

Blind Ocean Acoustic Tomography

presentation at the ENEA Workshop on

Ocean Acoustic Tomography: results and perspectives

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by

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Blind Ocean Acoustic Tomography

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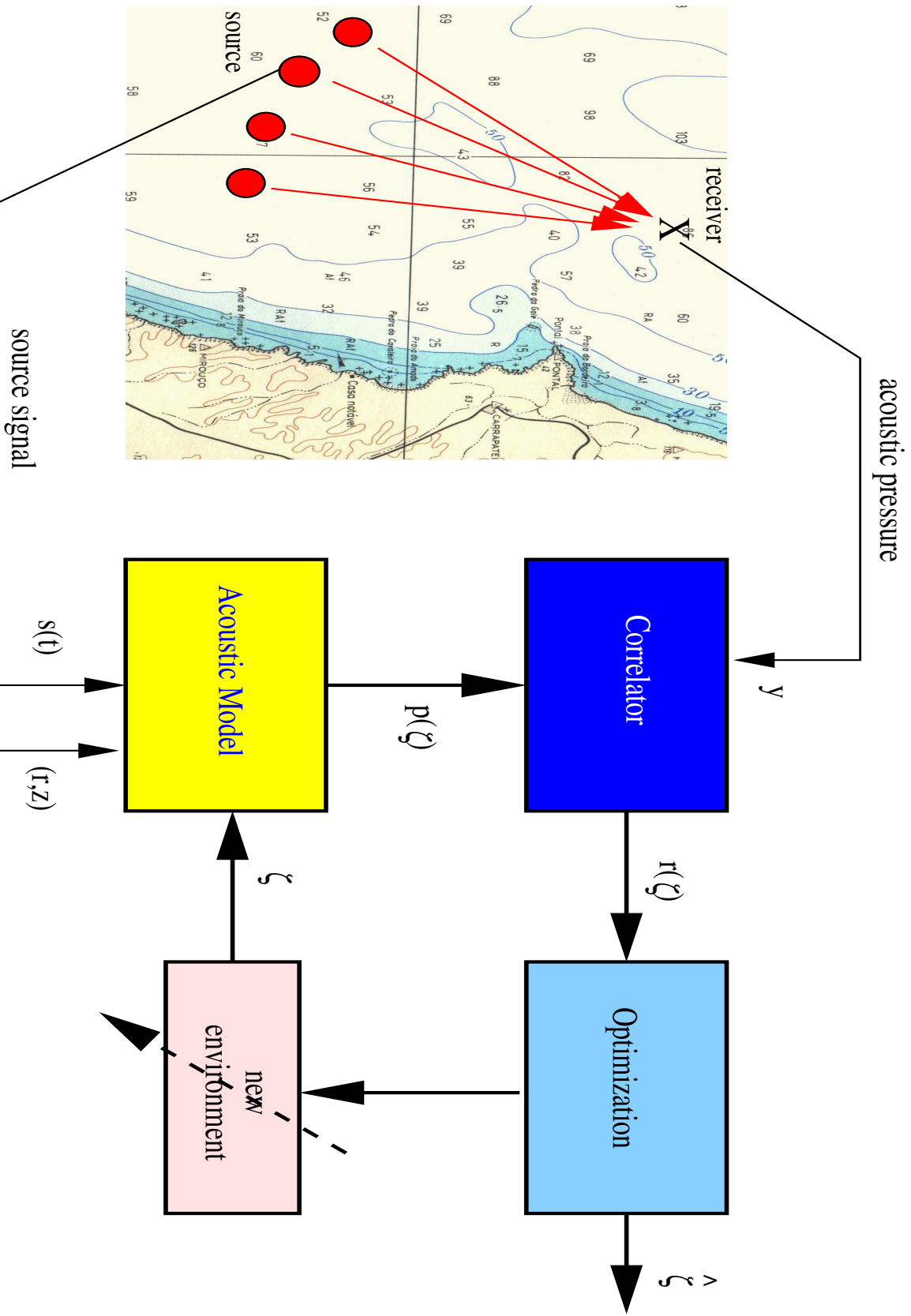
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Outline

- *the game of the name* and motivation
- the INTIFANTE'00 sea trial
- environmental inversion
- active tomography
- passive tomography
- summary





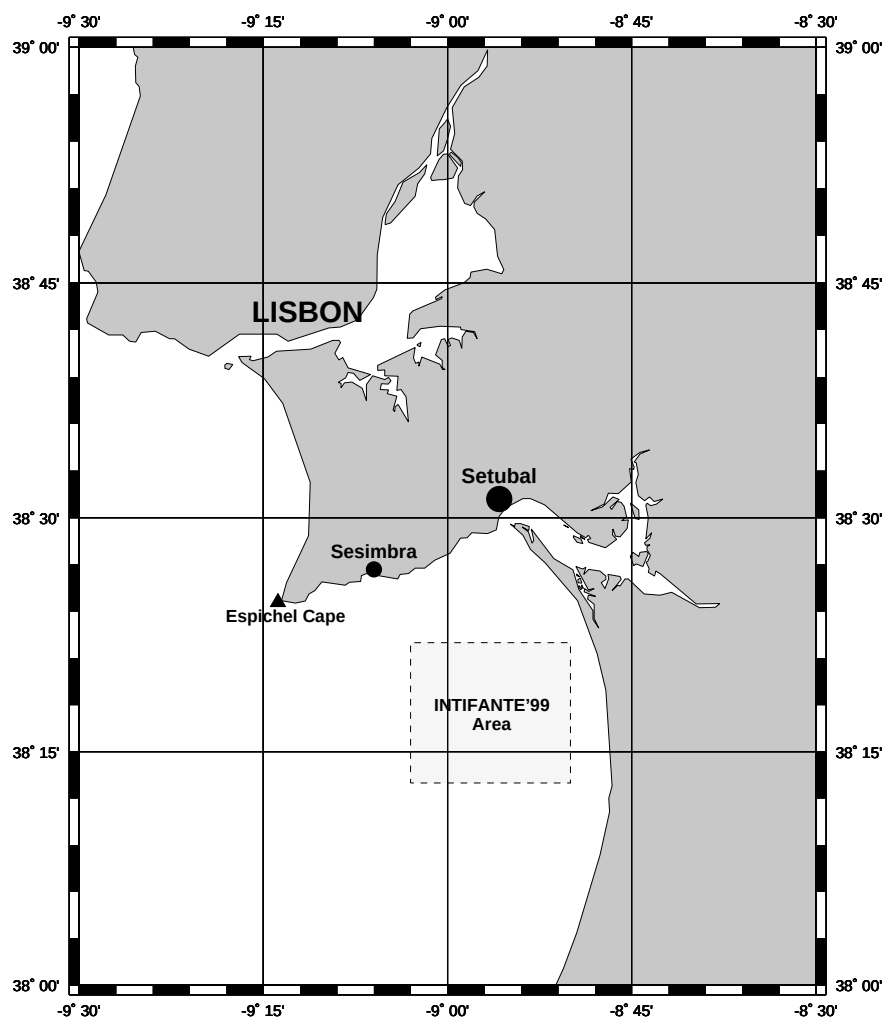
Motivation

$\Rightarrow$

- decrease the dependency on source knowledge (emitted signal and source position)
- increase the (time-space) adaptivity
- ability to use non-co-operative (noise) sources

