Climate Change Impacts in Hawai'i

Chip Fletcher
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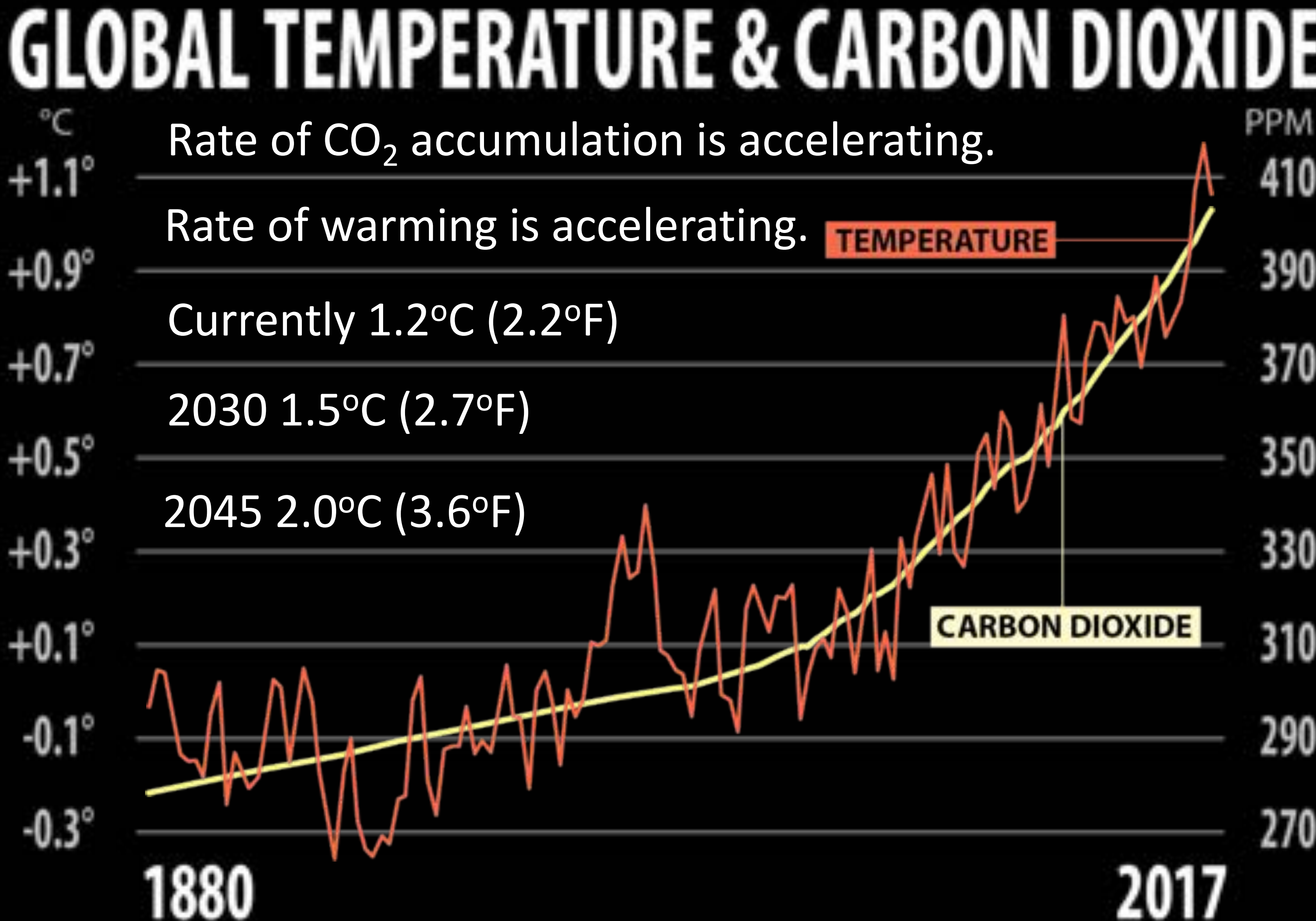
University of Hawai'i at Mānoa
Hono'lulu Climate Change Commission



Rate of CO_2 accumulation is accelerating.

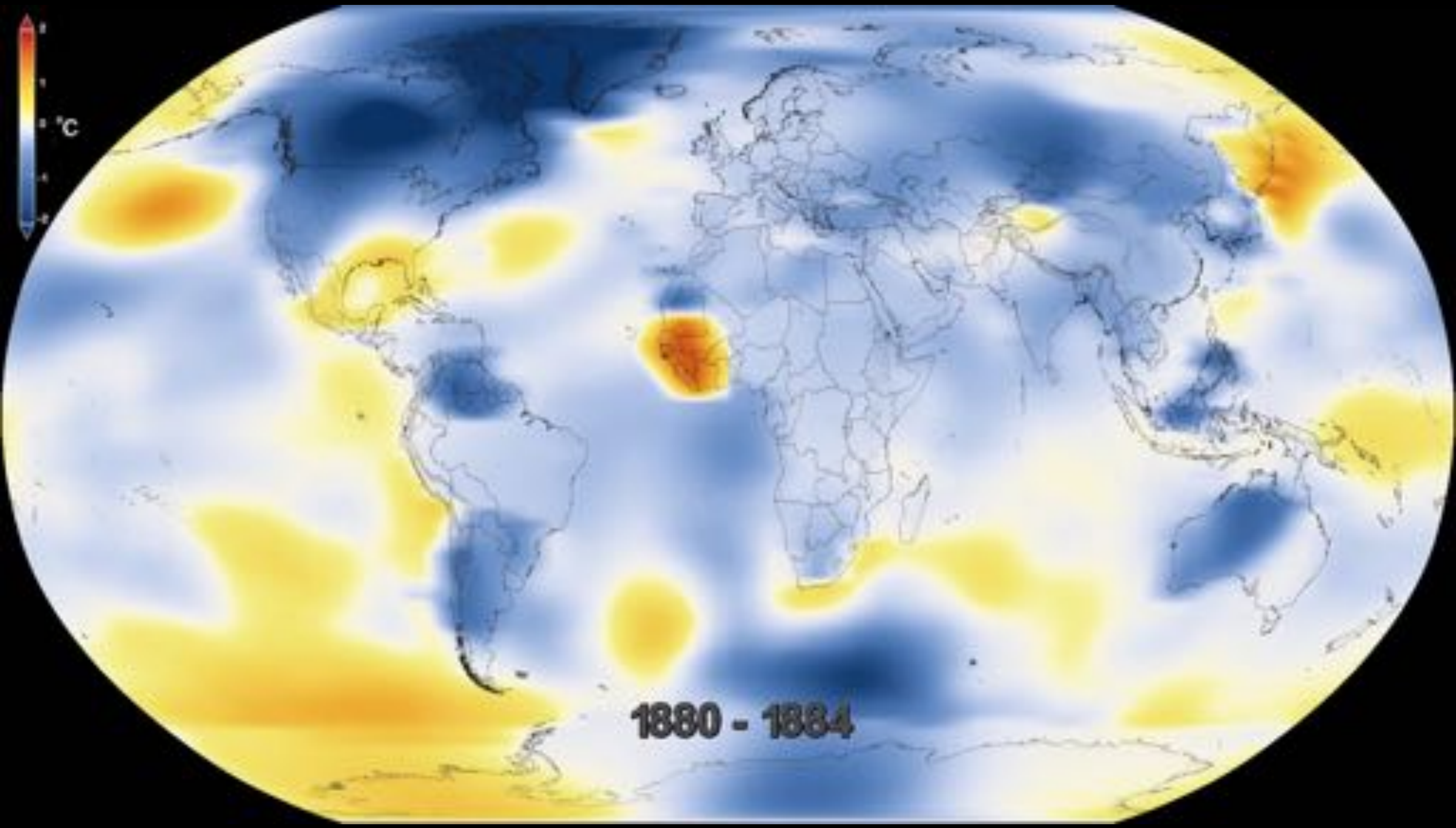
Rate of warming is accelerating.

Currently 1.2°C (2.2°F)

2030 1.5°C (2.7°F)

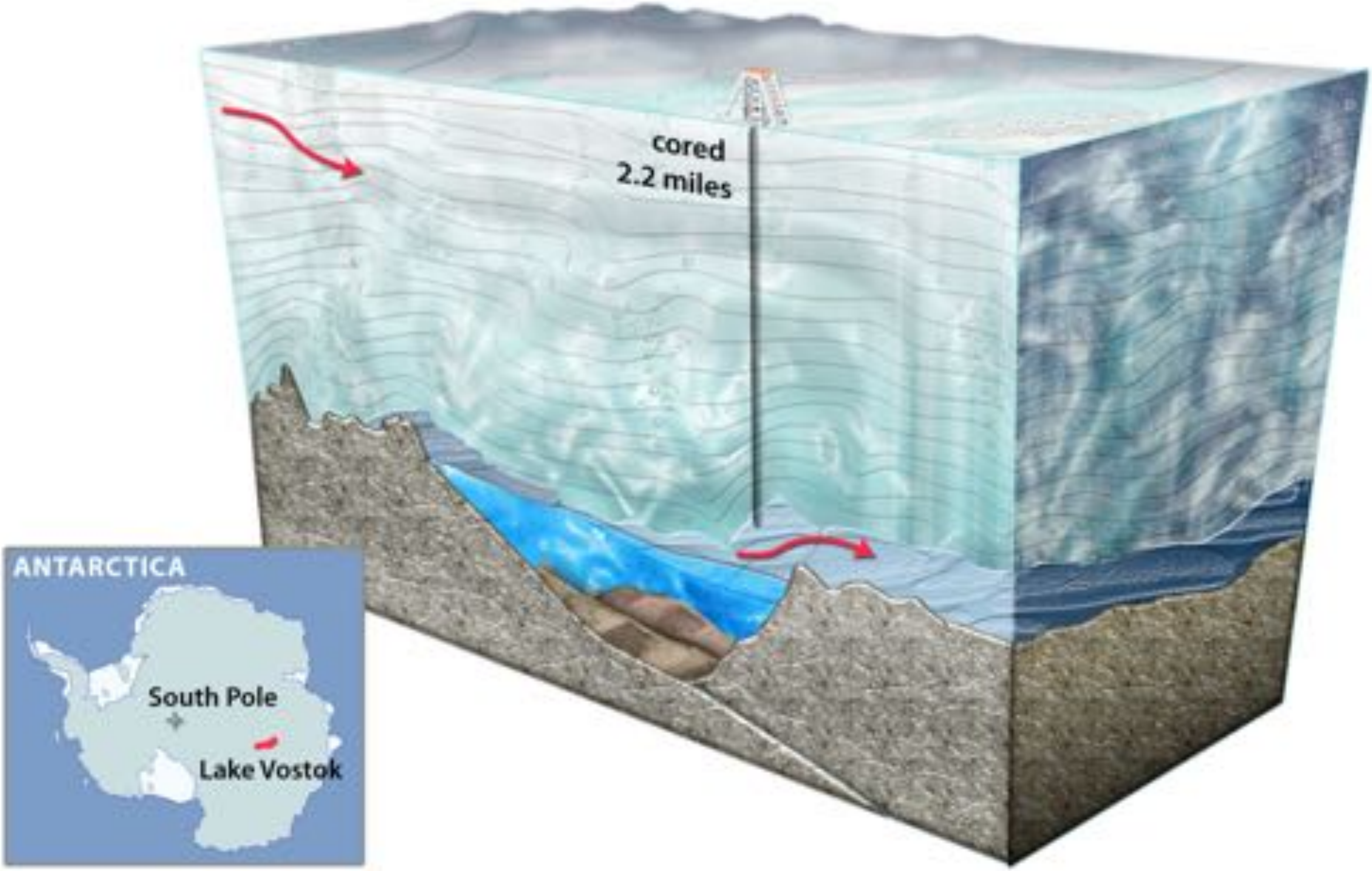
2045 2.0°C (3.6°F)

The world is now 1.2°C (2.2°F) warmer



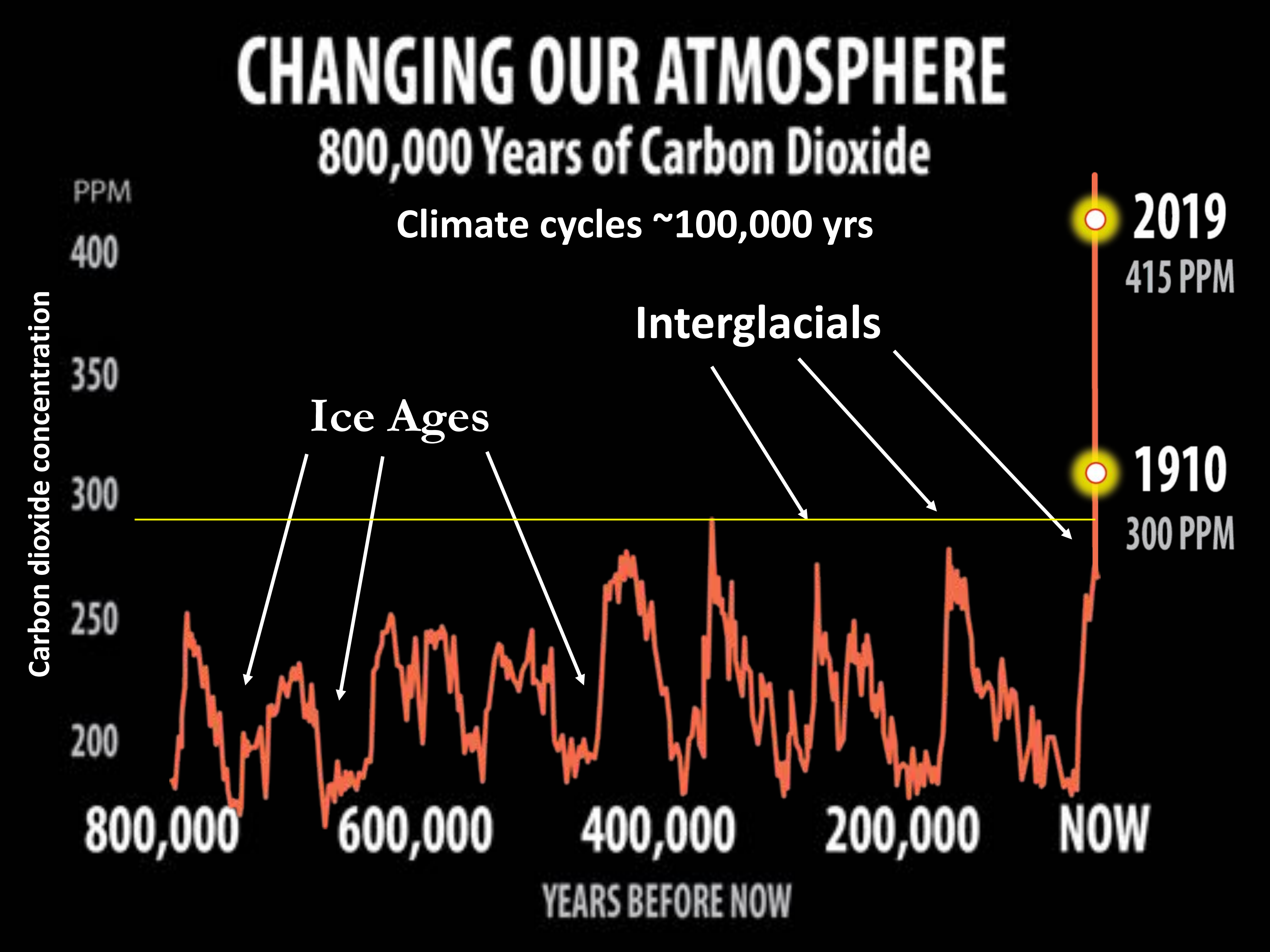
https://www.youtube.com/watch?v=Z4bSxb5THm4

Is global warming part of a natural cycle?


