Preparing for X/Ka Band radio occultations of Venus with VERITAS and EnVision: Retrieving Sulfur Species Abundances

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Background

Future missions to Venus will be the first to conduct simultaneous X (8.3 GHz) and Ka (32 GHz) band radio occultations, providing a proof-of-concept simultaneous retrieval of sulfur species unattainable before.

How accurately can we quantify the abundances of H_2SO_4 and SO_2 in the cloud-level atmosphere?

We explore this question with a novel data-driven retrieval approach.

Figure 1. Data-driven algorithm flowchart

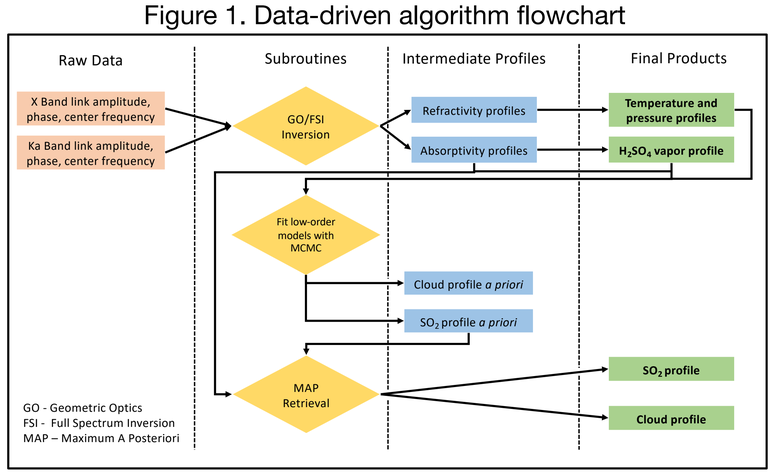
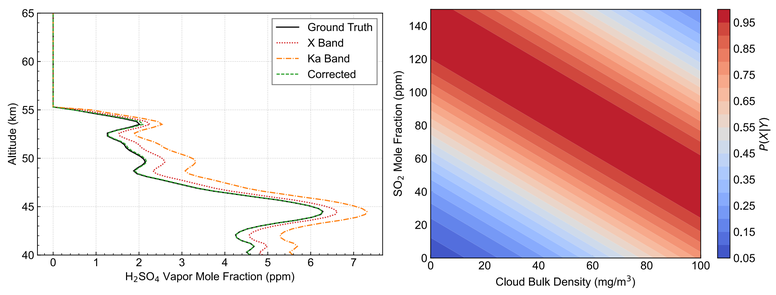


Figure 2: (Right) Dual X/Ka band occultations of Venus will achieve equivalent or greater accuracy in retrieved H_2SO_4 vapor abundance compared to prior S and X band occultations [1]. (Left) Retrieval of H_2SO_4 aerosol bulk density and SO_2 mole fraction, however, is non-unique, as illustrated by the likelihood distribution for retrieval at a single altitude.

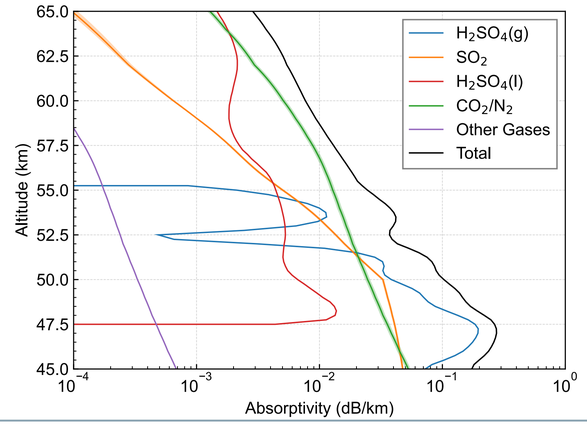


Model Uncertainty

Uncertainties in absorption model parameters for H_2SO_4 and SO_2 have been determined by assessing the likelihood of occurrence against laboratory measurements under simulated Venus conditions [2].

$$p(a|\mathbf{x}) \propto c * \prod_{i=1}^{n} p(x_i|a, \sigma_i)$$

Figure 3: Venus atmosphere absorptivity profile at 32 GHz



Simulated Retrievals

Figure 4: The results of chemistry/transport models and prior atmospheric measurements, representing an ensemble of vertical distributions of sulfur species abundances, were used to simulate retrievals of H_2SO_4 and SO_2.

