Sea-level modelling and forecasting in the Mediterranean Sea using data assimilation

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The correct reproduction of the **sea levels** is crucial for managing and forecasting **coastal flood risk**. The combination of **observations** and **numerical models** is particularly important in coastal regions with poor monitoring resources. In this study, we investigate the benefits of **assimilating sparse observations** from **tide gauges** into an unstructured hydrodynamic model for simulating sea level in the **Mediterranean Sea**.

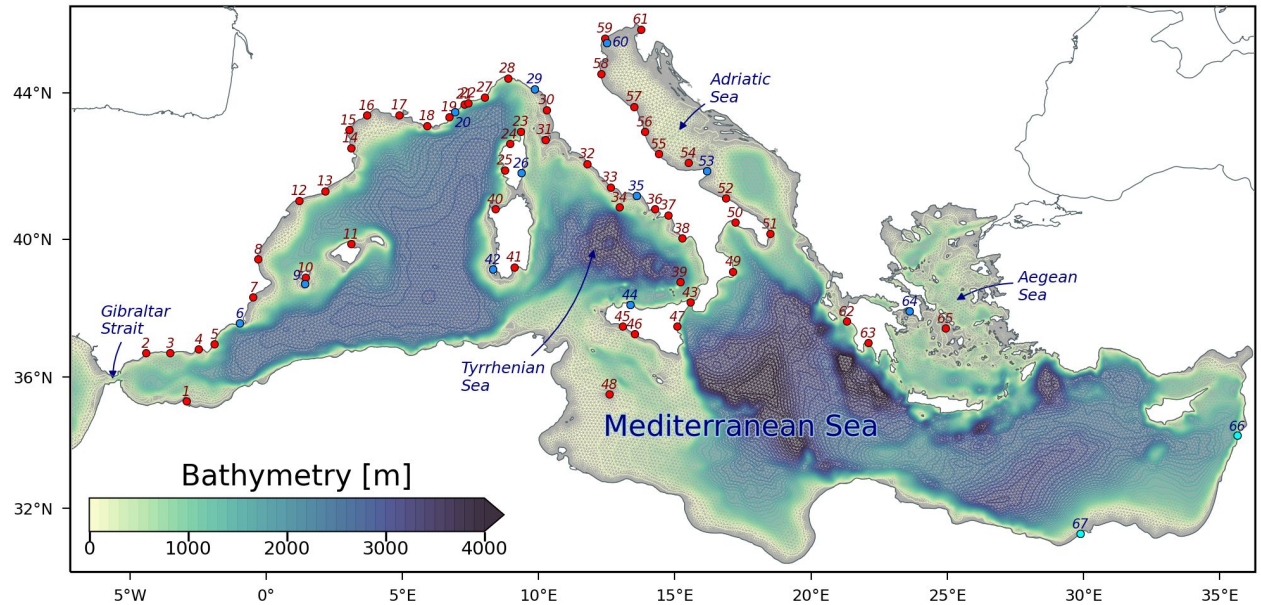
This work is part of the Interreg Italy-Croatia **STREAM** project.

European Regional Development Fund

The modelling approach

SHYFEM hydrodynamic model - https://github.com/SHYFEM-model/shyfem

The numerical domain covers the whole **Mediterranean Sea** with approximately 163,000 triangular elements of variable shape and size. **Assimilation** of hourly sea-level data from sparse tide gauge (JRC and GESLA3 datasets) is performed using the Ensemble Kalman filter approach. We performed both **reanalysis** and **forecast** simulations.



