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European Global Ocean Observing System

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Advances in operational oceanography: Expanding Europe's ocean observing and forecasting capacity

Storm surge forecasting and predictability in the Goro lagoon (Italy)

Breakout Session 4: Extreme Events and Hazard Forecasting

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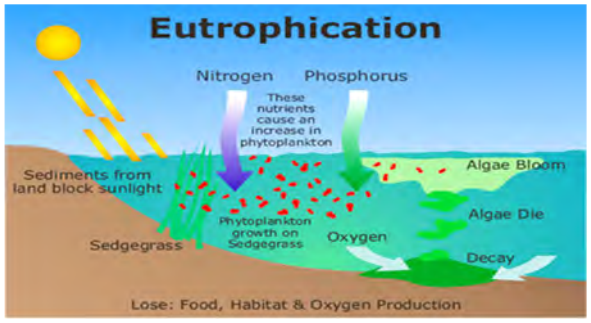
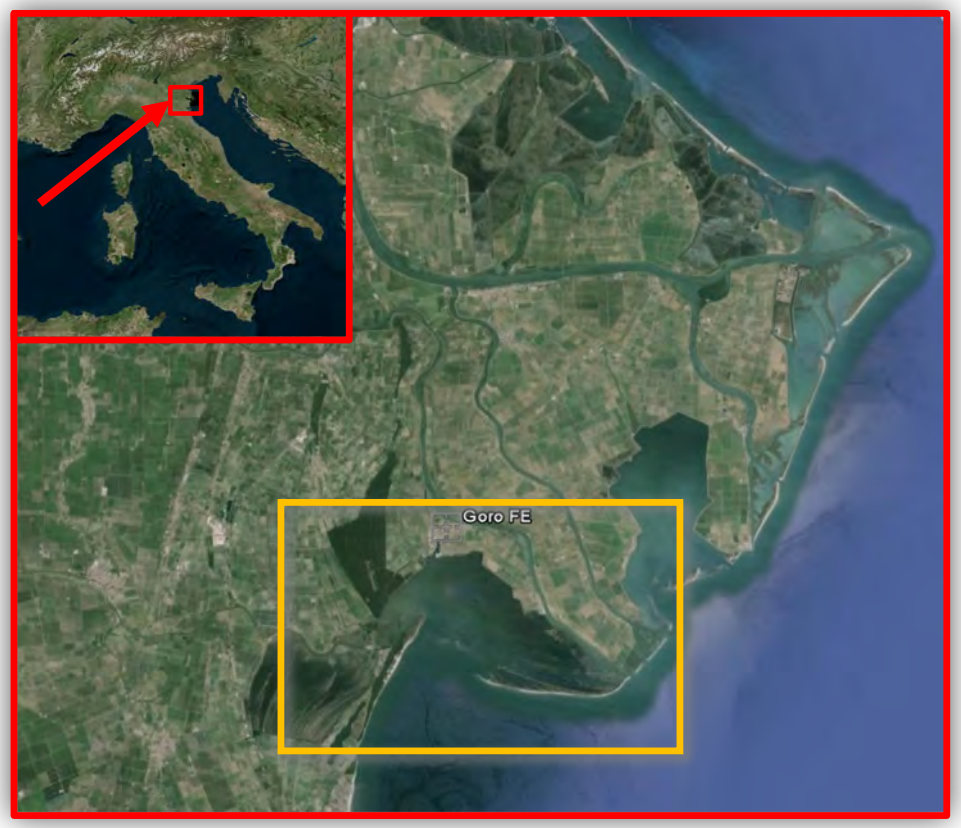
The Goro lagoon ecosystem

GOLFEM (Goro Lagoon Finite Element Model; Maicu et al., 2021) is the implementation of the SHYFEM model in the Goro lagoon developed at Arpae-SIMC with the contribution of the University of Bologna and the CNR-ISMAR.

- The Goro lagoon extend over an area of about **2,000 hectares**, part of the Emilia-Romagna **Po Delta Park**, enclosed between two branches of the wide **Delta of the Po river** (Po of Goro and the Po of Volano).
- The main problems are connected to the eutrophication of the lagoon, threatening the clams farms, and inundation of the towns surrounding the lagoon.

