GUIDE 01: COMPUTATION OF TOTAL WATER LEVELS and IDENTIFICATION OF THRESHOLDS

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1. ECFAS aims

The main aims of the ECFAS project concerning the hazard components were to (i) provide pan-European validated operational forecasts of coastal Total Water Levels (TWL) and to (ii) provide thresholds of TWL that can trigger coastal flood mapping and that were used to produce the flood and impact catalogues (refer to *Guide 02: flood and impact maps*).

2. ECFAS glossary

Coastal points: points (~30000) along the coast where the values of TWL are computed, with spacing ranging from 1.5 to 4.5 km

Water level (WL): coastal sea level resulting from the contributions of mean-sea level, storm-surges and tides. The vertical reference is Mean Sea Level (MSL) over 1992-2012.

Wave set-up: mean elevation of the coastal water level due to wave breaking. Parameterized as 20% of the offshore significant wave height.

Total water level (TWL): coastal sea level resulting from all contributions and forcing coastal flooding. Calculated as Water level + Wave set-up. The vertical reference is Mean Sea Level (MSL).

Forecast: the short-term (order of days in advance) prediction of the total water levels, produced with models that run operationally, typically on a daily basis. Since the future is unobserved, the prediction skill typically decays as one predicts further into the future (known as *lead time*).

Best analysis: prediction of total water levels for past instances in time, using operational forecast models which are constrained by past observations (*assimilation*).

Hindcast: reproduction of the historical total water levels, typically over multidecadal timescales, using a fixed set of models and settings to ensure consistency. In this case, the model is partly constrained by observations.

3. Methods

TWL computation

Coastal TWLs are composed of stereodynamic sea level, astronomical tides, meteorological surges and wave contributions (Zhongming et al., 2021). The wave contributions can be split into wave setup – the mean sea level change induced by wave-breaking – and wave swash -the time-varying wave runup on the beach face (Dodet et al., 2019). Given the prohibitive high resolutions (order of metres) needed to resolve wave contributions, and the lack of corresponding beach geometry information at European scales, wave contributions to the coastal TWL have been parameterized following formulations which rely on deep water wave information (Stockdon et al., 2006). They have also been reduced to the wave-setup component to avoid introducing large uncertainties associated with the wave-runup dependency on the unknown local beach profile. The wave setup is hence computed as 20% of the offshore significant wave height (e.g., Vousdoukas et al., 2016).

In the ECFAS platform, 5-day operational forecasts of pan-European, hourly coastal TWLs are provided for each coastal point along EU coastlines (Figures 1 and 2), updated daily. These are computed by combining water level and wave forecasts provided by the Copernicus Marine Service

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ocean and wave regional operational models (https://marine.copernicus.eu/). The regional models for the Baltic Sea (BAL), Mediterranean Sea (MED), Northwest Shelf (NWS), Iberian Biscay and Ireland (IBI), Black Sea (BS) and Arctic (ARC) are used to provide a pan-European coastal coverage. Both ocean and wave models offer coastal resolutions ranging from 1.5 to 4.5 km, benefit from the assimilation of observations and include coupling processes between ocean and waves. These forecast products in Copernicus Marine Service are under continuous development and are subjected to regular updates, which are inherited by the ECFAS system. For an overview of the latest model characteristics, the user is referred to the Copernicus Marine Service website.

The capability of these operational ocean models to forecast coastal extreme water levels at European scale was evaluated. Storm-driven extreme sea level events from tide-gauge records in 2018-2020 were detected, for which the event peak representation was validated, and the impact of forecast lead was also evaluated.

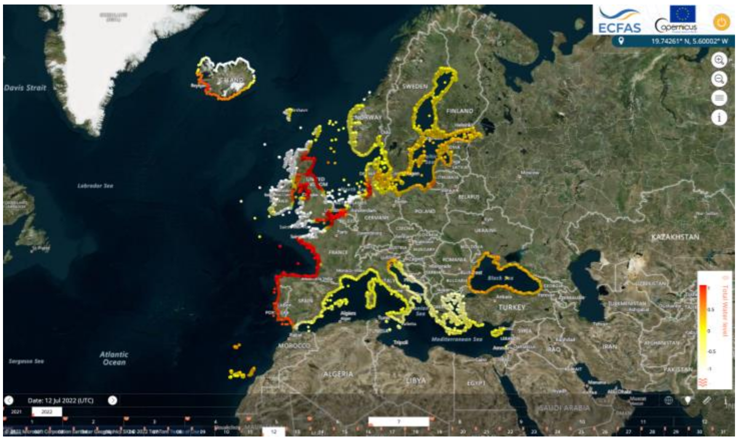

Figure 1: ECFAS web platform showing coastal points.