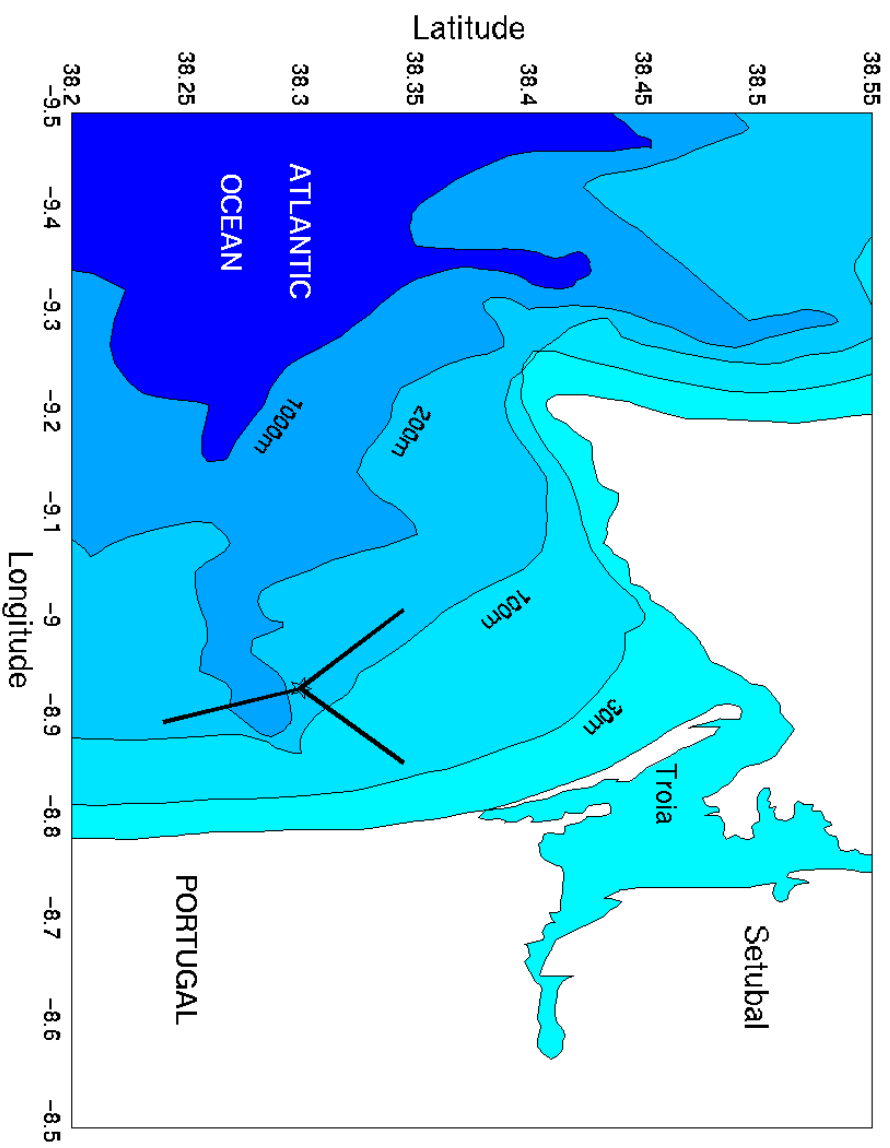


INTIFANTE'00 Experimental Site

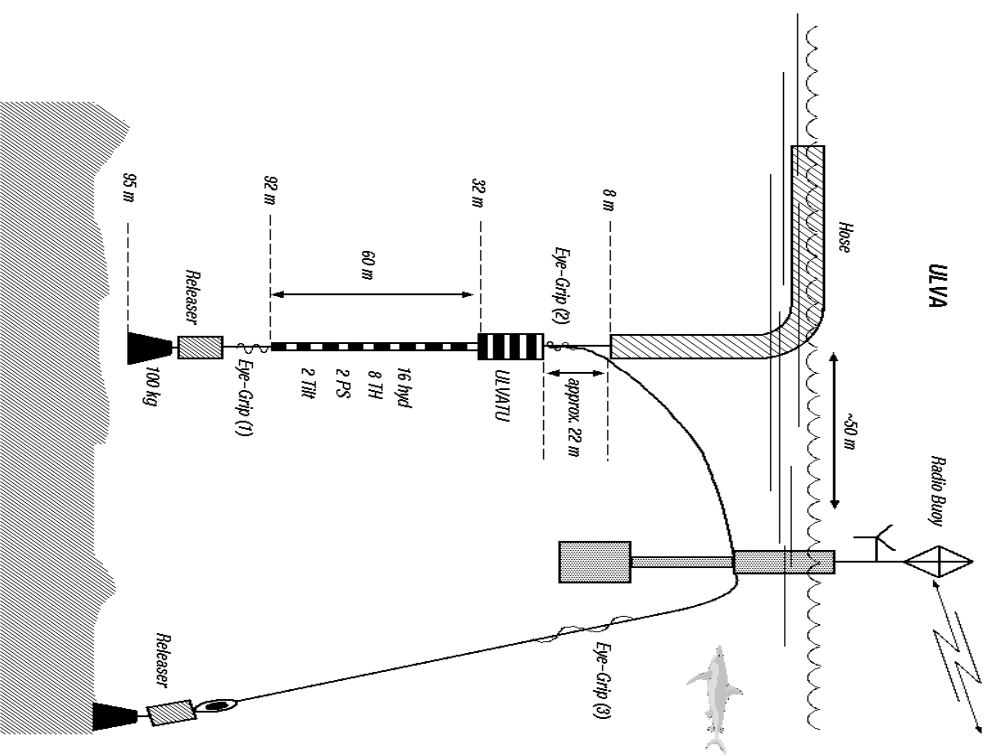




Geometry and Bathymetry

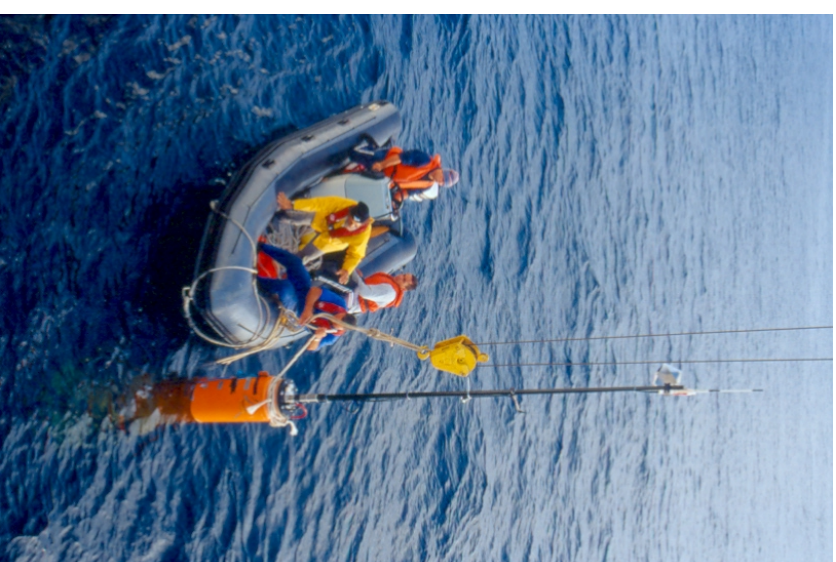
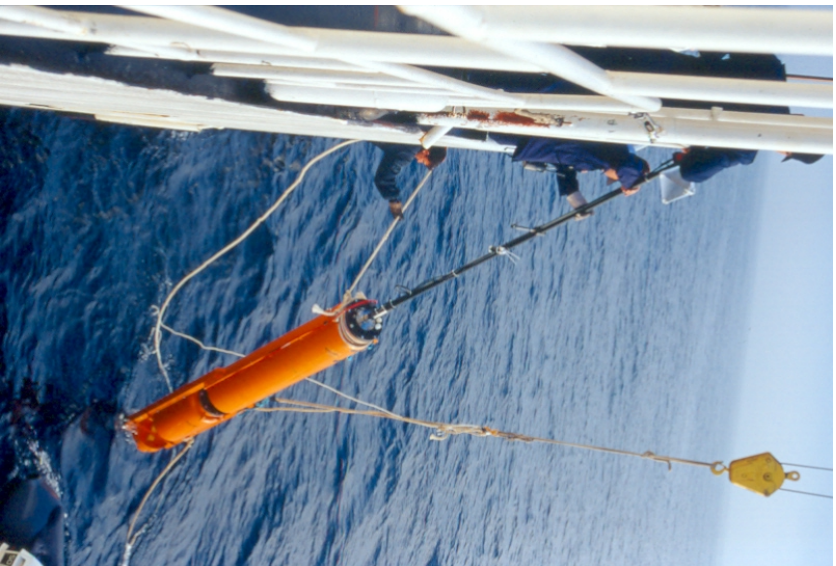


