Projections of Extreme Precipitation: Process and Overview

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Boston Climate Report, 2016 & current

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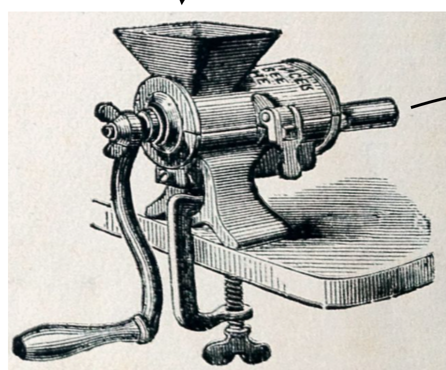
How do we assess the likelihood of future changes in extreme precipitation, and why should you care?

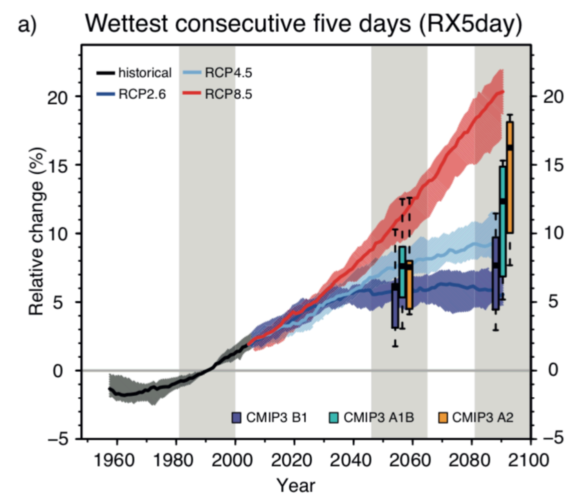
$$\rho \frac{D\mathbf{u}}{Dt} = -\nabla p + \rho \mathbf{g} - \rho \Omega \wedge \mathbf{u} + \mathbf{F}, \qquad (2.1)$$

$$\frac{D\rho}{Dt} = -\rho \nabla \cdot \mathbf{u}, \qquad (2.2)$$

$$c_p \frac{D}{Dt} \ln \theta = \frac{Q}{T}, \qquad (2.3)$$

$$p = \rho R T. \qquad (2.4)$$





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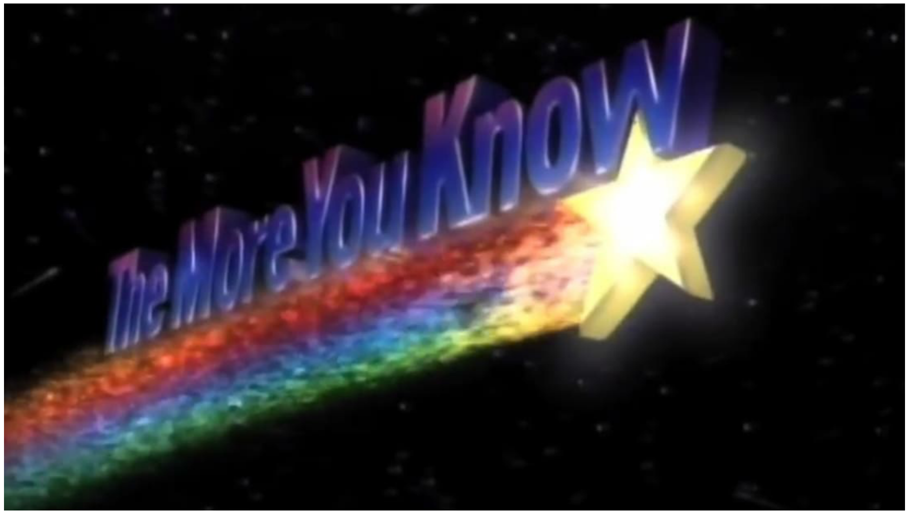
There are multiple sources and types of uncertainty in the projections



Understanding the process allows better understanding and management of uncertainty

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Projections of Extreme Precipitation: Process

Physical Understanding
+
Earth System Models
+
Observed Changes

→

Understanding

"Big Picture" Assessment

Quantitative Projections

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Projections of Extreme Precipitation: Process

This Talk

Physical Understanding
+
Earth System Models
+
Observed Changes

→

Understanding

"Big Picture" Assessment

Quantitative Projections

Next Talk

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Projections of Extreme Precipitation: Process

Physical Understanding
- expectations based on basic physical processes
- qualitative

+

Earth System Models
- quantification of physical understanding

+

Observations
- has it happened in the deep past, is it already happening now?

