Confronting models with long-term changes in the shape of the precipitation distribution from station observations

Jingya Han [1], Angeline G. Pendergrass [1, 2]

1: Cornell University, Ithaca NY USA; 2: National Center for Atmospheric Research, Boulder CO USA

Overview

Background

Grounding the understanding from model simulations of long-term projected change in observations has been challenging. Precipitation is very noisy, satellite records of high-time frequency (daily or shorter) are too short for calculating trends, and gridded products based on stations are not designed for studying long-term changes or trends in the intensity distribution; changes in the observing network over time introduce biases to precipitation intensity at a grid point. The key question we address here is:

- Is the change in the shape of the precipitation distribution in CMIP6 models consistent with that in station observations?

Data

- To quantify present–day precipitation as we experience it, we analyze station precipitation from the Global Historical Climatology Network – Daily dataset (Menne et al., 2012), and gridded annual temperature anomaly from the NOAA GlobalTemp dataset (Huang et al., 2022).
- To quantify projected precipitation change, we analyze historical simulations of precipitation and temperature from one ensemble member of each of the 39 CMIP6 models (Brunner et al., 2020).

Metrics and their application to present-day

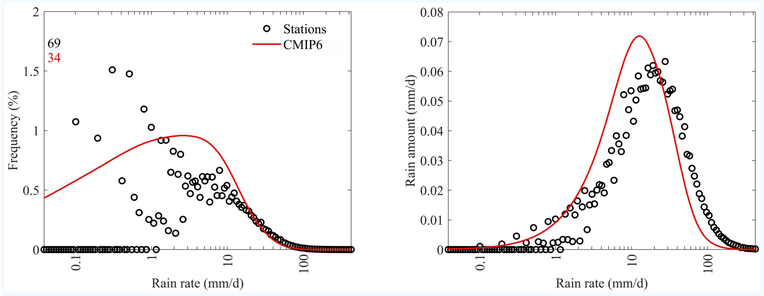
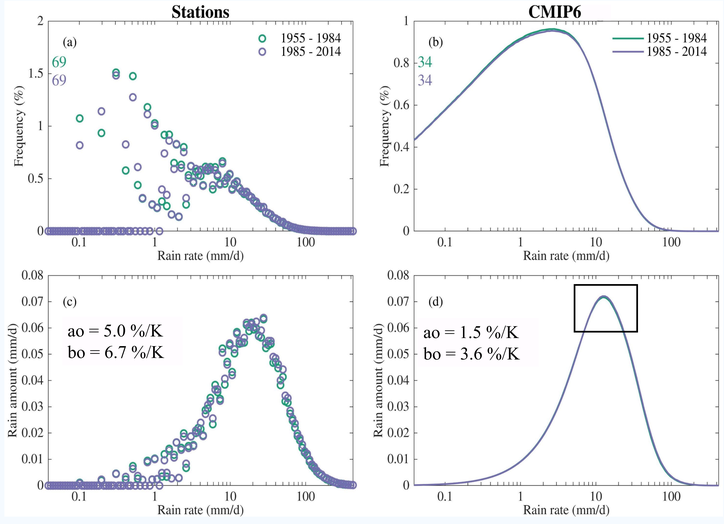


Figure 1. Precipitation frequency and amount distribution climatologies in the multi-model mean of CMIP6 models (red lines) and station observations (black dots) during the period of 1955 to 2014. Numbers in the left corner denote the dry day frequency.

- **In observations, the relative difference in average precipitation over the two periods (ao) is about 5.0 %/K, and the relative change in the daily precipitation accumulation at which half of the cumulative total precipitation occurs for each period (bo) is around 6.7 %/K.**
- **CMIP6 historical simulations can capture the shape of precipitation distribution but underestimate the magnitude of ao (1.5 %/K) and bo (3.6 %/K).**



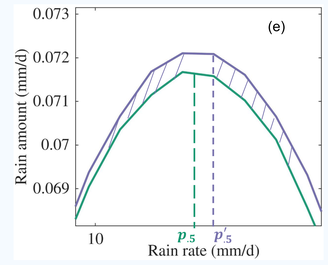
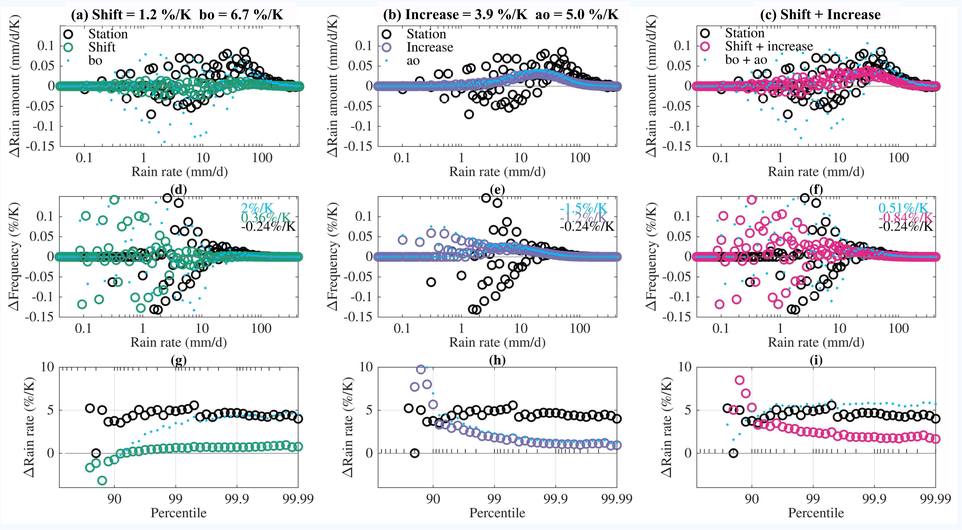


