Towards underwater channel impulse response estimation using sources of opportunity

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Research Goals and Presentation Objectives

1. Estimate the transfer function of the ocean using ships of opportunity.
2. Estimate the time-evolving state of the ocean volume in a region.

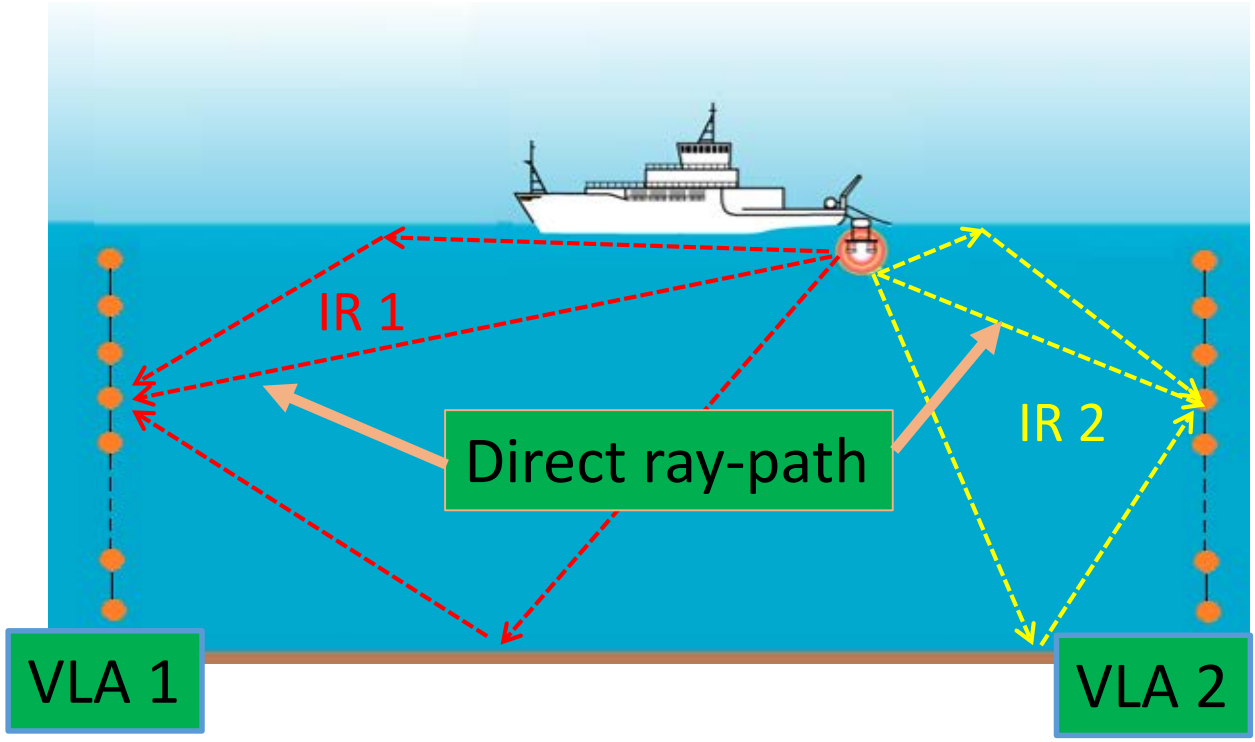
- Demonstrate workflow and results of modular signal processing components: beamforming, source signature estimation, additional processes present, deconvolution, sequential processing, geo-acoustic inversion, ‘ground truths’, etc.

- Initial results are demonstrated using the Noise Correlation 2009 experiment. Application to the Santa Barbara Channel Experiment 2016 is discussed.

