COWCLIP: Coordinated Ocean Wave CLimate Project

Baylor Fox-Kemper

Brown University, DEEP Sciences

With: Qing Li (Brown) & Mark Hemer (CSIRO)

baylor@brown.edu

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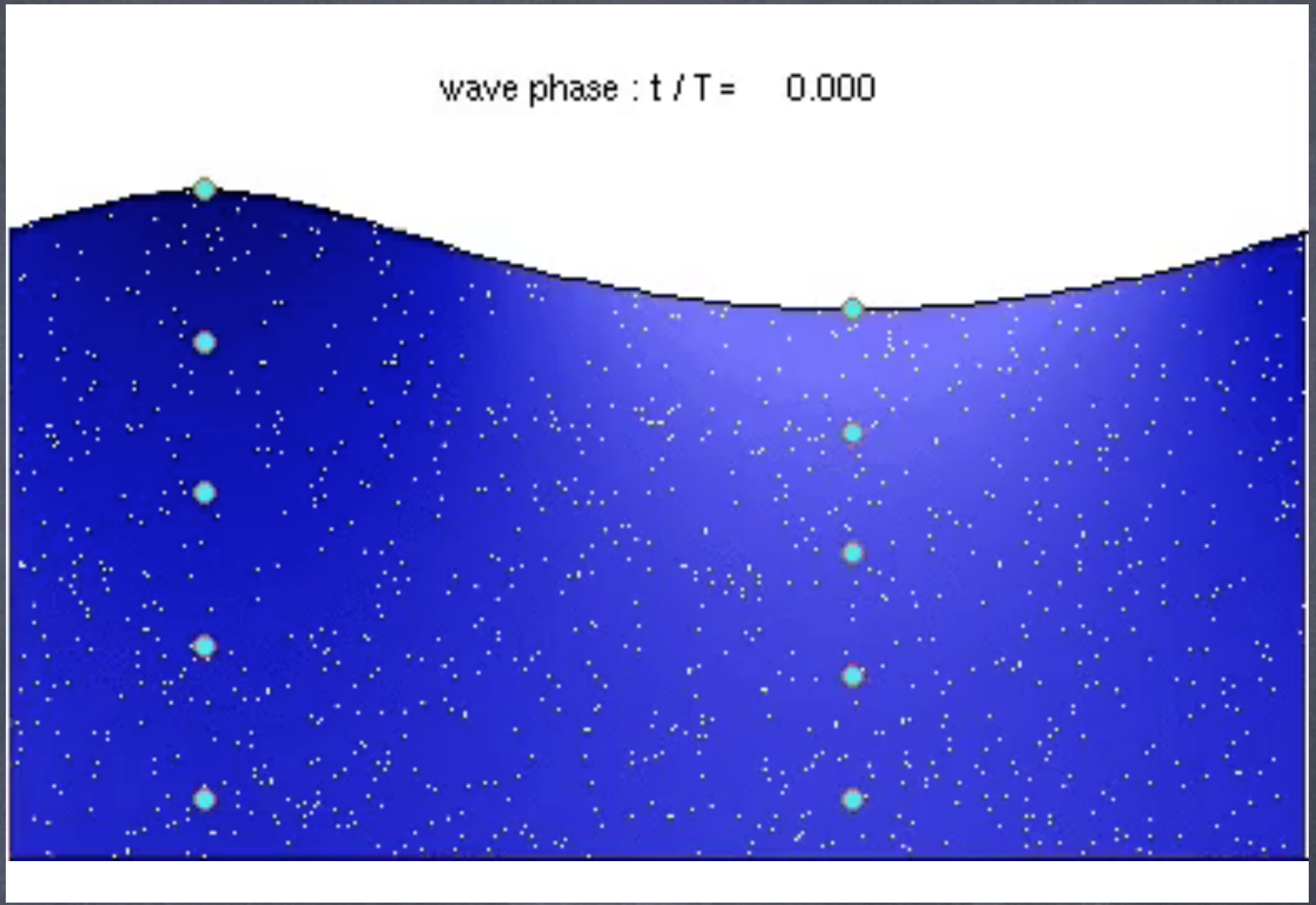
Surface Waves are…

Fast, small, approx. irrotational solutions of the Boussinesq Equations

Have a Stokes drift depending on sea state (wave age, winds)



A. Webb and B. Fox-Kemper. Wave spectral moments and Stokes drift estimation. Ocean Modelling, 40(3-4):273-288, 2011.

A. Webb and B. Fox-Kemper. Impacts of wave spreading and multidirectional waves on estimating Stokes drift. Ocean Modelling, 96(1):49-64, 2015.

