Global implications of surface current modulation of the wind-wave field

Emilio Echevarria[1,2,3], Mark Hemer[1], Neil Holbrook[2,3], Salman Saeed Khan[1]

[1] Commonwealth Scientific and Industrial Research Organisation, Oceans and Atmosphere, Australia. [2] Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, TAS, Australia. [3] Australian Research Council Centre of Excellence for Climate Extremes, University of Tasmania, Hobart, TAS, Australia.

Introduction

The ocean circulation can influence wind-waves in various ways. Surface currents can modify wave properties such as height and frequency through exchanges of energy with the mean flow mediated by the radiation stress, and non-uniform currents can refract waves and change their direction of propagation. In addition, the relative wind can be different than the real wind in the presence of currents. While all these processes have been understood for a long time, the global implications of wave-current interactions are still mostly unknown. In this work we investigate the sensitivity of wave modelling to the inclusion of surface current forcing from a global reanalysis.

Methodology

We have run two sets of WAVEWATCH III simulations for the years 2014-2016, one forced with surface current data taken from the Bluelink Reanalysis (Oke et al., 2013), and another without currents forcing, and then analysed the differences between these two. In each case the model was forced with 10m winds and ice concentration data taken from the CFSR reanalysis. Two grids were implemented: a global one (0.4° resolution) and one in the Southern Ocean (from -65°S to -28°S, 0.1° resolution). To assess the performance of both simulations, the modelled wave heights were compared against the altimeter dataset processed by Ribal and Young (2019). In addition, Sentinel-1 satellite 2D wave spectra observations were used to compute peak swell directions, and these were compared against modelled wave direction from both sets of simulations.

