Plasma microturbulence simulation of instabilities at highly disparate scales

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Abstract

This work reports on studies of the multi-scale interaction between small-scale electron turbulence and large-scale ion turbulence in tokamak plasmas. Traditionally, the long-wavelength, low-frequency turbulence driven by ion-scale instabilities (ion-temperature-gradient and trapped-electron modes) is studied separately from the short-wavelength, high-frequency turbulence driven by electron-scale instabilities (electron-temperature-gradient modes). High-resolution, massively parallel simulations have uncovered a number of physically-important discoveries. First, we find that a popular simplified model of ion physics previously used in studies of electron-scale turbulence can lead to nonphysical runaway of electron heat transport. We have shown that this nonphysical runaway is eliminated when correct long-wavelength ion physics is self-consistently included. We have also found that under normal conditions most of the electron heat transport arises from large-scale instabilities. However, when these large-scale instabilities are suppressed by plasma rotation or other processes, the electron instabilities survive and may dominate the loss of electron heat from the plasma. A further remarkable finding is that strong turbulence at long scales can act to reduce the intensity of turbulence at short scales. Simulations were carried out on the Cray X1E computer at ORNL, with the largest runs taking about a week on 720 multi-streaming processors.