Scour Detection Using Infrasound: A case study of the Feather River Bridge of State Highway 20 (the 10th Street Bridge) in Yuba City, CA

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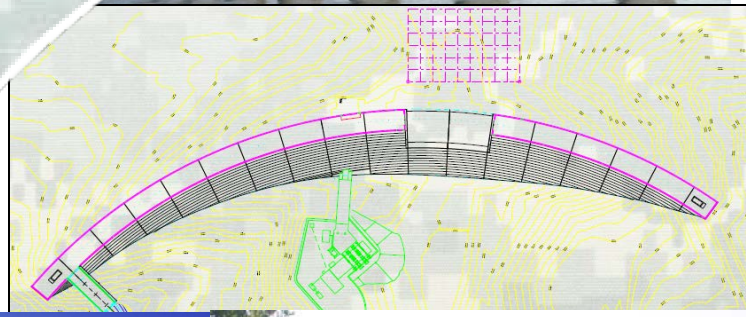
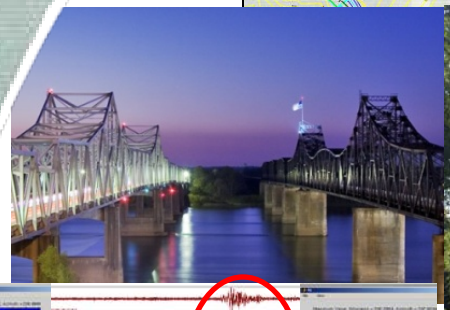
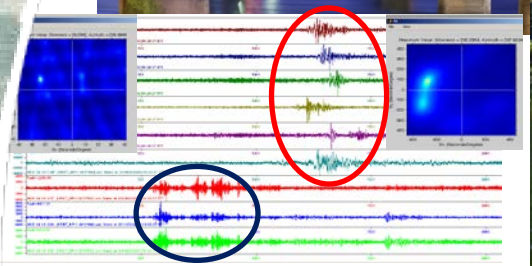






Overview

- Persistent Scour Monitoring
- What is Infrasound?
- Previous Research Efforts
- Current Research
  - Urban Infrasound
  - Portugues Dam, Ponce, Puerto Rico
  - Infrasound for Scour Detection and Assessment
- Feather River Bridge
  - Array set up
  - Data collection
  - Signal Processing and Data Analysis
- Future Research Efforts

Persistent Scour Monitoring
Current Practice

- As the infrastructure of the U.S. ages, issues with scour and unknown foundations are becoming increasingly prominent.

- A more cost effective allocation of resources must be found to better define and monitor critical structures as well as prioritize rehabilitation and construction efforts.

Persistent Scour Monitoring
Current Practice

- Both scour critical bridges and bridges with unknown foundations require a Plan of Action (POA) that typically involves additional monitoring.
  - Visual/physical inspection
    - Discrete point in time that does not capture scour's cyclical nature
    - Cannot be conducted during high flow events when scour is most critical
  - Instrumentation (portable or fixed monitoring systems)
    - High velocity flows
    - Debris
    - Ice forces
    - Sediment loading
    - Severe water temperatures
    - Vandalism

Persistent Scour Monitoring
Complimentary Approach

- Ideally, monitoring of scour critical bridges would:
  - **Be done remotely and cost effectively**
  - **Provide continuous monitoring**
  - **Provide data and warning when scour is most critical**

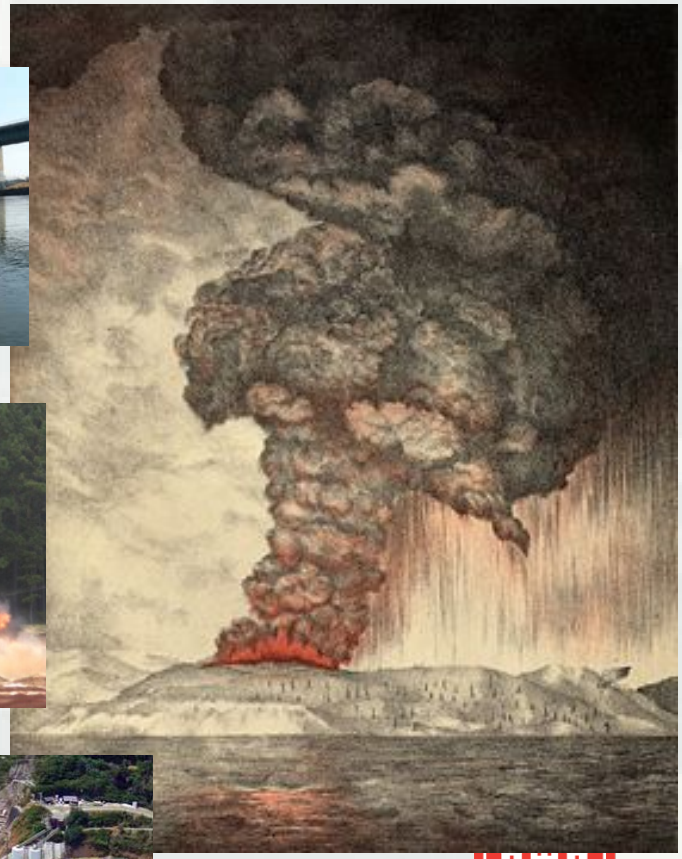
- Initial proof of concept studies show that infrasound shows promise as a complementary approach in the persistent monitoring of critical bridges.

What is infrasound?

Infrasound is a low frequency, sub-audible sound propagated over long distances and typically within the 0.1 to 20 Hz range.