Results

H_S comparisons

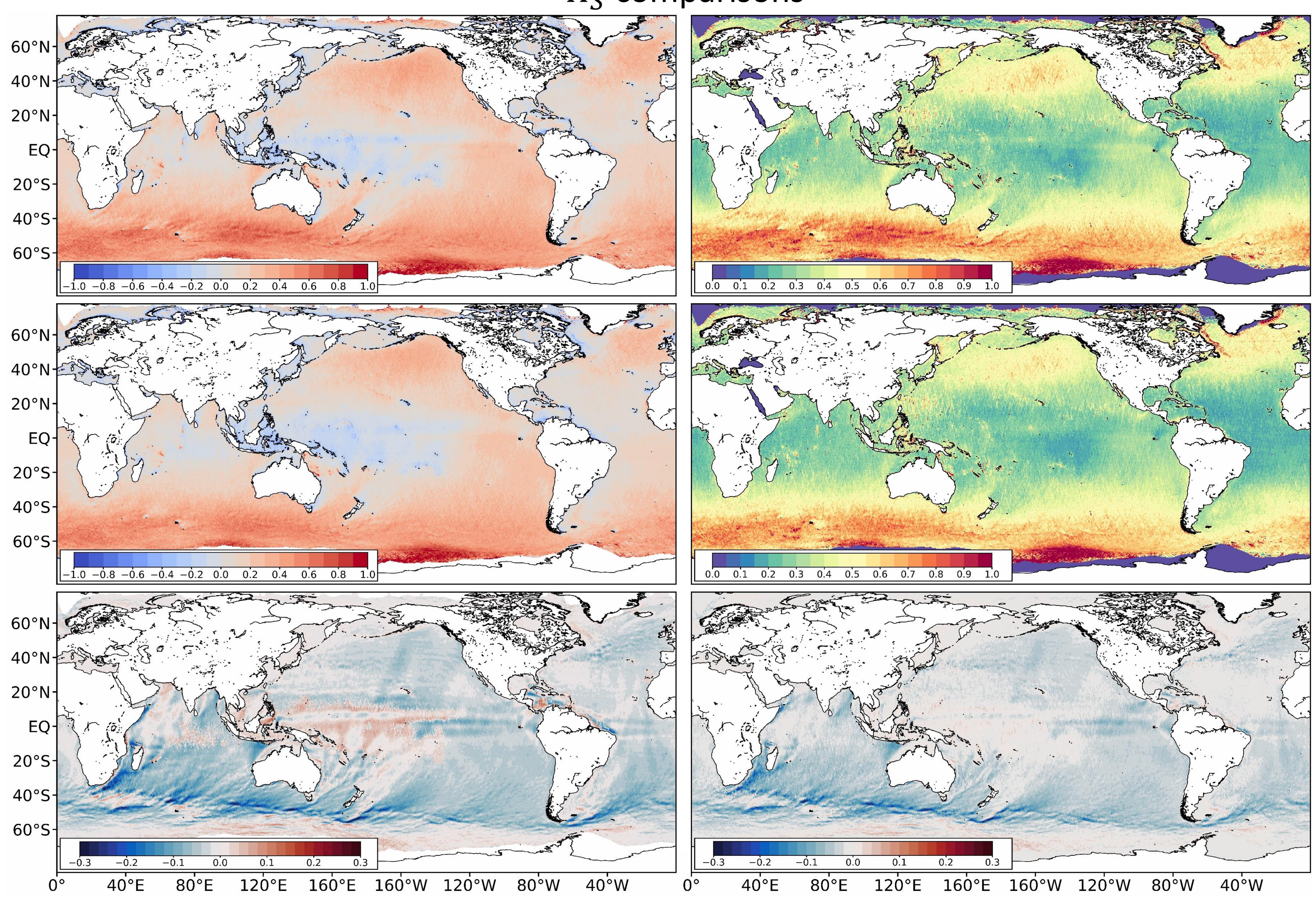
