Instructions and Data to Produce
Bias-Corrected Stochastic Analog (BCSA) downscaled climate variables for Southeast U.S.

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Summary

This document provides instructions and links to the codes and data required to produce BCSA downscaled results for 9 CMIP5 GCMs. The codes and data in this archive can be used to produce BCSA downscaled retrospective and future climate projections at a 12 km by 12 km resolution for watersheds within the Southeast USA. The data and original codes were used in Chang, S., Graham, W., Geurink, J., Wanakule, N., and Asefa, T.: Evaluation of impacts of future climate change and water use scenarios on regional hydrology, Hydrol. Earth Syst. Sci., 22, 4793-4813, https://doi.org/10.5194/hess-22-4793-2018, 2018. The research was supported in part by the Florida Water and Climate Alliance, a stakeholder-scientist partnership committed to increasing the relevance of climate science data and tools at relevant time and space scales to support decision-making in water resource management, planning and supply operations in Florida.

Introduction

General circulation models (GCMs) are used to simulate retrospective, contemporary and potential future climate projections for quantitative climate impact assessments (Wilks, 1999; Karl and Trenberth, 2003; Fowler et al., 2007). However, the coarse resolution of existing GCMs (model grids typically > 100 km by 100 km) precludes the reproduction of realistic local-scale circulation patterns or the resulting local-scale spatial variability of climate variables. Furthermore, mismatch of the spatial resolution between GCMs and hydrologic models generally precludes the direct use of GCM outputs to predict hydrologic impacts.

A number of statistical techniques have been developed that downscale coarse GCM climate data over the continental USA, e.g. BCSD, BCCA and LOCA (see https://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html . However, many of them do not accurately reproduce the small-scale spatiotemporal variability of precipitation exhibited by observed meteorological data, which is an important factor for predicting hydrologic response to climatic forcing. Hwang and Graham (2013) developed a new downscaling technique (Bias Correction and Stochastic Analog method; BCSA) to produce downscaled bias-corrected daily GCM precipitation fields that preserve both the spatial autocorrelation structure of observed daily precipitation sequences and the observed temporal variability and frequency distribution of daily rainfall over space. For more details on the BCSA method, and a comparison of BCSD, BCCA, SDBC and BCSA over the state of Florida see (Hwang & Graham, 2013 https://www.hydrol-earth-syst-sci.net/17/4481/2013/)

This archive contains the zip files of the source codes for BCSA downscaling technique written in MATLAB (R2015b or higher version), as well as the CMIP5 climate data and the Phase 2 of the North American Land Data Assimilation System (NLDAS-2) historic climate data required to produce BCSA bias-corrected downscaled GCM climate data for watersheds within the Southeast USA.

The CMIP5 GCM data included in this archive were obtained from https://cmip.llnl.gov/cmip5/data_portal.html. Files in this archive include retrospective data from 1982-2005, and data for four future Representative Concentration Pathway scenarios (RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5) for 2006-2100. The NLDAS-2 data included in this archive are used as reference (historic) climate data for bias correction and statistical downscaling the GCM precipitation. The NLDAS-2 data were obtained from https://ldas.gsfc.nasa.gov/nldas/NLDAS2forcing.php.

The codes and data in this archive can be used to produce BCSA downscaled retrospective and future climate projections at a 12 km by 12 km resolution for watersheds within the Southeast USA.

Attributes

- **Table 1: Climate variables available:**

Variables (click on link to download zip file)[1]	Abbreviation	Unit
Precipitation	pr	mm/day
Maximum temperature	tasmax	K
Minimum temperature	tasmin	K
Surface downward longwave radiation	rlds	W/m2
Surface downward shortwave radiation	rsds	W/m2
Wind speed at 10 meters above the surface	sfcWind	m/s
Penman Monteith reference evapotranspiration	ET0	Mm/day

[1] Please note the zip files range in size from 3-5.5 gigabytes. If the links don't open correctly from within your document, copy and paste them directly into a browser.

- **Time:**
  - Retrospective time period: 1982-2005
  - Future time period 2006-2100
  - Downscaled Resolution: Daily.

- **Space:**
  - Subdomains within 25.3750~40.00° N, 268.00~285.8750° E (most of Southeast U.S.) Note: Area of watershed for which downscaling is performed should be less than approximately 10,000- 15,000 km^2 (i.e. within approximately one GCM grid cell).

