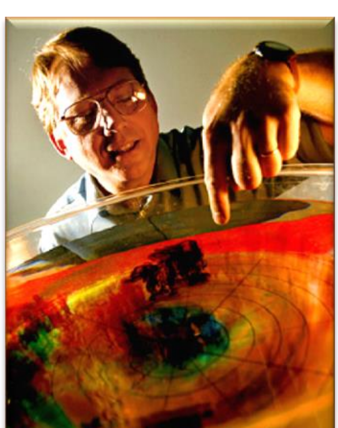
Physics & Space Sciences Department Colloquium

The Mars Global MACDA Atmospheric Reanalysis: Vorticity-Streamfunction Comparisons with Earth, Jupiter and Saturn

It is common in physics to keep experiment and theory as separate as possible, but in meteorology the practice is to use general circulation models (GCMs) to interpolate between observation points to produce a *reanalysis*, which has lower errors than either the observations or the model. This has recently been achieved for Mars by assimilating nadir soundings from the NASA Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES) into the UK version of the Laboratoire de Meteorologie Dynamique (LMD) Mars GCM. The result is the Mars Analysis Correction Data Assimilation (MACDA) reanalysis, which provides horizontal winds, temperatures and pressures for 3 Mars years (MY 24.39 to 27.24; 1 MY ~ 23 Earth months), on a 5x5-deg grid, from the surface to ~ 80 km altitude, every 2 hours (1 Mars day = 1 sol ~ 1 Earth day + 40 min). This talk summarizes recent results and comparative planetology using this MACDA reanalysis. Large-scale dynamics, including shear stability, is governed by vorticity waves (Rossby waves), whose intrinsic phase speed (engineering: celerity) is proportional to the gradient of the potential vorticity (PV; astrophysics: vortensity), a fluid-dynamical variable obtained from an all-in-one combination of momentum, mass and energy conservation. We use scatter plots of PV vs. streamfunction to characterize the dynamics, the slope of which is related to the analogue of the Mach number for vorticity waves, “Ma”. Because vorticity waves are uni-directional, “Ma” is a signed quantity, positive when the intrinsic phase speed is upwind and negative when it is downwind. A key result is from this dynamical point of view, the atmosphere of Mars lines up in detail with Earth’s lower mesosphere.

We now have evidence, in order of discovery, from Jupiter, Saturn, Earth and Mars, that the PV field tends to evolve towards “Ma” -> 1 or equivalently towards 1/“Ma” -> 1, which we refer to as “PV choking”, in analogy to the phenomenon of sonic choking at the constriction of a converging-diverging rocket nozzle. This is in contrast to the widespread idea of “PV mixing”, 1/“Ma” -> 0, which arises from the mathematically more tractable “Ma” < 0 branch of the theory, and includes the textbook shear-stability theorems of Rayleigh, Kuo, Charney-Stern and Fjortoft. By thinking in terms of “supersonic” flow, “Ma” > 1, which is stable via Arnol’d’s 2nd shear-stability theorem, we make the novel physical argument that the shock of vorticity waves in shear is the on-off switch of shear instability itself. Given the mathematical analogies between rotating fluid flow and magnetized plasmas, this line of thinking has implications for the control of zonal (poloidal) flow in fusion reactors.



Dr. Timothy Dowling
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Friday, April 28, 2017
4:00-5:00 P.M.
OPS Room 140

Light refreshments will be served