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Turbulent kinetic energy spectra and cascades in the polar atmosphere of Saturn

Peter L. Read[1], Arrate Antuñano[2], Simon Cabanes[3], Greg Colyer[1], Teresa del Rio-Gaztelurrutia[4], and Agustin Sánchez-Lavega[4]
[1]Atmospheric, Oceanic & Planetary Physics, University of Oxford, Oxford, UK
[2]Department of Physics & Astronomy, University of Leicester, Leicester, UK
[3]DICEA, Sapienza Universita di Roma, Italy
[4]Departamento de Física Aplicada I, E.T.S. Ingeniería, Universidad del País Vasco, Bilbao, Spain

The regions of Saturn's cloud-covered atmosphere polewards of 60^{o} latitude are dominated in each hemisphere near the cloud tops by an intense, cyclonic polar vortex surrounded by a strong, high latitude eastward zonal jet. In the north, this high latitude jet takes the form of a remarkably regular zonal wavenumber m=6 hexagonal pattern that has been present at least since the Voyager spacecraft encounters with Saturn in 1980-81, and probably much longer. The origin of this feature, and the absence of a similar feature in the south, has remained poorly understood since its discovery. In this work, we present some new analyses of horizontal wind measurements at Saturn's cloud tops polewards of 60 degrees in both the northern and southern hemispheres, previously published by Antuñano et al. (2015) using images from the Cassini mission, in which we compute kinetic energy spectra and the transfer rates of kinetic energy (KE) and enstrophy between different scales. 2D KE spectra are consistent with a zonostrophic regime, with a steep (~n^{-5}) spectrum for the mean zonal flow (n is the total wavenumber) and a shallower Kolmogorov-like KE spectrum (~$n^{-5/3}$) for the residual (eddy) flow, much as previously found for Jupiter's atmosphere (Galperin et al. 2014; Young & Read 2017). Three different methods are used to compute the energy and enstrophy transfers, (a) as latitude-dependent zonal spectral fluxes, (b) as latitude-dependent structure functions and (c) as spatially filtered energy fluxes. The results of all three methods are largely in agreement in indicating a direct (forward) enstrophy cascade across most scales, averaged across the whole domain, an inverse kinetic energy cascade to large scales and a weak direct KE cascade at the smallest scales. The pattern of transfers has a more complex dependence on latitude, however. But it is clear that the m=6 North Polar Hexagon (NPH) wave was transferring KE into its zonal jet at 78^{o} N (planetographic) at a rate of $\prod_E \approx 1.8 \times 10^{-4}$ W kg^{-1} at the time the Cassini images were acquired. This implies that the NPH was not maintained by a barotropic instability at this time, but may have been driven via a baroclinic instability or possibly from deep convection. Further implications of these results will be discussed.

References

Antuñano, A., T. del Río-Gaztelurrutia, A. Sánchez-Lavega, and R. Hueso (2015), Dynamics of Saturn's polar regions, J. Geophys. Res. Planets, 120, 155–176, doi:10.1002/2014JE004709.

Galperin, B., R. M.B. Young, S. Sukoriansky, N. Dikovskaya, P. L. Read, A. J. Lancaster & D. Armstrong (2014) Cassini observations reveal a regime of zonostrophic macroturbulence on Jupiter, Icarus, 229, 295–320.doi: 10.1016/j.icarus.2013.08.030

Young, R. M. B. & Read, P. L. (2017) Forward and inverse kinetic energy cascades in Jupiter's turbulent weather layer, Nature Phys., 13, 1135-1140. Doi:10.1038/NPHYS4227