#### Global Warming $+1.2^{\circ}C$ ( $\sim 2.2^{\circ}F$ )



https://data.giss.nasa.gov/gistemp/graphs\_v4/customize.html

#### Temperature change relative to global average

**Continents** warming faster than oceans, breadbaskets and communities at risk

Arctic Amplification Arctic warming faster than global average





#### Oceans are warmer than they've ever been in recorded human history

0-700m 9 700-2000m



Horwath, M., et al. (2022) Global sea-level budget and ocean-mass budget, with a focus on advanced data products and uncertainty characterization, Earth Syst. Sci. Data, 14, 411–447, https://doi.org/10.5194/essd-14

<u>411-2022</u>.

# Greenland melting has quadrupled since 2010



Bevis, M. et al. (2019) Accelerating changes in ice mass within Greenland, and the ice sheets sensitivity to atmospheric forcing. PNAS, 116, 1934-1939. King, M.D., *et al.* (2020) Dynamic ice loss from the Greenland Ice Sheet driven by sustained glacier retreat. *Commun Earth Environ* **1**. https://doi.org/10.1038/s43247-020-0001-2

#### Antarctic ice melt has tripled since 2010 ~6% of GMSLR

West Antarctic Glaciers are in Irreversible Retreat Ice loss, billions of tonnes Antarctica Mass Variation Since 2002 RATE OF CHANGE 47 () Data source: Ice mass measurement by NASA's GRACE satellites. Gap represents time between missions. Gigatonnes per year Credit: NASA 0 -500 Antarctica mass (Gt) -1000 -1500 -2000 -2500 2004 2007 2010 2013 2016 2019 YEAR Antarctic Ice Loss (meters water equivalent relative to 2002) -3 -1 1 "The natural buffer system preventing Pine Island and Thwaites glaciers from flowing rapidly is **breaking down**.

The ice shelves are showing **new damage areas** that are the first signs of structural weakening and precondition these ice shelves for **disintegration**."

Lhermitte, S., et al. (2020) Damage accelerates ice shelf instability and mass loss in Amundsen Sea Embayment. Proceedings of the National Academy of Sciences, Sept. 14; DOI: 10.1073/pnas.1912890117





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## Groundwater Depletion ~10%

## IPCC, 2021 Assessment Report 6

Sea level is committed to rise for centuries to millennia due to continuing deep-ocean warming and ice-sheet melt and will remain elevated for thousands of years (high confidence). [AR6 WGI SPM p.21 B.5.4]

Global mean sea level will rise by about

- 6.5 to 10 ft at 1.5°C,
- 6.5 to 20 ft at 2°C and
- 62 to 72 ft with 5°C of warming,
- and it will continue to rise over subsequent millennia

IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., et al. (eds.)]. In Press.

### Sea level rise, an unstoppable reality

Photo, S. Habel

#### Global Mean Sea Level Rise

Latest MSL Measurement 15 October. 2021

#### +3.51 mm/yr

Reference GMSL - corrected for GIA



https://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/mean-sea-level.html

#### NOAA/NASA SLR Planning Scenarios Honolulu SLR



https://sealevel.nasa.gov/task-force-scenario-tool

#### SLR Flooding: Nuisance and Permanent



Storm drain backflow

#### Groundwater Inundation



## Waikiki Dec. 5, 2021

- Sea level rise flooding today involves
  - Rain
  - Extreme tides
  - Onshore winds
  - Large waves



# Rain + High Tide = Flooding



The second second second second



Home / Shoreline Impacts / Sea Level Rise / State of Hawai'i Sea Level Rise Viewer

SHARE f У 🦻 in 🔤

#### Sea Level Rise : State of Hawai'i Sea Level Rise Viewer





McDonald's

Chevron 5

US Post Office 🖂

+

🖸 🌌 🛛 Select a site..

nes Campbe

Ewa Beach Community Park

#### Contraction of

Honolulu Observatory

Pacific Tsunami Warning Center

105

The Church of Jesus Christ of Latter...

BASEMAPS COASTAL EROSION SEA LEVEL RISE BY YEAR SEA LEVEL RISE BY FEET WAVE INUNDATION OTHER OVERLAYS

expand · collapse · clear

Summer wave run-up 2 ft

Ewa Beach Golf Club 📀

Aloha Community Church

Puuloa Range Training Facility

Wave Inundation 16 Vater depth 12 8 4 (ft)

200 m

500 ft







#### Sunset Beach 3.2 ft SLR

Ehukal Beach

Rocky Point

Sunset Beach Park

Kālunawaika'ala Stream

Banzai Rocks

Annual wave Run-up

Erosion

Paumalū Gulch

# Climate Resiliency Collaborative

- Modeling:
  - Coastal erosion, Groundwater inundation, Annual wave runup, Storm drain back flow
  - *SLR Exposure Area-* A new Planning District
- Sea level rise research products used in
  - Kaua'i coastal setback
  - Kaua'i exclusion zone
  - Maui coastal setback
  - Oʻahu coastal setback
  - Oahu Capital budgeting
  - Rail design & planning
  - Real Estate Disclosure Law (nations first)
  - State seawall ban



# SLR Viewer 2.0, Office Naval Research

- 1 ft increments of sea level rise w/ local interagency scenarios (chronology)
- 2D coastal erosion
- 2D wave run-up
- Groundwater monitoring
- Storm drain monitoring
- Storm surge
- Compound events rain + high tide













Drainage Failure
Impassable Roadway

Habel, S., Fletcher, C., Anderson, T., & Thompson, P. 2020. Sea-Level Rise Induced Multi-Mechanism Flooding and Contribution to Urban Infrastructure Failure. Nature Scientific Reports, 10: 3796 DOI:10.1038/s41598-020-60762-4

1 m

Miles

0.25

0

0.5





#### Sea Level Rise: 5 ft (MHHW)

Drainage Failure
 Impassable Roadway

# Thank you