Extreme event attribution

Attribution for Individual extreme events

Extreme event attribution

- Some attribution studies attempt to address more particular questions, such as how climate change has influenced a specific heatwave, or how much climate change has contributed to the extreme precipitation of a specific hurricane.
- These studies seek a quantitative attribution on climate change impacts on extreme weather events.
- Extreme event attribution helps inform risk management and adaptation planning.

General Methods

- There are two general approaches (Knutson et al. 2017):
  - using observations to estimate a change in probability of magnitude of events
  - using model simulations to compare an event in the current climate versus that in a hypothetical "counterfactual" climate not influenced by human activities.
    - This includes the so-called ingredients-based attribution approach, in which the impact of certain environmental changes (for example, higher SST or atmospheric moisture) on the character of an extreme event is examined using model experiments, all else being equal.
- We will use Hurricane Harvey as an example.
  - Hurricane Harvey made landfall in August 2017 as the first land-falling category 4 hurricane to hit Texas since 1961.
  - Harvey stalled near the southeast Texas coast for several days after landfalling and induced extreme flooding

Method I: Hindcast attribution method

Regional numerical model simulations are used and two sets of experiments are carried out.

1. Actual ensemble simulations: initialized with the observed conditions and driven by observed boundary forcings
2. Counterfactual ensemble simulations: the climate change signals are removed
    - For example, differences (or “deltas”) in the three-dimensional air temperature, three-dimensional specific humidity, and two-dimensional sea surface temperature are subtracted to the observed initial conditions to remove the effects of climate change.
    - “deltas” can be derived from climate model simulations with and without anthropogenic forcing or based on linear trends of the observations.

- Statistics from the actual and counterfactual simulations are compared to estimate the impacts of climate change on Hurricane Harvey.

The box and whisker plots show the (*a*) the ratio of simulated precipitation and (*b*) minimum sea level pressure relative to the observation from different ensemble runs.

- Control run is the “actual” run
- DSST: the linear trend of SST is removed
- DAIR: trends are removed from all tropospheric variables
- DSST+DAIR: both SST and tropospheric variables are detrended

Wang et al. (2018) suggested that post-1980 climate warming could have contributed to the extreme precipitation by approximately 20% and contributed to the storm intensity.

