MEETINGS

Exploring Planetary Atmospheres

AGU Chapman Conference: Crossing the Boundaries in Planetary Atmospheres—From Earth to Exoplanets; Annapolis, Maryland, 24–27 June 2013

PAGES 425–426

The past decade has been an exciting time to study atmospheres. Fundamental studies of Earth's general circulation and hydrological cycle have been stimulated by questions about past climates and the future impacts of humankind's activities. Long-term spacecraft and Earth-based observations of solar system planets have reinvigorated the study of comparative planetary climatology. The explosion in discoveries of planets outside our solar system has made atmospheric science integral to understanding the diversity of our solar system and the potential habitability of planets outside it. Thus, the AGU Chapman Conference: Crossing the Boundaries in Planetary Atmospheres—From Earth to Exoplanets, gathered Earth, solar system, and exoplanet scientists to share experiences, insights, and challenges from their individual disciplines and to discuss areas in which thinking broadly might enhance scientists' fundamental understanding of how atmospheres work.

An overarching topic of the conference was classification of planetary atmospheres, which requires insight into the physics that defines the boundaries between classes. The most basic boundary separates planets that can and cannot retain an atmosphere. Traditionally, this has been viewed in terms of escape velocity and thus planet mass and atmospheric composition. However, this alone cannot explain the moons Titan and Ganymede, one with a thick atmosphere and the other without one. Recent research described at the conference suggests that the difference may be the more energetic impacts to which Ganymede has been subjected, removing more volatiles than are delivered by impacts.

For a planet that retains an atmosphere, the planet mass, stellar flux, rotation rate, and composition influence the atmospheric structure and dynamics. For example, hydrogen abundance and carbon-oxygen ratio distinguish the chemistry of gas giants from rocky planets with oxygen-rich, carbon dioxide/carbon monoxide–rich, water-rich, or hydrocarbon-rich atmospheres, with planet mass and incident stellar flux controlling which regime exists. This has been the basis for historical estimates of the width of the habitable zone. The boundaries are defined in one-dimensional models as an inner edge constrained by erosion of the tropopause at warm temperatures, buildup of stratospheric water vapor, and subsequent water loss to space; and an outer edge limited by carbon dioxide condensation, clouds, and the maximum greenhouse effect of carbon dioxide and water. Recent research presented at the conference has explored the possible ameliorating climatic role of molecular hydrogen for exoplanets, early Earth, and early Mars. In our present solar system, molecular hydrogen plays this role on Titan.

Earth's atmosphere offers perspectives on other uncertain factors, including the climate forcing due to aerosol hazes and the climate sensitivity to cloud feedbacks. Anticipating the hazes and clouds on other planets is a major challenge; these are not well constrained even for the giant planets in our own solar system, where clouds have traditionally been predicted based solely on thermochemical equilibrium models. On Earth, however, clouds are regulated by and influence the general circulation, and cloud feedback depends on how these interactions respond to external forcing. Recent research presented at the conference suggests that cloud greenhouse warming might explain Earth's emergence from past ice-covered "snowball" states, while reflective dayside clouds on a tidally locked planet might make it habitable at higher stellar fluxes than previously assumed. Exoplanet thermal phase curves (emission versus time during a transit) obtained in the future will test this hypothesis.

Another lesson from Earth is the role of dynamical heat transports that mitigate climate extremes. This realization has led to the increasing use of general circulation models (GCMs) to study other worlds. Flexible GCMs described at the conference can simulate almost any solar system planet with an atmosphere and are being applied to exoplanets as well, both "hot Jupiters" and potentially Earth-like rocky exoplanets. However, theoretical studies are demonstrating the roles that parameters such as rotation rate play in the ability of an atmosphere to mitigate climate extremes, something not generally considered by astronomers.

In general, the conference discussions proved invaluable in breaking down boundaries between observers, who define the hierarchy of planets in terms of observables, and modelers, who view planets through the lens of physical processes. The conference concluded with next steps toward continuing this dialogue across funding barriers and with international cooperation. A website hosted by the Lunar and Planetary Institute (http://www.lpi.usra.edu/planetary_atmospheres) has been created with links to many of the talks, announcements of future relevant meetings, and a mailing list that readers are invited to join to facilitate further communication.

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