AREA
Adaptive Rapid Environmental Assessment

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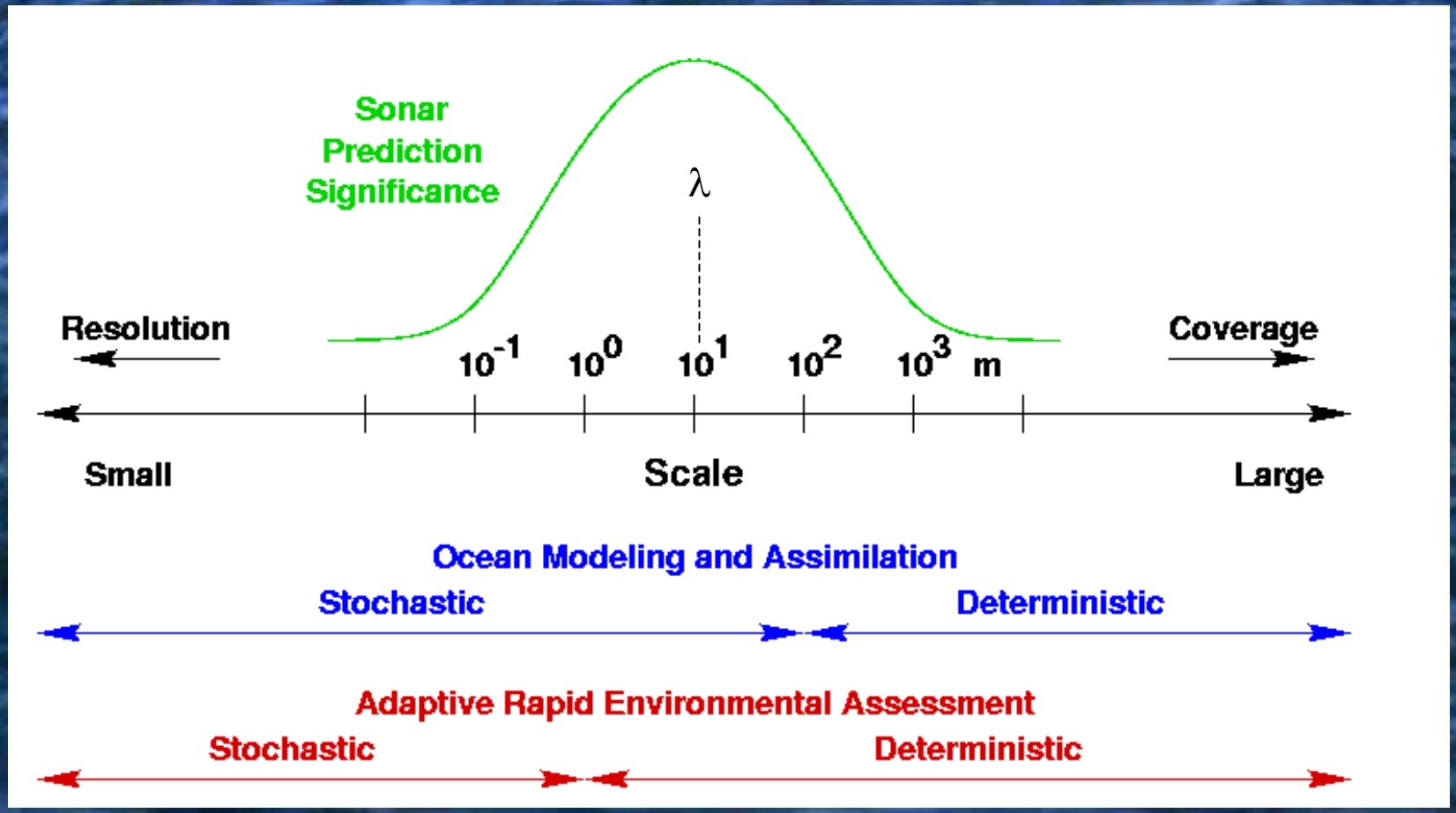
AREA
Motivation

- Uncertainty of acoustic environment directly affects sonar 'dB-budget' and detection/false-alarm statistics
  - Ocean will always remain undersampled: We cannot do anything about the '5 dB' stochastic variability.
  - We can do something about the deterministic uncertainty.
- Data-driven ocean modeling provides large scale ($L >> \lambda$) 4-D oceanographic field and uncertainty estimates, inadequate for sonar performance prediction.
- Ocean forecasts must be supplemented by in-situ measurements, but REA constrained by limited operational resources
- Can sonar detection/false-alarm statistics be robustly improved by optimizing in real time the deployment of REA resources based on nested ocean forecasts?

Ocean Environmental Scales



GOATS'2000 JRP

Generic Oceanographic Array Technology Systems

Objectives

Rapid Environmental Assessment (REA)

Map Procchio Bay with AUVs and fixed sensors
Validate bottom classification algorithms

Mine Countremeasures (MCM)

3-D scattering from rippled sea floor, and proud and buried targets
Multi aspect classification of proud targets by AUV SSS

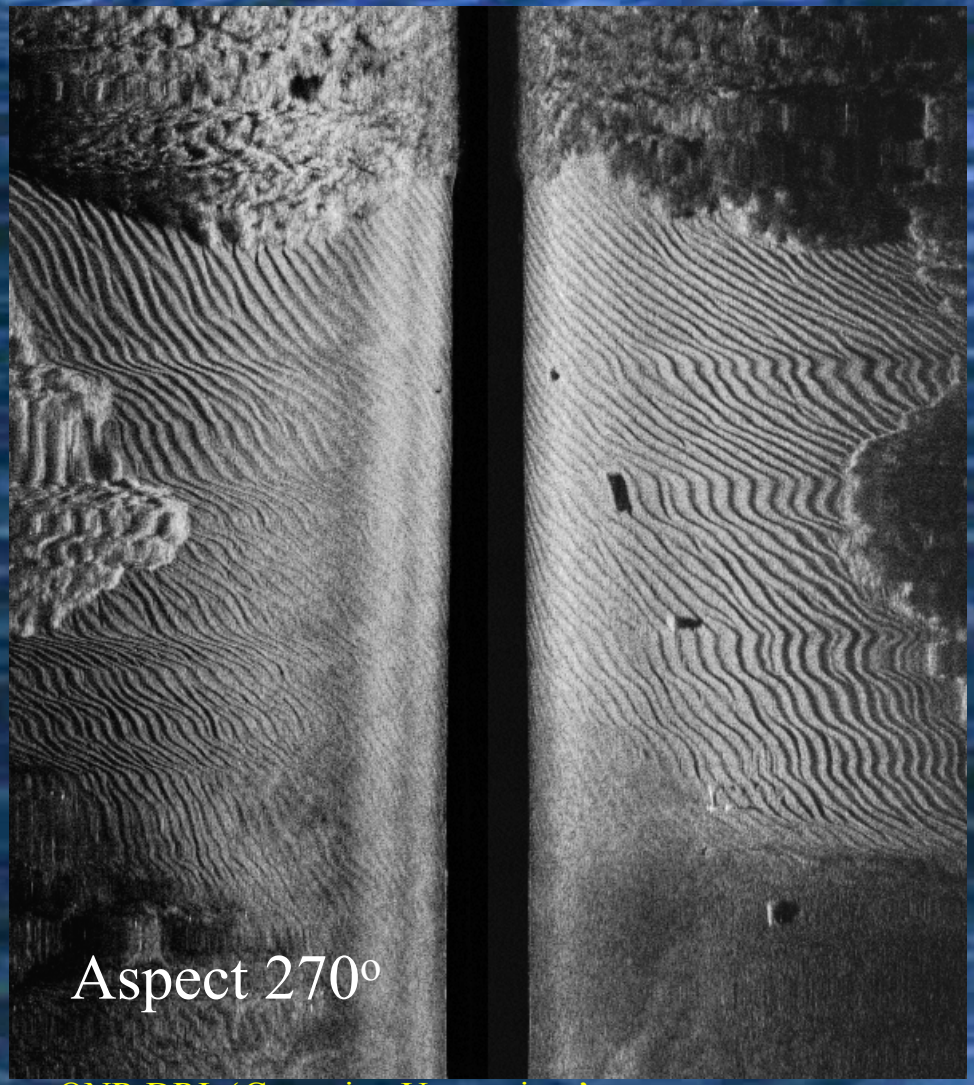
AUV technology

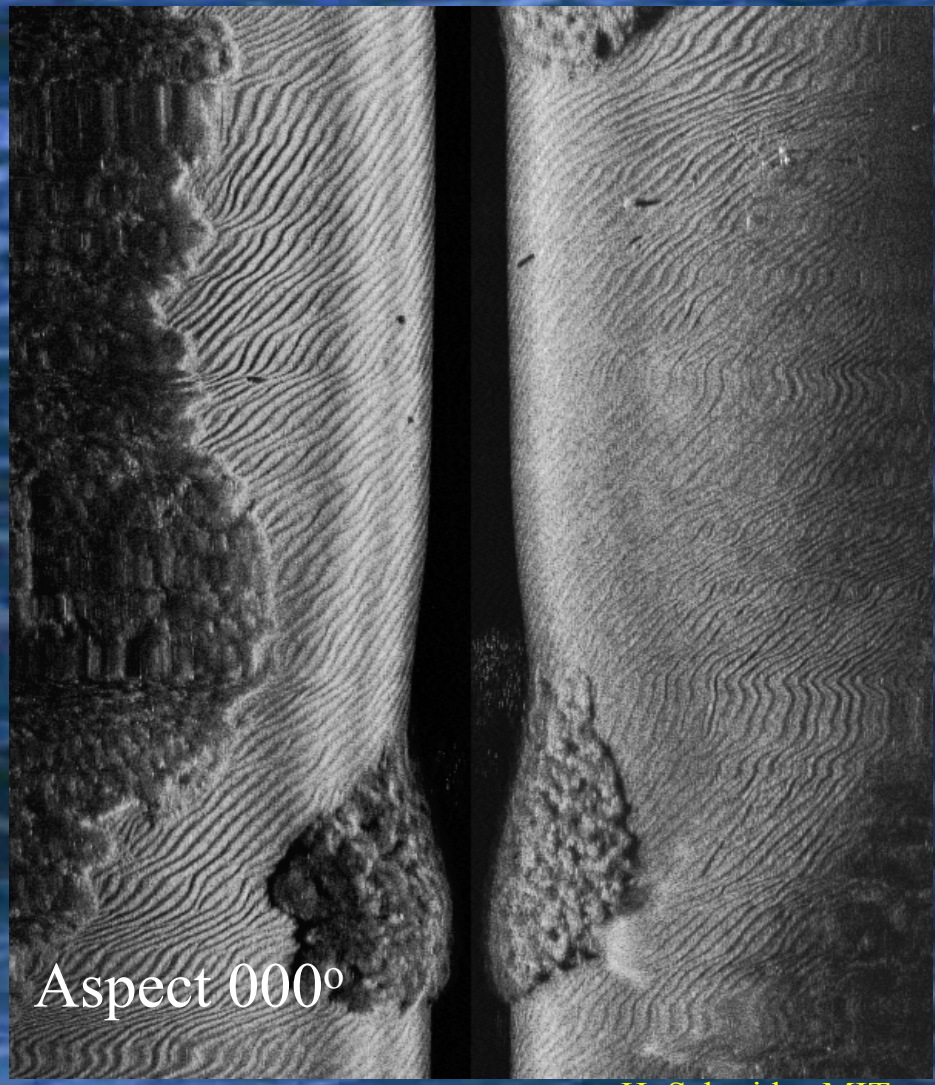
Validate bathymetric navigation algorithms
Target identification by AUV video processing
AUV cooperative behavior & adaptive sampling

