Is Climate Change Redefining the Speed Limit of Tropical Cyclones?

Kieran T. Bhatia[1*], Gabriel Vecchi[2], James Kossin[3], Thomas Knutson[4], and Hiroyuki Murakami[4]

[12]Princeton University, Princeton, New Jersey

[3]NOAA/National Center for Environmental Information, Center for Weather and Climate, University of Wisconsin, Madison, WI

[4]NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey

Supported by: Princeton University, Carbon Mitigation Initiative, and National Science Foundation

**Corresponding author email: kieran.bhatia@noaa.gov*

33rd Conference on Hurricanes and Tropical Meteorology
Sawgrass Marriott, Ponte Vedra Beach, Florida
16th-20th April 2018

Poster: 107

The recent upward trend in the most extreme 24-hour tropical cyclone (TC) intensification rates is outside of the "normal" natural variability of the climate system. Therefore, anthropogenic forcing is hypothesized to increase the likelihood of TCs rapidly intensifying, which will result in more difficult forecasts and vulnerable coastal communities.

Observational Datasets

IBTrACS

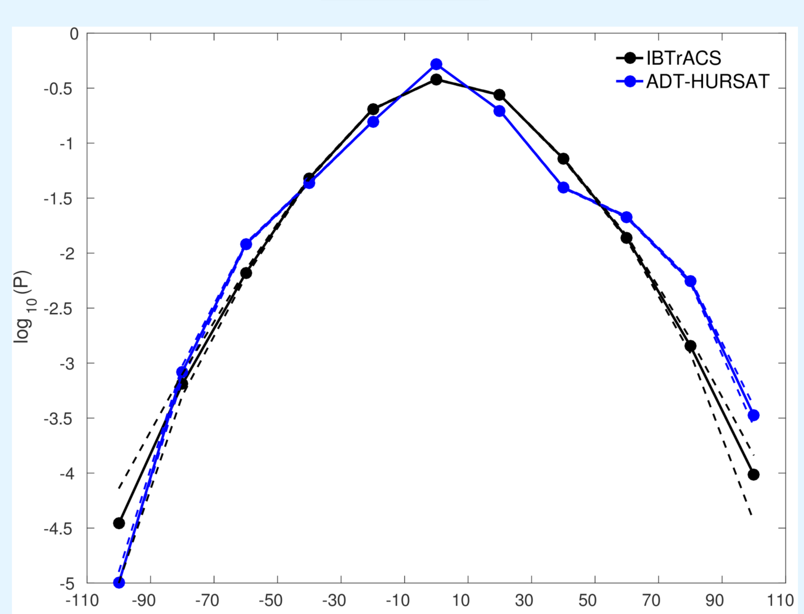
- International Best-Track Archive for Climate Stewardship produced by the National Hurricane Center (NHC) and the Joint Typhoon Warming Center (JTWC) (Knapp et al. 2010)
  - ➢ IBTrACS (v03r09) is comprised of global "best track" data, which are recordings of TC locations and intensities from forecasting agencies across the world.
  - ➢ Best track data start as operational estimates of the intensity and track of a TC and are refined at the end of a TC's lifetime with a combination of in situ (e.g. dropsondes, scatterometers, buoys), radar, and satellite measurements.
  - ➢ Best track intensity and position estimates are available every six hours and are recorded to the nearest 5 knots (1 kt = 0.5144 m s^{-1}) and 0.1° latitude/longitude (Landsea and Franklin 2013).