Low frequency acoustics (0.01 – 20 Hz) created by:

- **Volcanoes**
- **Earthquakes**
- **Explosions in the atmosphere**
- **Sub-surface explosions**
- **Surf**
- **Missiles**
- **Rockets**
- **Urban Noise**
- **Large Infrastructure**

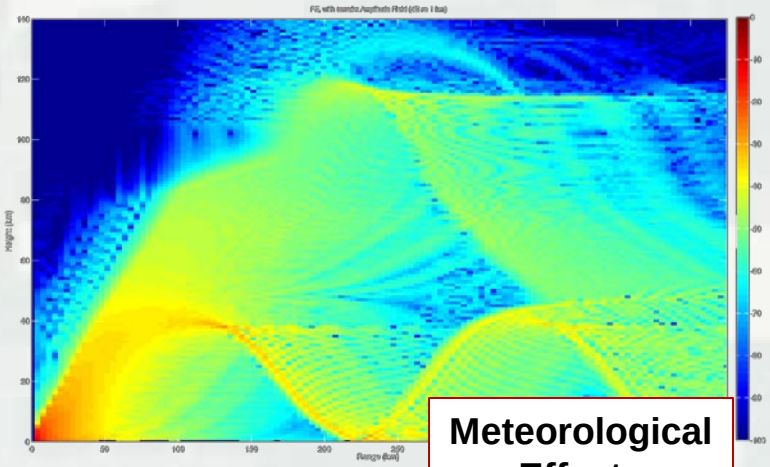


Structures generate coupled low frequency acoustics as fundamental modes of motion.

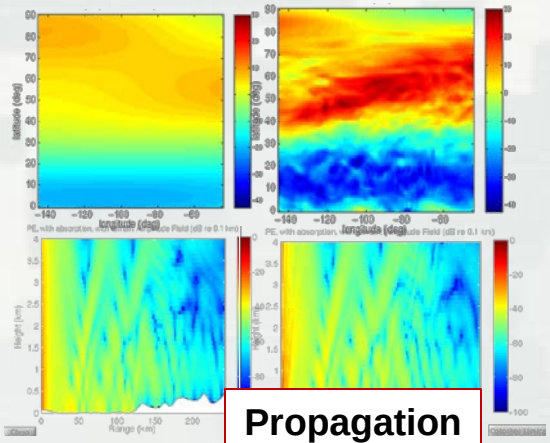
What is Infrasound?

Challenges

- Terrain Interaction
- Meteorological Effects
- Propagation Physics
- Adaptation of Signal Processing
- Urban Environment

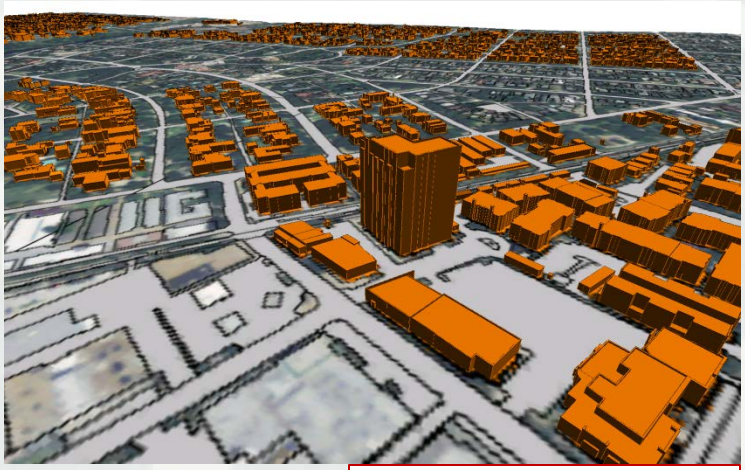


Meteorological Effects



Propagation Physics

Terrain Interaction



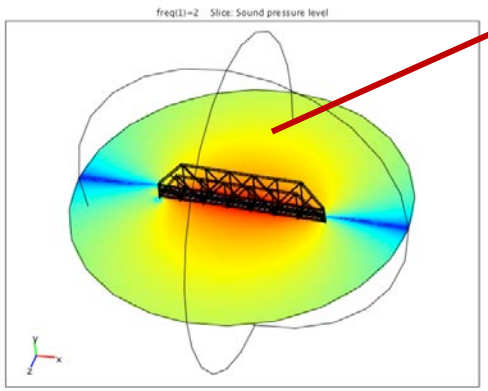
Urban Environment

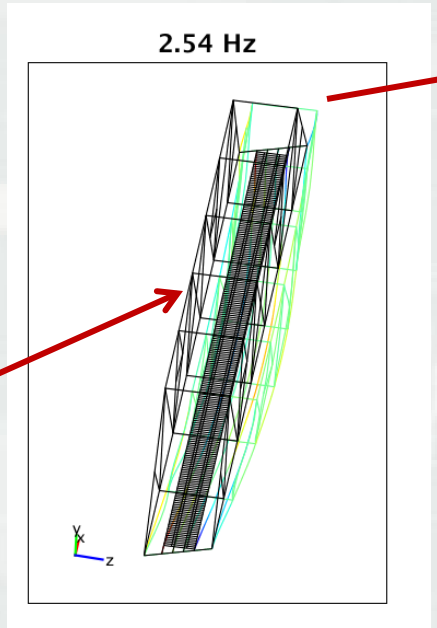
Previous Research:
Ft. Leonard Wood Truss Bridge

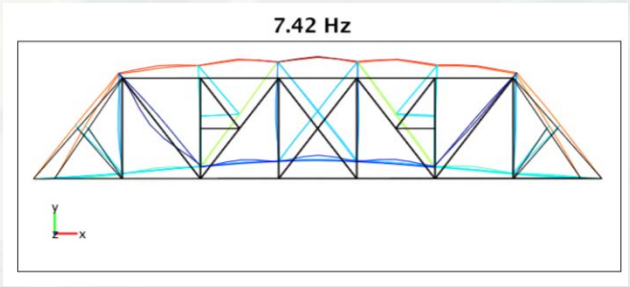
Information about a structure is contained in its modal signatures.

