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# Extreme weather in a changing climate

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- ❖ “Climate is what you expect...
  - ❖ ...weather is what you get!”

Ed Lorenz

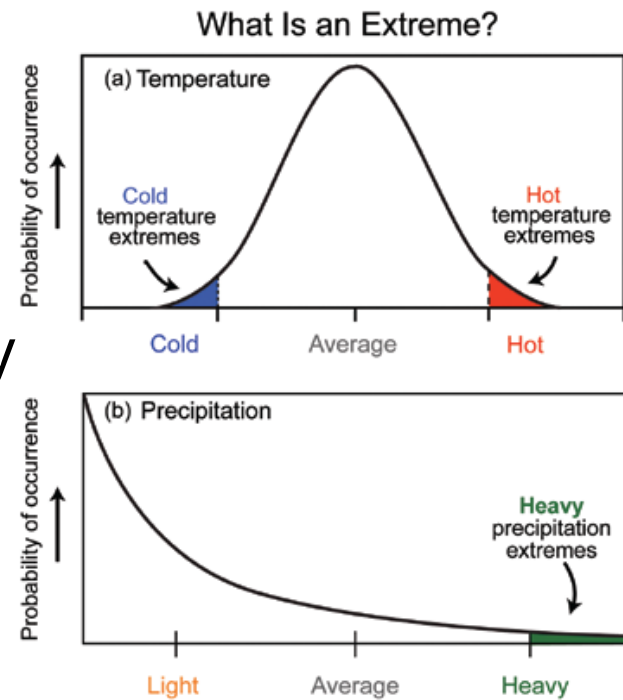
# Extreme weather events can be devastating

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- ❖ Heat waves
- ❖ Cold snaps
- ❖ Drought
- ❖ Floods
- ❖ Violent storms
  - Hurricanes
  - Tornadoes

# What makes an event extreme?

- ❖ Categorizing an event as “extreme” is a somewhat arbitrary procedure.
  - What is extreme at one space and time may be typical at another.
  - Extremes are at the tails of the distribution. How is “tail” defined?
  - Does extreme mean “rare” or simply high impact?



# Modeling extreme weather

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- ❖ The coarsely resolved (~200km) global models used for the IPCC AR4 poorly simulate intense storms.
  - But multiple models are necessary to provide better estimates of projection uncertainty.
- ❖ High resolution regional models (~20-50km) have provided our best estimates of changes in extreme weather.
- ❖ Until now...

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# CAM5 hi-resolution simulations (0.25°, prescribed aerosols)

