Climate Change, Extreme Events, and Human Health

Radley Horton

Center for Climate Systems Research

Health and Climate Colloquium
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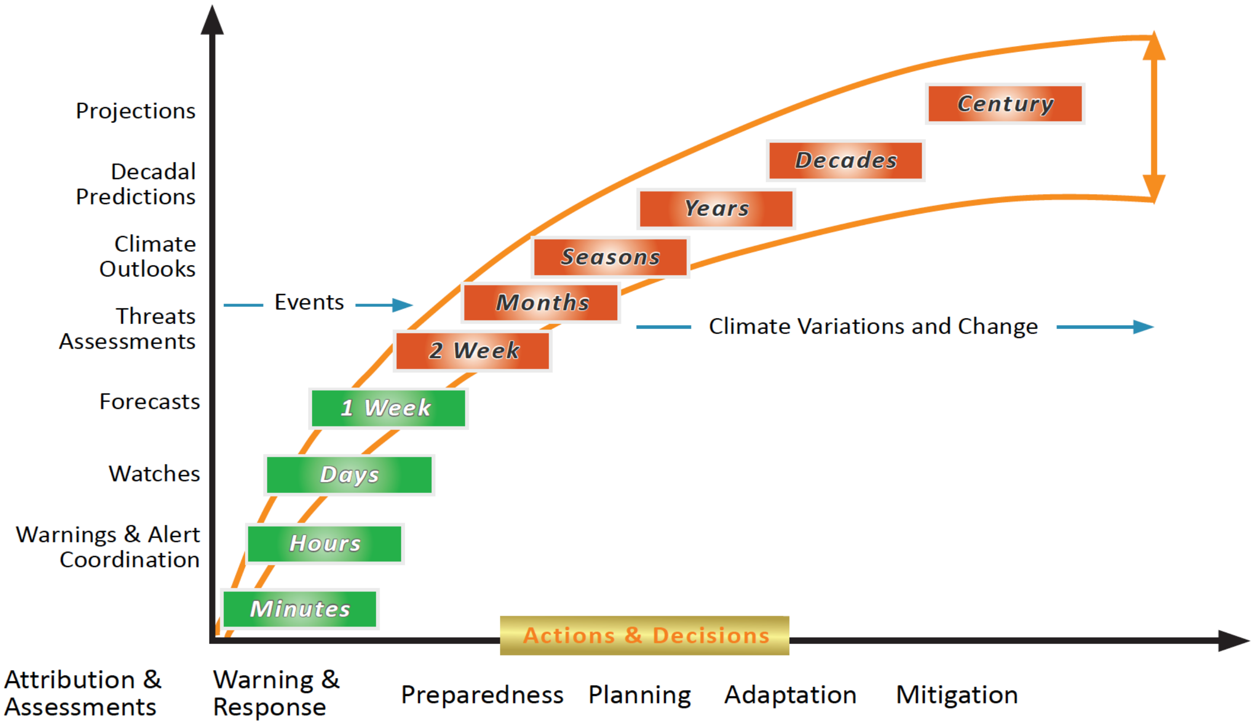
Outline

- Climate change and extreme events

- Temperature-mortality case studies

- Emerging topics

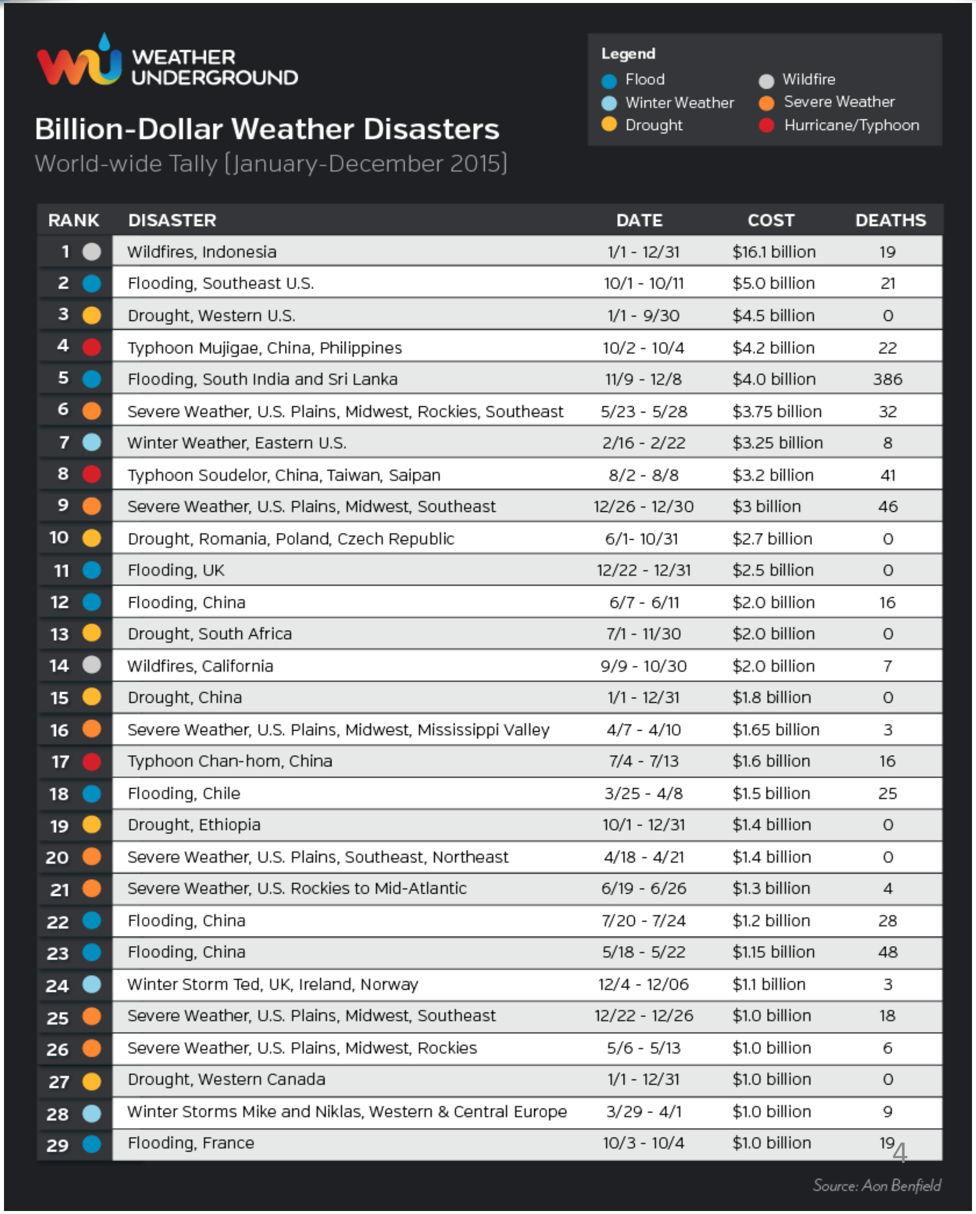
Characteristics of Extreme Events



- They are (at least somewhat) rare
- Extreme events operate across a spectrum of time and space scales
- They are often multivariate
- They can have many ‘causes’

