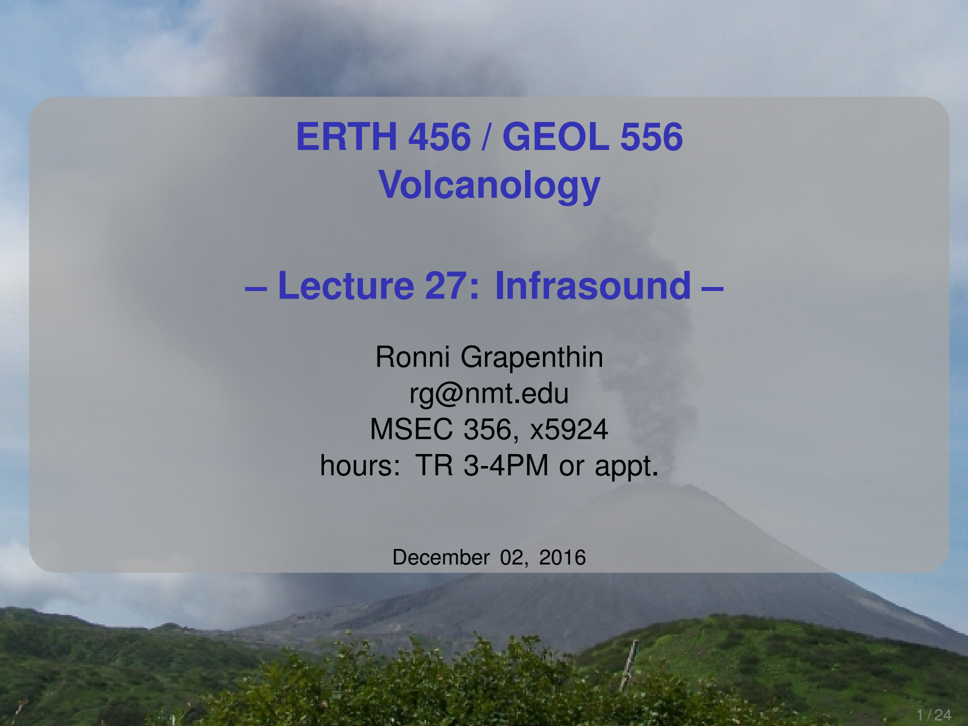

ERTH 456 / GEOL 556
Volcanology

– Lecture 27: Infrasound –

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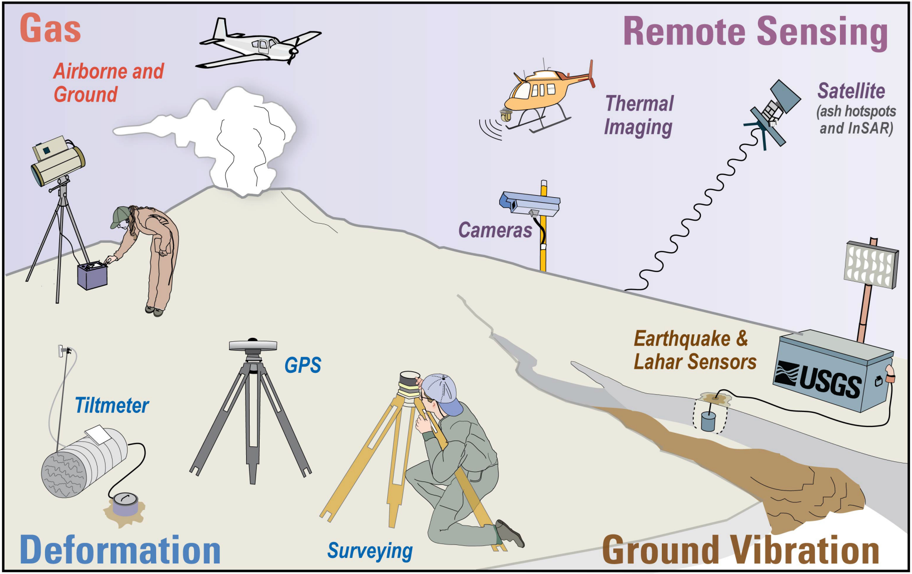
hours: TR 3-4PM or appt.

