Global ocean wind wave model hindcasts forced by different reanalyzes: a comparative assessment

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Motivation

Disagreement between the wind data sets arise from GCM models developed by ECMWF, NCEP and NASA centers (spatial-time resolution, data assimilation systems and physical parametrizations)

The main **objective** is to perform **a comparison of four wind - wave hindcasts** based on modern reanalyzes by

- establishing the accuracy of the wave height in hindcasts
- presenting the results with regard to global significant wave height (SWH) wave climate and global trend patterns

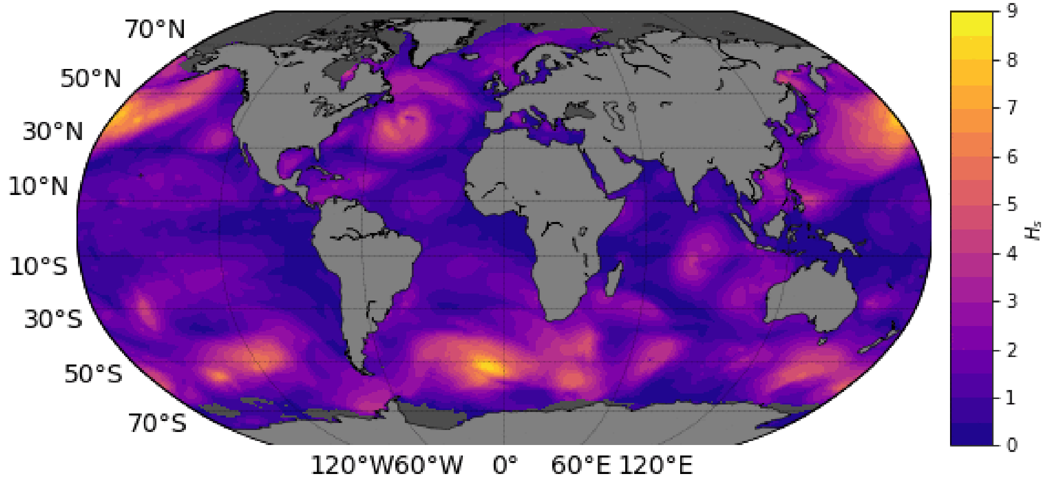
Methods

We performed 4 long-term (1980-2019) hindcasts via WaveWatch III (WW3) model

Set-up of the Hindcasts

Wind wave hindcast with WW3	Forcing function				Time steps of WW3 integration (sec)			
	Reanalysis	Model resolution	Data Assimilation	Spatial Resolution of output (lat x lon)	Δt_g	Δt_{xy}	Δt_k	Δt_s
ERA5-WW3	ERA5	T636 L137	4D-Var + EDA	$0.25° \times 0.25°$	1,800	225	900	60
ERAi-WW3	ERA-Interim	T255 L60	4D-Var	$0.7° \times 0.7°$	1,200	600	600	60
CFSR-WW3	NCEP CFSR (v2)	T382 L64	3D-Var SSI	$0.312° \times 0.312°$	1,800	300	900	30
MERRA2-WW3	MERRA2	1/2 x 2/3 L72	3D-Var + IAU	$0.5° \times 0.625°$	1,200	600	600	60

ERA5-WW3



- ST4 physics package
- Spectral resolution: 25 frequencies, 24 directions
- DIA for non-linear wave interactions

Global accuracy of wind-wave hindcasts

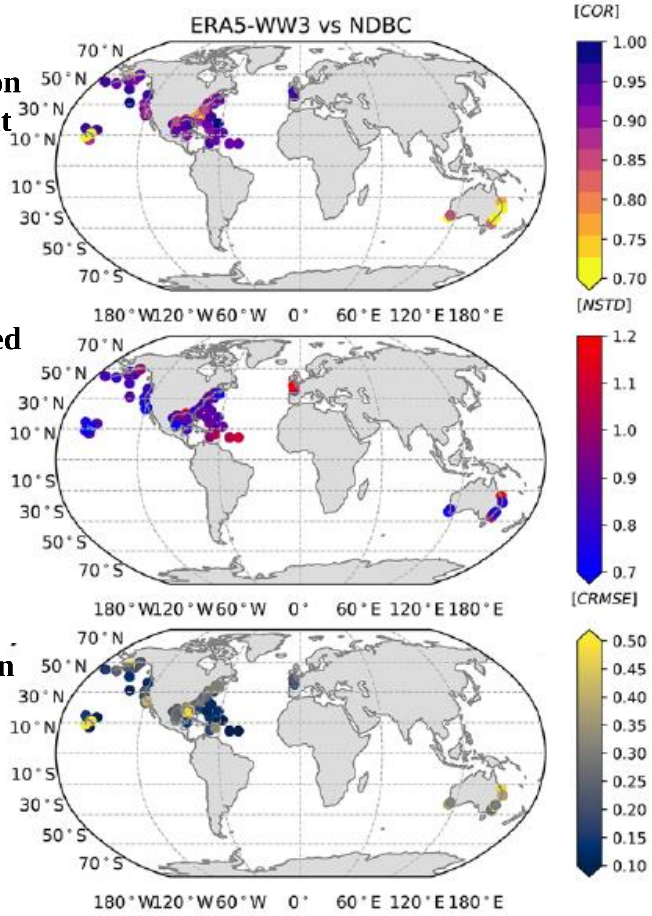
versus buoy data, satellite altimetry and visual VOS

ERA5-WW3 vs NDBC Jan-Mar 2011

Pearson's Correlation Coefficient

Normalized Standard Deviation

Centered Root Mean Square Error



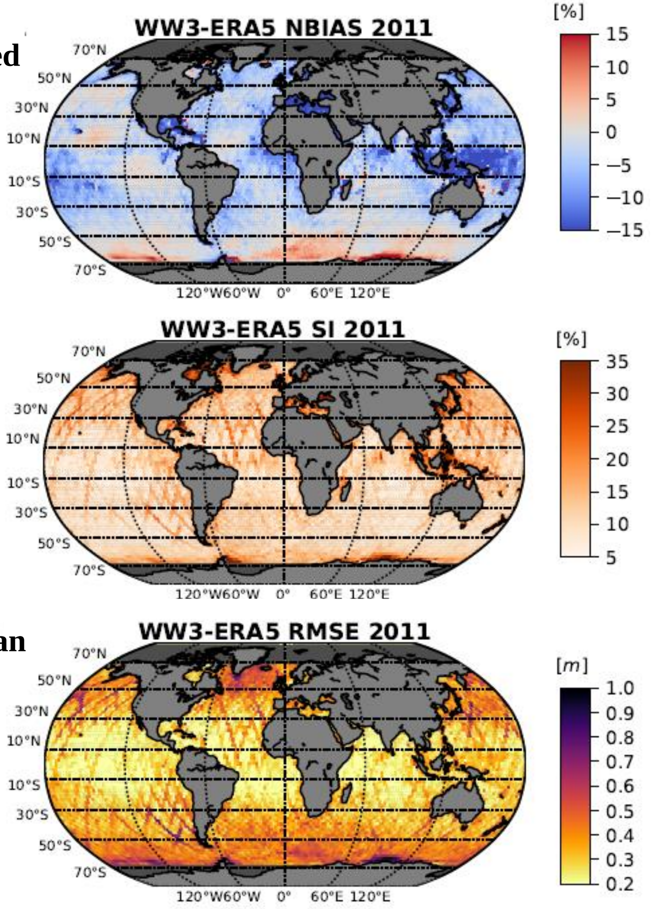
(Sharmar et al., 2021)

