Evaluating Surface Turbulent Heat Fluxes Over Tropical Oceans in a Channel Model

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Abstract: Accurately modeling weather and climate across the world is highly dependent on simulating surface latent and sensible (turbulent) heat fluxes over tropical oceans. A tropical channel model (TCM) based on the Weather Research and Forecasting (WRF) Model was used to simulate latent and sensible heat fluxes from January 1, 2010, through December 31, 2014. The flux simulations were compared to the Objectively Analyzed air-sea heat Fluxes (OAFlux) dataset over the same time period on annual and seasonal timescales. It was also compared to published results to analyze its performance compared to atmospheric general circulation models (AGCMs). The model followed expected hemispheric and seasonal trends but had large biases and small correlation coefficients. The TCM performed worse than the AGCMs and AGCM ensemble despite being a regional model with higher resolution. More investigation should be done to find out why the TCM performed worse, as it should have been better than the AGCMs.

Introduction

Numerical models are extremely important for understanding and predicting the weather and climate on regional and global scales. The accuracy of forecasts depend on the surface turbulent heat fluxes, especially latent (Q_{LH}) and sensible (Q_{SH}) heat fluxes, over tropical oceans. For assessing these fluxes at lower latitudes, it is more beneficial to use a tropical channel model (TCM) rather than a global atmospheric general circulation model (AGCM). By definition, a TCM must have a zonally continuous global domain with meridional bounds (Ray et al., 2012). There are several benefits to using a TCM over AGCMs including isolation from extratropical influences, higher resolution, more detailed display, and more sophisticated physics (Ray et al., 2012).

The main purpose of this work is to determine the accuracy of the modeled turbulent heat fluxes compared to observations. The mean fluxes and biases will be compared to previous works to determine whether the regional-based TCM is more accurate than AGCMs (Zhou et al., 2020).

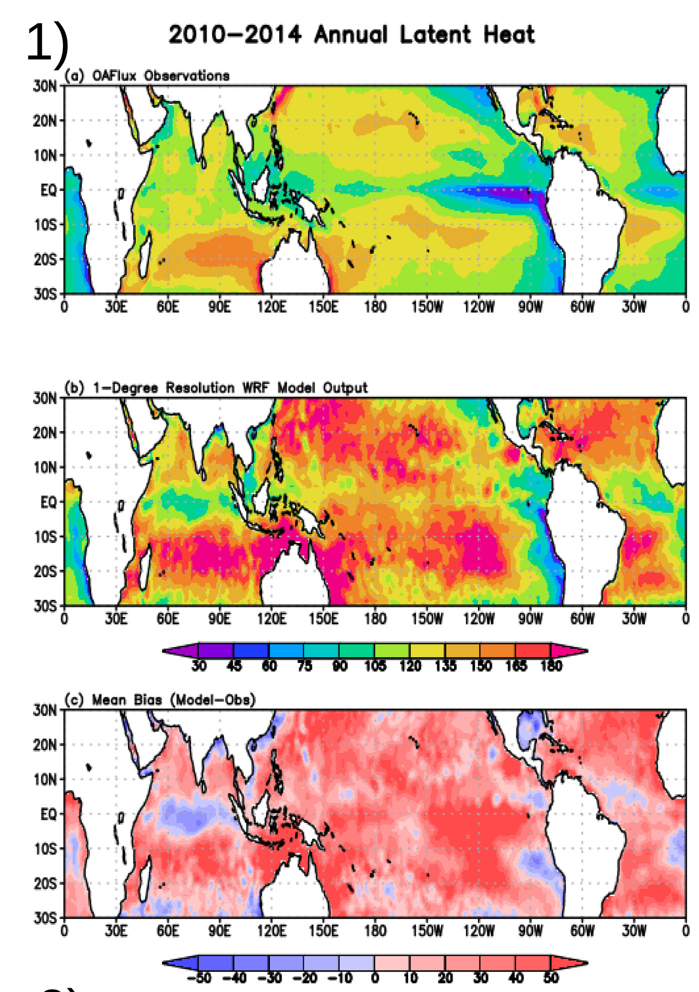
Data and Methods

The model being used is a TCM based on the National Center for Atmospheric Research's Weather Research and Forecasting (WRF; Skamarock et al., 2019) Model, which will be referred to as the Tropical-WRF (TWRF). The TWRF has a 1° horizontal resolution with a continuous zonal domain (0°E–360°E) and bounded meridional domain (35°S–35°N). The observed fluxes are from the Objectively Analyzed air-sea heat Fluxes (OAFlux) dataset (Yu & Weller, 2007), which contains calculated heat fluxes in a 1° grid across the world's oceans (0°E-360°E, 90°S-90°N).

