



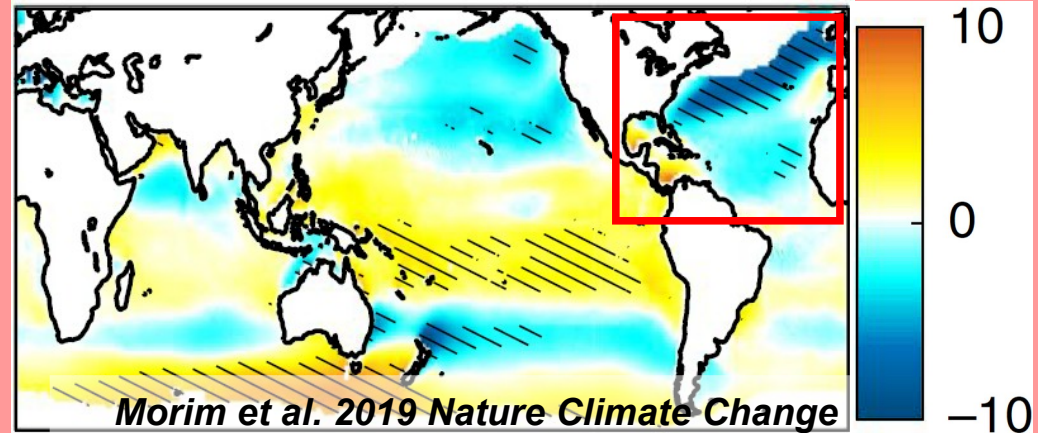
Projected future changes in tropical cyclone-related wave climate in the North Atlantic

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F. Chauvin (Météo-France/CNRM/GMGEC/AMACS)
R. Pilon, P. Palany (Météo-France/DIRAG/ECMPF)

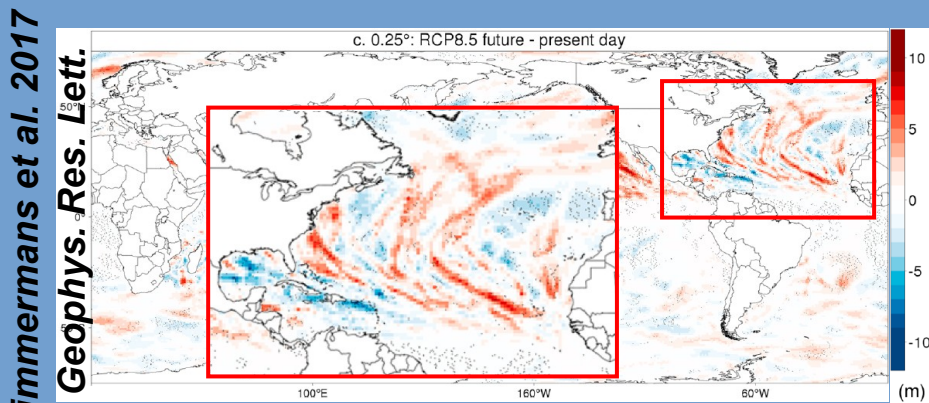
ESA Sea State CCI : User Consultation Meeting #2, 23/03/2021

Projected North Atlantic Wave Climate State of the Art

- **Reduced average wave heights** 5-10 % year-round
- Coarse-resolution multi-ensemble approach $\sim 0.5/1^\circ$ wind/waves



Projected changes in mean significant wave height (%) in JJA for 2081-2100 (RCP8.5) compared to 1979-2004

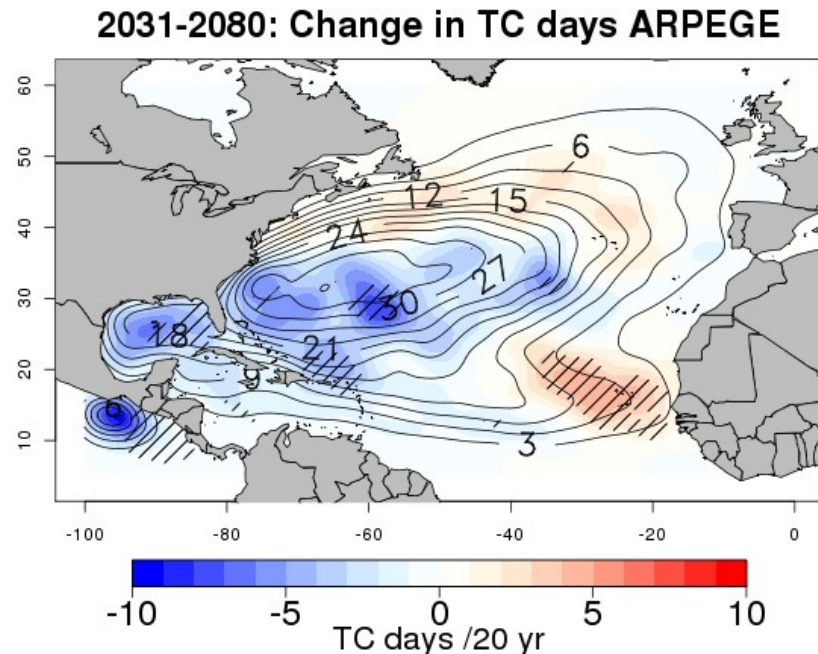
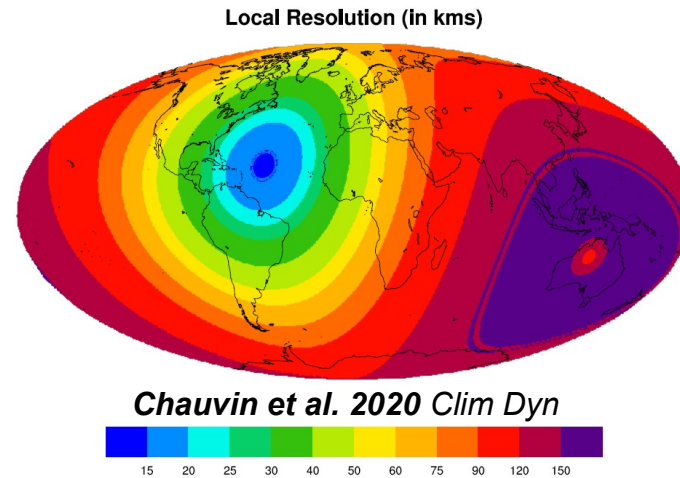


Projected changes in 20-year significant wave height (m) for 2081-2099 (RCP8.5) compared to 1995-2005

