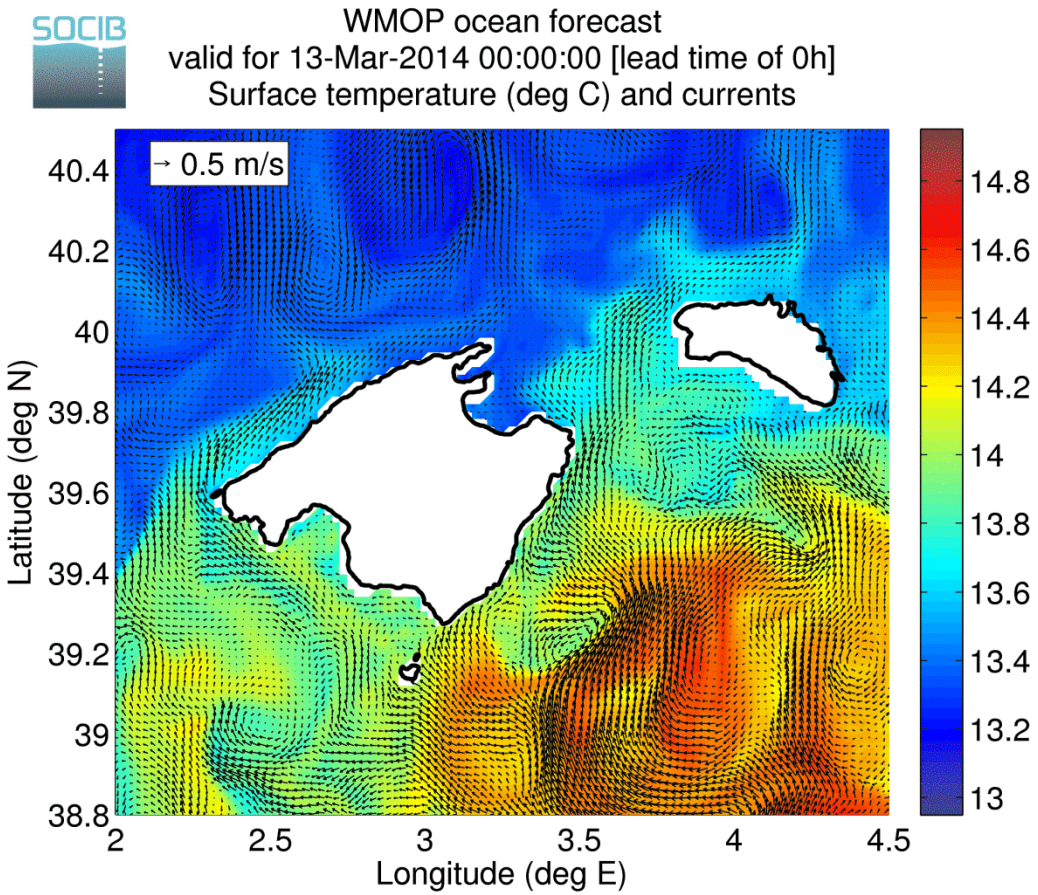
Predicción oceánica: el nuevo papel de los planeadores submarinos



Baptiste Mourre

SOCIB Balearic Islands Coastal Observing and Forecasting System

IMEDEA - 13 de marzo de 2014

Outline

1) Introduction

Ocean prediction models, underwater gliders and data assimilation.

2) Impact of glider fleet data assimilation in the Ligurian Sea

3) Glider adaptive sampling

Concept and glider mission planning.

At-sea experiment.

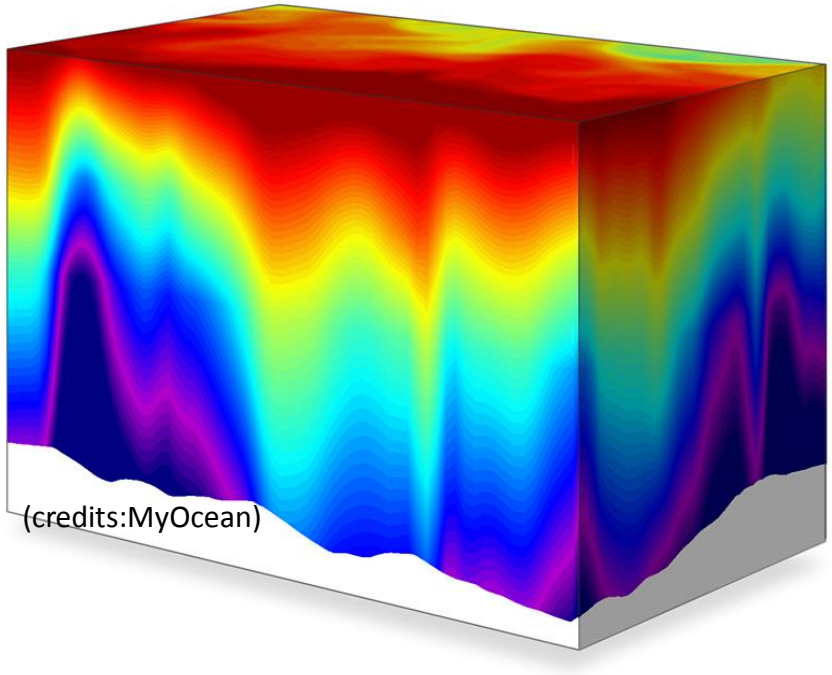
Observing System Simulation Experiments.

4) Conclusions

Introduction: models

Why models ?

3D representation of the state of the ocean (in terms of physical variables: temperature, salinity, currents) from surface to bottom, over extended areas, at any time of a simulated period.



Introduction: models

What do ocean models do ?

Numerically integrate in time the equations describing the ocean flow, given **an initial state** and the **external forcing** (atmosphere, rivers, lateral open boundaries) during the simulation period.

$$\frac{\partial \mathbf{U}_h}{\partial t} = -\left[(\nabla \times \mathbf{U}) \times \mathbf{U} + \frac{1}{2}\nabla(\mathbf{U}^2)\right]_h - f\mathbf{k} \times \mathbf{U}_h - \frac{1}{\rho_o}\nabla_h p + \mathbf{D}^U$$

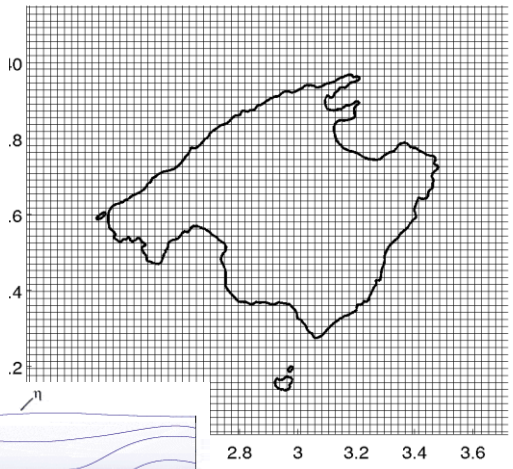
$$\frac{\partial p}{\partial z} = -\rho g$$

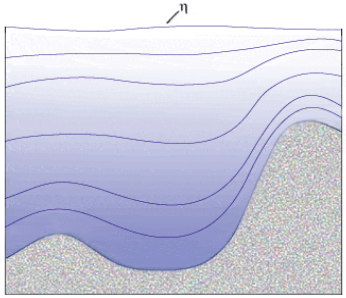
$$\nabla \cdot \mathbf{U} = 0$$

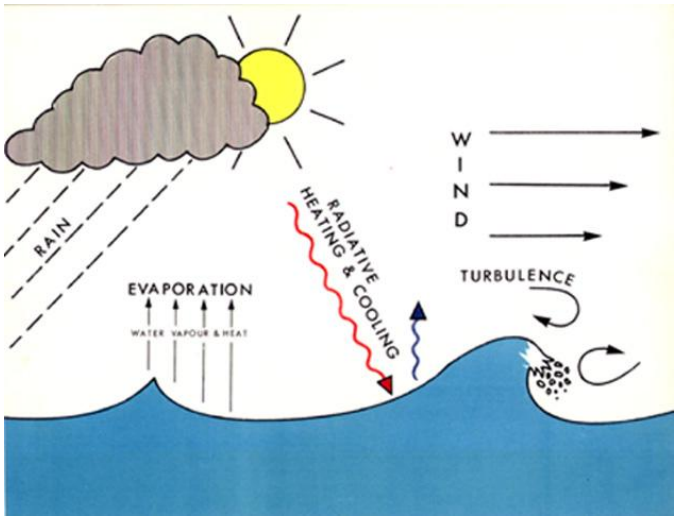
$$\frac{\partial T}{\partial t} = -\nabla \cdot (T\mathbf{U}) + D^T$$

$$\frac{\partial S}{\partial t} = -\nabla \cdot (S\mathbf{U}) + D^S$$

$$\rho = \rho(T, S, p)$$





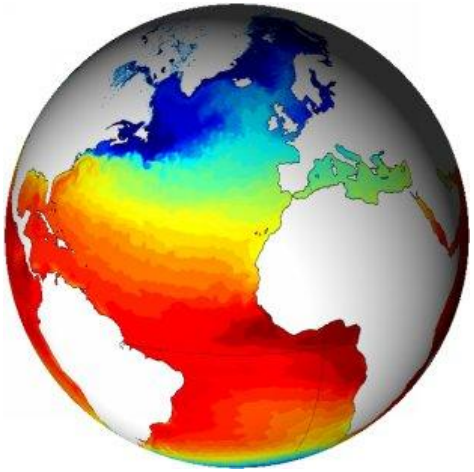


(credits:NOC)

Introduction: models

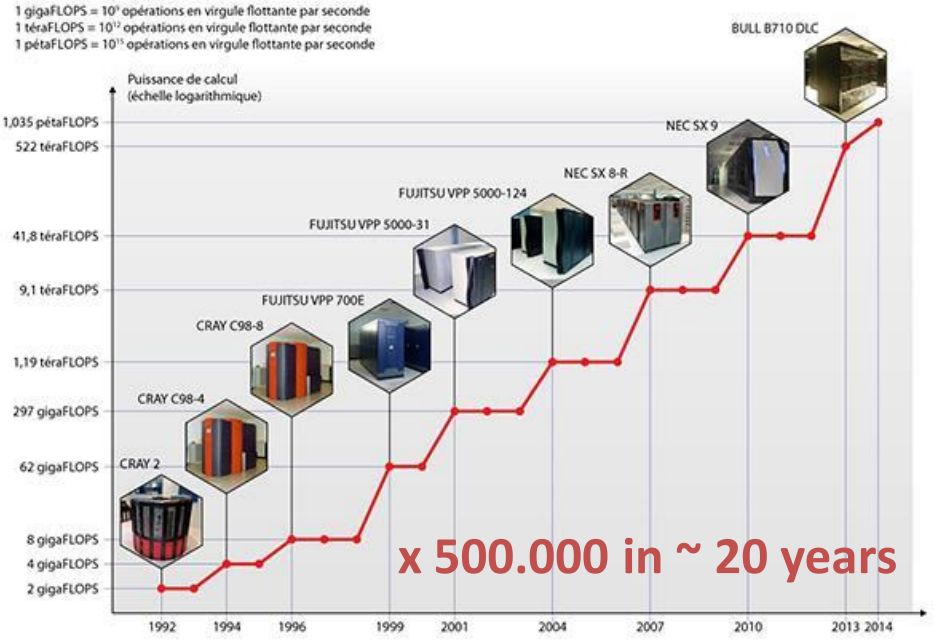
Over the last few years, operational high-resolution regional predictions have become affordable due to:

1) Maturity of global/basin-scale operational predictions



(credits: Mercator-Océan)

2) Exponentially increasing computing capacity

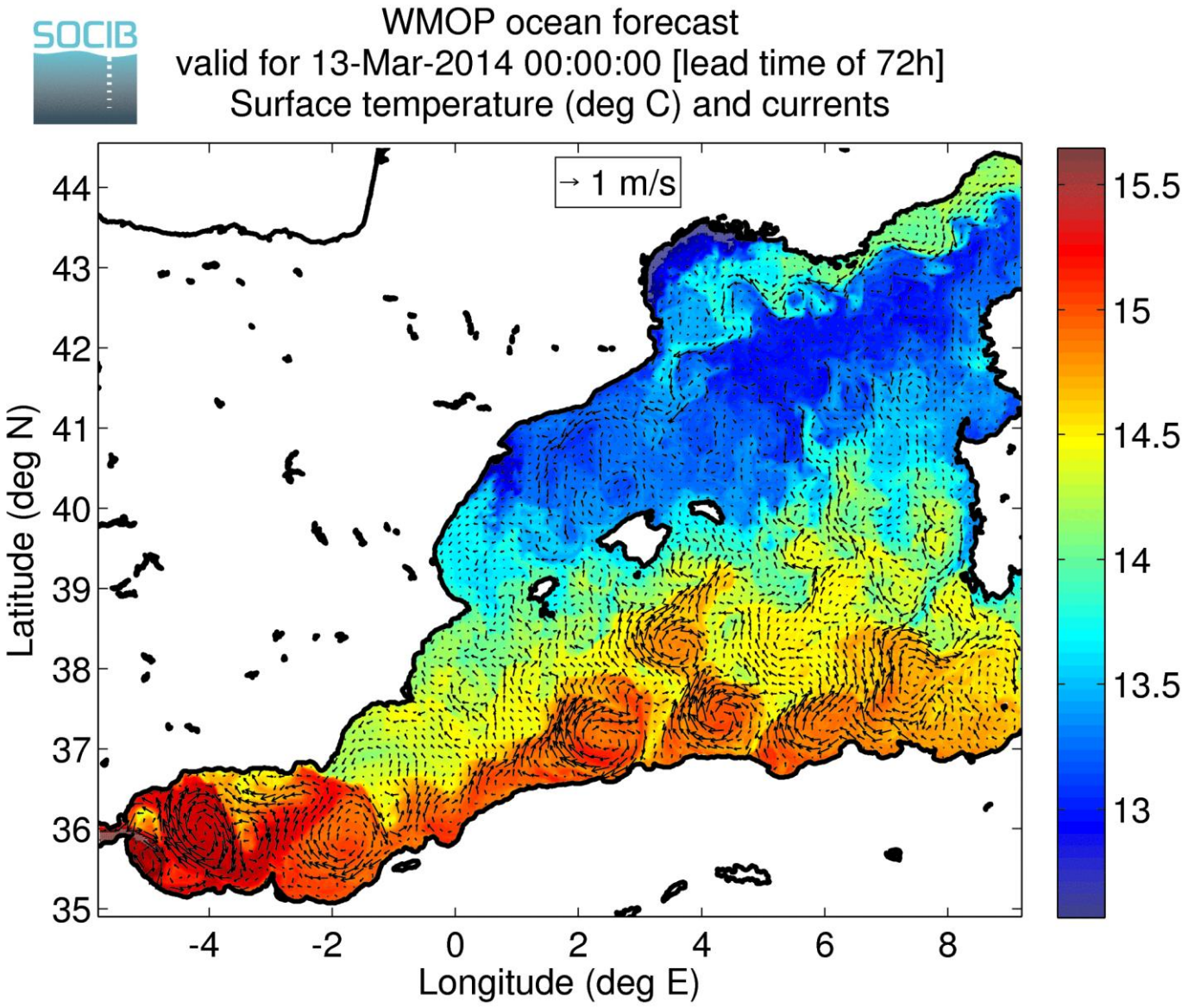


(credits: Meteo France)

