CIMP5 derived dynamical global wave simulations versus altimeter observations

Justin E. STOPA[1], Alvaro SEMEDO[2], Mikhail DOBRYNIN[3], Jean BIDLOT[4], Arno BEHRENS[5], Joana STANEVA[5]

1 (justin.stopa@ifremer.fr), Univ. Brest, CNRS, IRD, Ifremer, Labortoire d'Oceanographie Physique et Spatiale (LOPS), France
2 UNESCO-IHE Institute for Water Education, Det, The Netherlands
3 Institute of Oceanography, University of Hamburg, CEN, Germany
4 European Centre for Medium-Range Weather Forecasts Shinfield Park, United Kingdom
5 Helmholtz-Zentrum Geesthacht Centre for Materials and Coastal Research, Geesthacht, Germany

1) Motivation and datasets

Global climate simulations do not capture the exact time history making it difficult to compare them with observations and assess their skills in reproducing climate conditions. Since ocean waves are not included in climate simulations, the Coordinated Ocean Wave Climate Project (COWCLIP) set forth an international effort to generate future wave climate scenarios (e.g. *Mori et al.*, 2010; *Hemer et al.*, 2012; *Semedo et al.*, 2013). Most studies verify the wave climate projections by comparing with wave hindcasts (e.g. *Hemer and Trenham*, 2015).

In this work, our goal is to asses a 7-member dynamical wave climate ensemble, produced using EC-Earth winds with altimeter observations with the 2 main objections:

1) Sample the wave simulations so that the statistical properties match those of the altimeters (the altimeter measurements changes in time and space! e.g. **Figure 1**).
2) Compare the near surface wind speeds (U10) and significant wave heights (Hs) to the altimeter observations

Merged Altimeters (1996-2005): U10 & Hs from many altimeter platforms are quality controlled with sensor biased removed by Queffeulou and Croize-Fillon (2016). For the period analyzed 1996-2005 we have 6 missions ERS1, ERS2, ENVISAT, TOPEX, JASON1, and GFO.

Wave simulations: Seven wave simulations were produced by forcing WAM with U10 from EC-Earth on a 1-degree grid for 1970-2005.

Systematic sampling: performed the best out of several sampling techniques so it was simulate the altimeter coverage in time and space from the climate simulations.

3) Model performance

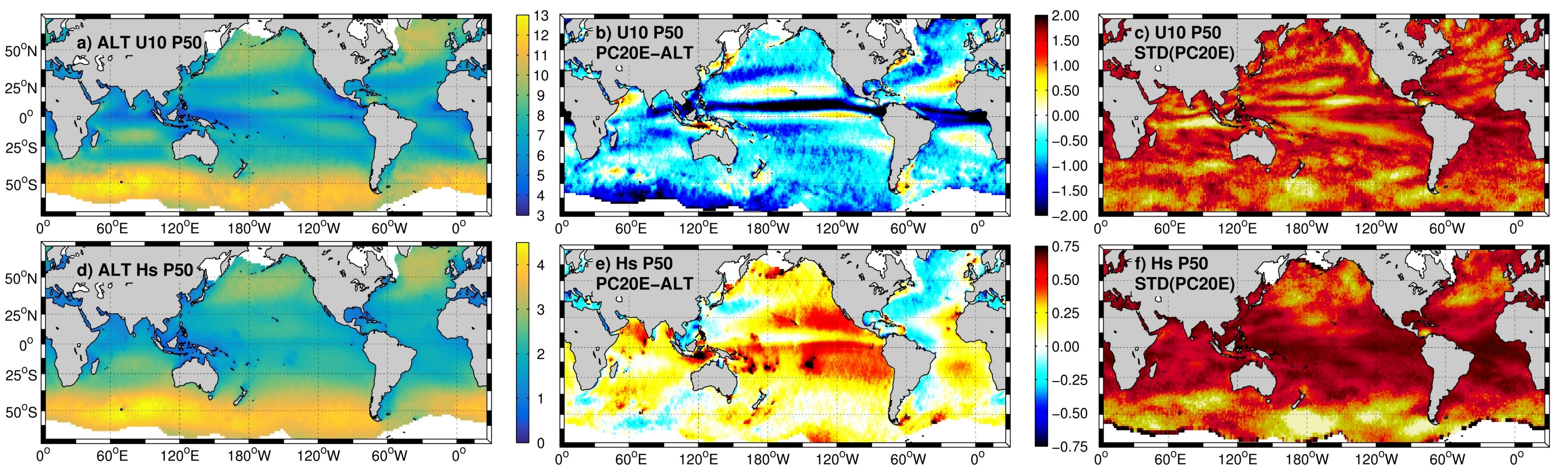

Figure 2: Wind speed (U10) (a,b,c) and wave height Hs (d,e,f) comparisons of the median (P50) in units of ms^{-1} and m respectively. (a,d) are the altimeter observations for reference. (b,e) display the difference between PC20-E and the altimeters. (c,f) display the standard deviation of 7-member ensemble.