Littoral Ocean Observation and Forecasting

Multiscale coastal ocean forecasting for MCM and REA
Multiscale adaptive sampling (Satellite remote sensing, ships, AUVs)

Multi Aspect
Side Scan Sonar Imaging





MEANS

Multi-scale Environmental Assessment Network Studies

UC

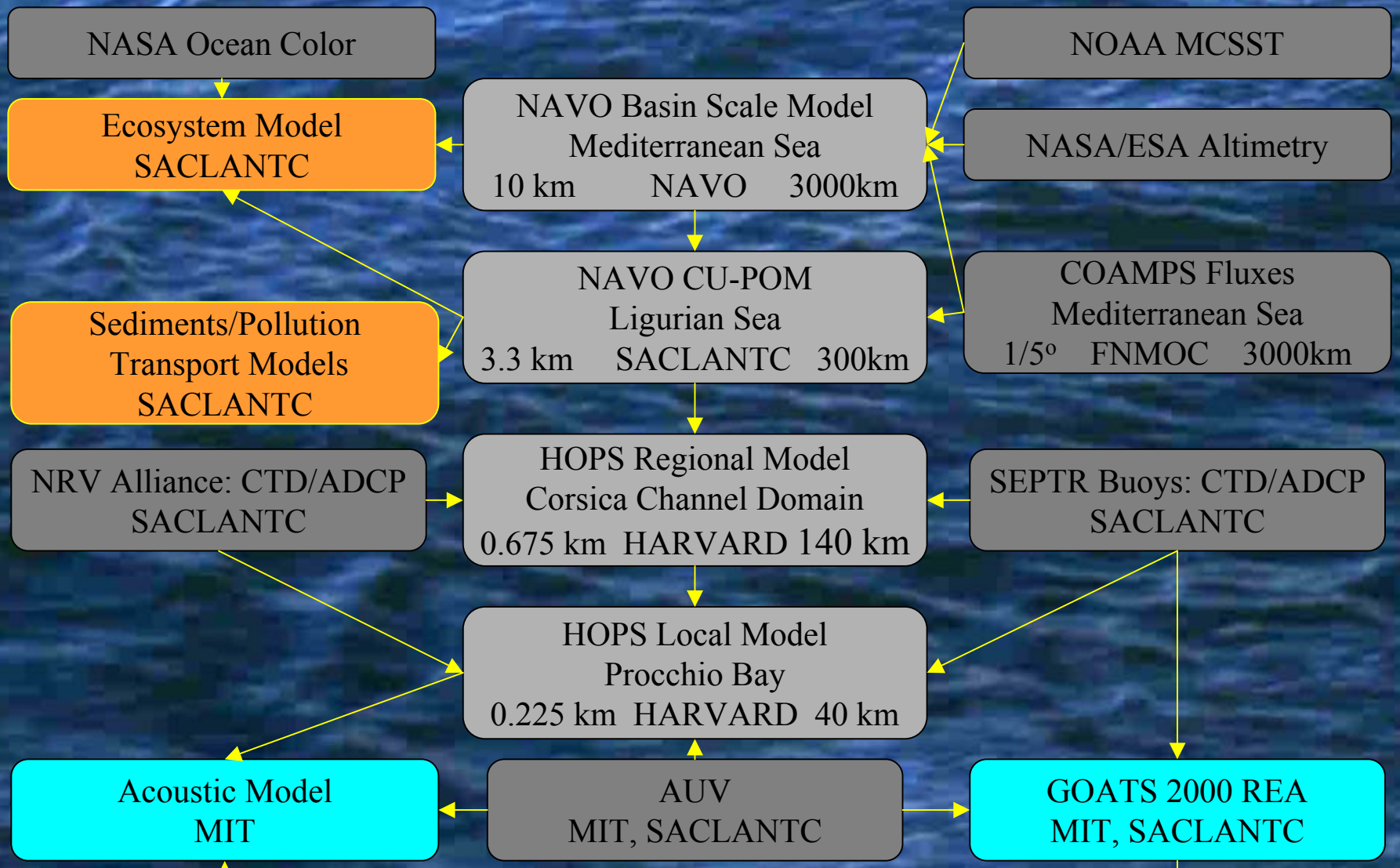
Motivation

- Advanced, high-resolution sonar processing and robust acoustic communication require accurate estimates of acoustic environment.
- Inadequate predictive skills of coastal acoustic environment
- Ocean environment will always remain under-sampled.
- Data-driven ocean modeling and forecasting can produce 4-D ocean field and error estimates.

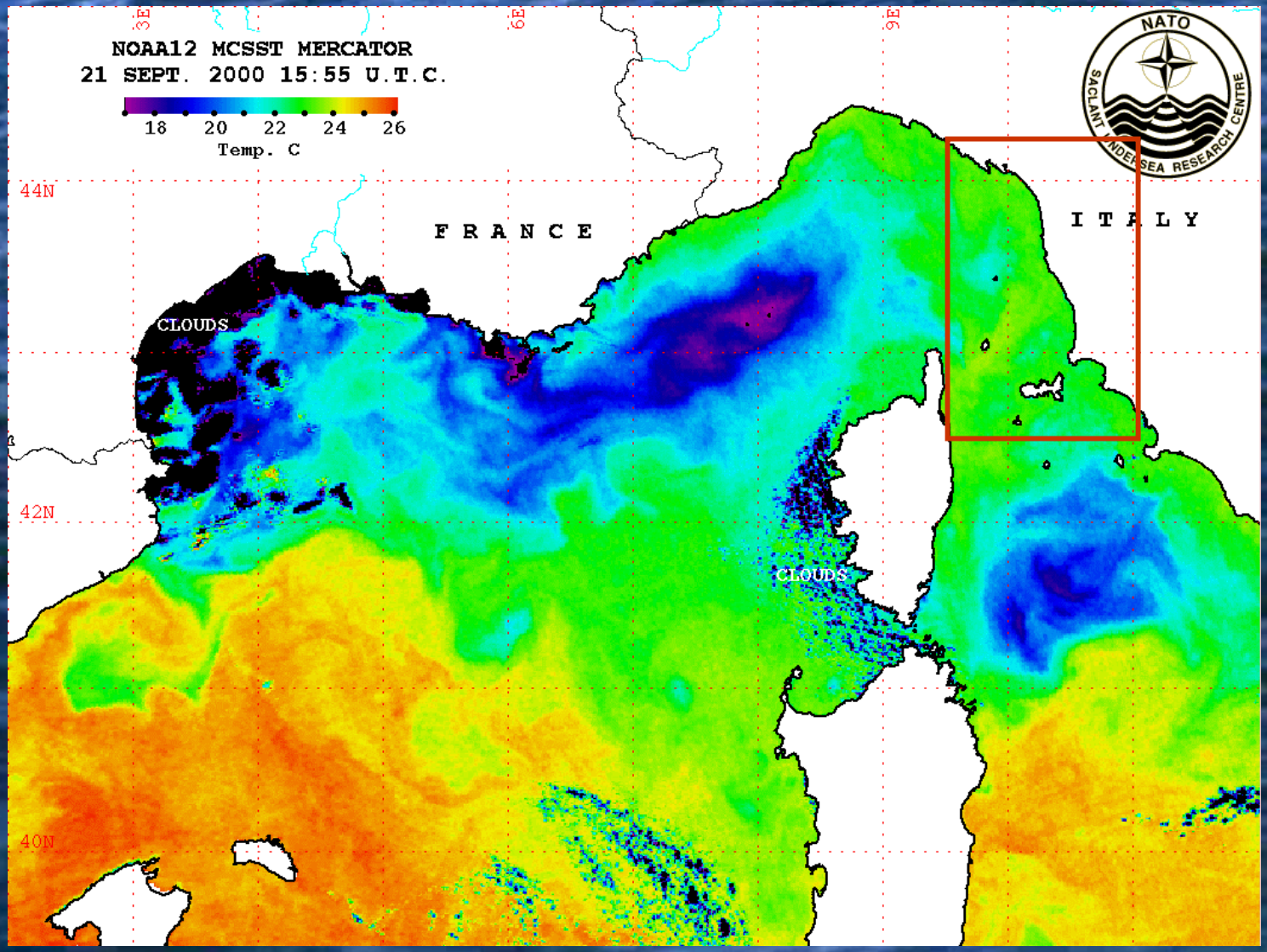
Objectives

- Investigate predictability of littoral acoustic environment by assimilation of multi-scale data streams into nested models.
- Predictability of VSW MCM environment. (SSP, Waves, Surf, Seabed ripples etc.)
- Investigate improvement by adaptive deployment of sampling resources.
- Significance of individual data streams to acoustic predictability.