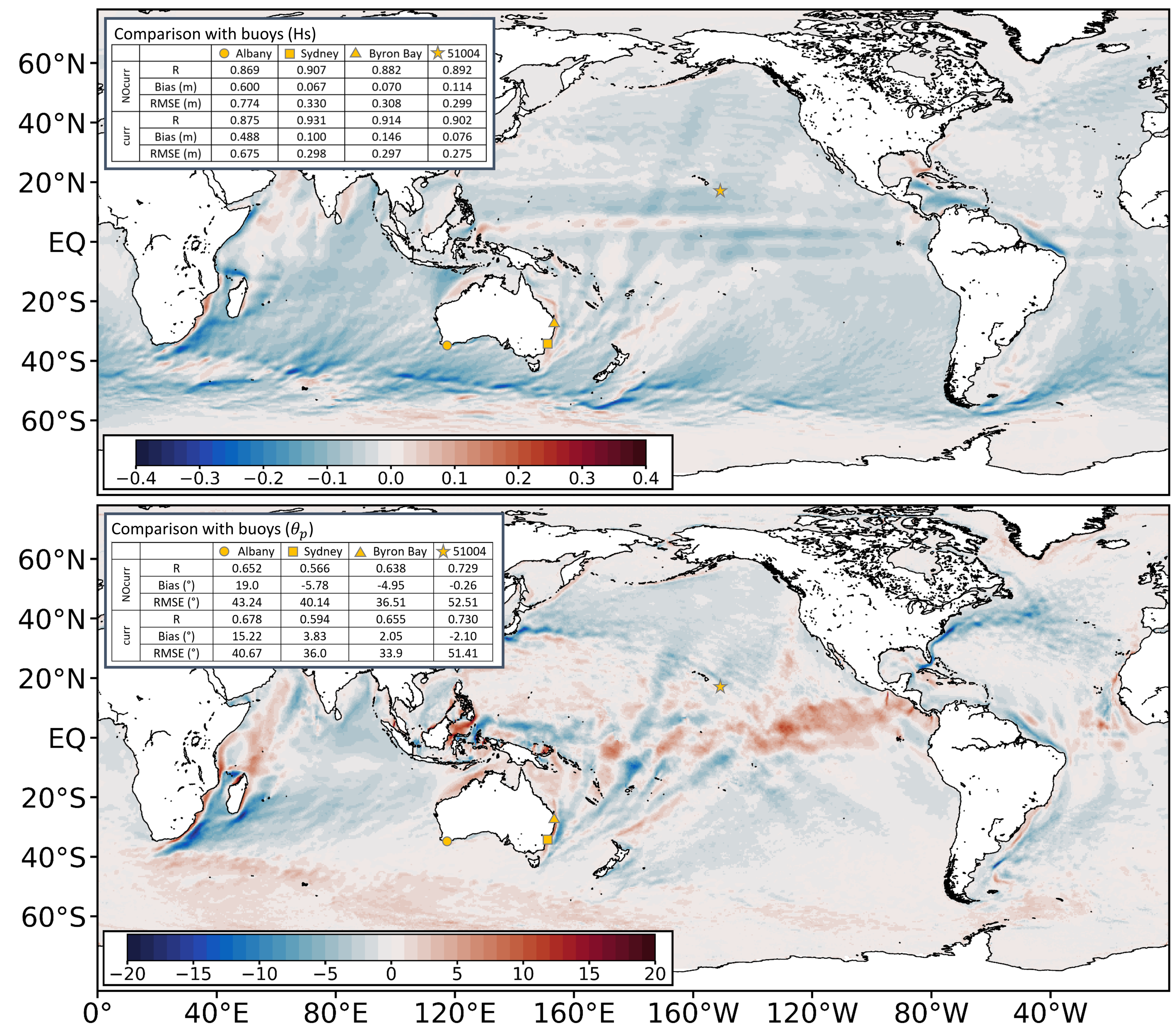


