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Azimuthally dependent scattering of high frequency vertical component seismic data at the Large N array, Source Physics Experiment

PRESENTED BY

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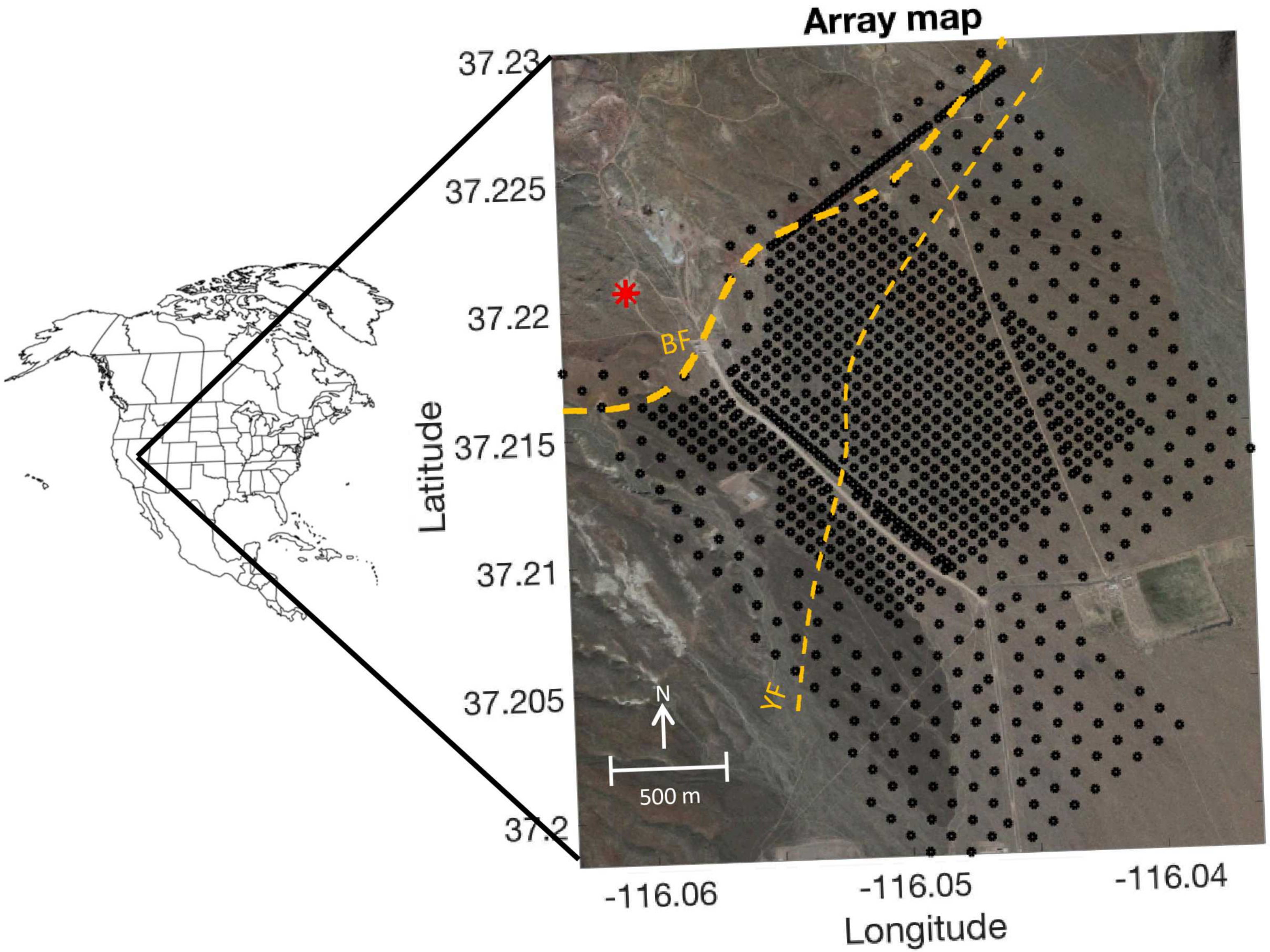
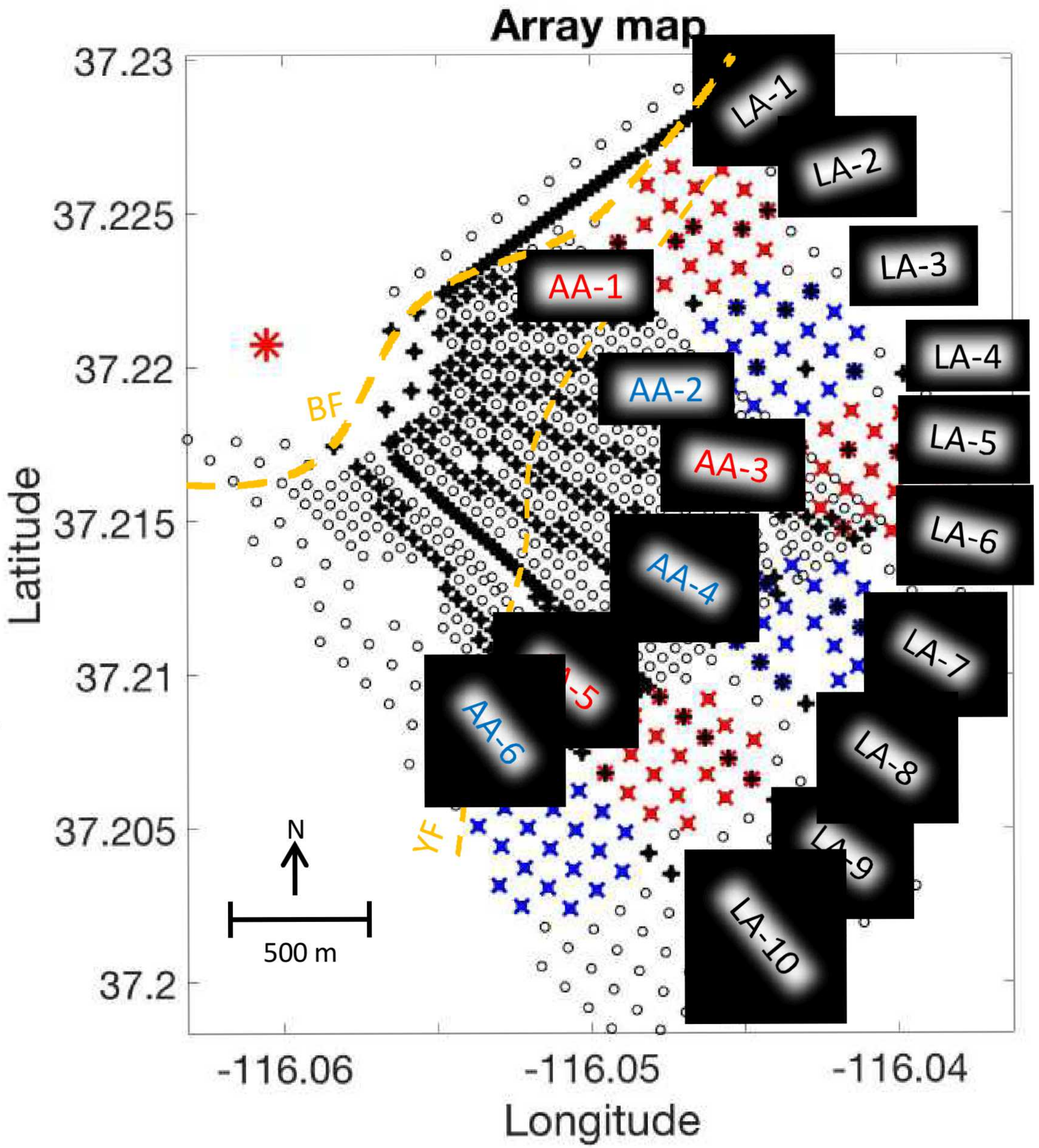
Background