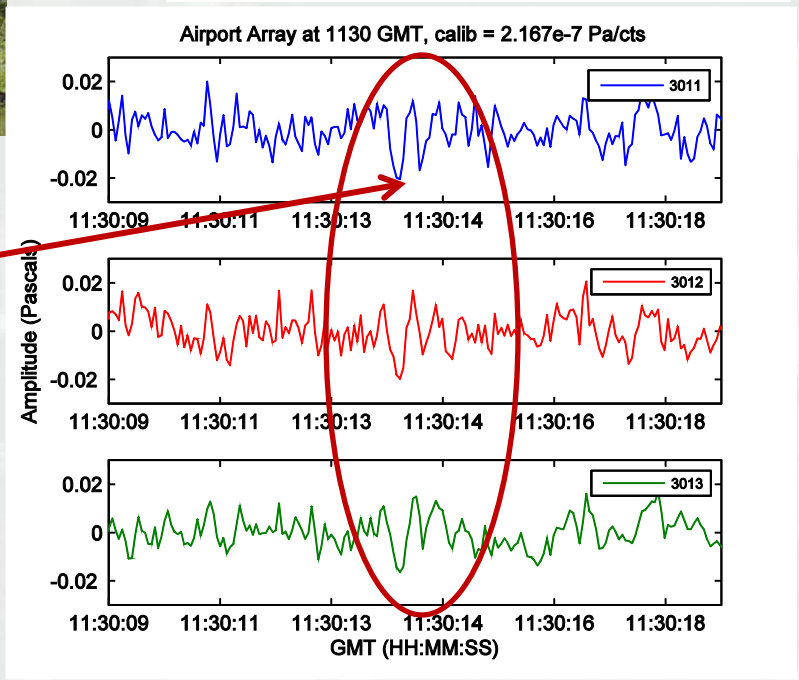
FLW Bridge over the Little Piney River in Ft. Leonard Wood, MO. With monitoring infrasound arrays at distances up to 26 km.

Complex sources signals such as those from bridges may travel relatively uncomplicated energy pathways, but through very complex atmospheres.

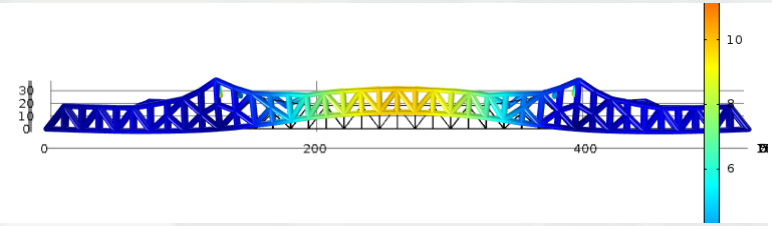


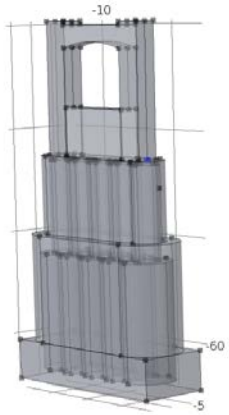


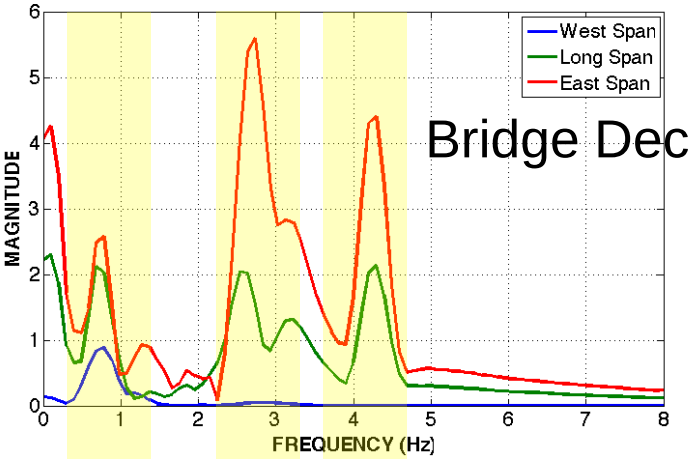




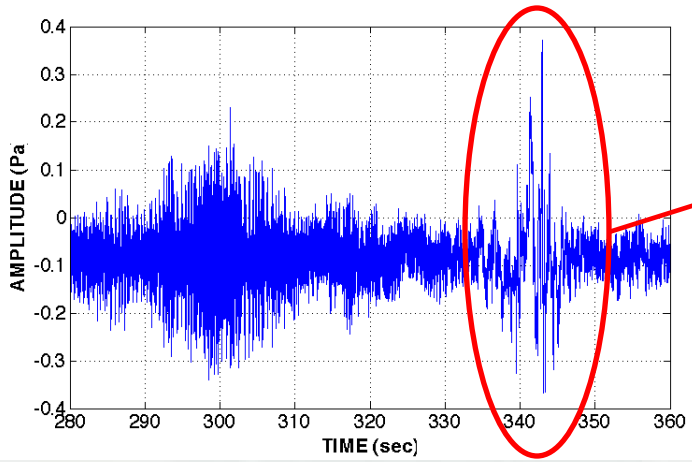
Previous Research:
Bridge-Barge Impact I-20 MS River Bridge

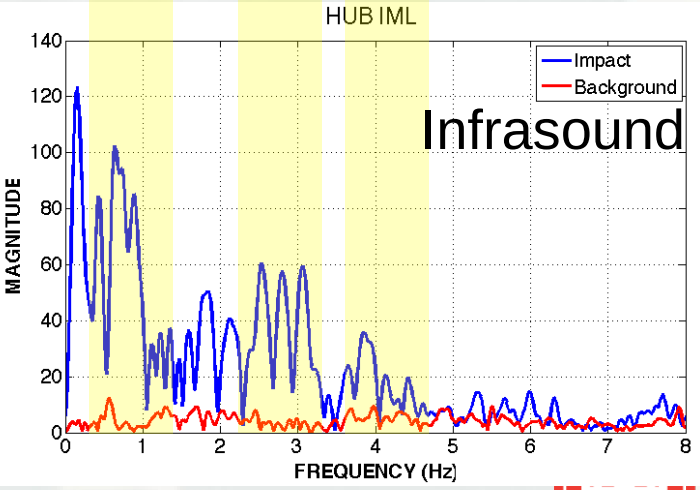




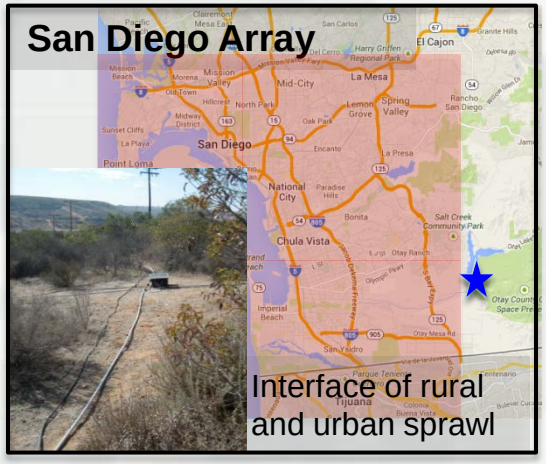


- Frequency spectrum of the infrasound signals
  - Real time data from infrasound signal at time of the crash (bottom left)
  - Detected 0.9 Hz, 3 Hz and 4 Hz peaks (bottom right)
  - Excellent agreement with bridge deck vibrations (top right)





