Fine-scale processes regulate the response of extreme events to global climate change

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Diffenbaugh et al., *PNAS*, 2005

- Jeremy Pal, Filippo Giorgi

  Abdus Salam International Center for Theoretical Physics

- Jeff Trapp

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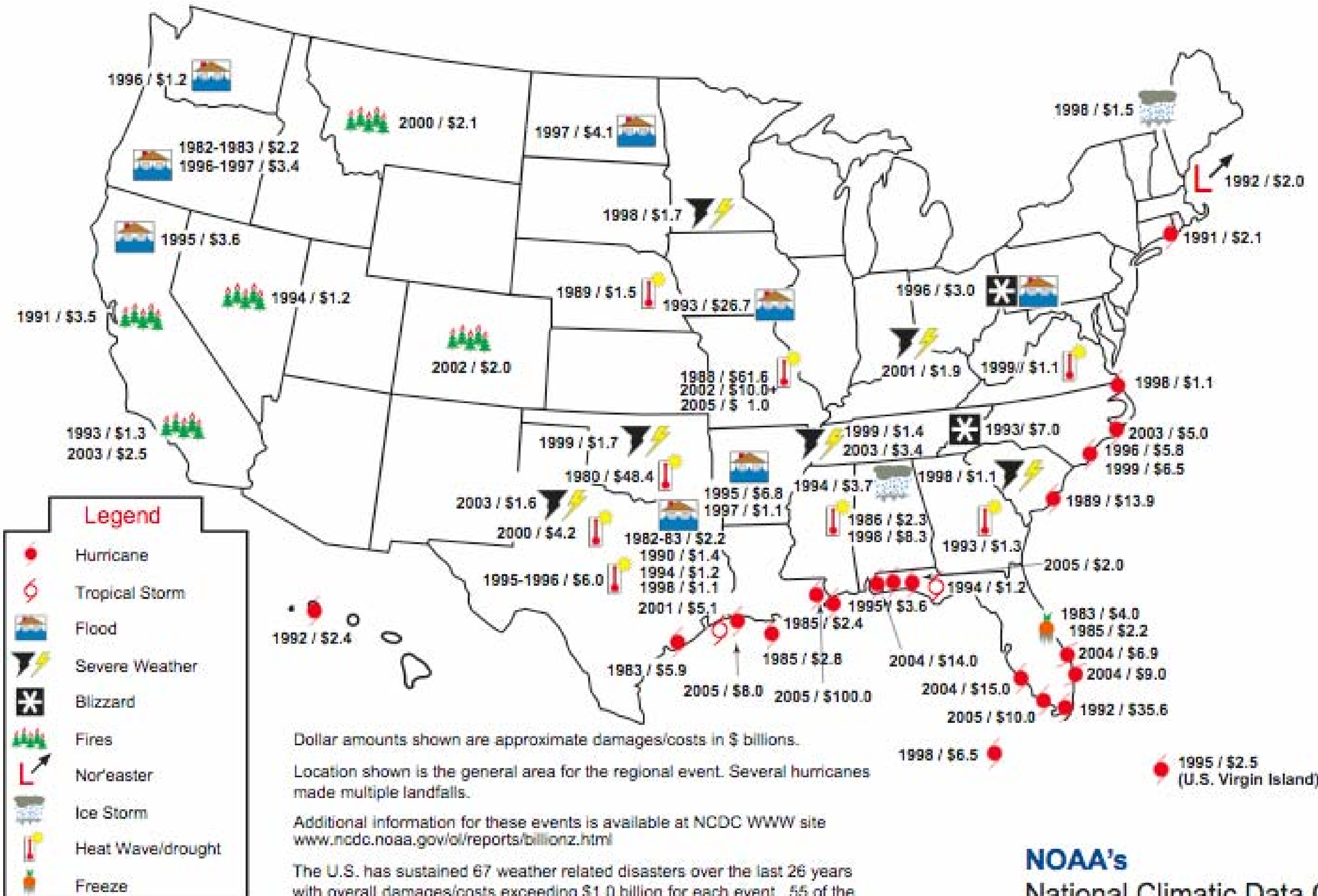
Billion Dollar Weather Disasters 1980 - 2005



Dollar amounts shown are approximate damages/costs in $ billions.

Location shown is the general area for the regional event. Several hurricanes made multiple landfalls.

Additional information for these events is available at NCDC WWW site www.ncdc.noaa.gov/ol/reports/billionz.html

The U.S. has sustained 67 weather related disasters over the last 26 years with overall damages/costs exceeding $1.0 billion for each event. 55 of the disasters occured during or after 1990. Total costs for the 67 events were over $500 billion using an inflation/wealth index.

NOAA's
National Climatic Data Center

Questions

- What are the dynamics that control the response of extreme climate to enhanced greenhouse gas forcing?

  => What is the role of fine-scale climate processes?

The Experiment

- 2 cases

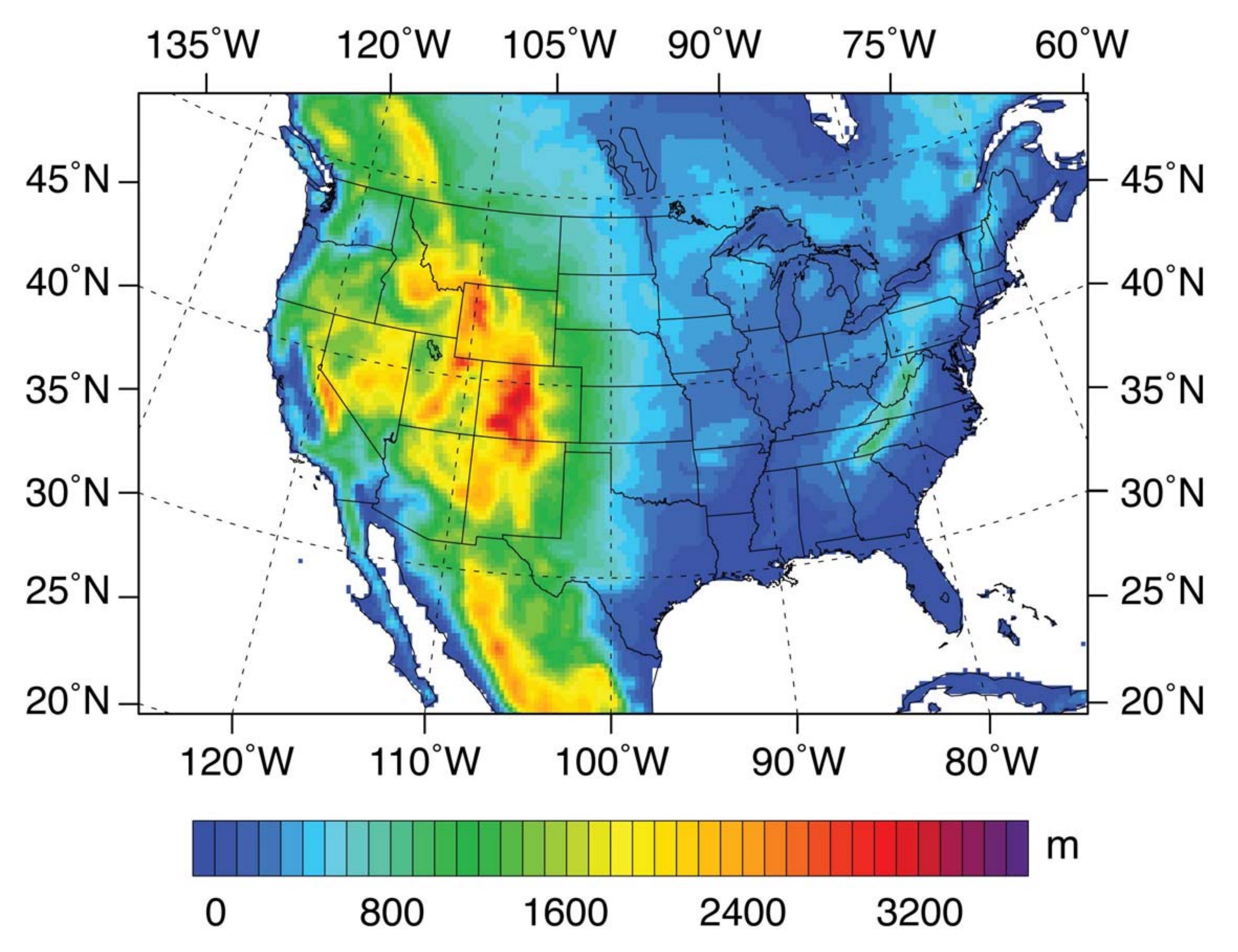
Reference	1961 – 1985
A2 Scenario	2071 – 2095

