# On the Assimilation of Trajectories into the Mediterranean Forecasting System

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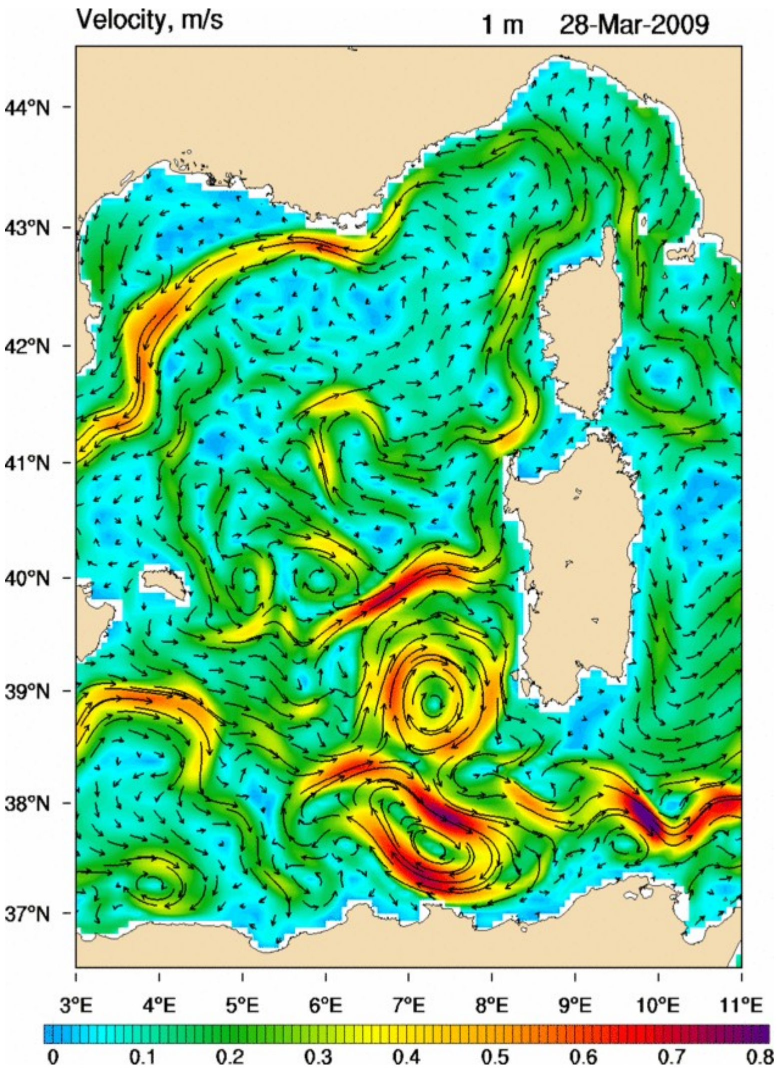
# Motivation




The ocean current forecasts can be used to for:

- tracking oil spill, or
- search and rescue missions

The circulation is characterized by well-defined coastal currents, and meso-scale-eddy structures in the interior of the basin.

This type of highly variable dynamical structures in the ocean are less than easy to simulate.

A method to improve the model performance is to assimilate trajectories and hence constrain the modeled velocity fields.

# The Mediterranean Forecasting System

The MFS has been in operational use for nearly a decade, and it is continuously providing analyses on a weekly basis for the region (Pinardi et al., 2003).

These forecasts are of great importance as they provide local and basin-scale information of the state of the sea.

## The MFS is based on 3 cornerstones:

- the data collection network,
- the Ocean General Circulation Model (here OPA), and
- the 3DVAR assimilation scheme.

# Observational data sets

## Assimilated in operations

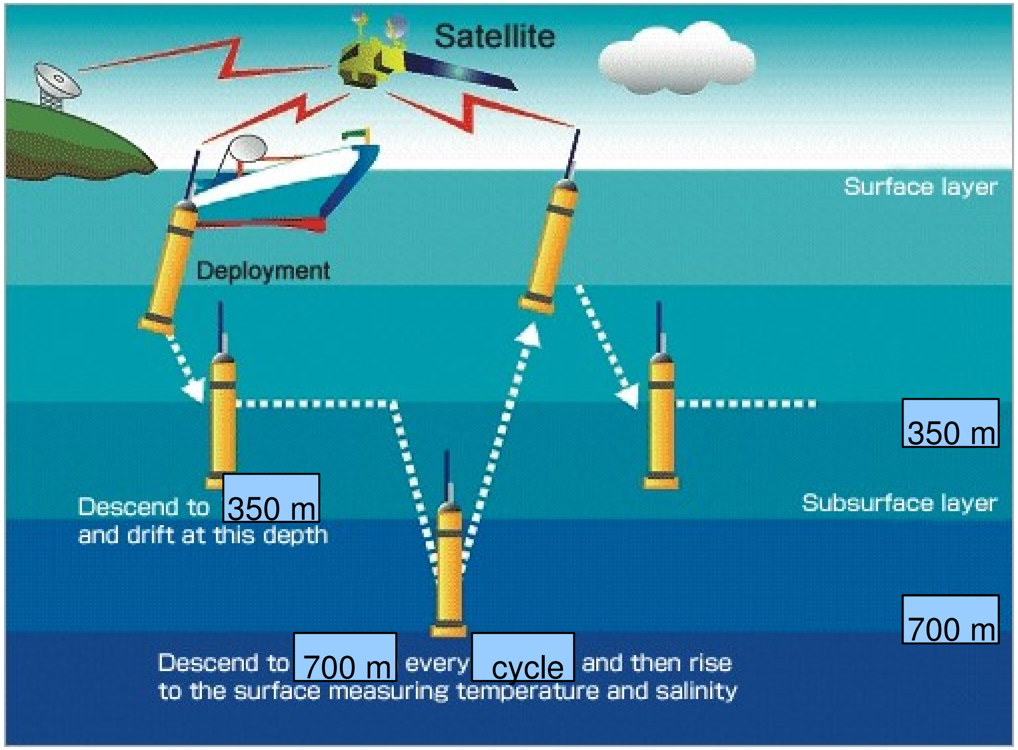
- Sea Level Anomalies (LeTraon et al., 2003)
- Temperature from XBTs (Manzella et al., 2007)
- Argo float temperature and salinity profiles (Poulain et al., 2007)

