

Assessing Wave Climate Trends in the Bay of Biscay Through an Intercomparison of Wave Hindcasts and Reanalysis

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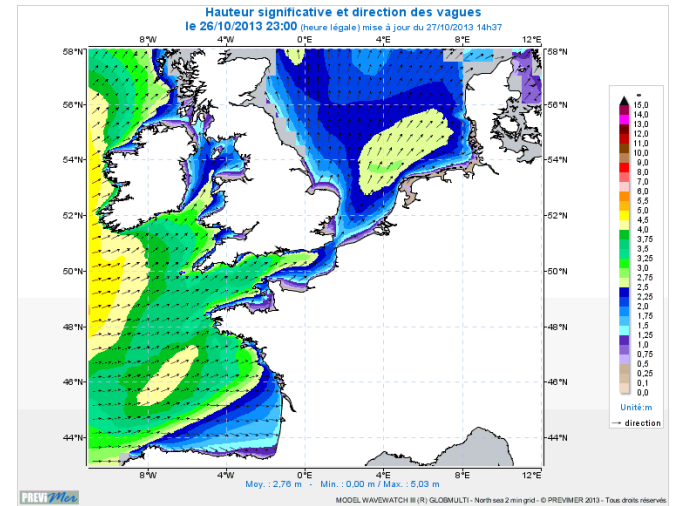
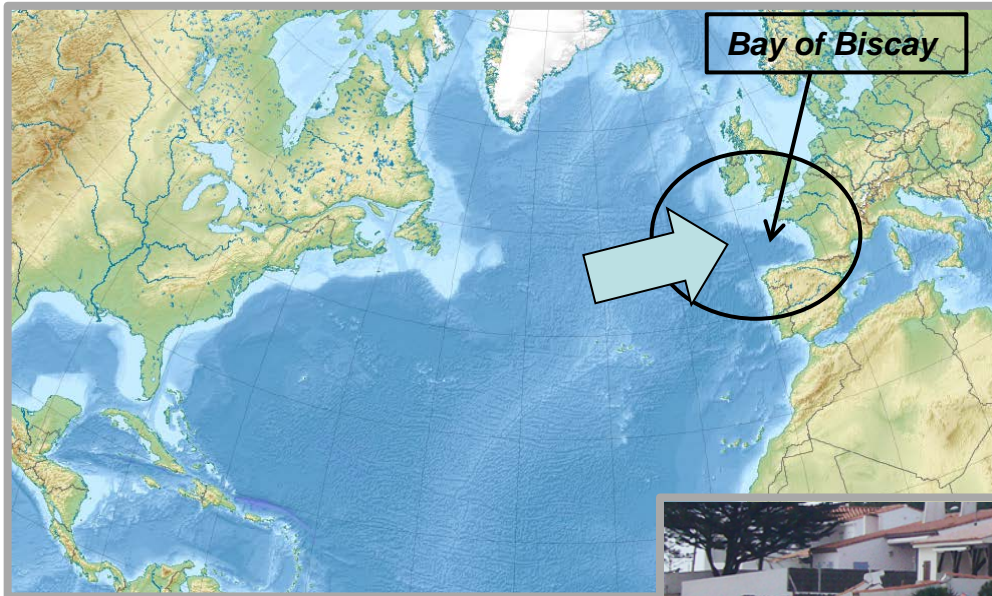
BRGM – French national geological survey
Coastal Risks and Climate Change Unit

13th International WorkShop on Wave Hindcasting & Forecasting
4th Coastal Hazards Symposium
Banff, Alberta, Canada Oct. 27th - Nov 1st, 2013



Motivations

- The Bay of Biscay is exposed to energetic waves coming from the North Atlantic
- Understand wave climate evolution in this region
- Better understand coastal hazards and impact on the coastal morphology



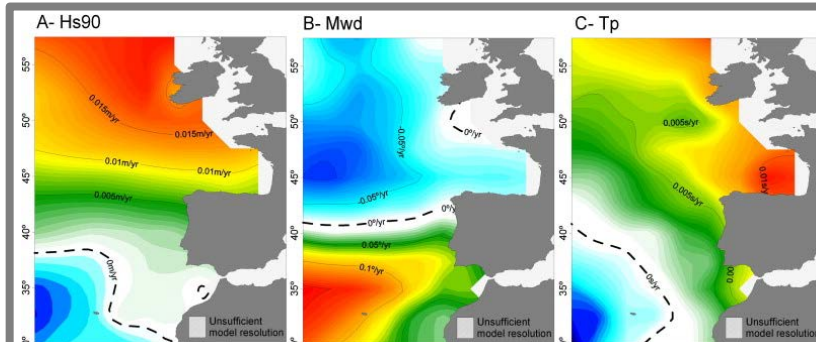
A changing wave climate ...

Several studies investigate wave climate change
In North Atlantic :

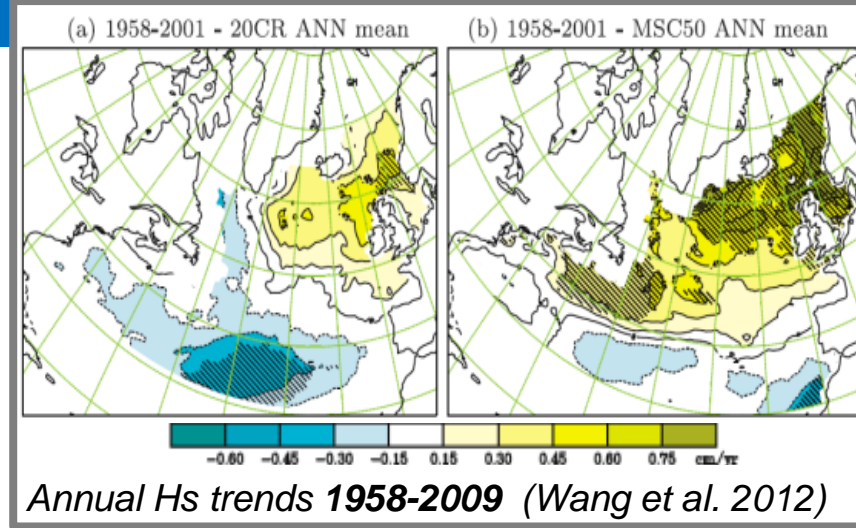
- ⇒ A general increase (Hs) north of 50°N / decrease south of 40°N
- ⇒ Bay of Biscay = intermediate zone

In the area of the Bay of Biscay :

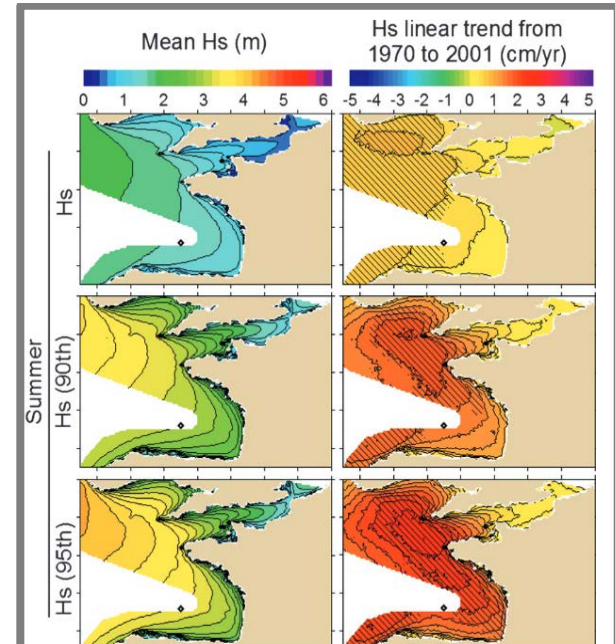
- ⇒ Difficult to compare results of studies (period investigated, parameters, seasonal or annual means, highest quantiles ...)
- ⇒ Results of the different studies are not contradictory



Annual wave parameters trends 1953-2009 (Dodet et al. 2010)



