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Studies of large- and fine-scale atmospheric structure using dense seismic networks

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Several studies have shown that the fit of infrasound synthetics to recorded data can be improved by adding small-scale structure to atmospheric models. However these findings have been based on sparse recordings. Although the IMS infrasound network gives unprecedented coverage of the atmosphere, and this network has been infilled in some regions, there are still not enough stations for close examination of the complexity of the infrasound wavefield, which is due to spatial and temporal variability of the atmosphere. There is a pressing need for more stations, deployed at small offsets, to rigorously test atmospheric models, in particular currently popular hybrid models that include realizations of small-scale structure.

Infrasound signals couple to seismic at the Earth's surface. In some regions there are considerably more seismic stations than infrasound stations. For example, the USArray Transportable Array (TA) comprises 400 stations deployed on a 70 km spaced Cartesian grid spanning approximately 2,000,000 sq km. In our study we use the TA, and the more dense High Lava Plains (HLP) network, to study the spread of the infrasound wavefield from large ground-truthed explosions at the Utah Test and Training Range (UTTR). The TA provides a broad spatial coverage while the HLP network offers a detailed look at how infrasound branches vary with range from near UTTR to a distance of about 800 km at an azimuth of 300°.

We have used these networks to evaluate two types of atmospheric model, 1) mesoscale G2S atmospheric models, and 2) G2S models that include realizations of gravity waves. We evaluate these models for predicting the spatial extent of the infrasound wavefield (in particular the limits of the "zones of silence" near the source), signal travel times and the duration of recorded signals. We have used ray theory for the bulk of our analysis. Both the unperturbed and perturbed models provide accurate predictions of acoustic travel times although rays shot through the unperturbed models consistently overpredict the extent of the shadow zones and underpredict the duration of recorded signals. By varying the parameters of the gravity wave perturbations we find a physically reasonable distribution of gravity waves that yield rays that match the dimensions of the wavefield recorded by both the TA and HLP networks. The perturbed rays that land near each station also consistently arrive in a lengthy packet that matches the onset time and duration of the observed signals. A small percentage of perturbed rays arrive before the unperturbed rays, perhaps due to gravity wave structure near the turning point. The bulk of rays travel longer paths to the stations and arrive later. We know that rays do not capture all the physics of wave propagation through the atmosphere, in particular the hybrid models we have used, however there is remarkable agreement between the statistical distribution of rays in time at each recording station and the corresponding recorded waveforms.