# High-Resolution Operational Forecasting of Extreme Sea Levels along the Portuguese Coast

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## Introduction

The **inundation of estuarine and coastal areas** may cause **casualties and severe damage** (e.g. winter 2014, Portuguese coast). **Forecast** (FS) and **Early Warning Systems** can help to **prevent** some of the most **adverse impacts**, by **antecipating events** and facilitating **evidence-based risk management**.

## Objectives

1. Operationalise a real-time FS for extreme sea levels along the Portuguese coast
2. Demonstrate the forcing of FS for local models using regional models
3. Enhance scientific knowledge on flood inundation processes in estuarine margins

## Models Setup

**State-of-the-art numerical models are coupled to simulate waves, tides and storm surges.**

At the **regional scale**, North Atlantic and Portuguese coast, **waves are computed with NOAA's WaveWatch III** (WW3) model (Tolman, 2014, http://polar.ncep.noaa.gov/waves/wavewatch/), while **tides and surges are computed with the SCHISM model** (http://ccrm.vims.edu/schism/), derived from SELFE (Zhang and Baptista, 2008). Subsequently, latter results are used with the **SCHISM-WWM model** (Roland et al., 2012) **to estimate waves, tides and surges at estuarine-scales**. The complete procedure is automatically executed daily, producing **48-hour forecasts**.

The setup of the models is summarised in Table 1. For inundation purposes, the SCHISM-WWM grid extends inland from the line of maximum high tide of equinoctial spring tides.

*Table 1.* Setup of the models used in LNEC's forecast system.

| Model | Min. Res. | Forcings |
|---|---|---|
| WW3 Regional | 0.5-0.05º | GFS (http://www.ncdc.noaa.gov/) wind |
| SCHISM Regional | 250 m | FES2012 tides (Carrère et al., 2012), inverted barometer effect, tidal potential, GFS wind and pressure fields |
| SCHISM-WWM Tagus | 10 m | SCHISM regional water elevations, GFS wind and pressure fields, WW3 |

## Models Validation

A summary of a validation of results for the regional and local-scale models used in LNEC's FS, is presented in Figures 1 to 4. In Figure 1, the results from LNEC's FS are compared with results from the Copernicus Marine Environment Monitoring Service model (MyOcean, http://marine.copernicus.eu/).

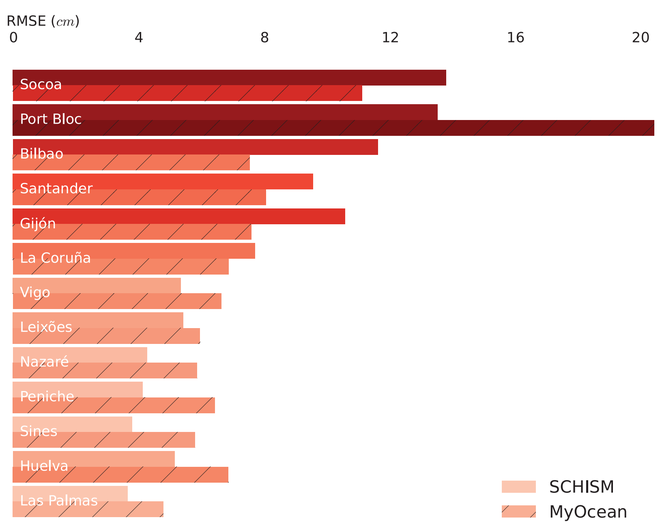


*Figure 1.* Root-mean-square errors of SCHISM regional model forecast, Mar-May 2015, and for the corresponding MyOcean results, at tide gauge stations along Portuguese, Spanish and French coasts.

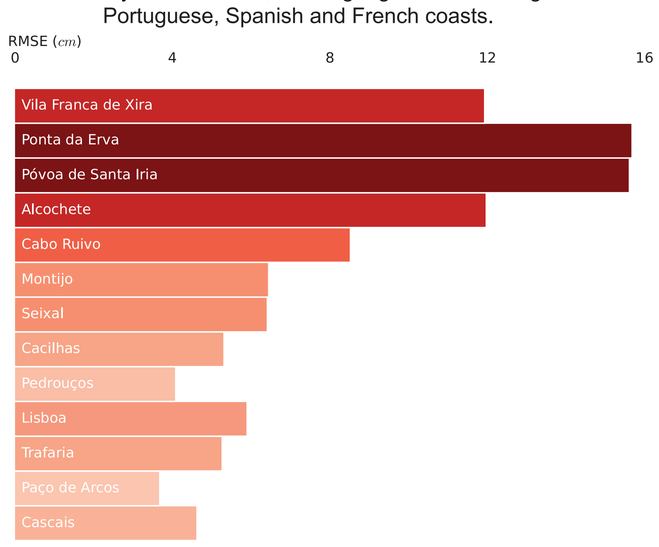


*Figure 2.* Root-mean-square errors of SCHISM-WWM Tagus model hindcast simulation for the year 1972 at tide gauge stations along estuarine margins.