Annual Hs trends 1958-2009 (Wang et al. 2012)



Seasonal Hs trends 1970-2001 (Charles et al. 2012a)

Methodology – Brief summary

Aim of our study :

⇒ **Characterize the trends of the present wave climate in the Bay of Biscay through a robust and homogeneous intercomparison of different raw datasets.**

Intercomparison of the datasets :

- 1) **Collecting wave datasets (hindcast and reanalysis)**
- 2) **Assessment of the quality / compare with buoys measurements**
- 3) **Comparison of the long-term trends**
- 4) **Analysis of trends (relevance, consistency)**

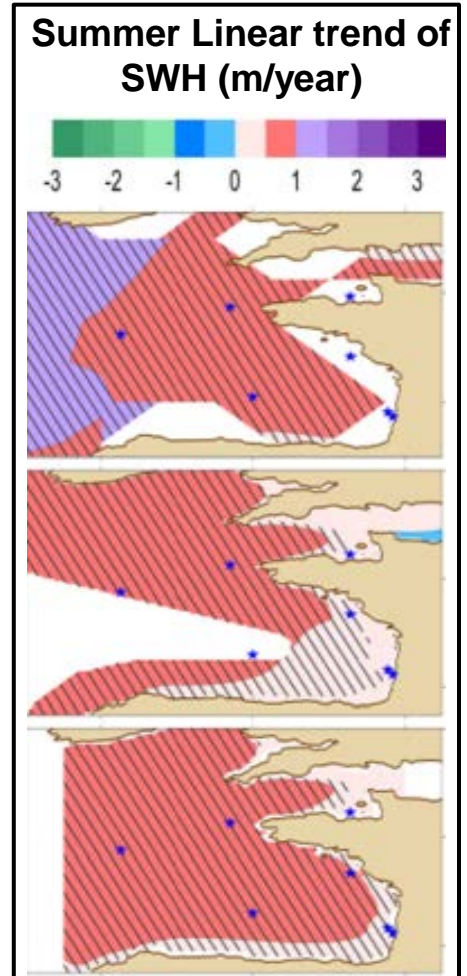
Summary of conclusions

Quality of the datasets

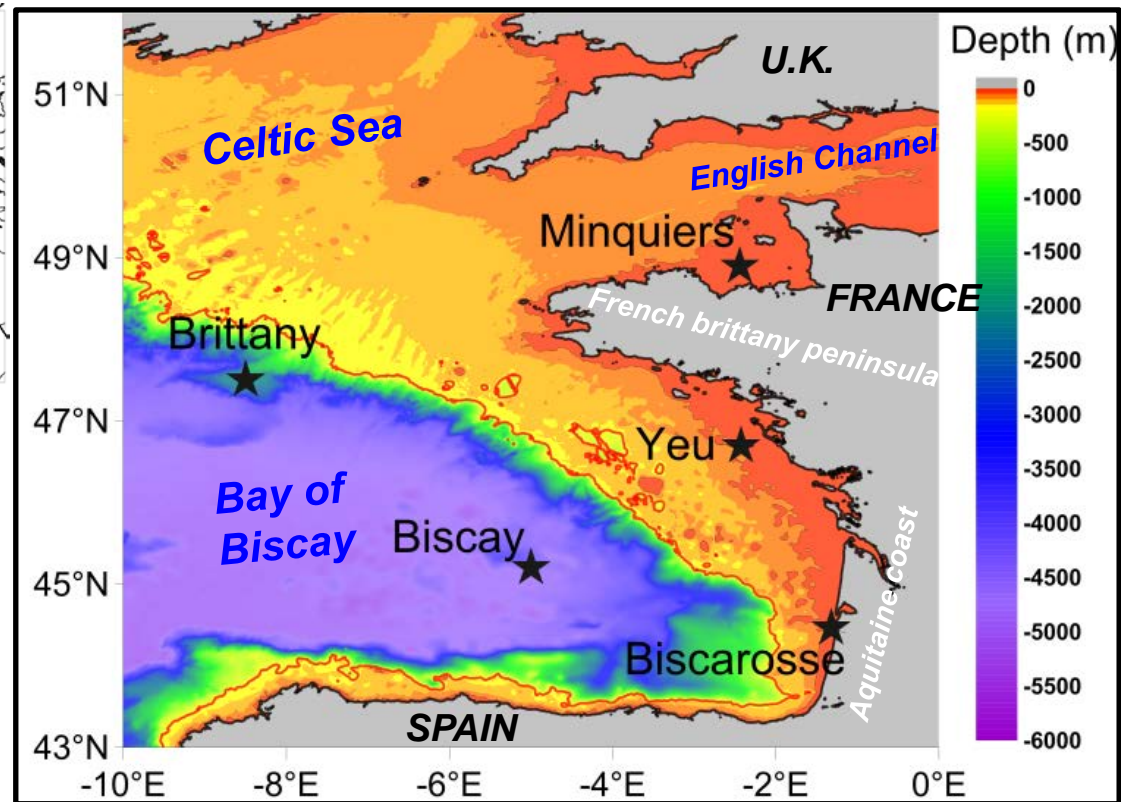
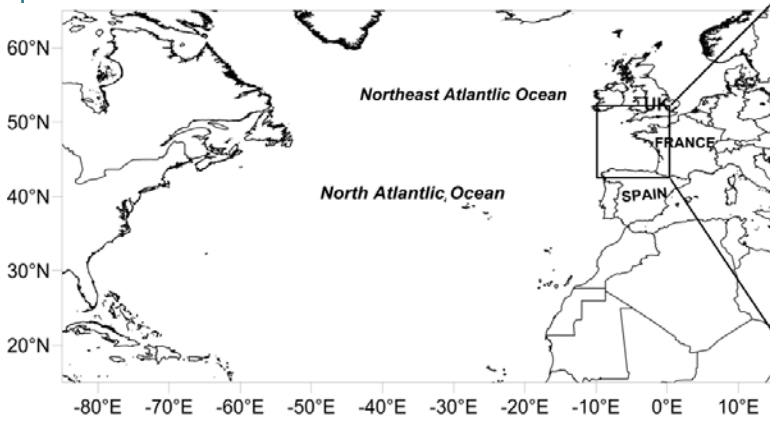
- BoBWA represent best the wave measurements in the coastal area of Bay of Biscay, specially for highest wave heights

Trends in summer are found to be consistent

- mean wave height and mean wave period increase
- southerly shift of mean wave directions



Area description



- 2 offshore buoys : Brittany (2100 m depth) and Biscay (4500 m depth)
- 3 coastal buoys : Biscarosse (26 m depth), Yeu (35 m depth) and Minquiers (38 m depth)

