CELEBRATING TWO DECADES OF THE PROGRAM FOR CLIMATE MODEL DIAGNOSIS AND INTERCOMPARISON

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Twenty years ago, W. Lawrence (Larry) Gates approached the U.S. Department of Energy (DOE) Office of Energy Research (now the Office of Science) with a plan to coordinate the comparison and documentation of climate model differences. This effort would help improve our understanding of climate change through a systematic approach to model intercomparison. Early attempts at comparing results showed a surprisingly large range in control climate from such parameters as cloud cover, precipitation, and even atmospheric temperature. The DOE agreed to fund the effort at the Lawrence Livermore National Laboratory (LLNL), in part because of the existing computing environment and because of a preexisting atmospheric science group that contained a wide variety of expertise. The project was named the Program for Climate Model Diagnosis and Intercomparison (PCMDI), and it has changed the international landscape of climate modeling over the past 20 years.

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THE 20TH ANNIVERSARY OF THE PROGRAM FOR CLIMATE MODEL DIAGNOSIS AND INTERCOMPARISON

WHAT: To celebrate the twentieth anniversary of PCMDI and to honor its founder, W. Lawrence Gates, more than 100 specialists and leaders in climate modeling met to discuss PCMDI's history and the future of climate modeling
WHEN: 6 April 2009
WHERE: Bethesda, Maryland

In spring 2009 the DOE hosted a 1-day symposium to celebrate the twentieth anniversary of PCMDI and to honor its founder, Larry Gates. Through their personal experiences, the morning presenters painted an image of climate science in the 1970s and 1980s, that generated early support from the international community for model intercomparison, thereby bringing PCMDI into existence. Four talks covered Gates's early contributions to climate research at the University of California, Los Angeles (UCLA), the RAND Corporation, and Oregon State University through the founding of PCMDI to coordinate the Atmospheric Model Intercomparison Project (AMIP). The speakers were, in order of presentation, Warren Washington [National Center for Atmospheric Research (NCAR)], Kelly Redmond (Western Regional Climate Center), George Boer (Canadian Centre for Climate Modelling and Analysis), and Lennart Bengtsson [University of Reading, former director of the European Centre for Medium-Range Weather Forecasts (ECMWF)]. The afternoon session emphasized the scientific ideas that are the basis of PCMDI's success, summarizing their

evolution and impact. Four speakers followed the various PCMDI-supported climate model intercomparison projects, beginning with early work on cloud representations in models, presented by Robert D. Cess (Distinguished Professor Emeritus, Stony Brook University), and then the latest Cloud Feedback Model Intercomparison Projects (CFMIPs) led by Sandrine Bony (Laboratoire de Météorologie Dynamique). Benjamin Santer (LLNL) presented a review of the climate change detection and attribution (D & A) work pioneered at PCMDI, and Gerald A. Meehl (NCAR) ended the day with a look toward the future of climate change research.

THE PROGRAM. Anna Palmisano, associate director for the DOE's Office of Biological and Environmental Research (BER), opened the symposium by giving an overview of the research sponsored by her office. BER supports interdisciplinary research to address critical national needs by engaging national laboratories, universities, and the private sector to generate the best possible science.

Next, Washington presented an early look at Gates's contributions to the 1975 National Academy of Sciences report, *Understanding Climate Change: A Program for Action*. Washington recalled that Gates "really took charge" of the whole report. Gates's intention was "to recommend a comprehensive research program" for the United States that would "increase significantly our understanding of climatic variation." The report's recommendations were as follows:

1) Establish a national climatic research program with international coordination;
2) Establish a climatic data analysis program, to study the impact of climate change on food, water, and energy supplies;
3) Develop a climatic index monitoring program . . . a national watchdog for climate change;
4) Establish a climatic modeling and applications program (CMAP), and explore possible future climates using coupled general circulation models (GCMS);
5) Adopt and further develop an international climatic research program (ICRP); and
6) Develop an international paleoclimatic data network for the reconstruction of past climates.

Washington concluded with praise for Gates's leadership and ability to have a larger view of the problems facing climate change research.

The next speaker, Redmond, was the state climatologist for Oregon State University near the end of Gates's tenure there. He emphasized Gates's contributions to a variety of topics in climate research, including the use of downscaling as an important diagnostic tool. Redmond reminisced about the early days and reported that the applied climatology community continues to make use of many of the concepts and data that have been provided by PCMDI through Gates's leadership.

Boer's presentation outlined some of the problems in early efforts at climate modeling. During that time, analysis was often minimal, observations were difficult to obtain, and modelers were often fiercely protective of their results. Questions arose in these early discussions on how to make progress and improve models. Comparing model results subjected to similar numerical experiments was one promising research avenue. Boer went on to discuss the beginning of the model intercomparison projects ("MIPs") and their legacy in the wide array of model intercomparison projects that have evolved since.

