GPC Newsletter

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APS TOPICAL GROUP ON THE PHYSICS OF CLIMATE

IN THIS ISSUE

Message from the Editor

We invite comments, event notices, letters, and especially specific suggestions for content. Any of the above, addressed to GPCnews@aps.org, will be gratefully acknowledged in a timely fashion.

Targeting the Known Unknowns in Climate Science, *Barbara Goss Levi*

Decades of work devoted to observing and simulating Earth's complex climate system have enabled researchers to define more clearly the factors that are key to achieving even greater understanding. Not only can researchers pinpoint areas requiring further study, but those studies are more likely to be productive, thanks to better data and tools.

In a recent *Nature Geoscience* paper, a group of atmospheric scientists led by Sandrine Bony of the Laboratoire de Météorologie Dynamique in Paris and Bjorn Stevens of the Max-Planck Institute for Meteorology in Hamburg, pose four questions about the role of clouds, which are known to have a large impact on the climate system. A better understanding of the interaction between clouds and circulation can yield large benefits in the ability to make more precise predictions of how much the global atmosphere might warm in response to a given increase in greenhouse gases (a quantity known as the climate sensitivity) and of how the regional patterns of rainfall and temperature might change. Currently, climate models that simulate Earth's response to a doubling of atmospheric carbon dioxide levels agree that the global temperature would rise, but the predicted long-term increases range from 1.5 – 4.5 K—quite a significant difference for policy makers who might want to plan for possible consequences of climate change or anticipate regional impacts.

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GPC-Organized Events at the APS March Meeting

The program for the 2016 APS March meeting, to be held March 14-18 in Baltimore, Maryland, will include several events of interest to GPC members. The GPC program committee has organized a "Climate Science Café," an invited session, and a focus session (cosponsored by GNSP and DFD). All invited speakers will be devoting part of their presentations to providing the audience with the broader context of, and background to, their research. Look for these events when the program details appear on the APS website this fall.

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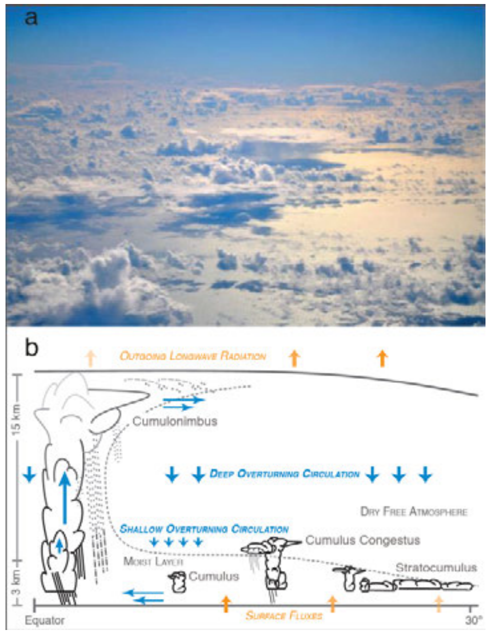
Targeting the Known Unknowns in Climate Science – *continued from p. 1*

To answer the four questions posed in *Nature Geoscience*, researchers will need to apply an understanding of processes at different length scales, from the mesoscale (as in convection and cloud formation) to the global (as in large-scale circulation patterns). Historically, these processes have been considered separately but Bony and her colleagues assert that current capabilities should now allow a merging of the two approaches. Already, the community has started to work together on these questions, in a continuing series of workshops, says Bjorn Stevens. "The field is ripe for an integrated approach," comments Paul Kushner of the University of Toronto, who was not involved in the *Nature Geoscience* paper. He adds that "our computational tools are now starting to capture the many scales of interactions in which clouds are involved: cloud cells are embedded in storm systems which are themselves drivers of circulation and temperature changes. There have also been great improvements in satellite-based measurements of cloud structure, and important advances in melding observations and simulation through data assimilation."

Grand challenges in climate science

The questions of clouds, circulation and climate sensitivity considered in the *Nature Geosciences* paper are the focus of one of six "Grand Challenges" that have been identified by the World Climate Research Program. (WCRP was started in 1980 by the International Council for Science and the World Meteorological Organization and is now also sponsored by the Intergovernmental Oceanic Commission of UNESCO.) The other Grand Challenges are: Changes to the Cryosphere, Climate Extremes, Regional Climate Information, Regional Sea-Level Rise and Water Availability. For each of these grand challenges, WCRP is promoting workshops, conferences and strategic planning meetings to identify high priority and exciting research questions, such as those that Bony, Stevens and colleagues have identified. (The list of grand challenges is evolving, with regional climate information soon to be replaced by a new challenge on d ecadal-climate predictability.

