Exploring the feasibility of detecting seismically-generated infrasound waves on Venus using balloon platforms

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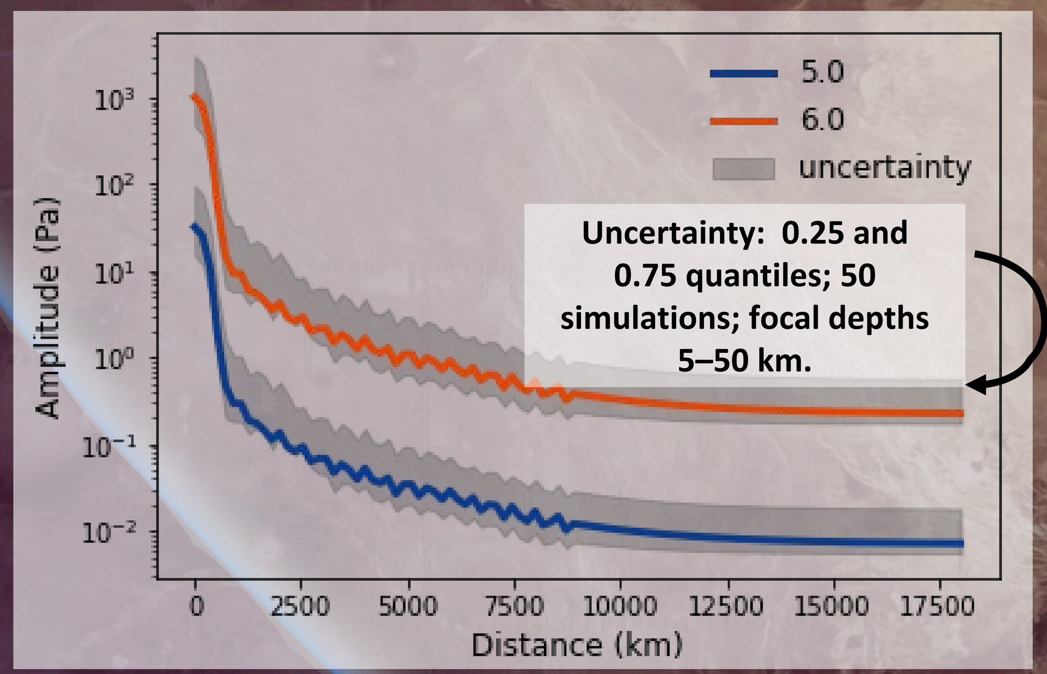
INTRODUCTION

- Due to the harsh surface environment with high pressure and temperature, balloon platforms might be one of the only realistic option to investigate Venus' seismicity [1].
- Seismoacoustic coupling is efficient on Venus due to its dense atmosphere: seismic waves couple to the atmosphere as infrasound which can be recorded by a balloon.
- Here we provide the first assessment of the global detectability of these seismic infrasounds at high altitude based on numerical modeling.

METHODS

#1 **Estimate the spatial and temporal venusquake distribution λ_q** in terms of magnitude, based on Earth scalings [2,3].

#2 **Infrasound amplitude modeling** using seismic Green's functions and ground-to-balloon scaling for a 2-layer Venus subsurface.