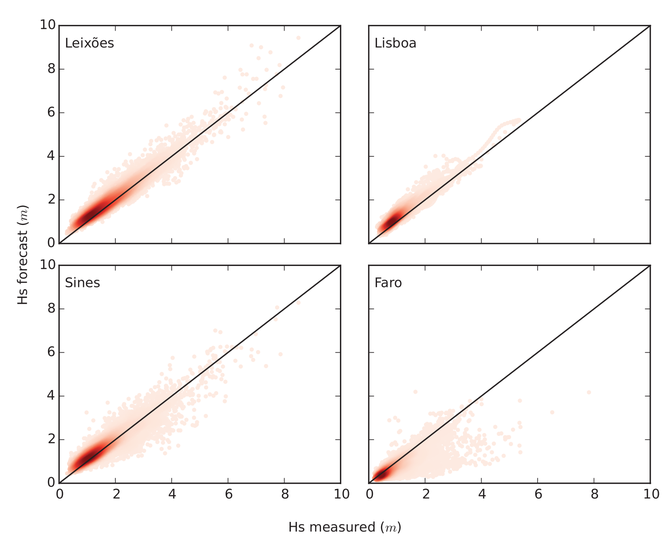


*Figure 3.* Comparison between measured and forecasted significant wave heights in four wave buoys located along the Portuguese coast. Shades of colour are proportional to the density of points.

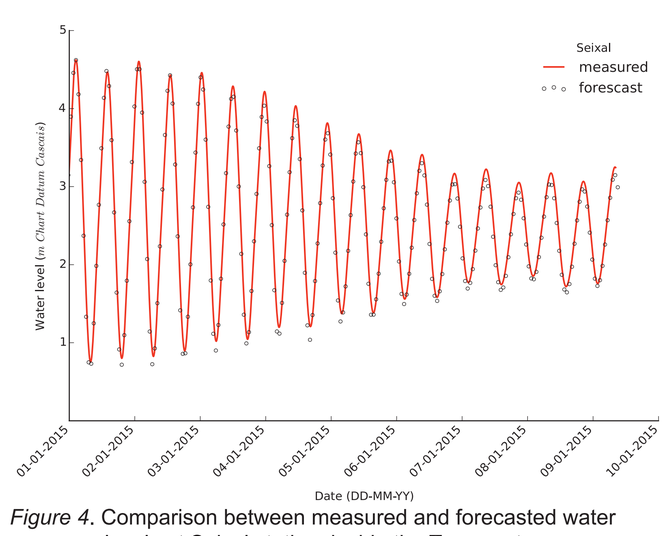


*Figure 4.* Comparison between measured and forecasted water levels at Seixal station, inside the Tagus estuary.

## Water Information and Forecasting Framework (WIFF)

The **WIFF platform**, developed at LNEC, **integrates the entire information and FS into a webGIS** (Oliveira et al., 2014). **Products**, including means to evaluate the reliability and confidence on model predictions, **are provided through online access** to automatic comparisons between forecasts and real-time data. Results of the regional models are publicly available at http://ariel.lnec.pt/, while detailed local models results are only available to registered users. Figure 5 gives an overview of the framework, and Figures 6 and 7 are examples of WIFF products.

