

Future Changes of Extremes from Global Coupled Climate Models

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Question V subtopics:

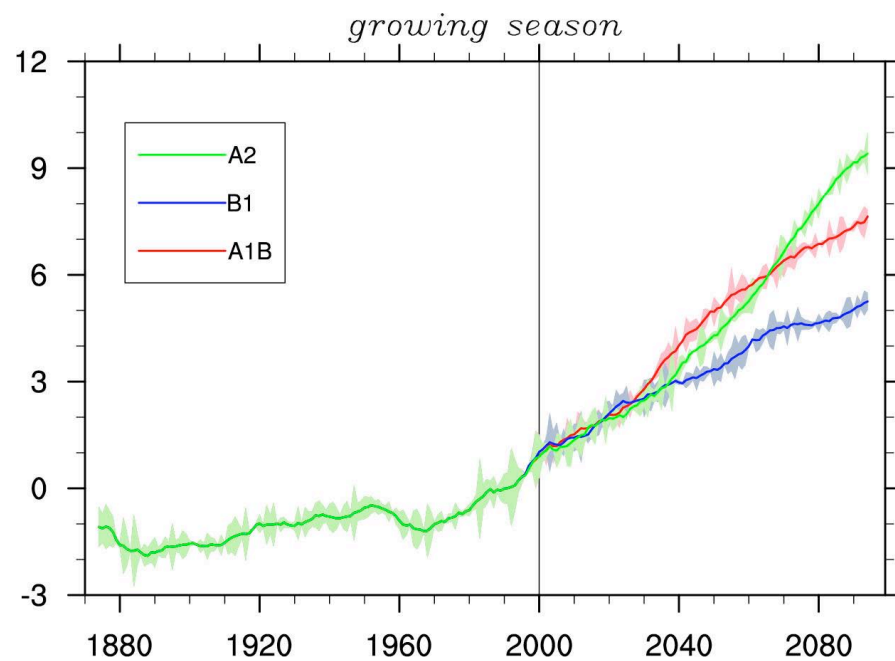
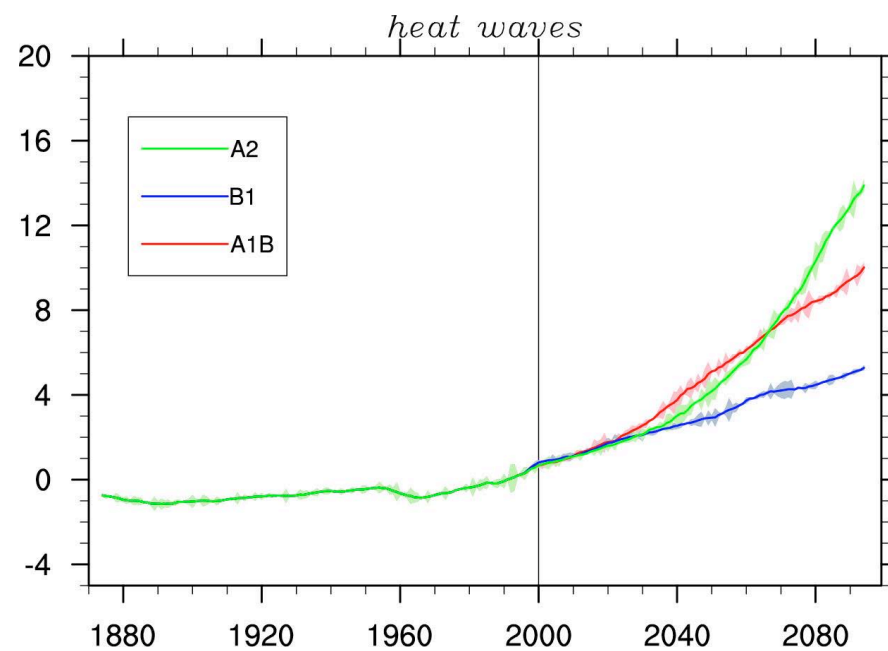
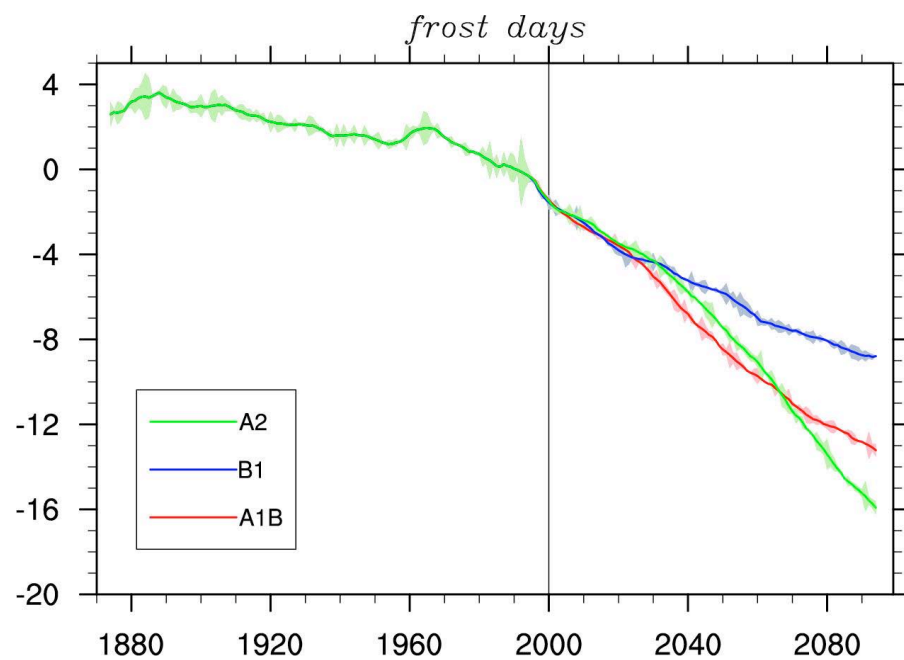
- 1) What do models say about future changes?
- 2) How do models simulate extremes already observed and how does this affect our confidence in extremes?

