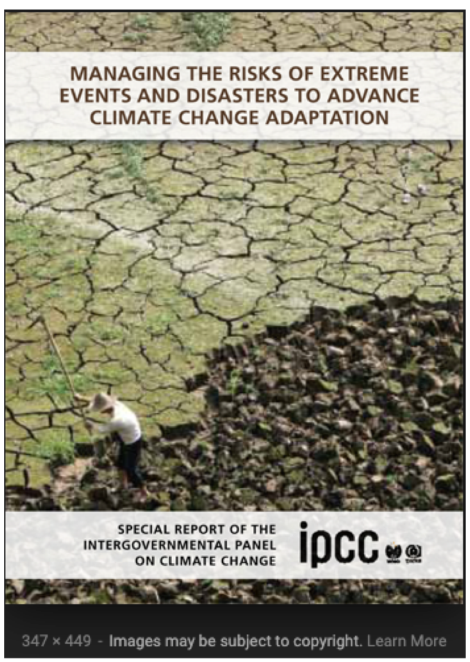
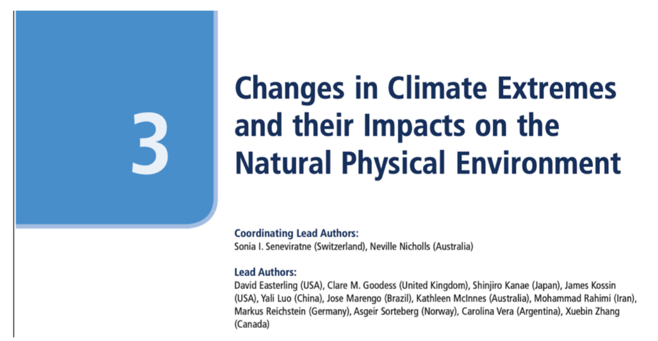
Extremes: State of the science

Erin Towler

July 25, 2019

Climate and Weather Extremes Tutorial





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Changes in Climate Extremes and their Impacts on the Natural Physical Environment

Coordinating Lead Authors:
Sonia I. Seneviratne (Switzerland), Neville Nicholls (Australia)

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For more information, see Chapter 3 of the SREX report at:

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Categories of Weather and Climate Events Relevant to Extremes

1. Weather and climate variables
    - temperature, precipitation, wind
2. Phenomena Related to Weather and Climate Extremes
    - Monsoons, El Nino and other modes of variability, tropical and extra tropical cyclones
3. Impacts on the natural physical environment
    - droughts, floods, extreme sea level and coastal impacts, other physical impacts.

There is no exact definition of an extreme.

2 (Main) Ways to Define Climate Extremes

1)“Extreme indices” (Abby’s Talk)

- Based on probability of occurrence (relative) – e.g., 90th percentile of observed Tmax.
- Based on specific (possibly impact-related) threshold (absolute).
- These are “moderate extremes”, use up to 5% of the sample.

2)Extreme value Theory (EVT) (Erin’s Talk)

- For more “extreme extremes”, need EVT because of sampling issues (typically < 1-5% of total sample
- Can be use to estimate probabilities of “values never seen”.

Caveats:

- Even if an event is extreme, it may not have an extreme impact (not considering vulnerability or exposure).
- What is “extreme” is location dependent (what’s “hot” in Boulder vs in Florida?)
- Some extreme impacts are because of cumulative moderate impacts (drought) or compound events (wildfire followed by rain).

