

# **Robust effects of super-parameterization on simulated daily rainfall intensity statistics and their response to climate change**

**Gabriel Kooperman**

**University of California, Irvine  
Department of Earth System Science**

**Michael Pritchard, Melissa Burt,  
Mark Branson, and David Randall**

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# How will rainfall change in the future?



What changes are most important to society?



Impacts on society:

Flood and drought risks, and availability of fresh water.

Prediction requires:

Average rainfall, frequency, intensity, runoff, infiltration, intercept, throughflow, etc.



How well do ~~models~~ **models** capture changes in these statistics?



EOS

Photo: Federal Emergency Management Agency

Schultz [2014]

## Droughts



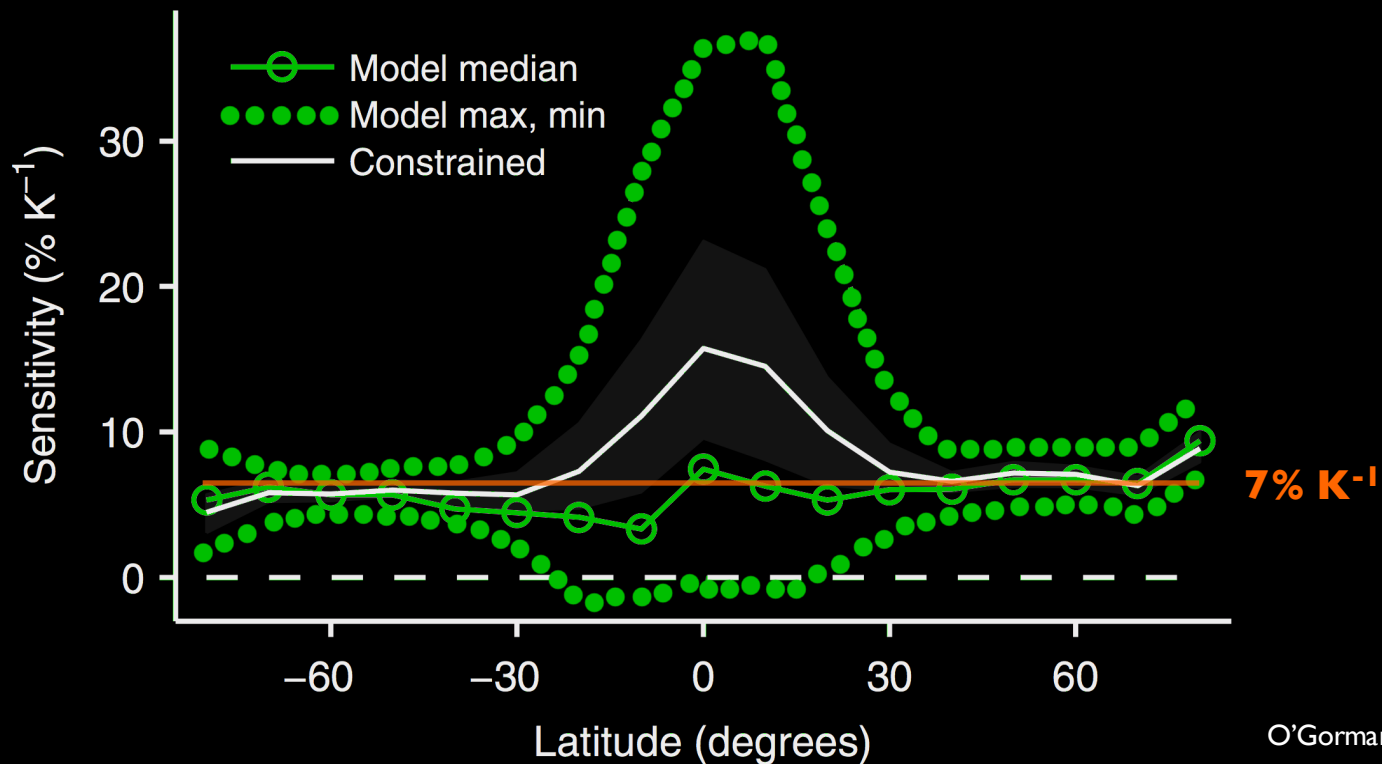
EOS

Photo: California Department of Water Resources

Weiler [2014]

# GCMs have major challenges capturing rainfall intensity in regions of organized convection

## 99.9<sup>th</sup> Percentile Precipitation Rate Change



- Water vapor is expected to increase 7% K<sup>-1</sup> globally, but regionally extreme rain in the tropics is expected to increase more due to changes in moisture convergence.

