A Detailed Dataset of Surface Winds Over Puerto Rico from a WRF Simulation of Hurricane Maria (2017)

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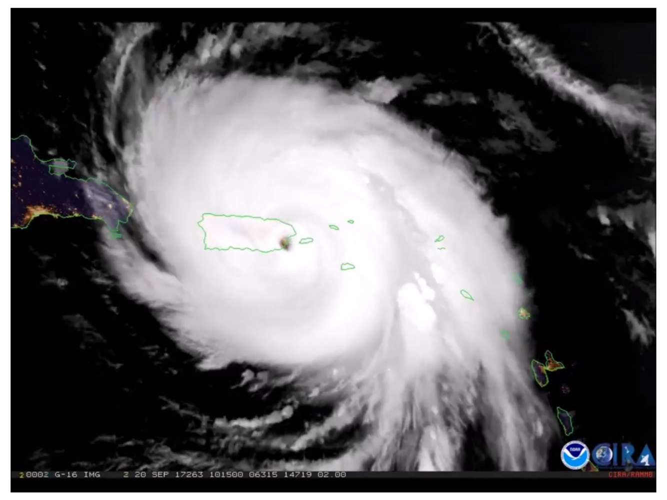
Background

- The Category 4 winds produced by Hurricane Maria (2017) upon landfall in Puerto Rico resulted in widespread devastation across the island, warranting a high-resolution and accurate model simulation of the surface wind fields for further research.

- Achieving the closest possible representation of the actual surface wind field requires extensive validation of the simulated wind fields with land observations, yet such validation studies have rarely been performed on hurricane models, which in fact are not currently used to forecast real-world hurricane wind fields over land.



Hurricane Maria at landfall on Puerto Rico. Image credit: NOAA & Colorado State University

Model and vortex initialization

- The Advanced Research Weather Research and Forecasting (WRF-ARW) model, Version 3.9.1.1, is used with a parent domain of 9 km grid resolution with two storm-following inner nests of 3 km and 1 km resolution and 60 vertical levels.

- Boundary conditions were provided by GFS analyses. For greater control over the evolution of the vortex size, track, and intensity, we used the readjustment technique given by Rappin et al. (2013), sometimes called vortex "bogussing."

- The new vortex wind profile follows a modified Rankine vortex that gently decays past a specified cutoff radius.

