Evolution of Future Extreme Drought Frequency in Two Climate Model Large Ensembles

Cha Zhao[1] François Brissette[1] Jie Chen[2] Jean-Luc Martel[1,3]
[1]École de technologie supérieure | [2]Wuhan University | [3]LaSalle | NHC

Introduction

Recent studies project a significant increase in drought frequency over most continents over the 21st century. Droughts have often been regarded as the most severe natural disaster because other catastrophes, such as floods, are typically restricted to relatively localized areas and over a well-defined time interval.

Understanding the evolution of future droughts in a changing climate is of great economic importance in terms of the capacity to implement efficient adaptation measures. However, few studies have specifically looked at extreme droughts, defined here as having a return period larger than 20 years.

Data and Methodology

The following data were required to complete the research:

- Observed monthly precipitation and temperature
- Global gridded temperature and precipitation (CanESM2 and CESM1)
- Modelled temperature and precipitation over the 5797 North American watersheds

Meteorological droughts were assessed by 1-month Standardized Precipitation Index (SPI) calculated by monthly precipitation data.

Hydrological droughts were assessed by 1-month Standardized Drought Index (SDI) calculated by monthly streamflow data.

Climate model outputs were first bias-corrected (daily bias correction method, DBC) before feeding to the hydrological model (GR4J-CemaNeige-Oudin).

The following equation was used for calculating the return periods:

$$T = \frac{N + 0.2}{m - 0.4} \tag{1}$$

Global Droughts

Both ensembles display similar spatial patterns for all three return periods. Increases in drought frequency are particularly noticeable for the SH. Patterns are similar for all three return periods, but changes in drought frequency become more severe for larger return periods.

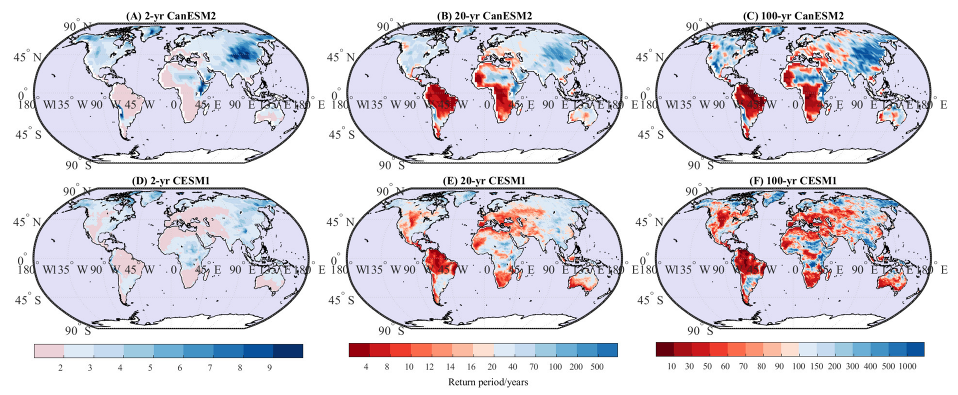

Figure 1: Change in the mean annual 1-month meteorological drought frequency in the far future (2070-2099) reference period (1980-2009)

Compared to the annual scale, the patterns are more severe for all regions and particularly so for the NH. CESM1 predicts more significant changes in extreme meteorological droughts. The amplitude of changes gets larger for the larger return period.

