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Research Interests: infrasound, seismology, array processing methods

Kris Walker has focused on several atmospheric infrasound projects during 2009-10. Most of these projects have led (or are leading) to scientifically interesting results. The other projects are geared toward building infrastructure that will benefit future research.

Infrasonic Source Imaging with the USArray:
In collaboration with Michael Hedlin, Catherine de Groot-Hedlin, and other researchers at the Naval Research Lab and Commissariat à l'Energie Atomique, Kris compared the performances of the USArray and four globally spaced infrasound arrays to analyze a meteor explosion that occurred in northeast Oregon in 2008 (Walker et al., in press). He used reverse-time migration to back-project USArray vertical broadband recordings of acoustic-to-seismic coupled signals that were observed out to a range of 800 km. The source imaging suggests that these signals are explained by a terminal burst rather than a line source associated with a hypersonic trajectory through the atmosphere. Using the bootstrap method, he determined the 95% confidence region of the source location in 3-D space and time (Fig. 1). The source altitude, video camera constraints, and variance in final source locations provided by different algorithms suggest that the hypersonic trajectory had a minimum speed of 40 km/s. The spatial source location uncertainty was an order of magnitude smaller than that typically provided by globally spaced infrasound arrays, suggesting that despite the complexities associated with station-to-station variations in subsurface geology, it is more useful, for location purposes of energetic events, to analyze seismic recordings from dense seismometer networks than to analyze infrasound recordings from infrasound arrays with an average inter-array spacing of 2300 km.

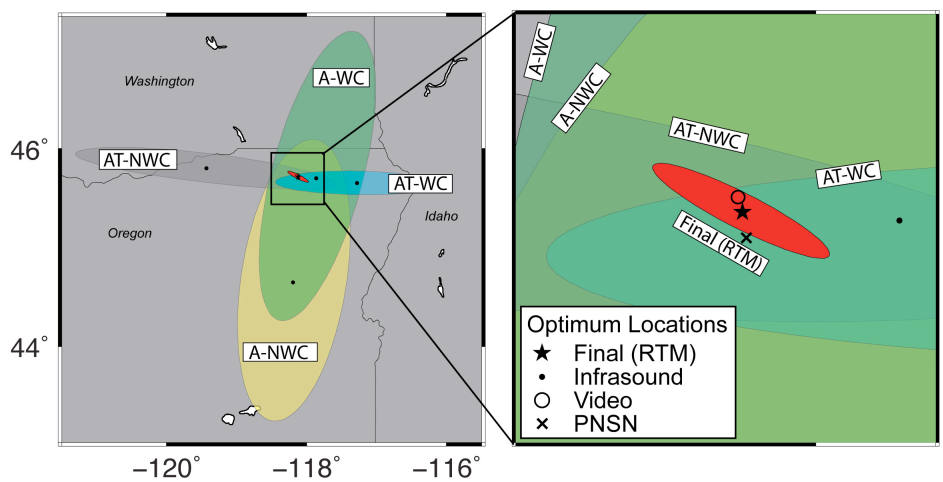

Fig. 1. Comparison of source locations and 95% confidence regions for the bolide burst source location estimated with the USArray seismic network (Final RTM) and infrasound arrays in North America. The infrasound array source locations are derived with different techniques and assumptions depending on if only back azimuths were used (A), if both back azimuths and times were used (AT), and if a wind correction is performed (WC or NWC). PNSN is the Pacific Northwest Seismic Network source location.

Kris is also using reverse-time migration (RTM) with the USArray to systematically locate infrasonic sources with undergraduate Richard Shelby and Michael Hedlin. Hundreds of sources have been detected thus far using this technique in 2008. For example, Fig. 2 is a USArray "infrasonic image" of a Vandenberg Air Force Base rocket launch. This figure shows the analyst's picking tool used to identify events of interest by manually inspecting peaks in an automatically calculated detector function, which is based on the RTM data. There is on average one U.S. event observed per day. More interesting are the propagation and source patterns observed in the data. Kris submitted an NSF proposal to extend this study to span 2004-2009. The development of a catalog of events detected with the USArray has a broader impact in infrasound research because there are generally few publically available ground truth catalogs of infrasonic events, which can be used to test a variety of infrasound propagation hypotheses as well as validate new 4-D velocity models.

