

A buoy network system for acoustic monitoring

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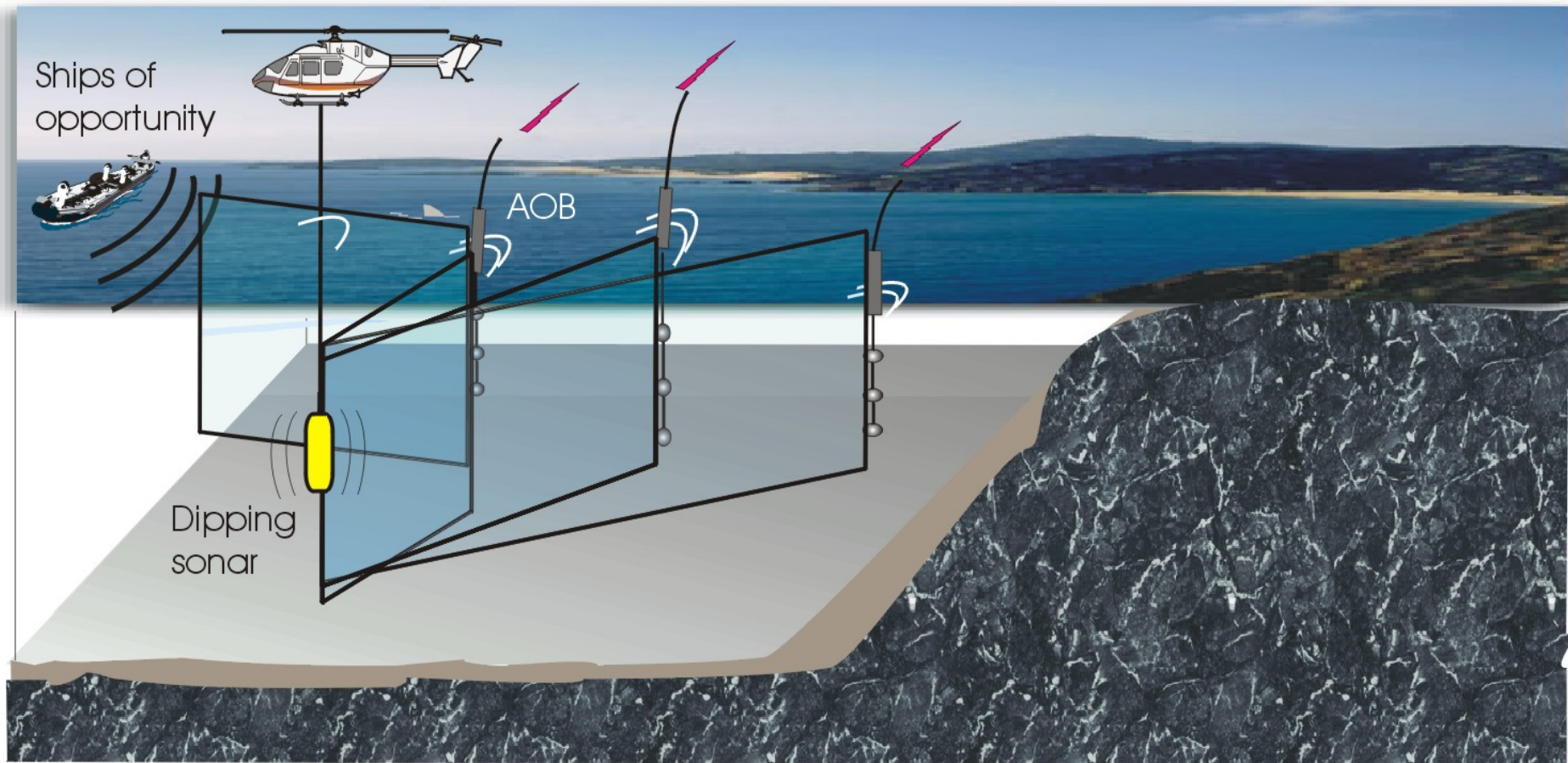
Contributors

Absil F.G.J., Ampolo Rella, M., Arnone, R., AUV REMUS team, Boni, P., Brogini A., Brouwer, P.A.I., Canepa, G., Carrière, O. Cernich, F., Christenson, R., Coelho E., Dekeling, R., Dyamond, R., Felisberto, P., Fioravanti, S., Folegot, T., Frantsen, P.J., Gassie, L., Grasso, R., Janmaat, J., Lam, F.P.A., Martins, C., Martins N., Mazzi, M., Meyer, M., Michelozzi, E., Nardini, P., Parisi, G., Planchon, D., Quaresma L., Rixen, M., RNLNC team, Sapienza, A., Schouten, M.W., Silva, A., Simons, D., Snellen, M., Soares C., Spina, F., Stoner, R., Trees, C., van Leijen, V., Zabel, F.



The Acoustic-Oceanographic Buoy (AOB) network concept

Easily deployable/reconfigurable AOB - based system



Cape Teulada

Drifting buoy-based initiatives: historical perspective

1996 SEAGO EU proposal, sonobuoy network for geo-acoustic inversion

1997 ENVERSE'97 & 98, geo-acoustic inversion (Hermand, NURC)

2002 LOCAPASS project (MoD, Portugal) - develop AOB1, 4 sensors

2003 **AO-Buoy JRP**: NURC, UALG, ULB, NLDA and IH
⇒ MREA'03 sea trial - AOB1 test at sea (Elba, Italy)

2004 MREA'04: AOB1 test (Setúbal, Portugal)

2004 **RADAR** (FCT, Portugal) w/ ULB participation - 2×AOB2, 16 sensors

2005 MakaiEx (Hawai, USA): AOB2 first test (Kauai(HI), US)

2007 ⇒ MREA BP'07: AOB2 network test (S. Elba, Italy)
⇒ RADAR'07: AOB2 network test (Setúbal, Portugal)

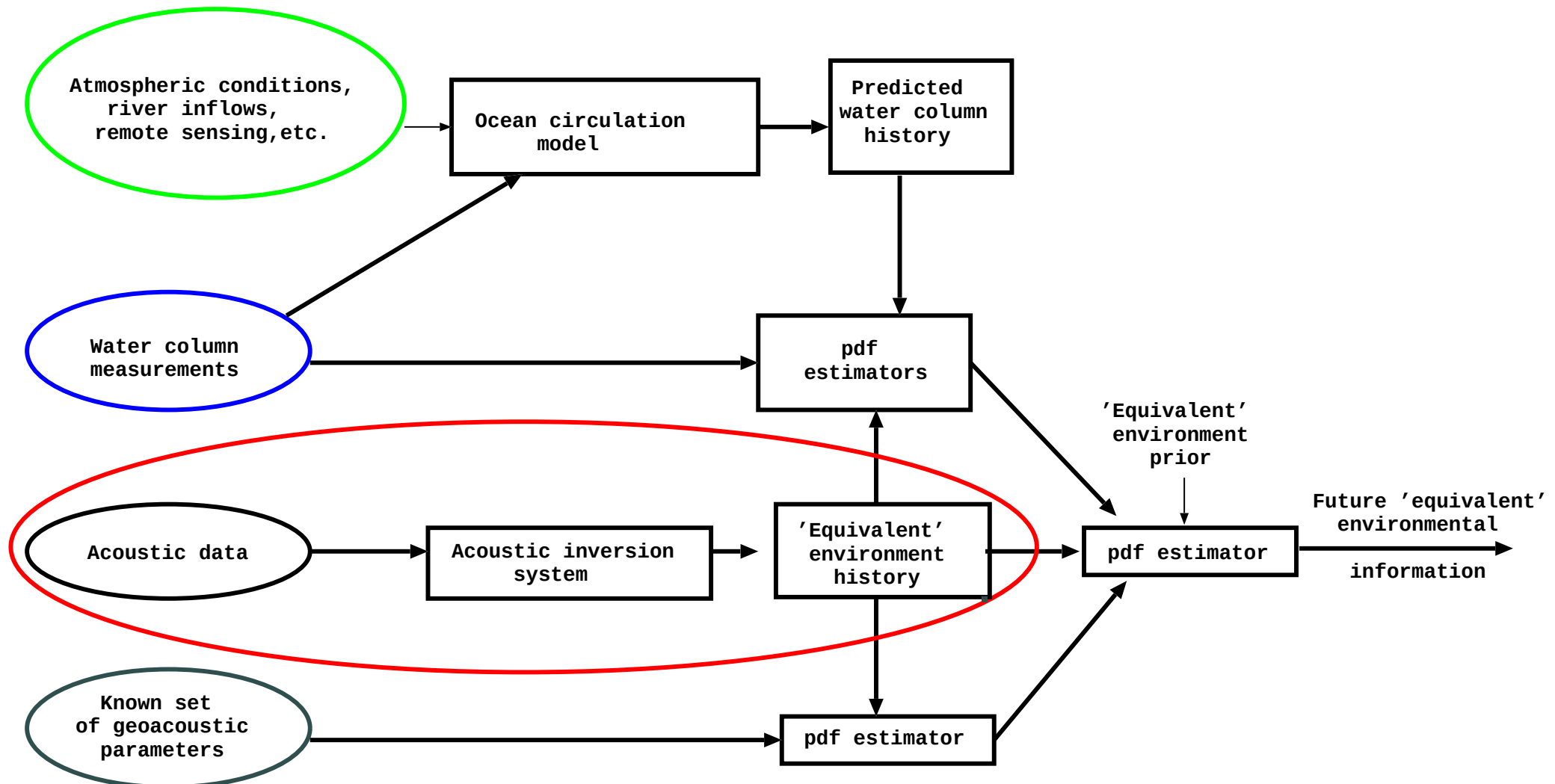
Simple statement

“There is no guarantee that the best environmental prediction provides the best acoustic prediction”

⇒ imperfect data / physical model

⇒ geometrical / model mismatch

An approach to the acoustic prediction problem



An approach to the acoustic prediction problem (cont.)

$$p(\mu_F | \omega, o_F, g, \alpha, \psi) \propto \int \int \frac{\delta(\mu_F - U(n_{wF}, n_b)) p(n_{wF} | \omega, o_F, \psi) p(n_b | g)}{p(n_b)} \times \\ \int \frac{p(\nu_w, n_b | \alpha) p(\nu_w | \psi)}{p(\nu_w)} d\nu_w dn_b dn_{wF}$$

$p(n_{wF} | \omega, o_F, \psi)$: future ‘equivalent’ water column | measurements, ocean forecast,

$p(n_b | g)$: equivalent geoacoustics | history geoacoustics,

$p(n_b)$: prior on ‘equivalent’ geoacoustics,

$p(\nu_w, n_b | \alpha)$: acoustic inversion ‘equivalent’ environment | acoustic data,

$p(n_w | \psi)$: ‘equivalent’ water column | water column measures,

$p(n_w)$: ‘equivalent’ water column prior.

An approach to the acoustic prediction problem (cont.)