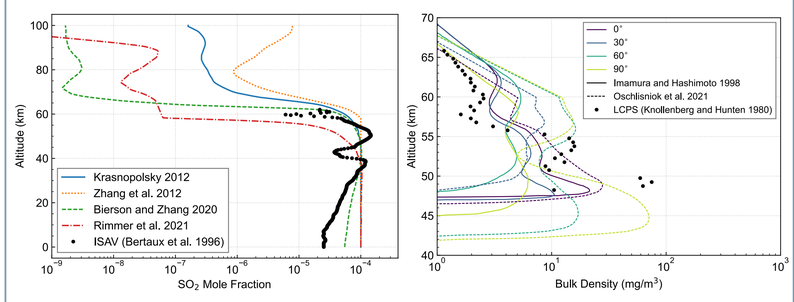


Table 1: Model atmospheres used to test retrievals

Set Number	H_2SO_4 vapor	H_2SO_4 aerosol	SO_2
1	VEX VeRa, 18°	Imamura and Hashimoto, 0°	Krasnopolsky
2	VEX VeRa, 45°	Imamura and Hashimoto., 30°	Bierson and Zhang 2020
3	VEX VeRa, 80°	Oschlisniok et al., 60°	Rimmer et al.
4	VEX VeRa, 85°	Oschlisniok et al., 90°	Bertaux et al., ISAV-1

Figure 5: Low-dimension models for SO_2 and cloud abundances

SO_2
- x_0: Base abundance
- h_0: Depletion altitude
- s_0: Depletion scale height

Cloud
- b_0: cloud base
- b_1: 1st layer boundary
- b_2: 2nd layer boundary
- b_3: cloud top
- m_0: Layer 1 bulk density
- m_1: Layer 2 bulk density
- m_2: Layer 3 bulk density

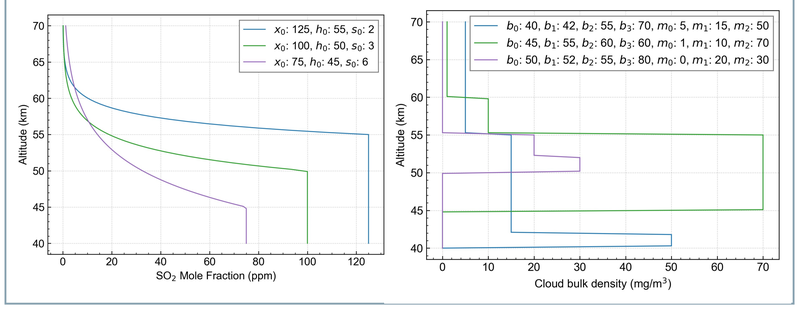
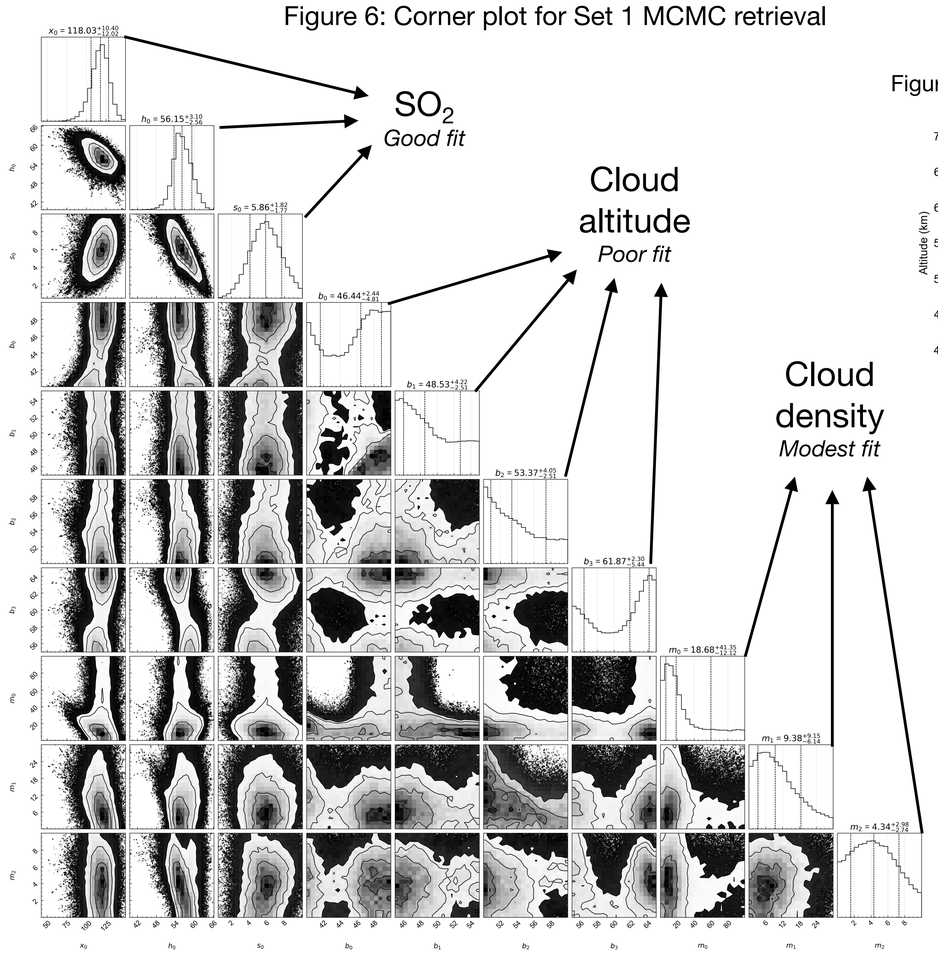