- Modern satellite-derived land cover

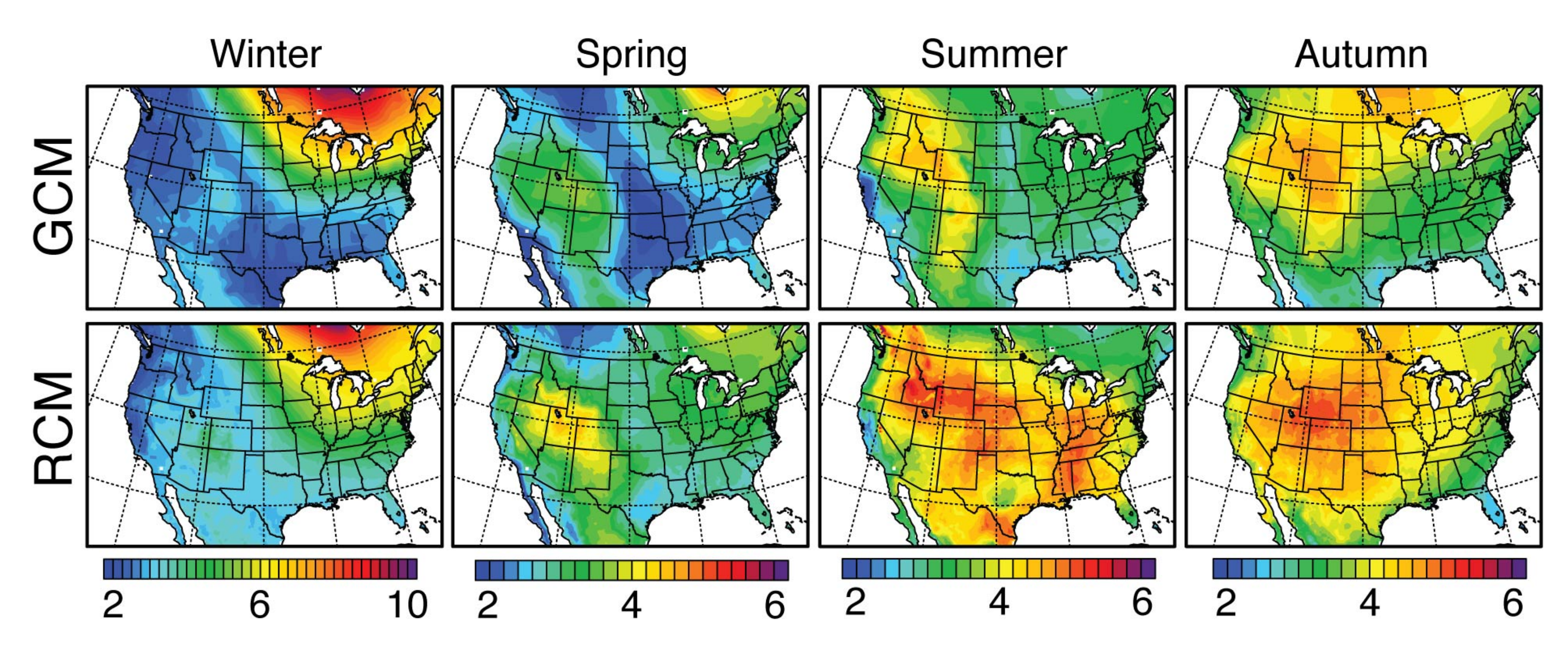
- NASA finite volume GCM provides large-scale conditions

High-Resolution Model Domain (25 km)

Topography



Change in Temperature (˚C)



- Fine-scale physics alter the response to greenhouse forcing

Extremes Method

An *event* is the daily rainfall or daily maximum/minimum temperature.

- Top and bottom 5% of events in a year are considered extreme

Index Definition:

- Long term indices of extreme temperature and precipitation created based on the methods of Salinger & Giffiths (2001, *Intl. J. Climatol.*)

$$I_{95} = \frac{\left(\sum_{i=1}^{Y} X_i[\, 0.95 \text{ x } N \,] \right)}{Y}$$

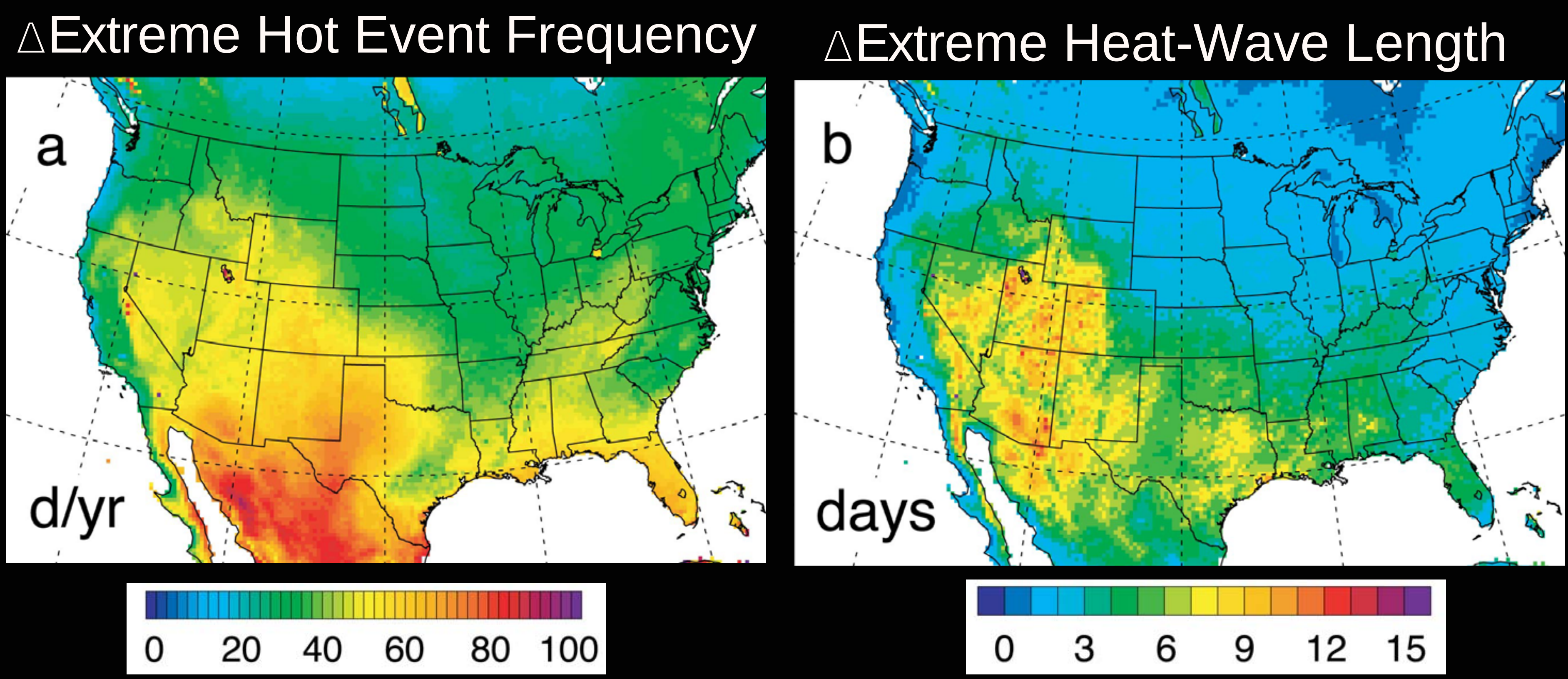
Y = Total number of years
X = A sorted list of N elements
N = Total number of events per year
I_{95} = Long term 95th percentile index

