Focused Acoustic Forecasting-05 (FAF05): Real-Time Physical-Acoustical Modeling, Predictions and Adaptive Sampling

Pierre F.J. Lermusiaux, Ding Wang (MIT)
P.J. Haley, Jr., W.G. Leslie, H. Schmidt et al.

Thanks to:

NURC: **E. Coelho, E. Nacini and A. Cavanna**

Cro. Met. Service: **M. Tudor**

HU: **A. Robinson**

http://www.deas.harvard.edu/~leslie/FAF05/

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1. **Collaborative Goals and Objectives**
2. **Results and Accomplishments**
3. **Methodology and Conclusions**

MIT, FAF-05 Hot-Wash-up, Sept 12, 2005

FAF'05:
July 11-29, 2005
Isola di Pianosa, Italy

FAF-05: Collaborative Goals and Objectives

Emphasis on methodology development and engineering tests

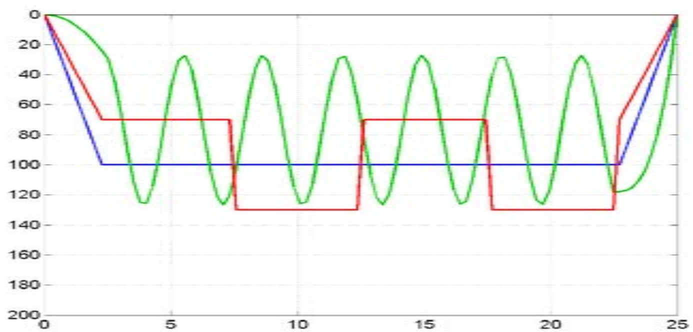
- **Develop new algorithms and software for initiating the coupling of Harvard and MIT methodologies/software**
  - HU real-time ocean environmental modeling, uncertainty prediction and adaptive sampling methodologies
  - MIT adaptive rapid environmental assessment and acoustic predictions
- **Test and improve these algorithms and software in real-time**
- **Issue physical-acoustical adaptive sampling recommendations every day**, aiming to
  - Capture the vertical variability of the thermocline (due to fronts, eddies, internal waves, etc)
  - Minimize the corresponding uncertainties.

  Adaptive sampling plans are computed based on 1-to-2 days environmental forecasts of fields and uncertainties.

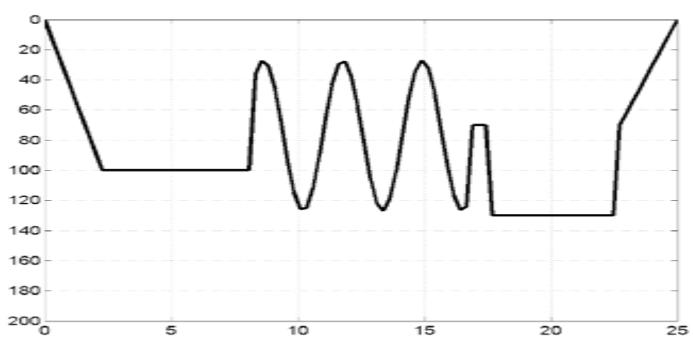
Adaptive Sampling in Vertical Cross-Sections

