Blind Ocean Acoustic Tomography

presentation at the ENEA Workshop on

Ocean Acoustic Tomography: results and perspectives

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Santa Teresa, Lerici, Itália

by

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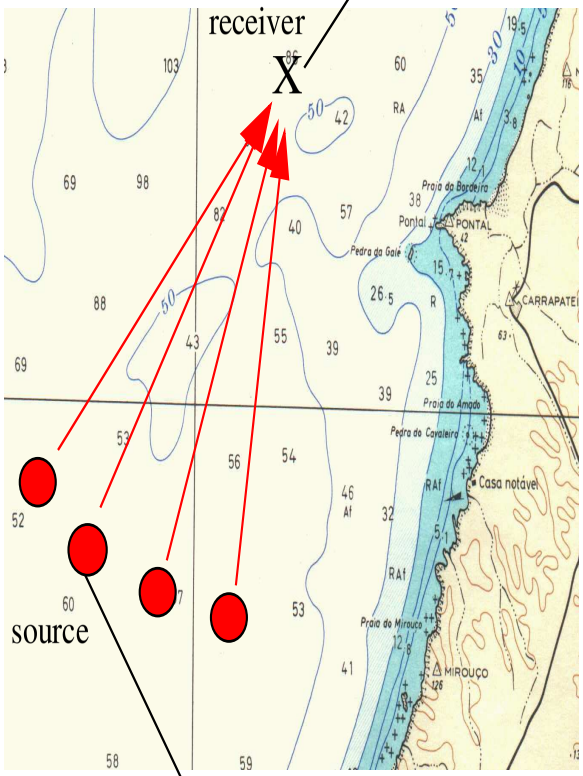
Outline

