Modelling the Storm Surge in the Adriatic Sea using satellite data

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Summary

- Introduction of storm surge in the Adriatic Sea
- Present status of the hindcast using deterministic model
- The hindcast experiments using satellite data
- Recommendations

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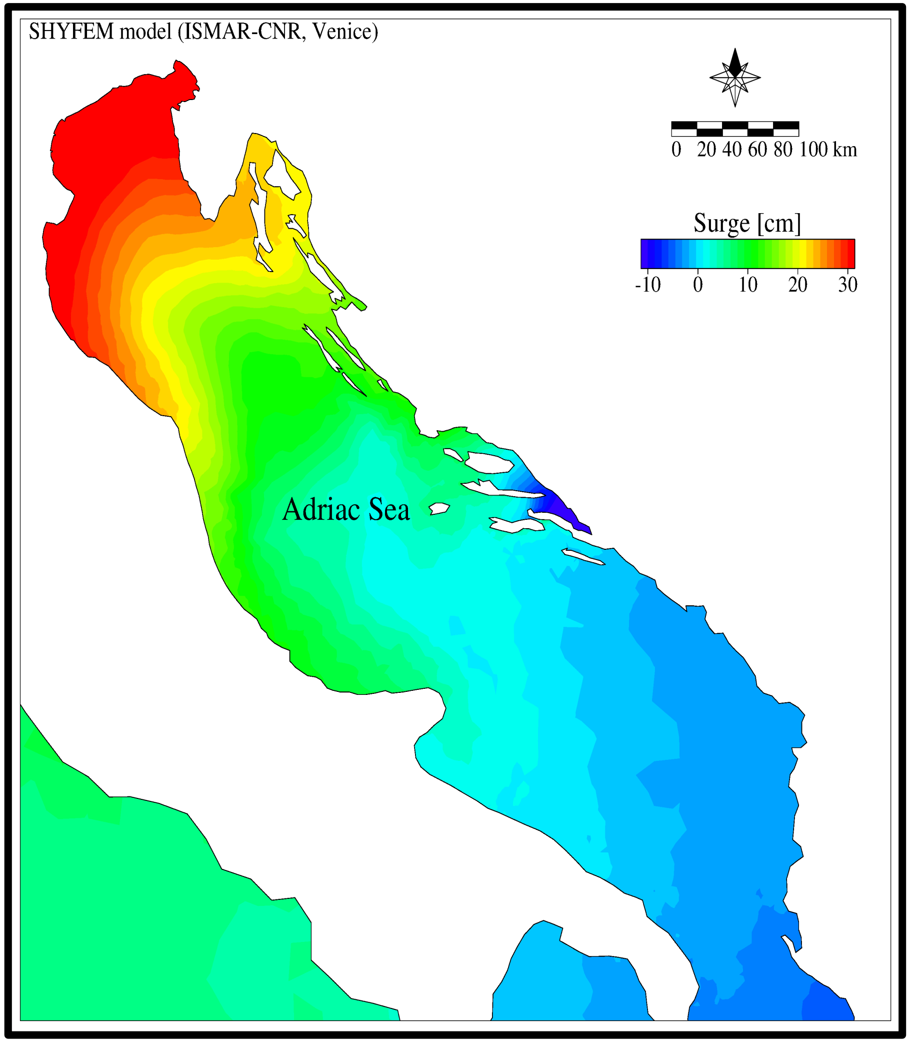
Geophysics of storm surge in the Adriatic Sea

Storm Surge in Adriatic Sea: main contributions to the Storm Surge Level (SSL)

The storm surge in the Adriatic Sea is mainly governed by low atmospheric pressure and strong winds (mainly ***Sirocco***). The ***Storm Surge Level (SSL)*** added to the astronomical tide forms the **Sea Surface Height (SSH).**

The Adriatic Sea geometry causes the setup of free oscillations, called ***seiches***, that persist for several days after their generation by meteorological forcing. *These oscillations* ***are of the order of the original disturbance*** for the first 2 days, after that they decay exponentially.

Other contributions, like ***the wave set-up, non-linear interactions between storm surge, astronomical tide and waves, baroclinic forces and river discharges are generally negligible*** and can be quantify by ***less than 2 cm*** (*Lionello et al., 2006, Roland et al, 2009*). Thus, in the Adriatic Sea the SSL may be thought ***essentially as the effect of the wind blowing over the basin plus the inverse barometric effect (IB), and the initial sea surface configuration***. It is very difficult to quantify IBE (Wunsch at Stammer, 1997) which, however, can be estimated of the order of ***10-20 cm maximum***.