Advantages

- acoustic prediction satisfies an acoustic cost criteria
- acoustic modeling/mismatch trends are 'learned' for future detrending
- optimal combination of ocean predictions, measurements and inversion outcomes

Expected drawbacks:

- stationarity assumptions required for pdf estimation not met
- lack of data, to estimate pdfs in early stages of the iterative process
- pdfs interp/extrap may lead to unrealistic statistical relationships

Environmental Inversion: the strategy

Bottom

low/mid frequency 0.3 - 1.6 kHz

a priori information

adaptive geoacoustic sampling (patches)

⇒ “known” space-variant geoacoustic parameters

Water Column

a priori information

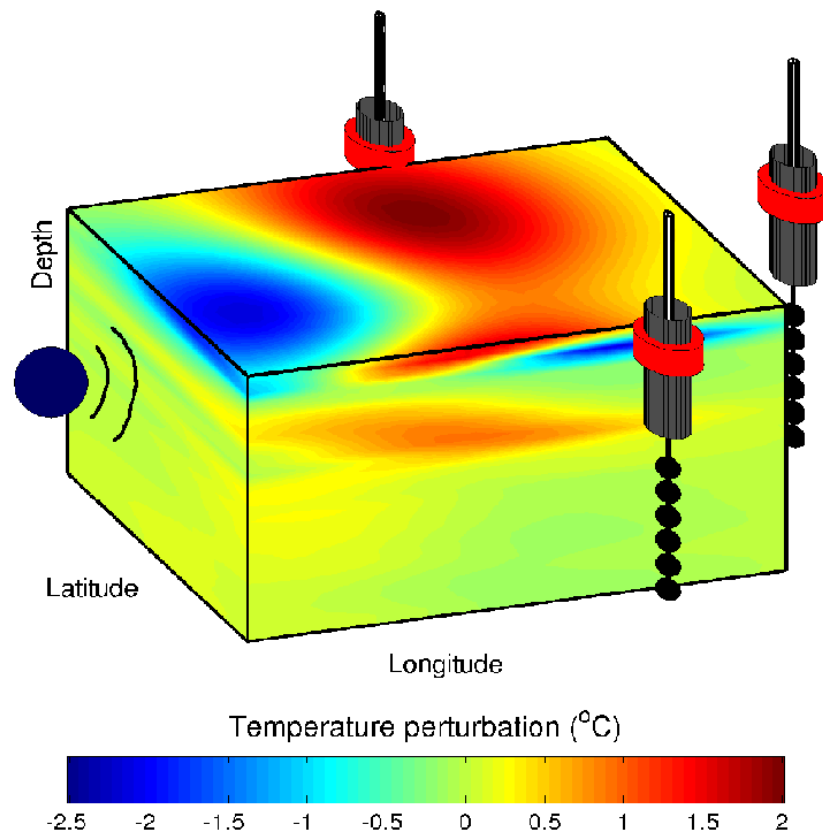
regularization / constraining

spatial coverage / coherence

⇒ *a posteriori* pdfs for 'equivalent' model

Acoustic Rapid Environmental Assessment (AREA)

Measured CTD from MREA'03 (N.Elba)



Actual:

- up to 20×20 km
- water column and geo-acoustic inversion
- sources of opportunity

Objective:

- 3D EOF's constrained
- multiple array coherent inversion

Acoustic Oceanographic Buoy V1 (AOB1)

AOB1 - main characteristics

weight: 90 Kg in air

dimensions: 1.5×0.30 m

autonomy: 6 hours

bandwidth: 16 kHz

hydrophones: 4



MREA'04, April 2004, Setúbal (Portugal)

MREA'03/04: setup and environmental model

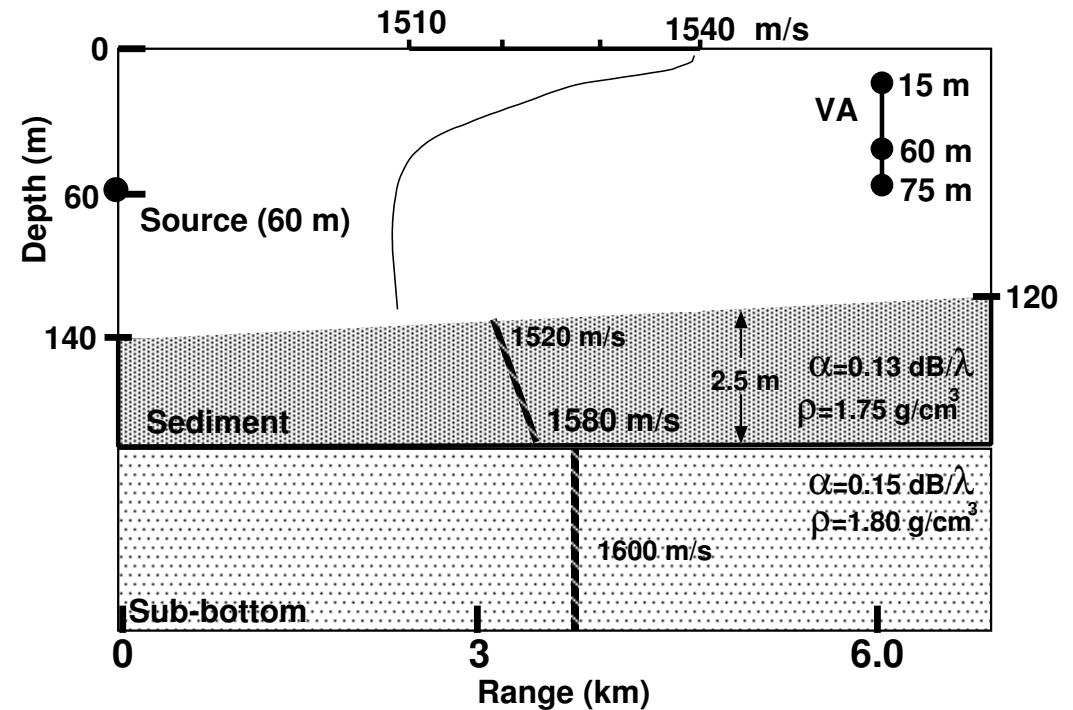
AOB1 - prototype

- single buoy
- small aperture/3-4 phones

Processing issues

- high ambiguity
- high parameter adaptivity

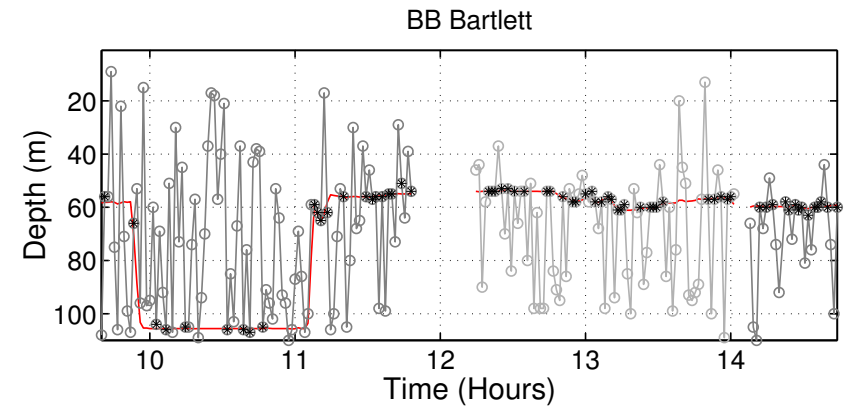
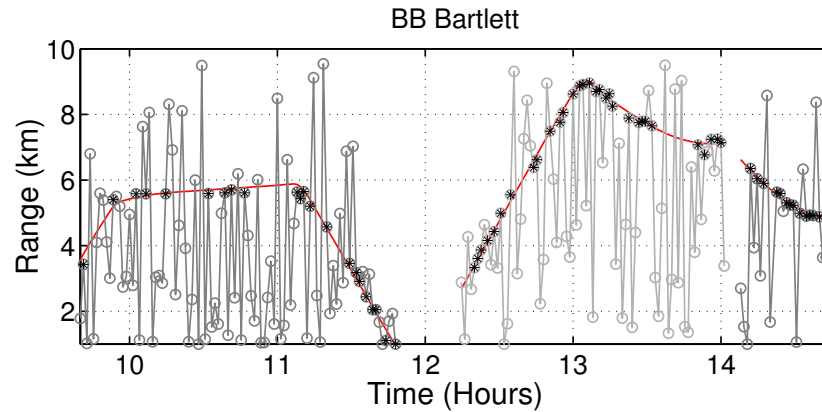
- ⇒ broadband: 500 -1200
- ⇒ high-resolution hypersurfaces
- ⇒ focalization
- ⇒ validation of results



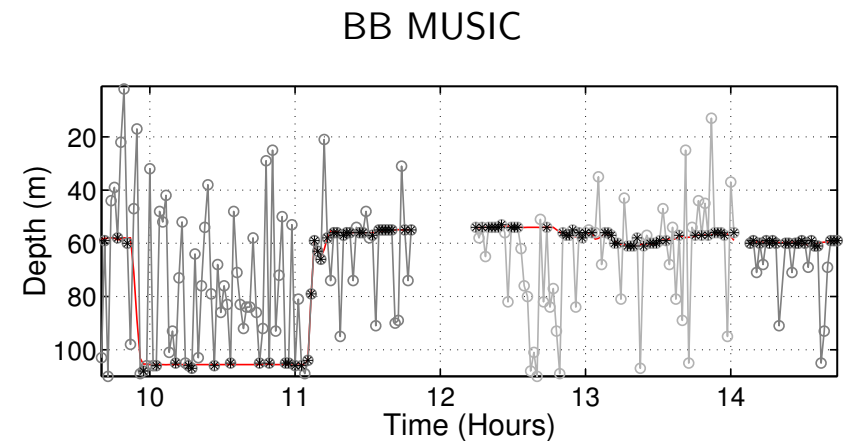
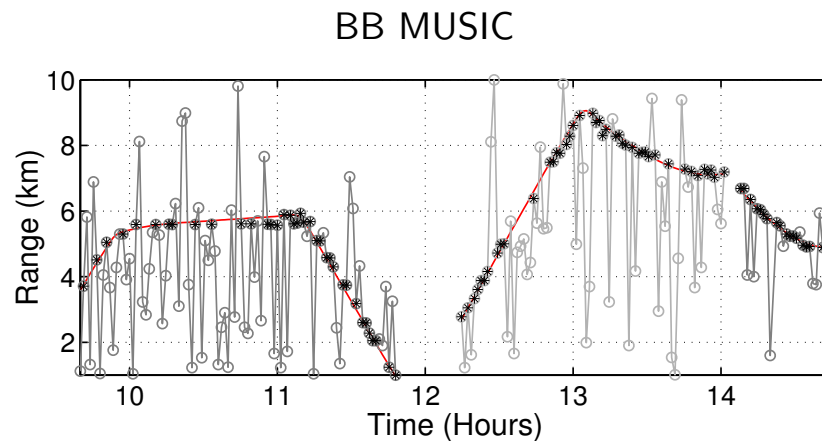
MREA'03/04 conceptual RD model.

MREA'03/04: inversion validation by source localization.