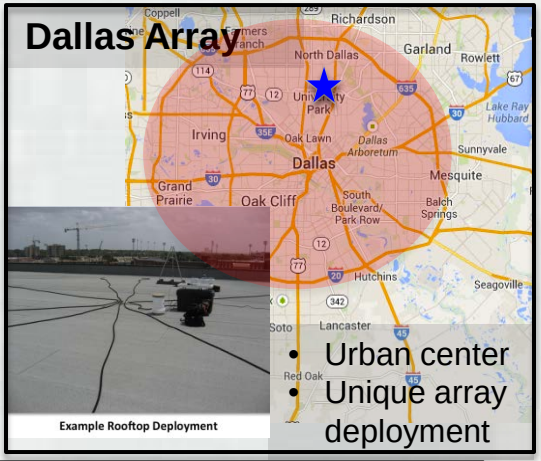
Urban Infrasound Monitoring



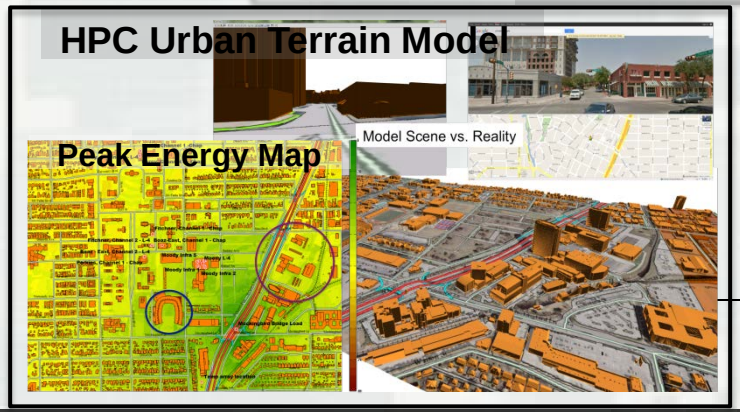
Purpose:
Improve the understanding of how to monitor infrasound sources in urban environments; specifically source generation mechanisms, propagation path effects and distinguishability of specific sources

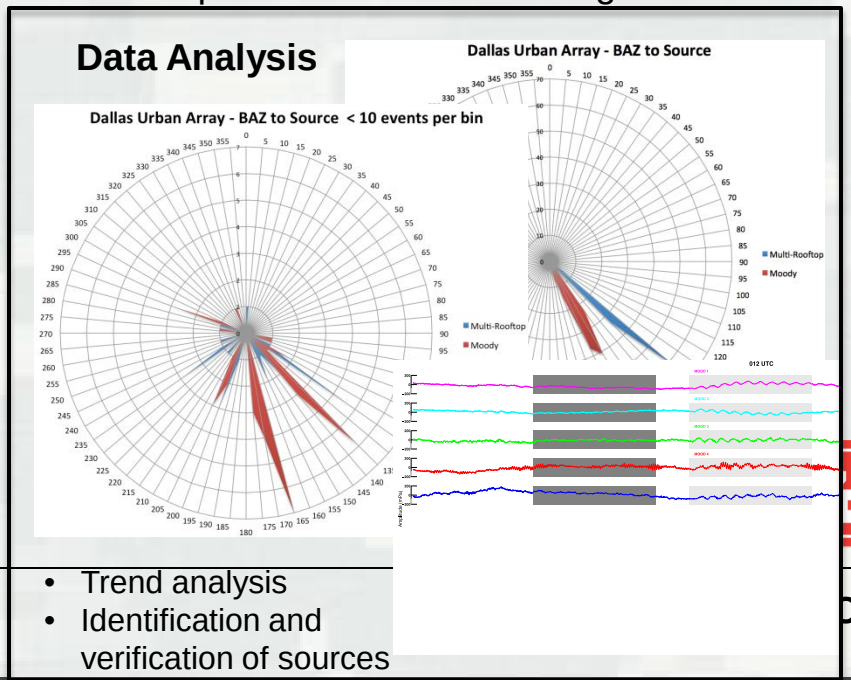
Results:

- TTPs for deploying arrays in various levels of urban buildup
- Improved urban terrain modeling techniques to reduce required detail needed for modeling of the urban scape
- Trends for acoustical field levels for seasonal variations, environment variations and variations of urban buildup
- Techniques for monitoring infrasound sources in urban environments



Payoff:
Rapid remote assessment of infrastructure for support to Force Projection, Early Entry, and Humanitarian Assistance and Disaster Relief Operations in urban settings





Portugues Dam Infrasound Assessment

Research Objectives

- Allows for persistent surveillance of various structures of interest
- Provides a unique opportunity to study a dam empty, while filling, and during operation.
- Strategic deployments of infrasound sensors/arrays over the course of all four seasons before and after the opening of the dam will provide a seasonally variable database.