Frich et al. extremes indices for temperature

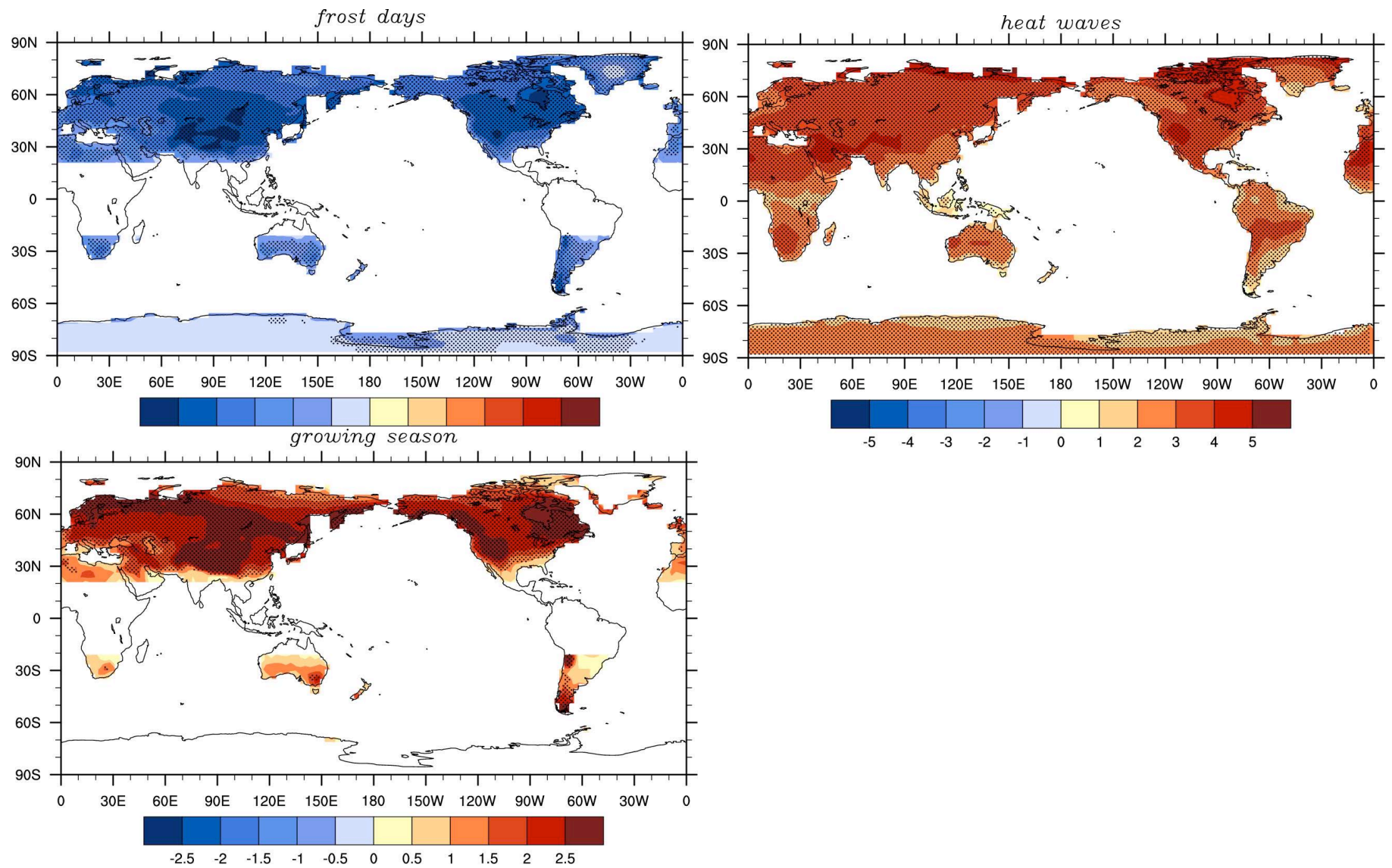
- Total number of **frost days**, defined as the annual total number of days with absolute minimum temperature below 0_C
- Intra-annual **extreme temperature range**, defined as the difference between the highest temperature of the year and the lowest
- **Growing season length**, defined as the length of the period between the first spell of five consecutive days with mean temperature above 5_C and the last such spell of the year
- **Heat wave** duration index, defined as the maximum period of at least 5 consecutive days with maximum temperature higher by at least 5_C than the climatological norm for the same calendar day
- **Warm nights**, defined as the percentage of times in the year when minimum temperature is above the 90th percentile of the climatological distribution for that calendar day

Frich et al. extremes indices for precipitation

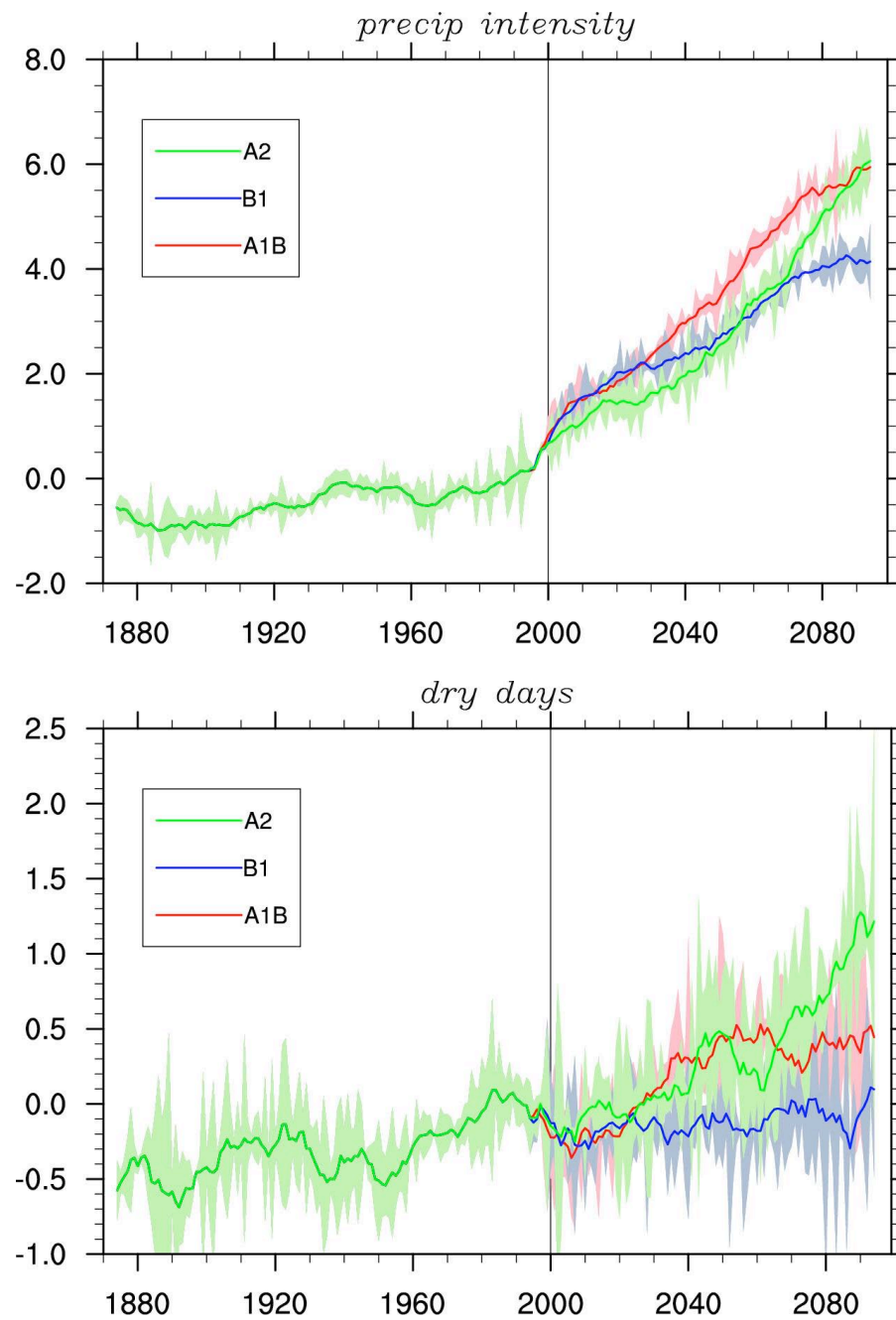
- Number of days with precipitation greater than 10 mm
- Maximum number of consecutive dry days
- Maximum 5-day precipitation total
- Simple daily intensity index, defined as the annual total precipitation divided by the number of wet days
- Fraction of total precipitation due to events exceeding the 95th percentile of the climatological distribution for wet day amounts