Compound extreme events

1) two or more extreme events occurring simultaneously or successively

   Drought -> wildfire ->precipitation -> flooding

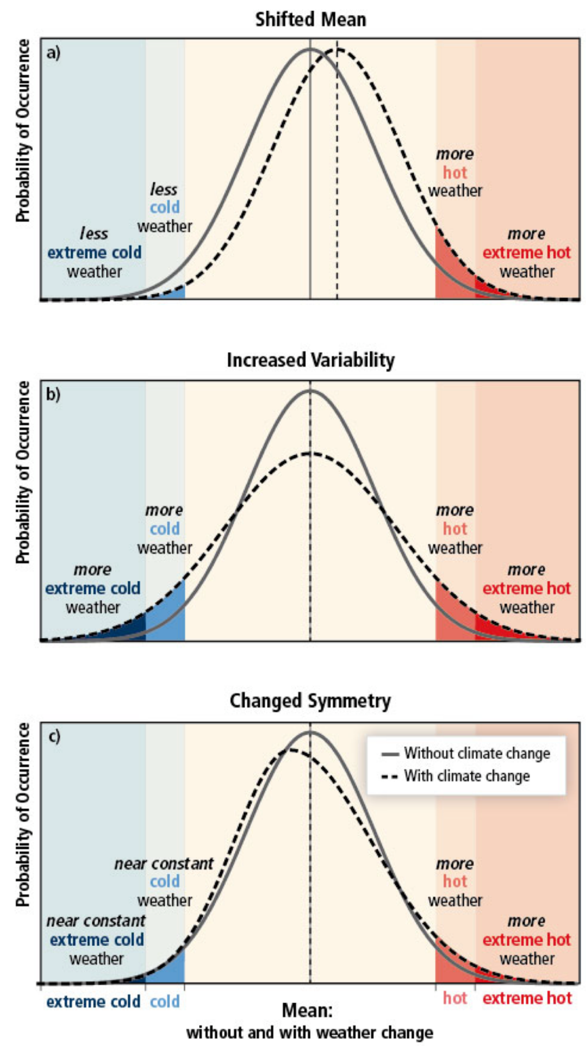
2) combinations of extreme events with underlying conditions that amplify the impact of the events

   High tide/sea level rise -> tropical cyclone landfall -> flooding

3) combinations of events that are not themselves extremes but lead to an extreme event or impact when combined.

   Cumulative days without precip & above avg temps -> drought

Relationships between extremes and mean climate



IPCC SREX 2012

Do changes in extremes related to changes in the mean?

- Sometimes, but not whole story: extremes also change with scale and shape of distribution.
- We are generally more confident in changes in long-term averages than extremes

Challenges to detecting changes in observed extremes

- Data
  - Extremes are rare by definition
  - Temporal resolution (e.g., sub-daily obs are not often available)
  - Data availability (data may not be freely available in some countries)
  - Data quality (satellite era in 1970s).
  - Data homogeneity (recording instruments change, stations are moved, cities are built, reporting protocol changes)
- Methods
  - Depends on definition of extreme (extreme index vs EVT approach)
  - Relative extreme indices (95th percentile) depend on baseline, which may be changing.
  - For storm tracking, depends on algorithm.
  - Differences between evaluating extremes and averages .

How can we understand the causes behind the changes in extremes (attribution)?*

1. Physical understanding
    - Greenhouse gas effect
    - Clausius-Clapeyron relationship (specific humidity increases 7% for every 1 deg temp)
2. Model experiments
    - Run simulation with and without external forcing (e.g., greenhouse gases, aerosols).

*Most literature/studies deal with attributing changes in mean, not extremes.

How can we project changes in extremes?

1. GCMs (General Circulation Models)
    - Many parameterizations for small scale processes (but extremes happen at small scales!)
2. Downscaling of GCM simulations
    - Dynamical downscaling: High-resolution models using GCM boundary conditions (Cindy's talk)
        - 1- 5-km is convection permitting (Andreas' talk)
    - Statistical downscaling: Develop statistical relationships between large-scale info and local climate variables (Erin's talk)
3. Physical understanding of the processes
4. Recently observed climate change.

What are the uncertainties of changes in extremes?

- There are many sources of uncertainty! (James' talk).
  - Uncertainty exists at every modeling step (cascading uncertainty), and this impacts extremes.

    The main three:

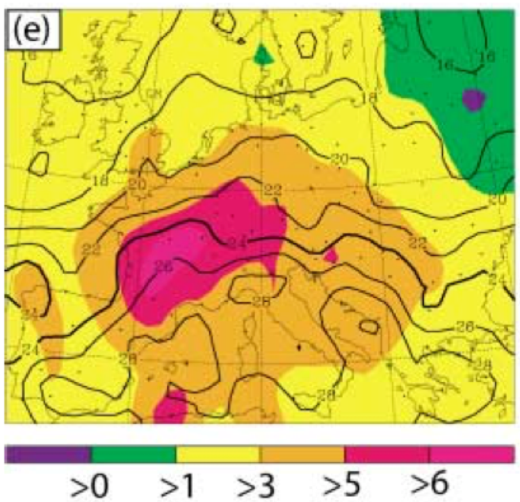
    1. Emission scenario from socioeconomic development pathways (e.g., RPC 8.5)
    2. Model uncertainty (structural uncertainty)
    3. Natural variability uncertainty.

