Evaluation of global wave models for storm analysis in coastal areas

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INTRODUCTION

Barrier islands, coastal landforms consisting mostly of sand, are particularly exposed to coastal hazards. To analyse the impact of storms in these systems, a characterization of the wave climate must be performed with available in-situ data and global wave models for past conditions (i.e. reanalysis). When validated and calibrated, wave reanalysis allows to extend the assessment to periods and locations that are not covered by wave buoys, increasing the scope to investigate extreme oceanic events.

OBJECTIVES

- Validate and calibrate two global wave reanalysis (ERA5 and WAVERYS) to improve their predictive skill for coastal areas, where they are usually less accurate due to the complexity of the bathymetry and the physical processes involved;
- Focus on the improvements obtained for the prediction of the extreme wave conditions, which are particularly relevant for storm hazards assessment in vulnerable and exposed coastal environments.

MATERIALS AND METHODS

Two recent global reanalysis (derived from the assimilation of ocean data from models, satellites and in-situ observations) have been assessed: ERA5, the latest reanalysis released by the European Centre for Medium-Range Weather Forecasts (ECMWF), and WAVERYS by the Copernicus Marine Service (CMEMS). Six buoys have been selected, located on coastal waters offshore barrier island systems, and distributed around the world (Fig. 1). The timeseries of wave height, mean and peak period and direction from the reanalysis (extracted from the closest cell to the buoys position, Fig. 2) were compared with the buoy data and calibrated by choosing the optimal fit (Fig. 3), corresponding to the best statistical correlation with the measured data. The directions have been rotated to align with buoy data (Fig. 4).
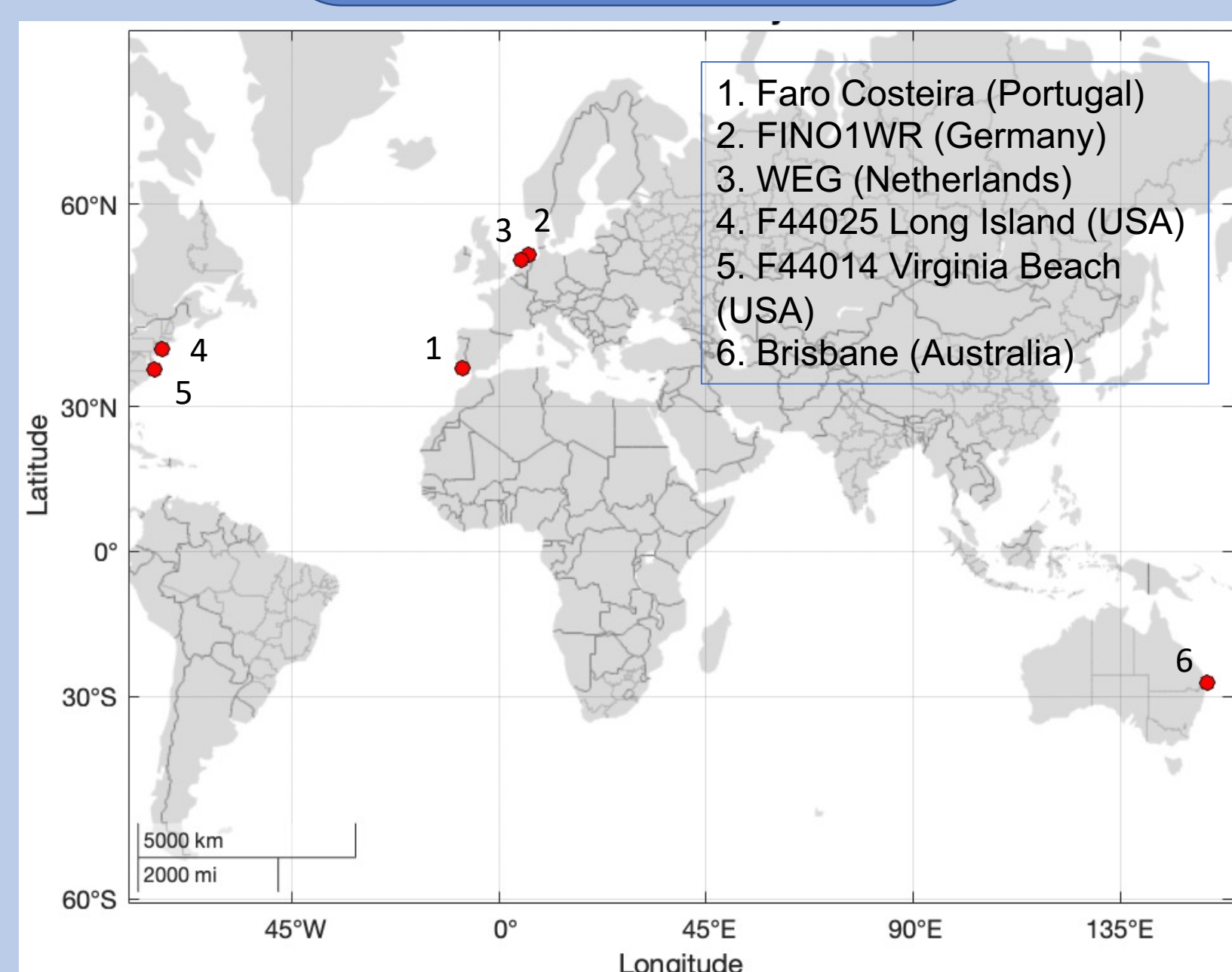
Data Collection