►EC-Earth underestimates U10 majority of the globe. Despite the U10 underestimation, Hs are overestimated. Note that the inter-model variability is small in relation to the model-altimeter differences.

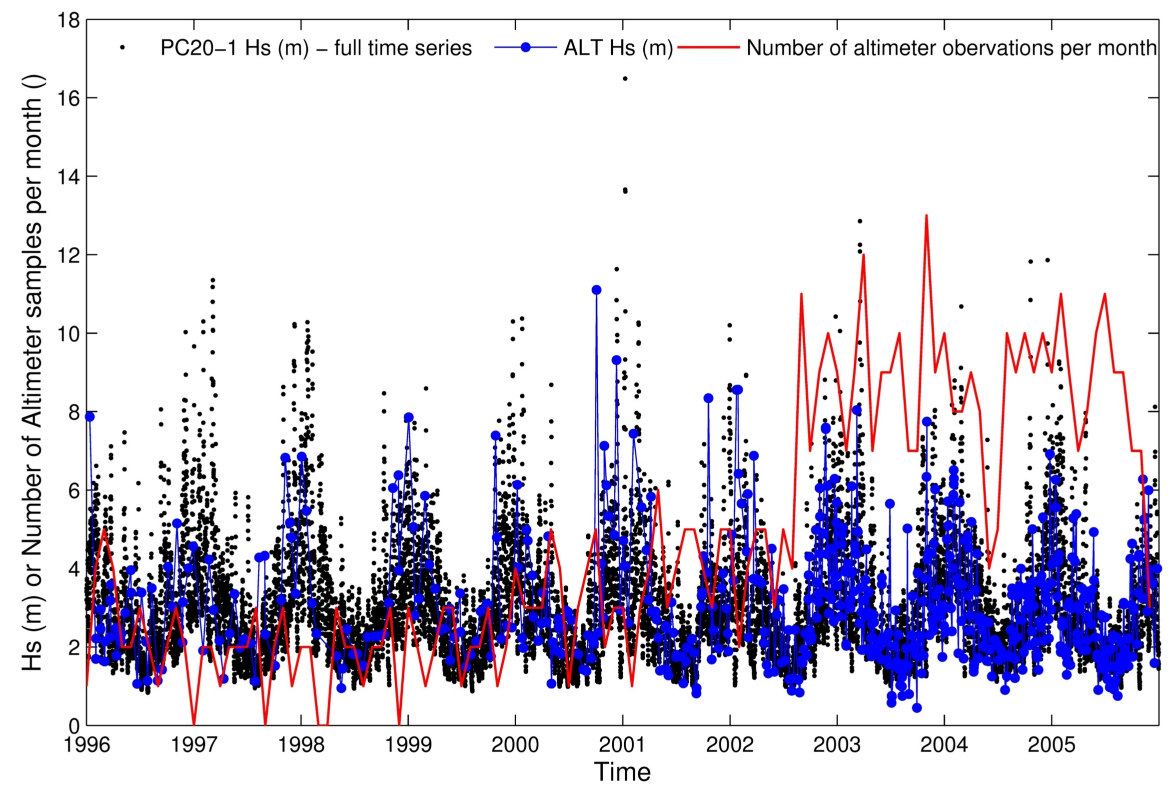

Figure 1: Example Hs time series from the North Atlantic (20W,46N). The black dots shows wave simulations, the blue circles show the altimeter Hs, and the red line shows the number of altimeter samples per month.

►It is essential to capture the statistical properties of the altimeters and this is difficult since the number of satellite observations changes in time and space