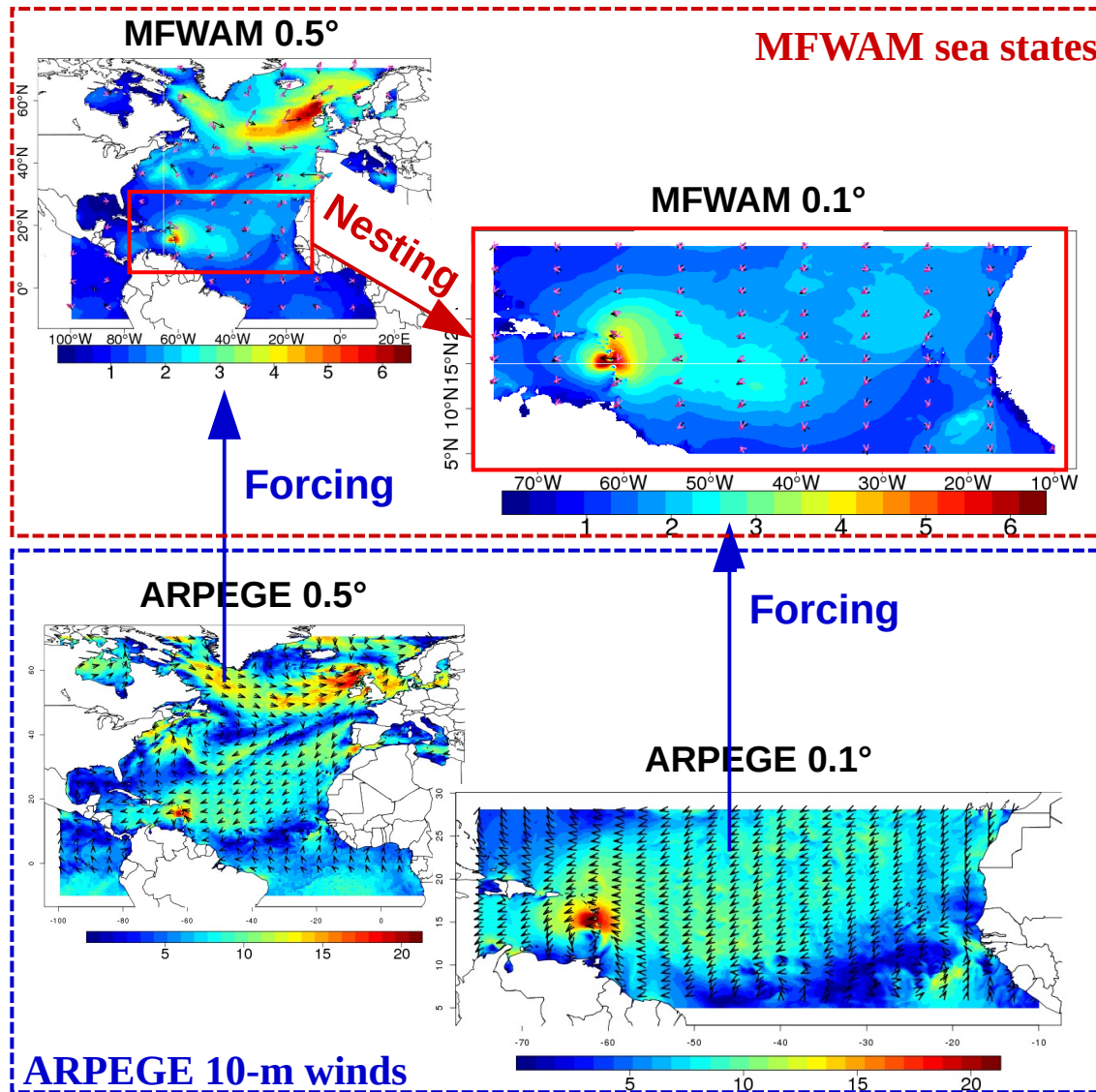
- **TC wave heights** : noisy patterns of change influenced by individual TCs => ~ 20 yrs too short for robust projections in the Atlantic
- Single-model 25km wind/waves

Projected Tropical Cyclone Activity

- **Arpege-Climat v6.2**
2 historical + RCP8.5 expts.
5 members
 - **TC tracking**
 - **Realistic TCs** but underestimated numbers in the tropics
 - Future projections:
 - (slightly) **less TCs** except near Cape-Verde & mid-latitudes
 - more TCs in **September**
 - Increase in the proportion of **major hurricanes**
- => Effects on wave climate?**



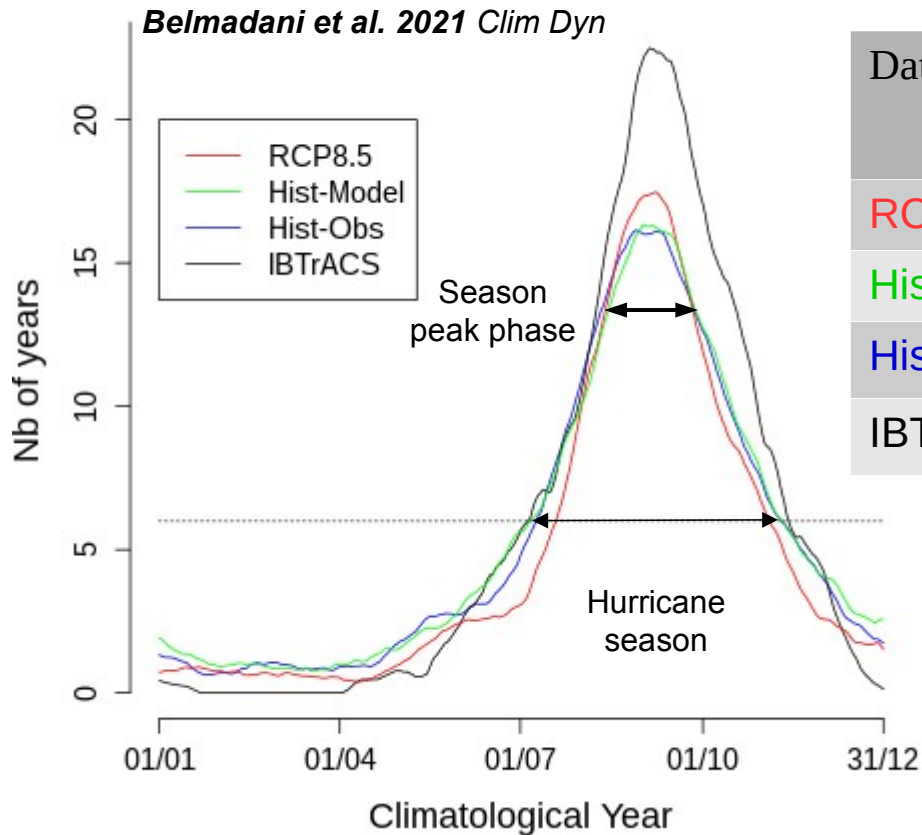
Wave Model Forcing & Nesting



Definition of the Hurricane Season

Nb of TC years in ARPEGE and IBTRaCS

Belmadani et al. 2021 Clim Dyn

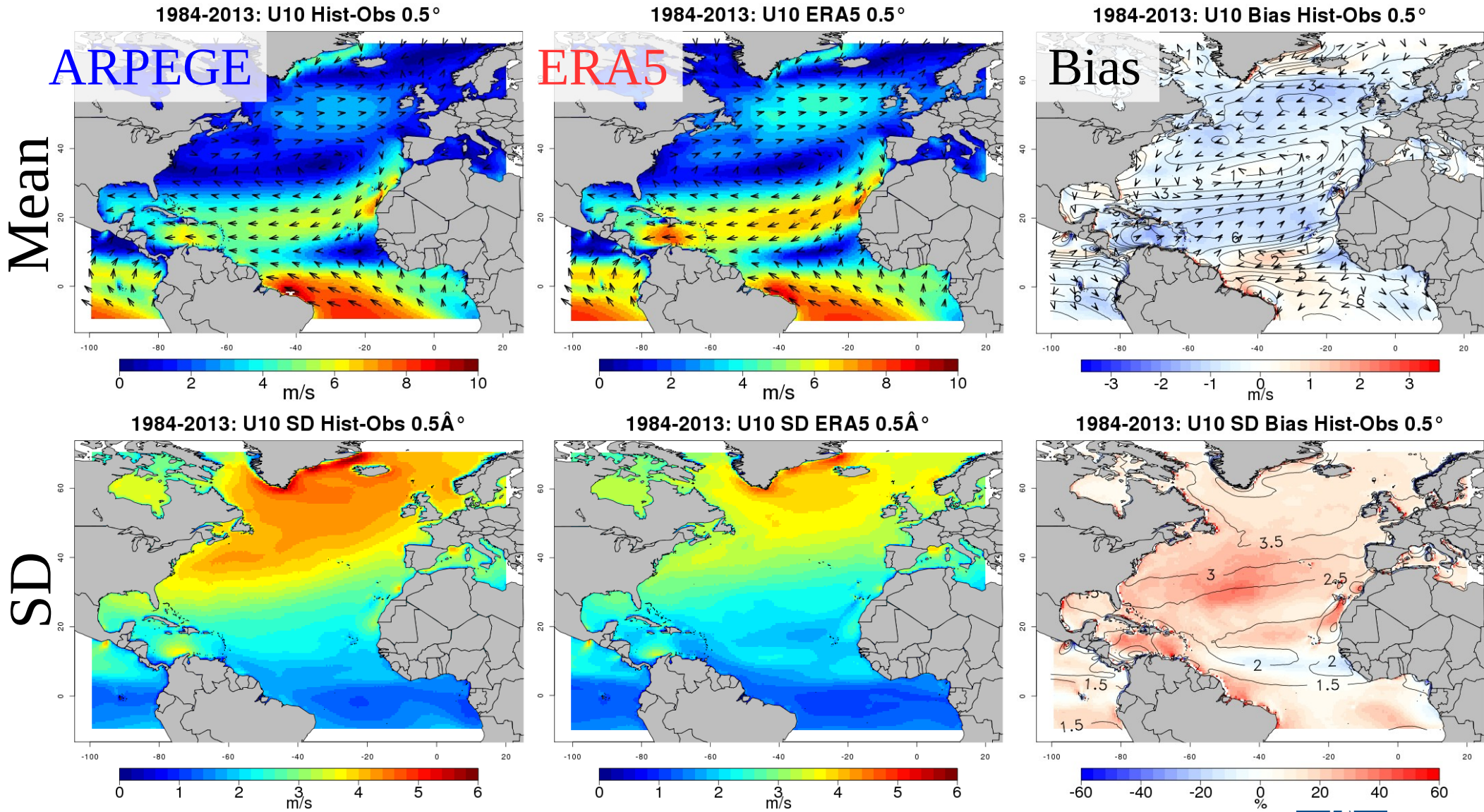


Data	Time span	Hurricane Season	Season Peak Phase
RCP8.5	2051-2030	20 Jul – 3 Nov	17 Aug – 18 Sep
Hist-Model	1984-2013	6 Jul – 10 Nov	17 Aug – 15 Sep
Hist-Obs	1984-2013	9 Jul – 9 Nov	
IBTRaCS	1984-2013	5 Jul – 13 Nov	