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June 1, 2011

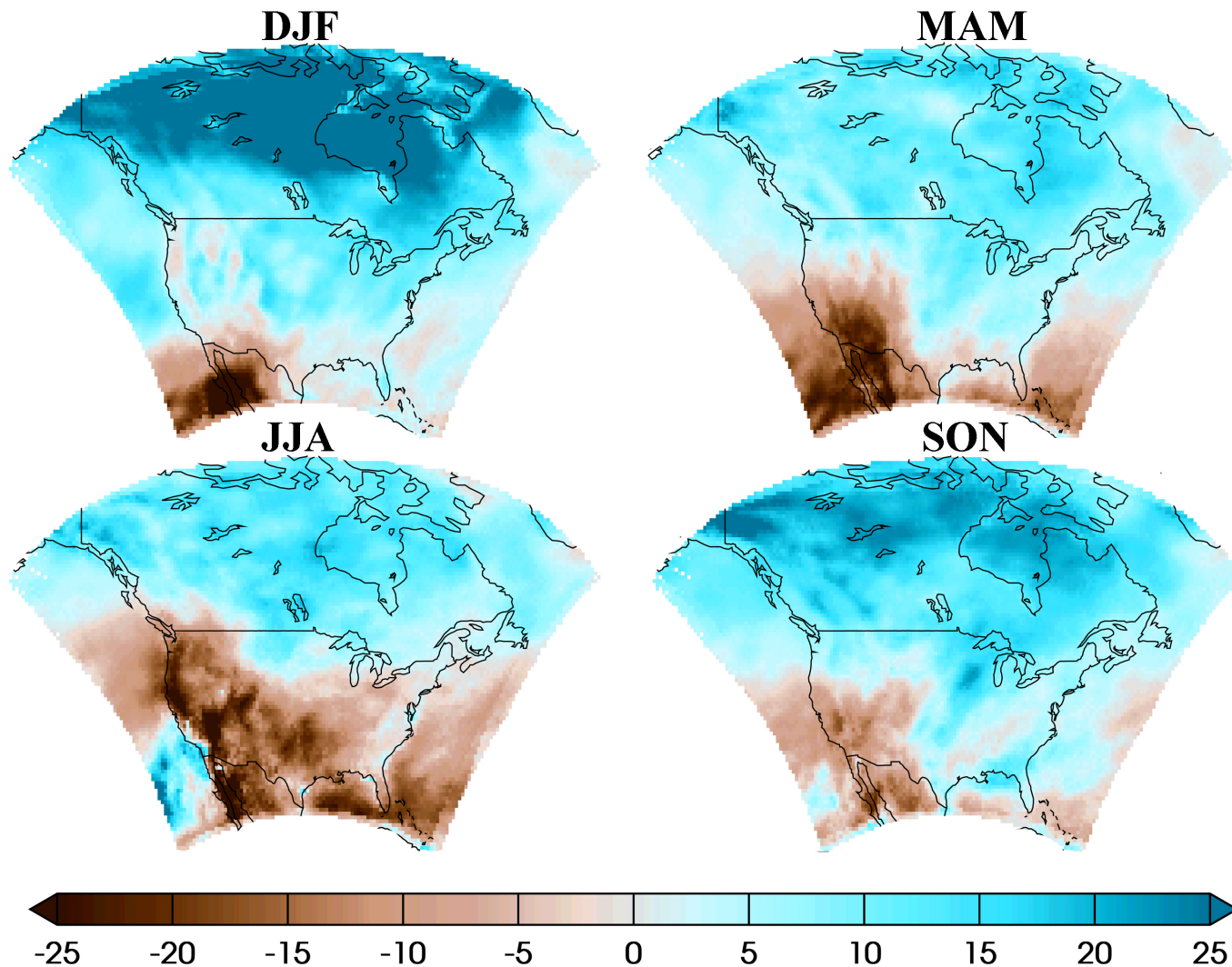


# Modeling extreme weather

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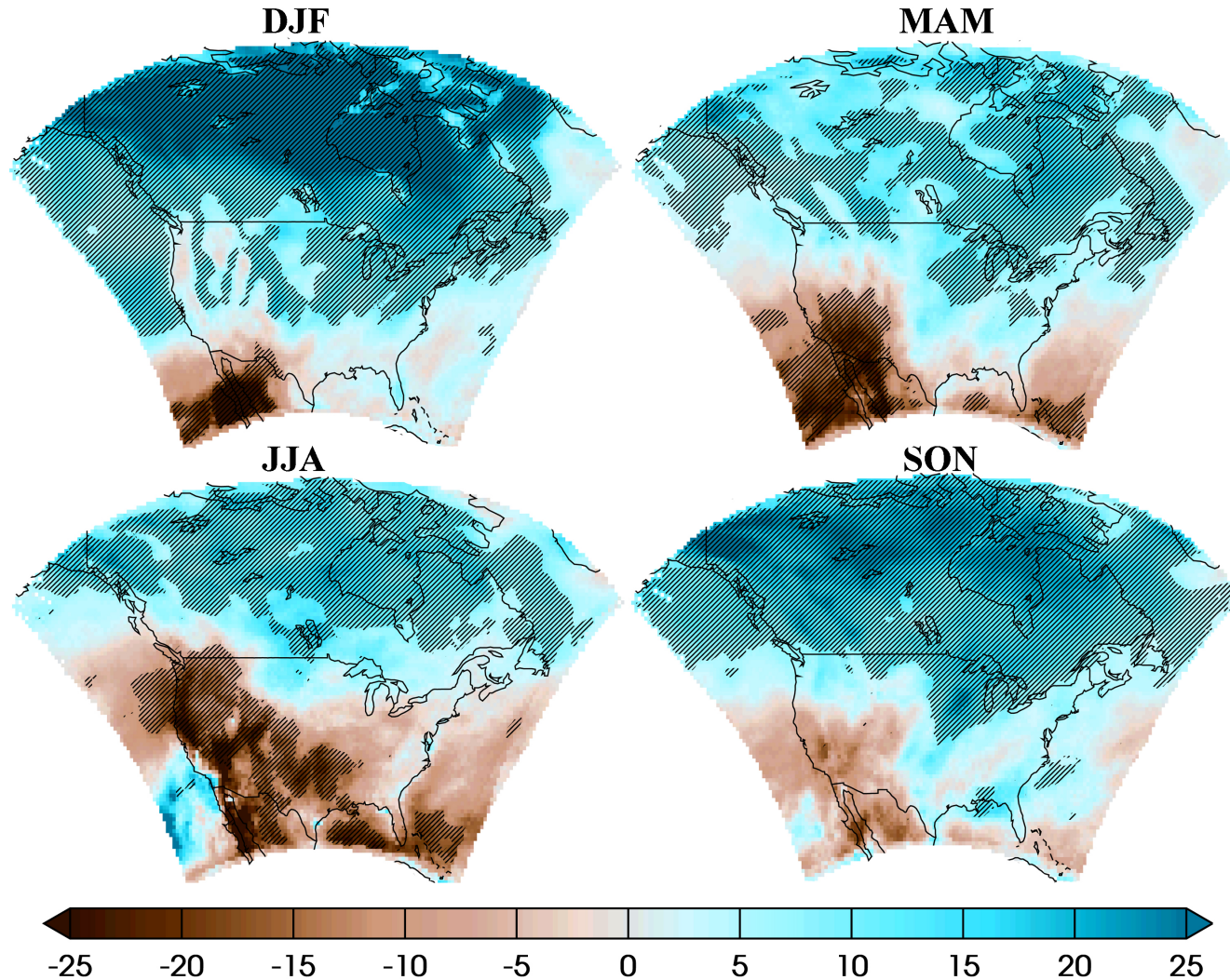
- ❖ 25km global models are computationally feasible.
  - On today's computers.
  - No lateral boundary conditions.
  - Any area of the globe can be analyzed.
  - A developing art, only a few models available.
  - Downscaling may not be required.
  - Fully coupled ocean-atmosphere models are under development for the next generation of computers.

