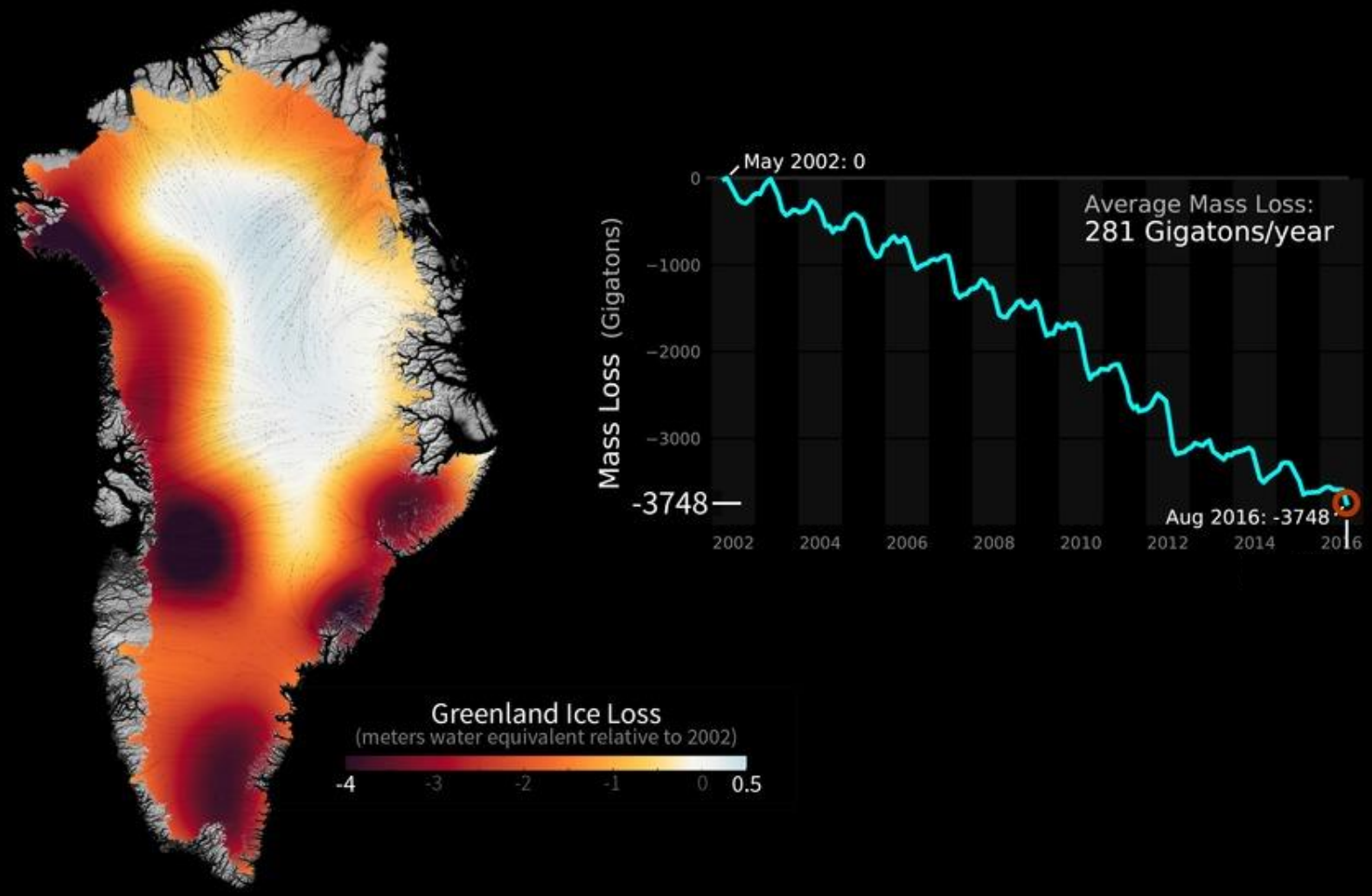
Sea Level Rise

Chip Fletcher, Professor and Associate Dean
School of Ocean and Earth Science and Technology, University of Hawai'i at Mānoa
808-294-0386; fletcher@soest.hawaii.edu

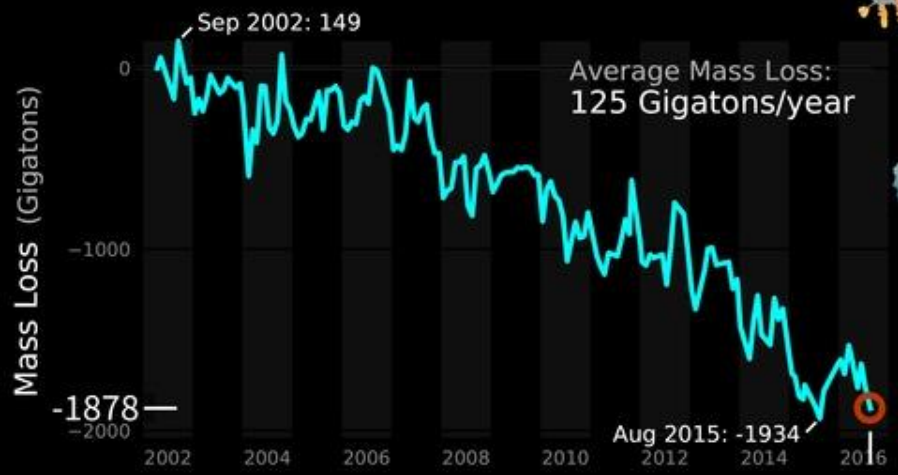
Ice is melting – 600 billion tons each year and accelerating