Introduction: models

< 2km resolution

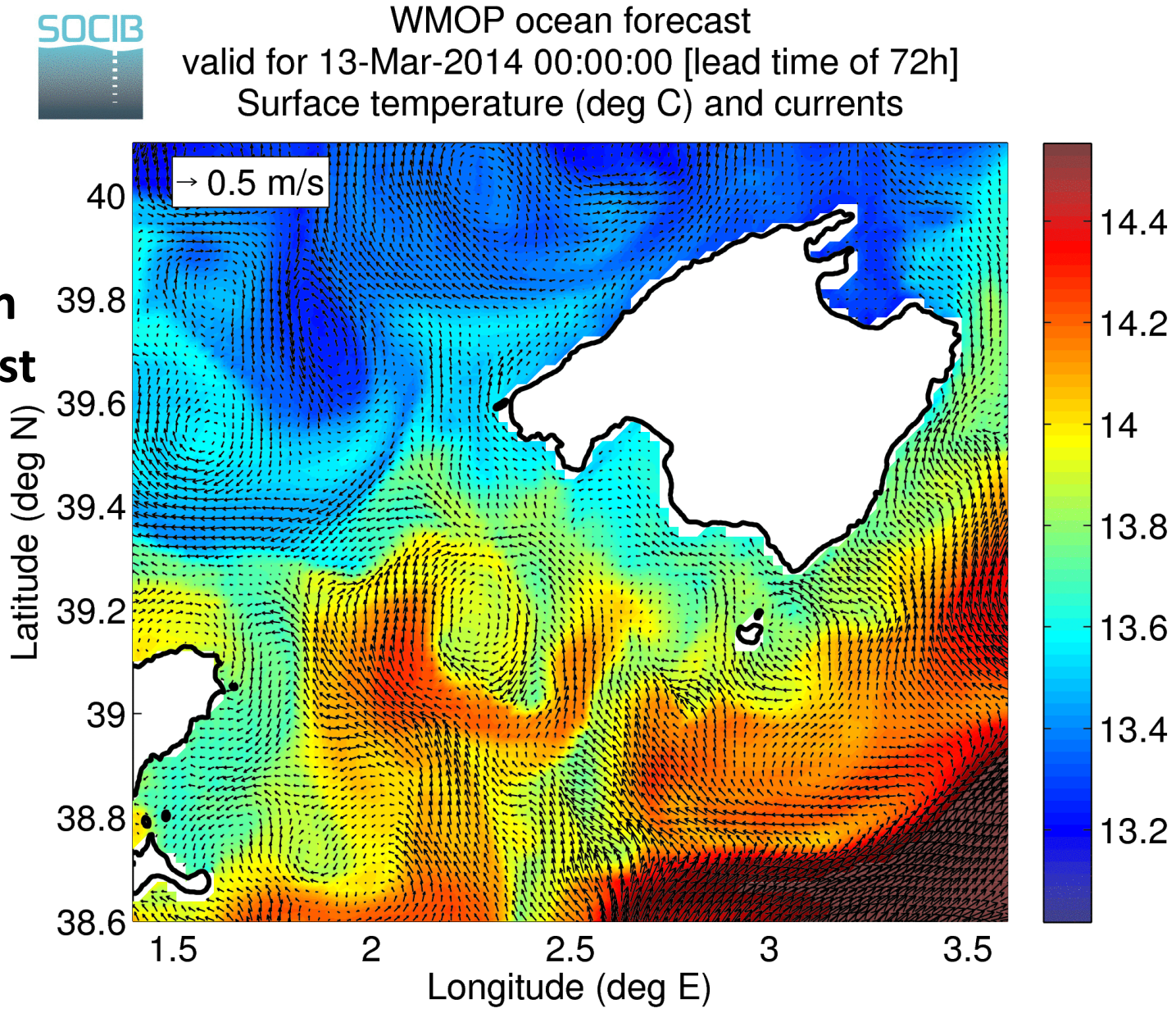
1h15 computation for a 3-day forecast



Introduction: models

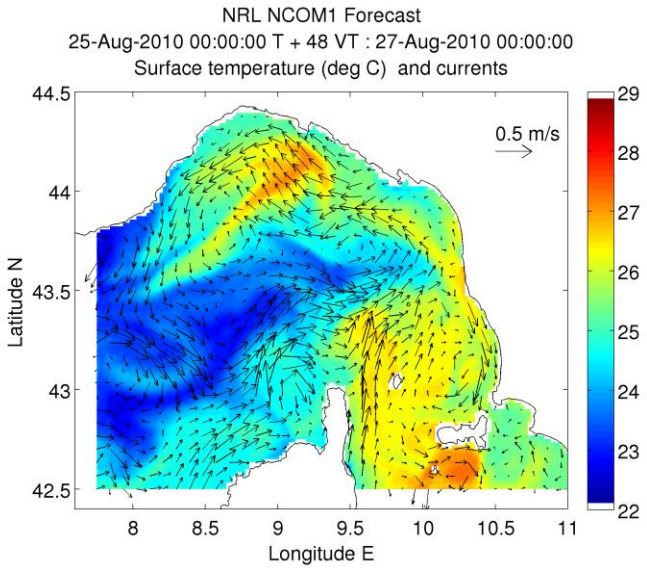
< 2km resolution

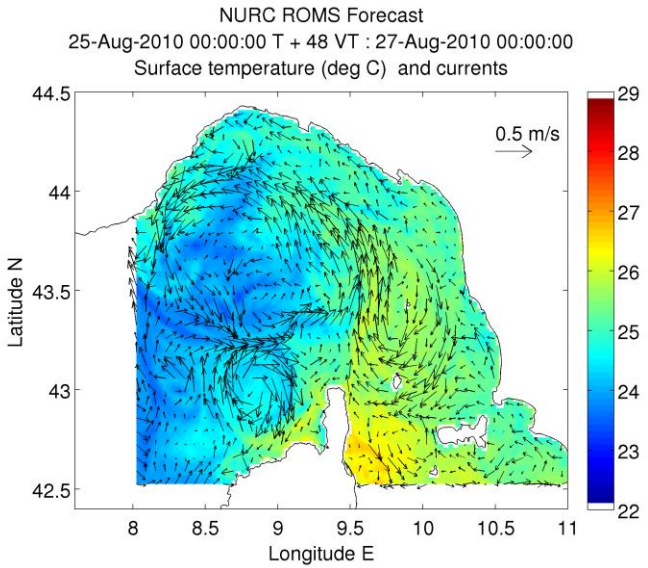
1h15 computation for a 3-day forecast

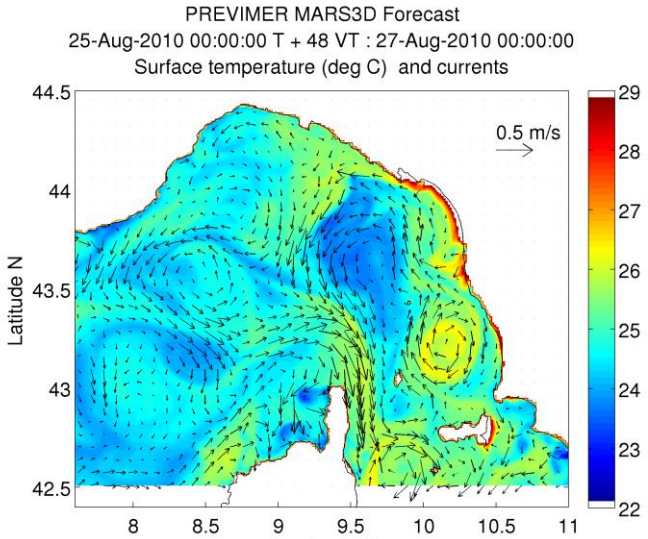


Introduction: models

Are these predictions reliable ?

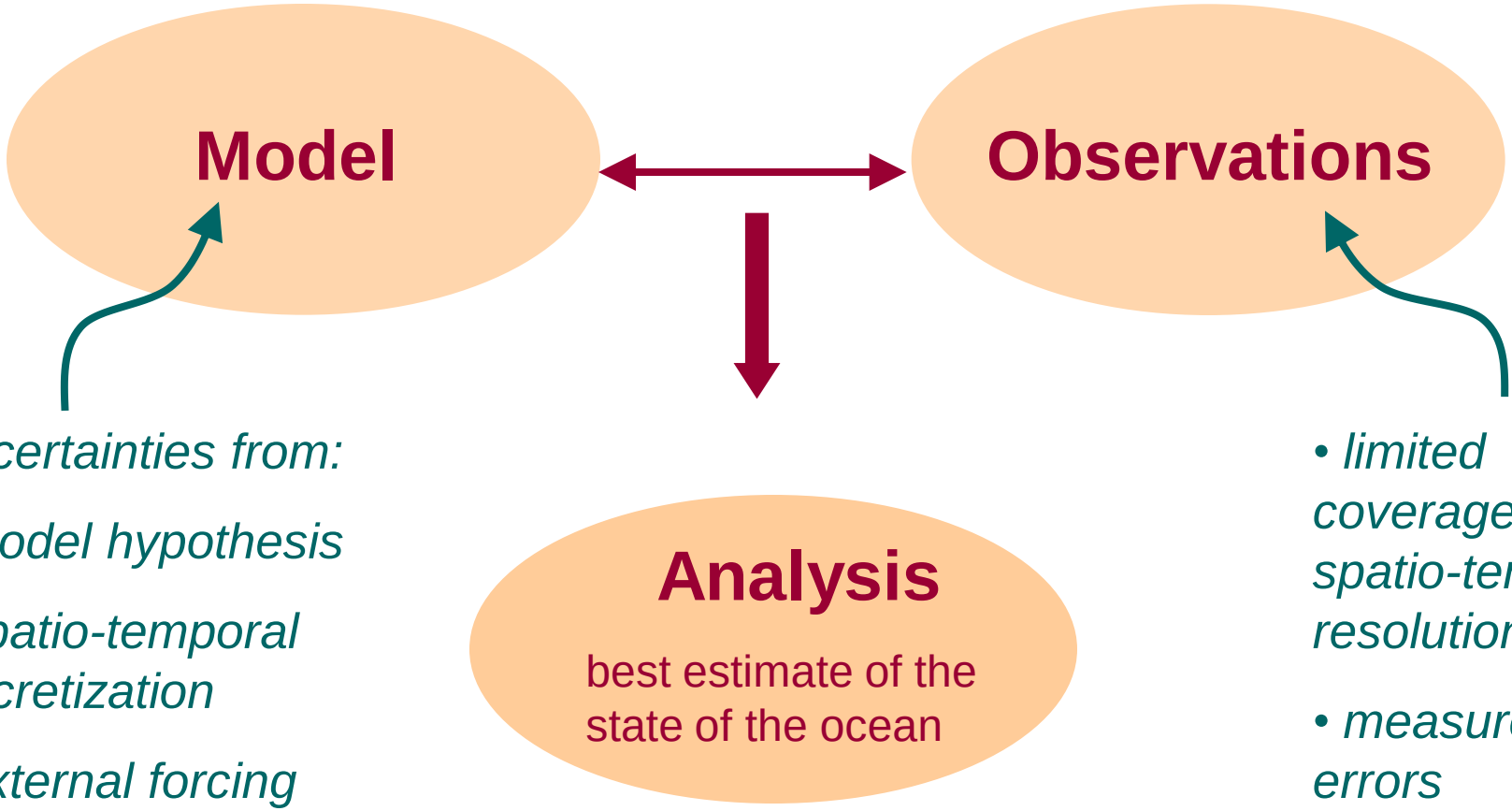






Introduction: data assimilation

Need for data assimilation !



Uncertainties from:

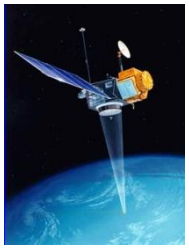
- *model hypothesis*
- *spatio-temporal discretization*
- *external forcing*
- *…*

- *limited coverage and spatio-temporal resolution*
- *measurement errors*

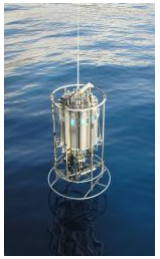
Introduction: observations

Ocean observations:

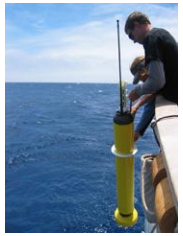
Satellite



Ship-based CTDs



Profiling floats



Gliders

Moorings

Surface drifters

HF radar

Multi-platform observations, available in near real-time.

→ ocean observatories

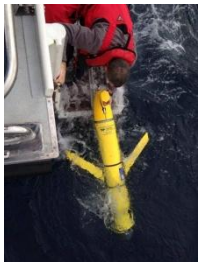
Introduction: observations

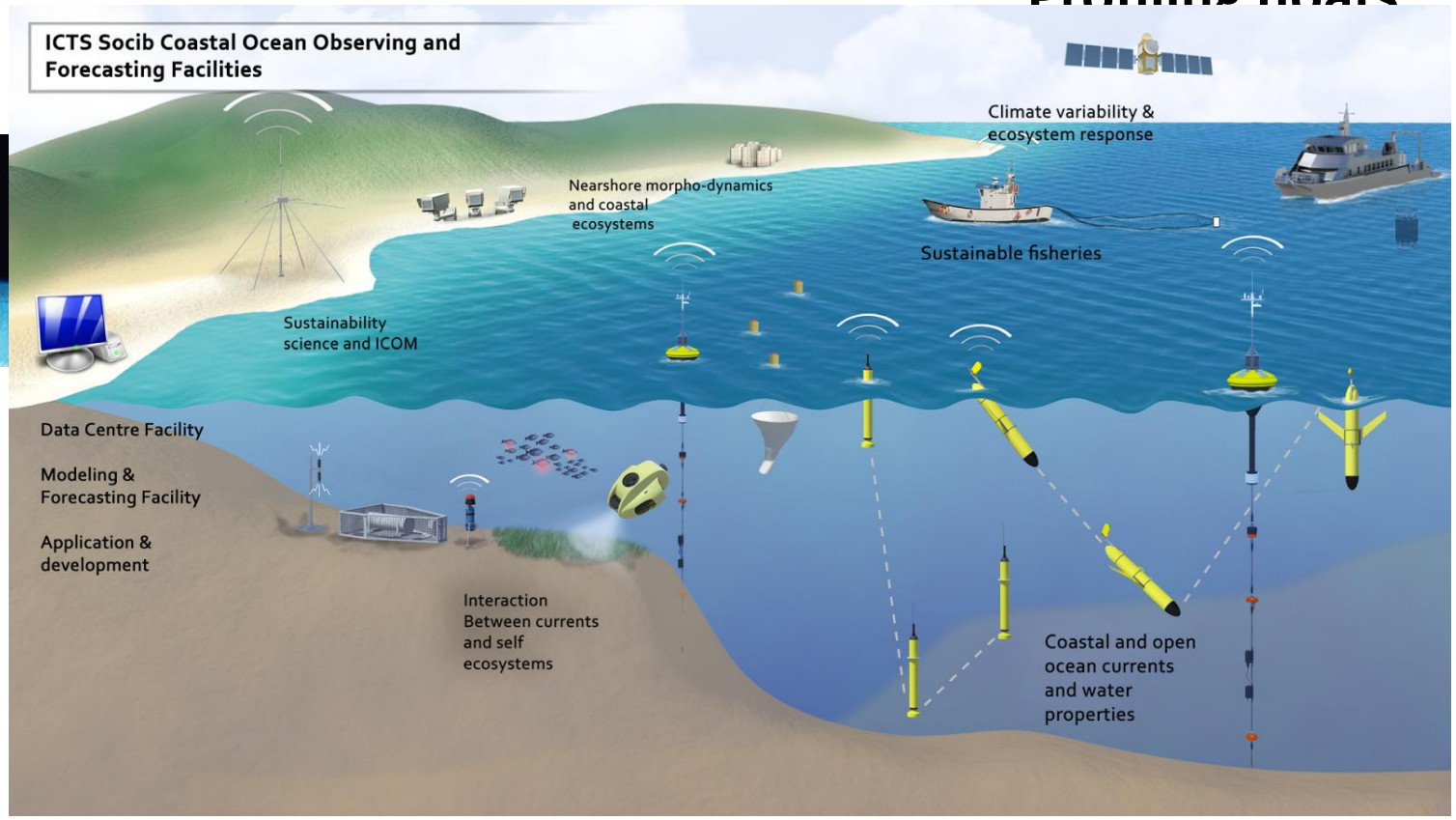
Ocean observations:

Profiling floats

Satellite

Gliders





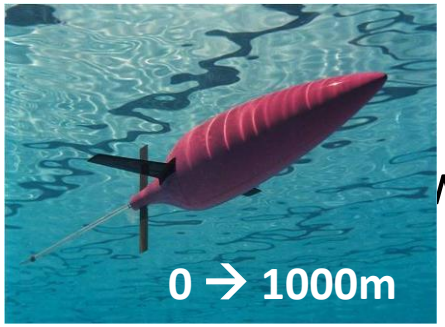
Multi-platform observations, available in near real-time.