AUV-Track Base Lines - For - Specific Sound-speed Features

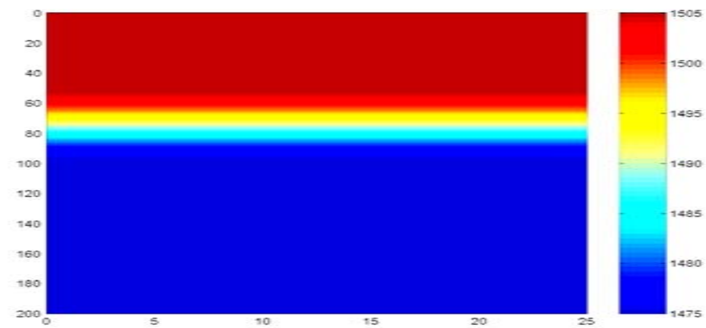
Base Lines



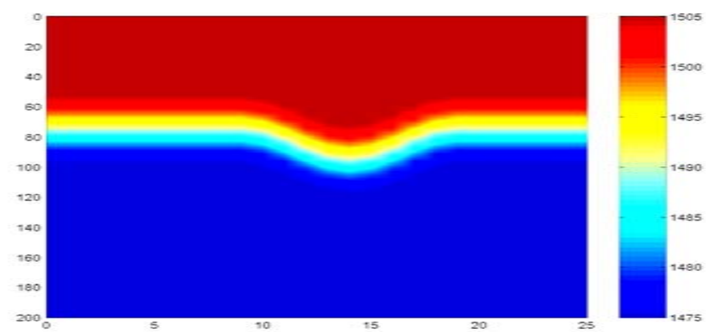
Composite Base Lines



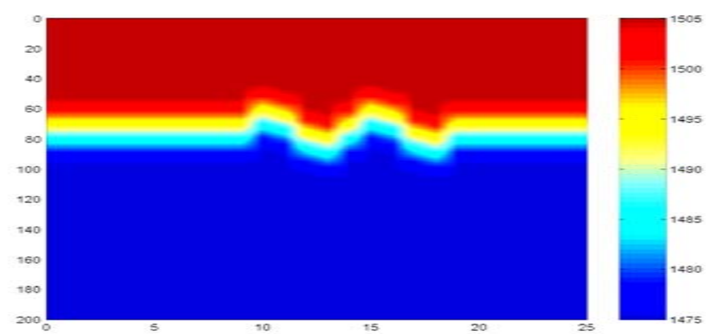
Thermocline



Eddy



Internal Wave

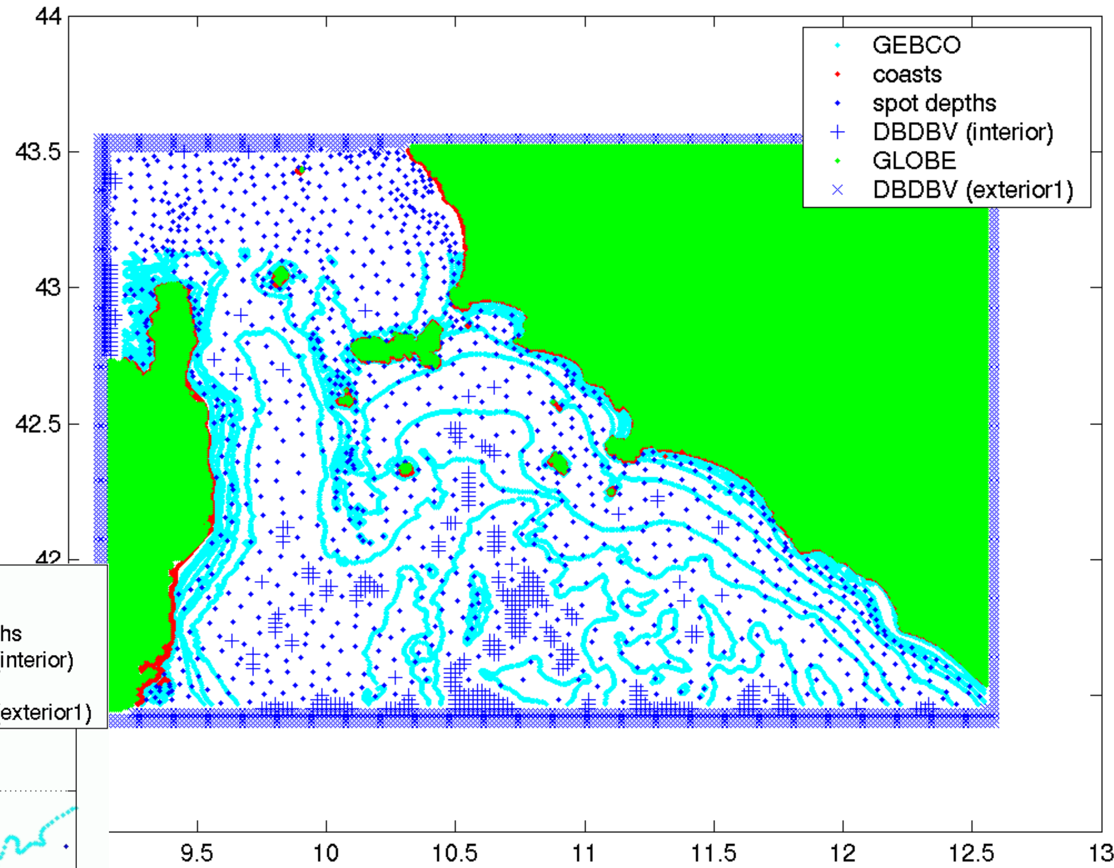


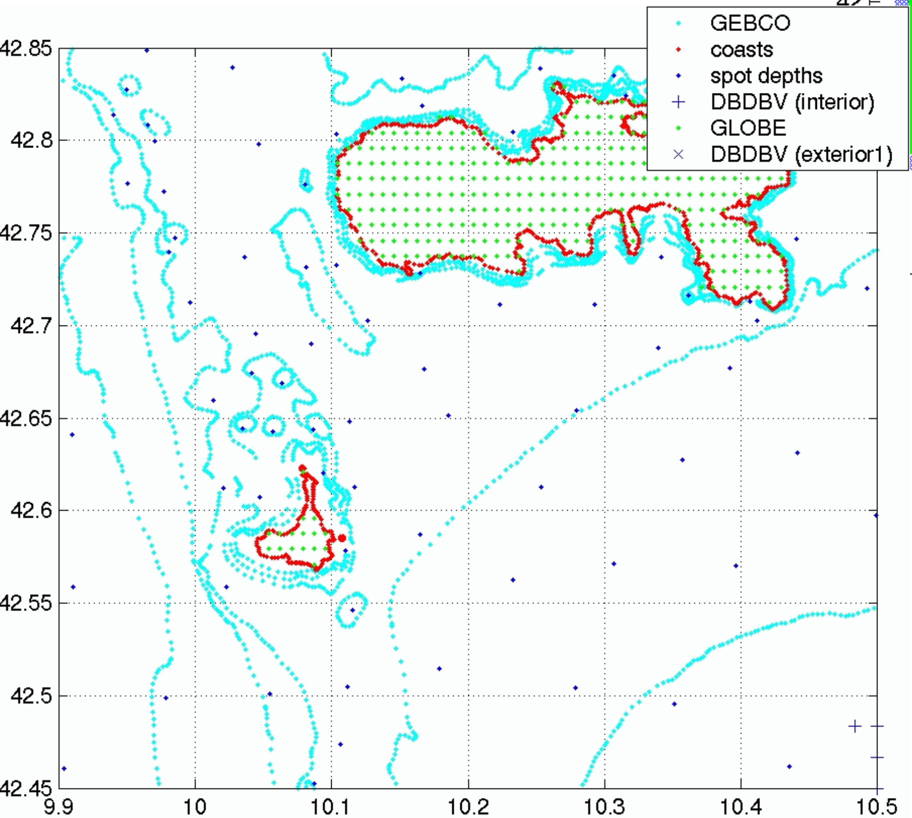
FAF-05: Major Harvard-MIT Accomplishments

- **Initiated coupling of Harvard and MIT methodologies/software**
  - Ocean environmental fields and uncertainties predicted daily by HOPS' ocean model and ESSE approach
  - Ensemble (various scenarios) of 0.5-2 days predictions of sound-speed sections computed and transferred to Ding Wang
  - Corresponding ensemble of acoustic TLs computed using RAM
  - Sound-speed sections and TL curves were input to Ding's optimization algorithm, to estimate ideal parameters for the AUV's yoyo sampling of the next 1-2 day(s)

- **Issued physical-acoustical adaptive sampling recommendations every day**, aiming to
  - Capture the vertical variability of the thermocline, due to: daily cycle, atmospheric-driven vertical mixing and mesoscale features (eddies, etc)
  - Minimize the corresponding uncertainties.

