FUTURE PLANETARY PROBE DOPPLER WIND EXPERIMENT TECHNIQUES UTILIZING ADVANCED TRACKING & RANGING SUBSYSTEMS.
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Introduction: The atmospheres of the planets, including composition, clouds, energy structure, and dynamics, reflect conditions from the time the solar system formed, and the dynamical and chemical evolution of the solar system from that time. A key element of the integrated study of planetary atmospheres is dynamics: the winds, waves, convection, and turbulence that are responsible for horizontal and vertical mixing of atmospheric constituents and the upwelling of disequilibrium species that provide diagnostics of deep atmosphere compositions and chemistries. Atmospheric winds and waves are necessary to understand the overall meteorology of the planet, including the structure, location, and life cycle of clouds, and momentum transfer and energy structure within the atmosphere. Importantly, the altitude profile of the winds places valuable constraints on the location of solar energy deposition, which affects cloud structure and the static stability of the atmosphere, and can provide an indication of the relative importance to the atmospheric energy structure of solar energy relative to internal energy sources.

Measurement of the composition, cloud structure, and dynamics of the upper atmosphere beneath the clouds requires *in situ* sampling from an entry probe. Dynamics of the atmosphere can be inferred utilizing Doppler techniques to track the motions of a probe during descent. Accurate reconstructions of the probe entry and descent profile, including location, altitude, and descent speed, and the assumption of predominantly zonal (east-west) winds are used to extract the relatively small signature of probe motions resulting from atmospheric dynamics, reflected as Doppler residuals in the probe radio link frequency profile. From the Doppler residuals, the vertical profile of zonal winds can be retrieved utilizing iterative inversion algorithms that account for the integrated effect of the winds on the probe descent longitude.

Traditional Doppler wind methodologies, demonstrated on the Galileo probe mission to Jupiter [1] and the Huygens probe mission to Titan [2] depend strongly on the target – whether a large, rapidly rotating giant planet or a smaller, more slowly rotating terrestrial planet (including Titan) [3]. However, these techniques utilize only a single Doppler channel, and therefore rely on the assumption of *a priori* knowledge of probe location, descent speed, and meridional winds (usually assumed to be zero) and result in only a single component of probe motion that must be back-projected onto the local zonal direction at the probe location.

Other possible Doppler wind methodologies utilize uplink and multiprobe techniques. Uplink one-way ranging techniques from Earth to a descent probe can be used to improve the accuracy of planetary wind profiles retrieved using traditional single probe, single channel Doppler wind techniques. Advances in Radio Science flight instrument technologies and post-processing capabilities provide the opportunity to utilize one-way carrier and sequential ranging signals transmitted from Deep Space Network antennas. The DSN signals can be recorded onboard a probe-mounted radio science open-loop receiver with onboard post-processing algorithms to produce precision measurements of probe range, position, and velocity with a significant improvement to atmospheric wind retrievals [4], [5].

Doppler tracking of multiple probes by a single receiver provides the opportunity to simultaneously characterize a single component of the atmosphere dynamics at multiple locations. Additional, techniques that utilize multiple radio links comprising 1) uplink carrier and ranging from Earth to both an orbiter and probes (one signal), 2) carrier and ranging between an orbiter and probes, and 3) science telemetry from individual probes to an orbiter provide for the retrieval of multiple components of the wind dynamics at at the location of each probe.

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