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

Ocean Acoustic Tomography - synoptic

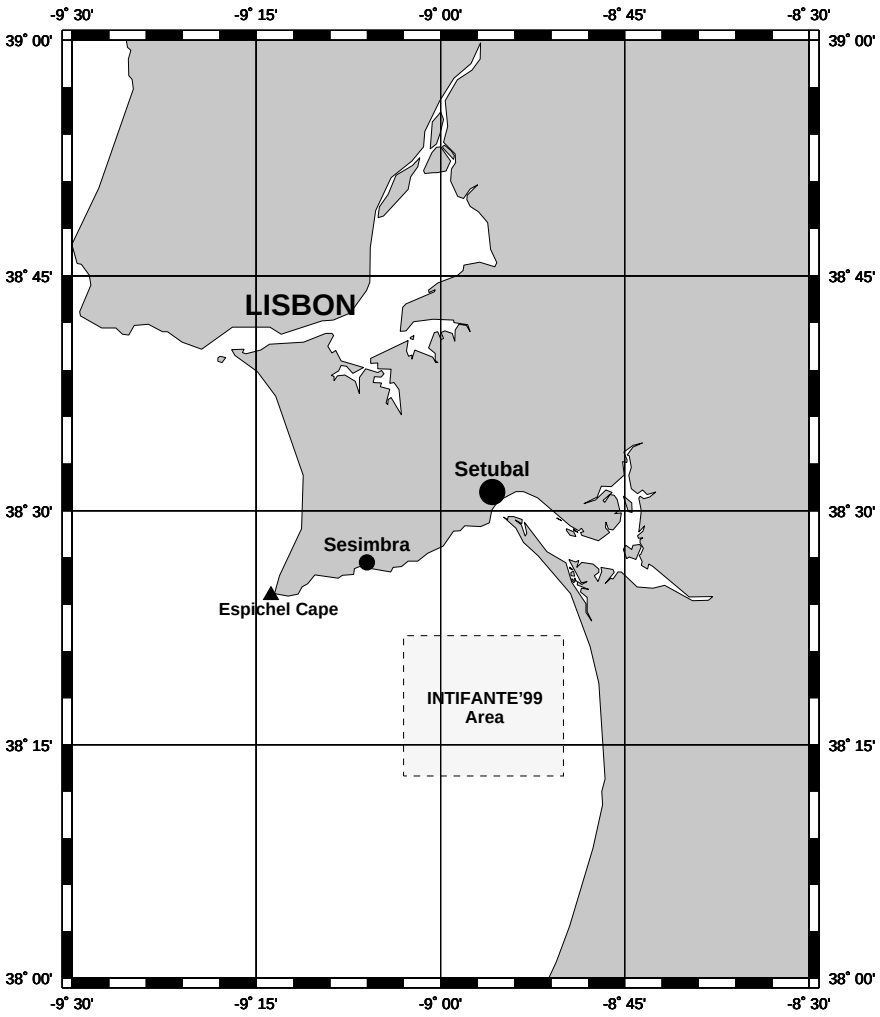


Motivation

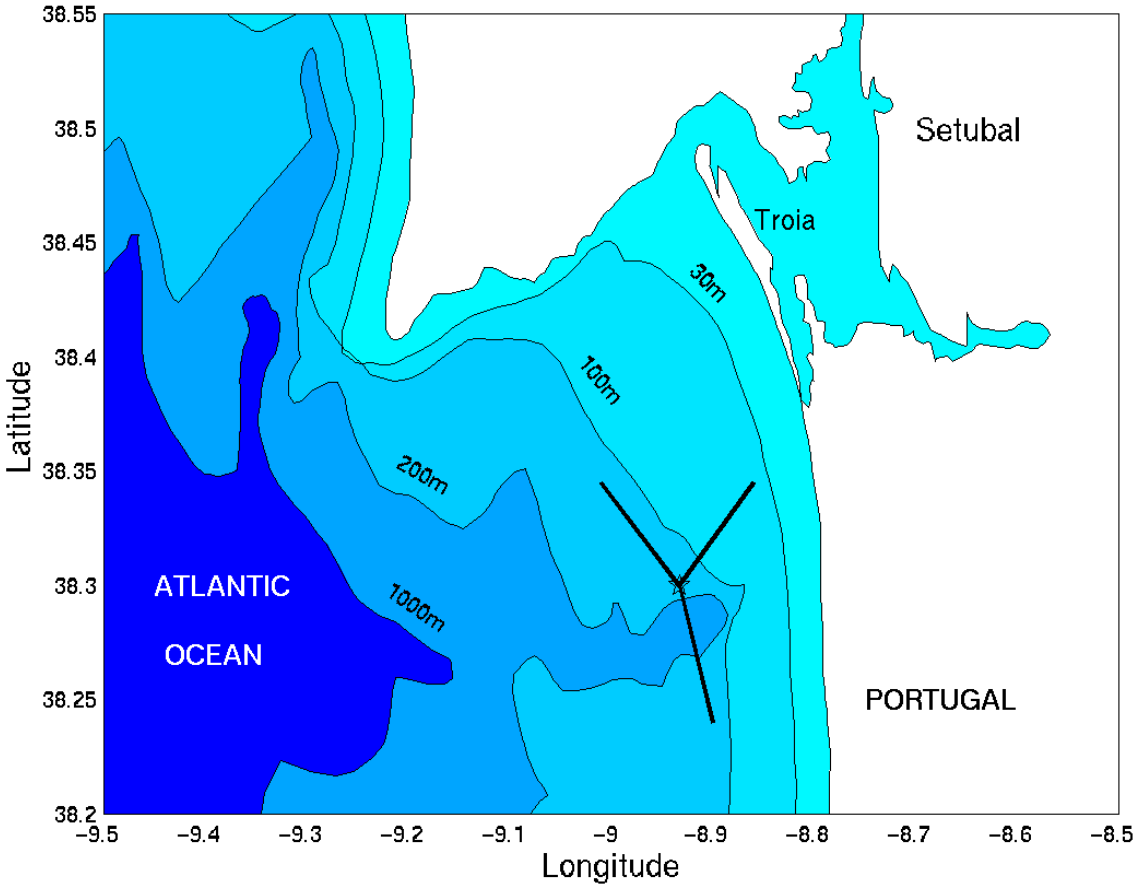
$\Rightarrow$

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

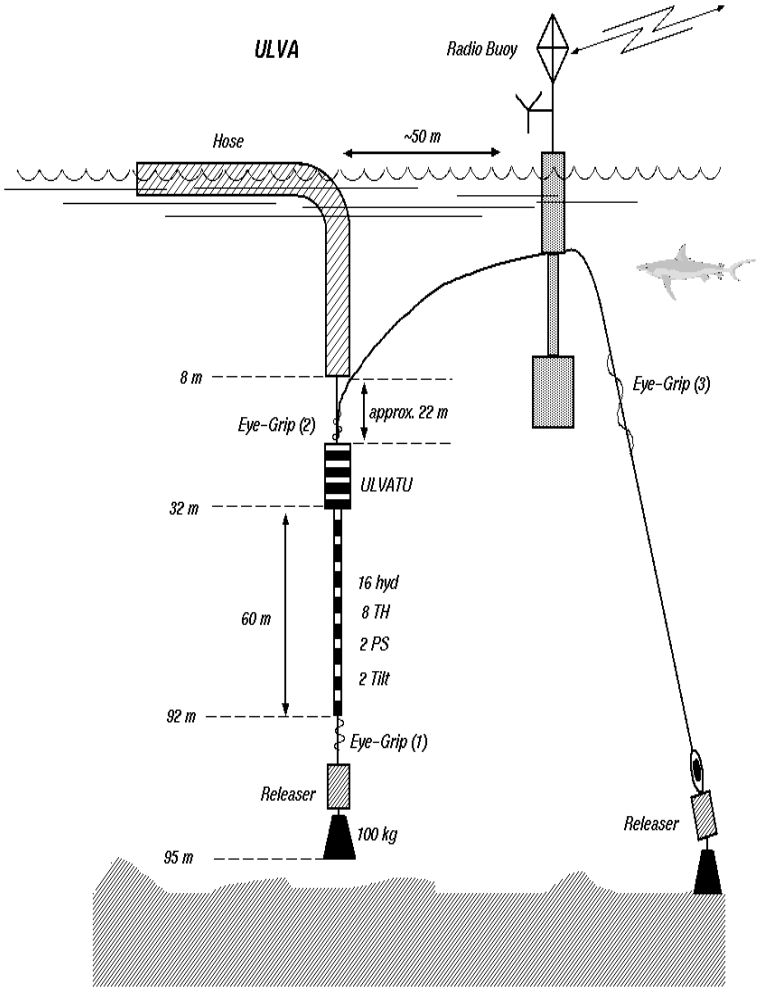
INTIFANTE'00 Experimental Site



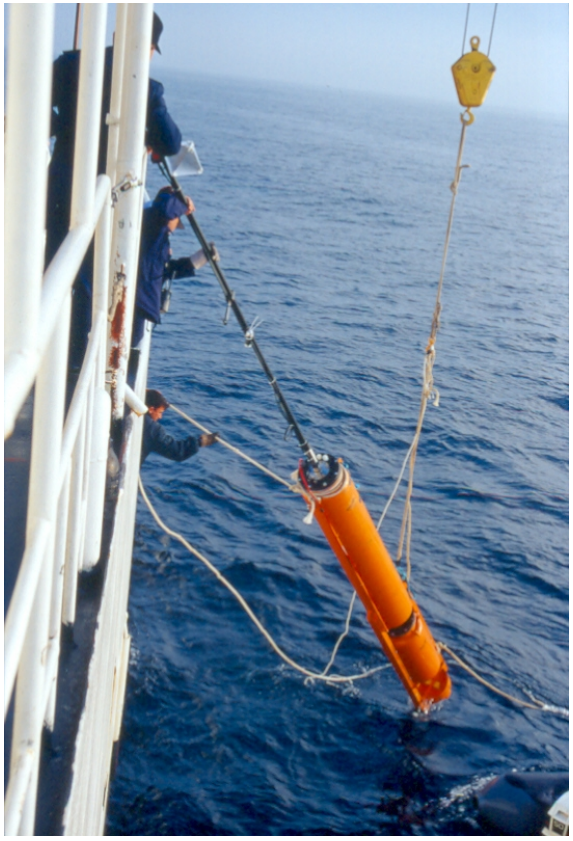
Geometry and Bathymetry

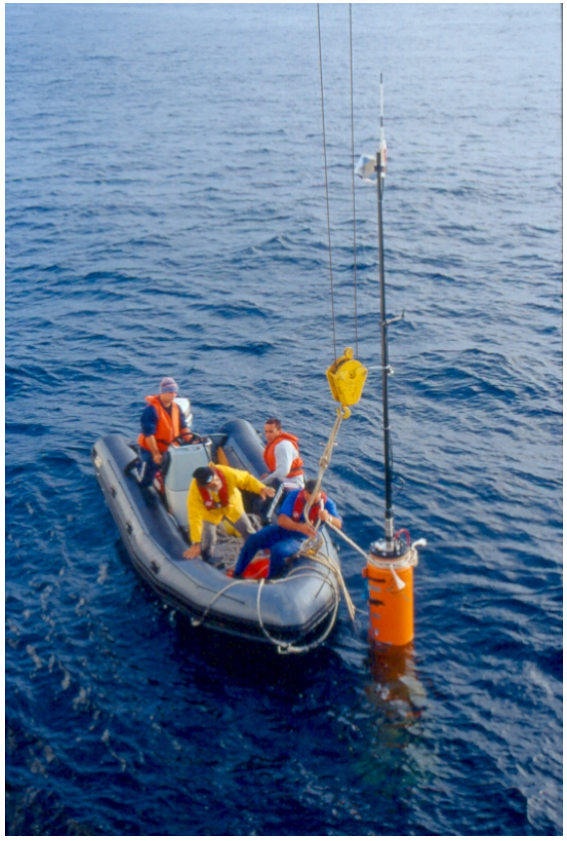


Vertical Line Array



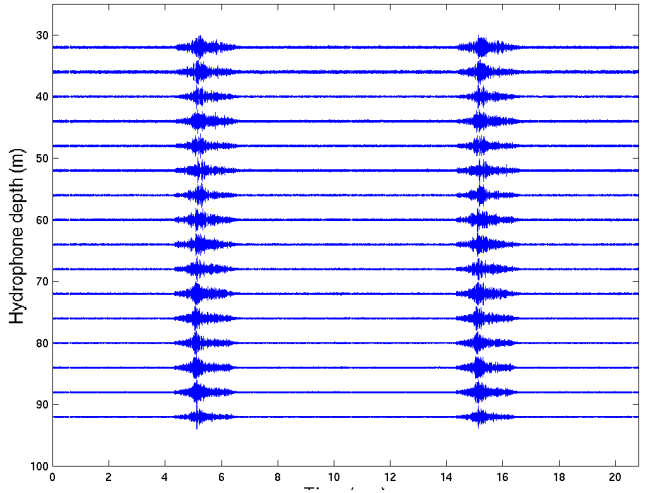
Radio Buoy: deployment and setup

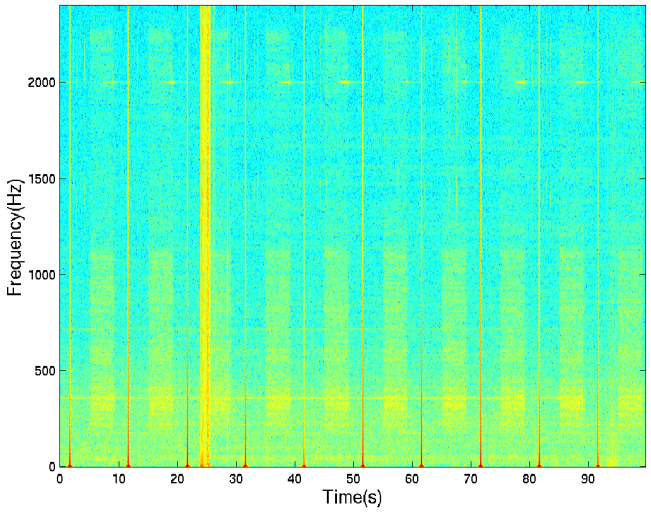




