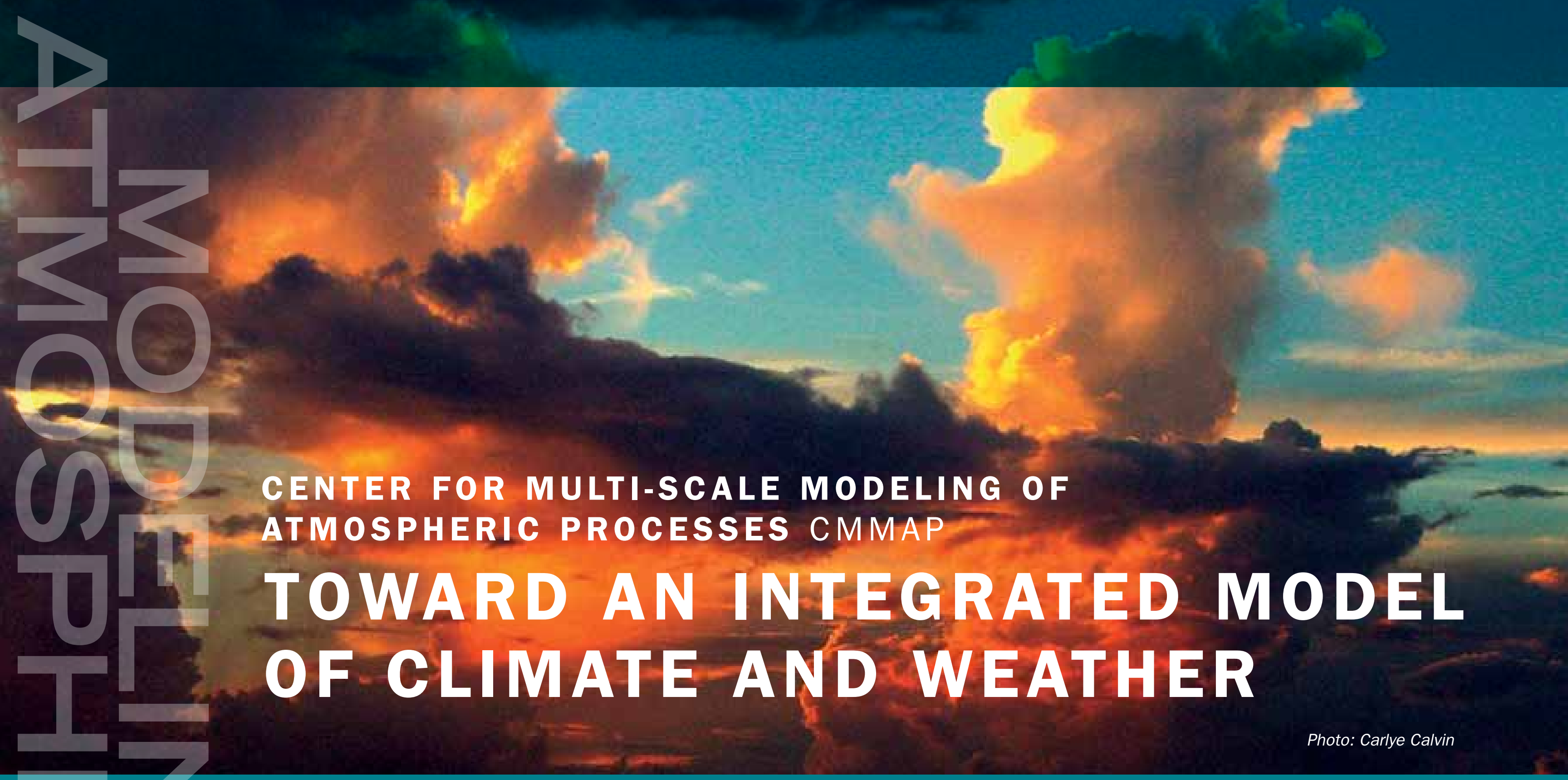


MODELING OF ATMOSPHERIC PROCESSES

CENTER FOR MULTI-SCALE MODELING OF ATMOSPHERIC PROCESSES CMMAP

TOWARD AN INTEGRATED MODEL OF CLIMATE AND WEATHER

Photo: Carlye Calvin

Critical mass can be defined as an amount necessary to have a significant effect or to achieve a result. For scientists in the field of atmospheric science and climate change, the creation of the Center for Multi-Scale Modeling of Atmospheric Processes (CMMAP) provides the critical mass needed to tackle fundamental problems that have remained mysteries for far too long.

CMMAP's research and knowledge-transfer goals are to improve climate and weather forecasting for scientists around the globe by building atmospheric models that will more accurately describe cloud processes than anything developed thus far.

Established in July 2006, and based at Colorado State University in Fort Collins, CMMAP is a partnership of nine degree-granting institutions and many additional collaborators. The center brings together scientists from a broad range of disciplines to work towards this common goal. In addition, like all STCs, its mission goes beyond research to include a range of education and diversity programs.