ERA5-WW3 vs Jason1 2011

Normalized Bias

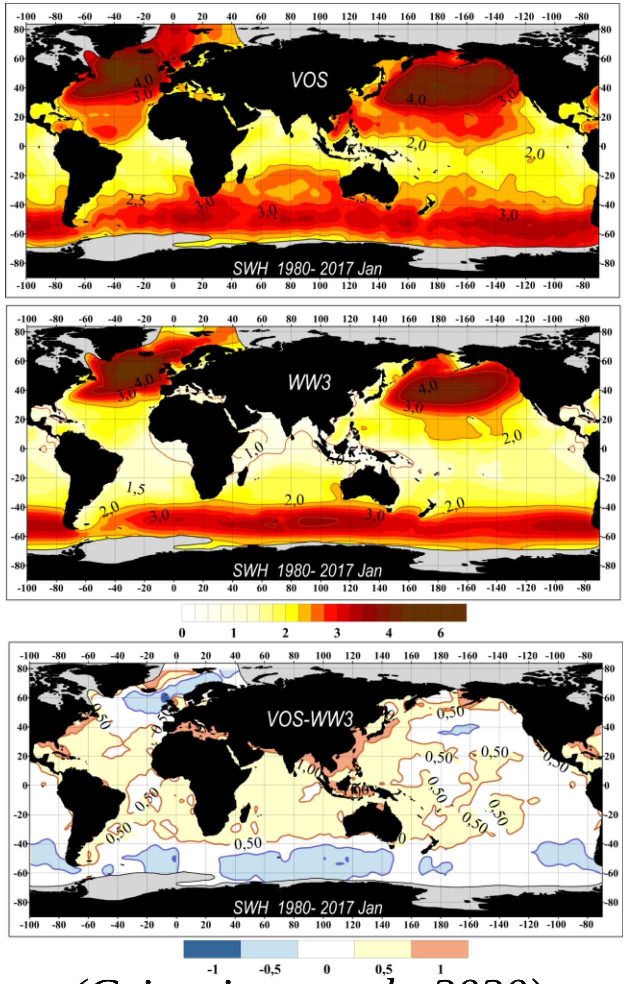
Scatter Index

Root Mean Square Error



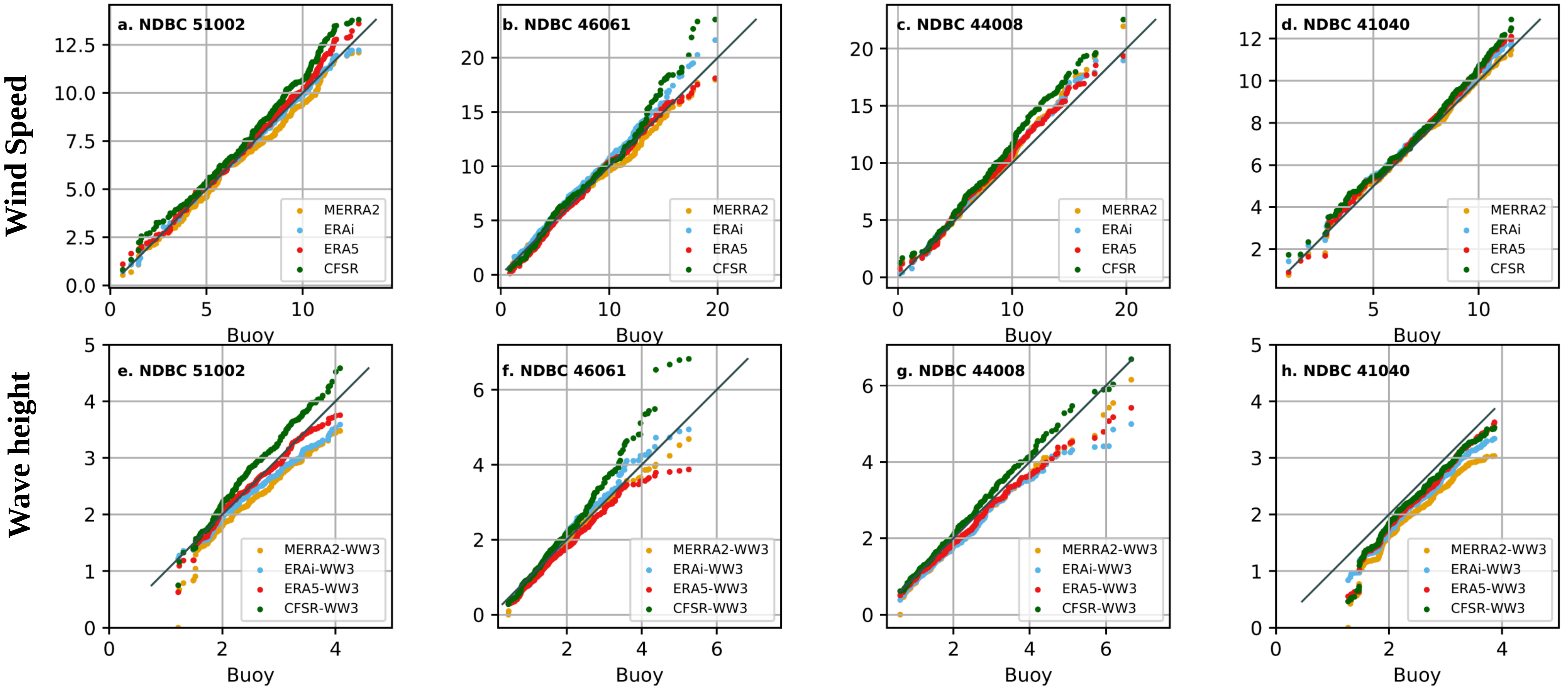
(Sharmar & Markina, 2020)

MERRA2-WW3 vs VOS Jan 1980-2017



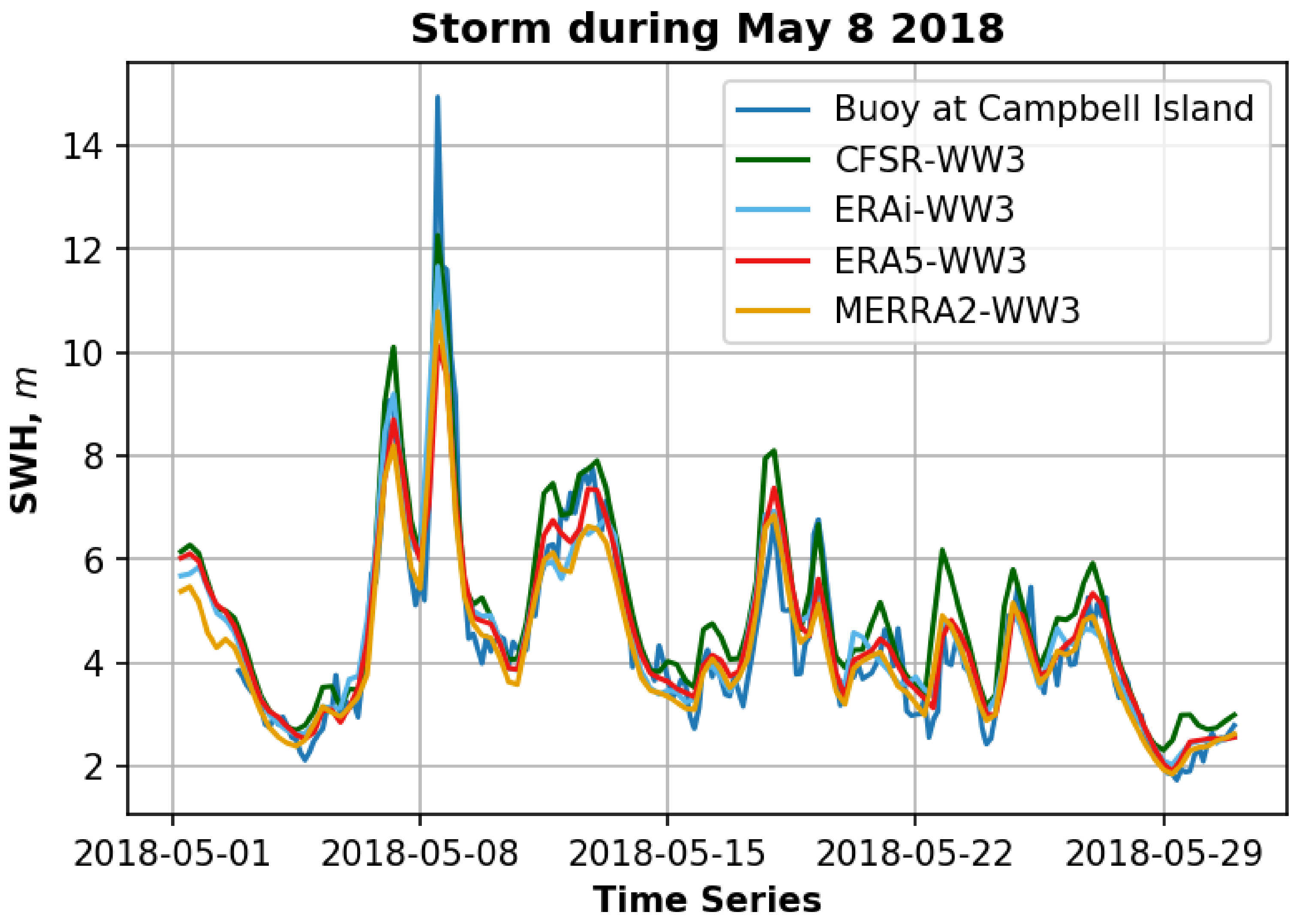
(Grigorieva et al., 2020)

Q-Q plots of wind speed and SWH at selected buoys for 2011 (Jan – Mar)

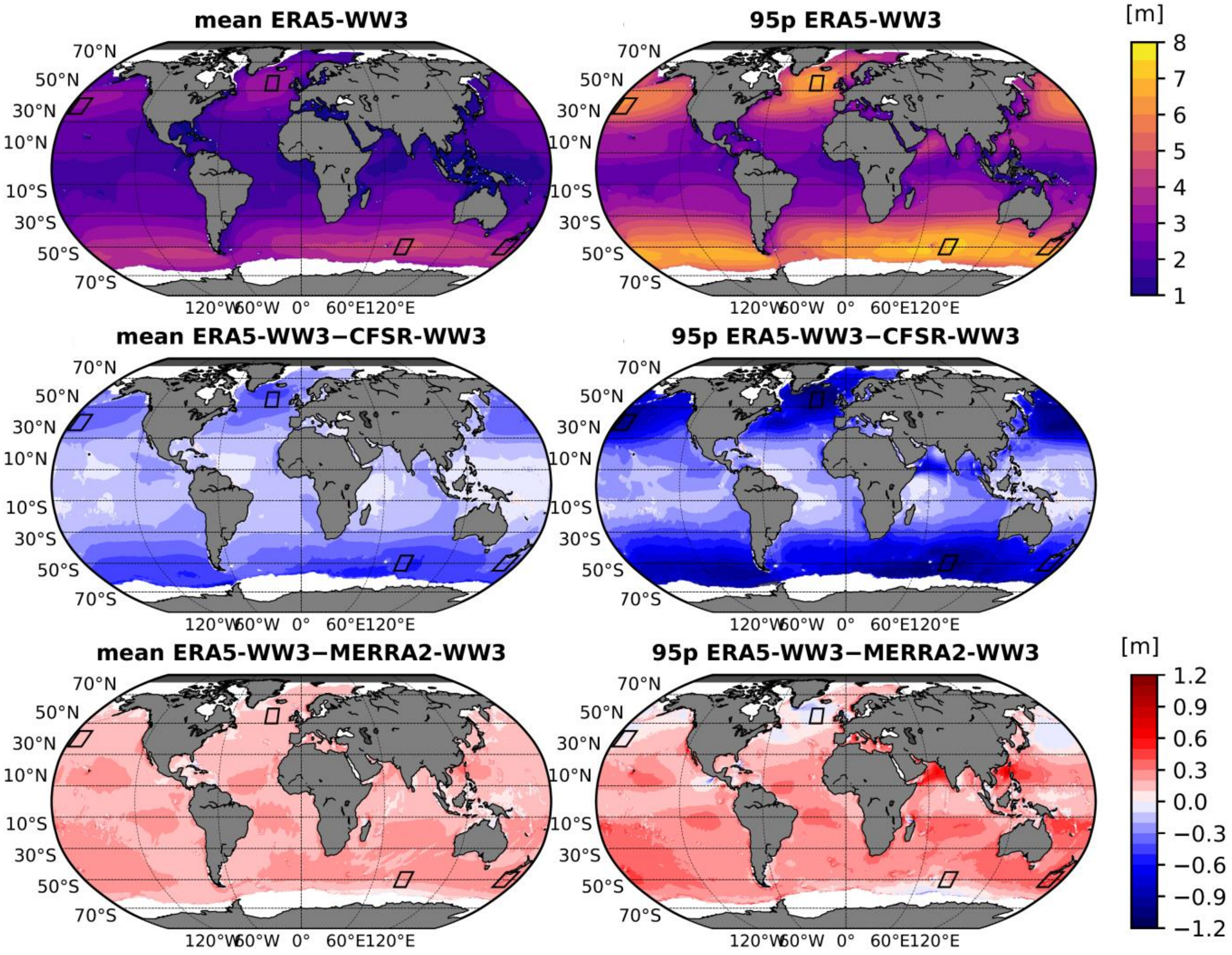


deep water near Hawaii	shallow water in the Gulf of Alaska	shallow water in the Northwest Atlantic	deep water in the tropical North Atlantic

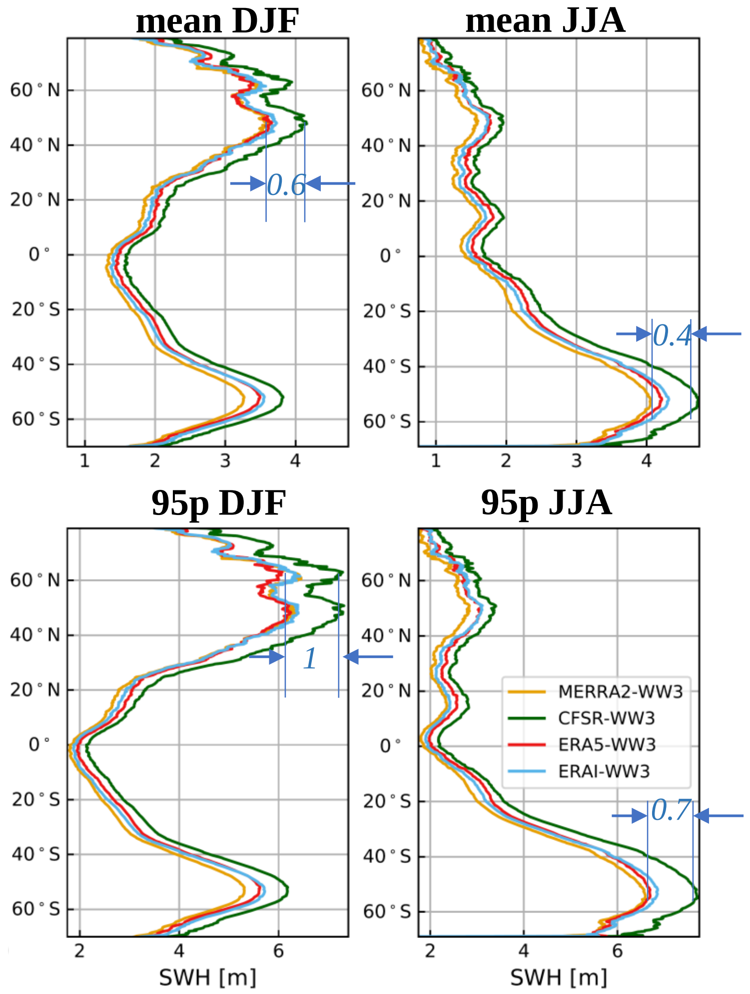
Time series of SWH for case study near Campbell Island



Disagreement in annual and seasonal wave climatology



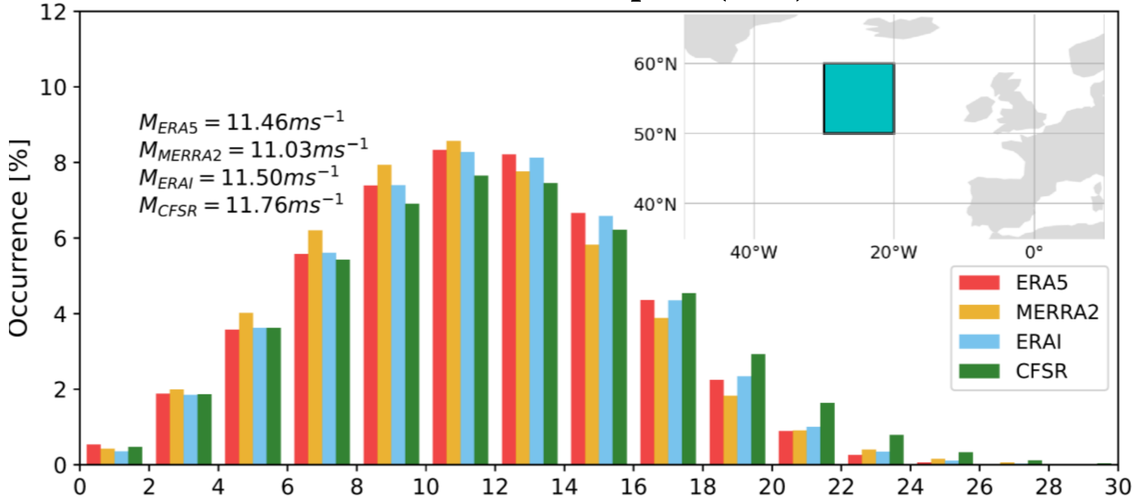
Seasonal zonally averaged SWH



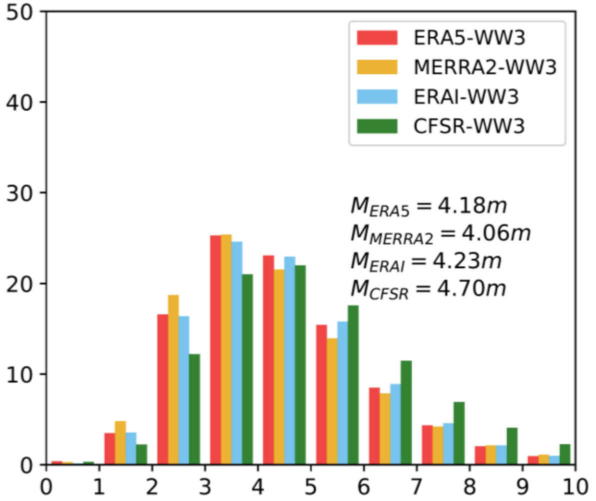
- The largest differences in zonally averaged SWH are observed in the Southern Ocean (JJA)
- In DJF the largest differences are attributed to the midlatitudes of the Northern Hemisphere at 48°N and 62°N

