Seasonality of Tropical Cyclone Maximum Intensity in the North Atlantic and Western Pacific

Daniel M. Gilford[1,2] (daniel.gilford@rutgers.edu), Susan Solomon[2], Kerry Emanuel[2], and Daniel Rothenberg[3]

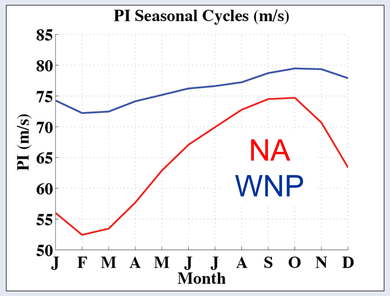
[1]Department of Earth and Planetary Sciences, Rutgers; [2]Department of Earth, Atmospheric, and Planetary Sciences, MIT; [3]Center for Global Change Science, MIT

Motivation

Gilford et al. (2017) showed that the seasonality of Potential Intensity,

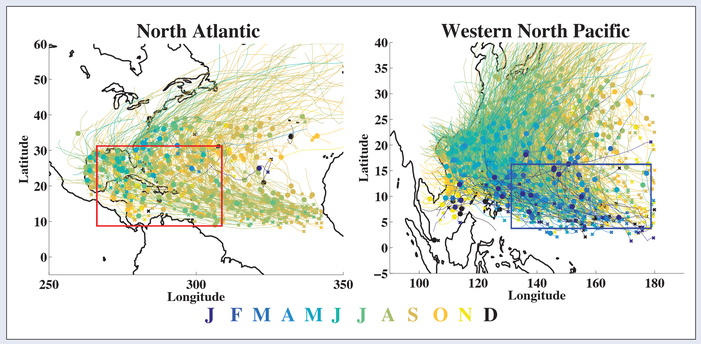
$$PI^2 = \frac{C_k}{C_D}\frac{T_s - T_0}{T_0}(h_o{}^* - h^*)$$

is substantially flatter in the **WNP** than in the **NA**



Do observed TC maximum intensities exhibit seasonal cycles similar to that predicted by potential intensity?

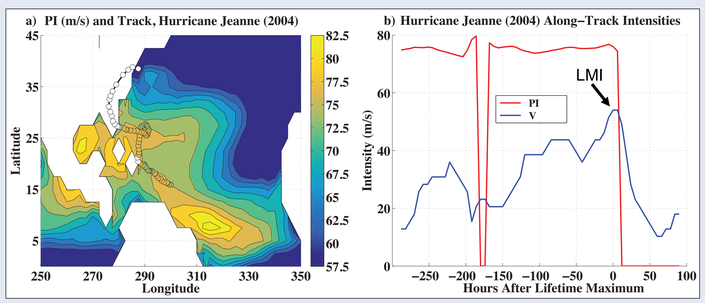
Along-track Climatology



Observed Storms:
- Best tracks & intensities, 6-hourly (1980-2015), 5 kt. precision
- Find lifetime maximum intensities (LMI)

Links for best track data and BE02 algorithm at my website:

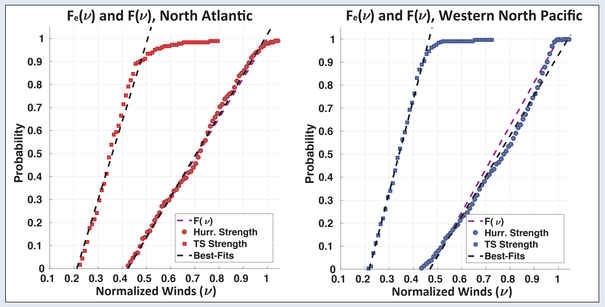
Potential Intensity Calculations:
- MERRA2 environmental conditions, monthly (1980-2016), 2.5° x 2.5°, 31 vertical levels (1000-10 hPa)
- Bister and Emanuel (2002) algorithm
- Interpolated to observed tracks to find "along-track" PI



Hurricane Jeanne track & intensity, illustrating the methods used to create the along-track dataset

Intensity Seasonal Cycles

Normalized Wind ($\nu = \frac{LMI}{PI}$) distributions appear uniform:

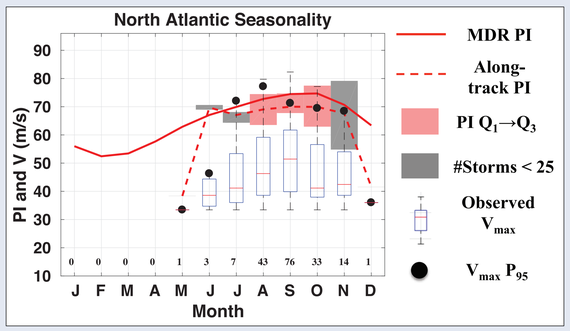


CDFs of normalized intensity are either described with linear best-fits or idealized as uniform

