climate extreme events

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

Outline

- Changes in Climate Extremes and their Impacts on the Natural Physical Environment
- 1.1 Weather and Climate Events Related to Disasters
- 1.1.1. Categories of Weather and Climate Events Discussed in this Chapter
- 1.1.2. Characteristics of Weather and Climate Events Relevant to Disasters
- 1.1.3. Compound (Multiple) Events
- 1.1.4. Feedbacks
- 1.1.5. Confidence and Likelihood of Assessed Changes in Extremes
- 1.1.6. Changes in Extremes and Their Relationship to Changes in Regional and Global Mean Climate
- 1.1.7. Surprises / Abrupt Climate Change
- References

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

This chapter addresses changes in weather and climate events relevant to extreme impacts and disasters.

1.1 Weather and Climate Events Related to Disasters

A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of weather and climate extremes, and can result in unprecedented extremes. As well, weather or climate events, even if not extreme in a statistical sense, can still lead to extreme conditions or impacts, either by crossing a critical threshold in a social, ecological, or physical system, or by occurring simultaneously with other events. Some climate extremes (e.g., droughts, floods) may be the result of an accumulation of weather or climate events that are, individually, not extreme themselves.

Changes in extremes can also be directly related to changes in mean climate.

1.1.1. Categories of Weather and Climate Events Discussed

This chapter addresses changes in weather and climate events relevant to extreme impacts and disasters grouped into the following categories:

1. Extremes of atmospheric weather and climate variables (temperature, precipitation, wind)
2. Weather and climate phenomena that influence the occurrence of extremes in weather or climate variables or are extremes themselves (monsoons, El Niño, tropical and extratropical cyclones)
3. Impacts on the natural physical environment (droughts, floods, extreme sea level, waves, and coastal impacts, as well as other physical impacts, including cryosphere-related impacts, landslides, and sand and dust storms).

- The distinction between these three categories is somewhat arbitrary, and the categories are also related.
- Most of the impacts on the natural physical environment discussed in the third category are extremes themselves, as well as often being caused or affected by atmospheric weather or climate extremes. For instance, both floods and droughts are related to precipitation extremes, but are also impacted by other atmospheric and surface conditions (and are thus often better viewed as compound events).
- Another arbitrary choice made here is the separate category for phenomena (or climate or weather systems) that are related to weather and climate extremes, such as monsoons, El Niño, and other modes of variability. These phenomena affect the large-scale environment that, in turn, influences extremes. For instance, El Niño episodes typically lead to droughts in some regions with, simultaneously, heavy rains and floods occurring elsewhere. A change in the frequency or nature of El Niño episodes (or in their relationships with climate in specific regions) would affect extremes in many locations simultaneously.
- Similarly, changes in monsoon patterns could affect several countries simultaneously.

1.1.2. Characteristics of Weather and Climate Events Relevant to Disasters

In this chapter, we focus on the assessment of changes in ‘extreme climate or weather events, does not directly consider the dimensions of vulnerability or exposure, which are critical in determining the human and ecosystem impacts of climate extremes.

This report defines an ‘extreme climate or weather event’ or ‘climate extreme’ as “the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable”. Several aspects of this definition can be clarified thus:

- Definitions of thresholds vary, but values with less than 10, 5, 1%, or even lower chance of occurrence for a given time of the year (day, month, season, whole year) during a specified reference period are often used.
- Absolute thresholds can also be used to identify extreme events (e.g., specific critical temperatures for health impacts).
- Some climate extremes (e.g., droughts, floods) may be the result of an accumulation of moderate weather or climate events (this accumulation being itself extreme). Compound events, that is, two or more events occurring simultaneously, can lead to high impacts, even if the two single events are not extreme per se (only their combination).
- Not all extreme weather and climate events necessarily have extreme impacts.

1.1.2. Characteristics of Weather and Climate Events Relevant to Disasters

- The distinction between extreme weather events and extreme climate events is not precise, but is related to their specific time scales:
  - An extreme weather event is typically associated with changing weather patterns, that is, within time frames of less than a day to a few weeks.
  - An extreme climate event happens on longer time scales. It can be the accumulation of several (extreme or non-extreme) weather events (e.g., the accumulation of moderately below average rainy days over a season leading to substantially below average cumulated rainfall and drought conditions).
- For simplicity, we collectively refer to both extreme weather events and extreme climate events with the term 'climate extremes' in this chapter.
- From this definition, it can be seen that climate extremes can be defined quantitatively in two ways:

1. Related to their probability of occurrence.
2. impact-related.

Compound events can be viewed as a special category of climate extremes, which result from the combination of two or more events, and which are again 'extreme' either from a statistical perspective (tails of distribution functions of climate variables) or associated with a specific threshold.