ADT-HURSAT

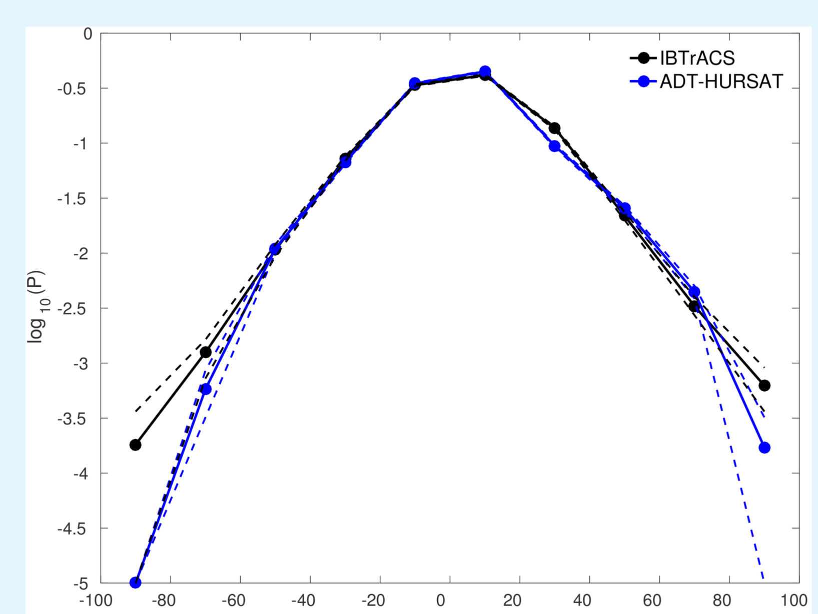
- Advanced Dvorak Technique-Hurricane Satellite-B1 (Kossin et al. 2013)
  - ➢ Geostationary satellite imagery is first analyzed from International Satellite Cloud Climatology Project (ISCCP)-B1 data (Knapp and Kossin 2007; Knapp 2008a,b).
  - ➢ Data are centered on IBTrACS TCs and subsampled to be both spatially and temporally homogeneous.
  - ➢ A simplified version of the advanced Dvorak technique (Olander and Velden 2007) is used to evaluate the data and determine a maximum TC wind speed.
  - ➢ ADT-HURSAT data are produced every three hours based on satellite data that has been uniformly subsampled to a horizontal resolution of 8 km, and wind speeds are recorded to the nearest knot.

24-Hour Intensity Change Comparison: 1982-2009

Global



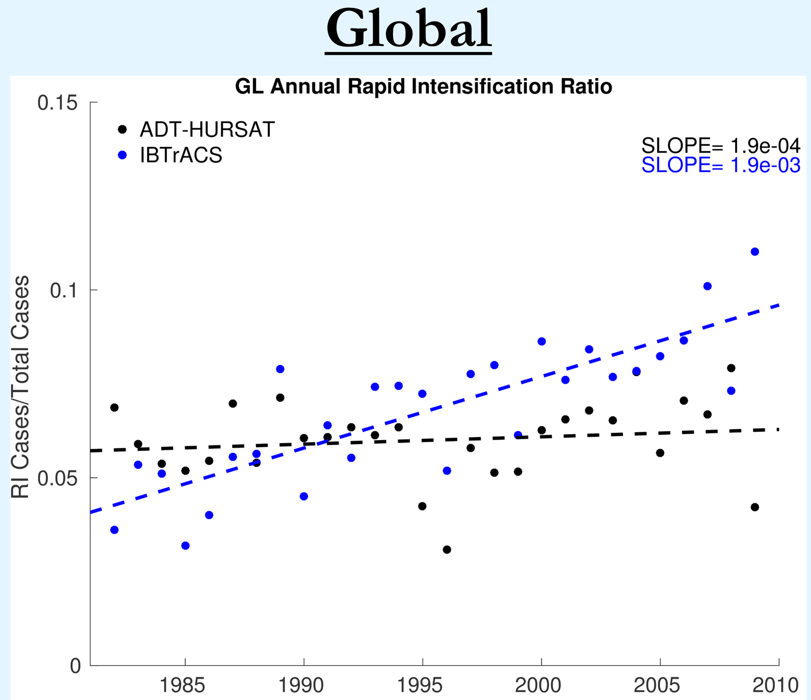
Atlantic



- The PDFs of 24-hour intensity changes for ADT-HURSAT and IBTrACS are the most similar in the Atlantic basin.
  - ➢ A majority of the highest intensification changes occur in other basins.
  - ➢ IBTrACS maintains the most homogeneous retrieval techniques in this basin.