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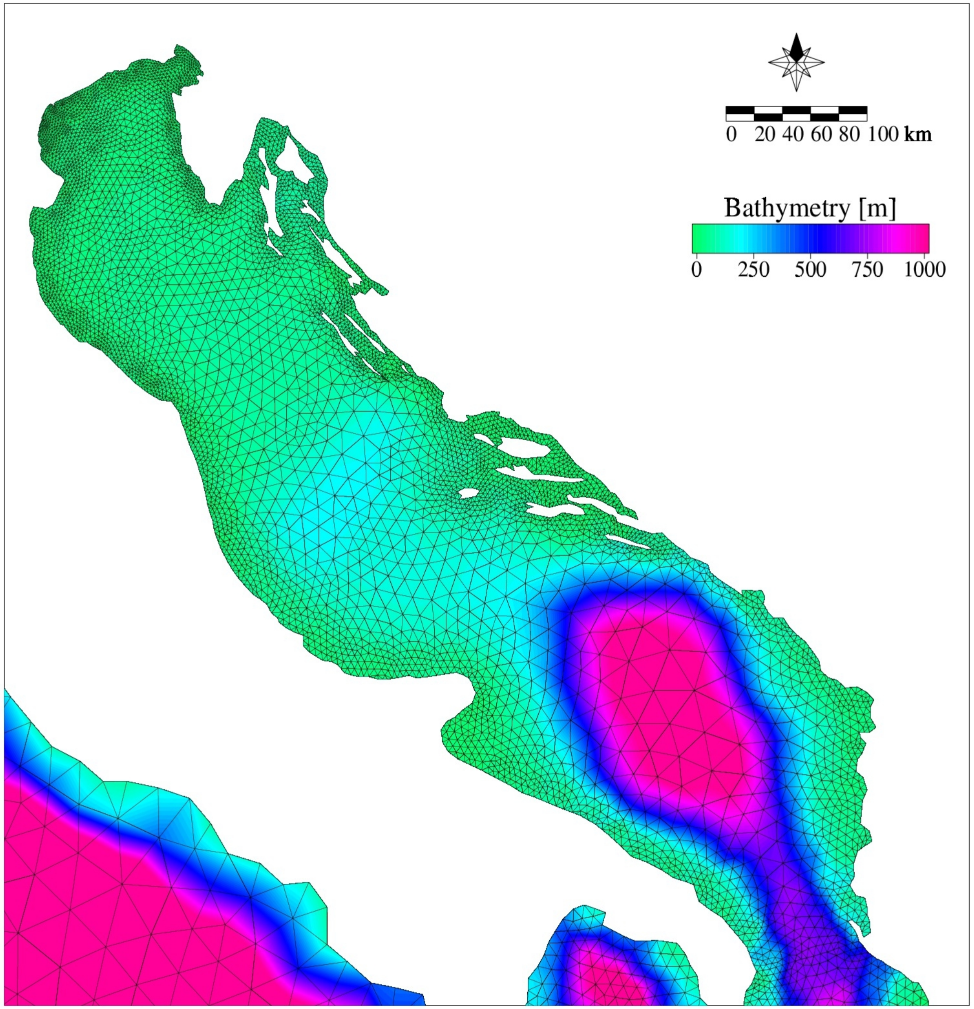
eSurge-Venice project: the SS model



The existing model

The forecasting system is the Shallow water HYdrodynamic Finite Elements Model **(SHYFEM)**, a 2D shallow water numerical model based on the finite element method (*Umgiesser et al., 2004*). **SHYFEM** is open source.

The operational system predicts the surge each day 120 h ahead (5 days starting from 00 UTC). It consists of two different applications: a simulation in the Mediterranean Sea and a second one only in the Adriatic Sea. The surge is computed in front of the Venice lagoon. Here the influence of the Adriatic Sea surge and seiches are taken into account, without astronomical tides. This value is then corrected applying the bias obtained from the mean sea level of the day before and the astronomic tide.

