The seamod.ro Black Sea operational stochastic forecasting system

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Introduction

The GHER hydrodynamical model is implemented in the Black Sea[1], and run operationally since 21/12/2011. The model runs daily in free mode and as a data-assimilative ensemble run,
The ensemble is built by applying multiple, random but physically consistent perturbations[3] to the members.
The ensemble forecast allows to estimate the *a priori* forecast uncertainty.
When observations become available,
- model performance is assessed (validation of the ensemble mean)
- the forecast uncertainty is evaluated *a posteriori* (validation of the ensemble spread)
- observations are assimilated using an EnKF (OAK[4])
Operational forecasts of the ocean state and it's expected uncertainty (as estimated with the ensemble) are publically available on http://www.seamod.ro

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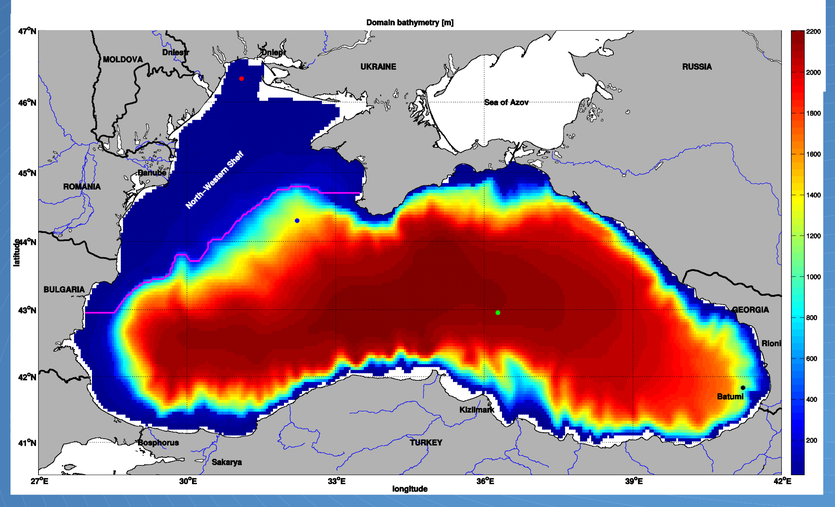
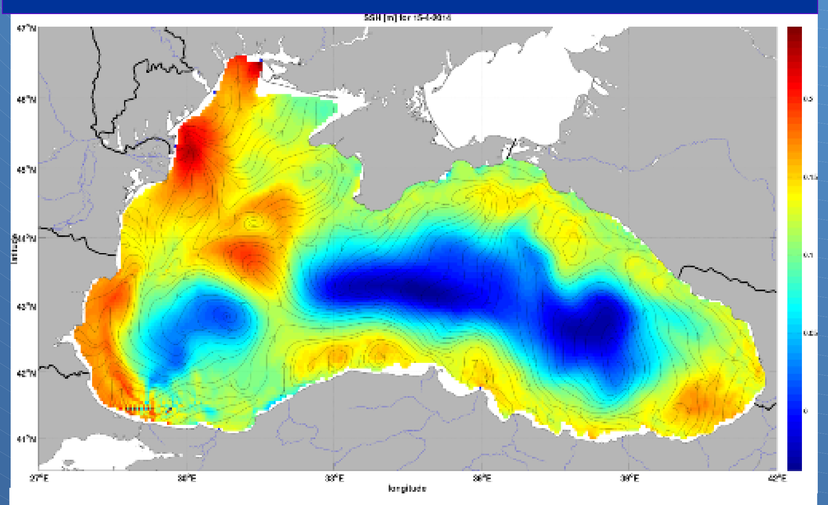
GHER hydrodynamic model

- model already implemented in different studies of the Black Sea
- **long-term, extensive validation (see [2])**
- horizontal resolution ~4km
- 31 vertical double-sigma levels
- Baroclinic timestep: 10 minuts
- 6 rivers, Bosphorus channel
- Bulk formulae using atmospheric fields downloaded from NOAA NCEP GFS