→ ocean observatories

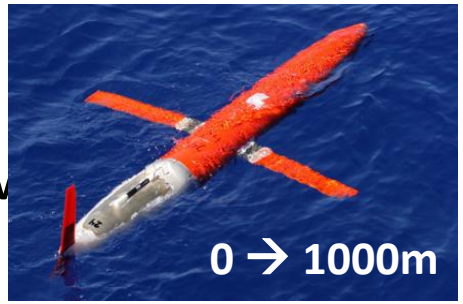
Introduction: observations

underwater gliders

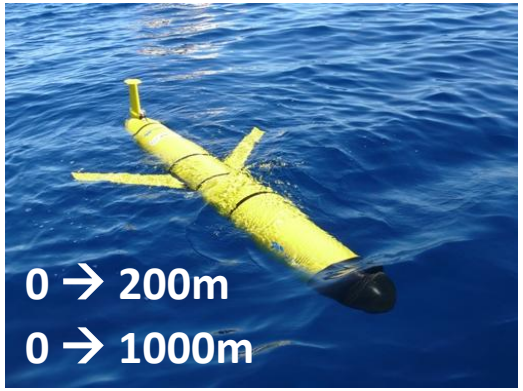
allow an autonomous, controllable, cost-effective, long-duration, high-spatial-resolution sampling of the ocean in both coastal and deep environments



Seaglider



Spray



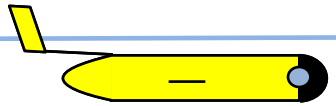
Slocum

SeaExplorer

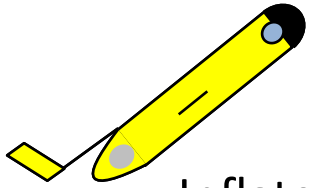
How does a Slocum glider work ?

Control Centre

Satellite
Communication
GPS



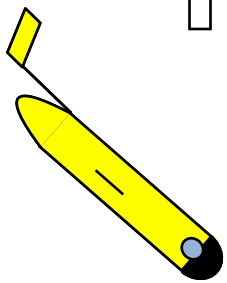
Pump water in
& slide battery pack
Standard diving angle: 26º



Inflate bladder

Extra buoyancy: 250gr

Negative buoyancy



Expel water
& slide battery pack

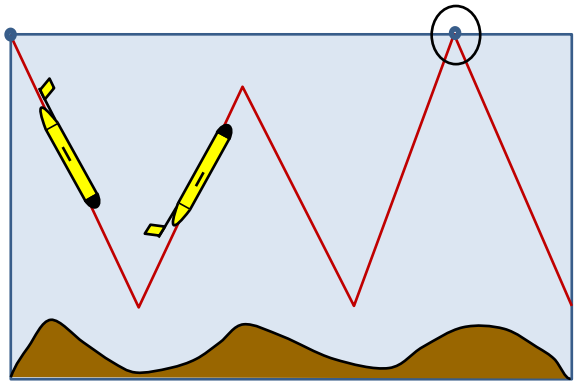
How does a Slocum glider work ?

Horizontal distance ~ 800 m (for a 200-m dive)