Buoys

Figure 1. Location of the buoys.

1. Faro Costeira (Portugal)
2. FINO1WR (Germany)
3. WEG (Netherlands)
4. F44025 Long Island (USA)
5. F44014 Virginia Beach (USA)
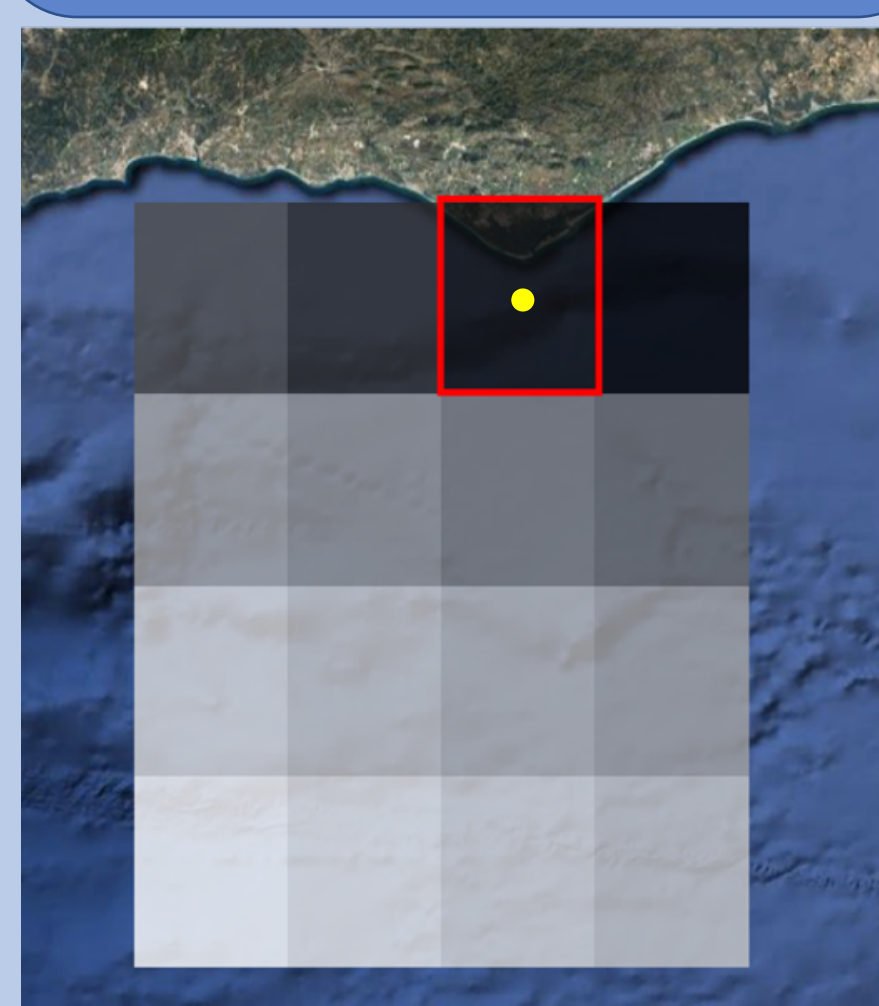6. Brisbane (Australia)

Reanalysis

Figure 2. Example of cell selection from reanalysis data (centre of the red square) for comparison with buoy data (yellow dot).

