Hawaii's Changing Climate: Sea Level Rise

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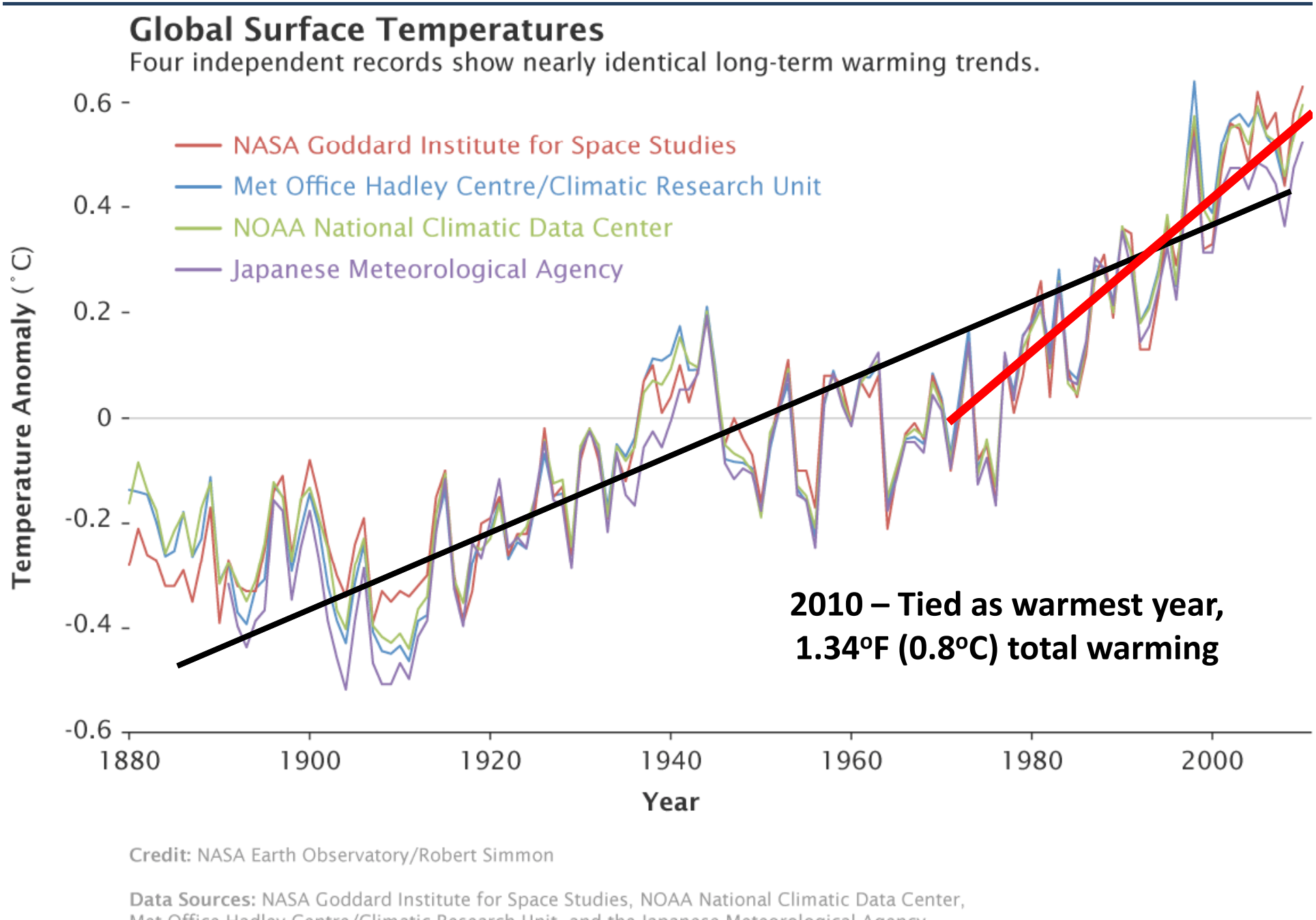
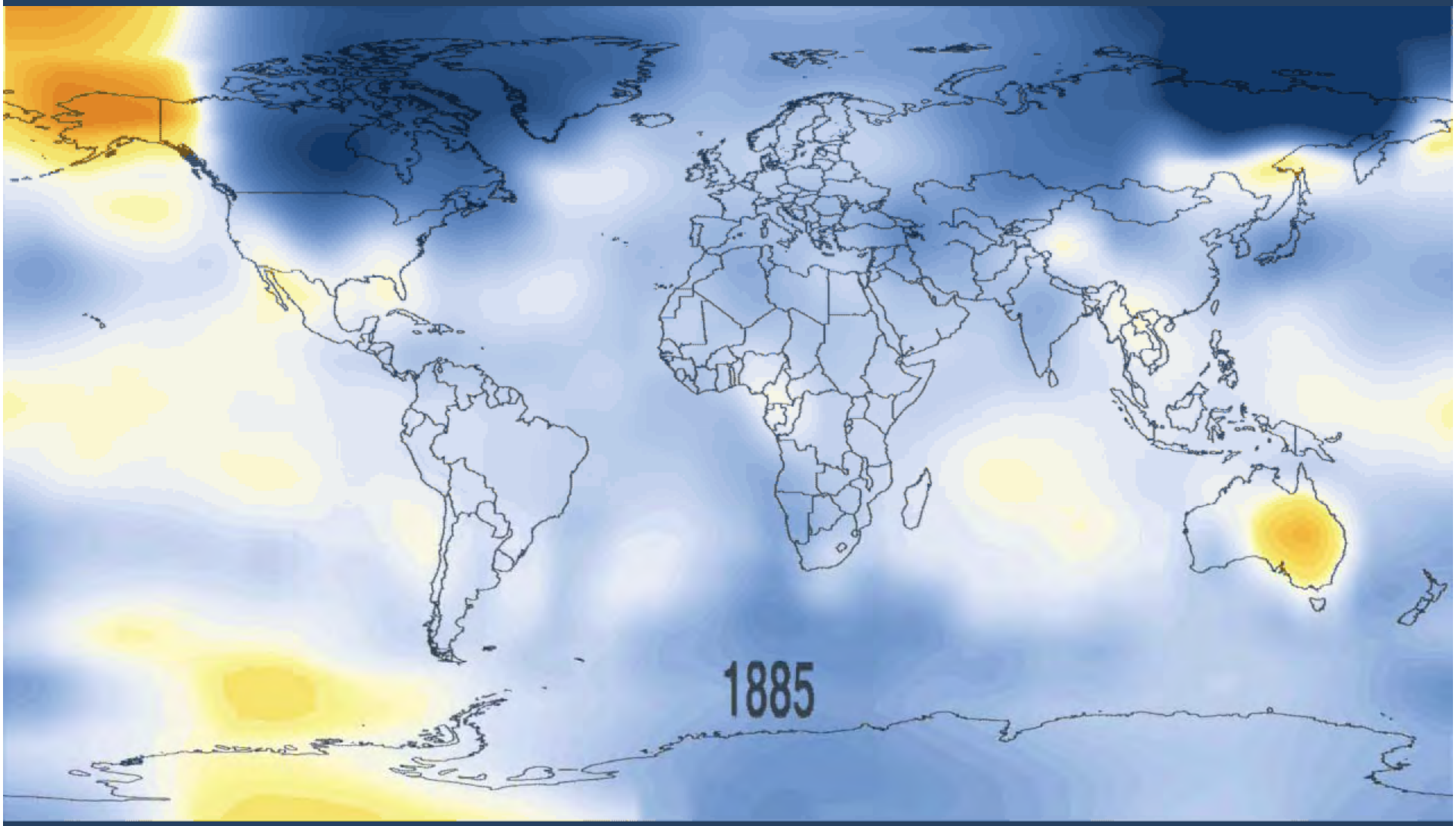
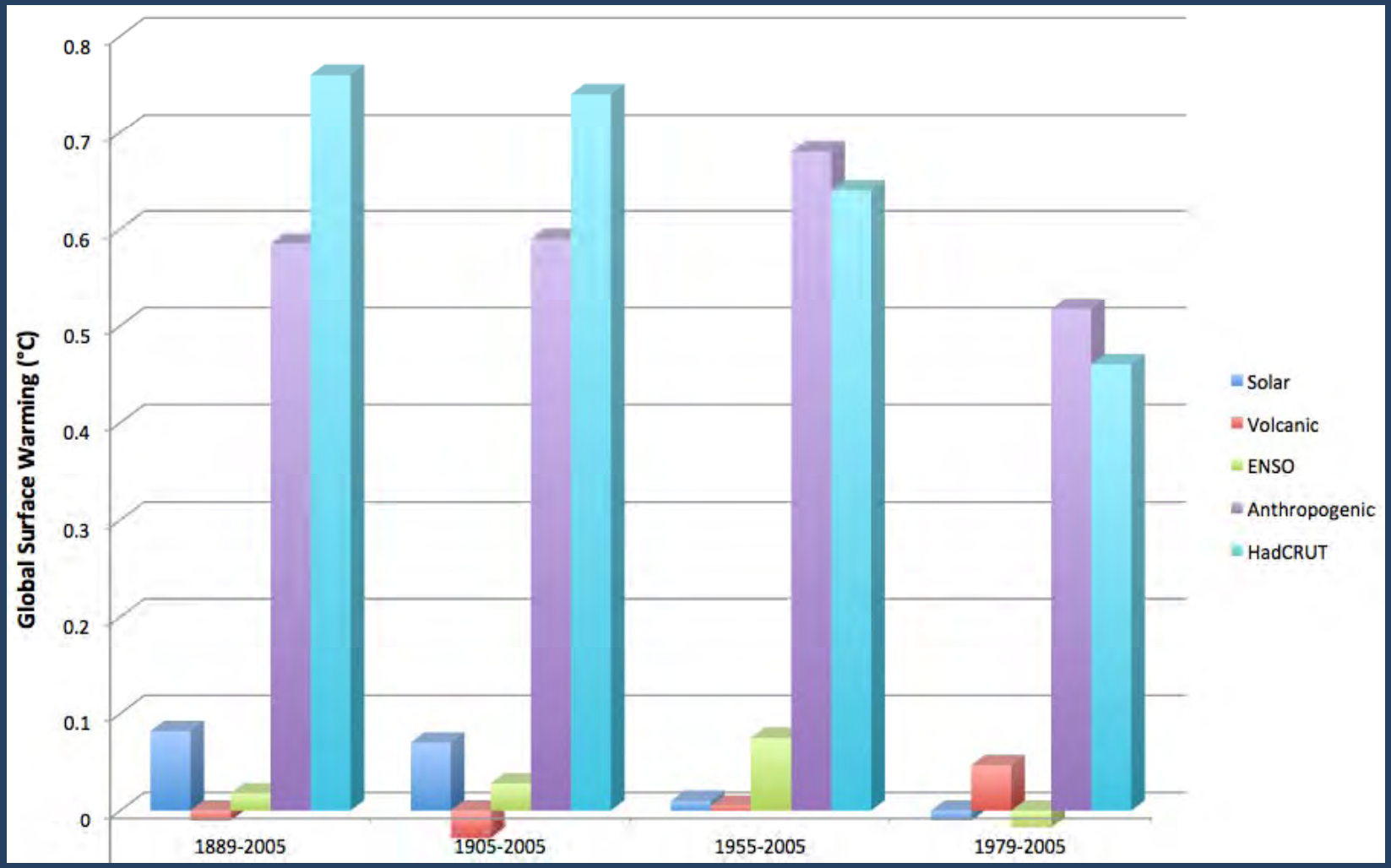


Global Surface Temperature Change, J. Hansen, R. Ruedy, M. Sato, K. Lo, 2010, NASA Goddard Institute for Space Studies, NY, NY



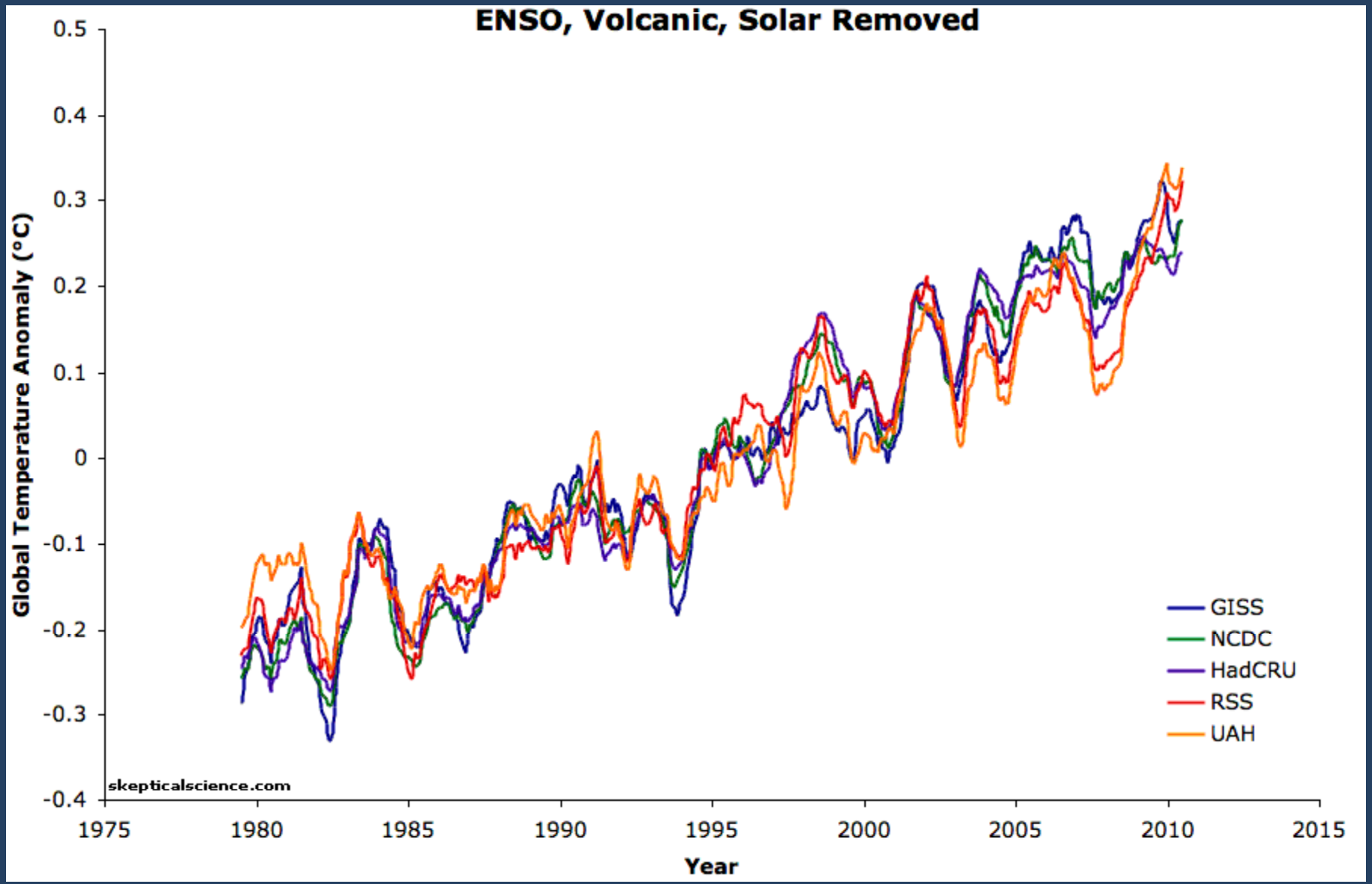
NASA Goddard Institute for Space Studies, NY, NY http://data.giss.nasa.gov/gistemp/

Causes of climate change



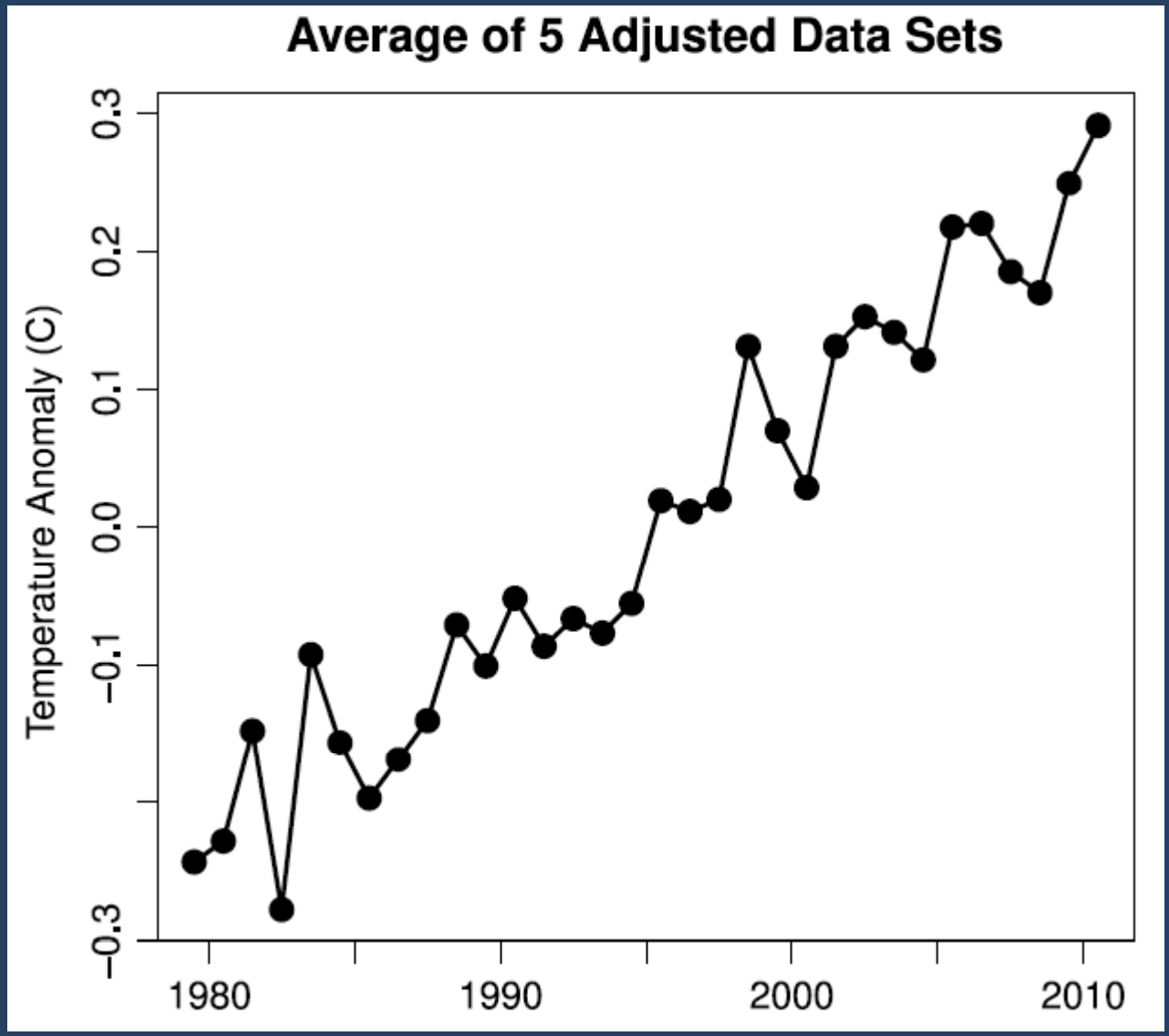
Lean, J. L., and D. H. Rind, 2009, How will Earth's surface temperature change in future decades? Geophysical Research Letters, v. 36, L15708, doi:10.1029/2009GL038932.

Causes of climate change



Foster, G., Rahmstorf, S. (2011) Global temperature evolution 1979-2010 , Environmental Research Letters 6, 044022 (8pp) doi:10.1088/1748-9326/6/4/044022

Causes of climate change



Foster, G., Rahmstorf, S. (2011) Global temperature evolution 1979-2010 , Environmental Research Letters 6, 044022 (8pp) doi:10.1088/1748-9326/6/4/044022

U.S. National Academy of Science and Engineering

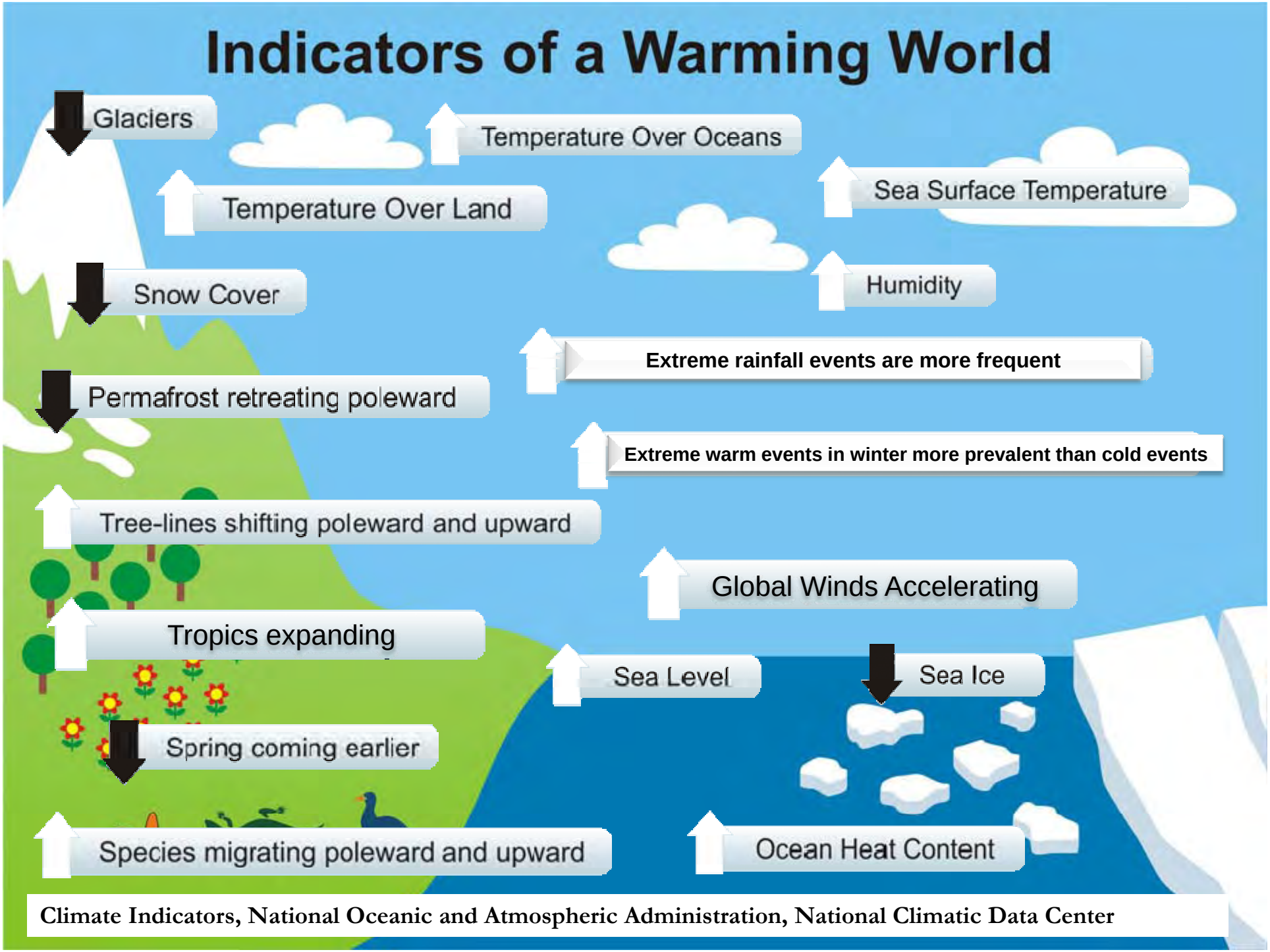
May 29, 2011

Some scientific conclusions have been so thoroughly examined and tested, and supported by so many independent observations and results, that their likelihood of being found wrong is vanishingly small. Such conclusions are then regarded as **settled facts**. This is the case for the conclusions that the Earth system is warming and that much of this warming is very likely due to human activities.

very likely = 90-99% probability

…strong evidence on climate change underscores the need for actions to reduce emissions and begin adapting to impacts.

Advancing the Science of Climate Change – National Academies: http://americasclimatechoices.org/

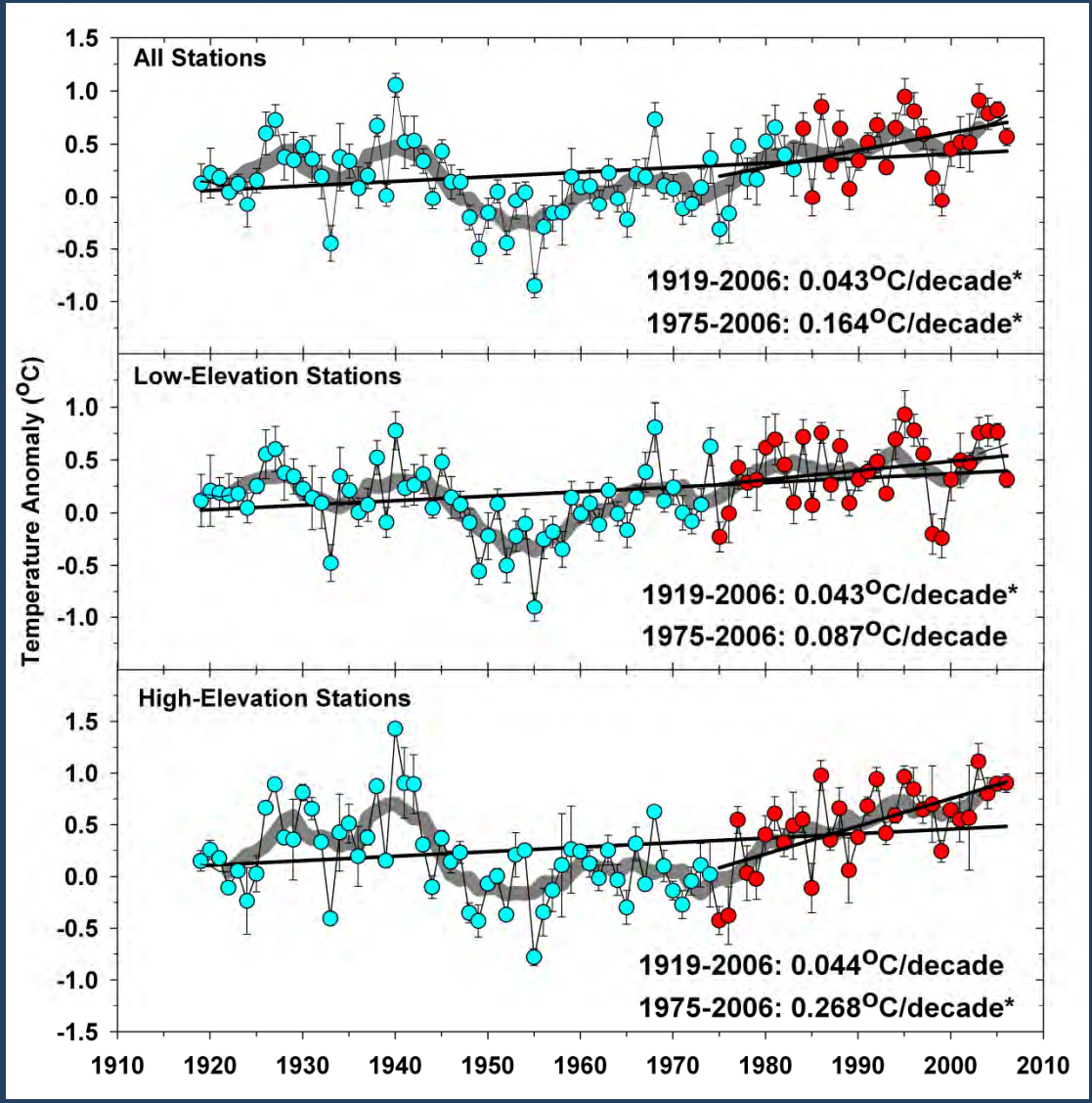

Indicators of a Warming World
Glaciers
Temperature Over Oceans
Temperature Over Land
Sea Surface Temperature
Snow Cover
Humidity
Extreme rainfall events are more frequent
Permafrost retreating poleward
Extreme warm events in winter more prevalent than cold events
Tree-lines shifting poleward and upward
Global Winds Accelerating
Tropics expanding
Sea Level
Sea Ice
Spring coming earlier
Species migrating poleward and upward
Ocean Heat Content
Climate Indicators, National Oceanic and Atmospheric Administration, National Climatic Data Center

