

Does the scaling of extreme precipitation depend on emissions scenario?

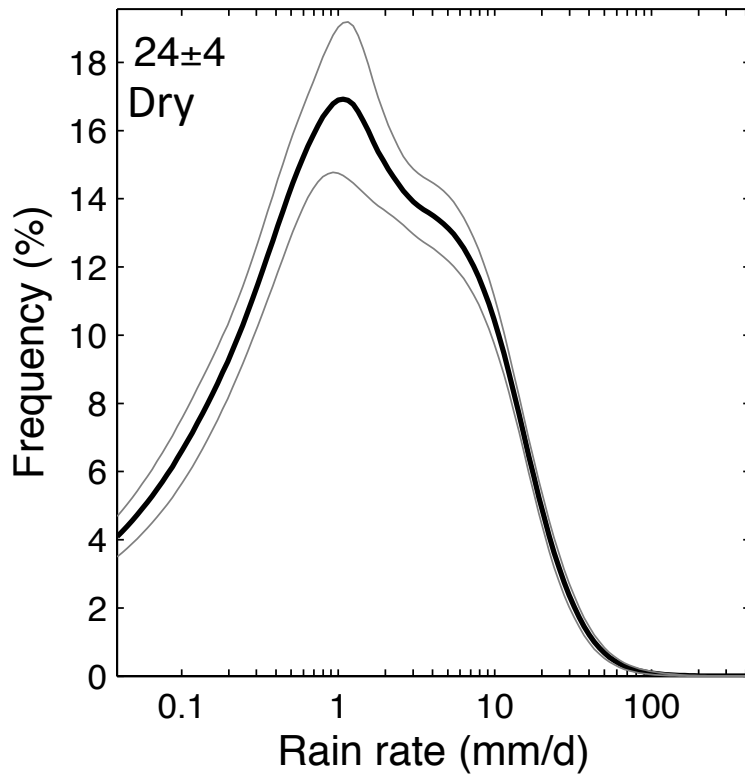
Angeline Pendergrass

NCAR
Climate and Global Dynamics Division
> Climate Analysis Section
Advanced Studies Program

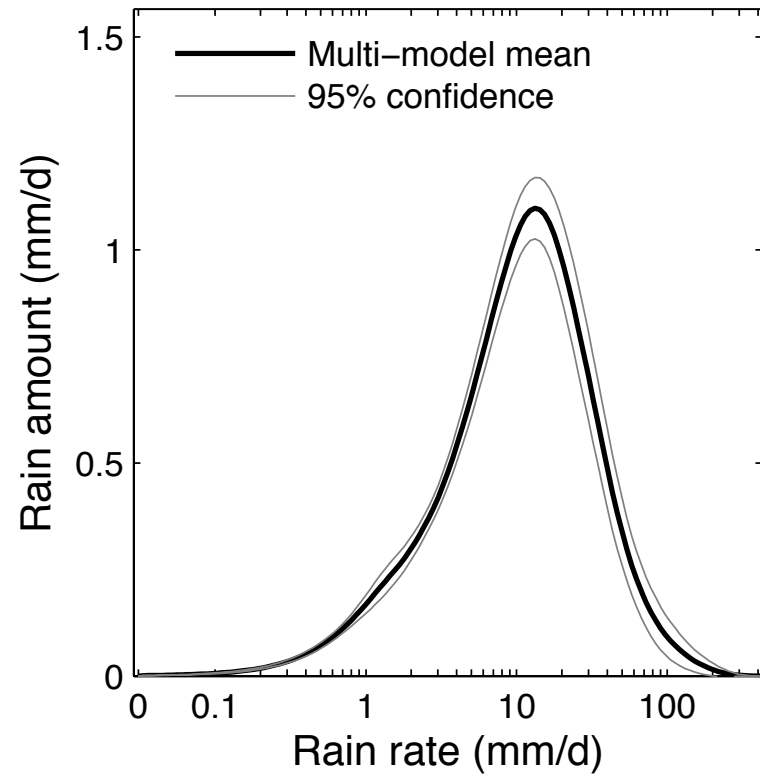
What do we mean by *precipitation*?

- Let's take a look at the distribution of rain:
At what rain rate does rain fall?
 - Globally...
 - As a function of latitude, season, location?
 - How does this change?
- Just models today