Source: NOAA/PSD Draft Strategic Plan

Extreme Events in 2015



WEATHER UNDERGROUND

Billion-Dollar Weather Disasters

World-wide Tally [January-December 2015]

Legend

● Flood	● Wildfire
● Winter Weather	● Severe Weather
● Drought	● Hurricane/Typhoon

RANK		DISASTER	DATE	COST	DEATHS
1	●	Wildfires, Indonesia	1/1 - 12/31	$16.1 billion	19
2	●	Flooding, Southeast U.S.	10/1 - 10/11	$5.0 billion	21
3	●	Drought, Western U.S.	1/1 - 9/30	$4.5 billion	0
4	●	Typhoon Mujigae, China, Philippines	10/2 - 10/4	$4.2 billion	22
5	●	Flooding, South India and Sri Lanka	11/9 - 12/8	$4.0 billion	386
6	●	Severe Weather, U.S. Plains, Midwest, Rockies, Southeast	5/23 - 5/28	$3.75 billion	32
7	●	Winter Weather, Eastern U.S.	2/16 - 2/22	$3.25 billion	8
8	●	Typhoon Soudelor, China, Taiwan, Saipan	8/2 - 8/8	$3.2 billion	41
9	●	Severe Weather, U.S. Plains, Midwest, Southeast	12/26 - 12/30	$3 billion	46
10	●	Drought, Romania, Poland, Czech Republic	6/1- 10/31	$2.7 billion	0
11	●	Flooding, UK	12/22 - 12/31	$2.5 billion	0
12	●	Flooding, China	6/7 - 6/11	$2.0 billion	16
13	●	Drought, South Africa	7/1 - 11/30	$2.0 billion	0
14	●	Wildfires, California	9/9 - 10/30	$2.0 billion	7
15	●	Drought, China	1/1 - 12/31	$1.8 billion	0
16	●	Severe Weather, U.S. Plains, Midwest, Mississippi Valley	4/7 - 4/10	$1.65 billion	3
17	●	Typhoon Chan-hom, China	7/4 - 7/13	$1.6 billion	16
18	●	Flooding, Chile	3/25 - 4/8	$1.5 billion	25
19	●	Drought, Ethiopia	10/1 - 12/31	$1.4 billion	0
20	●	Severe Weather, U.S. Plains, Southeast, Northeast	4/18 - 4/21	$1.4 billion	0
21	●	Severe Weather, U.S. Rockies to Mid-Atlantic	6/19 - 6/26	$1.3 billion	4
22	●	Flooding, China	7/20 - 7/24	$1.2 billion	28
23	●	Flooding, China	5/18 - 5/22	$1.15 billion	48
24	●	Winter Storm Ted, UK, Ireland, Norway	12/4 - 12/06	$1.1 billion	3
25	●	Severe Weather, U.S. Plains, Midwest, Southeast	12/22 - 12/26	$1.0 billion	18
26	●	Severe Weather, U.S. Plains, Midwest, Rockies	5/6 - 5/13	$1.0 billion	6
27	●	Drought, Western Canada	1/1 - 12/31	$1.0 billion	0
28	●	Winter Storms Mike and Niklas, Western & Central Europe	3/29 - 4/1	$1.0 billion	9
29	●	Flooding, France	10/3 - 10/4	$1.0 billion	19

