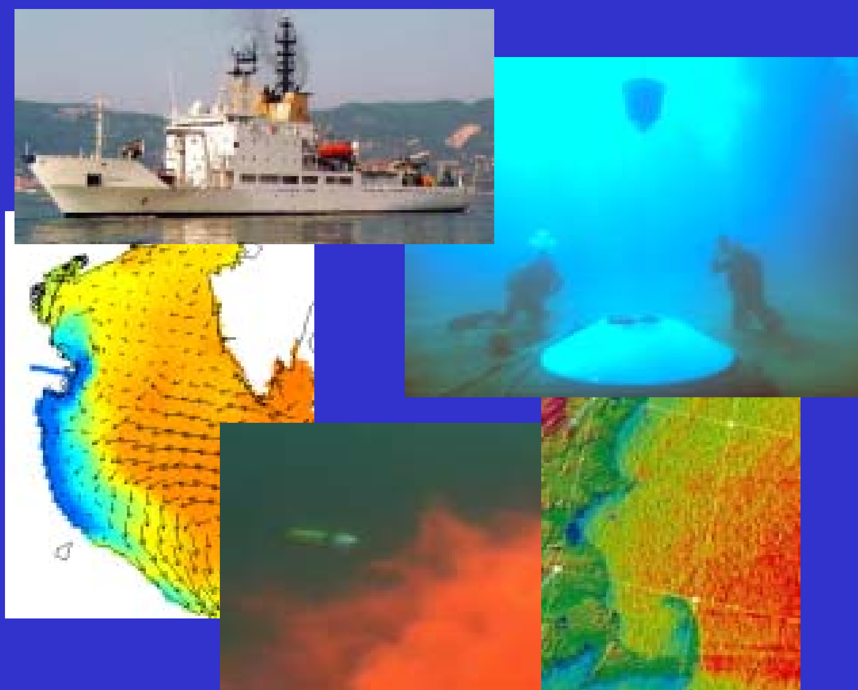
NATO Tactical Ocean Modeling



The mini-HOPS strategy in the MREA03 trial

Emanuel Ferreira Coelho
Saclant Undersea Res. Centre
and
Allan Robinson
Harvard University

Motivation

$$\partial/\partial t\, \vec{U} = -\vec{U}.\nabla\vec{U} - 1/\rho f.\vec{k}\times\vec{U} + \text{Forcing} - \text{Damping}$$

Local Acceleration = Advection + Coriolis Acceleration

- Any time changing dynamical phenomena can trigger Inertial Motion

- Though Inertial Motion is one of the most frequent Ocean phenomena, it is not easily included into NATO available operational forecasting systems

Motivation

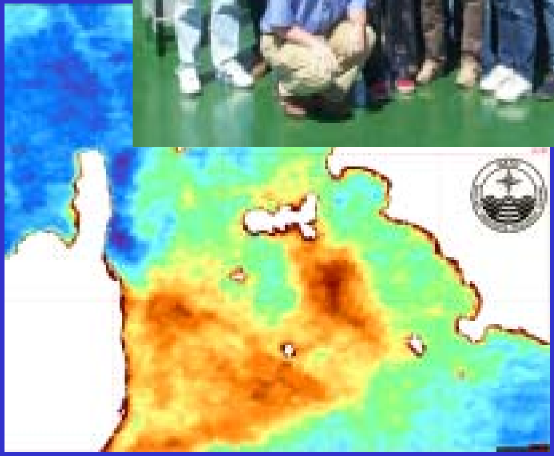
$$\partial/\partial t\, \vec{U} = -\vec{U}.\nabla\vec{U} - 1/\rho f.\vec{k}\times\vec{U} + \text{Forcing} - \text{Damping}$$

Local Acceleration = Advection + Coriolis Acceleration

- Once Inertial Motion is established it can go through interactions with the surrounding medium:
  - Topography → generating coastal trapped waves
  - Stratification → generating high frequency Internal Waves
  - Underlying flow → generating distorted patterns and near-inertial Internal Waves

ASCOT 02 (SLC-HARV Univ)

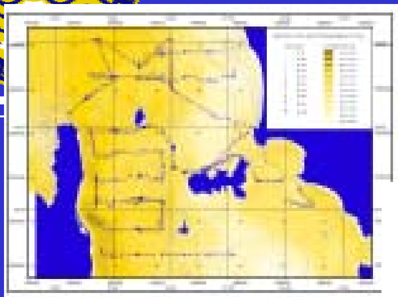
OCEAN MODELING SURVEY
7-17 MAY 2002

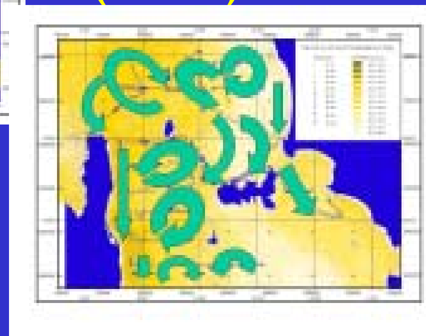


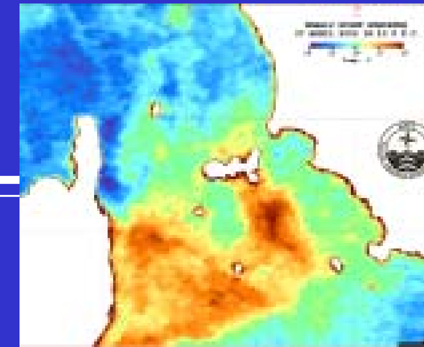
- Satellite, ship and mooring data collection
- AUV Environmental Missions
- Real-time data processing
- Real-time modeling with water column data assimilation