Simulation details:

- November-December 2019
- MSLP and 10m wind BOLAM 8km hourly fields
- MFS sea level boundary conditions at Gibraltar
- Perturbations of surface and lateral boundary conditions and bottom friction
- 54 tide gauges assimilated
- 13 tide gauge stations used only for validation
- Different simulations for tide, surge and total sea level

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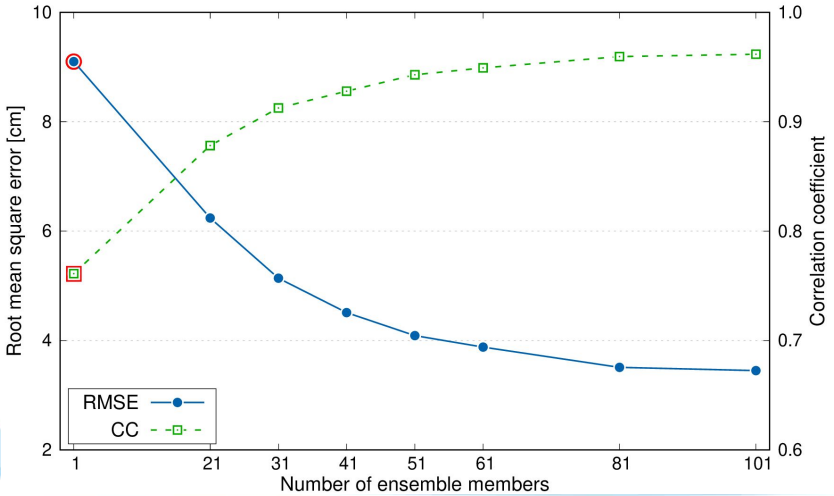
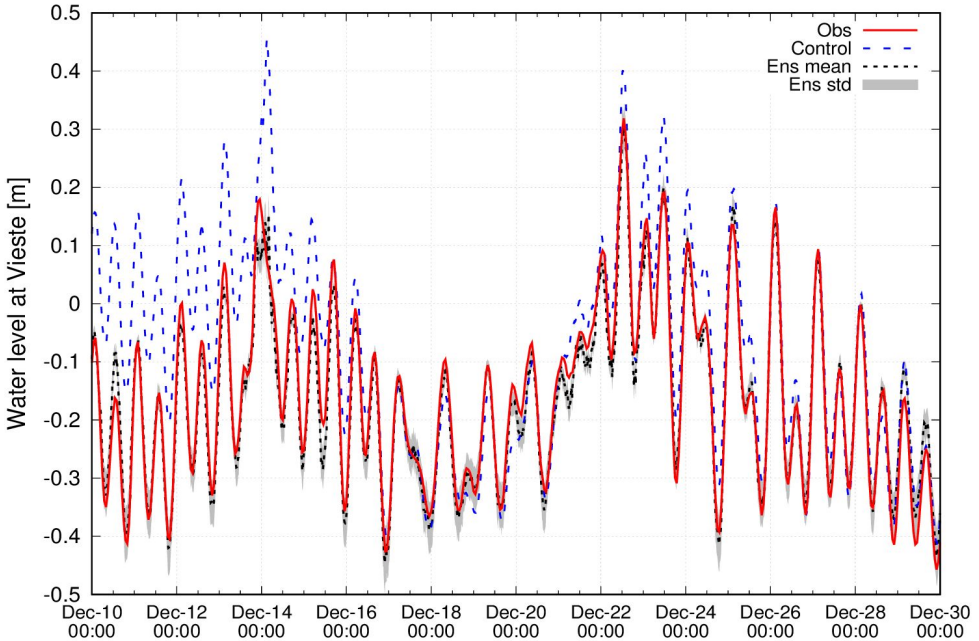
Sea level reanalysis

The **number of members** is a crucial parameter in ensemble data assimilation. The approximation of the background covariance matrix with the ensemble perturbations becomes **perfect** when the number of ensemble members goes to **infinity**.

Performance increases with the increase of the members of the assimilation scheme. We decided to use an ensemble of **81 members** (80 perturbed + 1 control).





Results in not-assimilated stations show **large improvements** over the whole Mediterranean Sea.