December 02, 2016

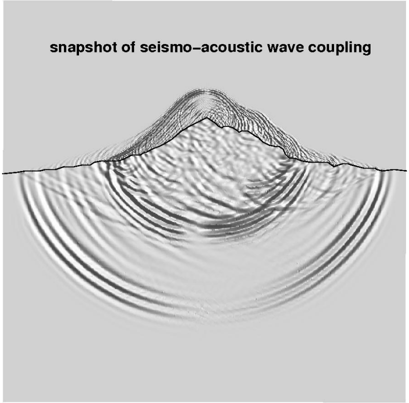
Monitoring & Analysis Overview



USGS, Lisa Faust

What is Infrasound?

- low-frequency sound waves $<$ 20 Hz (due to large lengths scales at volcanoes)
- generated around volcanoes by **shallow** processes coupling with atmosphere
- propagates as acoustic energy; low attenuation at low frequencies in atmosphere
- at speed of sound $\approx$ 340 m/s: takes 15 min to travel 300 km.



Universität München

What is Infrasound?

- can be used to detect, locate, characterize volcanic processes
- need information on atmosphere; particularly for long-range observations (100s km)
- examples:
  - explosion - impulsive burst
  - tremor - long duration vibration
  - lava dome collapse, rockfalls
  - pyroclastic flow

ISS Crew, 2008

Acoustics

- Speed of sound in ideal gas:

$$c = \sqrt{\gamma R T}$$

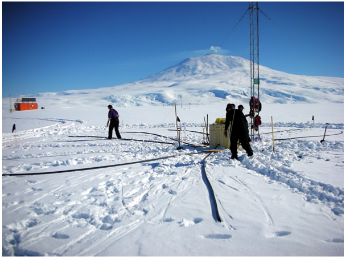
- γ: specific heat ratio
- R: universal gas constant
- T: temperature
- speed of sound proportional to sqrt of temperature
- wind affects propagation and travel times

Signal Distortion

- attenuation (energy loss) due to
  - absorption (kinetic energy -> heat)
  - geometrical spreading
- low absorption in infrasound band: ($\approx 10^{-6}$ dB/km at 0.1 Hz vs. $\approx$2.4 dB/km at 125 Hz)
- geometric spreading = waveform expansion: pressure decrease $\frac{1}{r}$, r is distance, for point source
- topography causes scattering and amplitude losses; important to account for in near-field
- wind is primary noise source (microporous hoses, dense forests)

Sensors

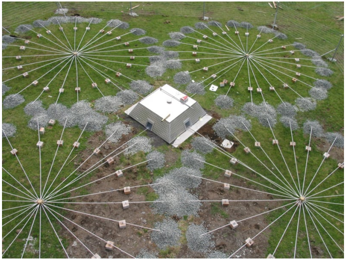
- barometers were earliest infrasound sensors; recorded Krakatau 1883
- measure pressure changes relative to ambient atmospheric pressure
- amplitude in near field 0.1-100 Pa



Geophysical Institute, UAF

Sensors

- deployed as single sensor or array
- array deployments allow azimuth determination as wave traverses array
- allow wind noise reduction as it's incoherent across elements



IS49, UK, *Internet*

Comprehensive Nuclear-Test-Ban Treaty

- International Monitoring System (IMS) includes infrasound sensors
- 60 stations globally distributed, increased interest in volcano accoustics

Comprehensive Nuclear-Test-Ban Treaty

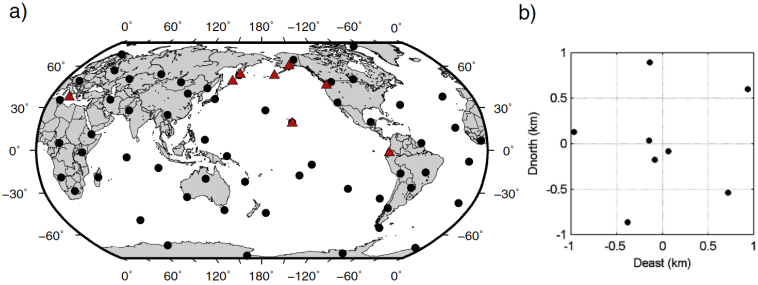
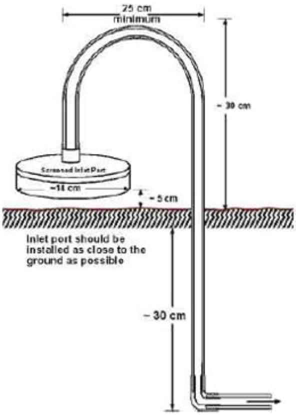


Fig. 1. Global map of infrasound arrays. a) Map of IMS arrays (black circles) and volcanoes discussed in detail in this paper (red triangles). An example IMS array configuration (from IS53, Fairbanks, AK) is shown in b). The array consists of eight elements arranged in an outer pentagon and inner triangle.