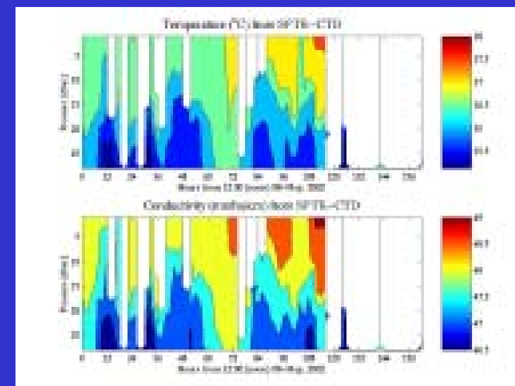
ASCOT02

(sub) mesoscale example



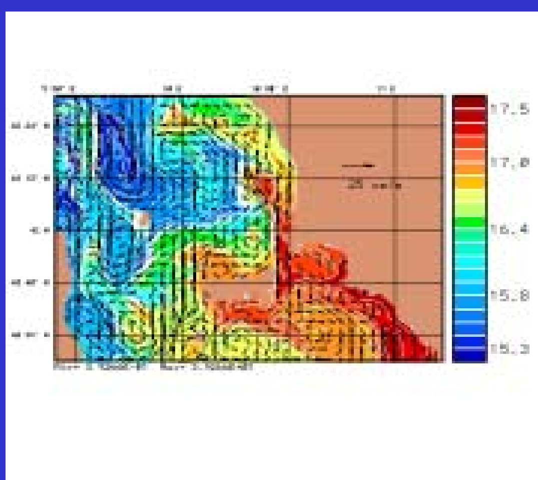




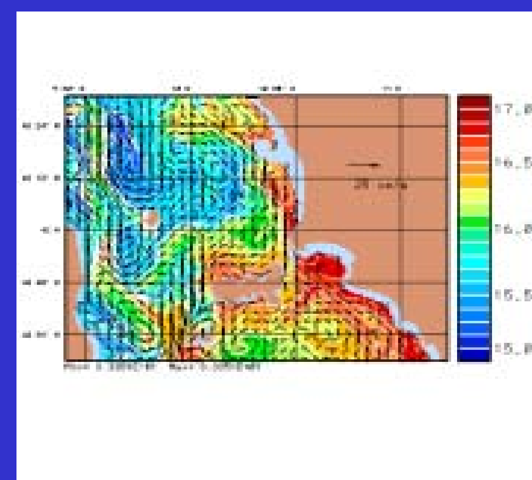


OBSERVED FIELD DATA

REAL TIME MODELING FIELDS



5m depth



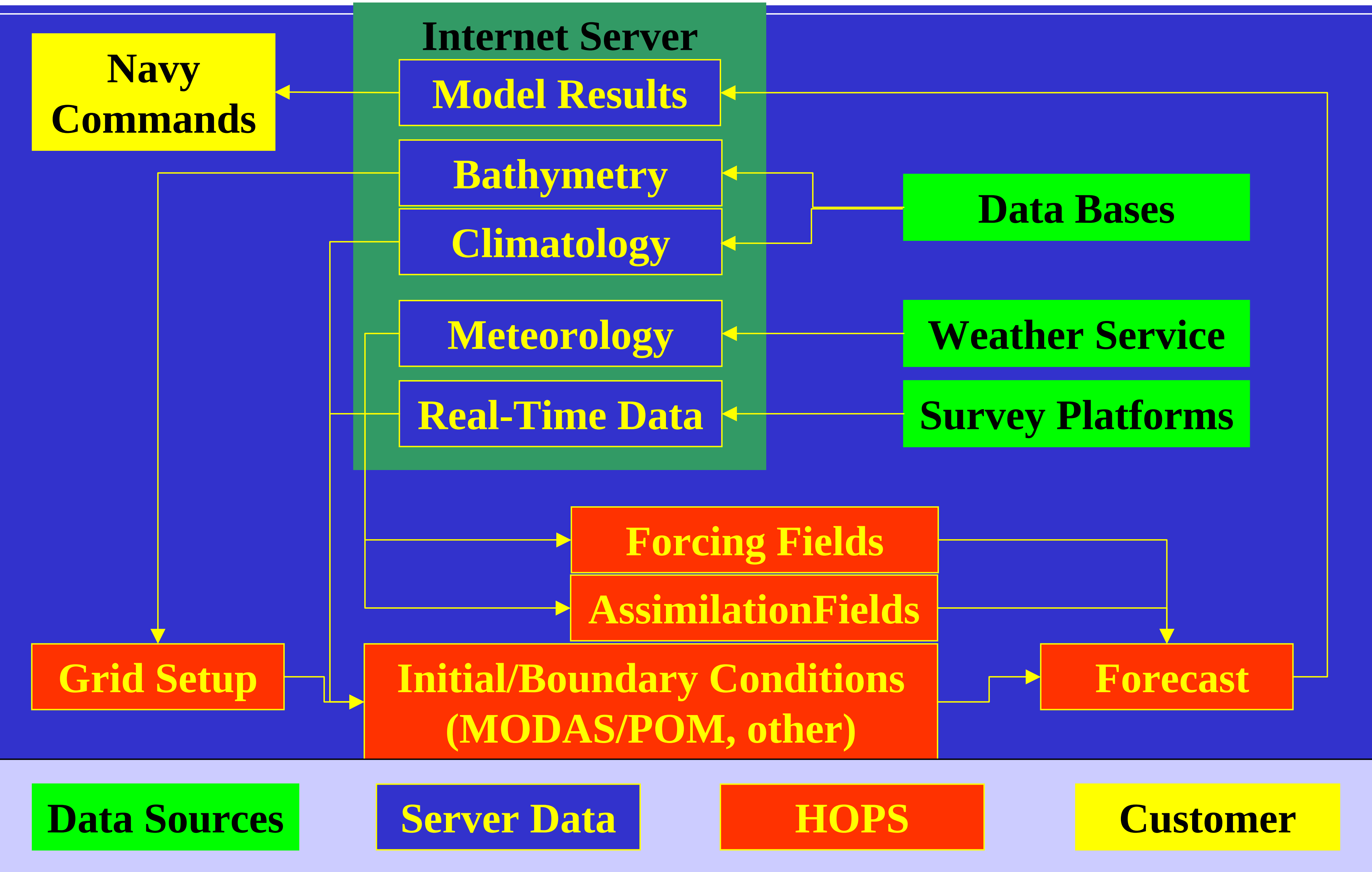
25m depth

Modeling fields from Harvard University Ocean Prediction System and Reiner Onken (SLC)

