

# Application of Ensemble Kalman Filter for satellite altimetry data assimilation in the Mediterranean Sea

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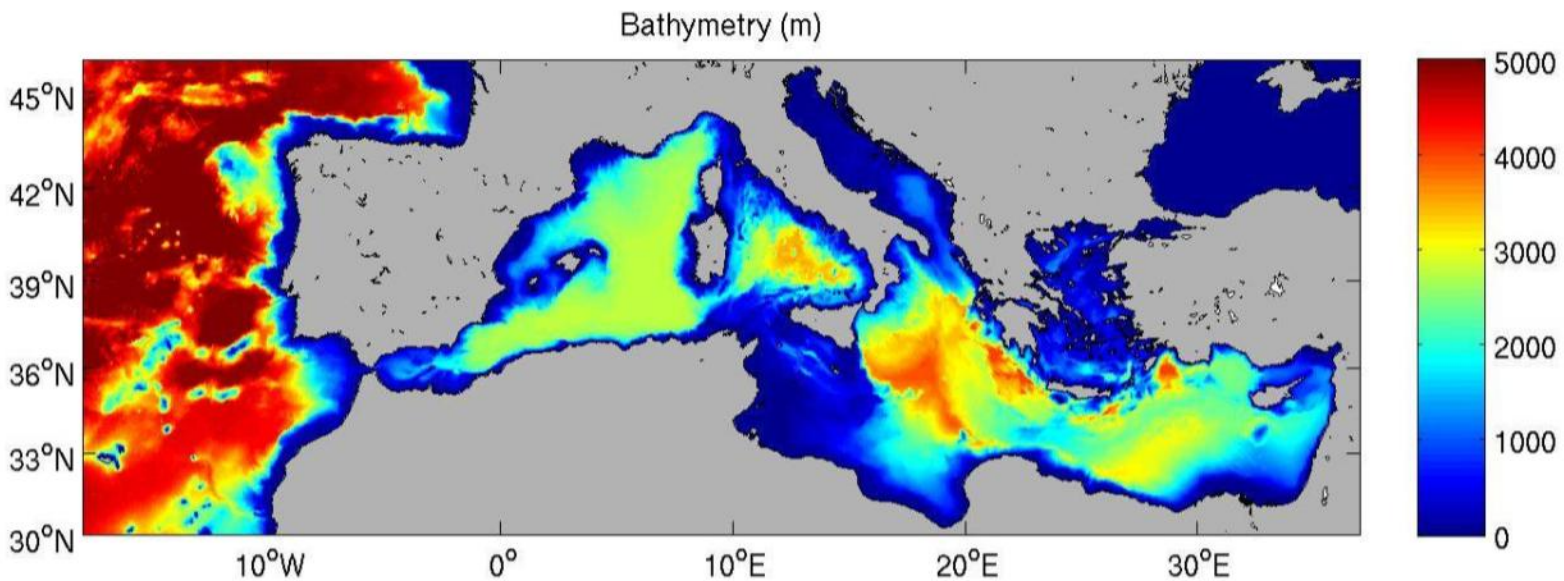


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# Objectives

- Test sbPOM + ENKF for application in the Mediterranean Sea using controlled experiments.
- Implement coastal ocean forecasting in the western Mediterranean Sea using real-time HF radar, glider, and satellite observations.

