Volcanic Jet Noise from the Kilauea Fissure 8 Eruption

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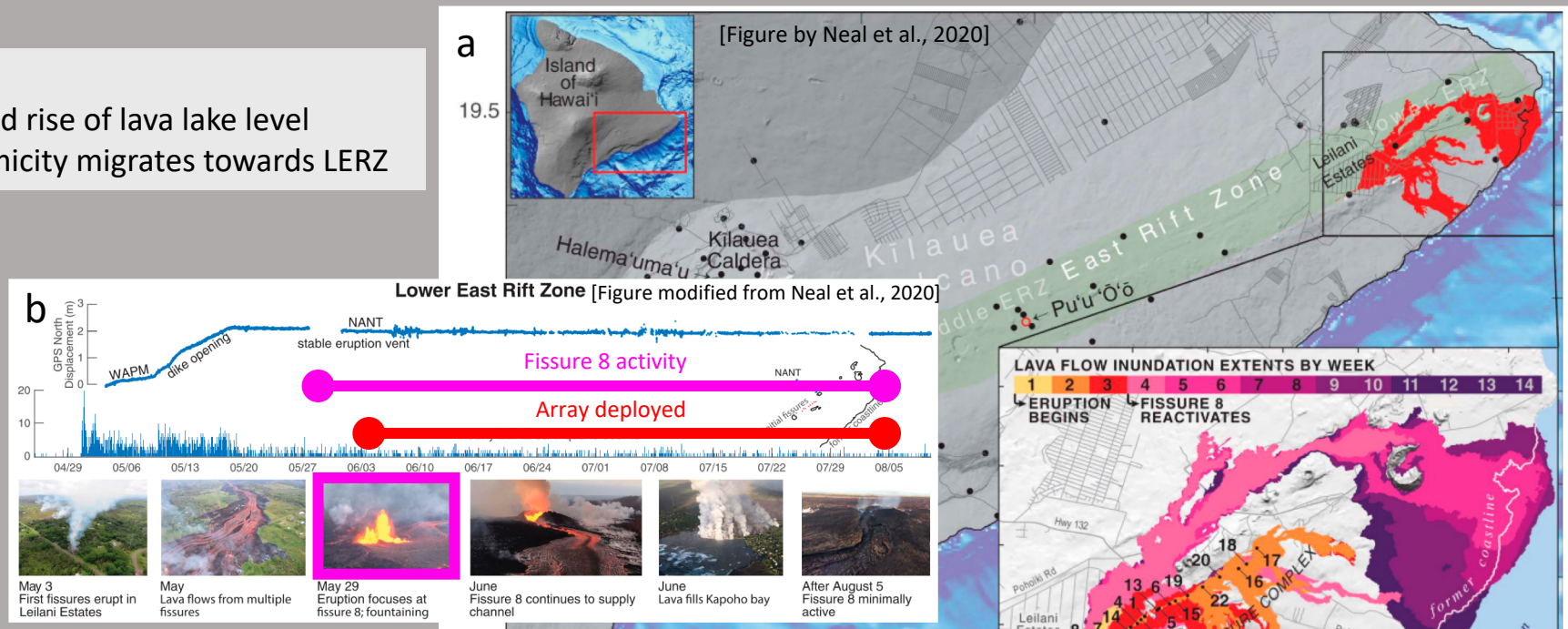
Pre-eruptive Activity:
March-April: pressure increase – deformation and rise of lava lake level
April 30: Collapse of Pu‘u ‘Ō‘ō crater floor – seismicity migrates towards LERZ

Fissure 8 (F8):
Start: May 27, 2018
End: August 4, 2018

Lava fountain up to 80 m tall
SO_2: >50,000 t/day
Effusion rate: 50-200 m^3/s
Erupted volume: ~0.8 km^3

Infrasound Array:
Ca. 480 m from F8
June 4 – August 4, 2018
4 elements
400 Hz sampling rate