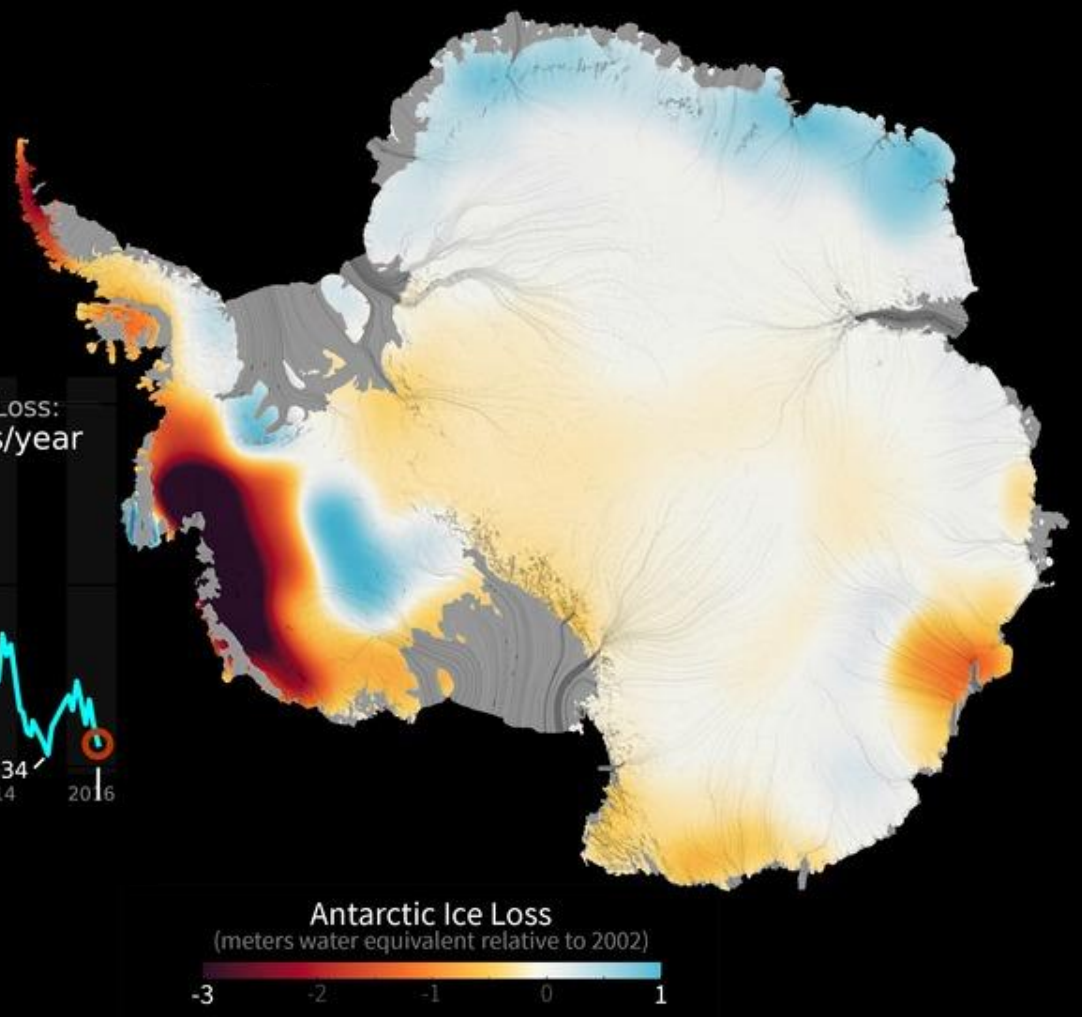


https://climate.nasa.gov

Ice is melting – 600 billion tons each year and accelerating

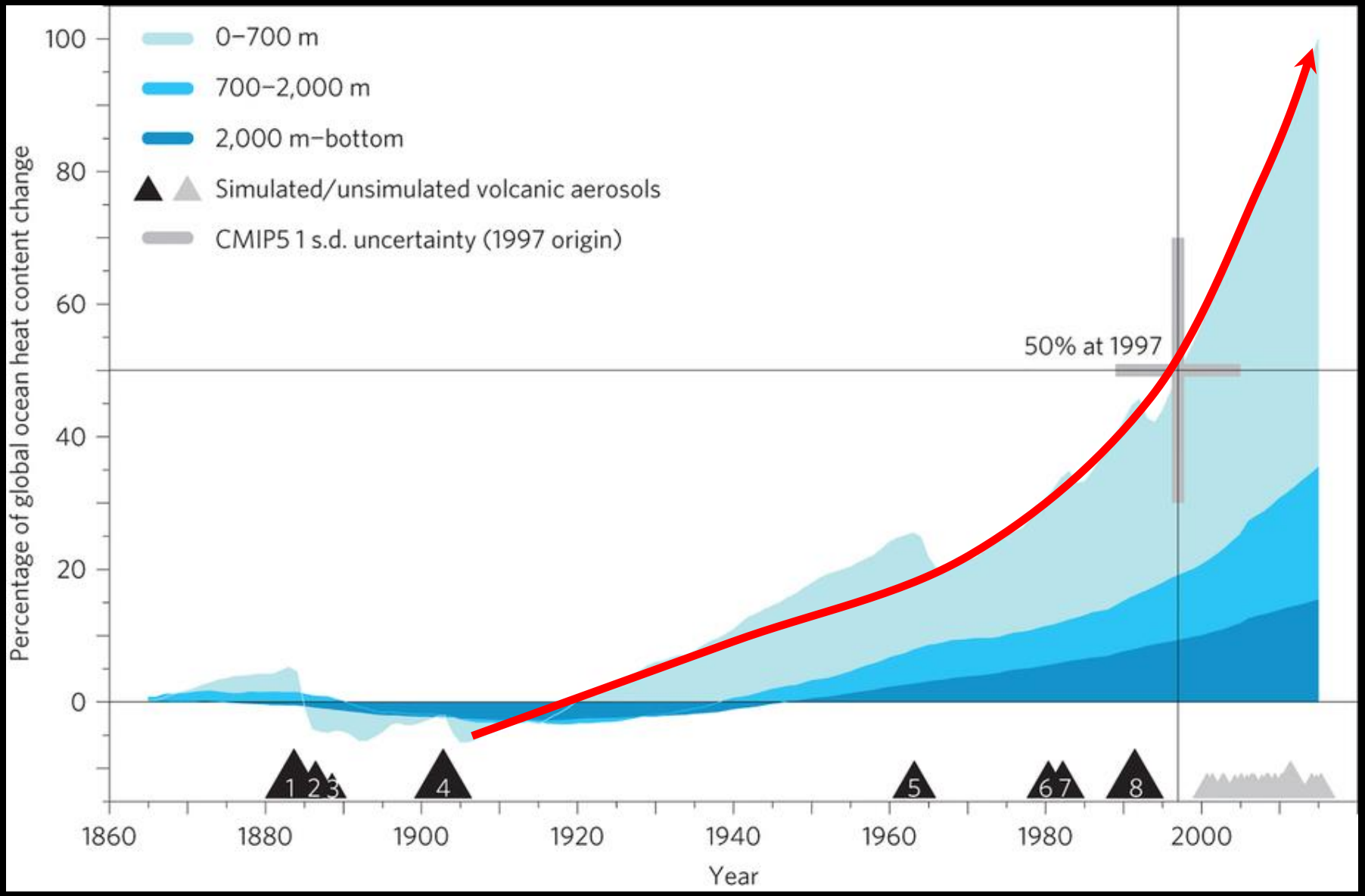
Antarctic ice melt has 'tripled over past five years'





https://climate.nasa.gov

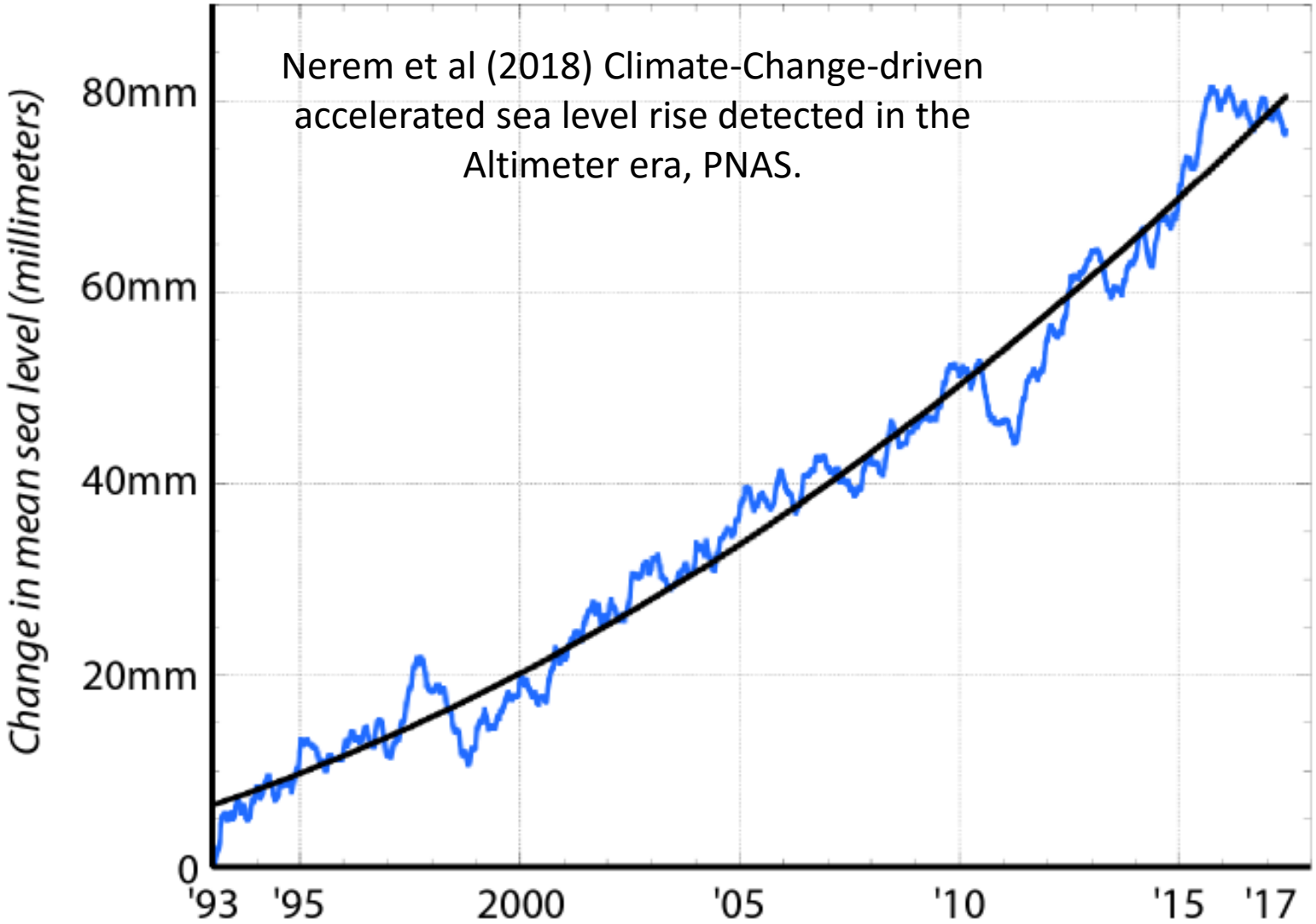
Today the oceans absorb heat at twice the rate they did 18 yrs ago