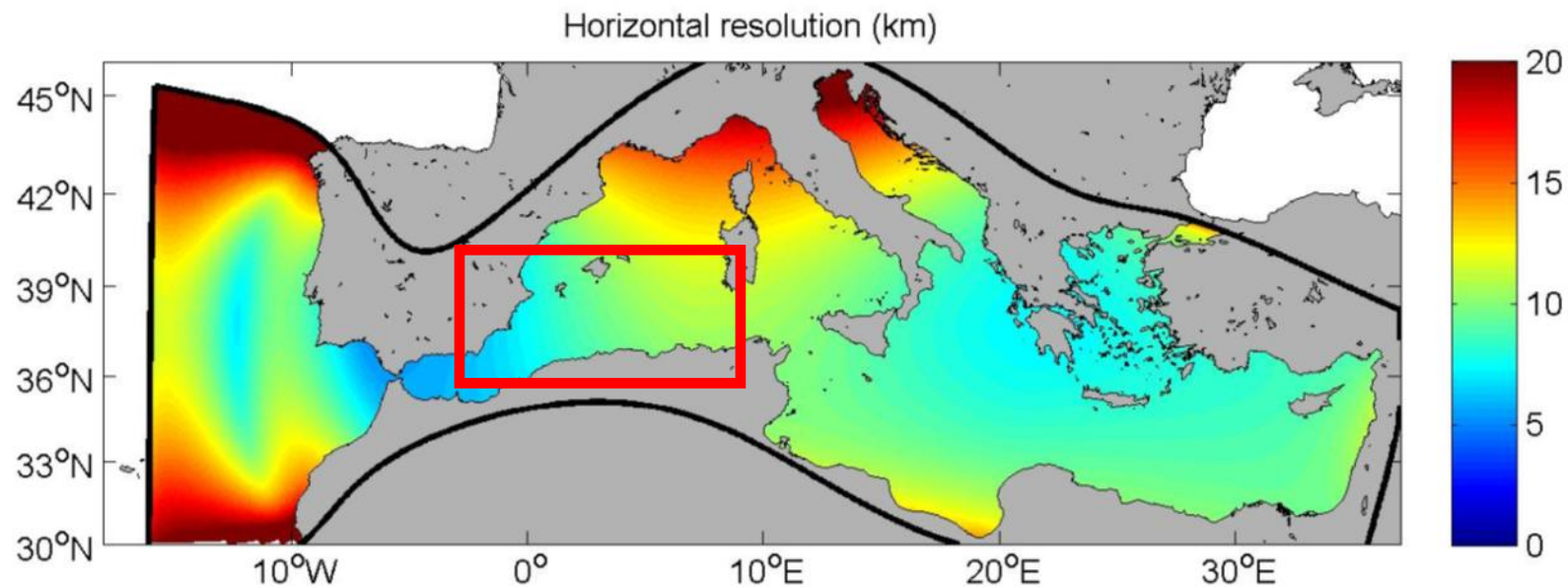


# True ocean: POP model

- High-resolution ( $1/16^\circ$ ) parallel ocean program (POP) in the Mediterranean with 72 non-uniform vertical levels.  
*(Jordi and Wang, 2009, Ocean Modeling).*
- A 12-year simulation forced by a perpetual high-resolution atmospheric forcing corresponding to year 1987.
- Observations of SSH are generated from the last January of the simulation on the  $1/8^\circ$  regular grid where satellite altimetry data is provided at daily interval.

# Assimilation: sbPOM +ENKF

- Implementation of the sbPOM model in the Mediterranean Sea with variable horizontal resolution (674 x 226 grid points) and 31 non-uniform sigma levels. The resolution is ~3 km in the Strait of Gibraltar.
- The simulations run for 30 days. Assimilation steps are daily.
- 32 ensemble members generated by independent initializations and wind fields.