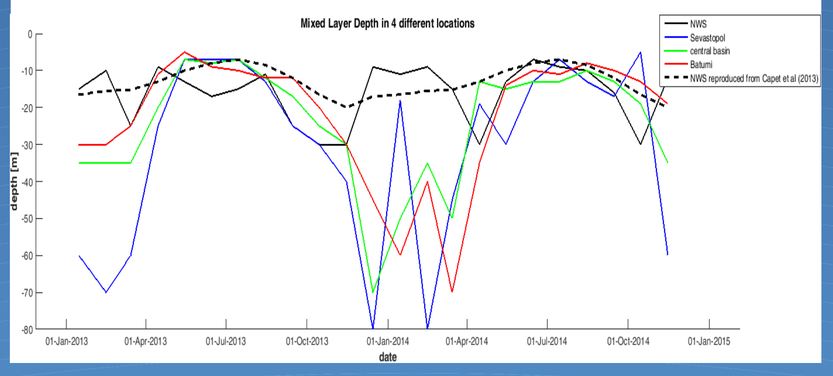
Model validation



- operational model simulates well the large scales [2]:
  - Rim current position
  - semi-permanent eddies
  - elevation difference from coastal areas and open see ~ 20 cm
  - surface and deep salinity values
  - hydrodyanmic regime on the shelf

- Also simulates well shelf-open sea exchanges
- Also simulates well the mixed layed depth
  - spatial distribution

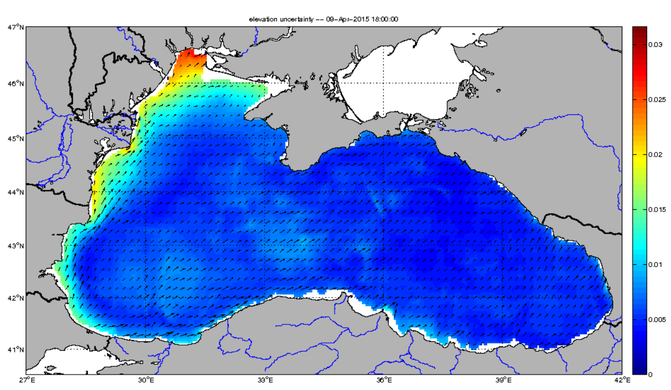
- temporal evolution: 4 points (left map)

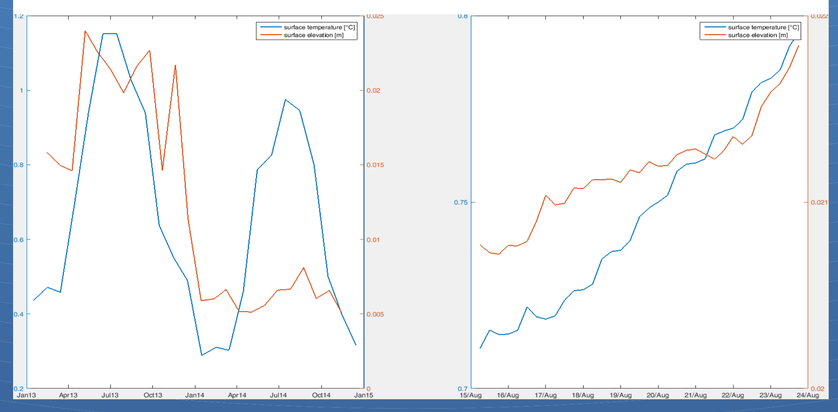


Ensemble simulation

ENSEMBLE GENERATION
Model parameters, inputs… that are not perfectly known are different in each ensemble member
- rivers flow and diffusion coefficients
- when (exceptionally) creating a new member, initial conditions are perturbed using the WCE[3] method
- atmospheric forcing fields are perturbed using their EOFs

Example of ensemble spread for SSH (*a priori* error) :





