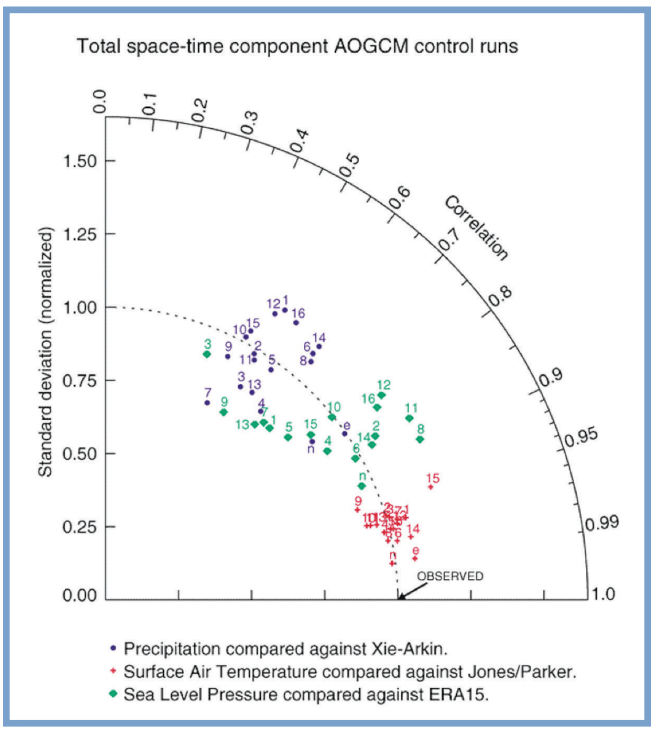
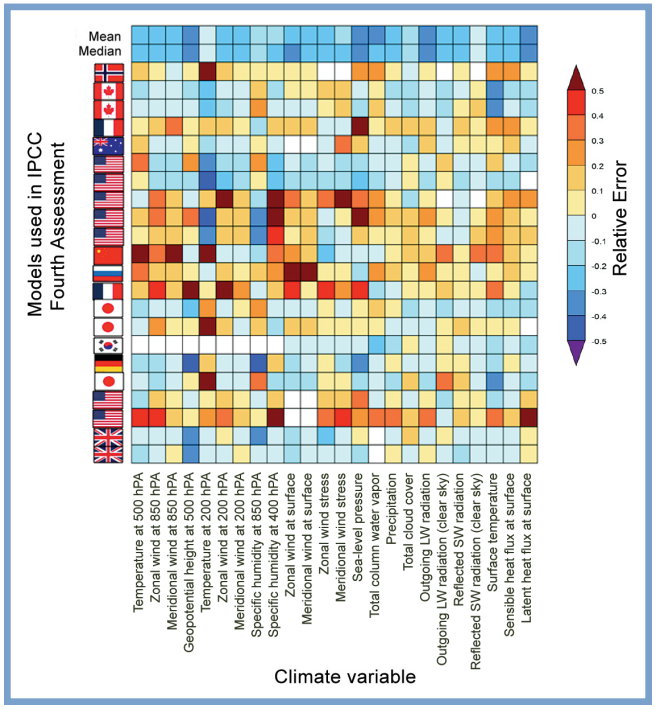
PROGRAM FOR CLIMATE MODEL DIAGNOSIS AND INTERCOMPARISON (PCMDI)

Established by the U.S. Department of Energy at Lawrence Livermore National Laboratory, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) fosters and engages in research aimed at providing a systematic and comprehensive evaluation of climate models. Working with international partners, PCMDI has inspired a fundamental cultural shift in the climate research community, which now expects access to output from climate simulations, enabling widespread scrutiny and analysis.

A notable product of PCMDI's leadership of coordinated modeling activities is the Coupled Model Intercomparison Project (CMIP) that subjects models worldwide to an evolving set of standardized numerical experiments. The CMIP model output is made freely available to all researchers, leading to many hundreds of peer-reviewed publications. In addition, many of the conclusions appearing in each of the five assessment reports prepared by the Intergovernmental Panel on Climate Change are drawn from the scientific foundation of the multi-model collection of CMIP projections of future climate change.



Taylor diagrams, invented at PCMDI, are now commonly used to summarize model skill. This example appeared in the model evaluation chapter of IPCC's Third Assessment Report (2001).

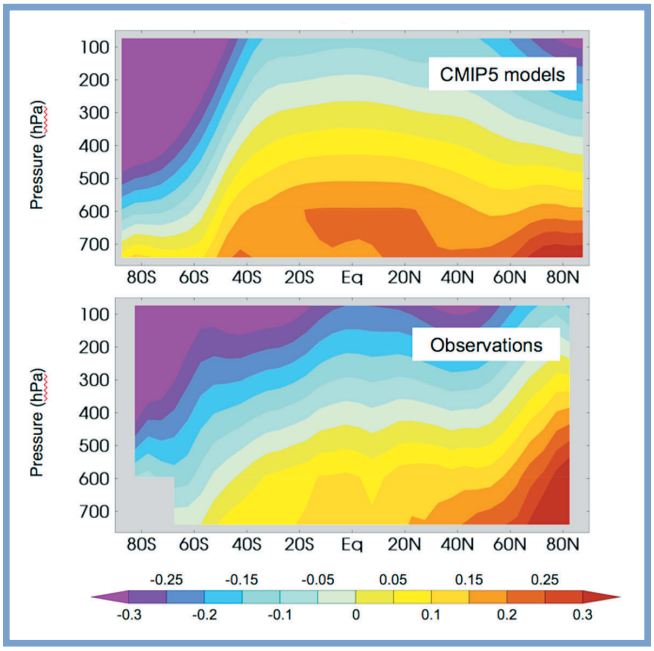


Model performance "portrait plots" show that climatological mean simulation errors are usually smaller for the statistical mean of a multi-model ensemble relative to the individual models comprising the ensemble. (Source: Gleckler et al., Journal of Geophysical Research, 2008)

