South Central CASC 2022 Fall Science Meeting

Understanding Changes in Climate Extremes to Inform Climate Adaptation

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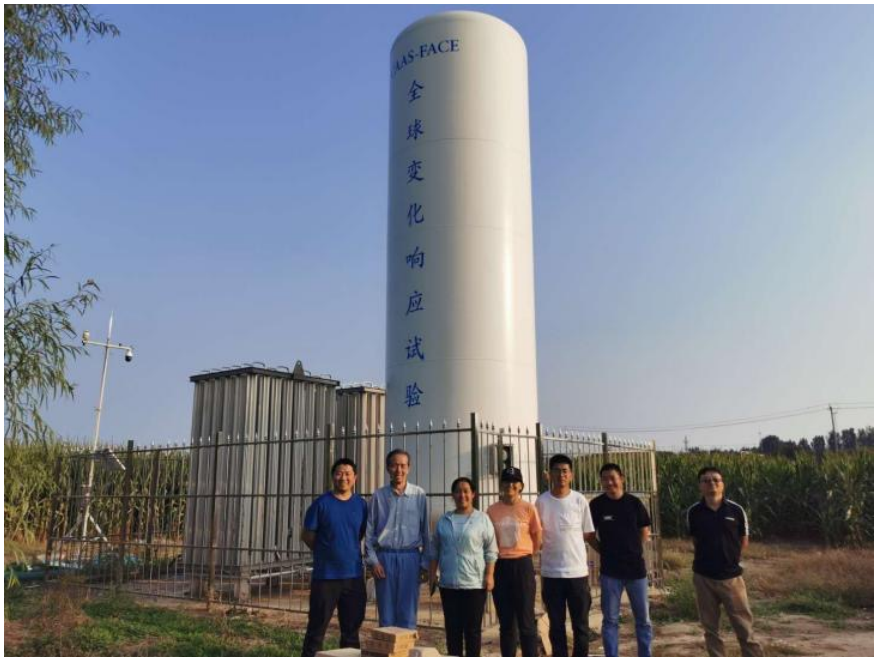
11/10/2022

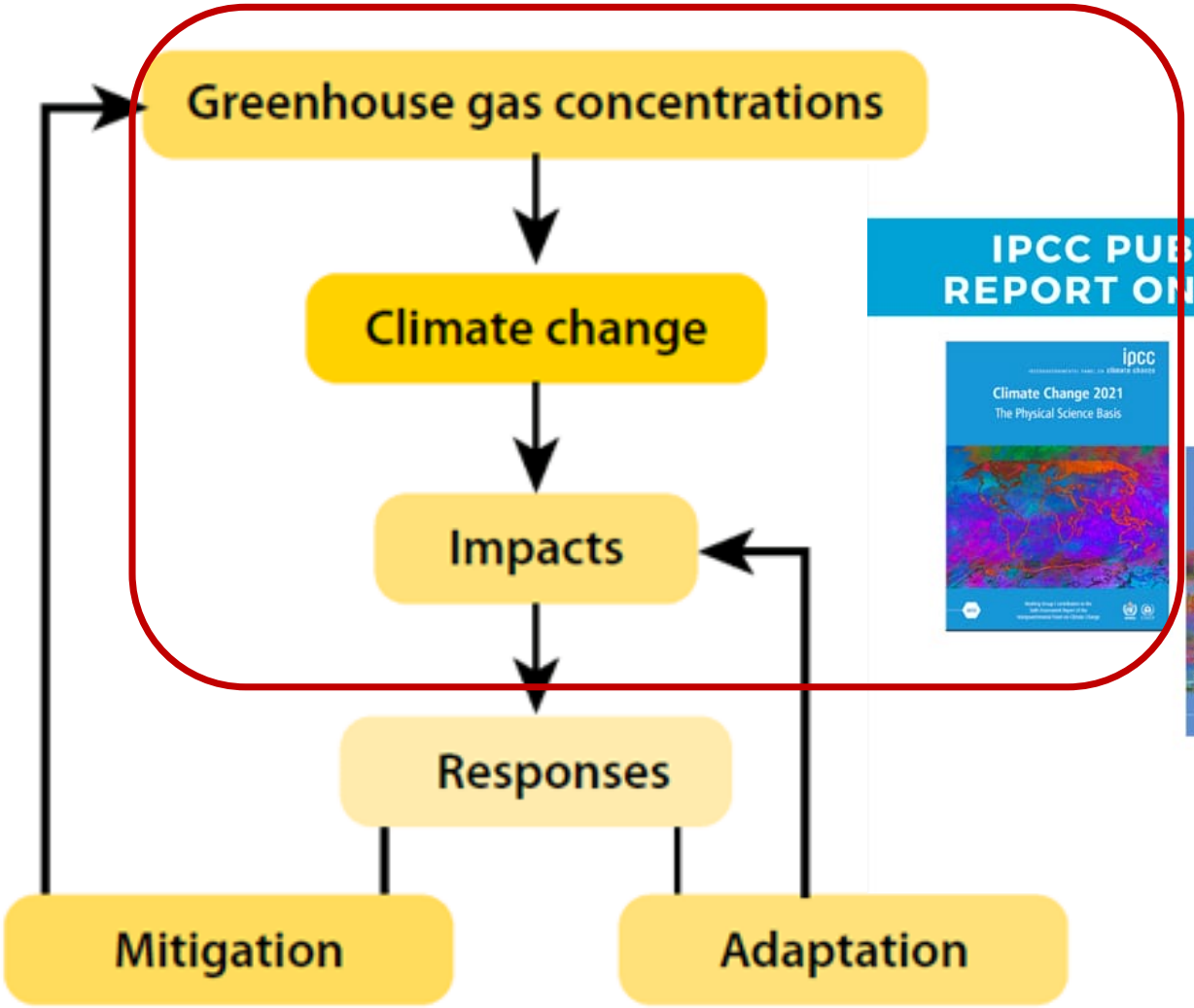
My climate research career started here …

Free Air CO_2 Enrichment (FACE) Experiment



Research focus: Climate extremes & modeling

Climate Change – an integrated framework



https://www.weadapt.org/knowledge-base/nature-based-solutions/forests-and-synergies-between-adaptation-and-mitigation

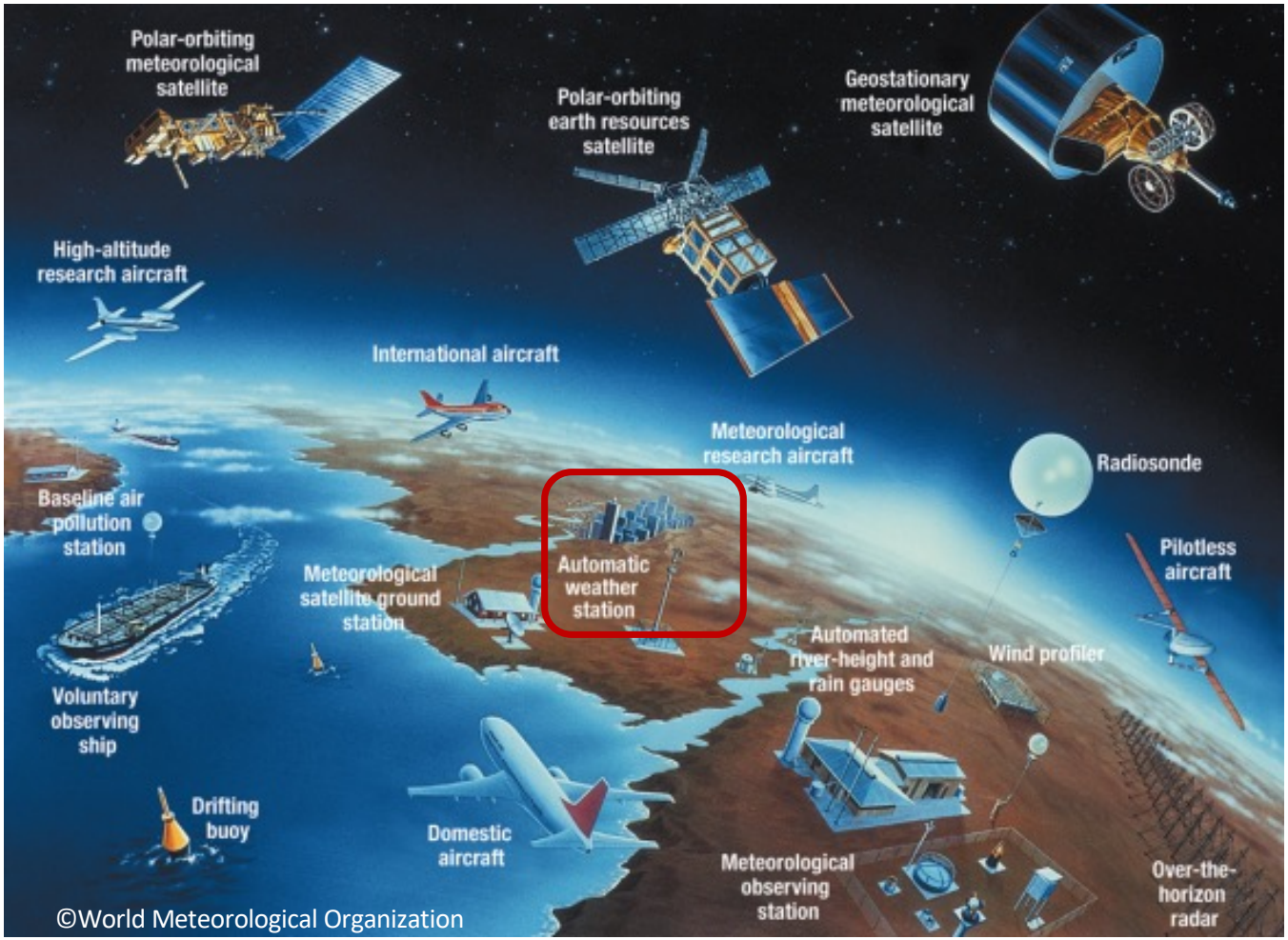
https://www.ipresas.com/en/ipresas-report-climate-change-ipcc/

Outline

- How has climate extremes change?
- Why did they change?
- How will climate extremes change?

