Projected 21st Century changes in extreme wind-wave events from an ensemble of global ocean wave climate models

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The missing piece

Extremes uncertainty

Past uncertainties:

- Wave model
- Atmospheric model
- Observations
- Statistical

Future uncertainties:

- Emissions scenarios
- GCMs

Background

Design Sea State: Typically defined as the maximum significant wave height which can be expected over an N year period.

Collaroy (NSW) 2016 storm

(Hinkel et al., 2014)

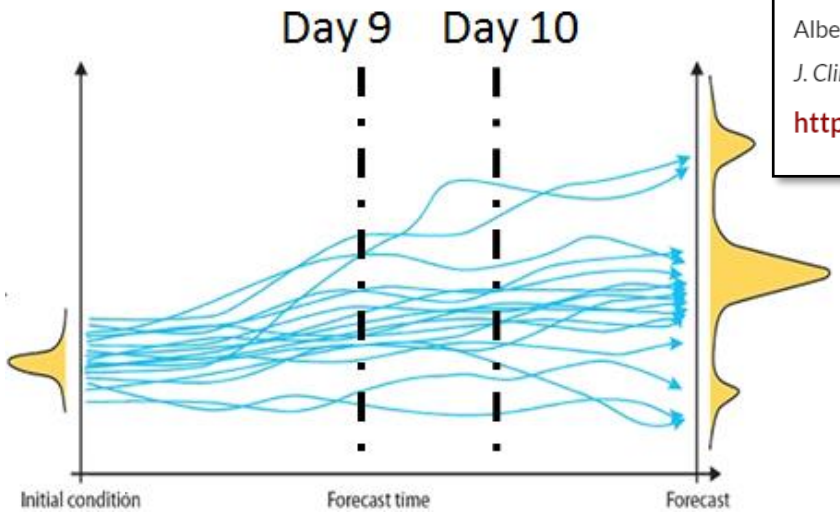
In 2010, **290 million** people worldwide lived **below the 100-year flood level** and *US$9600 billion* of assets were exposed to inundation

1 in **100 years** significant wave height

Extreme Value Analysis (EVA)

Ensemble approach to EVA

1. Single-model ensemble



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Wind and Wave Extremes from Atmosphere and Wave Model Ensembles

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(Meucci et al., 2018)