We've been busy on wave-current dynamics & Langmuir mixing:
3 Postdocs, 3.8 PhDs, 2 MAs,
>18 papers.

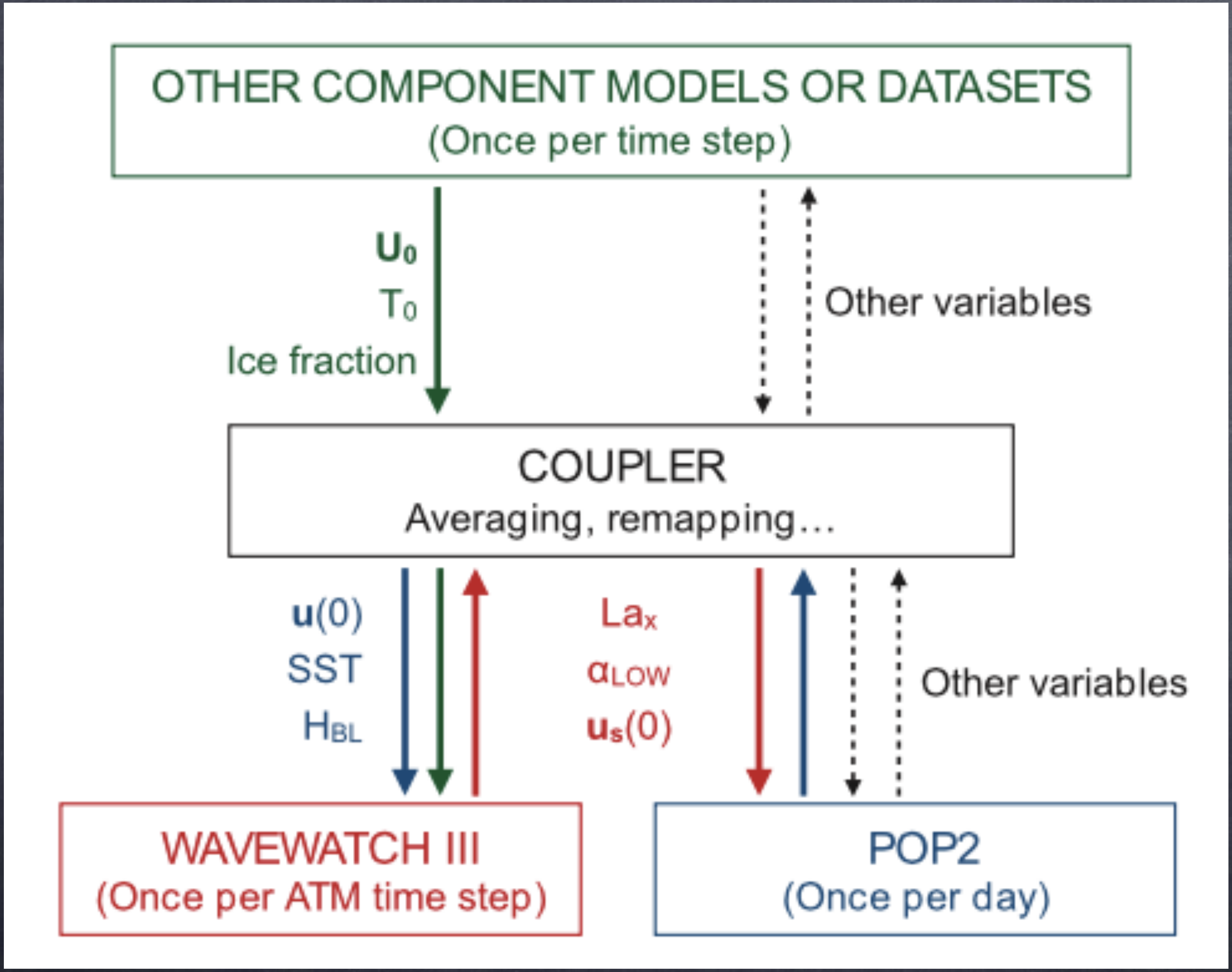
With a few exceptions, not too much about the waves themselves.