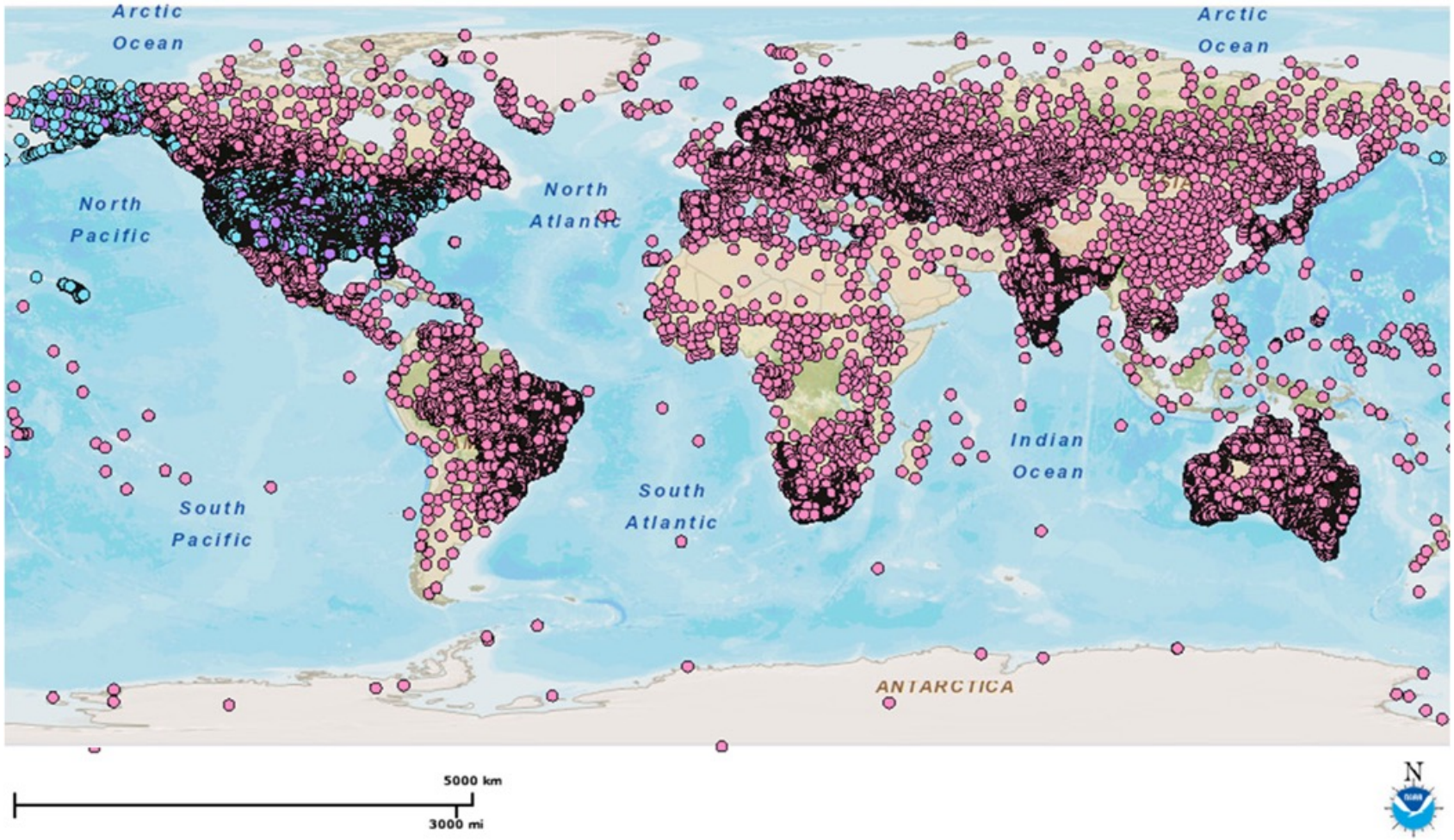
Observations document modern climate

World Meteorological Organization – Global Observing System



Observations document modern climate

Global Historical Climatology Network (90,000 stations)



Observations document modern climate

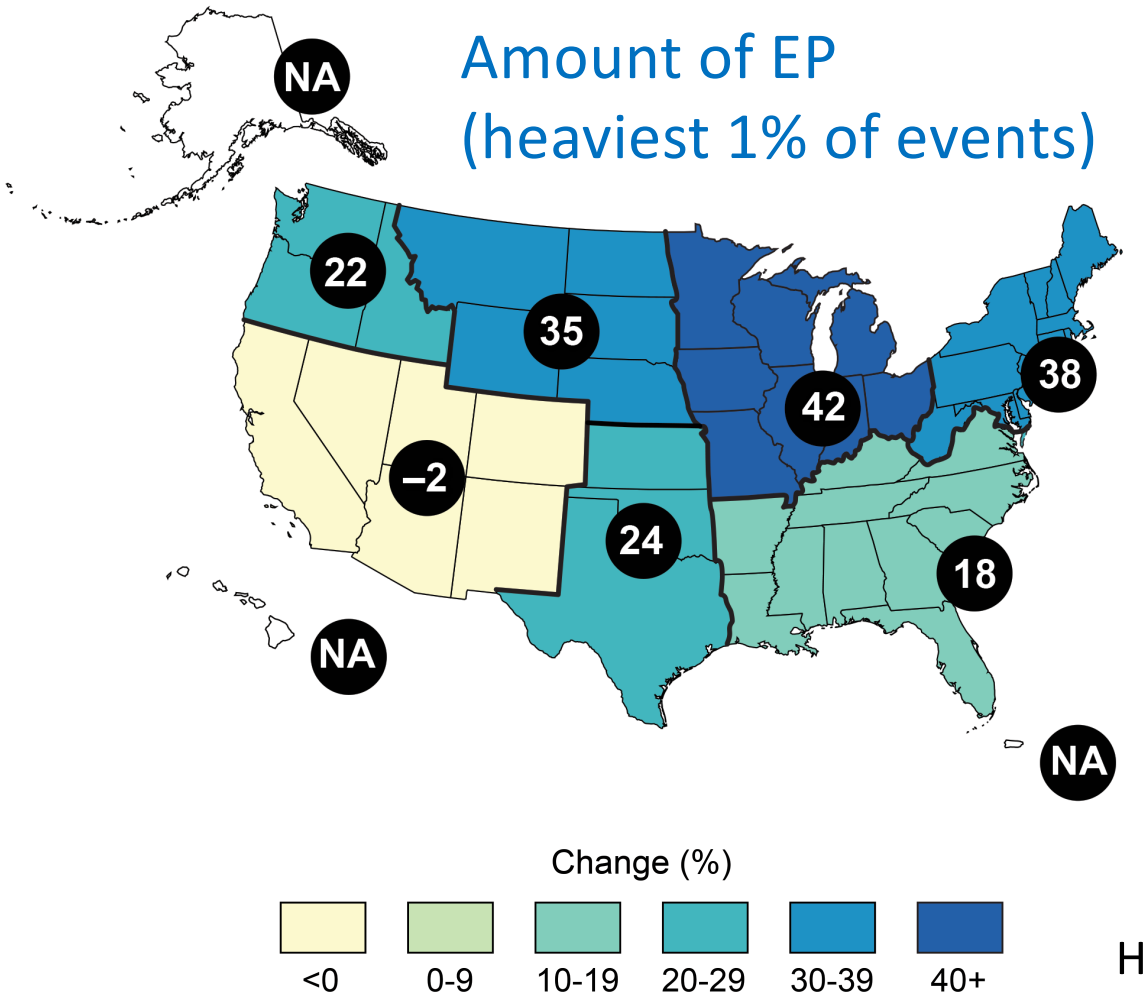
DAILY RAINFALL: LSU (Howe-Russell Rooftop) Year: 2022
CoCoRaHS Station: LA-EB-33
Observation Time: 9AM

Day	January	February	March	April	May	June	July	August	September	October	November	December
1		T	0	0	.12	.05	.07	.04	0	0	0	
2	.96	.27	0	0	0	.21	.64	.36	0	0	0	
3	0	.09	0	0	0	0	.02		0	0	0	
4	0	.68	0	0	0	.35	.05	3.58	2.06	0	0	
5	0	.01	0	1.14	0	0	0	.55	.09	0	1.27	
6	0	0	0	.32	.82	0	.22	0	.01	0		
7	.23	0	0	0	0	0	0	.03	T	0		
8	0	0	0	0	0	0	0	.04	.12	0		
9	T	0	T	0	0	0	0	.09	.29	0		
10	.10	0	0	0	0	0	0	.42	.43	0		
11	0	0	.05	0	0	.38	T		0	0		
12	0	0	.14	.13	0	.12	T	2.07	0	0		
13	0	.03	0	1.20	0	0	.05	.03	0	.07		
14	0	0	0	1.62	.31	0	.21	.22	0	0		
15	0	0	1.09	0	0	0	.11	0	0	0		
16	.04	0	0	T	.04	0	2.06	0	0	0		
17	0	.91	0	0	0	.68	.17	0	0	0		
18	0	.25	.05	.04	0	0	0	0	0	0		
19	0	0	0	0	0	0	0	0	0	0		
20	.34	0	0	0	0	0	0	.47	.07	0		
21	T	0	0	0	0	0	0	1.09	0	0		
22	0	.01	0	0	.30	0		.18	0	0		
23	0	0	1.38	0	2.04	.07	1.98	1.27	0	0		
24	0	0	0	0	.33	0	0	.64	0	0		
25	.57	.74	0	.43	.33	0	0	.09	0	.05		
26	T	T	0	.08	.34		.31	.82	0	0		
27	0	.10	0	0	0	1.62	0	.06	0	0		
28	0	0	0	0	0	.19	.08	0	0	0		
29	0	—	0	0	0	0	.01	0	0	0		
30	0	—	0	0	0	0	0	.01	0	.29		
31	0	—	1.25	—	0	—	.31	.01	—	0	—	
Sum	1.74	2.19	3.96	4.96	4.63	3.67	6.29	12.07	3.07	0.41		

1.27”

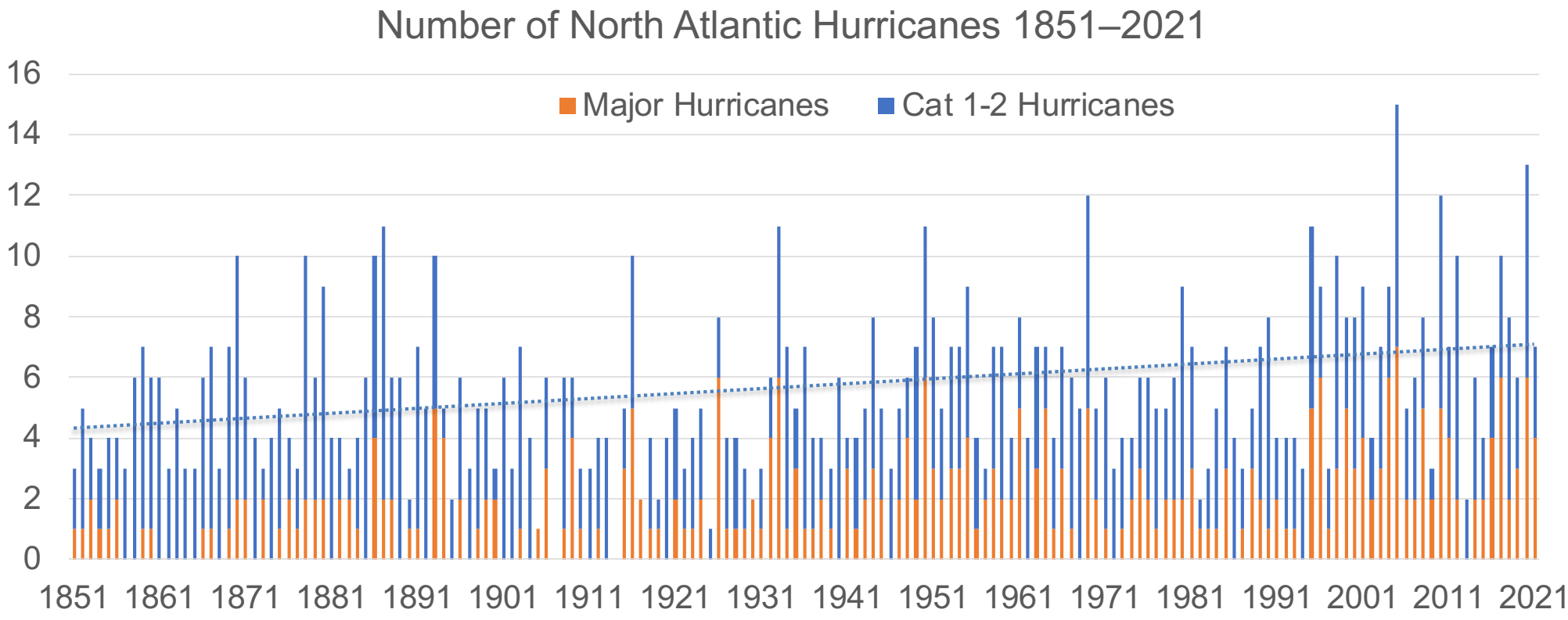
Observed change in extreme precipitation (EP)

(1986–2016 relative to 1901–1960)