# Generation of ensembles

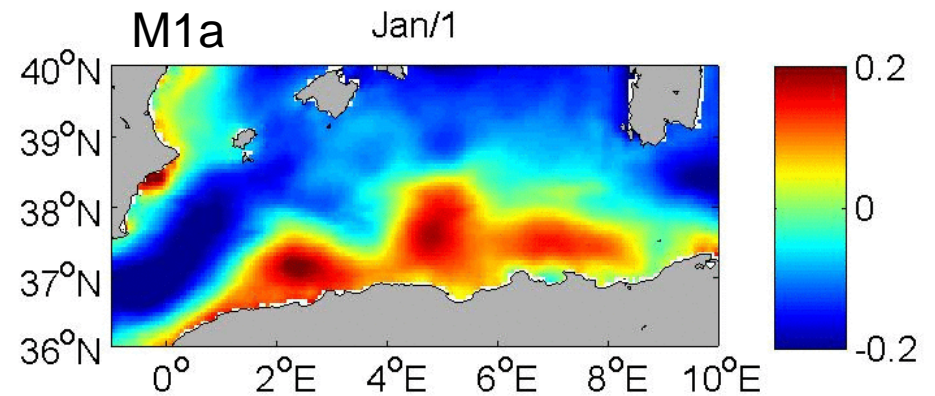
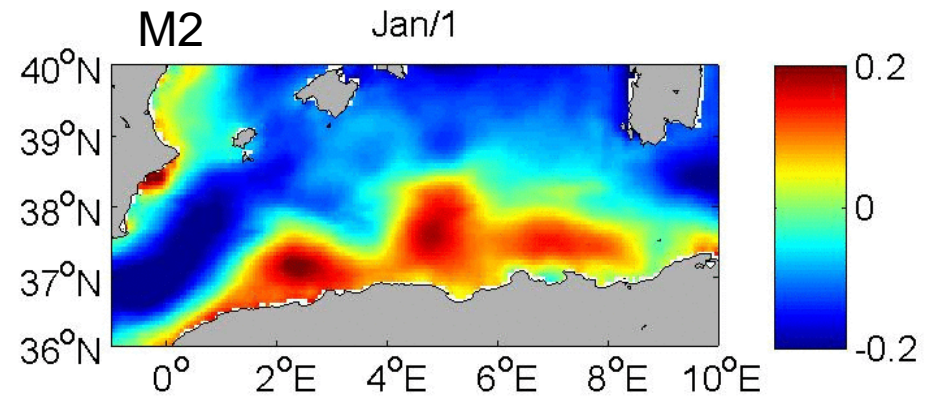
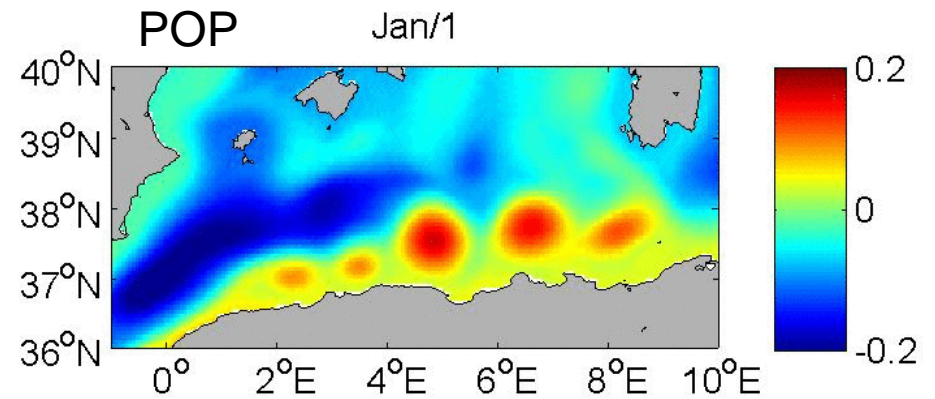
- 8 initial model states are generated by sampling the POP model every January 1<sup>st</sup> for the last 8 years of simulation. This method ensures that initial ensembles are representative of the full real (POP) phase space.
- 32 wind fields are generated by decomposing the real wind as sums of EOFs. The weights of the decomposition are multiplied by a random coefficient in the range  $1 \pm 0.4$ . The perturbed wind fields are obtained by summing back the weighted EOFs.

# Assimilation experiments

- **M0**: a free run of the ensemble members (no assimilation) is performed to compare the relative gain of the ENKF.
- **M1**: assimilation with a reduced model state:
  - **M1a**: the subsurface temperature and salinity are projected (T, S).
  - **M1b**: the subsurface currents are projected (u, v).
- **M2**: assimilation with full model states (SSH, transport, u, v, T, S).