Figure 1. Left panels: mean bias for the simulation without (top) and with (middle) current forcing, and the difference between biases (current – NOcurrent, bottom). Right panels: same as left panels but for RMSE. Units in m.



Comparison with buoys (Hs)

		Albany	Sydney	Byron Bay	51004
NOcurr	R	0.869	0.907	0.882	0.892
	Bias (m)	0.600	0.067	0.070	0.114
	RMSE (m)	0.774	0.330	0.308	0.299
curr	R	0.875	0.931	0.914	0.902
	Bias (m)	0.488	0.100	0.146	0.076
	RMSE (m)	0.675	0.298	0.297	0.275

Comparison with buoys (θ_p)

		Albany	Sydney	Byron Bay	51004
NOcurr	R	0.652	0.566	0.638	0.729
	Bias (°)	19.0	-5.78	-4.95	-0.26
	RMSE (°)	43.24	40.14	36.51	52.51
curr	R	0.678	0.594	0.655	0.730
	Bias (°)	15.22	3.83	2.05	-2.10
	RMSE (°)	40.67	36.0	33.9	51.41

Figure 2. Time averaged differences (current – NOcurrent simulation) in significant wave height in meters (top) and in mean direction in degrees (bottom).

θ_p comparisons

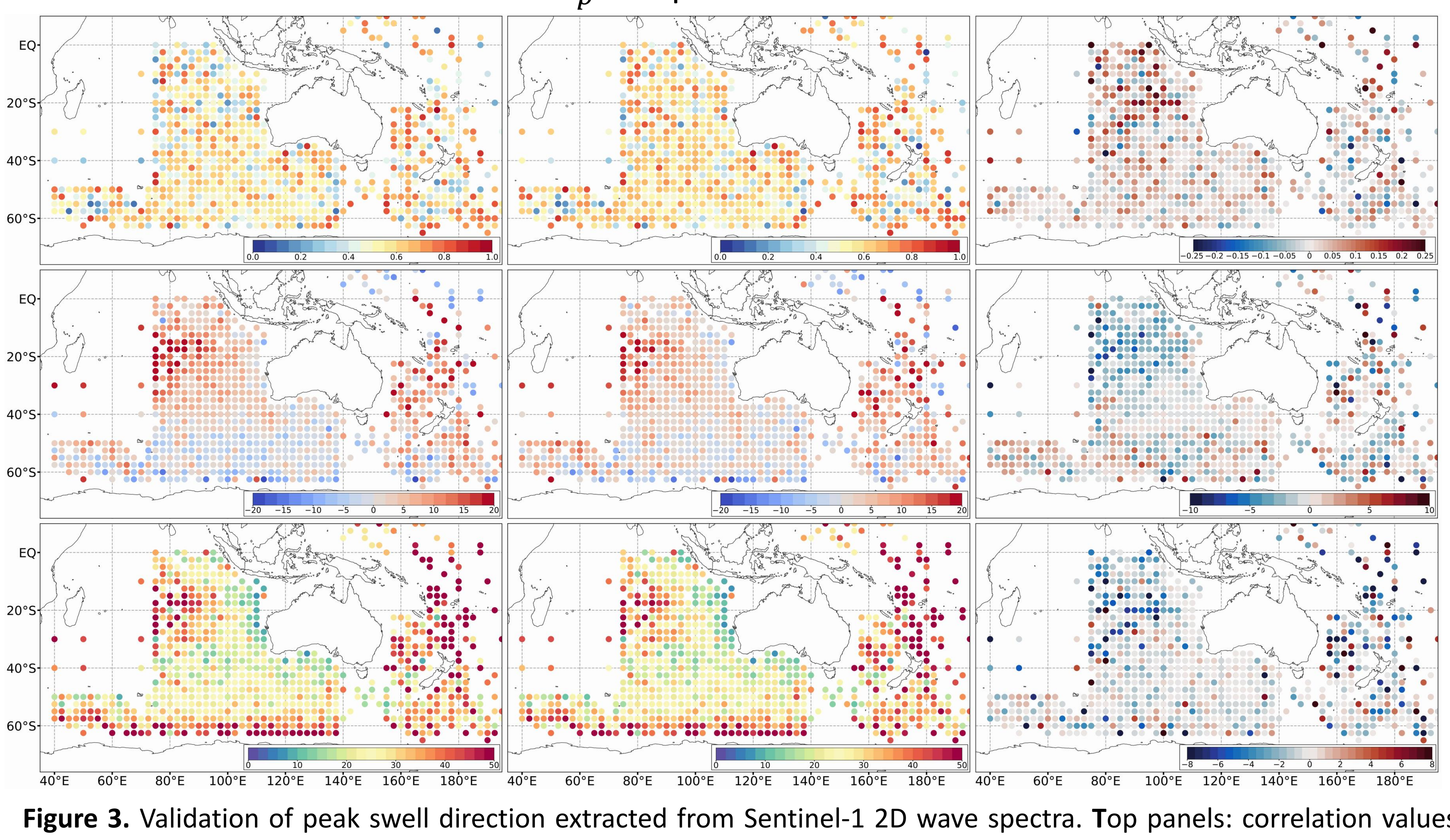


Figure 3. Validation of peak swell direction extracted from Sentinel-1 2D wave spectra. **T**op panels: correlation values for the simulation without (left) and with currents (centre), and the difference between correlation values (current – NOcurrent, right). Middle and bottom: same as top panels but for mean bias and RMSE, respectively. Units in degrees.

Conclusions

Including surface current forcing from the Bluelink Reanalysis into WAVEWATCH III simulations significantly improves the significant wave height in most areas of the world, especially in the Southern Ocean. In addition, the peak swell direction estimates are greatly improved in the Indian Ocean. In general, the inclusion of currents reduces the wave heights due to decreased relative wind in areas with co-flowing winds and currents, and the current-induced refraction changes the waves direction, especially in the Western Boundary Currents and equatorial regions.

References

Oke, P. R., Sakov, P., Cahill, M. L., Dunn, J. R., Fiedler, R., Griffin, D. A., ... & Schiller, A. (2013). Towards a dynamically balanced eddy-resolving ocean reanalysis: BRAN3. Ocean Modelling, 67, 52-70.

Ribal, A., & Young, I. R. (2019). 33 years of globally calibrated wave height and wind speed data based on altimeter observations. Scientific data, 6(1), 77.