



# AOS & CICS Newsletter

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## Six-Year Southern Ocean Initiative Launched

Until now, the vast Southern Ocean encircling Antarctica has remained relatively mysterious to scientists due to the difficulty of obtaining observations from this remote part of the world. Now thanks to a six-year initiative that will advance understanding of the role of the Southern Ocean in climate change and biogeochemistry, some of the secrets of the Southern Ocean may finally be revealed.

The newly launched Southern Ocean Carbon and Climate Observations and Modeling program (SOCCOM) will be housed at Princeton under the Directorship of AOS Director Jorge Sarmiento. SOCCOM will draw on the strengths of teams of investigators from the University and 10 partner institutions, with support from the National Science Foundation's Division of Polar Programs and additional support from NOAA and NASA.



**SOCCOM**  
Southern Ocean Carbon and Climate Observations and Modeling

The program will apply new high-resolution Earth system models to study the Southern Ocean, and also greatly extend sparse observations in this region. Using an expanded computational capacity, and hundreds of robotic floats outfitted with biogeochemical sensors deployed around

Antarctica, scientists will be able to study multidimensional profiles of the ocean once impossible to obtain.

Why all this attention on the Southern Ocean? Studies show that although the Southern Ocean comprises only about 30% of the world's ocean area, it accounts for half the ocean's uptake of anthropogenic carbon from the atmosphere and the majority of its uptake of heat. Second, models indicate that upwelling in the Southern Ocean delivers nutrients to lower latitude surface waters that are critical to ocean ecosystems around the world. Third, the impacts of ocean acidification from rising CO<sub>2</sub> are projected to be most severe in the Southern Ocean, with ecosystem tipping points being reached in a few decades.

"There's a sense of urgency when it comes to global climate change and carbon chemistry changes like acidification of the ocean," Sarmiento said. "This is our opportunity to obtain vast amounts of data as never before."

SOCCOM's augmented biogeochemical versions of the nearly 4,000 Argo floats deployed worldwide to measure ocean salinity and temperature will provide almost continuous information related to the ocean's carbon, nutrient (nitrate, in particular) and oxygen content, both at the surface and deep beneath it. According to Sarmiento, these floats are revolutionary and will increase monthly data coming out of the Southern Ocean by 10 to 30 times. That data will be used to improve recently developed high-resolution, Earth system models that will heighten our understanding of the Southern Ocean and allow for better projections of Earth's climate and biogeochemical trajectory. The initiative itself marks the first large-scale deployment of these biogeochemical floats.

In addition to administering SOCCOM, Sarmiento and his Princeton colleagues

*Program in Atmospheric and Oceanic Sciences (AOS) & The Cooperative Institute for Climate Science (CICS)*

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TigerTransit/Shuttle Services  
Operating Schedule:

<http://www.princeton.edu/transportation/troutes/EoprestalFall2014.pdf>

will participate in the modeling component of the initiative, which is led by the University of Arizona and includes collaborators from the University of Miami. GFDL researchers will carry out high-resolution Earth system simulations in support of the modeling effort. The broader-impacts component of the program will communicate data and results freely to the public, as well as take a lead role in coordinated data management.

Senior researchers at the Monterey Bay Aquarium Research Institute, Oregon State University, Scripps Institution of Oceanography at the University of California-San Diego, the University of Arizona, the University of Miami, and the University of Washington will participate as co-investigators at the center. With the support of NASA, researchers from the University of Maine and Rutgers University will also lead a complementary project that will equip the floats with bio-optical sensors intended to gather data about biological processes in the water. In addition to GFDL's contribution, NOAA is providing funding for floats and support through its Pacific Marine Environmental Laboratory and Atlantic Oceanographic and Meteorological Laboratory. Climate Central, a non-profit journalism and research organization that promotes understanding of climate science, will lead SOCCOM's broader-impacts component out of their Princeton offices.

"SOCCOM will provide an unmatched collaborative opportunity to explore a region of the globe that has been up until this point largely under-explored," Sarmiento said. "It truly is an idea whose time has come." ■

## Student-Led Workshop Explores Interplay between Ice and Climate System

Most climate scientists agree that the cryosphere provides some of the most useful indicators of climate change, yet is one of the most under-sampled domains of the Earth System. With that in mind, the second annual AOS Program Workshop was held September 3-5, 2014 at GFDL with a focus on the role of the cryosphere

in climate science as understood through theory, observations, and models.

"The students chose to have a workshop on the cryosphere because our exposure to the topic has been somewhat limited in our coursework," said AOS Graduate Student Hannah Zanowski, a co-organizer of the workshop. "In light of the cryosphere's importance in the climate system, we wanted to obtain a more detailed knowledge of its processes and its interactions with climate, and thus 'Ice in the Climate System' was born."



*AOS graduate students attend the "Ice in the Climate System" Workshop panel discussion.*

The three-day, student-run workshop afforded many in the AOS community, students in particular, the opportunity to interact with experts outside of the University while providing a framework for stimulating thought and discussion surrounding the challenge of having the cryosphere adequately observed, understood, and represented in climate and Earth System models.

