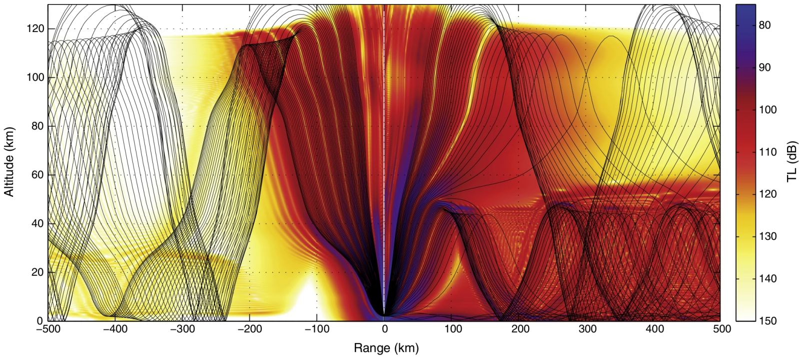
Volcano Infrasound Propagation Affected by Vent Topography

Keehoon Kim

University of North Carolina at Chapel Hill

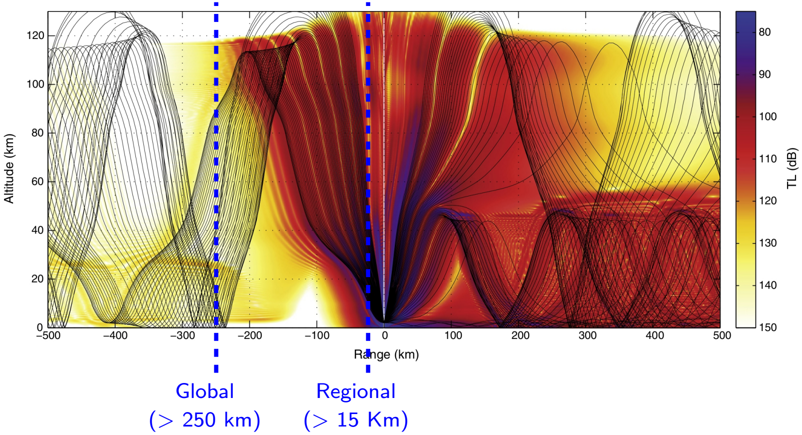
July 25, 2013

Volcano Infrasound Propagation



Global infrasound propagation (Fee and Matoza, 2013)

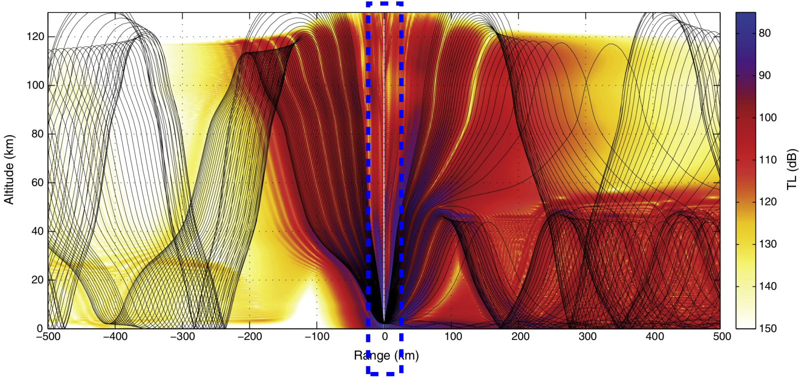
Volcano Infrasound Propagation



Spatiotemporal variability of the atmosphere

- Wind
- Velocity structure

Volcano Infrasound Propagation



In the local (< 15 Km)

- Acoustic source properties
- Topography

Mathematical Representation of Acoustic Sources

$$\hat{p}(x) = \int \hat{s}(x_0) \frac{e^{ikR}}{R} dV_0 \qquad \text{(Rossing, 2007)}$$

$$\Downarrow$$

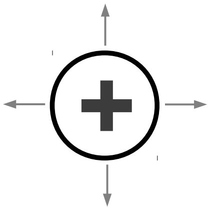
$$\hat{p} = \hat{S}\frac{e^{ikr}}{r} - \sum_{\nu=1}^{3} \hat{D}_\nu \frac{\partial}{\partial x_{nu}} \frac{e^{ikr}}{r} + \sum_{\mu,\nu=1}^{3} \hat{Q}_{\mu\nu} \frac{\partial^2}{\partial x_\mu \partial x_\nu} \frac{e^{ikr}}{r} + \cdots$$