WAVERYS
1993 – 2019
3 – hourly data
0.2°×0.2° grid

ERA5
1950 – present
1 – hourly data
0.5°×0.5° grid

Timeseries Comparison

- Hs: significant wave height (m)
- Tm: mean wave period (s)
- Tp: peak wave period (s)
- Dir: mean direction (°)

WAVERYS
RMSE=0.235)
y=1.05x (RMSE=0.228)
y=0.81x+0.13 (RMSE=0.227)
y=0.96x$^{0.89}$ (RMSE=0.227)

Calibrated WAVERYS y=ax^b
R=0.9242
Ra=0.9968
RMSE=0.2275
CRMSE=0.3819
Bias=-0.0031
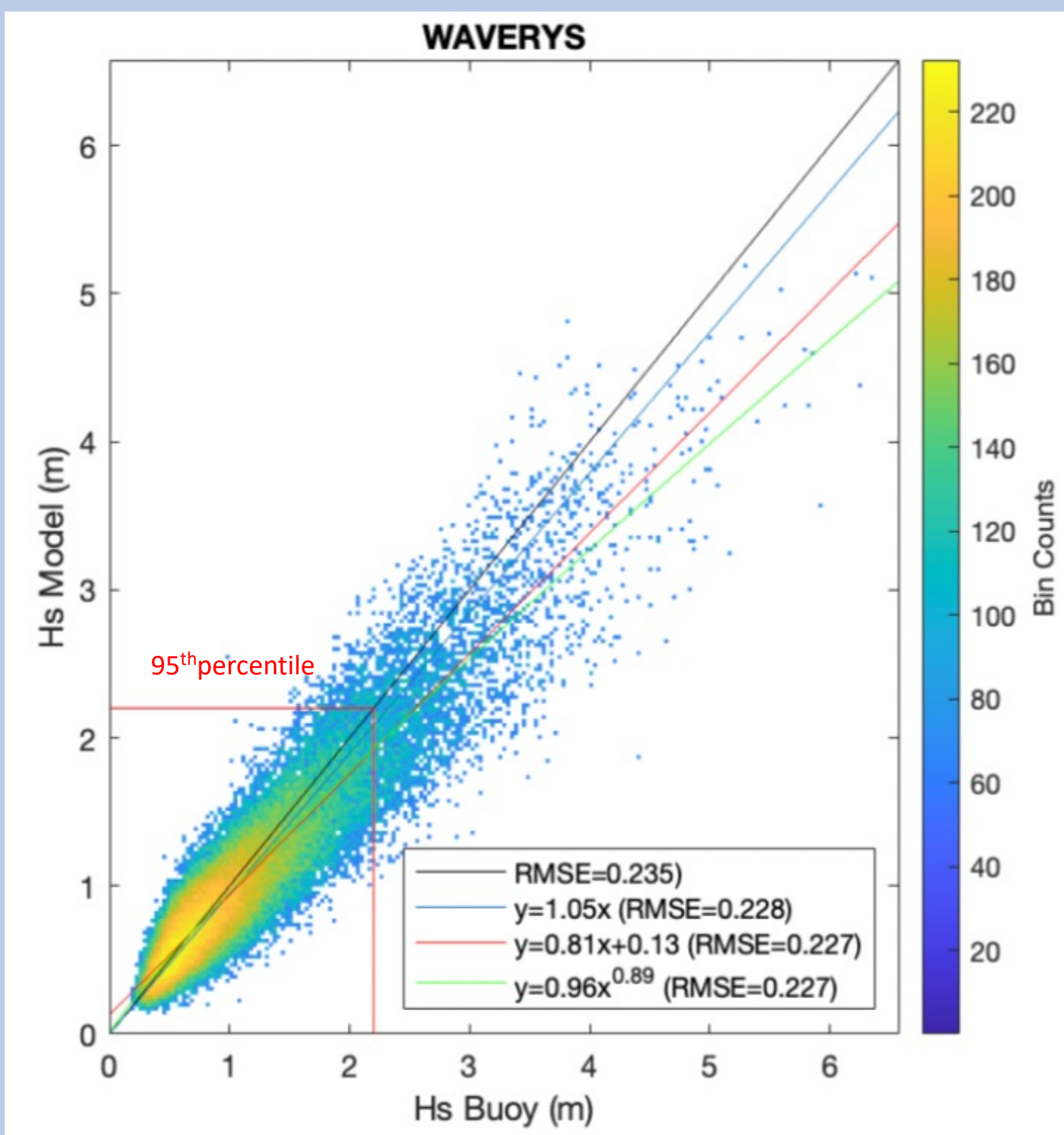StDev=0.2275
NSD=0.9332
SI=0.2344