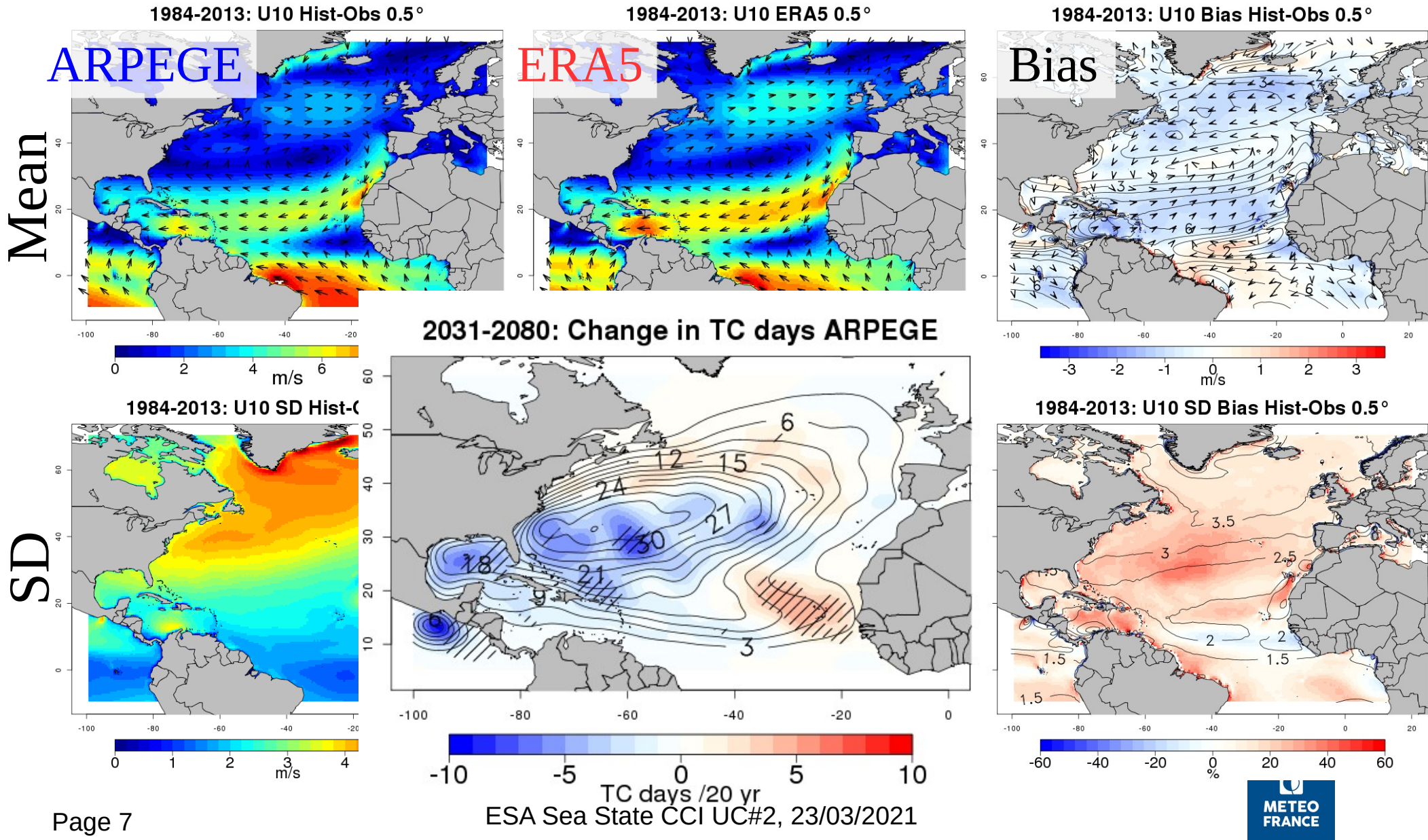
3 expts x 5 members x 30 years = 450

MFWAM05&01: 450 hurricane seasons

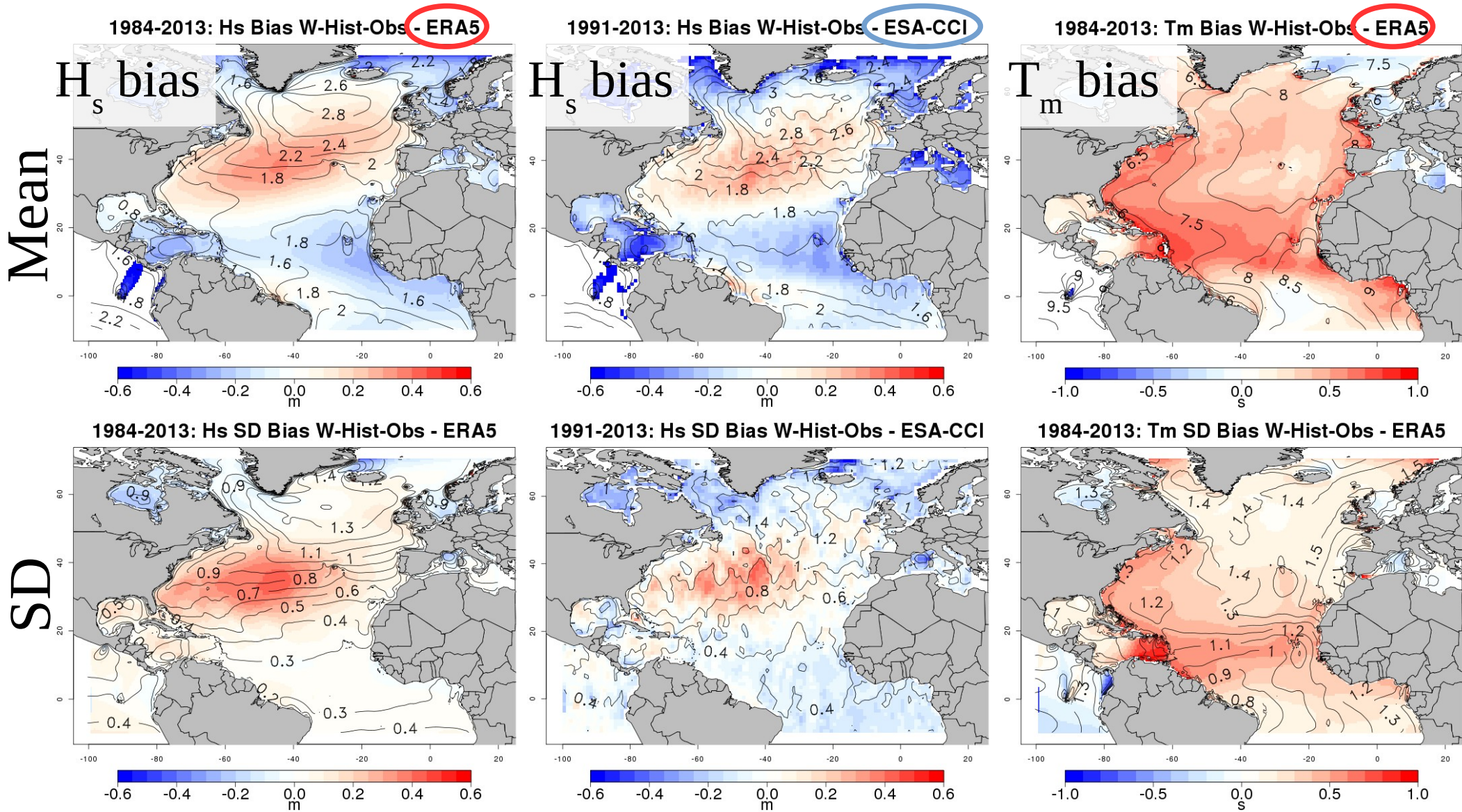
Atmospheric Model Performance



Atmospheric Model Performance



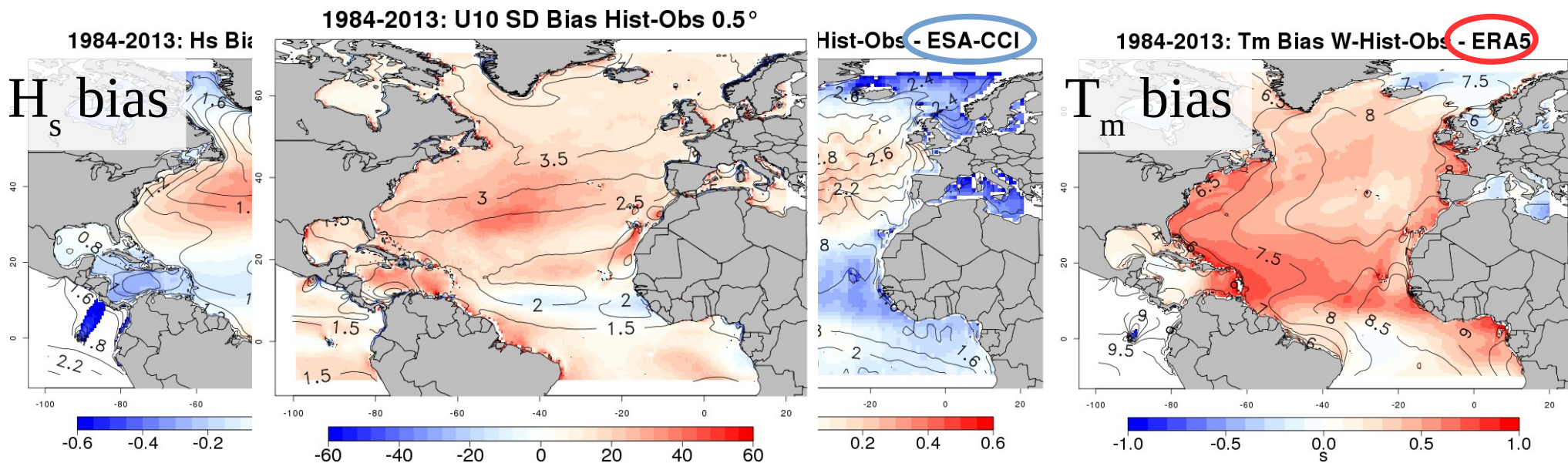
Wave Model Performance



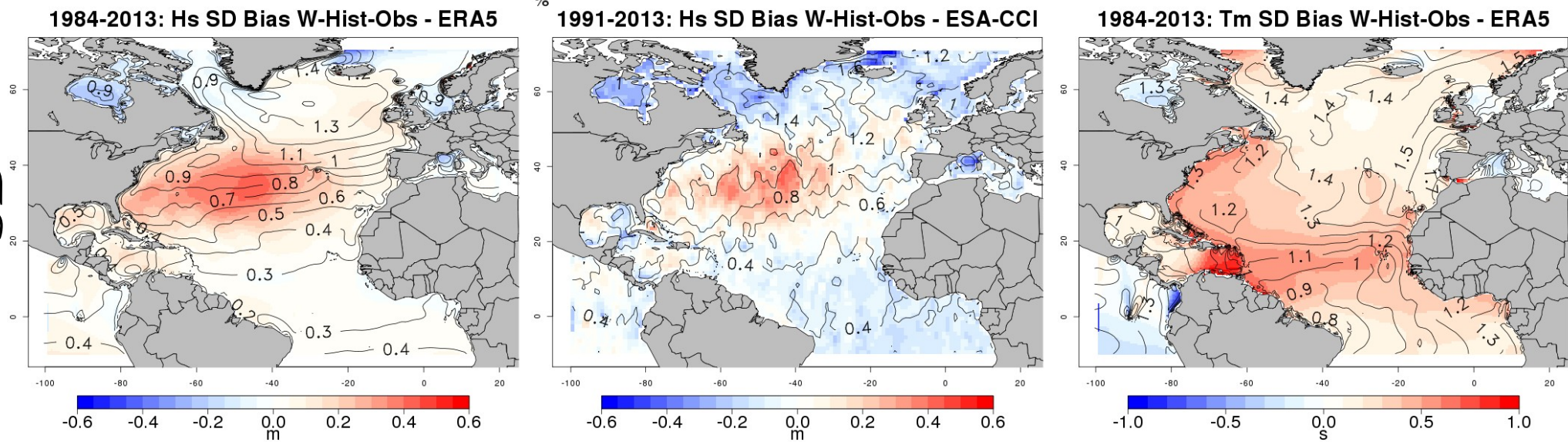
Wave Model Performance

L4 v1.1 $\sigma = \sqrt{\frac{1}{N} \sum_{m=1}^{69} \sum_{p=1}^{n_m} h_{mp}^2 - \overline{H_s}^2}$
 ASO $N = \sum_{m=1}^{69} n_m$
 1991-2013 \uparrow swh_squared_sum
 swh_count