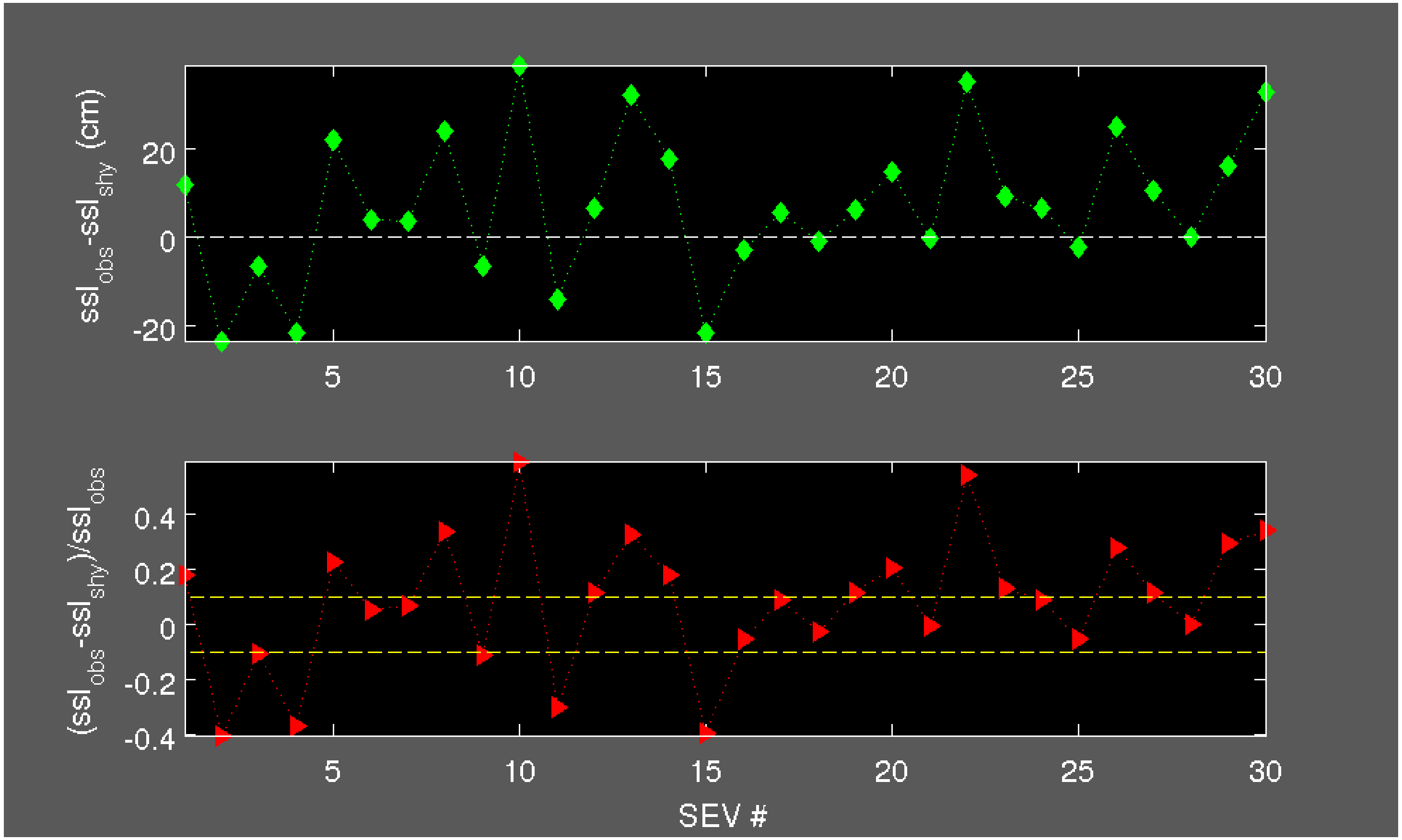
Initial conditions

At every run of the model a "restart" file is prepared for the next model run. The "restart" procedure allows to supply the model with a reasonable background field avoiding the spin-up phase, which would require up to 20 days.

Forcing

Wind and atmospheric pressure data are provided by the ECMWF, which supplies the forecasts at synoptic hours 00, 06, 12, 18 UTC.