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

AVERAGE GLOBAL SEA LEVEL RISE

In millimeters as measured by satellite, 1993-2017

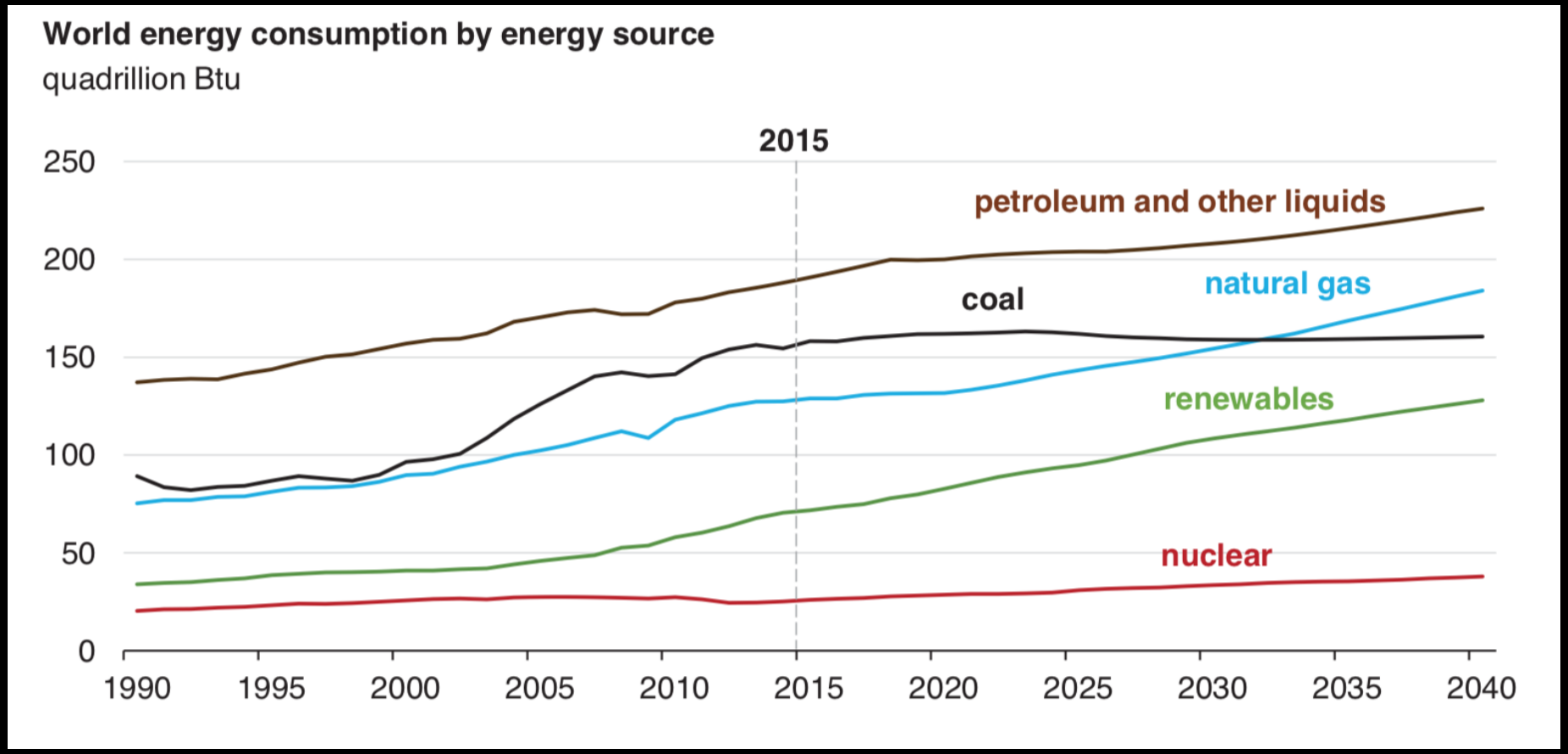


SOURCE: Steve Nerem/University of Colorado, Boulder

InsideClimate News

U.S. Energy Information Administration

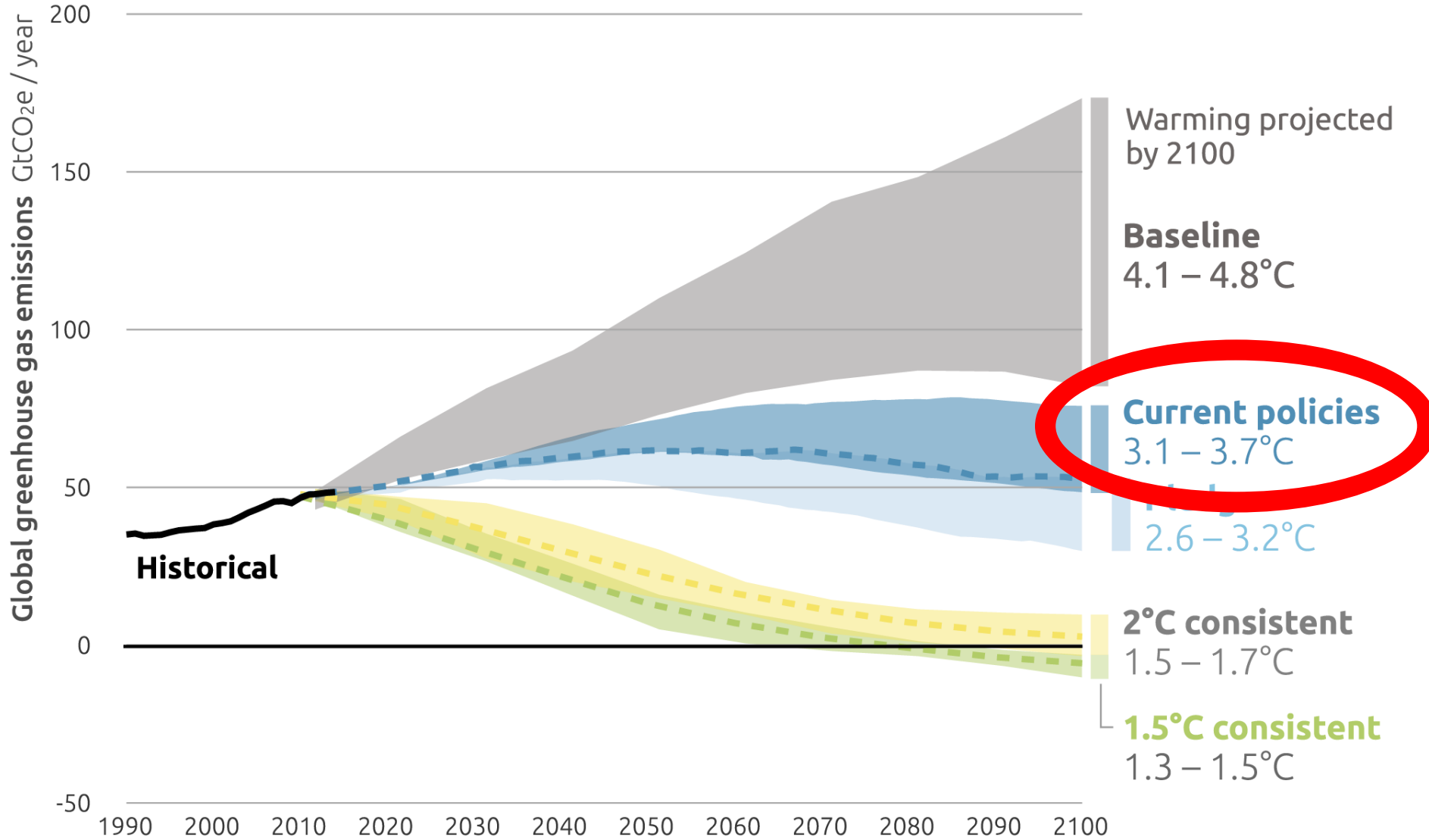
Energy Consumption increases to 2040 for all fuels but coal



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

2100 WARMING PROJECTIONS

Emissions and expected warming based on pledges and current policies

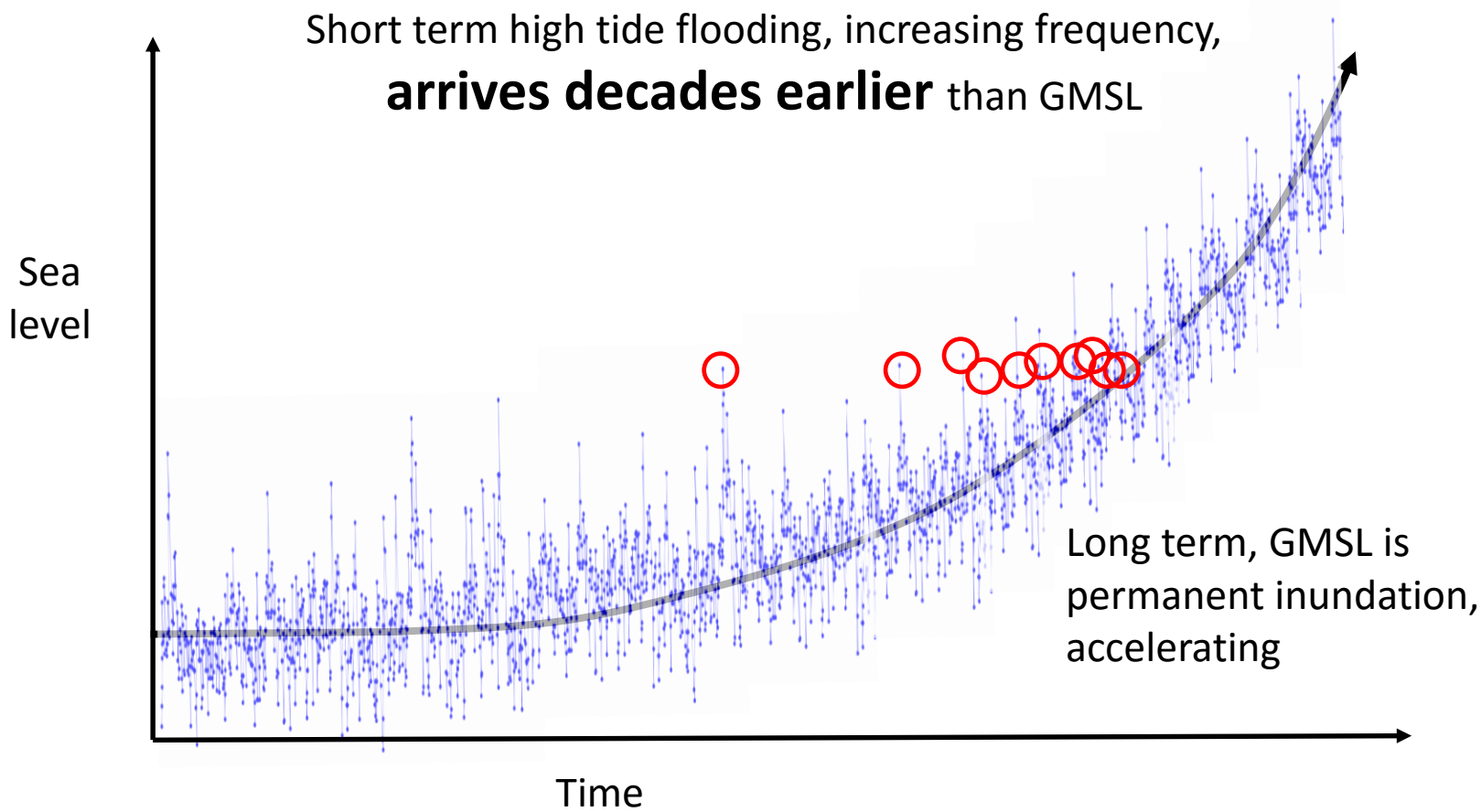


https://climateactiontracker.org/publications/improvement-warming-outlook-india-and-china-move-ahead-paris-agreement-gap-still-looms-large/

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
- Future emissions 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*).

Sea level rises in 2 styles



Storm Drain Flooding at High Tide

Groundwater Inundation

Groundwater inundation

Rain + High Tide = Flooding

Rain + High Tide = Flooding

Rain + High Tide = Flooding

Coastal erosion and beach loss

Coastal roads are threatened by erosion on every island

Environment

A $15 Billion Price Tag To Protect Hawaii Highways From Climate Change

As the state braces for sea level rise, vulnerable roads could be moved inland — and tunneled through mountains.

By Marcel Honore / About 8 hours ago

In 2016, heavy surf pounding Oahu's Windward Coast tore off two large chunks of Kamehameha Highway near Kaaawa in a three-week period.

Residents had already watched their beach gradually disappear, but they'd never seen the waters claim part of the highway.

Crews rushed to repair the road — a scenic, vital passage that hugs the eastern edge of Hawaii's most populous island. State transportation officials said the fixes would better protect the highway against erosion.