MEANS
Nested Modeling and Observation Network



NOAA MCSST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21 SEPT. 2000 15:55 U.T.C.
18 20 22 24 26
Temp. C
3E
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ITALY
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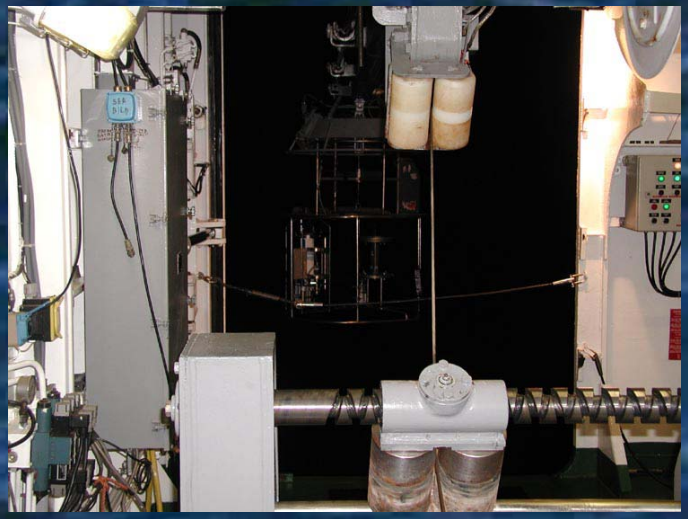
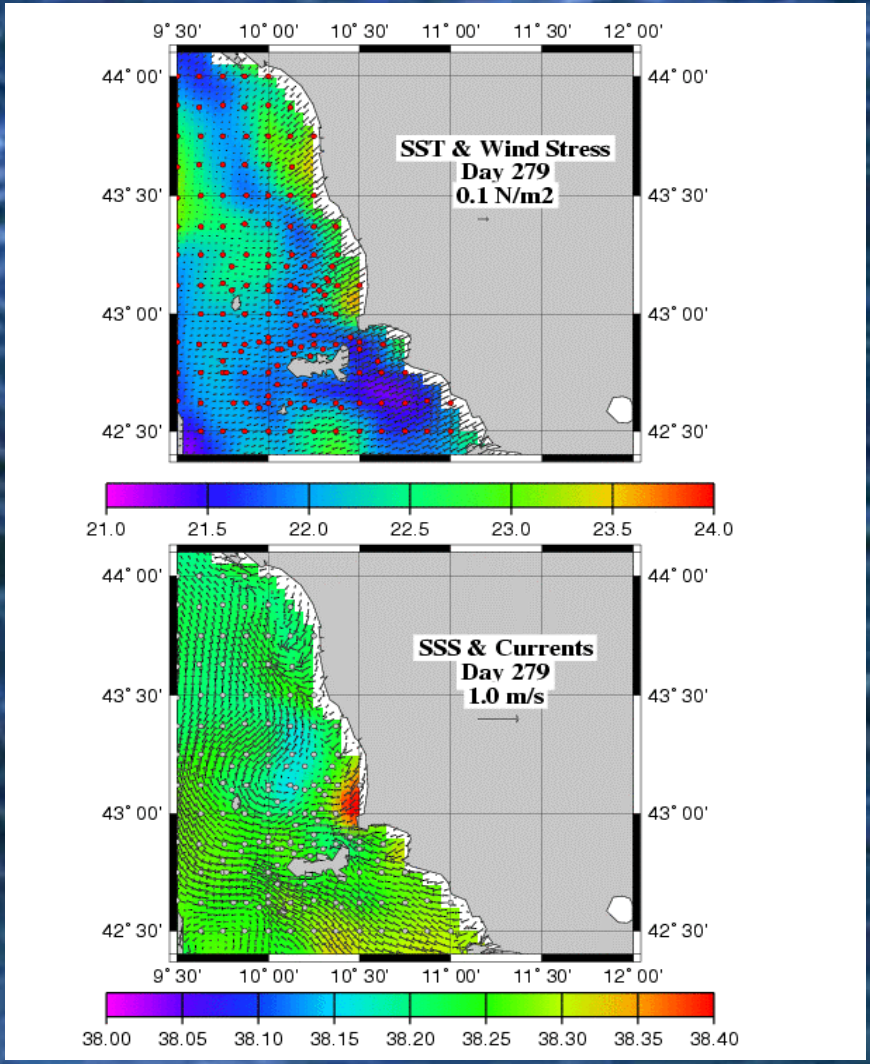
NATO
SACLANT UNDERSEA RESEARCH CENTRE

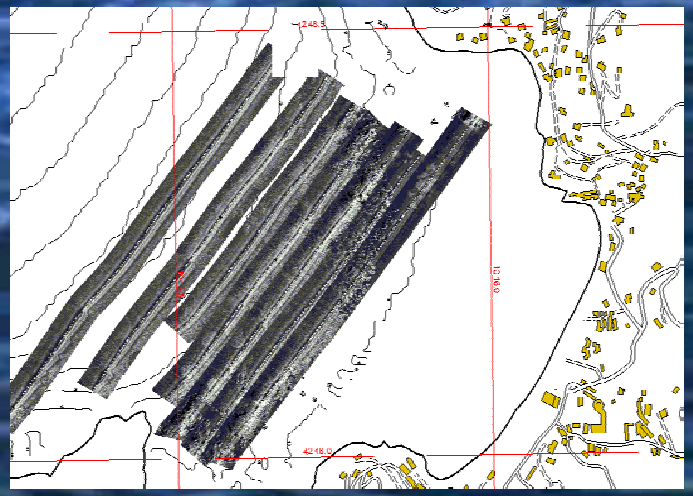
Initialization and Adaptive Sampling
R/V Alliance CTD/ADCP