In addition to studying clouds and radiation, WCRP has other climate projects, such as those focusing on climatic roles of the cryosphere (CLiC), oceans (CLIVAR), and stratosphere (SPARC) and their interactions



Climate models are sensitive to the coupling of shallow convective clouds (a) to the larger-scale circulation, the vertical distribution of water vapor, surface turbulent fluxes and atmospheric radiation. As illustrated in (b), this coupling links regions of shallow convective clouds to remote areas of deep convection. Figure reprinted by permission from Macmillan Publishers Ltd: Nature Geoscience 8, 261, copyright (2015).

with other elements of the Earth system. Matching programs sponsored by US agencies (NOAA, NSF, NASA and DOE) such as the USGCRP and USCLIVAR collaborate with and complement these international programs.

Many members of the APS Topical Group on Physics of Climate are already involved in applying their physics training to Grand Challenge problems such as climate-related fluid mechanics and turbulence, thermodynamics across scales, data sciences and uncertainty quantification. For those physicists not yet involved in climate science, the *Nature Geosciences* paper puts forth some of the challenges and opportunities in climate science. As reported in *Nature*,[2] atmospheric scientists like Bony and Stevens would welcome more physics and math students to the discipline.

Physicists attending the March 2016 meeting of the American Physical Society in Baltimore can learn more about challenging research in climate by attending the Focus Session and the Invited Session being organized by the Group on the Physics of Climate. [See the story on p. 1 about GPC organized events at the March Meeting.]

Four questions

Understanding the role of clouds in the climate is complex, largely due to the many ways in which they modulate convective and radiative transfers within the environment.[4] Clouds can cool Earth by reflecting incoming sunlight or warm Earth by absorbing infrared radiation from the surface and reradiating it partially back to the surface. They can warm or cool the atmosphere as cloud droplets condense or evaporate and they can transport moisture, heat and momentum through convection. Bony and her colleagues point out that clouds are not merely tracers of circulation but that they are "increasingly understood to influence and shape the very circulations in which they are embedded."

What role does convection play in cloud feedbacks? That's the first question posed in the *Nature Geoscience* paper. In today's globally averaged climate, the cooling effect of clouds (albedo) dominates over the warming (greenhouse) effect. But how might that balance change in a warming climate? Much of the cooling stems from widespread low clouds. One might expect that greater evaporation from a warmer ocean would cause more clouds to form. On the other hand, some studies suggest that a warmer climate, especially in the tropics, will cause the boundary layer to deepen, so that convection might draw in more dry air from higher in the atmosphere, resulting in fewer clouds.[3] The large spread in predicted climate sensitivity stems largely from how different models parameterize this cloud feedback. Bony et al suggest testing various ideas by "suppressing or altering processes in comprehensive models in ways that are guided by results from observations or more fundamental models."

The second question asks: **What controls the position, strength and variability of storm tracks?** The focus of this question is on extratropical storms. Typically, storms organize and decay along localized regions known as "storm tracks." The storm tracks tend to be roughly aligned with the global jet streams (eastward, upper level wind currents). The interaction between the storm tracks and the jet streams can sometimes cause "blocking" events that reroute storms away from their normal tracks, causing unusual weather and contributing to annual temperature variability. It's important to know what, if any, external forcings control the storm tracks. For example, there is evidence that they are affected by meridional temperature gradients. Any change in such gradients stemming from a perturbed atmosphere would cause a shift in those storm tracks. Furthermore, the storm tracks might be affected by the clouds within them, for example, through radiative processes within the clouds. Bony and colleagues ask whether those radiative effects might alter the temperature gradients that gave rise to the storm tracks in the first place.

The third question is: **What controls the position, strength and variability of the tropical rain belts?** In the tropics, the rain tends to be concentrated in bands. Over the oceans, the Intertropical Convergence Zone contains some of the rainiest regions in the world, and these in turn are closely associated with the monsoons that bring fresh water to large populations. The position and intensity of the rain belts might be influenced by the clouds within them, especially because those high, dense clouds have large radiative effects. The position of the rain belts might also be coupled to circulations on the mesoscale or even planetary scale, so that any change in those circulations in turn affects the rain belts.

The final question asks: **What role does convective aggregation play in climate?** Researchers would like to understand better the factors affecting convective organization. There's some evidence that convection can self organize even in the absence of external drivers. Furthermore, the degree of self organization might increase with temperature. Hence, a convective aggregation could feed back on climate changes driven by other influences. These questions are important because of the possible role that aggregation plays in the dynamics of the climate system.

The *Nature Geosciences* paper does not discuss explicitly the role of aerosols in Earth's climate, although the authors acknowledge the importance of understanding more about its complex influence. Many aerosols, such as sulfate particles, reflect incoming sunlight and others, such as soot particles, can absorb it, all depending on factors such as size, composition and color. Moreover, aerosols can act as cloud condensation nuclei and thus impact cloud cover, which can increase both the planetary albedo and the absorption of outgoing long wave radiation. It would be interesting, Bony comments, to understand better how aerosols affect the tropical rain belts and the storm tracks through their impact (local and/or remote) on the atmospheric radiative heating and surface temperatures.

