Stakeholder Advisory Group

Board of Water Supply
City & County of Honolulu

Thursday April 25, 2019

Dave Ebersold

Facilitator

WELCOME

Public Comments on Agenda Items

Meeting Objectives

- Welcome new stakeholders
- Receive updates regarding the BWS
- Accept notes from meeting 29
- Increase our understanding of climate change and its impacts on Oahu
- Take group photo

New Stakeholders

- Dan Kouchi, Chamber of Commerce, Hawaii
- Chase Shigemasa, Resident of Council District 7

Ernest Lau
BWS Manager and Chief Engineer

BWS UPDATES

Mahalo!

Questions & Answers

Action

Review and accept notes from

- Stakeholder Advisory Group Meeting #29 held on Thursday, January 24, 2019

Mahalo!

Questions & Answers

CLIMATE CHANGE PANEL DISCUSSION

Climate Change Panel Experts

Dr. Charles H. Fletcher, III (Chip)

Associate Dean for Academic Affairs and Professor of Earth Sciences at the School of Ocean and Earth Science and Technology (SOEST), University of Hawaiʻi at Mānoa, and is also Vice-Chair of the Honolulu Climate Change Commission

Dr. Thomas Giambelluca

Professor in the Department of Geography and Environment at the University of Hawaiʻi at Mānoa

Joshua Stanbro

Honolulu's Chief Resilience Officer, and serves as the Executive Director of the Office of Climate Change, Sustainability and Resiliency

Barry Usagawa

BWS Water Resources Program Administrator

WATER FOR LIFE

Safe, dependable, and affordable water now and into the future

Board of Water Supply

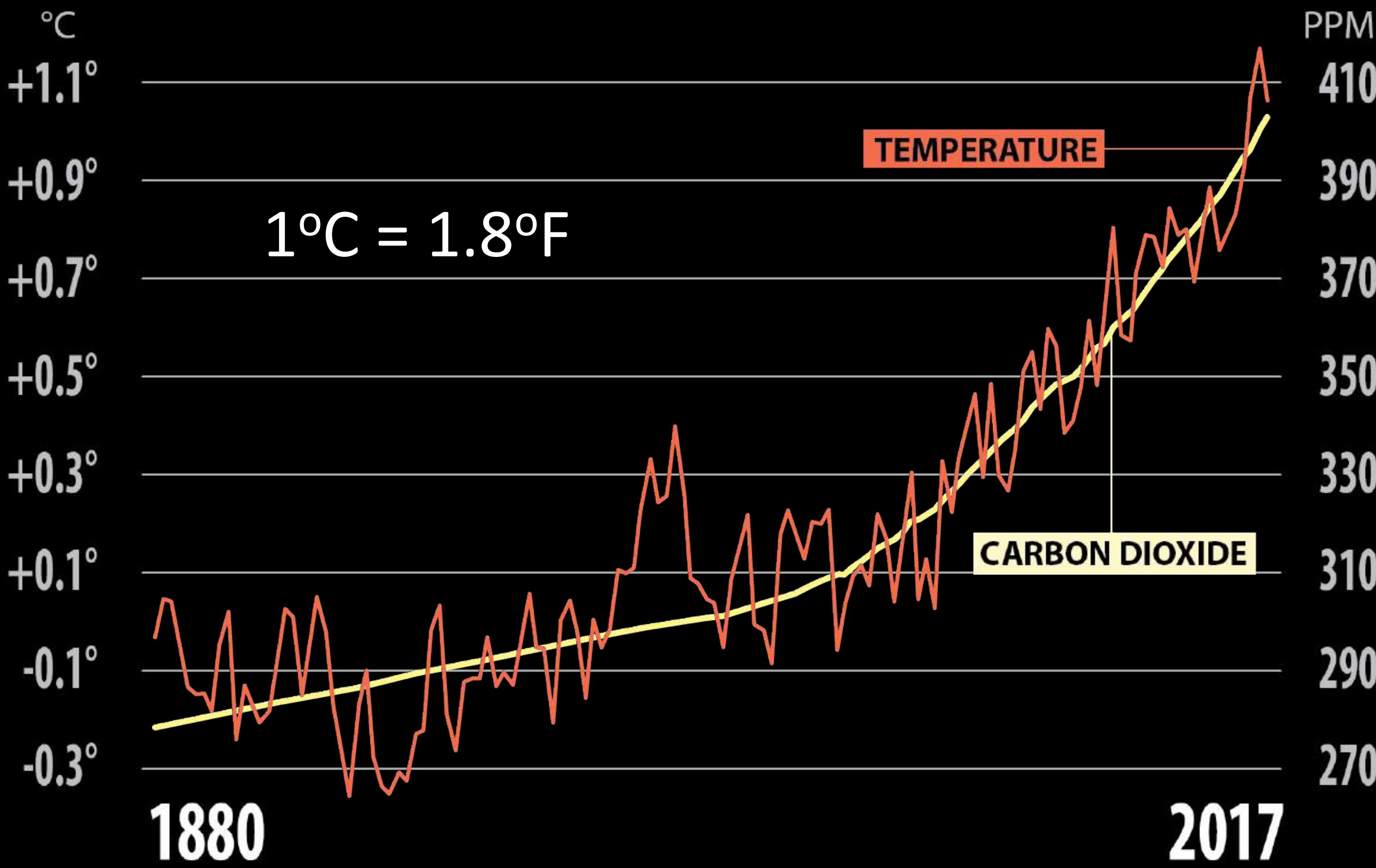
Dr. Charles H. Fletcher, III (Chip)

Associate Dean for Academic Affairs and Professor of Earth Sciences
School of Ocean and Earth Science and Technology (SOEST)
University of Hawaiʻi at Mānoa
Vice-Chair of the Honolulu Climate Change Commission

CLIMATE CHANGE PANEL DISCUSSION

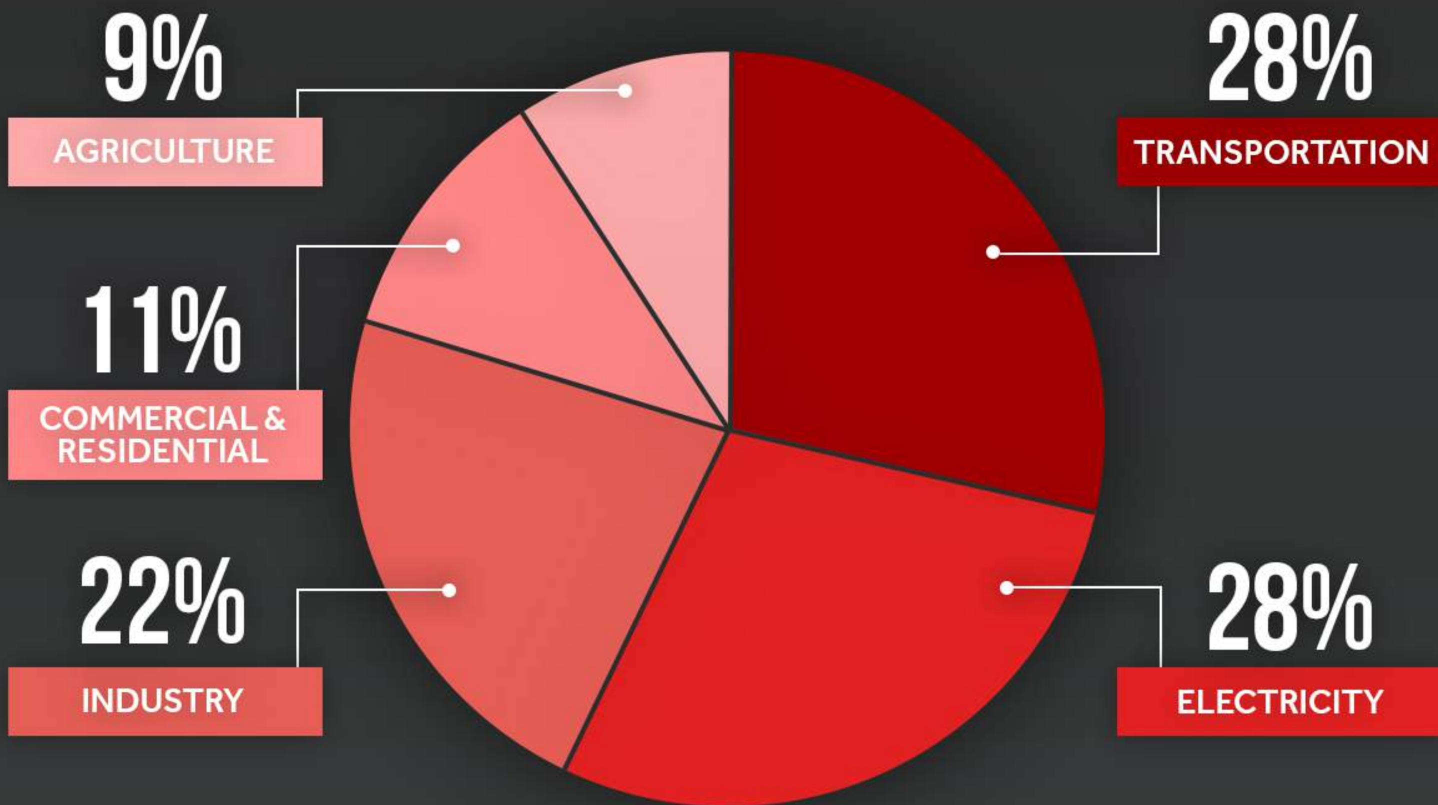

We have 10
years to cut
emissions
by 50%

GLOBAL TEMPERATURE & CARBON DIOXIDE



GREENHOUSE GAS SOURCES

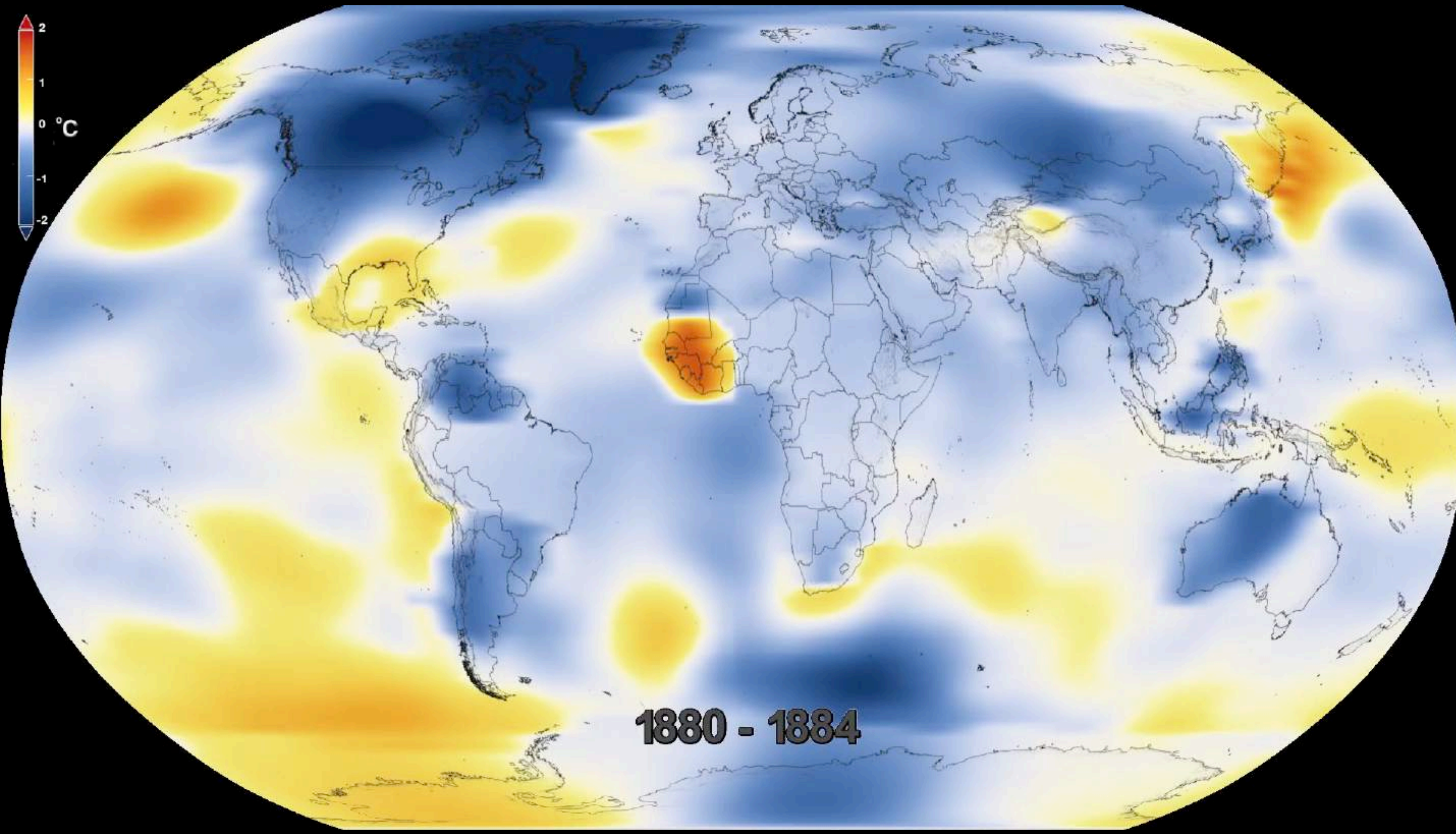
United States Greenhouse Gas Emissions by Sector



Source: US EPA

CLIMATE CENTRAL

The world is now 1°C (1.8°F) warmer



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

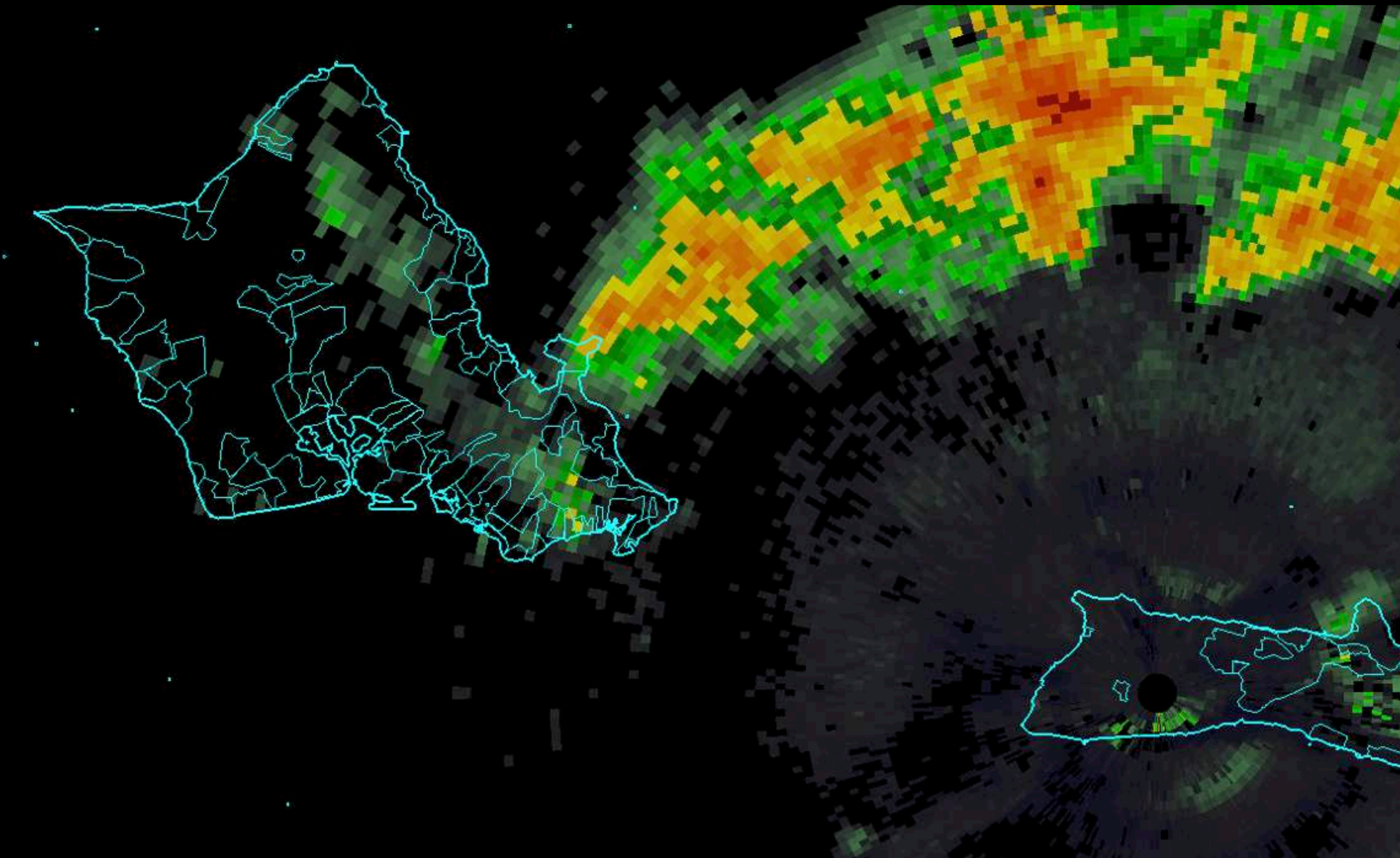
Extreme rainfall has increased 12%

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

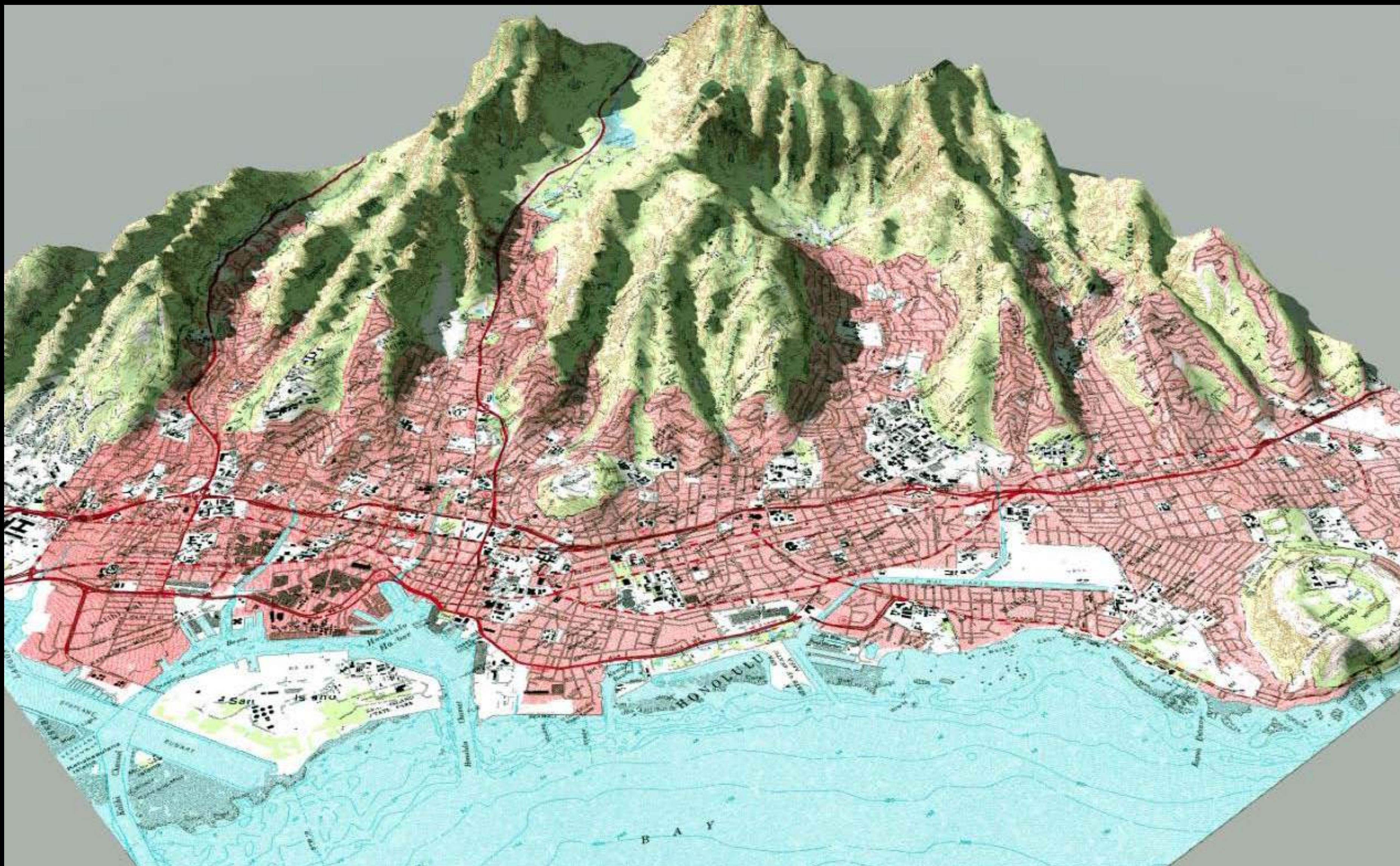
Extreme rainfall has increased 12%

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

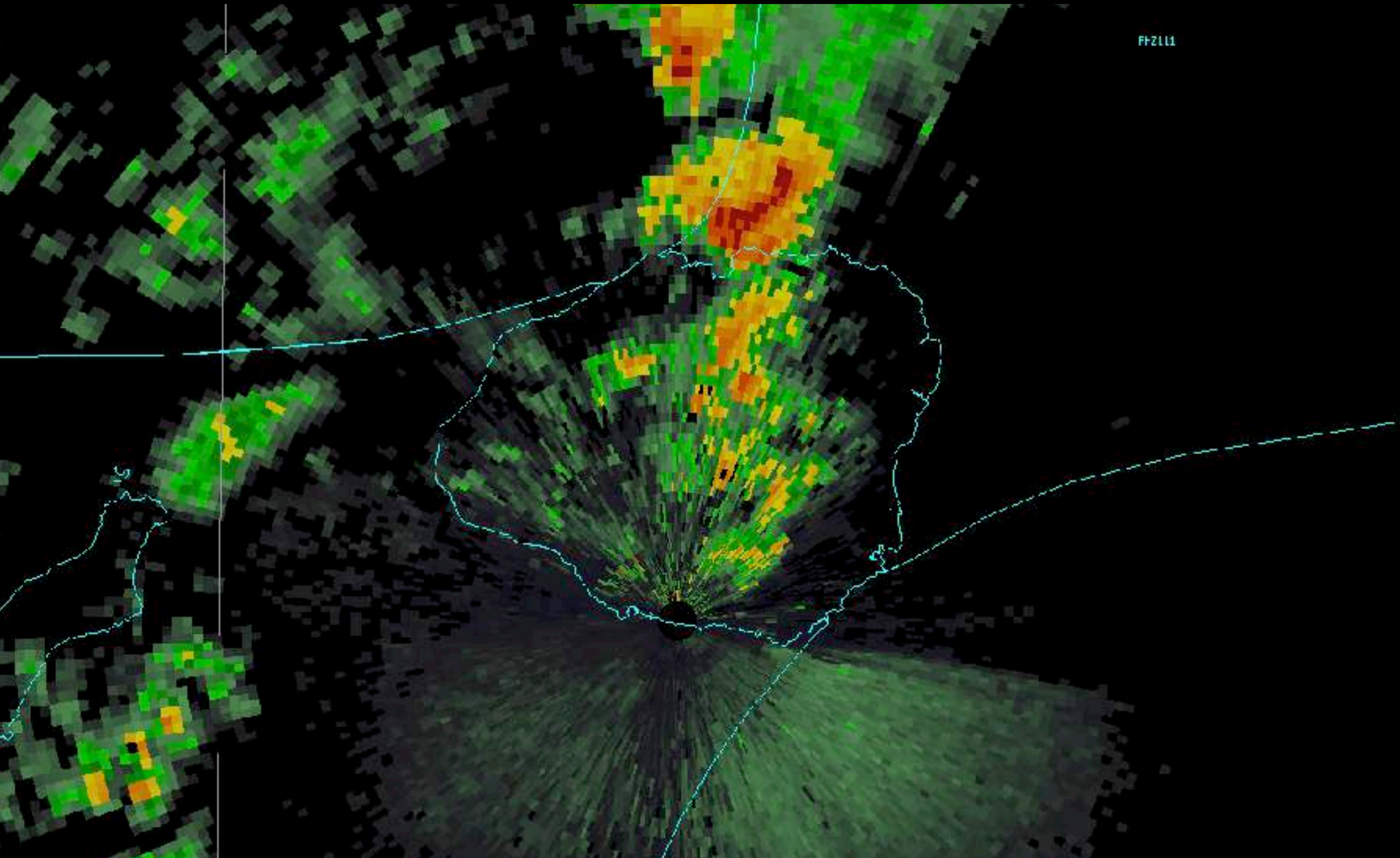
O‘ahu, April 2018
State of Emergency, $124 million



Short steep watersheds w/ heavy development promote flooding



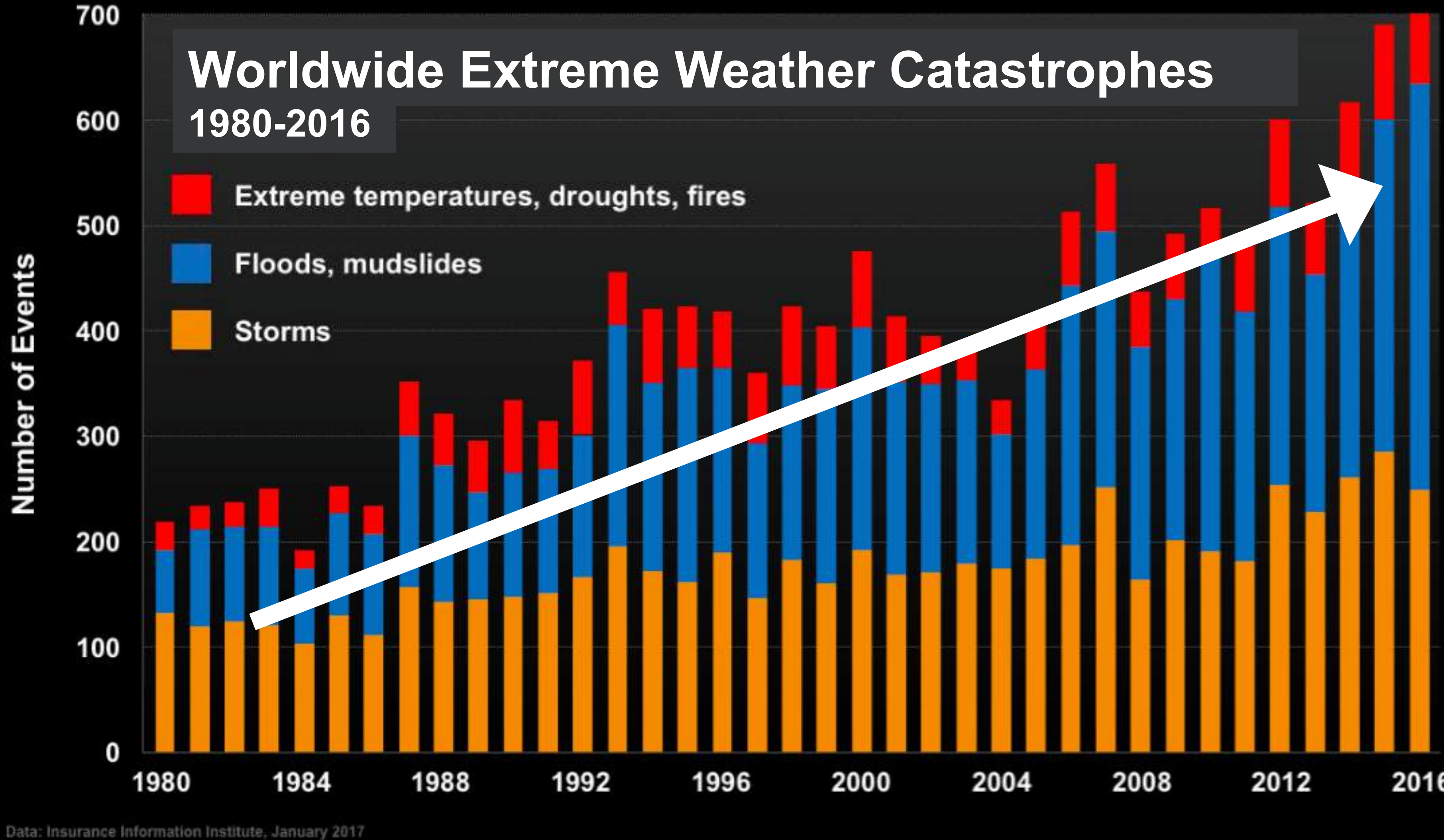
Kaua‘i, April 2018
49.69 inches of rainfall in a 24-hour period, national record




VOLVO

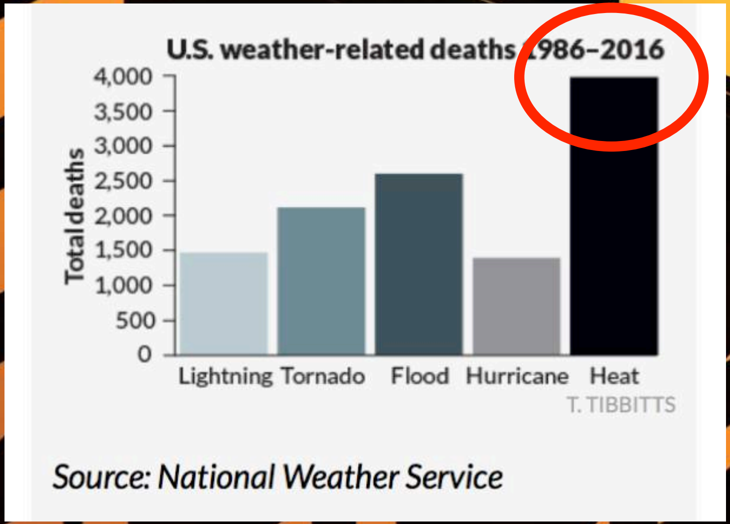
Weather disasters have doubled in two decades

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
Data: Insurance Information Institute, January 2017

Kitzberger T, et al.(2017) Direct and indirect climate controls predict heterogeneous early-mid 21st century wildfire burned area across western and boreal North America. PLoS ONE 12(12). https://doi.org/10.1371/journal.pone.0188486
Abatzoglou, J.T., Williams, A.P. (2016) Impact of anthropogenic climate change on wildfire across western U.S. forests. *Proceedings of the National Academy of Sciences*; 201607171 doi: 10.1073/pnas.1607171113

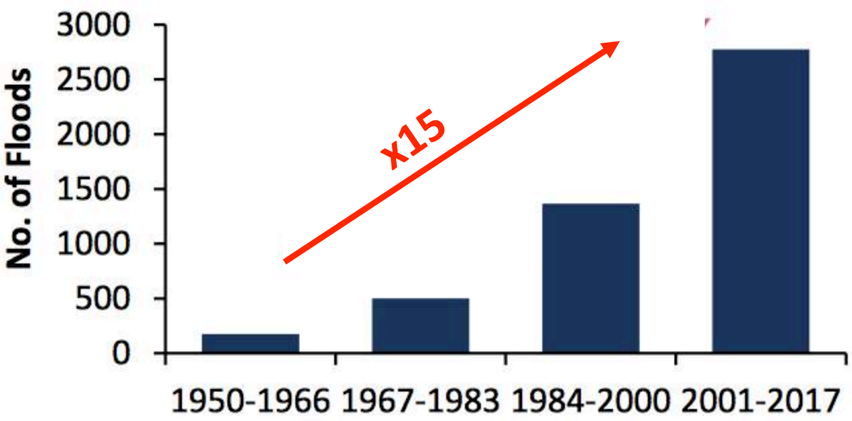
Heat waves are the deadliest natural disaster in the U.S.



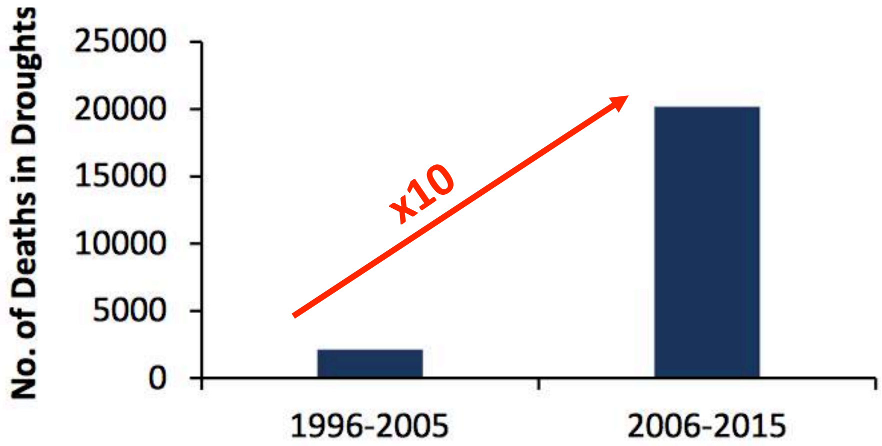
Center for Climate and Energy Solutions: https://www.c2es.org/content/heat-waves-and-climate-change/

Global extreme weather events on the rise

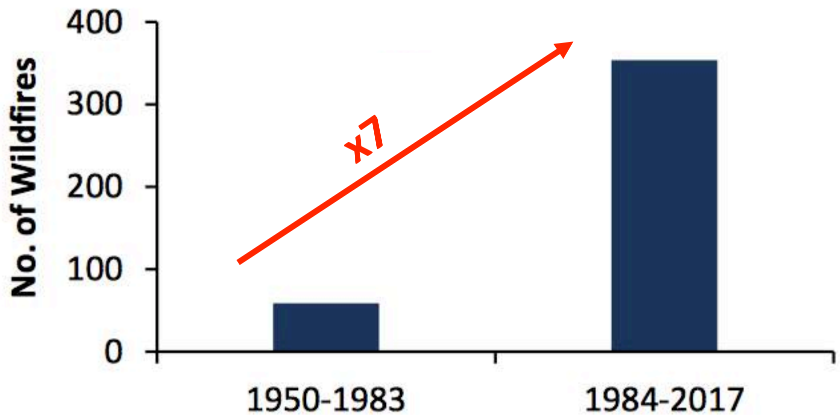
Floods



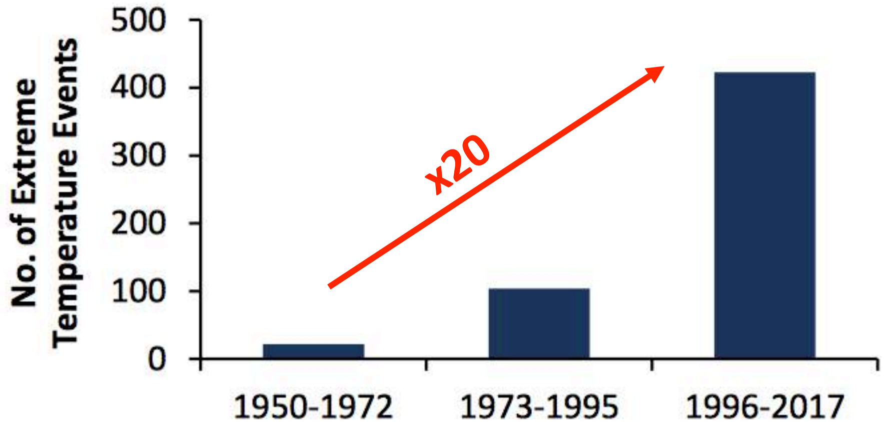
Drought Mortality



Wildfires



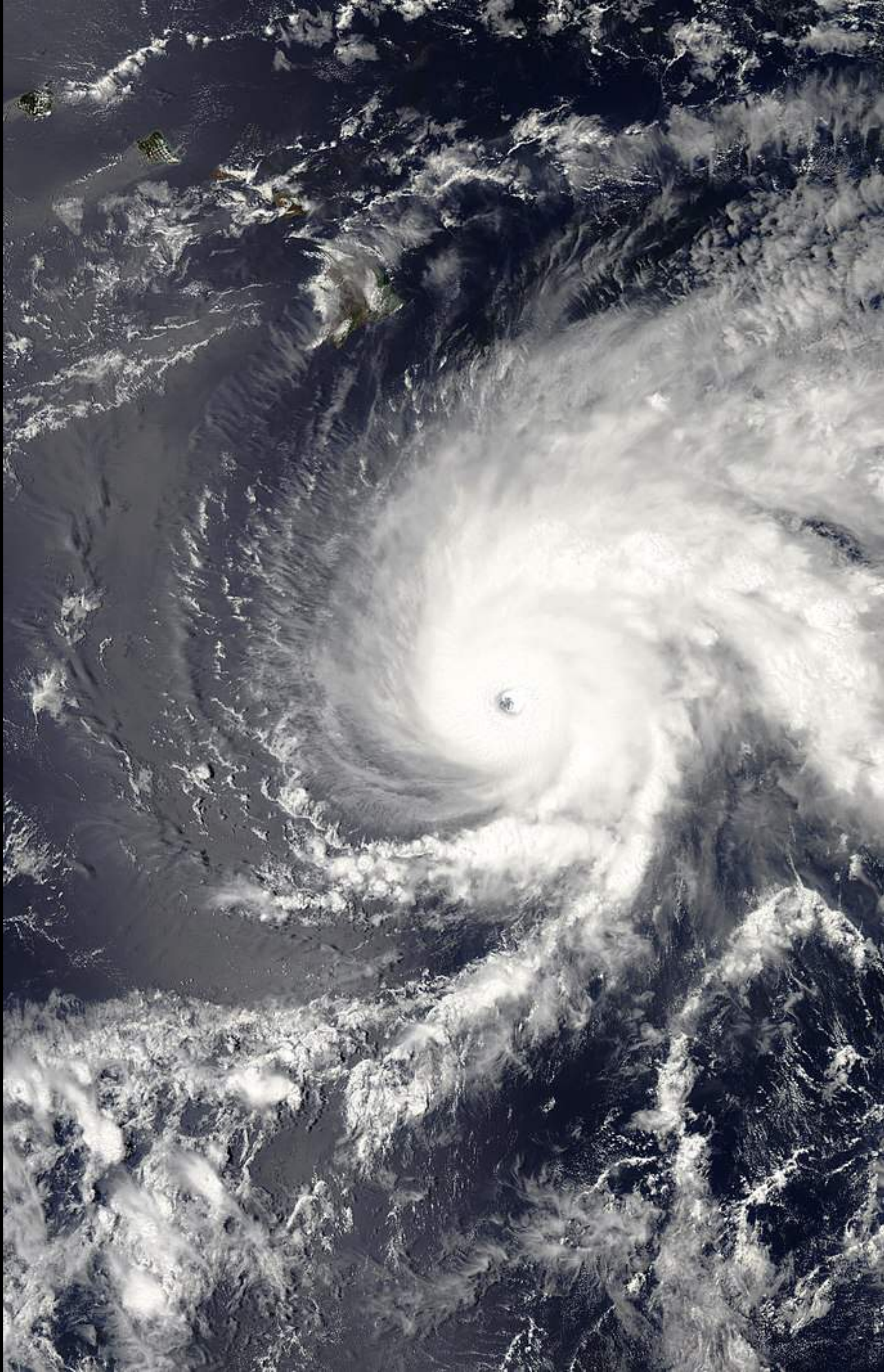
Extreme Temperature Events



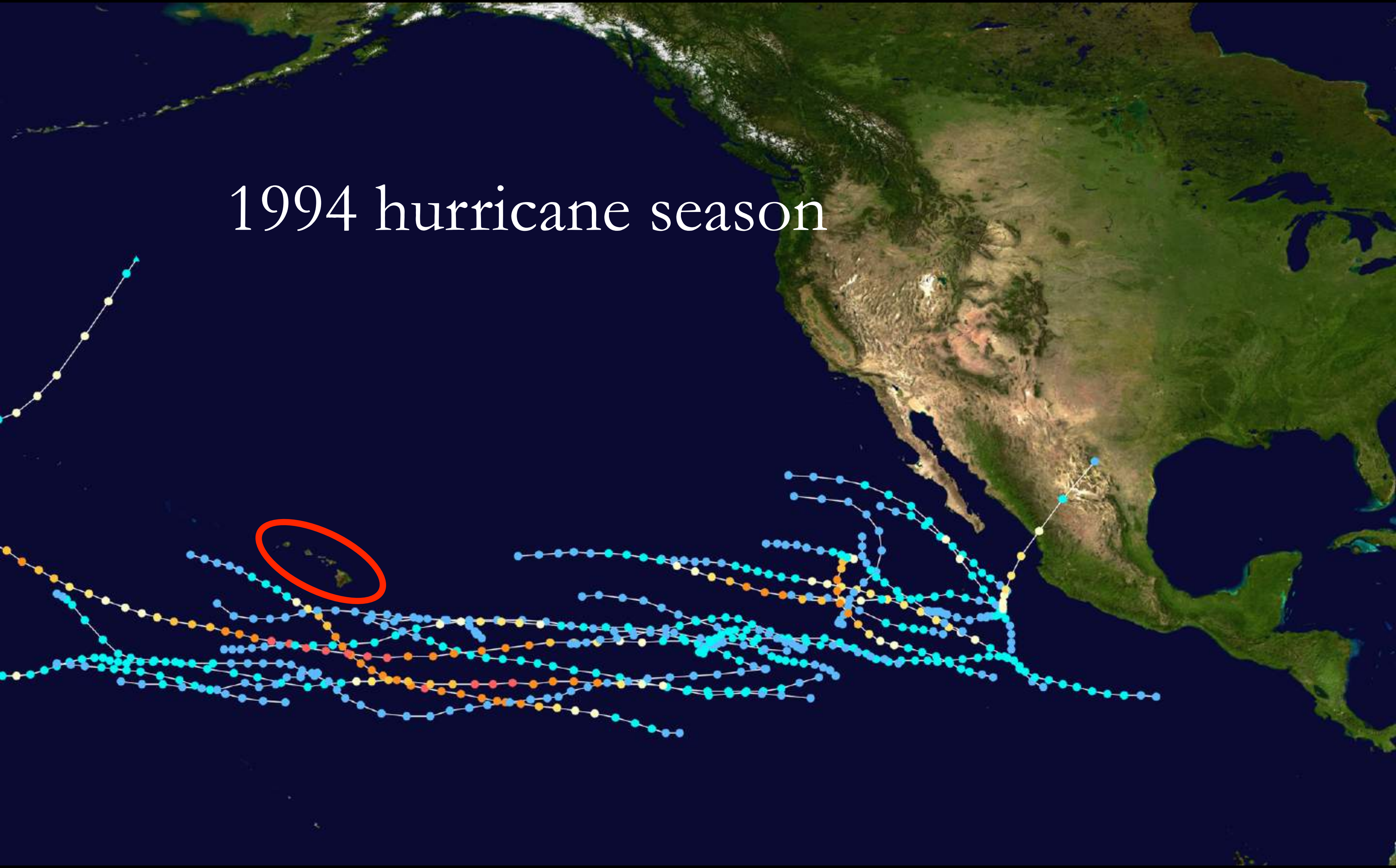
https://www.gmo.com/docs/default-source/research-and-commentary/strategies/asset-allocation/the-race-of-our-lives-revisited.pdf?sfvrsn=4. International Disasters database: https://www.emdat.be

Hurricanes and Climate Change

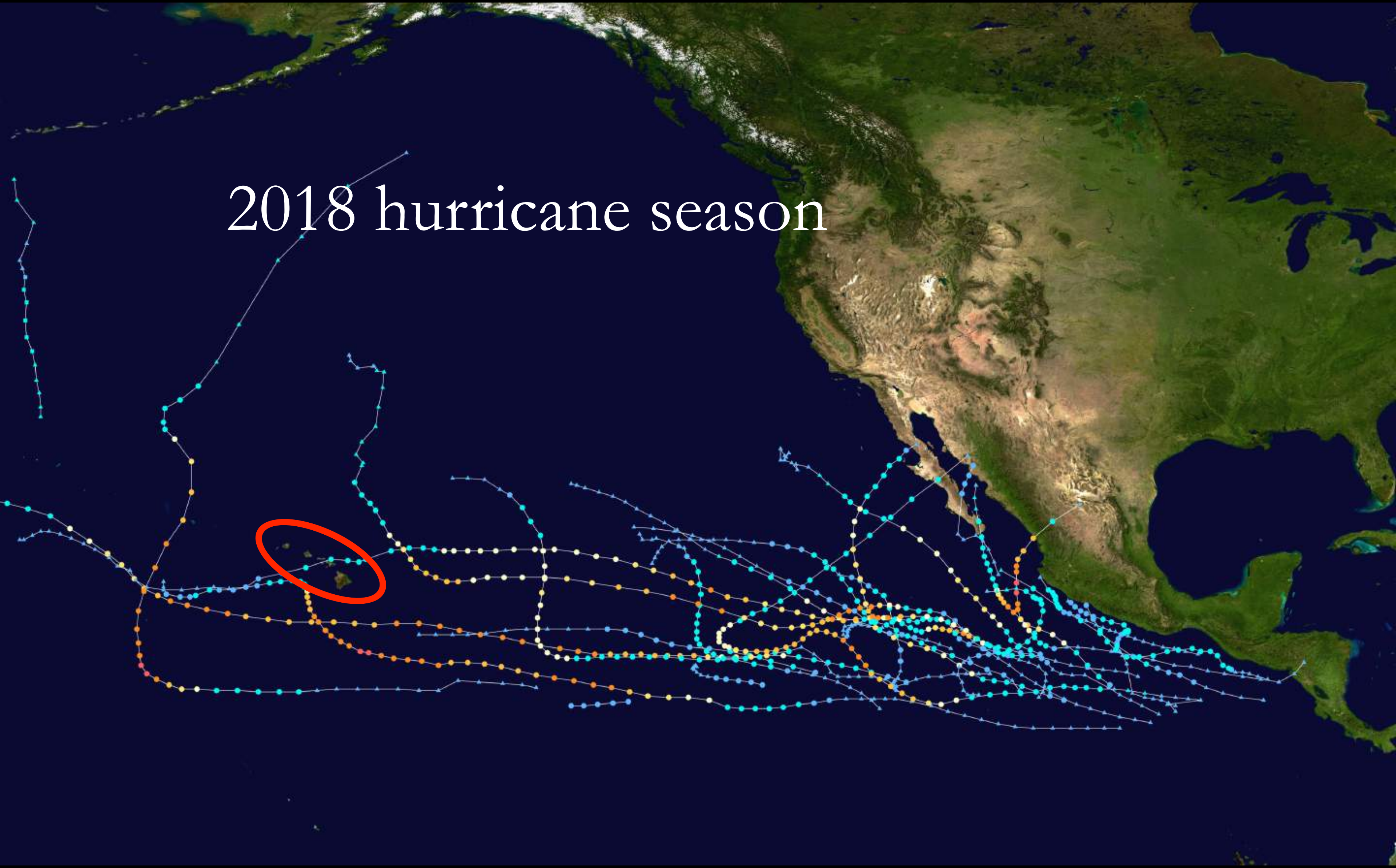
- Warmer water = More fuel
- Larger
- More rain
- Stronger wind = Higher category
- Slower = More damage
- Higher storm surge
- Shifting away from equator



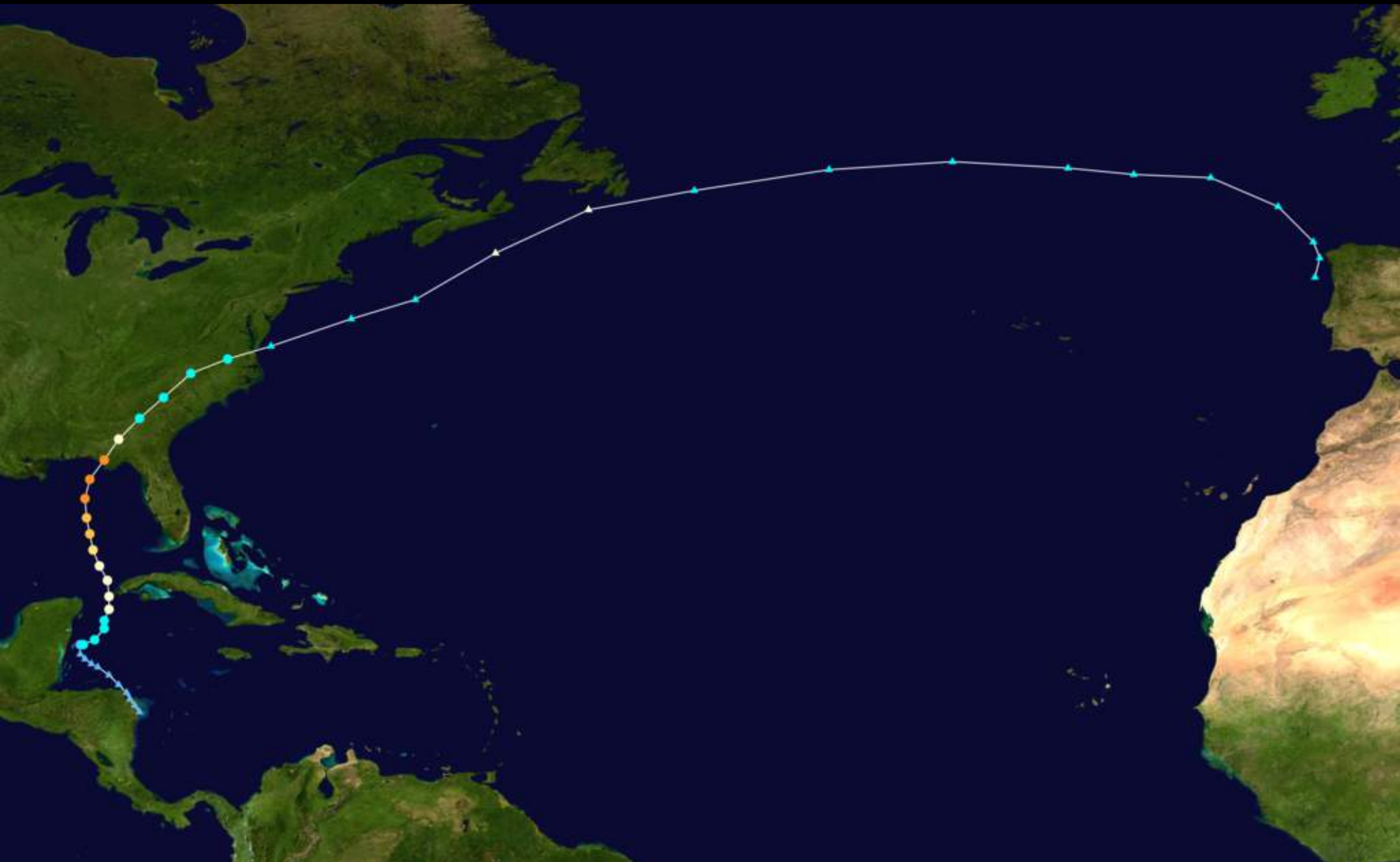
Does Global Warming Make Hurricanes Stronger? http://www.realclimate.org/index.php/archives/2018/05/does-global-warming-make-tropical-cyclones-stronger/


1994 hurricane season

2018 hurricane season



Hurricane Michael, Florida Panhandle, October, 2018

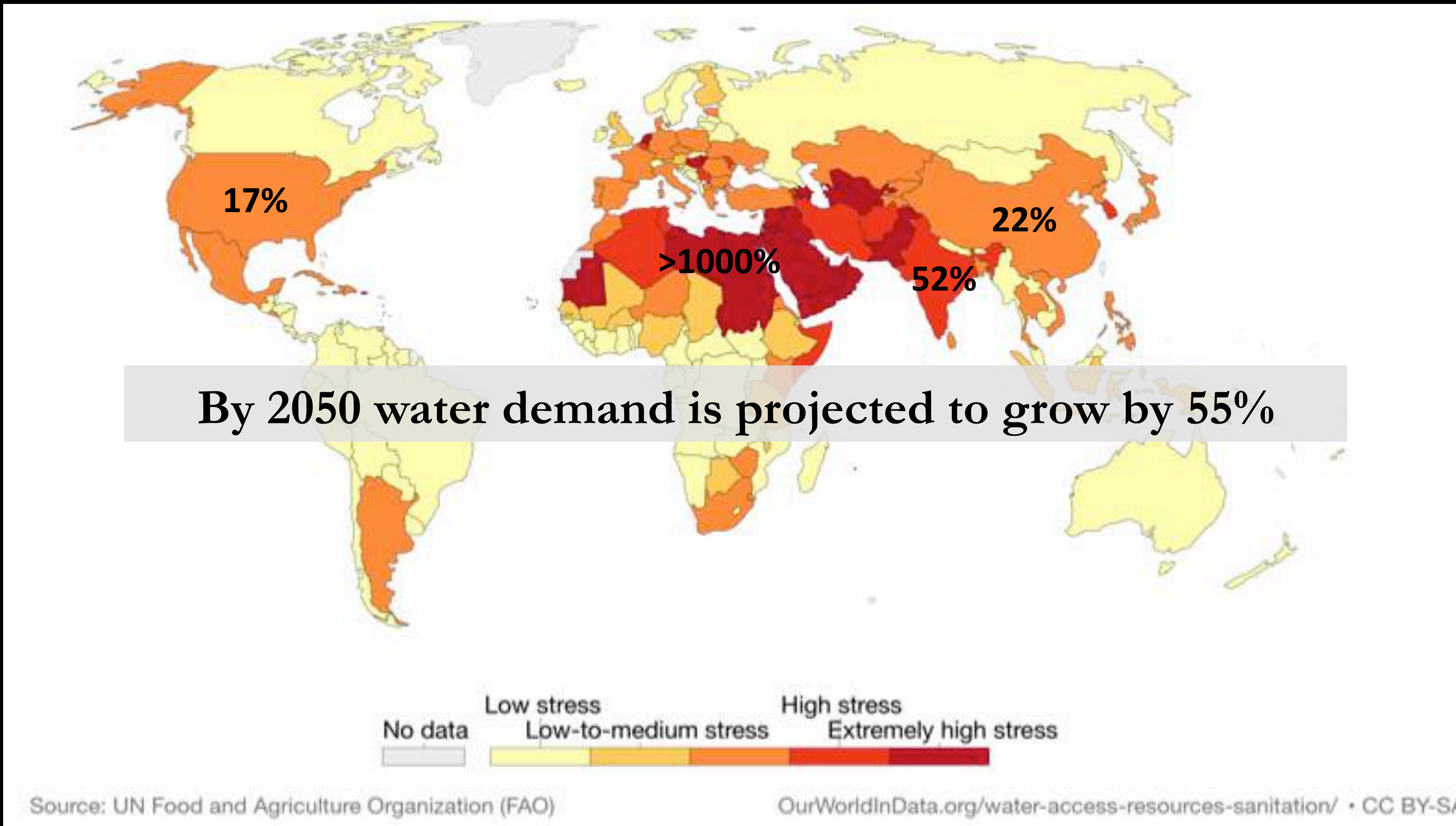


Hurricane Michael, Florida Panhandle, October, 2018

By 2030 global water requirements will exceed sustainable water supplies by 40%.

https://www.dni.gov/files/documents/Special%20Report_ICA%20Global%20Water%20Security.pdf

Freshwater withdrawals are already exceeding internal sources



https://ourworldindata.org/water-access-resources-sanitation#water-stress-and-scarcity

Food is less nutritious.