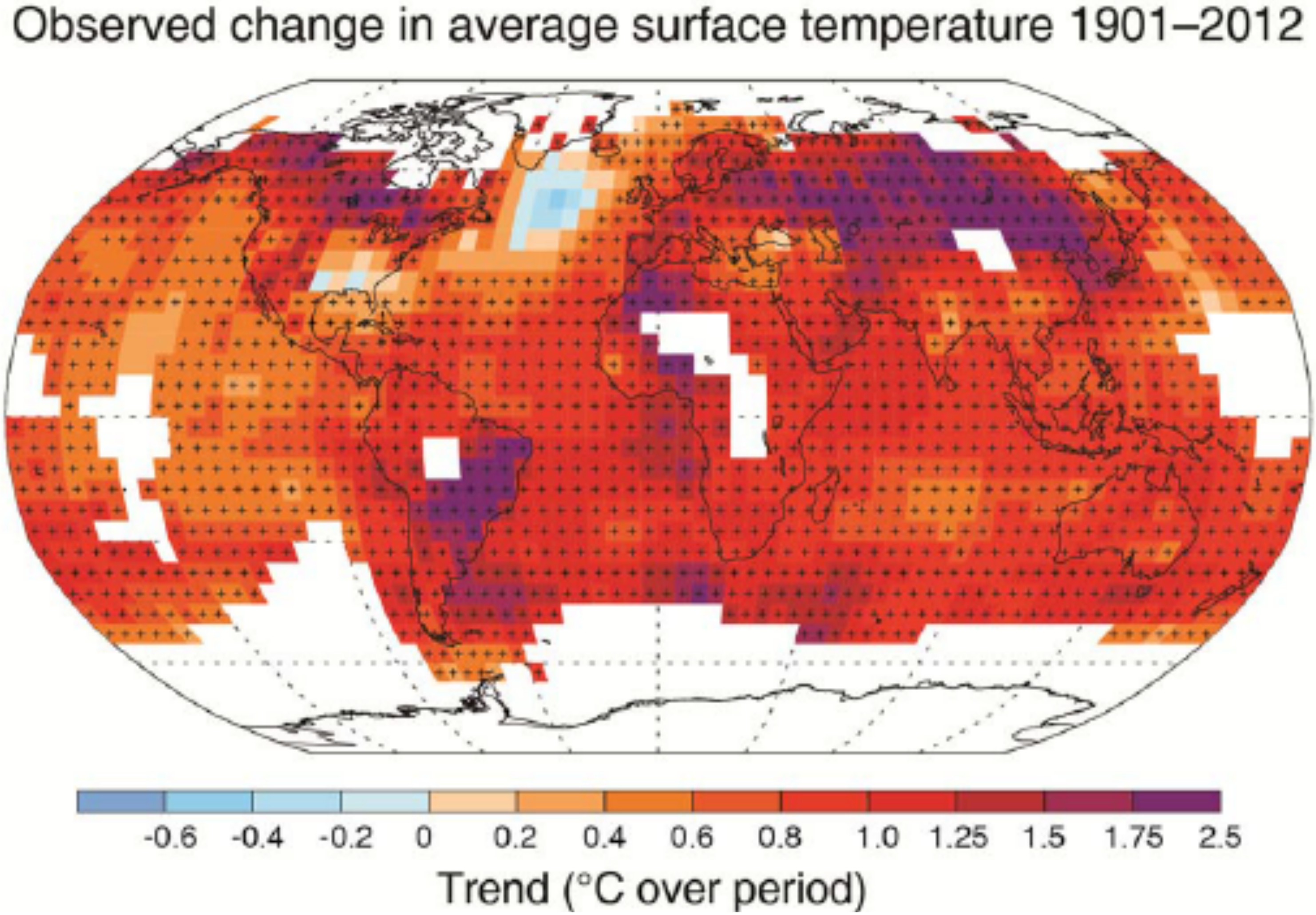
Source: Aon Benfield

Source: Weather Underground

Climate Change and Extreme Events

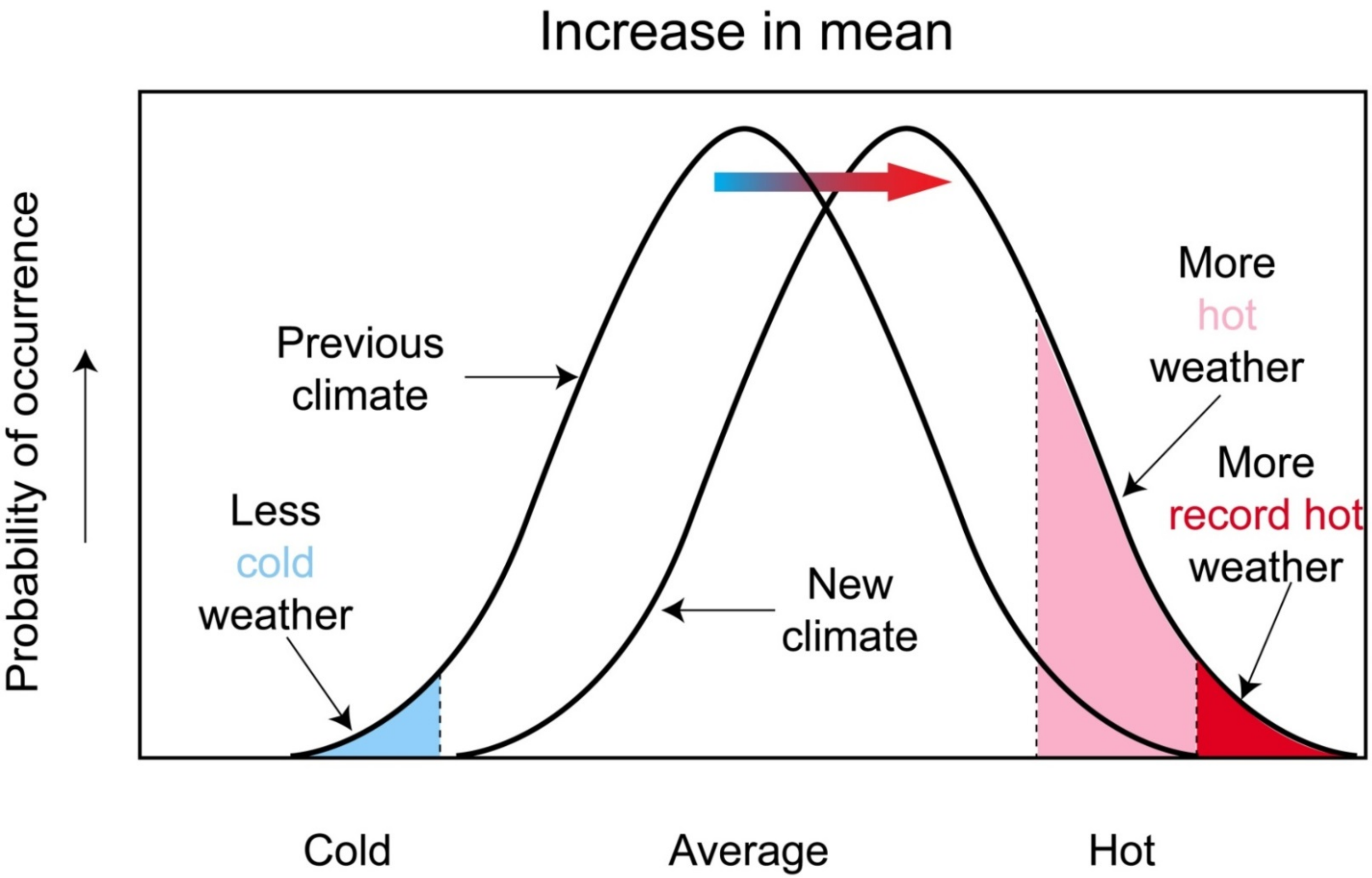
- Small shifts in average conditions (e.g. 2 C warming) can mean large shifts in extreme event statistics
  - Temperature extremes
  - Intense precipitation and drought
  - Sea level rise and coastal flooding