Rather than a broad overview, workshop sessions focused on key topics or questions taking advantage of the inter-disciplinary scientific background of workshop participants, according to AOS Graduate Student Jeffrey Strong, who co-organized the workshop with Zanowski and fellow students Junyi Chai and Anna FitzMaurice. The invited speakers each gave a plenary lecture, led tutorials on a specific aspect of the cryosphere, and participated in small group discussion sessions with graduate students and postdocs.

Wednesday's lecture, entitled "Sea level – Ice sheet interactions" was presented by Natalya Gomez (NYU) and focused on the physics of static sea-level changes and glacial isostatic adjustment following variations in the distribution of grounded ice. The influence of these changes on the

stability and dynamics of marine ice sheets was further discussed.

"New perspectives on the ocean's role in transient climate change" was the title of Kyle Armour's (MIT) talk on the second day of the workshop. It featured new perspectives on the fundamental and dynamic role of the ocean in setting the pace of global and regional climate changes and underscored the varying nature of Earth's effective climate sensitivity.

On the final day of the workshop, Valentina Radic (UBC) addressed the question "Modeling glacier mass balance and global scales: How precise can models be?" She reviewed some of the recent attempts to model glacier mass changes on regional and global scales, including the recently completed Randolph Glacier Inventory, and discussed the primary challenges these models face.

"The workshop was an excellent opportunity for AOS students to expand their knowledge of the frozen parts of the climate system, which are little discussed in the regular curriculum. I found the discussion of the connections between ice sheet change and solid earth geophysical phenomena particularly interesting," AOS Graduate Student Todd Mooring said.

Tutorials and small group discussions rounded out the talks and gave students and postdocs an overview of the speakers' subfields and results. They also provided an opportunity to share insights into future research directions. Beyond the formal events, the workshop afforded ample opportunities for casual interaction between the speakers and the participants over meals and breaks, including a barbeque outside of GFDL for students and faculty and dinner at the Triumph Brewing Company in Princeton.

"With such a broad range of research interests between AOS and GFDL, it can be quite a task to settle on a workshop topic that pleases everyone," Zanowski said. "Our hope was that inviting speakers that each studied a different aspect of the cryosphere--sea ice (Armour), ice sheets (Gomez), and glaciers (Radic) --we could pique the interest of as many people as possible without detracting from the overall structure and cohesiveness of the workshop. I think we did exactly that, and as a result the workshop was a great

success!”

The “Ice in the Climate System” workshop is a follow-up to the inaugural AOS Program workshop on “Using Diverse Observations in Climate Modeling Research” held in September of 2013. The workshop was made possible by the generous support of AOS Faculty Member and GFDL Senior Scientist Isaac Held, who was awarded the BBVA Foundation Frontiers of Knowledge Award in Climate Change in 2012. ■

## Majkut Selected as Congressional Geoscience Fellow

Former Graduate Student Joe Majkut was selected as the 2014-2015 William L. Fisher Congressional Geoscience Fellow by the American Geosciences Institute (AGI). He will spend the next year working on science policy issues with Senator Sheldon Whitehouse (D-RI), a strong advocate for addressing the challenges of a changing climate.



*Former AOS Graduate Student Joe Majkut*

In September, Majkut joined more than two dozen other scientists and engineers for an intensive orientation program on the legislative and executive branches, organized by the American Association for the Advancement of Science (AAAS), which also guides the placement process and provides educational and collegial programs for the fellows throughout the year.

According to the Institute, the fellowship provides geoscientists with a valuable opportunity to gain first-hand experience in the legislative process and to make real-

world contributions to the effective and timely use of geoscience information on issues relating to the environment, resources, natural hazards, and other federal policies. Majkut will be writing source material with the Senator’s communication team and working on corporate outreach programs. Throughout the year, he will be working on legislation to manage climate change.

Majkut, a member of the Sarmiento group, successfully defended his Ph.D. on variability and trends in the carbon cycle in August. He studied the ocean carbon cycle and how CO<sub>2</sub> emissions, and the associated warming, affect the ability of the natural carbon sinks to remove excess CO<sub>2</sub> from the atmosphere. As a PEI STEP fellow from 2011-2013, Majkut explored the policy dimensions of his research.

“Joe will be excellent at navigating one of science’s most crucial frontiers - the complex nexus between science and policy,” AOS Director Jorge Sarmiento said. “The experience garnered through the STEP fellowship he was awarded while at Princeton will surely be an asset in Washington.”

The American Geosciences Institute is a nonprofit federation of 50 geoscientific and professional associations that represents more than 250,000 geologists, geophysicists and other earth scientists. ■

## GFDL Hosts First Poster Expo

**Contributed by Maria Setzer, GFDL Communications Director**

GFDL recently hosted a unique event that showcased the breadth of research done by the broader GFDL community. The Poster Expo, held on July 16, 2014 drew dozens of current and former interns, students and researchers from GFDL and its partner institutions. Nearly half of the posters were presented by graduate students, post-doctoral researchers, and scientists from Princeton University. CICS and AOS were especially well represented, with 11 out of 30 posters.

