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science for a changing world

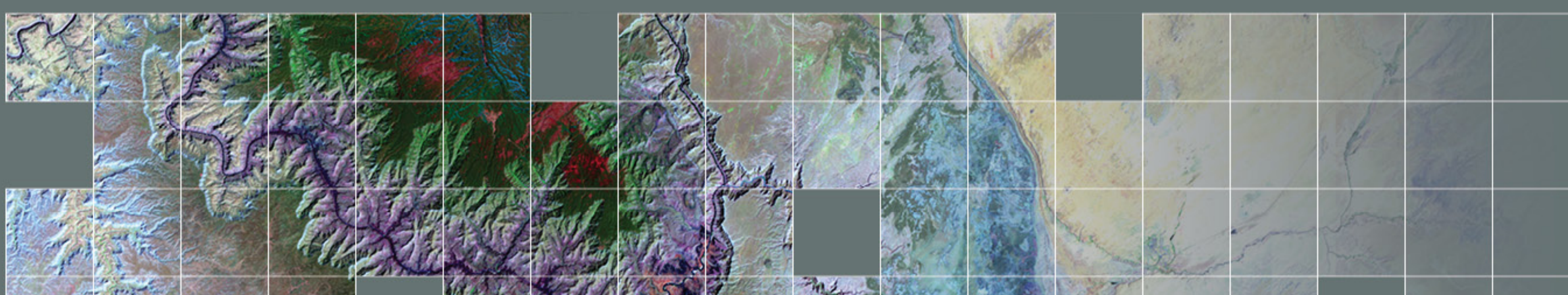
Climate Hazards Center
UC SANTA BARBARA

USAID
FROM THE AMERICAN PEOPLE

Climate and Land Use Change
Earth Resources Observation and Science (EROS) Center

Drought, Fire, Flood: Monitoring and Modeling more Frequent Catastrophes
Walter Orr Roberts Memorial Public Lecture

Chris Funk, Director, Climate Hazards Center



Chris Funk, USGS/UCSB Climate Hazards Center

U.S. Department of the Interior
U.S. Geological Survey

Background

In 1995 I had a dream ….

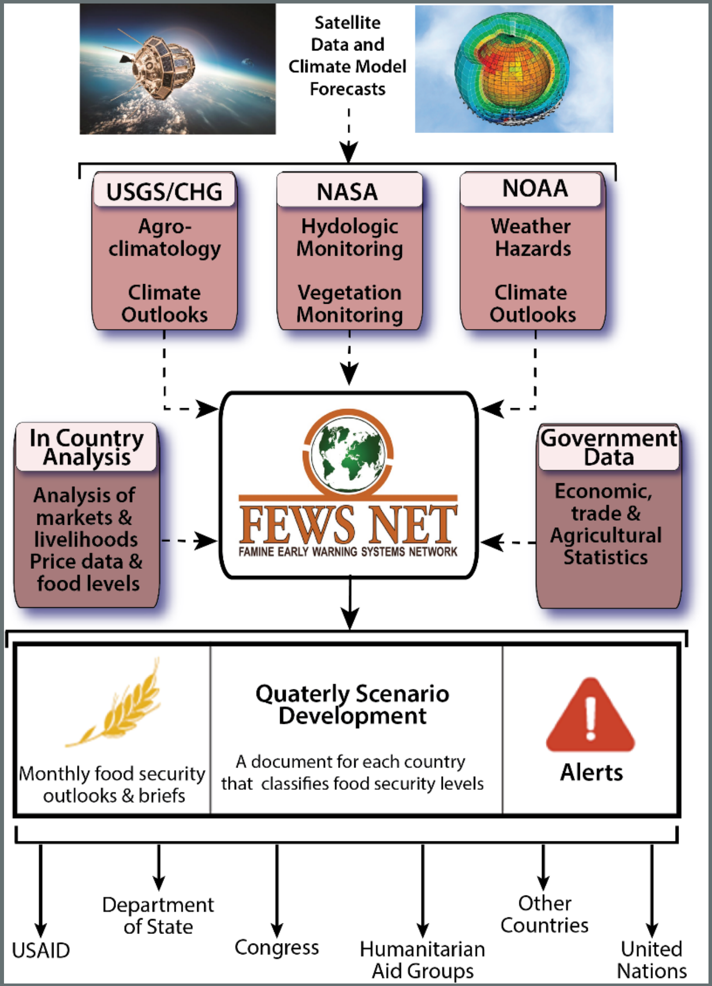
In 1996 I drove to California and started graduate school …

In 1997 became fascinated by potential humanitarian applications of climate science and satellite data …

And remain so today …

Famine Early Warning Systems Network

An activity of the USAID Office of Food for Peace



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"to ensure that appropriate…emergency food aid is provided to the right people, in the right places, at the right time, and in the right way"

Climate Hazards Center

~28 papers 2018/19

~14 training workshops 2018/19

~20K downloads per month

Monthly input to FEWS NET, Harvest, SERVIR

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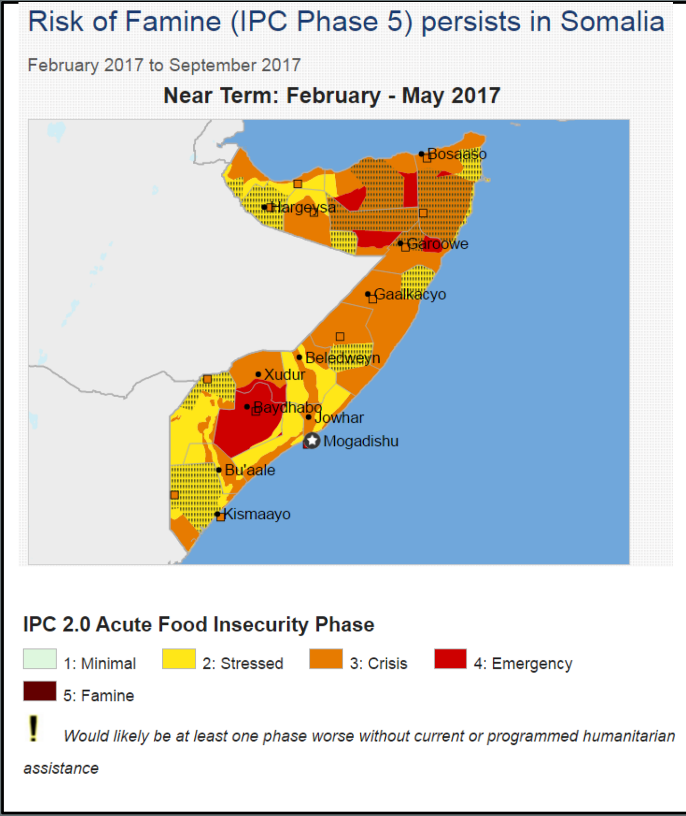
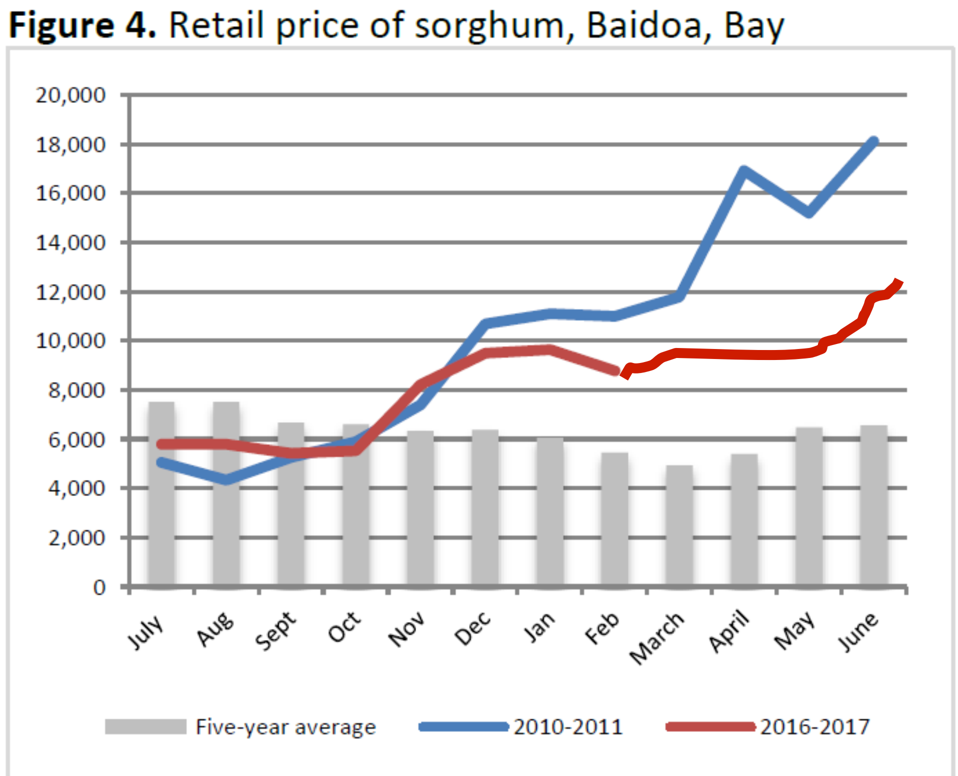
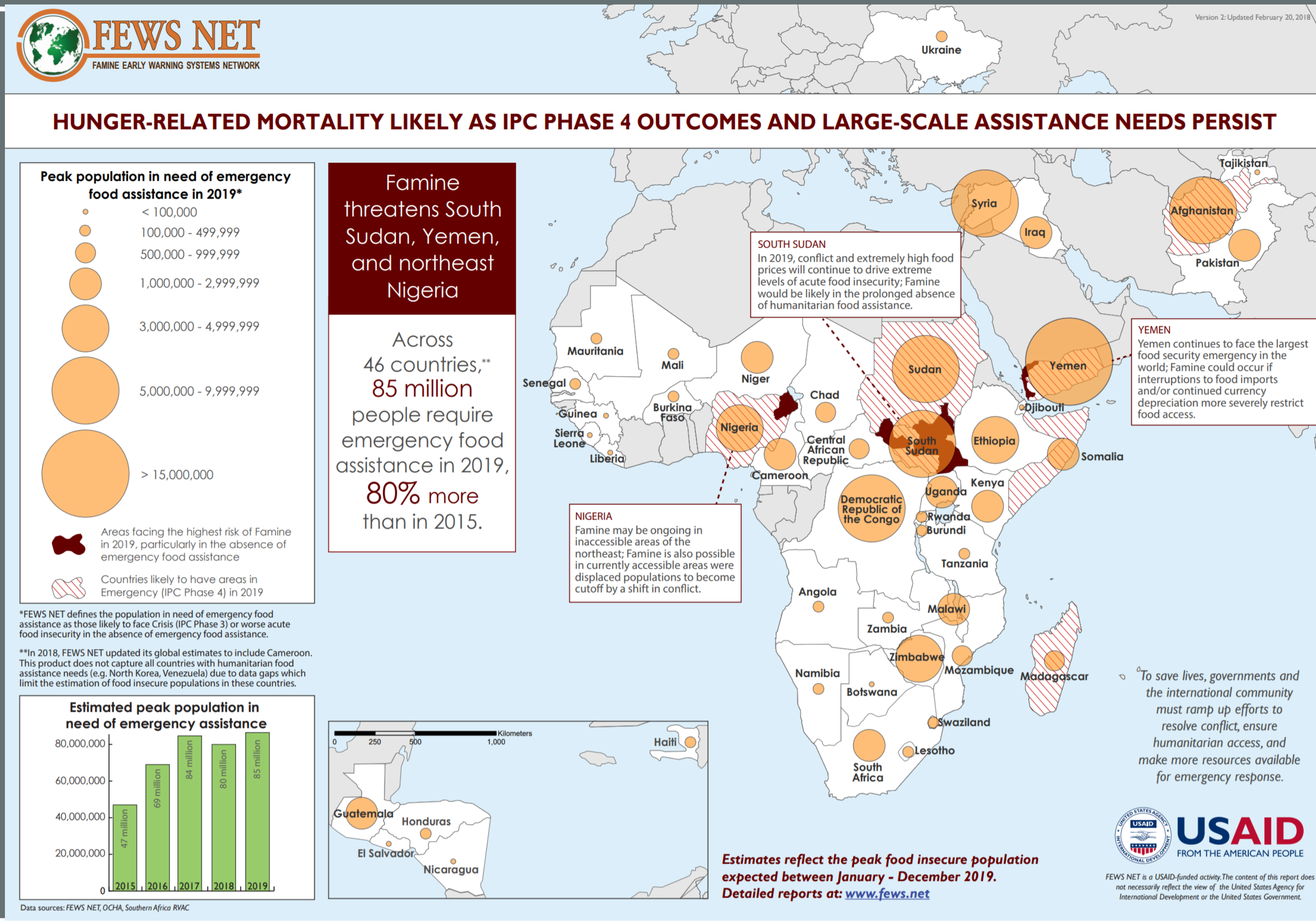
Somalia Example:
Food Shocks Can Kill, Early Warning Can Help





![USGS logo]

Context – unprecedented levels of Food Insecurity – 85 million people



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Eight-Five million people is equivalent to the combined of population of New York, Los Angeles, Washington, Boston, Chicago, London, Rome, Mexico, Tokyo, Delhi, Sydney, Moscow and Shanghai.

