Geophysical Research Abstracts
Vol. 12, EGU2010-4953, 2010
EGU General Assembly 2010

A comparative analysis of Simplified General Circulation Models of Venus atmosphere

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With the successful Venus Express mission and future missions planned for Venus exploration in the near future, study of the Venus atmosphere has been rapidly expending in the last few years. The development of General Circulation Models (GCMs) has focused on helping researchers to understand the details of the superrotation mechanism and other interactions within this complex atmospheric system.

Several groups that have been developing such tools have joined together within the framework of a working group supported by the International Space Science Institute (ISSI, Berne, Switzerland), and have started to compare how the different models behave under the same forcing conditions. The goal of this intercomparison project is to test how robust the response of the different numerical models is to identical constraints.

Such a project has already been conducted recently at CalTech (Lee and Richardson, JGR in press, 2009) using three different dynamical cores within a common model frame, and we wanted to build upon this first study. We developed a common protocol and conducted many simulations of Venus atmospheric circulation with five additional GCMs, using different types of dynamical cores (spectral, finite differences or finite volumes). The baseline common parameters include resolution, initial conditions, planetary and atmospheric parameters as well as several physical parameterizations: thermal forcing, upper and lower boundary conditions. In this work, thermal forcing is reduced to a simple newtonian cooling parameterization with diurnally averaged conditions and no orbital variation of solar forcing.

Comparison among the models shows how the different models spin up, yielding different final states. Though all models do reach states with significantly positive superrotation, the amplitude and shape of the zonal wind fields is highly variable between different GCMs. We discuss the angular momentum transport mechanism, as well as the response of the different models to variations in key parameters (resolution, boundary conditions, the form of the temperature forcing function, ...).

Though this work is done using a simplified thermal forcing and therefore may not be fully representative of the real Venus atmosphere, it brings some guiding elements to the community on the degree of complexity and sensitivity of the GCMs currently developed for the Venus atmosphere. It also illustrates interesting differences between dynamical model cores of the type in common use in terrestrial GCMs under conditions which lead to small residual differences becoming highly significant.