Rain frequency

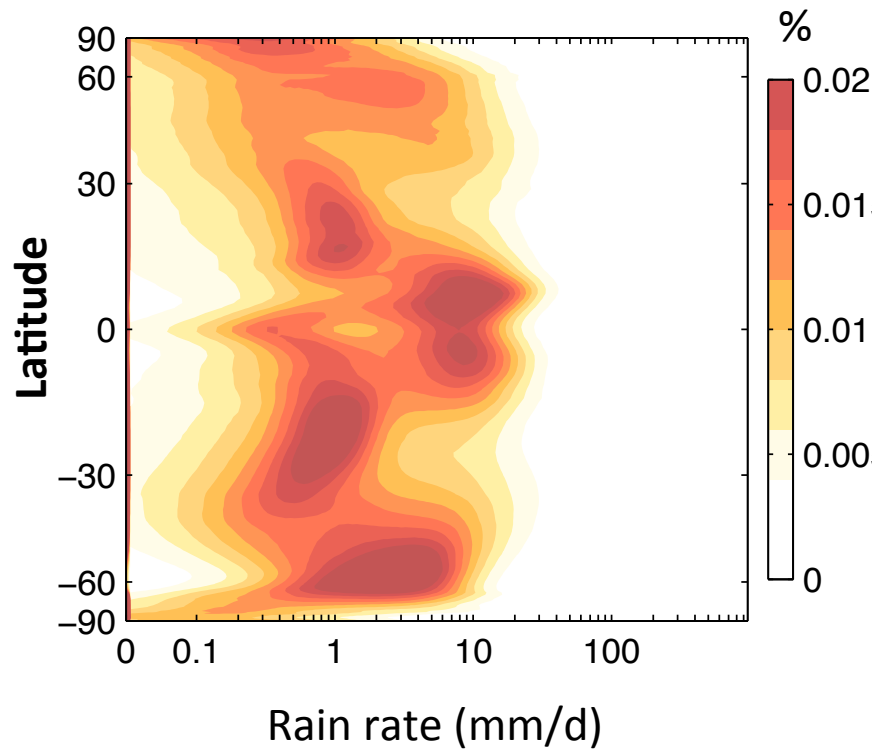


Rain amount

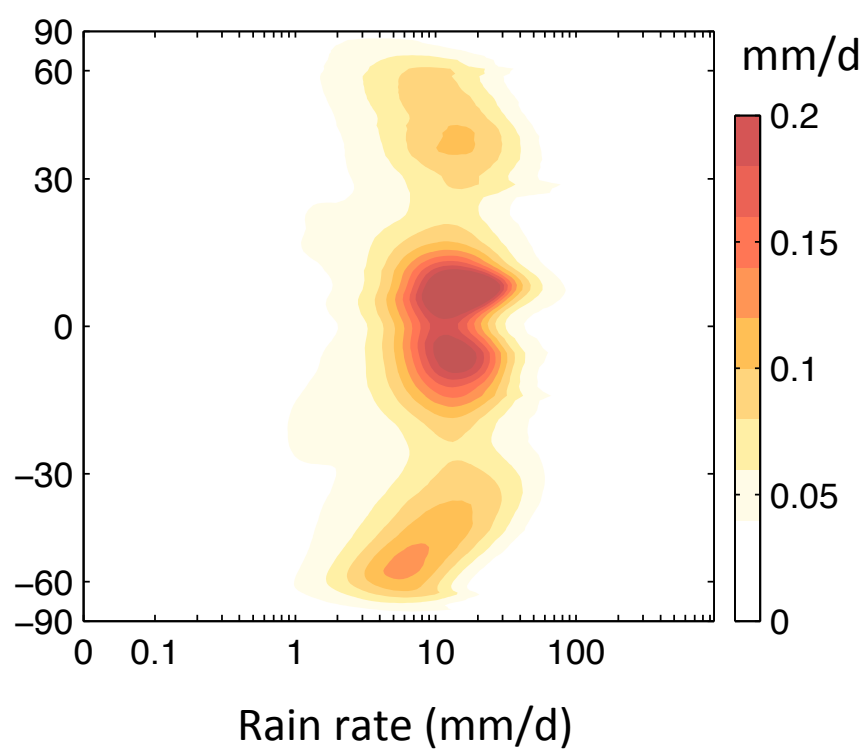


CMIP5 multi-model mean

Rain frequency

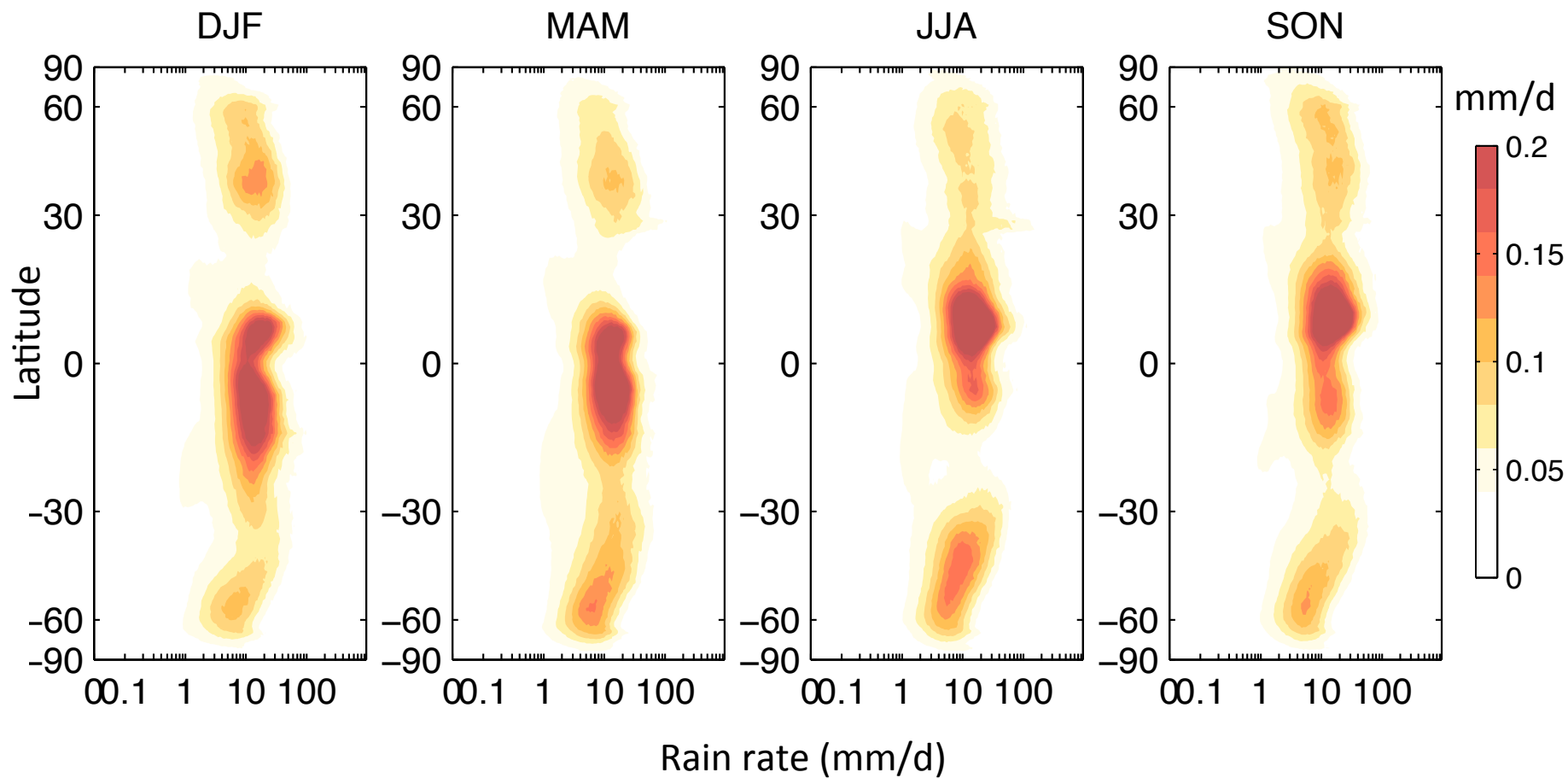


Rain amount



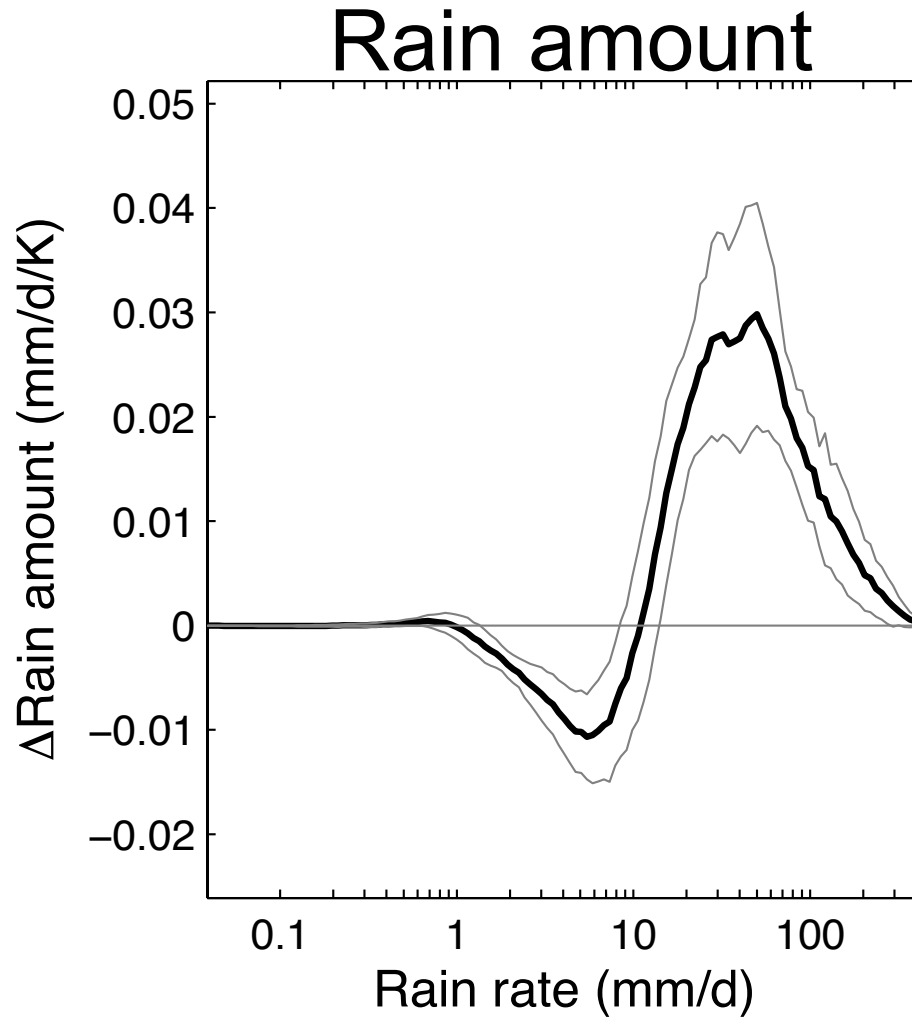
CESM Large Ensemble

Rain amount



CESM Large Ensemble

Response to warming

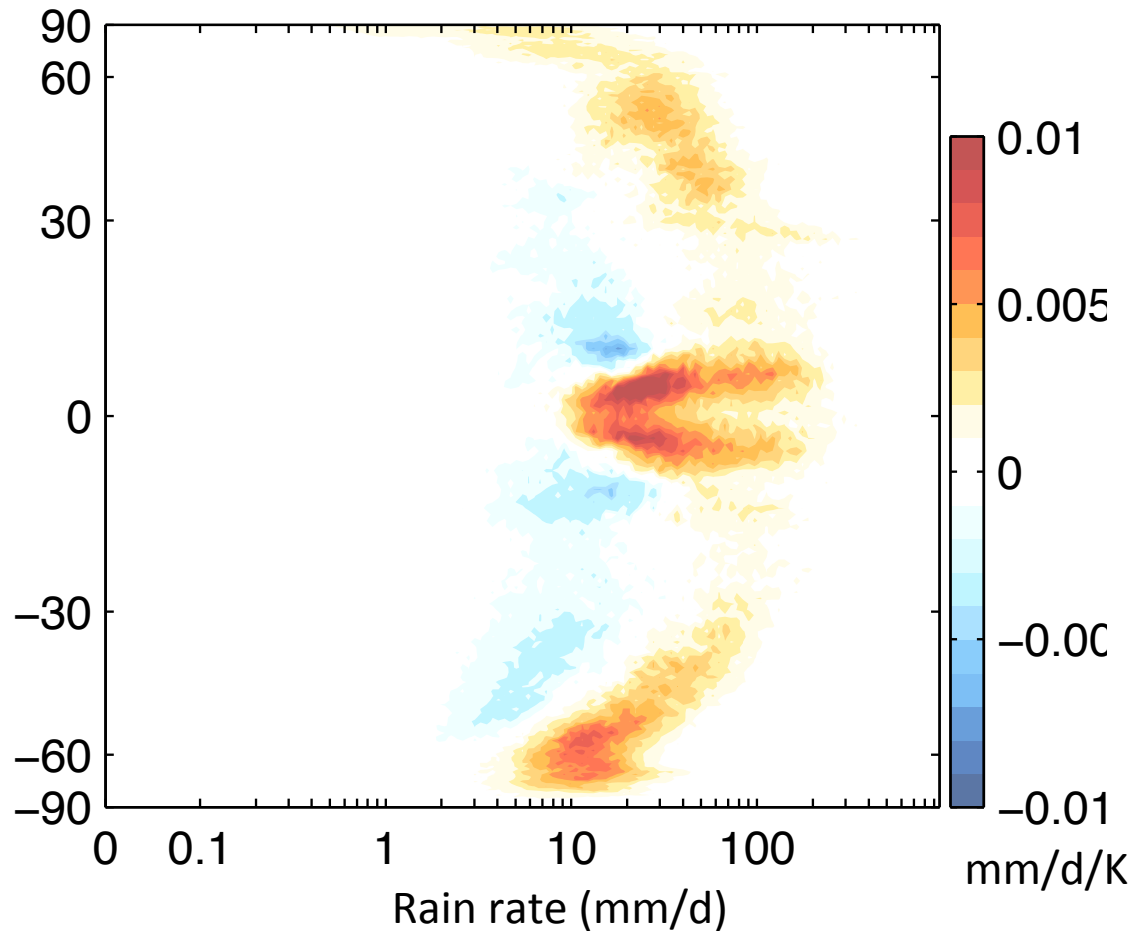


Pendergrass and
Hartmann (2014) *J Clim*

CMIP5 multi-model mean