Observed Trends: 1982-2009

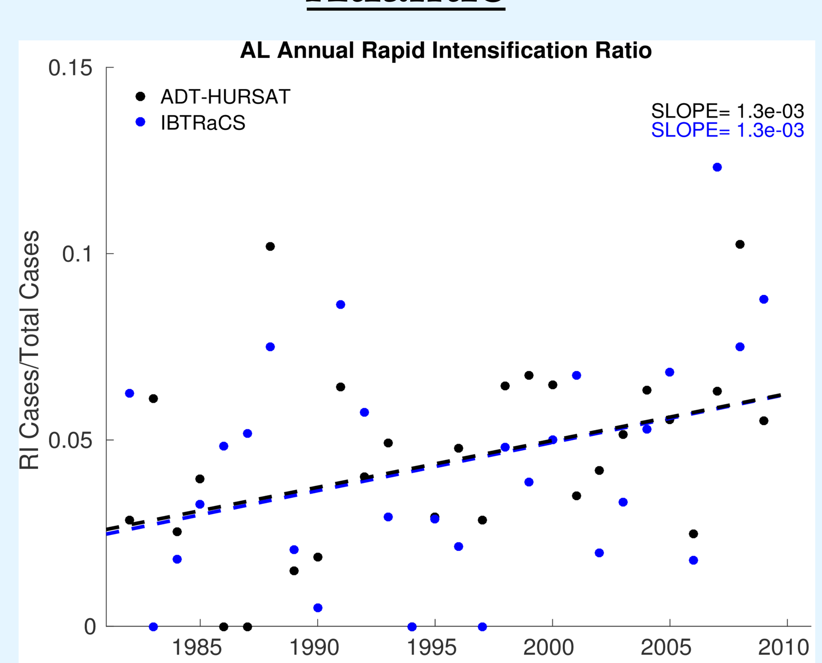
Global



Between 1982-2009, there is a significant upward trend in the global RI ratio for IBTrACS but almost no trend in this quantity for ADT-HURSAT.

$$\text{RI Ratio} = \frac{\text{24 Hr Intensity Changes} > \text{30 kts}}{\text{Total 24 Hr Intensity Changes}}$$

Atlantic



Between 1982-2009, there is a significant, almost identical, upward trend in Atlantic basin RI ratio for IBTrACS and ADT-HURSAT.

HiFLOR

Intensity Change Case Selection

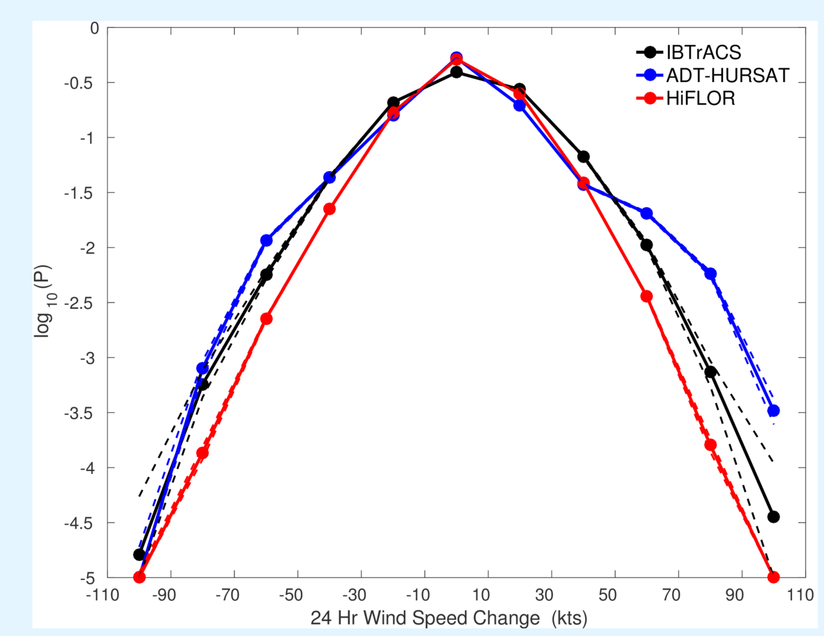
- To be included in our 24-hour intensity change analysis, TCs must:
  - ➢ Be detectable for at least 72 hours and exceed wind speeds of 34 knots for at least 36 hours
  - ➢ Be located over the ocean at the beginning and end of the 24-hour period
  - ➢ Stay between 40°N and 40°S and above 34 knots at the beginning and end of the 24-hour period
- HiFLOR, ADT-HURSAT, and IBTrACS all must meet this criteria and HiFLOR has additional warm core criteria
- Wind speeds are rounded to the nearest 5 knots

Model Description

- HiFLOR incorporates a high-resolution atmospheric/land model (0.25° × 0.25°) coupled to a low-resolution oceanic/sea ice model (1° × 1°, Murakami et al. 2015).
- We use four control simulations in which anthropogenic forcing was fixed at years 1860, 1940, 1990, and 2015.
- The simulations vary in length and the first fifty years of each simulation were discarded to avoid model drift::
  - ➢ 1860 (1500 years)
  - ➢ 1940 (200 years)
  - ➢ 1990 (300 years)
  - ➢ 2015 (200 years)