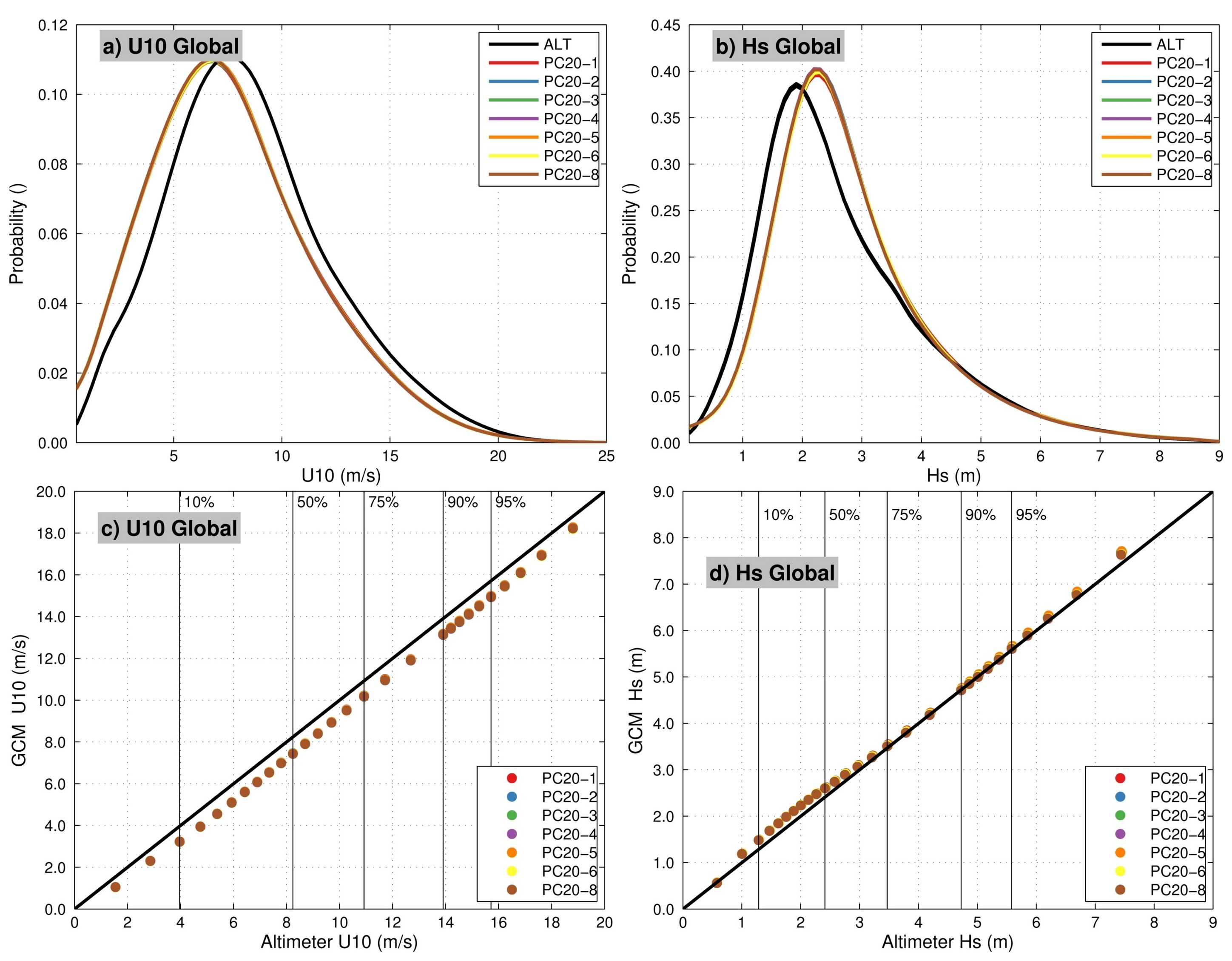

Figure 3: Probability density functions for U10 (a) and Hs (b) for each ensemble member and the altimeters. Quantile-quantile comparisons for U10 (c) and Hs (d) for each ensemble member and the altimeters.

►The EC-Earth simulations underestimate U10. The discrepancies are the same for all wind speeds - meaning the model is capturing the important statistical properties.

►The wave simulations overestimate Hs: Hs<3 m & Hs>5.5 m are overestimated by 10-30 cm.