Many of those in attendance saw it as a great opportunity to exchange ideas and explore possible collaborations. Jasmin John, a research scientist at GFDL and the lead organizer, noted “the collegiality and

networking on display during the event.” All of GFDL’s local partners – Princeton, Rutgers, UCAR Visiting Scientists -- were invited to present posters or attend the event. The expo brought together students or researchers who were presenting their research for the first time, with others who were experienced at presenting their research in a variety of formats and venues. Posters covered a wide range of topics, from ice microphysics to nitrate aerosols, and even included climate policy.

In addition to the 30 presenters, approximately 45 colleagues from the local community attended the event. Future Poster Expos are planned, with the next one likely taking place in the winter.



*AOS Postdoctoral Research Associate Nir BenMoshe explains his poster on spectral bin microphysics to GFDL Scientist Ron Stouffer.*

After the event, the organizers used a survey to elicit feedback, which will guide the planning for future events. Ms. John was joined on the organizing committee by Fanrong Zeng, Marian Westley, and Cathy Raphael.

More details, including a list of all the posters that were presented at the expo, can be found here:

<http://www.gfdl.noaa.gov/poster-expo>

## Student/Postdoc Retreat 2014

Bidding farewell to summer and welcoming the start of a new academic year, AOS graduate students, postdocs, and faculty came together for the Program’s third annual retreat on Thursday, September 11, 2014.

Held at Mountain Lakes House in Princeton, the retreat was organized by AOS students and faculty to provide a

forum for scientific discussions and social interactions between students, researchers, and faculty. The event also provided an opportunity for faculty, current students, and research staff to welcome new students.



*Retreat Committee Member Jeff Strong flanked by fellow AOS graduate students during a game of Kubb*

While upholding customary activities from previous years, like a morning ice-breaker session and interactive poster session highlighting faculty research, this year's committee also introduced the game of "Kubb" – a lawn game of Viking chess, and Jeopardy style trivia, related to the morning poster session, to foster a sense of community among attendees. A "science fair" session was also added to this year's agenda, featuring a set of four self-guided experiments that exemplify the broad range of research interests that fall under the umbrella of atmospheric and oceanic sciences.

"I liked the addition of the "science fair" to the AOS retreat this year - it was a good chance for us modelers to get out from behind our computers," Graduate Student Anna FitzMaurice said.



*AOS faculty, research staff, & students conduct an experiment with a tethered sonde.*

As in past years, an organizational committee comprised of graduate students and faculty members oversaw the planning and implementation of the retreat, including scientific and social activities. Committee members include AOS Graduate Students Rob Nazarian and Jeff Strong, and Faculty Members Stephan Fueglistaler and Steve Garner, who served on the committee every year since the inaugural event in 2012. AOS Graduate Secretary Anna Valerio lent administrative support to the committee members during the planning process.

"The annual AOS retreat has grown since its inception into a large and anticipated event to meet the incoming class and start the new academic year in a fun and informal setting," Strong said. "This year's iteration was another success with several events aimed at a more open and scientific occasion. Y'all will have to wait and see what we have in store for next year."

The 2014 retreat was well attended with approximately 40 people gathered on the grounds of the nature preserve for the day-long event. ■

## Jane Baldwin Selected for PECS Group



*AOS Graduate Student Jane Baldwin*

AOS Graduate Student Jane Baldwin is one of eight recently-selected students who will contribute their talents and climate and energy expertise to the current group of Princeton Energy and Climate Scholars (PECS) during the 2014-2015 academic year. She joins an outstanding group of former PECS scholars and AOS graduate students, including Ian Lloyd (2009-2011), Ilissa Ocko (2010), Joe Majkut (2011-

2013), Geeta Persad (2011-2013), and Spencer Hill (2012-2013).

Baldwin's research uses a combination of dynamical climate models and atmospheric observations to elucidate the ties between global and regional climate, and move towards useful predictions of climate change at regional levels. Inspired by previous study in China and interests in environmental policy and history, she is currently studying the extratropical arid regions that stretch across interior Asia. She hopes to improve understanding of the controls on this region's basic climate, as a prerequisite to examining its environmental change. Baldwin is advised by Gabe Vecchi, a lecturer in the Department of Geosciences and the AOS Program.

"I'm thrilled to be part of PECS starting this fall! It is a unique opportunity to connect with graduate students from related disciplines, and think deeply about the climate-energy-policy nexus," said Baldwin. "I look forward to broadening my horizons with this group of motivated young researchers."



PECS was founded in 2008 to encourage the interdisciplinary exchange of ideas on energy and climate change. It aims to provide a platform for Ph.D. students working on any aspect of energy and climate research to interact, collaborate, gain first hand understanding of research areas outside of their own discipline, and ultimately broaden their horizons both as scholars and as citizens.