The model and observations were analyzed from January 1, 2010, through December 31, 2014. The model data contains 3-hourly Q_{LH} and Q_{SH}, and the OAFlux data contains daily fluxes. To compare the model to the observations, the model had to be re-gridded via linear interpolation to match the observation grid. To compare performance, the mean biases, root mean square errors (RMSE), and correlation coefficients (CC) between the model and observations were calculated and compared to previous literature.

Results

1)



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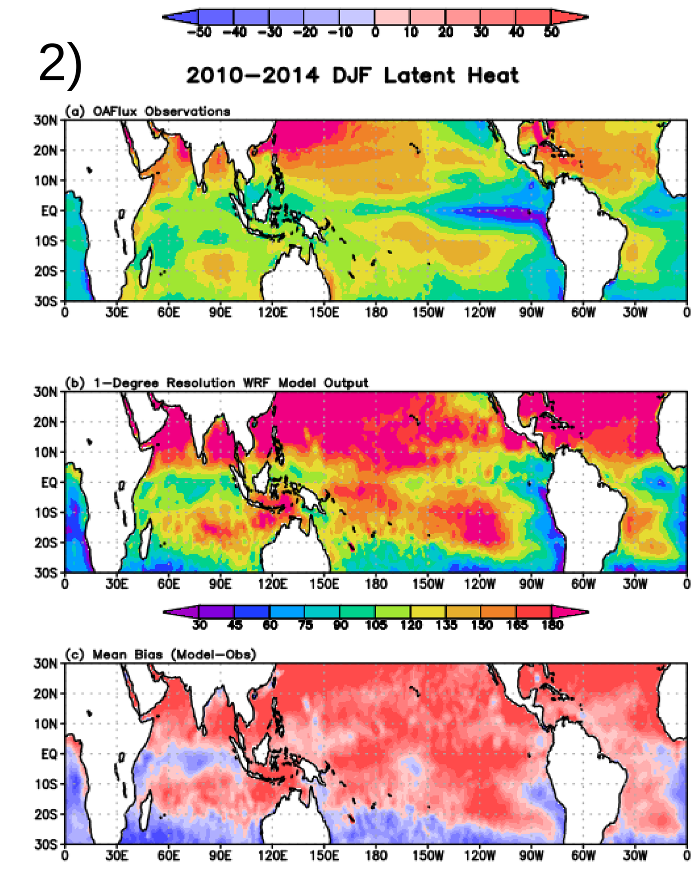

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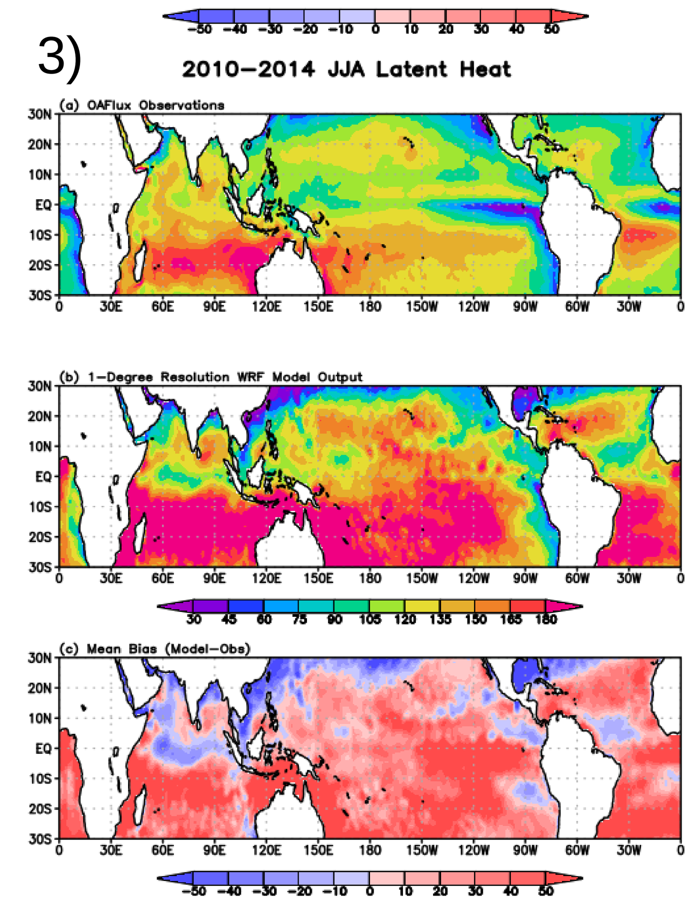