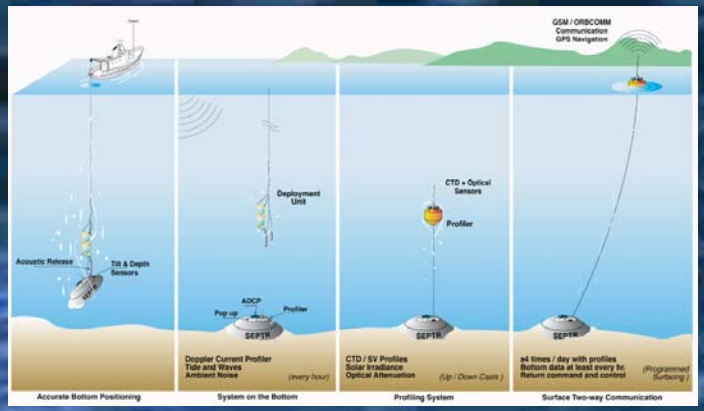


Rapid Environmental Assessment
AUV SSS/SBP - SEPTR CTD/ADCP

Side Scan Tiled Images



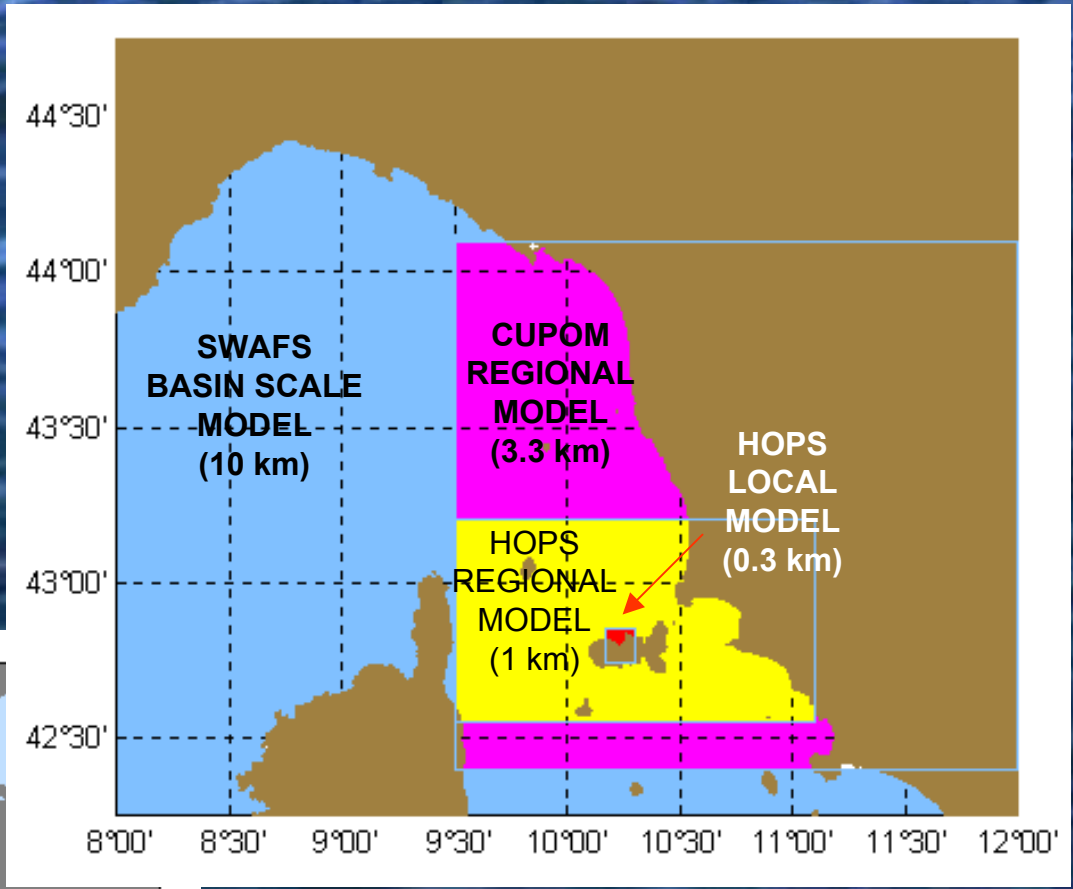
SEPTR ADCP /CTD Profiler

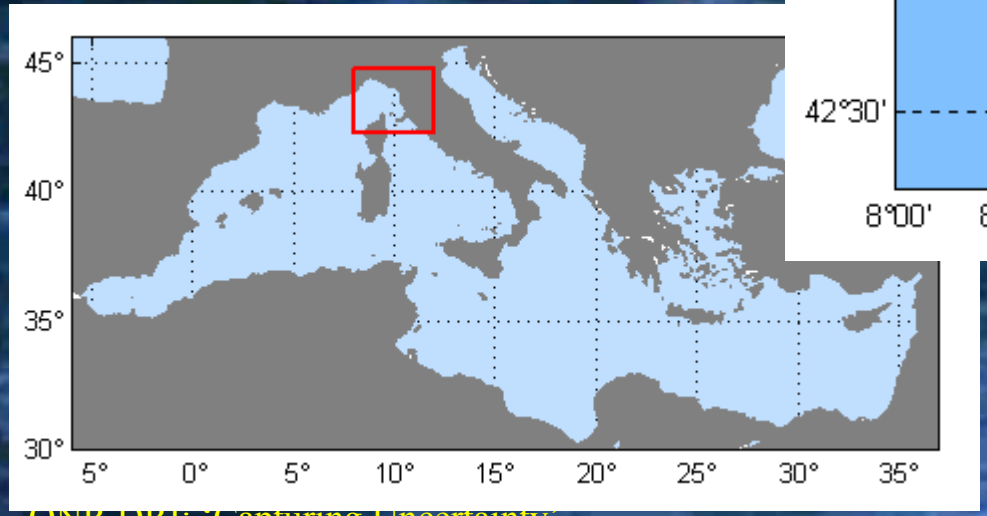


OEX

Triply Nested Ocean Circulation Models

Mediterranean	SWAFS
Ligurian	CUPOM
Channel	HOPS
Procchio Bay	HOPS

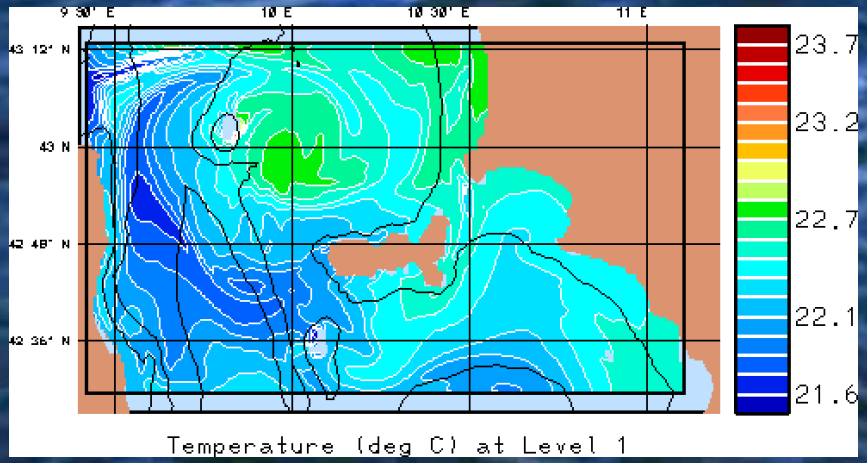




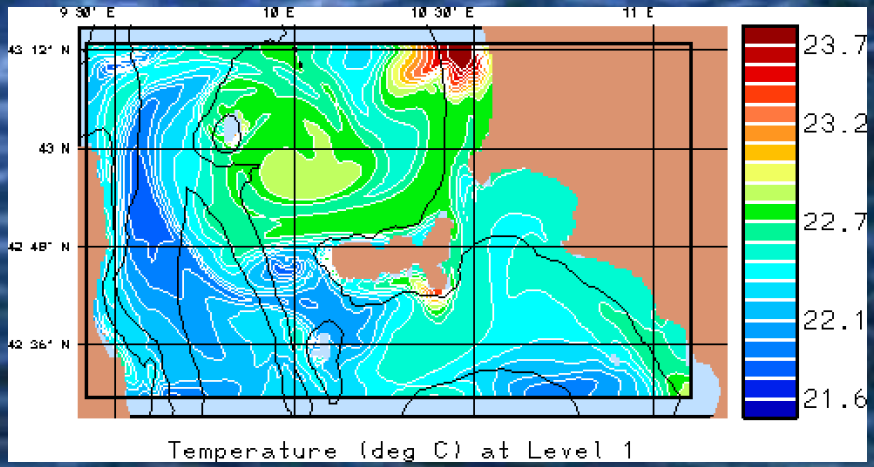
All models with "primitive equation" and about 20 "sigma" layers.

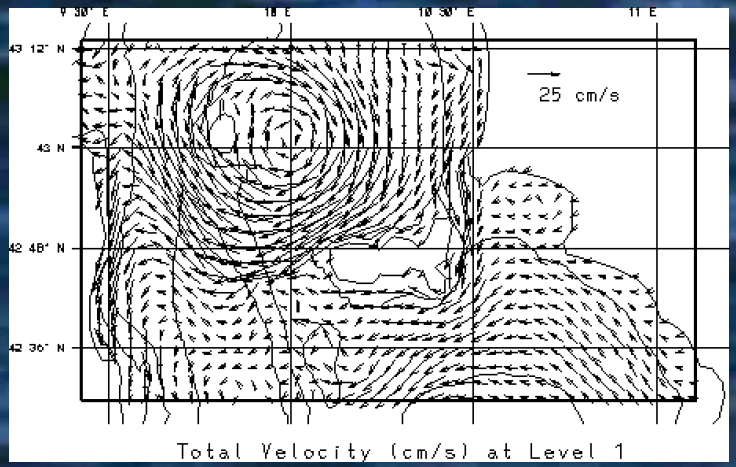
CUPOM - HOPS Nesting
04 Oct. 2000

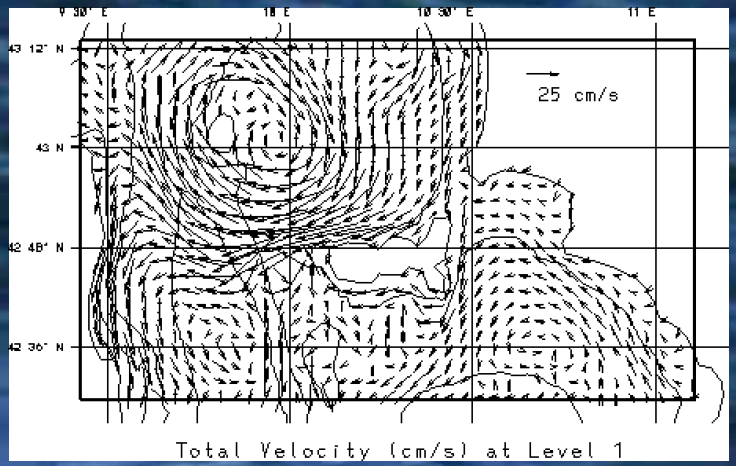
HOPS w/o CU-POM Boundary Conditions



HOPS with CU-POM Boundary Conditions



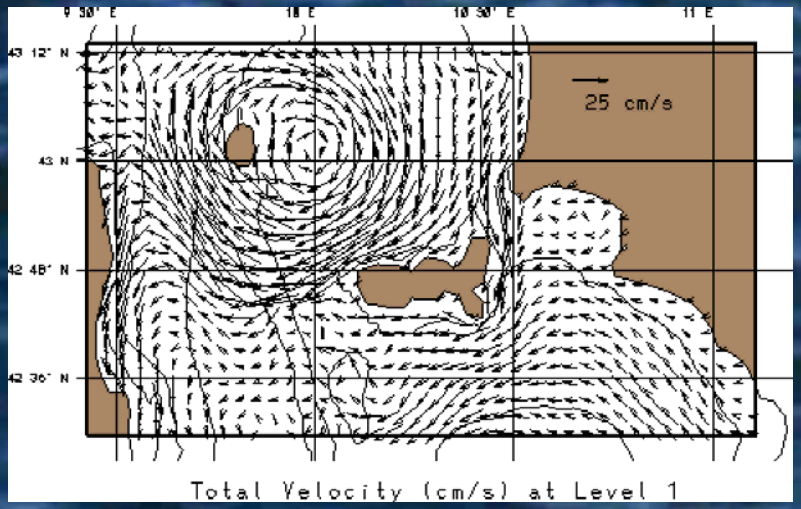




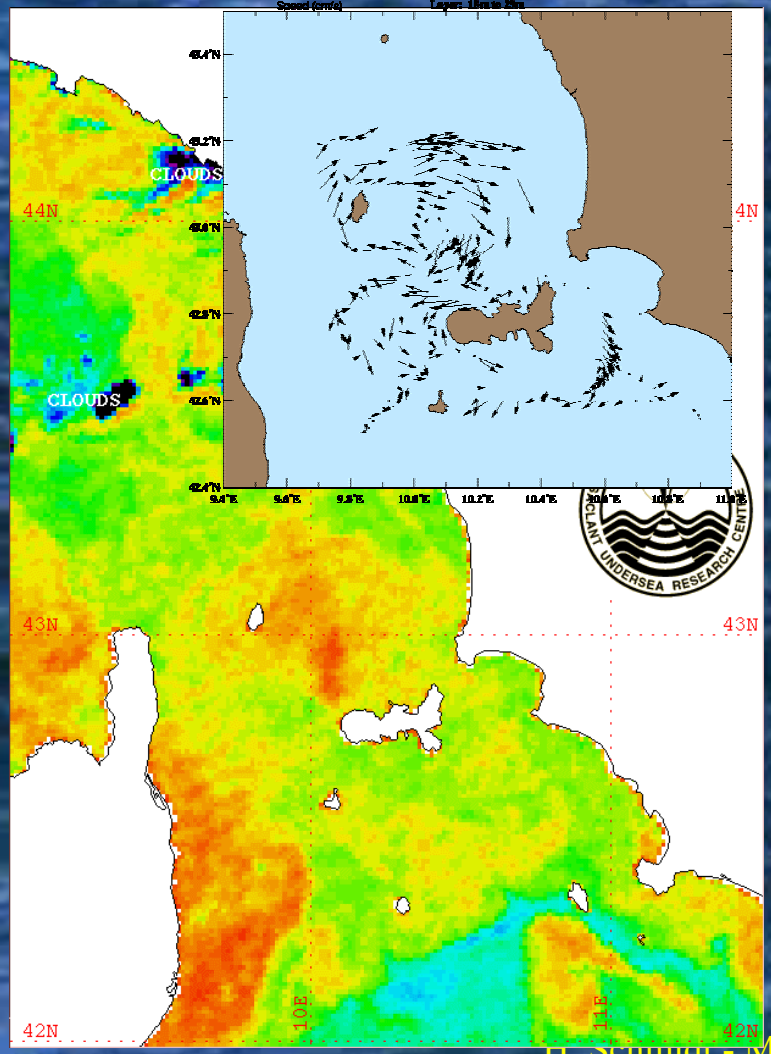
Mesoscale Activity Forecasting

- Sep. 25 2000: The warm surface water N of Elba forms the centre of an anticyclonic eddy

