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The thermal response to waves propagating through Jupiter's middle atmosphere

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Abstract

Using high-spectral resolution ground-based observations of methane emission in the mid-infrared and modeling them with a line-by-line radiative transfer program, we infer the 3-dimensional temperature structure of a portion of Jupiter's mid- to low-latitude stratosphere in January 2005 and October 2009. The retrieved temperatures display strong evidence for Jupiter's equatorial Quasi-Quadrennial Oscillation, QQO, and a serendipitous discovery of what appear to be several vertically and horizontally resolved thermal structures at northern mid-latitudes in October 2009. We report on our observations, inferred temperatures, and our attempt to connect the partial latitude and longitude coverage of our high-spectral resolution observations to mid-infrared imaging observations in order to place our 3D temperature retrievals into a global context.

1. Introduction

Orton et al. [1] examined over a decade of IRTF raster scans of Jupiter at 7.8 μm, a wavelength sensitive to methane (CH_4) emission from Jupiter's stratosphere. Because methane is well mixed, these observations tracked temperature variations in the stratosphere, sensitive to 10-30 mbar. They noted that approximately every 4 (Earth) years, the relative amplitudes of temperatures (i) at the equator and (ii) at ±14° latitude would reverse. Leovy et al. [2] interpreted these periodic reversals as a manifestation of the oscillation of a mean zonal wind. They suggested that a phenomenon similar to the Earth's Quasi-Biennial Oscillation (QBO) occurs in the Jovian stratosphere. The QBO, discovered in the Earth's atmosphere by [3] has been intensively studied because its phase is linked to inter-annual variability in the strength of the polar vortex, ozone abundances and aerosol abundances [4]. That such a phenomenon exists in Jupiter's atmosphere is important in understanding the potential role the phenomenon may play in the transfer of energy and momentum in Jupiter's stratosphere. Leovy et al. [2] suggested the name Quasi-Quadrennial Oscillation (QQO) for the wave phenomenon in Jupiter to emphasize its close relationship with the QBO.

Since the QQO is made manifest to remote sensing by vertically alternating warm and cold levels that descend to higher pressures over time, observations capable of retrieving vertical information within Jupiter's stratosphere should reveal this wave in unprecedented detail. It was for this reason that we chose to scan map Jupiter's mid- to low-latitudes in 2005 and 2009 using TEXES, the Texas Echelon cross-dispersed Echelle Spectrograph [5], mounted on the NASA infrared telescope facility, IRTF.

2. Observations

We observed Jupiter in January 2005 and October 2009 using the high-spectral resolution mid-infrared spectrograph TEXES mounted on the IRTF. By stepping the entrance slit of TEXES across Jupiter by half slit width steps we were able to map CH_4 emission between 1244 and 1251 cm^{-1} from Jupiter with a spatial resolution of 4º of longitude and latitude at the sub-Earth point. This spectral region, containing 6 strong and 3 moderate emission features, is sensitive to Jupiter's stratosphere between 5 and 0.01 mbar. This vertical sensitivity combined with the mapping capability of TEXES allowed for the retrieval of data sensitive to zonal, meridional, and vertical variations in stratospheric temperatures.

3. Results

Due to the fact that the QQO is a vertical wave which is associated with the mean zonal jet and hence is

nearly the same at all longitudes, we zonally averaged the TEXES data to increase the signal to noise. The results of the temperature retrievals using the forward modelling method described by [6] are presented in Figure 1.

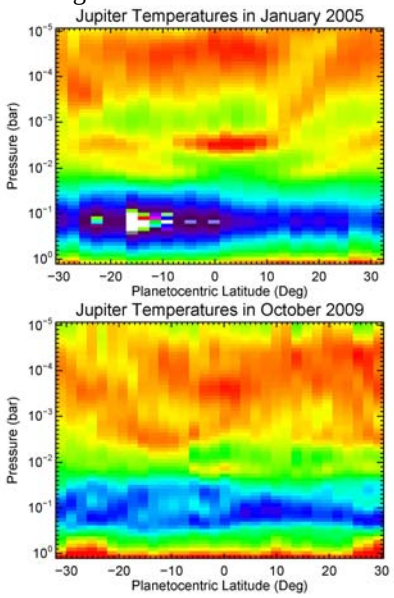

Figure 1: Side view of the retrieved temperatures of Jupiter's QQO from TEXES observations of CH_4 emission in Jan. 2005 (top) and Oct. 2009 (bottom).

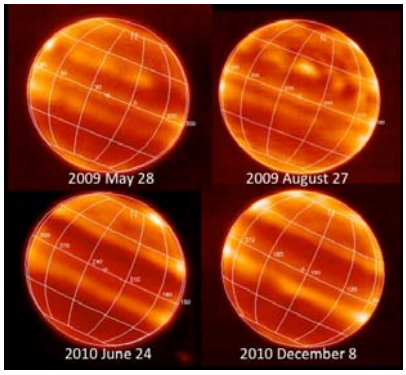

Figure 2. Brightness variations in these MIRSI images correspond to temperature variations in Jupiter's stratosphere. Note the wave pattern at ~20º lat. seen in the 2009 images fades by June 2010.

Modeling the TEXES fully resolved longitude and latitude scan maps from October 2009 uncovered what appears to be a portion of a planetary scale wave at ~20º latitude. However, due to the limited longitude coverage of the TEXES dataset a global view was not possible. We remedy this by coupling our observations and temperature retrievals with mid-infrared imaging of CH_4 emission from Jupiter recorded with the MIRSI imager on the NASA IRTF (Fig. 2). The vertical information on the mid-latitude wave retrieved from the TEXES observations combined with the spatial and temporal information provided by MIRSI images, offer an unprecedented glimpse of stratospheric wave interactions in Jupiter's stratosphere.

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