A Final Report to

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Galileo Net Flux Radiometer Data Analysis

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Submitted by

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Galileo Net Flux Radiometer Data Analysis

I. INTRODUCTION

This report describes analysis of the Galileo Net Flux Radiometer (NFR), an instrument mounted on the Galileo probe, a spacecraft designed for entry into and direct measurements of Jupiter's atmosphere. The grant period for NAG2-1028 began on 1 April 1996, nearly four months after Jupiter atmospheric entry on 7 December 1995, and at which time the probe data were fully recovered and quick look analysis completed. This grant supported the detailed data analysis, resulting in a preliminary paper in Science in May 1996 and a final paper in the Journal of Geophysical Research in September 1998, with conference papers presented within this period.

II. BACKGROUND

The Galileo Net Flux Radiometer is a probe instrument designed to measure net radiation flux and upward flux in five spectral bands during descent into the Jovian atmosphere. Solar energy deposition and planetary radiation losses from the 0.1 bar level to at least the 10 bar level were to be measured to assess the nature of radiative drive for atmospheric motions, the location and optical properties of clouds and hazes, and the amount of water vapor. (Because of a late parachute deployment the starting pressure level was about 0.4 bars.) Our Space Science Reviews paper (Sromovsky et al., 1992) describes the science objectives, instrument design, and expected performance of the NFR; detailed calibration methods and results were published in the proceedings of The Fourth Infrared Sensor Calibration Symposium (Sromovsky and Fry, 1994).

During the nearly 4-year Galileo launch delay resulting from the Challenger explosion the NFR instrument was modified to improve its performance and calibration. New detectors were procured and installed, digital and analog electronics were modified to improve optical chopping symmetry, the detector package was sealed in Xenon to eliminate both pressure perturbation noise and crosstalk, and a new bearing and bearing support fixture were installed. This ultimately resulted in a hybrid flight instrument consisting of the SN02R2 electronics mated to the SN01R2 optical head. For a detailed report of this work see the report by Sromovsky and Best (1990).

The calibration of the NFR was made especially difficult by its extremely wide spectral range, large field of view, and widely varying detector and optics temperatures. Although we were able to complete extensive calibration and characterization of the flight instrument (in non-flight configurations) prior to launch, there remained unresolved issues regarding spectral response and temperature dependence that required additional measurements of spare components and the flight spare instrument, and considerable additional analysis. Much of this was completed with previous grant support, but some required additional support by NAG2-1028. Unfortunately, some possibly important aerodynamic effects were not fully investigated due to limited resources.

In preparation for data analysis we developed radiation transfer tools for treating wavelengths from UV to far infrared, solar and planetary radiation, including emission and scattering simultaneously. In the solar channels the interpretation is complicated by strong azimuthal variations as the probe spins. We also improved our spectroscopic data base of line position, strength, and shape in order to best interpret instrument measurements.

III. RESULTS OF NFR DATA ANALYSIS

A) NFR Data Archival in the Planetary Data System

Raw digital counts, algorithms and calibrations used to convert raw digital counts into physically meaningful science products, the science products we derived, and documentation concerning the instrument and analysis procedures were placed into the PDS archive, following NASA format requirements.

B) Presentation of Results at Scientific Meetings

The following presentations were supported by the subject grant. Copies of the published abstracts are attached.

"Ammonia Ice Cloud Structure at the Probe Entry Site" by L.A. Sromovsky, M.T. Lemmon, and A.D. Collard (1997) *Bull. Am. Astron. Soc.* **29**, 1006.

"The Deep Jovian Water Abundance from Remote and In-Situ Observations" by A.D. Collard, L.A. Sromovsky, and G.L. Bjoraker (1997) *Bull. Am. Astron. Soc.* **29**, 1006.

"Thermal Radiative Fluxes in Jupiter's Atmosphere: Implications of the Galileo Probe Net Flux Radiometer Results" by A.D. Collard, L.A. Sromovsky, P.M. Fry, G.S. Orton, MK.T. Lemmon, and M.G. Tomasko (1996) *Bull. Am. Astron. Soc.* **28**, 1134.

