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Evolution and System Dependent Properties of Zonal Flows and GAMs in Tokamaks and Planet Atmospheres

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We have studied the evolution of the zonal flows (ZF) in first principles two-fluid and gyrokinetic turbulence simulations, while artificially controlling the starting conditions or time dependence of the flows to find the rules governing the flow evolution, the preferred, stable and unstable states, and the influence of inhomogeneities, i.e., the effects of the boundary conditions and of radially varying plasma parameters and other non-Boussinesq effects.
Thus a robust functional describing the parallel and perpendicular Reynolds stresses has been determined, which inserted into a 1D momentum balance equation is able to reproduce the evolution of the self-consistent radial ZF pattern from noise to the stationary state. Thereby a qualitative difference was discovered between toroidal ion temperature gradient (ITG) turbulence and sheared cylinder resistive drift wave (DW) turbulence induced flows. While in the ITG case, the wavelength of the flow pattern is fixed independent of the initialization, the DW turbulence maintains the period of any initialized pattern while enforcing a square wave shearing rate profile. In a way, the DW-ZF system can be regarded as a digital storage medium with two admissible flow shear states, while the ITG-ZF system has no memory.
For the GAMs the deterministic part of the turbulence dramatically changes the dispersion relation, resulting in orders of magnitude higher radial drift speeds and determines the preferred GAM wavenumber. This can lead to bursting GAM and turbulence activity, which depends on the sign of the grad-B drift with respect to the closest X-point.
A comparative study of rotating planetary (Jovian) turbulence using the novel NAN (Navier Stokes, anelastic turbulence) code incorporating the associated density contrasts, shows that here ZFs are being generated similarly by a Reynolds stress based self amplification, control turbulence (bursting and profile modulation is observed) and interact with the turbulence modes through wave kinetic effects. The contrast between these notions and the ones in the geophysical framework, which focus on the transport and stretching of vorticity (not momentum as by Reynolds stress) will be reviewed in the contribution.

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