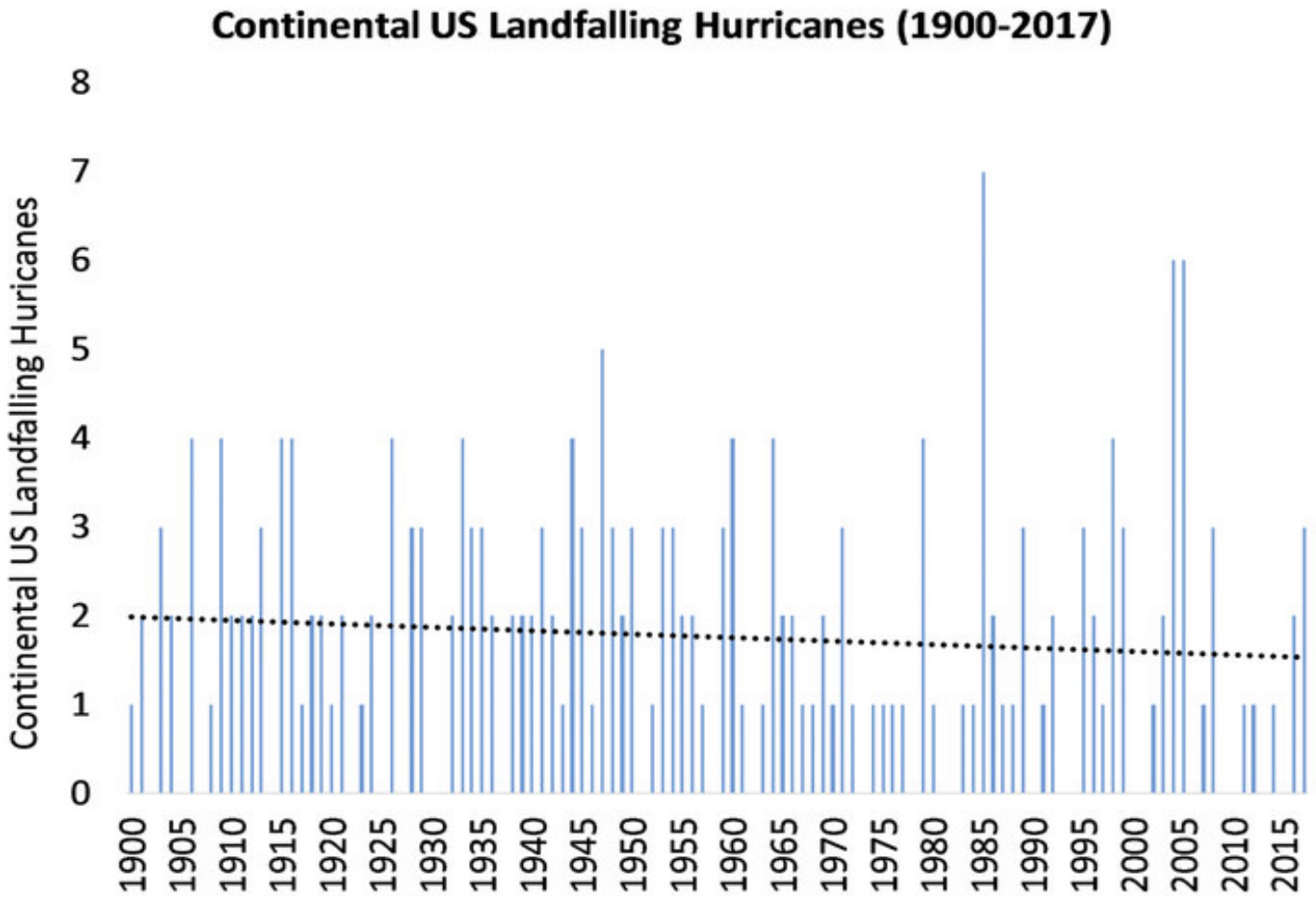
Hayhoe et al., 2018

There has been a significant increase in hurricane frequency.



Data source: NOAA National Hurricane Center

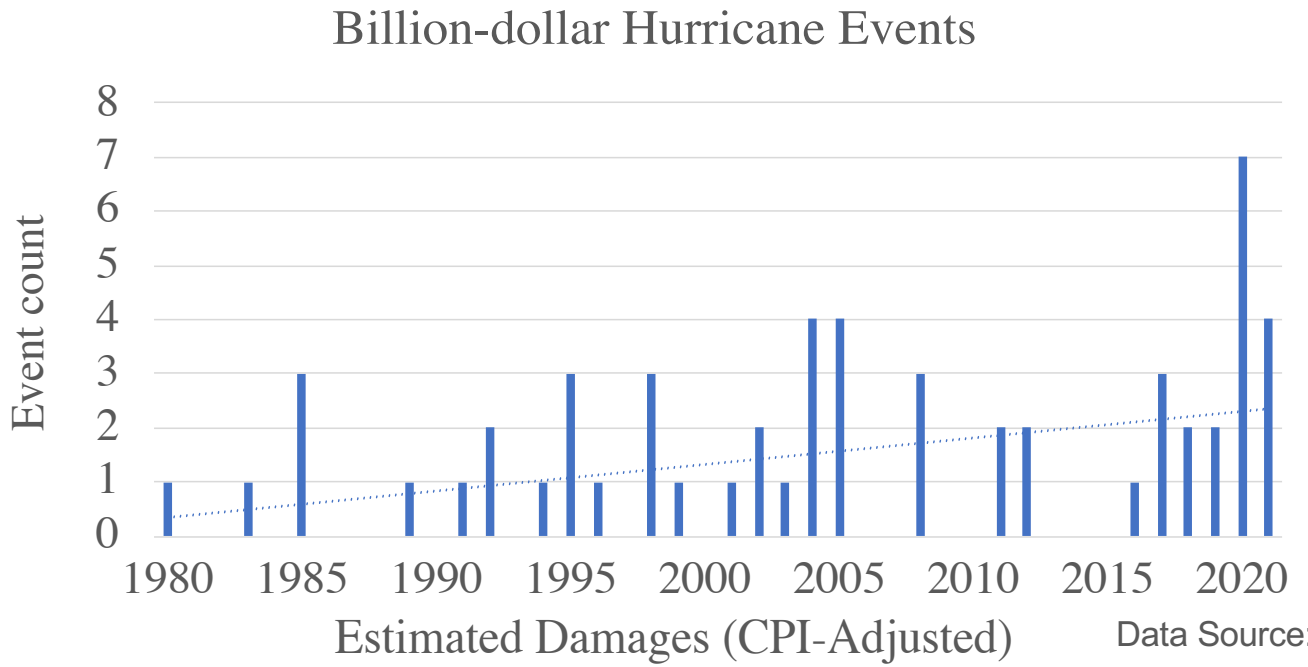
But the trend in US landfalling hurricanes is insignificant.



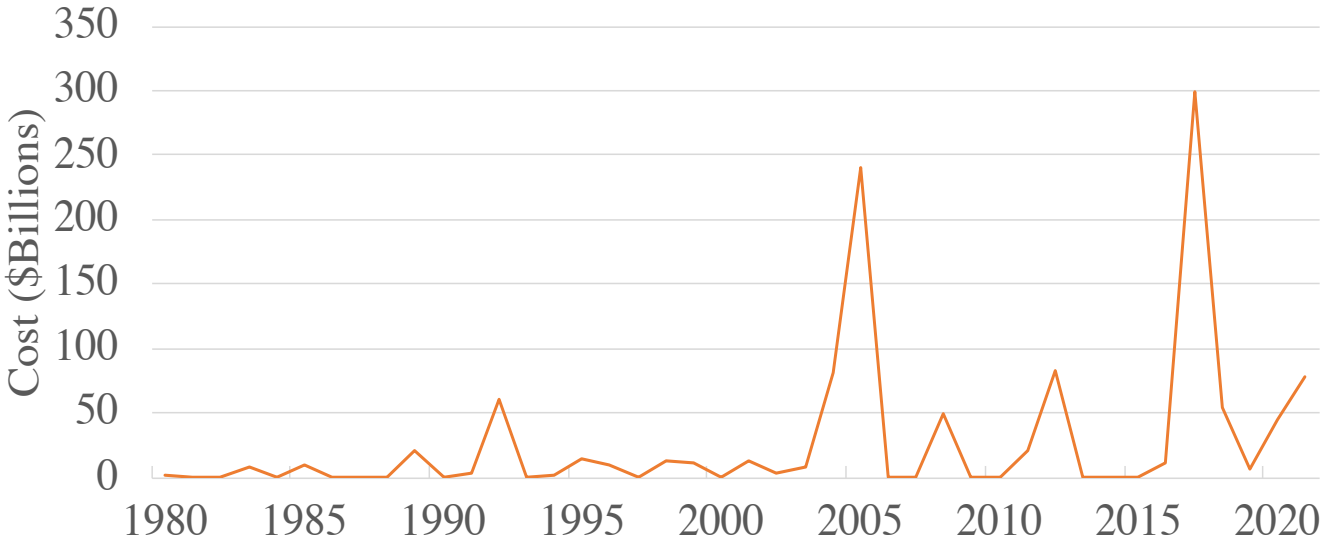
2018: 2
2019: 2
2020: 6
2021: 2
2022: 2

Klotzbach et al., 2018

US hurricane hazards are more frequent & costlier!