Seasonal PDFs for wind speed and SWH

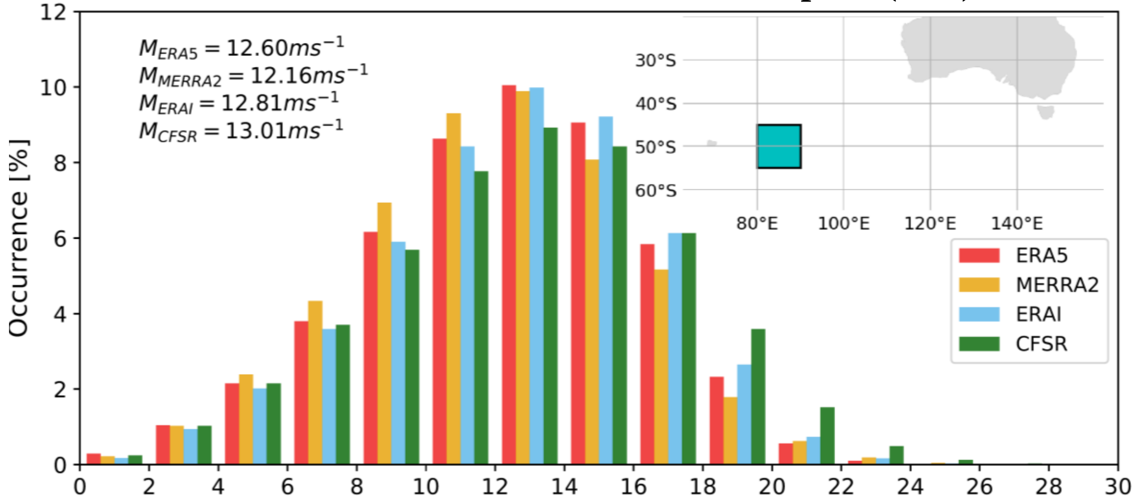
North Atlantic wind speed (DJF)



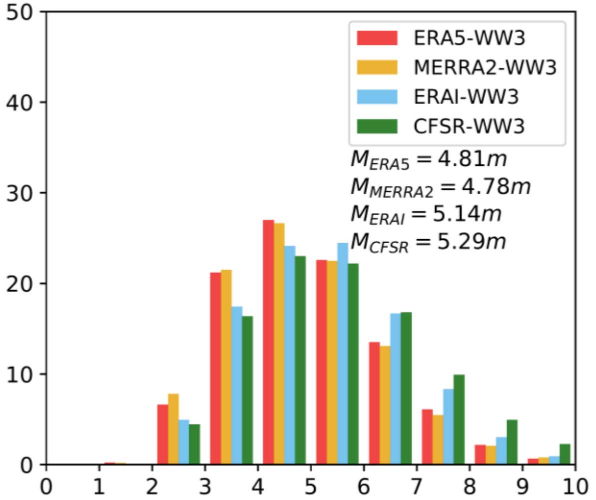
North Atlantic SWH (DJF)



Southern Indian Ocean wind speed (JJA)



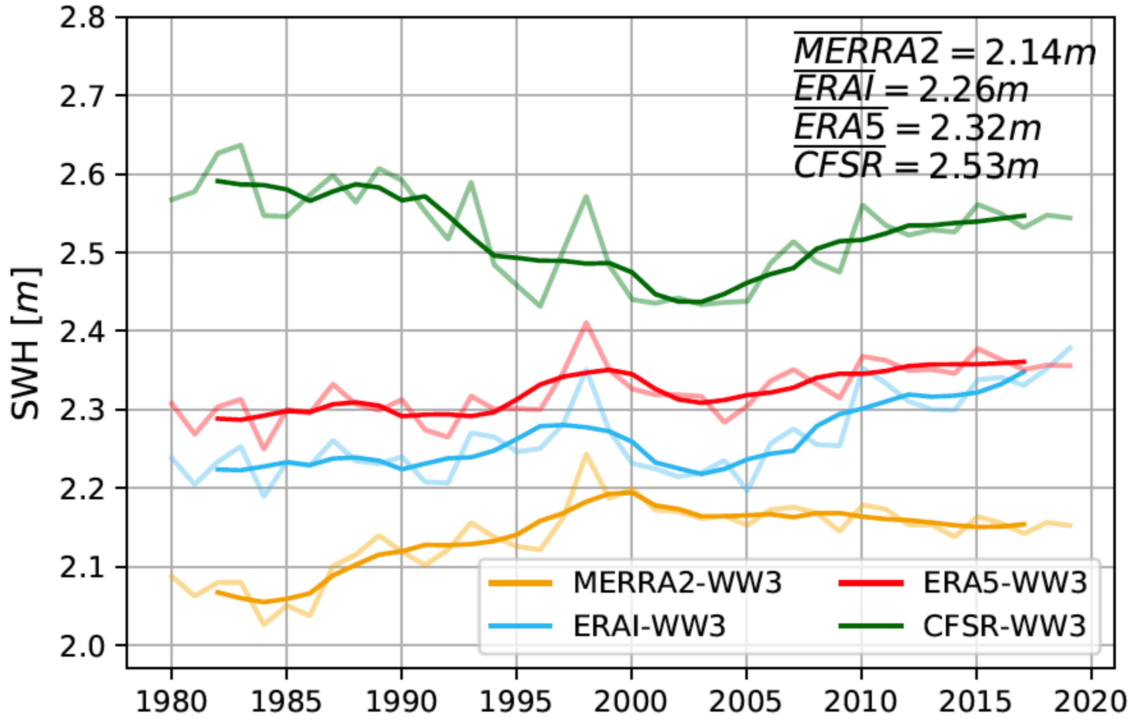
Southern Indian Ocean SWH (JJA)



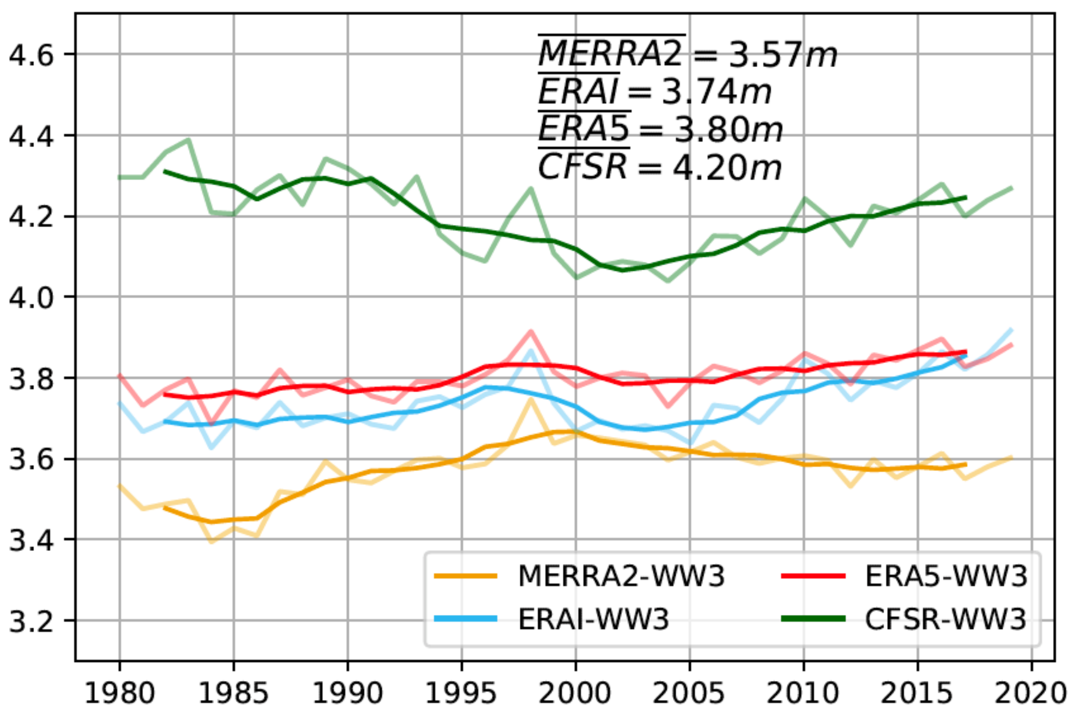
- CFSR shows the occurrence of wind speeds higher than 20 ms^{-1} from 1.4% to 5.8% in selected regions
- Similarly, CFSR-WW3 shows the occurrence of SWH higher than 7 m from 5.5% to 17.1%
- In the Southern Indian Ocean the higher occurrence of high wind speeds is observed for CFSR and ERAi, which is also mirrored in the SWH distributions