$$\hat{S} = \int \hat{s}(x) dV, \qquad \text{Monopole}$$

$$\hat{D}_\nu = -\int x_\nu \hat{s}(x) dV, \qquad \text{Dipole}$$

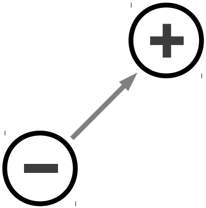
$$\hat{Q}_{\mu\nu} = \frac{1}{2!} \int x_\mu x_\nu \hat{s}(x) dV. \qquad \text{Quadrupole}$$

Point Source Approximation



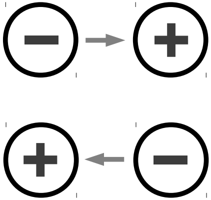
Monopole

- Mass flux
- Omni-directional
- Explosion



Dipole

- No net mass flux
- Directional
- Mass movement, force



Quadrupole

- No net mass flux
- Directional
- Turbulance

Compact or Finite Dimensional Source?

Karymsky, Russia

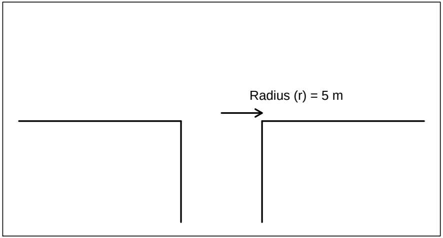
Tungurahua, Ecuador

Acoustic source is compact if $k \cdot l << 1$ (l : source dimension)

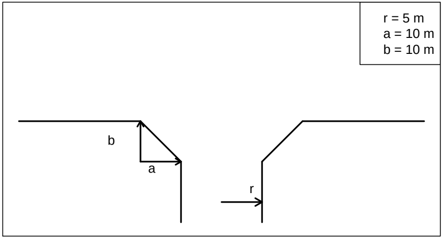
- Karymsky: $k \cdot l = \frac{2\pi f l}{v} = \frac{2\pi(1Hz)(80m)}{340m/s} \simeq 1.47$
- Tungurahua: $l = 100$m, $k \cdot l \simeq 1.87$

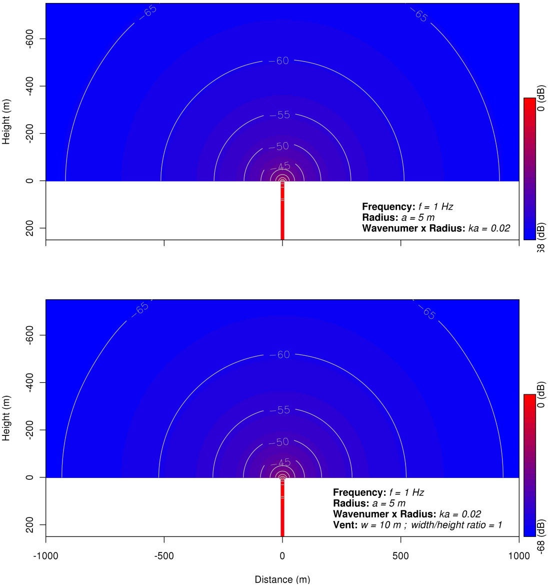
Finite Difference Modeling of Sound Propagation

Geometry of a conduit (constant radius)



Geometry of a conduit with a widening exit





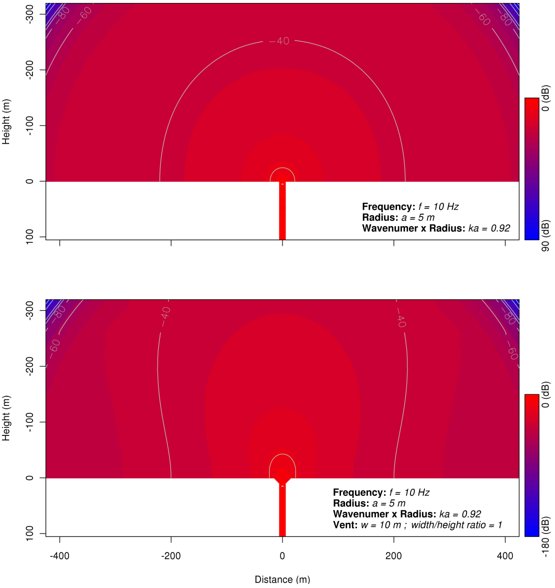
Frequency: f = 1 Hz

Radius: a = 5 m

Wavenumber × Radius:

ka = 0.02

Radiating Energy from Vent (2)



