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Supplementary Materials for

Human influence on tropical cyclone intensity

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The PI was calculated based on (11). In the case of the ERA-40 reanalysis (84), the period 1971-2000 was used for the climatology shown in Figure 1(b).

The 26 CMIP5 models and simulations considered here are described in Table 1 of (72), as described in (85). First the PI for each ensemble simulation was calculated, then the ensemble mean of each model, and finally the multi-model mean PI was obtained. The historical (RCP8.5) multi-model mean climatology in Figure 1 was calculated for the period 1971-2000 (2071- 2100).

The PI trends in Figure 3 were calculated by calculating (i) the PI anomaly in each model (based on the model PI historical climatology), (ii) the seasonal hemispherical mean (northern hemisphere June to November, southern hemisphere December to May) of the PI anomaly, (iii) the multi-model mean PI anomaly, (iv) the 5 year running-mean. Similarly to (72), only a subset of the CMIP5 models are included, namely those that have available the greenhouse gases only and the aerosols only simulations, besides the historical and RCP8.5 simulations. The observed PDI for the northern hemisphere was calculated using the best-track datasets from the National Hurricane Center for the Atlantic and eastern North Pacific (86) and the Joint Typhoon Warning Center (87) for the western North Pacific and North Indian Ocean. The synthetic PDI calculations are described in the text and used the CMIP5 models PI and the observed PDI.

Supplementary Text

The impact of increasing potential intensity on lifetime maximum intensity quantiles

The cumulative distributions of LMI normalized by storm PI in the North Atlantic and western North Pacific are nearly linear[27]. This implies that, conditional on a particular value V_p of PI, the frequency distribution of LMI is uniform between some lower limit and that value of PI:

$$P(V \mid V_P) = \frac{1}{V_P}\Theta(V_P - V)$$

where V is the LMI.

Figure S1 shows a schematic of such a uniform frequency distribution (upper panel) and linear cumulative distribution (lower panel) for two values of PI. Comparing the quantiles of the LMI distribution (upper panel) for high and low PI values shows that the lowest quantiles change the least with PI, while the highest quantiles change the most, consistent with behavior seen in quantile regression trend analysis (61). The rate of change of the quantiles between low and high PI is in fact proportional to the quantile probability and the change in PI. Likewise, the change in the cumulative LMI frequency (lower panel) is greater for high thresholds than for low ones, and the change in frequency scales linearly with the quantile probability.

In reality, the PI sampled by TCs is not itself uniform, but varies in space and time. The combination of the intensity distribution for a given PI and the PI distribution comprises the overall intensity distribution by the law of total probability:

$$P(V) = \int_0^\infty P(V \mid V_P) P(V_P) dV_P$$

For illustration we assume the PI distribution $P(V_P)$ to be Gaussian. Fig. S2 (top) shows two such PI distributions whose means are shifted by 5 m/s. Fig. S2 (middle) shows the resulting intensity distributions P(V). Finally, Fig S2 (bottom) shows the quantile-by-quantile difference (red minus blue) of the two LMI distributions. A positive shift in the mean PI results in increased intensity whose magnitude is greatest at the highest quantile. That is, increasing PI has the greatest intensity impact on the most intense TCs.

In Fig. S3, we show PI histograms constructed from climate model simulations done under the Fifth Coupled Model Intercomparison Project (CMIP5), using the historical and RCP8.5 scenarios. We constructed this distribution using the same 26 models that were included in (72). For each model, we first calculated the ensemble mean PI (if the model had more than one ensemble member). Then we calculated the monthly PI climatologies for each model for the periods 1971-2000 (historical) and 2071-2100 (RCP8.5). The multi-model mean PI was then calculated. In the histograms, we considered the data for the annual maximum PI at each grid point over the tropics (40S – 40N) for each of the scenarios.

