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Jets and macroturbulent “cascades" in atmospheres, oceans and the laboratory (Lewis Fry Richardson Medal Lecture)

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The banded organization of clouds associated with intense zonal (east-west) jet streams and large-scale oval vortices on Jupiter and Saturn have long fascinated astronomers and atmospheric dynamicists for many years. The current view is that these features are a manifestation of strongly anisotropic energy transfers within a highly turbulent fluid on a rapidly rotating, spherical planet that is energised at relatively small scales, either by free convection or baroclinic instabilities. The details are still not fully understood, however. Energy exchanges in the Earth’s atmosphere and oceans, and on other planets, are similarly complex, with evidence of both upscale and downscale transfers and formation of zonal jet-like features. In this lecture we will explore insights from laboratory experiments on both small scales and on the Coriolis platform in Grenoble, France that investigate plausible physical analogues of such atmospheric or oceanic circulations, energized mainly by free thermal convection with strong background rotation. Weak, eddy-driven jets may be obtained through anisotropic energy exchanges, though (for reasons to be discussed) it is not possible to match Jupiter’s parameter regime very closely in the laboratory. We will compare the dynamics and energetics of our laboratory experiment with new measurements of energy exchanges, spectra and structure functions in Jupiter’s atmosphere from analysis of Cassini spacecraft images, which indicate some new directions for models of gas giant atmospheric circulations.