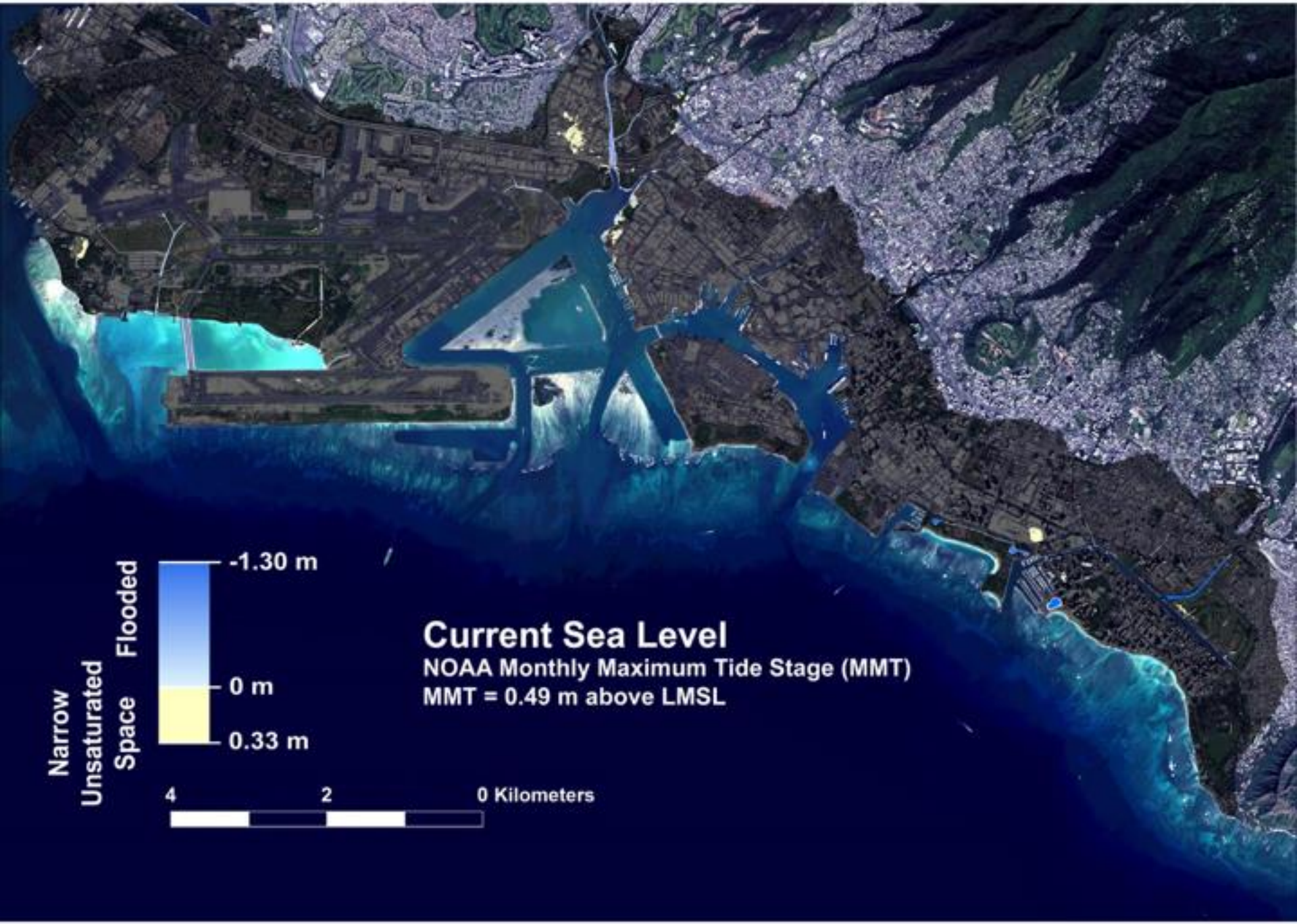
But they acknowledged it wasn't a permanent solution.

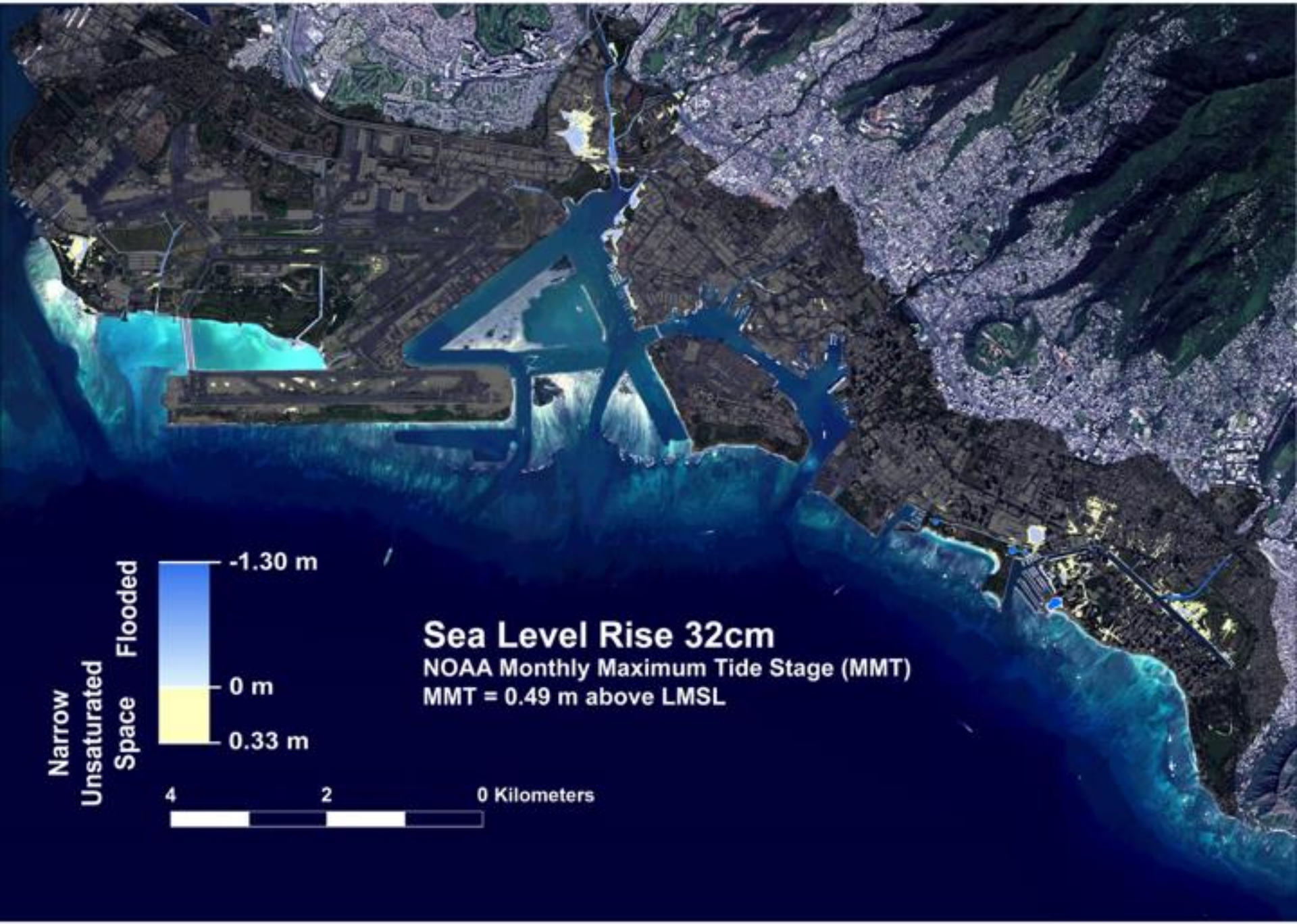
Sandbags were used to protect the Kamehameha Highway near Kaaawa in March.

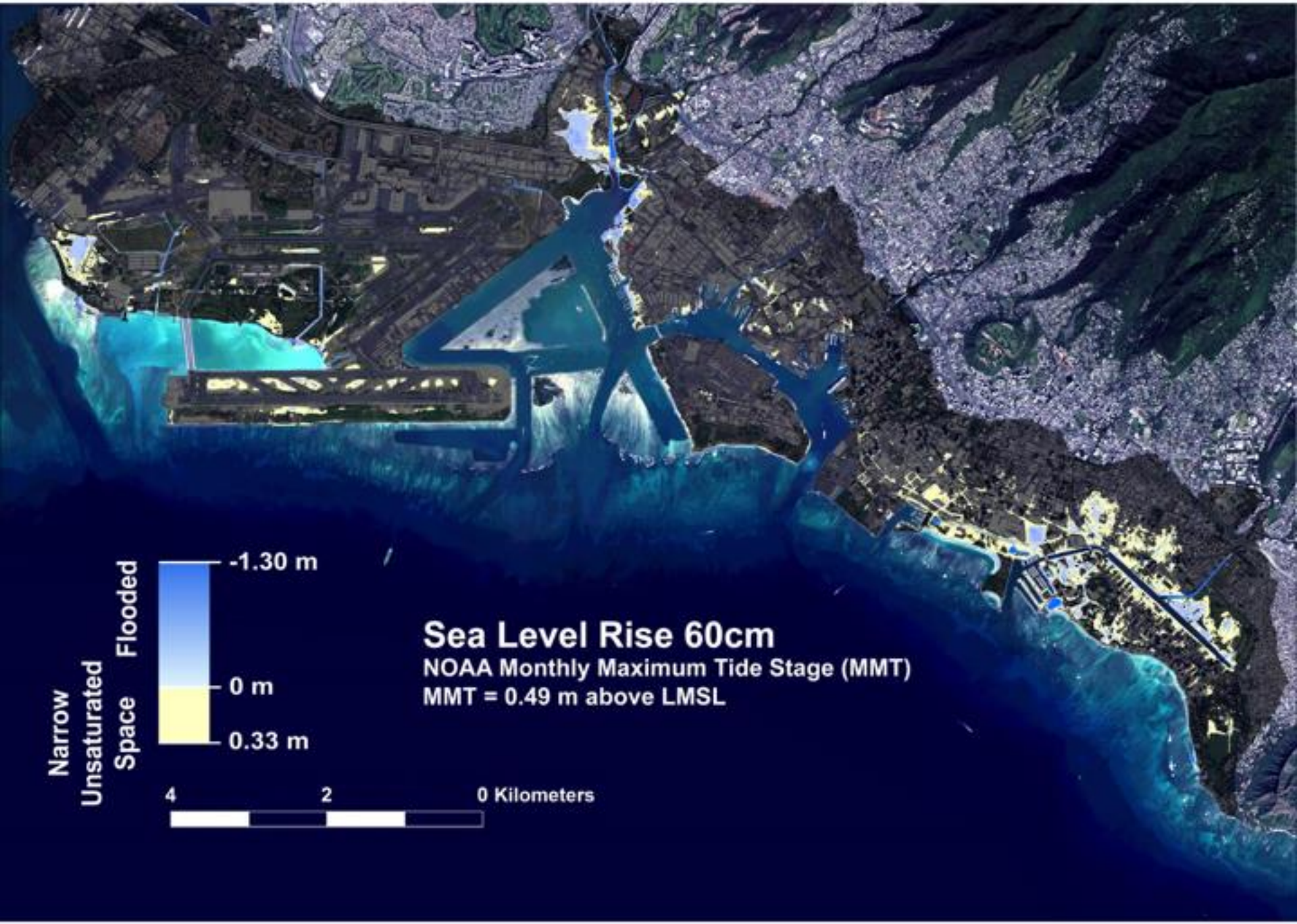
Hawaii will need **$15 billion** to protect highways from sea level rise.