Fee & Matoza, 2013, JVGR

Sensors



IS07, Warramunga, Australia, *Internet*

Sensors

Qaanaaq, Greenland, *Internet*

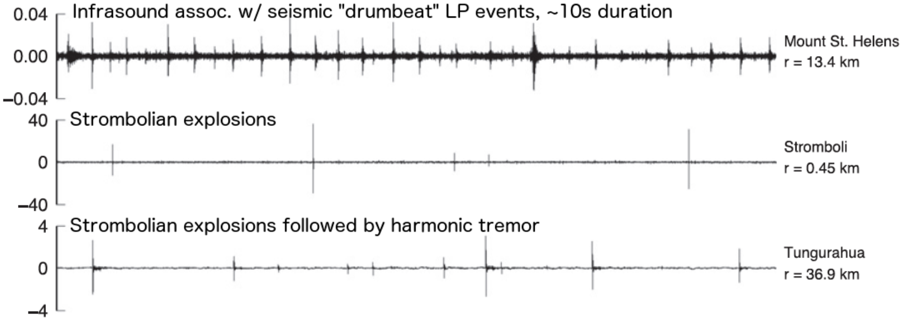
Event Types

- event nomenclature follows volcano seismology
- **infrasonic tremor:** continuous vibration of atmosphere, seconds to months long
- **harmonic tremor:** frequency spectrum with fundamental frequency and several harmonics
- **monochromatic tremor:** single peak in spectrum (less common)
- **spasmodic tremor:** individual tremor bursts separated in time

Fee & Matoza, 2013, JVGR

Event Types

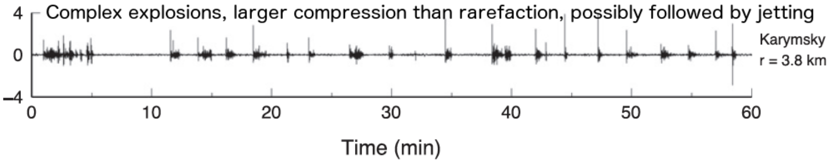
- **explosion:** transient event, rapid volume expansion (compression), followed by rarefaction (decompression), seconds to minutes with impulsive onset and coda
- **LP seismic events:** commonly observed with shallow degassing, jets, repeated puffs of steam/ash



