Precipitation variability increases in a warmer climate

Angeline G. Pendergrass[1], *R. Knutti[1,2], F. Lehner[1], C. Deser[1], B.M. Sanderson[1]*

1: National Center for Atmospheric Research, Boulder CO USA; 2: ETH-Zurich, CH

catalyst

Cooperative **a**greement **t**o **a**nalyze variability, change and predictab**il**ity in the earth s**yst**em

Overview

Background

Precipitation variability connects mean and extreme precipitation. Despite that both mean and extreme precipitation increase in a warming climate, precipitation variability has not been studied as extensively as the changes in mean and extremes.

Approach

We diagnose the change in precipitation variability in the CMIP5 multi-model ensemble, supplemented with single-model ensembles and daily station observations.

Does precipitation variability increase with warming?

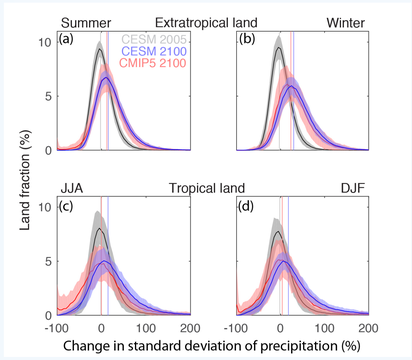


Figure 1. Spatially aggregated precipitation variability change. Land area fraction experiencing a given change in the standard deviation of seasonal mean precipitation over extra-tropical land in (a) summer and (b) winter, and tropical land in (c) JJA and (d) DJF at individual grid points from 1976-2005 to 2071-2100 forced by the RCP8.5 scenario, and changes expected from natural variability sampled as differences between randomly-drawn members of the CESM1 single-model ensemble for 1976-2005 (grey shading). Shading indicates the 5-95% confidence interval. Vertical lines indicate the median of each distribution.

Mean, variability, and extremes: spatial pattern

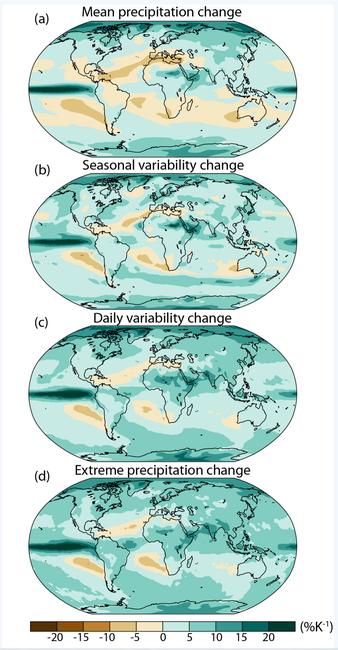
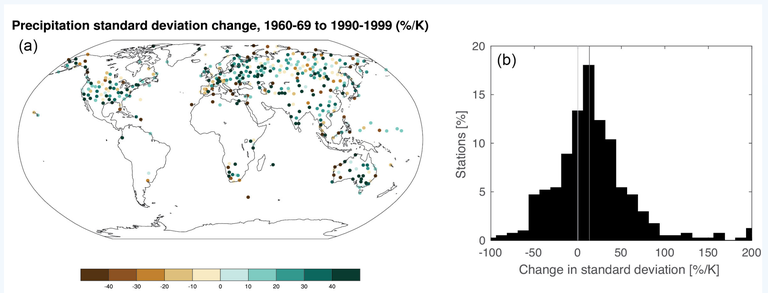


Figure 2. Spatial patterns of change in mean, variability and extreme precipitation. Change in precipitation (a) mean, (b) seasonal standard deviation, (c) daily standard deviation, and (d) daily maximum for the CMIP5 multi-model mean in 2071-2100 relative to 1976-2005 normalized by the change in global mean surface air temperature.

Observations



Firgure 5. Observed daily precipitation variability change. Change in the standard deviation of daily precipitation from 1960-1969 to 1990-1999 per degree global mean surface temperature change, (a) at station locations and (b) aggregated as a histogram. Dark gray line in (b) is the median change across stations.

How much does precipitation variability change?

Hypothesis 1
Precipitation standard deviation change could follow mean precipitation change (Rind et al 1989)

$$\overline{p_2} = a\overline{p_1} \qquad \sigma_2 = a\sigma_1$$

Change in variability of ~2 %K^{-1}

Hypothesis 2
Precipitation standard deviation change could respond to moisture change (Raisanen 2002)

$$r \sim wq$$

Change in variability of ~6 %K^{-1}, less circulation change

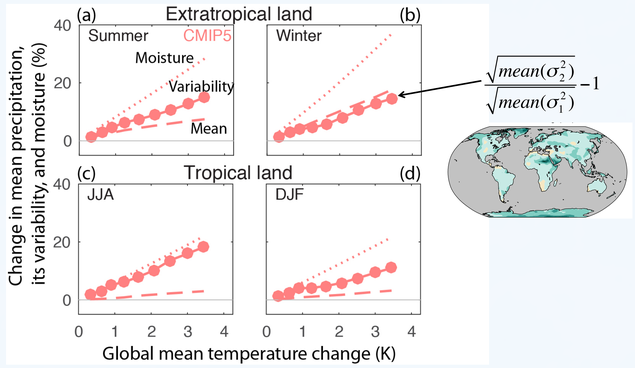


Figure 3. Rate of change of variability with warming. Change in seasonal mean, standard deviation, and moisture averaged over extra-tropical land in (a) summer and (b) winter, and tropical land in (c) JJA and (d) DJF as a function of global-mean surface temperature for the CMIP5 multi-model mean. Each marker indicates a 30-year period centered on consecutive decades between 2006 and 2086 relative to the 1976-2005 base period.

Variability across timescales

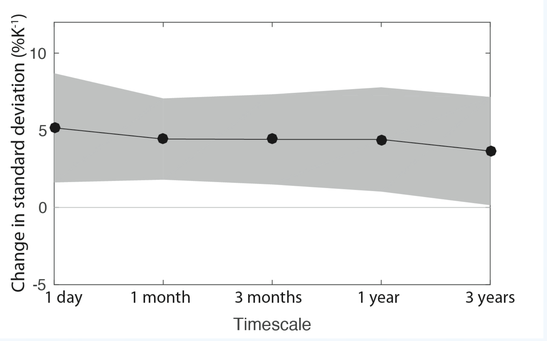


Figure 4. Precipitation variability change by timescale. The change in standard deviation of precipitation averaged over all land grid points divided by the change in global-mean surface air temperature in 2071-2100 relative to 1976-2005 in the CMIP5 multi-model mean for time scales ranging from 1 day to 3 years (note that the value at 3 years represents the change in 2050-2100 relative to 1955-2005; see text for details). Gray envelope denotes the 95% confidence interval according to a two-tailed student's *t*-test.

Conclusions

- Precipitation variability increases over most land areas, consistent with the expectation from increases in mean and extreme precipitation.
- The rate that precipitation variability increases is at least as high as mean precipitation and no higher than the rate of moistening.
- The rate of increase of variability is similar across timescales from daily to decadal.
- Observed variability of daily precipitation increased at most stations than in the last half of the 20th century.

U.S. DEPARTMENT OF ENERGY | Office of Science

Pendergrass, A.G., Reto Knutti, Flavio Lehner, Clara Deser, and Benjamin M. Sanderson, 2017: Precipitation variability increases in a warmer climate. *Scientific Reports*, doi:10.1038/s41598-017-17966-y.

NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH