The resolution dependence of US precipitation extremes in response to CO_2 forcing

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Motivation and methods

Extreme precipitation events may have widespread negative impacts on societies and ecosystems around the world. It is therefore important to provide reliable projections of how these extreme events may change in response to global warming.

In this study, we test the impact of horizontal atmospheric resolution in a global coupled model framework on:

1. the quality of simulated precipitation extremes,
2. changes in precipitation extremes in response to CO_2 forcing.

A family of global coupled models has been developed at GFDL with the same physical parameterizations. The models differ only in horizontal atmospheric resolution (below) and all use the same 100 km ocean model.

LOAR	**200 km**	(C48)
FLOR	**50 km**	(C180)
HiFLOR	**25 km**	(C396)

Quality of simulated extreme precipitation

There is a systematic improvement of the spatial pattern of simulated extreme precipitation (Fig. 1). If compared at similar horizontal grids, there is a consequent reduction of model bias and RMSE, and a consequent improvement of pattern correlation with increasing atmospheric resolution.

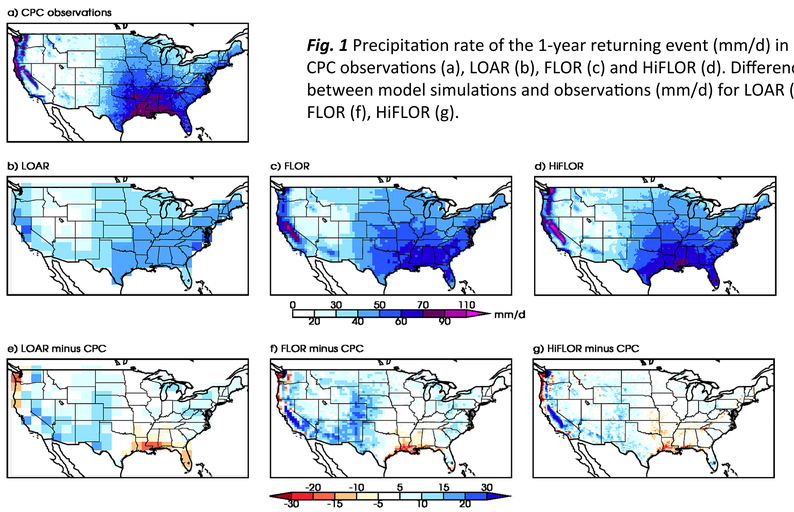

Fig. 1 Precipitation rate of the 1-year returning event (mm/d) in CPC observations (a), LOAR (b), FLOR (c) and HiFLOR (d). Differences between model simulations and observations (mm/d) for LOAR (e), FLOR (f), HiFLOR (g).

The seasonality of extreme precipitation events improves significantly with increasing atmospheric resolution (Fig 2).

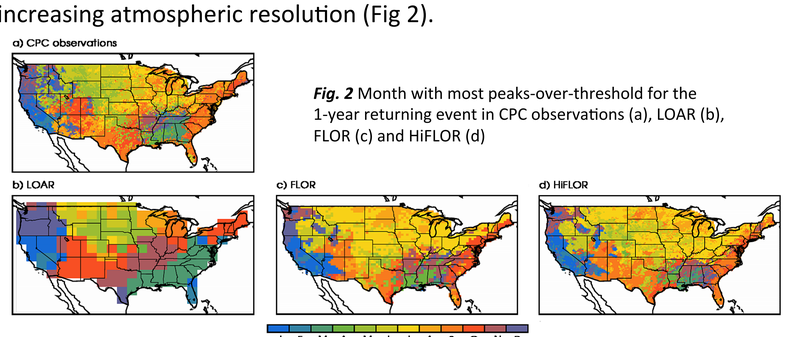

Fig. 2 Month with most peaks-over-threshold for the 1-year returning event in CPC observations (a), LOAR (b), FLOR (c) and HiFLOR (d)

Changes in 2×CO_2

All models simulate an increased precipitation rate associated with the 1-year returning event in response to 2×CO_2 forcing (Fig. 3a-c). The US mean increase is about 3-4 %/K surface warming.

However, regional patterns of change are different between the models and these differences are larger if seasonal extreme events are taken into account (Fig. 3d-o).

