Projected North Atlantic tropical cyclone intensity through 2100 based on thermodynamic modifications of historical environments

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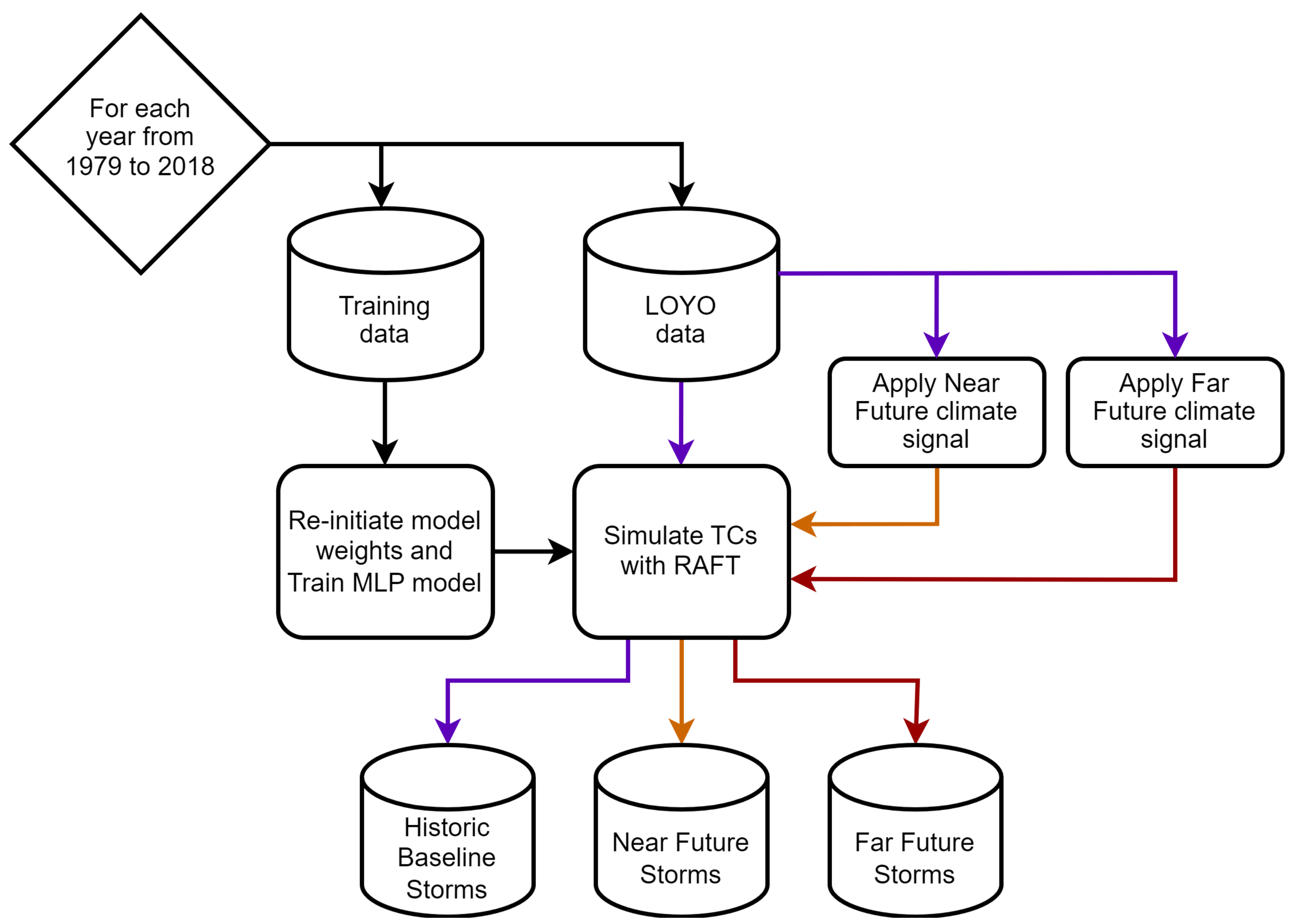
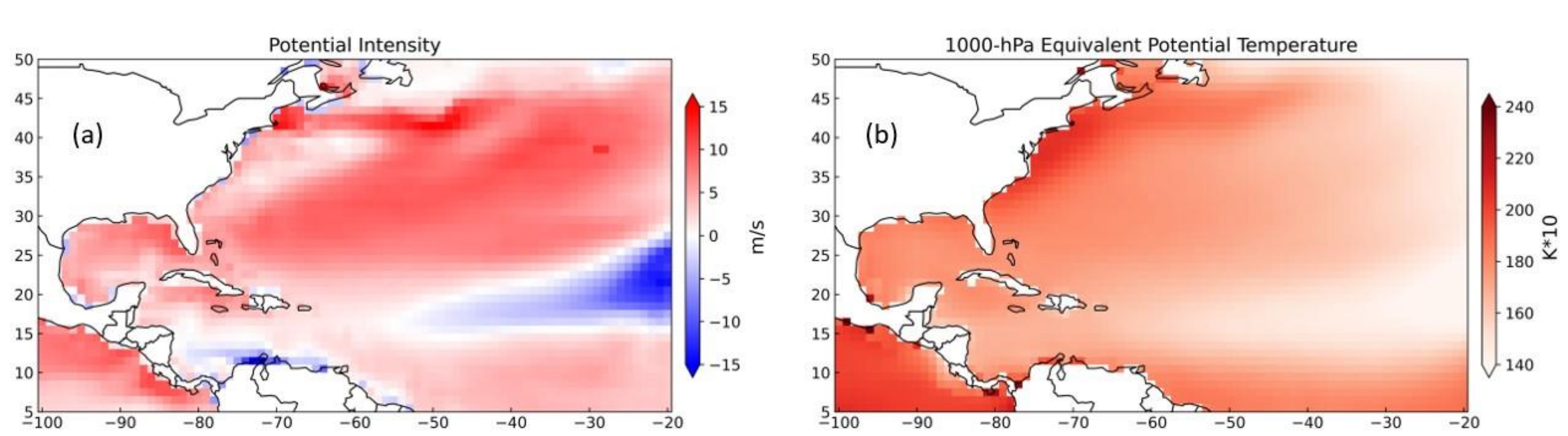
Introduction