32%

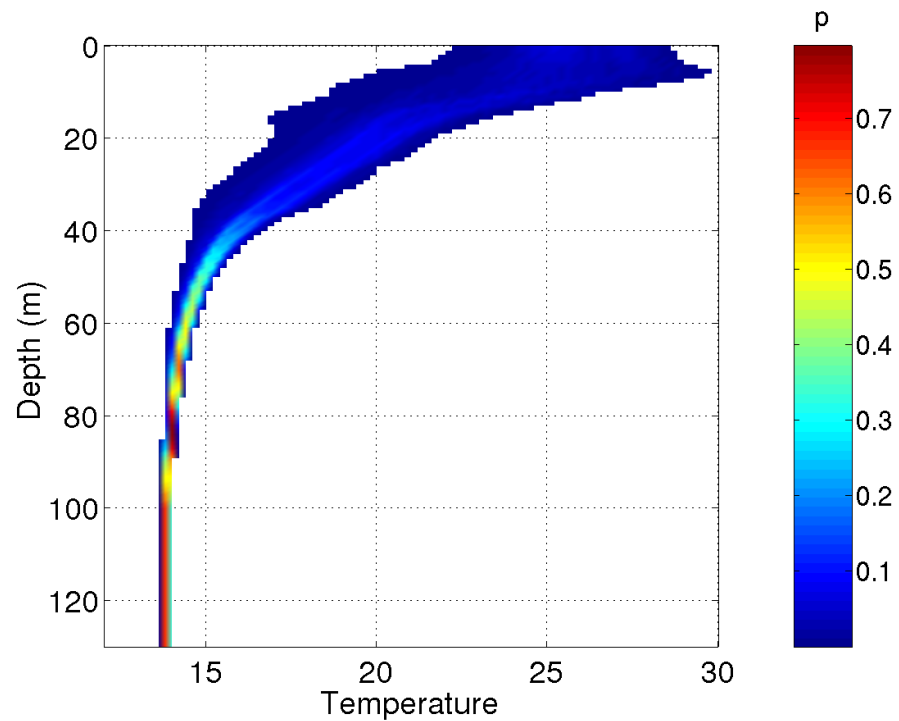


48%

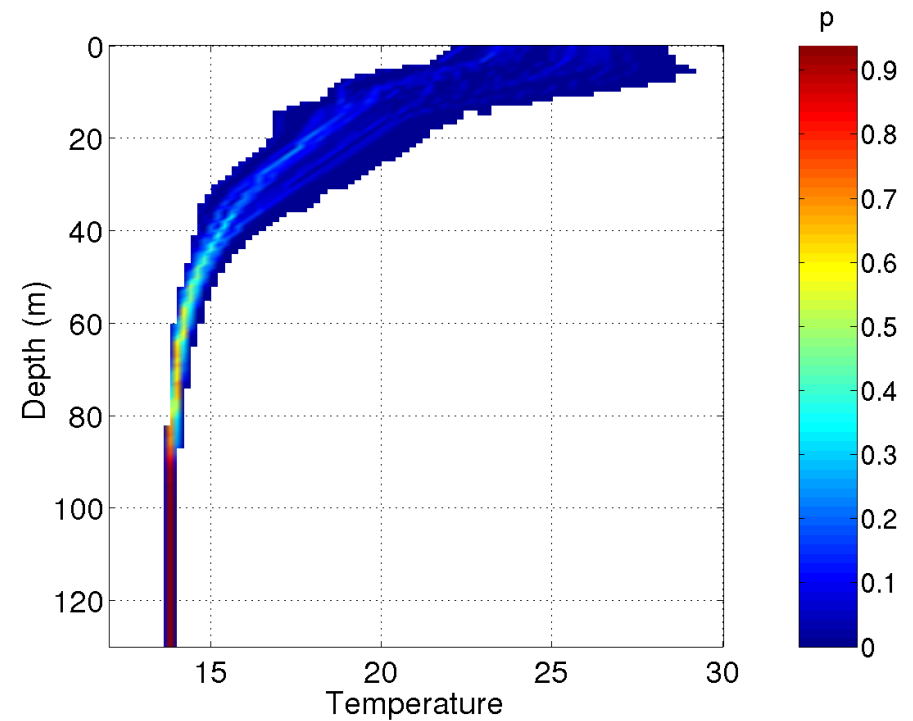


MREA'03/04: inversion statistics.

Bartlett



Music



Acoustic Oceanographic Buoy V2 (AOB2)

AOB2 - main characteristics

DSP on the buoy processing

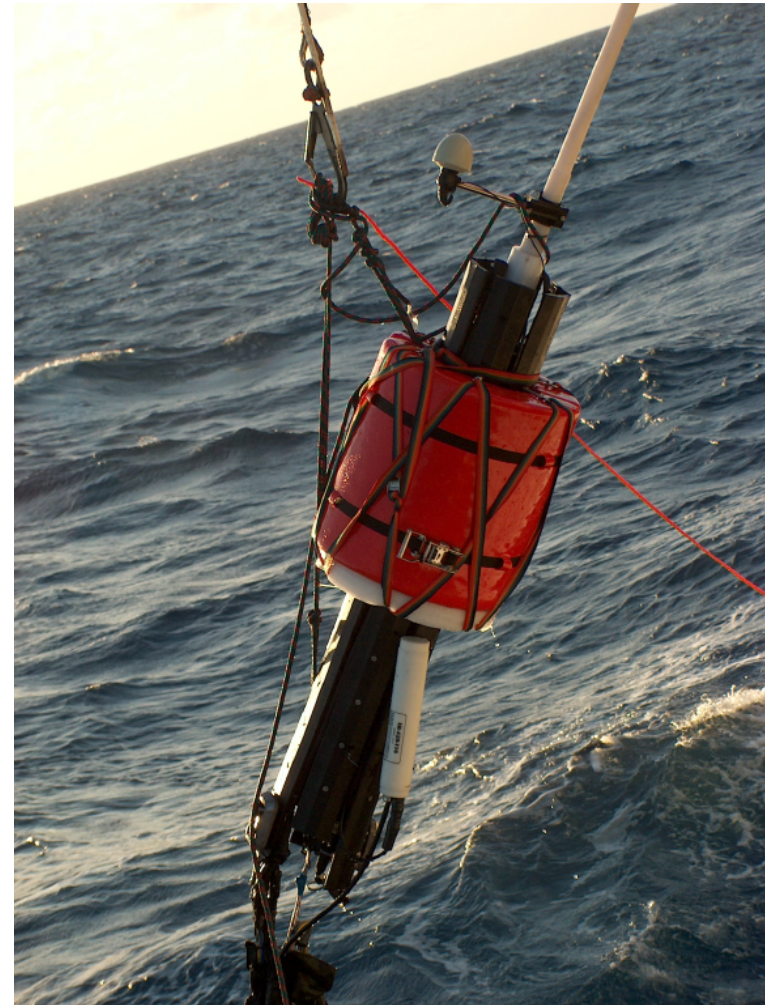
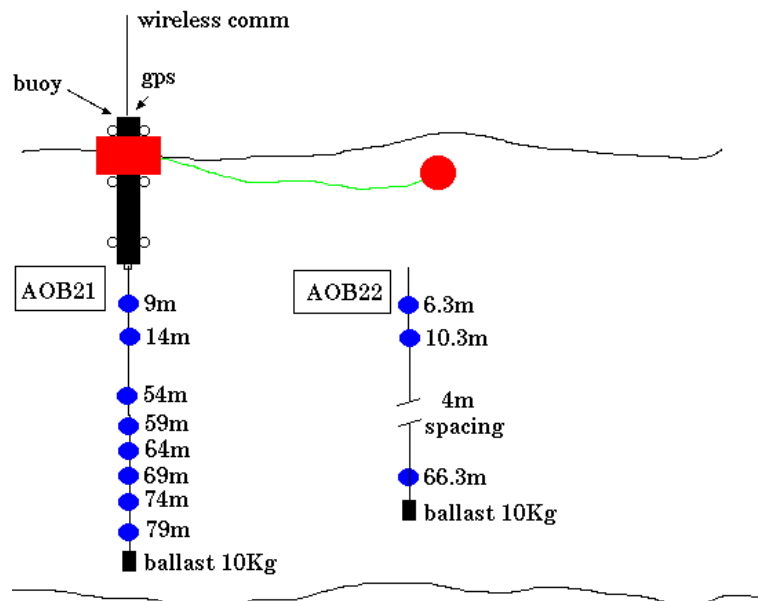
weight: 40 Kg in air

