
# Assessing Sea Level Rise at the Regional to Local Scale Using Earth Observations

Ben Hamlington, NASA JPL
Team Lead of NASA Sea Level Change Team

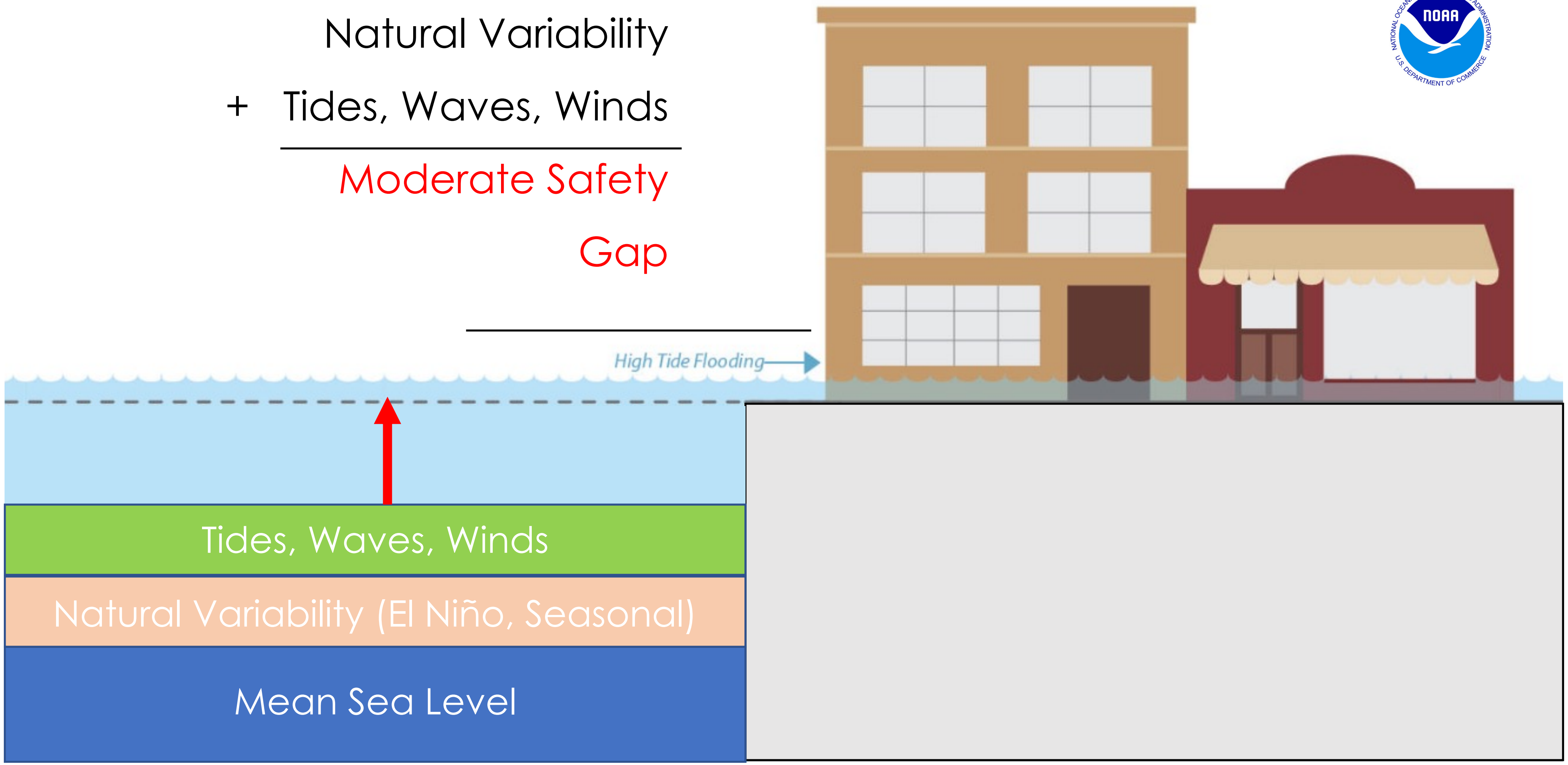
August 24, 2021

# Contributors to Sea Level Rise

- <u>Sea Level in Past:</u>

Mean Sea Level
Natural Variability
\+ Tides, Waves, Winds

Moderate Safety
Gap



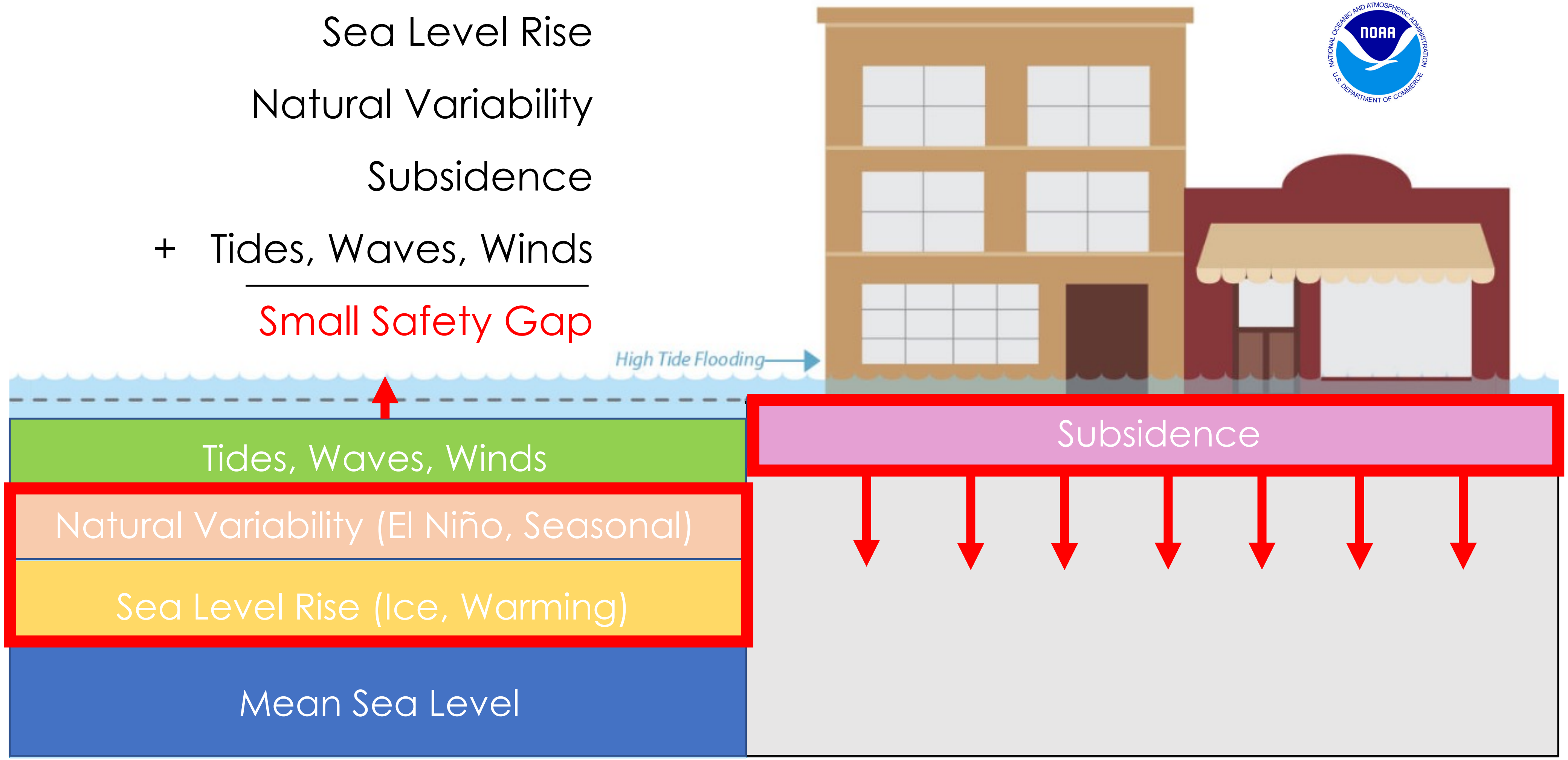
# Contributors to Sea Level Rise

- <u>Sea Level Now:</u>

Mean Sea Level
Sea Level Rise
Natural Variability
Subsidence
\+ Tides, Waves, Winds

Small Safety Gap

LOCAL
REGIONAL
GLOBAL



# Why is sea level rising globally?

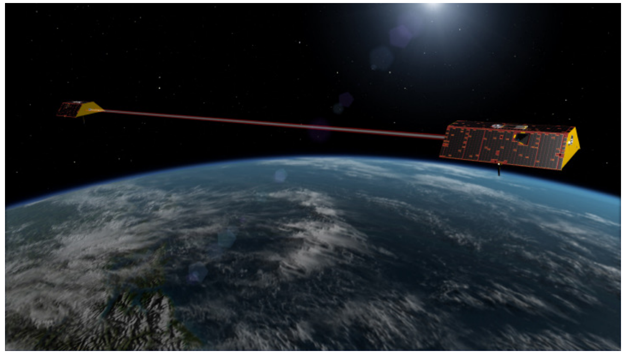
- There are two reasons that sea level is rising on global scales:

  1. The ocean is warming → water expands (thermal expansion).

  2. Ice on land is melting and the melt water is going into the ocean.

# Why is sea level rising globally?

Ice (GRACE-FO)



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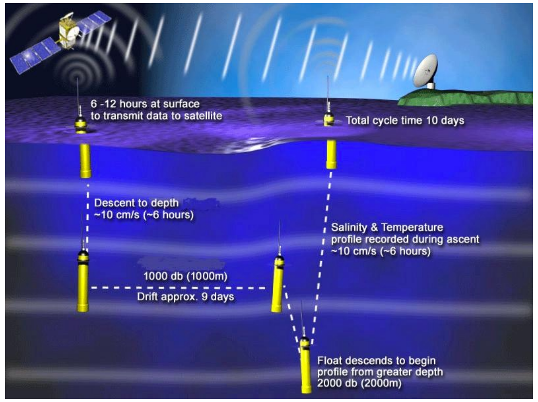


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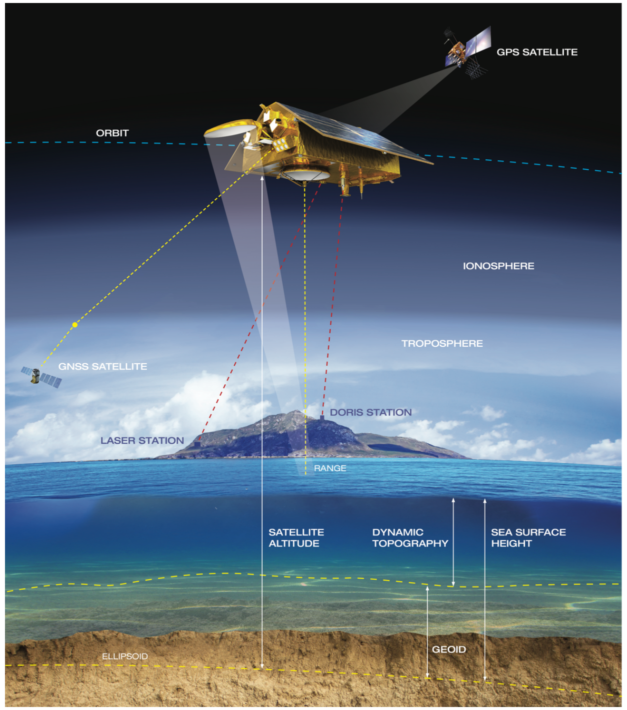
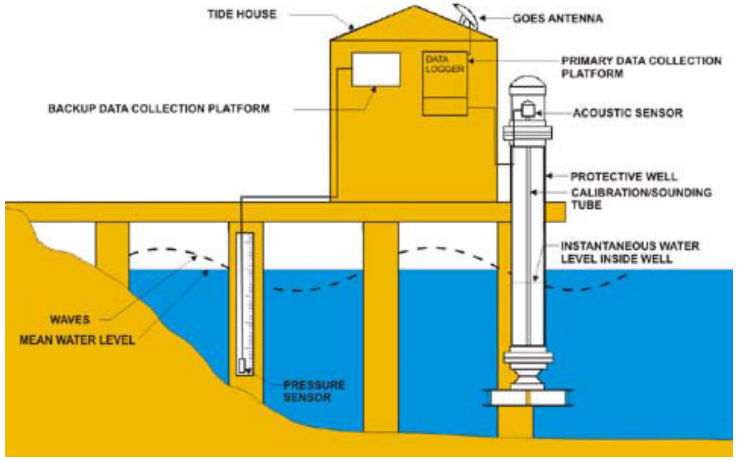
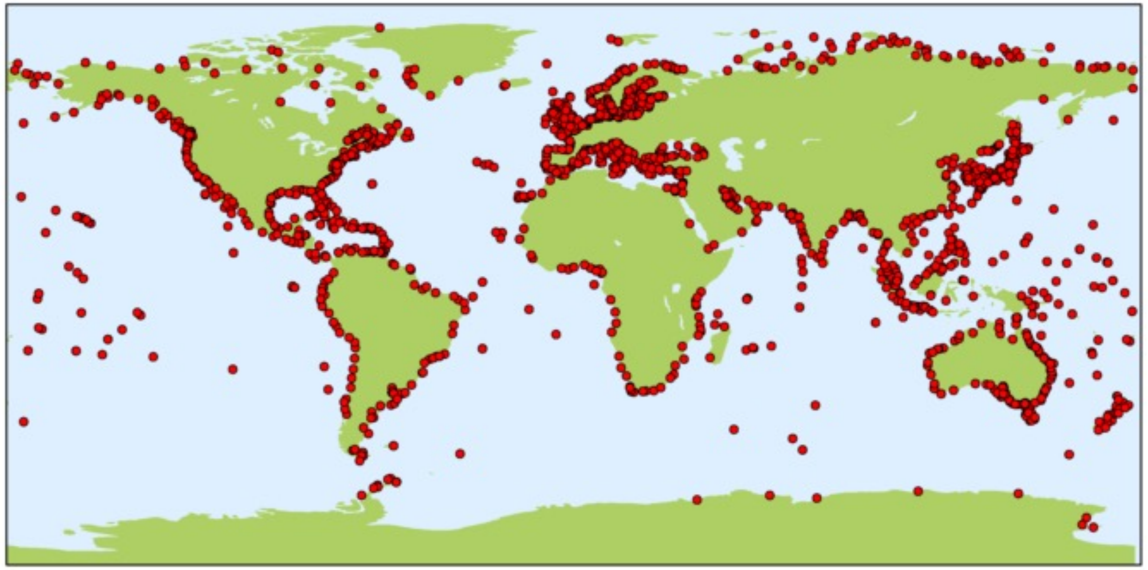
Total Sea Level (Altimetry)



# How do we measure global sea level change?

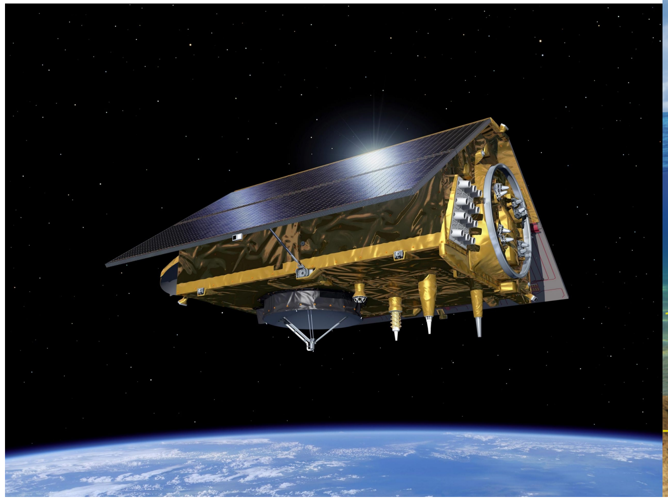
- For the last century, tide gauges have been used to measure sea level change along the world’s coastlines.
- Challenges associated with combining these records and estimating global mean sea level.

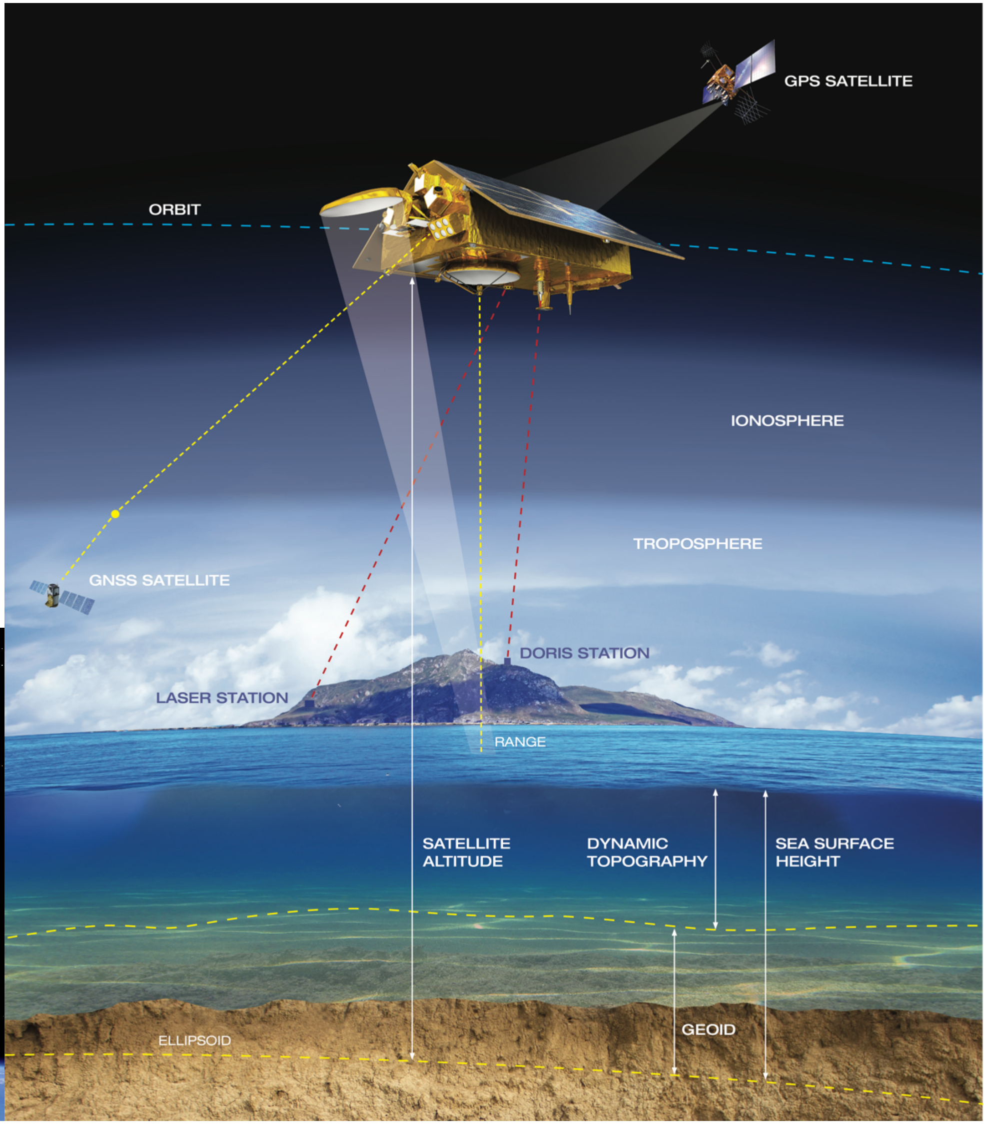


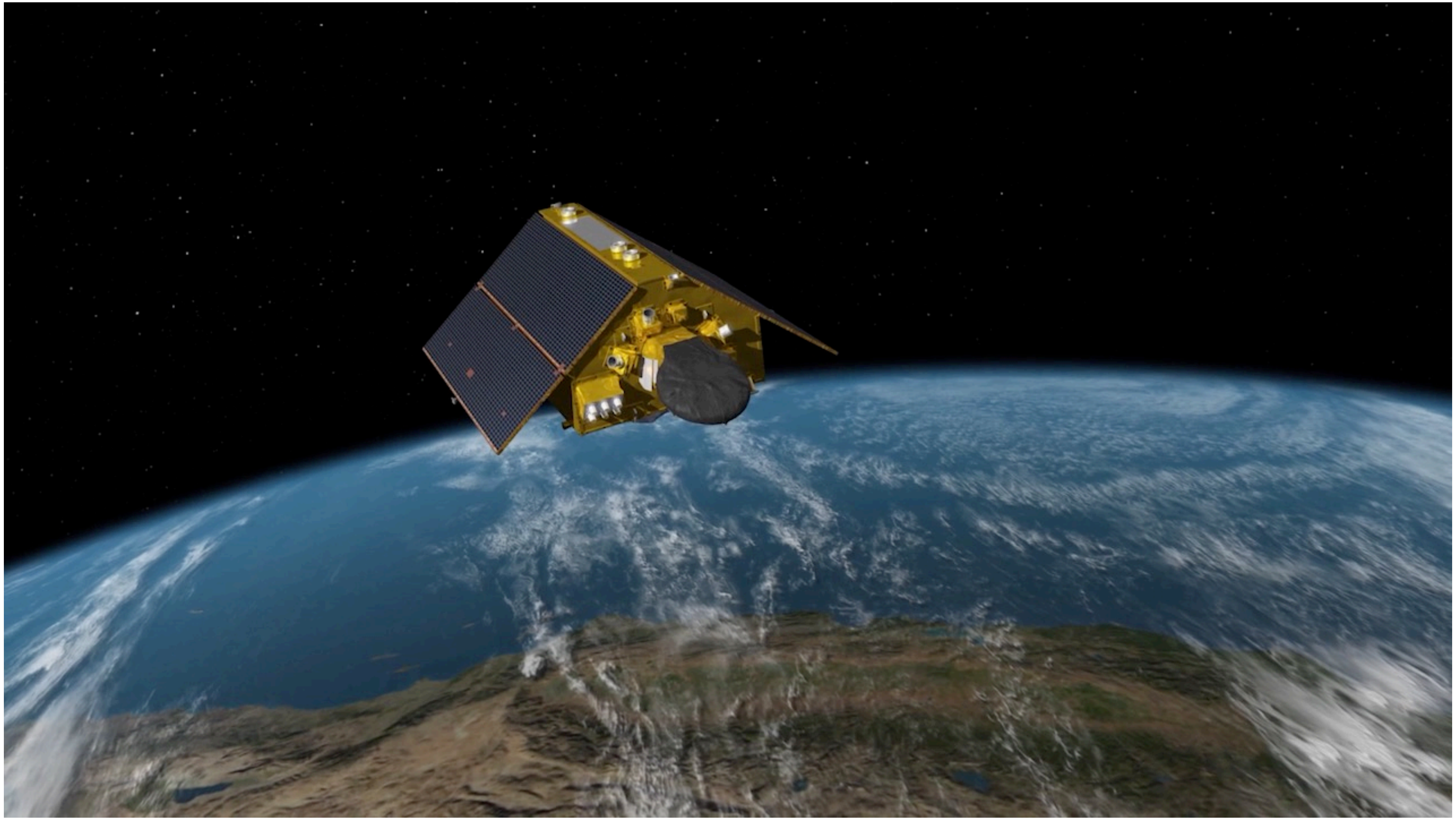
# How do we measure global sea level change?