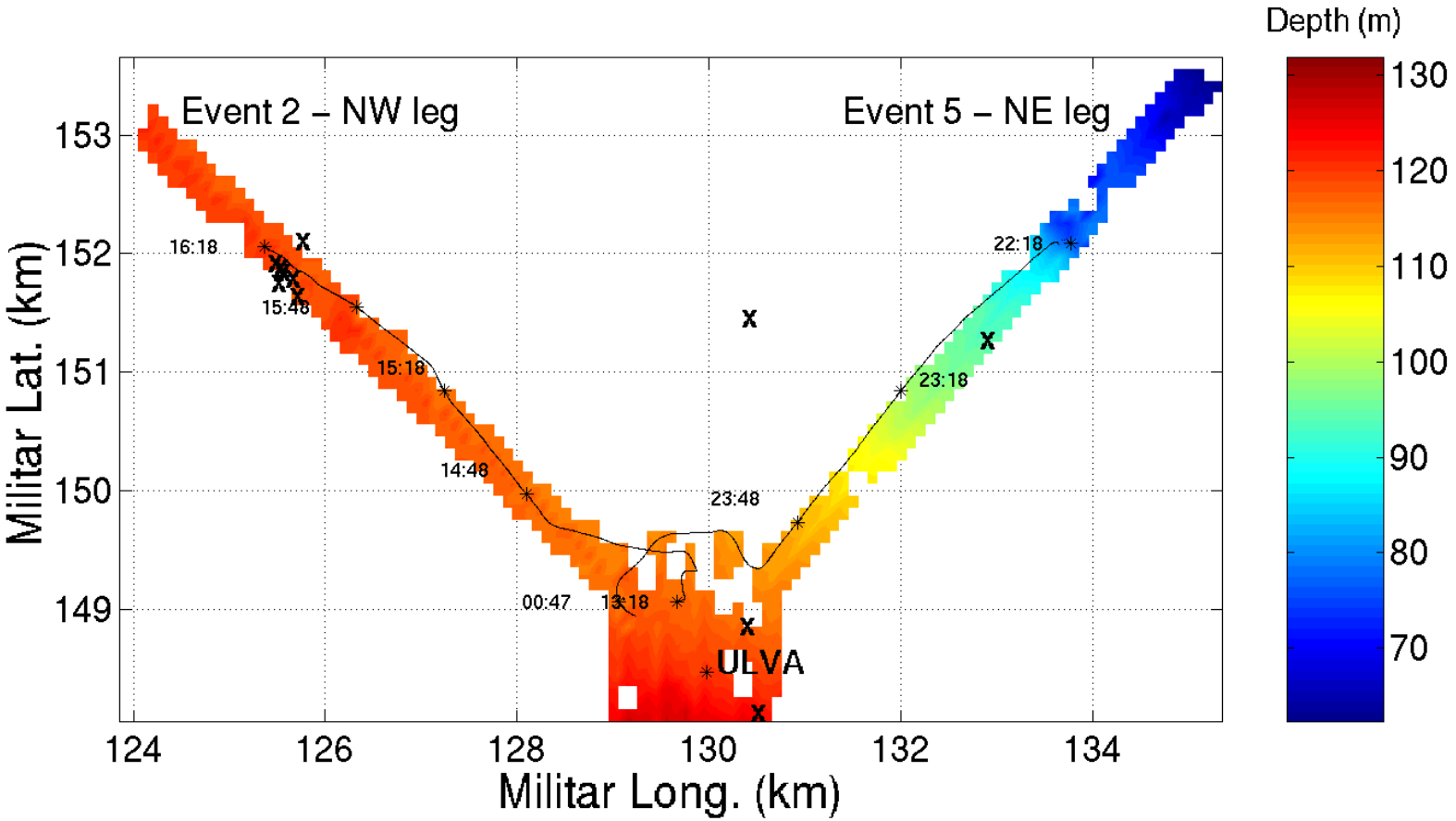
Recovering the Telemetry Unit

Sound source and emitted signals

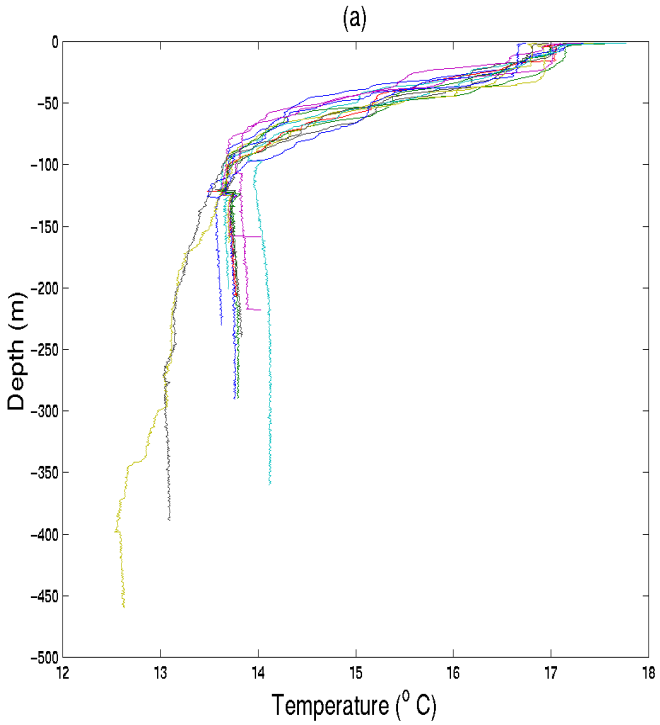


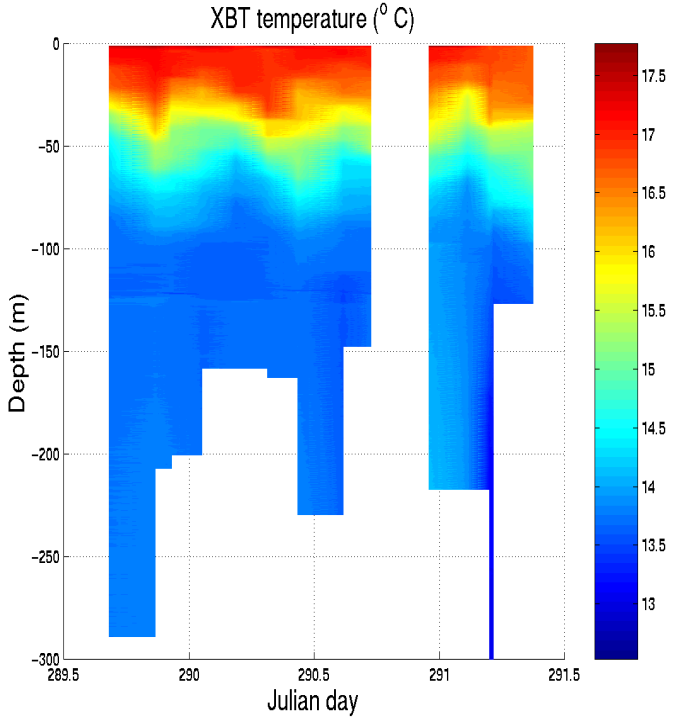


Events 2 and 5: bathymetry and runs



Temperature evolution (XBT)

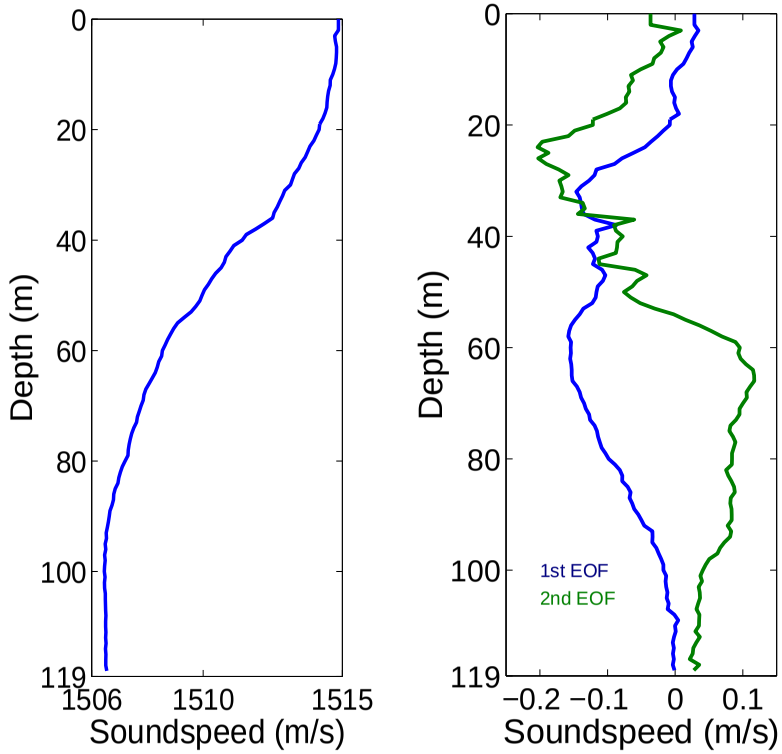




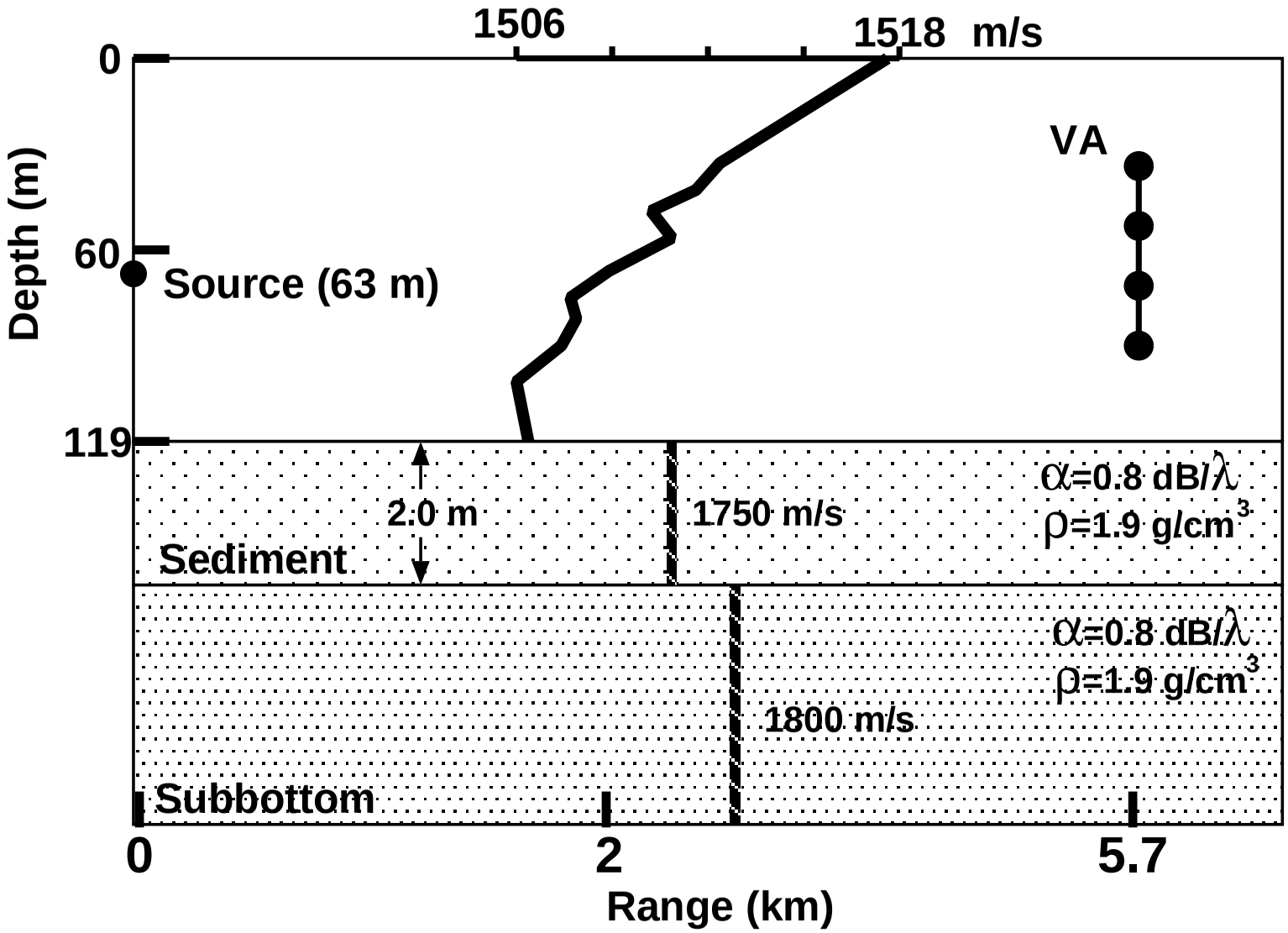
Empirical Orthogonal Functions

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

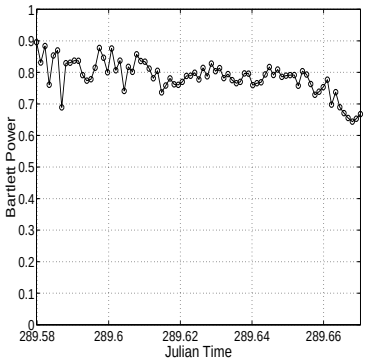
$$\hat{N} = \min_{N} \{ \frac{\Sigma_{n=1}^{N} \lambda_n^2}{\Sigma_{m=1}^{M} \lambda_m^2} > 0.8 \}$$

