

HURRICANE HINDCASTS ARE MISSING THE PEAKS

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1. ABSTRACT

Hurricanes produce the most intense wind speeds over Earth's oceans, resulting in extreme sea states. Understanding ocean wave development under hurricane conditions is important for safety and operations offshore, yet operational hindcasts tend to under-predict the highest sea states [1–3].

Following [4], ref. [2] combined hurricane track information in the North Atlantic [5, 6] and observations of significant wave height from satellite altimeter [7, 8]. Using a coordinate transformation based on hurricane radii and orientation [9–14], ref. [2] produced spatial maps of wave heights, amalgamating 1,286 altimeter passes. Ref. [2] showed the variation of wave height as a function of hurricane intensity and translation speed that revealed evidence of extended fetch [15].

Comparing to the hindcast from the Institut français de recherche pour l'exploitation de la mer (Ifremer), which was forced by the Climate Forecast System Reanalysis (CFSR) produced by the U.S. National Oceanic and Atmospheric Administration (NOAA) National Center for Environmental Prediction (NCEP)[16], ref. [2] showed a pattern of bias in the estimated wave heights under hurricane conditions. Figure 1 a) reproduces the wave height bias map along with contours of wave height as observed by altimeter. Fig. 1 a) shows that although wave heights tend to be overestimated in the right sector, the highest wave heights are underestimated near the hurricane eye. This is the spatial analog to missing the peak of a time series [1].

Here we extend the work of ref. [2] by looking directly at wind speeds that drove the hindcast. altWIZ¹, a system for pairing altimeter measurements with models, point observations, and storm tracks [17], was updated to include wind speed. Fig. 1 b) shows percent bias of model wind speed with contours of observed wind speed overlaid. Wind speed is overestimated except for an area of severe underestimation within 2R. The low winds around the eye explain the under-generation of peak swell waves that dominate the eye region and left and rear sectors. Ongoing work extends this analysis to extra-tropical cyclones[18].

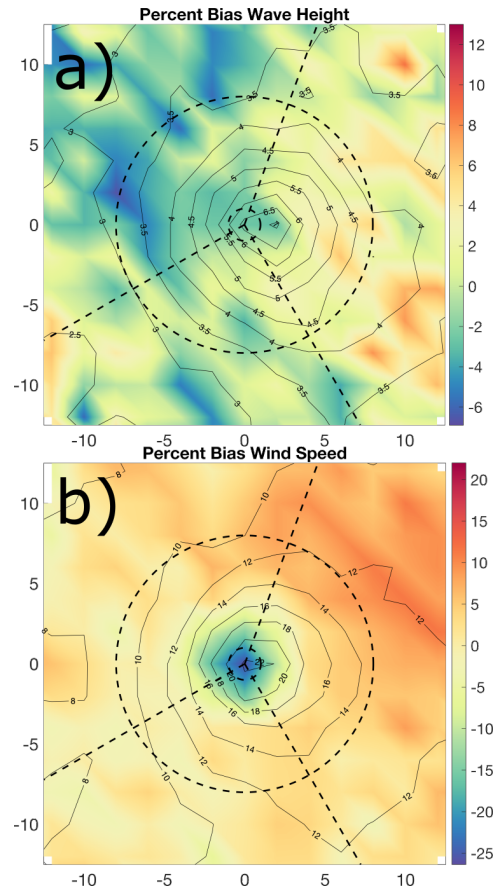


FIGURE 1: PERCENT BIAS OF (A) WAVE HEIGHT AND (B) WIND SPEED FROM IFREMER HINDCAST COMPARED TO OBSERVATIONS BY ALTIMETERS IN A HURRICANE-CENTERED REFERENCE FRAME AVERAGED IN 2R X 2R BINS. R IS THE DISTANCE NORMALIZED BY RADIUS OF MAXIMUM WINDS. ALL DATA ARE FROM HURRICANE CONDITIONS (MAXIMUM WIND SPEED ≥ 33 M/S). CONTOURS SHOW THE ALTIMETER OBSERVATIONS OF (A) WAVE HEIGHT AND (B) WIND SPEED. SMALL DASHED CIRCLE IS $R = 1$; LARGER DASHED CIRCLE IS $R = 8$. DASHED LINES SHOW HURRICANE SECTORS. THE ORIENTATION IS SUCH THAT THE HURRICANE IS MOVING FORWARD UP THE PAGE. NOTE THE CHANGE IN COLOR SCALES.