Bengtsson joined the symposium via a video conference from his office in Reading, United Kingdom. His presentation emphasized new tools for climate research, including model intercomparison and the use of reanalysis. He discussed the early days of model intercomparison, which involved the exchange of maps and diagrams, and then pointed out the improvements to model development and evaluation infrastructure that PCMDI contributed under Gates's leadership.

The symposium shifted emphasis to PCMDI's accomplishments and its ongoing legacy with the afternoon talks. Michael Riches (senior technical advisor, BER) discussed the DOE's pioneering role in the formation of PCMDI and its continued support. In 1989, Riches, along with Fred Koomonoff (now deceased), initiated the funding that supports PCMDI. After discussing PCMDI's roots, Riches emphasized the importance of PCMDI's current missions: diagnostic tool development; a GCM parameterization test bed; and, most significantly, the storage and distribution of terascale datasets from multiple coupled ocean–atmosphere GCM simulations for use by the world's researchers to study climate variability and change.

Cess led the first organized model intercomparison project in 1984, which laid the foundation for a larger, federally supported model intercomparison effort. His presentation discussed the primary results from the Feedback Analysis of GCMs and Intercomparison with Observations (FANGIO), in which he demonstrated that cloud feedback could be assessed using a simple experiment prescribing a ±2°C perturbation to the model sea surface temperature and

then diagnosing the corresponding change in net radiative forcing. The process saved a significant amount of computer time—a necessity at that time. The FANGIO team reached the conclusion that cloud feedback differences among climate models were largely responsible for the wide range of sensitivities seen in different models' responses to the same imposed forcing. Cess pointed out that this range in model sensitivity has continued to confound climate modelers, and it has shown no signs of narrowing.

Bony presented a talk on the current state of GCM cloud feedback analysis, the field of study originated by Cess. She pointed out that not much has changed in the range of uncertainty. The study of cloud feedback has taken on a new sense of importance, and a new model intercomparison project has evolved from interest in the topic. She leads the international Cloud Feedback Model Intercomparison Project, which is supported by the World Climate Research Programme through the Working Group on Coupled Modelling (WGCM). She stressed that the role of cloud feedback has not diminished and that differences in how models simulate low-level clouds are now known to be the main contributors to the wide range of model cloud feedbacks. In addition, aerosol–climate interaction has increased the pathways for cloud processes to affect climate projections. Bony then described how cloud feedbacks affect the simulation of large-scale dynamics in the atmosphere, including the Hadley and Walker circulations, the Madden–Julian oscillation (MJO), and El Niño–Southern Oscillation (ENSO).

One of PCMDI's major missions has been the D & A of climate change. Santer has led this effort at PCMDI, and he presented a history of the process using climate model evaluation along with the observational record to help detect human-induced climate change. He went on to discuss the "fingerprint detection" strategy to demonstrate how different factors that influence climate have different spatial and temporal response patterns in model fields, particularly temperature. Santer described how the single-forcing climate modeling experiments have helped researchers understand the contribution of various climate elements to produce the comprehensive climate change picture. He went on to discuss the future of detection and attribution and how the next step is to identify anthropogenic fingerprints on continental and regional scales.

Meehl presented a short history of the Coupled Model Intercomparison Project (CMIP) coordinated experiments and the partnership with PCMDI. He outlined the initial CMIP experiments and the role PCMDI played in the storage and distribution of the data that were used to make significant contributions to the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report, released in 2001. At the second CMIP workshop in 2003, the new PCMDI director, David Bader, agreed that PCMDI would collect, archive, and distribute the next CMIP experiment data for the IPCC Fourth Assessment Report (AR4). This unprecedented database of multimodel results positioned PCMDI for a major role in the AR4, with 31 terabytes of model output data collected and distributed to more than 1,200 scientists, who authored more than 300 journal articles. The AR4 was released in 2007.

The success of the effort by PCMDI and the CMIP phase 3 (CMIP3) organization has led to an even more ambitious effort envisioned for the next IPCC assessment: PCMDI will be the central clearinghouse for a much larger-scale set of experiments, including decadal predictions with model resolutions near 50 km, first-generation earth system models (ESMs) with a coupled carbon cycle, and lower-resolution models for long-term feedback studies.

The importance of model intercomparison is now broadly recognized as a cornerstone of climate model evaluation and error identification. Nevertheless, when PCMDI was created to enable systematic model intercomparison studies, the argument was not so obvious. Back then—and even now to some extent—many did not understand the need to develop and apply multiple climate models, each with its own combination of experts' judgments. In this light, we consider the following quote by Cess et al. (1990) to be prophetic: "if only one model were available, we could not so confidently conclude that cloud feedback is a key issue for climate dynamics."

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