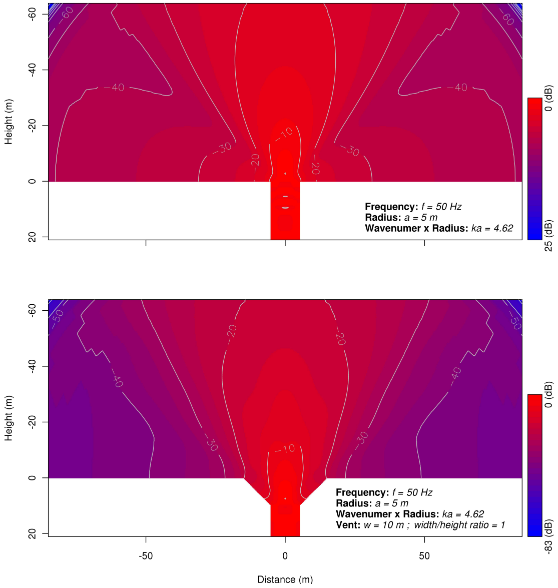
Frequency: f = 10 Hz

Radius: a = 5 m

Wavenumber × Radius:

$ka = 0.92$

Radiating Energy from Vent (3)



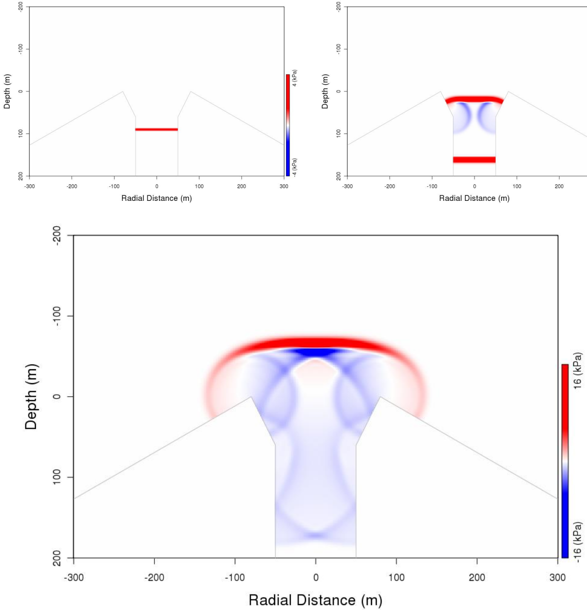
Frequency: f = 50 Hz

Radius: a = 5 m

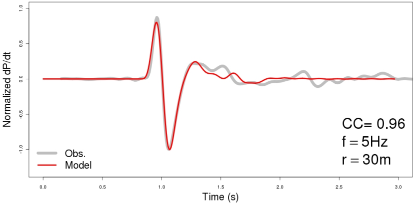
Wavenumber × Radius:

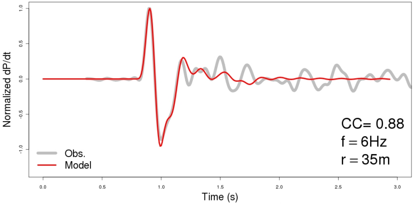
ka = 4.62

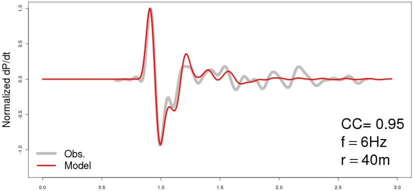
Crater Rim Diffraction



Diffraction at Karymsky (Kim and Lees, 2011)