Changes in Surface Temperatures



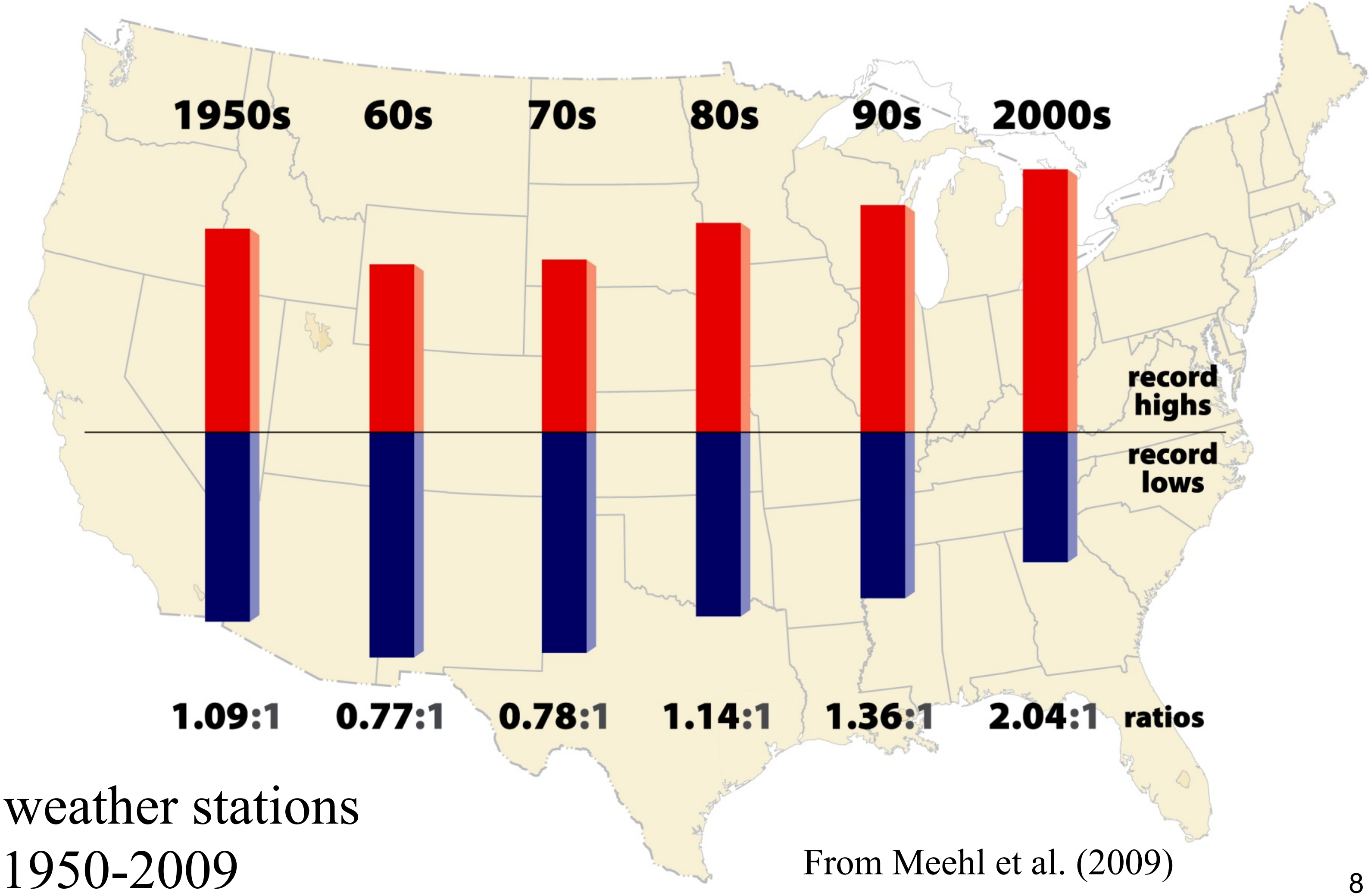
IPCC AR5 Draft SPM

Shifting Climate Extremes



- *Natural variability will continue to occur*
- *Small shifts in mean values can lead to large changes in the frequency of extremes*

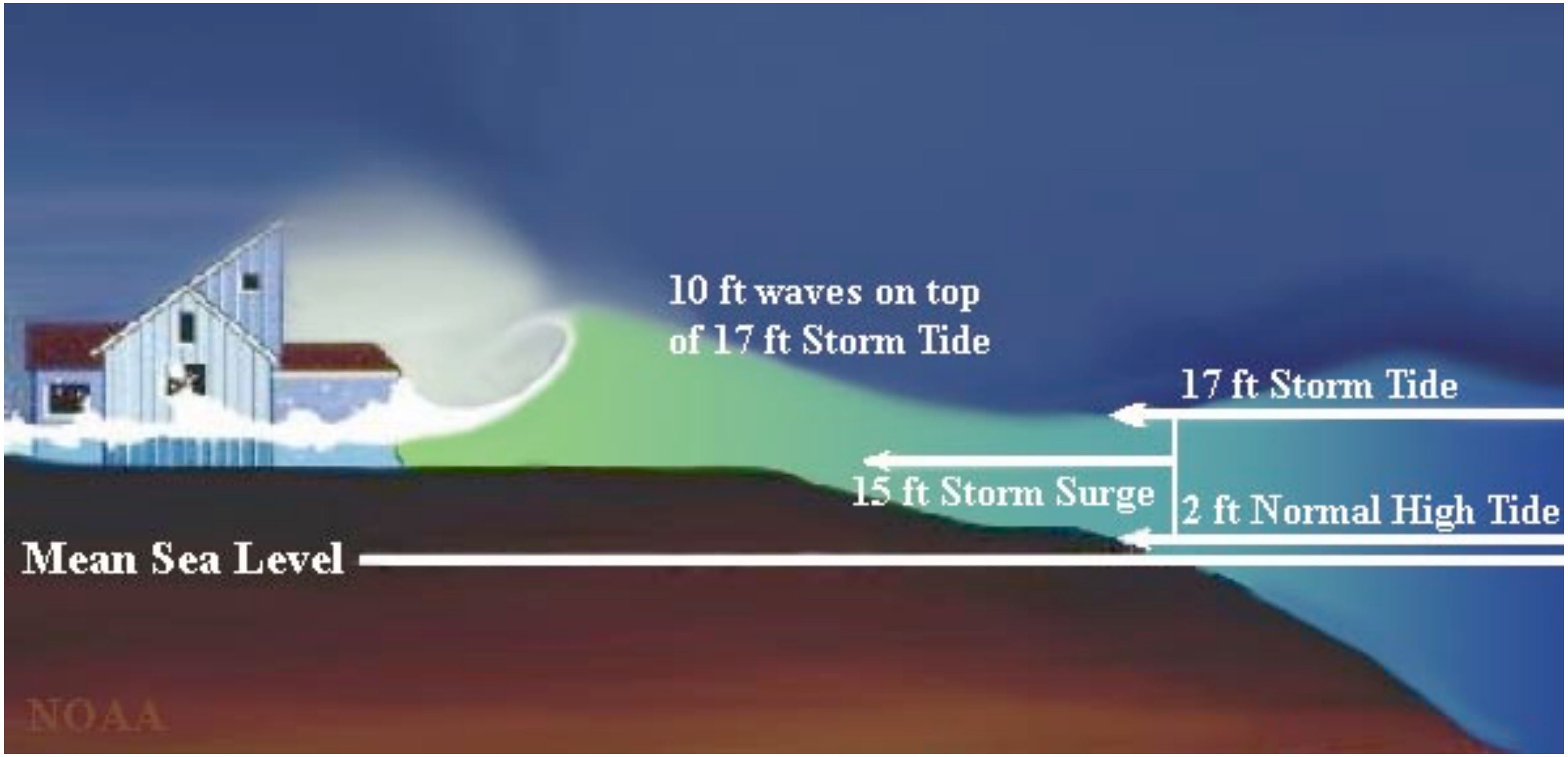
Increasing trend: U.S. breaking many more heat records than cold records