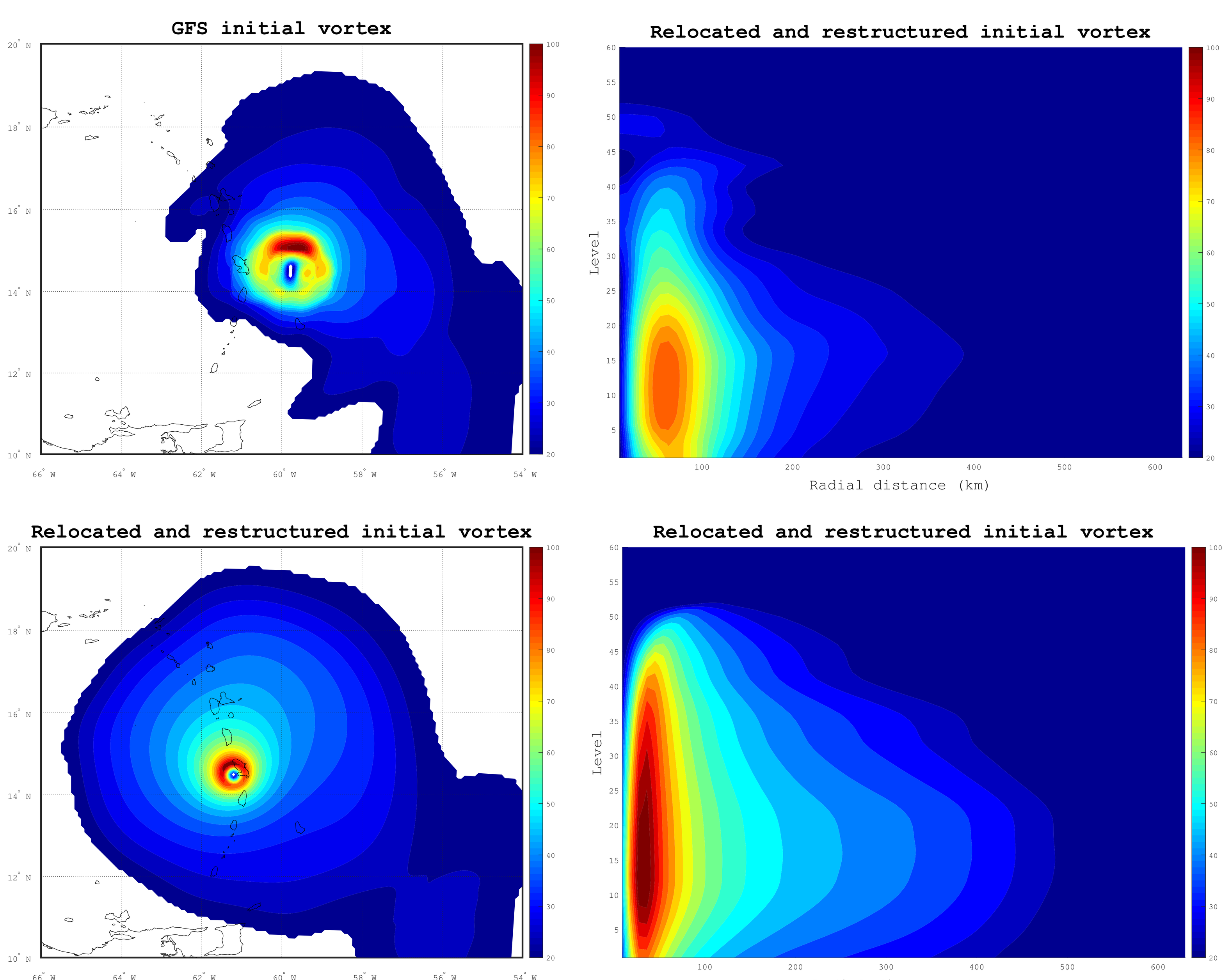


Figure 1: The "surface" (i.e., lowest model level) wind field and radial cross section of the GFS analysis vortex (top) and a readjusted vortex (bottom) at 12:00 UTC on 9/18/17. The new vortex pictured was shifted 1.5 degrees west from its original location, given a radius of maximum winds (RMW) of 27 km and maximum surface winds of 100 kt (51.5 m s^{-1}). Moisture was also added into the inner core to spur convection and intensify the storm.