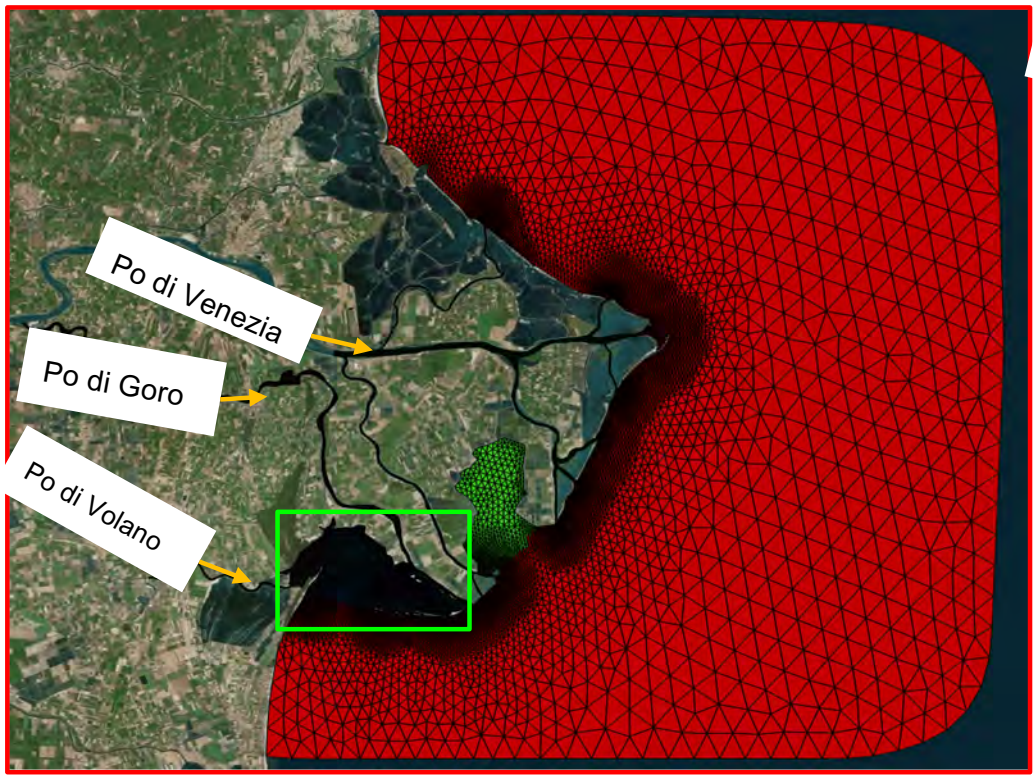


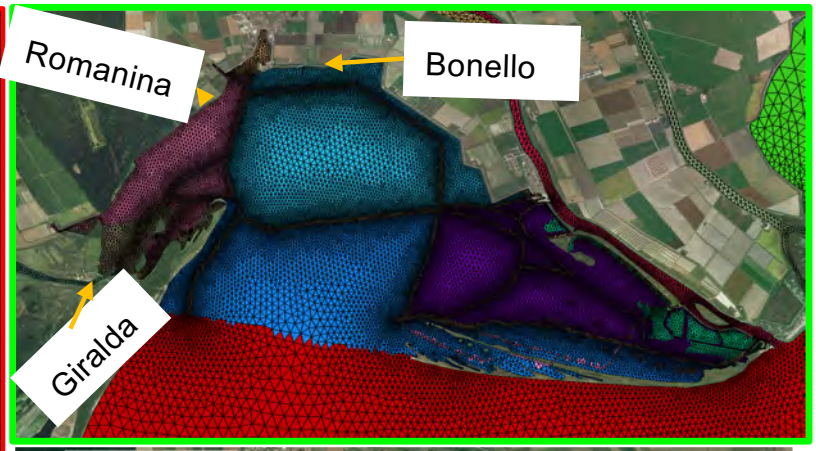


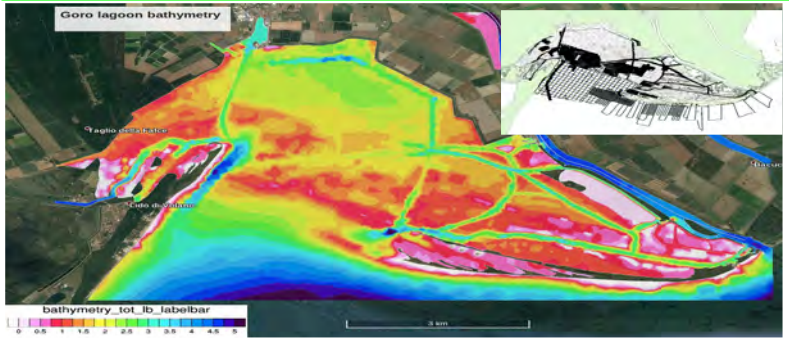
Model set-up, grid domain and bathymetry

- **SHYFEM** (Shallow water HYdrodynamic Finite Element Model; Umgiesser et al., 2004) is a three-dimensional finite element model, that solves the primitive equations for the ocean under hydrostatic and boussinesq approximation.
- **Unstructured grid** approach on arakawa B-type grid triangular mesh (Bellafiore and Umgiesser, 2010; Ferrarin et al., 2013).

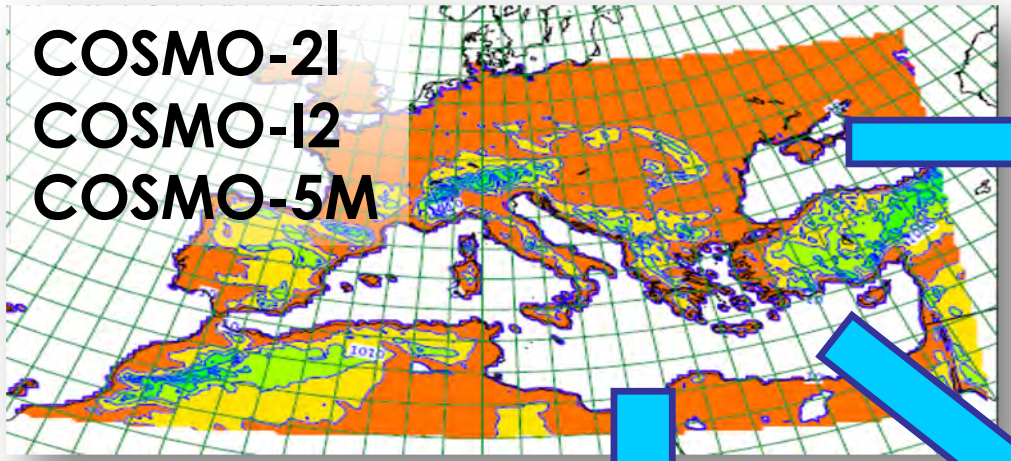
Freshwater inflow is an important forcing, as the Po river can reach discharge of more than **10000 m3/s**

