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On the content of minor species in the upper Jupiter troposphere as inferred from JIRAM Juno data

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Abstract

The content of several minor species (water, ammonia, phosphine, germane, arsine) in the upper troposphere of Jupiter has been inferred from the measurements of the Jovian Infrared Auroral Mapper (*JIRAM*) - on board of the Juno NASA spacecraft - acquired during thirteen perijoves passages between Aug. 27th 2016 and Sept. 7th 2018. The resulting retrievals set, albeit sparse in space, allows one to compute averages over longitudes at a fixed latitude, to create latitudinal profiles for infrared-bright regions.

1. Introduction

The Jupiter InfraRed Auroral Mapper (JIRAM) instrument on the NASA Juno spacecraft hosts an imager operating around 5 µm and a spectrometer operating between 2 and 5 µm, with a spectral resolution of about 15 nm. The imager and the spectrometer have a spatial resolution of 250 µrad and are operated simultaneously [1]. While most regions of Jupiter are usually affected by a thick cloud coverage, clearance areas (with cloud total opacities < 1 in the 5 µm range) exist in several locations, including, among others the hot spots frequently observed between the equatorial zone and the north equatorial belt [2]. In these conditions, JIRAM spectra are sensitive to the contents of ammonia, water vapour, phosphine and – in lesser degree – germane and arsine at the approximate levels between 5 and 3 bar [3-4], well below the Jupiter tropopause.

2. Materials

In this work we review the retrievals of the mixing ratios of minor components as derived from the JIRAM spectral data acquired between PJ1 and PJ15 (Aug 27th 2016 - Sep 7th 2018) over the entire disk of Jupiter. Analysis was performed according the methods presented in [3] and limited to spectra with emission angle lower than 40° (to mitigate modelling uncertainties), higher signal (R@ 5000 nm > 20 µW/[cm^2 sr µm], retrievals are not significant in regions with thick cloud coverage) and an IFOV smaller than 500 km. Results were further selected on the basis of fit quality and final retrieved opacity, discarding cases where $\tau > 2$ @ 5µm. These filters reduce retrievals population to $3.5 \cdot 10^5$ cases. This population is suitable to derive latitudinal trends of minor species (by average over different longitudes), keeping in mind that our results are unavoidably biased toward bright regions.

3. Results

Water vapor relative humidity (figure 1) is – by far – the most variable parameter among those retrieved. It shows a well defined pattern of maxima and minima along latitude, varying from < 1% to well above 15% in the southern polar region.

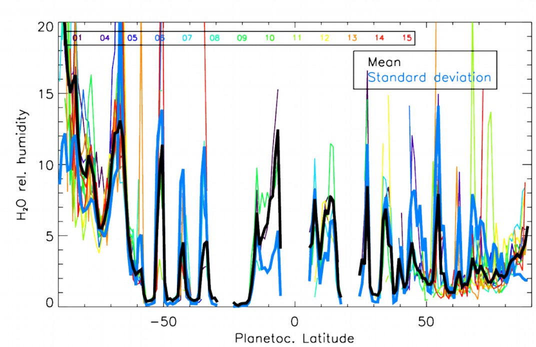

Figure 1: Latitudinal profile of average water vapour relative humidity as inferred from JIRAM data

Noteworthy is the asymmetry of the two hemispheres for latitudes greater than 55 degrees, being the southern one much wetter, rising from <1% at 55S to above 15% at 85S against an increase from about 1% at to 5% observed between 55N at 85N.

Ammonia latitudinal profile (Figure 2) shows, as main feature, a marked increase at both borders of the equatorial zone, albeit the Equatorial Zone itself is not covered by retrievals due to high opacity. A strong depletion (mixing ratio < $1.5\cdot10^{-4}$) is observed at 10N, without a southern counterpart. Both features are in qualitative and quantitative agreement with the Juno MWR measurements described by [5]. At other latitudes trends are less pronounced. On the northern hemisphere north of 25N, ammonia is relatively constant between 2.5 and $3\cdot10^{-4}$, with a possible slight increase only above 80N. In the southern hemisphere, we note a more gradual increase from $2.5\cdot10^{-4}$ at 20S to $2.5\cdot10^{-4}$ close to the south pole. Along this general southward increase, two local maxima at 68S and 52S seem to persist over different PJs; notably, the same locations were also interested by local maxima of water vapor.