- Source Physics Experiment:
- Nevada National Security Site
- Single chemical explosion
  - 5035 kg TNT equivalent
  - 76.5 m below surface
- Large N array
  - 974 vertical component geophones
  - Goal: high resolution velocity model (P and S)



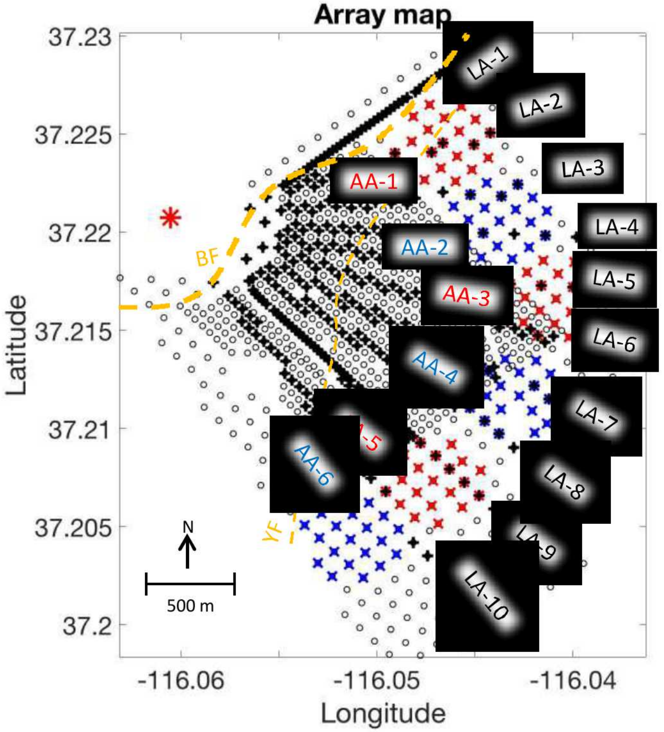
Background

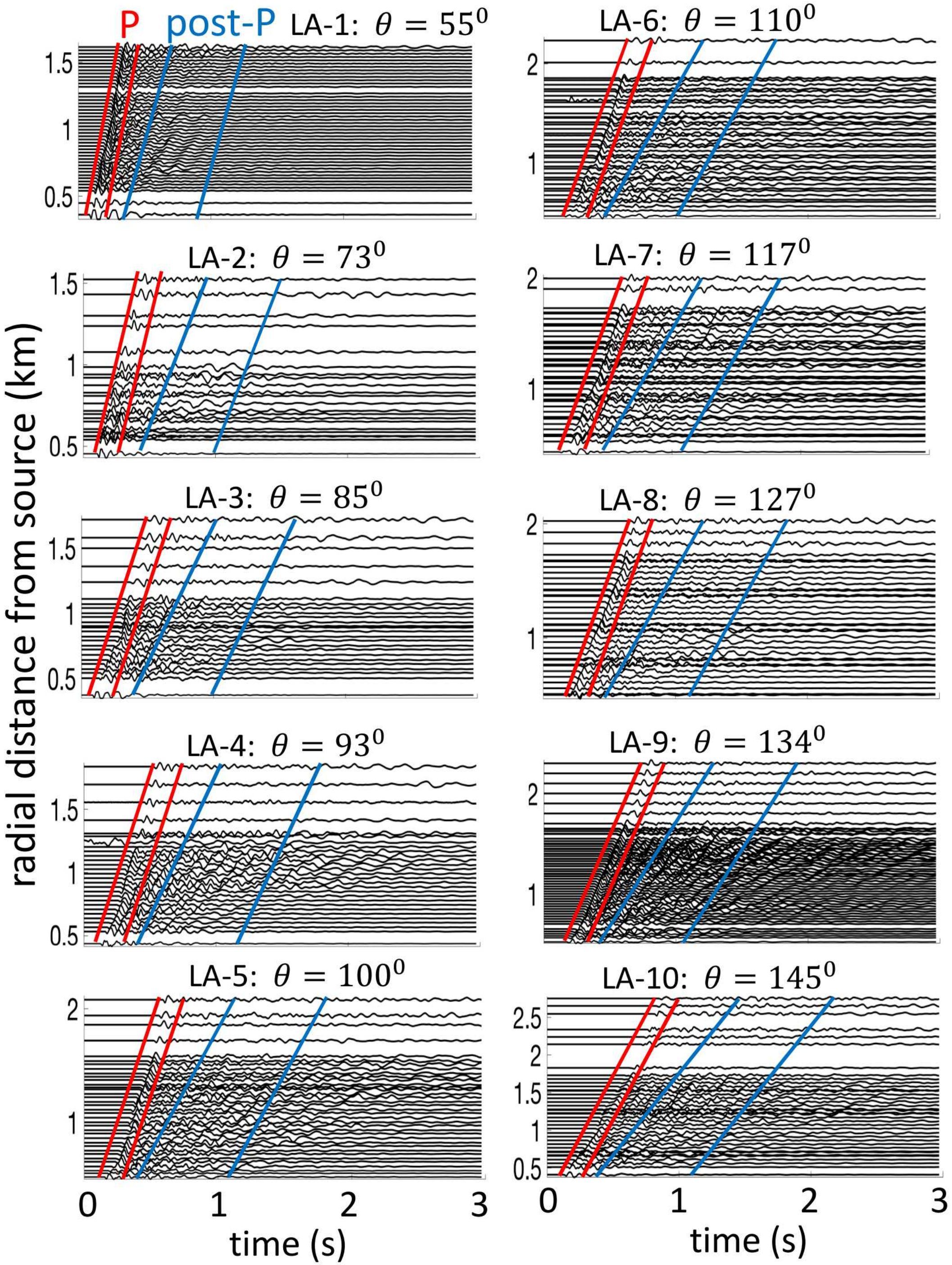
- Shear and surface waves difficult to resolve due to scattering
- Observation:
  - Scattering appears azimuthally dependent
- Hypothesis:
  - Scattering is controlled by anisotropic geologic structure
    - anisotropic texture
    - faults
- Analysis:
  - Form ten linear arrays, each with a unique source-receiver azimuth
    - estimate coherency of P and "post-P"
  - Form six areal arrays
    - estimate wave vector



Raw Data: linear arrays

- P-wave (red) has high coherency for all linear arrays
- post-P (blue): Shear waves, surface waves, converted body phases
- potential S-wave: LA-3, LA-5?
- surface waves:
  - pronounced on LA-1
  - intermittent on other linear arrays





Analysis methods: coherency and array analysis

1) Coherency as a proxy for wave scattering
    - Scattering as a function of source-receiver azimuth and inter-station distance
    - Two methods for cross-validation: magnitude squared coherence and peak normalized cross correlation

2) Array processing: determine the origin of scattered waves
    1) Slowness vector of scattered waves for different regions of the Large-N

1) Magnitude-squared coherence
    - frequency domain
    - coherency for each frequency

2) Peak normalized cross correlation
    - time domain
    - coherency averaged over passband of data

