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Downscaling meteorological quantities for waves and storm-surges hind-casts over French coasts in IncREO project

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Extended Abstract

IncREO (Increasing Resilience through Earth Observation) is a two-year European project, with nine partners from industry, science and public institutions. It aims at providing Earth Observation-based solutions to civil protection and disaster management to improve preparedness and mitigation planning for areas highly vulnerable to natural disasters and already affected by noticeable climate change trends. As a multi-risk designed project, any type of natural disaster is addressed. However, selected use cases (dam failure, extreme storm surge and wave height, flood and landslide) and the transfer of solutions to a specifically multi-risk prone area are covered as well.

Météo-France and Bulgarian National Institute of Meteorology and Hydrology provide a numerical representation of winds, waves and storm surges over French and Bulgarian coastal regions for some extreme events. Characterizing the impact of the climate change requires first a better knowledge of the present and past climate and in particular to what extent our coast are vulnerable to the extremes in present climate. In this presentation, we will focus on wind storms affecting Atlantic and Mediterranean French coasts.

The first step is the selection of studied cases. We consider stormy conditions leading to large waves and noticeable storm-surge. One of the criteria considered is the data availability. Indeed, without enough observations, no validation can be achieved. The second point is the strength of the event in terms of known damages. For example, the Xynthia storm over Atlantic coast (28 Feb 2010) caused 59 fatalities and millions euros of material damages (Figure 1). Nevertheless the main criterion is the strength of the event. Different thresholds had to be considered since each coast is and the extremeness is therefore related to different thresholds for total sea level, storm surge and instantaneous storm surge. We finally choose 20 cases along French coasts, from 1924 to 2010.

Figure 1. La Faute-sur-mer (France) after Xynthia storm.

Wave and storm surge numerical models need atmospheric forcing. We decided to hind cast these situations with a Numerical Weather Prediction (NWP) system to provide very accurate forcing conditions to wave and storm surge models. Here, we use ARPEGE[1] model as its resolution (about 10 km over France) is particularly suitable to the simulation of mid-latitude cyclones leading to wind storms. Moreover, we need the best available initial conditions for ARPEGE. The ERA ECMWF[2] re-analysis with a downscaling procedure has been chosen as it is the best re-analysis dataset available. These re-analyses assimilate more data than in real time and with a better use of the data thanks to the use of an up to date data assimilation scheme. Three types of re-analyses are used: ERA-Clim (cases between 1924 and 1957; Stickler *et al.*, 2014), ERA-40 (cases between 1957 to 1979; Uppala *et al.*, 2005) and ERA-Interim (cases between 1979 to 2010; Dee *et al.*, 2011).

We first deal with a simple downscaling. We interpolate ERA ECMWF files into ARPEGE format. With this new file, we perform an ARPEGE forecast. 6-h to 18-h hourly forecasts are then forcing the waves and storm surge models to hind cast the selected situations. We are able to reproduce quite well past events such as the March 1937 storm (Figure 2**Error! Reference source not found.**).

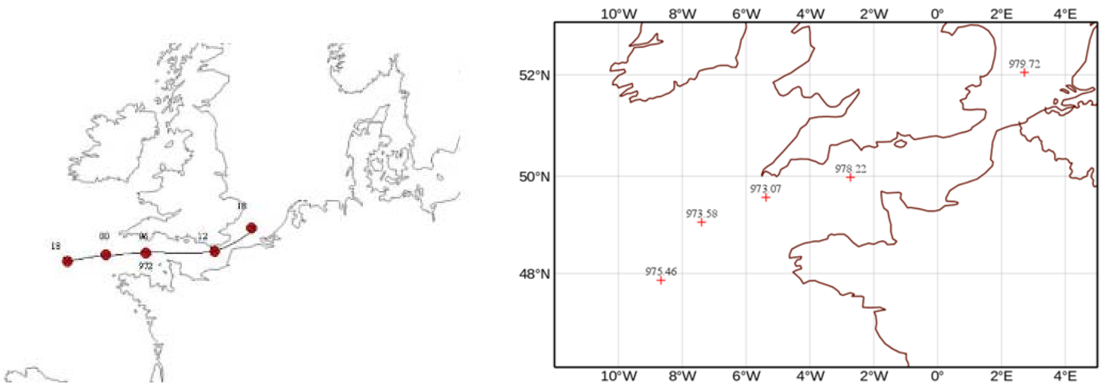

Figure 2. Observed (left panel) and simulated (right panel) trajectory of the lower sea pressure for the March 1937 storm. One point each 6 hour, from 13th March at 18 UTC to 14th March at 18 UTC