Cavaleri, L., Fox-Kemper, B. and Hemer, M., 2012. Wind waves in the coupled climate system. Bulletin of the American Meteorological Society, 93(11), pp.1651-1661.

A. Webb and B. Fox-Kemper. Impacts of wave spreading and multidirectional waves on estimating Stokes drift. Ocean Modelling, 96(1):49-64, December 2015.

A. Webb and B. Fox-Kemper. Wave spectral moments and Stokes drift estimation. Ocean Modelling, 40(3-4):273-288, 2011.

In CESM2, though… waves are routine.

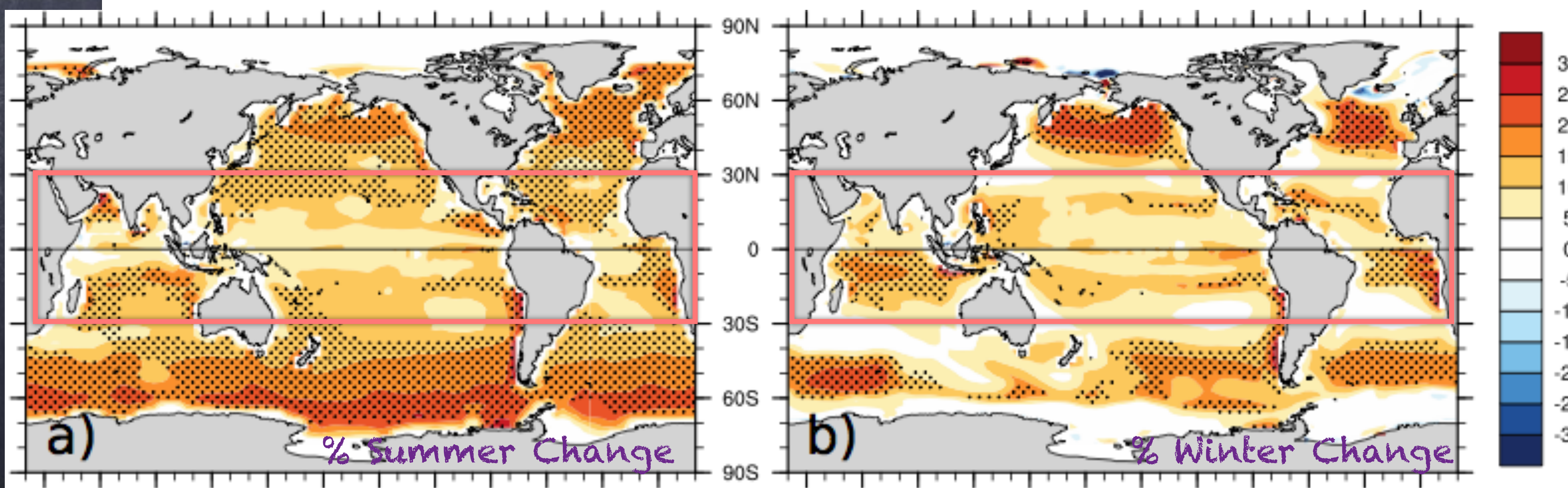


Q. Li, A. Webb, B. Fox-Kemper, A. Craig, G. Danabasoglu, W. G. Large, and M. Vertenstein. Langmuir mixing effects on global climate: WAVEWATCH III in CESM. Ocean Modelling, 103:145-160, July 2016.

Langmuir Mixing in Climate: Boundary layer Depth Improved

	Case	Summer			Winter		
		Global	South of 30°S	30°S-30°N	Global	South of 30°S	30°S-30°N
Control	CTRL	10.62±0.27[a]	17.24±0.48	5.38±0.14	43.85±0.38	57.19±0.76	12.57±0.28
		(13.40±0.19)[b]	(21.73±0.32)	(6.71±0.09)	(45.50±0.40)	(56.53±0.59)	(16.16±0.29)
Competition	MS2K	15.37	15.47	17.03	119.91	171.92	40.31
	SS02	36.79	63.83	7.54	99.32	164.34	17.39
3 versions of Van Roekel et al	VR12-AL	9.06	13.47	6.49	40.45	50.33	14.52
	VR12-MA	8.73±0.30	12.65±0.47	6.61±0.22	40.99±0.37	51.78±0.65	14.23±0.30
		(11.83±0.29)	(18.13±0.62)	(7.52±0.16)	(42.02±0.39)	(50.78±0.67)	(15.67±0.35)
	VR12-EN	8.95	10.52	8.91	41.94	52.98	19.58

dotted when statistically significant



L. P. Van Roekel, BFK, P. P. Sullivan, P. E. Hamlington, and S. R. Haney. The form and orientation of Langmuir cells for misaligned winds and waves. Journal of Geophysical Research-Oceans, 117:C05001, 22pp, May 2012.

