**Millimeter-Wavelength Remote Sensing of the Tropospheric Structure of Venus: Exploratory Simulations** A. B. Akins[1] and P. G. Steffes[1], [1]Georgia Institute of Technology School of Electrical and Computer Engineering, 777 Atlantic Drive NW, Atlanta, GA, 30313. Corresponding author e-mail: aakins6@gatech.edu

**Introduction:** Microwave and millimeter-wavelength continuum remote sensing observations of Venus can be used to retrieve atmospheric temperature and constituent abundance profiles for microwave absorbing gases and aerosols from the surface to the lower cloud deck. Millimeter-wavelength observations from 2-4 mm are sensitive to emission from 40 to 55 km. Venus disk images derived from 2-4 mm observations show longitudinal spatial variations in brightness temperature on the order of 30-80 Kelvins. These variations appear only on the nightside and appear to be uncorrelated to topographical features. The features seen in these images can be interpreted through inversion of a microwave radiative transfer model of the Venus atmosphere

**Model Inputs:** While the dominant source of millimeter-wavelength opacity at Venus is collisional absorption from the $CO_2/N_2$ atmosphere, trace gases such as $SO_2$ and $H_2SO_4$ vapor provide additional sources of opacity, as do $H_2SO_4$ cloud aerosols. Models for $SO_2$ and liquid $H_2SO_4$ absorption are given by Fahd and Steffes [1,2]. Recent laboratory measurements of $H_2SO_4$ vapor opacity at millimeter wavelengths suggest an absorption model based on the JPL Spectral Line Catalog [3]. Additional lineshape opacity models are included for $H_2O$, OCS, and CO. The abundance profiles for all non-$H_2SO_4$ constituents are sourced from chemical models [4]. $H_2SO_4$ vapor abundance profiles are sourced from radio occultation results, and cloud bulk density profiles are sourced from the Pioneer Venus LCPS experiment [5,6]. Temperature and pressure profiles are also sourced from Pioneer Venus entry probe results.

**Simulation Methods:** Possible causes of the observed millimeter-wavelength brightness temperature variations are explored by varying the abundances of $SO_2$, $H_2SO_4$ vapor, and the cloud aerosol by up to ten times nominal values and calculating the resulting brightness temperature through the forward model. The $H_2SO_4$ vapor abundance and cloud bulk density is modified by scaling the abundance and shifting the location of maximum abundance between 40 and 58 km. Variations in the vertical structure of $SO_2$ are explored by scaling features observed in UV retrievals of $SO_2$ abundance from ISAV-1 and ISAV-2 data [7]. Since the abundance and thermal profiles are uncoupled in the model, these results of these simulations are not completely realistic. Local variations in thermal structure were also not explored.

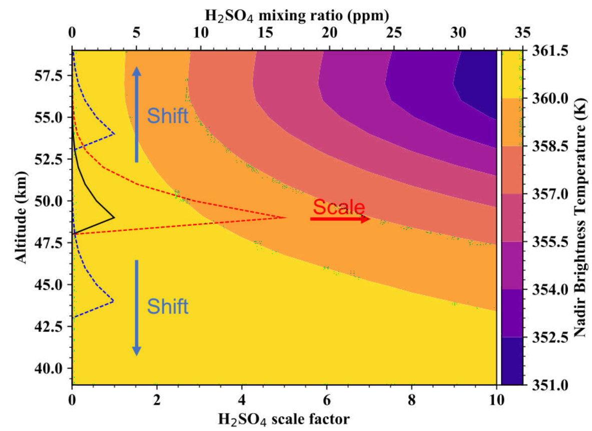


*Fig. 1 Change in observed brightness from shifting and scaling the $H_2SO_4$ vapor abundance profile*

**Simulation Results:** Significant variation in observed emission is likely not caused directly by spatial variation in the $H_2SO_4$ vapor profile, as shown in Fig. 1. However, longitudinal variations of $SO_2$ vertical structure on the same order of magnitude as the ISAV retrievals could explain the images. Orders of magnitude changes in the cloud bulk density have a similar effect.

**Conclusions and Future Work:** While it is clear that $H_2SO_4$ vapor abundance changes would not be visible in millimeter-wavelength images, variations in $SO_2$ or cloud bulk density on the nightside could explain such observations. Furthermore, opacity due to cloud bulk density is less frequency-dependent than that of $SO_2$. Homogeneous features in multi-wavelength observations would imply substantial cloud bulk density variation, while heterogeneity would suggest $SO_2$ as the source. These significant variations in $SO_2$ abundance could be due to enhanced nightside convection [8]. This analysis also excluded the possibility of cloud aerosols > 300 microns in diameter. Scattering from these particles could be visible in the millimeter-wavelength continuum.

**References:** [1] Fahd, A. K. and Steffes, P. G. (1991) *JGR: Planets 96,* pp. 17471–17476. [2] Fahd, A. K. and Steffes, P. G. (1992) *Icarus,* 97, pp. 200-210 . [3] Akins, A. B. and Steffes P. G. (2017) *49th DPS Meeting,* Abstract #417.04 [4] Krasnopolsky V. A. (2007) *Icarus,* 191, pp. 25-37. [5] Kolodner, M. A. and Steffes, P. G. (1998) *Icarus*, 132, pp 151-169 [6] Knollenberg, R. G. and Hunten, D M. (1980) *JGR*, 85, pp. 8039-8058 [7] Bertaux, J. L. et al. (1996) *JGR Planets*, 101, pp. 12709-12745 [8] Imamura, T. et al. (2014) *Icarus*, 228, pp. 181-188.