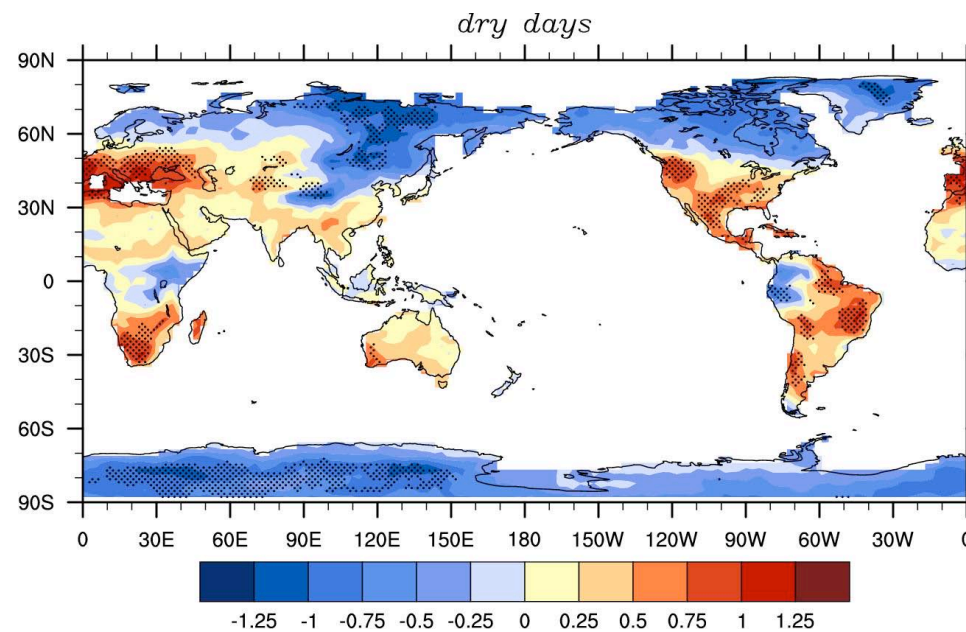
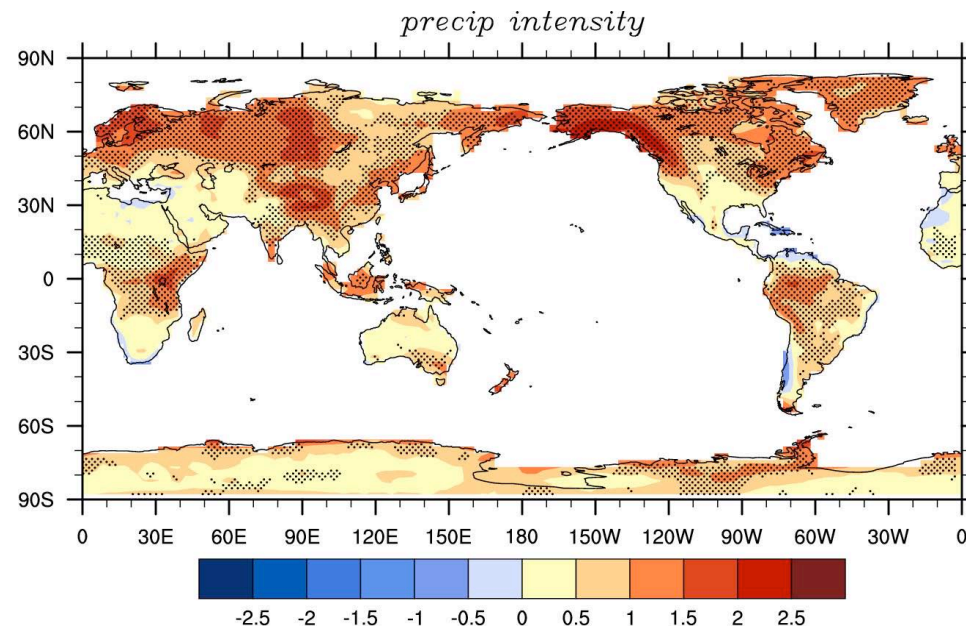
(Tebaldi et al., 2005; from 8 AOGCMs)



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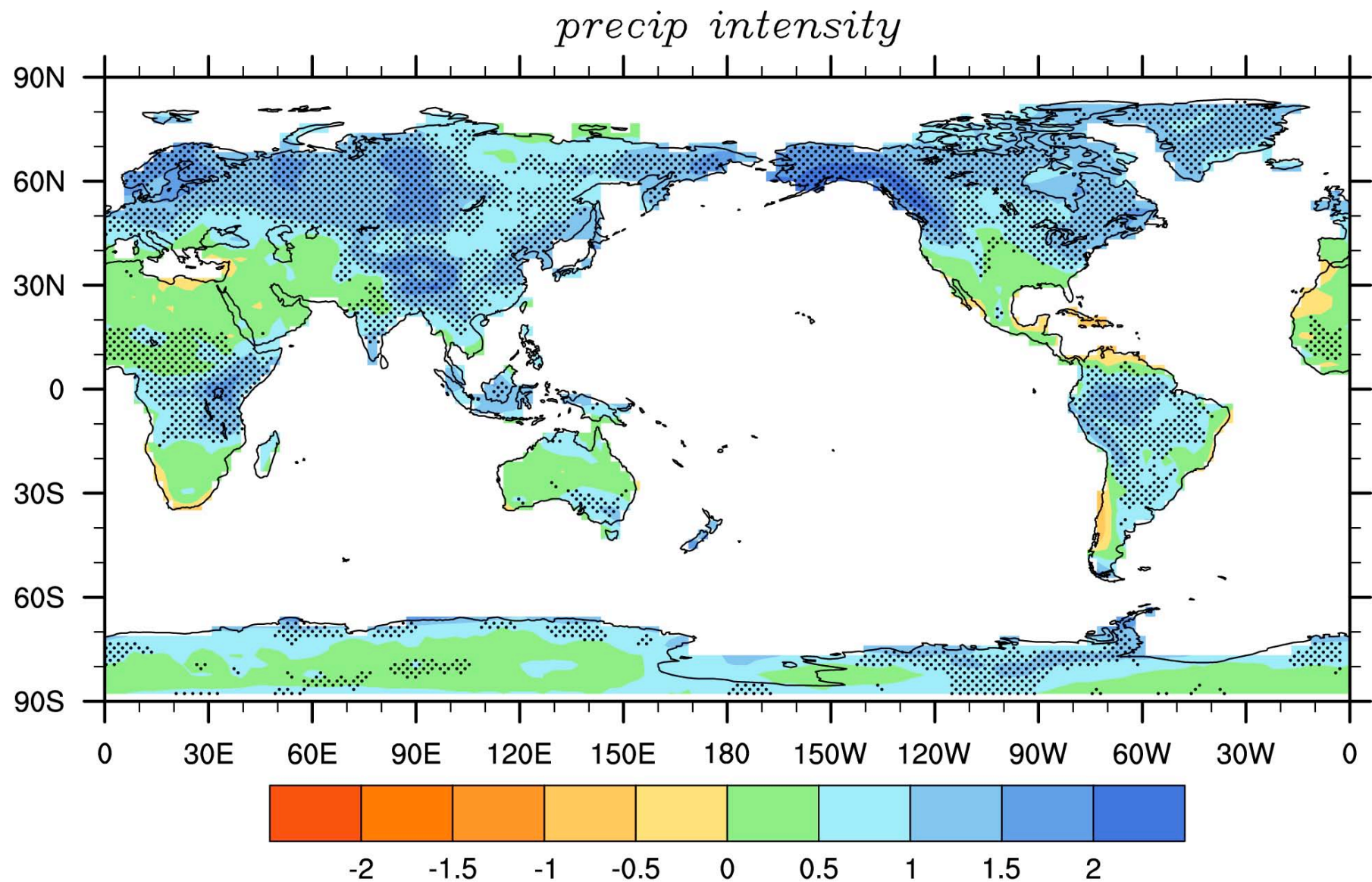