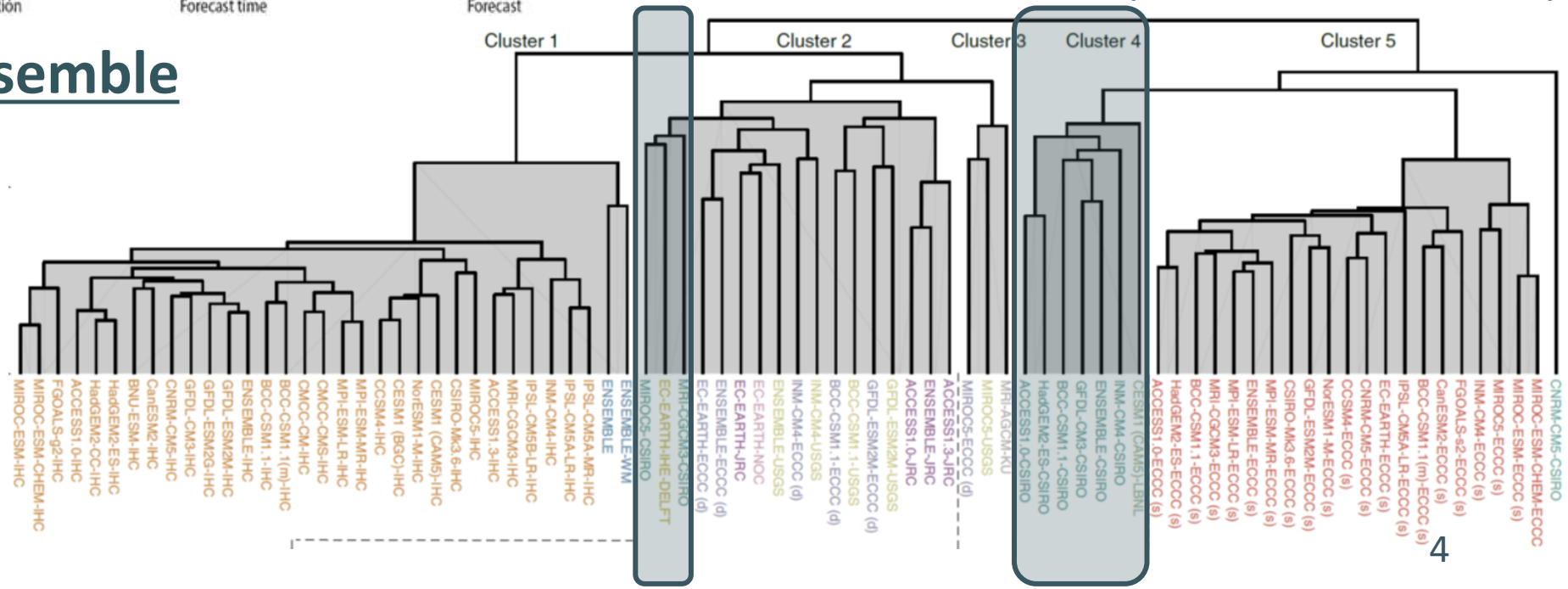
Equivalent of 750 years dataset

(Morim et al., 2019)

2. Multi-model ensemble

SEVEN 6-hourly wave **model runs** with CMIP5 GCM surface wind forcing

(Hemer et al., 2016)