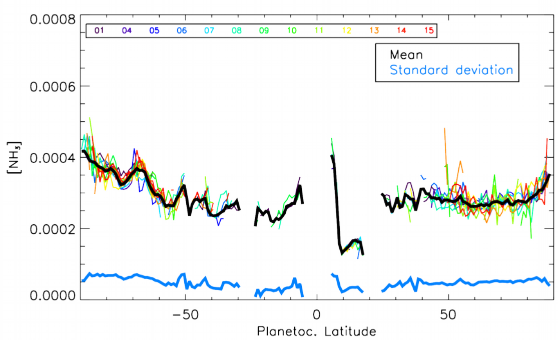

Figure 2: Latitudinal profile of average ammonia volume mixing ratio as inferred from JIRAM data

Phosphine latitudinal profile (figure 3) has a strong minimum at 10N (at the same location where the ammonia minimum was observed), where it falls below $2.5\cdot10^{-7}$. In the northern hemisphere we observe a very smooth decrease from about $9\cdot10^{-7}$ at 40N to $8\cdot10^{-7}$ at the north pole. In the southern hemisphere values are are between 7 and $8\cdot10^{-7}$ between 15S and 50S, to increase to $10\cdot10^{-7}$ at the south pole. Also for phosphine, a local maximum is observed at 68S, in a consistent manner over different PJs.

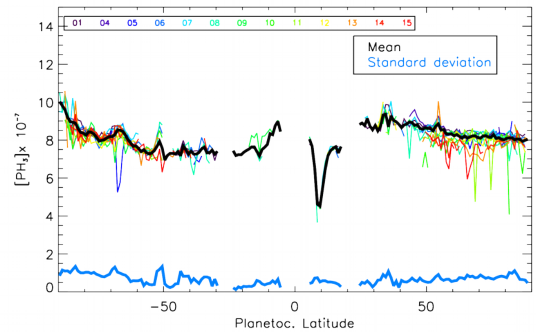

Figure 3: Latitudinal profile of average phosphine volume mixing ratio as inferred from JIRAM data

Germane (figure 4), albeit affected by inherently higher retrieval errors, shows a marked latitudinal trends. Retrievals at both sides of the Equatorial Zone indicate a strong depletion over the equator, while the maximum value ($9\cdot10^{-10}$) is achieved 15S, without a northern hemisphere counterpart. Observed trends at the borders of North and South Tropical Zones (centered at 25S and 23N respectively) are also suggestive of local germane depletions. Poleward of 40 degrees latitude, on both hemispheres, germane decreases essentially monotonically, being the decrease steeper in the south. On both poles mixing ratio is close to $2\cdot10^{-10}$.

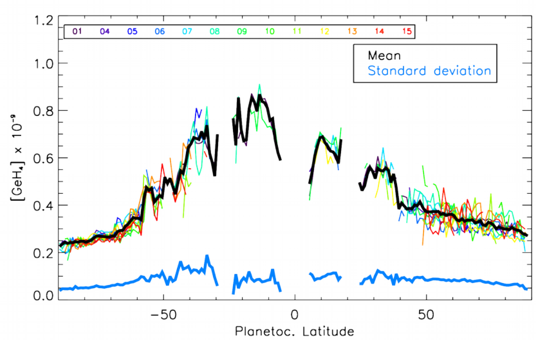

Figure 4: Latitudinal profile of average germane volume mixing ratio as inferred from JIRAM data

Arsine (figure 5) also shows a marked latitudinal behavior. The entire region between 50S and 40N presents mixing ratio values around below $2\cdot10^{-10}$, with a possibly significant peak to $3\cdot10^{-10}$ at 10N (on the same location noted for minima in ammonia and phosphine mixing ratios) and minima of $3\cdot10^{-10}$ at 20S. Poleward of this large latitudinal range, arsine strongly increases toward both poles. In the northern hemisphere, it gradually reaches a value between 5 and 6 $\cdot 10^{-10}$, while on the south it abruptly rises from $2 \cdot 10^{-10}$ to $6 \cdot 10^{-10}$, from 55S to 70S (the same location of water, phosphine and ammonia maxima) to remain constant afterward toward the pole.

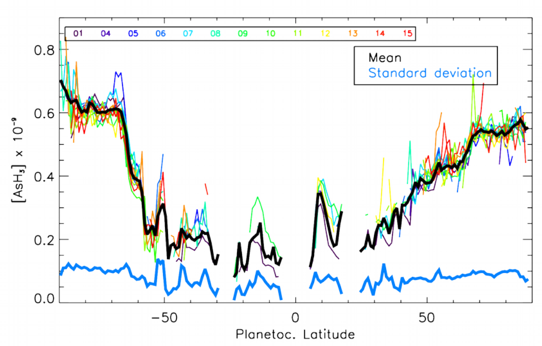

Figure 5: Latitudinal profile of average arsine volume mixing ratio as inferred from JIRAM data

4. Discussion

A global interpretation of the observed trends is still missing. Among the several features that need to be considered in such an effort are: 1) the asymmetry of longitudinal trends in the tho hemispheres for all the species 2) the very different behaviors of the three disequilibrium species (phosphine, germane and arsine) 3) the local maximum observed at 68S for water, ammonia and phosphine. Correlation against the properties of clouds - such as opacity mean value and variability, especially in polar regions - is another point that could prove useful in explaining the occurring phenomena.

Acknowledgements

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The JIRAM instrument was conceived and brought to reality by our late collaborator and institute director Dr. Angioletta Coradini (1946-2011).

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