How many people is 85 million?

Enough people to
circle the globe ~13 times!

~1 out of 100 face severe
food insecurity now

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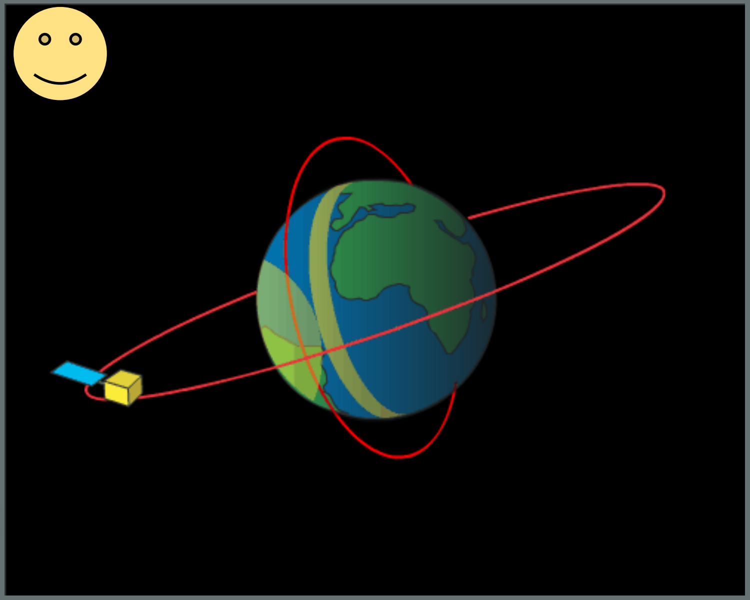
Overview

Understanding HOW Warmer Temperatures Contribute to Extremes

Increasing Food Insecurity and More Frequent Catastrophes



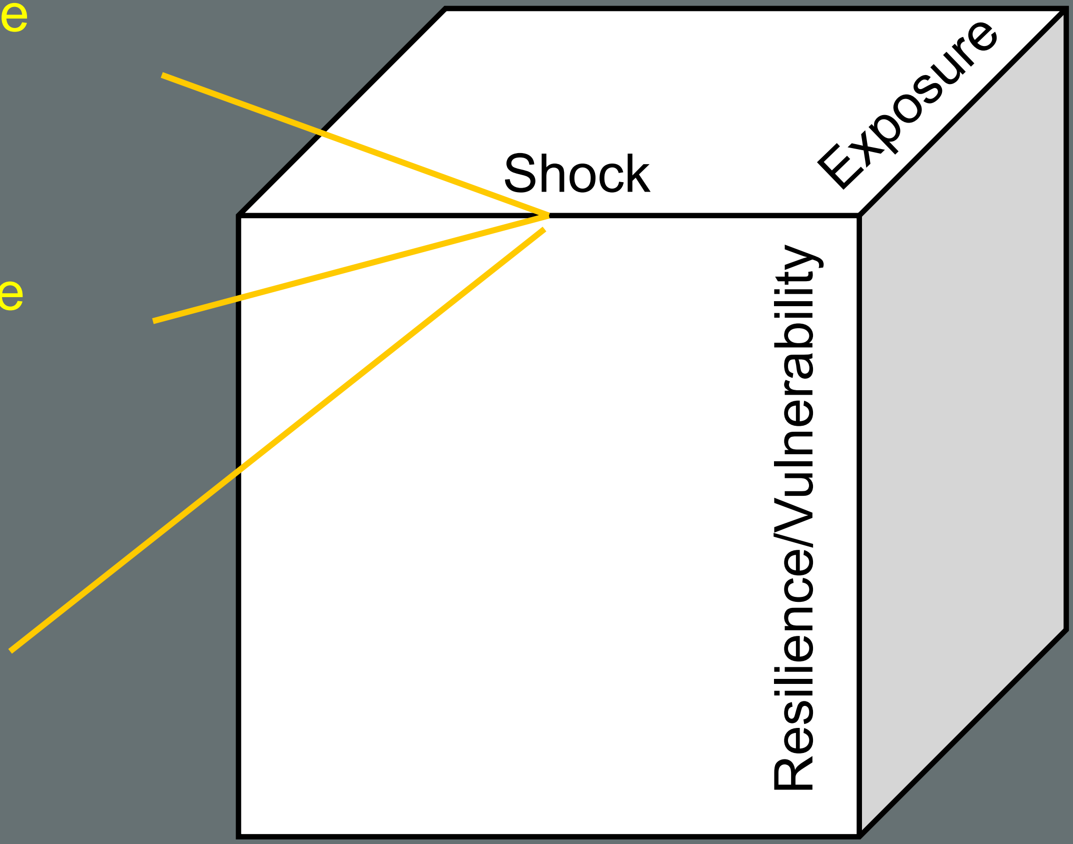
Designing and Implementing Integrated Systems to Monitor and Predict Extremes

Climate Hazards operate on multiple dimensions

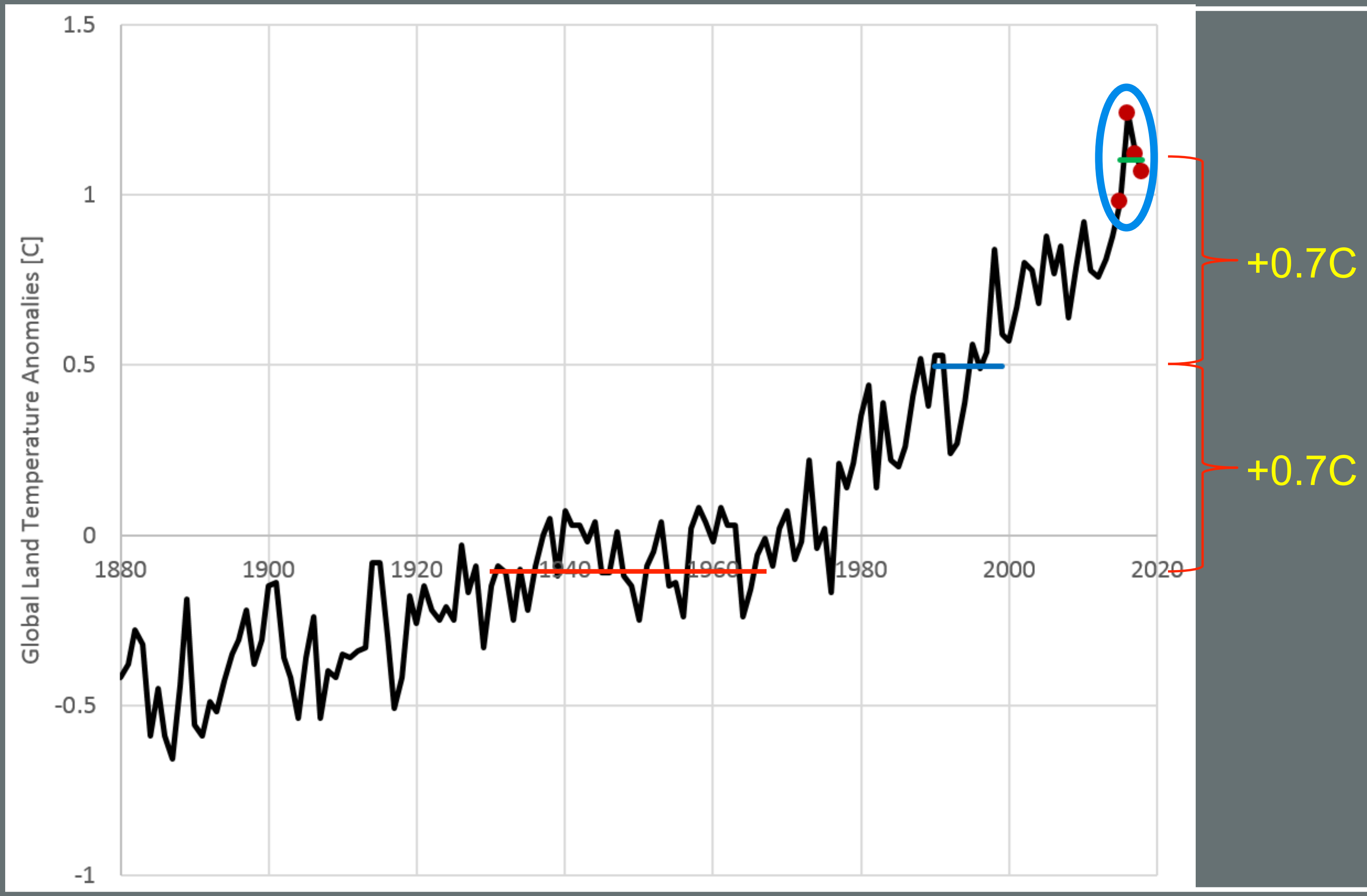
Climate change can increase atmospheric drying

Climate change can increase precipitation extremes

Warming surface temperatures can trigger droughts



Global Air Temperatures Have Jumped Dramatically since the 1990s



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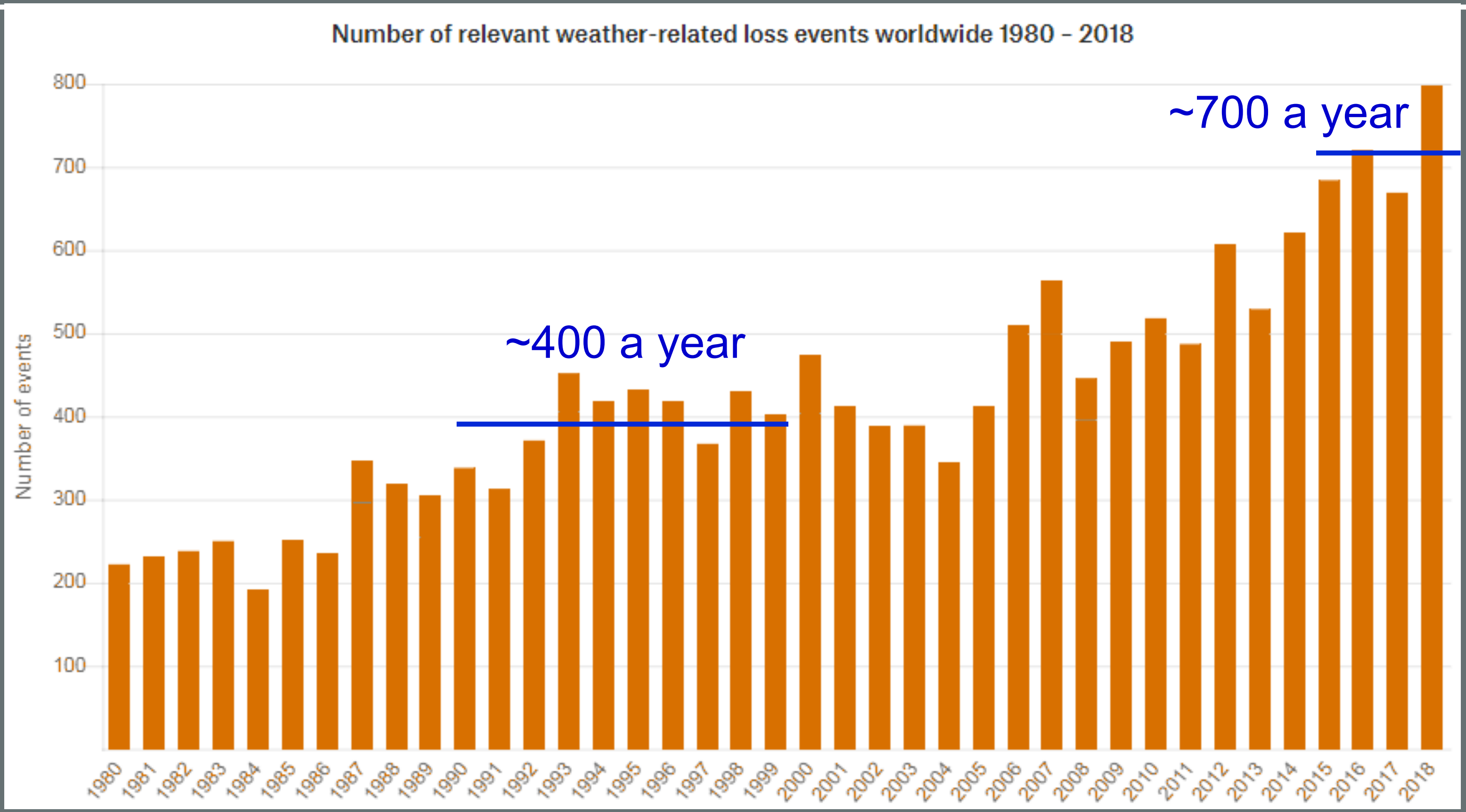
The number of weather-related loss events