Mean

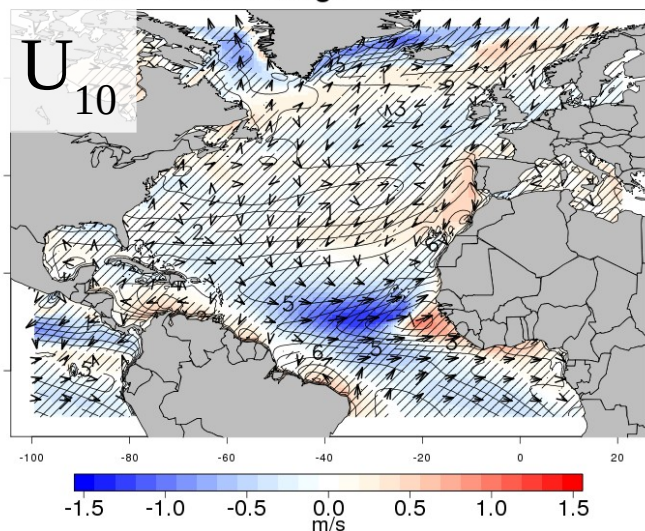


SD

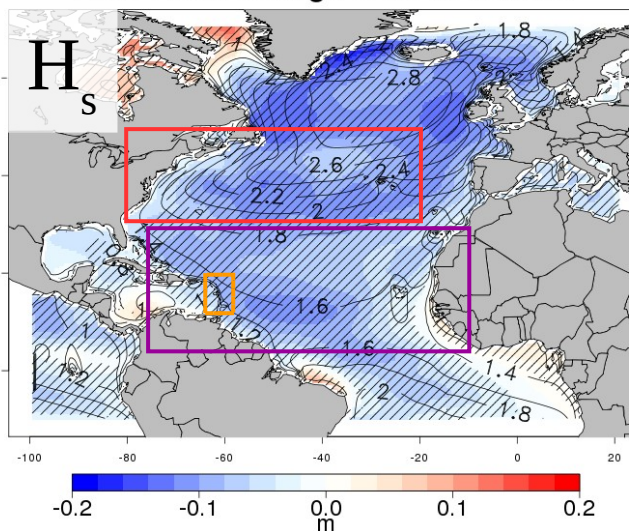


Projected Seasonal-mean Wave Climate

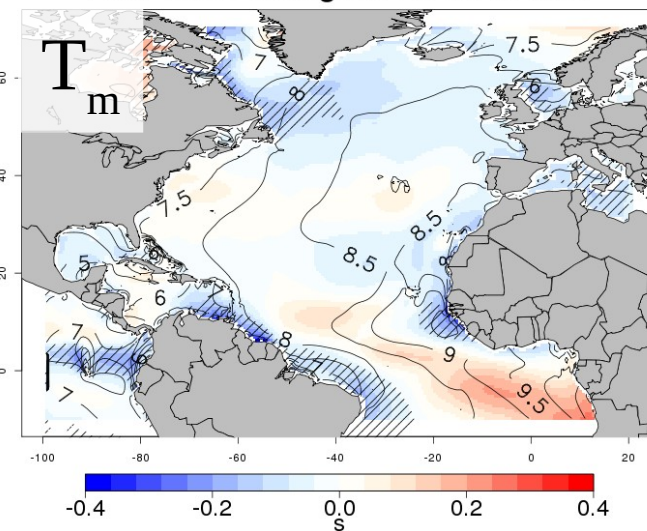
2051-2080: Change in U10 ARPEGE



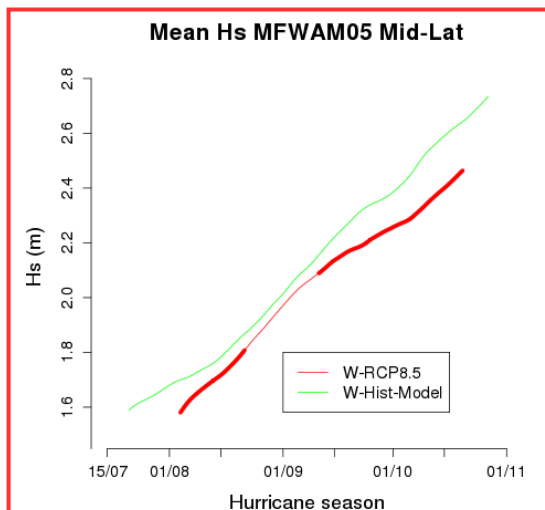
2051-2080: Change in Hs MFWAM05



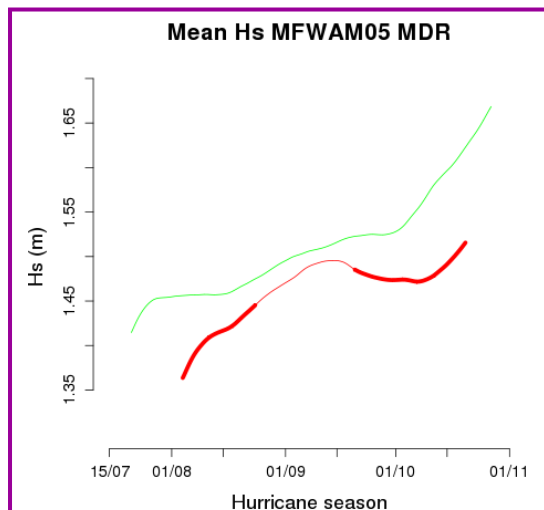
2051-2080: Change in Tm MFWAM05



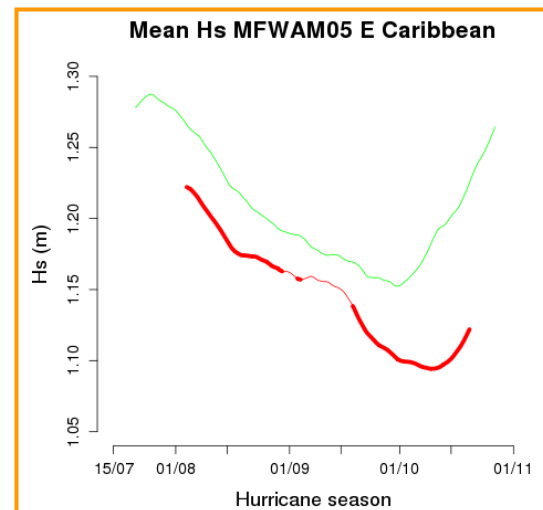
Mean Hs MFWAM05 Mid-Lat



Mean Hs MFWAM05 MDR

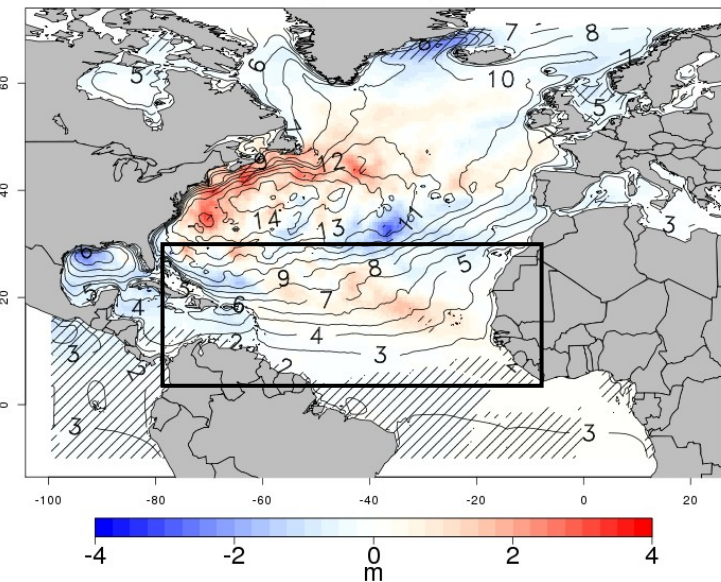


Mean Hs MFWAM05 E Caribbean

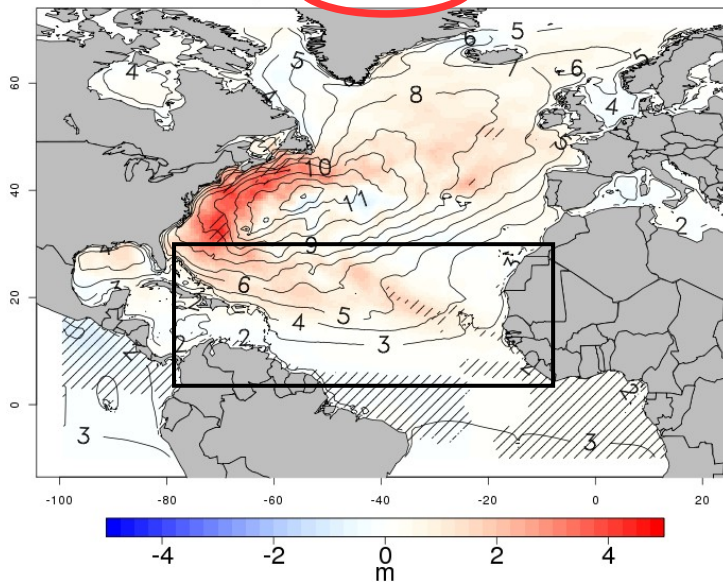


Projected Extreme TC-related Wave Heights

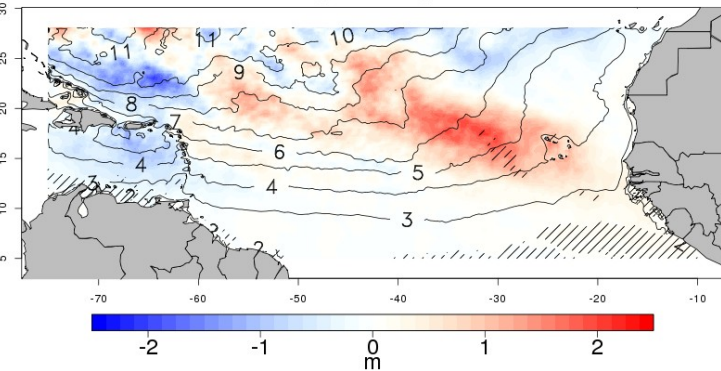
2051-2080: Change in 10-yr Hs MFWAM 05



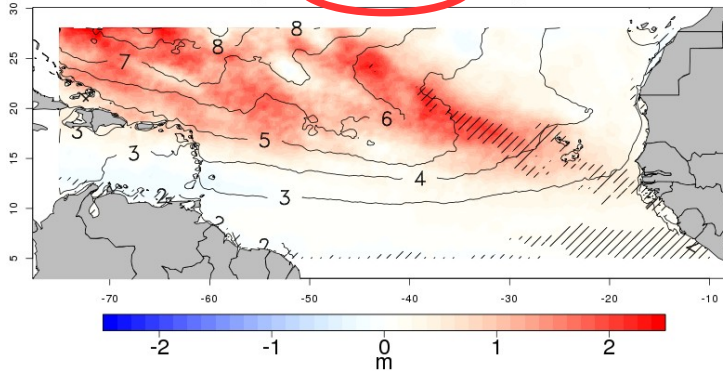
2051-2080: Change in **peak-season** 10-yr Hs MFWAM 05



