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Jupiter's atmospheric circulation

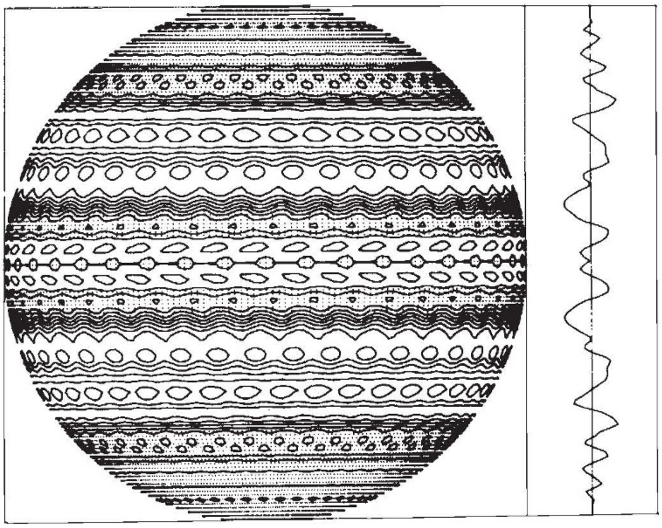
By numerical integration of conventional meteorological equations at appropriate parameter values we have been able to reproduce most of the major characteristics of the Jovian atmosphere.

The axisymmetry and scale of the bands, the oval-shaped disturbances, the waves and the Great Red Spot are all essentially characteristics of turbulent barotropic vorticity exchanges in a rapidly rotating planetary atmosphere. They are produced by the interaction in a spherical domain of a two-dimensional (horizontal) turbulent cascade and Rossby wave propagation, a process that we shall refer to as global turbulence. This interaction occurs at a length scale $L_\beta = \pi(2u/\beta)^{1/2}$, where u is a measure of the zonal velocity and β is the northward gradient of the Coriolis force, that closely matches the observed size of the bands. This hypothesis has been verified by solutions obtained for a stochastically forced barotropic equation, see for example Fig. 1.

The complete Jovian thermodynamical system can be reasonably well reproduced by using a standard (that is, Phillips's) terrestrial general circulation model under Jovian parameter conditions (see Fig. 2, for example). Apart from the characteristic banded structure the solutions also reveal the existence of an intra-jet circulation or gyre in which the flow resembles that surrounding the Great Red Spot. The planet also seems to have a heat transfer (index) cycle with a 4 to 5-yr period that accounts for long term variability. Clouds are produced by vertical circulation cells induced by frictional Ekman pumping.

Our theoretical flows suggest that the Great Red Spot can be thought of as essentially the core of an intra-jet circulation or as an eddy of global turbulence (as defined above). Like the ovals, the Great Red Spot plays an important role in the energy cascade that maintains the multiple zonal currents. The persistence of the Great Red Spot is due to the fact that (1) energy cascades toward larger scales in two-dimentional turbulence and (2) under the appropriate conditions large intra-jet circulations such as that forming the Great Red Spot are an integral part of this type of multiple-jet global circulation.

Fig. 1 An example of simulated Jovian turbulence. Sphere contains stream function contours with negative values shaded by 1/4 of grid points. Profile of longitudinally averaged zonal flow has a scale of 100 m s^{-1} in right-hand side diagram. State is transient and early in atmospheric evolution to final form. Although more orderly than final state it illustrates basic elements more clearly. A cine film of this solution is available on request.



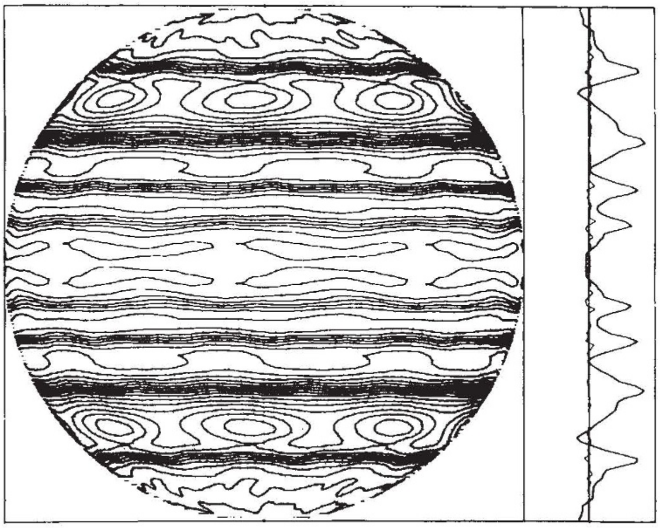


Fig. 2 The global circulation as given by a terrestrial general circulation model integrated in the Jovian parameter range. Calculations were made over a limited sector and repeated for global display. Model is not valid at the equator.

Thus Jupiter's atmosphere seems to have the same dynamical ingredients as the terrestrial atmosphere and ocean. The processes occur on different scales, however, and act in different proportions. As in the terrestrial and Martian systems, baroclinic instability again seems to be the primary energy conversion process. A complete description of the meteorology of Jupiter and Saturn has been submitted for publication elsewhere.

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Noble gases in an Hawaiian xenolith

The noble gas record in meteorites and lunar samples has been the subject of many investigations aimed at determining their age, the history of their exposure to cosmic rays and to the solar wind, and the early chronology of events in the Solar System (see review in ref. 1). Information on the latter is contained primarily in the isotopes of xenon, where the decay products of extinct ^{129}I and ^{244}Pu provide a record of the synthesis of elements and the early history of planetary solids (see review in ref. 2). The occurrence of radiogenic xenon in CO$_2$ well gas from Harding County, New Mexico is the only clear evidence that extinct radioactivities were present in the early history of the Earth[3,4], but the suggestion that this radiogenic xenon had been brought near the Earth's surface in hot magmas was not confirmed by recent analyses of xenon in lava rock from this region[5].

The present investigation of noble gases in a volcanic xenolith containing high-purity inclusions of liquid CO$_2$ was undertaken to see if radiogenic xenon might be associated with