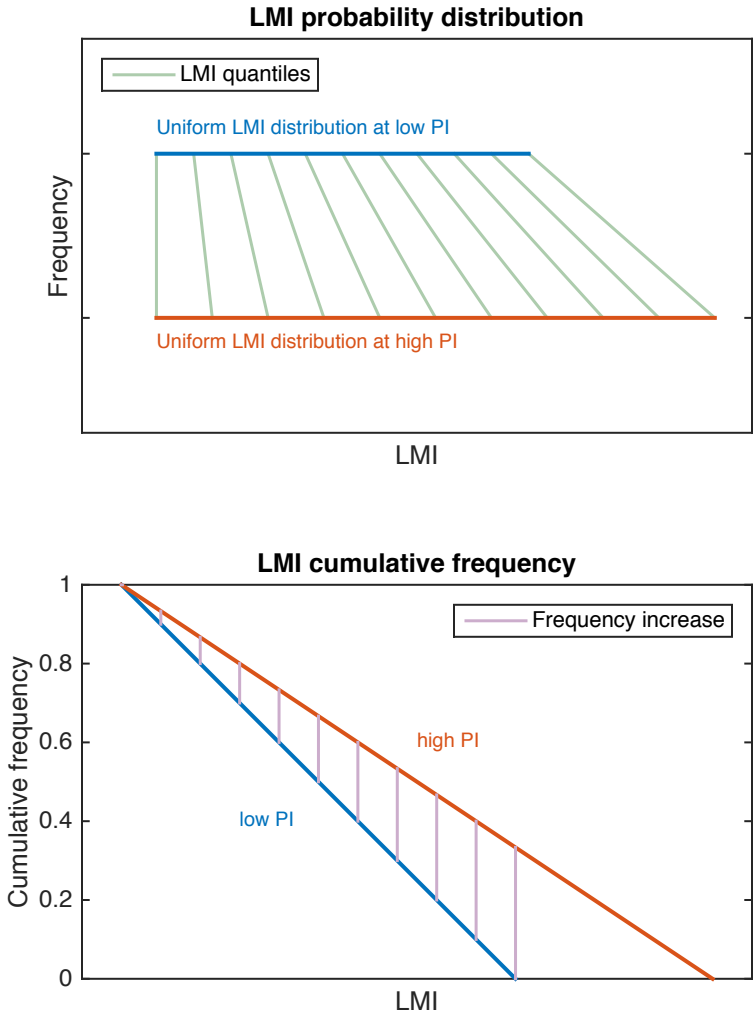

Fig. S1. The upper panel shows the uniform distributions of lifetime maximum intensity (LMI) for low (blue) and high (red) values of potential intensity (PI). Green lines connect equal percentiles of the two distributions. The lower panel shows the corresponding linear cumulative frequency distributions with purple lines connecting frequencies of the two distributions for the same threshold.

