Multidimensional risk in a nonstationary climate: changes in joint probability of extreme conditions in space and time

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August Complex, Ruth Lake, September 27, 2020
(Mike McMillan/US Forest Service)

What are “compound extremes”?

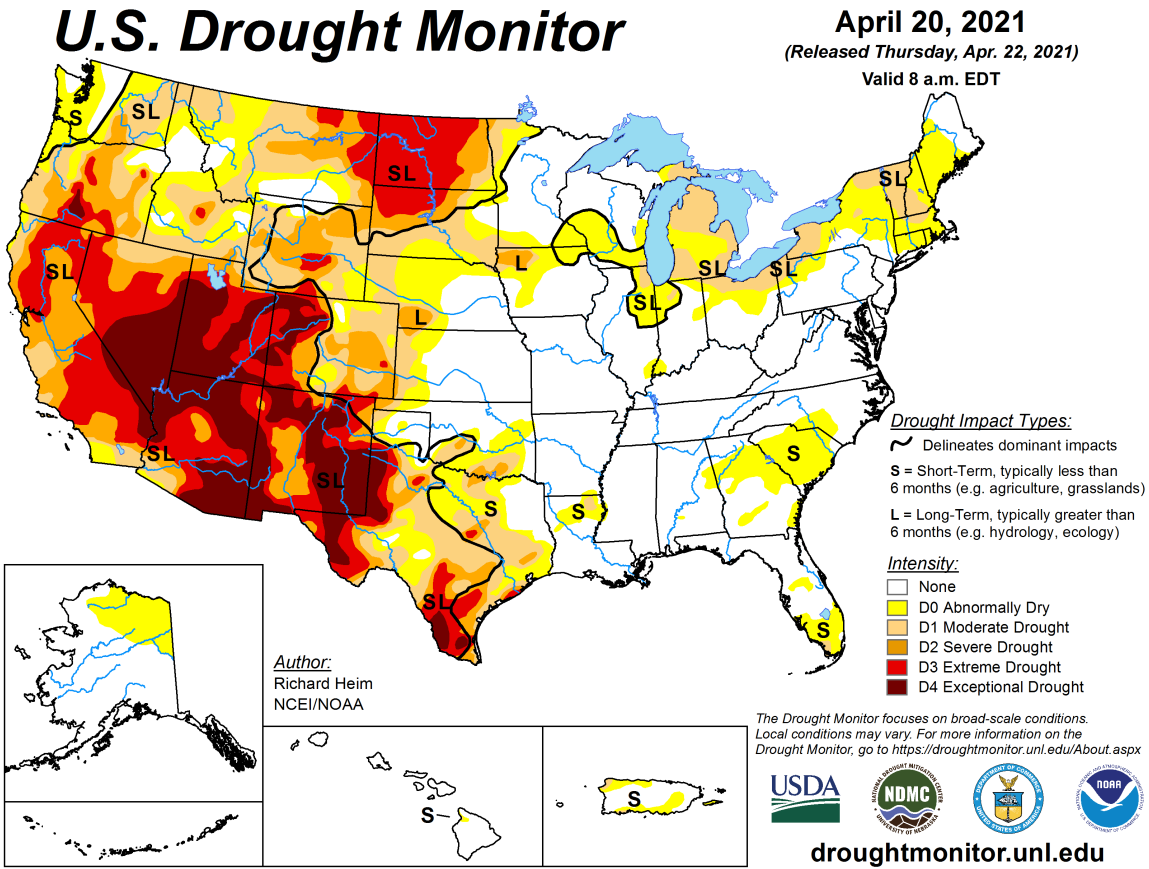
- **co-occurrence (or rapid succession) in the same place/region**

- **co-occurrence (or rapid succession) in different places/regions**

⇒ In some respects, we have been studying “compound extremes” for decades (e.g., drought indicators, wildfire weather indicators)

⇒ ***But non-stationarity is increasingly stressing natural and human systems***

Example of simple analysis: role of temperature in drought



Most of western US currently in drought

(large areas in extreme/ exceptional drought)

Many studies of previous droughts in western US and around the world….