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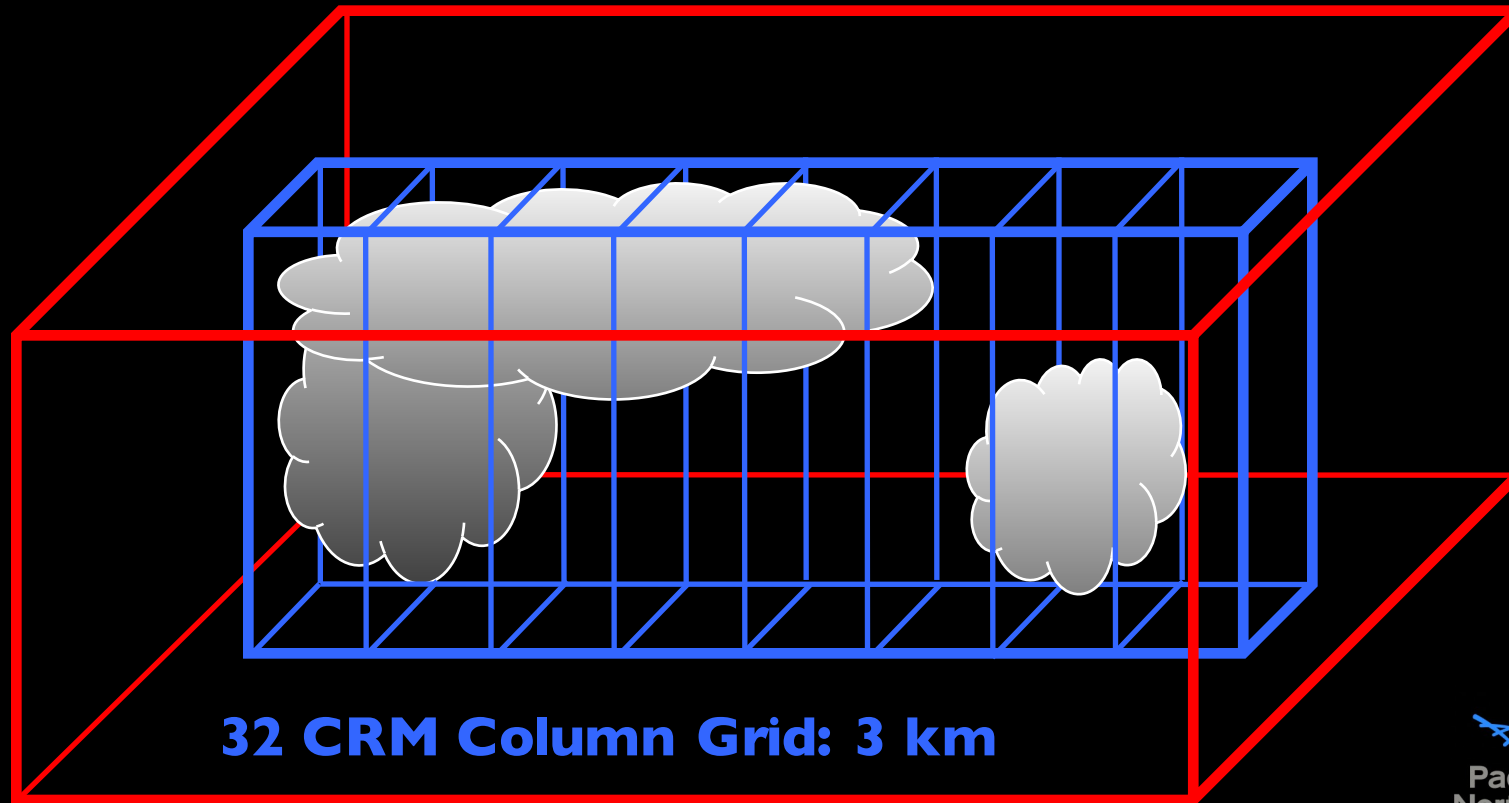
Baseline rain intensity and future changes in the tropics are uncertain and weak in GCMs, and don't improve with resolution.