The group is student-led, though a core group of faculty provides supervision and sponsorship. Included among the Faculty Board are AOS Assistant Professor Stephan Fueglistaler, AOS Senior Scientist Syukuro (Suki) Manabe, and AOS Assistant Professor David Medvigy. Students are selected through a competitive application process. Throughout the year, PECS fellows meet together and with representatives of the PECS faculty board to discuss dimensions of the climate and energy challenge. ■

## AOS & GEO Welcomes New Graduate Students

The AOS and GEO community welcomed incoming graduate students to campus during new student orientation programs held on Tuesday, September 9, 2014. The programs are designed to provide an introduction to graduate studies and life in Princeton's Geosciences Department and Program in Atmospheric and Oceanic Sciences.

Following breakfast in the Great Hall of Guyot Hall, Bess Ward, Chair, Department of Geosciences, GEO Director of Graduate Studies George Philander, and Isaac Held, AOS Director of Graduate Studies, led a joint morning welcome and introduction session. Before returning to the Forrestal Campus, seven new AOS students, along with their GEO counterparts, attended an Information Technology (IT) presentation, a session on web communications, and a facilities/lab safety overview by GEO staff. They were also introduced to Lewis Library and its many resources by Science and Technology Reference Librarian Louise Deis.

Once in Sayre Hall, the new AOS students heard a presentation by the AOS Graduate Work Committee, led by Held, and were subsequently introduced to the AOS administrative staff. Following a luncheon with faculty and current students, the new students went on a student-guided tour of GFDL and, upon returning to Sayre Hall, met with AOS Graduate Secretary Anna Valerio to go over Program-specific resources and procedures.

An orientation highlight included individual meetings with faculty advisors to discuss areas of possible mutual research interest. After meeting with advisors, V. Balaji, Head, Modeling Systems Group, AOS, provided an introduction to the GFDL modeling environment.

On Friday, September 12<sup>th</sup>, the students were invited back to Main Campus for a picnic dinner behind Guyot and Eno Halls. The Program extends a warm AOS welcome to its newest members: Chiung-Yin Jenny Chang, Xin Rong Chua, Spencer Clark, Michelle Frazer, Tsung-Lin Hsieh, Chin-Ho Justin Ng, and Sarah Schlunegger. ■

## AOS Graduate Students Lead Summer Course

For graduate students, summertime oftentimes means a slower pace of work, carving out larger blocks of time for research projects and papers, and a break from classes. This summer, however, AOS graduate students teamed up to informally "resurrect" AOS 577: Weather and Dynamics, a course that is currently no longer offered and was taught by Gabriel Ngar-Cheung Lau, a former lecturer with rank of professor in the AOS Program and lead scientist of the Climate Diagnostics Group at GFDL.

Following Lau's departure from the Program in 2013, many students, according to AOS Graduate Student Jeffrey Strong, "thought it necessary and fitting to share the knowledge learned in AOS 577" -- primarily how the atmosphere and the oceans systems work together to produce weather -- with the younger students who had not had the opportunity to take the course. The summer course also afforded upper-year graduate students the opportunity to gain valuable teaching experience.

The project, scheduled to last the length of the summer with one or two classes per week, was spearheaded by AOS Graduate Students Geeta Persad and Hannah Zanowski and covered the first half of the traditional course lectures. Instructors included AOS Graduate Students Kit-Yan Choi, Spencer Hill, Jaya Khanna, Todd Mooring, Geeta Persad, Jeffrey Strong, and Hannah Zanowski.

The experience culminated with Lau teaching the final lecture of the course during a summer visit to the Program. ■

## Q&A with David Crisp, Orbit Carbon Observatory-2 (OCO-2) Science Team Leader at NASA's Jet Propulsion Laboratory (JPL) and AOS Alum



*AOS Alum David Crisp*

When NASA launched its first mission dedicated to studying atmospheric carbon dioxide, the principal human-produced driver of climate change, from Vandenberg Air Force Base, California on July 2, 2014, one AOS alumnus breathed a long-awaited sigh of relief.

David Crisp, a senior research scientist at JPL who earned his Ph.D. from Princeton's Geophysical Fluid Dynamics Program in December of 1983, under the mentorship of Stephen Fels, is the Orbit Carbon Observatory-2 (OCO-2) Science Team Leader. After the launch vehicle malfunction of the original Orbit Carbon Observatory (OCO) mission and failure to reach orbit in 2009, Crisp, the principle investigator of the original mission, was instrumental in leading the effort to see the realization of a replacement mission. This new mission will have the accuracy, resolution, and coverage needed to provide the first complete picture of the geographic distribution and seasonal variations of both human and natural sources of carbon dioxide emissions and sinks on regional scales at monthly intervals.

In this Q&A, Crisp discusses the OCO-2 mission and the role AOS played in his career:

*Save the Date!*  
\*\*\*\*\*  
*2014 GEO/AOS  
Retreat  
Nov. 7<sup>th</sup> - Nov. 9<sup>th</sup>*

**After the launch failure of OCO, why was it so important to you to see the mission fly again?**

The short answer to your question is that we can only manage what we can measure. With fossil fuel combustion and other human activities now adding more than 40 billion tons of carbon dioxide to the atmosphere each year, the need to manage carbon dioxide emissions is more urgent than ever.

