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Preface

"The record of marine storminess along European coastlines"

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Abstract. The main objective of the European-funded MICORE project (www.micore.eu) was to develop and demonstrate online tools for the reliable prediction of storm impact on coastlines and to develop and enhance existing civil protection strategies. The magnitude and frequency of storms was analysed at 9 diverse European sites in order to determine storm trends over a period spanning between 30 and 100 yr.

Meteorological and marine data available at national and European level are included in the analysis presented in this volume. Results from the coastal regions in this study therefore support the conclusion that there are no significant trends detected in the magnitude or frequency of storms in Europe during the study period.

Recent extreme hydrometeorological disasters in coastal areas have highlighted the devastating effects that can occur from low-frequency events. Even countries that have an advanced level of disaster risk reduction (DRR) have suffered painful experiences when the "not likely to occur" occurred. The experiences of Hurricane Katrina that struck the city of New Orleans as well as Xynthia storm in France have shown to communities living on both sides of the Atlantic Ocean what can go wrong when engineering design is subjected to forcing beyond its design conditions and when civil evacuation and management plans fail. The economic and social costs of Xynthia were severe and affected all parts of the local production system such as the oyster farming industry, agriculture, tourism, shipping and ecosystems. It is difficult to estimate the real costs of such disasters: despite the experience developed after Katrina (Hallegatte, 2008), no standardized method for overall damage assessment has been generally established (Lequeux and Ciavola, 2012; Meyer et al., 2013). Genovese and Przyluski (2013) present a general summary of the costs of Xynthia, quantifying a direct damage of 2.5 billion EUR and 1.5 billion EUR as the costs to insurers.

Although Xynthia was the largest European coastal disasters of the last 50 yr with 47 people killed in France only, similar events have previously impacted Europe. The 1953 storm surge in the North Sea, which resulted in over 2000 deaths and extensive flooding across the Netherlands, England, Belgium and Scotland, is still in the memory of those countries that were affected as well as the starting point of flood defence schemes that were carried out afterwards. On a longer timescale, we discover the impact of the very extreme storm of 1634 AD that devastated the Wadden Sea causing thousands of deaths along the coast (Fruergaard et al., 2013). Despite this cumulative experience, coastal risk generated by storms in Europe is still poorly considered in civil protection plans. A review carried by Ferreira et al. (2009a) found that at European level only northern countries were underpinning coastal risk evaluation with a solid scientific background, and almost everywhere operational approaches (e.g. early warning systems) were missing.

Due to economic constraints it is simply not possible to design, fund and build engineering schemes to protect vulnerable coastal areas across Europe from every extreme event foreseeable. Moreover, even without economic constraints, it is not likely realistic to design engineering works to fully protect the coast, due to other reasons such as environmental or social costs. Indeed in a rapidly changing global climate, there is a considerable degree of uncertainty as to how extreme events will behave in the future, particularly with regards to the intensity, magnitude and duration of coastal storms. Future changes in wave and surge climates predicted by coupled atmosphere–ocean general circulations models

(GCMs) often show a large sensitivity to the nature of the models used to generate the forcing (i.e. wind field), increasing consequently the uncertainty of the obtained projections (e.g. Woth et al., 2006; Sterl et al., 2009; Hemer et al., 2003).

Hence, there is a pressing need to develop management frameworks able to deal with this inherent uncertainty and to minimize the impact of extreme conditions that fall outside the design conditions of both current and future protection works. In order to estimate meaningful return periods of events, engineering design must start planning for the long term, as well as going beyond the classic 1/100 return period as even the EU Floods Directive (Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007) only considers that as a maximum probabilistic assessment for coastal flooding. This may not be enough. For example in the Netherlands, safety level of dune and dykes is currently designed for a 10 000 yr return period event. However, wave and surge observations are barely available in most European countries for more than a few decades to allow reliable values associated with very long return periods.