Fig. 1: The 8 member multi-model ensemble mean *precip intensity* difference from Tebaldi et al (2005) for A1B, 2080-2099 minus 1980-1999.

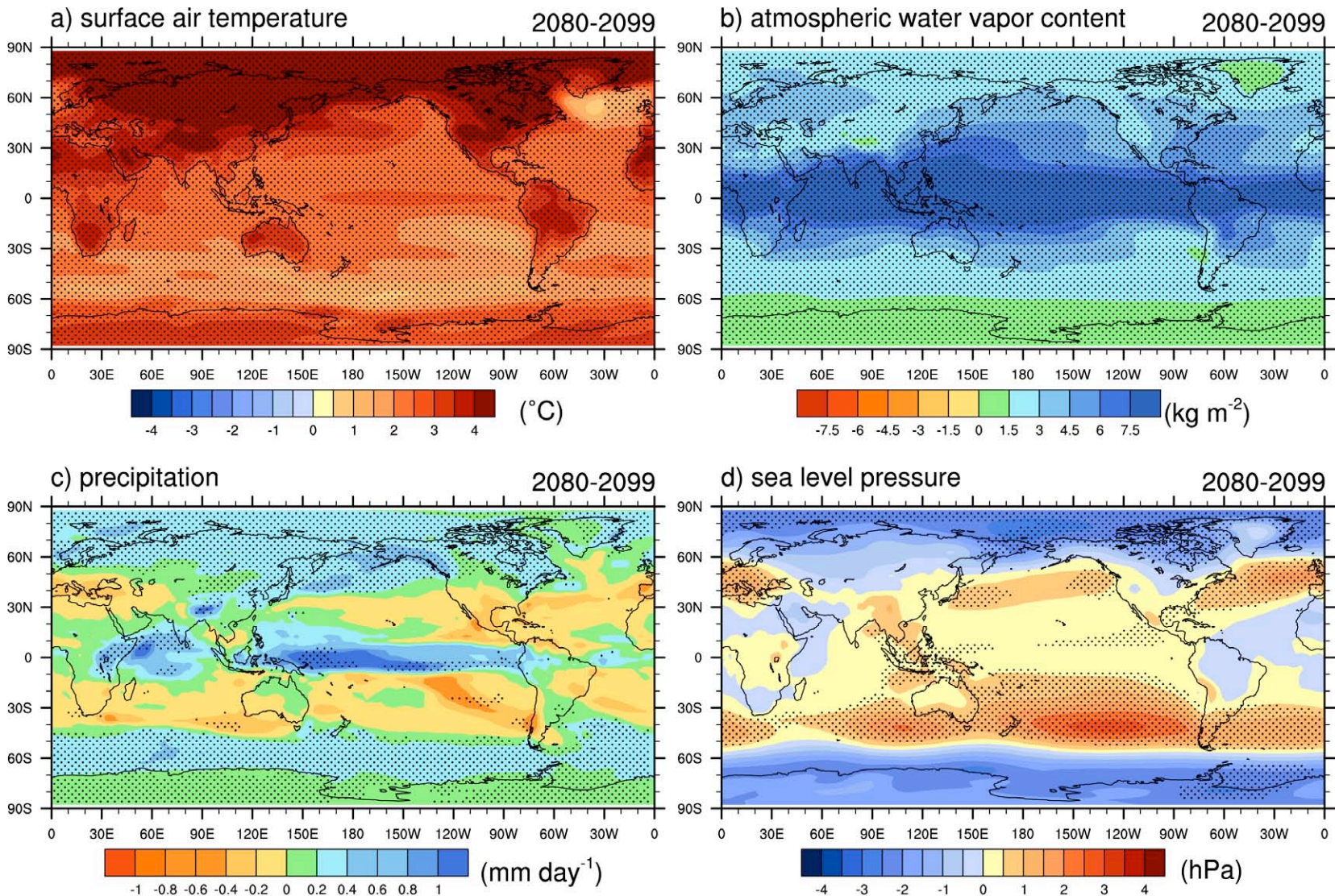
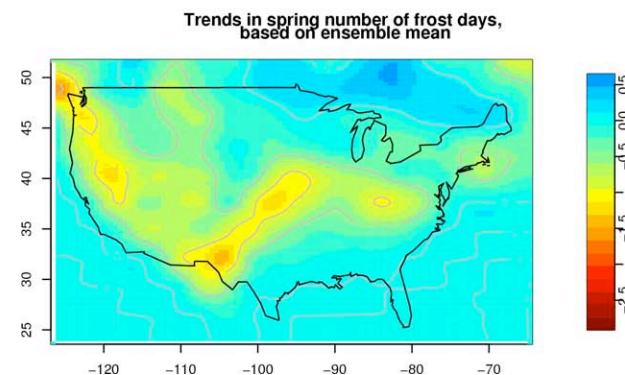