2051-2080: Change in 10-yr Hs MFWAM 01

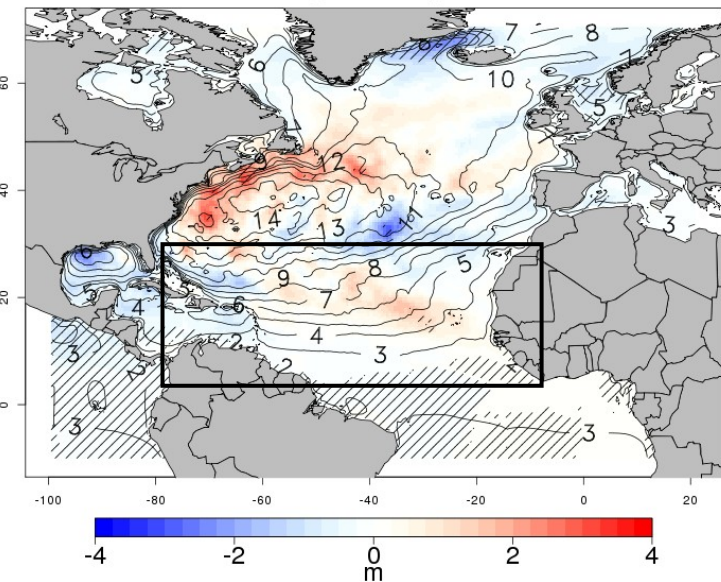


2051-2080: Change in **peak-season** 10-yr Hs MFWAM 01

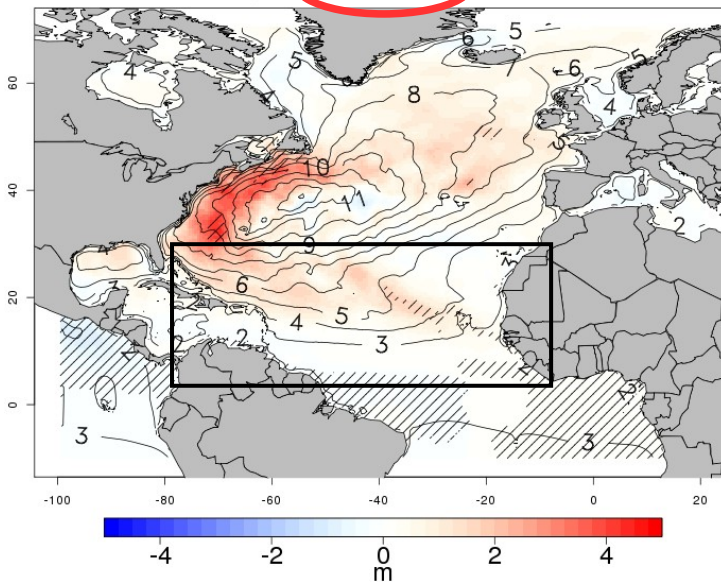


Projected Extreme TC-related Wave Heights

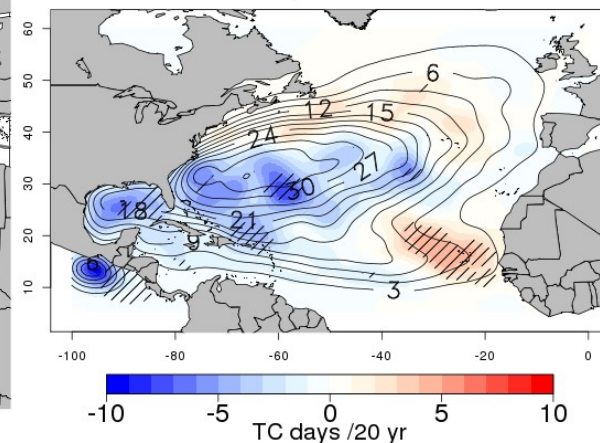
2051-2080: Change in 10-yr Hs MFWAM 05



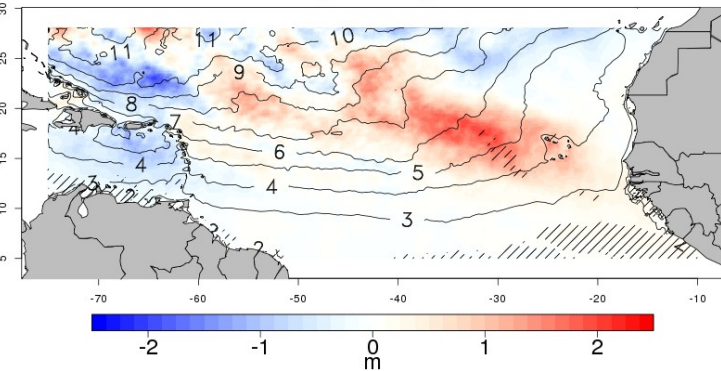
2051-2080: Change in **peak-season** 10-yr Hs MFWAM 05