Decreased zinc, iron, and protein

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International journal of science

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Letter

Increasing CO_2 threatens human nutrition

Samuel S. Myers, Antonella Zanobetti, Itai Kloog, Peter Huybers, Andrew D. B. Leakey, Arnold J. Bloom, Eli Carlisle, Lee H. Dietterich, Glenn Fitzgerald, Toshihiro Hasegawa, N. Michele Holbrook, Randall L. Nelson, Michael J. Ottman, Victor Raboy, Hidemitsu Sakai, Karla A. Sartor, Joel Schwartz, Saman Seneweera, Michael Tausz & Yasuhiro Usui

Nature **510**, 139–142 (05 June 2014)
doi:10.1038/nature13179
Download Citation
Environmental health

Received: 25 November 2013
Accepted: 24 February 2014
Published online: 07 May 2014

Abstract

Dietary deficiencies of zinc and iron are a substantial global public health problem. An estimated two billion people suffer these deficiencies[1], causing a loss of 63 million life-years annually[2,3]. Most of these people depend on C_3 grains and legumes as their primary dietary source of zinc and iron. Here we report that C_3 grains and legumes have lower concentrations of zinc and iron when grown under field conditions at the elevated atmospheric CO_2 concentration predicted for the middle of this century. C_3 crops other than legumes also have lower concentrations of protein, whereas C_4 crops seem to be less affected. Differences between cultivars of a single crop suggest

Editorial Summary

Crop nutrient loss in high CO_2

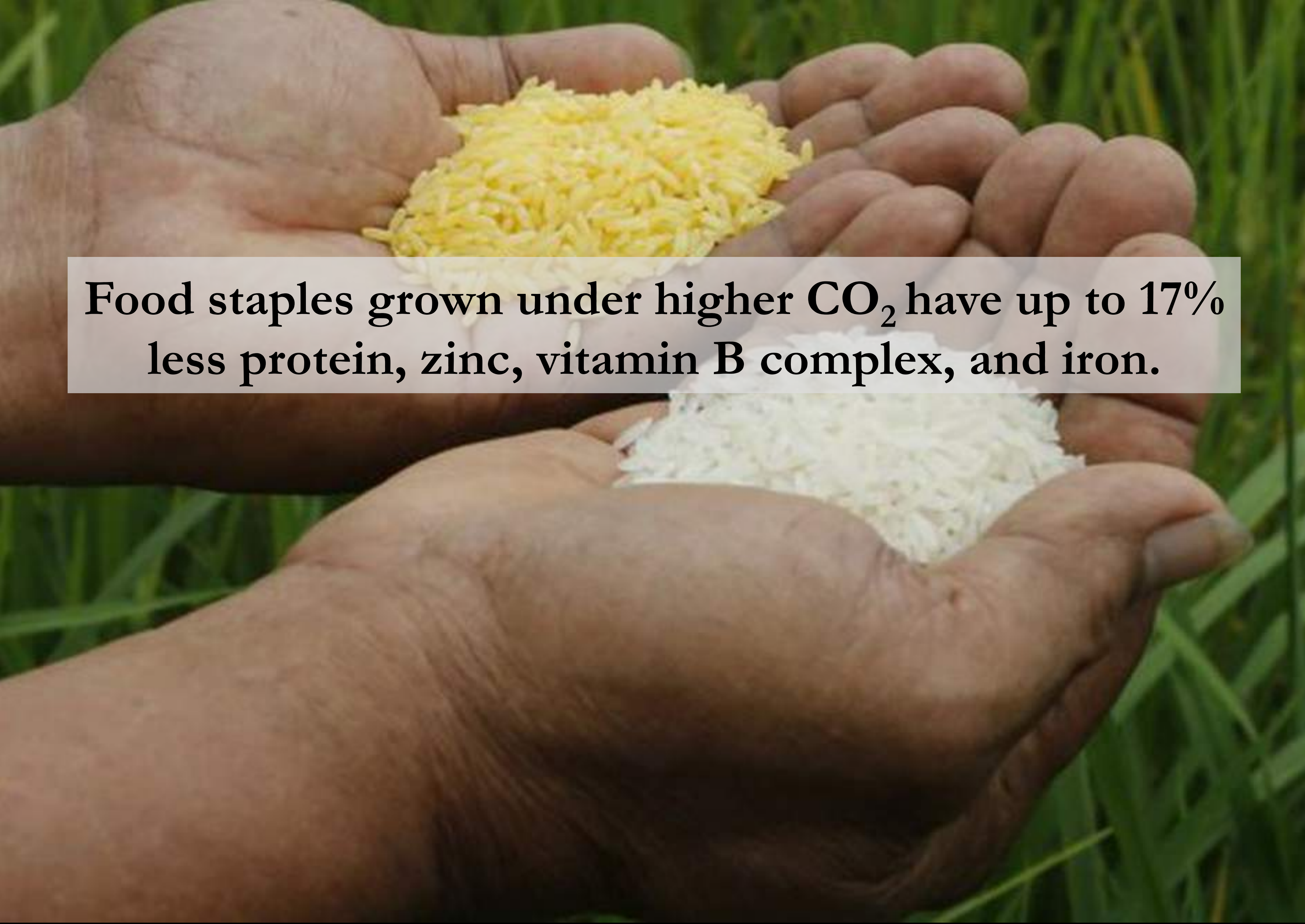
It has been suggested that the conce
of important nutrients such as zinc a
in food crops will decrease with incr
atmospheric CO_2 levels. However, so
studies have not found this, and som
those that have relied on non-field c
or did not focus on edible crop parts
Myers *et al.* have assembled the large
set to date from free-air CO_2 enrichm
experiments and find that C_3 crops (
and grasses) do indeed have reduced
iron levels under the elevated CO_2 co
predicted for the middle of this cent
Crops using the C_4 photosynthetic p
are less affected. These findings sugg
breeding cultivars for reduced sensit
elevated CO_2 may be an important p
health priority in many parts of the w
show less

Associated Content

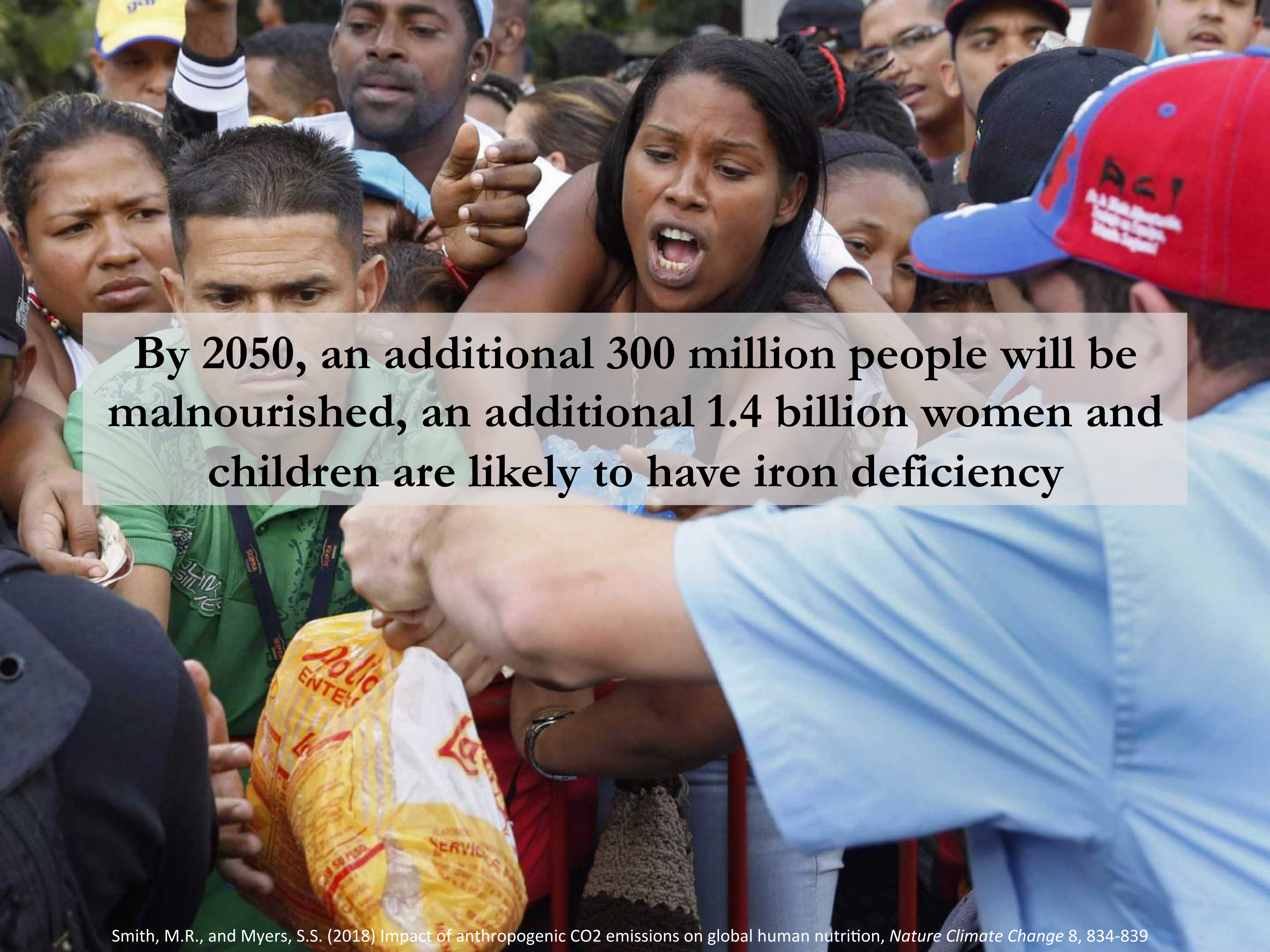
Scientific Data | Data Descriptor | OPEN

Impacts of elevated atmosphe
on nutrient content of importa
crops

Lee H. Dietterich, Antonella Zanobetti [...]
Myers



Chunwu, Z et al (2018) Carbon dioxide levels (CO2) this century will alter the protein, micronutrients, and vitamin content of rice grains with potential health consequences for the poorest rice-dependent countries, *Science Advances*, May 23, v. 4, no. 5. Myers, S.S., et al. (2014) Increasing CO_2 threatens human nutrition, *Nature*, 510, 139-142, doi: 10.1038/nature13179.



By 2050, an additional 300 million people will be malnourished, an additional 1.4 billion women and children are likely to have iron deficiency

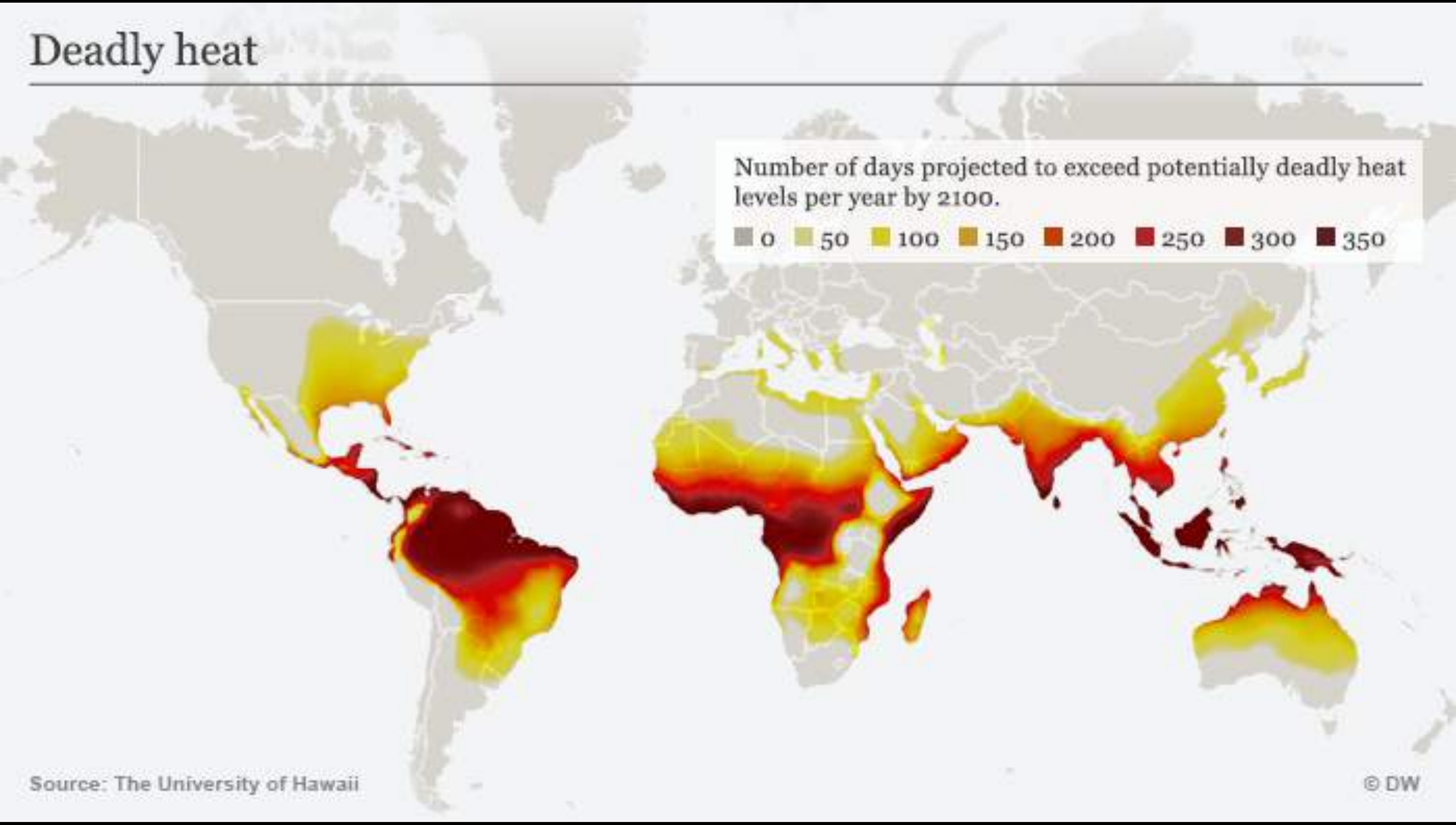
Smith, M.R., and Myers, S.S. (2018) Impact of anthropogenic CO2 emissions on global human nutrition, *Nature Climate Change* 8, 834-839

Food Shortages

- Global wheat provides 20% of human protein.
  - Yield is threatened by drought, flood, higher CO_2
  - By 2050 demand will increase by 60% (9 billion people)
  - But wheat yields will decline by 15%.

Deutsch, C.A., et al. (2018) Increase in crop losses to insect pests in a warming climate, *Science*, 31 August, v. 361, Iss. 6405, p. 916-919
Springmann, M. et al. Global and regional health effects of future food production under climate change: a modelling study. The Lancet, March 2, 2016 DOI: 10.1016/S0140-6736(15)01156-3. Myers et al, 2014 Increasing CO_2 threatens human nutrition, Nature 510, 139-142. Feng et al, 2015 Constraints to nitrogen acquisition of terrestrial plants under elevated CO_2, Global Change Biology, DOI: 10.1111/gcb.12938

The Tropics are Becoming Unlivable

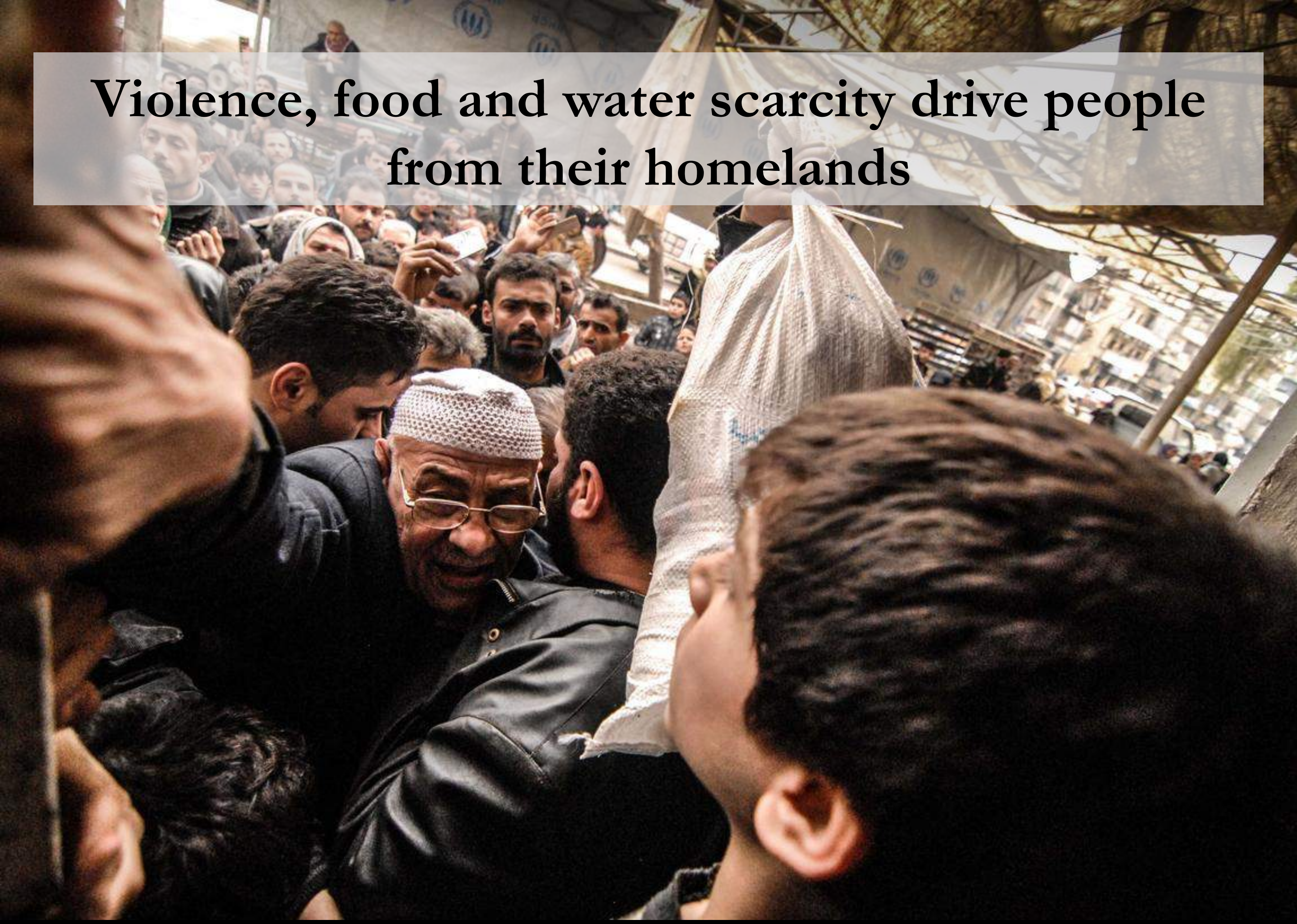


Mora C, et al. (2017) Global risk of deadly heat. *Nature Climate Change 7,* 501-506

Food and water shortages can lead to violent conflict, refugee crises

Mora, C., et al. (2017) **Global risk of deadly heat.** *Nature Climate Change*; DOI: 10.1038/NCLIMATE3322

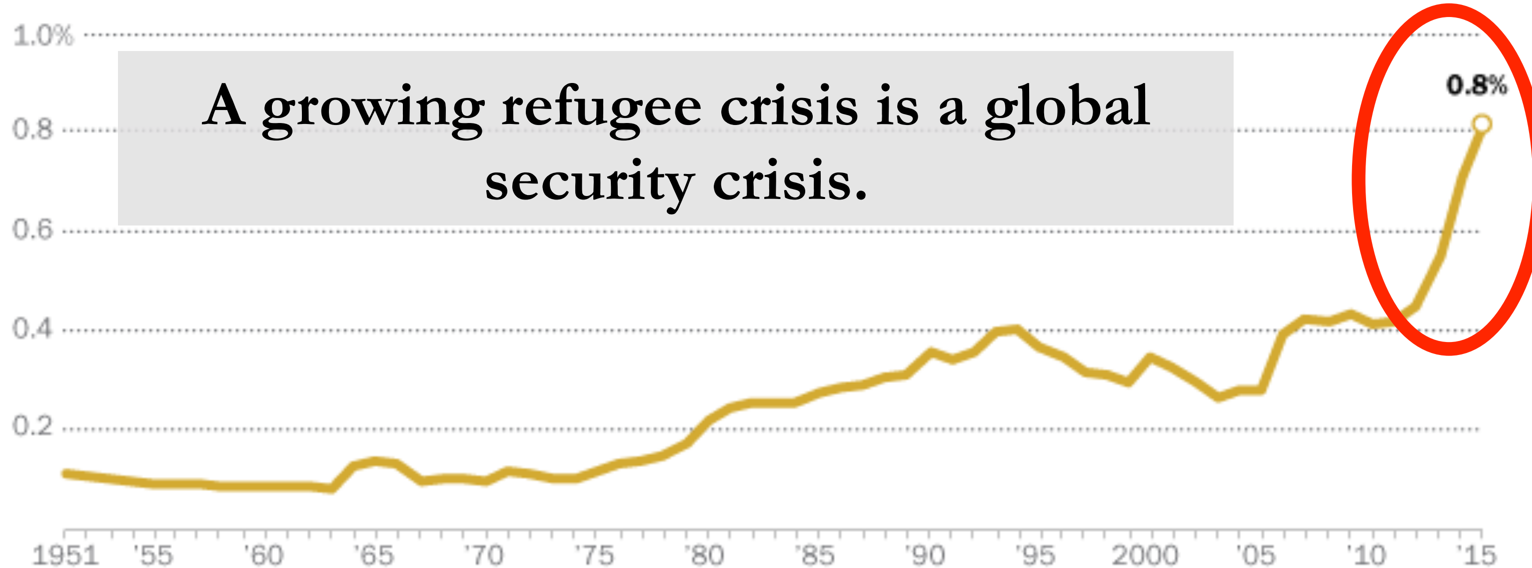
Violence, food and water scarcity drive people from their homelands



Worldwide nearly 1% of humanity are displaced from their homes

A record-high share of the world's population is displaced from their homes

% of world population that is forcibly displaced



Note: Displaced includes internally displaced persons within their birth country, refugees and asylum seekers living in a different country who have yet to resettle permanently, and Palestinian refugees registered with the United Nations Relief and Works Agency (UNRWA) in Jordan, Lebanon and Syria.

Source: Pew Research Center analysis of United Nations data, accessed July 20, 2016.

PEW RESEARCH CENTER

http://www.pewresearch.org/fact-tank/2016/08/03/nearly-1-in-100-worldwide-are-now-displaced-from-their-homes/

Drought in Syria led to civil war and terrorism

…worst drought in 1000 yrs, causing widespread crop failure and a mass migration of farming families to urban centers.

…the drought had a catalytic effect, contributing to political unrest.

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NEW RESEARCH IN Physical Sciences

Climate change in the Fertile Cresc… implications of the recent Syrian dro…

Colin P. Kelley, Shahrzad Mohtadi, Mark A. Cane, Richard Seager, and Yocha…

PNAS 2015 March, 112 (11) 3241-3246. https://doi.org/10.1073/pnas.1421533112

Edited by Brian John Hoskins, Imperial College London, London, United Kingdom, and approved Ja… (received for review November 16, 2014)

Article | Figures & SI | Authors & Info | PDF

Significance

There is evidence that the 2007–2010 drought contributed to …nflict in Syria. It was the worst drought in the instrumental record, causing wide…ad crop failure and a mass migration of farming families to urban centers. Century-l…g observed trends in precipitation, temperature, and sea-level pressure, supported by climate model results, strongly suggest that anthropogenic forcing has increased the probability of severe and …sistent droughts in this region, and made the occurrence of a 3-year drought as severe …at of 2007–2010 2 to 3 times more likely than by natural variability alone. We …ude that human influences on the climate system are implicated in the current Syrian …t.

…tract

…Syrian uprising that began in 2011, the greater Fertile Crescent experienced the …ught in the instrumental record. For Syria, a country marked by poor governa… …stainable agricultural and environmental policies, the drought had a catalytic effect, co… …to political unrest. We show that the recent decrease in Syrian precipitation is a combina… …natural variability and a long-term drying trend, and the unusual severity of the observed dro…ght is here shown to be highly unlikely without this trend. Precipitation changes in Syria are linked to rising mean sea-level pressure in the Eastern Mediterranean, which also shows a long-term trend. There has been also a long-term warming trend in the Eastern Mediterranean, adding to the drawdown of soil moisture. No natural cause is apparent for these trends, whereas the observed drying and warming are consistent with model studies of the response to increases in greenhouse gases. Furthermore, model studies show an increasingly drier and hotter future mean

…s Classification

Physical Sciences

- Ising model and ecology
- F-donating electrolyte for 5-V Li metal battery
- Abrupt change of superconducting gap in $FeSe_{1-x}S_x$

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Earth, Atmospheric, and Planetary Sciences

- Precipitation formation from cloud seeding
- Eocene tropical SST from clumped isotopes

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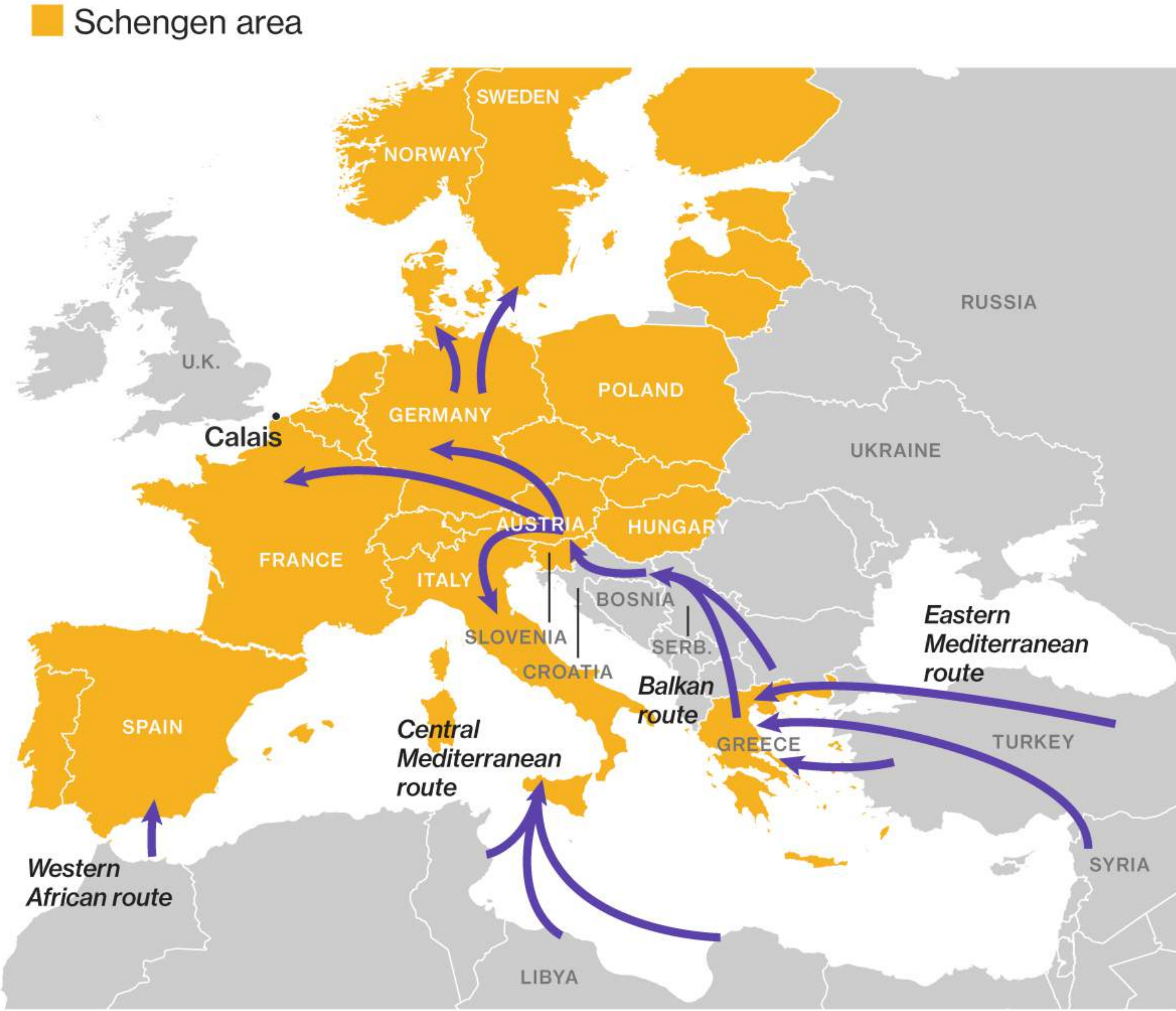
Migratory Routes



Sources: Frontex, i-map

Bloomberg Graphics


JUST

Syrian refugees flooded into Europe by the millions

… creating a backlash among residents

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WATCH LIVE 8:42 AM Collins, Mu

October 19,

N

By

Sebastian Kurz…..campaigned on the need for tougher immigration controls, quickly deporting asylum-seekers whose requests are denied and outlawing the practice of Islam.

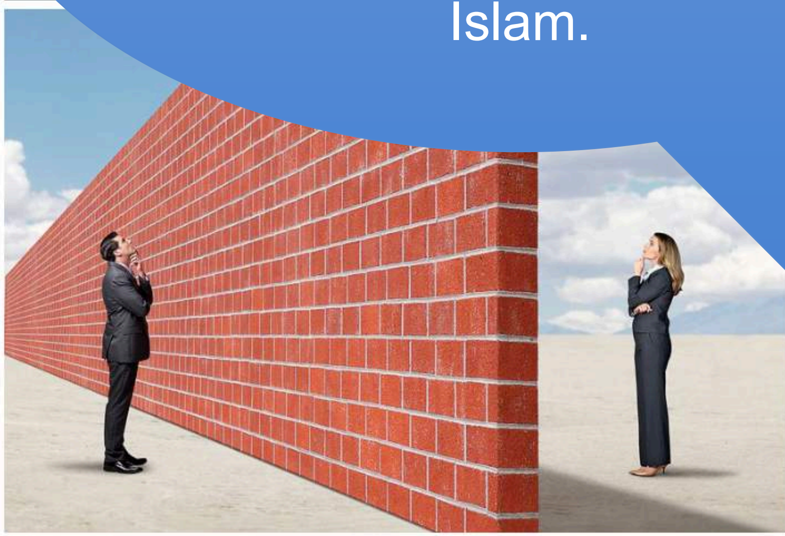

PHOTO ILLUSTRATION: 731; PHOTOS: BLOOMBERG (1), GETTY IMAGES (2)

As Europeans assess the fallout from the U.K.'s Brexit referendum, they face a series of elections that could equally shake the political establishment. In the coming 12 months, four of Europe's five largest economies have votes that will almost certainly mean serious gains for right-wing populists and nationalists. Once seen as fringe groups, France's National Front, Italy's Five Star Movement, and the Freedom Party in the Netherlands have attracted legions of followers by

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Austria likely takes a right turn as 31-year-old minister declares victory in election

- Ballot projections show Austrian foreign minister Sebastian Kurz's People's Party leading in a national vote.
- This puts Kurz on course to become Europe's youngest head of government.
- The party has focused on concerns about immigration and Islam.

Published 12:09 PM ET Sun, 15 Oct 2017 | Updated 22 Hours Ago

AP

Gallup | Getty Images

n Foreign Minister and leader of the conservative Austrian Peoples Party (OeVP) n Kurz speaks to media as he arrives to cast his ballot in Austrian parliamentary n October 15, 2017 in Vienna, Austria.

Austria year-old foreign minister declared victory for his party Sunday in tional election that set him up to become Europe's youngest lea and puts the country on course for a rightward turn.

Foreign Minister Se astian Kurz claimed the win as final results announced by the Interior Ministry showed his People's Party had a comfortable lead with almost all the ballots counted.

Noting that his center-right party had triumphed over the rival Social Democrats only twice since the end of World War II, Kurz called it a

CLIMATE KINGS

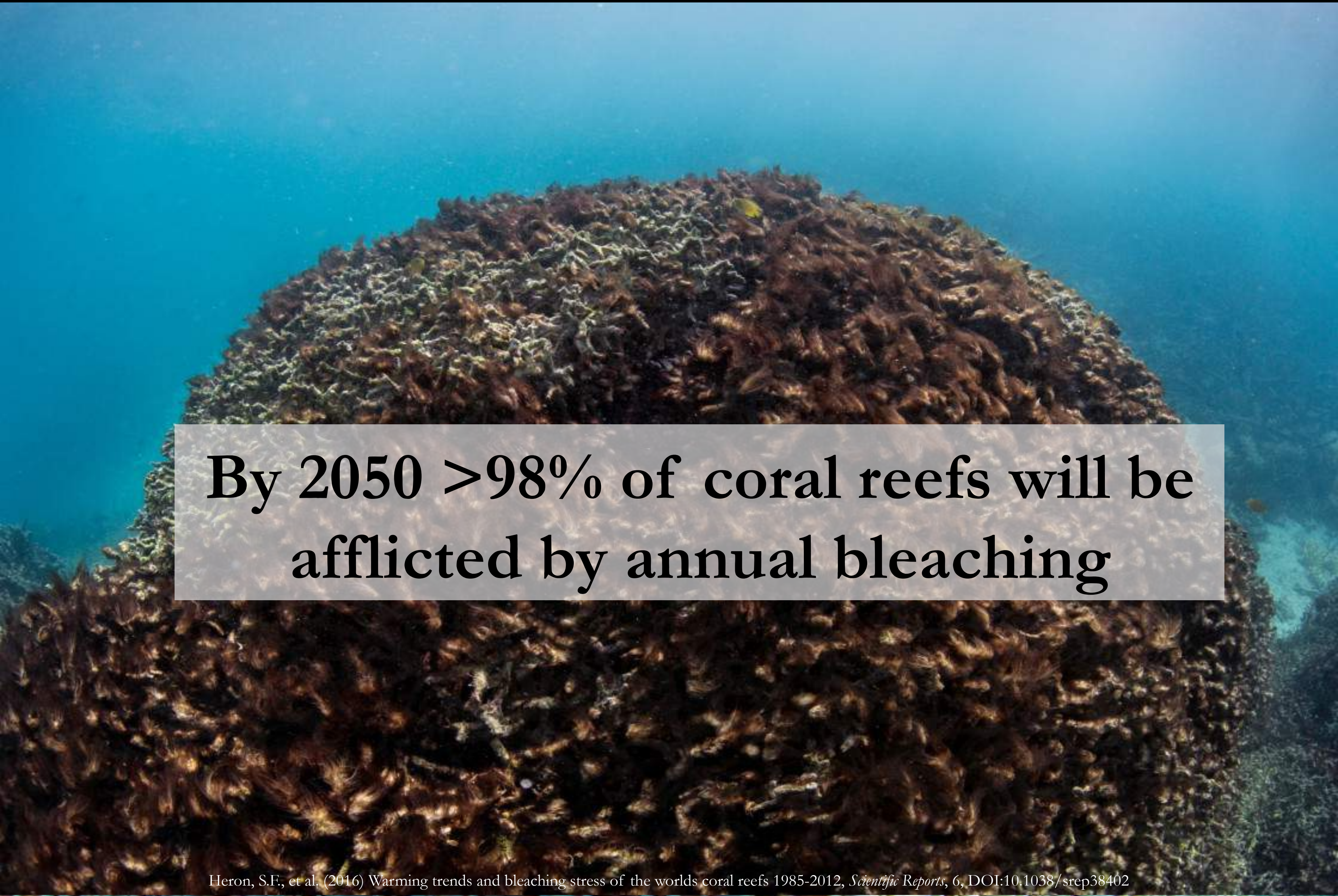
How a new generation of authoritarian leaders are using climate change to seize power.

By SAMUEL MILLER MCDONALD | July 30, 2018

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

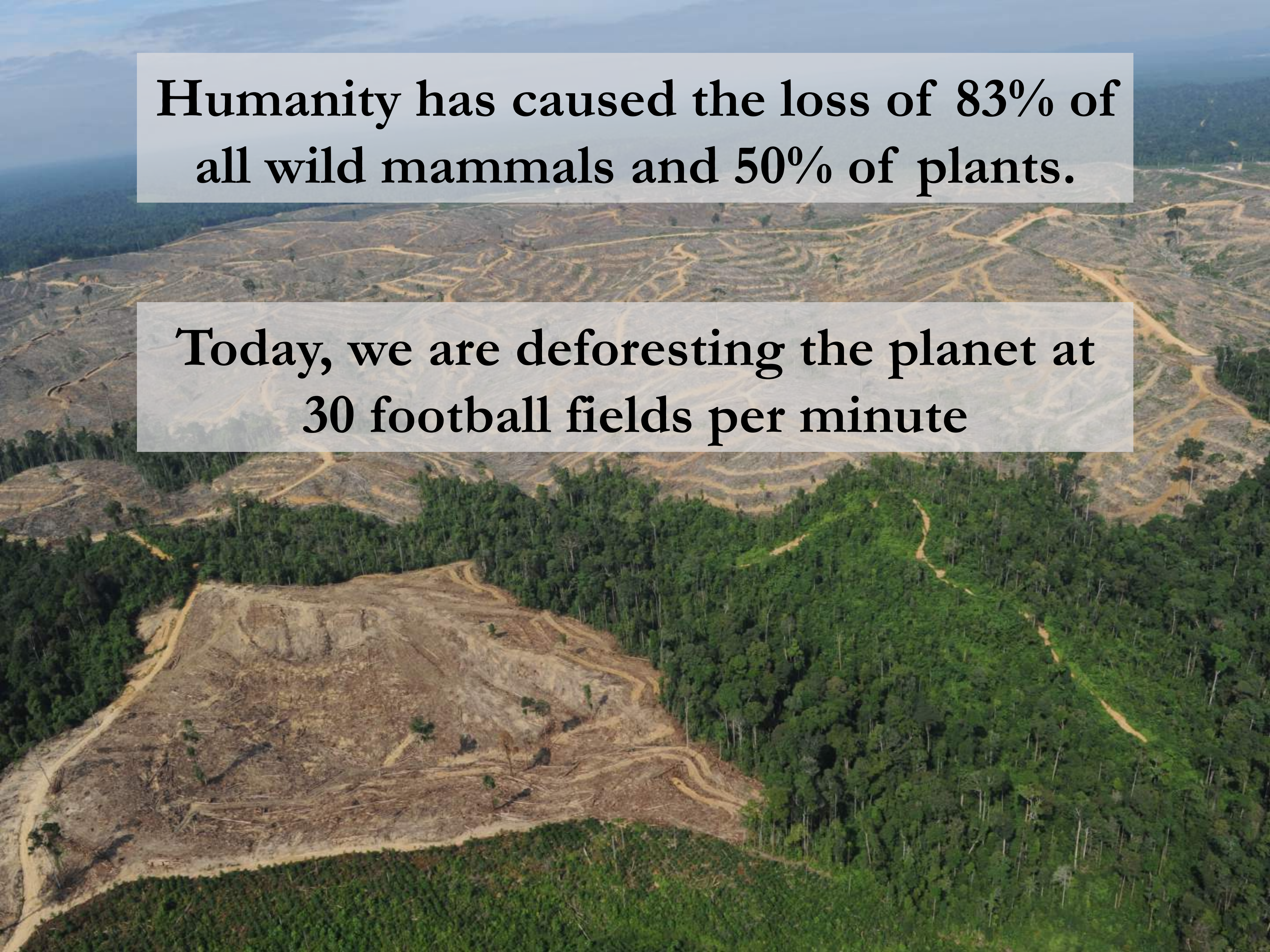
Cheng LJ and Zhu J (2018) 2017 was the warmest year on record for the global ocean. *Adv. Atmos. Sci.* Friedrich T et al (2012) Detecting Regional Anthropogenic Trends in Ocean Acidification against Natural Variability, *Nature Climate Change*. Takamitsu I et al (2017) Upper Ocean O trends: 1958-2015,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

Four global bleaching events since 1998, none prior



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

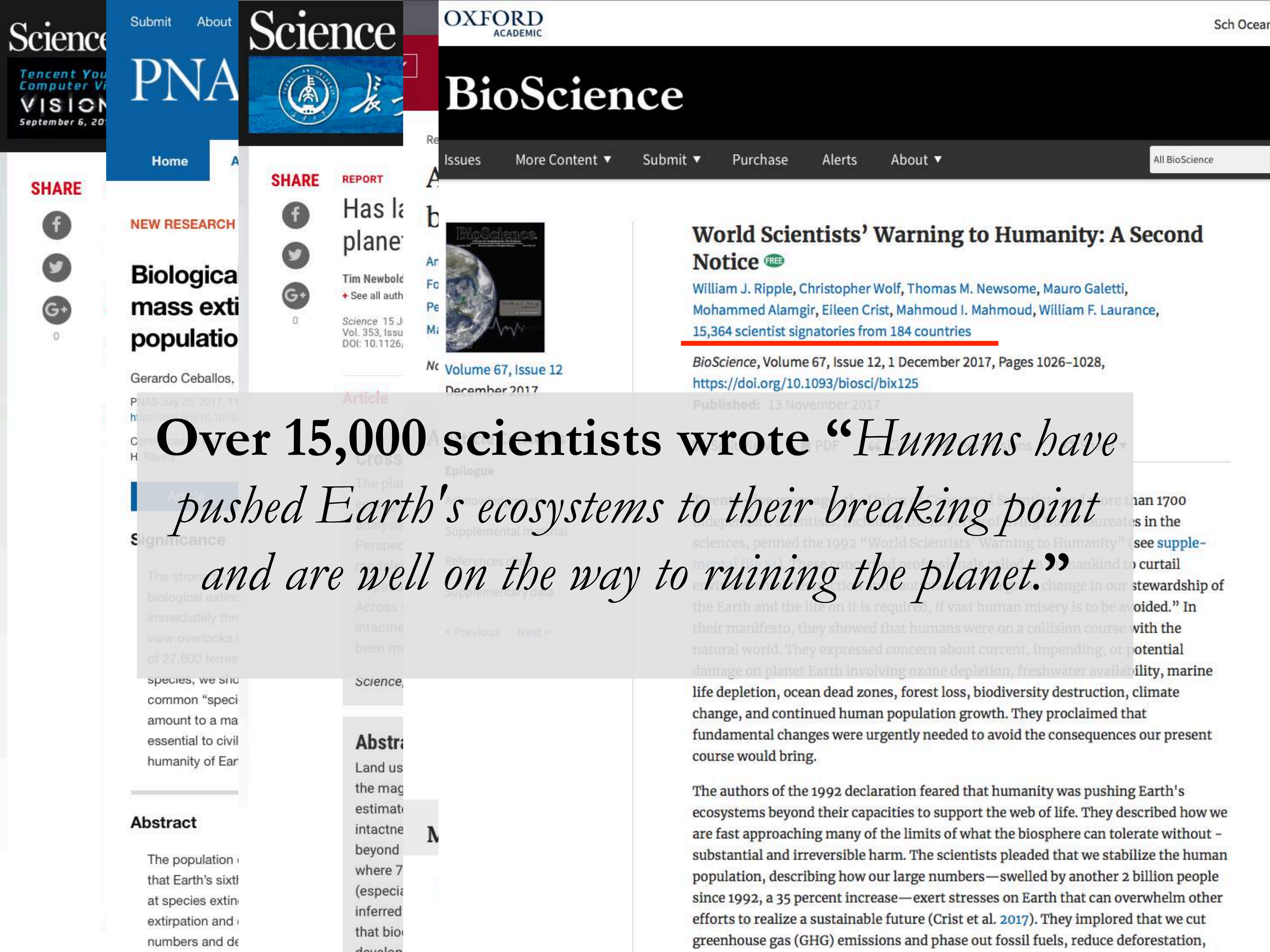
Heron, S.F., et al. (2016) Warming trends and bleaching stress of the worlds coral reefs 1985-2012, *Scientific Reports*, 6, DOI:10.1038/srep38402


Humanity has caused the loss of 83% of all wild mammals and 50% of plants.
Today, we are deforesting the planet at 30 football fields per minute

Of all mammals on Earth, 96% are livestock and humans, 4% are wild.

Of all birds, 70% are chickens and other poultry, 30% are wild.

