SA51B CC: 518 C Friday 0830h

General Circulation Models, Global Dynamics, Energetics, and Composition in Solar System Atmospheres II *(joint with P, SM)*

Presiding: **I Mueller-Wodarg,** Imperial College London**; G Crowley,** Southwest Research Institute

SA51B-01 0830h INVITED

On Striving to Simulate All Known Atmospheres Equally Well

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Creating a single general circulation model (GCM) that achieves both accuracy and impartiality for gas-giant and terrestrial atmospheres, and is implemented for all known atmospheres, is the primary development goal for the Explicit Planetary Isentropic-Coordinate (EPIC) atmospheric model. The idea is to make it easy to practice comparative planetology on the now more than one dozen atmospheres observed inside and outside the solar system, and—given that many parameterizations are needed to make GCMs work—to make it hard to fall into the trap of artificial tuning. Towards the goal of accuracy, we are using an isentropic vertical coordinate, which minimizes vertical truncation errors and increases the accuracy of long-range transport of chemical species and of moisture; interestingly, the latter yields better predictions than non-isentropic coordinate models even for non-isentropic storm activity, because the "fuel" is delivered more precisely. However, the isentropic-coordinate approach is not accurate at the bottom of either terrestrial or a gas-giant atmospheres, each for a different reason. For terrestrial atmospheres, isentropes tend to intersect topography at steep angles, causing technical headaches, and for gas giants, convection in their interiors renders entropy nearly constant and therefore not a viable coordinate. Enter the idea of a hybrid-isentropic vertical coordinate, which smoothly transitions into a pressure coordinate towards the bottom of the model. The hybrid idea provides both accuracy and impartiality because topography can be handled with a terrain-following pressure coordinate, traditionally called sigma, and a sigma coordinate works equally well for the deep atmospheres of gas giants, where the model's bottom layer may be chosen conveniently to be a constant-pressure surface. We describe the implementation of this idea in the EPIC model, including our definition of the hybrid coordinate, the calculation of the hybrid vertical velocity, and the calculation of potential temperature (the preferred isentropic variable in meteorology), all of which are new. In addition to core features like its coordinate system, the choices one makes in developing GCM components affect how well they can handle a variety of atmospheres. On the one hand, it is not obvious at this point that we know enough to develop a planetary boundary layer (PBL) model that is equally accurate for Venus, Mars, Earth, and Titan, not to mention Io, Triton, and Pluto. On the other hand, we arguably do know enough to achieve this goal for other subgrid-scale processes, most notably turbulence and cloud microphysics. As an example of the tenor of algorithm we seek, a new turbulence model for EPIC is under development based on the Detached Eddy Simulation (DES) approach, which, unlike the traditional Reynolds Averaged Navier-Stokes (RANS) or Large-Eddy Simulation (LES) approaches, is equally accurate for modeling both wall-bounded and inflow flows.

URL: http://www.louisville.edu/research/cpl/epic.html

SA51B-02 0850h

Insights from the Extended Canadian Middle Atmosphere Model on the Dynamics of the Terrestrial Mesosphere and Lower Thermosphere

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The extended Canadian Middle Atmosphere Model (CMAM) is a general circulation model extending from the ground to a height of 200 km. It is based on the standard CMAM model and includes the relevant physics for describing the neutral atmosphere up to these heights. A sponge layer is not needed at its upper boundary since molecular diffusion supplies the necessary dissipation to appropriately damp upward propagating waves. In its current form this model does not include ionospheric forcings and ion chemistry. It was developed primarily to allow dynamical signatures in the mesosphere and lower thermosphere to be diagnosed without interference from sponge layer effects. Results from this model show the large scale wave motions in the mesosphere and lower thermosphere to be significant with strong migrating, non-migrating and planetary wave signatures present during all seasons and at all latitudes. There is evidence of non-linear interactions between these various modes. The fields resulting from the superposition of these modes exhibit substantial latitudinal and longitudinal variability. This variability is large enough that the use of mean profiles in the calculation of energy and constituent budgets in the mesosphere and lower thermosphere must be undertaken with caution. It is likely that similar considerations hold for the analysis of these budgets for Mars and Venus.