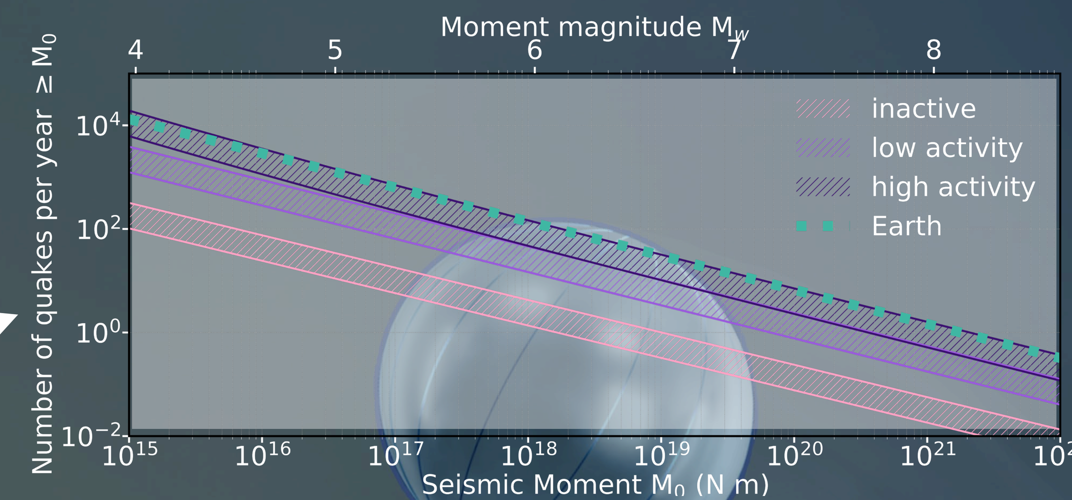


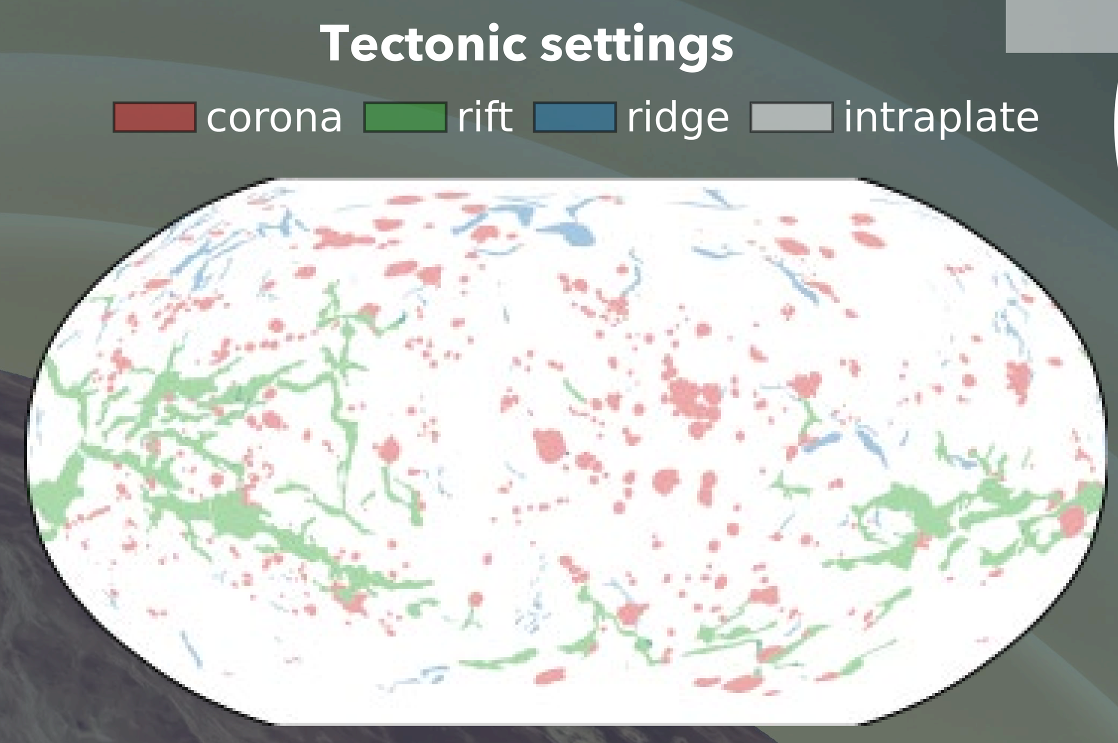
#3 **Determine probability of observing at least one venusquake with $SNR > d$** over a time period t, i.e., the Poisson process: $\mathbb{P}(SNR > d, x_t^{obs}, t) = 1 - \exp[\lambda(\lambda_q, SNR > d)t]$.