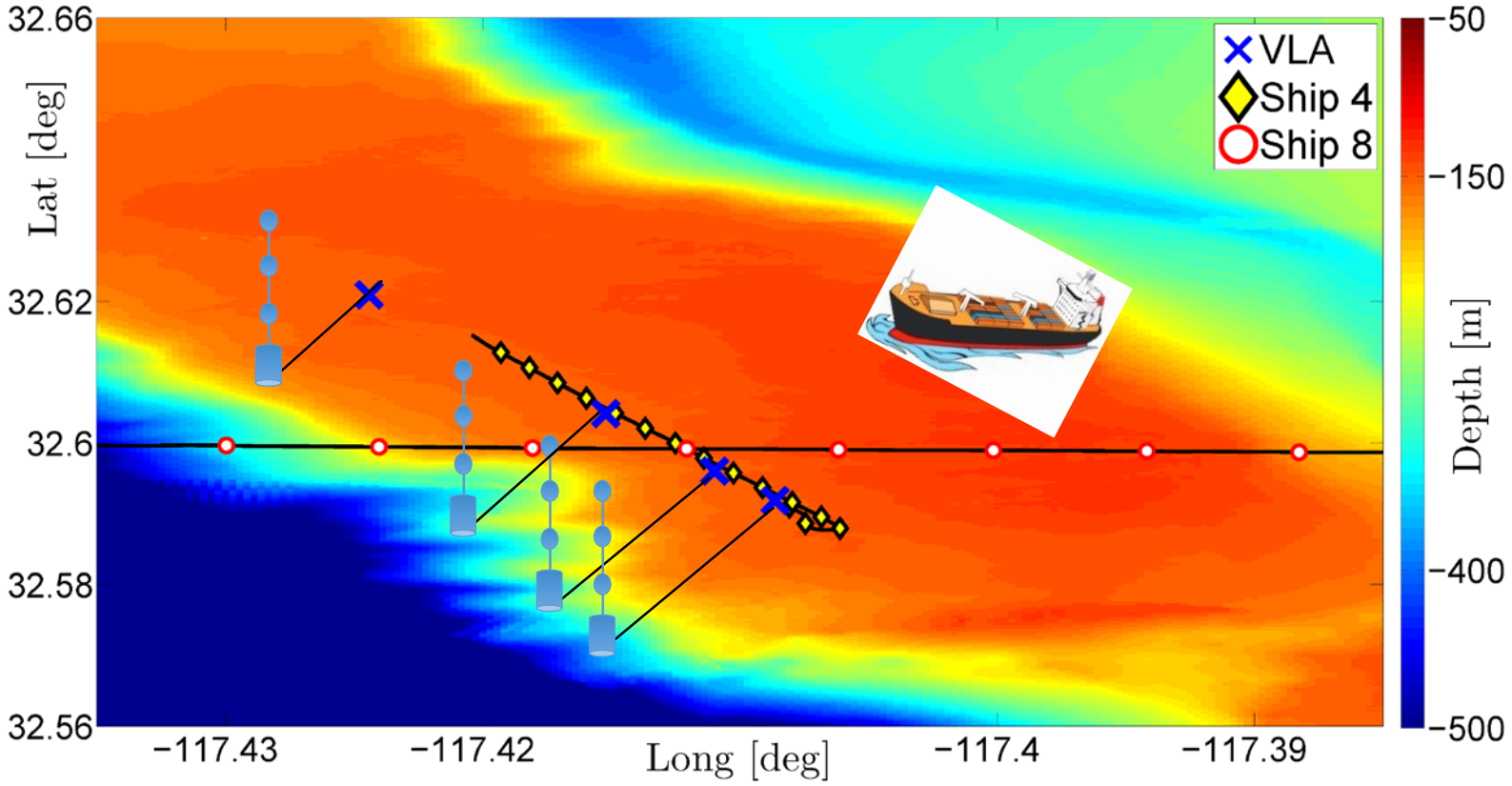
Approach for Case 1 & 2

- Exploit information content of a random signal in noise
- Beamforming on a vessel's direct ray-path received on a vertical line array (VLA) yields an estimate of the source signal
  - known signal in noise used as a phase-matched-filter on VLA 1 yields Impulse Response (IR) 1
- Independent array deconvolution: repeat beamforming and IR estimation individually at each VLA
  - source timing uncertainty
- Simultaneous array deconvolution: use the beamformed signal estimated at VLA 1 as a phase-matched-filter on VLA 2
  - Same source signal (reduced uncertainty)
  - requires a more complex model:

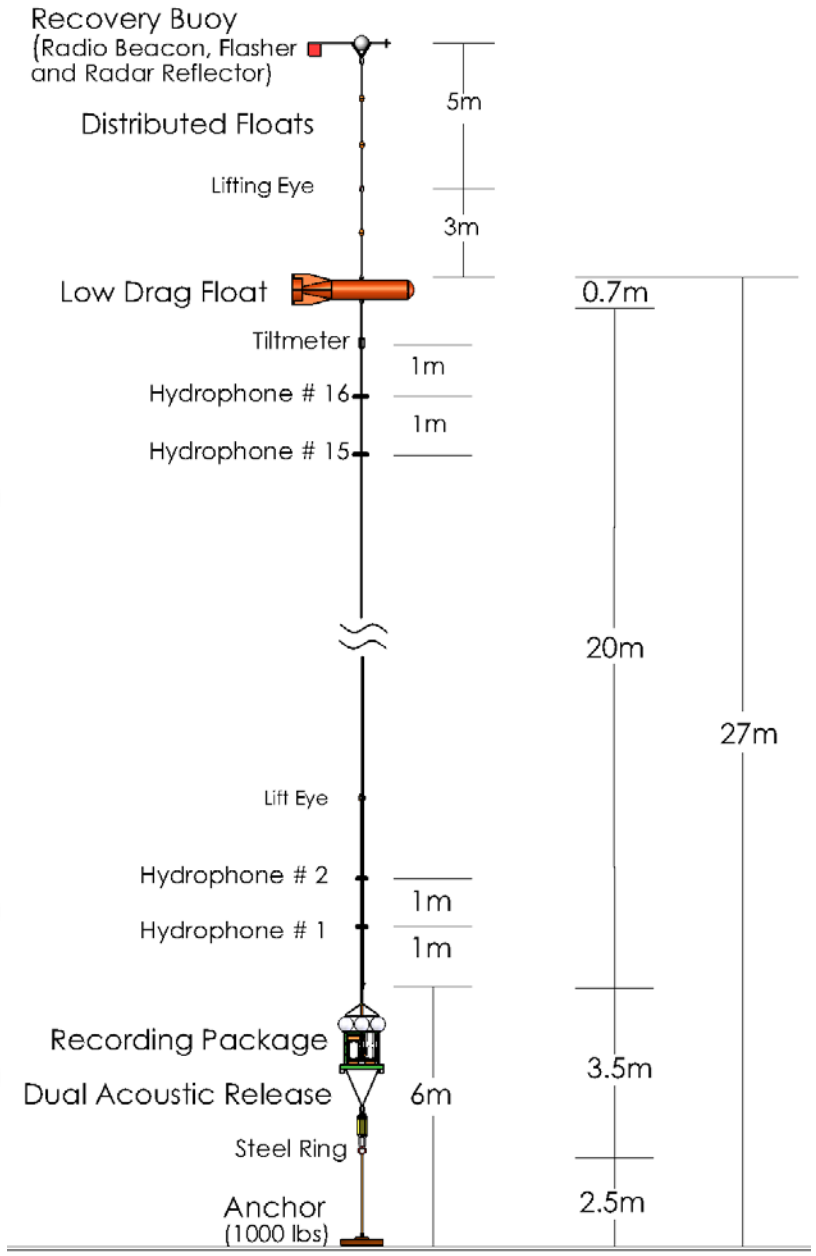
  known signal with unknown parameters



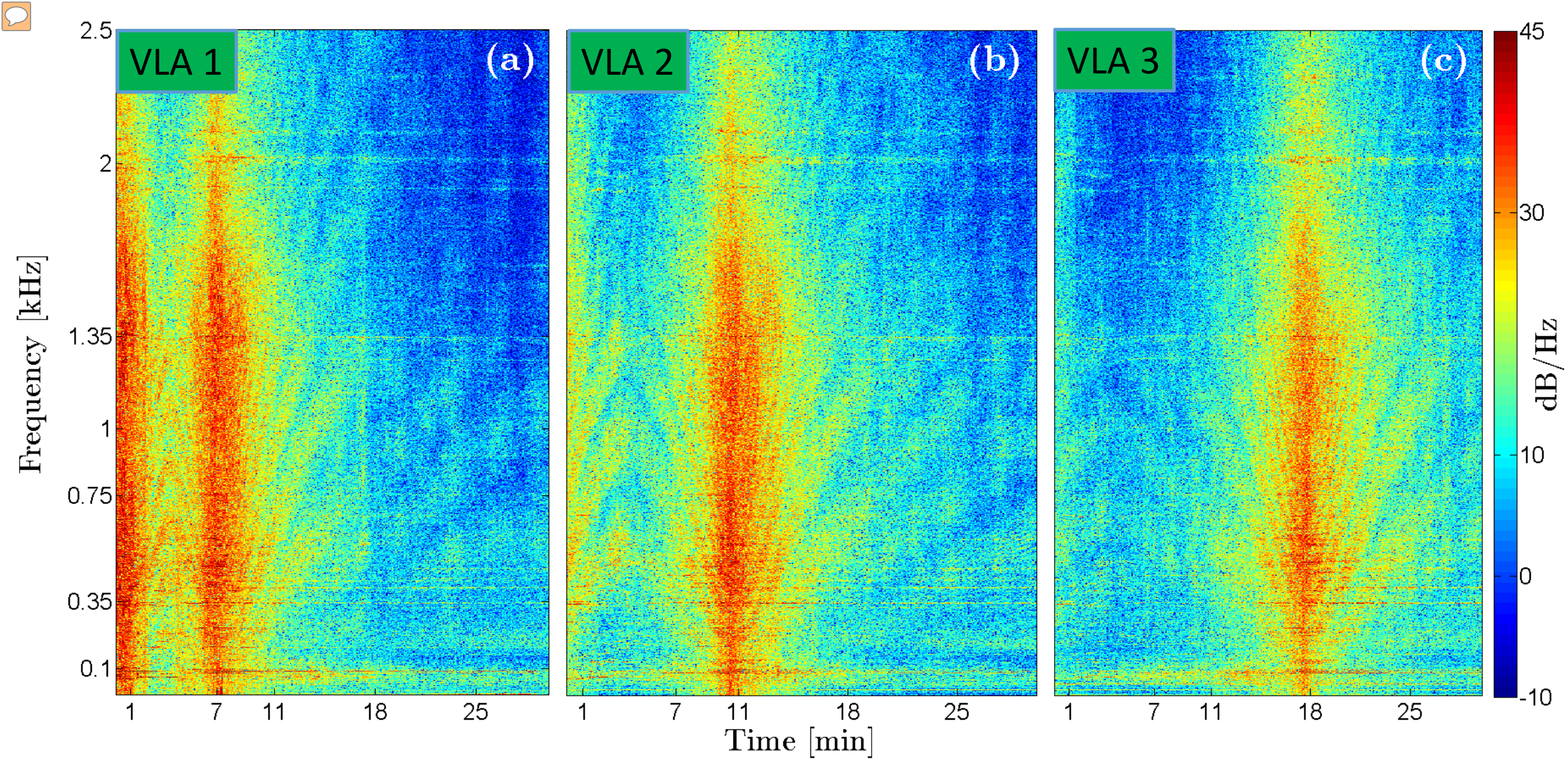
Noise – 09
Experiment configuration