Response to warming

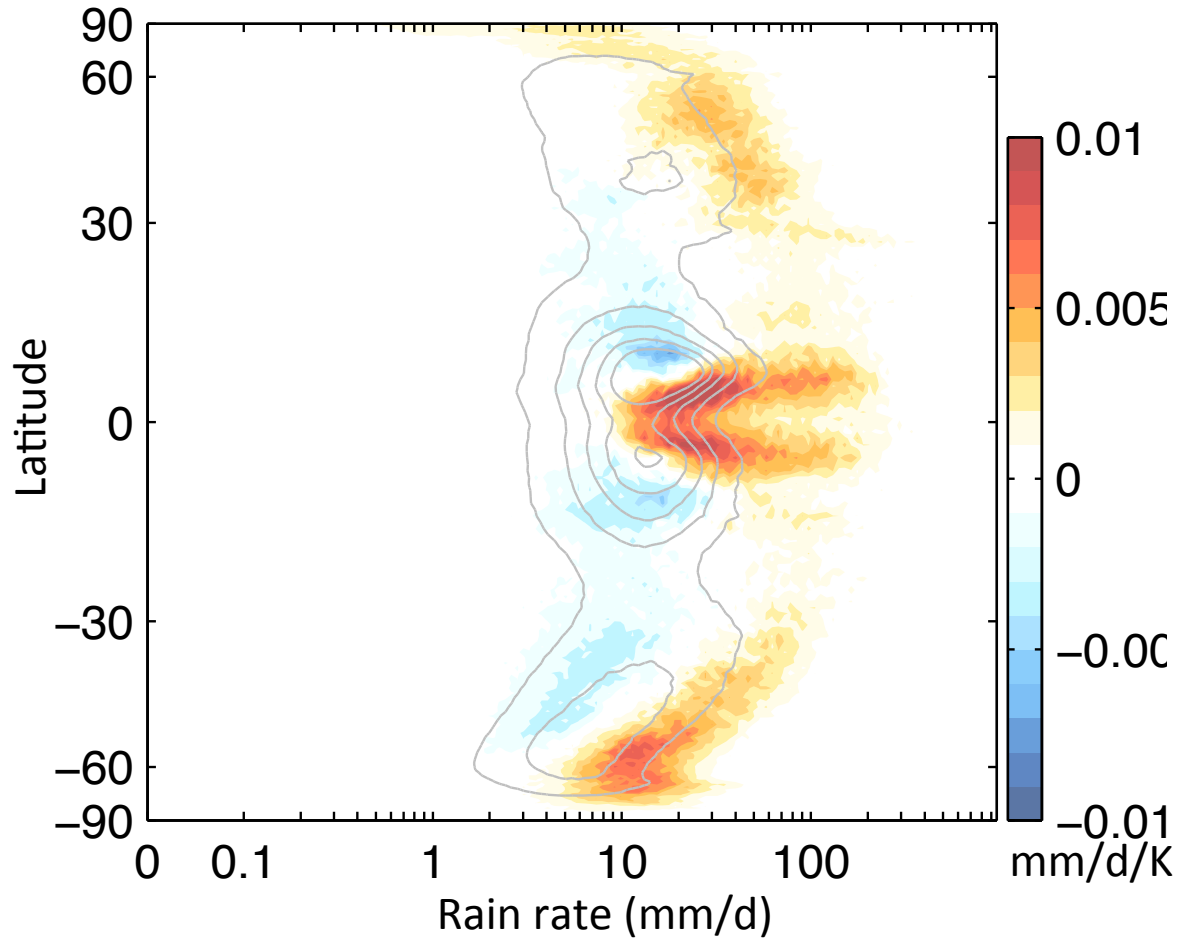
Rain amount



CESM Large Ensemble, RCP8.5 scenario

Response to warming

Rain amount

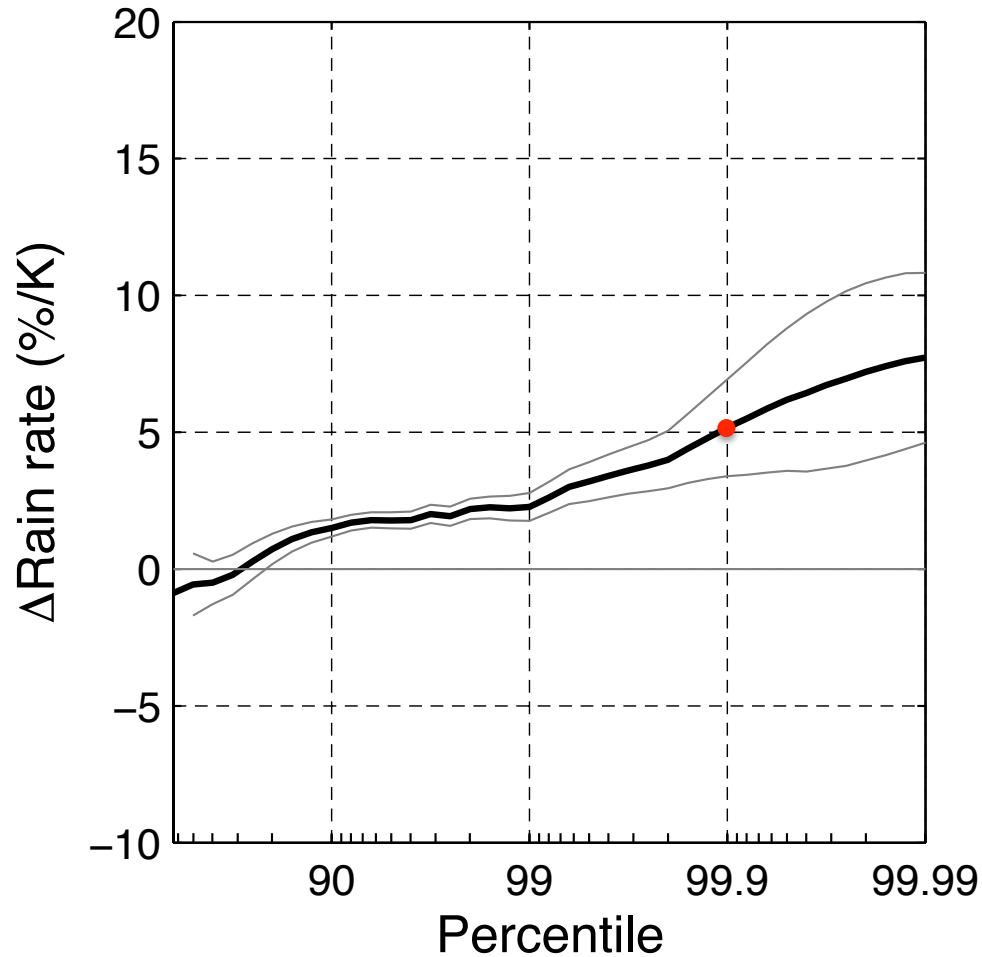


CESM Large Ensemble, RCP8.5 scenario

What do we mean by ***extreme precipitation?***

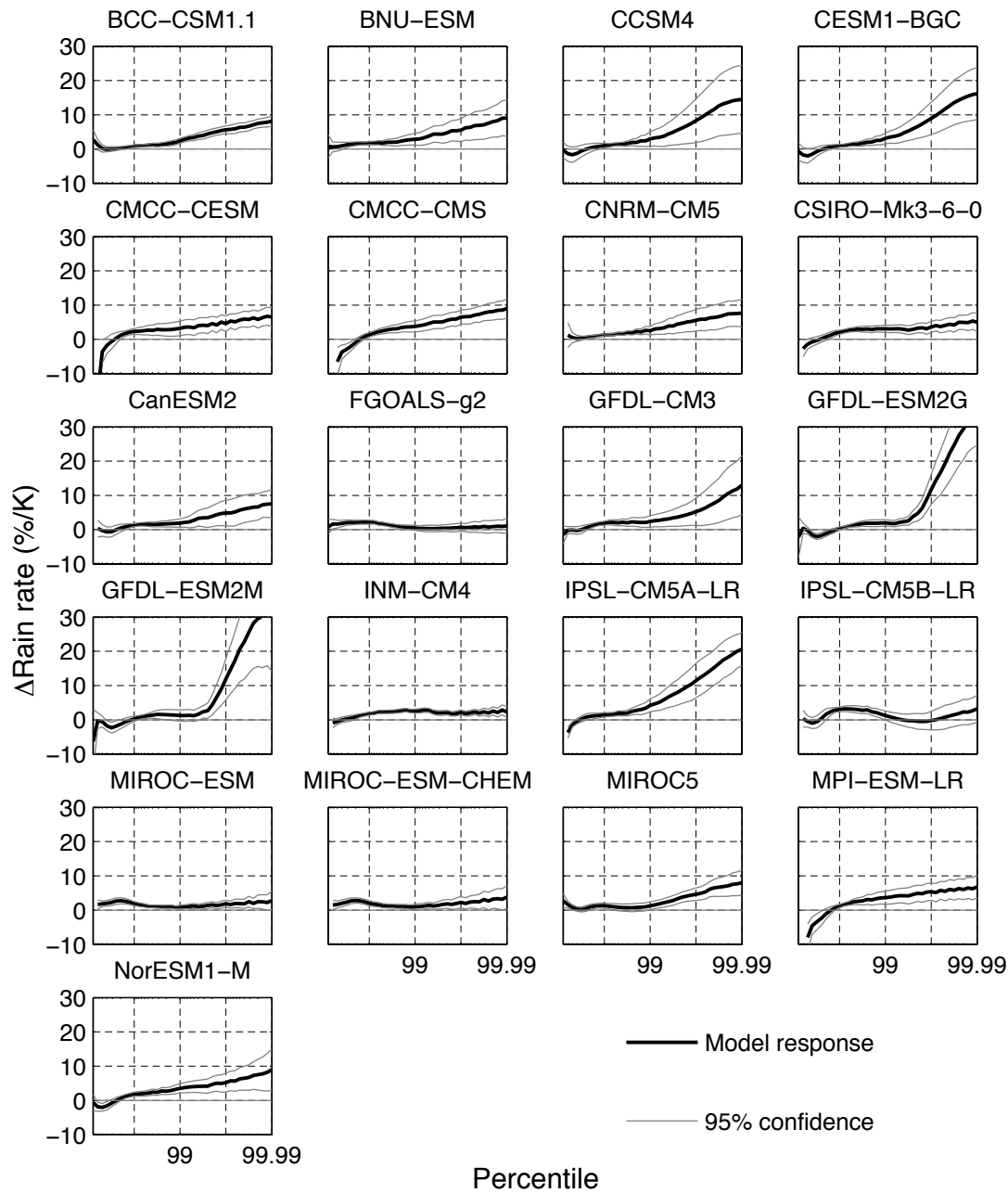
- **Extreme rain rate:** How hard the **hardest** rain events are
 - The rain rate at a percentile of the cumulative frequency distribution