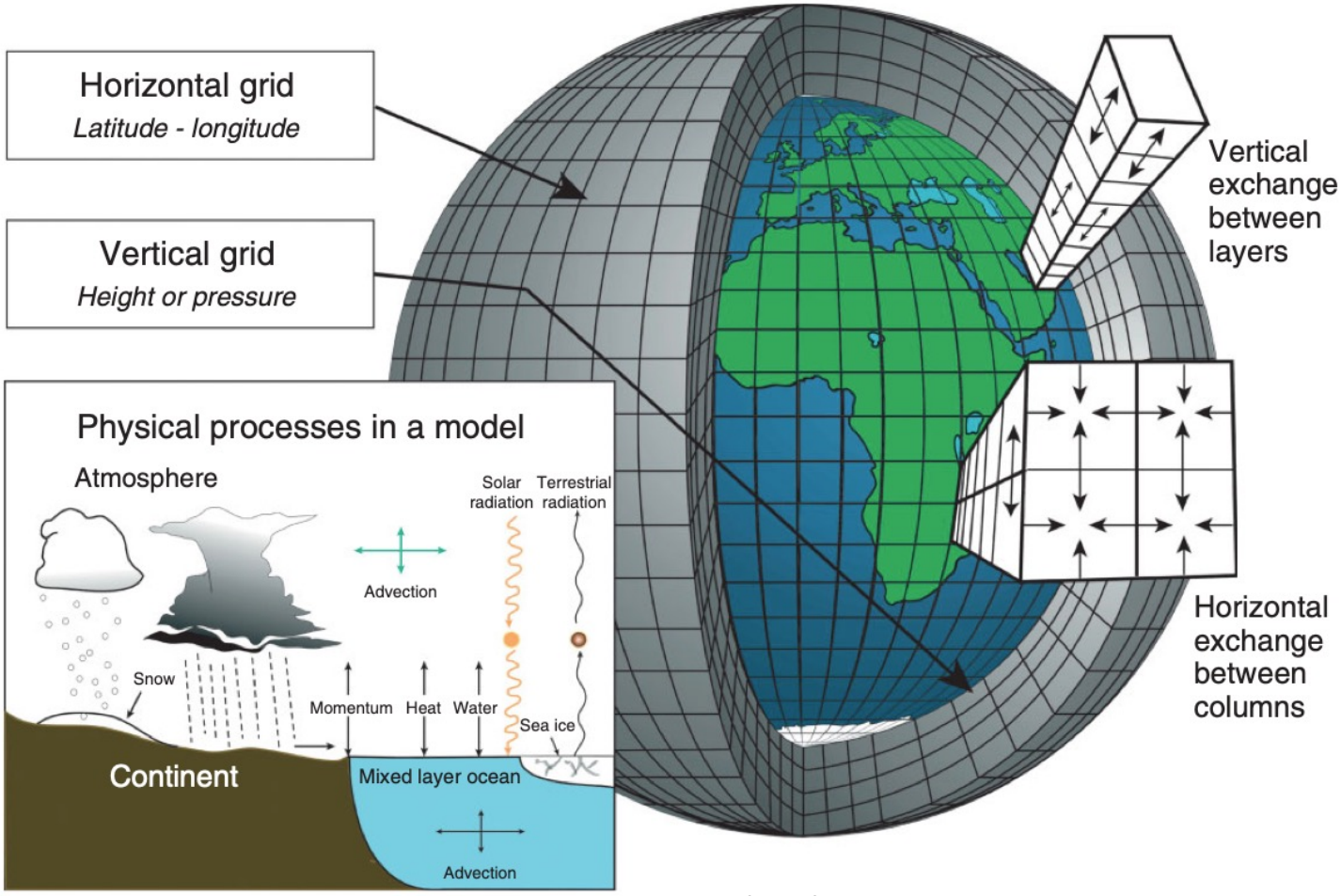
Data Source: NOAA NCEI



Outline

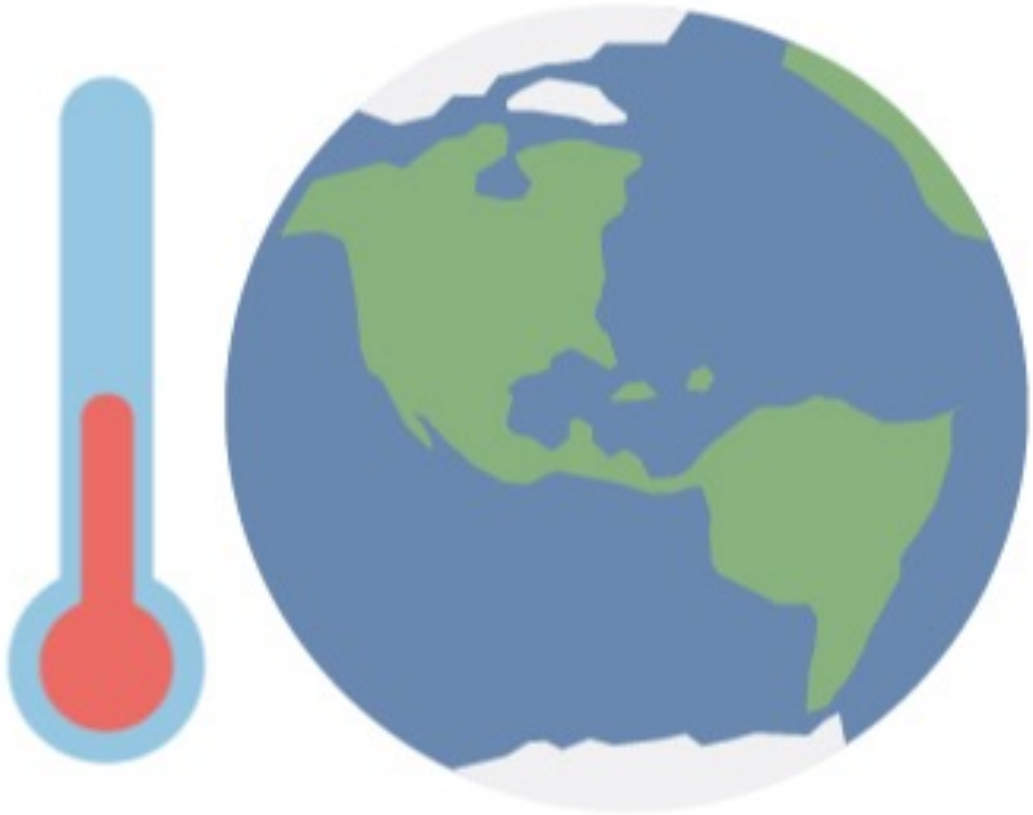
- How has climate extremes change?
- Why did climate extremes change? Did human activities (e.g., greenhouse gases emissions) play any role?
- How will climate extremes change?

Observations can't detect & attribute climate change. We need more powerful tools – global climate models.



Edwards 2011

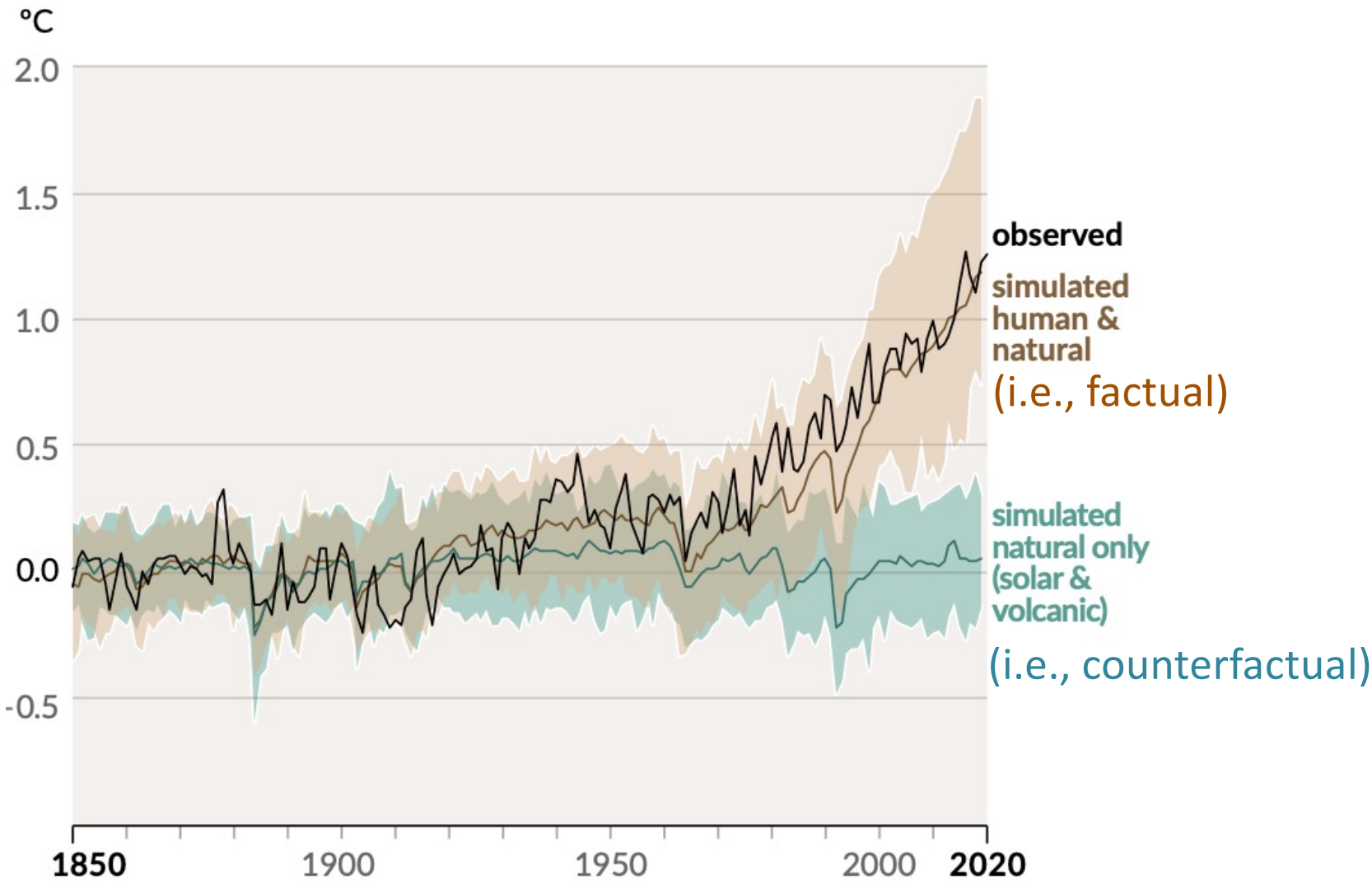
How can climate models be used to detect & attribute climate change?



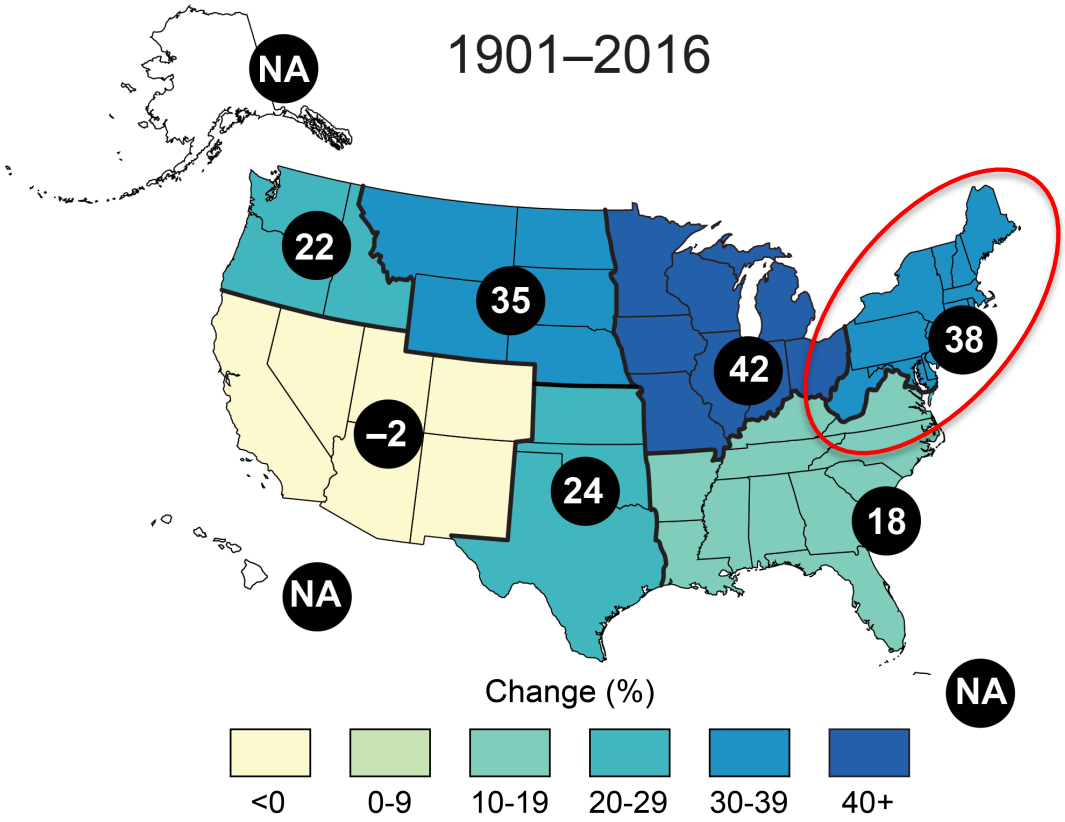
©NASA

Intergovernmental Panel on Climate Change (IPCC) 2021:

Human drivers (greenhouse gas emissions) warm the planet!



Case study: Detect & attribute the change in Northeast extreme precipitation (EP)

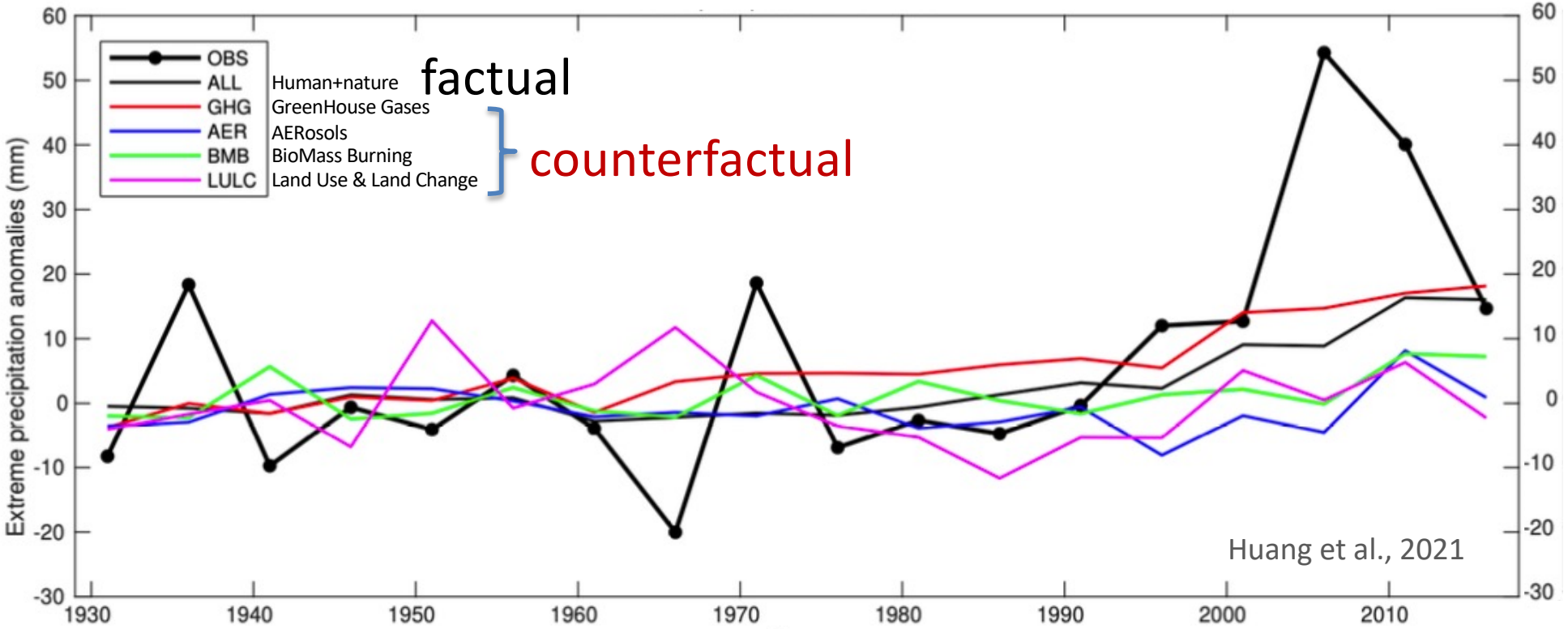


Was the EP increase attributable to external forcings or internal variability?