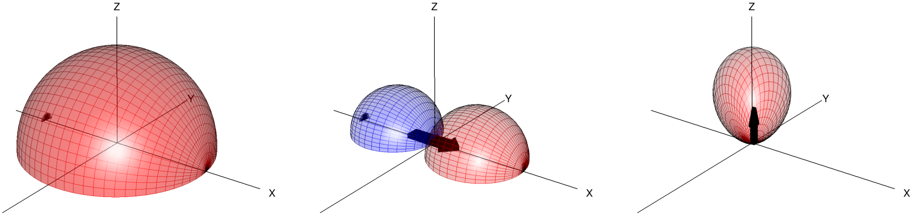




Multipole Source Inversion

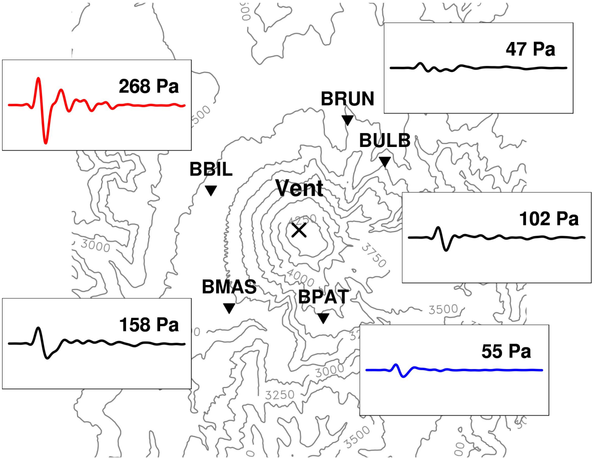
$$p(\mathbf{r}, t) = p_M + p_H + p_V$$ (Kim et al., 2012)

$$p(\mathbf{r}, t) = \frac{1}{2\pi r}\left[\dot{S}(t - \frac{r}{c}) + \frac{x}{cr}\dot{F}_x(t - \frac{r}{c}) + \frac{y}{cr}\dot{F}_y(t - \frac{r}{c})\right]$$



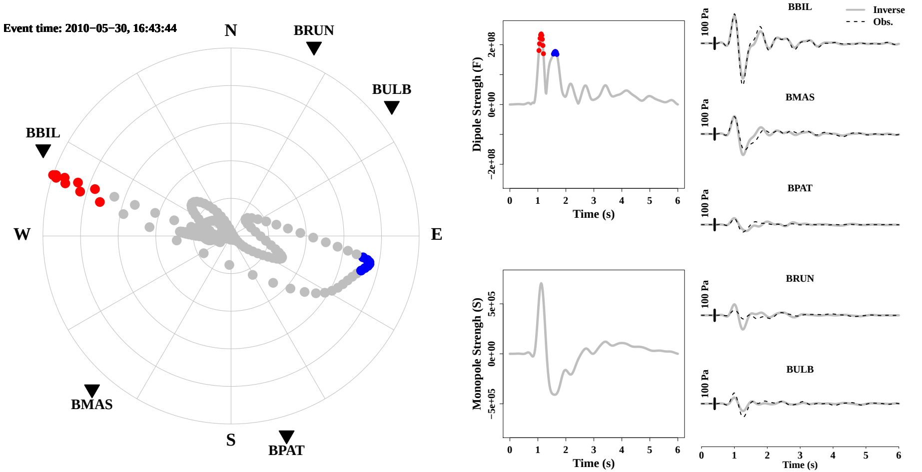
Monopole ***Horizontal Dipole*** ***Vertical Dipole***