- Since 1992, satellite altimeters have been used to measure sea surface height in the ocean.
- Continuous measurements with near-global coverage.
- **Sentinel-6/Michael Freilich continues this record.**





# Satellite Altimetry



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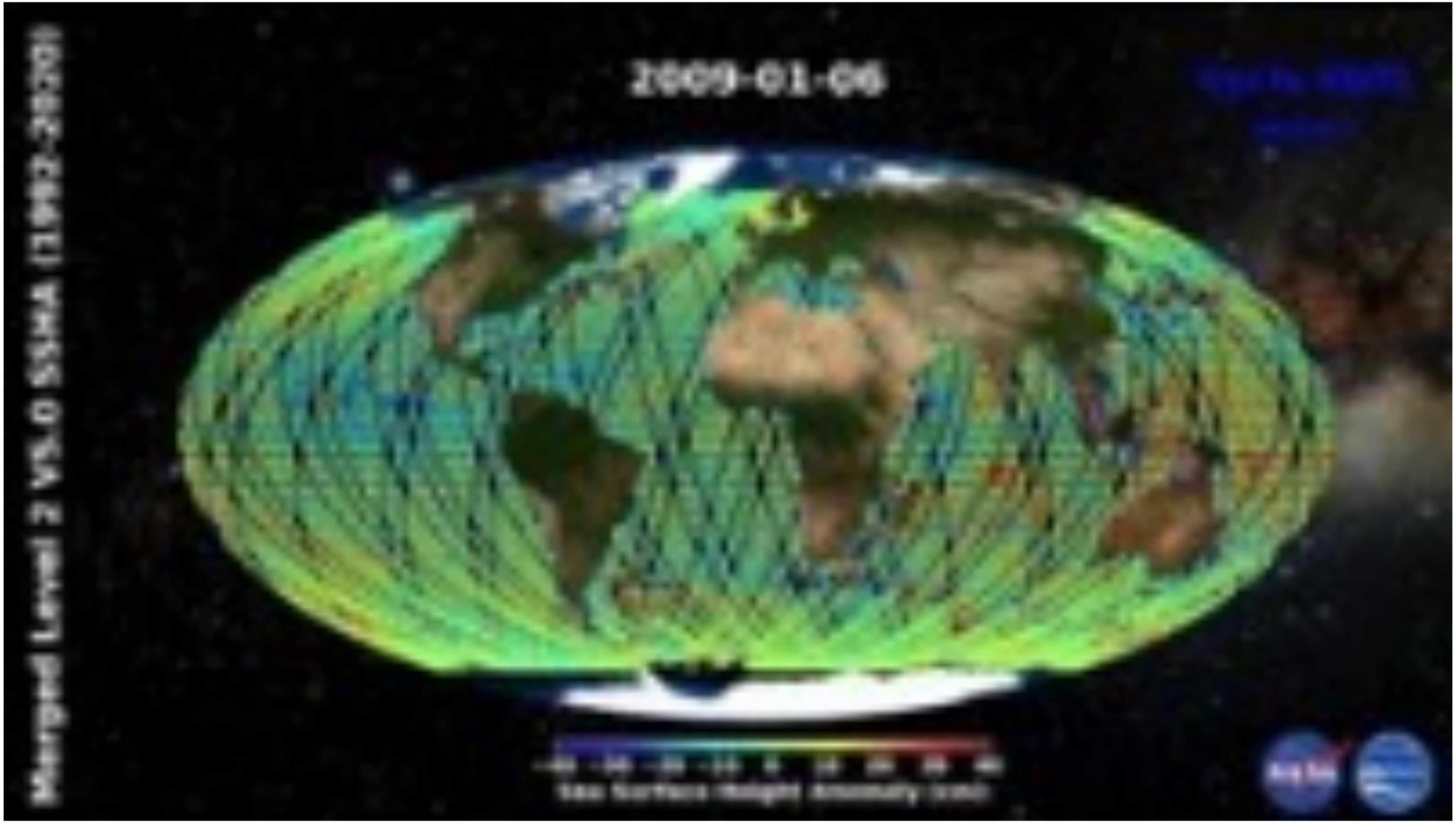
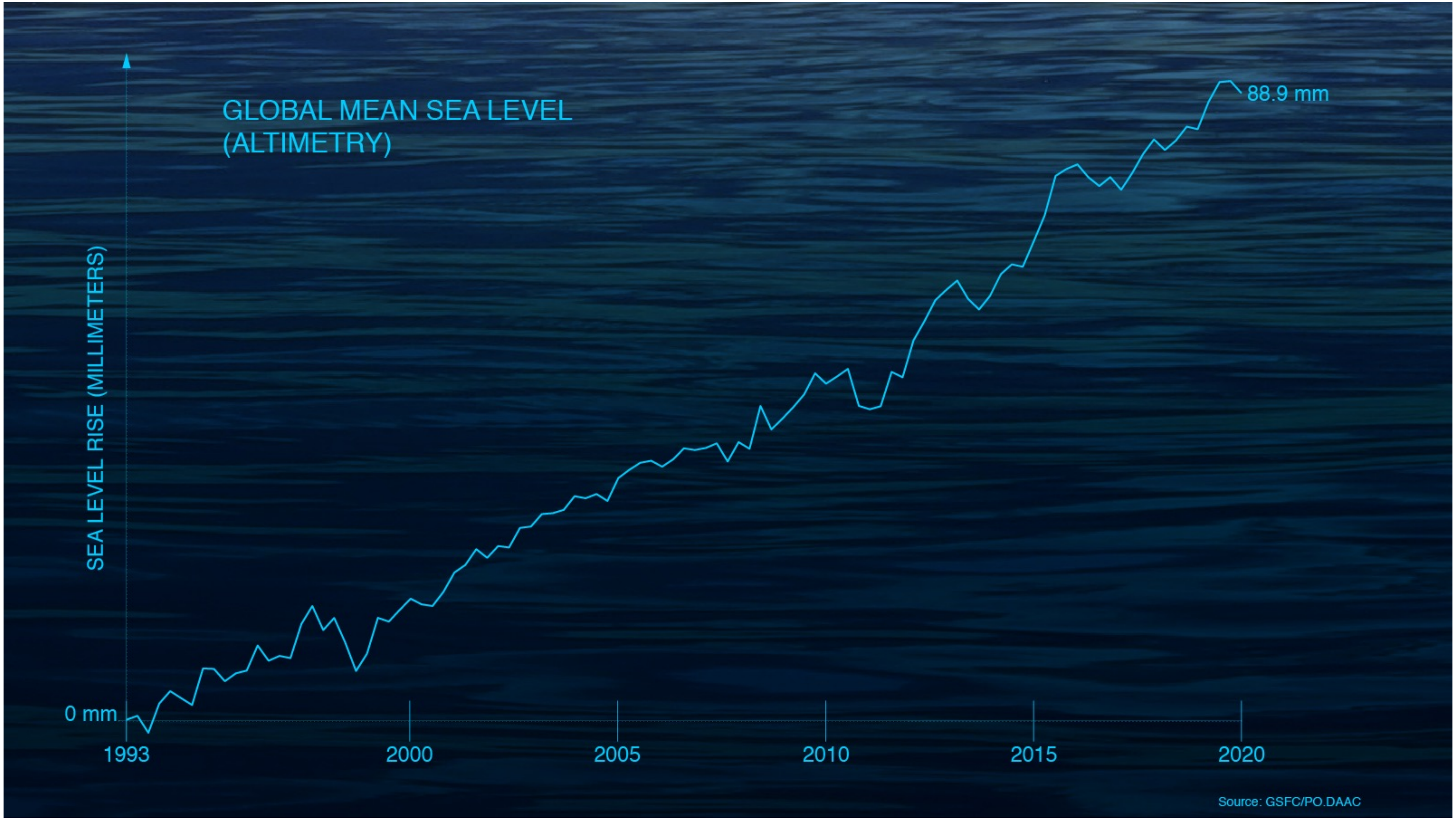
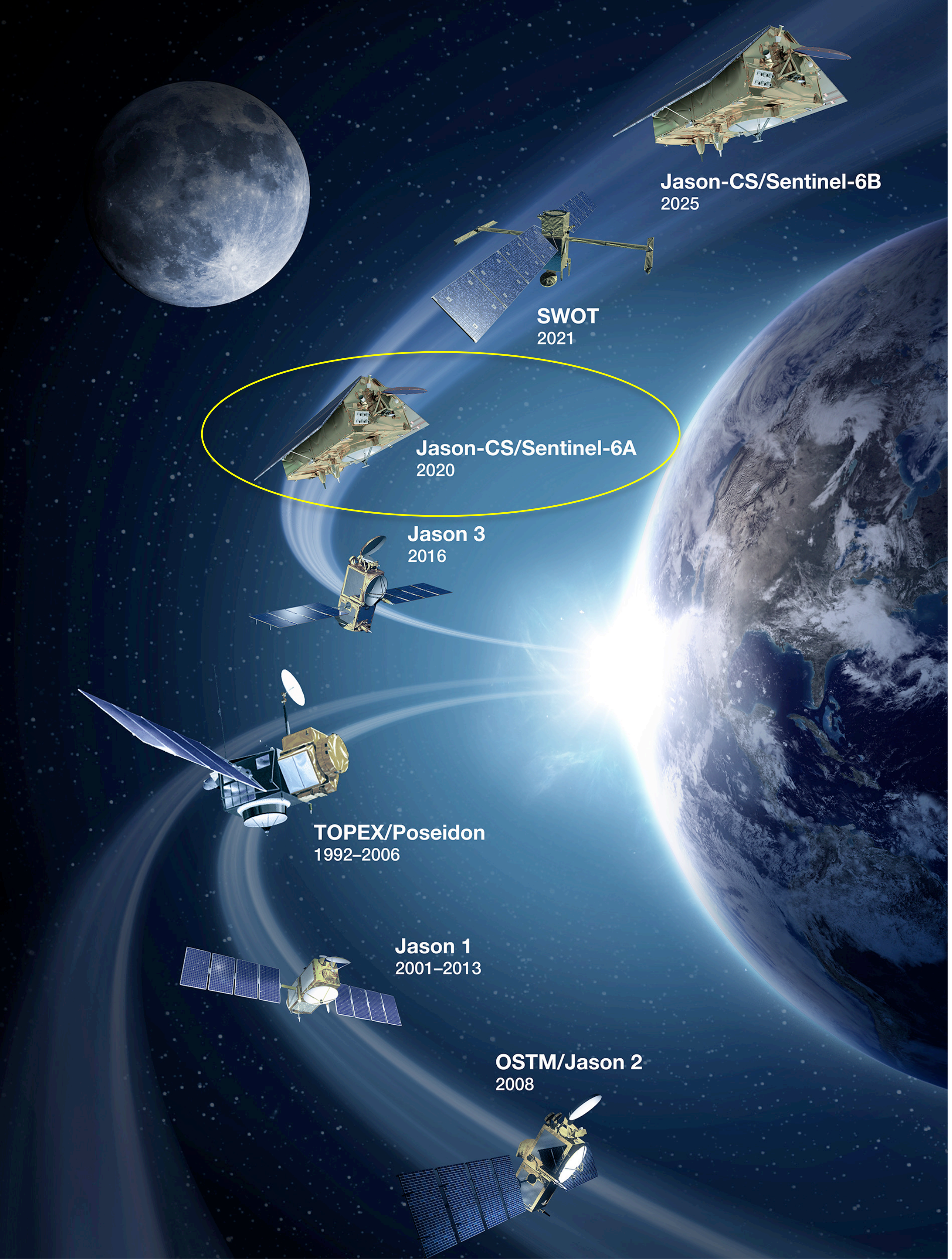


# Global Mean Sea Level from Satellite Altimetry



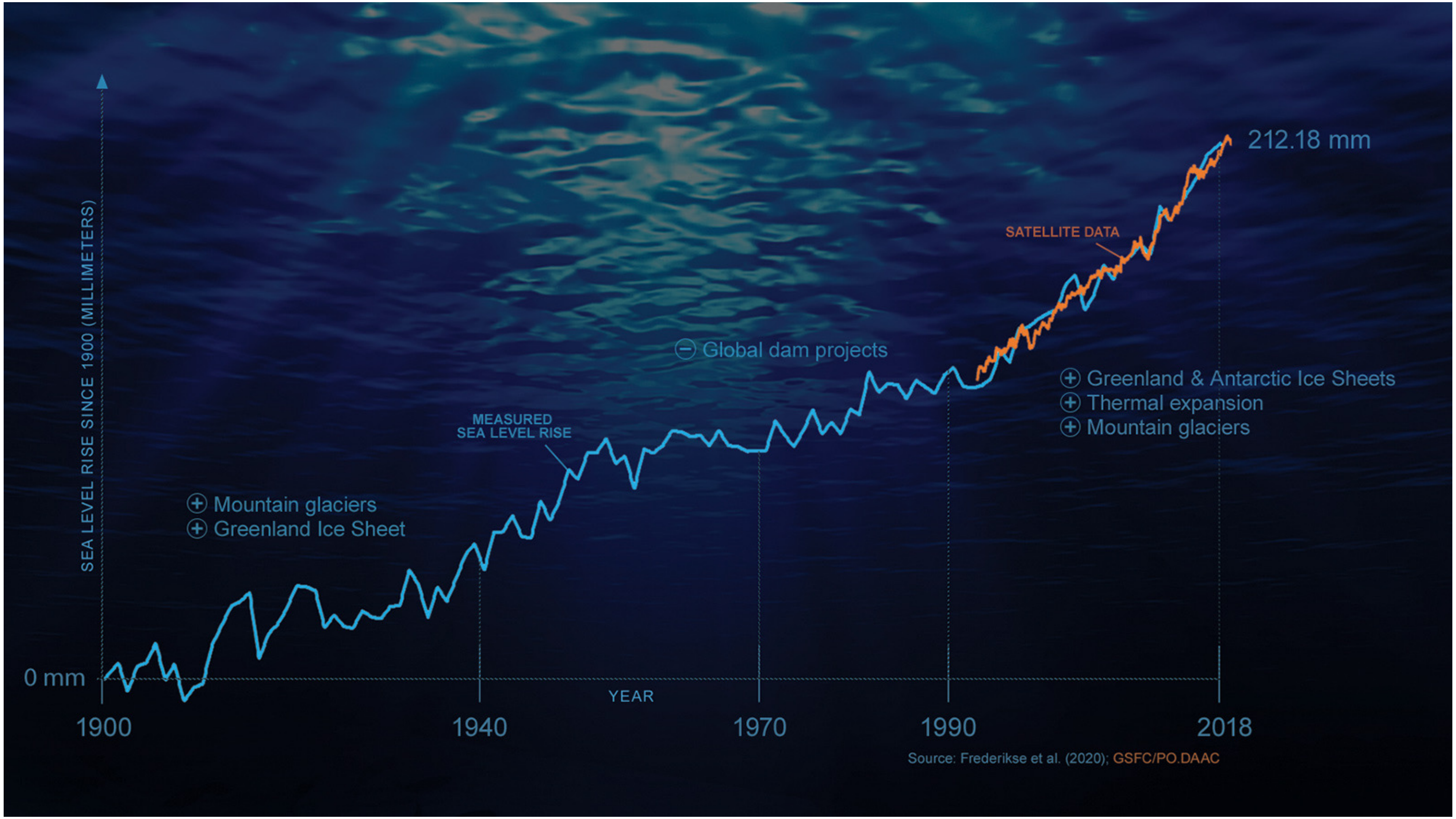



# Sentinel-6 continues 27+ years of sea level measurement from space.

With the launch of Sentinel-6A/Michael Freilich and Sentinel-6B in 2025, this record will surpass 40 years in length.

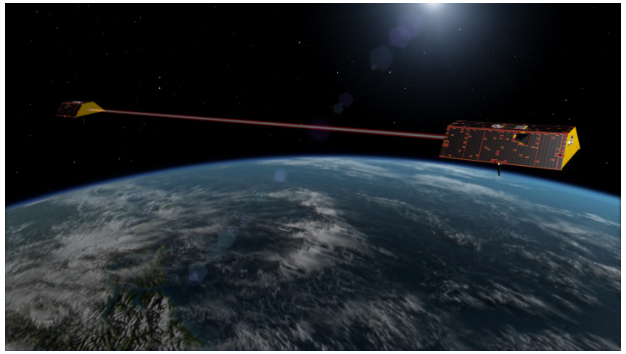
Why is the long record important?