**Describe the day the spacecraft successfully launched.**

It was a long day. Because the launch window opened on July 1<sup>st</sup> at 2:56:44 AM Pacific Daylight Time (PDT; 5:56:44 Eastern Daylight Time), our day started on June 30. That day was filled with Project and Science Team meetings, pre-launch reviews, public briefings, and other public outreach activities to inform the over 900 guests who attended the launch. At 6 PM, I slipped away to get a couple of hours of sleep before I reported to my console.

At 10:30 PDT that evening, those of us on console in one of the control rooms reported to our posts and began reviewing the launch procedures, which were printed out in thick notebooks. I had to make a quick run across the Vandenberg Air Force Base just after midnight to do an interview for NASA TV. At 12:30 AM on July 1, the guests boarded their buses and headed to the launch viewing area. Soon after that, I dashed back across base to my console seat. We were carefully watching the weather forecast. The morning low clouds and fog had rolled in and there was a light drizzle, reducing the visibility of the launch site, but not raising any issues for the launch. Everything seemed to be going smoothly as the countdown proceeded through the final hour. Then, as we were going through the final minute of the countdown, at 46 seconds before liftoff, we heard the words over our headphones: "HOLD HOLD HOLD," and the launch was aborted. Apparently, a solenoid-operated valve that was supposed to activate the water flow for the launch pad noise suppression system had failed. The launch was scrubbed and the team quickly and methodically shut down and disarmed the launch vehicle. It was almost dawn before the decision was made to reschedule the launch the following morning. Some of us were disappointed, but I mostly felt

relief that the launch vehicle and spacecraft were safe, and ready for another try.

The 1<sup>st</sup> was another long day of meetings. On that evening, we followed the same schedule as before. The weather was just as foggy, and the drizzle had picked up slightly, but the weather board showed "green" for launch. This time, the launch countdown proceeded even more smoothly as we proceeded through the last minute, and then the last 10 seconds, (. 10.. 9.. 8.. 7.. 6.. 5.. 4.. 3.. 2.. 1..) and then Liftoff. I had the entire schedule memorized to the second, and counted off the seconds as the Delta-II's solid rocket boosters burned out and then were ejected. The first stage burned out and was dropped. The second stage ignited on schedule and a minute later, about 5 minutes after liftoff, the fairing ejected ... exactly as it was supposed to. The entire control room erupted in cheers and applause. We then got back to our procedures. As we reached our target altitude, the second stage engine cut off, and all was well. The spacecraft and upper stage then coasted for about 40 minutes before restarting the second stage for a quick correction burn. We were right on target. Shortly afterwards, the separation of the OCO-2 spacecraft from the launch vehicle was captured by a video camera installed on the launch vehicle. As it separated, another cheer rose from the control room. OCO-2 was finally on its way! Less than two minutes later, the solar panels deployed successfully, and we received the news that the spacecraft was "power positive." Another cheer arose, and I think that's when I finally started to breathe a little easier.

**What was your role in the mission?**

As the Principle Investigator of the original Orbiting Carbon Observatory mission, I was responsible to NASA Headquarters for all aspects of the mission, including its design, development, testing, and delivery for integration with the NASA supplied launch vehicle, all with a tight, cost-capped budget. I organized and led the team that proposed the mission to the NASA Earth System Science Pathfinder (ESSP) program. This program supports small "exploratory science" missions that address all areas of Earth Science. In the summer of 2000, a few months before the ESSP call was issued, we started the mission formulation process from the proverbial blank sheet of paper. About one year later, we submitted the "Step-1" proposal to the

ESSP program as one of 33 concepts submitted in response to the 2001 solicitation. In September of that year, the OCO proposal was one of the 4 proposals that were selected to proceed to a more detailed concept study, documented in a 450-page "Step-2" proposal. That proposal was submitted in February of 2002, followed by a site visit in May of that year. Later that year, OCO was selected as the primary mission of that ESSP opportunity, and we were off. That project was delayed repeatedly as NASA encountered budget shortfalls and our team encountered technical difficulties, but we eventually made it to the launch pad in February of 2009, only to have the launch vehicle malfunction and fail to reach orbit.

I then led the effort to organize the science community and find the resources needed to restart the OCO mission. After a 10-month effort, the White House directed NASA to build a "carbon copy" of OCO, which came to be known as OCO-2. However, unlike OCO, this was not a competitively-selected, Principal Investigator mission. It was now a "Directed Mission" like the larger NASA flagship missions, such as the Hubble Space Telescope, the Mars Rovers and the EOS platforms. These missions are assigned to a NASA center, and led by a "project manager" selected by that center. To maintain as much heritage with OCO as possible, NASA Headquarters assigned the mission to the Jet Propulsion Laboratory (JPL), and appointed Tom Livermore, the OCO project manager, to lead the mission. NASA HQ appointed me to serve as the "Science Team Leader" of OCO-2. In this capacity, I was responsible for leading the NASA selected science team for the mission. In addition, because I was involved in all aspects of the design and development of OCO, I served as a technical advisor to the project. I also continued to serve as the principal technical interface to the Japanese Greenhouse gases Observing SATellite (GOSAT) team.

Now that OCO-2 is in orbit, I look forward to returning to my role as a scientist. Within the next month, I will finally get to start addressing some of the questions that led us to propose this mission so many years ago.