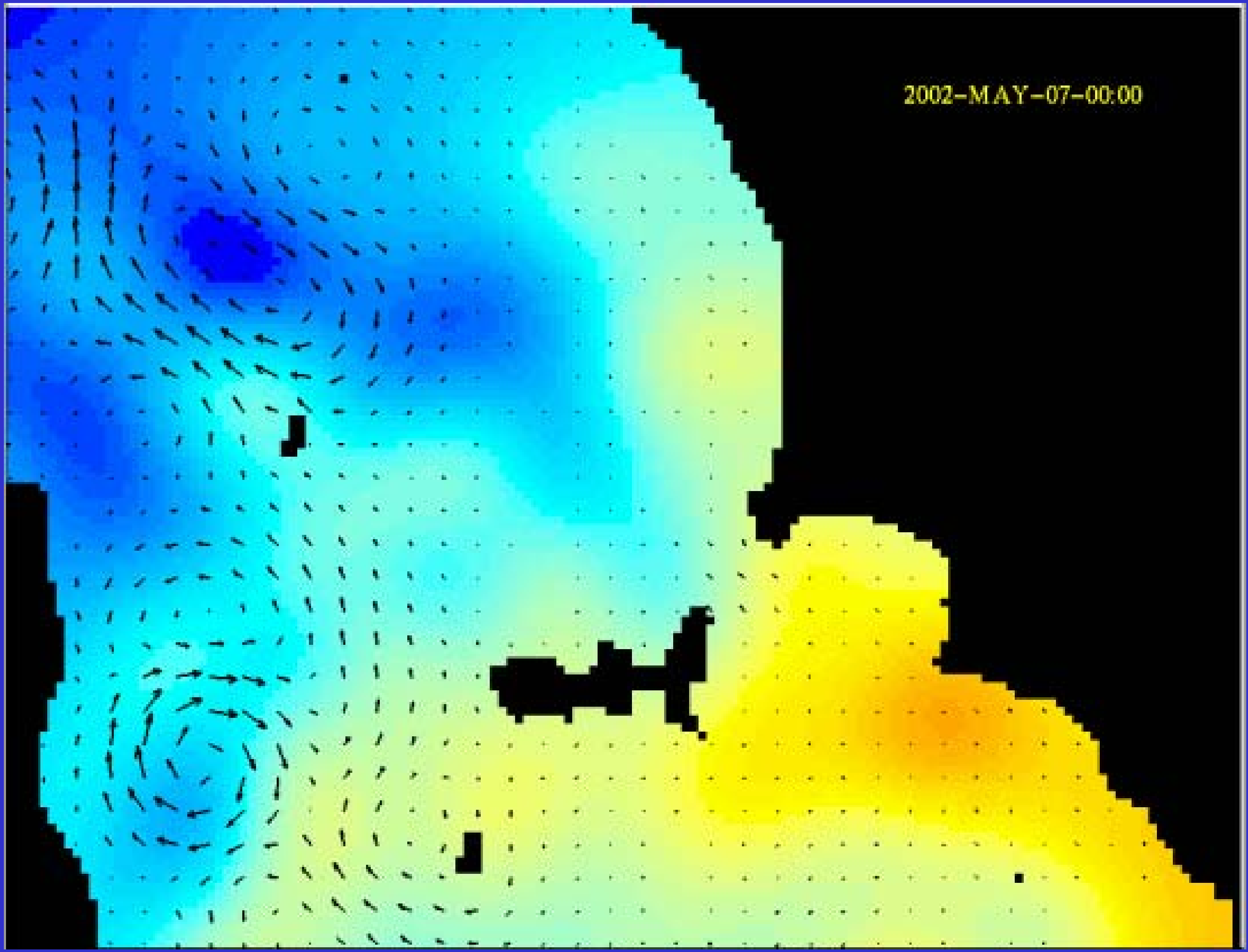
NATO UNCLASSIFIED

REAL-Time Modeling Data Flow

Courtesy of Reiner Onken



High variability observed at the surface fields (3 hours time steps



Modeling fields from Harvard University Ocean Prediction System and Reiner Onken (SLC)

ISSUES TO BE CONSIDERED

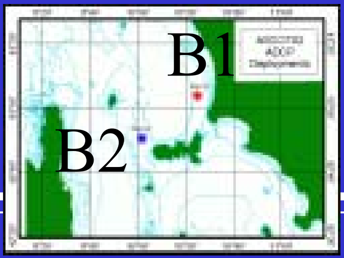
1 – For operational usage what water velocity estimates should be considered? (direct model outputs or averages?)
2 – What is the uncertainty of these field estimates?

Need to define a strategy to use operational and real-time modeling in the presence of high frequency phenomena

option 1 to be tested: separate high frequency variability from the lower frequency and use it as an incremental parameter for uncertainty estimation

Option 2 to be tested: obtain high frequency data and nest small domains running real-time modeling for local uncertainty reduction (mini-HOPS strategy)