# Percent change in average precipitation





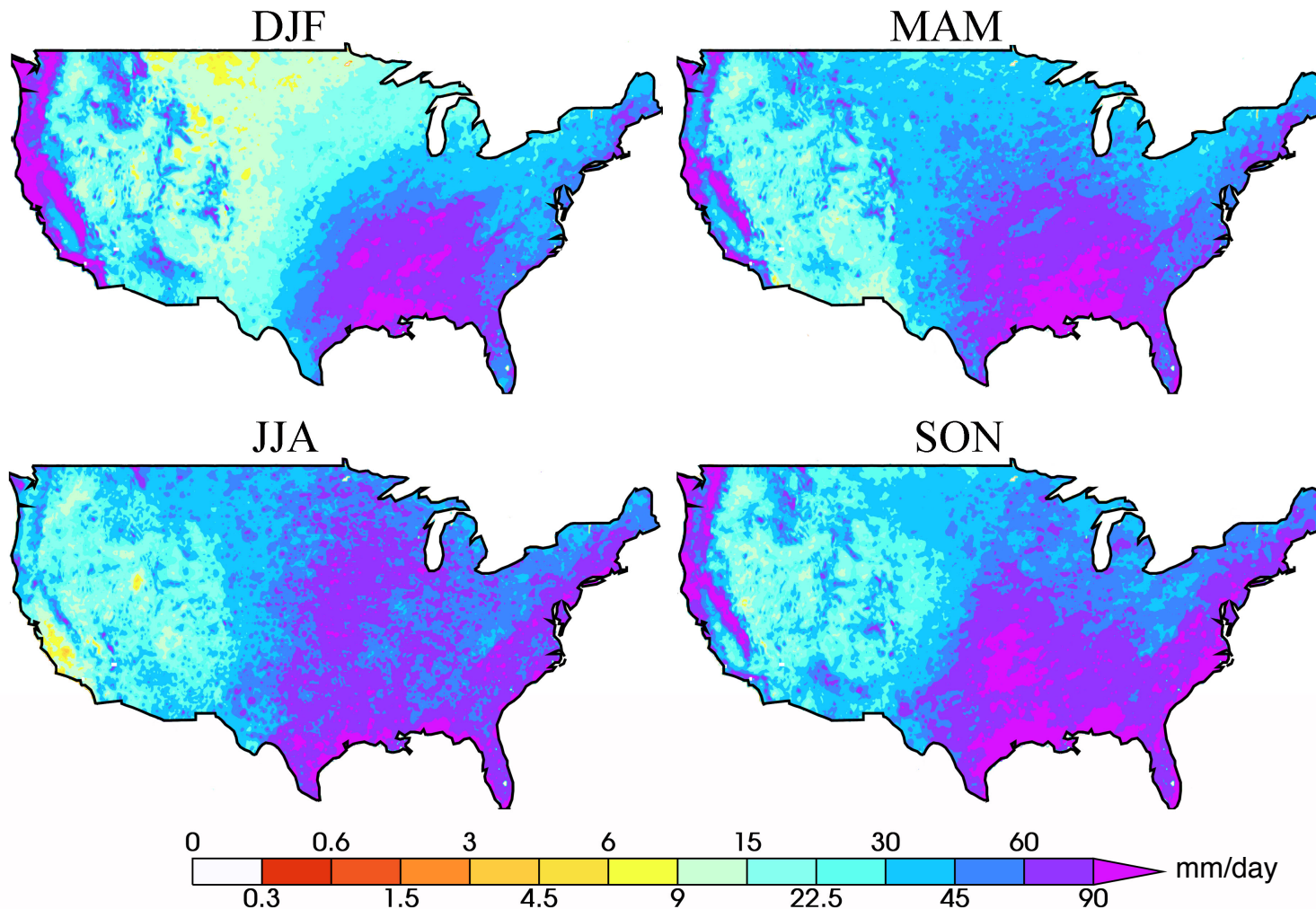
# Percent change in average precipitation