dimensions: 1.2×0.16 m

autonomy: 12 hours

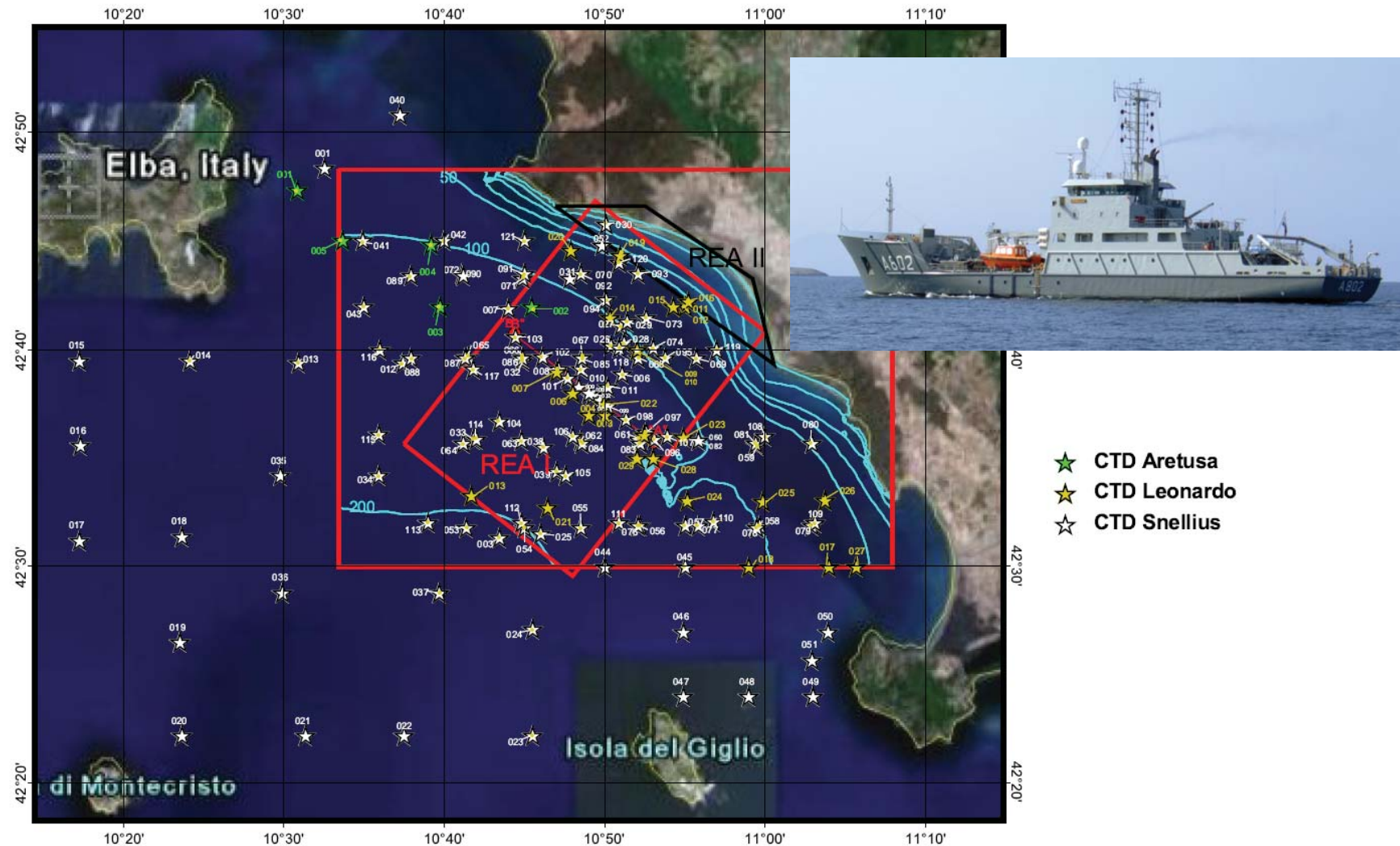
bandwidth: 16 kHz

16 temp. sensors

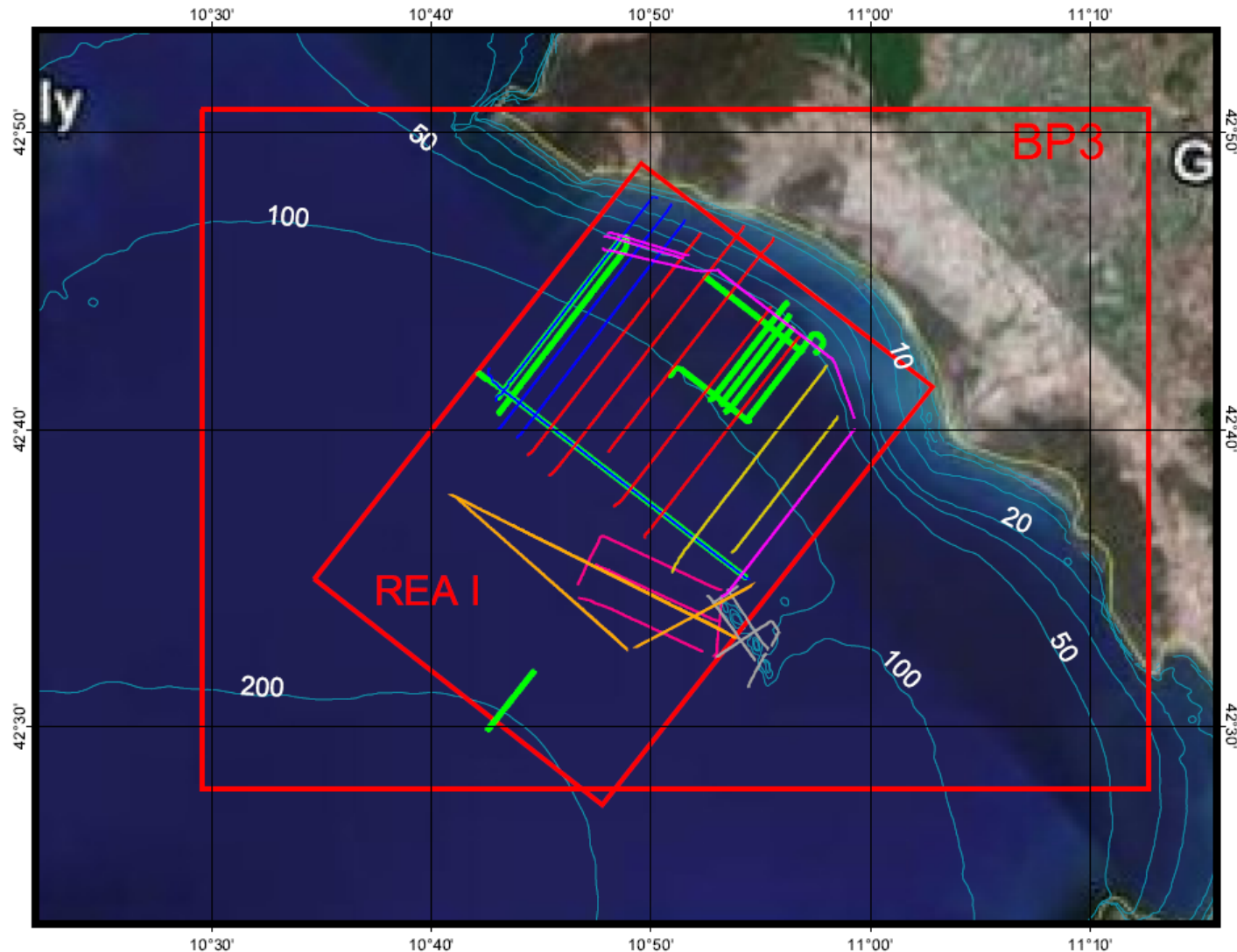


Makai Ex, Sep 2005, Hawaii (USA)

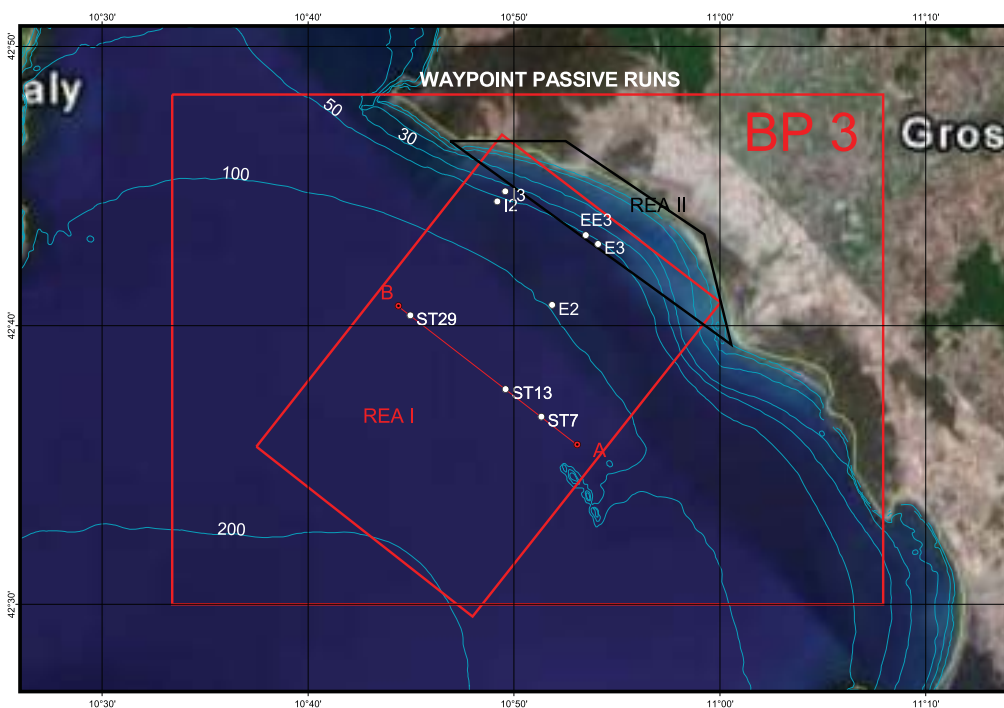
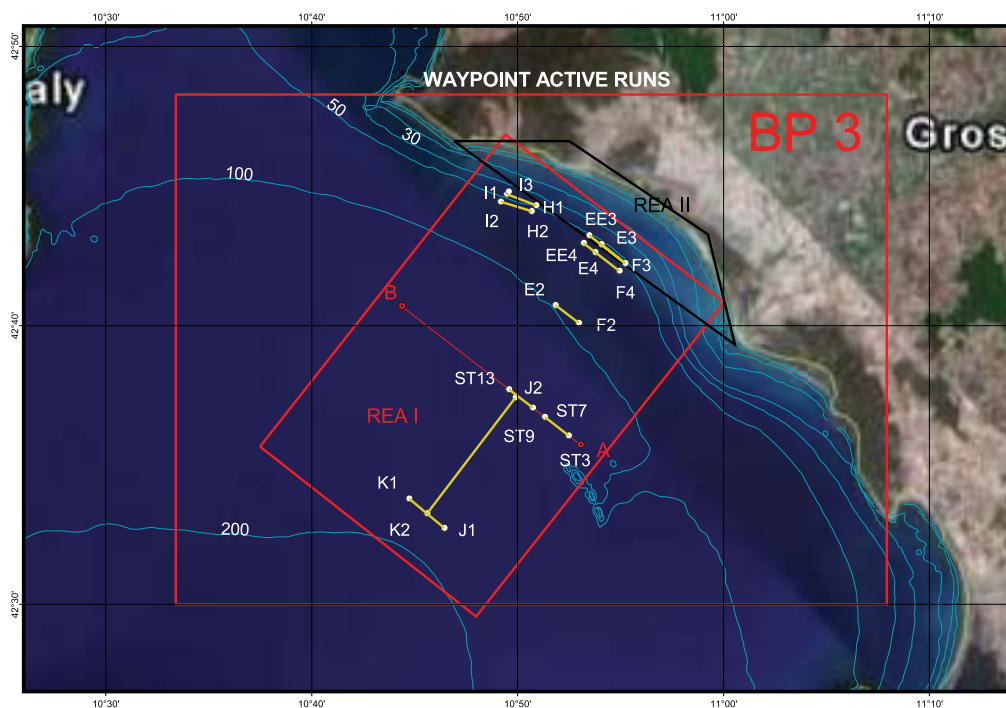
MREA/BP'07 (April/May 2007)