SA51B-03 0905h INVITED

The Martian Atmosphere, Climate, and General Circulation Models

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Our understanding of the Martian atmosphere, and the embodiment of this understanding in GCM models, sits part way between that of the Earth's atmosphere and that of the other planets in the solar system. Compared to the Earth, it is incomplete even as it applies to certain basic, elementary components and it is studied by a very limited community. Compared to the other planets in the solar system, most elements of the circulation are understood in outline, the data sets are vast and rich, and a number of well-staffed, competing modeling groups exist. Given this "middle sibling" status of Martian atmospheric science, an obvious issue arises as to whom it should be compared: Is the paucity of our understanding compared to the Earth motivation for redoubled efforts, or advanced state of knowledge cause to refocus on other planetary bodies? In this presentation, I will review the components of the Martian circulation and the progress that has been made in their understanding through the synthesis of data with GCMs. I will also review the aspects of Martian climate that uniquely influence the atmosphere. These include the lofting of dust by large-scale winds and thermal convection, resulting in a permanent (if varying) dust haze that significantly increases atmospheric temperatures, and occasionally leading to the generation of global dust storms. The spontaneous generation of such storms in a GCM has only very recently been accomplished. The condensation of the major atmospheric constituent (CO_2) onto the surface to form massive seasonal ice caps in the frigid polar winter also generates a significant climate signal and a pole-to-pole condensation flow. Finally, Mars possesses an active water cycle with the development of clouds, formation of seasonal water ice deposits, and storage of water in the near-sub surface as adsorbate. The water cycle is fundamentally driven by exchange with a residual water ice cap at the northern (and not the southern) pole. Such asymmetries abound in the Martian atmosphere and climate system - some are tied to the planetary eccentricity and some to the difference in topographic elevation of the two hemispheres. Many significant questions remain open regarding how these climate system elements interoperate and how they might have changed the face of Mars as forcing, due to abundance of greenhouse gases or the pattern of insolation associated with particular obliquity or orbital parameter values, have changed.

SA51B-04 0925h

Global Modeling of Photochemistry, Diffusion and Ring Shadowing in Saturn's Ionosphere

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A time-dependent one-dimensional photochemical model of Saturn's ionosphere has been developed as an intermediate step towards a fully coupled Saturn-Thermosphere-Ionosphere-Model (STIM). A global circulation model (GCM) of the thermosphere provides the latitude and local time dependent neutral atmosphere. In the ionosphere, photochemical calculations are shown to be valid for most latitudes below 2000 km, while above diffusive processes dominate. In this context, comparisons are made with the terrestrial F2 and E ionospheric layers. Voyager UVS occultation data are adapted to model the UV optical depth radial profile of the rings. Shadowing from the rings leads to attenuation of solar flux, the magnitude and latitudinal structure of which depends on season. During solstice, the season for Cassini's encounter with Saturn, attenuation has a maximum of two orders of magnitude, causing a reduction in modeled electron densities over mid-latitude locations by as much as a factor of five.

SA51B-05 0940h INVITED

Responses by the Mars and Jupiter Upper Atmospheres to External Forcings : Contrasts from TGCM Simulations

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The long-term objective of our program in comparative planetary atmospheres is to contrast and compare the physical and chemical processes responsible for the observed structure and dynamics of the thermospheres of non-magnetic (e.g. Venus, Mars, Titan) versus magnetic (e.g. Earth, Jupiter, Saturn) planets or moons of our solar system. Fundamental planetary parameters for these bodies are sufficiently unique to provide independent "laboratories" to examine the changing roles of various thermospheric processes controlling their energetics, dynamics, and composition. The different responses by these upper atmospheres to external forcings from above and below (e.g. solar photon fluxes, auroral particle or Joule heating, upward propagating waves) are important to investigate. The application of 3-dimensional Thermospheric General Circulation Models (TGCMs) is crucial to understanding the relative importance of these forcing agents and coupling processes for each planetary body. Two planetary upper atmospheres are selected for comparison (Mars and Jupiter), since they represent extremes for which the impacts of a very weak (Mars) and very strong (Jupiter) intrinsic magnetic field are manifested in their upper atmospheric structure and dynamics. New TGCM simulations for Mars and Jupiter are presented and contrasted to one another and to recent spacecraft datasets (e.g. Mars Global Surveyor, Mars Odyssey, Galileo). Features such as the horizontal redistribution of light species, the global wind systems, vertical temperature profiles, radiative plus dynamical heat balances, and the temporal variability of these thermospheres will be discussed. Clearly, Jupiter's thermospheric structure and dynamics are expected to be dominated by its auroral and Joule heating processes at all times over the entire globe. By contrast, the Mars structure and dynamics are typically driven by solar EUV/UV processes with significant modification by upward propagating tides.