1.1.3. Compound (Multiple) Events

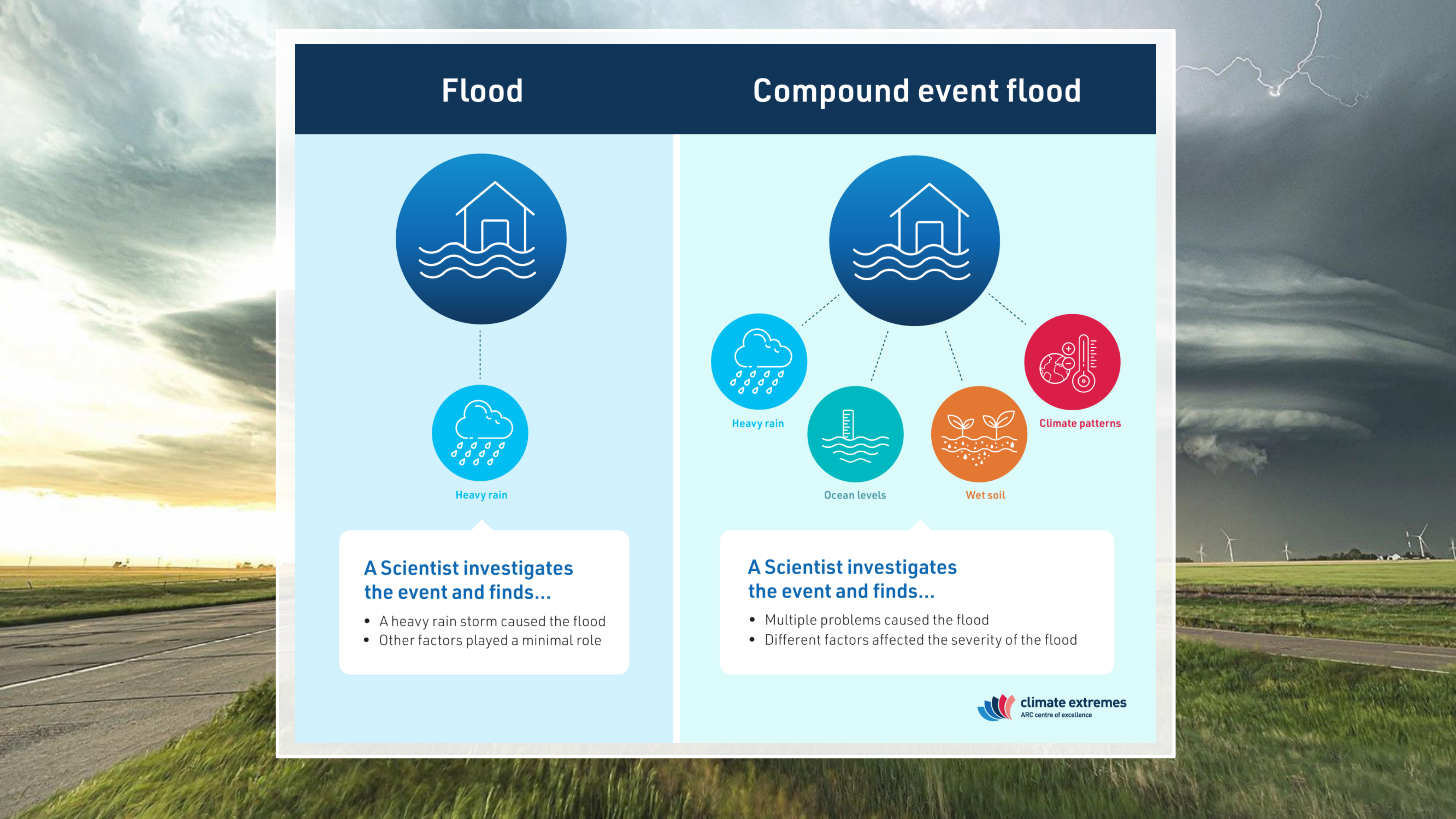
In climate science, compound events can be

1. two or more extreme events occurring simultaneously or successively.
2. combinations of extreme events with underlying conditions that amplify the impact of the events.
3. combinations of events that are not themselves extremes but lead to an extreme event or impact when combined.