Anthropogenic warming has increased drought risk in California

Noah S. Diffenbaugh[a,b,1], Daniel L. Swain[a], and Danielle Touma[a]

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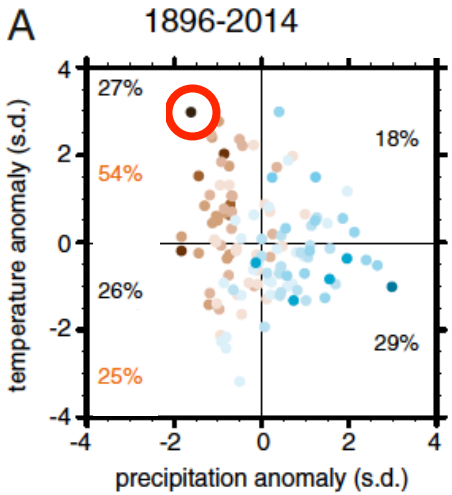
Edited by Jane Lubchenco, Oregon State University, Corvallis, OR, and approved January 30, 2015 (received for review November 22, 2014)

California is currently in the midst of a record-setting drought. The drought began in 2012 and now includes the lowest calendar-year

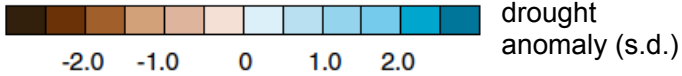
which steered Pacific storms away from California over consecutive seasons (8–11). Although the extremely persistent high

Diffenbaugh et al., 2015

Observations



O = 2014



drought anomaly (s.d.)

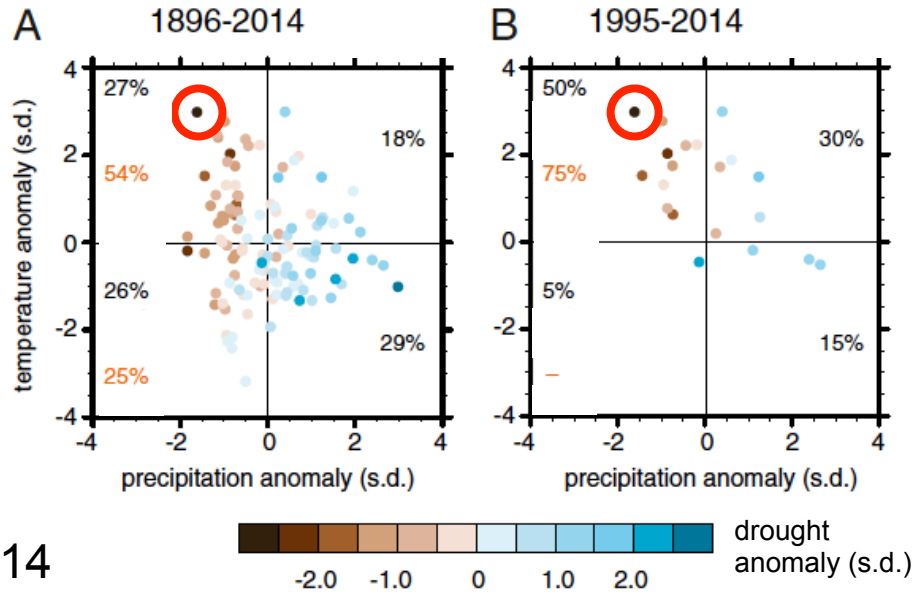
% of years that fall in quadrant

% of low precipitation years that produce drought

Historically, low precipitation years have been >2x as likely to produce drought if they co-occur with warm conditions

Diffenbaugh et al., 2015

Observations



= 2014

% of years that fall in quadrant

% of low precipitation years that produce drought

In the past two decades, 80% of years have been warm

Probability that =>

1. there is a drought
2. that low precipitation years are also warm
3. that negative precipitation years produce drought

=> have all doubled

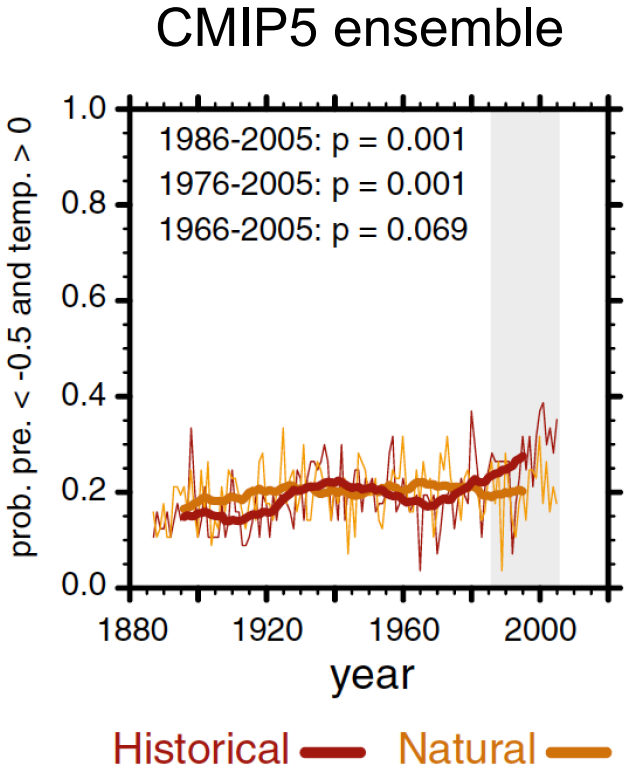
Diffenbaugh et al., 2015

How do we test cause and effect?