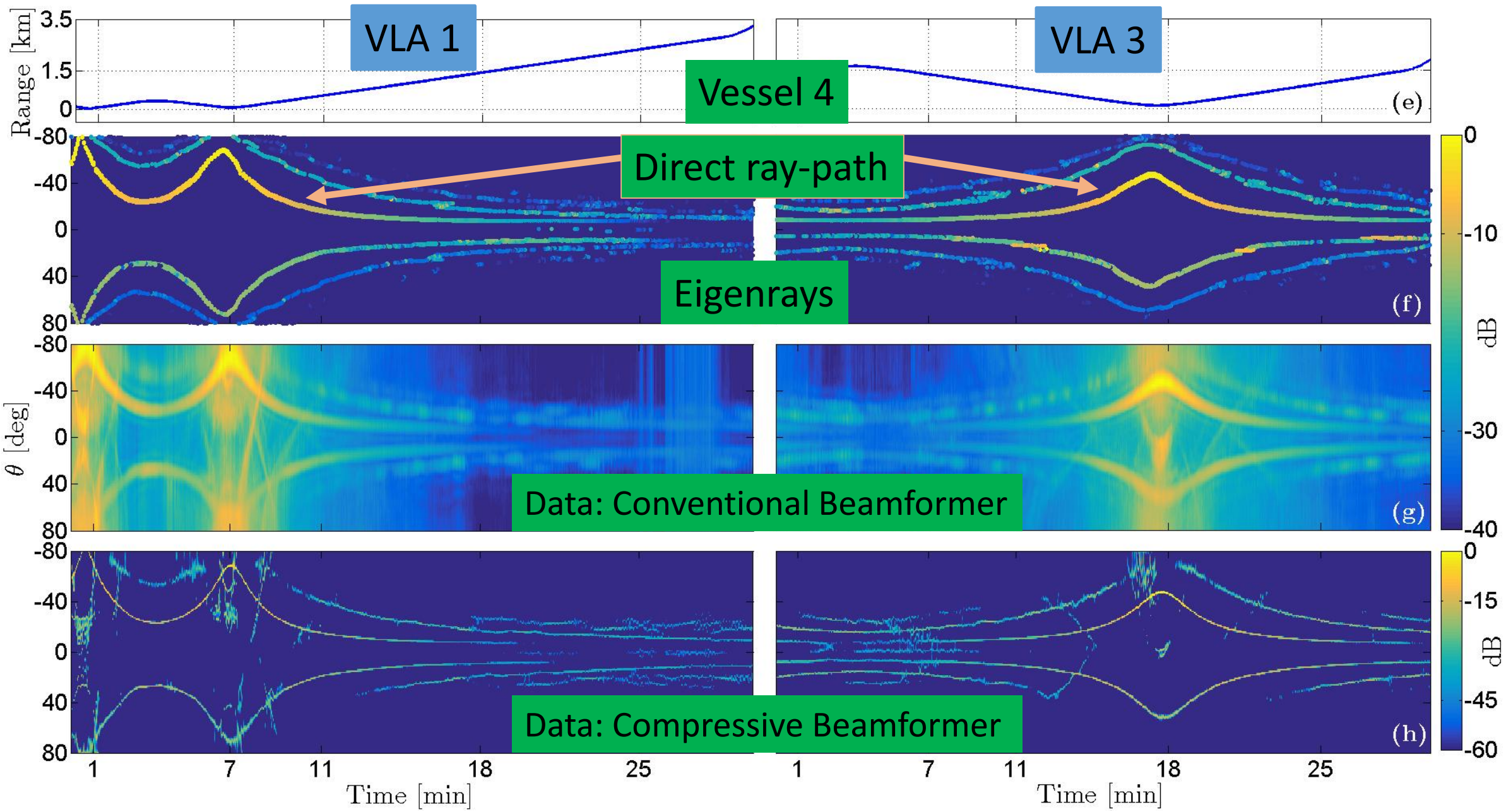
Coronado Bank with deployed VLAs and ship tracks.
We use Ship 4 for analysis (30 min event).