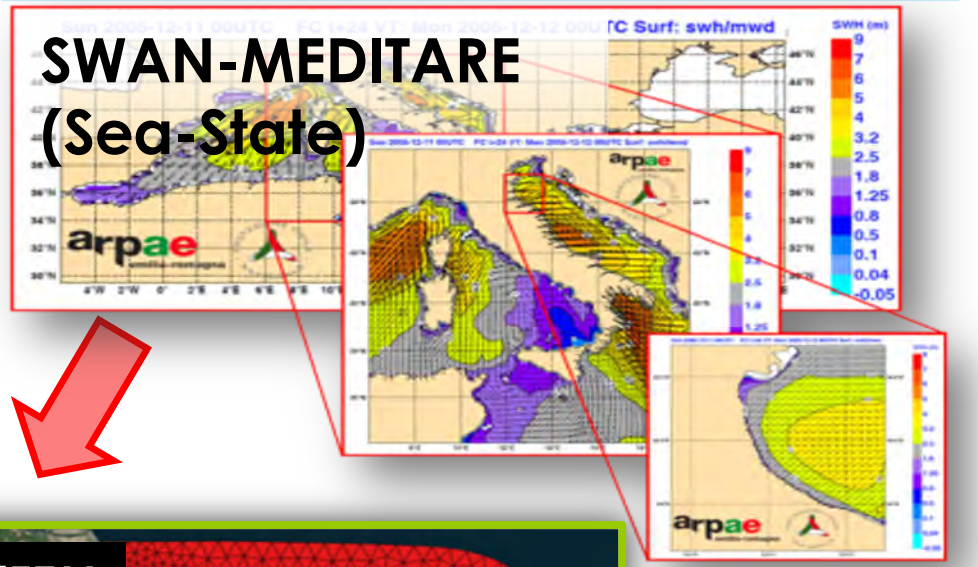


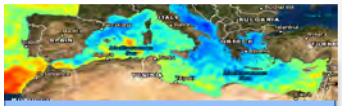




Forecasting chain nesting







Copernicus
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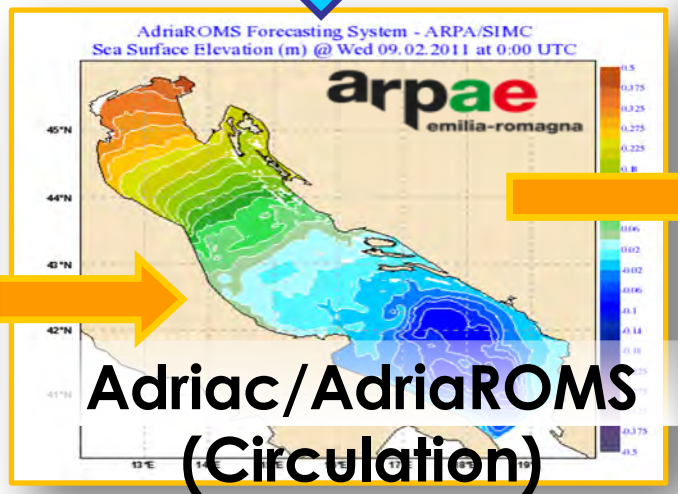
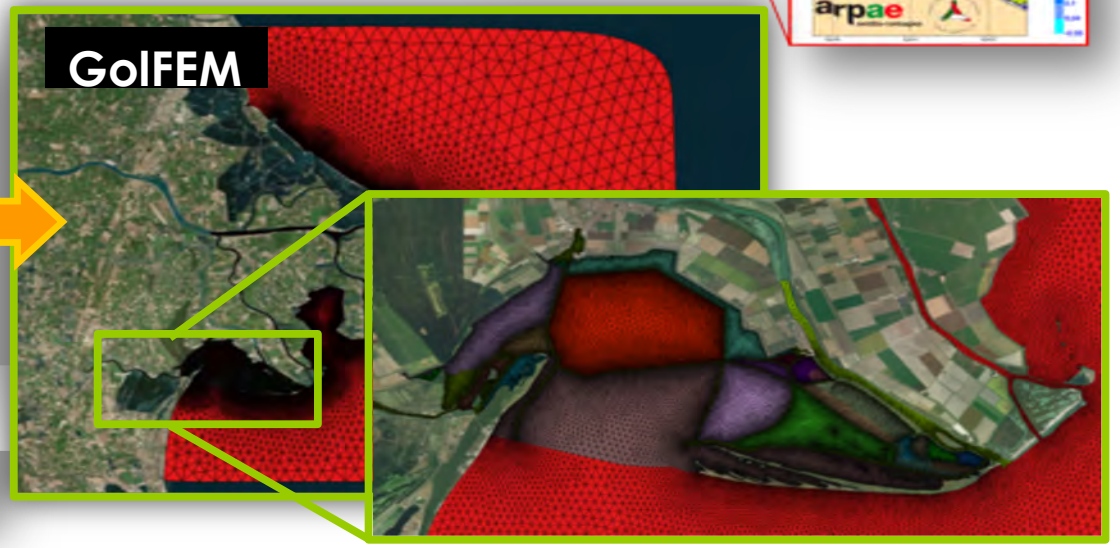


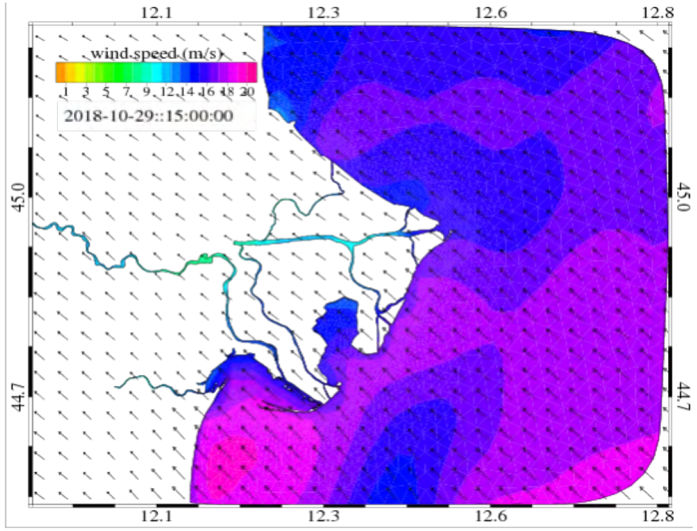


Selected storm surge events

Date	Tide Gauge max P. Garibaldi (time, m)	Tide Gauge max Faro Goro (time, m)	Impacts	Notes	State
08/12/2020	15:20 -> **1.23**	15:50 -> **1.10**	ferrarese	Venti E-SE	✓
02/12/2020	09:20 -> **1.25**	09:30 -> **0.93**	Impatti diffusi	Venti N-NE	✓
23/12/2019	08:40 -> **1.17**	08:50 -> **1.21**	Impatti diffusi	Venti NE	✓
12/11/2019	20:50 -> **1.22**	20:40 -> **1.15**	Impatti diffusi	Venti NE	✗
02/02/2019	22:50 -> **0.91**	23:10 -> **0.85**	Ferrarese ravenna	Venti ENE	✗
29/10/2018	16:30 -> **1.06**	14:50 -> **1.07**	Ferrarese	Venti SE	✓
18/03/2018	23:10 -> **1.14**	23:10 -> **1.04**	Ferrarese	Venti E-NE	✗
13/11/2017	09:00 -> **1.0**	07:00 -> **0.70**	Ferrarese	Venti NE	✗
16/06/2016	18:40 -> **0.93**	18:30 -> **0.88**	Impatti diffusi	Venti SE	✗
29/02/2016	02:50 -> **0.91**	02:50 -> **0.88**	Impatti diffusi	Venti E-NE	✗