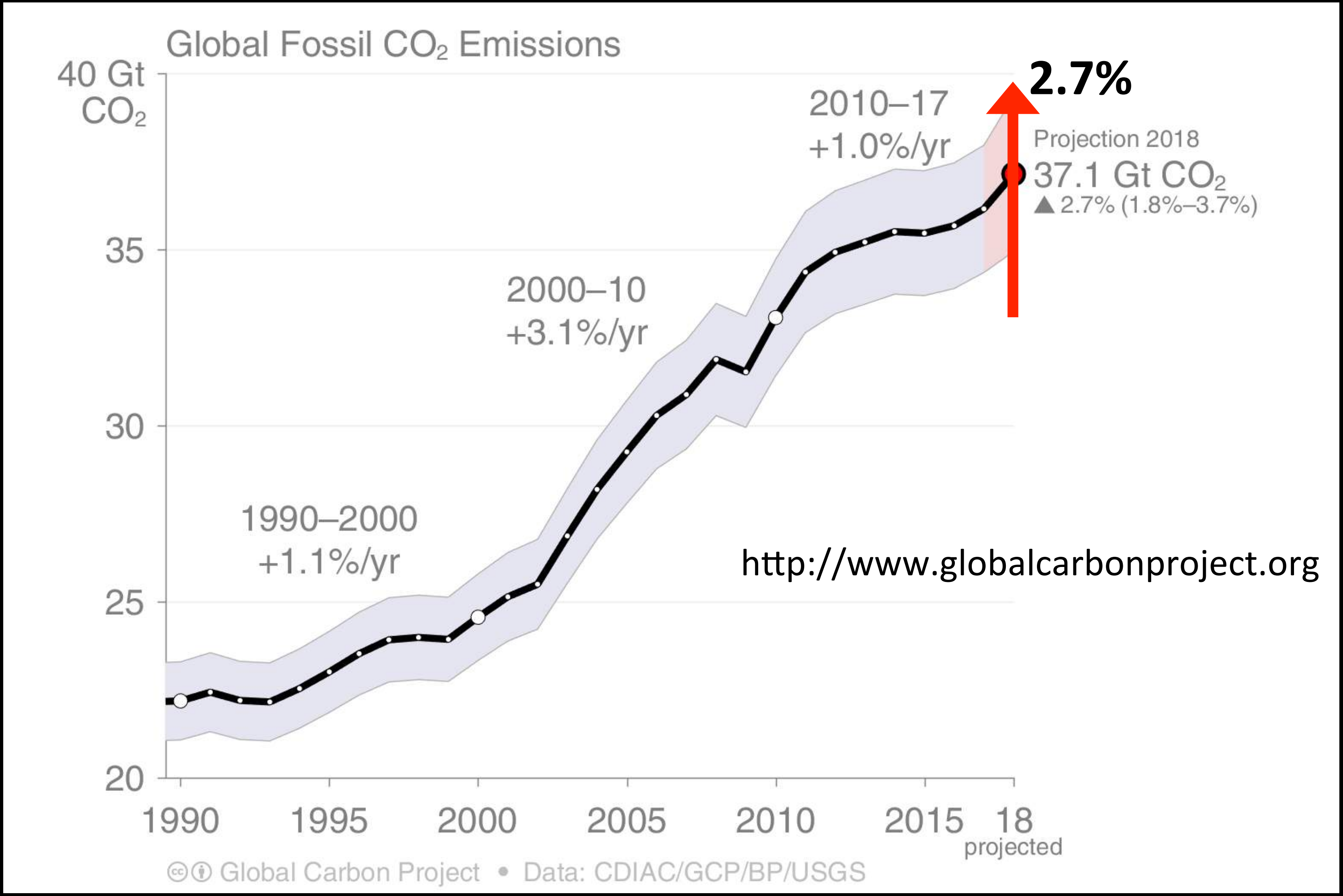
Bar-On, Y.O, Phillips, R., Milo, R. (2018) The biomass distribution on Earth, *PNAS*, 201711842; DOI:10.1073/pnas.1711842115



Over 15,000 scientists wrote "*Humans have pushed Earth's ecosystems to their breaking point and are well on the way to ruining the planet.*"

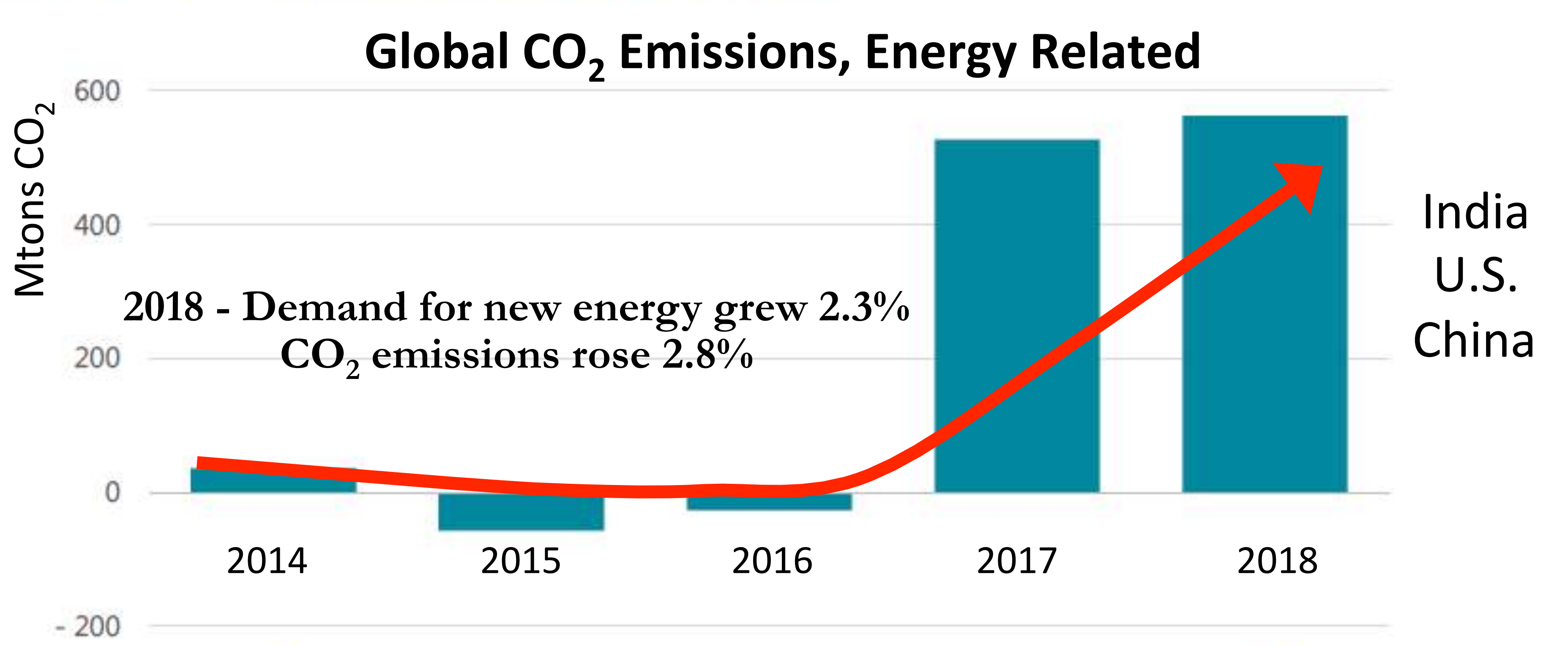
All of this is bad news…. But we‘re doing something about it, right?

Carbon Dioxide Emissions Have Risen 3 yrs in a Row



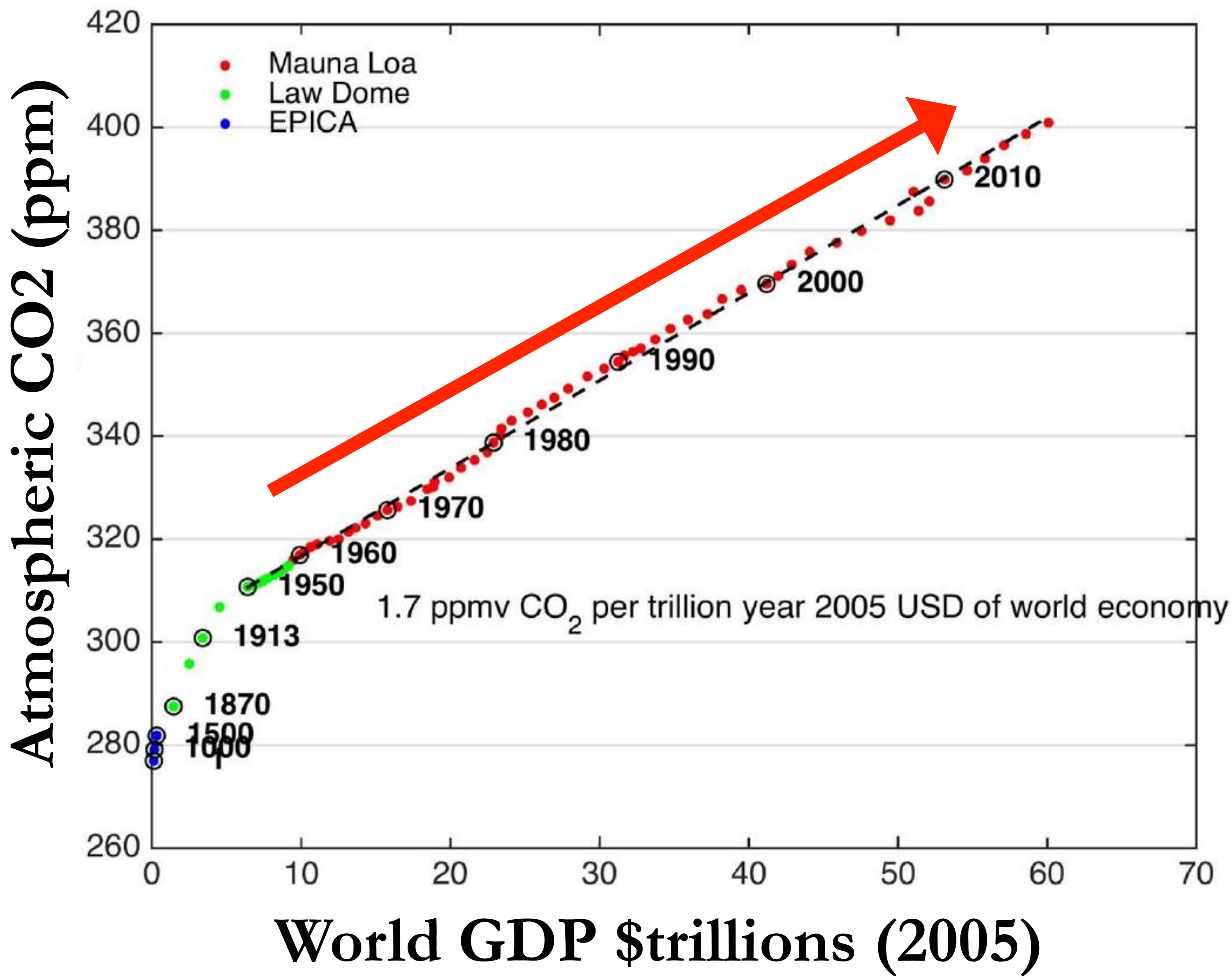
CO₂ Emissions rose because climate policy could not overcome economic growth.

The biggest factors pushing emissions down were energy efficiency & renewables, but they would have to be about **three times larger to overcome economic growth**.



https://twitter.com/Peters_Glen/status/1110454130441707523. IEA (2019) Global Energy and CO2 Statu Report, https://www.iea.org/geco/

Emissions Follow World GDP, +130% by 2050



Price Waterhouse Consultants (PwC) https://www.pwc.com/gx/en/issues/economy/the-world-in-2050.html

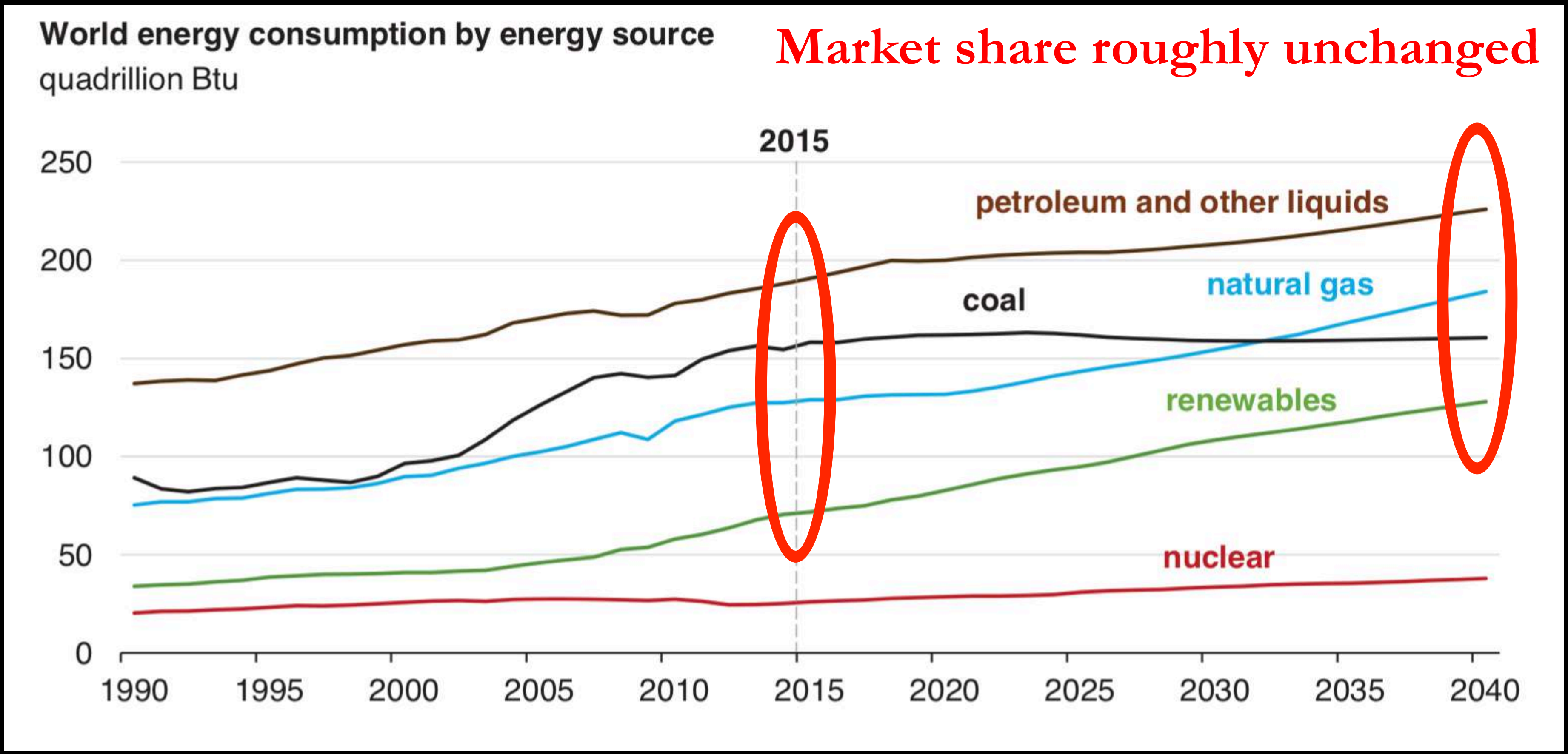
Tim Garrett - https://twitter.com/nephologue/status/1051218794679390209 Garrett, T. J.: No way out? The double-bind in seeking global prosperity alongside mitigated climate change, Earth Syst. Dynam., 3, 1-17, https://doi.org/10.5194/esd-3-1-2012, 2012.

- Energy demand set to grow >25% by 2040
- Renewables make up only two-thirds of new capacity
- Oil consumption grows due to rising demand for petrochemicals, trucking, aviation, energy
- CO_2 emissions continue to increase to mid-century

https://www.iea.org/weo/

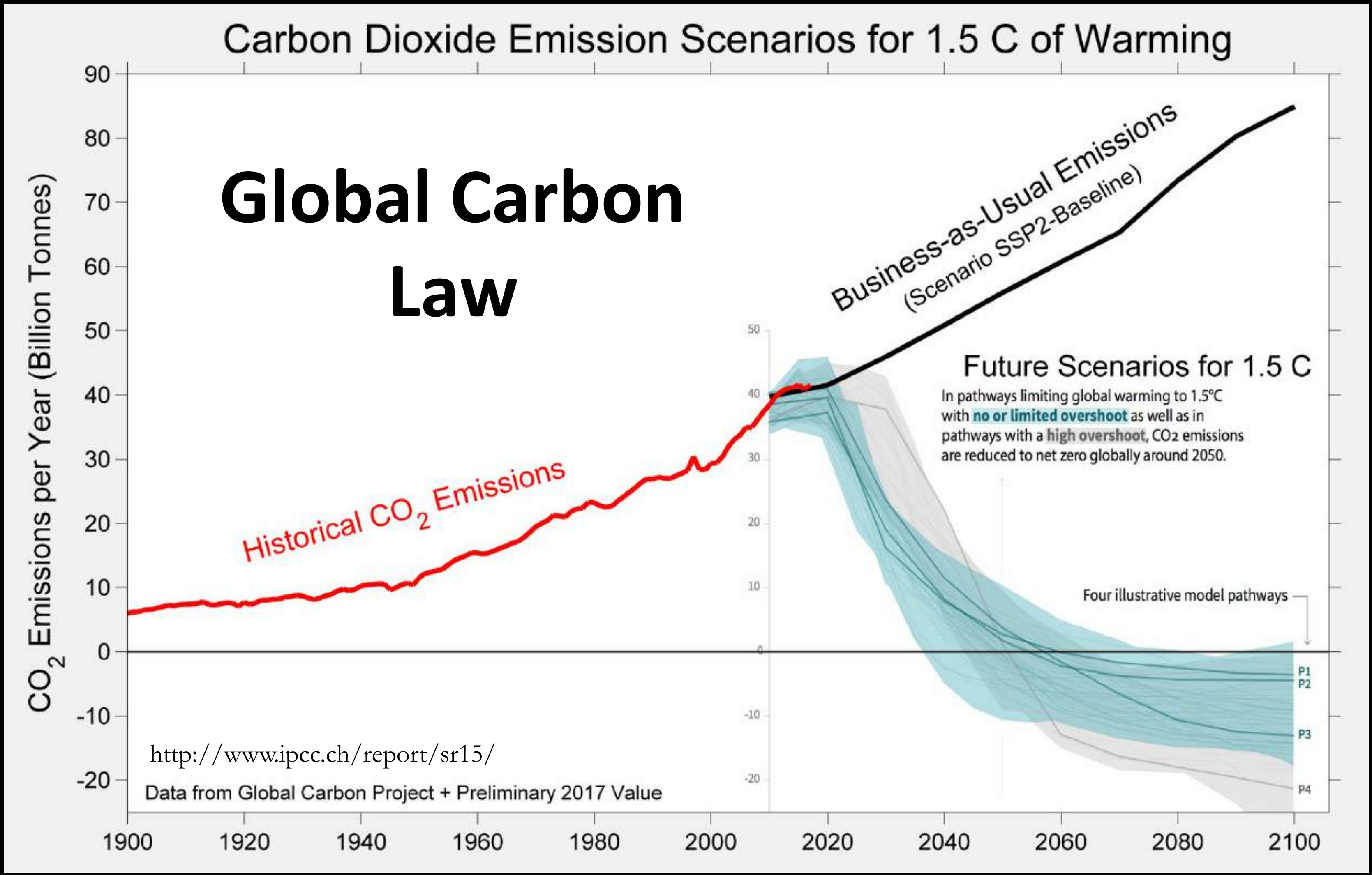
U.S. Energy Information Administration

Energy Consumption increases to 2040 for all fuels but coal

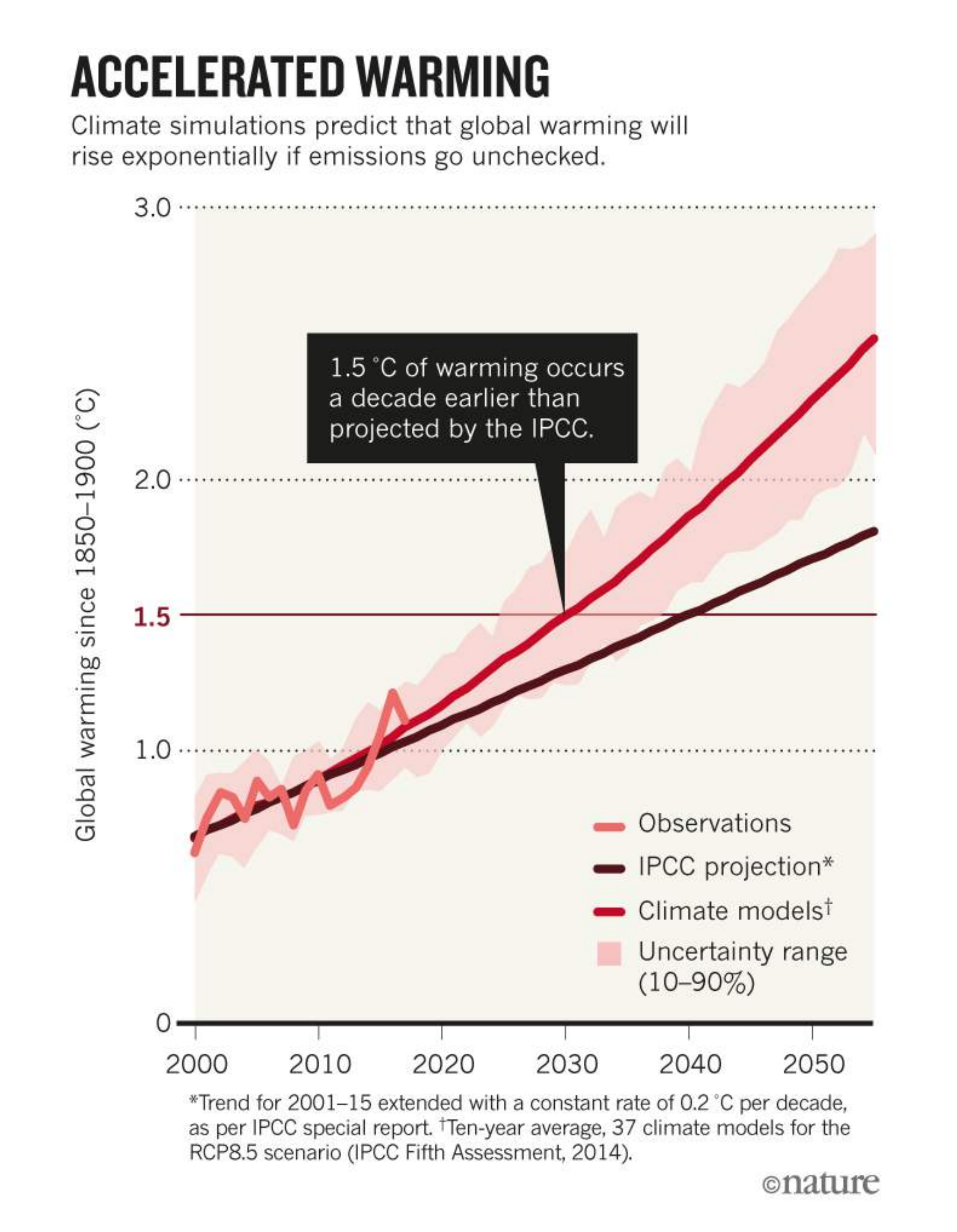


https://www.eia.gov/outlooks/ieo/exec_summ.php

Global emissions must cut 50% by 2030

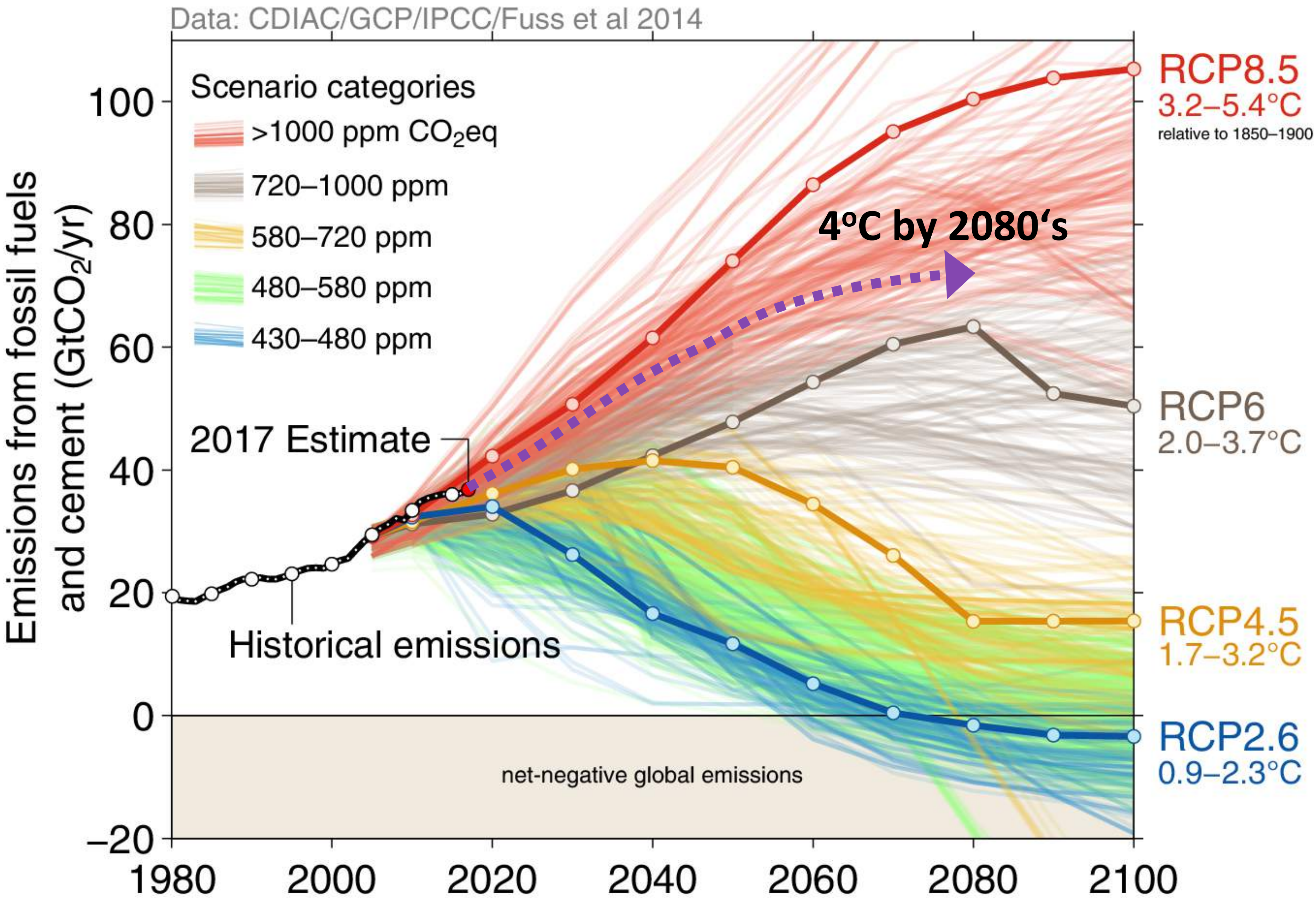


Rockström, J. et al. (2017) A roadmap for rapid decarbonization. *Science*, 355 (6331): 1269. Gasser, T., et al. (2015) Negative emissions physically needed to keep global warming below 2oC, *Nature Communications* 6, DOI: 10.1038/ncomms8958.



- Global Warming is Accelerating
  - Emissions rising
  - Emissions cleaner
  - Decreased ocean circulation
  - Pacific releasing heat (IPO)
- 1.5°C by 2030
- 2.0°C by 2045

…, Y. et al. (2018) Global warming will happen faster than we think, *Nature*, v. 564, Dec. 6



Data: CDIAC/GCP/IPCC/Fuss et al 2014
Scenario categories
>1000 ppm CO_2eq
720–1000 ppm
580–720 ppm
480–580 ppm
430–480 ppm
Emissions from fossil fuels and cement ($GtCO_2$/yr)
100
80
60
40
20
0
–20
1980
2000
2020
2040
2060
2080
2100
2017 Estimate
Historical emissions
net-negative global emissions
4°C by 2080's
RCP8.5
3.2–5.4°C
relative to 1850–1900
RCP6
2.0–3.7°C
RCP4.5
1.7–3.2°C
RCP2.6
0.9–2.3°C

Thank You For Your Time

Dr. Thomas Giambelluca

Professor
Department of Geography and Environment
University of Hawaiʻi at Mānoa

CLIMATE CHANGE PANEL DISCUSSION

Hawai‘i Climate Change and Water

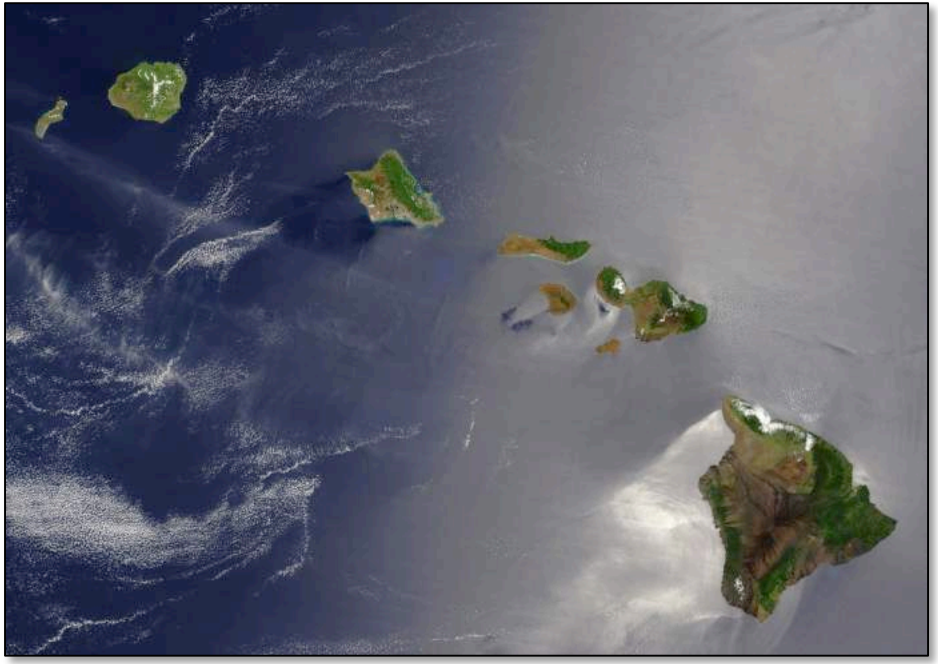
Thomas W. Giambelluca
Department of Geography & Environment
University of Hawai‘i at Mānoa

Board of Water Supply
Stakeholder Advisory Group – Workshop 30
Neal S. Blaisdell Center
25 April 2019

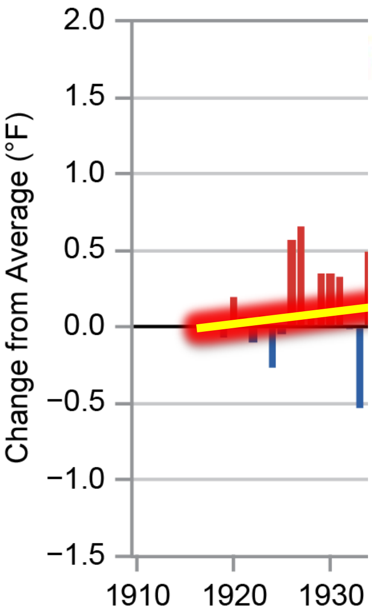
Board of Water Supply

Climate Change in Hawai‘i

How much change have we already seen?



How much more should we expect?



Received: 16 March 2018 | Revised: 9 February 2019 | Accepted: 19 February 2019

DOI: 10.1002/joc.6053

International Journal of Climatology RMetS

RESEARCH ARTICLE

Temperature trends in Hawai'i: A century of change, 1917–2016

Marie M. McKenzie | Thomas W. Giambelluca | Henry F. Diaz

Department of Geography and Environment, University of Hawai'i at Mānoa, Honolulu, Hawaii

Correspondence
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Email: mariemm@hawaii.edu

Funding information
University of Hawai'i at Hilo

Based on a revised and extended multi-station Hawai'i Temperature Index (HTI), the mean air temperature in the Hawaiian Islands has warmed significantly at 0.052°C/decade ($p < 0.01$) over the past 100 years (1917–2016). The year 2016 was the warmest year on record at 0.924°C above the 100-year mean (0.202°C). During each of the last four decades, mean state-wide positive air temperature anomalies were greater than those of any of the previous decades. Significant warming trends for the last 100 years are evident at low (0.056°C/decade, $p < 0.001$) and high elevations (0.047°C/decade, $p < 0.01$). Warming in Hawai'i is largely attributed to significant increases in minimum temperature (0.072°C/decade, $p < 0.001$) resulting in a corresponding downward trend in diurnal temperature range (−0.055°C/decade, $p < 0.001$) over the 100-year period. Significant positive correlations were found between HTI, the Pacific Decadal Oscillation, and the Multivariate ENSO Index, indicating that natural climate variability has a significant impact on temperature in Hawai'i. Analysis of surface air temperatures from NCEP/NCAR reanalysis data for the region of Hawai'i over the last 69 years (1948–2016) and a mean atmospheric layer temperature time series calculated from radiosonde-measured thickness (distance between constant pressure surfaces) data over the last 40 years (1977–2016) give results consistent with the HTI. Finally, we compare temperature trends for Hawaii's highest elevation station, Mauna Loa Observatory (3,397 m), to those on another mountainous subtropical island station in the Atlantic, Mt. Izaña Observatory (2,373 m), Tenerife, Canary Islands. Both stations sit above the local temperature inversion layer and have virtually identical significant warming trends of 0.19°C/decade ($p < 0.001$) between 1955 and 2016.

KEYWORDS
climate change, El Niño-southern oscillation, Hawai'i, Pacific decadal oscillation, radiosonde observations, temperature trends

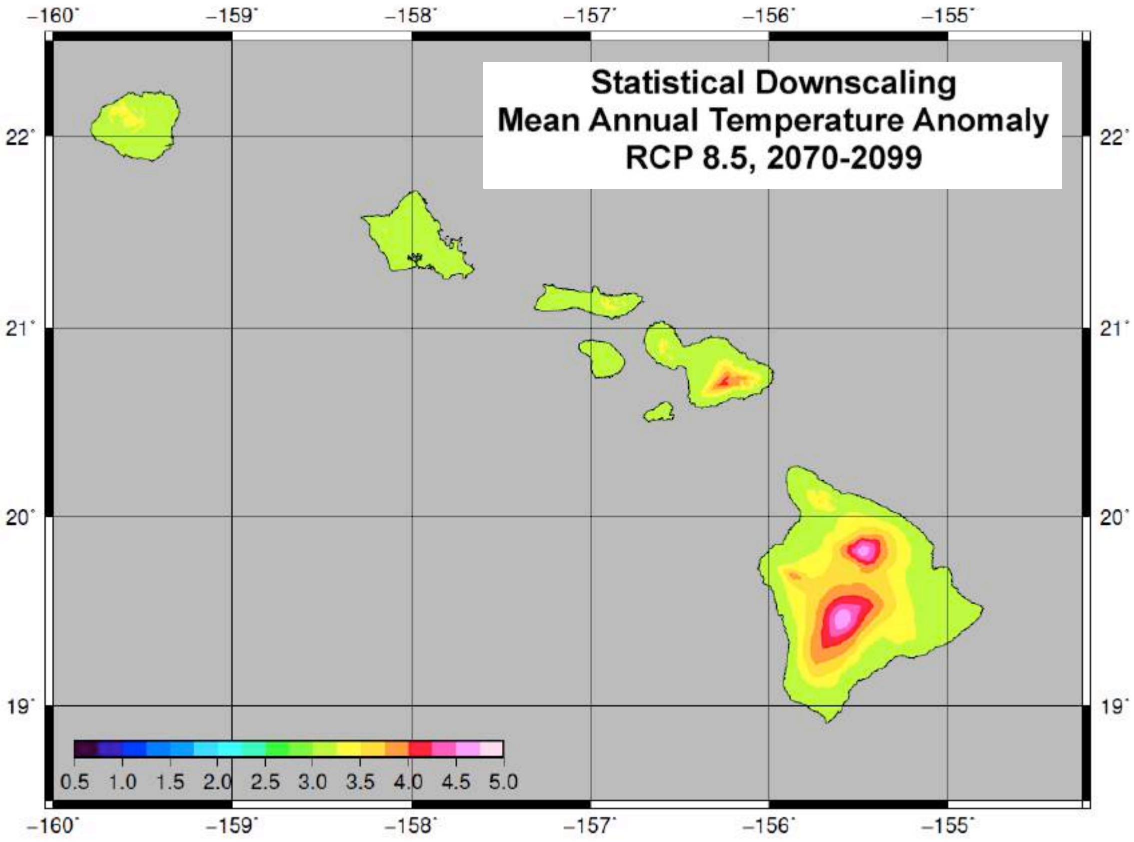
1 | INTRODUCTION

trends, both at the surface and higher elevations in the atmo-

r change = +0.52°C (+0.94°F)

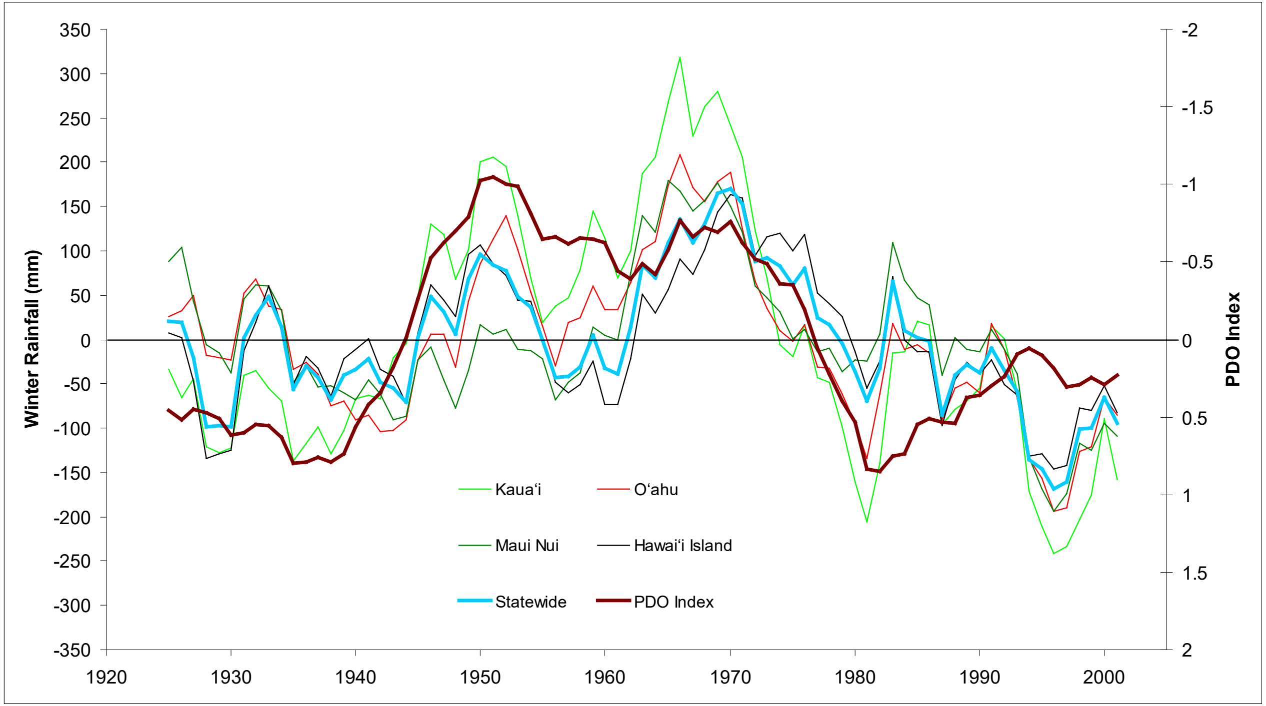
McKenzie, M. … gional
temperature t…
International .

Model Projections

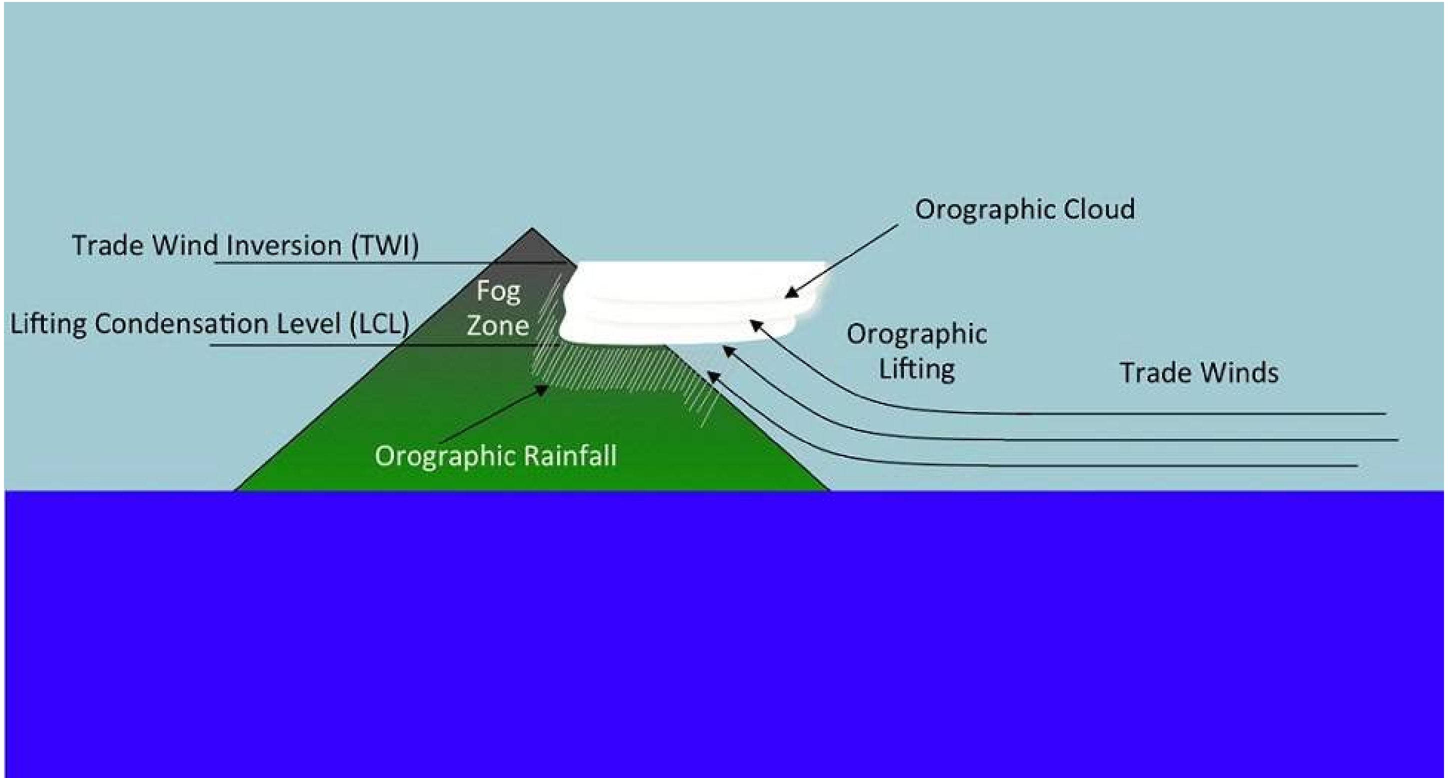


How About Rainfall Change in Hawai‘i?

Changing Rainfall



The Orographic Cloud



Two Ingredients Needed to Produce Rainfall

1. Moist air
2. Rising Air

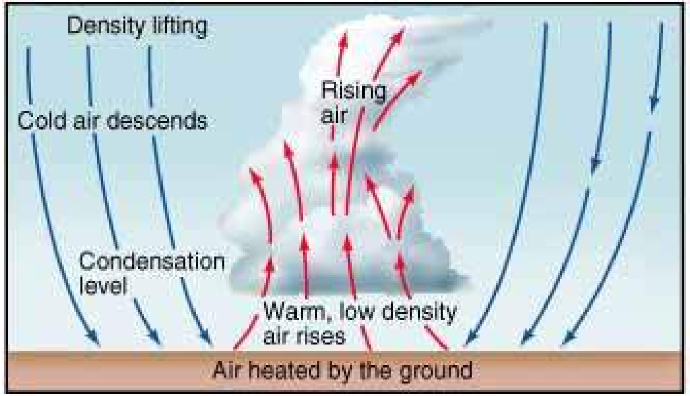
Cloud Formation

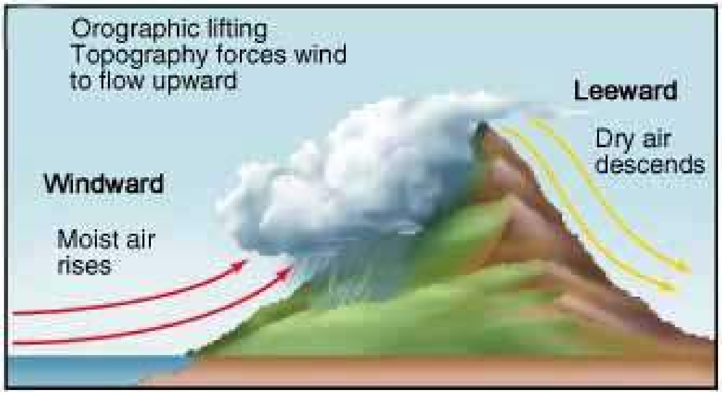
- Clouds in Hawai‘i are made up of tiny liquid drops
- The drops form through condensation

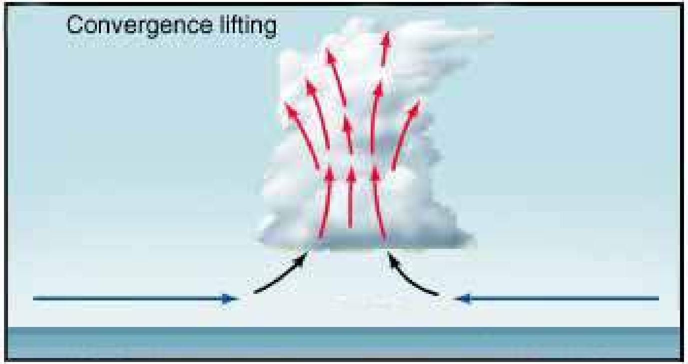
CONDENSATION

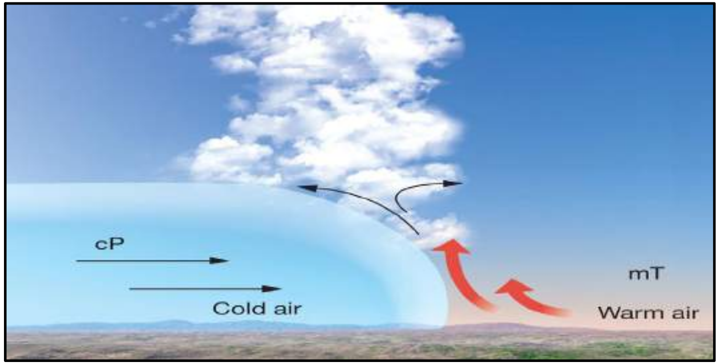
- Air with water vapor has to be cooled to cause condensation
  - Cold Heineken
  - Cool windshield
- How does moist air get cooled to form a cloud?
  - By being forced to rise
  - Rising air cools by expanding

Mechanisms for Cloud Formation





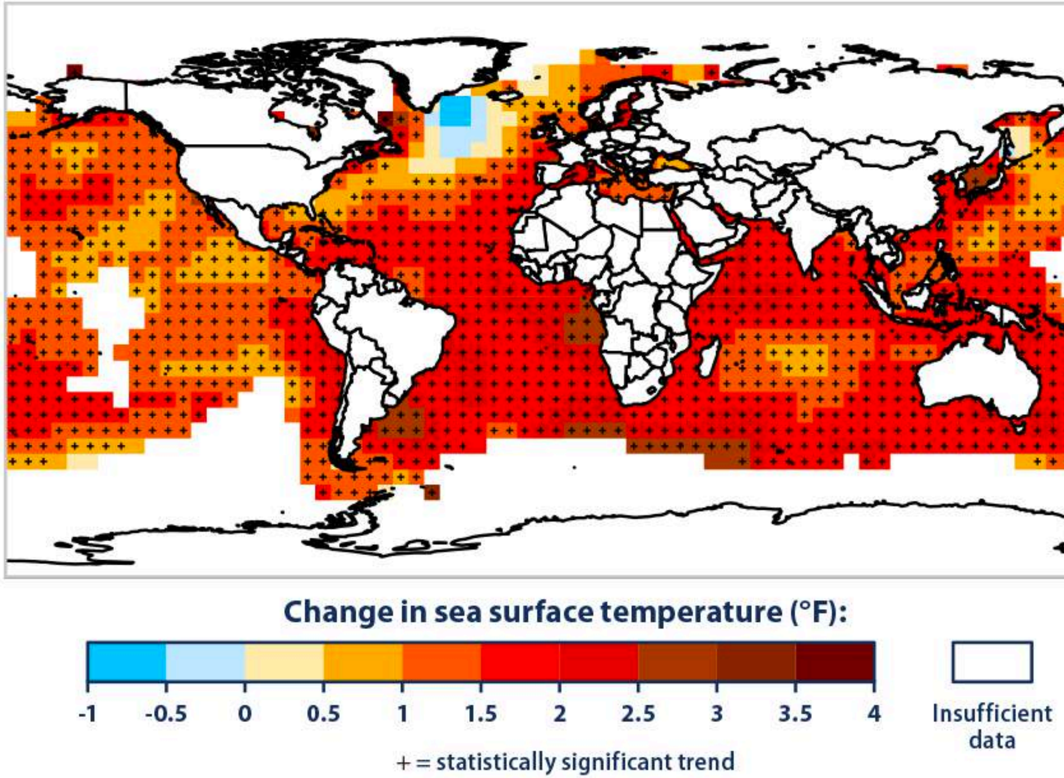




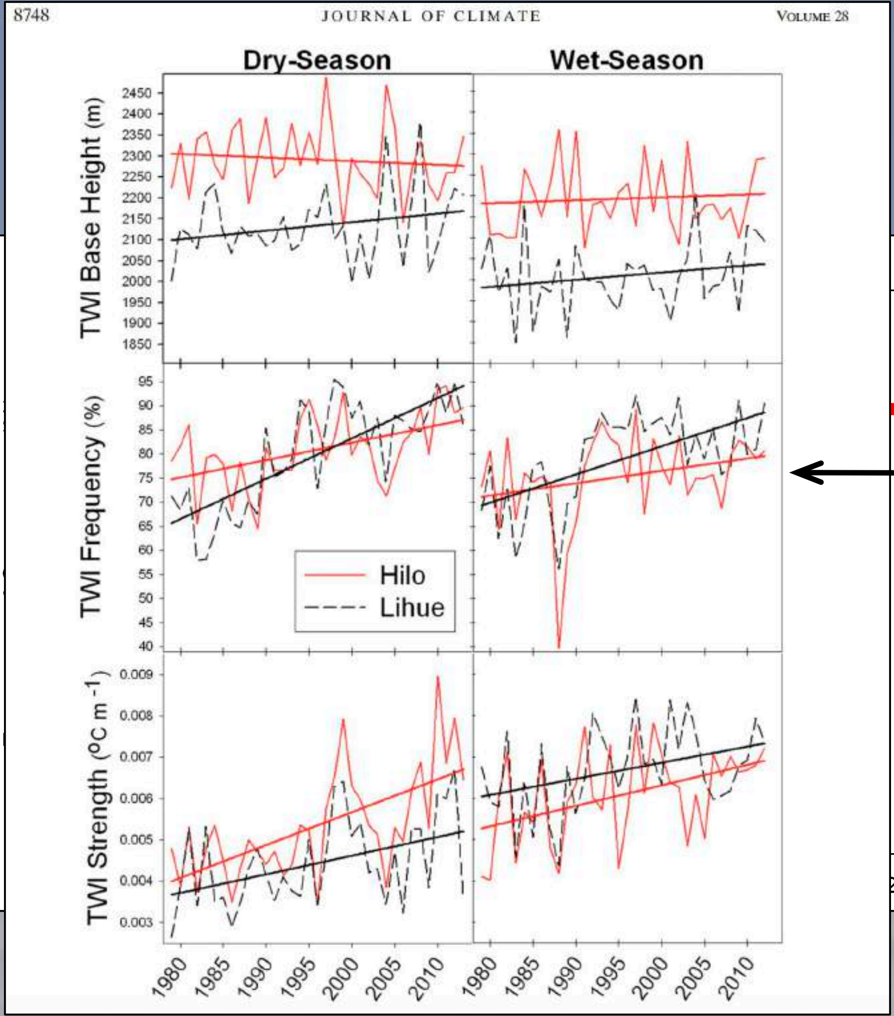
Climate Change Can Affect Our Rainfall by:

- Making the air more or less moist
- Making it easier or harder for air to rise

As Climate Warms:
Air Becomes More Moist



Trade Wind Inversion



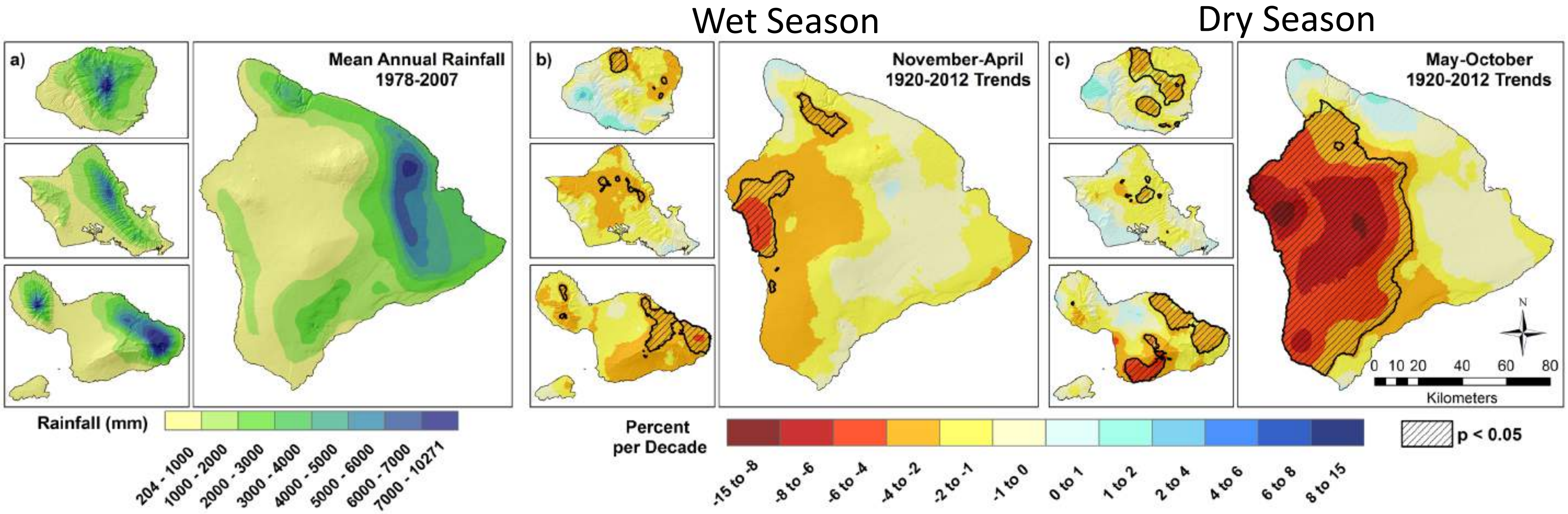
The pattern of more TWI days per year has continued.