Bathymetry Data





Data sources indicated are:

- GEBCO isobaths
- coastlines
- soundings ("spot depths")
- DBDBV 1 minute bathymetry
- GLOBE 30 second elevation

Historical and Synoptic Ocean Data, Atmospheric Forcing

Historical Data

- MREA03/BP03: Real-Time Mini-HOPS modeling in the Ligurian Sea/Elba. May-June 2003

Synoptic Data (FAF05)

- R/V Leonardo-AUVs: Sound-speed profiles east of Pianosa
- R/V Alliance: CTD profiles, Meteo Data
- NURC: Satellite Sea surface Temperature (SST)

Atmospheric Forcing (Ocean-Atmos. Fluxes)

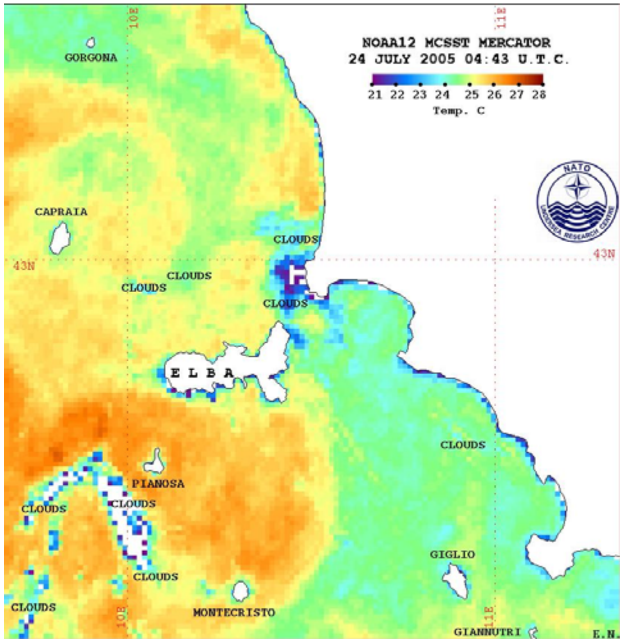
- Cro. Met. Service: Aladin forecasts and analyses (~ 8 km resolution)
- FNMOC: Coarse resolution forecasts and analyses
- NURC: COAMPS forecasts and analyses

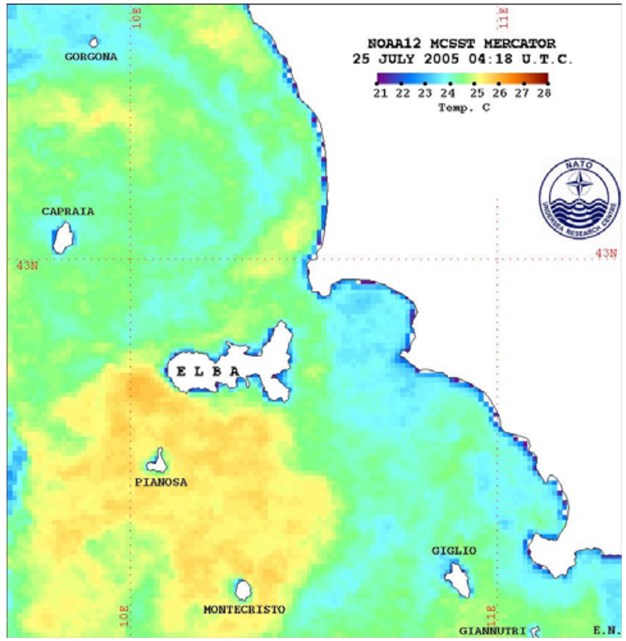
Satellite Sea Surface Temperature (SST):

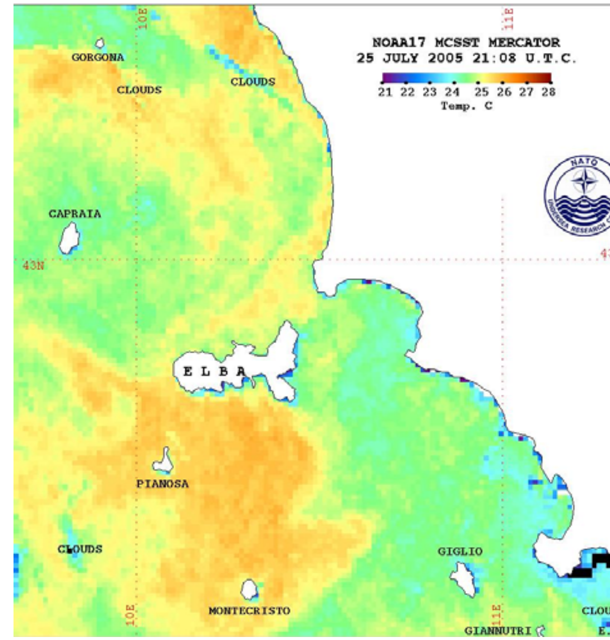
24 July - 0443

25 July - 0418

25 July - 2108







Day-by-day variability

Day-light warming & skin effects

http://people.deas.harvard.edu/~leslie/FAF05/AVHRR/index.html

HOPS' Ocean Dynamics Model: Primitive-Equations

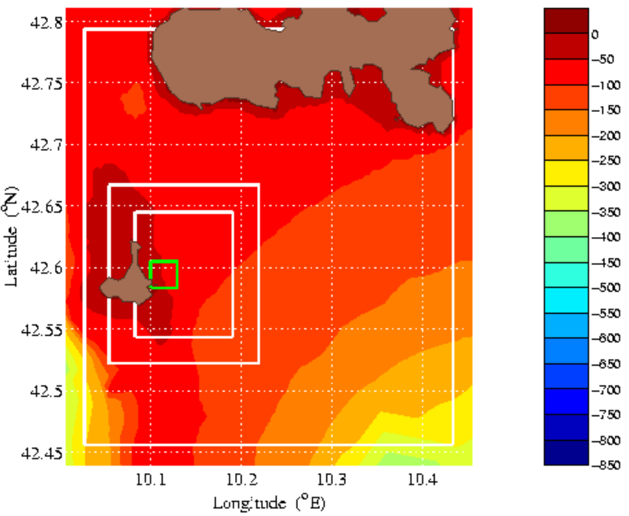
Fundamental equations are Navier-Stokes in rotating frame of reference

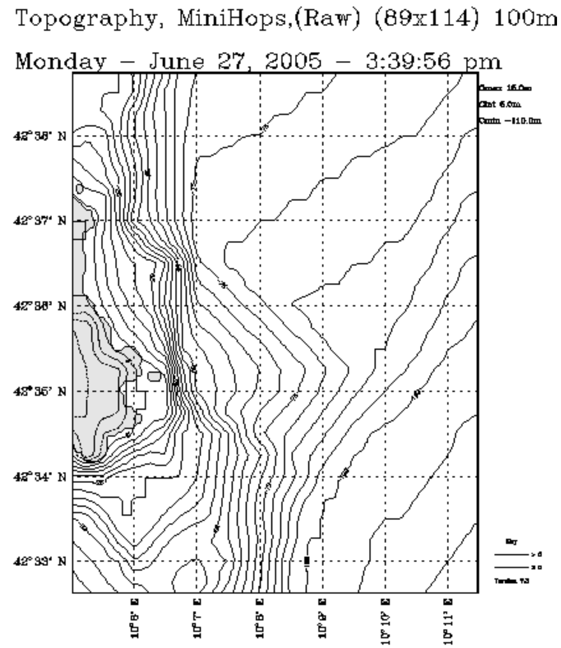
Additional practical assumptions limit the range of modeled scales in time and space:

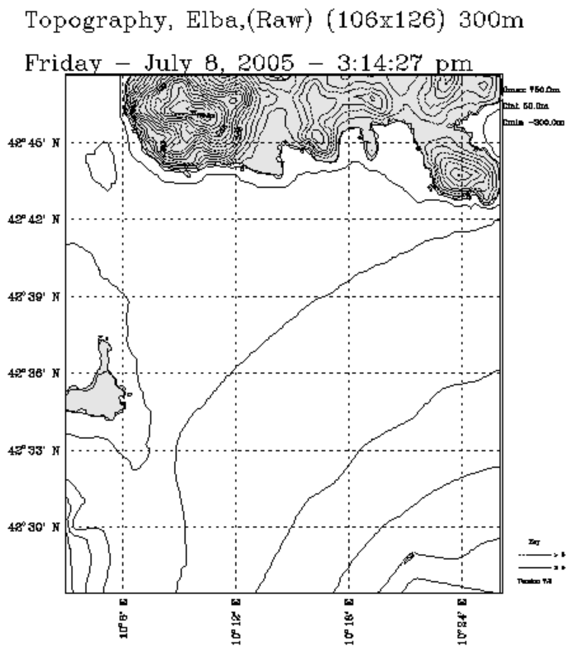
1. Boussinesq fluid (small variations of density about a state of reference)
2. Turbulent flow reduced to scale window of interest, here:
   - Sub-mesoscale, mesoscale to large-scale ocean processes
   - Processes outside this window are averaged and their effects parameterized (turbulent closures)
3. Thinness approximation (H/L <<1)

