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Turbulence in the Edge of Magnetized Plasmas: Emergent Structures and Transport

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What have the likelihoods for fine weather in summer and for a future use of fusion energy got in common? Both the atmosphere and magnetized fusion plasmas are determined by similar structure formation processes in quasi-two-dimensional periodic nonlinear dynamical systems. Self-organization of waves and vortices on small scales leads to large-scale flows, which are, depending on conditions, either stable for a long time - or can break apart intermittently and expel large vortex structures. In the case of earth's atmosphere, a possible stabilization of the polar jet stream over northern Europe by warming around July 7th (!) leads to a high probability for stable hot midsummer weather in central Europe. The efficient utilization of nuclear fusion in a power plant also depends if a stabilization of such mean zonal flows ("H mode") may be sustained by heating of the plasma. However, instabilities may ruin by rain our summer holidays ("icelandic lows"), as well as lead to tempestuous eruptions ("ELMs") of energy and particles from the edge of a fusion plasma onto the walls of the reactor. Plasma physicists are - similar to meteorologists - therefore interested in accurate predictions of these processes.

In our present Austrian START project "TEMP:EST", turbulence and structure formation in magnetized plasmas are studied by means of computation and comparison to experiment. In particular, the physical mechanisms and scalings of ideal ballooning mode ELM bursts in high confinement tokamak edge plasmas, which evolve from a macro-scale linear instability into a fully developed micro-scale turbulent phase, are analysed numerically. We present nonlinear gyrofluid simulations of edge localised ideal ballooning mode events in the edge pedestal of toroidal magnetised plasmas. The range of scales reaches below the ion gyroradius, and the self-consistent evolution of the equilibrium is taken into account. The necessity of resolution to the ion gyroradius scale is shown directly by consistency checks: converged cases are not otherwise obtained. Even with the finite beta well above the ideal MHD threshold, the results are outside of either the MHD or collisional Braginskii paradigms, on which other approaches are based.