Subsurface Supergranular Vertical Flows as Measured Using Large Distance Separations in Time-Distance Helioseismology

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Abstract:

As large-distance rays (say, 10-24 deg) approach the solar surface approximately vertically, travel times measured from surface pairs for these large separations are mostly sensitive to vertical flows, at least for shallow flows within a few Mm of the solar surface. All previous analyses of supergranulation have used smaller separations and have been hampered by the difficulty of separating the horizontal and vertical flow components. We find that the large separation travel times associated with upergranulation cannot be studied using the standard phase-speed filters of time-distance helioseismology. These filters, whose use is based upon a refractive model of the perturbations,reduce the resultant travel time signal by at least an order of magnitude at some distances. More effective filters are derived. Modeling suggests that the center-annulus travel time difference in the separation range 10-24 deg is insensitive to the horizontally diverging flow from the centers of the supergranules and should lead to a constant signal from the vertical flow. Our measurement of this quantity for the average supergranule, 5.1 s, is constant over the distance range. This magnitude of signal cannot be caused by the level of upflow at cell centers seen at the photosphere of 10 m/s extended in depth. It requires the vertical flow to increase with depth. A simple Gaussian model of the increase with depth implies a peak upward flow of 240 m/s at a depth of 2.3 Mm and a peak horizontal flow of 700 m/s at a depth of 1.6 Mm.