## In progress

- Argo float trajectories
- Surface drifter trajectories

# The Argo floats

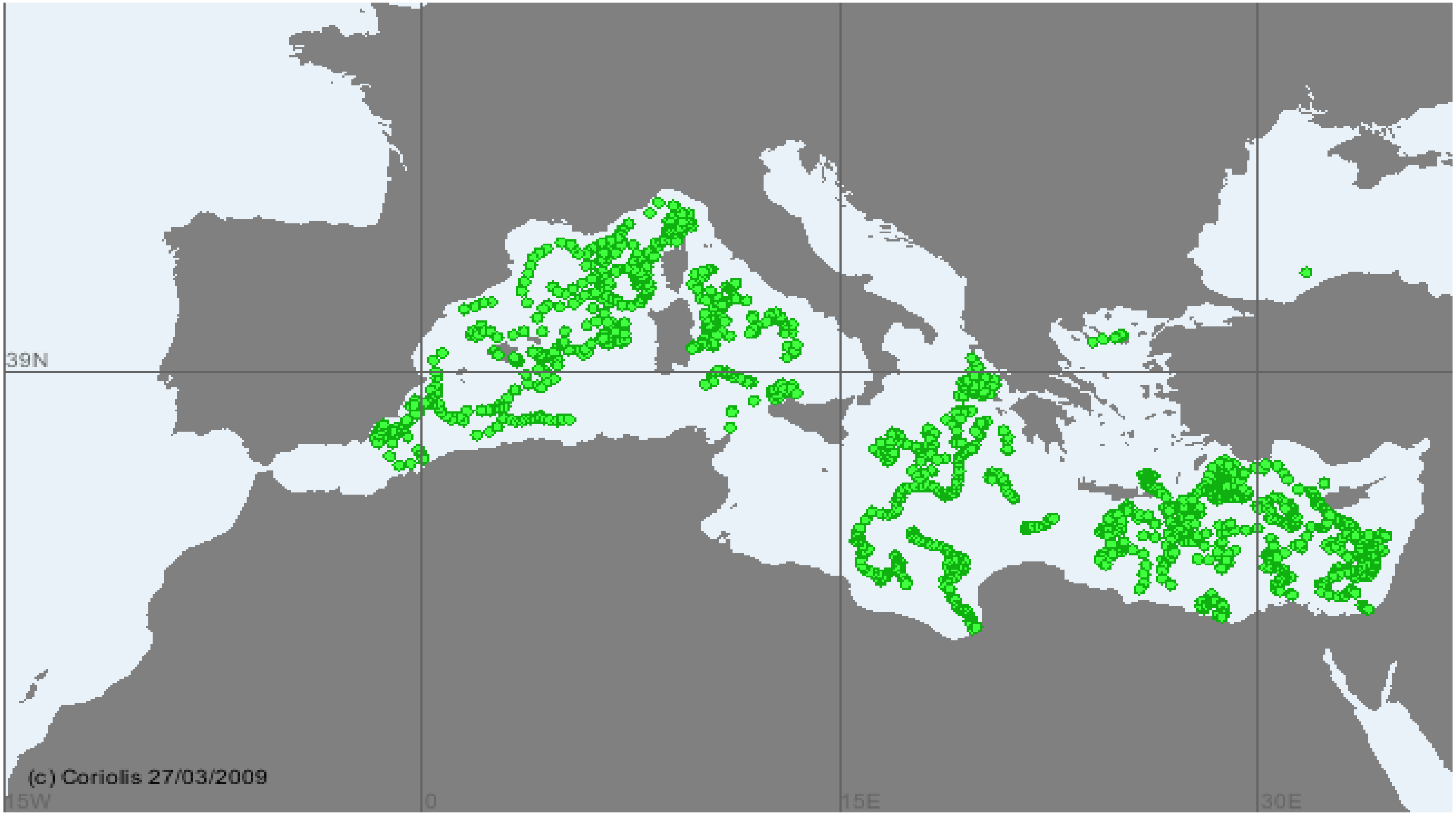

- 5-day cycle
- Parking depth 350 m; the float dives to 700m before ascension
  (2000m every 10th cycle)




Measures temperature and salinity
Provides float coordinates when surfacing
Data transmission over the ARGOS satellite system

# Data collection and selection

Argo float data was provided by OGS for the Apex and Provor floats.




Data from floats drifting in shallow areas (depth <400 m) were excluded in order to avoid spurios trajectory data (approx. 4% of the data was removed).