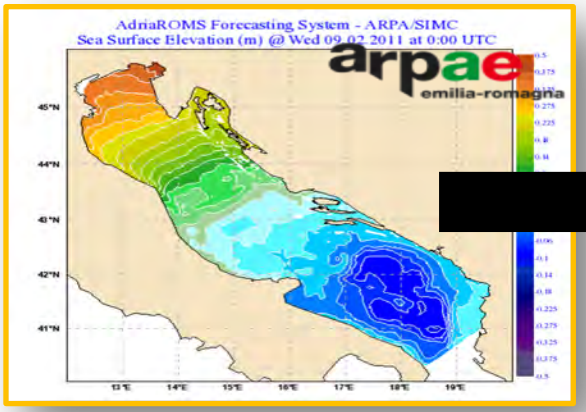
Storm surge of the 29 october 2018

Exp	Events	open boundary	prevailing wind
G1	29-31 oct 2018	AR an	South-East
G1+TPXO		AR+TPXO	

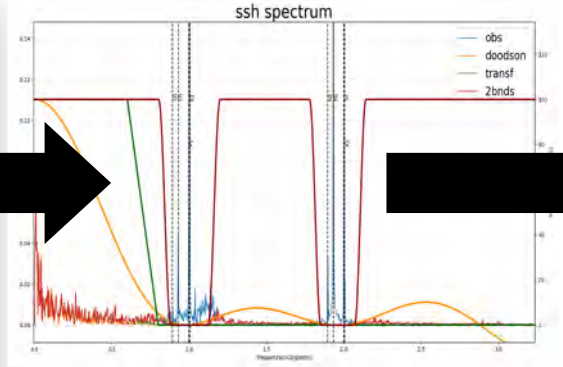


A “detiding” procedure is tested at the open boundaries input and tides from TPXO are added to the model

