Towards a Coherence Model for Infrasound Signals Recorded at International Monitoring System Arrays

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1. Introduction

- Infrasound array design and infrasound signal detectors are influenced by the spatial correlation (or coherence) structure of signals.
- An a-priori signal coherence model would allow more effective array design and detectors to be identified.
- Our work uses a suite of signals recorded across International Monitoring System (IMS) arrays to identify how signal correlations vary with inter-sensor separation.
- These observations can be used to validate any future a-priori signal coherence models.

2. Methods

For each event:

- Identify best fitting beam using P-detector.
- Choose signal and noise windows.
- Choose-beam - identify best fitting signal characteristics (back-azimuth, apparent velocity).
- Calculate maximum signal cross-correlation for each pair of sensors.
- Calculate least-square regression for correlation as a function of sensor separation:
  \[ y = (a + \beta z) \]
- Correlation prediction
- Correlation intercept
- Correlation loss gradient
- Inter-element separation

3. Global Ground Truth Events

- 35 high signal-to-noise signals chosen.
- Only arrays with five or more sensor elements used (minimum of 10 sensor pairs).
- Wide range of correlation structures recorded; large variety in correlation loss gradient, \( J \) (Fig. 3b and Methods).
- Many factors may influence \( J \), including:
  - Source dimensions
  - Path atmospheric conditions
  - Propagation path length
  - Signal-to-noise ratio
- Correlation residuals, \( s \), do show consistent structure (Fig. 3c). This agrees with the longer-period signal observations of Mack and Flinn (1971).
- Correlation values are consistently higher (\( \gamma_{\text{corr}} \)) measured along the direction of wave propagation compared to those measured perpendicular to the propagation direction (\( \gamma_{\text{perp}} \)).
- However, to explain the observed correlation structure we require a wider range of scattering parameters than modelled by Mack and Flinn (1971), see Section 4.


- We estimate velocity and angular scatter parameters by minimising the misfit between our correlation, \( C \), results (Fig. 3) and the Mack and Flinn (1971) model:

\[ \text{Misfit} = \sum \left( c_i - \sqrt{\Delta K \times K_i} \sin \theta \right)^2 \]

- Our results (Fig. 4) are consistent with and, extend, the findings of Mack and Flinn (1971).

A wide range of velocity (\( \Delta \xi \)) and angular scatter (\( \gamma \)) are observed, but the ratio \( \Delta \xi / \gamma \) remains approximately constant.

5. Future Directions

- Results show coherence variability is complex. In order to provide a-priori signal coherence models we need to further understand what propagation conditions generate a given coherence structure.
- To understand the implications for array design, we need to combine our understanding of signal coherence with a better understanding of noise coherence (e.g., Figure 5).

Figure 5. The correlation of noise series at the 15 element IS23 array (Kerguelen) for less than ten days following a major eruption, compared to the positive and negative correlation model that the correlated noise from microbaroms (from the erupting volcano) dominates during some periods of the eruptive phase. Noise correlation only peaks at low frequencies and at short inter-element distances (b).

Further Information

Many of the events used in this study are found in the IMS infrasound ground-truth database. [http://www.mcs.unr.edu/ims/database/content.html](http://www.mcs.unr.edu/ims/database/content.html)

For further information about the datasets used, and the methods employed, please contact David Green at dgreen@blacknest.gov.uk

Literature Cited