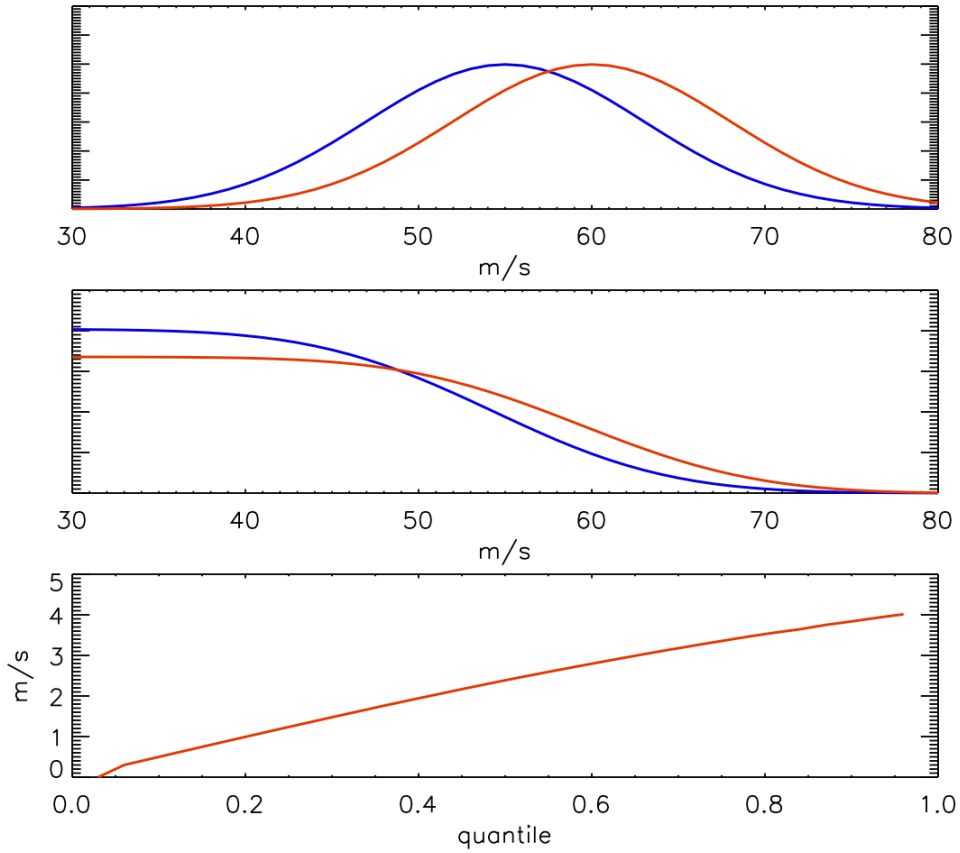

Fig S2. Two hypothetical PI distributions whose means differ by 10 knots (top), the corresponding intensity distributions (middle), and the quantile-by-quantile difference of the intensity distributions (bottom).

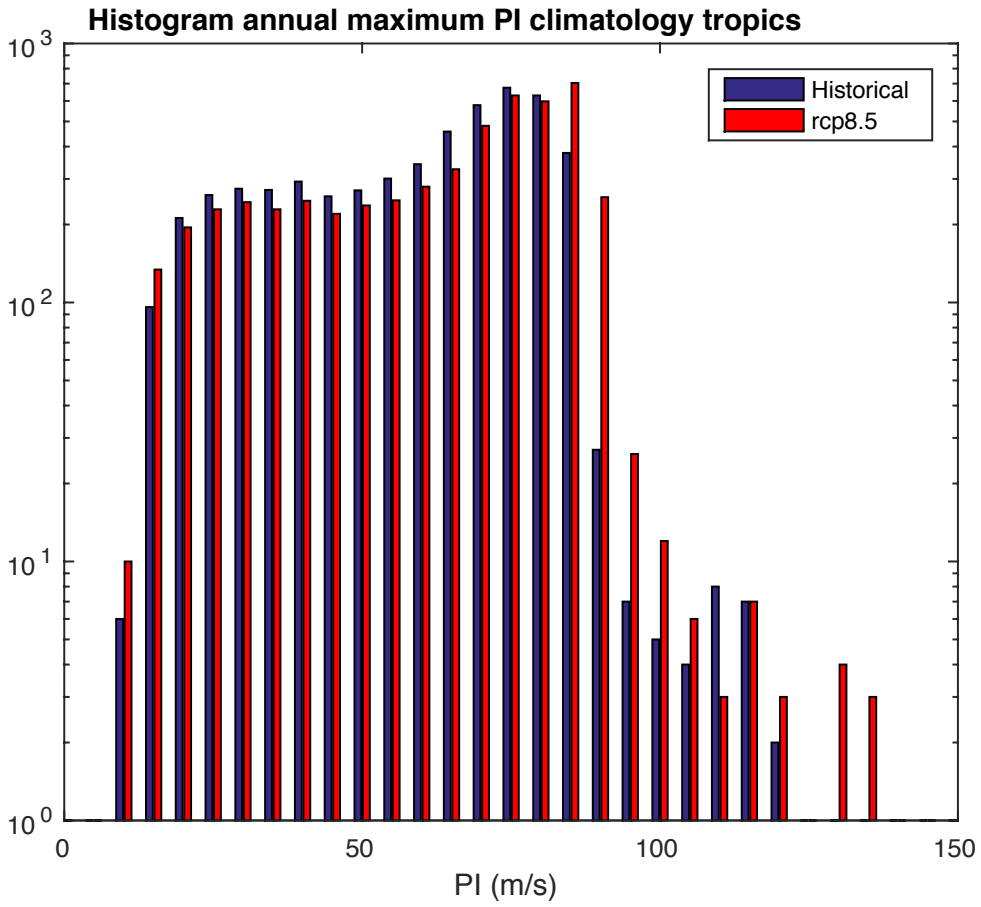

Fig. S3: Histograms (on a logarithmic scale) of annual maximum PI climatology for the CMIP5 multi-model mean over tropical (40S-40N) ocean points, for the historical (1971-2000) and RCP8.5 (2071-2100) scenarios.

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