Longman et al. (2015)

Hawai‘i Climate Change

It’s getting drier, especially in Kona

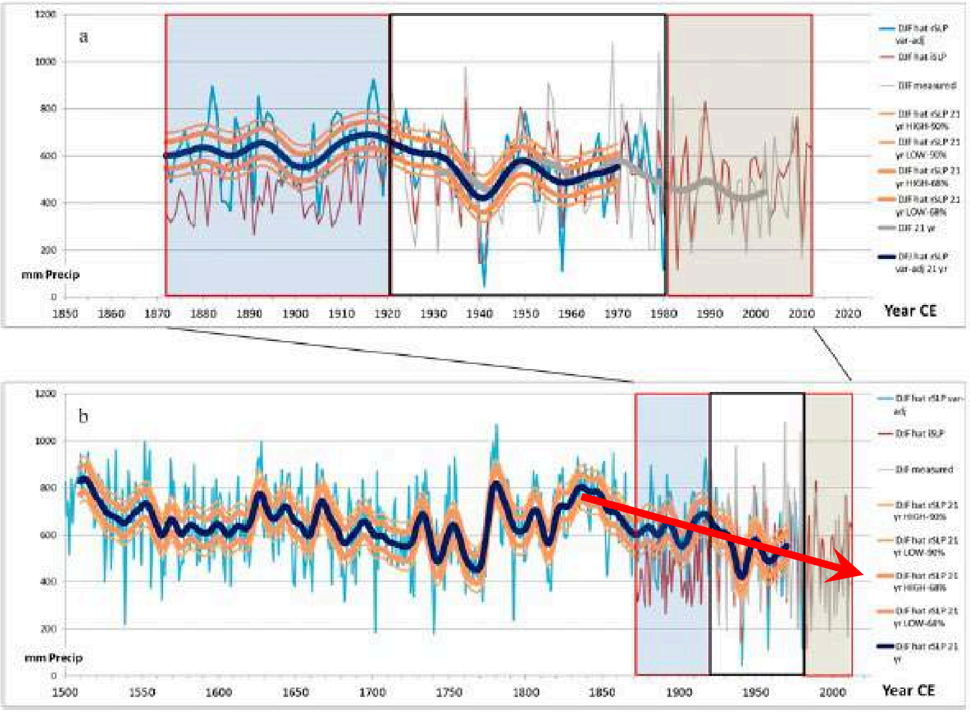
Decreases statewide — including most of O‘ahu



Frazier et al. (2018)

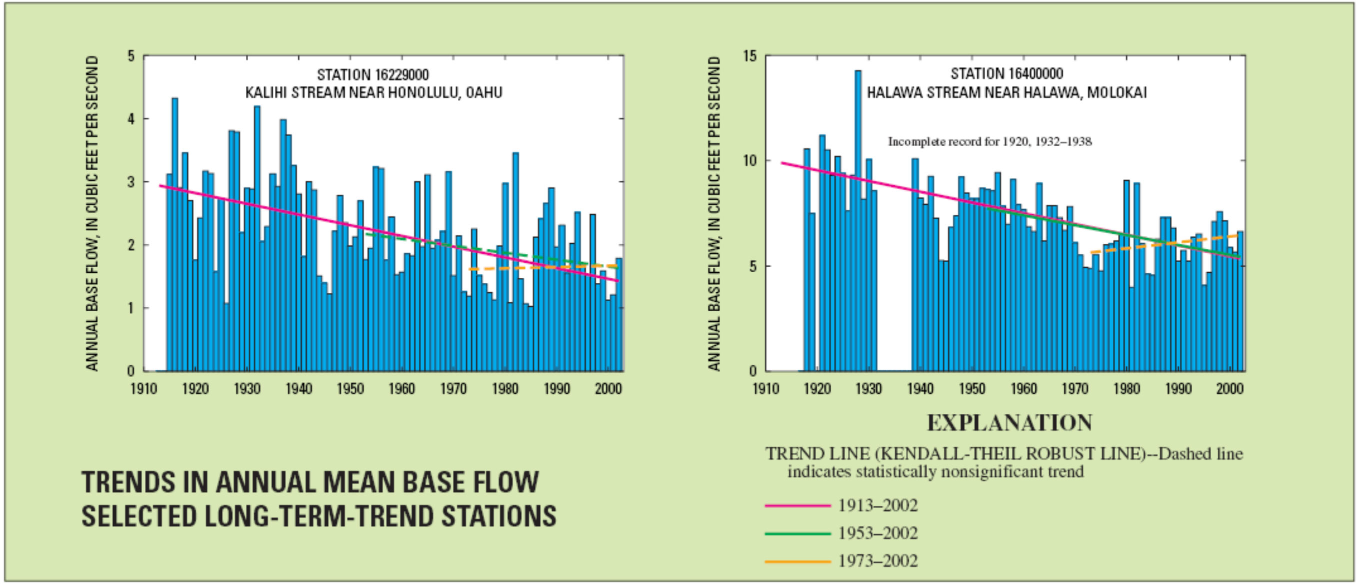
500-yr Hawaiian Winter Rainfall Reconstruction

5670 JOURNAL OF CLIMATE VOLUME 29



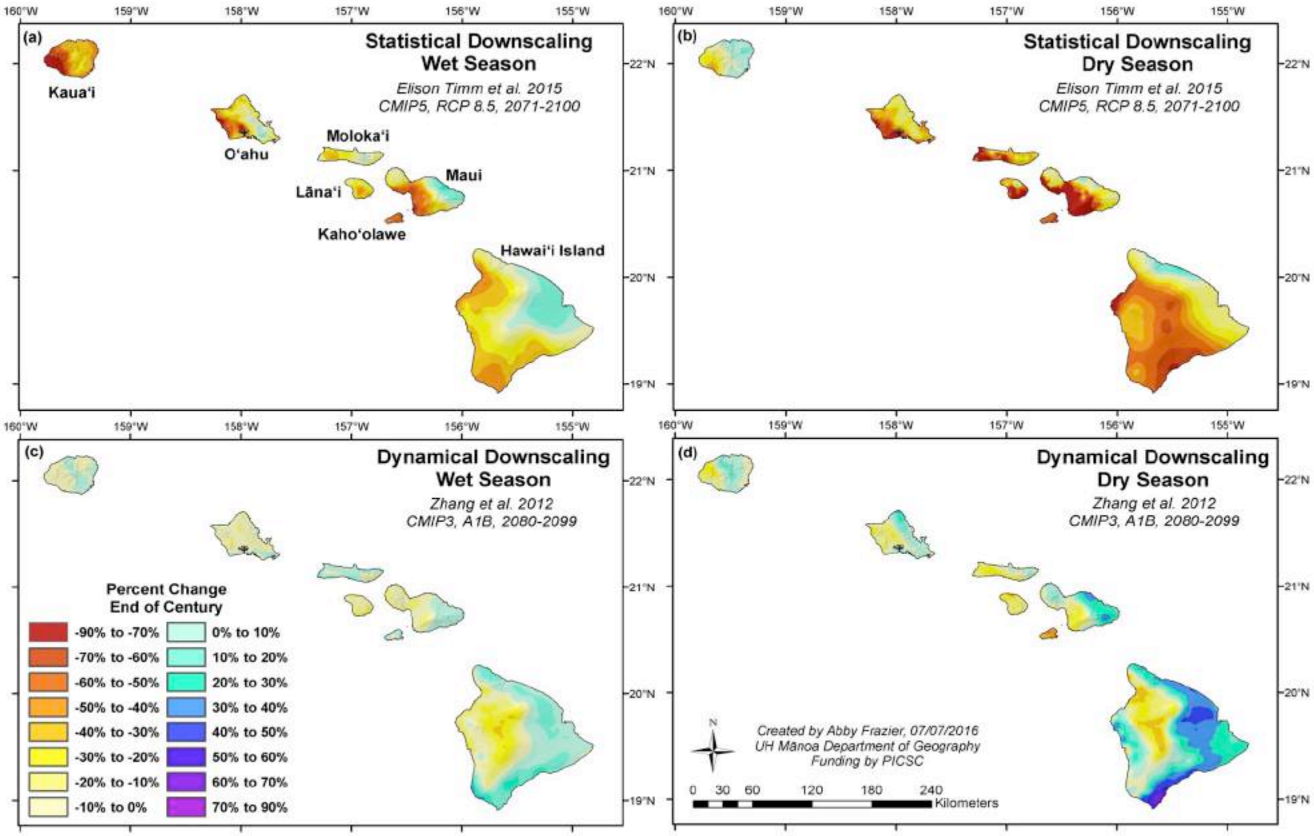
Diaz et al. (2016)

Stream Base Flow Also in Decline



Oki, D.S., 2004, Trends in Streamflow Characteristics in Hawaii, 1913-2003: U.S. Geological Survey Fact Sheet 2004-3104, 4 p.

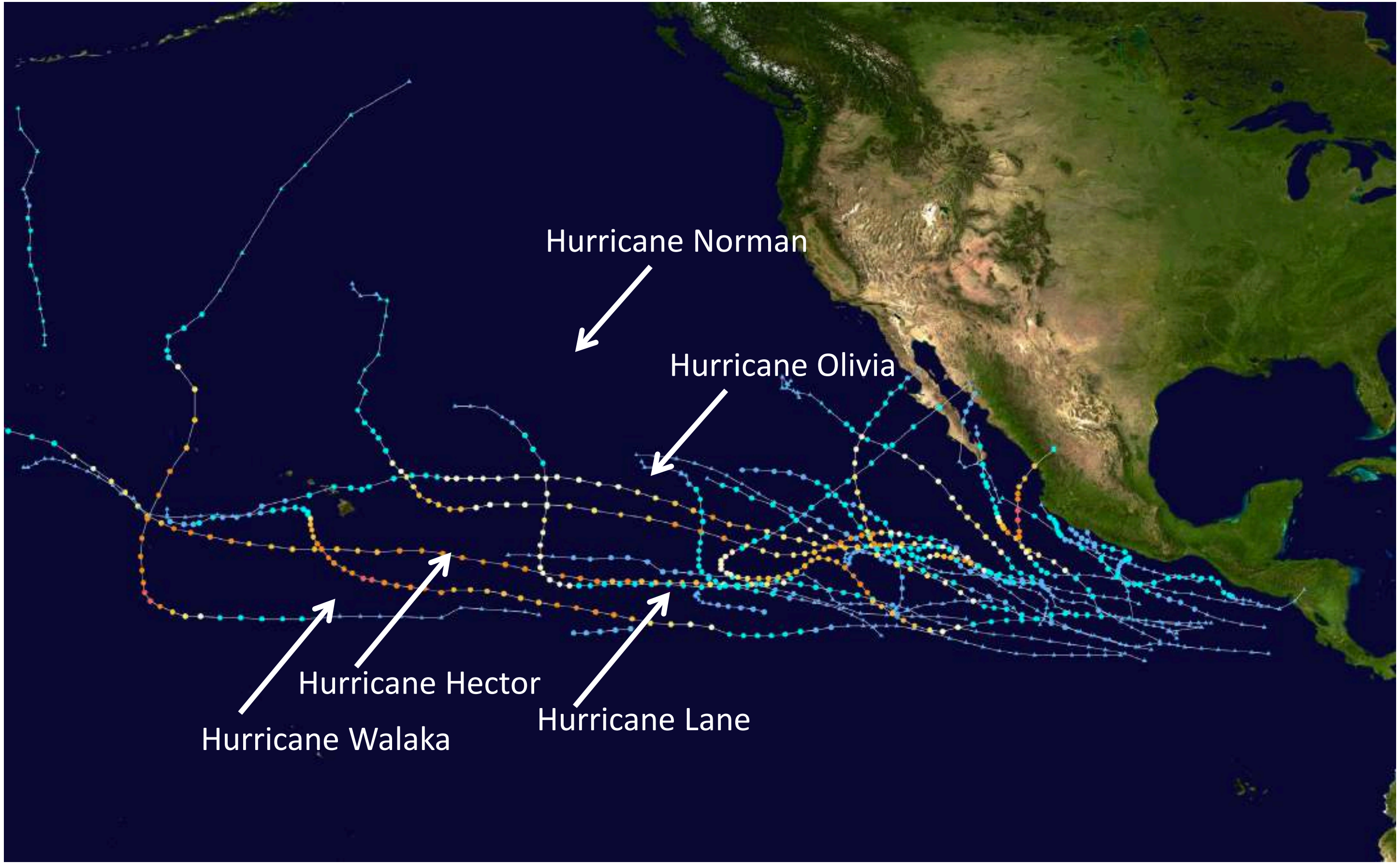
Model Projections



Rainfall Extremes

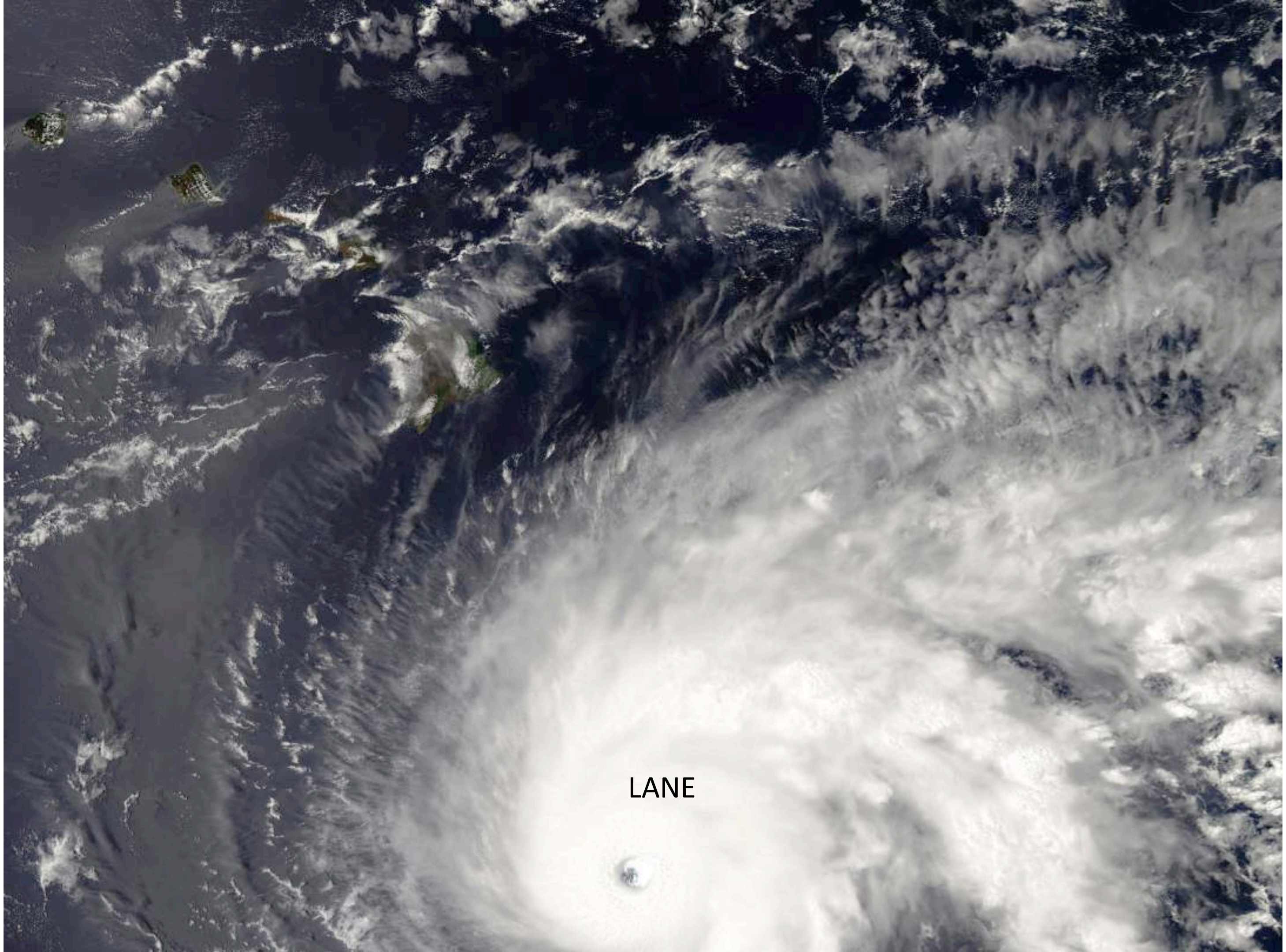
Kaua‘i: April 2018 – 49.69 inches – A new US record for 24-hr rainfall

2018 Eastern and Central North Pacific Tropical Storm/Hurricane Season

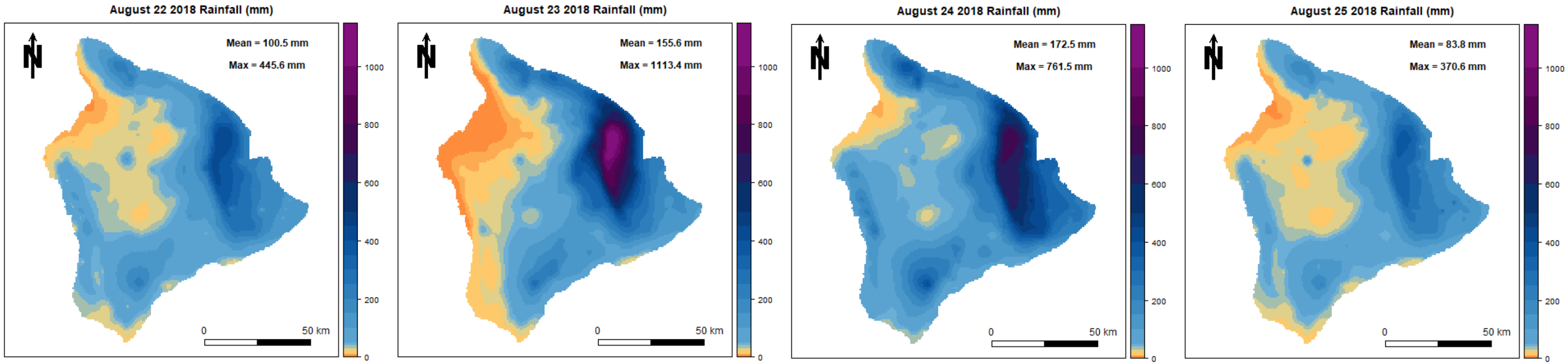


Five <u>hurricanes</u> passed near or though the islands last season

- Change in number of storms uncertain.
- Storms becoming stronger.
- Storms to produce more intense rainfall.


LANE

Hurricane Lane Rainfall



Observed
Max = 401 mm (16 in)

Observed
Max = 646 mm (25 in)

Observed
Max = 655 mm (26 in)

Observed
Max = 434 mm (17 in)

Climate Change in Hawai‘i

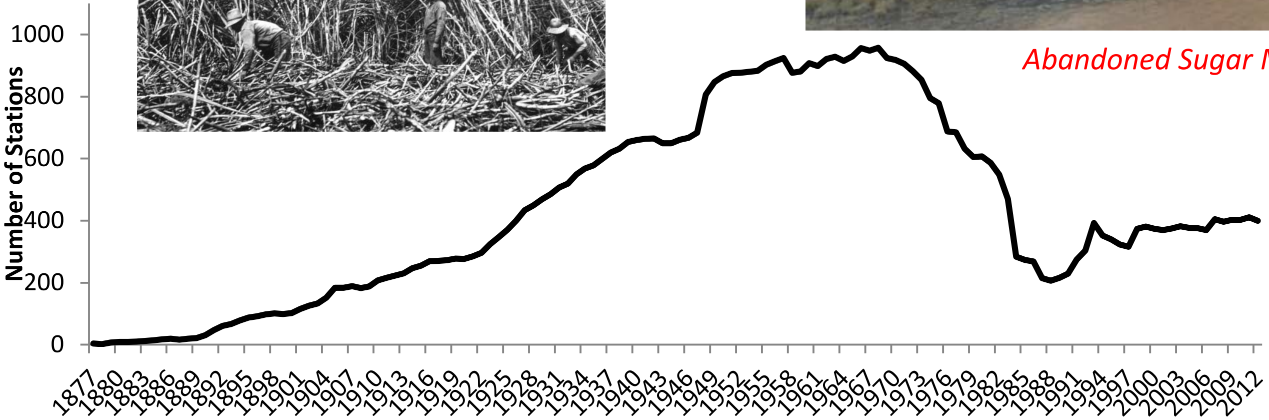
- Warming at a faster rate — ET Increase, More heat waves
- Air becoming more moist: RF Increase
- Lifting becoming more difficult: RF Decrease
- Windward areas become wetter
- Leeward and high elevation areas become drier
- Storms become less frequent but more intense
  - More droughts
  - More wildfires
  - More floods
  - Higher proportion of rainfall running off
- Sea level rise
  - Coastal flooding

Hawai‘i’s Rain Gauge Network

- Number of stations operating at any given time
  - Peaked in 1968 (over 950 stations)
  - Large declines since the 1980s

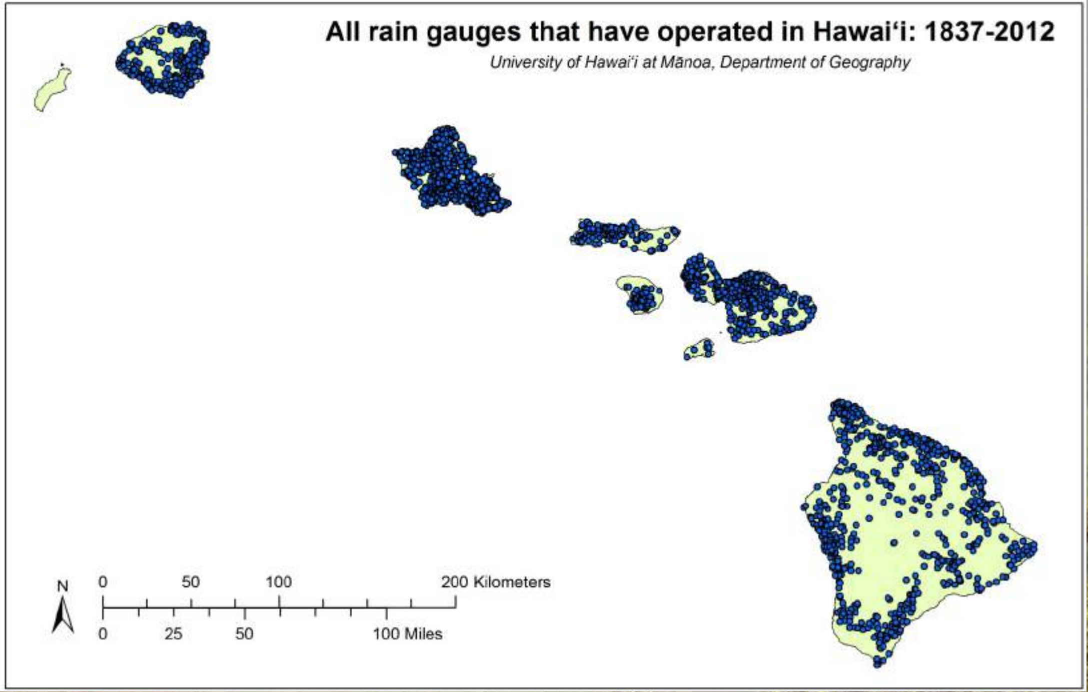
Plantation Agriculture

Abandoned Sugar Mill



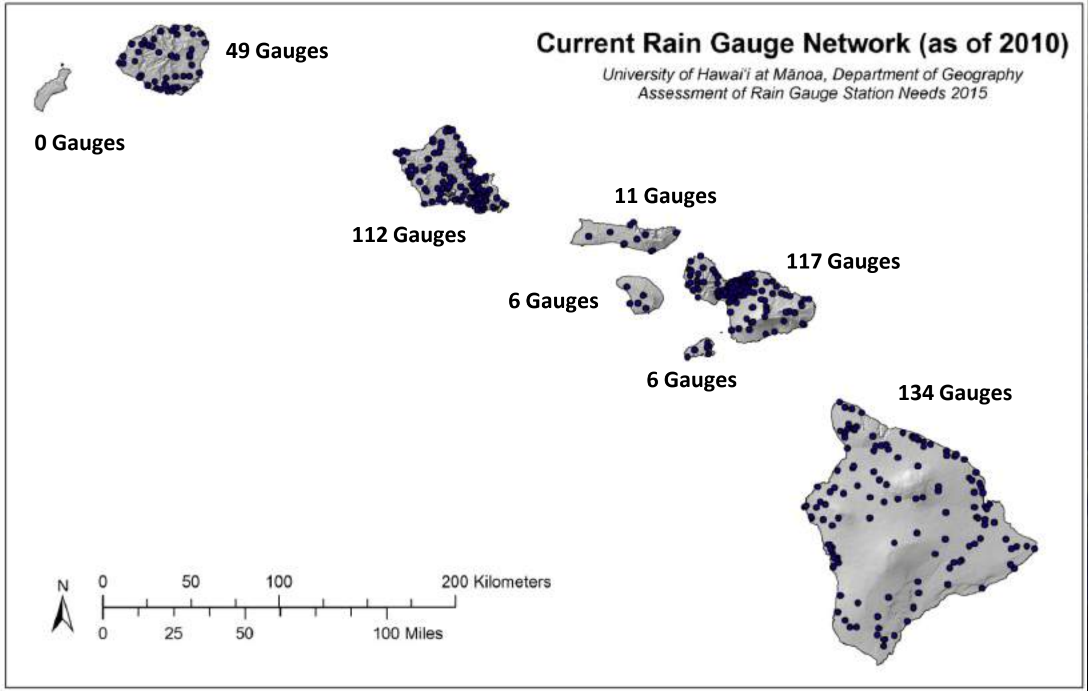
The Rain Gauge Network

- Monthly RF database of 2,224 rain gauge sites (1837-2012)
- Average length of record: 24 years

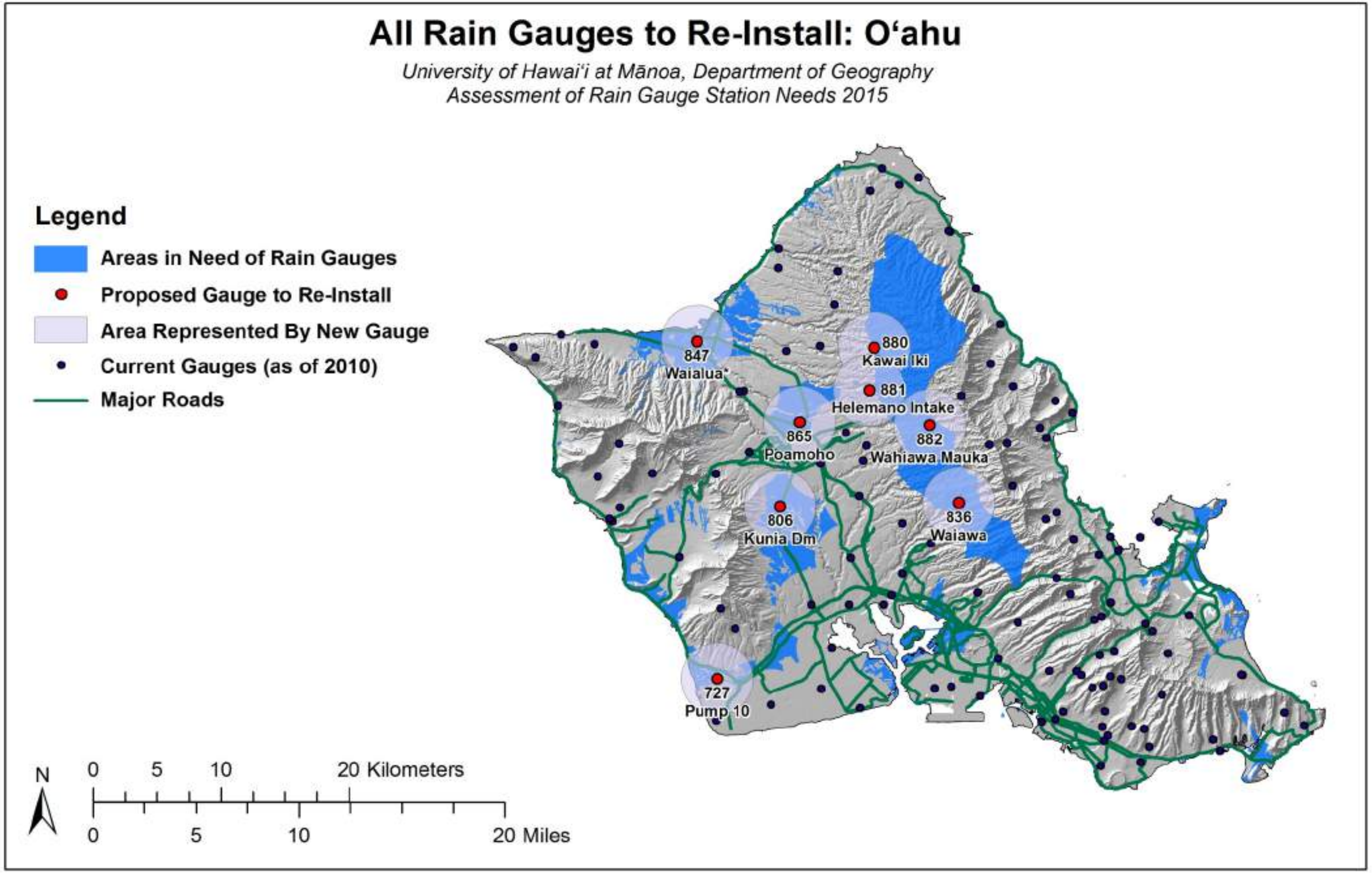


Current Rain Gauge Network

- # Current Stations (as of 2010): **435**
- # Current Stations with > 50 years of data: **130**
  - *Most of the current stations were installed within the last 30 years*

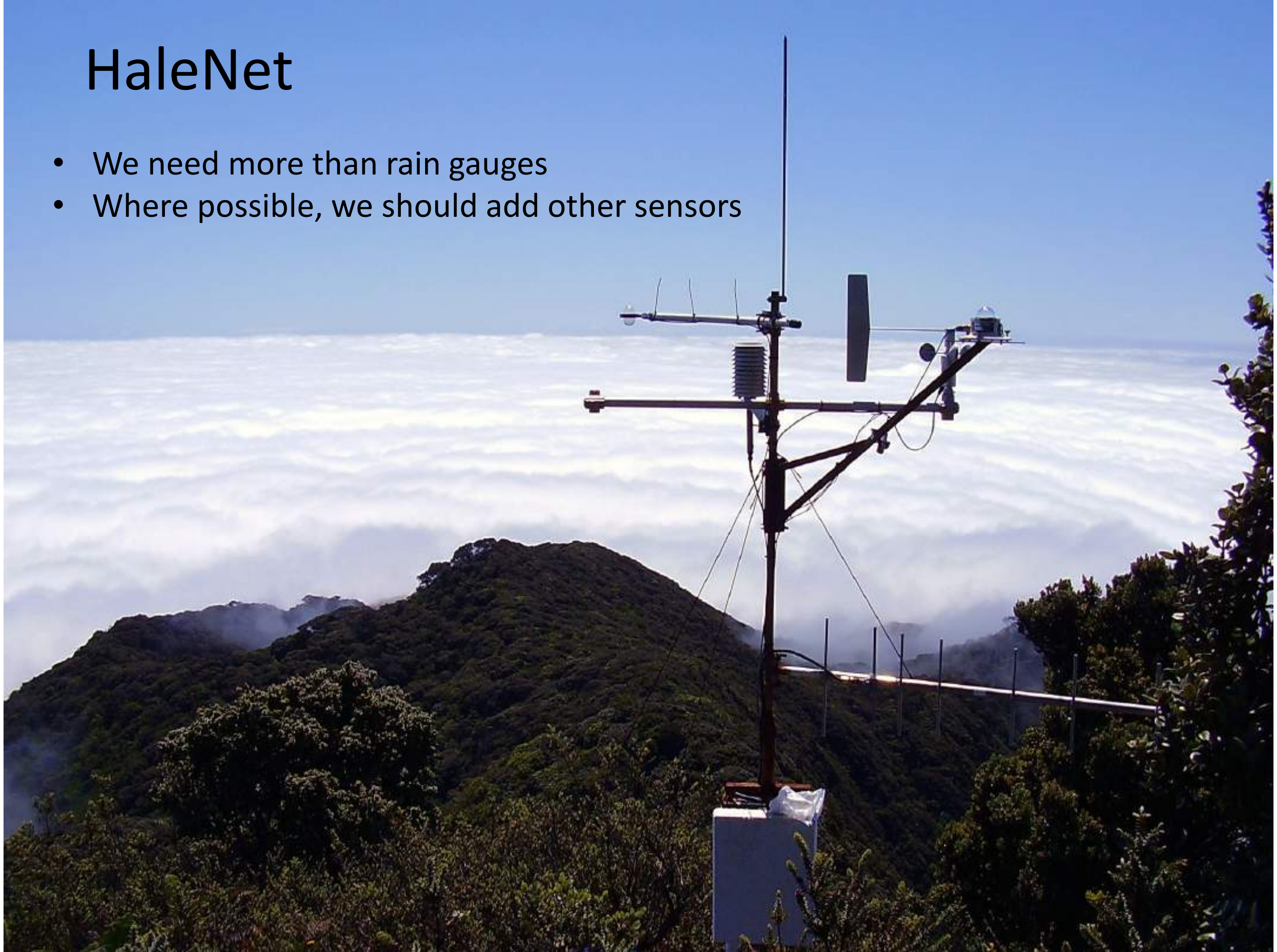


8 Gauges Proposed



HaleNet

- We need more than rain gauges
- Where possible, we should add other sensors



Mahalo!



Dr. Charles H. Fletcher, III (Chip)

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School of Ocean and Earth Science and Technology (SOEST)
University of Hawaiʻi at Mānoa
Vice-Chair of the Honolulu Climate Change Commission

CLIMATE CHANGE PANEL DISCUSSION

Global Sea Level Has Been Rising for Over a Century


Jason 3
2016
OSTM/Jason 2
2008
Jason 1
2001
TOPEX/Poseidon
1992–2006

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NEW RESEARCH IN Physical Sciences Social Sciences

Climate-change–driven accelerated sea-level rise detected in the altimeter era

R. S. Nerem, B. D. Beckley, J. T. Fasullo, B. D. Hamlington, D. Masters, and G. T. Mitchum

PNAS published ahead of print February 12, 2018 https://doi.org/10.1073/pnas.1717312115

Edited by Anny Cazenave, Centre National d'Etudes Spatiales, Toulouse, France, and approved January 9, 2018 (received for review October 2, 2017)

Article Figures & SI Authors & Info PDF

Significance

Satellite altimetry has shown that global mean sea level has been rising at a rate of ~3 ± 0.4 mm/y since 1993. Using the altimeter record coupled with careful consideration of interannual and decadal variability as well as potential instrument errors, we show that this rate is accelerating at 0.084 ± 0.025 mm/y^2, which agrees well with climate model projections. If sea level continues to change at this rate and acceleration, sea-level rise by 2100 (~65 cm) will be more than double the amount if the rate was constant at 3 mm/y.

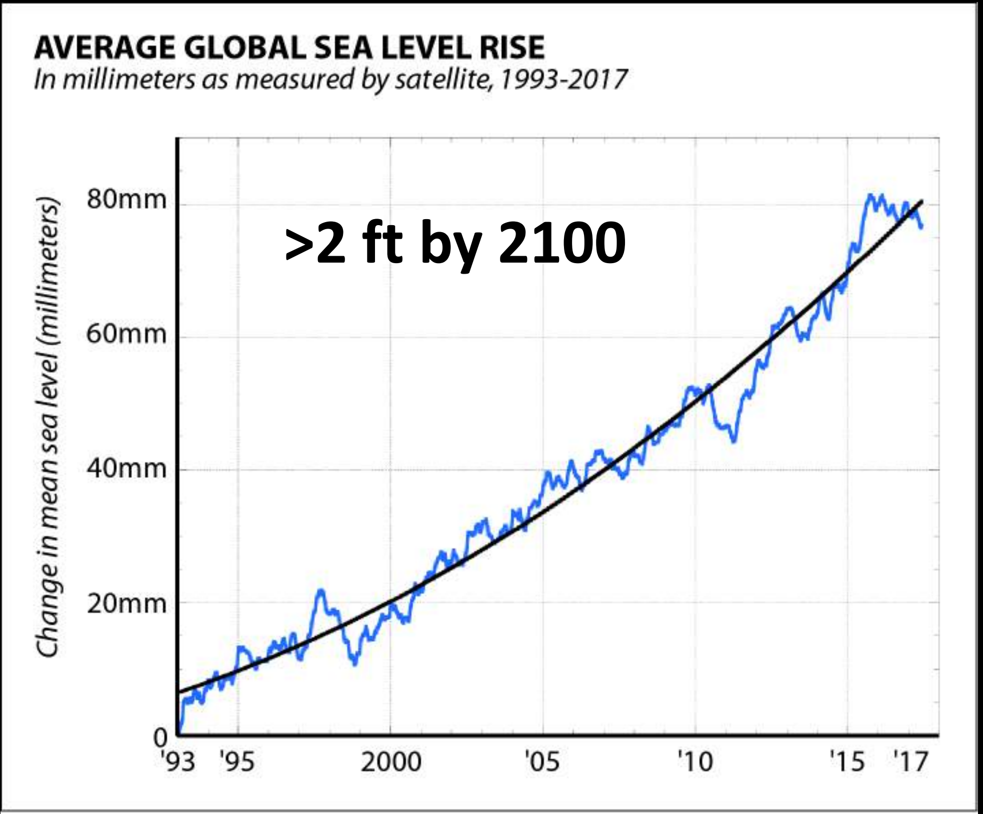
Abstract

Using a 25-y time series of precision satellite altimeter data from TOPEX/Poseidon, Jason-1, Jason-2, and Jason-3, we estimate the climate-change–driven acceleration of global mean sea level over the last 25 y to be 0.084 ± 0.025 mm/y^2. Coupled with the average climate-change–driven rate of sea level rise over these same 25 y of 2.9 mm/y, simple extrapolation of the quadratic implies global mean sea level could rise 65 ± 12 cm by 2100 compared with 2005, roughly in agreement with the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5) model projections.

sea level acceleration climate change satellite altimetry

Satellite altimeter data collected since 1993 have measured a rise in global mean sea level

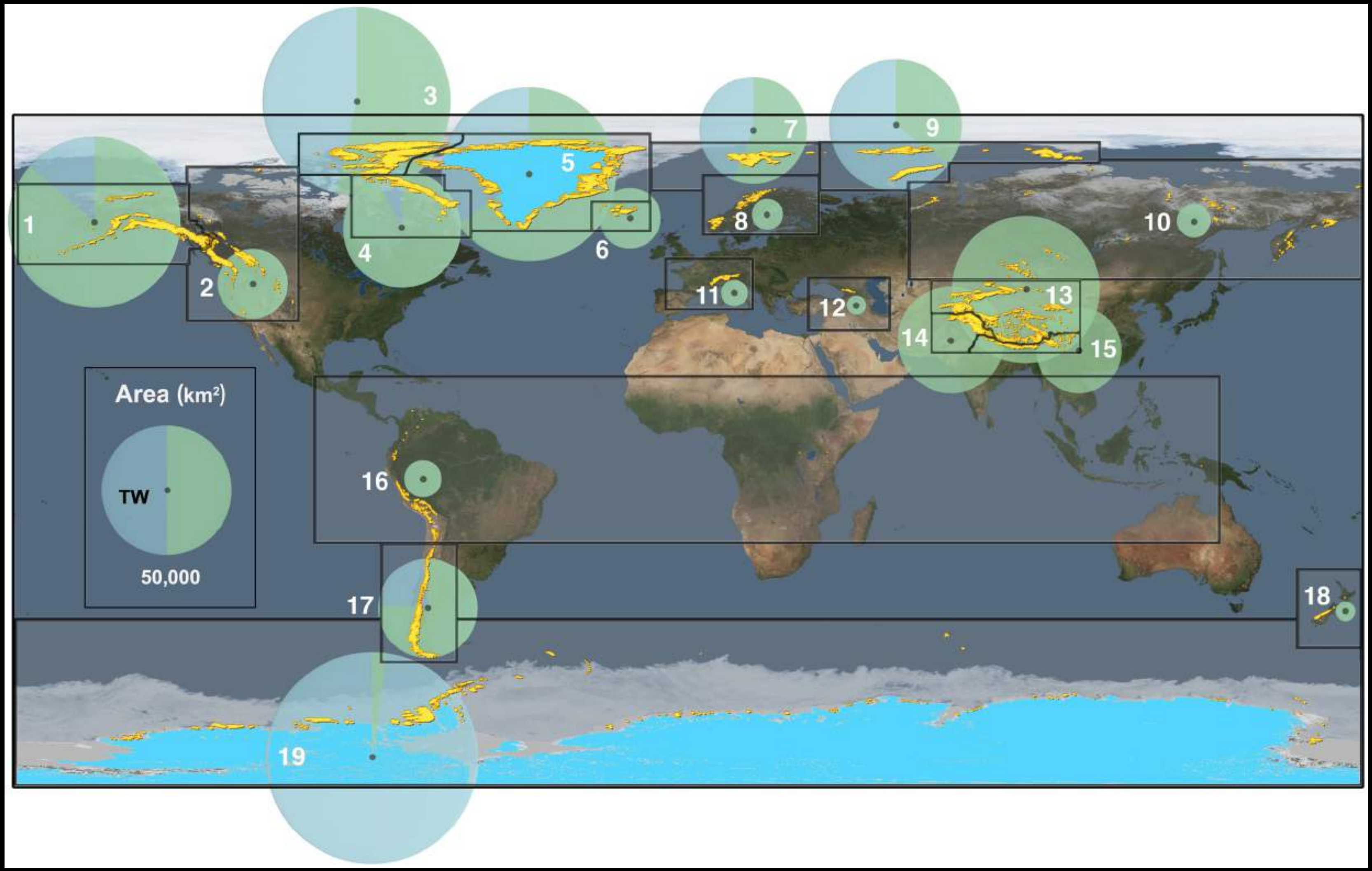
Sea Level Rise has <u>Accelerated</u>



SOURCE: Steve Nerem/University of Colorado, Boulder InsideClimate News

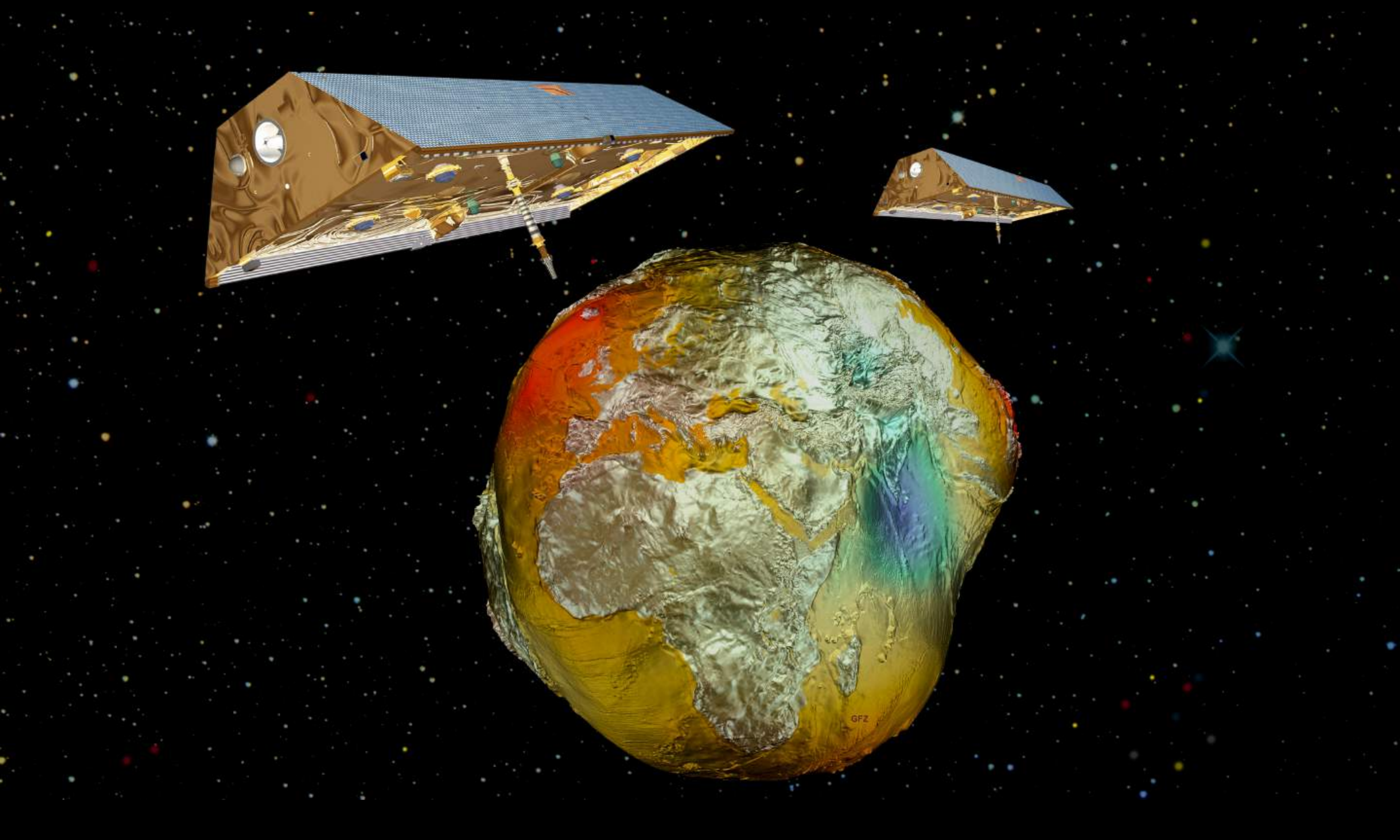
665 Billion Tons of Ice Melt Each Year

Greenland 37%   Mountain Glaciers 34%   Antarctica 29%

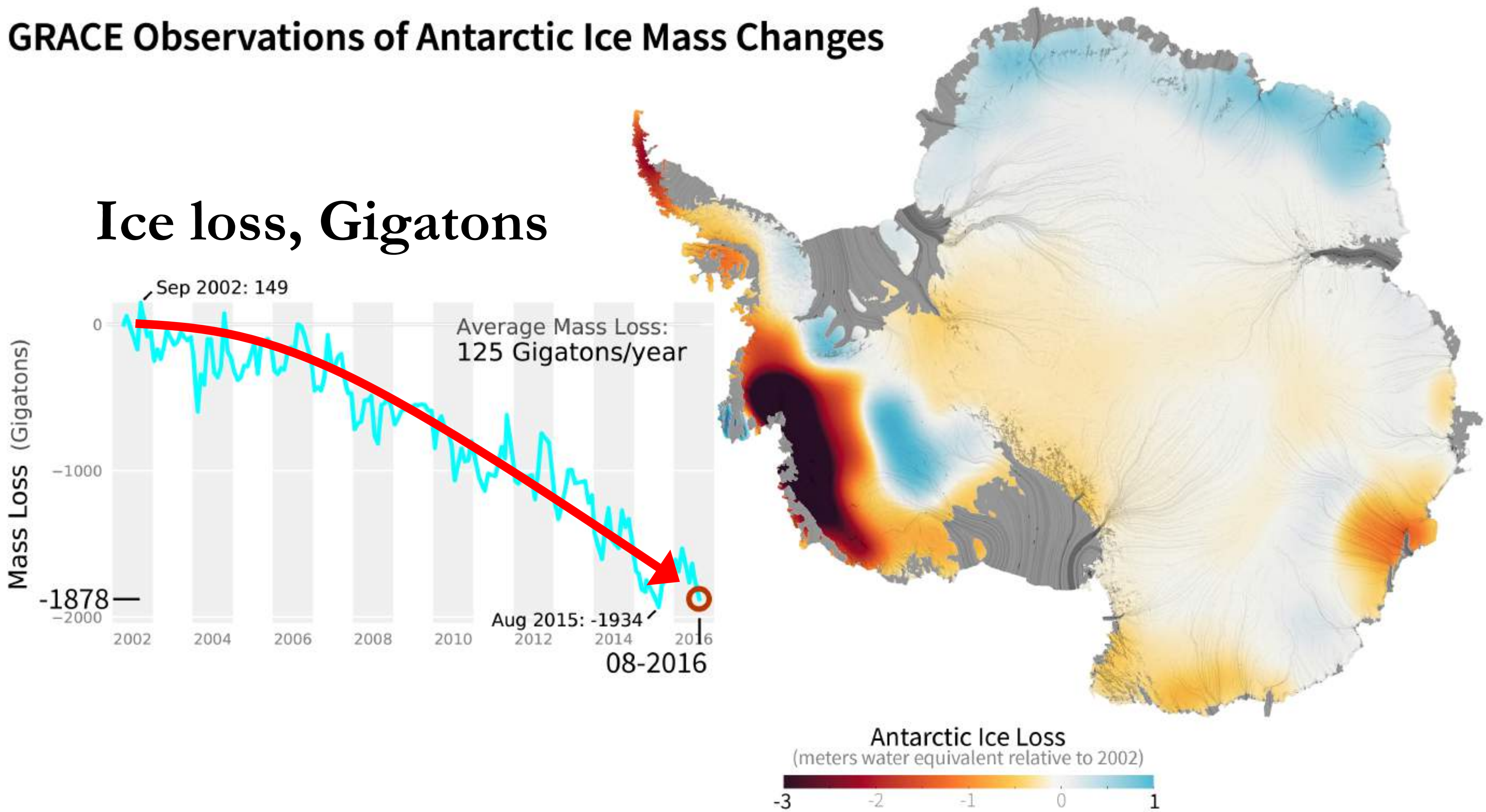


Bamber, J.L., et al (2018) The land ice contribution to sea level during the satellite era, Environ. Res. Lett. 13 https://doi.org/10.1088/1748-9326/aac2f0