cored
2.2 miles
ANTARCTICA
South Pole
Lake Vostok

Ice Cores contain fossil air bubbles

Melting an ice sample to capture the ancient air it contains


CHANGING OUR ATMOSPHERE
800,000 Years of Carbon Dioxide
PPM
Climate cycles ~100,000 yrs
2019
415 PPM
Interglacials
Ice Ages
1910
300 PPM
400
350
300
250
200
Carbon dioxide concentration
800,000
600,000
400,000
200,000
NOW
YEARS BEFORE NOW

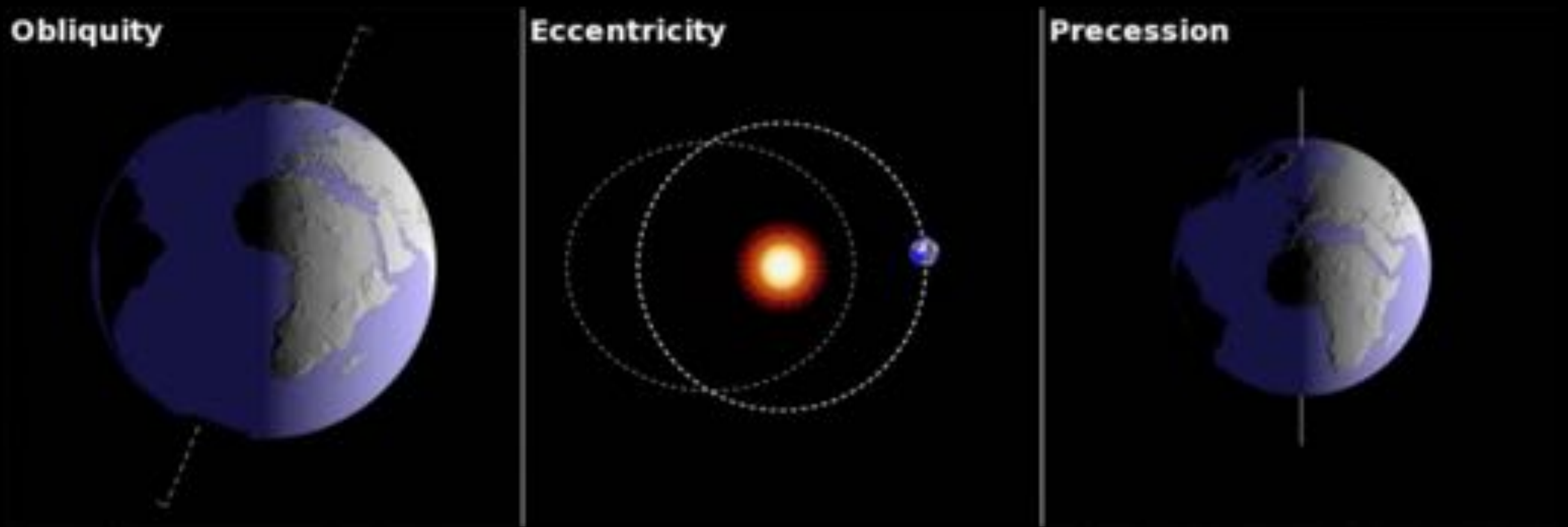
Natural Climate Change is fairly well understood

Orbital Parameters *determine the intensity and duration of* ***Arctic summer*** *and lead to* ***ice ages*** *and* ***interglacials****.*

Axial Obliquity– 41,000 yrs

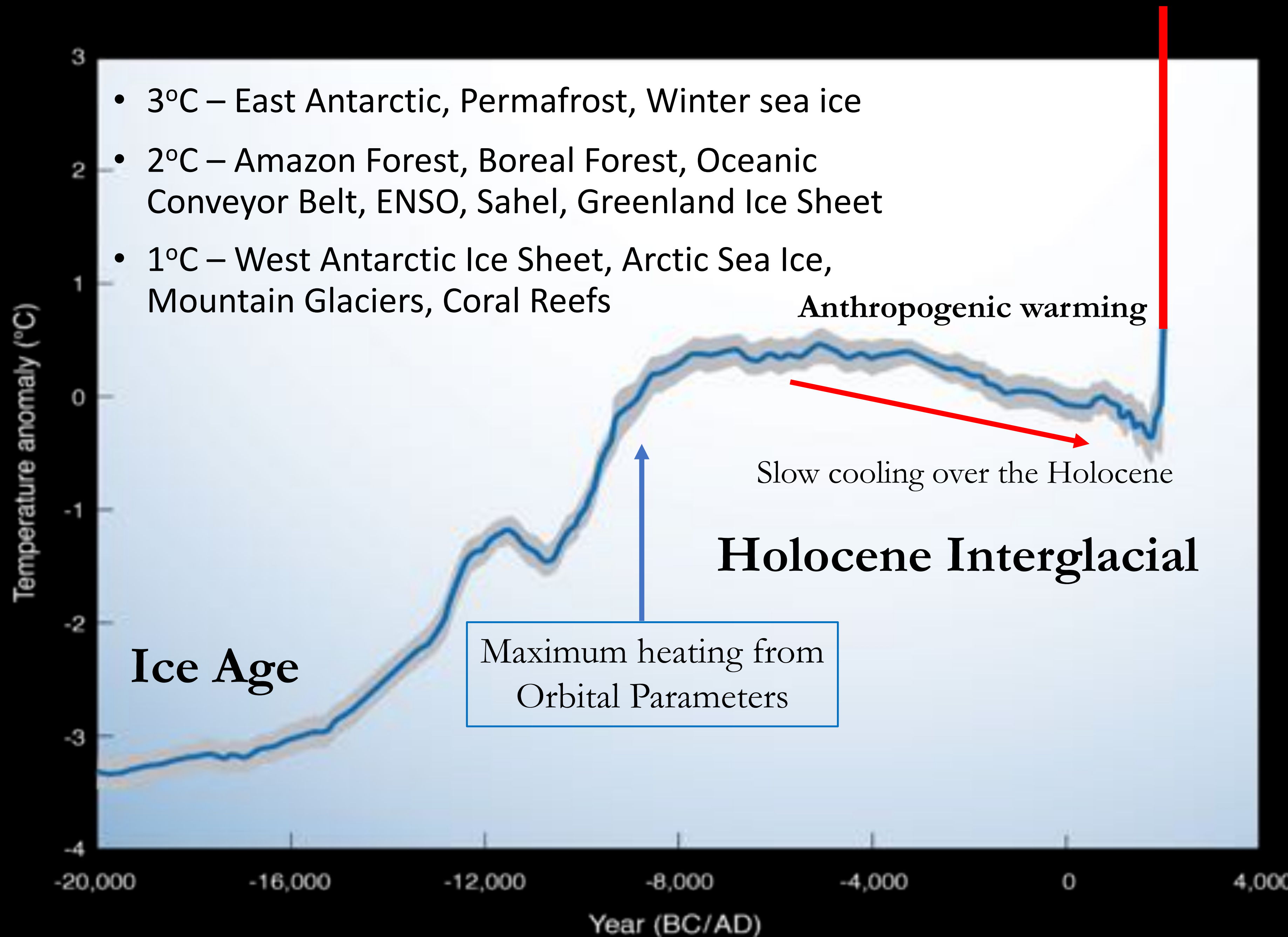
Eccentricity
100,000 and 400,000 yrs

Axial Precession – 26,000 yrs



Ice Age

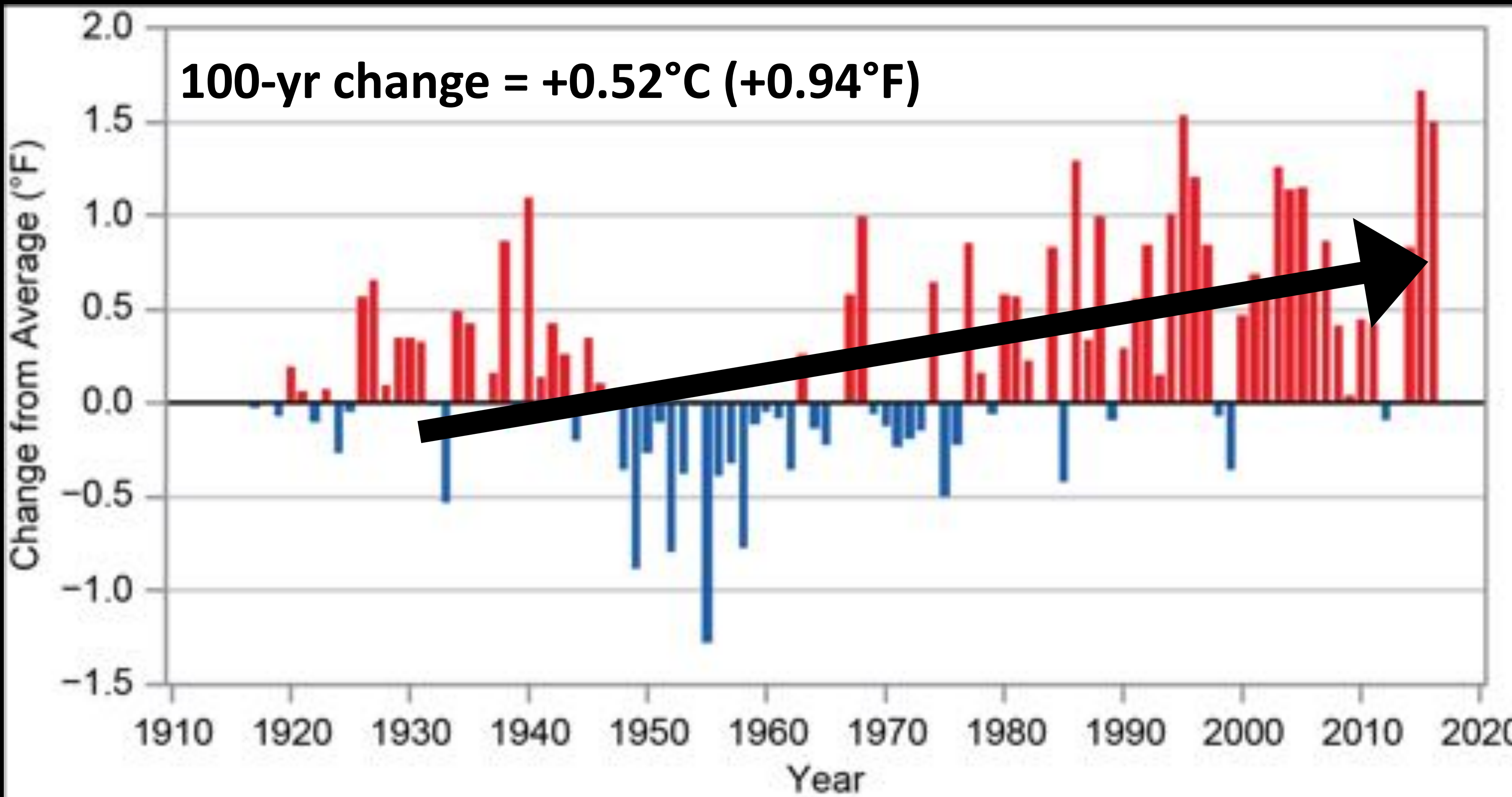
Interglacial



Marcott, S.A., 2013, A Reconstruction of Regional and Global for the Past 11,300 Years, *Science,* 08 Mar: 1198-1201Temperature. Schellnhuber, H.J., et al. (2016) Why the right climate target was agreed in Paris, Nature Climate Change, v. 6, July

What are the impacts of climate change in Hawai‘i?

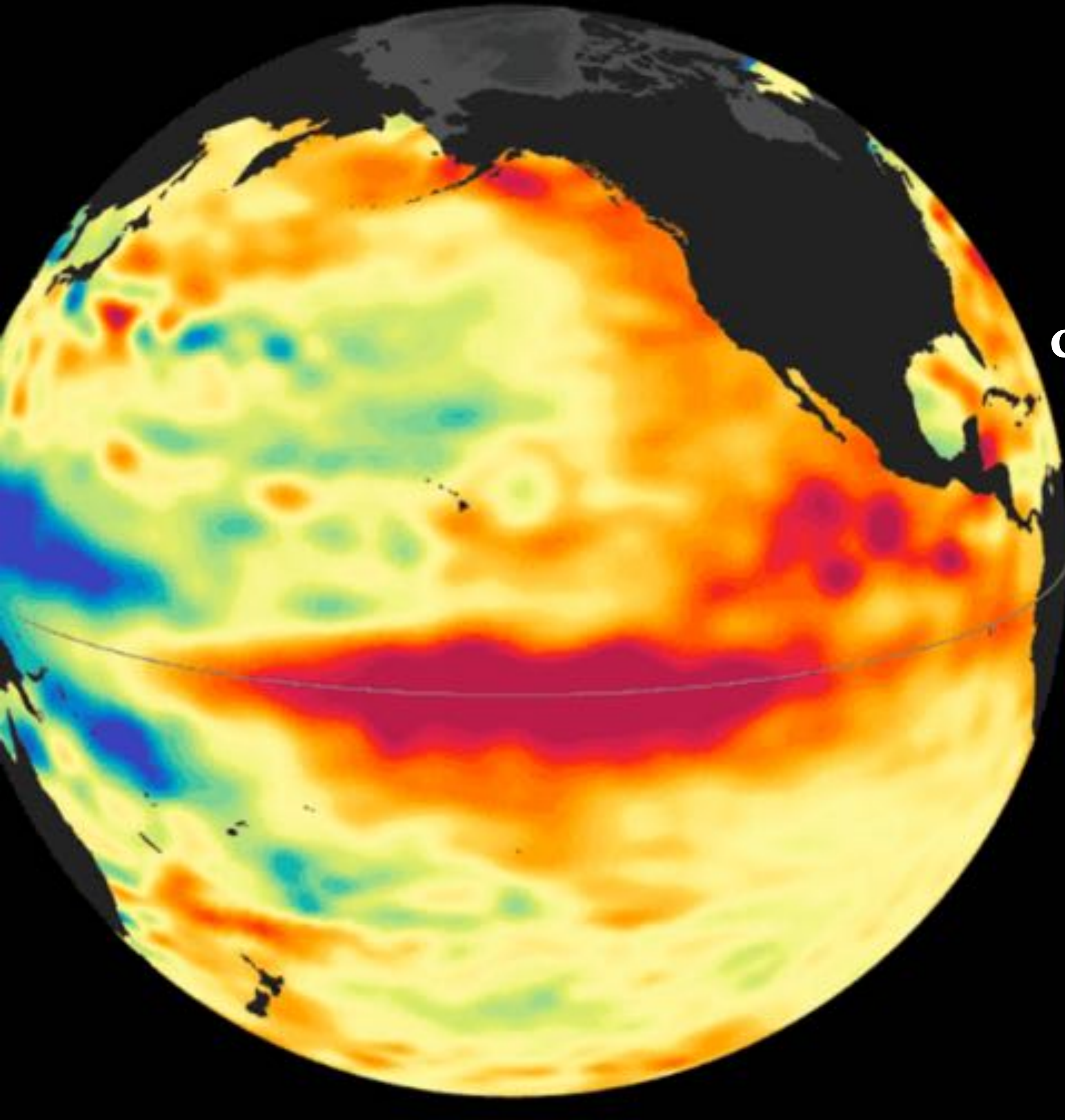
Hawai‘i is getting warmer



McKenzie, M.M., Giambelluca, T.W., and Diaz, H.F. Accepted. Regional temperature trends in Hawai‘i: a century of change, 1917-2016. *International Journal of Climatology*.