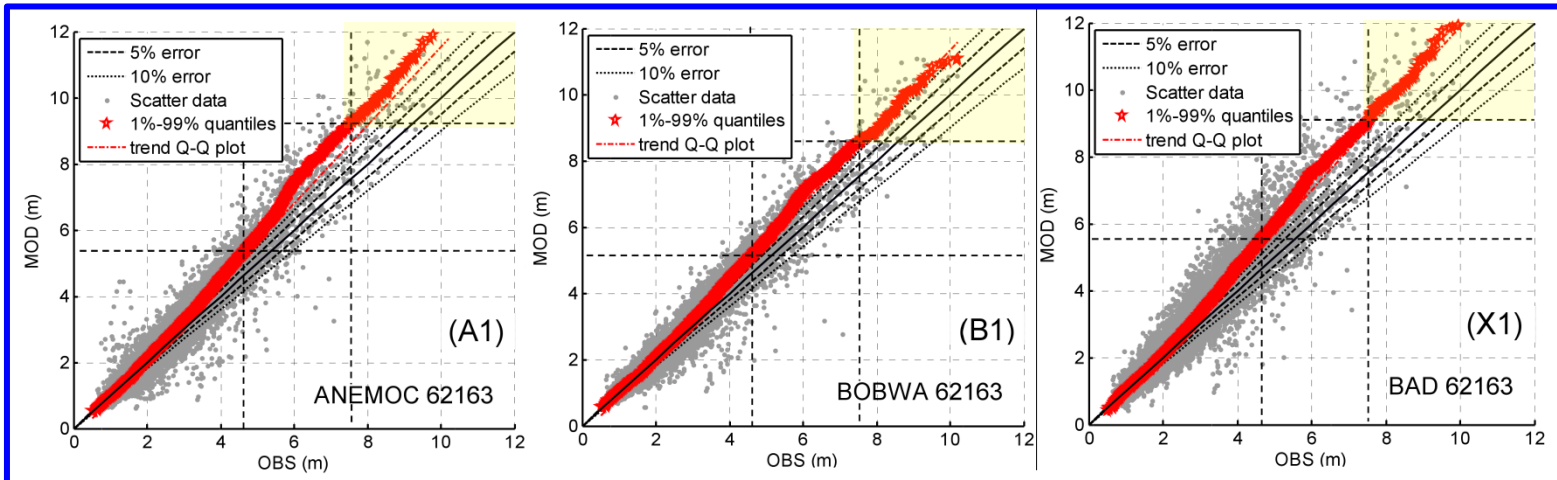
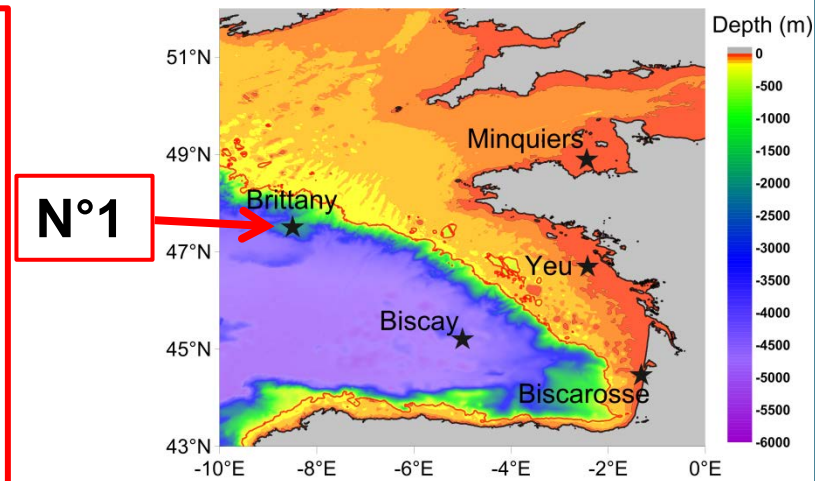
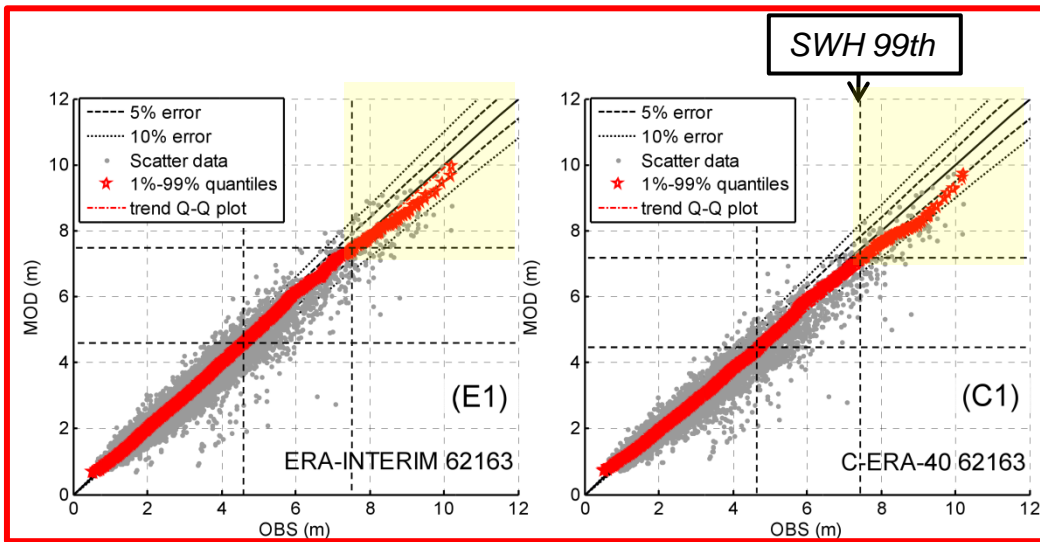
Description of the wave data contributions

Wave Reanalysis or Hindcasts	Temporal & Spatial coverage	Temporal & Spatial resolution	Wave model Wind fields forcing	Validation / Calibration
C-ERA-40 (ECMWF, 2005)	1957-2002 Global	1,5° 6h	WAM Ocean atmospheric coupled model (ECMWF's IFS)	Nonparametric regression to correct ERA-40 Hs with TOPEX measurements
ERA-Interim (ECMWF, 2011)	1979-2011 Global	0.7° 6h	WAM Ocean atmospheric coupled model (ECMWF's IFS)	
ANEMOC (EDF CETMEF, 2004)	1979-2002 North Atlantic	1°(offshore) to 3 km (coast) 1h	TOMAWAC ERA-40 wind	<i>Not mentioned</i>
BAD (Bertin And Dodet, 2010)	1953-2009 Bay of Biscay	0.2° 6h	WW3 (TEST441) NCEP/NCAR wind	3% increased NCEP/NCAR wind fields
BoBWA-10kH (BRGM -Charles et al. 2012a)	1958-2001 Bay of Biscay	0.1° 6h	WW3 (TEST441) ERA-40 wind	Calibration of the wind height in the model input (adjustement)

SAME WIND FORCING

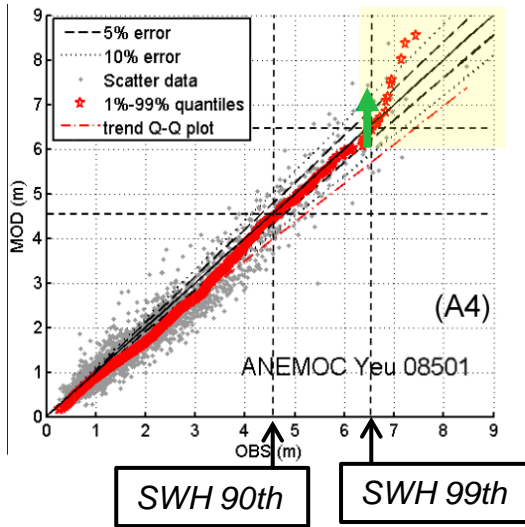
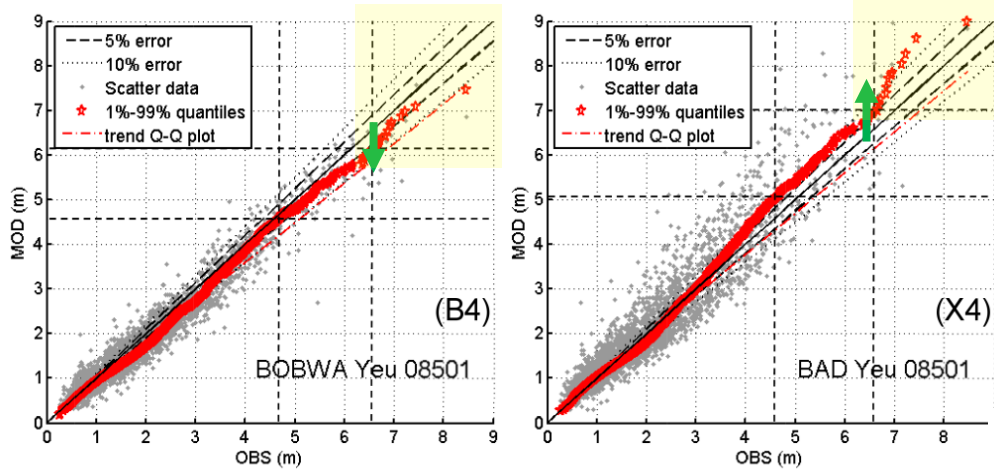
SAME WAVE MODEL