GRACE – Gravity Recovery & Climate Experiment, 2002-2017

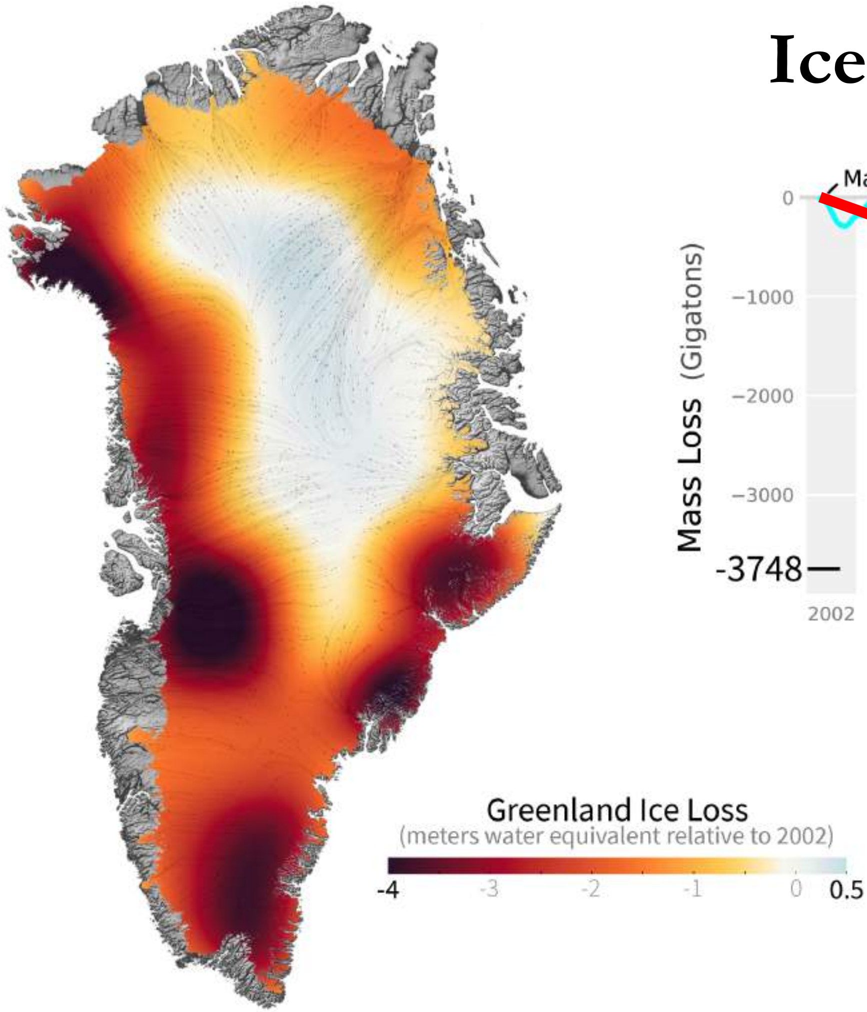


Antarctic ice melt has ‘tripled over the past five years’

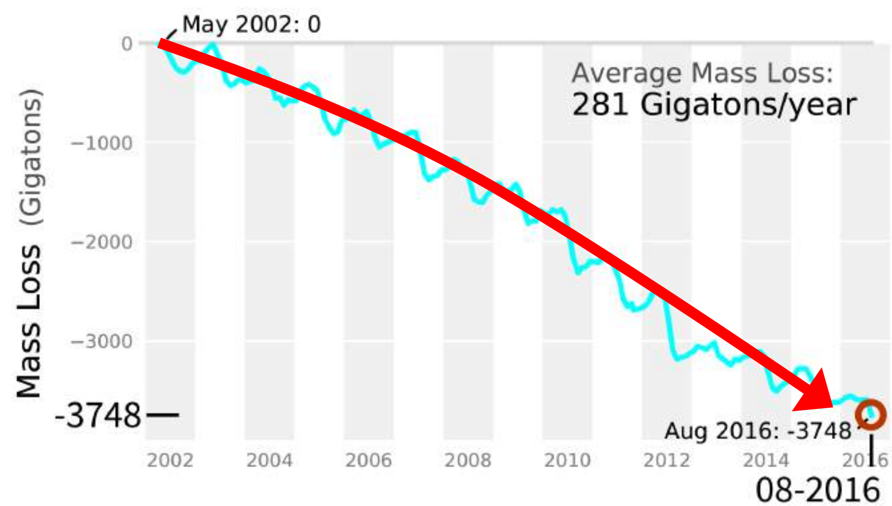


The IMBIE team (2018) Mass Balance of the Antarctic Ice Sheet, *Nature*, 558, pages219–222, https://doi.org/10.1038/s41586-018-0179-y

Greenland faces a 66% chance that melting will become unstoppable at 1.8^oC

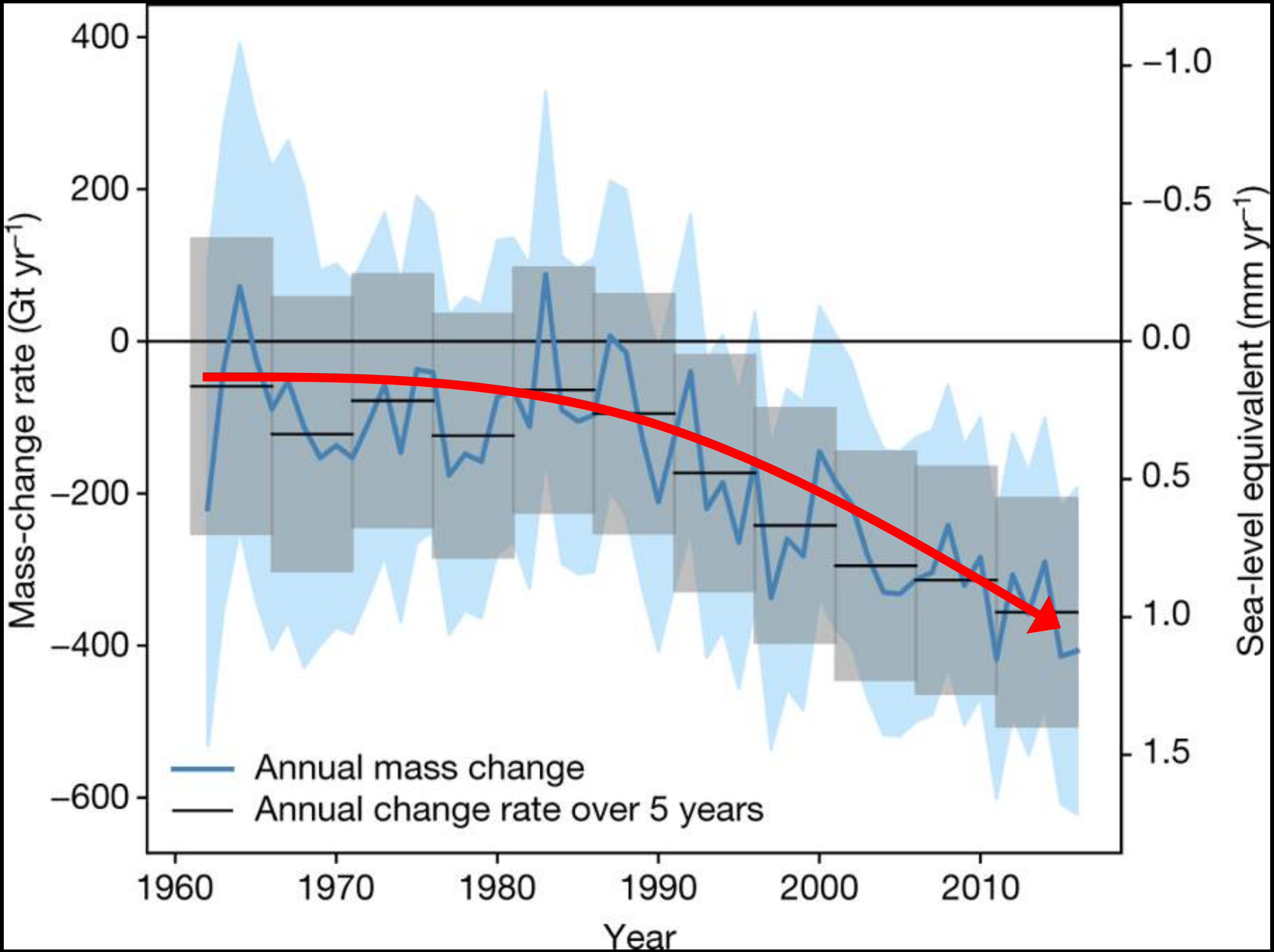


Ice loss, Gigatons



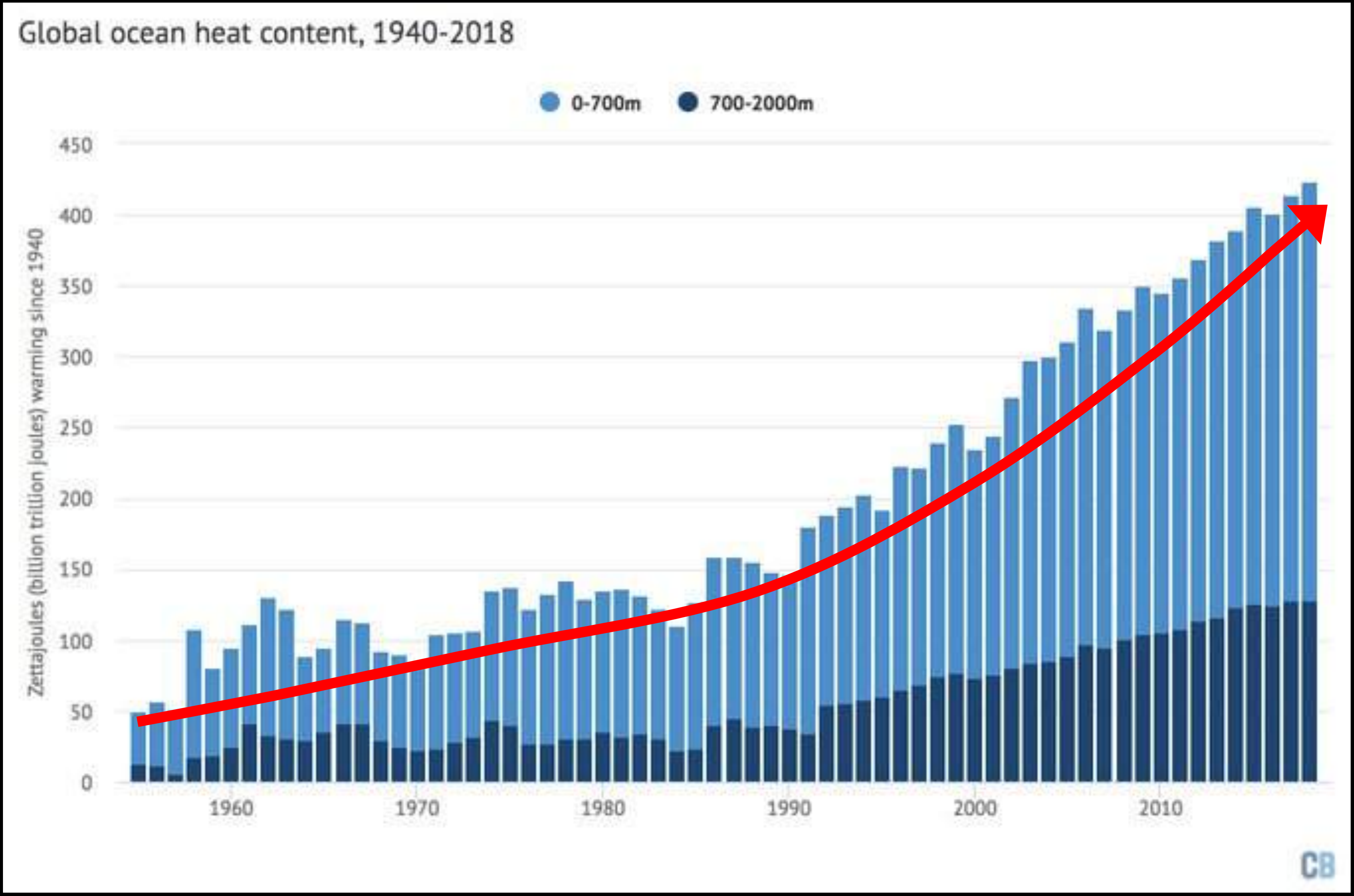
Trusel, et al., 2018 Nonlinear rise in Greenland runoff in response to post-industrial Arctic warming, 104, *Nature*, v564, 6 December: https://doi.org/10.1038/s41586-018-0752-4

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.

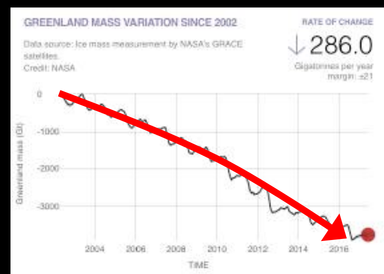


Cheng, L., et al. (2019) How fast are the oceans warming? *Science*, 2019 DOI: 10.1126/science.aav7619; Cheng L. J. Zhu, and J. Abraham, 2015: Global upper ocean heat content estimation: recent progress and the remaining challenges. Atmospheric and Oceanic Science Letters, 8. DOI:10.3878/AOSL20150031. ; 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?

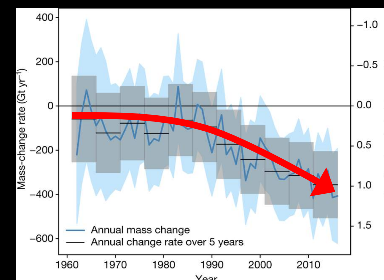
Antarctic ice loss

+



Greenland ice loss

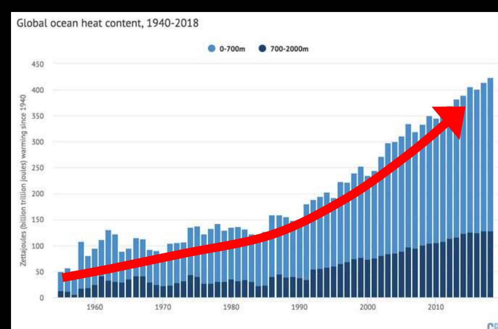
+



Mountain glacier ice loss

= 0.8m

0.8m +



Thermal expansion

= 1m by 2100

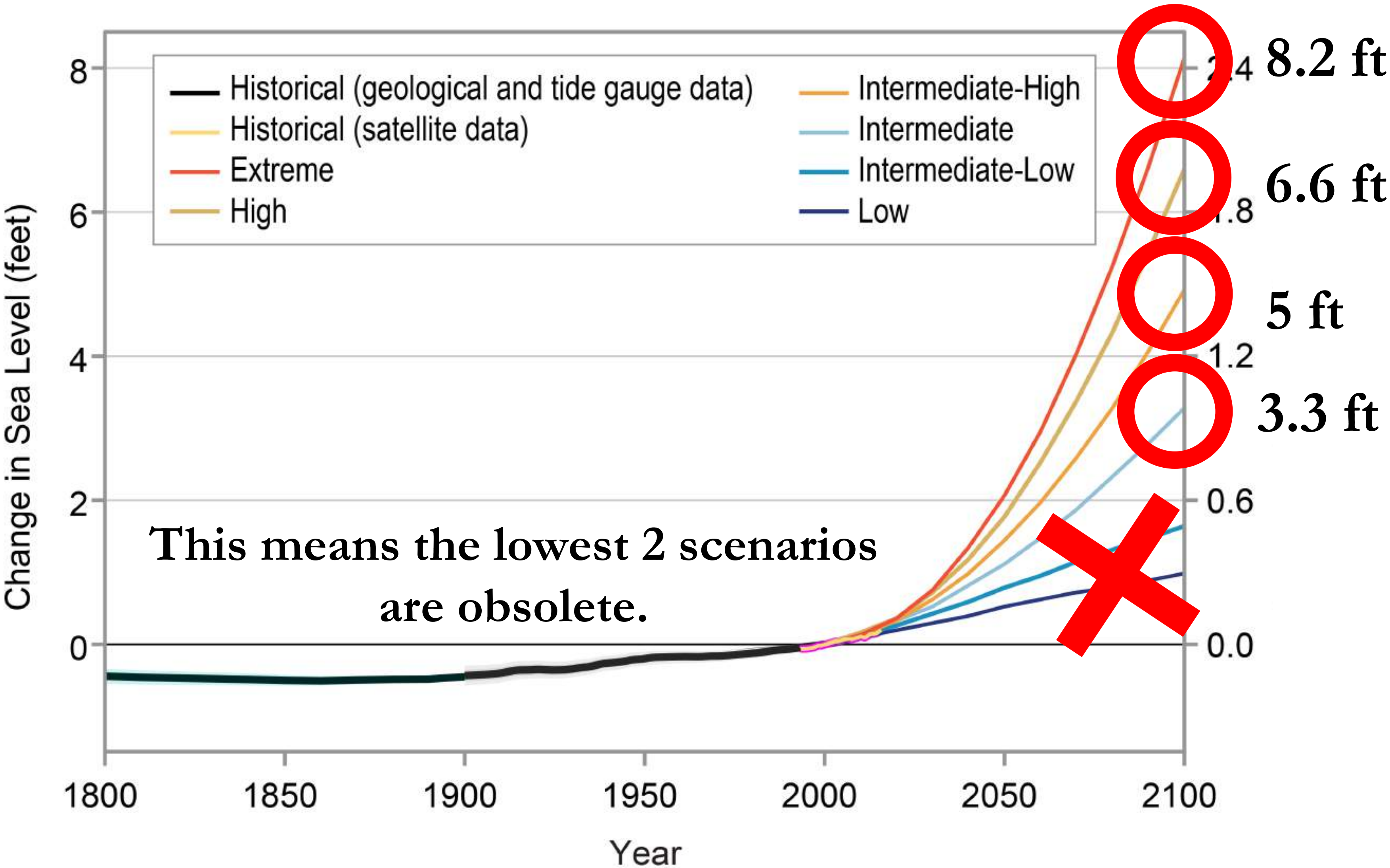
E. Rignot (2019) pers. comm.: http://sites.nationalacademies.org/SSB/SSB_191179

https://science2017.globalchange.gov

How High Sea Level?

- *Very likely* to rise 0.3–0.6 feet by 2030
- 0.5–1.2 feet by 2050
- 1.0–4.3 feet by 2100
- Emissions now and over the next 20-30 yrs have little effect on SLR in the first half of the century
- But significantly affect SLR for the second half of the century
- Emerging science on Antarctica suggests, for high emission scenarios, a SLR exceeding 8 ft by 2100 is physically possible
- It is *extremely likely* that SLR rise will continue beyond 2100 (*high confidence*).

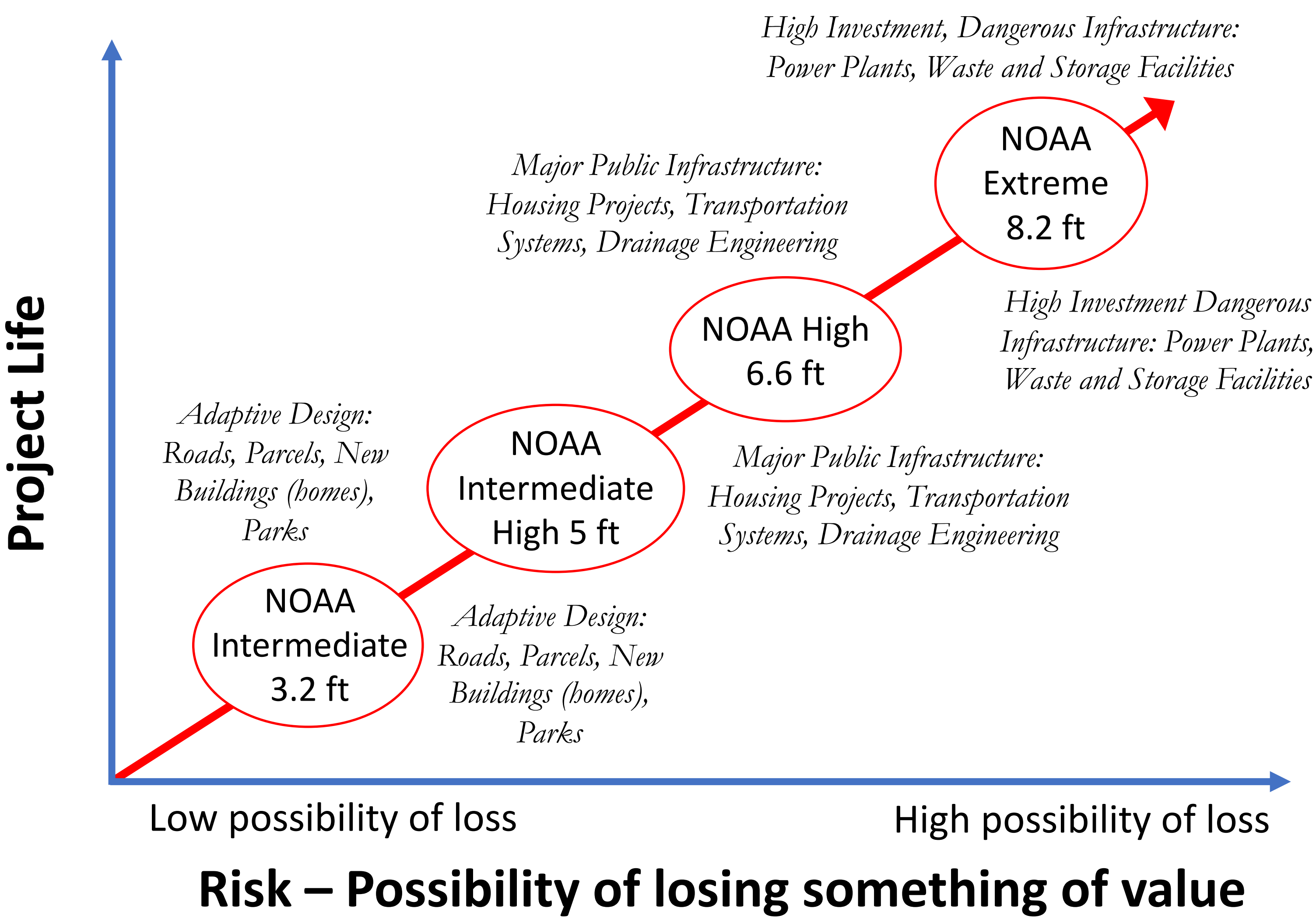
NOAA & 4thNCA SL Scenarios



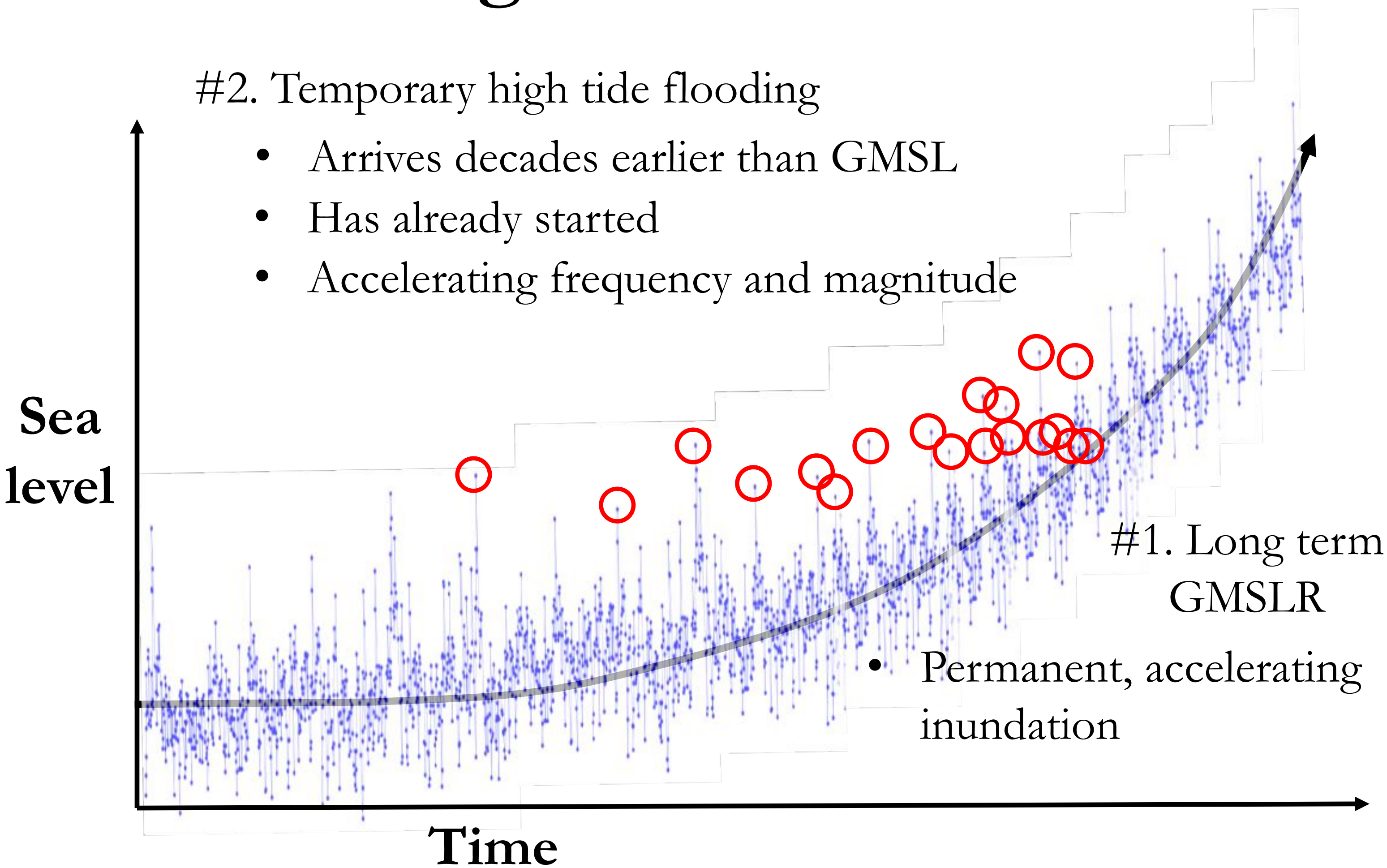
Sweet, W.V., et al. 2017 Sea level rise. In: *Climate Science Special Report: Fourth National Climate Assessment, Volume I*[Wuebbles, D.J., et al. (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 333-363, https://science2017.globalchange.gov/chapter/12/

SLR Scenario Planning

decision-making under conditions of uncertainty



SLR Flooding: Nuisance and Permanent

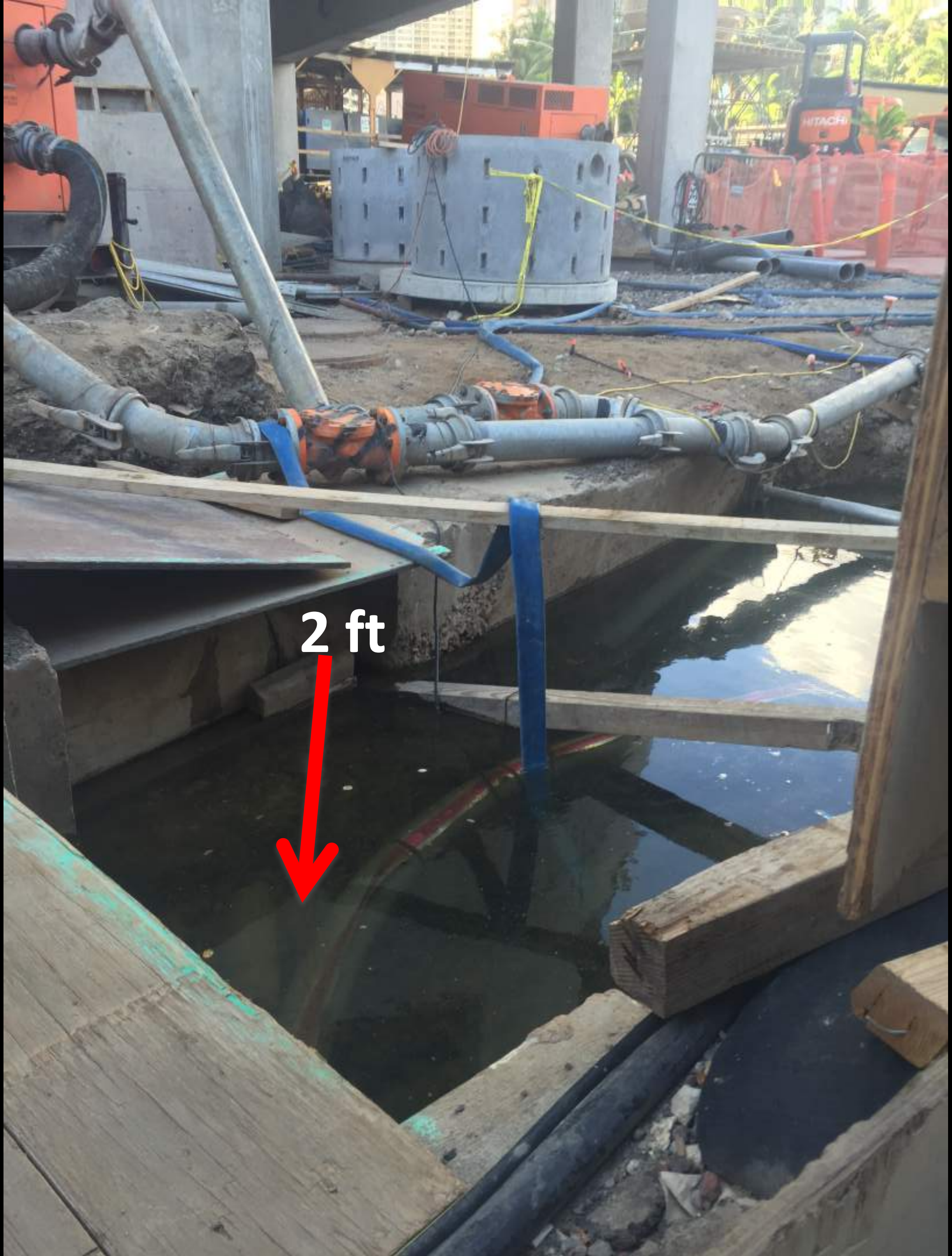


Disruptive High Tide Flooding by Mid-Century

Storm Drain Backflow at High Tide

Disruptive High Tide Flooding by Mid-Century

Groundwater Inundation



Rain + High Tide = Flooding

Disruptive High Tide Flooding by Mid-Century

Groundwater Pollution

Summer wave run-up 2ft

Summer wave run-up 3ft

Coastal Erosion and Beach Loss

Department of Transportation

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


Sunset Beach
3 ft of SLR
Rocky Point
Paumalū Gulch
Sunset Beach Park
'Ehukai Beach Park
Kālunawaika'ala Stream
Banzai Rocks
Sunset Beach Neighborhood Park
Kamehameha Hwy
Girl Scout Camp Rd
Pukea Rd
Opae Rd
83
Annual wave Run-up
Erosion

Waikiki at 1m SLR

SCIENTIFIC REPORTS

Article | OPEN | Publi

Modeling … reveals up… compared… methods

TOP 100
– READ ARTICLES –
2018
OFFICIAL AUTHOR
SCIENTIFIC REPORTS

Tiffany R. Anderson, … no &
Jade M.S. M. S. Delevau

Scientific Reports **8**, Arti

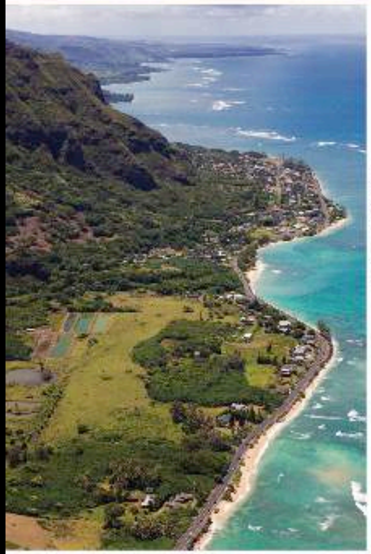
https://www.nat

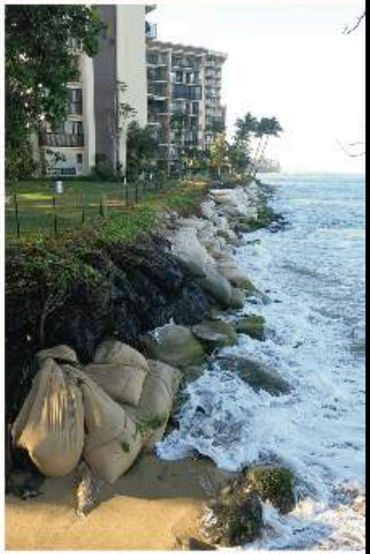
Abstract

Planning community resilience to sea level rise (SLR) requires information about where, when, and how SLR hazards will impact the coastal zone. We augment passive flood mapping (the so-called "bathtub" approach) by simulating physical processes posing recurrent threats to coastal infrastructure, communities, and ecosystems in Hawai'i (including tidally-forced direct marine and groundwater flooding, seasonal wave inundation, and chronic coastal erosion). We find that the "bathtub" approach, alone, ignores 35–54 percent of the total land area exposed to one or more of these hazards, depending on location and SLR scenario. We conclude that modeling dynamic processes, including waves and erosion, is essential to robust SLR vulnerability assessment. Results also indicate that as sea level rises,

Hawai`i Climate Change Mitigation & Adaptation
Pili Na Mea A Pau

Hawai´i Sea Level Rise Vulnerability and Adaptation Report





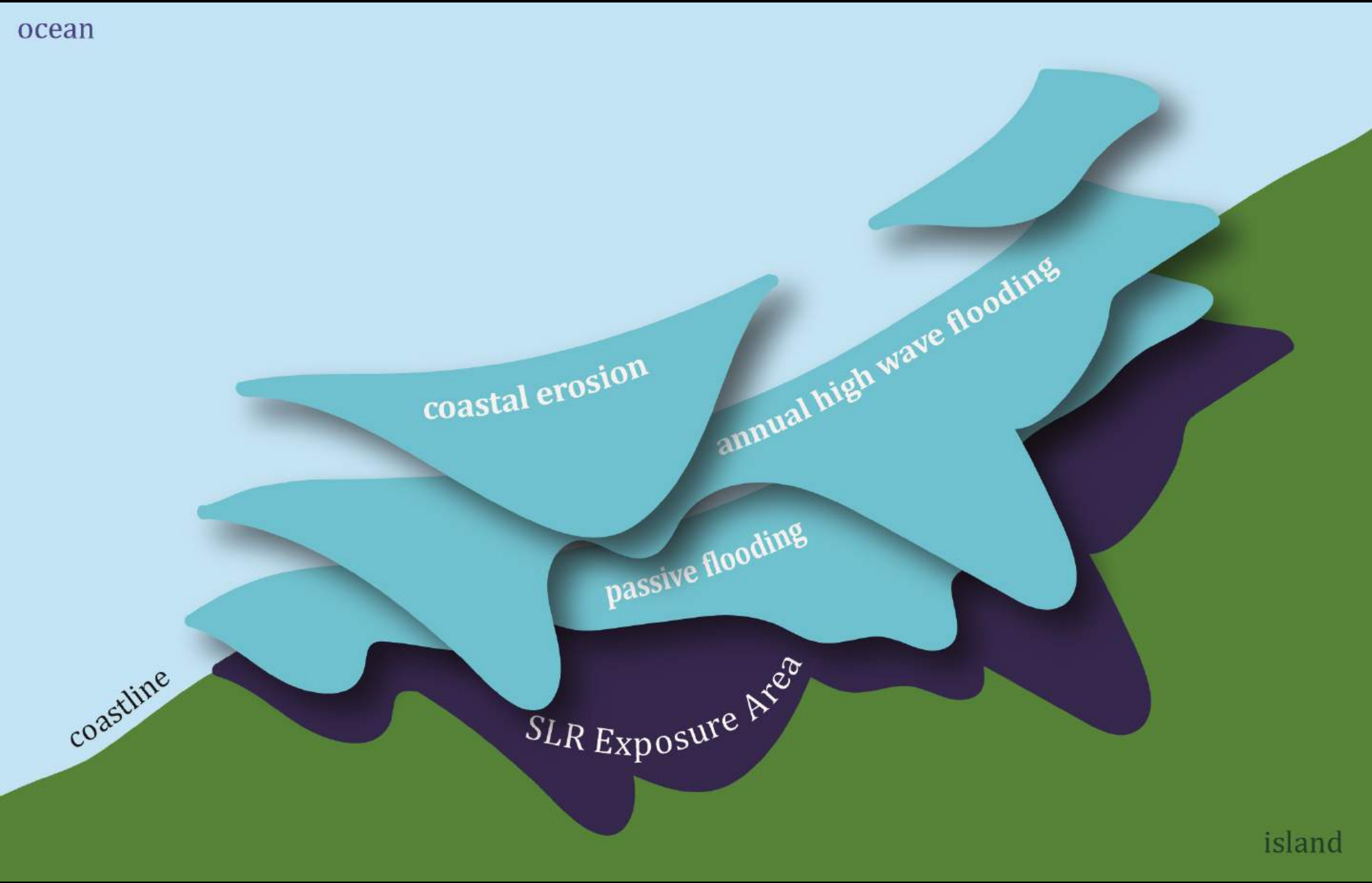
State of Hawaii, Office of Planning

TETRA TECH

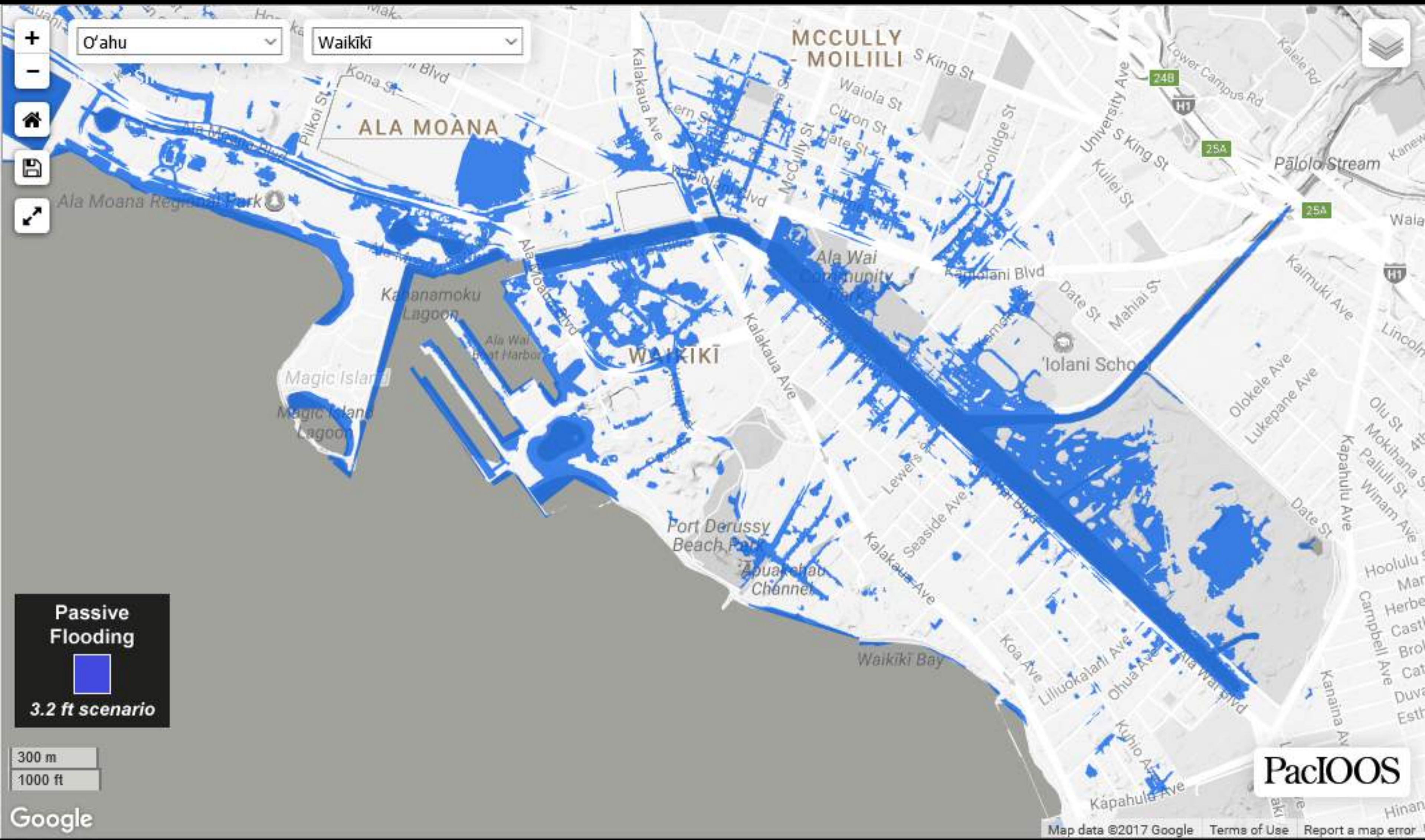
SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY

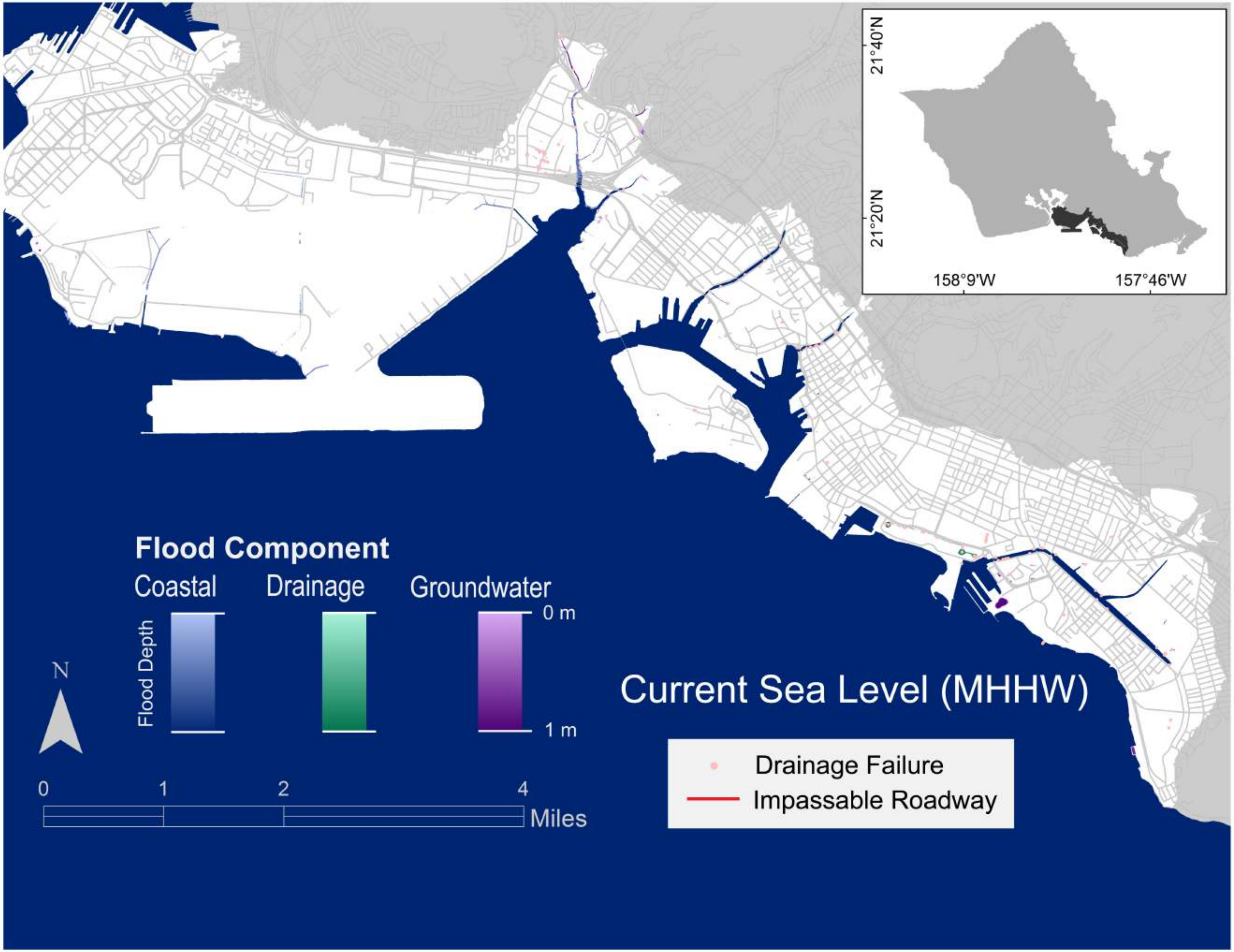
Sea Grant

PICSC


ocean
coastal erosion
annual high wave flooding
passive flooding
SLR Exposure Area
coastline
island

The 3.2SLR-XA
Location of both King Tide Flooding and Permanent Inundation





21°40'N
21°20'N
158°9'W
157°46'W
Flood Component
Coastal
Drainage
Groundwater
Flood Depth
0 m
1 m
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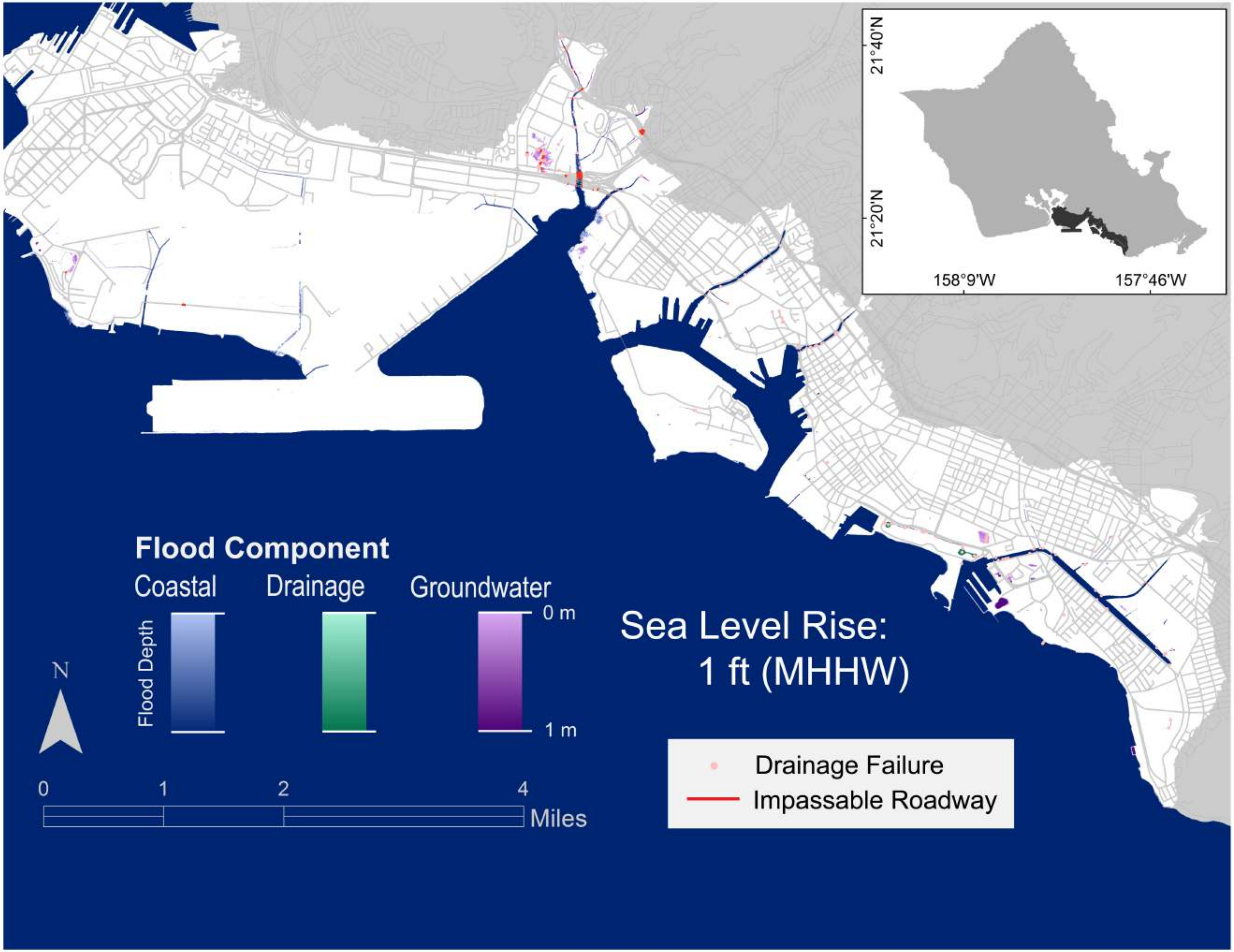
2
4
Miles
Current Sea Level (MHHW)
Drainage Failure
Impassable Roadway



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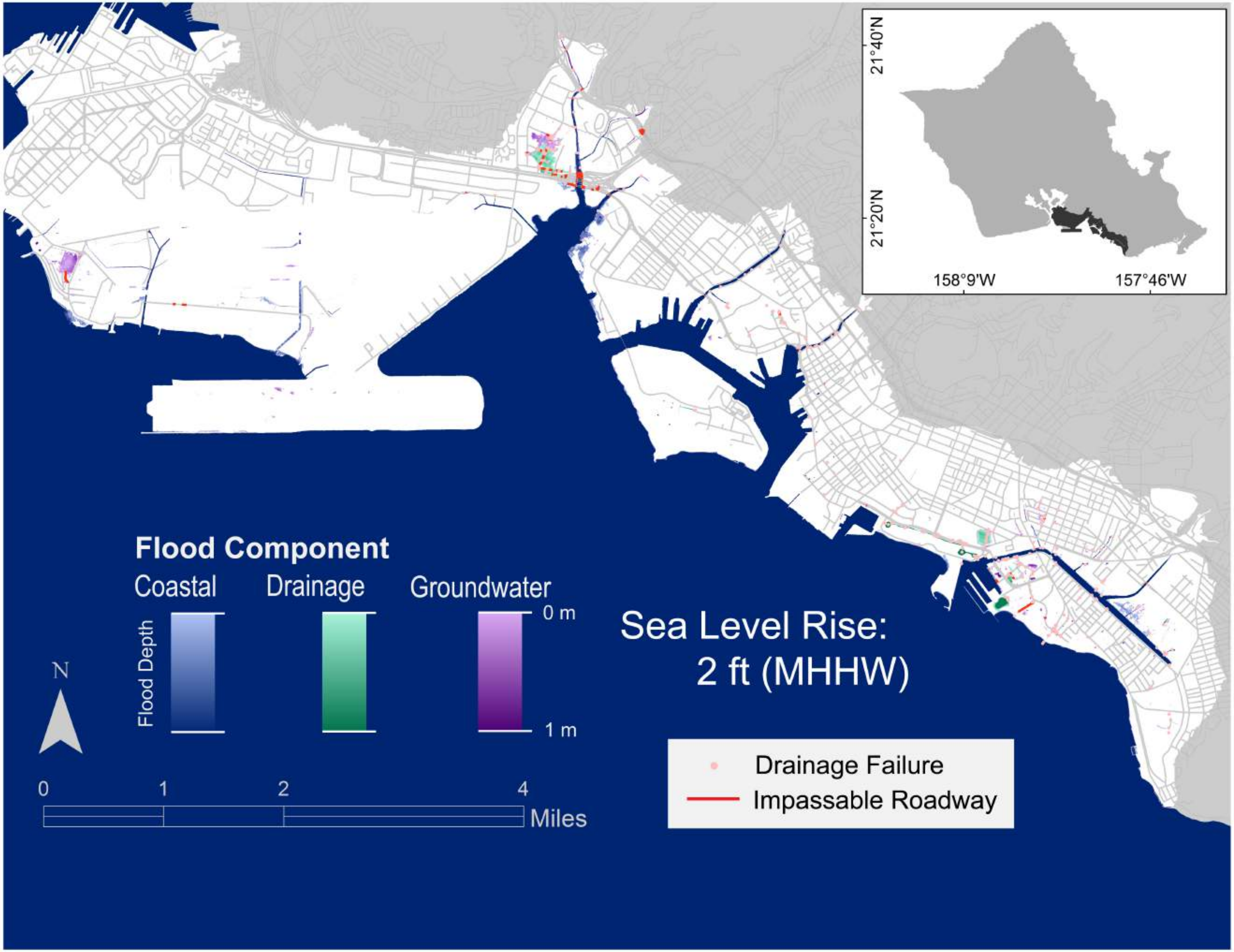
Miles
Sea Level Rise:
1 ft (MHHW)
Drainage Failure
Impassable Roadway