Travel time ~ 45 min

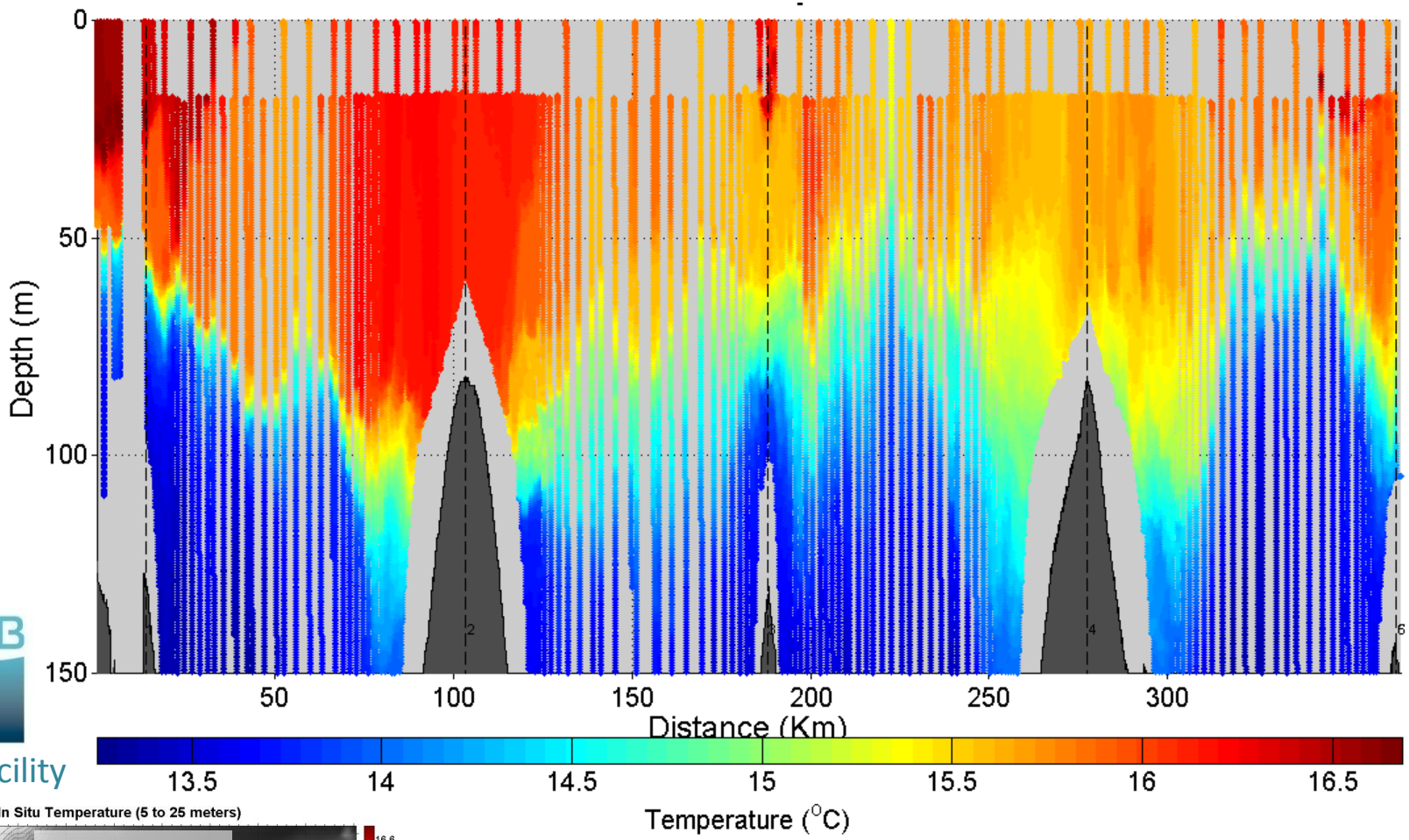
Horizontal speed 0.2-0.4 m/s

Vertical Speed 0.1-0.2 m/s



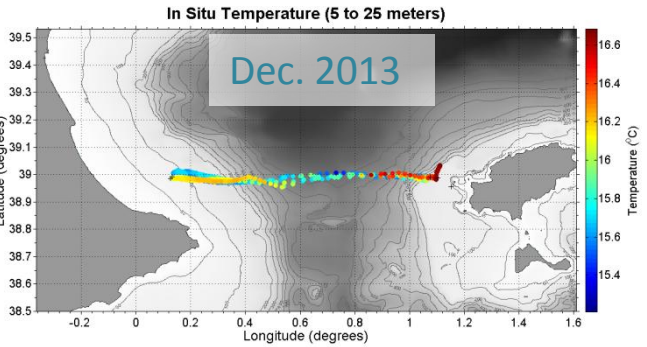
➡ http://followtheglider.com/

Typical glider temperature data set

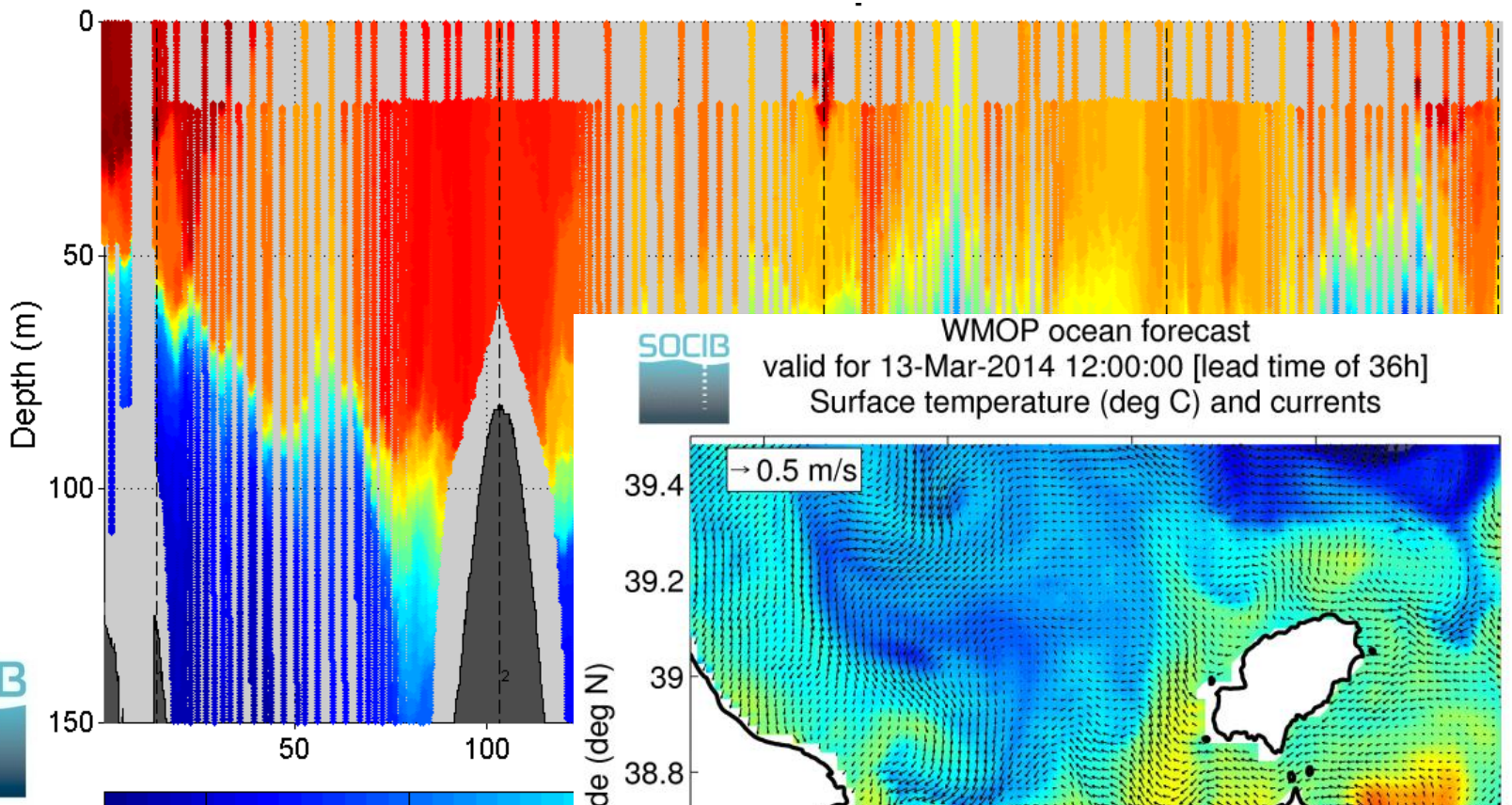


SOCIB

Glider facility

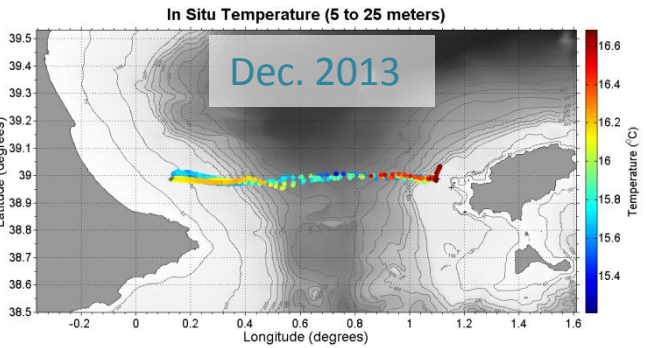


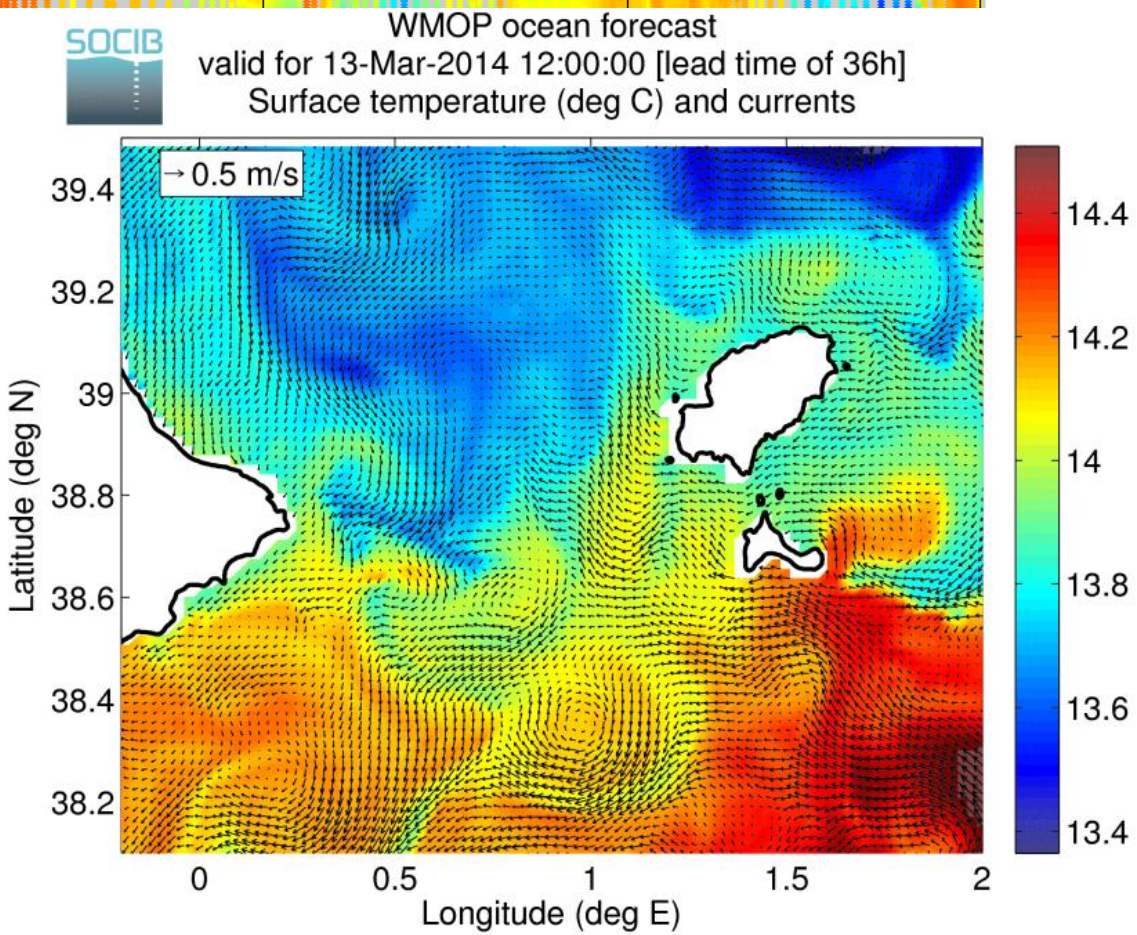
Typical glider temperature data set



SOCIB

Glider facility





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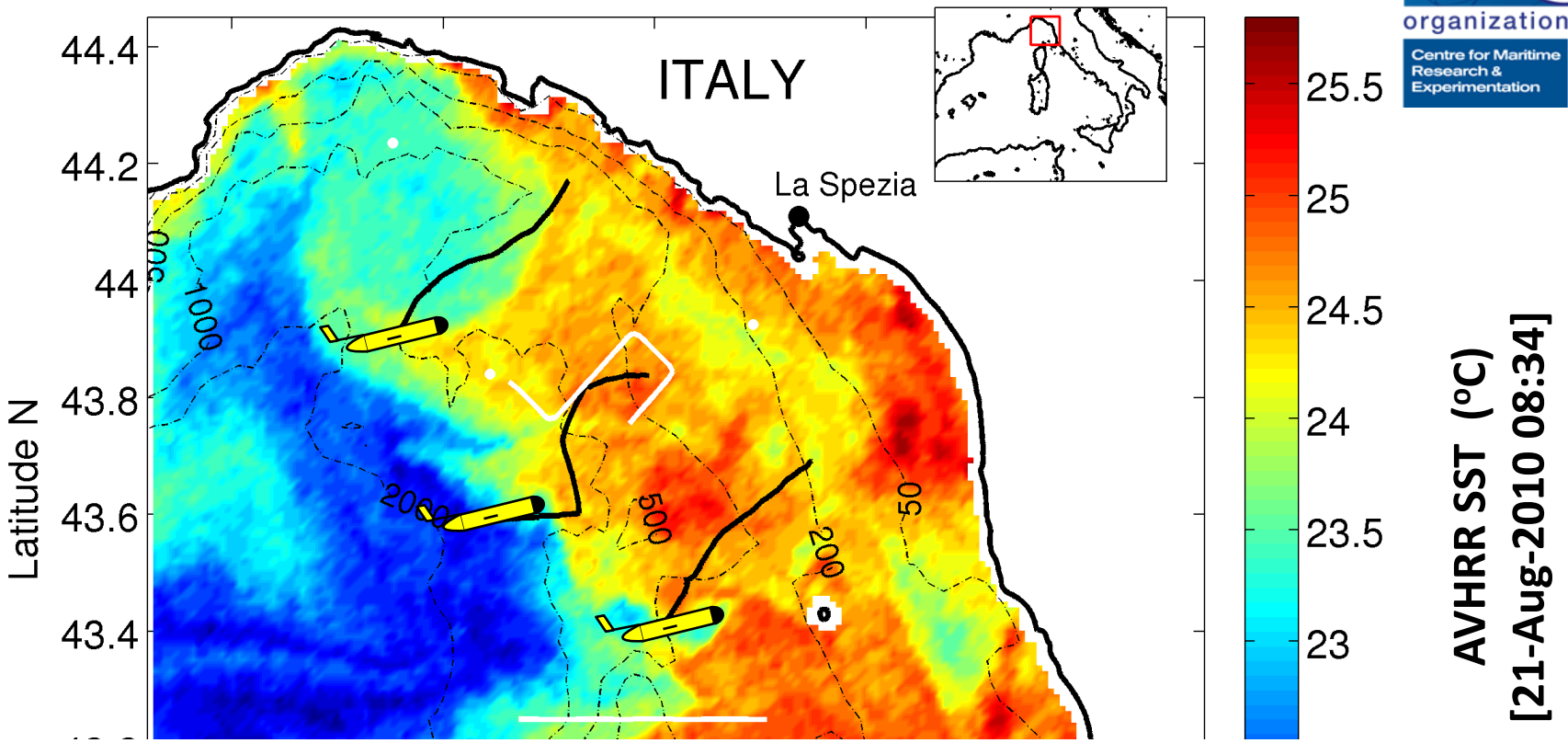
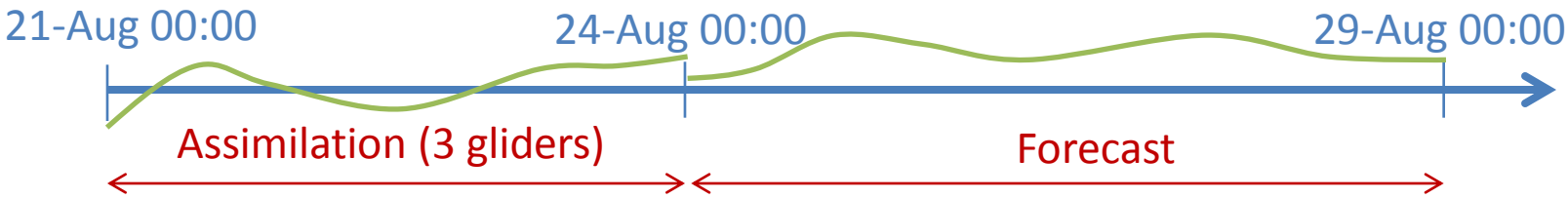
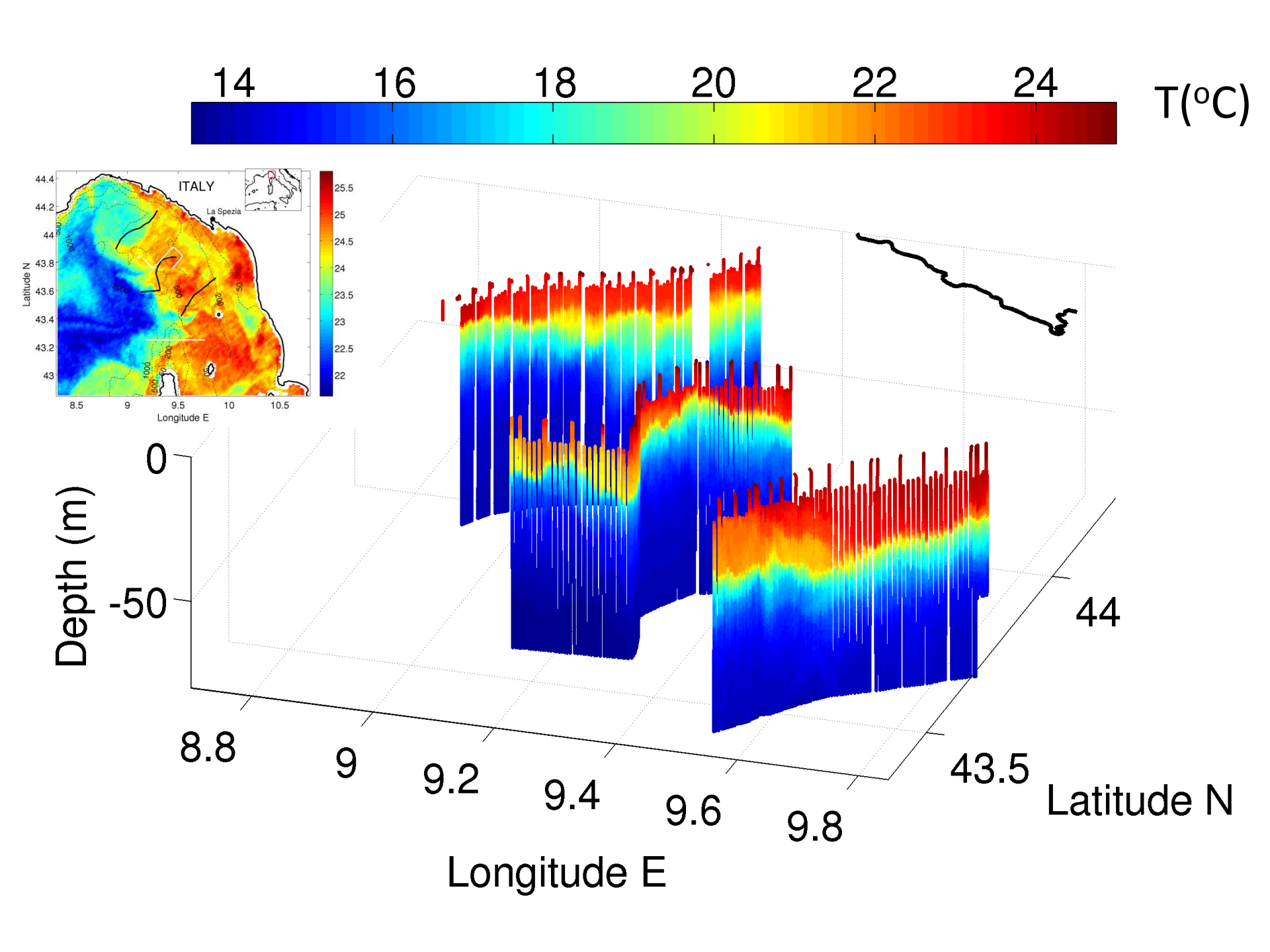
Glider fleet data assimilation experiment





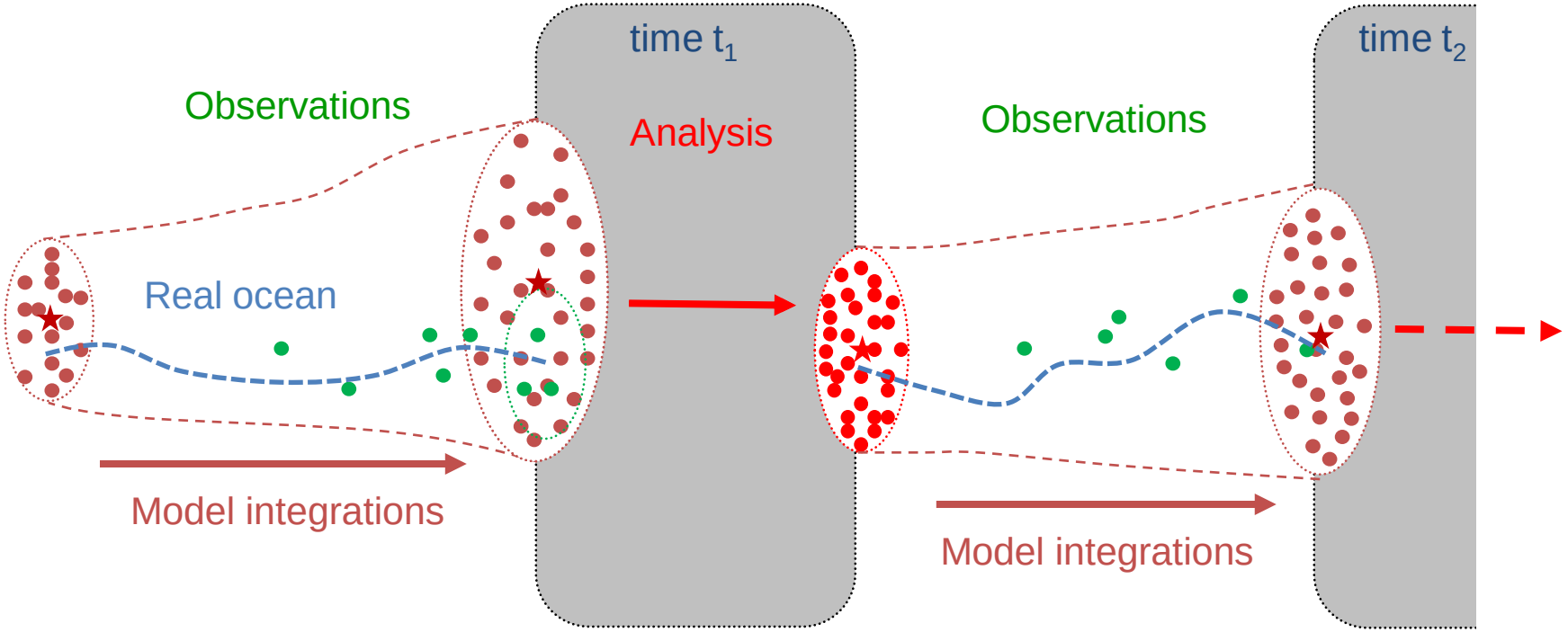
ROMS model with 1.8 km resolution.


14
16
18
20
22
24
T(°C)
ITALY
La Spezia
Latitude N
Longitude E
Depth (m)
0
-50
8.8
9
9.2
9.4
9.6
9.8
43.5
44
Latitude N
Longitude E

Glider fleet data assimilation experiment

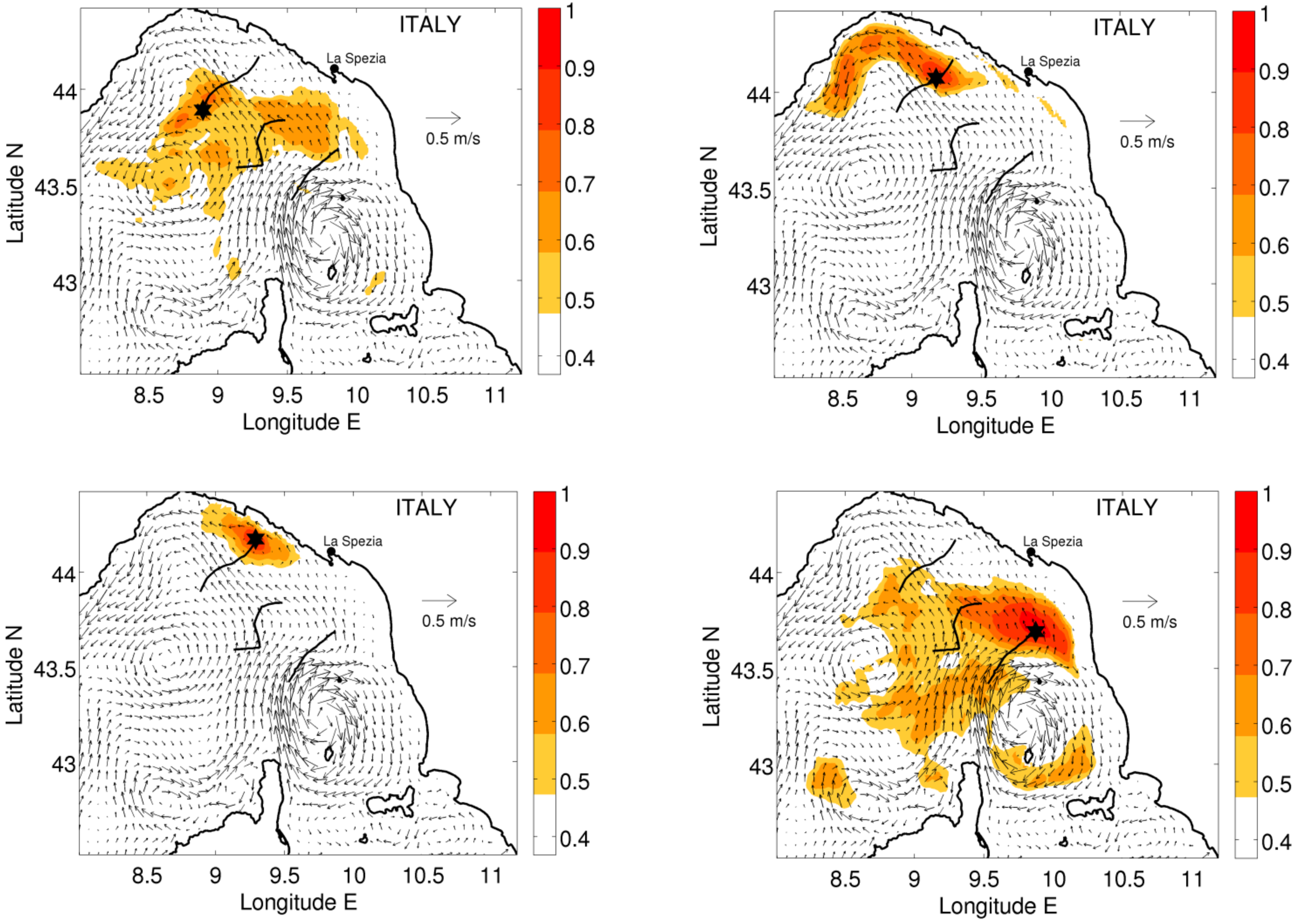
Data assimilation: ensemble Kalman filter

Ensemble of 96 simulations, including perturbations of the initial conditions, wind and lateral boundaries.



