Site Visit Report, Year 6, May 15, 2012

Science and Technology Center for Multiscale Modeling of Atmospheric Processes (CMMAP)

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The 6th year review was held at NSF in Arlington Virginia. The agenda is shown in Appendix 1 and the site visit team is listed in Appendix 2.

Executive Summary

The site visit team (SVT) would like to thank all members of the Center for their insightful presentations and candor in addressing site visit team questions. The SVT recognizes that this annual review process distracts the Center staff from their core mission, and is appreciative of the time and care that was devoted to the review.

Center staff made presentations on the overall goals and mission, research, knowledge transfer, education and diversity, management and the sustainability activities beyond the STC funding. The Center also provided the SVT with a web site that included past SVT reports and responses and documents summarizing the Center's strategic vision and results to date.

The Center is clearly leading the atmospheric modeling community in developing new tools for simulating and predicting the multi-scale interaction associated with weather and climate. The efforts have led to new insights in how convection and atmosphere large-scale dynamics interact.

The Center has been effective in meeting its educational goals, but continued focus on diversity issues is desirable. Institutional commitments remain a challenge.

The knowledge transfer appears to be progress well. Of particular not is the partnership with NCAR and CESM development. But, possible addition two-way interactions that go beyond individual PI relationship are encouraged. An example that is an emerging opportunity is the recent push to develop the next generation of the NOAA Climate Forecast System.

The management continues to be effective and responsive to emerging needs and opportunities.

The current Center planning for sustainability is encouraging. The SVT team finds that well defined plans should be developed.

The following expounds on the major strengths, challenges and opportunities for the Center in the near future.

A) Intellectual Merit

The Center's research mission is to take advantage of rapidly increasing computer speed to achieve major advances in out ability to understand and predict the effects of clouds on weather and climate. This is particularly challenging problem since the horizontal cross sectional area of a medium-sized cloud is 100 million times smaller that the area of the Earth's surface. The tradition approach of parameterized clouds based on simplified statistical theories has known limitations, and as such, the Center advocates and has led the development of a Multiscale Modeling Framework (MMF).

The Center's director (Randall) and members of the scientific leadership team (Moeng, Denning, Helly, Krueger) reported on several aspects of the Center's research activities. CMMAP student presentations were also provided to the SVT on the second day of the review.

The Center's research activities are broken down into: (i) a set of tools or models, (ii) small scale physical processes of interest and (iii) and a set of large scale processes processes that test the idea of multi-scale interactions. The tools or models include the so-called super-parameterizated community atmospheric model (SP-CAM), the second generation version of the super-parameterization which is referred to as the quasi-three-dimensional (Q3D-MMF), and cloud resolving models implemented at both global and local scales. The physical processes of interest are radiation, cloud micro-physics, turbulence, land-surface processes and cumulus parameterization. The climate phenomena include the MJO, monsoons, climate change, ENSO and the diurnal cycle.

The main research thrusts are: (i) application of the MMF to monsoon dynamics, MJO and climate change; (ii) enhancing the MMF to include land-surface heterogeneity, turbulence parameterizations, development of Q3D-MMF, and a scale aware or unified parameterization; and (iii) development of global cloud resolving models.

The SVT finds that the Center's research activities are progressing smoothly and rapidly, and the intellectual merit of the Center is very high. The following notes some particular strengths and potential weaknesses or opportunities that should be addressed.

Strengths:

1) Development of set of innovative modeling tools that have the potential to revolutionize atmosphere modeling.

- The SP-CAM MMF work is clearly defining the leading edge in atmospheric modeling and has lead to noted improvements in the simulation of the MJO,

reduction of the so-called double ITCZ problem and noted improvements in coupled ocean-atmospheric processes associate with ENSO.
- The climate change scenario tested with SP-CAM raises challenging questions regarding our understanding of the response of the climate system of large increases in CO2.
- The proposed development of the Q3D version has the potential is introduce even greater understanding of multiscale interactions and feedbacks.
- The efforts in global cloud resolving models also have great potential.

2) The Center is extremely productive producing on the order of 80 peer-reviewed publications in just the last year alone. This is an extremely high level of productivity and attests the strong scientific leadership in the Center.

3) The Center's research on radiation for dynamic models across scales has improved the parameterization of radiative transfer that is applicable to the diversity of atmospheric models used worldwide. This activity in particular shows how the Center's high-risk high pay-off approach to research benefits the entire modeling community.

4) The use of cloud resolving models to develop turbulence parameterizations or sub-grid scale (i.e., less than 1-4km) transport that are applicable in the MMF is progressing well and is ready for implementation. This specific project is an excellent example of how the Center has developed productive collaborations with the Nation's major modeling centers.

5) The Center is well positioned to examine how land surface heterogeneity can be incorporated into the MMF, and the confrontation of the land surface models in global atmospheric models has lead to systematic improvements in the simulation of large-scale climate.