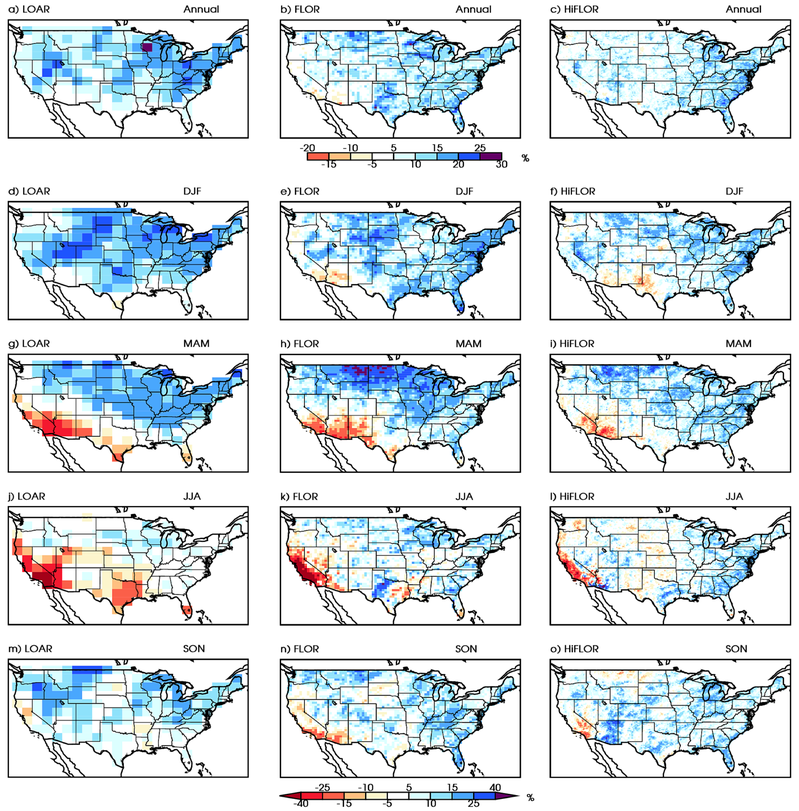

Fig. 3 Relative increase of the precipitation rate of the 1-year returning event in a 2×CO_2 climate (2×CO_2 -CTRL)/CTRL) for LOAR (left column, a,d,g,j,m), FLOR (middle column, b,e,h,k,n) and HiFLOR (right column, c,f,i,l,o). Time periods shown: annual (a,b,c), DJF (d,e,f), MAM (g,h,i), JJA (j,k,l) and SON (m,n,o).

Trends in the observed record

The observed record shows trends in the number of extreme precipitation events (Fig. 4a). These trends are not reproduced in an ensemble of historical simulations with the models due to large internal variability.

In 1978 a climatic shift is observed (Fig. 4b). Besides climate change, this could have been caused by the shift in the Pacific decadal oscillation or changes in observational methods in the 1980s.

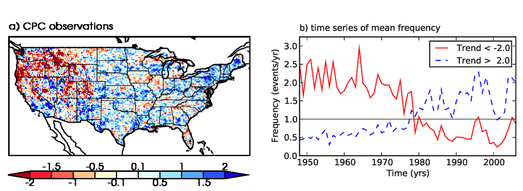

Fig. 4 (a) Observed trend of the number of peaks-over-threshold of the 1-year returning event of daily precipitation. (b) Time series of event frequency for all grid points with trends exceeding ±2.0 events/yr/100yrs.

Conclusions

Increased horizontal atmospheric resolution in a global coupled model improves the quality of simulated precipitation, including:

- patterns of mean precipitation,
- patterns of extreme precipitation (Fig. 1),
- intensity of extreme precipitation,
- seasonality of extreme precipitation (Fig. 2).

Annual US precipitation extremes are expected to increase in intensity in response to CO_2 forcing (Fig. 3a-c). However, regional patterns of modeled change depend on model resolution.

For example, the increase found in FLOR and HiFLOR along the South Atlantic coast during the hurricane season is not found in LOAR (Fig. 3j-o). Note that FLOR and HiFLOR are tropical cyclone permitting models and have the correct seasonality in the region (Fig. 2).

Despite the fact there are significant trends in the number of extreme precipitation events in the observed record (Fig. 4), no evidence was found in historical model simulations that these trends can be attributed to climate change. This is in large part due to large internal variability in the climate system.

Recommendations

→ For any study of climate change, carefully consider the minimum required model resolution for the specific research topic of interest.

→ The models show an increase of precipitation extremes in response to CO_2 forcing and suggest the observed record is too short to identify whether such changes have already occurred in the natural environment. Both aspects are of interest to decision makers.

→ The coincidence of the observed changes with changes in observational methods show the need for a systematic evaluation of the impact of changes in the observing system on estimates of trends in the record.

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