Hawai′i Climate is Changing

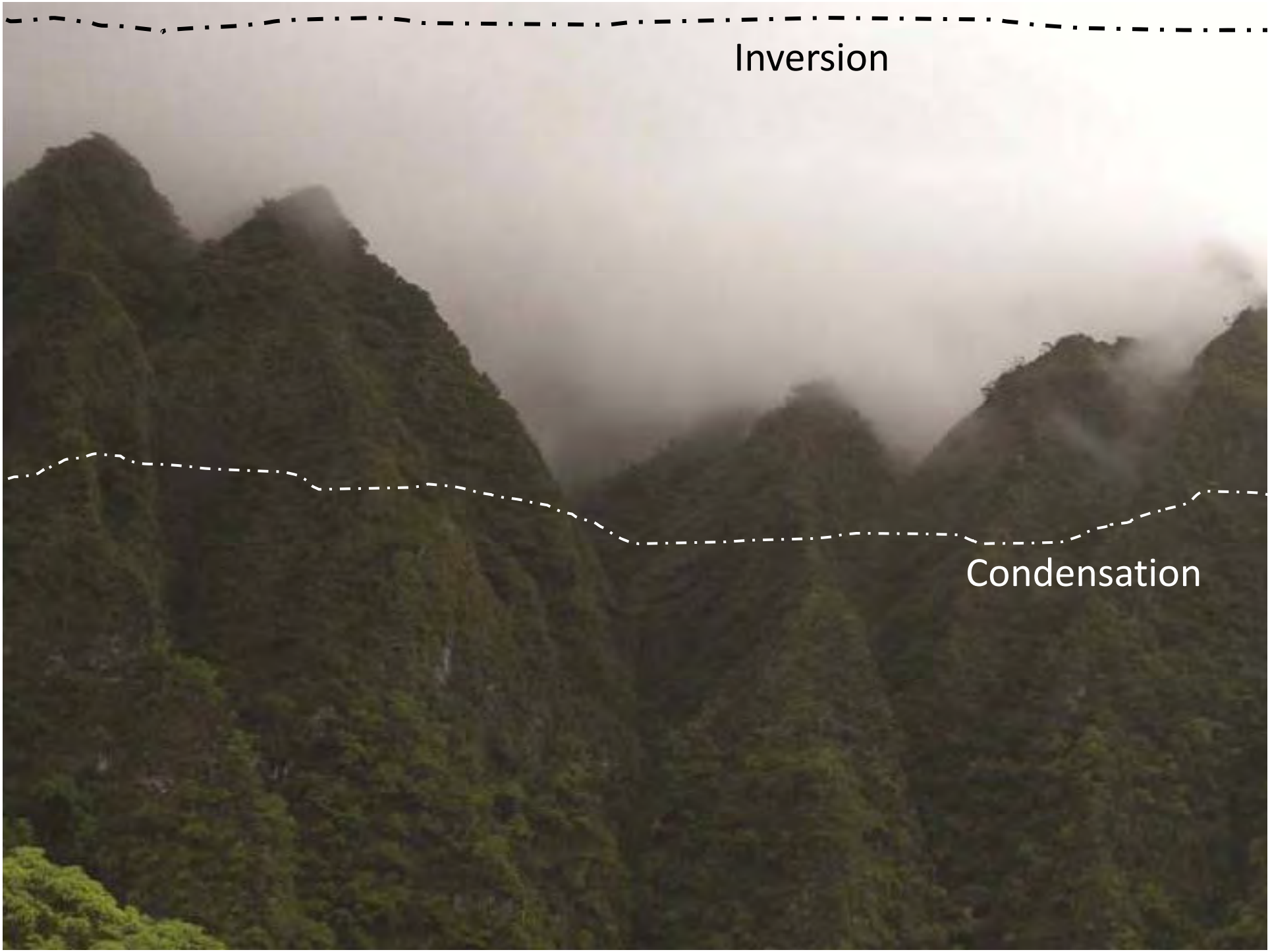
- Air temperature is increasing (0.3°F/decade)
- Rainfall (-15%) and base-flow to streams have decreased
- Sea surface temperature is rising (0.22°F/decade)
- Ocean has grown more acidic
- Sea level is rising

Fletcher, C.H. (2010) Hawaii's Changing Climate (7p) University of Hawaii Sea Grant College Program, Center for Island Climate Adaptation and Policy, Honolulu

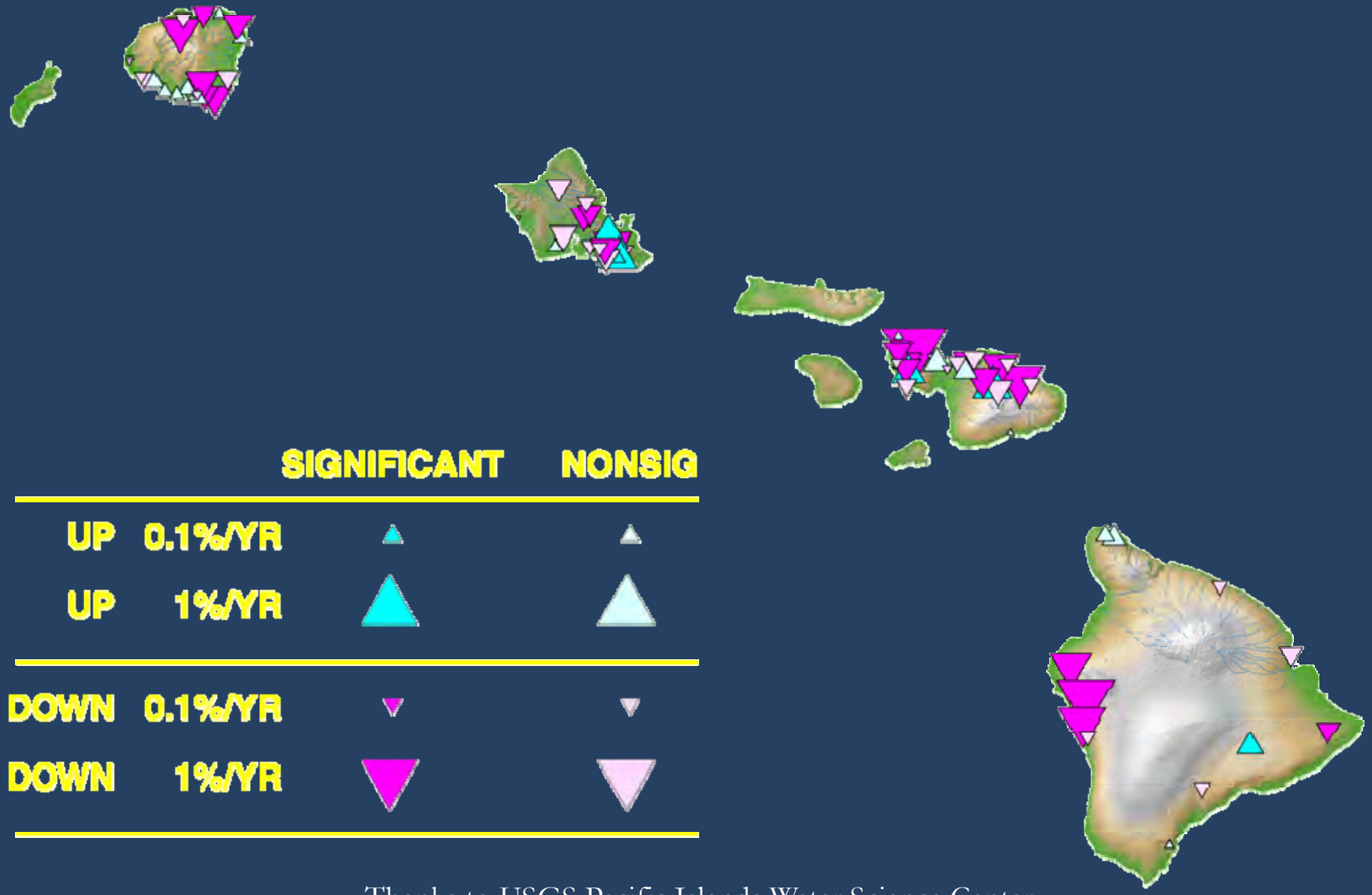
Hawai‘i Temperature Index



T. W. Giambelluca, H. F. Diaz, and M. S. A. Luke, 2008 “Secular Temperature Changes in Hawai‘i” *Geophysical Research Letters*, 35:L12702.