## Why is this mission so important?

The Orbiting Carbon Observatory (OCO) was NASA's first mission designed specifically to measure atmospheric carbon dioxide with the accuracy, resolution, and coverage to locate and characterize the human activities and natural processes emitting this gas into the atmosphere (sources) and the natural processes (sinks) that absorb it at the surface.

While we were building OCO-2, carbon dioxide emissions from fossil fuel combustion and other human activities pushed its atmospheric concentration to levels beyond 400 parts per million, a level not seen since the Australopithecus Afarensis, Lucy, was walking across the African savanna. In spite of international efforts to control greenhouse gas emissions, such as the Kyoto Protocol, carbon dioxide emissions are now increasing at more than 2 percent per year, their fastest rate ever. Much of this increase is coming from the rapidly developing world, which is now responsible for about 60% of all carbon dioxide emitted by human activities.

So far, the natural sinks in the land biosphere and oceans have kept up with our increasing emissions and are continuing to absorb more than half of all the carbon dioxide emitted by human activities, reducing the buildup rate by 50%. In spite of their importance in reducing the rate of carbon dioxide buildup, the identity, location, and processes controlling these natural sinks are still poorly understood. Because of this, we don't know whether we can continue to depend on them in the future, as the climate changes. Will they continue to clean up half of our mess, or will they saturate and start giving it all back. We don't know.

The availability of data from the Japanese GOSAT has provided a great deal of new insight into the methods for estimating the atmospheric carbon dioxide concentration from space based measurements. However, like the ground based network, this satellite does not provide enough measurements to identify and quantify surface sources and sinks. The OCO-2 instrument will gather over a million measurements over the sunlit hemisphere each day, more than 96 times as many as GOSAT. We expect that at least 10% of these measurements will be sufficiently

cloud free return precise, full-column estimates of carbon dioxide. So, while we are a little late to the party, I still firmly believe that OCO-2 has quite a bit to offer both the science and policy communities.

## What role did the AOS Program play in your career/research interests (and this mission specifically - if any)?

I don't know where to begin. When I arrived at Princeton in the fall of 1979 to start my studies in what was then called the "Geophysical Fluid Dynamics Program," I was on an adventure whose outcome was far from certain. As it turned out, it may have been the biggest break in my life. I was a poor kid from government subsidized housing project in a Texas border town, called Brownsville. I held a degree in Education from Texas A&M University, where I was then working on my M.S. in Physics. I was creative, energetic, and inquisitive, and had published a few papers the field of planetary science as an undergraduate, but I had very little formal background in math and physics. I later learned that my primary advocate in the graduate student selection process was Stephen B. Fels, a man who held a B.S., M.S., and two Ph.D. degrees in Physics from Harvard. He must have seen some promise in me that was missed by others. Steve later became my thesis advisor, and I don't think I have ever met anyone who would have served better in that role. In any case, I was not going to let him down. I had held steady jobs since I was twelve, but I had never worked as hard as I did in the GFD Program at Princeton. I did not realize at the time that those work habits were on the job training. I still work 80+ hour weeks. Steve made sure that I filled the gaps in my physics and math training. More importantly, he gave me an unparalleled background in atmospheric radiative transfer that has served me throughout my career. The OCO instrument originated from a line-by-line radiative transfer simulation performed with a model that I designed to simulate radiative processes in the atmospheres of Venus, Earth, and Mars. Steve would have been proud.

## What's next for you?

The adventure continues. Now that the OCO-2 is in orbit, I look forward to addressing the questions that we built that satellite to explore. ■

## AOS & CICS Research in Action

*[This column is intended to focus on AOS & CICS research accomplishments and milestones, past, present, and future. In this issue, we highlight the accomplishments of AOS Associate Research Scholar Allison Smith who spent four years in the AOS Program.]*



*Former AOS Associate Research Scholar Allison Smith*

Allison Smith joined the AOS program as postdoctoral research associate in July, 2010 to work with Jorge Sarmiento and GFDL scientists, Charles Stock and John Dunne. Allison's educational background is in the biological sciences, and she wanted to know more about how IPCC-class climate models could be used for physiological and ecological studies. First, she needed to learn ocean biogeochemistry and physical oceanography so she spent her first several months attending classes taught by Sarmiento and former GFDL scientist, Anand Gnanadesikan, in the Princeton Geosciences Department.

The research Allison conducted while in the AOS program was focused on the mesopelagic zone, which is the depth range between ~150 m and 1500 m. The mesopelagic zone has importance for the global carbon cycle because a fraction, estimates range from ~10% to ~40%, of the organic carbon from the surface ocean is exported to the mesopelagic zone in sinking particles. The deeper the organic carbon is transported before being remineralized to CO<sub>2</sub> by heterotrophic microbes and zooplankton, the longer the CO<sub>2</sub> remains in the ocean because deeper water has slower ventilation rates. Slight shifts, 10's of meters, in the depth of remineralization has dramatic consequences for the air-sea balance of

CO<sub>2</sub>. Therefore, particles sinking from the surface ocean, although only a small fraction of the surface biomass, are a key process in the global carbon cycle.