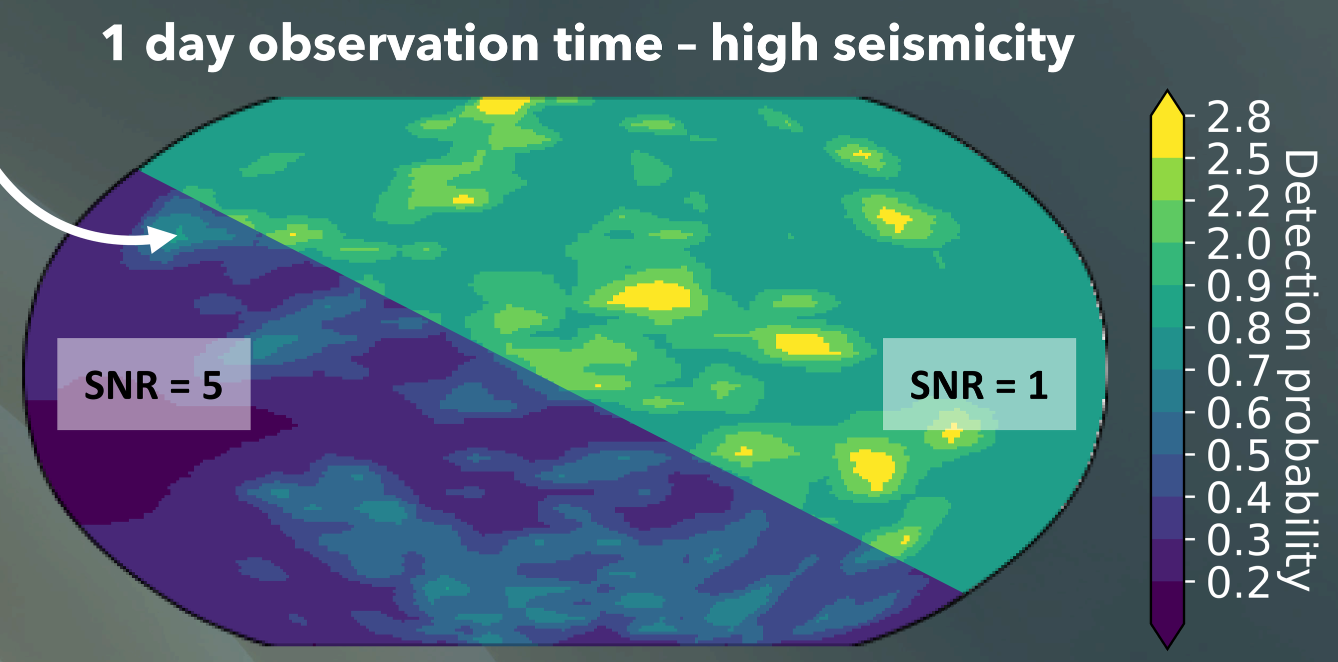
#4 **Integrate probability #3 along a balloon trajectory** freely drifting with horizontal winds