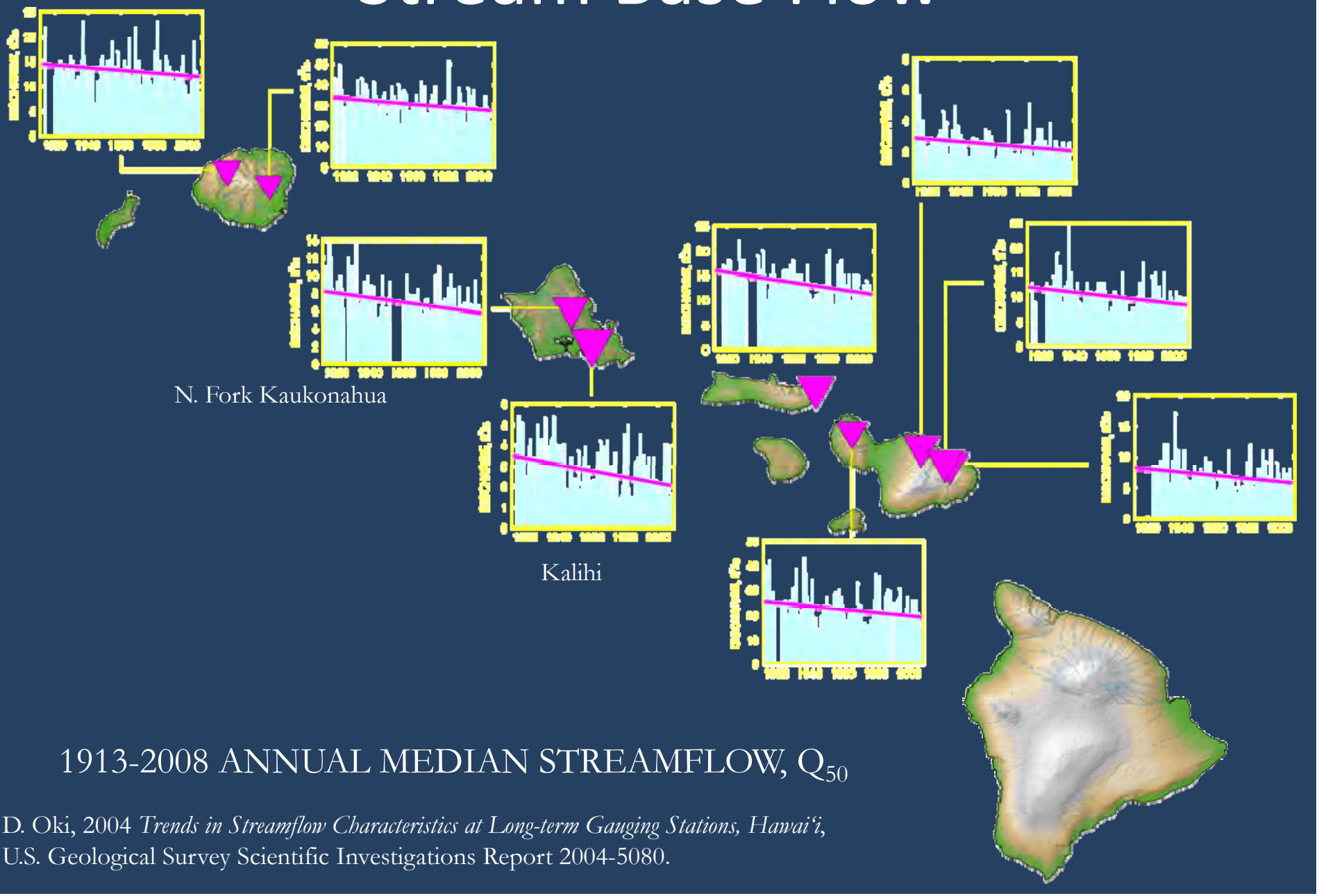

Inversion
Condensation

1913–2008 ANNUAL RAINFALL



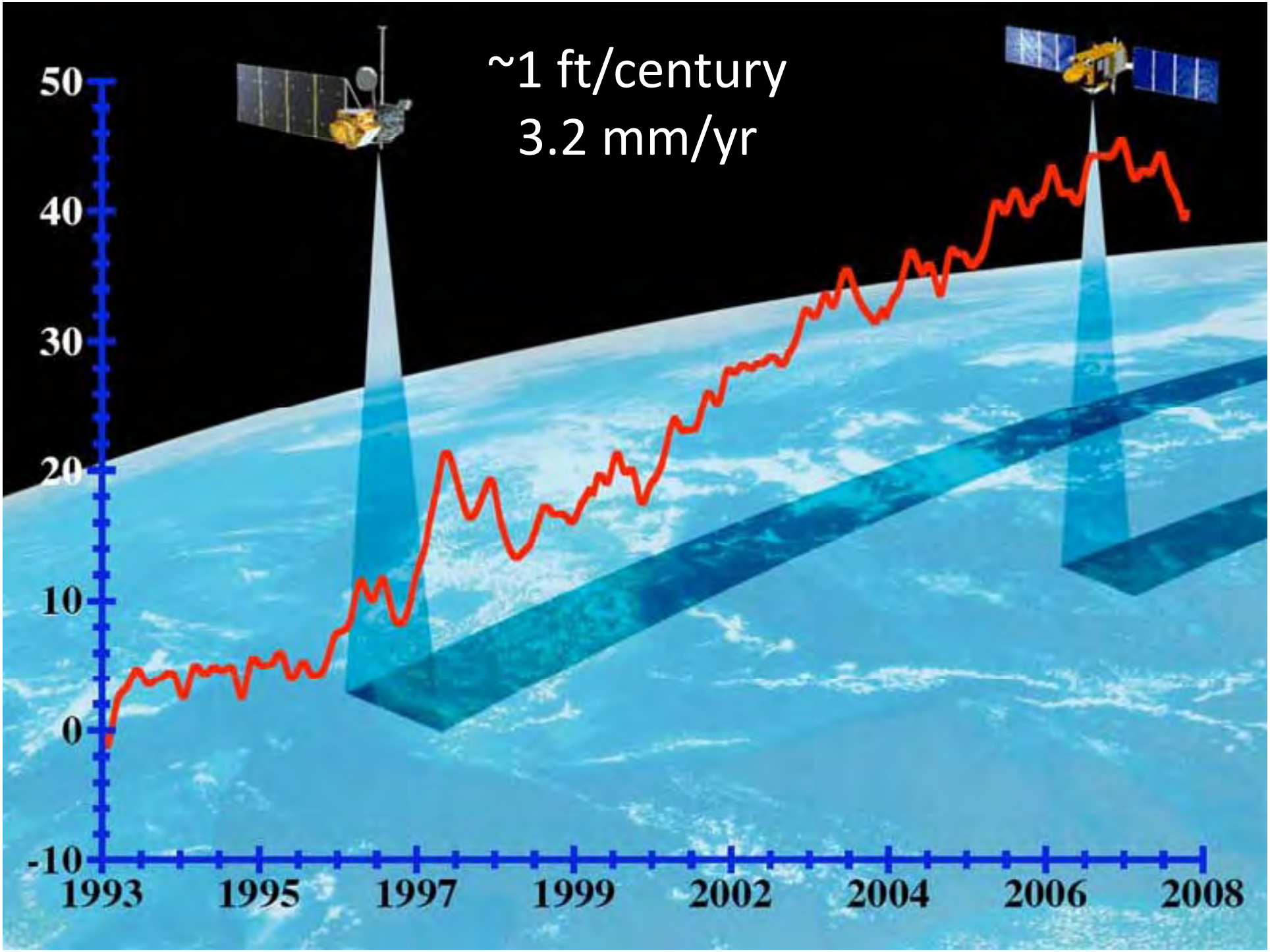
Thanks to USGS Pacific Islands Water Science Center

Stream Base Flow

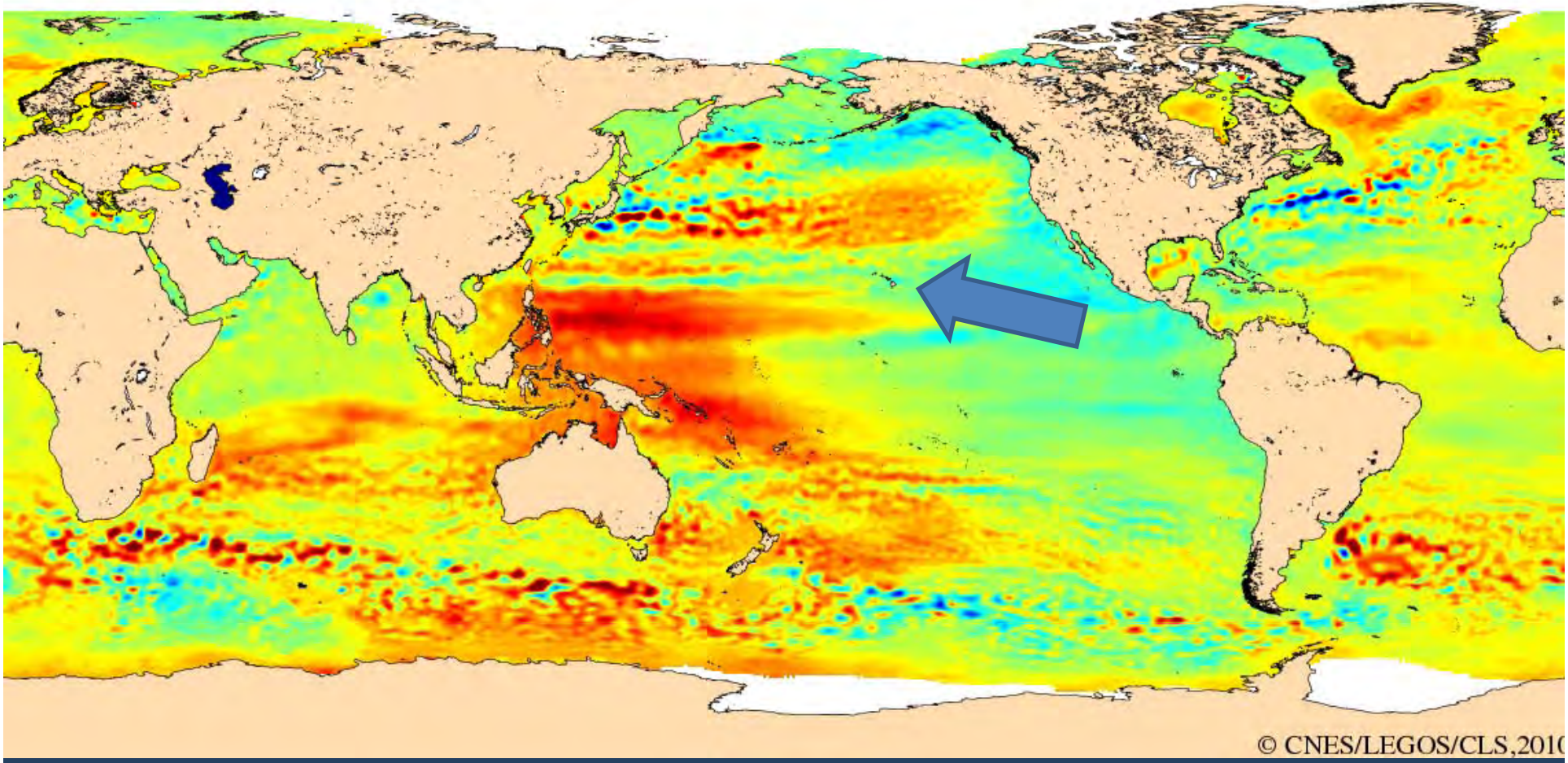


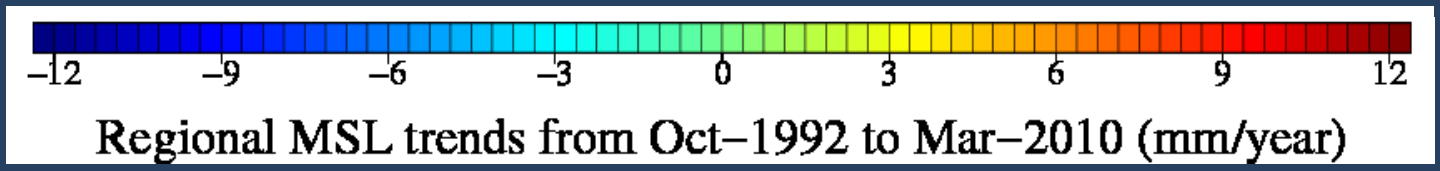
1913-2008 ANNUAL MEDIAN STREAMFLOW, Q_{50}

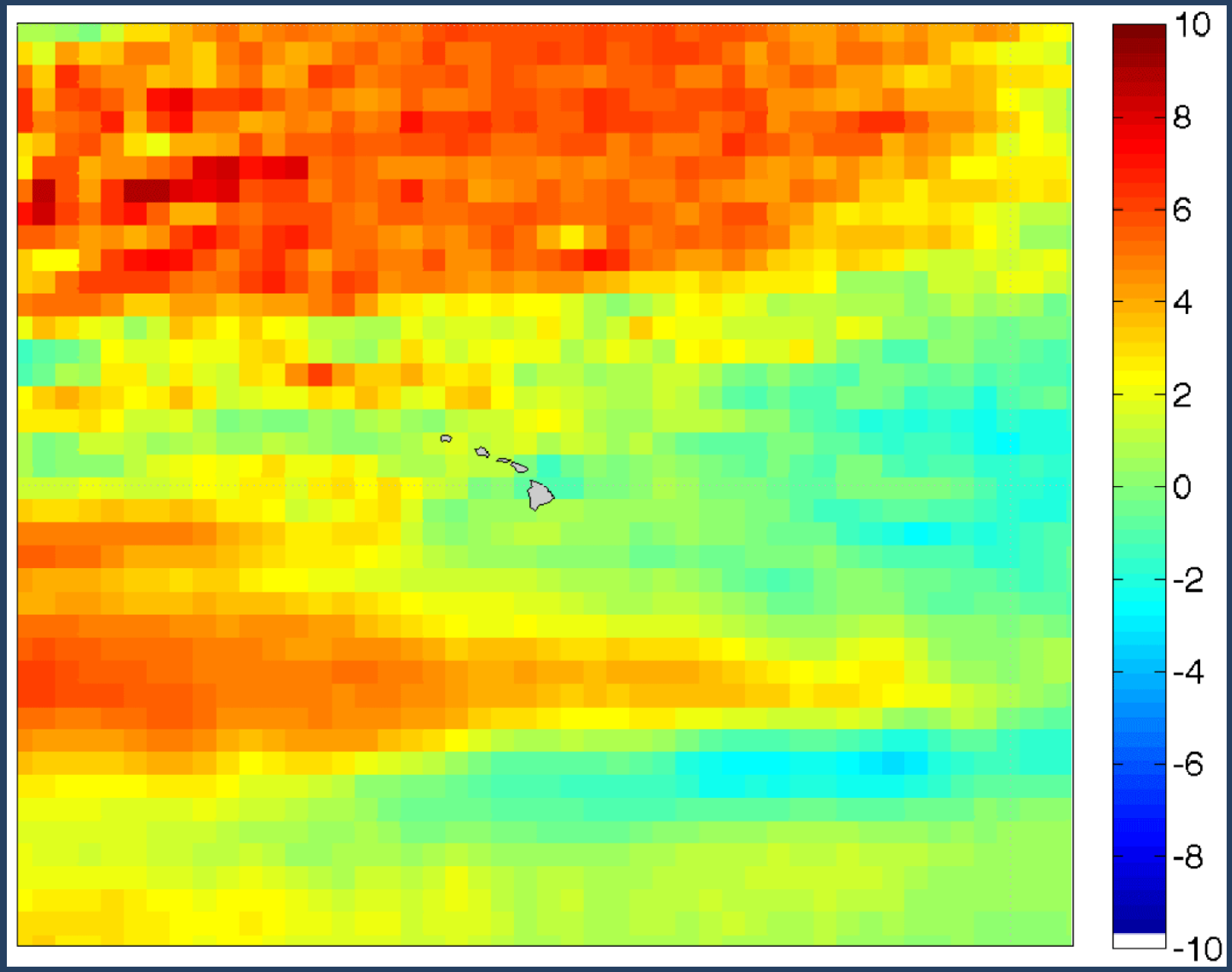
D. Oki, 2004 *Trends in Streamflow Characteristics at Long-term Gauging Stations, Hawai'i*, U.S. Geological Survey Scientific Investigations Report 2004-5080.