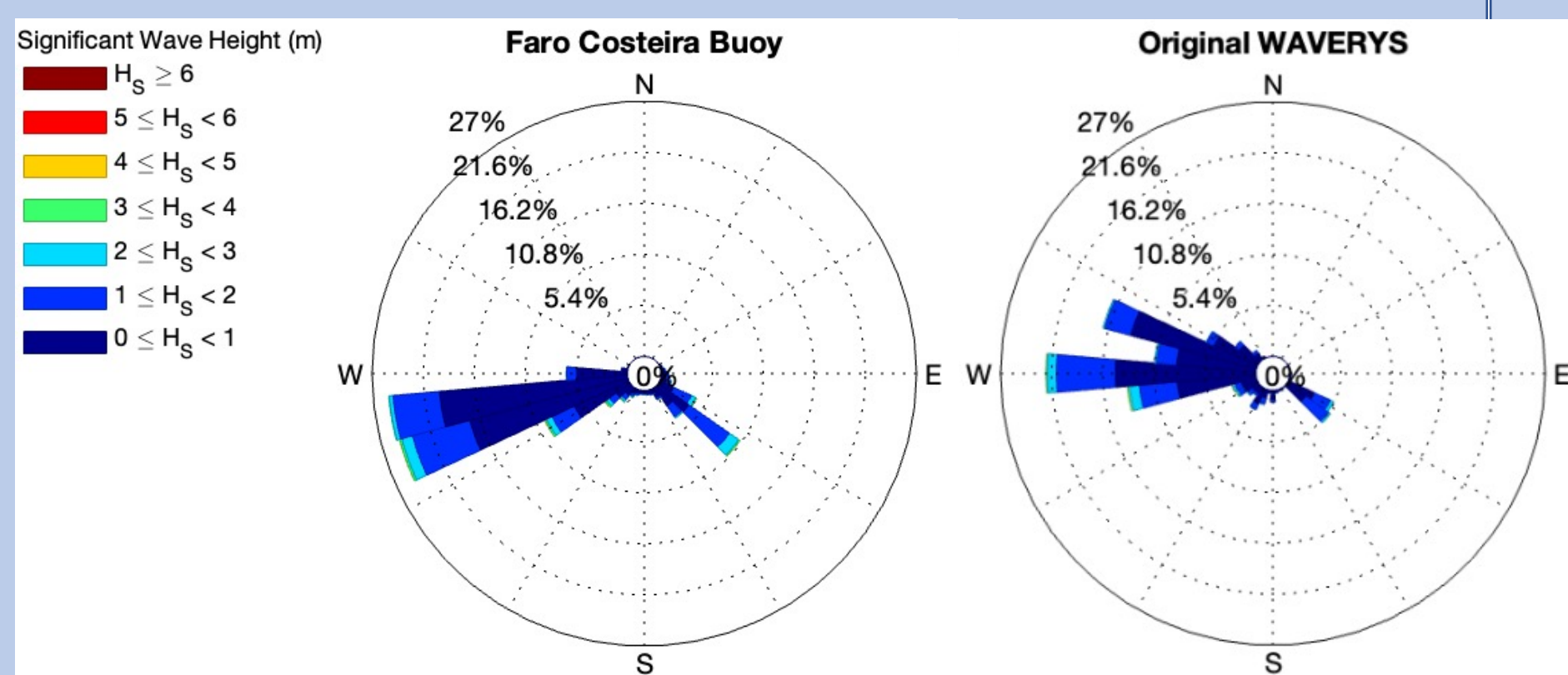Figure 3. Hs buoy vs reanalysis data before (left) and after (right) calibration with selected best fit.

Figure 4. Example of calibration of mean directions from WAVERYS versus Faro Costeira Buoys.

