ADVANCES TOWARDS BALLOON-BASED SEISMOLOGY ON VENUS. S. Krishnamoorthy[1], L. Martire[2], D. C. Bowman[3], A. Komjathy[1], J. A. Cutts[1], M. T. Pauken[1], R. F. Garcia[2], D. Mimoun[2], V. Lai[4], J. M. Jackson[4]
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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 similar to those being performed by the InSight lander on Mars. Therefore, despite multiple visits from several landers, 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 [4]. The intensity of seismic infrasound generated depends strongly on the relative density of the atmosphere and the planet's crust. Here, 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].

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.

Earth as Venus Analog: In order to achieve the aim of performing geophysical experiments from an atmospheric platform, we are developing technologies for detection of infrasonic waves generated by earthquakes from a balloon in the Earth's atmosphere, thereby using the Earth as a Venus analog. By closely studying infrasound generation and propagation in the Earth's atmosphere, we can develop tools and methods that will allow for the detection, location and characterization of Venusquakes from a balloon floating in the relatively benign conditions in its upper atmosphere.

Progress in 2018: Significant progress was made in the year 2018 towards improving seismic infrasound detection and characterization on balloon platforms. Using data gathered in an active seismic experiment in Pahrump, NV in 2017 [4], where artificial seismic signals were generated using a seismic hammer, we demonstrated that the seismic infrasound signal as detected by balloon-borne barometers reflects the frequency content of the ground motion that produced it. Using time-of-arrival techniques, we were also able to geolocate seismic activity using its infrasound signature. Further, seismo-acoustic numerical simulations were performed and validated against these data [6]. We also began the development of a new "vector" infrasound sensor that incorporates the balloon's response to an incoming infrasound wave to generate the source's location using a single station as opposed to an array of sensors. This development is expected to greatly reduce the mass, power, and complexity of the eventual infrasound instrument to fly on Venus. Lastly, in late 2018, balloon-based barometers were deployed over chemical explosions as part of independent experiments in the state of Nevada and in a limestone quarry in southern France. Sub-surface chemical explosions are expected to produce stronger ground motion signals with better spectral similarity to natural earthquake events than the seismic hammer experiment.

Presentation Content: In this presentation, we will share detailed analysis from our various field campaigns and significant results from 2018. Our results in the last year have greatly advanced our capabilities towards performing balloon-based seismology on Venus. We will also present our plans for the future, which involve overflight of artificial and natural seismic events, characterization of the stratospheric infrasound background on Earth and development of automated detection and classification schemes for balloon-based infrasound signals.

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