Figure 2. Precipitation frequency (a, b) and amount (c, d) distribution during 1955—1984 and 1985—2014 for station observations (a, c) and the multimodel mean of CMIP6 historical simulations (b, d). Schematic of the modes of change of precipitation distribution introduced in (e): ao is a first guess for the magnitude of the increase mode; bo is a first guess for the magnitude of the shift mode. The values of ao and bo in panel (d) denote the multimodel mean of the global average of ao and bo over the co-located grid points. The values of ao and bo in panel (c) are the global average of ao and bo in station observations.

Change in the shape of precipitation distribution



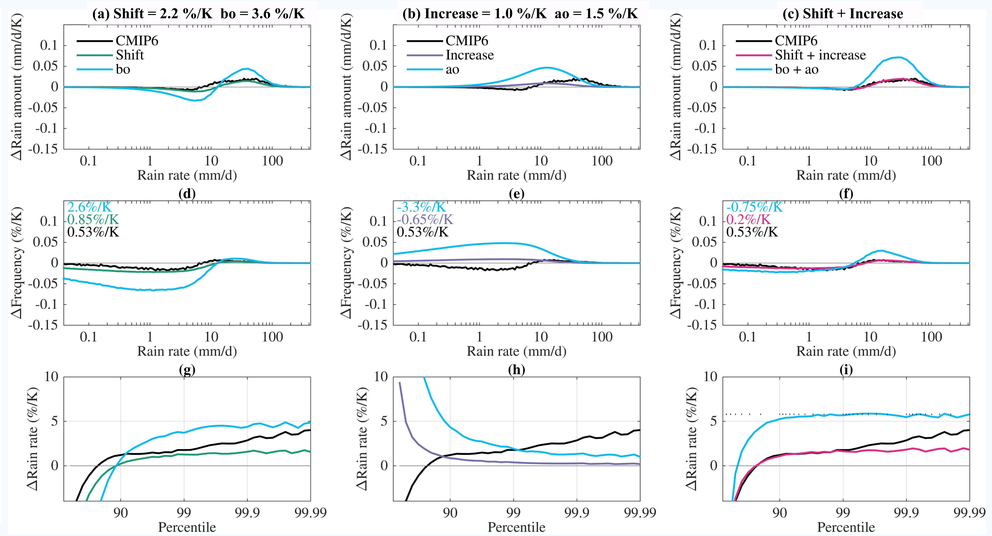


Figure 3. The change in precipitation amount (a, b, c), frequency (d, e, f) and extreme precipitation (g, h, i) in the station observations (black), and the changes resulting from an increase (purple and blue in panels (b, e, h)), a shift (green and blue in panels (a, d, g)) and a shift-plus-increase (pink and blue in panels (c, f, i)) in precipitation intensity. Numbers in panels (d, e, f) denote the changes of dry day frequency. See Pendergrass and Hartmann (2014a, b) for details.

- **The CMIP6 simulated change of the shape of precipitation distribution can be captured by two modes: an "increase mode" in which the amount of rain falling at every rain rate increases by about 1.0 %/K, and a "shift mode" in which the same amount of rain falls at a 2.2 %/K heavier rain rate.**
- **The shift-plus-increase mode roughly resembles the observed change in the distribution of precipitation amount.**

Figure 4. The same to Figure 3, but for CMIP6 multi-model mean.

Table 1. The average magnitude of shift and increase modes and the first guesses of the shift (bo) and increase (ao) computed across stations and at the co-located grid cells across CMIP6 models.

	Shift	Increase	bo	ao
Stations	1.2 %/K	3.9 %/K	**6.7 %/K**	**5.0 %/K**
CMIP6	**2.2 %/K**	**1.0 %/K**	**3.6 %/K**	**1.5 %/K**

References:
Huang et al., 2022, *Artificial Intelligence for the Earth Systems;* Menne et al., 2012, *J. Atmos. Oceanic Technol;* Brunner et al., 2020, The ETH Zurich CMIP6 next generation archive; Pendergrass and Hartmann, 2014 a,b, *J. Clim.*

Preliminary results

- **The change in** the shape of **precipitation distribution in** multimodel mean of **CMIP6** historical simulations **resembles the observed change in stations for heavy rain rates**.
- The observed and simulated **change in the precipitation amount distribution can be roughly captured by the shift and increase modes**.
- The multimodel mean of **CMIP6 models underestimates** the magnitude of **the increase in precipitation distribution**.

Funding acknowledgement:
NOAA COM NA23OAR4310441