=> global climate models

There is very high statistical confidence that human emissions of greenhouse gases have caused:

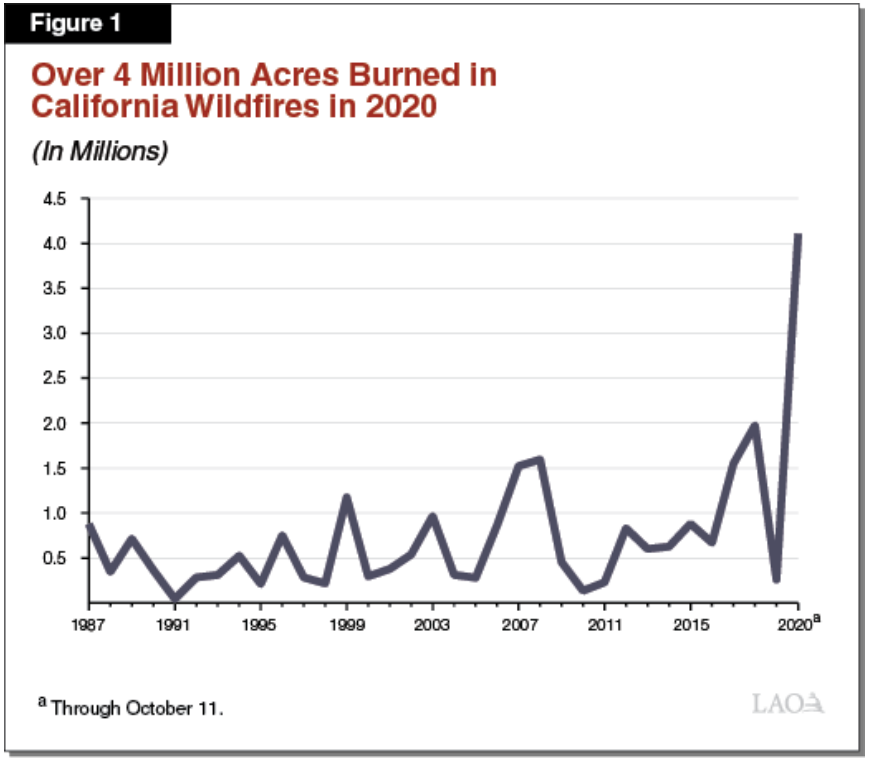
- The observed long-term warming of California
- The observed increase in the percentage of low precipitation years that are also warm



Diffenbaugh et al., 2015

Example of less simple analysis: recent California wildfires

2020 was most severe year in California's recorded history



2020 in historical context:

Largest area burned

Largest fire

5 of top 6 largest

6 of top 20 largest

=> Arose from confluence of multiple climatic and non-climatic conditions

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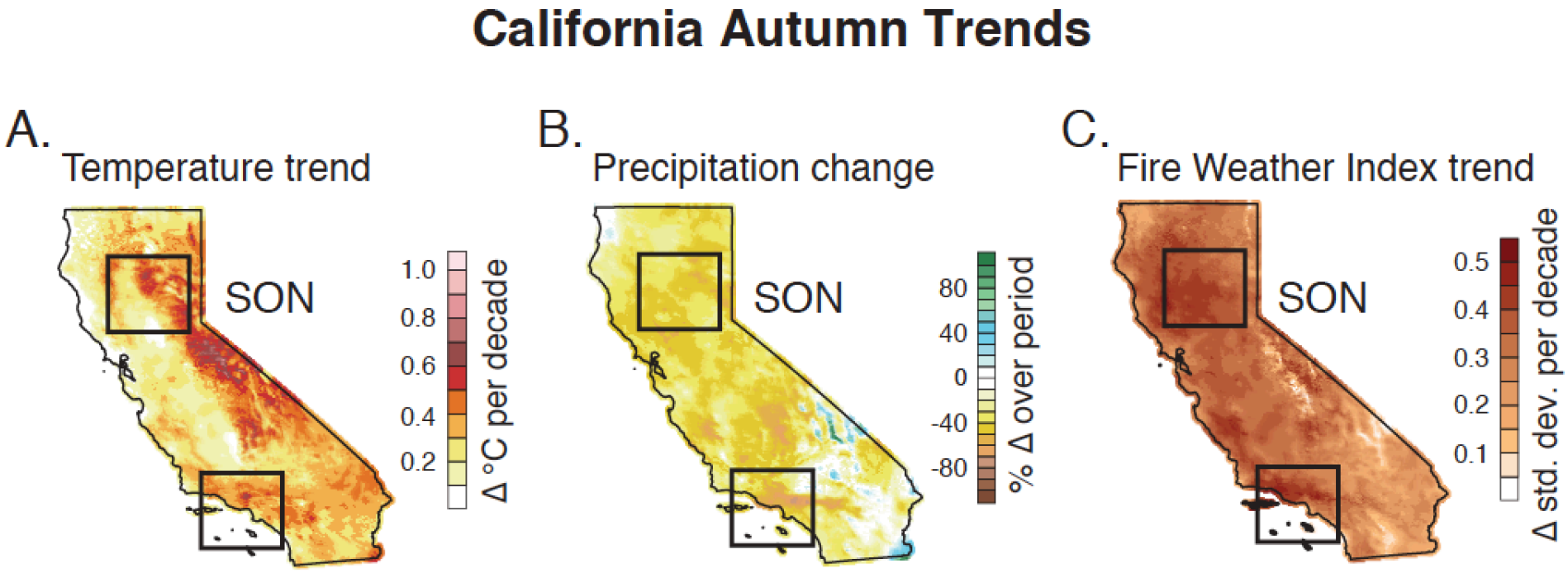
Environmental Research Letters