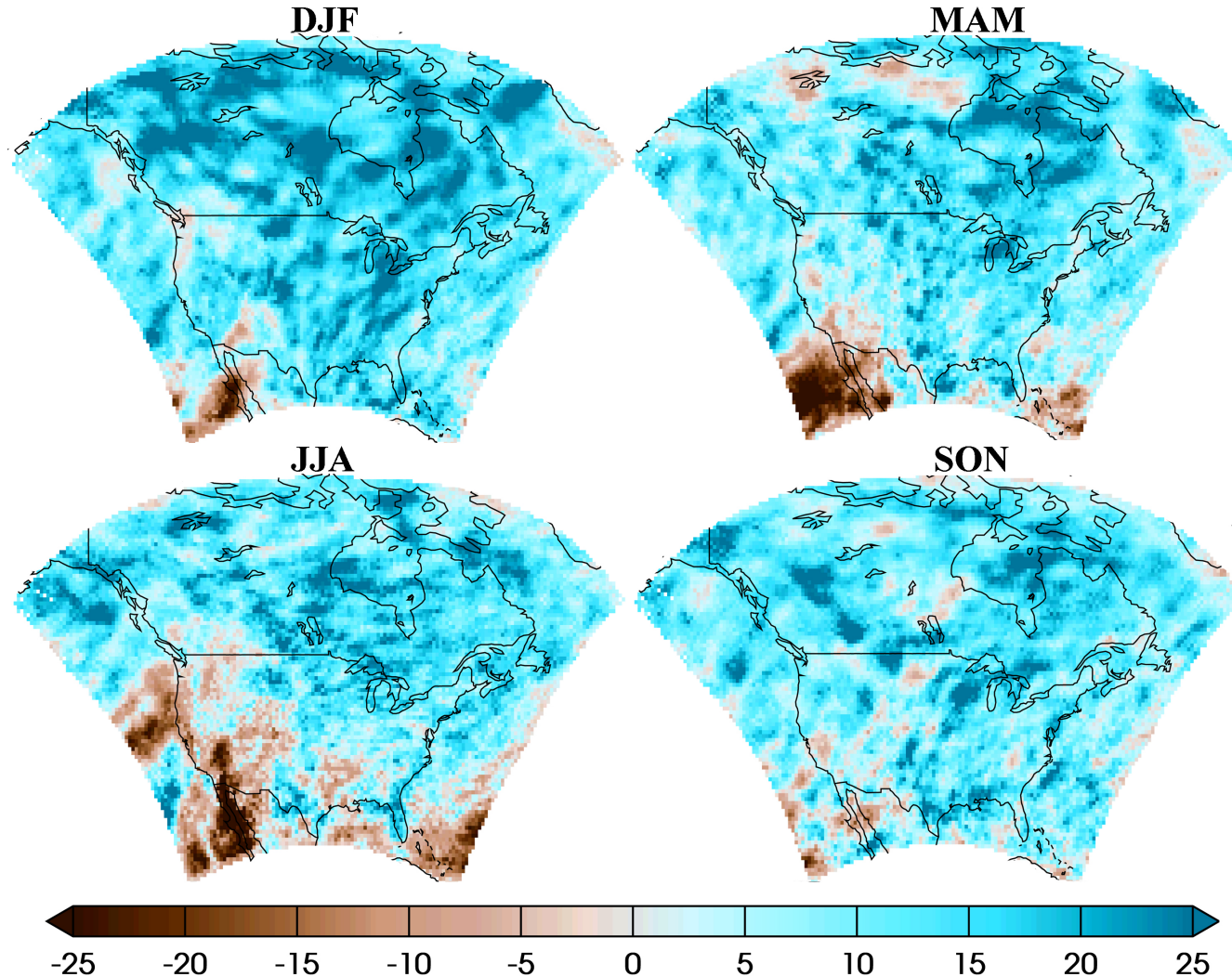
# Extreme Precipitation

## ❖ 20 year return value of the season maxima

- Gridded observations (Maurer et al. 2002)

