

Report of the First U.S. Climate Modeling Summit (USCMS)
NOAA Center for Weather and Climate Prediction, College Park MD
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1. Introduction

The First annual USGCRP IGIM Climate Modeling Summit was held on 10 February, 2015, at the NOAA Center for Weather and Climate Prediction in College Park, Maryland. The Summit convened the leads from the six major national climate model development groups together with representatives of their sponsoring agencies and the USGCRP.

The overarching goal of the meeting was to enhance coordination toward a common national climate modeling strategy that includes a component involving communication with the broader modeling community. Subsidiary objectives were to:

- Enhance shared understanding of modeling groups' directions and implementation strategies;
- Identify opportunities for better coordination and synergy among modeling groups; and
- Identify outreach opportunities to user communities.

A principle theme of the meeting was to identify opportunities for shared strategy, coordination, and outreach by the centers in order to enhance the scientific mission of each center and to further the application of their research in broader scientific and societal enterprises. The motivation for the Summit was to begin realizing the opportunities from sharing strengths that could be brought to bear on the major scientific priorities identified by recent comprehensive assessments, including crosscutting issues around extremes, energy/water/food resources, and risks of impacts from rapid changes in the cryosphere.

The benefits conferred the Climate Model Summit stems from spirited discussions concerning a wide variety of topics and opportunities, including (but not limited to):

- Increase communication of big picture modeling issues;
- Explore scope for shared infrastructure; diagnostics/DA/forcing datasets;
- Coordinate better understanding and publications ; and
- Explore opportunities for multi-center mini-MIPs -- bespoke scenarios for other US agencies/interests (e.g., EPA, FAA, DOT).

The report of the proceedings described herein follows the outline of the summit objectives given to the group representatives prior to the meeting (see appendices). It should be noted that while the groups were advised to focus their attention on the first of three major topics (§2, on shared programmatic directions and implementation strategies), there was considerable discussion of opportunities for enhanced coordination (§3) and outreach opportunities (§4), and hence the report includes the results of these discussions as well. Ideas concerning possible follow-on activities are summarized in §5. Plans by each of the modeling centers are given in §0.

2. Enhancing shared understanding of modeling groups' programmatic directions and implementations strategies

2.1. *Develop a common vision for national climate modeling and a roadmap for the respective roles of the various groups within that vision.*

There are several imminent challenges that could serve as rallying points for the U.S. modeling community, principally:

- Enormous changes in and expansion of the database that helps us understand our environment. New data sources include the suite of data from NASA's SMAP, GPM, and GRACE missions with SWOT forthcoming and the advent of space-based wind

imaging. NASA funds GMAO to use this data and is supporting the insertion of the new wind data into NCEP's analyses via JCSDA. Critically, this leaves open the question of how the long-range prediction efforts (i.e., GFDL, GISS, CESM, and ACME) could benefit from these data, which in sum represent a generational transformation in our observational capabilities.

- There are disruptive changes in computing technology that will compel rapid advances and transformation of the scientific, mathematical, and computational implementations of the codes. For the foreseeable future, it will be necessary to mitigate risk by actively developing and supporting a diverse portfolio of solutions and implementations to hedge against sudden redirections in computer architecture and supporting software infrastructure. This challenge is accompanied by comparable changes associated with the storage, processing, and preservation of exponentially increasing volumes of model output.
- At the same time, these changes in data and computing represent real opportunities to advance the formulation of Earth system models. For example, the new generations of machines should enable the development of global cloud-resolving models useful for both NWP and long-range climate prediction, a goal long anticipated to remove the uncertainties associated with parameterized convection.

2.2. Document groups' scientific goals and model strengths, including differences and commonalities among modeling groups.

The group recognizes that while there are slight differences in mission, focus, and strategy among the various centers, there is also a lot of commonality. It would be useful to make the common threads of the groups' missions, and the common gaps and challenges that all groups face, much more explicit.

There was a useful exchange of the high-level developmental priorities at each of the six centers represented at this meeting. The promising developments include:

- Widespread adoption of greater spatial resolution across the Earth system, typically ranging from 10 to 50 km in many of the next-generation components.
- More advanced formulations of the fluid dynamics permitting nesting and variable grid refinement to target computation at regions of interest, and exploration of multiple formulations as the community transitions to eddy-permitting ocean resolutions and nonhydrostatic atmospheric resolutions.
- Further advances in a broad range of critical Earth-system processes that govern the concentrations of short-lived and long-lived radiative forcing species.
- Extensions in assimilation systems, for example inclusion of data assimilation for new data sets and other components of the Earth system besides the atmosphere.
- Incorporation of new capabilities that address stakeholder applications, e.g., the incorporation of NOAA's wave height model into both NWP and climate codes.

These developments are on track for deployment and application in the next one to three years, partly in response to the timelines set by the CMIP6 process.

Application areas that are emerging as priorities include:

- Climate prediction and predictability using massive ensembles;
- Resilience to hazards, including heat waves, floods, and droughts;
- Effects of climate variability and change on food productivity and biogeochemical

cycles;

- Near- and long-term evolution of hydrological cycles, especially water resources; and
- Risks of accelerated sea-level rise due to rapid changes in land ice and rest of the cryosphere

One strategic form of diversity is that two of the groups represented at the USCMS, namely the CFS and GEOS-5 teams, are heavily involved in operational data assimilation while the remaining four (GFDL ESM, Model E, CESM, and ACME) use assimilation in a research mode. NCEP and GMAO provide reanalyses using CFS and GEOS, respectively, while GFDL and NCAR are heavily invested in determining the limits of predictability at the decadal scale. The group recognizes that this diversity is of net benefit; for example, NCEP can benefit from other groups in the context of evaluating model results against observations.