# Global Mean Sea Level

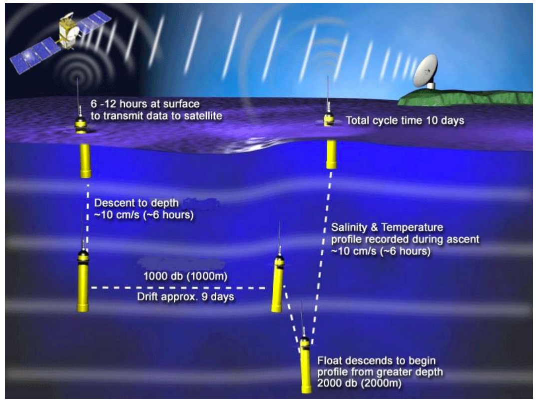


# Why is sea level rising globally?

Ice (GRACE-FO)



Thermal Expansion (Argo)

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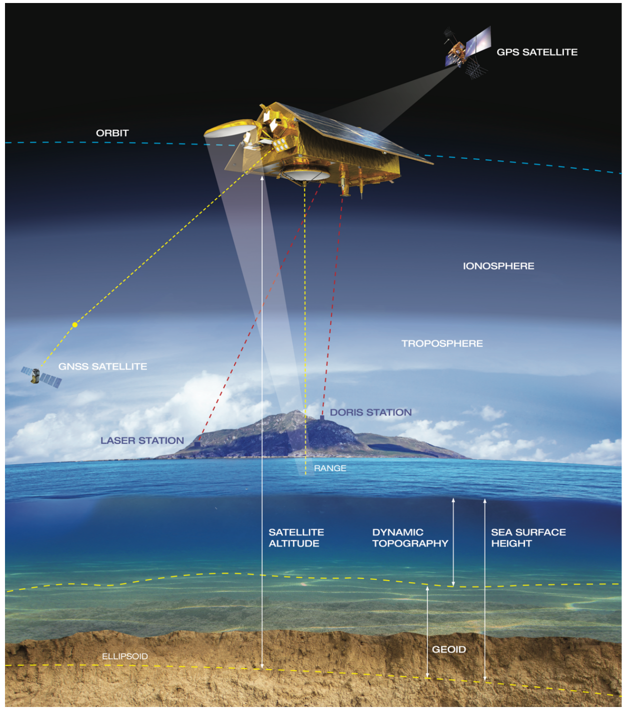
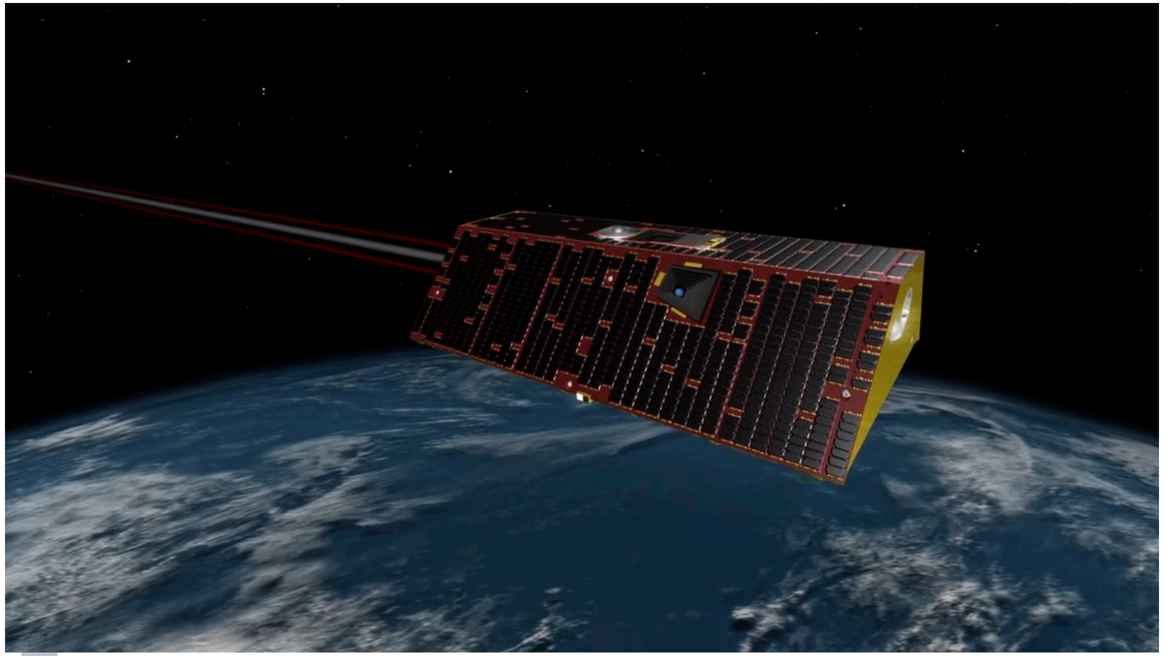
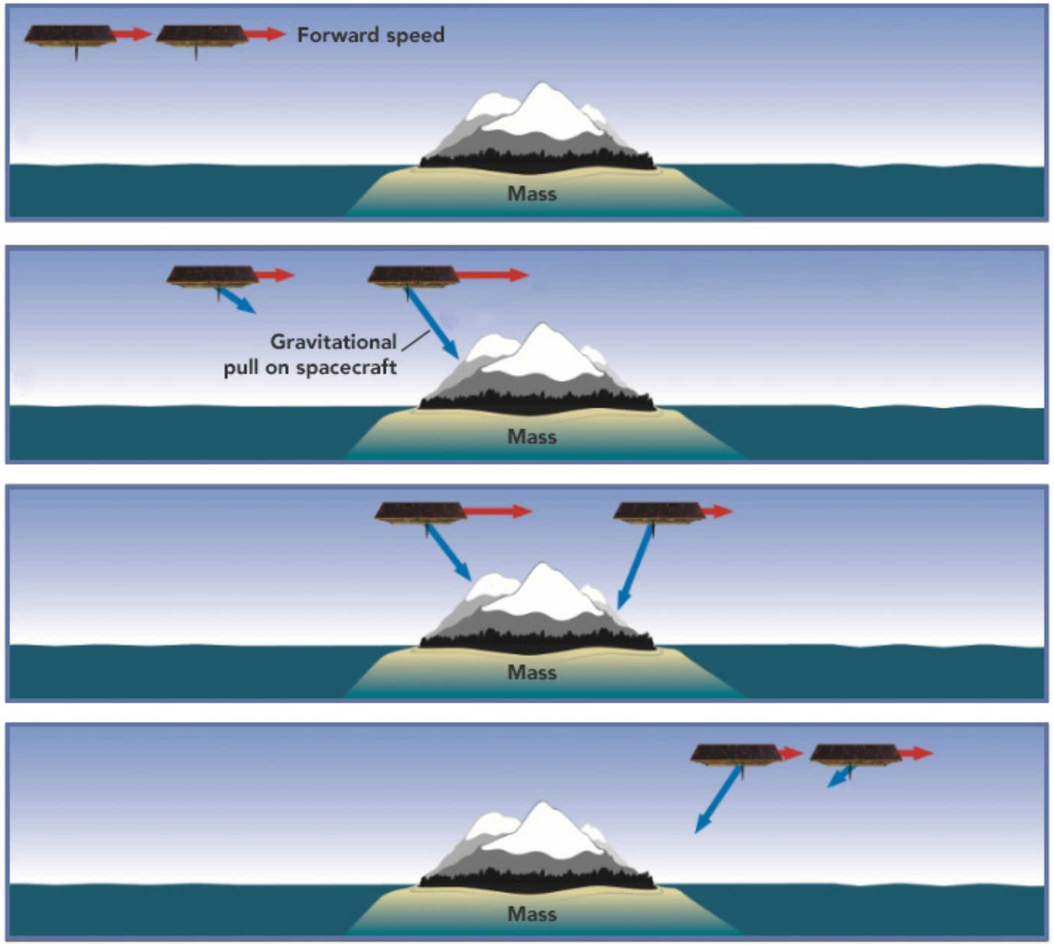


# GRACE and GRACE-FO

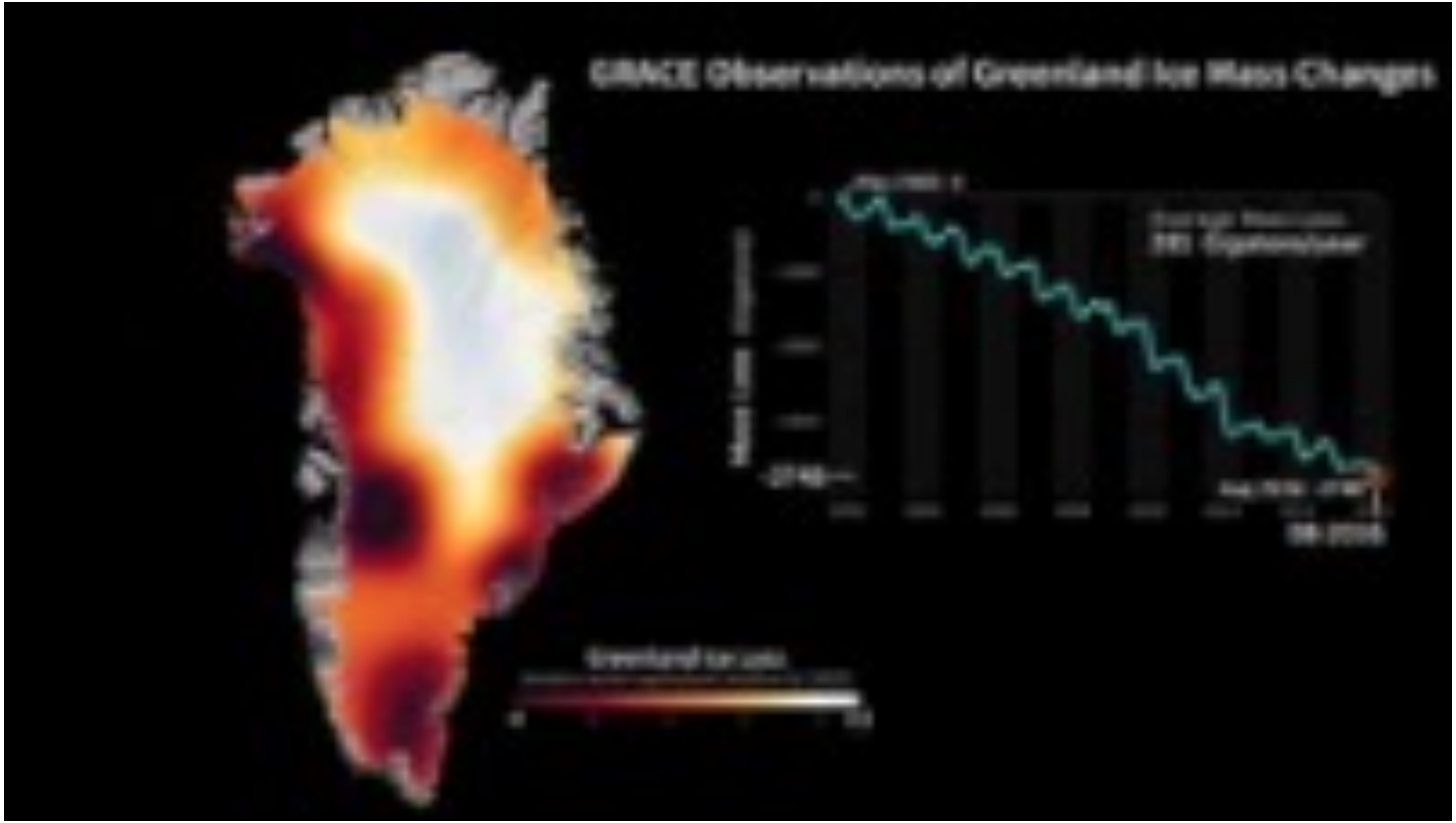
- Gravity Recovery & Climate Experiment (GRACE; 2002-2016) and GRACE Follow-On (GRACE-FO; 2018-pres.) measure gravity changes on Earth.
  - These satellites can tell us how much ice is being lost.
  - They also tell us about the movement of water on Earth.



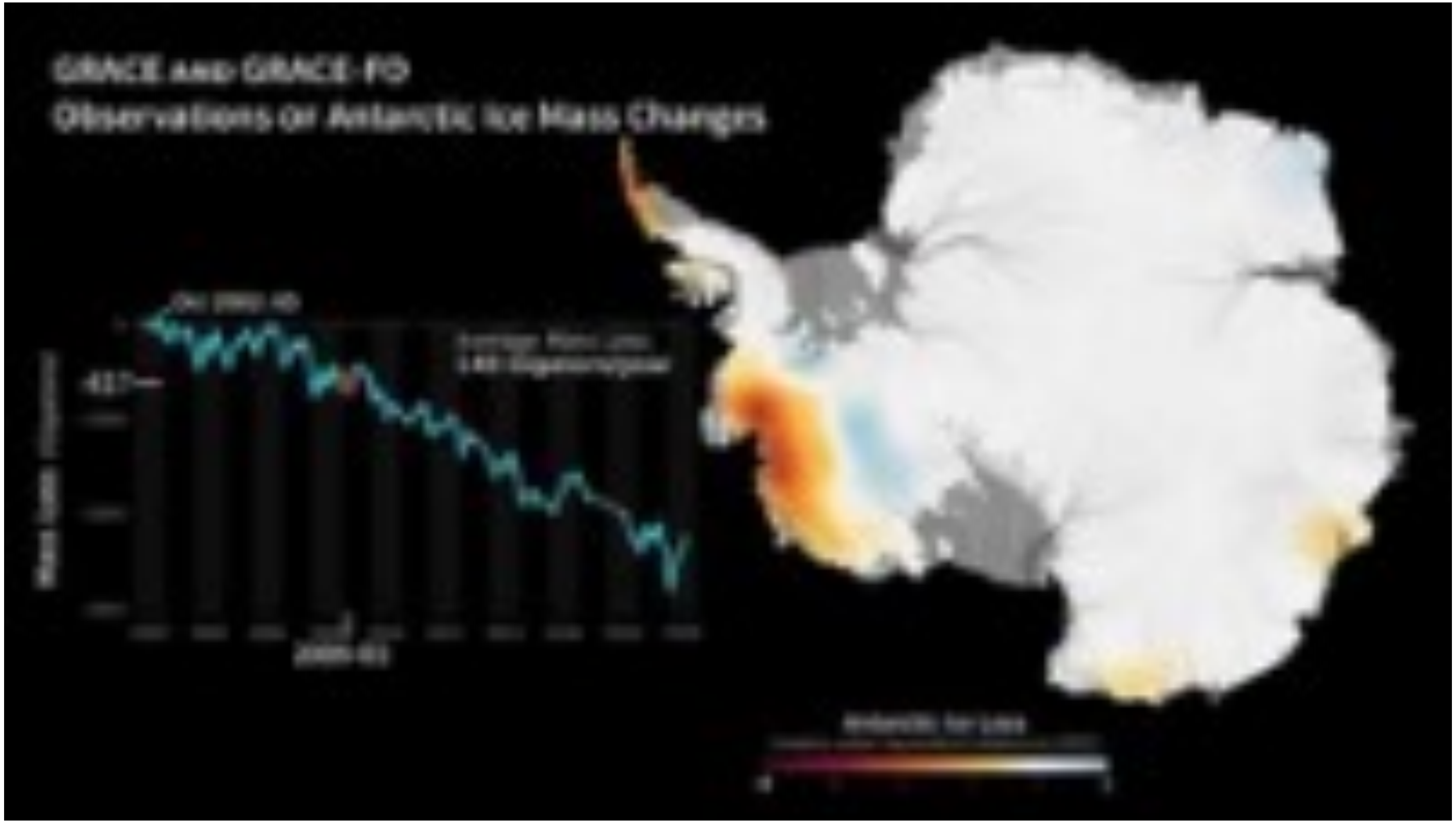



https://earthobservatory.nasa.gov/

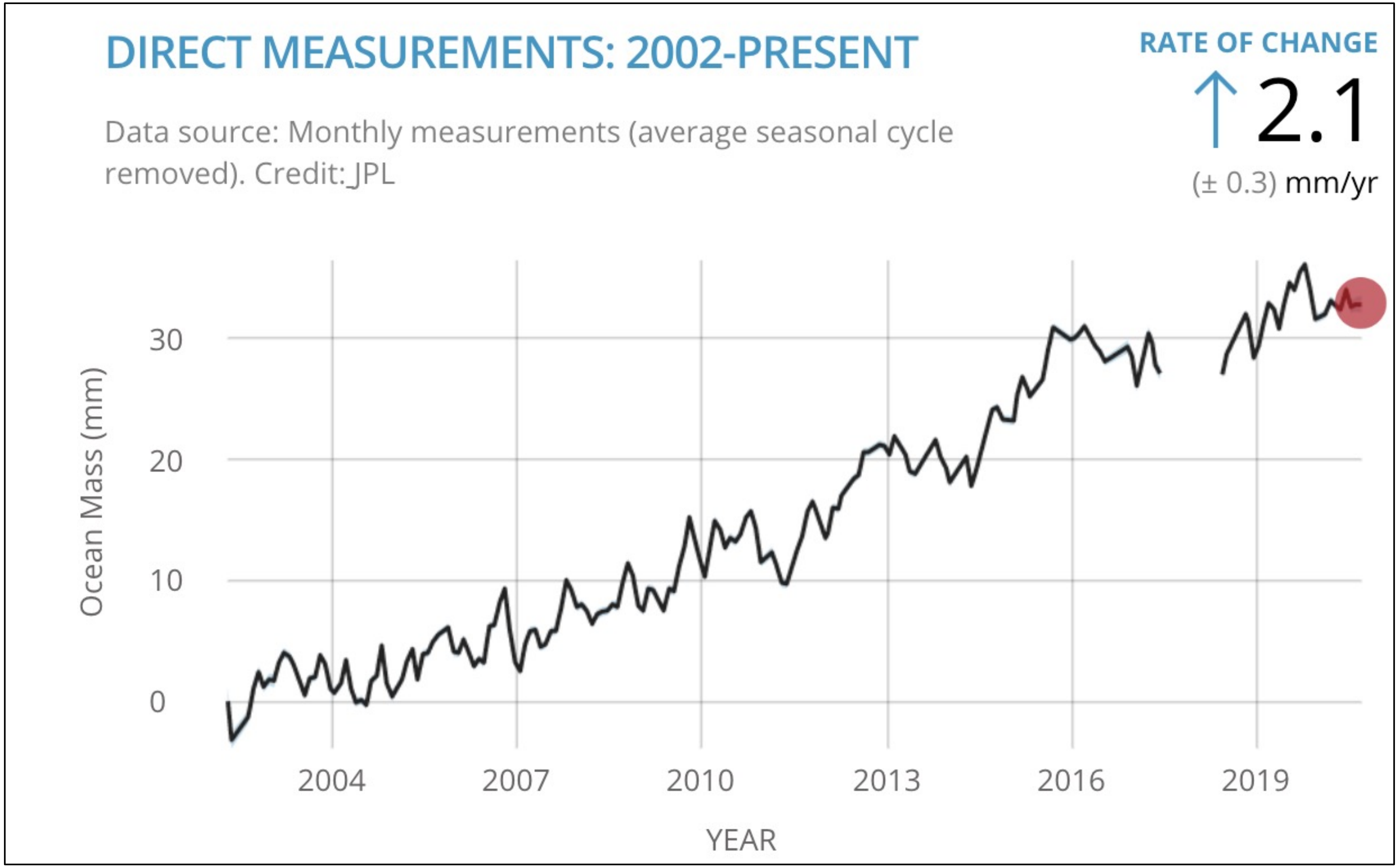
# Greenland Ice Sheet Mass Loss



# Antarctic Ice Sheet Mass Loss



# Sea Level Change from Ice Loss



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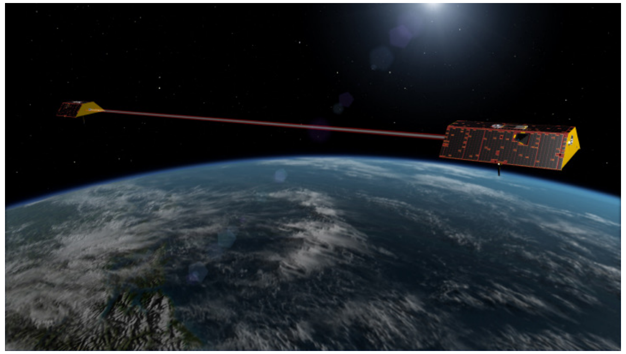

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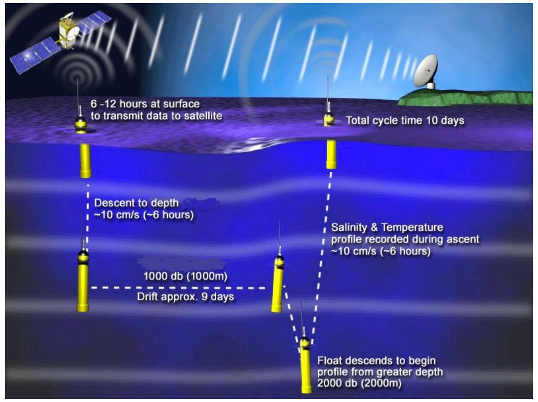