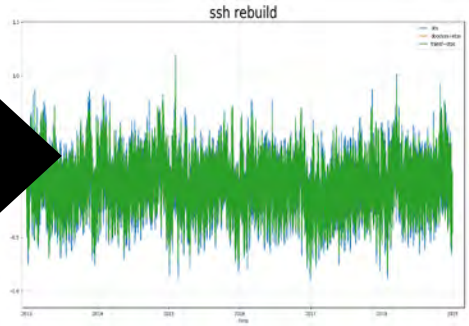
AdriaRoms (AR) sea level



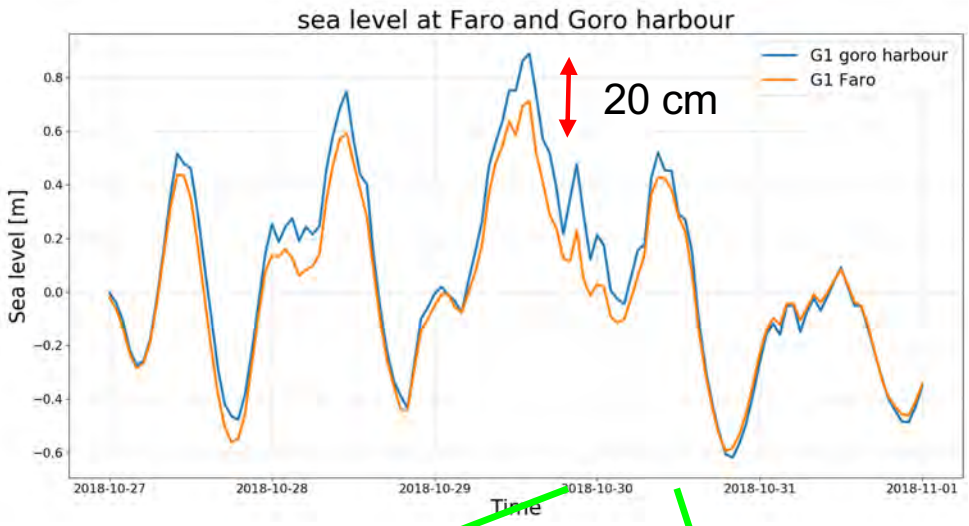
Tidal digital filter

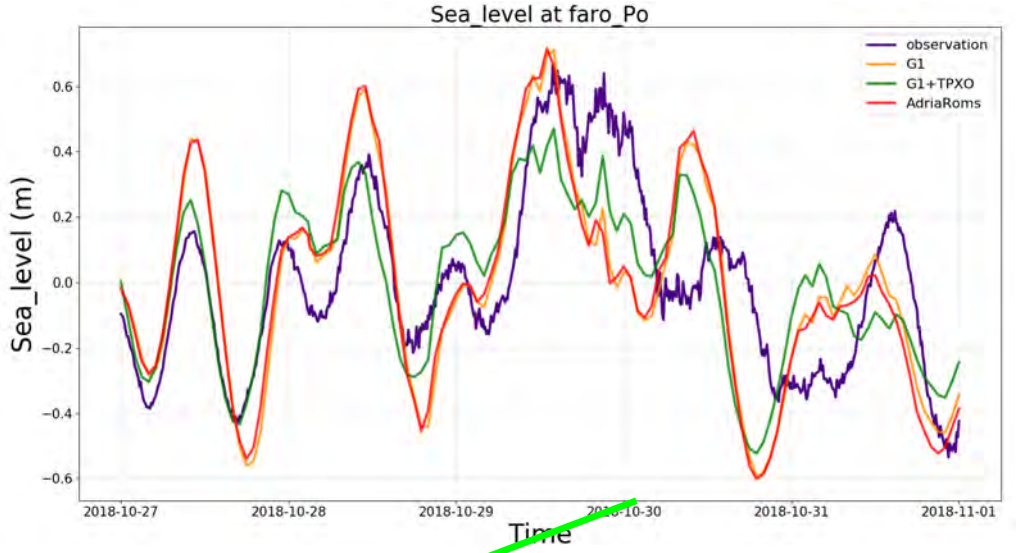


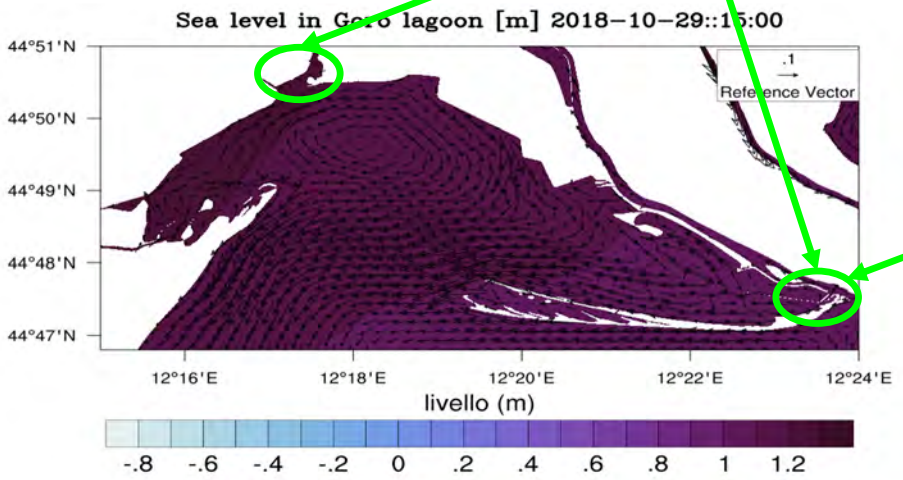
detided signal + TPXO tides



Storm surge of the 29 october 2018





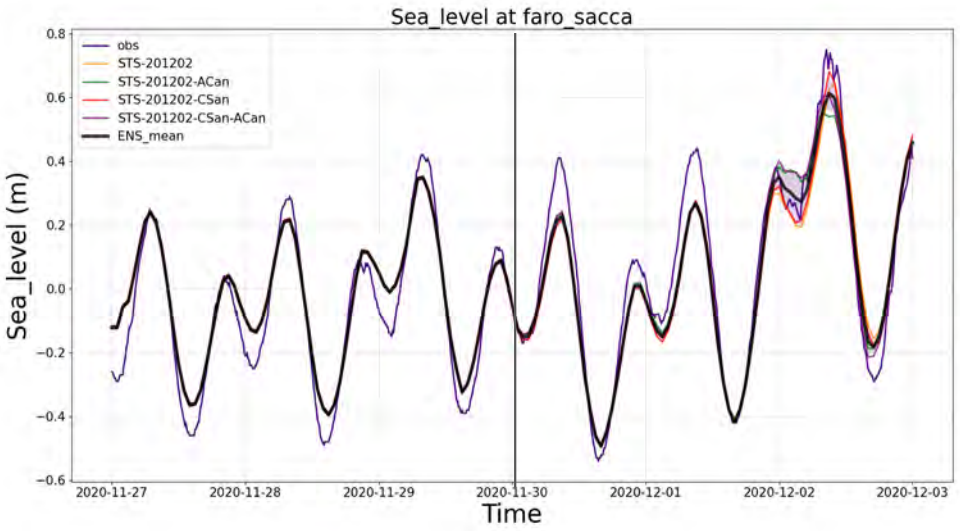


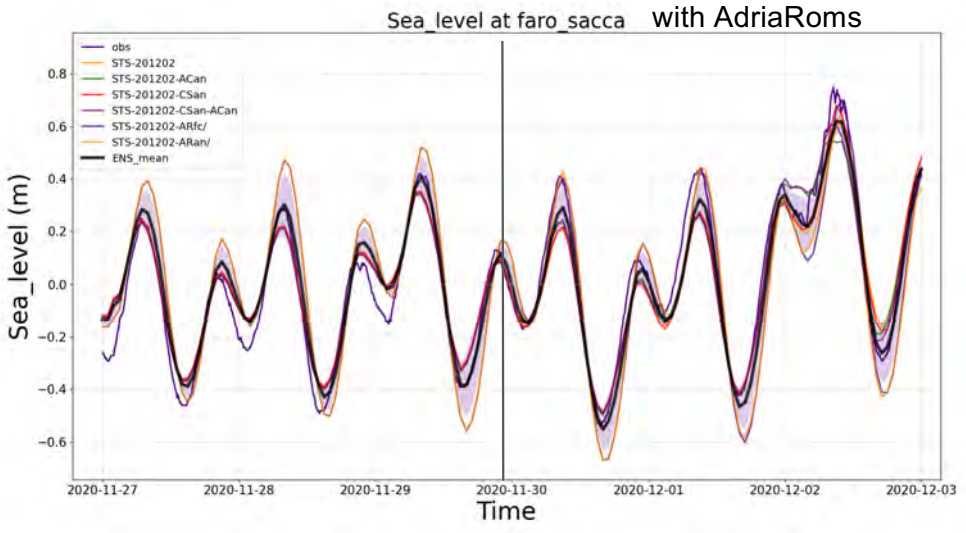
Statistics	G1	G1+TPXO
R coefficient	0.692	0.705
RMSE [m]	0.23	0.20

First studies for an ensemble forecasting system

Run name	Run description	Meteo Analysis	Meteo Forecast	Ocean Analysis	Ocean Forecast
STS-YYMMDD	3d SU + 3d FC	COSMO-2I from -3 to 0	COSMO-2I/5M from 0 to +3	Adriac from -3 to 0	Adriac from 0 to +3