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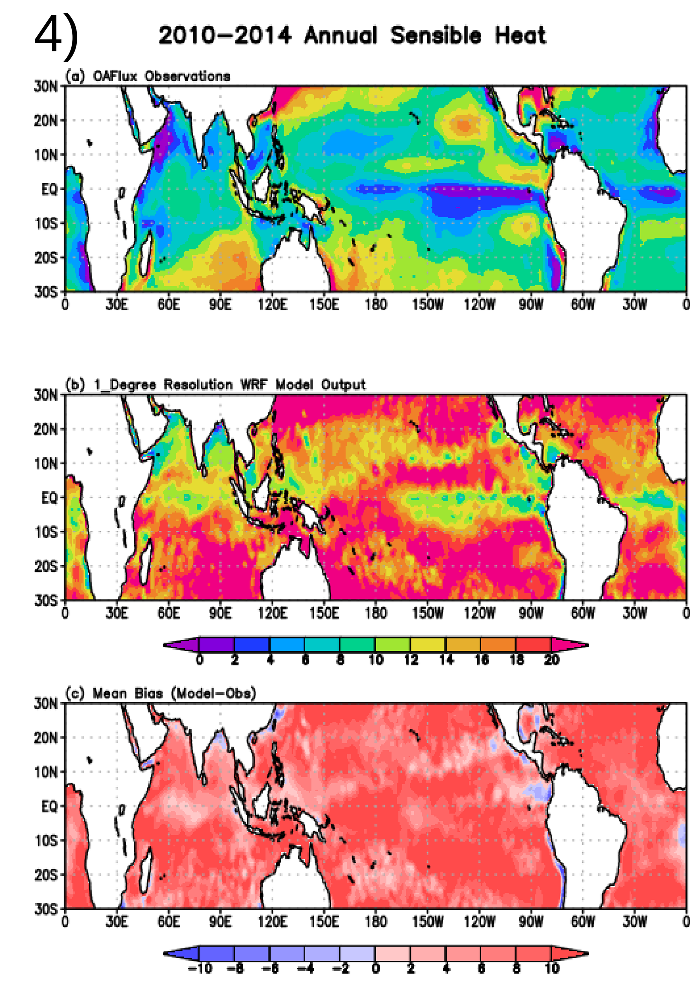

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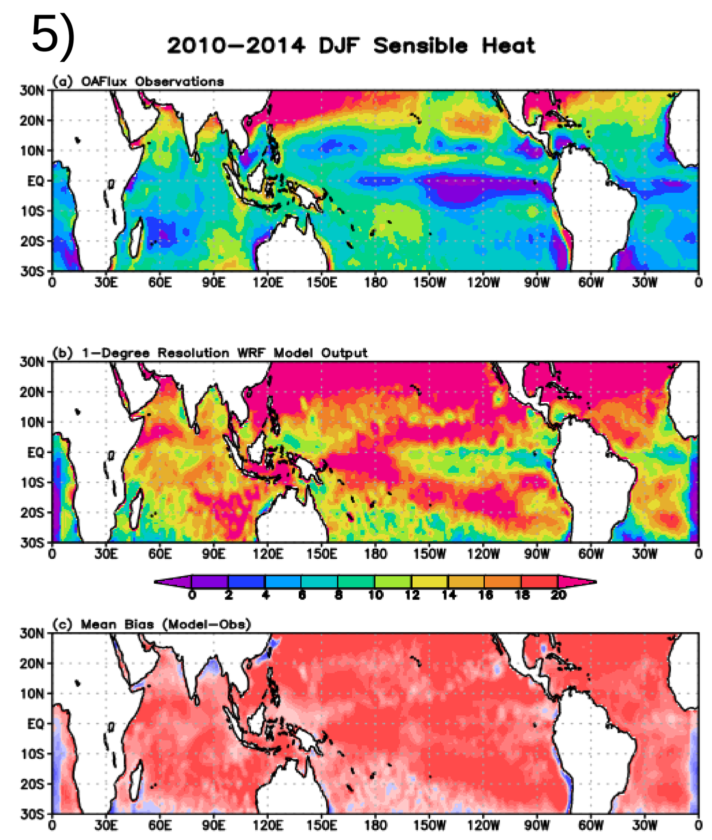