Reanalysis Calibration

y = ax^b
y = ax + b
y = ax

The best fit is selected

R
RMSE
StDev
Bias
SI

RESULTS AND CONCLUSIONS

Improvements obtained after the calibration of the global wave reanalysis WAVERYS and ERA5:

- The rotated directions from WAVERYS and ERA5 are in better agreement with the directions from the buoys, as well as the calibrated Hs, Tm and Tp.
- The mean and the extremes from the reanalysis are closer to those of the buoys (Fig. 5).
- The reduction in the Bias for Hs was about 90% for all the buoys, while the RMSE have improved in between 0-50% with a mean improvement around 10%, identical to SI (Fig. 7).
- For all the buoys the correlation with the reanalysis is between 0.8 and 0.9 with RMSE between 0.2 and 0.4 m and standard deviations within 0.5 and 0.9 (Fig. 8).
- Both reanalysis showed underestimation of the upper percentiles for Hs, Tm and Tp when compared to the buoys. The calibration improved the results but minor underestimation is still present (Fig. 6).

WAVERYS performed better than ERA5, as already stated by Chune et al. 2021, but for both models an underestimation of extreme events was observed, that improved after the calibration. These calibrated reanalysis will allow to extend backwards in time the analysys of the wave climate for the areas of interest, where in-situ observations are only available for shorter time periods.
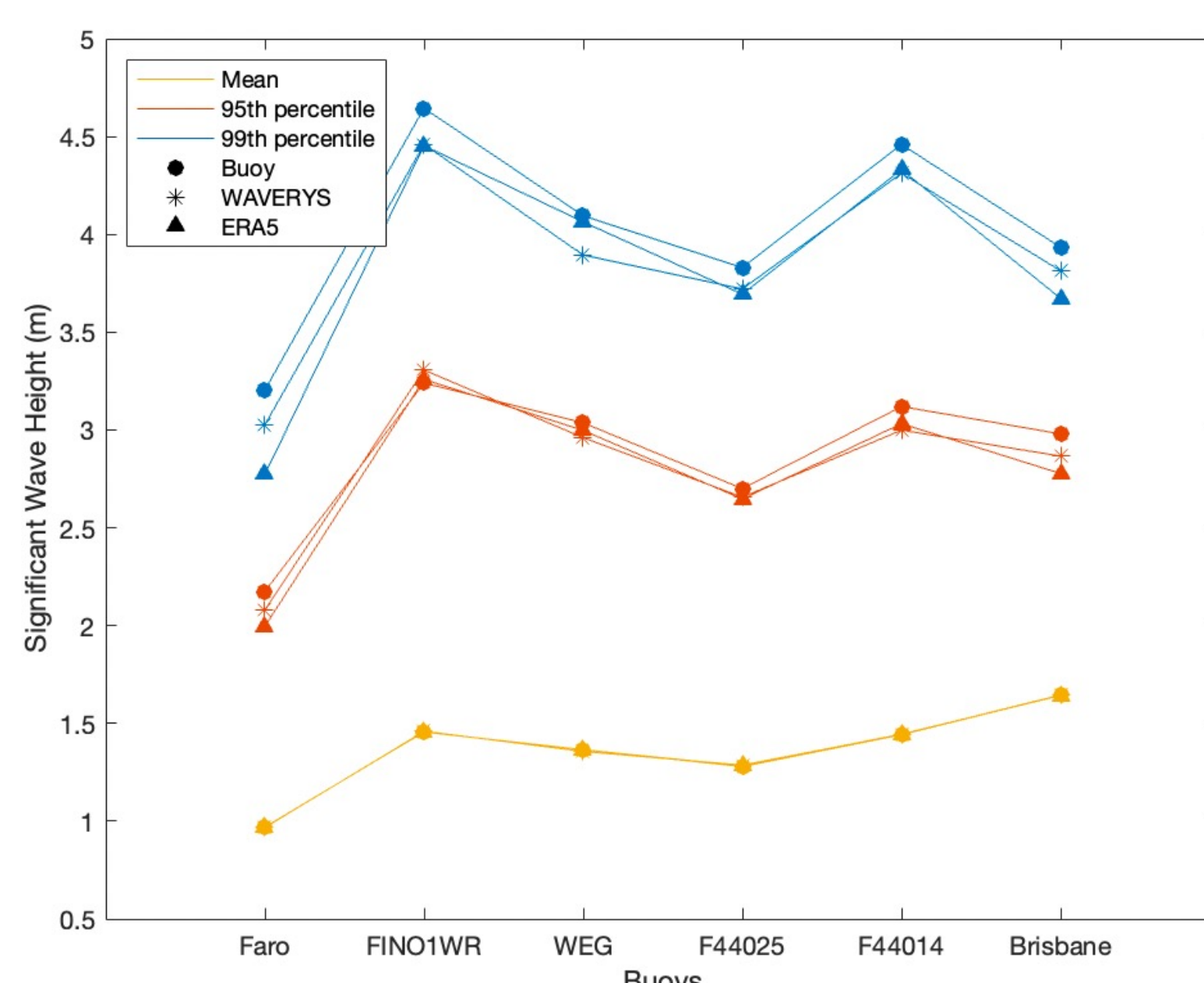

