# Bifurcation in Resistive Drift Wave Turbulence

R. Numata, R. Ball, R.L. Dewar, L. Stals*

*Department of Theoretical Physics, Research School of Physical Sciences and Engineering, The Australian National University, Canberra, ACT 0200, Australia*

*∗Department of Mathematics, Mathematical Sciences Institute, The Australian National University, Canberra, ACT 0200, Australia*

Fusion plasmas and other turbulent flows in two dimensional (2D) geometry can undergo a spontaneous transition to a turbulence suppressed regime. In plasmas such transitions dramatically enhance the confinement and are known as L-H transitions. From theoretical and experimental work, it is now widely believed that generation of stable coherent structures such as shear flows suppresses cross-field turbulent transport and leads to the confinement improvement.

We consider the modified Hasegawa-Wakatani (MHW) model,

$$\frac{\partial}{\partial t}\zeta + \{\varphi,\zeta\} = \alpha(\tilde{\varphi}-\tilde{n}) + D\nabla^2\zeta, \tag{1}$$

$$\frac{\partial}{\partial t}n + \{\varphi,n\} = \alpha(\tilde{\varphi}-\tilde{n}) - \kappa\frac{\partial\varphi}{\partial y} + D\nabla^2 n, \tag{2}$$

which describes electrostatic resistive drift wave turbulence in 2D slab geometry: $-L_x/2 \le x \le L_x/2$, $-L_y/2 \le y \le L_y/2$. $\zeta = \nabla^2\varphi$ is the vorticity, $\varphi$ is the electrostatic potential, $n$ is the density, $\alpha$ is the adiabaticity parameter, $\kappa = -\partial/\partial x(\ln n_0)$ is the background density profile, $D$ is the dissipation coefficient. $\{a,b\} = (\partial a/\partial x)(\partial b/\partial y) - (\partial a/\partial y)(\partial b/\partial y)$ is the Poisson bracket, and $\tilde{f} = f - \langle f\rangle$, $\langle f\rangle = 1/L_y\int_{-L_y/2}^{L_y/2} f \mathrm{d}y$ gives the zonal component. The modified version of the Hasegawa-Wakatani model can handle an interaction between turbulence and zonal flow consistently[1].

We start numerical simulations from small amplitude random perturbations. The perturbations grow linearly due to the resistive drift wave instability, and saturate in the nonlinear regime where the energy input and dissipations balance. In a certain parameter range, we see that coherent zonal flows are generated in the saturated state (Fig.1). However, the zonal flows are lost if we change the parameters $\kappa$ and $\alpha$. In Fig.2, we show the zonal flow kinetic energy normalized by the total kinetic energy

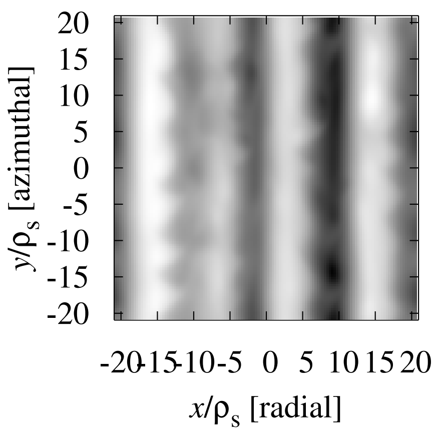


Figure 1: Contour plot of saturated electrostatic potential for $\kappa = 1$, $\alpha = 1$. Zonally elongated structure is clearly visible.

in nonlinearly saturated state for different $\kappa$ and $\alpha$. We observe that the system exhibits a sudden transition from the zonal flow dominated state to the turbulence dominated state. This transition may be ascribed to the instability of the zonal flow.

In this study, we consider the Kelvin-Helmholtz (K-H) type instability of the generated zonal flow. We assume perturbations of the form $f = f(x)\exp\mathrm{i}(k_y y - \omega t)$, and linearize the MHW equations around the equilibrium containing the zonal flow $V(x) = V_0 \sin(k_v x)$, then we obtain the Rayleigh's eigen value equation modified by the effect of $\alpha$ and $\kappa$,

$$\frac{\mathrm{d}^2}{\mathrm{d}x^2}\varphi(x) - k_y^2\varphi(x) + \frac{k_y V''}{\omega - k_y V}\varphi(x) = \frac{\mathrm{i}\alpha}{\omega - k_y V + \mathrm{i}\alpha}\frac{\omega - k_y V - k_y\kappa}{\omega - k_y V}\varphi(x) \qquad (3)$$

By analyzing this equation, we discuss the relation between the transition in the MHW system and the stability of the zonal flow against the K-H instability.

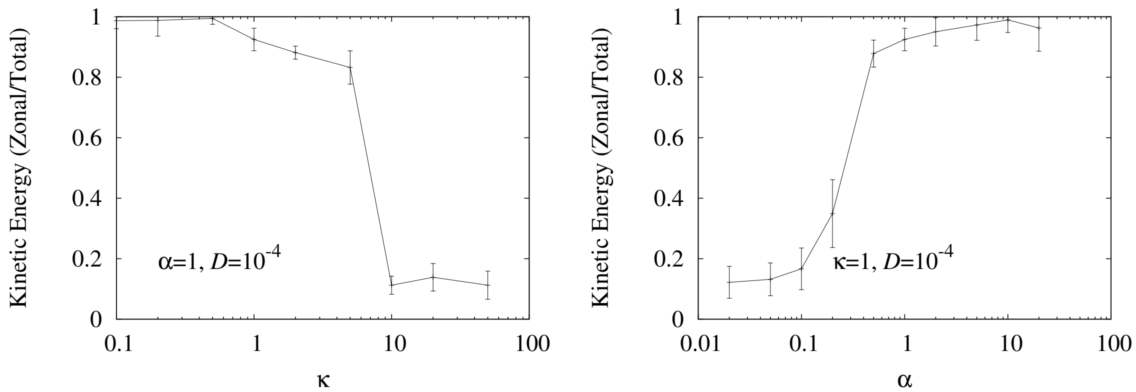


Figure 2: Parameter dependence of zonal flow kinetic energy normalized by total kinetic energy.

## References

[1] R. Numata, R. Ball, R.L. Dewar, Proceedings of the CSIRO/COSNet Workshop on Turbulence and Coherent Structures, Canberra, Australia, 10-13 January 2006 (World Scientific, 2007, in press, eds. J.P. Denier and J.S. Frederiksen), pp. 431-442.