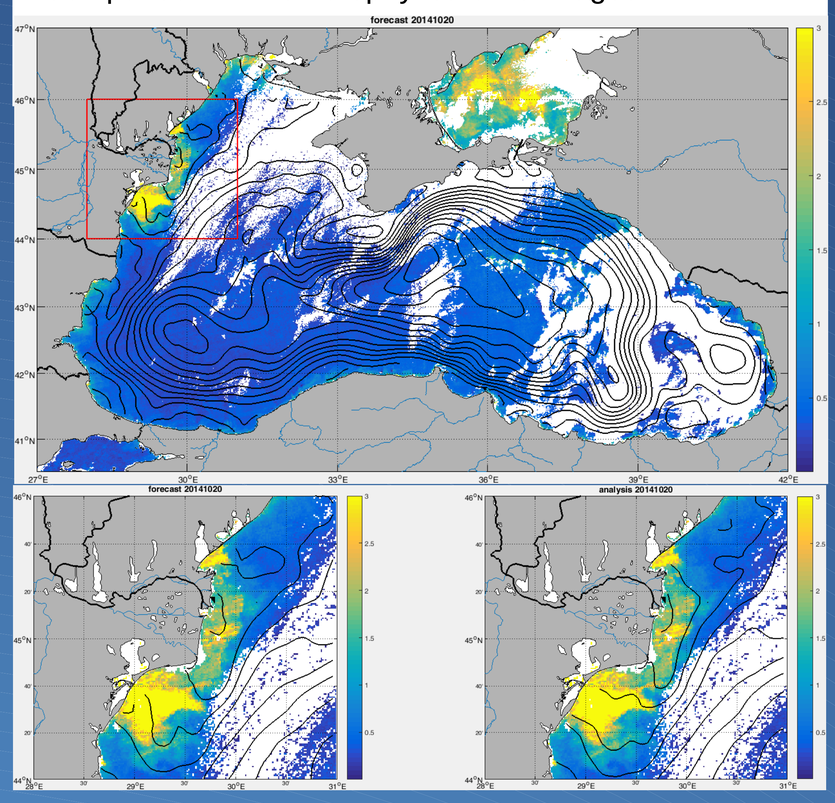
Data assimilation

DATA ASSIMILATION[4]
- daily assimilation of SST and ARGO profiles
- observations uncorrelated, rms : 0.25°C , 0.05psu
- data assimilation localisation radius ~ 100km
- correction limited to 1°C (temperature), 0.3psu (salinity), 5cm/s (velocity), 3cm (elevation)

COMPARISON W/ INDEPENDENT OBSERVATIONS
Temperature rms error (average over 2014):

Lead days	1	2	3	4	5
rms error	0,71	0,76	0,85	0,92	0,96

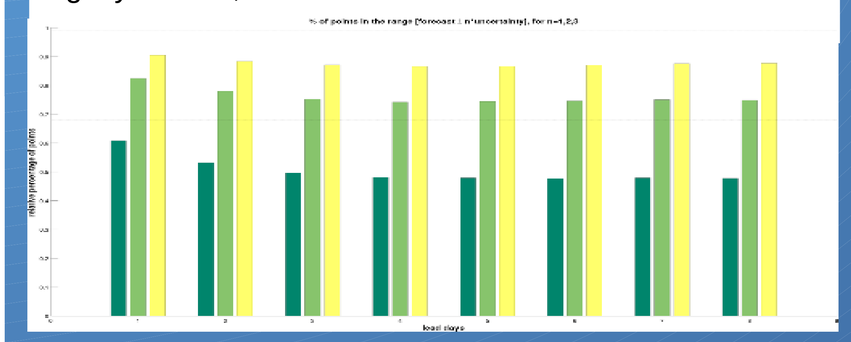
Comparison with Chlorophyl satellite images:



Validation of the ensemble

The *a priori* error (estimated by the ensemble spread) corresponds well to the *a posteriori* error (ensemble mean minus observations), suggesting that the ensemble initialization and perturbations during the simulation are sized relatively well.
Differences between *a priori* and *a posteriori* errors indicate that the ensemble slightly underestimates the error (e.g. ~0.1° for temperature).

If the error distribution were Gaussian, 60,85 and 90% of points would fall within 1,2, and 3 std.dev. around the mean. The ensemble simulation has slightly lower amounts of points, again indicating that the ensemble spread is slightly too low,



References

1 Vandenbulcke et al, Onboard implementation of the GHER model for the Black Sea with SST and CTD data assimilation. J. of Operational Oceanography, 2010
2 Capet et al, Interannual variability of the Black Sea's hydrodynamics and connection to atmostpheric patterns. Deep Sea Research part II, 2012
3 Barth et al, Dynamically constrained ensemble perturbation – application to tides on the West Florida Shelf. Ocean Science, 2009
4 Ocean Assimilation Kit, Barth et al, see publication list and software source on: http://www.data-assimilation.net/mediawiki/index.php/Ocean_Assimilation_Kit