Fee & Matoza, 2013, JVGR

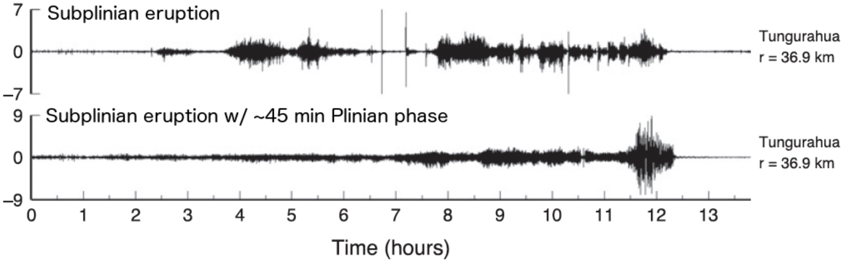
Event Types

- jet flow: broadband noise due to continuous, vigorous gas release



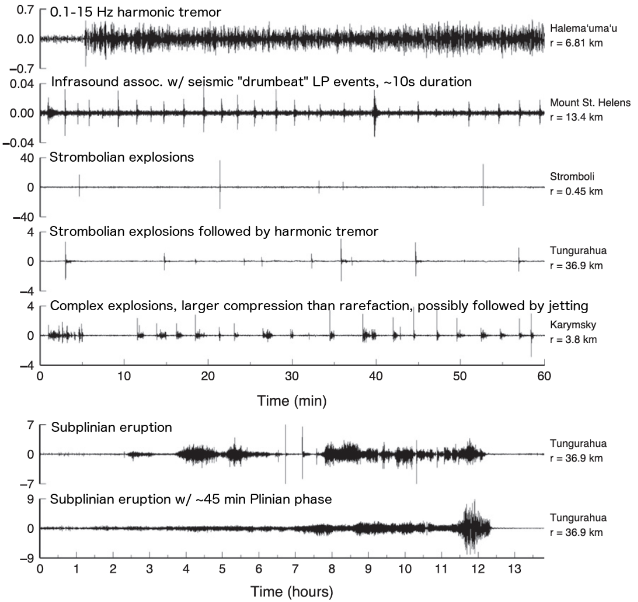
Fee & Matoza, 2013, JVGR

Event Types - Subplinian/Plinian



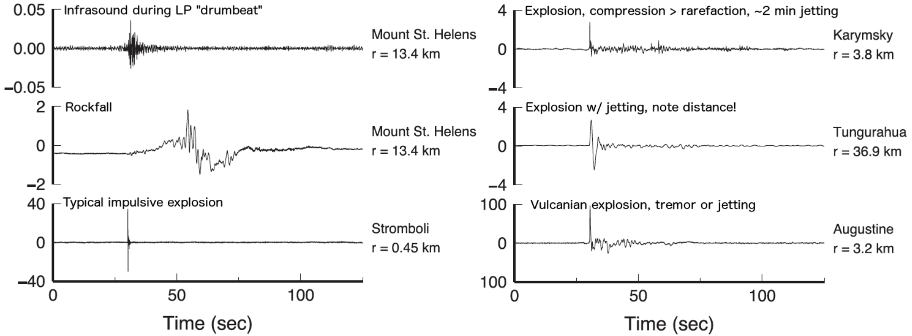
Fee & Matoza, 2013, JVGR

Event Types - Comparison



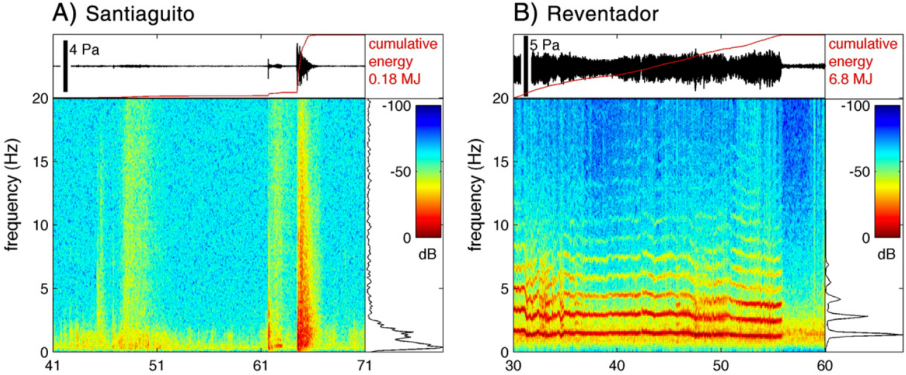
Fee & Matoza, 2013, JVGR

Event Types - Comparison



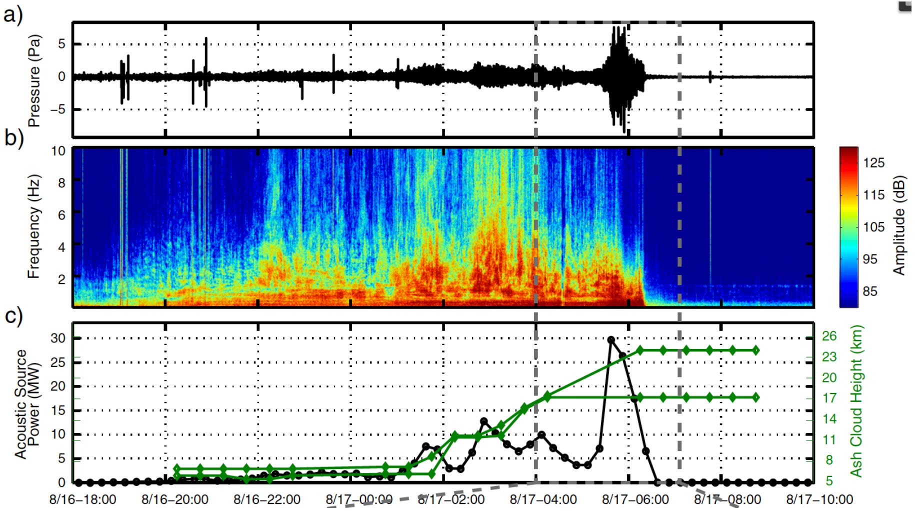
Fee & Matoza, 2013, JVGR

Event Types - Comparison



Johnson & Ripepe, 2013, JVGR

Event Types - Comparison



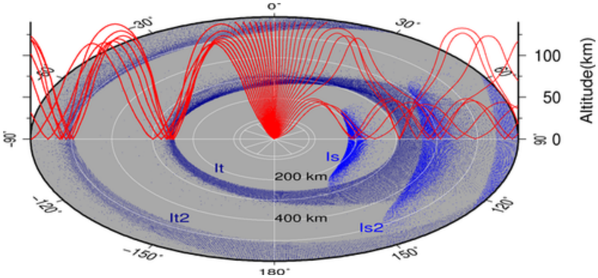
Fee & Matoza, 2013, JVGR

Propagation (regional/global)