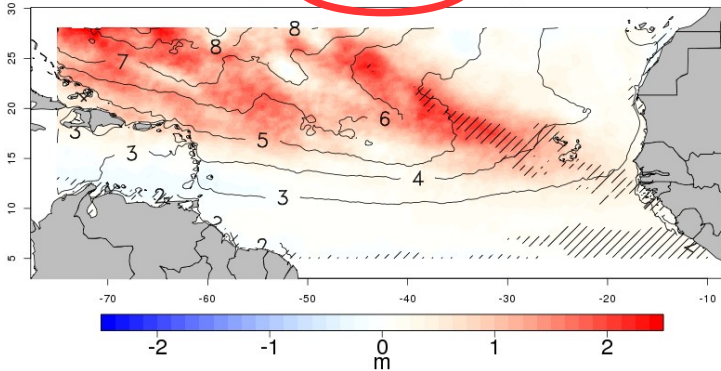
2031-2080: Change in TC days ARPEGE



2051-2080: Change in 10-yr Hs MFWAM 01

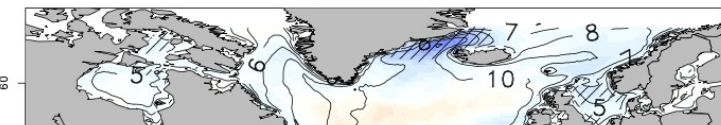


2051-2080: Change in **peak-season** 10-yr Hs MFWAM 01

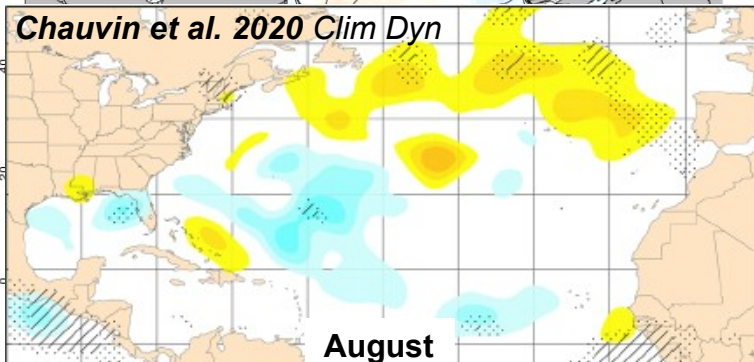


Projected Extreme TC-related Wave Heights

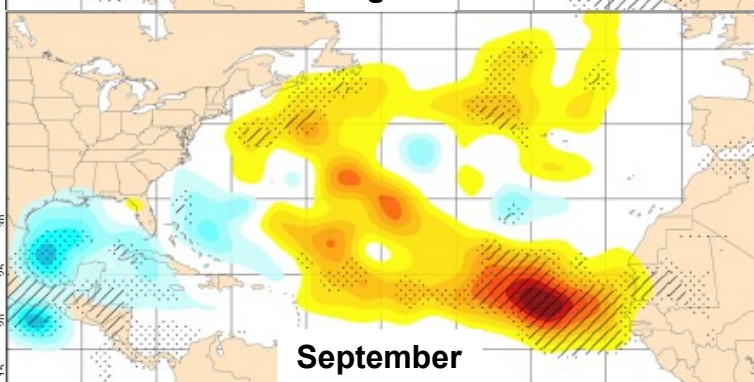
2051-2080: Change in 10-yr Hs MFWAM 05



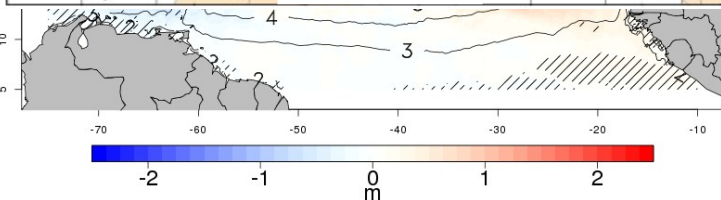
Chauvin et al. 2020 Clim Dyn



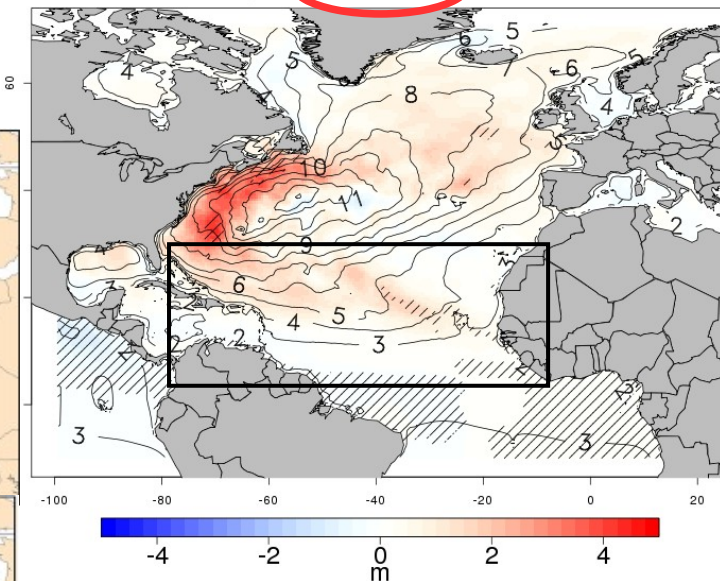
August



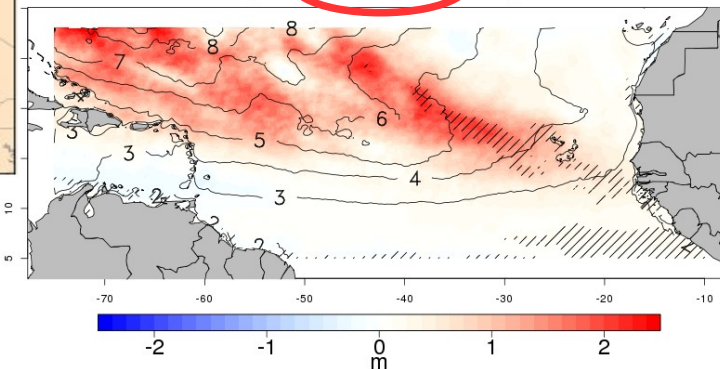
September