2.3. Articulate linkages between the US model development enterprise and the international modeling and science community.

A central USGCRP priority is to determine how modeling groups could benefit from an interagency committee. Having a unified national voice in the international arena is also important.

2.4. Inform one another and the sponsoring agencies on the status of the modeling activities, updates in plans (including participation in MIPs), and progress in applications, including an assessment of the rate of progress.

It would be useful to consider the elements of successful collaboration among the groups, particularly in a budgetary environment where OMB would presumably welcome evidence for enhanced complementarity and collaboration. Communication of existing and prospective collaborations to OMB, particularly in a unified voice, would be especially beneficial. OMB is particularly interested in understanding how much coordination exists among agencies engaged in modeling enterprises.

From the IGIM's view, having a common vision of the modeling effort in the US is would be valuable, particularly since IGIM is frequently being asked about potential redundancy, etc. Several agencies are committed to multi-agency investments in collaborations.

2.5. Identify gaps in US climate modeling capabilities that are critical for the science and societal goals.

The groups need to argue for resources to address the appreciable computing and data utilization challenges facing Earth system modeling over the next decade (§2.1).

Due to the rapid expansion in the breadth of processes and capabilities incorporated in ESMs, there are large sections of the code that are becoming scientifically or technically obsolete. In the absence of commensurate expansion of the teams maintaining these models, it is becoming increasingly infeasible to scrutinize and update the entire code simultaneously. The challenge is how to target developments towards the best representation of critical processes that can be attained given current scientific understanding and computational resources. Another possible metric for prioritizing development is the best representation of broad scale and emergent phenomena, for example, the Madden-Julian Oscillation (MJO). There was diversity of opinion regarding which metric could be suitable across multiple groups, particularly spanning the operational to more purely investigative axis.

Scientific challenges identified by modeling centers in their reviews of their own programs include how best to:

- Emulate ocean eddies in current non-eddy-permitting ocean models;
- Determine the aerosol-cloud interactions necessary and sufficient for NWP and climate-change simulations and to capture and represent these processes with sufficient fidelity using a combination of benchmark models and field data;
- Simulate critical boundary layer and low-cloud feedbacks on climate change, particularly since explicit treatment requires regional-to-global models operating at currently unattainable large-eddy simulation (LES) scales;
- Initialize land ice models given the huge remaining uncertainties in their internal state, interactions with continents underneath, and surface mass balances; and
- Balance developments in process complexity, spatial resolution, information content and uncertainty quantification, and human dimensions.

3. Identifying opportunities for enhanced coordination and synergy among modeling groups

3.1. Consider potential areas of collaboration on shared infrastructure (e.g. data standards, workflows, archives, etc.), software, and modeling approaches.

The groups recognize the opportunities afforded by possibly consolidating diagnostic frameworks. Some consolidation is already underway, as packages for diagnostics and analysis now being merged for CMIP6. There is value in collectively assessing the diagnostics that the modeling community is using beyond the obs4MIPs framework and in possibly coordinating further development of, or in identifying common approaches for, these packages. The value proposition is particularly acute for the operational NWP groups.

There may be concrete benefits from standardization of hardware and maintenance of the complete software stack. Hardware standardization could facilitate exchange of best practices and “lessons learned” among the modeling groups wrestling in isolation with the rapid evolution of HPC platforms. The current absence of standards for computing infrastructure optimized for climate represents an opportunity for future standards setting. Conversely, portability of codes across computer architectures invites community model and modeling efforts.

There are already numerous concrete examples of shared components, including LANL’s sea-ice and land-ice models, oceans (e.g., the use of GFDLs’ MOM at multiple centers). The group felt that the U.S. should build on such examples, while recognizing that discussions around interoperability have been ongoing for years, if not decades, and have not advanced as rapidly as might be desirable due to inertia. While there are elements of common software infrastructures that are being used, often these components don’t provide quite what people hoped they’d provide, and the components may not be quite as common as people would hope owing to sociological and other issues.

New modules designed with modern software standards present perhaps the best opportunities for component exchange. A recent example is the CPT work on ocean mixing that has recently united approaches developed separately at NCAR, LANL, and GFDL. Much greater attention to interface standardization (or at least standards) and to unit testing of codes would facilitate exchange and co-development of new capabilities. This would be particularly useful for NCEP as it straddles new development in both the operations and research arenas.

Flexible coding structures and standardization are important, and past efforts to implement both are starting to deliver tangible benefits. This is particularly true at operational centers such as NCEP, which is not in the business of developing in-house components for all parts of a

coupled modeling system and is therefore reliant on ESMF and other types of infrastructure for exchange. This infrastructure allows the various groups to implement different combinations of existing sub elements to achieve their specific objectives.

3.2. Consider development of a unified weather-climate capability for the US.

In some sense, some of the foundations are already occurring thanks to the advent of non-hydrostatic dynamical cores under several of the modeling projects represented, including GFDL and ACME. In addition, groups like GMAO are already serving as both operational analysis centers and as long-range predictive efforts. While the development of a single unified capability was not a major topic at this initial summit, there was universal recognition of the scientific and societal imperatives to examine the nexus between weather and climate (§5). Note that climate is defined differently at different centers, with NCEP's definition of climate is distinguished by its focus on relatively short weekly to annual timescales.

3.3. Discuss coordination of U.S. model participation in Model Intercomparison Project (MIP) research activities to optimize investments.

