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Research Interests: Analysis of acoustic signals from large-scale atmospheric phenomena; study of seismo-acoustic phenomena, nuclear test-ban verification.

Infrasound: The study of subaudible sound, or infrasound, has emerged as a new frontier in geophysics and acoustics. We have known of infrasound since 1883 with the eruption of Krakatoa, as signals from that event registered on barometers around the globe. Initially a scientific curiosity, the field briefly rose to prominence during the 1950's and 1960's during the age of atmospheric nuclear testing. With the recent Comprehensive Test-Ban Treaty, which bans nuclear tests of all yields in all environments, we have seen renewed interest in infrasound. A worldwide network of infrasound arrays, being constructed ostensibly for nuclear monitoring, is fueling basic research into man-made and natural sources of infrasound, how sound propagates through our dynamic atmosphere and how best to detect infrasonic signals amid noise due to atmospheric circulation.

Research at L2A: The new Laboratory for Atmospheric Acoustics (L2A) is the home of research in this field at IGPP. Several faculty, post-docs and PhD students work full or part time in L2A, supported by engineers and technicians in the lab and the field. Presently we study a broad suite of problems related to both natural and man-made sources.

Seismic network observations of atmospheric events: The global infrasound network is unprecedented in scale however it is still very sparse, with on the order of 100 stations operating worldwide. To increase the density of sampling of the infrasonic wavefield to study atmospheric phenomena and propagation of infrasound through the atmosphere we have used acoustic–to-seismic coupled signals recorded by dense regional seismic networks, such as the 400-station USArray. We have studied propagation from large bolides and other events, such as large explosions. The seismic network is allowing us to study in detail acoustic branches from large atmospheric events that are akin to seismic branches. We are using the network to create a catalog of atmospheric events in the United States similar to commonly used seismic event catalogs. The acoustic catalog is used in part to find sources of interest for further study and to identify regions where large atmospheric events are prevalent.

USArray upgrade: We were recently funded to upgrade the USArray with infrasound microphones and barometers. Our sensor package will be sensitive to air pressure variations from D.C. to 20 Hz, at the lower end of the audible range. We expect that over the coming year the entire USArray will be retrofitted with these new sensors to create the first-ever semi-continental-scale seismo-acoustic network. The network will span ~ 2,000,000 square km in the eastern United States before being redeployed in Alaska.

Miscellaneous studies: 1) Ocean noise: Using data from our permanent array in the Anza-Borrego desert and two more arrays near San Diego we detect surf noise from along the coast of California. Infrasonic waves from the crashing surf propagate through the stratosphere to our stations up to 200 km away. We see further avenues for research in this area in that lower frequency signals, known as microbaroms, are known to propagate 1000's of km and can be used to probe atmospheric structure**. 2) Natural hazards**: Our group is using infrasound energy to detect and monitor emerging hazards (such as volcanic eruptions, major storms at sea, tornadoes).

We are particularly interested in the use of infrasound sensors to monitor volcanoes, such as Mount Saint Helens, that have a history of releasing ash into the stratosphere. **3) Study of seismo-acoustic phenomena:** The Earth's free-surface is rich in sources that generate both downgoing seismic and upgoing acoustic energy. We believe to properly characterize such sources it is necessary to study the entire seismo-acoustic wavefield. We have recently completed a study of Mount Saint Helens using both types of sensors (Robin Matoza, PhD thesis). Studies of other seismo-acoustic sources (such as shallow earthquakes) are currently underway.

Field operations: Our group has built two permanent infrasound arrays in the US and one in Africa. In recent years we have deployed infrasound arrays across the southwestern US to record signals from high-altitude explosions and natural phenomena. We currently operate research arrays located near San Diego with another to be deployed near Chico, California in late 2010. A typical temporary array comprises 4 to 8 aneroid microbarometers or fiber-optic sensors spanning an area 100 to 300 meters across, with data recorded using 24-bit Reftek digitizers and telemetered in realtime to our lab in La Jolla. We use Sun workstations and a suite of Macintosh G5 computers. All data from the field is archived on a multi-TB RAID. All computers, and supporting peripherals such as printers, are linked via a broadband communications network.

Relevant Publications

Arnoult, K., Olson, J., Szuberla, C., McNutt, S., Garces, M., Fee, D. and Hedlin, M.A.H., 2010, Infrasound observations of the 2008 explosive eruptions of Okmok and Kasatochi volcanoes, Alaska, Journal of Geophysical Research – Atmospheres (in press). Arrowsmith, S.J., Drob, D.P., Hedlin, M.A.H. and Edwards, W., 2006, A joint seismic and acoustic study of the Washington State bolide: Observations and modeling, in review with Journal of Geophysical Research. v**112**, D09304, doi:10.1029/ 2006JD008001.

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Matoza, R.S., Hedlin, M.A.H., Garces, M.A., 2006, An infrasound array study of Mount St Helens, *Journal of Volcanology and Geothermal Research*. **v160**, issues 3-4, p249-262.

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Matoza, R.S., Fee, D., Garces, M.A., Seiner, J.M., Ramon, P.A. and Hedlin, M.A.H, 2009, Infrasonic jet noise from volcanic eruptions, *Geophysical Research Letters,* **v 36**, doi:10.1029/2008GL036486. Walker, K., Walker, K. and Hedlin, M.A.H., 2010, A review of infrasound wind noise reduction technologies, *Global Continuous Infrasound Monitoring for Atmospheric Studies, Springer Geosciences,* p141-182.

Zumberge, M., Hedlin, M.A.H., and Shearer, P., .., 2007, Methodologies for determining infrasound phase velocity direction with an array of directional acoustic sensors, *J. Acoust. Soc. Am. **124**, 2090-2099.*