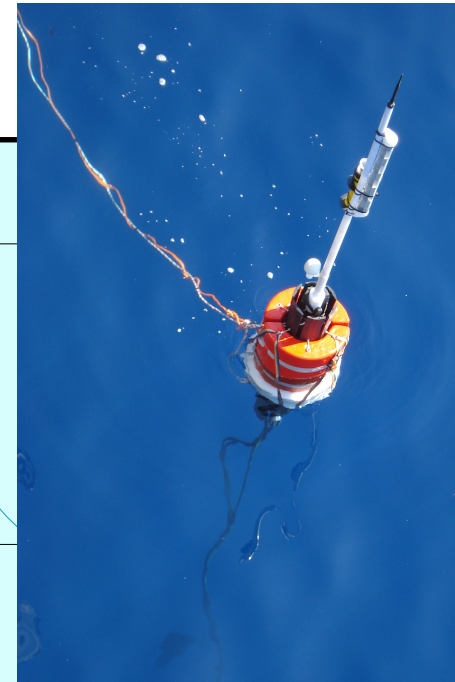
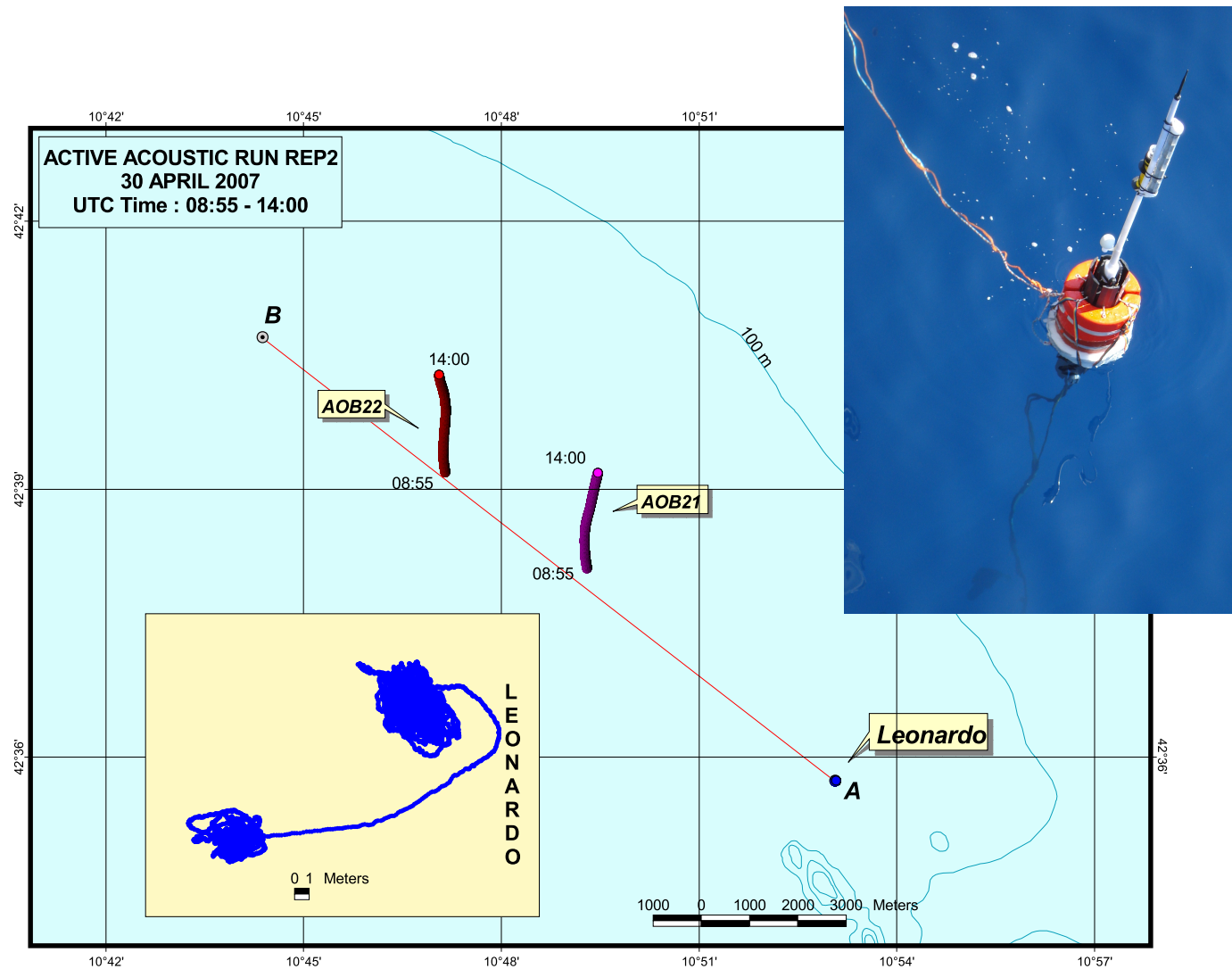
MREA/BP'07: geophysical survey



MREA/BP'07: active and passive runs



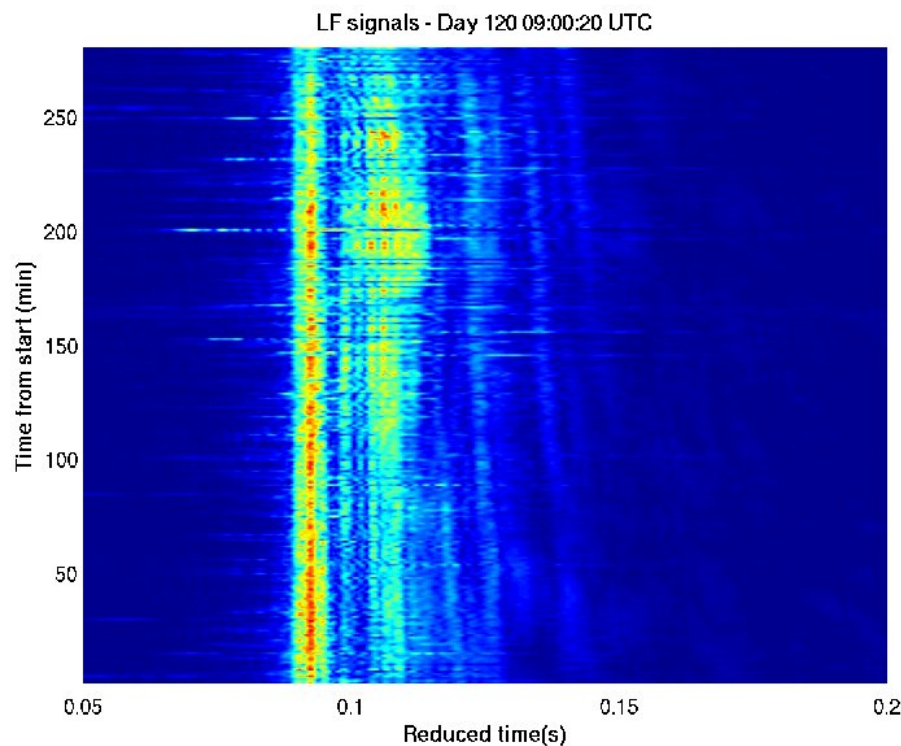
MREA/BP'07: AOB drift April 30, 2007



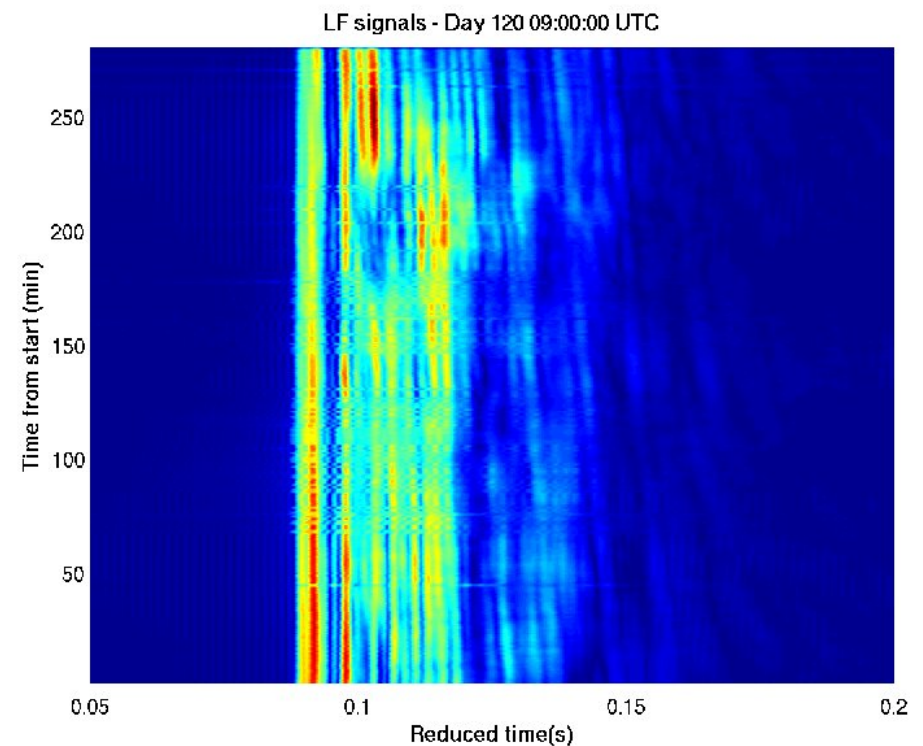
MREA/BP'07: data collection April 30, A-B line

Band: 300 - 800 Hz

7 km range, 62 m depth



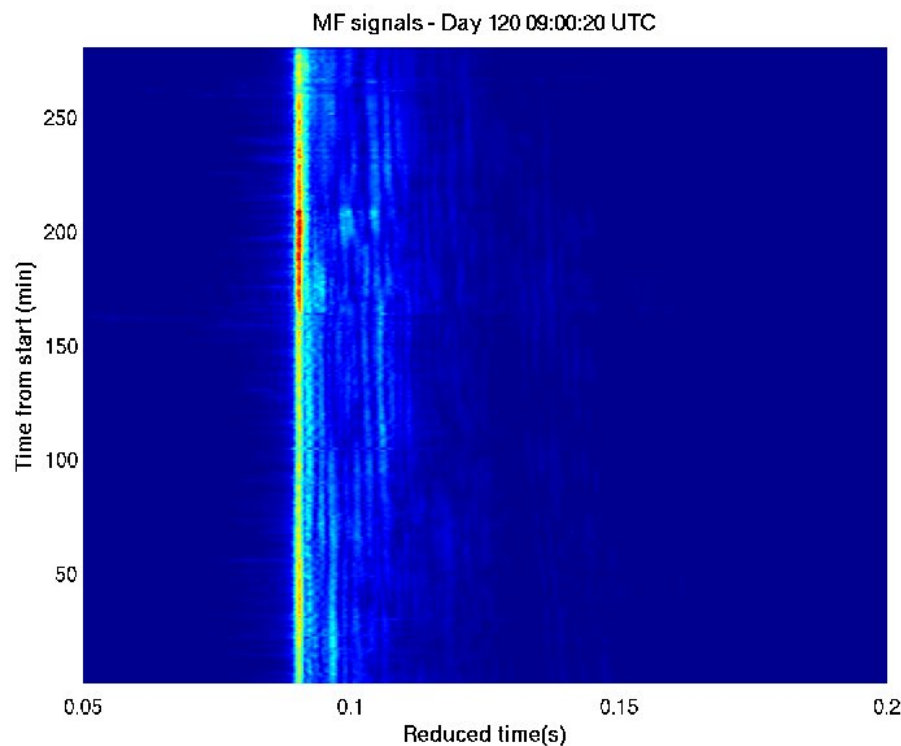
11 km range, 70 m depth



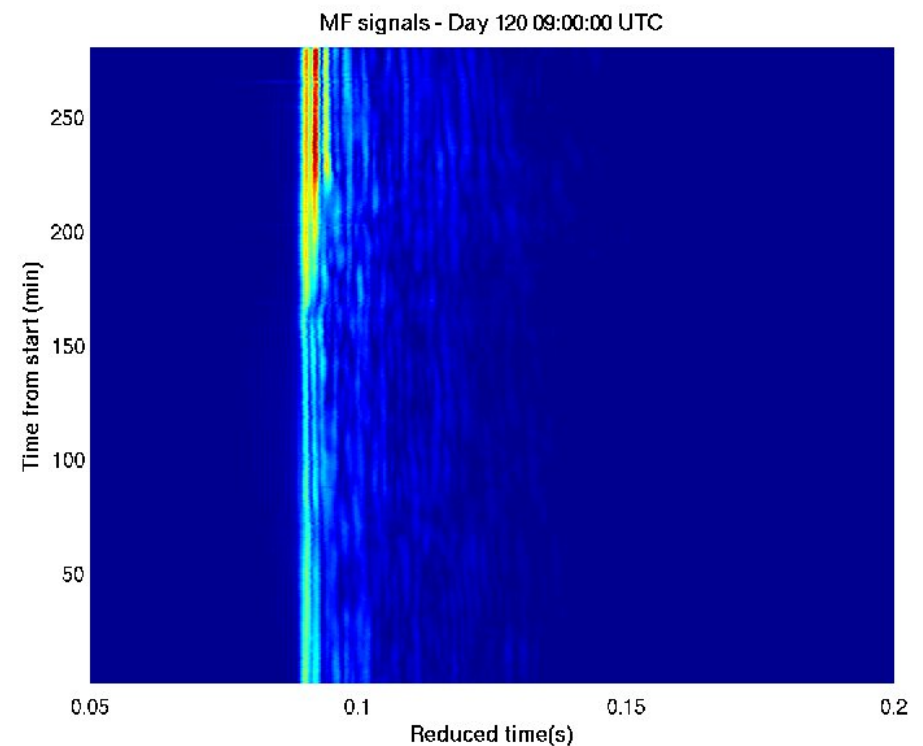
MREA/BP'07: data collection April 30, A-B line