Result: the so-called **Primitive-Equations of Ocean Dynamics**

High-Resolution Nested Ocean Modeling Domains

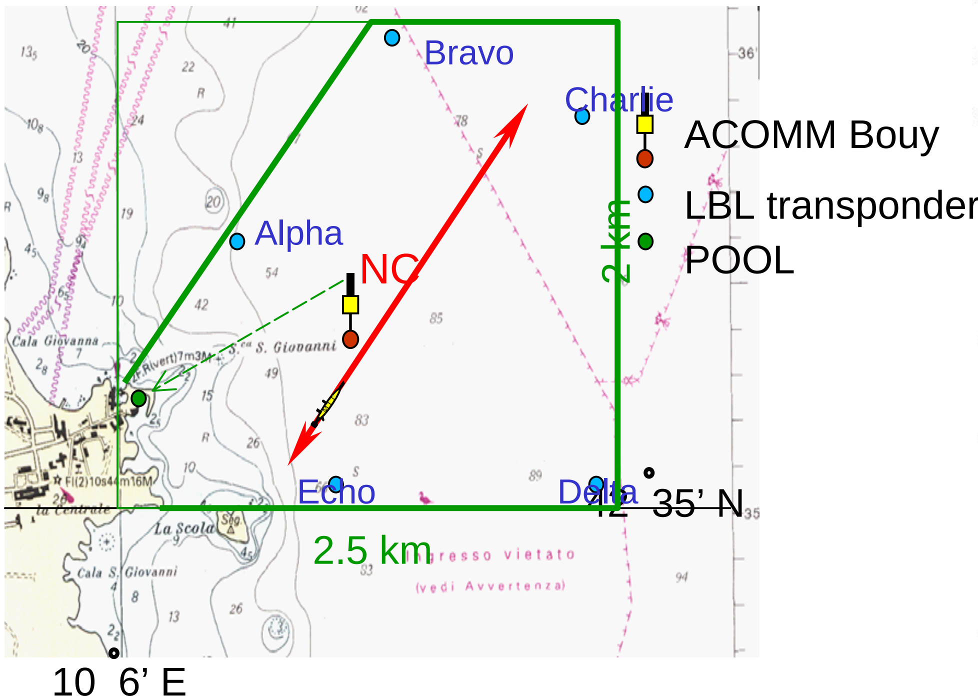


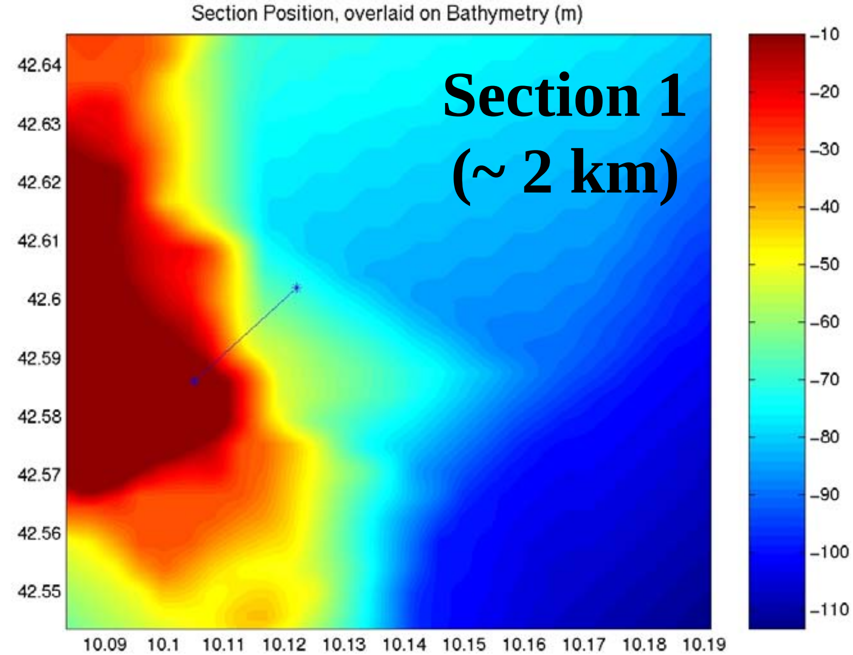


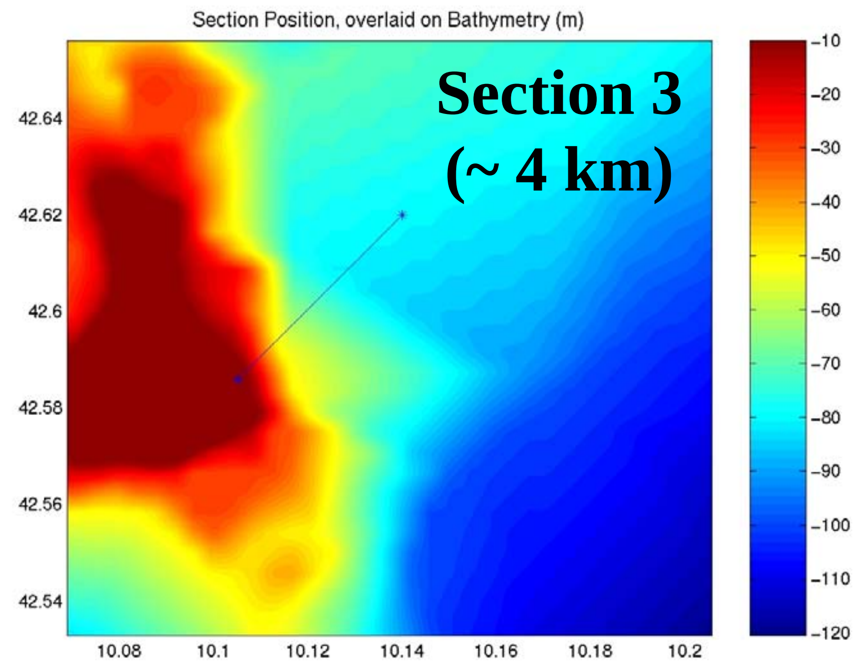


		Mini-HOPS	Elba
Resolution		**100m**	**300m**
Size	*nx × ny × nz*	89×114×21	106×126×21
	Extent	8.8×11.3 km	31.5×37.5 km
Domain center		42.59°N, 10.14°E	42.63°N, 10.24°E
Domain rotation		0°	0°
Speed	*dt=50s*	90 minutes/(model day)	120 minutes/(model day)
	dt=300s	15 minutes/(model day)	20 minutes/(model day)

Characteristic Acoustic Sections



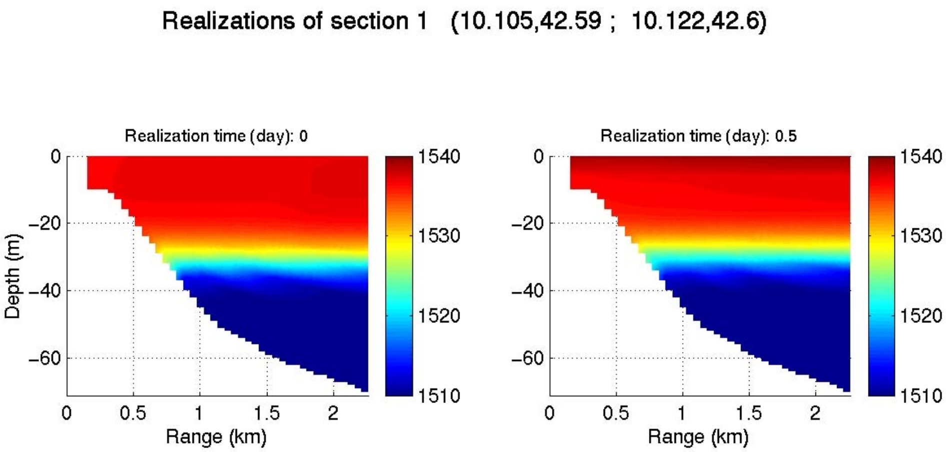




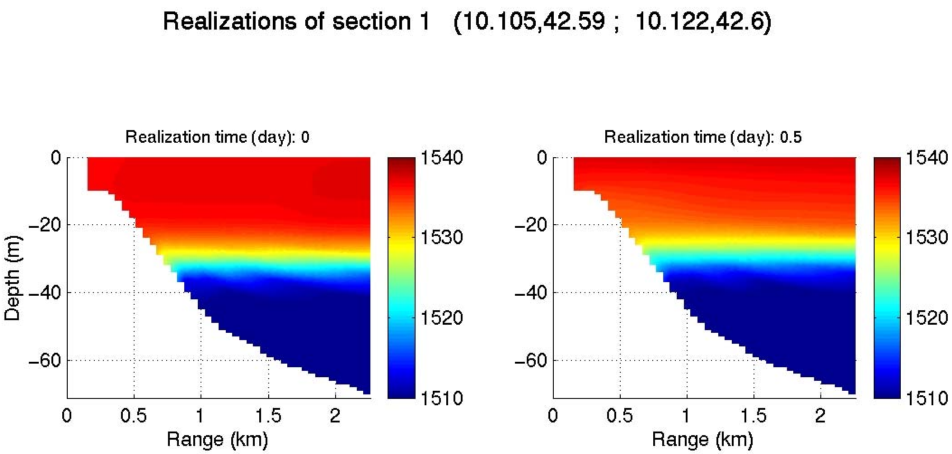
Small Ensemble of Acoustic Sections, Created based on Different scenarios