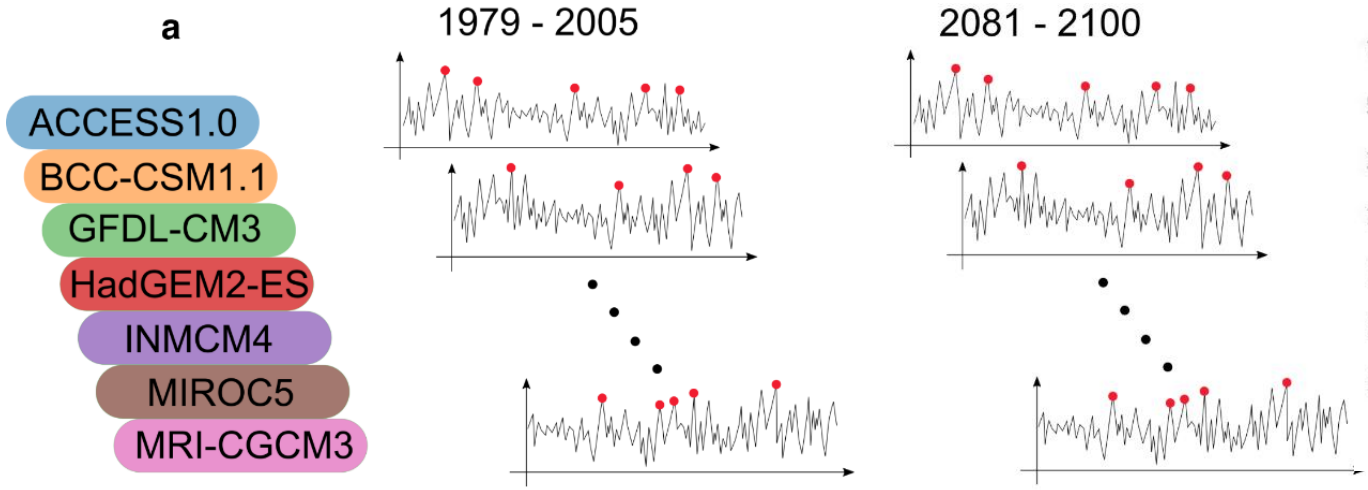
Selection of extremes

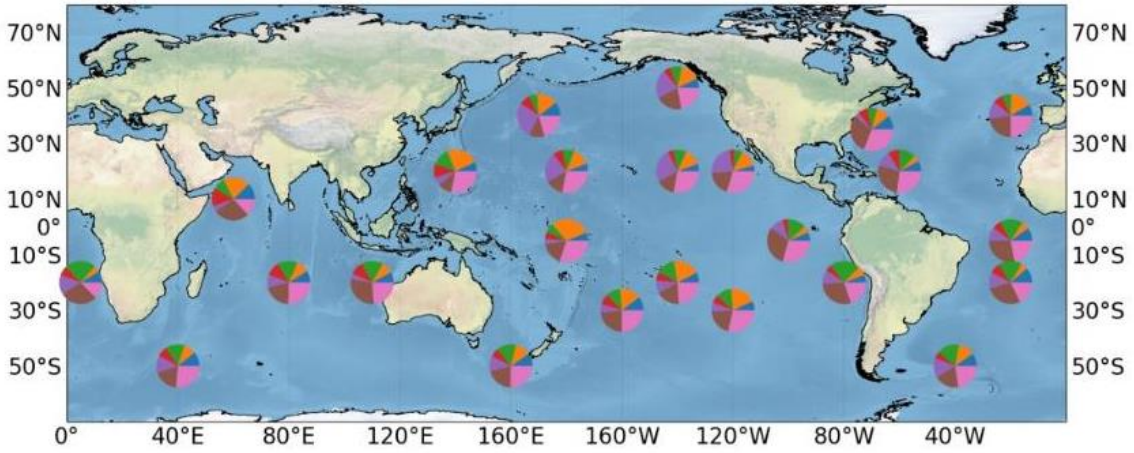
(Hemer et al., 2016)

1000 highest peaks

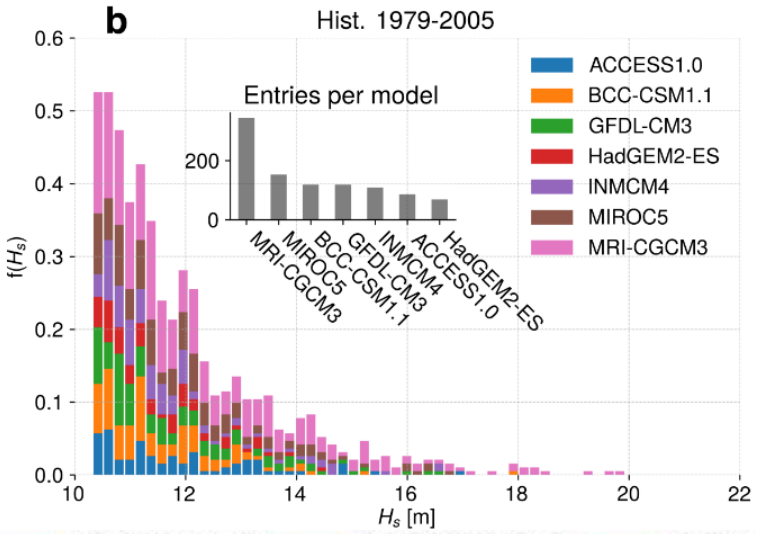
peaks over 90th percentile threshold for each model -- 48h storm independence

(Lopatoukhin et al., 2000)

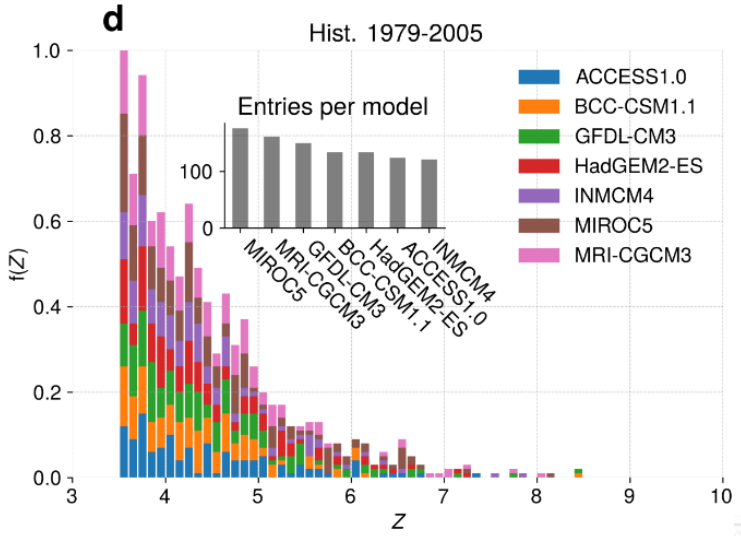




6-hourly Hs without Bias Correction



Standardized Z



Bias correction:

$$Z_m = \frac{H_{s,m} - \mu_m}{\sigma_m}$$

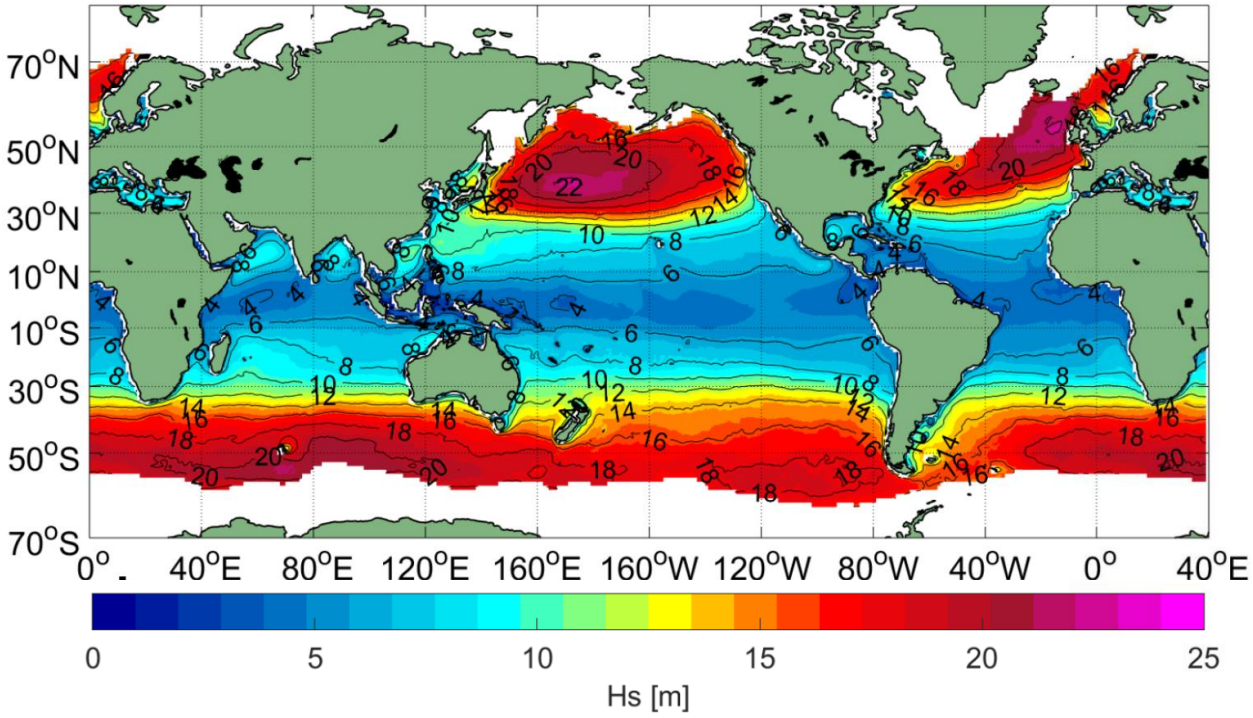
(Aarnes et al., 2017)

