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Zonal Jets

Zonal jets are the horizontal bands of fluid motion that are found on gaseous giants and even in Earth's oceans. Jets are an extreme form of the mean circulation: localized, elongated, energetic flows, usually with persistence in time). Large-scale flows in planetary atmosphere and oceans are caused by many planetary systems. When the Coriolis force is balanced by an external force and a concentration is caused by the β-effect, flows are directed into horizontal rows flowing in alternating directions around the planet (Rhines 1). The β-effect is caused when scientists take into account the varying angular velocities bodies have at different latitudes. Compact sources of momentum, heat or mass can radiate jet-like plumes along latitude circles leading to the formation of zonal jets (Rhines 1). The β-effect can also influence the formation of jets directly by organizing random external stirring into the thick bands of motion (Rhines 1). Internally, the jets can be created when instable mass field movements generate zonal flow, which concentrate into jets (Rhines 1). Bottom topographic obstacles such as mountain ridges, island chains, trenches, and plateaus can focus currents into large-scale flows (Rhines 1).

Classical jets are formed from boundary conditions, usually the pumping of momentum and mass (liquid) out through a nozzle. "Large-scale natural jets tend to be the result of momentum forcing or exotic concentration mechanisms like the β-effect (from sides or above and below) rather than upstream boundary conditions" (Rhines 1). Therefore, there is a mystery behind the formation of zonal jets because there is no "nozzle" existing to direct them. Furthermore, the jets are in constant motion, meaning the processes don't loose there momentum quickly. The key ingredient is the β-effect because it is what directs the jets in ubiquitous flows around the planet. External forcing, usually from the β-effect, leads to mass convergence. Incoming wave radiation and attendant momentum convergence is another way the jets gain size. A final ingredient in the generation is combined action of thermal convection and planetary rotation confinement (Rhines 1).

An example of zonal jets can be observed on Jupiter. "The visible bands are formed by clouds moving along a stable set of alternating zonal (east-west) jets" (Galperin 2). Jets on Jupiter are similar to jets in Earth's oceans in that they both have "quasi-two-dimensionality stemming from the large disparity between the horizontal and vertical scales of circulation" (Galperin 2). Such systems are also similar because of the extreme vertically stable stratification, which lead to energy release in the form of eddies. Eddies are essentially the instable "swirls" that result in between two alternating jets. A final important consideration of Zonal jets is the inverse energy cascade. Such a cascade leads to the conservation of energy as well as enstrophy.

Recently, Rossby waves have been argued to provide the required dynamical mechanism for the formation of zonal jets (Weichman 1). Rossby waves represent huge vortices in the atmosphere and ocean (Balk 1). They help account for the inverse energy cascade of large-scale flows. However, well defined Rossby waves only exist at mid-latitudes, and since zonal jets appear on the equators, a more complete mechanism is required (Weichman 1). Accounting for Rossby waves requires one to consider an extra invariant, other than energy and enstrophy. This extra variant is unique and since it is conserved, "ensures the energy transfer to the *large scale zonal flow*" (Balk 2).

Zonal jets like those on Jupiter exist on our planet. The uniqueness of them lies in that they are formed <u>not</u> by boundary conditions, but existing external forces such as the β-effect. Their large-scale size indicates that they are important to understand because they directly control the weather. Furthermore, their evolution dictates the climate changes across the globe.

Bibliography