There may be considerable value in coordinating MIPs among the six groups that could serve our collective scientific interests with considerably more specificity and agility than can be readily obtained through the MIP process underway for CMIP6, although the groups understand the necessity and value of participating in the CMIP6 exercise. The U.S. groups are generally participating in MIPs that fit their specific scientific objectives and interests and are using the DECK experiments to try multiple configurations of their core models.

3.4. Consider common experiments or approaches to tackle climate modeling science and climate prediction and projections challenges.

The group discussed several candidates for common initiatives, including

- *Predictability of the hydrological cycle at various critical length and time scales*
The periodicities of interest for the water cycle span weather system, seasonal, and climate time scales. This topic is responsive to increasing interagency focus on water, for example the USDA's interests in the availability of water for crops, forests, and the carbon cycle. The new National Water Center formed by NOAA, USGS, and the Army Corps of Engineers shares some of the same foci.
- *Climate and air quality*
The issues around climate and air quality are already being addressed through a spectrum of model intercomparison projects (MIPs) with center collaboration.
- *Hydrometeorological extremes*
The challenges posed by realistic emulation of extremes in the present climate and reliable projection of changes in these phenomena in a warmer climate certainly represents a common interest among groups performing both operational and long-range future simulations. Agency attendees noted the needs around robust production of elevated risks of heat extremes.
- *Fire prediction and impact*
Most of the groups are already developing capabilities in this arena and would be ready to help NCEP by sharing these codes. This is a good example of how to address NCEP's mission to address stakeholder needs through collaboration.
- *Harmonization of forcing data sets*
Despite best efforts in CMIP5, it is still evident that historical forcing data sets exhibit a large diversity, particularly associated with concentrations of short-lived species such as anthropogenic and volcanic aerosols. GMAO indicated that such work would benefit from the detailed treatment and assimilation of aerosol satellite products in the

GEOS-5/MERRA-2 system. It could prove quite useful to compare the spread and uncertainty in these data sets through studies designed to be complementary to the intercomparisons planned for CMIP6.

The groups then discussed how best to prioritize among these various options, perhaps by comparison and identification of common directions among the groups' strategic plans.

The concept of "mini-MIPs" (i.e., MIPs conducted just by the U.S. centers) was floated and met with considerable interest, since it could be focused around our common interests and simultaneously demonstrate for technical and political reasons that support for the climate-modeling program is beneficial to taxpayers.

The smaller group assembled for this first USCMS also provides an opportunity to collectively explore small-scale processes critical to large-scale climate. One possible avenue of collaboration is to jointly identify certain topics (e.g. cloud aerosol interactions) that would be amenable to study by this smaller group.

4. Identify outreach opportunities to enhance the understanding and usability of climate model output

4.1. Convene targeted meetings to enhance communication within the broader modeling community (e.g. regional climate modelers) and model users.

Both agency representatives and group leads concur that identification of common issues for focused workshops would be particularly useful. While there is obvious value in eventual expansion of these workshops to include the stakeholder community, initially it might be advisable to build closer working collaborations among the physical modeling groups. These workshops could address, for example, common scientific challenges faced by the various groups (§3.4), the grand challenges around utilization of new climate data and new computing platforms (§2.1), lessons learned and best practices for engagement with stakeholders and decision makers (§4.2), and other issues where greater coordination and/or information exchange would be mutually beneficial. The workshops could also focus on important questions or critical gaps identified through feedback from each center's community of outside scientific collaborators and/or similar outreach activities by the USGCRP.

A periodic meeting of modelers to exchange ideas/views on methods to address difficult development issues, and on opportunities for common solutions, would be useful.

Since there are already several such activities underway by the operational weather services, the value-added proposition of engaging the climate-research centers would need to be clearly articulated. One example of current activities is the development by the NWS of an end-to-end assessment of what would be required for a weather-ready nation – perhaps the centers could provide input to a parallel assessment of requirements for a climate-ready nation, including approaches to minimize adverse impacts and to maximize benefits from adaptation.

4.2. Coordinate interaction with climate model stakeholder communities.

There is an urgent need to increase communication of big picture modeling issues. There is also an imperative to better articulate what is entailed in building Earth system models. Stakeholders are particularly interested and need to be informed regarding how well ESMs simulate the present-day climate.

The group recognized that while proposing some areas where increased fidelity could be useful (e.g., in projected rainfall over the U.S.), it would be critical to develop a prioritized list with input from the stakeholders themselves. It will be especially important to solicit the key gaps in climate information directly from the decision makers. The groups also felt that it would be

advisable to target some of the common experiments discussed (§3.4) toward stakeholder needs and, perhaps, to explore ultimately having stakeholders drive identification of some of the common experiments. The group identified several plausible topics for engagement, e.g. the issues around coincidence of heat extremes, elevated ozone, and reduced air quality in warmer climates, but elected to defer further discussion and prioritization until such meetings occur.

The weather service provides a potential model for such engagement, since 40% of the staff are out in regional offices and work frequently and closely with their local stakeholder communities. This suggests that one way to proceed is to embed early-career scientists trained by the climate modeling groups into particular fields and sectors.

4.3. Foster a program for climate model interpreters.

There was common recognition of the need for interpreters who can work with the stakeholder community and who understand the climate models, their limitations, and best practices regarding downscaling at a much higher level than appears to be typical at present. It remains an open question who would be responsible for the creation and support of such a community. There was some sentiment that training of these interpreters would be a more natural fit with the university partners of the modeling centers than the centers themselves. At present, despite the existence of programs that are aligned correctly and could serve a coordinating function, there is insufficient funding to train a sufficient cadre of students to enter this field and to support their activities once they do.