Average daily wind speeds are declining

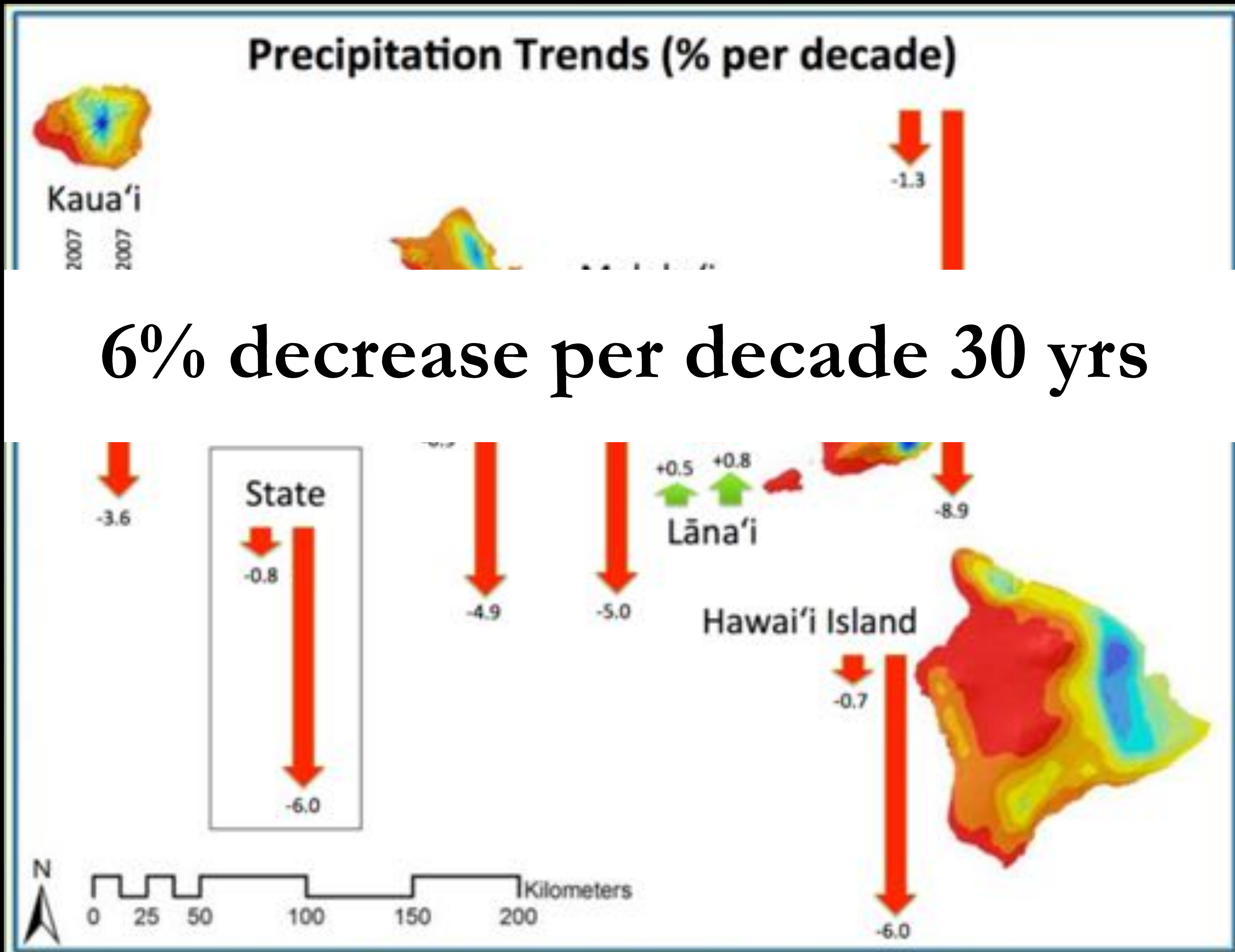
Marra, J.J., and Kruk, M.C. (2017) State of Environmental Conditions in Hawai'i and the U.S. Affiliated Pacific Islands under a Changing Climate: https://coralreefwatch.noaa.gov/satellite/publications/state_of_the_environment_2017_hawaii-usapi_noaa-nesdis-ncei_oct2017.pdf.



Sea surface temperatures are rising – especially during El Niño

32 Record Hot Days May 16- June 9, 2019

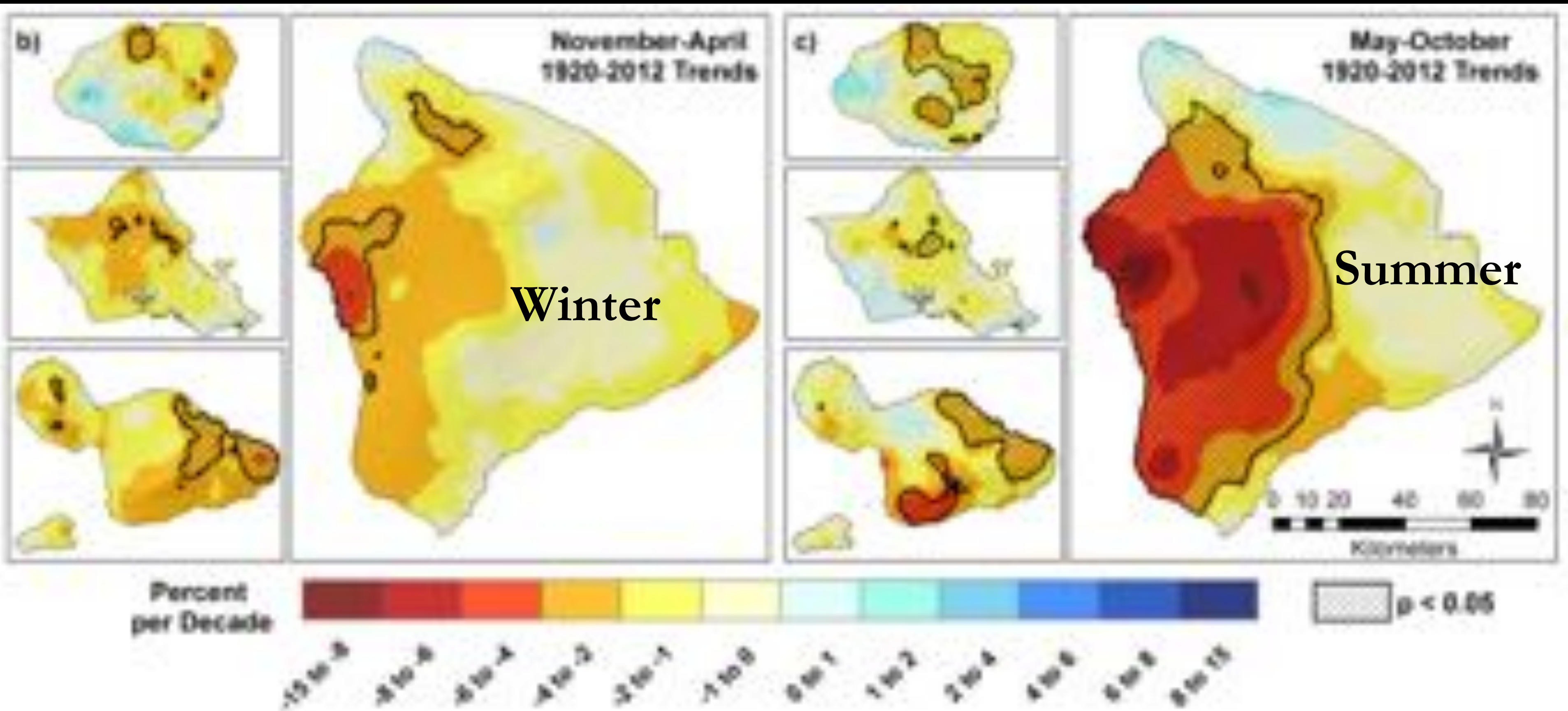
Hawai‘i is getting drier



Annual precipitation trends for 1920-2007 and 1978-2007, statewide and by island. Frazier et al. (2011)

Giambelluca, T.W., Diaz, H.F., Elison Timm, O., Takahashi, M., Frazier, A.G., and Longman, R. 2011. Regional climate trends in Hawai‘i. American Geophysical Union Fall Meeting, San Francisco, December 2011.

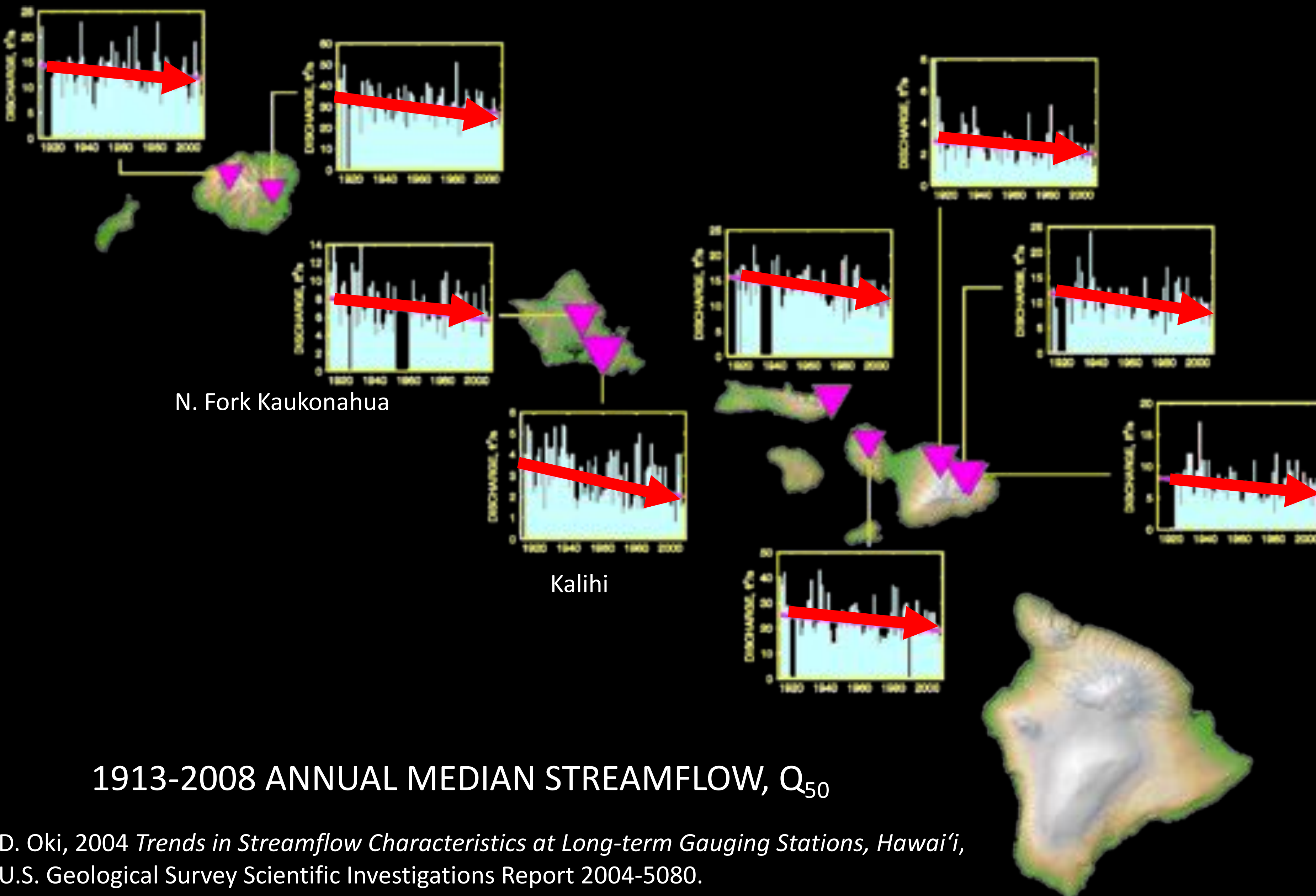
Declining rainfall in wet and dry seasons; affecting all the major islands.



Frazier, A.G., Elison Timm, O., Giambelluca, T.W. and Diaz, H.F. (2018) The influence of ENSO, PDO and PNA on secular rainfall variations in Hawaiʻi. *Climate Dynamics*, 51, 2127–2140. https://doi.org/10.1007/s00382-017-4003-4.

Kona drought has been especially intense

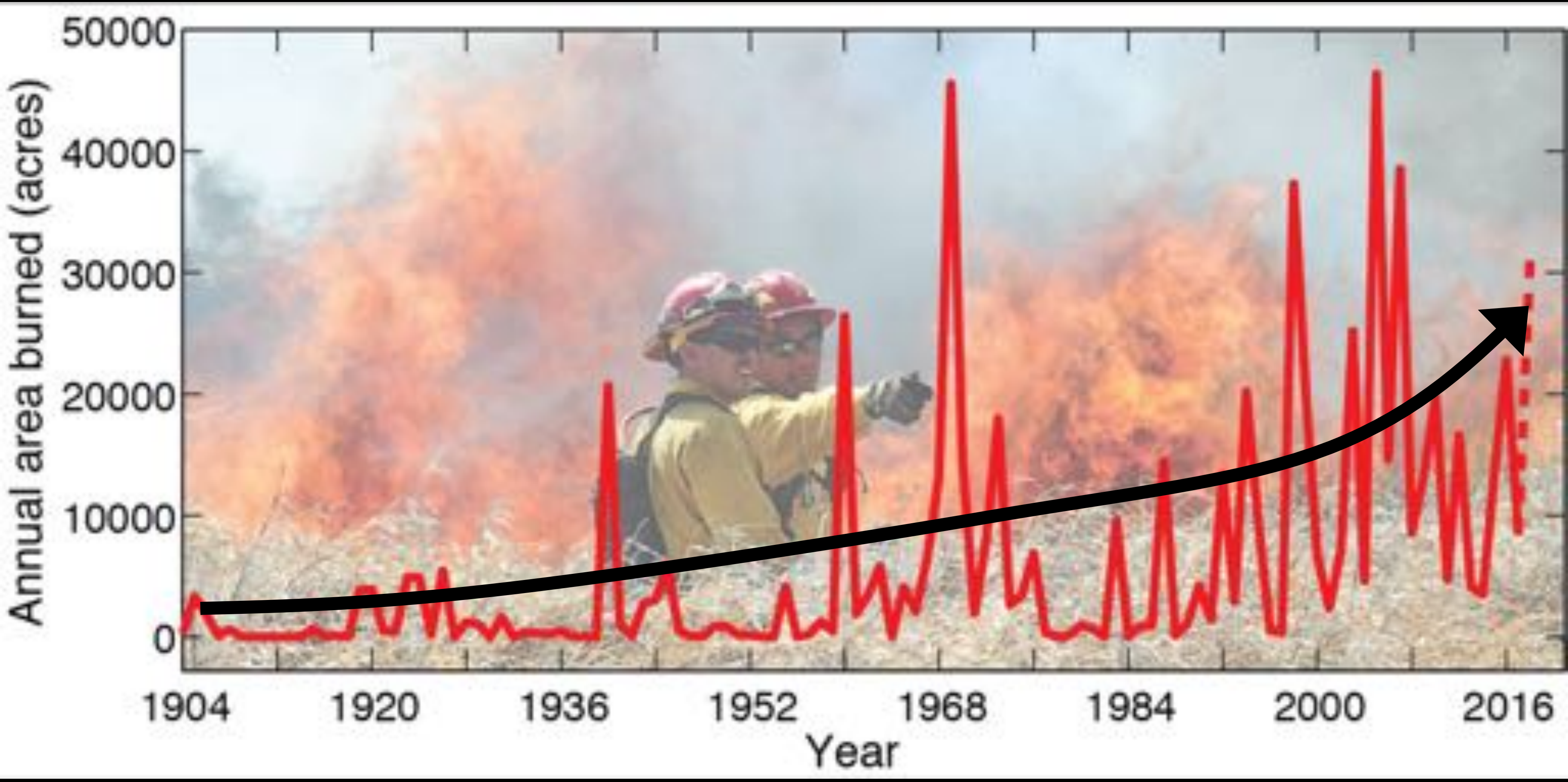
Stream Base Flow



1913-2008 ANNUAL MEDIAN STREAMFLOW, Q_{50}

D. Oki, 2004 *Trends in Streamflow Characteristics at Long-term Gauging Stations, Hawai'i*, U.S. Geological Survey Scientific Investigations Report 2004-5080.

