INVESTIGATION OF LONG-LIVED EDDIES ON JUPITER

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Quasi-geostrophic, two layer models of the Jovian atmosphere are under development; these may be used to simulate eddy phemonena in the atmosphere and include tracer dynamics explicitly. The models permit the investigation of the dynamics of quasi-geostrophic eddies under more controlled conditions than are possible in the laboratory. (See the presentation by Read at this conference.) They can also be used to predict the distribution and behavior of tracer species, and hence to discriminate between different models of the mechanisms forcing the eddies, provided suitable observations can be obtained. At the same time, observational strategies are being developed for the Near Infrared Mapping Spectrometer on the Galileo Orbiter, with the objective of obtaining composition measurements for comparison with the models. Maps of features at thermal infrared wavelengths near 5 μm, and reflected sunlight maps as a function of wavelength and phase angle will be obtained. These should provide further useful information on the morphology, composition and microstructure of clouds within eddy features. Equilibrium chemistry models which incorporate advection may then be used to relate these results to the dynamical models and provide additional means of classifying different types of eddies.

The poster presentation summarizes recent and ongoing work on these problems with some preliminary results.

Compact, oval eddies, comparable in scale to the east-west bands of wind and cloud (belts and zones) are observed at various latitudes in the Jovian atmosphere, centered in shear zones between jets close to where the gradient of potential voticity with latitude is zero (e.g., Ingersoll *et al.* 1981), the most striking example being the Great Red Spot centered at 25 deg S of the equator. Other examples include the White Ovals, Brown Barges and White Spots. Most seem to be anticyclonic in circulation, with many similarities in shape, morphology of flow and thermal fields, cloud texture, etc. Some cyclonic examples exist (e.g., Barges) with opposite characteristics. All have long lifetimes compared with a typical advection timescale (L/U). Remote sensing instruments on the Galileo Orbiter will produce a wealth of new information about the planet's atmosphere. The complexity of the dynamics and radiative transfer within the atmosphere makes direct interpretation of much of this data difficult. The aim of the work described here is to produce physical models of processes within the Jovian atmosphere and to use these models to predict the values of observables and to test dynamical theories in an efficient way.

Hide (1980, 1981) has suggested that the long-lived eddies observed on Jupiter may be dynamically similar to the steady, regular baroclinic eddies produced in laboratory experiments on thermal convection in an internally heated rotating fluid. Read and Hide (1983) show a streak photograph of an anti-cyclonic eddy in a rotating annulus which appears to have many of the features of the Great Red Spot on Jupiter including a stagnant, relatively warm core, a peripheral jet stream, and a descending collar.

Baroclinic eddies have several aspects in common with other, recently suggested, models of Jovian eddies, especially "modon" solutions (Ingersoll 1973, Ingersoll and Cuong 1981) since both are characterized by a potential vorticity equation where the Jacobian of stream function and potential vorticity vanishes to first order in a frame moving with the zonal velocity of the shape-preserving solution. The essential difference is that weak, steady effects (in particular diabatic heating) are invoked to balance dissipation in the case of baroclinic eddies whereas Ingersoll and Cuong (1981) invoke transient effects to balance friction.

A quasi-geostrophic, two-level model is currently under development to investigate such eddy solutions. The flow is decomposed spectrally into zonal mean and wave components, which allows calculation of the non-linear interactions between modes represented to be exact. Currently a zonal mean mode is forced which corresponds to internal diabatic heating, but other means of forcing may be incorporated. Dissipation is achieved via various viscous terms.

The model may be used to study the stability of long-lived features in a background flow of suitable configuration, the role of interaction of transients with an eddy and internal forcing processes in the maintenance of the flow against dissipation, and may be used to simulate the transport of quasi-conserved passive Lagrangian tracers given suitable source and sink functions. The vertical motion field may also indicate the cloud morphology expected in the region of an eddy, especially once the resolution of the model is extended.

Advantages of such a model over laboratory experiments such as those performed by Read and Hide (1983) are that the types of forcing and dissipation in use may be specified explicitly, the 'beta effect' (variation in Coriolis parameter with latitude due to the curvature of the planet) may be included, and flow configurations unattainable in the laboratory may be investigated.

Observations of minor chemical species made by instruments on the Galileo Orbiter, e.g., the Near Infrared Mapping Spectrometer, are potentially extremely valuable in helping to discriminate between dynamical models of eddy features. Provided that the mixing and advection timescales are of the right order (see e.g. Read 1985) such species may be used as quasi-conserved passive Lagrangian tracers. For example, McIntyre and Palmer (1983) use satellite observations of ozone in the Earth's atmosphere to derive maps of Ertel potential vorticity on isentropic surfaces.

The NIMS instrument will produce maps of the planet at 408 wavelengths between 0.7 and 5.2 μm with a spatial resolution of better than 400 km at closest approach. (The Great Red Spot has a diameter of around 26,000 km.) This spectral range may provide measurements of the abundances of the minor constituents PH_3, H_2O, NH_3, GeH_4 and CH_3D for example (Taylor and Calcutt 1984). At the shorter wavelength end of the spectrum ($\lesssim 3\mu m$) scattered sunlight becomes more important than emitted radiation and should provide more information on the morphology and microstructure of clouds within and around eddy features. This may provide further means of classifying different types of eddies.

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