2051-2080: Change in **peak-season** 10-yr Hs MFWAM 05

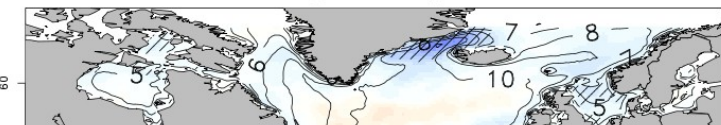


2051-2080: Change in **peak-season** 10-yr Hs MFWAM 01

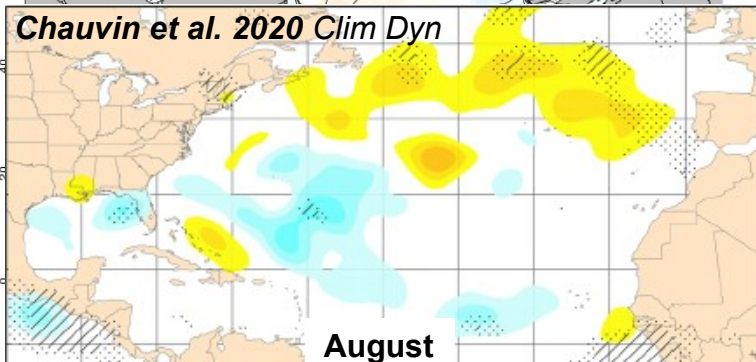


Projected Extreme TC-related Wave Heights

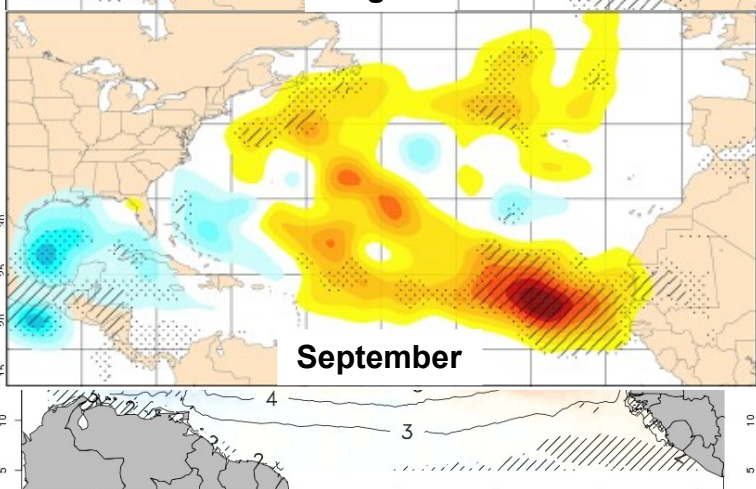
2051-2080: Change in 10-yr Hs MFWAM 05



Chauvin et al. 2020 Clim Dyn

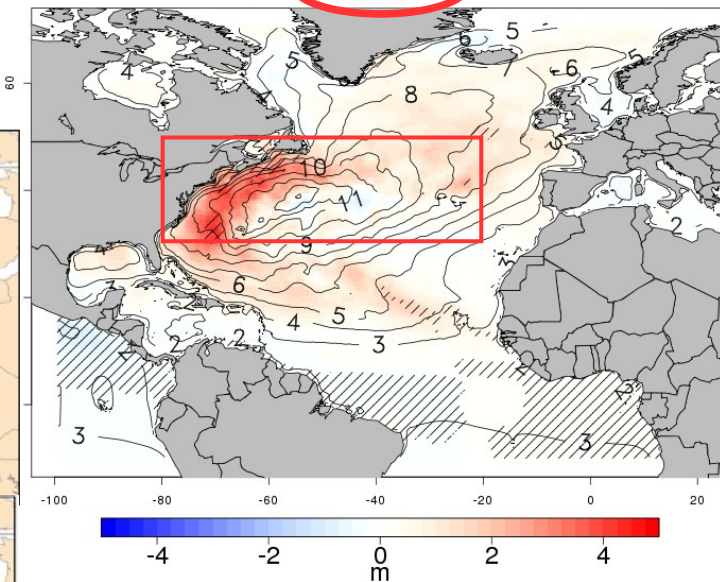


August

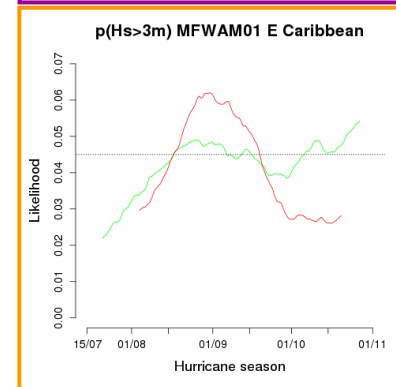
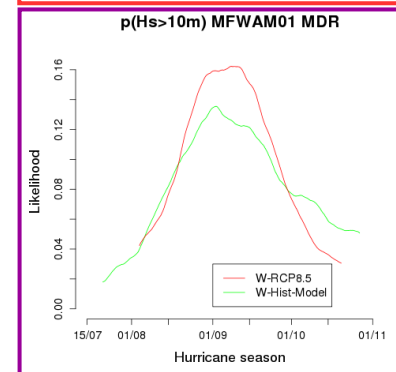
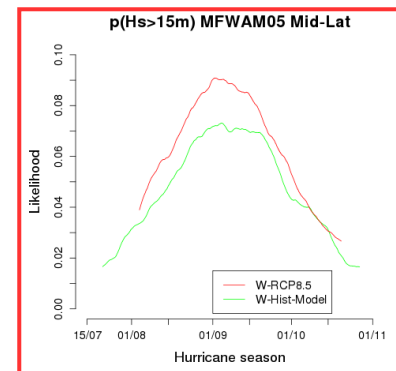
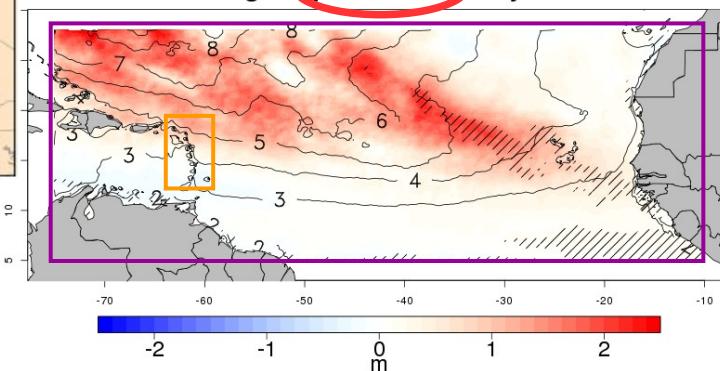


