

CAPT: THE CLOUD-ASSOCIATED PARAMETERIZATIONS TESTBED

Despite the many advances made in climate modeling, large systematic errors are still present in their simulated mean state of climate. However, fully understanding the cause of these systematic errors in a climate system is difficult because the climate is a complicated non-linear system, and even a good simulation could result from compensating errors in representing various dynamical and physical processes. To address this problem, a team of researchers at Lawrence Livermore National Laboratory, in collaboration with scientists at the National Center for Atmospheric Research, has been working to diagnose the sources of these errors—many of which are known to result from imperfect representation of clouds in climate models.

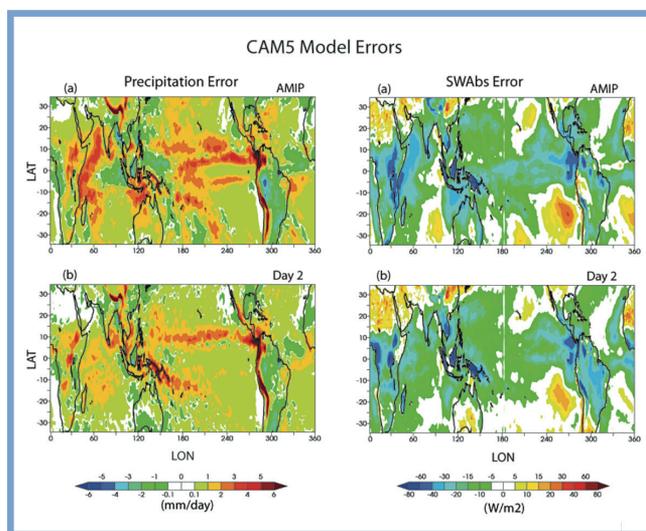
For almost 10 years, the Cloud-Associated Parameterizations Testbed (CAPT) project has been diagnosing parameterization-related errors in the atmospheric models used for climate prediction. CAPT uses the unique technique of performing weather forecasts—actually hindcasts—with climate models. Simply stated, realistically initialized climate models are integrated in forecast mode to determine their initial drift from observations, thereby gaining insights on model parameterization deficiencies. The hindcasts are particularly effective:

- to diagnose the origins of errors in simulated climate
- to more effectively compare climate models to point observations such as those collected at ARM sites
- to assess the relative strengths and weaknesses of alternate parameterizations of atmospheric physical processes—particularly those associated with cloud processes.

CAPT is sponsored by the U.S. Department of Energy’s Office of Science through the Regional and Global Model Analysis and Atmospheric System Research programs.

MANY FORECAST ERRORS ARE CLIMATE ERRORS

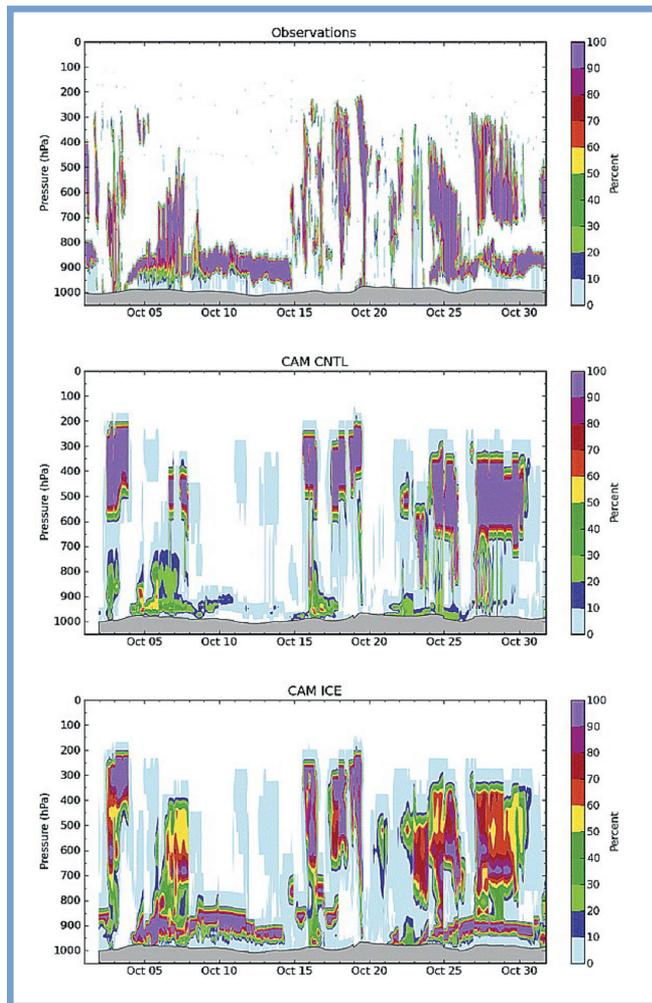
The mean errors in hindcasts bear a striking resemblance to climate errors. This is particularly true for precipitation errors in the tropics and the overestimate of net shortwave absorbed radiation in the stratocumulus cloud decks over the eastern subtropical oceans. This tells researchers that these errors result from errors in the fast cloud processes and are not the result of errors in simulating the large-scale state of the atmosphere. Some errors, such as the double Intertropical Convergence Zone, are not apparent in the hindcasts, suggesting these result from long-time feedbacks with the large-scale circulation. Studying the error growth in hindcasts helps to understand what model components need fixing.



