GYRO simulations supporting the TGLF transport model

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TGLF[1] is a theory based local gyroBohm transport model fitted to nonlinear gyrokinetic simulations from the GYRO [2] code. The TGLF model and the GYRO code reviewed here have the comprehensive physics thought to be needed for an accurate and realistic description (and prediction) of core tokamak confinement in all micro-turbulent transport channels: electron and multi-species ions (including impurities and energetic particles), trapped and passing particles, collisions, finite beta, real shaped geometry, equilibrium ExB shear, as well as finite rho-star profile variation effects (the last in GYRO only). Transport from the moderately low-k ITG/TEM, high-k ETG, and (recently) very low-k TAE/EPM modes are treated. The status of recently revised TGLF fits to GYRO and tests against a large experimental confinement database is reported. Here we focus on how GYRO simulations were used to establish and accurately test two key scientific elements in the construction of the TGLF model: (1) *quasilinear transport approximation* (QLTA) itself [3], and (2) the *predator-prey paradigm* model [4] for the *nonlinear spectral* (electric field) *intensity*. The quasilinear transport flow in each channel is a spectral convolution of a *quasilinear weight* and a *nonlinear spectral intensity* common to all channels. Using the mode spectrum of *quasilinear weights* from linear GYRO runs and the leading mode *nonlinear spectral intensity* from nonlinear runs, the *overage* ratio of quasilinear to nonlinear flows is 1.4-1.8 and (as a measure of success) remarkably constant over a variety of cases. (The average *overage* is always renormed to 1.0 in models.) A frequency spectrum version the QLTA (not used in transport models) is tested with tracer transport linear and nonlinear simulations with a smaller 1.2-1.4 *overage*. A breakdown in the QLTA was found for strongly pinched particle flows (even when QLTA energy flows remain accurate). In a series of GYRO simulation numerical experiments which isolated and varied the *zonal flow residual* (dependent on q) and the *geodesic acoustic mode* (GAM) *frequency* and damping rate (dependent on R and q) independent of the drift wave driving rate, it was found that the usual *predator-prey* drift wave -zonal flow *paradigm*[5] underestimates the role of GAM ExB shearing in the nonlinear saturation. Drift wave - drift wave nonlinear coupling (with different n-numbers) was confirmed to be negligible in both low-k ITG/TEM and high-k ETG saturation. The *nonlinear spectral intensity* consistently scaled as the *predator-prey* product of the drift wave ($n > 0$) driving rate and the ($n=0$) GAM frequency at both high- and low-q.

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