Downscaled Climate Projections Suitable for Resource Management

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The general circulation model (GCM) experiments conducted under the Coupled Model Intercomparison Project Phase 5 (CMIP5) [*Taylor et al.,* 2012], which is being conducted in preparation for the Intergovernmental Panel on Climate Change's Fifth Assessment Report, provide fundamental data sets for assessing the effects of global climate change. However, efforts to assess regional or local effects of the projected changes in climate are often impeded by the coarse spatial resolution of the GCM outputs, as well as potential local or regional biases in GCM outputs [*Fowler et al.,* 2007].

As a result, natural resource managers, urban planners, and other decision makers face questions that they have little means to answer, such as "What is the range of possible maximum summer temperatures 25 years from now in my town, a local watershed, or a nearby national park?" or "What are the predicted changes in precipitation, and how might they affect water supplies in the coming decades for agricultural production or for our town's growing population?" Statistical downscaling methods are often introduced to construct climate change information at the higher resolutions needed for resource management. Such methods distill information from GCM simulations and merge it with regional- to local-scale meteorological records.

Specifically, these downscaling methods combine empirical techniques with high-resolution gridded historical climate data to add fine-scale climate information to the coarse-scale GCM simulations. The end result is a more spatially detailed picture of what future climate change could mean at local levels.

Using this approach, a new archive of downscaled CMIP5 climate projections for the conterminous United States at 30-arc-second (~800 meter) spatial resolution has been developed on the NASA Earth Exchange (NEX) scientific collaboration platform [*Nemani et al.,* 2011] and is being distributed through the NASA Center for Climate Simulation (NCCS) (https://portal.nccs.nasa.gov/portal_home/published/NEX.html). Called the NEX Downscaled Climate Projections at 30 arc-seconds (NEX-DCP30) (doi:10.7292/W0WD3XH4), the data set is being released to support scientific analyses of regional climate change impacts and to serve as a tool for natural resources managers in the United States.

Useful Data Products From Downscaled Climate Projections

Demonstrating the utility of these downscaled climate projections, Figure 1 shows the time series and spatial patterns of projected changes in the springtime (March-April-May) mean temperature, T_{spring}, over the conterminous United States from 1950 to 2099. Springtime temperatures are particularly important because they regulate the start of the growing season for ecosystems and agricultural crops, as well as processes such as melting of the winter snowpack. The average T_{spring} of the conterminous United States is projected to increase from roughly 12°C in 1950 to about 15°C by the end of the 21st century under the Representative Concentration Pathway 4.5 (RCP4.5) greenhouse gas emissions scenario where concentrations level off mid-century [*Meinshausen et al.,* 2011].

As shown by the maps in Figure 1, an important consequence of the rapidly rising temperature is the projected decrease in area where T_{spring} is below or equal to 0°C (the zero-degree isotherm), from roughly 2.5 million square kilometers in the 1950s to about 600,000 square kilometers by 2099. The high resolution of the downscaled climate projections provides the spatial detail that is required to resolve the retreat of the springtime zero-degree isotherm over mountainous regions, a feature that is difficult to accurately delineate at the native scale of the GCM outputs. Other potential applications of the NEX-DCP30 data set include modeling the species' response to future climate patterns, assessing changes in vegetation water stress and fire risk, and predicting changes in water supply.

The entire NEX-DCP30 data set is available from NCCS through the Earth System Grid Federation (ESGF) portal. In addition, projections for a specific location of interest can be retrieved from the NEX-DCP30 data set from the web data portal by selecting the desired RCP, selecting a specific GCM experiment or a statistical summary of all model experiments for the RCP (e.g., the ensemble average), and entering the relevant time period and latitude and longitude boundaries into the subsetting tool. Data can be retrieved via multiple web