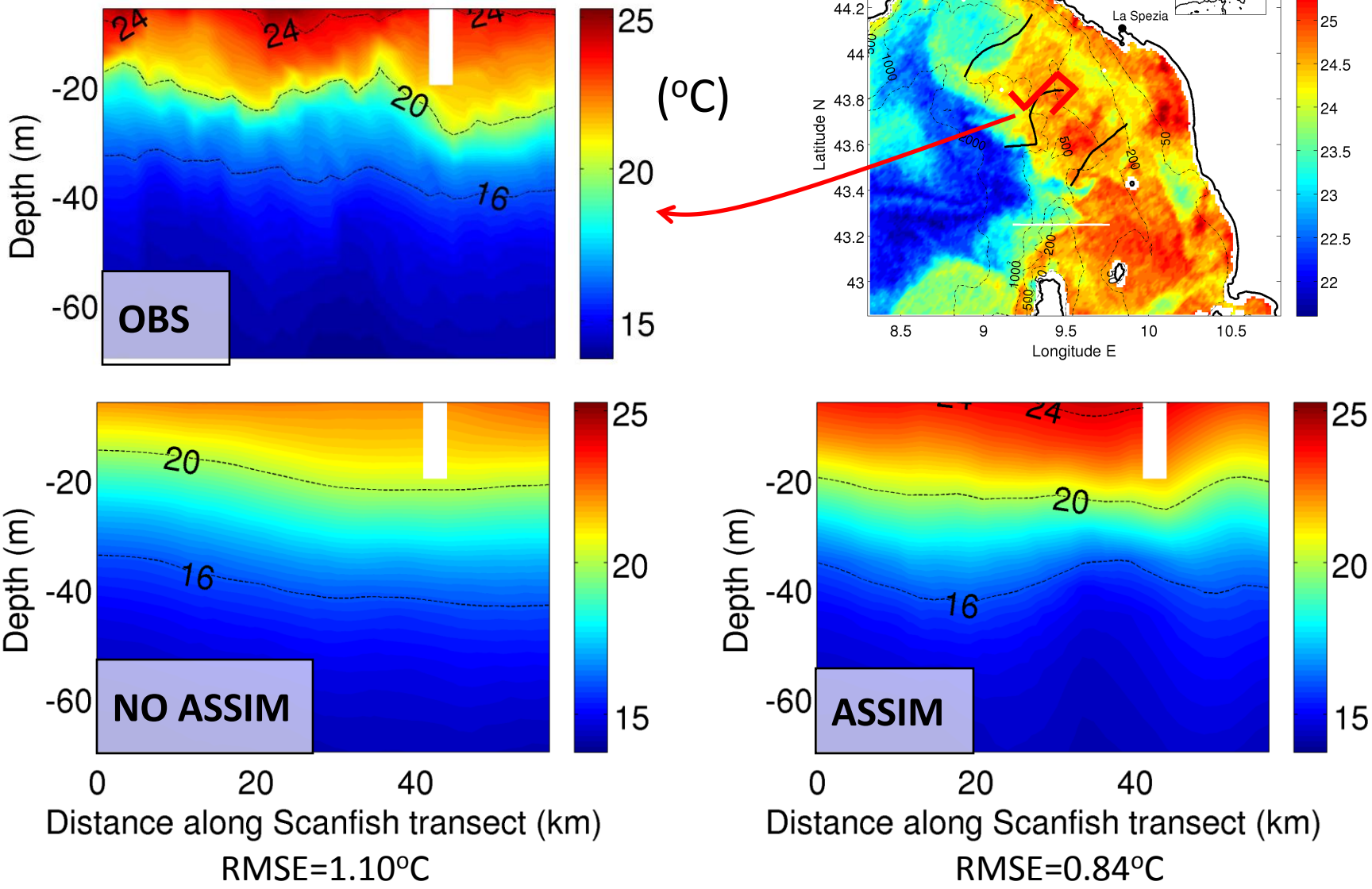
★ Ensemble mean: best estimate.
Ensemble spread: associated error.
Ensemble covariances (spatio-temporal and multivariate): used to correct non-observed areas/variables.

Temperature model error correlations at 20m



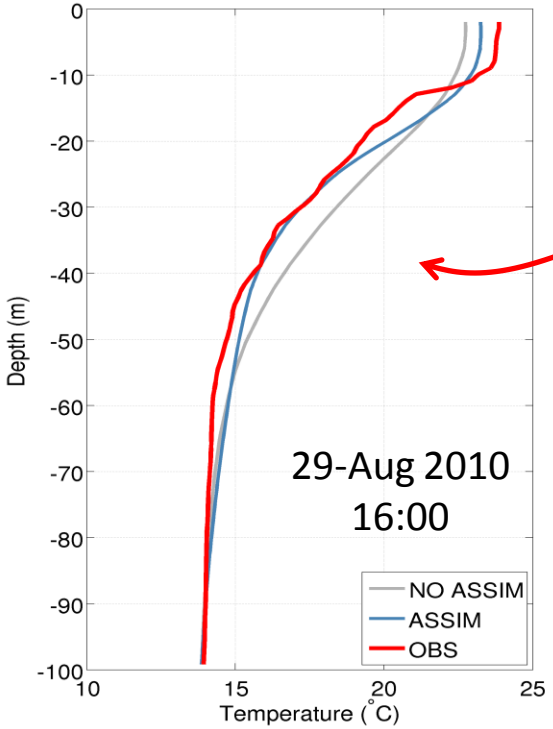
Glider fleet data assimilation experiment

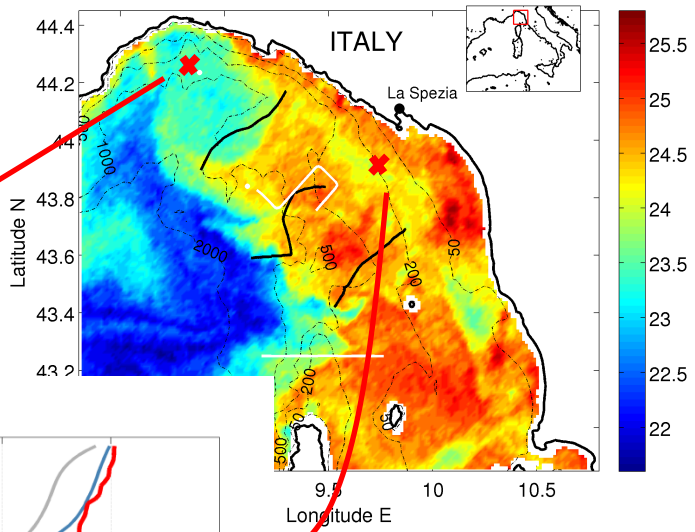
Validation against Scanfish data

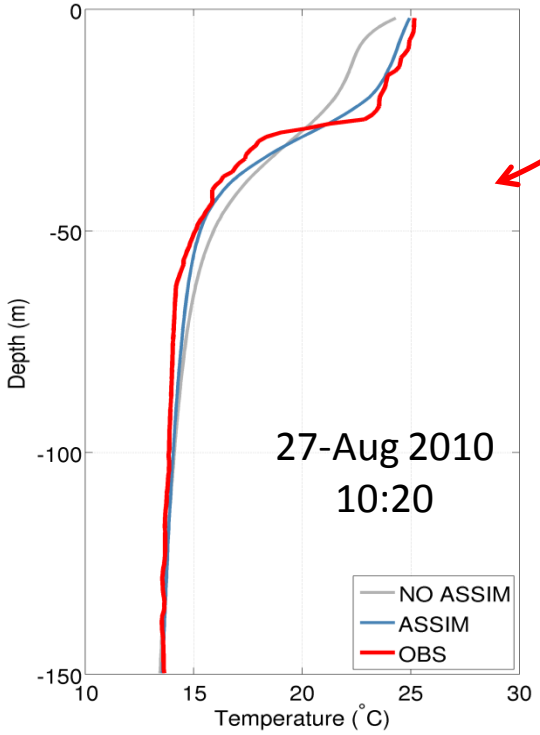


Glider fleet data assimilation experiment

Validation against CTD data

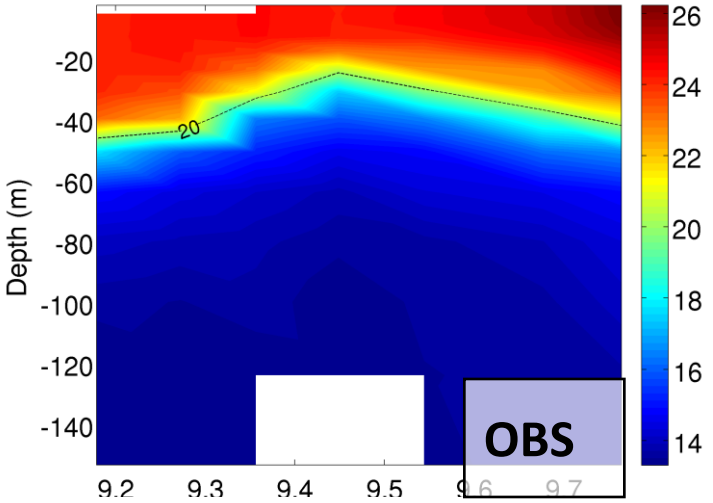






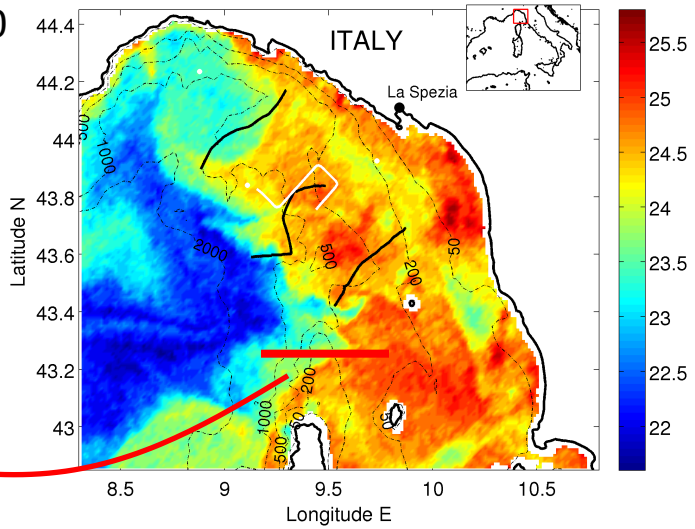
Glider fleet data assimilation experiment

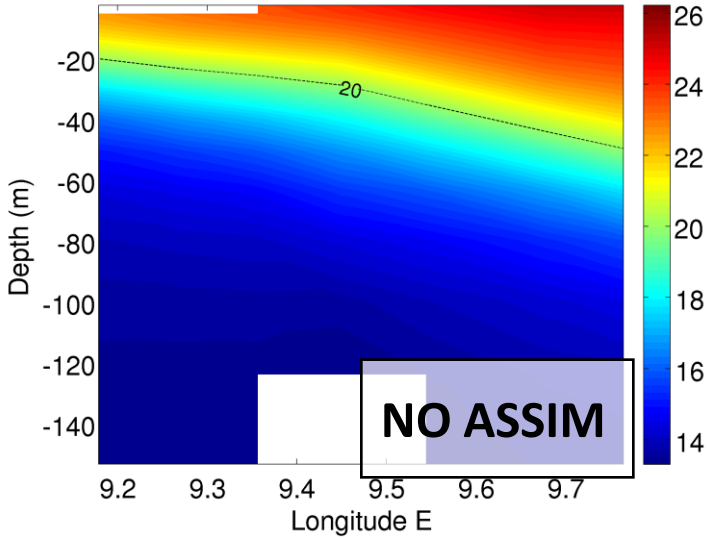
Validation against CTD data



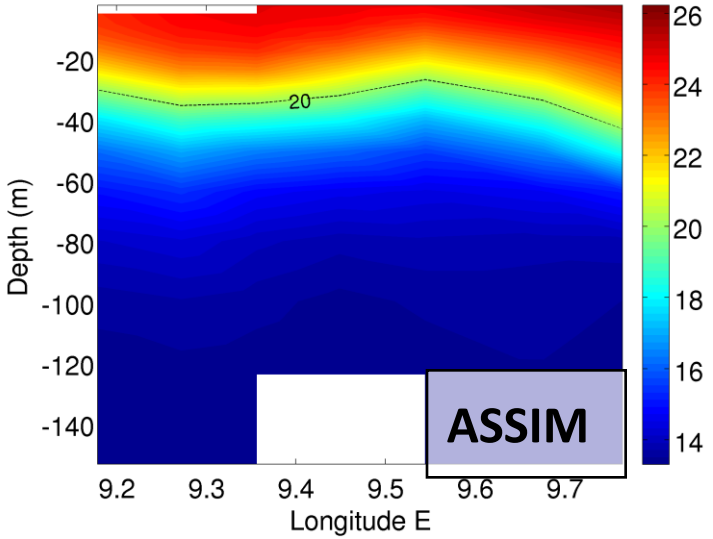
27-Aug 2010
22:00

(ºC)