6) The Center is leading new understanding of the MJO (e.g., how cumulus momentum transport my not as important as previously thought, but that moistening is very important), monsoon processes, and mid-latitude meso-scale convective systems.

7) The graduate student research presented to the SVT is of high quality and clearly supports research mission of the Center.
- Presentations included a detailed comparison of how the cumulus parameterization in CAM3.5 differs from the MMF in terms of down drafts and how this could be potentially used to improve the parameterization in CAM.
- Students are using the MMF in "forecast" mode over North America in order to confront the super parameterization and CAM3.5 with high-resolution observational data.

- Results with the MMF highlight how North American summer precipitation is improved over CAM3.5

8) The Center's research activities are reasonably balanced with greatest emphasis on the tropical processes and mid-latitude meso-scale systems. Recent application of MMF to Arctic processes was also noted as a positive development in that it is a somewhat independent test of the modeling approach.

Challenges and Opportunities:

1) The SVT found that most of the presentations on the Center's research focused on the development of modeling tools (e.g., unified parameterization, Q3D …), but did not emphasize how the modeling activities have led to new overarching insights and scientific understanding of the physics and dynamics of multiscale processes. We note that in terms of some specific processes, e.g., the MJO and monsoons, the Center is enabling new science and is leading the field (see strength 6 above).

- For example, seeking to inform the modeling community what are the limits to what sub-grid scale processes are "parameterizable" and what needs to be resolved and represented in terms of first principles would be beneficial.

2) One important measure of success of the Center will be how well the modeling tools developed will be adopted by the broader research community. The Center is progressing in this regarding, but best MMF practices should be developed.

B) Education

The educational objectives of CMMAP aim to promote and enhance climate and earth-science literacy/awareness through interactions mainly with the K-to-"gray" population, undergraduates, and post-graduates. The center addresses these objectives through community-reaching hands-on activities (like workshops), the development of undergraduate classes and summer internships, and through stewardship of graduate students. Leadership from CMMAP is evident in most of the key educational aspects. Personnel and budgetary resources are likewise appropriately dedicated to ensure success.

Strengths:

1) Ample of evidence in strong integration of research and education activities through undergraduate and graduate studies

- Numerous graduate students (~47 students) are supported through CMMAP (associated with CSU and other institutions)
- Career development workshops/colloquiums for graduate students (e.g., grant-writing, proposal writing).
- Healthy CMMAP summer undergraduate internships

2) Educational activities with wide-spread and potentially lasting impacts

- Undergraduates summer internships (REU/SOARS) demonstrate evidence of positive effects on interest in atmospheric science or related field
- Community-based activities (e.g. LSOP, teacher work) show promise of lasting impact and has apparent lasting legacy
- Development and dissemination of undergraduate and K-12 materials (e.g. new courses at CSU and Colorado College, you-tubes, learning kits)

3) Good involvement of educational activities with existing activities at CSU as well as external institutions

- Involvement of Colorado College, UCAR/NCAR SOARS
- CMMAP graduate students from various partnering institutions
- Inclusion of other CSU departments (Psychology, Sociology, and Political Science)

4) Involvement of Center's leadership, all faculty, graduate students in education agenda

- Graduate students participate in teaching through
- Physics undergraduates participate in LSOP
- CMMAP leaders are fully involved in research and education.

Challenges and Opportunities:

1) Lack of evidence showing participation of post-docs in the education of undergraduate/graduates – this is part of professional development.

2) Additional documentation of how (other than graduate) educational activities connected to each of the CMMAP research themes is desirable.

3) Educational activities are primarily confined to CSU region.

4) Clarify recruiting strategies so that successful approaches can be documented and communicated.

5) How can other undergraduate institutions capitalize on CMMAP integration and educational activities?

6) Pursue more partnership of LSOP ("franchise") with other regions.

7) Pursue education-related funding to sustain effort (e.g., NSF TUES).

C) Diversity

The diversity plan of CMMAP aims to increase the number of diverse students pursuing graduate degrees in atmospheric sciences. Several mechanisms have been implemented to promote diversity gain such as a summer internship program and CMMAP funding for graduate students. Through CMMAP efforts, the numbers of underrepresented groups have increased from 1 graduate student to approximately 8 at present. One student will graduate and begin as an Assistant Professor at the University of Louisiana at Monroe. While the impacts of CMMAP on diversity have been demonstrated, additional opportunities and pathways to enhance impacts can be accomplished. This can occur through stronger interactions with administration (Chair, Dean, Provost) but especially at the Dean's level. In particular, a "buy-in" for diversity at an institutional level with some commitment of resources could be essential to further development and sustainability. The Center has a unique opportunity to encourage the Department and the University to enhancing diversity.

