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QUASI-GEOSTROPHIC 'FREE MODE' MODELS OF LONG-LIVED JOVIAN EDDIES: FORCING MECHANISMS AND CRUCIAL OBSERVATIONAL TESTS

P. L. Read
Meteorological Office, U. K.

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Recent modelling studies concerning the nature and generation of the longest-lived eddies in the atmospheres of Jupiter and Saturn (including Jupiter's Great Red Spot and White Ovals) are reviewed and shown to reduce to the derivation of steady, shape-preserving solutions to an appropriate homogeneous potential vorticity equation in a zonal shear flow as their (zeroth order) starting point. Crucial differences between the models arise from the ways in which the solutions maintain themselves against the inevitable effects of weak dissipation. Ingersoll and Cuong (1981, J. Atmos. Sci. *38, 2067-2076), for example, invoke small-scale transient eddy-forcing to maintain a time-averaged large-scale eddy, while the laboratory analogue of Read and Hide (1983,* Nature *302, 126-129; 1984,* Nature *308, 45-49) is shown to correspond to the diabatic forcing of a quasi-steady eddy. From a consideration of the potential vorticity budget for closed-streamline quasi-geostrophic flows, and of the nature of small-scale transient eddies as either a 'dissipation' or 'forcing,' the crucial difference between diabatically- and transient eddy-forced recirculating flows is shown to lie in the resultant direction of the cross-streamline flux (in the time average) of potential vorticity. By Ertel's theorem, the direction of the transport of other passive, quasi-conserved tracers can also be inferred, hence suggesting a potentially conclusive observational test of these models, provided adequate maps of suitable passive chemical tracers can be obtained. Some suggestions for the use of Galileo observations will be made, with particular reference to the use of the Near Infrared Mapping Spectrometer (see also the paper by Lewis* et al. *in this proceedings).*

DR. WEST: I suggest perhaps stratospheric aerosols as a possible tracer which has interesting vertical and latitudinal concentrations towards the pole.

DR. INGERSOLL: I'm also concerned about how you can test things. You see things entering and leaving what is, on a time average, a closed eddy. You do see that all the time because things like the Red Spot are gulping smaller spots and the smaller spots are identifiable and the gulping is always incomplete. Maybe you've got it right in the movie.

DR. READ: Maybe I have, but has anyone actually looked at such a system using time-average statistics? Just because the Red Spot gulps in spots sometimes and expels them at other times, what you actually want to determine is what the final...what net exchange of material takes place between the long-lived eddy and the smaller spots outside. That's what I'm asking.

DR. BEEBE: When we see a small spot enter the Red Spot or White Oval they go in and they leave a trail, and simply spiral and get stretched out to the point that they become translucent. You can see structures underneath them, through the trails as they wind in.

DR. READ: OK, but is it just between individual spots of either sense of circulation?

DR. BEEBE: We see the anticyclonic ones.

DR. READ: So what does coalescence amount to in these interactions in the presence of strong shear?

DR. BEEBE: I don't think I've ever seen anything come out of the spot. You almost get the impression that any of the subsiding regions are covered by an overlying cloud layer that masks the activity.

DR. READ: I think we ought to be rather careful to make sure we're actually looking at something that's a conserved tracer as well.

DR. BEEBE: That's right.

DR. READ: In interactions between spots, material (and potential vorticity) may be exchanged. If the interactions involve changes in the vertical motion field, however, the cloud structures may be affected on a similar timescale to that of the interaction itself. This is why we must look at [the budgets of long-lived] chemical tracers, as well as tracking cloud systems, because it's the motion of the individual fluid parcels that you want to infer. Not necessarily the products of upward and downward motion.

DR. BEEBE: You have to remember that almost all the observations we have of Jupiter have resolutions larger than the pressure scale height. We haven't seen any features with smaller dimensions.

DR. READ: What you're wondering is why I've listed all these chemical tracers is it, as a way of attributing direction rather than use the clouds themselves?

DR. LEOVY: One encouraging thing that I think there is in the cloud images is the correlation between the edges of the belts and zones, and the jets. One has the impression, and I don't know whether it's valid, but I think maybe looking at some of your images from this point of view that in some regions, such as as the latitudinal band of the GRS, the clouds are relatively long-lived. What someone would expect to see for a true long-lived tracer is a correlation between the edge of a tracer and velocity maxima. This is because long-lived tracers would correlate with potential vorticity, which is essentially vorticity itself at the jet level. Consequently, tracer cloud edges would correlate with velocity extrema over a range of scales. If one sees this behavior in areas other than the belt-zone edges, and on a somewhat finer scale, then one would be encouraged that in those regions you've got a long-lived tracer.