Tide (mean RMSE cm)	**Residual level** (mean RMSE cm)	**Total level** (mean RMSE cm)
4.7 ⇨ 1.1	**8.7 ⇨ 3.4**	**9.1 ⇨ 3.5**

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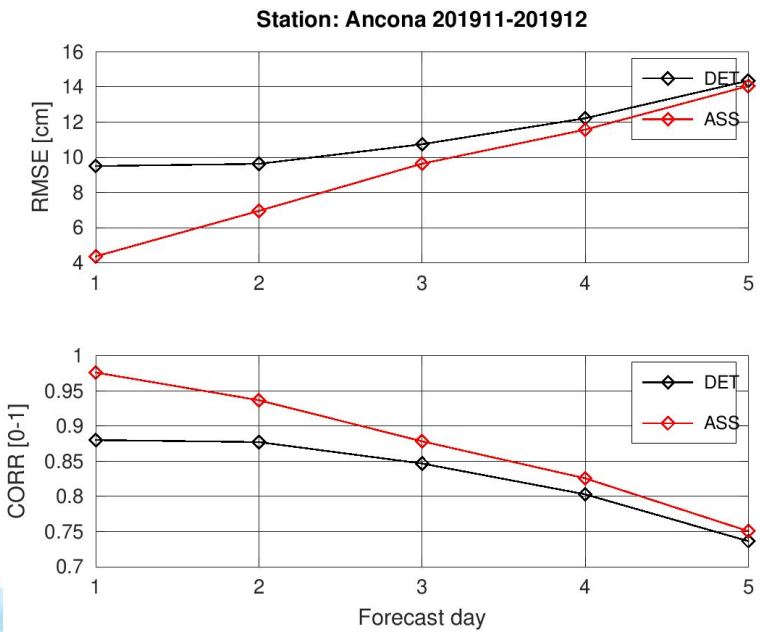
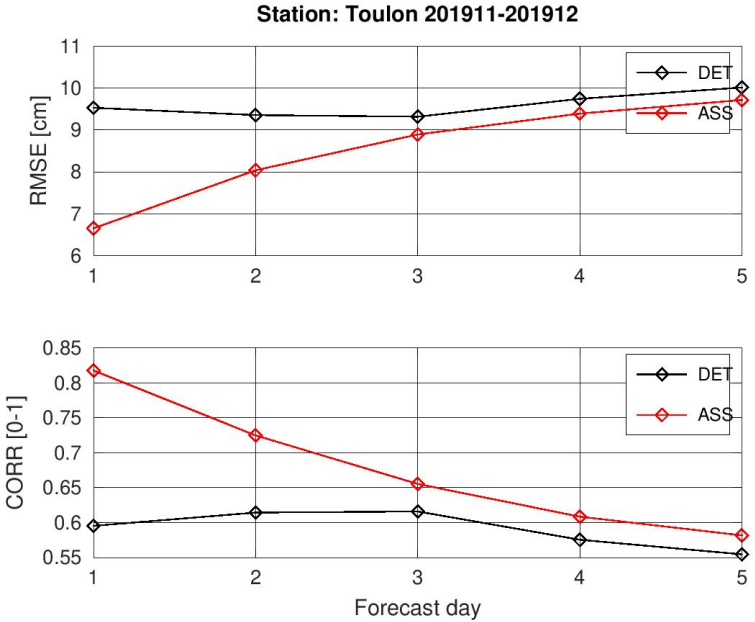
Residual sea level forecast

Forecasts cover **five** days, starting at 00UTC from analysis.