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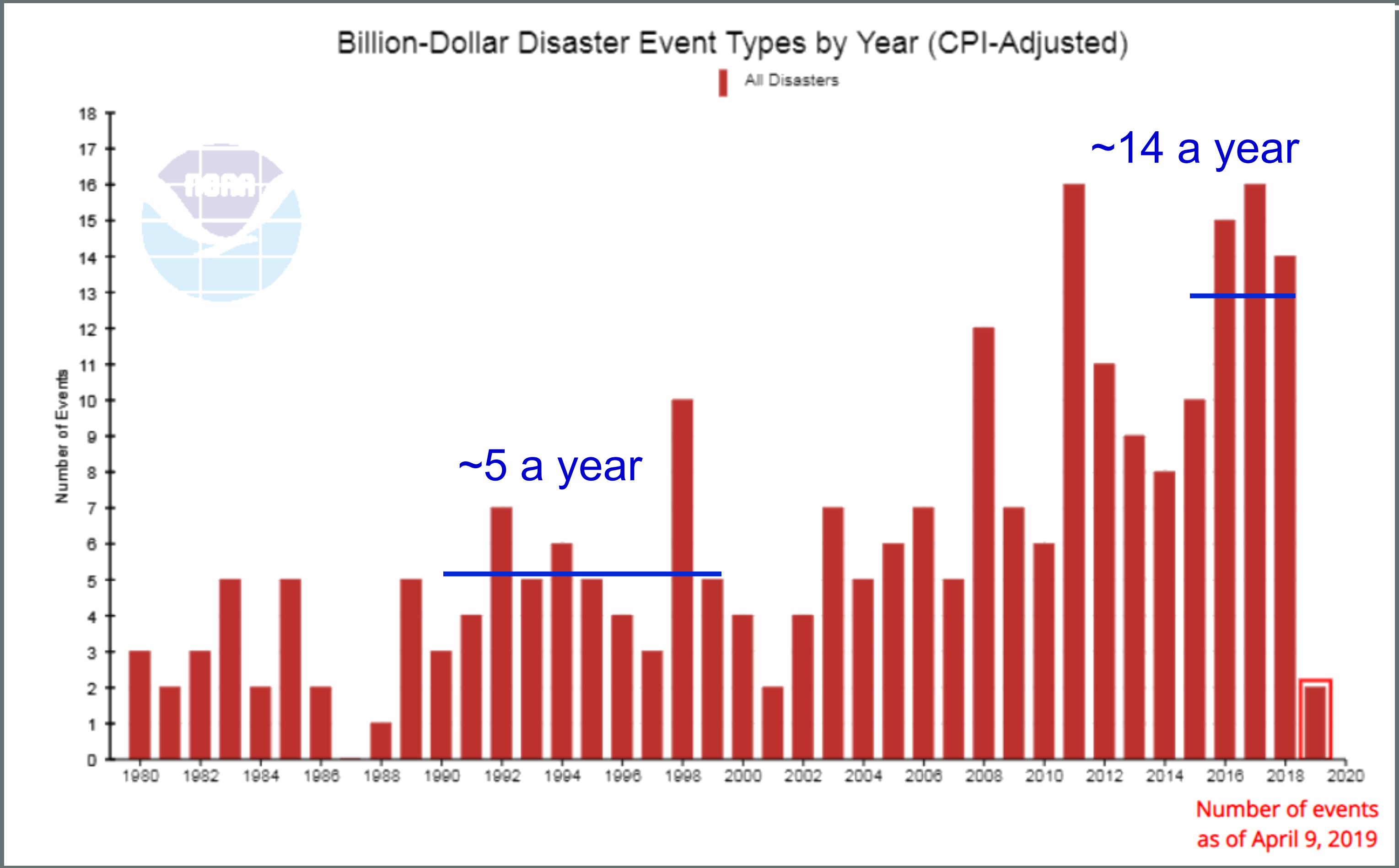
Based on the Munich Re reinsurance company's natural catastrophe database

The number of $1 Billion Dollar US Disasters is increasing



Total 2015-2018 CPI Adjusted Losses: $481 billion

Aon Benfield Loss Events

Exhibit 1: Top 10 Global Economic Loss Events

Date(s)	Event	Location	Deaths	Economic Loss (USD)	Insured Loss (USD)
Aug. 25 – Sept. 2	Hurricane Harvey	United States	90	~100 billion	~30 billion
September 18-22	Hurricane Maria	Caribbean Islands	Hundreds+	~65 billion	~27 billion
September 4-12	Hurricane Irma	U.S., Caribbean Islands	134	~55 billion	~23 billion
October	Wildfires	United States	43	13 billion	11 billion
Summer	Flooding	China	116	7.5 billion	300 million
Summer & Autumn	Drought	Southern Europe	N/A	6.6 billion	700 million
September 19	Earthquake	Mexico	370	4.5 billion	1 billion
July	Flooding	China	37	4.5 billion	125 million
August 23-25	Typhoon Hato	China	22	3.5 billion	250 million
May 8-11	Severe Weather	United States	0	3.4 billion	2.6 billion
			All Other Events	90 billion	38 billion
			Totals	**353 billion[1]**	**134 billion[1,2]**

Exhibit 2: Significant 2017 Economic Loss Events[3]

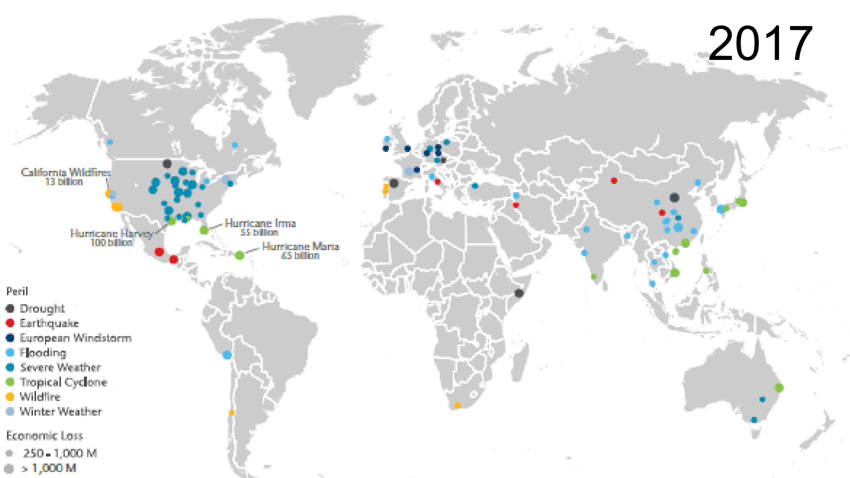
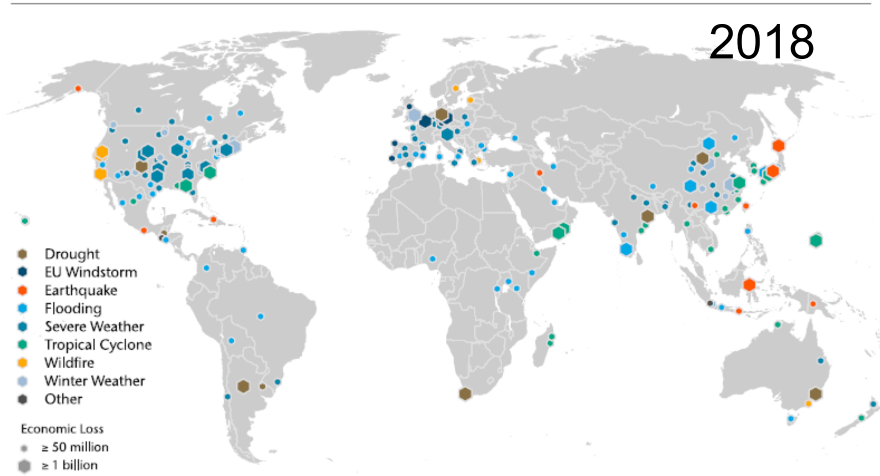


Exhibit 1: Top 10 Global Economic Loss Events

Date(s)	Event	Location	Deaths	Economic Loss (USD)	Insured Loss (USD)
October 10-12	Hurricane Michael	United States	32	17.0 billion	10.0 billion
September 13-18	Hurricane Florence	United States	53	15.0 billion	5.3 billion
November	Camp Fire	United States	88	15.0 billion	12.0 billion
September 4-5	Typhoon Jebi	Japan	17	13.0 billion	8.5 billion
July 2-8	Flooding	Japan	246	10.0 billion	2.7 billion
Spring & Summer	Drought	Central & Northern Europe	N/A	9.0 billion	0.3 billion
September 10-18	Typhoon Mangkhut	Oceania, East Asia	161	6.0 billion	1.3 billion
July – September	Flooding	China	89	5.8 billion	0.4 billion
November	Woolsey Fire	United States	3	5.8 billion	4.5 billion
August 16-19	Tropical Storm Rumbia	China	53	5.4 billion	0.3 billion
			All Other Events	123 billion	45 billion
			Totals	**225 billion[1]**	**90 billion[1,2]**

Exhibit 2: Significant 2018 Economic Loss Events[3]



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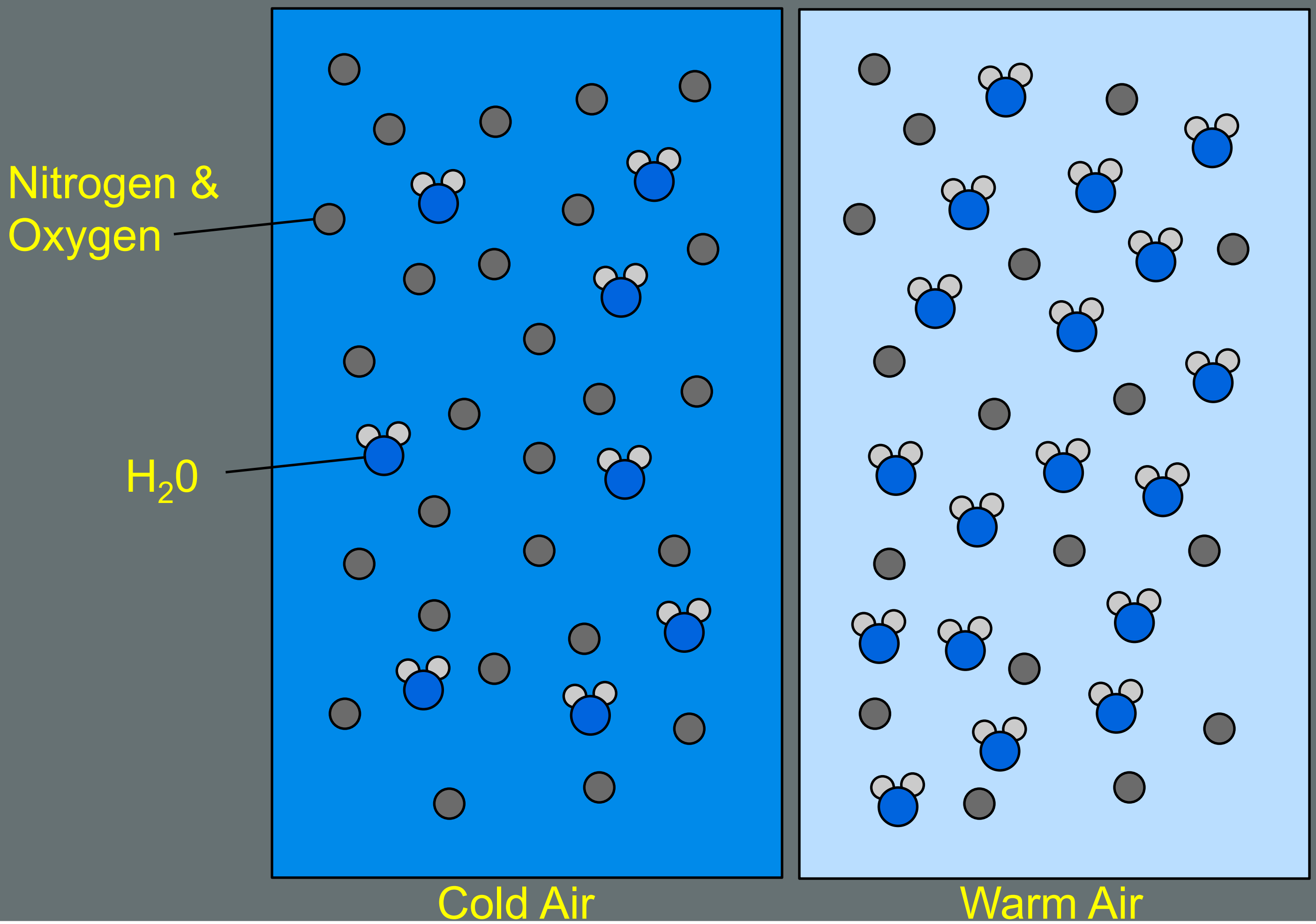
Warmer air amplifies disasters by holding more water at a given relative humidity