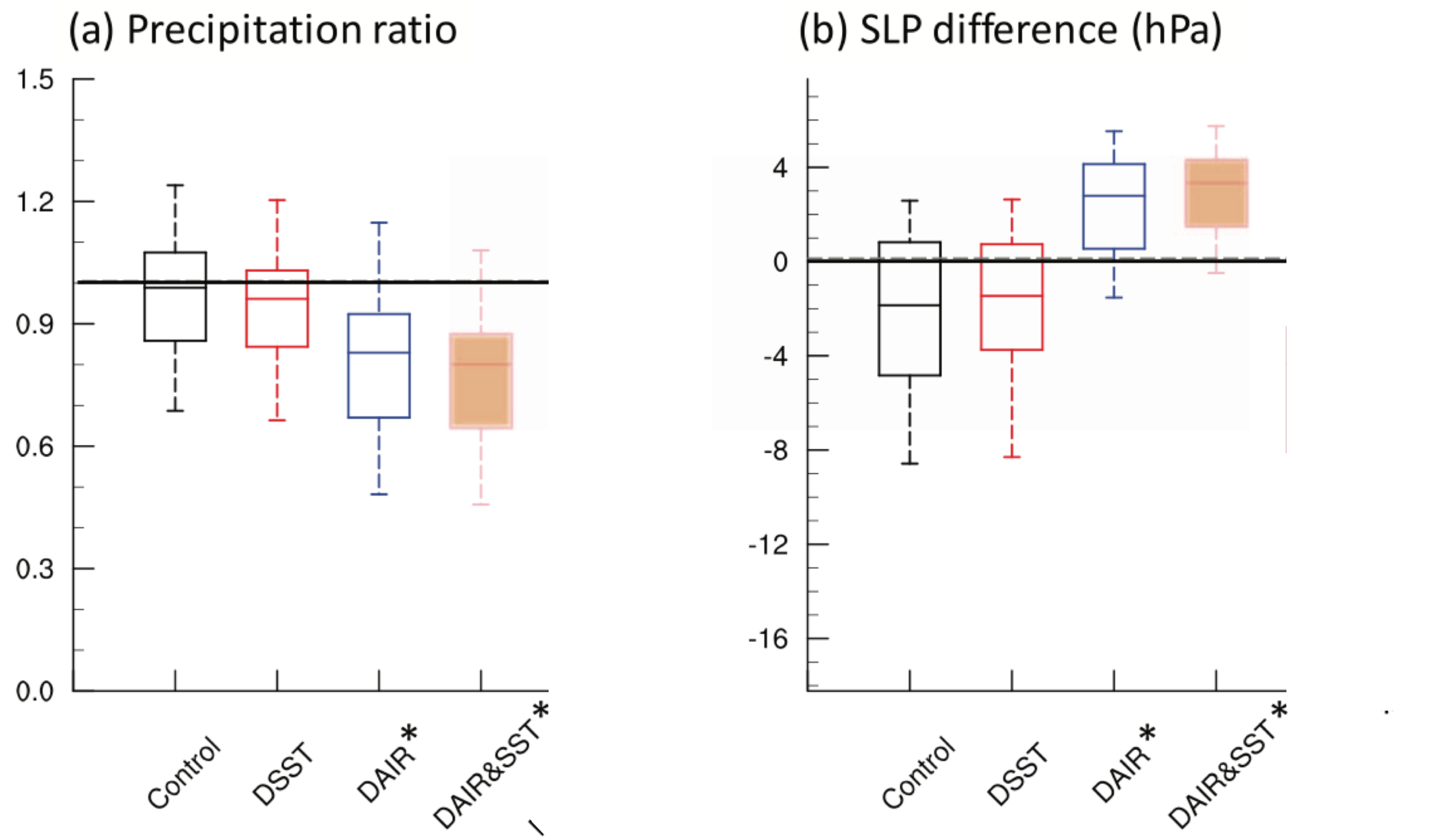

Figure 4. Box and whisker plots of (*a*) the ratio of simulated precipitation and (*b*) minimum sea level pressure relative to the observation with 60 ensemble members each, derived from (left to right) control, DSST, DAIR, DAIR+DSST (color filled), and DB runs. The *x*-axis labels marked with * indicate a significant difference from control runs at 95% confidence interval per *t*-test.

Wang et al. 2018

Method II: Synthetic Hurricane Simulations

- The technique begins by randomly seeding with weak hurricane-like disturbances in the large-scale, time-evolving state given by the global climate data.
- These seed disturbances are assumed to move with the large-scale flow in which they are embedded, plus a westward and poleward component owing to planetary curvature and rotation.
- Their intensity is calculated using a simple, circularly symmetric hurricane model coupled to a very simple upper-ocean model to account for the effects of upper-ocean mixing of cold water to the surface.
- It is computationally cheap to run such simulations due to the model simplicity.
- The model is run with different climate states to estimate the impacts of climate change.