Hayhoe et al., 2018

What caused the EP increase?

Extreme precipitation anomalies (relative to 1929–1958)



Greenhouse gases from **human activities** are the primary cause!

Human activities have contributed to observed EP increase in nearly half of subcontinents.

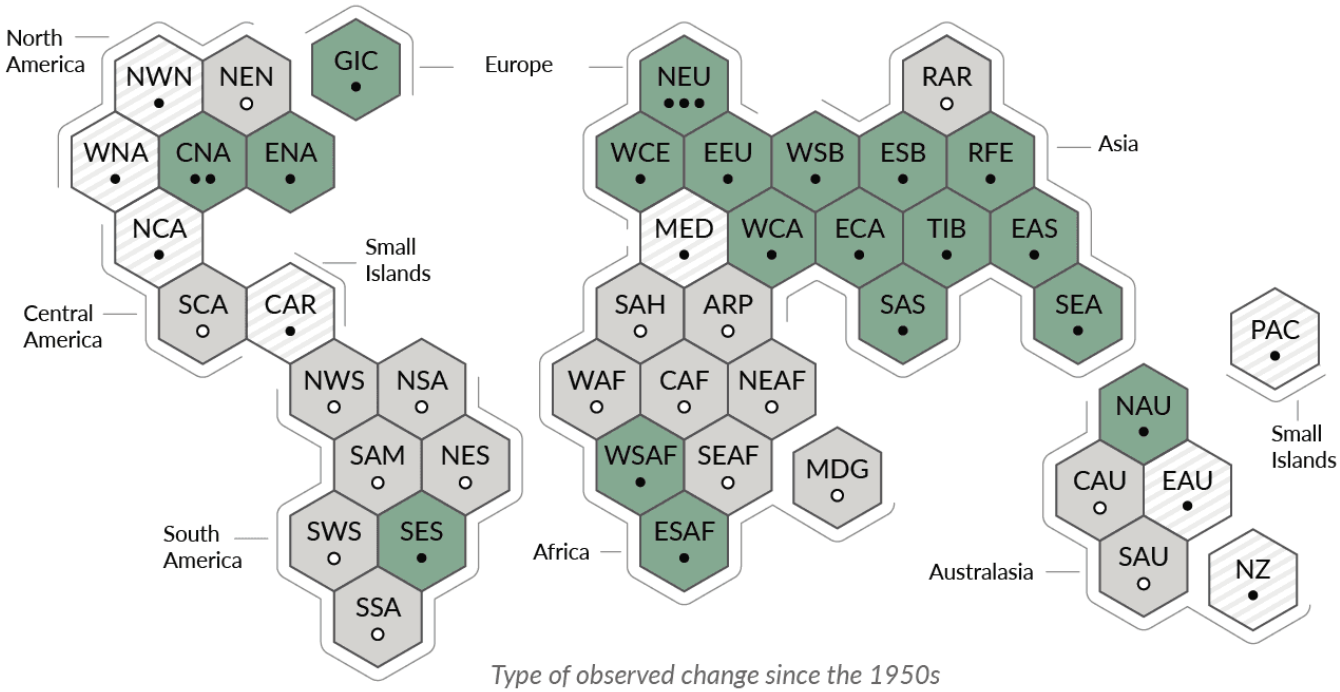
(b) Synthesis of assessment of observed change in **heavy precipitation** and confidence in human contribution to the observed changes in the world's regions

Type of observed change
in heavy precipitation

- Increase (19)
- Decrease (0)
- Low agreement in the type of change (8)
- Limited data and/or literature (18)

Confidence in human contribution
to the observed change

- ●●● High
- ●● Medium
- ● Low due to limited agreement
- ○ Low due to limited evidence



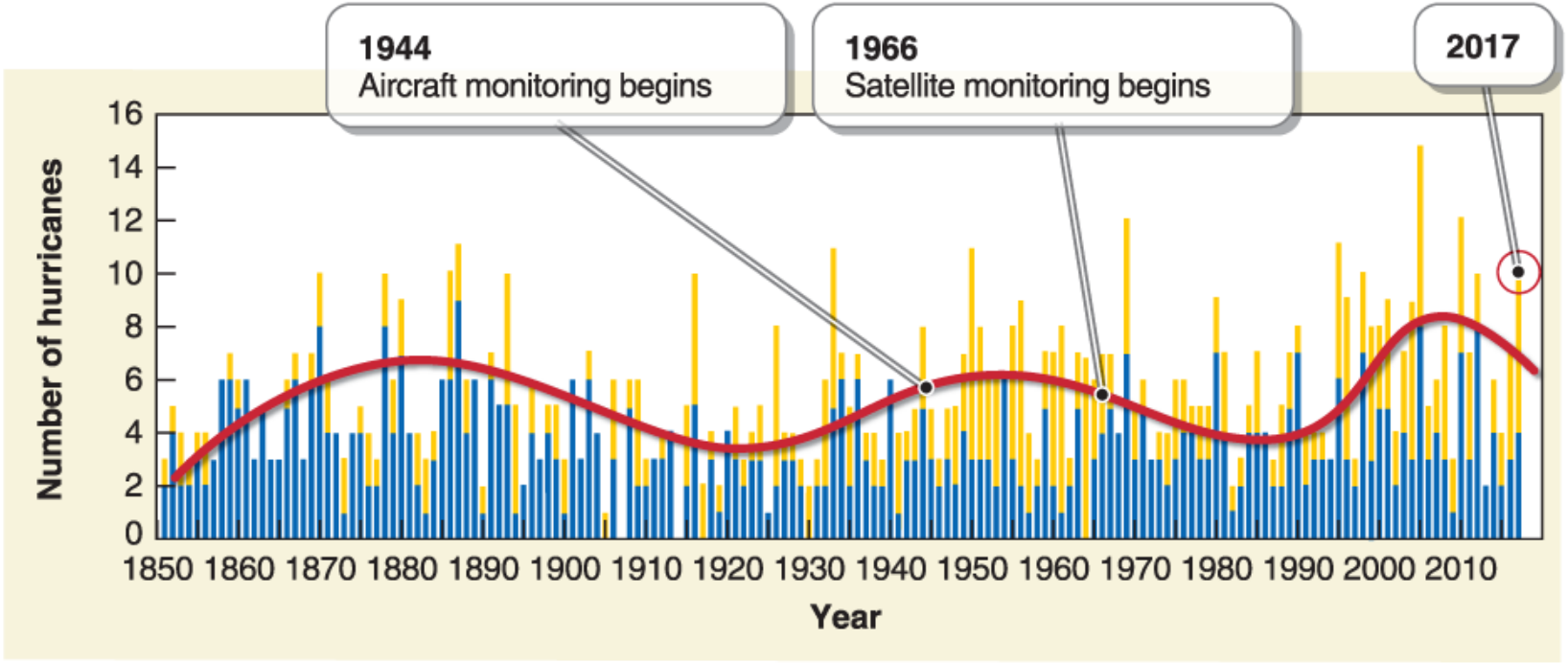
Type of observed change since the 1950s

IPCC 2018

LSU

Detection and attribution of hurricane activity has been very challenging

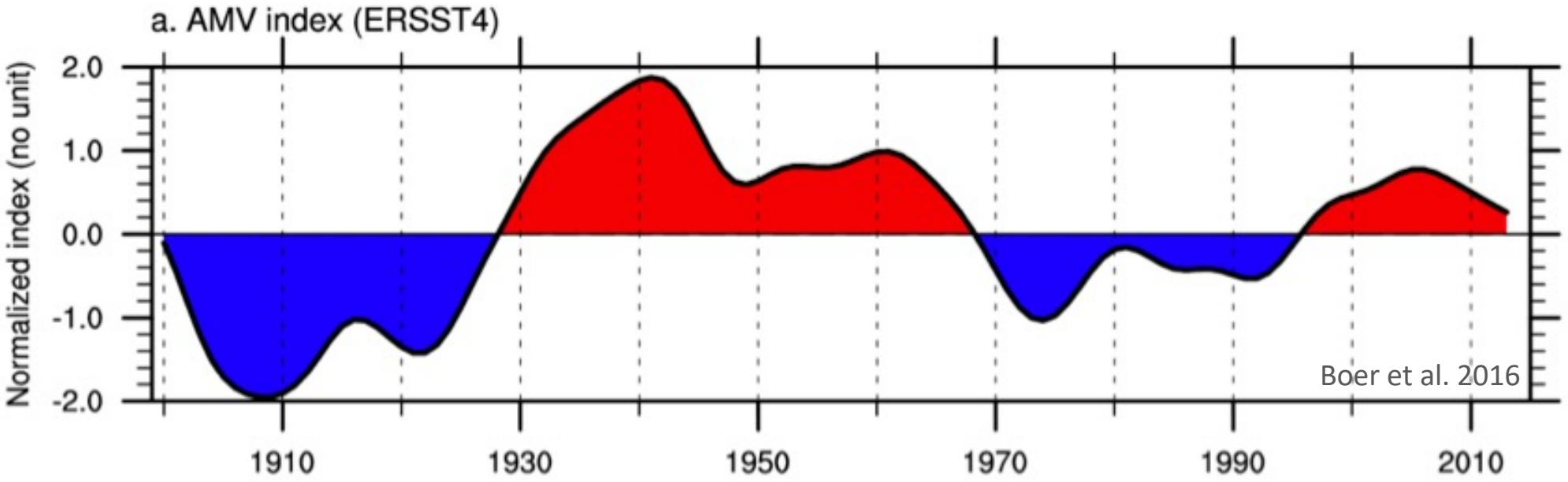
- Difficulty obtaining accurate and temporally consistent measures of hurricanes, especially in the pre-satellite era



A

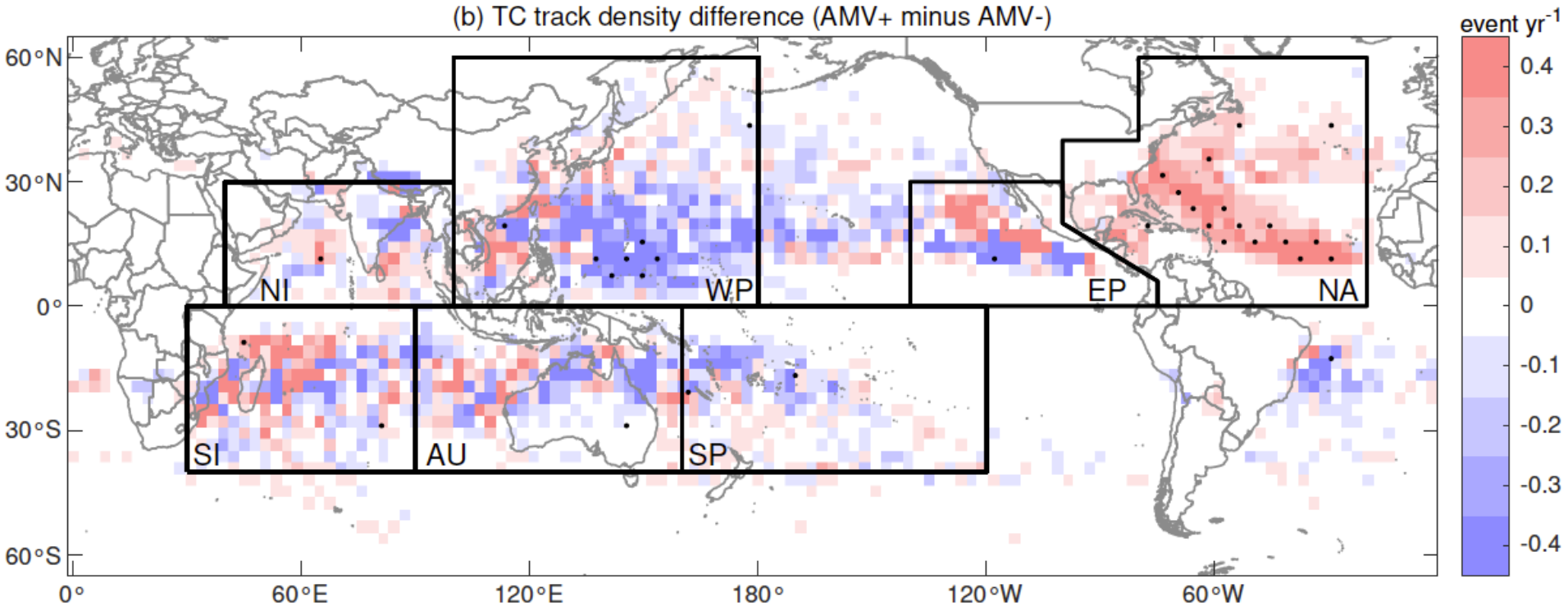
Gervais, *Living Physical Geography*, 2e, © 2019 W. H. Freeman and Company