We here compare (RMSE and CC) the **deterministic** run with the **ensemble mean.**





- **Strong** improvements in all the stations, both assimilated and not-assimilated
- High benefits in forecasting cases of **seiche** oscillations (especially in the northern Adriatic Sea)

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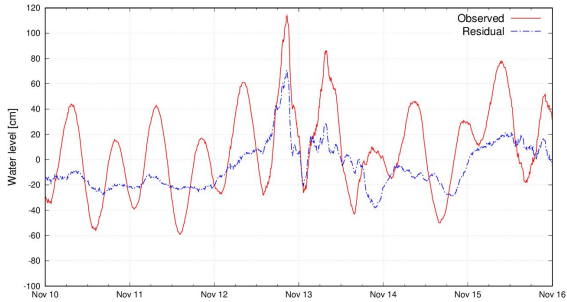
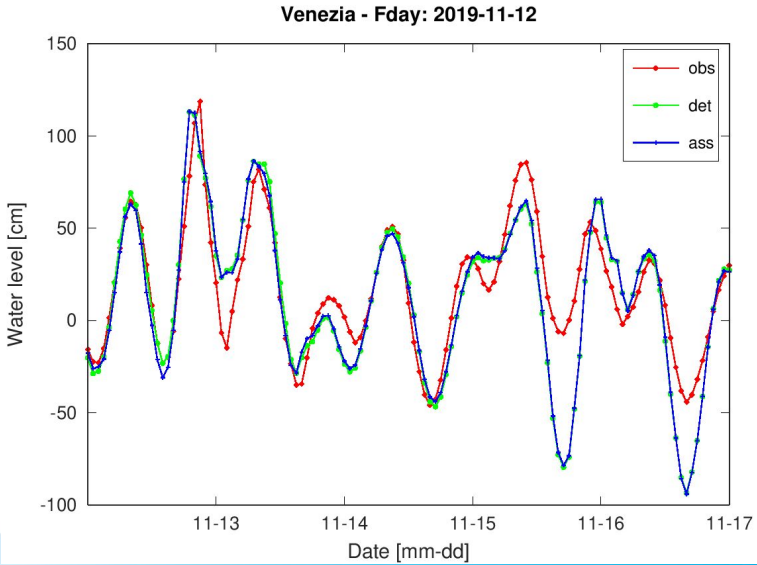
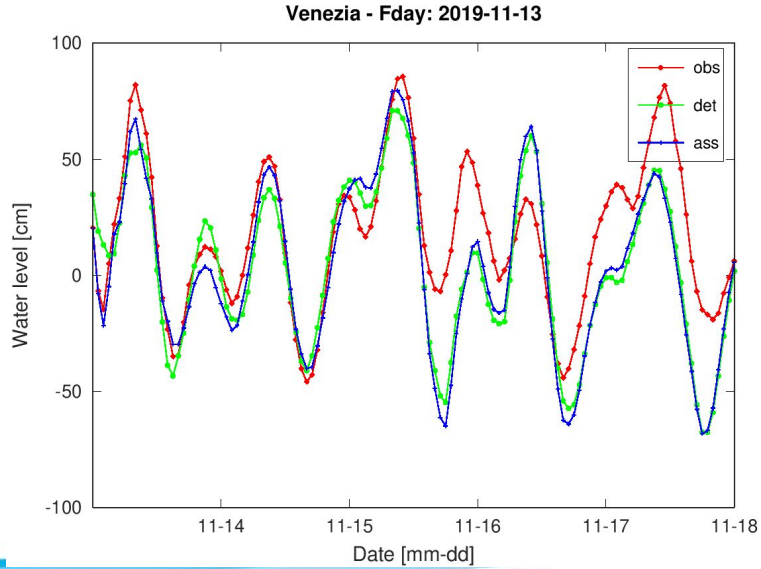
Extreme events in the Adriatic Sea



12-13 November 2019

- On 12 November the 2nd highest sea level ever recorded occurred;
- Good peak reproduction by the deterministic -> no further improvement with DA;
- DA slightly correct a small seiche oscillation on 13 November.