Extreme rain rate response to warming

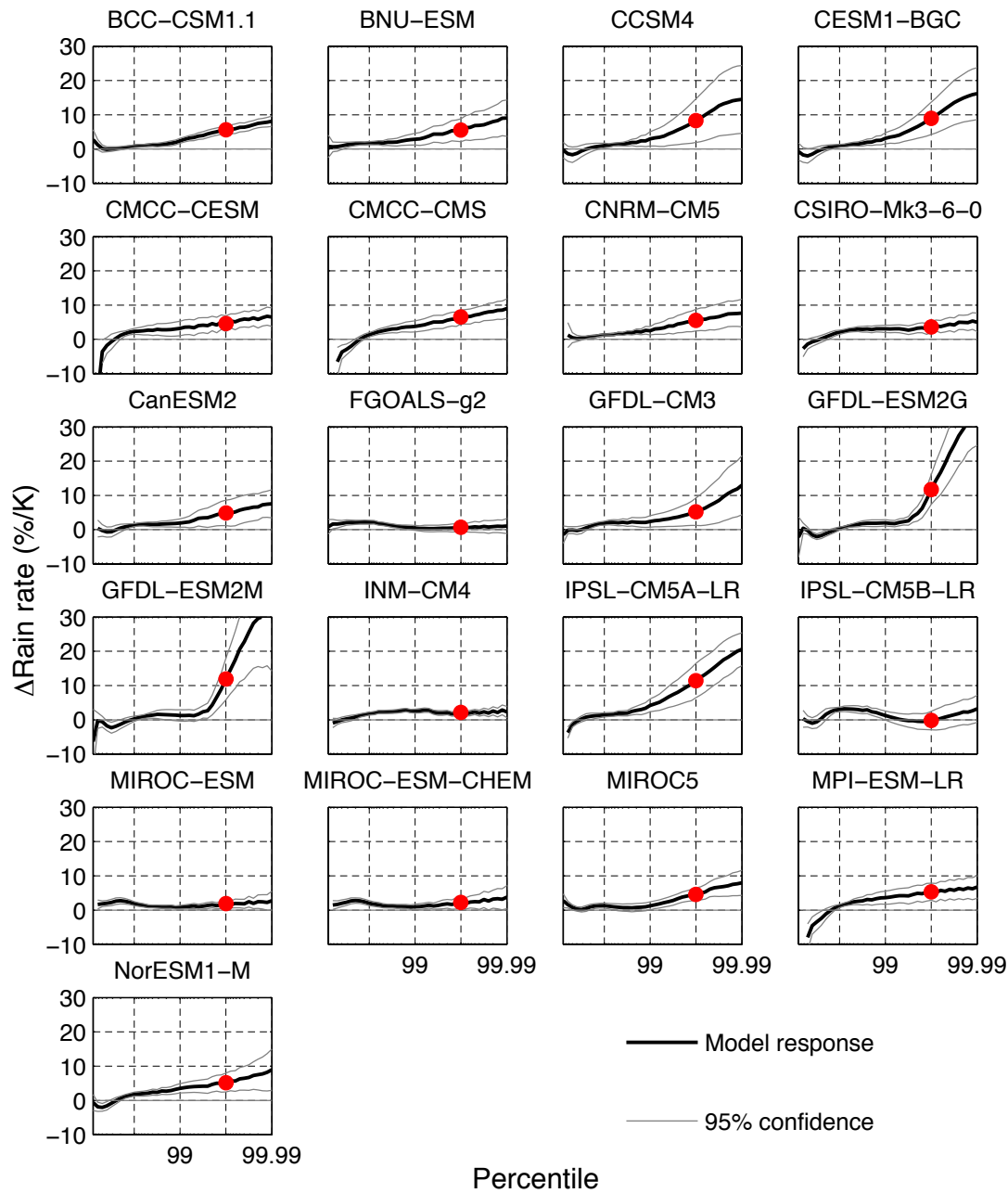


CMIP5 multi-model mean, RCP8.5 scenario

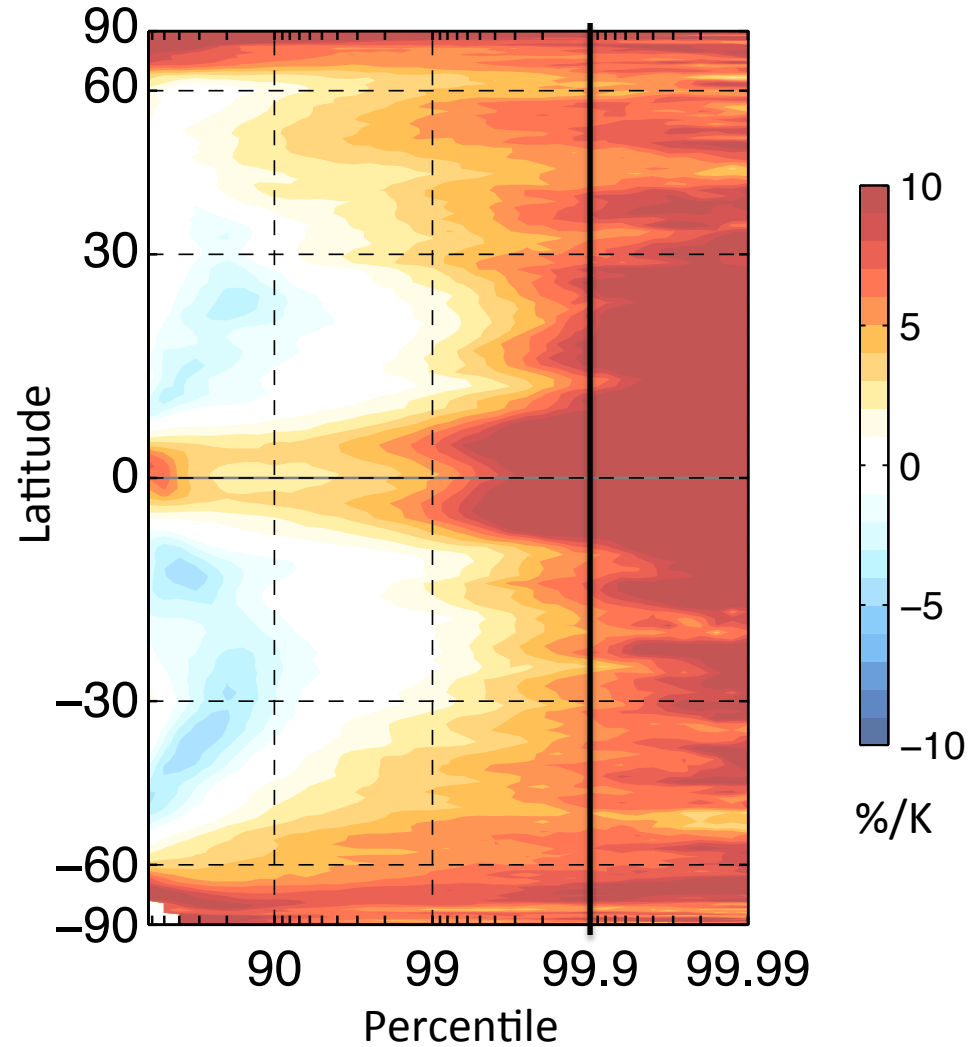
CMIP5 models mean,
RCP8.5 scenario



CMIP5 models mean,
RCP8.5 scenario



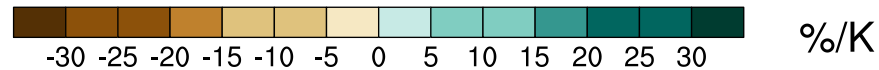
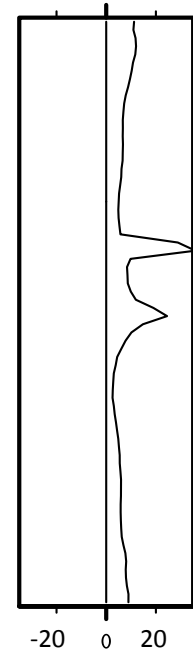
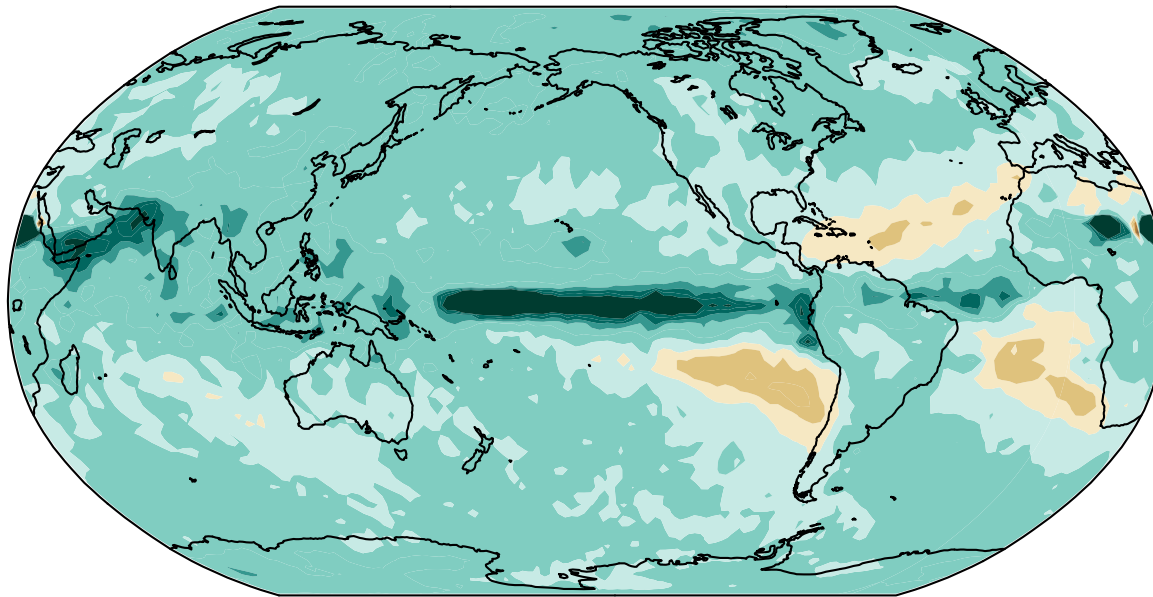
Extreme rain rate response to warming



CESM Large Ensemble, RCP8.5 scenario

Multi-model mean change in extreme rain rate: spatial pattern

CMIP5 multi-model mean,
RCP8.5 scenario



Summary: things we just learned about rain

With latitude...

The rate at which heavy rain falls varies surprisingly little
Light rain falls in the subtropics

With season...

Tropical rain migrates north and south
Extra-tropical rain modulates in frequency

With warming...

Tropical rain migrates equatorward
Extreme rain events get heavier in most places

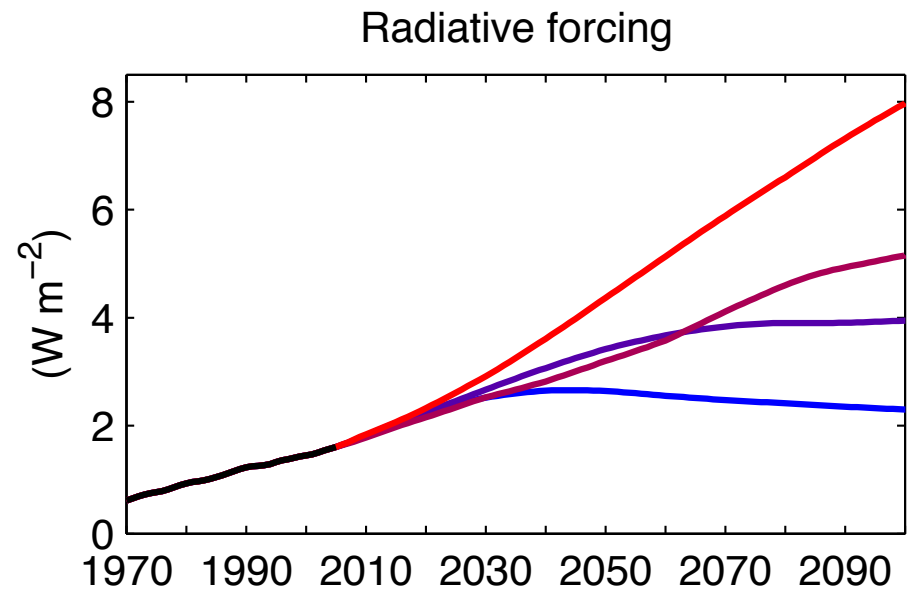
Does the scaling of extreme precipitation depend on emissions scenario?

No.

What do we mean by *emissions scenario*?