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¹<https://github.com/Tripphysicist/altWIZ.git>

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REFERENCES

- [1] Cavaleri, Luigi. "Wave modeling—Missing the peaks." *Journal of Physical Oceanography* Vol. 39 No. 11 (2009): pp. 2757–2778.
- [2] Collins, Clarence, Hesser, Tyler, Rogowski, Peter and Merrifield, Sophia. "Altimeter observations of tropical cyclone-generated sea states: Spatial analysis and operational hindcast evaluation." *Journal of Marine Science and Engineering* Vol. 9 No. 2 (2021): p. 216.
- [3] Rogowski, Peter, Merrifield, Sophia, Collins, Clarence, Hesser, Tyler, Ho, Allison, Bucciarelli, Randy, Behrens, James and Terrill, Eric. "Performance assessments of hurricane wave hindcasts." *Journal of Marine Science and Engineering* Vol. 9 No. 7 (2021): p. 690.
- [4] Tamizi, Ali and Young, Ian R. "The spatial distribution of ocean waves in tropical cyclones." *Journal of Physical Oceanography* Vol. 50 No. 8 (2020): pp. 2123–2139.
- [5] Knapp, KR, Diamond, HJ, Kossin, JP, Kruk, MC and Schreck, CJ. "International best Track Archive for Climate Stewardship (IBTrACS) Project, Version 4.0, North Atlantic." *NOAA Natl. Centers Environ. Information*. <https://doi.org/10.25921/82ty-9e16>. Accessed 30-09-2020 Vol. 26 (2019).
- [6] Vigh, Jonathan L., Gilleland, Eric G., Williams, Christopher L., Dorst, Neal M., Chavas, Daniel R., Done, James M., Brown, Barbara G. and Holland, Greg J. "TC-OBS: The Tropical Cyclone Observations-Based Structure Database (pre-release version 0.40)." *Tropical Cyclone Data Project, National Center for Atmospheric Research, Research Applications Laboratory, Boulder, Colorado*. [Downloaded from: <https://verif.rap.ucar.edu/tcdata/historical/>.] Accessed 30-09-2020. (20156).
- [7] Ribal, Agustinus and Young, Ian R. "33 years of globally calibrated wave height and wind speed data based on altimeter observations." *Scientific data* Vol. 6 No. 1 (2019): pp. 1–15.
- [8] Dodet, Guillaume, Piolle, Jean-François, Quilfen, Yves, Abdalla, Saleh, Accensi, Mickaël, Ardhuin, Fabrice, Ash, Ellis, Bidlot, Jean-Raymond, Gommenginger, Christine, Marechal, Gwendal et al. "The Sea State CCI dataset v1: towards a sea state climate data record based on satellite observations." *Earth System Science Data* Vol. 12 No. 3 (2020): pp. 1929–1951.
- [9] Young, Ian Robert. "Parametric hurricane wave prediction model." *Journal of Waterway, Port, Coastal, and Ocean Engineering* Vol. 114 No. 5 (1988): pp. 637–652.
- [10] Young, Ian Robert. "Observations of the spectra of hurricane generated waves." *Ocean Engineering* Vol. 25 No. 4–5 (1998): pp. 261–276.
- [11] Young, Ian Robert. "Directional spectra of hurricane wind waves." *Journal of Geophysical Research* Vol. 111 No. C08020 (2006).
- [12] Young, Ian Robert. "A review of parametric descriptions of tropical cyclone wind-wave generation." *Atmosphere* Vol. 8 No. 10 (2017): p. 194.
- [13] Young, Ian Robert. "A review of the sea state generated by hurricanes." *Marine Structures* Vol. 16 No. 3 (2003): pp. 201–218.
- [14] Collins, CO, Potter, H, Lund, B, Tamura, H and Graber, Hans C. "Directional wave spectra observed during intense tropical cyclones." *Journal of Geophysical Research: Oceans* Vol. 123 No. 2 (2018): pp. 773–793.
- [15] Young, Ian Robert. "An 'extended fetch' model for the spatial distribution of tropical cyclone wind-waves as observed by altimeter." *Ocean Engineering* Vol. 70 (2013): pp. 14–24.
- [16] Spindler, Deanna M, Chawla, Arun and Tolman, Hendrik L. "An initial look at the CFSR Reanalysis winds for wave modeling." Technical Report No. 290. 2011.
- [17] Collins III, Clarence O. and Hesser, Tyler. "altWIZ: A System for Satellite Radar Altimeter Evaluation of USACE Wave Information Study Hindcast." Technical Report No. CHETN- -. US Army Engineer Research and Development Center, Duck, NC. accepted.
- [18] Lodise, John, Merrifield, Sophia, Collins, Clarence, Rogowski, Peter, Behrens, James and Terrill, Eric. "Global climatology of extratropical cyclones from a new tracking approach and associated wave heights from satellite radar altimeter." *Journal of Geophysical Research: Oceans* Vol. 127 No. 11 (2022): p. e2022JC018925.