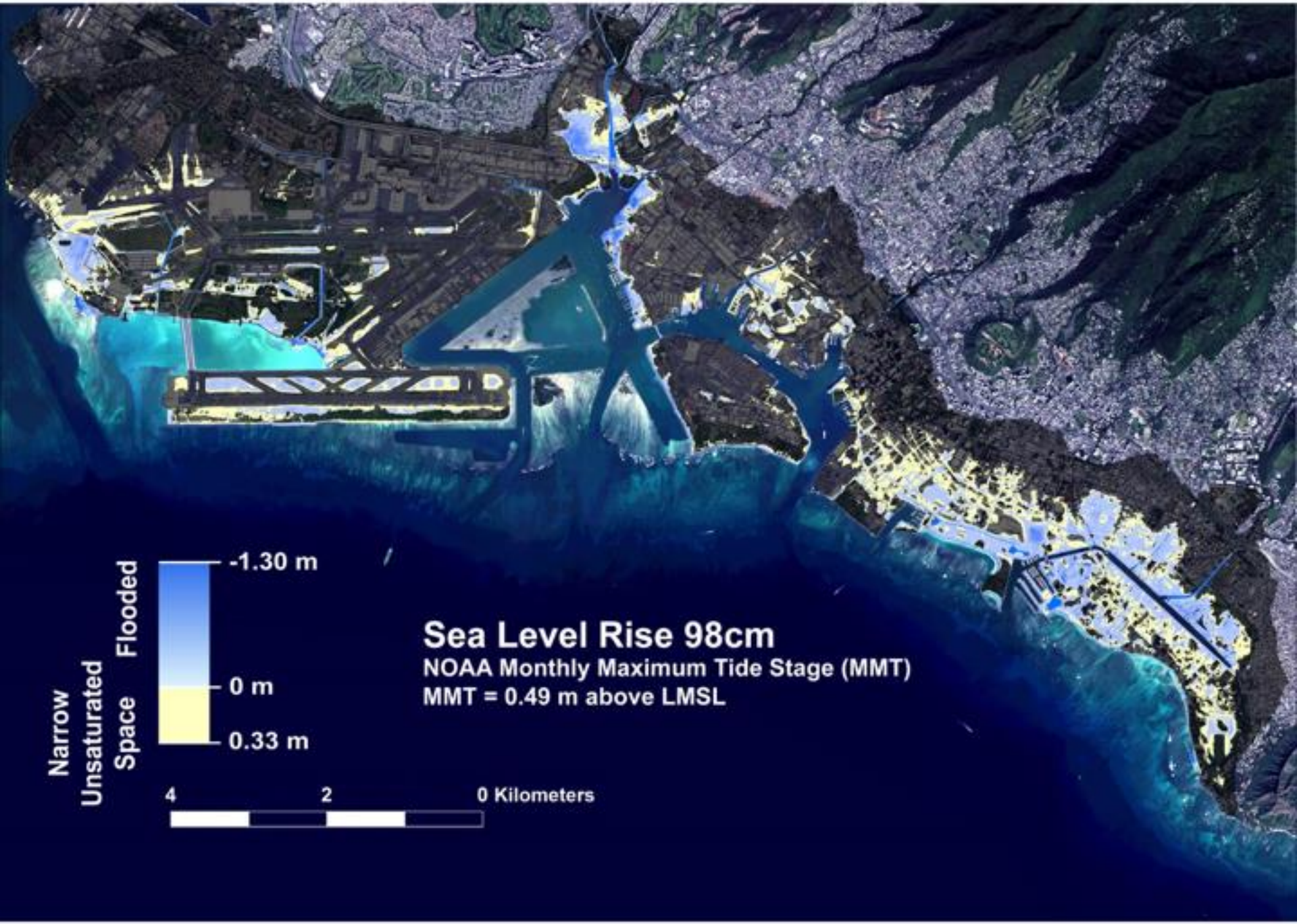
$7.5 million for every mile of road that must either be raised, pushed back or relocated in the next 50 to 100 years.

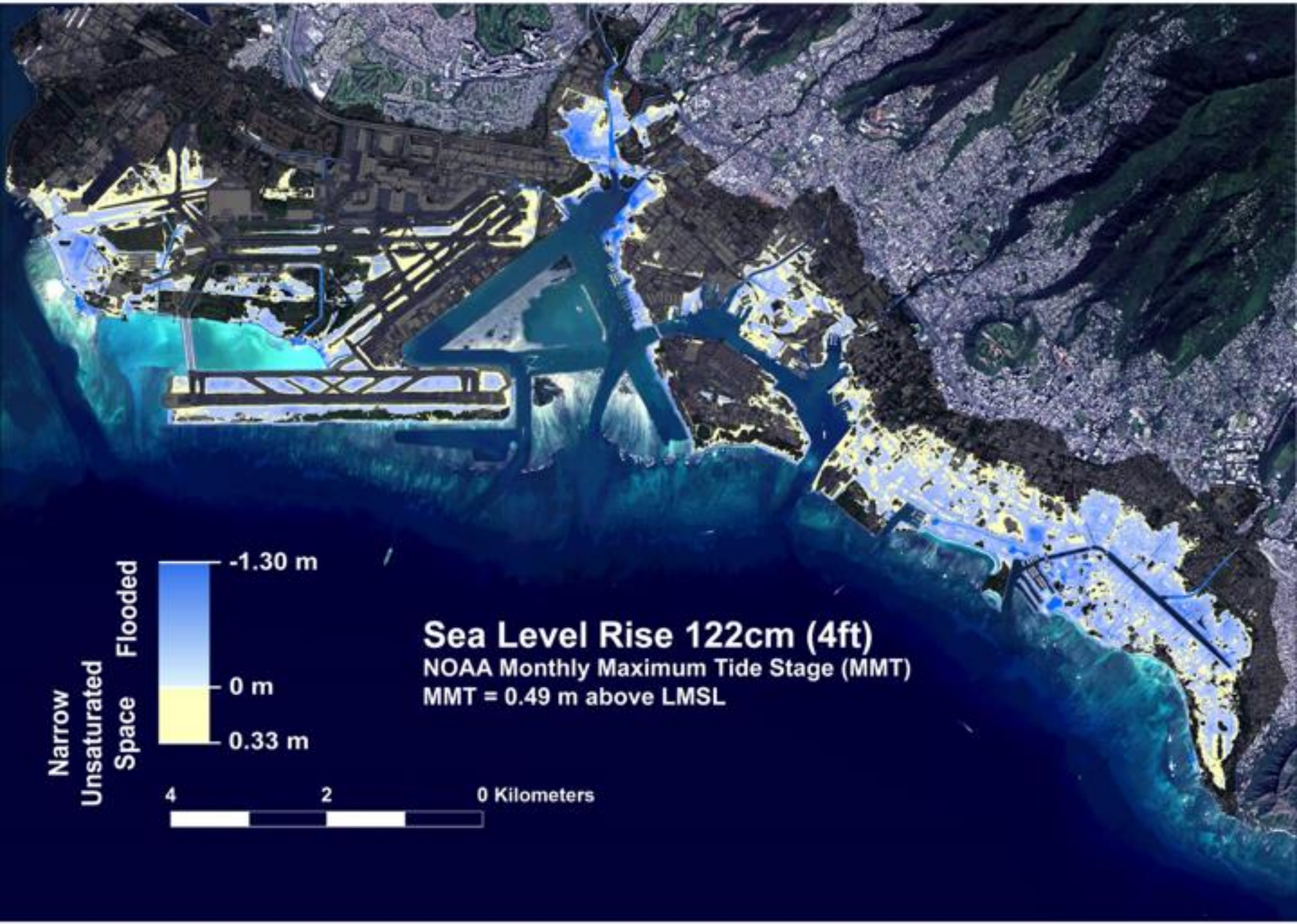
$40 million for every mile of bridge.

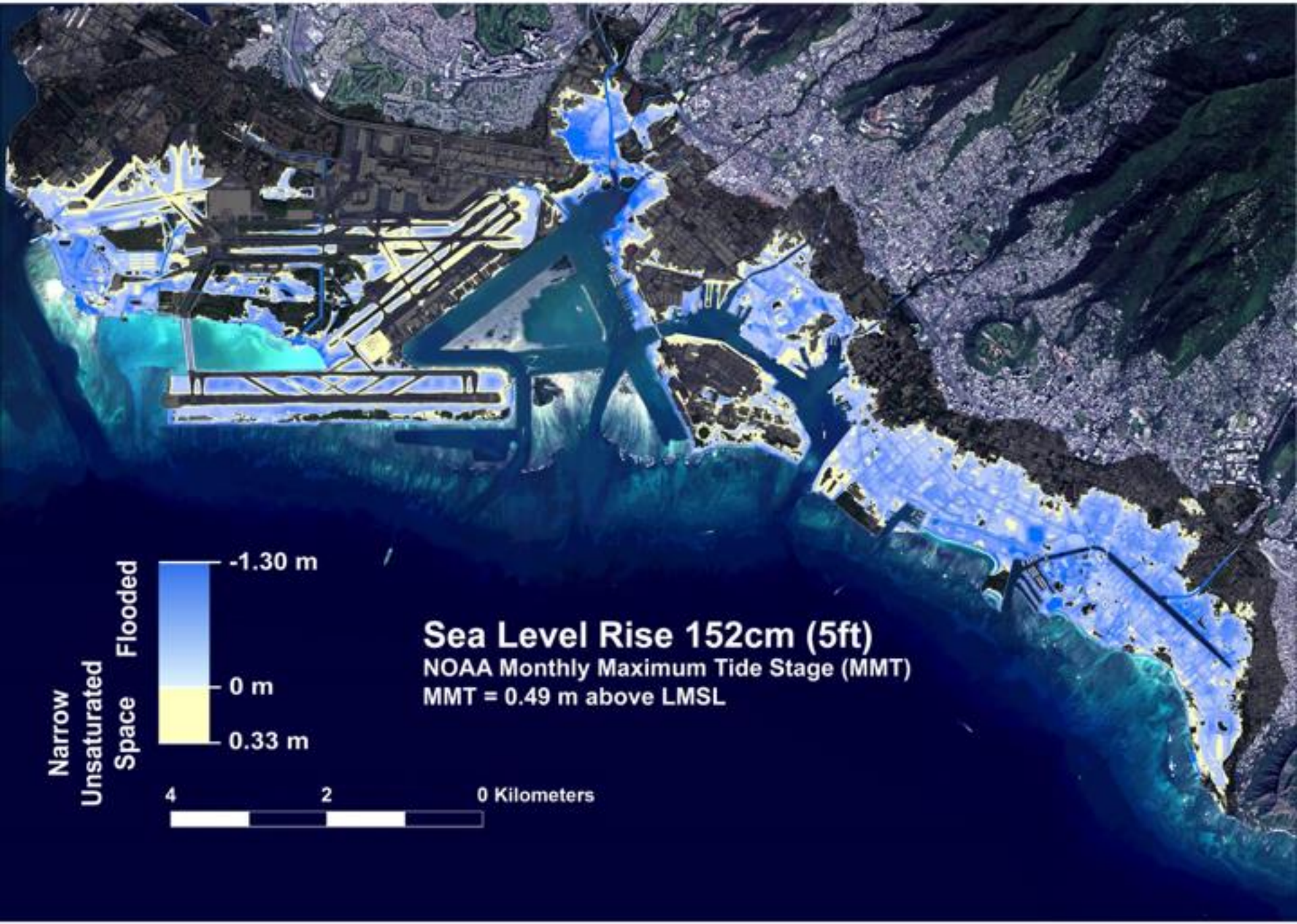

Current Sea Level
NOAA Monthly Maximum Tide Stage (MMT)
MMT = 0.49 m above LMSL
Flooded
Narrow Unsaturated Space
-1.30 m
0 m
0.33 m
4
2
0 Kilometers