Historical records can provide an important source of help. First, the use of artistic (e.g. paintings) and written reports can provide important clues about the past impact of marine storms and flooding. Camuffo et al. (2000), using historical sources, managed to correlate events across the northern Mediterranean during the last millennium. Garner and Surville (2010) proved that the part of France hit by Xynthia was historically exposed to sea flooding; however, the presence of the embankment that protected the flooded urban areas was giving a false sense of security as the state of the century-old dikes was not known. Thus, there is scope for using historical records in a better way or for recreating complete time series through a mixture of data compilation and numerical reconstruction. Considering the difficulties mentioned above regarding economic assessments of damage, Andrè et al. (2013) stated that historical storm data should be exploited, taking as example the damage to residential buildings induced by storms Johanna (2008) and Xynthia (2010) in France. Surveys done after the passage of Superstorm Sandy in the eastern US (New Jersey) found that two comparable stretches of coastal dune behaved quite differently during the event (Irish et al., 2013). One segment was more resistant than the other because of an old sea wall, constructed in 1882, that was buried under the dune, dissipating wave energy of a factor of two, and protecting the coastal community behind it. Thus, even mapping of old coastal defences using historical records shows potential for an efficient coastal risk assessment.

Currently, Europe lacks a comprehensive database of marine storm occurrence and their impact on all coastlines. Although in some cases national databases exist (for instance developed by insurance and reinsurance agencies like CCR in France) or may be under development, they often only contain data collected after World War II. As these disasters are not confined by national boundaries, there is a cost–savings benefit to standardize data collection protocols across the EU and to make the database accessible to a wide range of end users and scientists.

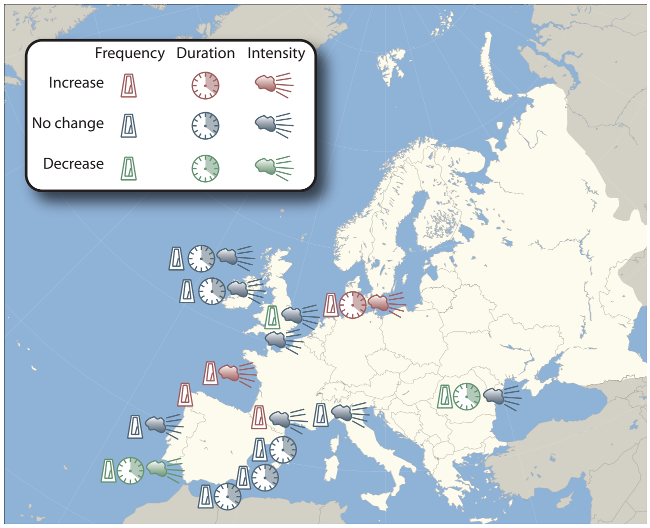

Fig. 1. Trends in European storminess after data discussed in Ciavola et al. (2011).

The main objective of the European-funded MICORE project (www.micore.eu) was to develop and demonstrate online tools for the reliable prediction of storm impact on coastlines and to develop and enhance existing civil protection strategies. The magnitude and frequency of storms was analysed at 9 diverse European sites in order to determine storm trends over a period spanning between 30 and 100 yr.

Meteorological and marine data available at national and European level were included in the analysis performed by the project and released publicly as a report by Ferreira et al. (2009b). The aim of the work was to improve the understanding of coastal response to changes in storminess, and only events above a locally defined storm threshold were considered. This overcame the problems associated with the integration and comparison of information from widely dispersed geographical locations in Europe. The results of the study are visualized as a meta-analysis of trends in Fig. 1; further details on the significance of indicators can also be found in Ciavola et al. (2011) and in Baart (2013).

The storm duration analysis performed for France (Aquitaine and Mediterranean), Italy (northern Adriatic), Portugal (west coast), Spain (Catalonia) and UK (eastern Irish Sea) did not find any statistically significant change during the studied period. Similarly, no significant trends were observed for the Bulgarian and southern Portugal sites. The Polish site was the exception, showing a slight increase in storminess over the period studied. Unfortunately this was only a qualitative trend of low statistical significance. No clear trends in storm intensity were found for Italy (northern Adriatic; waves and winds), Portugal (west coast), and UK (eastern Irish Sea). Similarly, Belgium, the Netherlands and Spain (Atlantic Andalusia; waves) did not detect any statistically significant trends. However, data from the Bulgarian and southern Portuguese coastlines indicated a slightly decreasing storminess trend. In contrast, a slight increase in storm frequency was observed in France (Aquitaine and Mediterranean; from the 1970s till 1990s), Italy (northern Adriatic; only surges), Poland (significant both for surges and waves) and Spain (Andalusia; significant for wind). Results from the coastal regions in this study therefore support the conclusion that there are no significant trends detected in the magnitude or frequency of storms in Europe during the study period.