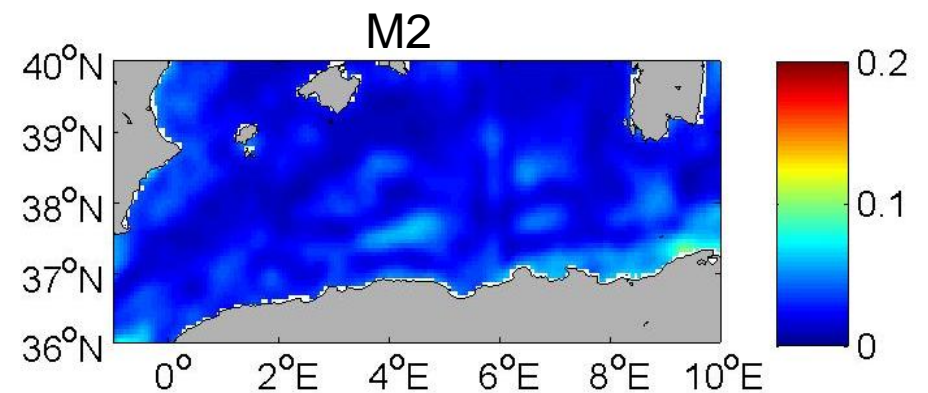
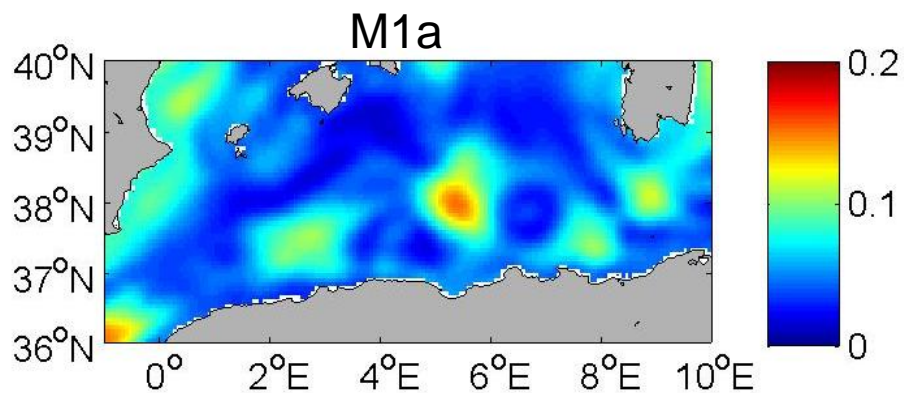
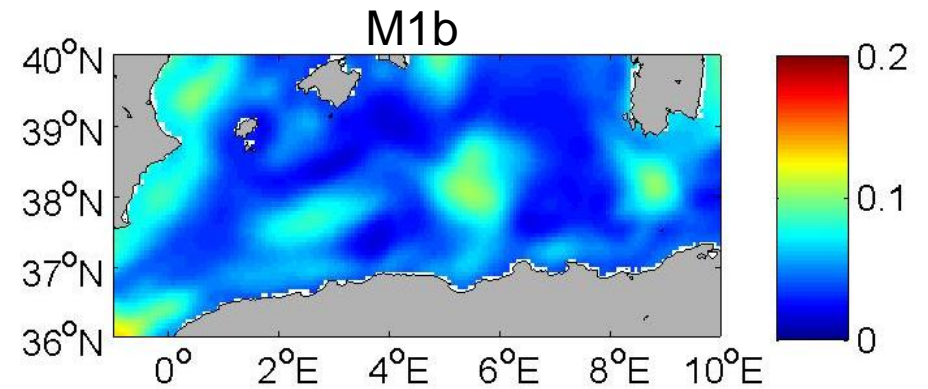
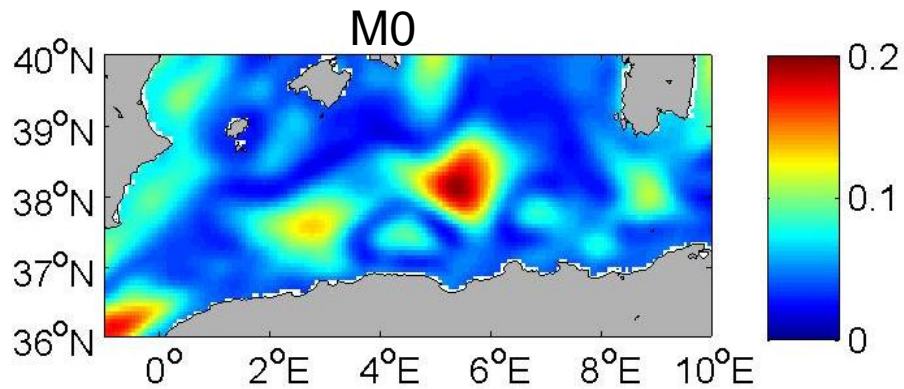
# Results -

Animations of SSH (m) from real ocean (POP) and ensembles averages.