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Drainage
Groundwater
Flood Depth
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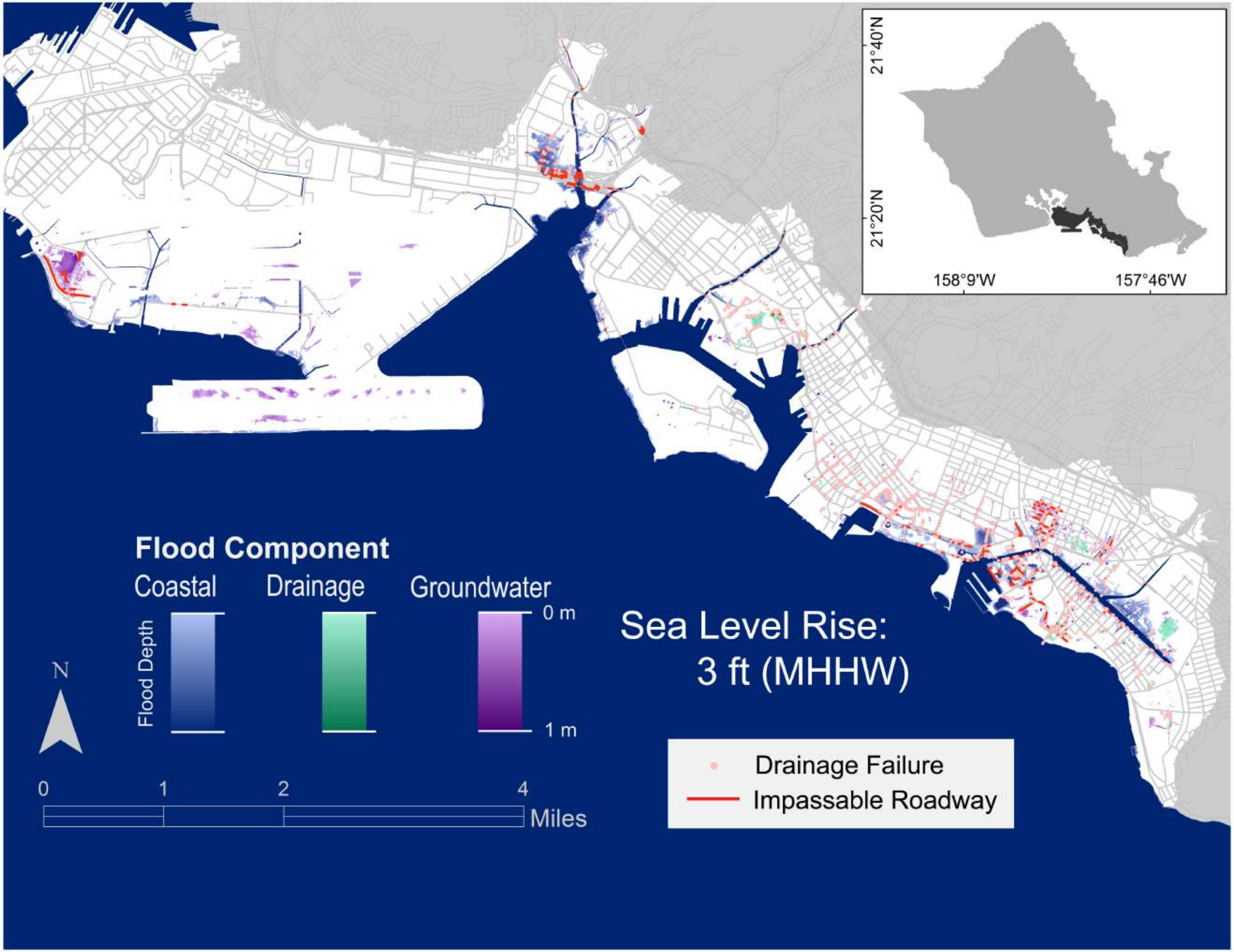
Miles
Sea Level Rise:
2 ft (MHHW)
Drainage Failure
Impassable Roadway



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Flood Component
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Drainage
Groundwater
Flood Depth
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Sea Level Rise:
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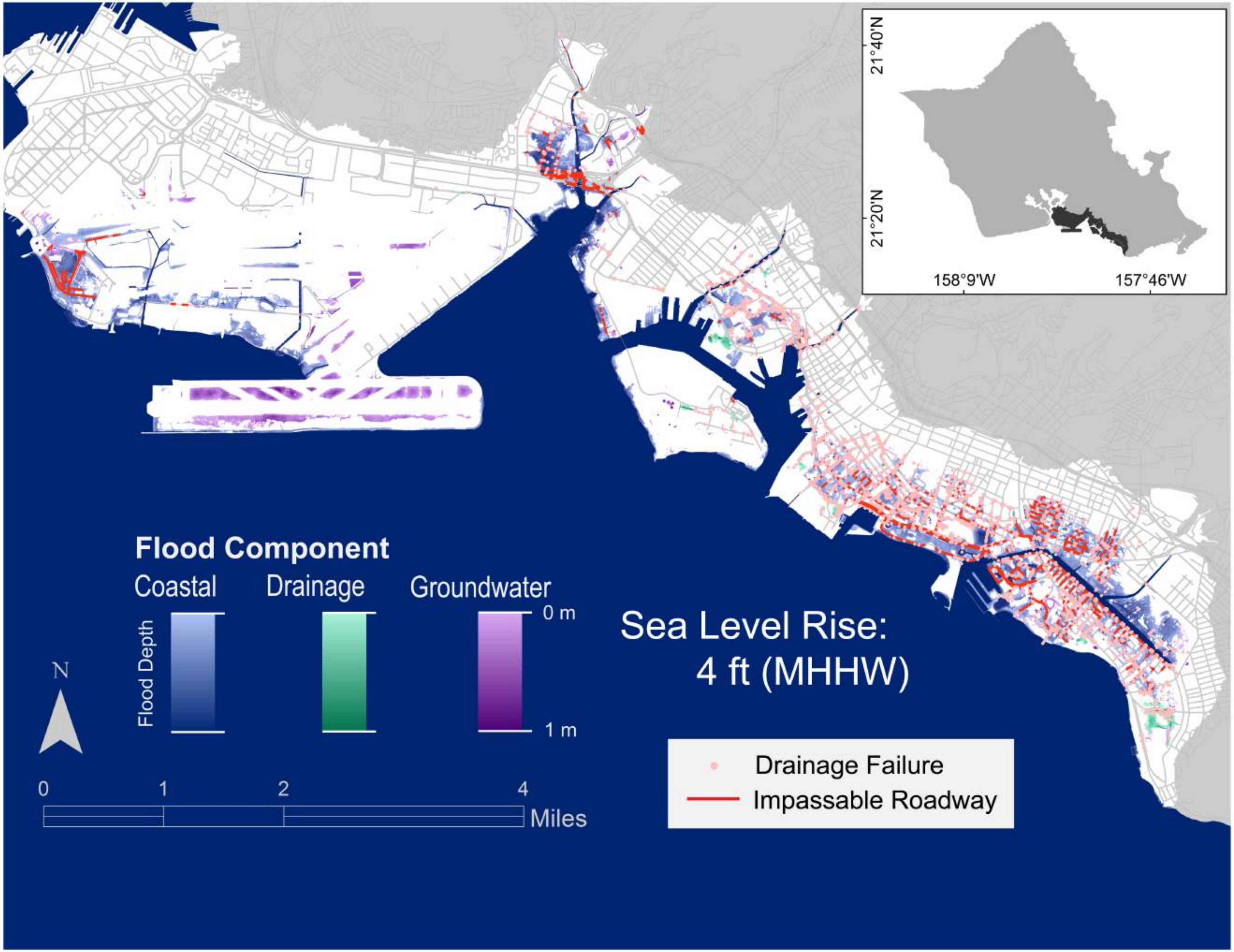
Miles
Drainage Failure
Impassable Roadway



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Drainage
Groundwater
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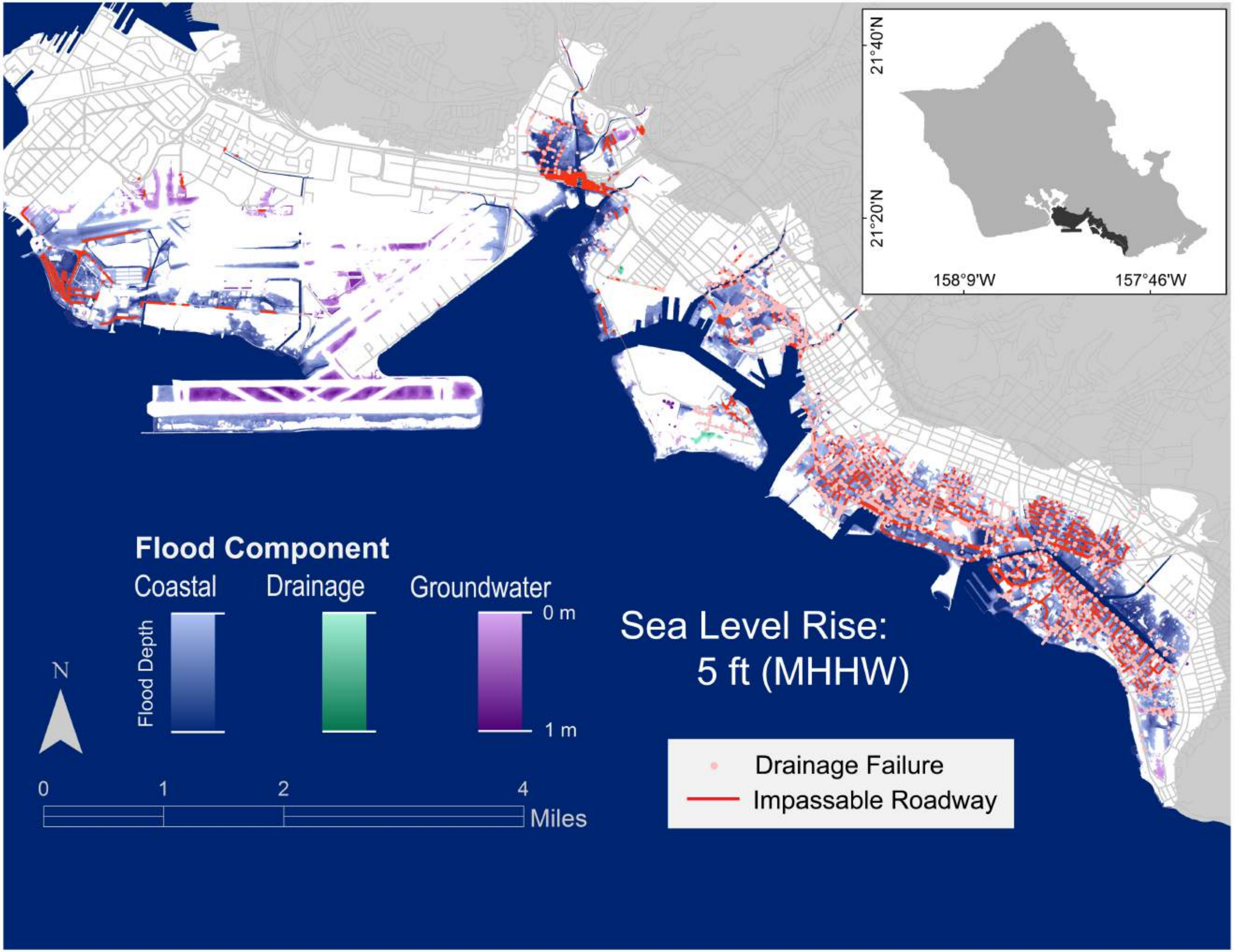
Miles
Drainage Failure
Impassable Roadway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Drainage
Groundwater
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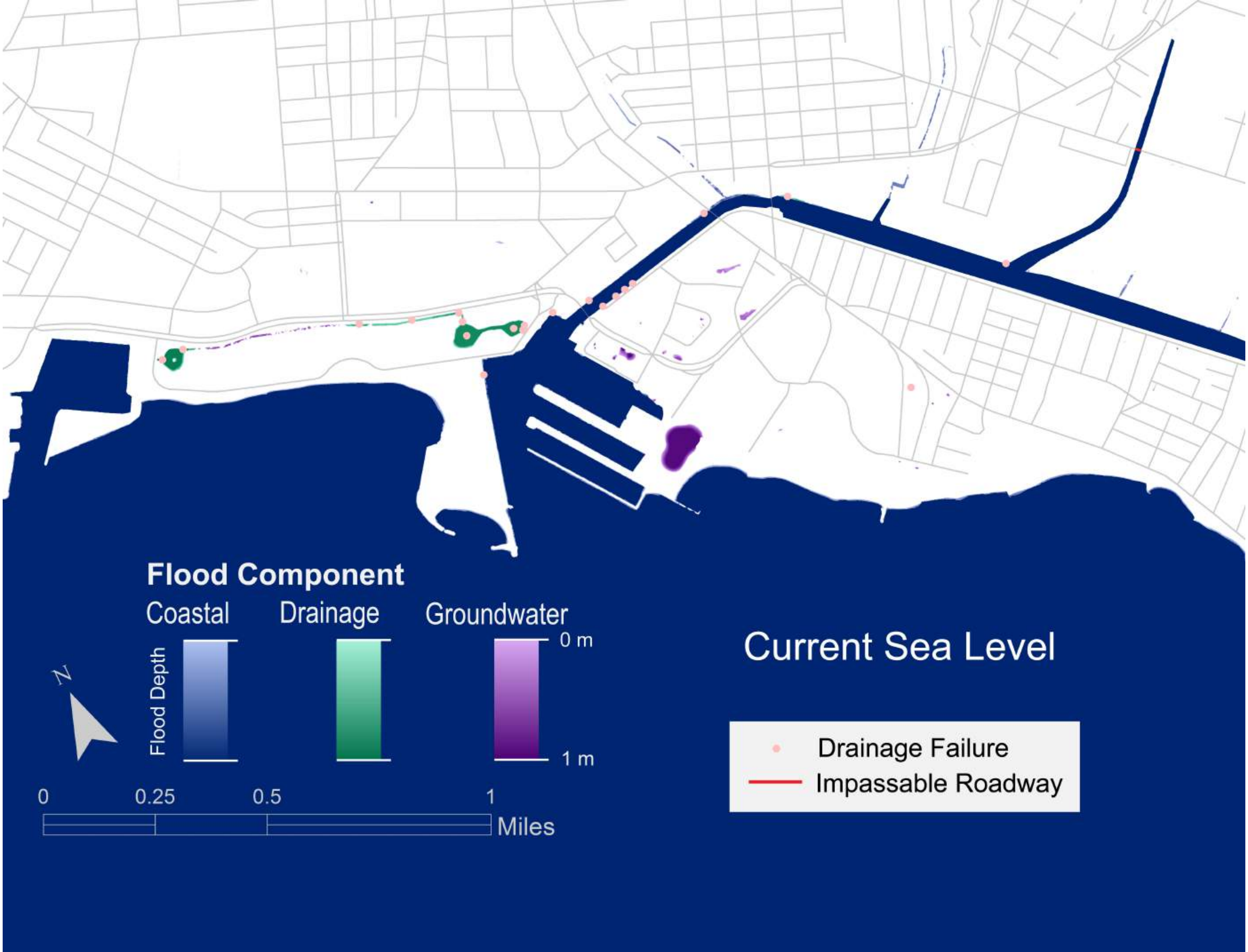
Miles
Sea Level Rise:
5 ft (MHHW)
Drainage Failure
Impassable Roadway



Flood Component
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Drainage
Groundwater
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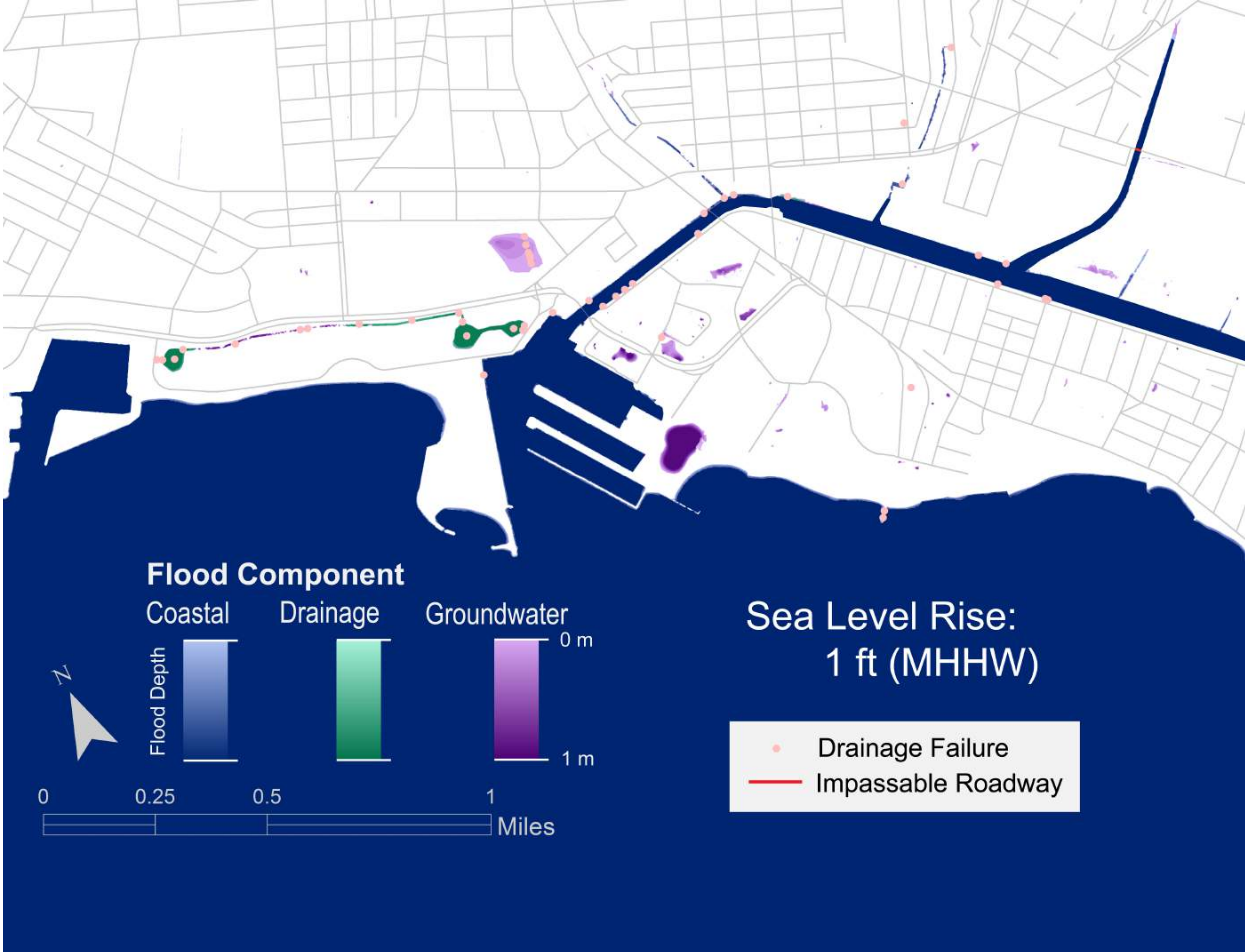
Miles
Current Sea Level
Drainage Failure
Impassable Roadway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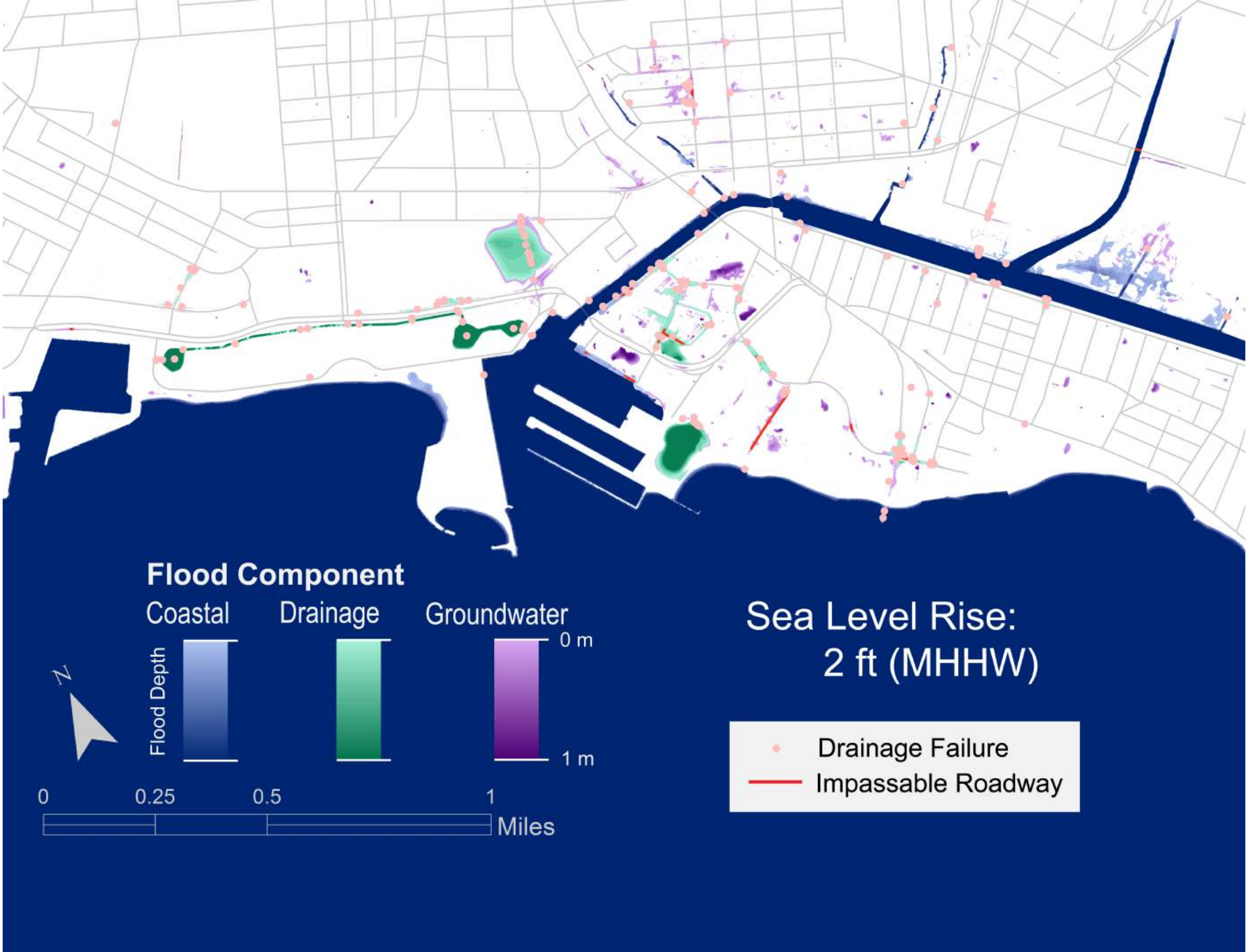
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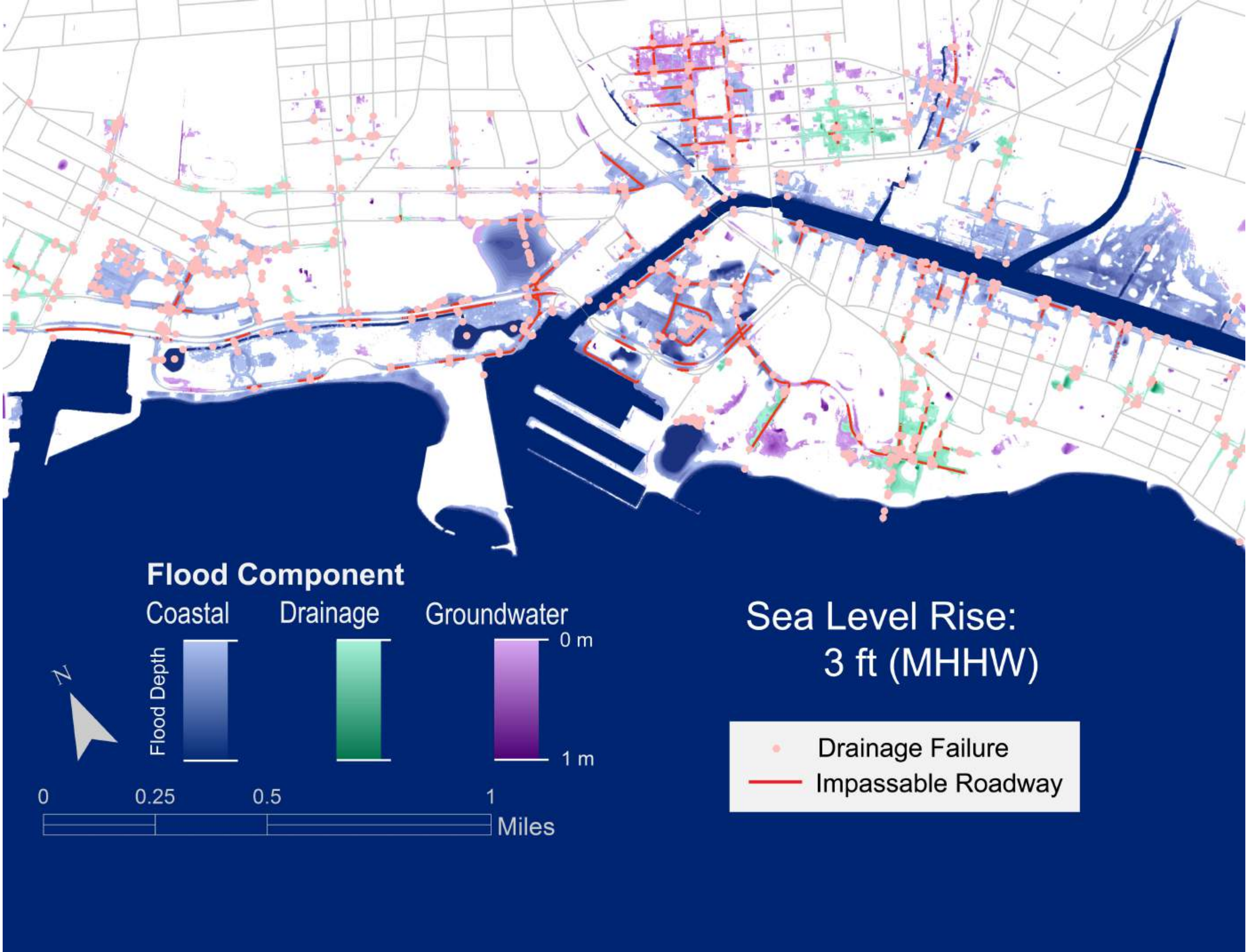

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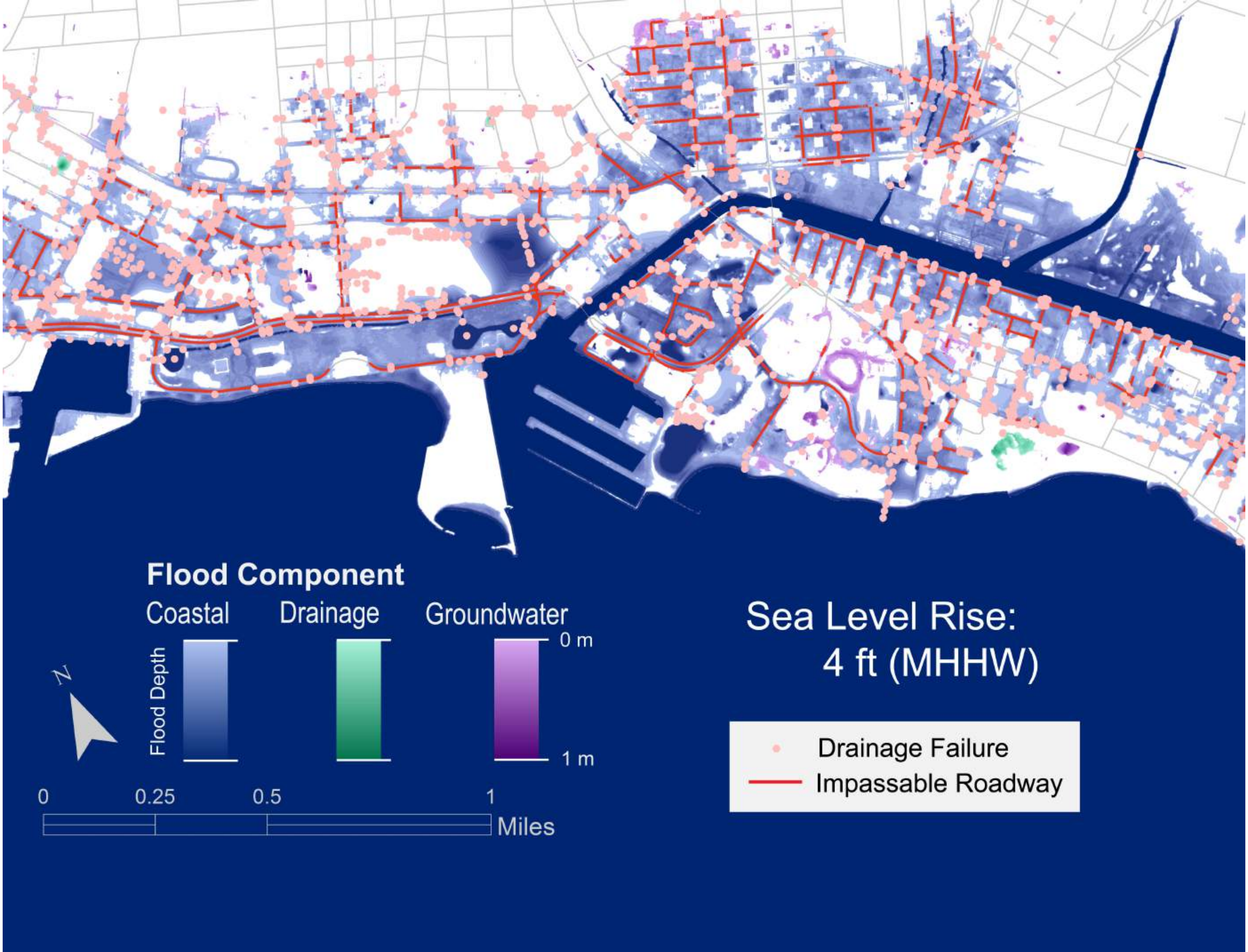
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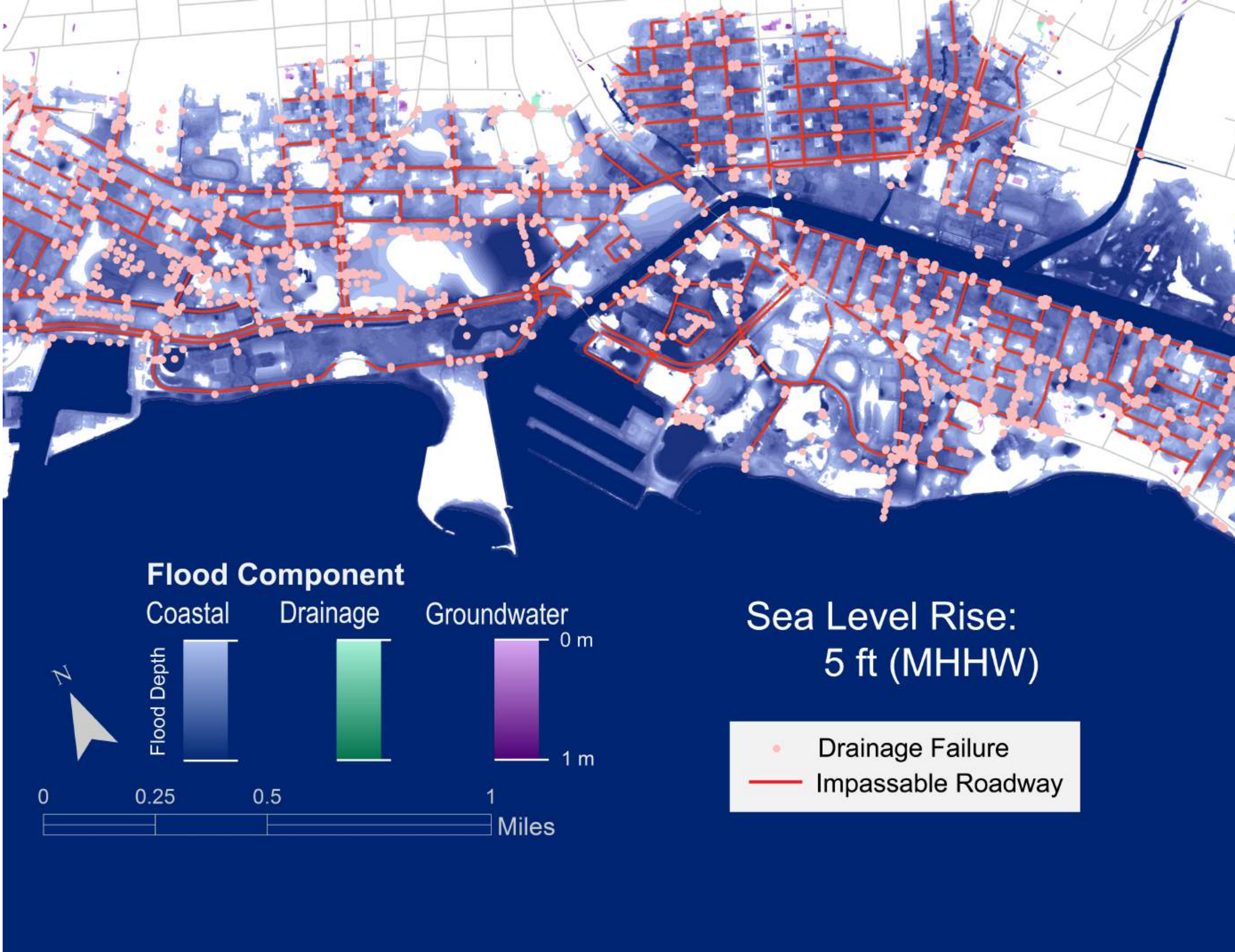
Drainage Failure
Impassable Roadway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Drainage
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Miles
Sea Level Rise:
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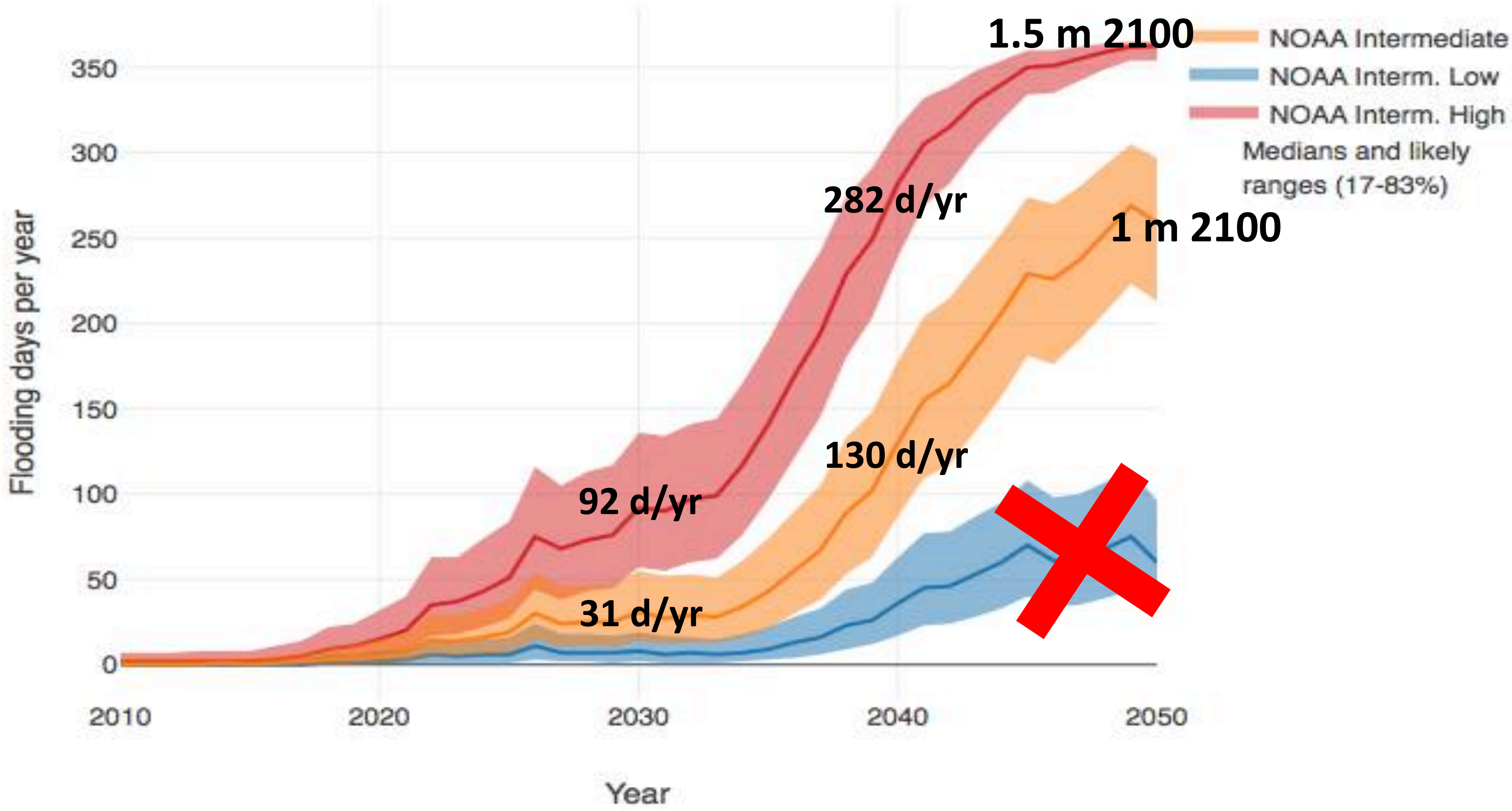
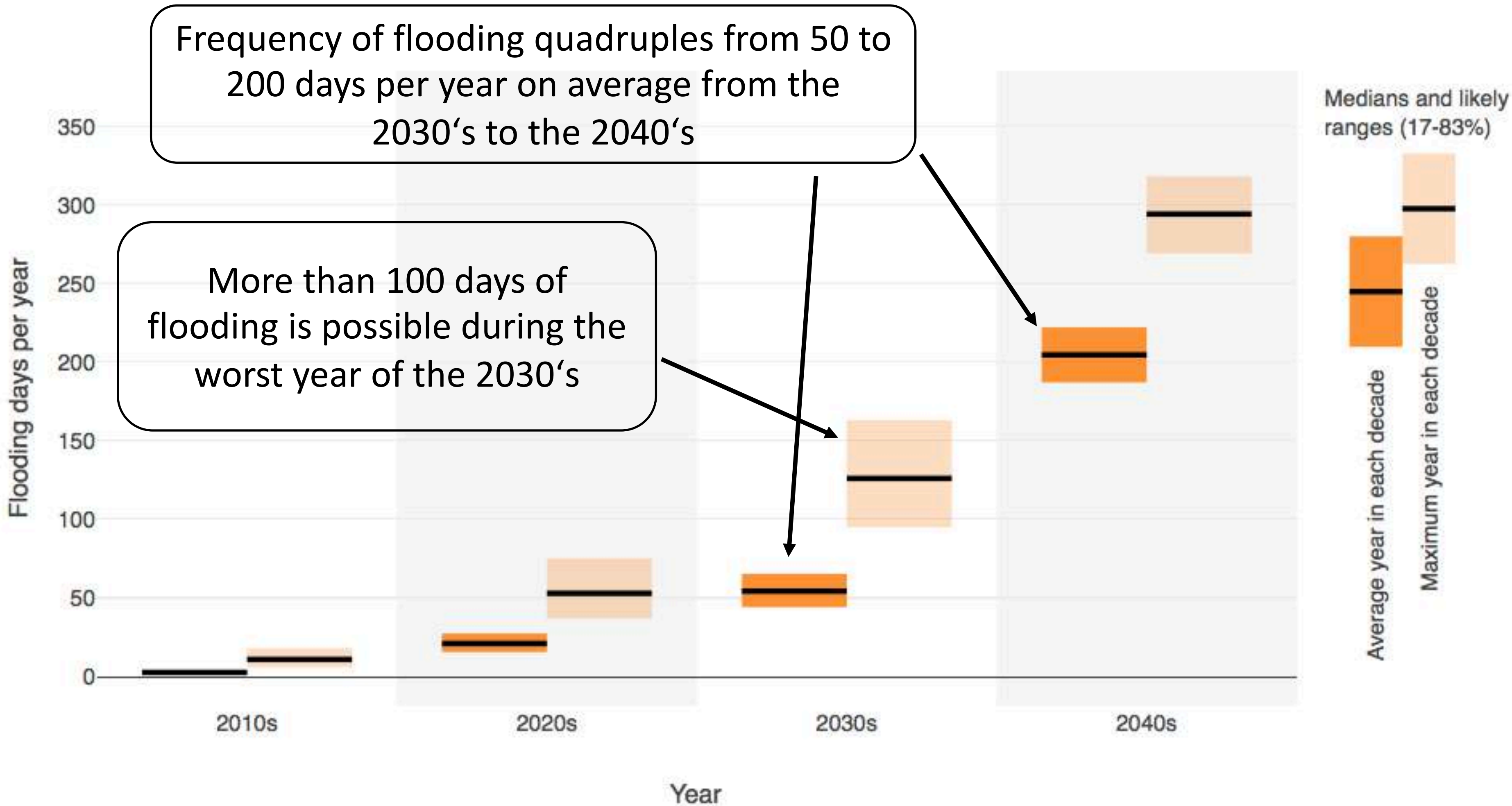
Drainage Failure
Impassable Roadway

High Tide Flooding in Coastal Honolulu by Decade



Thompson et al. (2019) A statistical model for frequency of coastal flooding in Honolulu Hawaii, during the 21st Century, JGR Oceans, 10.1029/2018JC014741
UH Sea Level Center: https://uhslc-flooding-test.soest.hawaii.edu

High Tide Flooding in Coastal Honolulu by Decade



Thompson et al. (2019) A statistical model for frequency of coastal flooding in Honolulu Hawaii, during the 21st Century, JGR Oceans, 10.1029/2018JC014741
UH Sea Level Center: https://uhslc-flooding-test.soest.hawaii.edu

Thank you for your Time

Joshua Stanbro

Honolulu's Chief Resilience Officer and Executive Director
Office of Climate Change, Sustainability and Resiliency
City and County of Honolulu

CLIMATE CHANGE PANEL DISCUSSION

Board of Water Supply Stakeholder Advisory Committee – April 25, 2019

City and County of Honolulu
Office of Climate Change, Sustainability and Resiliency

RESILIENT O'AHU

RESILIENT O'AHU

The Resilience Office is a Charter-mandated City office created to respond to climate change, resilience, and other sustainability challenges.

Green
City Operations

Reduce Climate
Emissions & Impact

Promote Resilient
Communities

Coordinate with
Federal & State Agencies

Ensure Sustainable
City Plans & Policies

Facilitate Climate
Change Commission

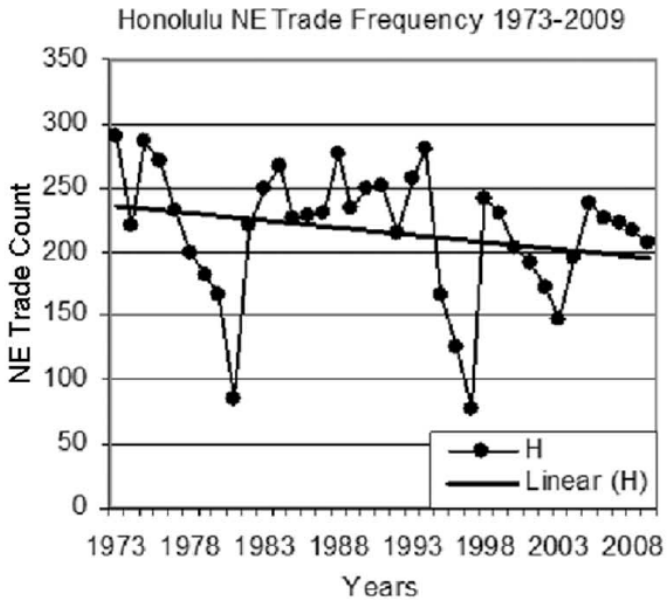
Resilience

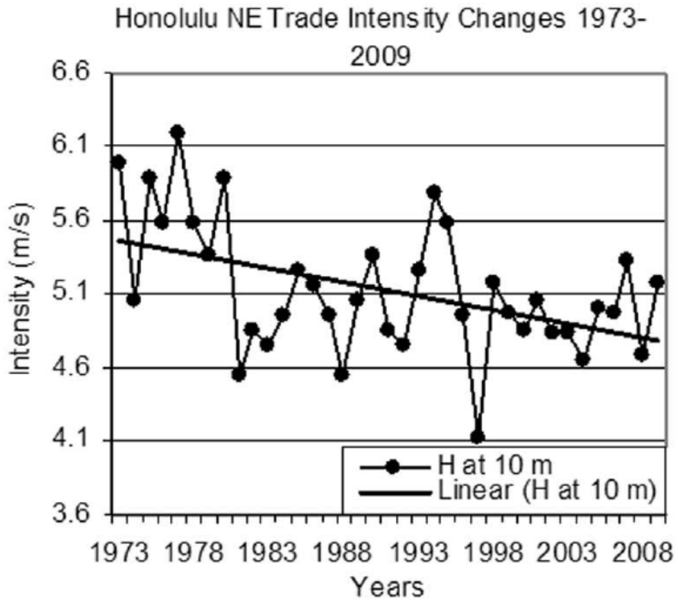
The capacity of individuals, communities, institutions, businesses, and systems to survive, adapt, and thrive no matter what kinds of chronic stresses and acute shocks they experience.