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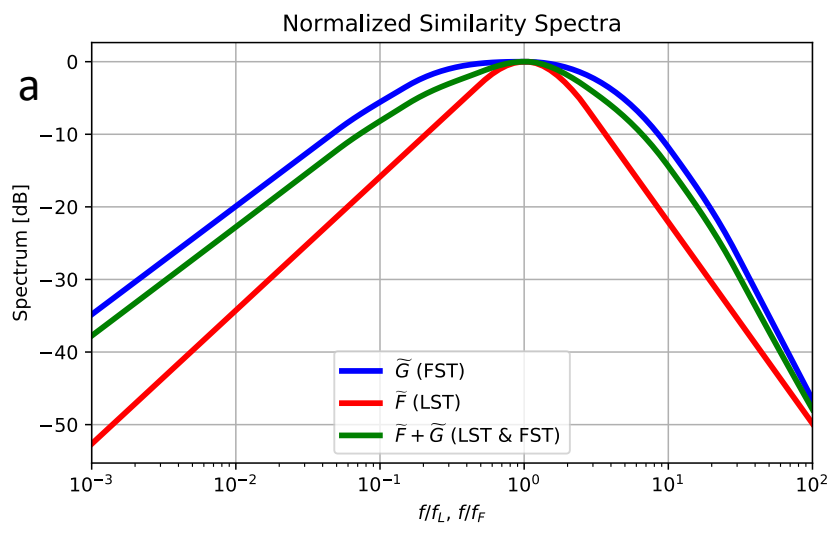
What is Volcanic Jet Noise and Similarity Spectra?

Volcanic Jet Noise:
Turbulence-related sound from the volcanic jet

Jet Noise Similarity Spectra:
Analytical model spectra of man-made jet noise (Tam et al., 1996)

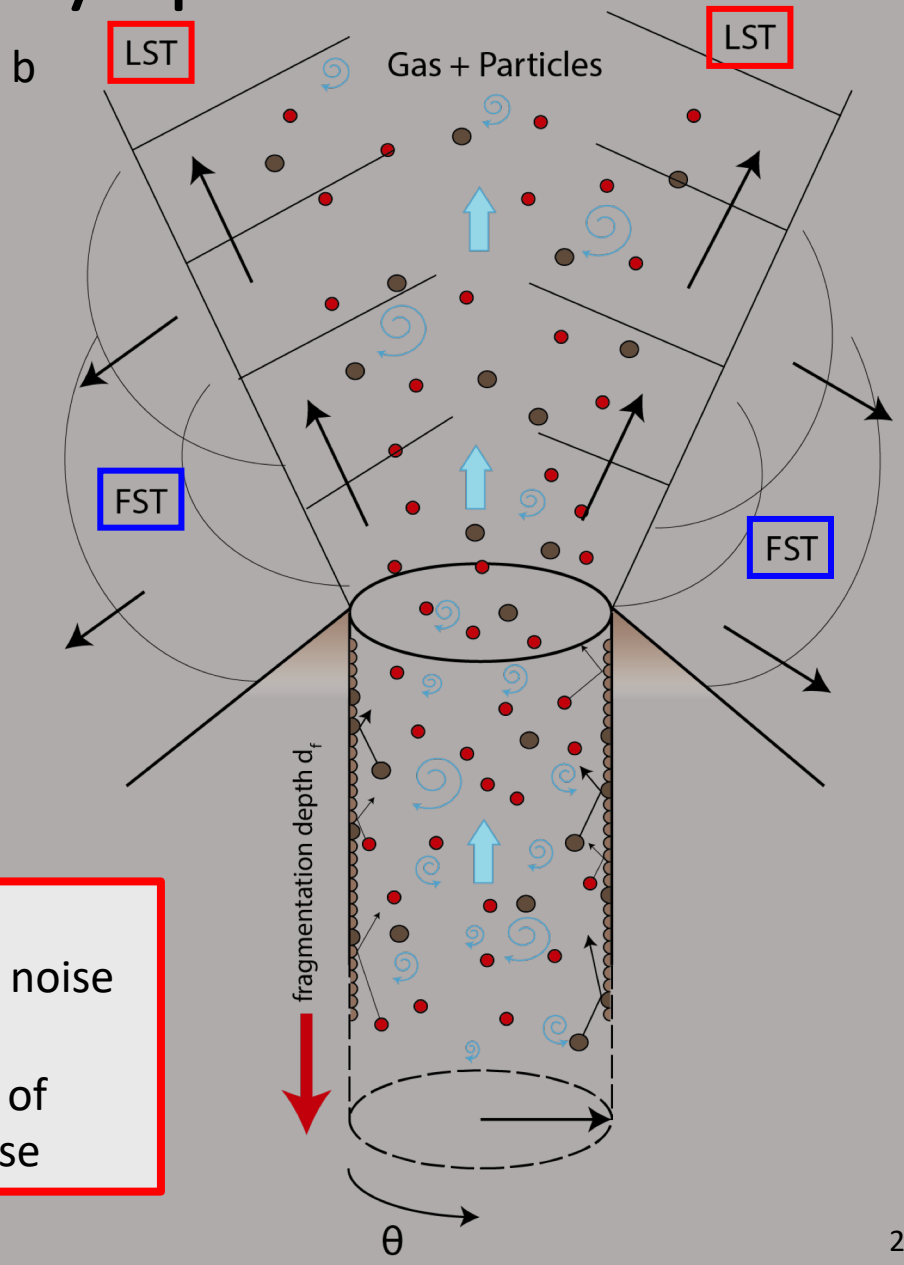
Fine Scale Turbulence (FST)
- Incoherent, chaotic motion of gas
- Nearly isotropic radiation
- Dominates outside of LST cone (larger angles and upstream)