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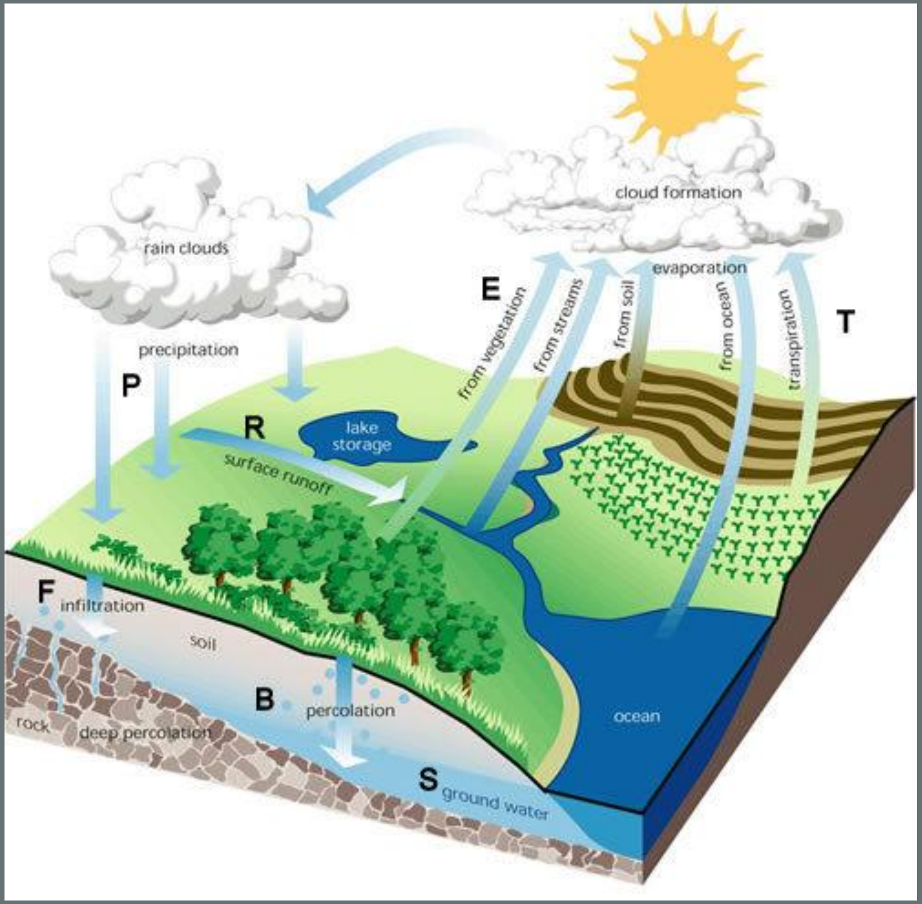
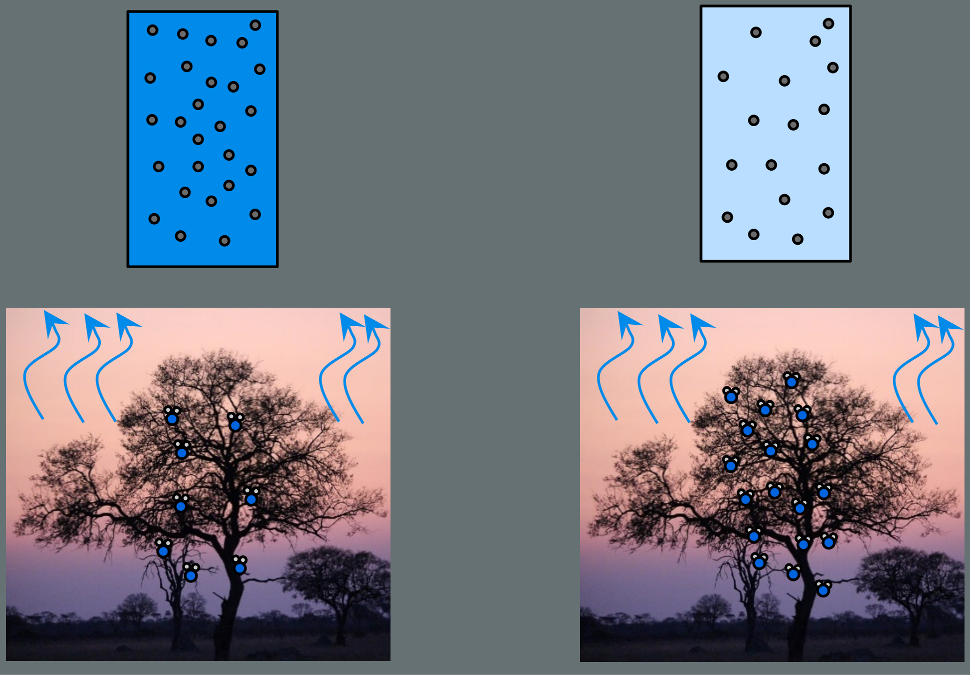
~+7% per degree Celsius

Increasing air temperatures can dry soils, plants and increases the magnitude of fires



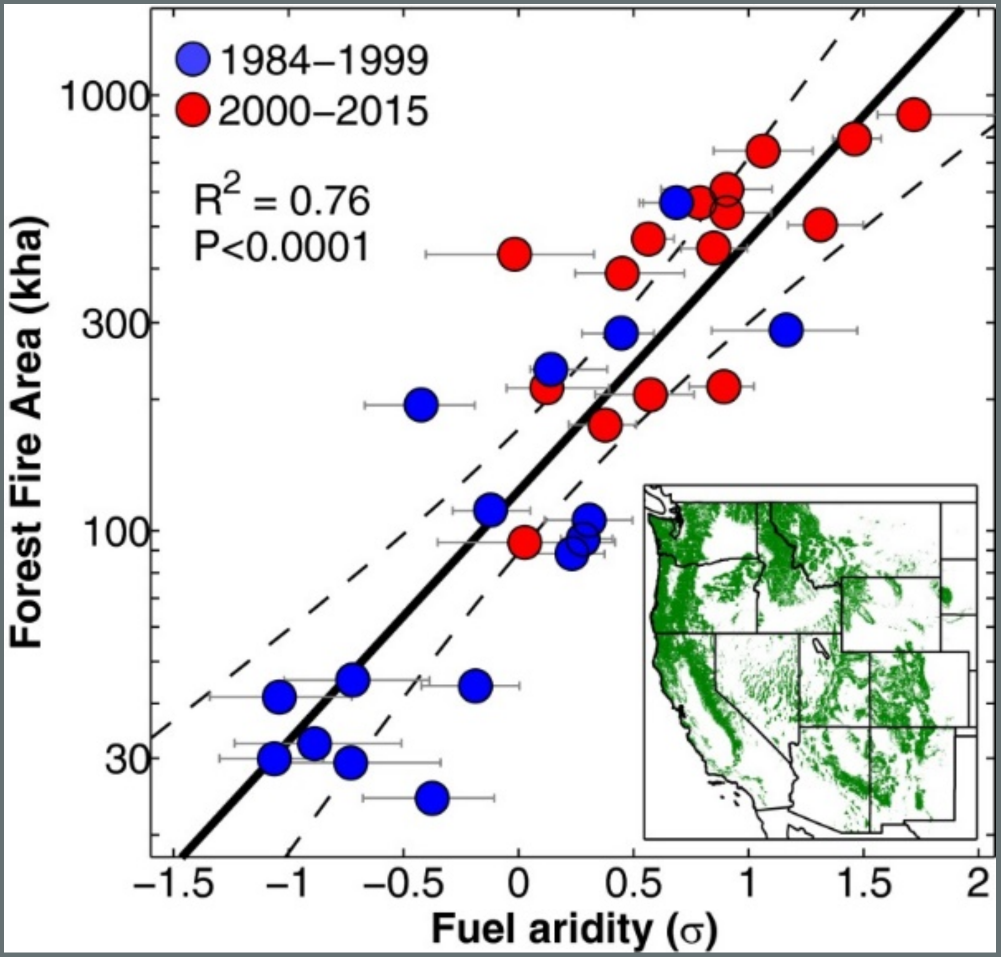
Warmer air holds more water supporting enhanced evapotranspiration



Cold Air

Warm Air

Relating Aridity to Wildfire Extent



Abatzoglou and Williams' Figure 1 from ***Impact of anthropogenic climate change on wildfire across western US forests***. The x-axis shows a measure of aridity, taking into account both precipitation and temperature. The vertical y-axis shows the total area burned in each year since 1984.

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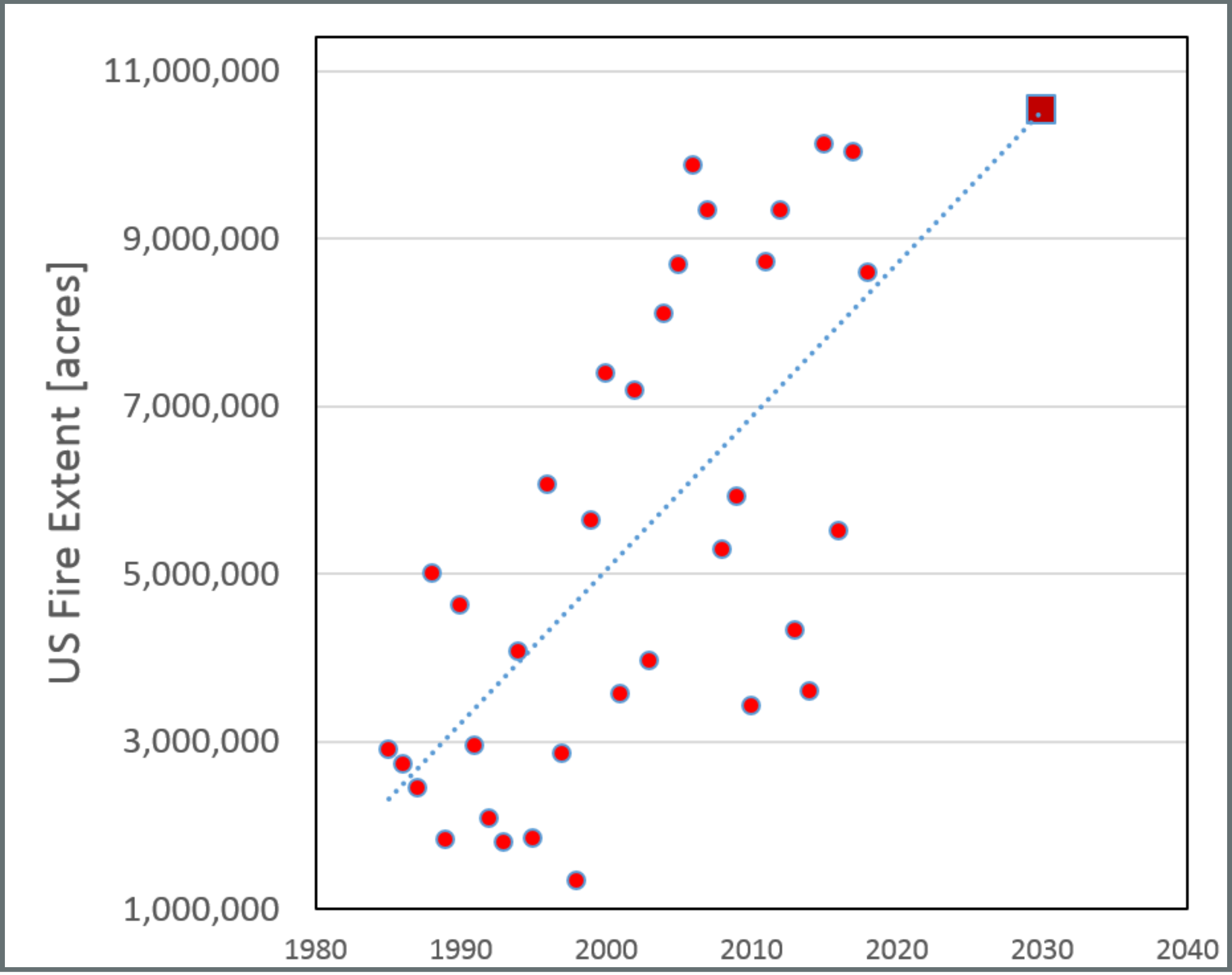
US Wildfire extents increasing