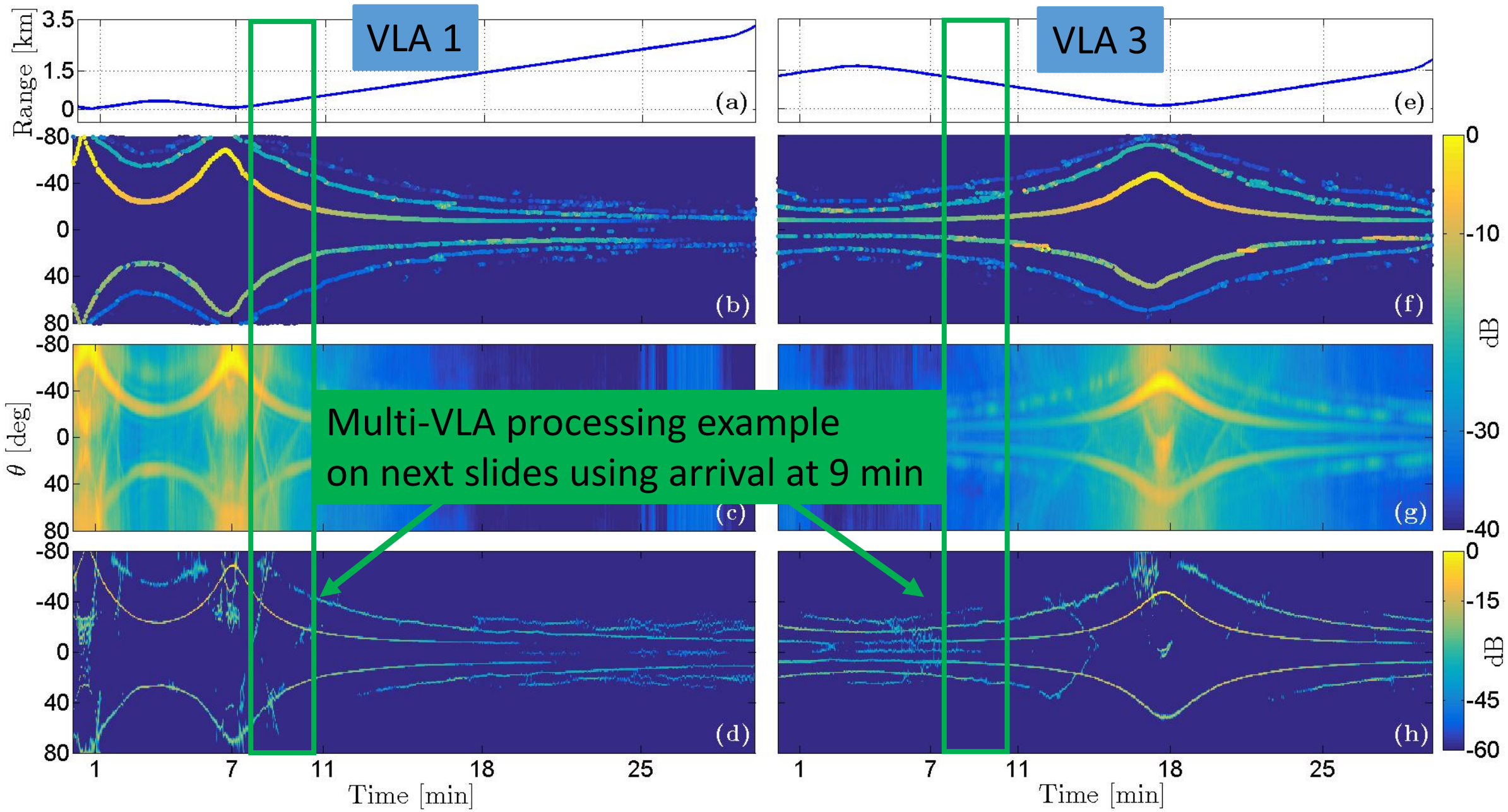
Vertical line array used during the Noise Correlation 2009 Experiment deployed at approximately 150 m depth.



