PRESENT AND FUTURE WAVE CLIMATE ALONG THE FRENCH MAINLAND ATLANTIC COAST, USING DYNAMICAL DOWNSCALING

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CONTEXT

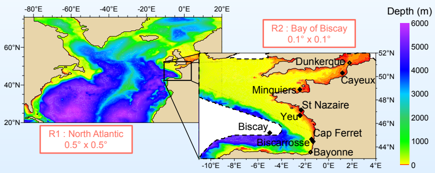
Climate change impacts on wave conditions are of many concerns, regarding offshore and coastal hazards. In the North Atlantic Ocean, 21st century climate simulations project a poleward shift of storm tracks (Yin 2005) and an increase in wave heights at mid-latitudes (Wang and Swail 2006).
However, regionally, in the Bay of Biscay (France), **no projections of wave climate are available at a sufficient spatial resolution and spatial and temporal coverage.**

OBJECTIVES

- Investigating the present wave climate variability in the Bay of Biscay and its relation with large-scale atmospheric variables
- Assessing the potential climate change impacts on the wave climate in the Bay of Biscay towards the end of the 21st century

WAVE MODELLING

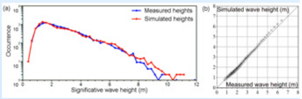
We set up a wave modelling system to provide long-term (several decades) datasets of wave conditions, covering the study site at a fine resolution (about 10 km), and for the present and the future climate. The wave model WAVEWATCH III (Tolman 2009) and the TEST441 source terms parameterization (Ardhuin et al. 2010) are chosen to compute the waves over the whole North Atlantic Ocean in order to capture all waves propagating towards the French mainland Atlantic coast.



Model domains with bathymetry used for the simulations with WW3 wave model. The position of buoys used for validation are indicated by diamonds.

- Wind input: ERA-40 reanalysis (1958-2002)
- Calibration: 8 buoys on the period 1998-2002
- Validation: 11 buoys on the period 1980-2002

→ Error statistics show a good performance of the model to reproduce wave heights, directions, and a bias of about +1 s on wave periods.



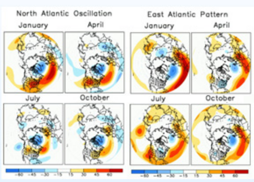
Histogram and quantile-quantile plot of measured and simulated wave heights at the Biscay buoy.

		Significant wave height				Mean period T02				Peak direction	
Buoy	Period	Bias	RMSE	R²	SI	Bias	RMSE	R²	SI	Bias	RMSE
Bayonne	1989-1992	-10 cm	39 cm	0,87	23%	1,27 s	1,85 s	0,66	19%	-	-
Biscarrosse	1980-2000	10 cm	35 cm	0,87	24%	0,90 s	1,71 s	0,56	22%	-	-
Cap Ferret	2001-2002	0 cm	28 cm	0,92	15%	0,84 s	1,38 s	0,70	16%	-	-
Biscay	1998-2002	-1 cm	38 cm	0,94	15%	-0,17 s	0,77 s	0,82	10%	-	-
Yeu 1	1992-1998	-9 cm	32 cm	0,93	16%	0,62 s	1,24 s	0,71	17%	-	-
Yeu 2	1998-2000	-4 cm	28 cm	0,92	16%	0,69 s	1,14 s	0,70	15%	-3 °	24 °
Yeu 3	2000-2002	4 cm	30 cm	0,94	16%	0,80 s	1,35 s	0,71	17%	-	-
St Nazaire	1999-2002	-7 cm	25 cm	0,77	30%	1,14 s	1,89 s	0,36	33%	-	-

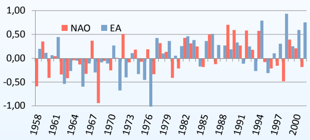
Comparison between the model and the French Mainland Atlantic coast buoy measurements : bias, root mean square error (RMSE), squared correlation coefficient (R2) and scatter index (SI) are calculated for wave heights and periods, bias and RMSE for wave directions.

PRESENT WAVE CLIMATE: a link with large-scale variables ?

Global atmospheric circulation can be simplified in different preferred patterns. In the area of interest, predominant teleconnection patterns are the North Atlantic Oscillation (NAO) and the East Atlantic Pattern (EA).



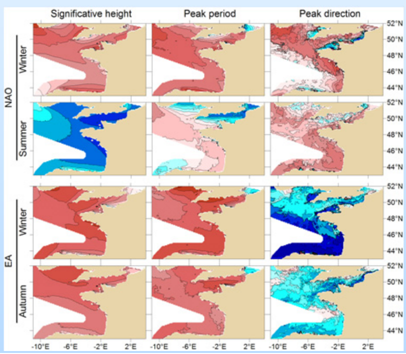
Maps of monthly standardized 500-mb geopotential height anomalies (m) for the positive phase of the specified teleconnection pattern and month (from NOAA/CPC)



Evolution of NAO and EA indices from 1958 to 2001 (from NOAA/CPC)

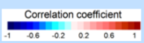
Method: we compare seasonal means of Hs, Tp and Dp (dataset ERA-40 wind-generated waves) to the seasonal means of NAO and EA indices from 1958 to 2001.

→ NAO index is correlated to an increase of Hs and Tp (R=0.3 to 0.5) during winter, to a decrease of Hs (R=-0.3 to -0.5) during summer, and to a northerly shift of Dp (R=0.2 to 0.6) during summer and winter.