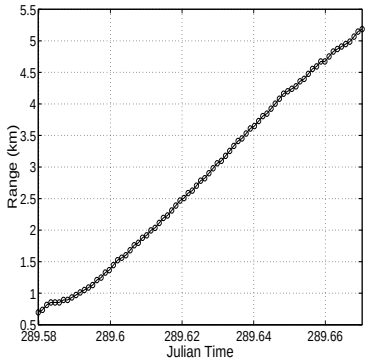


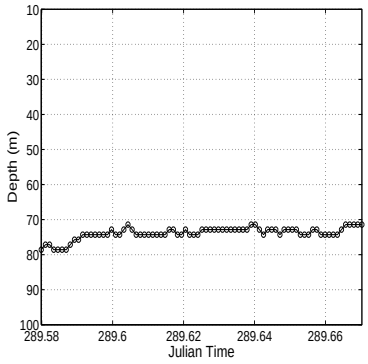
Physical model - NW/NE track

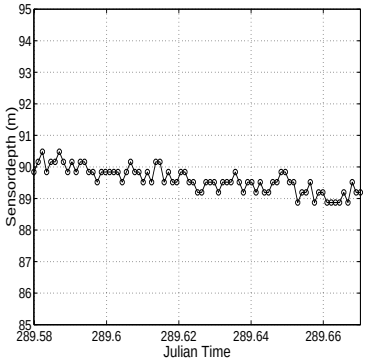


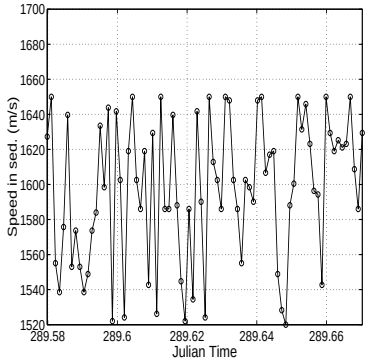
Inversion results for Event 2

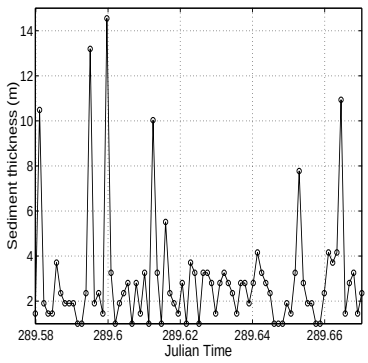


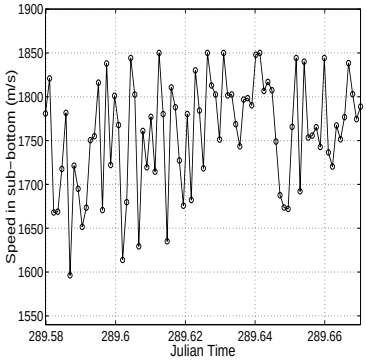


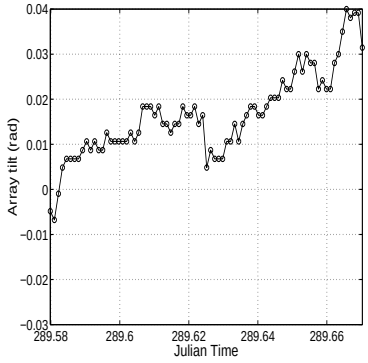


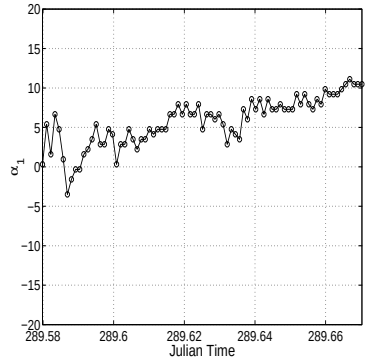


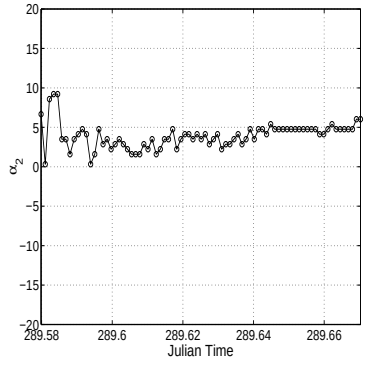


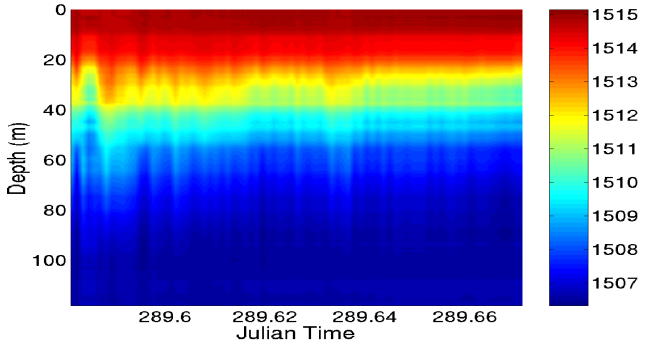




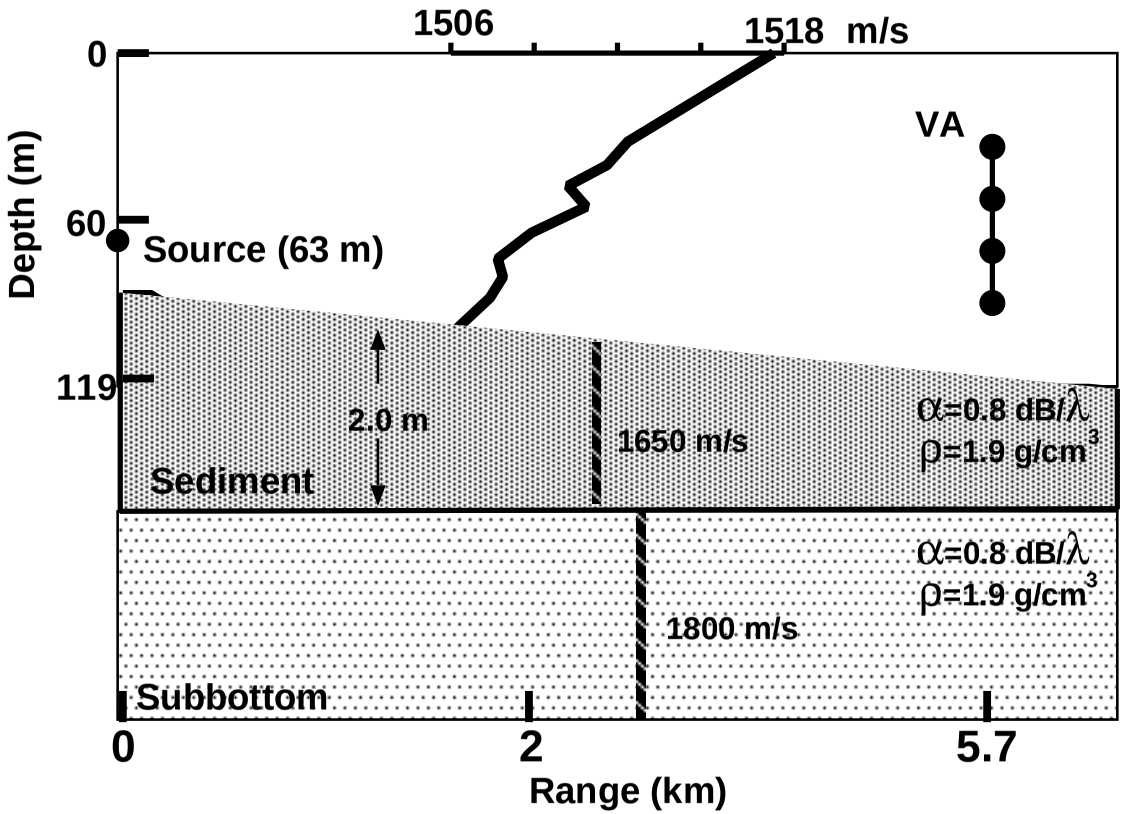




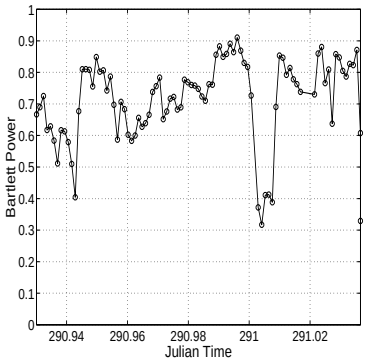


