Measurements of atmospheric dynamics and composition from radiometric tracking of an ice giant entry probe

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Abstract

The dynamics of planetary atmosphere including winds, waves, tides, and turbulence is a tie-point between multiple aspects of planetary structure and processes, including atmospheric composition and compositional gradients, thermal and energy structure, and the location and properties of the clouds. Radiometric tracking of an ice giant entry probe would provide the only direct measurements of the atmospheric dynamics along the probe descent path, as well as measurements of the abundance of microwave absorbing molecules along the probe relay signal raypath, expected to be primarily ammonia (NH3) or hydrogen sulfide (H2S).
The technique of Doppler tracking of a probe throughout descent has been demonstrated at Jupiter with the Galileo probe and at Titan with the Huygens probe. By utilizing an ultrastable oscillator on both the transmit and receive sides of the probe telemetry relay signal, the time variation of the measured relay signal frequency provides a direct measure of the line of sight component of probe speed. Under the assumption of predominantly zonal winds and negligible meridional winds, as well as an accurate reconstruction of probe descent speed from Atmospheric Structure Instrument measurements of atmospheric pressure and temperature, the vertical profile of absolute zonal wind speeds can be retrieved with an altitude resolution that depends on descent speed, from several km in the upper atmosphere to several hundred meters in the deeper atmosphere. Additionally, careful analysis of the Doppler residuals can provide the signature of atmospheric waves, convection, and turbulence, along with other probe dynamical effects such as pendulum motion under the parachute, probe spin, and aerodynamic buffeting.

If two receivers are available to track the probe relay signal, either with secondary receivers in orbit such as MarCO-type smallsats, or from Earth, a second component of the wind speeds can be retrieved thereby providing a two-dimensional wind determination.

Measurements of the time-varying relay link signal strength at the receiver would provide a profile of atmospheric absorbers along the probe raypath. This measurement would complement composition measurements made the probe mass spectrometer. A more difficult measurement would be to characterize the scale size of atmospheric turbulence along the probe relay signal raypath by measuring the effect of atmospheric scintillation on the probe

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relay signal strength measured at the receiver.

The impact on probe instrumentation, power, mass, and mission design would be relatively minor. Reconstruction of the probe release, coast, and entry interface arrival point, probe entry trajectory reconstruction including the time profile of heat shield ablation and overall probe mass during entry, and accurate reconstruction of the initial probe descent location is needed to provide the most accurate wind retrievals. Additionally, the proper evolution of the probe-carrier relative geometry would provide additional enhancement to the wind retrieval accuracy.
This presentation will present the scientific objectives, measurement requirements, and expected accuracies of the profile of zonal winds and atmospheric absorption, with a preliminary attempt to quantify the effect of variations in probe descent trajectory reconstructions and carrier overflight trajectory.

Keywords: Doppler Wind Experiment, Atmospheres, Dynamics, Descent Probe