- Downscaled Resolution: 0.125° (~12 km, NLDAS-2 resolution)

- **Table 2: GCMs available (note some GCMs do not include all RCP scenarios):**

Model	Resolutions	Leap Year	Reference
BNU-ESM	2.8° lat ×2.8° lon	No	Ji et al. (2014)
GFDL-CM3	2.0° lat ×2.5° lon	No	Guo et al. (2014)
GFDL-ESM2G	2.0° lat ×2.5° lon	No	Taylor et al. (2012)
MIROC-ESM	2.8° lat ×2.8° lon	Yes	Watanabe et al. (2011)
MPI-ESM-LR	1.87° lat ×1.87° lon	Yes	Block &Mauritsen (2013)
MRI-CGCM3	1.12° lat ×1.12° lon	Yes	Yukimoto et al. (2012)
NorESM1-M	1.9° lat ×2.5° lon	No	Bentsen et al. (2013)
BCC-CSM1.1	2.8° lat ×2.8° lon	No	Xiao-Ge et al. (2013)

Instructions for obtaining downscaled data

1. Select a specific climate variable from Table 1 above and download zip file. Unzip the zip file. The zip file contains source codes (*.m) and GCM and NLDAS-2 data files saved as MATLAB data format (*.mat). Please note the zip files range in size from 3-5.5 gigabytes. If the links don't open correctly from within your document, copy and paste them directly into a browser.
2. Open MATLAB R2015b or higher version. (The source codes were tested on MATLAB R2015b and R2017b. They may not be compatible for older versions than MATLAB R2015b).
3. Open the source code "Main_BCSA_for_all_GCMs_NLDAS2_variable_name.m".
4. Set desired watershed spatial boundaries in the "Set boundary box" of "Main_BCSA_for_all_GCMs_NLDAS2_variable_name.m". Note: for boundary box coordinates, longitude should be eastward values, i.e., use 270E not 90W.
5. Set the beginning year and ending year for desired future period in "Set future period" of "Main_BCSA_for_all_GCMs_NLDAS2_variable_name.m".
6. Set desired RCP scenario (RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5 should be rcp26, rcp45, rcp60, and rcp85, respectively).
7. Set output file name in "Set output file name" in "Main_BCSA_for_all_GCMs_NLDAS2_variable_name.m". The file will be saved as FILE_NAME.mat. The default file name is "BCSA_downscaled_climate_variable.mat".
8. Run "Main_BCSA_for_all_GCMs_NLDAS2_variable_name.m" on MATLAB R2015b or higher version (Press Run button (Green arrow) on Editor tab or press F5). Note that depending on computer speed these programs may take several hours to run. They are running correctly if comments continue to appear in the command window.

9. Output file will be automatically saved as the file name set in “Set output file name”. Output file contains four variables. Details about output file can be found in the output file section.

Output file

Output file will be saved in the working directory. The output file is MATLAB data format (.mat). Output file contains four variables (BCSA, BCSA_fut1, lat, and lon).

1. BCSA: Bias corrected and statistically downscaled climate variables of retrospective GCMs. Each variable has cell array format that are identical to reference climate (NLDAS-2).
2. BCSA_fut1: Bias corrected and statistically downscaled climate variables of future GCMs. Each variable has cell array format that are identical to reference climate (NLDAS-2).
3. lat: Latitude of cell array (rows of BCSA or BCSA_fut1).
4. lon: Longitude of cell array (columns of BCSA or BCSA_fut1).

Bibliography

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Hwang, S. and Graham, W. D.: Development and comparative evaluation of a stochastic analog method to downscale daily GCM precipitation, Hydrol. Earth Syst. Sci., 17, 4481–4502, doi:10.5194/hess-17-4481-2013, 2013.

Karl, R. T. and Trenberth, E. K.: Modern global climate change, Science, 302, 1719–1723, doi:10.1126/science.1090228, 2003.

Wilks, D. S.: Multisite downscaling of daily precipitation with a stochastic weather generator, Climate Res., 11, 125–136, 1999.

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Links

Note if links don't open correctly from within your document, copy and paste them directly into a browser

Precipitation:
http://ufdcimages.uflib.ufl.edu/IR/00/01/05/42/00001/BCSA_pr.zip
Maximum Temperature:
http://ufdcimages.uflib.ufl.edu/IR/00/01/05/41/00001/BCSA_tasmax.zip
Minimum Temperature:
http://ufdcimages.uflib.ufl.edu/IR/00/01/05/40/00001/BCSA_tasmin.zip
Surface downward longwave radiation:
http://ufdcimages.uflib.ufl.edu/IR/00/01/05/43/00001/BCSA_rlds.zip
Surface downward shortwave radiation:
http://ufdcimages.uflib.ufl.edu/IR/00/01/05/44/00001/BCSA_rsds.zip
Windspeed at 10 meters above the surface
http://ufdcimages.uflib.ufl.edu/IR/00/01/05/45/00001/BCSA_sfcWind.zip
Penman Monteith Reference ET
http://ufdcimages.uflib.ufl.edu/IR/00/01/05/39/00001/BCSA_ET0.zip