Band: 800 - 1600 Hz

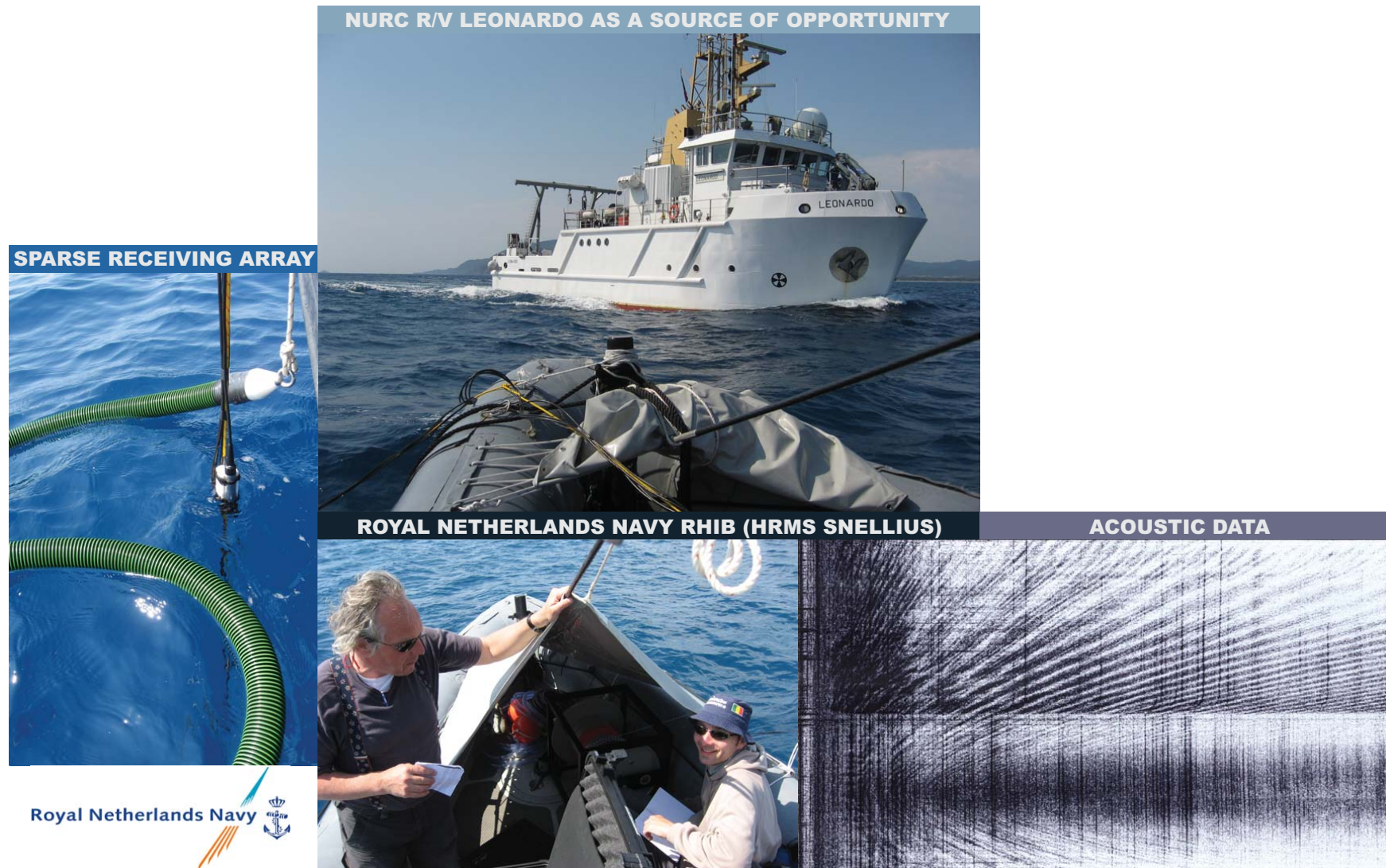
7 km range, 62 m depth



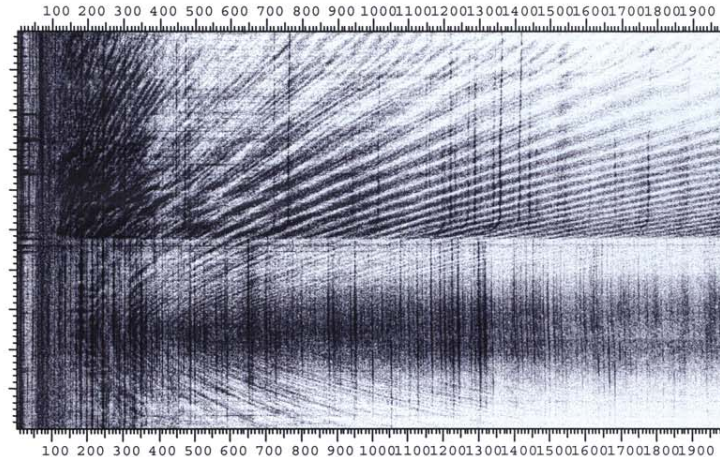
11 km range, 70 m depth



MREA/BP'07: geoacoustic inversion with sources of opportunity



MREA/BP'07: inversion results



**SPECTROGRAM OF LEONARDO SELF-NOISE
TIME (10 MIN) VS. FREQUENCY (0 - 2 KHZ)**

Objective function is based on:

8 frequencies (Hz):

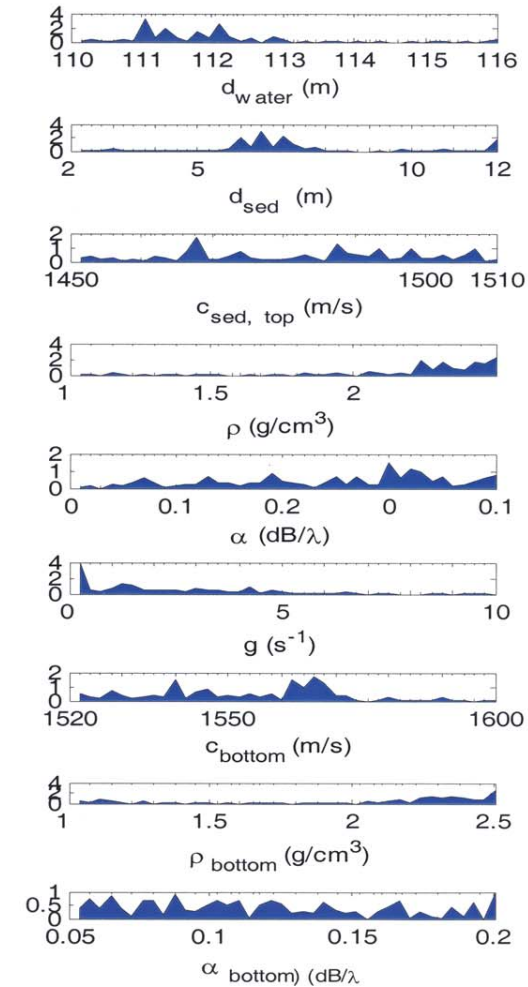
226.2	452.6	486.1	582.9
698.5	948.5	1163.4	1239.3

9 ranges(km):

0.689	0.706	0.723	0.740
0.758	0.775	0.792	0.809
0.827			

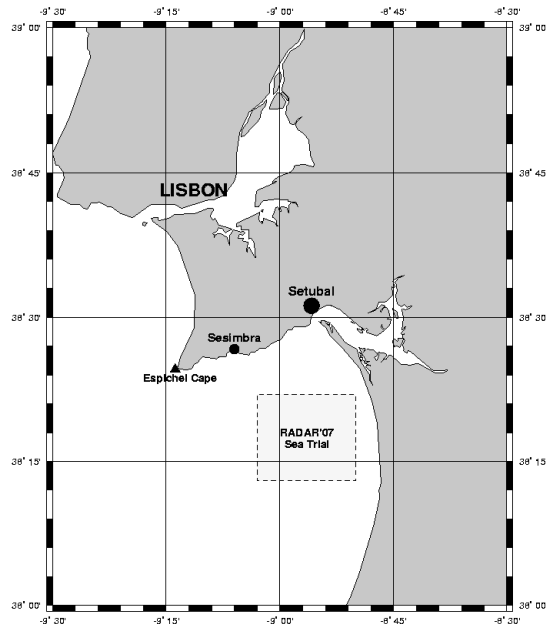
4 depths (m):

19.04	24.01	28.98	33.95
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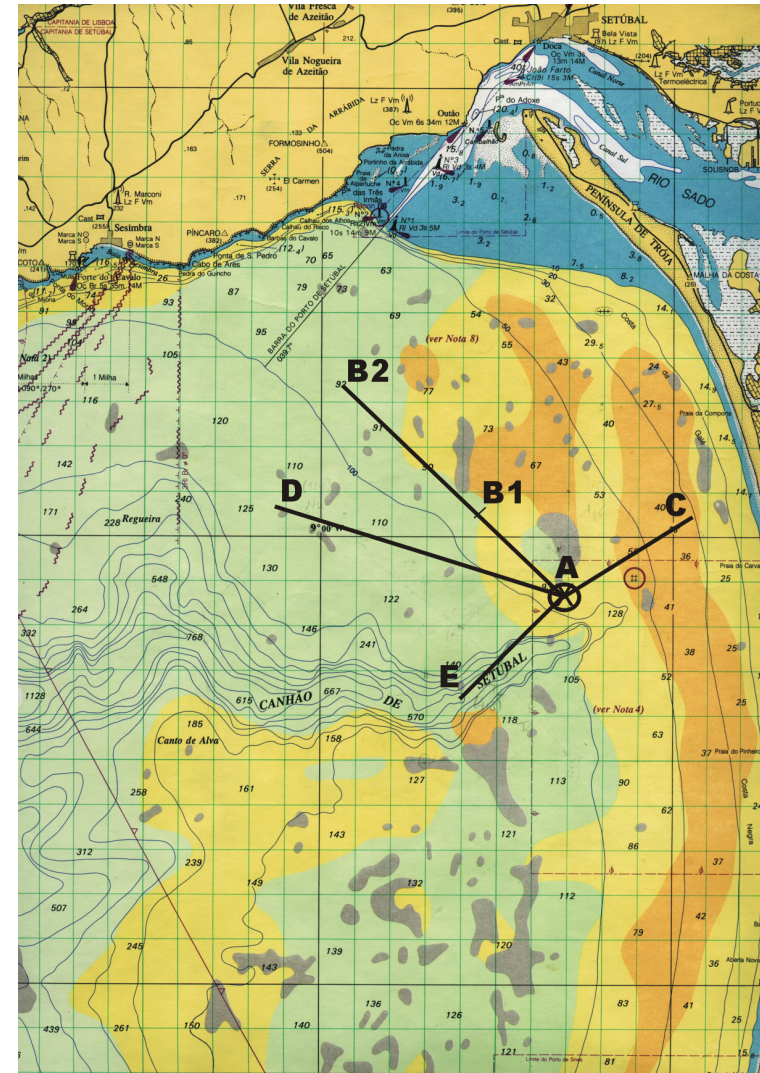