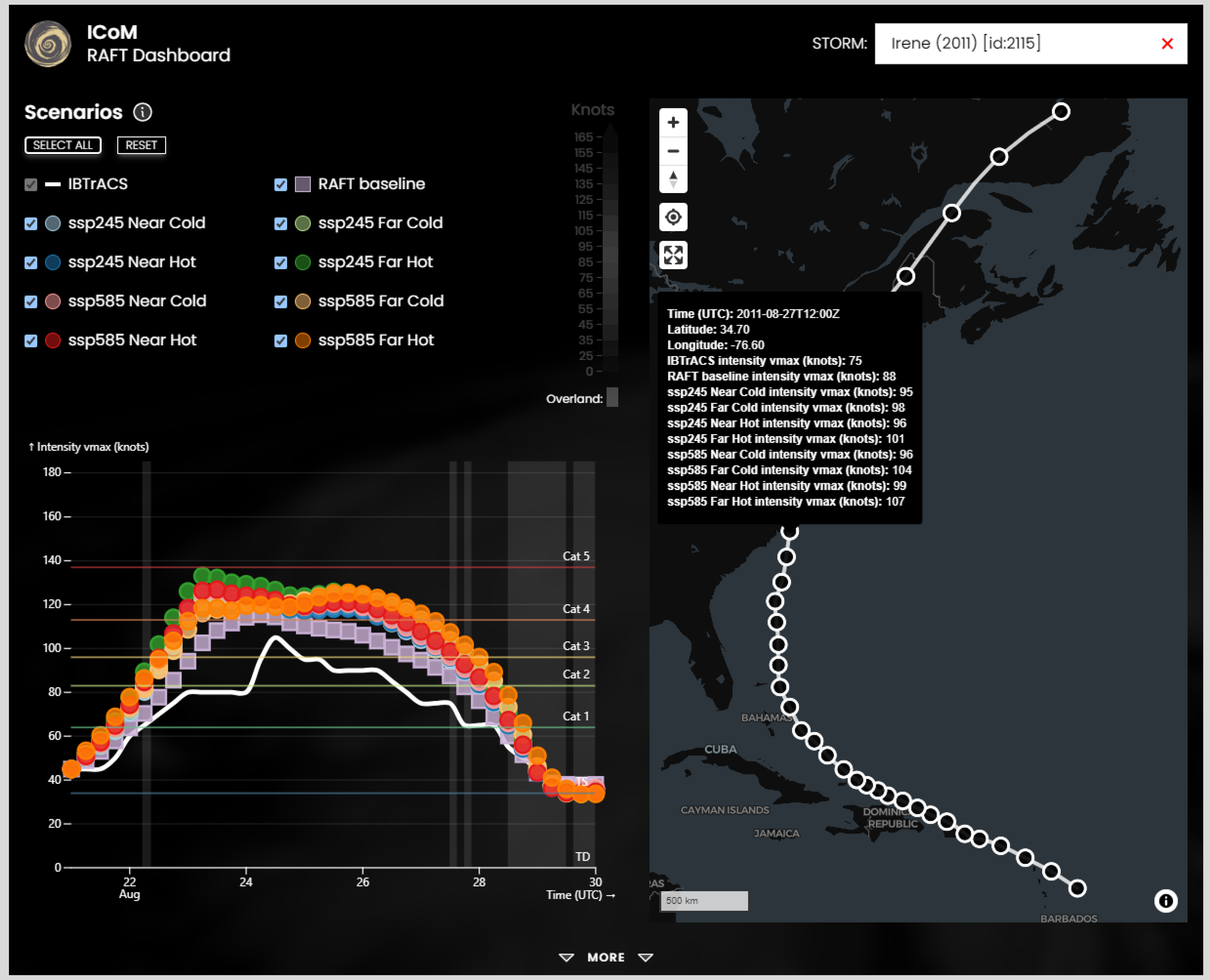
Tropical cyclones (TCs) rank as the most deadly and financially crippling natural disasters in the United States for the last half-century. It is imperative to assess potential shifts in TC intensity within the paradigm of an evolving climate. We have modeled 620 historical TC events' intensities in the North Atlantic basin using RAFT's deep learning intensity model[1]. A thermodynamic warming signal, extrapolated from Global Climate Models, is utilized to rerun historical events under eight different future climate scenarios, providing a spectrum of potential intensity outcomes. This dataset facilitates a systematic exploration of the discrete effects that changes in the Earth's thermodynamics have on the intensities of tropical cyclones.