ACCESS1.0 BCC-CSM1.1 GFDL-CM3 HadGEM2-ES INMCM4 MIROC5 MRI-CGCM3

Historical H_s^{100} 1979-2005

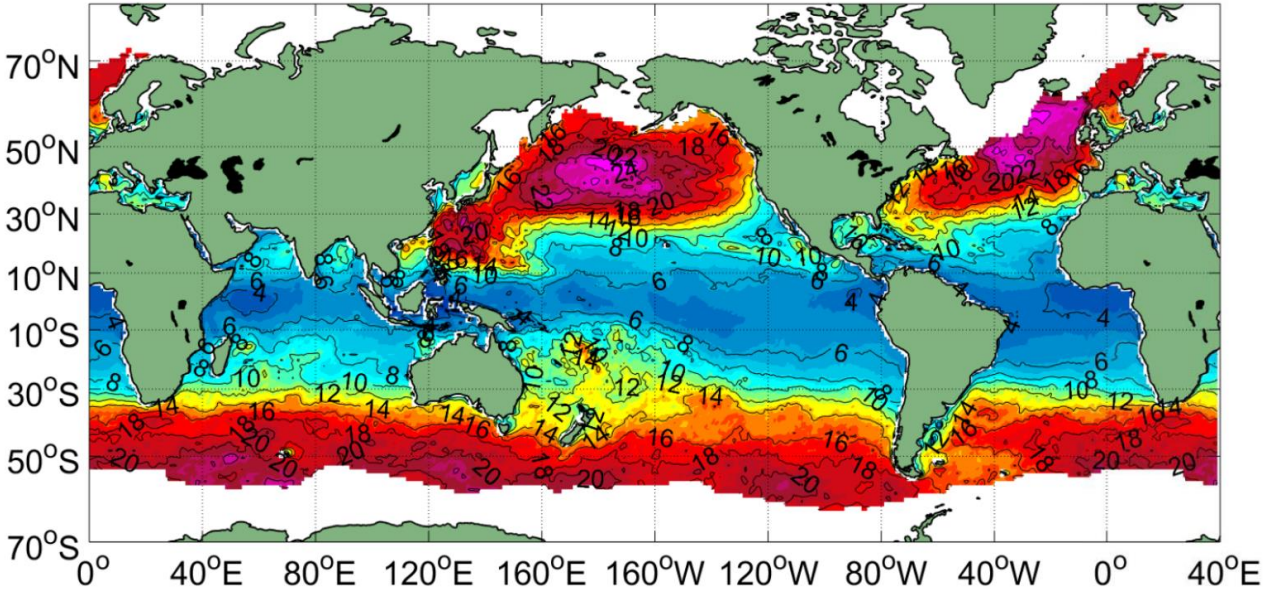
(Meucci et al., 2020)