"Assessment of Uncertainties in the Galileo Net Flux Radiometer Measurements" by F. Best, L.A. Sromovsky, A.D. Collard, P.M. Fry, and H.E. Revercomb (1996) *Bull. Am. Astron. Soc.* **28**, 1134.

"Inversion of Galileo Net Flux Radiometer Solar Channel Observations for Cloud Properties" by M.T. Lemmon, M.G. Tomasko, L. Sromovsky, and A. Collard (1996) *Bull. Am. Astron. Soc.* **28**, 1144.

"Initial Results from the Galileo Net Flux Radiometer" by L.A. Sromovsky, A.D. Collard, P.M. Fry, H.E. Revercomb, F.A. Best , G. S. Orton, M.G. Tomasko, M. Lemmon, R.S. Freedman, J.L. Hayden (1996), presented at the July 1996 COSPAR meeting in Birmingham, England.

"Modelling of Observations by the Net Flux Radiometer on the Galileo Entry Probe" by A.D. Collard, L.A. Sromovsky, P.M. Fry, G.S. Orton, R.S. Freedman, M. Lemmon, and M.Tomasko (1996), presented at the July 1996 COSPAR meeting in Birmingham, England.

"Implications of Galileo Probe Data for the Structure and Dynamics of Jupiter's Atmosphere" by G. Schubert, D. H. Atkinson, D. M. Hunten, G. S. Orton, A. Seiff, L. Sromovsky, and R. E. Young. Paper presented in the Special Galileo Session at the spring meeting of the American Geophysical Union, abstract published in *EOS*, 20 May 1996.

"Early Results of the Galileo Net Flux Radiometer Experiment" by L.A. Sromovsky, A.D. Collard, P.M. Fry, H.E. Revercomb, F.A. Best ,G. Orton, M.G. Tomasko, M. Lemmon, R. Freedman, and J. Hayden. Paper presented in the Special Galileo Session at the spring meeting of the American Geophysical Union, abstract published in *EOS*, 20 May 1996.

C) Publication of Results in Peer-Reviewed Journals

1) Science

The preliminar NFR results were published in the 10 May 1996 issue of Science in the article listed below. A copy of the abstract page is attached.

"Solar and Thermal Fluxes in Jupiter's Atmosphere: Initial Results of the Galileo Probe Net Flux Radiometer" by L. A. Sromovsky, F.A. Best, A.D. Collard, P.M. Fry, H.E. Revercomb, R.S. Freedman, G.S. Orton, J.Hayden, M.G. Tomasko, and M. Lemmon (1996) *Science* **272**, 851-854

2) Journal of Geophysical Research

The final NFR results were published in the Galileo Probe special issue of the Journal of Geophysical Research on 25 September 1998. The reference details are given below and a copy of the abstract page is attached.

"Galileo Probe Measurements of Thermal and Solar Radiation Fluxes in the Jovian Atmosphere" by L. A. Sromovsky, A.D. Collard, P.M. Fry, G.S. Orton, M.T. Lemmon, M.G. Tomasko, and R.S. Freedman (1997) *J. of Geophys. Res.* **103** (E10), 22775-22790.

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Sromovsky, L.A., F.A. Best, A.D. Collard, P.M. Fry, H.E. Revercomb, R.S. Freedman, G.S. Orton, J.Hayden, M.G. Tomasko, and M. Lemmon (1996b) Solar and Thermal Fluxes in Jupiter's Atmosphere: Initial Results of the Galileo Probe Net Flux Radiometer. *Science* **272**, 851-854

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V. ATTACHMENTS

dicated, although the degree of depletion is much less than that inferred from the Voyager result. Another argument in favor of an actual depletion of He is the large depletion of Ne observed by the mass spectrometer on the Galileo probe (*17*). A plausible explanation that deserves further exploration (*18*) is that Ne is soluble in the He-rich drops and is carried down by them.