- Index values are defined in the control simulation

after *Bell et al., 2004*

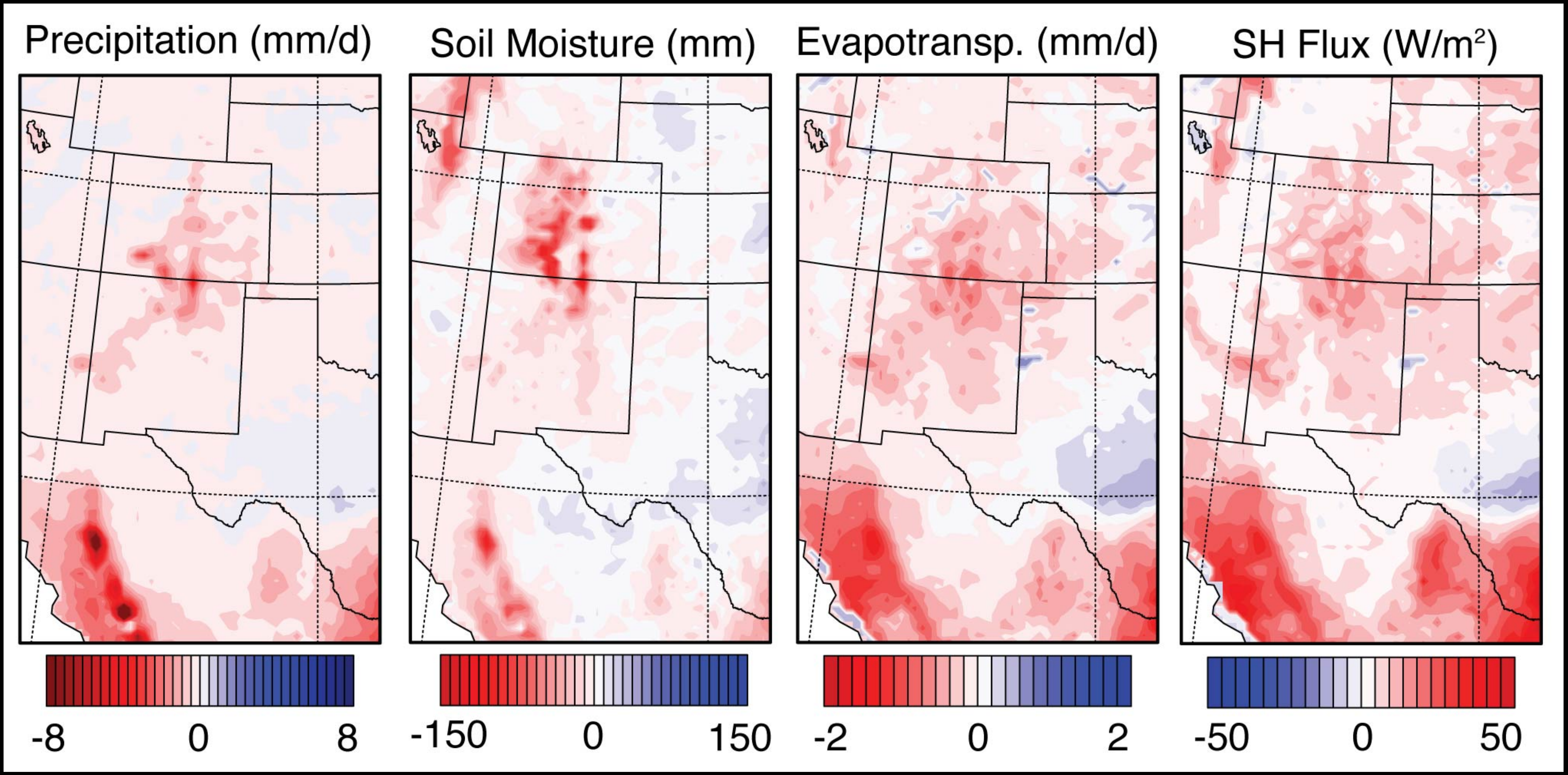
Results:
Extreme Temperature

Change in Extreme Hot Events



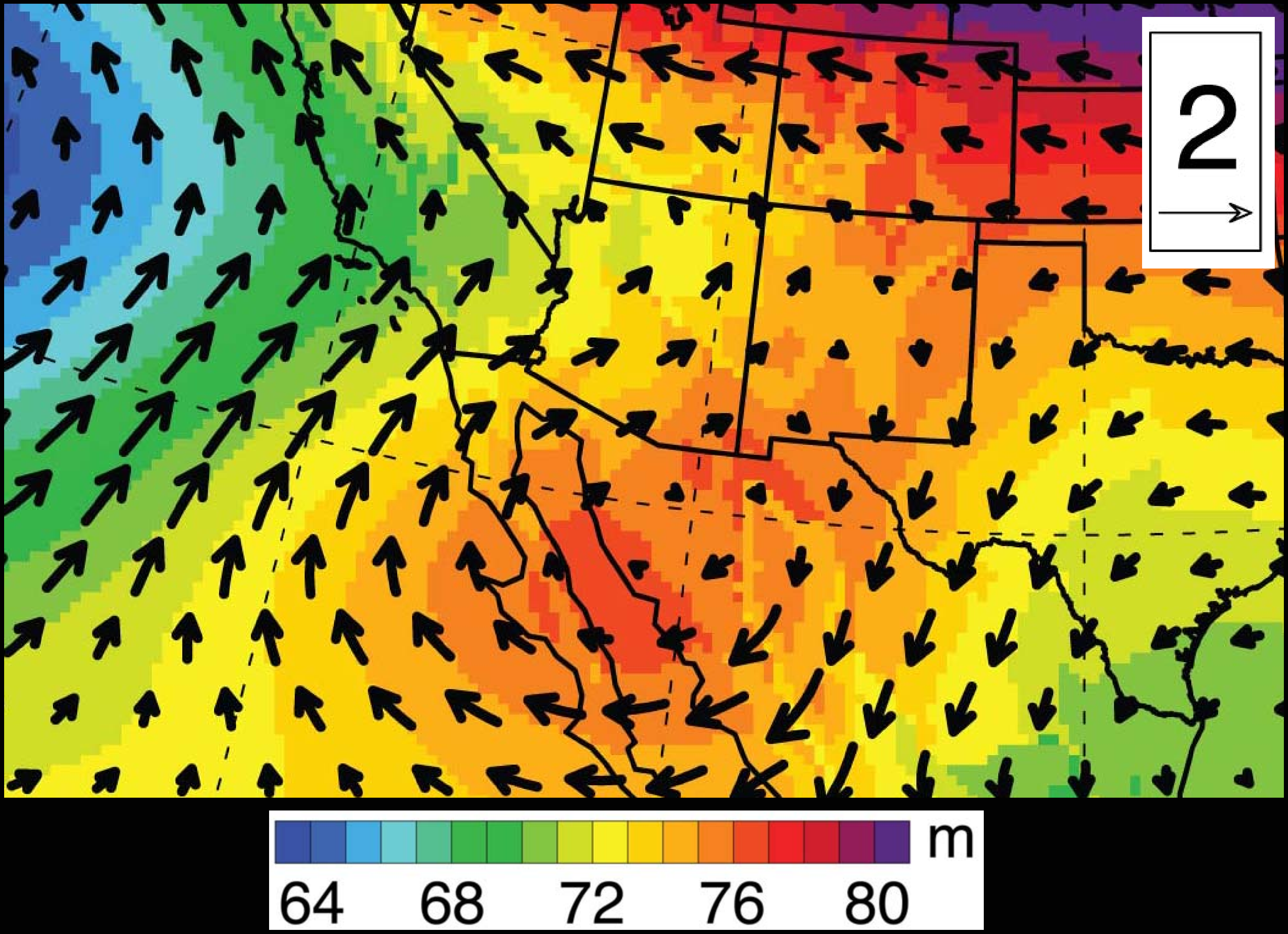
- Increases of 100 to 560 % in frequency and 50 to 550 % in duration

△Jun-Jul-Aug Moisture Balance



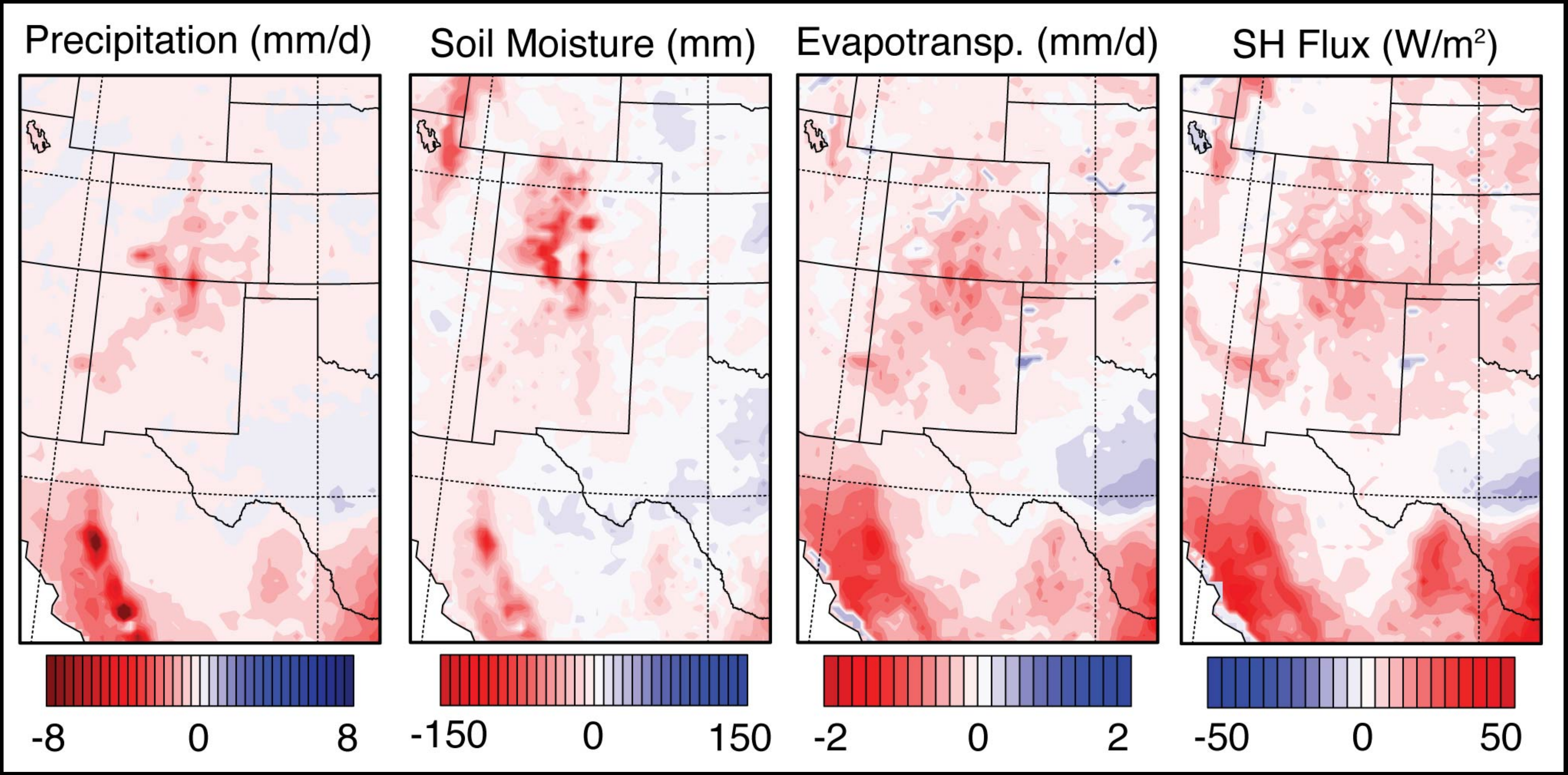
- Change in surface moisture balance enhances warming