Quality of the datasets : SWH at offshore buoys

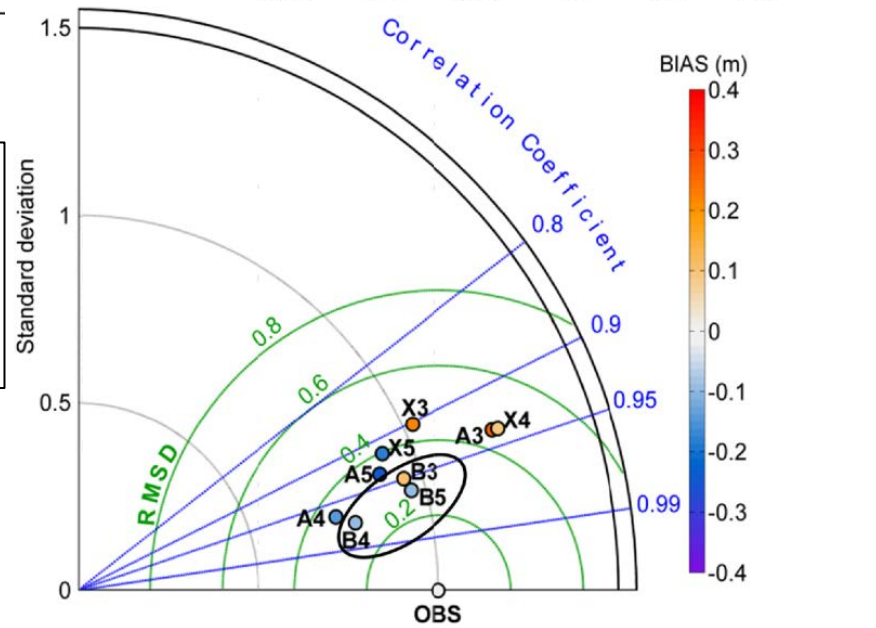
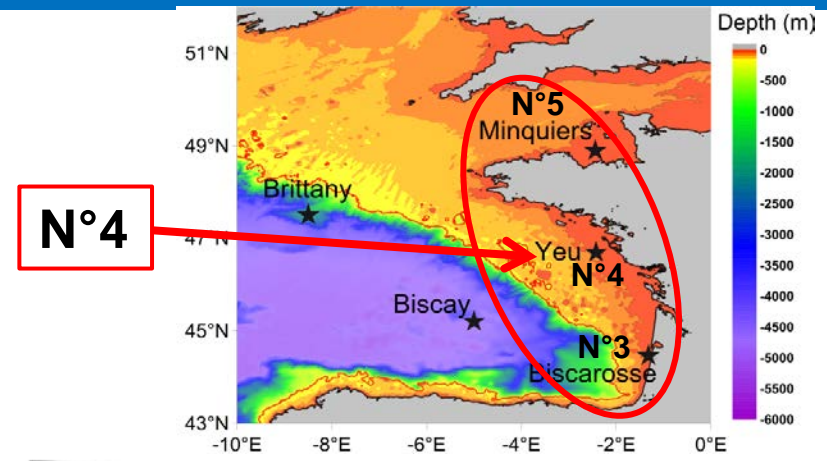


- Global models slightly underestimate SWH
- Regional models overestimate SWH
- BoBWA and ERA-interim compare the best with offshore buoy observations

Quality of the datasets : SWH at coastal buoys

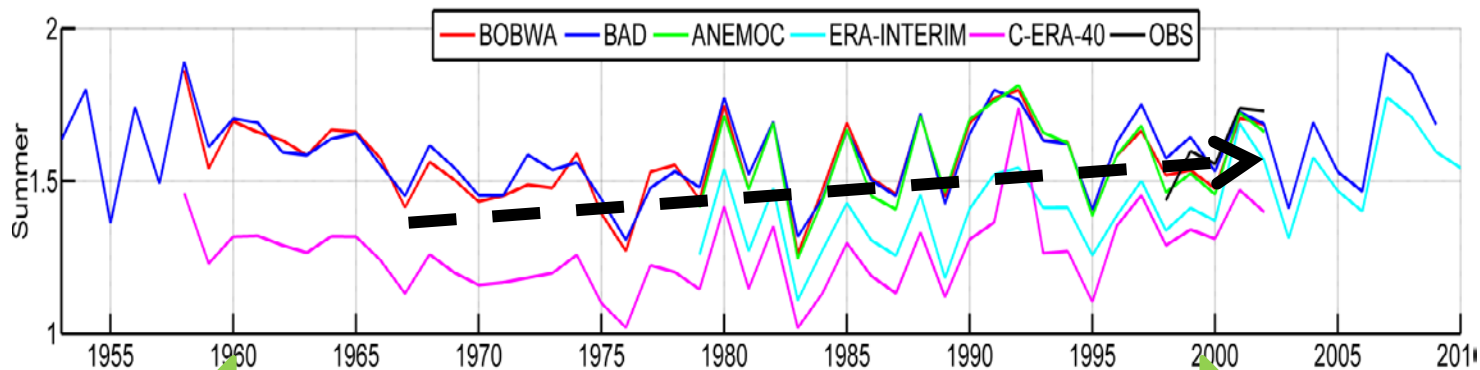


- A : ANEMOC**
- B : BOBWA-10kH**
- C : C-ERA-40**
- E : ERA-INTERIM**
- X : BAD**



→ At costal locations, BoBWA-10kH represent best the wave measurements
 → Other regional models tend to overestimate the highest quantiles

Trend analysis : Method



1958 -2001 (3 datasets)

1970 -2001 (3 datasets)

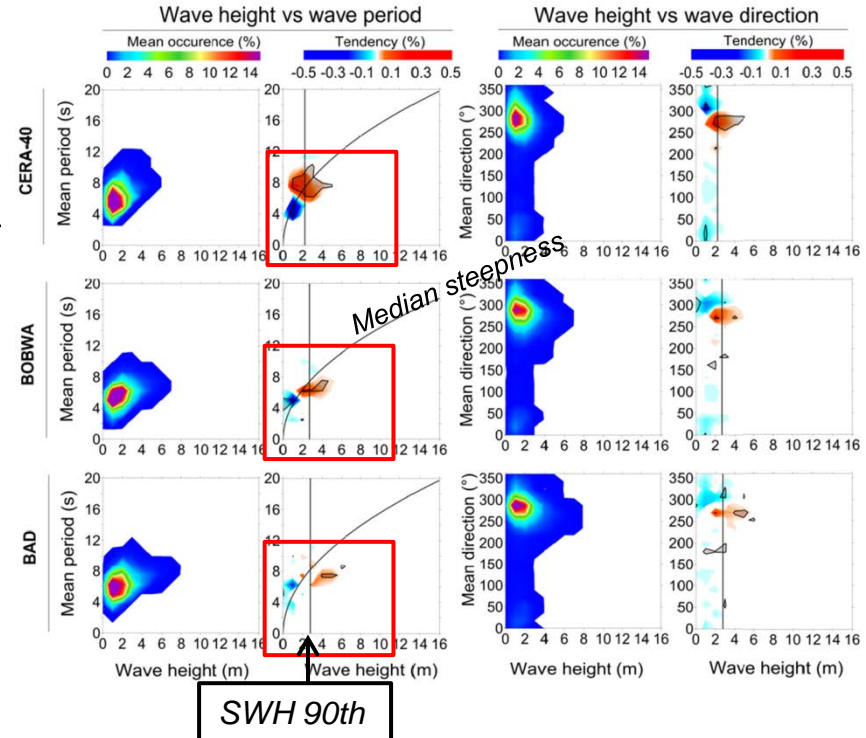
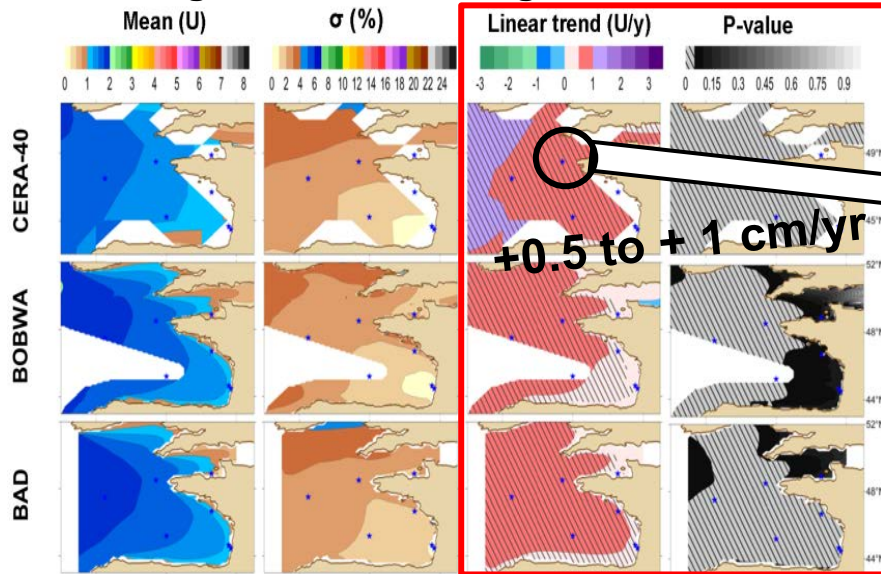
1979 -2001 (5 datasets)