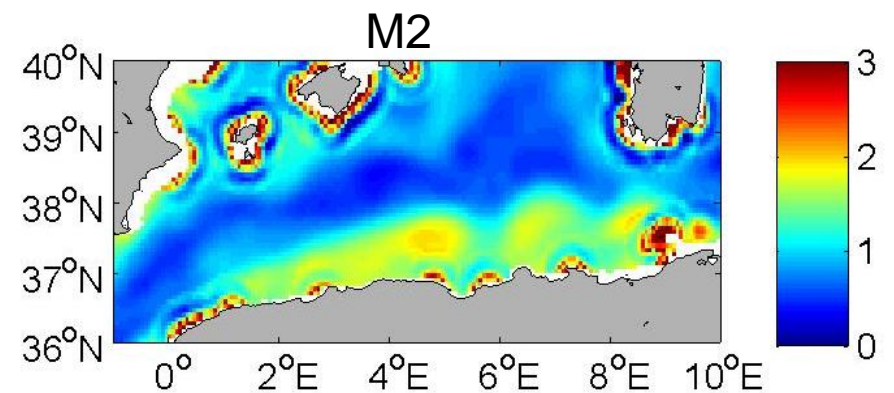
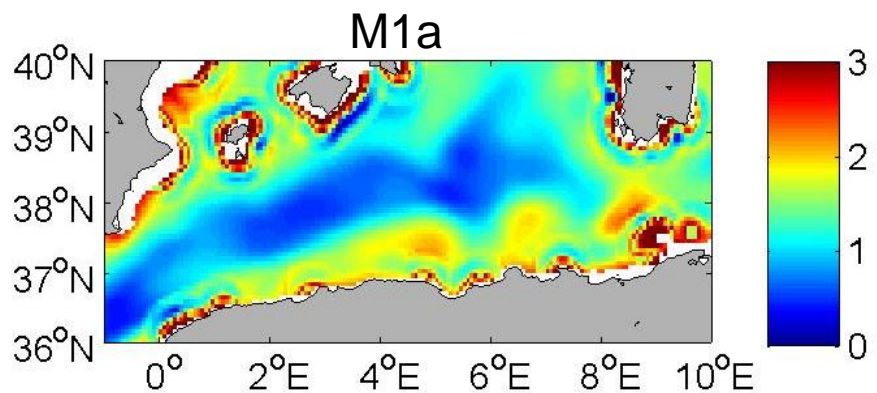
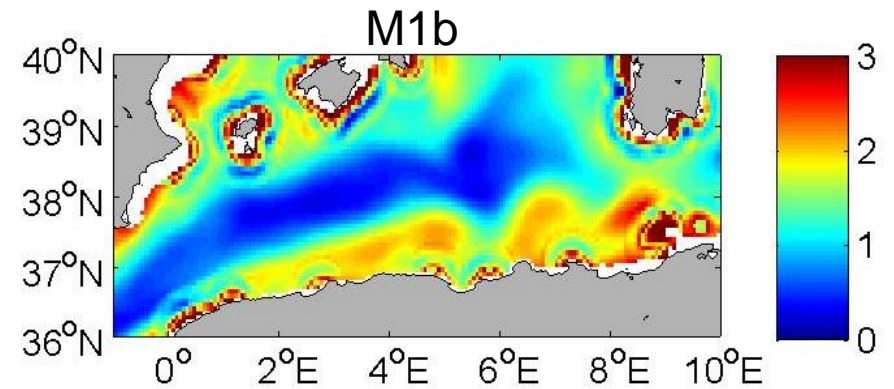
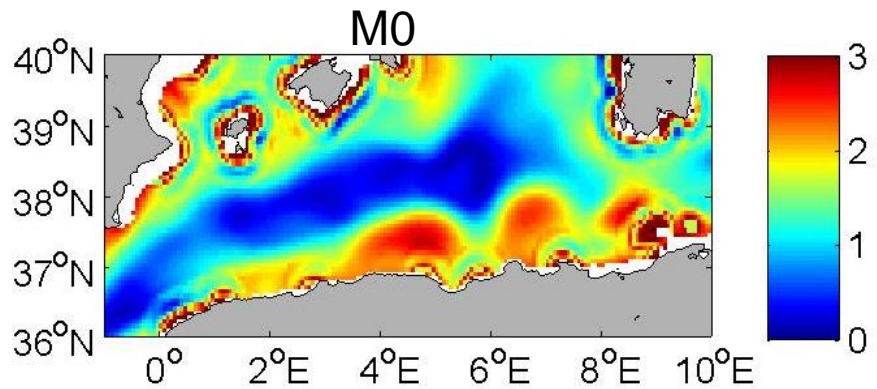