# OPA

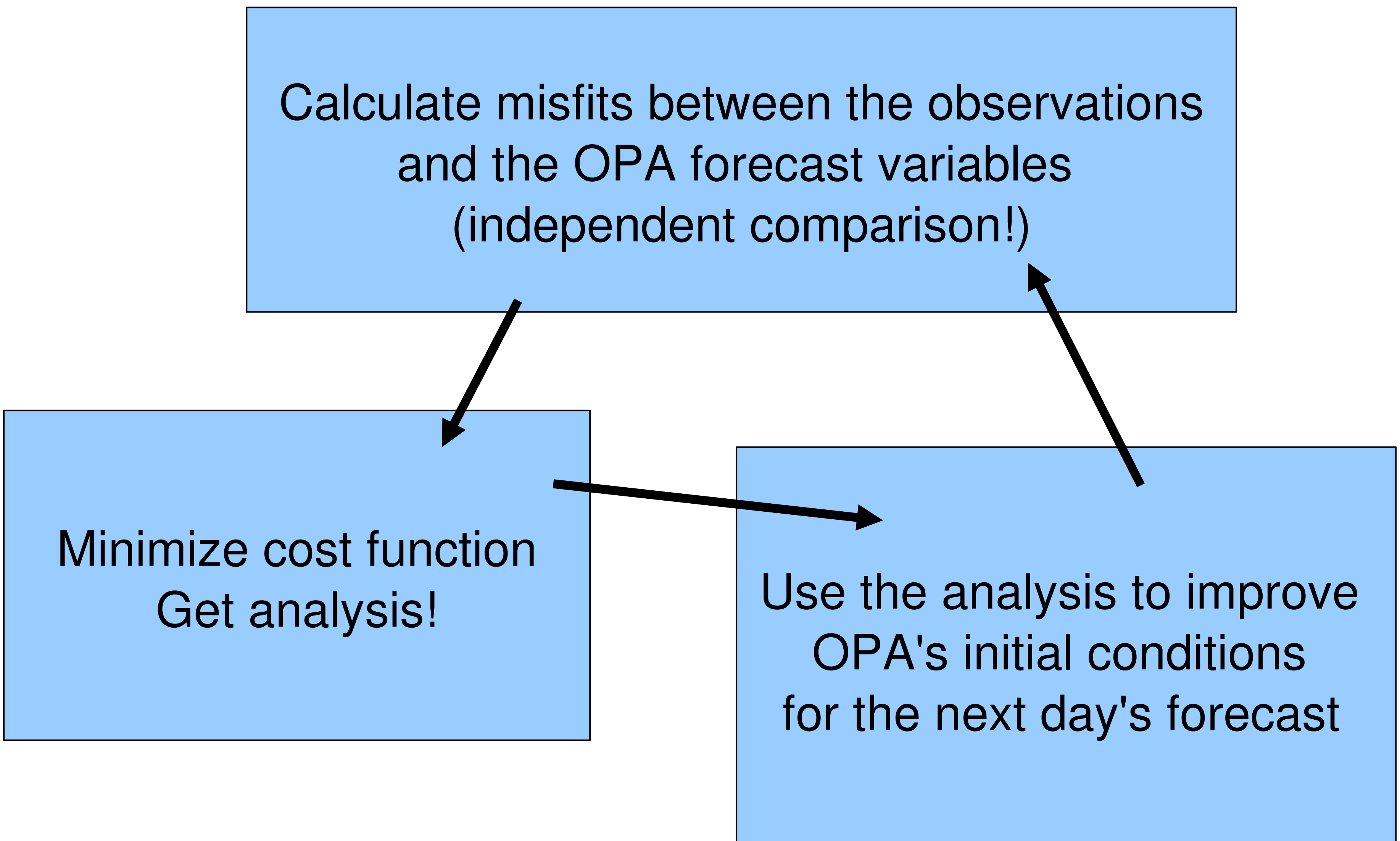
The Océan Parallélise code (Madec et al., 1998) was modified by Tonani et al. (2008) and used as OGCM for the Mediterranean Sea.

Meso-scale eddy resolving (1/16° ×1/16°, ~ 6.5 km), and a telescopic 72-level vertical resolution, with a 3-m grid size in the surface layer and 300 m near the bottom.

Meteorological 6-h forcing fields from ECMWF. Model time step 600s.

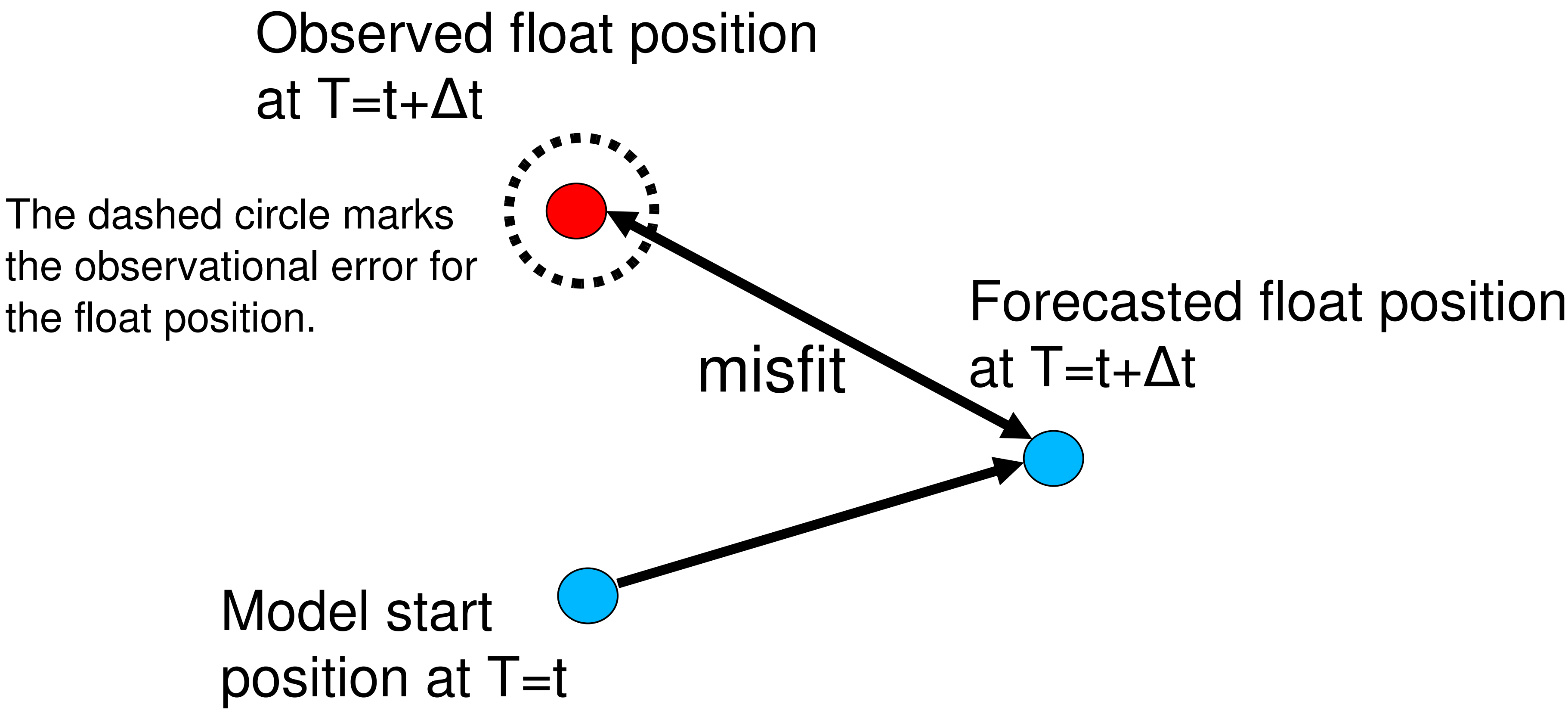
Provides daily forecasts for sea level, temperature, velocity fields etc.