**GEOACOUSTIC PARAMETERS
PROBABILITY DISTRIBUTIONS**

RADAR'07: area and resources



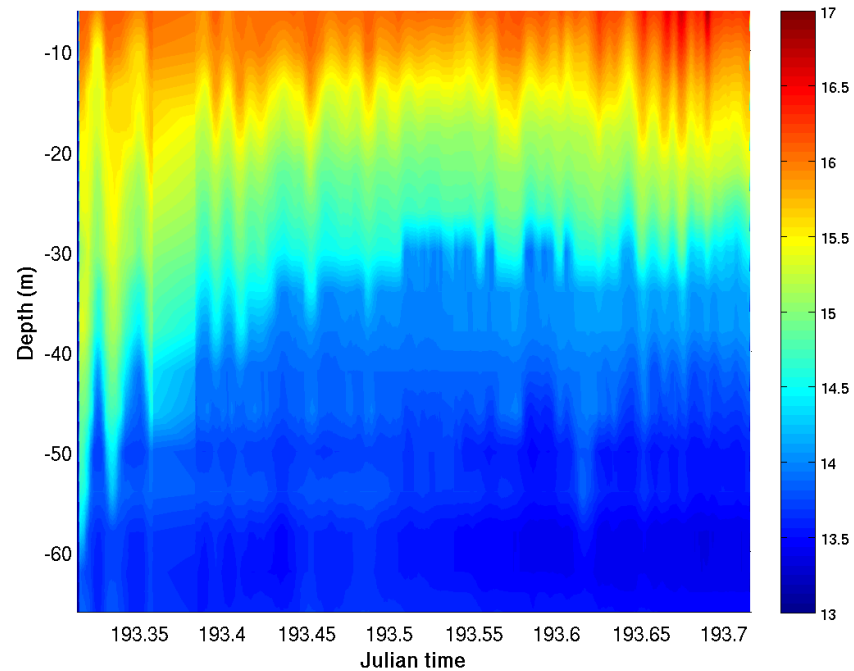
- NRP D. Carlos I (PO Navy)
- 2 drifting AOB2 (1 TS)
- 1 moored array
- 500 - 15 kHz
- 2 ADCP, 2 TS



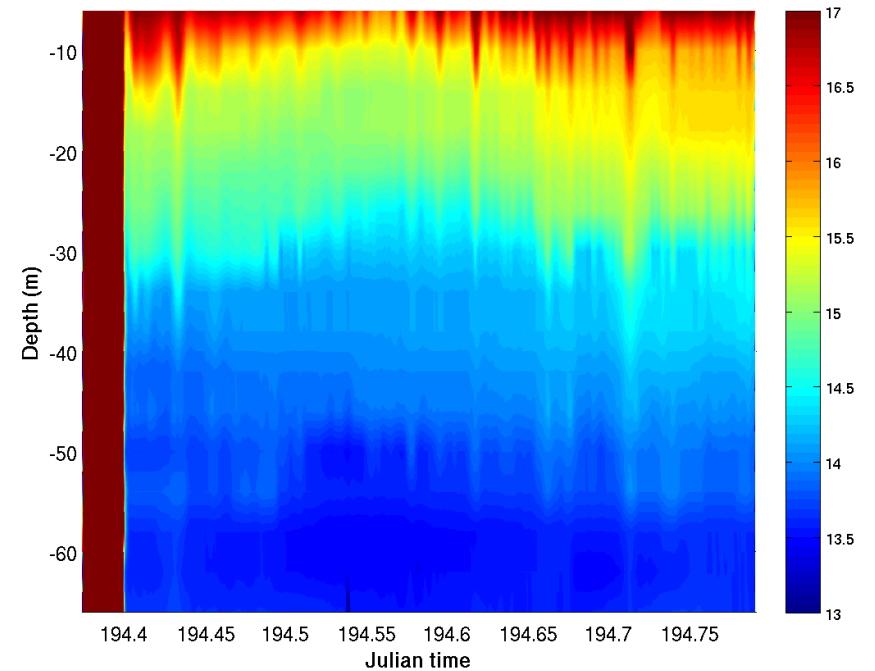
Setúbal test area (Portugal)

RADAR'07: AOB low-resolution thermistor string

July 12, 2007

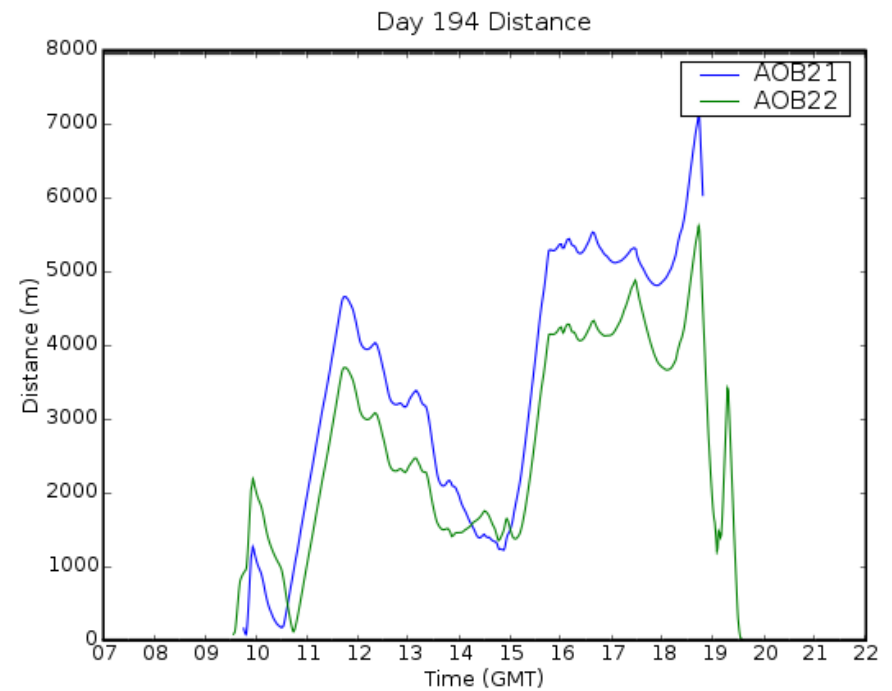
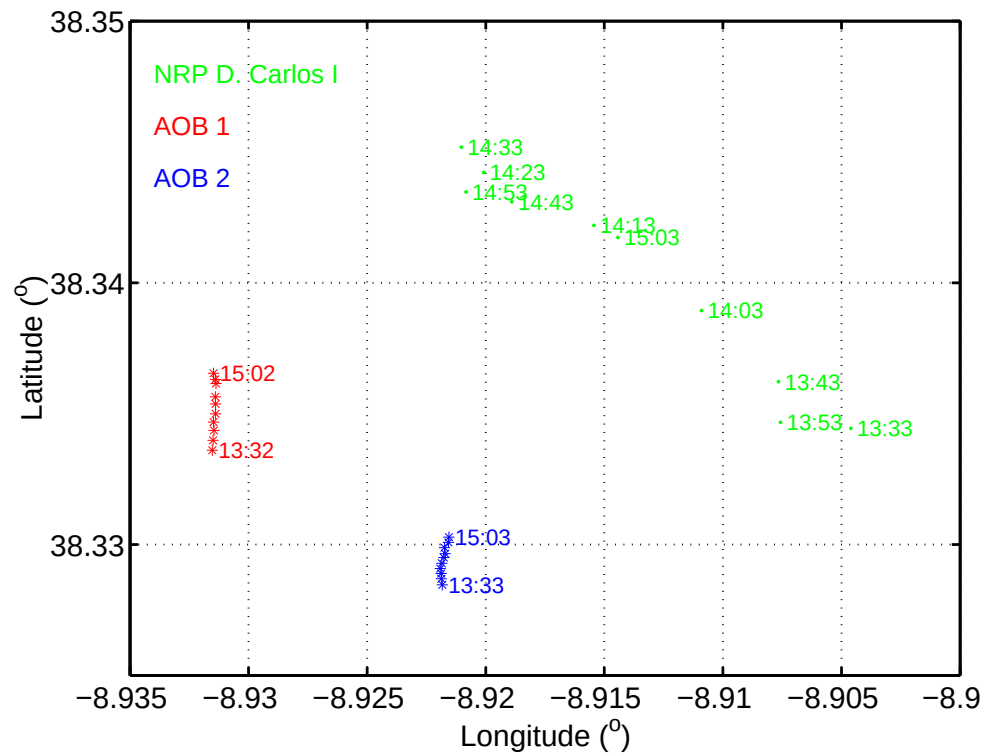


