Chemically-distinct regions of Venus' atmosphere revealed by MESSENGER-measured N_2 concentrations. P. N. Peplowski[1*], D. J. Lawrence[1], and J. T. Wilson[1]. [1]Johns Hopkins Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel MD 20723

Introduction: Despite over fifty years of robotic exploration at Venus, including thirteen successful atmospheric probes and landers, our knowledge of N_2, the second-most-abundant compound in the atmosphere, is highly uncertain [1]. We report a measurement of the nitrogen content of Venus' atmosphere at altitudes between 60 and 100 km. Our result, 5.0±0.4 v% N_2, is significantly higher than the value of 3.5 v% N_2 reported for the lower atmosphere (<50 km altitude; Figure 1). Our data require Venus' homopause – the boundary between the well-mixed and mass-differentiated regions of the atmosphere – to be ~50 km altitude. The currently accepted homopause altitude is between 120 and 135 km.

Methodology: Our N_2 measurement was made via a re-analysis of MESSENGER Neutron Spectrometer (NS) data collected during MESSENGER's second flyby of Venus, on 5 June 2007. The re-analysis benefits from improvements to the data reduction and modeling resulting from an unrelated effort to measure the neutron lifetime using the same dataset [2].

The NS measured thermal (<0.2 eV) neutrons escaping Venus' atmosphere, following their production during cosmic-ray-induced nuclear breakup reactions in the atmosphere. Nitrogen is an effective thermal neutron absorber via the $^{14}N+n \rightarrow ^{15}N$ reaction.

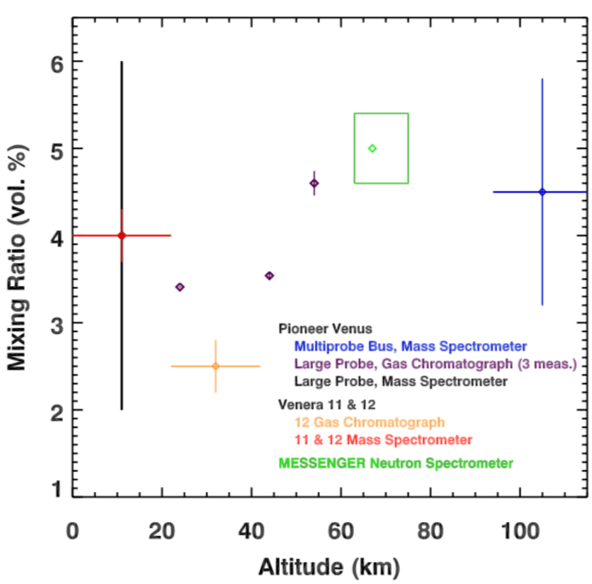

Figure 1. Altitude-dependent N_2 concentration in Venus' atmosphere, made by descent probes in 1978 and MESSENGER in 2007. The green box denotes the new, MESSENGER-derived values and confirms a sudden increase at an altitude of ~50 km, consistent with the 1978 measurements.

Consequently, the atmosphere-escaping thermal neutron flux is inversely proportional to the nitrogen content of the atmosphere [3]. Comparison of measured and modeled neutron fluxes were used to determine the best-fit atmosphere composition for the NS measurements. That result is shown in Figure 1.

Discussion: Observations of Venus' upper atmosphere have also been used to infer conditions at the surface. For instance, [4] suggested that a sudden rise and subsequent gradual decrease of the SO_2 content of the upper atmosphere may have been a consequence of an unseen, contemporaneous volcanic eruption. Similar events were subsequently observed in the 2000s by Venus Express, at long and short timescales [5]. [5] proposed that the SO_2 injections are instead manifestations of cyclic mixing of lower and upper regions of Venus' atmosphere. The mechanisms that control this mixing and its frequency are still under investigation [6,7], however this study identifies two compositionally-distinct regimes within the atmosphere, with non-equivalent mechanisms for vertical diffusion, a necessary prerequisite for the cyclic-SO_2-mixing model.

Venus is commonly used as benchmark for understanding and interpreting astronomical observations of exoplanets with thick atmospheres (e.g. [7,8]). That fundamental parameters of Venus' atmosphere, such as the location of the homopause and the altitude-dependent abundance profiles of major constituents, are still being revealed following over fifty years of remote and in-situ measurements is a vivid reminder of the uncertainties associated with interpreting telescopic observations of an exoplanet's upper atmosphere. The exploration of Venus demonstrates that an understanding of a planet's atmosphere requires systematic measurements of the concentrations of multiple species, at multiple altitudes, along with a reliable temperature profiles obtained at multiple local solar times. This type of data is essential for rigorous modeling of planetary atmosphere conditions. None of these conditions are met for any exoplanet to date.

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