- Seasonal linear trends are performed (Winter DJF ,Spring MAM ,Summer JJA ,Autumn SON)
- Significance test is done (Student's T-test)
- Map of significance linear trends is done for SWH, SWH90, MWP, MWD
- Bivariate diagrams of wave densities (SWH/MWP and SWH/MWD) are done

WAVE TRENDS ATLAS : <http://infoterre.brgm.fr/rapports/RP-61651-FR.pdf>

Trend analysis : Summer

Significant Wave Height – 1970-2001



1970-2001 (32 years)

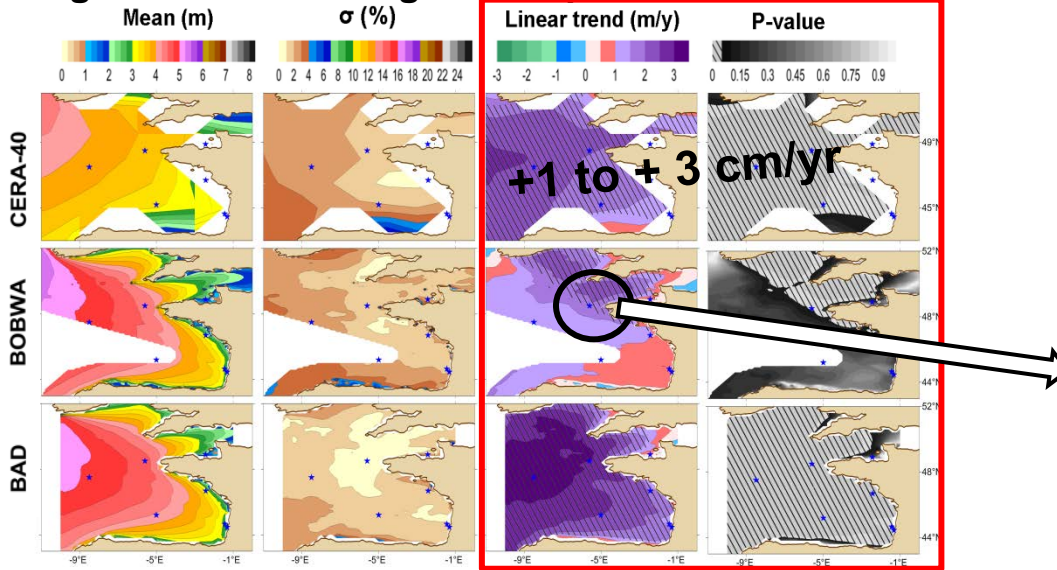
- Significant increase of wave height
 - +15 to +30 cm for SWH
 - +15 to +60 cm for SWH 90th
- Significant increase of MWP
 - + 1.2 s for MWP
- Southerly shift of MWD (-12°N)

Bivariate diagrams :

- SWH/MWP : A significant increase of the relative occurrence of energetic waves
- SWH/MWD : A significant increase of the highest waves with directions in [250°N – 300°N]

Trend analysis : Autumn

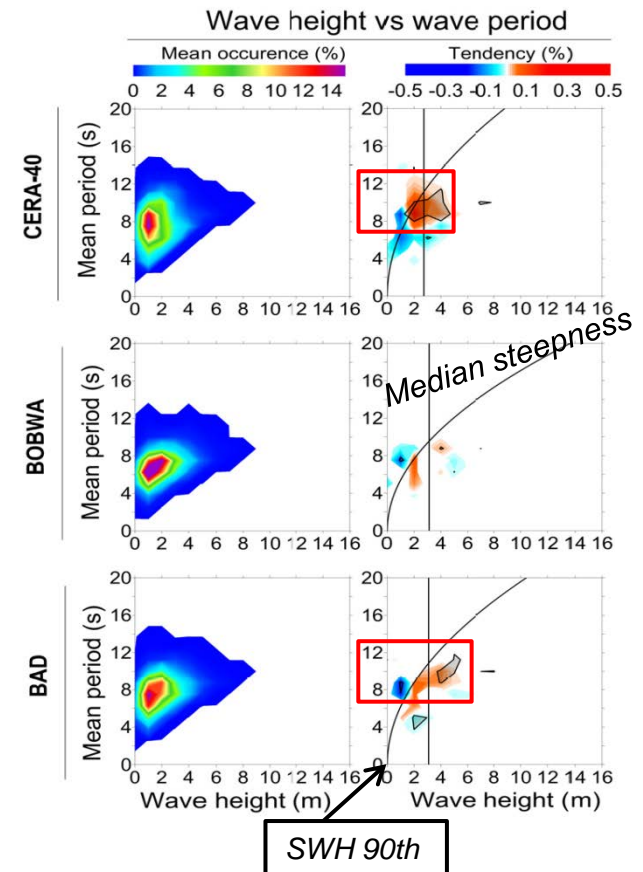
Significant Wave Height 90th quantile – 1970-2001



1970-2001 (32 years)