5. Discussion regarding follow-on activities

The groups discussed possible follow-on activities to maintain the lines of communication and build momentum towards greater synergy among the six U.S. centers. These activities include:

- Development of a document, perhaps a BAMS paper, which expresses the complementarity of the centers. The paper could include the basic visions and objectives of each modeling effort and could identify both shared and distinctive goals. However, if this idea is pursued, it should be done so carefully to avoid giving the impression of replication and duplication of effort.
- Further exploration of the nexus between weather and climate involving participants from both the operational NWP centers and the more research-oriented climate-science centers. This could involve, for example, examining weather-scale phenomena produced by both NWP and ESM codes. Extreme phenomena of interest include statistics on heat waves and deviations in the jet stream leading to severe winter storms.
- A wider forum building on the foundations from this first meeting, although the group advises that such a forum would be most useful if the six centers could further refine where the coherences are and what types of collaborations would be responsive to their and their funding agencies' respective missions and objectives. The advisability of including stakeholders and/or university investigators is still an open question and the group explored the advantages and disadvantages of doing so at this early stage. There was some discussion about possible focal topics, for example a water extreme workshop that would have national visibility.
- There was also interest in the establishment of regular meetings just among the six centers oriented around, for example, one or more mini MIPs. The topics could address U.S.-centric questions that are not targeted by CMIP6 but that are of great interest to the centers and their sponsors.

6. Plans by each of the modeling centers

6.1. NOAA/Geophysical Fluid Dynamics Laboratory

NOAA's Geophysical Fluid Dynamics Laboratory (GFDL), located on the Forrestal Campus of Princeton University in New Jersey, engages in comprehensive long lead-time, use-inspired research central to NOAA's mission in weather and climate. GFDL's objective is "*to advance scientific understanding of climate and its natural and anthropogenic variations and impacts, and improve NOAA's predictive capabilities, through the development and use of world-leading computer models of the Earth System*". GFDL's research contributes directly to an improved scientific understanding of the changing climate system and its impacts, and assessments of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decisions.

Earth System modeling incorporates core disciplines including meteorology, oceanography, hydrology, physics, fluid dynamics, chemistry, applied mathematics, ecology and numerical analysis. Scientists at GFDL construct mathematical models of the Earth System comprising the atmosphere, oceans, biosphere, and cryosphere, based on fundamental principles, with the system of equations solved numerically on high-performance supercomputers. GFDL's state-of-the-art models provide timely and reliable knowledge on natural climate variability and anthropogenic changes, with the research addressing challenges such as quantifying weather and climate impacts, including hurricane research and prediction and seasonal forecasting, as well as advancing the understanding and projection of global-to-regional climate variations and change out to centennial time scales. Since its inception in 1955, GFDL has been actively engaged in National and international research on the modeling of global climate, and the lab has played a significant role in the World Meteorological Organization and Intergovernmental Panel on Climate Change assessments, and in the U.S. Global Change Research Program.

GFDL research aims to account for the complexity of the Earth System while simultaneously focusing on developing high-spatial-resolution models to obtain credible information at space scales of relevance for society. The scope encompasses: the understanding, predictability and sensitivity of global and regional climate on a variety of time scales; the structure, variability, dynamics and interaction of the atmosphere and ocean; ways that the atmosphere and oceans are influenced by various trace constituents; and climate change detection, attribution, and impacts, from the past to present to future. GFDL is developing an understanding of, and prediction systems for, climate extremes on time scales of seasons to decade. Comprehensive model development is underway to synthesize a number of activities, including advanced representations of: atmospheric chemistry, aerosols, and clouds, to better capture the nexus between atmospheric composition, the hydrologic cycle, air quality and climate; ocean, sea- and land-ice interactions, to quantify changes in sea-level and circulation; terrestrial and ocean biogeochemistry, to determine the interactions between the atmosphere, oceans, and land involving heat and carbon cycles, and the impacts of climate on marine ecosystems.

Research is enhanced by the [Cooperative Institute in Climate Science](#), a partnership between NOAA and Princeton University. Faculty, research scientists, and graduate students, including those from Princeton's [Atmospheric and Oceanic Sciences Program](#) (AOS), participate in joint research with GFDL scientists on frontier problems.

6.2. National Center for Atmospheric Research

Overview

- CESM is the primary Earth System Model used by the University community
- It can be configured and used for broad array of application, from classroom teaching to cutting-edge scientific problems
- This flexibility in applications requires
 - A high-quality, well-tested model
 - A flexible, portable and high-performance software
 - Extensive scientific and software engineering support through liaisons, working groups and bulletin board

Top science goals

Short-term

- Climate prediction and predictability
- Resilience to hazards
- Climate variability and change

Long-term

- Emphasis on high-resolution (atmosphere and ocean, including vertical) and variable grids
- Coupling with land-ice and sea-level rise
- Human dimension and impact focus
- Representation of the continuous Sun-Earth System
- Efficiency on Leadership Class Facilities

Strengths

- CESM1-CAM5 is ranked very highly in multiple CMIP5 (and other additional MIPs) analyses
- Extensive development and analysis through community involvement. This relies on the CESM working group structure that has proven to be quite successful in providing continuous improvements in the model capability and performance
- Through its range of applications, CESM takes advantage of its modeling approach that links weather-scale applications, data assimilation and climate modeling
- Broad distribution of simulation results (e.g. CESM1 Large Ensemble)

Challenges

- Having access to sufficient computational infrastructure for model development and applications, especially in view of the competing demands associated with large ensembles and high-resolution
- Uncertainty on upcoming computational architectures, thereby limiting our ability to plan for coding strategies
- The generation of data is outpacing the capacity of users to perform data analysis but also the overall dissemination of such results to outside interested parties

Maintain workhorse versions and bleeding-edge capabilities to satisfy the demands of the whole CESM community.