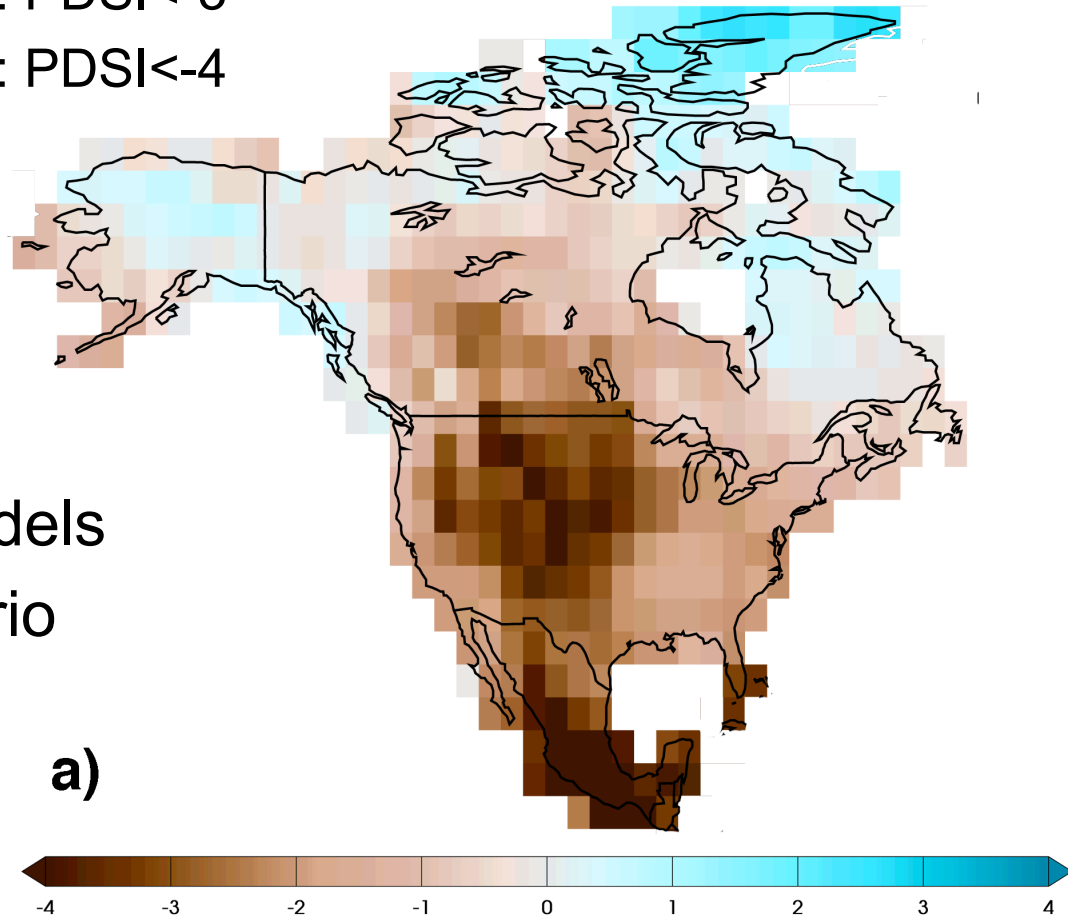


# Percent change in 20 year return value



# Drought will be the new “normal”

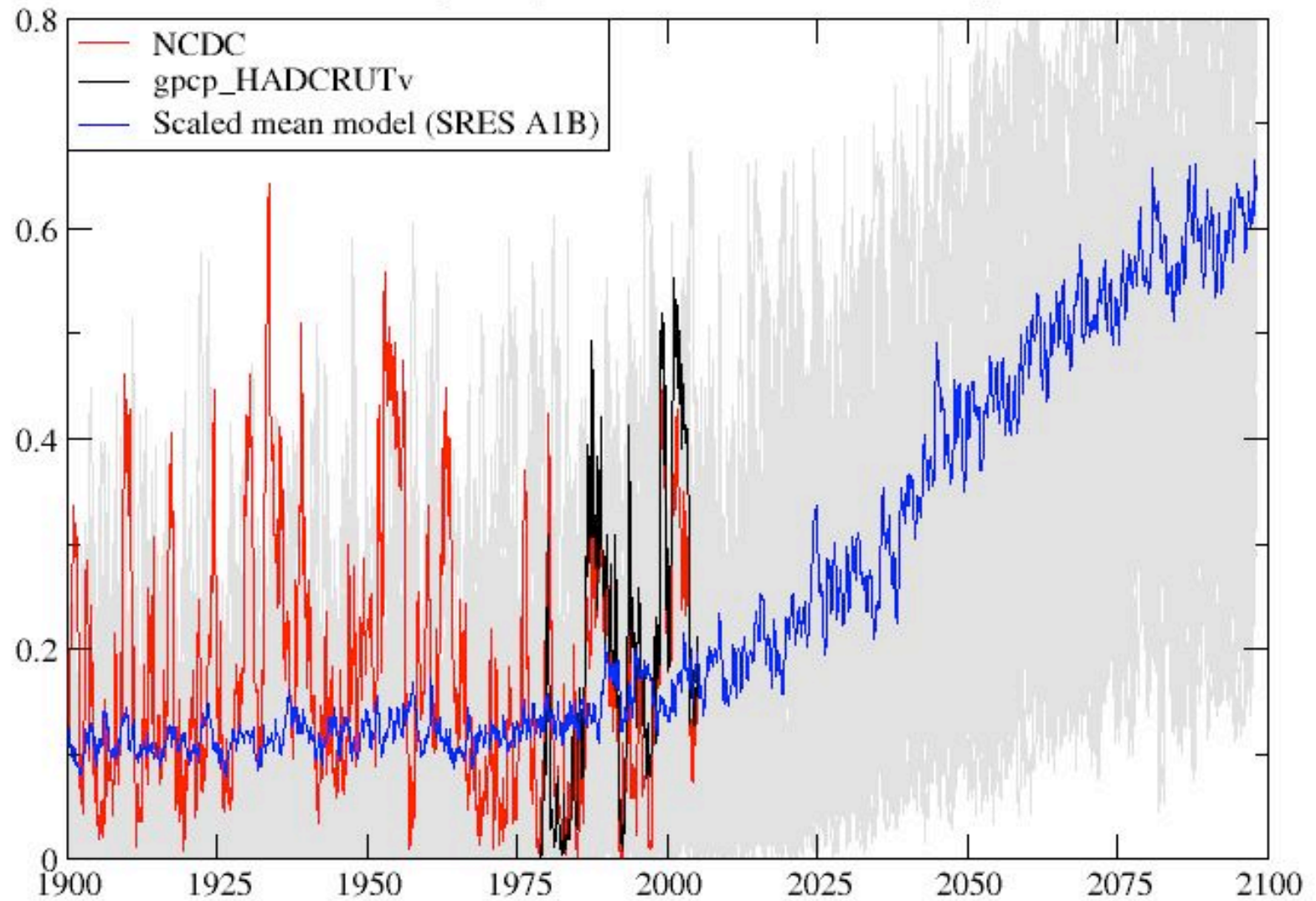
- ❖ Palmer drought severity index (PDSI)
- ❖ Moderate drought:  $\text{PDSI} < -2$
- ❖ Severe drought :  $\text{PDSI} < -3$
- ❖ Extreme drought :  $\text{PDSI} < -4$