The workflow for training models and simulating tropical cyclones (TC) in the North Atlantic basin. Each year in the 40-year period, a new model is trained without the selected year's data to maximize training data while avoiding data leakage. The Leave One Year Out (LOYO) data is used to simulate the current year's TCs (purple). Utilizing Jones et. al.'s thermodynamic warming signal method in a simplified way, Near Future (orange 2019-2058) and Far Future (red 2059-2098) climate signals are applied to the historic data to simulate these historic storms in the context of future climates[2].

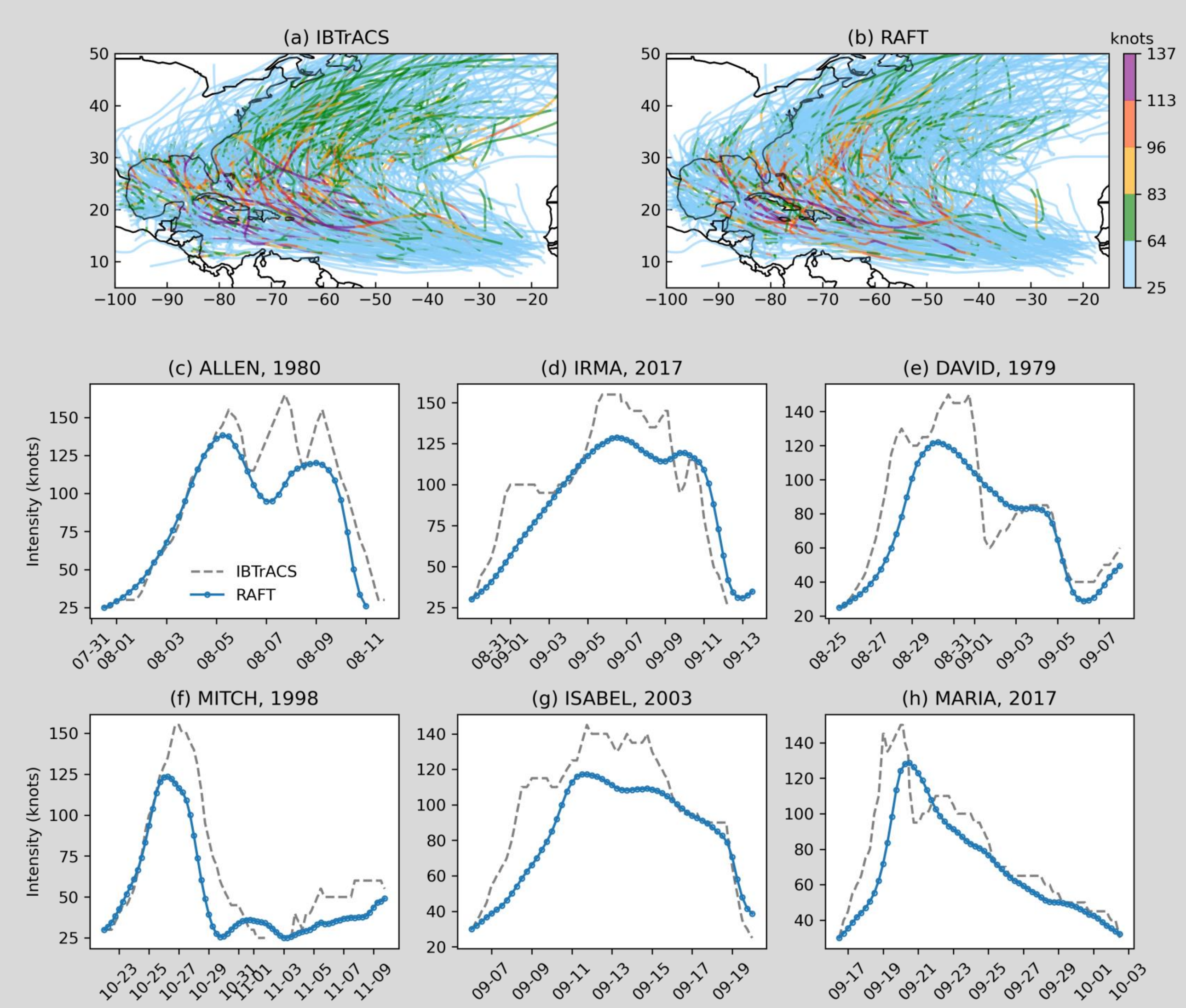


(above) The changes between a 40-year hurricane seasonal mean in ssp585 far future hot model mean and historic data visualized for two key environmental factors for TC intensification: (a) Potential Intensity, (b) 1000-hPa EPTK.



RAFT-warming-projections.msdlive.org

Web dashboard for data exploration comparing a historical simulation reproducing Irene in 2011 with eight future climate scenarios. A difference in simulated landfalling intensity between the historical reproduction and ssp585 far future hot model mean shows an increase of roughly 20 knots escalating landfall from a Category 2 to a Category 3.