∆Jun-Jul-Aug 500 hPa Heights and Winds

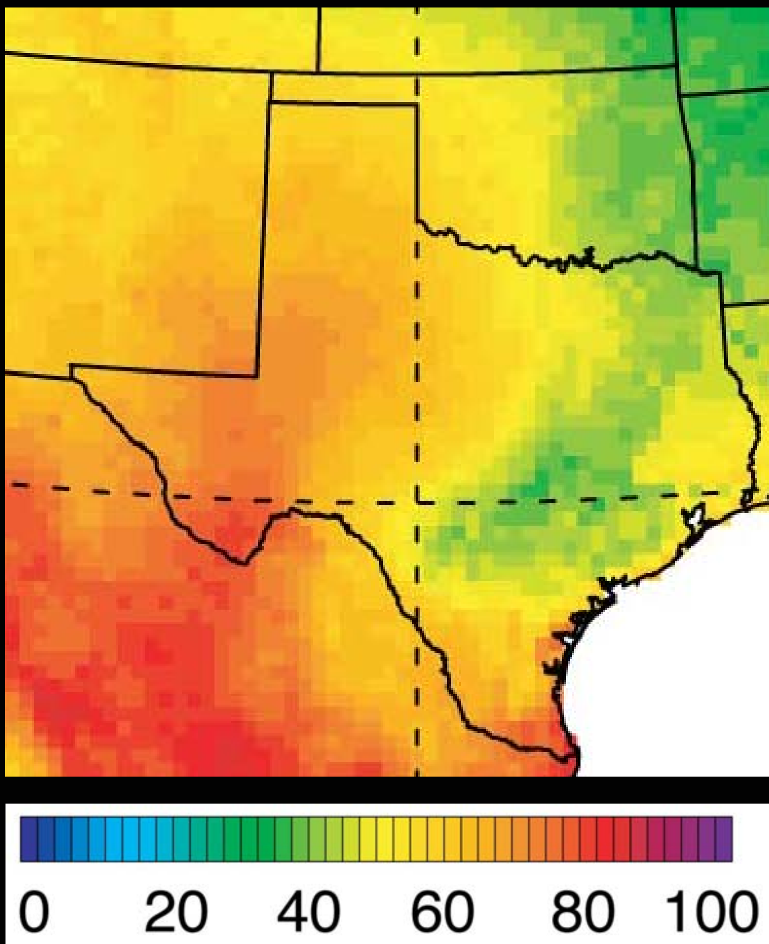


- Anticylonic flow = hotter, drier conditions

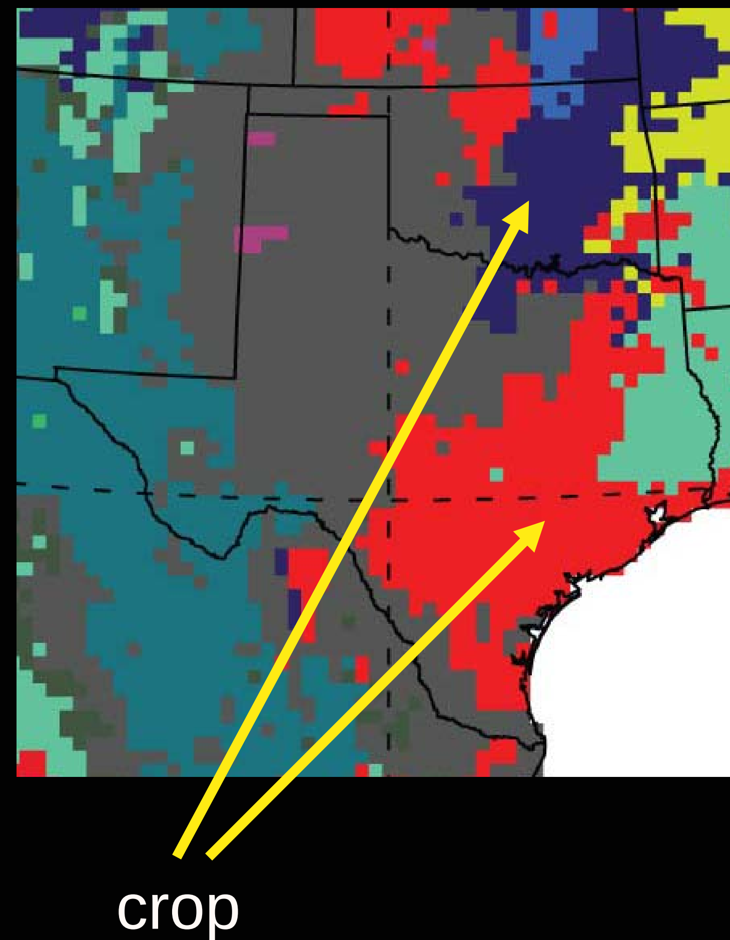
ΔJun-Jul-Aug Moisture Balance



ΔExtreme Hot Frequency

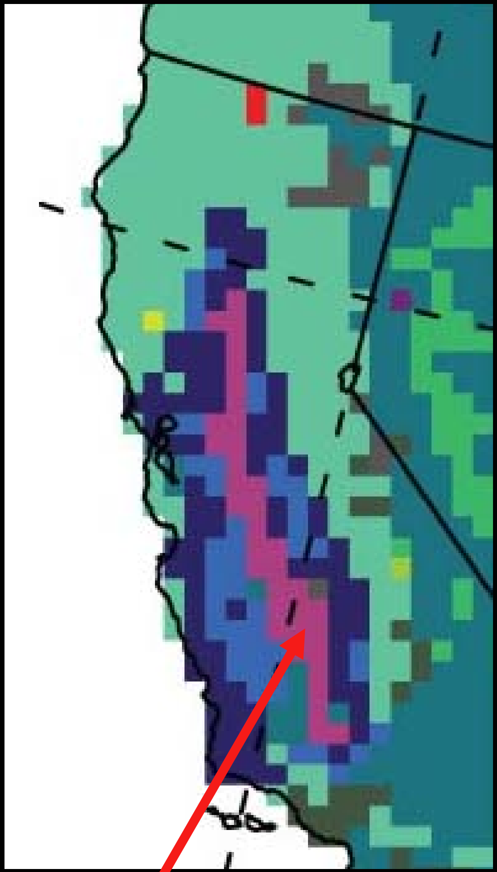


Land Use

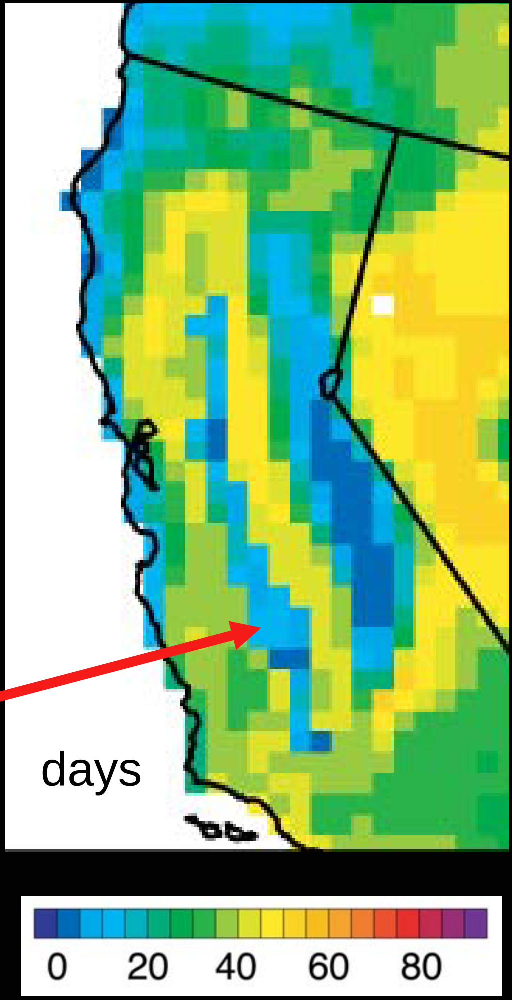


- Response of extreme hot events muted in crop areas