19 IPCC AR4 models  
2090, A1B scenario

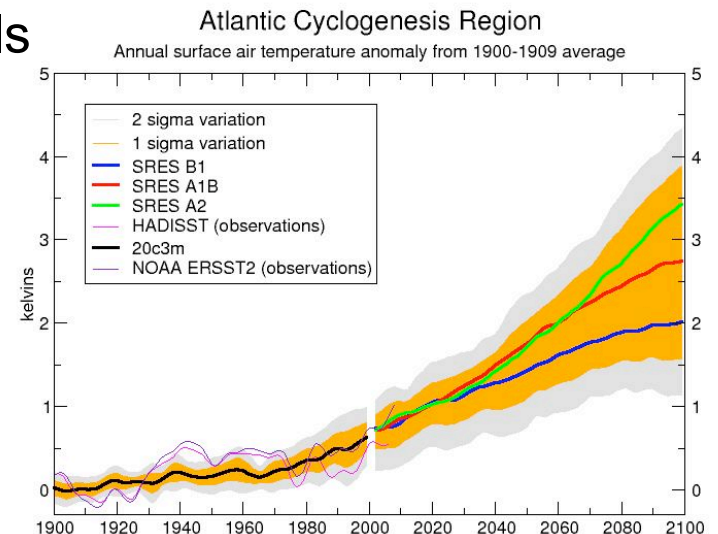
# Fractional drought area USA & Mexico

Monthly average PDSI < 2.0; Scaled climatology



# Hurricanes

- ❖ Even in conservative scenarios, predictions of Atlantic cyclogenesis region temperatures are far above anything yet realized in human history.
- ❖ Implications for the Gulf coast of US and Mexico are immediate.
  - The entire 20<sup>th</sup> century observed warming in the ACR could be doubled by 2020.
- ❖ Direct simulation with high resolution models suggests more intense tropical cyclones. And perhaps more in all categories!



# Conclusions

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- ❖ Global modeling of regional climate change is now feasible.
  - Many realistic storm features are simulated.
- ❖ Changes in extreme events under plausible future emissions scenarios are severe for both surface air temperature and precipitation.
- ❖ Drought becomes the normal state in many temperate regions.
- ❖ Increased risk for future seasonal and flash floods.
- ❖ Increased risk for severe heat waves. Reduced risk of cold snaps.
- ❖ Changes in cyclogenesis region temperatures since 1950 are highly likely to be human induced.
  - Given the strong relationship between intense hurricane activity and sea surface temperature, predictions of the coming decades are sobering.

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Today's rare events become commonplace.



# Policy implications?

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- ❖ Is this type of information useful?
  - If not, what is?
- ❖ Uncertainty quantification is critical.
  - Uncertainty increases as scales decrease and as time horizons increase
- ❖ Overly detailed projections amidst substantial uncertainties can be meaningless.
  - Many traps to fall in...

# More information

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- ❖ The Climate Change Science Program (CCSP)  
Synthesis and Assessment Products
  - <http://www.climatescience.gov>
  - Product 3.3: “Weather and Climate Extremes in a Changing Climate”
- ❖ US Global Change Research Program
  - <http://www.globalchange.gov>
  - “Global Climate Change Impacts in the US