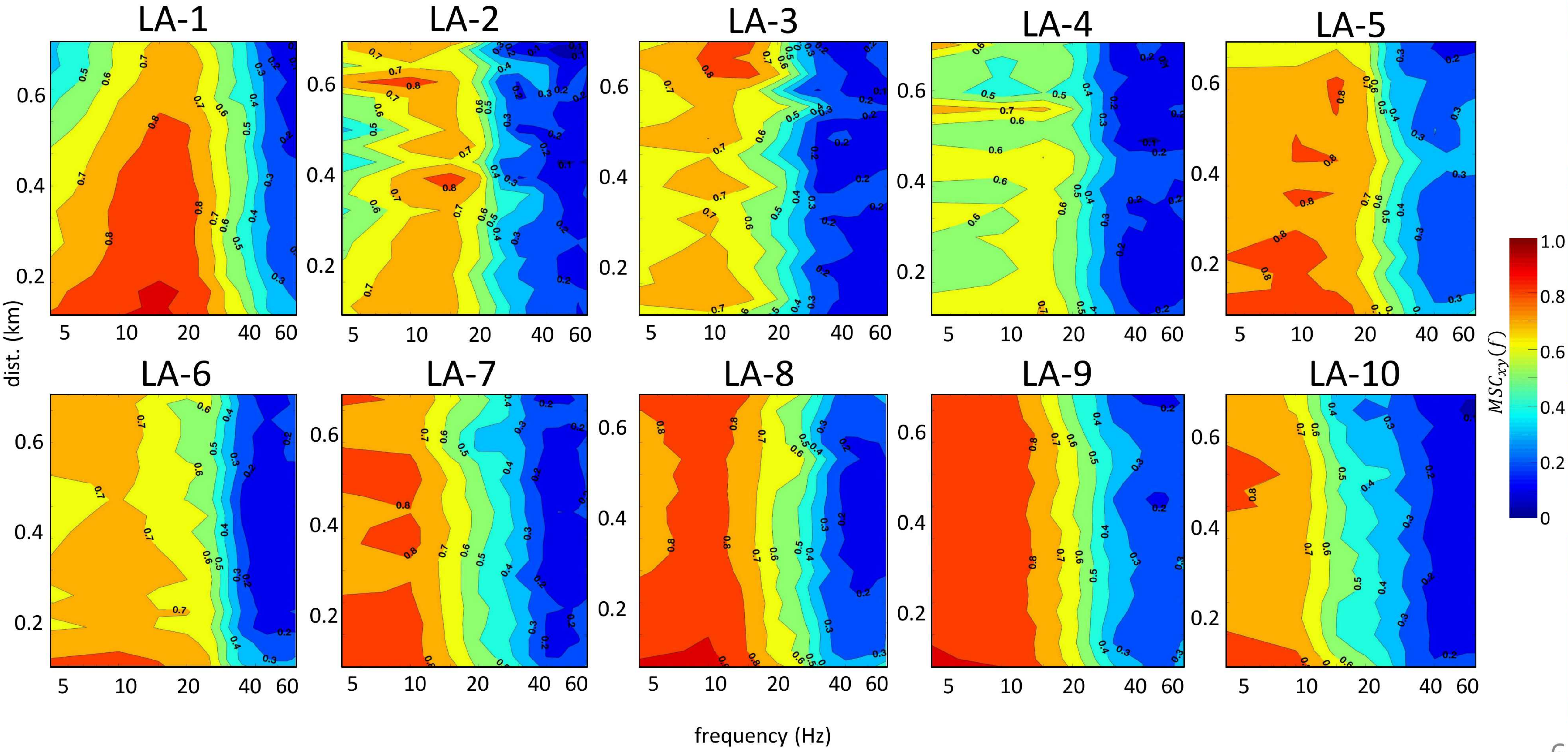
cross power spectral density for seismograms x and y