LETTER

Climate change is increasing the likelihood of extreme autumn wildfire conditions across California

Michael Goss[1,10], Daniel L Swain[2,3,4], John T Abatzoglou[5,6], Ali Sarhadi[1], Crystal A Kolden[5,7], A Park Williams [8] and Noah S Diffenbaugh[1,9]

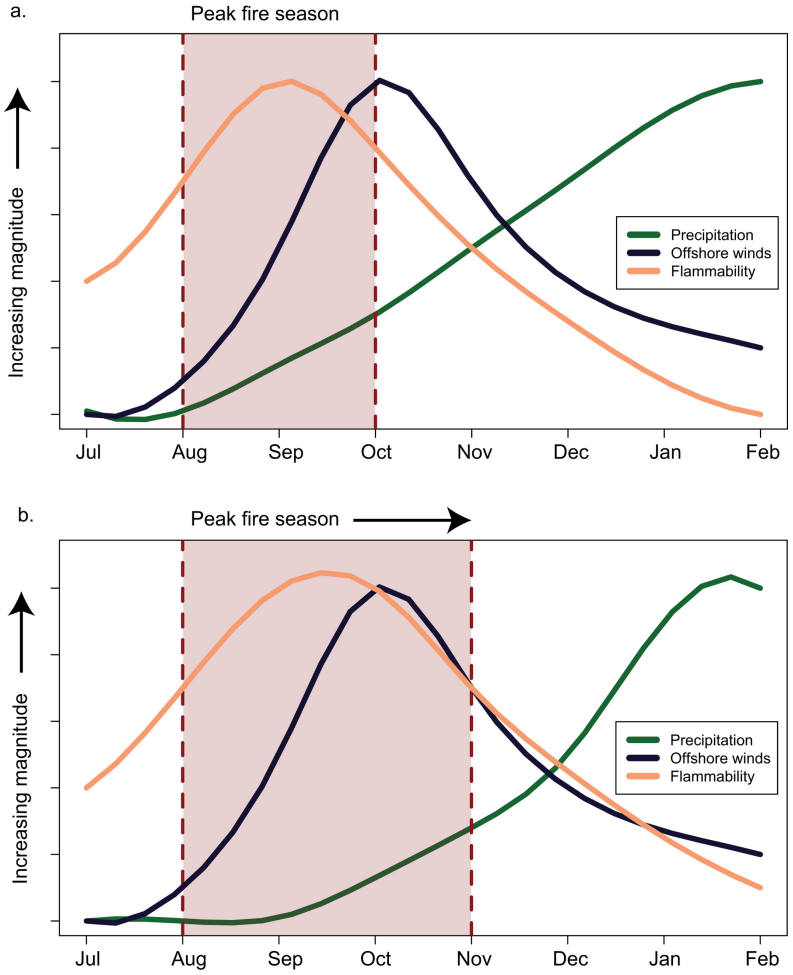
Historical trends in climate variables



Goss et al., 2020

(Even) with no change in winds, (i) warming of late-summer and autumn and (ii) delayed onset of rainy season will each increase occurrence of weather conditions conducive to large, destructive wildfires

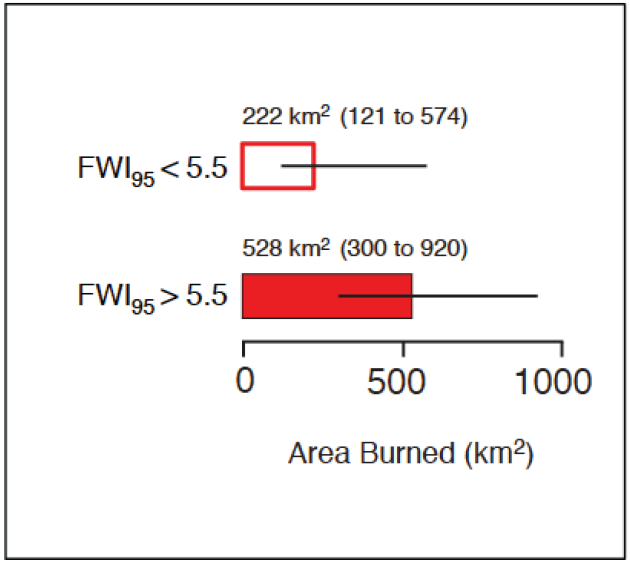
=> What are implications of rising “compound” risk?



