

## BEST PRACTICES FOR PROCESS STUDIES

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**W**e live in an age when publicly funded scientific research must demonstrate a benefit to society. For climate-related science, this often implies improvements in climate prediction. Furthermore, the formulation of responsible environmental and energy policies requires that human-induced climate impacts be identified separately from natural climate variations. This societally important task is challenging, as modeled climate responses vary widely. The goal of reducing the uncertainties cited in the 2007 Intergovernmental Panel on Climate Change (IPCC) report will require the participation of the entire research community, including both observationalists and modelers. For example, increasingly complex climate models are being developed to improve the realism of climate projections. These new models include more physical processes than their predecessors, but key physics remain insufficiently represented or resolved. Processes occurring below the model gridscale are typically still parameterized. The understanding necessary to develop the parameterizations, and observations used to calibrate them, are generally obtained through intensive field campaigns (process studies).

The transfer of new findings from process studies into climate models is essential if we are to accelerate progress in climate research and support the U.S. contribution to the IPCC. In this spirit, an underlying philosophy of the U.S. Climate Variability and Predictability (U.S. CLIVAR) program, vested primarily in the Process Study and Model Improvement (PSMI) panel formed in 2005, is that model uncertainties can

be reduced through an improved understanding and model representation of the physical processes governing climate and its variations. Given that modelers have a vested interest in the observational studies of complex processes, findings from a field study are likely to have a more immediate and significant impact upon the modeling community if modelers and observationalists collaborate both in the design and analysis of the study.

There is, of course, no straight and easy path from a field program to model improvement. Indeed, the critical “realization” may be made by a graduate student many years after the field program is complete, which is only possible if the data still exist and continue to be accessible. Traditionally, historical datasets are created in an ad hoc manner, in formats convenient first to the principal investigator and second to a broader community. The Internet was also not a viable option for data access until a mere 15 years ago. The rapid adoption of new forms of storage media allows the possibility that data stored in older forms, such as on magnetic tapes, are increasingly difficult to distribute successfully. Consequently, although the data may be publicly available, they may not be easily accessible, and often only the investigators directly involved in the process study are equipped to understand them and use them properly.

In an effort to help ensure that U.S. CLIVAR process studies ultimately lead to model improvements, the PSMI panel established a set of recommended “best practices” for process studies (see sidebar). Although developed for U.S. CLIVAR process studies, PSMI’s best practices are broadly applicable to all process studies, and the panel hopes that they will become widely accepted. Written with the future graduate student in mind, they encourage the broad use of data. Through adoption of these best practices, it is the hope of the panel that a culture of data archiving will develop that fosters open and centralized data access, and that the value of the process-study dataset will only increase with the passage of time.

An example of a best-practices process study is the U.S. CLIVAR Variability of the American

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## PROCESS STUDY “BEST PRACTICES”

- Modelers and observationalists should be integrated in the study from the planning stage onward.
- Integrated and synthesized datasets should be generated from the process study observations to provide model-comparable data that can be used as benchmarks for assessing and validating models. Furthermore, diagnostics shown in much-cited published figures should be provided in digital format as “synthesis products.”
- Broad use of the data should be encouraged through
  - open data policies;
  - centralized access to all components of the experiment; and
  - data archiving in a user-friendly format, and with sampling information (“metadata”) that is necessary for understanding the measurement.

Monsoon Systems (VAMOS) Ocean–Cloud–Atmosphere–Land Study Regional Experiment (VOCALS-REx). Conducted in the autumn of 2008, VOCALS-REx studied the southeastern Pacific stratocumulus region with scientific goals ranging from addressing large-scale sea surface temperature (SST) model biases, to aerosol impacts upon cloud properties. The combined involvement of modelers and observationalists is evident in a model evaluation making use of ship and satellite data of 2006 conditions for the region preceding the field experiment. This prepared the stage for a more comprehensive model evaluation of conditions sampled during the actual field experiment. The open and centralized data archiving was conducted by NCAR’s Earth Observing Laboratory ([www.eol.ucar.edu/projects/vocals](http://www.eol.ucar.edu/projects/vocals)) and includes program documents and an ongoing publications list. An integrated dataset, designed to ease model evaluations, was created as a legacy of the predecessor field experiment, East Pacific Investigation of Climate (EPIC, available through [www.eol.ucar.edu/projects/epic](http://www.eol.ucar.edu/projects/epic)), and is expected to serve as a model for a similar VOCALS integrated dataset. The open documentation of these efforts is expected to continue application of VOCALS data within modeling studies into the future.

Another U.S. CLIVAR process study underway is the Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean (DIMES; <http://dimes.ucsd.edu>), while several others are still in their planning stages. Those in postfield stages that also illustrate the use of best practices include the Kuroshio Extension System Study (KESS; <http://uskess.org>), the CLIVAR Mode Water Dynamic Experiment (CLIMODE; <http://climode.org>), and the North American Monsoon Experiment (NAME; [www.eol.ucar.edu/projects/name](http://www.eol.ucar.edu/projects/name)).

The U.S. CLIVAR process studies to date have been primarily supported within the United States by the National Science Foundation and NOAA agencies. The Department of Energy and NASA also contribute to U.S. CLIVAR research, and many of the climate field programs have international support as well. The U.S. CLIVAR oversight by the Process Study and Model Improvement panel can be requested by the funding agency or by the climate scientists themselves. The immediate advantage of PSMI panel involvement for the process study is greater visibility and exposure to the larger research community. Another advantage is that the broader umbrella serves to encourage greater synthesis of the individual field experiment findings into a more global analysis. The combination of results from geographically disparate locations can provide tests of the parameterizations over a wider range of environmental conditions than provided by the individual study.

We encourage scientists conducting future process studies to think along similar lines as one way to enhance their own legacy. The concept of best practices is too new to allow a statistical evaluation of the ultimate scientific impact of a process study, often evaluated through publication statistics. It is also arguably unfair to apply the standard to historical experiments that preceded the electronic age. Nevertheless, it is intuitive that field experiments that are more visible, guided by principal investigators that promote professional data access, with a centralized Web site providing visibility to resulting publications, are more likely to enhance their impact in ways both tangible and intangible.

The authors of this article are former and current coauthors of the U.S. CLIVAR Process Study and Model Improvement panel. For more information on panel activities, see [www.usclivar.org/psmi.php](http://www.usclivar.org/psmi.php).