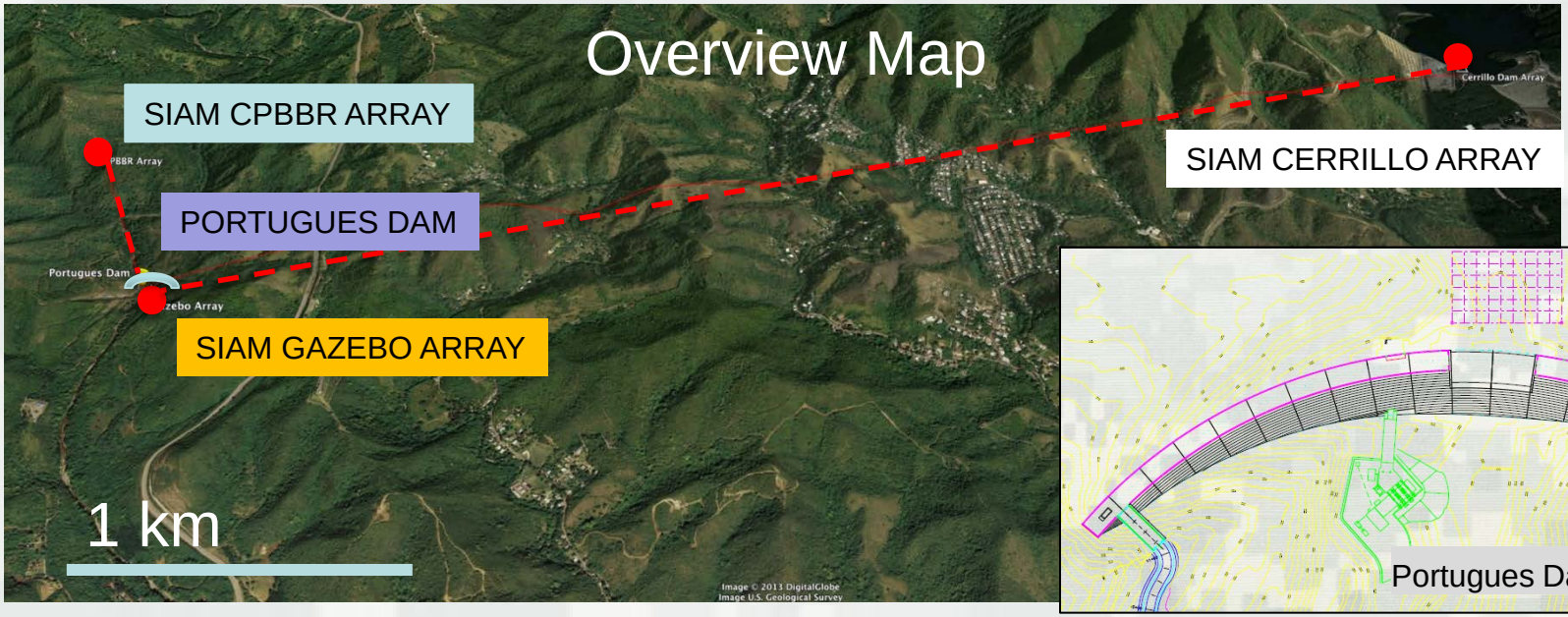
Approach

Analytical Model

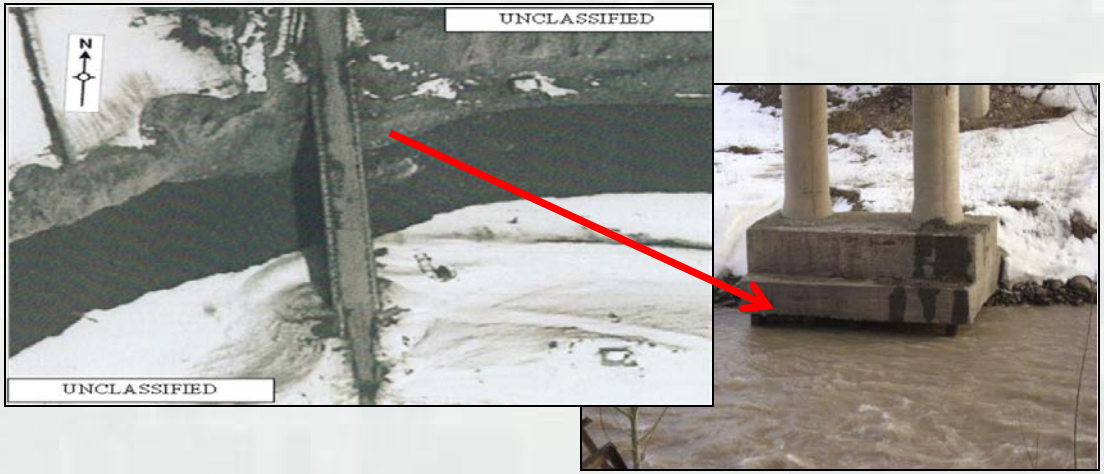
- Develop model to assist in testing
- Extend to model infrasound propagation

Field Experiment

- Data Collection Methods
  - 3 Infrasound Arrays with Met Stations
  - 3 Strong Motion Gauges
  - 21 Accelerometers on crest of dam
- Modal frequencies and mode shapes
  - Cold Gas Thruster (CGT) Impulse
- Performance indicators
  - Response amplitudes



Infrasound for Scour Detection and Assessment



Purpose:

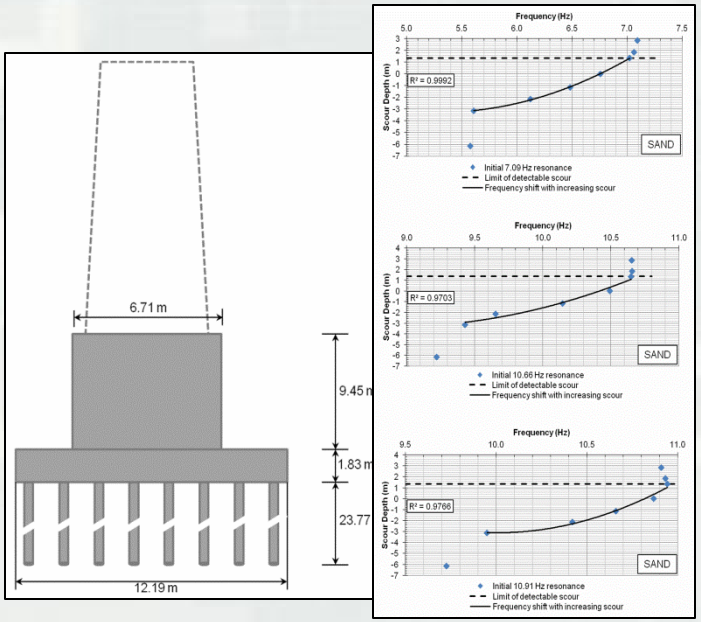
- Provide persistent standoff assessment and monitoring for the purpose of stability analysis, structural health monitoring, and failure phenomenon analysis in both military and civil works applications utilizing infrasound as a means of scour detection/assessment.

