EPSC Abstracts
Vol. 6, EPSC-DPS2011-1399-1, 2011
EPSC-DPS Joint Meeting 2011

Saturn Probe Doppler Wind Experiment

D.H. Atkinson (1), T.R. Spilker (2), and S.W. Asmar (2)

(1) University of Idaho, Moscow, ID 83844-1023 USA (atkinson@uidaho.edu / Fax 1-208-885-7579), (2) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109-8099, USA

Abstract

The atmospheres of the giant planets represent time capsules dating to the epoch of solar system formation. For a complete and self consistent understanding of a giant planet, an integrated knowledge of the structure of the planet's atmosphere is needed, including composition, clouds, energy structure, and dynamics. In particular, atmospheric dynamics - winds, waves, convection, and turbulence - are responsible for horizontal and vertical mixing of atmospheric constituents including principal volatiles and their associated isotopes, and upwelling of disequilibrium species providing diagnostics of deep atmosphere composition and chemistries. Winds and waves are essential to understanding the meteorology including the structure, location, and life cycle of clouds, and momentum transfer and overall energy structure of the atmosphere. The altitude profile of the winds places valuable constraints on the location of solar energy deposition which can affect cloud structure and the static stability of the atmosphere, and can also provide an indication of the relative importance to the atmospheric energy structure of solar energy relative to internal energy sources.

Although some measurements of the composition, cloud structure, and dynamics of upper atmospheres are possible from remote sensing, to measure beneath the clouds requires *in situ* sampling from an atmospheric entry probe. Additionally, the dynamics of the atmosphere can be inferred by utilizing Doppler techniques to track the probe motions throughout descent. Accurate modelling of the entry and descent profile of an entry probe, 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 is retrieved utilizing an iterative inversion algorithm that accounts for the integrated effect of the winds on the probe descent longitude. Further analysis of the probe radio link frequency residuals can also provide evidence of atmospheric waves and turbulence, as well as probe microdynamics including spin and pendulum motion.

The heritage of outer solar system Doppler wind retrievals comprises measurements of the zonal winds on Jupiter by the Galileo probe in 1995 and the Titan zonal winds by Huygens a decade later. The Jovian zonal wind profile along the probe descent was retrieved under the assumption of negligible meridional winds. Accurate modelling of the probe descent speed from measurements of atmospheric pressure and temperature, and the assumption of hydrostatic equilibrium allowed the development of a Doppler residuals inversion algorithm to retrieve the zonal winds while accounting for both the initial uncertainty in probe descent longitude and the changing probe longitude due to the integrated effect of the winds. Prior to the arrival of the Galileo probe, virtually all models predicted the Jupiter zonal winds would decrease with depth. The discovery of a large positive shear layer between 1 and 4 bars has revolutionized our thinking of the energy structure and overall dynamics of the Jovian atmosphere. In 2005 the profile of zonal winds on Titan was measured using a significantly simpler retrieval algorithm that did not include probe longitude drift effects in the first iteration, since the small size and slow rotation of Titan make the effect of initial uncertainties and the integrated winds on the probe descent longitude negligibly small.

A Saturn probe Doppler Wind Experiment will be comparable to the Galileo Jupiter Doppler wind methodology. Measurement of the Saturn zonal wind structure will depend on a mission design that includes a rapidly varying probe/carrier (receiver) geometry, preferably including probe meridian crossing by the carrier. The only hardware requirements are ultrastable oscillators on both the probe (transmitter) and carrier (receiver) sides of the radio link, a significantly smaller cost than most instruments comprising the probe science payload. The relatively low cost, and small impact on the mass

and power budget required to perform the Saturn probe Doppler wind measurement provides a very high science return and makes the Saturn probe Doppler Wind Experiment an attractive option for enhancing total mission science return with minimal impact on mission resources (mass and cost) and mission design.