Earth Observation in Storm Surge Forecasting: the Lesson Learnt from the eSurge-Venice Project, and the Transition to Operational Forecasting in Venice (Adriatic Sea)

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INTRODUCTION
Coastal areas are subject to flooding caused by storm surges. One of the most exposed region of the Mediterranean Sea is the Gulf of Venice, in the Adriatic Sea. The Tide Forecast and Early Warning Center (Centro Previsioni e Segnalazioni Marea - CPSM) of the Venice Municipality runs operational storm surge models to predict the surge and mitigate the impact of the floods. The output of atmospheric models (sea surface wind and pressure) is used to force the storm surge models. The performance of the atmospheric model output in coastal areas is generally lower than in open-ocean: in the Adriatic Sea the surface wind forecasts are often underestimated [Zecchetto and Accadia, 2014]. eSurge-Venice, a project funded by the Data User Element (DUE) Programme of the European Space Agency (ESA), has demonstrated the improvement of the storm surge forecasting with the use of earth observation data, focusing on the Gulf of Venice. The main outcome of eSurge-Venice has been the development of a methodology (wind bias mitigation) to reduce the bias between the sea surface wind observed by the scatterometers and that supplied by numerical weather prediction (NWP) models, for storm surge forecasting applications. This methodology is now being implemented in the pre-operational storm surge forecast chain of the CPSM.

THE SCATTEROMETER-MODEL WIND BIAS
Fig. 1 right shows the spatial pattern of the relative bias (Δw/w) for scatterometer-model data for two years (Jan 2008 - Nov 2009) in the Adriatic Sea: it ranges from -5% to +20% of the scatterometer wind. A bias is found also in the wind direction: it will not be considered here. Left: distributions of wind speed and direction for scatt and model, in the same two years.

- Scatterometer observations from QuikSCAT and ASCAT
- NWP model data from the ECMWF deterministic model

WIND BIAS MITIGATION: HOW IT WORKS
Atmospheric model winds are scaled by a spatial factor (1+α) before being fed into the storm surge model. α is derived from the statistics of the scatterometer-model-bias of the three days before, and thus varies in space and time [Zecchetto et al., 2015]. Eight different mathematical formulations of α have been tested, originating from four mathematical approaches:
1. Euristic (original formulation in [Zecchetto et al., 2015]);
2. Euristic alternatives (variations of the above);
3. Analytical solution;
4. Least square regression (LSR).

For the latter, four different cost functions have been considered:
- Linear LSR (LLSR): the cost function depends on the differences of the scatt and model wind speeds;
- Linear LSR (LLSR): the cost function depends on the differences of the scatt model squared wind speeds;
- Relative LSR (RLSR): the cost function depends on the ratio of the scatt-model wind speeds and of the scatt wind speed;
- Relative LSR (RLSR): the cost function depends on the ratio of the scatt squared and model wind speed differences and of the scatt wind speed.

ROADMAP:
- Model wind bias mitigation pre-operational chain ready in Jan 2019.
- Introduction of corrective factor for the wind direction mid 2019.
- Wind speed and wind direction biases are completely independent, but they should be regressed simultaneously using a linear least square regression approach. The starting point is to write a cost function (CF) to be minimized, where the optimal values of the two parameters α and β are determined at the same time, constrained by the condition on the wind speed (the factor of the Lagrange multiplier λ):

\[ \lambda \left( \sum \left( \frac{w_{scat}}{w_{model}} - (1+\alpha) \right)^2 + \sum \left( \frac{w_{scat}}{w_{model}} - (1+\beta) \right)^2 \right) = \frac{1}{\alpha} \sum \left( w_{scat} - w_{model} \right)^2 + \frac{1}{\beta} \sum \left( w_{scat} - w_{model} \right)^2. \]

BIBLIOGRAPHY