Land Use



ΔHot Days

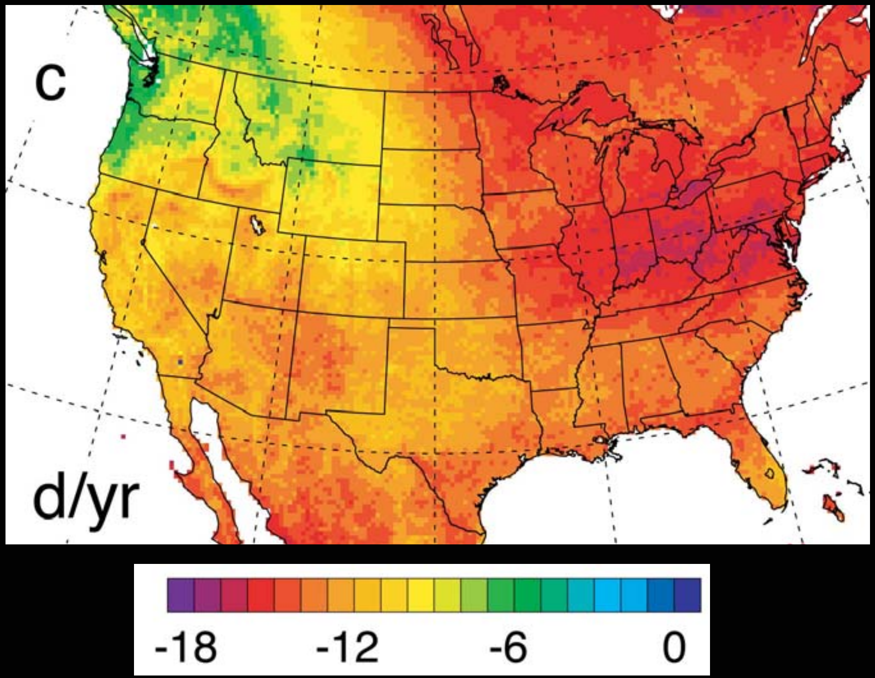


Growing
Season
Hot Days

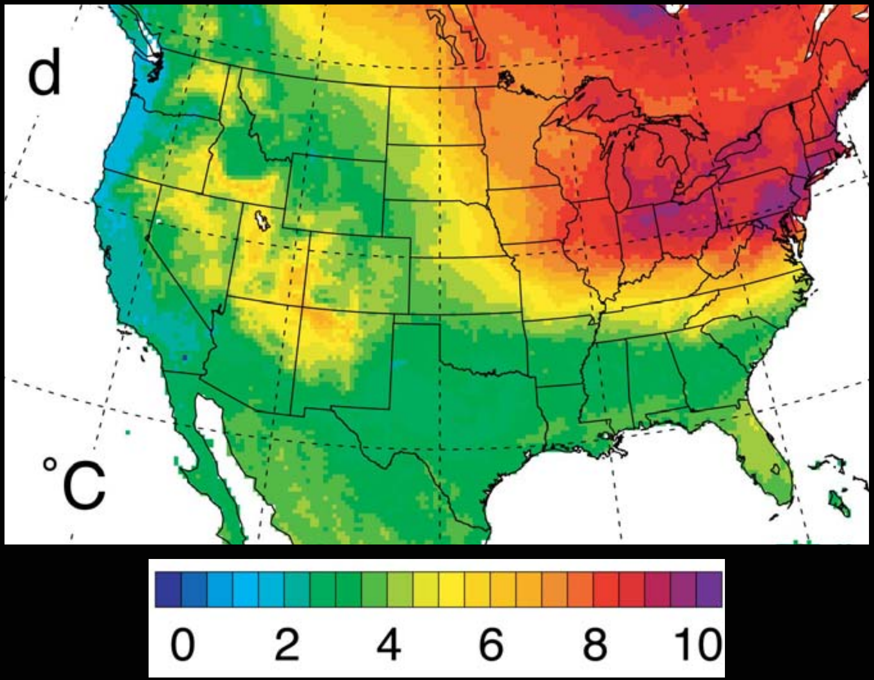
Irrigated crop

Change in Extreme Cold Events

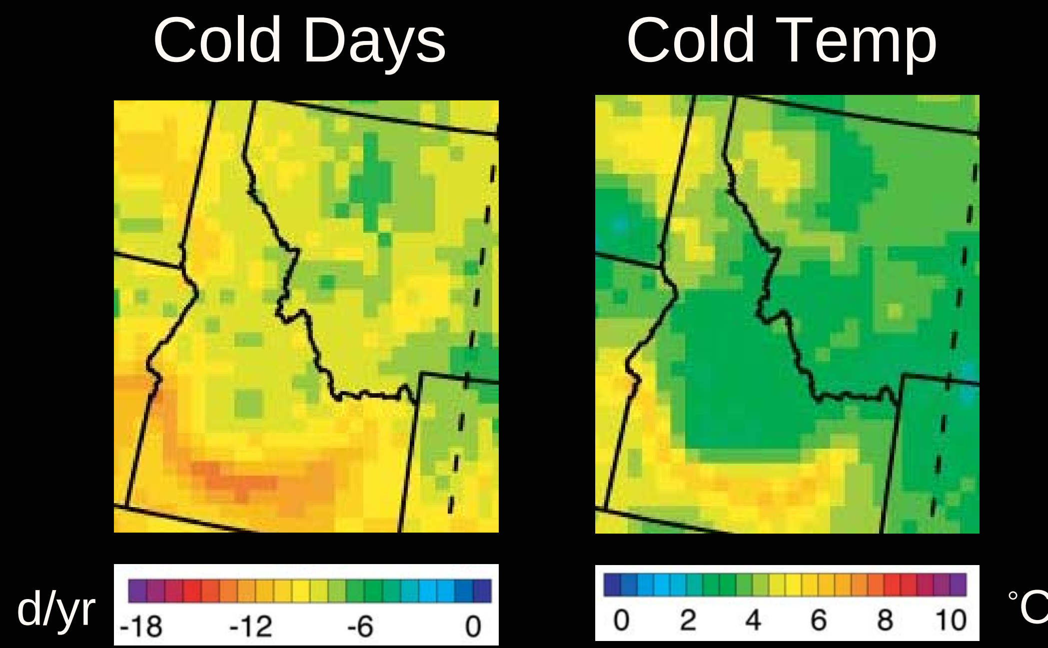
ΔExtreme Cold Frequency



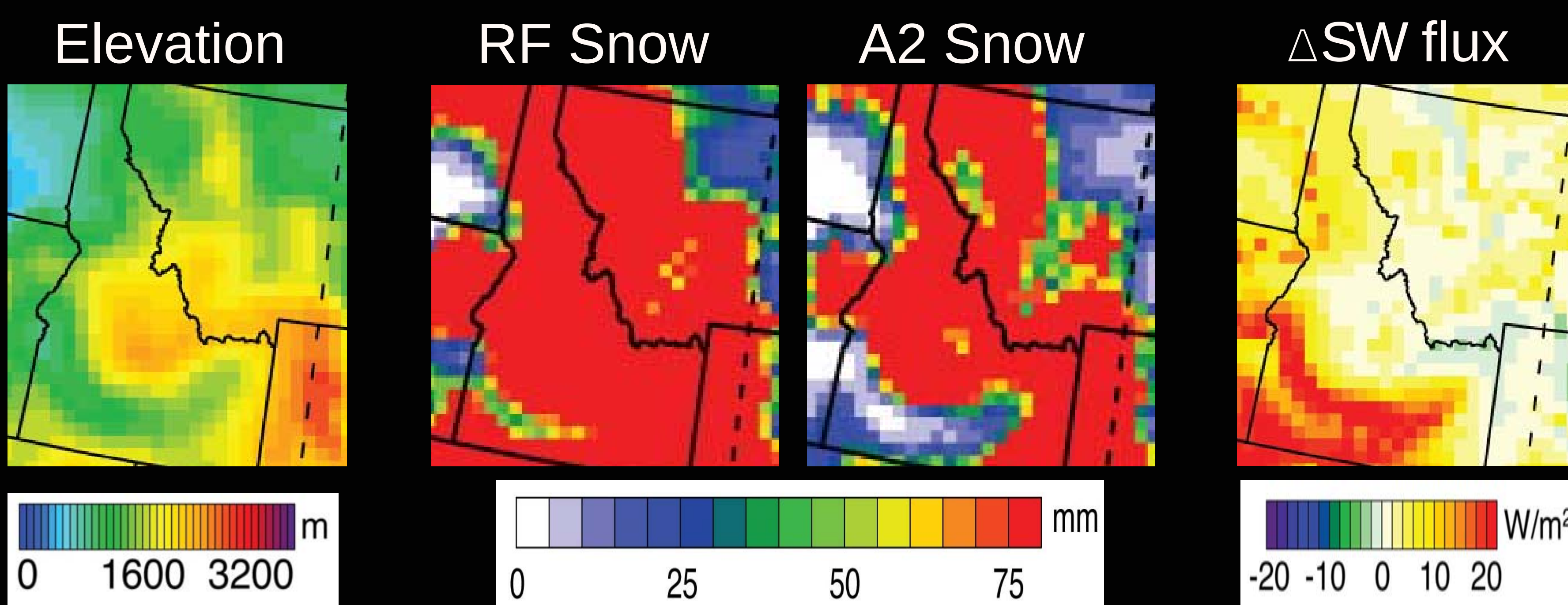
ΔExtreme Cold Magnitude



- Decreases of 25 to 90 % in frequency