6.3. NASA Goddard Institute for Space Studies

The climate modeling activities at NASA GISS are focused on understanding the drivers of climate change on decadal-to-centennial-to-millennial timescales and the processes and feedbacks that determine the response, with a strong emphasis on the use of NASA observations to constrain and evaluate our understanding. The current modeling framework (ModelE) is a flexible coupled ocean-atmosphere-cryosphere-carbon-land surface-interactive atmospheric composition model that has been a strong contributor to CMIP activities. GISS science has been at the forefront of many steps forward in understanding the climate system through framing the issue of radiative forcing, the exploration of new feedbacks and interactions, quantification of the drivers of climate change, out-of-sample evaluation of climate models and innovative comparisons to observations.

As one of the smaller US modeling groups, GISS is focused on maintaining flexibility of approaches to allow for nimble exploration of new themes or ideas. Efforts are focused on three broad themes: increasing the connectivity, realism and accuracy of different physical components, expanding the exploration of structural uncertainty within and across models, and enabling a broader range of scientific and operational questions to be asked of the models. For instance, we have pioneered the use of forward modeling of remote sensing diagnostics and paleo-climate proxies, quantifying upper atmospheric effects on climate and emergent forcings (black carbon on snow, irrigation, aerosol indirect effects, solar indirect effects) and evaluating the credibility via simulations of past climate change. We have a specific focus on climate impacts, particularly on agriculture and urban environments. An important new direction involves estimating impacts of specific policies affecting emissions on air quality, climate and public health. Additionally, in collaboration with planetary science groups, we are extending the flexible modeling system to incorporate simulations of other rocky planets in the solar system and further afield.

The challenges we face are many-fold, for instance, the difficulty in easily evaluating model output against credible multivariate process-based diagnostics. It is also a challenge to maintain and continue to explore necessary structural diversity in modeling approaches – particularly for the ocean components. With respect to applications, finding ways to fund and create inter-agency cooperative projects on policy-specific scenarios remains difficult. GISS collaborations with other US modeling groups are ongoing, but could be made more efficient and effective.

6.4. DOE Accelerated Climate Model for Energy

6.4.1. The ACME Vision

The Accelerated Climate Modeling for Energy Project is an ongoing, state-of-the-science Earth system modeling, simulation and prediction project that optimizes the use of U.S. Department of Energy (DOE) laboratory resources to meet the science needs of the Nation and the mission needs of DOE.

In this context, “laboratory resources,” include the people, programs and facilities, current and future. They collectively represent a unique combination of scientific and engineering expertise as well as leadership computing and information technologies required to construct, maintain and advance an Earth system modeling capability that is needed by the country and DOE. A major motivation for the ACME project is the coming paradigm shift in computing architectures and their related programming models as capability moves into the Exascale era. DOE, through its science programs and early adoption of new computing architectures, traditionally leads many scientific communities, including climate and Earth system simulation, through these disruptive changes in computing.

6.4.2. The ACME Ten-Year Goal

Over the next ten years the ACME project will assert and maintain an international scientific leadership position by its ability to design, execute and analyze climate and Earth system simulations that address the most critical scientific questions to the United States and DOE
ACME will achieve this goal through four intersecting project elements:

1. A series of **prediction and simulation experiments** addressing scientific questions and mission needs;
2. A well documented and tested, continuously advancing, evolving and improving **system of model codes that comprise the ACME Earth system model**;
3. The ability to use effectively **leading (and “bleeding”) edge computational facilities** soon after their deployment at DOE National Laboratories; and
4. **An infrastructure** to support code development, hypothesis testing, simulation execution and analysis of results.

6.4.3. The ACME Ten-Year Goal

This project is designed to accelerate the development and application of a fully coupled, state-of-the-science Earth system model (ESM) for scientific and Energy mission applications. The model will be optimized for deployment on systems in the DOE’s Leadership Class Facilities (LCFs) and the National Energy Research Scientific Computing center (NERSC). While the goal is to build a state-of-the-science Earth modeling system for the full complement of DOE’s mission-related goals and needs, initial scientific development of the system will be dictated by the team’s focus on three climate change thematic areas (called “science drivers” hereafter). These science drivers cover broad, important areas of science requiring an accurate treatment of climate system processes for more accurate simulation and prediction of climate change. The drivers align closely with the Climate and Environmental Science Division’s (CESD) mission objectives to advance DOE’s leadership in the computational formulation, empirical evaluation and calibration, and use-inspired application of climate models.

The three drivers are:

- (Water Cycle) How do the hydrological cycle and water resources interact with the climate system on local to global scales?
- (Biogeochemistry) How do biogeochemical cycles interact with global climate change?
- (Cryosphere Systems) How do rapid changes in cryospheric systems interact with the climate system?

6.5. NASA Goddard Modeling and Assimilation Office

Research and development activities in the Global Modeling and Assimilation Office (GMAO) aim to maximize the impact of satellite observations on Earth System analysis and prediction. Timescales of interest range from “weather” (hours-days), through seasonal, to multi-decadal. The work addresses aspects of the physical, chemical and biological aspects of the global Earth System at spatial resolutions as fine as several kilometers. A unique aspect of GMAO’s mission is strong connection of the GEOS-5 modeling system to NASA’s satellite observations. This includes the generation of ultra-high (kilometer-scale) resolution global simulations, including the recently released 7-km GEOS-5 Nature Run.