Q. Li, A. Webb, BFK, A. Craig, G. Danabasoglu, W. G. Large, and M. Vertenstein. Langmuir mixing effects on global climate: WAVEWATCH III in CESM. Ocean Modelling, 103:145-160, July 2016.

COWCLIP

- COWCLIP aspires to understand climate change in global wave statistics
- IPCC has sought this info since AR4.
- Wave models have been run offline, with CMIP saved winds, &tc.
- We will do projection with waves coupled online in CESM2

Hemer, M.A., Wang, X.L., Weisse, R. and Swail, V.R., 2012. Advancing wind-waves climate science: The COWCLIP project. Bulletin of the American Meteorological Society, 93(6), pp.791-796.

Hemer, M.A., Fan, Y., Mori, N., Semedo, A. and Wang, X.L., 2013. Projected changes in wave climate from a multi-model ensemble. Nature climate change, 3(5), pp.471-476.

Wang, X.L., Feng, Y. and Swail, V.R., 2014. Changes in global ocean wave heights as projected using multimodel CMIP5 simulations. Geophysical Research Letters, 41(3), pp.1026-1034.

Hemer, M.A. and Trenham, C.E., 2016. Evaluation of a CMIP5 derived dynamical global wind wave climate model ensemble. Ocean Modelling, 103, pp.190-203.