Greenhouse gas emissions trajectory

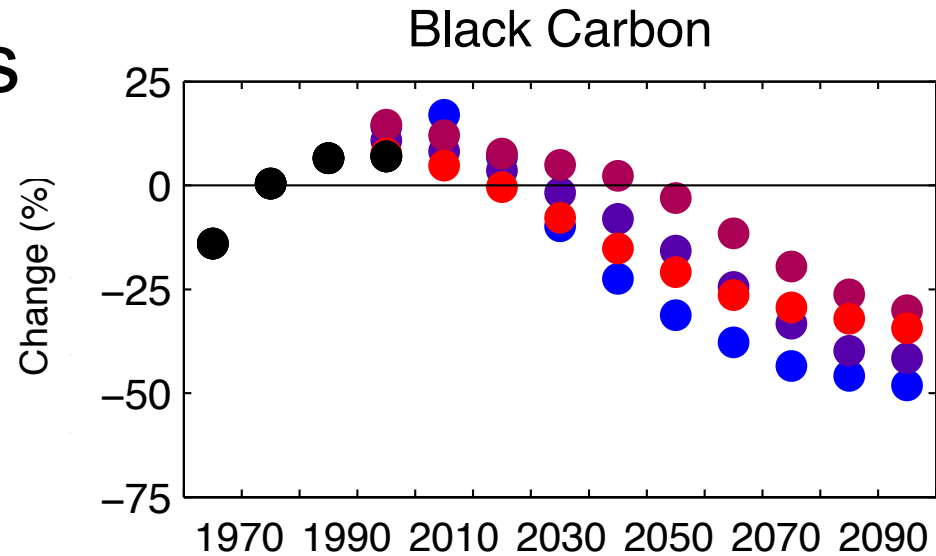
- RCP26
- RCP45
- RCP60
- RCP85



What do we mean by *emissions scenario*?

Aerosol emissions trajectory

- RCP26
- RCP45
- RCP60
- RCP85



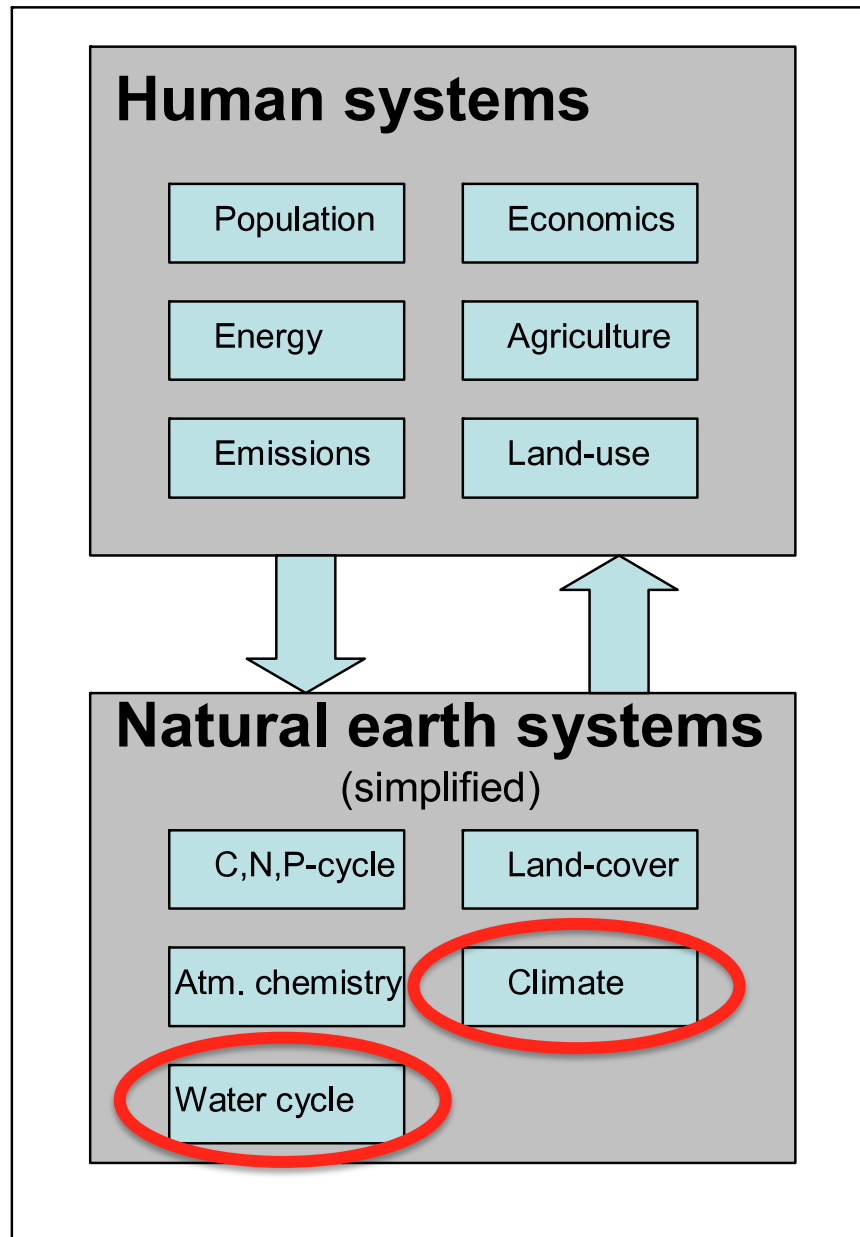
Why would we care
whether extreme precipitation depends
on emissions scenario?

For simplified representations of climate
change.

Integrated **Assessment Modeling (IAM)**

Pattern scaling

Integrated Assessment Models (IAMs)



Why would we care

**whether extreme precipitation depends
on emissions scenario?**

IAMs try to model the economy and infrastructure in detail, and the climate system as simply as possible.

What is the simplest way to represent fields that affect the economy and infrastructure?

Is global mean surface warming enough?

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

$$\frac{\Delta P}{\Delta T}$$

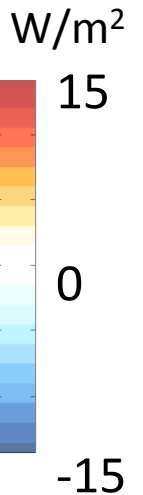
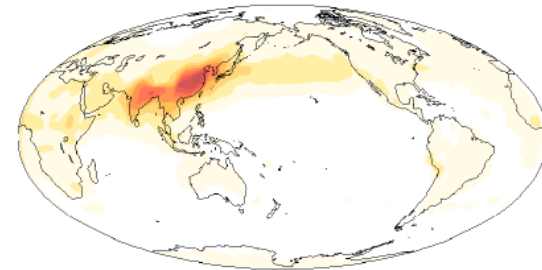
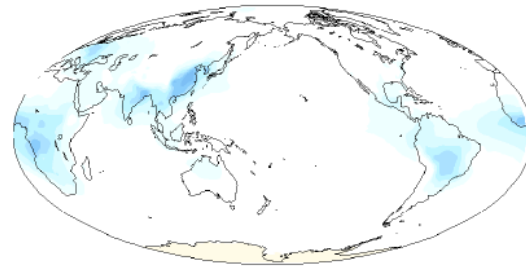
NCAR CCSM 3.0