Vertical Line Array





Radio Buoy: deployment and setup



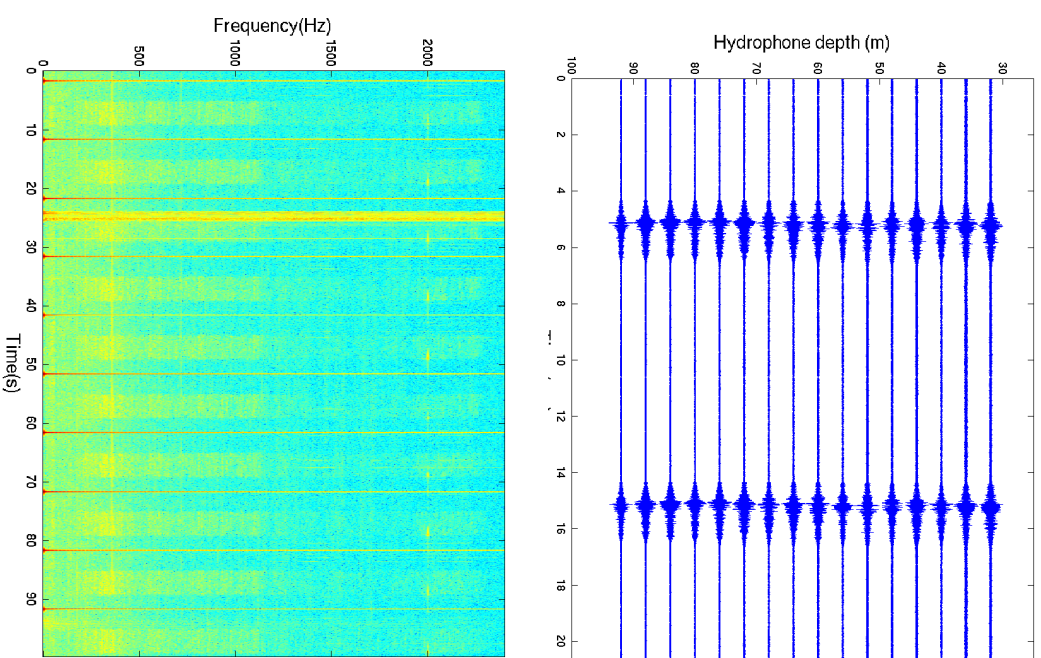


Recovering the Telemetry Unit

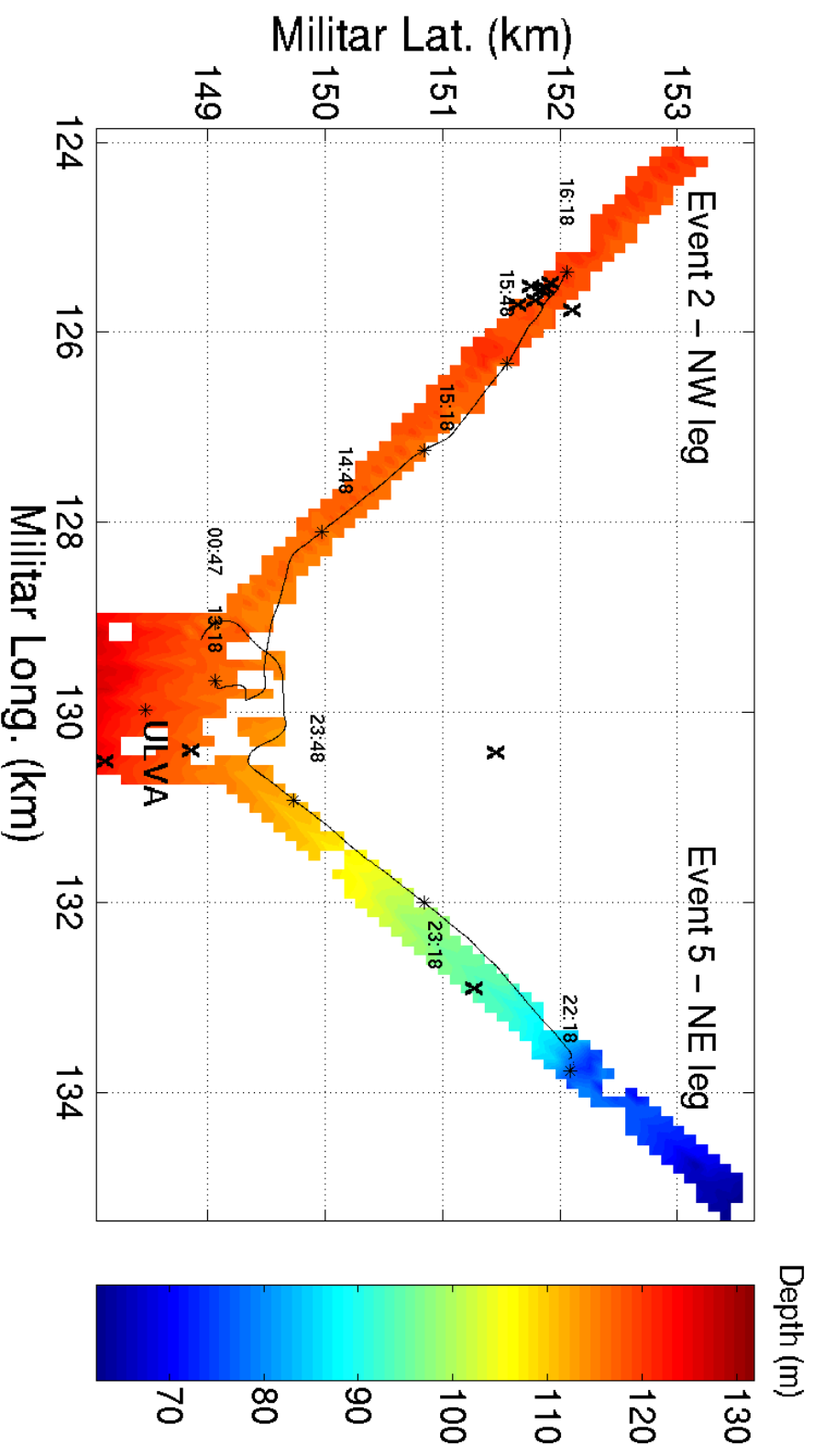




Sound source and emitted signals

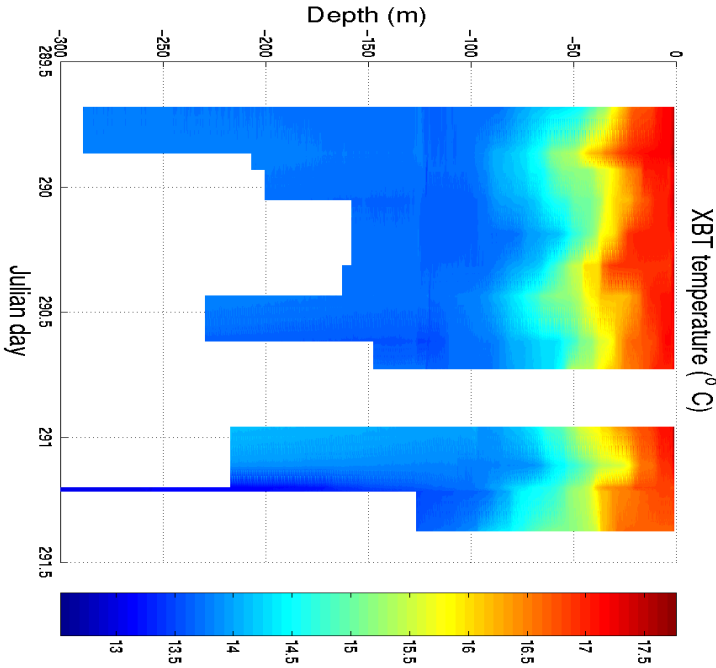
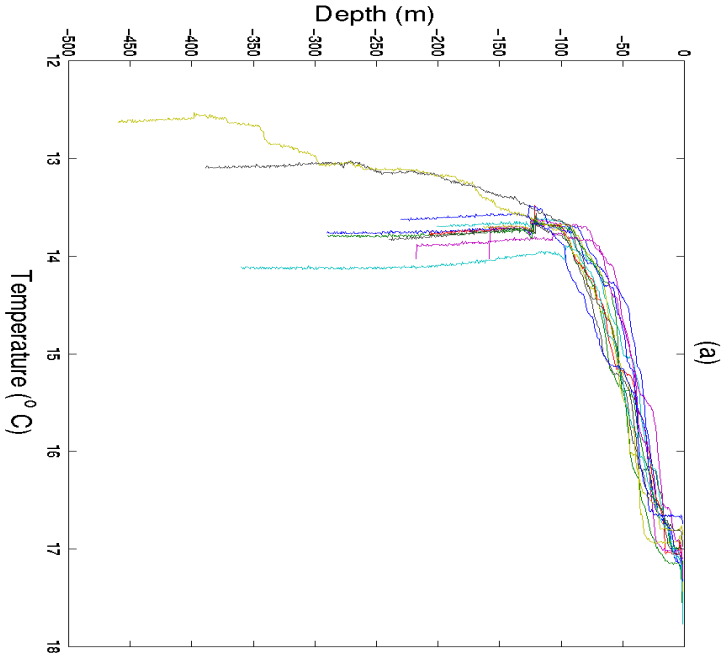


Events 2 and 5: bathymetry and runs





Temperature evolution (XBT)

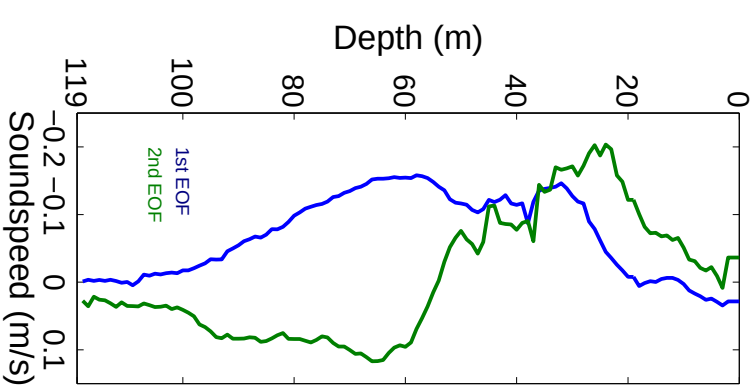
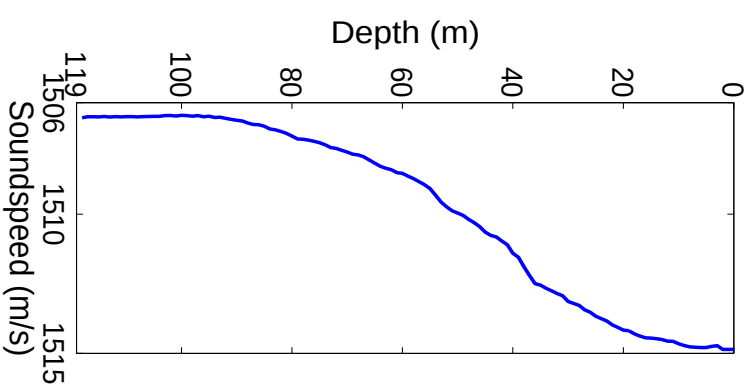