References

1. S. Bony et al, *Nature Geoscience* **8**, 261 (2015).
2. Q. Schiermeier, *Nature* **520**, 140 (2015).
3. S. C. Sherwood et at., *Nature* **505**, 37 (2014).
4. B. Stevens, S. Bony, "Water in the Atmosphere," *Physics Today* **66**, 29 (2013).

GPC-Organized Events at the APS March Meeting– *continued from p. 1*

Climate Science Café

GPC program chair Juan Restrepo of Oregon State University describes this evening café as an informal gathering of the session speakers and APS meeting attendees in an informal setting to discuss topics covered in the previous article on "Known Unknowns," their work, and answer further questions.

Invited Session: Climate Science Frontier: Cloud and Precipitation Physics

Clouds and precipitation are important to many process associated with weather and climate: Clouds affect the albedo in the radiation balance, the water and temperature fluxes of oceans, the thermodynamics of the atmosphere, and the chemistry and transport of the global carbon cycle. Moreover, the impact of clouds is high at virtually every dynamic scale. These complexities make their measurement, study and modeling essential to climate physics and a rich topic for interdisciplinary research and the application of advances in a multitude of disciplines within physics. The talks in this session, by Elisabeth Moyer (U. Chicago), David Romps (UC Berkeley), David Neelin (UCLA), Darryl Holm (Imperial College), Leo Donner (GFDL/Princeton), and Chris Bretherton (U. Washington) , will present current issues and challenges in cloud and precipitation physics. Whenever possible speakers in this session will be encouraged to enumerate potential collaborative opportunities. They will also be asked to contextualize their research and scientific methodologies when describing the findings and the significance of their research, within climate and weather dynamics.

Focus Session: Climate as a Non-Equilibrium and Stochastic System

Earth's climate system is driven far out of equilibrium by the flux of incoming shortwave solar radiation that is ultimately converted to longwave radiation flowing back out into space. The climate is also highly complex with many interacting subsystems (atmosphere, oceans, cryosphere, biosphere) and with non-linear dynamics operating over an enormous range of spatial and temporal scales. This Focus session will explore the non-equilibrium and stochastic statistical mechanics of the climate system. The talks, including invited presentations by Gregory Eyink (Johns Hopkins) and Valerio Lucarini (U. Hamburg), will explore how experimental, observational, computational, and theoretical physics can improve our understanding of the climate system.

Revised APS Climate Change Statement, *John Wettlaufer*

Every five years the APS formally reviews its statements. It was as part of that process that the APS Panel on Public Affairs (POPA) reviewed the 2007 APS statement on Climate Change along with the associated commentary of 2010. This process led POPA to revise the statement, and this past spring all APS Members were invited to comment on their draft.

The fact that the GPC is often conflated with POPA gives many of our members the impression that our organization was formally involved in the process of revising the statement on Climate Change. However, public affairs are outside of the GPC mandate, though our members, like all APS members, were welcomed to comment during the month long interval available to them. Hence, those with interests and expertise had a voice in the process and POPA engaged in a review of all the comments from the membership, which will be reviewed at the Council of Representatives meeting this November.

More details regarding the history and timeline of the process are available on the APS website http://www.aps.org/policy/statements/climate/.

Meanwhile, our program committee has been working diligently to put together an engaging scientific program—in collaboration with other APS groups—for the 2016 March Meeting and the November meeting of the Division of Fluid Dynamics, and hence GPC and POPA continue to play distinct roles.

Upcoming Events and Other Links of Interest

The American Geophysical Union (AGU) conference list, including the 2015 Fall Meeting (San Francisco, CA, Dec. 14-18), and the 2016 Ocean Sciences Meeting (New Orleans, LA, Feb. 21-26).

The American Meteorological Society (AMS) conference list.

68th Annual APS DFD Meeting, Boston, MA, Nov. 22-24, will include several cosponsored GPC events (sessions E31, H30, M29).

47th Annual APS DAMOP Meeting, Providence, RI, May 23-27, 2016, will likely include a GPC cosponsored session.

Mathematics of Planet Earth program, EPSRC-CDT, Imperial College London and University of Reading.

Dresden MPI climate physics meeting, July 16 - 22, 2017 at the Max Planck Institute for Complex Systems in Dresden, Germany. The workshop is part of a month-long seminar on "Climate Fluctuations and Non-Equilibrium Statistical Mechanics: An Interdisciplinary Dialogue". Organizers: Joachim Krug, Brad Marston, Jeff Weiss and Royce Zia.