Effects of Observed Conditions on Tropical Cyclone Potential Intensity

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ABSTRACT # 244680

Introduction

Tropical cyclone Potential Intensity (PI) predicts the maximum intensity that a tropical cyclone (TC) can attain given a sea-surface temperature (SST), tropopause temperature, and an environmental sounding.

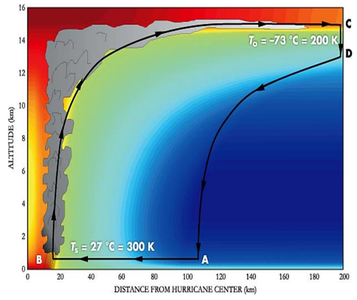

Figure 1: Schematic of the Carnot cycle underlying PI theory (Emanuel 2006). Entropy is imported into the storm from ocean-air fluxes at point B and exported at point C. This exchange drives the storm's winds.

The observed TC boundary layer differs from the idealizations of PI theory.

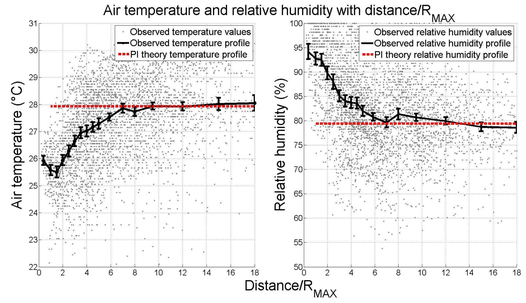

Figure 2: Observed surface layer air temperature and RH for 88 TCs compared to the radial profiles assumed in conventional PI theory (red lines). Observations are plotted relative to the radius of maximum winds (R_{MAX}) of the corresponding TC. PI theory assumes a radially isothermal boundary layer with constant RH outside R_{MAX}.

Methodology

PI is calculated for 27 Atlantic hurricanes (1997-2011) using seven tests.

Surface layer observations obtained from buoy and dropsonde data.

Three tests in which environmental conditions around each storm are varied: Observed conditions, Dunion 2011 sounding, and SHIPS environmental conditions.

Four tests in which temperature and/or moisture within each storm prior to ocean-air fluxes under the eyewall (R_{MAX}) are varied based on observed conditions or theoretical profiles.

PI for every storm and average PI are compared among tests.

Acknowledgment: *We thank NSF grant ATM–1322532 for funding this work and George Young for his valuable input.*

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Environmental and storm conditions in each test

Test Name	Environmental Conditions	R_{MAX} Temperature	Unsaturated R_{MAX} Mixing Ratio
Observed Environment Test	Sounding created from observed surface layer environmental conditions	Set at environmental temperature (PI theory)	Small increase from environment due to lower pressure (PI theory)
Modified Dunion Test	Temperature-modified Dunion (2011) mean moist tropical sounding	Set at environmental temperature (PI theory)	Small increase from environment due to lower pressure (PI theory)
SHIPS Environment Test	Sounding created from SHIPS environmental conditions	Set at environmental temperature (PI theory)	Small increase from environment due to lower pressure (PI theory)
Observed Temperature Test	Sounding created from observed surface layer environmental conditions	Set at average observed temperature between 1-2 R_{MAX}	Small increase from environment due to lower pressure (PI theory)
Constant Moisture Test	Sounding created from observed surface layer environmental conditions	Set at average observed temperature between 1-2 R_{MAX}	Set at environmental value
Inner Core Test	Sounding created from observed surface layer environmental conditions	Set at average observed temperature between 1-2 R_{MAX}	Calculated using average observed temperature and relative humidity between 1-2 R_{MAX}
Outer Core Test	Sounding created from observed surface layer environmental conditions	Set at average observed temperature between 2-3 R_{MAX}	Calculated using average observed temperature and relative humidity between 2-3 R_{MAX}