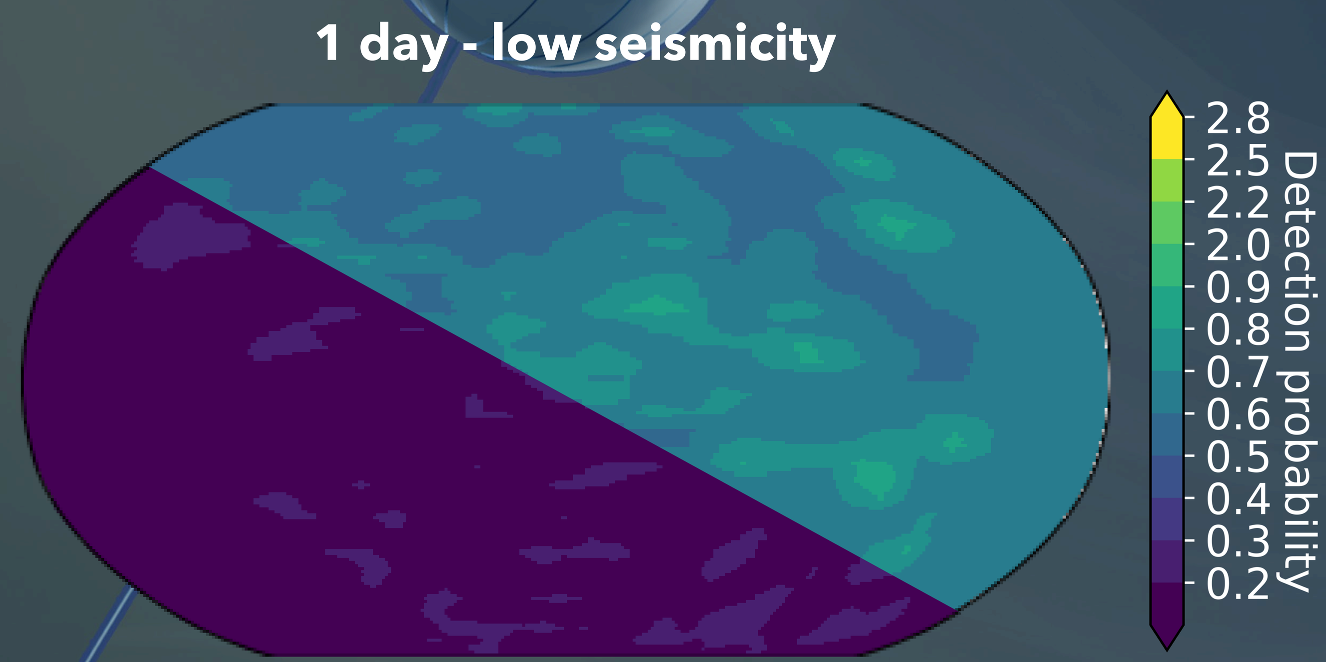
$$\mathbb{P}(SNR > d, x^{bal}) = 1 - \prod_{t \le t_{max}} [1 - \mathbb{P}(SNR > d, x_t^{obs})]$$

HOW DOES SEISMICITY INFLUENCE DETECTABILITY?