July 13, 2007

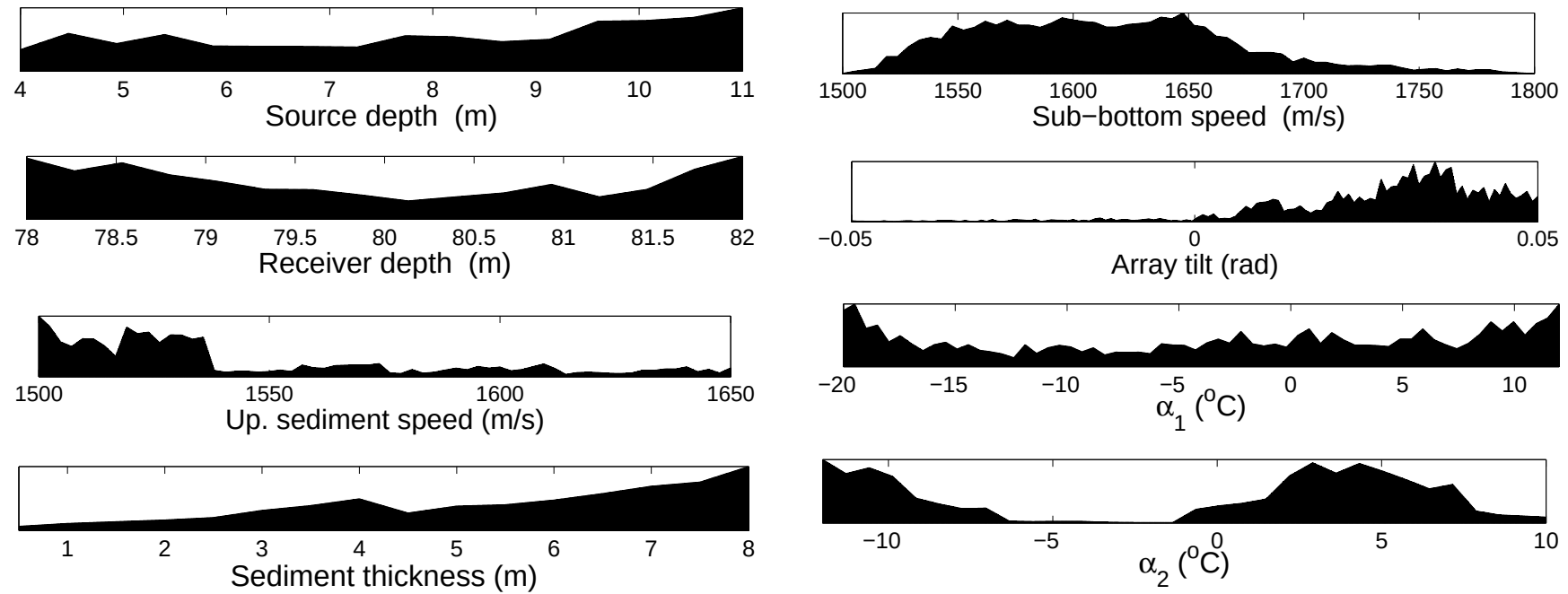


RADAR'07: experiment geometry

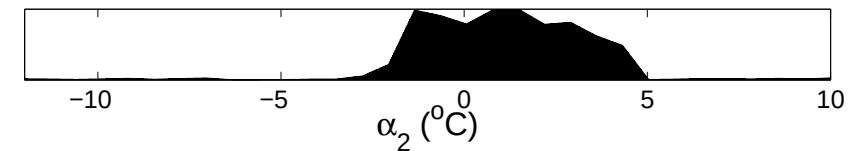
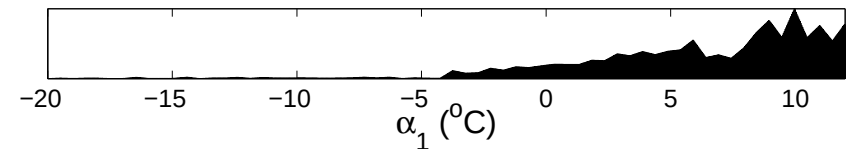
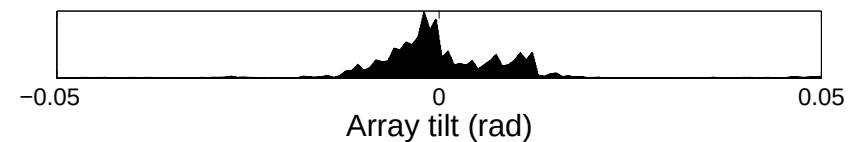
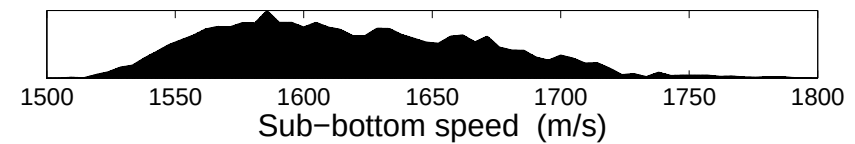
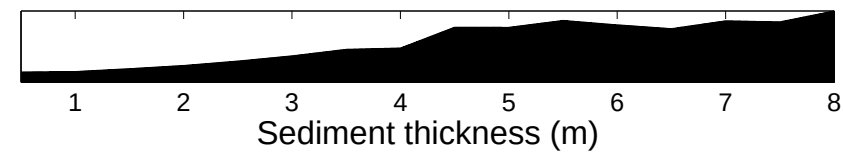
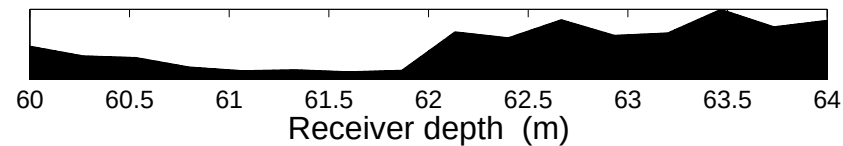
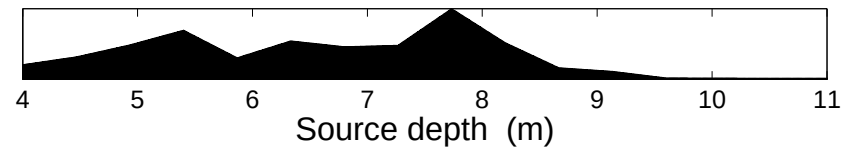
AOB drift, July 13, 2007



RADAR'07: AOB1 *a posteriori* distributions

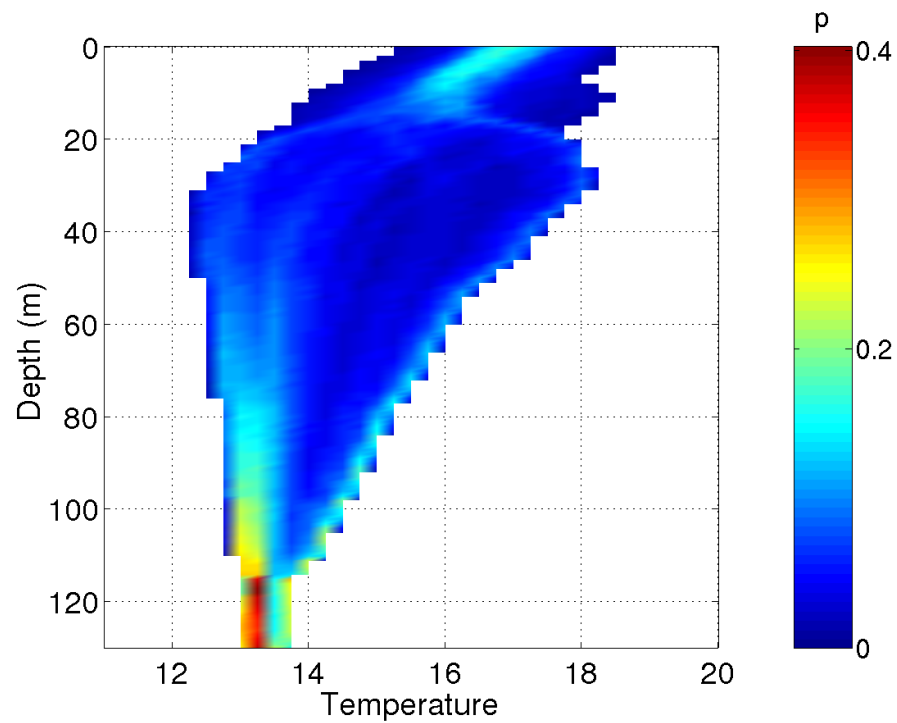


RADAR'07: AOB2 *a posteriori* distributions

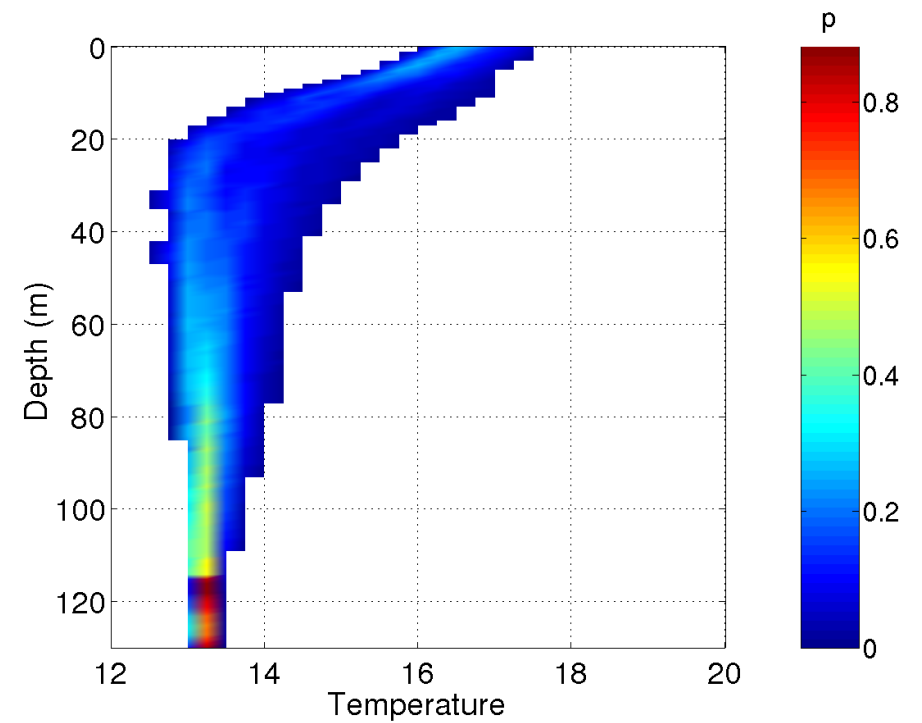


RADAR'07: inversion statistics.

AOB1

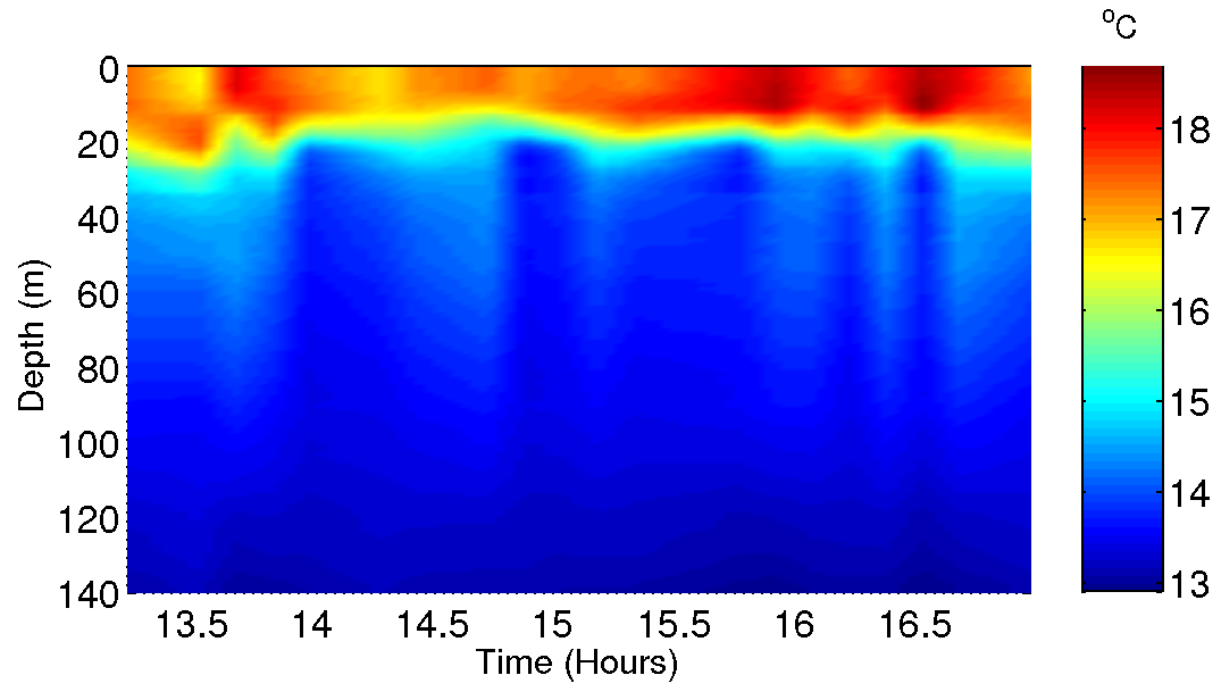


AOB2



RADAR'07: estimated temperature July 13, 2007

AOB22 - 16 hyd, 500 - 1000 Hz



Conclusions and perspectives

- continuous evolution of both methodologies and required technologies for REA
- support of sea-based operations as demonstrated through MREA-BP-RADAR
- acoustic/oceanic model integration
- spatially coherent processed buoys/sparse arrays
- include adaptive geoacoustic estimation