Interannual variability of global SWH

Global mean SWH for 1980-2019 (5-yr running mean)



Global 95p SWH for 1980-2019 (5-yr running mean)

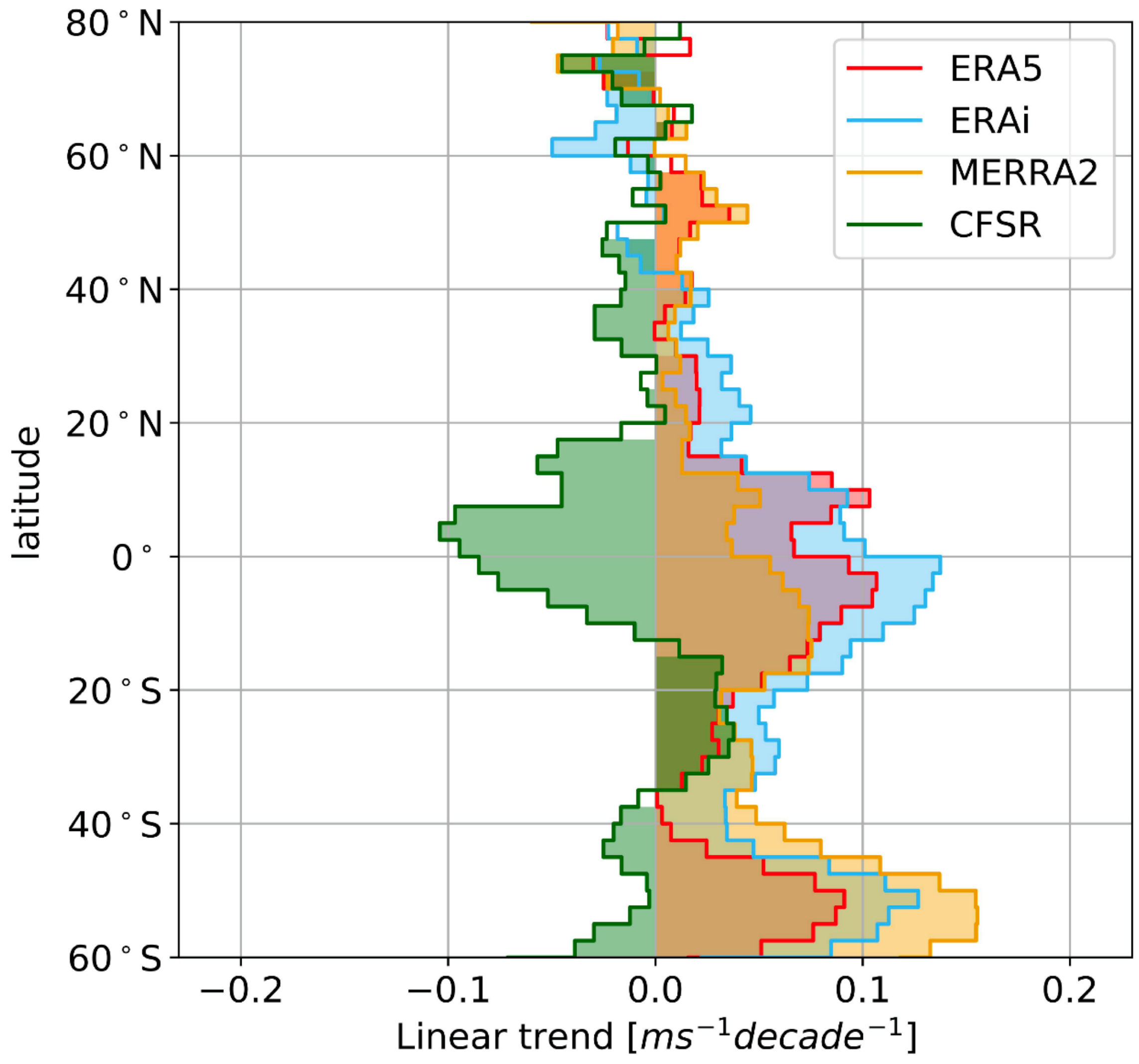


- The largest difference amounts up to 0.4 m for SWH (2.5 m in CFSR-WW3 and 2.1 m in MERRA2-WW3)

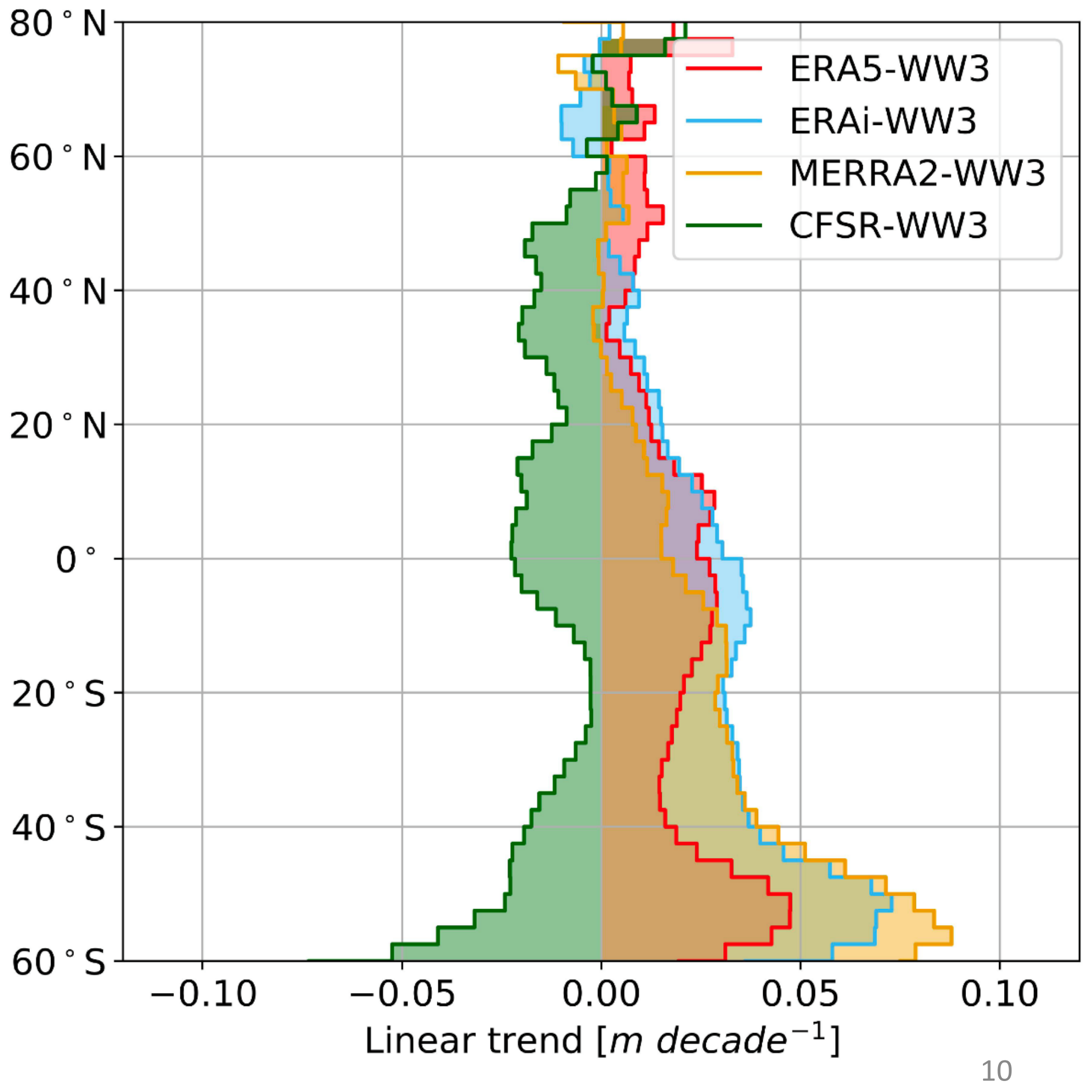
- 95p SWH show a difference of up to 0.6 m for SWH (4.2 m in CFSR-WW3 and 3.6 m in MERRA2-WW3)

Linear trends in annual mean wind speed and SWH (1980-2019)

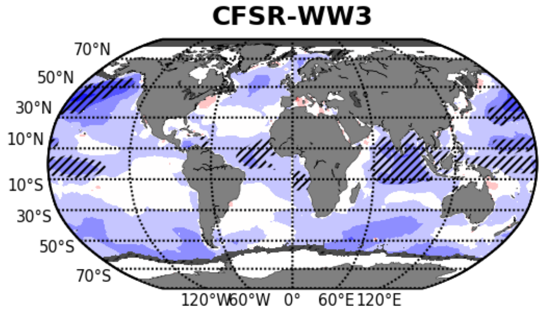
Zonally averaged trends in mean wind speed