Spectrograms of synchronized (a) VLA 1, (b) VLA 2, and (c) VLA 3 showing received acoustic energy at hydrophone 16. Horizontal ticks at approximately 7, 11 and 18 min mark the CPA of Vessel 4 at each respective VLA during its passage.



Left panels display results for VLA 1 and right panels display results for VLA 3: (a,e) Vessel 4 to VLA distance, (b,f) eigenrays computed with the Bellhop model, (c,g) Bartlett (550-850 Hz) and (d,h) SBL (80-1000 Hz).



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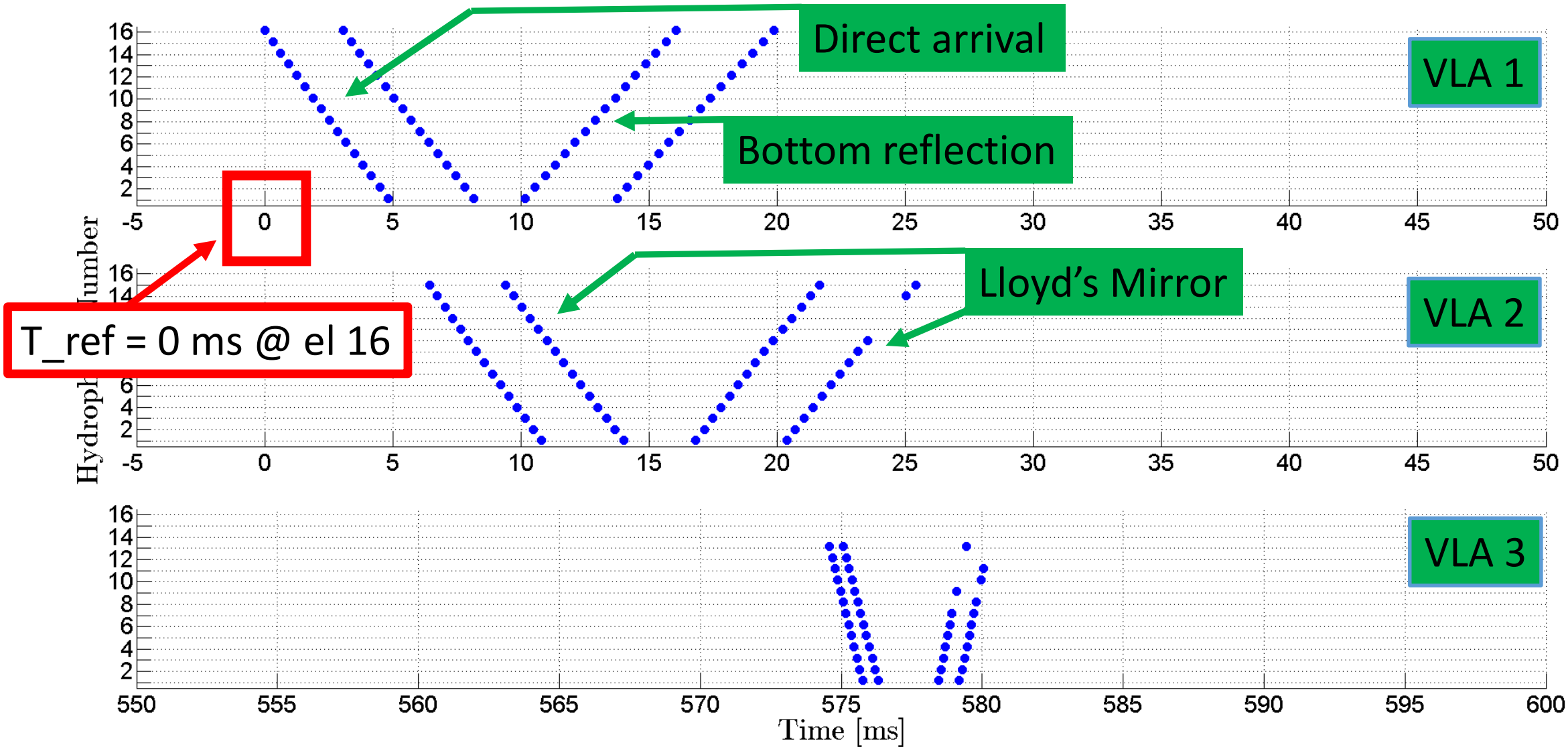
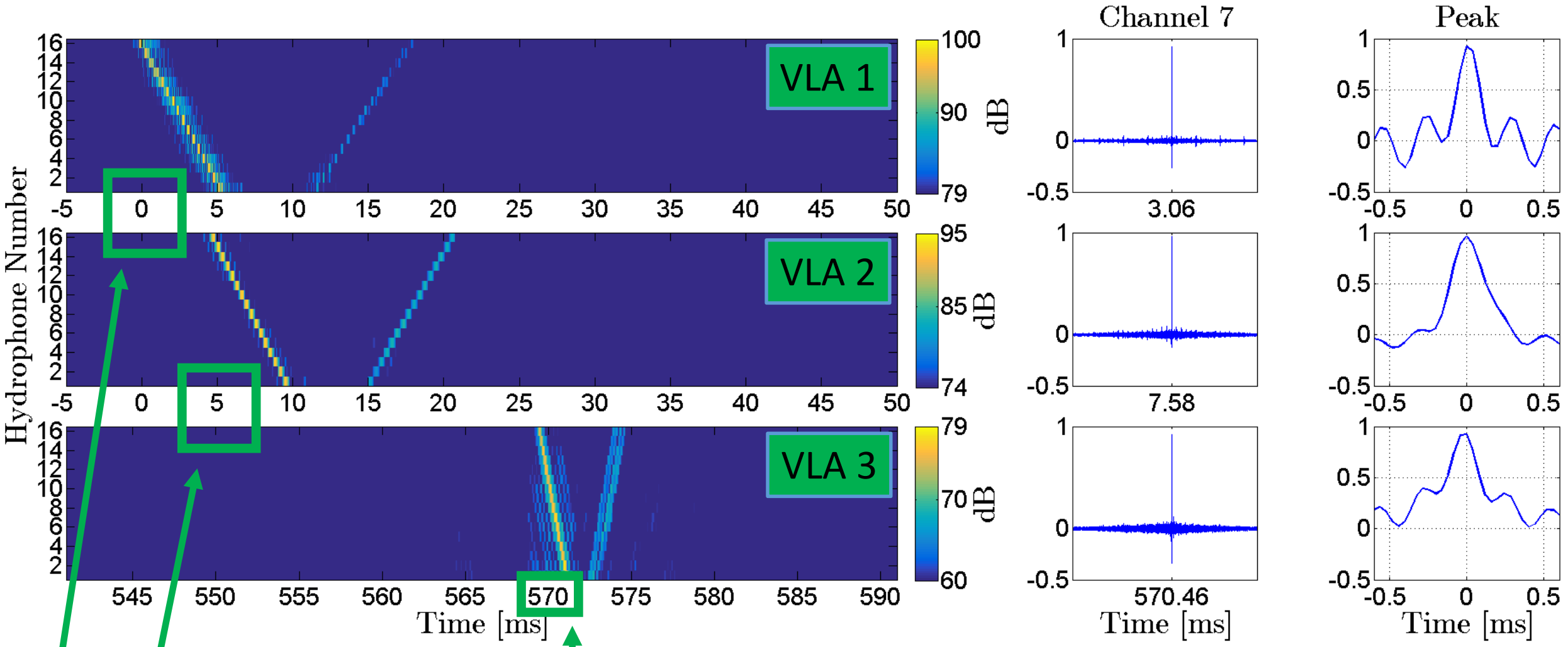
Simulation at 9 min: Bellhop eigenrays