1800 weather stations
from 1950-2009

From Meehl et al. (2009)

Storm Surge and Storm Tide



Source: NOAA

Coastal Flood Heights and Recurrence

			2020s			2050s		
		Baseline	Low-estimate	Middle range	High-estimate	Low-estimate	Middle range	High-estimate
Coastal Floods at the Battery	Annual chance of today's 100-year-flood	**1.0 %**	**1.1 %**	**1.2 to 1.5 %**	**1.7 %**	**1.4 %**	**1.7 to 3.2 %**	**5.0 %**
	Flood heights associated with 100-year flood (stillwater + wave heights)	15.0 feet	15.2 feet	15.3 to 15.7 feet	15.8 feet	15.6 feet	15.9 to 17 feet	17.6 feet
	Stillwater flood heights associated with 100-year flood	10.8 feet	11.0 feet	11.1 to 11.5 feet	11.7 feet	11.4 feet	11.7 to 12.8 feet	13.4 feet

Estimates in the top row refer to the values for projected sea level rise. Low-estimate indicates 10th percentile, middle range indicates 25th to 75th percentile, and high-estimate indicates 90th percentile. Flood heights for the 2020s and 2050s are derived by adding the sea level rise projections for the corresponding percentiles to the baseline values. Baseline flood heights associated with the 100-year flood are based on the stillwater elevation levels (SWELs). For 100-year flood, height is also given for stillwater plus wave heights. Flood heights are referenced to the NAVD88 datum.

Coastal flooding is very likely to increase in frequency, extent, and height as a result of increased sea levels

Temperature-Mortality Case Studies

- Climate projections are based on a range of (downscaled) global climate models and scenarios of future greenhouse gas concentrations
- Historical relationships between daily weather and total mortality/morbidity are extended into the future

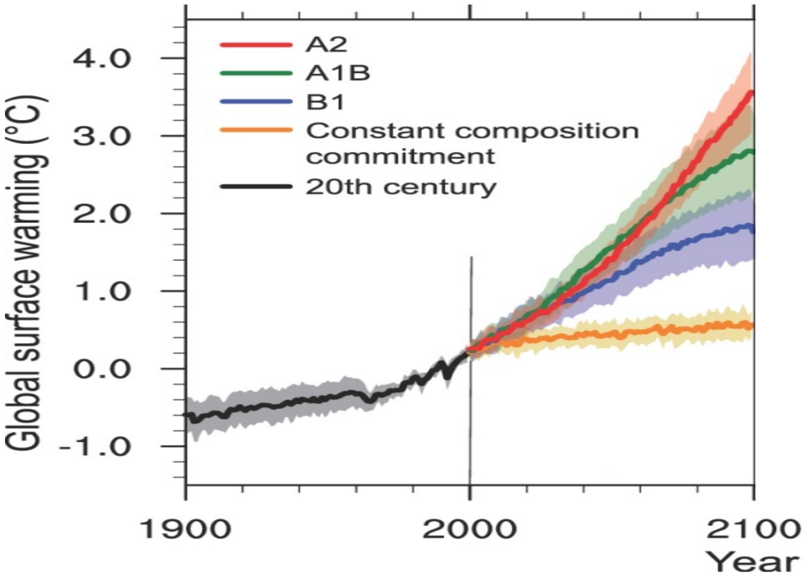
Climate Projections

- **Use calibrated climate models to make "projections" of the future**

  -With greenhouse gas emissions

- **Emissions scenarios of the future depend upon**
  - Energy technologies
  - Economic growth
  - Population

- **If we stop all greenhouse gas emissions now we still get warming**



IPCC, 2007

Scenario	Temperature Change (2090 – 2099) relative to (1980 – 1999)
A2	~ 6 °F
A1B	~ 5 °F
B1	~ 3 °F
Constant Commitment	~1 °F

Projections of Temperature-Related Deaths for Manhattan, New York

Source: *Environmental Health Perspectives*

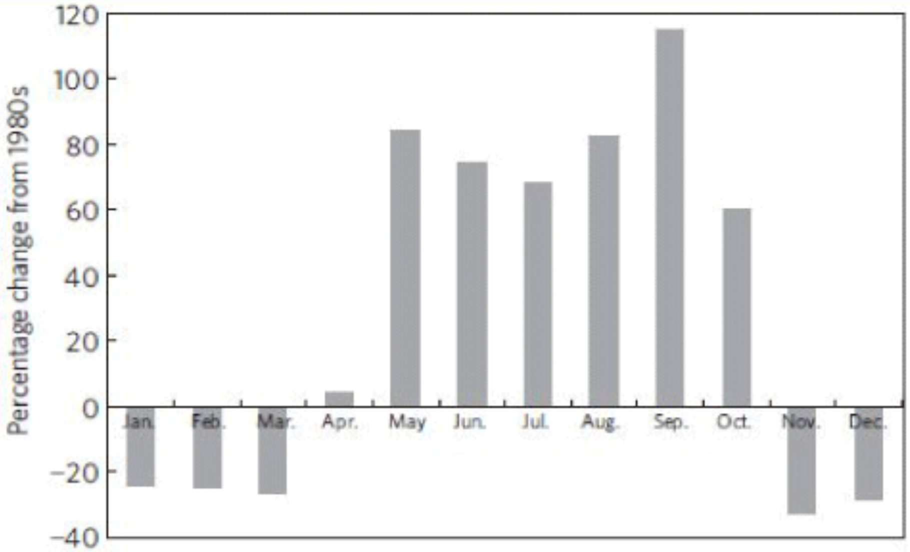


Figure 3 | Percentage change (average over 16 models) in monthly temperature-related deaths in the 2080s versus the 1980s for the A2 scenario. The largest percentage changes are seen for the months of May and September.