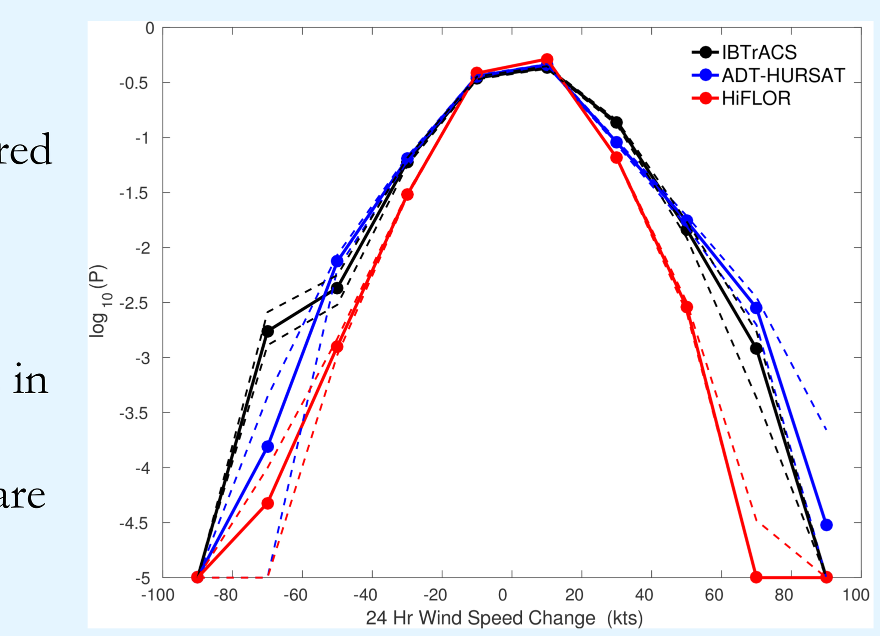
24-Hour Intensity Change Comparison: HiFLOR 1990 CNTRL vs. OBS

Global



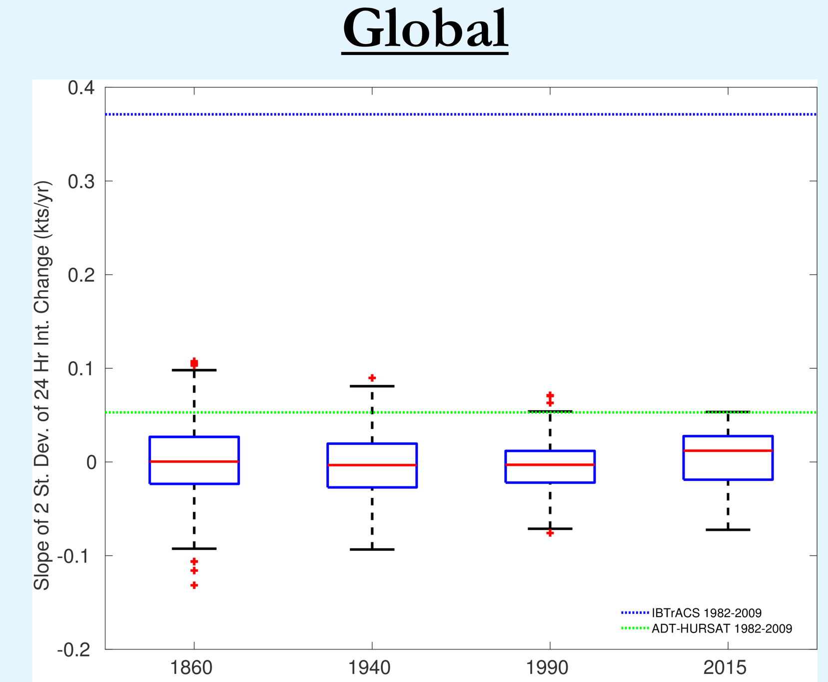
- The PDFs of 24-hour intensity changes for ADT-HURSAT and IBTrACS (1982-2009) are compared to HiFLOR's 1990 control simulation.
  - ➢ HiFLOR has too few of the highest intensification changes in the Atlantic basin and globally.
  - ➢ Quantile mapping techniques are being tested to resolve this discrepancy.