What is our confidence and likelihood of changes in extremes?

Depends on the variable! Recall our categories:

1. Weather and climate variables
    - **temperature, precipitation**, wind
2. Phenomena Related to Weather and Climate Extremes
    - Monsoons, El Nino and other modes of variability, **tropical cyclones**, and extra tropical cyclones
3. Impacts on the natural physical environment
    - **droughts**, floods, extreme sea level and coastal impacts, other physical impacts.

Temperature is associated with many extreme characteristics and impacts.



August 2003 temperature anomaly over Europe.
(Fink et al 2004)

Extreme heat led to 15,000 deaths in France, Portugal, and Italy (WHO 2003).

SREX report offers state of the science summaries: **Temperature**

Observed Changes (since 1950)

Very likely decrease in cold days/nights
Very likely increase in # of unusually warm days and nights
Medium confidence in increase in length of # warm spells in many (but not all) regions.
Low or medium confidence in trends in temp extremes (lack of obs or varying signal).

Attribution of Observed Changes

Likely anthropogenic influence on trends in warm/cold days/nights at global scale.

Projected Changes

Virtually certain decrease in frequency and magnitude of unusually cold nights at global scale.
Virtually certain increase in frequency and magnitude of unusually warm days and nights at global scale.
Very likely increase in length, frequency, and/or intensity of heat waves over most land areas.

Precipitation extremes have uncertainties that challenge their analysis and prediction

- No single/global definition of precipitation extreme
- Data can be limited.
- Physical processes responsible for extreme precipitation occur on small scales
  - Need high resolution models for their prediction.

SREX report offers state of the science summaries: **Precipitation**

Observed Changes (since 1950)

Likely statistically significant increase in the number of heavy precipitation events (e.g., 95th percentile) in more regions than there are decreases, but strong regional variations in trend.

Attribution of Observed Changes

Medium confidence that anthropogenic influences have contributed (increase due to enhanced moisture content in the atmosphere)

Projected Changes

Likely increase in heavy precipitation events, especially in the high latitudes and tropical regions, and northern mid-latitudes in winter

Drought is a complex phenomenon…

- Drought has many different definitions
  - Few direct observations of drought variables, especially soil moisture, so many drought indices have been developed. Different indices give different answers!
- Drought is relative to location
- Drought can have multiple drivers is influenced by lack of precipitation, wind speed, high temperatures, etc.
- Can be a compound event

SREX report offers state of the science summaries: **Drought**

Observed Changes (since 1950)

Medium confidence in more intense and longer droughts in some regions of world (but opposite trends also exist).

Attribution of Observed Changes

Medium confidence in anthropogenic influence on some obs changes.

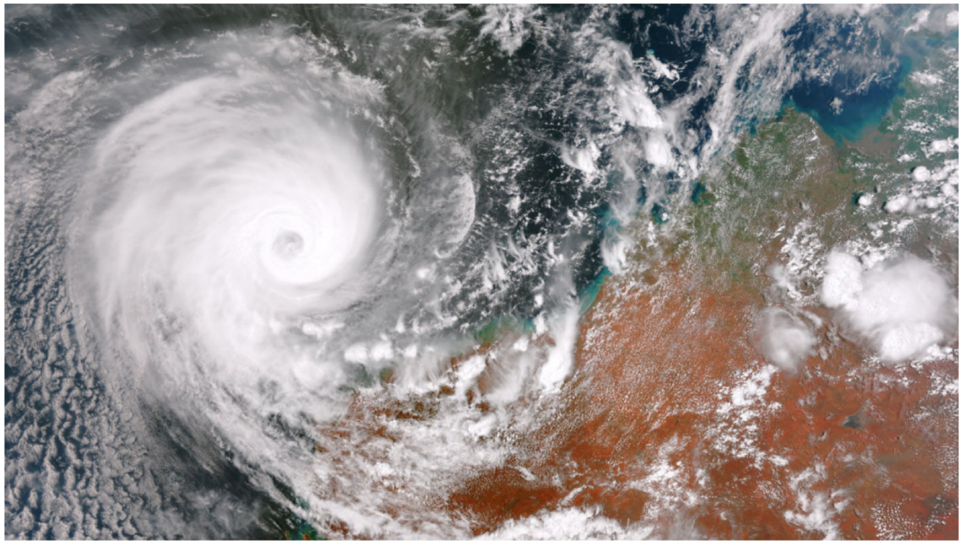
Low confidence in attribution of changes.