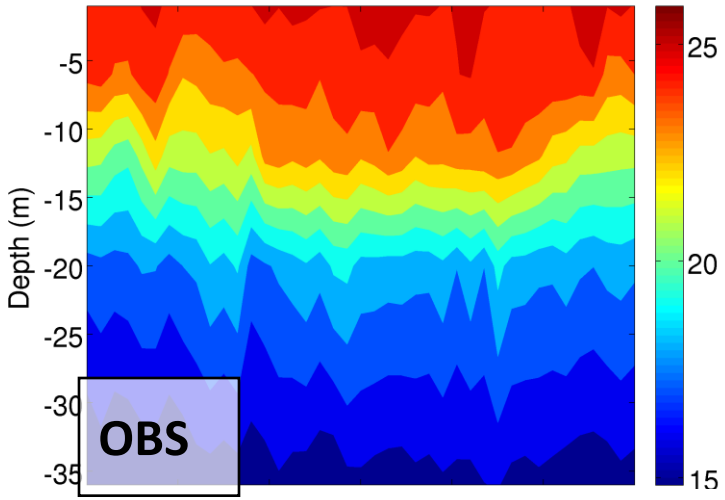
RMSE=1.95ºC



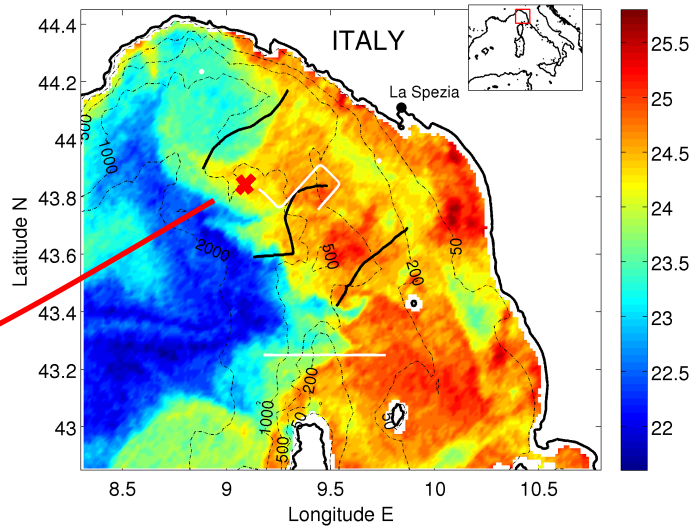
RMSE=1.16ºC

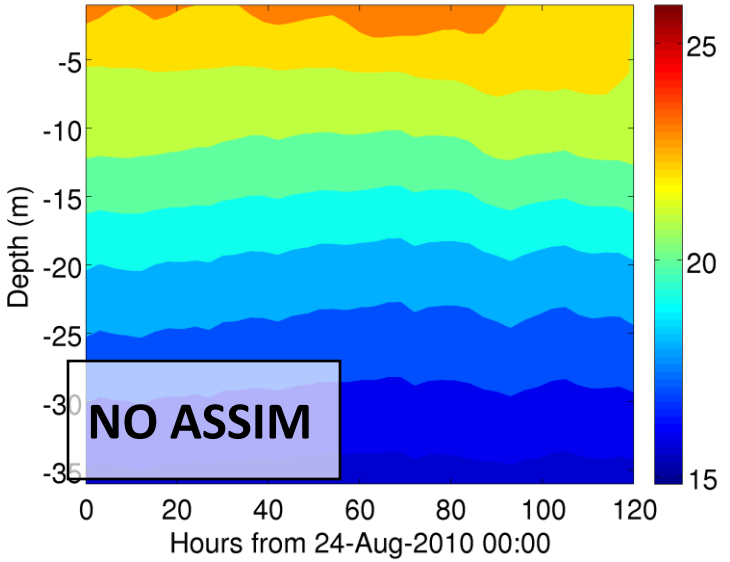
Glider fleet data assimilation experiment

Validation at ODAS mooring

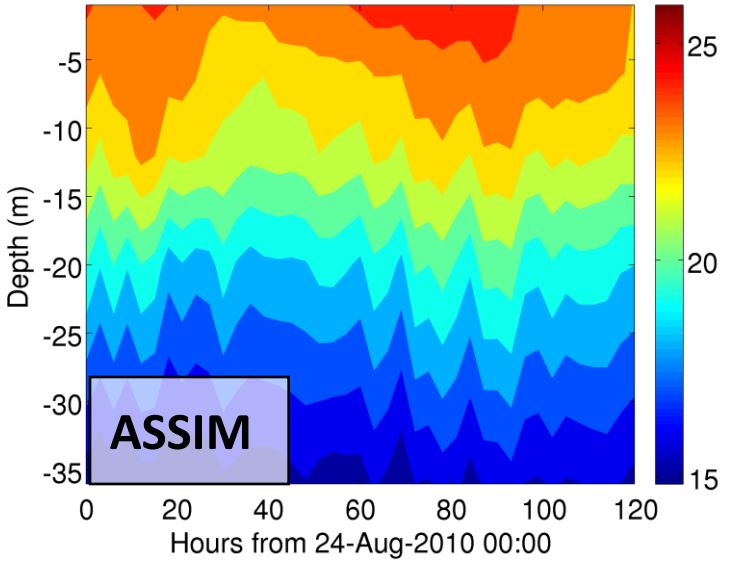


(ºC)





RMSE=1.66ºC



RMSE=1.15ºC

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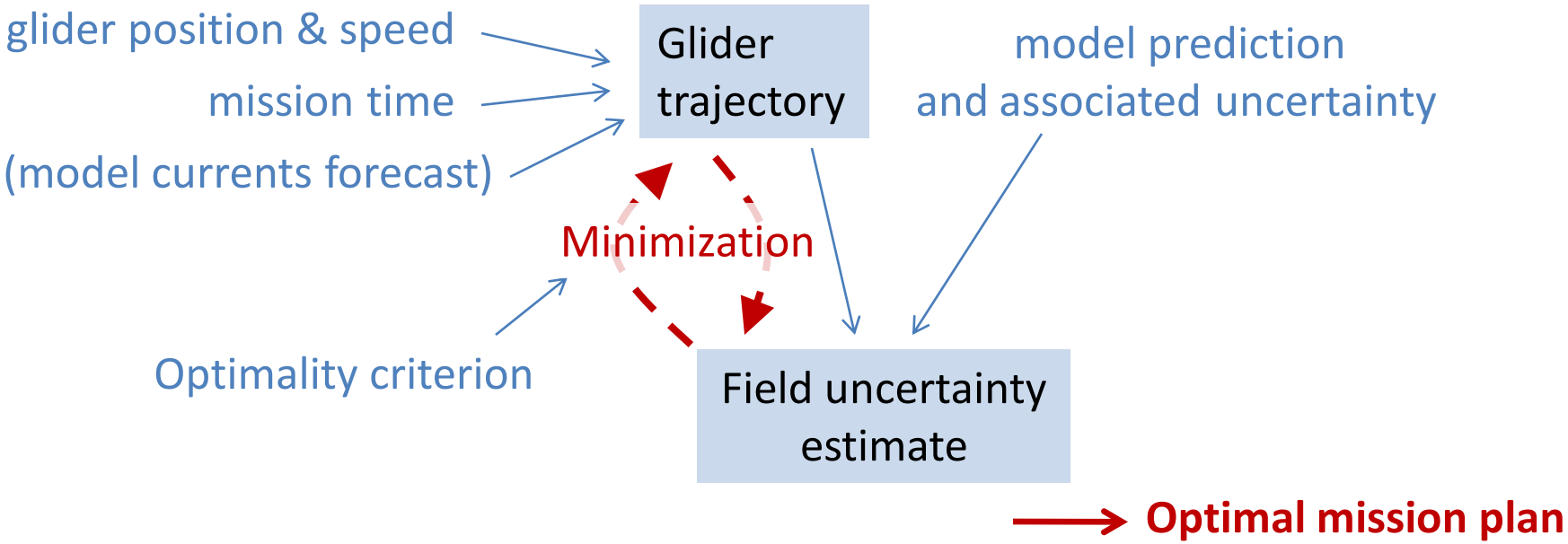
4) Conclusions

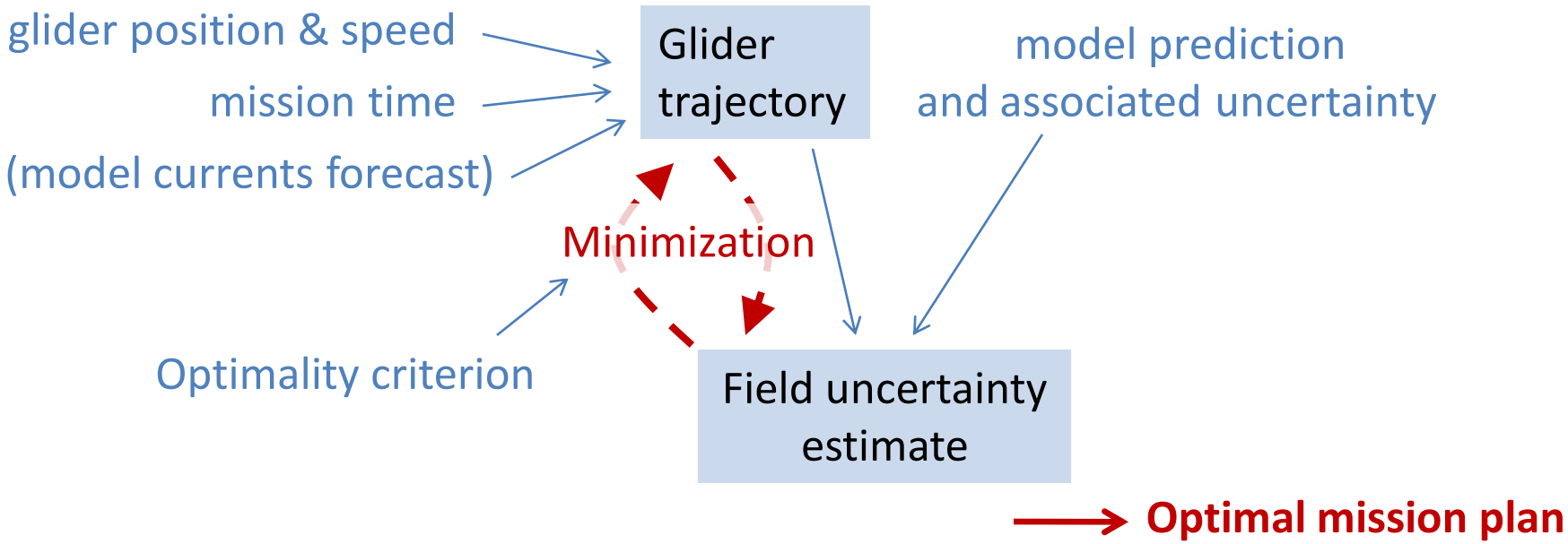
Adaptive sampling: concept

Two-way satellite communications: gliders are controllable !

The glider sampling can be adapted each time the glider communicates at the sea surface, so as to minimize the ocean model forecast uncertainty.

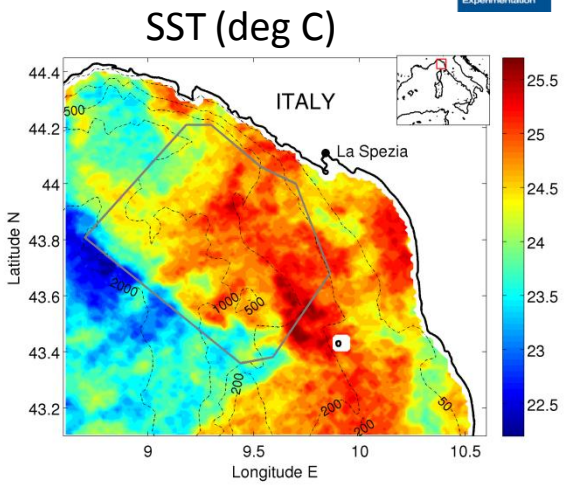


Adaptive sampling: concept



- Process aiming at defining **timely reachable** trajectories.
- During the mission, the glider surfaces several times between two waypoints and **corrects its heading** according to (i) its actual position and (ii) the estimation of the local oceanic current field deduced from the mismatch between the planned and actual positions of the platform.

Adaptive sampling: at-sea experiment



(i) A first glider is piloted to reduce the model temperature uncertainties (here 3DSE) in a limited area of the Ligurian Sea during three 48-hour cycles from 20 to 26 August 2010.

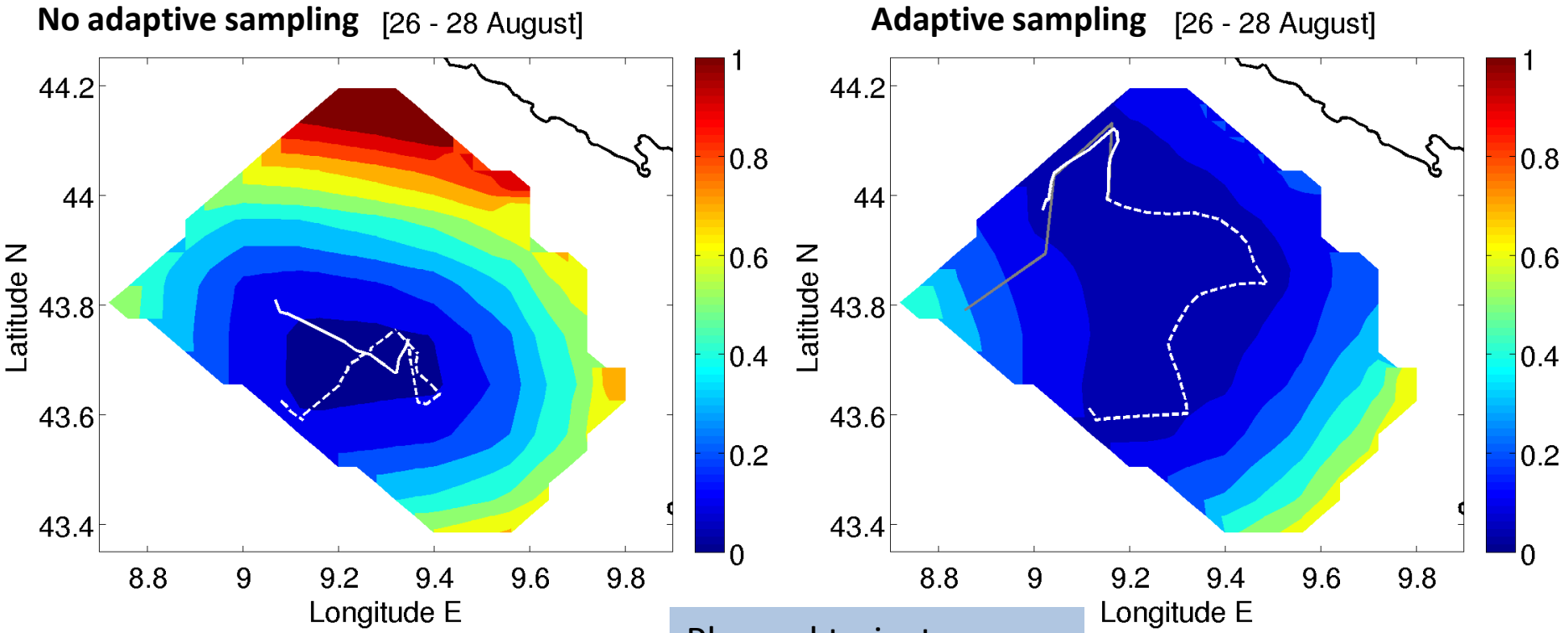
(ii) During the same period, a second glider flies in the same area but without any adaptive sampling control.

(iii) Two model forecasts are produced assimilating either the first or second glider.

(iv) Independent data from CTDs, gliders, ship surface CTD, Scanfish and ODAS mooring are used to evaluate the forecasts.