Wildfire is increasing in Hawai‘i



Trauernicht, C., E. et al. 2015 The contemporary scale and context of wildfire in Hawaii. Pacific Science 69:427-444

Less than half of the landscape in Hawai‘i is still dominated by native plants

Jacobi, J. D., J. P. Price, L. B. Fortini, G. 'Ohukani'ohi'a III Samuel M., and P. Berkowitz, 2017: Baseline land cover. Baseline and Projected Future Carbon Storage and Carbon Fluxes in Ecosystems of Hawai‘i. Selmants, P. C., C. P. Giardina, J. D. Jacobi, and Z. Zhu, Eds., U.S. Geological Survey, Reston, VA, 9–20. URL

Avian malaria threatens Hawaiian forest birds. The threat increases with rising temperature.

Fortini, L. B., A. E. Vorsino, F. A. Amidon, E. H. Paxton, and J. D. Jacobi, 2015: Large-scale range collapse of Hawaiian forest birds under climate change and the need 21st century conservation options. *PLOS ONE*, **10**, e0144311. doi:10.1371/journal.pone.0140389

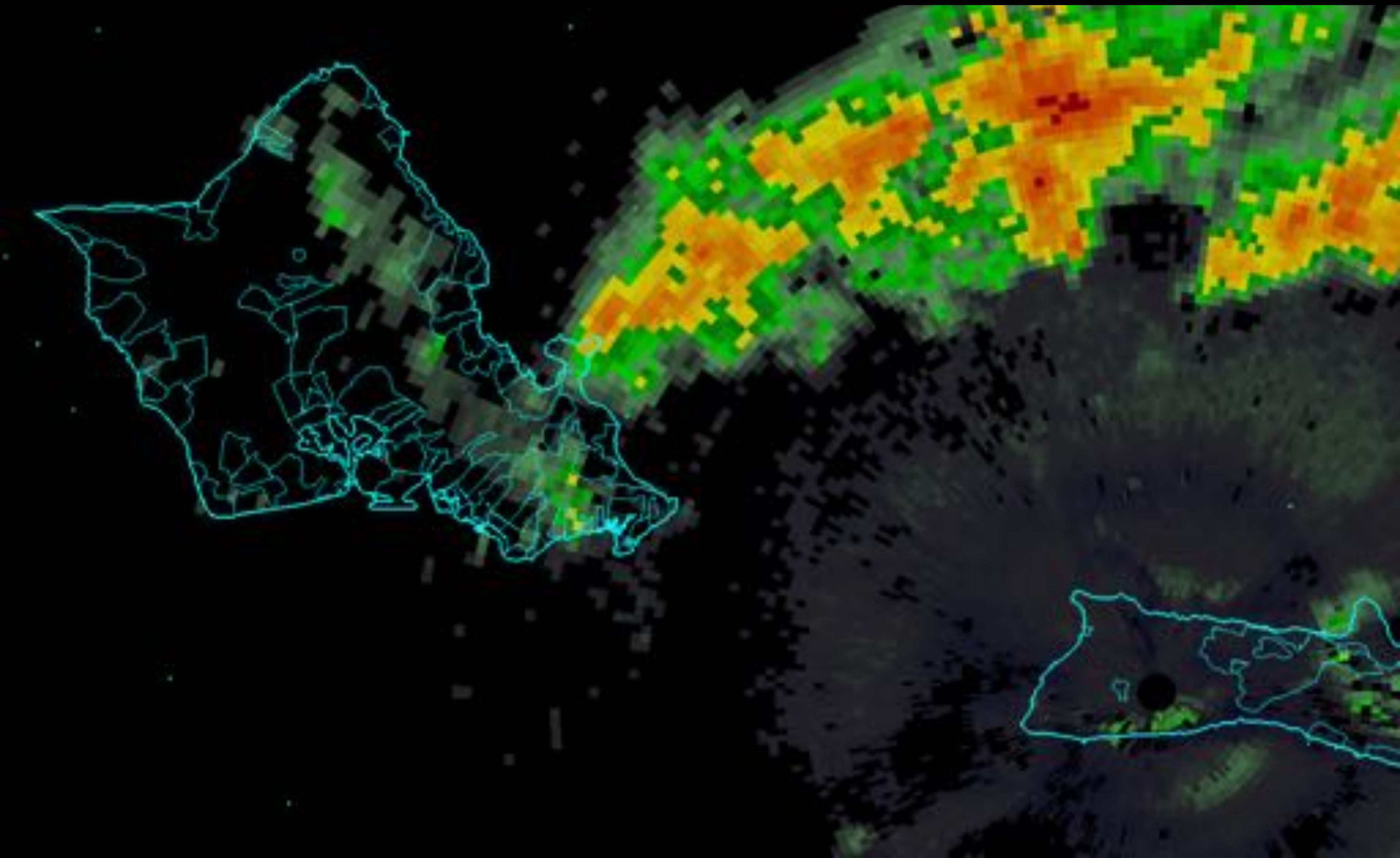
Global extreme rainfall has increased 12%

Lehmann, J., et al. (2015) Increased record-breaking precipitation events under global warming, *Climatic Change*, doi: 10.1007/s10584-015-1434-y

Global extreme rainfall has increased 12%

Lehmann, J., et al. (2015) Increased record-breaking precipitation events under global warming, *Climatic Change*, doi: 10.1007/s10584-015-1434-y

O‘ahu, April 2018
State of Emergency, $124 million



Short steep watersheds w/ heavy development promote flooding

O‘ahu, April 2018
Water in Wailupe Gulch rose 8 ft

Kaua'i, April 2018
49.69 inches in 24-hour, national record

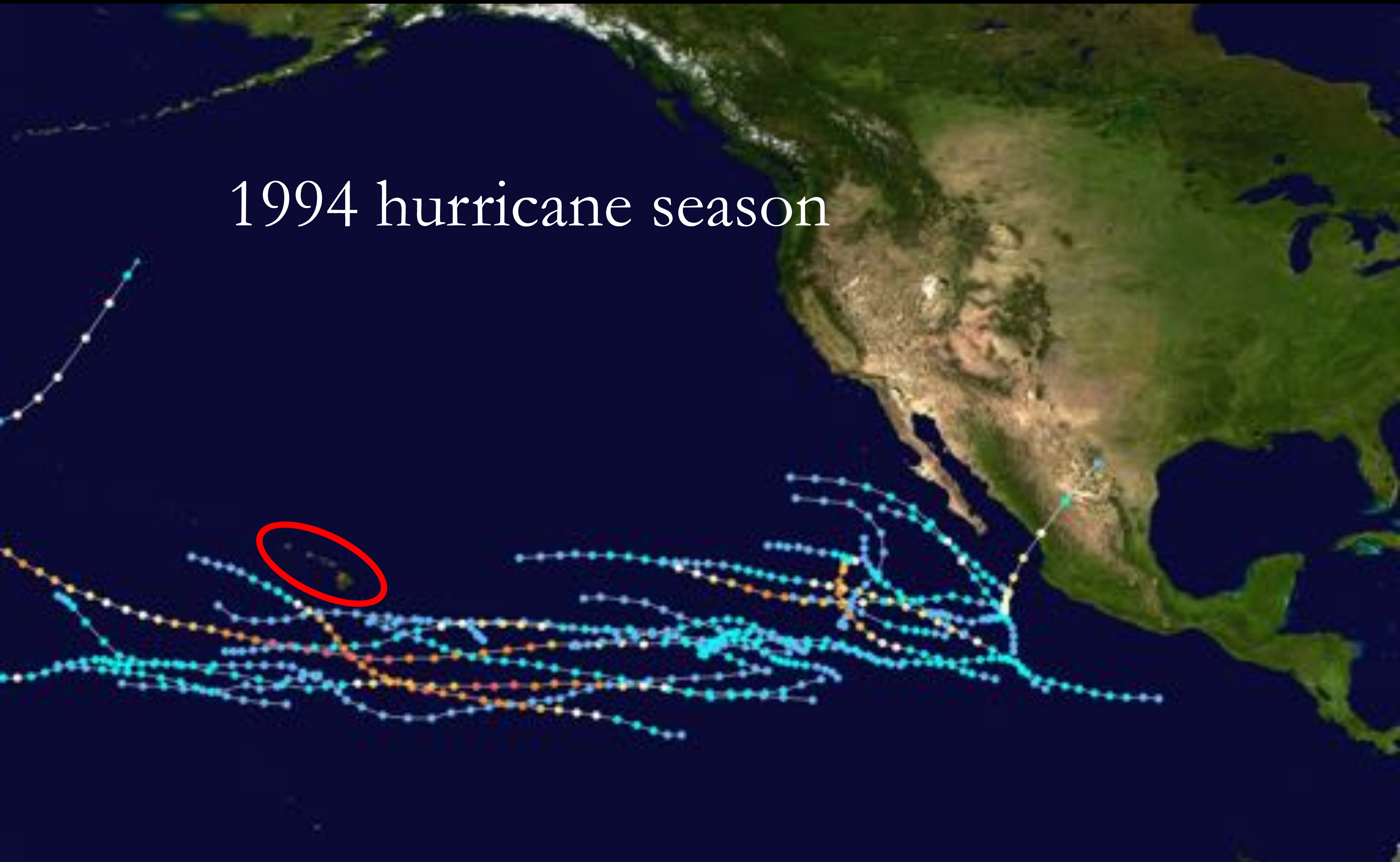
Kaua'i, April 2018
Hanalei River rose 15 feet

Kaua'i, April 2018
Hanalei River jumped its bank and carved a new channel

Hurricanes and Climate Change

- Warmer water = More fuel
- Larger
- More rain
- Stronger wind = Higher category
- Slower = More damage
- Higher storm surge
- Shifting away from equator

Does Global Warming Make Hurricanes Stronger? http://www.realclimate.org/index.php/archives/2018/05/does-global-warming-make-tropical-cyclones-stronger/


1994 hurricane season


2018 hurricane season

nature
climate change

Letter

Projected increase in tropical cyclones near Hawaii

Hiroyuki Murakami, Bin Wang, Tim Li & Akio Kitoh

Nature Climate Change **3**, 749–754 (2013)
doi:10.1038/nclimate1890
Download Citation
Climate sciences

Received: 28 August 2012
Accepted: 02 April 2013
Published online: 05 May 2013

Abstract

Projections of the potential impacts of global warming on regional tropical cyclone activity are challenging owing to multiple sources of uncertainty in model physical schemes and different assumptions for future sea surface temperatures[1]. A key factor in projecting climate change is to derive robust signals of future changes in tropical cyclone activity across different model physical schemes and different future patterns in sea surface temperature. A suite of future warming experiments (2075–2099), using a state-of-the-art high-resolution global climate model[1,2,3], robustly predicts an increase in tropical cyclone frequency of occurrence around the Hawaiian Islands. A physically based empirical model analysis[3,4] reveals that the substantial increase in the likelihood of tropical cyclone frequency is primarily associated with a northwestward shifting of the tropical cyclone track

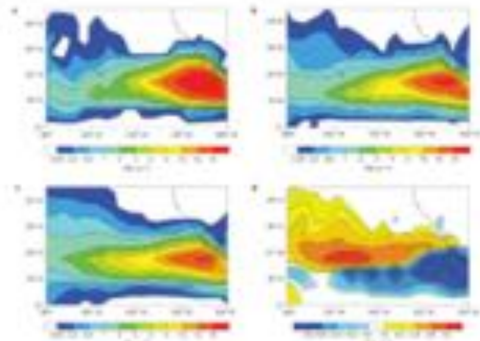
Associated Content

Nature | Research Highlights

Climate science: More cyclones for Hawaiian Islands

Sections Figures References

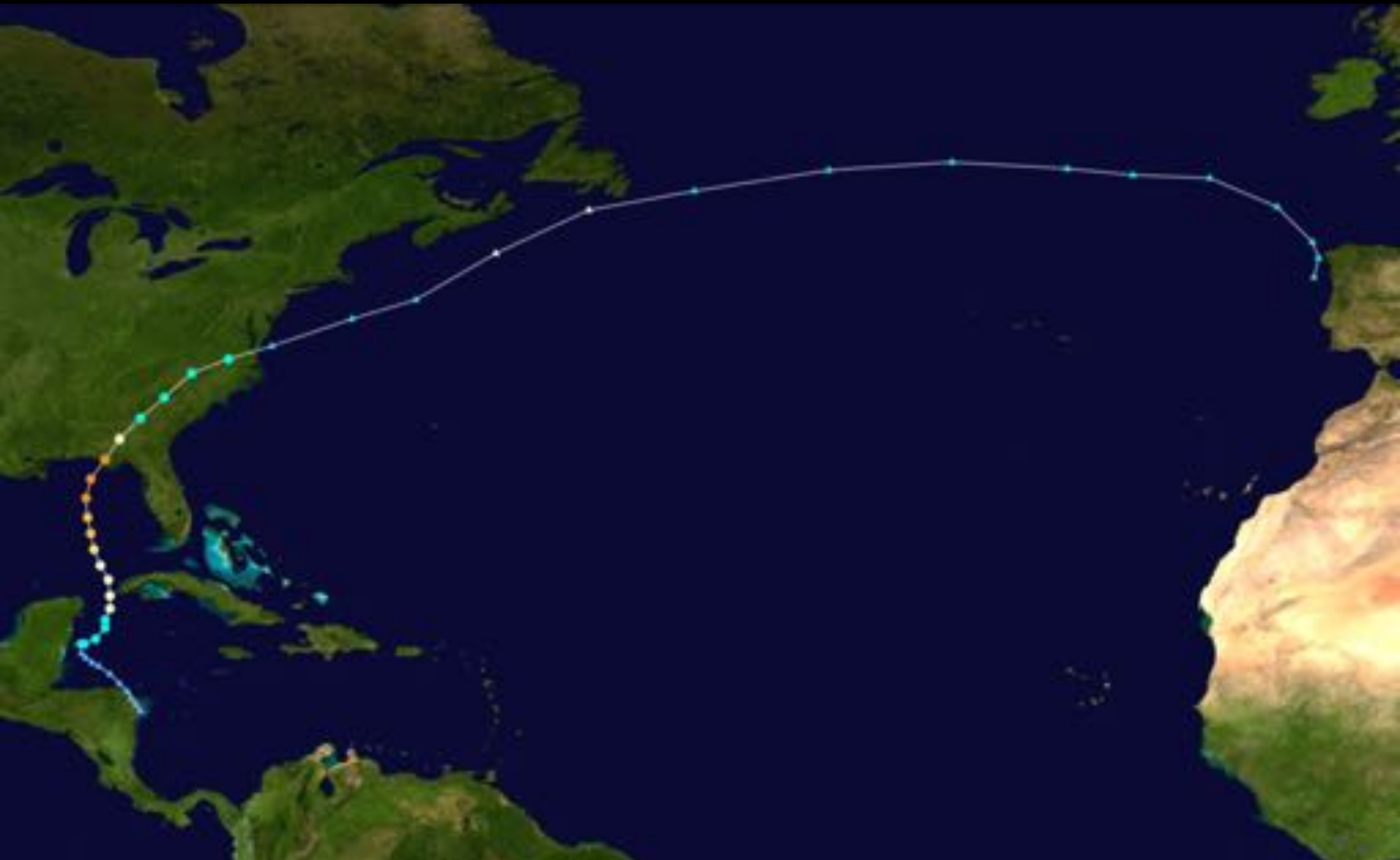
Figure 1: Annual mean of TCF (number per year, colour scale) counted at every 5°×5° grid cell.



View in article Full size image »

Figure 2: Ensemble mean contribution of each term to changes in TCF (colour scale) calculated by the empirical statistical analysis.