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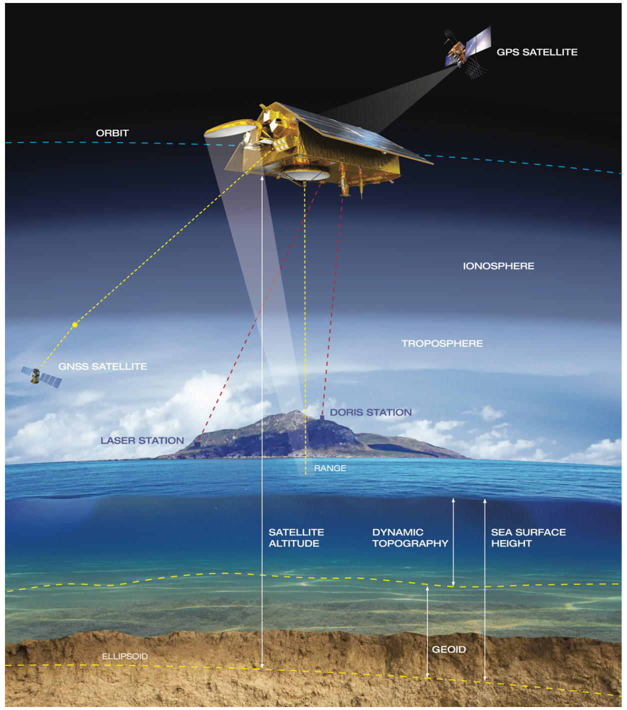
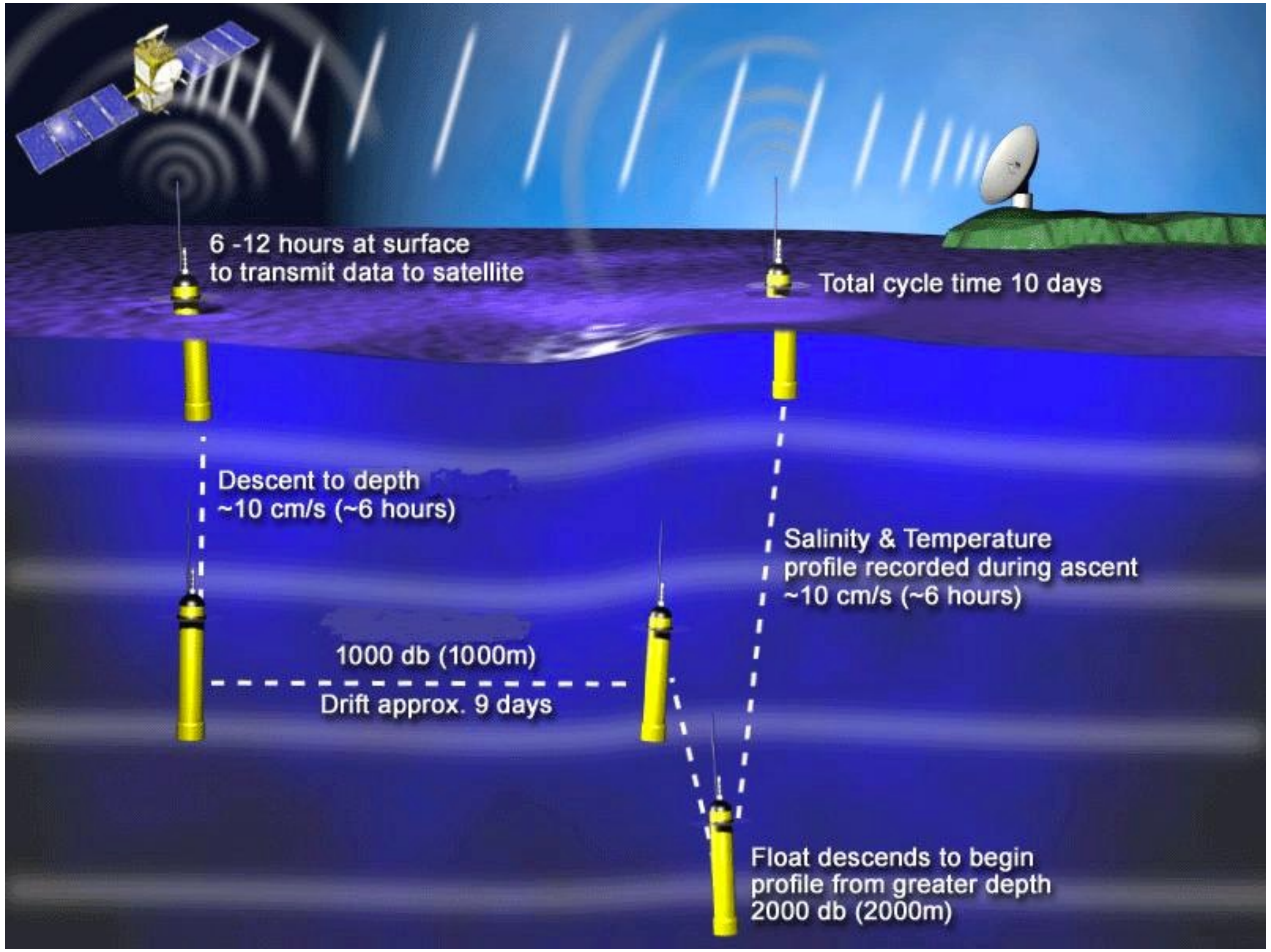
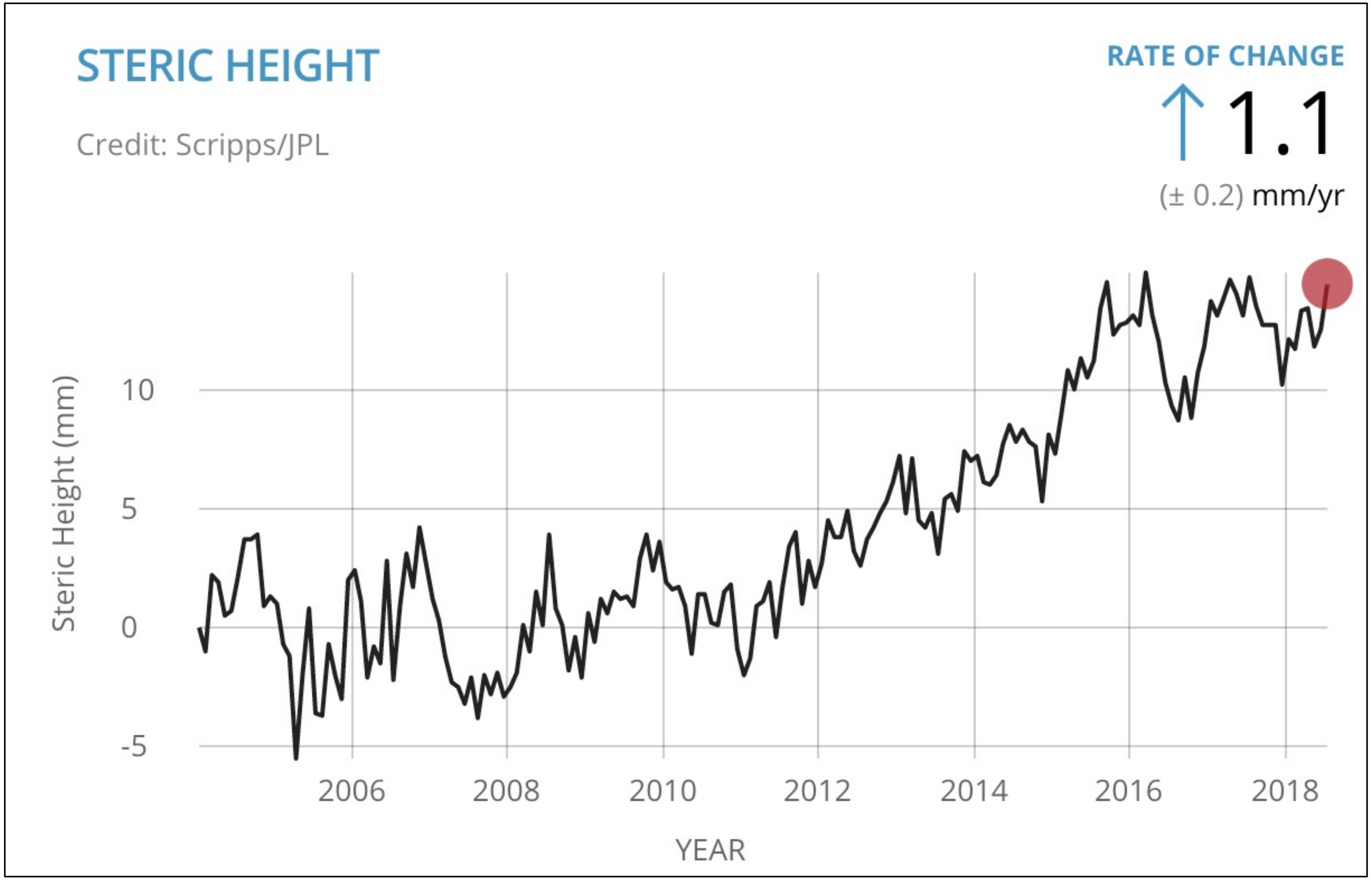


# Argo Profiling Floats

- Since ~2005, Argo profiling floats have been measuring the temperature and salinity of the ocean from 0 to 2000 m below the surface.
- From these measurements we can estimate the impact of thermal expansion on sea level rise.



# Sea Level Change from Thermal Expansion



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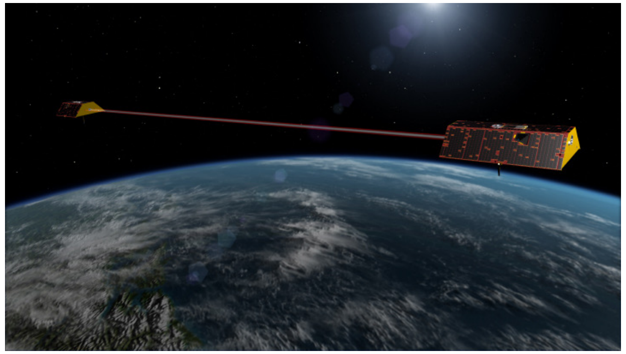

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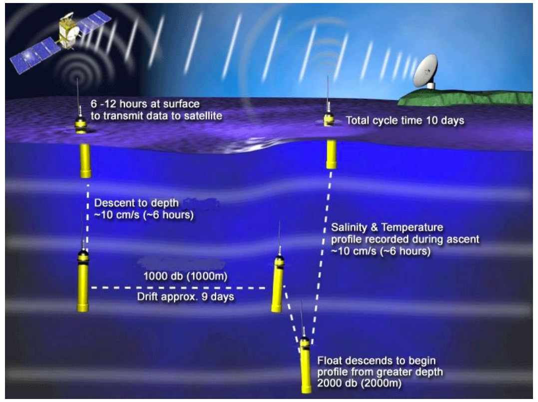


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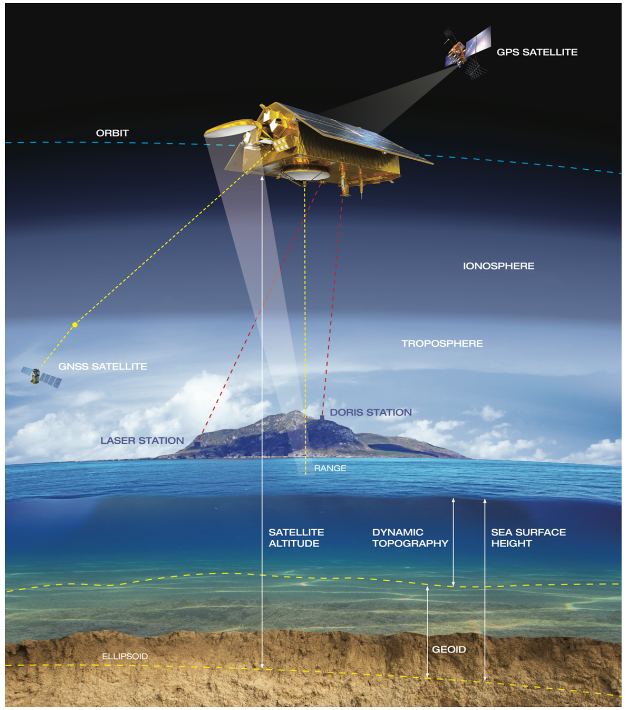
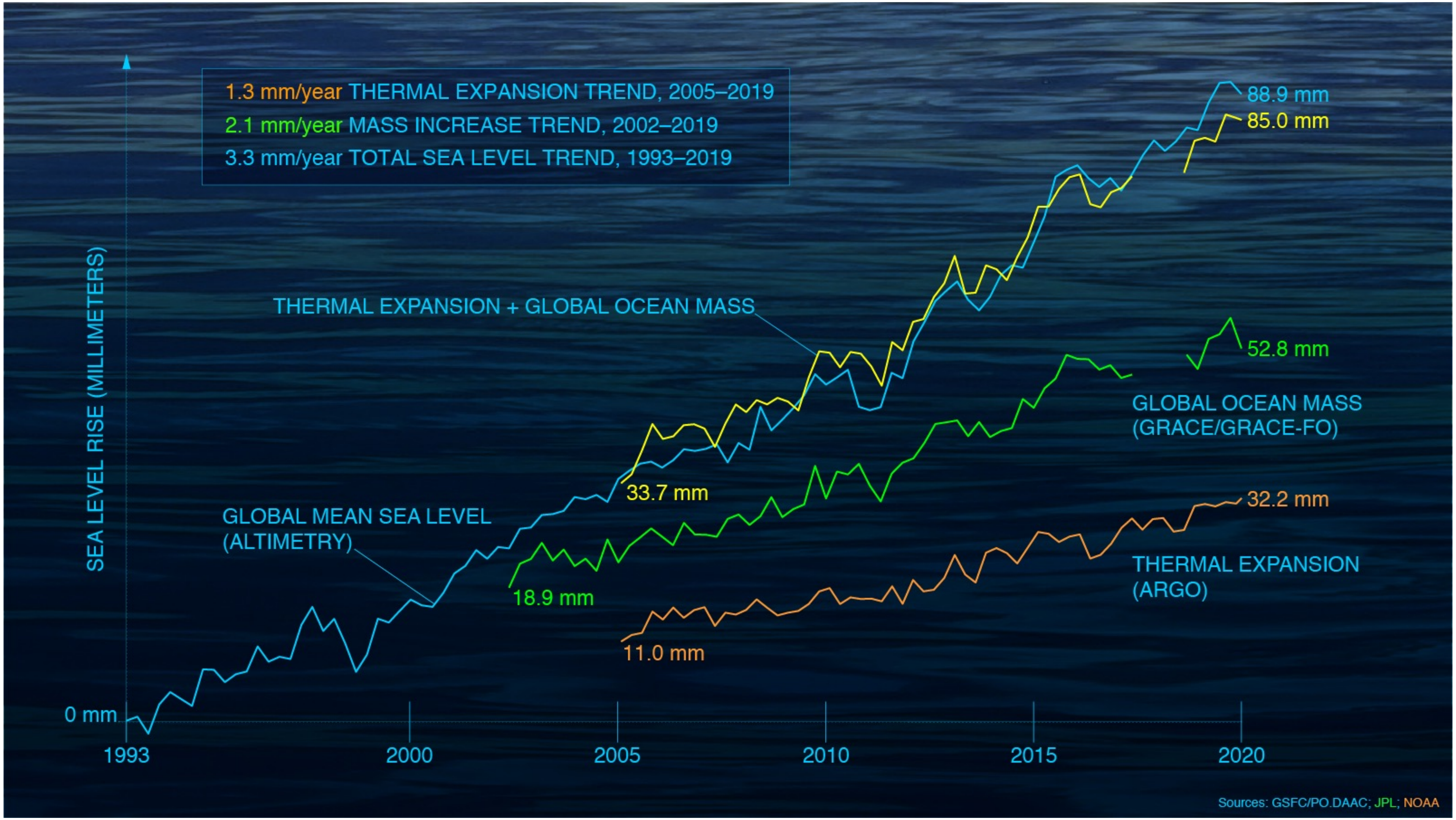
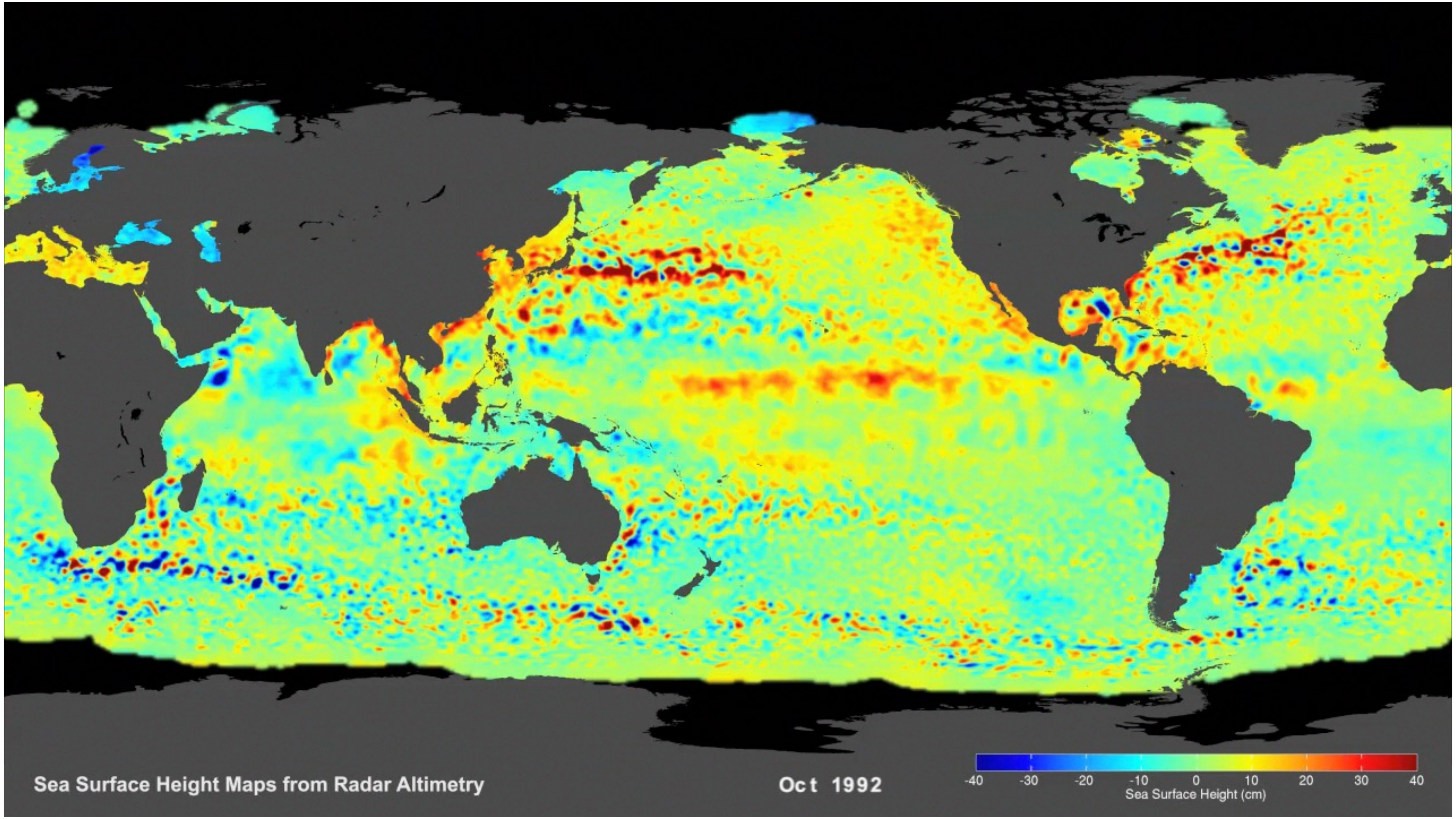


# Closing the Sea Level "Budget"



# Regional Sea Level Change



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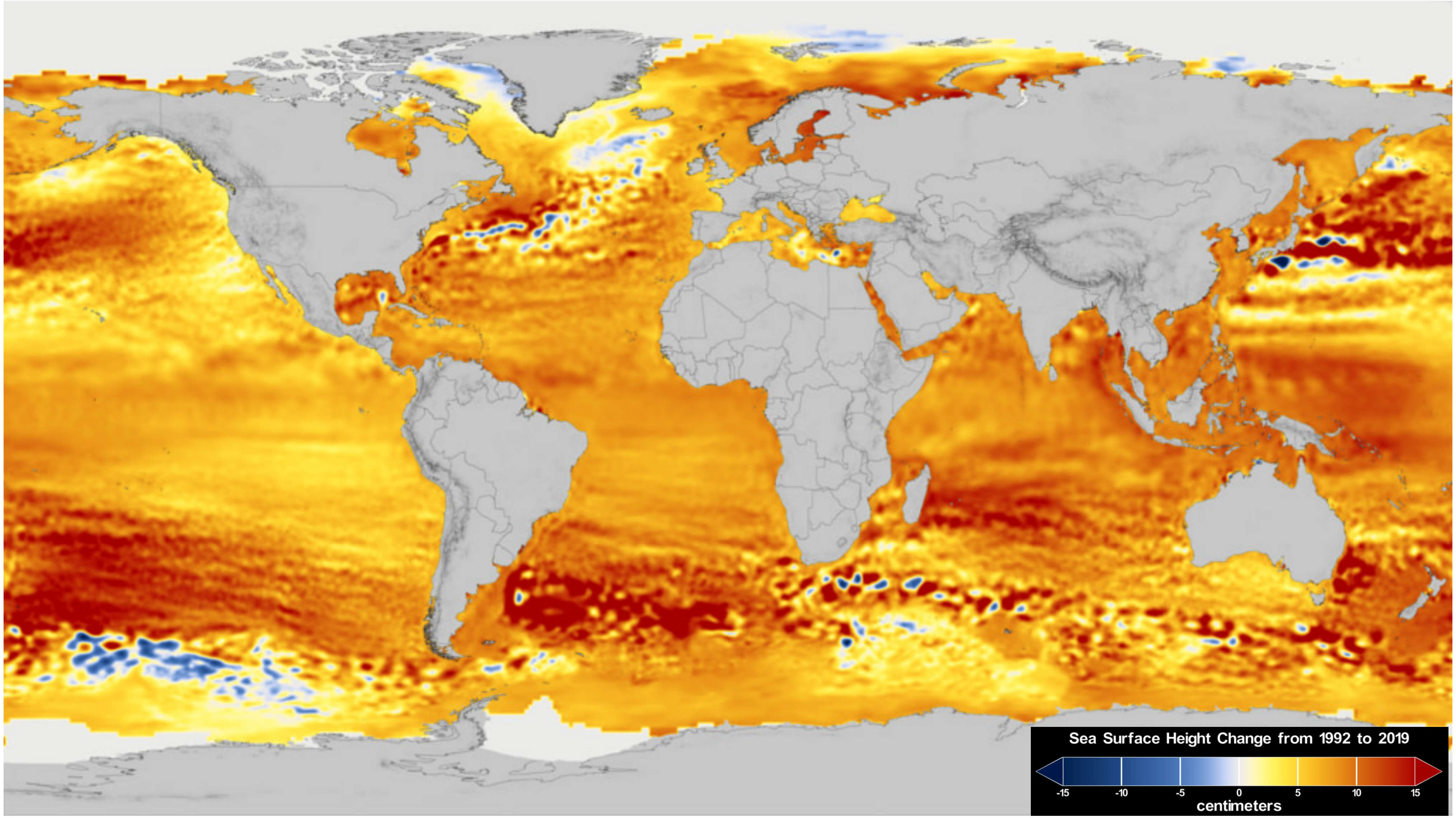
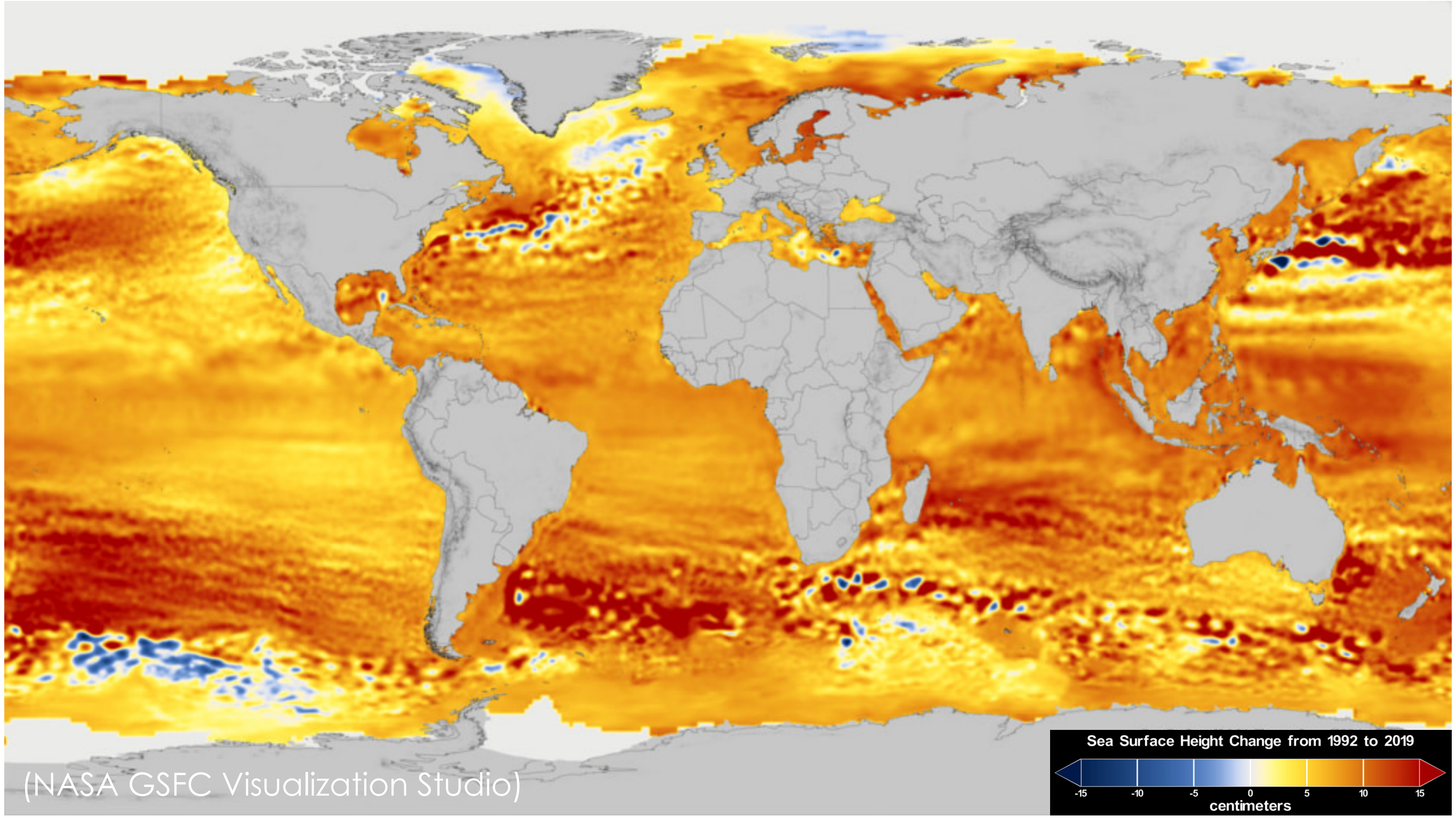