Allison developed a microbial remineralization model to better understand the biological mechanisms controlling remineralization and improve predictions of remineralization length scales. The microbial remineralization model explicitly incorporates the interactions between sinking particles and heterotrophic bacteria. The first application of the model has been to determine the role of bacterial group behavior in particle remineralization. Major findings were: diffusion and advection caused rapid loss of hydrolysate and exoenzymes from particles; optimal exoenzyme production based on bacterial abundance consistent with quorum sensing behavior emerged as a property of the model; and bacterial uptake and retention of hydrolysate altered bacterial production and remineralization depths

Allison is also interested in the vertical distribution of zooplankton and fish that live in the mesopelagic zone. The habitat compression hypothesis predicts that in the future there will be decreases in the thickness of the water column with sufficient oxygen for resident and migrating organisms because increasing temperatures will increase water column stratification and decrease mixing which supplies oxygen to deeper depths. Predicting the effects of habitat compression on marine ecosystems requires understanding how organisms respond to hypoxia simultaneously with additional stressors associated with climate change including warmer temperatures and higher concentrations of carbon dioxide. Oxygen is delivered from the gills to tissues by a respiratory protein, hemoglobin or hemocyanin. The binding of oxygen to respiratory proteins is sensitive to both temperature and the presence of carbon dioxide so it is hypothesized to be a key physiological mechanism restricting the water column utilization by marine organisms living above hypoxic zones. In ongoing work, she is evaluating the earth system models from the Coupled Model Intercomparison Project Phase 5 (CMIP5) to determine where and when the binding of oxygen to respiratory proteins will be impacted by climate change. She also collaborated with former AOS graduate student, Daniele Bianchi, to look at global patterns of zooplankton migrations into the

mesopelagic zone using acoustic scattering data from shipboard acoustic doppler current profilers.

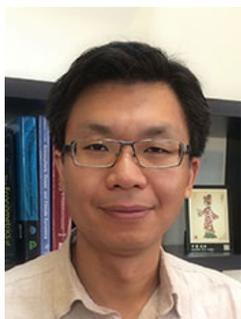
During her time in Princeton, Allison actively engaged in working with undergraduates. Allison mentored two Princeton undergraduates who did summer internship projects on zooplankton and salmon migrations. She also worked with a senior thesis student studying the geographic spread of two invasive fish species.

“For Allison, being a good scientist is synonymous with being a good mentor,” Sarmiento said. “She has an exceptional level of ability and expertise, and was incredibly generous with her time and energy when it came to working with undergraduates and participating in outreach events, particularly with young women; we miss her already.”

Allison recently moved to the University of Washington where she is conducting research in the eScience Institute and the School of Oceanography.

“CICS provided me with the opportunity to do interdisciplinary research under the mentorship of exceptional scientists. I was able to work on both model development and earth system model applications as part of my research projects which really helped my growth as scientist. In addition, I learned about the chemistry and physics of the ocean environment which expanded my research horizons. It was all very stimulating, and shifted my research in many new and exciting directions! I want to thank Jorge, Charlie, and John for their sage input and advice. I hope that there will be many opportunities for collaborations in the future.” ■

## AOS & CICS News



*Geosciences and AOS Lecturer  
Yi Ming*

Congratulations to AOS Faculty Member **Yi Ming** on being awarded the Henry G. Houghton Award, by The American Meteorological Society (AMS), for “major advances in the understanding and modeling of the role of atmospheric aerosols in the radiative forcing of regional and global climate.”

The Henry G. Houghton Award is given “to an individual in recognition of research achievement in the field of physical meteorology, including atmospheric chemistry. The award is given to promising young or early-career scientists who have demonstrated outstanding ability.”

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Congratulations to former AOS Faculty Member **Ngar-Cheung (Gabriel) Lau** on being selected as the AMS Bernhard Haurwitz Memorial Lecturer for 2015, for “pioneering work on atmospheric circulation systems, from oceanic storm tracks to atmospheric ‘bridges’ connecting ocean anomalies in different basins, using observations and global models.”



*Former AOS Lecturer &  
GFDL Scientist Gabriel Lau*

The Bernhard Haurwitz Memorial Lecturer is chosen “in recognition of significant contributions to the understanding of atmospheric and oceanic fluid dynamics, the circulation of the middle atmosphere, or the dynamics of climate.”

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Congratulations to AOS Faculty Member **Tom Delworth** for being elected an AMS Fellow. Fellows are selected each year for their “outstanding contributions to the atmospheric or related oceanic or hydrologic sciences or their applications during a substantial period of years.”



*AOS Faculty Member Tom  
Delworth*

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Congratulations to **Joe Majkut** who successfully defended his Ph.D. Thesis "Variability and Trends in the Carbon Cycle" on August 1, 2014. Joe has accepted an AGI Congressional Science Fellowship effective September 1st.

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Congratulations to **Sam Potter** who successfully defended his Ph.D. Thesis "Superrotation and Tropical Waves in Idealized Atmospheric Models" on August 15, 2014. Sam has accepted a postdoc position with the Joint Institute for the Study of the Atmosphere and Ocean at the University of Washington.