Does resolving convection in a super-parameterized GCM better constrain intensity?

# Super-parameterization resolves both small- and large-scale processes simultaneously

CAM Grid:  $1^\circ \sim 100\text{km}$



## Super-Parameterized CAM

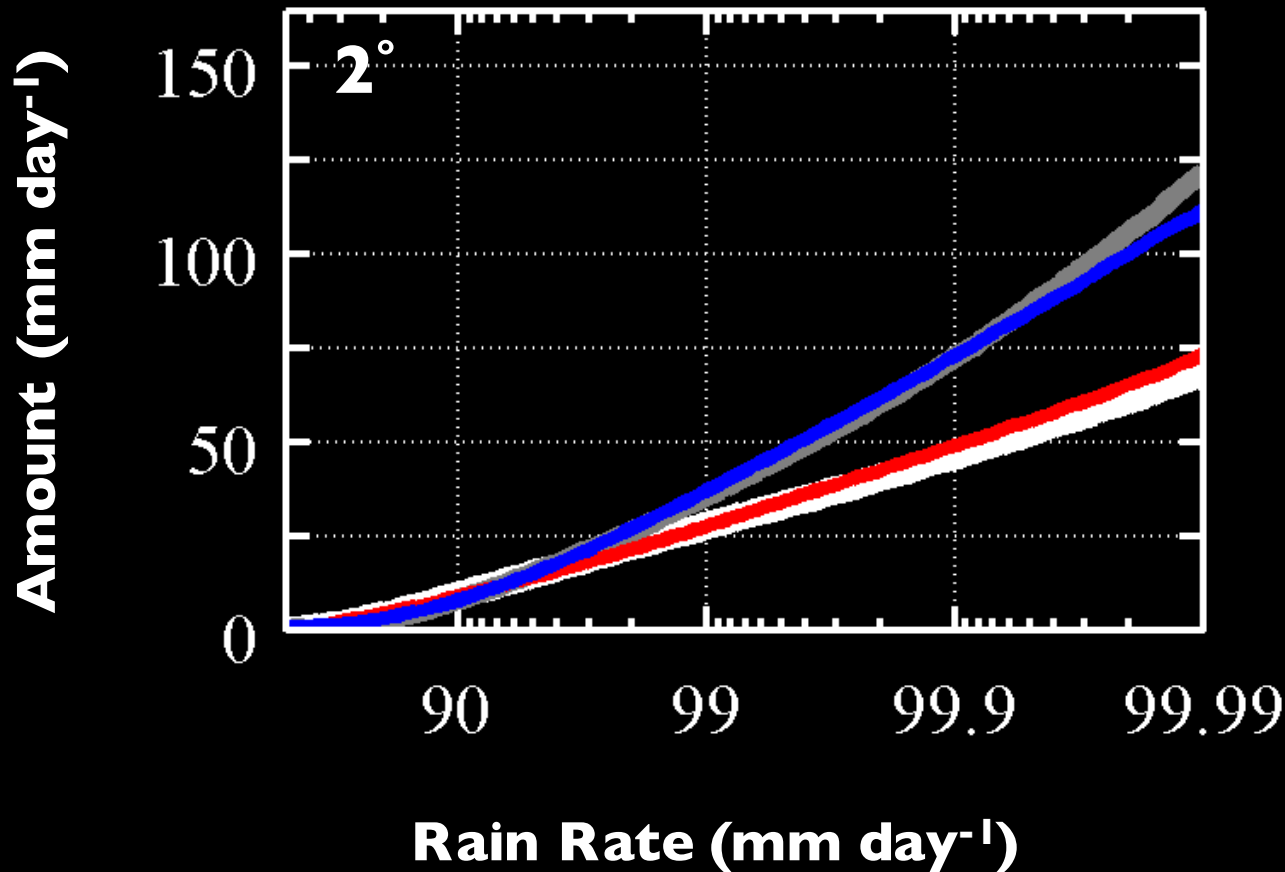
- Idealized 2D cloud resolving models are embedded in each grid column of a GCM to replace conventional parameterizations and explicitly represent sub-grid convection.



# SPCAM rain intensity agrees with TRMM over the tropics without sensitivity to resolution

## Annual Rainfall Distribution

- SPCAM, TRMM, and GPCP agree over land, but not CAM.