Hurricane Maria simulations

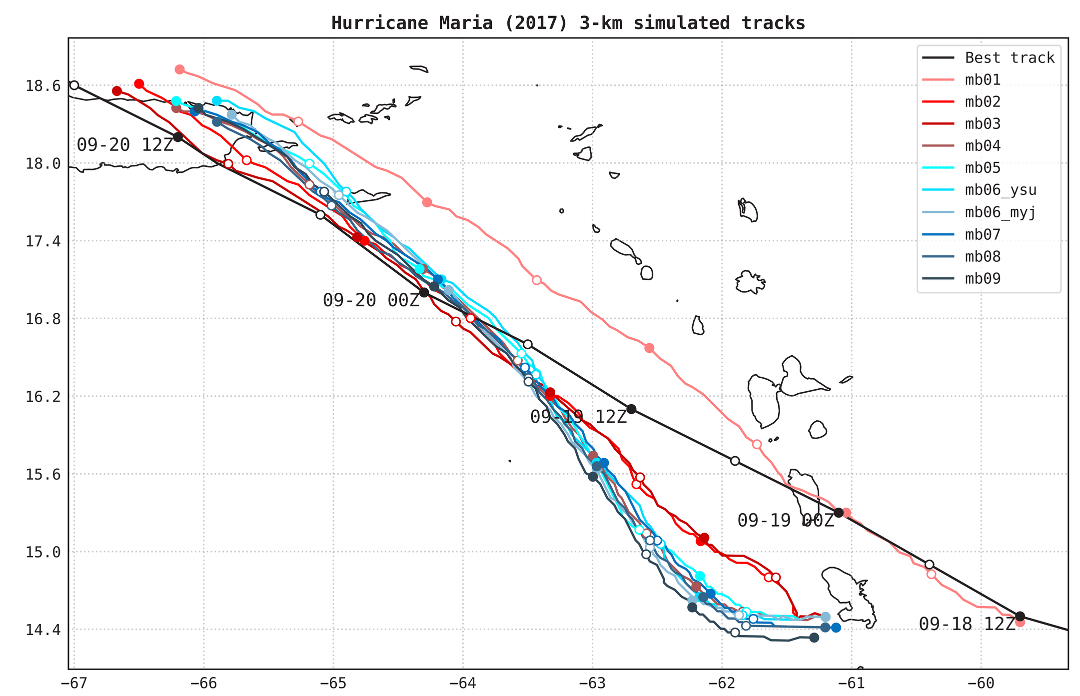


Figure 2: Tracks of ten 48-hour simulations of Hurricane Maria from 9/18 12:00 UTC to 9/20 12:00 UTC.

Red-shaded tracks were initialized with a 27-km RMW vortex; blue-shaded tracks were initialized with an 18-km RMW.