# Regional Sea Level Change

- Sea level changes on a wide range of space and time scales.
    - The ocean does not behave like a bathtub.
- Contributions to the pattern of regional sea level change:
    - Natural variability signals like El Niño-Southern Oscillation and North Atlantic Oscillation.
    - Ice-sheet "fingerprints".



(NASA GSFC Visualization Studio)

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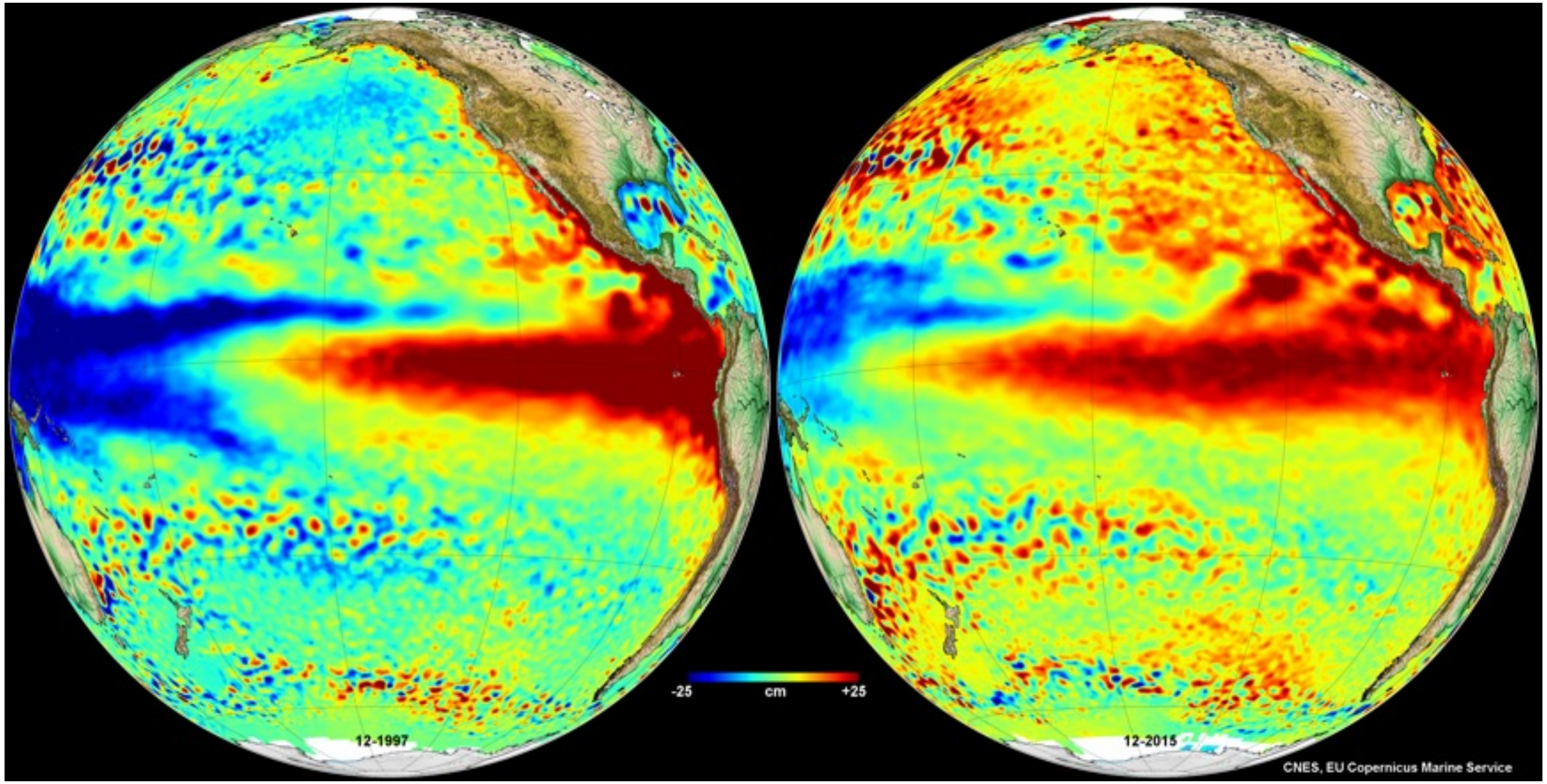

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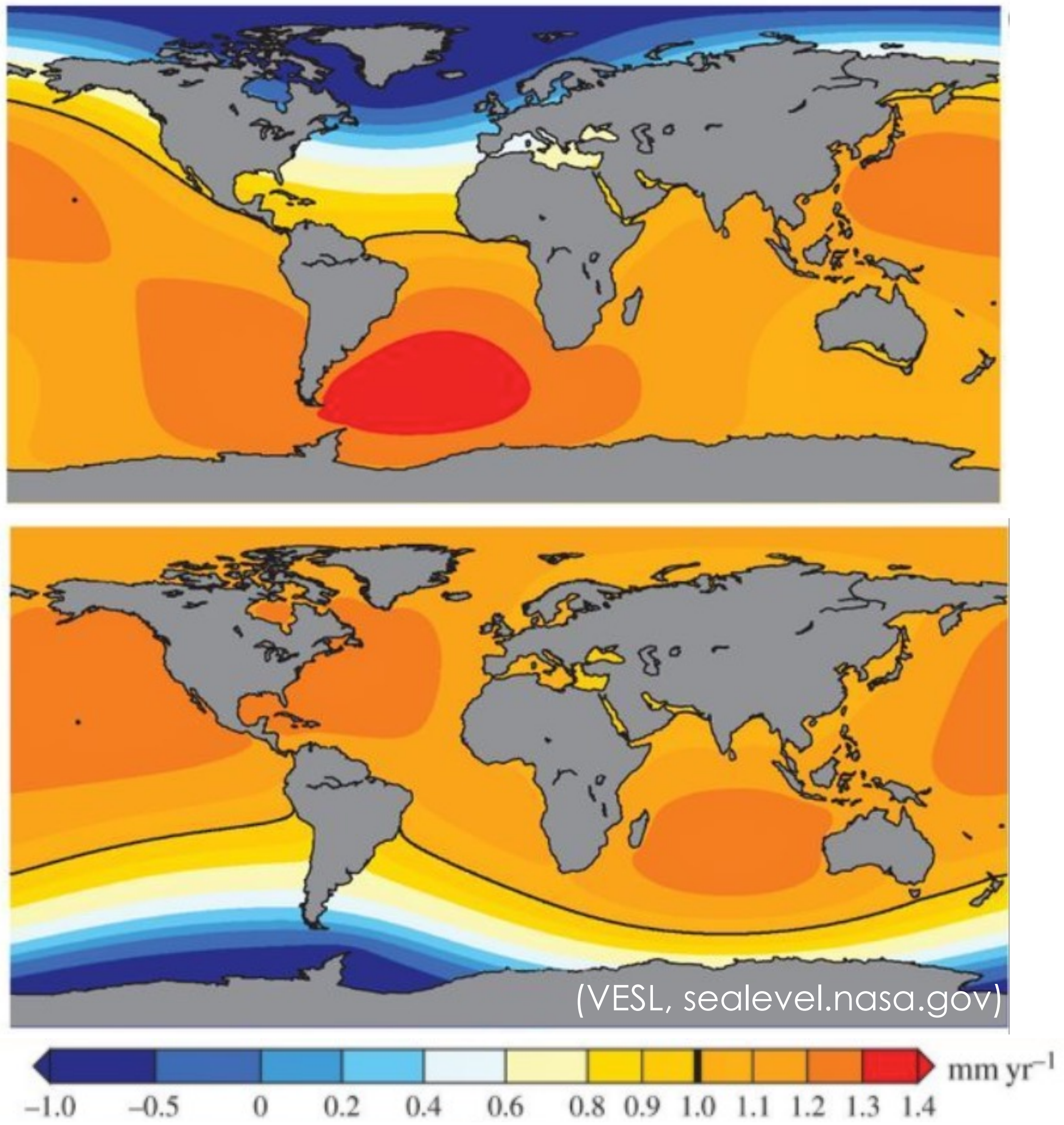

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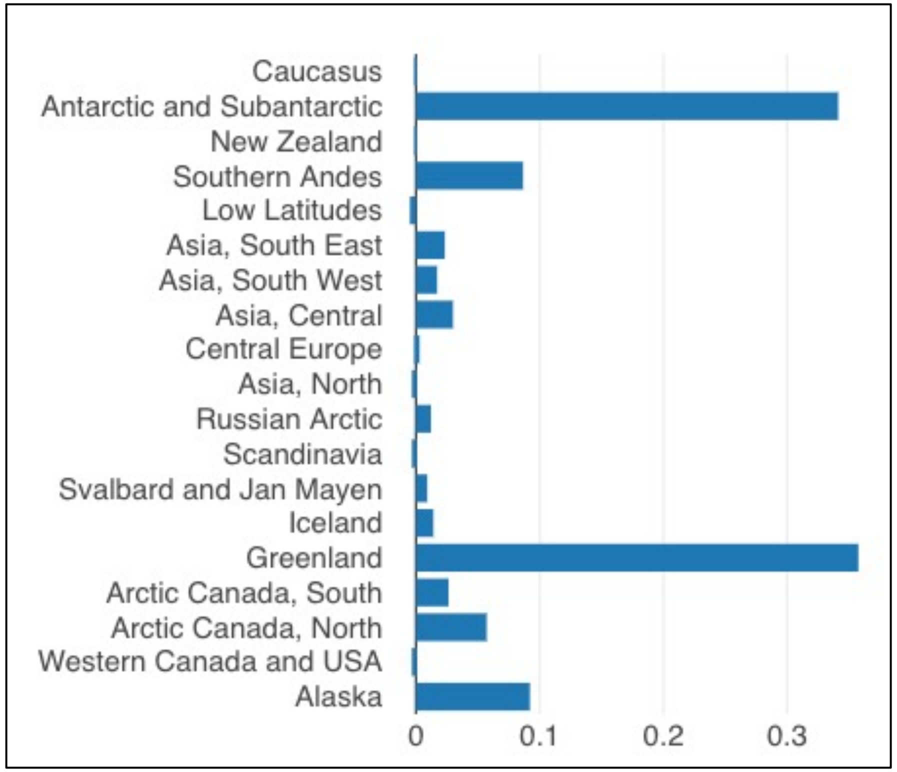
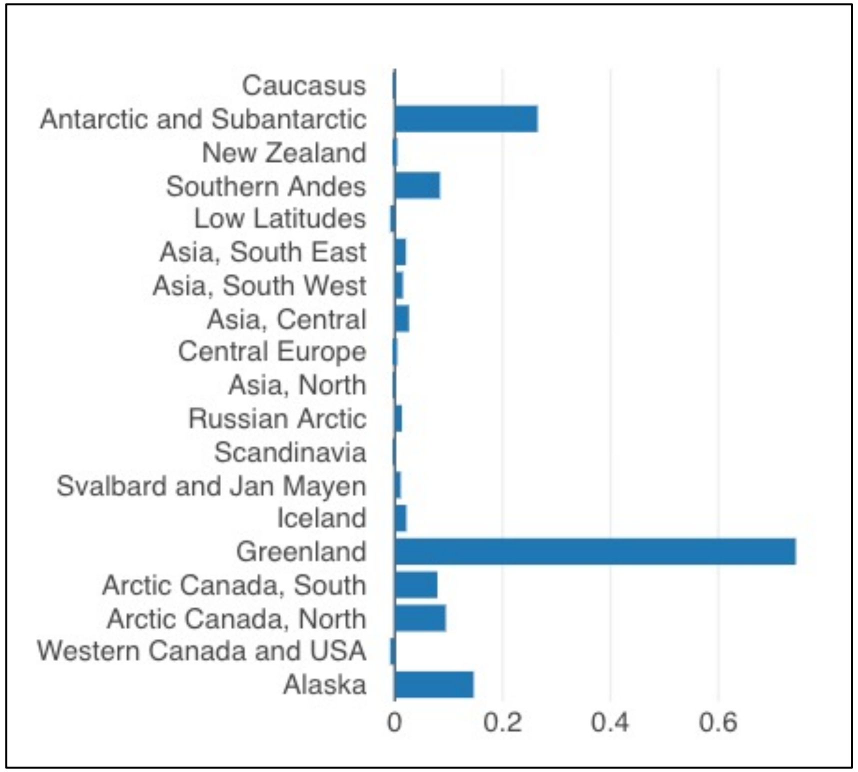
New York City: 1.06 mm/yr




Sydney: 1.50 mm/yr

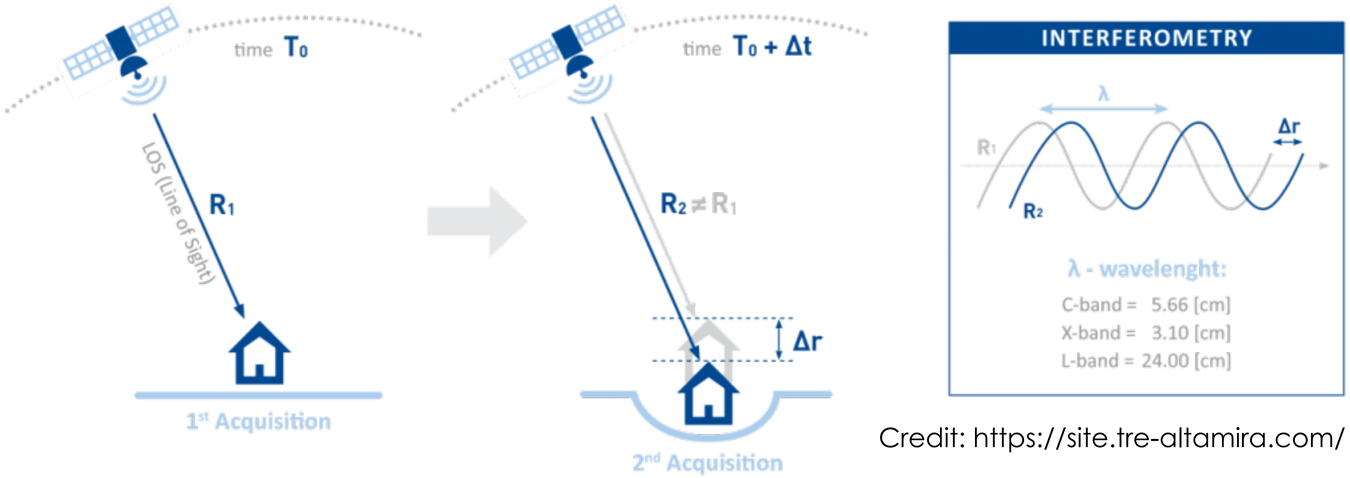



(VESL, sealevel.nasa.gov)

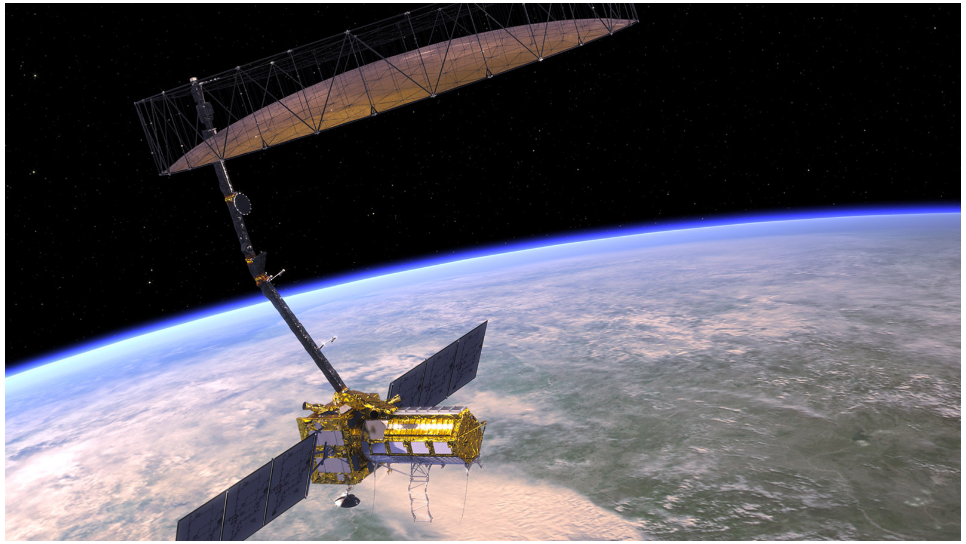
# Coastal Subsidence

- In addition to the ocean rising, many coastal regions around the world are sinking. This contributes to a rise in *relative sea level*.
  - Groundwater withdrawal, glacial isostatic adjustments, and tectonics.

- Interferometric Synthetic Aperture Radar Analysis (InSAR) can be used to estimate this movement of land at high spatial resolutions.
  - Satellite measures change from one pass to another over the same location.