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8. To write down the aggregate equation for calculating q_{He} we introduce the refractivities $R = 10^6\,(n - 1)$. Also, all parameters with the superscript 0 are taken at standard temperature and pressure. Other symbols are defined in the text before Eq. 2. One then obtains

$$q_{\mathrm{He}} = + \frac{R^0_{\mathrm{H}_2} Z^0_{\mathrm{H}_2} - R^0_r Z^0_r}{R^0_{\mathrm{H}_2} Z^0_{\mathrm{H}_2} - R^0_{\mathrm{He}} Z^0_{\mathrm{He}}} + \frac{1}{R^0_{\mathrm{H}_2} Z^0_{\mathrm{H}_2} - R^0_{\mathrm{He}} Z^0_{\mathrm{He}}} \left(\frac{10^6\,\lambda P^0}{LT^0}\right)\left(\frac{F^e - F^l}{P^e_s/T^e_s Z^e_s - P^l_s/T^l_s Z^l_s}\right) + \frac{R^0_r Z^0_r}{R^0_{\mathrm{H}_2} Z^0_{\mathrm{H}_2} - R^0_{\mathrm{He}} Z^0_{\mathrm{He}}}\left[1 - \frac{P^e_r/T^e_r Z^e_r - P^l_r/T^l_r Z^l_r}{P^e_s/T^e_s Z^e_s - P^l_s/T^l_s Z^l_s}\right] \tag{3}$$

$$- (0.03301)q_{\mathrm{He,uncorr.}} - 0.02189 + (7.933 \times 10^{-5})T_{\mathrm{absorber}}$$

9. For a binary gas mixture of H_2 and He, the mass fraction Y is obtained from the He mole fraction q_{He} by

$$Y = \frac{q_{\mathrm{He}}}{m_{\mathrm{H}}\dfrac{2}{m_{\mathrm{He}}} + \left(1 - m_{\mathrm{H}}\dfrac{2}{m_{\mathrm{He}}}\right)q_{\mathrm{He}}} \tag{4}$$

with m_{H2} and m_{He} being the masses of a H_2 molecule and a He atom, respectively ($m_{\mathrm{H2}}/m_{\mathrm{He}}$ = 0.5036).
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19. We thank our many colleagues and students for their diligent and untiring efforts on behalf of the HAD experiment. Over the years, H. J. Hoffmann contributed heavily to the instrument development effort; W. Mett was responsible for radiation hardening of instrument subsystems and W. Schulte for laboratory simulations of the instrument descent into the jovian atmosphere; H. Schütze performed the calibration and environmental tests of the three units of HAD instruments; H. Schütze and G. Lehmacher supported integration of the instrument into the spacecraft and systems tests; K. Pelka and G. Lehmacher assisted us through software development; and W. B. Hubbard was most helpful with advice on the high-pressure behavior of H-He mixtures. The interferometer part of the HAD instrument was developed by C. Zeiss, Oberkochen, Germany, and the other portion of the HAD was developed by Messerschmitt-Bölkow-Blohm, Ottobrunn, Germany. Supported by grants 50QJ90060 and 50QJ9501 of DARA GmbH; the German Space Agency, Bonn; and contract 958696 from the Jet Propulsion Laboratory.

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Solar and Thermal Radiation in Jupiter's Atmosphere: Initial Results of the Galileo Probe Net Flux Radiometer

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M. G. Tomasko, M. T. Lemmon

The Galileo probe net flux radiometer measured radiation within Jupiter's atmosphere over the 125-kilometer altitude range between pressures of 0.44 bar and 14 bars. Evidence for the expected ammonia cloud was seen in solar and thermal channels down to 0.5 to 0.6 bar. Between 0.6 and 10 bars large thermal fluxes imply very low gaseous opacities and provide no evidence for a deep water cloud. Near 8 bars the water vapor abundance appears to be about 10 percent of what would be expected for a solar abundance of oxygen. Below 8 bars, measurements suggest an increasing water abundance with depth or a deep cloud layer. Ammonia appears to follow a significantly subsaturated profile above 3 bars. Unexpectedly high absorption of sunlight was found at wavelengths greater than 600 nanometers.