Multi-model ensemble

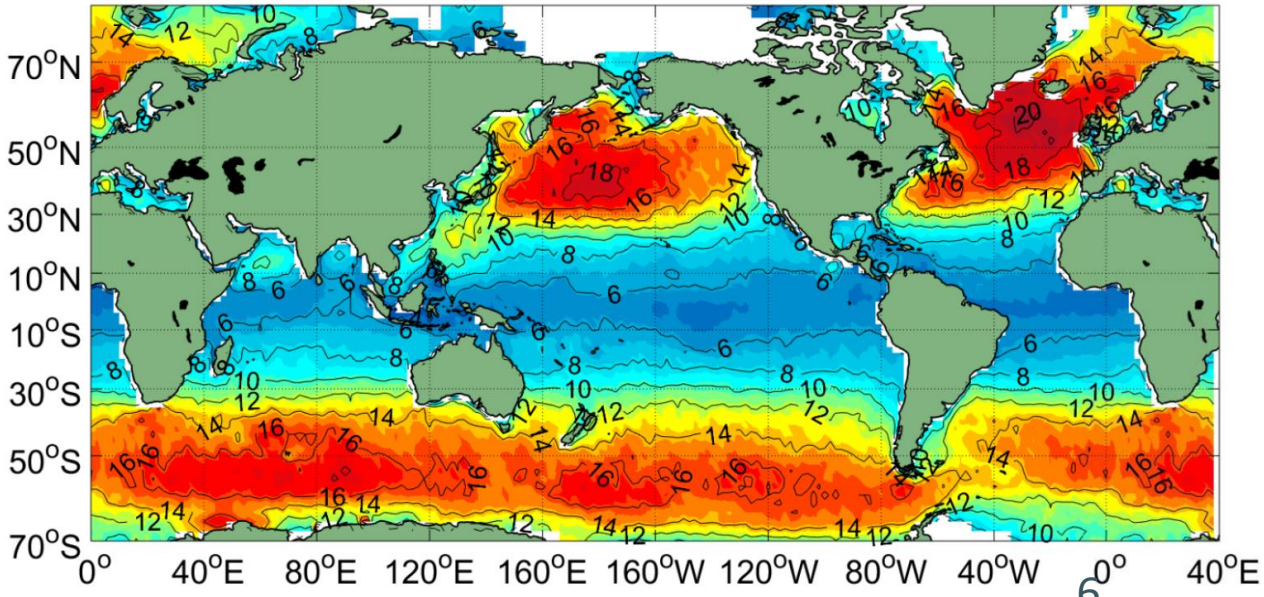


T_{eq} = 27 years · 365 · 4 hindcasts a day · **6h** · 7 GCMs = **189 years**

Wave model - CFSR winds

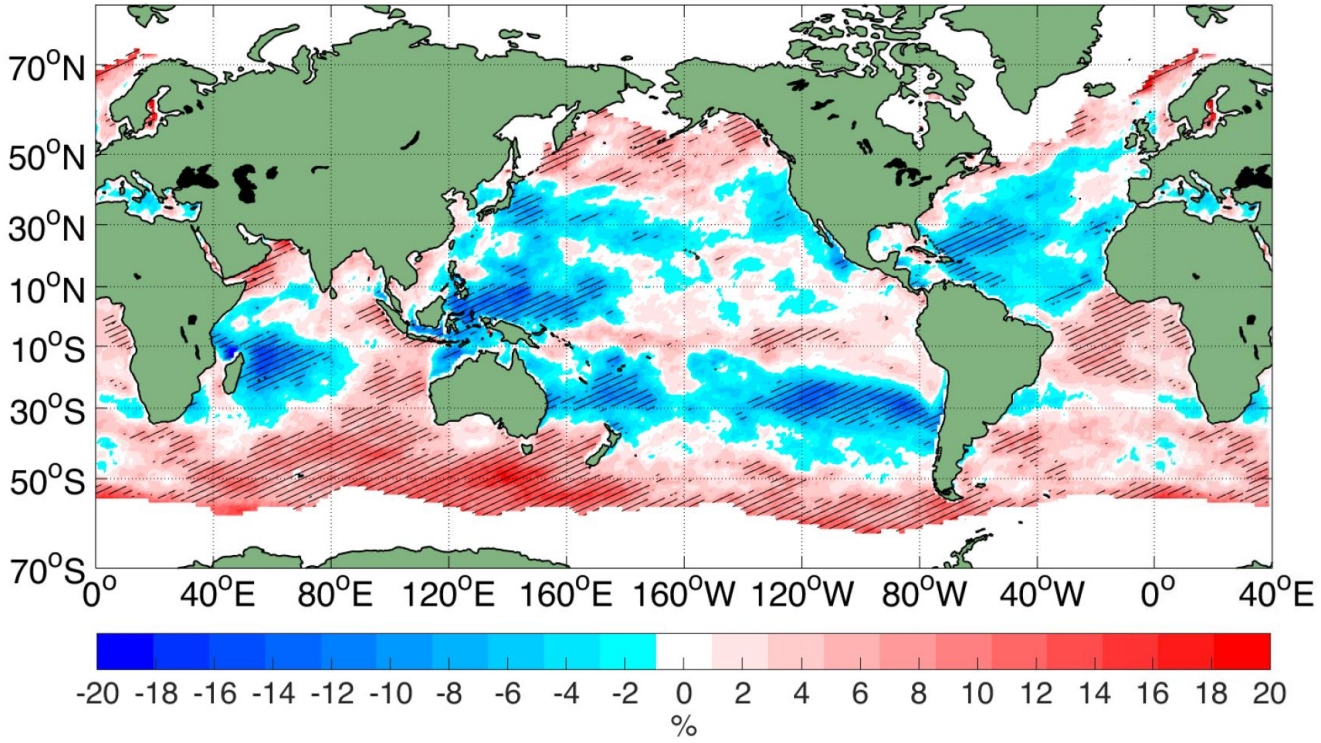


Satellite Altimeter (Young and Ribal, 2019)



