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Title: MHD Instability and Turbulence in the Tachocline

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In this quarter we have begun simulations on the Cray T3E at the Pittsburgh Supercomputer Center. We have also ported our T3E code to the Terascale Computing System (TSC), but still have not managed to completely debug the port. Our simulations on the T3E are investigating stratified shear simulations with the magnetic field aligned with the shear flow with passive tracer particles included. We estimate the simulations will require two months of computing, factoring in the interruptions associated with job continuation.

While those simulations are computing, we have turned to analysis of some neutral simulations in order to establish a basis for comparison with the magnetically conducting cases. From our neutral simulations we have concentrated on validating the computed solutions against measurements conducted for turbulent stratified shear flows. This has proven difficult because laboratory experiments are carried out at comparable Reynolds numbers as the simulations, so they do not allow us to examine relevance to higher Reynolds number flows. Atmospheric field experiments offer a glimpse at higher Reynolds numbers (as high as Re=10^7 to 10^9), but measured quantities are more limited than that which can be attained in the lab. We note that Re=10^9, though lower than solar interior values, is still considerably higher than can be achieved numerically.

We have evaluated the relevance of the simulations to high Reynolds number flows by obtaining fits for the 2nd-order structure functions for velocity and temperature with height. The inner scale, spectral slope, and structure function parameter were all compared with values from atmospheric observations at much higher Reynolds number. We were able to verify the measured universal constants C_theta = 3.3 and C = 2.1 which relate the structure function parameters with the thermal and viscous dissipation rates. We also verified that the inner scale for the temperature field is 7.4 times the Kolmogorov scale (computed from the viscous dissipation rate), and We verified deviations from Kolmogorov's 5/3 law observed in atmospheric measurements. The results give us confidence that the solutions are relevant, through scaling relationships, to much higher Reynolds number flows.

We have also examined the mixing dynamics of the stably stratified simulations. Inside the well-mixed domain scalar fluctuations possess low amplitude. At the edges of the well-mixed part of the domain, entrainment dynamics prevail where quiescent fluid exterior to the well-mixed layer encounters well-mixed interior fluid. The nature of the dynamics in the layers edges is of lower Reynolds number relative to the interior, which is encouraging because it means the DNS simulations have a better chance of illuminating the behavior. Unfortunately, however, the anisotropy in the edge regions is pronounced, and the entrainment dynamics is the least-well understood in atmospheric, oceanic, or laboratory studies.

To address the layer anisotropy, we have compared the computed results with the isotropy relation connecting longitudinal and transverse spectra. At midlayer, deviations ranging from 10% to 80% are evident, depending on the wavenumber. Departures from isotropy in the layer edges are more severe, ranging between 200% and 300%.

To evaluate the nature of the anisotropy, we have examined streamwise, spanwise, and vertical components of the RMS velocity and vorticity. From these tests we see that the streamwise direction establishes near axisymmetry, albeit with slight effects due to stratification in the vertical. The importance of the vertical direction (and hence, stratification) becomes more pronounced as the flow evolves.

To explore the degree of anisotropy at the smallest length scales in the flow, we compare terms that comprise the dissipation field d_i u_j d_k u_l, where d_i is the derivative in the i direction, and u_j is the velocity in the j direction. Here we found agreement with axisymmetry relations for the various terms, with a deviation from spherical symmetry by approximately 60%. Though axisymmetry is better satisfied, deviations of roughly 8% persist. These deviations are identified with buoyancy, with vertical length scales and velocities both reduced by 8%.

In addition to the analysis presented above, we continue to make progress with the optimal perturbation solutions and the educational web page.

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13. ABSTRACT *(Maximum 200 words)*

In this quarter we have begun simulations on the Cray T3E at PSC and we are debugging our code on the TSC. The PSC simulations are examining stratified shear turbulence with a flow-aligned magnetic field and passive tracer particles. We have conducted analysis of neutral simulations to establish a firm basis of comparison. Second-order structure functions have been computed, fit, and compared to theoretical expressions relating the dissipation fields and the structure-function-fit parameters. Agreement with high-Reynolds number observations is excellent, giving us confidence that the lower-Re simulations are relevant to higher-Re flows. We have also evaluated the neutral layer anisotropy.

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