September

2051-2080: Change in **peak-season** 10-yr Hs MFWAM 05



2051-2080: Change in **peak-season** 10-yr Hs MFWAM 01

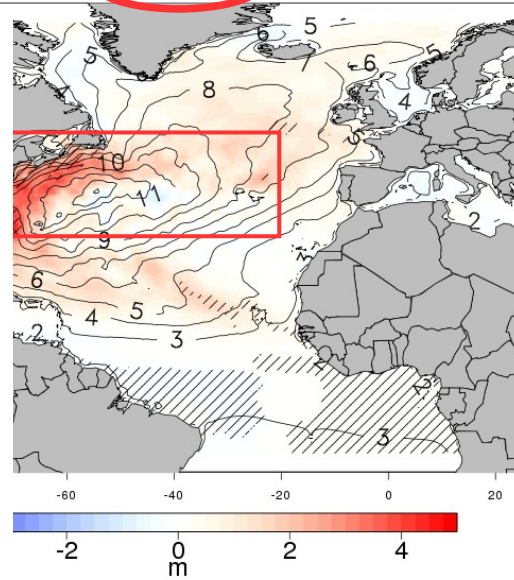
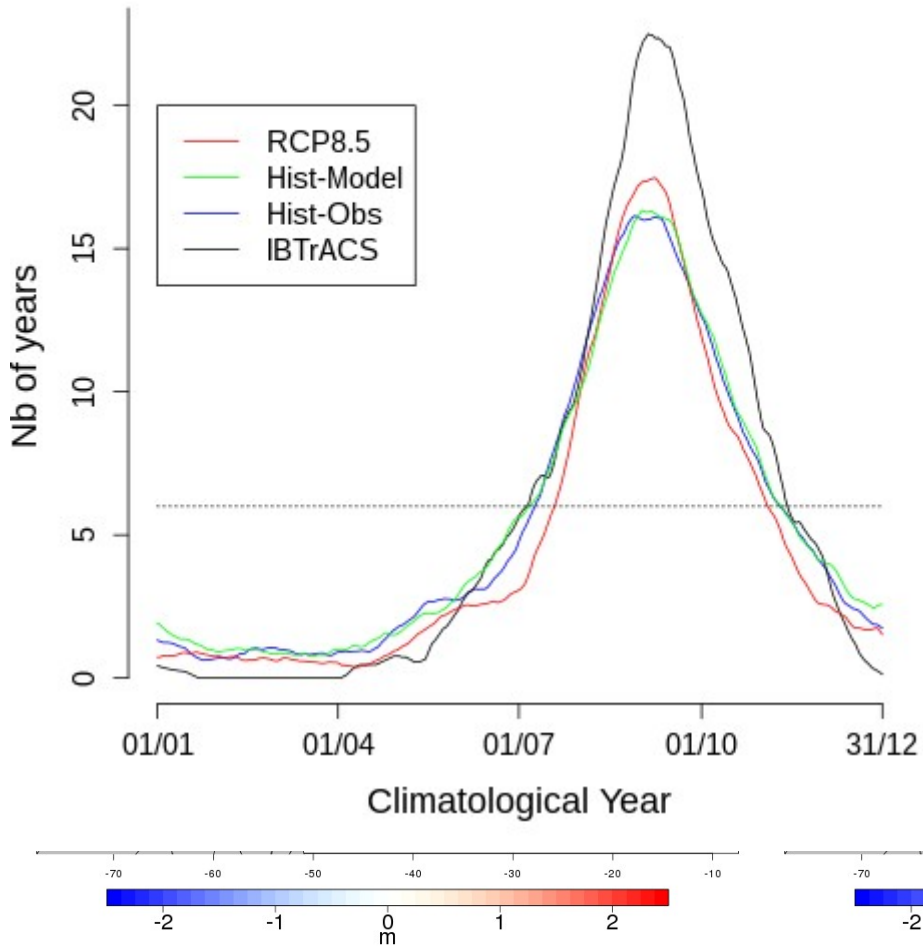


Projected Extreme TC-related Wave Heights

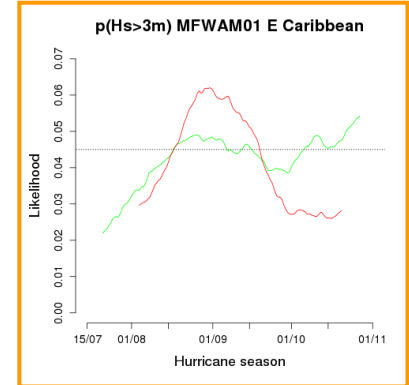
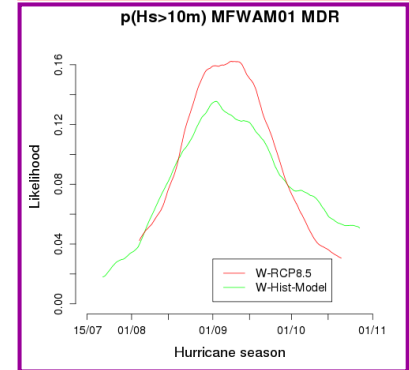
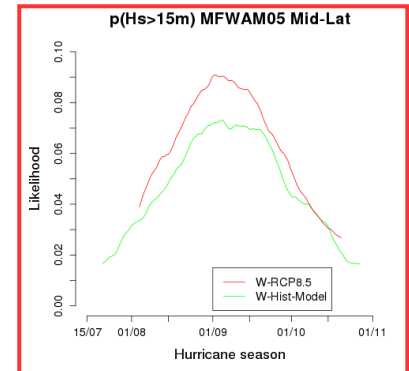
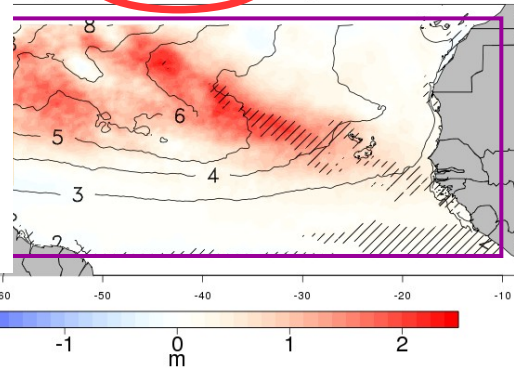
2051-2080: Change in 10-yr Hs MFWAM 05

2051-2080: Change in **peak-season** 10-yr Hs MFWAM 05

Nb of TC years in ARPEGE and IBTRaCS



Change in **peak-season** 10-yr Hs MFWAM 01



Conclusion

- **900 wave climate simulations** of the hurricane season performed with adapted Météo-France operational wave models & high-resolution Arpege-Climat winds
- Good skill for N Atlantic sea states despite some biases due to biased TC spatial distributions in Arpege-Climat
- **Mean wave heights projected to decrease** across the sub-basin during the hurricane season (weakened trade winds/westerlies)
- **Extreme TC-related wave heights projected to increase** 1) offshore US East Coast & SE Canada, 2) in the MDR ; particularly in August-September (strengthened TC activity at the season peak)
- Current work:
 - Downscaling over the Lesser Antilles (450 WW3 simulations performed)
 - Winter season (NDJFMA), 1350 simulations performed

Thanks for your attention !

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