Characterization of planetary atmospheric dynamics by Doppler tracking of a constellation of small entry probes

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The characterization of the dynamics of the atmosphere of a solar system body is an important element in understanding the overall structure of the atmosphere. The efficacy of Doppler tracking of entry probes for the in situ retrieval of wind fields has been successfully demonstrated multiple times at Venus with Venera, VEGA, and Pioneer, and more recently at Jupiter and Titan with the Galileo and Huygens probes, respectively. However, in all but one case (Pioneer Venus), the vertical profile of zonal winds was retrieved along the descent path of only a single probe. For a more complete understanding of a planet's or moon's circulation and dynamical structure, near-simultaneous wind measurements at multiple locations are needed. Of particular importance is the variation of winds at different latitudes and correspondingly different solar insolations, and diurnal changes at different longitudes/time of day. Potential targets in the solar system for new atmospheric multi-probes includes Jupiter, Saturn, Titan, Uranus, Neptune, and Venus.

The accuracy of Doppler wind retrievals is limited by the stability of both the on-board clock used to generate the probe telemetry signal and the receiver clock that is measuring the received signal frequency, and by the accuracy of the probe descent location and speed reconstruction. On-board measurements of atmospheric pressure and temperature during descent is used to determine probe descent speed, thereby removing one vector component of the probe motion. The remaining Doppler residuals will then be due to the horizontal winds alone. If the signal from each probe can be simultaneously received by the carrier spacecraft as well as from a second spacecraft or from Earth, east-west vs. north-south components of the horizontal winds can be separated.

Multiple small probes independently targeted to enter and descend through a planet's or moon's atmosphere at widely separated latitudes and longitudes can provide a more complete global characterization of a planet's atmospheric dynamics and overall circulation. Each probe would be equipped with a parachute system providing a controlled terminal descent speed, a transmit-only telecomm system including a small ultrastable oscillator with an Allan Deviation of $\sim 10^{-13}$ (100 seconds), and atmospheric structure sensors to measure atmospheric pressure and temperature. Including both dynamic and static pressure sensors permits the body-centered and atmosphere-relative descent speeds to be determined, thereby offering the capability of measuring vertical motions due to convection or atmospheric waves.