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The Dynamics of Zonal Jet Migration

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Zonal jets, sometimes known as zonal flows, are strong and persistent east-west flows that arise spontaneously in a variety of geophysical and astrophysical fluids. They are ubiquitous, with key examples including mid-latitude jets in the Earth's troposphere, flows on gaseous giant planets such as Jupiter and Saturn, in addition to flows in the solar tachocline. Turbulent flows on a beta-plane (described by the Charney-Hasegawa-Mima equation) lead to the spontaneous formation and equilibration of persistent zonal jets. However, the equilibrated jets are not steady and the nature of the time variability in the equilibrated phase is of interest both because of its relevance to the behaviour of naturally occurring jet systems and for the insights it provides into the dynamical mechanisms operating in these systems.

Variability is studied within a barotropic beta-plane model, damped by linear friction, in which stochastic forcing generates a kind of turbulence that in more complicated systems would be generated by internal dynamical instabilities such as baroclinic instability. This nonlinear (NL) system is used to investigate the variability of zonal jets across a broad range of parameters. Comparisons are made with a quasilinear (QL) model in which eddy-eddy interactions are neglected[1]. Both systems reveal a rich zoology of dynamics, nevertheless, key differences exist. The NL model admits the formation of systematically migrating jets, a phenomenon that has not been previously identified within such a simple system. Jets migrate north or south with a speed of translation that is a function of the Rhines scale and the frictional damping rate, occasionally changing their direction of migration. The QL model does not exhibit jet migration, but a generalised quasilinear (GQL) model, in which certain eddy-eddy interactions are systematically restored[2], does, demonstrating that long waves (sometimes known as zonons[3]), generated by such interactions, play a key dynamical role.

References
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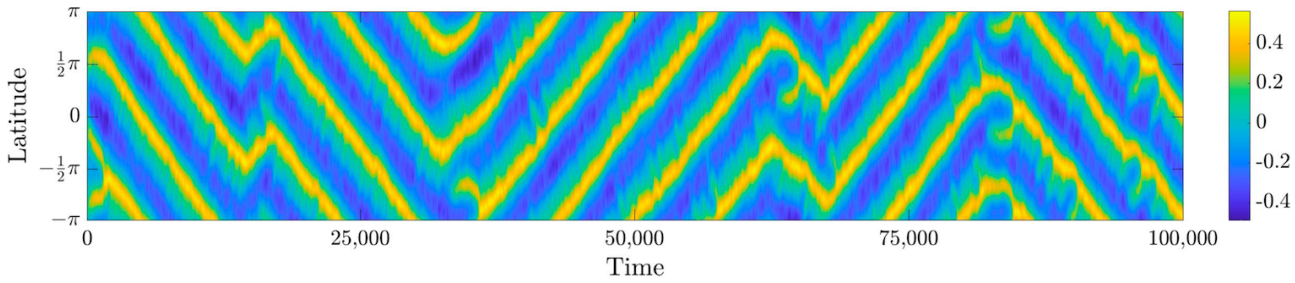

Figure 1. A latitude-time plot illustrating the zonal mean zonal velocity field from the NL model. A pair of jets equilibrate and systematically migrate either north or south, occasionally and spontaneously changing their direction of migration.