One-dimensional Microphysics Model of Venusian Clouds from 40 to 100 km

Impact of the Middle-atmosphere Eddy Transport and SOIR Temperature Profile on the Cloud Structure

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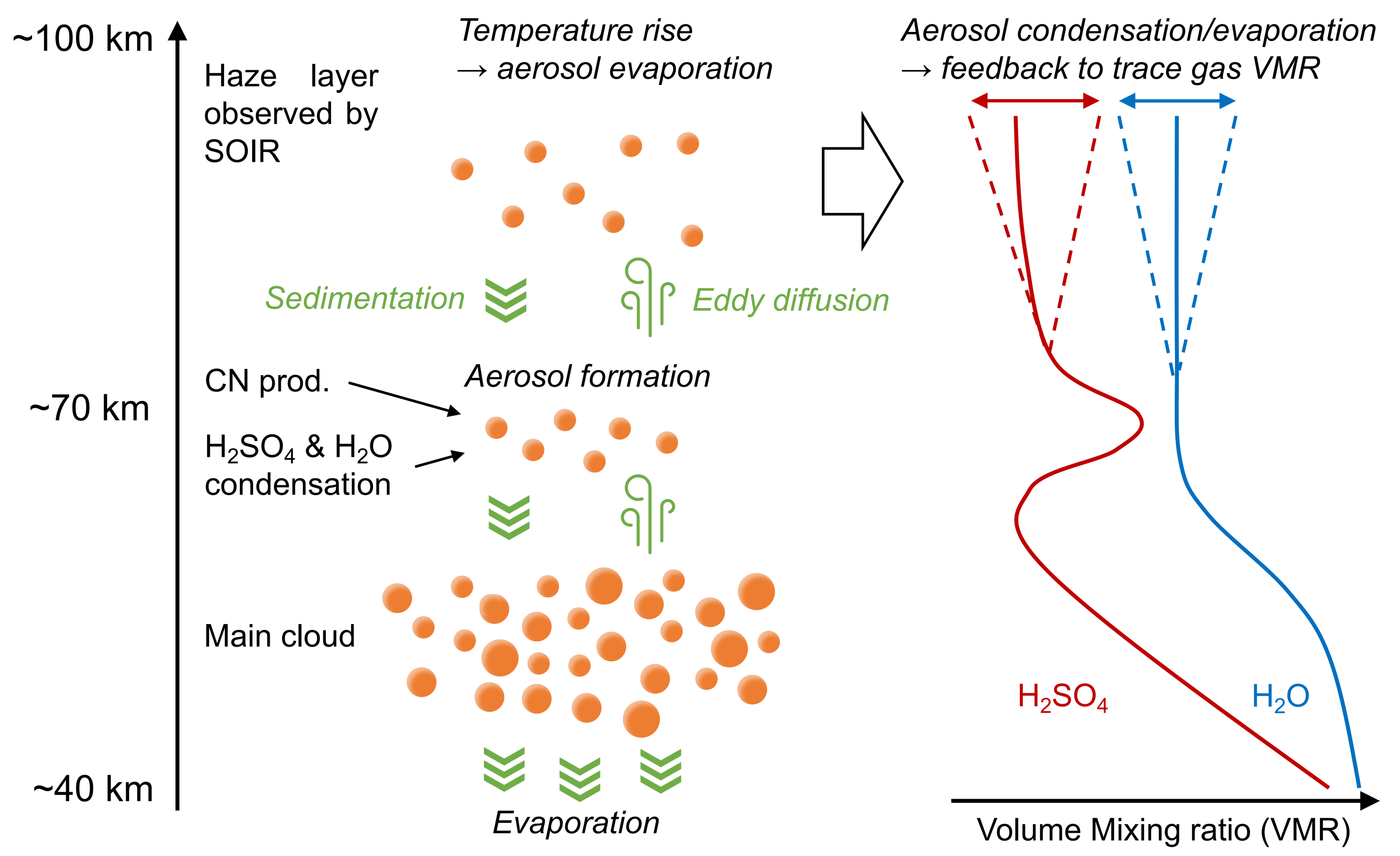
Takeaways