→ Significant increase of wave height

- +30 to +45 cm for SWH
- +30 to +90 cm for SWH 90th

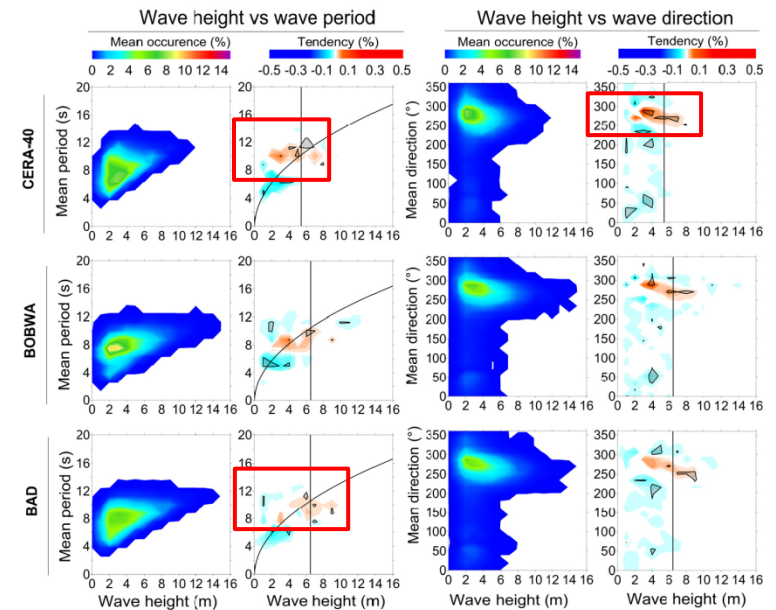
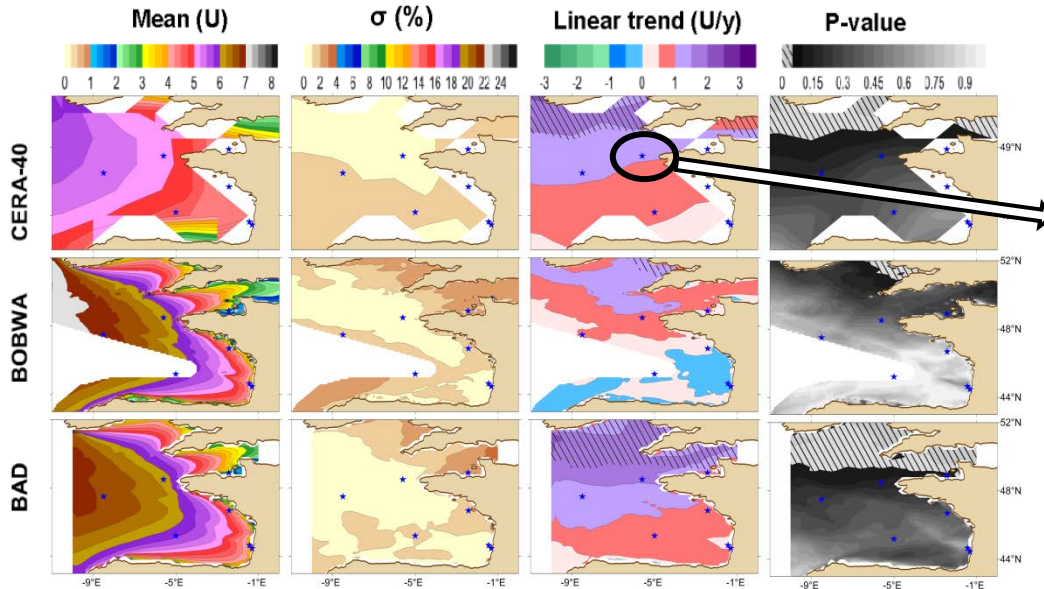


Bivariate diagram SWH/MWP :

- A significant increase of waves of intermediate type
- Increase more pronounced for highest wave (> SWH 90th)

Trend analysis : Winter

Significant Wave Height 90th quantile – 1958-2001



1958-2001 (44 years)

- Significant increase of highest waves
 - +45 to +65 cm for SWH 90th north of 48°N
- Slight increase of wave periods
 - +1 s for MWP along the south French coast

Bivariate diagram SWH/MWP and SWH/MWD :

- An increase of energetic waves with longer periods and higher waves

Conclusions / Discussion : Quality of the datasets

- **Offshore** : BoBWA and ERA-INTERIM represent best the wave measurements
- **Costal locations** : BoBWA represent best the wave heights measurements, specially for highest wave heights

- **Is quality depends on wave model or wind fields forcing ?**
- **Methods and calibration data?**

On going works

- Create a new extreme wave atlas with BOBWA dataset

Conclusions / Discussion : trends

- The most important and significant trends are similarly presents in the datasets (C-ERA-40 / BAD / BoBWA-10kH)
- A general increase of wave heights is detected at the end of the 20th century, especially in summer for the period 1970 2001
- Trends have been related to different modifications of the wave types' occurrence depending on the season, but the understanding of the causes still requires further investigations.

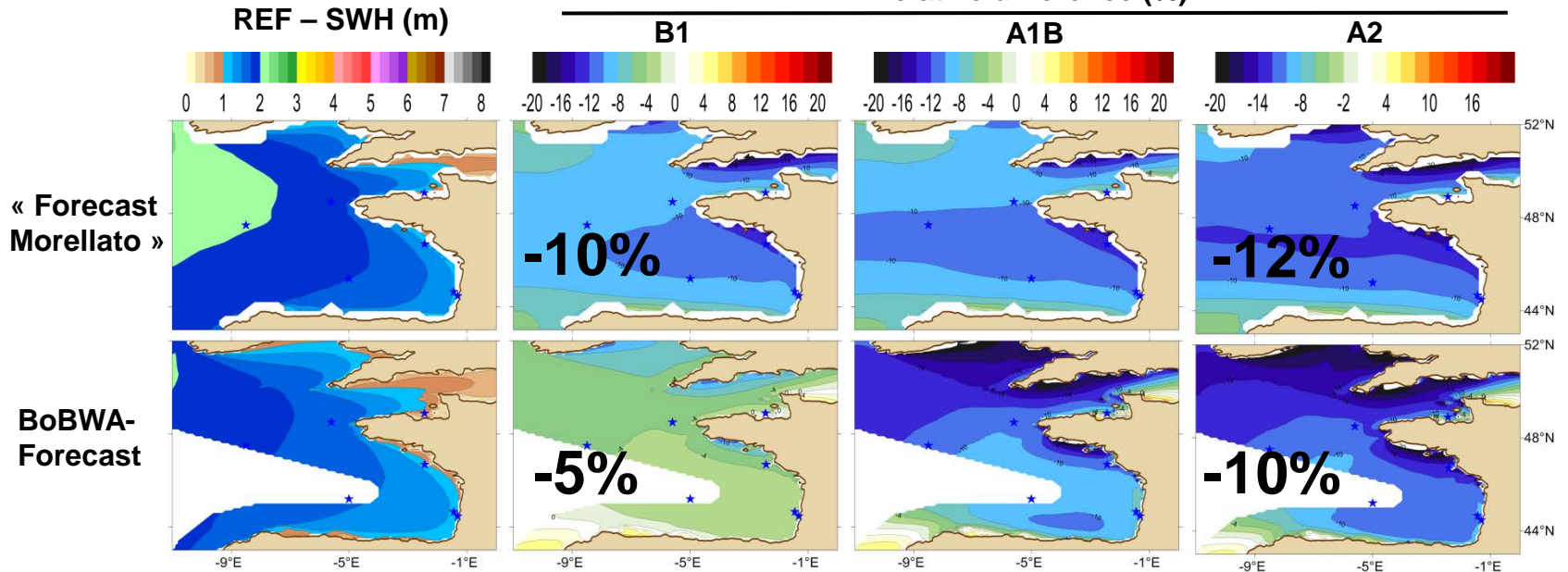
Future evolution ...

Examination of wave climate changes

- A general decrease of wave heights between the end of the 20th century and the 21th century
- More pronounced for the more pessimistic scenario

Summer evolution of SWH between [1961-2100] and [2061-2100]

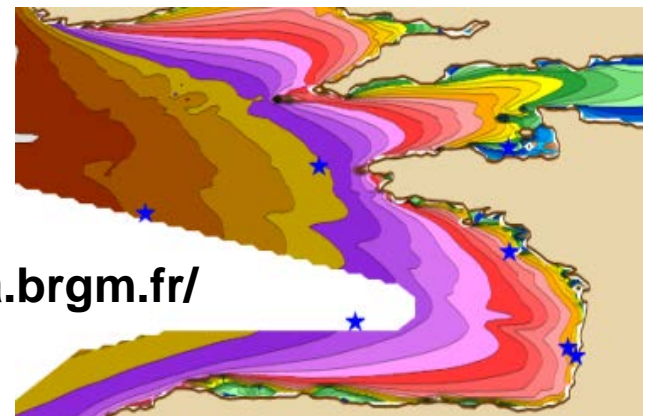
Relative difference (%)