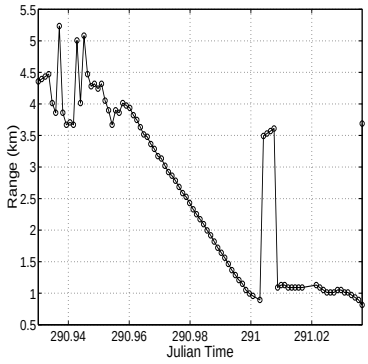


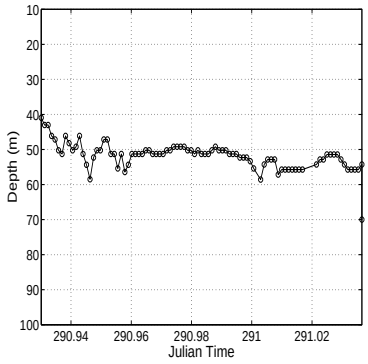
Physical model - NW/NE track

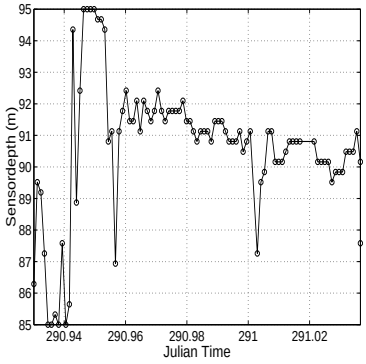


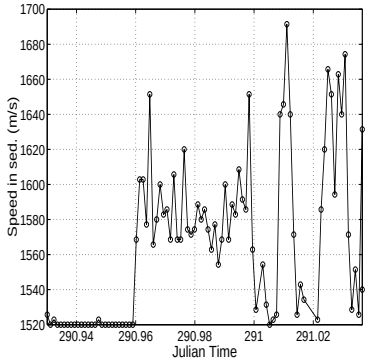
Inversion results for Event 5

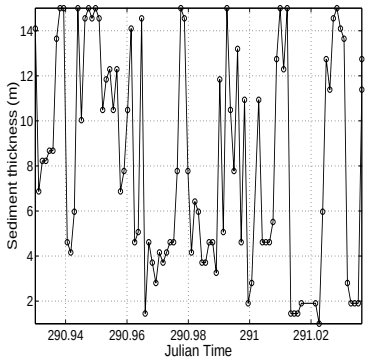


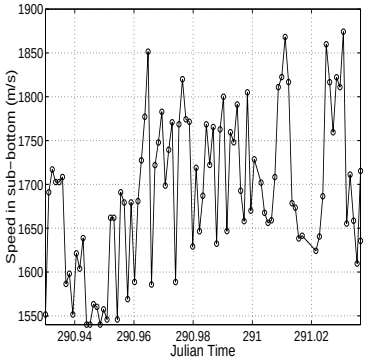


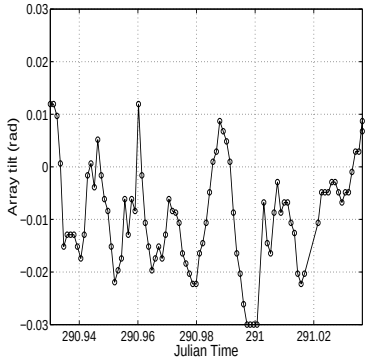


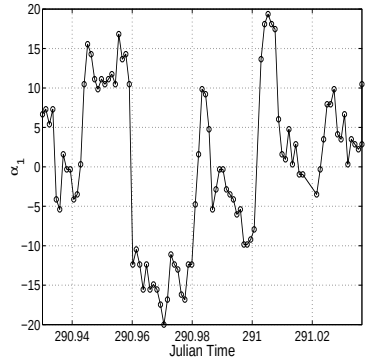


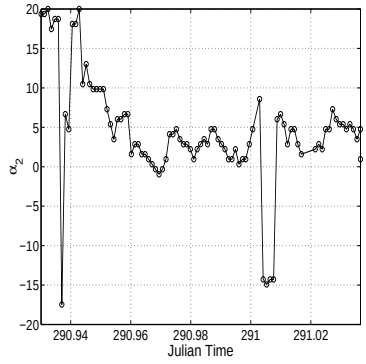


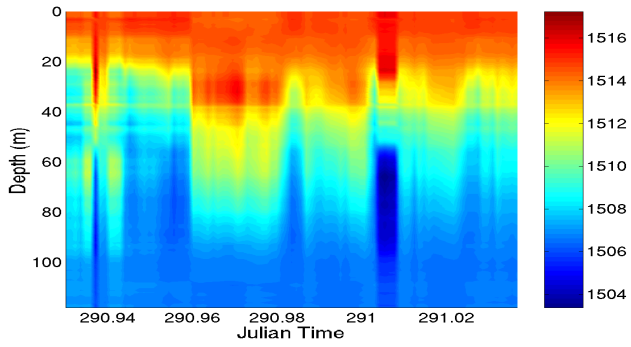




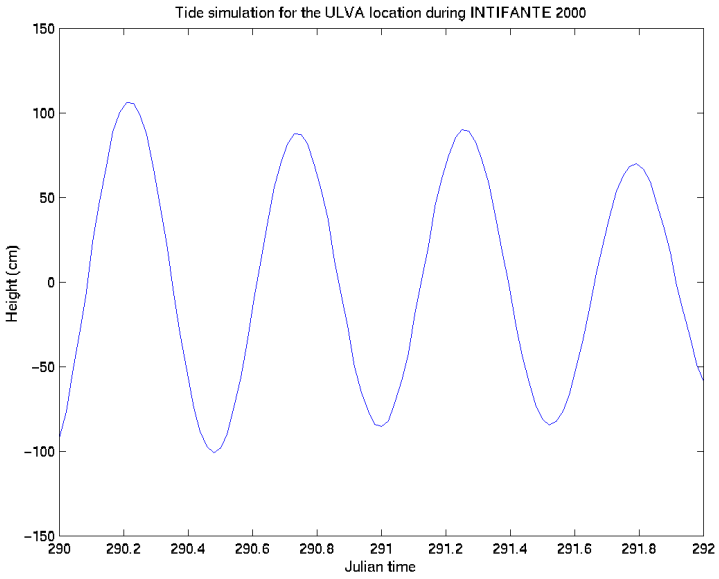


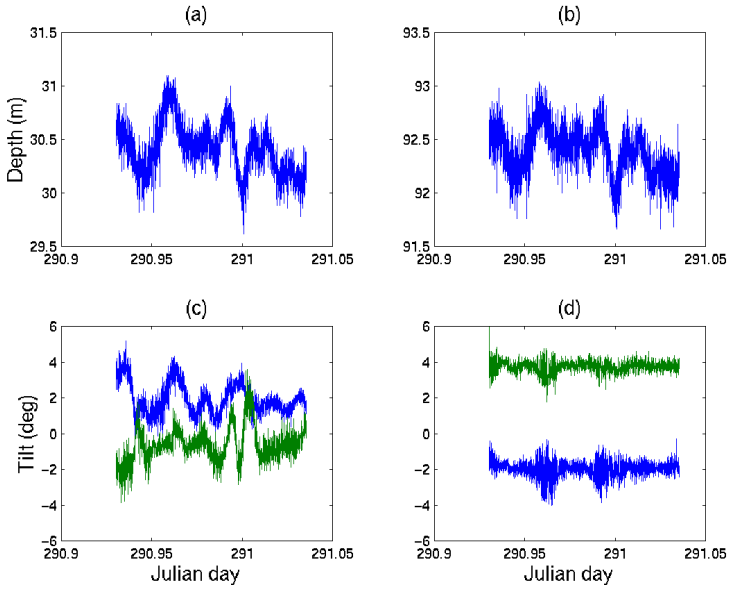




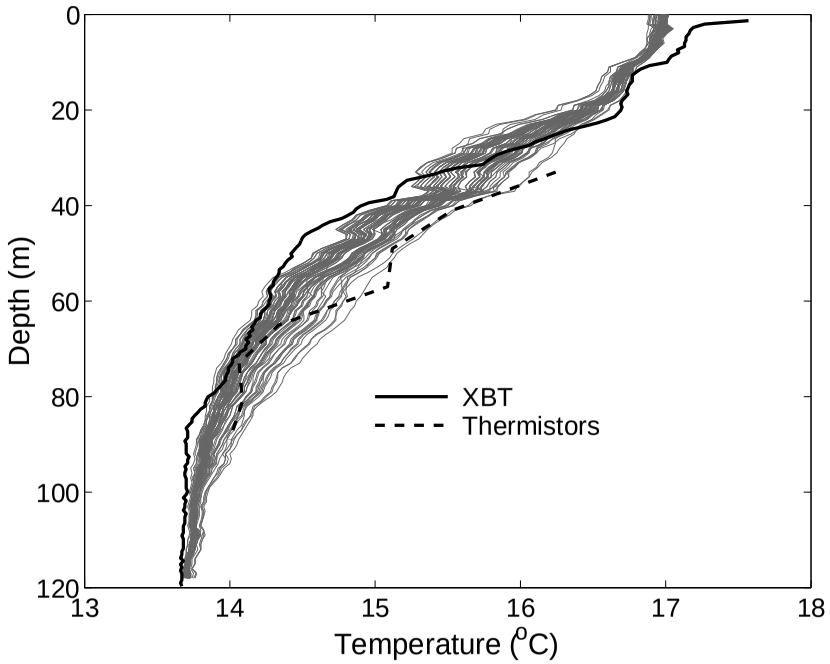