Here, different atmospheric forcing and SST assimilation

Scenario 1



Scenario 2

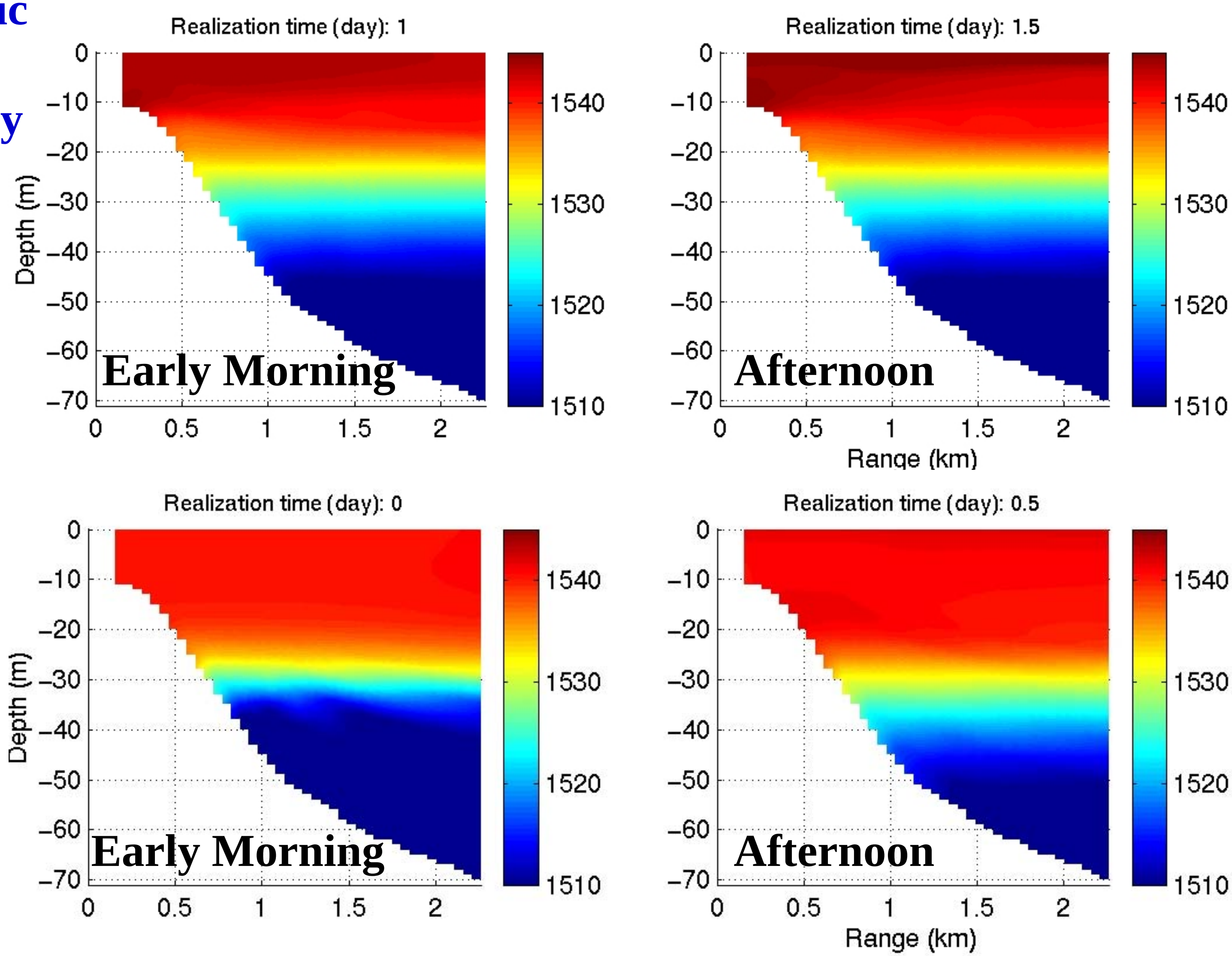


Day-to-day Variability Significant in Sound-speed Sections

Due to: Atmospheric forcing, Mesoscale oceanography, Daily cycle, etc.

July 23:

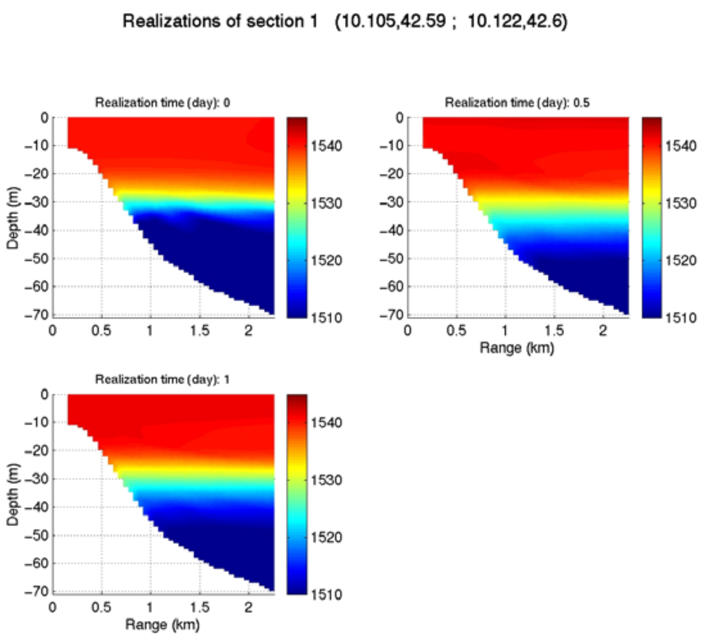
July 24:

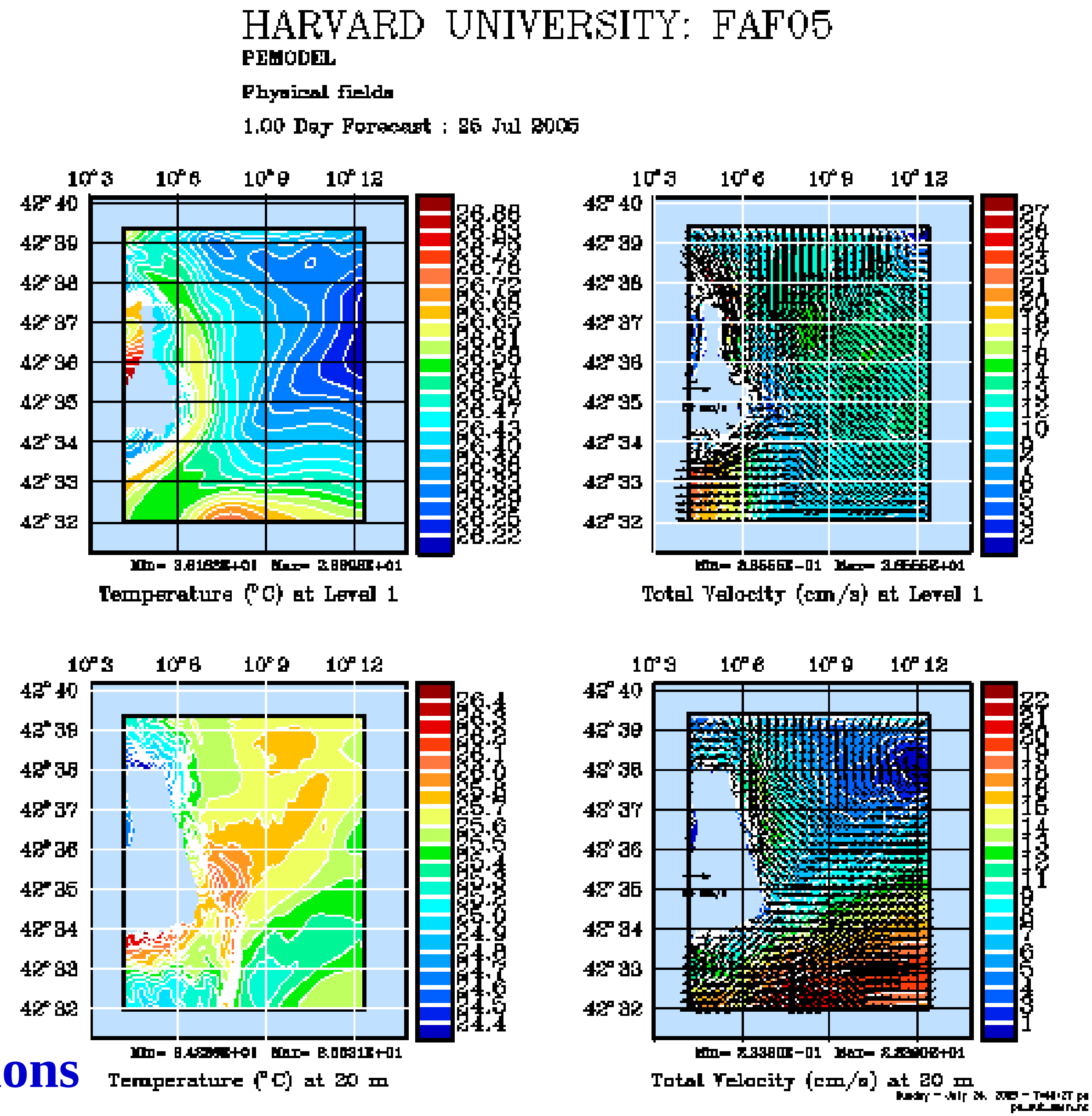


Here: due to the predicted stronger winds in 23-24 July, sound speeds reduced in the surface and the thermocline deepened.

Result Example: Horizontal Maps of Fcst T and Currents (25 Jul)

Pianosa Domain (100 m res.)





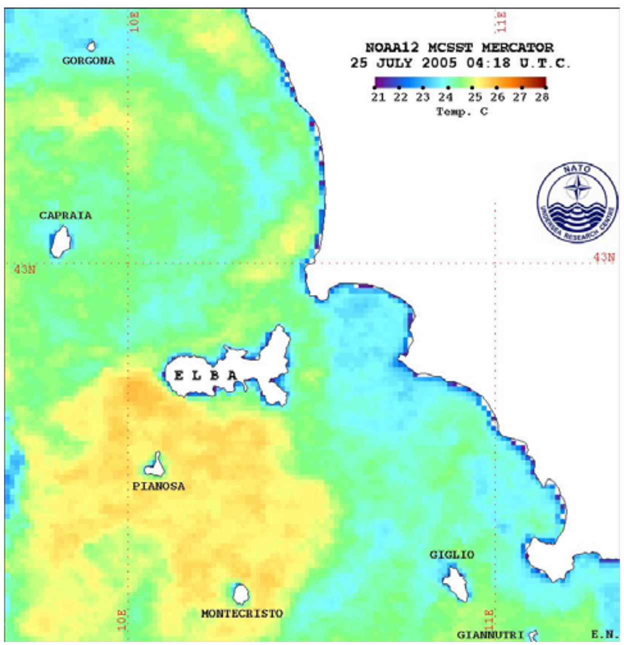
Corresponding FAF05 Sections

http://people.deas.harvard.edu/~leslie/HOPS/HOPS.html

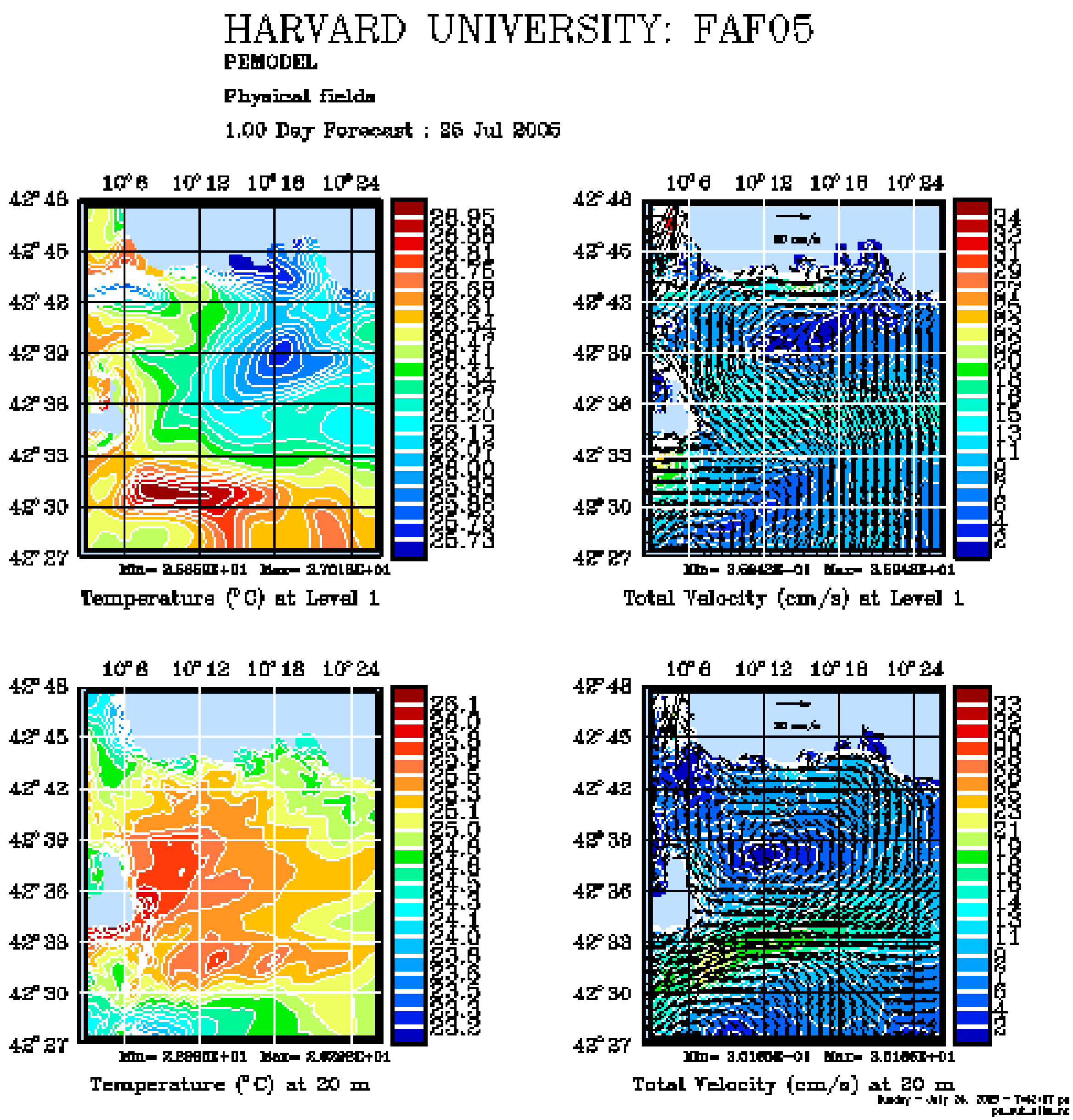
Result Example:
Horizontal Maps of Fcst T and Currents (25 Jul)

Elba Domain (300 m res.)