Thank you for your attention

Contact : f.paris@brgm.fr

Access to the BoBWA-10kH data online : <http://bobwa.brgm.fr/>



Annex : Linear trends in SWH from VOS (1950-2002)

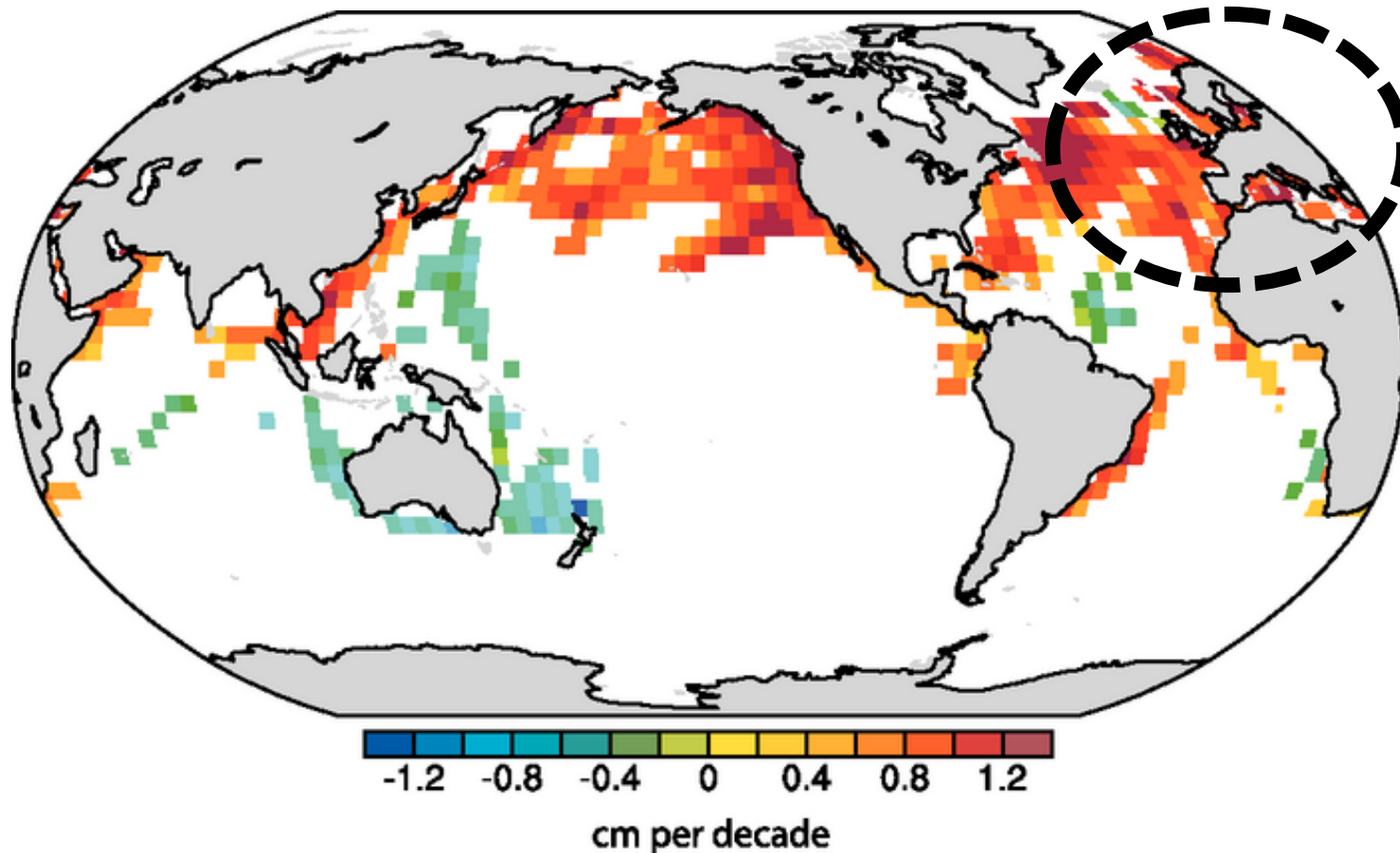
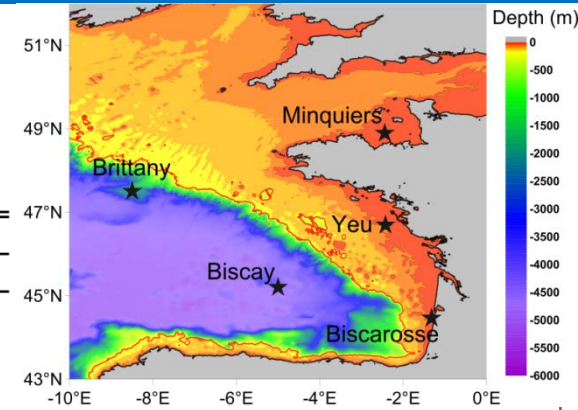


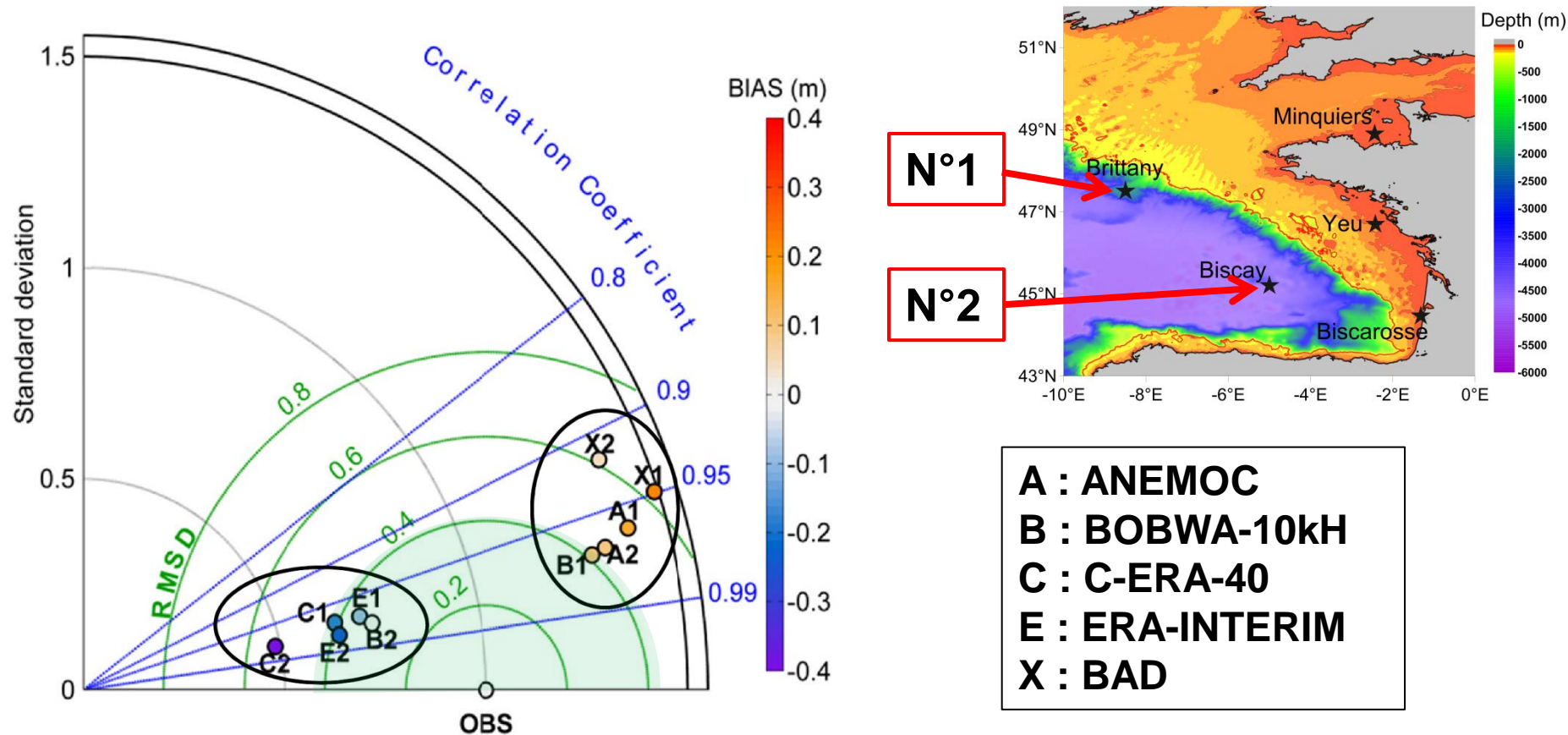
Figure 3.25 of IPCC AR4 WG-1 report : Estimates of linear trends in significant wave height (cm per decade) for regions along major ship routes of the global ocean for 1950 to 2002. Trends are shown only for locations where they are significant at the 5% level. Adapted from Gulev and Grigorjeva (2004).