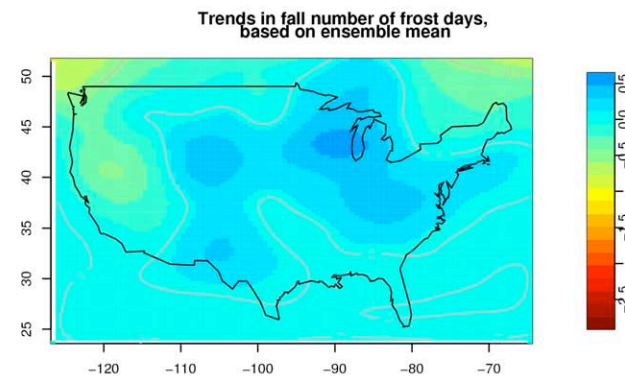
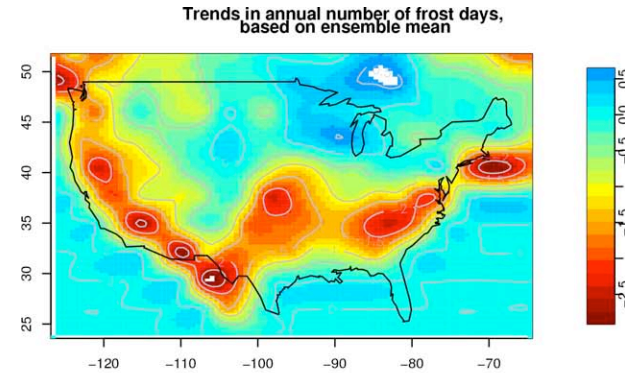
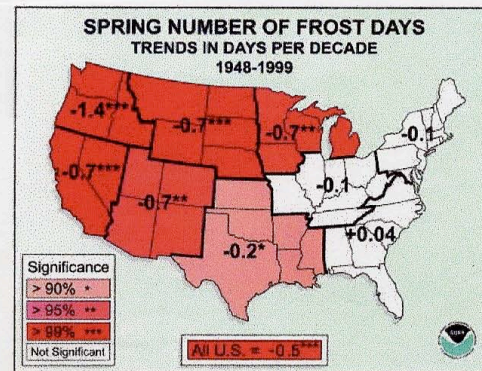
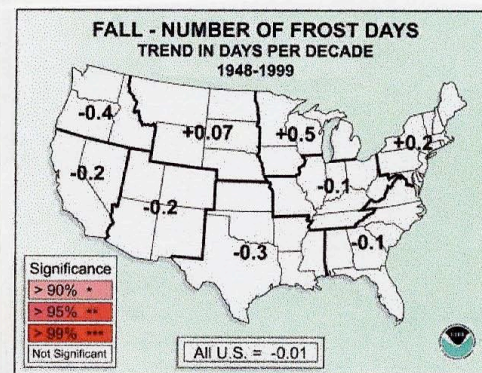
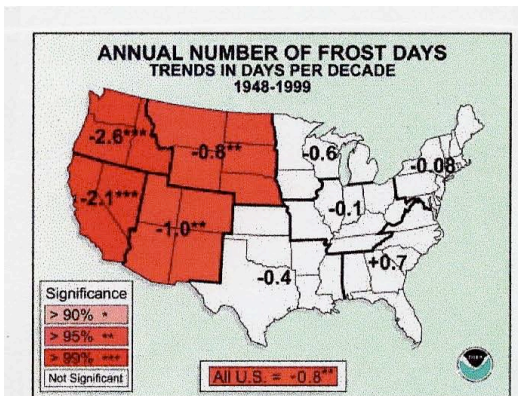
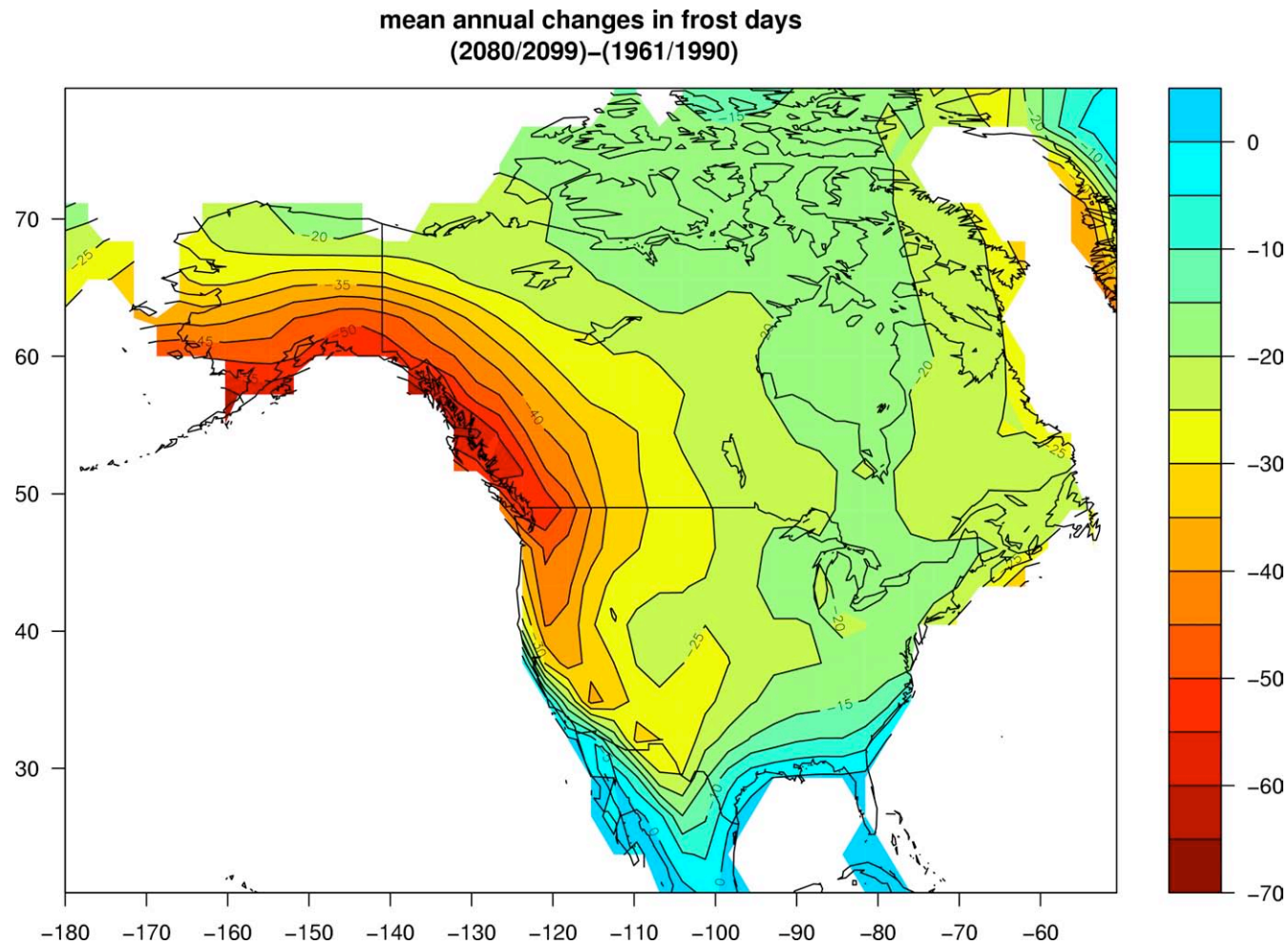