Strong Near-Inertial Motion Observed



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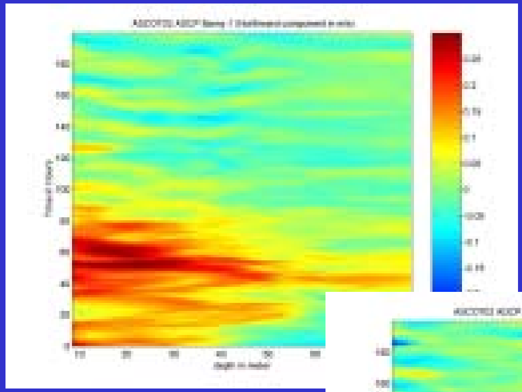
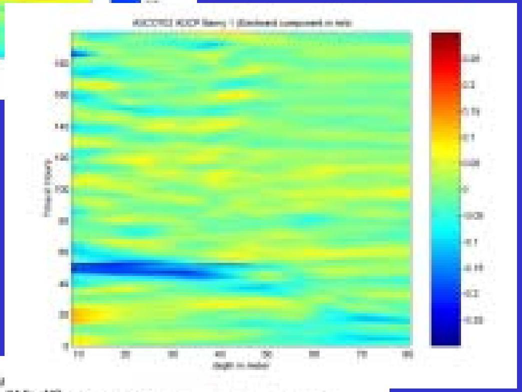
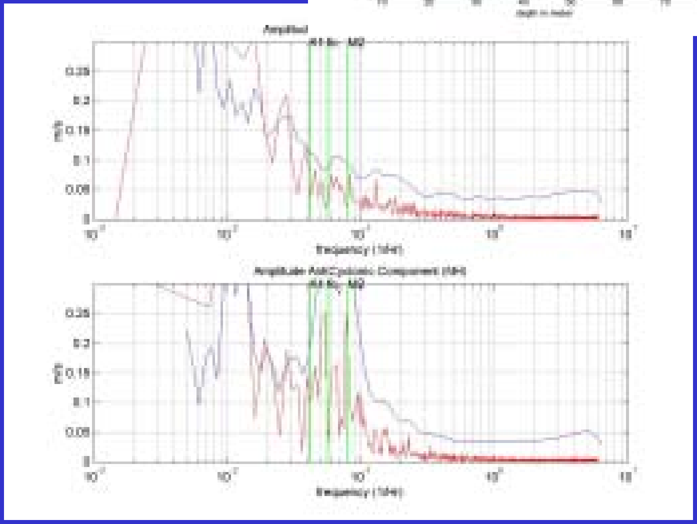
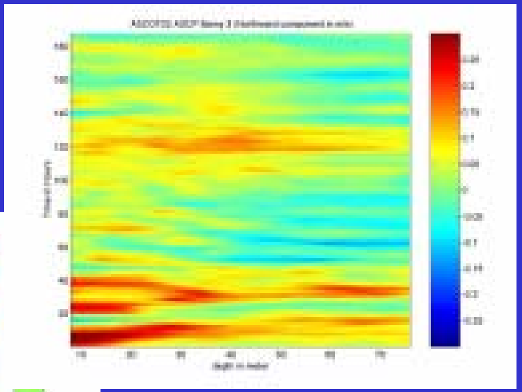
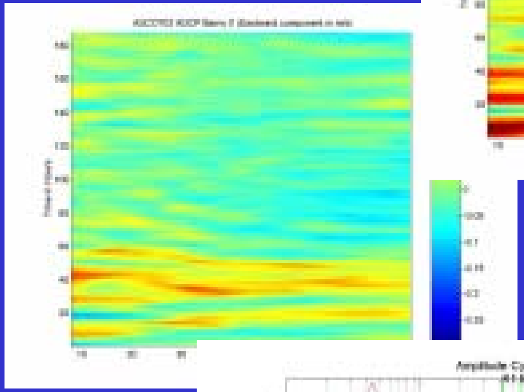
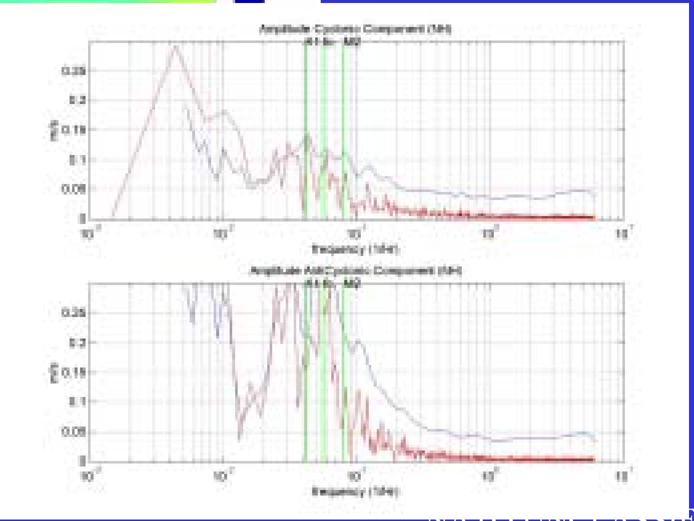




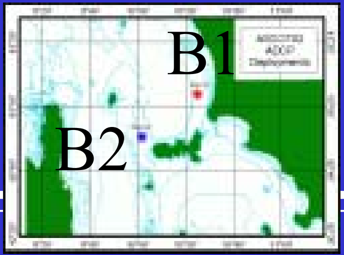








HOPS velocity estimates with large relative RMS deviations



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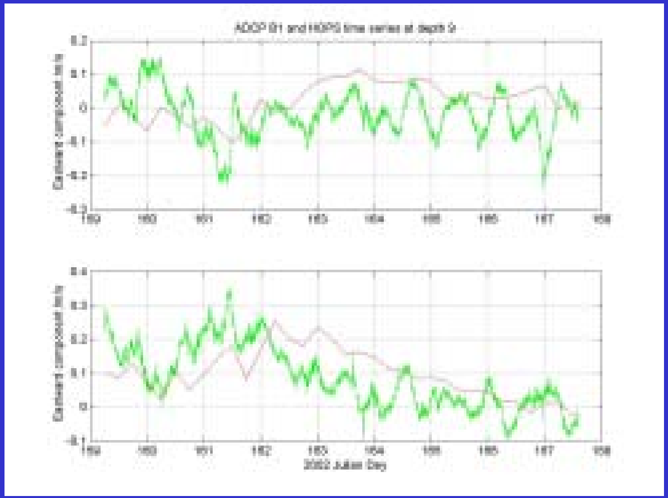
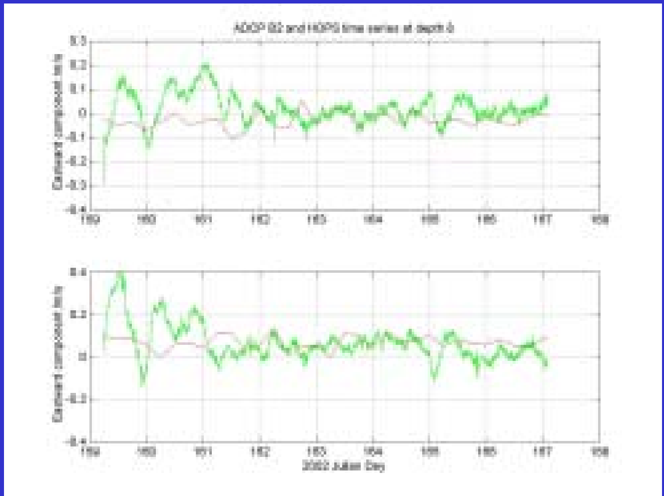
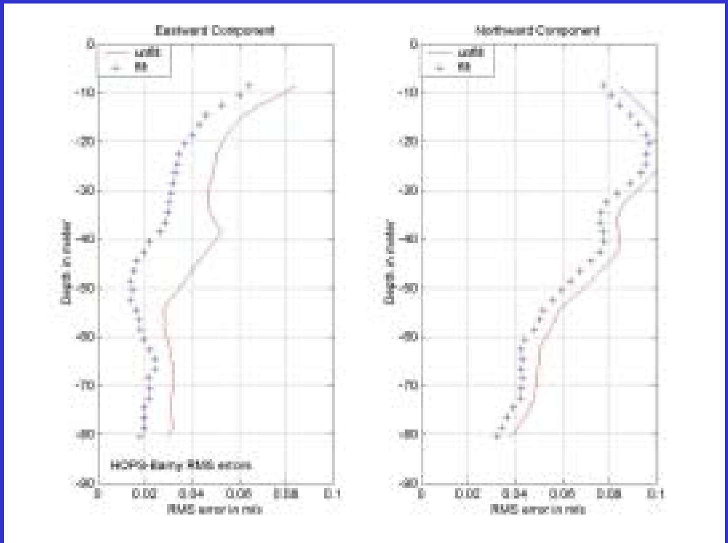
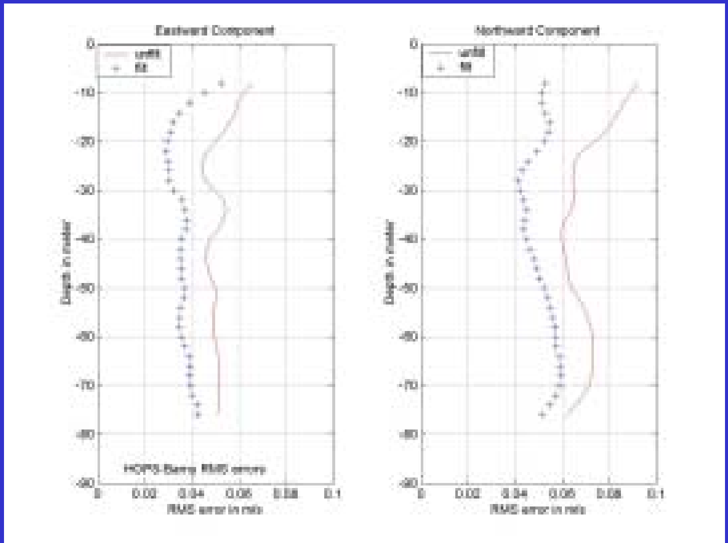