Annex : Significant wave height and mean wave period statistics of the different hindcasts & reanalysis products vs. buoy measurements

Buoys	n	Dataset	Significant wave height (SWH)				Mean wave period (MWP)			
			R ²	Bias	Rmse	SI	R ²	Bias	Rmse	SI
Brittany 62163	10664	BoBWA	0.97	0.09	0.41	0.15	0.89	1.60	1.87	0.26
		ANEMOC	0.96	0.15	0.52	0.19	0.91	-0.23	0.74	0.10
		BAD	0.95	0.22	0.63	0.23	0.87	1.61	1.87	0.26
		ERA-INTERIM	0.97	-0.09	0.36	0.13	0.92	1.42	1.56	0.22
Biscay 62001	6023	BoBWA	0.98	0.00	0.32	0.13	0.93	-0.45	0.75	0.10
		ANEMOC	0.97	0.10	0.45	0.17	0.90	-0.21	0.91	0.12
		BAD	0.92	0.05	0.61	0.24	0.81	-0.02	1.02	0.14
		ERA-INTERIM	0.98	-0.24	0.39	0.15	0.93	1.29	1.48	0.20
Biscarosse 17585	17585	BoBWA	0.95	0.11	0.28	0.21	0.66	1.08	1.87	0.29
		ANEMOC	0.94	0.26	0.45	0.33	0.67	0.68	1.58	0.24
		BAD	0.90	0.22	0.45	0.33	0.74	1.01	1.79	0.28
Yeu 1 8368	8368	BoBWA	0.97	-0.10	0.29	0.15	0.72	0.78	1.74	0.20
		ANEMOC	0.96	-0.14	0.35	0.18	0.69	-1.35	2.17	0.25
		BAD	0.94	0.10	0.46	0.24	0.75	-1.36	2.00	0.23
Minquiers 2 2202	15278	BoBWA	0.96	-0.09	0.22	0.17	0.75	0.24	1.02	0.19
		ANEMOC	0.94	-0.25	0.35	0.28	0.55	0.46	1.78	0.33
		BAD	0.92	-0.18	0.33	0.27	0.72	0.93	1.52	0.28

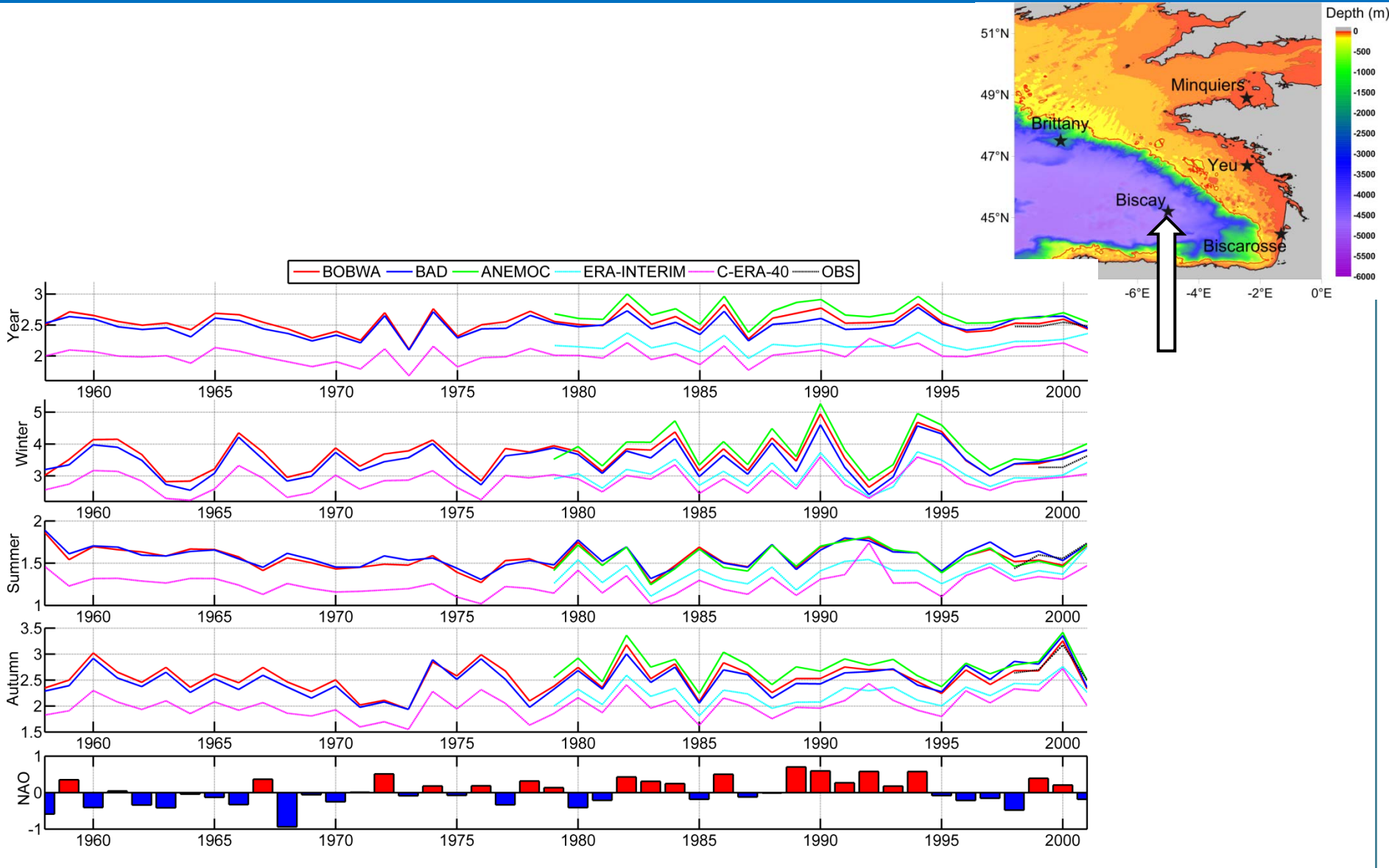


Quality of the datasets : SWH at offshore buoys



- Global models slightly underestimate SWH
- Regional models overestimate SWH
- ERA-INTERIM and BoBWA-10ks compare the best with offshore buoy observations

Annex : Interannual & seasonal variation of wave heights at the Biscay buoy and NAO annual index.



Annex : long-term trends in the 20th century

Our study (over the 2nd part of the 20th century):

- A general increase of wave heights is detected at the end of the 20th century for summer; winter and autumn seasons.
- The most important and significant trends are similarly presents in the datasets (C-ERA-40 / BAD / BoBWA-10kH)
- Trends have been related to different modifications of the wave types' occurrence depending on the season

Others studies (over the entire 20th century) based on the NOAA-20 Century Reanalysis (Compo et al., 2011)

- Statistical reconstruction of SWH from 20CR (Wang et al. 2012)
- Dynamical reconstruction of SWH (Bertin et al. 2013)
- ⇒ Both show an increase of annual SWH over the 20th century in the northern part