$$MSC_{xy}(f) = \frac{|P_{xy}(f)|^2}{P_{xx}(f)P_{yy}(f)}$$

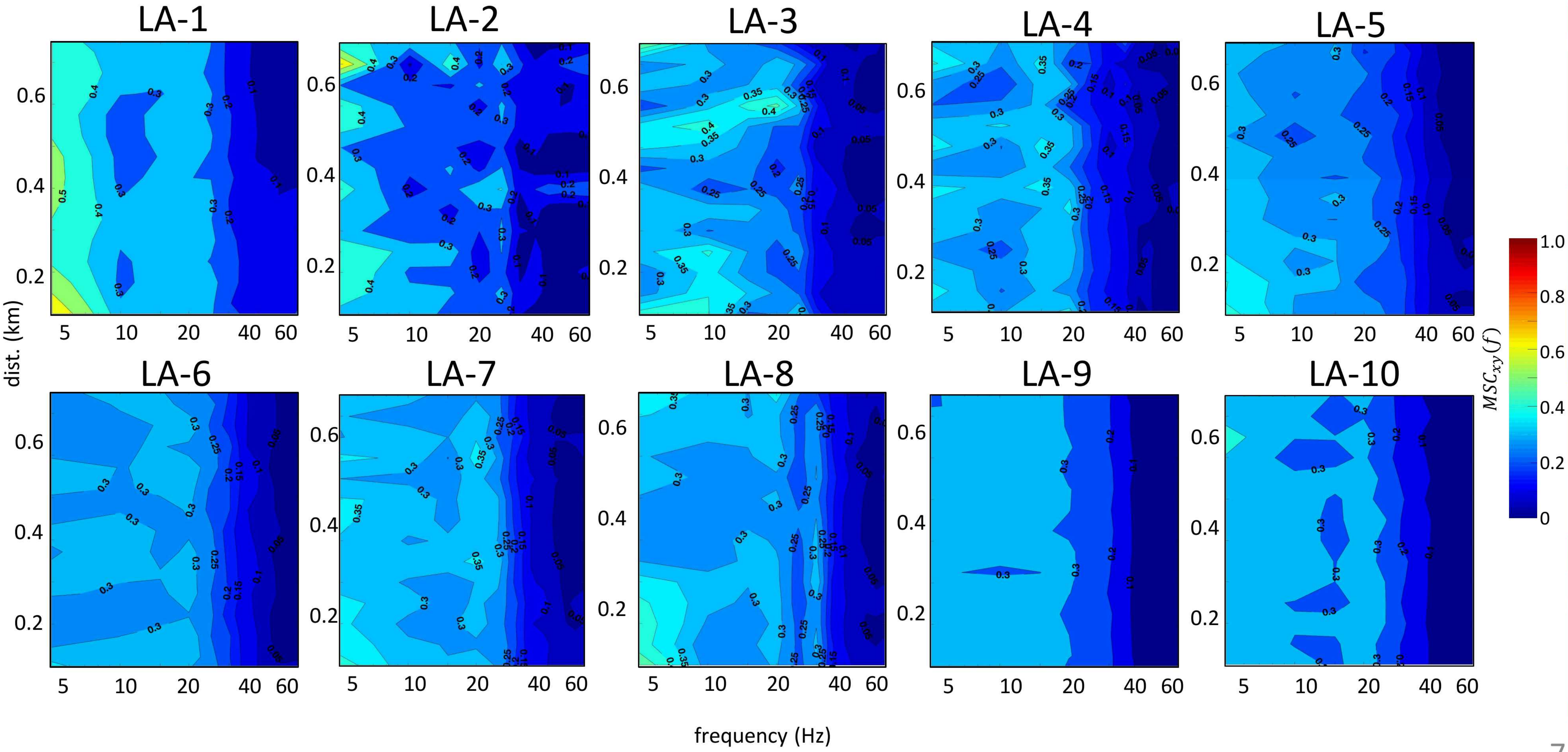
cross correlation for seismograms x and y

$$C_{xy}^{\{f_c\}} = \max_{1\leq\tau<N} \frac{\sum_{n=1}^{N} x_n\, y_{n+\tau}}{\sqrt{\sum_{n=1}^{N} {x_n}^2 \sum_{n=1}^{N} {y_n}^2}}$$

