Jupiter's stratospheric dynamics and links with the troposphere

Dr.Roland Young, +97137136143, roland.young@uaeu.ac.ae

Description

This PhD project will study Jupiter's stratospheric general circulation and the links between its stratosphere and troposphere, extending an existing Jupiter General Circulation Model into the stratosphere and adding representations of gravity wave drag and stratospheric hazes.

Nearly fifty years on from the first spacecraft fly-by of Jupiter in 1973, many aspects of its atmosphere remain poorly understood. As NASA's *Juno* spacecraft unlocks the secrets of Jupiter's deep interior, and with future missions such as ESA's *JUICE* and potential missions to the ice giants in mind, the coming years will be crucial for our understanding of giant planet atmospheres. Jupiter and the other giant planets in our Solar System are archetypes for gaseous planets around other stars, and are some of the best natural examples of 2D turbulence on a rotating sphere. Important phenomena not yet fully understood about the giant planets include the energy sources for large scale circulation, moist convective processes, the relationship between flow on different scales, the vertical structure below the clouds and into the deep interior, the evolution of large-scale flow, the source of small-scale waves and equatorial stratospheric oscillations, Saturn's polar hexagon, the cyclones at Jupiter's poles, the distribution of lightning and ammonia, large storms, and the effects of impacts and other events.

Numerical simulations are key to further advances in these areas. They help test ideas in the absence of complete observations, identify the smallest set of processes that explain particular phenomena, and allow the effects of particular physical processes to be isolated. In recent years significant progress has been made simulating giant planet atmospheres using numerical simulations of varying complexity. The Jason GCM, based on the MITgcm and developed at the University of Oxford, simulates Jupiter's upper troposphere and lower stratosphere. It qualitatively reproduces several of the major features of Jupiter's weather layer, such as the banded jet structure, eastward equatorial jet, typical zonal jet speeds, and a variety of turbulent vortices.

This PhD project will extend the Jason GCM further into the stratosphere, to represent the important physical processes that occur at higher altitudes, to use the model to study these processes, and to study how they affect the general circulation. Important steps towards understanding the stratosphere will include:

- Extending the model's domain into the stratosphere, by reconfiguring the vertical grid and physical parametrizations for high altitudes.
- Adding a representation of Gravity Wave Drag (GWD) to the model. This represents how vertically-propagating waves break at an atmospheric critical layer. On Earth this drives the Quasi-Biennial Oscillation, and similar behaviour exists on Jupiter and

Saturn. We shall investigate this phenomenon and how it links the stratosphere and troposphere, running the GWD scheme at high vertical resolution.

- Studying Jovian stratospheric haze, which affects the radiative balance of the stratosphere. The model has a cloud scheme which the haze can be added to.
- Mapping 3D stratospheric winds and potential vorticity by combining Cassini cloud-level winds with Cassini CIRS temperature measurements.

This project will suit a keen theoretical/computational person who is excited about using state-of-the-art numerical simulations and recent spacecraft observations of the giant planets. There may be opportunities for collaboration with colleagues in the UK, France, and the USA.

Recommended reading

A. R. Vasavada & A. P. Showman (2005), "Jovian atmospheric dynamics: an update after Galileo and Cassini", *Rep. Prog. Phys.*, 68, 1935-1996, 10.1088/0034-4885/68/8/R06.

R. M. B. Young et al. (2019) "Simulating Jupiter's weather layer. Part I: Jet spin-up in a dry atmosphere", *Icarus*, 326, 225-252, 10.1016/j.icarus.2018.12.005.

S. Guerlet et al. (2018), "Equatorial Oscillation and Planetary Wave Activity in Saturn's Stratosphere Through the Cassini Epoch", *J. Geophys. Res. - Planets*, 123, 246-261, 10.1002/2017JE005419.

R. Cosentino et al. (2017), "New Observations and Modeling of Jupiter's Quasi-Quadrennial Oscillation", *J. Geophys. Res. - Planets*, 122, 2719-2744, 10.1002/2017JE005342.

Candidate Profile

Masters in Physics, Mathematics, or similar.

A good grade in advanced calculus is essential. A candidate who has taken courses in atmospheric physics, fluid dynamics, or computational physics will be particularly attractive.

An aptitude for computer programming is essential, and experience would be highly beneficial. Any experience with Fortran will be looked upon very favourably.