SEISMIC INFRASOUND AS A GEOPHYSICAL PROBE FOR VENUS. S. Krishnamoorthy[1], A. Komjathy[1], J. A. Cutts[1], M. T. Pauken[1], L. Martrire[2], R. F. Garcia[2], D. Mimoun[2], V. H. Lai[3], J. M. Jackson[3], D. C. Bowman[4], S. Kedar[1], S. E. Smrekar[1] and J. L. Hall[1]

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Introduction: The study of a planet's seismic activity is critical to the understanding of its internal structure. However, extremely high temperature and pressure conditions on the surface of Venus [1] present a significant technological challenge to performing long-duration seismic experiments. Therefore, despite multiple visits from many spacecraft since Mariner 2 in 1962, the internal structure of Venus still remains a mystery.

Seismic disturbances are known to generate infrasonic (frequency < 20 Hz) waves by coupling energy from ground motion into the atmosphere. These waves have been detected from earthquakes and volcanic activity from terrestrial stations on Earth [2,3]. Seismic infrasound may also be detected from balloon-borne pressure sensors. In fact, Krishnamoorthy et al. [4] recently showed that the noise level on a pressure sensor that floats with the prevailing wind can be much lower than that of a ground-based platform (Fig. 1). The intensity of seismic infrasound generated depends heavily on the relative density of the atmosphere and the planet's crust. Venus offers a unique opportunity – due to its dense atmosphere, energy from seismic activity couples with the Venusian atmosphere up to 60 times stronger than Earth [5].

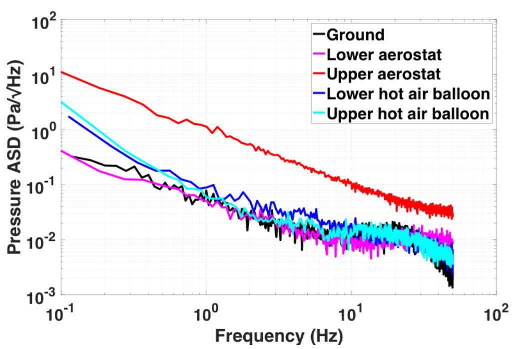

Figure 1 (from [4]): Noise detected by barometers on various platforms. Floating platforms reduce the wind noise experienced by barometers.

These results offer a unique opportunity to explore the internal structure of Venus using balloons floating in the mid and upper atmosphere, without needing to land and survive on its surface for long durations.

Test Campaign on Earth: In order to achieve the aim of performing geophysical experiments from an atmospheric platform, JPL and its partners (ISAE-SUPAERO and California Institute of Technology campus) are in the process of developing technologies for detection of infrasonic waves generated by earthquakes from a balloon. The first set of experiments

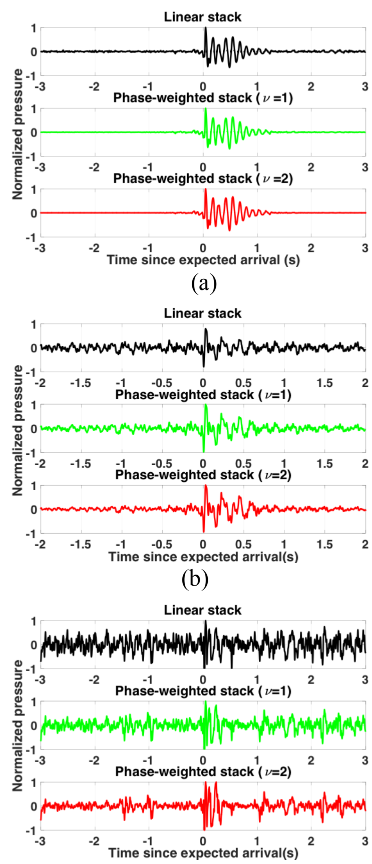

Figure 2 (from [4]): Stacked signals from different barometers. (a) Ground barometer, (b) lower aerostat (or moored balloon) barometer, (c) upper aerostat barometer

took place in Pahrump, NV in June 2017, where the ground was repeatedly struck with a seismic hammer to create artificial earthquakes. The strikes generated infrasound signals, which were detected by ground-based and balloon-borne barometers.

A variety of signal processing techniques were used to discern the weak (~ 1 Pa) infrasound signal from the background, including signal filtering, stacking (Fig. 2) and wavelet transforms. Further, barometer records were correlated with ground motion gleaned from geophones deployed near the seismic hammer site. Complex simulations incorporating elastodynamics for the solid Earth coupled with Navier-Stokes equations for the Earth's atmosphere [6] were used to generate and compare expected waveforms with the measured signals. Results from the analyses above will be presented in the final presentation.

After the successful demonstration of this technique in the lower troposphere, we plan to measure infrasound generated by artificial seismic sources with much larger source strength (underground explosions, for example). Further, we will deploy our barometers in the stratosphere over regions of high seismicity to detect infrasound from naturally occurring earthquakes. Proving the feasibility of this technology in the Earth's stratosphere would make a strong case for the detection of similar signals on Venus, where the coupling of seismic waves with the atmosphere is much more efficient than the Earth.

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