Asymmetric Radiation of Volcano Infrasound



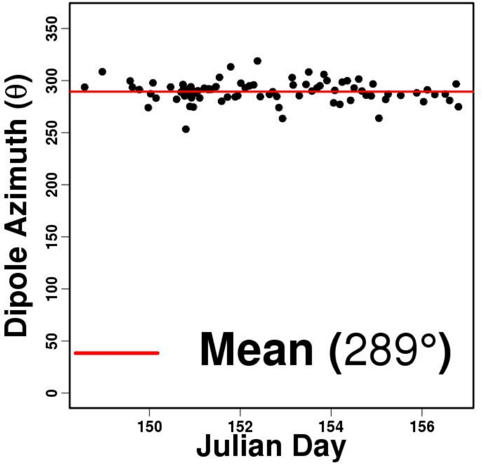
Tungurahua, Ecuador, 2010

Multipole Inversion Results

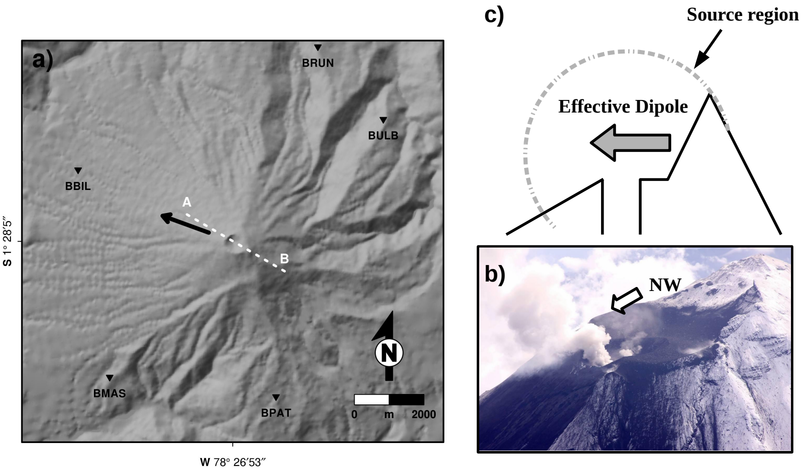


THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

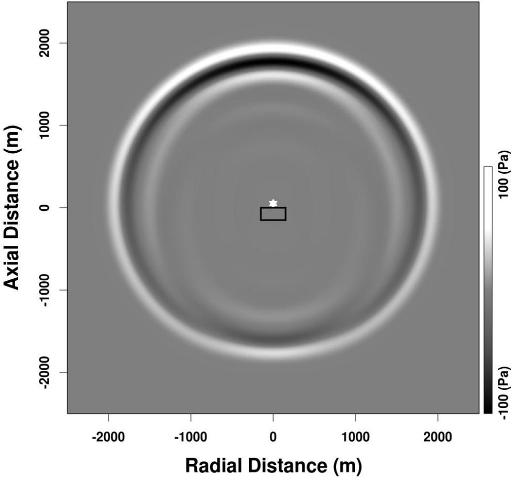
Mean Dipole Orientation



Origin of the Horizontal Dipole

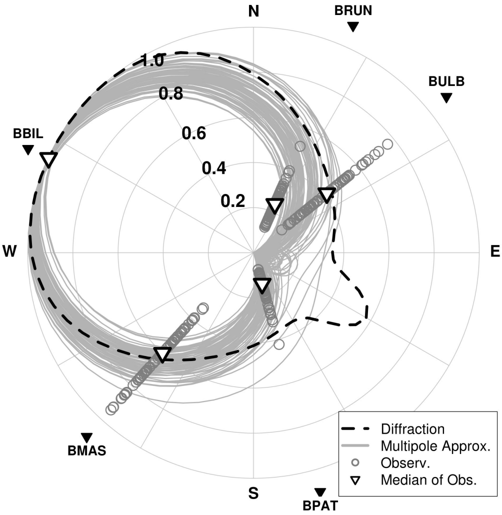


Sound Diffraction Modeling



THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Diffraction vs. Multipole Model



- Sound-solid interaction
  - Reflection
  - Diffraction
- Fluid-solid interaction (Curle, 1955)

Conclusion

- Acoustic wavefields are significantly affected by diffraction at the crater rim. This effects have to be taken into account when interpreting source physics of volcanic explosions.
- Fluid-solid interactions in the vicinity of volcano vents may play a critical roles for the source properties of volcano infrasound.

THE UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL

Curle, N. (1955). The influence of solid boundaries upon aerodynamic sound. *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences*, 231(1187):pp. 505–514.

Fee, D. and Matoza, R. S. (2013). An overview of volcano infrasound: From hawaiian to plinian, local to global. *Journal of Volcanology and Geothermal Research*, 249(0):123 – 139.

Kim, K. and Lees, J. M. (2011). Finite-difference time-domain modeling of transient infrasonic wavefields excited by volcanic explosions. *Geophysical Research Letters*, 38(6):L06804.

Kim, K., Lees, J. M., and Ruiz, M. (2012). Acoustic multipole source model for volcanic explosions and inversion for source parameters. *Geophysical Journal International*, 191(3):1192–1204.

Rossing, T. (2007). *Springer handbook of acoustics*. Springer Verlag.