~1 ft/century
3.2 mm/yr
50
40
30
20
10
0
-10
1993
1995
1997
1999
2002
2004
2006
2008

Satellite Altimetry – global average 3.2 mm/yr

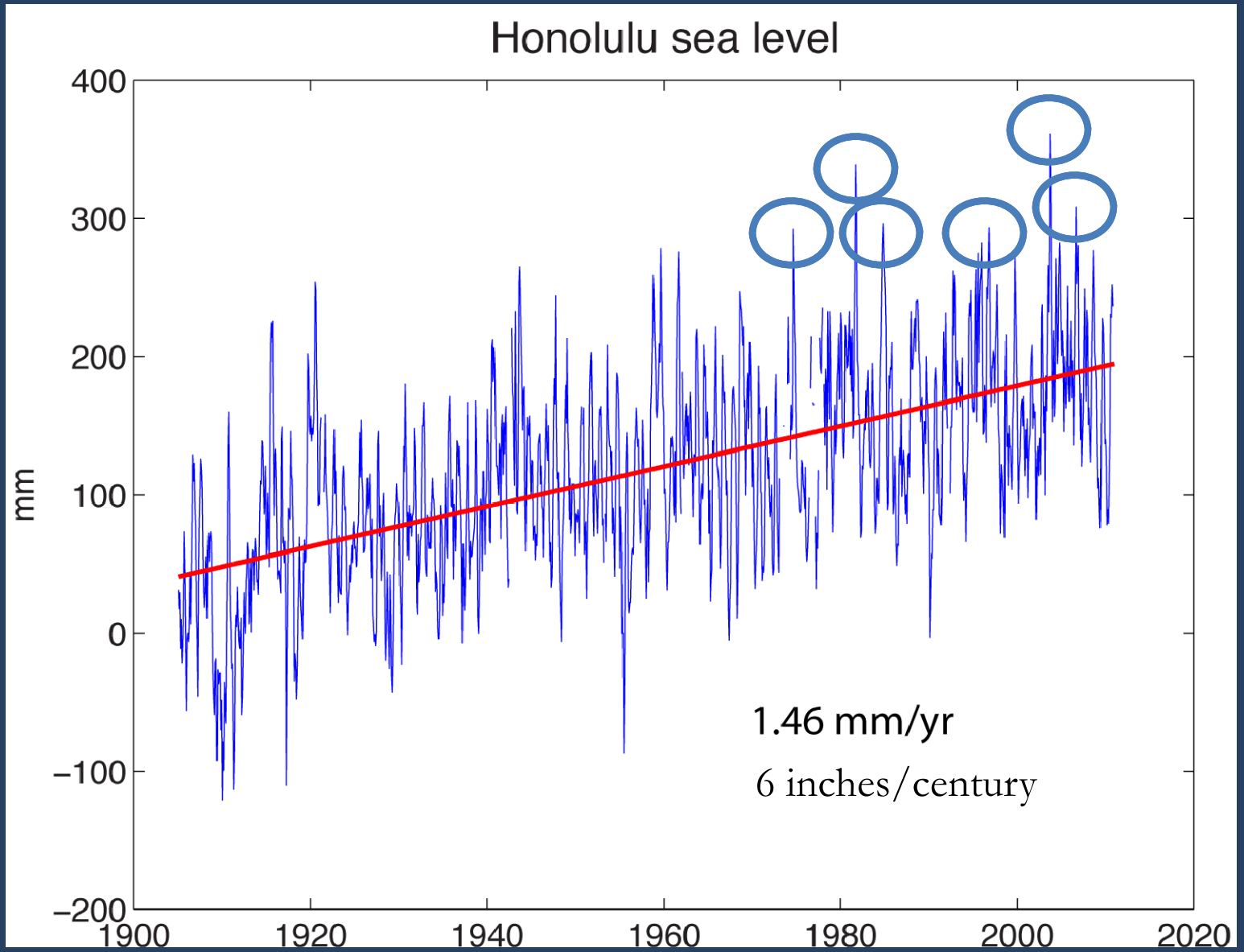






Mahalos to UH Oceanography Professor Mark Merrifield, UH Sea Level Center, Joint Institutes for Marine and Atmospheric Research

Honolulu Sea Level



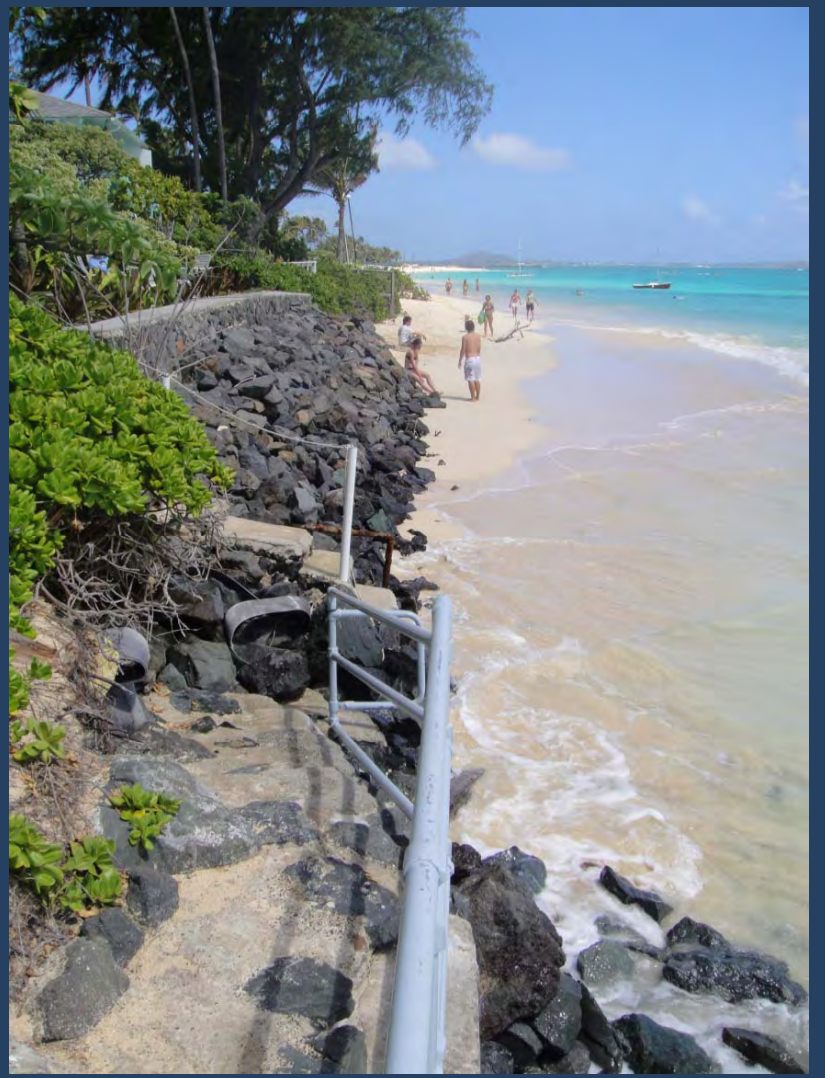
Mahalos to UH Oceanography Professor Mark Merrifield, UH Sea Level Center, Joint Institutes for Marine and Atmospheric Research

Extreme Tides

Erosion is the dominant trend on Hawaii beaches

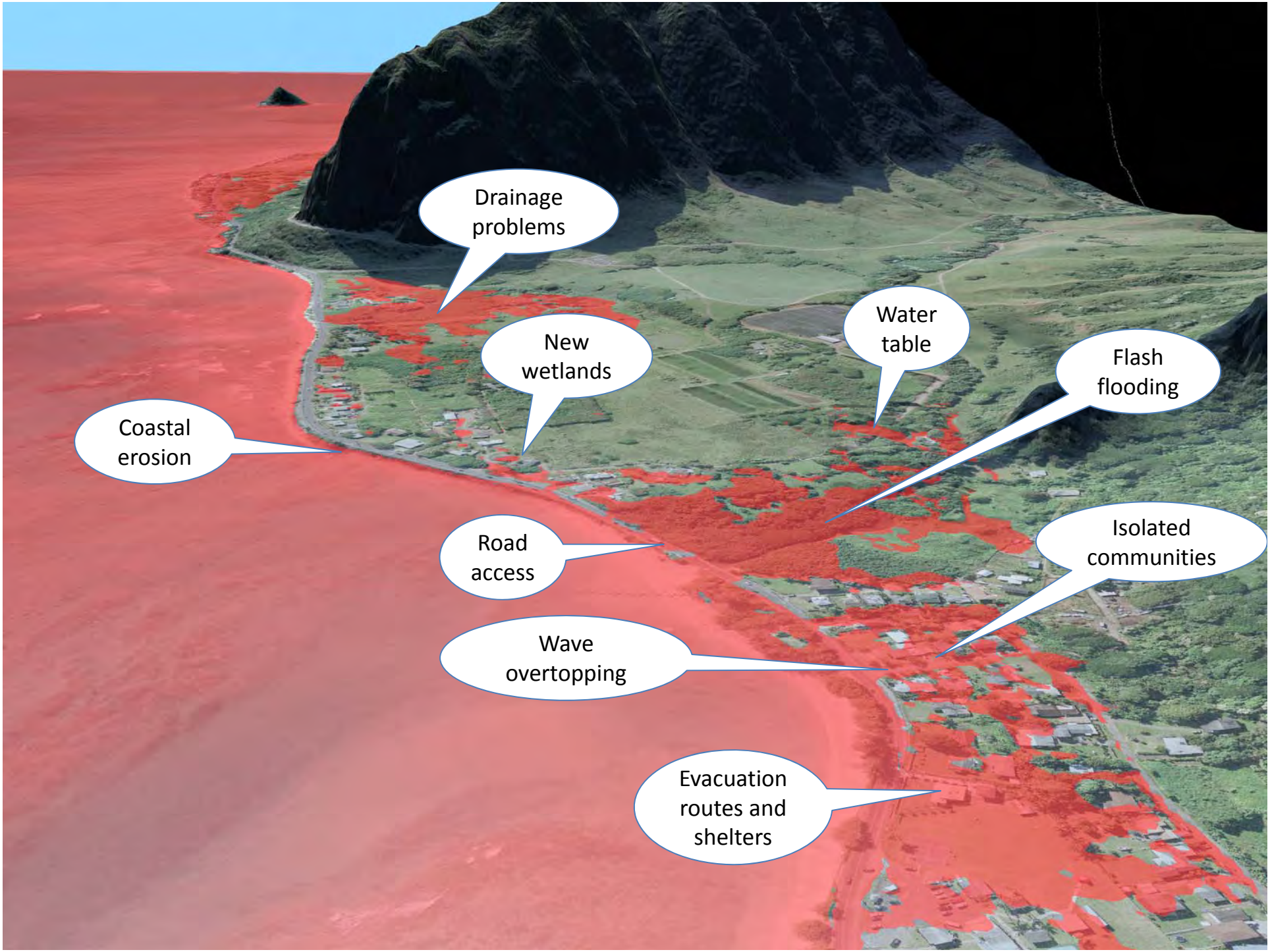
Hawaii, overall (Kauai, Oahu, Maui)

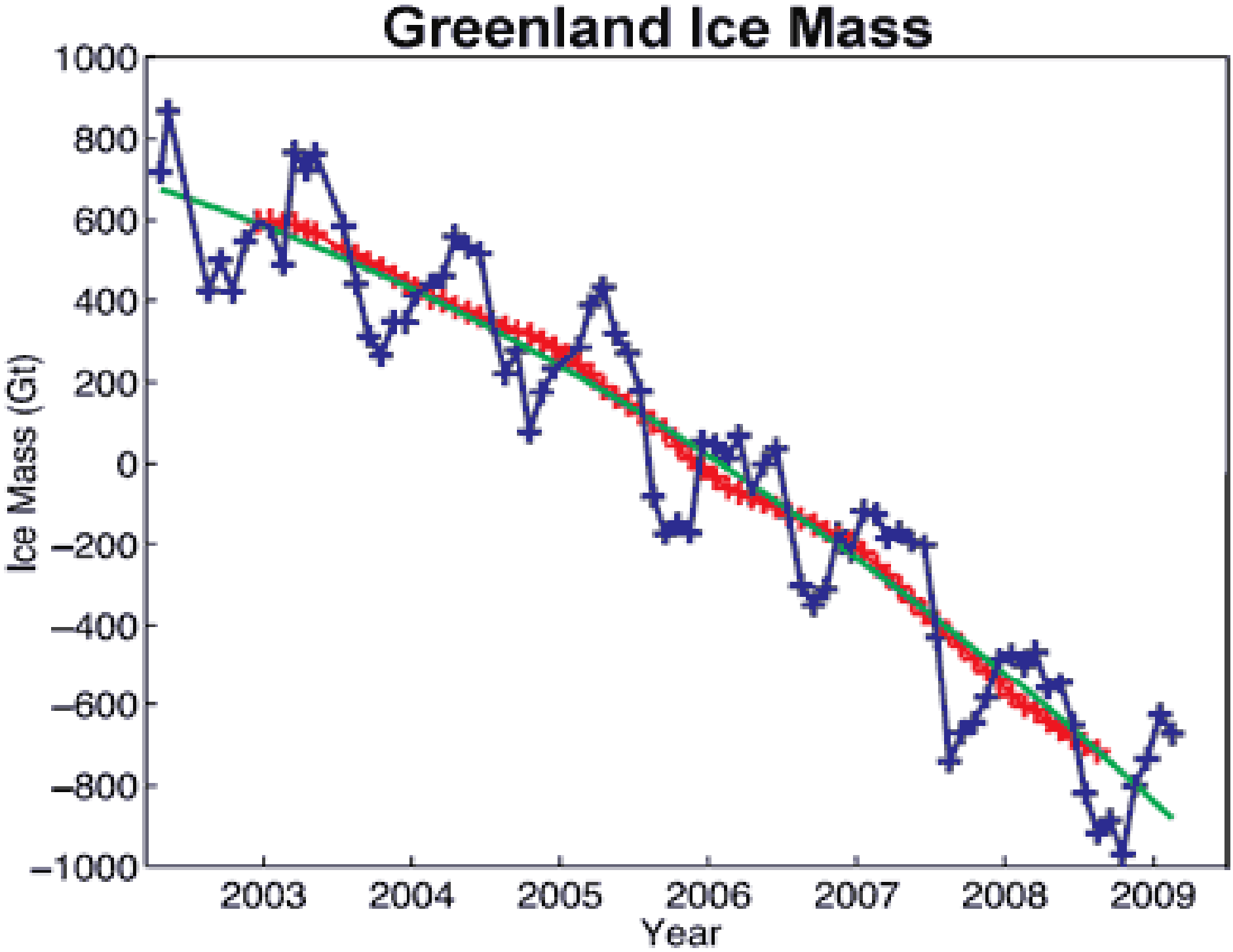
- 70% of beaches eroding
- 13.6 miles (9%) of beaches completely lost to erosion
- Avg. rate = -0.8 ft/yr