Independent deconvolution: 3 source signals

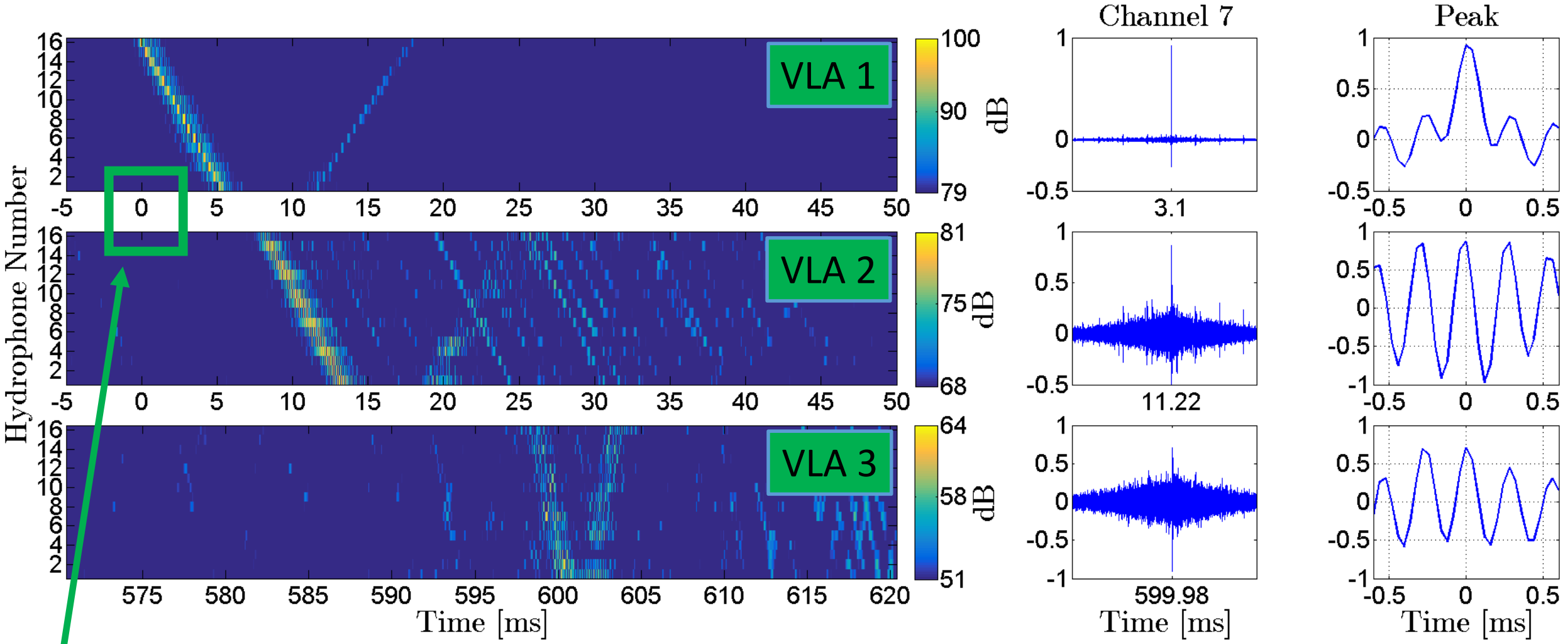


3 arbitrary reference times

σ_t = [20, 24, 46] µs

T=5s, BW: 2 kHz

Simultaneous deconvolution: 1 source signals



One arbitrary reference time

σ_t = [20, ?, ?] µs

T=5s, BW: 2 kHz

Conclusions

- Independent array deconvolution: We demonstrated that it is possible to estimate 3 IRs individually recorded at horizontally separated (approximately 1.5 km) VLAs. Computed arrival uncertainties will be used to estimate the ocean state.
  - Processing subsequently will be applied to Santa Barbara Channel Experiment 2016.

- Simultaneous array deconvolution: This case requires further analysis to improve the coherence of a single source-signal recorded at horizontally separated VLAs. We will explore the Lloyd's Mirror effects and the anisotropic radiation pattern of a vessel.

End of presentation