Credit: https://site.tre-altamira.com/

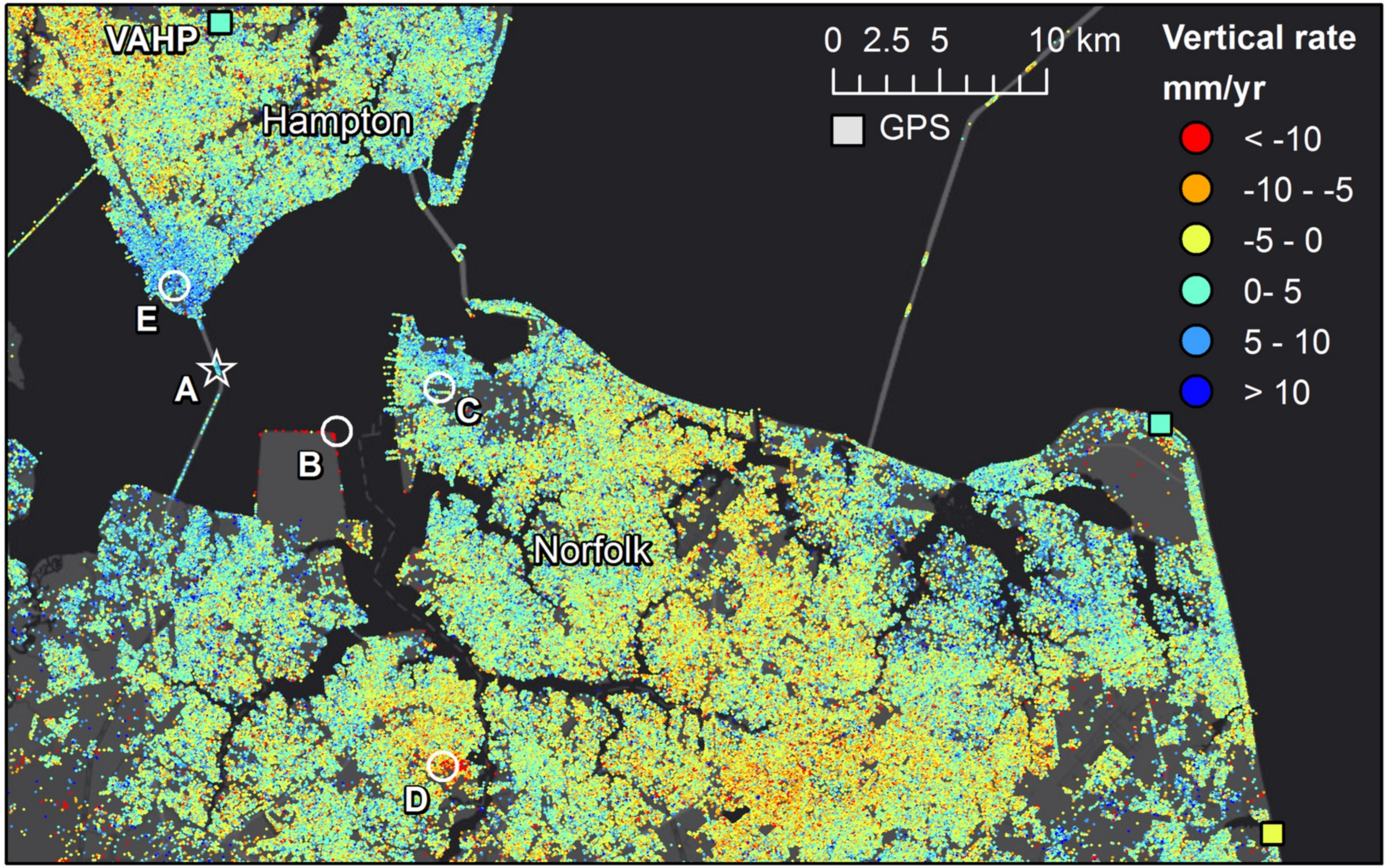


https://nisar.jpl.nasa.gov/

# Coastal Subsidence

- NASA is using InSAR in coastal locations threatened by sea-level rise to estimate vertical land motion.

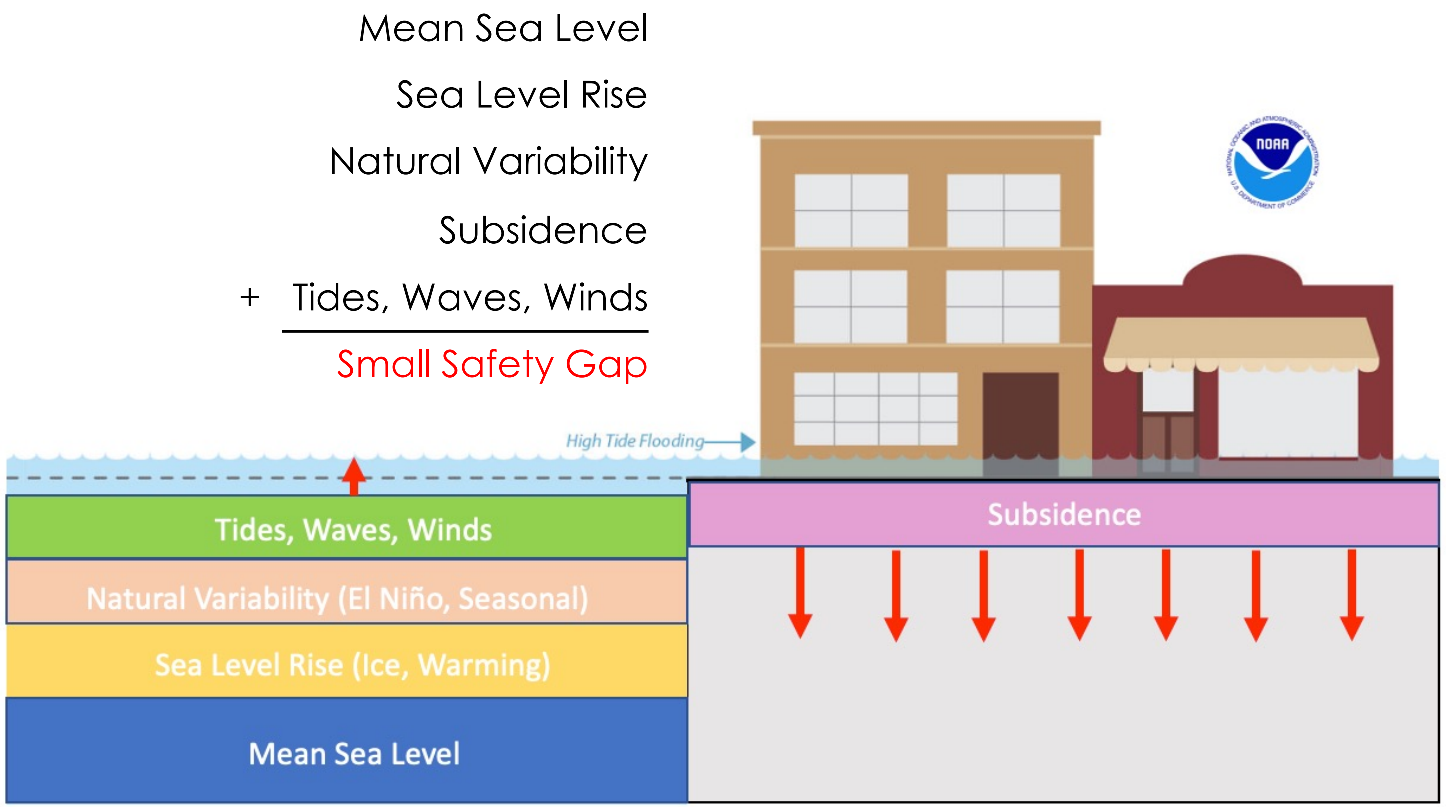

Zoom over Norfolk and Hampton Roads




(Bekaert et al., 2016)

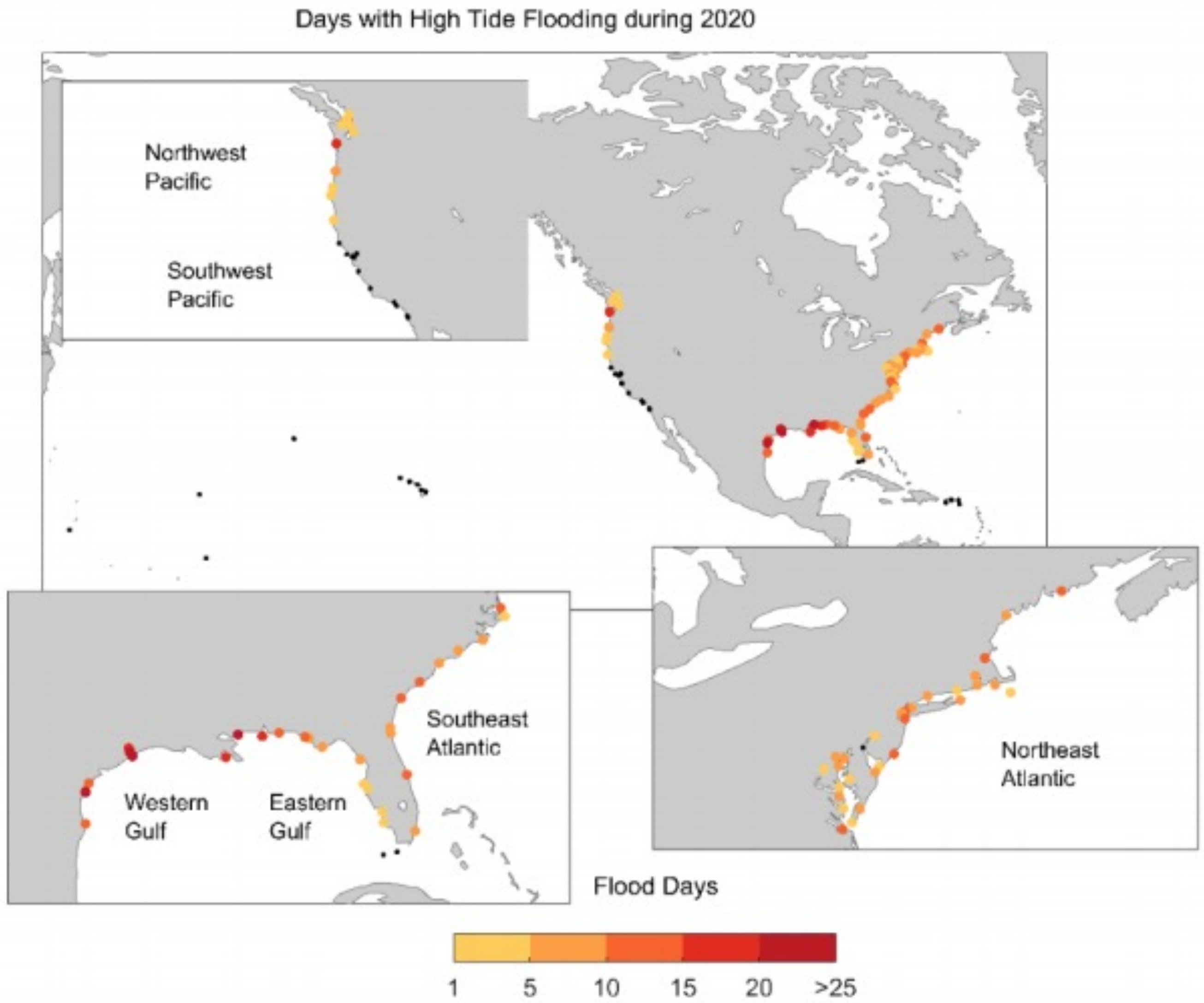
# Assessing Coastal Impacts

- Sea level is a global problem, but the impacts are local.
  - Flooding
  - Coastal Erosion
  - Saltwater Intrusion
  - Coastal Migration
  - Exposed Infrastructure
- A wide range of sea level “processes” can lead to coastal impacts.
- Important to consider how these processes combine and the timescales on which they combine.



# Coastal Impact Case Study: High Tide Flooding

- High-tide floods (HTF), previously known as nuisance floods, are already a problem along some U.S. coastlines.
- HTF is generally minor flooding that occurs at high tides in low-lying coastal locations (viewed as separate from storm-related flooding).
- HTF impacts coastal communities broadly, leading to business closures, transportation problems, and utility challenges.
- Accumulated effect over time can have a big impact on coastal infrastructure.
- Assessments of future HTF are critical for annual budgeting and long-term planning.
- Also, HTF is not always "minor".




NOAA Technical Report, 2021

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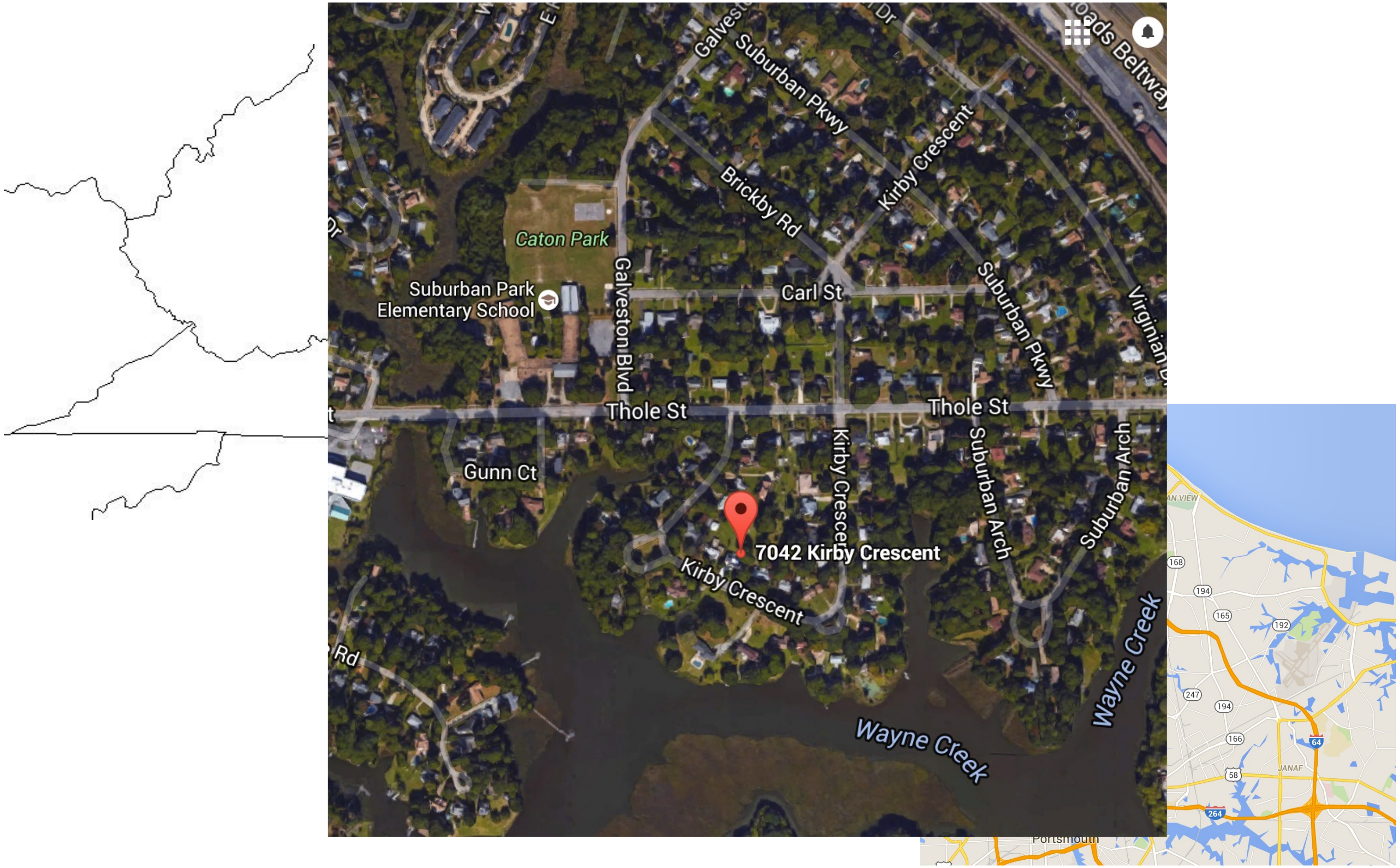

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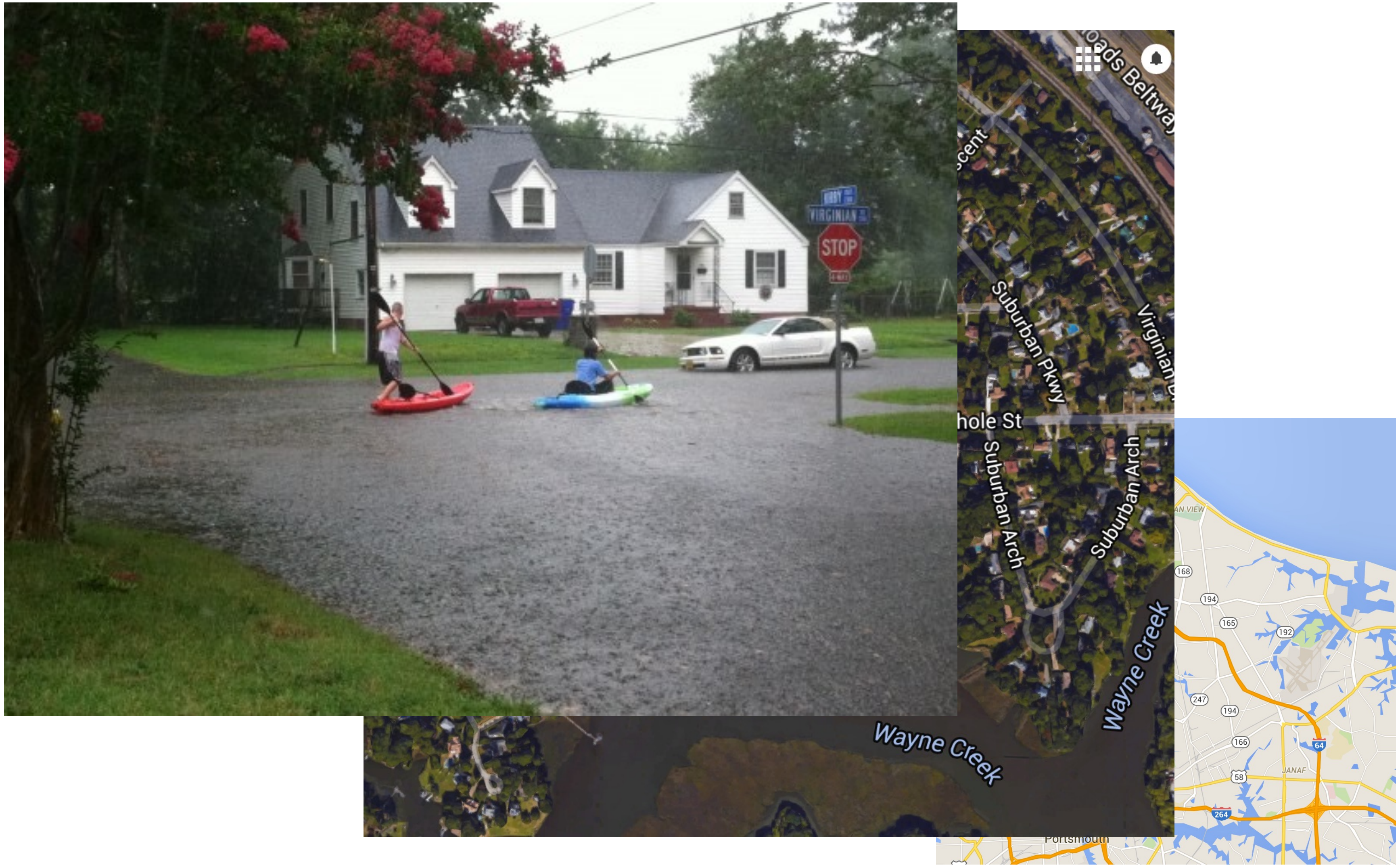

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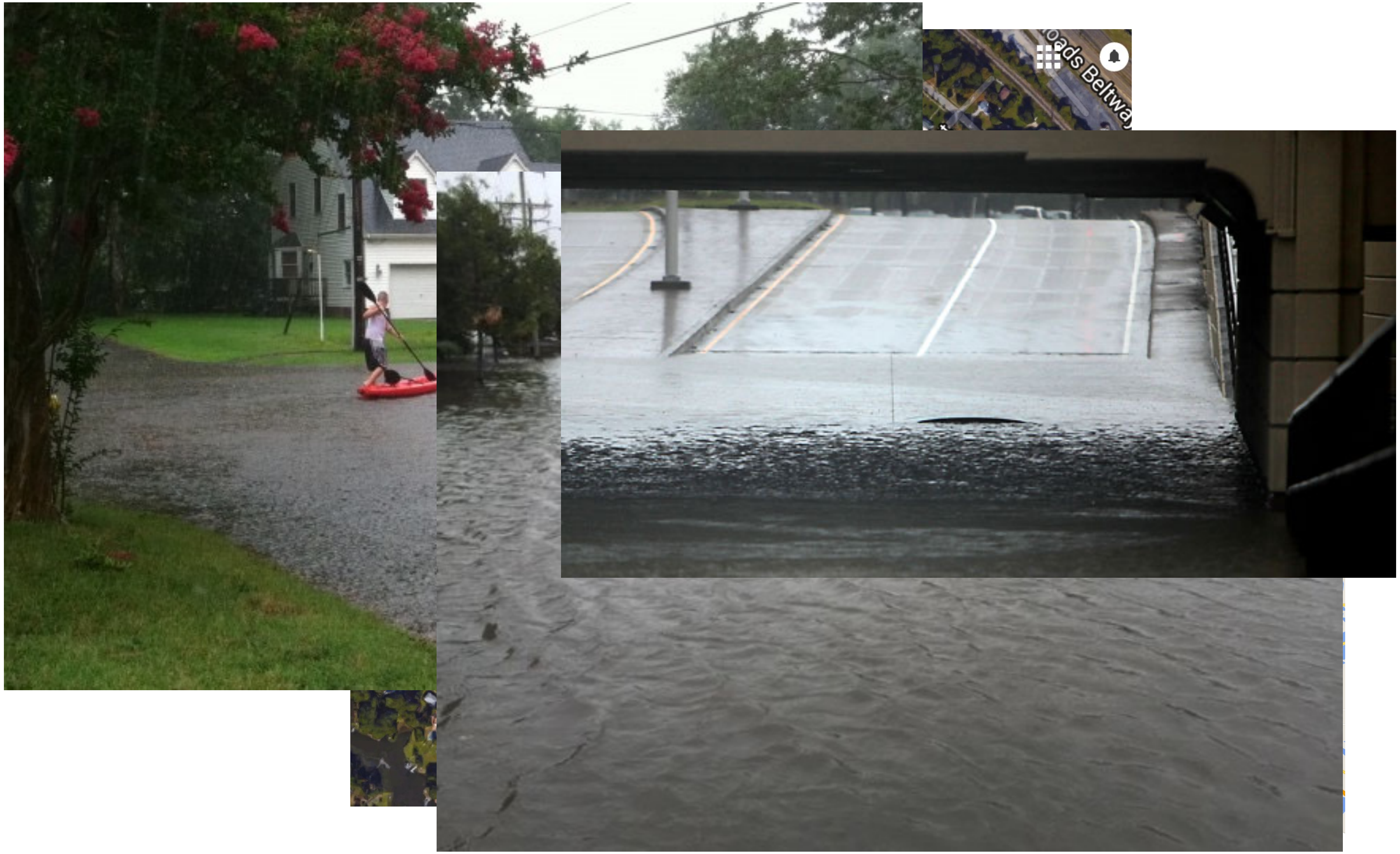