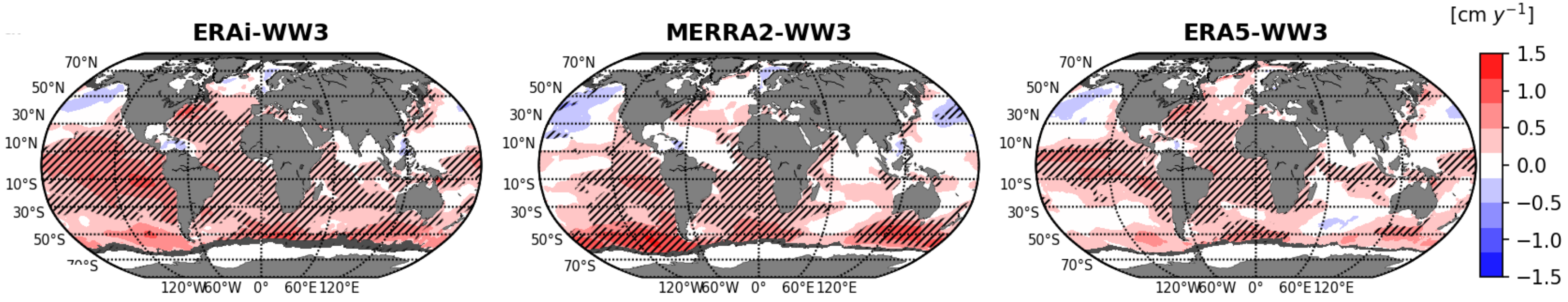
Zonally averaged trends in mean SWH

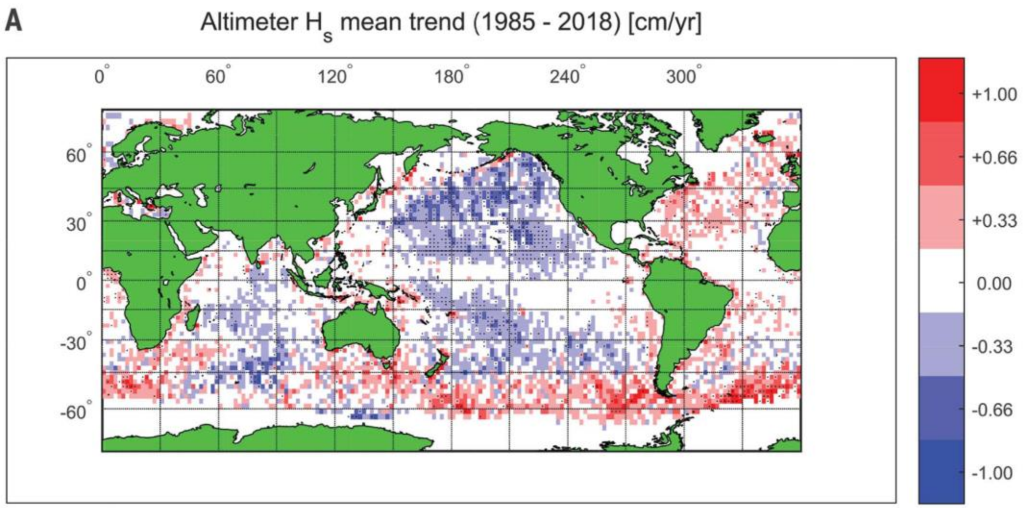


Intercomparison of trends between hindcasts and multiplatform satellite datasets (1985-2018)



- CFSR-WW3 agrees in negative linear trends in the North Pacific, while magnitudes are twice

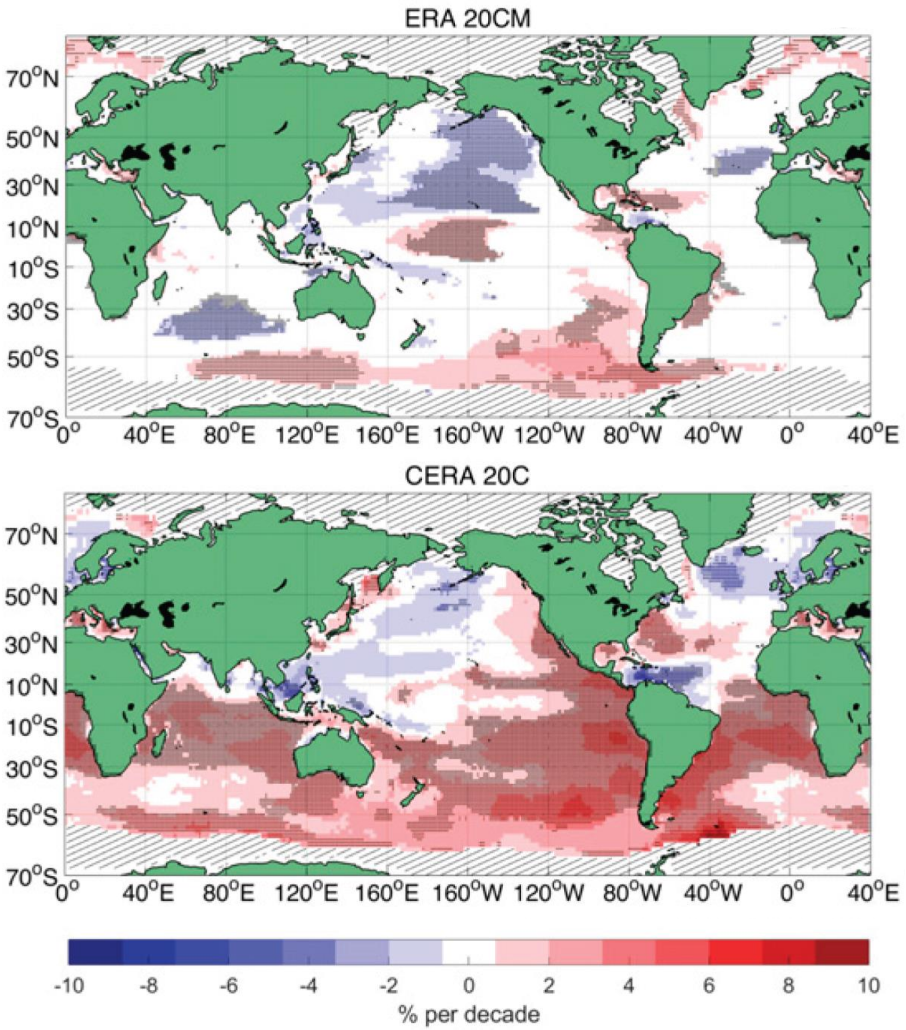




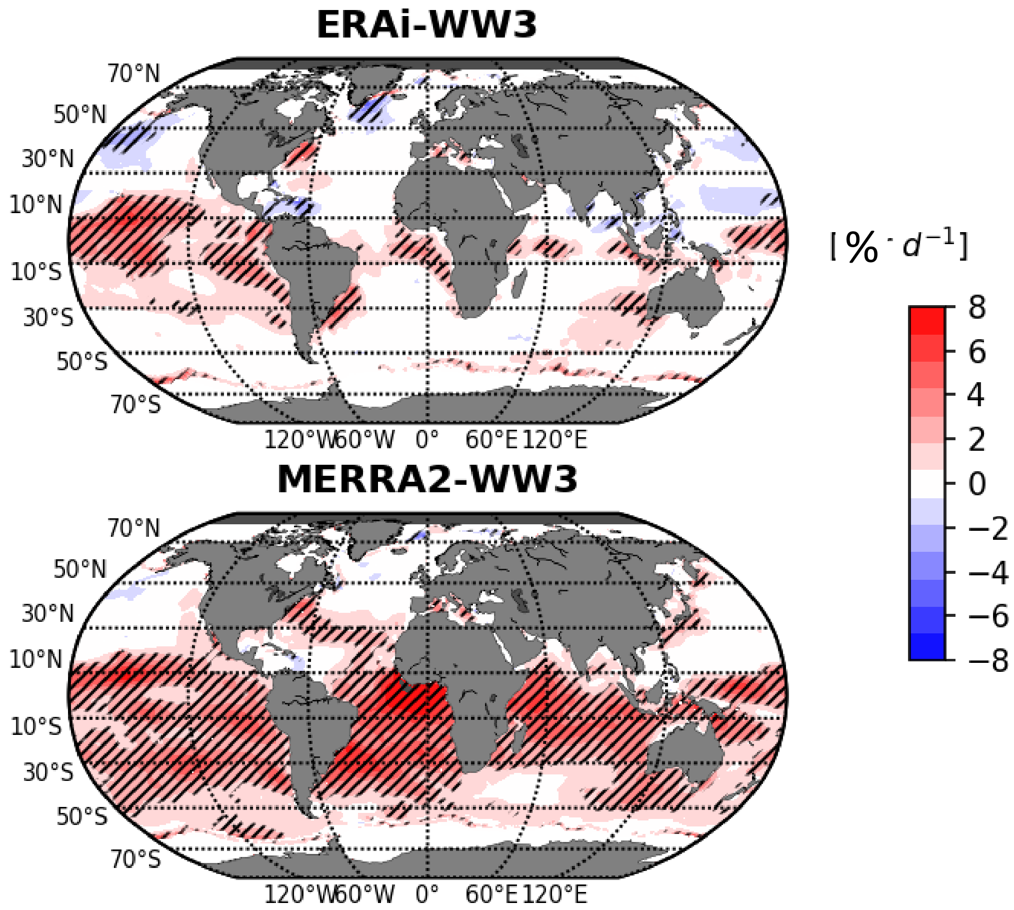
- Positive linear trends in SWH in are consistent in the South Atlantic and have magnitudes of 0.9-1 cm/yr.