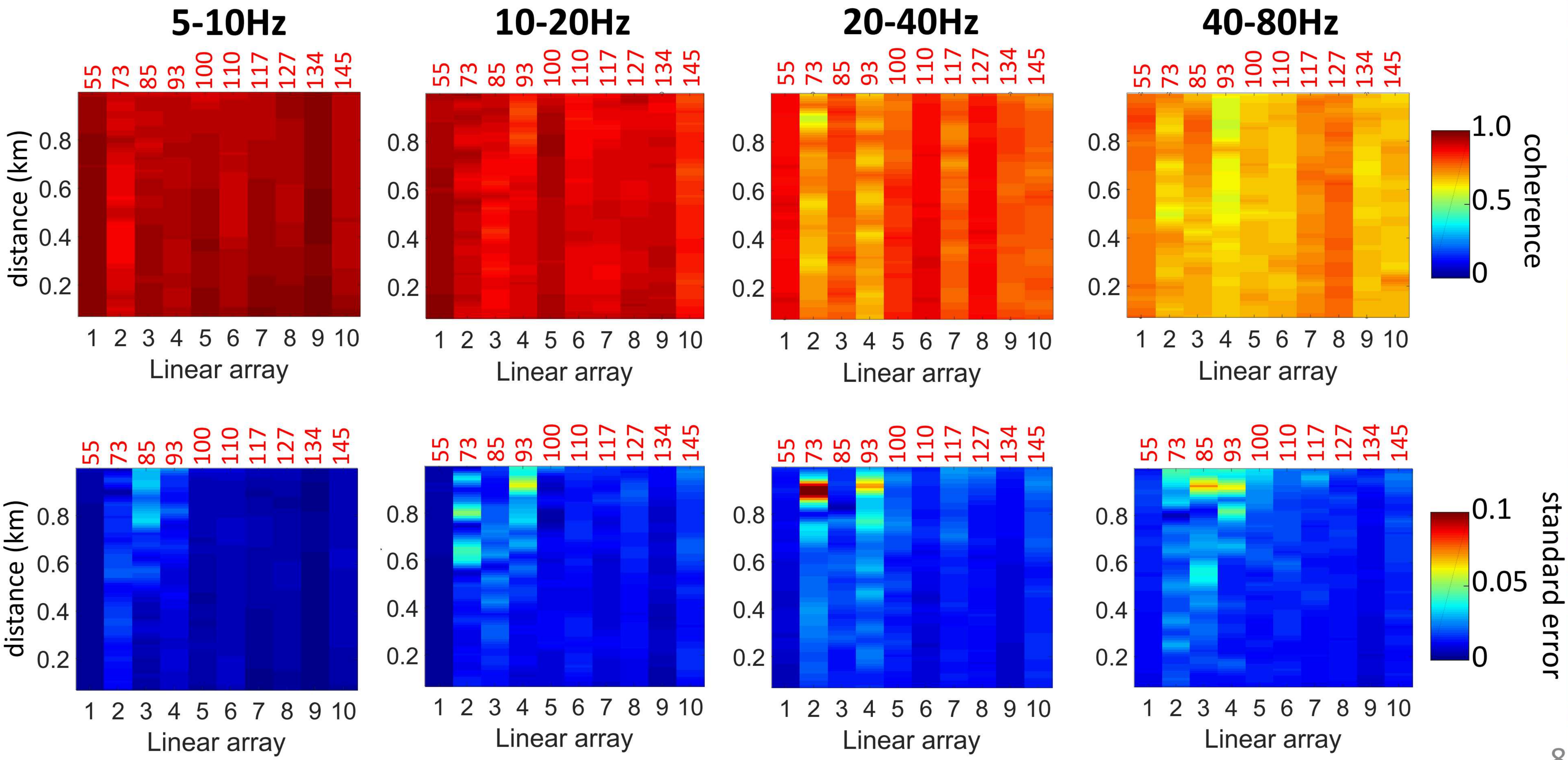
Magnitude squared coherence: P wave



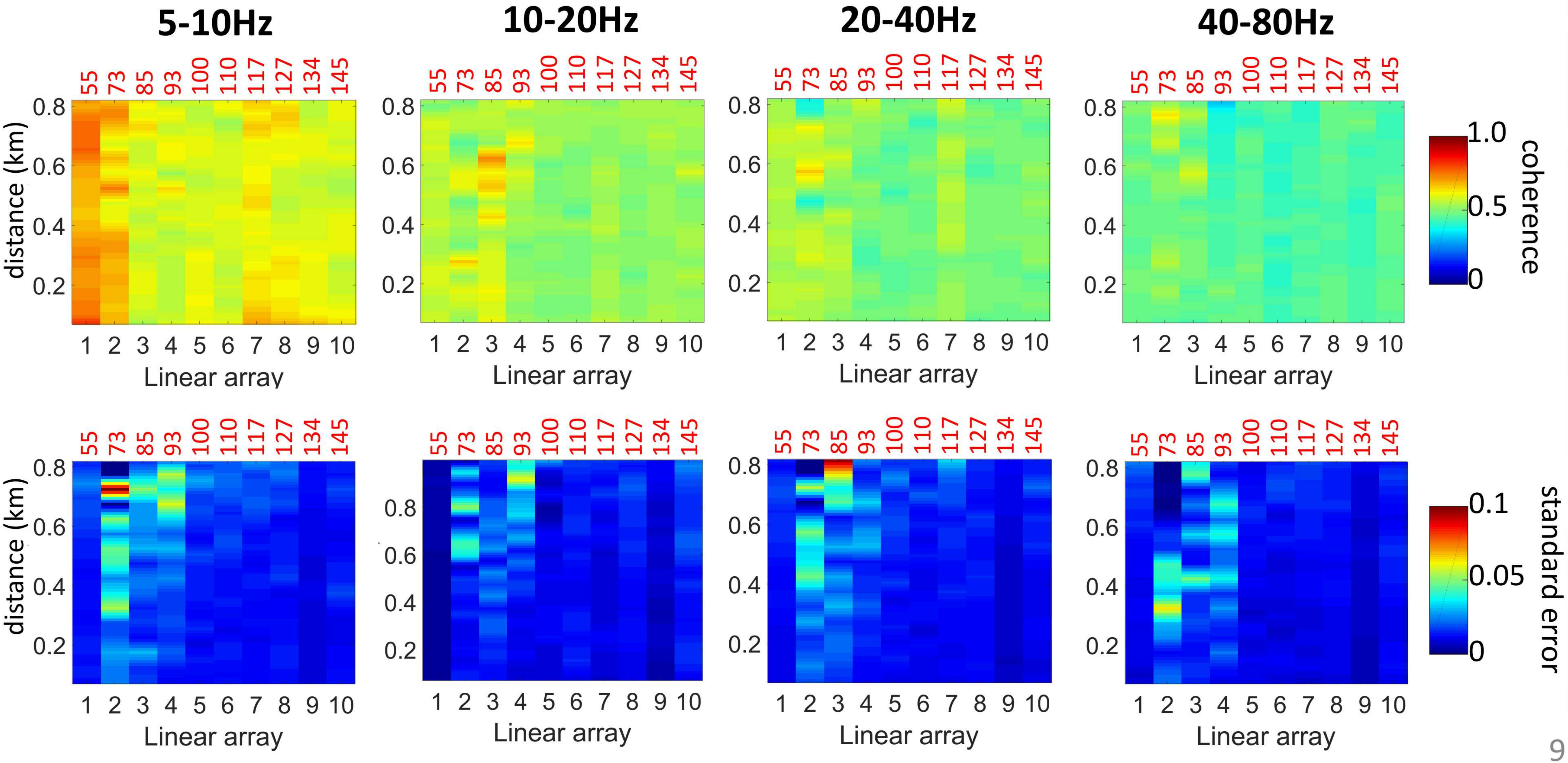
Magnitude squared coherence: scattered waves