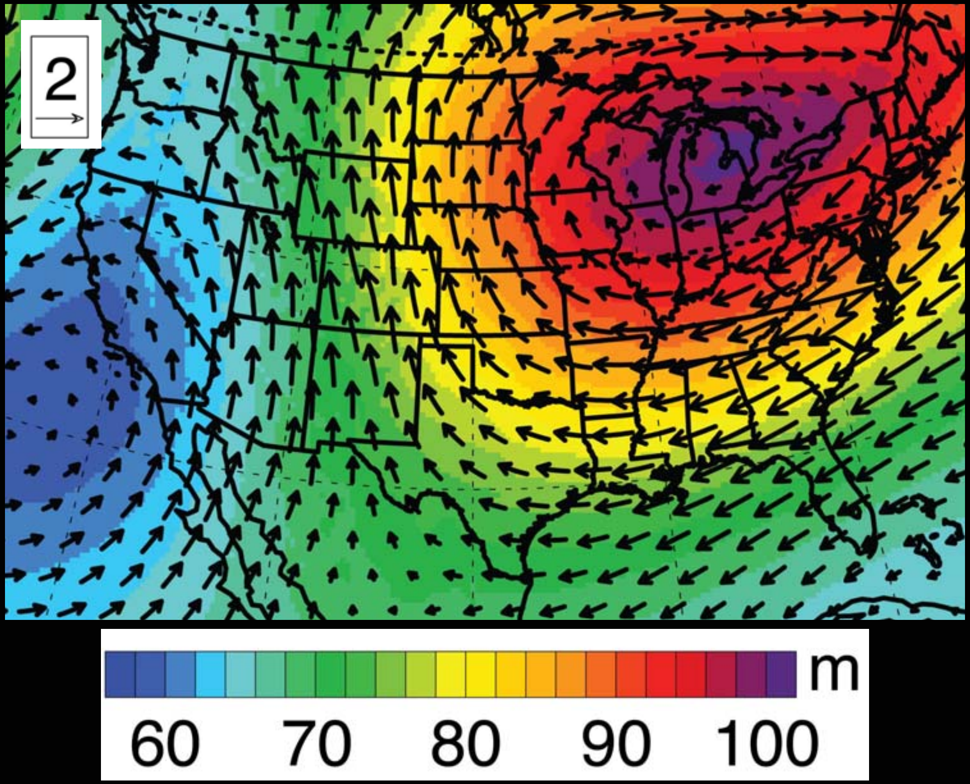


• snow-albedo feedbacks enhance warming at lower elevations

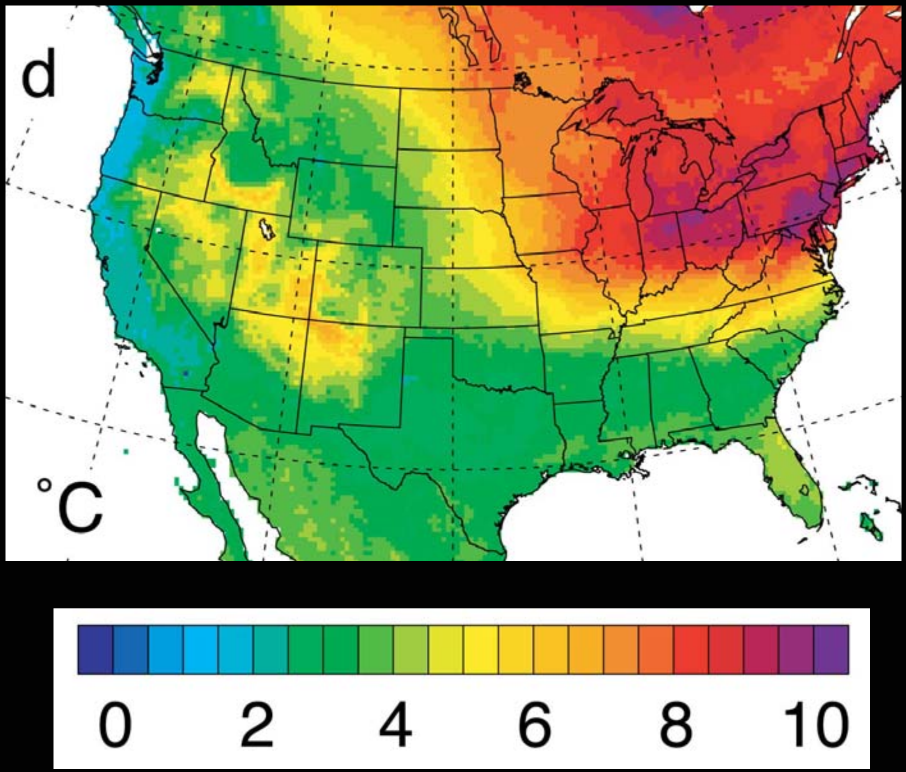


Changes in Large-Scale Dynamics

ΔNov-Dec-Jan 500 hPa Heights



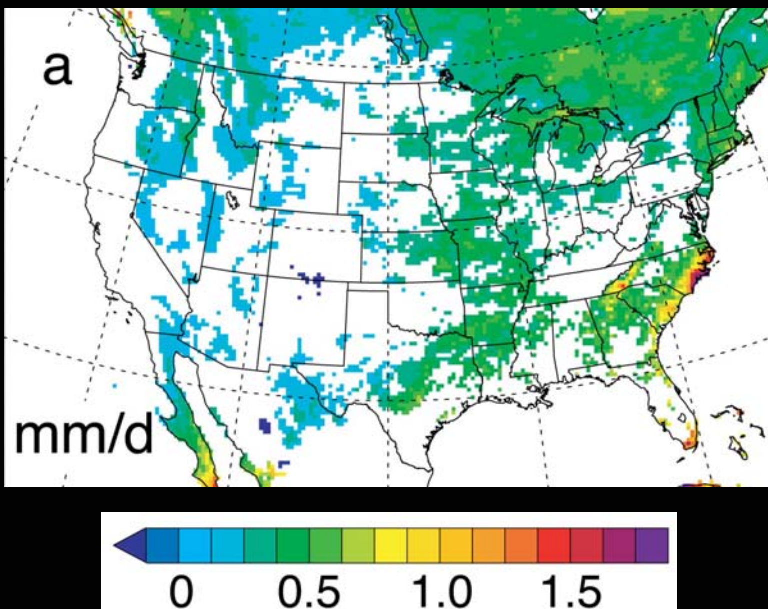
ΔExtreme Cold Magnitude



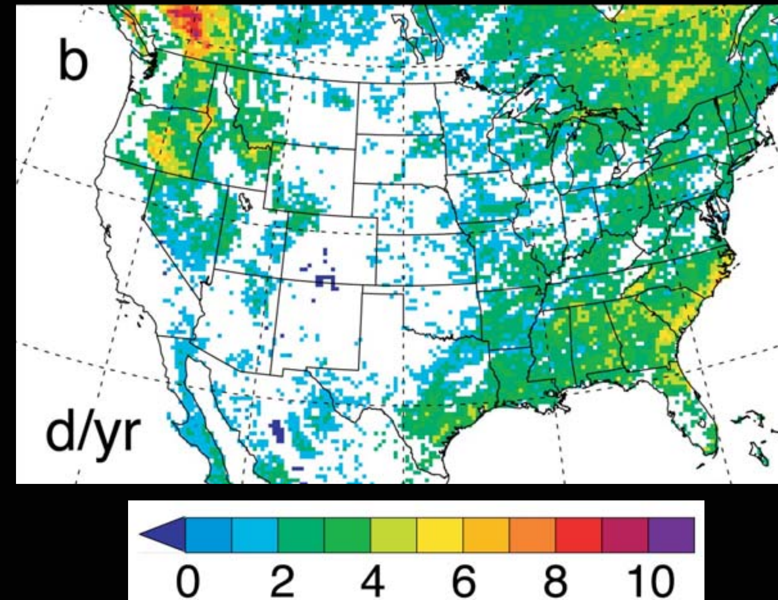
- enhanced anticyclonic flow aloft limits penetration of arctic air