STS-YYMMDD-CSan	meteo analysis	COSMO-2I from -3 to +3	-	Adriac from -3 to 0	Adriac from 0 to +3
STS-YYMMDD-ACan	ocean analysis	COSMO-2I from -3 to 0	COSMO-2I/5M from 0 to +3	Adriac from -3 to +3	-
STS-YYMMDD-CSan-ACan	analysis	COSMO-2I from -3 to +3	-	Adriac from -3 to +3	-
STS-YYMMDD-ARfc	3d SU + 3d FC with AdriaRoms	COSMO-2I from -3 to 0	COSMO-2I/5M from 0 to +3	AdriaRoms from -3 to 0	AdriaRoms from 0 to +3
STS-YYMMDD-ARan	ocean analysis (AdriaRoms)	COSMO-2I from -3 to 0	COSMO-2I/5M from 0 to +3	AdriaRoms from -3 to +3	-

Storm surge of the 2 december 2020





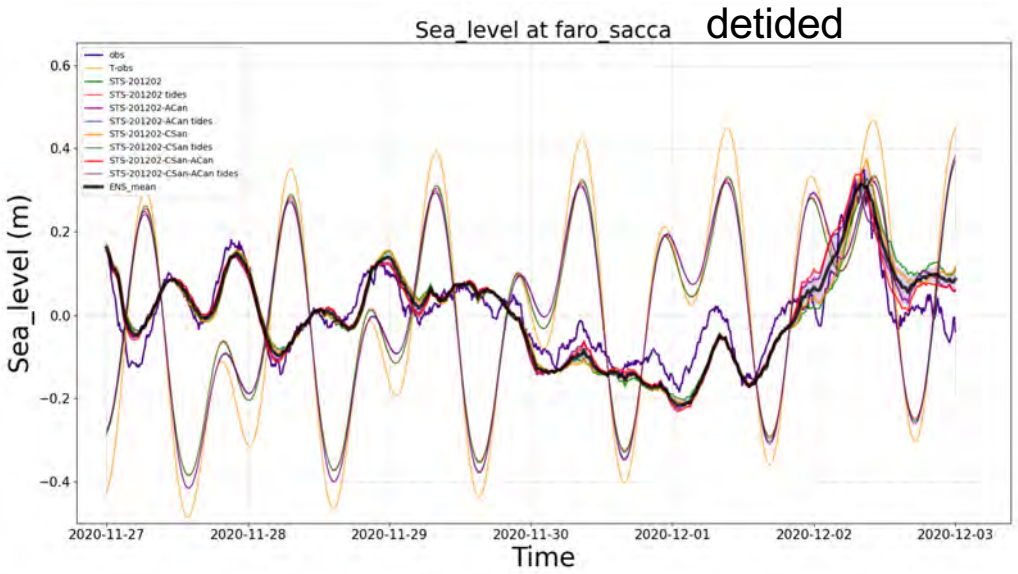
Name	Correlation R	RMSE (m)
STS-201202	0.965	0.084
STS-201202-ACan	0.970	0.077
STS-201202-CSan	0.966	0.081
STS-201202-CSan-ACan	0.969	0.076
ENS-mean	0.972	0.075