1. We constrained eddy diffusion profiles by reproducing vertical distributions of aerosol, H_2SO_4 gas VMR, and H_2O gas VMR.
2. H_2SO_4 vapor is highly supersaturated in the mesosphere, suggesting the possibility of sulfur source and homogeneous nucleation.
3. The mesospheric H_2O abundance is significantly influenced by condensation and evaporation of aerosols, suggesting that hydrogen escape is likely affected by the aerosol layers.
4. For more information, please see Karyu et al. (2024), *PSJ*.

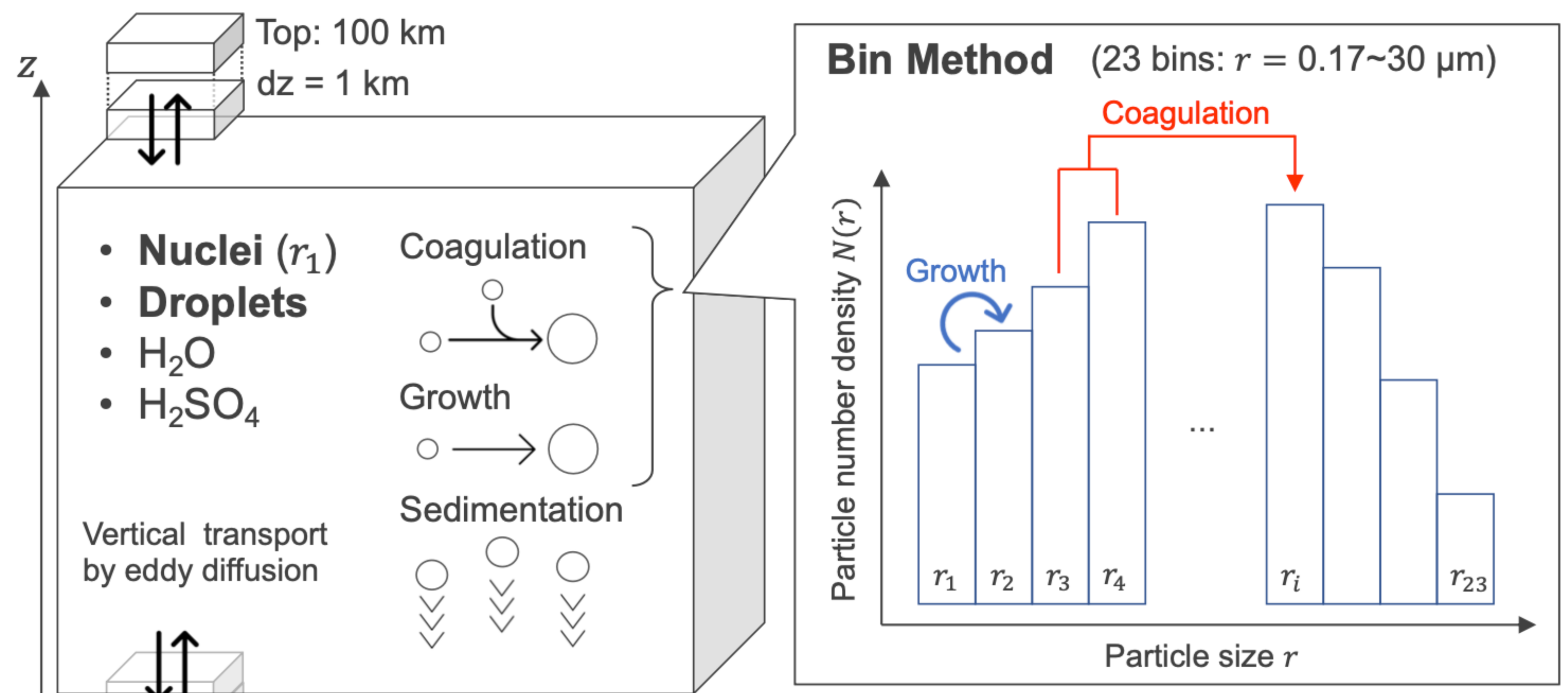
1. Motivation

Q. Which eddy diffusion profile reproduces aerosol, H_2SO_4, and H_2O distributions?

Q. What role do the aerosols play in determining the abundance of condensational species?



2. Model & Settings

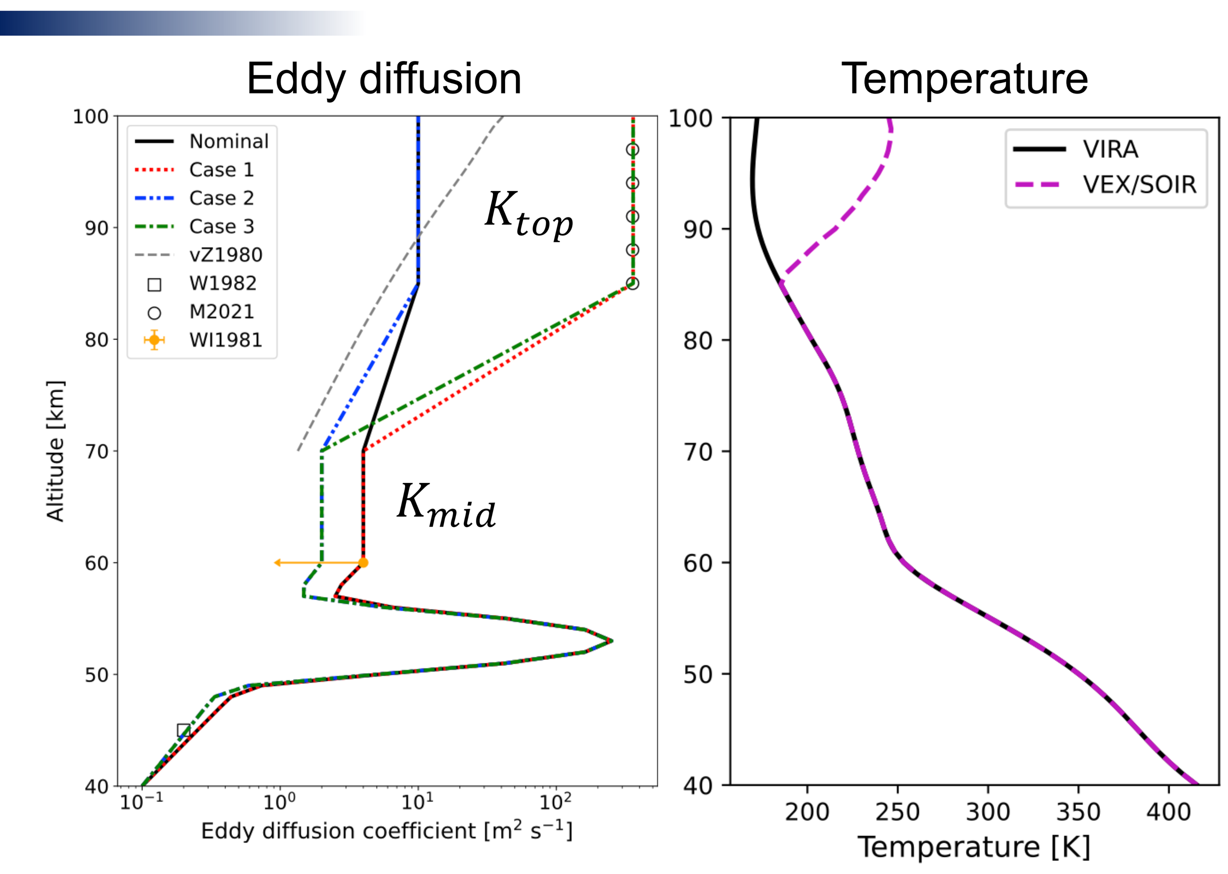


Settings based on Imamura & Hashimoto (2001)