Thresholds identification

The system is composed of two thresholds, the triggering threshold to trigger the system and the duration threshold to assess the duration of the event. The identification of the thresholds was carried out by applying an Extreme Value Analysis (EVA) on the ECFAS combined Hindcast and linking these values to the Best Analysis (BA). The ECFAS combined hindcast of TWL were built from the linear addition of the different water level components (mean sea level from CMEMS global reanalysis, wave setup from CMEMS regional hindcast, tides from FES2014 and storm surge from ANYEU-SSL for the 2010-2020 period.

The EVA was performed to estimate the different TWLs for established return periods (1, 2, 5, 10, 20 and 50 years) on the ECFAS combined hindcast of TWL. The results of the EVA analysis were validated by comparison with historical storm events.

The selected threshold to trigger the system is the return level of 1 year return period, and the percentile 99th for the duration threshold. Moreover, given the differences in the modelling systems used to produce the ECFAS combined hindcast of TWL and the forecast TWLs, that the system uses, a methodology was developed to link the values. In order to relate the two datasets, while avoiding statistical inconsistencies given the different temporal coverage between datasets, the percentile equivalent to the triggering and duration thresholds were found in the overlapping period between datasets and applied to the forecast TWL, hence defining a mapping of the triggering and duration thresholds between the two systems with a common recurrence. Finally, besides characterising peak values, a range of plausible coastal storms duration scenarios were defined to feed the Flood Catalogue. These duration scenarios were identified through a coastal storm isolation algorithm adapted from Harley (2017) and focused on events over the triggering threshold. The method was validated against known historical storms.

4. Results

TWL computation performance

For best analyses, the forecast models show satisfactory performance, but with a general underprediction of peak magnitudes during storm events of 10% for water levels and 18% for surges. On average, the models are capable of independently flagging 76% of the observed extreme events. Forecasts show limited lead time impact up to a 4-day lead time, demonstrating the suitability of the systems for early warning applications.

Thresholds for system activation and flood mapping

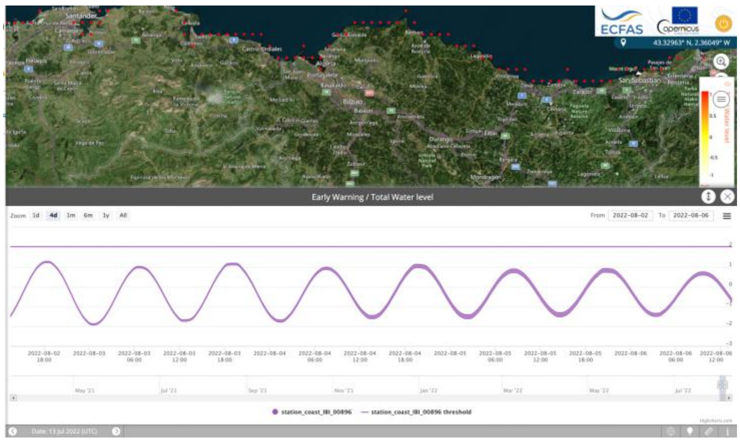

Figure 2: ECFAS web platform view showing a zoom on coastal points (upper panel) and TWL timeseries (forecast) and the identified thresholds (purple horizontal line in the lower graph).

The identified thresholds are specific for each coastal region. The 1-year return period level is used to trigger the ECFAS system, and the 99th percentile is the duration threshold (Figure 2). The TWL return periods used to produce the flood catalogue (see *Guide 02: flood and impact maps*) are in the range 1-50 years. The storm durations correspond to 12, 24 and 36 hours. The file with the triggering and the duration thresholds for 38736 coastal points is available through the ECFAS website.

5. References

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All the data in the ECFAS web platform are provided under the Open Database License

Find out more about the datasets and how to cite them here and refer to Deliverable 4.1 - Deliverable 4.2 – Deliverable 4.3