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Observations of convection in the giant planets: results from space missions

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Abstract. The giant planets are fluid objects; their solid cores occupy much less than half of their volumes. The largest planet, Jupiter, is over ten times the size of Earth. The giant planet atmospheres are powered in roughly equal parts by sunlight and by internal heat, which is left over from planetary formation. In most cases, the winds are measured by tracking clouds relative to the internal magnetic fields. Saturn is the exception, since the internal field is axisymmetric and therefore provides no evidence of rotation. In all four giant planets, the winds blow mainly in the east-west (zonal) direction, and the coloured cloud bands are aligned with the winds. The patterns are organized by rotation and not by the energy sources, since the sun at zenith moves from one pole to the other during the course of a year on Uranus, and yet the winds do not change. Although the power per unit area - the sum of absorbed sunlight and internal heat - is 20 times greater at Jupiter than at Neptune, the winds at Neptune are stronger. In fact Jupiter has the weakest winds of all the giant planets, although it is closest to the sun. Besides the zonal winds, the giant planets have long-lived vortices that have the same sign of vorticity as the latitude bands in which they sit. These large vortices exhibit a variety of behaviours, including oscillation in shape, position, and orientation, merging and splitting, and filament ejection. The anticyclones have a compact, oval shape; the cyclones are more elongated and diffuse. The cyclones contain lightning, which is a sign of moist convection. The cyclones therefore have a more disturbed appearance, since the convective storms are vigorous and chaotic. The convective storms are more frequent on Jupiter, but they are apparently more energetic on Saturn. The convective storms maintain a Reynolds stress that pumps momentum into the zonal jets in what is known as an inverse energy cascade. The depth to which the zonal winds extend is largely unknown. The winds could be confined to the outer 1 percent of the planets radii, or they could extend down into the fluid interiors, where the electrical conductivity and magnetic field become important.