RESEARCH ADVANCES

Capitalizing on the multi-model CMIP simulations that PCMDI manages, in-house research focuses on the evaluation of climate models. An overarching goal is to gauge the relative merits and limitations of individual climate models and to quantify and reduce uncertainty in model projections of climate change. PCMDI scientists have developed innovative graphical methods for displaying multiple aspects of model performance. The "Taylor diagram," for example, is now routinely used throughout climate sciences to summarize the fidelity of simulated fields. More comprehensive summaries of model performance can be presented using the PCMDI-developed "portrait plots." These plots help identify relative strengths of different models.

PCMDI is also a recognized leader of detection and attribution (D & A)–research that seeks to identify causes of recent climate change. Work in this area at PCMDI utilizes results from the CMIP multi-model ensemble to define anthropogenic "fingerprints" of climate change that can be identified unambiguously in climate observations. Capturing results from multiple models and examining multiple aspects of climate (e.g., temperature, water vapor, ocean



"Fingerprinting" with changes in the vertical structure of atmospheric temperature: The average of eight CMIP-5 models with anthropogenic forcing (upper panel) and satellite observations from Remote Sensing Systems (lower panel) both show coherent warming of the troposphere and cooling of the stratosphere. (Source: Santer et al., Proceeding of the National Academy of Sciences, submitted)

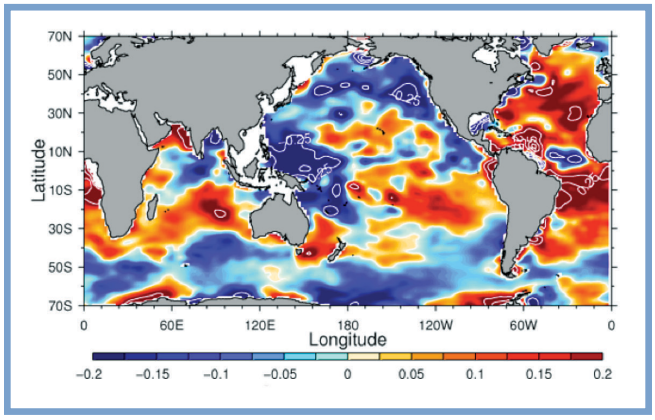
heat content, precipitation), the D & A research is uncovering the multifaceted characteristics of human-induced climate change. In line with PCMDI's overall mission, an important aspect of this research is that the models used to identify the anthropogenic climate change signal and to estimate the noise of natural variability are subjected to quality assessment tests. In the face of model differences and uncertainties, this permits sound conclusions to be reached.

Additional research at PCMDI examines the ability of models to simulate a wide range of processes and phenomena, from the variety of observed modes of atmospheric variability (e.g., the Madden-Julian Oscillation, ENSO, and atmospheric waves) to changes in land hydrology, ocean salinity, or climate feedbacks (e.g., involving cloud changes).

SUPPORT OF CLIMATE MODELING INFRASTRUCTURE

To facilitate community-wide use of climate data, PCMDI established and now supports data standards, enabling general tools to be developed to access, ingest, and analyze data from various sources. PCMDI plays a leading role in maintaining the Climate and Forecast (CF) Metadata Standard (*http://cf-pcmdi.llnl.gov/*) that has been widely adopted for use by the climate research community.

To encourage analysis of CMIP results, PCMDI supports development of software to enable users to search and retrieve CMIP data distributed across data nodes around the world. In this regard, PCMDI is responsible for the first widespread application of the Earth System Grid Federation infrastructure (*http://pcmdi9.llnl.gov/esgf-web-fe/*) infrastructure. In addition, PCMDI has nurtured the development of a rich set of DOE-supported analysis tools (currently known as Ultra-scale Visualization



Analysis of surface salinity changes from 1950 to 2000 show that some regions are becoming saltier and others fresher, consistent with changing precipitation patterns. (Source: Durack et al., Science, 2012)

Climate Data Analysis Tools, *http://uv-cdat.llnl.gov/*), designed to capitalize on the data standards established for CMIP output.

FUTURE DIRECTIONS

Building on its success in promoting comprehensive evaluation of climate models through intercomparison projects like CMIP, PCMDI now contributes in additional ways. For example, PCMDI, in collaboration with the National Aeronautics and Space Administration, helped establish a new activity called Obs4MIPs, which aims to make observational products more accessible for climate model intercomparisons (http://obs4mips.llnl.gov:8080/wiki/). This project facilitates evaluation of models by encouraging processing and archiving of observational data in conformance with the CMIP model output standards. In addition, PCMDI explores ways model quality information can be conveyed more widely to the research community, by, for example, leading an internationally recognized metrics panel working to establish a suite of standard metrics that will be used to monitor changes in performance as models evolve. Once established, these metrics—backed by standard diagnostic procedures and a library of analytical tools—will provide the basis for routine and transparent benchmarking of model development. The aim is to distill the information derived from the expanding community effort devoted to climate model analysis and to communicate those insights that might be of special interest to the groups attempting to improve the models.

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Project Websites
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