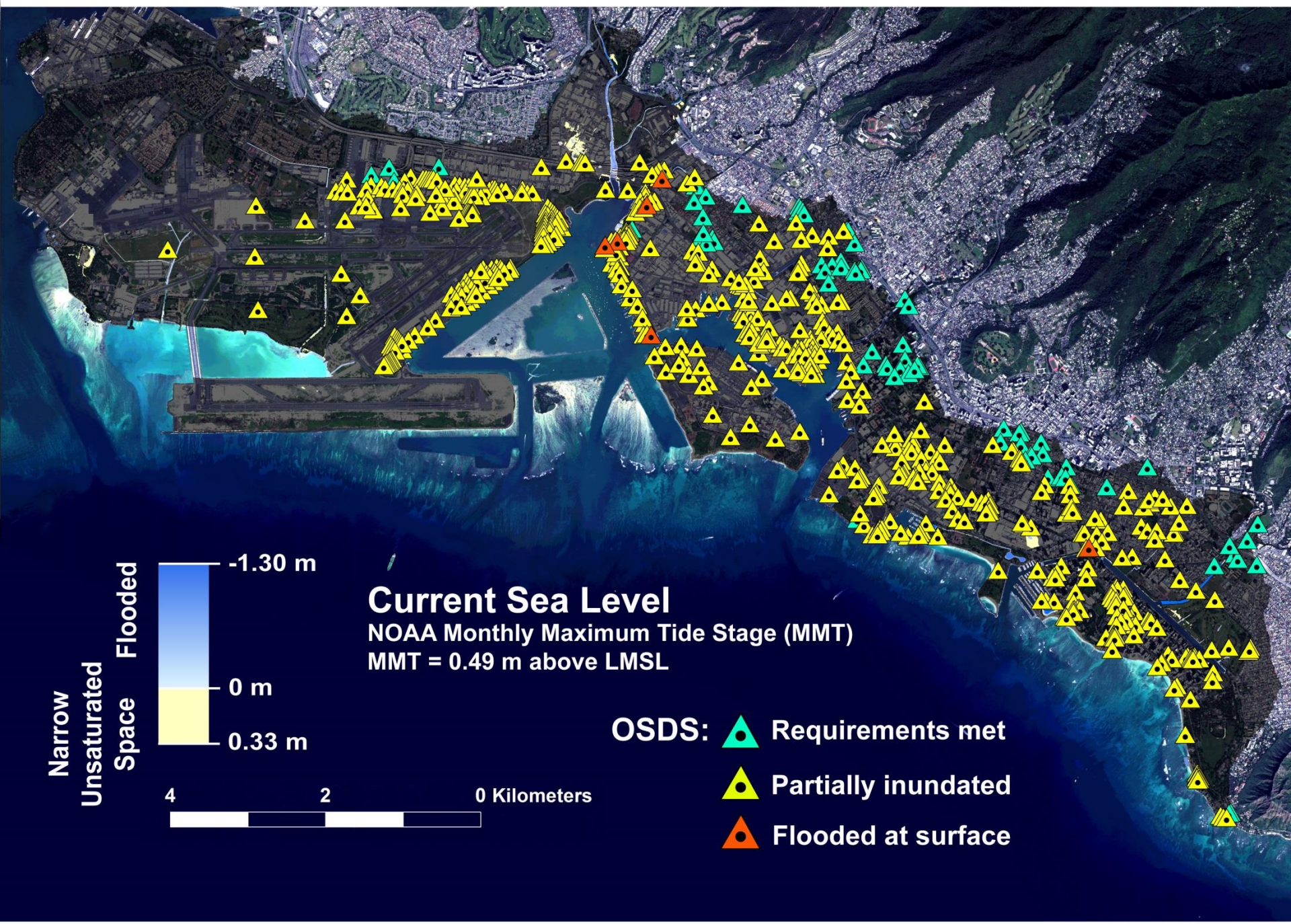

Sea Level Rise 32cm
NOAA Monthly Maximum Tide Stage (MMT)
MMT = 0.49 m above LMSL
-1.30 m
0 m
0.33 m
Flooded
Narrow Unsaturated Space
4
2
0 Kilometers


Sea Level Rise 60cm
NOAA Monthly Maximum Tide Stage (MMT)
MMT = 0.49 m above LMSL
-1.30 m
0 m
0.33 m
Flooded
Narrow Unsaturated Space
4
2
0 Kilometers


Sea Level Rise 98cm
NOAA Monthly Maximum Tide Stage (MMT)
MMT = 0.49 m above LMSL
-1.30 m
0 m
0.33 m
Flooded
Narrow Unsaturated Space
4
2
0 Kilometers


Sea Level Rise 122cm (4ft)
NOAA Monthly Maximum Tide Stage (MMT)
MMT = 0.49 m above LMSL
-1.30 m
0 m
0.33 m
Flooded
Narrow Unsaturated Space
4
2
0 Kilometers

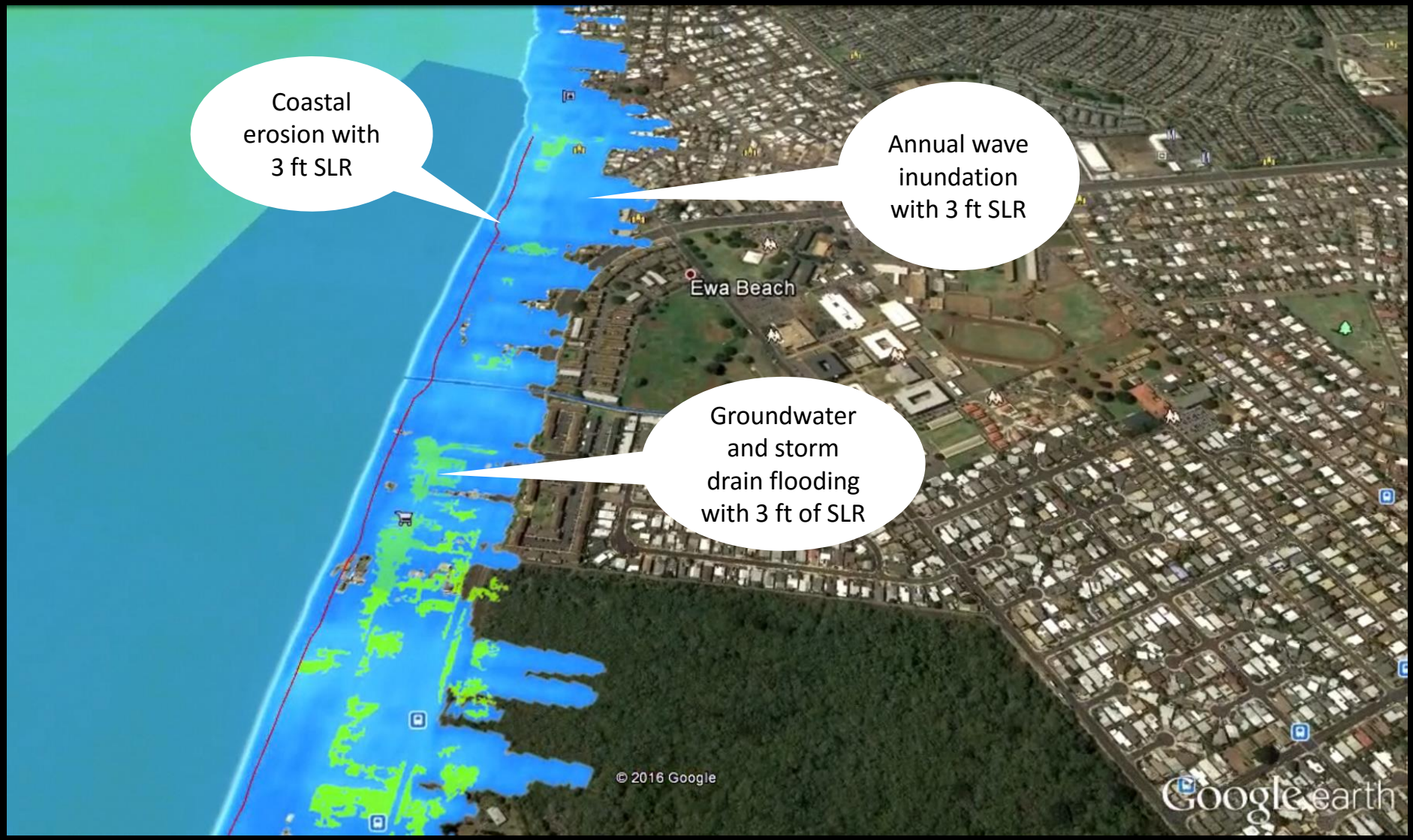

Sea Level Rise 152cm (5ft)
NOAA Monthly Maximum Tide Stage (MMT)
MMT = 0.49 m above LMSL
-1.30 m
0 m
0.33 m
Flooded
Narrow Unsaturated Space
4
2
0 Kilometers


Current Sea Level
NOAA Monthly Maximum Tide Stage (MMT)
MMT = 0.49 m above LMSL
-1.30 m
0 m
0.33 m
Flooded
Narrow Unsaturated Space
4
2
0 Kilometers
OSDS:
Requirements met
Partially inundated
Flooded at surface

Search address or 9-digit TMK...
O'ahu
Select a site...
BASEMAPS
COASTAL EROSION
SEA LEVEL RISE BY YEAR
SEA LEVEL RISE BY FEET
WAVE INUNDATION
OTHER OVERLAYS
expand · collapse · clear
Summer wave run-up 2ft
Wave Inundation
16
12
8
4
water depth (ft)
200 m
500 ft
PacIOOS
Hanakahi St
Kiwi St
Kalapu St
Ahona St
Kuhina St
Hanaloa St
Kaulki St
Halamu St
N Rd
The Church of Jesus Christ of Latter...
Kailoa St
Kaimalie St
McDonald's
US Post Office
Chevron
Papipi Rd
Fort Weaver Rd
Makule Rd
Alkanaka Rd
James Campbell High School
Our Lady of Perpetual Help
Kilinahe St
Kilipoe St
Kilaha St
Honolulu Observatory
Ewa Beach Golf Club
Puuloa Range Training Facility
Aloha Community Church
Cormorant Ave
Pacific Tsunami Warning Center
Ewa Beach Elementary School
Ewa Beach Community Park
Ewa Beach Park
Kulana Pl
Kuliioloa Pl
Ewa Beach Rd
Paaloha St
Onelua St
Oama St
Ihipehu St
Pohakupuna Rd
Tripod Reef
cursor: 21.3154°, -158.0006°