Results:
Extreme Precipitation

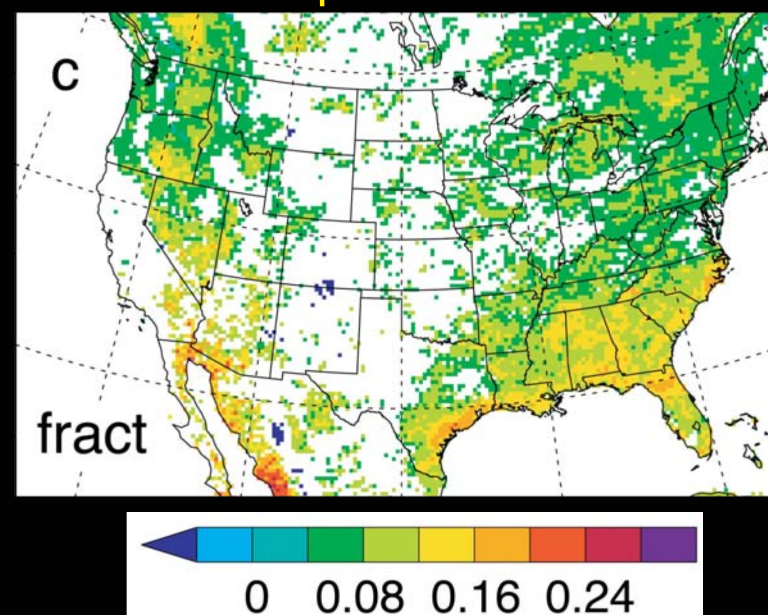
△Mean Annual Precipitation

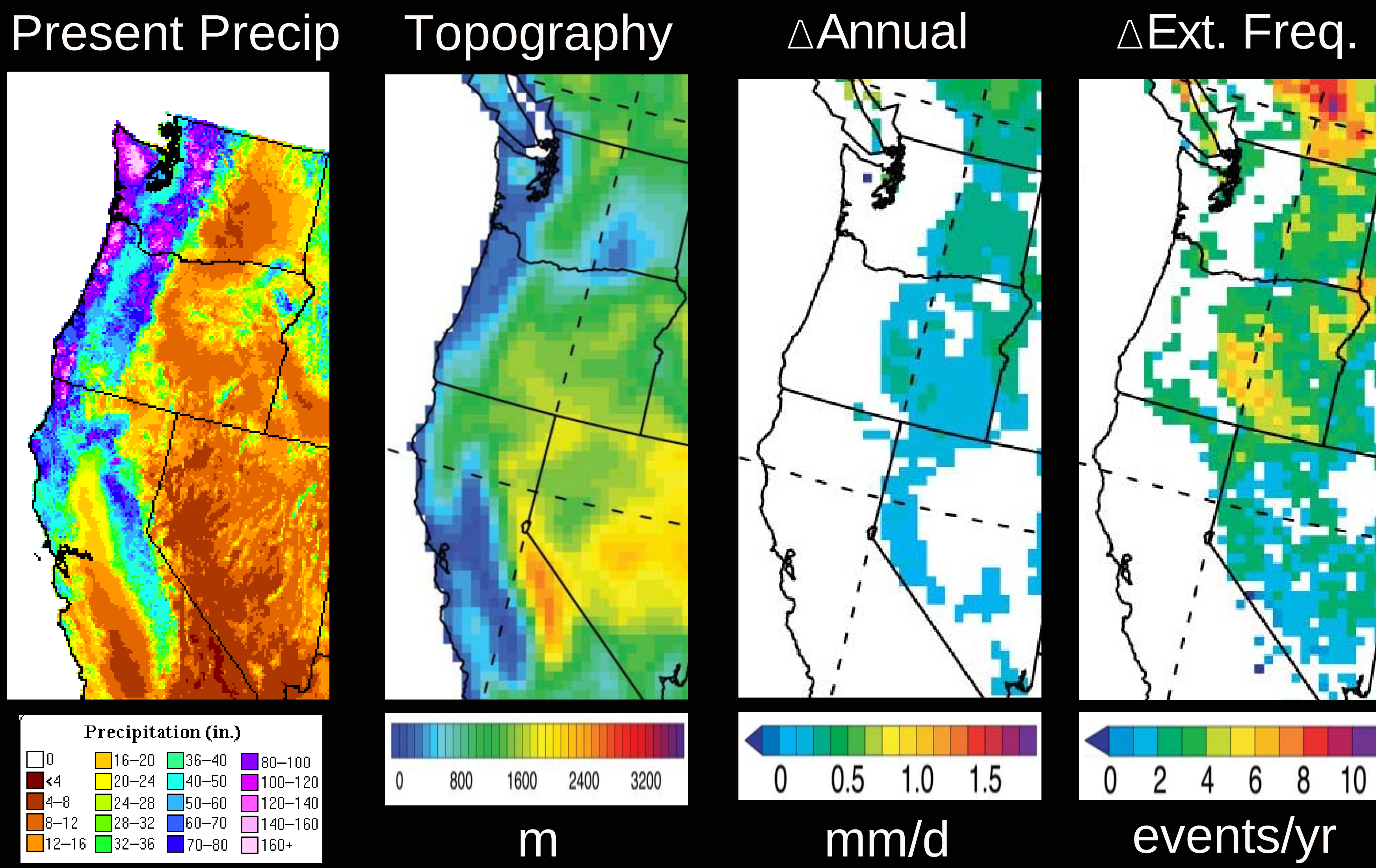


△Extreme Precipitation Frequency

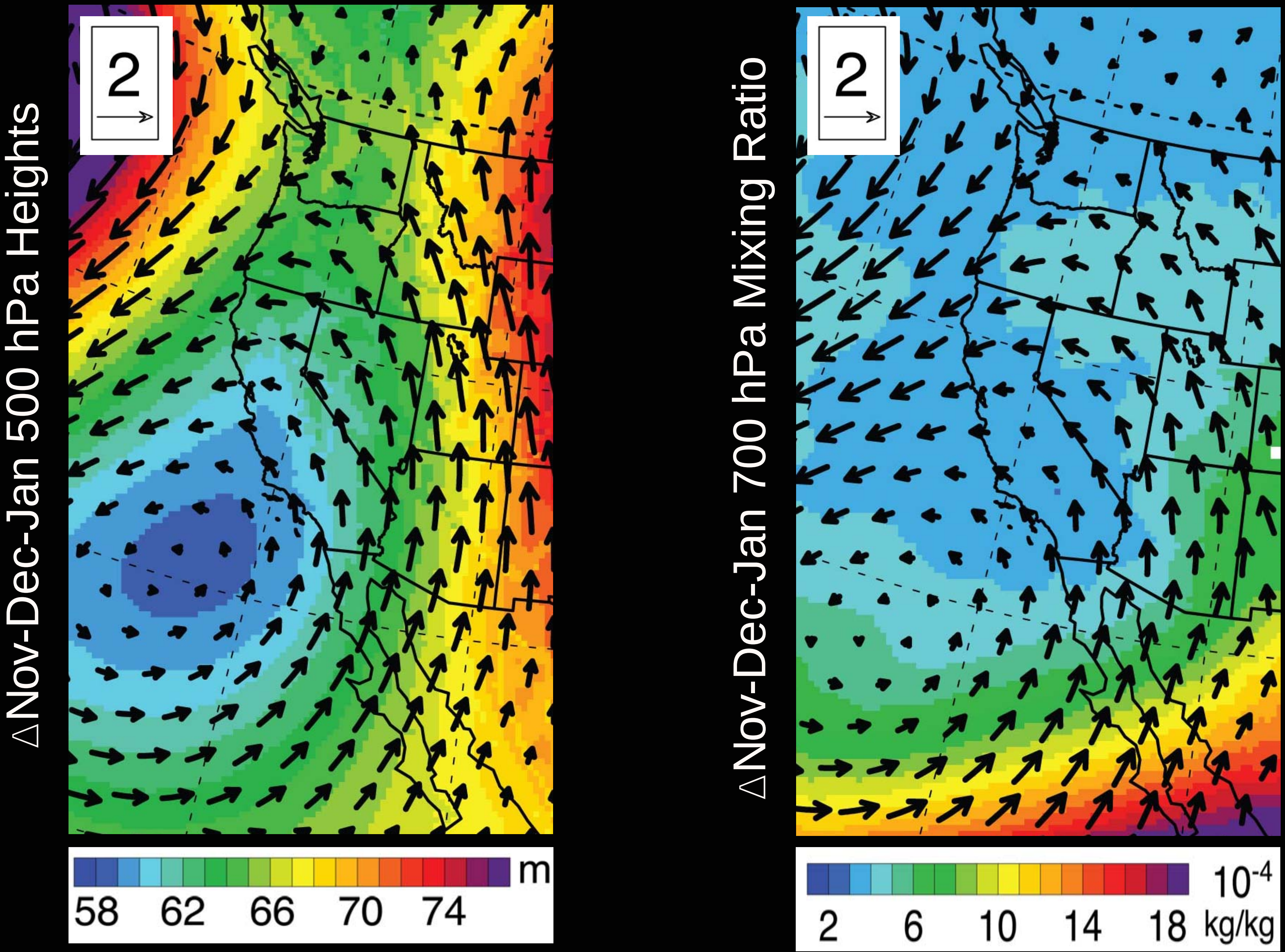


△Extreme Precipitation Contribution

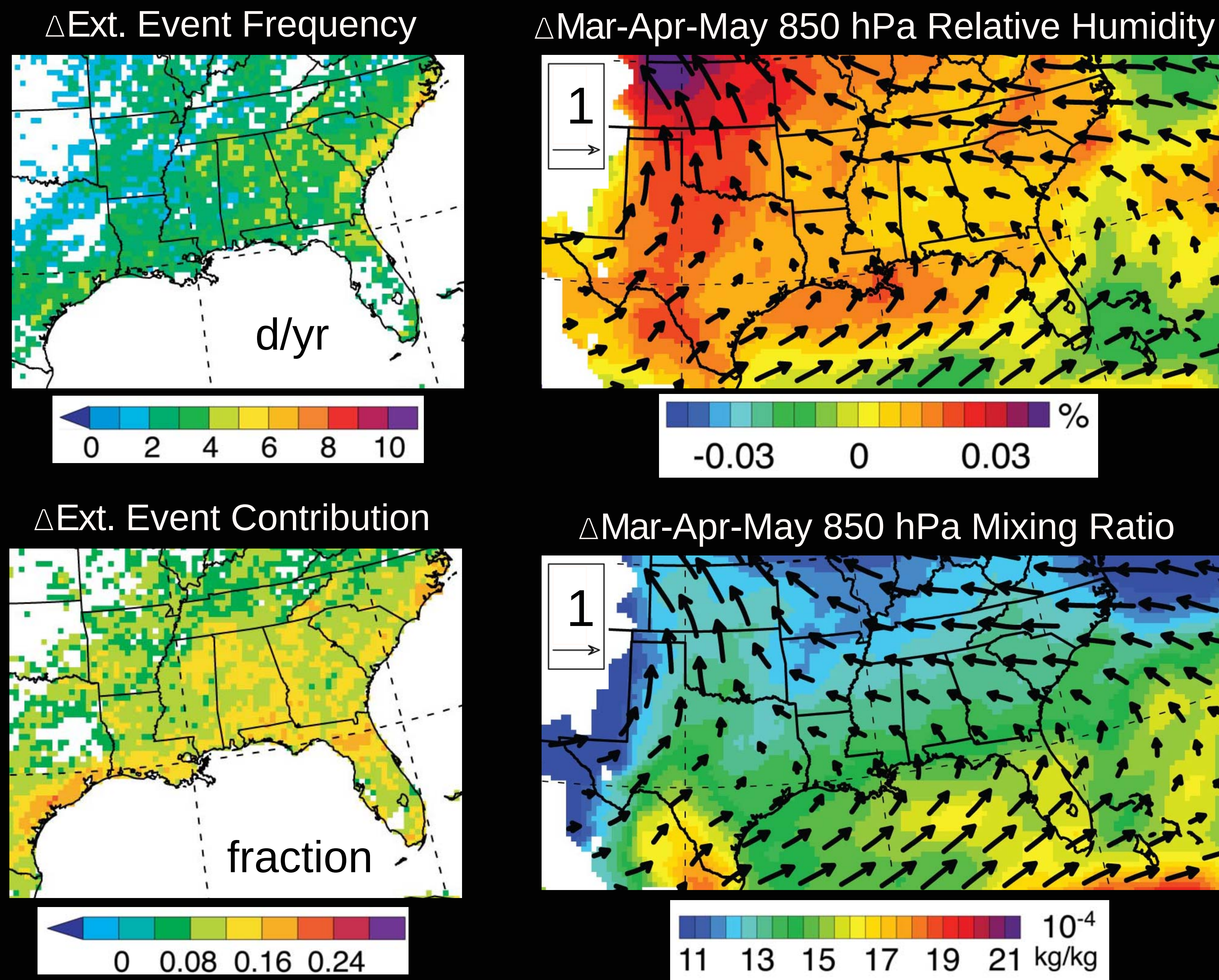




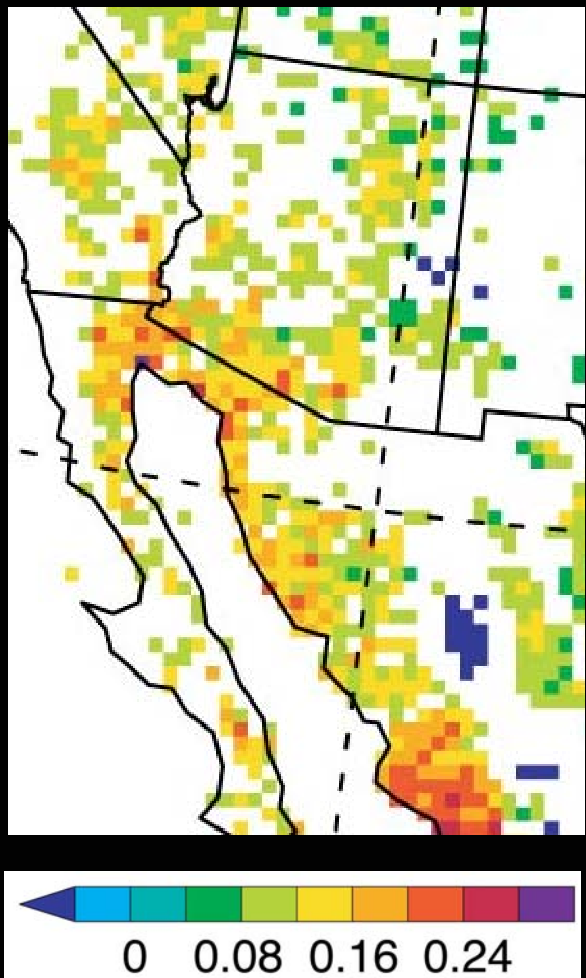
- weakening of Pacific rain shadows



- enhanced cyclonic flow aloft = steering from the subtropics, greater atmospheric instability

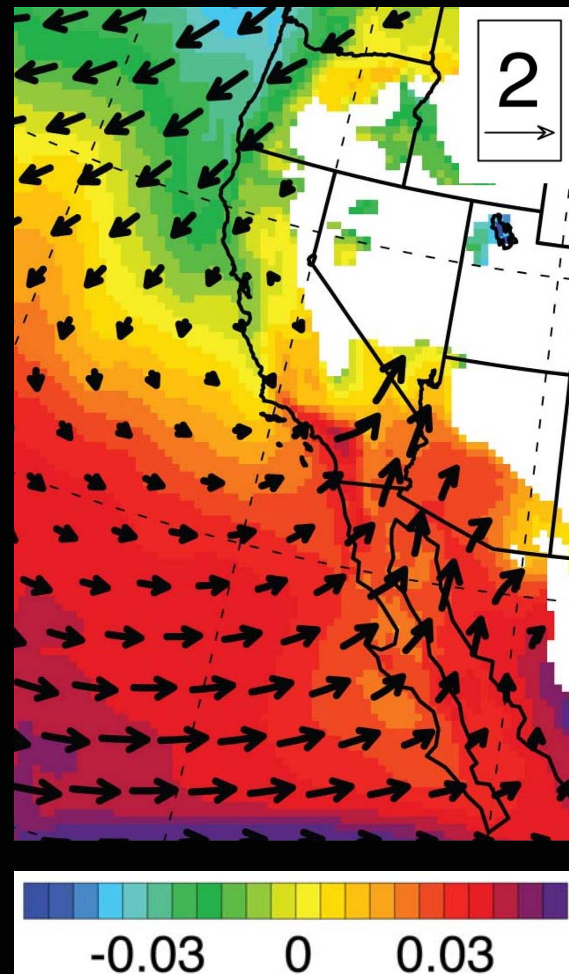

ΔExt. Event Frequency
d/yr
0 2 4 6 8 10
ΔMar-Apr-May 850 hPa Relative Humidity
1
%
-0.03 0 0.03
ΔExt. Event Contribution
fraction
0 0.08 0.16 0.24
ΔMar-Apr-May 850 hPa Mixing Ratio
1
10-4
11 13 15 17 19 21 kg/kg

ΔExtreme Event Contribution



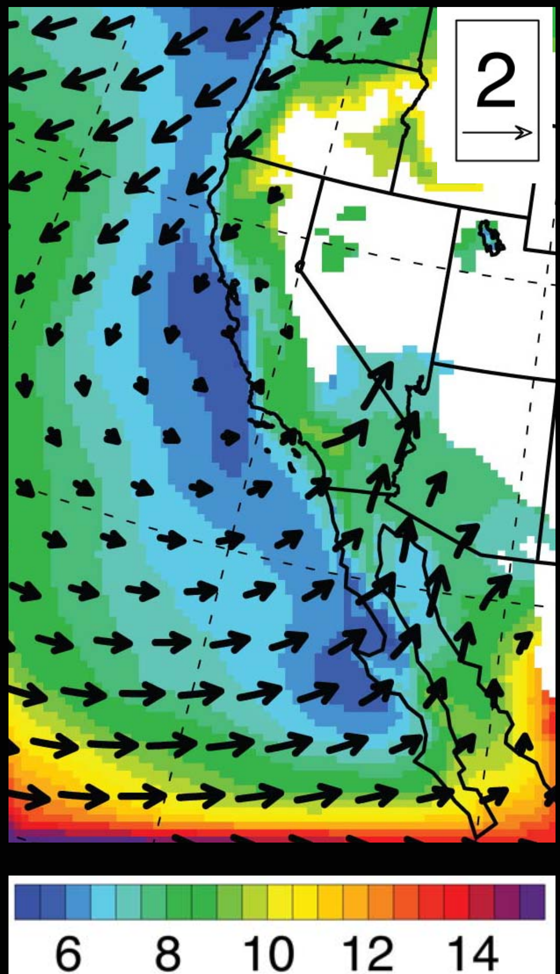
fraction

Mar-Apr-May 850 hPa Relative Humidity



%

Mar-Apr-May 850 hPa Mixing Ratio



10^{-4} kg/kg

Extreme Temperature Summary

- Hot events: substantial increases in frequency and duration
- Cold events: substantial decreases in frequency and severity
- Changes in large-scale circulation important
- Fine-scale snow albedo and surface moisture feedbacks regulate

Extreme Precipitation Summary

- Increases in frequency and contribution of extreme precipitation events

- Large-scale changes (enhanced cyclonic circulation, elevated atmospheric moisture content)

- Fine-scale regulation (topographic effects, land-sea contrast)

In response to elevated greenhouse forcing:

- Fine-scale processes regulate the *response* of extreme events

- Response of extreme events to could have substantial *impacts*

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