- The model used in this study is described in Karyu et al. (2024).
- H_2SO_4 and condensation nuclei (CN) production rate is prescribed by the photochemical model by Krasnopolsky (2012).
- The lower boundary conditions for CN, H_2O, H_2SO_4 are 4×10^7 m^{-3}, 30 ppm, and 4 ppm, respectively. The upper boundary conditions are set as no VMR gradient for all species.

Sensitivity studies

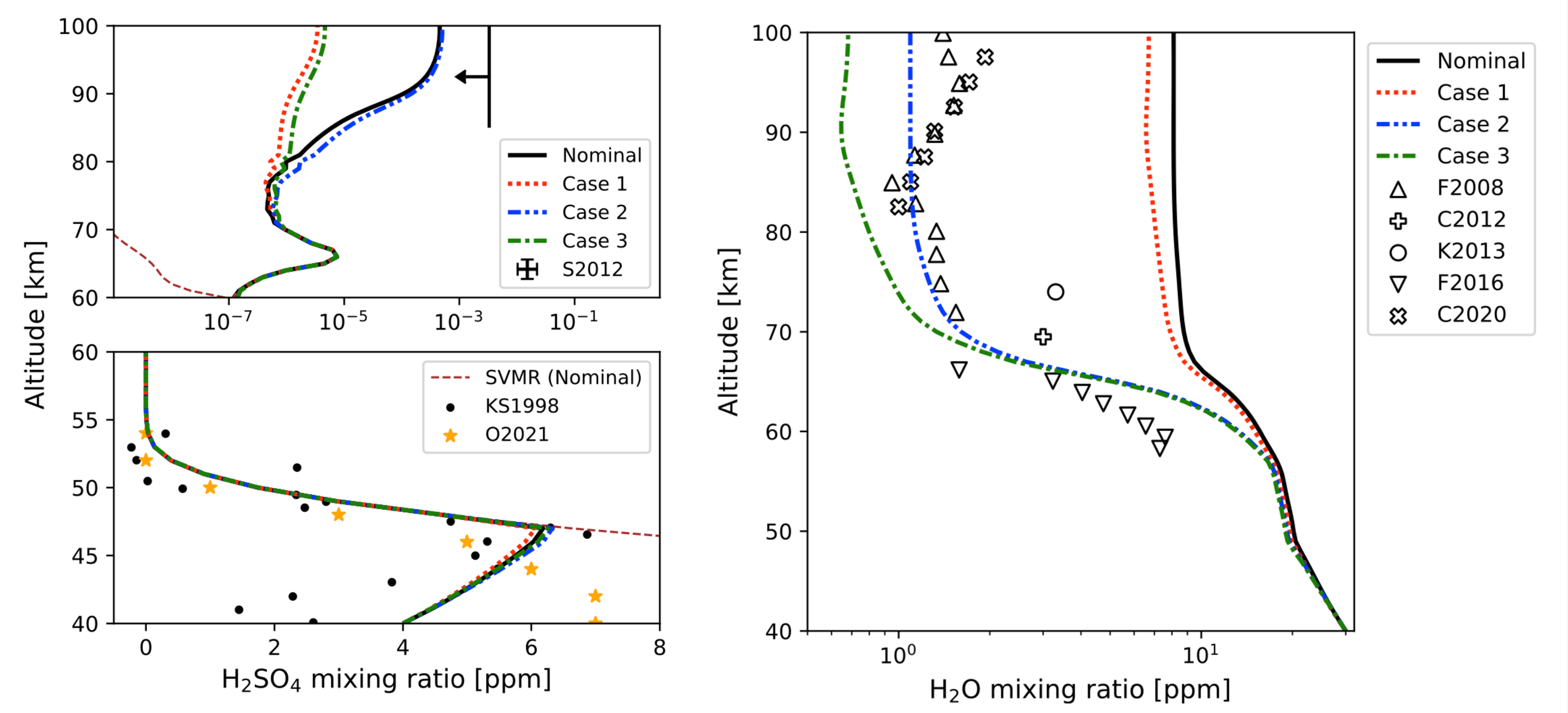
- 4 types of eddy diffusion profiles based on previous observations.
  → effect of transport
- 2 types of temperature profiles based on VIRA and VeX/SOIR.
  → effect of temperature