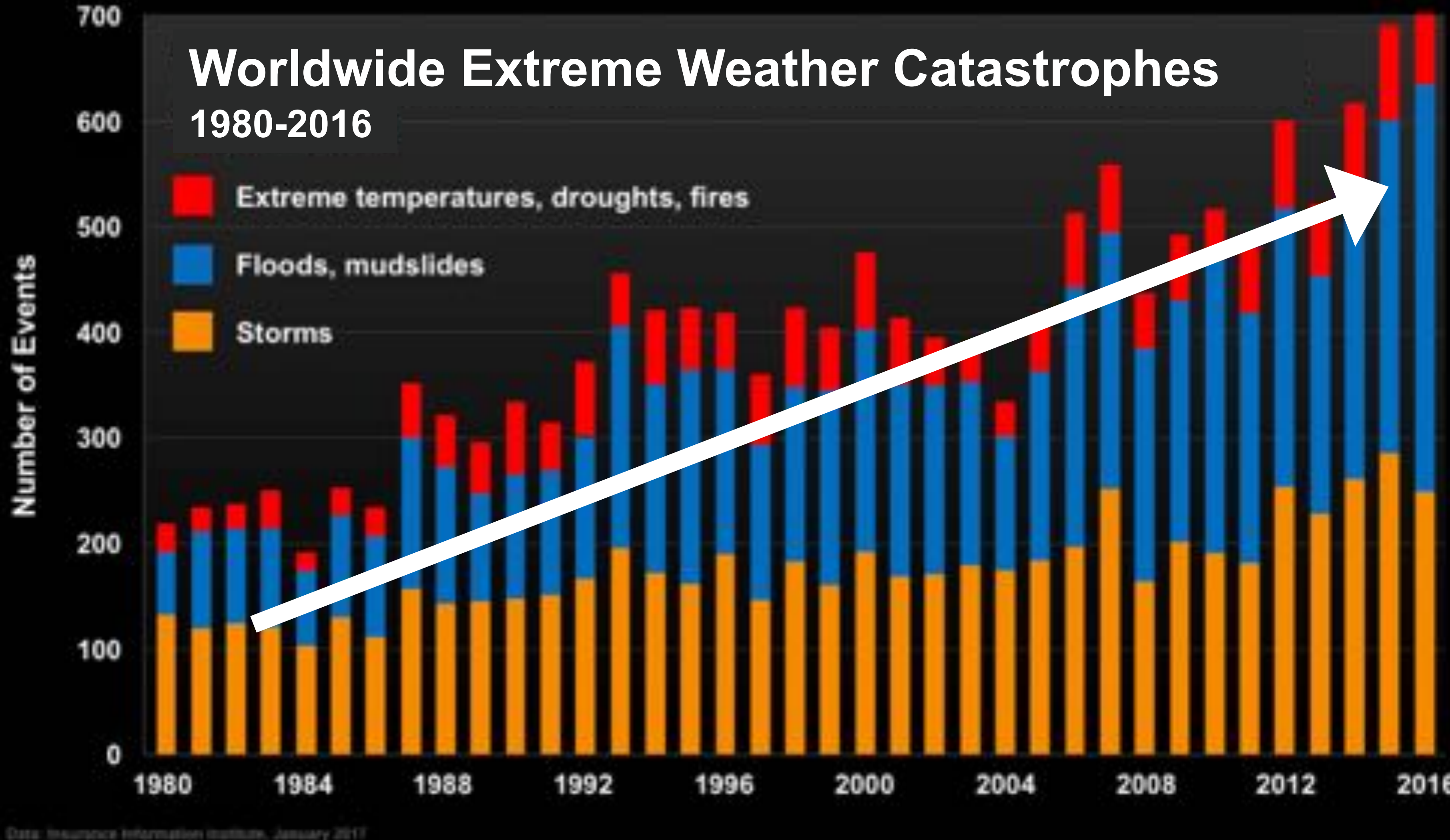
Hurricane Michael, Florida Panhandle, October, 2018



Hurricane Michael, Florida Panhandle, October, 2018

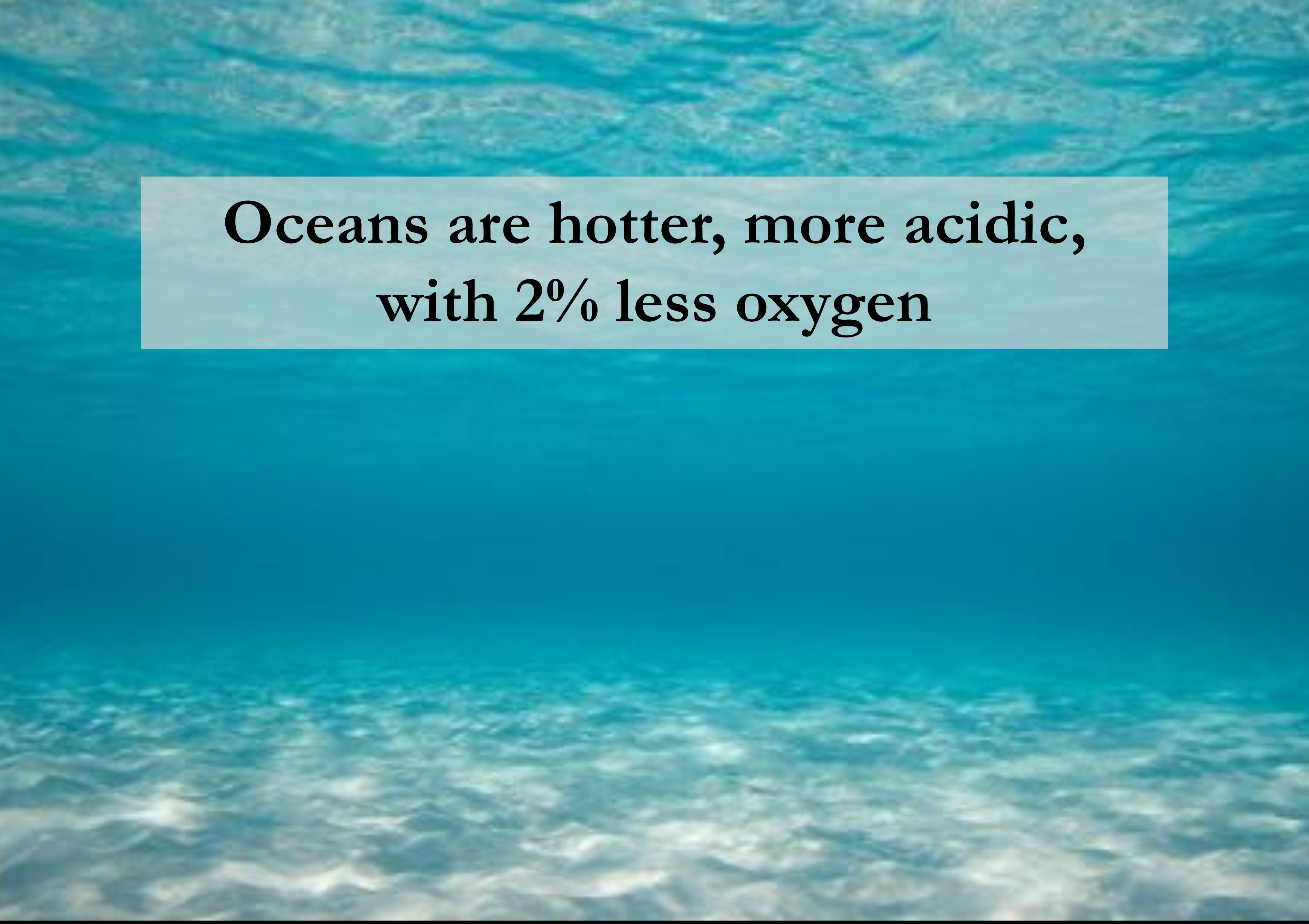
Global weather disasters have doubled in two decades

Centre for Research on the Epidemiology of Disasters, UN International Strategy for Disaster Reduction: http://reliefweb.int/report/world/human-cost-weather-related-disasters-1995-2015



Worldwide Extreme Weather Catastrophes
1980-2016
Extreme temperatures, droughts, fires
Floods, mudslides
Storms
Number of Events
0
100
200
300
400
500
600
700
1980
1984
1988
1992
1996
2000
2004
2008
2012
2016

Oceans are hotter, more acidic, with 2% less oxygen



Cheng LJ and Zhu J (2018) 2017 was the warmest year on record for the global ocean. *Adv. Atmos. Sci.* Friedrich T et al (2012) Detecting Regional Anthropogenic Trends in Ocean Acidification against Natural Variability, *Nature Climate Change*. Takamitsu I et al (2017) Upper Ocean O trends: 1958-2015, *GRL*

Reefs are projected to decline to 10-30% of former cover at 1.5°C and to less than 1% at 2°C

By 2050 >98% of coral reefs will be afflicted by annual bleaching

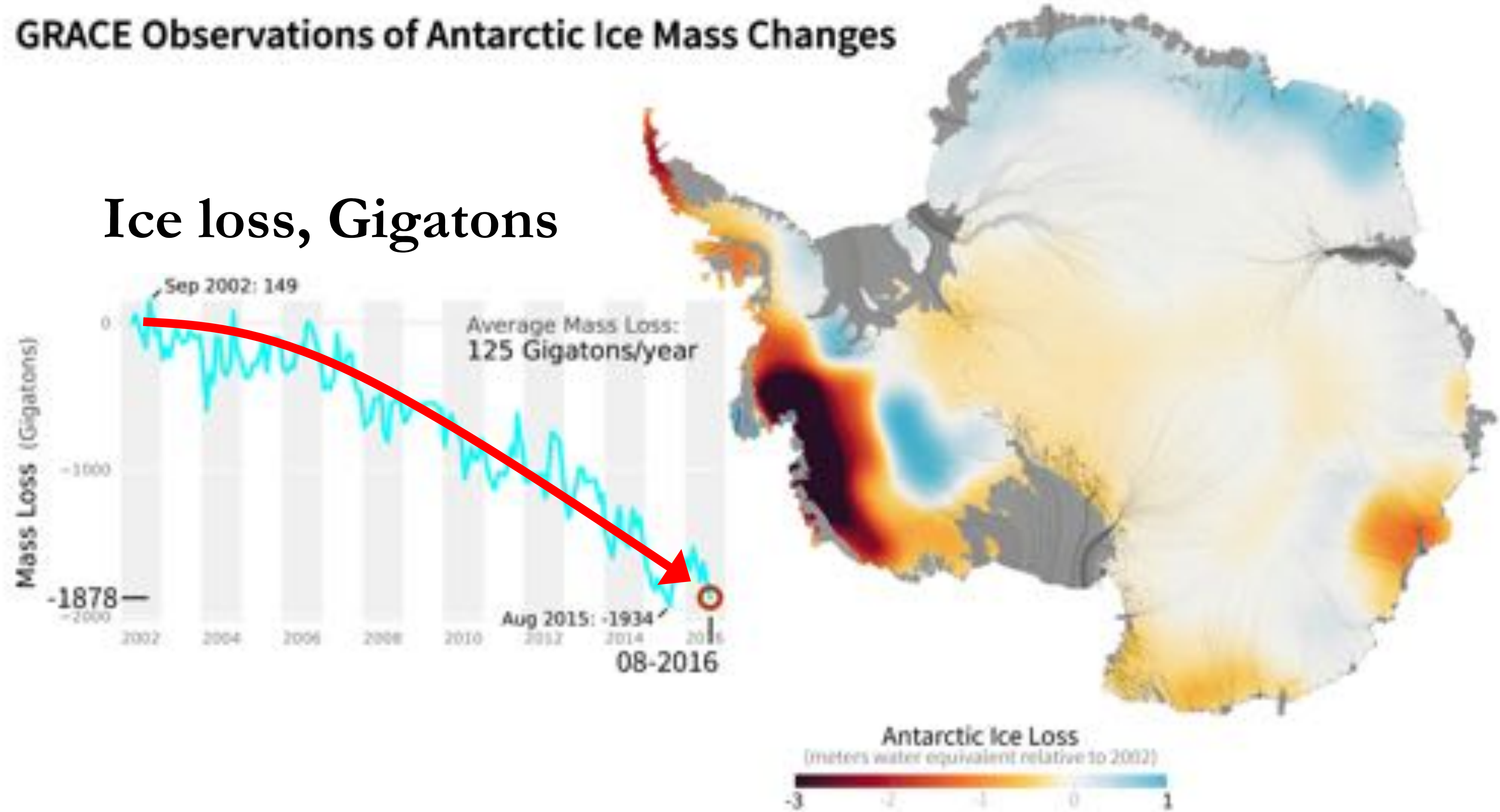
Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services - ADVANCE UNEDITED VERSION – 6 May 2019; http://www.ipbes.net/sites/default/files/downloads/spm_unedited_advance_for_posting_htn.pdf?utm_source=Nature+Briefing&utm_campaign=ef727151d6-briefing-dy-20190507&utm_medium=email&utm_term=0_c9dfd39373-ef727151d6-43423877

Invasive Species

Reef Collapse

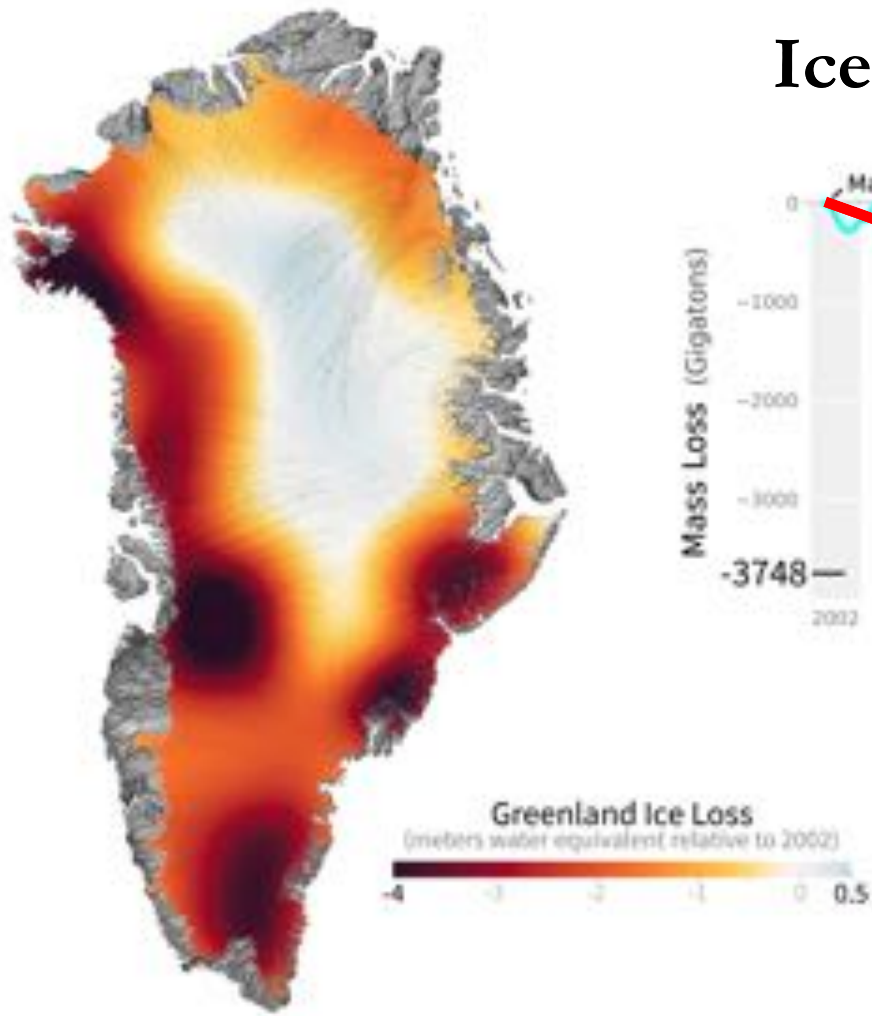
Yates, K. K., Zawada, D. G., Smiley, N. A., and Tiling-Range, G. (2017) Divergence of seafloor elevation and sea level rise in coral reef ecosystems, *Biogeosciences*, 14, 1739-1772, https://doi.org/10.5194/bg-14-1739-2017, 2017.