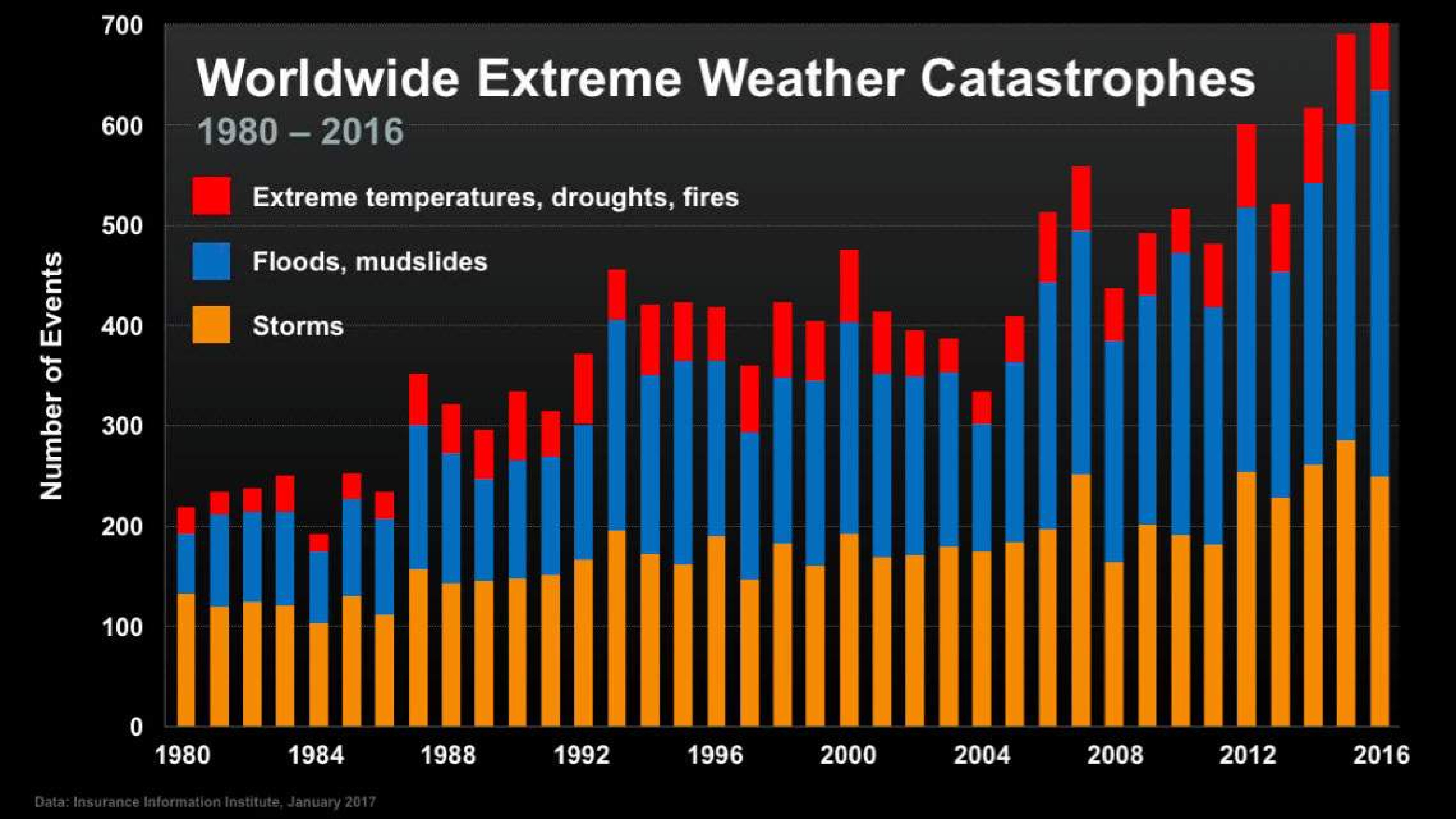
Our Climate

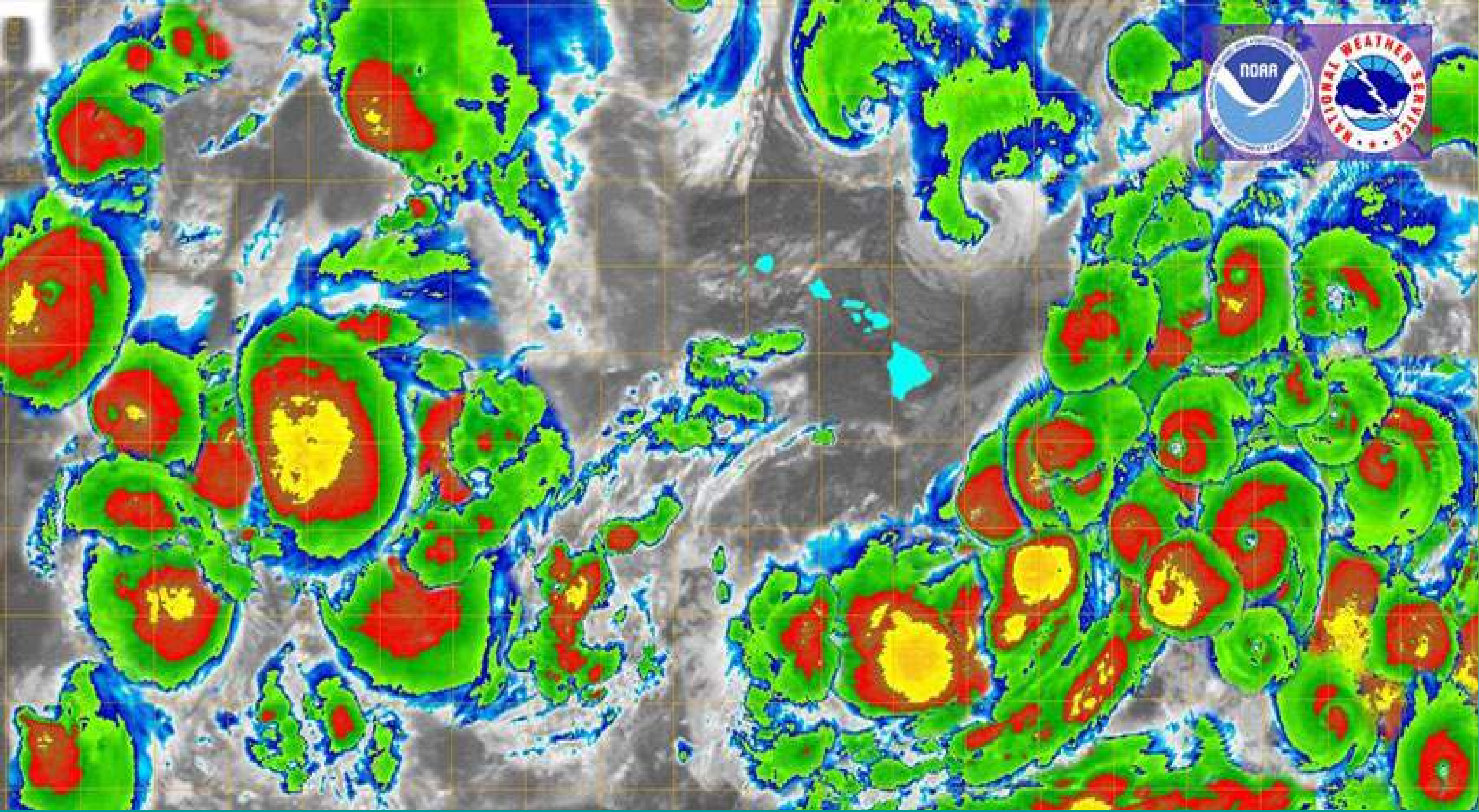
Climate Change is Now

Office of Climate Change, Sustainability and Resiliency



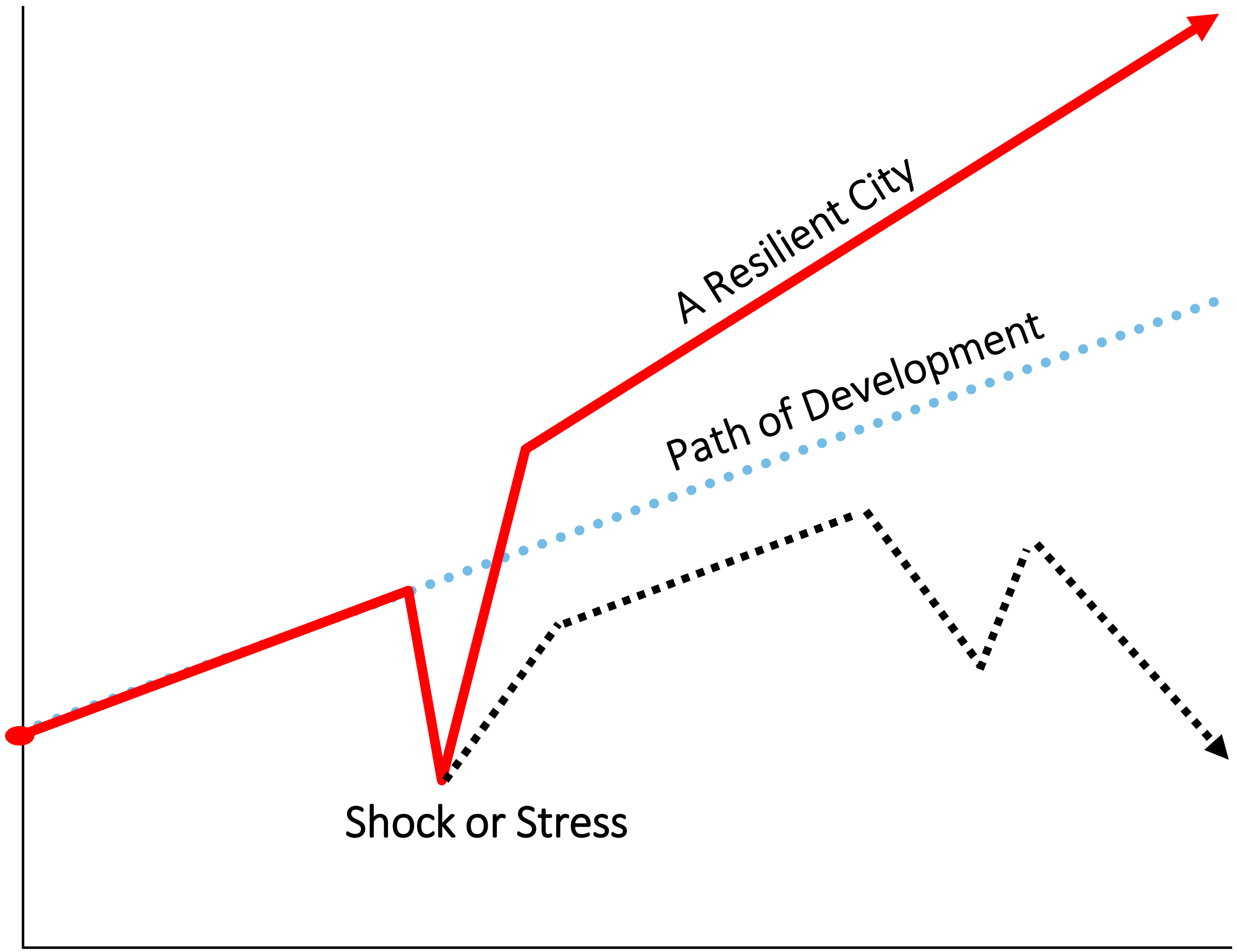



Worldwide Extreme Weather Catastrophes
1980 – 2016
Extreme temperatures, droughts, fires
Floods, mudslides
Storms
Number of Events
0
100
200
300
400
500
600
700
1980
1984
1988
1992
1996
2000
2004
2008
2012
2016
Data: Insurance Information Institute, January 2017


NOAA
NATIONAL WEATHER SERVICE

APRIL 2018


BREAKING NEWS
KALANIANAOLE HIGHWAY UNDER WATER
EAST OAHU
khon2.com
82° 6:10 PM


A Resilient City
Path of Development
Shock or Stress

How do we roll the windows down?

Early Progress

100% Renewable Ground Transportation Goal

35% Tree Canopy Commitment

LED Streetlights, Bike Lanes, Biki & Electric Bus Trials

Mayor's Directive on Climate Change

Office of Climate Change, Sustainability and Resiliency

City Climate Change Commission

- Required to meet at least 2x/yr
- First met on February 7, 2018
- Have met 12x in 13 months

www.resilientoahu.org/about-the-commission

City Climate Change Commission

June 5, 2018, adopted:

Climate Change Brief

Sea Level Rise Guidance

www.resilientoahu.org/guidance-and-publications

July 16, 2018, **Mayor's Directive on Climate Change** (Directive 18-2): *"… the need for **both climate change mitigation and adaptation**… take a proactive approach in **both reducing greenhouse gas emissions and adapting to impacts**…"*

www.resilientoahu.org/s/Mayors-Directive-18-02.pdf

PROJECT DESIGN/REVIEW EXAMPLES

City Center rail station areas planning and design (*HART*)

Prior to Directive 18-2, proactively increased SLR design parameters from 2014 data to 2017 State Report data

Iwilei-Kapālama (*DPP, DDC, CCSR*)

Kapālama Canal, updated SLR data and design conditions for catalytic linear park project

I-K Infrastructure Needs Assessment

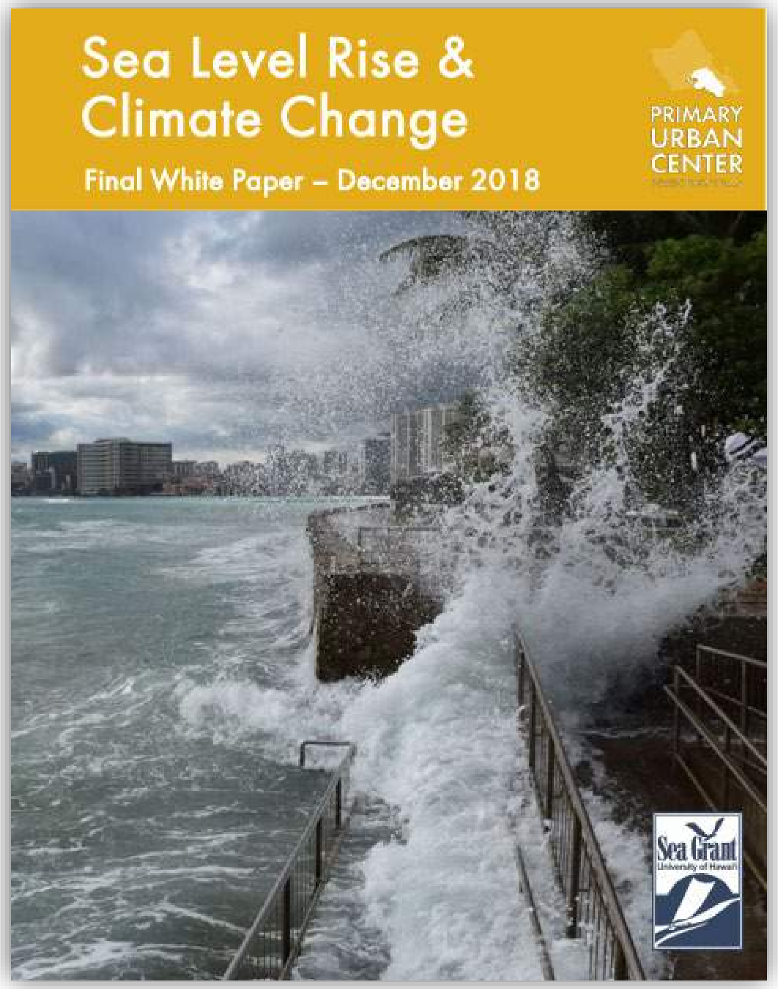
Sand Island Wastewater Treatment Plant Secondary Treatment Facility (*ENV*)

Inclusion of 6 ft SLR, high wave flooding, plus additional uncertainty risk factors for preliminary grading designs

Standard Comments for action reviews (*DPP*)

Office of Climate Change, Sustainability and Resiliency

Primary Urban Center Development Plan



PRIMARY URBAN CENTER
DEVELOPMENT PLAN

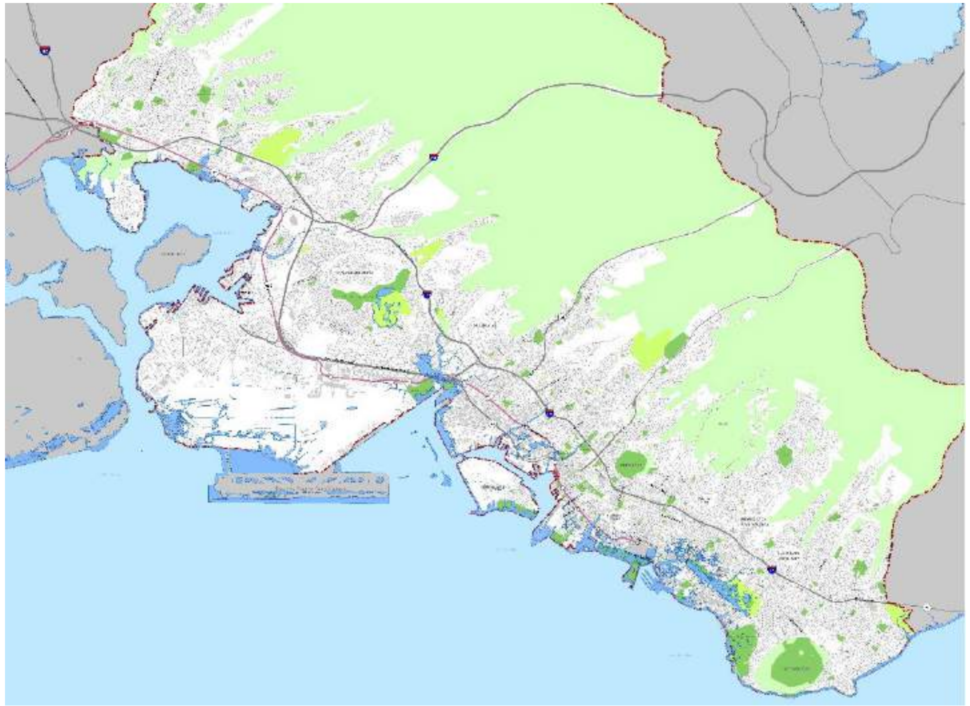
https://www.pucdp.com/copy-of-background-documents

Land Use & Zoning Recommendations
Use of data
SLR-XA maps at summer workshops for targeted community engagement on land use strategies
Concurrently, **TOD Climate Adaptation Guidelines** (*DPP, Resilience Office*)

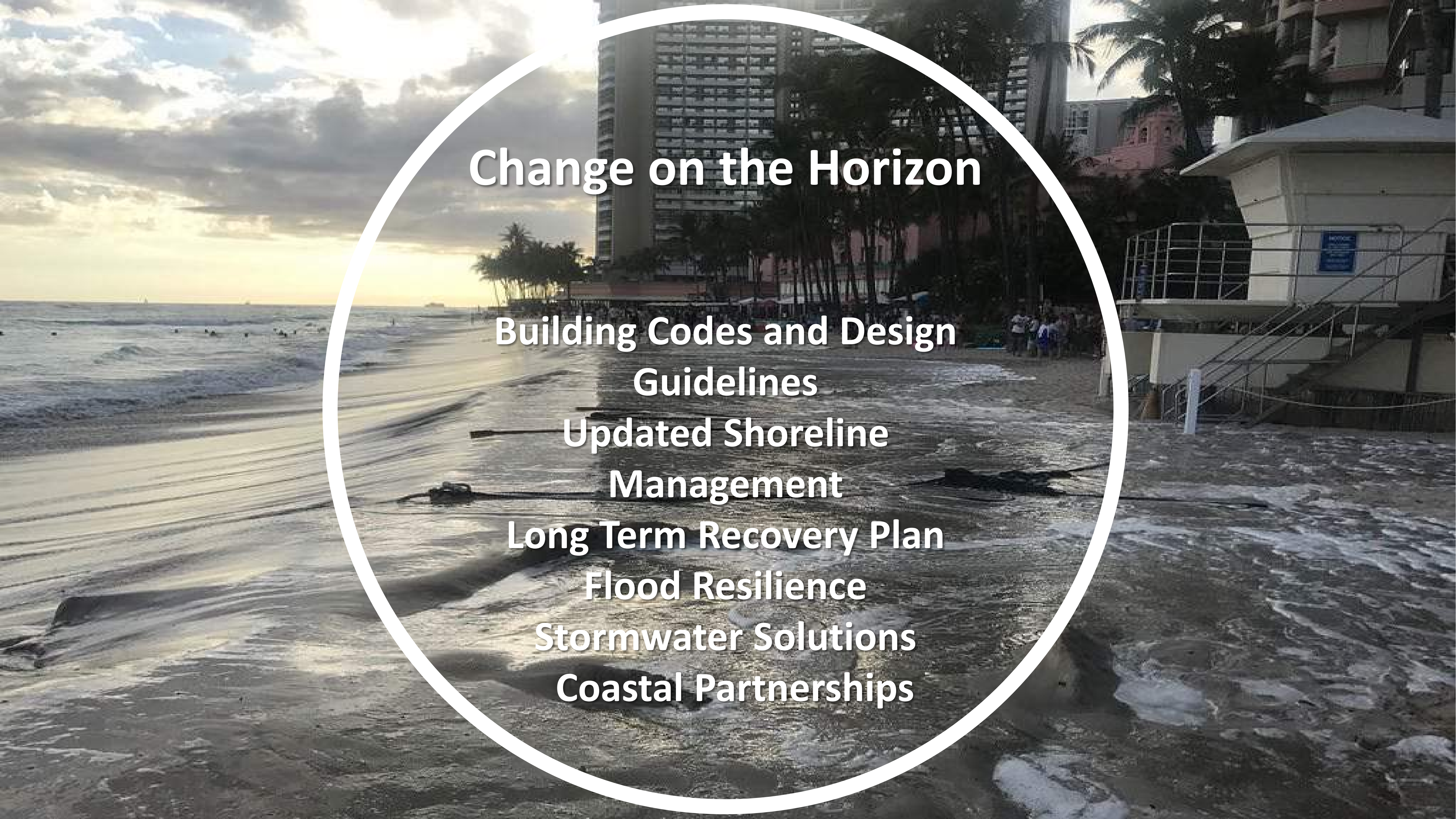
HB1487 HD1 SD2, “Establishes the Honolulu shoreline climate protection project…”

City-State-Federal Coordination, *examples*

- **San Diego, CA**: MOA between Commander, Navy Region SW and San Diego Unified Port District regarding *Coordination and Cooperation Related to Potential Sea Level Rise in the San Diego Bay Region*
- **Norfolk & Virginia Beach, VA**: *Joint Land Use Study* for Navy installations located in the Cities of Norfolk and Virginia Beach
- **State TOD Council Planning and Infrastructure Coordination between the State & City**, Iwilei-Kapālama



DPP, PUC DP
SLR and Climate Change White Paper



Change on the Horizon

Building Codes and Design Guidelines
Updated Shoreline Management
Long Term Recovery Plan
Flood Resilience
Stormwater Solutions
Coastal Partnerships

Office of Climate Change, Sustainability and Resiliency

Annual Sustainability Report

OUR COMMITMENTS

Paris
Aloha+
Chicago
Carbon-Free Economy
2-1.1 | 18-221 | 6-503(c)

Paris
Aloha+
Chicago
Sustainable City Operations
17-67 | 6-107

Paris
Aloha+
Chicago
Clean Transportation
32 | 17-166 | 6-903

Paris
Aloha+
Chicago
100% Renewable Energy
2-8.4 | 16-46 | 6-1703 (g)

Paris
Aloha+
Chicago
Water Security
41-13 | 18-55

Paris = Paris Climate Agreement
Aloha+ = Aloha+ Challenge
Chicago = Chicago Climate Charter

City Charter | City Ordinance | City Council Resolution

To learn more about our City commitments, visit resilientoahu.org/major-initiatives.

In 2016, the same year Honolulu was selected as a member of The Rockefeller Foundation's 100 Resilient Cities, voters created the Office of Climate Change, Sustainability and Resiliency.

Two years later, Honolulu has become one of the leading cities in addressing the impacts of climate change. Honolulu is now signed onto the Paris climate agreement, Chicago Climate Charter, is a member of the Powering Past Coal Alliance, and most recently, was announced as one of 25 winning cities in the $70 million Bloomberg Philanthropies' American Cities Climate Challenge.

In December 2018, the City Council adopted Resolution 18-221 demonstrating strong City support for achieving a 100% renewable-powered City transportation fleet by 2035, as well as a 100% clean energy and carbon neutrality future island-wide by 2045.

This demonstrates that the commitment to a climate resilient O'ahu is one shared by both branches of City government and is institutionalized in the City Charter.

Office of Climate Change, Sustainability and Resiliency

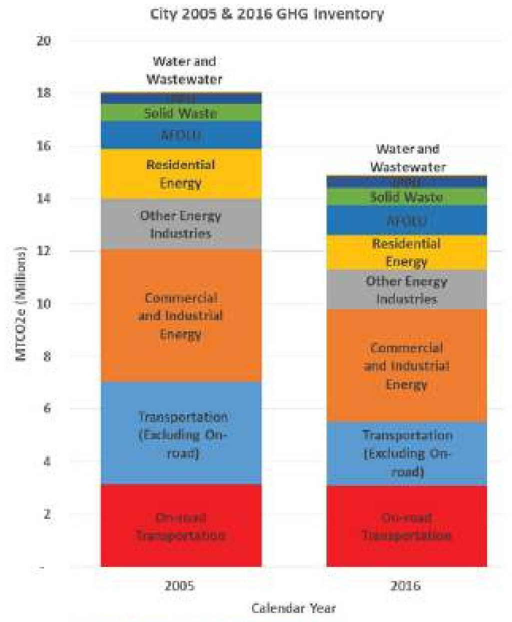
Annual Sustainability Report

ACHIEVING A CARBON NEUTRAL ECONOMY

As part of its commitment to the Paris climate agreement, the City completed its first GHG inventory for calendar years 2005, 2015, and 2016 in the fall of 2018. A GHG Inventory is an accounting of the annual total amount of carbon pollution emissions by sector and source in our island economy, and serves as a benchmark to reduce our emissions each year moving forward. The GHG Inventory is also used to identify the largest sources of emissions so we can set island-specific carbon reduction targets and pinpoint clear strategies to achieve those goals.

The City utilized the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC Protocol) along with state-of-the-art modelling tools to develop the inventories. We also worked with experts from ICLEI – Local Government for Sustainability, development partner, AECOM, the County of Hawai'i, County of Kaua'i, County of Maui, and the State of Hawai'i to ensure that our inventory is accurate and compatible with other county inventories in the State. The general guidance from climate scientists is that we must decrease our carbon emissions by 50% each decade going forward to avoid the most catastrophic impacts of climate change, and the State has a mandate to be carbon neutral by 2045.

From 2005 to 2016, O'ahu's total GHG emissions decreased by 17.4%



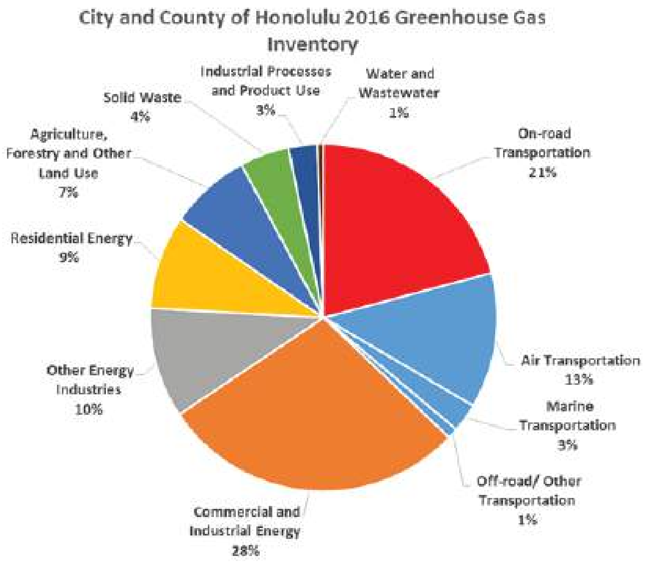
and, per capita emissions decreased by 24.48%.

Office of Climate Change, Sustainability and Resiliency

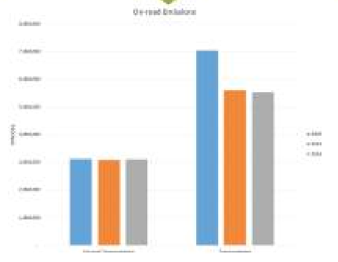
Annual Sustainability Report

ACHIEVING A CARBON NEUTRAL ECONOMY

OUR PATH TO SUCCESS

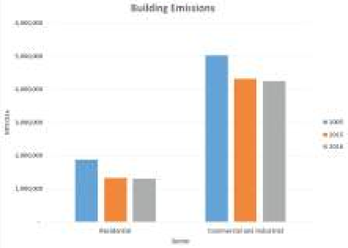


On-Road Transportation Emissions



From 2005 to 2016, on-road transportation emissions **decreased by only 0.27%** while overall transportation emissions decreased by 21.3%.

Residential Building & Commercial and Industrial Building Emissions



Total building emissions **decreased 19.8%** from 2005 to 2016, but is still the largest category of emissions.

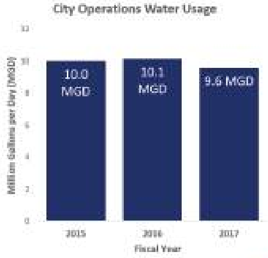
While overall estimated GHG emissions went down between 2005 and 2016, we have further to go to achieve the Paris climate agreement goal of 26% to 28% by 2025, and the State's carbon neutrality and 100% renewable energy goals by 2045. Reductions in emissions in the on-road and off-road transportation categories have lagged these gains. **This data confirms the urgency and need for the City Administration's commitment to 100% renewable fuels for transportation island-wide by 2045, and for the City fleet by 2035.** Energy use in buildings is another area where we need to become more efficient. Energy use in O'ahu's built environment represents 37% of our carbon footprint.

Annual Sustainability Report

SUSTAINABLE CITY OPERATIONS

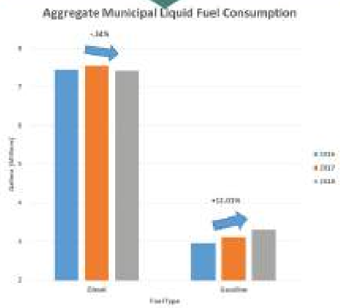
OUR PATH TO SUCCESS

TRACKING — Municipal Water Usage



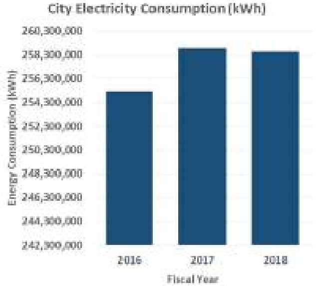
In FY2017, City operations consumed **9.6 million gallons per day** of water and was billed **$11.9 million** for water consumption.

TRACKING — City Fleet Fossil Fuel Usage



Gasoline usage **increased by 12%** from FY2016 to FY2018. Diesel usage **decreased by 0.3%**

TRACKING — Municipal Energy Consumption



In 2018, the City operations used **258,593,973 kWh**, a 1.30% increase from 2016.

TRACKING — On-site Re-use of Methane

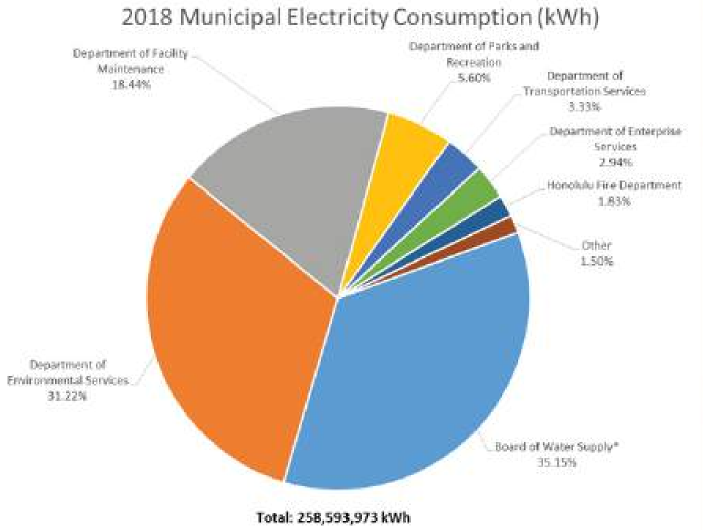
Methane is a potent greenhouse gas but can offset our power needs. A pilot wastewater plant generates approximately **800,000 THERMS** of energy annually, enough to power 0.86% of O'ahu households.

ISLAND-WIDE LED STREET LIGHT CONVERSION PROJECT

The City is in the process of replacing 53,500 streetlights with LED (light-emitting diode) lights across O'ahu. At a total project cost of $46 million, fully-financed by a local bank and guaranteed by an energy performance contract, the project is on schedule to be completed by December 2019. In addition to providing high-quality, warmer, and safer lighting levels, the high-efficiency LEDs are forecasted to save taxpayers $5 million per year and reduce GHG emissions by 14,400 tons – the equivalent of 2,800 homes.

ELECTRICITY USAGE

SUSTAINABLE CITY OPERATIONS



DEPARTMENT OF DESIGN AND CONSTRUCTION:

- DDC began converting the City's approximately 53,500 legacy street lights to LED.

DEPARTMENT OF LAND MANAGEMENT:

- Hawai'i Smart Program installed energy saving projects in affordable housing worth $177,150. These energy saving projects resulted in savings of $123,674.
- Chinatown Gateway Plaza Parking Garage Light Improvements: The lighting modernization project in the building and parking garage is expected to save 176,777 kWh per year and $42,957 per year.

BOARD OF WATER SUPPLY:

- Photovoltaic systems continue to be installed at outlying stations. Beretania Complex carport PV construstion starts at the end of CY2018 and will continue through CY2019 as part of their Energy Savings Performance Contract.

2016
255,272,128 KWH

2017
258,840,468 KWH

2018
258,593,973 KWH

TOTAL COST:
$66,141,752

ANNUAL CITY ENERGY USE

FUEL USAGE

SUSTAINABLE CITY OPERATIONS

BOARD OF WATER SUPPLY:

- BWS continued implementation of their Energy Savings Performance Contract (ESPC) which included replacing seventeen conventional combustion engine vehicles with sixteen hybrid vehicles and one plug-in hybrid vehicle.

DEPARTMENT OF TRANSPORTATION SERVICES:

- 2035 fleet goals: DTS Continued development of plans to install depot EV charging stations at Middle Street, testing of e-buses to redesign route and rate structures to support electrification, and budgeting for purchases of battery electric buses.

Department	Diesel	Biodiesel	Gasoline	Propane	Total Consumption
Department of Transportation Services	5,421,841		1,191,322		6,613,163
Honolulu Police Department	2,365		1,385,150	1,476	1,388,981
Department of Facility Maintenance	1,173,835	293,459	464,036	10,780	1,942,110
Board of Water Supply	61,400		174,600		236,000
Honolulu Fire Department	166,480		45,517	2,333	214,330
Department of Environmental Services	111,966	27,992		18,172	158,130
Honolulu Emergency Services Department	101,592	25,398	15,633		142,623
Department of Enterprise Services	15,930	3,982	31,563		51,475
Honolulu Authority for Rapid Transit	5,947		1,446	62	7,454
Department of Community Services			6,313		6,313
Department of Parks and Recreation	3,404	851		3,374	7,629
Department of Emergency Management	0				0
Customer Services Department	0				0
TOTAL	7,064,750	351,682	3,314,570	36,197	10,767,207

*Future reports will reflect increasing specificity in data available for specific fuel types (diesel versus B20 diesel)

2016
10,219,333 GAL

2017
10,358,855 GAL

2018
10,415,525 GAL

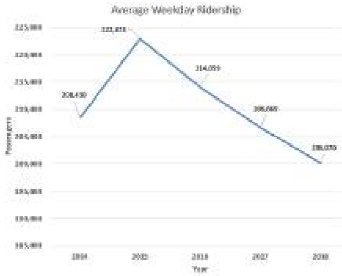
TOTAL COST:
$28,454,251

ANNUAL CITY FOSSIL FUEL USE

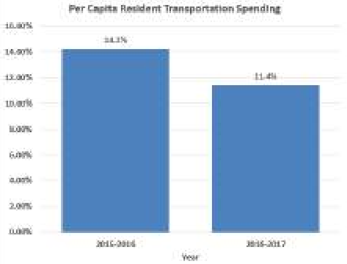
CLEAN & AFFORDABLE TRANSPORTATION

OUR PATH TO SUCCESS

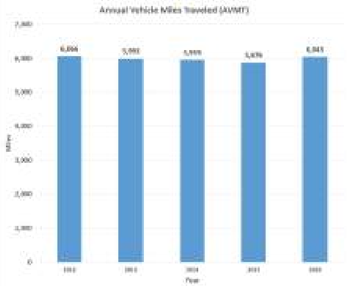
TRACKING	TRACKING	TRACKING	GOAL
Public Transportation Use	Per Capita Resident Spending on Transportation	Reduce Per Capita Vehicle Miles Traveled	Increase Dedicated Bike Lanes 40% by 2021



Average weekday ridership of TheBus has **decreased 4.9%** since 2014.



In FY2017, residents spent an average of **11.4%** of their household income on transportation.



In 2016, the total per capita AVMT was **6,042.86**, an increase of **2.8%** from 2015

In 2018, the City added **1.47 miles** of dedicated bike lane. To meet our goal, we must add **0.39 miles** per year through 2021.

ELECTRIC BUS FLEET

The Mayor's commitment to convert the City's fleet to 100% renewable fueled vehicles by 2035 is driven by transitioning our Bus fleet to electric buses. In spring of 2018, the City tested Proterra electric buses on 23 routes across O'ahu. With our bus fleet using over 6 million gallons of fuel per year, moving to electric buses will help our island community become more sustainable and resilient. JTB, the private transportation company, also launched private e-buses in early 2019 proving that green transportation solutions work on O'ahu.

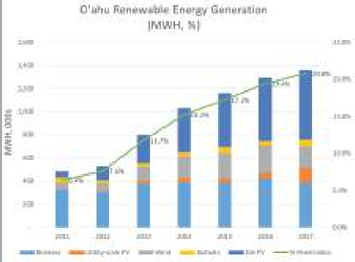
Office of Climate Change, Sustainability and Resiliency

Annual Sustainability Report

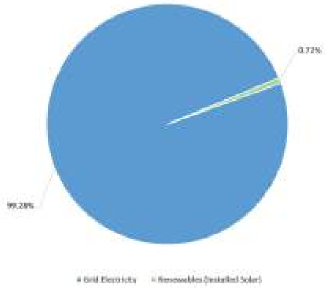
100% RENEWABLE ENERGY FUTURE

OUR PATH TO SUCCESS

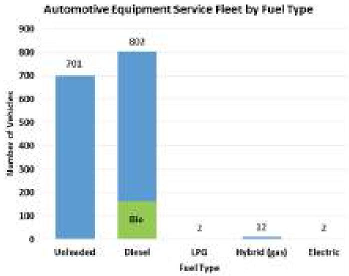
GOAL	TRACKING	GOAL	GOAL
100% of Oahu's Energy Will Come From Renewables by 2045	City On-site Renewable Energy Generation	100% Renewable City Fleet by 2035	100% Renewable Energy Ground Transportation by 2045



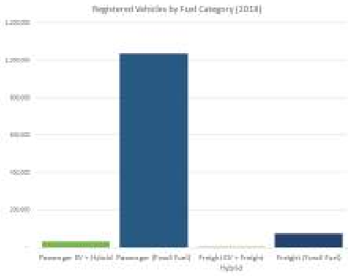
In 2017, renewable energy accounted for **20.8%** of all energy generation on O'ahu, an increase of 1.4% over 2016.



In 2018, on-site City renewable generation was **0.72%** versus **99.28%** grid electricy.



In FY2018, the City passenger fleet included **2 electric** and **12 hybrid** vehicles.



In 2018, **3.13%** of registered passenger vehicles on O'ahu were electric or hybrids.

SOLAR PENETRATION

Honolulu remains #1 in the U.S. for per capita solar capacity.

"I am proud that Honolulu continues to lead the nation with the highest solar PV capacity per capita. As more residents install rooftop solar to power their homes, heat their water, and lower their energy costs, our city moves closer to achieving the goal of decarbonizing our economy."

- Mayor Kirk Caldwell

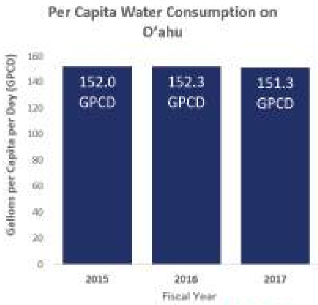
Office of Climate Change, Sustainability and Resiliency

Annual Sustainability Report

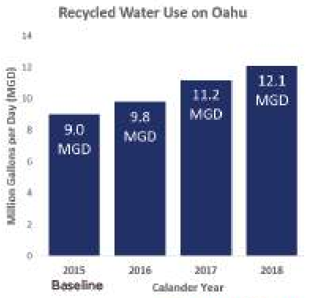
WATER SECURITY & GREEN INFRASTRUCTURE

OUR PATH TO SUCCESS

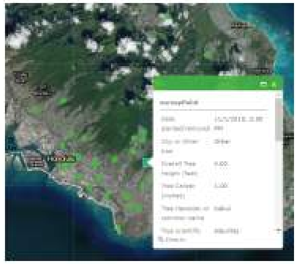
GOAL	TRACKING	GOAL	GOAL
Reduce Per Capita Water Consumption to 145 Gallons Per Day by 2045	Double the Amount of Wastewater Reused by 2030.	Plant 100,000 Trees Across O'ahu by 2025	Increase Oahu's Urban Tree Canopy to 35% by 2035



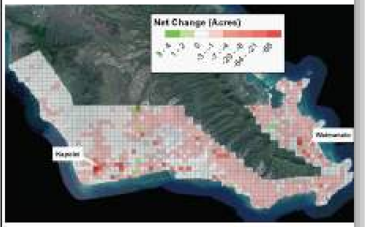
O'ahu residents consume **151.3 gallons** per capita per day.



O'ahu currently uses **12.1 million gallons per day** of recycled water.



Since December 2017, **2,147** trees have been planted by the City across O'ahu.



In 2013, tree canopy coverage decreased nearly 5% from 2010 to **23%**.

TREE PLANTING APP

The Resilience Office maintains a map tracking the 100,000 tree goal, where both City and other tree plantings can be recorded toward this effort. This app is available at https://www.resilientoahu.org/urbanforest/. The Resilience Office is working with the Department of Parks and Recreation Division of Urban Forestry to expand this platform and make sure community groups and citizens across O'ahu utilize it.

CLIMATE RESILIENCE

OUR PATH TO SUCCESS

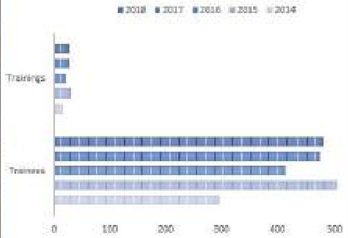
TRACKING
Beach Loss

O'ahu has approximately 66 miles of sandy shoreline and beach. Since 1949, about **25%** of O'ahu's sandy beach has narrowed or been completely lost in part due to to artificial hardening of the shoreline.

TRACKING
Hurricane Preparedness

It is estimated that **64%** of all single-family homes on O'ahu lack sufficient hurricane wind resistance.

TRACKING
Community Response



480 individuals CERT (Community Emergency Response Team) trained in 2018 at **27 trainings.**

TRACKING
Informed Residents

49,801 HNL.info app downloads

HNL.info gives users a real-time, direct connection to City information. In an emergency situation, the app could be utilized to distribute critical messages and updates.

COMMUNITY PREPAREDNESS

The City participated in nine community-organized disaster preparedness fairs across the island in 2018. From Mānoa to the Wai'anae Coast, departments including the Honolulu Fire Department, Honolulu Police Department, Department of Emergency Management, Board of Water Supply, and the Resilence Office have had informational tables at these events where they helped educate the public about how to be better prepared for hazards such as floods, fires, storms, tsunamis, and earthquakes. Over 8,300 residents attended the preparedness fairs.

HOW WE COMPARE: NATIONAL GRADES & RATINGS

While we recognize O'ahu is unique, its helpful to compare our progress to other communities as we all race to become more sustainable and resilient. Year over year, we will track our progress in these national benchmarks and continue to improve our progress over time.

CDP Carbon Disclosure Project
Progress Toward Environmental Stewardship
C
Scale: A to D-

UN Sustainable Development Goals
Sustainable Cites & Communities
#10
Out of 100 US Cities

ParkScore 2018
ParkScore
Acreage, Investment, Amenities, & Access
#48
Out of 100 US Cities

W WalletHub
WalletHub
Greenest Cities in America
#6
Out of 100 US Cities

The City has submitted information to be included in the American Council for an Energy Efficient Economy *2019 Clean City Energy Scorecard*. The results of this scorecard will be included in the next edition of this report.

ACEEE
American Council for an Energy-Efficient Economy

RESILIENT O'AHU


Mahalo
RESILIENT O'AHU
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Barry Usagawa

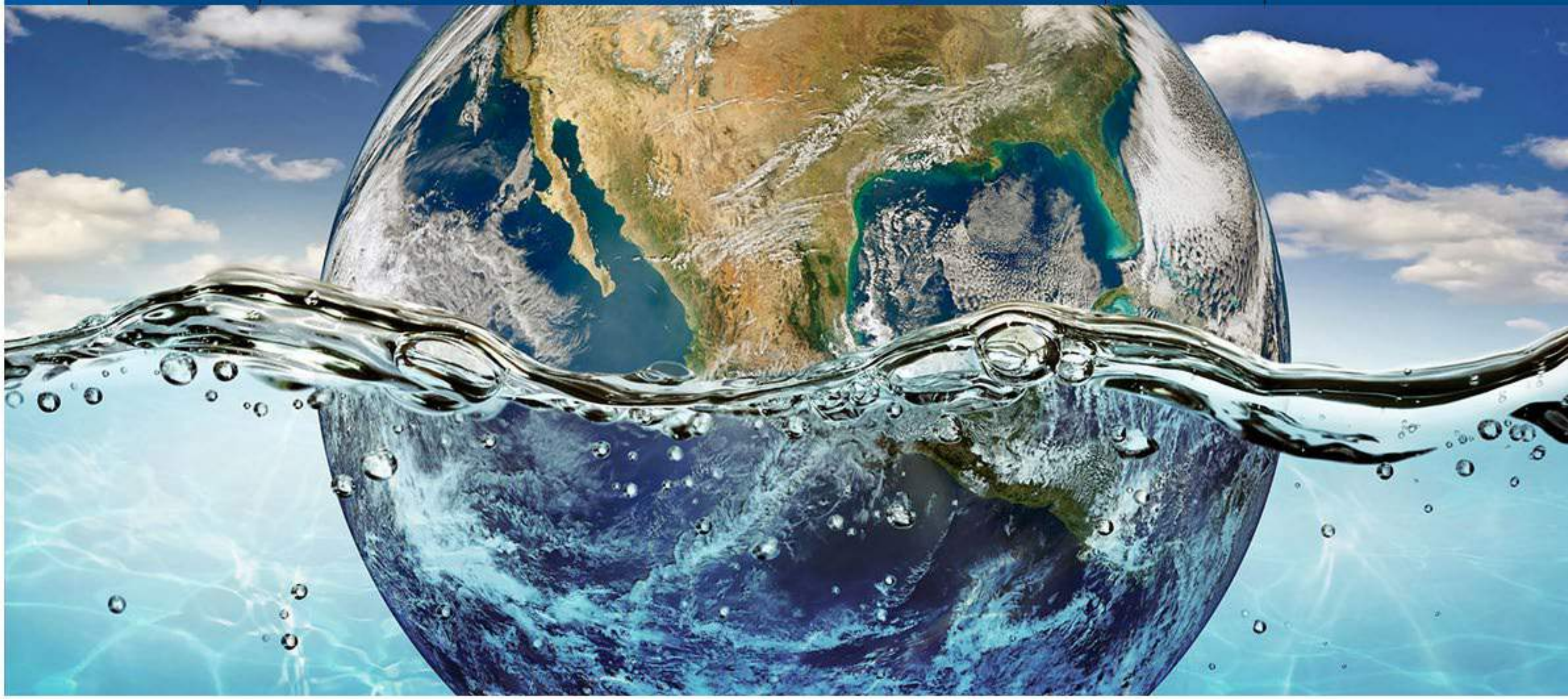
Program Administrator
Water Resources Division
Honolulu Board of Water Supply
City and County of Honolulu

CLIMATE CHANGE PANEL DISCUSSION

BWS Strategic Plan

Water Utility Climate Alliance

About Us | Member Agencies | Plans & Publications | Training & Presentations | Contact



Delivering reliable, high-quality water requires a delicate balance between water supplies and customer demands.

While water managers continually strive to maintain this supply-and-demand balance through long-term water resource planning and demand management, new challenges exist due to the impacts of climate change, putting the world's water resources at risk.

The Water Utility Climate Alliance (WUCA) is dedicated to enhancing climate change research and improving water management decision-making to ensure that water utilities will be positioned to respond to climate change and protect our water supplies.

April 25, 2019

Impacts of Climate Change on Honolulu Water Supplies and Planning Strategies for Mitigation

Barry Usagawa, P.E., Water Resources, Board of Water Supply

Objectives

- Evaluate climate change impacts on Honolulu Board of Water Supply (BWS) infrastructure and water supply
- Develop a suite of strategies to address the anticipated changes

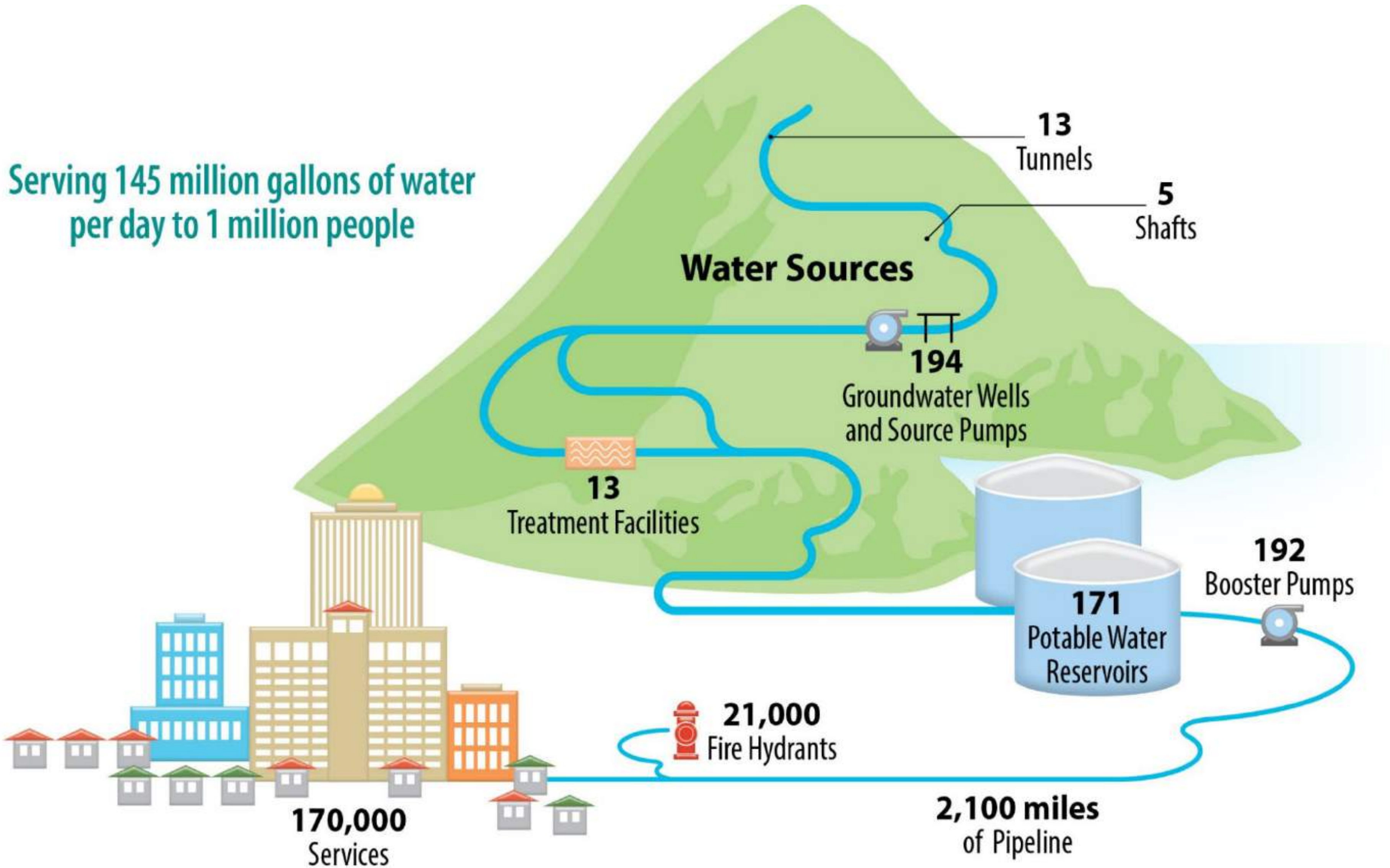
This project supports Water Research Foundation's (WRF) Climate Change Strategic Initiative objective to provide water utilities with a set of tools to assess their vulnerabilities and develop applicable adaptation strategies.