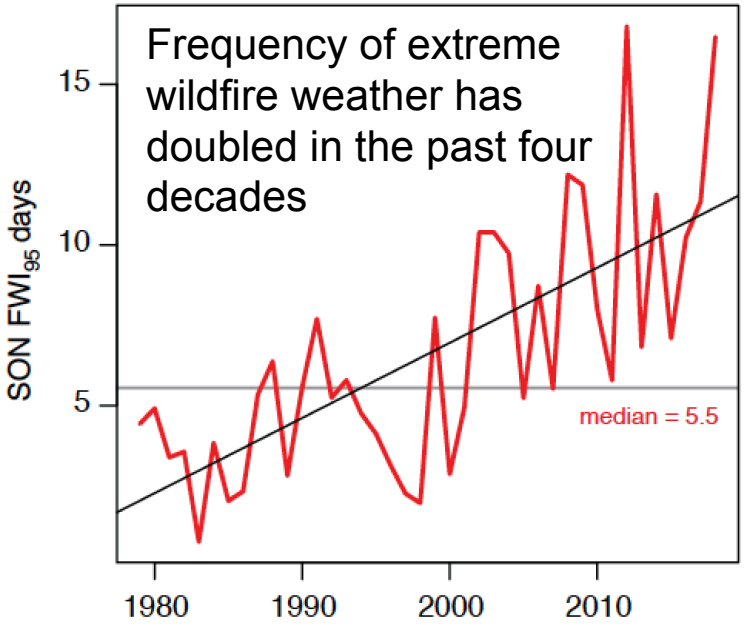
Swain, 2021

Influence of extreme wildfire weather on wildfire risk

Mean Autumn Area Burned (1984-2018)
for SONs with FWI_{95} days above/below median



California Frequency of Autumn Days
with mean FWI exceeding 95th percentile (FWI_{95})



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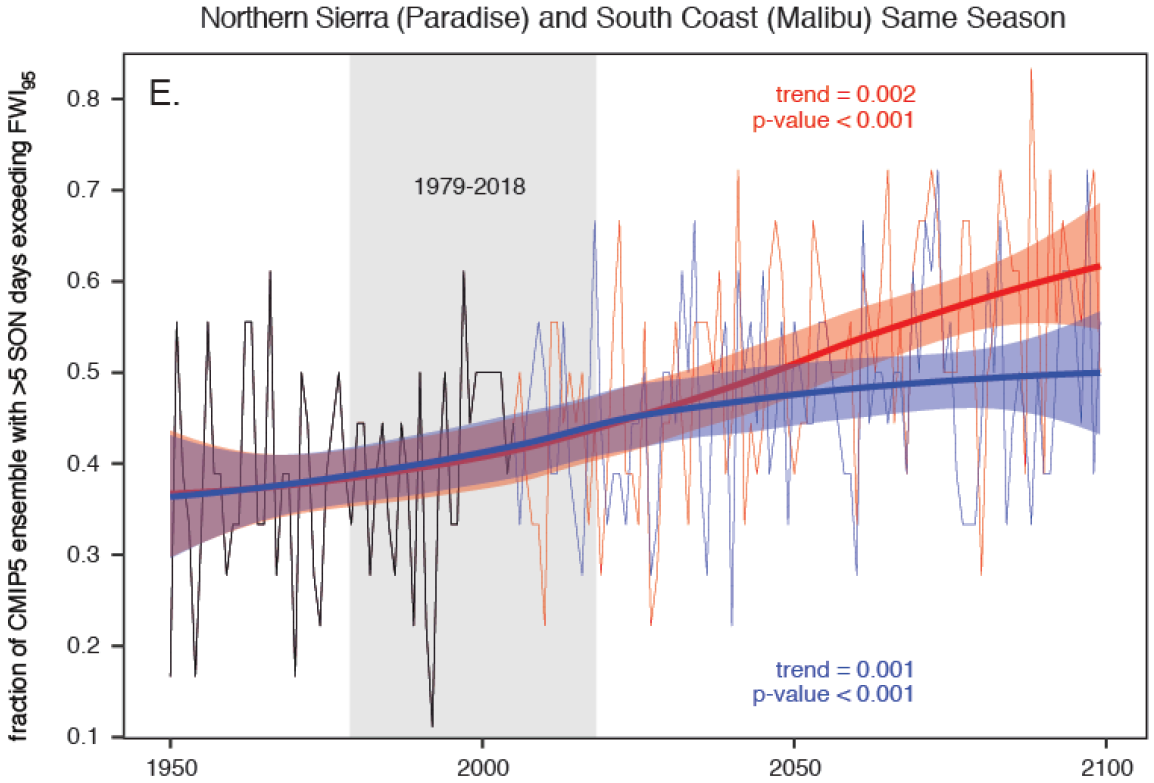
Goss et al., 2020

What are risks now and in the future?