- of most interest: lower 140 km of atmosphere
- winds vary temporally & spatially
- wind components: zonal (east-west, positive east), meridional (north-south, postitive north)
- jet stream $\approx$ 12 km height at mid-latitudes

Propagation (regional/global)

- zonal stratospheric jet results in ducting (changes direction winter/summer), most important for global detections
- complex refraction patterns depending on temperature, wind, topography,



TU Delft

St. Helens Atmosphere Profile, Feb. 01 2012

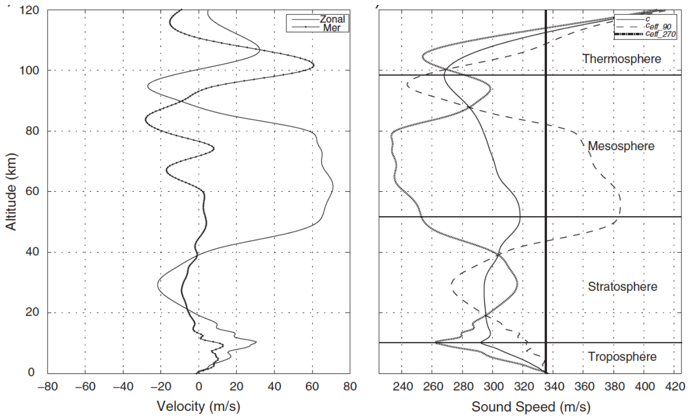
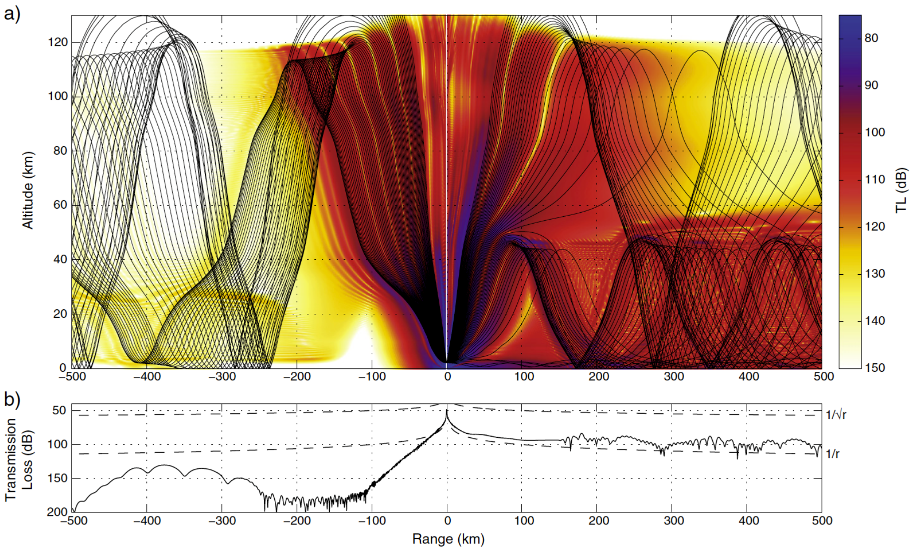


Fig. 6. G2S atmospheric specifications above Mount St. Helens on 1 February 2012 0000 UTC. a) Zonal (east–west, positive corresponds to easterly blowing) (solid line) and meridional (north–south, positive northerly) (solid-dot) winds show a broad, strong easterly wind jet in the stratosphere and strong easterly tropospheric jet at ~10 km (the jet stream). b) Static (c) and effective sound speed profiles for propagation to the east (c_{eff_90}) and west (c_{eff_270}). The static sound speed has a typical shape, with c decreasing with height in the troposphere, increasing in the stratosphere, decreasing in the mesosphere, and then increasing again in the thermosphere. The effective sound speed profiles reflect the strong zonal wind jets, with a duct predicted to the east (c_{eff_90}) in the troposphere at ~10 km and a deep duct beginning at ~45 km height. Thermospheric ducting is predicted for propagation in both directions at ~110 km.

Fee & Matoza, 2013, JVGR

St. Helens Raytracing, Feb. 01 2012



Fee & Matoza, 2013, JVGR