Figure 5. Mean, 95th, 99th percentile of Hs for buoys and calibrated reanalysis.
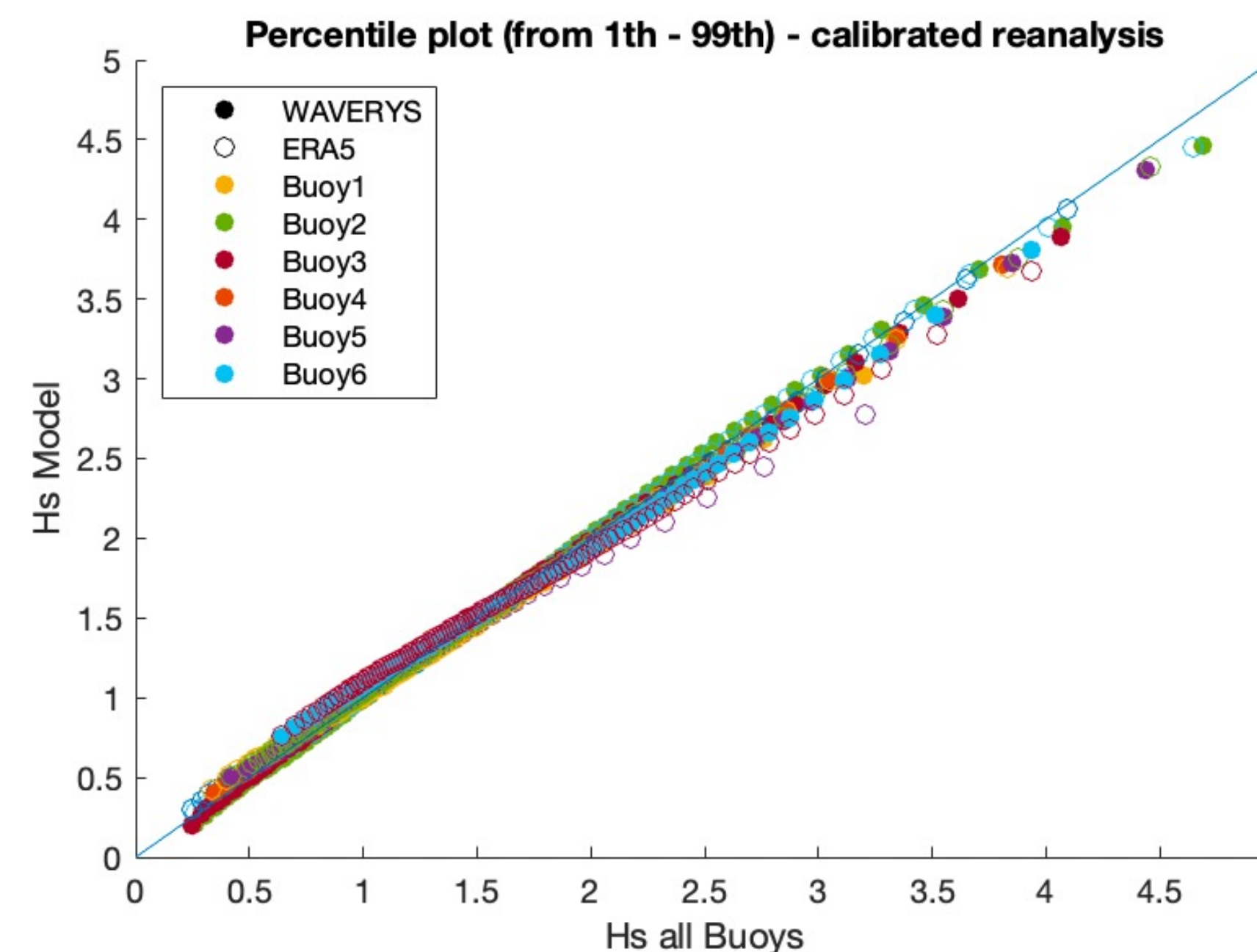