The center is undertaking work on many of the same atmospheric science topics that scientists have been targeting for years. What sets the center apart, however, is the scale at which they are able to tackle these issues. "We're using new mathematical methods to simulate in the computer the way the clouds interact with the global circulation of the atmosphere, relying on extremely powerful computers in a way that wasn't possible before," says center director David Randall. Today, many of the world's major modeling centers are moving quickly to develop such capabilities, he notes.

With enough computing power, center researchers are developing the ability to actually simulate individual clouds and atmospheric circulation. This critical mass in computing power and resources is allowing the center to tackle several phenomena that scientists have long sought to understand. The end results include improved understanding of important climate phenomena, such as the Asian Monsoon, a seasonal reversal of winds in the Northern Hemisphere.

Scientists go through multiple phases in their research, first developing a new model that will more accurately represent the atmospheric effects of interest and evaluating the model based on comparisons with actual observations, and then eventually applying the model to understand how clouds interact with global systems like oceans and land surfaces. Projects range from the macro to the micro scales: everything from observations of entire weather systems to the properties of individual ice crystals.

Until now, groups of research studying these phenomena have had trouble communicating because there weren't global models that took into account data sets from these different scales.

Historically, modeling has been done in roughly

AN INTERVIEW WITH CENTER DIRECTOR
David Randall

three levels of granularity, or resolution: global climate models, which operate on the scale of thousands of kilometers; cloud system resolving models, which represent processes between 1 and 500 km in scale; and large-eddy simulation models representing individual clouds on a scale between 10 m to 1 km. These distinctions in resolution are done for practical purposes and have little to do with the existence of actual differences in nature. Center researchers are trying to incorporate information from these different scales into one unifying model. □

Q: What should the public know about interdisciplinary centers?
NSF has struck a good balance between single principal investigator projects and the centers. Most NSF money goes to single-PI projects, but we need larger centers to attack the bigger problems.

CMMAP is a center, not a project, in part because it brings together scientists from a broad range of disciplines at dozens of institutions. The team includes climate modelers, cloud modelers, and experts on turbulence, radiation, cloud physics, and observations. In addition, like all STCs, its mission goes far beyond research. CMMAP devotes enormous amounts of time and energy to its education and diversity programs.

Q: How do you view the interaction between research and education in the center?
STCs are special because they aim to change a whole field of research, and because they provide an opportunity to combine research and education in creative and interesting ways. With the perspective that comes from almost four years of nurturing the center, we can see that CMMAP's education mission is highly complementary to its research and knowledge transfer missions. Our education activities make our research activities work better, and vice versa. The interdisciplinary collaborations within the Center allow us to accomplish more than either component could do separately.

Q: How did you get to this point in your career?
It's not what I expected. When I took my faculty position in 1988, I came from a job in NASA. I thought that I'd get my feet under me and I'd have three or four grad students and a postdoc and that would be my lifestyle. It turns out that's not my natural mode of operation, and I found that out as it happened. I apparently tend to naturally build these collaborations, these structures like the STC—it was a bit of self-discovery.

Q: What advice would you give to students in high school and college now about how to prepare themselves for careers in science or research in the future?
I think that people that want careers in the sciences need to understand how important it is to be able to communicate well, both in presentation and writing. It's very common for people to have good ideas but to be unable to communicate them.

From left to right: A. Scott Denning, director for education and diversity; David Randall, center director; and researcher Wayne Schubert.

Background photo: Carlye Calvin

Above: Little Shop of Physics director Brian Jones, a CMMAP education partner, and a group of students use a fish tank full of gelatin to demonstrate light scattering in the atmosphere and why the sky is blue. Jones is the 2011 recipient of the Robert A. Millikan Medal given by the American Association of Physics Teachers to recognize educators who have made notable and creative contributions to the teaching of physics.

Photo: University Corporation for Atmospheric Research

CMMAP EDUCATIONAL PROGRAMS REACH DIVERSE AUDIENCES

As CMMAP looks to improve education in climate science at all levels, CMMAP scientists and educators are also looking at fresh and novel ways to connect with a diverse range of students, teachers, and communities.

Broader education is very much a part of CMMAP's strategy. The center has the advantage of being situated at Colorado State University, where there is already an active educational outreach program called the Little Shop of Physics, directed by physics education guru Brian Jones, which provides hands-on experiments to K-12 students.

Because Little Shop of Physics (LSOP) involves undergraduate students at CSU, the effort delivers a double impact. "The undergraduates have lots of face time with the kids, learning about teaching and learning about working with schools," says CMMAP education and diversity director Scott Denning. "We're delivering the material, but we're also developing science educators."

Denning and Jones have developed a 2-credit course on Weather and Climate for Teachers that combines advanced undergraduate content with pedagogical innovation and a library of classroom inquiry modules to give teachers the tools they need to succeed. The course has so far been offered to 170 K-12 teachers over five summers, and is available as a "kit" including all science content, media, and inquiry activities at http://www.cmmap.org.