HOPS 48 h Forecast

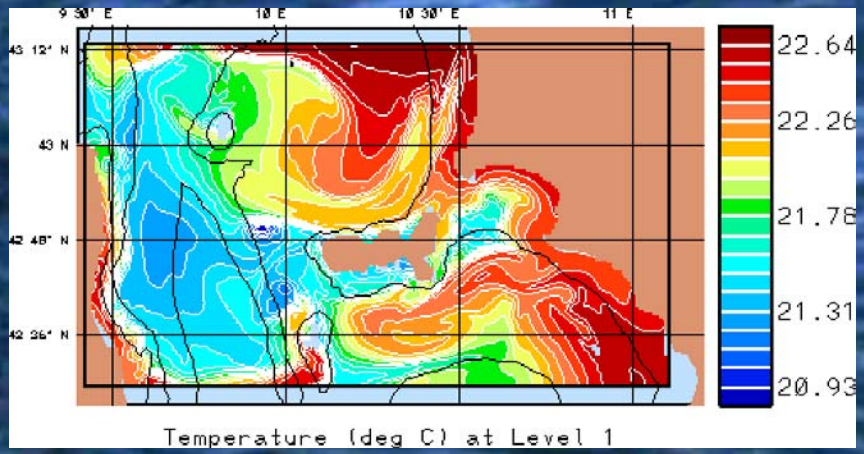


SST and ADCP Measurements

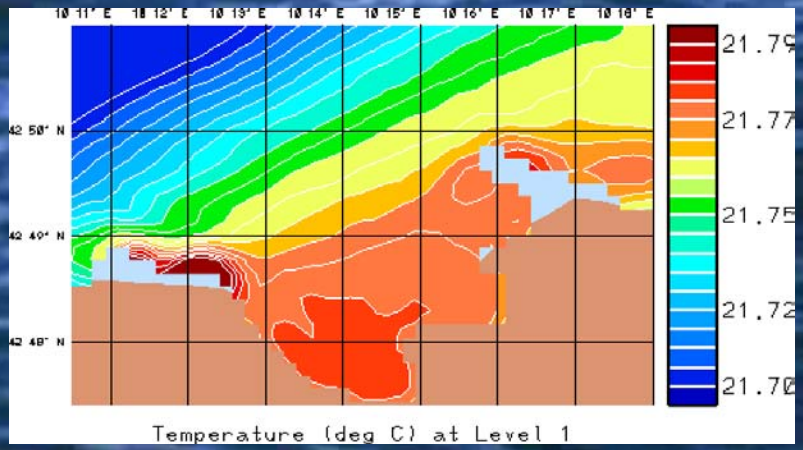


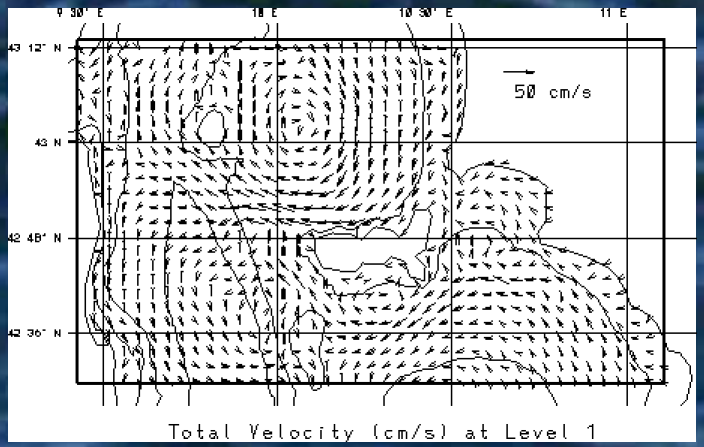
Regional/Local HOPS Nesting
09 Oct. 2000

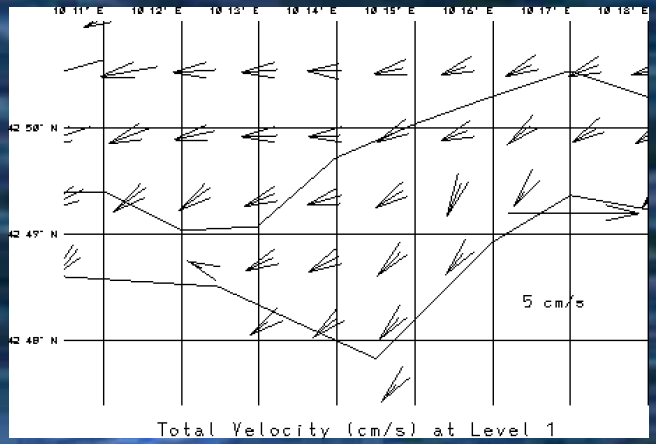
Regional Ligurian Sea HOPS Forecast



Local Procchio Bay HOPS Forecast





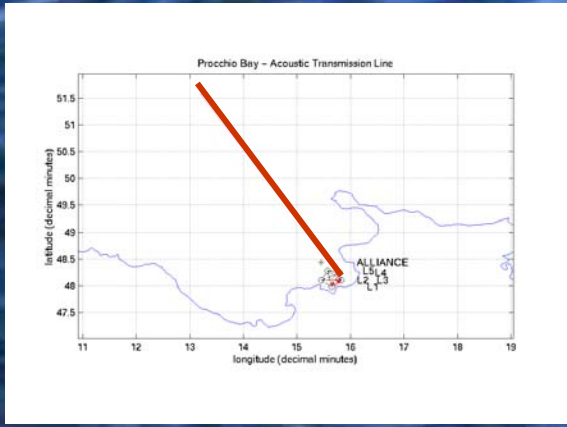


MEANS
Conclusions

- Data-driven, nested ocean modeling and forecasting provide field and error estimates consistent with direct measurements in coastal environment.
- Multi-disciplinary and multi-scale data streams are crucial to robust and accurate littoral acoustic environment prediction.
- Adaptive deployment of sampling resources enhances forecasting performance significantly.
- Forecast resolution and uncertainty inadequate for littoral acoustic predictability.

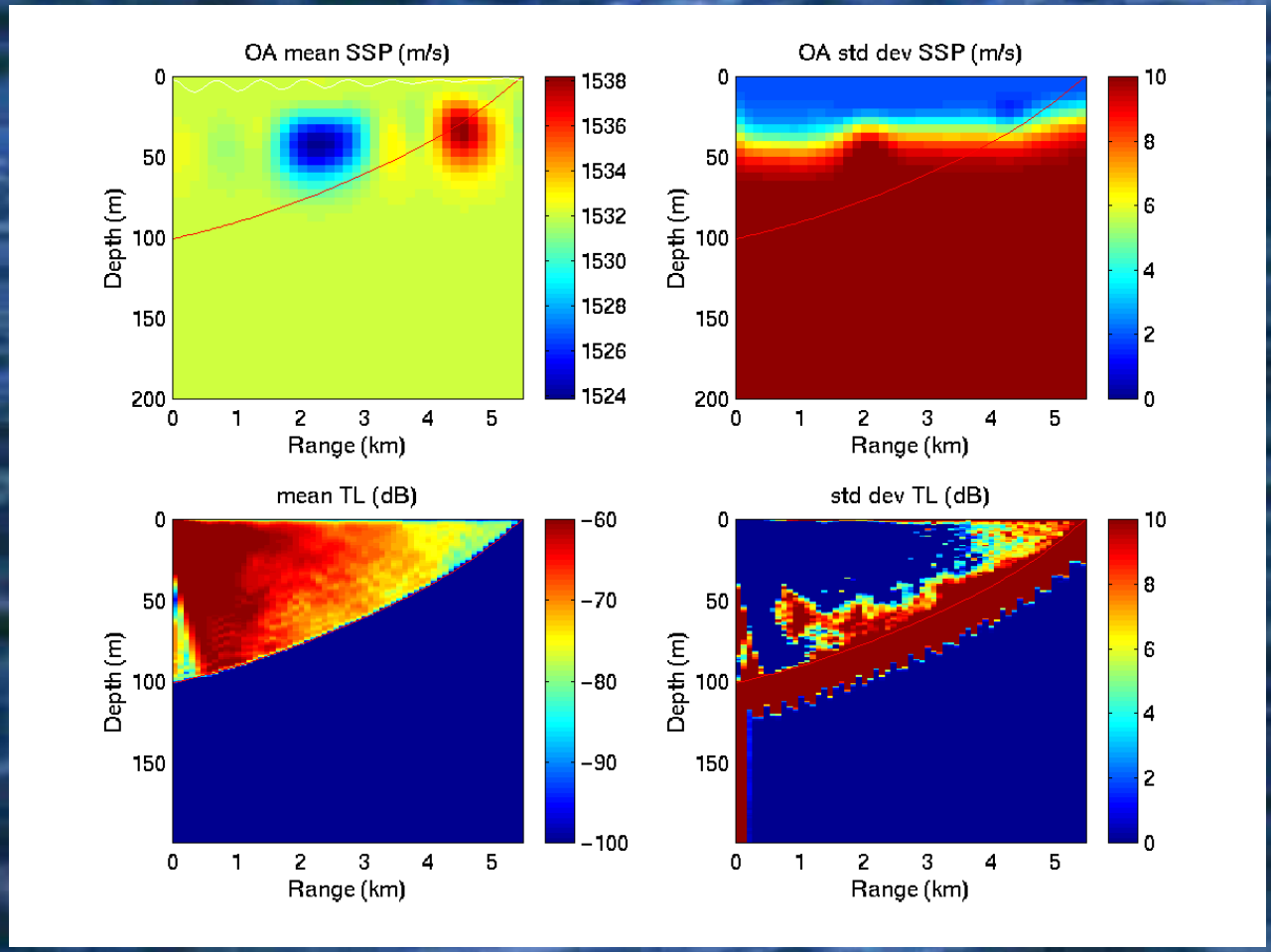
http://goats.saclantc.nato.int

Acoustic Environment Predictability SRS-SST

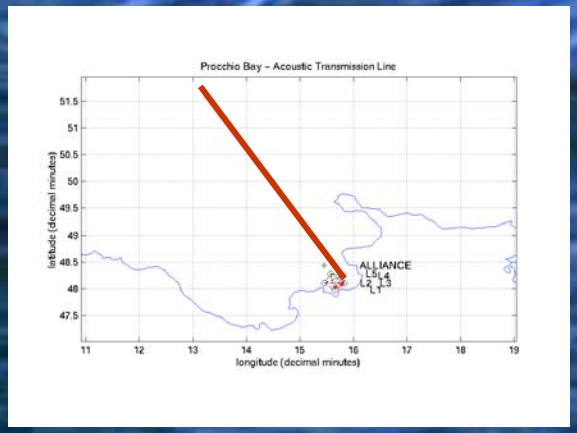


- Procchio Bay SSP model forecast by HOPS.
- Sampled by Satellite remote sensing (SST)
- Acoustic source:
  - SD = 20 m
  - F = 1 kHz
- SSP Statistics:
  - Lh = 500 m
  - Lv = 20 m