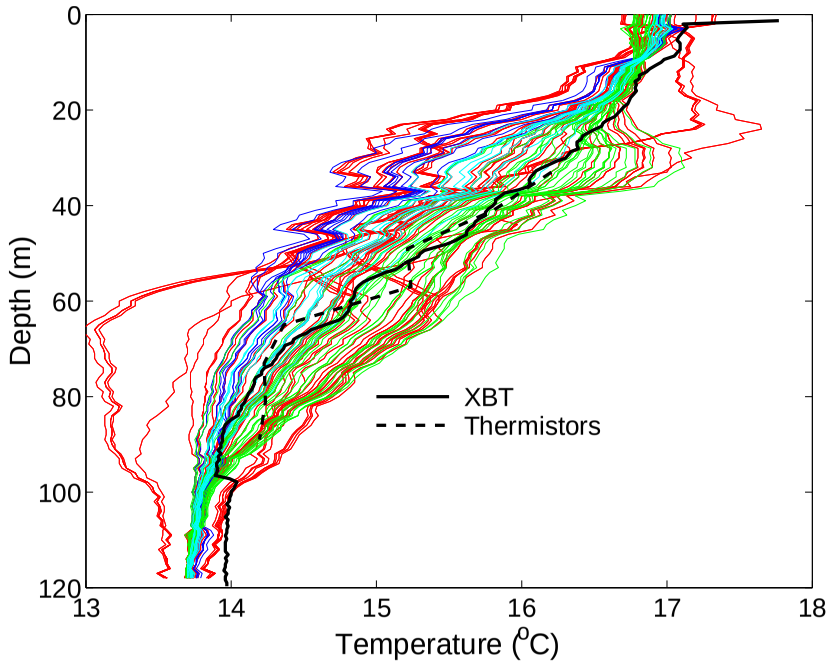
Tide evolution and VA moving





Estimated temperature profiles - Event 2 & 5

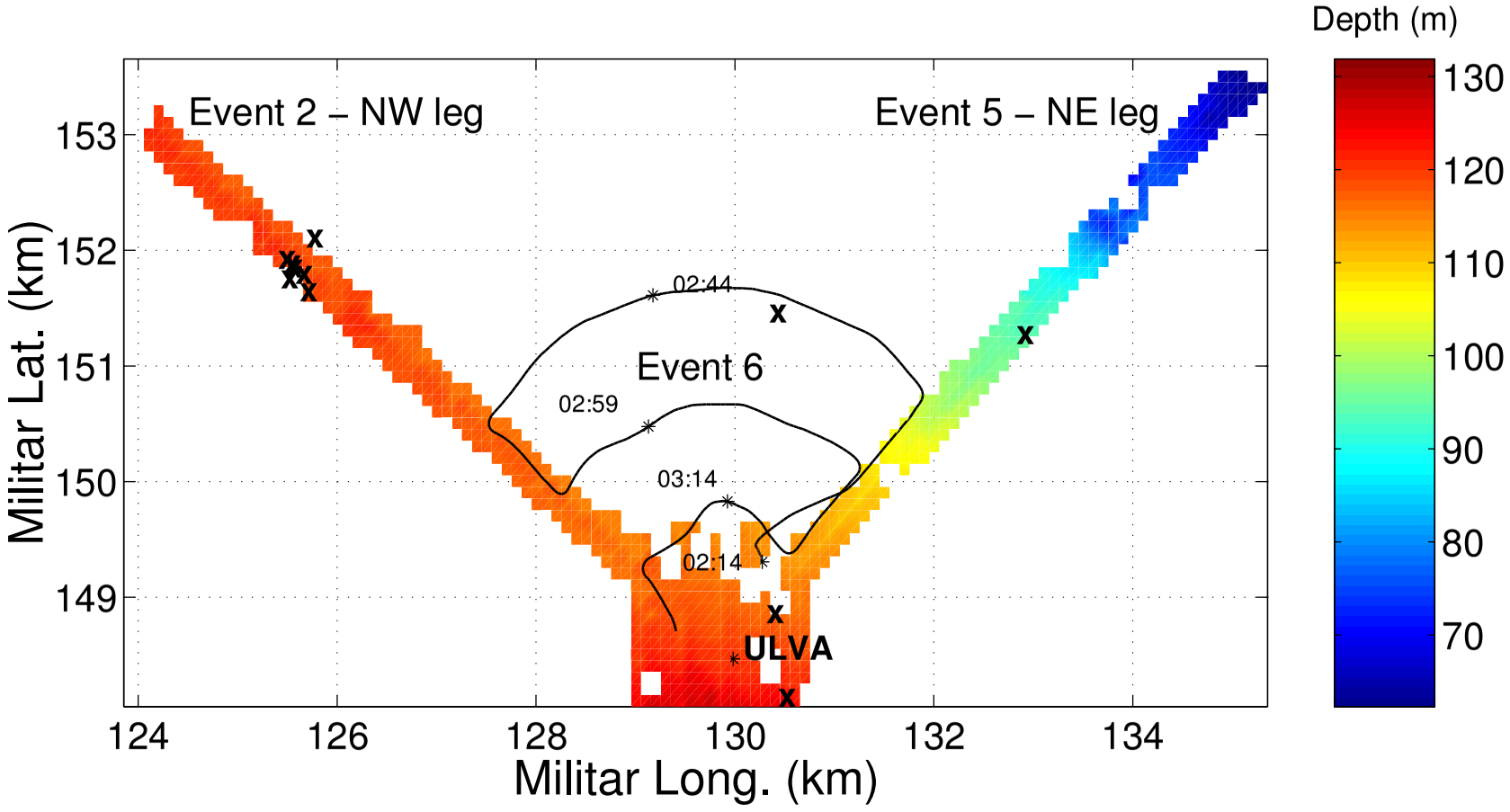




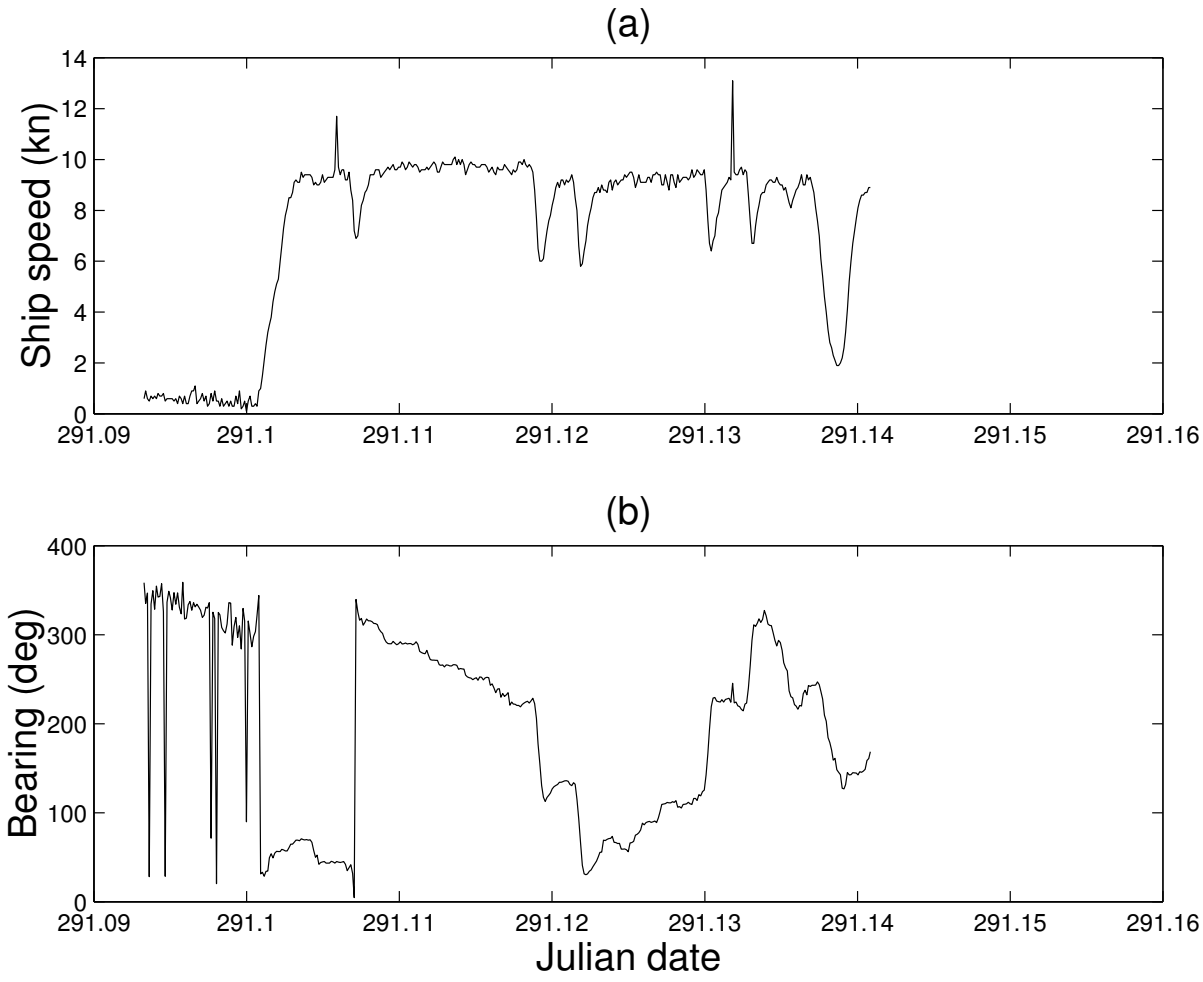
NRP D. Carlos I

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

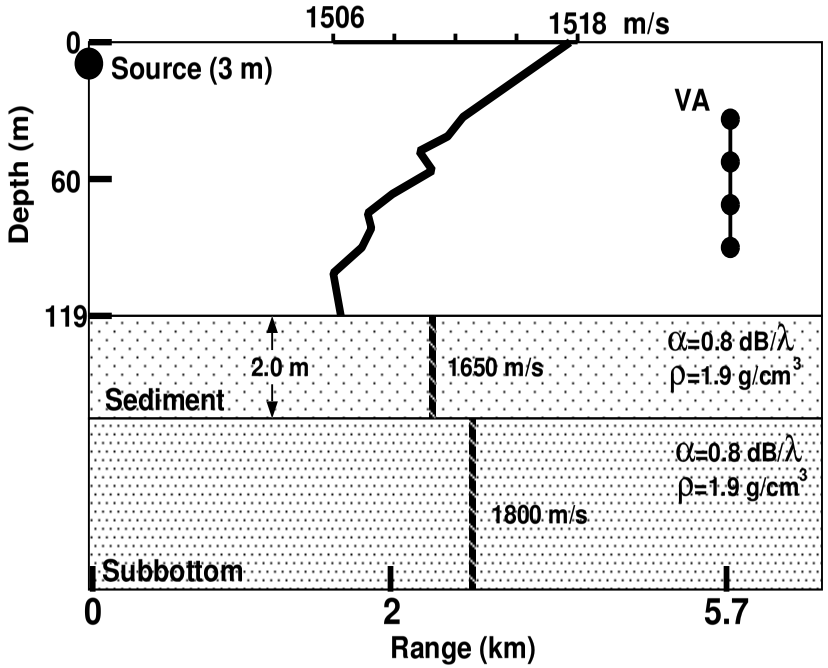
Event 6: bathymetry and source run



NRP D. Carlos I speed and heading

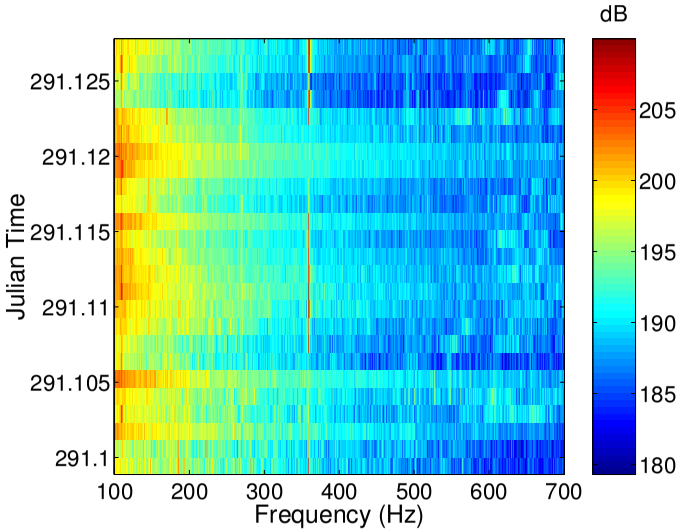


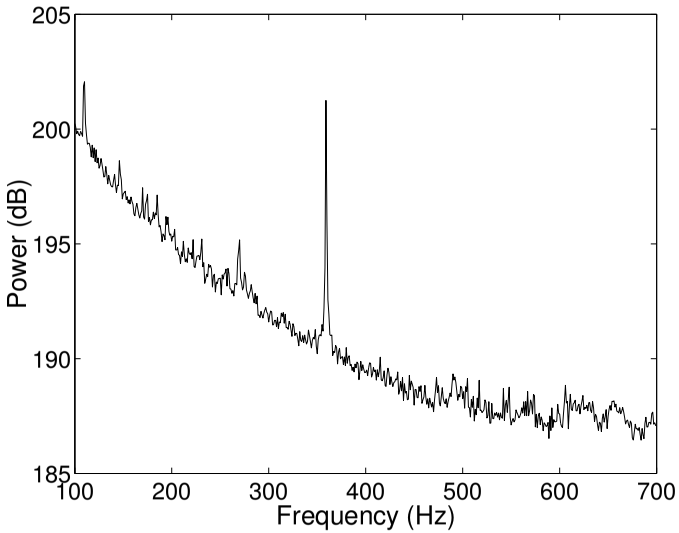
Physical model and search parameters

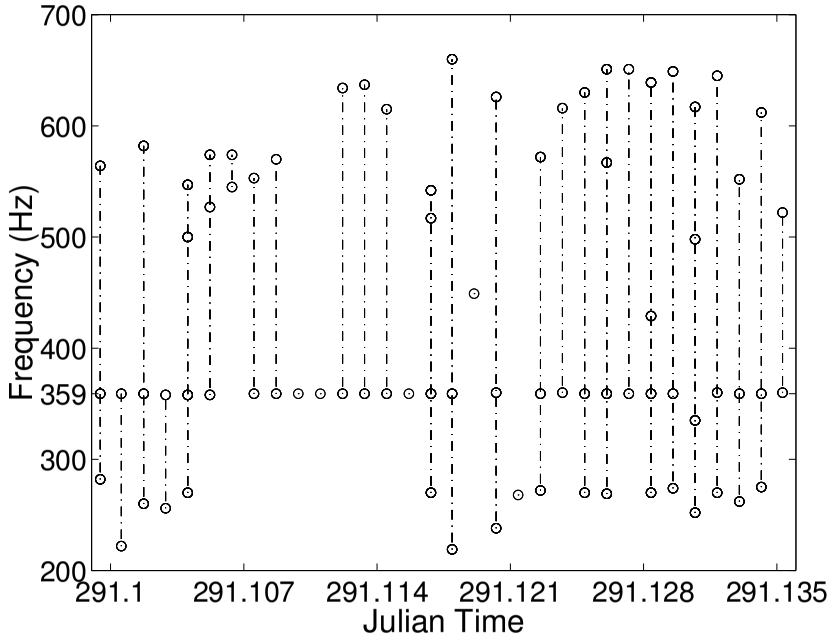


Symbol	Unit	Search int.		/Steps