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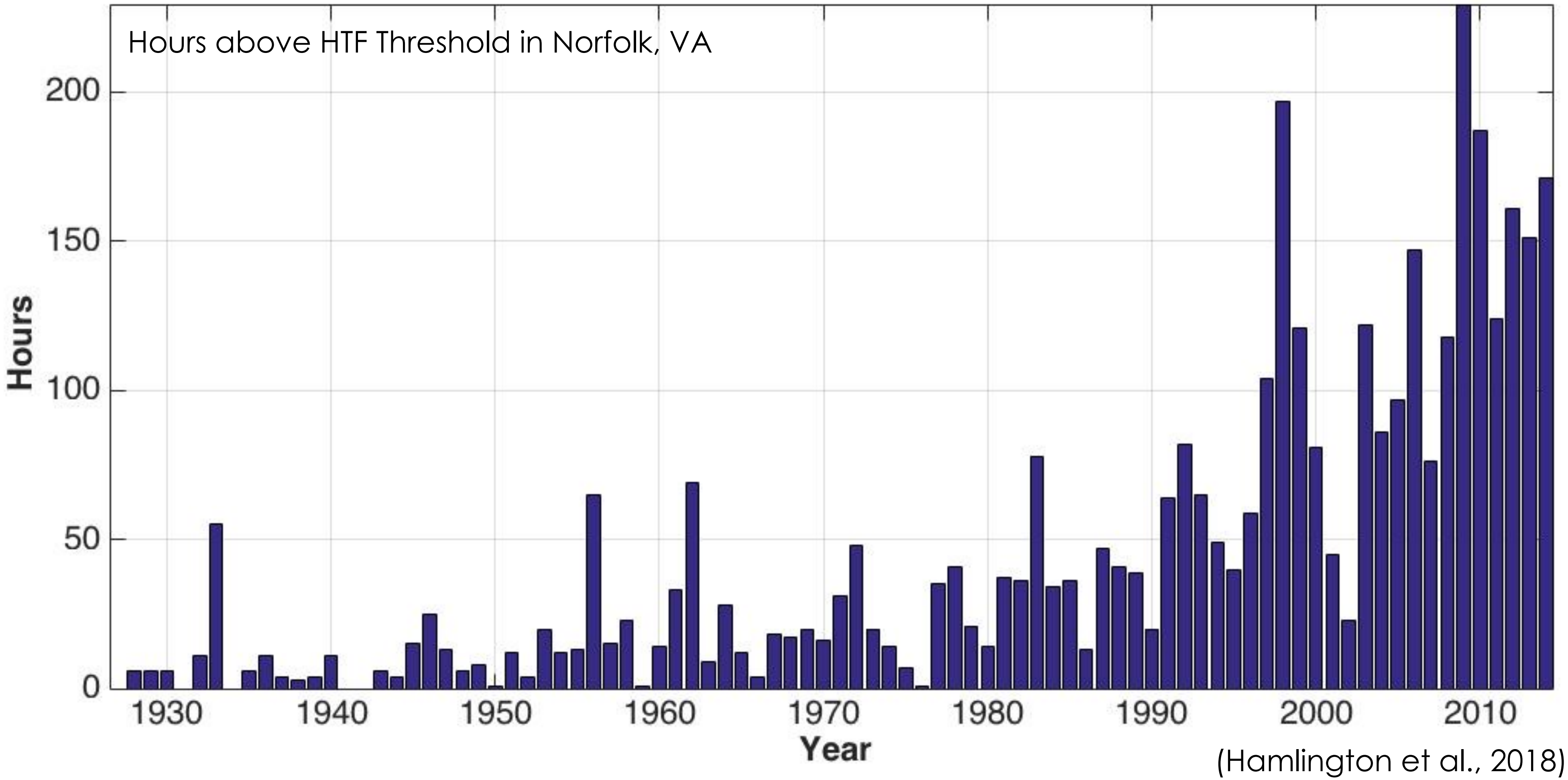
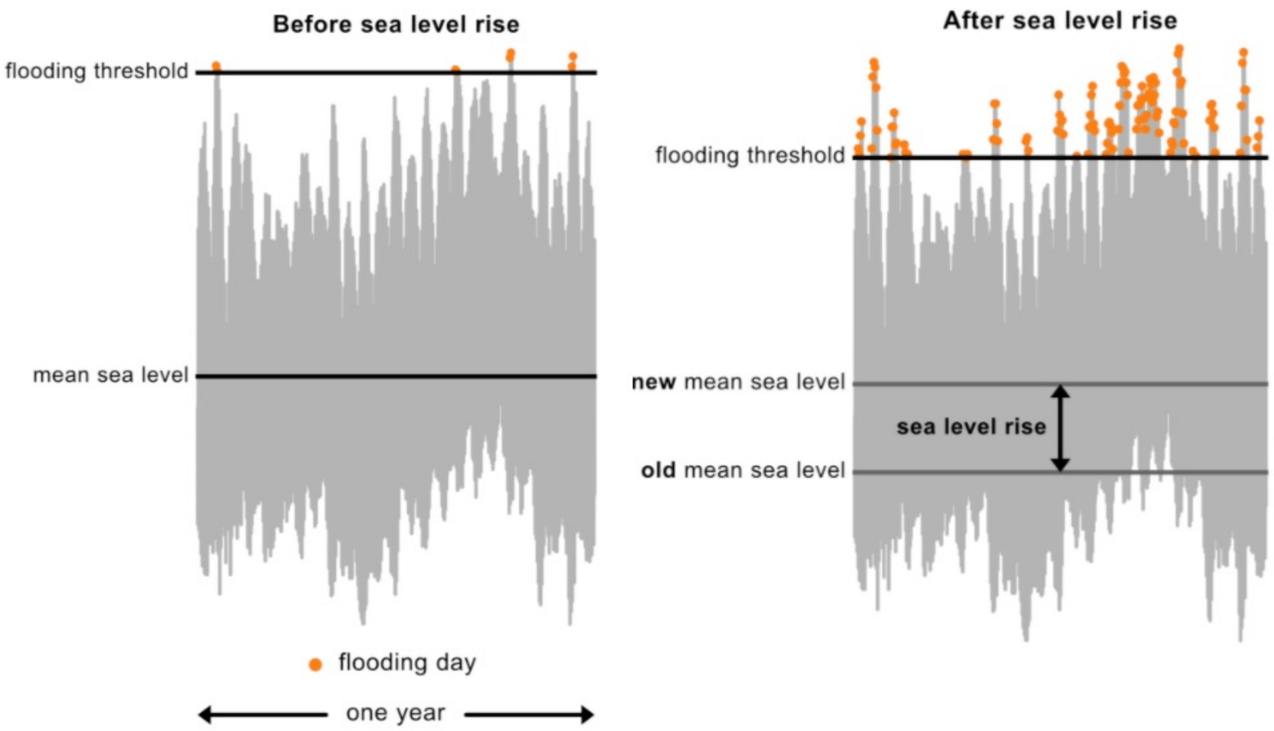
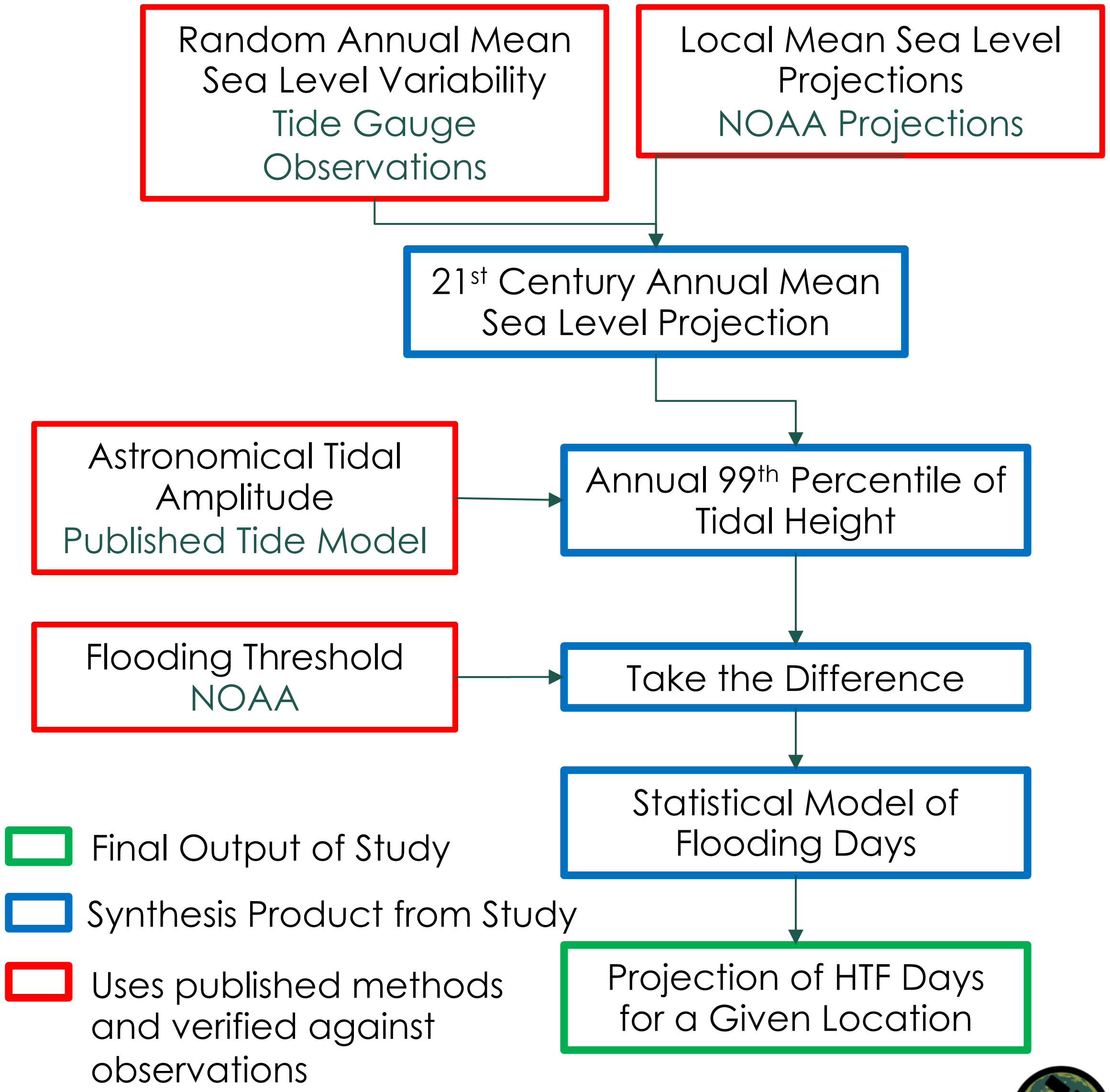



(Hamlington et al., 2018)

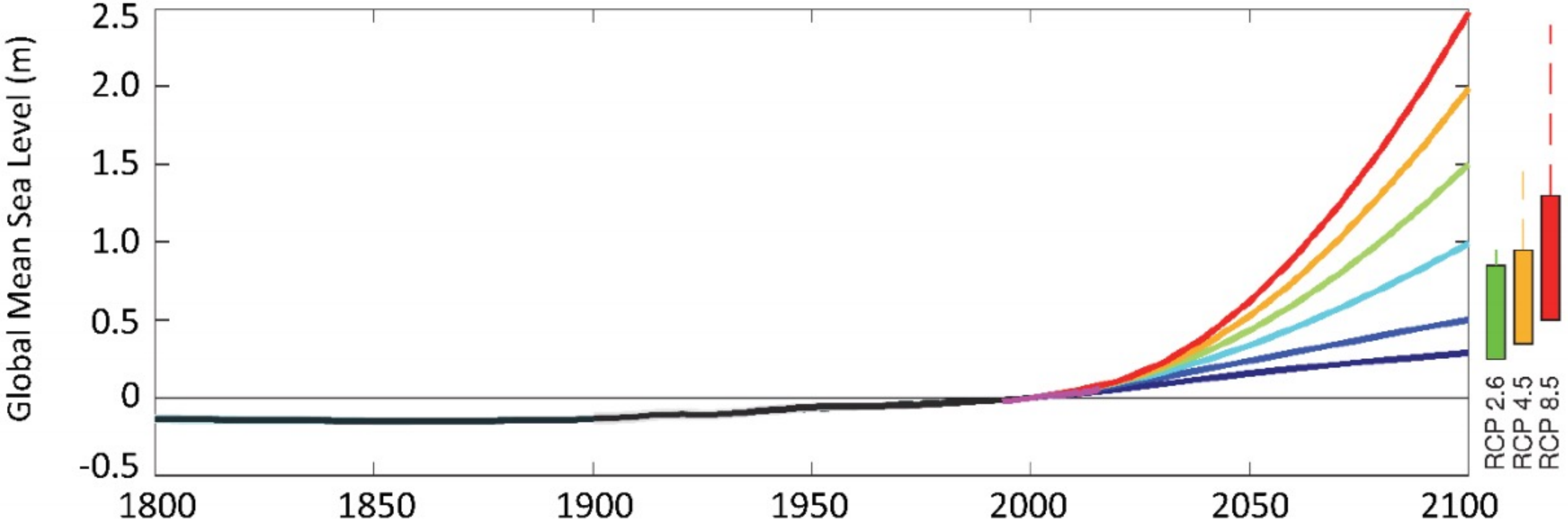
# Putting the Pieces Together

- In Thompson et al. (2021), a statistical framework was developed to assess the combined impact of the processes that drive HTF using the best available information on each process.



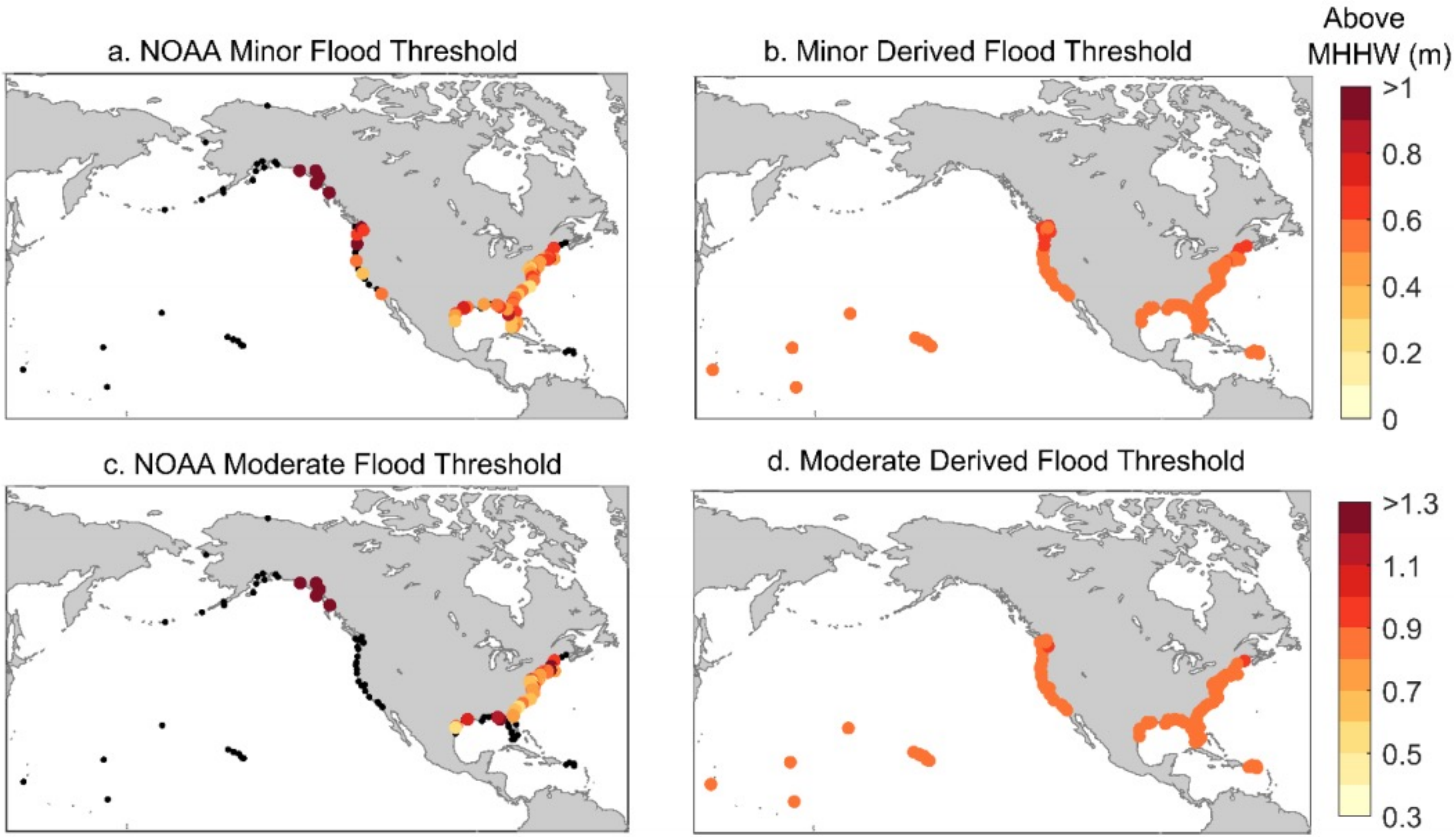
# Sea Level Scenarios and Projections




| GMSL Scenario (meters) | 2010 | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 | 2080 | 2090 | 2100 | 2120 | 2150 | 2200 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Low | 0.03 | 0.06 | 0.09 | 0.13 | 0.16 | 0.19 | 0.22 | 0.25 | 0.28 | 0.30 | 0.34 | 0.37 | 0.39 |
| Intermediate-Low | 0.04 | 0.08 | 0.13 | 0.18 | 0.24 | 0.29 | 0.35 | 0.4 | 0.45 | 0.50 | 0.60 | 0.73 | 0.95 |
| Intermediate | 0.04 | 0.10 | 0.16 | 0.25 | 0.34 | 0.45 | 0.57 | 0.71 | 0.85 | 1.0 | 1.3 | 1.8 | 2.8 |
| Intermediate-High | 0.05 | 0.10 | 0.19 | 0.30 | 0.44 | 0.60 | 0.79 | 1.0 | 1.2 | 1.5 | 2.0 | 3.1 | 5.1 |
| High | 0.05 | 0.11 | 0.21 | 0.36 | 0.54 | 0.77 | 1.0 | 1.3 | 1.7 | 2.0 | 2.8 | 4.3 | 7.5 |
| Extreme | 0.04 | 0.11 | 0.24 | 0.41 | 0.63 | 0.90 | 1.2 | 1.6 | 2.0 | 2.5 | 3.6 | 5.5 | 9.7 |

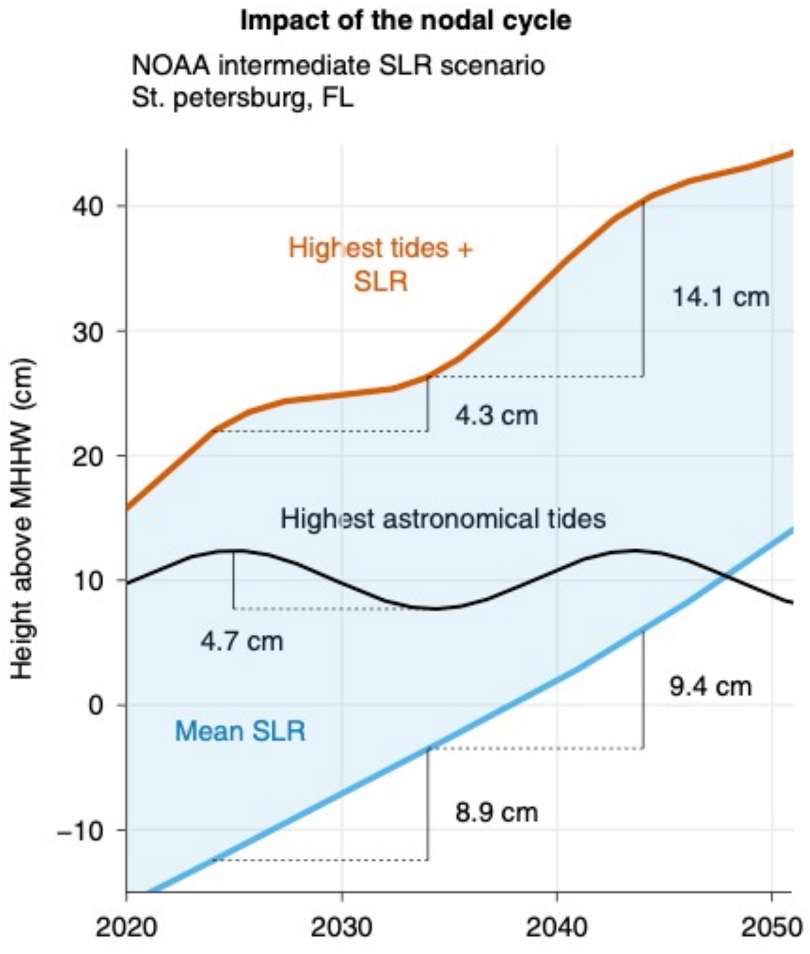
(NOAA Technical Report, 2017)