- Large climate variability, especially the Atlantic Multidecadal Variability (AMV)*



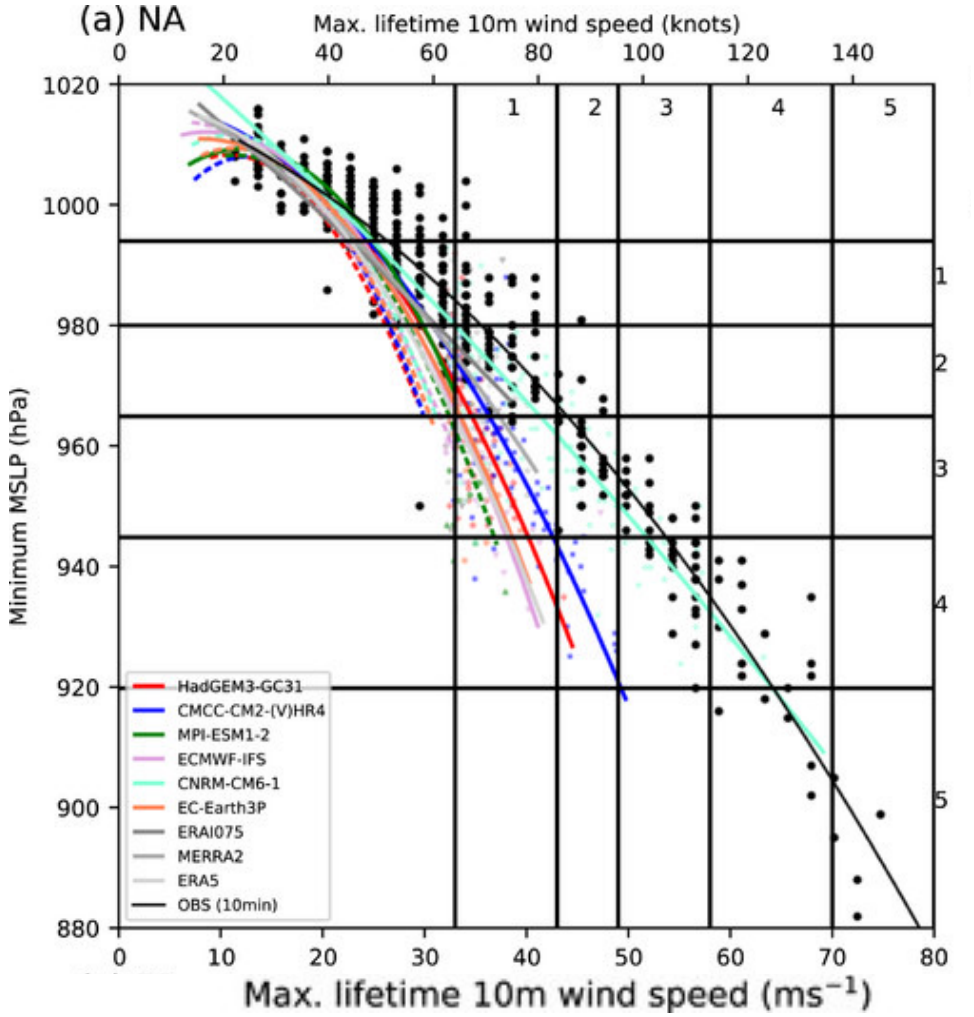
*AMV: detrended SST anomalies averaged over the North Atlantic

AMV+ produces more frequent hurricanes in the North Atlantic.