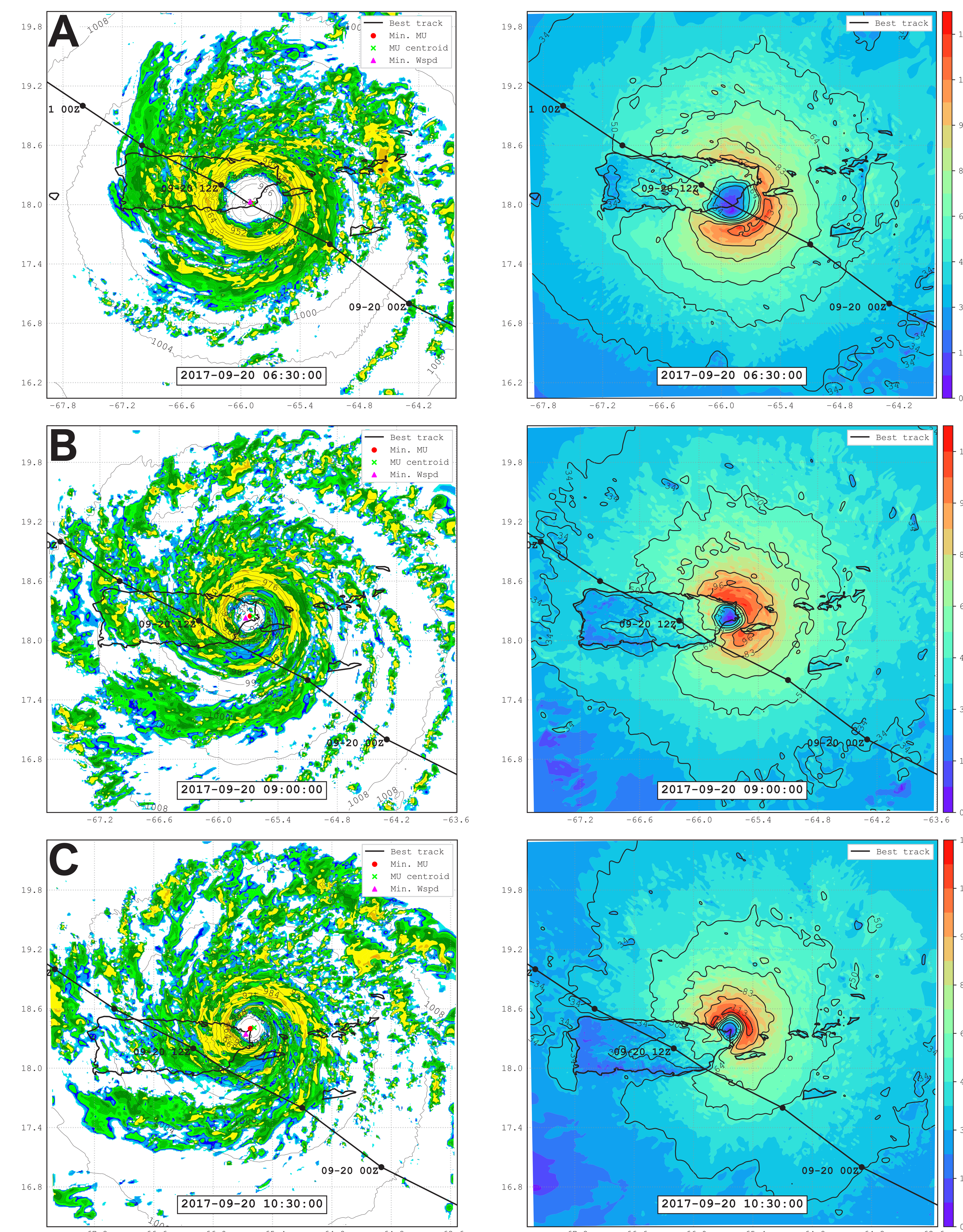
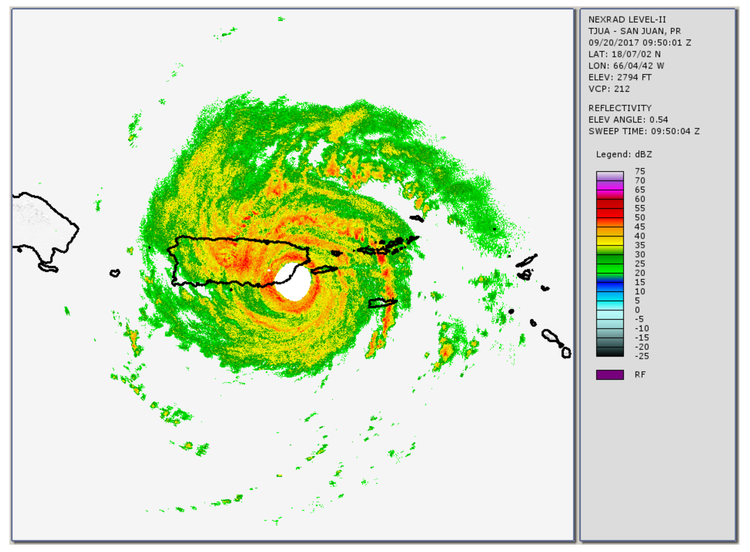


Figure 3: The simulated reflectivity (left) and 10-meter wind speed (right) for three cases: A) vortex initialized with 27-km RMW and 175-km R34 ("mb03"); B) 27-km RMW and 113-km R34 ("mb04"); and C) 18-km RMW and 76-km R34 ("mb06_ysu"). Note that the times indicated are simulation times.

Selected case



The 27-km RMW, 175-km R34 initial vortex (mb03; Fig. 3A) was chosen to be simulated with a surface field output frequency of 10 seconds, since the simulated track and intensity (125 kt, 928 hPa) were fairly close to the observed values (135 kt, 920 hPa). The simulated eyewall radius is similar to the observed outer eyewall radius (Left: Radar image from San Juan at 09:50 UTC on 9/20 with the weak remnant inner eyewall removed for comparison).