Agreement gives confidence

But uncertainties: future emissions, model limitations, natural variations

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Projections of Extreme Precipitation: Process

Physical Understanding
+
Earth System Models
+
Observed Changes

Done at multiple levels:

International: Intergovernmental Panel for Climate Change (IPCC)

US: National Climate Assessment

Regional: Northeast Regional Climate Center

+ additional state and local assessments (including Boston climate report)

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Physical Understanding 101

Warmer air
→ potential for more water in atmosphere*
→ deeper storms**

verified in models and observations

So: **we can expect strongest storms to be stronger**

*via the Clausius-Clapeyron equation
**A warming column of air expands, via the hypsometric equation

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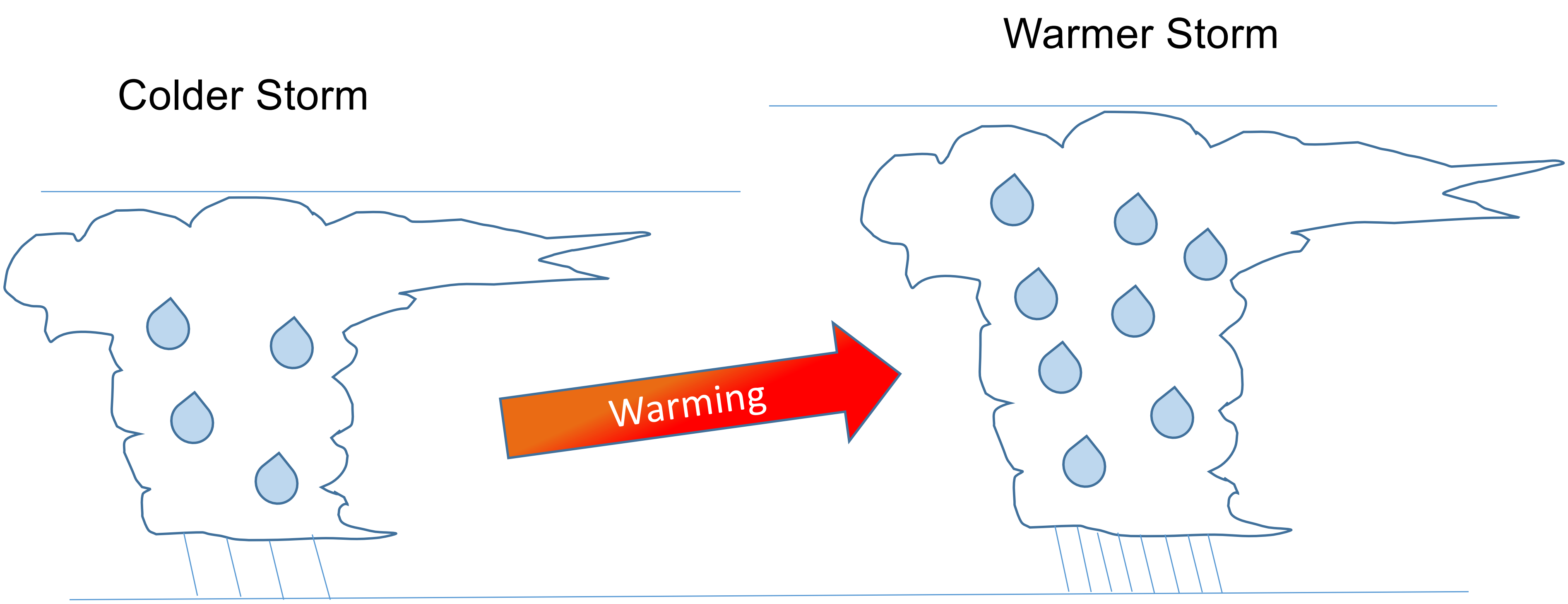
Physical Understanding 101



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Or, put more directly …

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More of This: Mar 2018, Quincy

Photo: National Guard

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More of this: Oct 2016, Worcester

Photo: WBZ

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More of this: Jan 2018, Revere

Photo: Adam Abougalala

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But also more dry spells …

Counter-intuitively, we can also expect more drought at the same time (sometimes in the same season):

-Greater variability in precipitation due to enhanced hydrologic cycle with more moisture

-Higher evaporation with higher temperatures

IPCC AR5 WGI, CH 12: “more intense downpours, leading to more floods, yet longer dry periods between rain events, leading to more drought”

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General factors in favor of increase in extreme precipitation:

Physics*.* Based on fundamental physical principles, the upper limit on atmospheric water vapor will experience notable increases as the climate system warms. The degree to which this upper limit will be realized, and how frequently, is subject to complex regional and local factors.

Model consistency*.* While regional projections vary, all the individual results show increases in maximum intensity. This consistency increases confidence although it is not a guarantee of an accurate result, especially given known limitations such as those associated with hurricanes.

Historical trend. The Northeast has already exhibited notable increases in extremes. The prominence of the trend, especially in combination with the consistency in the sign of the model projections is highly suggestive of future increases, and sets a minimum level of what is physically possible.