An advanced “weather” assimilation system is built around the GEOS-5 model. It ingests observations from the operational satellites, using the same analysis system as the National Weather Service (NWS). This is in part to provide support to NASA’s space-based platforms and field missions. GMAO has developed and implemented a method to assess the impacts of individual observation types on the skill of weather forecasts. This includes the impacts of NASA’s unique research satellites: if the benefits of these datasets are substantial, they can be transferred to operational systems at the NWS. One current GMAO activity is the implementation of all-sky microwave radiance data from the Global Precipitation Mission.

Advances in weather analyses are of benefit to one of the main climate products from the GMAO: reanalyses. The Modern-Era Retrospective analysis for Research and Applications (MERRA) was released in 2011 and will be superseded by an upgraded product, MERRA-2, in mid-2015. MERRA-2 includes numerous updates over MERRA, including an improved version of the underlying GCM and inclusion of additional data types, such as the JPSS instruments, GPS-RO data, and ozone and temperature from NASA’s EOS-Aura platform. A pioneering aspect of MERRA-2 is the interactive aerosol assimilation, based on NASA’s EOS-Terra and Aqua satellite observations, which enables direct computation of aerosol radiative forcing. This is a step toward a more complete Earth-System reanalysis on the 2018 time horizon, which will include couplings among ocean, ice, land and atmosphere as well as among physical, chemical and biological processes. These additional Earth-System components will build on expertise developed through GMAO’s regularly produced ocean analyses, which in turn are used in the initialization of GMAO’s regular, quasi-operational seasonal forecasts.

The global GEOS-5 systems used for GMAO’s products form the core of a research and development program. The research work includes the study of regional extreme events in the global context, with particular foci on studies of drought and floods, other extreme events including tropical cyclones, chemistry-climate coupling, and emerging capabilities in polar prediction. An ensemble of AMIP simulations will be provided to broaden the research questions that can be tackled with MERRA-2. Research work is also examining multi-decadal simulations with the coupled GEOS-5 system. GMAO’s activities in this regard are directed primarily at isolating uncertainties in near-future climate change, in order to guide design of new NASA climate observation programs. The scope of the GEOS-5 system enables this mission planning to be directed towards diverse areas, including physical climate, aerosols and cloud interactions, and biogeochemical feedbacks.

6.6. National Centers for Environmental Prediction Climate Forecasting System

The Climate Prediction Center uses the Climate Forecasting System (CFS) for several critical applications, including monthly and season temperature and precipitation outlooks, seasonal hurricane outlooks, experimental Arctic sea ice outlooks, and experimental multi-weekly outlooks.

Currently CFS consists of the Global Forecast System (GFS) atmospheric model running at T382 lateral resolution and 64 vertical levels, a Noah-based land model, the Sea Ice Simulator (SIS), and the MOM version 4 ocean model with 40 levels and $\frac{1}{4}^{\circ}$ to $\frac{1}{2}^{\circ}$ lateral resolution. Assimilation of observations is based upon the Global Data Assimilation System (GDAS) for GFS, the Land Data Assimilation System (LDAS) for the land model, ice extent for SIS, and the 3D variational Global Ocean Data Assimilation System (GODAS) for MOM.

The development of the next generation CFS is underway following a tentative four-year update cycle. The current plan is to release CFS-v3 in 2018, which is already under construction and will feature several major model improvements, followed by a release of CFS-v4 in 2022, which will deploy assimilation across the fully coupled model and will provide reanalysis and reforecast capabilities. These new capabilities will be critical components of future NCEP products beyond actionable weather predictions.

These developments are part of the Environmental Modeling Center's (EMC's) goal of constructing a unified coupled global modeling system with a second objective to support community modeling. CFS is effectively the prototype for such a unified global model, and the National Environmental Modeling System (NEMS) Earth System Modeling Framework (ESMF) represents the architecture for community infrastructure to support interoperability of coupled model components. NEMS is a modular system for both coupling high-level components and for introducing generality and extensibility at the interfaces inside components as well, for example at the interface between atmospheric dynamics and physics. NEMS also provides a unified suite of optimized procedures for input and output. Using NEMS, NOAA's Earth System Research Laboratory (ESRL) provides support for multiple atmospheric dycores, ocean models, sea ice modules, and predictive ocean wave and swell models. For example, EMC is now experimenting with HYCOM as well as new versions of MOM for the ocean component, with CICE and KISS as well as new versions of SIS for the sea ice component, and with the addition of NASA's GOCART aerosol module for the simulation of atmospheric particulates.

These efforts are closely connected and interact with other relevant programs, including the North American Multi-Model Ensemble (NMME) and the Next Generation Global Prediction System (NGGPS) project. Connections also include the Earth System Prediction Capability (ESPC), a collaboration among NOAA, NASA, DOE, and the U.S. Navy and Air Force. Additional partners include the Climate Prediction Center, the Climate Prediction Office, and the National Oceanographic Partnership Program.



Department of Energy
Office of Science
Washington, DC 20585

DATE: October 7, 2014

SUBJECT: Establishment of the Climate Modeling Summit, by the US Global Change Research Program, and invitation to first meeting

TO: Bill Lapenta, NCEP (Bill.Lapenta@noaa.gov)
Ramaswamy, GFDL (v.ramaswamy@noaa.gov)
Gavin Schmidt, GISS (gavin.a.schmidt@nasa.gov)
Steven Pawson, GMAO (steven.pawson@nasa.gov)
Jean-Francois Lamarque, CESM (lamar@ucar.edu)
Dave Bade, ACME (bader2@llnl.gov)

FROM: Gary Geernaert, Vice-Chair, US Global Change Research Program (USGCRP)

NARRATIVE:

The USGCRP Interagency Group on Integrated Modeling (IGIM) hereby convenes a U.S. Climate Modeling Summit (USCMS), consisting of the leads from U.S. "CMIP-class" climate model development centers, as well as those developing models for operational climate prediction¹.