2.1 W m⁻² K⁻¹

GFDL CM 2.0

0.73 W m⁻² K⁻¹

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

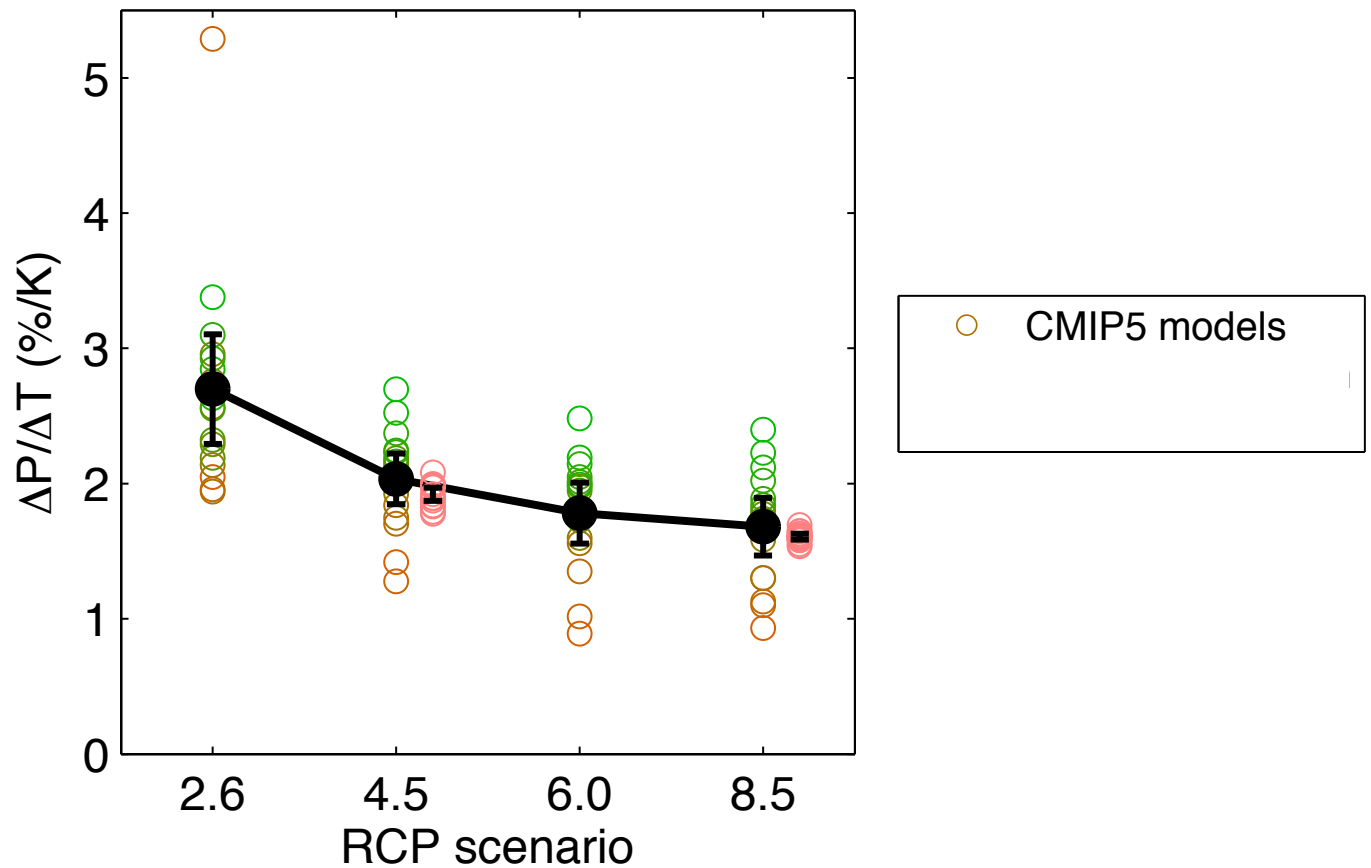


Global mean surface temperature change does not

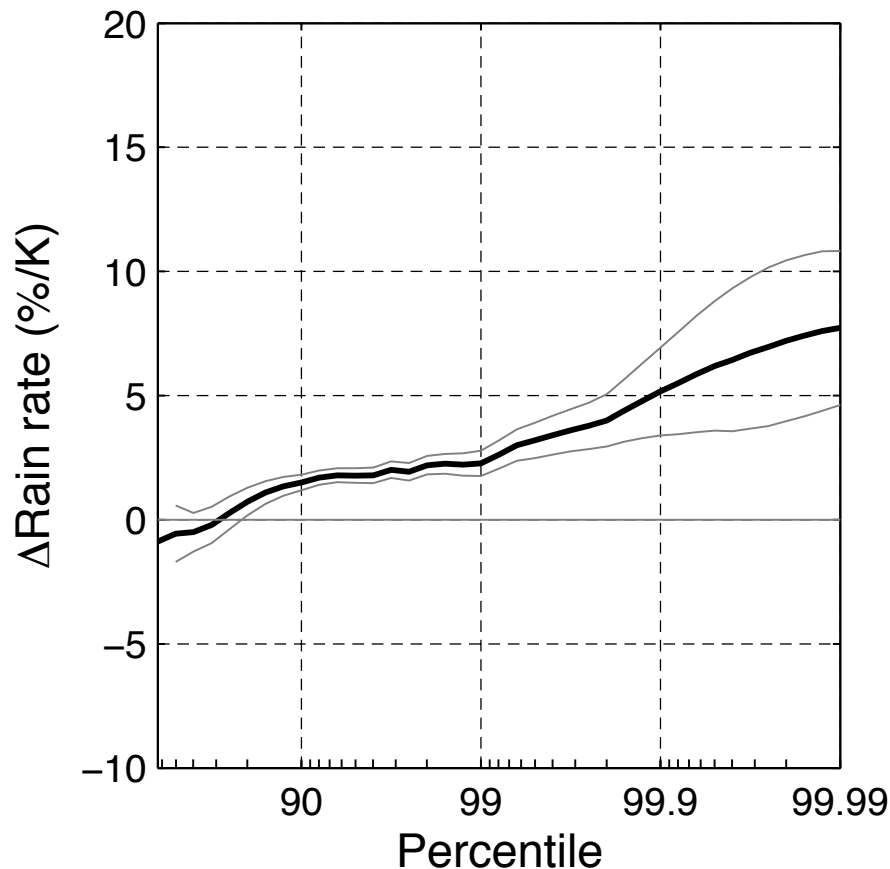
Pendergrass and Hartmann (2012), *GRL*

See also Frieler et al (2011),
Shiogama et al (2010)

Mean precipitation does depend on emissions scenario.

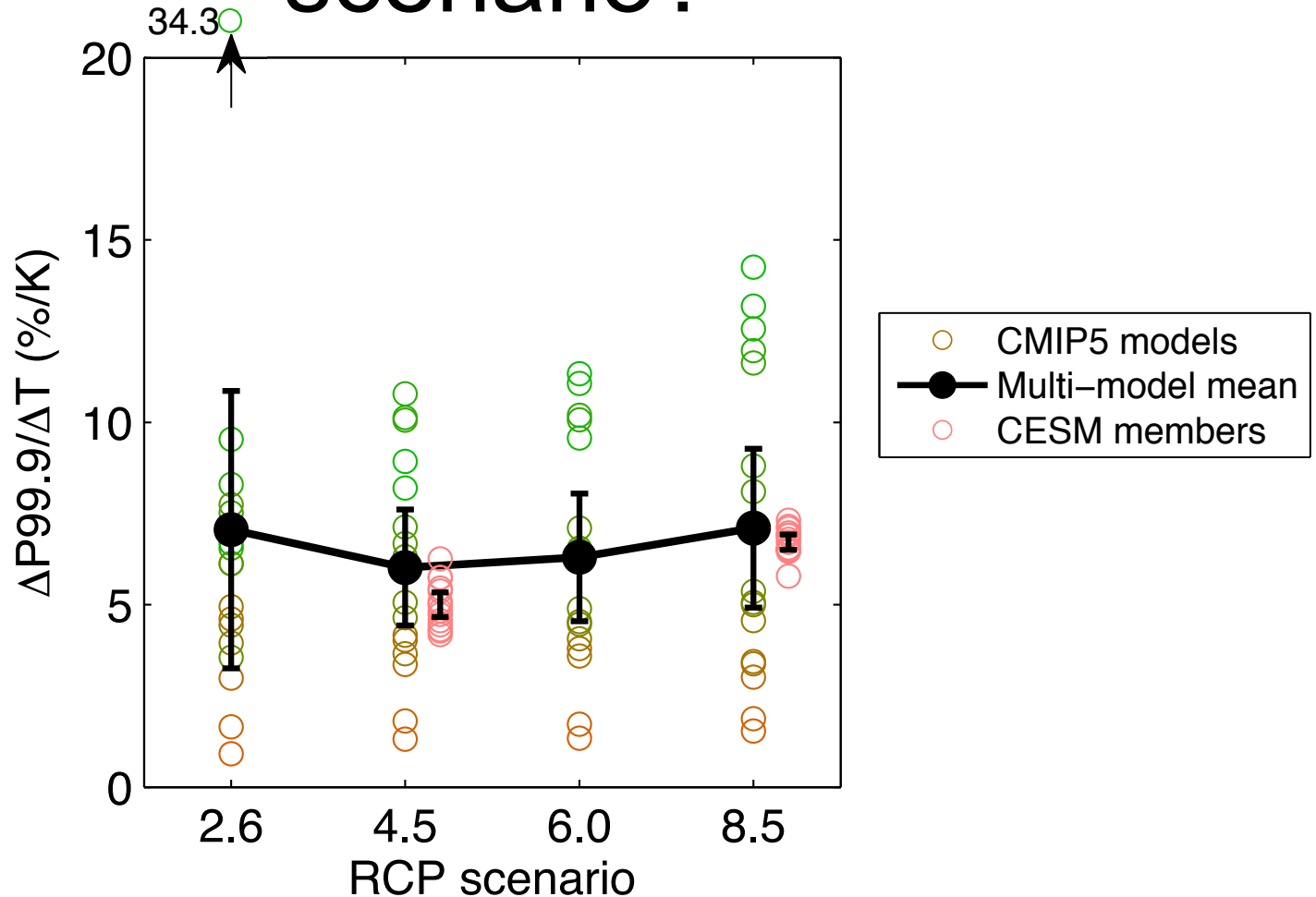


But extreme precipitation does not necessarily behave the same way as mean precipitation

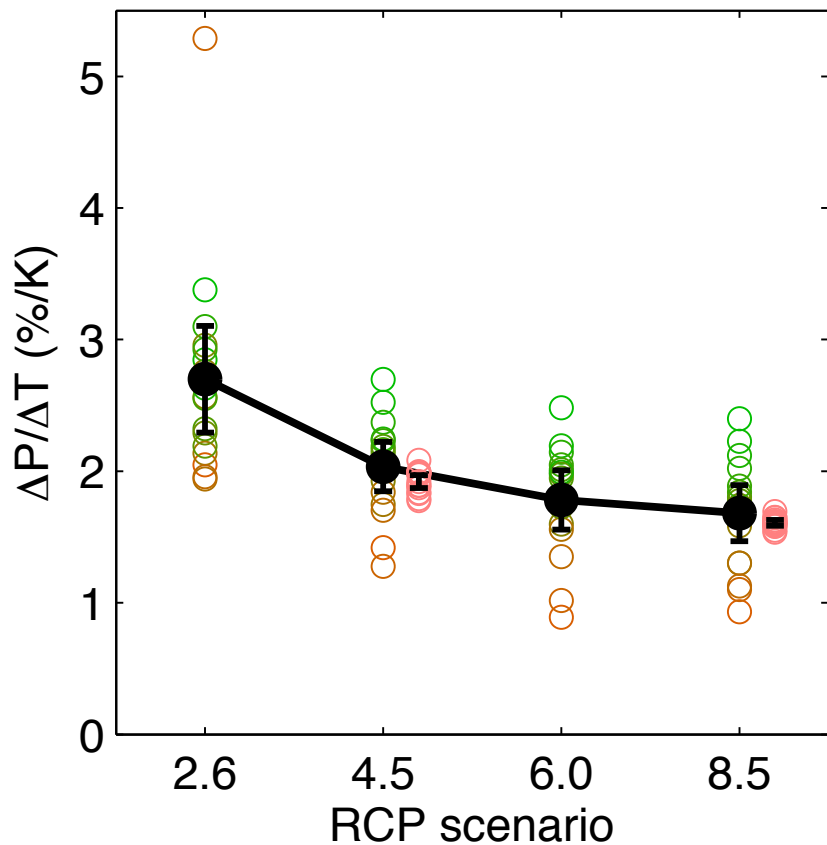


Does extreme precipitation depend on emissions scenario (like mean precipitation)? **Or not** (like surface temperature)?

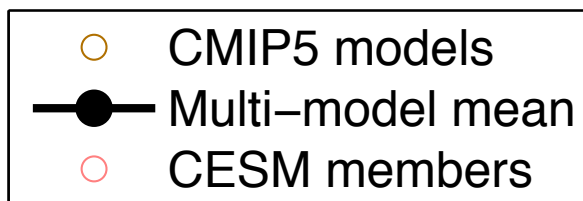
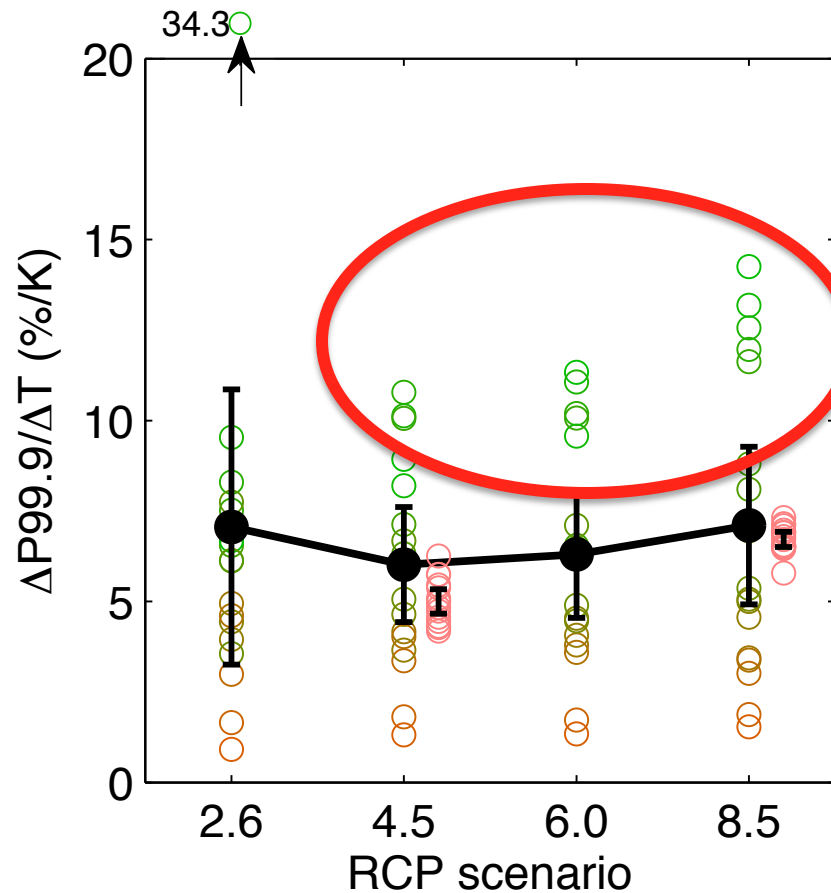
Does the scaling of **extreme precipitation** depend on emissions scenario?