As the Galileo probe descended into Jupiter's atmosphere, the net flux radiometer (NFR) measured net solar and thermal radiation fluxes to determine where and how the atmosphere was being heated and cooled by radiation. The net flux, which is the difference between upward and downward fluxes, is useful because its divergence is equal to the radiative power per unit volume absorbed by the atmosphere. Thus, the vertical derivative of the NFR measurements defines the vertical distribution of radiative heating and cooling, which leads to buoyancy differences that power atmospheric circulations. NFR data also contain information about the opacity structure of Jupiter's atmosphere, which helps determine the distribution of particles and gases through which radiative transfer occurs. The relation between opacity sources and the radiative energy exchanges is important to understand in applying these very local measurements at the probe entry site, where exceptional atmospheric clarity is implied by ground-based observations (*1*), to other regions of Jupiter having different cloud structures and absorbing gas profiles.

The NFR (*2*) used an optical head that extended through the probe wall to obtain views of the jovian atmosphere. It sampled upward and downward fluxes with 40° (full angle) conical fields of view centered at directions ±45° from horizontal, avoiding most of the direct solar beam, but admitting a small fraction near the limits of its angular response. The NFR made measurements in five parallel spectral channels (Fig. 1). Two

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Galileo probe measurements of thermal and solar radiation fluxes in the Jovian atmosphere

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Abstract. The Galileo probe net flux radiometer (NFR) measured radiation fluxes in Jupiter's atmosphere from about 0.44 to 14 bars, using five spectral channels to separate solar and thermal components. Onboard calibration results confirm that the NFR responded to radiation approximately as expected. NFR channels also responded to a superimposed thermal perturbation, which can be approximately removed using blind channel measurements and physical constraints. Evidence for the expected NH_3 cloud was seen in the spectral character of spin-induced modulations of the direct solar beam signals. These results are consistent with an overlying cloud of small NH_3 ice particles (0.5–0.75 μm in radius) of optical depth 1.5–2 at 0.5 μm. Such a cloud would have so little effect on thermal fluxes that NFR thermal channels provide no additional constraints on its properties. However, evidence for heating near 0.45 bar in the NFR thermal channels would seem to require either an additional opacity source beyond this small-particle cloud, implying a heterogeneous cloud structure to avoid conflicts with solar modulation results, or a change in temperature lapse rate just above the probe measurements. The large thermal flux levels imply water vapor mixing ratios that are only 6% of solar at 10 bars, but possibly increasing with depth, and significantly subsaturated ammonia at pressures less than 3 bars. If deep NH_3 mixing ratios at the probe entry site are 3–4 times ground-based inferences, as suggested by probe radio signal attenuation, then only half as much water is needed to match NFR observations. No evidence of a water cloud was seen near the 5-bar level. The 5-μm thermal channel detected the presumed NH_4SH cloud base near 1.35 bars. Effects of this cloud were also seen in the solar channel upflux measurements but not in the solar net fluxes, implying that the cloud is a conservative scatterer of sunlight. The minor thermal signature of this cloud is compatible with particle radii near 3 μm, but it cannot rule out smaller particles. Deeper than about 3 bars, solar channels indicate unexpectedly large absorption of sunlight at wavelengths longer than 0.6 μm, which might be due to unaccounted-for absorption by NH_3 between 0.65 and 1.5 μm.

1. Introduction

On December 7, 1995, the Galileo probe net flux radiometer (NFR) made the first in situ measurements of radiative fluxes within Jupiter's atmosphere. The instrument's first targets were the primary drives for atmospheric motions: absorbed solar radiation and the flux of energy from the planet's interior. Because solar radiation absorption and planetary emission occur at different places and altitudes, net radiative heating and cooling result in buoyancy differences that force atmospheric motions. An understanding of Jovian circulation thus requires knowledge of the vertical profile of radiative heating and cooling and also its horizontal distribution. The NFR contributed to this understanding by measuring the difference between upward and downward radiation fluxes, the net flux, as a function of altitude during probe descent. Because the radiative power per unit area absorbed by an atmospheric layer is equal to the difference in net fluxes at the boundaries of the layer, the vertical derivative of the net flux defines the radiative energy absorbed per unit volume and thus defines the radiative heating (or cooling) of the atmosphere.

However, because the Galileo probe provided only one sample profile of Jovian atmospheric conditions at one location and time, it is especially important to understand why the measured radiative energy deposition occurs: we might then have some idea of how to apply the results to other atmospheric regions which were not sampled. The NFR experiment contributes to understanding horizontal variations by making spectral measurements that illuminate the mechanisms by which radiation interacts with the atmosphere. Five broad spectral bands were used to separate the vertical distribution of radiative heating by sunlight from the vertical distribution of radiative cooling and heating by exchanges of thermal radiation. The profiles of radiation flux also contain signatures of the substances that absorb and emit radiation (gases and particulates) and thus provide important independent constraints on models of atmospheric composition and cloud structure.

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Abstracts for the AGU Spring Meeting
May 20—24, 1996
Union

Planetology

P11A CC: 319 Mon 0830h

Galileo Jupiter Encounter I

(joint with A, SM)

Presiding: **R E Young,** NASA Ames Research Center; **T V Johnson,** NASA Jet Propulsion Laboratory

P11A-4 0915h

Implications of Galileo Probe Data for the Structure and Dynamics of Jupiter's Atmosphere

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Results from the Galileo probe experiments will be analyzed for their implications regarding the structure and dynamics of Jupiter's atmosphere at the probe entry site. Present data on the composition, water content, cloud particle density, and thermal structure reveal no evidence at this location on Jupiter for the moist convective water cloud region expected prior to the Galileo mission. The atmosphere at the probe entry site is close to dry adiabatic over a significant fraction of the pressure interval explored by the Galileo probe. The probe entry site has been identified as within, or in close proximity to, a 5μm hotspot. A major issue is the relevance of the probe data to other locations on Jupiter. The persistence of the measured zonal winds to the deepest depths probed argue that the source of the winds lies in a deep global-scale convective system responsible for the upward transport of Jupiter's internal heat flux.

P11A-12 1135h INVITED

Early Results of the Galileo Net Flux Radiometer Experiment

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During the Galileo probe's descent into Jupiters atmosphere the Net Flux Radiometer (NFR) measured vertical profiles of upward and net radiation fluxes from about 450 mb to approximately 13 bars. Two solar channels (B = 0.3 - 3.5 microns, E = 0.6 - 3.5 microns) measured the vertical distribution of solar heating and the differential absorption effects of cloud particulates and methane gas. Three thermal channels (A = 3.5- 200 microns; C = 3.5 - 5.8 microns; D = 14 - 35 microns) measured the vertical distribution of cooling and heating via planetary radiation, and the differential effects of cloud and gaseous absorption. A blind channel (F) measured non-radiative detector thermal perturbations needed for correcting radiometric channels. Evidence for the expected ammonia cloud was seen in the attenuation of signal modulations produced by probe spin, and heating by planetary radiation near the expected base of the cloud (approximately 600mb). Radiative signatures (local radiative heating or cooling) were not seen for any cloud layers between 600 mb and 13 bars, and thermal net flux levels in this range were much larger than expected, implying water vapor mixing ratios that are 5-10 times less than solar in the 3 - 13 bar range and that both ammonia and water are significantly subsaturated for p ¡ 3 bars. Solar flux profiles indicate larger than expected absorption of radiation in the red part of the spectrum. These conclusions apply only at the probe entry site and may be modified by improved corrections for detector thermal perturbations.