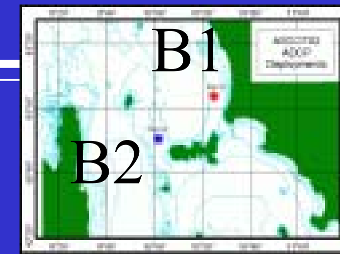


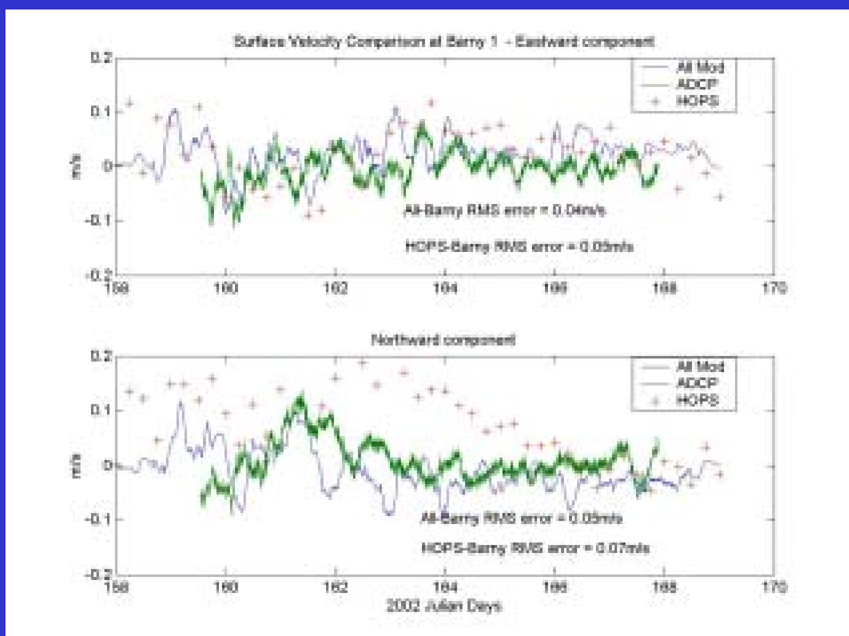
(mostly due to observed high frequency variability)





HOPS system is not reducing the uncertainty of local instantaneous surface velocity estimates (when compared to simple model estimates using shipborn observed winds)





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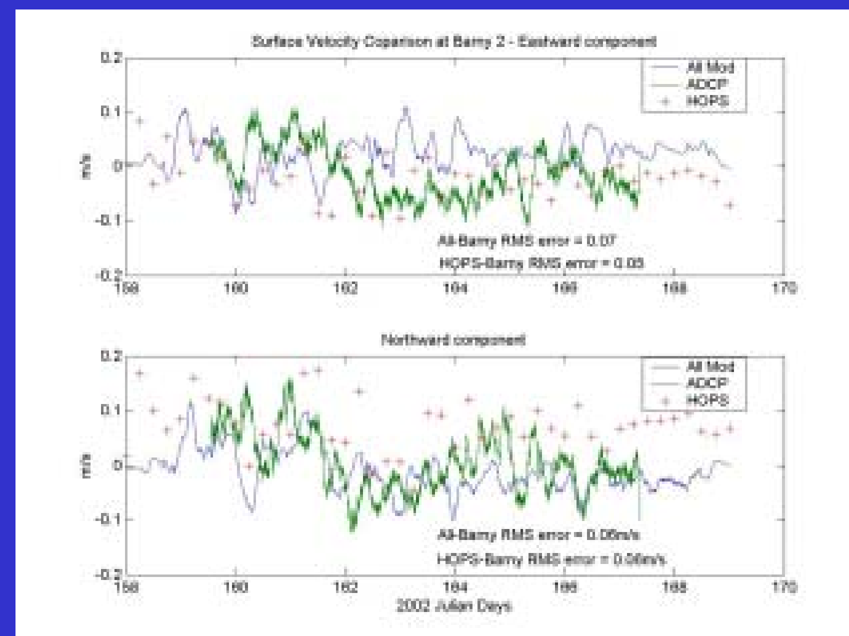
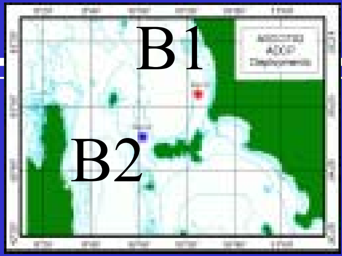


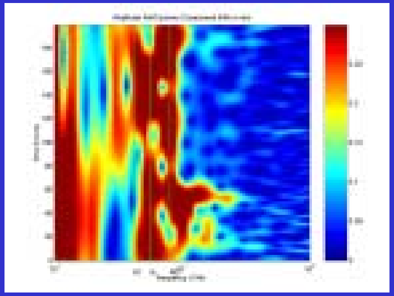
B2

Though the HOPS is not reducing uncertainty is capturing better the observed dominant sub-inertial to inertial energy of local instantaneous surface velocity estimates