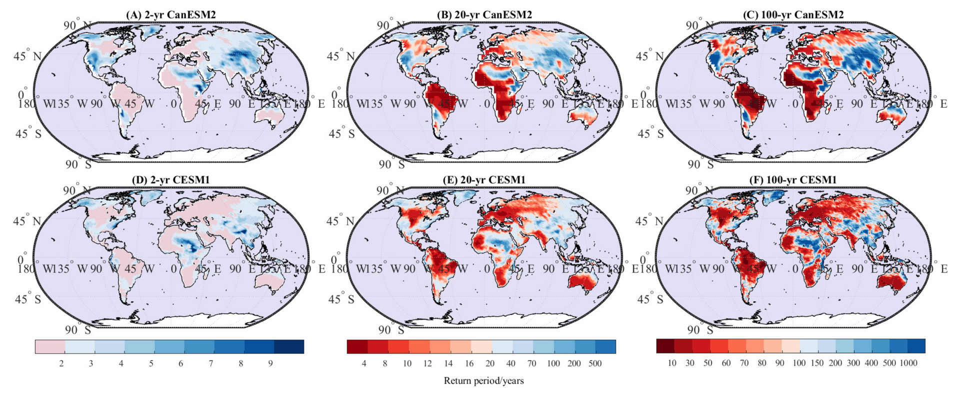

Figure 2: Same as Figure 1, but for the mean JJA 1-month SPI drought frequency

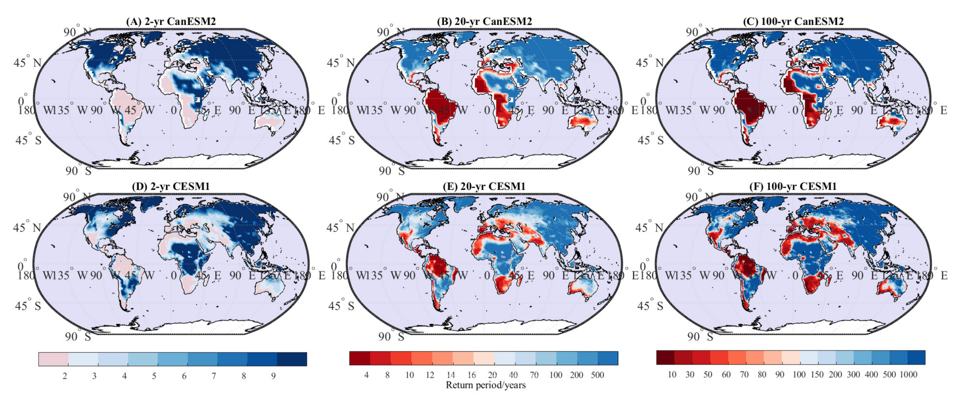

Figure 3: Same as Figure 1, but for the mean annual 24-month SPI drought frequency

A much smaller percentage of land areas is affected by a worsening of droughts, compared to short-term droughts. North America, with the exception of Southwestern USA, and most of Asia are predicted to see a decrease in the frequency of long-term meteorological droughts.

North American Droughts

Moderate and extreme meteorological droughts head in the same direction for each climate model. There are obvious differences between the two climate models in both the direction and magnitude of the changes.

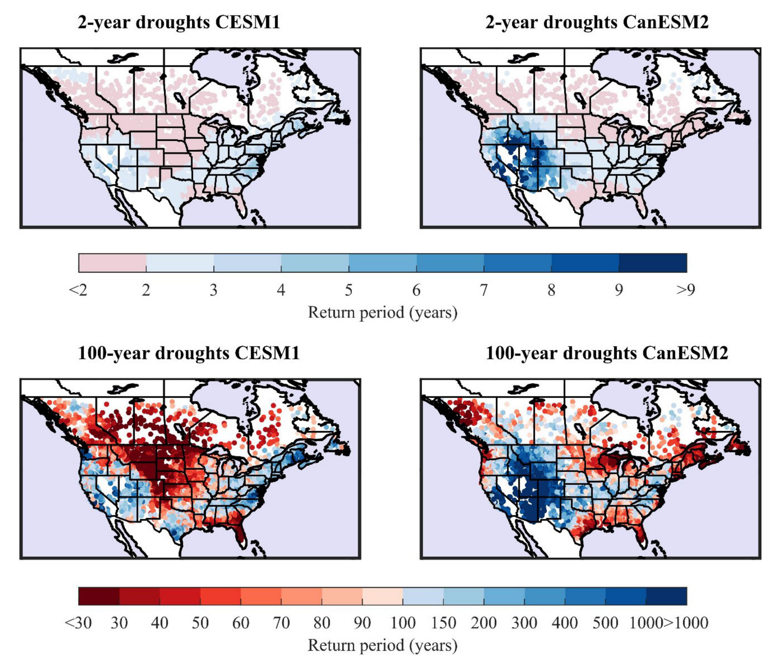

Figure 4: Change in the mean summer 1-month meteorological drought frequency in the far future (2070-2099) reference period (1980-2009)