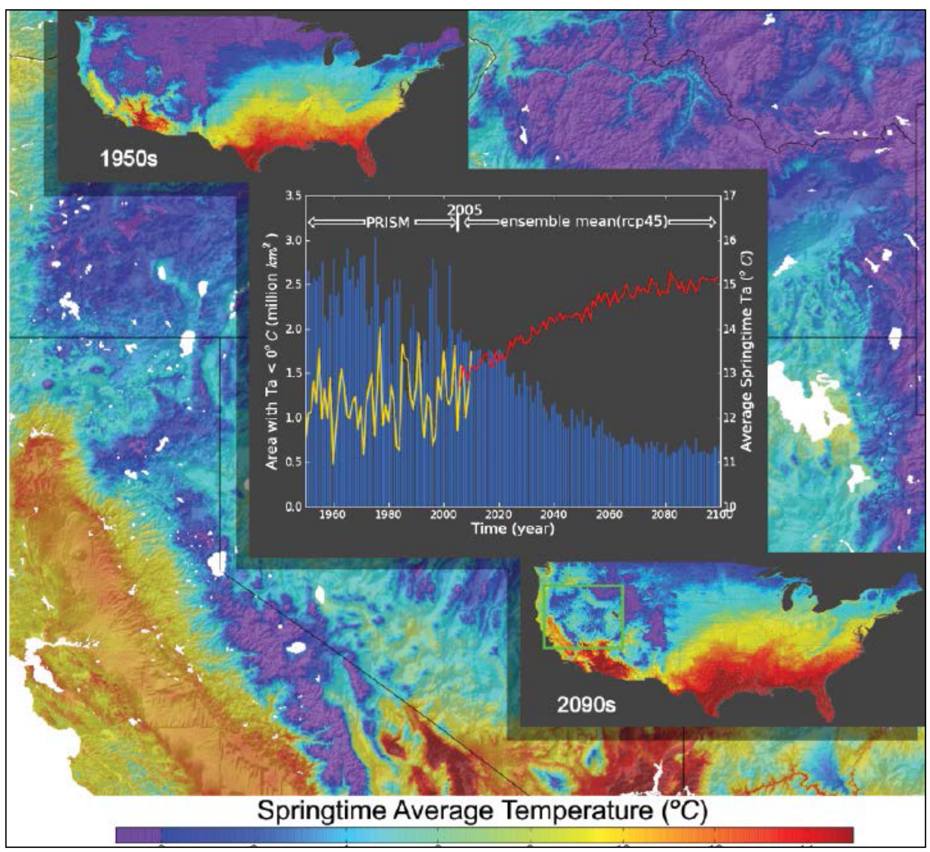

Fig.1 Changes in springtime (March-April-May) mean temperature, T_{spring}, over the conterminous United States from 1950 to 2099. The upper left map shows the observed mean U.S. T_{spring} in the1950s (based on Parameter-Elevation Regressions on Independent Slopes Model (PRISM) data), while the lower right map shows the corresponding T_{spring} in the 2090s (as suggested by the ensemble mean of the NEX-DCP30 projections from the RCP4.5 scenario). The time series in the yellow line indicates the changes in the aggregated T_{spring} for the conterminous United States between 1950 and 2010, and the red line indicates the ensemble mean for RCP4.5 from 2006 to 2099. The blue bars show the corresponding changes in surface area where T_{spring} is below or equal to 0°C (i.e., purple shades on the T_{spring} maps). The map in the background shows the 2090s T_{spring} at the downscaled resolution (~800 meter) over the Southwestern United States, highlighting the spatial detail provided by the downscaled climate projections.

services that return data in Network Common Data Form (NetCDF), ASCII, and other formats.

For example, a user can examine how January minimum temperatures could change in Sacramento, Calif., over the 21st century according to the output from a specific GCM and RCP. The user would select the corresponding data catalog, enter spatial bounding coordinates of the city in latitude and longitude and the specific time range, and press "submit". Once the request is processed by the web service, a small file consisting of monthly average minimum temperatures for each January from 2006 to 2099 is downloaded to the user's computer, where it can be analyzed as desired. This process can be repeated on output from other GCMs to create an easily manageable ensemble of local-scale projections.

Generating the New Projections: How Does NEX-DCP30 Work?

NEX-DCP30 was developed through use of the computational resources provided by NEX, which leverages the NASA Advanced Supercomputing (NAS) facility at NASA Ames Research Center, Moffett Field, Calif. The archive comprises more than 100 downscaled climate projections from 33 CMIP5 GCMs and 4 RCP scenarios developed for the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5). Monthly average precipitation, maximum temperature, and minimum temperature were downscaled from each of the CMIP5 GCMs and RCP scenarios for the period 2006–2099, as well as the historical runs for the period 1950–2005. In addition, NEX-DCP30 includes a set of ensemble statistics composed of averages and the 25th, 50th, and 75th percentiles for each RCP, resulting in a total data volume of more than 12 terabytes (1 terabyte is 1 trillion bytes).