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### Fall Foliage Arriving Later, Lasting Longer

Climate change could postpone fall leaf peeping in some areas of the United States as summer temperatures linger later into the year, [Princeton University researchers report](#) in the journal *Global Ecology and Biogeography*. Trees need daily temperatures to be low enough and daylight hours to be short enough to produce the vivid vistas of fall, explained senior author AOS Faculty Member **David Medvigy**, an assistant professor of geosciences. He and first author **Su-Jong Jeong**, a former AOS postdoctoral associate now at NASA, found that daily temperature and daylight hours can not only be used to predict the timing of leaf coloration, but that the influence of these factors depends on the individual tree species and the specific geographic area. [full story](#)

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### Study Investigates Role of Aerosol Absorption in Driving Clear-Sky Solar Dimming over East Asia

The amount of solar radiation reaching the surface is a major driver of the surface energy balance and influences regional circulation and precipitation. Over East Asia, observations show a significant reduction in clear-sky surface solar radiation since the 1960s, colloquially referred to as "dimming," primarily caused by large regional increases in anthropogenic aerosol emissions. A recent paper, led by AOS Graduate Student **Geeta Persad**, constitutes a novel mechanistic investigation of the drivers of East Asian

clear-sky dimming that sheds light both on the nature of the observed dimming trends and on the behavior of the aerosol formulations in GFDL's models. **Yi Ming**, an AOS lecturer, and GFDL Director **V. Ramaswamy** are coauthors of the study published in the [Journal of Geophysical Research-Atmospheres](#).

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### New Study Examines the Influence of Asia's High-Mountain Seasonal Cycle on Regional Differences in Climate Change

A new study led by AOS Postdoctoral Research Fellow **Sarah Kapnick** compares a set of high-resolution models simulations with the latest available observations to focus on the distinct seasonal cycles and resulting climate change signatures of Asia's high-mountain ranges. The findings, published in [Nature Geoscience](#), suggest a meteorological mechanism for regional differences in the glacier response to climate warming.

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### Arrivals

The AOS Program extends a warm AOS welcome to our new graduate students: **Chiung-Yin Jenny Chang, Xin Rong Chua, Spencer Clark, Michelle Frazer, Tsung-Lin Hsieh, Ching Ho Justin Ng,** and **Sarah Schlunegger**.

**Roberta Hotinski**, the new SOCCOM (Southern Ocean Climate & Carbon Observations & Modeling Program) Project Manager arrived in early September. She will be responsible for the management and administrative functions of this newly launched program and facilitating its overall goals.

**Mei-Ling Tang**, a visiting student from the National Chung Hsing University, Taiwan, arrived in early September. She will be working with Isaac Held and Ben-Jei Tsuang, a visiting research scholar from the same institution, for the next eight months

**Jingyi Li** arrived in late August after receiving her Ph.D. from Texas A&M. She will be working with Jingqiu Mao and Larry Horowitz as a postdoctoral research associate.

**Ben Mater** arrived in mid-August from Colorado State. He will be working with Bob Hallberg and Sonya Legg as a postdoctoral research associate.

### Departures

Associate Research Scholar **Martin Jucker** accepted a postdoctoral associate position at the Courant Institute at New York. While at Princeton, Martin focused on stratospheric dynamics which allowed him to derive a simple yet powerful stratospheric setup for idealized atmospheric models. In addition, he developed software for three-dimensional visualization. He won first prize in the 2013 Art of Science competition with one of the visualizations resulting from this software. Martin left Princeton at the end of August.

Postdoctoral Research Associate **Kara Sulia** accepted a research faculty position at SUNY Albany at the end of August. Her research interests center on mixed-phase cloud layer parameterizations with a focus on ice microphysics. Kara employs Large-Eddy Simulations on both small (cloud) and large (global) scales to study the effect of ice habit growth on the evolution of these clouds.

In early September, Associate Research Oceanographer **Brendan Carter** accepted a position as a research associate with the Joint Institute for the Study of the Atmosphere and Ocean at the University of Washington. His research attempts to answer the following questions: "How does carbon cycle through the oceans?" and "How might we better constrain and decrease the uncertainties on our knowledge of the marine carbon cycle?" As co-chief scientist on a recent oceanographic cruise, Brendan played a lead role in what promises to be a major observational initiative that will give the scientific community unprecedented year-round coverage of biogeochemistry in the Southern Ocean.

**Philip Pika** returned to ETH Zurich in late August, after spending a few months in the Sarmiento group as an intern.

## Birth Announcements

Congratulations to AOS Collaborator **Thomas Frölicher**, a former AOS postdoc, and his wife, Tamara, on the birth of their daughter, Anja Emilia, on July 15, 2014.

Congratulations to former AOS Postdoctoral Research Associate **Rym Msadek** and her husband, David, on the birth of their daughter, Inès, on September 8, 2014.

Congratulations to AOS Postdoctoral Research Associate **Desiree Tommasi** and her husband, Carlos, on the birth of their twin boys, Felix and Lucas, on September 25, 2014.

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