Tiantian Li, Radley Horton and Patrick Kinney

Emerging Topics

- Better characterization of tails of each climate variable's distribution
- Additional dimensions of health impacts
- Joint hazards
  - Multivariate: Large-scale temperature interactions with humidity, air quality, availability of electrical power, the urban heat island, etc.
  - Spatial and temporal interactions

Wet bulb temperature and thresholds

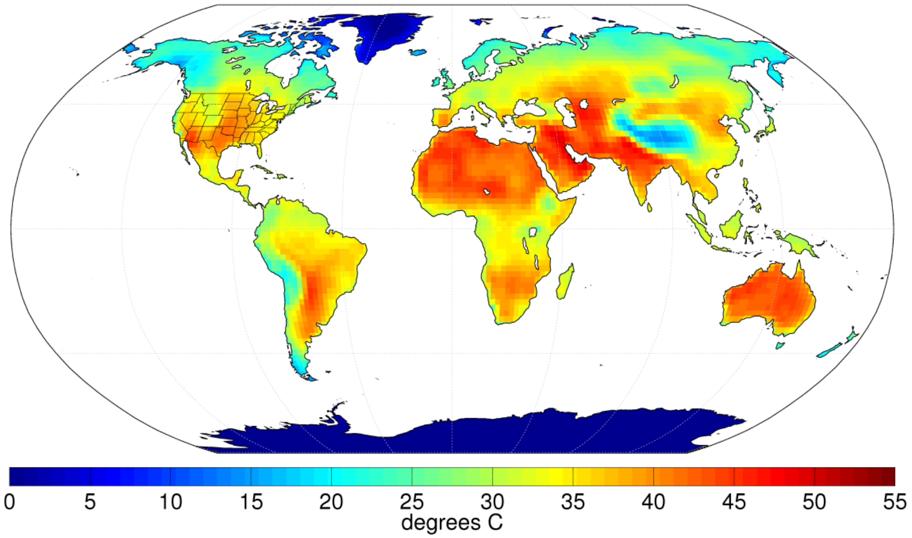
- Lowest temperature that can result from evaporative cooling
- Max in recent heatwaves: 31°C
- Theoretical max for human tolerance: 35°C (Sherwood, Huber, 2010)

Coffel, E., R.M. Horton, and A. De Sherbinin, Population exposure to heat stress in the 21st century (in preparation)

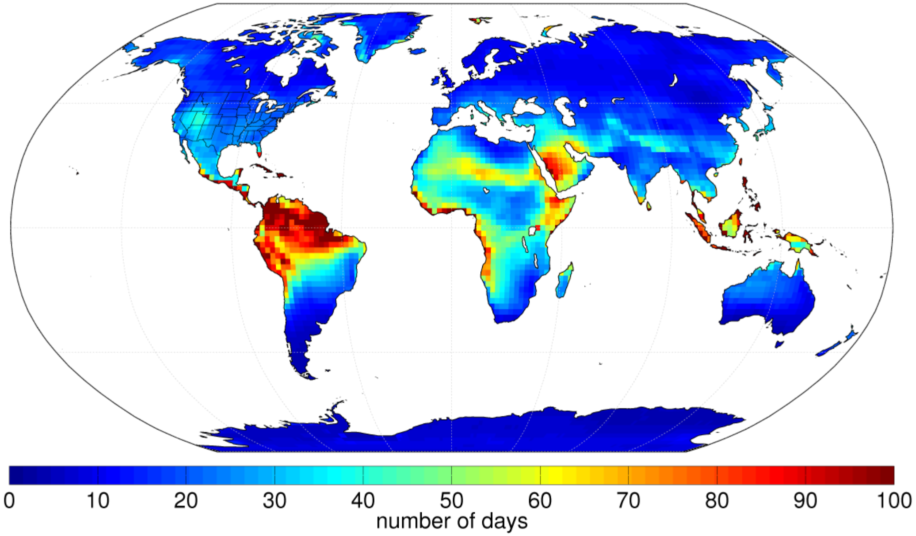
Temperature Recurrence

Current once-per-year temperatures become normal by 2060s

CMIP5 annual maximum temperature (1985-2005)

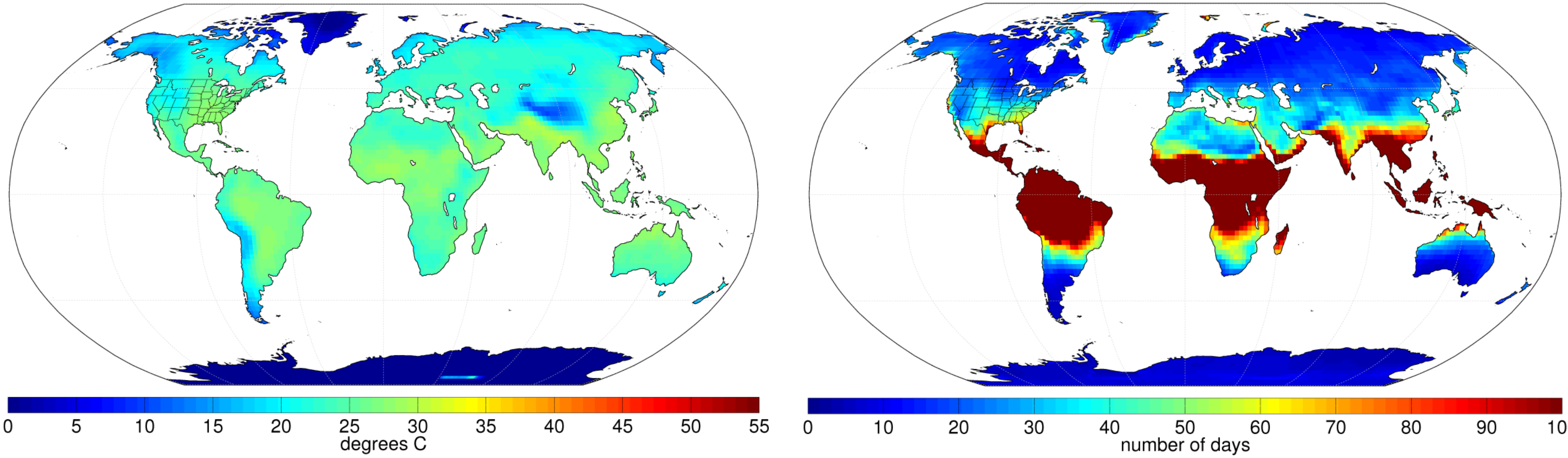


Number of days exceeding base annual maximum (2060s)



Wet Bulb Temperature Recurrence

Less wet bulb variability results in much higher recurrence frequencies, especially in the tropics