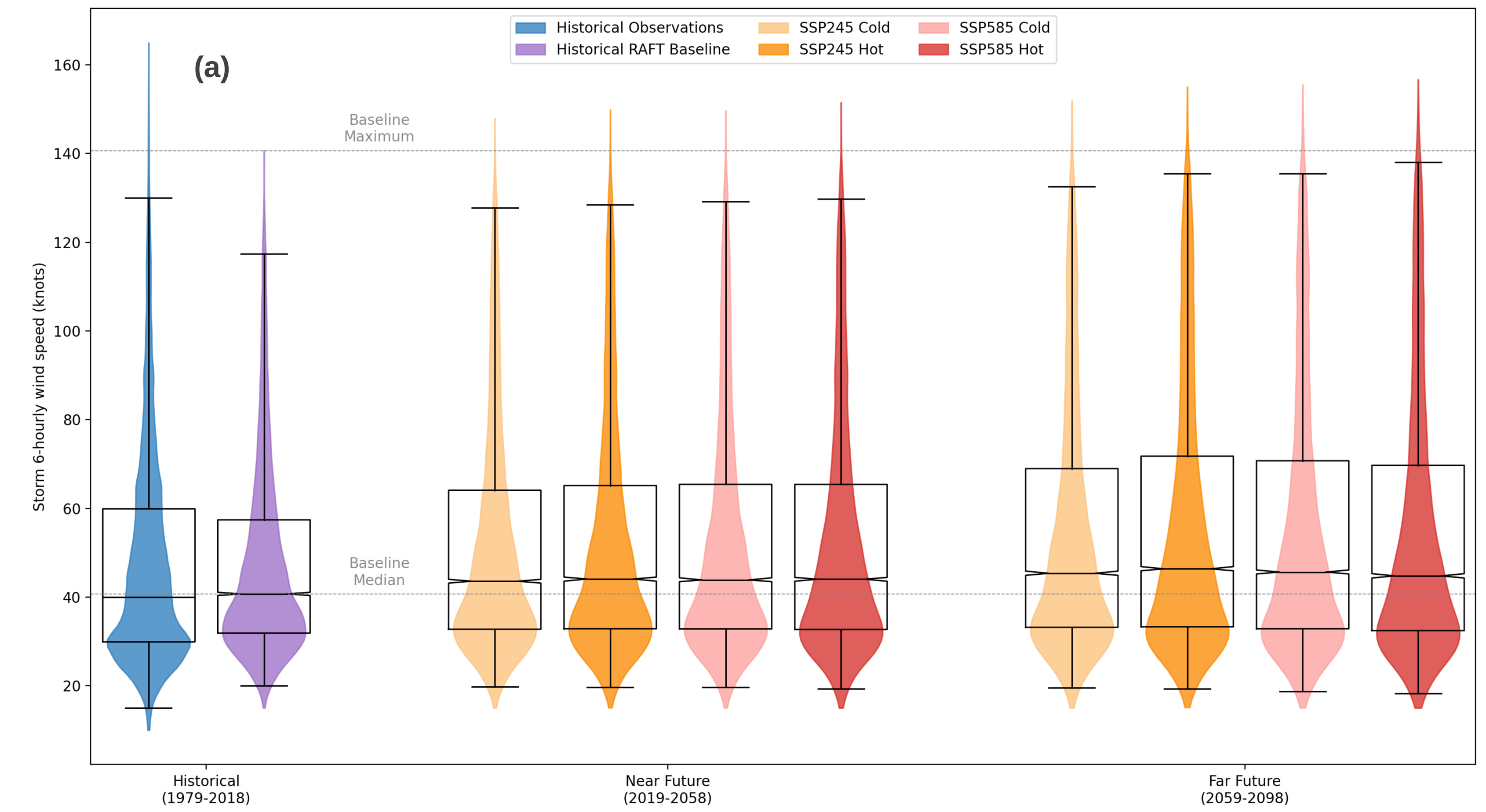
Historical Validation

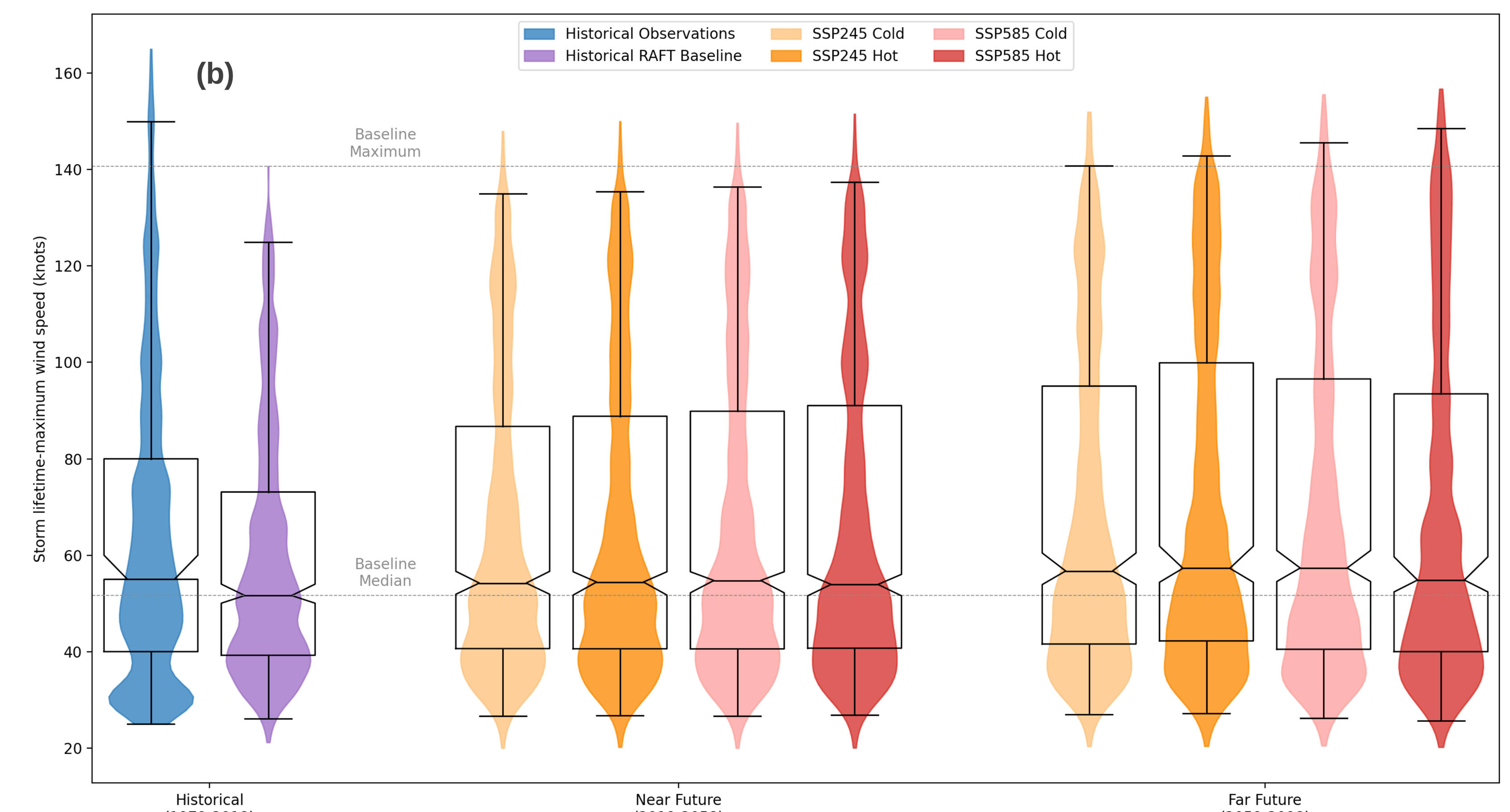
620 TCs in the North Atlantic basin from IBTrACS (a) and RAFT's historical simulations (b) between 1979 and 2018[3]. RAFT reproduces intensity changes for all storms along fixed historical tracks with the following error given in knots: -0.66 ME, 13.96 MAE, and 20.18 RMSE.

(c),(d),(e),(f),(g) and (h) are the six TCs in the North Atlantic basin with the longest time spent as Category 5 in the 40 year time period simulated in this dataset. RAFT can simulate storms of all categories exceeding the TC modeling capabilities of traditional atmospheric models that can struggle with Category 4 and 5s[2,4].

Future Projections

(below) Violin and box plots comparing the changes between RAFTs TC simulations in the historical reproduction and eight future climate scenarios: (a) all instantaneous maximum wind speed and (b) per storm lifetime maximum wind speed.





References

1.Xu, W., et al. (2021). Deep learning experiments for tropical cyclone intensity forecasts. *Weather and Forecasting*, 36, 1453–1470. https://doi.org/10.1175/WAF-D-20-0104.1

2.Jones, A. D., Rastogi, D., Vahmani, P., et al. (2023). Continental United States climate projections based on thermodynamic modification of historical weather. *Scientific Data*, 10, 664. https://doi.org/10.1038/s41597-023-02485-5

3.Knapp, K. R., Kruk, M. C., Levinson, D. H., Diamond, H. J., & Neumann, C. J. (2010). The International Best Track Archive for Climate Stewardship (IBTrACS): Unifying tropical cyclone best track data. *Bulletin of the American Meteorological Society*, 91. https://doi.org/10.1175/2009BAMS2755.1

4.Shaevitz, D. A., et al. (2014). Characteristics of tropical cyclones in high-resolution models in the present climate. *Journal of Advances in Modeling Earth Systems*, 6, 1154–1172. https://doi.org/10.1002/2014MS000372

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