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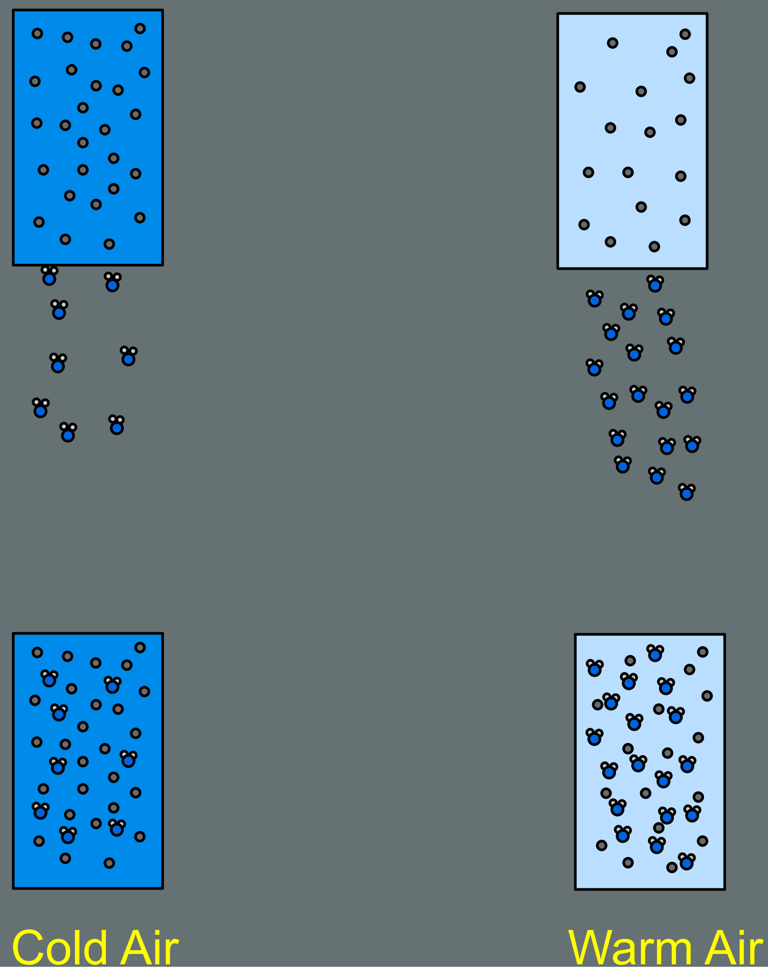
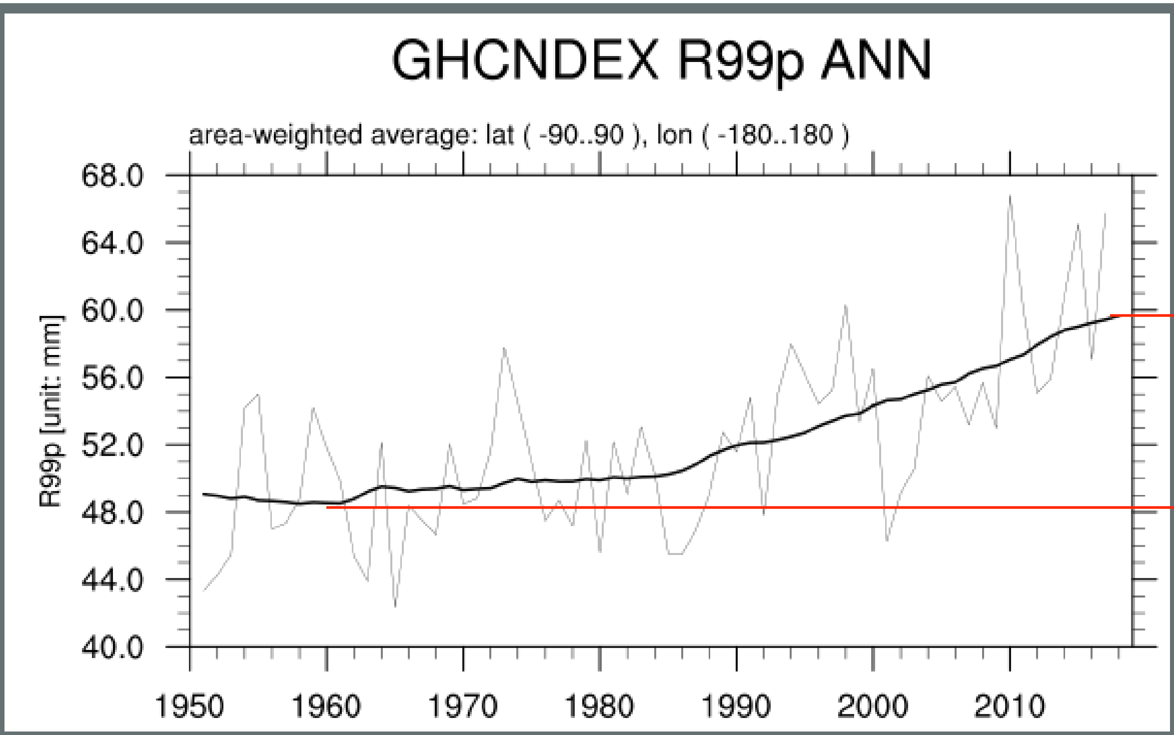
Annual US Fire Extent - acres. Trend shown with a dashed line (R^2=0.42) - along with a regression estimate for 2030 wildfire extent.

Warmer air holding more water can increase the frequency of intense flood events



~+7% per degree Celsius

Observed changes in very extreme daily rainfall totals



2.4”

1.9”

$\frac{(60-48)}{48} = 25\%$

Extremes may be increasing faster than 7% per degree Celsius

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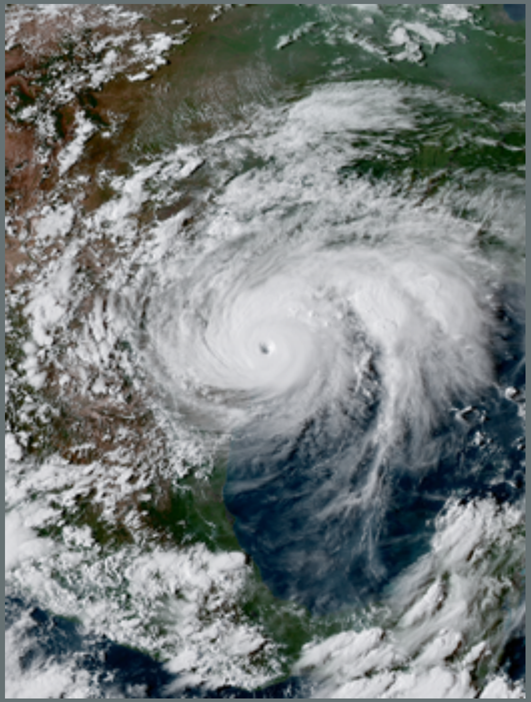
Water vapor may ‘concentrate’ climate change

- Hurricane Harvey struck the Houston area with 50” of rain in August 2017, causing ~$125 billion dollars in damage.
- 9 TRILLION gallons of water is equivalent to a cube of water two miles long, two miles wide and two miles high.
- The total energy associated with evaporating 9 billion gallons of water is about 76 quintillion Joules
- In 2017, the world consumed about 630 quintillion Joules of energy – or just 8.3 times the amount of energy released by Harvey



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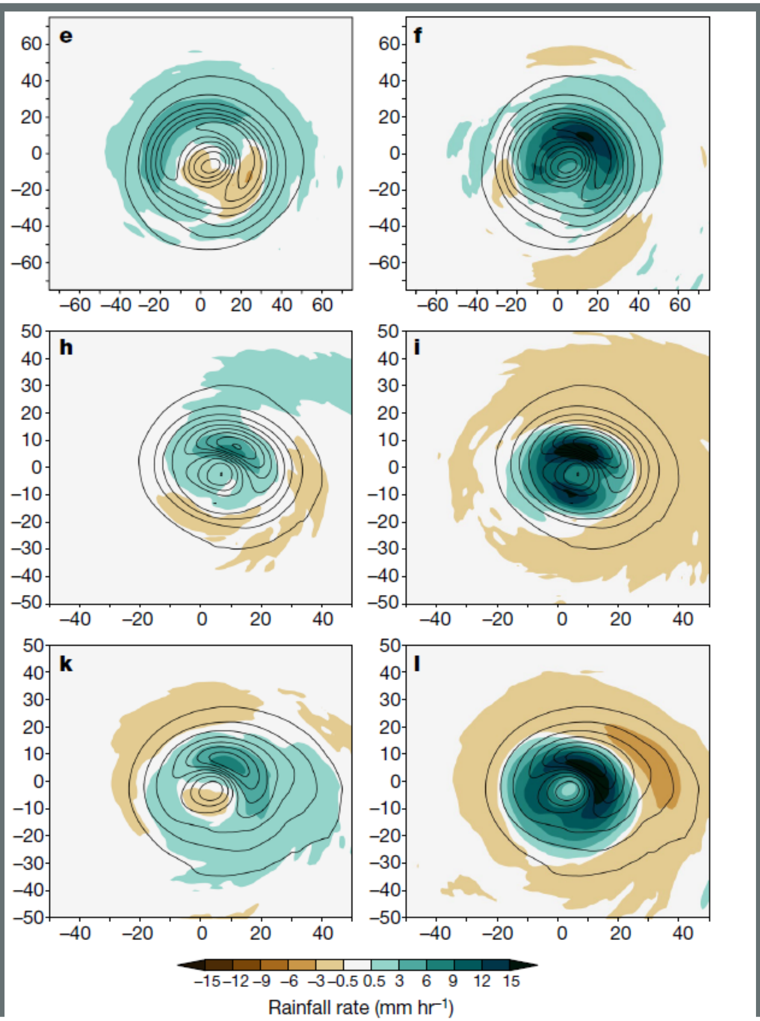
Patricola and Wehner Hurricane Attribution (Nature)