Projected Changes

Medium confidence in projected increase in duration and intensity of drought in some regions (but low confidence in other regions)

Tropical Cyclones

- Data quality concerns: Heterogeneity of observed records makes trend detection difficult. Natural variability makes trends hard to tell.
- Hurricanes often associated with extreme winds, but coastal and inland flooding drive most losses.
- Hurricane modeling is sensitive to tracking algorithm and model resolution



SREX report offers state of the science summaries: **Tropical Cyclones**

Observed Changes (since 1950)

Low confidence that observed long-term (i.e., 40 years or more) increases in hurricane activity are robust (bc of changing observing capabilities)

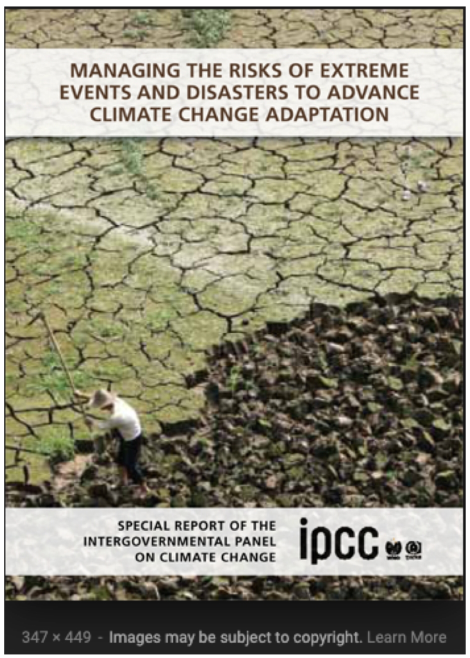
Attribution of Observed Changes

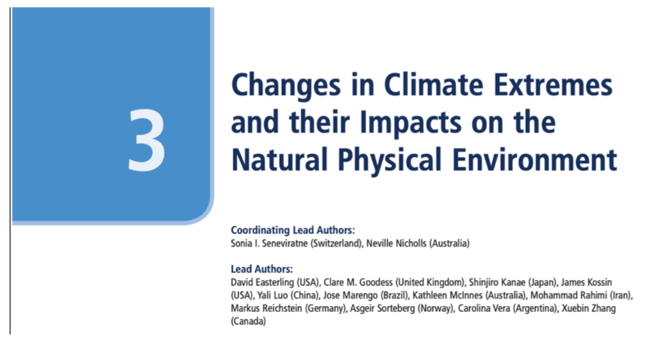
Low confidence in attribution due to uncertainties in tropical cyclone record, incomplete understanding of physical mechanisms, and degree of variability

Projected Changes

Likely decrease or no change in frequency of TCs.
Likely increase in mean max wind speed, but not everywhere
Likely increase in heavy rainfall associated with TCs.
Low confidence in projections of changes in tropical cyclone genesis, location, tracks, duration, or areas of impact.

Summaries for state of the science on extreme wind, monsoon, ENSO, extra-tropical cyclones, and more:





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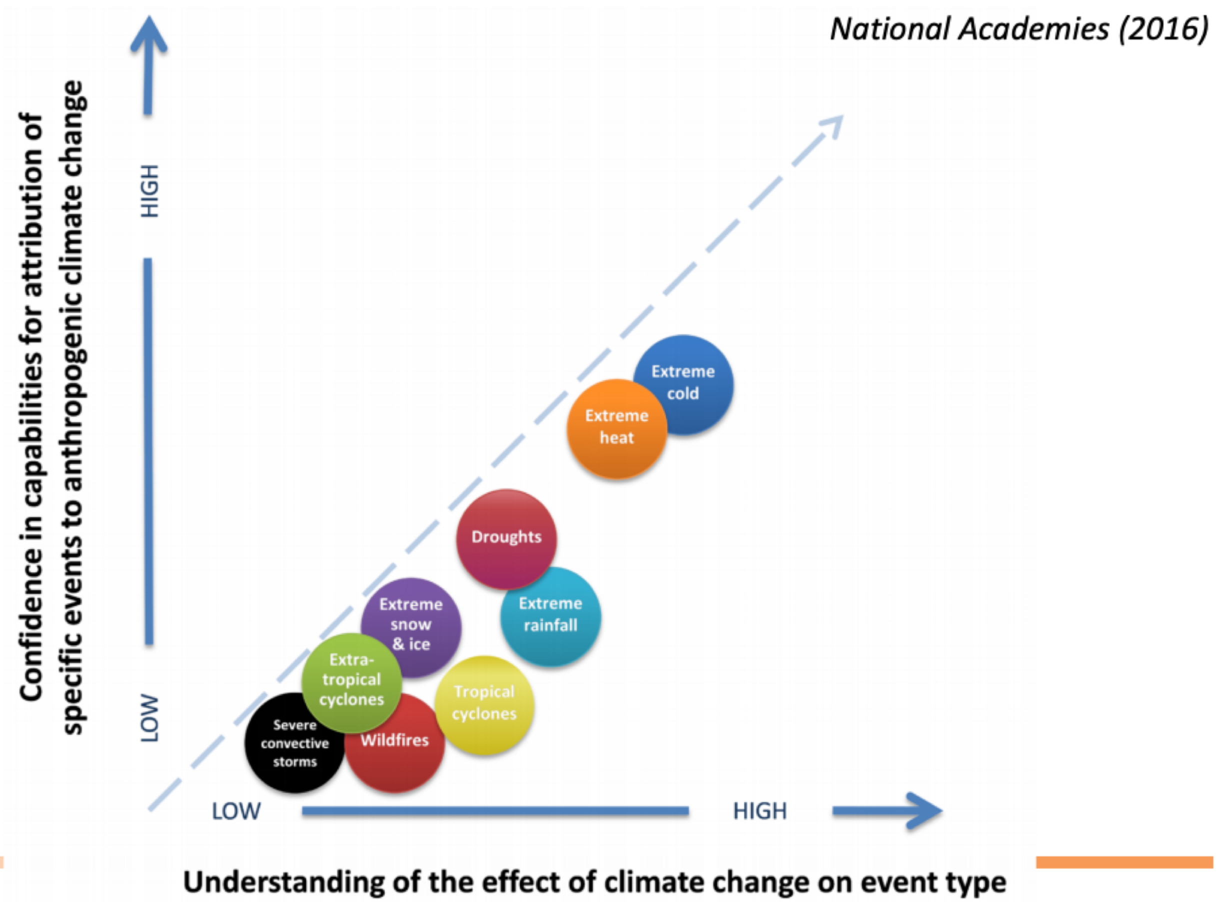
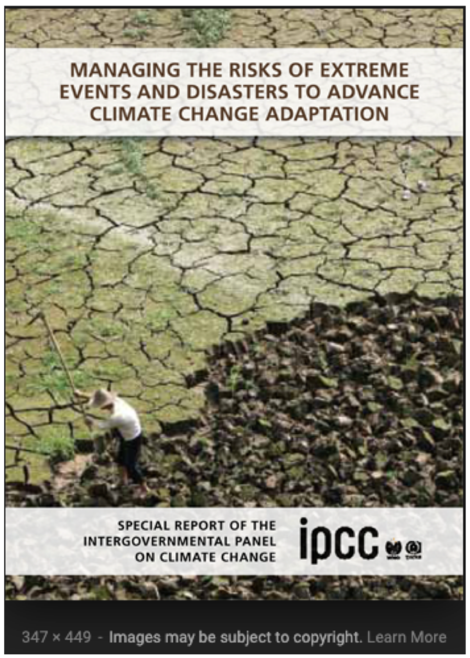
Understanding varies by phenomenon.



Thank you!

Questions?



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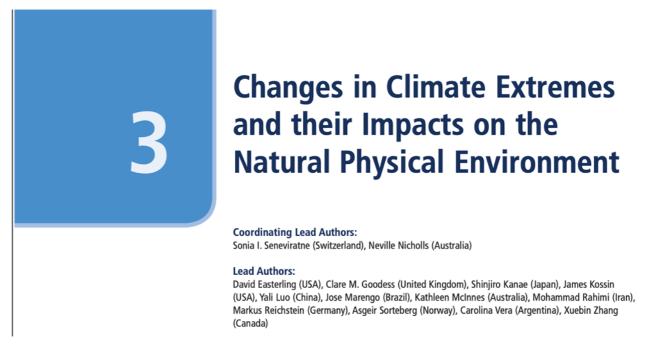

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