PROGRESS TOWARDS BALLOON-BASED SEISMOLOGY ON VENUS IN 2020-2021. S. Krishnamoorthy[1], L. Martire[1], D. C. Bowman[2], J. Jacob[3], B. Elbing[3], E. Hough[3], Z. Yap[3], M. Lammes[3], H. Linzy[3], T. Swaim[3], A. Vance[3], P. M. Simmons[3], A. Komjathy[1], M. T. Pauken[1], J. A. Cutts[1], Q. Brissaud[4], J. M. Jackson[5], R. F. Garcia[6], and D. Mimoun[6]
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Introduction: Adverse conditions on the surface of Venus have thus far prevented long-duration seismic studies. Traditional seismology on the surface of Venus using a long-lived lander is decades away. Since 2016, we have been developing remote sensing technology that would enable the detection and characterization of putative Venusian seismic activity from balloons in its upper atmosphere. In this presentation, we will discuss the progress our group has made in the last year.

Infrasound Remote Sensing: Infrasound has been recorded from a variety of events on Earth. Of particular interest to Venus exploration are infrasound signals from quakes, volcanic eruptions, thunderstorms, and meteors. Venus offers a unique opportunity for the use of infrasound as an investigative tool for surface ground motion– due to its dense atmosphere, energy from seismic activity couples with the Venusian atmosphere up to 60 times more efficiently than Earth. Infrasound is also known to propagate long distances from generating events with relatively little attenuation, thereby making it an effective alternative to placing sensors on the surface of Venus. Acoustic sensors used to capture infrasound may also be used to investigate low-frequency, large-scale planetary atmospheric features such as planetary-scale gravity waves.

The main advantage of performing balloon-based infrasound science on Venus is the extension of mission lifetimes by virtue of being in a more benign environment. Compared to 460 C temperature and 90 atmospheres pressure on the surface, atmospheric conditions are more Earth-like at 55-60 km altitude on Venus. Further, acoustic sensors greatly benefit from being on a platform that floats with the wind, leading to higher coverage and lower wind noise.

Recent Significant Results: In this presentation, we will discuss several significant recent advances made towards balloon-based seismology on Venus. Notably, these include:

1. **Ridgecrest Balloon-Based Earthquake Detection:** The Owens Valley region of California experienced over 10,000 aftershocks of magnitude 1.5 or greater in the 6 weeks after the July 4 and 6, 2019 main shocks with magnitude 6.4 and 7.1 near Ridgecrest, CA. We conducted four balloon flights in the area, each balloon equipped with up to two microbarometers. This experiment led to the first detection of an earthquake from a balloon. The magnitude 4.2 earthquake was detected by a slowly-rising balloon nearly 80 km horizontal distance from the epicenter at an altitude of 4.8 km above sea level. The detected signal was seen at the balloon approximately 40 seconds after the earthquake and was generated by a Rayleigh wave produced by the earthquake.

2. **Epicentral infrasound detection from buried chemical explosion:** In 2019, the Department of Energy detonated a chemical charge with a yield of 10-tons TNT equivalent at a depth of 51.6 meters below the ground. The resulting explosion generated surface displacement at ground zero, which in turn generated seismic infrasound. The infrasound signal was detected on a balloon-borne barometer at 56 km horizontal range and 20 km altitude. This result demonstrates that epicentral infrasound from strong earthquakes may be detectable from a balloon platform.

3. **Completion of the first BASS summer flight campaign in Oklahoma:** The Balloon-based Acoustic Seismology Study is funded through the NASA Planetary Science and Technology through Analog Research (PSTAR) program. In September 2021, we completed the first summer of flights in Oklahoma in search of infrasound signals from fracking-generated earthquakes. Oklahoma State University students launched and recovered over 30 flights of "heliotrope" solar-heated balloons in a period of 2 months from July to September 2021. These balloons floated for greater than 10 hours each flight day and recorded infrasound data using JPL's infrasound sensor packages. This dataset is the first seismic infrasound monitoring of its kind and is currently being analyzed for weak earthquake signatures.