# Flow scheme of the 3DVAR (OceanVar)

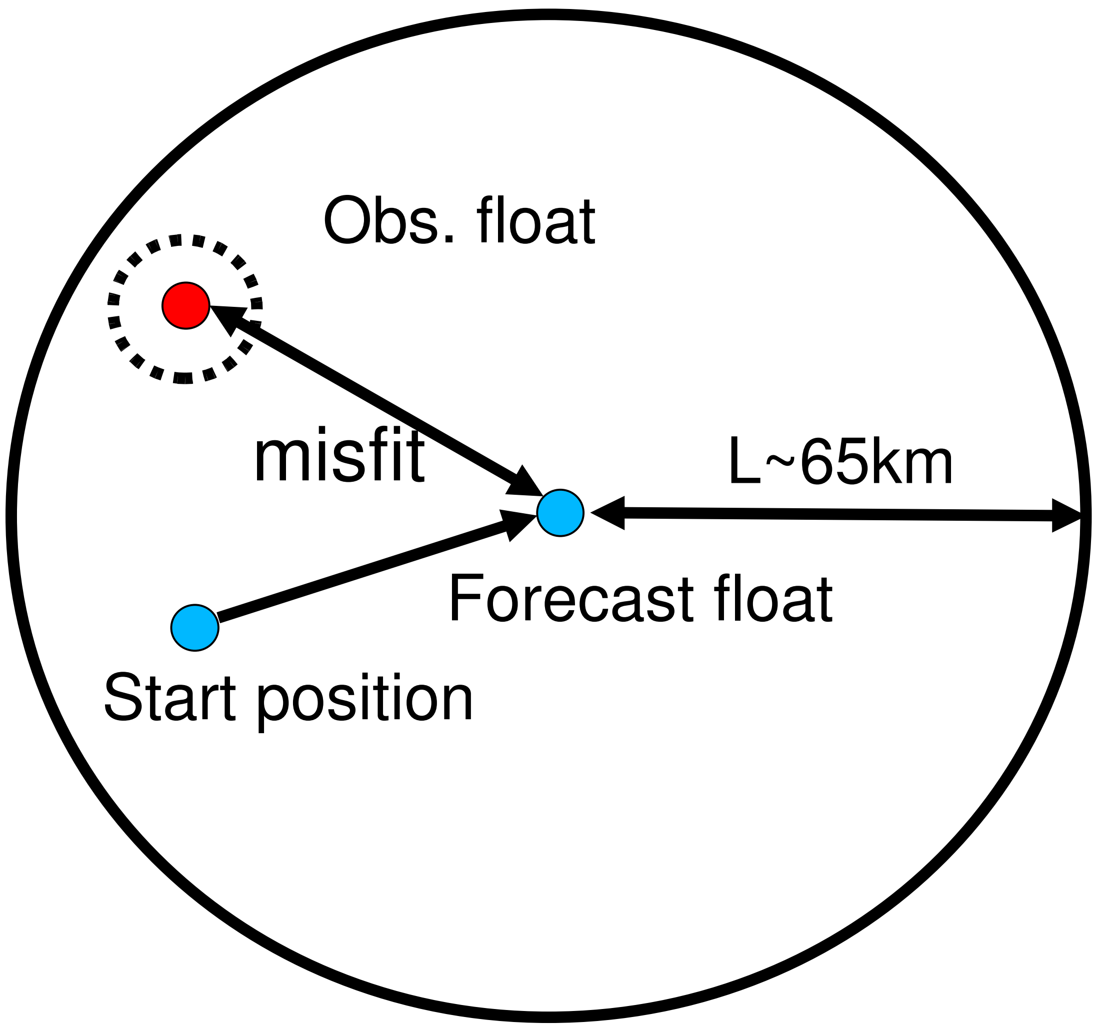


# Trajectory modelling

The forecasted float position is calculated by integration of the Lagrangian advection equation over the time interval $\Delta t$=5days (Taillandier et al., 2008).



# Residual check of trajectory data




If MISFIT<L, then assimilate
If MISFIT>L, then ignore observation

# Minimization of cost function

The 3DVAR minimizes the cost funcion J:

$$J = (x - x^{bck})^T B^{-1} (x - x^{bck}) + (H(x) - y)^T R^{-1} (H(x) - y)$$

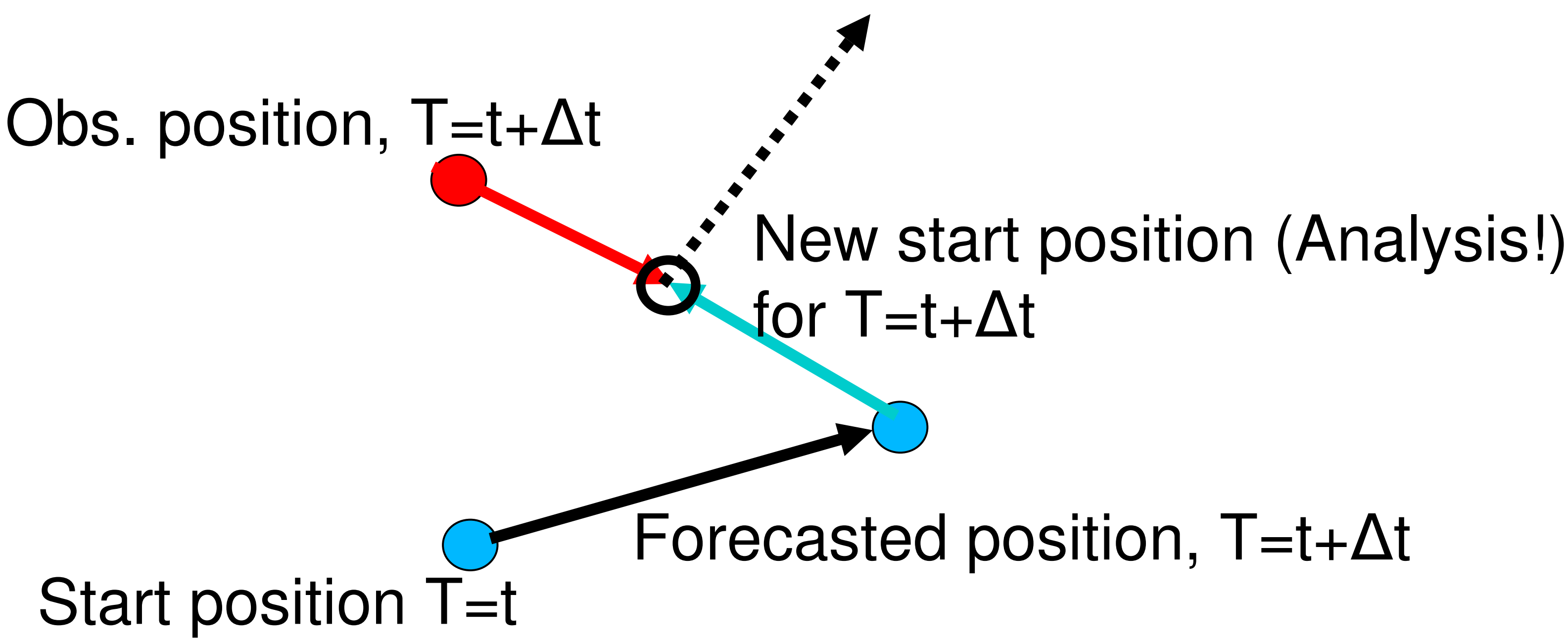
which consists of *weighted squared differences* between modeled and observed variables.

**x**: analysis state vector,
$\mathbf{x}^{bck}$ : background state vector,
**y**: observational vector,
**B**: background error covariance matrix,
**R**: observational error covariance matrix, and
*H*: non-linear observational operator.

*The modeled forecast variables (provided by OPA) are compared to their observed counterparts, and if the observations are found reliable and representative, the model state estimate will be adequately changed (cf. Dobricic and Pinardi, 2008).*

# Assimilation of observed float positions

The 3DVAR provides OPA with new (modified) initial conditions for the next day's forecast. This should increase the model forecast skill, specially in terms of providing more accurate subsurface velocity fields.



# RMS errors

The skill of the model performance is quantified in terms of monthly-Mediterranean-mean RMS errors.

1. Independent check of MISFITS: observations - forecasts,
2. *A posteriori* check: observations - analyses.

$$\mathrm{RMSerror} = \frac{\sum_{i}^{N} \left( obs - model \right)_i^2}{N}$$

The RMS errors were calculated for the SLA, temperature, salinity, and the Argo float positions.

# “Unknown” observational errors...

*http://www.argo.ucsd.edu/FrArgo_in_schools.html*

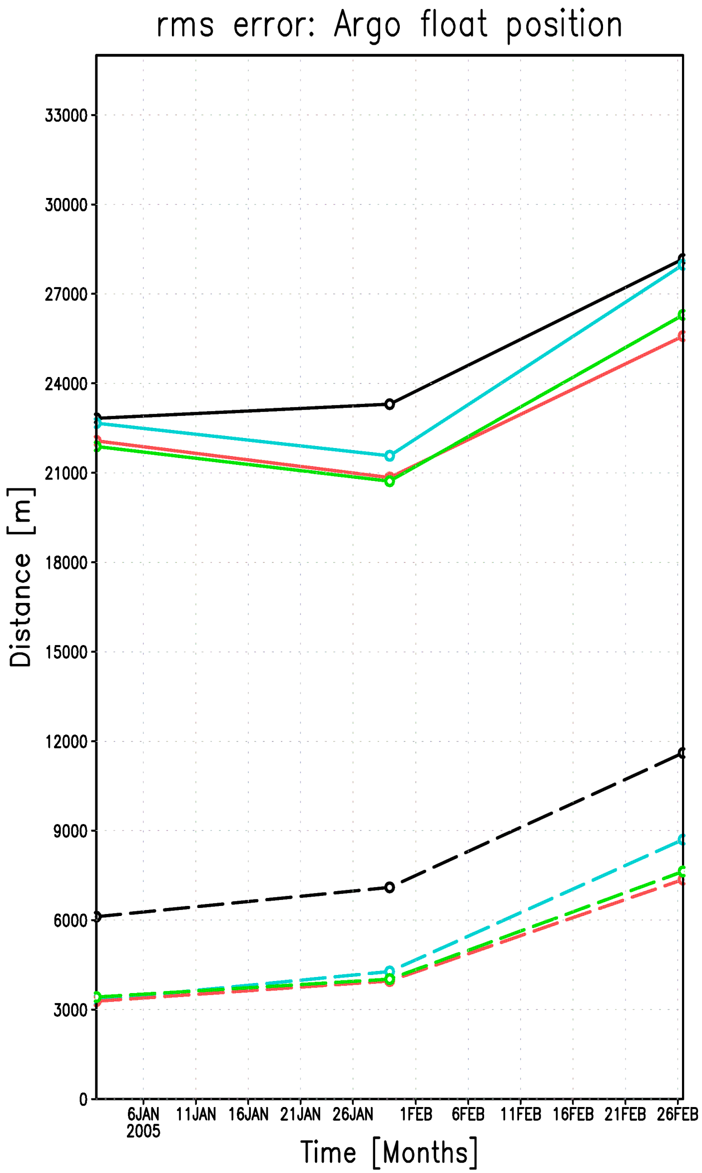
Eliana Snell (12 yrs old) loves the Argo robots in the ocean, however, she is worried about the floats being attacked by Orca whales.