Projected changes in wind-wave extremes - RCP8.5

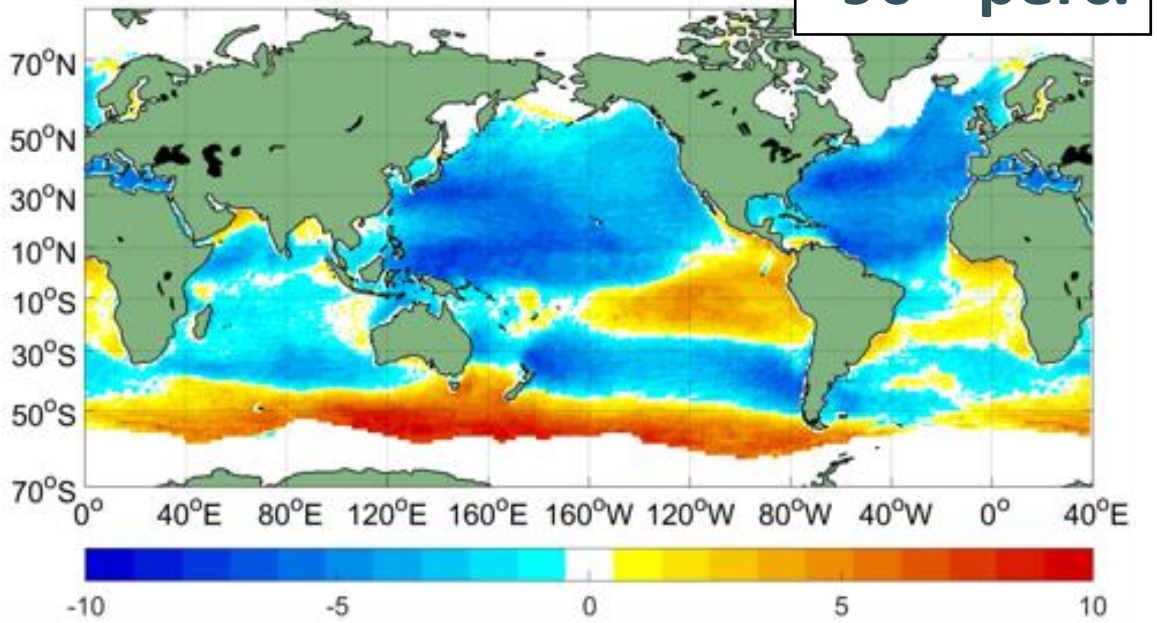
Changes in H_s^{100} (Meucci et al., 2020)

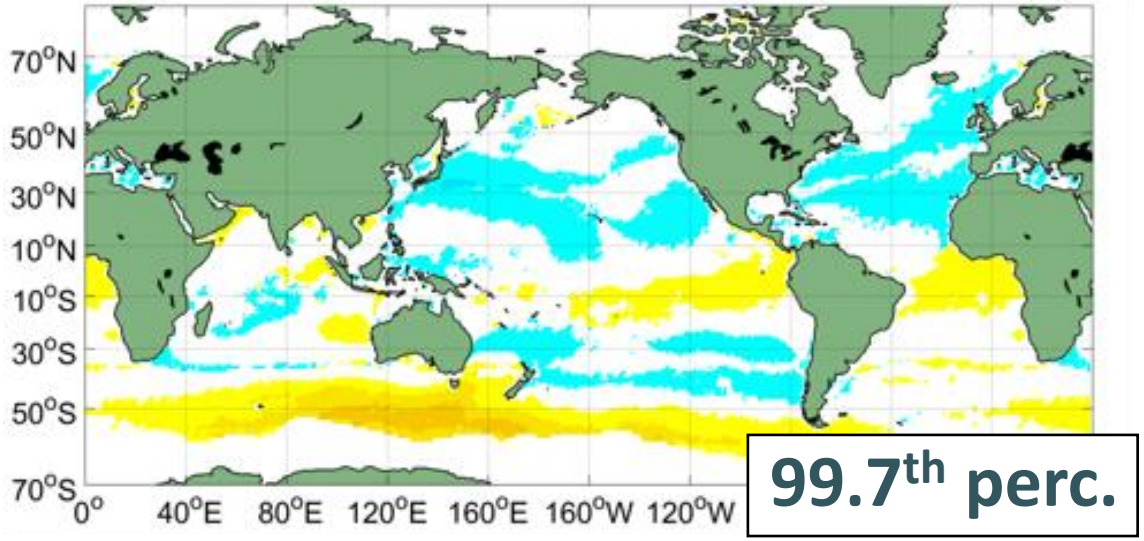


$$\Delta H_S^{100} = \frac{H_{S,proj}^{100} - H_{S,hist}^{100}}{H_{S,hist}^{100}}$$

n. extremes per year

90th perc.





99.7th perc.