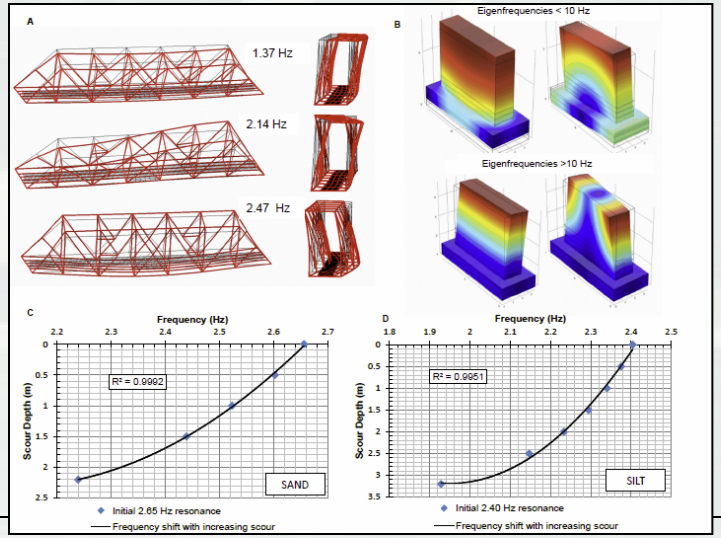
Results:

- Remotely detect and assess scour of bridge piers and abutments

Payoff:

- Protection for soldiers, systems, and critical assets during movement of troops and supplies
- Protection for general populous and first responders following natural disasters

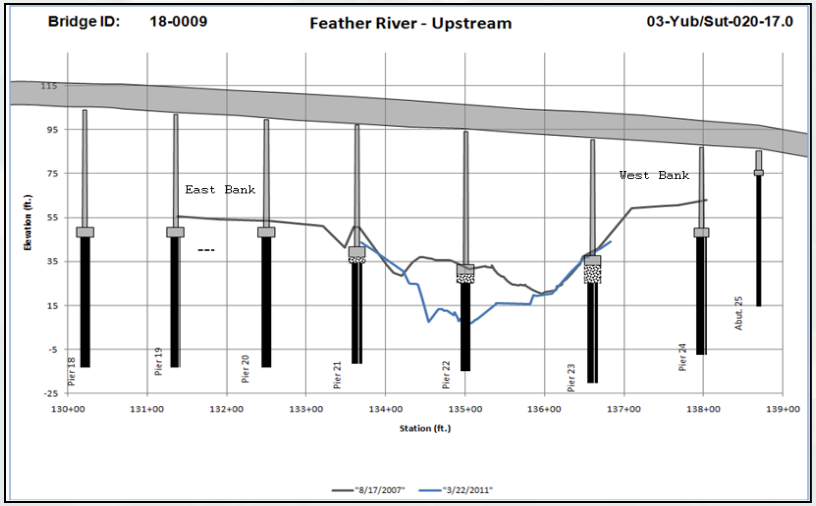




Infrasound for Scour Detection at Br 18-0009

Why this bridge?

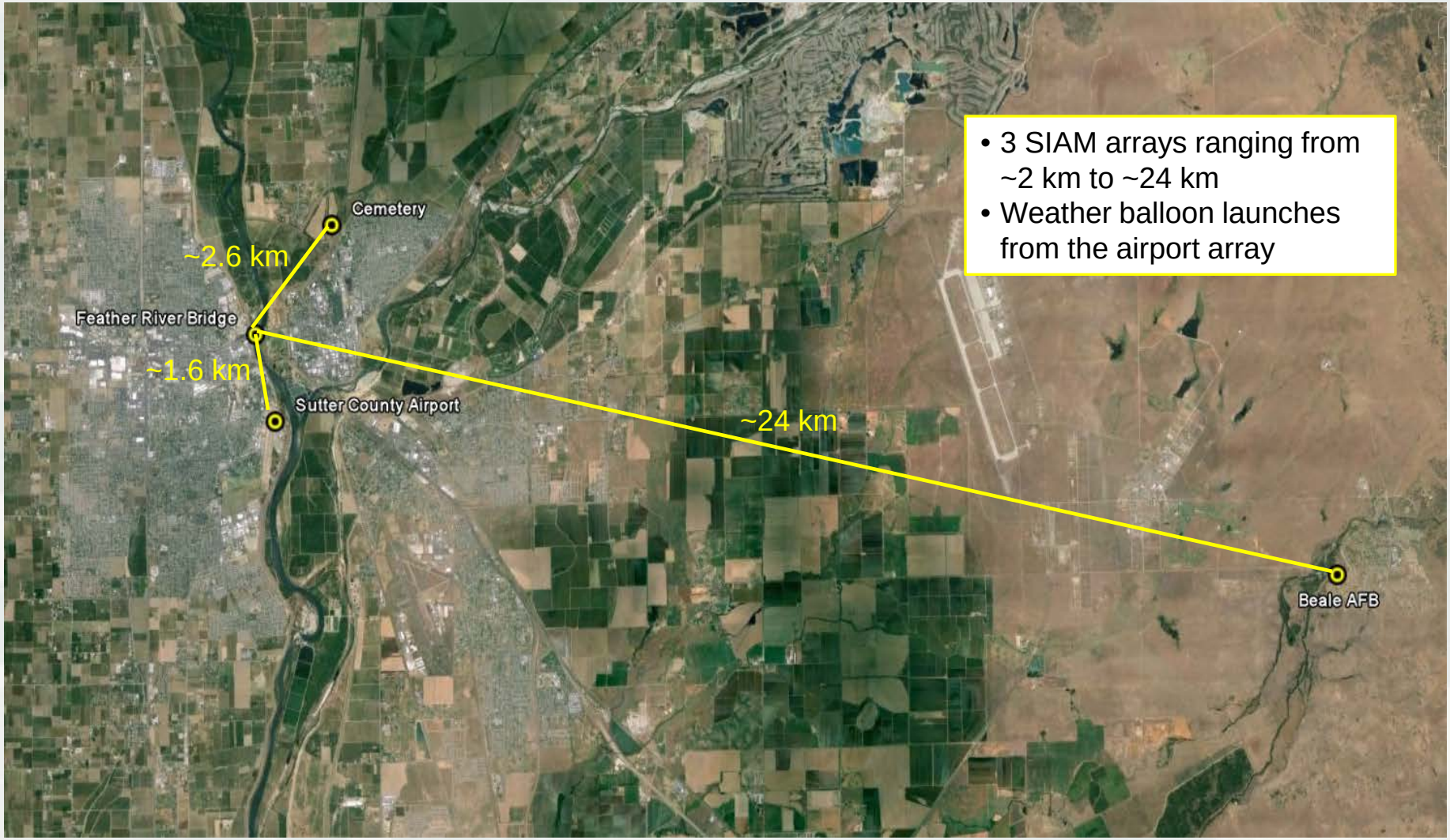
Bridge 18-0009 has a known, well-documented scour issue. There is also a significant amount of data for the structure for model calibration.