Emanuel et al. 2017

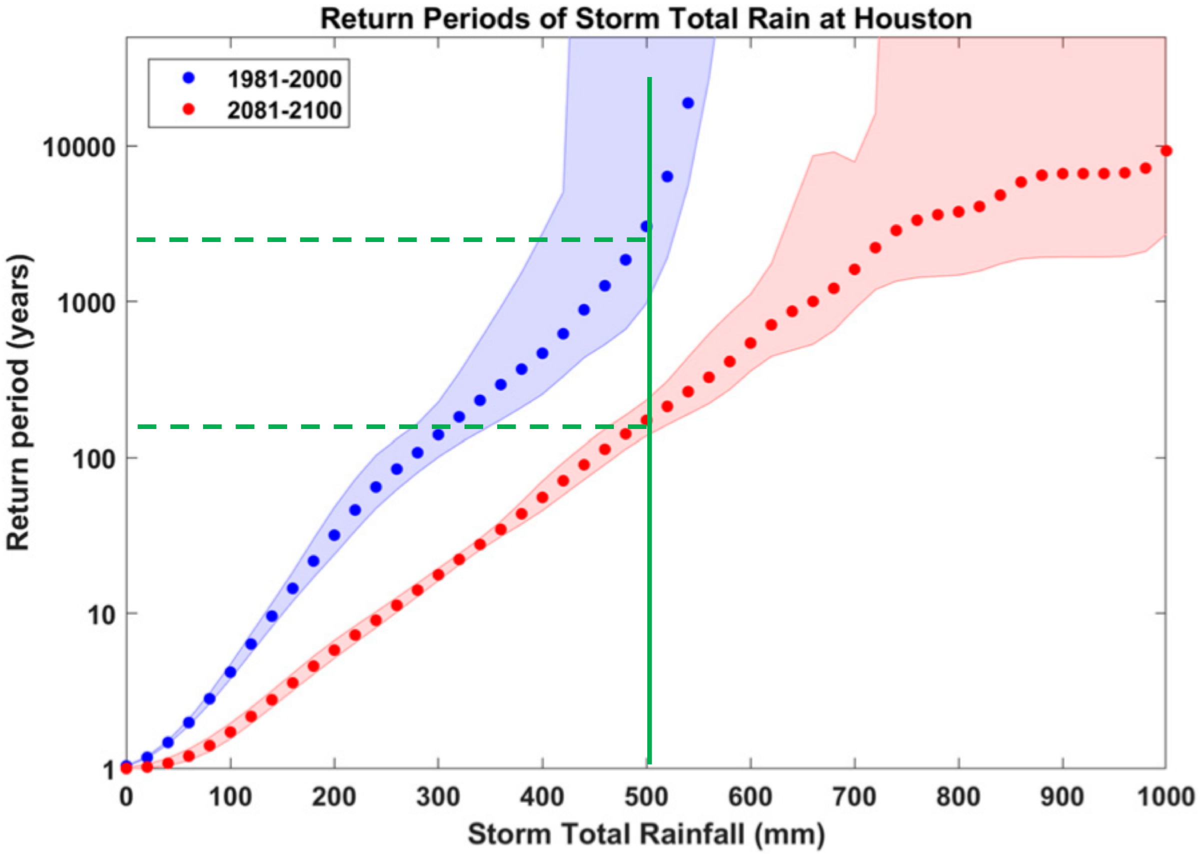

Fig. 4. Return periods of hurricane total rainfall (millimeters) at the single point of Houston, Texas, based on 3,700 simulated events each from six global climate models over the period 1981–2000 from historical simulations (blue), and 2081–2100 from RCP 8.5 simulations (red). The dots show the six-climate-set mean and the shading shows 1 SD in storm frequency, remapped into return periods.

Emanuel et al (2017) estimate that rainfall greater than 500 mm in Houston is around a once in 2,000-y event in the late 20th century, becomes a once in a 100-y event by the end of this century. If we were to assume that the frequency of hurricane rain is changing linearly between the two periods considered, then the return period of rainfall greater than 500 mm in the year 2017 would be about 325 y. Or the probability is enhanced by a factor of six due to anthropogenic forcing.

Emanuel et al (2017)

A brief summary

- Knutson et al. (2017) summarized a report by the National Academy of Sciences on attribution and detection:
  - *Confidence in attribution findings of anthropogenic influence is greatest for extreme events that are related to an aspect of temperature, followed by hydrological drought and heavy precipitation*
  - *Event attribution is more reliable when based on sound physical principles, consistent evidence from observations, and numerical models that can replicate the event.*
  - *Statements about attribution are sensitive to the way the questions are posed*
  - *Assumptions used in studies must be clearly stated and uncertainties estimated in order for a clear, unambiguous interpretation of an event attribution to be possible.*

Challenges Faced in Attribution Studies

- Natural variability and externally forced variability are not independent of each other
    - For example, Meehl et al. (2009) suggested that external forcing contributes to the phase transition of the PDO in 1970s. This means that it is not always possible to separate natural variability from external forcing.
- Limitations of observations:
    - Observational records may be too short to separate internal decadal/multidecadal variability from linear trends.
    - The quality of observations needs to be considered to ensure that a detected change is not an artifact of a changing observing system. An example is Atlantic hurricane frequency before the satellite era.
- Model uncertainties:
    - Models may have difficulty in reproducing the observed internal variability and its impacts.
- Regional climate: subject to other external forcings with large uncertainties, such as aerosols and land use changes.
- Variables other than temperature: less physically constrained and associated with larger model uncertainties.

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