The results of this study were obtained on the basis of the work presented in the current volume through further analysis of the datasets described above, which showed enough statistical robustness for further data exploitation. Nevertheless, the published set of papers covers well the Atlantic southern European margin (Almeida et al., 2011; Ribeira et al., 2011), the Irish Sea (Esteves et al., 2011), the North Sea (Baart et al., 2011; Van den Eynde et al., 2012), and the Black Sea (Valchev et al., 2012).

Esteves et al. (2011) searched for evidence of climate change along the Sefton Coast of the western Irish Sea, using a set of instrumental records (water levels, surges, wave heights, wind speed and barometric pressure), ERA-40 hindcasts and shoreline change (maps and aerial photos) over the period 1895–2005. Despite the use of sophisticated numerical methods (e.g. wavelet analysis), they did not find a clear connection between changes in forcing and shoreline variability. However, some connection was found between phases of the NAOw (North Atlantic Oscillation winter) index and shoreline change.

Ribera et al. (2011) reconstructed winter storms over the Gulf of Cádiz matching newspaper reports for the period 1929–2005 with wave heights from hindcasts in the HIPOCAS database (Guedes Soares et al., 2002) for the period 1958–2001. They concluded that no clear trends were present in storm occurrence if the overlap period between historical sources and quantitative estimations was considered. However, when the analysis was extended back to the 1920s, a clear connection with NAO was seen in the form of a higher storm occurrence when the NAO was in a negative phase.

Almeida et al. (2011) reconstructed for a similar period (1952–2009) the wave climate for the southern Algarve coast, using a nested third-generation spectral wave model, calibrating the results with buoy observations for the period 1995–2006. They did not find significant trends, with an oscillation of storm characteristics of magnitude over periods of 7–8 yr. However the occurrence of NAO could only partially explain this variability, which they ascribe to local factors.

Baart et al. (2011) provide a very innovative application of historical reconstruction of storms, managing to extract quantitative information on surges using paintings of a coastal church tower from the 18th century, dated shell lags in dunes left over by surge events, and flood marks in written literature sources. Using inverse morphological modelling techniques, they reconstructed the water levels during the three largest storm surges of that century (1717, 1775, 1776). Such an approach allows going beyond "traditional" probabilistic analyses, towards the 1/10 000-year event required by Dutch regulations.

Van den Eynde (2012) only used measured time series (wind, waves, tides) for the Belgian coast along the North Sea, spanning in their analyses from 1927 to 2006 (water levels). They could not detect any trend in wind or in wave storms.

Finally Valchev et al. (2012) used a series of nested numerical models (WAM-SWAN) to hindcast storms for the period 1948–2010 on the western Black Sea. One the one hand, they did not find significant trends if there was no shortening of storm duration, possibly due to a shift in prevailing directions towards the north. On the other hand, during the intense phase of the storms, wave energy remained constant. They also found teleconnections with the NAO.

The Italian study site in the northern Adriatic was left out because of poor data coverage and/or low statistical significance of the analyses performed. For the northern Adriatic wave observations are scarce, non-continuous and often non-directional. Unlike other parts of the Mediterranean, the use of the HIPOCAS dataset is limited due to downscaling sensitivity of this basin (Sotillo et al., 2008). Despite this, Martucci et al. (2010) using ERA-40 driven runs of the WAM model suggest a decadal decrease in wave height over the second half of the 20th century.

The MICORE study provided some evidence that storminess variability is much higher than the observed trends at the timescales used in this work (i.e. more than 3 decades). It was, however, not possible to observe any clear association between storminess changes and changes in the global climate. This does not imply that global climate change consequences will not have an influence on European storminess and on storminess impact in the future.

It is important to note also that although no clear trends in storminess emerge from the present study, this result does not necessarily imply that longer term trends are absent. The study so far did not consider changes in the occurrence of "clusters" of events (i.e. the occurrence of several medium-energy events over a short timescale). This may have an important role in generating strong coastal erosion and loss of dune sediment stock, thus making the system less resilient even to subsequent "ordinary" (e.g. 1 yr return period) events.

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