	Nominal	Case 1	Case 2	Case 3	Case 4	Case 5
K_{top} [m^2 s^{-1}]	10	360	10	360	10	360
K_{mid} [m^2 s^{-1}]	4	4	2	2	4	2
Temp. (>85 km)	VIRA	VIRA	VIRA	VIRA	SOIR	SOIR

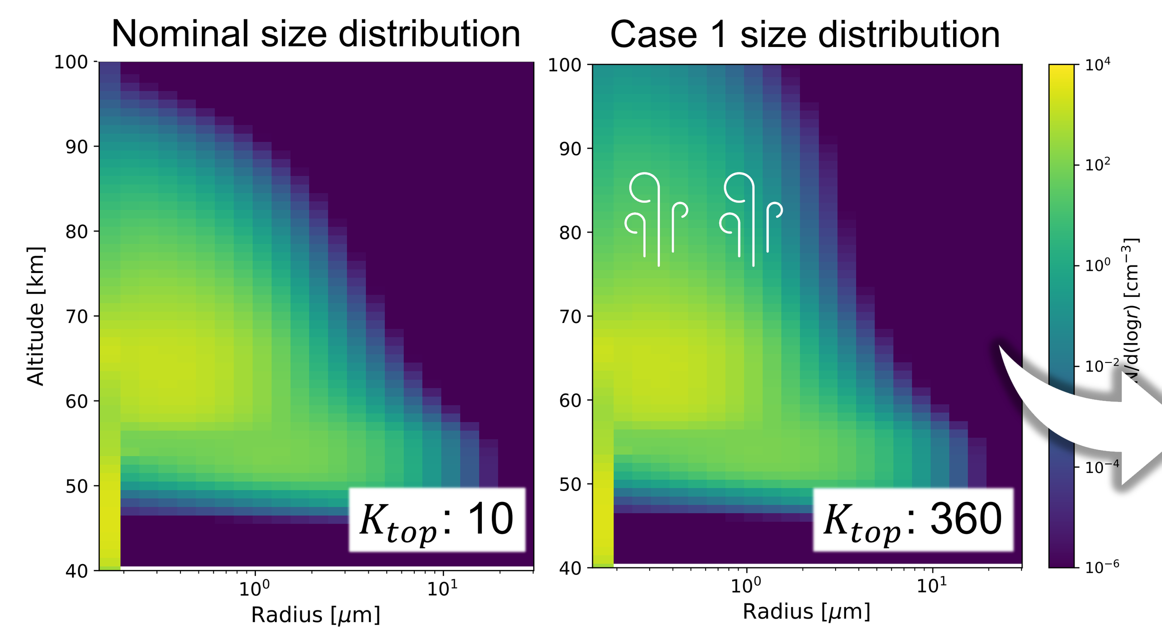
3. Eddy Diffusion Sensitivity Studies

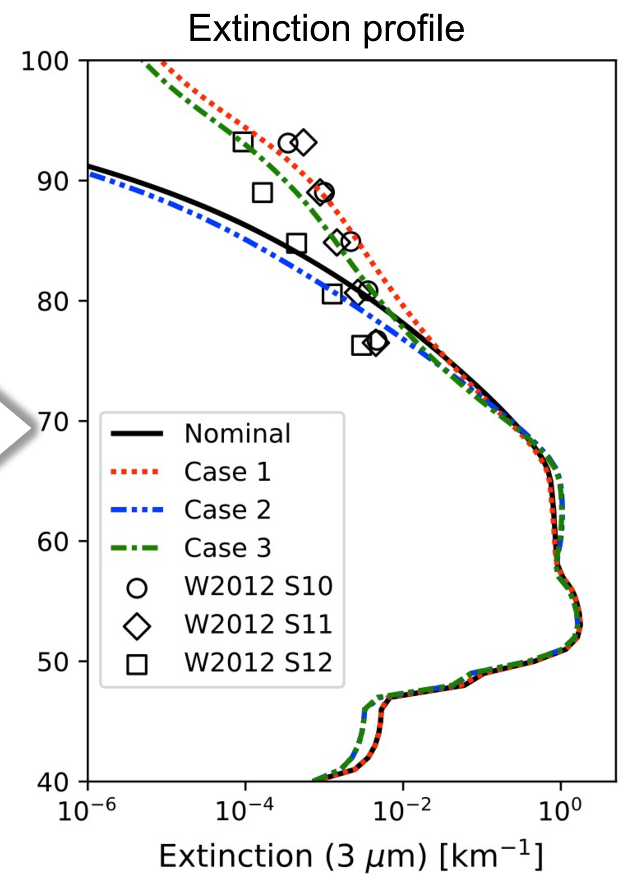
Trace gas VMR (H_2SO_4 & H_2O)



- High supersaturation of H_2SO_4 above 60 km altitude.
- Strong dependence of H_2O VMR profile on K_{mid}.