SEVs selected: starting point of SSL forecast

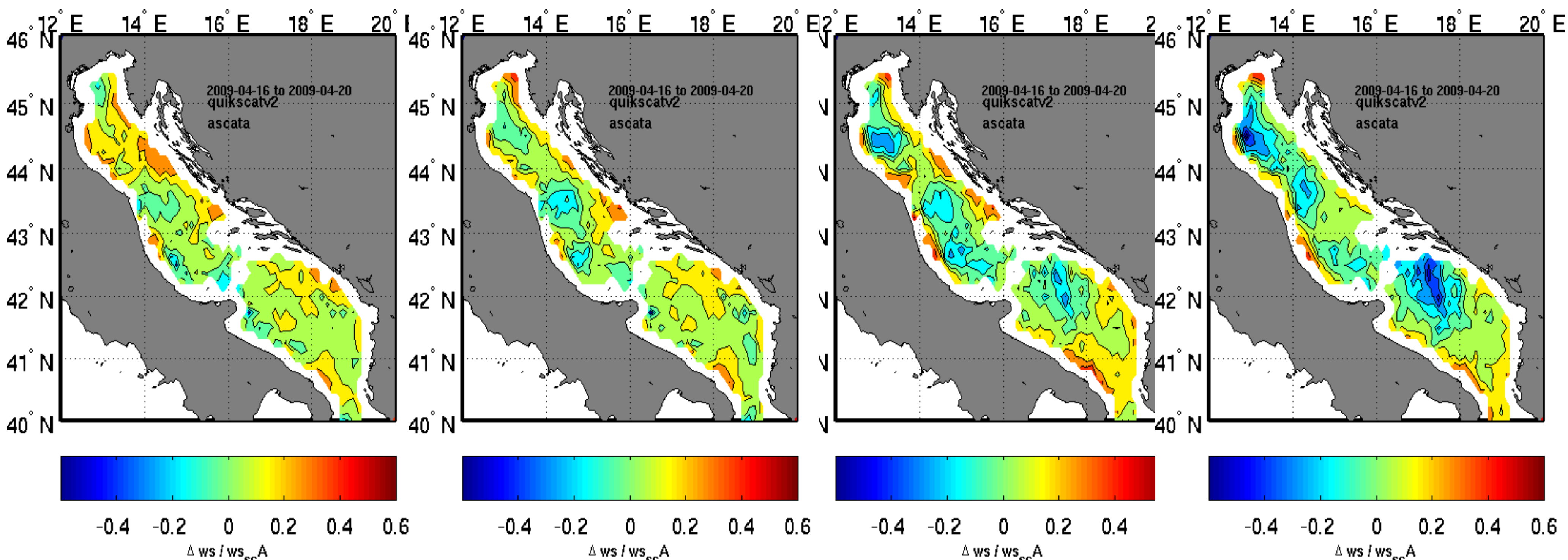


Observation-model

For ~50% of cases the obs-model difference is > 10%

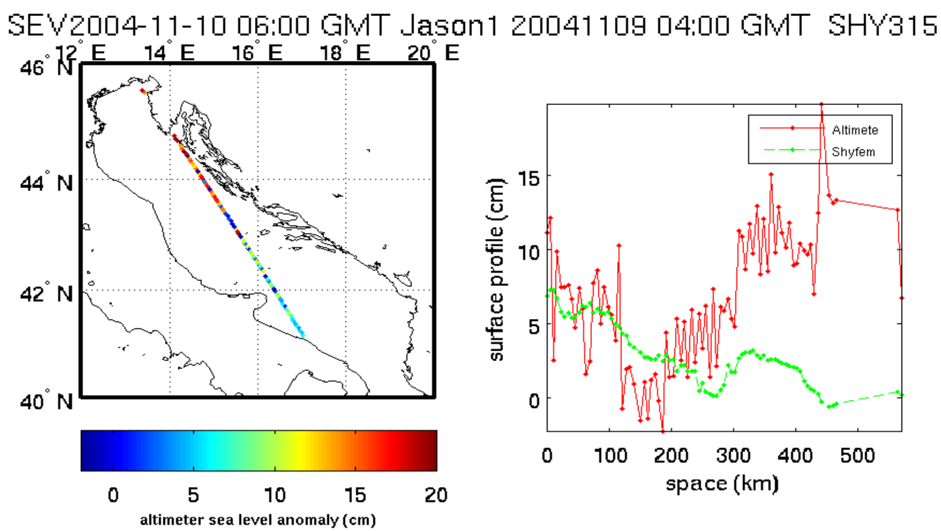
What we know about the model winds in the Adriatic Sea