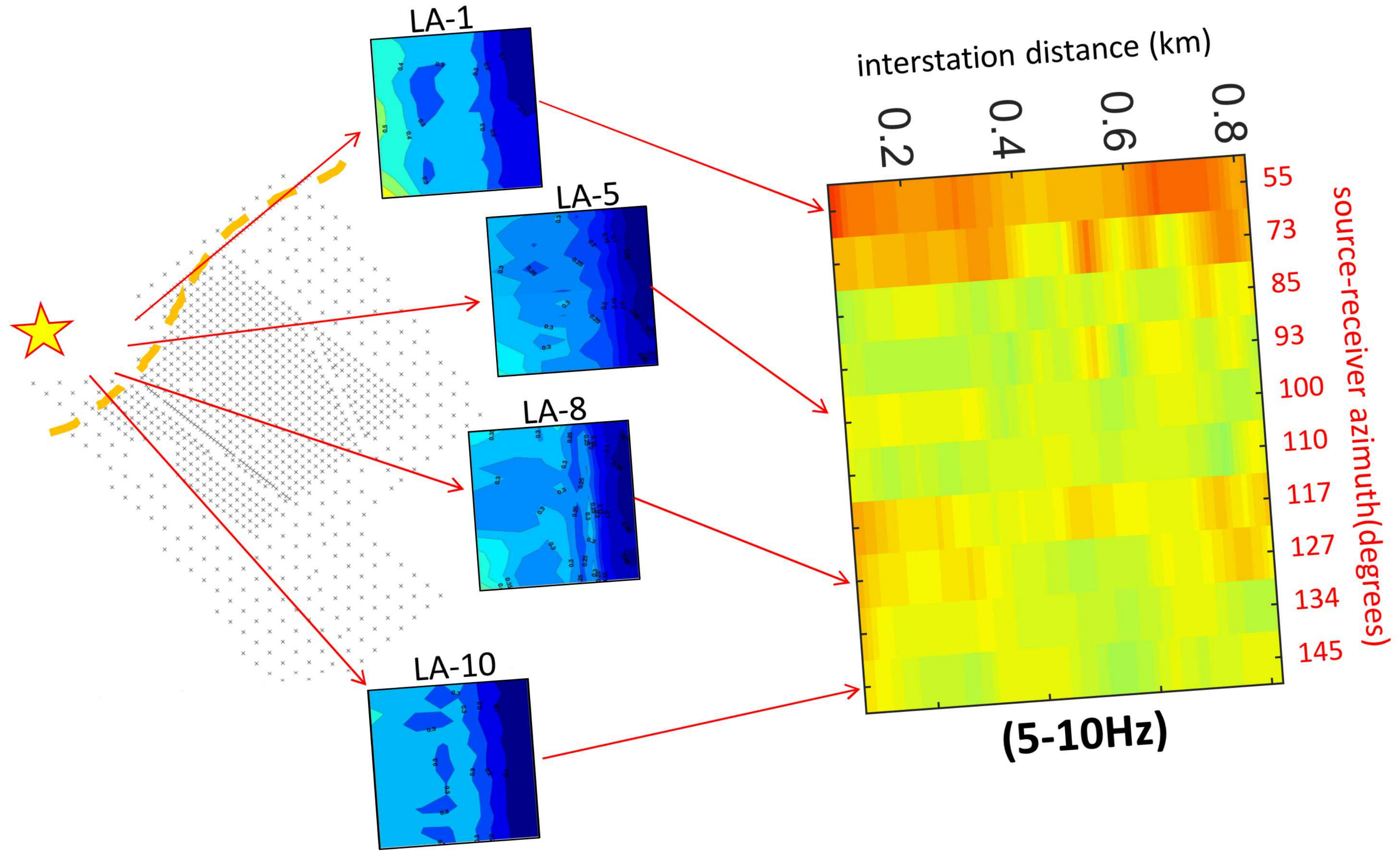
Peak normalized cross correlation: P-wave



