hydrologic model application in west-central Florida, and we are using local station data for this study. However presentation of these results in this paper would unreasonably increase the length and number of figures required. To respond this comment, we will revise the introduction of the manuscript to generally discuss the types of hydrologic applications where there is a strong need to accurately represent the spatiotemporal variability of daily precipitation fields, i.e. low-relief, rainfall-dominated watersheds as opposed to high-relief snow-dominated watersheds.

——— Comment: . . .how is the prediction skill of the method, say if you force your GCM with forecasted SST for the season of interest. I know that GCMs poorly predict summer rainfall in the SE US. I think even with the simulation period I will not be so optimistic if you find low predictability.

Response: We are not sure we understand this comment. Our paper presents a new

methodology for downscaling GCM outputs and compares that methodology to 3 other methods for a set of existing CMIP3 GCM predictions. The significant differences we found in the spatial patterns of downscaled precipitation among the methods will be exhibited regardless of the GCM predictions used, or the data used to force the GCM. While improvements in the GCMs, or improvements in the data used to force them, will (hopefully) reduce the need for bias-correction, downscaling of the GCMs for local hydrologic applications will still be required. Thus the use of improved GCMs would not change the major findings of the study: that interpolation based spatial disaggregation methods produce downscaled precipitation field that are significantly more spatially uniform than observed precipitation fields, and therefore should not be used for applications where reproducing spatial variability of rainfall is important. We will revise the conclusions section of the manuscript to more clearly discuss these issues.

——— We thank the reviewer for his/her constructive review and comments.

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