# Results - RMS error of SSH (m)

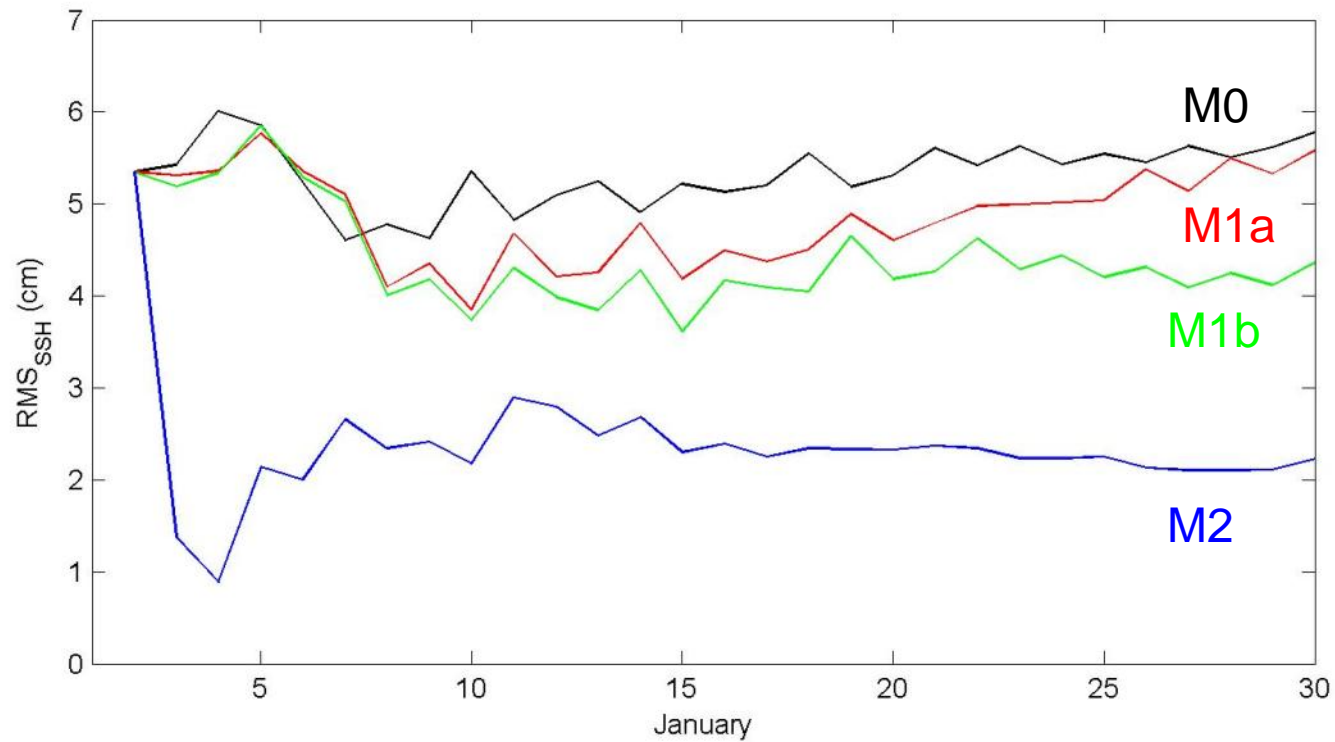




# Results - RMS error of T ( $^{\circ}$ C) at 100 m depth



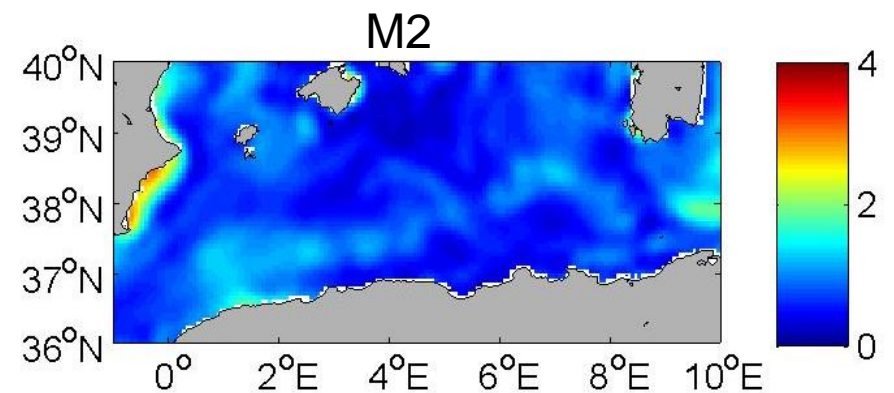