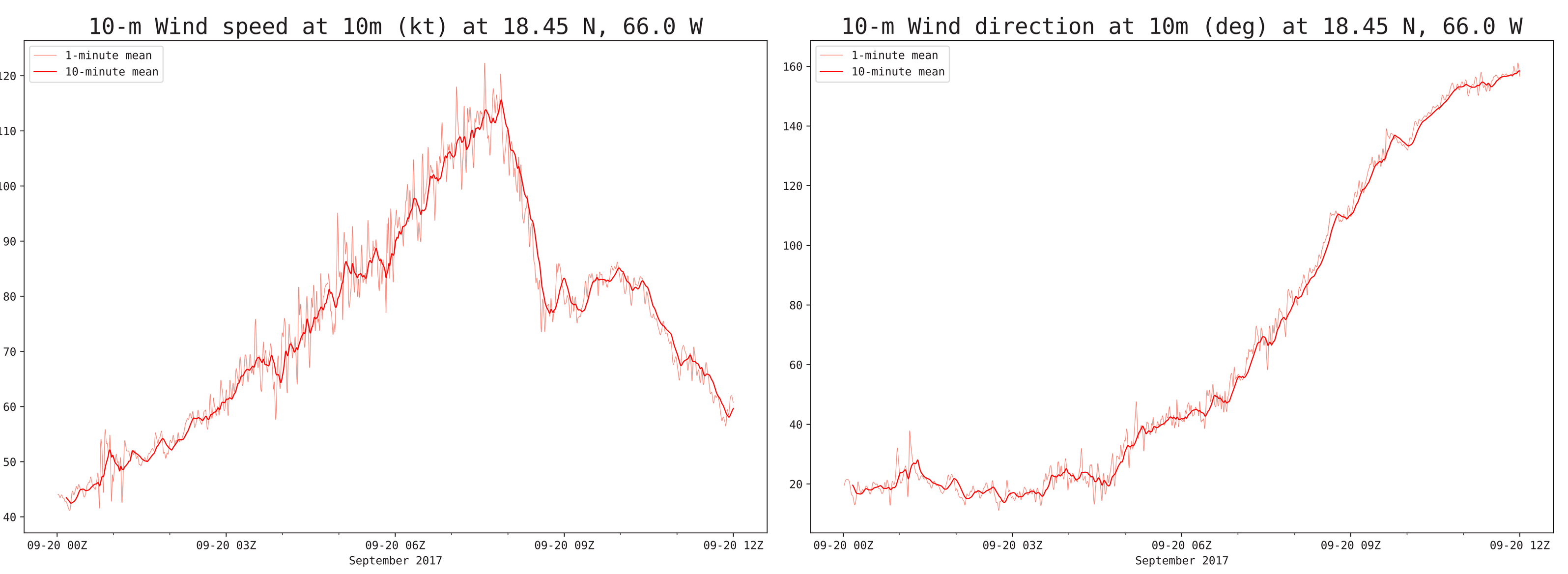


Figure 4: Simulated time series of 10-meter wind speed and direction at a San Juan International Airport. With the high-frequency data, we can also compare the structure of the storm by matching with time series of observed winds taken at weather stations.

Conclusions and future work

- A dataset of Hurricane Maria's surface winds over Puerto Rico has been produced with grid spacings down to 1 km and surface wind field output frequency of 10 seconds.

- More intensive validation work is required, especially regarding the inner core size. This will consist of taking simulated time series of winds at fixed points (like in Fig. 4) and comparing to available wind measurements taken at weather stations across Puerto Rico before the instruments failed.

- This dataset may eventually be used for a number of different projects, e.g., comparing planetary boundary layer schemes or studying the surface winds over the San Juan urban canopy.

References

- R. J. Pasch, A. B. Penny, and R. Berg. Tropical cyclone report, Hurricane Maria. National Hurricane Center, National Weather Service, 48 pp. [Available online at https://www.nhc.noaa.gov/data/tcr/AL152017_Maria.pdf.]
- Rappin, Eric D., D. S. Nolan, and S. J. Majumdar, 2013: A Highly Configurable Vortex Initialization Method for Tropical Cyclones. *Mon. Wea. Rev.*, **141**, 3556-3575.

Acknowledgements

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