The contributing events can be of similar (clustered multiple events) or different type(s).

- There are several varieties of clustered multiple events, such as tropical cyclones generated a few days apart with the same path and/or intensities, which may occur if there is a tendency for persistence in atmospheric circulation and genesis conditions.
- compound events resulting from events of different types are varied – for instance, cold and dry conditions, or the impact of hot events and droughts on wildfire
- Compound events can even result from 'contrasting extremes', for example, the projected occurrence of both droughts and heavy precipitation events in future climate in some regions.
- Impacts on the physical environment are often the result of compound events. For instance, droughts are the result of pre-existing soil moisture deficits and of the accumulation of precipitation deficits and/or evapotranspiration excesses, not all (or none) of which are necessarily extreme for a particular drought event when considered in isolation.
- Also, impacts on human systems or ecosystems can be the results of compound events, for example, in the case of health-related impacts associated with combined temperature and humidity conditions.
- Although compound events can involve causally unrelated events, the following causes may lead to a correlation between the occurrence of extremes (or their impacts):

a. A common external forcing factor for changing the probability of the two events (e.g., regional warming, change in frequency or intensity of El Niño events)
b. Mutual reinforcement of one event by the other and vice versa (e.g., extreme soil moisture levels and precipitation conditions for floods).


Flood
Compound event flood
Heavy rain
Heavy rain
Ocean levels
Wet soil
Climate patterns
A Scientist investigates the event and finds...
• A heavy rain storm caused the flood
• Other factors played a minimal role
A Scientist investigates the event and finds...
• Multiple problems caused the flood
• Different factors affected the severity of the flood
climate extremes
ARC centre of excellence

1.1.4. Feedbacks

A special case of compound events is related to the presence of feedbacks within the climate system, that is, mutual interaction between several climate processes, which can either lead to a damping (negative feedback) or enhancement (positive feedback) of the initial response to a given forcing. Feedbacks can play an important role in the development of extreme events, and in some cases two (or more) climate extremes can mutually strengthen one another. One example of positive feedback between two extremes is the possible mutual enhancement of droughts and heat waves in transitional regions between dry and wet climates. This feedback has been identified as having an influence on projected changes in temperature variability and heat wave occurrence in Central and Eastern Europe and the Mediterranean and possibly also in Britain, Eastern North America, the Amazon, and East Asia. Two main mechanisms that have been suggested to underlie this feedback are:

1. enhanced soil drying during heat waves due to increased evapotranspiration (as a consequence of higher vapor pressure deficit and higher incoming radiation).
2. higher relative heating of the air from sensible heat flux when soil moisture deficit starts limiting evapotranspiration/latent heat flux.

Feedbacks with soil moisture and snow affect extremes in specific regions (hot extremes in transitional climate regions, and cold extremes in snow-covered regions), where they may induce significant deviations in changes in extremes versus changes in the average climate. Other relevant feedbacks involving extreme events are those that can lead to impacts on the global climate, such as modification of land carbon uptake due to enhanced drought occurrence.

1.1.5. Confidence and Likelihood of Assessed Changes in Extremes

All assessments regarding past or projected changes in extremes are expressed following the new IPCC Fifth Assessment Report uncertainty guidance . The new uncertainty guidance makes a clearer distinction between confidence and likelihood. The following procedure was adopted in this chapter:

- For each assessment, the confidence level for the given assessment is first assessed (low, medium, or high), as discussed in the next paragraph.
- For assessments with high confidence, likelihood assessments of a direction of change are also provided (virtually certain for 99-100%, very likely for 90-100%, likely for 66-100%, more likely than not for 50-100%, about as likely as not for 33-66%, unlikely for 0-33%, very unlikely for 0-10%, and exceptionally unlikely for 0-1%).
- For assessments with medium confidence, a direction of change is provided, but without an assessment of likelihood.
- For assessments with low confidence, no direction of change is generally provided.