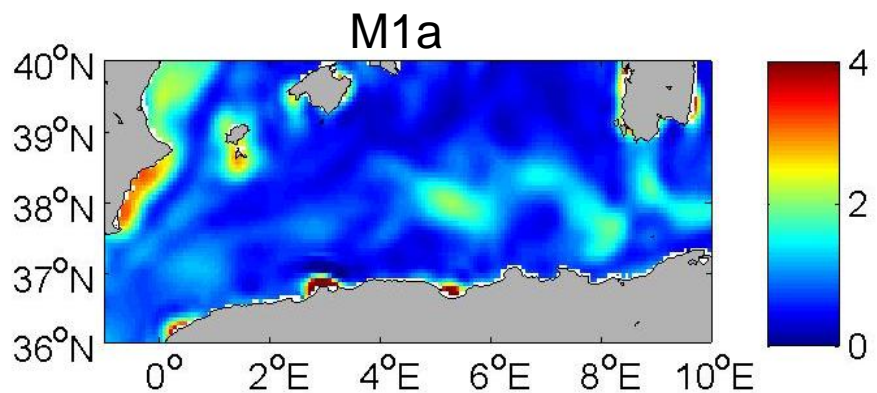
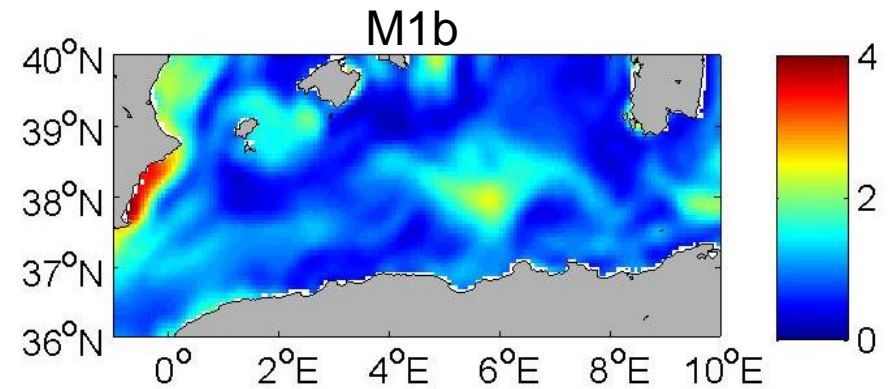
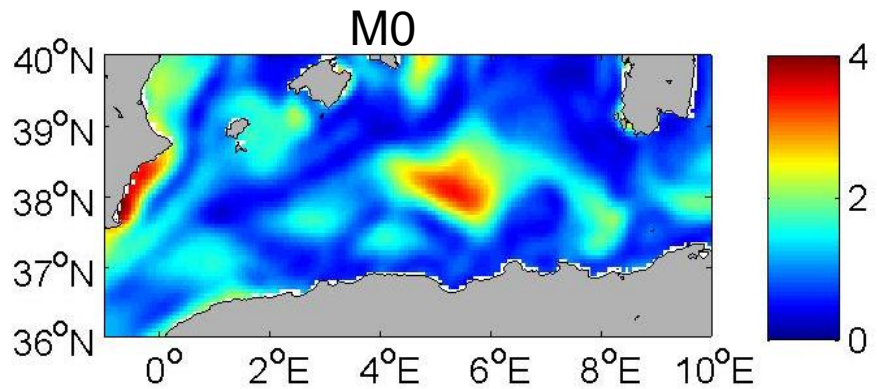
# Results - RMS of SSH (cm) averaged in the Algerian basin