IGIM is launching this Summit as a means to enhance U.S. climate modeling strategic planning, communication, and organization, with the expectation that this is to become an annual event. The attached document summarizes the IGIM vision and goals for the USCMS, as well as the scope and draft agenda for the first meeting.

We at IGIM expect that the USCMS will enhance coordination among U.S. climate modeling centers toward a common national climate modeling strategy and also facilitate communication with the broader modeling community and interested users on important cross-cutting issues. The USCMS will also provide important information for IGIM and USGCRP-wide strategic planning for FY2016 and beyond.

You are kindly invited to attend the 2015 USCMS together with another leading representative for your center that you may designate. The 2015 US Climate Modeling Summit is to be held in the DC area for one full day. The current plan is to hold this meeting at the National Science Foundation on February 10, 2015. It will be a one-day meeting.

Please confirm your ability to attend by notifying me before October 15, 2015. Please also let us know who else from your center will be attending the USCMS and have them confirm their attendance by the same deadline.

¹ Currently these include GFDL, NCEP, GISS, GMAO, CESM and ACME.

Once you have confirmed your attendance, the 2015 USCMS host will follow-up with logistical information regarding the meeting venue and associated travel and lodging information. I look forward to hear from you.

Sincerely, and on behalf of the USGCRP Interagency Group on Integrated Modeling (IGIM),

A handwritten signature in black ink, appearing to read "G. L. Geernaert". The signature is written in a cursive style with a large initial 'G'.

G. L. Geernaert, Ph.D.
Vice Chair, US Global Change Research Program; and
Director, Climate and Environmental Sciences Division
US Department of Energy

CC: IGIM group; USGCRP Chair Tom Karl

U.S. Climate Modeling Summit (USCMS) Scope and Organization

Overview, General scope, and proposed agenda

1. Overview

The USGCRP Interagency Group on Integrated Modeling (IGIM) proposes to convene an annual U.S. Climate Modeling Summit (USCMS), consisting of the leads from U.S. “CMIP-class” climate model development groups, as well as leads representing operational climate prediction efforts, to enhance coordination toward a common national climate modeling strategy and communication with the broader modeling community and interested users on important cross-cutting issues.

High-level USCMS objectives include:

- Enhance shared understanding of modeling groups’ directions and implementation strategies
- Identify opportunities for enhanced coordination and synergy among modeling groups
- Identify outreach opportunities to enhance the understanding and usability of climate model output

Specific objectives that define the scope of the USCMS are listed on the following page.

There are six climate modeling centers that we have identified to be part of this Summit: GFDL CM/ESM, CFS, Model E, GEOS-5, CESM and ACME, and attendance should be limited to two leaders per modeling center for focused Summit discussions. The U.S. Climate Modeling Summit will be organized under the auspices of the USGCRP IGIM. The participating IGIM agencies (NOAA, DOE, NASA, and NSF) that sponsor the aforementioned climate modeling centers will be responsible for arranging the annual meeting site for the USCMS.

The first meeting is planned for February 10, 2015 at NSF. The meeting will have an IGIM kick-off and will focus on the development of a common vision for USCMS with unique roles for each center, and a national strategic roadmap for climate modeling; this first meeting will also include a task to identify priorities for future USCMS activities. A draft agenda for this 2015 USCMS meeting is on page 4.

2. General Scope

The IGIM proposes a USCMS scope to include three broad areas of climate modeling, described below, to enhance coordination of: strategic planning, collaboration, and planning of outreach activities embodied in the specific objectives described below. The first USCMS will focus on the first of these areas. Follow-on USCMS activities, in the context of the general scope described here, will be discussed at the first meeting as well.

The first set of USCMS objectives aims at enhancing shared understanding of modeling groups' programmatic directions and implementations strategies:

1. Develop a common vision for national climate modeling and a roadmap for the respective roles of the various groups within that vision.
2. Document groups' scientific goals and model strengths, including differences and commonalities among modeling groups.
3. Articulate linkages between the US model development enterprise and the international modeling and science community.
4. Inform one another and the sponsoring agencies on the status of the modeling activities, updates in plans (including participation in MIPs), and progress in applications, including an assessment of the rate of progress.
5. Identify gaps in US climate modeling capabilities that are critical for the science and societal goals.

A second set of goals for the USCMS aim at identifying opportunities for enhanced coordination and synergy among modeling groups:

6. Consider potential areas of collaboration on shared infrastructure (e.g. data standards, workflows, archives, etc.), software, and modeling approaches.
7. Consider the development of a unified weather-climate capability for the US.
8. Discuss coordination of U.S. model participation in Model Intercomparison Project (MIP) research activities to optimize investments.
9. Consider common experiments or approaches to tackle climate modeling science and climate prediction and projections challenges.

Thirdly, the USCMS is to discuss and potentially identify outreach opportunities to enhance the understanding and usability of climate model output. For example the opportunity to:

10. Convene targeted meetings in order to enhance communication within the broader modeling community (e.g. regional climate modelers) and with model users.
11. Coordinate interaction with climate model stakeholder communities.
12. Foster a program for climate model interpreters.

Annual USCMS may focus on a subset of the goals listed above.

3. 2015 USCMS - Inaugural meeting and Agenda

Scope

The USGCRP Interagency Group on Integrated Modeling (IGIM) working group will convene a 2015 U.S. Climate Modeling Summit (USCMS) as the first of series of annual meetings. The high-level goal of the USCMS is to enhance coordination toward a common national climate modeling strategy and communication with the broader modeling community and interested users on important crosscutting issues.