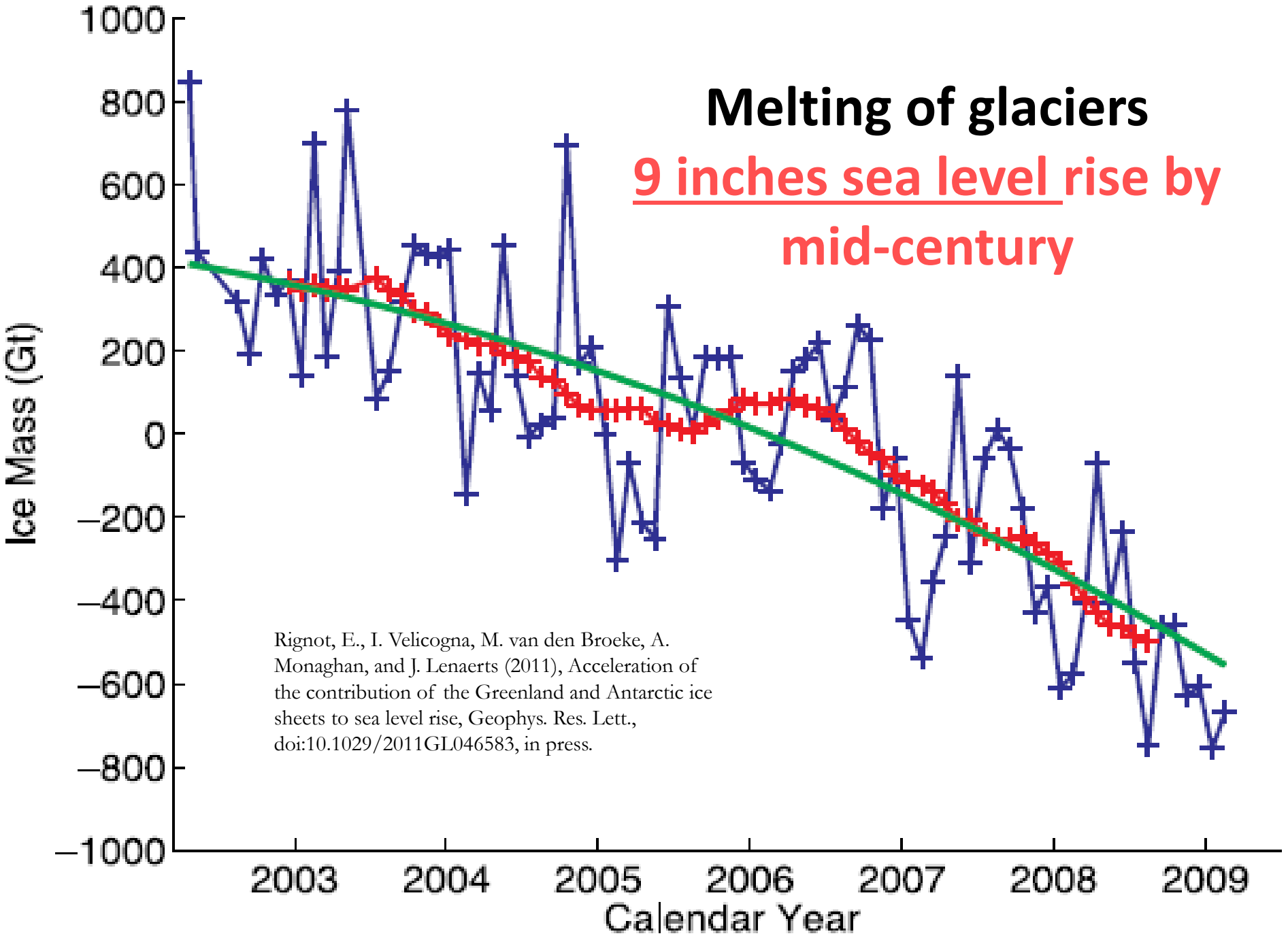


Source: Fletcher, *et al*., (in press) National assessment of shoreline change: historical shoreline changes in the Hawaiian islands. USGS open-file report.

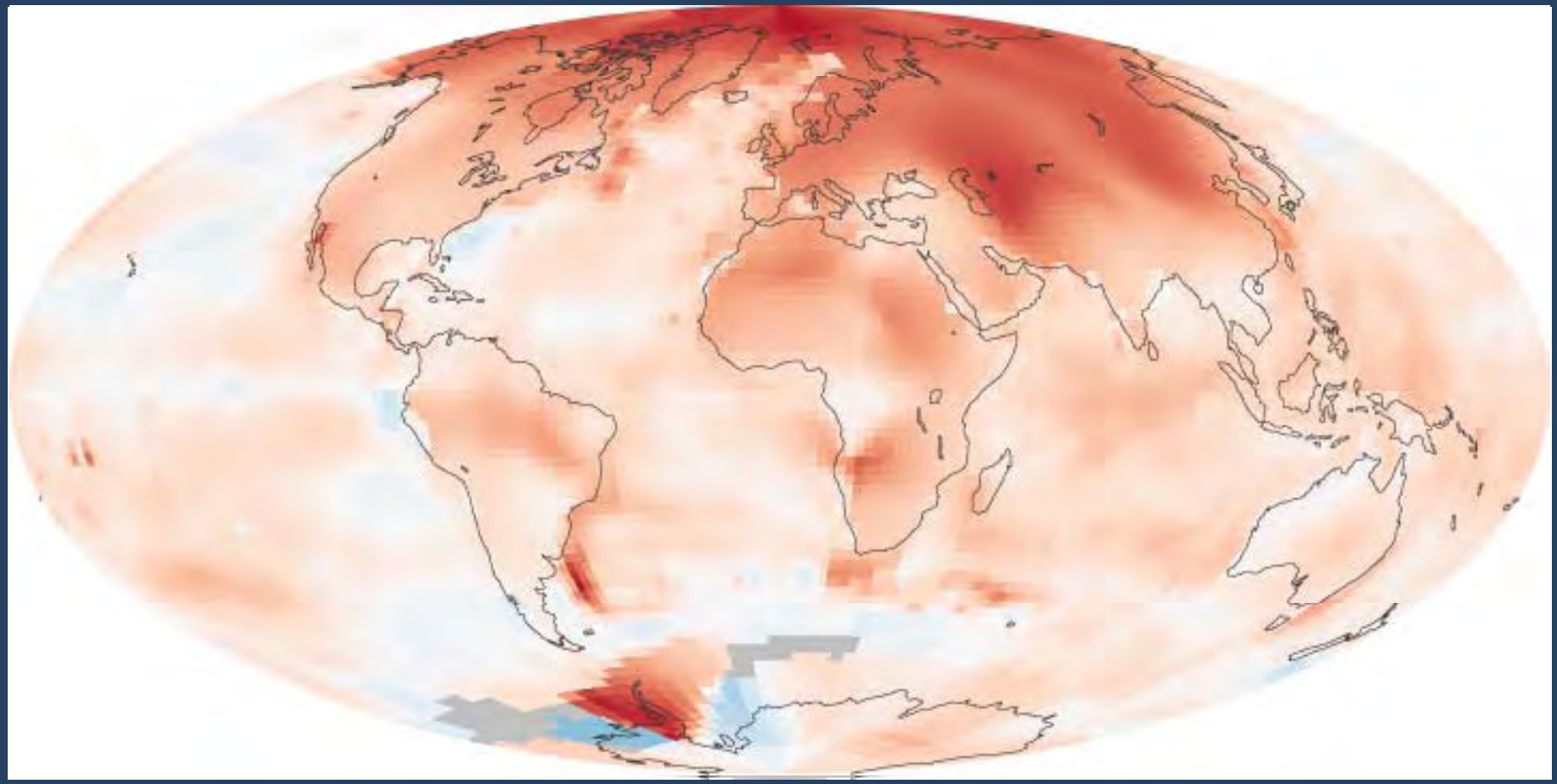

Storm drains
backed up at
high tide.


Drainage problems
New wetlands
Water table
Flash flooding
Coastal erosion
Road access
Isolated communities
Wave overtopping
Evacuation routes and shelters


Greenland Ice Mass
1000
800
600
400
200
0
−200
−400
−600
−800
−1000
Ice Mass (Gt)
2003
2004
2005
2006
2007
2008
2009
Year


Melting of glaciers
9 inches sea level rise by mid-century
Rignot, E., I. Velicogna, M. van den Broeke, A. Monaghan, and J. Lenaerts (2011), Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise, Geophys. Res. Lett., doi:10.1029/2011GL046583, in press.
Ice Mass (Gt)
1000
800
600
400
200
0
−200
−400
−600
−800
−1000
2003
2004
2005
2006
2007
2008
2009
Calendar Year

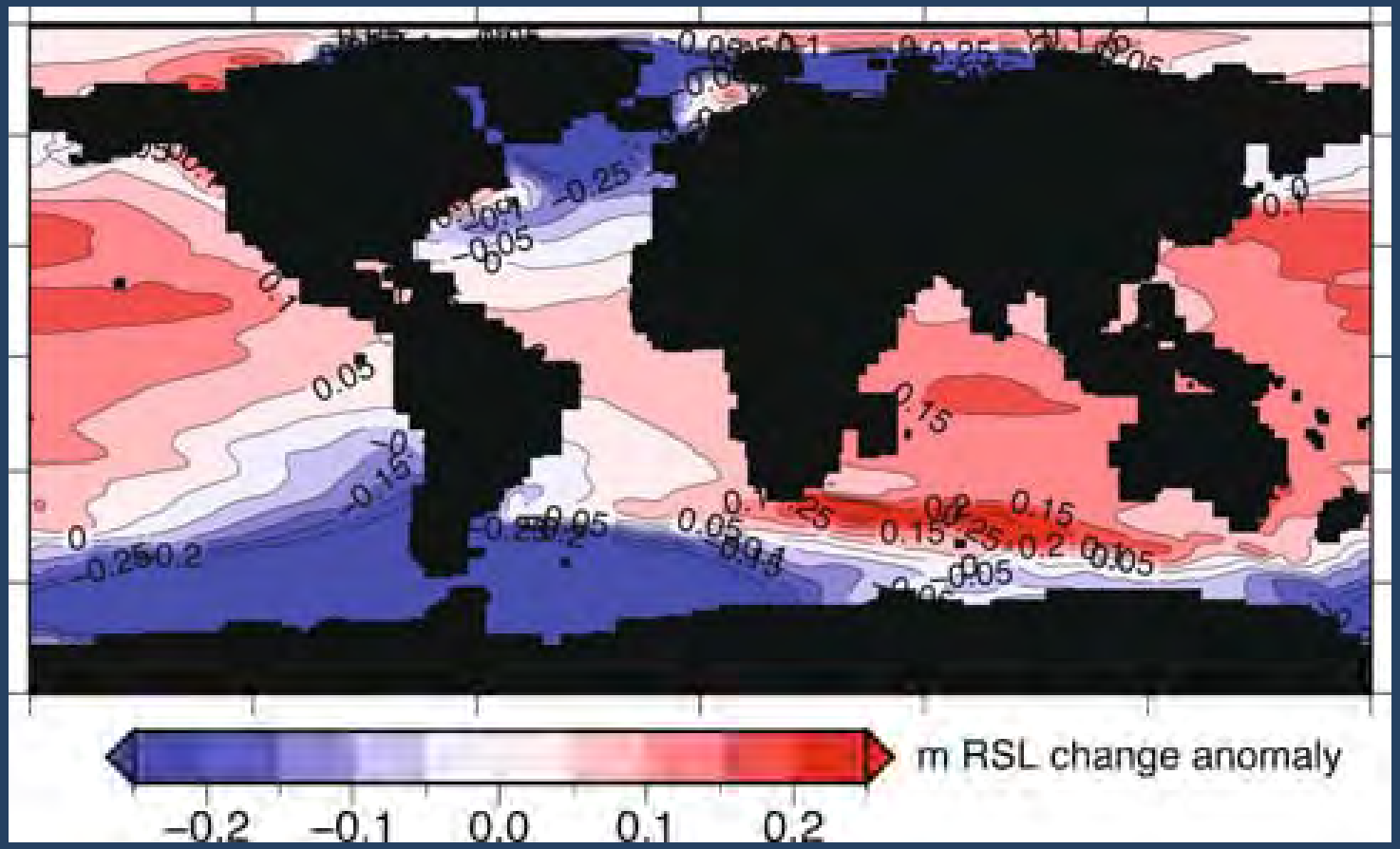
Thermal expansion of shallow ocean
TOTAL = 1 foot of sea level rise by mid-century
3.5 inches sea level rise by mid-century