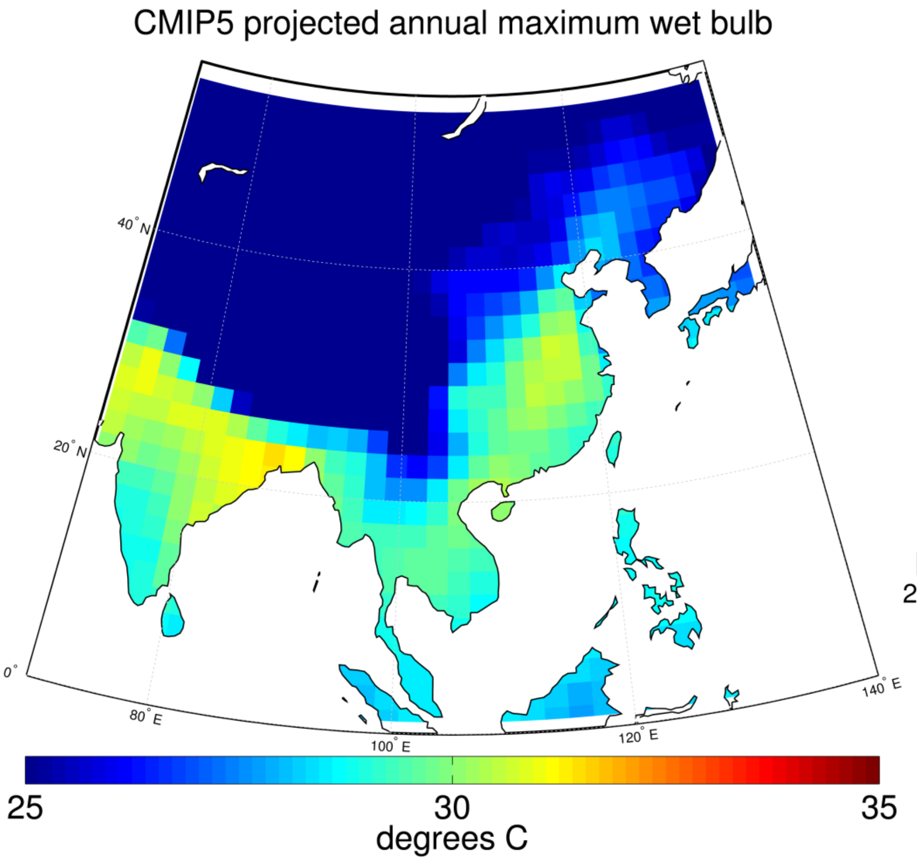


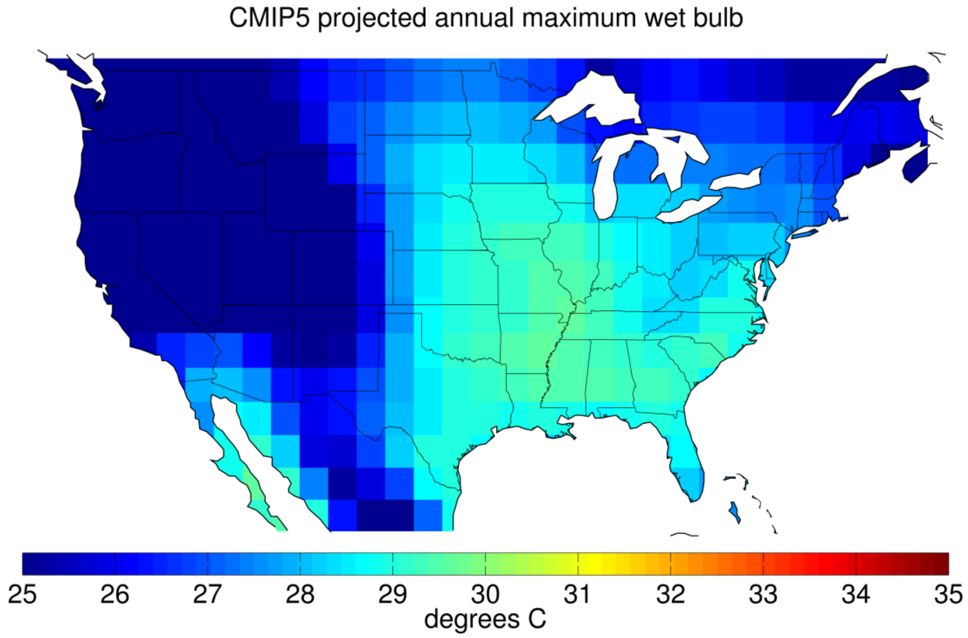
CMIP5 annual max wet bulb temperature (1985-2005)

Number of days exceeding base annual maximum (2060s)

Future Wet Bulb Temperatures

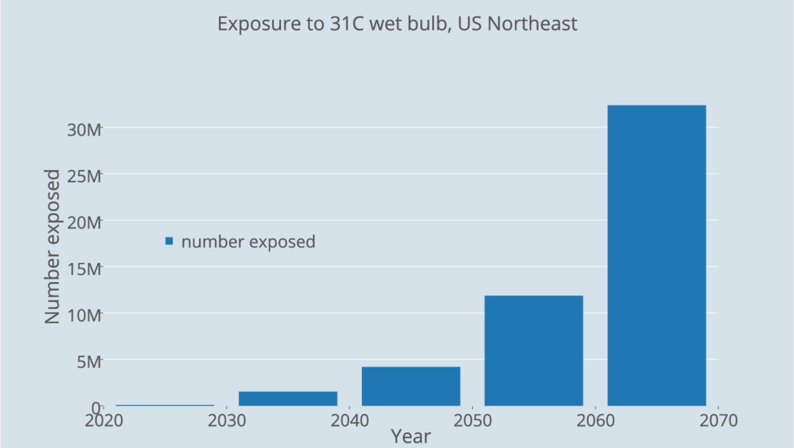
Mean annual maximum wet bulb of 30-32°C in India, and 29-30°C in the US southeast



