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SOME OCEAN-JUPITER CONNECTIONS

by Gareth Williams

The turbulence of oceanic mesoscale flows and global Jovian flows appear to have much in common, both being characterized by a large value of the relative vorticity parameter $\hat{\beta} = \beta L^2/U \sim 50$. Rhines (Hot Line News No. 26) has shown how the energy cascade of two-dimensional turbulence in such a system is terminated at a length scale of $L_\beta = \pi(2U/\beta)^{1/2}$ by the onset of Rossby waves. Williams (1975) has shown that this process is also responsible for producing the characteristic banded structure of Jupiter's global circulation. Some of the results of this Jupiter study may be useful in understanding oceanic processes.

One of the models used consisted simply of the barotropic vorticity equation on a rotating sphere:

$$\frac{D\zeta}{Dt} + \beta v = \nu\nabla^2\zeta + F \quad ,$$

where ν is a small viscosity parameter that removes energy from small scales. The vorticity source F was generated by a stochastic sequence, being random in space-time but having predetermined space-time scales. For Jupiter, the forcing represents the internal forcing by small-scale ($<L_\beta$) baroclinic instability, as was verified by a baroclinic model. For the ocean, F could represent the external forcing by the surface wind stress associated with atmospheric storms or by eddy interactions with bottom topography.

A typical solution is shown in Figure 1. During the initial stages of flow build-up, the streamfunction field mainly reflects the forcing (Figure 1a). Energy continues to

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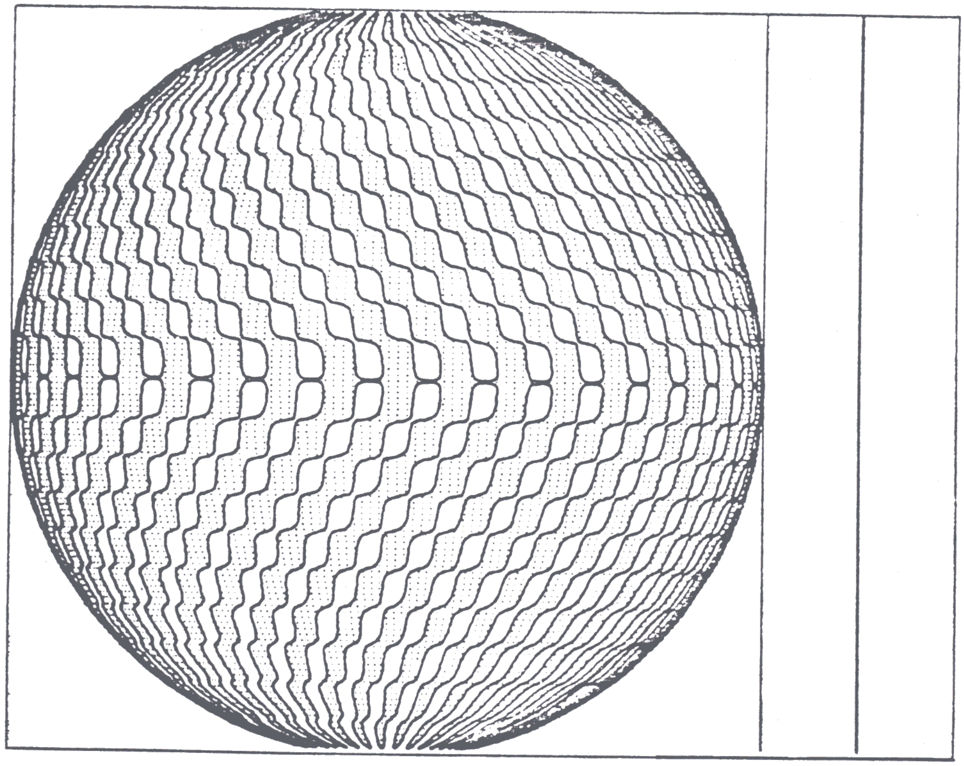
cascade to larger scales as described by Rhines until Rossby wave propagation sets in. Then the eddies no longer grow in size, and the mean field becomes organized into a zonal flow pattern (Figure 1b), related to that observed on Jupiter. The amplitude of F was globally uniform and leads to currents of alternating direction. Enhanced forcing in a given zone tends to produce an eastward flow in that zone.

In the oceanic context, this zonal flow production mechanism could contribute significantly to the global Antarctic circumpolar current. The kinetic energy density of flows behaves as Fk^{-2} where k is the wavenumber forcing. So, if in the ocean case $k^{-1}FH$ is of the order of 1 dyne cm^{-2}, currents of the order $(kH)^{-1/2}$ cm/sec are produced. For H = 4 km and k^{-1} = 100 km, this would give currents of a realistic 5 cm/sec magnitude.

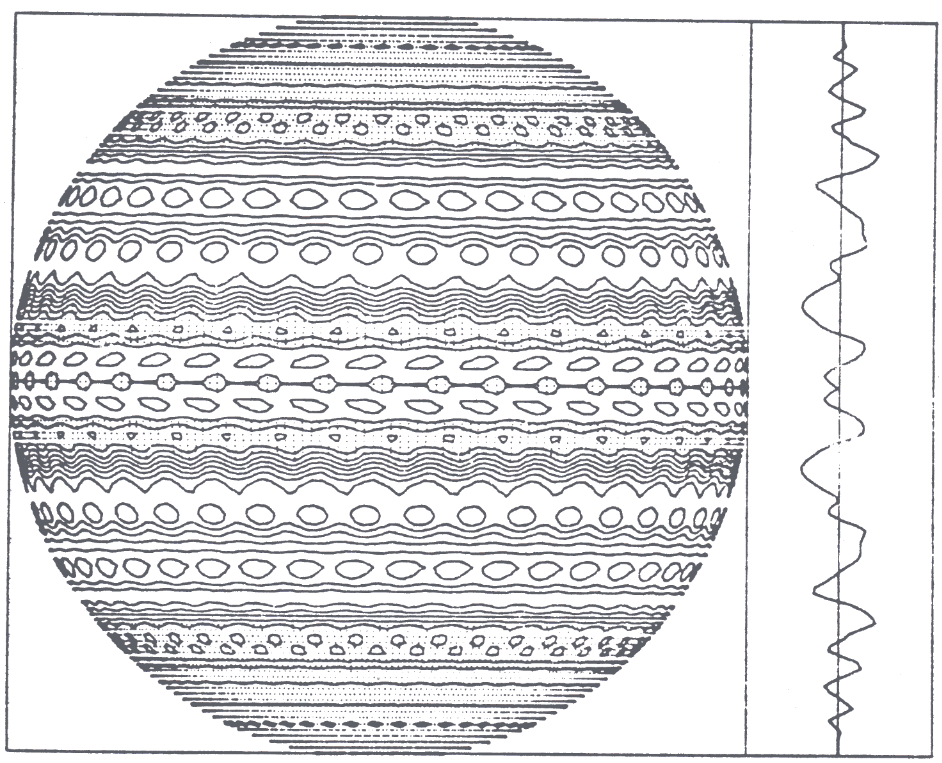
It would be of value to explore this problem further to see how important random vorticity sources are in generating the actual ocean currents.

Reference

Williams, G. P, 1975 Jupiter's atmospheric circulation, Nature (submitted to).



(A)



(B)

Streamfunction contours with negative values shaded by ¼ of grid points. Profile of longitudinally averaged zonal flow has a scale of 100 m/sec in rhs profile. (A) is early and (B) is later in flow development.

Figure 1 (Williams)