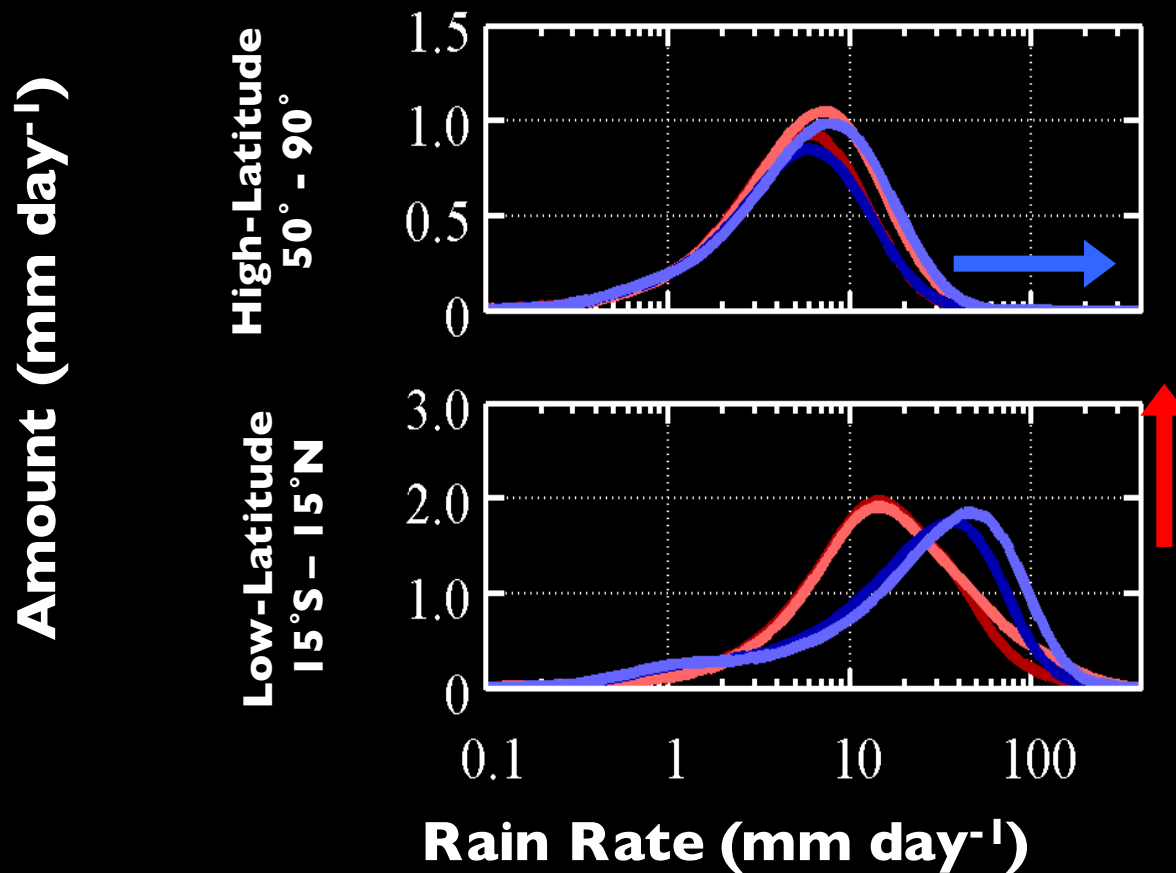


— GPCP — TRMM — CAM — SPCAM

(1°) CAM.

# SPCAM's intensity response is fundamentally different, with a smooth shift across all rates

## Annual Distribution Change



- Distributions broaden and shift right toward heavier rates more in SPCAM than CAM.
- The median does not shift in CAM, only the most extreme rainfall increases separately.