Fig. 2: a) annual mean surface temperature differences ($^{\circ}\text{C}$), 2080-2099 minus 1980-1999, for A1B from the 8 member multi-model ensemble; b) same as (a) except for vertically integrated water vapor differences (kg m^{-2}); c) same as (a) except for precipitation differences (mm day^{-1}); d) same as (a) except for SLP differences (hPa). Dotted regions correspond to areas where the multi-model mean divided by the multi-model standard deviation is greater than 1 (Meehl et al., 2005, GRL, submitted)

Changes in frost days in the late 20th century show biggest decreases over the western and southwestern U.S. in observations and the model

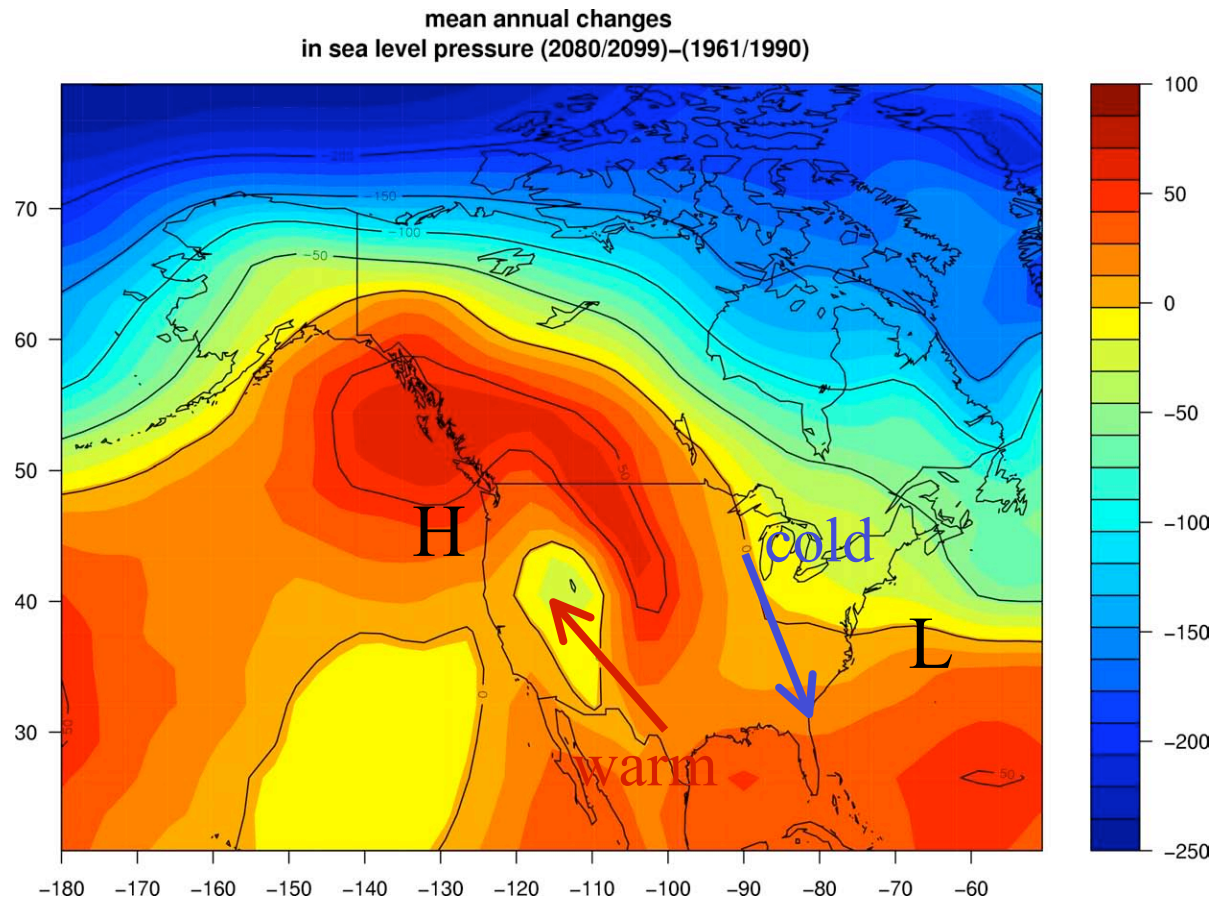


Future changes in frost days from the climate model
show greatest decreases in the western and
southwestern U.S., similar to late 20th century



Large-scale changes in atmospheric circulation affect regional pattern of changes in future frost days

Anomalous ridge of high pressure brings warmer air to northwestern U.S. causing relatively less frost days compared to the northeastern U.S. where an anomalous trough brings colder air from north



(Meehl, Tebaldi and Nychka, 2004: Changes in frost days in simulations of twentyfirst century climate, *Climate Dynamics*, 23, 495--511)

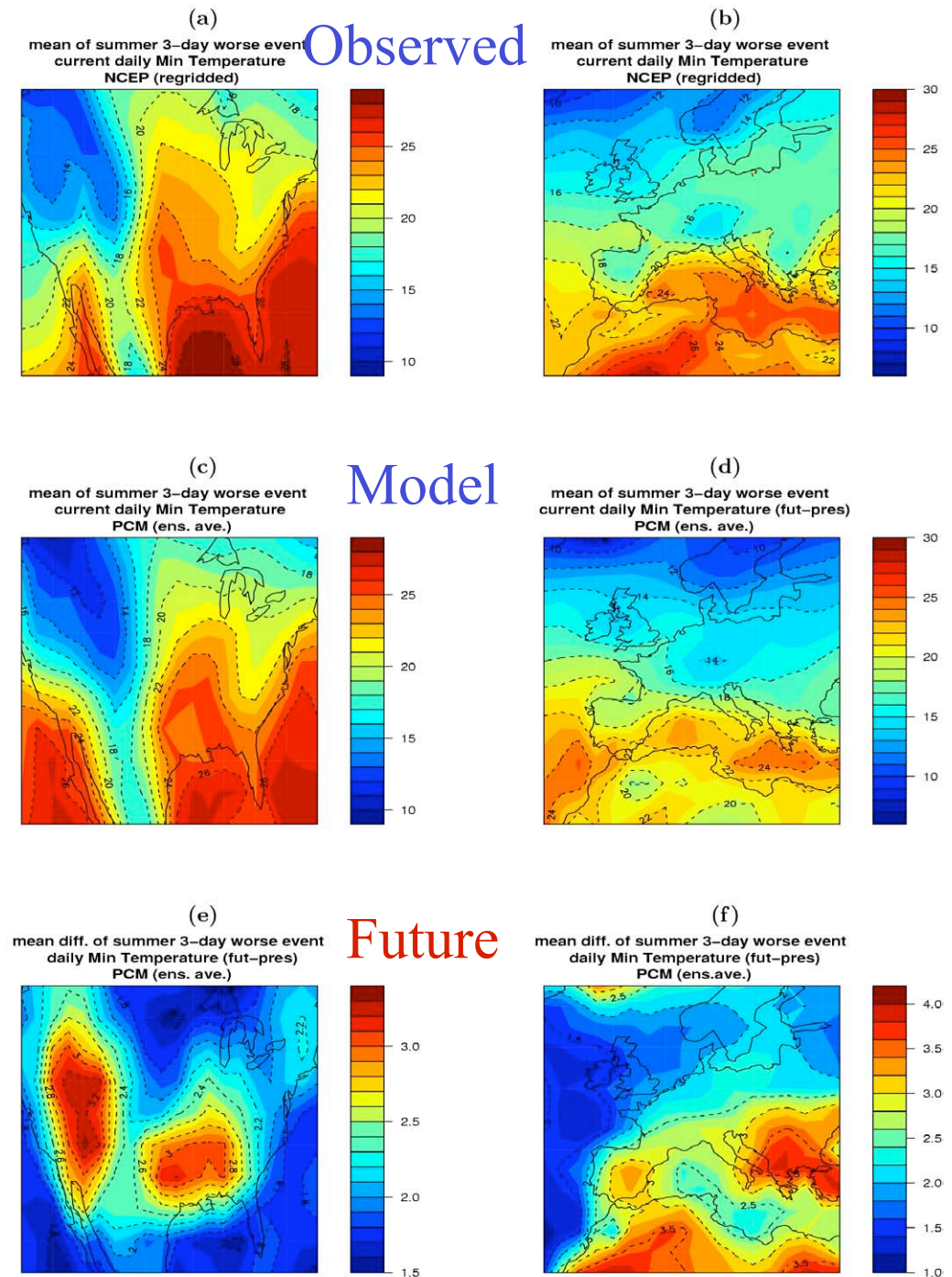
Climate models can be used to provide information on changes in extreme events such as heat waves