Adaptive sampling: at-sea experiment

Model predicted uncertainty (°C)
[26-28 August]



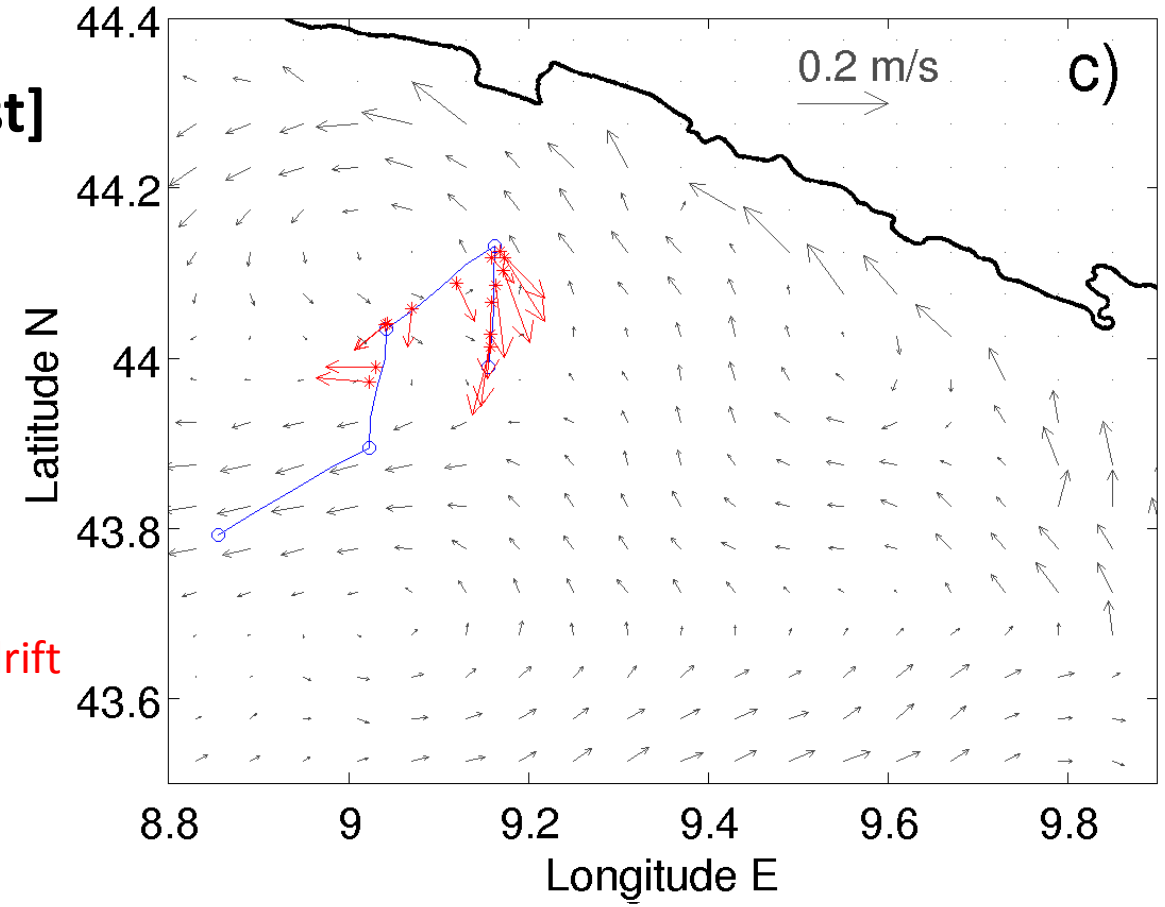
Mean value: **0.42 °C** **0.19 °C**

Reduction of the predicted uncertainty with adaptive sampling

Adaptive sampling: at-sea experiment

Significant errors in the predicted ocean currents prevented the glider from completing the planned trajectories.

[24-26 August]



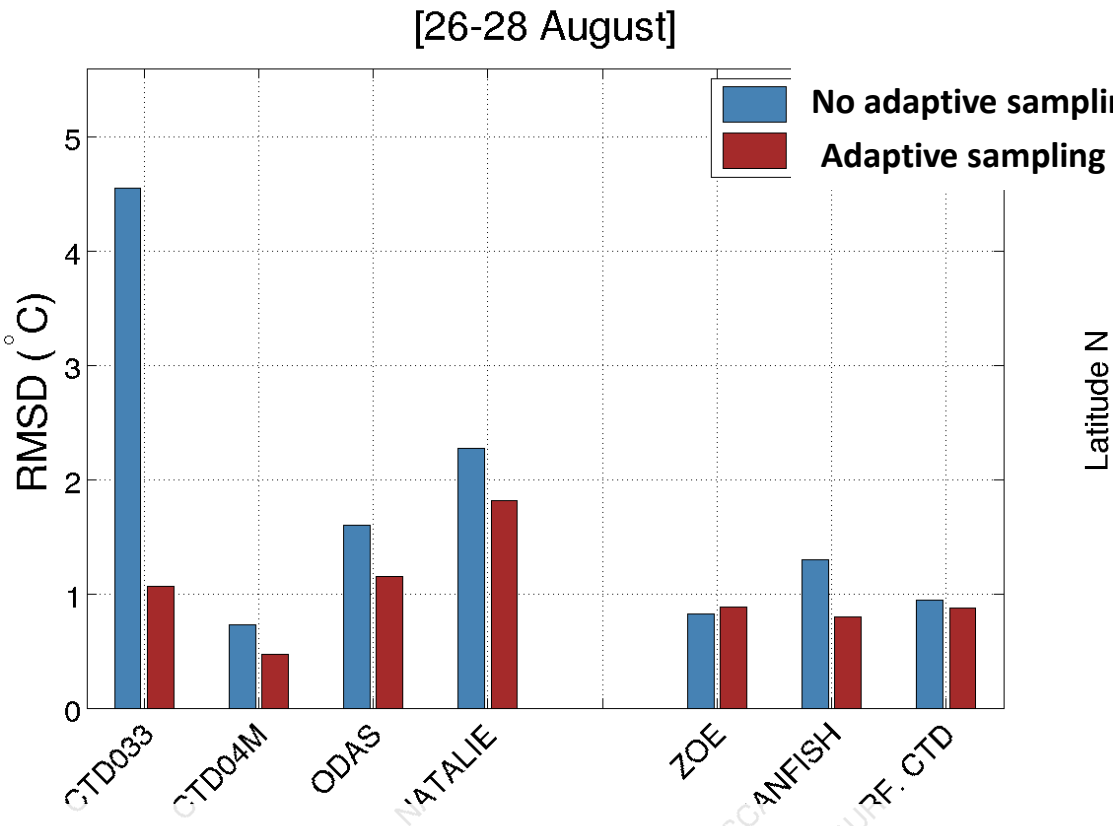
Planned trajectory

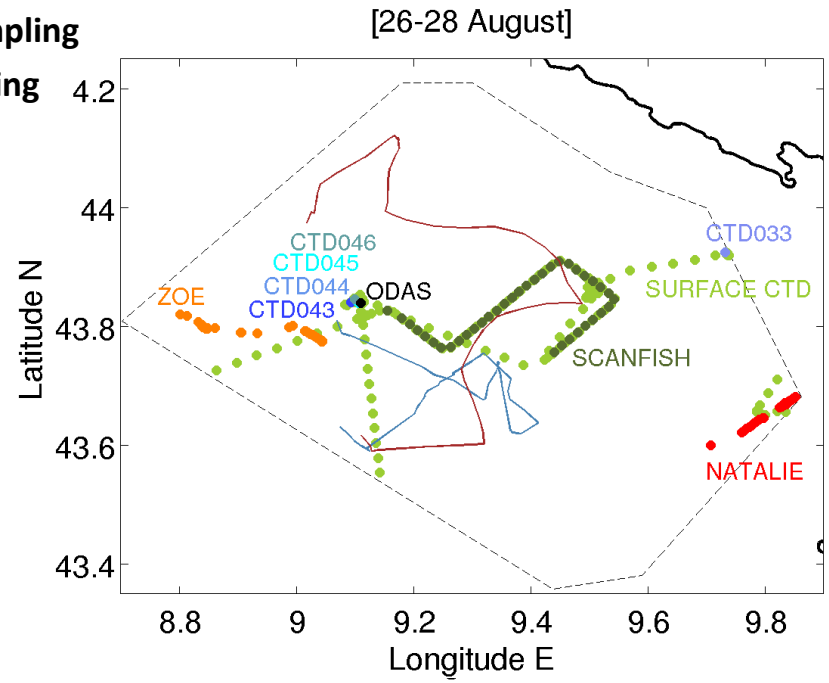
Vel. estimated from glider drift

Vel. predicted by the model

Adaptive sampling: at-sea experiment

Root-Mean-Square Differences between model predictions and observations (temperature)

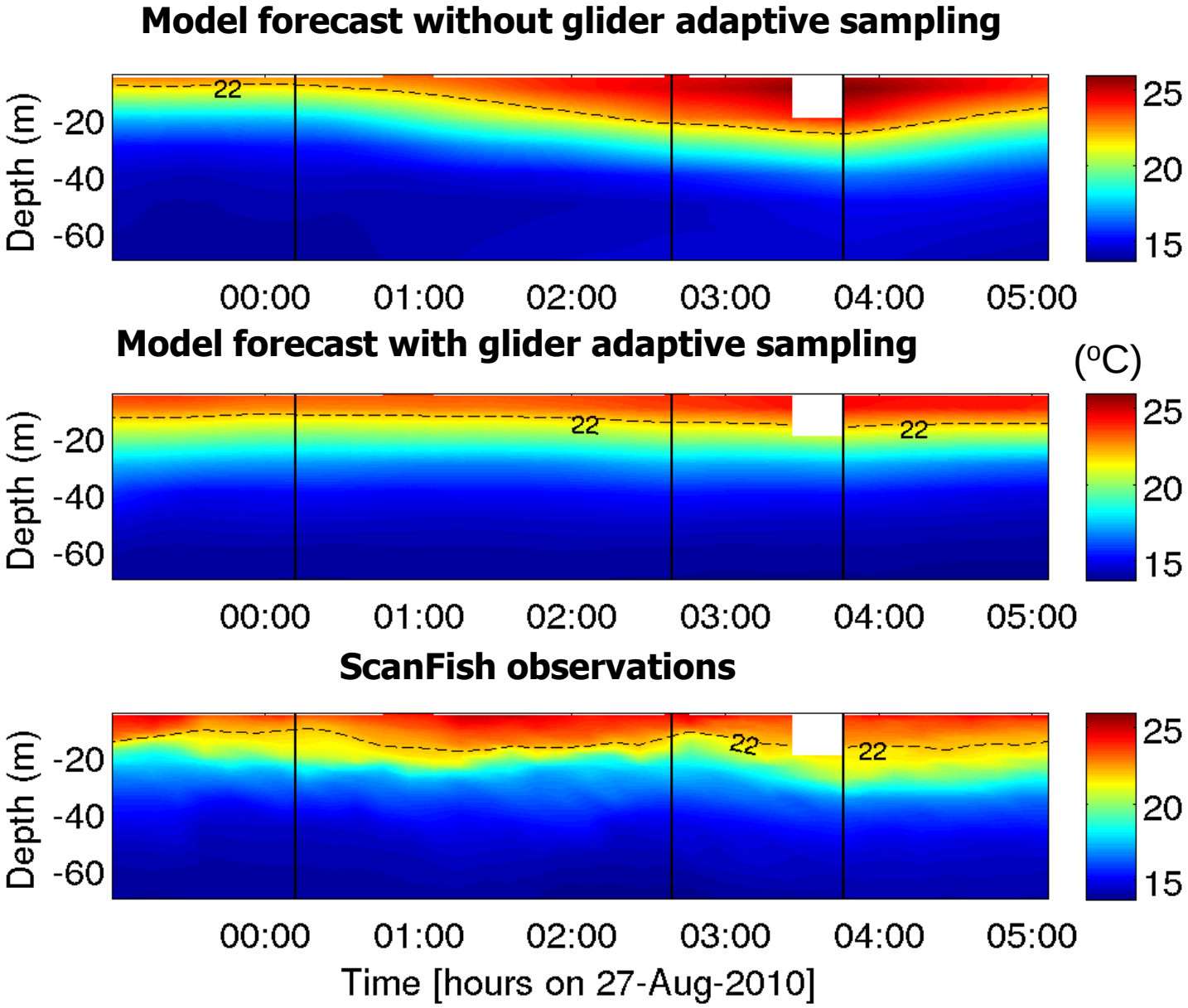




Reduction of the temperature error with adaptive sampling

(total error reduced by 18%)