(Young et al., 2019)

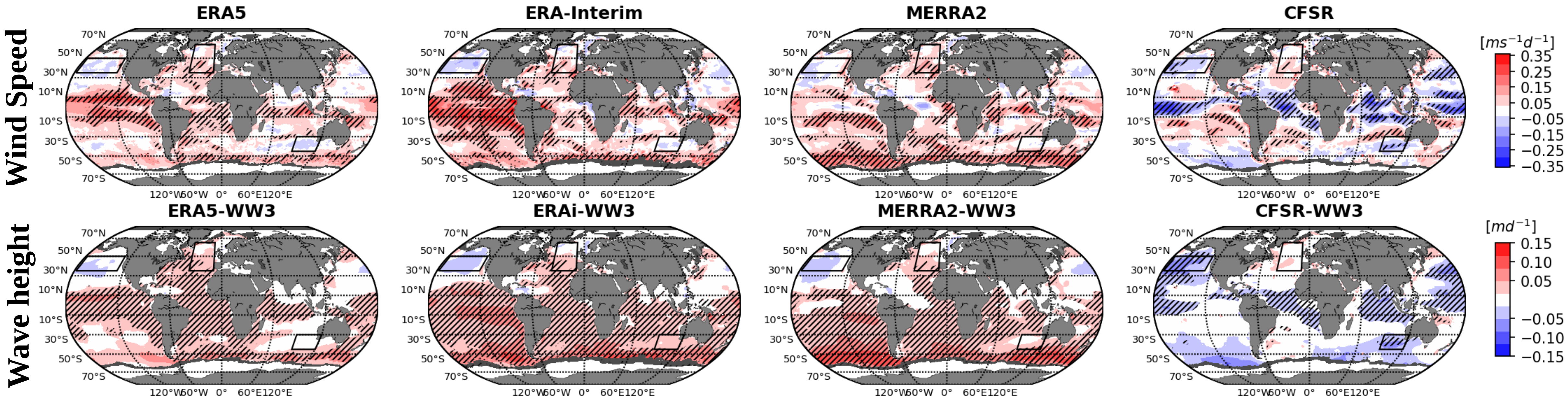
Intercomparison of trends between hindcasts and two century-long reanalyzes (1985-2010)



(Meucci et al., 2019)



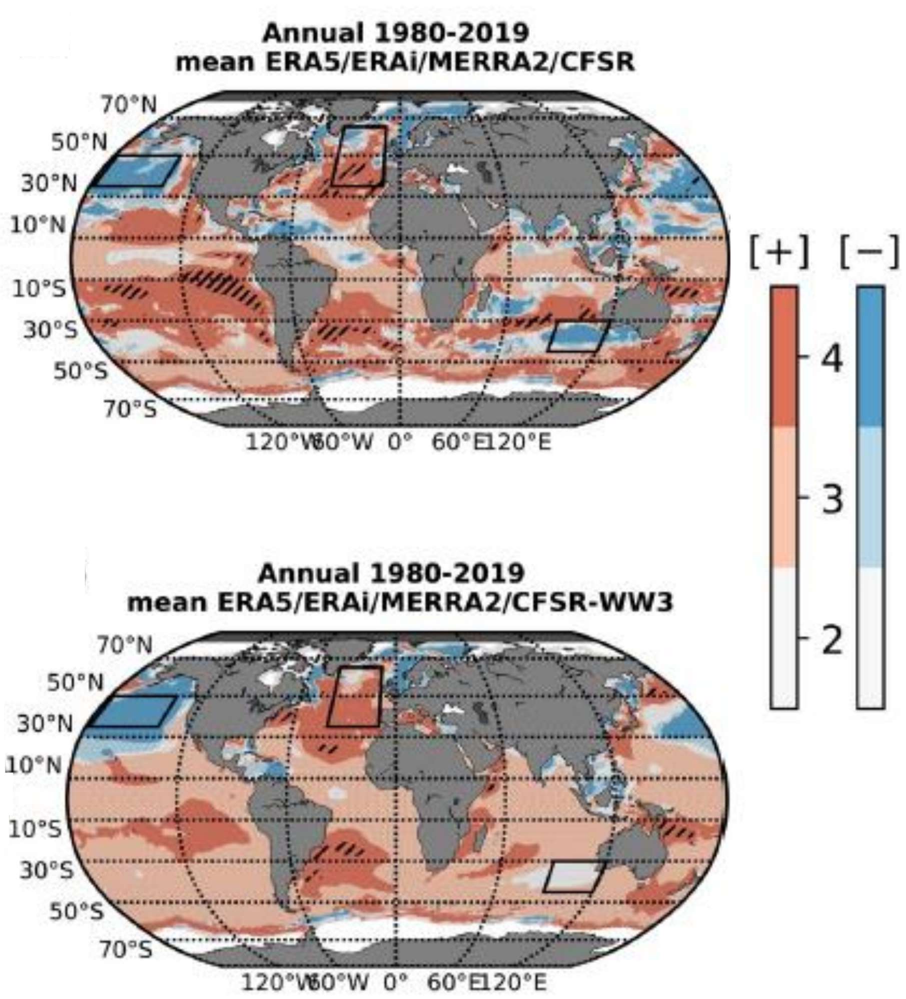
Linear trends in annual mean wind speed and SWH (1980-2019)



Agreement in sign of linear trends among reanalyzes and hindcasts

Wind Speed

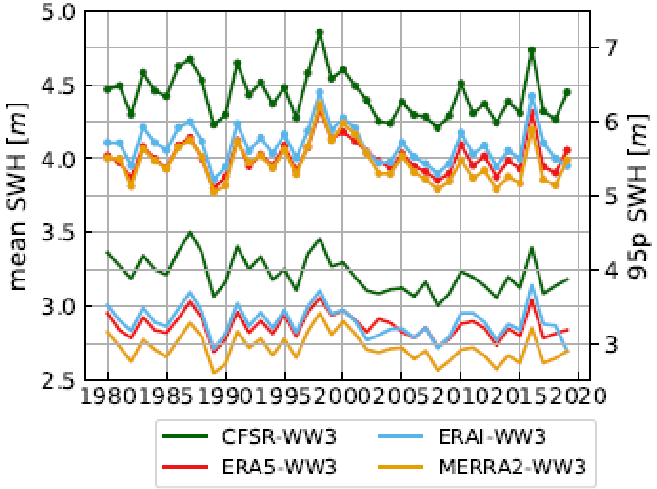
Wave height



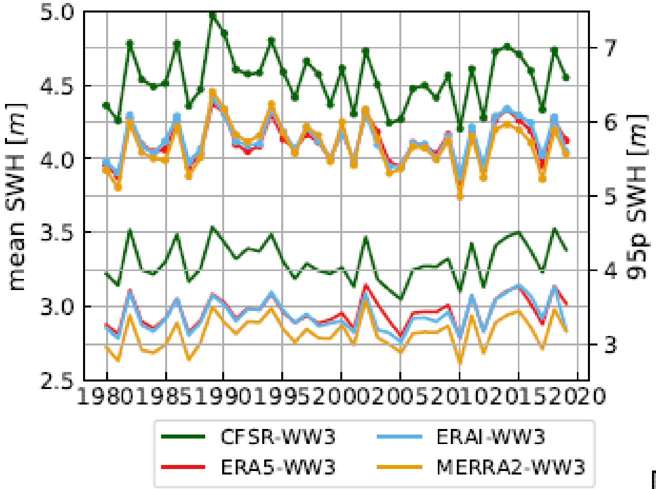
- In the **North Atlantic midlatitudes** and **subtropics, western South Atlantic midlatitudes** and the **tropical South Pacific** all datasets agree on the positive sign of linear trends in mean wind speed and SWH demonstrating the robustness of this patterns.
- There is also an agreement in all four reanalyzes on the negative trends in wind speeds over the eastern North Pacific midlatitudes, which is translated into the negative trends in SWH.
- The four datasets do not agree on the sign of the trend in extreme wind speeds and in SWH in the eastern North Atlantic midlatitudes