Peak normalized cross correlation: scattered waves



Summary of results: scattered wave coherency



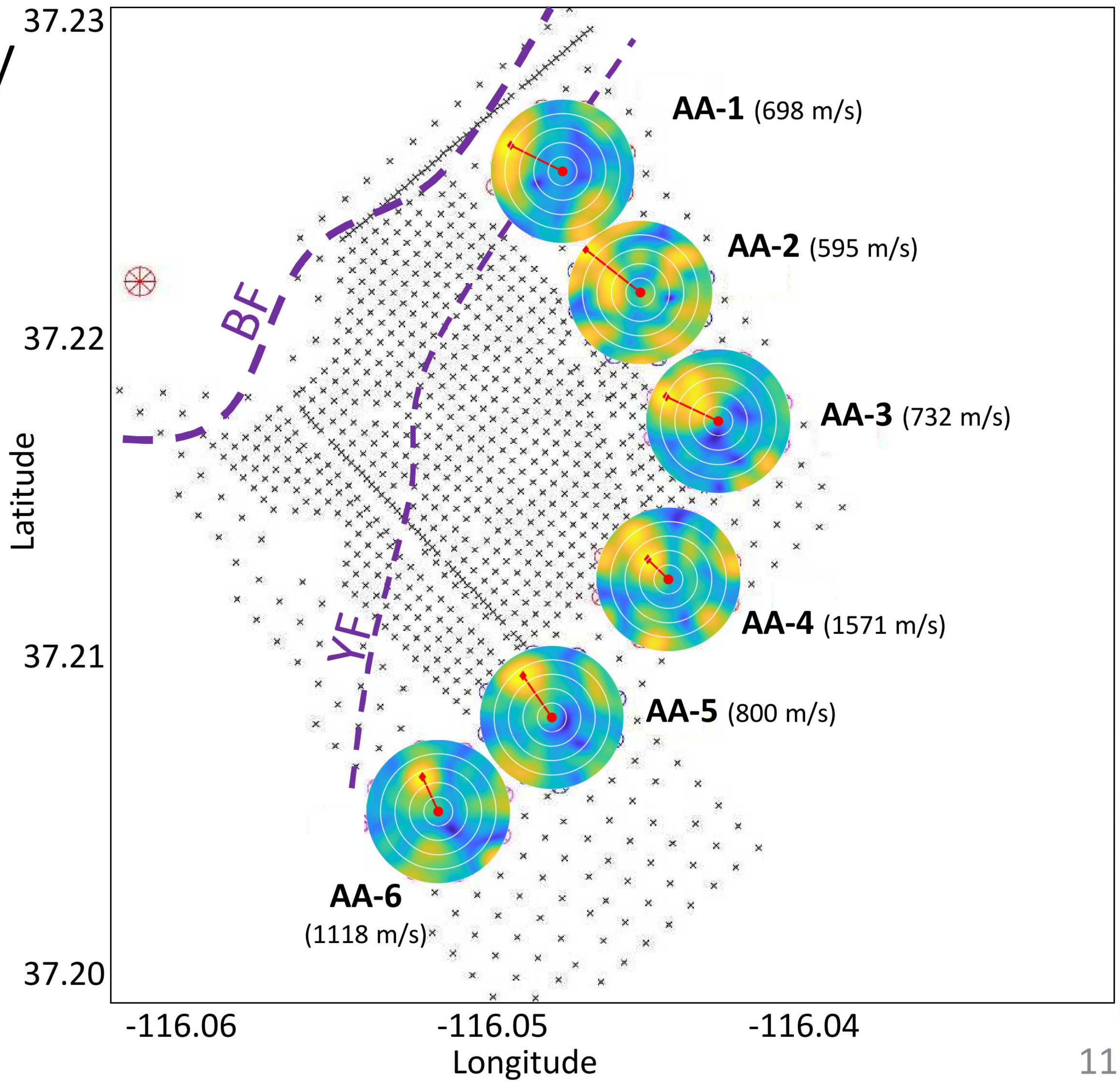
Generally, both measures of coherency decrease as the azimuth of propagation goes from fault-parallel to fault-perpendicular

Array analysis: summary

- Specifics:
  - Scattered wave window
  - Passband 2-5Hz
  - Red line denotes direction of maximum slowness.

- Results:
  - AA-1 and AA-2 show that most of the scattered energy radiates from the Boundary Fault.
  - Other arrays do not show this

- Interpretation
  - The Boundary Fault is a source of scattered wave energy
  - This energy quickly attenuates
  - Away from fault: scattered energy appears to originate from the source



Discussion and Future Work

- Documentation of azimuthally dependent seismic scattering
  - P wave results have high coherency, indicating minimal scattering for P wave arrivals
  - LA-1 contains the highest coherency values for both P and scattered wave arrivals
  - General decrease in coherency as propagation azimuth goes from fault-parallel to fault-normal.
  - Boundary and Yucca faults potentially act as a frequency-specific waveguide
  - Substantial amount of low frequency scattered wave energy radiating normal to the strike of the boundary fault
- Implications
  - Radiation pattern of P and scattered waves are source-related AND propagation dependent
  - Caution in using seismic amplitudes for yield estimation, as azimuthal bias may exist
  - Sources of anisotropic scattering are likely from fault (in this case), however may be due to anisotropic textural fabric