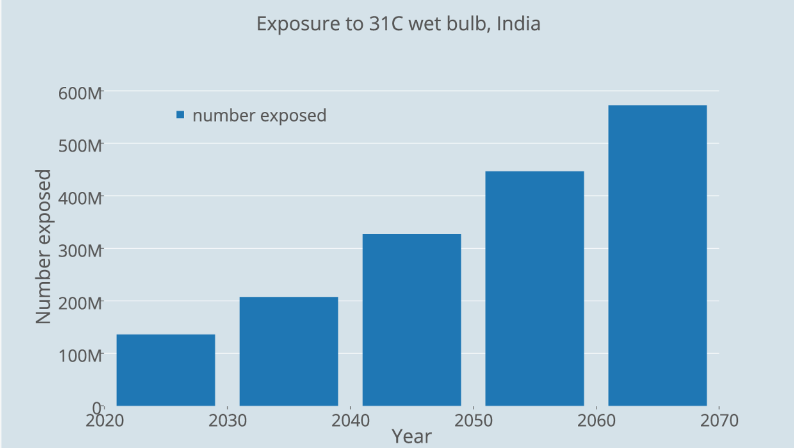


Regional Population Exposure

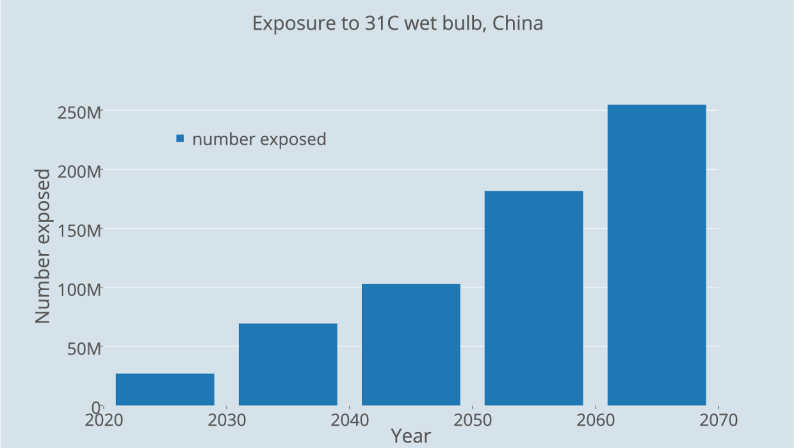
31°C, US Northeast, ~30M



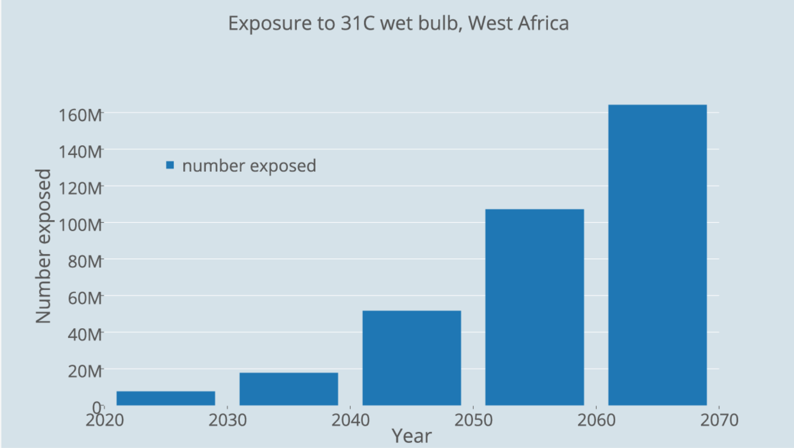
31°C, India, ~550M



31°C, China, ~250M

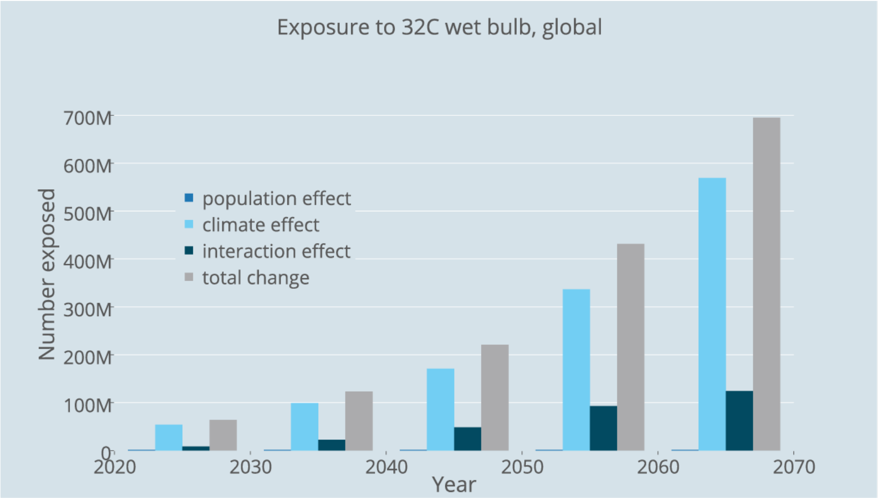


31°C, West Africa, ~160M



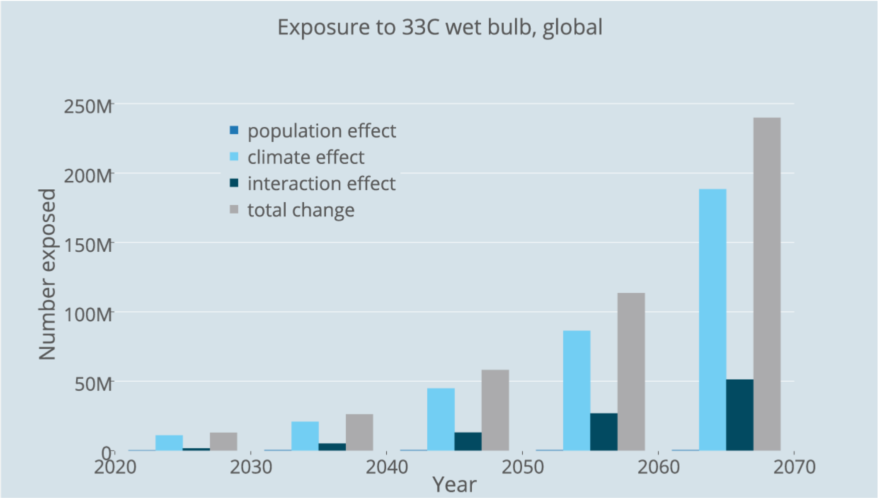
Global Population Exposure

32°C



Constant climate	~0
Constant Population	~600M
Total	**~700M**

33°C



Constant climate	~0
Constant Population	~200M
Total	**~250M**

With about 50M exposed to 34°C annually

Study Conclusions

- By 2060s, significant annual exposure to wet bulb temps near the human tolerance limit

- Recent extreme heat waves become annual events globally

- Direct heat stress may frequently make outdoor activity difficult and occasionally impossible in densely populated regions

Key Points and Recommendations

- Small shifts in averages can lead to large impact on extremes
  - The distribution can change as well

- We simply can't quantify how these extremes may change. Why
  - Some are so rare, it is hard to know their baseline risk
  - Multifaceted nature adds complexity. How will each driver change, and how will drivers interact
  - High potential for surprises—emergent non linear behavior

- We need more process based studies

- We can offer qualitative, scenario based approaches.

- Integration of different types of information in risk assessment (Oppenheimer et al. 2016)

- Stakeholder-scientist collaborations are critical to advancing both the science and the decision-making

- Evaluating (potential) adaptation strategies in the context of rare extremes; can systems be 'stress-tested'?