The CMMAP-LSOP team is forging new connections with Native American communities that are traditionally underrepresented in math and science fields. Each week of the academic year, the LSOP team of undergraduate interns and professional educators takes a van of hands-on instructional materials to schools. Over school breaks, the team makes extended trips to the Navajo, Southern Ute, Moutain Ute, Shoshoni, Arapaho and Lakota reservations.These trips are conducted in partnership with Colorado State University's Native American Cultural Center (NACC).

Scott Denning is in the forefront of this photo, where outreach participants "bounce" around like molecules inside a box.

CENTER RESEARCH SHEDS LIGHT ON THE ASIAN MONSOON

The Asian monsoon is a seasonal reversal of winds that brings copious rain to the densely populated regions of India and Southeast Asia during the northern hemisphere summer. Monsoon rain is characterized by a cycle of heavy rainfall interspersed with comparatively dry spells. The cycle repeats about every 30 to 50 days.

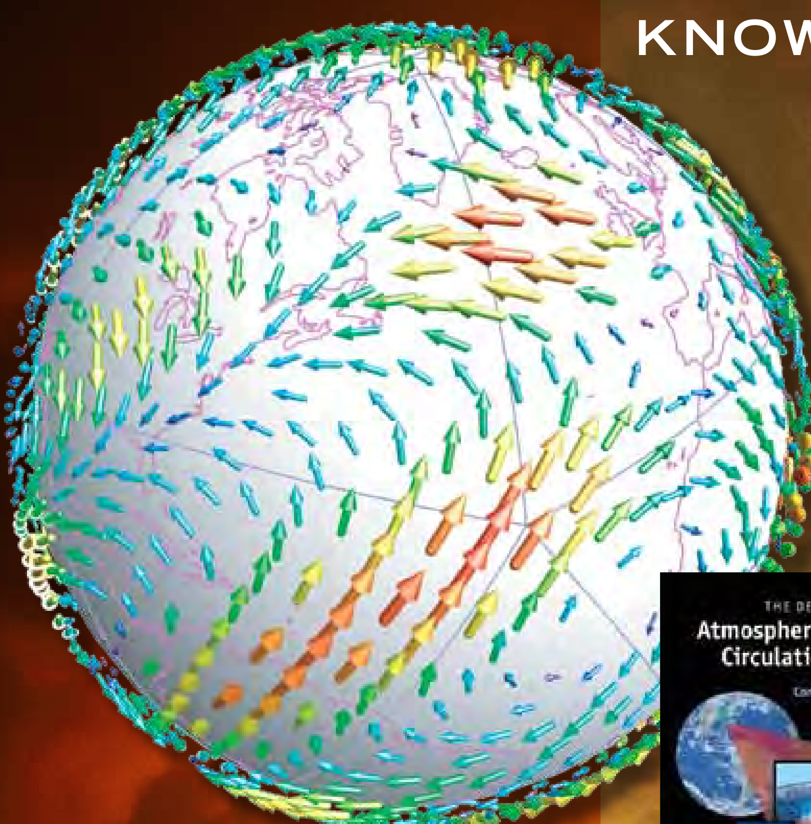
Despite recent advances in our understanding of what causes rainfall onset and dry periods, the simulation of the monsoon using atmospheric circulation models remains a challenge, notes Charlotte DeMott, CMMAP research scientist.

Most models can simulate the summertime average distribution of rainfall over India and Southeast Asia, but they struggle to simulate the wet-dry cycle of precipitation. In other words, monsoon rainfall in the models happens too frequently and too gently compared to the real world, where torrential rains fall for 1-2 weeks every 4-5 weeks.

"Scientists have understood for some time that the way models represent convection–that is, thunderstorms and other cloud types–is the likely culprit for the poor simulation of the monsoon," says DeMott. "These clouds are simply too small and evolve too fast for models to track them individually over the entire globe, even when the models are run on the world's fastest and biggest computers. Most models instead calculate the average effects of these clouds over areas of about the size of Connecticut, without modeling the clouds themselves."

CMMAP has developed a new way of representing convection. "Instead of trying to model all of the clouds everywhere and all of the time, we asked 'What if we just model some of the clouds everywhere and all of the time?'" says DeMott. "This is a job that modern super computers can handle. When we ran our model with these kinds of clouds, we found that simulated monsoon rainfall occurred with the expected wet-dry cycle. This type of model is now being tested to see if it can be used to improve forecasts of monsoon precipitation."

KNOWLEDGE TRANSFER



Sphere image: Ross Heikes

THE CMMAP LEGACY

CMMAP is working to disseminate information on a broader scale, beyond the formal education programs in place.

The Center's project to create a book, "The Development of Atmospheric General Circulation Models: Complexity, Synthesis, and Computation," is now completed, leaving an important legacy that documents the roots and evolution of the field of atmospheric science. Editing and final formatting were completed at the end in 2010 and the book was published by Cambridge University Press and made available to the public in January 2011. The Center acknowledges "the tremendous effort and attention to detail provided by Leo Donner that helped make this project a success."

And a journal launched by the Center in 2009 is now being published by the American Geophysical Union. Called the Journal of Advances in Modeling Earth Systems (JAMES), it is the first open-access journal to be published by AGU. Center Director David Randall, professor of atmospheric science at Colorado State University, continues as editor.