Summer wave run-up 3ft
Search address or 9-digit TMK...
O'ahu
Select a site...
BASEMAPS
COASTAL EROSION
SEA LEVEL RISE BY YEAR
SEA LEVEL RISE BY FEET
WAVE INUNDATION
OTHER OVERLAYS
expand · collapse · clear
Wave Inundation
16
12
8
4
water depth (ft)
200 m
500 ft
PacIOOS

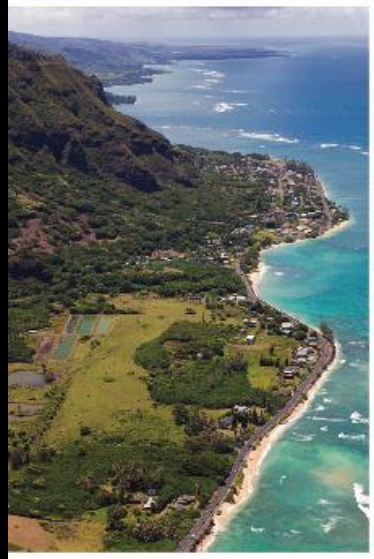
Ewa Beach 3.2 ft SLR

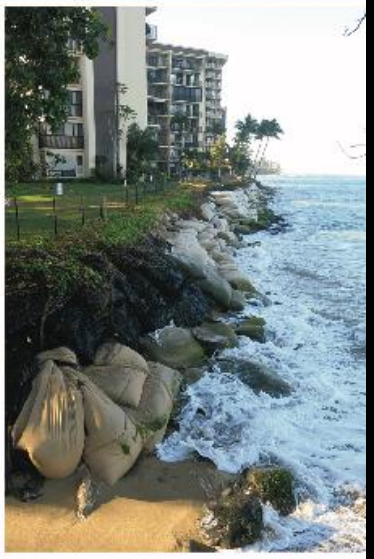


Waikiki

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

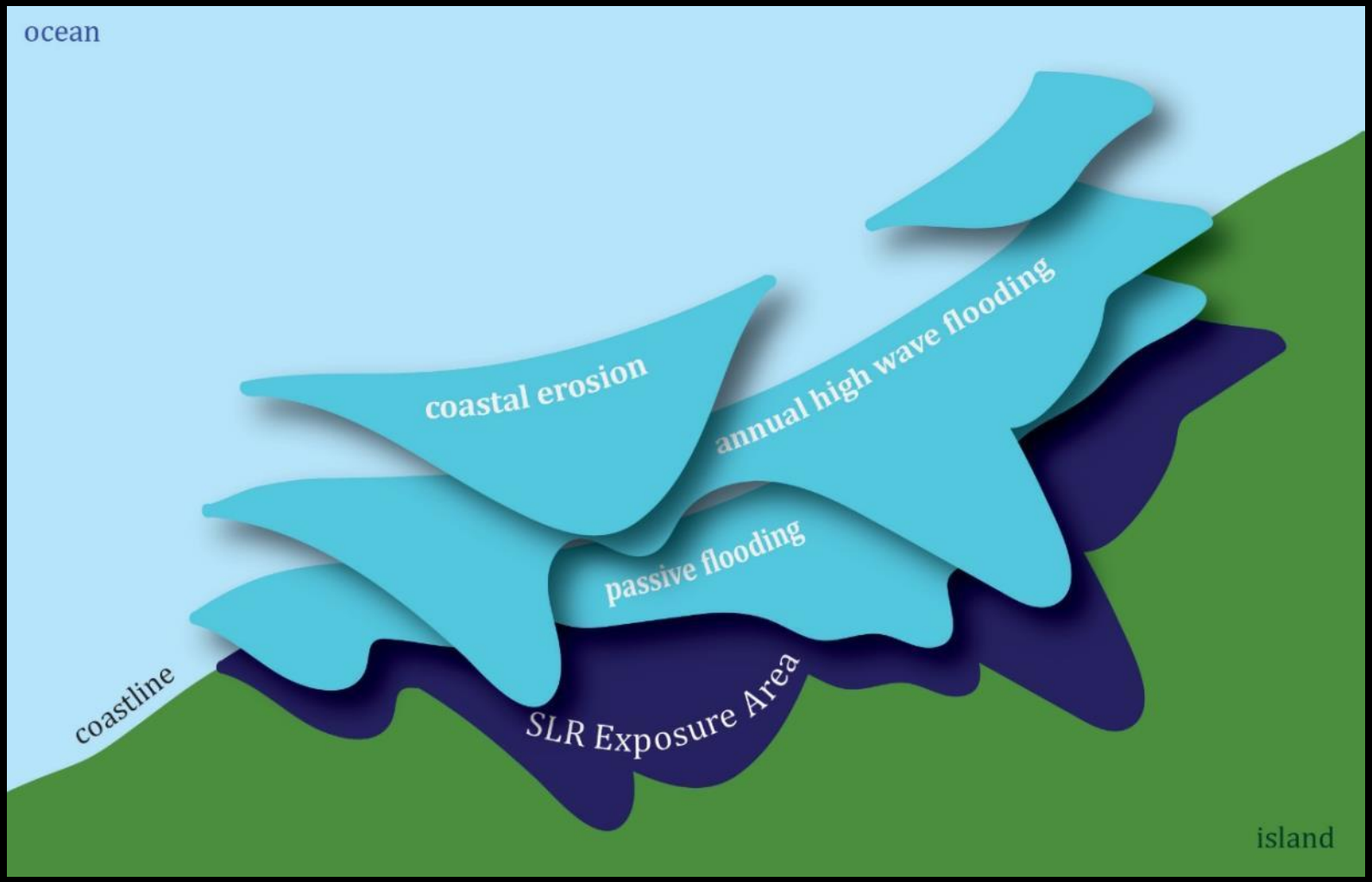
TETRA TECH

SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY

Sea Grant University of Hawai'i

PACIFIC ISLANDS CLIMATE SCIENCE CENTER PICSC

Sea Level Rise Exposure Area 3.2SLR-XA

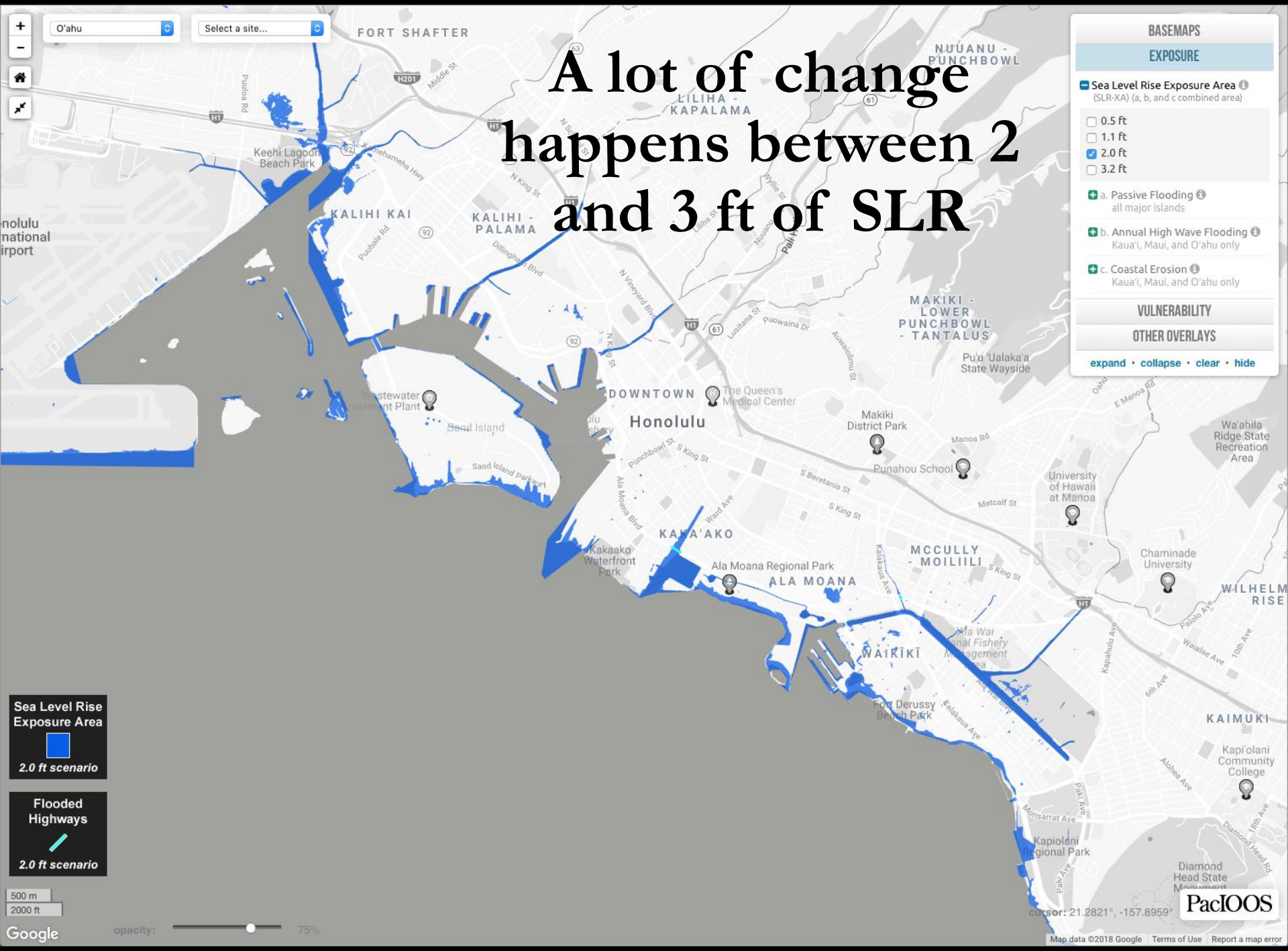


TETRA TECH

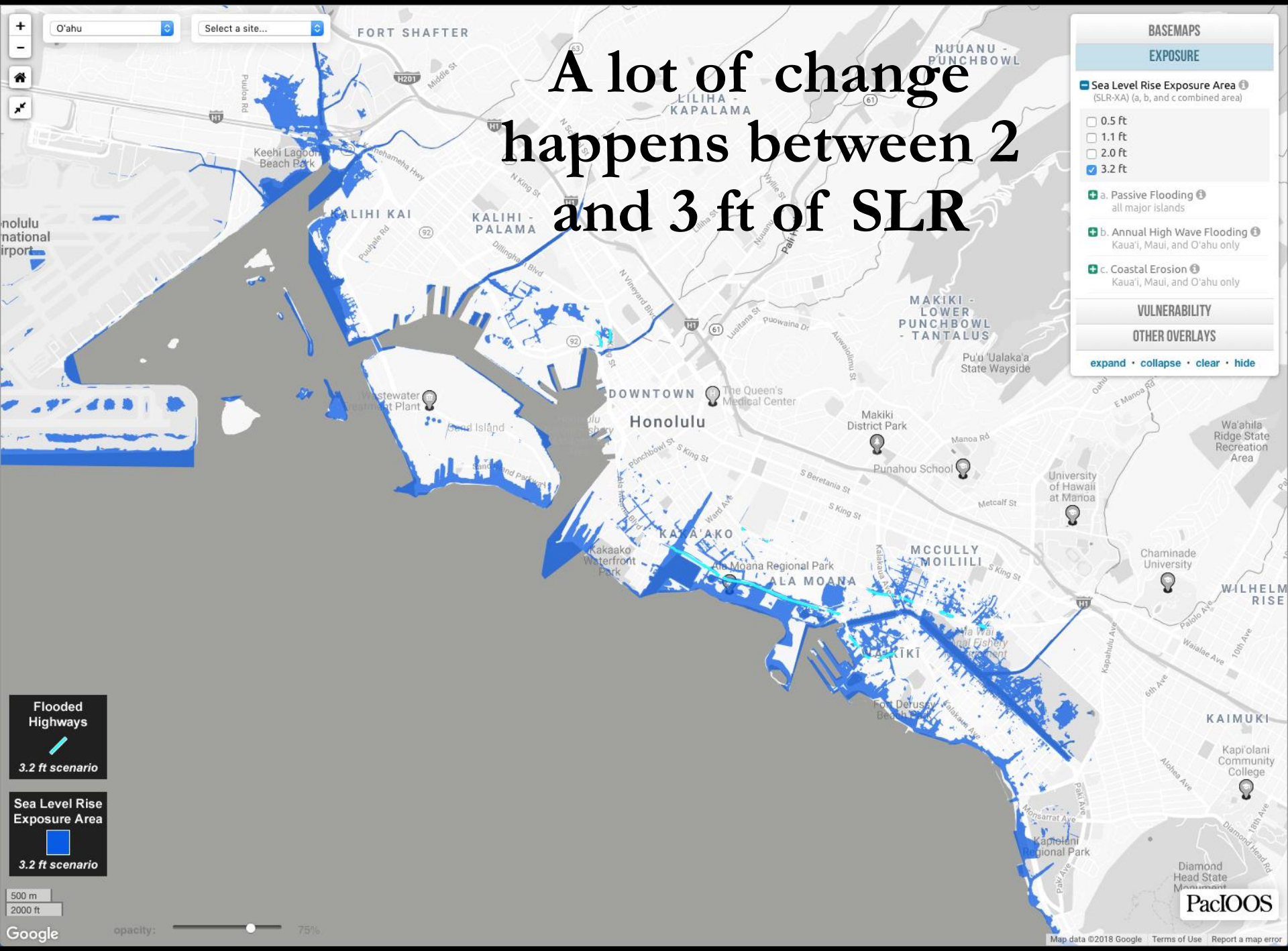
The 3.2SLR-XA

O'ahu
Waikīkī
MCCULLY - MOILIILI
ALA MOANA
WAIKIKĪ
Ala Moana Regional Park
Kaanamoku Lagoon
Magic Island
Magic Island Lagoon
Ala Wai Boat Harbor
Ala Wai Community Park
'Iolani School
Fort Derussy Beach Park
'Apuakehau Channel
Waikīkī Bay
Pālolo Stream
Kalakaua Ave
Kapiolani Blvd
Kapahulu Ave
Passive Flooding
3.2 ft scenario
300 m
1000 ft
Google
PacIOOS
Map data ©2017 Google
Terms of Use
Report a map error

A lot of change happens between 2 and 3 ft of SLR



A lot of change happens between 2 and 3 ft of SLR

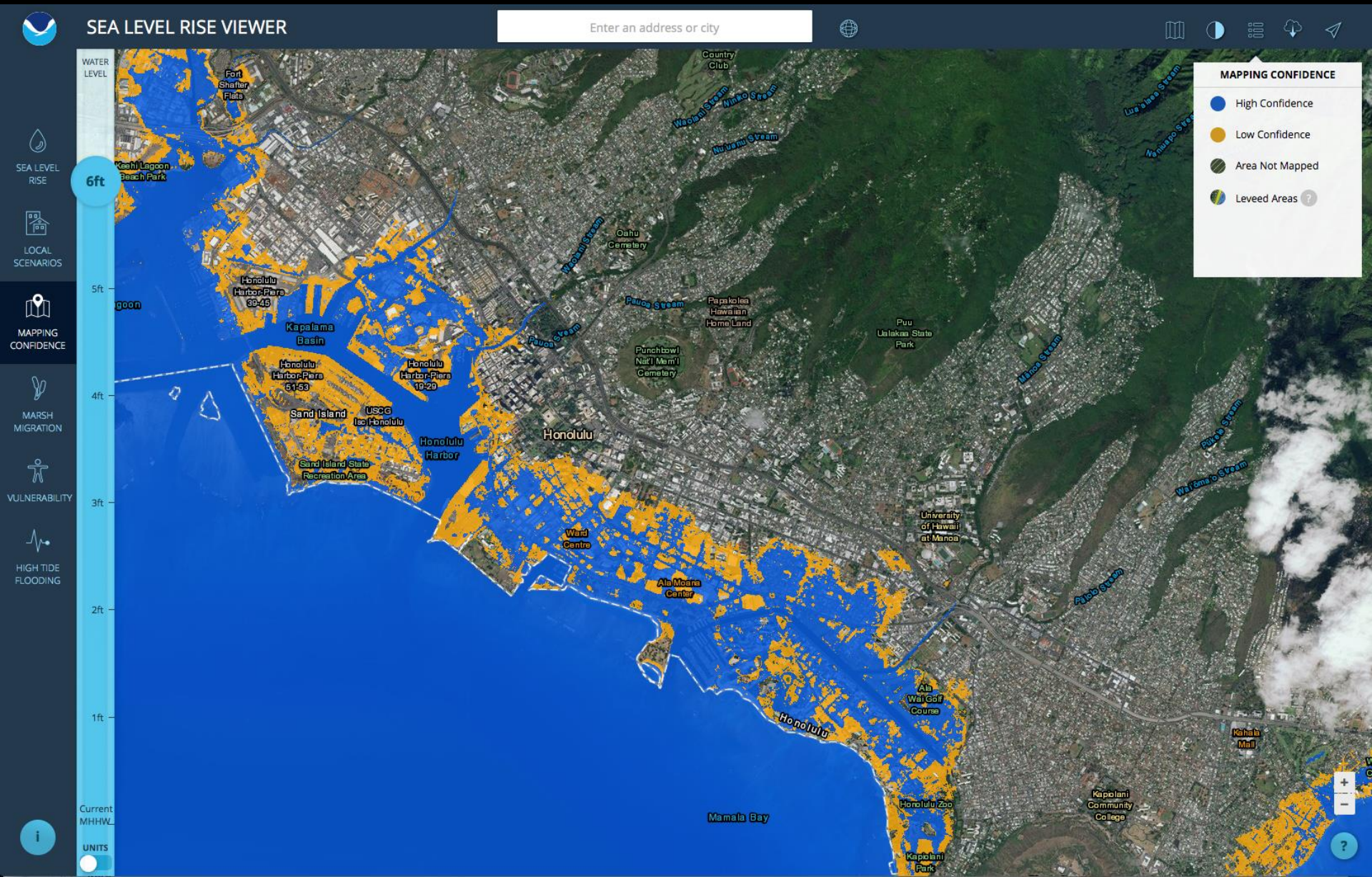


Honolulu Climate Change Commission
SLR Guidance

1. Use report and online viewer, for all baseline planning.
2. Plan for chronic high-tide flooding by mid-century in the 3.2SLR-XA.