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A comparison between historical ARPEGE forecasts, ERA re-analyses and ARPEGE forecasts with interpolated initial conditions has been performed. It appears that a better

[1] ARPEGE (Action de Recherche Petite Echelle Grande Echelle) is the operational global model in Météo-France
[2] ECMWF: European Centre of Medium-range Weather Forecast

agreement with observations is found with the atmospheric forcing fields (10-m wind and mean sea level pressure) resulting from the downscaling of ERA data using ARPEGE. Figure 3 presents the example of Klaus storm (23-24/01/2009). The low over Atlantic Ocean (red circle) is better described with downscaled winds than in ERA re-analysis or ARPEGE historical analysis.

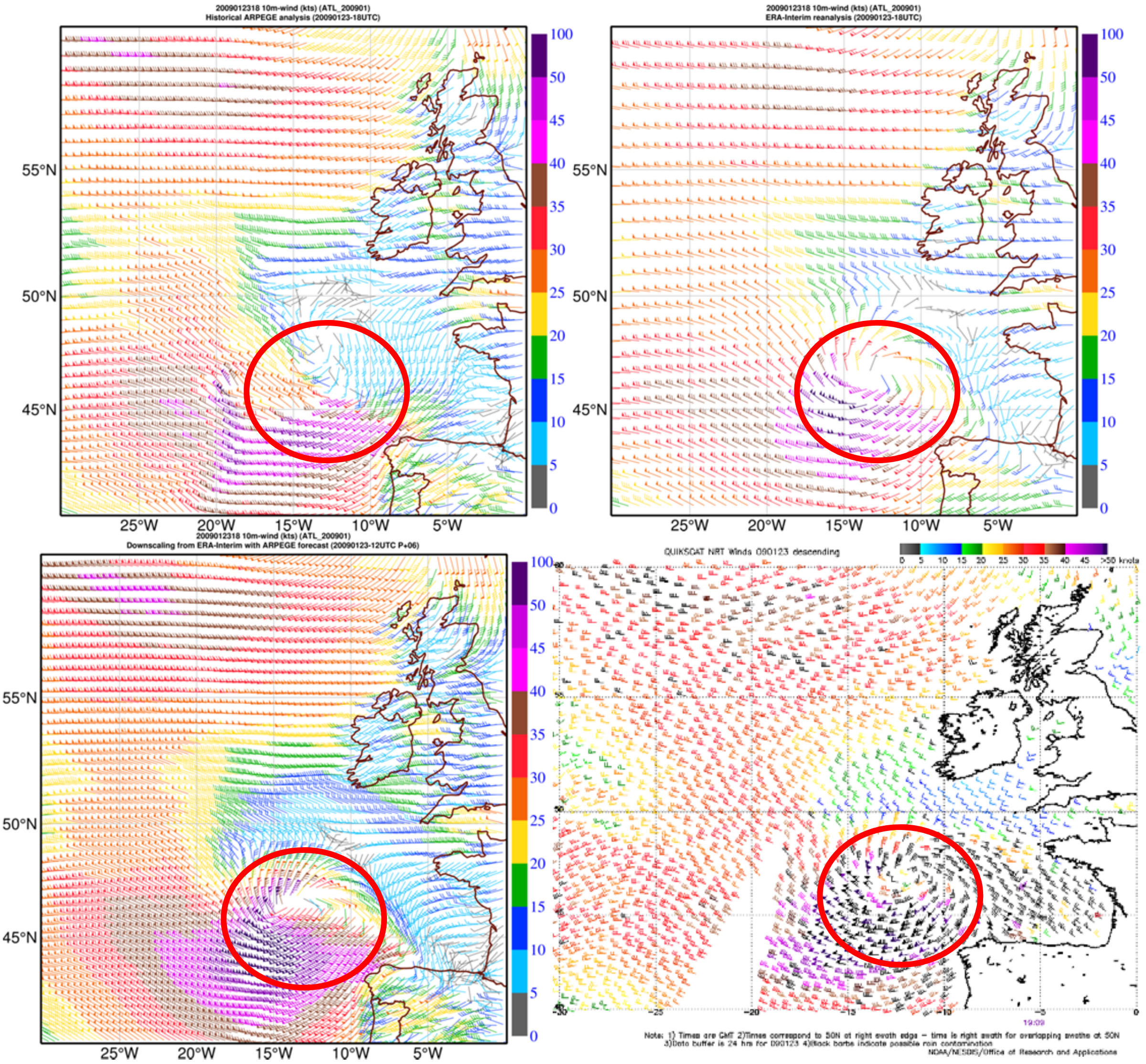

Figure 3.10-m winds (barbs, knots) on 23/01/2009 at 18 UTC for historical ARPEGE analysis(top left), for ERA-Interim re-analysis (top right), downscaled (bottom left). 10-m wind (barbs, knots) from QUIKSCAT scatterometer on 23/01/2009 at about 19 UTC.

