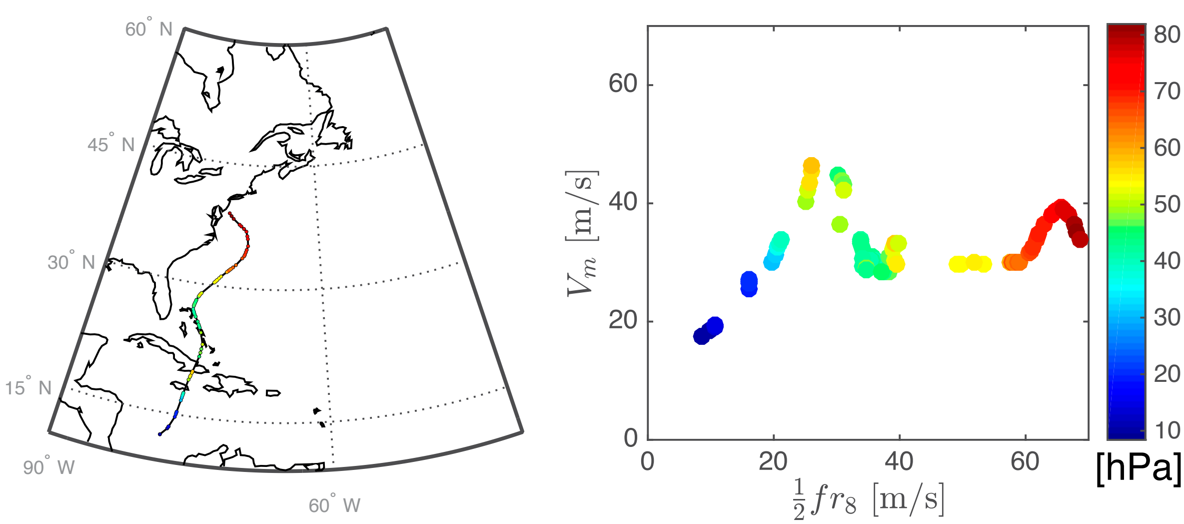
Physical Understanding of the Tropical Cyclone Wind–Pressure Relationship

Hurricane intensity is commonly defined using two different quantities: the maximum near-surface wind speed and the minimum central pressure, the latter of which can be converted to a central pressure deficit given by the difference between the minimum sea level pressure at the center of the storm and that of the environment outside of the storm. Previous empirical work has shown that the central pressure deficit increases (i.e., the central pressure decreases) primarily with increasing maximum wind speed and secondarily with increasing storm latitude and storm size. However, we lack a physical understanding of this relationship. Our work provides a theoretical explanation for these dependencies based on recent advances in our understanding of the structure of the near-surface wind field in a hurricane. The theory is tested on large datasets of historical hurricanes based on aircraft observations as well as in two types of simulation experiments: an Earth-like late-twentieth-century global climate simulation, and a highly-simplified Earth-like world covered in water in which tropical cyclones roam much of the planet's surface area. The theory performs well across this "hierarchy of models," which demonstrates both the basic understanding of the relationship in a simplified setting and the applicability to real storms on Earth.

Overall, our results explain physically how a large storm with a weaker maximum wind speed may possess the same central pressure deficit as a small storm with a stronger maximum wind speed. This is important because storm size is known to be a critical factor governing potential damage. A prominent example is Hurricane Sandy (2012), which possessed a central pressure typical of a category 3 hurricane despite having maximum wind speeds of only category 1, owing to its extremely large size leading up to landfall. Indeed, recent economic research has demonstrated that the central pressure is a better predictor of historical economic damages than maximum wind speed, both in the United States and globally. As an intensity measure that combines maximum wind speed and storm size, the central pressure deficit may be a more useful measure of storm risk than maximum wind speed alone.

Further research is needed to evaluate the pros and cons of these and other existing metrics of storm damage potential on the basis of simplicity, physical understanding, data availability, and societal factors that may promote or hinder uptake.—Daniel R. Chavas (Purdue University), K. A. Reed, and J. A. Knaff, "Physical understanding of the tropical cyclone wind–pressure relationship," presented at the 33rd Conference on Hurricanes and Tropical Meteorology, 16–20 April 2018, Ponte Vedra, Florida.



***Hurricane Sandy's Wind–Pressure Relationship*. (left) Storm track and central pressure deficit (color; hPa). (right) Central pressure deficit as a function of maximum wind speed V_m and a parameter ($1/2fr_8$) that combines storm size [radius (km) of winds exceeding 8 m s^{-1} r_8] and latitude (Coriolis parameter f). Values of maximum wind speed and this parameter are higher when the central pressure deficit is larger. Data are from aircraft observations and Global Forecast System operational analyses.**