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General factors that cause uncertainty:

Hurricanes. Important but not well-resolved in current models.

Naturally-occurring climate variability. On timescales of a few decades, influence of natural variability is expected to be comparable in importance to human-caused climate change at regional and local scales.

Differences among model results. Regional projections of precipitation extremes vary considerably between different models.

Changes to the jet stream. It is currently an open question as to whether global warming may be causing the jet stream to become "wavier" and support slower, stronger storms.

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uncertainty factors, cont.:

Tipping points. There appear to be "tipping points" in the climate system, where rapid and irreversible change is initiated, such as the collapse of the thermohaline circulation in the Atlantic Ocean. These may result in even larger, more rapid changes and our current understanding of these events is limited.

Limited model validation. At this time, we have only limited information on how well models simulate extreme precipitation processes for the Northeast US.

Known model limitations. Many small-scale processes are important but difficult to model, such as aerosol interactions and small-scale cloud processes.

Unknown unknowns. ???

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"Big Picture" Statements

Even with all the uncertainties, we can say:

(From the IPCC Fifth Assessment Report, Physical Science Basis, Chapter 12)

Globally, for short-duration precipitation events, a shift to more intense individual storms and fewer weak storms is *likely* as temperatures increase.

Over most of the mid-latitude land-masses and over wet tropical regions, extreme precipitation events will *very likely* be more intense and more frequent in a warmer world.

Next report in progress, out in 2021

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Key Recent & Upcoming Reports

•Fourth National Climate Assessment (NCA4), Volume II (2018): Northeast Region: https://nca2018.globalchange.gov/chapter/18/ ← regional impacts and projections

•IPCC Special Report on Oceans and Cryosphere (Sep 2019) ← will be newest assessment of sea level rise

•Updated Greater Boston Climate Report (Dec 2020) ← will be newest detailed local assessment

•IPCC Working Group 1, AR6 (Apr 2021) ← will be assessment of latest climate model projections, just now becoming available

Questions?

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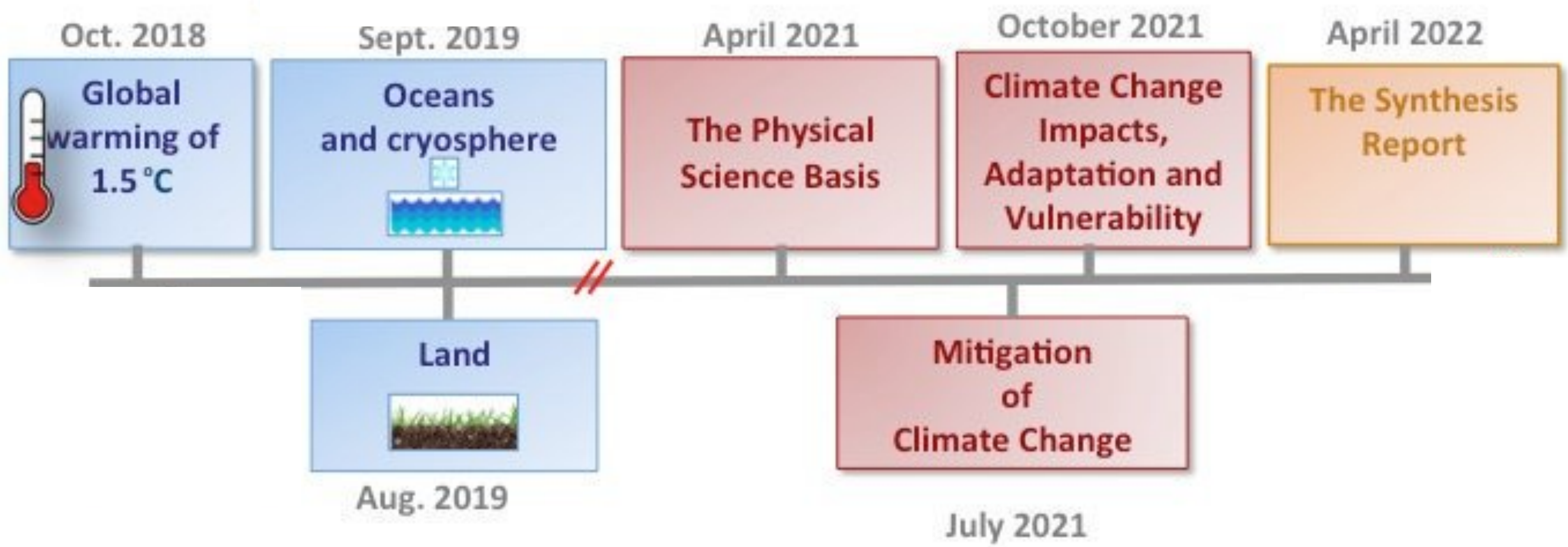
IPCC Sixth Assessment (AR6) Reports



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