Empirical Orthogonal Functions

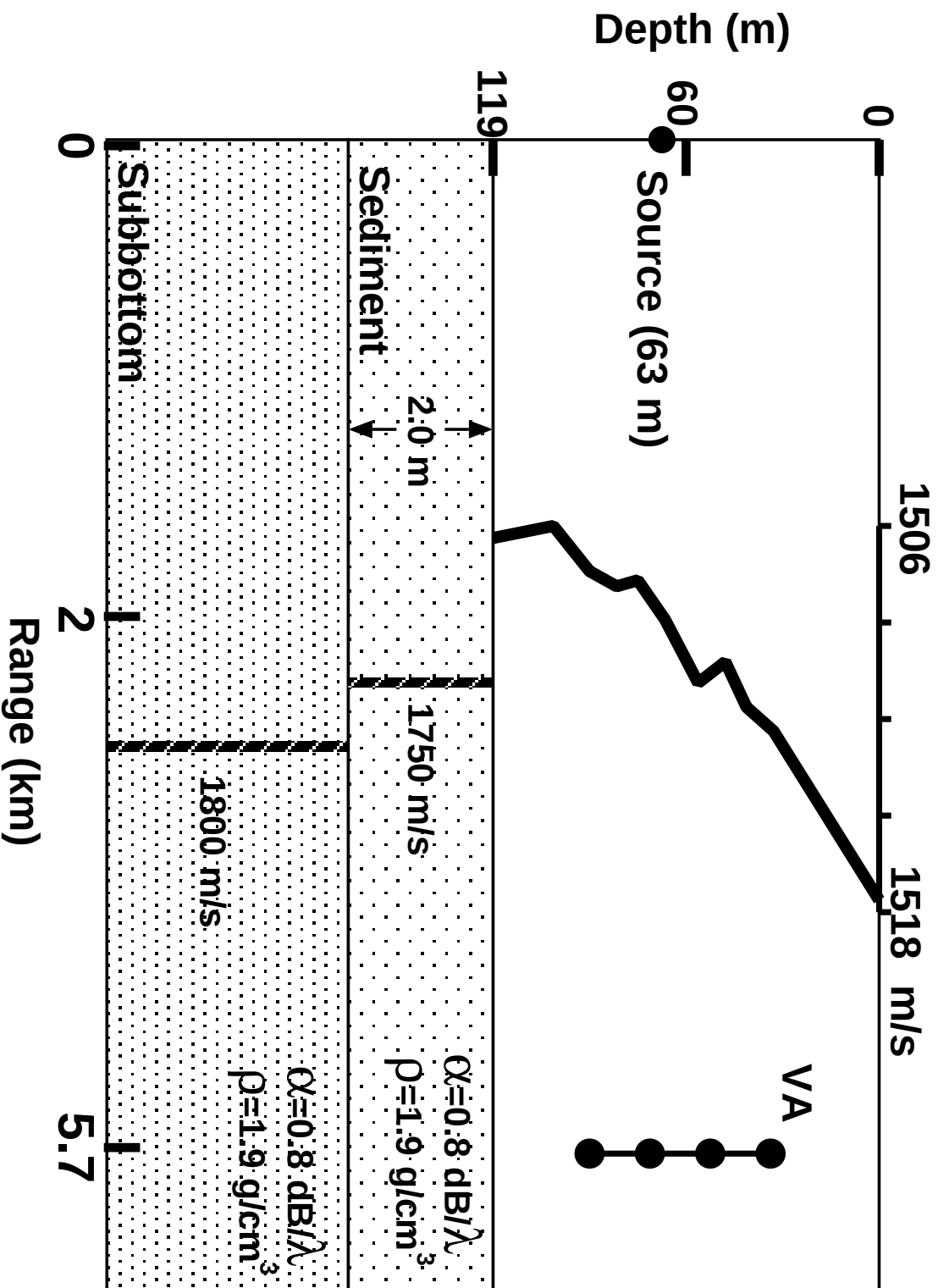
$$\mathbf{c}_{\text{EOF}} = \hat{\mathbf{c}} + \sum_{n=1}^N \alpha_n \mathbf{u}_n$$

$$\hat{N} = \min_N \left\{ \frac{\sum_{n=1}^N \lambda_n^2}{\sum_{m=1}^M \lambda_m^2} > 0.8 \right\}$$