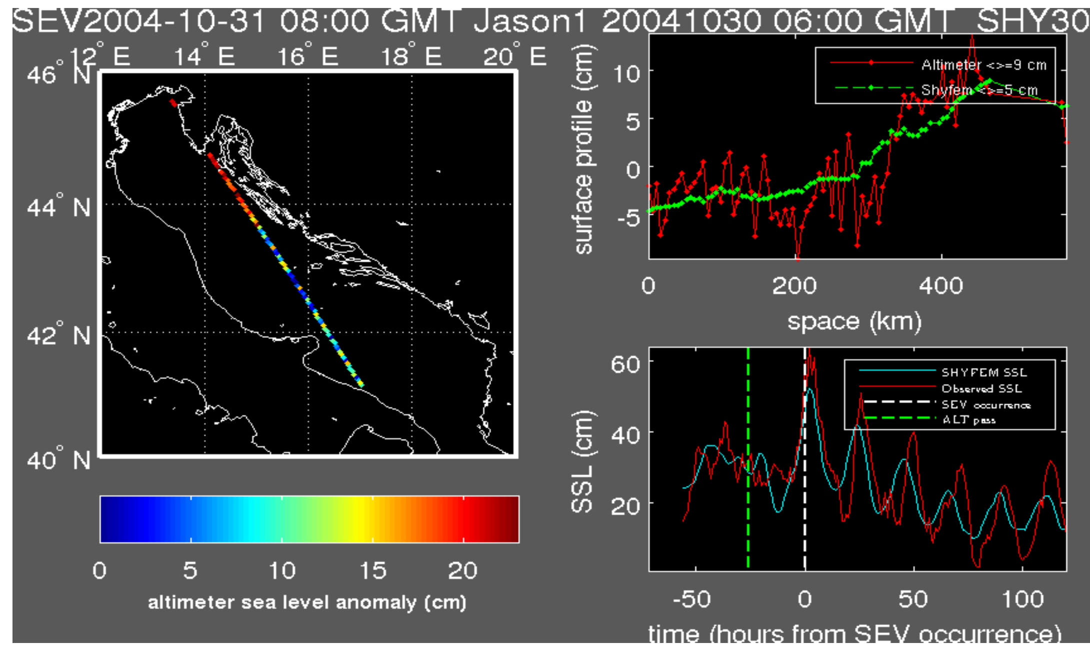
- ECMWF atmospheric model underestimates the wind speed with respect to satellite winds
- The differences between models and satellite data are variable in space and time



$\langle \Delta w_s / w_{sc} \rangle$ over 4 days as running mean at 1 day step

What we know about the model initial conditions for SSL forecast





Use of the coastal altimeter data to improve the SSM initial conditions (CTOH)

- **Jason-1 and 2**
- **Envisat**

These considerations led us to consider as the most important factors to investigate the wind and the sea surface configuration before the SS occurrence (linked to the previous days wind and seiches)

1. ***Use the satellite wind fields to verify/modify the ECMWF atmospheric model wind fields used as forcing into the SSM in the Adriatic Sea***
2. ***Use the altimeter SSH data to improve the SSM initial conditions***

Re-analysis experiments

1. A reference simulation (REF) with the original wind fields and no data assimilation. The reference simulations start 20 days before each SEV, to spin-up the dynamics of the system
2. A second simulation with the use of the modified wind fields (SCATT)
3. A third simulation with the original wind fields but with the assimilation of altimeter TWLE* data in a time window of 24 hours before the day of each SEV with variational data assimilation method (*dual 4D-Var)*
4. A fourth simulation with both the corrections (SCATT+TWLE*)

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TWLE* = TWLE-astronomical tide