Observed Time Evolution of Surface Spectral Estimates

HOPS Time Evolution of Surface Spectral Estimates



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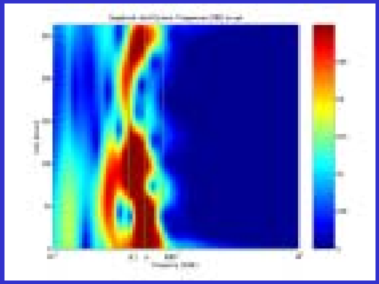
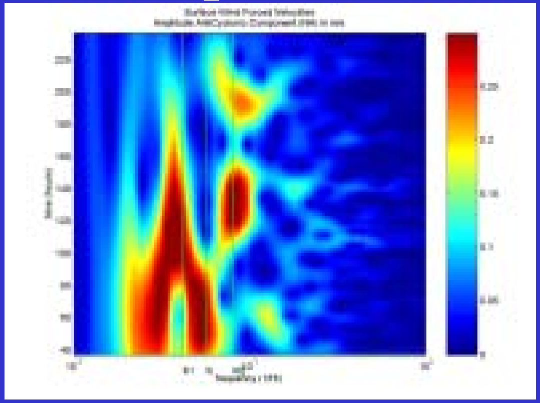
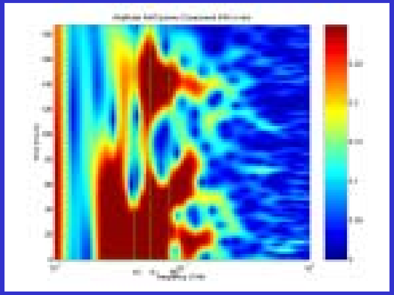


Simple model





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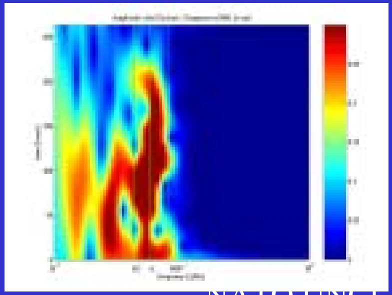
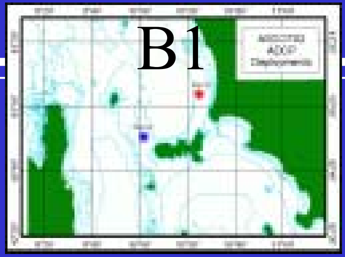
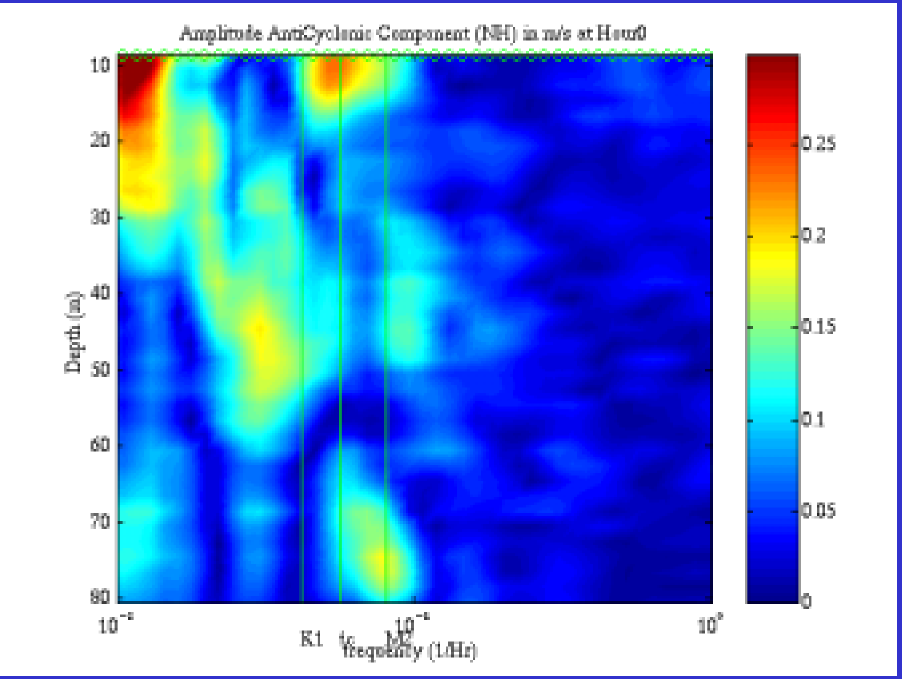


Though the HOPS is showing large RMS deviations is capturing most of the observed profile dominant sub-inertial to inertial energy



Observed Time Evolution of Spectral Estimates



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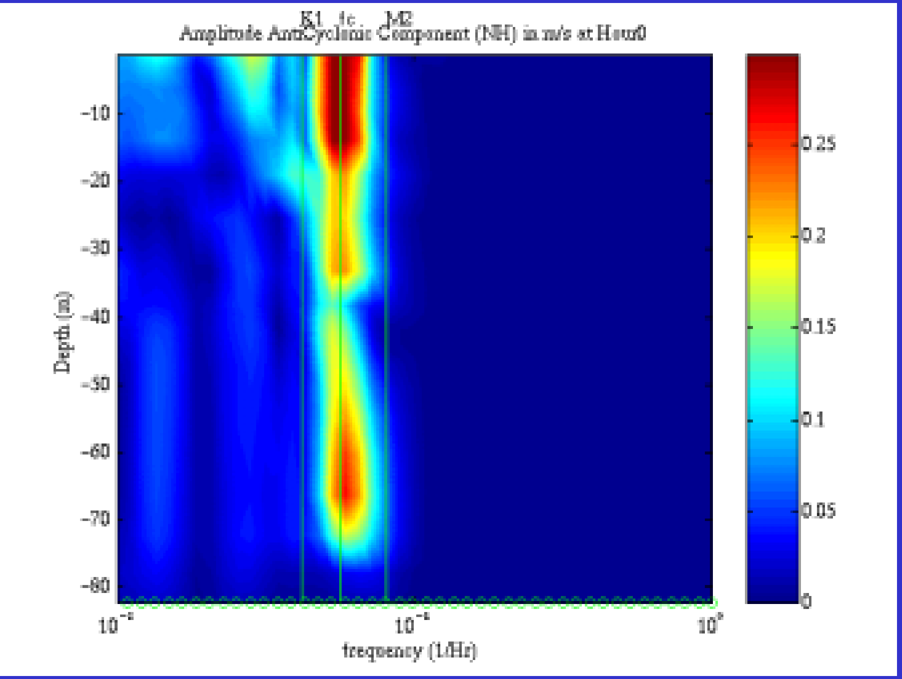