Katrina

Irma

Maria



w.o. CC with CC

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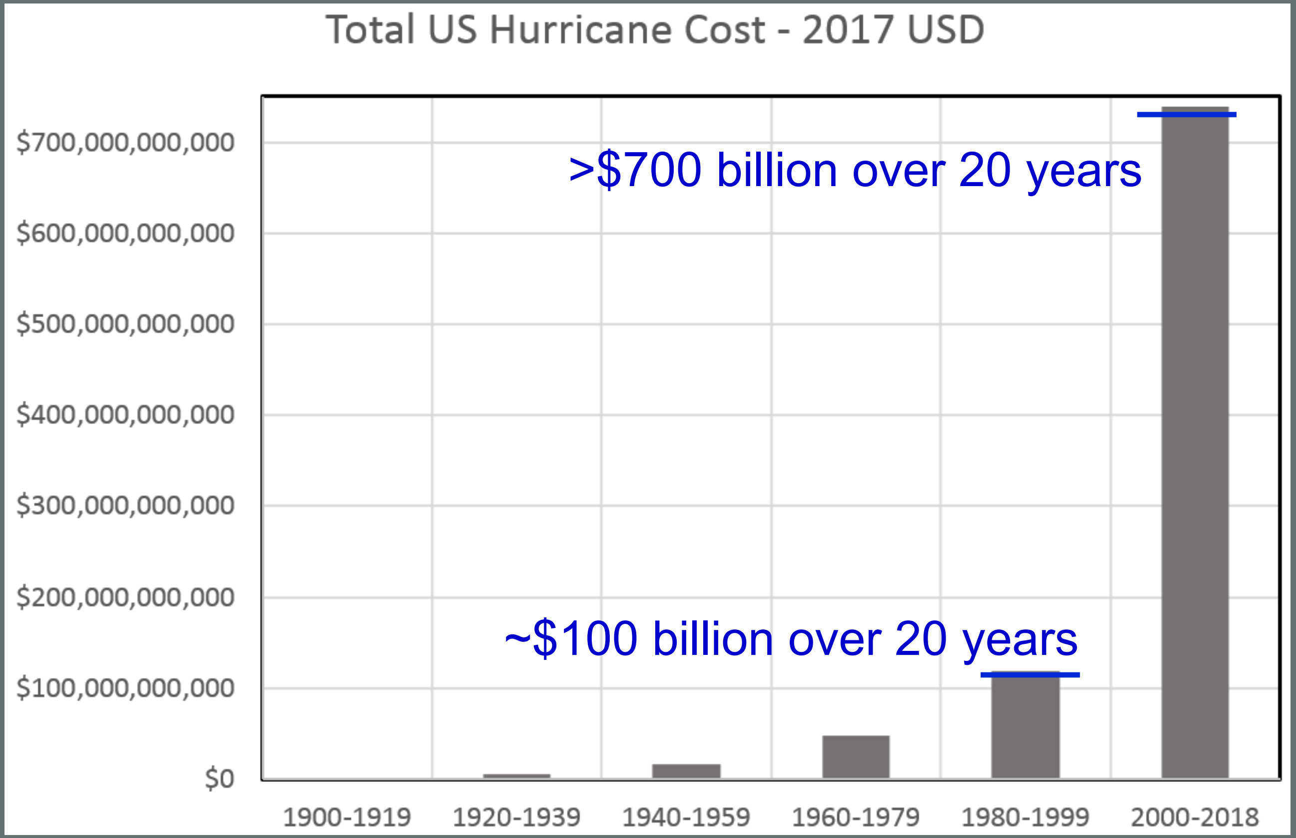
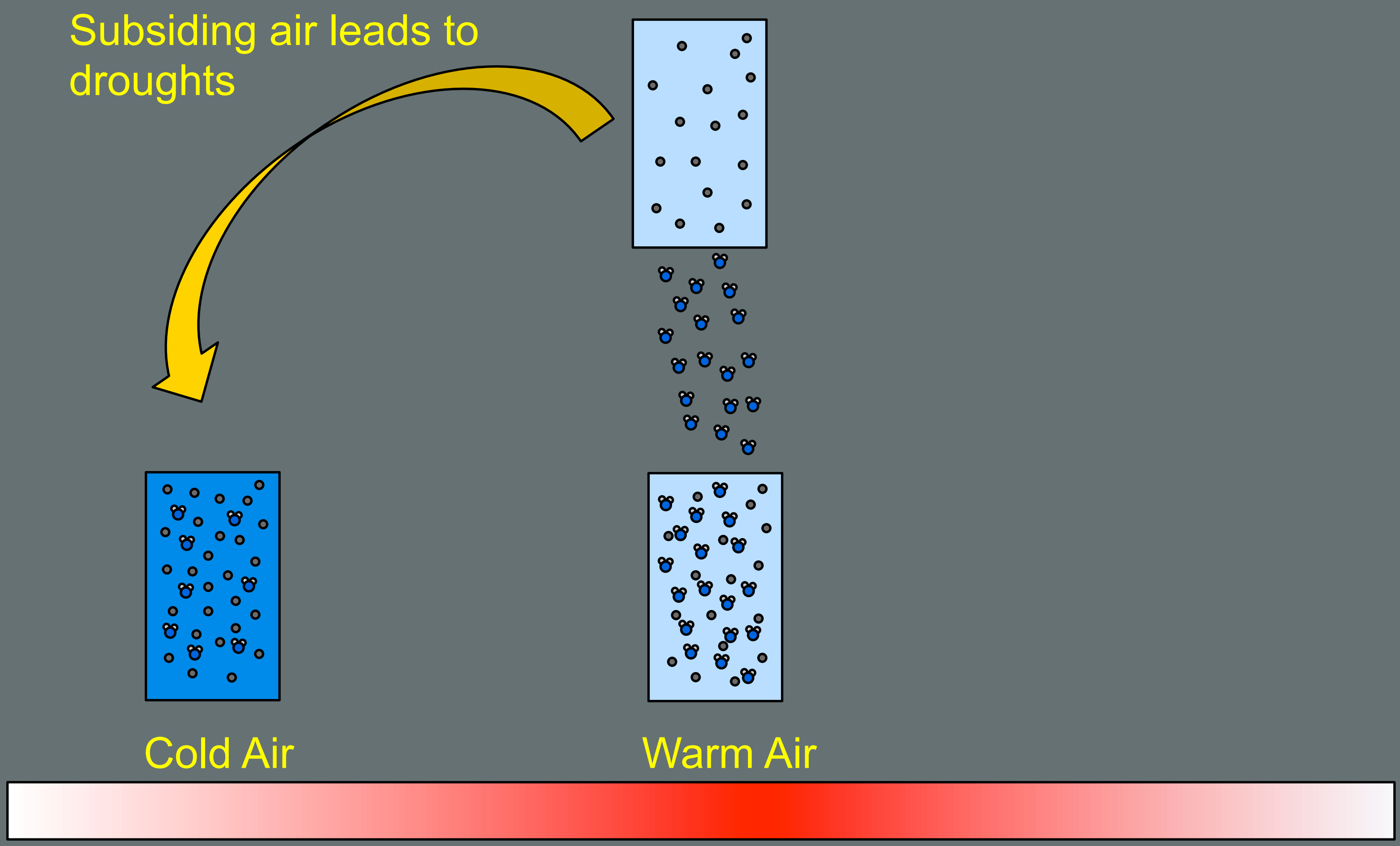
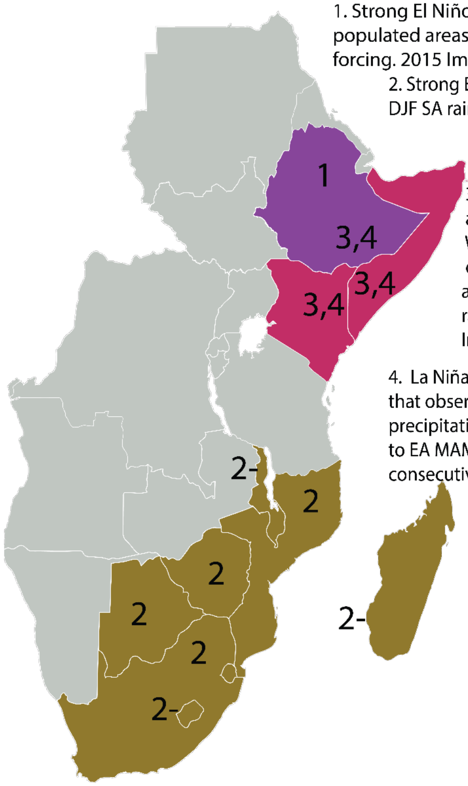
Costs of US Hurricanes



Increased sea surface temperatures also cause droughts



Schematic Figure of potential sequential droughts

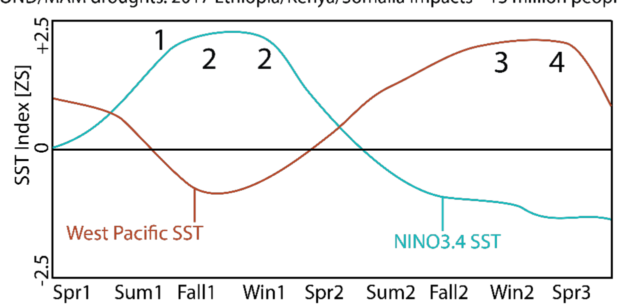


1. Strong El Niño forms during boreal summer of Year 1, disrupting Meher harvest in Ethiopia across densely populated areas of Ethiopia. Post-1980 JJAS East Pacific diabatic forcing ~70% greater than 1921-1980 diabatic forcing. 2015 Impact ~10 million people.

2. Strong El Niño continues through boreal fall and winter, disrupting rainfall across easterrn SA. Negative observed DJF SA rainfall/NINO3.4 SST relationship supported with CAM5 and CESM1 simulations. Strong El Niño events produce large circulation anomalies. CESM1 simulations indicate that strong ENSO events may be ~2.5 times more frequent now that in the 1920s. 2016 Impact ~10 million people. 2017 Impact ~16 million people.

3. La Niña-like conditions form in OND of Year 2. Since the late 1980s, this transition has often been accompanied by an upward jump in WEP and WNP SST. Strong and persistent warm SST anomalies in the West Pacific have been important for recent back to back OND and MAM EA droughts. During OND, observations, CAM5 and CESM1 simulations indicate a negative relationship between warmer WEP SST and EA OND rains on an interannual basis. Unlike in MAM, the OND response has not involved a decrease in rainfall through time. This may have to do with the comparatively limited influence of WEP warming on the Indian and Pacific branches of the Walker Circulation during OND.

4. La Niña-like conditions and warm WNP conditions tend to pesist into MAM of Year 3. Here we show that observations, CAM5 and CESM1 simulations all indicate that WNP SST plays an important role in modulating EA precipitation and the Indo-Pacific Walker Circulation. Increasing WNP SST and diabatic forcing are likely contributors to EA MAM rainfall declines. More frequent MAM droughts seem likely. Common West Pacific forcing may support consecutive OND/MAM droughts. 2017 Ethiopia/Kenya/Somalia Impacts ~13 million people.



Funk et al. QJRMS 2018

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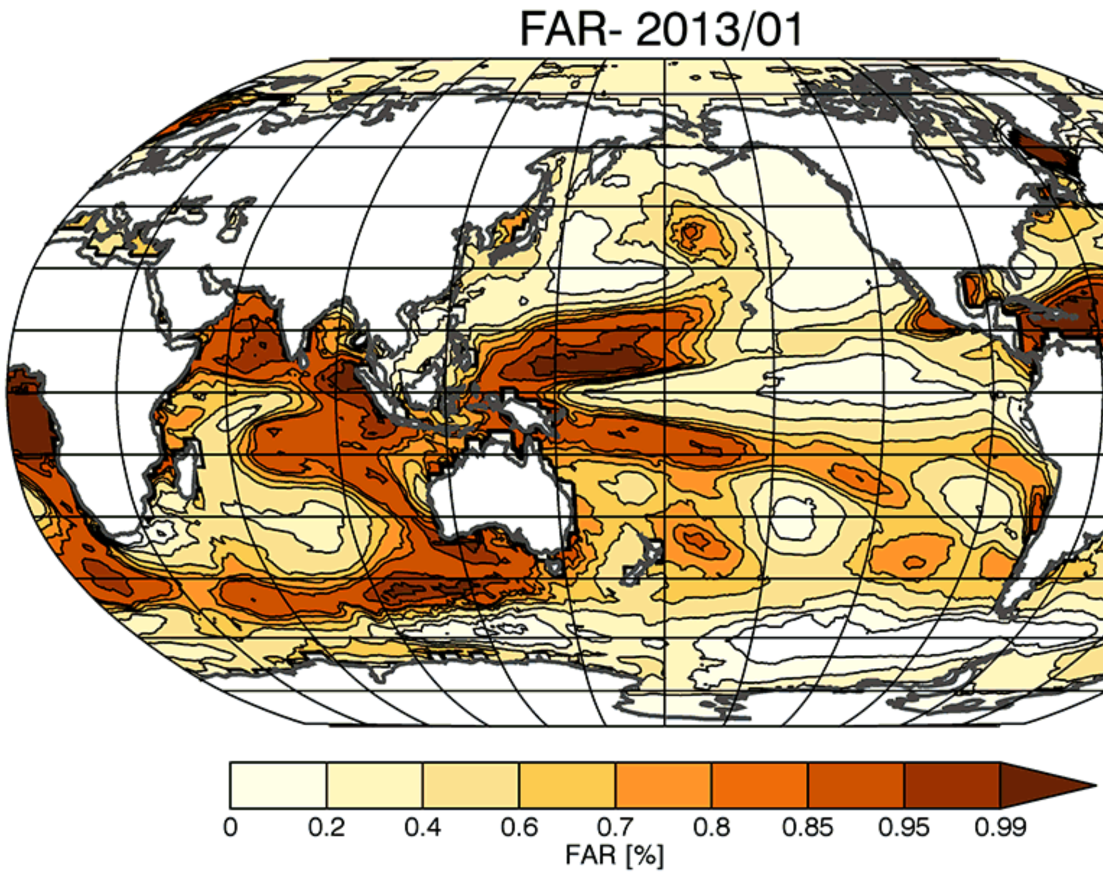
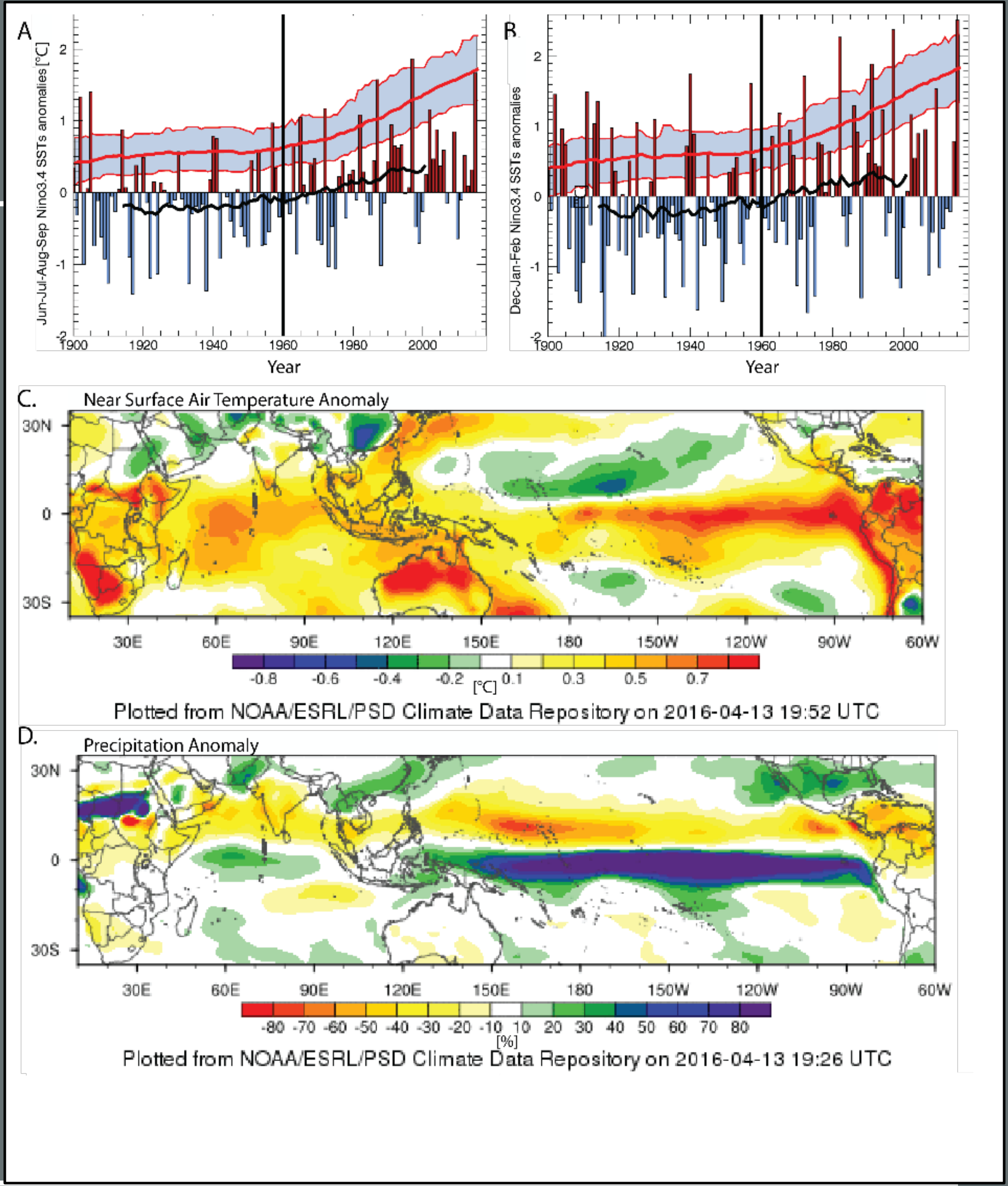
A climate hazards perspective – extremely warm SSTs produce droughts