Error in precipitation and absorbed solar radiation simulated by the Community Atmosphere Model in weather-prediction mode (“Day 2”) bear a striking resemblance to the errors simulated by the free-running model (“AMIP”). This correspondence suggests that many climate model errors in clouds and related processes result from an incorrect representation of the cloud-associated parameterizations and that they can be diagnosed with an economical weather forecast approach. (Source: Xie et al., 2012)

ARM PROVIDES CRITICAL OBSERVATIONS TO TEST MODELS

Sometimes critical data to test the simulation of clouds in models are available only from special observations at only a few locations. Integrating climate models in weather-forecast mode much more readily facilitates the comparison of models to these observations. An example of this is the records of the vertical occurrence of cloud observed by the cloud radar and lidar at the Atmospheric Radiation Measurement (ARM) user facility sites, such as that at the North Slope of Alaska. The CAPT project has performed extensive comparison to ARM data and helped modelers identify which parameterizations better simulate cloud and aerosol processes.



Time-height (pressure) cross-section of cloud frequency at ARM's North Slope of Alaska site during October 2004 from ARM cloud radar and lidar observations and two versions of the Community Atmosphere Model integrated as a weather-forecast model by CAPT. The ARM observations provide critical model tests and in this example show that when the parameterization of ice microphysics of CAM is modified ("CAM ICE") that the simulation of low mixed-phase clouds is improved relative to the default model ("CAM CNTL"), albeit with a degradation in higher-level clouds. (Source: Gettelman et al., 2010)

INCREASING MODEL RESOLUTION HELPS, BUT IS NOT A PANACEA

One approach to improve the simulation of cloud processes is to increase the model horizontal resolution. The CAPT project has been assessing the value of increasing the model horizontal resolution by asking which phenomena improve or whether further parameterizations would be more worthwhile. For tropical precipitation, the CAPT project has demonstrated improvements with resolution to the intensity distribution and land-sea breezes triggered by coastal circulations. However, increased resolution is not a panacea as the spatial patterns of global model biases in

time mean precipitation are largely unchanged over resolutions, and in some regions, the 0.25° model significantly overestimates the observed precipitation.

FUTURE DIRECTIONS

To date, all CAPT integrations have been with only the atmosphere component of climate models. However, it is clear that errors in representing cloud processes contribute to errors in the climate simulated by fully interactive ocean-atmosphere models. Thus, CAPT will be extending the concept of weather forecasts from the atmosphere to the fully coupled ocean-atmosphere model. This will allow researchers to more effectively improve the simulation of climate in the models used for climate change prediction.

ACCOMPLISHMENTS

Since the inception of CAPT in 2003, the project has resulted in 25 published papers in 10 years. The pioneering work on the application of weather forecasting techniques to climate models has been cited in the fourth and fifth assessment reports of the Intergovernmental Panel on Climate Change. The team has tested many parameterizations over the years as a service to the community of scientists developing new parameterizations. Numerous parameterization tests have been used in the process to decide what parameterizations should be included in a climate model.

CONTACTS

Renu Joseph, Ph.D.
 DOE Program Manager
 Regional and Global Modeling Analysis
renu.joseph@science.doe.gov

Sally McFarlane, Ph.D.
 DOE Program Manager
 Atmospheric Radiation Measurement
sally.mcfarlane@science.doe.gov

Stephen Klein, Ph.D.
 Principal Investigator
 Lawrence Livermore National Laboratory
klein21@llnl.gov

Shaocheng Xie, Ph.D.
 Principal Investigator
 Lawrence Livermore National Laboratory
xie2@llnl.gov

Project Website
<http://www-pcmdi.llnl.gov/projects/capt/index.php>