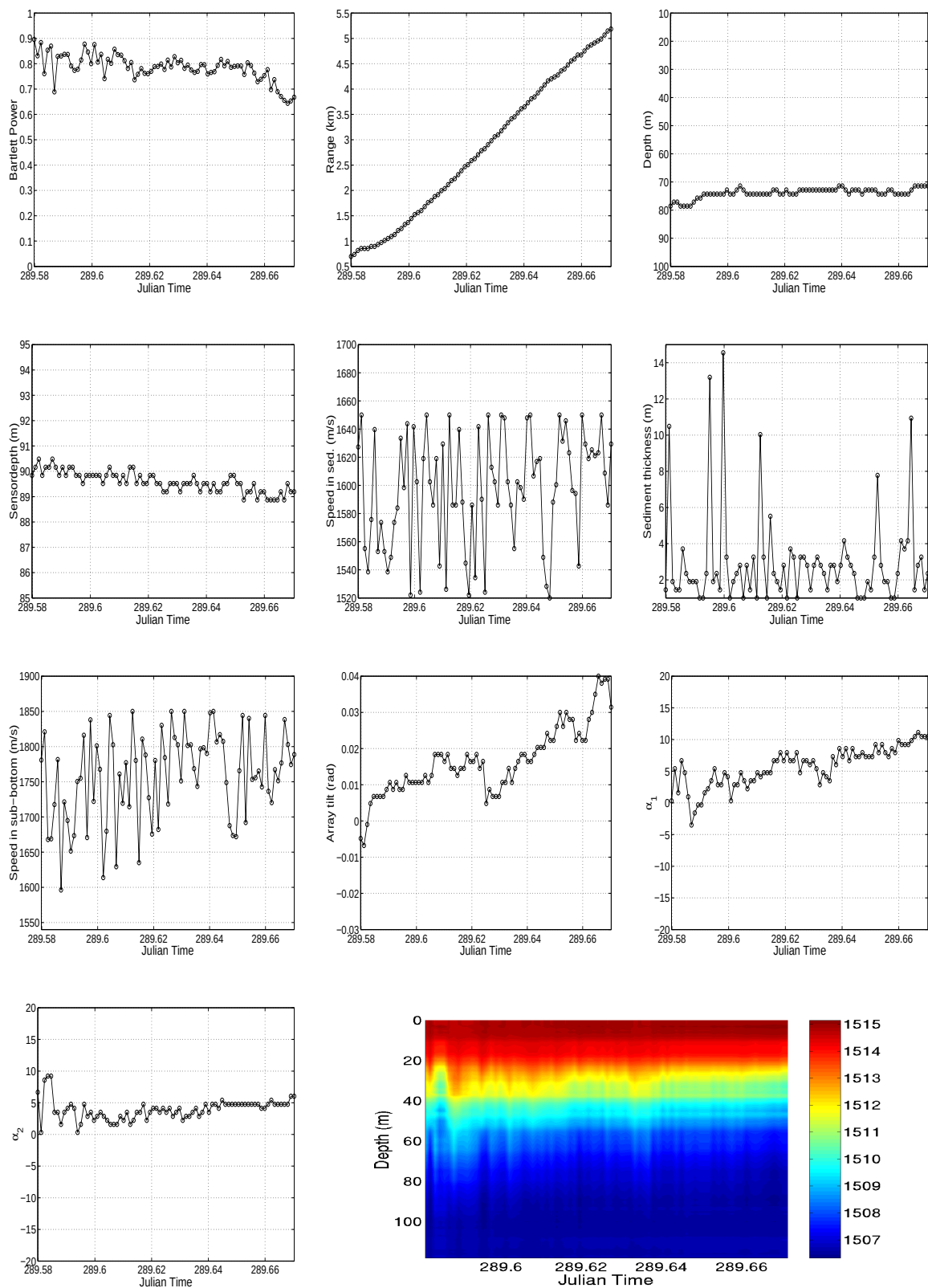


Physical model - NW/NE track

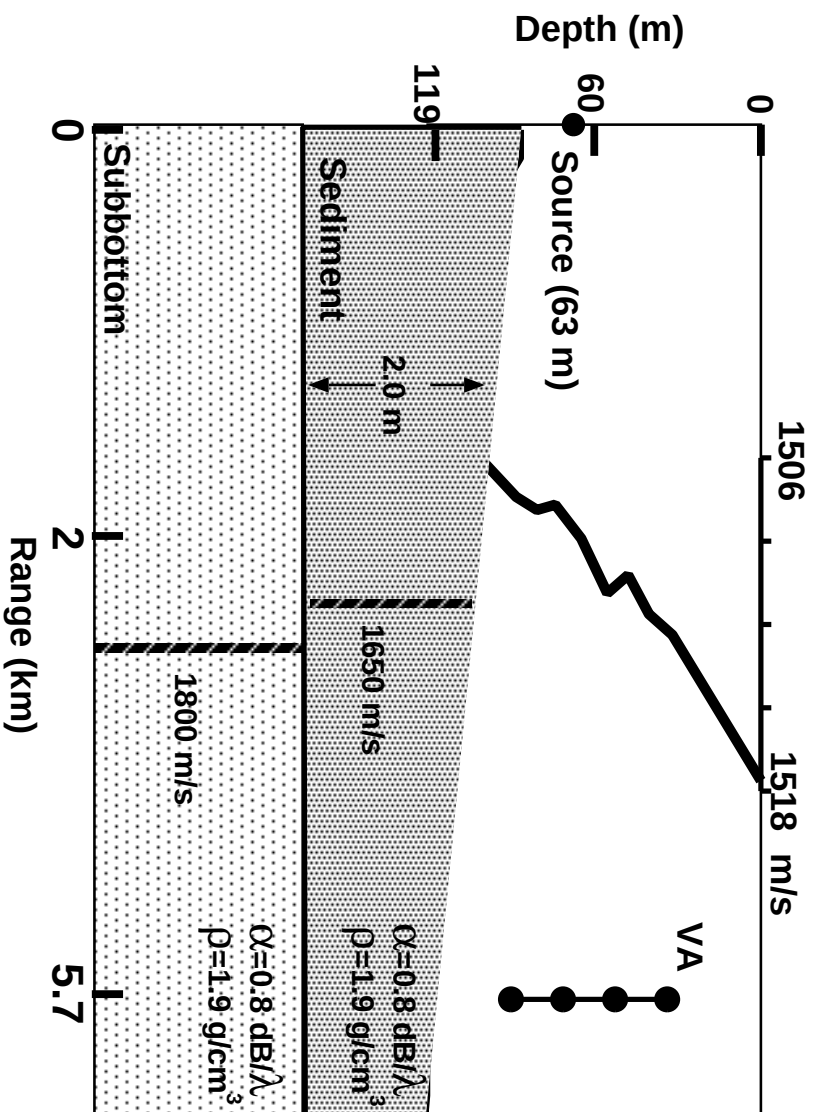




Inversion results for Event 2

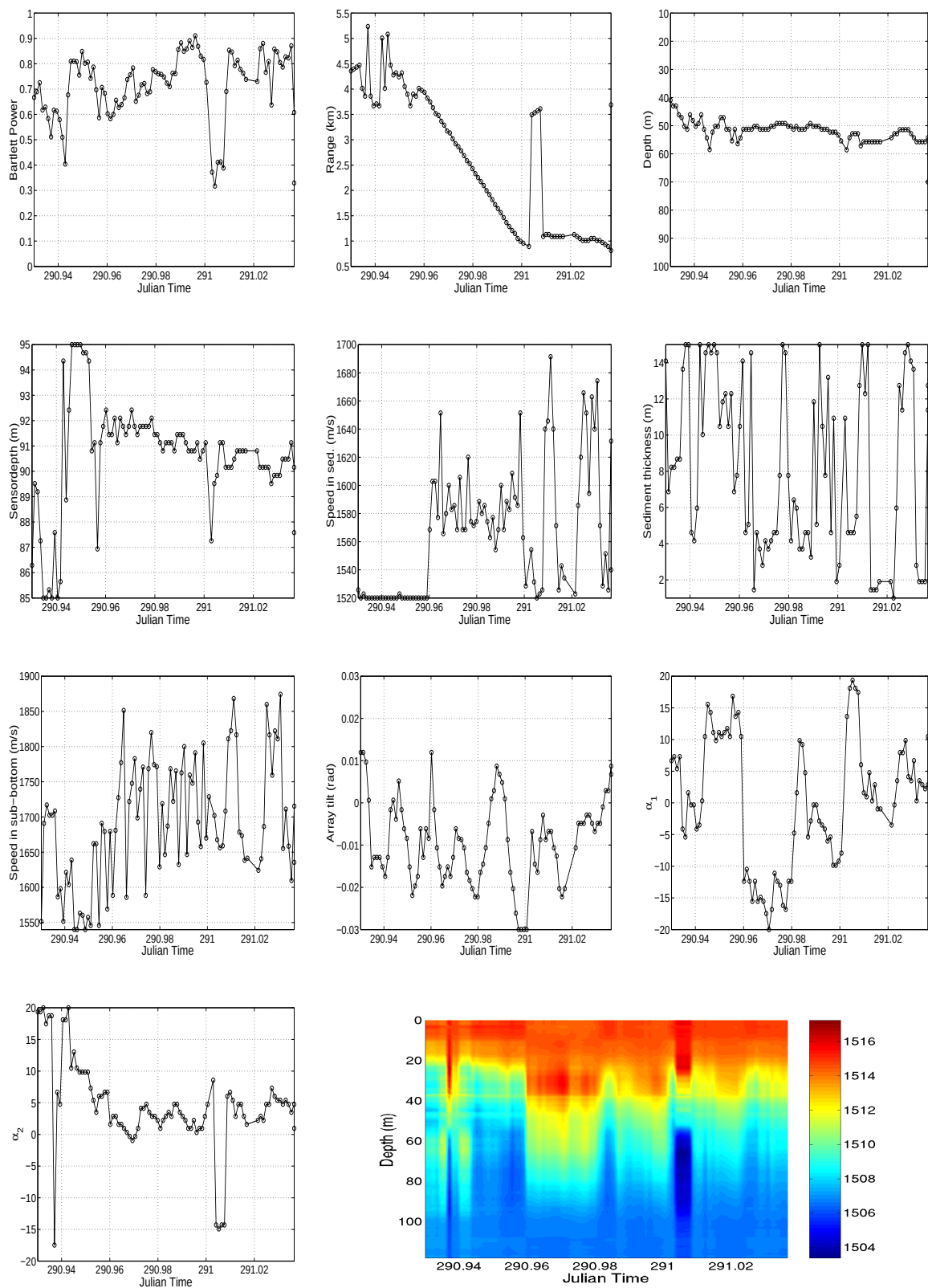


Physical model - NW/NE track



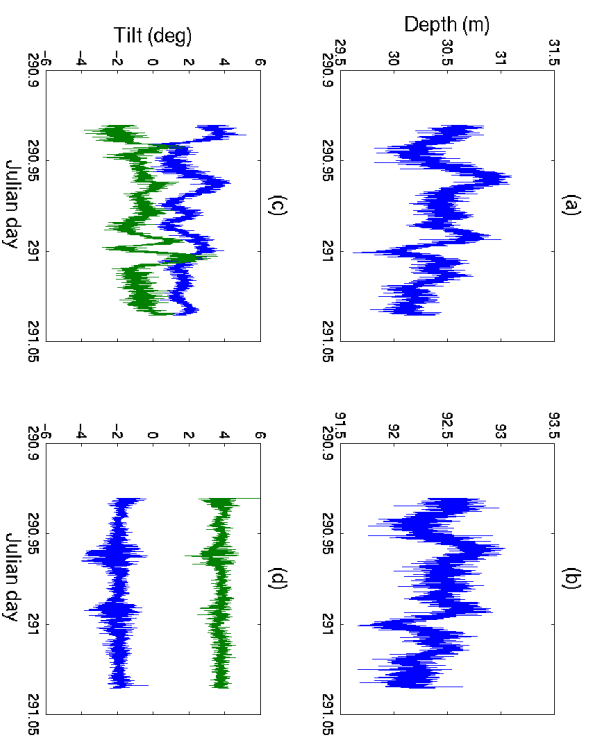
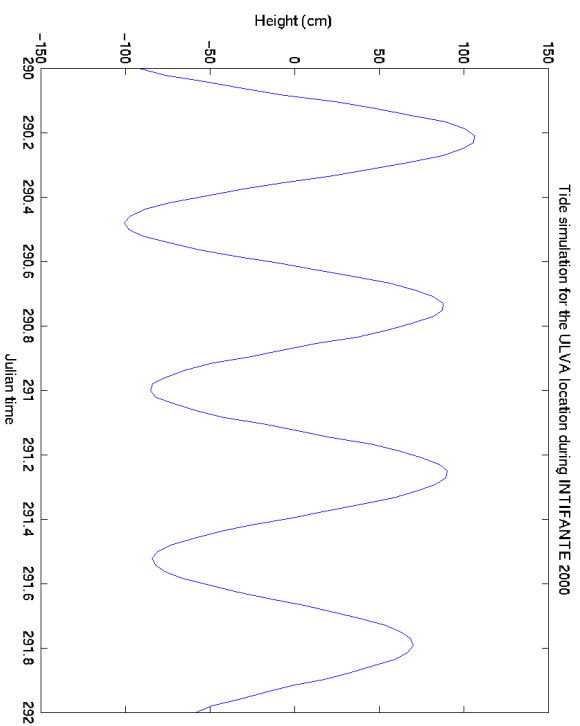


Inversion results for Event 5



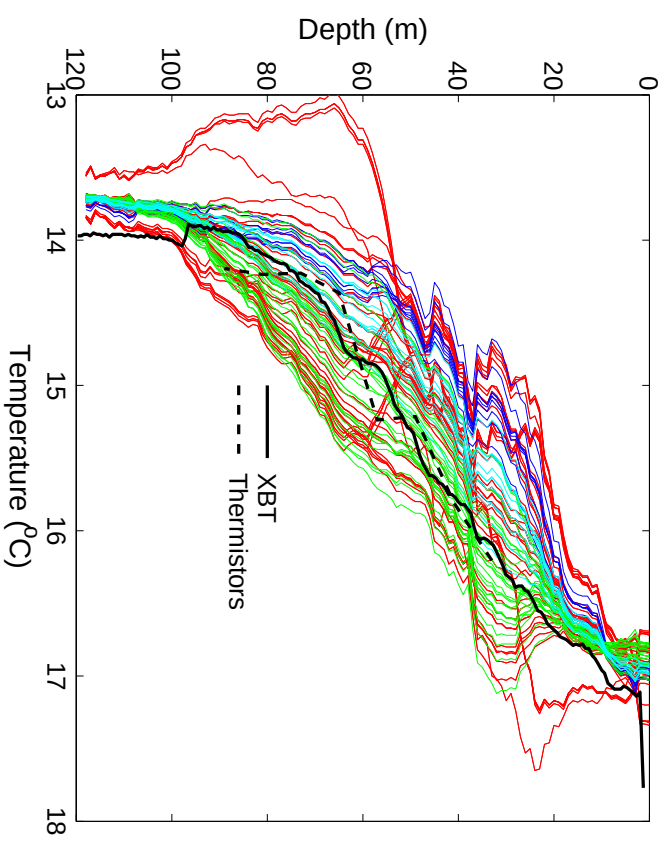
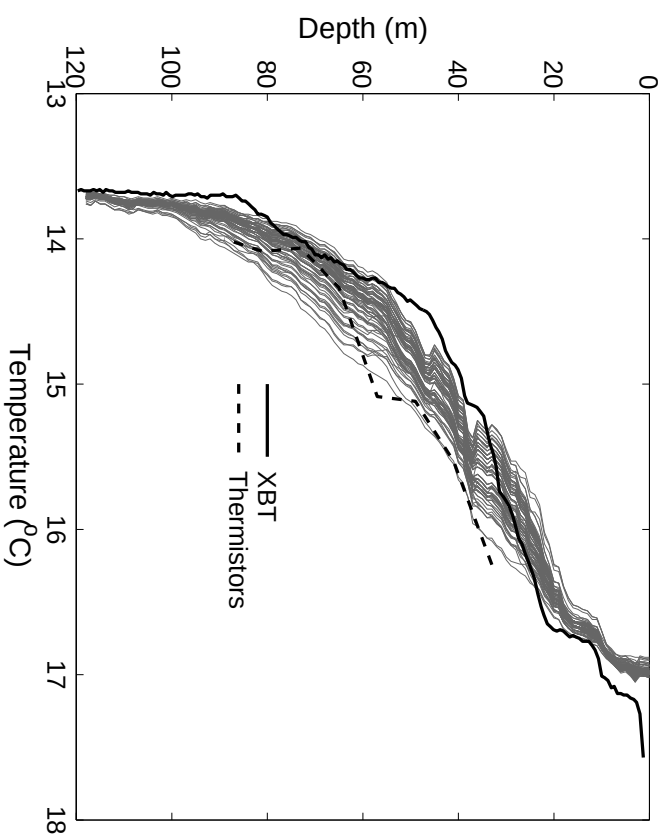