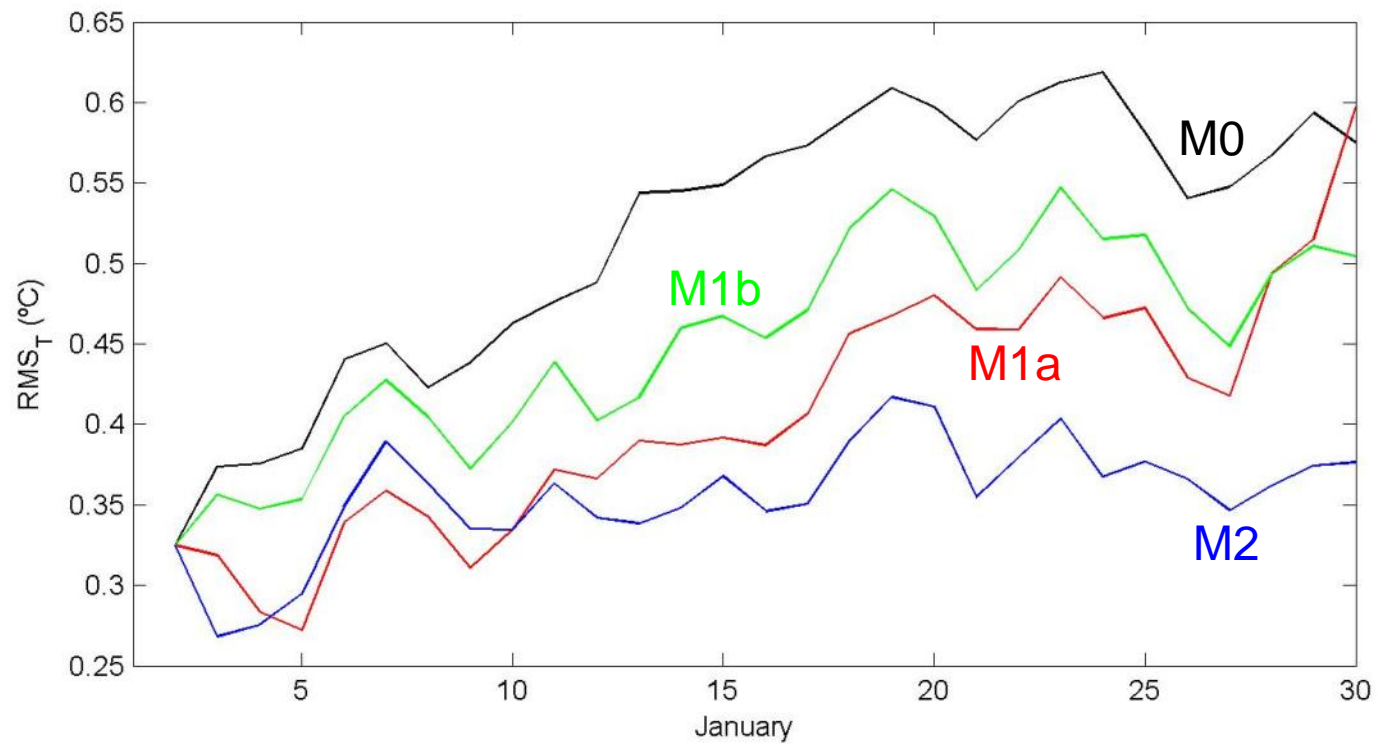
# Conclusion

- An advanced assimilation method (ENKF) is coupled to sbPOM. The sbPOM + ENKF works on parallel architectures ( $1028 = 32 \times 32$ ).
- The sbPOM + ENKF is able to reproduce the mesoscale activity of the Mediterranean Sea (Algerian basin) using synthetic observations of SSH from another ocean model (POP).
- A sbPOM + ENKF test case will be made available at the sbPOM web page.

# Results - RMS of SST ( $^{\circ}\text{C}$ ) averaged in time



# Results - RMS of SST ( $^{\circ}\text{C}$ ) averaged in Algerian basin



# sbPOM + ENKF

A parallel ENKF algorithm is coupled to the sbPOM. Modifications to sbPOM are minimal.

▼ enkf	ENKF code:
assimilation_tools.f	Main assimilation (ENKF) subroutines
ensemble_tools.f	Computations involving the ensemble members
io_tools.F	Parallel I/O for the ensemble members
model_tools.f	Communication with the model (sbPOM)
mpi_tools.f	Parallel tasks (communication between processors)
▶ in	Input files
▶ obs	Observations files
▶ out	Output files (ensembles averages and variances)
▶ pom	Original sbPOM code (with minimal modifications)
▶ prep	Matlab scripts to generate input files
▶ proc	Matlab scripts to process output files
enkf.h	ENKF dimensions (ensemble size, # model states, # observations...)
enkf.nml	Input control file for ENKF
enkf.sh	Script to run the code
main.f	Main driver
makefile	Make file (compile the code)
pom.h	Global and local dimensions for sbPOM model
pom.nml	Input control file for sbPOM