3. Plan for 6 ft SLR by end-of-century for infrastructure with low risk tolerance.
4. Revise the SMA boundary to include the 3.2SLR-XA.
5. Disclose properties in the 3.2SLR-XA and 6 ft SLR in Real Estate sales.
6. Adopt 3.2SLR-XA and 6 ft SLR as hazard overlay for all planning.
7. To mitigate impacts, direct all departments to use the Report, the 3.2SLR-XA, and the 6 ft SLR in their decisions.
8. Review and update all ordinances related to land development.
9. Support relevant departments to implement these recommendations and proactively plan for SLR.

“If you wage war with water, you will lose.”

6 ft SLR



SEA LEVEL RISE VIEWER
Enter an address or city
WATER LEVEL
SEA LEVEL RISE
LOCAL SCENARIOS
MAPPING CONFIDENCE
MARSH MIGRATION
VULNERABILITY
HIGH TIDE FLOODING
6ft
5ft
4ft
3ft
2ft
1ft
Current MHHW
UNITS
MAPPING CONFIDENCE
High Confidence
Low Confidence
Area Not Mapped
Leveed Areas
Fort Shafter Flats
Keehi Lagoon Beach Park
Honolulu Harbor-Piers 39-45
Kapalama Basin
Honolulu Harbor-Piers 51-53
Honolulu Harbor-Piers 19-29
Sand Island
USCG Isc Honolulu
Honolulu Harbor
Sand Island State Recreation Area
Honolulu
Ward Centre
Ala Moana Center
Honolulu
Mamala Bay
Honolulu Zoo
Kapiolani Park
Ala Wai Golf Course
Country Club
Oahu Cemetery
Papakolea Hawaiian Home Land
Punchbowl Nat'l Mem'l Cemetery
Puu Ualakaa State Park
University of Hawaii at Manoa
Kapiolani Community College
Kahala Mall
Waolani Stream
Ninito Stream
Nu'uanu Stream
Pauoa Stream
Manoa Stream
Pukele Stream
Wai'omao Stream
Palolo Stream