SST: 25 July - 0418



Corresponding satellite SST



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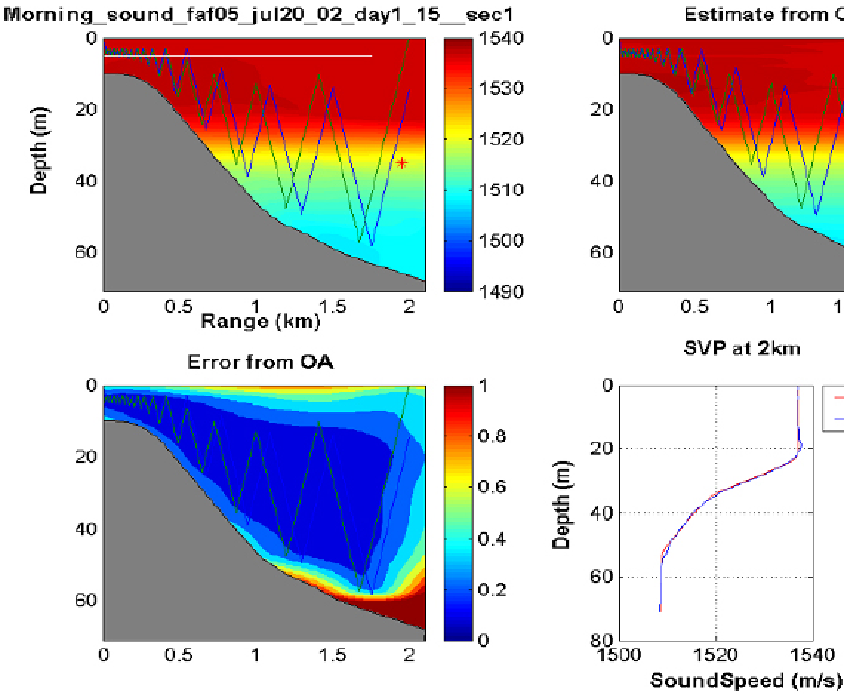
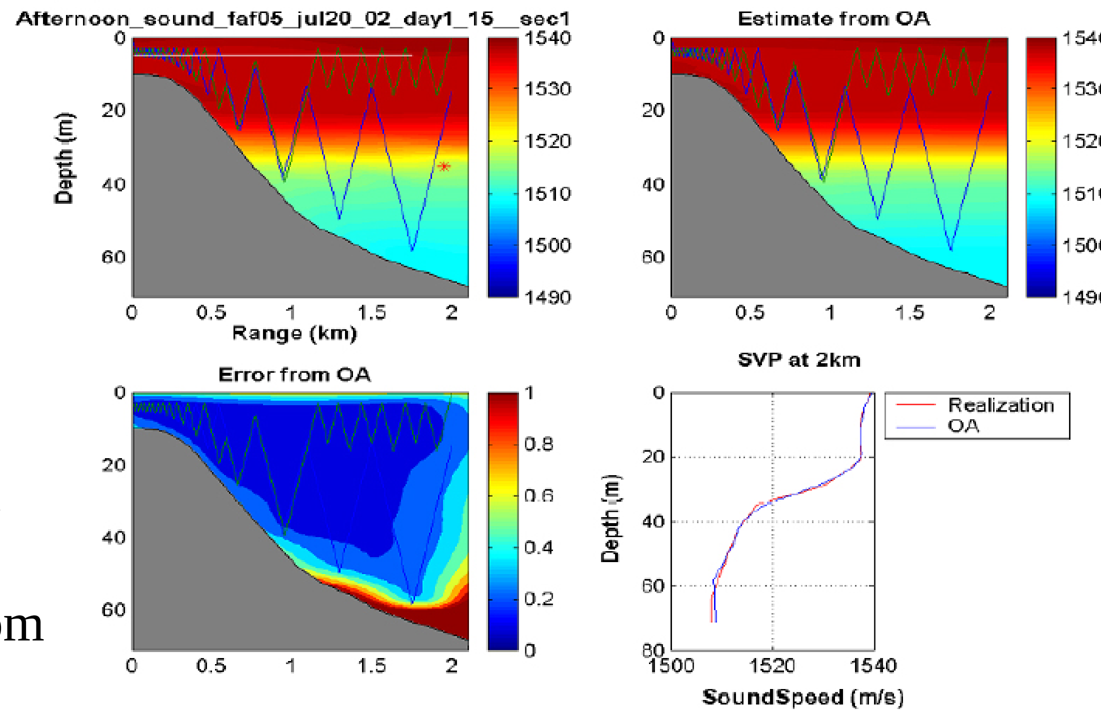
Example of Results of Yoyo Control

Jul 20-21: showing AUV capture of ``afternoon effects''



Morning

Afternoon



Legend:

- Blue line is the forward path.
- Green line is the backward path.
- AUV avoids surface/bottom by turning 5 m before surface/bottom

FAF-05: Methodology and Daily Protocols

- **Ocean physics nested model (Mini-HOPS) used for 4d predictions, initialization and data assimilation via Optimal Interpolation**
  - Assimilated satellite SST snapshots. Utilized synoptic sound speed profiles for tuning/evaluation.
  - Ocean model forced by high resolution atmospheric fluxes.
- **Environmental uncertainties estimated based on various scenarios**
  - Computed daily as a function of different initial condition estimates, assimilation procedures, modeling domains, numerical/physical model parameters, and time of day.
- **Ensemble of acoustic predictions (RAM) computed for ensemble of sound speed predictions (in interpolated sections)**
- **Optimized AUV yoyo parameters to capture the vertical variability of the thermocline (due to fronts, eddies, internal waves, etc) and minimize the corresponding uncertainties**
- **Optimal sampling parameter estimates and corresponding environmental and acoustical predictions emailed daily to the FAF05-MIT team at-sea aboard the R/V Leonardo**