The downscaling method adopted in creating NEX-DCP30 is the Bias-Correction Spatial Disaggregation (BCSD) algorithm [*Wood et al.,* 2002; *Wood et al.,* 2004]. BCSD compares the historical GCM outputs with corresponding historical observations over a common period and uses information derived from the comparison to adjust future climate projections so that they are (progressively) more consistent with the historical climate records and, presumably, more realistic for the spatial domain of interest. The algorithm also uses the spatial detail provided by the observational data set to interpolate the GCM outputs to the higher-resolution grid.

The observational climate data set used in this study is the Parameter-Elevation Regressions on Independent Slopes Model (PRISM) data set developed at Oregon State University [*Daly et al.,* 1994]. PRISM incorporates ground-based climate measurements, a digital elevation model, and expert analysis of complex climate phenomena (e.g., rain shadows) to produce continuously gridded estimates of climate variables over the conterminous United States at a 30-arc-second spatial resolution. Combining the strengths of BCSD and the PRISM data set, NEX-DCP30 provides a set of high-resolution, bias-corrected climate change projections that can be used to evaluate the effects of climate change on processes and hydrometeorologic variables that are sensitive to finer-scale climate gradients and local topography such as runoff, evapotranspiration, climatic water deficit, and environmental constraints on the range of species or ecosystems.

A Useful Tool for Policy Makers

The NEX-DCP30 climate projections provide high-resolution information on future climate conditions, and the data have been corrected to account for the effect of local topography (e.g., mountains) on temperature and precipitation patterns. The data set is publicly available from NCCS through multiple web services, and ongoing work will continue to enhance access for different types of users.

The ensemble provides data for a range of climate futures, which enhances the ability of practitioners, researchers, and policy makers to explore a variety of climate change outcomes for the systems or processes that are important to their local communities: changes in water supplies and winter snowpacks, urban heat island effects, the spread of vector-borne diseases, flood risk and potential impacts to critical urban infrastructure, wildfire frequency and severity, agricultural production, wildlife and biodiversity, and many others. While exploring these changes may require the incorporation of additional data and impacts models, the NEX-DCP30 climate projections address a major barrier to analyses of the local effects of climate change.

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References

Daly, C., R. P. Neilson, and D. L. Phillips (1994), A statistical-topographic model for mapping climatological precipitation over mountainous terrain, *J. Appl. Meteorol., 33,* 140–158.

Fowler, H. J., S. Blenkinsop, and C. Tebaldi (2007), Linking climate change modeling to impacts studies: Recent advances in downscaling techniques for hydrological modeling, *Int. J. Climatol., 27,* 1547–1578, doi:10.1002/joc.1556.

Meinshausen, M., et al. (2011), The RCP greenhouse gas concentrations and their extensions from 1765 to 2300, *Clim. Change, 109,* 213–241, doi:10.1007/s10584-011-0156-z.

Nemani, R., P. Votava, A. Michaelis, F. Melton, and C. Milesi (2011), Collaborative supercomputing for global change science, *Eos Trans. AGU, 92*(13), 109–110, doi:10.1029/2011EO130001.

Taylor, K. E., R. J. Stouffer, and G. A. Meehl (2012), An overview of CMIP5 and the experiment design, *Bull. Am. Meteorol. Soc., 93,* 485–498, doi: 10.1175/BAMS-D-11-00094.1.

Wood, A. W., E. P. Maurer, A. Kumar, and D. P. Lettenmaier (2002), Long-range experimental hydrologic forecasting for the eastern United States, *J. Geophys. Res., 107*(D20), 4429, doi:10.1029/2001JD000659.

Wood, A. W., L. R. Leung, V. Sridhar, and D. P. Lettenmaier (2004), Hydrologic implications of dynamical and statistical approaches to downscaling climate model outputs, *Clim. Change, 62,* 189–216, doi:10.1023/B:CLIM.0000013685.99609.9e.

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