Antarctic ice melt has 'tripled over the past five years'

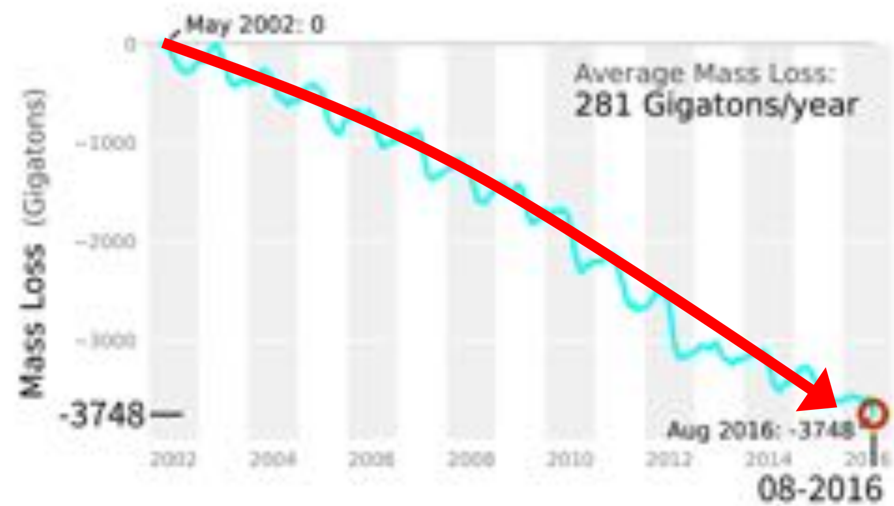


The IMBIE team (2018) Mass Balance of the Antarctic Ice Sheet, *Nature*, 558, pages219–222, https://doi.org/10.1038/s41586-018-0179-y

Greenland faces a 66% chance that melting will become unstoppable at 1.8°C

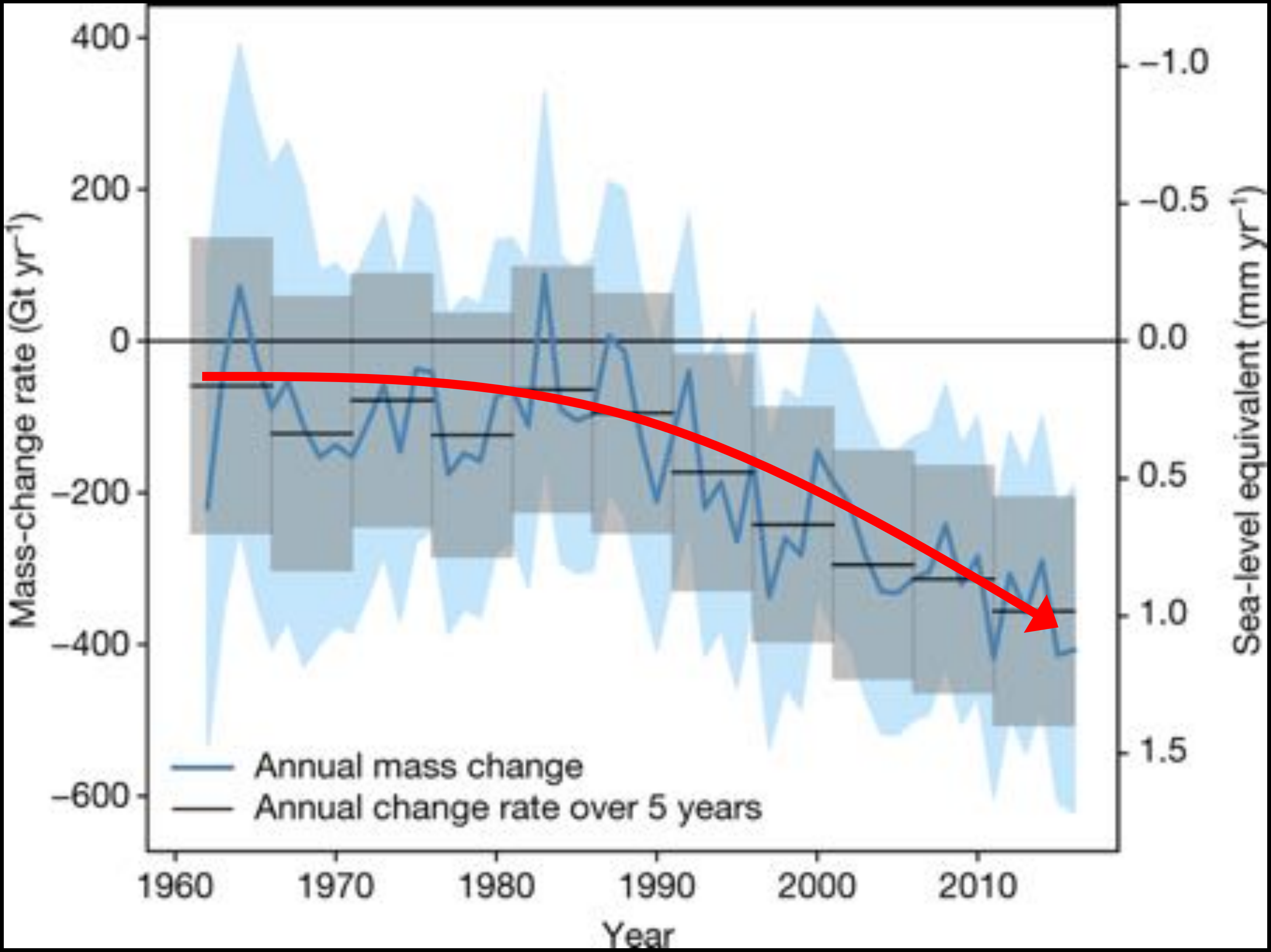


Ice loss, Gigatons



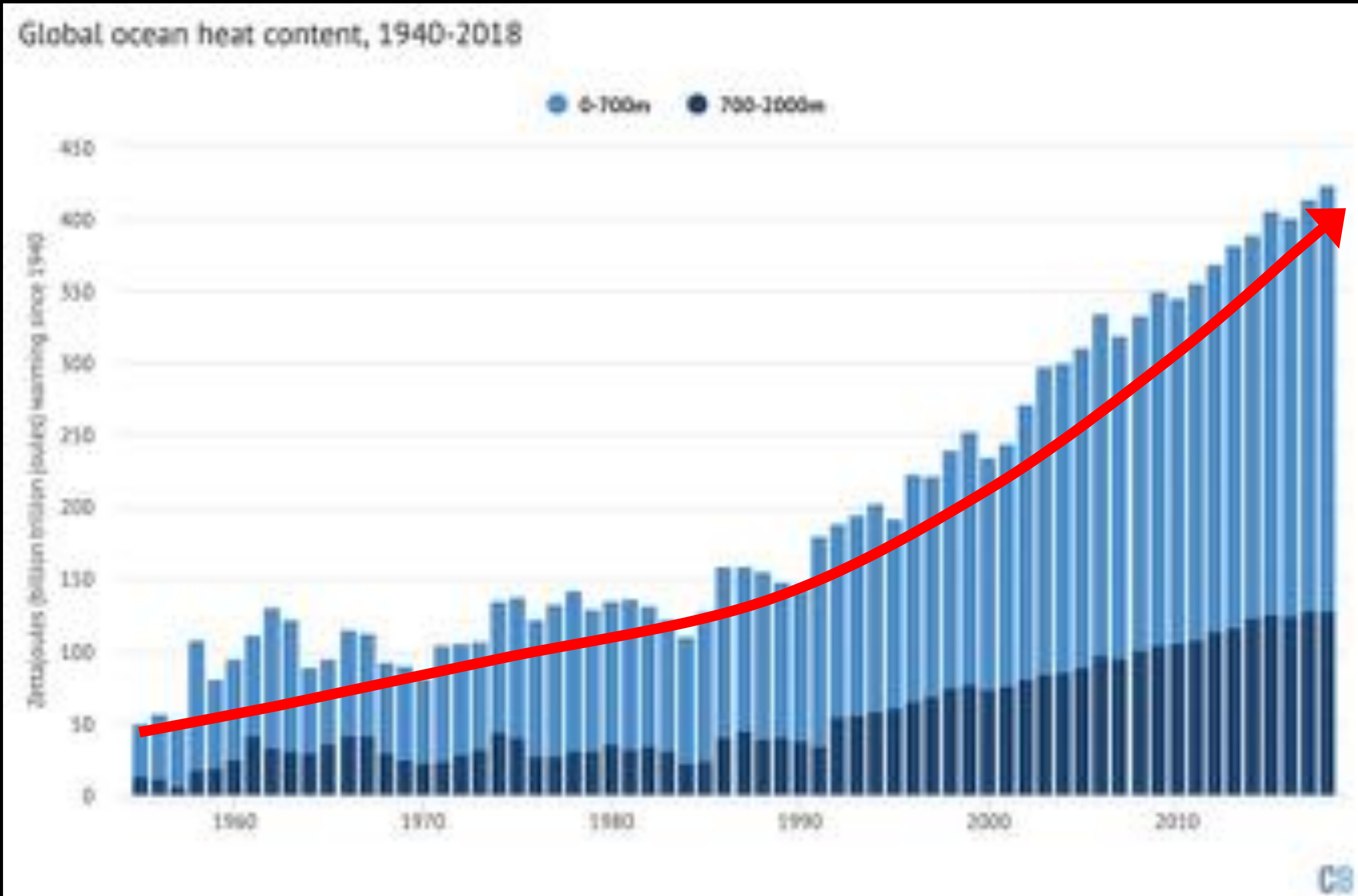
Trusel, et al., 2018 Nonlinear rise in Greenland runoff in response to post-industrial Arctic warming, 104, *Nature*, v564, 6 December: https://doi.org/10.1038/s41586-018-0752-4

Mountain Glaciers lost 9,625 billion tons of ice since 1961, raising sea level almost 1 ft



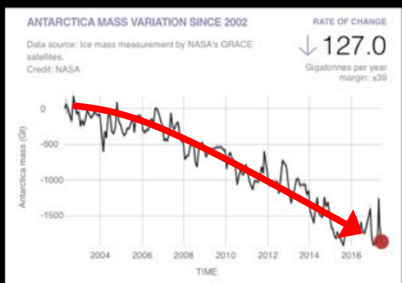
M. Zemp et al. Global glacier mass changes and their contributions to sea-level rise from 1961 to 2016, *Nature* (2019). DOI: 10.1038/s41586-019-1071-0

The ocean is 40% hotter than previously thought.



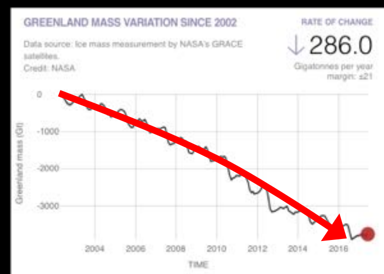
Cheng, L., et al. (2019) How fast are the oceans warming? *Science*, 2019 DOI: 10.1126/science.aav7619; Cheng L. J. Zhu, and J. Abraham, 2015: Global upper ocean heat content estimation: recent progress and the remaining challenges. Atmospheric and Oceanic Science Letters, 8. DOI:10.3878/AOSL20150031. ; Glecker, P.J., et al. (2016) Industrial era global ocean heat uptake doubles in recent decades. Nature Climate change. doi:10.1038/nclimate2915

How high will SL rise by 2100?



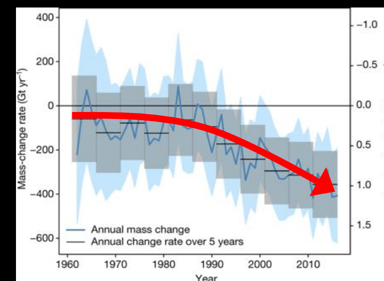
Antarctic ice loss

+



Greenland ice loss

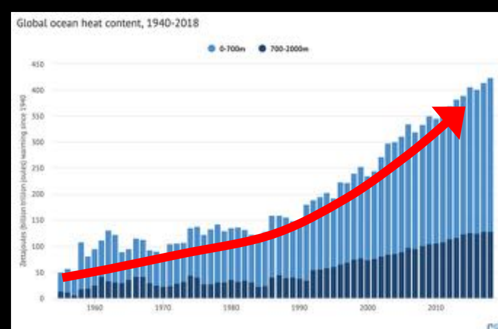
+



Mountain glacier ice loss

= 0.8m

0.8m +



Thermal expansion

= <u>1m by 2100</u>

E. Rignot (2019) pers. comm.: http://sites.nationalacademies.org/SSB/SSB_191179

Ice sheet contributions to future sea-level rise from structured expert judgment

Jonathan L. Bamber, Michael Oppenheimer, Robert E. Kopp, Willy P. Aspinall, and Roger M. Cooke

Despite considerable advances in process understanding, numerical modeling, and the observational record of ice sheet contributions to global mean sea-level rise (SLR) since the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change, severe limitations remain in the predictive capability of ice sheet models. As a consequence, the potential contributions of ice sheets remain the largest source of uncertainty in projecting future SLR. Here, we report the findings of a structured expert judgement study, using unique techniques for modeling correlations between inter- and intra-ice sheet processes and their tail dependences. We find that since the AR5, expert uncertainty has grown, in particular because of uncertain ice dynamic effects. For a +2 °C temperature scenario consistent with the Paris Agreement, we obtain a median estimate of a 26 cm SLR contribution by 2100, with a 95th percentile value of 81 cm. For a +5 °C temperature scenario more consistent with unchecked emissions growth, the corresponding values are 51 and 178 cm, respectively. Inclusion of thermal expansion and glacier contributions results in a global total SLR estimate that exceeds 2 m at the 95th percentile. Our findings support the use of scenarios of 21st century global total SLR exceeding 2 m for planning purposes. Beyond 2100, uncertainty and projected SLR increase rapidly. The 95th percentile ice sheet contribution by 2200, for the +5 °C scenario, is 7.5 m as a result of instabilities coming into play in both West and East Antarctica. Introducing process correlations and tail dependences increases estimates by roughly 15%.