=> Spatial co-occurrence is critical for wildfire response resources

What are risks now and in the future?



RCP8.5

RCP4.5

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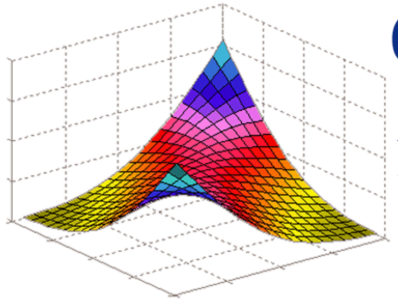
Goss et al., 2020

Changes in the spatial co-occurrence of extreme conditions is critical for a number of climate-sensitive concerns, including:

- agricultural markets
- food security
- poverty vulnerability
- supply chains
- weather-related insurance and reinsurance
- disaster preparedness and recovery

Is there a way to more rigorously quantify probability of spatial co-occurrence in non-stationary climate?



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FOR
HYDROLOGY
AND
CLIMATE

UNIVERSITY OF CALIFORNIA IRVINE, JUL 28 - AUG 1, 2014

SCIENCE ADVANCES | RESEARCH ARTICLE

CLIMATOLOGY

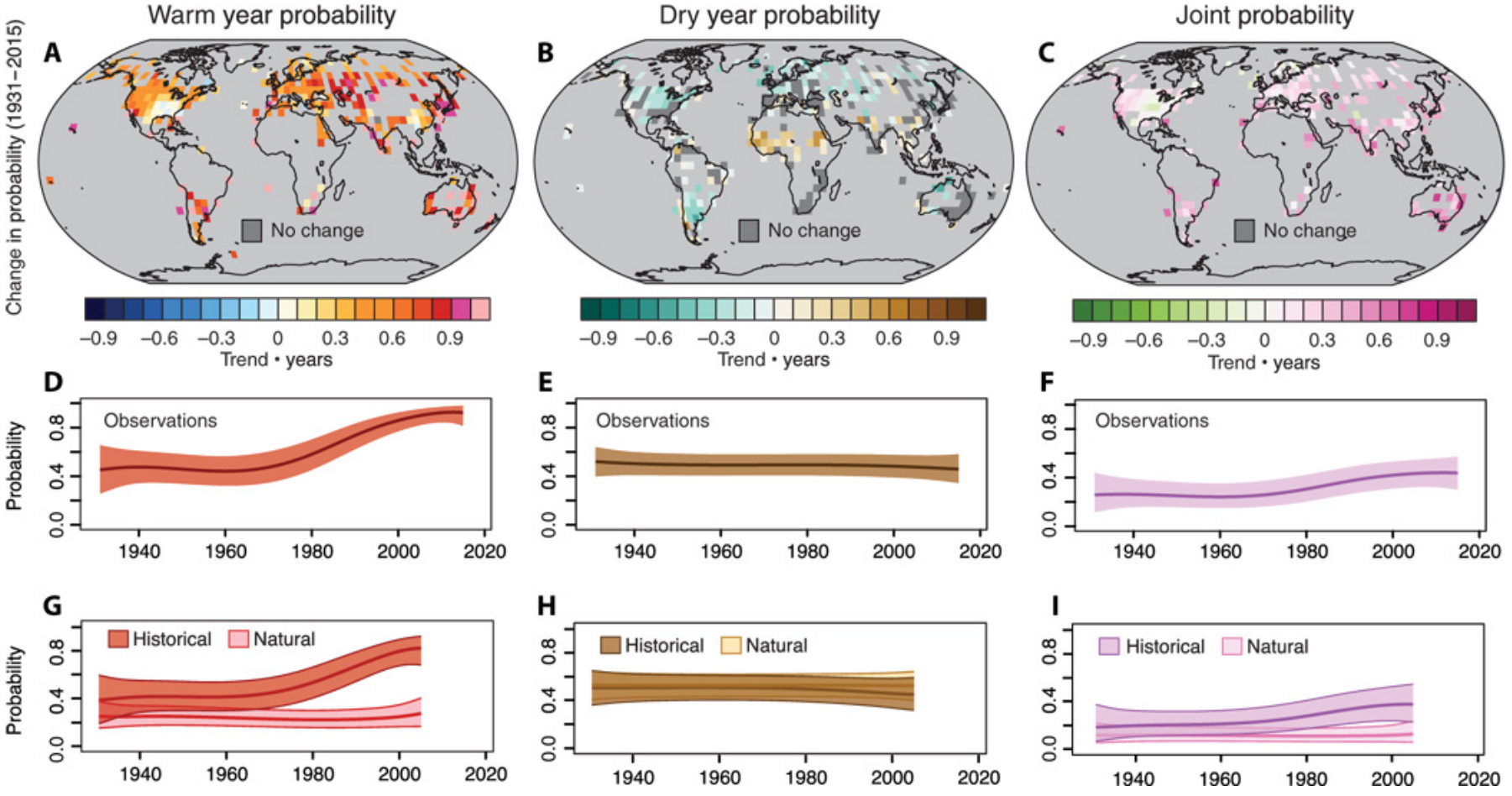
Multidimensional risk in a nonstationary climate: Joint probability of increasingly severe warm and dry conditions