Huang et al., in revision

- Climate models' limitation in simulating hurricanes

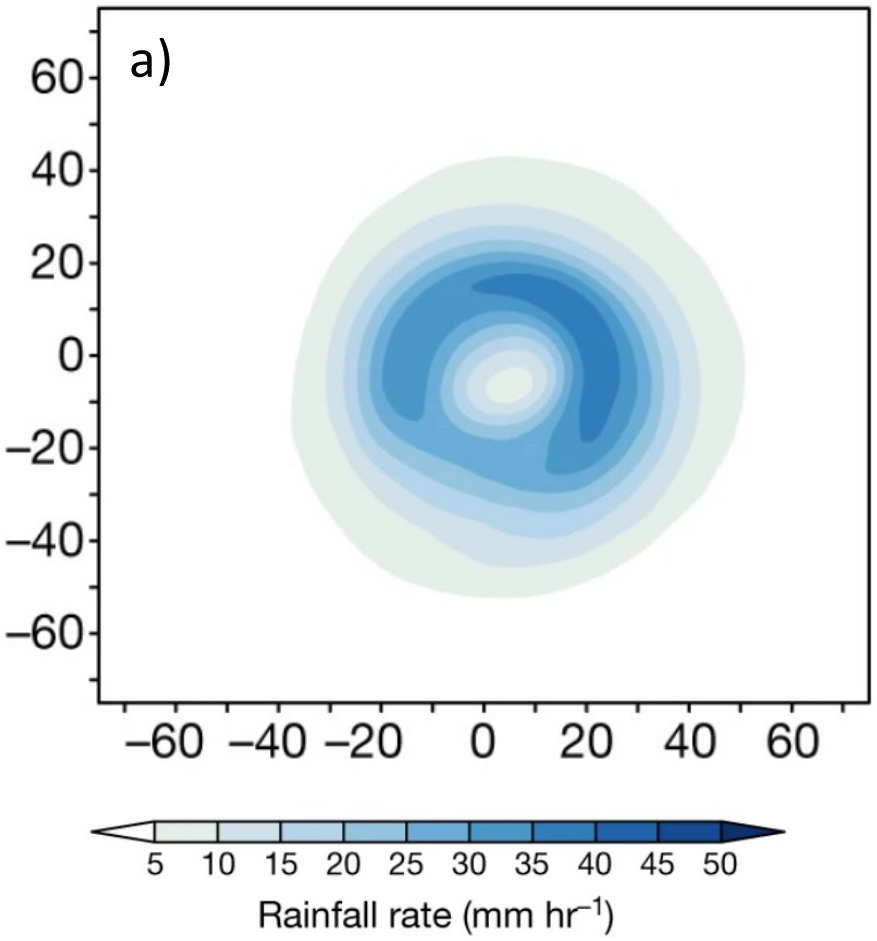


Roberts et al., 2020a

LSU

Human-induced climate change enhanced Katrina rainfall by 9%

Historical

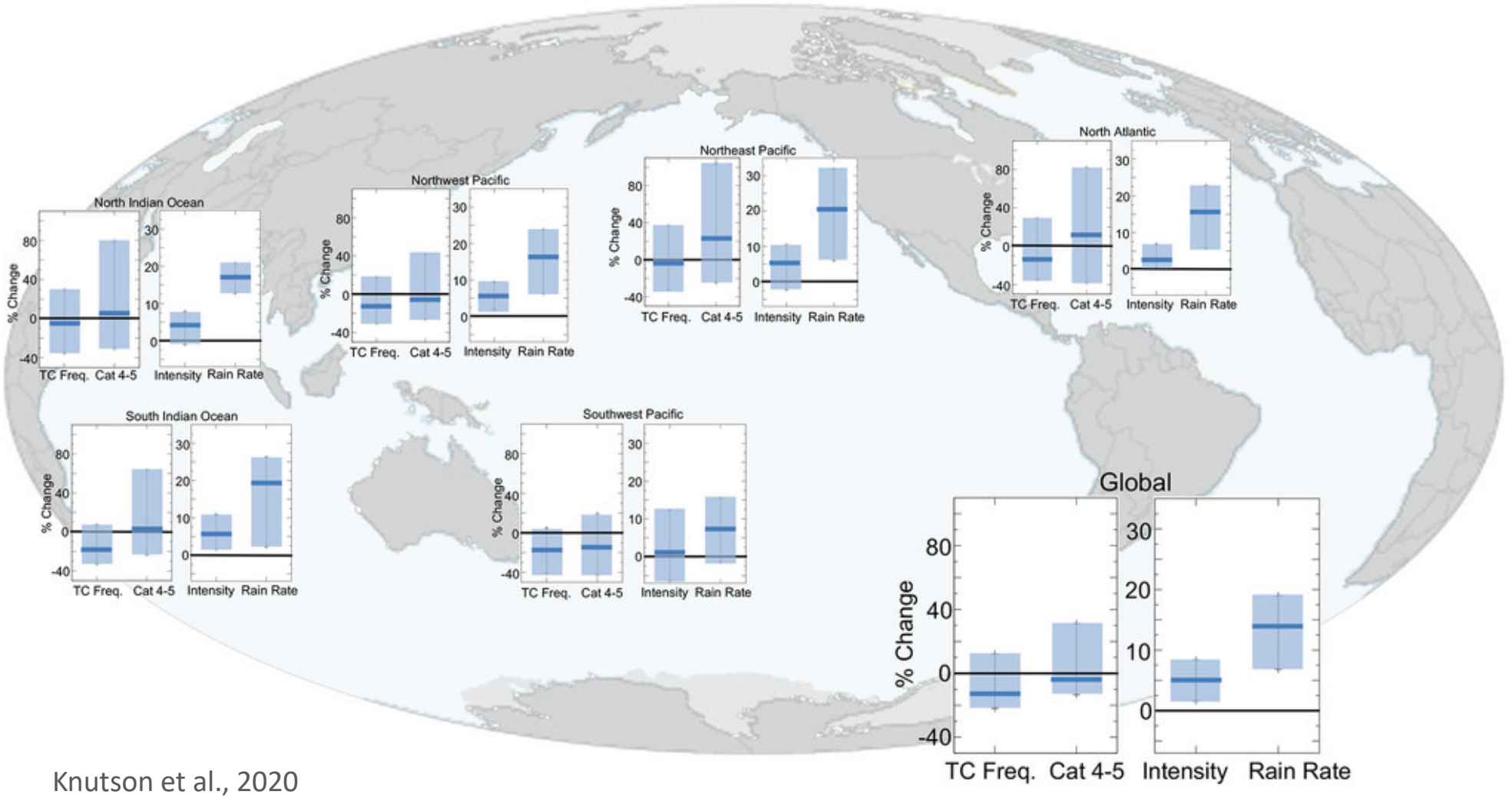


Patricola et al., 2018

Outline

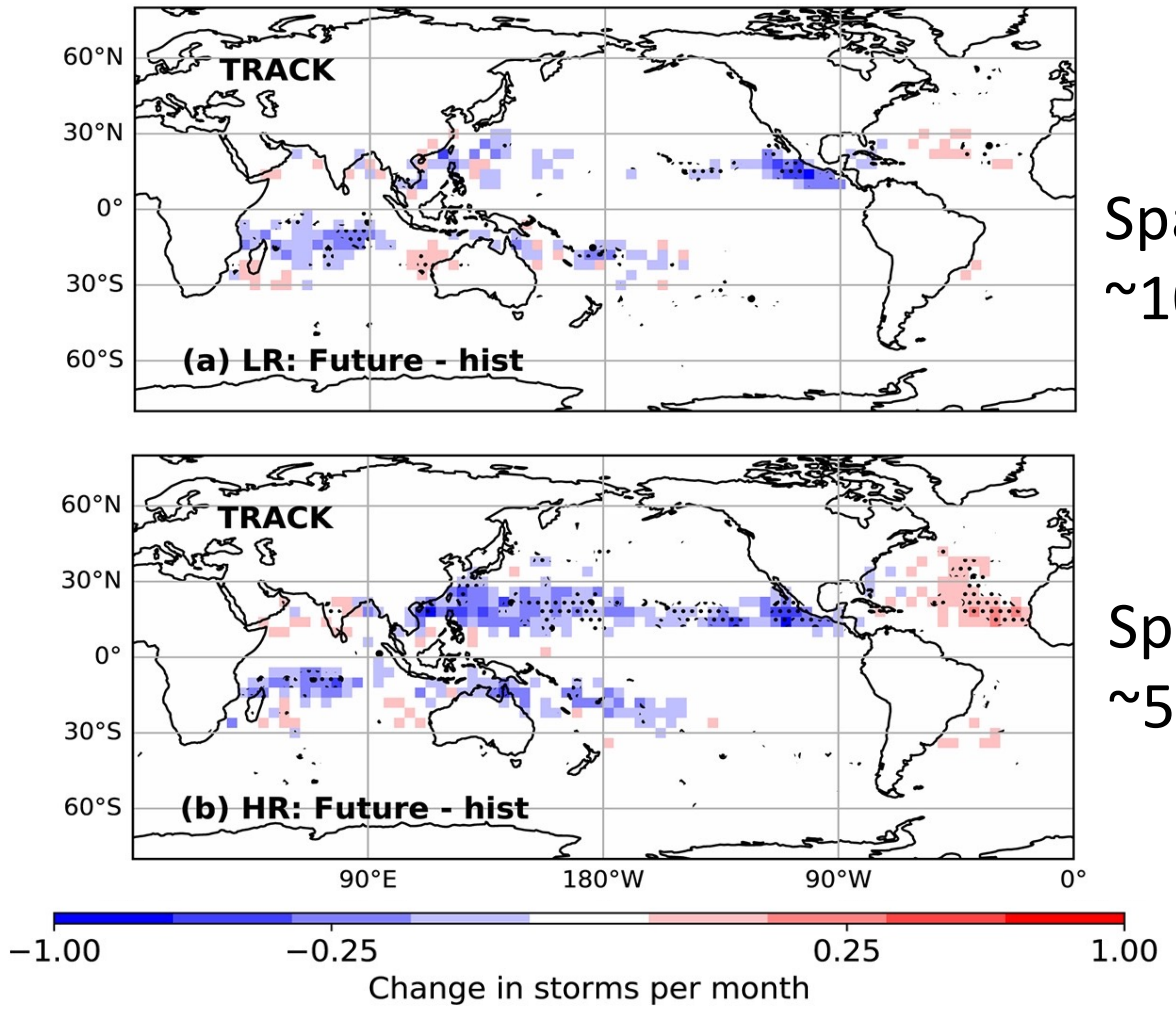
- How has climate extremes change?
- Why did they change?
- How will climate extremes change?

In the North Atlantic, there is a high confidence on future increases in hurricane intensity & rain rate.



Knutson et al., 2020

In the North Atlantic, there is a larger increase in simulated hurricane frequency at higher resolution.



Spatial resolution ~100 km

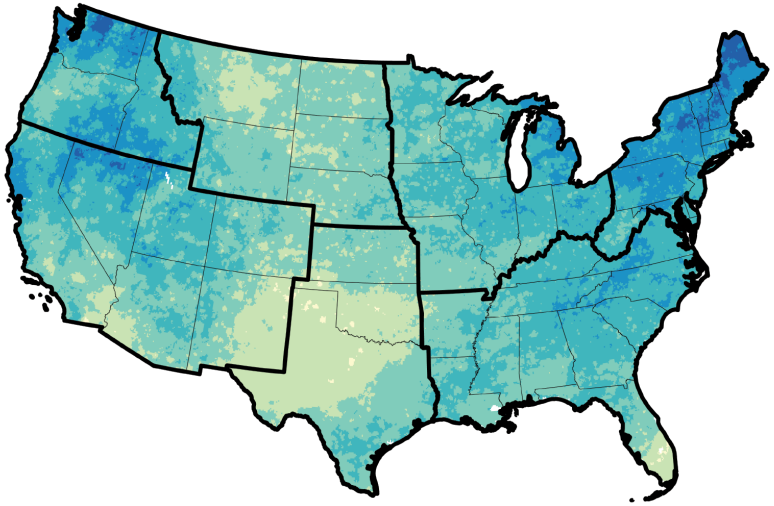
Spatial resolution ~50 km

Roberts et al., 2020b

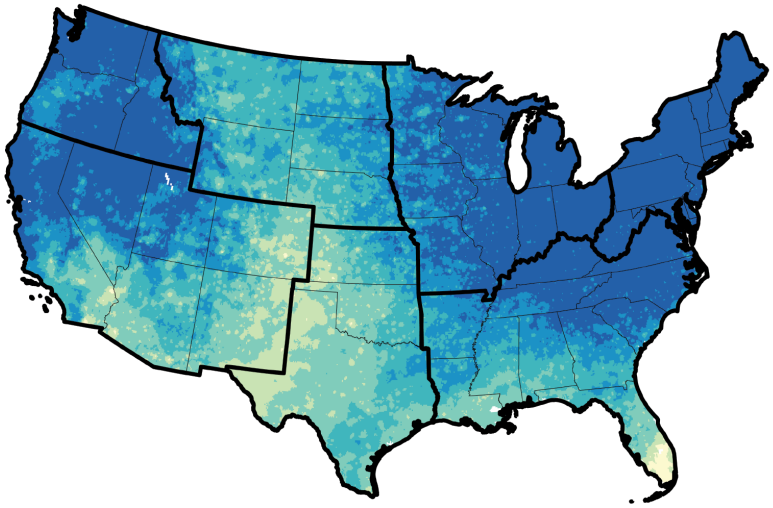
The higher greenhouse gases emissions, the more extreme precipitation

Projected Change in Total Annual Precipitation
Falling in the Heaviest 1% of Events by Late 21st Century

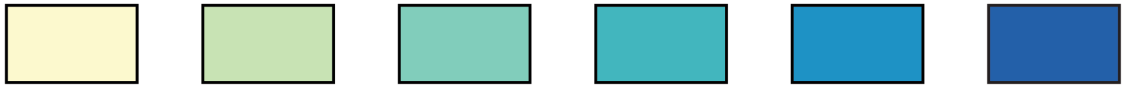
Lower Scenario (RCP4.5)



Higher Scenario (RCP8.5)



Change (%)



Hayhoe et al., 2018

LSU

Summary

- Hurricanes and extreme precipitation have increased over the past century.
- Anthropogenic climate change has increased extreme precipitation, but its influence on hurricanes is less clear.
- Future climate change will increase extreme precipitation, hurricane intensities & rain rate.

Acknowledgments

Doctoral Advisors

Jonathan M. Winter, Erich C. Osterberg (Dartmouth)

Postdoc Advisors

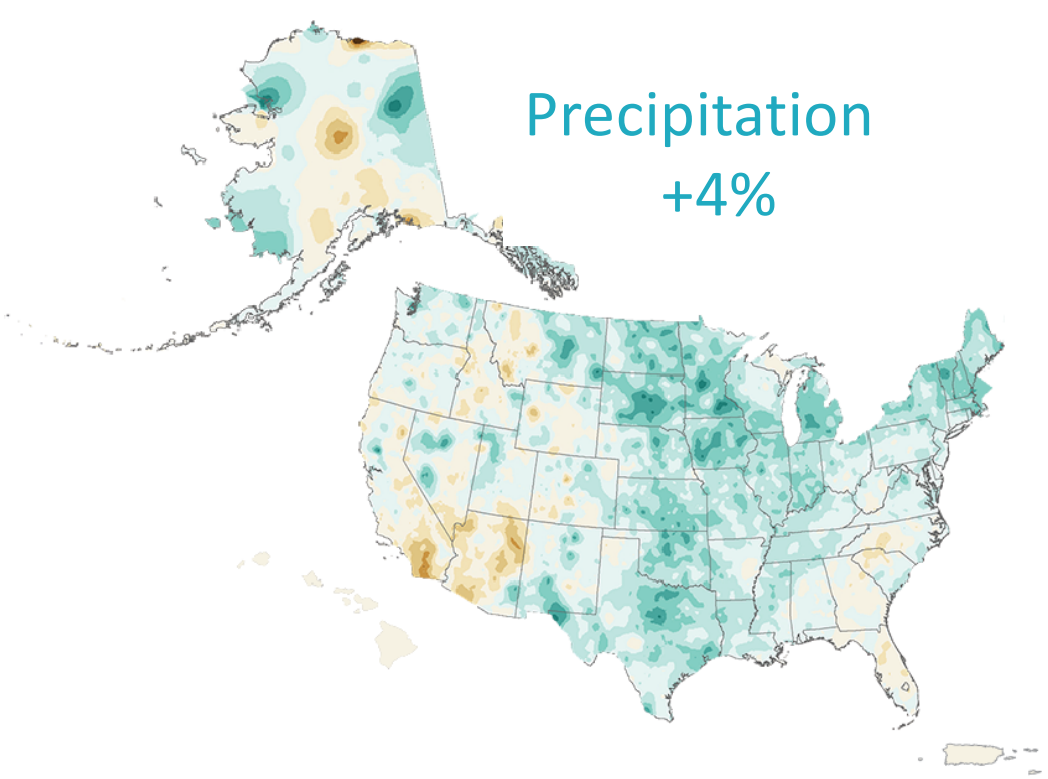
William (Bill) D. Collins (Berkeley Lab & UC Berkeley)

Christina M. Patricola (Berkeley Lab & Iowa State)

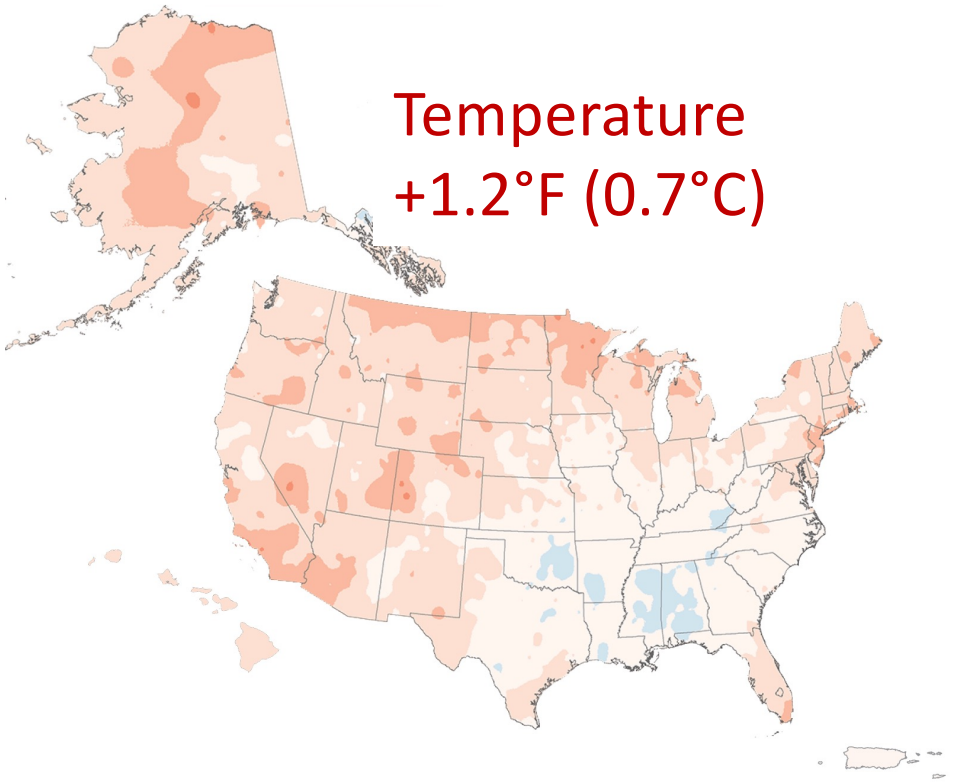
Collaborators

Observed climate change in the US

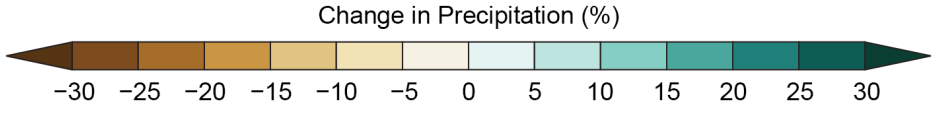
(1986–2016 relative to 1901–1960)