FAR = 1 – *P0 / P1*
(Allen, 2003)



2015/16 El Nino

Climate Change enhanced strength of El Nino & droughts in Ethiopia and Southern Africa



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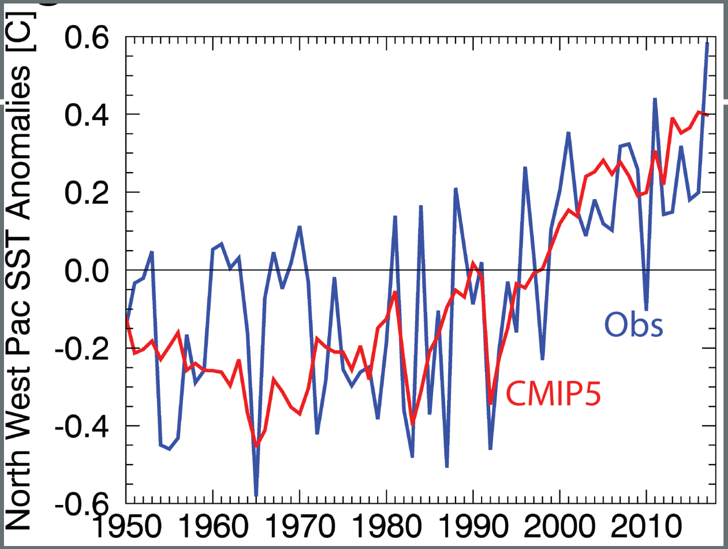
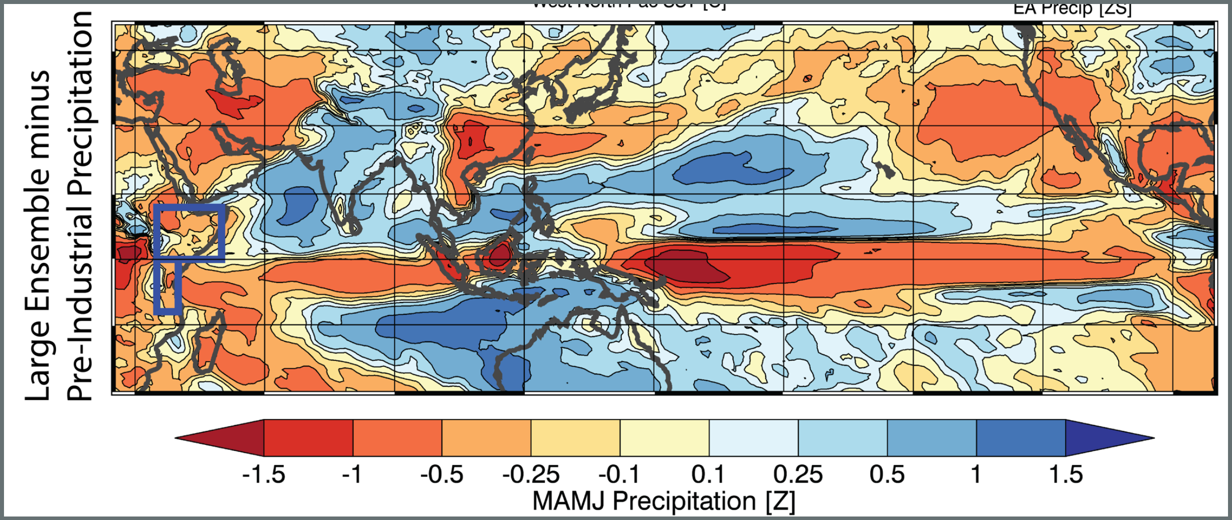
BAMS 2016, BAMS 2017, QJRMS 2018

2017/18 El Nino

Climate Change enhanced West Pacific SSTs and droughts in East Africa





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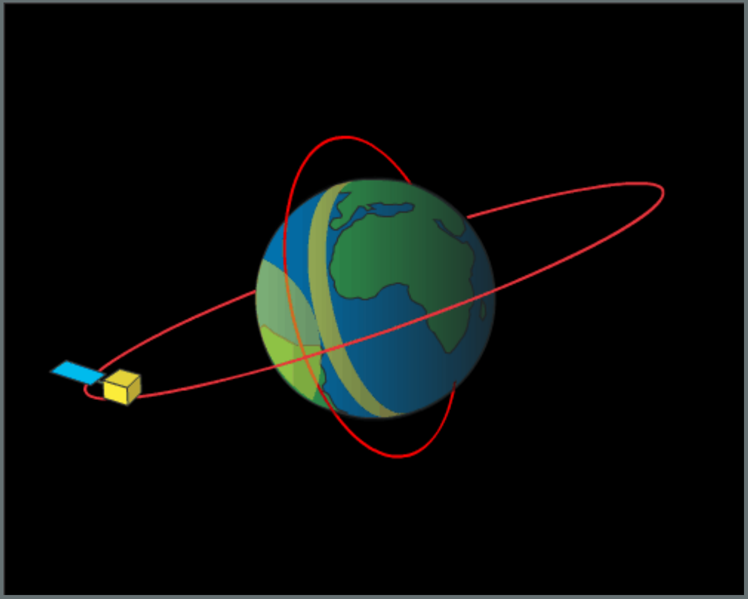
BAMS 2018, QJRMS 2018

Integrated monitoring-prediction systems can help anticipate extremes



Designing and Implementing Integrated Systems to Monitor and Predict Extremes

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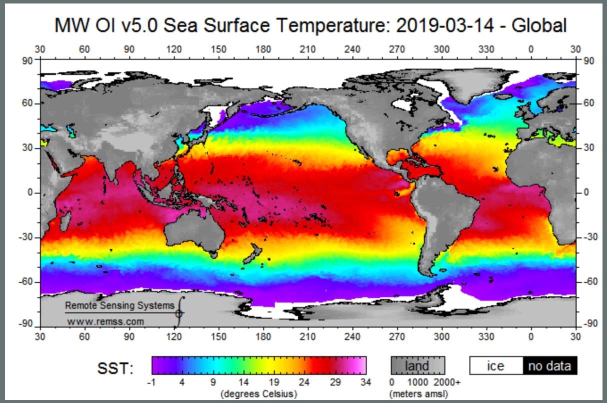
Sources of predictive skill

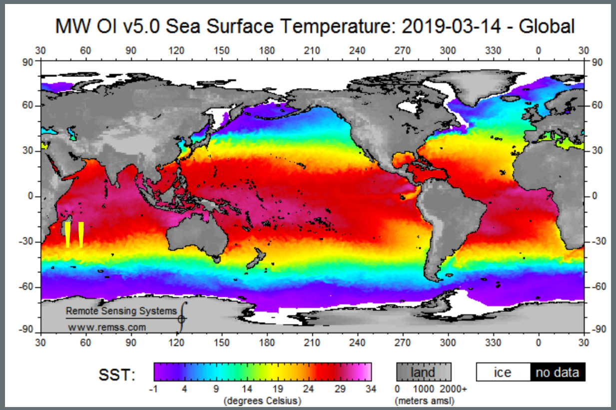


Ocean – Since sea surface temperatures change very slowly, they can be used to inform seasonal climate forecasts

Atmosphere – on one-to-two week time scales storms, heat waves and rainfall deficits are often predictable

Land – Soil moisture and vegetation extremes and deficits build up and persist over time, this persistence supports predictions

How climate change can exacerbate weather extremes



Ocean – Exceptionally warm sea surface temperatures can drive terrestrial precipitation extremes and drought

Atmosphere – Warmer air can hold more water, contributing to more extreme precipitation events

Land – A warmer atmosphere can draw more water from plants and soils, increasing the intensity of droughts

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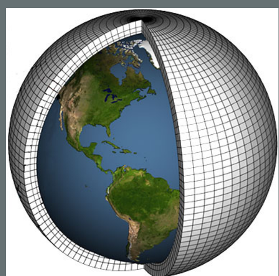
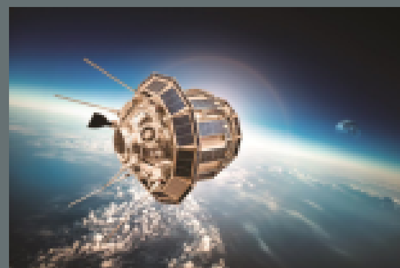
Integrated systems can provide effective early warning by using the best tools at the right time – drought example

Climate Model Predictions



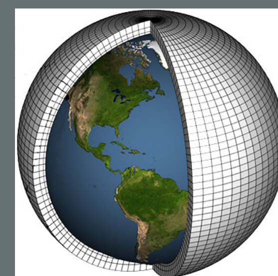
Provide alerts based on large scale climate conditions

Satellite Precipitation Observations



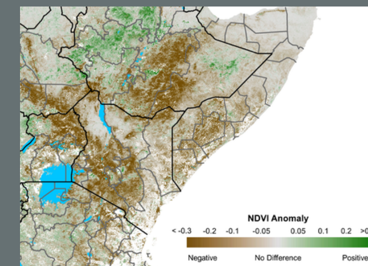
Quantify early-to-mid season rainfall deficits