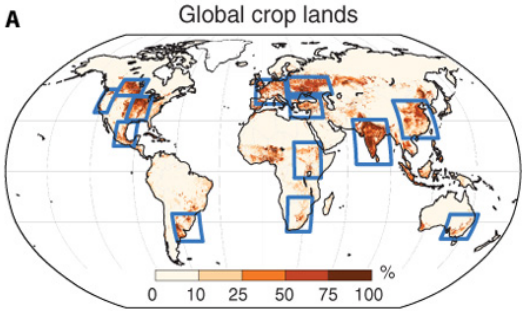
Ali Sarhadi[1,2]*, María Concepción Ausín[3,4], Michael P. Wiper[3], Danielle Touma[1], Noah S. Diffenbaugh[1,2]

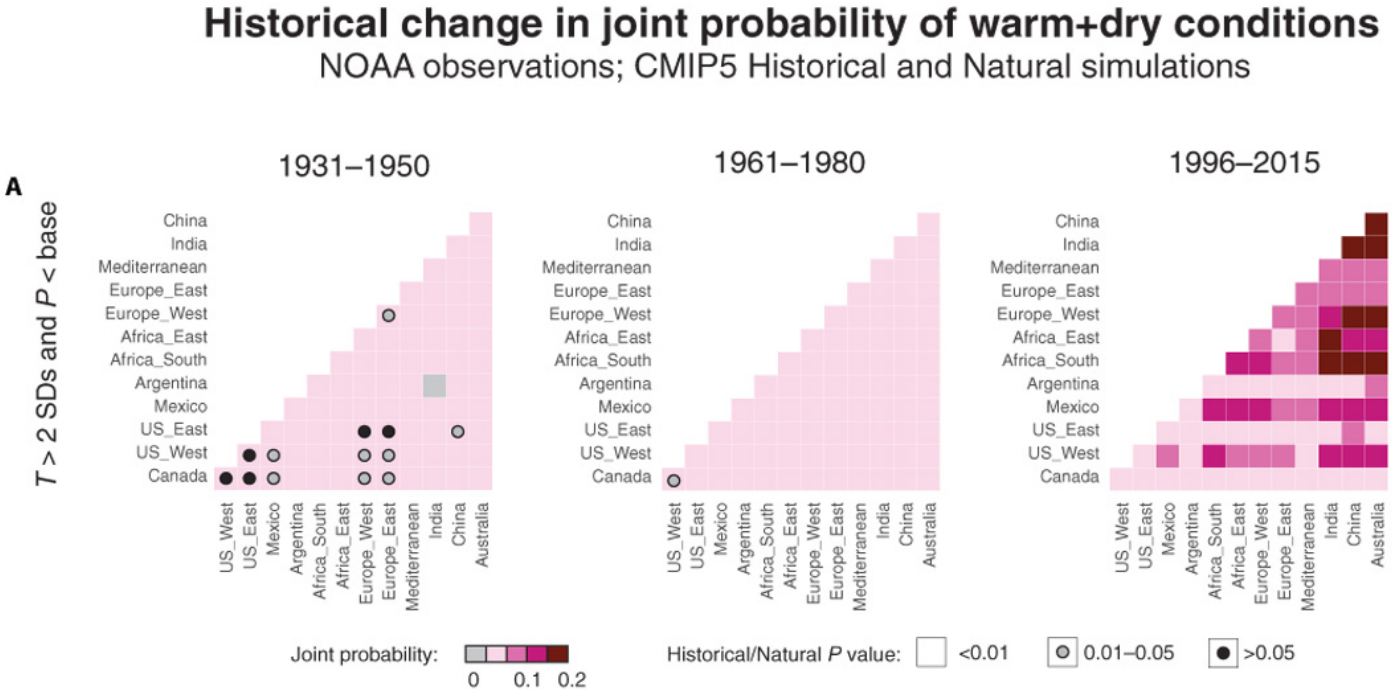
Sarhadi et al., 2018

Historical trend in probability of warm, dry, and warm+dry conditions

NOAA observations (1931–2015)