Jointly funded by Honolulu Board of Water Supply and Water Research Foundation through Water Research Foundation's Tailored Collaboration Program

Board of Water Supply

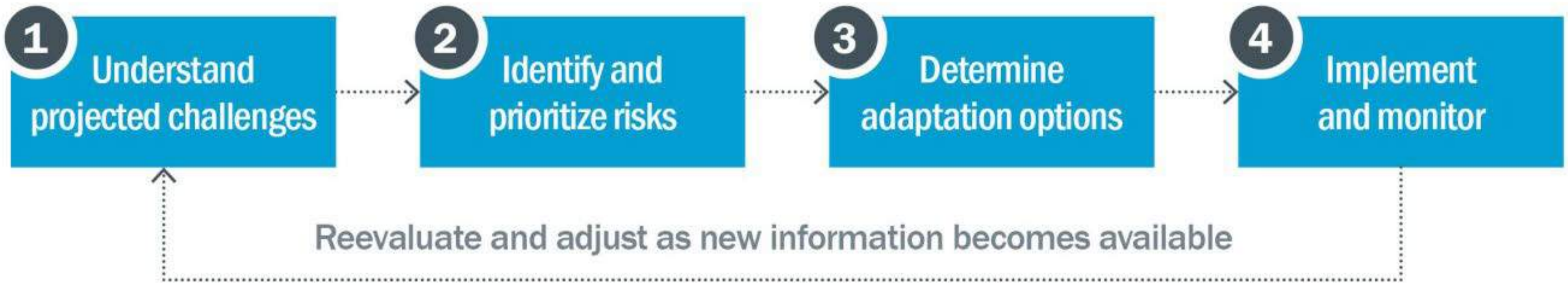
THE Water Research FOUNDATION

The BWS Water System is Large and Complex



Project Approach

- Adaptive management is an iterative process for flexible decision making in the face of uncertainties
- Utilized scenario planning to consider a range of potential changing conditions

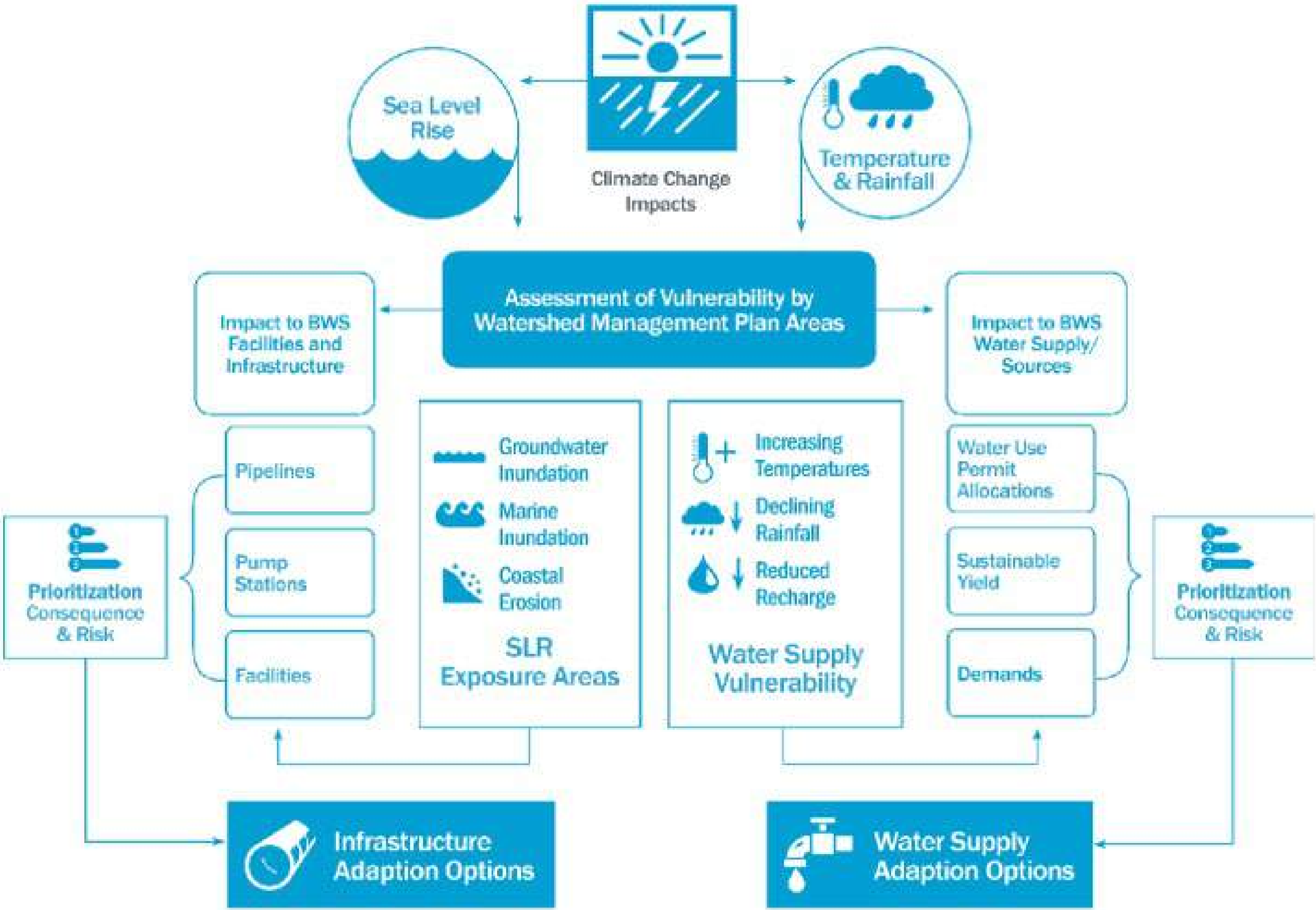


Vulnerabilities & adaptive management strategies identified for 3 time frames:

- Short-term (2020–2030)
- Mid-term (2030–2050)
- Long-term (2050–2100)

Goal is to develop policies and actions that encourage “no regrets” strategies.

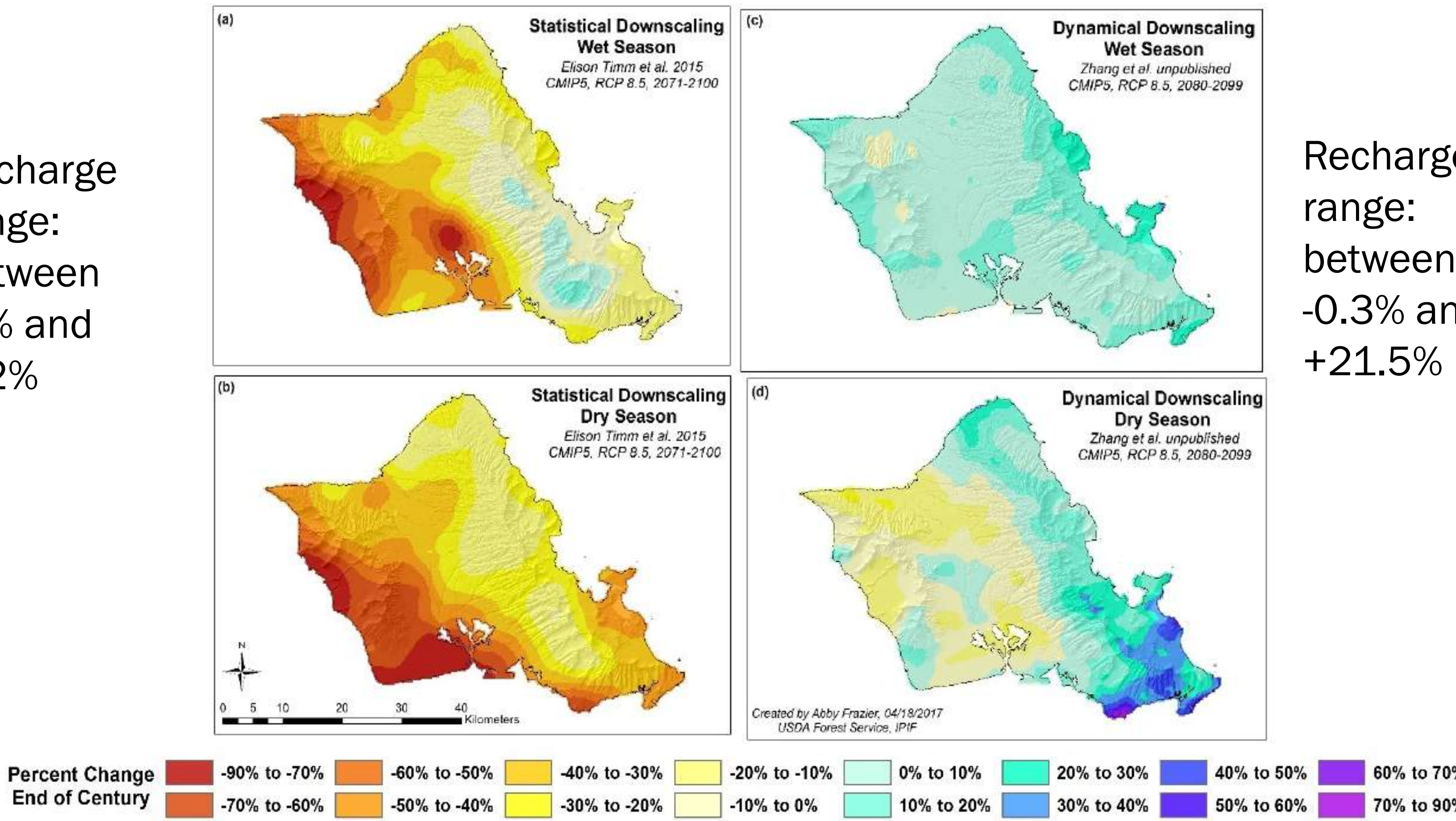
Vulnerability Assessment Approach



Downscaled Climate Models indicate a Range of Rainfall Futures

Climate Change - Rainfall Projections

Recharge range: between -4% and -72%

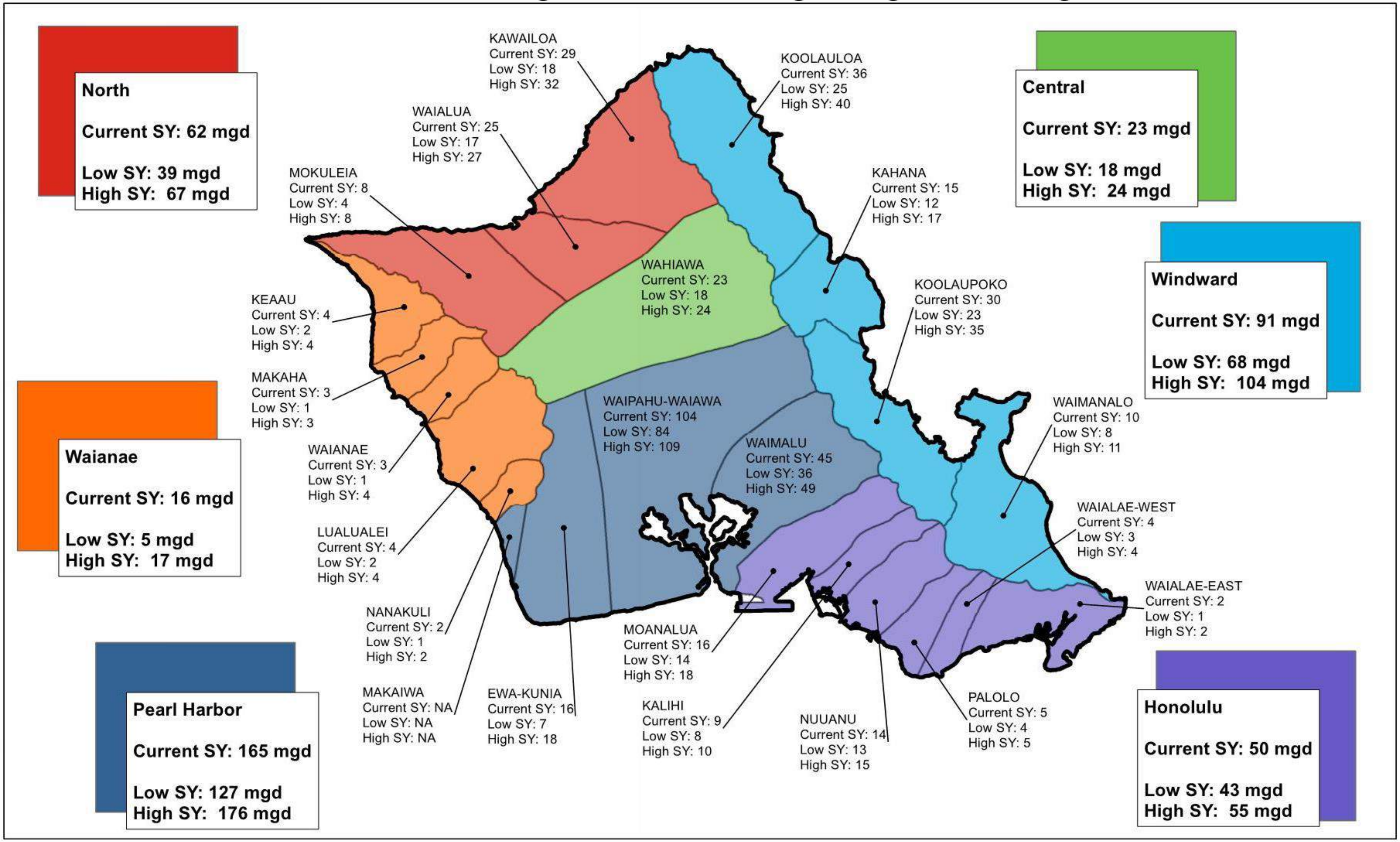


Recharge range: between -0.3% and +21.5%

Source: Figure developed by Abby Frazier April 2017

Current SY and Potential Range of SY from Climate Forecasts

Current: 407 mgd, Low: 300 mgd, High: 443 mgd



Preliminary Supply Adaptation Strategies:

Recharge could decrease Oahu sustainable yields by ~27%. Statistical model From 407 mgd to 300 mgd a difference of 107 mgd, Turk, Report #9, B&C.

- Reduce per capita water demand from 155 gpcd to 100 gpcd through aggressive water conservation, like dual plumbing with recycled water
- Storm water capture in Nuuanu and on-site for new development
- Expanded Reuse at Honouliuli, Mililani, Wahiawa and Schofield WWTP's
- On-site reuse
- Increase transfers from Wahiawa and Waipahu Waiawa aquifers to Waianae and Honolulu. Drill more wells in Wahiawa and Waipahu-Waiawa
- Assertion of Public Trust Water Rights for Domestic Use to retain water use permits in a revocation process
- More desalination in Ewa and possibly for Honolulu
- Desalinated reuse in Honolulu, Waianae and Hawaii Kai where wastewater effluent is too salty for irrigation
- Indirect or Direct Potable Reuse with RO desalination and UV/Ozone disinfection

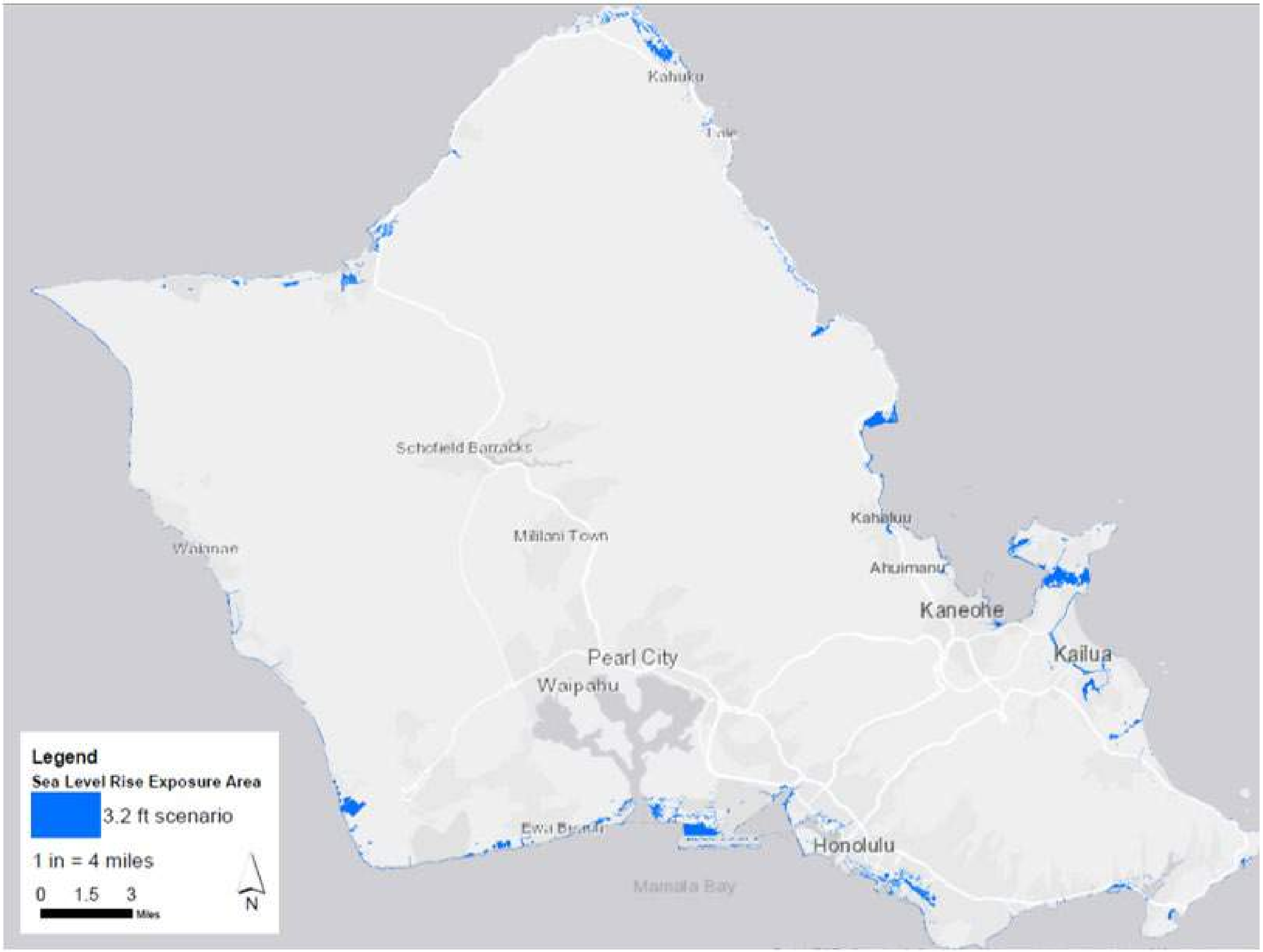
Infrastructure Impacts from Sea Level Rise

Brown AND Caldwell

Board of Water Supply

Water Research Foundation℠

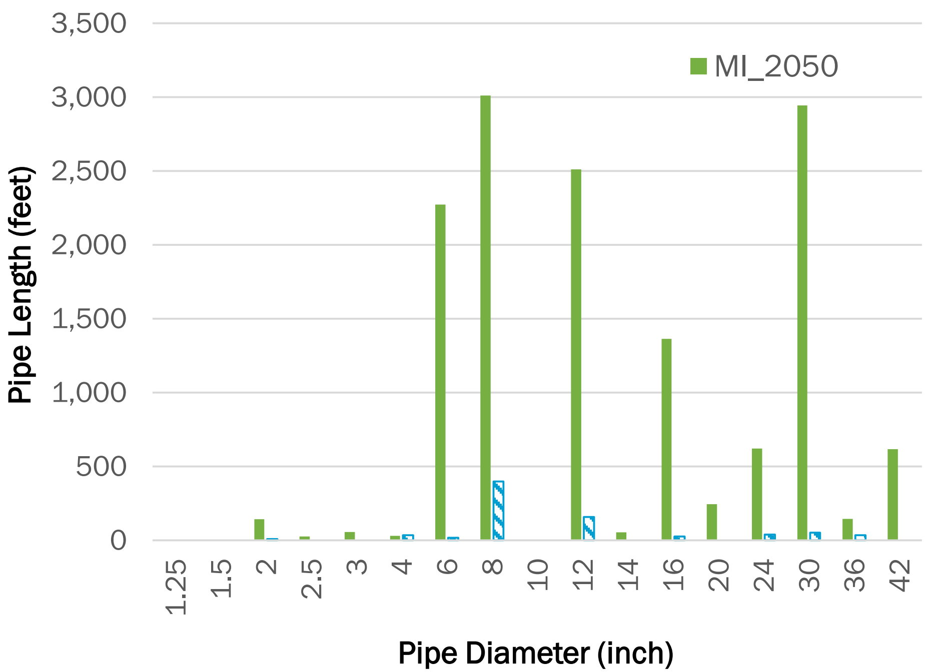
3.2 feet of SLR Exposure Areas on Oahu

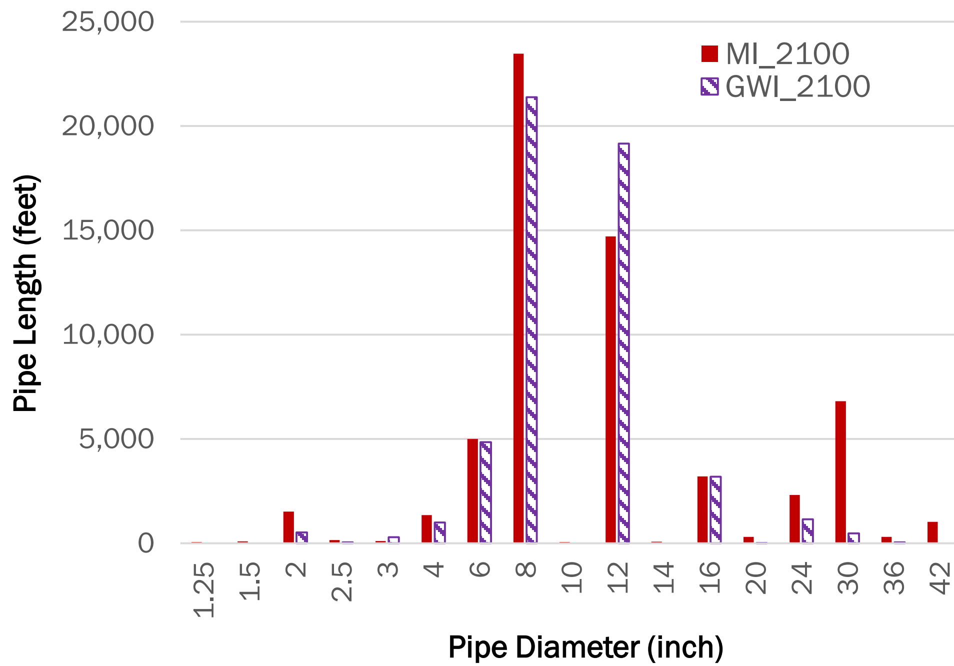


24 Low Elevation/Coastal Water Pipeline Bridge Crossings may be subject to coastal erosion impacts.

Corrosion impacts to 21 miles of metallic pipelines with 3.2’ of SLR by 2100

Pipe Lengths Impacted Island-wide by Hazard (feet)						
Time Period	Year	SLR (feet)	Pipe Length for All Diameters (1.25-inch to 42-inch (feet)		Percent of Total BWS Infrastructure Impacted	
			MI	GWI	MI	GWI
Mid-Century	2050	1	14,038	772	0.1%	0.01%
End-of-Century	2100	3.2	60,409	52,026	0.6%	0.5%





Nimitz & Alakawa, July 3, 2018, 8:00 am, Lowest high tide of the day. Highest tide 1’ higher

2017 - King Tide - Waikiki

Courtesy of OCCSR

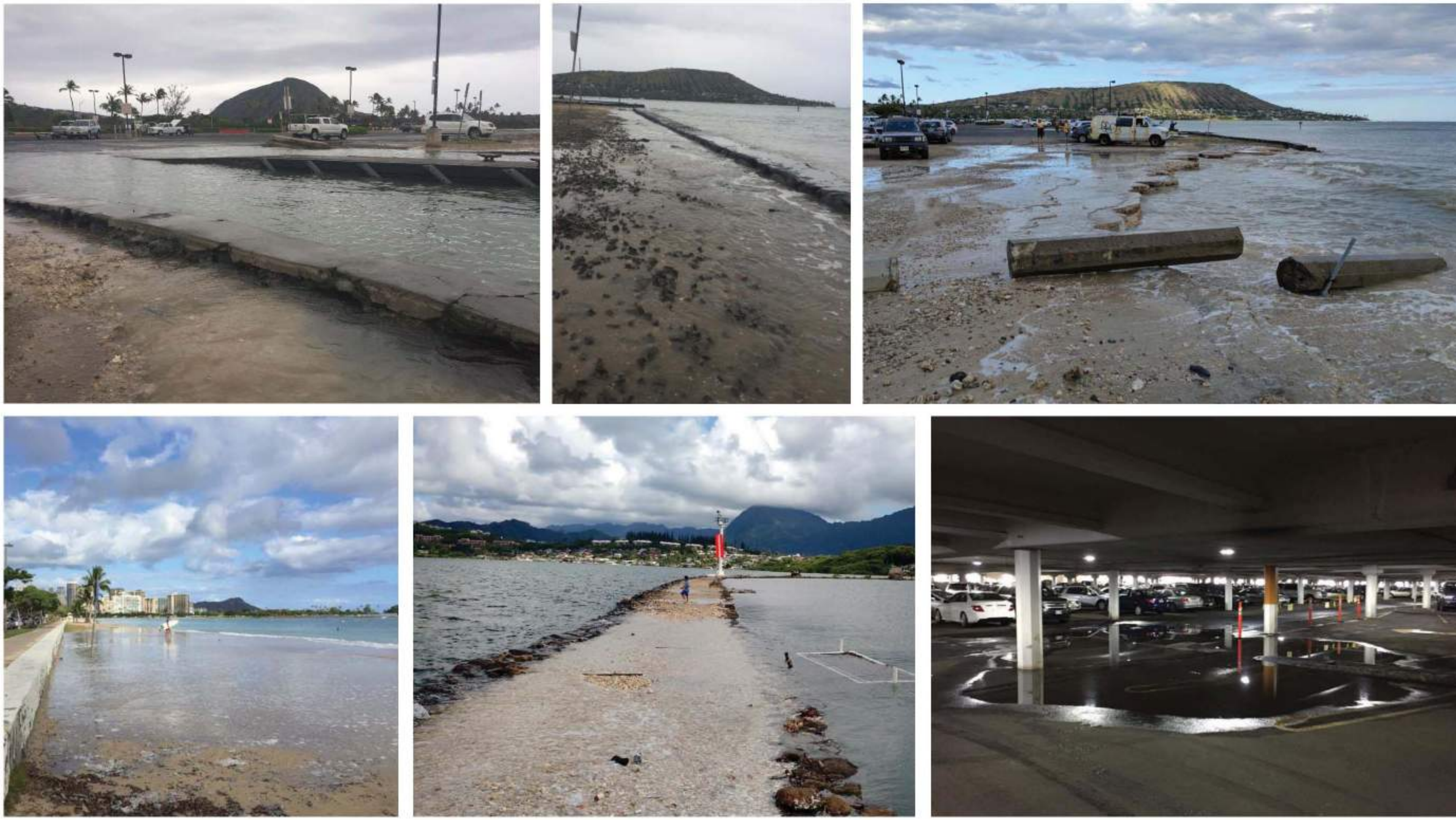
2017 - King Tide – Ala Wai Canal

Courtesy of OCCSR

2017 - King Tide - Mapunapuna

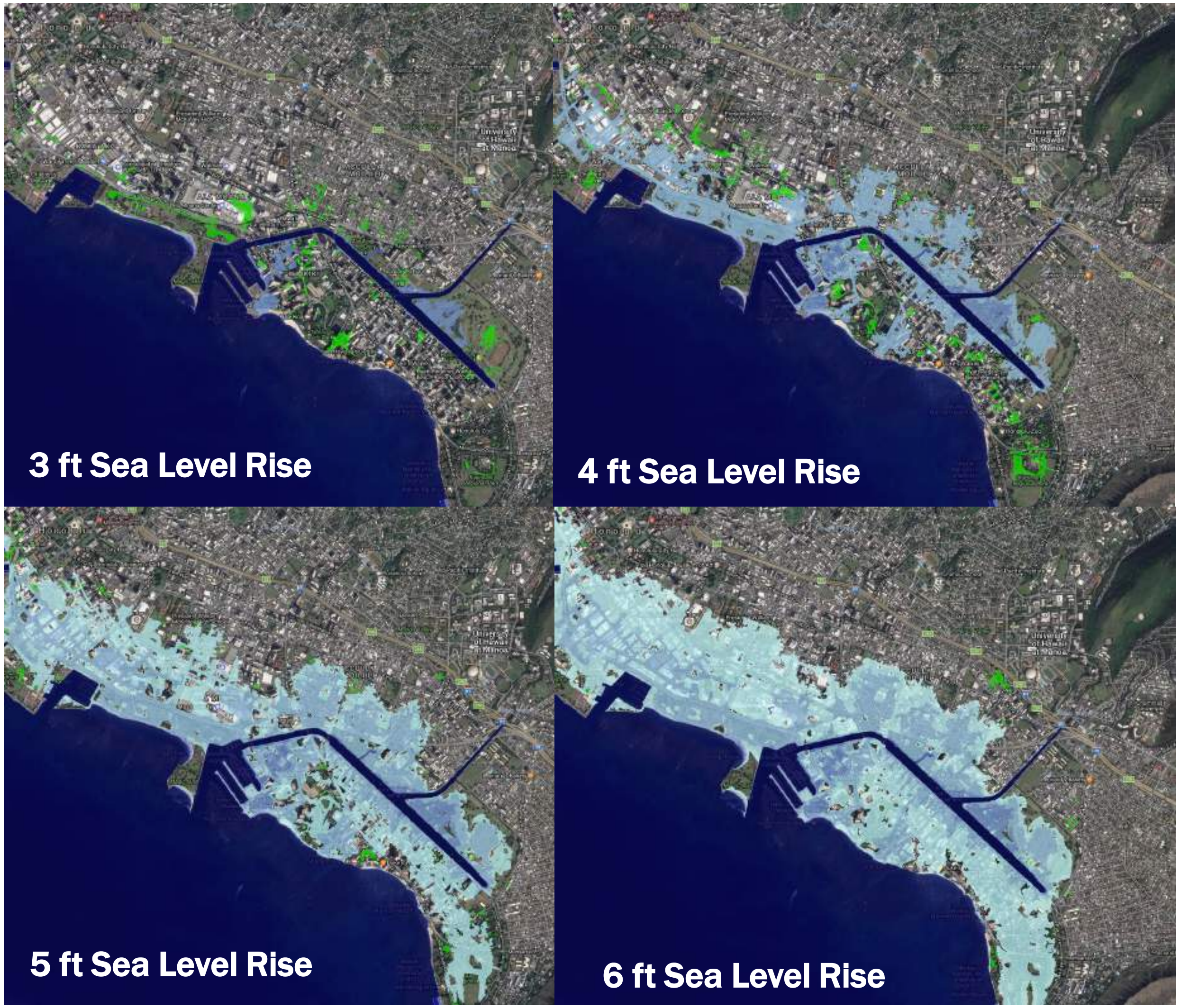
Courtesy of OCCSR

2017 - King Tide – Maunalua, Ala Moana



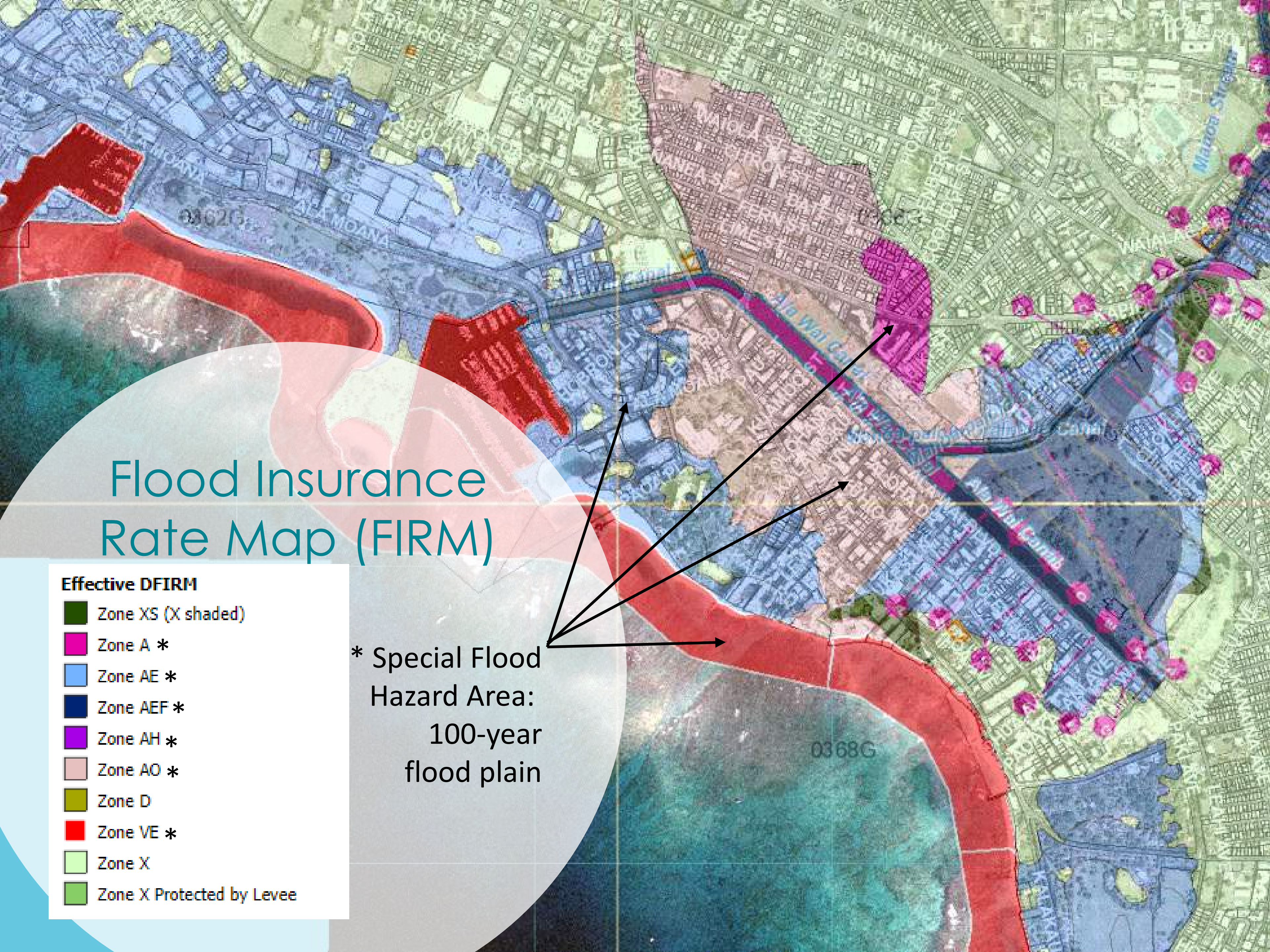
Courtesy of OCCSR

End-of-Century Sea Level Rise Could be Greater



Source: Habel et al. 2017

Flood Insurance Rate Map (FIRM)



Miami

STORMWATER MANAGEMENT MASTER PLAN

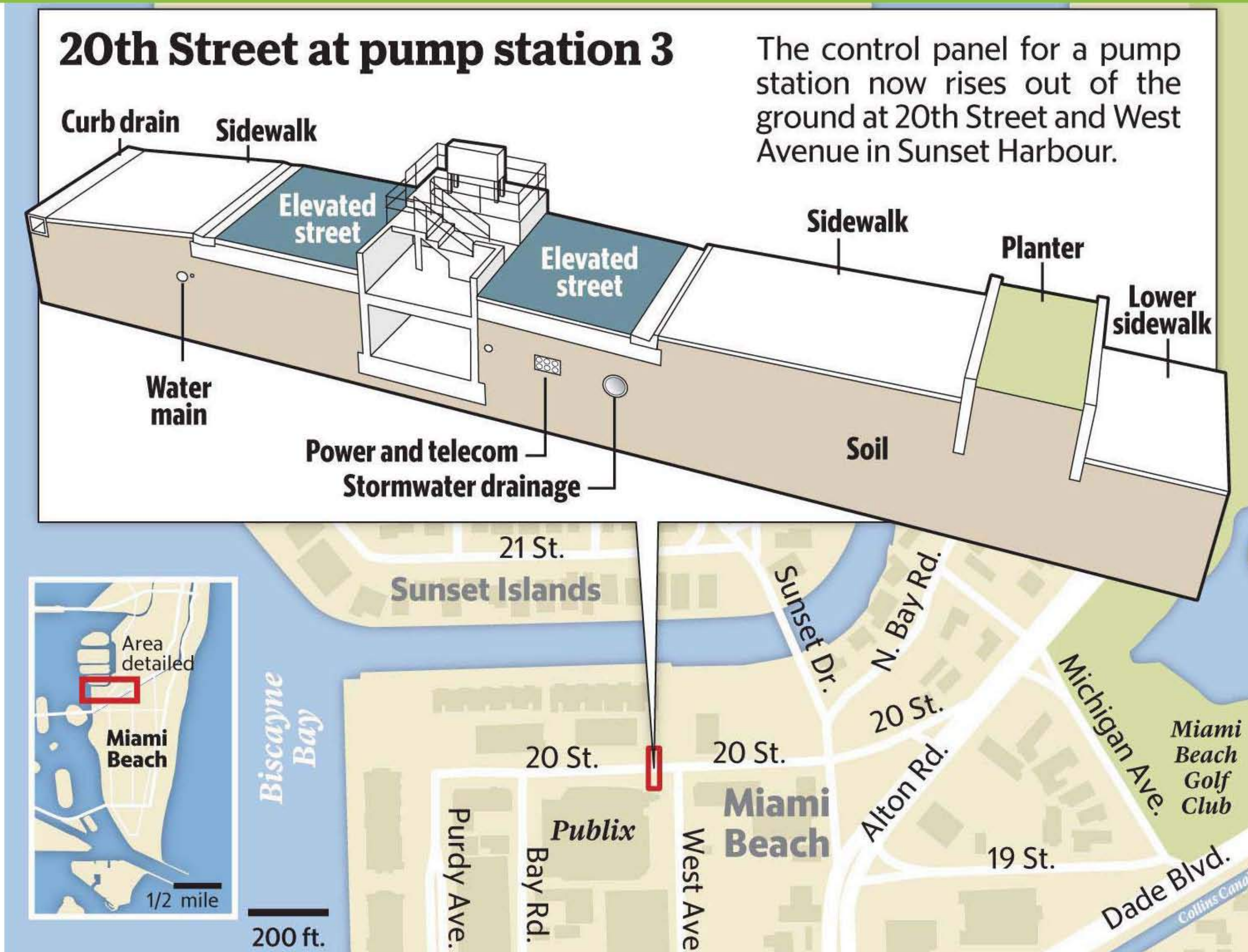


Impacts of Sea Level Rise

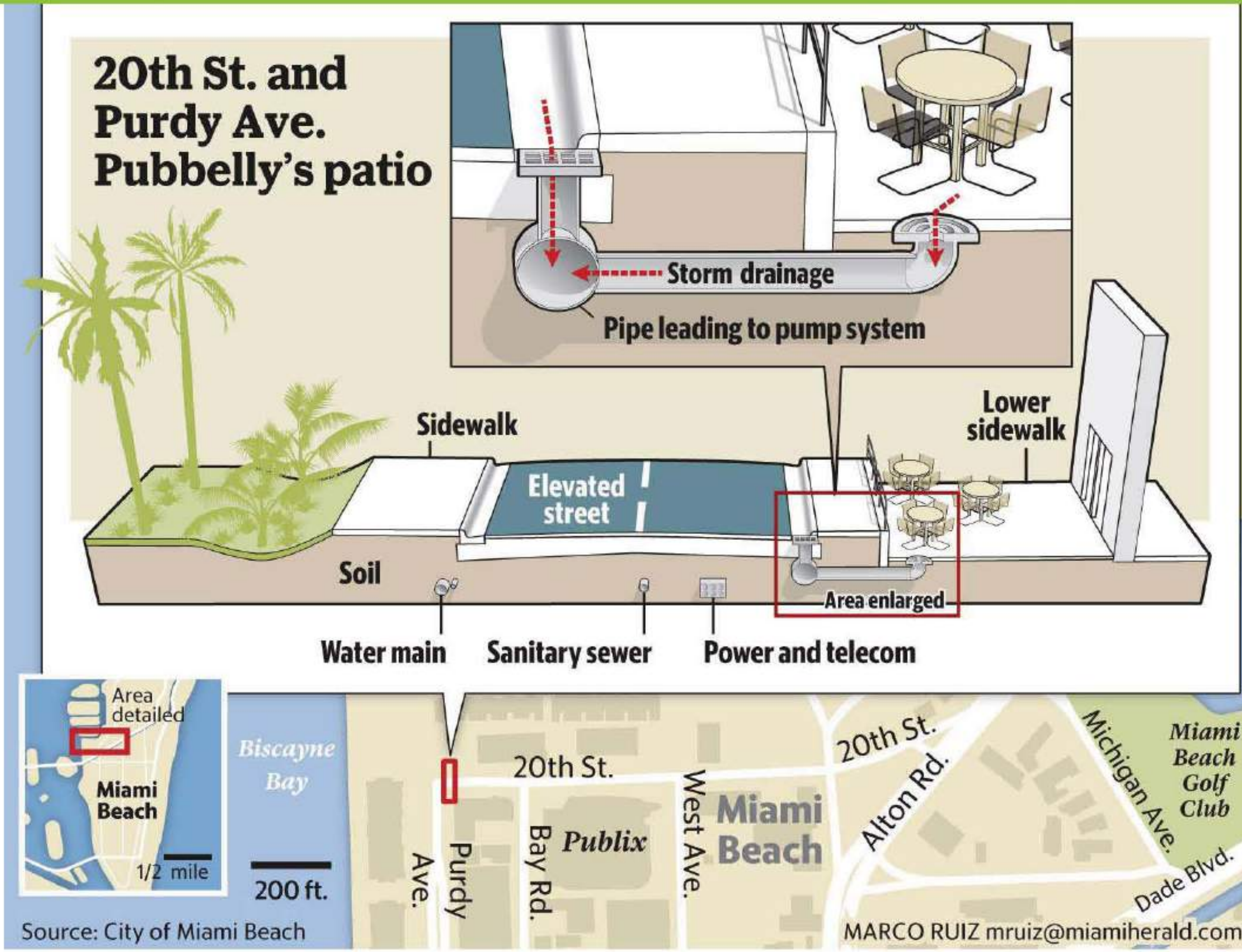
- Higher groundwater
- Higher tides
- Increased flooding
- Decreased effectiveness of the existing stormwater system

INFRASTRUCTURE RESILENCY

- Elevating Public & Private Infrastructure
- Stormwater Retrofits
- Updating/Replacing Utilities
- Green Infrastructure



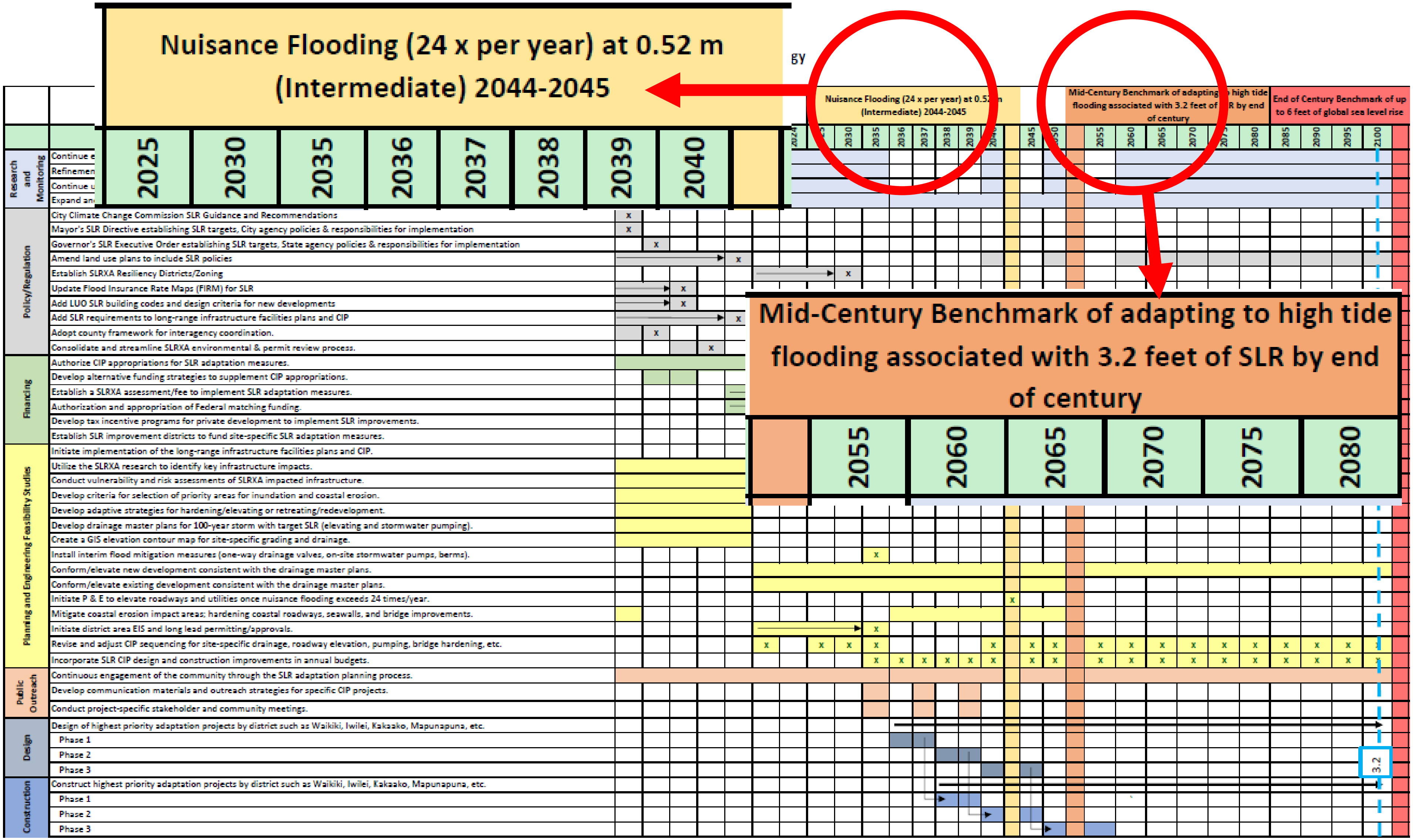
20th Street at pump station 3
The control panel for a pump station now rises out of the ground at 20th Street and West Avenue in Sunset Harbour.
Curb drain
Sidewalk
Elevated street
Elevated street
Sidewalk
Planter
Lower sidewalk
Water main
Power and telecom
Stormwater drainage
Soil
21 St.
Sunset Islands
Sunset Dr.
N. Bay Rd.
Area detailed
Miami Beach
1/2 mile
Biscayne Bay
20 St.
20 St.
20 St.
Alton Rd.
Michigan Ave.
Miami Beach Golf Club
Miami Beach
Publix
Purdy Ave.
Bay Rd.
West Ave.
19 St.
Dade Blvd.
Collins Canal
200 ft.



This rendering shows the elevated roadway at 20th Street and Purdy Avenue, in front of Pubbelly restaurant. To the right, the patio in front of Pubbelly is about two feet lower than the street. Floor drains down there feed into the same pipes that connect to the curb drains on the road, which routes water to the pump station.

Sunset Harbour
20 Street & Purdy Avenue

Draft Adaptation Framework/Action Plan



WRF Study Identified Two Candidate Pilot Areas for Sea Level Rise Adaptation

West Waikiki

Iwilei

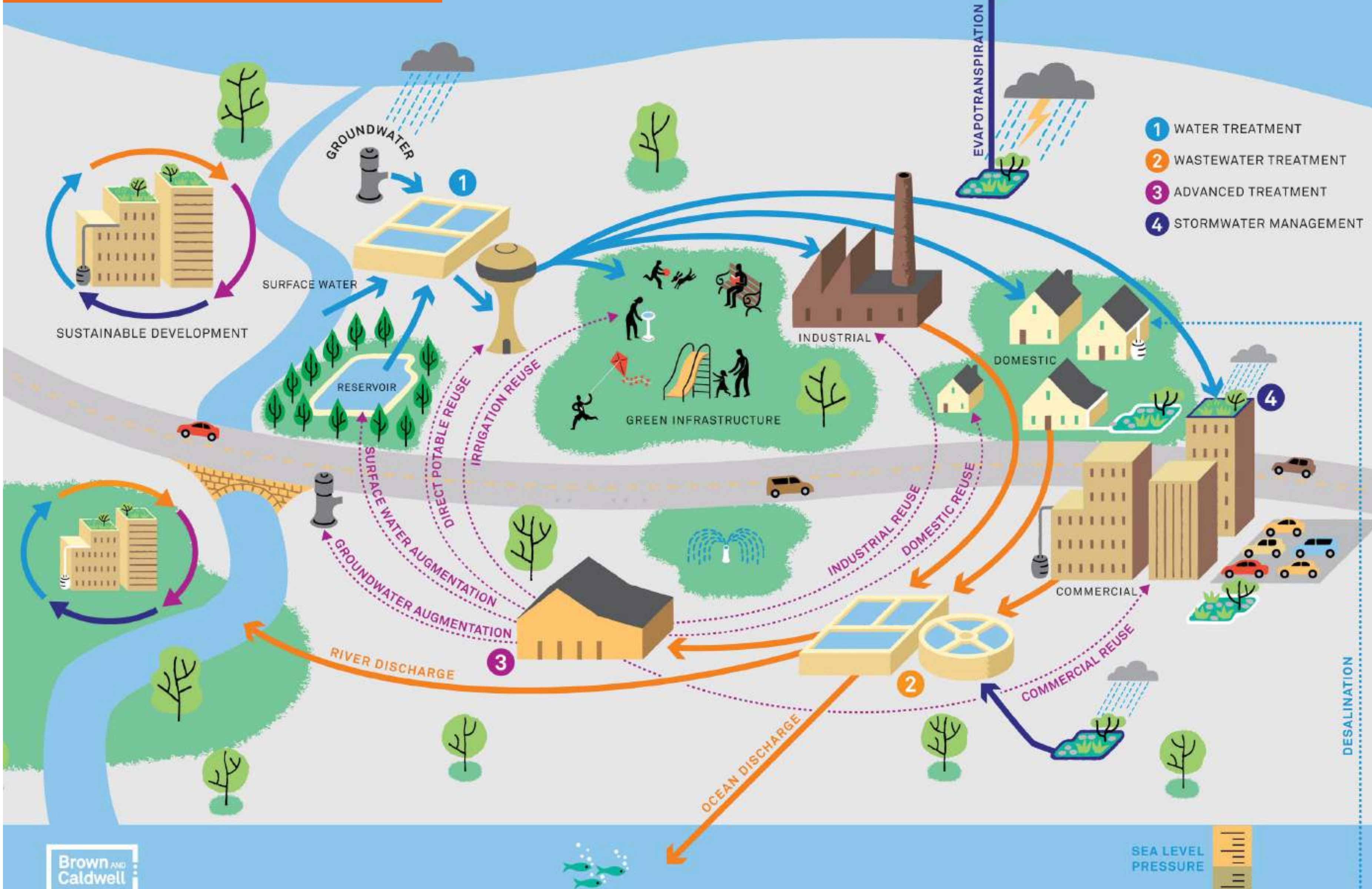
Possible Selection & Prioritization Criteria:

- Potential severity of social, economic, or environmental impacts
  - Taxable real estate; flood impacts to pedestrians, commercial and recreation activities, tourism, transportation and infrastructure.
- Opportunity to add SLR adaptation measures with proposed improvements
  - Ala Wai Flood Mitigation Project
  - Iwilei Transit Oriented Development Plan

Iwilei Redevelopment Concept to Live with Water

Concept, For Illustration Only

The One Water Cycle



Acknowledgements

Research Team

Principal Investigators

- Dean Nakano,
- Lynn Stephens, P.E.
- Jon Turk, P.G.

Project Team

- Susan Mukai
- Joanie Stultz

Brown AND Caldwell

Technical Advisory Committee

- Victoria Keener, PhD, Pacific RISA
- Tom Giambelluca, PhD, University of Hawaii (UH)
- Chip Fletcher, PhD, UH
- Scot Izuka, PhD, US Geological Survey (USGS)
- Delwyn Oki, PhD, USGS
- Lenore Ohye, Commission on Water Resource Management
- Joanna Seto, PE, Department of Health

Project Advisory Committee

- Nancy Matsumoto, Board of Water Supply
- Laurna Kaatz, Denver Water/Water Utility Climate Alliance
- Adam Carpenter, American Water Works Association
- David Yates, National Center for Atmospheric Research
- Kenan Ozekin, Water Research Foundation

Mahalo!

Questions & Answers

Dave Ebersold

Facilitator

SUMMARY AND NEXT STEPS

Next Stakeholder Advisory Group meeting

- Thursday, July 25, 2019
  4:00 – 6:30 pm
  Neal S. Blaisdell Center, Hawaii Suites