Atlantic



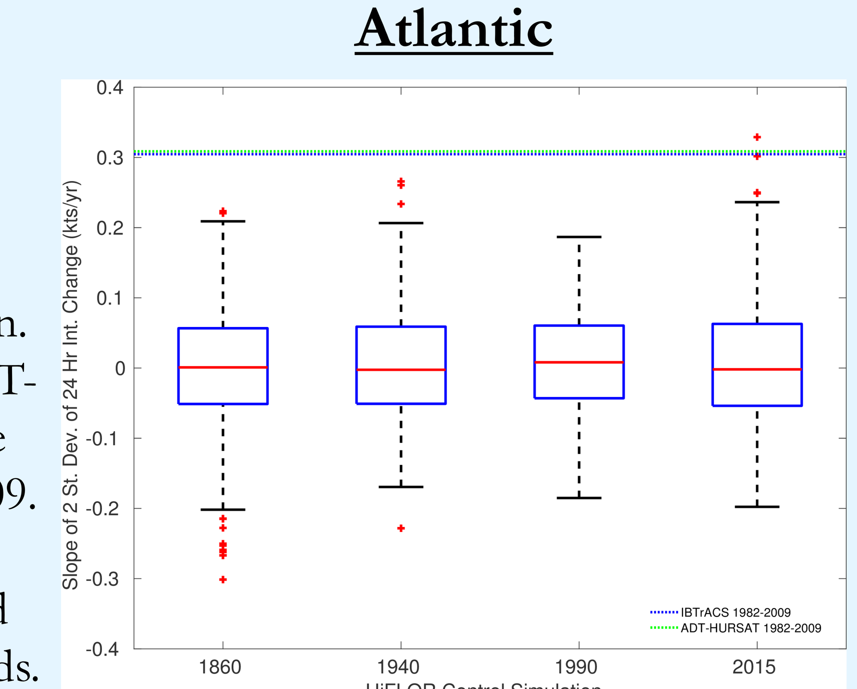
Observed Trends vs. Natural Variability in HiFLOR

Global



- Box and whisker plots capture the median and interquartile range of the slope of the intensity change value that corresponds to two standard deviations above the mean.
  - ➢ The slope for IBTraCS and ADT-HURSAT is calculated using the annual values between 1982-2009.
  - ➢ The slopes for each HiFLOR control simulation are calculated using overlapping 28-year periods.

Atlantic



Discussion

- IBTrACS and ADT-HURSAT show significantly different global trends in TC intensification rates but largely agree in the Atlantic basin.
- These disagreements are likely caused by:
  - ➢ spatial and temporal heterogeneities in IBTrACS
  - ➢ coarse resolution and documented issues with scene-type changes (from non-eye to eye) in ADT-HURSAT (Olander and Velden 2007)

References

- Knapp, K. R., 2008a: Calibration of long-term geostationary infrared observations using HIRS. J. Atmos. Oceanic Technol., 25, 183–195.
- Knapp, K. R., 2008b: Scientific data stewardship of International Satellite Cloud Climatology Project B1 global geostationary observations. J. Appl. Remote Sens., 2, 023548.
- Knapp, K. R., and J. P. Kossin, 2007: New global tropical cyclone data set from ISCCP B1 geostationary satellite observations. J. Appl. Remote Sens., 1, 013505.
- Knapp K.R., M.C. Kruk, D.H. Levinson, H.J. Diamond, and C.J. Neumann, 2010: The international best track archive for climate stewardship (IBTrACS) unifying tropical cyclone data. Bull Am Meteorol Soc, 91, 363–376.
- Kossin, J. P., T. L. Olander, and K.R. Knapp, 2013: Trend analysis with a new global record of tropical cyclone intensity. J. Climate, 26, 9960–9976.
- Landsea, C. W., and J. L. Franklin, 2013: Atlantic hurricane database uncertainty and presentation of a new database format. Mon. Wea. Rev., 141, 3576-3592.
- Murakami, H., G.A. Vecchi, S. Underwood, T.L. Delworth, A.T. Wittenberg, W.G. Anderson, J. Chen, R.G. Gudgel, L.M. Harris, S. Lin, and F. Zeng, 2015: Simulation and Prediction of Category 4 and 5 Hurricanes in the High-Resolution GFDL HiFLOR Coupled Climate Model. J. Climate, 28, 9058–9079.
- Olander, T. L., and C. S. Velden, 2007: The advanced Dvorak technique: Continued development of an objective scheme to estimate tropical cyclone intensity using geostationary infrared satellite imagery. Wea. Forecasting, 22, 287–298.