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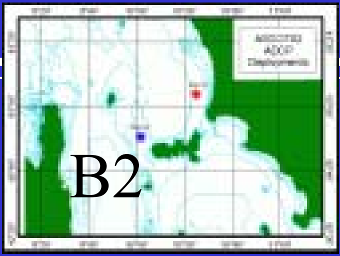

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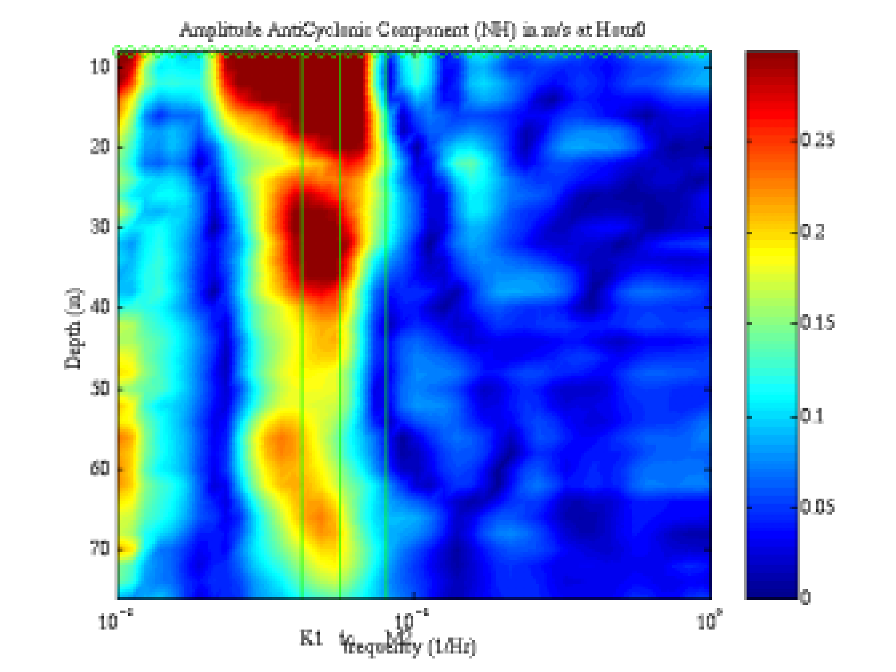

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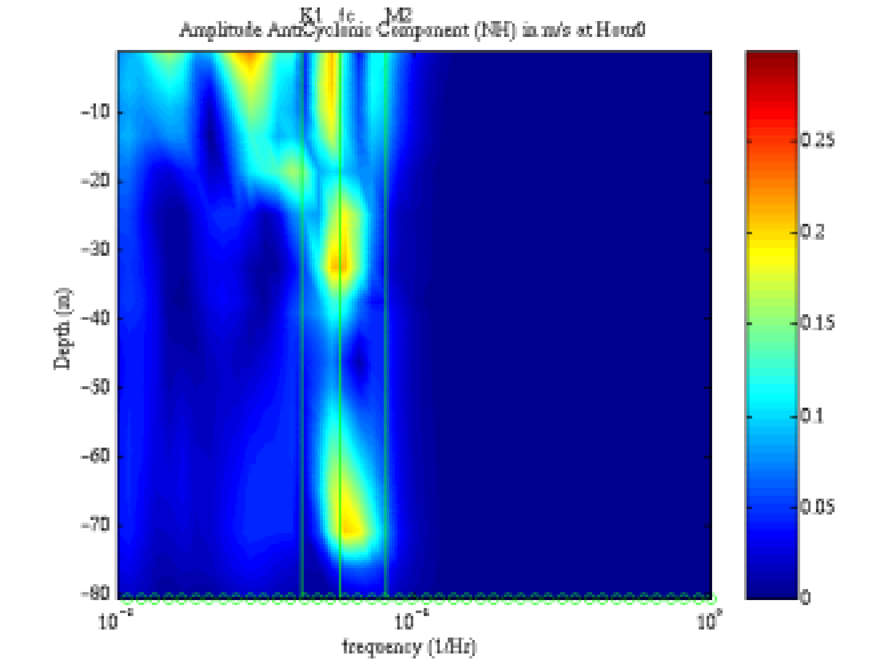


Discussion

- The North Elba region showed very strong inertial and sub-inertial dynamics
- The observed dynamics suggests strong internal wave and other sub-inertial phenomena being interacted and forced by inertial motion
- Inertial motion solution is impossible to obtain in a full regional domain (too expensive), but local data can be used to monitor local near-inertial dynamics
- Though the HOPS was not able to reduce local uncertainty, due to high inertial and sub-inertial variability, it contained the observed “physics” (attenuated and phase lagged).

Proposed solution

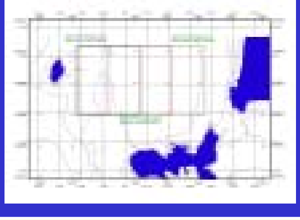
Mini-HOPS concept

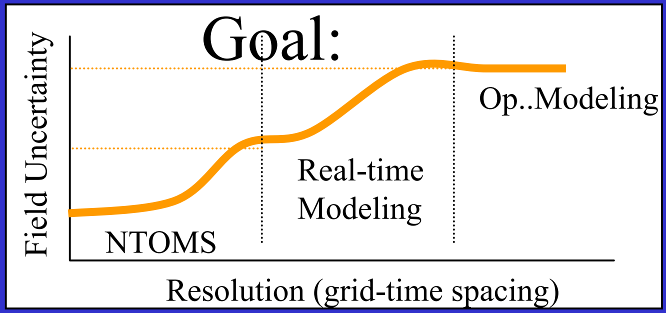
A. **Real-time modeling as been tested and widely demonstrated**
   - **Major advantage – can improve local consistency**
   - **Major disadvantage – requires local data gathering**

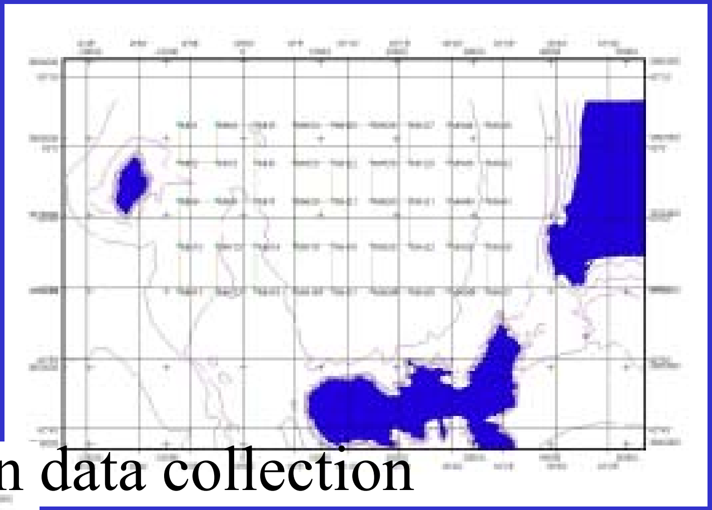
B. **Several global operational models are now becoming available (NCOM, FOAM, MERCATOR, etc)**
   - **Major advantage – fast and easy access**
   - **Major disadvantage – can have high local uncertainty**