Regional consistency of sign of linear trend on different time segments

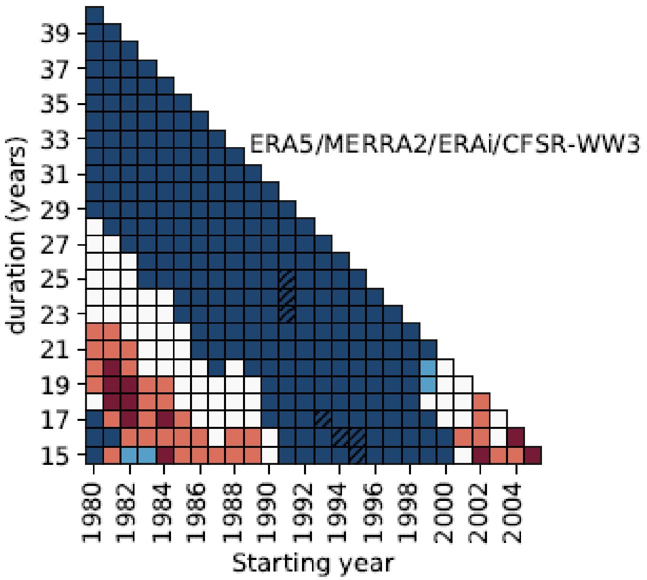
Northeast Pacific annual SWH



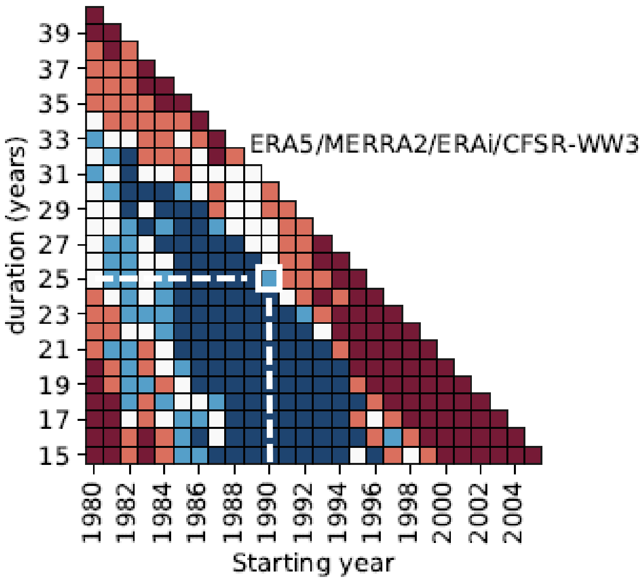
Northeast Atlantic annual SWH

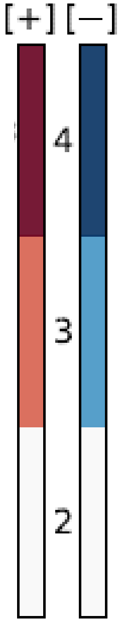


Northeast Pacific annual SWH



Northeast Atlantic annual SWH



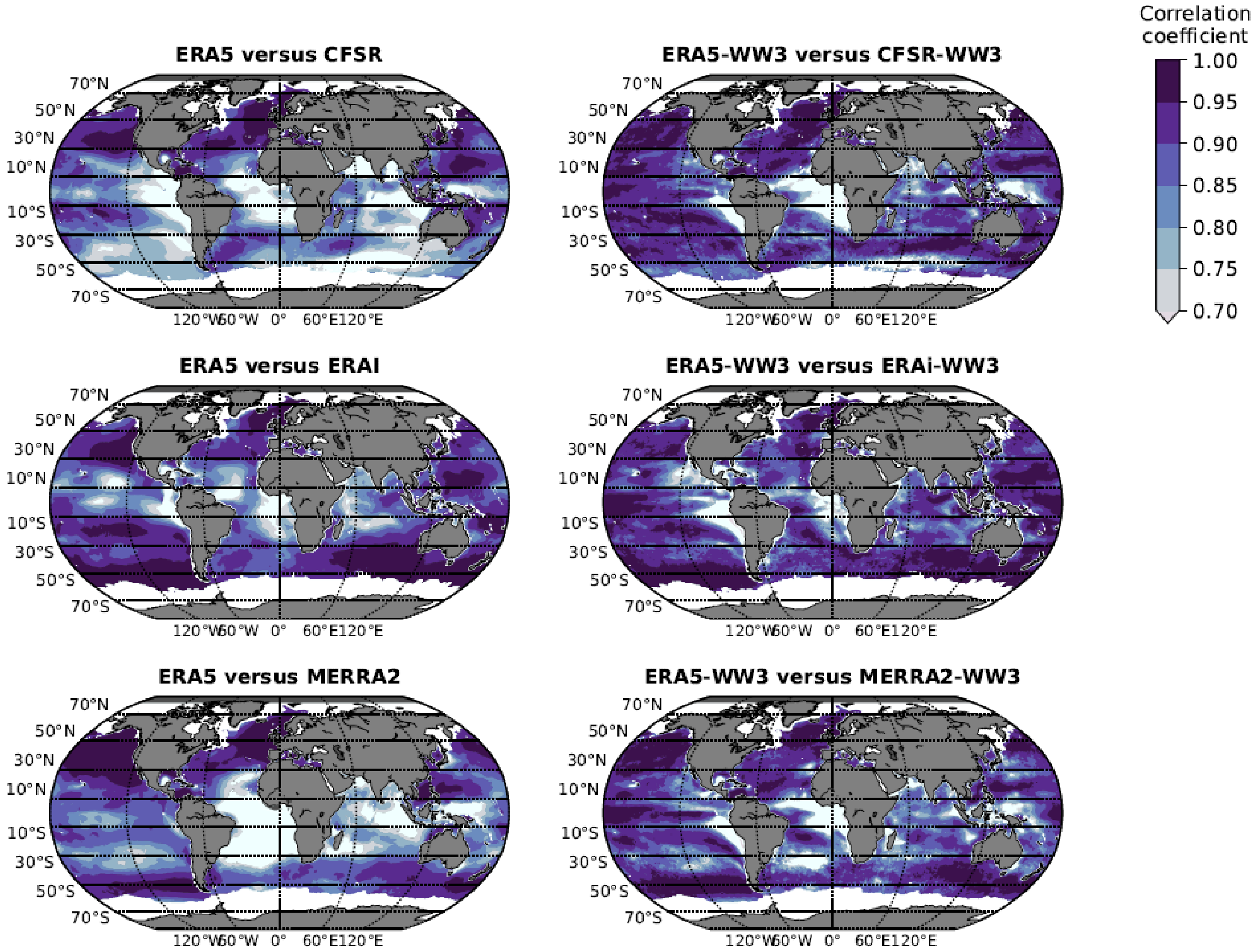


- In the Northeast Pacific all datasets agree on the negative trends in mean SWH over the entire period, and these trends are statistically significant in all hindcasts for 1991–2006

- There is little agreement on the sign of trends in the mean SWH for 1980–2004

- There is an agreement on positive trends in the Northeast Atlantic in mean SWH over the beginning (1980–1998) and the end (2001–2019) of the analyzed period

Point correlation between detrended time series of annual wind speed and SWH



- The correlations are generally higher in the NH, exceeding 0.9 nearly everywhere
- In the SH, the interannual variability in wind speeds is more consistent in ERA5 and ERAi, while in the Southern Ocean ERA5 is also closely correlated with MERRA2
- The largest correlation coefficients for both wind speeds and waves are observed in the eastern parts of the basins in midlatitudes

Conclusions

- Four wind wave hindcasts (**CFSR-WW3, ERA5-WW3, MERRA2-WW3, ERAi-WW3**) have been developed for 1980-2019
- They **are made freely available** to the users at 6-hourly time resolution: https://wave-hindcast.ocean.ru
- CFSR and CFSR-WW3 show the largest magnitudes of the mean and extreme wind speeds and SWH. **The largest differences between CFSR and ERA5** in **the extratropics** for annual characteristics amount **to 2.4 ms^{-1} for wind speeds** and **1.2 m for wave heights**
- **CFSR and CFSR-WW3** stand out with respect to remaining datasets, showing mostly **negative trends in** both mean and extreme wind speeds and **SWH in the Southern Ocean, central Pacific, equatorial and tropical Atlantic and Indian Oceans** where the remaining reanalyzes and hindcasts demonstrate upward changes.