SSP and TL Statistics

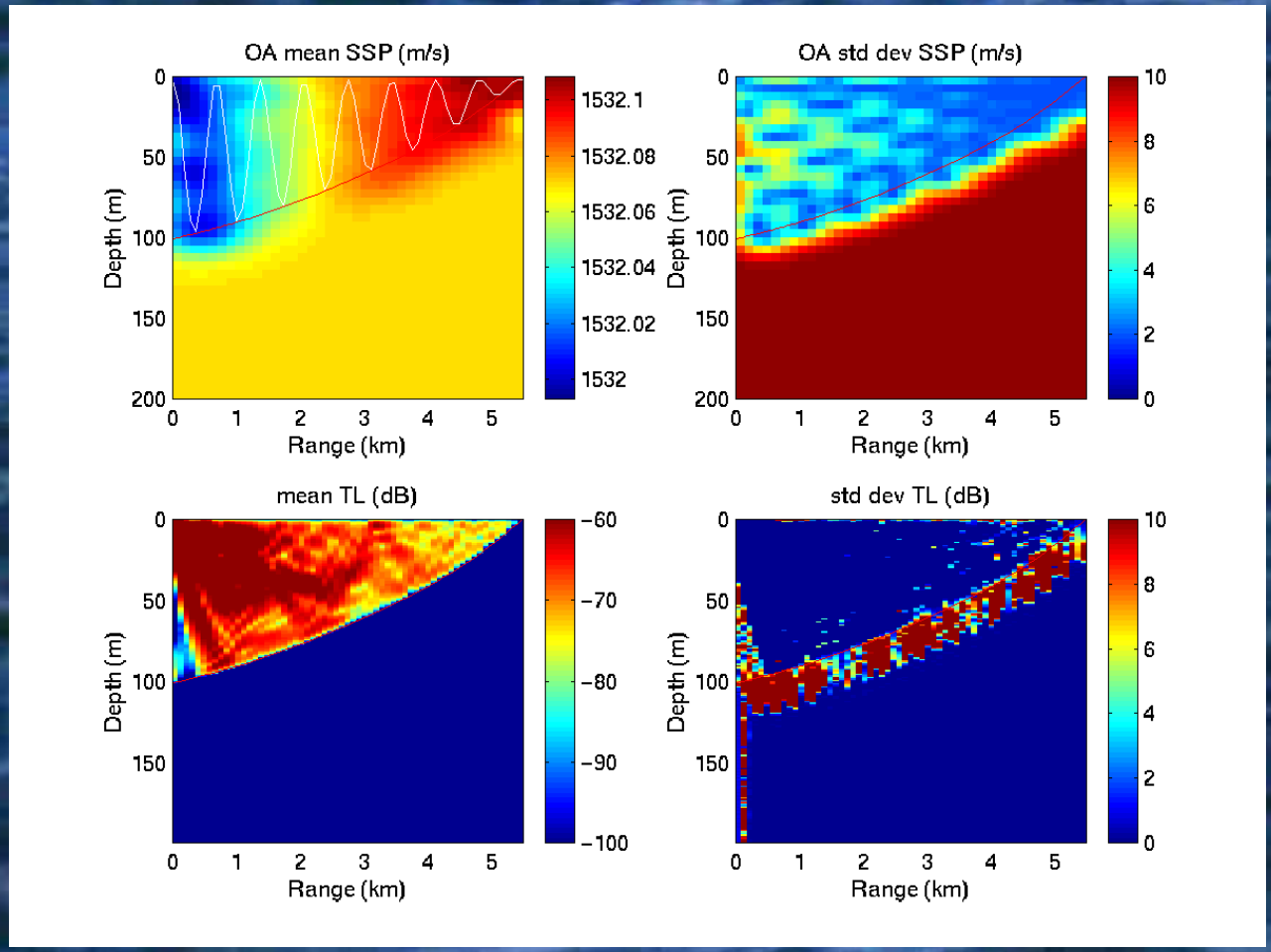


Acoustic Environment Predictability SRS-SST



- Procchio Bay SSP model forecast by HOPS.
- Sampled by AUV Yo-Yo CTD.
- Acoustic source:
  - SD = 20 m
  - F = 1 kHz
- SSP Statistics:
  - Lh = 500 m
  - Lv = 20 m

SSP and TL Statistics



AREA

Adaptive, Rapid Environmental Assessment

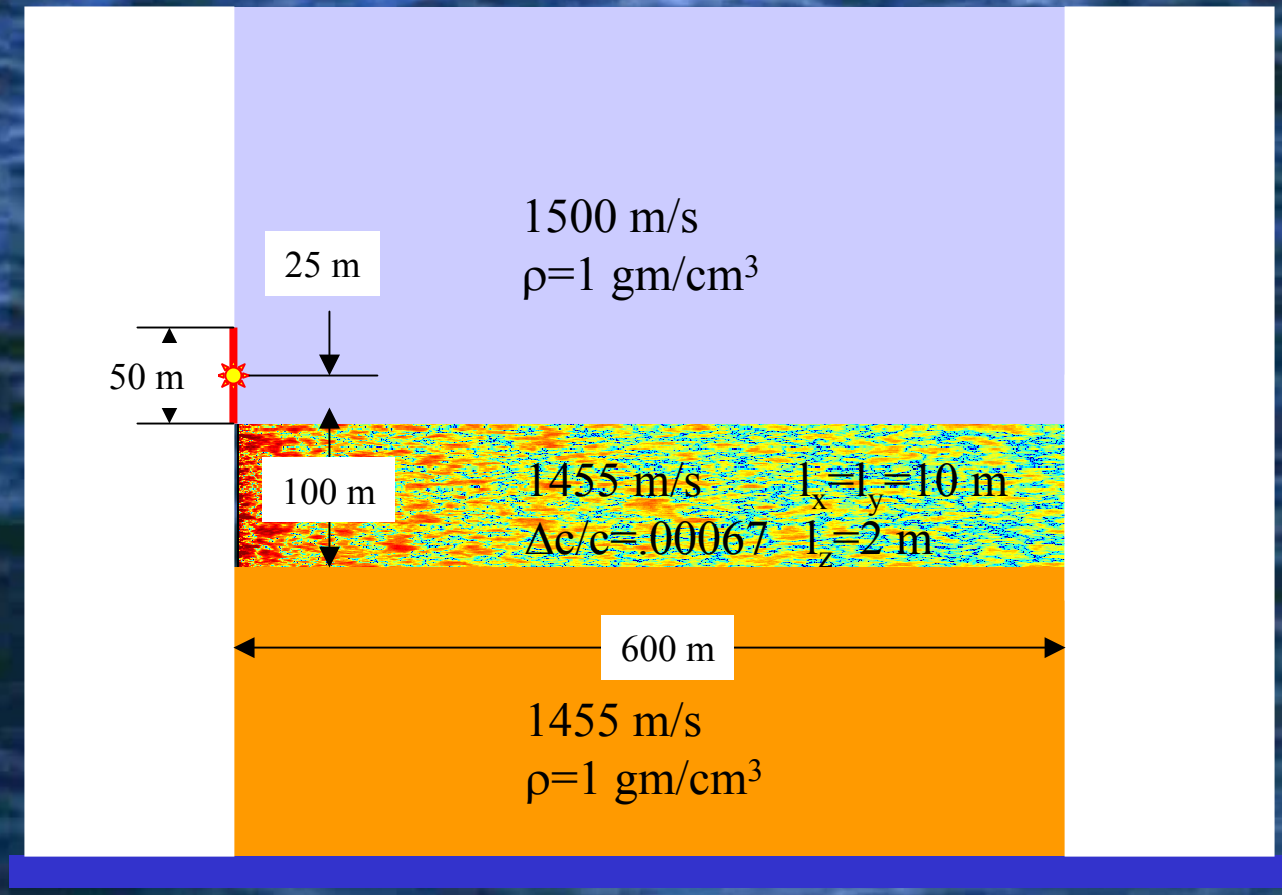
- Now- and forecasting of spatial and temporal statistics of ocean environment by nested modeling and assimilation
- Translate forecasted ocean statistics to acoustic uncertainty (mean TL, std. dev.) using Monte-Carlo simulations (PE)
- Derive PDFs of sonar performance uncertainty over oceanographic parameters
- Optimal deployment of REA resources for minimizing sonar performance uncertainty within operational/resource constraints.
- Updated ocean field estimate by objective analysis of REA data
- Reduced uncertainty of sonar performance prediction

AREA
Sonar Performance Modeling

- Use historical or forecasted environment statistics to generate realizations of acoustic environment
  - Water column oceanography
  - Seabed geophysics
- Use environmental acoustic models to model associated sonar signals for actual active or passive configuration
  - Passive, range-dependent: PE, adiabatic and coupled modes
  - Active: OASES-3D waveguide target scattering and reverberation model
- Monte-Carlo estimation of sonar performance PDFs