<A.B'> = mini-HOPS

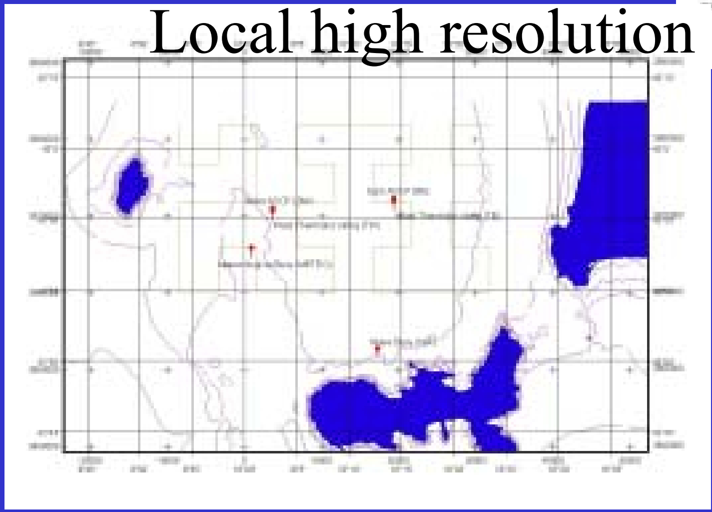
The Mini-HOPS in the MREA03 Trial







Local high resolution data collection



- start with an operational model run (NRL MODAS/POM)
- nest three 20x20Km 50% superimposed domains on a regional HOPS domain
- perform assimilation cycles within one inertial period
- provide and monitor hourly outputs for 24-48 hours forecasts

NTOMS

This strategy is part of the NATO tactical ocean modeling system being developed at SACLANTCEN + Partners, consisting on the following steps:

A. **Start with available operational ocean and meteorological models output analysis;**
B. **Use model available statistics, opportunity data, multiple model outputs and high frequency (sub-inertial structures) energy estimates to estimate overall uncertainty;**
C. **Decide if local uncertainty is satisfactory based on envisaged model output usage (at tactical or operator level);**
D. **If not, implement an hierarchical methodology from statistical/parametric modeling up to the mini-HOPS strategy (using DISCRETE and COVERT observational methods)**

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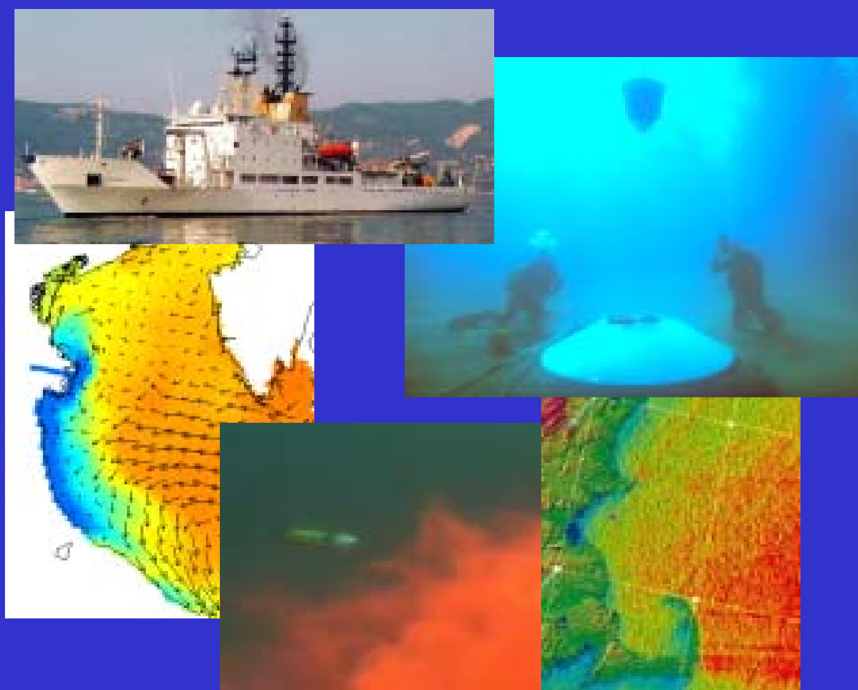

The mini-HOPS strategy in the MREA03 trial

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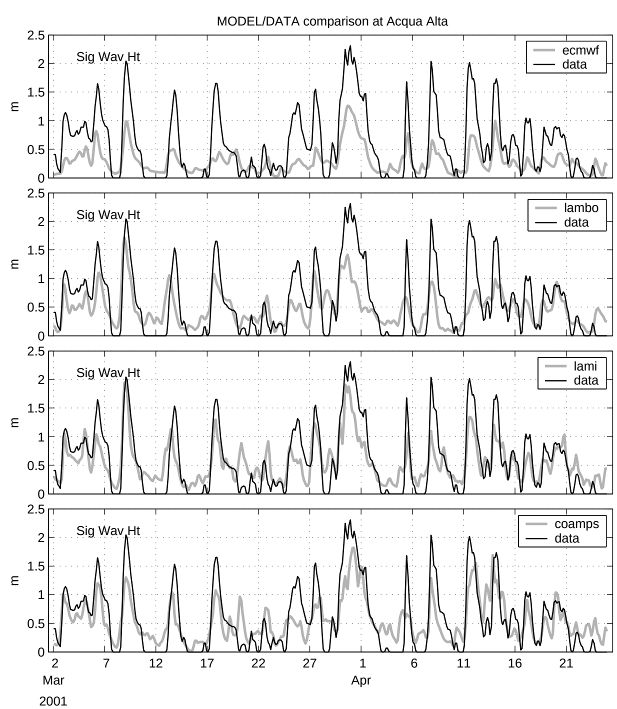
MET MODEL COMPARISON

To realistically track inertial motion, accurate meteorological forcing is essential



Courtesy of R.Signell