Weather model Rainfall predictions

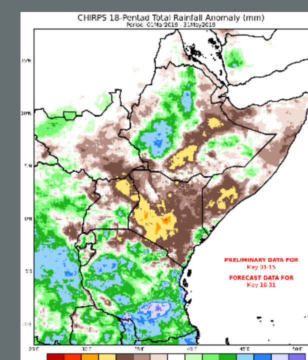


Predict mid-season rainfall deficits

CHC Early Estimates



Veg. Anomalies support late-season assessment



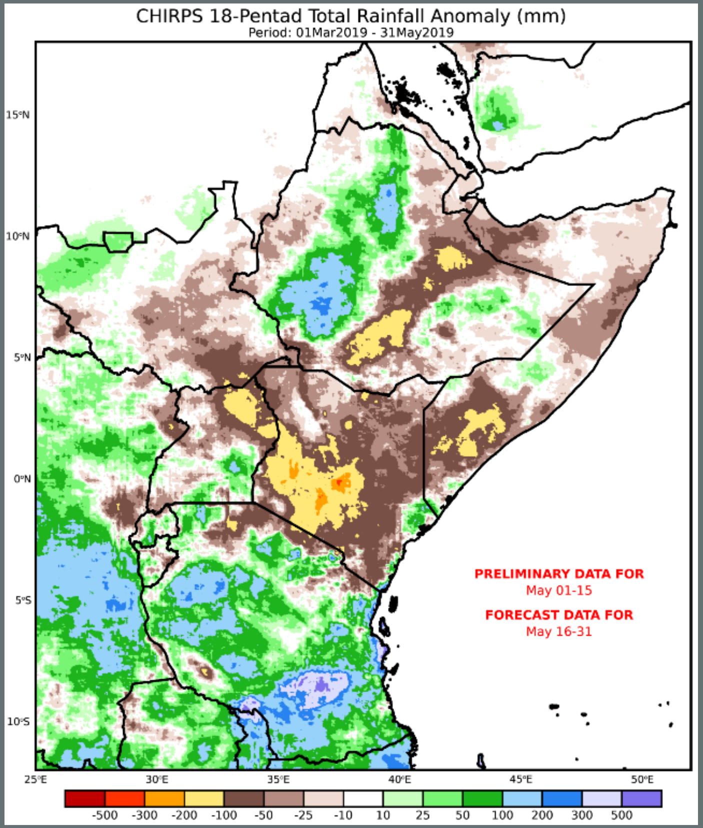
CHC Estimate May 20

USGS

Time --→

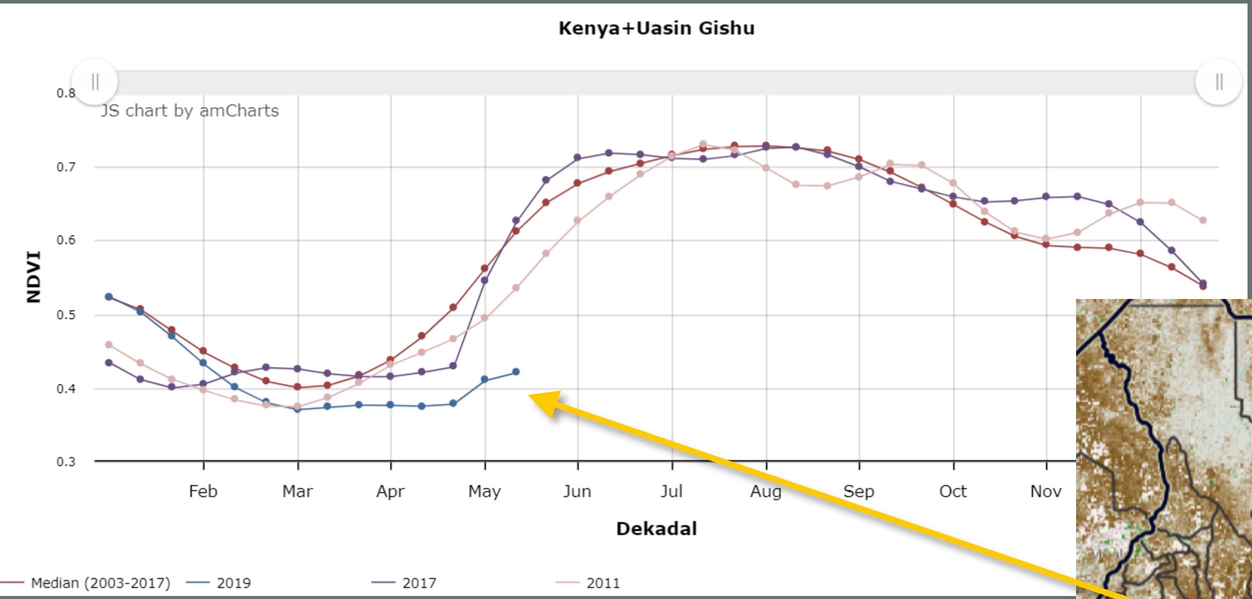
Drought Example CHC Estimate May 20th

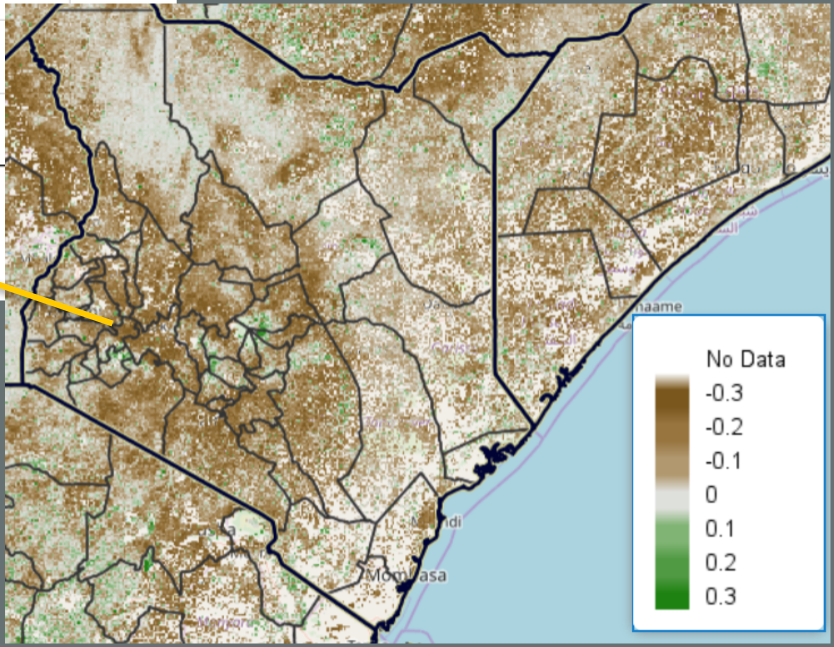
45 days CHIRPS + 15 days CHIRPS-GEFS =



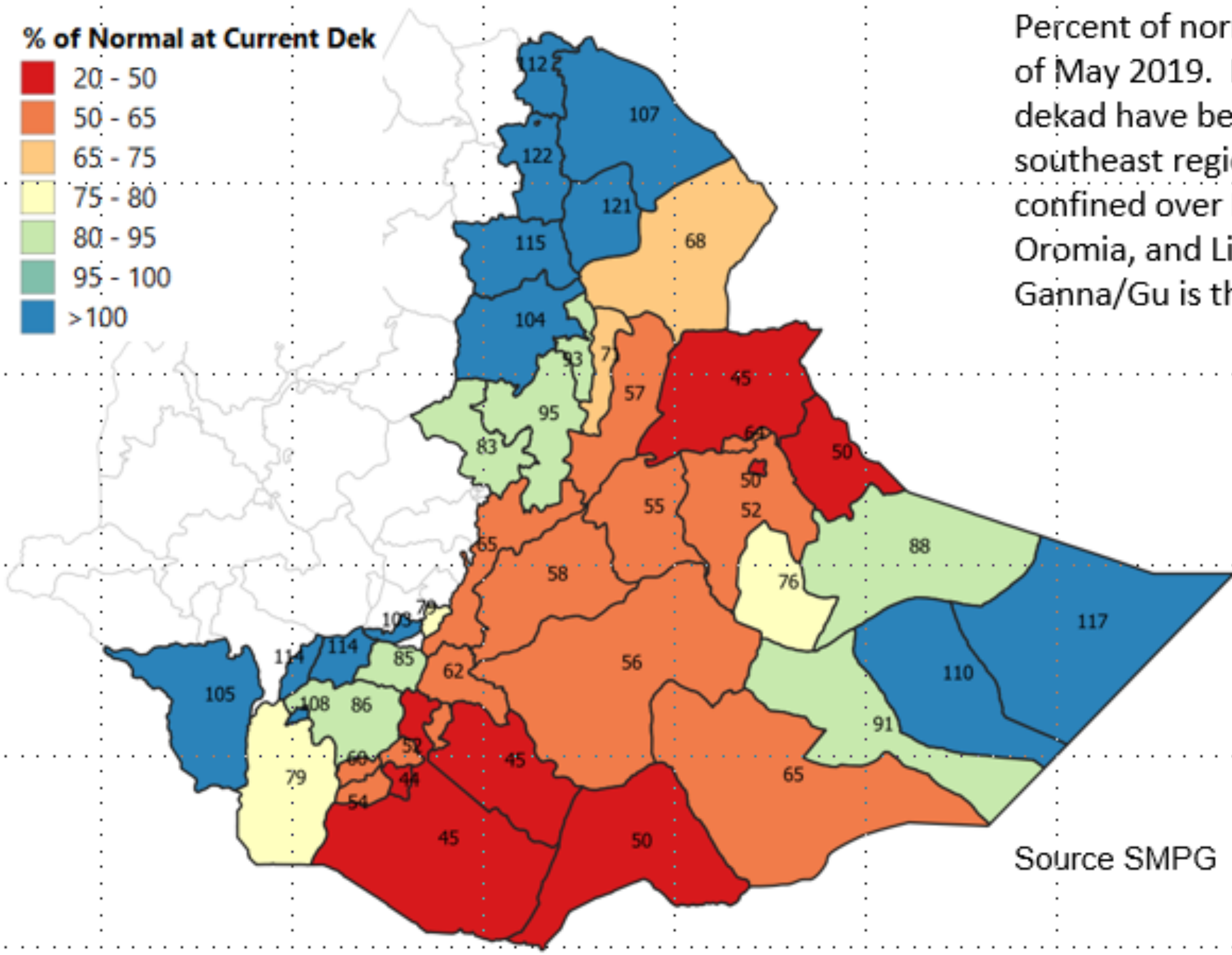
CHC Estimate May 20th

High Resolution Satellite Vegetation Anomalies





Percent of normal rainfall, for the Period Feb dek1- May dek2, 2019



Percent of normal rainfall up to the 2nd dek of May 2019. Rainfall totals to the current dekad have been below normal for most of southeast region, with severe epicenter is confined over Borena and Guji Zones of Oromia, and Liban Zone of Somali, where Ganna/Gu is the major rainy season.

Rainfall in far eastern Ethiopia is expected to improve based on forecast of dek 14.

Source SMPG

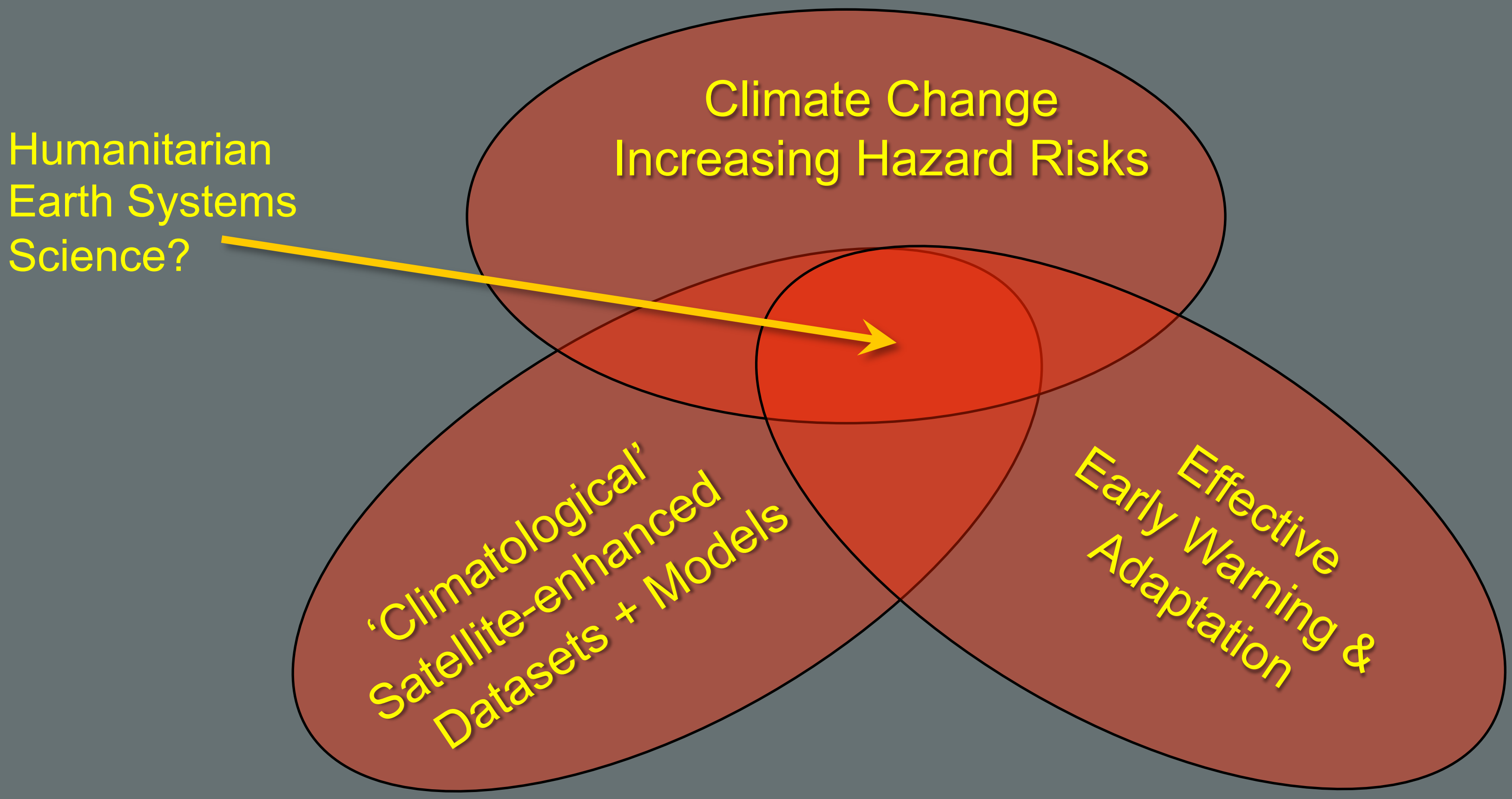
Closing thoughts

Climate change is amplifying extreme events – now (and people are being hurt)

We can understand how warming temperatures amplify extremes

We have a tremendous array of new satellite and modeling tools – but we need to link and use them well

Thanks!


Humanitarian
Earth Systems
Science?
Climate Change
Increasing Hazard Risks
'Climatological'
Satellite-enhanced
Datasets + Models
Effective
Early Warning &
Adaptation