Atmospheric super-rotation in solar system and extra-solar planetary atmospheres

Conference or Workshop Item

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Super-rotation is a common phenomenon in solar system planetary atmospheres. Out of the four substantial atmospheres possessed by solid bodies in the solar system, the slowly rotating planet, Venus, and moon, Titan, are both well-known to have atmospheres that rotate on average substantially more quickly than does the solid surface underneath. The more rapidly rotating planets, Mars and Earth, have much weaker global super-rotation, but both can exhibit time-varying prograde jets near the equator which rotate more rapidly than the local surface. Atmospheric super-rotation is not restricted to planets with solid surfaces and shallow atmospheres. Cloud-tracking observations of the gas giants Jupiter and Saturn show that they both possess rapid prograde equatorial jets and hence exhibit local super-rotation.

Simplified global circulation models of extra-solar planets, including representations of ‘hot Jupiters’ and Earth-like planets rotating at different rates, can also show sustained super-rotating equatorial jets in different dynamical regimes. In the extra-solar planet cases in particular, the quantitative results are highly sensitive to model parameters.

In each case the detailed mechanism, or combination of mechanisms, which produces the super-rotating jets might vary, but all require longitudinally asymmetric motions, waves or eddies, to transport angular momentum up-gradient into the jets. The mechanism is not always easy to diagnose from observations and requires careful modelling. We review both observations of solar system planets and recent global circulation model results, combined in the case of Mars and Earth in the form of atmospheric reanalyses by data assimilation, together with simplified extra-solar planet simulations.