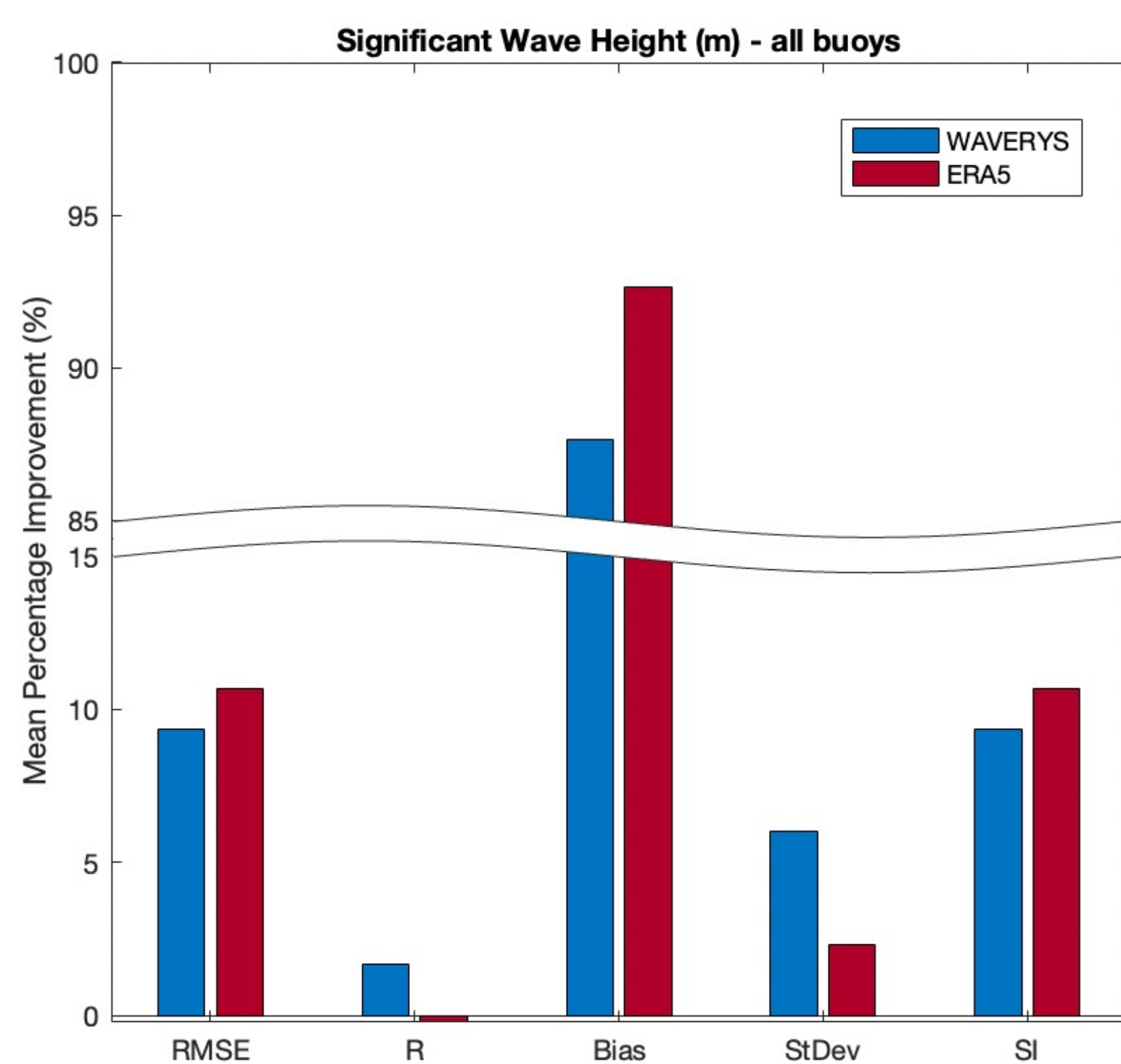Figure 6. Percentile plot of reanalysis versus buoy after calibration of Hs.