Figure 6: Corner plot for Set 1 MCMC retrieval



MCMC Fits

Figure 7: Markov Chain Monte Carlo draws for each set in Table 1

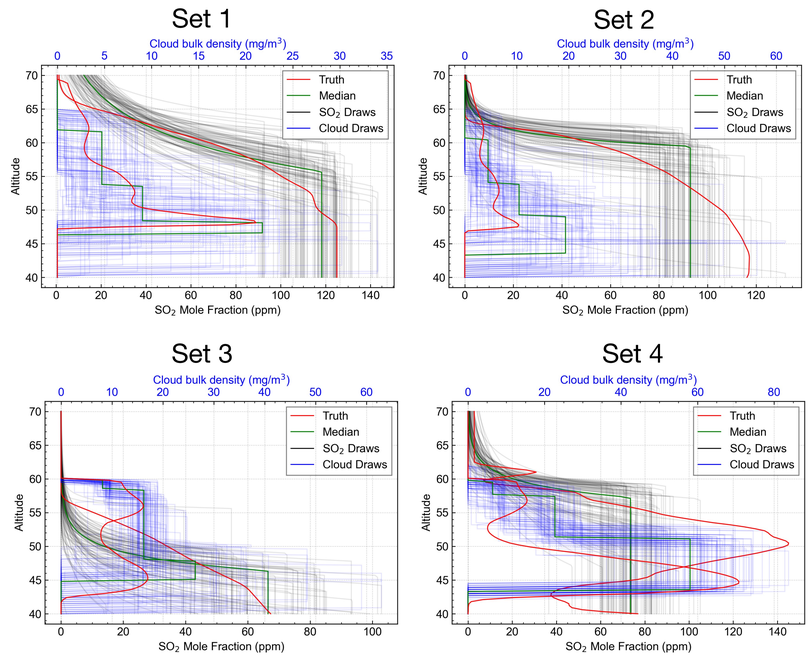


Figure 8: Set 1 Prior covariance matrix including variances from MCMC fits

$$S_{ij} = {\sigma_a}^2 e^{-|i-j|\delta z/h}$$

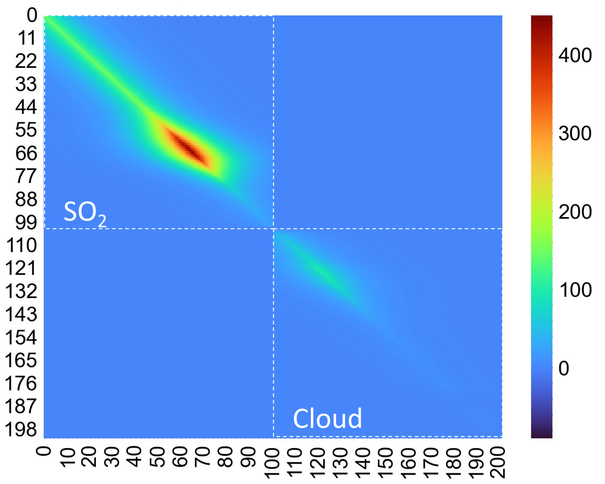
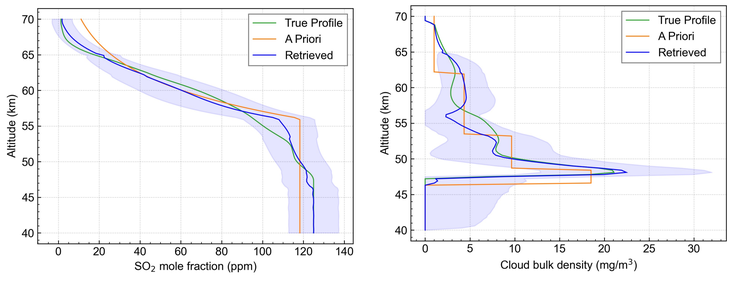


Figure 9: Final retrieval for Set 1 with h=10 for SO_2 and h=0.5 for cloud density



Conclusions

- Simulations suggest that X/Ka band occultations permit determination of SO_2 and H_2SO_4 aerosol vertical profiles, which was not possible on previous missions
- A novel data-driven retrieval algorithm has been demonstrated here, and a model-driven algorithm is also being assessed

References

[1] Oschlisniok, J., et al., *Icarus*, 362, 2020
[2] Akins, A. B., & Steffes, P. G., *Icarus*, 351, 2020
[3] Krasnopolsky, V. A., *Icarus*, 218, 2012
[4] Bierson, C. J., & Zhang, X., *JGR: Planets*, 125(7), 2020
[5] Rimmer, P. B. et al., *PSJ*, 2(4), 2021
[6] Bertaux, J.-L. et al. *JGR: Planets*, 101(E5), 1996
[7] Foreman-Mackey, D. et al., *PASP*, 125(925), 2013