

The Practitioner's Dilemma: How to Assess the Credibility of Downscaled Climate Projections

PAGES 424–425

Suppose you are a city planner, regional water manager, or wildlife conservation specialist who is asked to include the potential impacts of climate variability and change in your risk management and planning efforts. What climate information would you use? The choice is often regional or local climate projections downscaled from global climate models (GCMs; also known as general circulation models) to include detail at spatial and temporal scales that align with those of the decision problem. A few years ago this information was hard to come by. Now there is Web-based access to a proliferation of high-resolution climate projections derived with differing downscaling methods.

From our experience, often, the “practitioner's dilemma” is no longer the lack of downscaled projections; it is how to choose an appropriate data set, assess its credibility, and use it wisely. In practice, products are sometimes selected on the basis of availability, convenience of format, and familiarity with the provider. Sorting through the downscaling literature for guidance is challenging even for the expert, and often, that literature is insufficient to lead the practitioner to the most appropriate product. Systematic comparisons of downscaling methods are rare and not easily accessible. To address the practitioner's dilemma, we posit a need for a comprehensive and comparative evaluation of downscaled climate projections at local and regional scales that is accessible and informative to practitioners and climate scientists alike.

Evaluation and Credibility

We look at the practitioner's dilemma through the lens of *Cash et al.* [2002], who describe three attributes of usable information: credibility, salience, and legitimacy. Credibility, our primary focus, “refers to whether an actor perceives information as meeting standards of scientific plausibility and technical adequacy. Sources of knowledge must be deemed trustworthy and/or believable, along with facts, theories, and causal explanations invoked by these sources” [*Cash et al.*, 2002, p. 4]. By this definition, the credibility of downscaled climate data entails more than evaluation against historical observations. It is deeply rooted both in the state of the science and the

scientific method and in the “technical adequacy” to address practitioners' needs and applied questions. Below we pose some scientific questions related to downscaling and propose how they can be addressed in a comprehensive evaluation framework.

Credible downscaled projections are contingent upon GCMs that faithfully represent the large-scale processes and features of the climate system. Each successive generation of climate models has demonstrated greater fidelity in the simulation of historical climate, and there are ongoing efforts to quantify the biases of climate models. Yet how GCM biases affect a downscaled product is not always easily assessed. For example, some downscaling methods use bias-corrected GCM inputs, and regional climate models' physics may interact nonlinearly with the GCM biases.

Downscaling *may* add to the credibility of climate projections by representing fine-scale features such as strong temperature and precipitation gradients near coasts and mountain ranges, which are known to impact the systems practitioners manage. Statistical downscaling methods (using regression, change factors, and other empirical techniques) are usually trained or calibrated on historical data. The high-resolution detail may be represented explicitly through the use of predictor variables that capture local factors such as elevation or implicitly through the use of station or gridded data influenced by location-specific factors. By design, statistical downscaling methods generally reduce the biases of the GCM simulations for the historical period. A major scientific question facing the statistical methods is the assumption of stationarity—that the relationships derived from historical data, including the treatment of GCM bias, will be valid in the future.

In dynamical downscaling (using a regional climate model (RCM)), detail is obtained through explicit numerical modeling of land characteristics and mesoscale physics and dynamics. Examples are resolving coastlines and bodies of water and better representation of orographic processes and land-atmosphere feedbacks. RCMs, nonetheless, may exhibit biases due to factors such as limitations of the driving GCMs (or other sources of boundary conditions), artifacts near the lateral boundaries of the model domain, lack of two-way coupling between the GCM and RCM, and limitations of the RCM physics and resolution. A critical scientific

question is whether the improved fine-scale physics leads to a reduction in bias and a better representation of fine- and regional-scale climate features.

Developing an Evaluation Framework

How do we evaluate a downscaled data product in a way that addresses these scientific issues and meets the needs of practitioners? Evaluation of biases in a downscaling method typically begins with using observed or reanalysis data as either predictors or boundary conditions and validating against historical data. Subsequent evaluation of the method applied to GCM data is also needed to measure the compound effect of the GCM and downscaling biases on the data sets used in practice.

We advocate for the development of a community evaluation framework that builds on the above procedures to facilitate comparison among methods and data sets. We propose the use of common reference data sets, periods of analysis, cross-validation methods, and, most important, evaluation metrics developed collaboratively by scientists and practitioners.

For statistical downscaling, the ability to perform well in a changing climate can be evaluated in part using a “perfect model” approach. In this approach, downscaling methods are trained and evaluated using a high-resolution climate model simulation taken as a proxy for observations of past and future climate [*Dixon et al.*, 2013]. The perfect model evaluation informs us whether the downscaling method can capture those nonlinear physical effects inherent to a changing climate as simulated by the high-resolution GCM and whether the statistical relationship retains its validity.

The explicit representation of physical processes in RCMs is often thought to enable a realistic simulation of nonstationary climate conditions. However, biases in RCMs and in their boundary forcing may propagate into the future and raise questions about the credibility of the projections. We postulate that evaluation of regional climate features using process-based metrics may help establish credibility that such processes will be faithfully represented in future climates. A simple example is using moisture convergence to elucidate precipitation processes in the North American monsoon system.

A central issue faced by practitioners is the uncertainty of climate information, and evaluation has a role to play here too. To characterize climatic uncertainty, current scientific practice recommends using ensembles of climate projections that account for various sources of uncertainty: different emissions scenarios, global models, or downscaling methods. A comprehensive assessment of downscaling methods and resulting data sets will provide objective criteria for inclusion

of downscaled climate projections in climate change analyses and lead to a better understanding of the uncertainty contributed by downscaling.

Building a Community Evaluation Effort

To help address the practitioner's dilemma, the National Climate Predictions and Projections (NCPP; <http://earthsystemcog.org/projects/ncpp/>) platform teams are developing a framework (<http://earthsystemcog.org/projects/downscaling-2013/framework>) for evaluating downscaled and other fine-scale climate projections and implementing cyber infrastructure to support the generation, collection, and dissemination of these evaluations. NCPP, with primary support from the National Oceanic and Atmospheric Administration's Climate Program Office, is collaborating in this development with climate scientists and with practitioner working groups focused on agriculture, water, health, and ecosystems. To advance these activities, NCPP organized the Quantitative Evaluation of Downscaling workshop in August 2013 (<http://earthsystemcog.org/projects/downscaling-2013/>), which was attended by more than 80 people from diverse backgrounds. Comparative evaluations of downscaled GCM data sets through historical validation and the perfect model approach were demonstrated. To sustain the further development of a community evaluation framework, we welcome participation of inter-

ested partners (<http://earthsystemcog.org/projects/ncpp/contactus/>).

In closing, let's return our focus to the practitioner's dilemma through the lens of usable information. The proposed framework promotes legitimacy by enabling the choice of credible climate projections to be informed by objective criteria based on community-developed, open standards. To enhance the salience of the evaluations, we support co-development with practitioners, so that the evaluations "speak the language" of various applications. In the end, however, usability will depend also on additional factors inherent in decision making such as institutional constraints, decision and policy goals, and the level of skill needed to use the information [Tang and Dessai, 2012]. Although the application of the evaluation framework will not eliminate the need for expert judgment in solving the practitioner's dilemma, it will provide a stronger foundation upon which this judgment can rest.

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