Aerosol profiles

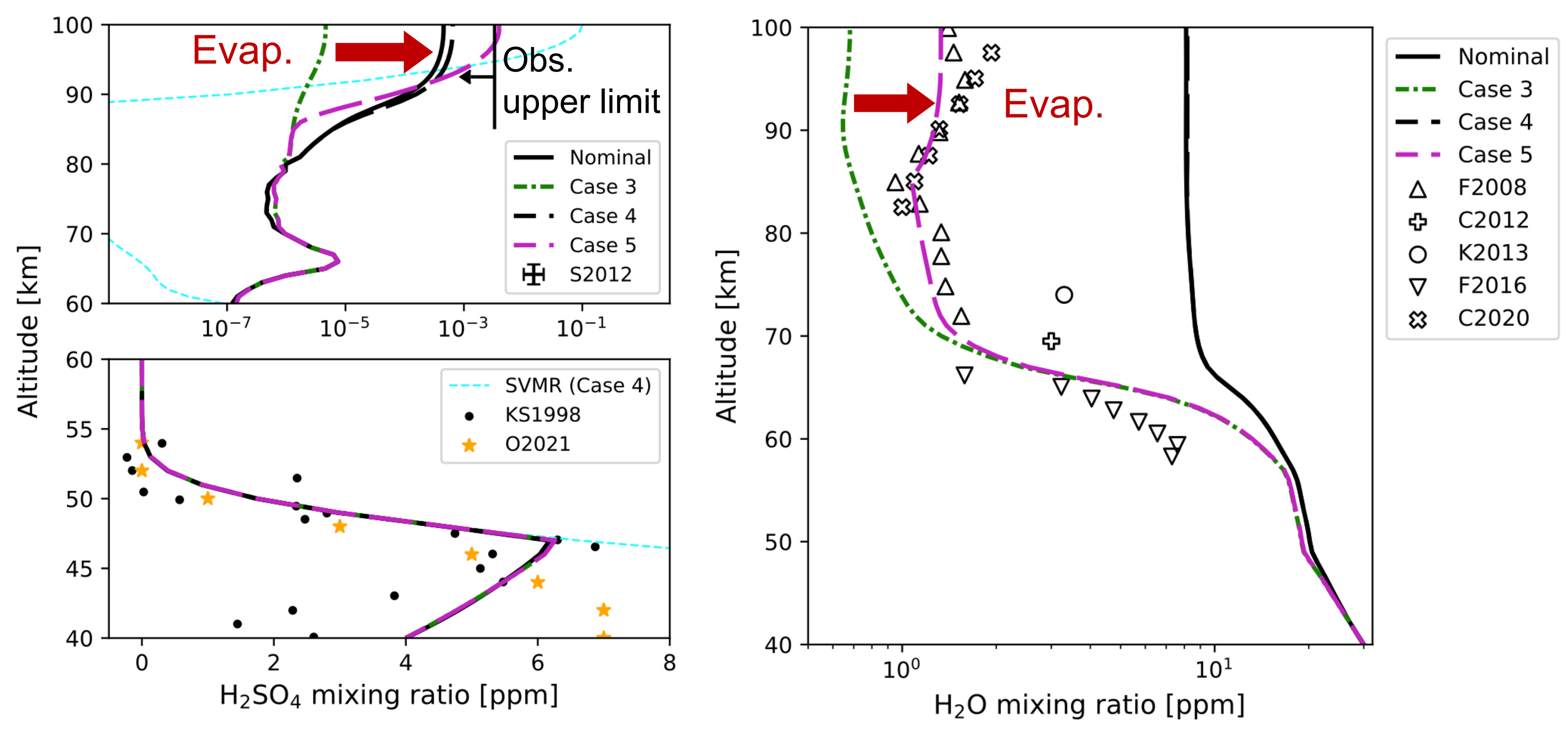




- Efficient eddy diffusion transport is necessary to explain VeX/SOIR observations.
- The best-fit eddy diffusion coefficient: K_{mid} = 2 m^2 s^{-1}, K_{top} = 360 m^2 s^{-1}

4. Temperature Sensitivity Studies

Trace gas VMR (H_2SO4 & H_2O)



- The VMR of condensational species increase due to aerosol evaporation.

5. Summary & Discussion

We found…

- Decreasing K_{mid} by half leads to tenfold decrease of the mesospheric H_2O VMR.
→ The H_2O abundance is strongly influenced by the competition between condensation and transport at altitudes between 60 and 70 km.
- The supersaturation degree of H_2SO_4 exceeds unity by several orders of magnitude.
- The aerosol evaporation increases the abundance of condensational gas species
→ ~3 orders of magnitude for H_2SO_4 and more than a factor of 2 for H_2O.

Implications

Atmospheric evolution: Aerosol processes affect the H_2O abundance below the homopause, and thus, the escape rate of H atoms. This effect should be considered in atmospheric evolution models.

Cloud microphysics: Homogeneous nucleation may be possible in the Venus mesosphere since H_2SO_4 is highly supersaturated.

Sulfur chemistry: The evaporation of aerosols may serve as a sulfur source. However, the simulated value is <3 ppb, which is orders of magnitude lower than the value used in photochemical model (Zhang et al., 2010) to explain the observed SO_2 abundance by Balyaev et al. (2012).

References

Karyu+ (2024), PSJ; Imamura & Hashimoto (2001), JAS; Woo & Ishimaru (1981), Nature; von Zahn+ (1980), JGR; Mahieux+ (2021), Icarus; Seiff+ (1985), PSS; Knollenberg & Hunten (1980), JGR; Wilquet+ (2012), Icarus; Sandor+ (2012), Icarus; Oschlisniok+ (2021), Icarus; Kolodner & Steffs, (1998); Fedorova+ (2008), Icarus; Cottini+ (2012), PSS; Krasnopolsky (2013), Icarus; Fedorova+ (2016), Icarus; Cottini+ (2020), Icarus; Dai+ (2020), JGR; Stolzenbach+ (2023), Icarus; Zhang+ (2010), NatGeo; Balyaev+, (2012), Icarus

Acknowledgments

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