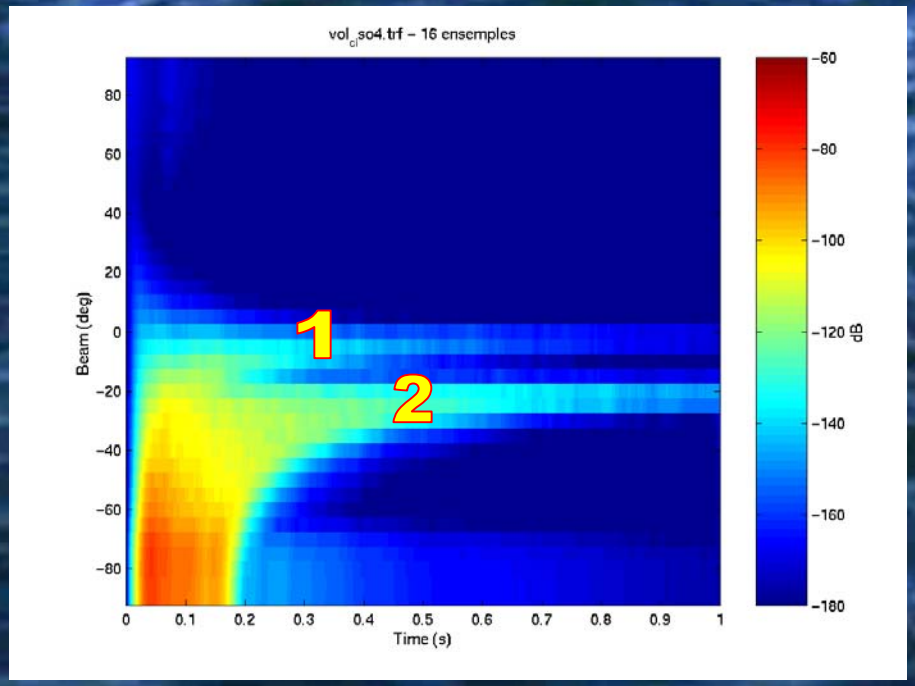
Scenario 1
Slow Sediment Layer

Monostatic Scattering geometry

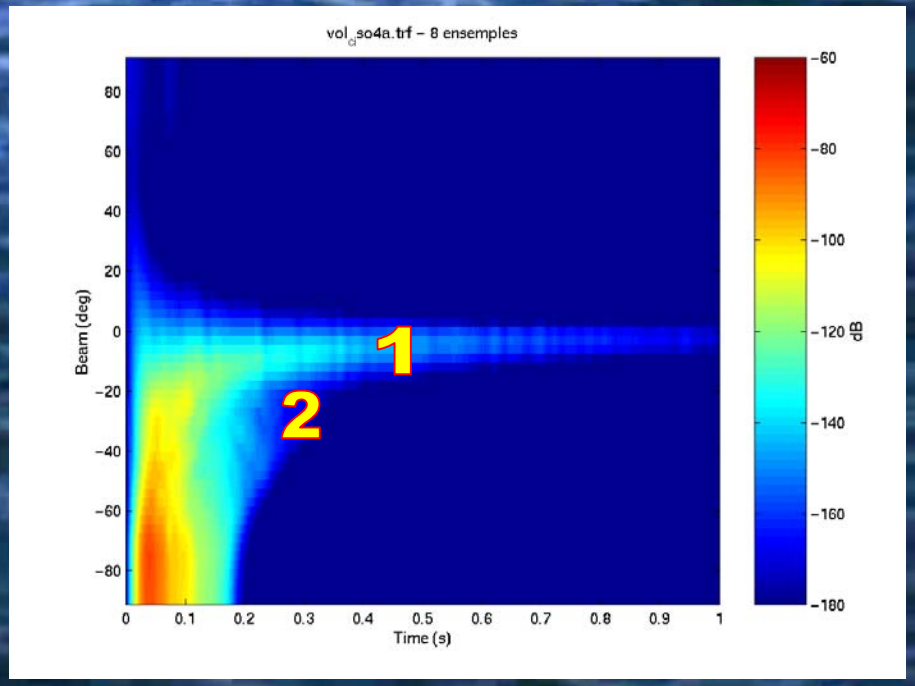


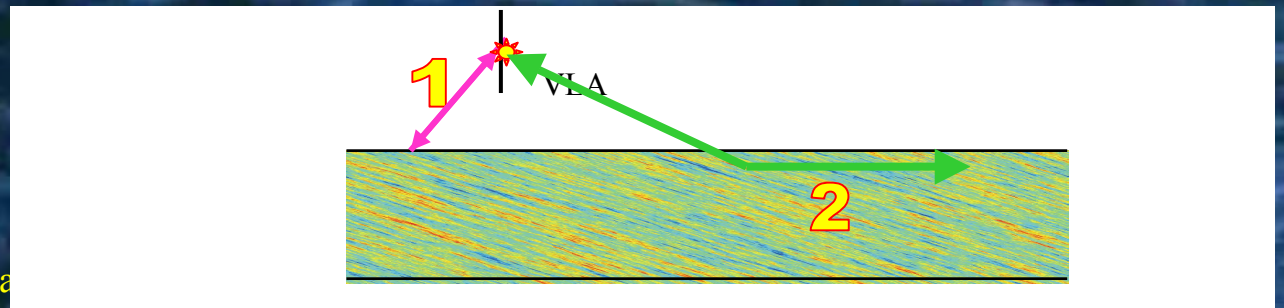
Relative Contribution of Scattering Evanescent and Head Waves

Lossless



0.5 dB/lambda



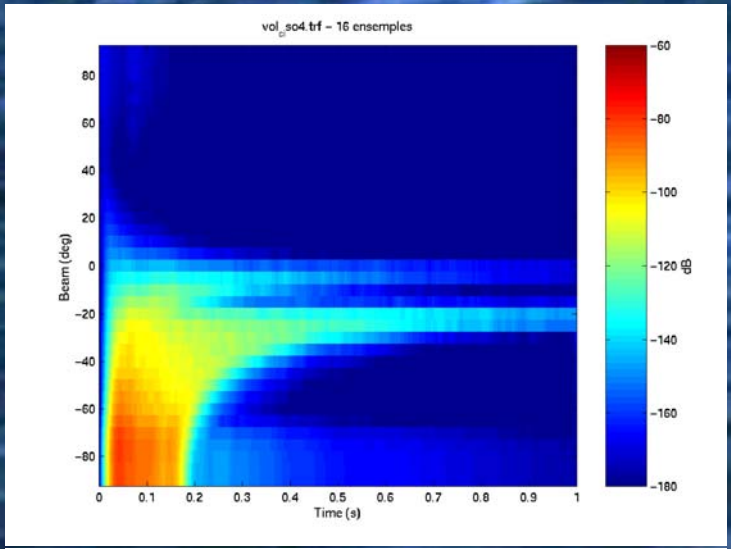


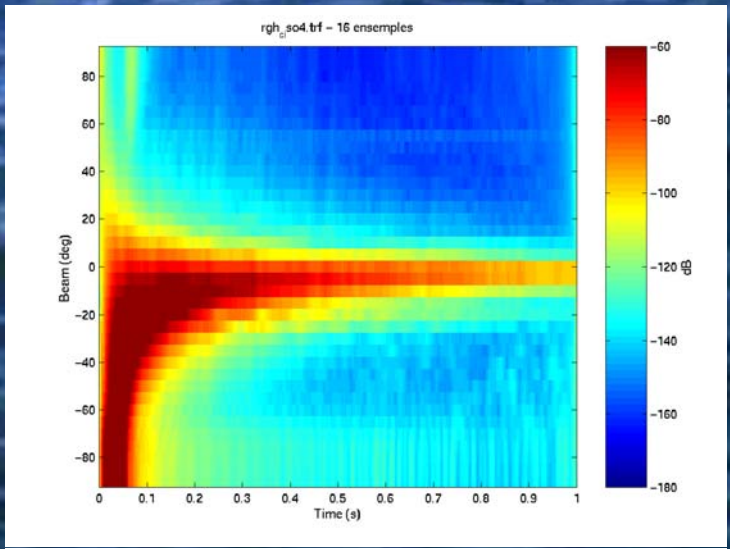
Variance of Backscattered Field Volume and Roughness