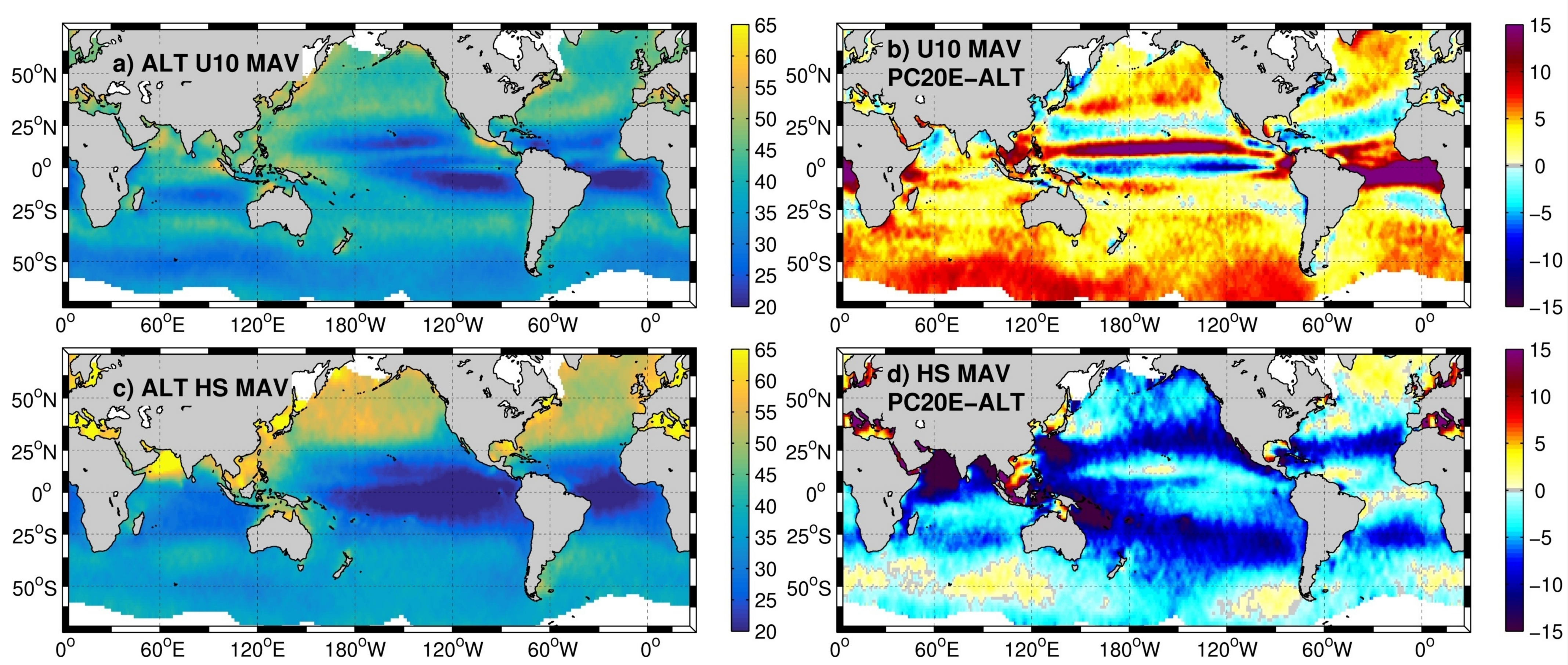

Figure 4: Mean annual variability (MAV) of the wind speed (a,b) and significant wave height (c,d) given in a percentage. Panels (a,c) display the altimeter observations for reference and (b,d) display the difference between the average MAV for PC20-E and the altimeters.

$$MAV = \overline{\left(\frac{\sigma_i}{\overline{x_i}}\right)}$$

where index *i* refers to the year, σ the standard deviation, and the overbar denotes average.

►The altimeter observations agree with CFSR (*Stopa et al*., 2013). EC-Earth U10 has more seasonal variability than the altimeters with the strongest variability in the Southern Ocean.

►The model underestimates the Hs seasonality by as much as 15% but typically 4-8%. It is possible the physical parameterizations in the wave model are not responding correctly to the input.

4) Conclusion

►This is first attempt to compare GCM drive wave simulations to altimeters
►Systematic sampling is used to sample the wave simulations to synthesize the altimeters
►EC-Earth U10 well matches the probability distributions of the altimeters but underestimates the magnitude
►The wave simulations overestimate Hs due to improper calibration of the wind-wave parameterization
►The inter-model variability and use of the ensemble improves our ability to predict the seasonal variation
►The wave climate ensemble captures the important features of the present global wave climate

References

Hemer, M. A., X. L. Wang, R. Weisse, V. R. Swail, 2012. Advancing wind-waves climate science: The COWCLIP project, BAMS, 93(6), 791-796. doi:10.1175/BAMS-D-11-00184.1

Hemer, M. A. and C. E. Trenham, 2015. Evaluation of a CIMP5 derived dynamical global wind wave climate ensemble. Ocean Modelling doi:10.1016/j.ocemod.2015.10.009.

Mori, N., T. Yasuda, H. Mase, T. Tom, Y. Oku, 2010. Projection of extreme wave climate change under the global warming. Hydro. Lett, 4, 15-19. doi:10.3178/hr1.4.15

Semedo, A., R. Weisse, A. Behrens, A. Sterl, L. Bengtsson, H. Gunther, 2013. Projection of global wave climate change toward the end of the twenty-first century. Journal of Climate 26(21), 8269-8288. doi:10.1175/JCLI-D-12-00658.1

Stopa, J. E., K. F. Cheung, H. L. Tolman, A. Chawla, 2013. Patterns and cycles in the climate forecast system reanalysis wind and wave data. Ocean Modelling, 70. doi:10.1016/j.ocemod.2013.12.006