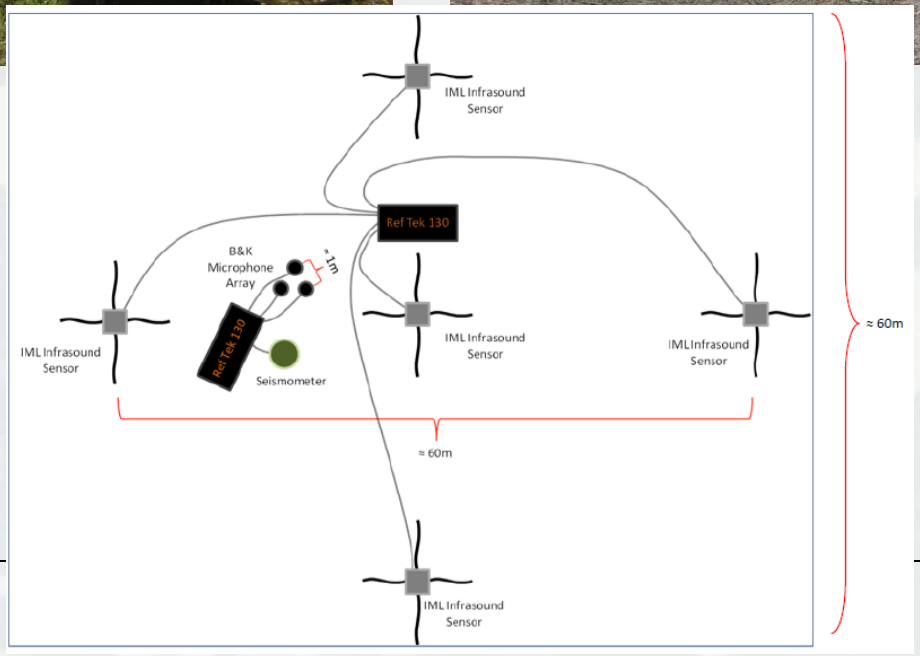
Research Objectives

1. Record and analyze infrasound and seismic records for Bridge 18-0009 located on Route 20 over the Feather River in Sutter County, CA between Yuba City and Marysville.
2. Differentiate between the infrasound signals from the bridge of interest and the other bridges in the surrounding area.
3. Model the local and near-regional infrasound propagation and the source mechanics of the vibrating bridge.
4. Localize specific piers of the bridge in an attempt to differentiate signals from shallow foundations vs. deep foundations.