Tide evolution and VA moving





Estimated temperature profiles - Event 2 & 5





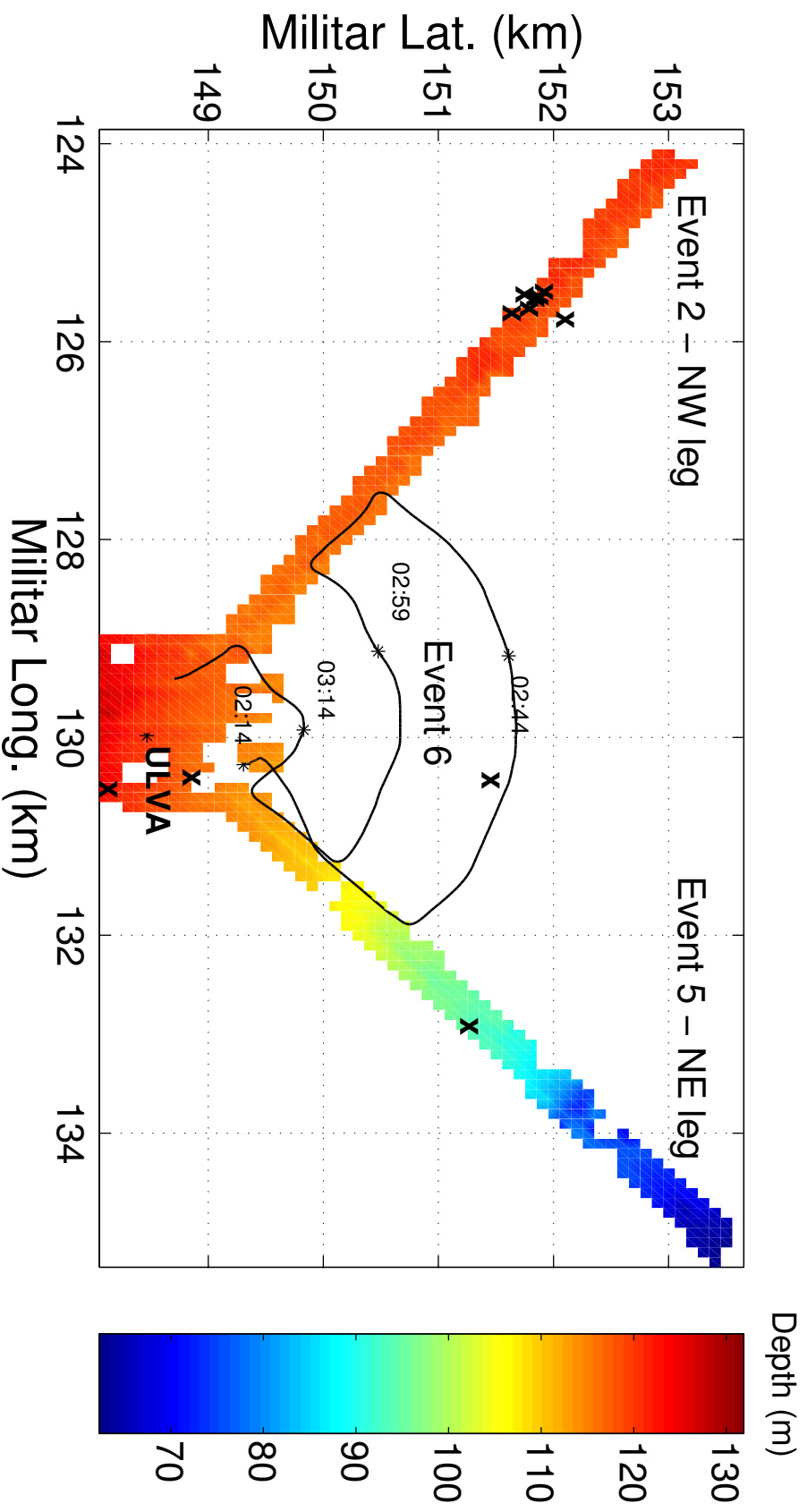
NRP D. Carlos I



Overall length (m)	68
Beam (m)	13
Gross displa. (ton)	2800
Two diesel-electric (HP)	800
Max speed (kn)	11
Crew	34
Scientific	15