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Bulletin
of the American Astronomical Society

19.05

Ammonia Ice Cloud Structure at the Galileo Probe Entry Site

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The Galileo Probe Net Flux Radiometer (NFR) measured in channel A (3 - 200μm) a radiative heating above 600 mb consistent with a large-particle NH_3 cloud of optical depth 2 at 0.5 μm. Evidence for this cloud also appears in the large correlated variation of the NFR solar channels between deployment and 500-600 mb, an effect expected from probe spin-modulation of direct solar beam input at the edge of the NFR field of view. The way the modulations decayed with depth seemed to require an optical depth of 1.5-2 of cloud material extending down to the 500-600 mb level (Sromovsky *et al.*, *Science* **272**, 1996), in accord with the NH_3 ice cloud base inferred from remote observations (West *et al.*, *Icarus* **65**, 1986). However, the low level of particulate scattering measured by the Nephelometer in this region (Ragent *et al.*, *Science* **272**, 1996) has been difficult to reconcile with this picture. Subsequently, a quantitative analysis of the much smaller solar modulations in channel A ($\lambda > 3\mu$m) has provided new insights: (1) the ratio of the Channel A modulation amplitude to that of Channel B (0.3-3.5μm) is a factor of 4-5 larger than would be expected for an unmodified solar spectrum, strongly suggesting that the cloud particles are small enough (< 1 μm) to attenuate B much more than A; and (2) the channel B modulation amplitude is too large to allow that attenuation unless the direct beam view is enhanced by a tilt of the probe spin axis, perhaps by as much as 15-20°. This scenario still requires a cloud optical depth of 1-2 to explain the A/B ratio, but that cloud need not reach the 600 mb level. The attenuation we initially attributed to accumulating cloud opacity during descent might instead be caused by a decay of the probe pendulum motion, thereby reducing the solar modulation amplitude without requiring local particulate opacity that was not seen by the Nephelometer.

19.06

The Deep Jovian Water Abundance from Remote and In Situ Observations

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We now have three independent sources of information concerning the deep water vapour volume mixing ratio (vmr) in a Jovian North Equatorial Belt (NEB) hot spot. To the remote spectral observations in the 5μm window from the Kuiper Airbourne Observatory (Bjoraker *et al.*, *Icarus* **66**, 1986) and from the Voyager IRIS instrument (Kunde et al., *Astrophys. J.* **263**, 1982; Carlson *et al.*, *JGR* **98**, 1993) the Galileo probe has added in situ observations by the Neutral Mass Spectrometer (NMS) (Niemann *et al.*, *Science* **272**, 1996) and the Net Flux Radiometer (NFR) (Sromovsky *et al.*, *ibid.*) plus more spatially resolved remote sounding measurements from the Near Infrared Mapping Spectrometer (Carlson *et al.*, *Science* **274**, 1996).

Inverting pre-Galileo 5μm hot spot spectra to obtain water vapour profiles was an ill-defined problem. The data could be equally well explained by approximately solar water vapour abundances and thick water cloud or by substantially sub-solar water vapour abundances and no deep cloud. This ambiguity was resolved when the Galileo Probe's instruments did not detect a deep, massive water cloud (the NFR and the Nephelometer (Ragent *et al.*, *Science* **274**, 1996)) and found substantially sub-solar water vapour vmrs (the NFR and the NMS).

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Assessment of Uncertainties in the Galileo Net Flux Radiometer Measurements

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The Galileo Net Flux Radiometer (NFR) measured vertical profiles of upward and net radiation fluxes in Jupiter's atmosphere beginning at 450 mb and extending to about 13 bars. Fluxes in two solar and three thermal spectral bands were separately measured to isolate the relative influences of particulates and gaseous absorbers on the radiative energy exchanges. All of these channels responded to both the desired radiation inputs and also to an undesired non-radiative thermal perturbation. The perturbation was measured by a sixth radiatively blind channel for use in correcting the other channels. However, the correction has been complicated by the fact that the perturbations clearly did not have the same amplitude in every channel. Preliminary results (Sromovsky *et al.*, Science, pp. 851-854, 1996) are based on subtracting from each detector signal a channel-dependent, but time-independent, fraction of the blind channel signal. These fractions were rather well determined for net flux measurements by requiring the corrected flux profiles to satisfy simple physical constraints, some of which are guided by radiation transfer model calculations. Because of fewer samples and larger noise levels, the same approach did not lead to very tight constraints on the upflux measurements. To further assess the validityof this correction procedure we examine internal consistency, the results of on-board calibration measurements, pre-launch instrument wind-tunnel tests, and thermal model simulations of detector responses to plausible perturbation mechanisms. A second correction, for a temperature dependent responsivity, is also a current source of uncertainty, mainly between 13 and 16 bars, because detector temperatures prematurely exceeded the range explored by pre-launch calibration measurements. New spare instrument tests can better define both the perturbation and responsivity uncertainties affecting the NFR results. This research was supported by grant NAG2-1028 from the NASA Ames Research Center.