Mean

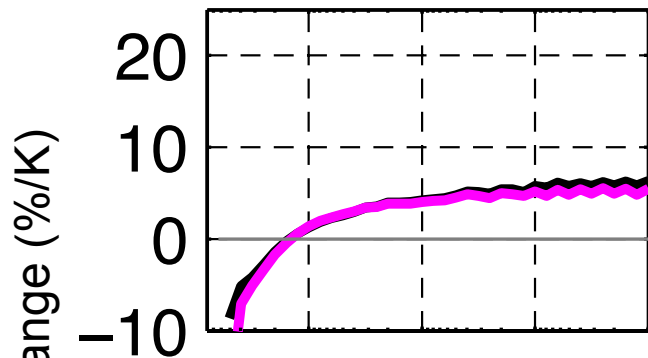


Extreme

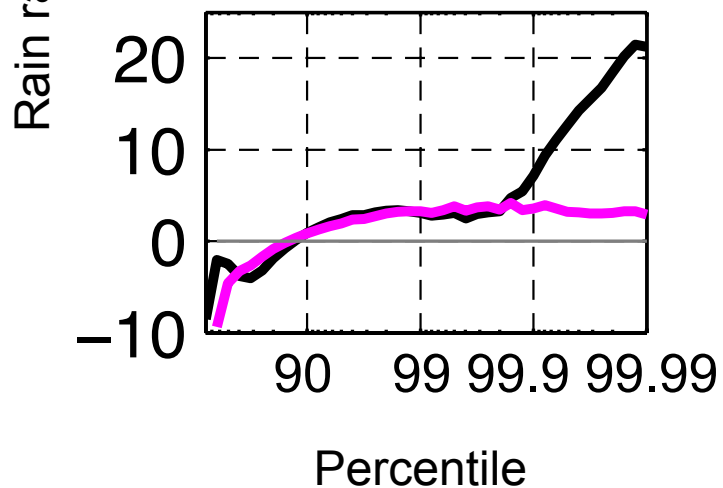


Extreme mode

MPI-ESM-LR

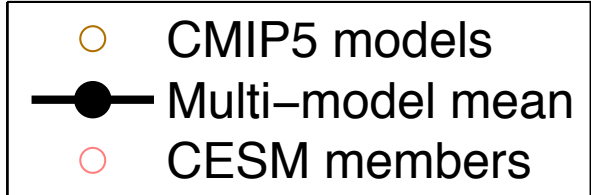
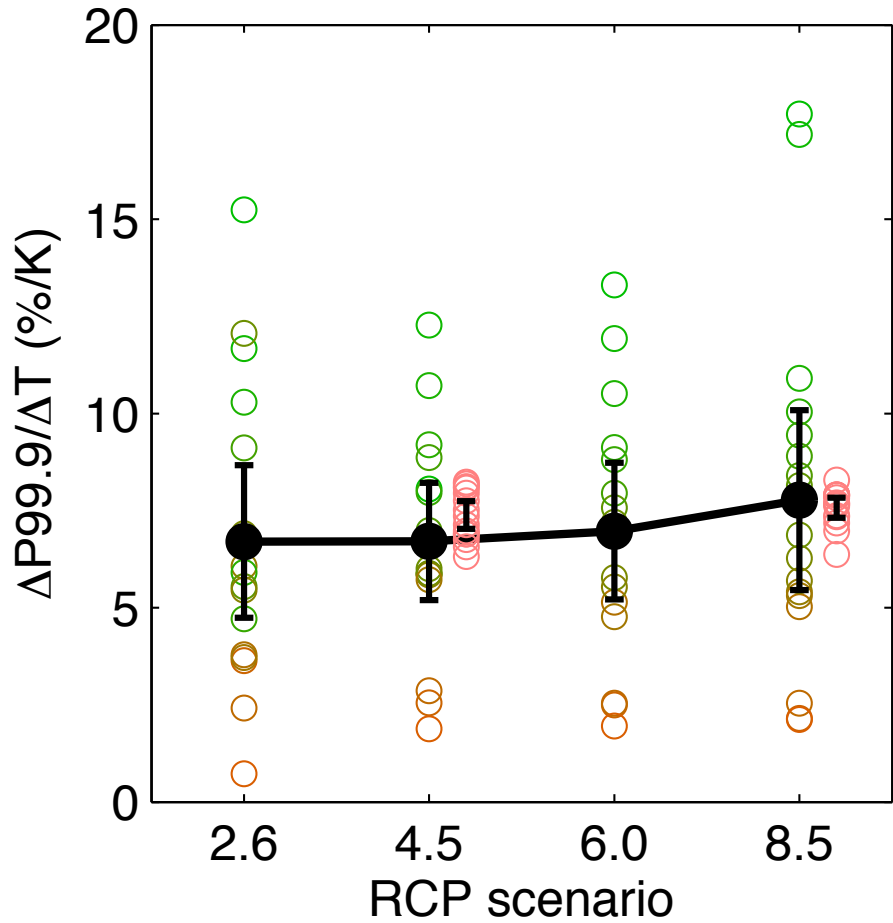


GFDL-ESM2G

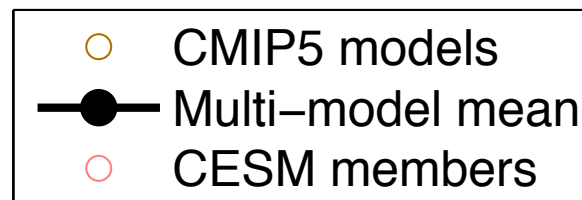
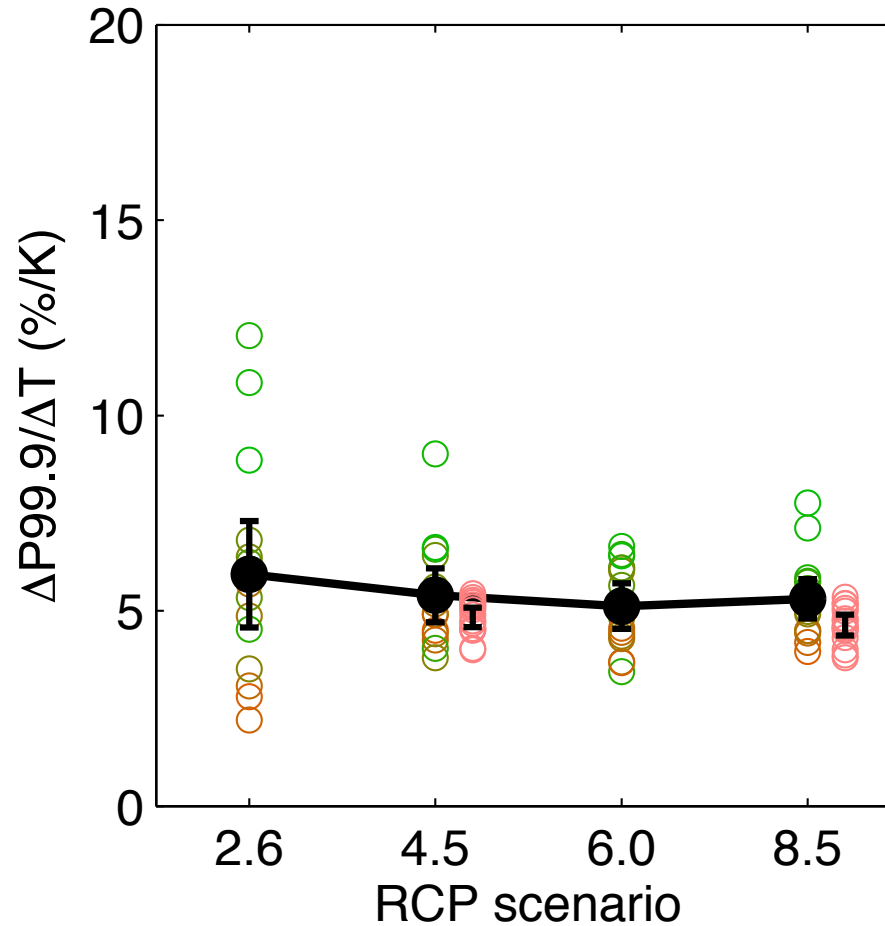


- Model response
- Shift+increase

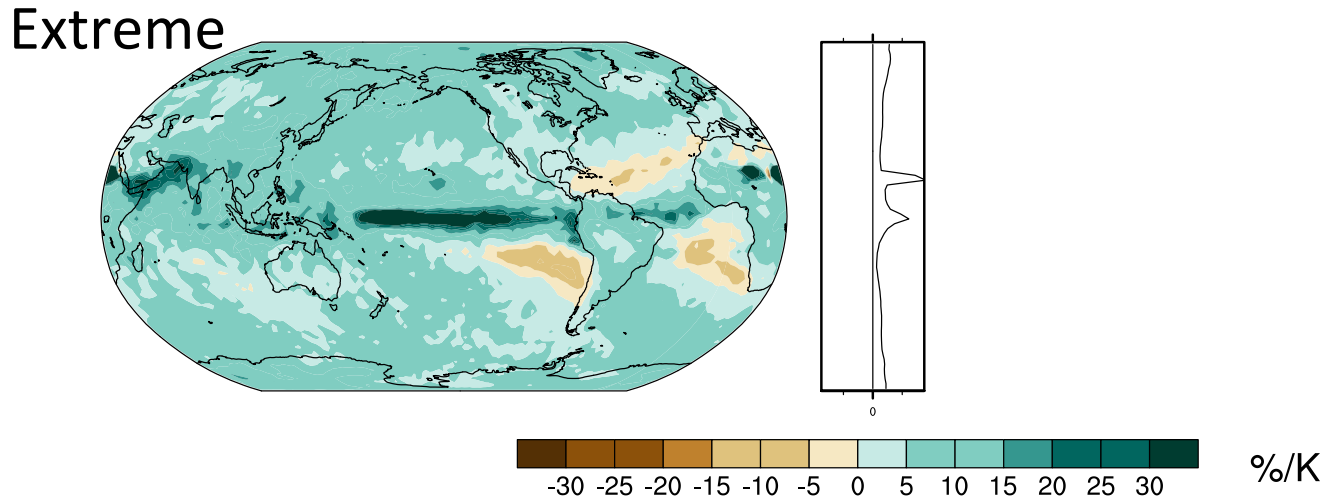
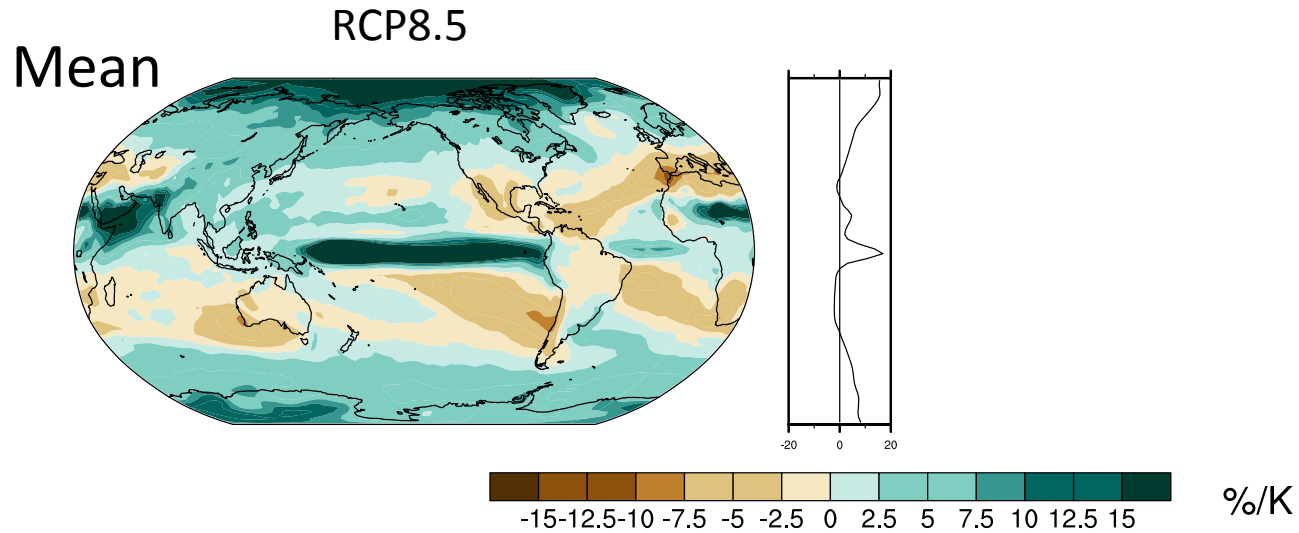
What if we restrict the analysis to *land*?



...*Extra-tropical land?*



Does it hold locally?



Does the scaling of extreme precipitation depend on emissions scenario?

No, I don't think so. (Are you convinced?)

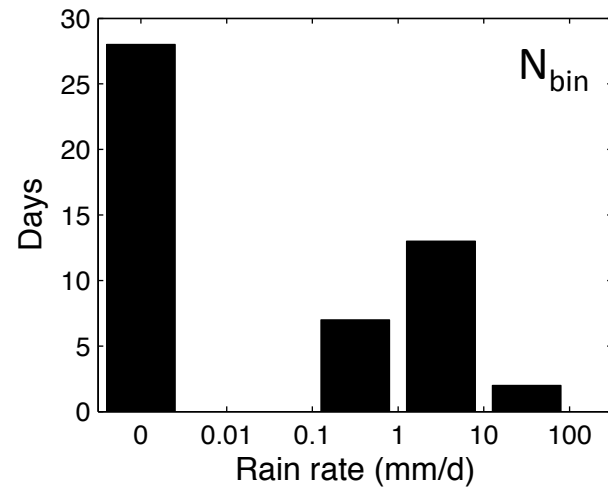
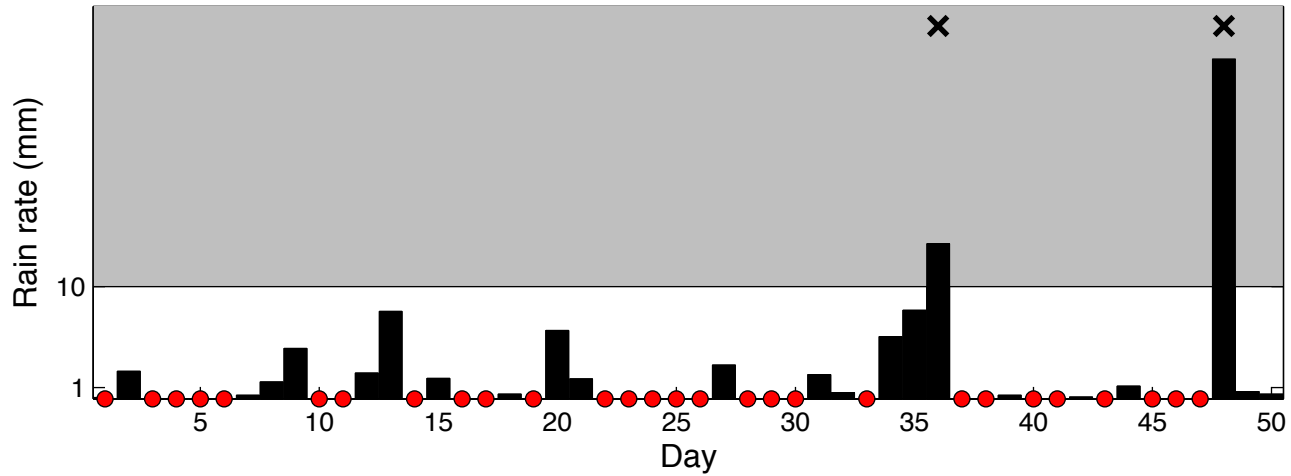
Caveat?: The extreme mode in some models.

The signal is most reliable in the extratropics.

Internal variability makes up half the signal across models (the other half is presumed structural).

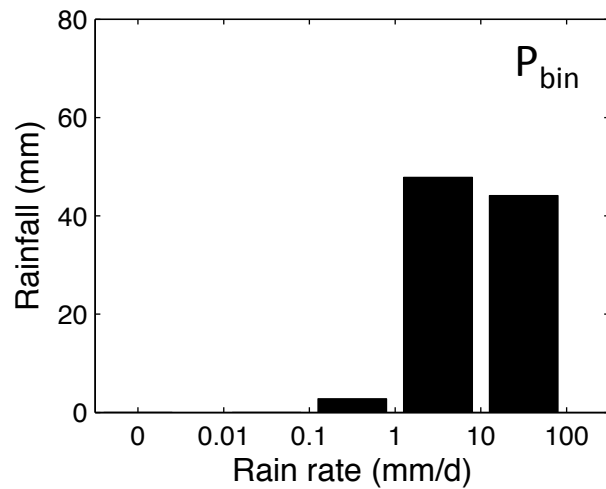
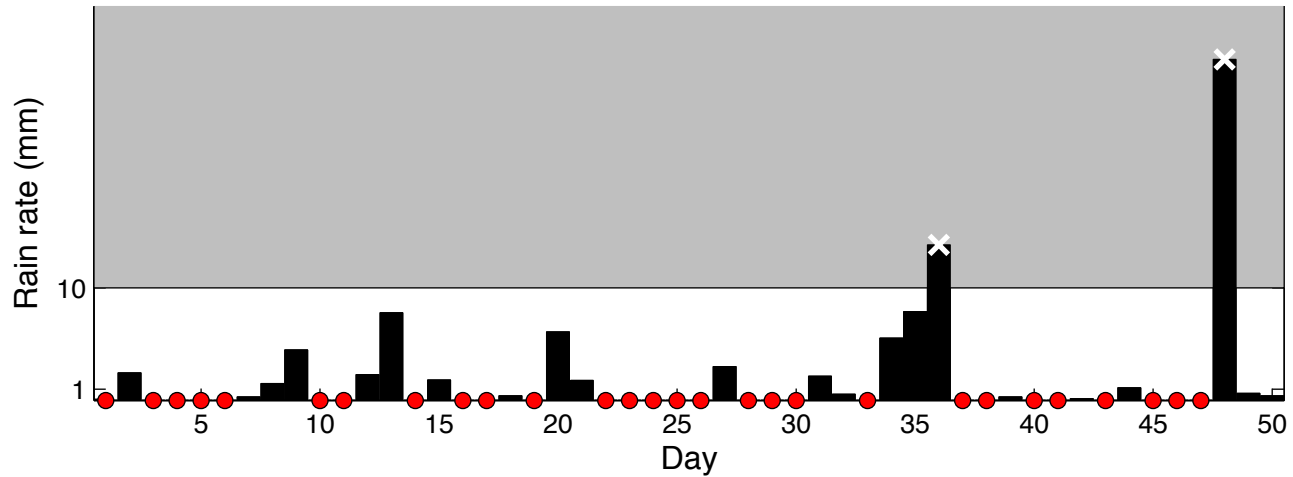
Rain frequency

The fraction of days falling in each bin

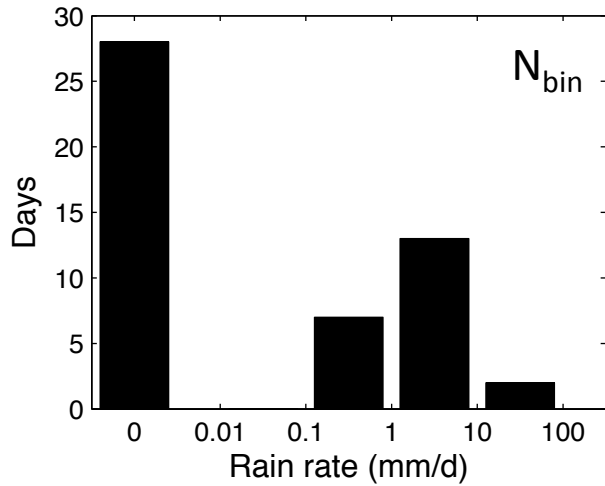


Rain amount

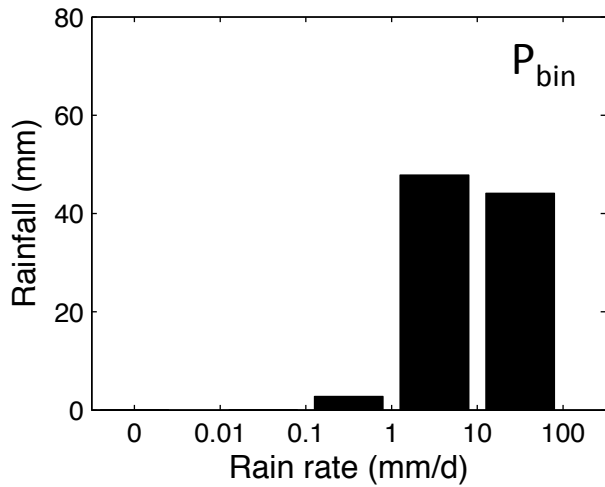
How much rain falls in each bin



Rain distribution



Rain
frequency



Rain
amount