sea-level rise | climate predictions | ice sheets | Greenland | Antarctica

Significance

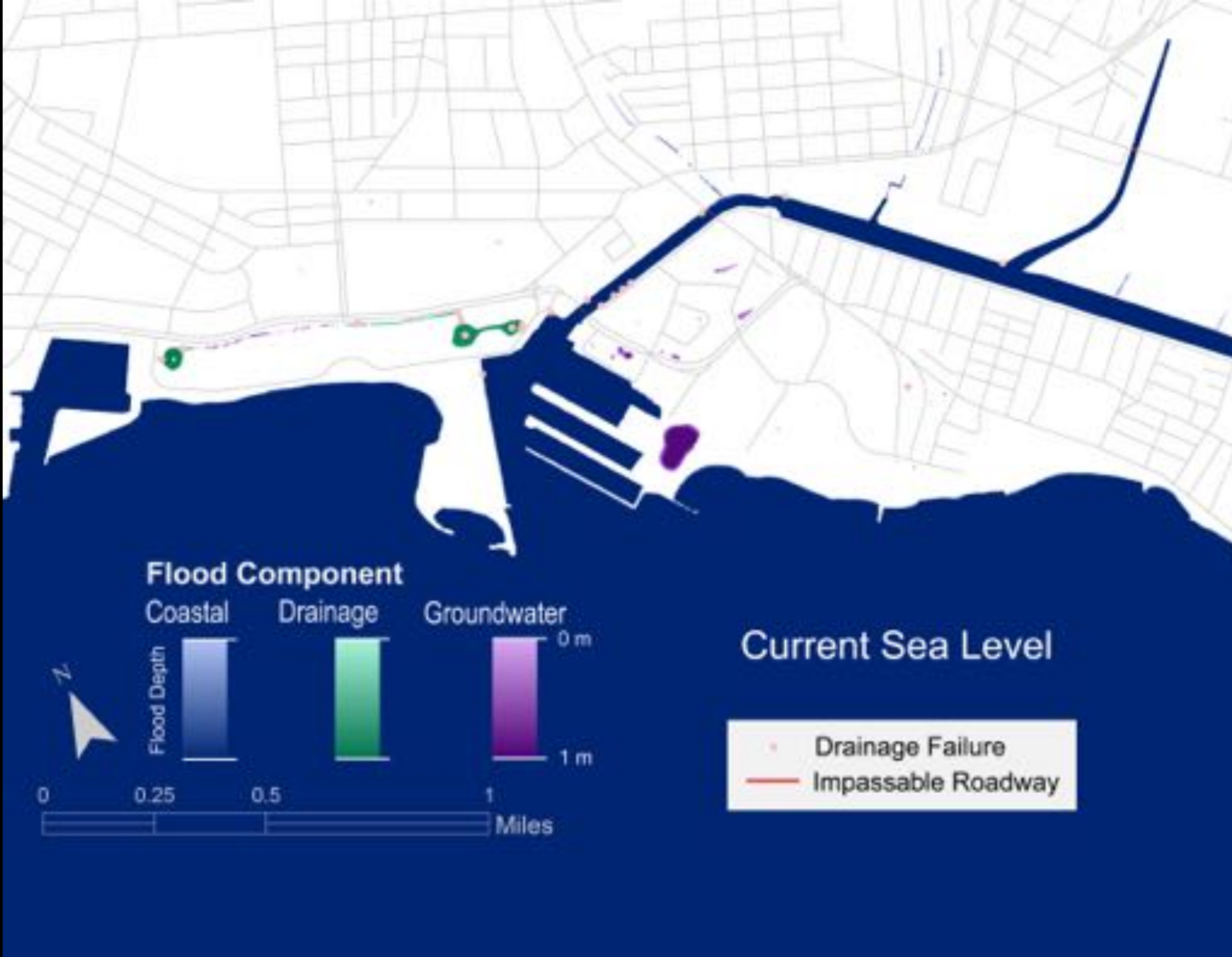
Future sea level rise (SLR) poses serious threats to the viability of coastal communities, but continues to be challenging to project using deterministic modeling approaches. Nonetheless, adaptation strategies urgently require quantification of future SLR uncertainties, particularly upper-end estimates. Structured expert judgement (SEJ) has proved a valuable approach for similar problems. Our findings, using SEJ, produce probability distributions with long upper tails that are influenced by interdependencies between processes and ice sheets. We find that a global total SLR exceeding 2 m by 2100 lies within the 90% uncertainty bounds for a high emission scenario. This is more than twice the upper value put forward by the Intergovernmental Panel on Climate Change in the Fifth Assessment Report.

10% chance of sea level exceeding 6.5 ft by 2100

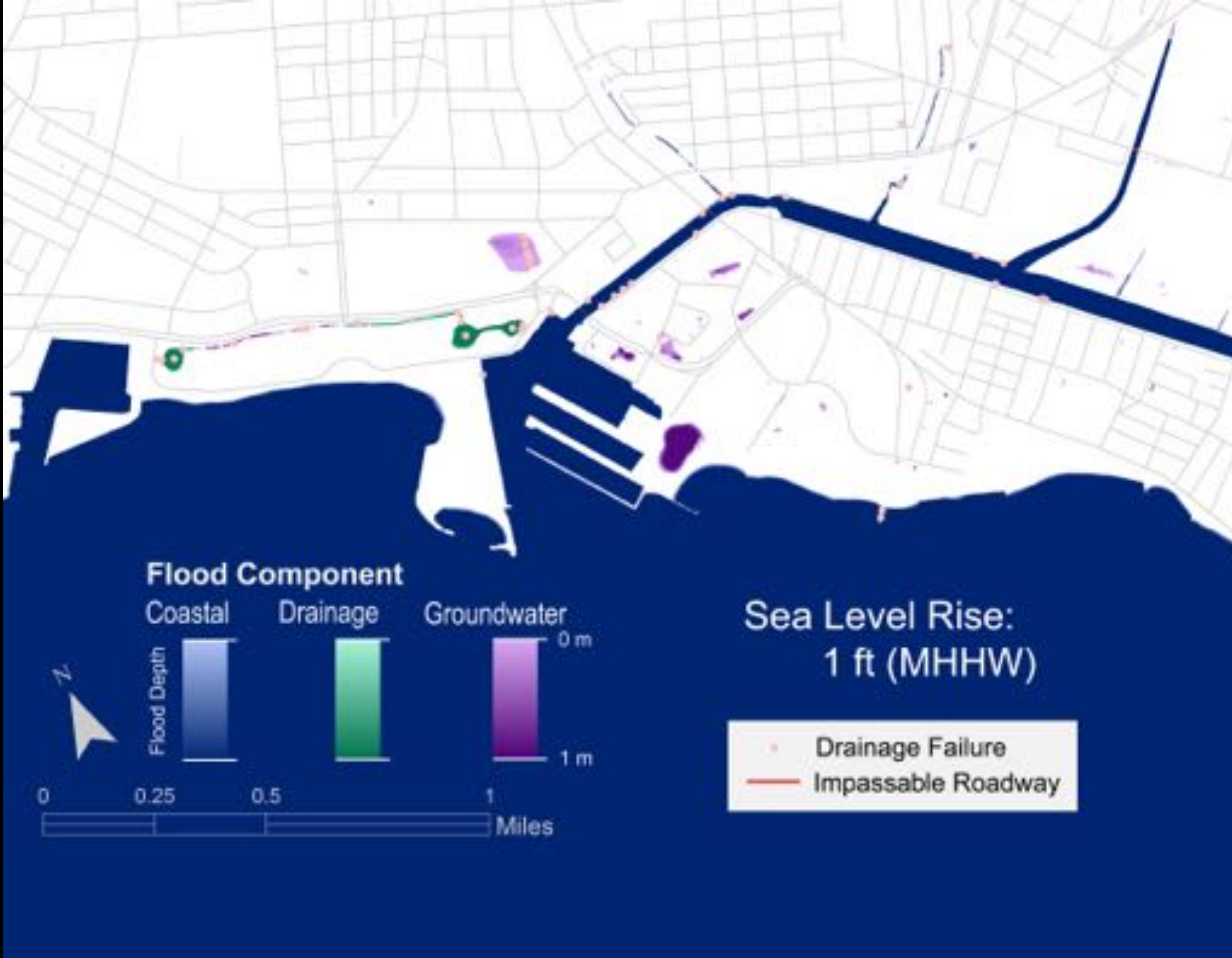
"Coastal decisions require long lead times. It would be nice if we could wait for the science to clear up, but we can't."

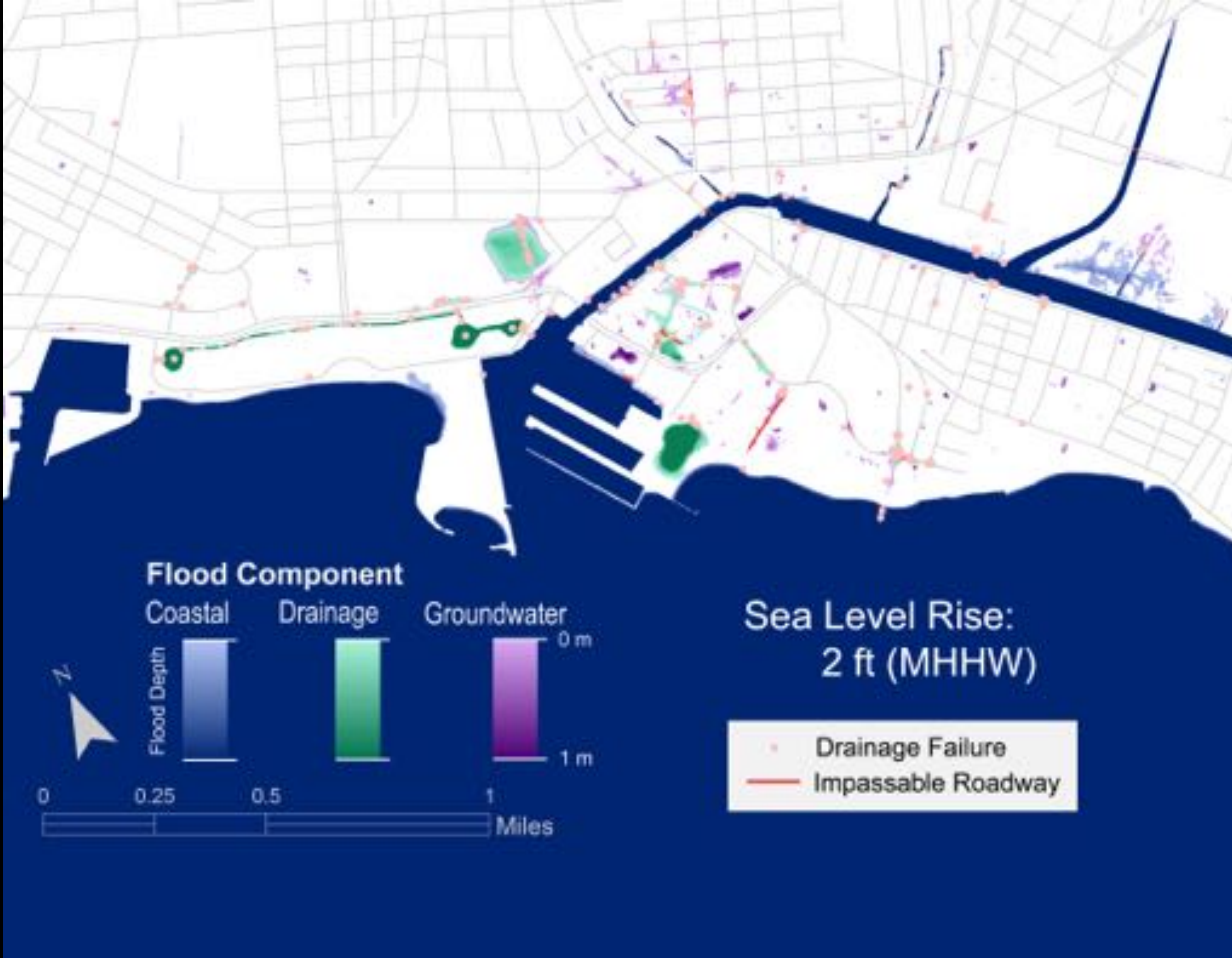
"If you knew there was a 10% chance a plane would crash, you wouldn't get on it. It's the same with sea level rise,"

J. L. Bamber, et al. (2019 Ice sheet contributions to future sea-level rise from structured expert judgment. *Proceedings of the National Academy of Sciences*, May 20, 2019; DOI: 10.1073/pnas.1817205116