The results with the simple downscaling are encouraging. However, the present approach presents a caveat: the small scales of ARPEGE (say horizontal scales of about 10 to 80 km) are not explicitly initialized with this procedure since the horizontal resolution of ERA is much coarser. Therefore, it does make sense to try to improve the present downscaling procedure. In the more elaborate downscaling method, the initial condition is build by a “blending” of an initial condition taken within ERA and small scales taken within a previous ARPEGE forecast. This process is iterated several times: ten days before the event, we interpolate ERA reanalysis and we produce an ARPEGE forecast. Six hours later, we take the interpolated ERA reanalysis at this time and we merge it with the filtered 6-h forecast. This file was filtered to keep only the small-scale information. This procedure generates a new initial file combining the best available large-scale analysis (ERA) and the finer available horizontal resolution of western Europe affordable with a global model (ARPEGE). We reproduce the same method during the whole experiment. Results are positive with a better fit to observations and a small but significant improvement regarding the simple procedure especially for the strongest windstorms. Figure 4 presents a comparison between the first (simple) downscaling and the second (more elaborate) one for the Lothar storm. This event was the first one of two winter storms affecting France. Lothar moved over the North of France and Germany. Pressures are deeper over the Northern France with the second method and better-fit observations.

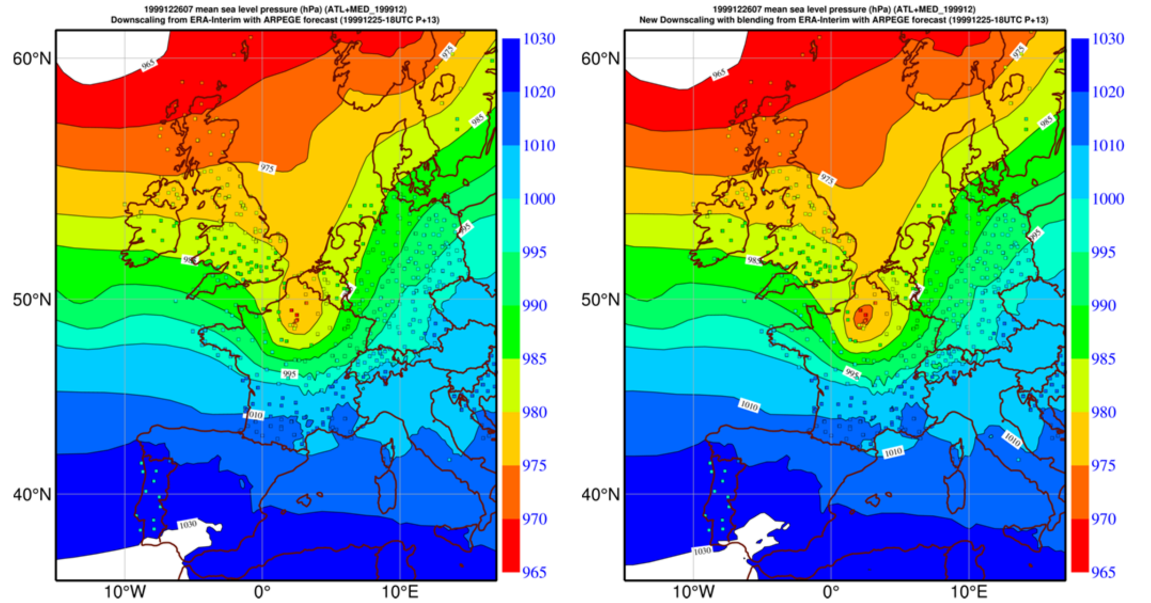

Figure 4. 13-h forecast mean sea level pressure (hPa) with simple downscaling (left panel) and more elaborate downscaling (right panel). Squares represent observations and areas simulated field (same colour scale). Valid time is 07 UTC on 26/12/1999 during Lothar storm.

Thanks to the available observations stored at Météo-France and the other European Meteorological services we are able to demonstrate that both downscaling approach provide reliable reference data although the more elaborate procedure is slightly better.
With a better representation of the stormy situations, wave and storm surge hind casts better fit the observations (see Poster AP1). These methods are transferable to another coast (Bulgaria for example; see Presentation AO6).

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