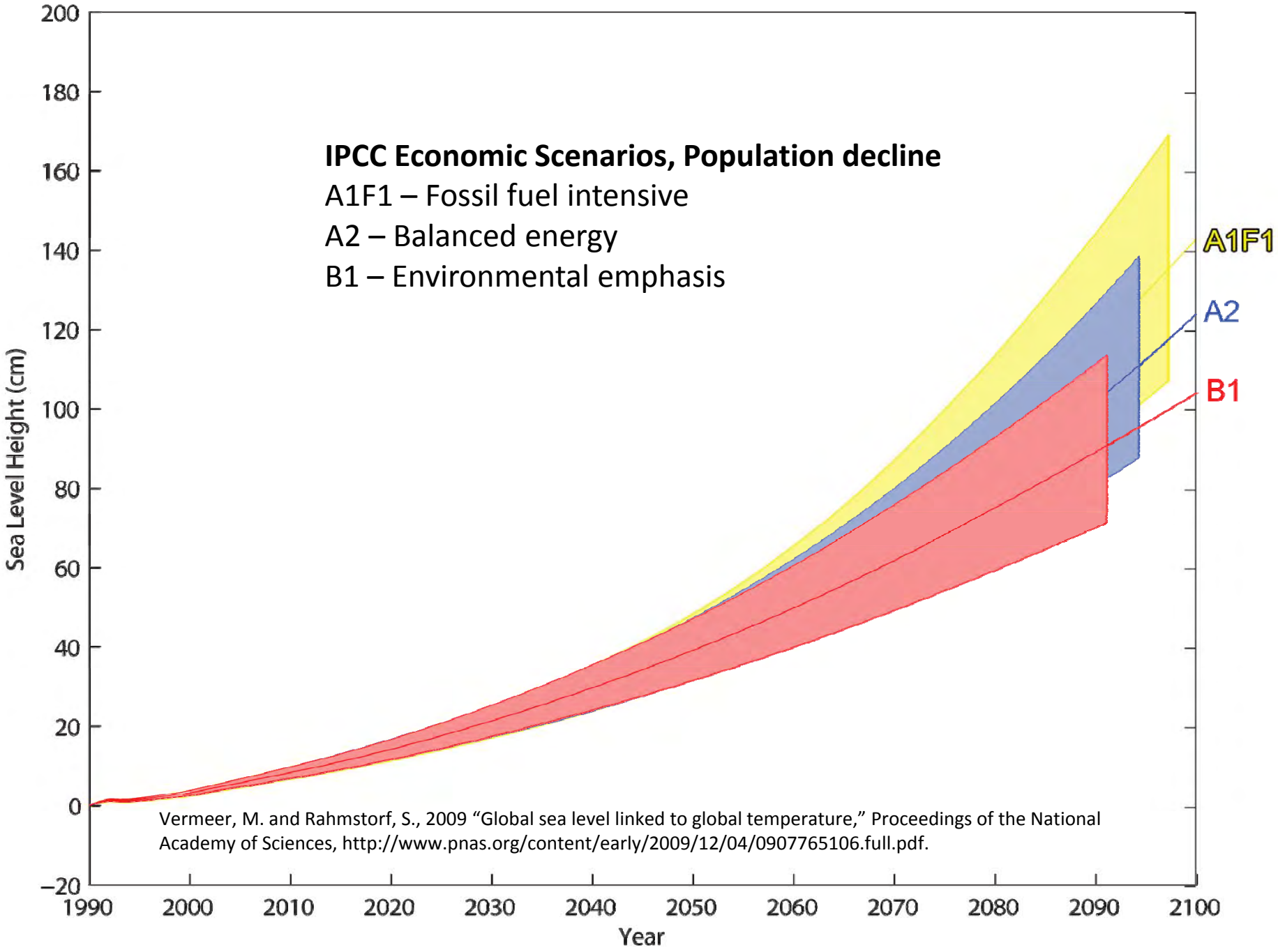
Hansen, J., R. Ruedy, M. Sato, and K. Lo (2010) Global surface temperature change, *Reviews of Geophysics,* doi:10.1029/2010RG000345.

Sea level estimates by end of century

Sea-level anomaly (m) w.r.t. global mean RSL change (1.02 m)

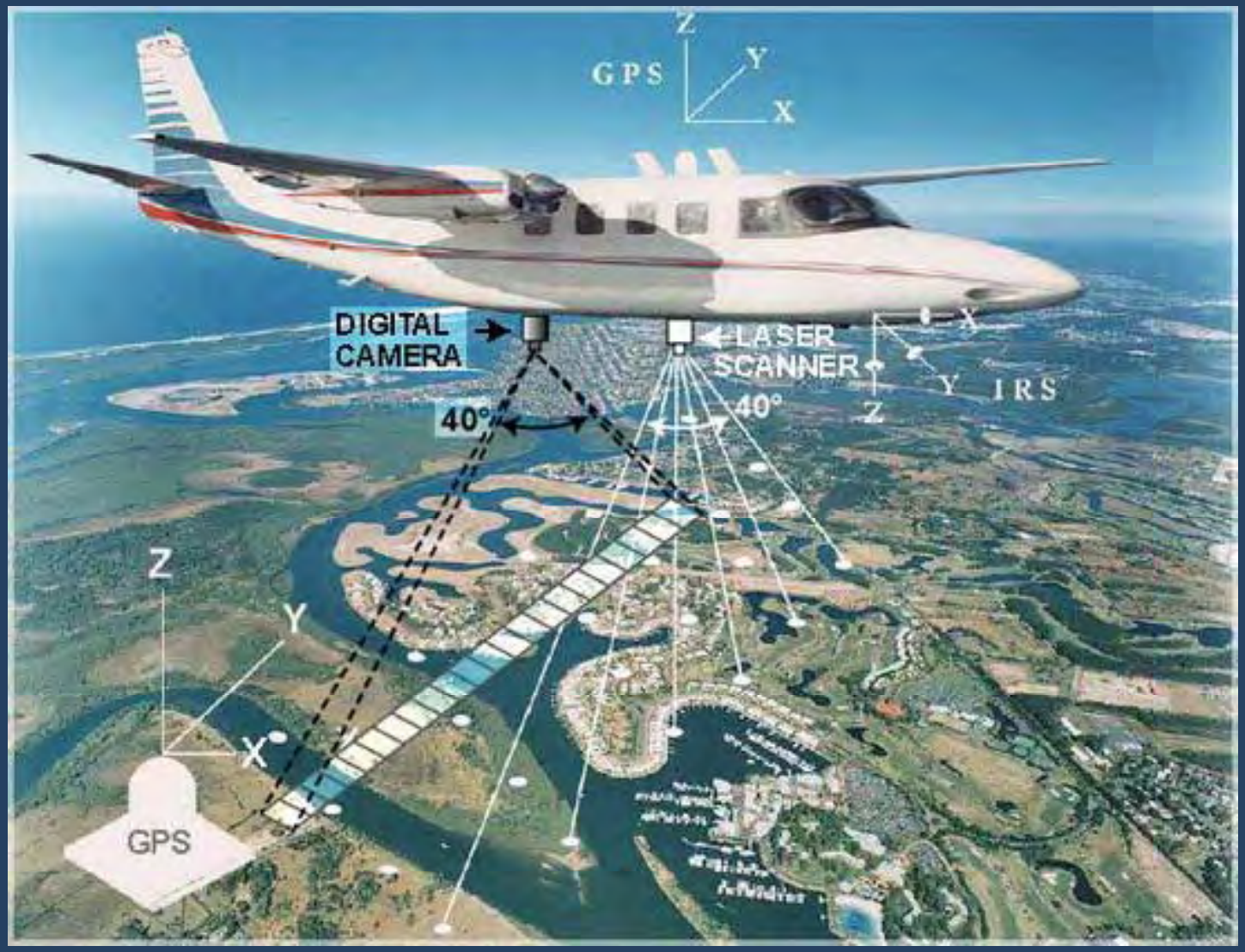


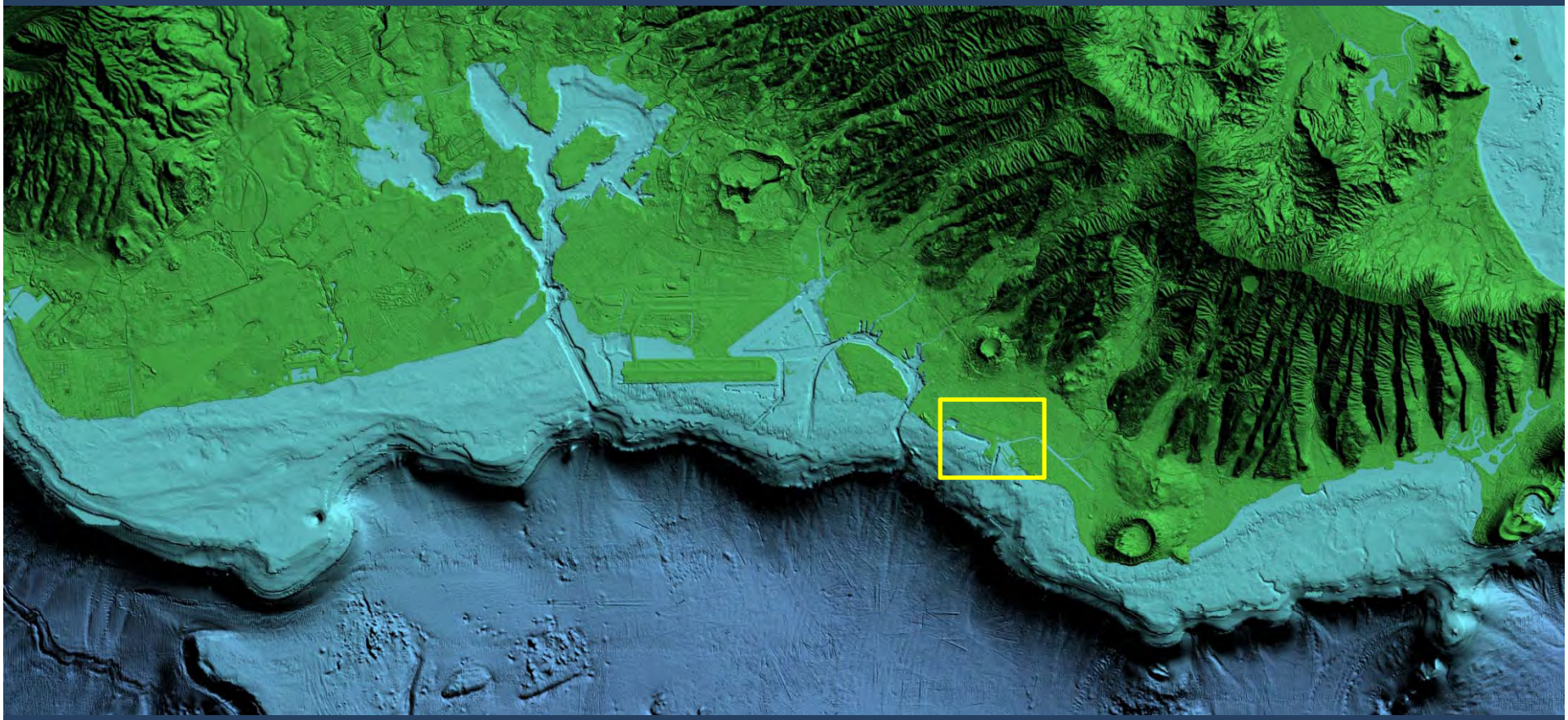
Slangen, A., C. Katsman, R. Van de Wal, L. Vermeersen, and R. Riva (2011) Towards regional projections of twenty-first century sea-level change based on IPCC SRES scenarios. Climate Dynamics. DOI: 10.1007/s00382-011-1057-6

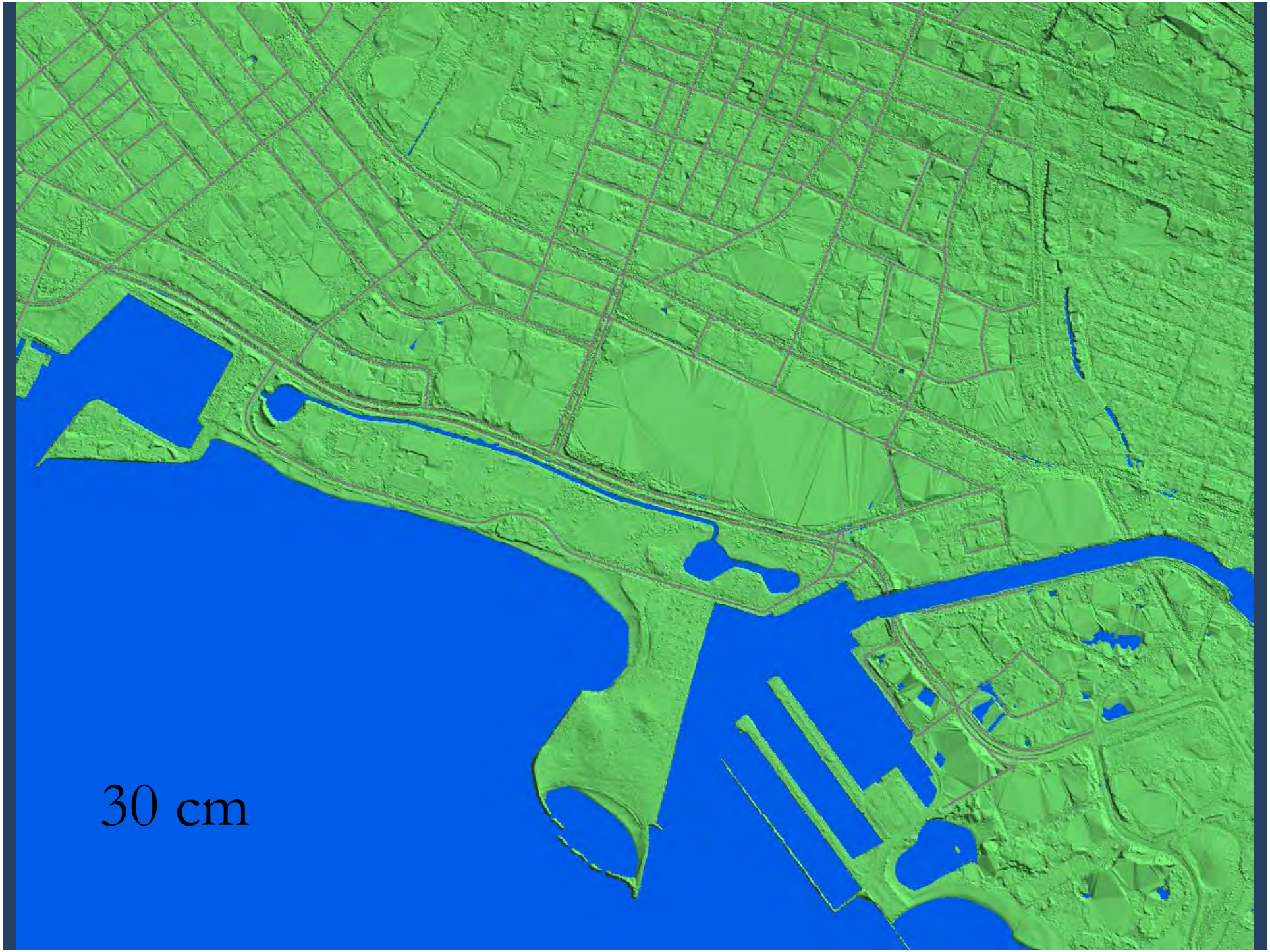


Vermeer, M. and Rahmstorf, S., 2009 "Global sea level linked to global temperature," Proceedings of the National Academy of Sciences, http://www.pnas.org/content/early/2009/12/04/0907765106.full.pdf.