Within the general scope of the USCMS, the 2015 USCMS will focus on enhancing shared understanding of modeling groups' programmatic directions and implementations strategies, and specifically:

1. Document groups' scientific goals and model strengths, including differences and commonalities among modeling groups.
2. Develop a common vision for national climate modeling and a roadmap for the respective roles of the various groups within that vision.
3. Articulate linkages between the US model development enterprise and the international modeling and science community.
4. Inform one another and the sponsoring agencies on the status of the modeling activities, updates in plans (including participation in MIPs), and progress in applications, including an assessment of the rate of progress.
5. Identify gaps in US climate modeling capabilities that are critical for the science and societal goals.

A second primary goal of the 2015 USCMS is to reflect on the USCMS scope as proposed by IGIM and delineate follow-up 2016 activities within the USCMS general scope.

An expected outcome of the meeting is a summary of conclusions (10 page max) from the USCMS discussions regarding US Modeling centers programmatic directions and implementation strategies and reflections on the USCMS scope as proposed by IGIM and follow-up 2016 activities within the USCMS general scope.

The 2015 USCMS participants are the leads from U.S. "CMIP-class" climate model development groups, as well as operational prediction leads (GFDL, NCEP, GISS, GMAO, NCAR and ACME). Attendance will be limited to two leaders per modeling center for focused Summit discussions.

The U.S. Climate Modeling Summit will be organized under the auspices of the USGCRP-IGIM.

1st US Climate Modeling Summit Agenda
February 11, 2015
NOAA Center for Weather and Climate Prediction, College Park MD

8:00-8:30 Coffee

8:30-8:45 IGIM welcome [Gary Geernaert] and NOAA welcome and charge [Annarita Mariotti]

8:45-9:00 Recap from CMIP6 meeting [Ron Stouffer]

9:00-11:00 Brief presentations by each US modeling group (20min each)

[Chair: Dave Bader]

GFDL, NCEP, CESM, ACME, GISS, GMAO

Presentations will provide high-level perspectives of priorities (top 3), challenges (top 3) and over-arching plans for the near term (3-years) and long-term (10-years)

11:00-12:00 Discussion regarding commonalities and differences among the US modeling centers activities

[Chair: Jean-Francois Lamarque, Rapporteur: Randy Koster]

12:00-1:00 Lunch

1:00-3:00 Discussion on developing a strategic roadmap

[Chairs: Ramaswamy, Gavin Schmidt; Rapporteurs: Hendrik Tolman, Steven Pawson]

Given the commonalities and differences among US modeling groups, how to articulate a strategic goal and roadmap that describes how the existing groups come into play nationally as part of the broader international context. Consider critical gaps that may limit or hinder a strategic vision.

3:00-4:00 Discussion on USCMS scope and follow-up 2016 activities

[Chair: Bill Lapenta; Rapporteur: Susanne Bauer]

Consider the defined scope of the USCMS. In particular, consider 2016 USCMS follow-up activities to be proposed within the general scope.

4:00-5:00 Open dialogue between IGIM and USCMS representatives [Chairs: David Considine and Anjuli Bamzai]

Following this meeting, Bill Collins and Bill Large will coordinate with USCMS participants to develop a summary of main points from the discussions (max 10 pages; notes will be provided by the Rapporteurs). This summary will be provided to IGIM within 1 month of the 2015 USCMS.

USCMS Participants

Bill Lapenta (NCEP)

Hendrik Tolman (NCEP)

Ramaswamy (GFDL)

Ron Stouffer (GFDL)

Gavin Schmidt (GISS)

Susanne Bauer (GISS)

Jean-Francois Lamarque (CESM)

Bill Large (CESM)

Dave Bader (ACME)

Bill Collins (ACME)

Steven Pawson (GMAO)

Randy Koster (GMAO)

US Climate Modeling Summit - Updated Logistical Information

When: February 11, 2015; 8-5 pm EST.

Where: NOAA Center for Weather and Climate Prediction (NCWCP)
Conference Center

5830 University Research Court
College Park, MD 20740

Participation:

If you haven't already replied to confirm your participation, please RSVP to Will Chong (william.chong@noaa.gov) ASAP. Participation is by invitation only.

Presenters:

The agenda includes 20 min presentations by GFDL, NCEP, CESM, ACME, GISS, GMAO. Presenters (one per center) please send your slides to Will Chong by **February 9th**.

Lunch & Coffee Breaks:

If you would like to place a box lunch order, please use the following [link](#) and make your order by **February 9th**.

The box lunches costs \$13 each and will be delivered to the meeting location. You also have the opportunity to pay for the two coffee breaks (\$12) that will be provided outside the conference room. If you elect to pay for both a box lunch and the coffee breaks at the time of purchase, you can save \$3, for a total cost of \$22. Please direct any questions you have about ordering lunch/breaks to Will Chong.

Casual Dinner on February 9th, 2015 (note the change of date):

A dinner is being organized for February 9th, 7pm at [Franklin's](#), a local casual Restaurant and Brewery. CMIP-6 workshop participants may also join.

Participants will pay own costs (either *a la carte* or a flat fee depending on the number of participants).

If you have already replied and your plans stay the same for the new date, you don't need to do anything.

If your plans have changed or you have yet to reply, please RSVP to Will Chong by **February 4th**.

Lodging Recommendation:

[College Park Marriott Hotel & Conference Center](#)

3501 University Blvd E

Hyattsville, MD 20783

[301-985-7300](#)

Use the following links for directions:

Reagan National [Airport to Hotel](#)

[Hotel to Conference Center](#)

[Conference Center to Reagan National Airport](#)

Note: Please make lodging and travel arrangements yourself.