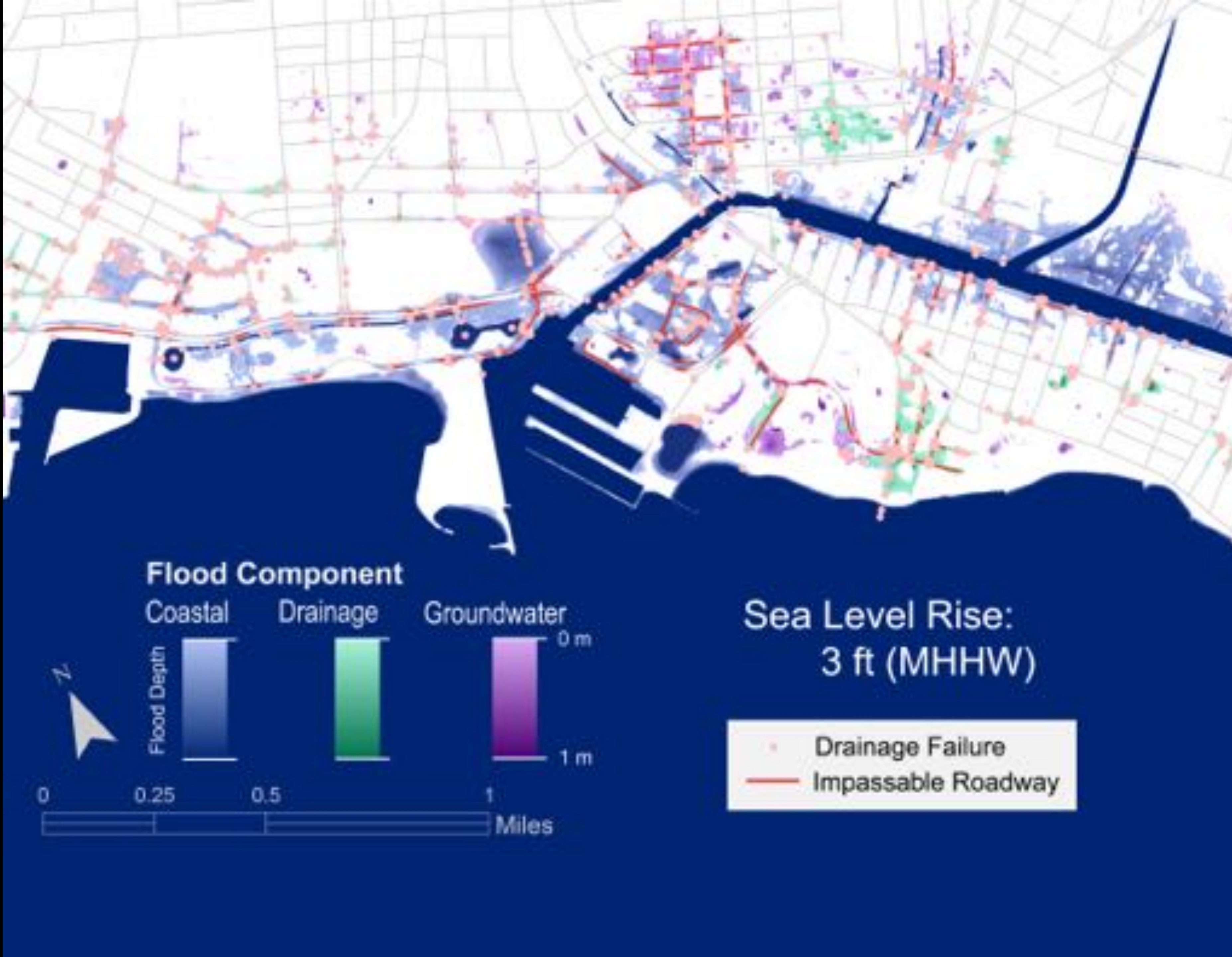


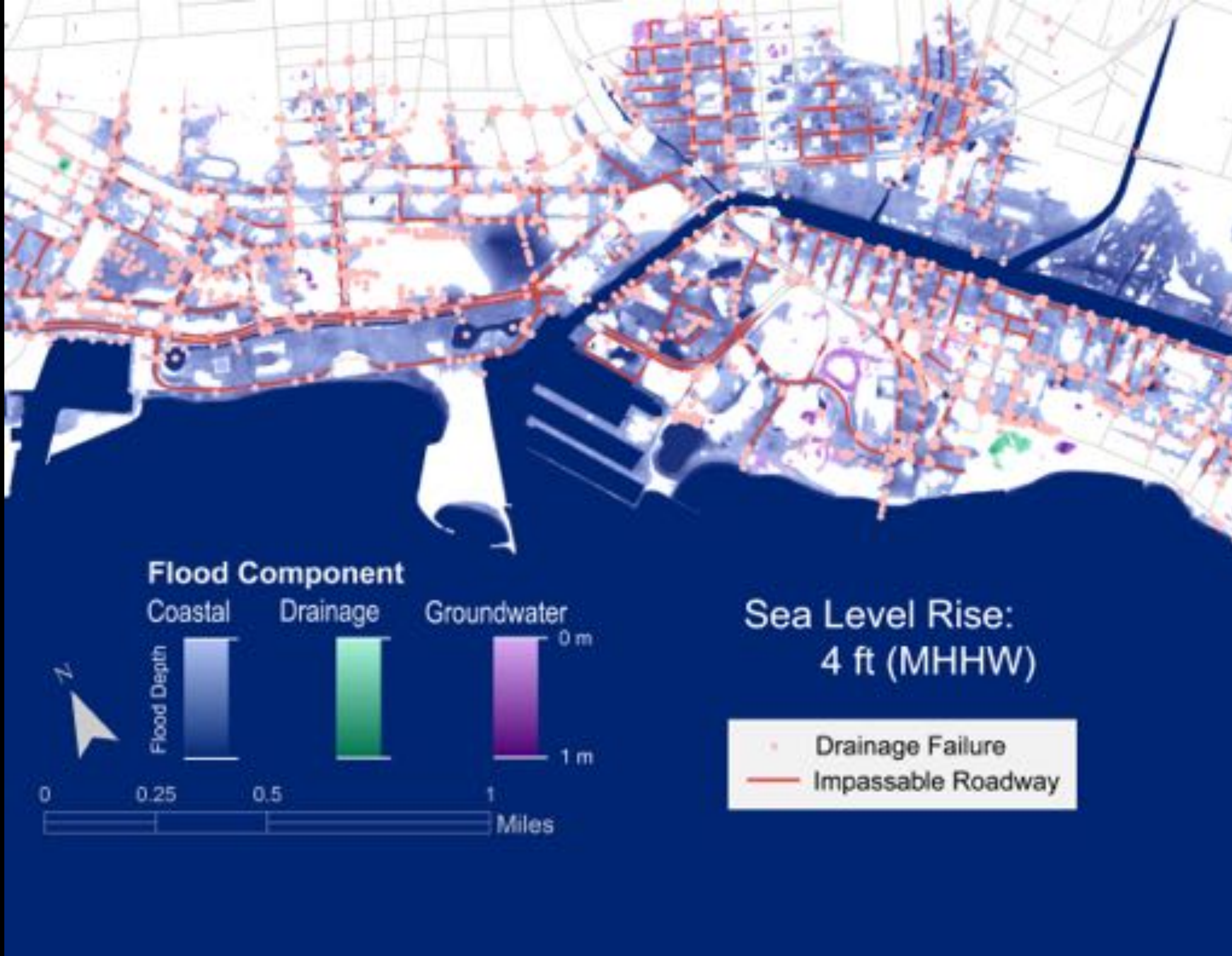
Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
0.25
0.5
1
Miles
Current Sea Level
Drainage Failure
Impassable Roadway

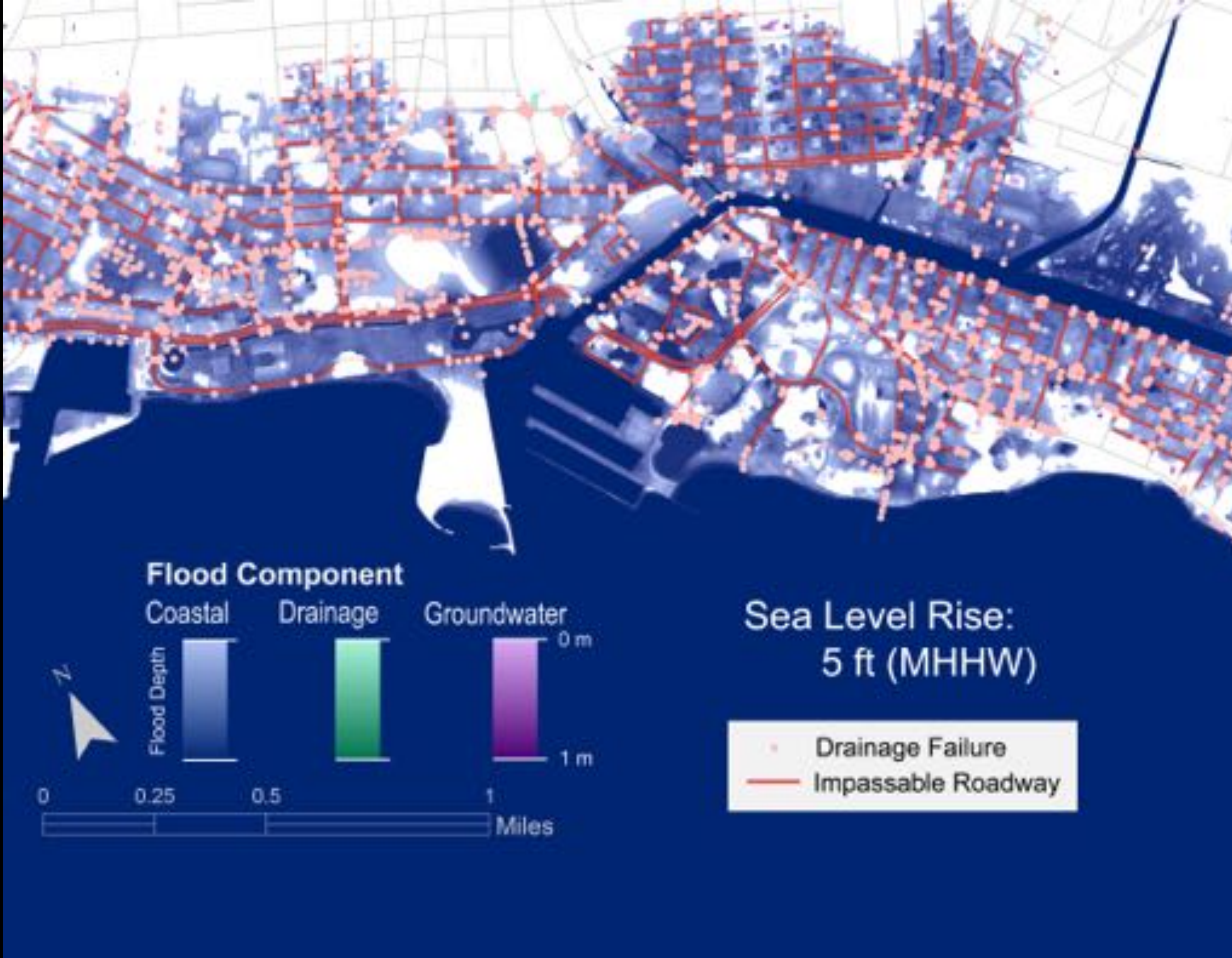

Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
0
0.25
0.5
1
Miles
Sea Level Rise:
1 ft (MHHW)
Drainage Failure
Impassable Roadway



Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
0.25
0.5
1
Miles
Sea Level Rise:
2 ft (MHHW)
Drainage Failure
Impassable Roadway


Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
0.25
0.5
1
Miles
Sea Level Rise:
3 ft (MHHW)
Drainage Failure
Impassable Roadway


Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
0.25
0.5
1
Miles
Sea Level Rise:
4 ft (MHHW)
Drainage Failure
Impassable Roadway


Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
N
0
0.25
0.5
1
Miles
Sea Level Rise:
5 ft (MHHW)
Drainage Failure
Impassable Roadway

Rain + High Tide = Flooding

Department of Transportation

- 140 miles
- 120 bridges
- 10-15% all roads
- $7.5M per lane mile
- $14M per bridge
- $15B total

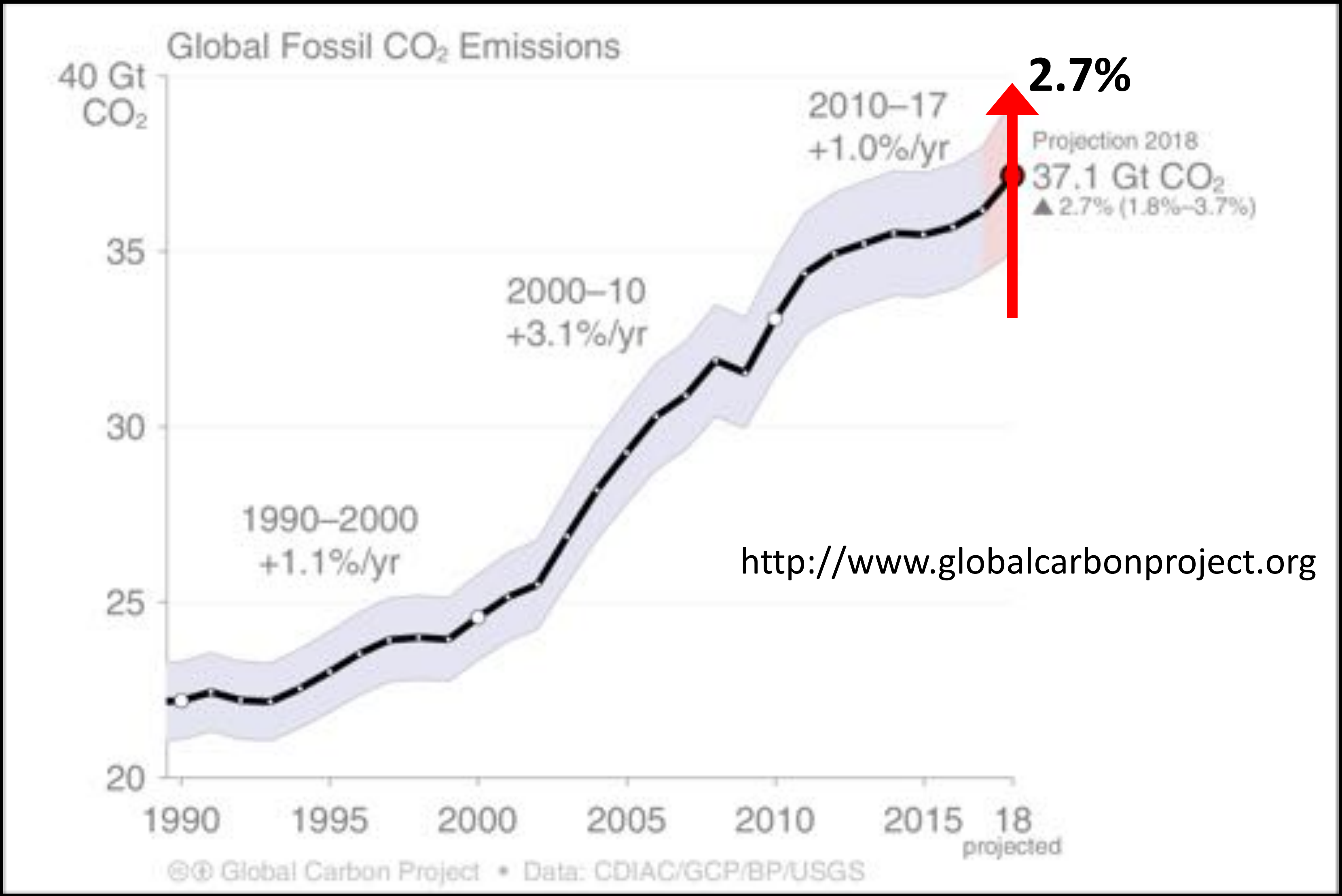
Coastal Erosion and Beach Loss

Summer wave run-up 2ft

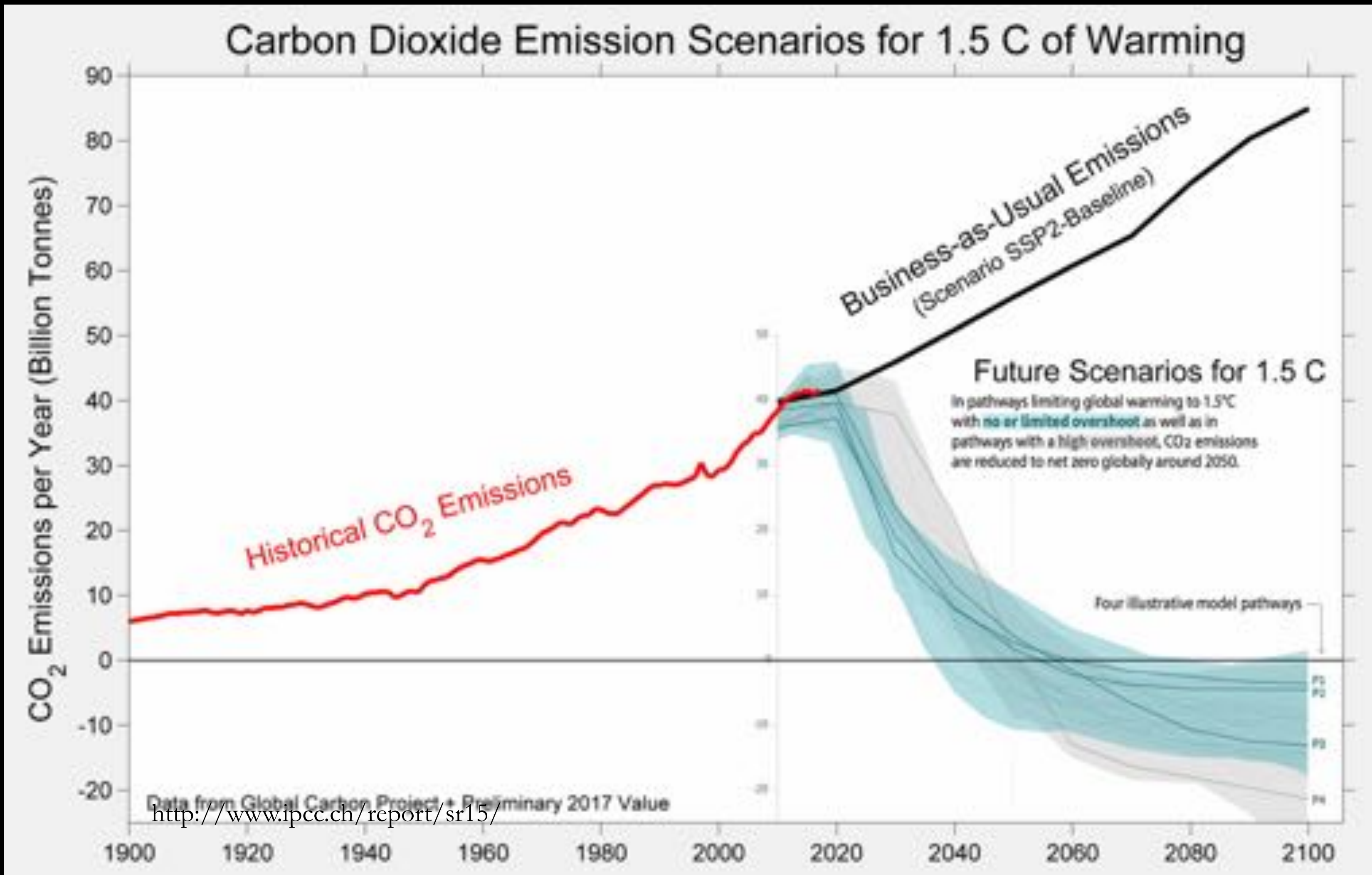
Summer wave run-up 3ft

Are global CO_2 emissions decreasing?

CO_2 emissions are rising at record levels



Global emissions must be cut 50% by 2030



http://www.ipcc.ch/report/sr15/

Rockström, J. et al. (2017) A roadmap for rapid decarbonization. *Science*, 355 (6331): 1269. Gasser, T., et al. (2015) Negative emissions physically needed to keep global warming below 2oC, *Nature Communications* 6, DOI: 10.1038/ncomms8958.

Hawaii is in a strong position to lead the world

- HECO has 7 new projects approved by the PUC
- One of these will be the single largest solar and storage deployment in U.S. history
- Phase II will replace our 180 MW coal plant and build a stand-alone 200 MW battery that will feed peak demand at less than current pricing.
- Farmers, cattle ranchers, and fish farms are going carbon negative and increasing our food security
- Seawater air conditioning is a cutting edge advancement
- Grid modernization strategy is installing “smart meters” to create new records of efficiency.

WAIKIKI
Marine Life
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District
Kapua
Entrance


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Kaluahole