The confidence assessments are expert-based evaluations that consider the confidence in the tools and data basis (models, data, proxies) used to assess or project changes in a specific element, and the associated level of understanding. It should be noted that an assessment of low confidence in observed or projected changes or trends in a specific extreme neither implies nor excludes the possibility of changes in this extreme. Rather the assessment indicates low confidence in the ability to detect or project any such changes. Overall, we can infer that our confidence in past and future changes in extremes varies with the type of extreme, the data available, and the region, season, and time frame being considered, linked with the level of understanding and reliability of simulation of the underlying physical processes.

1.1.6. Changes in Extremes and Their Relationship to Changes in Regional and Global Mean Climate

Changes in extremes can be linked to changes in the mean, variance, or shape of probability distributions, or all of these. Thus a change in the frequency of occurrence of hot days (i.e., days above a certain threshold) can arise from a change in the mean daily maximum temperature, and/or from a change in the variance and/or shape of the frequency distribution of daily maximum temperatures. If changes in the frequency of occurrence of hot days were mainly linked to changes in the mean daily maximum temperature, and changes in the shape and variability of the distribution of daily maximum temperatures were of secondary importance, then it might be reasonable to use projected changes in mean temperature to estimate how changes in extreme temperatures might change in the future. It should further be noted that not only do regional extremes not necessarily scale with global mean changes, but also mean global warming does not exclude the possibility of cooling in some regions and seasons, both in the recent past and in the coming decades: it has for instance been recently suggested that the decrease in sea ice caused by the mean warming could induce, although not systematically, more frequent cold winter extremes over northern continents. Some of these regional changes will depend on how forcing changes may alter the regional atmospheric circulation, especially in coastal regions and regions with substantial orography. Hence for certain extremes such as floods and droughts, regional projections might indicate larger changes than is the case for projections of global averages (which would average the regional signals exhibiting changes of opposite signs). This also means that signals at the regional scale may be more reliable (and meaningful) in some cases than assessments at the global scale. On the other hand, temperature extremes projections, which are consistent across most regions, are thus more reliable at the global scale ('virtually certain') than at the regional scale (at most 'very likely')

1.1.7. Surprises / Abrupt Climate Change

The possible future occurrence of low probability, high-impact scenarios associated with the crossing of poorly understood climate thresholds cannot be excluded, given the transient and complex nature of the climate system. And this can also lead to 'surprises,' that is, changes in extremes greater (or less) than might be expected with a gradual warming of the climate system. contrasting or multiple extremes can occur but our understanding of these is insufficient to provide credible comprehensive projections of risks associated with such combinations. Abrupt climate change is defined as follows in the Glossary: "The nonlinearity of the climate system may lead to abrupt climate change, sometimes called rapid climate change, abrupt events, or even surprises. The term abrupt often refers to time scales faster than the typical time scale of the responsible forcing. However, not all abrupt climate changes need be externally forced. Some changes may be truly unexpected, resulting from a strong, rapidly changing forcing of a nonlinear system." Thresholds associated with tipping points may be termed 'critical thresholds,' or, in the case of the climate system, 'climate thresholds'. For systems with critical bifurcations in the equilibrium state function two alternative stable conditions may exist, whereby an induced change may be irreversible. Such critical transitions within the climate system represent typical low-probability, high-impact scenarios, which were also noted in the AR4 provided a recent review on potential tipping elements within the climate system, that is, subsystems of the Earth system that are at least subcontinental in scale and which may entail a tipping point. Some of these would be especially relevant to certain extremes [e.g., El Niño-Southern Oscillation (ENSO), the Indian summer monsoon, and the Sahara/Sahel and West African monsoon for drought and heavy precipitation, and the Greenland and West Antarctic ice sheets for sea level extremes], or are induced by changes in extremes (e.g., Amazon rainforest die-back induced by drought). For some of the identified tipping elements, the existence of bistability has been suggested by paleoclimate records, but is still debated in some cases. There is often a lack of agreement between models regarding these low-probability, high-impact scenarios, for instance, regarding a possible increased drought and consequent die-back of the Amazon rainforest for dryness projections in this region), the risk of an actual shutdown of the Atlantic thermohaline circulation, or the potential irreversibility of the decrease in Arctic sea ice. For this reason, confidence in these scenarios is assessed as low.

References

- Extreme Events and Climate Change: A Multidisciplinary Approach. (2021). United Kingdom: Wiley.


Thank you