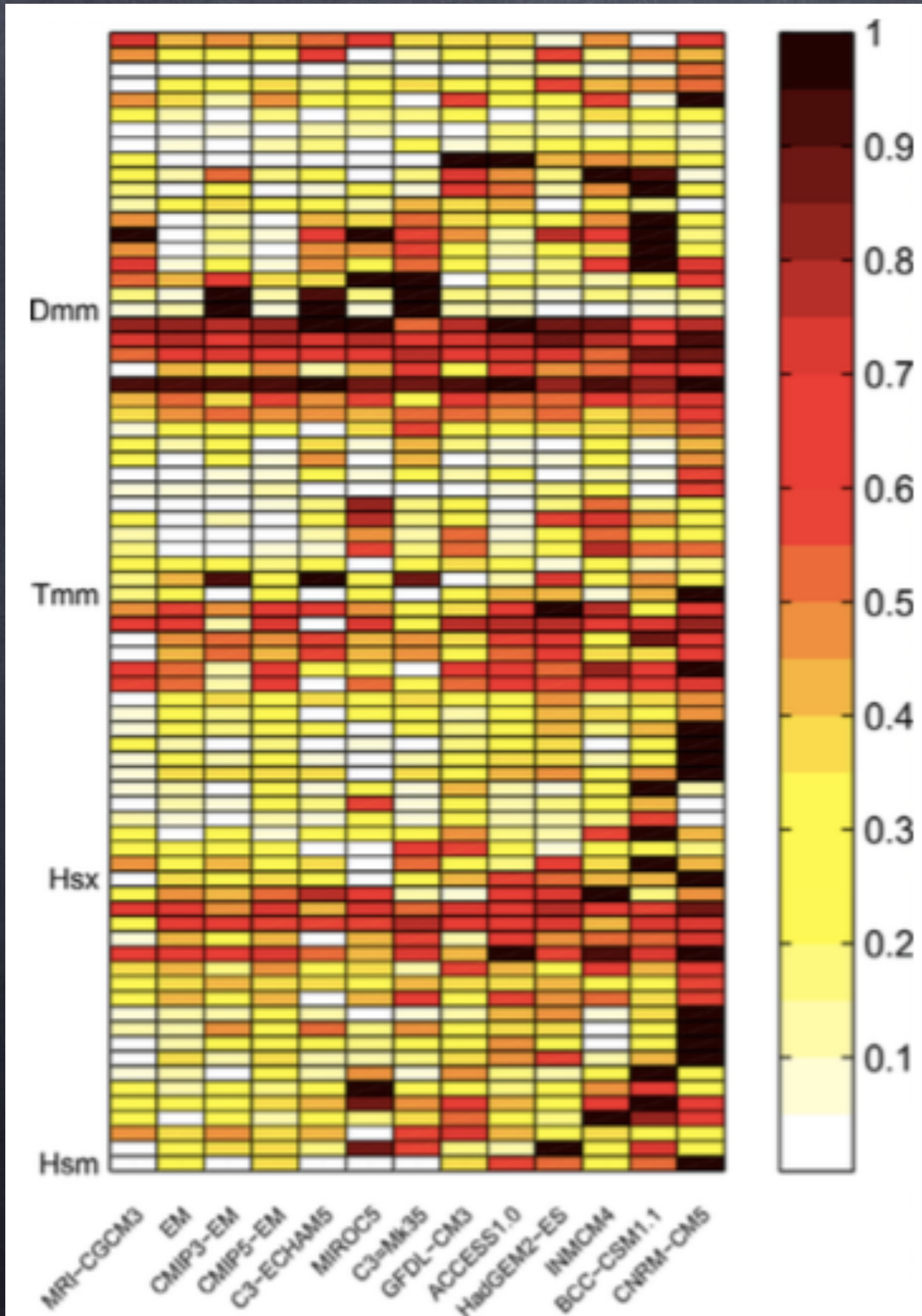
CMIP5 list of models

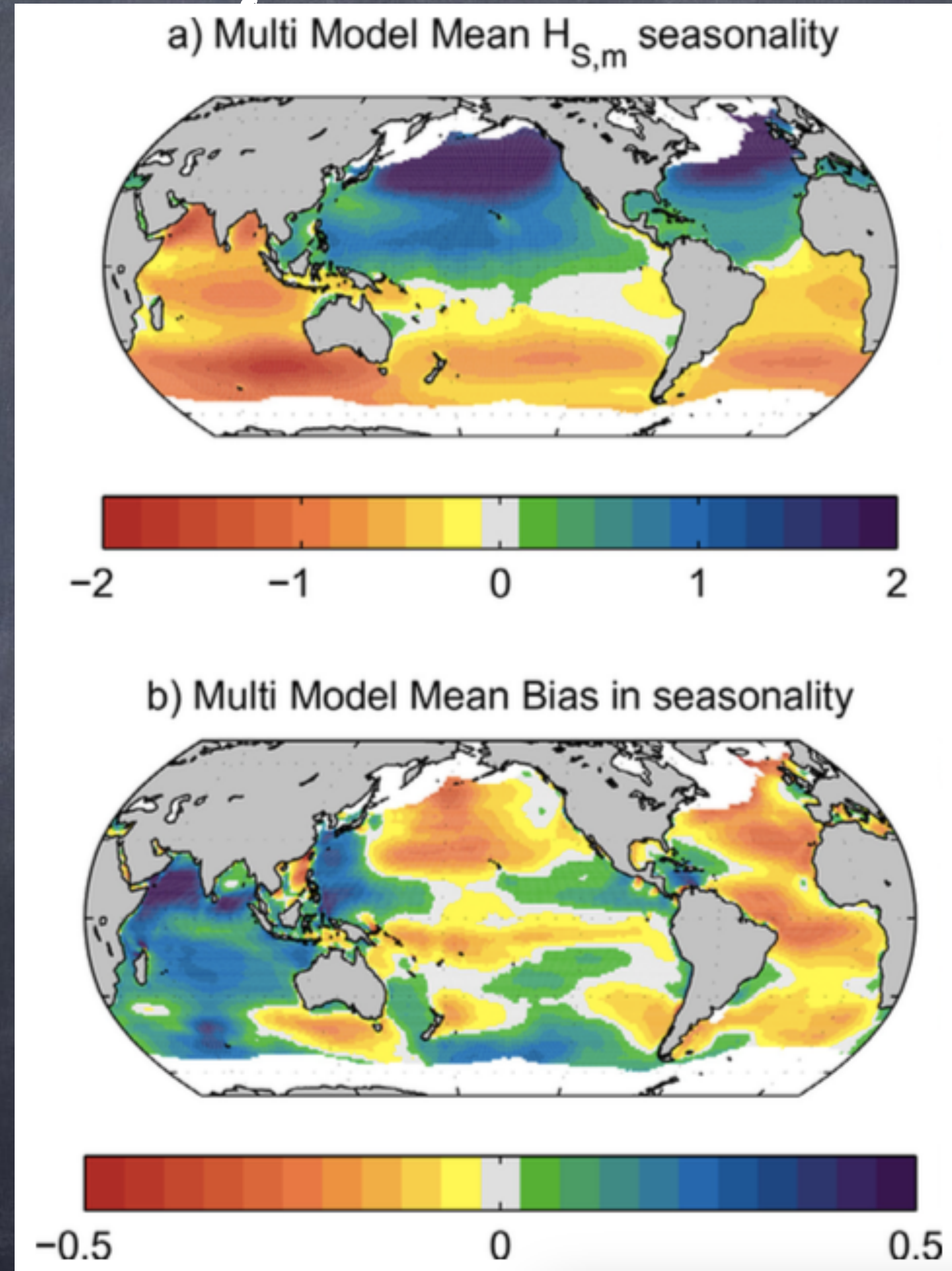
Table 1
CMIP models (Phase 3 and 5) used in the study. Description of the ensemble means assessed in the study are also given.