Heat wave severity defined as the mean annual 3-day warmest nighttime minima event

Model compares favorably with present-day heat wave severity

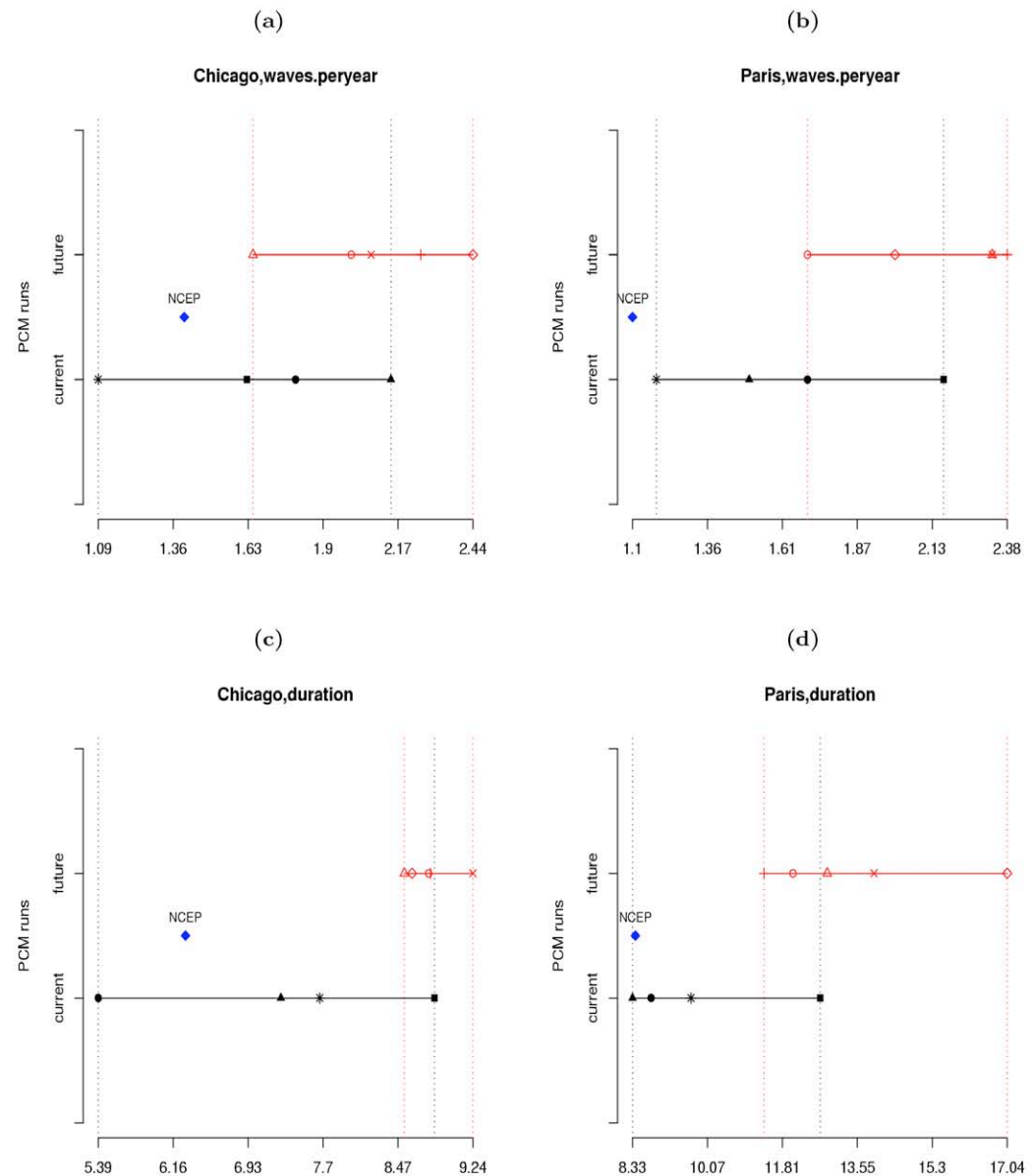
In a future warmer climate, heat waves become more severe in southern and western North America, and in the western European and Mediterranean region

Meehl, G.A., and C. Tebaldi, 2004: More intense, more frequent and longer lasting heat waves in the 21st century. *Science*, **305**, 994--997.