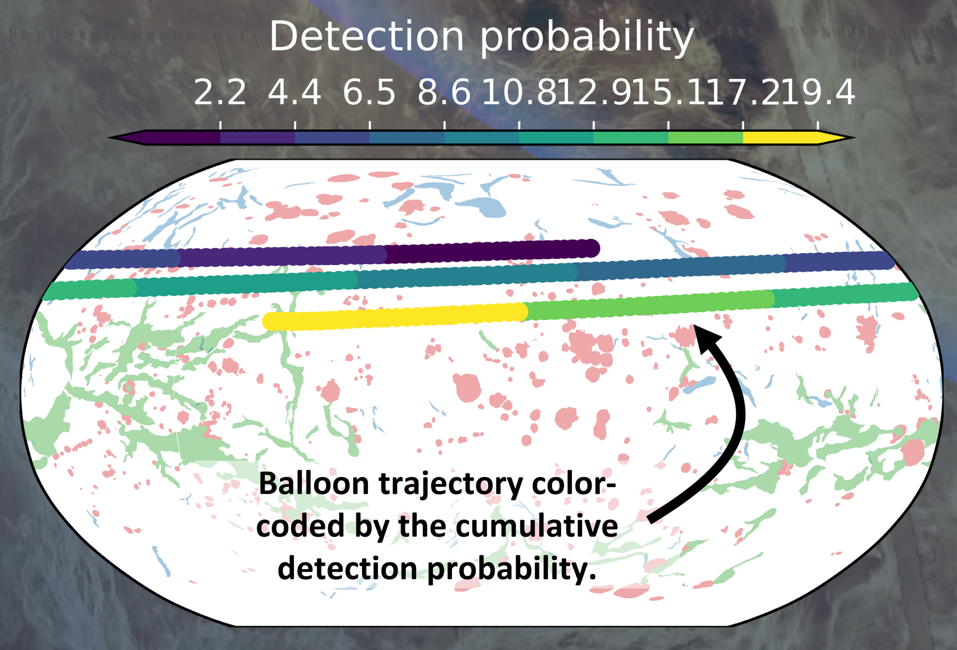


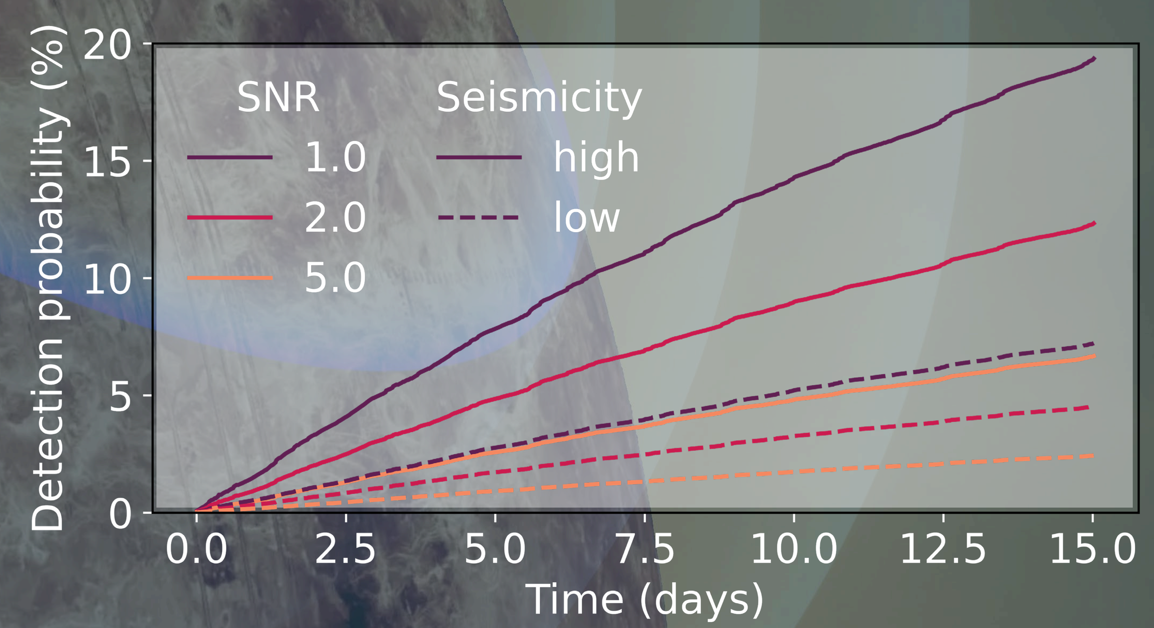




We estimate up to 12% chance to detect a venusquake over a 15-day balloon mission

CAN A BALLOON DETECT A VENUSQUAKE OVER THE ENTIRE DURATION OF A MISSION?





WHAT COULD THIS MEAN FOR FUTURE MISSIONS?

- Current seismicity models lead to **low detection probabilities (< 12.5 %) for short duration missions.**
- However, we have **large uncertainties** behind the predicted infrasound amplitudes **due to the choice of seismic velocities, attenuation, and atmospheric scaling.**
- **Several research questions should be addressed** to constrain the range of detectability:

a) How would amplitudes extracted from full-waveform simulations [4] affect detectability?
b) How sensitive are the predicted amplitudes on the choice of Venus subsurface models?
c) Can a balloon network vs a single balloon increase the detectability likelihood?
d) How accurately can we constrain the crust/mantle velocities from low-SNR infrasound?

[1] Krishnamoorthy, S. & Bowman, D. C. "A "Floatilla" of Airborne Seismometers for Venus." (2023) 10.1029/2022GL100978
[2] van Zelst, Iris, et al. "Estimates on the possible annual seismicity of Venus." (2023) 10.31223/X5DQ0C
[3] Sabbeth, L., et al. "Estimated seismicity of Venusian wrinkle ridges based on fault scaling relationships." (2023) 10.1016/j.epsl.2023.118308
[4] Martire, Léo, et al. "SPECFEM2D-DG, an open-source software modelling mechanical waves in coupled solid-fluid systems: the linearized Navier-Stokes approach." (2022) 10.1093/gji/ggab308

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