Large Scale Turbulence (LST)
- Coherent instability waves (Mach waves)
- Directional, cone-shaped



Scenarios:
LST dominates
FST dominates
LST & FST need to be considered

Research Question:
Is the source process of volcanic jet noise similar to that of jet engines?
→ *New tool* for automatic fitting of similarity spectra to volcanic jet noise



Fitting the Jet Noise Similarity Spectra

Model and Tool:

Non-linear model equation (Tam et al., 1996) for LST, FST and LST & FST

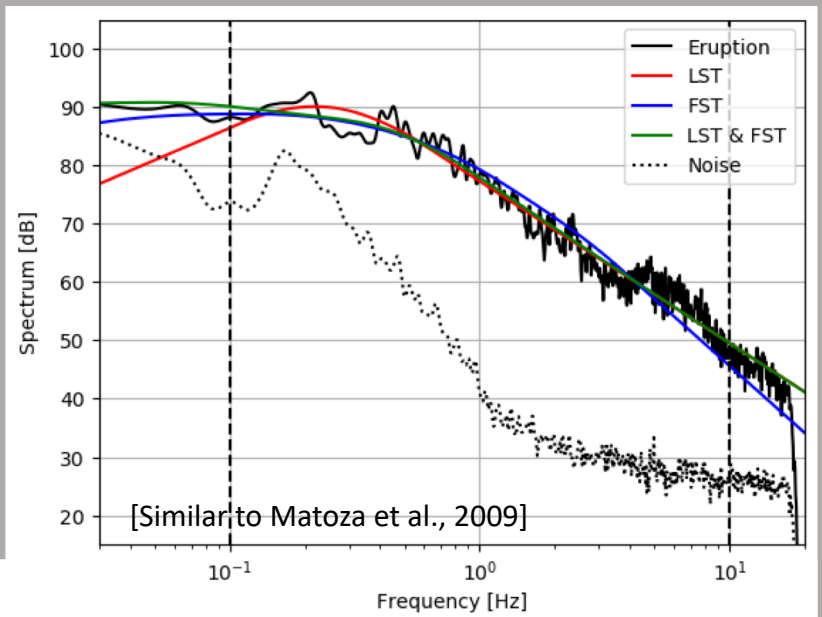
$$S_{dB} = 10\log_{10}\left(\frac{S}{p_{ref}^2}\right) = 10\log_{10}\left(\frac{A}{p_{ref}^2}\tilde{F} + \frac{B}{p_{ref}^2}\tilde{G}\right) - 20\log_{10}\underbrace{(r/D_j)}_{C}$$