Strengths

1) Actively seeking out underrepresented participants for the summer internship program nationwide and working with the SOARS program.

2) CMMAP supports 10 underrepresented students across the 7 CMMAP institutions.

3) Developing collaborations related to interdisciplinary research at other institutions.

Challenges and Opportunities

1) Beyond the level of graduate education there is no representation from minority groups among post-doctoral/research scientists or faculty members.

- For example, this deficiency can be addressed through a focused effort to promote diversity in the department or research centers through cost sharing between CMMAP and the Dean's office – a model used at many minority serving institutions (MSI) around the country. At the graduate level, the Dean's office can provide additional resources in the form of fellowships to increase the level of diversity at the largest US graduate department in atmospheric sciences.

2) No clear level of institutional commitment outside of CMMAP for diversity (no post-docs, research scientists, faculty of color in the department or at research centers).

3) No specific institutionalized MSI (or institutions supporting under-prepared students) partnerships (e.g., MOU; regularized student or faculty exchanges/visits) for pipeline or collaborative activities (teaching, research).

- For example, CMMAP could partner with regional colleges such at the Metro college of Denver, which has 24% minority population and has a meteorology program for a potential graduate student pipeline and collaborative research/educational efforts.

4) Given the location of CMMAP, participation from Native Americans at undergraduate/graduate levels is lacking.

5) Metrics do not quantitatively show trends and impacts of CMMAP diversity efforts at a refined level (African-American, Native American….).

D) Partnerships and Knowledge Transfer

The STC has taken very seriously its role in partnering with institutions outside CSU and transferring knowledge to the broader community. Clearly, connections with other leading researchers, particularly in the western US, are strong. Interactions are well facilitated by regular team meetings, and inclusion of all members of the team (from summer interns to senior scientists) helps strengthen this effort. The SVT commends Dr. Randall and all of the CMMAP leadership on these sincere and clearly effective efforts. As a result of the site visit, some clear successes, as well as areas of potential improvement, have been revealed.

Strengths:

1) Publication of the textbook on AGCMs is a fine legacy that could have strong impact, particularly in graduate education.

2) Creation of new journal, JAMES, could be viewed as a nice contribution, perhaps filling a gap in the constellation of journals.

3) Partnership with NCAR and CESM development is clearly strong, with reasonably good institutional commitment (at the J. Hurrell level). Geographic proximity makes this a logical partnership that can likely be effectively sustained. NCAR's role serving the broader academic modeling community is well-served by this connection. Transferring the CMMAP models to other departments through NCAR is a great way to test the applicability and extensibility of the model beyond what CMMAP can do itself.

Challenges and Opportunities:

1) Partnership with in-state, or SW US, Native American undergraduate population may be a somewhat missed opportunity. Focus on MSI's in far-flung areas (e.g., Puerto Rico, Louisiana) may be less reasonable than looking closer to home, if a

long-term impact on improving representation of historically under-represented groups is the real goal of these partnerships.

2) Partnerships with NOAA (or other national laboratories) are PI-based, derived from past collaborations, and focused on very specific problems, rather than on the broader, overarching potential contributions that CMMAP could make to the operational modeling enterprise (including both weather and climate simulations). An opportunity to work with NOAA/NWS/NCEP on CFSv3 is currently available, and even more extensive "infiltration" of NOAA's modeling effort could be attempted and might well be embraced by NOAA.

3) Transfer of technical knowledge regarding the modeling tools among CMMAP collaborators at different institutions, and from one generation of student to the next, could be improved by better documentation of code, establishment of a repository of FAQs/Blog and better version control of models.

4) The KT happens mostly one-way (e.g., to outside CSU). There are several university PIs who are also working on cloud resolving models or other similar models. Can CMMAP create a mechanism that can incorporate the new ideas or model improvements into its model developments and refinement?

- Broadening to industrial/commercial partnerships – is this possible?

5) Partnerships with observational activities addressing related sub-grid scale process issues require continued and enhanced emphases.

E) Center Value

The synergy demonstrated by CMMAP's scientific research, wider and integrated collaborations, knowledge transfer activities, and education, diversity activities would not have been possible without a Center funding structure. Such successful research-education integration and collaborations and accomplishments cannot be achieved by means of a collection of individual university-PI-oriented grants, or a operational center or laboratory.

Strengths:

1) As a center, CMMAP brings together scientists from a broad range of disciplines within CSU, and with outside partners, to work collectively to address highly complex and interdisciplinary cloud processes in the climate system. The team includes climate modelers, cloud modelers, and experts on turbulence, radiation, cloud physics, and observations. The end results include improved understanding of important climate phenomena and cloud feedbacks on climate change.