21.04

Thermal Radiative Fluxes in Jupiter's Atmosphere: Implications of the Galileo Probe Net Flux Radiometer Results

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The Galileo Probe Net Flux Radiometer (NFR) made *in situ* observations of the up-welling and net solar and thermal radiative fluxes in the Jovian atmosphere from the 0.4-bar level down to around 13 bars. Thermal flux measurements were made in three spectral channels: a broadband channel (A, 3.5–200 μm); a longwave channel (D, 14–35 μm); and a 5-μm window channel (C, 3.5–5.8 μm).

Preliminary results were presented by Sromovsky *et al.* (*Science, 272,* pp. 851–854, 1996). A two-stream line-by-line radiative transfer model was used to calculate the observed net and up-fluxes in the thermal channels. The net fluxes measured in both channels A and C were much larger than would be expected for near-solar abundances of water vapour and ammonia. It is found that a reduction in the volume mixing ratio of H_2O to 10% of the solar value in the deep atmosphere (below the 6-bar level) is required to match the observations. There is no indication of the predicted massive water cloud near 5 bars but there is evidence for clouds at 1.35 bars and 0.6 bars which would correspond to the predicted NH_4SH and NH_3 layers respectively. High channel A net fluxes in the early part of the descent imply very low abundances of NH_3 at pressures below 1 bar.

The derived cloud properties and abundances of NH_3 and H_2O are used to simulate total thermal flux profiles and heating rates, and the observations that would be expected from the Voyager IRIS experiment and ground-based observations from the NASA IRTF CSHELL instrument.

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INITIAL RESULTS FROM THE GALILEO NET FLUX RADIOMETER

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The Galileo Probe Net Flux Radiometer (NFR) measured the vertical profiles of upward and net radiation fluxes in Jupiter's atmosphere in five spectral channels. Two solar channels (B = 0.3 - 3.5 µm, E = 0.6 - 3.5 µm) measured the vertical distribution of solar heating and the differential absorption effects of cloud particulates and methane gas. An infrared window channel (C = 3.5 - 5.8 µm) sensed the combined effects of clouds and water vapor absorption. A water-sensitive channel with less cloud sensitivity (D = 14 - 35 µm) helped to separate the two absorber effects. A broadband thermal channel (A = 3.5- 200 µm) measured the vertical distribution of radiative cooling in Jupiter's atmosphere. A blind channel (F) measured offsets for use in correcting the radiometric channels. These observations contribute to our understanding of Jovian dynamics, to the detection of cloud layers and determination of their opacities, and to the estimation of water vapor abundance. However, their full interpretation requires detailed modeling of spectral radiances within Jupiter's atmosphere, including the effects of all gas species and particulates that contribute measurable energy exchanges.

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MODELING OF OBSERVATIONS BY THE NET FLUX RADIOMETER ON THE GALILEO ENTRY PROBE.

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The Net Flux Radiometer experiment entered the Jovian atmosphere on 7th December 1995 on the Galileo entry probe. During the hour-long descent, the net and upward radiative flux was measured for five channels. Two channels (B and E) sampled wavelengths shorter than 3.5µm, where solar radiation is dominant, while the remainder (A, C and D) observed thermal emission from the atmosphere.

Detailed modeling of the jovian spectrum in these spectral regions are required to properly interpret these data. This includes the modeling of the spectrum of various molecular species under jovian conditions and of the radiative characteristics of the clouds (NH_3, NH_4SH and H_2O) expected to be present. Using these calculations molecular abundances and cloud macrophysical and microphysical properties can be inferred from the NFR observations. These models are also used to infer the true radiative fluxes from the spectrally and angularly weighted fluxes directly measured by the NFR.

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