Does the scaling of extreme precipitation depend on forcing?

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(Starting today) (Until last week)
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Why would we think that extreme precipitation could depend on emissions scenario?

Because mean precipitation does.
Global mean precipitation change depends on black carbon forcing

\[ \frac{\Delta P}{\Delta T} \]

Change in clear-sky atmospheric SW absorption, removing effect of water vapor

NCAR CCSM 3.0

2.1 W m\(^{-2}\) K\(^{-1}\)

GFDL CM 2.0

0.73 W m\(^{-2}\) K\(^{-1}\)

Global mean surface temperature change does not

Pendergrass and Hartmann (2012), *GRL*

Atmospheric energetic constraint on mean precipitation change

- **Greenhouse gases**
  - Warming + direct forcing: 1.5 %K\(^{-1}\)

- **Reflecting aerosols**
  - Warming alone: 3 %K\(^{-1}\)

- **Absorbing aerosols**
  - Fewer aerosols = more precipitation
Let’s test the response of mean and extreme precipitation to different forcings

RCP scenarios are convenient for this
CMIP5 RCP scenarios:
similar aerosol forcing,
different GHG forcing
Regress global, annual mean precipitation against global, annual mean surface air temperature for each model and emissions scenario.
Mean precipitation

Does depend on emissions scenario
What about extreme precipitation?
What do we mean by extreme precipitation?

Extreme rain rate: How hard the hardest rain events are

The rain rate at a percentile of the cumulative frequency distribution
Extreme precipitation response to warming

CMIP5 multi-model mean, RCP8.5 scenario
CMIP5 models mean, RCP8.5 scenario
CMIP5 models mean, RCP8.5 scenario
What do we mean by extreme precipitation?

• Extreme rain rate:
  – The rain rate at a percentile of the cumulative frequency distribution

  OR

  – The heaviest day of rainfall each year (rx1day). Equivalent to 99.7\textsuperscript{th} percentile
What do we mean by extreme precipitation change?

• Extreme rain rate response to warming:
  
  – The heaviest day of rainfall each year (rx1day) regressed against global, annual mean surface temperature
Does extreme precipitation change depend on the forcing?

No...
Extreme mode

Rain rate change (%/K)

90 99 99.9 99.99
Percentile

Model response
Shift+increase
What if we restrict the analysis to *land*?

*No*, extreme precipitation change still doesn’t depend on forcing.
...Extra-tropical land?

No, it still does not depend on forcing
Summary

Does the extreme precipitation change per degree warming depend on forcing?

**No, despite that mean precipitation does.**

- We quantified extreme precipitation change by in spatially-averaged annual maximum daily rainfall (99.7\textsuperscript{th} percentile daily rain rate) regressed against global, annual mean surface air temperature.

- We examined the variations across the CMIP5 RCP scenarios, which have similar aerosol forcing change but different GHG forcing.

- The signal is most reliable in the extra-tropics.

- Potential caveat: The extreme mode in some models, mostly over tropical oceans.


Consistent with Kharin, Zwiers, Zhang, Wehner (2013), who did a related analysis and also examined different time periods.
Statistical test for difference across emissions scenario

Black box: higher emissions scenario has a smaller change in precipitation (like we expect for mean precipitation)

Distributions are different if $18 < \text{sum of black boxes} < 30$ (Signs test)