Measurements of gravity wave momentum fluxes using ground-based and satellite remote sensing techniques

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Gravity wave (GW) momentum transport from GW source regions in the lower atmosphere to regions of GW dissipation at greater altitudes has profound influences on atmospheric structure and variability. At lower altitudes, this momentum flux and its divergence induce systematic poleward motions above the tropospheric jets at middle and high latitudes and contribute to forcing of the quasi-biennial oscillation at equatorial latitudes. At greater altitudes, GW momentum flux divergence closes the mesospheric jets, induces a summer to winter inter-hemispheric mean (meridional and vertical) circulation that reverses the mean meridional temperature gradient, forces the equatorial stratopause and mesopause semiannual oscillations, and induces substantial tidal modulation and local variability. Substantial momentum fluxes also persist well into the thermosphere, but their effects at this time are largely unknown. GW momentum fluxes arise from correlated horizontal and vertical velocities (due to the GW dispersion relation) that can be measured in a number of ways. Dual-beam radar and lidar radial velocity measurements have been used most widely, and allow for valid estimates, when momentum fluxes are significant, in relatively short times, typically $\sim$1 hr. Momentum fluxes may also be estimated wherever GW amplitudes (in wind or temperature) and the intrinsic frequencies are known, even for spatially-localized and transient GW packets. The various measurement techniques have demonstrated 1) mean fluxes and divergence consistent with observed closure of the mesospheric jets , 2) systematic anti-correlations of momentum fluxes and low-frequency winds, 3) significant modulation by tidal motions, and 4) occasionally very large responses due to large-amplitude, localized GW packets. The importance of, and diverse responses to, GW momentum transports throughout the atmosphere, and the ability to make such measurements from space, have motivated a satellite mission awaiting an opportunity to fly that would quantify GW momentum fluxes and forcing throughout the lower and middle atmosphere.