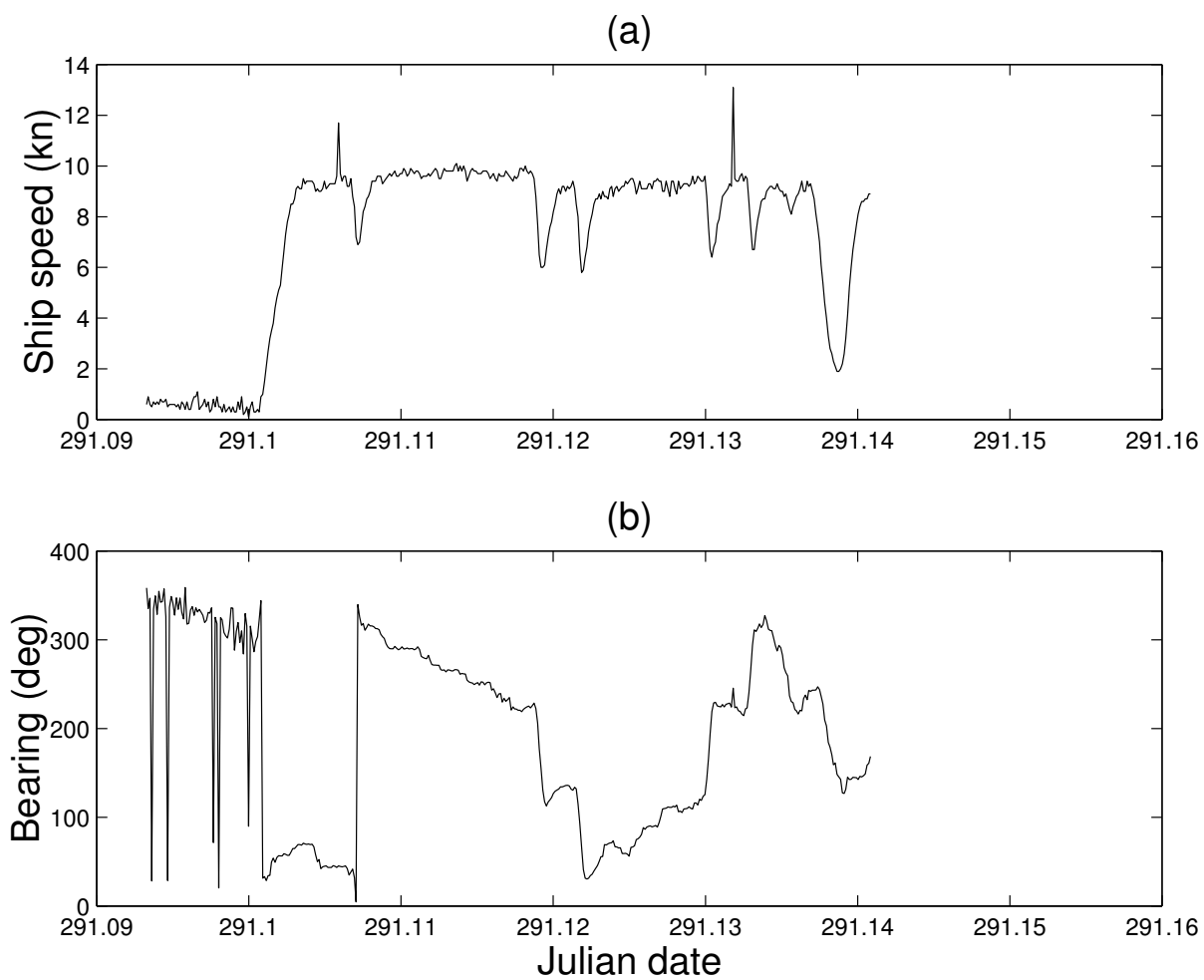


Event 6: bathymetry and source run



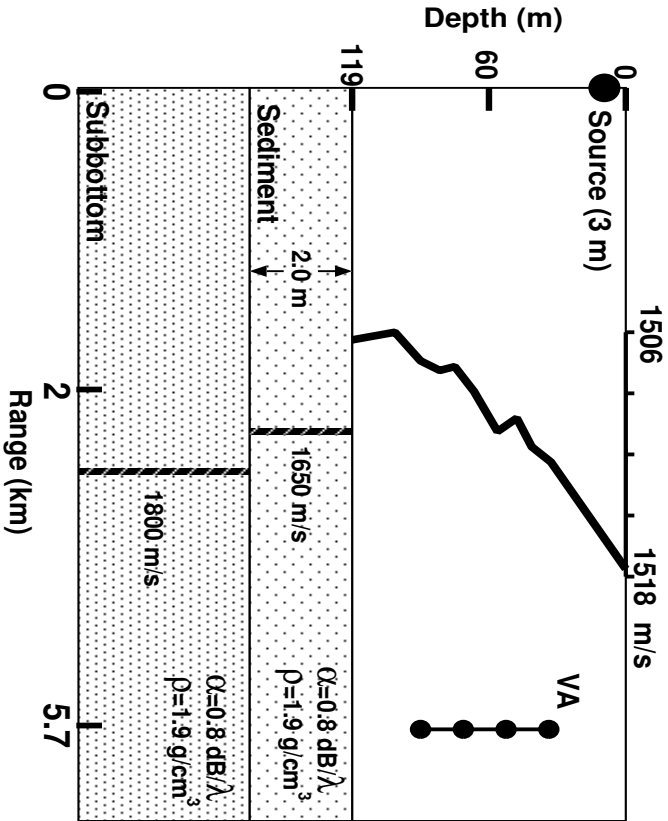


NRP D. Carlos I speed and heading





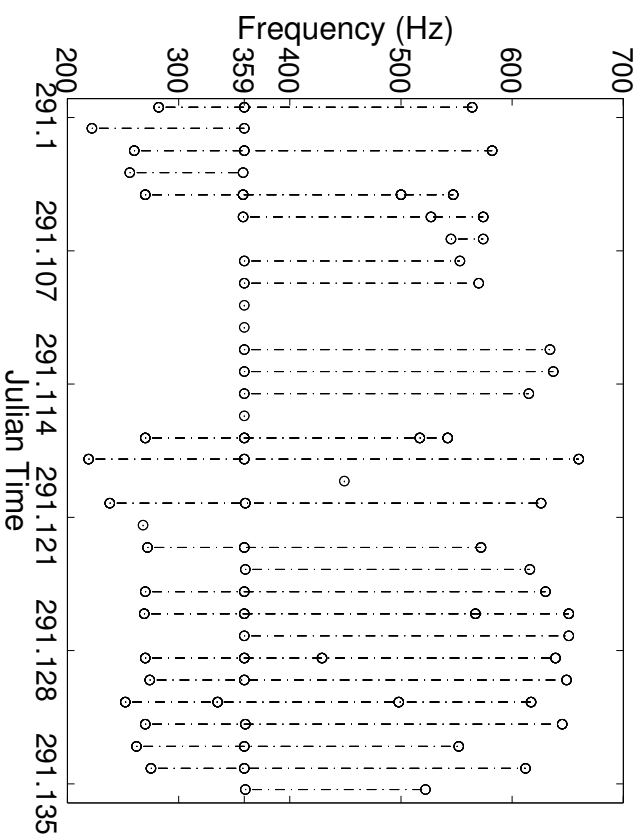
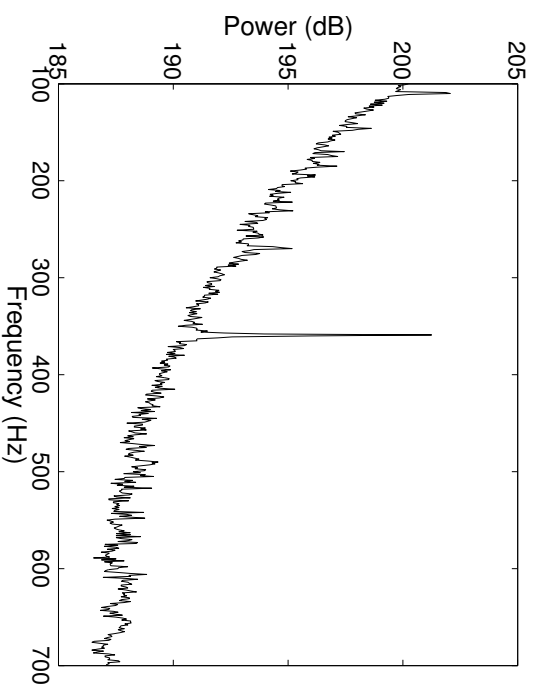
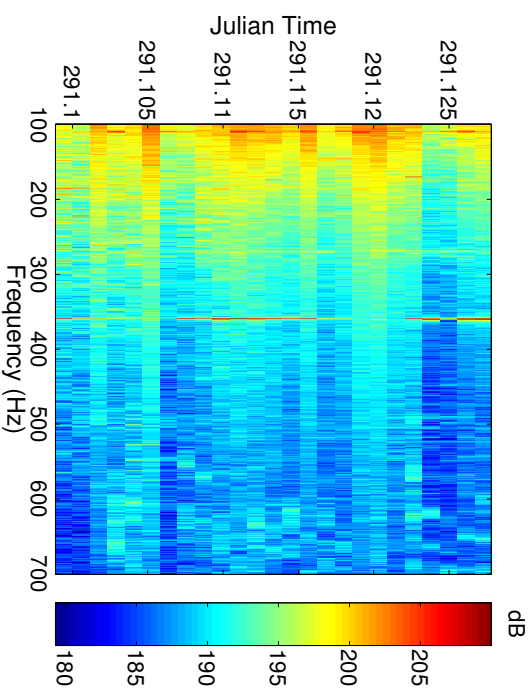
Physical model and search parameters



Symbol	Unit	Search	int.	Steps
α_1	m/s	-20	20	64
α_2	m/s	-20	20	64
sr	km	0.5	3.5	64
sd	m	1	10	32
rd	m	85	95	32
θ	rad	-0.03	0.03	32

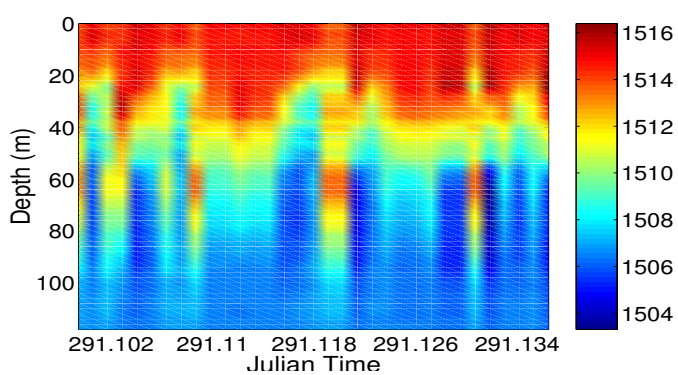
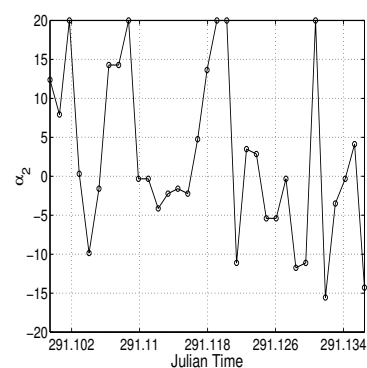
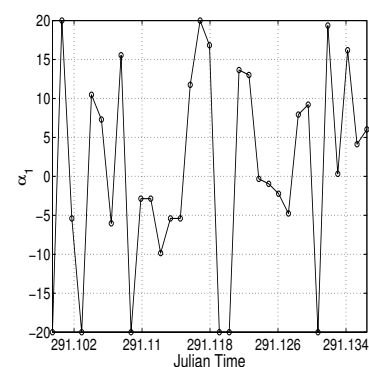
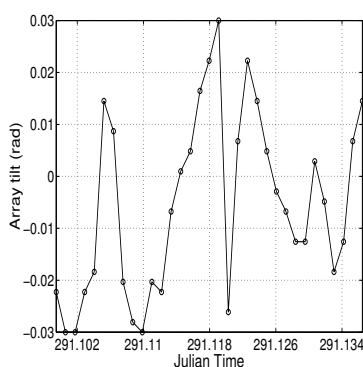
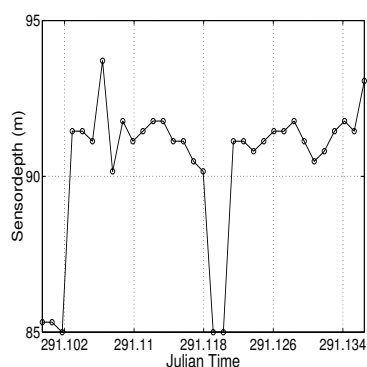
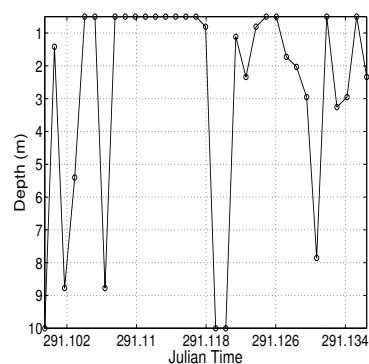
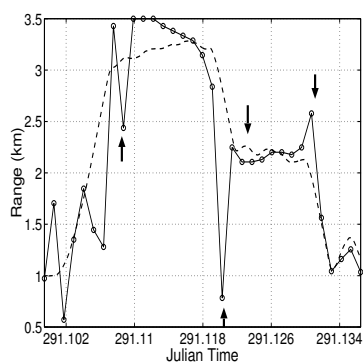
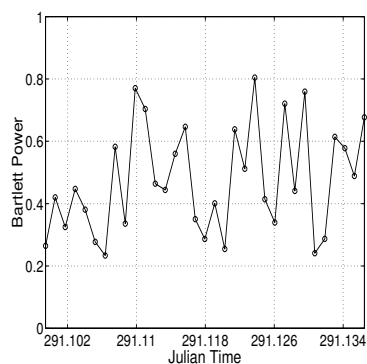