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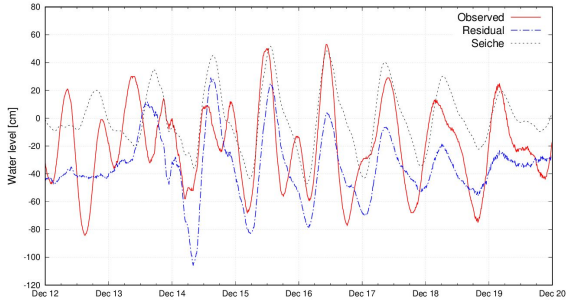
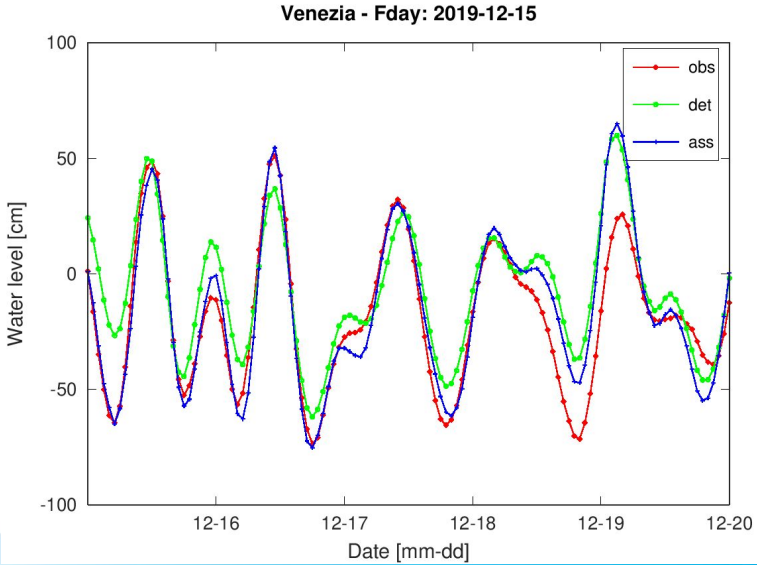
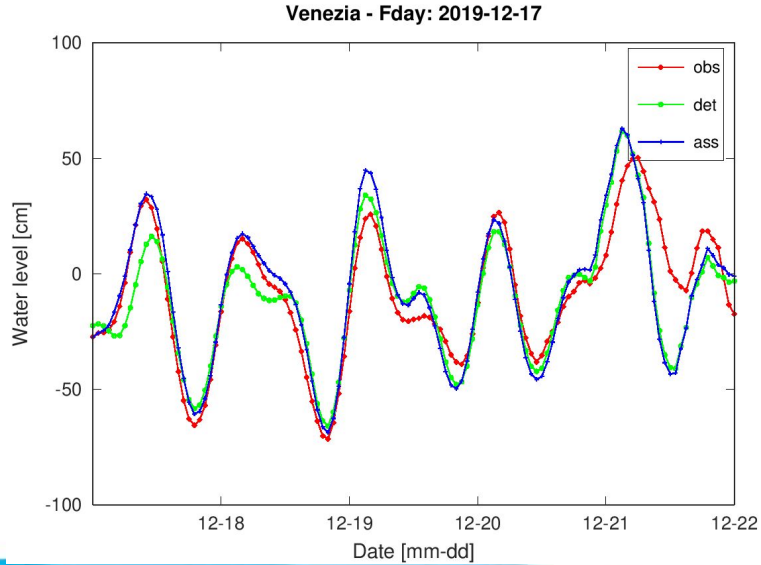


15-17 December 2019

- Period of strong seiche oscillations;
- Strong improvement of the initial state and of the barotropic oscillation, damping the days after.





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Conclusions

- Data assimilation (DA) has a positive impact on the reproduction of all the sea-level components, both in reanalysis and forecast, even in regions far from the assimilated stations (i.e., eastern Mediterranean Sea);
- The reanalysis of tides is particularly useful to determine the tidal characteristics in regions without monitoring stations;
- The DA impact on forecast is stronger in presence of seiches (excitations of barotropic modes of the basins). This point will be further studied in the future.
- We are planning to perform a 30-50 year sea level reanalysis over the whole Mediterranean Sea.

Interreg Italy-Croatia project
Strategic development of flood management

https://www.italy-croatia.eu/web/stream

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