α_1	m/s	-20	20	64
α_2	m/s	-20	20	64
sr	km	0.5	3.5	64
sd	m	1	10	32
rd	m	85	95	32
θ	rad	-0.03	0.03	32

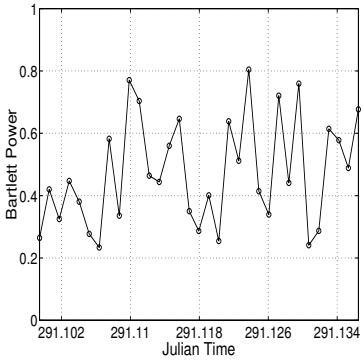
NRP D. Carlos I radiated noise

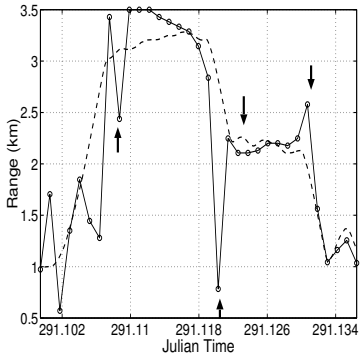


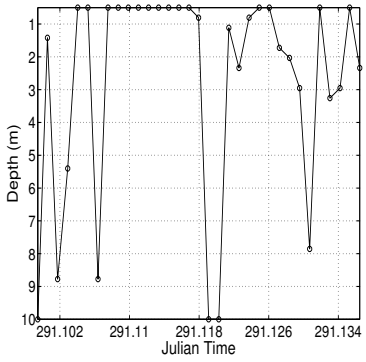


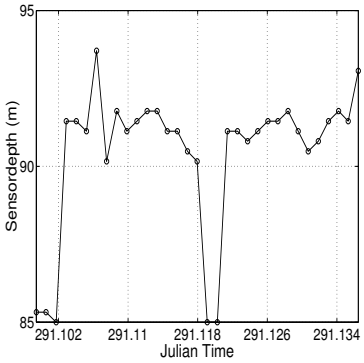


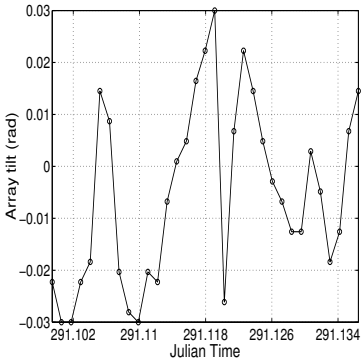
Inversion results for Event 6

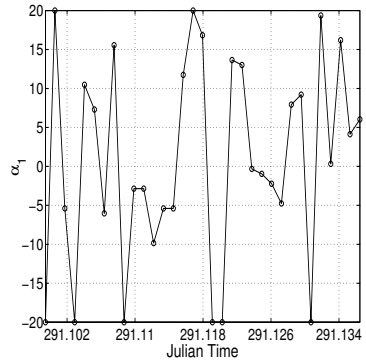


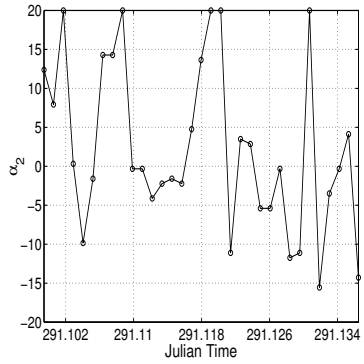


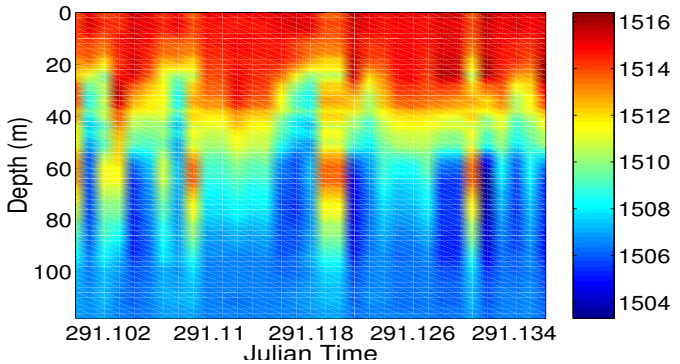












Theoretical background

- 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:

