EPSC Abstracts
Vol. 6, EPSC-DPS2011-1388, 2011
EPSC-DPS Joint Meeting 2011

A general circulation model for Jupiter's atmosphere

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Abstract

The mechanisms responsible for the formation and maintenance of the ubiquitous zonal jets on the giant planets, of which Jupiter's are the most spectacular example, are still poorly understood. Of particular interest is how energy is injected into the system at small scales. Well-established results in turbulence theory can be used to argue that such an energy injection combined with a planetary β-effect can lead to an inverse cascade of energy to large scales resulting in planetary-scale zonal jets. Observations of lightning on the giant planets suggest that moist convection might be the dominant process responsible [1].

These jets can be reproduced qualitatively using idealised models such as the 2D non-divergent equations on a sphere, and more recently using quasigeostrophic and simplified general circulation models (GCMs) that include a specific small-scale heat source [2, for example]. A GCM for giant planet atmospheres has been developed in Oxford over the last several years based on the dynamical core of the UK Met Office Unified Model. The basic weather model has been stripped down to the dynamical core and simple Jupiter-specific parametrisations of vertical diffusion, dry convection, radiation, cloud phase changes, and precipitation have been added, along with damping of the zonal velocity towards an observed latitudinal profile.

Earlier work applied this model to the troposphere and stratosphere of Jupiter over a limited area in latitude encompassing the south equatorial and temperate belts and the Great Red Spot [3]. We have extended the model to a global domain and are optimizing it for use on two supercomputing clusters available in Oxford. With these developments we are now in a position to include moist convection within the global model, using a scheme based on the concept of the atmosphere behaving as a heat engine [4]. In the model's current configuration jet structures do not form spontaneously when the zonal velocity damping is turned off. With moist convection as a source of small-scale energy injection into the atmosphere, however, and using the supercomputing cluster to resolve the flow at a higher resolution than Jupiter's deformation radius, we expect that jets should form spontaneously. We shall present our progress towards resolving the question of whether moist convection is sufficient to drive the formation and maintenance of jets in Jupiter's atmosphere.

Acknowledgements

We acknowledge support from the UK Science and Technology Facilities Council.

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