Investigation of Small-Scale Turbulent MHD Phenomena Using Numerical Simulations and NST Observations

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Recent progress in observational capabilities and numerical modeling have provided unique high-resolution information demonstrating complicated dynamics and structures of turbulent flows and magnetic field on the Sun. The realistic approach to numerical simulations is based on physical first principles and takes into account compressible fluid flow in a highly stratified magnetized medium, 3D multi-bin radiative energy transfer between fluid elements, a real-gas equation of state, ionization, and excitation of all abundant species, magnetic effects and sub-grid turbulence. We present new results of 3D radiative MHD simulations of the upper solar convection
zone and chromosphere that reveal a fundamental role of small-scale vortex dynamics, and compare the numerical results and predictions with observational results from the 1.6 m clear aperture New Solar Telescope (NST) at Big Bear Observatory. In particular, we investigate formation and dynamics of ubiquitous small-scale vortex tubes mostly concentrated in the intergranular lanes and their role in magnetic structuring and acoustic emission of the Sun. These whirlpool-like flows are characterized by very
strong horizontal shear velocities (7 - 11 km/s) and downflows (~7 km/s), and are accompanied by sharp decreases in temperature, density and pressure at the surface. High-speed whirlpool flows can attract and capture other vortices, penetrate into the low chromosphere, and form stable magnetic flux
tubes. The simulations also reveal a strong connection between acoustic wave excitation events and the dynamics of vortex tubes. In this talk, we will discuss different aspects of small-scale turbulent dynamics of the low
atmosphere from the high-resolution simulations in comparison with recent NST observations, and the strategy for future synergies of numerical simulations and observations with large aperture solar telescopes.