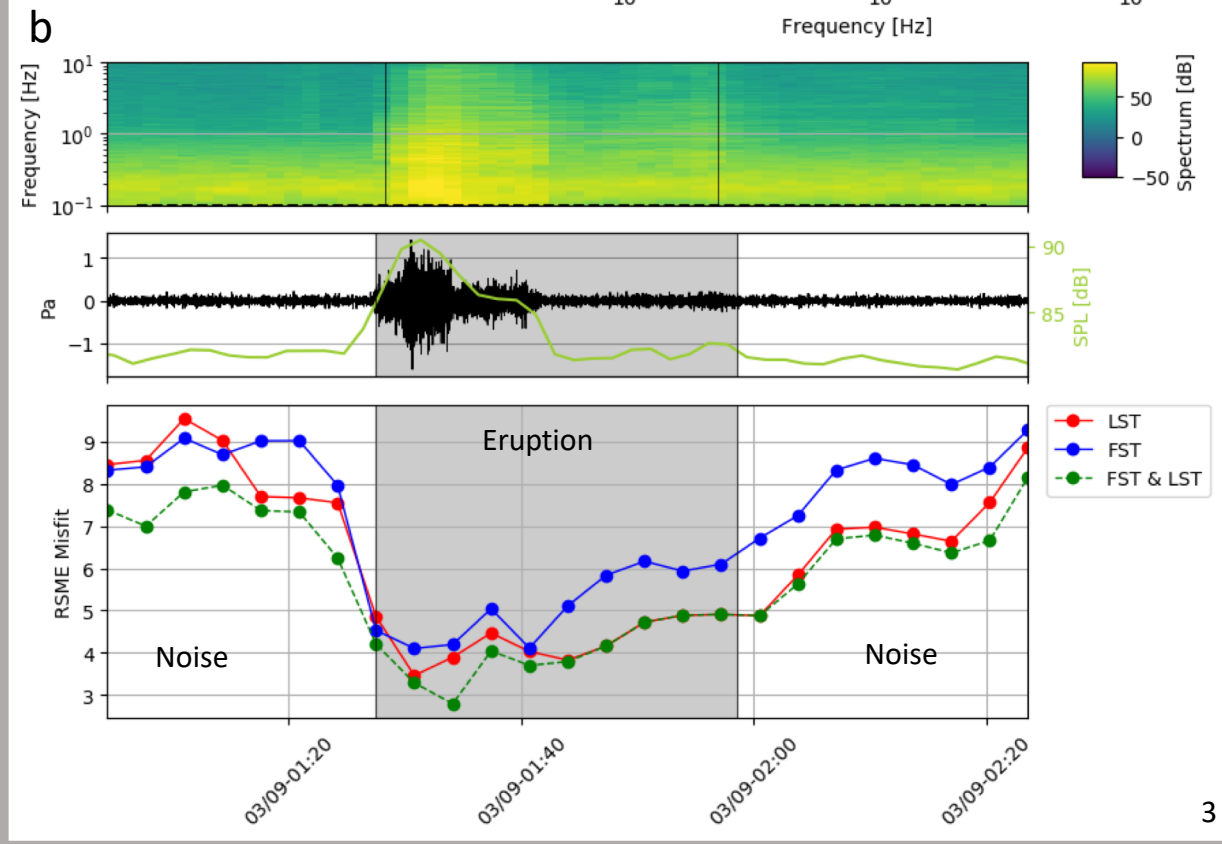
Using Gauss-Newton method to optimize least-squares fit with Root-Mean-Square Error (RSME) as misfit function

Example: Mount St. Helens March 16 2005

- Fitting between 0.1-10 Hz
- Spectral shape during eruption more similar to jet noise spectra (compared to times of noise) (a)
- Significant drop in misfit at start of the eruption (b)

Shows that times of eruption have similar spectra as man-made jet noise.
The spectra of non-eruptive periods are different.