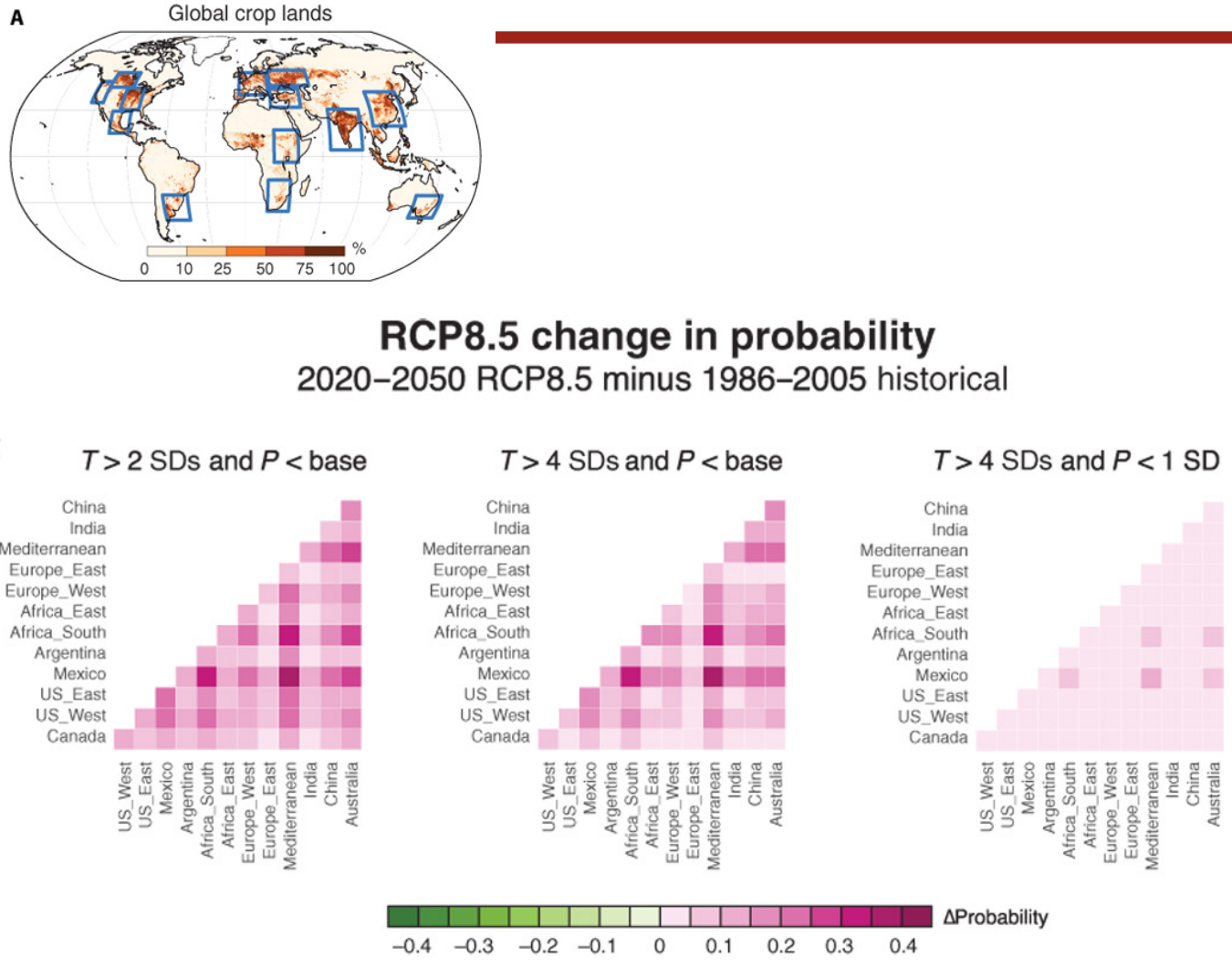






=> For example, probability that China and India experience below-mean precipitation and >2-SD temperature in same year has grown from <0.05 to >0.15

Sarhadi et al., 2018



=> And these changes in joint probability of extreme warm+dry conditions are very likely to intensify in response to further global-scale warming

Sarhadi et al., 2018

Quantifying probability of spatial co-occurrence of extreme conditions in non-stationary climate

⇒ Can use this type of approach to quantify joint probability of co-occurring extremes to specific impact metrics:

- extreme wildfire weather
- agricultural yields
- extreme events in multiple climate variables
- etc…

Thank you!