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Monitoring and imaging the atmosphere with infrasonic ambient noise correlations

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The existence of widespread infrasonic ambient noise (e.g., microbaroms) opens up the possibility of investigating atmospheric acoustic structure with new techniques designed for continuous stochastic signals. This is in contrast to classical approaches that use deterministic signals (e.g., explosions) with clear phase arrivals. Here, we review some recent advances in the monitoring and imaging of the atmosphere derived from analysis of continuous infrasound noise.

From two microbarometers located at Fourpeaked Volcano in Alaska, we observe coherent arrivals in cross-correlations of ambient noise in the microbarom band (0.2-0.5 Hz) at time lags that agree well with speeds expected for a direct infrasound wave in the atmosphere (300-340 m/s). A striking example of the dependence of the ambient noise correlations on atmospheric conditions is evident from a comparison with temperature and wind data measured on nearby ocean buoys. Application of the multiple-filter technique reveals that the group velocity of the infrasound wave is dispersive, with higher group velocities at lower frequencies. This supports the existence of a low-level atmospheric waveguide at Fourpeaked Volcano during the time period under study. We invert the observed time-dependent group velocity dispersion curves for average sound speed profiles as a function of time. The inverted sound speed profiles show that a time-dependent, surface-based inversion layer became stronger over a period of 24 hours, with a colder, denser, and lower sound speed layer moving between the stations. This layer is imaged in the lower 2 km of the atmosphere and demonstrates the sensitivity of ambient noise correlations to the atmospheric boundary layer. Independent analysis of meteorological data in and around Fourpeaked volcano from the same time period supports the results derived from the infrasound ambient noise correlations. We also show examples of ambient noise correlations from time periods of normal temperature gradient, when the infrasound propagates in a leaky waveguide.

To move beyond guided infrasound waves in the atmospheric boundary layer, we discuss the prospect of retrieving, from correlations, infrasound waves that have transmitted through the upper atmosphere. Such waves could be used, for example, to better delineate the structure and extent of Sudden Stratospheric Warming events. In addition, atmospheric flows in the stratosphere are more laminar than in the boundary layer and thus more conducive to long-range wave propagation. The situation for retrieval of infrasound from the upper atmosphere is similar to that encountered in exploration seismology, where seismic waves reflected from deep interfaces (1 km) must be extracted from surface measurements contaminated by large amplitude guided waves. We discuss the use of array-based techniques to preferentially attenuate large amplitude, laterally propagating guided waves in the atmospheric boundary layer. We expect wind direction and speed to play a major role in the propagation of infrasound in the upper atmosphere and discuss the effects of wind on the ambient noise correlations.