Where Climate Data Affects Impacts Uncertainty

**Scenario Uncertainty**

![Graph showing CMIP5 models and RCP scenarios](Knutti et al. 2013)

**Response Uncertainty**

![Diagram showing processes influencing the evolution of climate feedbacks](Knutti et al. 2017)

**Internal Variability**

Large Ensembles,…

**Projection Method Uncertainty**
What We Mean By „Projections“

- Calculating future impacts of climate change requires an estimate of the future climate
- Climate models are biased; raw future data can’t be used
- Climate projections used in impacts projections combine model output with historical weather data
Our Projection Philosophy, Commonly Used in Climate Economics

„Delta Change“:

\[
\text{Future climate} = \text{current observations} + (\text{future model} - \text{current model})
\]

Assumes that the changes in the model reflect real-world changes.

Can be used for any (combination of) characteristic of the climate - different variables, different moments (mean, standard deviation, skewness, different quantiles, etc.)
Question: How do changes in climate variability affect impacts projections?

Motivation:

Economic impacts of climate change are routinely calculated under assumptions that:
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Economic impacts of climate change are routinely calculated under assumptions that:

1. Climate variability does not change

(i.e. Schlenker, Hanemann, and Fischer 2005; Deschênes and Greenstone 2011; Hsiang, Burke and Miguel 2013)
Question: How do changes in climate variability affect impacts projections?

Motivation:

Economic impacts of climate change are routinely calculated under assumptions that:

1. Climate variability does not change
2. Only the seasonality of climate changes

(i.e. Fischer et al. 2005; Schlenker and Roberts 2009)
Question: How do changes in climate variability affect impacts projections?

Test: Sensitivity analysis of a well-known climate damage function to fine-scaled temperature variability changes
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Damage function: temperature vs. mortality, Deschênes and Greenstone, 2011

Base, fixed variability projection: ERA-INTERIM, scaled by CESM large ensemble yearly means (\textit{fixedvar}"

Ideal projection with fine-scaled variability changes: ERA-INTERIM, scaled by CESM large ensemble quantile changes (\textit{varchange}"

Result: omitting variability changes leads to overestimating future mortality in cold regions and underestimating it in warmer inland areas.
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„By how much will the coldest Jan 1st / median Apr 21 / hottest Aug 15 change in the future?“

- Based on the estimation of the shape of daily \( T \) distributions using quantile regression; distributional changes are imposed on historical ERA-INTERIM

- Basis functions are smooth cubic splines, allowing for
  - within year variation (seasonal cycle)
  - inter-year variation (long-term trend)
  - an interaction (long-term changes in the seasonal cycle)

- As a result, each quantile for each day-of-year (i.e. the median Jan 1st) is estimated using 40 runs x 121 years (1979-2099) = 4840 points

Variability Projection

1. Normalize

2. Estimate quantiles

3. Apply LENS change in matched quantiles

4. Un-normalize

LENs, 40 runs (projecting data)

ERA-INTERIM (reanalysis/base data)
Variability Projection

(average of [2068-2099] - average of [1979-2010] from LENS)
Variability Projection

Milwaukee County, WI

\[ \Delta T \text{ (°F)} \]

Historic Mean T (°F)

January  April  July  October

Quantile

Colorbar:

0.01 0.05 0.1 0.25 0.5 0.75 0.9 0.95 0.99
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Mortality Changes Under Variability Changes

'Varchange' projection, change historical vs. end-of-century

Difference in changes, 'varchange' - 'fixedvar' projection

Change in Annual Mortality Rate

/100,000

60

40

20

0

-20

-40

-60

Diff. in Changes in Annual Mortality Rate

/100,000

10

8

6

4

2

0

-2

-4

-6

-8

-10

Ignoring variability changes in projections overestimates future mortality

Ignoring variability changes in projections underestimates future mortality
Mortality Changes Under Variability Changes

Harris County, TX (Houston)
Mortality Changes Under Variability Changes

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Mortality Changes Under Variability Changes

1. Large ensembles allow us to extract more information from a given climate model, improving impacts projections

2. A better understanding of variability changes (estimated using large ensembles) suggests heat-related mortality changes from climate change in the US are underestimated

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