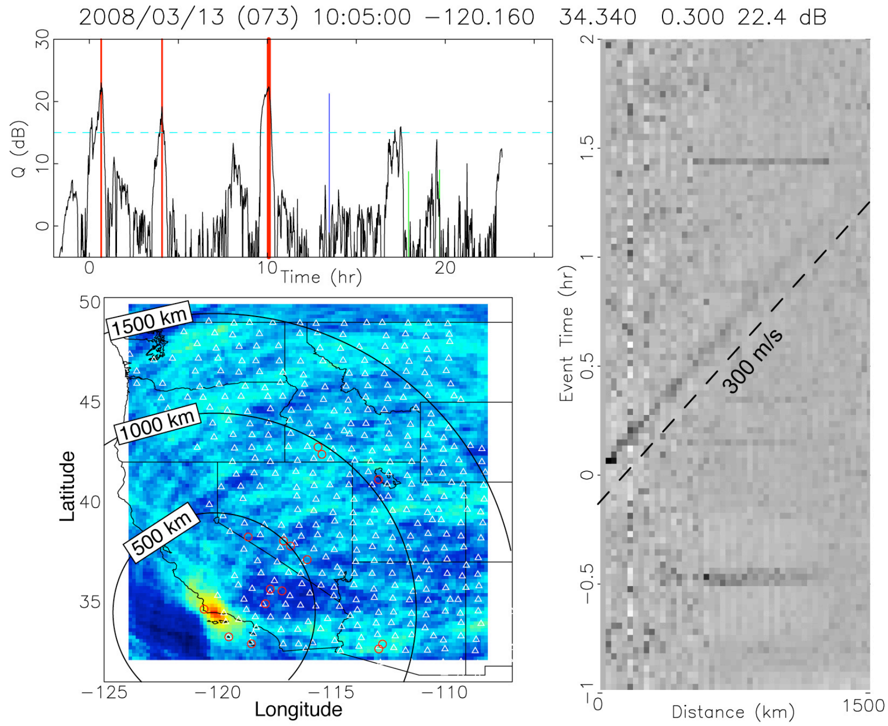

Fig. 2. The Q detector function (upper left) images the source in time; there is a peak at the launch time (thick red line) with a signal-to-noise ratio of 22 dB. Other colored lines indicate known regional and teleseismic earthquake times. The map shows the seismic energy migrated back to the source, where it constructively interferes, imaging the source in space at the source time. The record section to the right shows that the energy associated with the peak moves out at ~300 m/s, indicating that rocket infrasound is observed via acoustic-to-seismic coupling on USArray seismometers (white triangles in map) out to ~1500 km. Horizontally aligned signals are earthquakes.

Optical Fiber Infrasound Sensor (OFIS):

The second project Kris is working on is the development of a ruggedized, DC-powered OFIS for remote, autonomous deployments. The OFIS has proven to be more effective than pipe rosettes in mitigating the negative effects of wind in the measurement of infrasound (Walker and Hedlin, 2010). But until recently, this technology has been "fragile" and not been suitable for remote, autonomous deployments. This new development effort is an SIO collaboration with David Chavez, Michael Davis, Ph.D. graduate student Scott DeWolf, David Howitt, Mike Kirk, undergraduate Richard Shelby, Joel White, Frank Wyatt, and Mark Zumberge. In 2008, the OFIS system was an A/C powered research project with a large footprint comprising swappable rack modules, a bench-top laser, an optical polarization manipulation device, a digital signal processor, and a computer attached to an internet switch. The 2008 system also had an interferometer uptime issue associated with temperature change. Fabricated and tested in September 2010, OFIS v. 2.0 is a DC-powered system comprising miniaturized electronic boards, a lower-noise OEM laser with advanced feedback circuit, a low-power computer and digitizer, and a 900 MHz radio that transfers data to an internet switch. Scott DeWolf and Mark Zumberge addressed the uptime issue by adding Faraday mirrors to the sensing and reference optical paths, which eliminate the cumulative effects of temperature-dependent anisotropy. The new system will be deployed in northern California for one year as part of a NOAA-funded research project to study Pacific microbaroms. The new system is now capable of being deployed around volcanoes or in other remote environments where it is necessary to acquire high-quality, broadband recordings of infrasound in the presence of wind.

El Mayor Mw 7.2 Earthquake:
Kris is also collaborating with Catherine de Groot-Hedlin on a study of the infrasound generated by the Baja California Mw 7.2 earthquake (Walker and de Groot-Hedlin, 2010). Two infrasound arrays in southern California (MRIAR and I57) recorded a long infrasound wavetrain from this earthquake. Array processing of MRIAR data identifies a clear back azimuth rotation with time that spans the entire ~100 km long rupture. Ray tracing using 4-D velocity models suggests that the wavetrains are refracted thermospheric arrivals, which are inherently interesting because their existences are not predicted based on the classic thermospheric attenuation model. The ray tracing also shows that the MRIAR rotation of back azimuth with time is due to the fact that the northern end of the bilateral rupture is much closer to MRIAR than the southern end. Experiments suggest that we can image the rupture with the MRIAR data in a similar manner to earthquake rupture imaging (e.g. Walker and Shearer, 2009). More information is available at http://hpwren.ucsd.edu/news/20100413/.

Southern California Infrasound Network:
Southern California has an impressive seismic network. . Kris is working on the creation of an analogous infrasound array network, which will permit a number of studies in regional sources, propagation, signal processing methods, and wind noise reduction. This collaboration with Mark Zumberge and Michael Hedlin culminated in June 2010 with the deployment of SMIAR, the third southern California infrasound array. More information about SMIAR is available at http://hpwren.ucsd.edu/news/20100701/.

Infrastructure Building for Global and Regional Infrasonic Studies:
Infrasonics can be though of as surface-wave seismology turned upside down. There is a renewed interest in infrasonics because of the recent creation of the IMS global infrasound array network and the advent of 4-D global atmospheric velocity models. There are now many opportunities to make contributions to our understanding of infrasound sources, propagation, sensor development, and inversion methods. To facilitate future infrasonics research, Kris is also creating a database of global infrasound array network data and 4-D atmospheric velocity models with which to model infrasonic propagation. Roughly 60% of the global array data and 80% of the 4-D velocity models from 2004 to present are archived at IGPP. Some of these data are considered restricted, but may be published with permission from federal government entities, which is done routinely. Kris seeks undergraduate or graduate students interested in atmospheric acoustics to begin or assist with new research projects.

References:
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