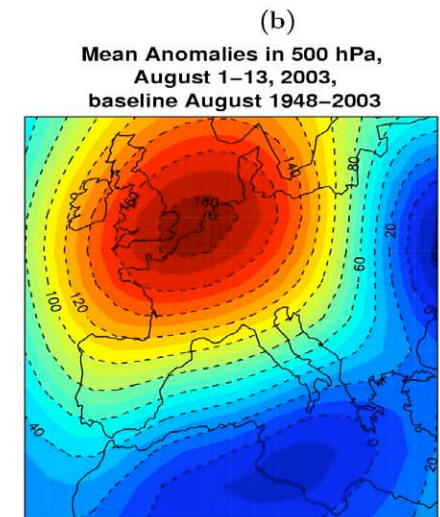
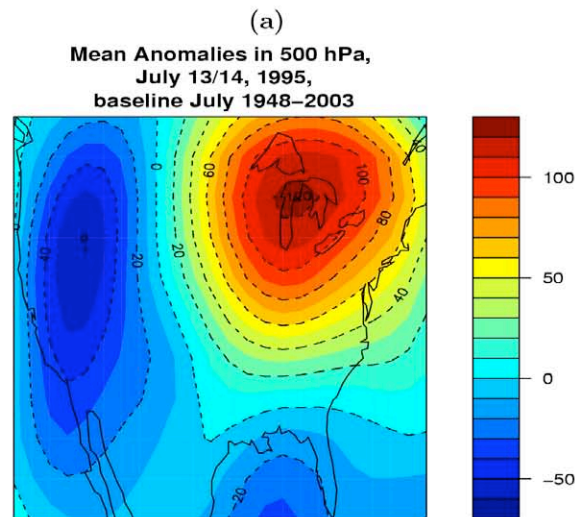


Climate model shows an increase in the average number of heat waves per year in the future (top) and an increase in heat wave duration (bottom)

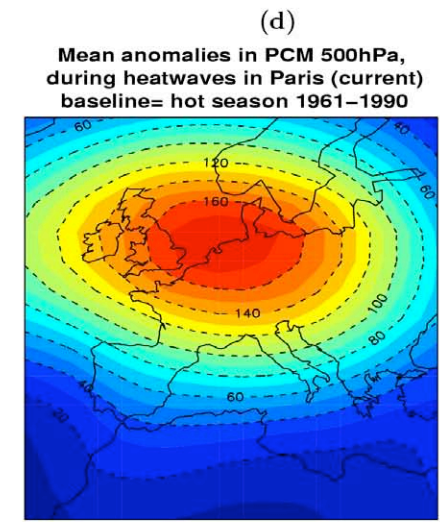
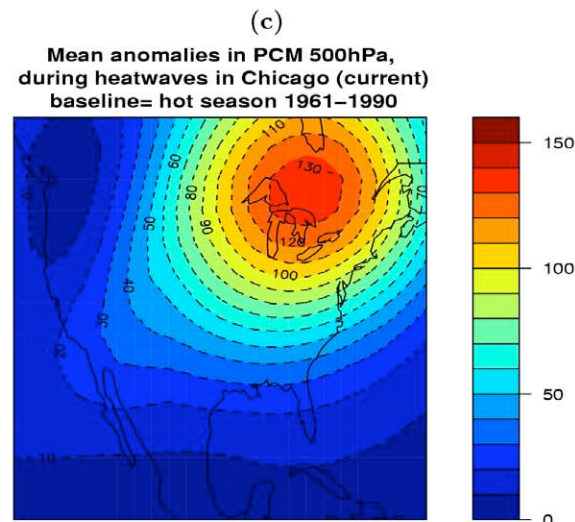
(model grid points near Chicago and Paris)



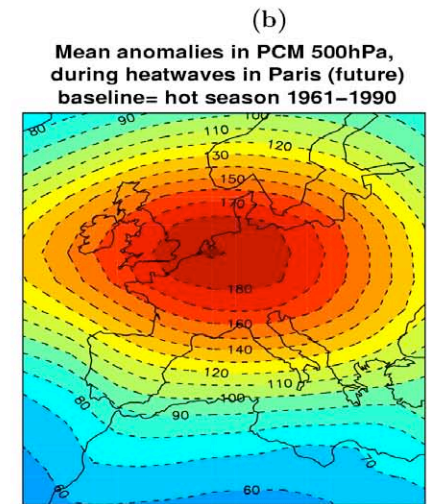
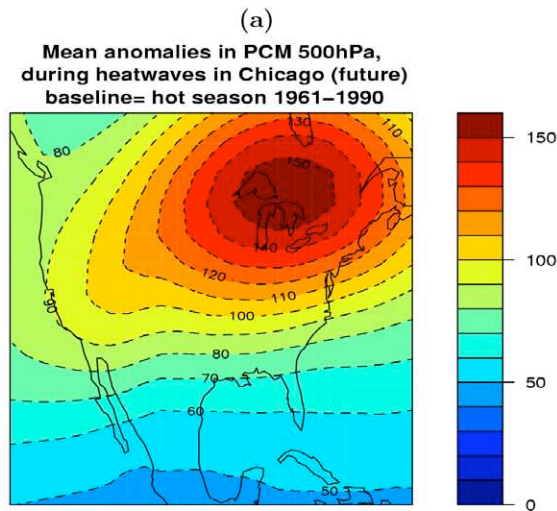
The Chicago (1995) and Paris (2003) heat waves show large positive 500 hPa height anomalies



For present-day heat waves near Chicago and Paris, the climate model also simulates large positive 500 hPa height anomalies

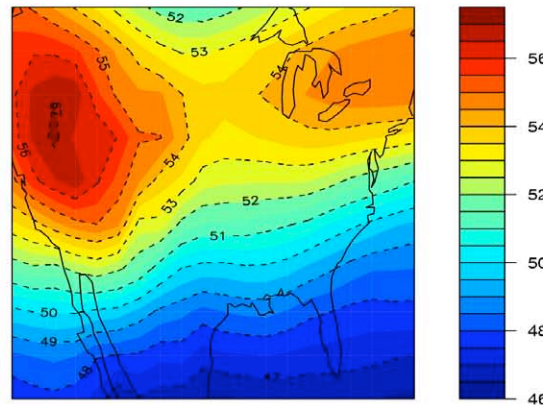


Atmospheric circulation
in heat waves becomes
more intense for future
climate (2080-2099)
compared to present-day
(1961-1990)

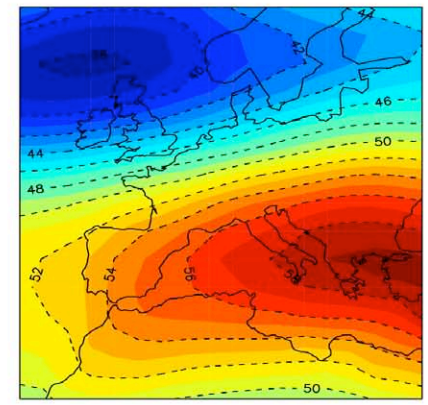


Future change in base
state (mean) atmospheric
circulation due to
increased CO2 is
conducive to more
intense heat waves

(c)
mean difference in Z500, future – present,
PCM (ens.ave.)



(d)
mean difference in Z500, future – present,
PCM (ens.ave.)



Summary

1. Current global coupled climate models can simulate observed seasonal and regional aspects of extreme events such as frost days and heat waves
2. The patterns of future changes in frost days, heat waves, and precipitation intensity depend mostly on the changes in atmospheric circulation caused mainly by projected increases in greenhouse gases
3. The Frich et al. extremes indices from the IPCC multi-model dataset provide large scale indications of possible changes of temperature and precipitation extremes over North America