Volume Scattering

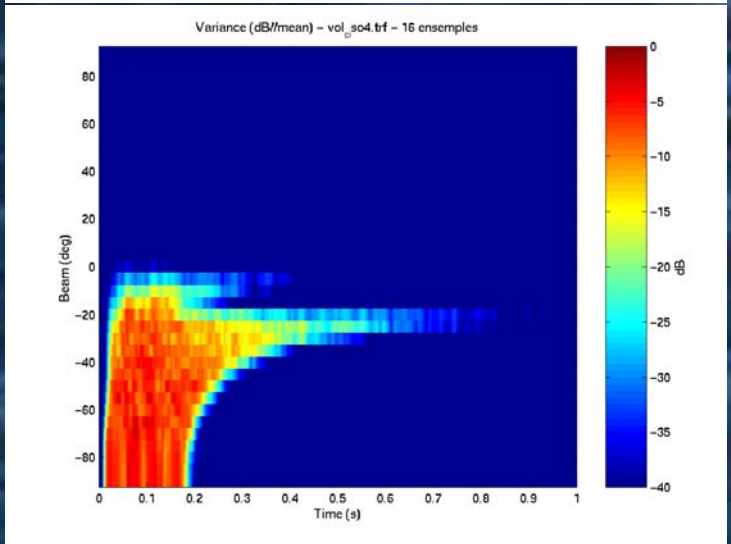
Seabed Roughness Scattering

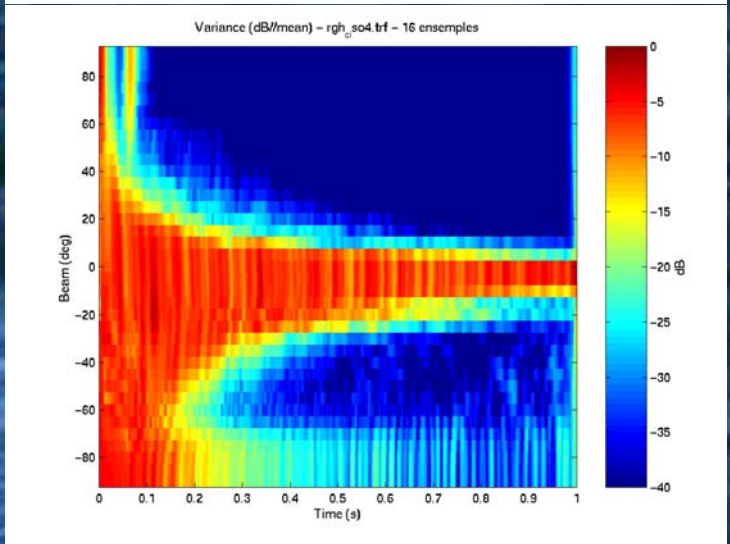
Mean Backscatter dB



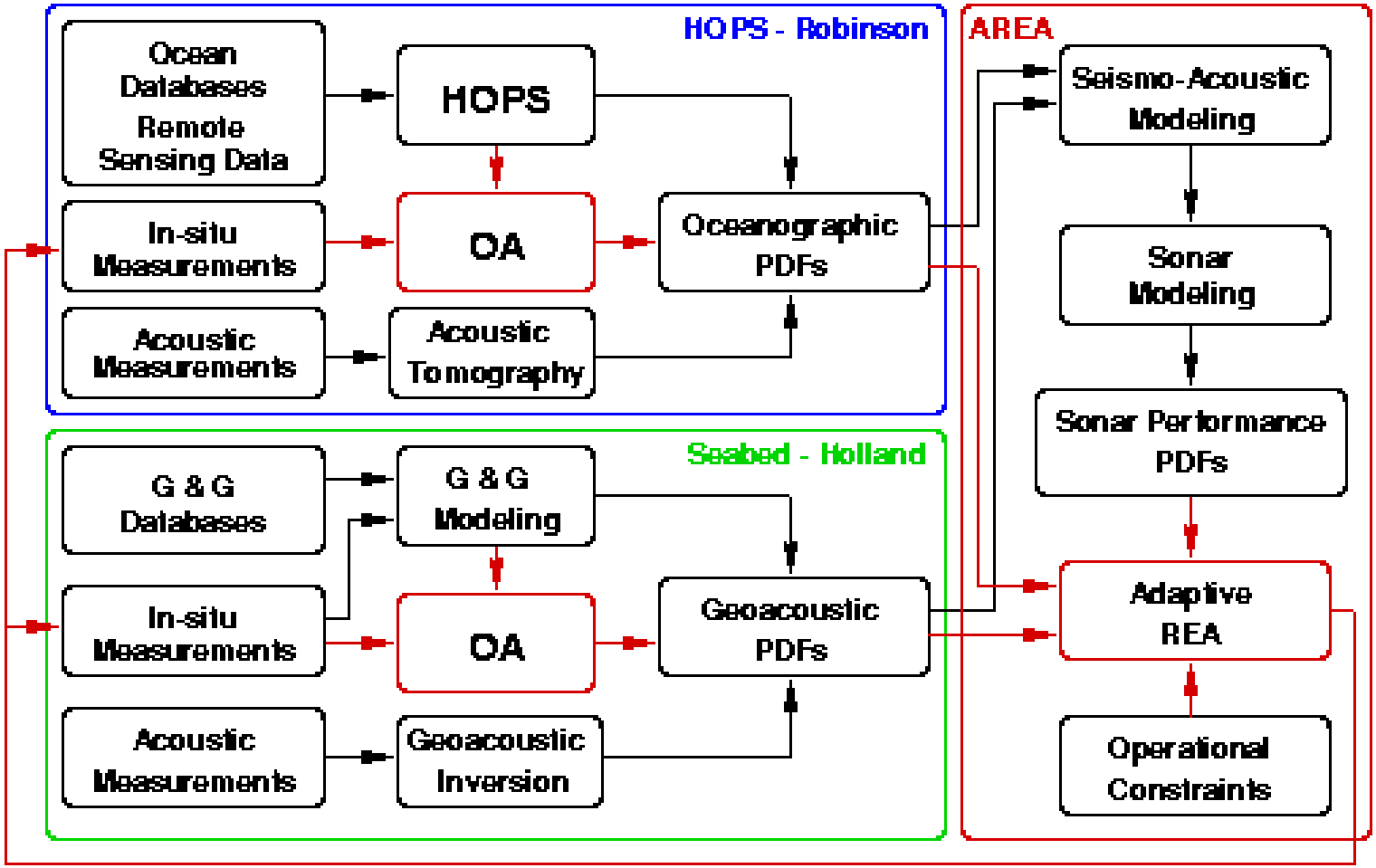


Variance dB//mean





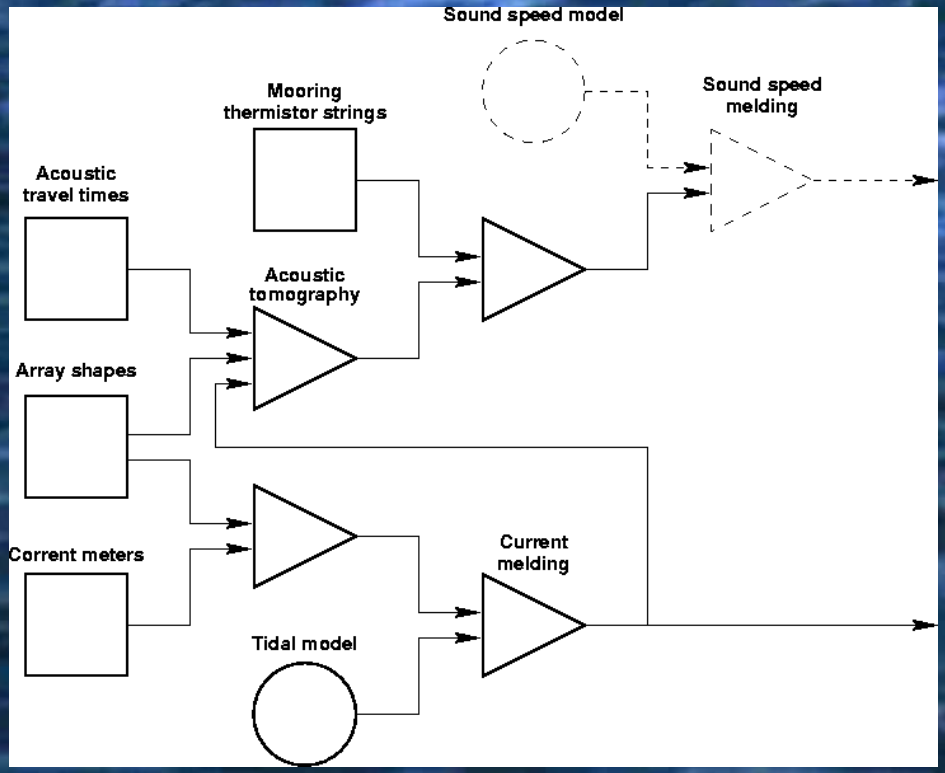
AREA
DRI Partnerships

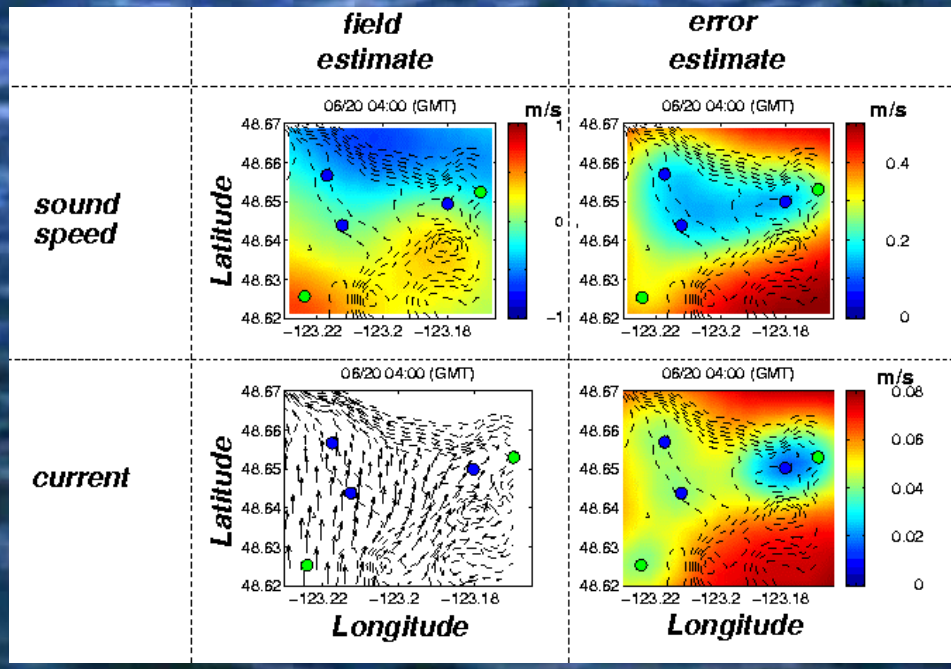


AREA
MIT DRI Research Plan

- For specific sonar configurations (e.g. HLA-MFP)
  - Characterize relative significance of oceanographic and geophysical parameters using theoretical parameter resolution bounds such as Cramer-Rao lower bounds
  - Investigate robust parameterizations which are quasi-orthogonal in sonar performance metric (AEOF).
  - Develop conditional probability distributions for optimal REA resource allocation for estimating AEOFs..
- Perform OSSEs in collaboration with other DRI teams:
  - 4-D HOPS forecasts from PRIMER and ASCOT01 experiments
  - Geophysical databases and in-situ measurements
  - Monte-Carlo sonar performance statistics using wave-theory seismo-acoustic models.
- Develop new consistent Acoustic Data Assimilation (ADA) concept in collaboration with HOPS team.

Haro Strait'96 Primer Experiment
Acoustic Data Assimilation





AREA
MIT DRI Research Plan

- 2004 AREA experiment with SACLANTCEN/HOPS
  - HOPS nested forecasting
  - MFP experiment
  - Real time Adaptive Rapid Environmental Assessment with AOSN.