Using tuned ECMWF wind forecast only

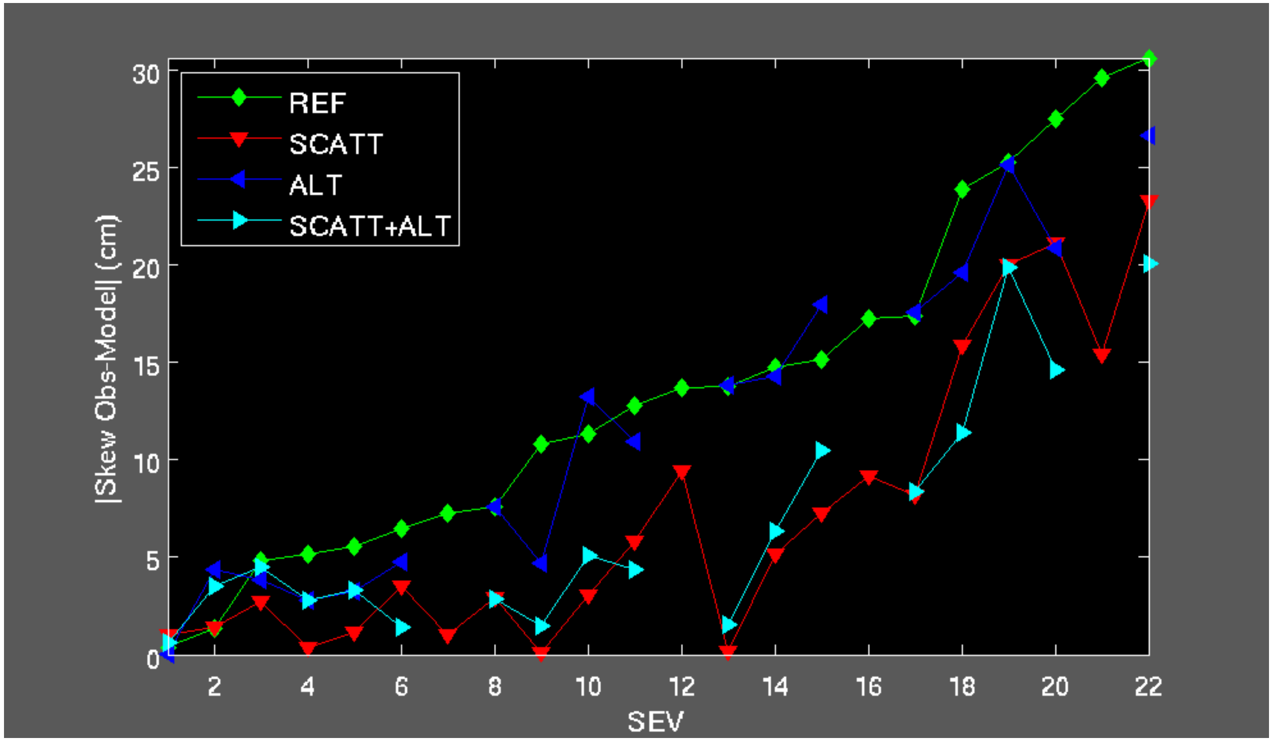
The skew surge from the simulations obtained using the original ECMWF forecast data (**REF**) and those tuned by scatterometer (**SCATT**) reduces the RMS error of all the SEVs skew surge from **16.3 cm to 10.2 cm**.

Assimilating altimeter TWLE* and using the reference ECMWF winds

The **TWLE*** assimilation slightly reduces the RMS error from 16.3 cm to 14.2 cm.

Assimilating altimeter TWLE* and using tuned ECMWF wind forecast

SCATT forcing plus the assimilation of **TWLE*** altimeter data (**SCATT+TWLE***). The RMS error decreases **from 16.3 cm to 9.0 cm**.



TWLE* = TWLE-astronomical tide
Skew = difference between the maximum observed water level and the maximum predicted level regardless of their timing

Scientific roadmap

In the framework of wind

- Use all the available scatterometer data (requires inter-calibration). At present 4 scatterometers are operative
- Assimilation of scatterometer data into LAM

In the framework of the SSM

- common reference for altimeter and SSM data
- In-situ tide gauge data for application of Madsen, 2007 methodology in the Adriatic Sea (for SSM initial conditions)
- assimilation of surface currents (from EO and HF radars)
- Abvailability of tide in-situ data on the Croatian and Albanian side

In the framework of Altimetry

- Use all the available altimeter data. At present 7 altimeters are operative;
- Establishing of a common vertical datum (geoid) for storm surge studies in the Adriatic Sea
- Re-computing a coastal mean sea surface and Mean Dynamic Topography with high-resolution SSH for better understanding ocean dynamics and for validation with non-repeating tracks
- Improve the quality and the spatial and temporal sampling of satellite altimetry products
- in-situ data for altimeter validation on the Croatian and Albanian side

Using ensemble techniques

Some reference

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