NRP D. Carlos I radiated noise





Inversion results for Event 6





Theoretical background

- Linear broadband data model:

$$\begin{aligned}\underline{Y}(\underline{\theta}_0) &= [\underline{Y}^T(\omega_1) \cdots \underline{Y}^T(\omega_L)]^T \\ &= \mathbf{H}(\underline{\theta}_0)\underline{S} + \underline{U}\end{aligned}$$

- Minimum variance signal estimator:

$$\hat{\underline{S}}(\hat{\underline{\theta}}_0) = [(\mathbf{H}^H(\hat{\underline{\theta}}_0)\mathbf{H}(\hat{\underline{\theta}}_0)]^{-1}\mathbf{H}^H(\hat{\underline{\theta}}_0)\sum_{n=0}^{N-1}\underline{Y}_n(\underline{\theta}_0)$$

- Broadband conventional processor:

$$P_{\text{inc}}(\underline{\theta}) = \frac{\sum_{k=1}^K |\hat{S}(\omega_k)|^2 \underline{H}^H(\omega_k, \underline{\theta}) \hat{\mathbf{C}}_{YY}(\omega_k, \omega_k) \underline{H}(\omega_k, \underline{\theta})}{\|\mathbf{H}(\underline{\theta})\underline{S}\|^2}$$



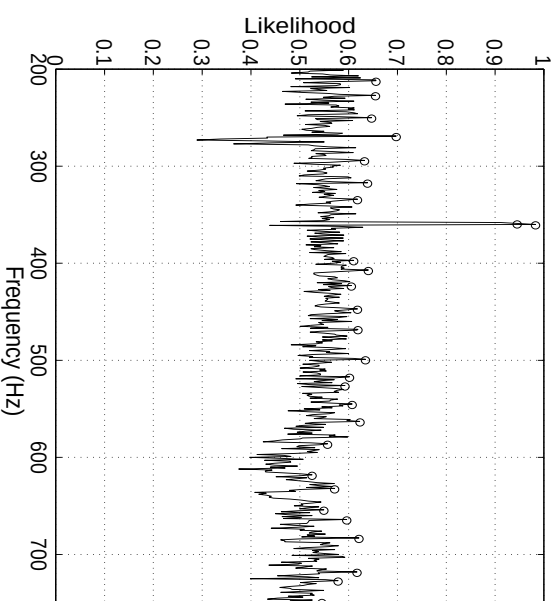
Frequency selection

- Variance at the k^{th} hydrophone:

$$V(\omega, k) = \frac{1}{T} \int_0^T [Y(\omega, t, k) - \mu_Y(\omega, k)]^2 dt,$$

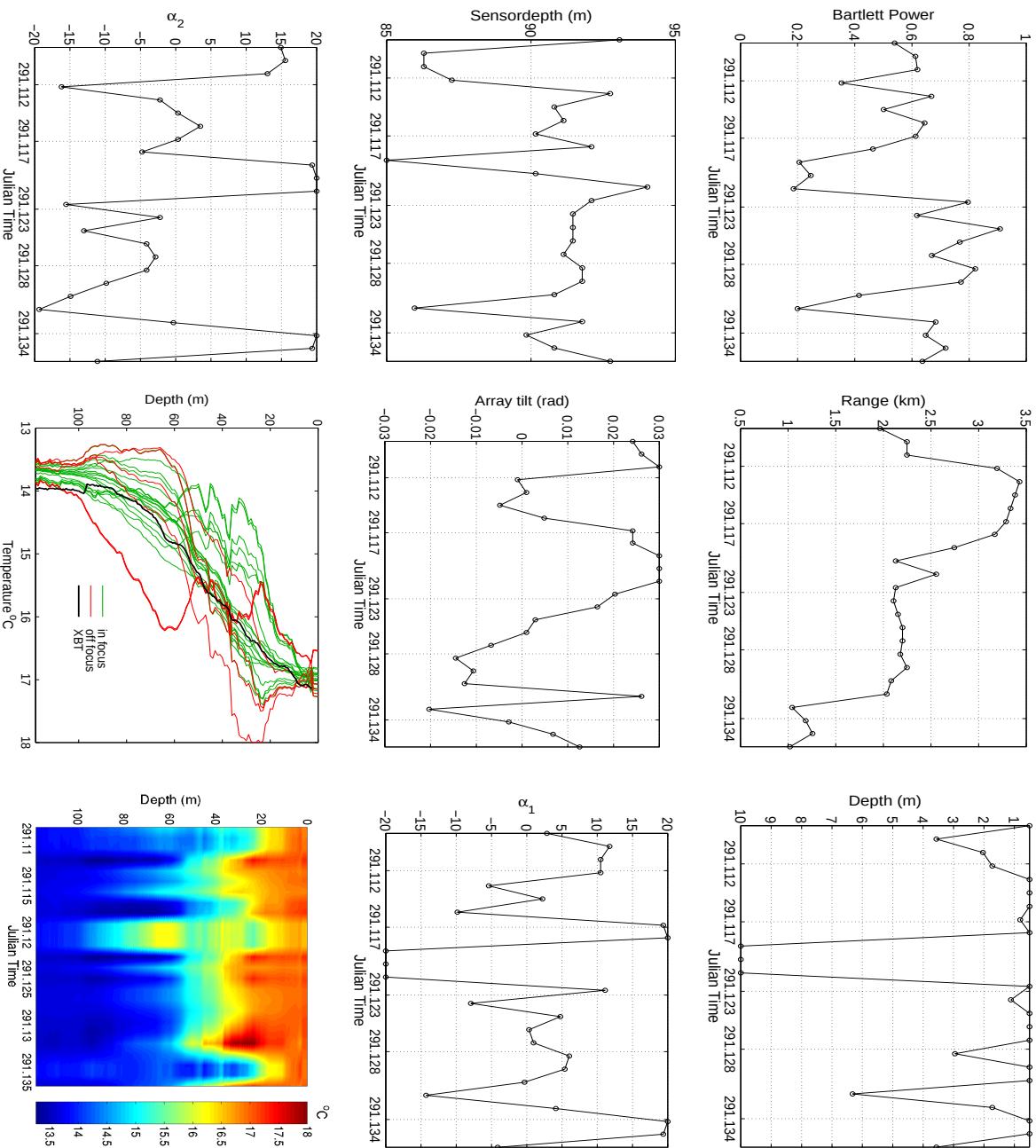
- Likelihood measure:

$$v(\omega) = \frac{K}{\sum_{k=1}^K V(\omega, k)}$$



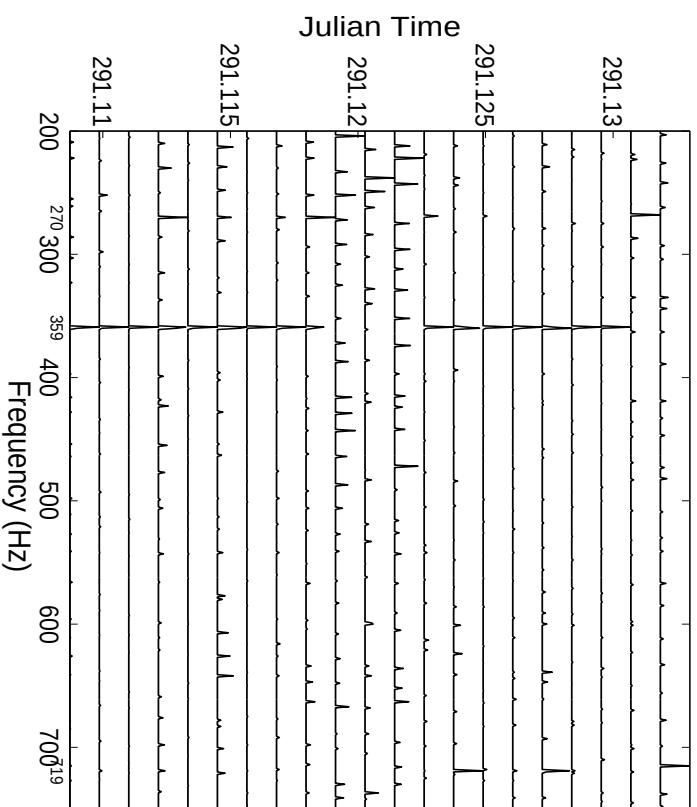


Event 6: Inversion results





Event 6: Ship power spectrum estimation





Summary

This is a preliminary test for ship noise tomography in a (assumed) unknown environment.

- strong correlation between ship speed/emitted power and accurate source tracking
 - when in focus geometrical and environmental parameter assume credible values
- more extensive data for oceanographic features observation
- enhanced search of ship noise spectral components