ID	Full model name	Model	CMIP phase
1	Australian Community Climate and Earth System Simulator 1.0	ACCESS1.0	5
2	Beijing Climate Centre, Climate System Model, 1-1	BCC-CSM1.1	5
3	Centre National de Recherches Meteorologiques Coupled Global Climate Model, version 5	CNRM-CM5	5
4	Geophysical Fluid Dynamics Laboratory Earth System Model 2M	GFDL-ESM2M	5
5	Hadley Centre Global Environmental Model 2, Earth System	HadGEM2-ES	5
6	Institute of Numerical Mathematics Coupled Model, version 4.0	INMCM4	5
7	Model for Interdisciplinary Research on Climate, version 5	MIROC5	5
8	Meteorological Research Institute Coupled Atmosphere-Ocean General Circulation Model, version 3	MRI-CGCM3	5
9	ECMWF Hamburg climate model, version 5, dynamically downscaled using CCAM	CMIP3-CCAM-ECHAM5	3
10	CSIRO Mk3.5 general circulation, version 3.5, dynamically downscaled using CCAM	CMIP3-CCAM-CSIROMk3.5	3
11	Ensemble mean of CMIP-5 simulations (models 1–8)	CMIP5-EM	–
12	Ensemble mean of CMIP3-CCAM simulations (models 9–10)	CMIP3-CCAM-EM	–
13	Ensemble mean of all simulations (models 1–10)	EM	–

Hemer, M.A. and Trenham, C.E., 2016. Evaluation of a CMIP5 derived dynamical global wind wave climate model ensemble. Ocean Modelling, 103, pp.190-203.

Waves are new diagnostic–constrained by Obs!





Wave extremes are important

The **getStat.f** is for calculating the following 7 statistics from an input wave data chosen by the user:

```
avg - the mean
p10 - the 10th Percentile
p50 - the 50th Percentile
p90 - the 90th Percentile
p95 - the 95th Percentile
p99 - the 99th Percentile
max - the maximum
```

In order to calculate these statistics for the COWCLIP-required 17 time-frames [12 monthly, 4 seasonal (DJF, MAM, JJA and SON), and an annual value], users need to run the program three times, one for each of the following 3 target time-frame resolutions:

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MLY - for monthly statistics
SNL - for seasonal statistics
ANL - for annual statistics
```

Future waves are interesting–
Societal value through inundation, erosion, etc.

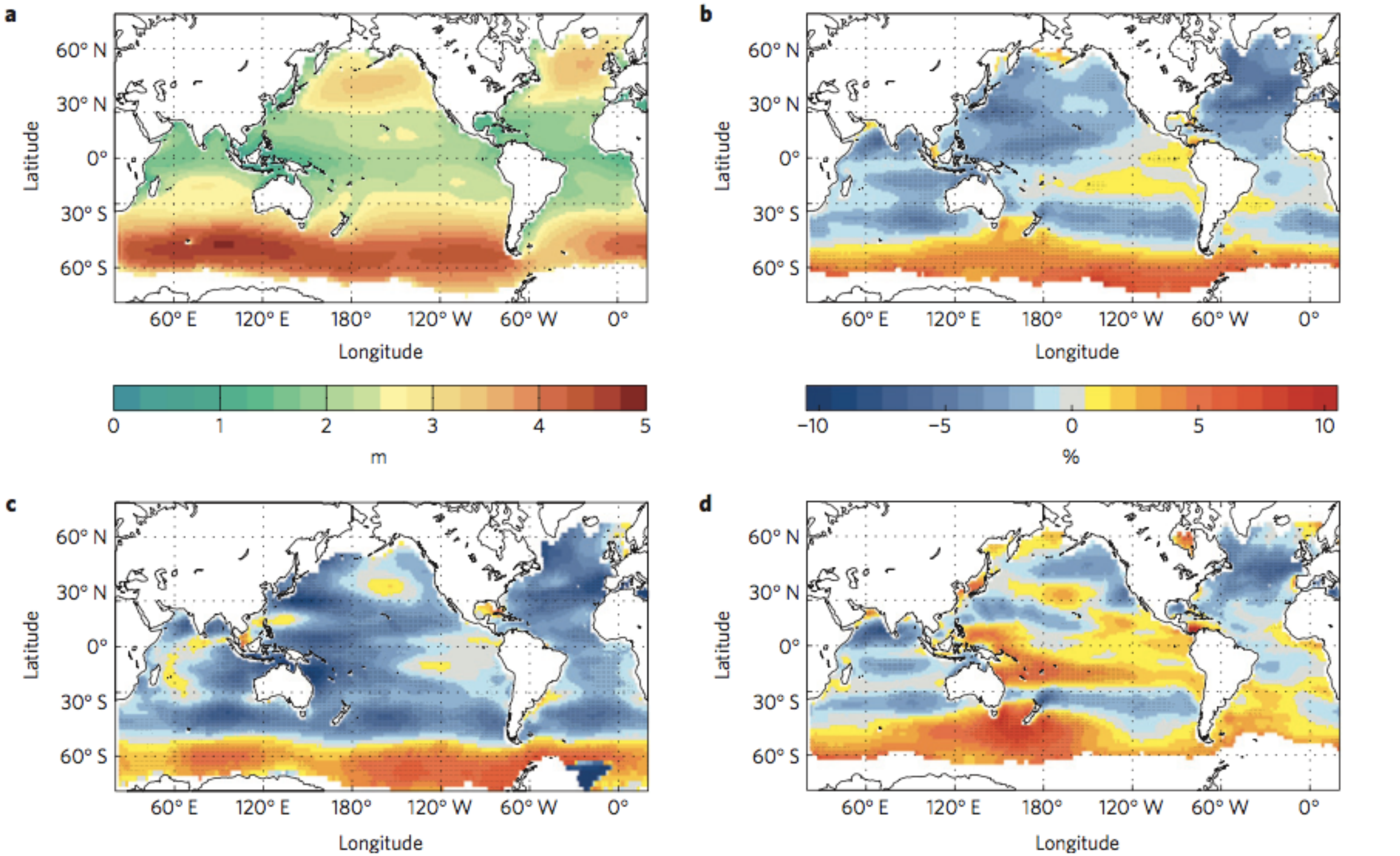

Figure 2 | Projected future changes in multi-model averaged significant wave height. a, Averaged multi-model annual significant wave height (H_S, m) for the time-slice representing present climate (~1979–2009). **b–d**, Averaged multi-model projected changes in annual (**b**), JFM (**c**) and JAS (**d**) mean H_S for the future time-slice (~2070–2100) relative to the present climate time-slice (~1979–2009) (% change). Stippling denotes areas where the magnitude of

Conclusions

- CESM2 is in a position to be the first model to submit a coupled ESM-wave model to COWCLIP

- The data is already output in "standard" WaveWatch configuration. We will collect & condense from DECK sims, etc., as required to match other centers

- COWCLIP is not a MIP formally, as it doesn't normally required coupled sims. Does have IPCC & WMO support.

- We hope to receive beneficial cross-comparison stats about our wave modeling system (resolution, etc.). Will also identify relative wind errors.

- CIME, NUOOPC will make upgrading WaveWatch from NCEP easier, as in-house wave expertise is limited.