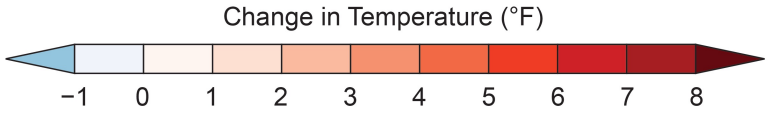


Precipitation
+4%



Temperature
+1.2°F (0.7°C)





LSU

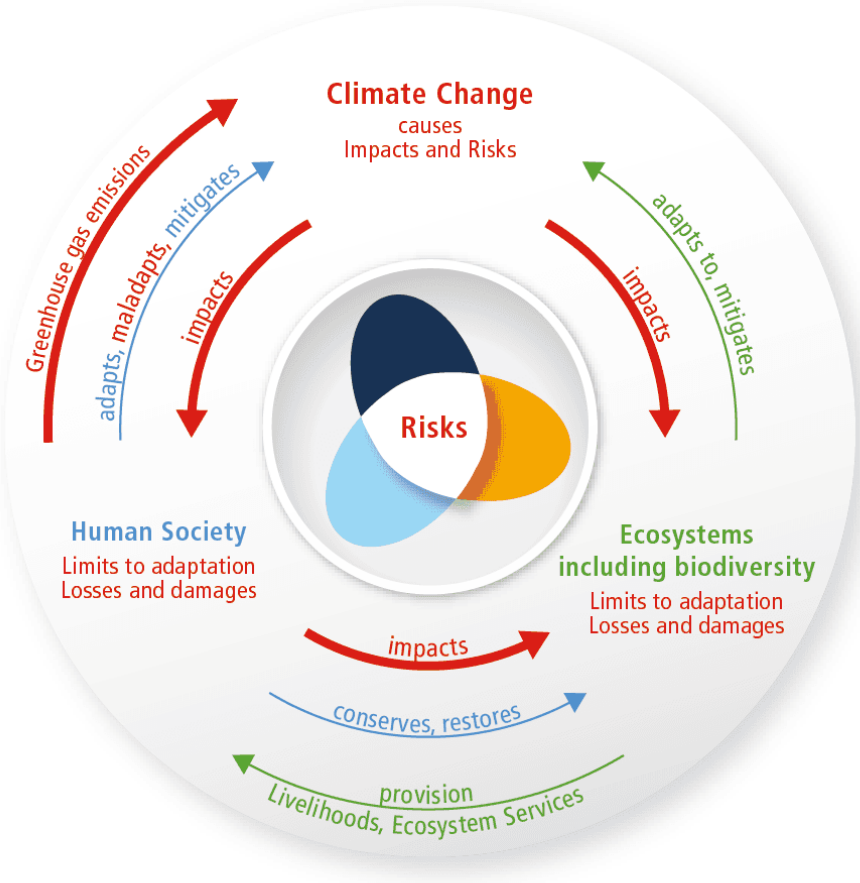
Globally, how will TC precipitation change?

CMIP6 High Resolution Model Intercomparison Project (HighResMIP v1.0) simulations covering 1950–2050

Haarsma et al. 2016

From climate risk to climate resilient development: climate, ecosystems (including biodiversity) and human society as coupled systems

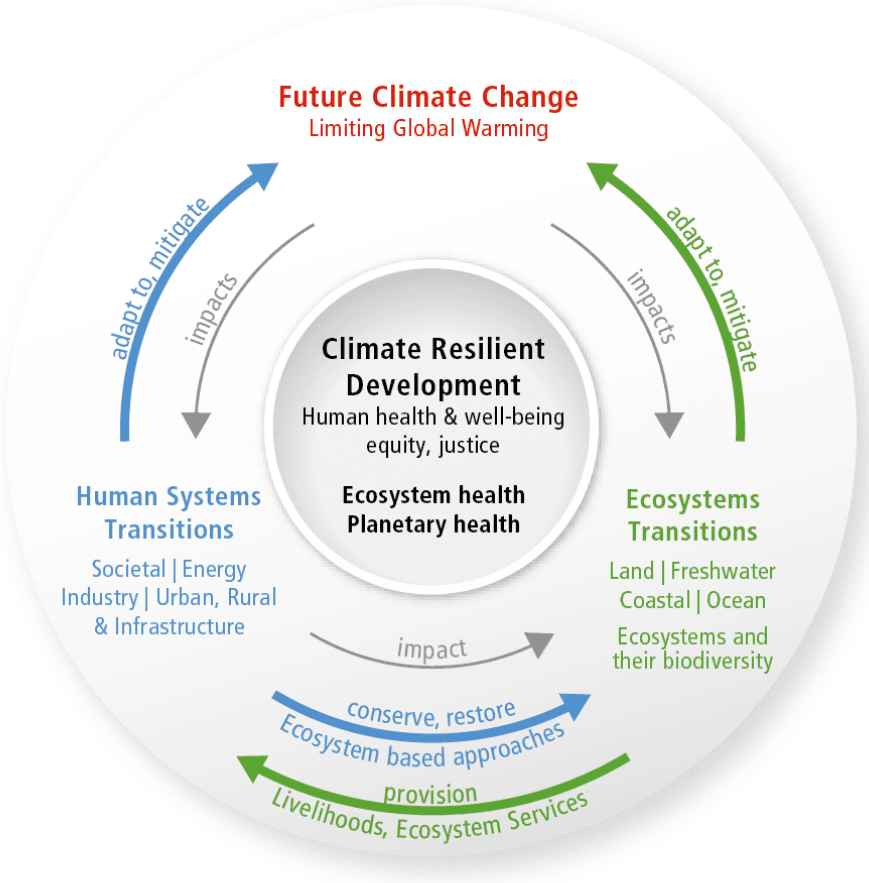
(a) Main interactions and trends



From urgent to timely action

Governance
Finance
Knowledge and capacity
Catalysing conditions
Technologies

(b) Options to reduce climate risks and establish resilience



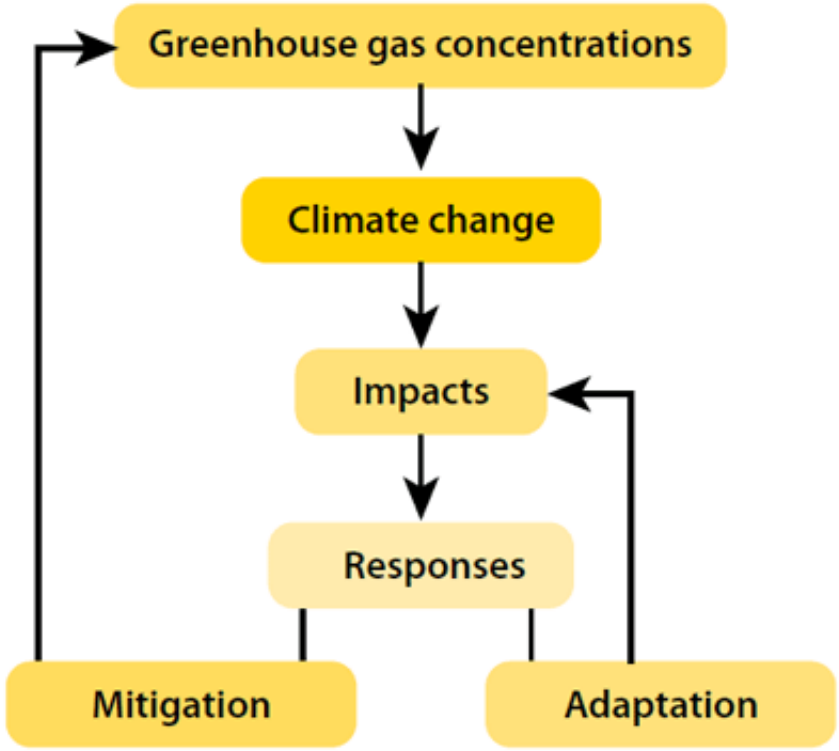
The risk propeller shows that risk emerges from the overlap of:

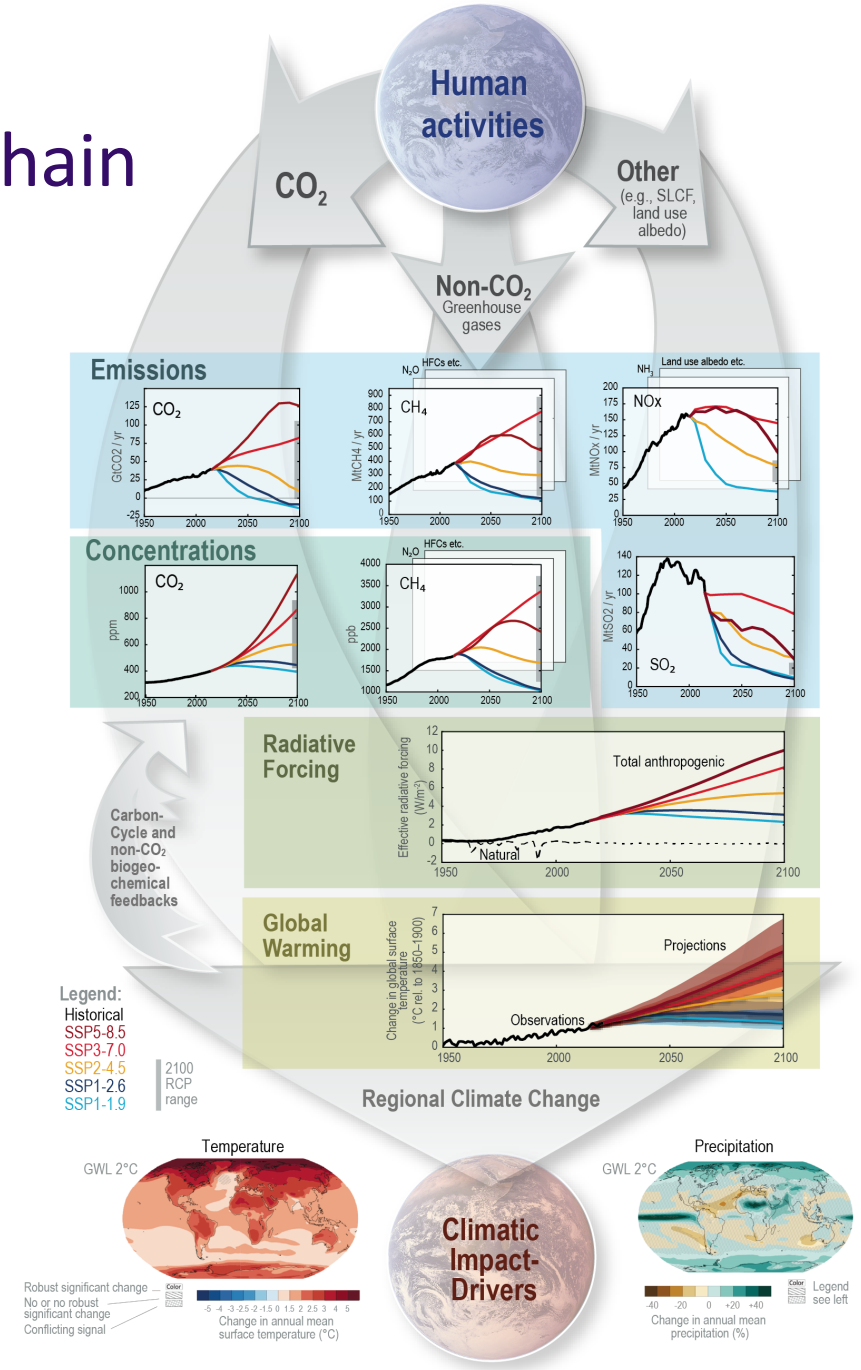
Climate hazard(s) Vulnerability Exposure

...of human systems, ecosystems and their biodiversity

https://www.ipcc.ch/report/ar6/wg2/figures/summary-for-policymakers/figure-spm-1

The climate change cause–effect chain





Arias et al. 2021