Other uncertainities:

How to quantify the shear drift that the Argo float is subjected to during ascension and descension?

# Float position errors

## a 2-month sensitivity study




- Black: 2000m error
- Green: 500m error
- Blue: 250m error
- Red: 500m error; no shear drift correction

The "red" experiment provides the best forecast quality for the Argo trajectories

# Numerical experiments

Four different numerical experiments were designed in order to evaluate the impact on the model output due to different data assimilation schemes, with special focus on the assimilation of Argo float positions.

**Exp. 1 :** SLA and XBT,

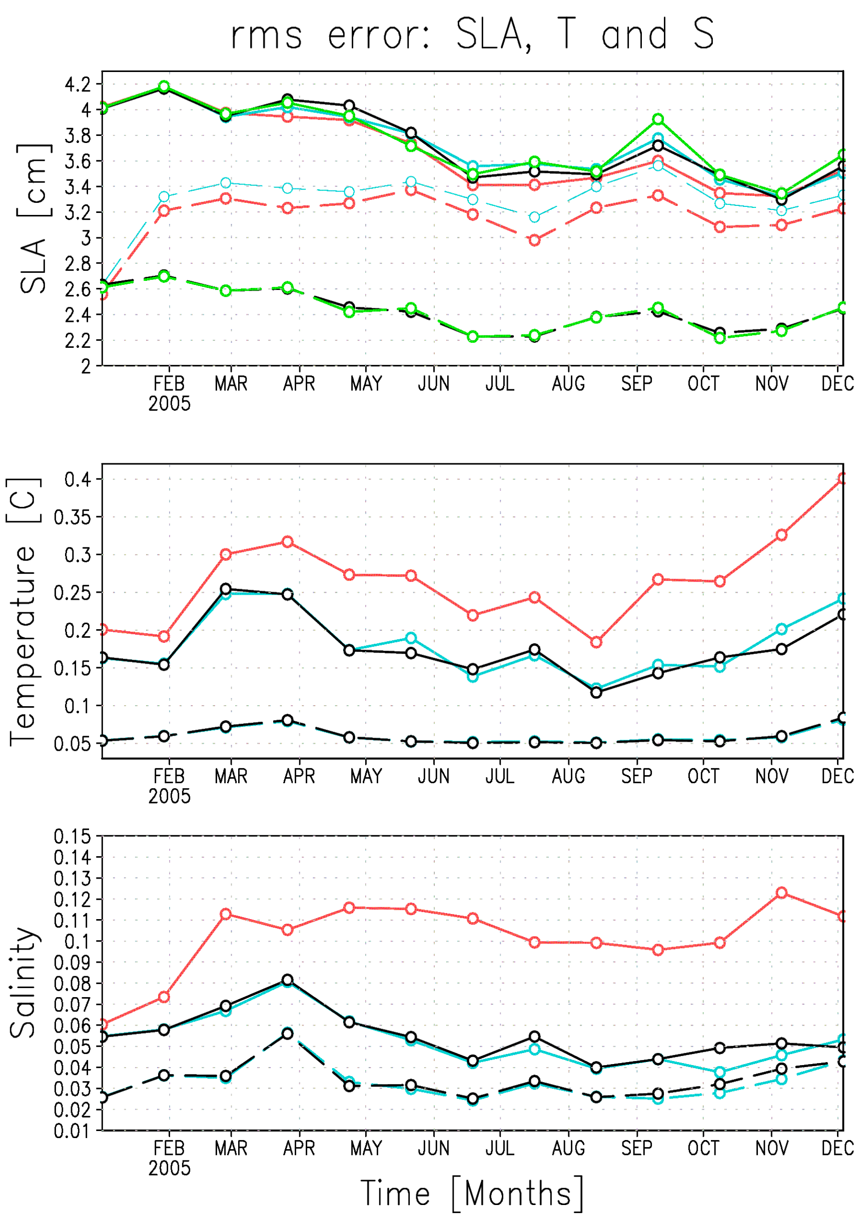
**Exp. 2 :** SLA, XBT and T&S profiles from the Argo floats,

**Exp. 3 :** SLA, XBT and Argo float trajectories,

**Exp. 4 :** SLA, XBT, Argo float T&S profiles and trajectories.

Due to the relatively large number of Argo float data available for 2005, this year was selected for the model run.