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

- Broadband conventional processor:

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

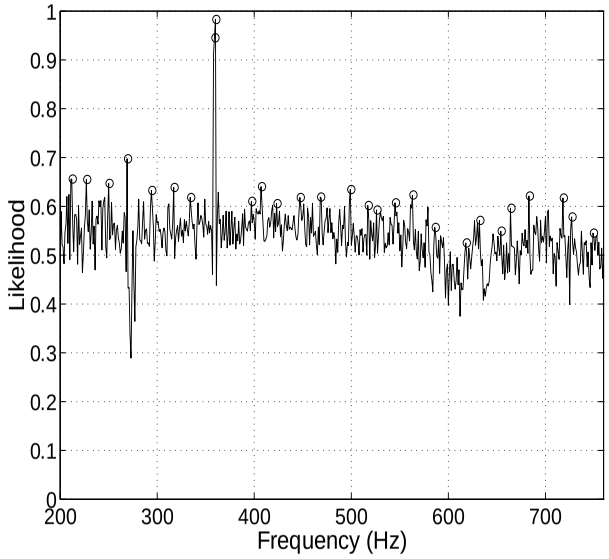
Frequency selection

- Variance at the kth hydrophone:

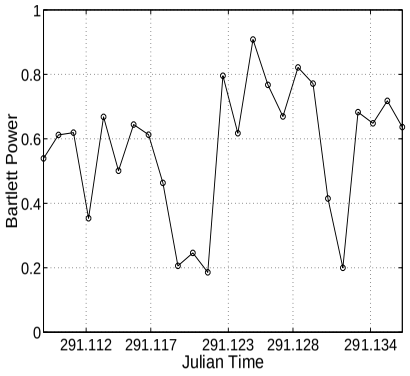
$$V(\omega,k)=\frac{1}{T}\int_0^T[Y(\omega,t,k)-\mu_Y(\omega,k)]^2dt,$$

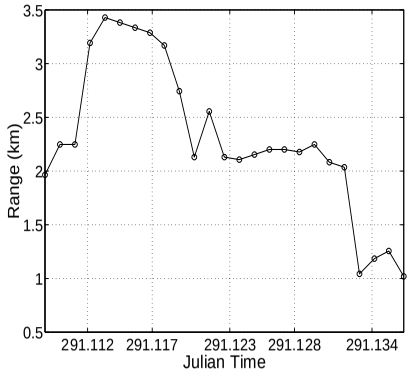
- Likelihood measure:

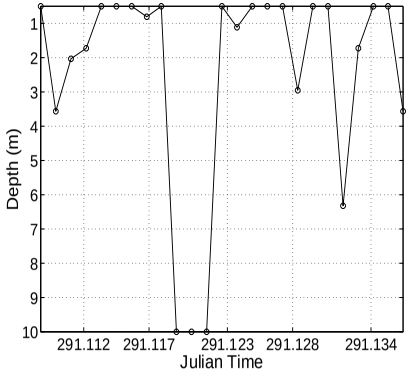
$$v(\omega)=\frac{K}{\sum_{k=1}^{K}V(\omega,k)}$$

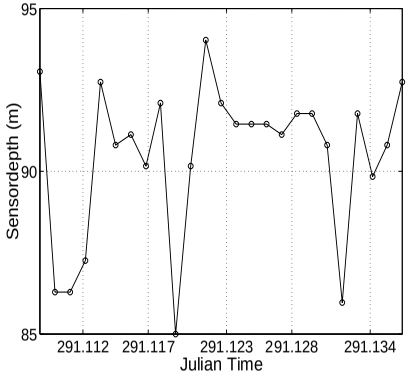


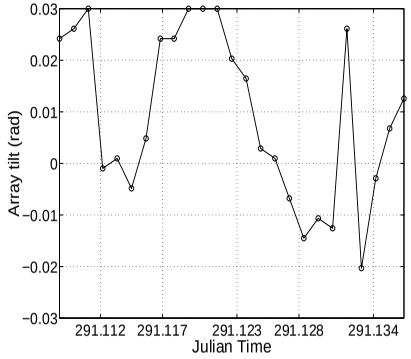
Event 6: Inversion results

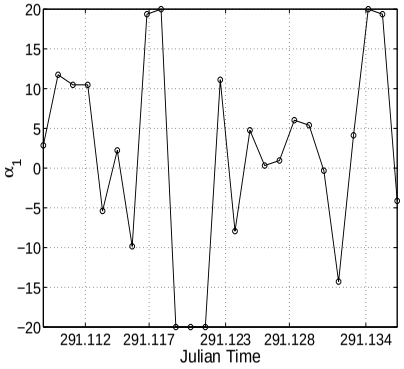


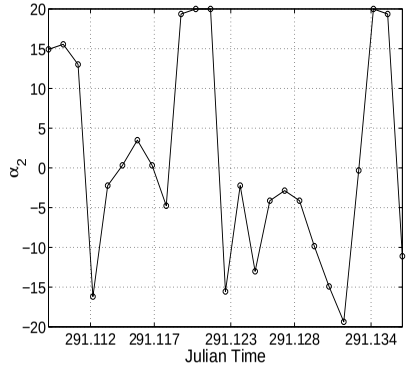


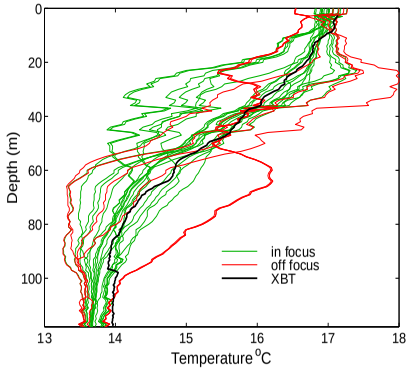


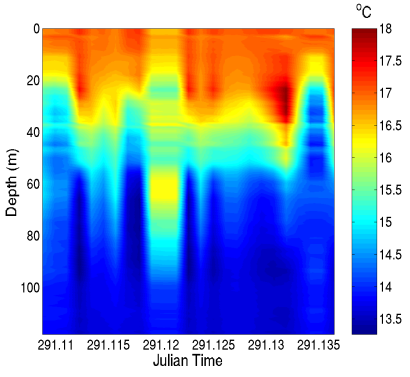




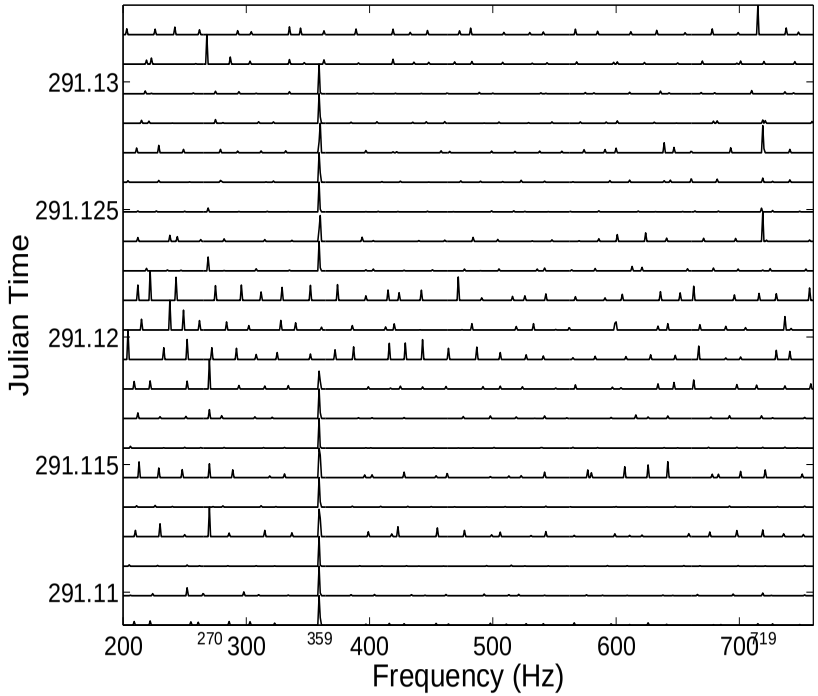








Event 6: Ship power spectrum estimation



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

$\rightarrow$ more extensive data for oceanographic features observation

$\rightarrow$ enhanced search of ship noise spectral components