→ EA index is correlated to an increase of Hs and Tp (R=0.4 to 0.6) and to a southerly shift of Dp (R=0.2 to 0.5) during winter and autumn.

Maps of correlation coefficients between seasonal NAO (top) and EA(bottom) indices and seasonal wave parameters from 1958 to 2001 for selected seasons. Hatching indicates areas with correlation coefficient significant at more than 95% (Student's T-Test).

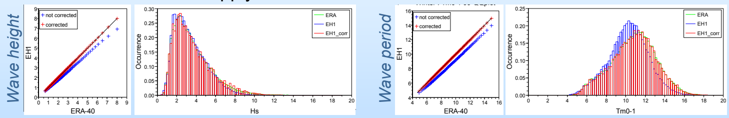


A thorough analysis of this dataset is done in (Charles et al. 2010 ; under review)

PROJECTIONS OF WIND AND BIAS CORRECTION

ARPEGE-Climat global climatic model (CNRM) generates wind fields for a control scenario REF (same GHG emissions as observed during 1961-2000) and for the three IPCC SRES scenarios **A1B, B1 and A2** for the period **2061-2100**.

To correct the global climatic model systematic errors, we use a quantile-quantile correction (Déqué 2007) on waves generated by ARPEGE wind fields. Seasonal quantiles of REF dataset Hs, Tm and Dm are corrected to be equal to the quantiles of the ERA-40 dataset. We apply this correction to future wave datasets.



QQ-plot and histogram of uncorrected and corrected REF waves compared to ERA-40 waves at the Biscay buoy

REGIONAL FUTURE WAVE CLIMATE: where are the main changes?

We compare seasonal means of corrected Hs, Tm and Dm obtained for the present climate (REF) and for the 3 future scenarios (A1B, A2, B1).

→ Changes towards the end of the 21st century are spatially homogeneous in the Bay of Biscay and depend on the season

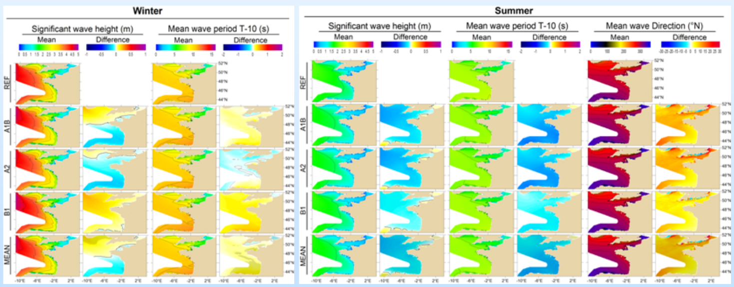
→ Table of changes commonly observed for A1B, A2 and B1:

	Hs	Tm	Dm
Winter		+ +	
Spring	- -	-	
Summer	- -	- -	+ +
Autumn	- -	-	+

We focus more particularly on winter and summer.

→ Winter: increase of Tm (+0.3 s) ; decrease of Hs for A1B and A2, no change for B1

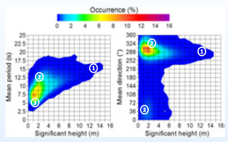
→ Summer: decrease of Hs (-0.1 m) and Tm (-0.5 s), northerly shift of Dm (+6°)



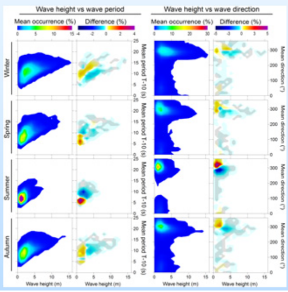
Mean winter (left) and summer (right) wave parameters for present and future scenarios. Differences between present and future are indicated in the second column of each wave parameter. The last row is the mean of the 3 future scenarios. We plot the difference with the present and indicate by hatching if the difference has the same sign in all future scenarios.

LOCAL FUTURE WAVE CLIMATE: which types of wave are impacted ?

We use bivariate diagrams to characterize the local wave climate at the Biscay buoy. Seasonal means and differences between present and future wave occurrence are computed for each scenario. We present here the results for the mean of A1B, A2 and B1 scenarios.



Bivariate diagrams of wave conditions during the scenario REF at the Biscay buoy. Percentage of waves in each cell are given by the color scale. (1), (2) and (3) are examples of, respectively, storm, swell and wind sea.



→ increase of swells during winter
→ increase of small waves during summer
→ northerly shift of directions during summer and autumn.

Seasonal bivariate diagrams averaging the 3 future scenarios. Differences of wave occurrence between present and future are plotted in the second column of each wave parameter. Hatching indicates if the difference has the same sign in all future scenarios.

MAIN RESULTS

- Present variability of the wave conditions in the Bay of Biscay (1958-2001) is highly correlated with NAO and EA indices.
- Future wave climate changes (2061-2100 vs 1961-2000) are:
  - an increase of wave age during winter, with larger and longer swells
  - a decrease of wave energy during summer, with more intermediate waves (small heights and periods)
  - a decrease of wave heights during autumn and spring
  - a northerly shift of wave directions during summer and autumn

WORK IN PROGRESS

- How those changes impact the wave climate nearer to the coast? Going on dynamical downscaling.
- Is there still a link between large-scale variables and local wave climate at the end of the 21st century? Projected wave climate is compared to projected NAO and EA.

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