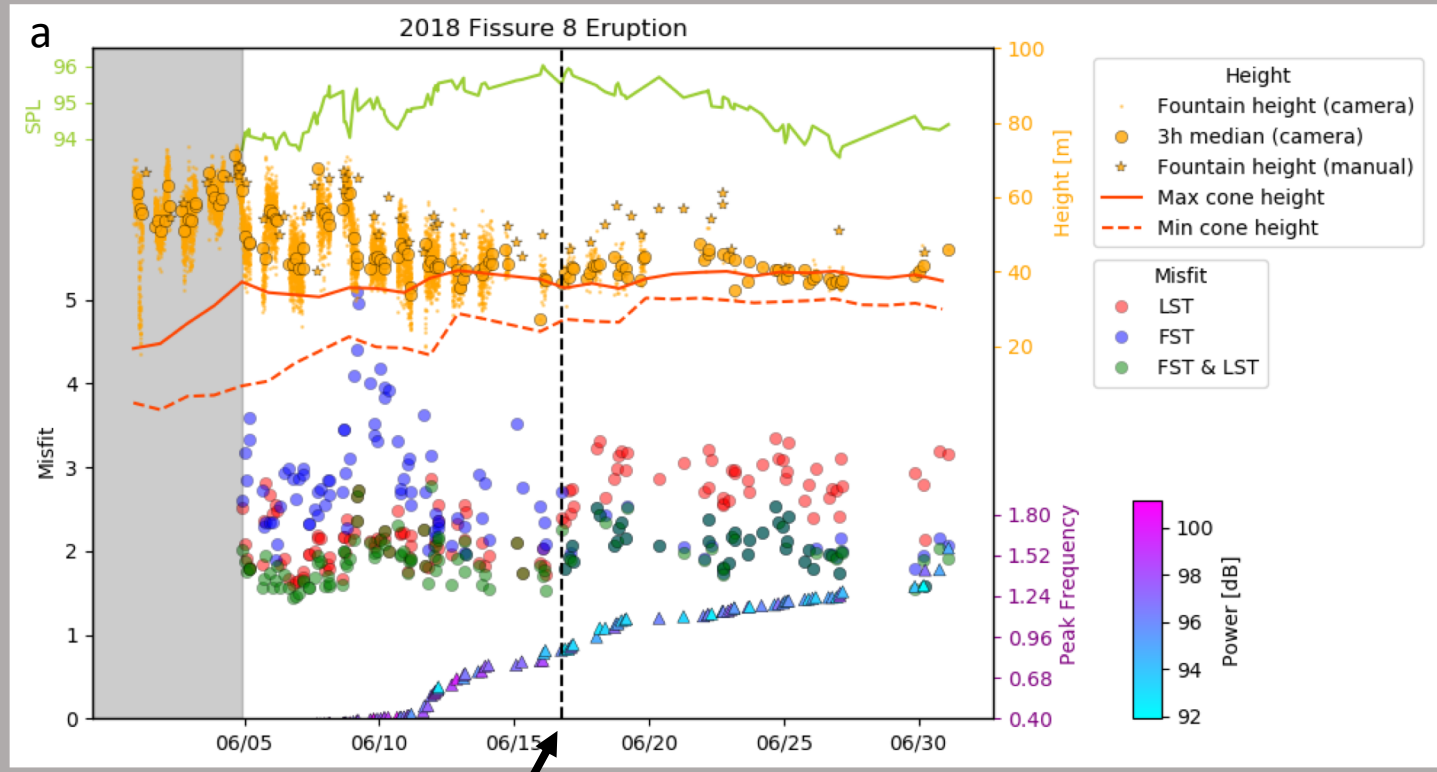


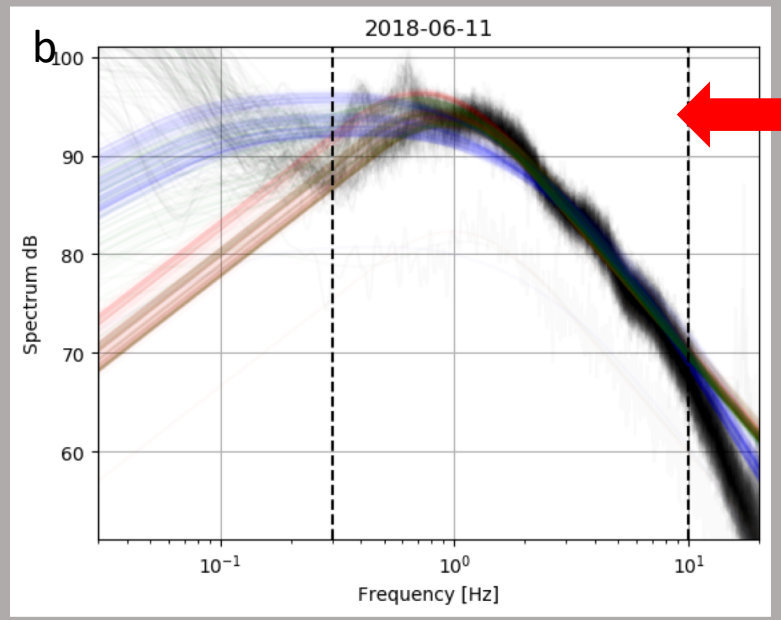


Overview of Kilauea F8 Eruption and Parameters

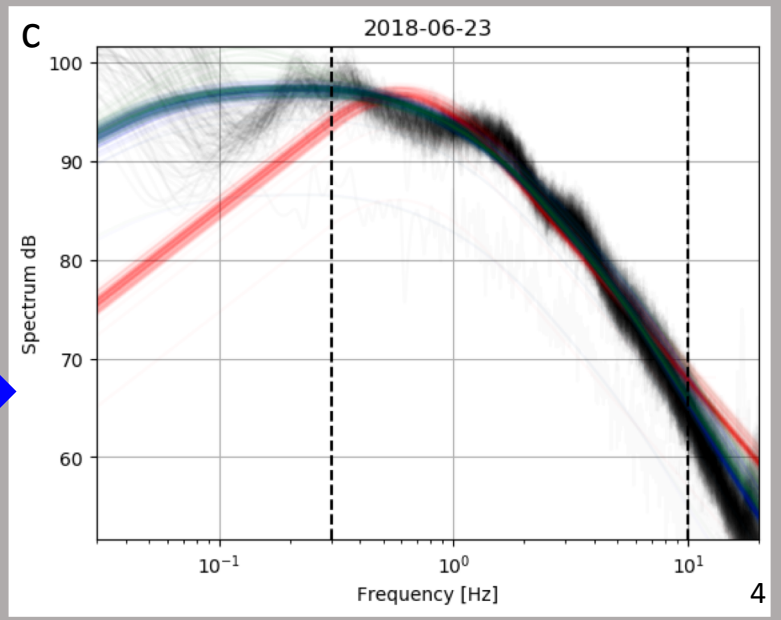
(Fountain Heights by Parcheta et al., personal communication)

- Reports of audible sound like “jet engines taking off”
- Overall sound from F8 fits similarity spectra → jet noise
- Variable fountain heights but dropping trend
- Cone grows over time
- Peak frequency shifts to higher frequencies with time





- Misfit: LST < FST until June 16
- June 16: FST misfit drops (black dashed line) – coincides with maximum of sound pressure level (SPL)
- Misfit : FST < LST after June 16



Summary

- We developed a tool to quantify the fit between infrasound and the jet noise similarity spectra

- The eruption spectrum of Mount St Helens can be modeled by the jet noise similarity spectra, non-eruptive periods can not

- Fissure 8 eruption of Kilauea produced sound similar to man-made jets
  - Dominance of large- and fine-scale turbulence changes throughout the eruption
  - Change coincides with variations in maximum sound pressure level (SPL)
  - No apparent correlation to fountain and cone heights found thus far


Source: HVO

Outstanding questions:
- Does the change in LST and FST misfit on June 16 reflect a change in eruption dynamics?
- What other metrics could be used to investigate F8 source properties with infrasound?

Future work on F8 data:
- Compare findings to video footage
  - Particle velocities,
  - Jet diameter,
  - Effusion rate, etc.
- Calculate Strouhal number

Other:
- Apply new similarity spectra tool to other eruptions such as Kilauea 2011, Tungurahua, Stromboli 2018 etc.
- Make tool operational and public

References:

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