How environmental conditions affect PI

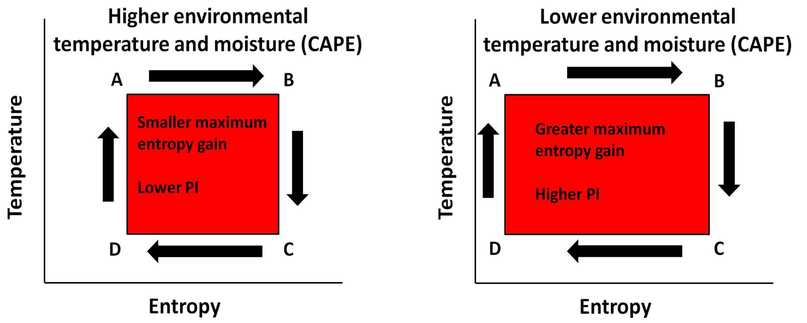

Figure 3: PI calculated using higher and lower environmental temperature and moisture. Lower environmental temperature and moisture results in higher PI because greater ocean-air energy flux occurs when environmental air is brought to R_{MAX}.

How conditions inside the storm affect PI

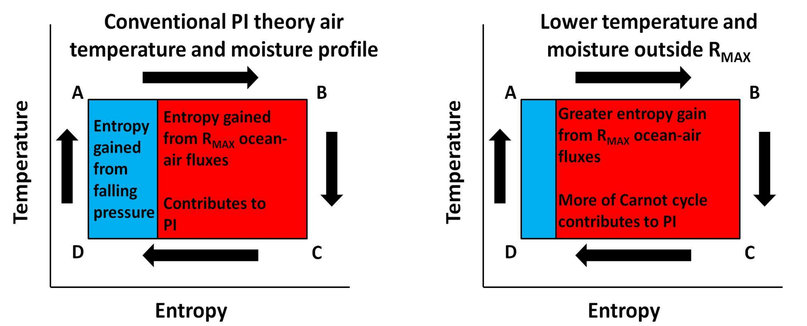

Figure 4: PI calculated using conventional PI theory and using lower temperature and moisture outside R_{MAX}. The maximum work done by the Carnot cycle remains the same regardless of conditions inside the tropical cyclone. However, when temperature and moisture outside R_{MAX} are lower, a greater fraction of the total entropy gain occurs from ocean-air fluxes at R_{MAX}. Because maximum winds depend on entropy gain at R_{MAX}, this results in higher PI.

Potential Intensity test results

Environmental conditions

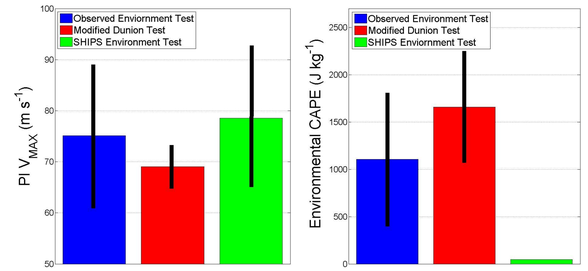

Figure 5: Average PI and environmental CAPE of the Observed Environment Test compared to the Modified Dunion Test and the SHIPS Environment Test . The Dunion test produces lower average PI values because it has higher environmental CAPE, representing a warmer, moister environment. The SHIPS test produces higher average PI values because it has lower environmental CAPE.

Conditions in the storm

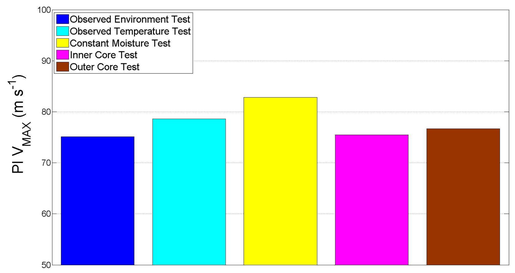

Figure 6: Average PI calculated using conventional PI theory compared to tests using different conditions within the storm . Using observed temperature just outside R_{MAX} and constant mixing ratio result in higher PI. Using both observed temperature and moisture results in PI values near the PI values calculated using conventional PI theory.

Results and conclusions

- Environmental variations can impact PI as much as a Saffir-Simpson category.
- Lower temperature and moisture just outside R_{MAX} result in higher PI.
- Using observed conditions causes some storms to have higher PI than conventional PI theory indicates.
- Using observed environmental conditions and observed conditions inside tropical cyclones could improve PI calculations of real-time storms.
- Further work is necessary to determine whether PI differences are reflected in observed intensity differences.