Array Locations for the Feather River Bridge Deployment



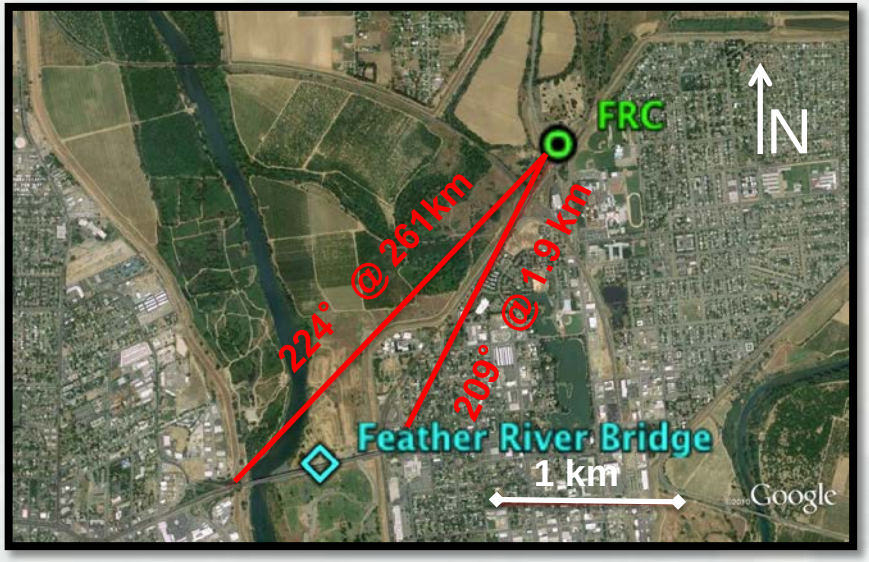
Infrasound Array and Layout

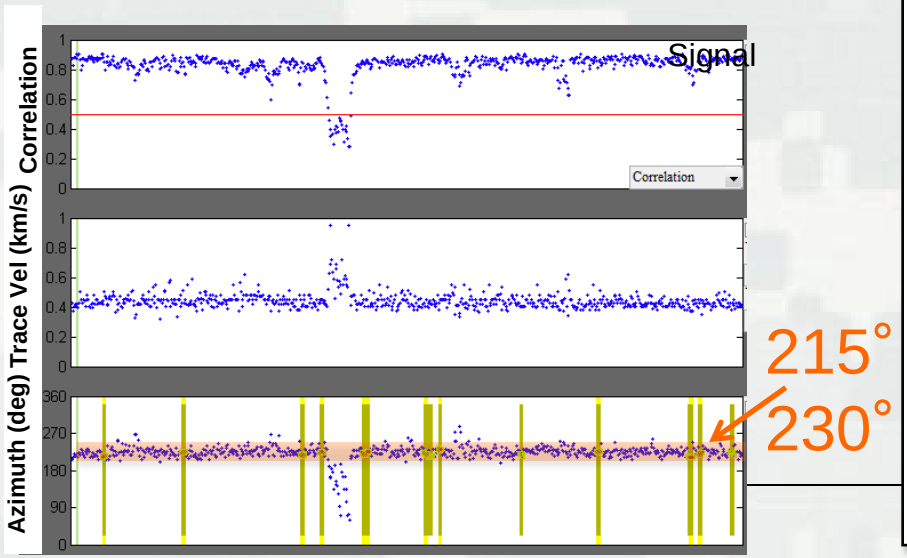


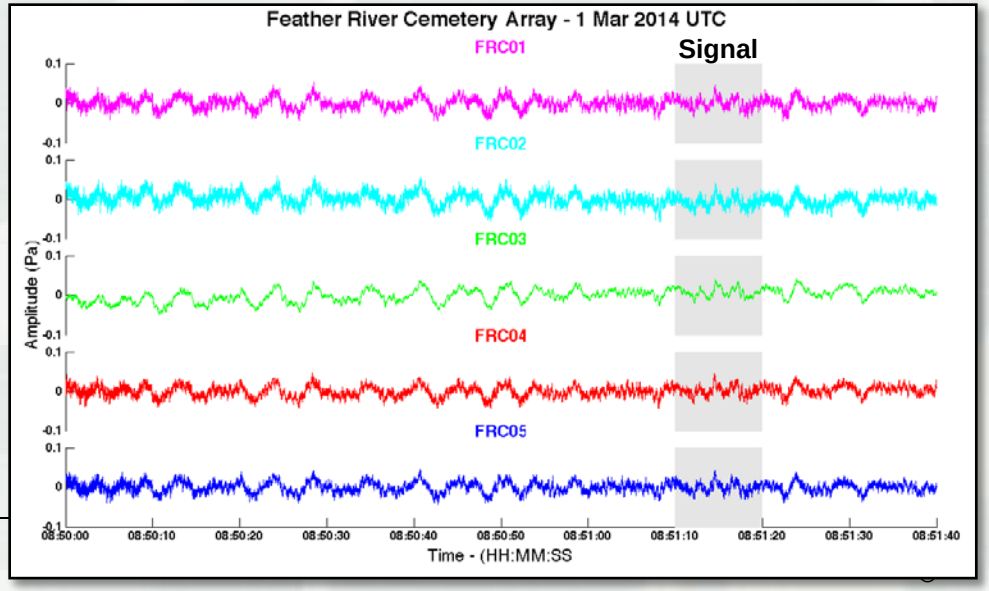
BUILDING STRONG®

Feather River Bridge Data Analysis

- Continuous-wave signal at fundamental mode of bridge, which varies with time
- First order processing completed with InfraTool and GeoTool
  - InfraTool to identify coherent signals on multiple channels and direction of signal
  - Geotool to explore signal characteristics

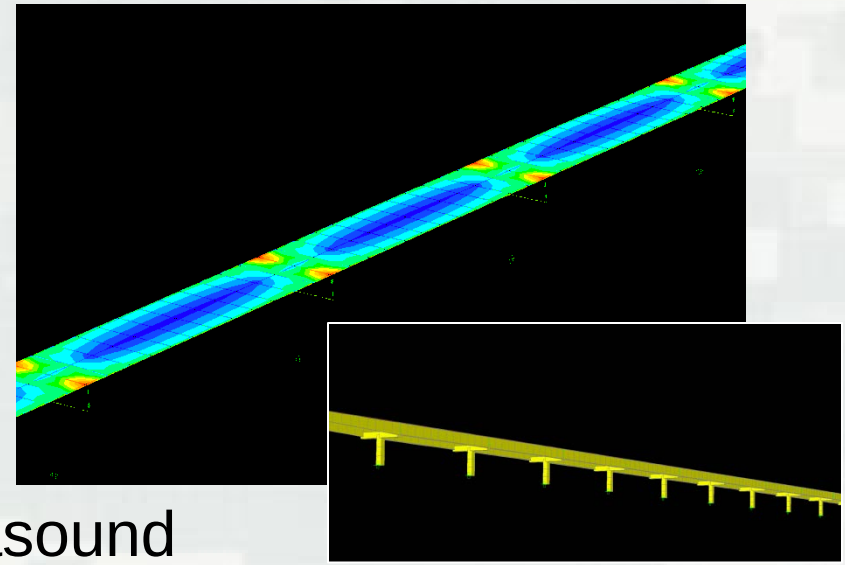






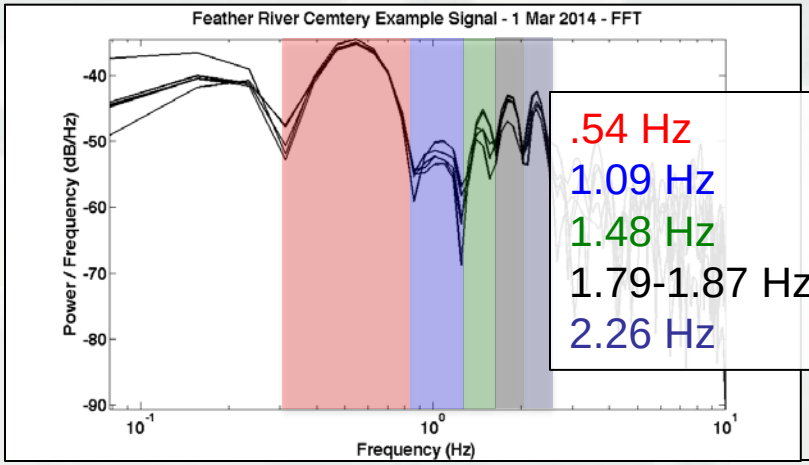
Feather River Bridge Data Analysis

Structural FEM modal analysis results align with observed infrasound signals



Mode	Frequency (Hz)
1	1.04
2	1.06
3	1.10
4	1.20
5	1.37
6	1.59

Infrasound



Structural Source Confirmation Method:

1. Confirm backazimuth of source
2. Determine if observed infrasound signal frequencies aligns with expected modal frequencies of structure

Future Research Efforts

- Future efforts include:
  - Continued data processing
  - Model refinement
  - Signal processing focused on the retrofitted piers
  - A second field deployment with additional instrumentation


Questions?

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