A Compact Infrasound Array for Deployment in Venus's Atmosphere. E. F. Young[1] and V. Klein[1], [1]Southwest Research Institute, 1050 Walnut St., Boulder CO, 80302 (efy@boulder.swri.edu).

Introduction: Infrasound is defined by its frequency range: below 20 Hz (a nominal limit of human perception). Because the attenuation of sound waves decreases with lower frequencies, infrasound can be used to detect distant disturbances. On Earth, the Comprehensive Test Ban Treaty Organization's International Monitoring System (CTBTO-IMS) has up to 60 infrasound stations around the world [1]. Each of these stations consists of several microphones, embedded in wind-filtering structures and over areas of roughly a square km. The large areal coverage helps determine the propagation directions of infrasound waves, which have wavelengths of ~300 m to 3 km at frequencies of 1 to 0.1 Hz, but large areas present a challenge for instrument arrays to be deployed on Venus. Here we describe a compact array that can determine propagation directions.

Infrasound on Venus: Several studies have demonstrated the close coupling between seismic events and infrasound wave waves in the atmosphere [2]. Given the very long distances over which infrasound waves can be detected, balloon-borne infrasound sensors could detect, locate and characterize earthquakes and volcanoes, as well as non-seismic events like bolides. In addition, balloon-borne infrasound sensors would be valuable for measuring wind and temperature fields on Venus. This application fills a compelling need in the study of Venus's circulation: the bulk of Venus's atmosphere, including the altitudes with the greatest concentration of angular momentum, lie below 40 km. Circulation in this region has been almost impossible to study: cloud tracking is unavailable, and radio occultations cannot probe below ~38 km because radio and light waves at that altitude are bent more than the radius of curvature of the solid planet. Even spacecraft-to-spacecraft transmissions cannot probe below ~38 km.

In contrast, infrasound is well-suited to probing Venus's lower atmospheric circulation. In a general medium, a wave's bending angle is the derivative of its propagation delays in the plane perpendicular to the direction of travel. The speed of sound (in m/s) in a CO_2 atmosphere is roughly 15.6 times the square root of the temperature (K), so temperature field variations affect the direction of infrasound propagation. Similarly, gradients in wind fields affect propagation directions. Infrasound detected at one or more balloons would constrain the wind and temperature fields between infrasound sources and the balloon-borne detectors, particularly the hard-to-observe regions below the cloud base. On Earth, the *ARISE* project leverages infrasound signals to improve meteorological predictions [3].

A Compact Infrasound Array: Balloon-borne infrasound sensors - on Earth and Venus - have an intrinsic advantage over ground-based stations: free-floating balloons are essentially immune to noise from ambient winds, which is the dominant noise source for ground stations.

A key design challenge for a meter-size payload is the detection of infrasound propagation directions: the sensor spacing is on the order of 0.1% of the signal's wavelength. This means that pressures need to be sampled at tens of KHz rates. We discuss SNR requirements and prospects for cross-correlating signals from sensors that are separated by ~1 m in order to determine 3d infrasound directions with resolutions of a few degrees.

A Venus-specific challenge is the acidity within the cloud decks (~47 - 70 km altitude), where balloons would likely be deployed. We discuss the vapor pressure of H_2SO_4 at these altitudes and the fact that its gas abundance can be quite low. This leads to design concepts with Gore-Tex-shielded microphones. We discuss the acoustic transmission of such membranes and their ability to protect microphones in Venus's cloud decks.

References:

[1] <https://www.ctbto.org/map/>

[2] Cutts, J. A. et al. "Balloon Infrasound Networks for Investigating the Venus Interior (2021). <https://www.hou.usra.edu/meetings/lpsc2021/pdf/2319.pdf>

[3] <http://arise-project.eu/infrasound.php>