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## Klima

### GRINSTED 2019

Aslak Grinsted, Peter Ditlevsen & Jens Hesselbjerg Christensen, *Normalized US hurricane damage estimates using area of total destruction, 1900–2018*. *PNAS* **116** (2019), 23942–23946.

[pnas116-23942-Supplement1.pdf](#), [pnas116-23942-Supplement2.xls](#)

Hurricanes are the most destructive natural disasters in the United States. The record of economic damage from hurricanes shows a steep positive trend dominated by increases in wealth. It is necessary to account for temporal changes in exposed wealth, in a process called normalization, before we can compare the destructiveness of recorded damaging storms from different areas and at different times. Atmospheric models predict major hurricanes to get more intense as Earth warms, and we expect this trend to eventually emerge above the natural variability in the record of normalized damage. However, the evidence for an increasing trend in normalized damage since 1900 has been controversial. In this study, we develop a record of normalized damage since 1900 based on an equivalent area of total destruction. Here, we show that this record has an improved signal-to-noise ratio over earlier normalization schemes based on calculations of present-day economic damage. Our data reveal an emergent positive trend in damage, which we attribute to a detectable change in extreme storms due to global warming. Moreover, we show that this increasing trend in damage can also be exposed in existing normalized damage records by looking at the frequency of the largest damage events. Our record of normalized damage, framed in terms of an equivalent area of total destruction, is a more reliable measure for climate-related changes in extreme weather, and can be used for better risk assessments on hurricane disasters.

**Keywords:** hurricane | damage | tropical cyclone | loss | normalization

**Significance:** We present an approach to normalize hurricane damage, where damage is framed in terms of an equivalent area of total destruction. This has some advantages over customary normalization schemes, and we demonstrate that our record has reduced variance and correlates marginally better with wind speeds and pressure. That is, it allows us to better address climatic trends. We find that hurricanes are indeed becoming more damaging. The frequency of the very most damaging hurricanes has increased at a rate of 330 % per century.

### ROXY 2019

M. K. Roxy, Panini Dasgupta, Michael J. McPhaden, Tamaki Suematsu, Chidong Zhang & Daehyun Kim, *Twofold expansion of the Indo-Pacific warm pool warps the MJO life cycle*. *nature* **575** (2019), 647–651.

The Madden–Julian Oscillation (MJO) is the most dominant mode of sub-seasonal variability in the tropics, characterized by an eastward-moving band of rain clouds. The MJO modulates the El Niño Southern Oscillation<sup>1</sup>, tropical cyclones<sup>2,3</sup> and the monsoons<sup>4–10</sup>, and contributes to severe weather events over Asia, Australia, Africa, Europe and the Americas. MJO events travel a distance of 12,000–20,000 km across the tropical oceans, covering a region that has been warming during the twentieth and early twenty-first centuries in response to increased anthropogenic emissions of greenhouse gases<sup>11</sup>, and is projected to warm further. However, the impact of this warming on the MJO life cycle is largely unknown. Here we show that rapid warming over the tropical oceans during 1981–2018 has warped the MJO life cycle, with its residence time decreasing over the Indian Ocean by 3–4 days, and increasing over the Indo-Pacific Maritime Continent by 5–6 days. We find that these changes in the MJO life cycle are associated

with a twofold expansion of the Indo-Pacific warm pool, the largest expanse of the warmest ocean temperatures on Earth. The warm pool has been expanding on average by  $2.3 \times 10^5$  km<sup>2</sup> (the size of Washington State) per year during 1900–2018 and at an accelerated average rate of  $4 \times 10^5$  km<sup>2</sup> (the size of California) per year during 1981–2018. The changes in the Indo-Pacific warm pool and the MJO are related to increased rainfall over southeast Asia, northern Australia, Southwest Africa and the Amazon, and drying over the west coast of the United States and Ecuador.