2) As a center, CMMAP's mission goes far beyond research. CMMAP devotes enormous amounts of time and energy to its education, diversity and knowledge

transfer components into multiple dimensions. The depth and breadth of these activities, populated by a variety of people with a range of interests, skills, goals, and ages, have exceeded beyond the sum of those of individual PIs. CMMAP's students, teachers, and researchers work productively as a team. The team is obviously collegial. CMMAP integrates atmospheric scientists, writers, sociologists, computer scientists, policy analysts, educational psychologists, and others, who work together towards common goals and help each other to succeed.

3) Unlike a regular project, CMMAP also has provided a comprehensive package of programs to bring individuals who have been underrepresented historically in the sciences and engineering workforce to its core mission.

4) CMMAP is more than a "project" in terms of management. As a center, CMMAP has put together a multi-institutional management team to address a broad range of goals through strategic planning, constant communication, diligent follow-through, and an openness to appropriate course adjustments.

F) Organization and Management

CMMAP's management continues to be effective in creating and nurturing a strongly focused community of researchers and educators and fostering collaborative relationships between the Center and other institutions.

Strengths:

The highlights in management during Year 6 of the project are:

1) The management is lean and effective.

2) Prof. Krueger from University of Utah rotated in as the director of knowledge transfer further strengths the partner institute involvement in governing CMMAP.

3) The addition of "internal advisory panel" led by the VP for Research since Year 5 has been highly beneficial for CMMAP to receive full support from CSU administration and to identifying new sources of support.

3) CMMAP managing staff, led by the director, Marcia Donnelson, continue to help grow and strengthen the management of the Center, especially the education and outreach projects and the marketing of the Center. An important legacy of the CMMAP, the nonprofit corporation, REACH, spearheaded by her has recently been recognized by the IRS as a 501(c)3 corporation. The center also newly recruited Claire Fleming as part of the management team and events coordinator. This strong staff management team is critical for supporting next phase knowledge transfer to broad climate research community, for example, planning workshop to train users of the SP-CAM, and setup portals to support community use of SP-CAM.

Challenges and Opportunities:

1) Balancing resource allocation between depth and breadth of the research, focused effort of model building vs. groundbreaking scientific understanding is appropriate, but requires continued attention.

2) Continuing to develop strategy and time-line for sustainability and legacy plan, including a long-term strategy to sustain diversity created by CMMAP. An initial milestones have been identified for Year 7: To get buy-in from the department, college, and VPR for overhead support, meeting with university development office and CSU PR to develop fund raising strategies for fund raising campaign, and announce formation of the Climate Simulation Institute.

3) Exploring ways to reduce environmental footprint.

G) Legacy and Sustainability

CMMAP has begin to plan for a transition during the ramp down of funding during years 9 and 10 as well as the future of the center after the 10th year of operation. While the planning process is at a preliminary stage, a broad vision has been outlined. Two major components of the future of CMMAP were articulated: The non profit organization, REACH and the Climate Simulation Institute (CSI).

REACH has been established as a nonprofit organization with a stated goal of raising awareness and educating the public about climate science. The board of trustees of REACH include Brian Jones, who is the director of the "Little shop of Physics", David Randall and Scott Denning. REACH is following a multi-pronged approach to education and outreach via science kits, computer applications, media productions and teacher training. REACH expects to raise funds via sales of the science kits, grants, services and private donations.

CSI is envisioned as a research facility with a state of the art computing platform (hardware, software, data archival and dissemination) to continue the research and development activities of CMMAP. It is expected that CSI will support up to 20 graduate students, couple of workshops annually and include research and administrative staff.

CMMAP also has a plan for Sustaining the ongoing efforts in improving ethnic and gender diversity in climate science. In addition to active effort aimed at attracting new graduate students and faculty members from traditionally underrepresented groups, the benefits are expected to cascade within wider community through the success of Alumni (PhD and MS graduates from CMMAP, who are entering the work force in academia and industry).

Strengths:

1) The investigators involved in CMMAP have a strong track record of vigorous research activities funded at high levels. Such level of funding will be necessary in order to sustain the activities of the center in the long-term.

2) A rough time line to begin negotiations with the university administration for support of the proposed CSI is in place.

3) The scope of the CSI appears to be broader than CMMAP. This will be helpful in attracting the participation of new research/faculty members.

4) The education component appears to be robust, and has a strong history of success. Of positive note is also the recent award of the Robert Millikan medal to Brian Jones.

Challenges and Opportunities:

1) Appropriate level of support from the Atmospheric Science department and the university may be harder to obtain than anticipated.

2) Contingency plans for the future operations of the center are not well developed. Institutional support for CSI must be defined. The role of the Dean's office and its relationship to the strategic plan of the College of Engineering should be solidified.

3) The broader scope of the CSI may bring this center in conflict with other groups involved in climate science.

4) Support for progress in diversity efforts (internship program, graduate fellowships) will need to be found through grants or institutional support.

5) Seek collaboration with US and international climate/weather groups for model development and future climate activities.

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