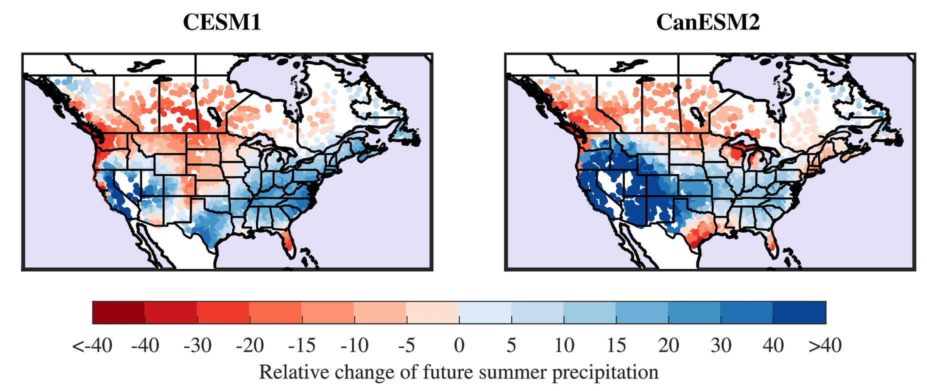

Figure 5: Change in the mean summer 1-month meteorological drought frequency in the far future (2070-2099) reference period (1980-2009)

A strong correlation between changes in extreme summer meteorological droughts frequency and relative changes in mean total summer precipitation. Changes in future summer precipitation explain most of the differences in the observed meteorological drought patterns.

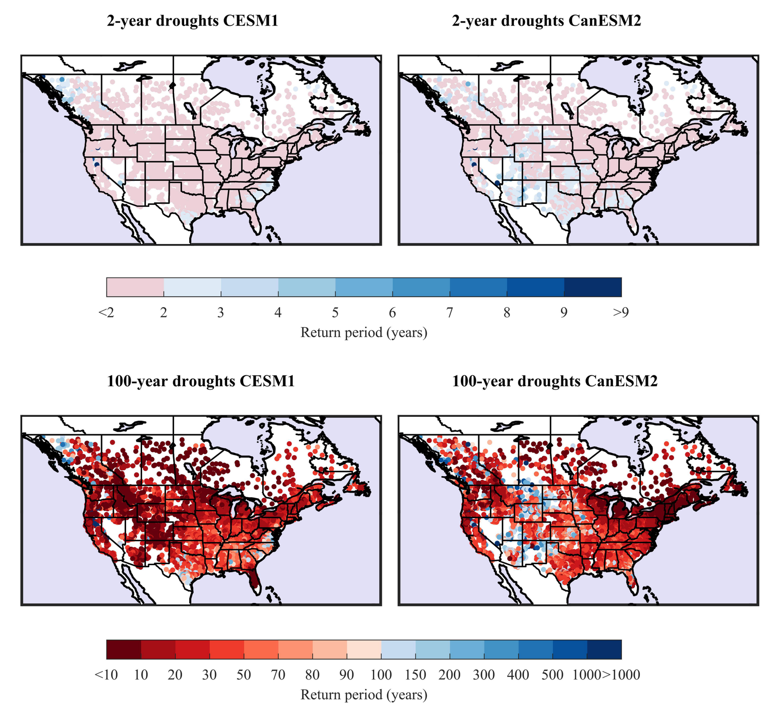

Figure 6: Same as Figure 4, but for 1-month summer hydrological droughts

Both models show large increases of frequency in hydrological droughts over almost all North American watersheds. The situation gets worse at the larger return periods. The increase frequency of future extreme hydrological droughts is clearly larger than that of for future meteorological droughts.

Conclusion

- Both ensembles do a good job at replicating spatial patterns and magnitude of precipitation and temperature and internal variability over the reference period.
- Projected increases in future extreme drought frequency are mostly consistent across both ensembles, although with regional differences.
- Hydrological drought conditions are much worse than meteorological droughts over North America. Projected changes get consitently worse for the longer considered return periods.

References

1. Cook BI, Smerdon JE, Seager R, Coats S (2014) Global warming and 21 st century drying Climate Dynamics 43:2607-2627 doi:https://doi.org/10.1007/s00382-014-2075-y
2. Dai A (2011) Drought under global warming: a review Wiley Interdisciplinary Reviews: Climate Change 2:45-65
3. Sheffield J, Wood EF (2008) Projected changes in drought occurrence under future global warming from multi-model, multi-scenario, IPCC AR4 simulations Climate dynamics 31:79-105