Present-Day

Climate-Change

— CAM — SPCAM — CAM — SPCAM

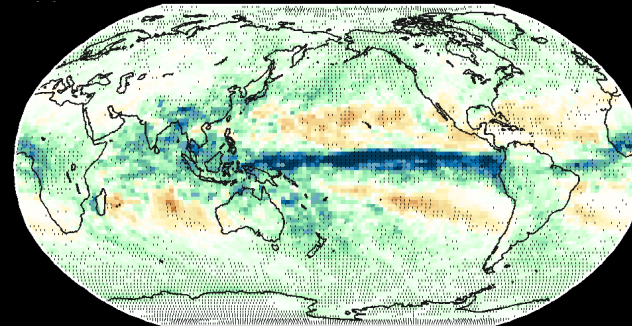
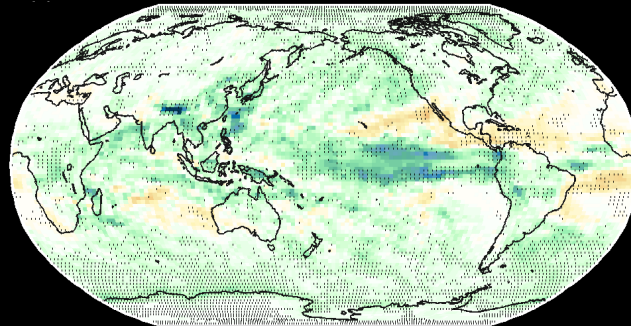


# Rain intensity is projected to increase almost everywhere, most significantly in the tropics

## Annual 99<sup>th</sup> Percentile Precipitation Rate

CAM 2°

SPCAM 2°



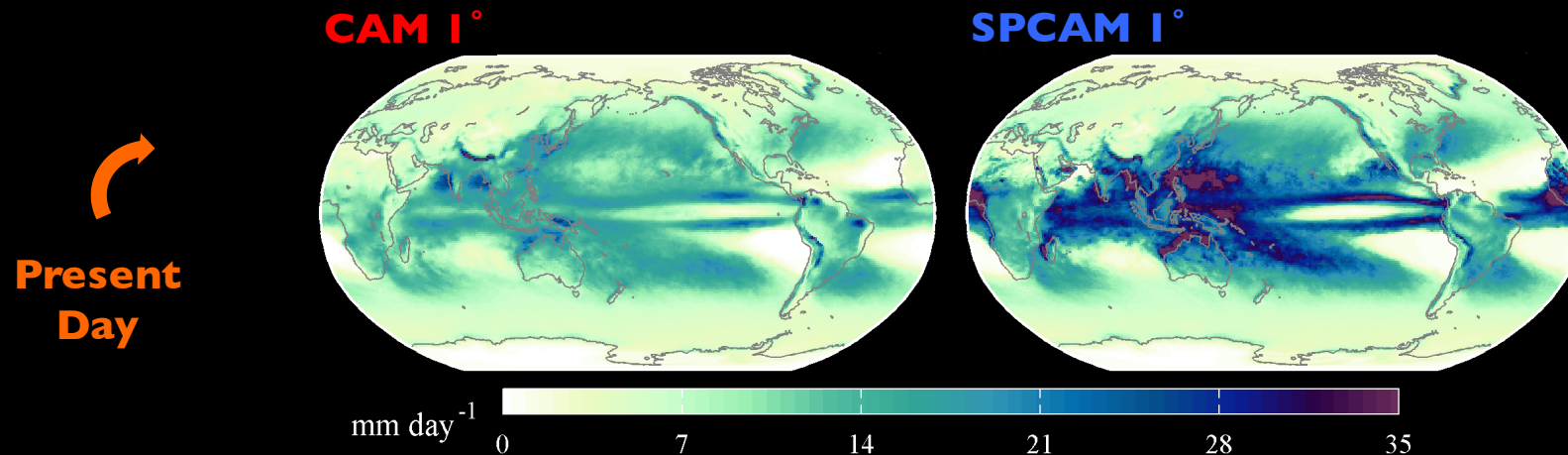
Present  
Resolution  
Models

- Present-day rain in the warm pool and monsoon regions is more intense in SPCAM.



# Moderate rates that generate most rain don't shift in CAM, but are more intense in SPCAM

## Annual Precipitation Amount Median



- Even 1° resolution CAM doesn't capture the median intensity of SPCAM and TRMM.

## **How will rainfall change in the future?**



- **SPCAM predicts a consistent shift in the distributions for all rates with a:**
  - **more intense amount median in tropical wave and MJO regions,**
  - **increase in extreme rain rates,**
  - **and intensification of ITCZ rain.**
- **CAM is sensitive to resolution and cannot capture the median response.**
- **A small median shift is visible across most parameterized CMIP5 models.**