Limitations

- Stationarity
- Inhomogeneous datasets
- Tropical Cyclones still not correctly reproduced by GCMs

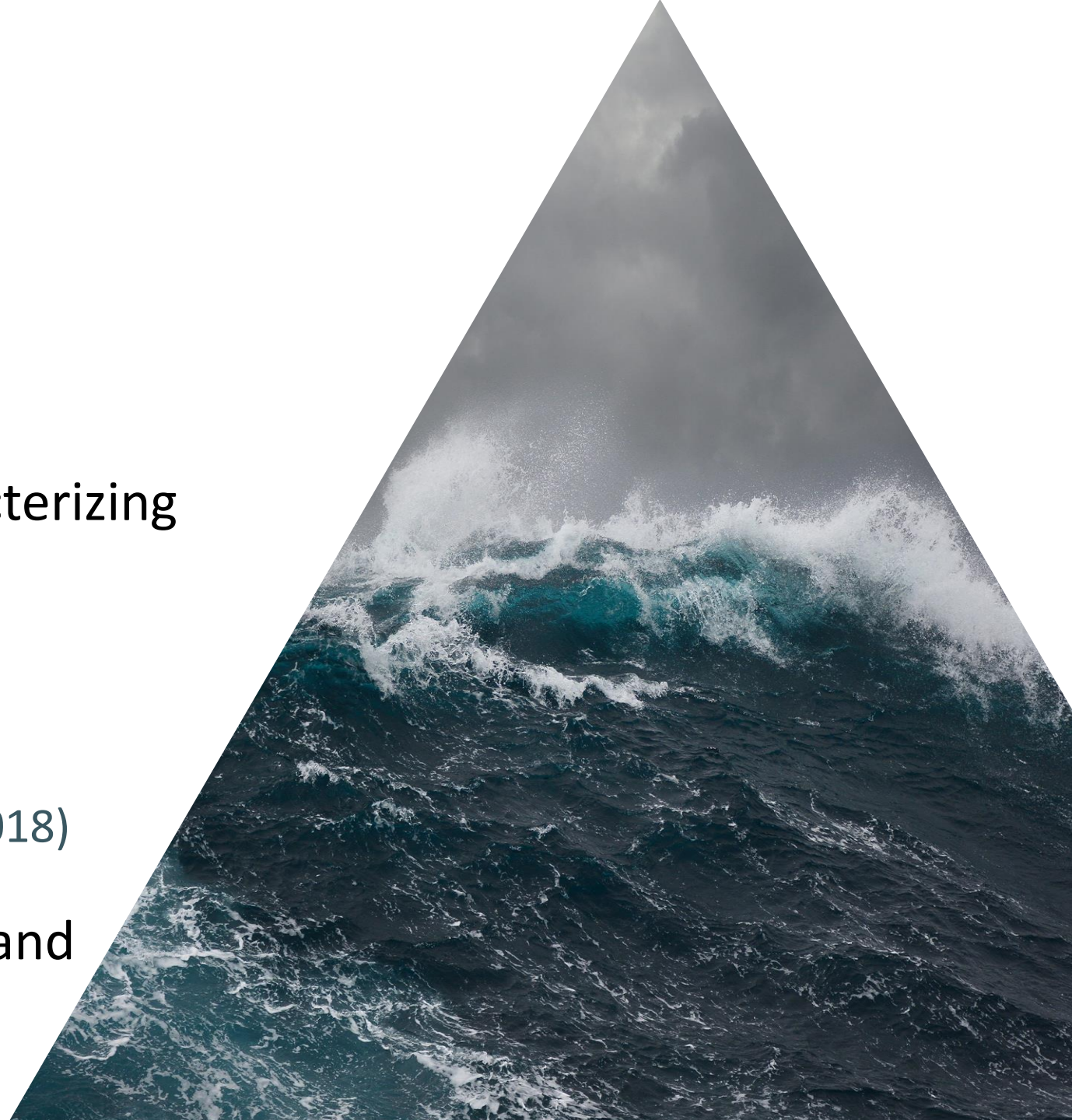
Potential

(Hemer et al. 2013; Wang et al. 2014; Aarnes et al. 2017; Morim et al. 2019)

- Results are consistent with previous studies
- Inter models low correlation guarantees independence
- Possibility to synthesize an equivalent time series of duration longer than the simulation period
- Increased dataset reduces confidence intervals

At what point are we?

- Higher resolution models needed
- Ensemble approach to TC areas
- Still many uncertainties are characterizing the observations of extremes
- Improved GCMs and additional models may allow Direct Return Estimates (Meucci et al., 2018)
- Updated EVA with CMIP6 models and latest wave modelling physics



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Supplementary material

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