- Observed storms have an equal probability of attaining any LMI between the marginal hurricane intensity and PI (Emanuel 2000)

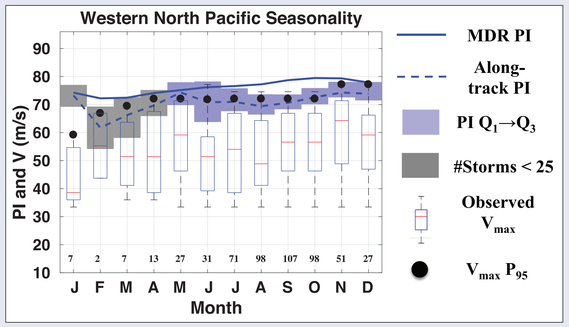
Via Extreme Value Theory and F(ν):

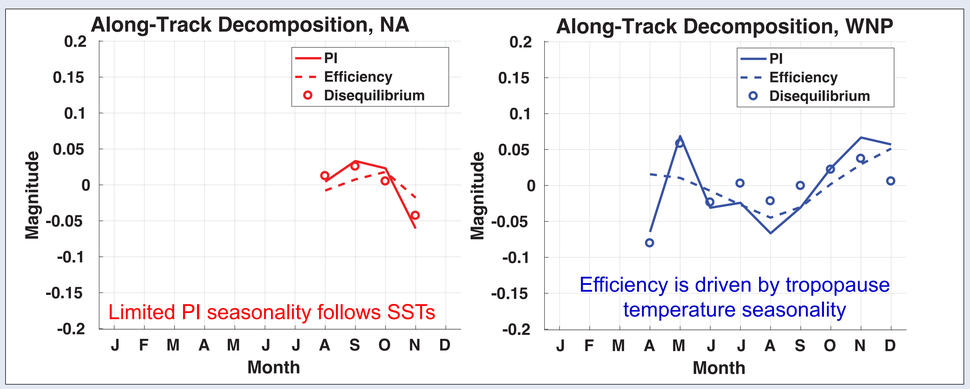
~25 storms must be observed to have a ~99% chance of observing a storm with $\nu \geq 0.9$



- Few observed storms outside the traditional hurricane season, limiting PI applicability outside those months
- July-Nov.: MDR PI is similar to along-track PI. Highest percentile LMIs often found near climatological PI values
- 4 land-falling storms have LMI > PI

- MDR PI and along-track PI are both seasonally damped
- Mid-summer depression in along-track PI results in a Nov.-Dec. peak
- Cat. 4+ TCs are observed in all months except Jan.; LMIs are consistent with along-track PI





PI is seasonally decomposed into its physical contributors by taking its logarithm in each month with at least 10 historical storms

Testing Uniformity

To connect PI fluctuations with those of observed maximum intensity, it is important to determine whether empirical normalized wind distributions, $F_e(\nu)$, are statistically uniform

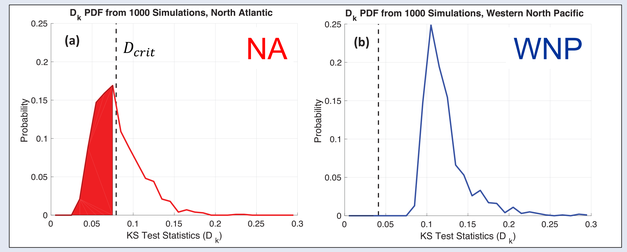
Kolmogorov—Smirnov Test

$$D_{KS} = \max|\underbrace{F(\nu)}_{\text{Theoretical}} - \underbrace{F_e(\nu)}_{\text{Empirical}}|$$

We implement a Monte-Carlo technique – repeat 1000 times:

Randomly split empirical data into two separate groups: training population (n=50), and test population (remaining storms) → Estimate $F(\nu)$ from the training population and $F_e(\nu)$ from the test population → Apply the KS Test → Compare the resulting KS test statistic, D_k, with a critical KS test statistic (e.g. 95% confidence: $D_{crit} = 0.866/\sqrt{n}$)

D_k values above D_{crit} reject the null hypothesis that the empirical distribution is uniform (at 95% confidence):



NA normalized wind distributions might be *statistically* uniform, WNP distributions are not

Summary

1. Incorporating TC frequency information highlights the viability of potential intensity theory in new contexts
2. Very intense (>65 m/s) **WNP** TCs may be observed in any month of the year. Consistency between LMIs and PI suggest that tropopause temperatures damp the seasonal cycle of real-world storm intensities
3. Observed **NA** maximum intensities are constrained by limited storm counts outside the boreal summer months
4. Although normalized wind distributions appear uniform, they are often not uniform in a strict statistical sense

Acknowledgements

This work was supported by NSF Grant AGS-1461517. DG was supported by NASA Headquarters under the NASA Earth and Space Science Fellowship Program by Grant NNX14AK83H.

April 2018