# RMS errors : SLA, temperature and salinity




**Exp. 1 :** SLA and XBT,

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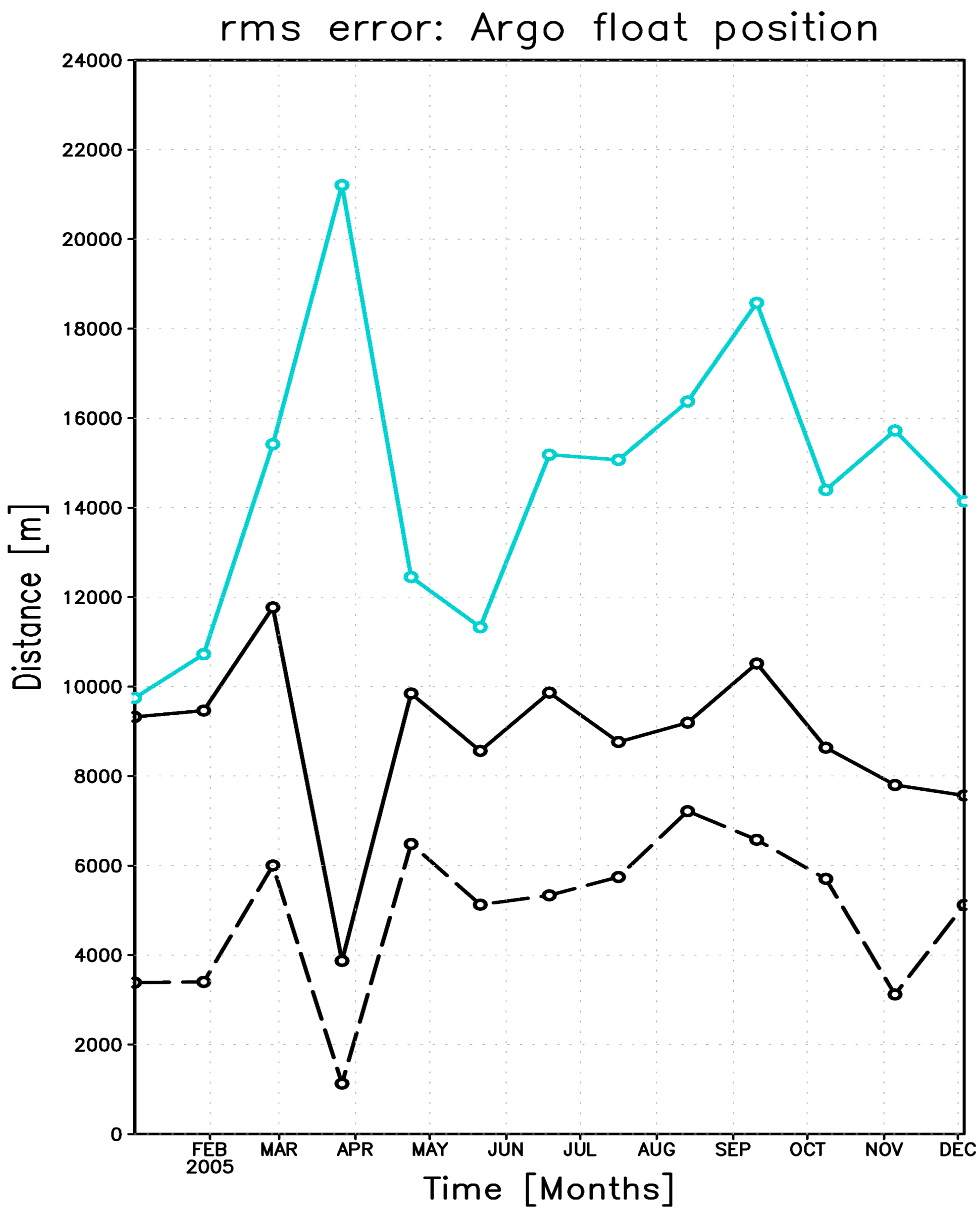
**Exp. 4 :** SLA, XBT, Argo float T&S profiles and trajectories.

**Solid lines:** Misfit RMS error (observations - forecast)

**Dashed lines:** RMS error on the difference between the observations and the analysis.

# RMS errors: Argo float positions




**Exp. 2:** SLA, XBT and T&S profiles from the Argo floats, and

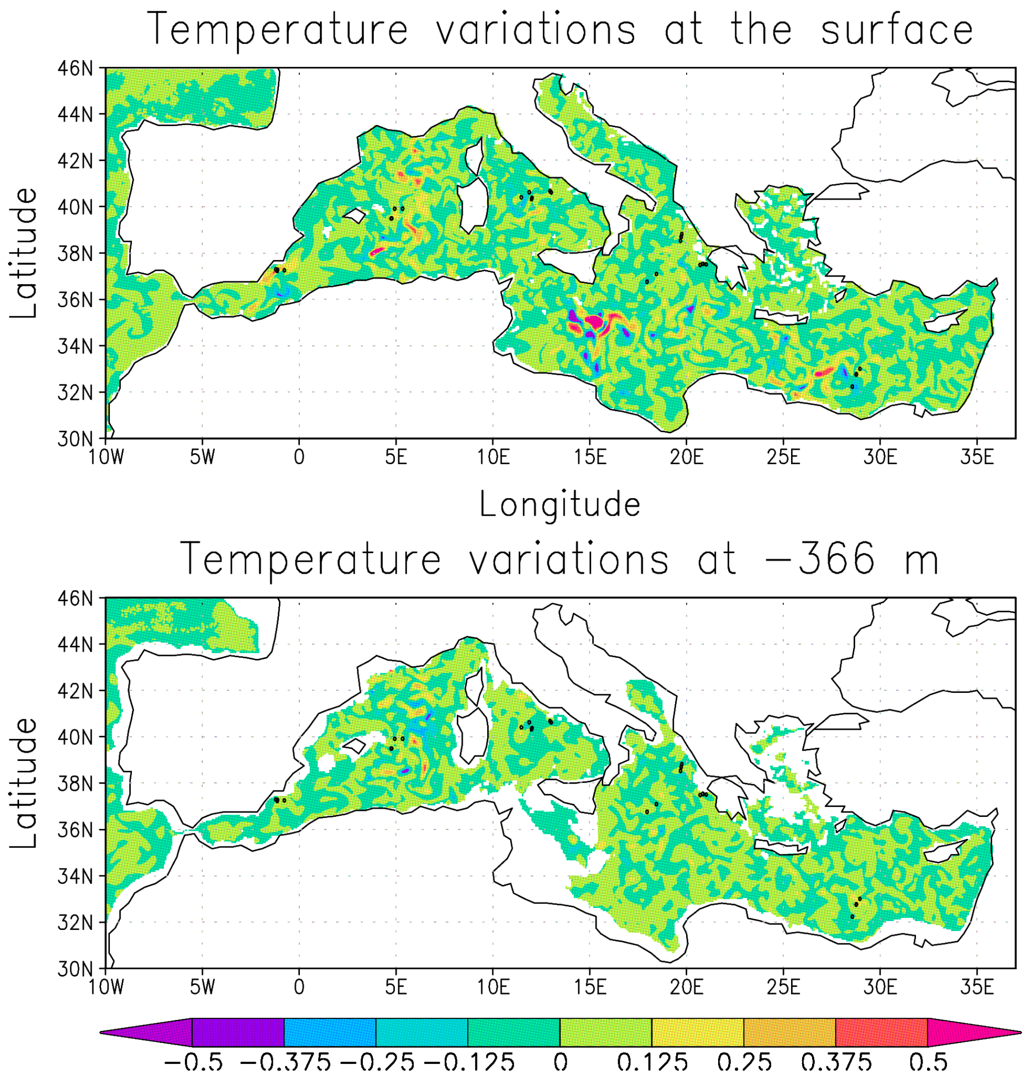
**Exp. 4 :** SLA, XBT, Argo float T&S profiles and trajectories.

