

The value of direct wind measurements in the middle atmosphere

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Brief Abstract:

Over the last three decades, satellite observations of temperature and of numerous constituents have contributed greatly to our understanding of the middle atmosphere on a global scale. The most notable advances attributable specifically to satellite have occurred in the extratropical winter stratosphere, where planetary Rossby waves and polar vortex interact to produce a variety of phenomena including (i) sudden warmings (a spectacular breakdown of the vortex), (ii) lateral exchange of momentum and constituents with the tropical stratosphere (via planetary wave breaking) and (iii) vertical transport between the mesosphere and stratosphere (due to diabatic descent). These processes are observable in temperature, because the associated motions either are in *gradient-wind balance* (as true of the primary horizontal circulation), or *are required in order to maintain balance* (as true of the secondary mean meridional circulation), driven by momentum and heat fluxes which, to a satisfactory degree, are attributable to balanced motions. Their effects on constituents are readily seen.

Significant progress has also been made in the tropical middle atmosphere and global mesosphere. Satellites have observed (i) the polar mesospheric cooling associated with stratospheric warming, (ii) a remarkable phase shift of planetary waves between the stratosphere and upper mesosphere, (iii) a variety of traveling disturbances attributable to barotropic and baroclinic instability (in addition to normal modes), and (iv) several equatorial waves and instabilities, including Kelvin waves responsible for vertical momentum transport in the QBO and SAO, and inertial instabilities responsible for lateral exchange of angular momentum near the equator. This impressive array of discoveries, however, comes with a significant caveat: many of these phenomena are not “balanced” in the same sense, or to same degree, as the extratropical stratospheric phenomena noted above. In order to make sense of the observations, one needs a higher-order understanding of the momentum and thermodynamic balance satisfied by the perturbations. To be sure, theory provides guidance on how to interpret the temperature perturbations in many cases. For example, the “pancake” temperature signature of inertial instability (observed by satellite) is plausibly associated with an overturning meridional cell (not observed by satellite). It is precarious, however, to derive quantitative information on velocity

from temperature observations alone, when the exact balance relation is not known, and when missing forces and/or heat sources may be involved.

The next generation of satellite instruments will likely include direct measurements of wind, significantly extending the HRDI and WINDII measurements from UARS. This talk will review some of the advances that should be possible, including (i) a better understanding of the stratopause region, where the largest and most rapid anomalies of large-scale motion occur; (ii) an improved representation of equatorial-wave spectra and their momentum transport in relation to the QBO and SAO; (iii) observation of anisotropic gravity-wave propagation by comparing retrievals along and across the phase fronts of upward-propagating waves; (iv) global measurements of asynchronous tides in the tropical stratosphere and their relation to the diurnal cycle of convective heating in the troposphere; and (v) direct measurement and assimilation of constituent fluxes. Simultaneous measurements of temperature and wind perturbations should provide a better understanding of the momentum and thermodynamic balances and the role of missing forces and/or heat sources not resolvable by satellite.