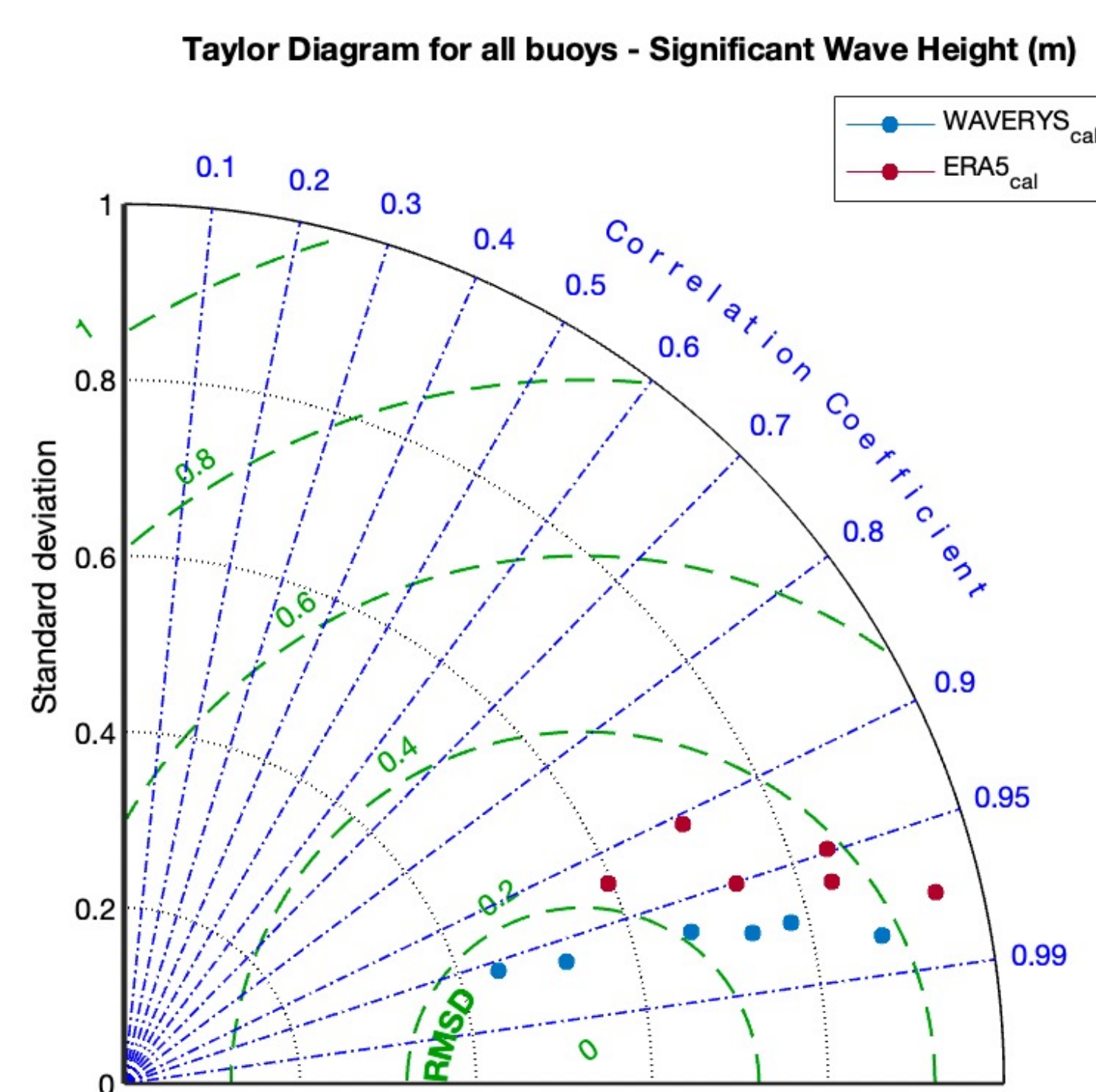Figure 7. Mean percentage improvement of statistical parameters after the calibration.

Figure 8. Error metrics for Hs from calibrated reanalysis compared with buoys.

REFERENCES

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