**Solid blue line:** Misfit RMS errors (observations - simulation)

**Solid black line:** Misfit RMS errors (observations - forecast)

**Dashed black line:** RMS errors on the difference between the observations and the analysis.

# Temperature and float distribution

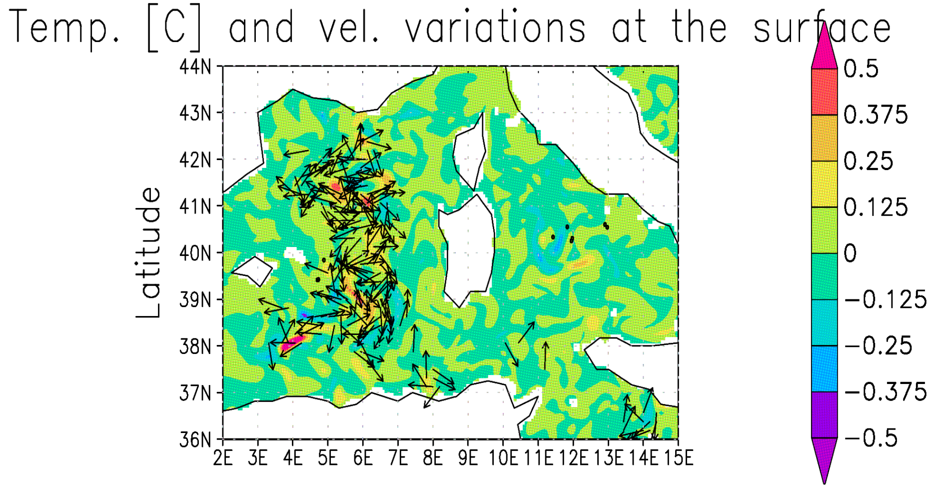


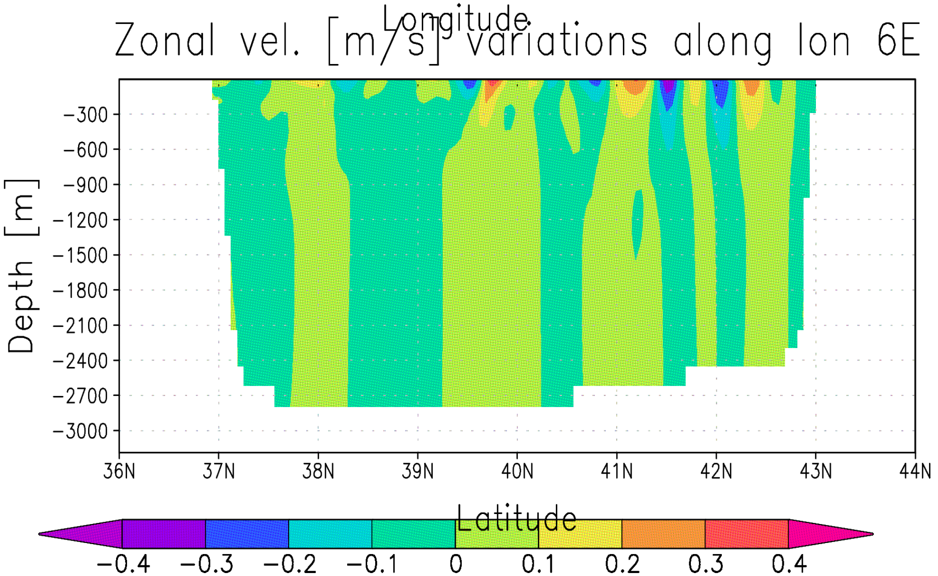

Variances in the temperature fields due to the assimilation of Argo float trajectories.

Top panel: at sea surface
Bottom panel : at approx. parking depth

The black dots show Argo float positions during the previous 10 days.

# Temperature and velocity fields




The surface and 366m-layer temperature and velocity fields display impact of the trajectory assimilation, both in the horizontal and vertical planes.

Areas with ”large” alterations of the velocity field are associated with distinct changes in the temperature field.

The trajectory assimilation is mainly affecting the mixed surface layer, above 400m.

# Conclusions

Assimilation of Argo float positions into the MFS improves the forecast quality notably, decreasing the basin-mean RMS error:

- for the SLAs from ∼3.7 cm (before assimilating trajectories) to 2.4 cm (analysis), and
- for the Argo float positions from ∼15 km to 5 km.

The 3DVAR assimilation scheme, including trajectories, does not seem to cause spurious data in the other model output variables and proves capable to constrain the subsurface (350m) velocity field.

Float position corrections made due to the shear drift does not seem to improve the forecast quality.