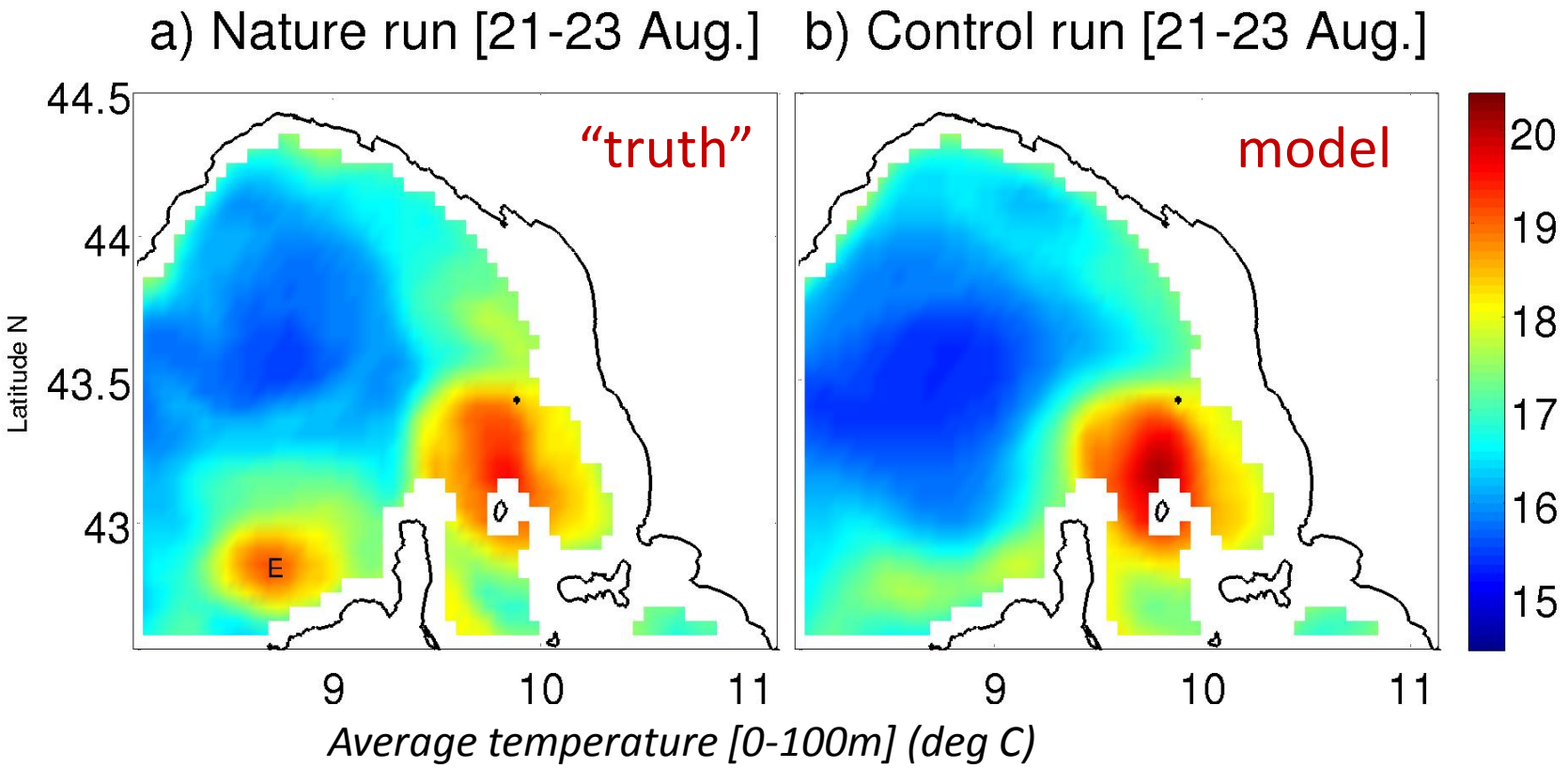
Adaptive sampling: at-sea experiment



Adaptive sampling: OSSEs

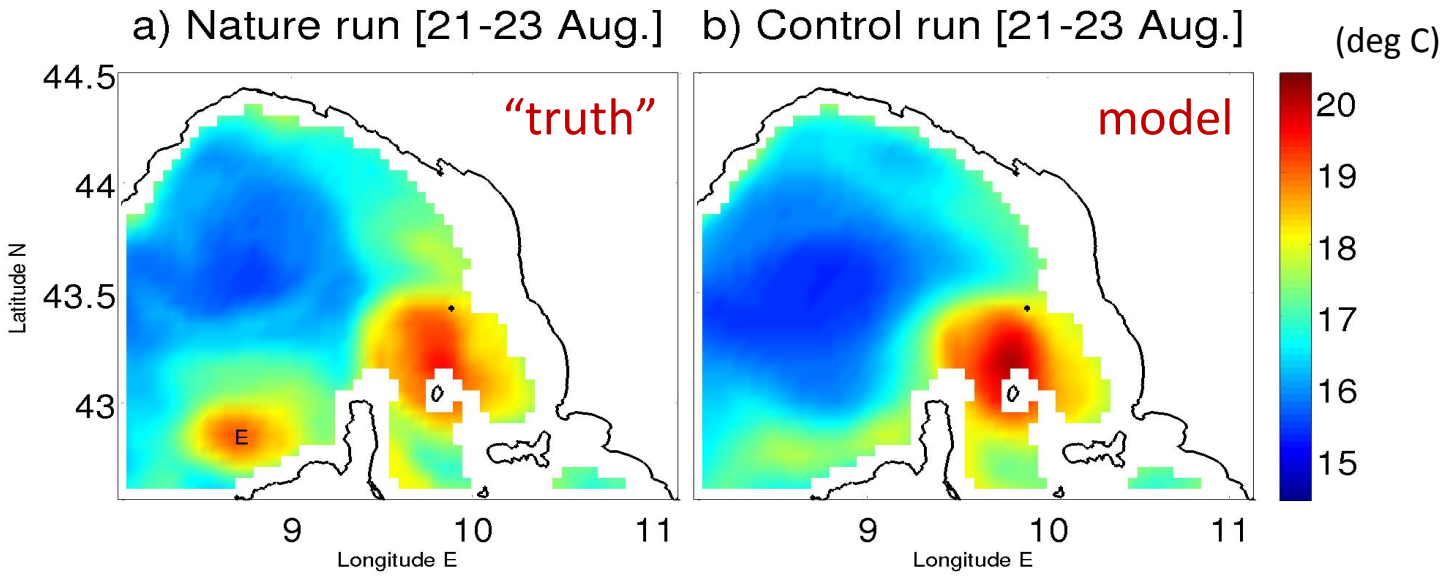
OSSEs: Observing System Simulation Experiments

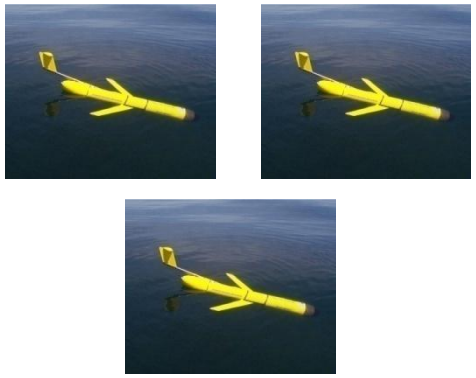
→ evaluate the potential contribution of observations to model forecasts

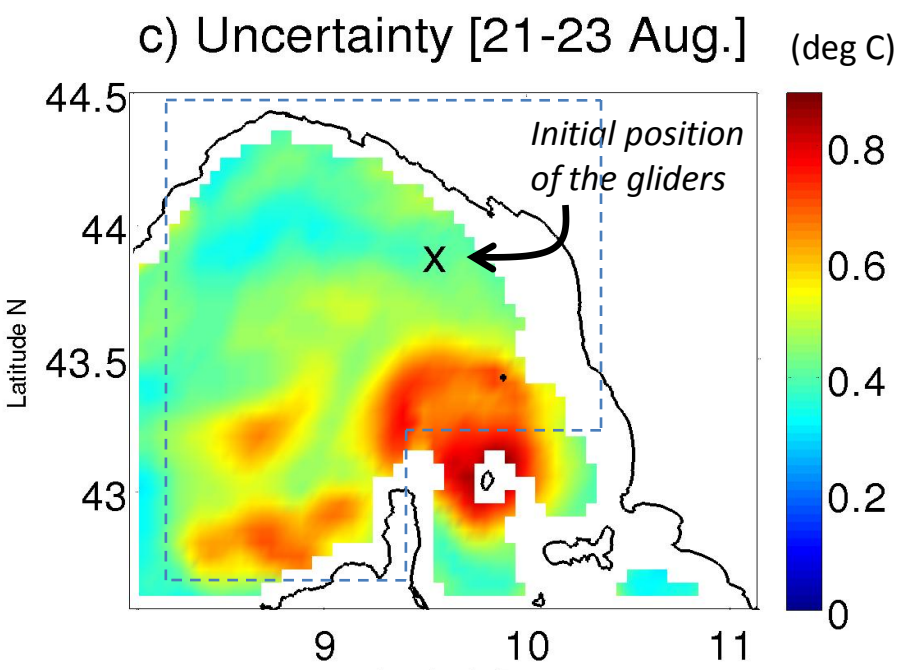


Observations simulated from the "truth" and assimilated in the control simulation.

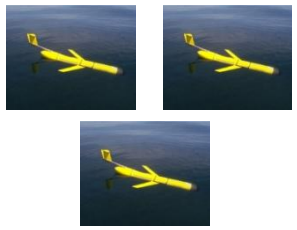
Adaptive sampling: OSSEs







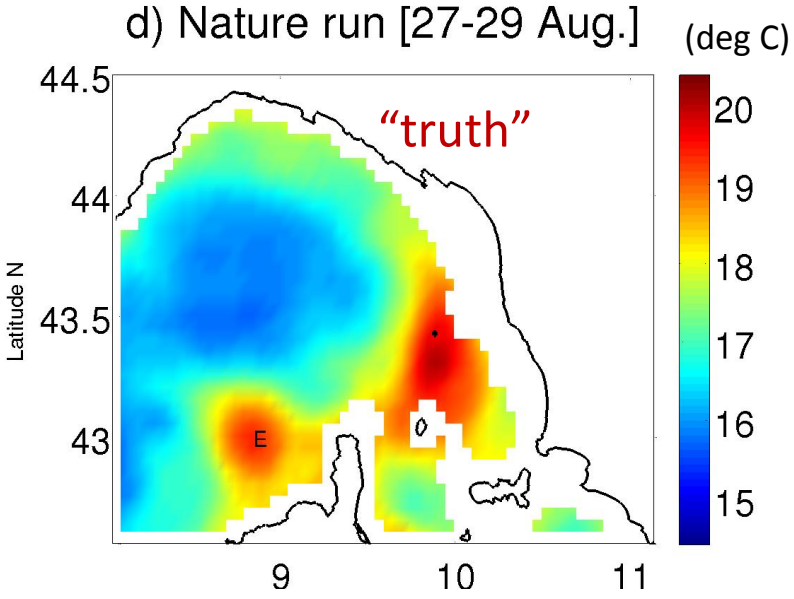
Adaptive sampling: OSSEs



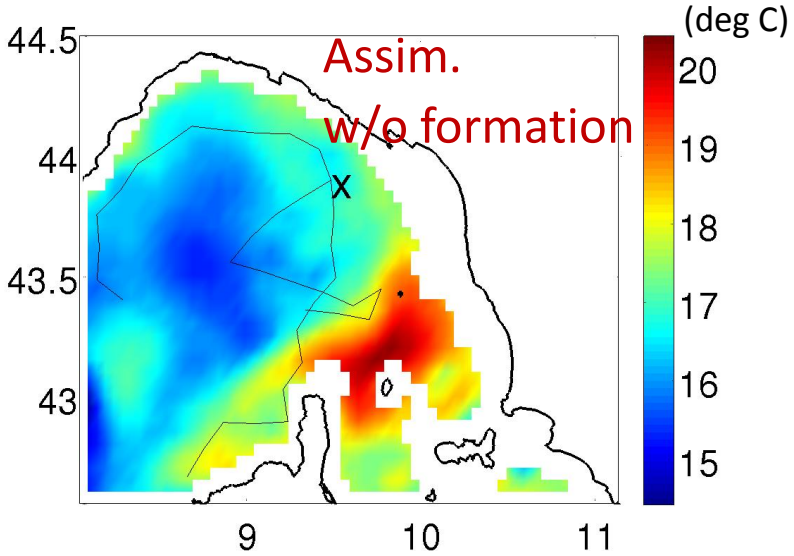
cooperative

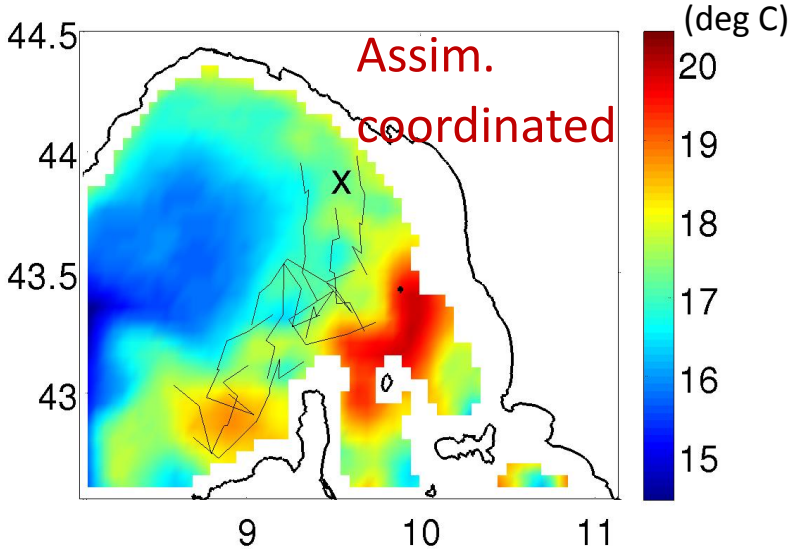
without formation

coordinated (triangular formation)



Average temperature [0-100m] (deg C)





Conclusions

1) Introduction

Ocean prediction models, underwater gliders and data assimilation.

2) Impact of glider fleet data assimilation in the Ligurian Sea

3) Glider adaptive sampling

Concept and glider mission planning.

At-sea experiment.

Observing System Simulation Experiments.

4) Conclusions

Conclusiones

Predicción oceánica:

modelos hidrodinámicos de alta resolución operacionales a escala regional
→ mesoescala / sub-mesoescala

Planeadores submarinos:

proporcionan secciones con observaciones oceánicas de alta resolución
(+ información sobre velocidades integradas sobre la vertical)

Asimilación de los datos de planeadores submarinos:

potencial para mejorar la predicción sobre zonas de ~100x100km^2

Muestreo adaptativo:

las plataformas están dirigidas hacía la zonas de mayor incertidumbre del modelo.

Campaña 2010: es 1) factible y 2) útil !

Reconstrucción de un remollino por una flota de 3 planeadores: formación geométrica necesaria para poder representar su estructura en el modelo.

Conclusiones

Predicción oceán

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→

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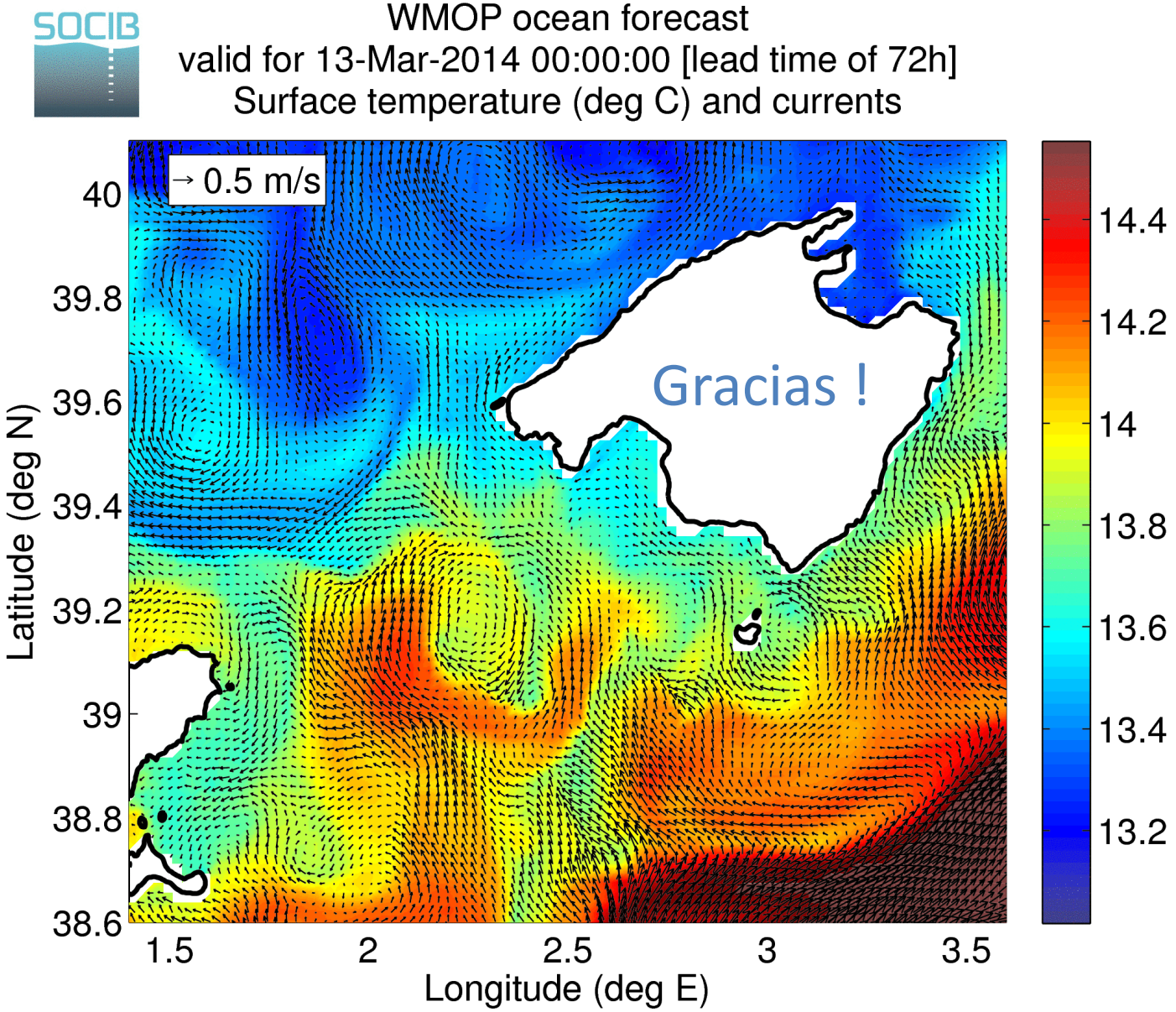

Optimum Sampling Designs for a Glider–Mooring Observing Network

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Instruments and Methods

Benefit assessment of glider adaptive sampling in the Ligurian Sea

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A comparison of the performance of the 3-D super-ensemble and an ensemble Kalman filter for short-range regional ocean prediction

By BAPTISTE MOURRE[1]*† and JACOPO CHIGGIATO[2], [1]*Centre for Maritime R and Experimentation, Viale San Bartolomeo 400, 19126 La Spezia, Italy*; [2]*Consiglio Nazionale Ricerche–Istituto di Scienze Marine (CNR-ISMAR), Arsenale – Tesa 104 Castello 2737/F, 30122 Ve*

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Oceanographic Field Estimates from Remote Sensing and Glider Fleets

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