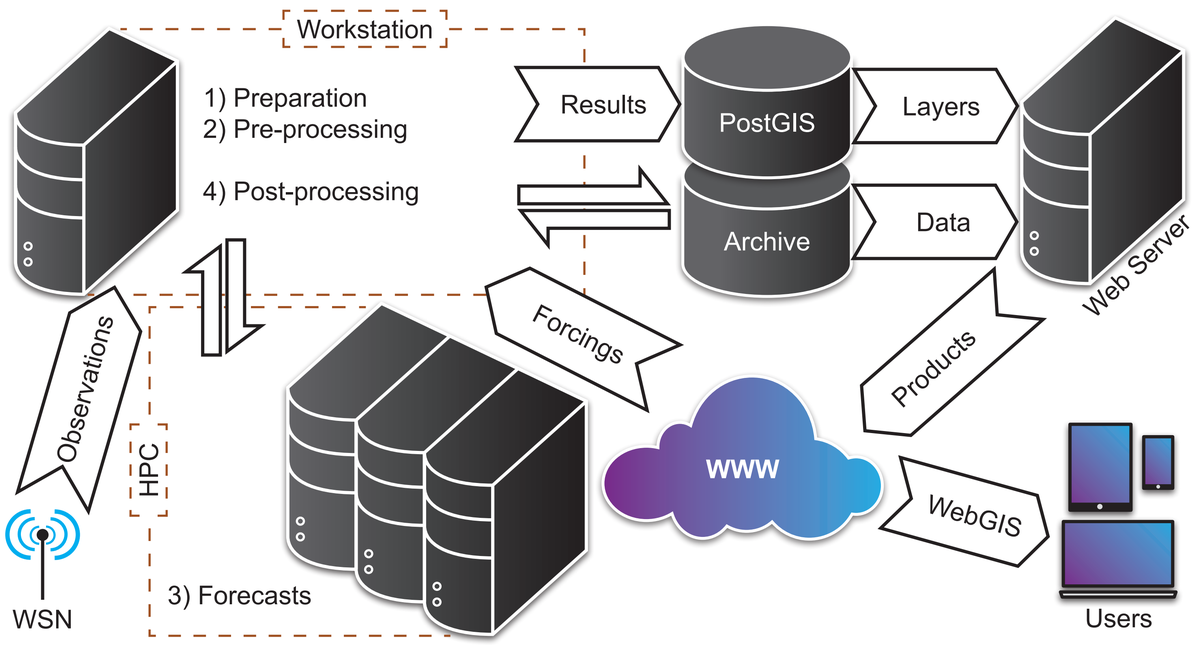


*Figure 5.* Water Information and Forecasting Framework workflow. WSN — Wireless Sensor Network; HPC — High Performance Computing infrastructure; WWW — World Wide Web

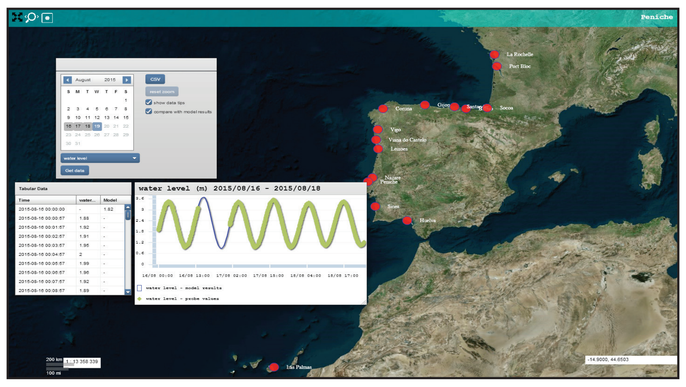

*Figure 6.* WIFF comparison between measured and modeled water level time series (in *m*) for a specific period. Red dots represent regional gauge stations.

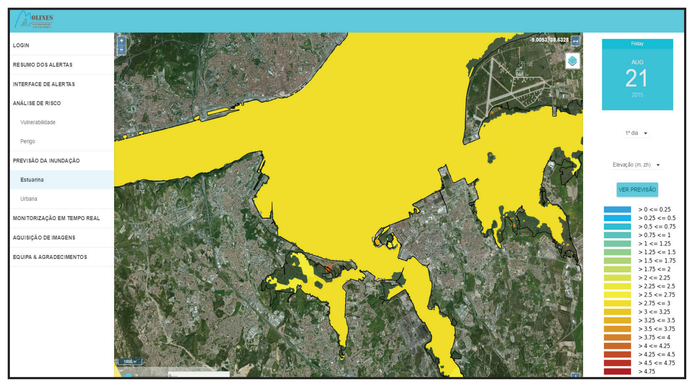

*Figure 7.* WIFF horizontal distribution of modeled water elevations (in *m*) inside the Tagus estuary, showing inundated areas, for a specific date and time.

## Discussion

LNEC has made operational, and maintains, an accurate and robust high-resolution FS of extreme sea levels for the Portuguese coast. The system is being improved and extended, so that a better service is provided. Simultaneously, objective risk criteria are being developed and will be implemented at local and regional scales. Risk thresholds will be used to issue automatic early warnings of extreme sea levels, potential flood and inundation.

## Acknowledgements

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