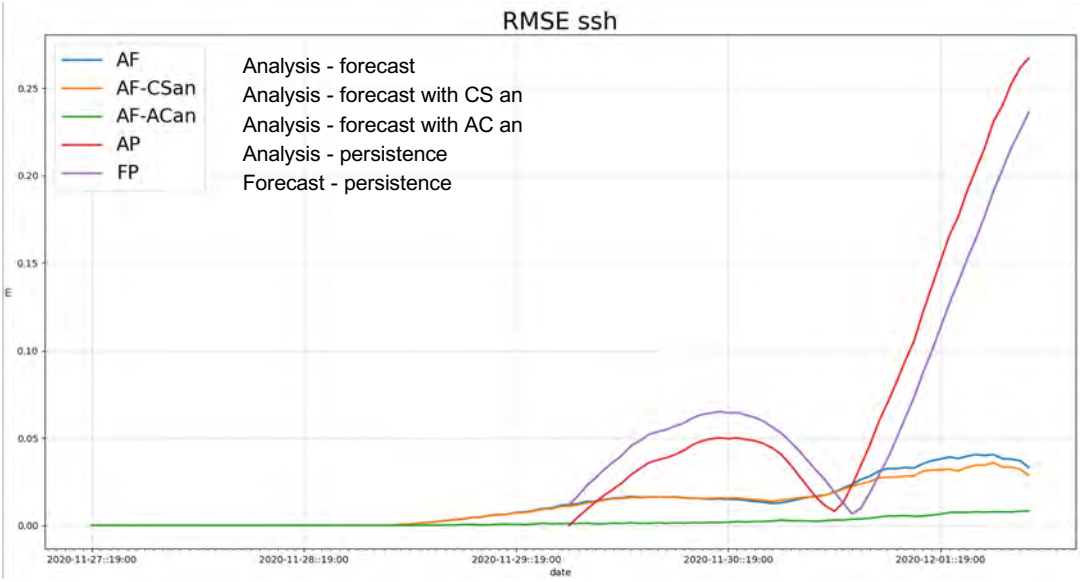
Adding AdriaRoms runs

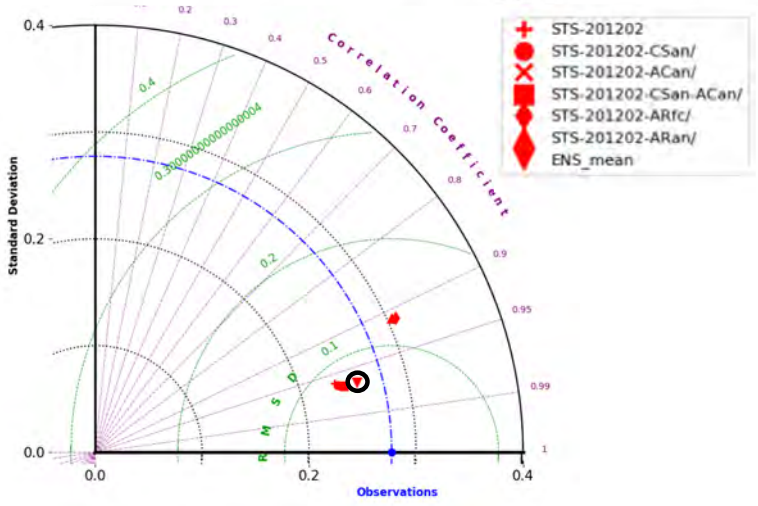
Name	Correlation R	RMSE (m)
STS-201202-ARfc	0.951	0.103
STS-201202-ARan	0.951	0.100

ENS-mean	0.983	0.058

Storm surge of the 2 december 2020







- A small ensamble simulation (6 members) is enough to show better statistics than single run (taylor plot and previous slide).
- As expected most of the uncertainties is concentrated at the peak of the extreme events
- In such a small domain uncertainties from lateral open boundary conditions may play an important role in sea level forecast.

Conclusions and future perspectives

- In a complex ecosystem such the goro lagoon a forecast system is of fundamental importance for the development of an adequate Early Warning System (EWS) for the prevention of flooding events.

- A calibrated and validated model as Golfem (Maicu et al. 2021) in cascade to the Arpae forecasting chain is a powerful tool for operational forecasting but **uncertainties from meteorological forcing and lateral open boundary conditions are the most important source of error**.

- An ensemble approach is used to assess the most important source of uncertainties in a small coastal domain. **Lateral open boundary conditions have a fundamental role in the sea level forecast but uncertainties due to meteorological forcing will be assessed more accurately.**

- The role of wave set-up contribution to the sea level will be assessed with the coupling of shyfem to a wind wave model (WaveWatch III).

Thank you !!!

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