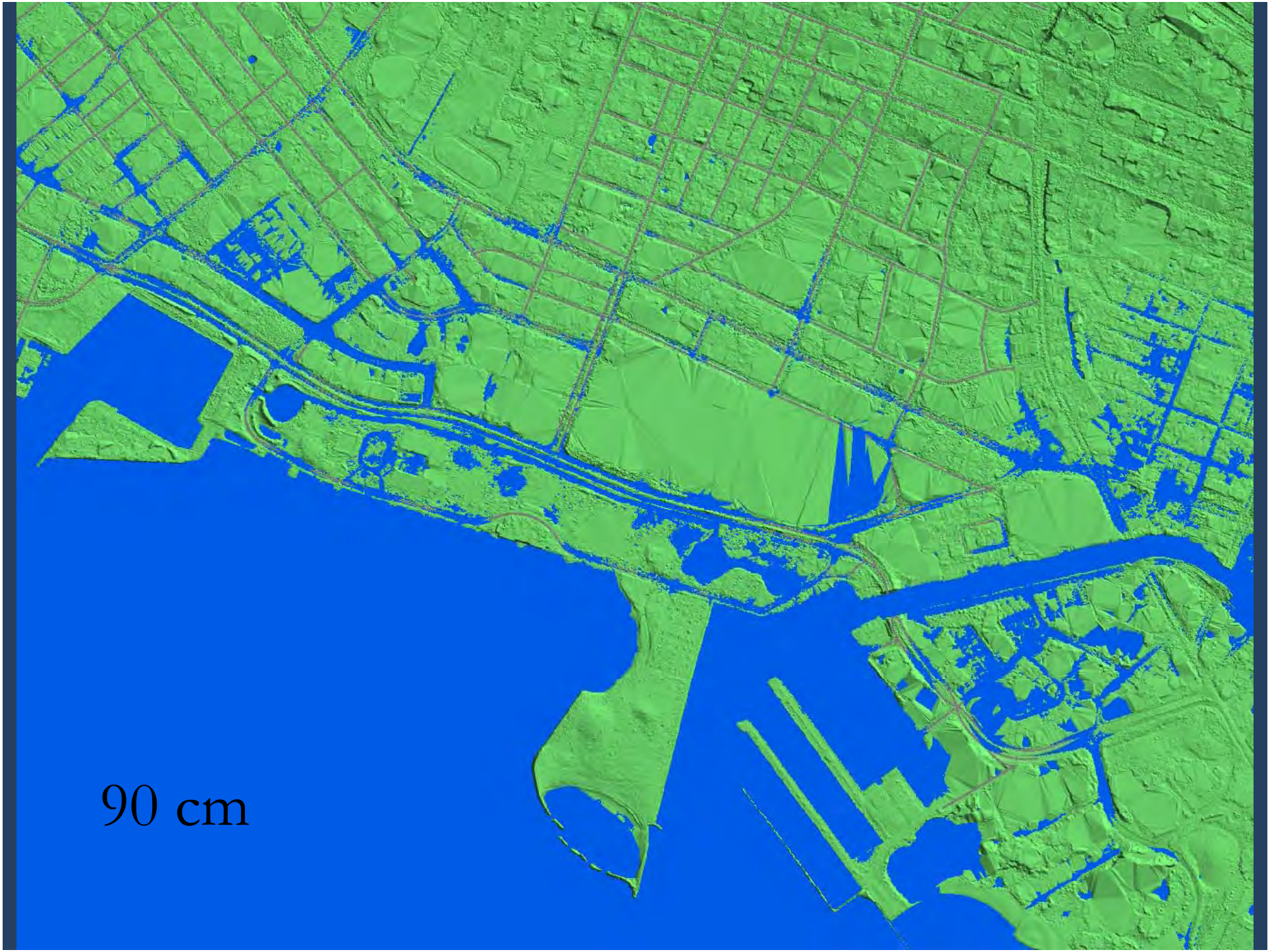
LiDAR – light detection and ranging

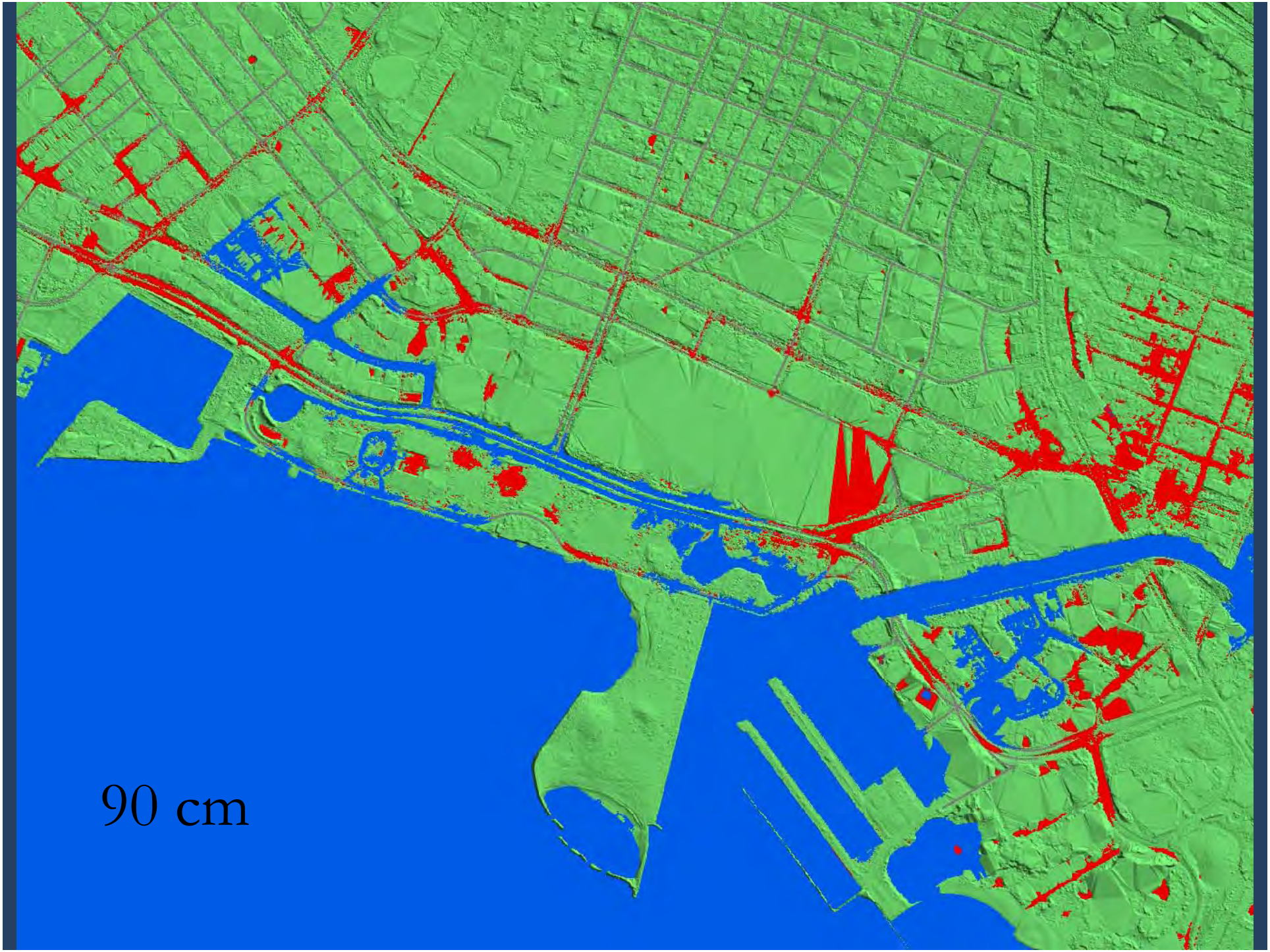


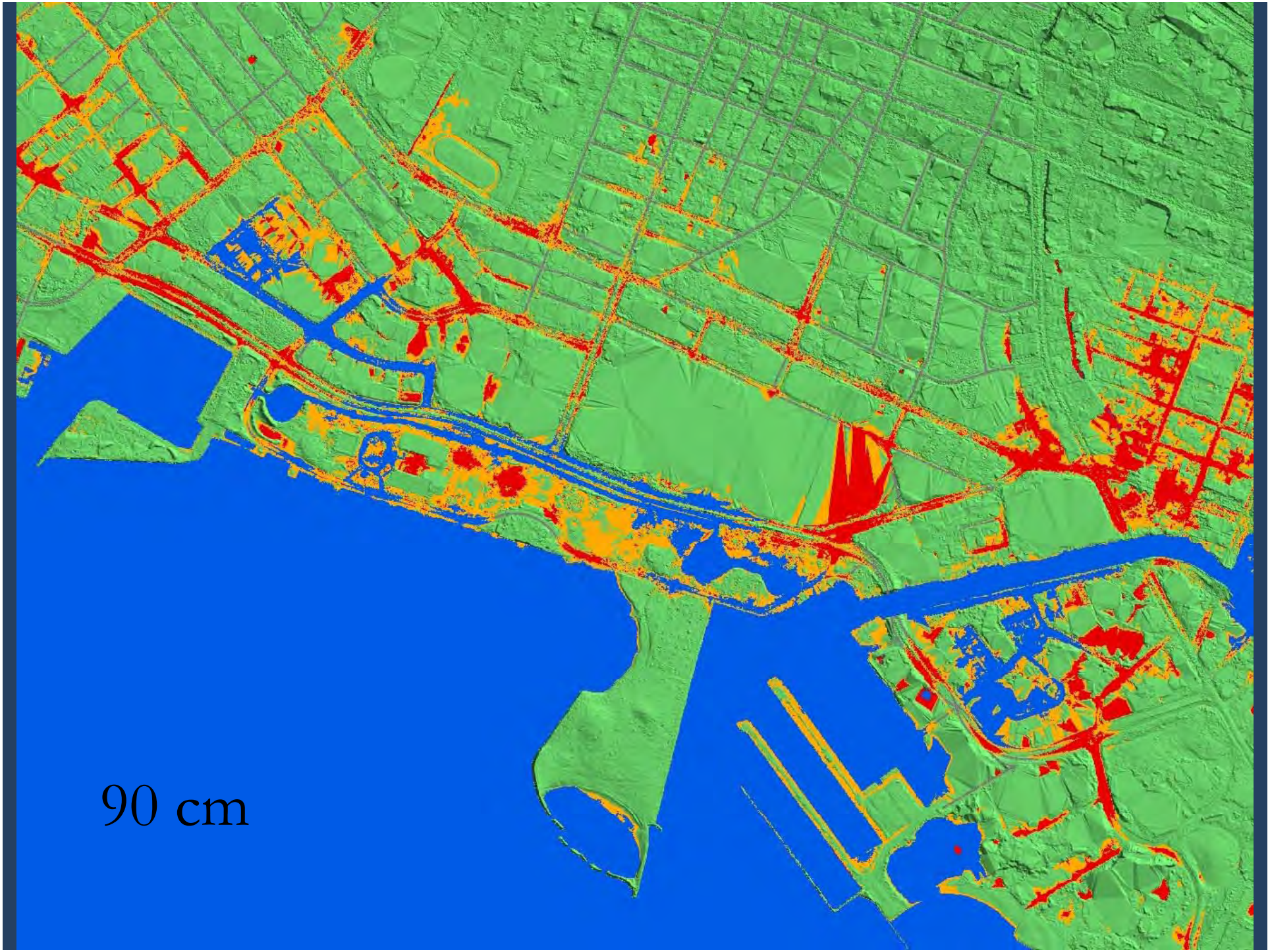



30 cm


60 cm


90 cm


90 cm


90 cm


99
92
H1
78
63
98
64
61
72
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Data USGS
Image USGS
Google earth


Thank you