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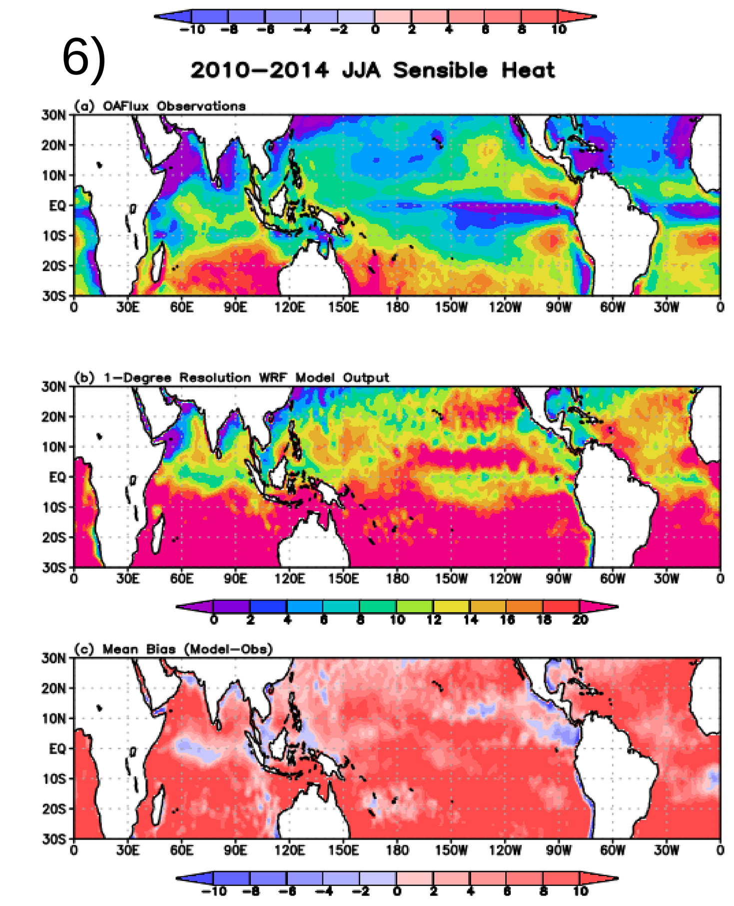

Figures 1-3: (1) annual, (2) boreal winter, and (3) boreal summer (a) OAFlux Q_{LH} and (b) TWRF Q_{LH} with (c) mean bias (model – observation) in W m^{-2}.
Figures 4-6: (4) annual, (5) boreal winter, and (6) boreal summer (a) OAFlux Q_{SH} and (b) TWRF Q_{SH} with (c) mean bias (model – observation) in W m^{-2}.

		30S-30N					10S-10N				
		TWRF Mean	OAFlux Mean	Mean Bias	RMSE	CC	TWRF Mean	OAFlux Mean	Mean Bias	RMSE	CC
Annual	Q_{LH}	142	116	26	36	0.63	132	106	26	35	0.52
	Q_{SH}	18	9	9	12	0.36	16	7	9	11	0.31
DJF	Q_{LH}	143	119	24	42	0.77	130	105	25	35	0.64
	Q_{SH}	18	9	9	12	0.72	16	7	9	11	0.40
MAM	Q_{LH}	135	114	21	41	0.43	125	102	23	37	0.32
	Q_{SH}	17	8	9	12	0.20	16	7	9	11	0.28
JJA	Q_{LH}	147	120	27	48	0.67	141	112	29	43	0.42
	Q_{SH}	19	9	10	13	0.46	17	8	9	12	0.21
SON	Q_{LH}	142	113	29	43	0.42	131	105	26	36	0.46
	Q_{SH}	18	9	9	12	0.24	16	8	8	11	0.23

Table 1: annual and seasonal TWRF mean fluxes, OAFlux mean fluxes, mean biases, and root mean square errors for Q_{LH} and Q_{SH} in W m^{-2}, and correlation coefficients between TWRF and OAFlux across 30°S-30°N and 10°S-10°N.

Discussion and Conclusion

The bias in the model followed expected hemispheric and seasonal trends. The biases for Q_{LH} and Q_{SH} were larger in the northern hemisphere during boreal winter, and larger in the southern hemisphere for boreal summer. Based on CC, the Q_{LH} was modeled more accurately than Q_{SH} on an annual timescale.

The regional TWRF performed worse than the AGCMs, which was an unexpected result. Compared to Zhou et al. (2020), the RMSEs were similar to the worst performing AGCMs and worse than the AGCM ensemble. Additionally, the CCs between the TWRF and OAFlux were much lower than in Zhou et al. (2020). Since regional models like the TWRF generally have more detailed model physics, it should have performed better than the AGCMs and AGCM ensemble. The results and applications of this study are limited until we can answer what caused the regional model to perform worse than AGCMs (model physics, calculation methods, etc.)

References

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Acknowledgements

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