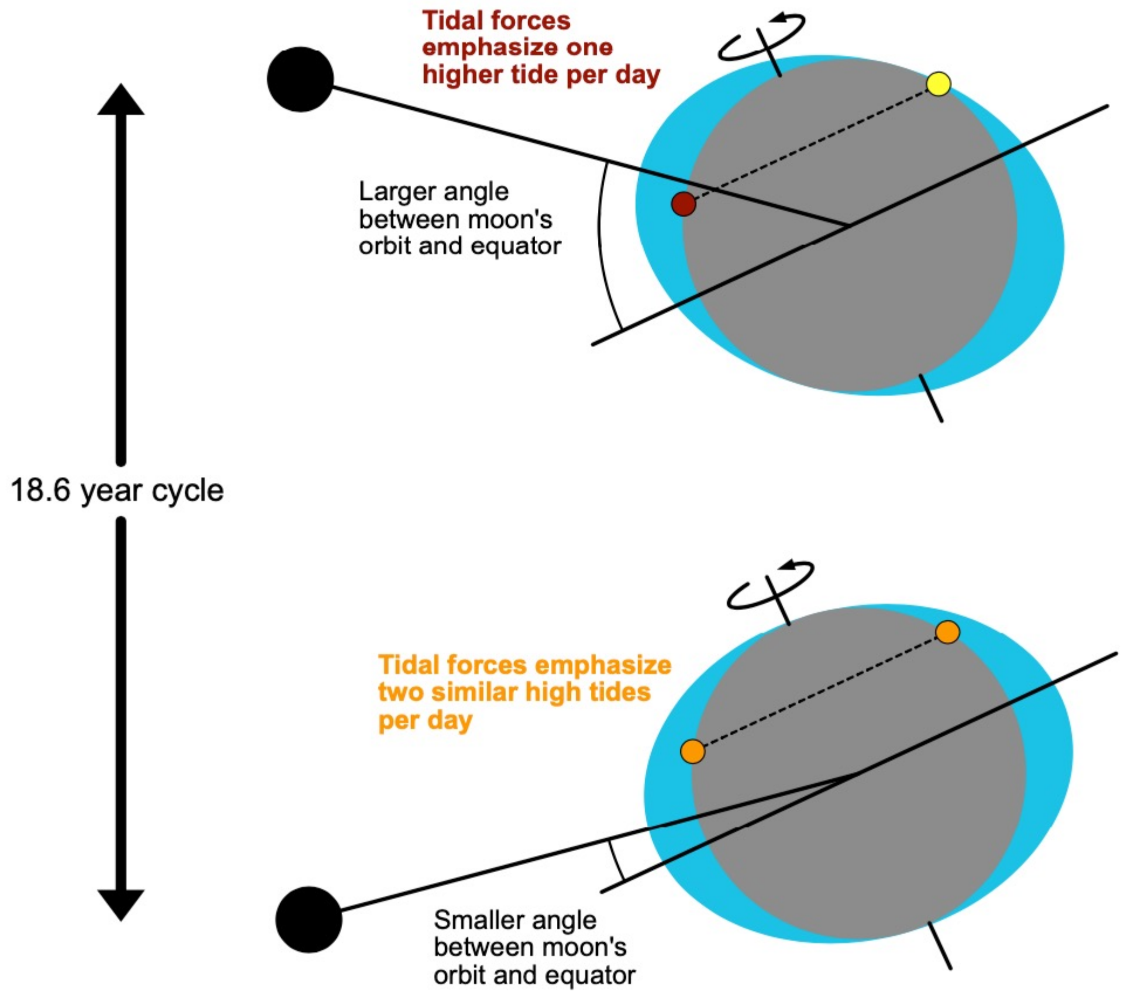
# Flooding Thresholds




(NOAA Technical Report, 2017)

# Tidal Variations




*Note: The angles between the moon's orbit and equator have beer*

Thompson et al., 2021

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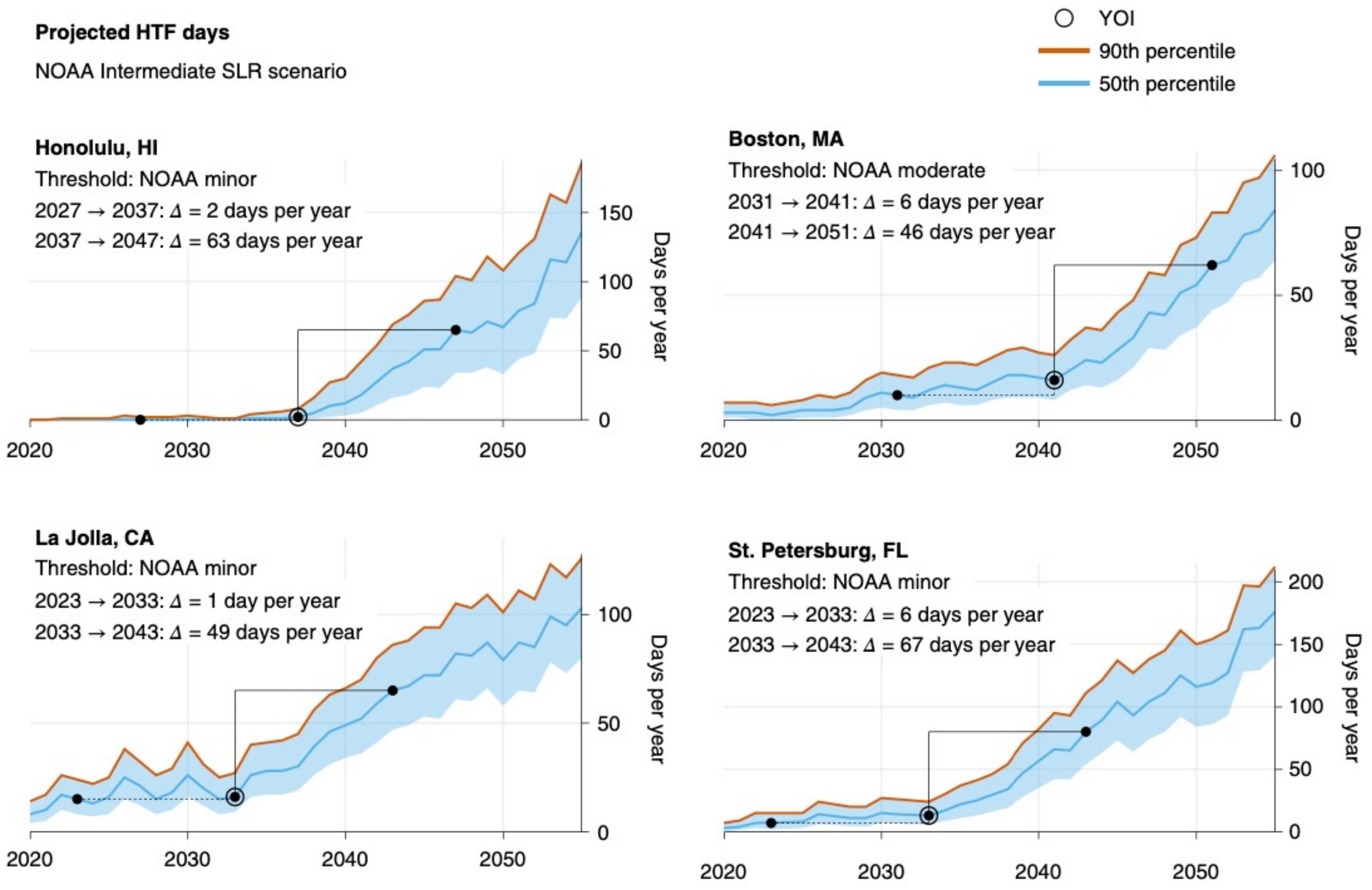


Thompson et al., 2021

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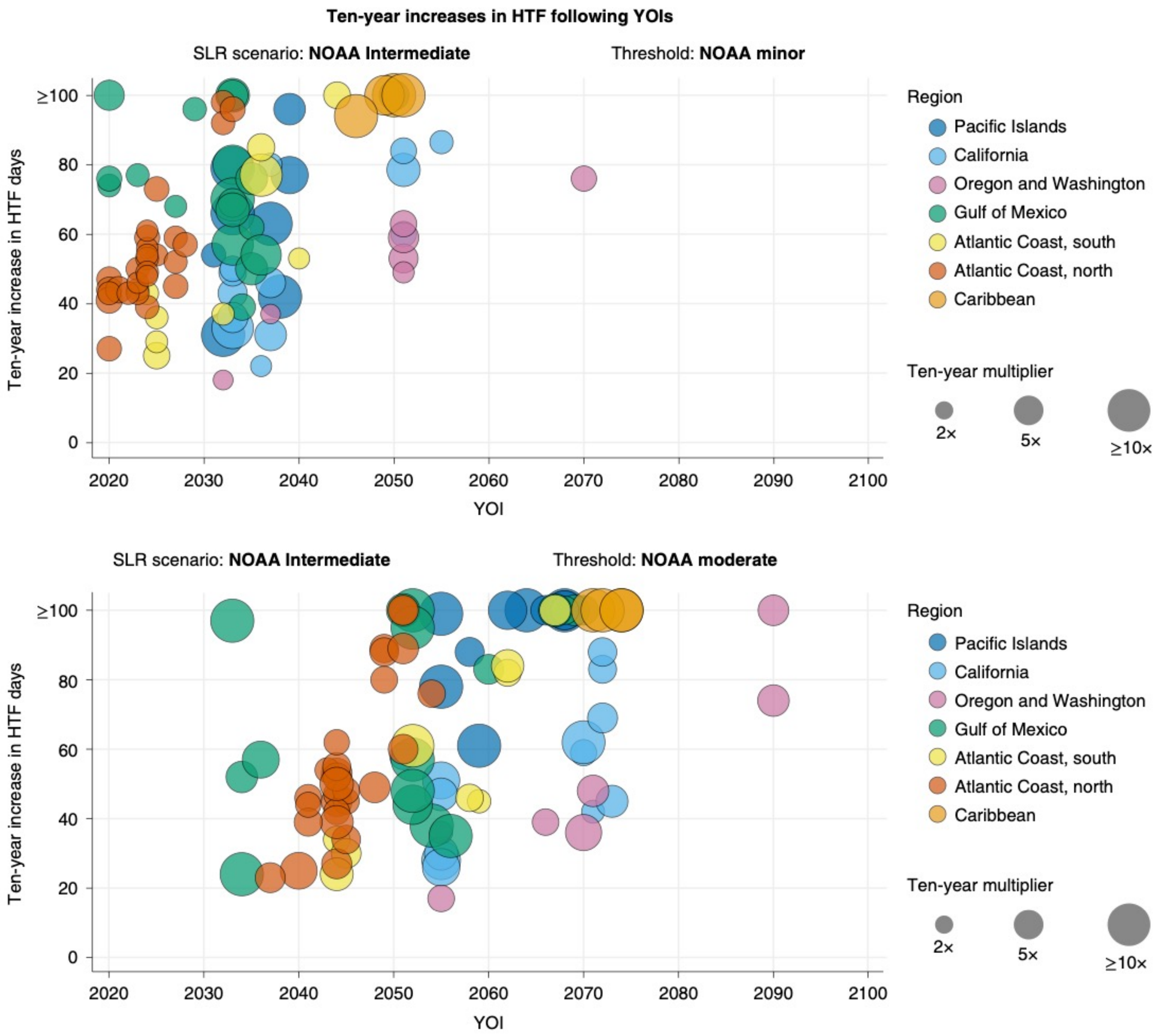
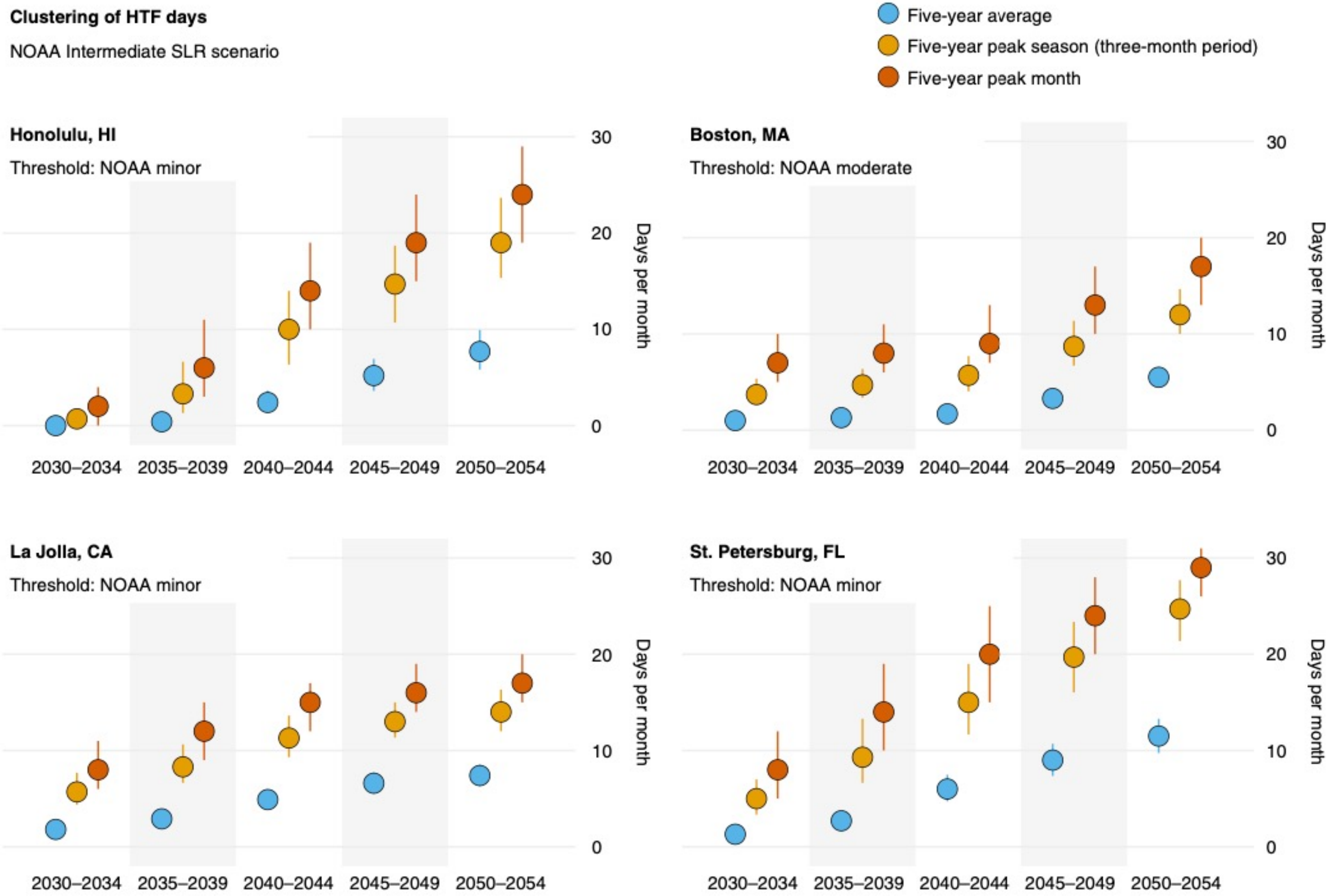



Thompson et al., 2021

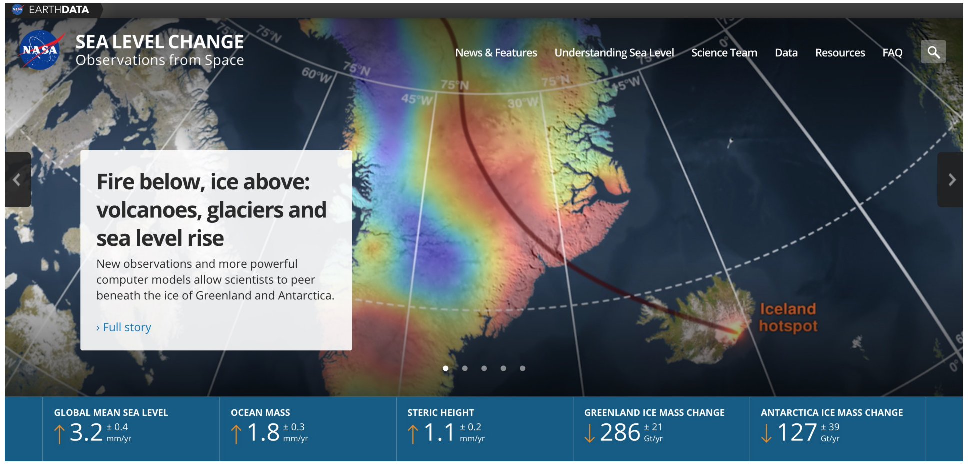
# Coastal Impact Case Study: High Tide Flooding

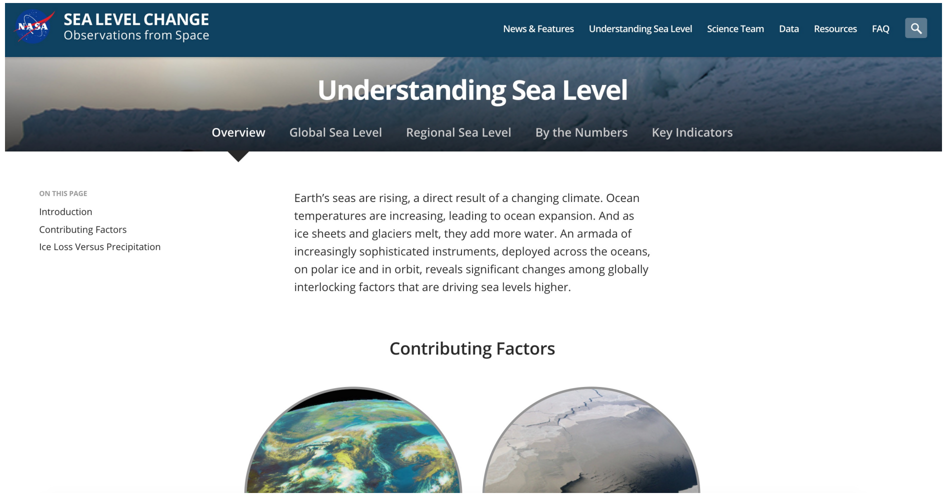



Thompson et al., 2021

# NASA Sea Level Change Team

- Satellites will play a critical role in monitoring these processes and providing important information to decision-makers and planners.
  - What can NASA do to provide “useful” information?
- **To meet this challenge, NASA created the NASA Sea Level Change Team (N-SLCT) in 2014.**
  - 70+ scientists from government and academia.
  - Web portal at [sealevel.nasa.gov](sealevel.nasa.gov) was created as part of this effort.
- **Two Goals:**
  - Science: Provide improved forecasts of sea level across a range of timescales.
  - Outreach: Connect with practitioners and stakeholders to define and provide ‘useful’ sea-level information.



# Satellite and Integrated Product Demo

- Full list of data tools on NASA sea level portal can be found here: https://sealevel.nasa.gov/data/tools.
- As a demonstration of how these tools and data can be combined to understand past, present, and future sea level, let's take a look at:
  1. Data Analysis Tool: https://sealevel.nasa.gov/data_tools/1
  2. Virtual Earth System Laboratory: https://sealevel.nasa.gov/data_tools/2
  3. Sea Level Evaluation and Assessment Tool: https://sealevel.nasa.gov/data_tools/16
  4. IPCC AR6 Sea Level Projection Tool: https://sealevel.nasa.gov/data_tools/17
  5. Flooding Days Projection Tool: https://sealevel.nasa.gov/data_tools/15

# Homework and Certificate

- One homework assignment:
  - Answers must be submitted via Google Form, accessed from the ARSET website.
  - Homework will be made available on August 26th.
  - Due date for homework: September 15, 2021
- A certificate of completion will be awarded to those who:
  - Attend all live webinars
  - Complete the homework assignment by the deadline
  - You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com

# Contacts

Trainers:

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Training Webpage:

- https://appliedsciences.nasa.gov/join-mission/training/english/arset-satellite-observations-analyzing-natural-hazards-small-island

ARSET Website:

- https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset

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# Questions

- Please enter your questions in the Q&A box. We will answer them in the order they were received.
- We will post the Q&A to the training website following the conclusion of the webinar.

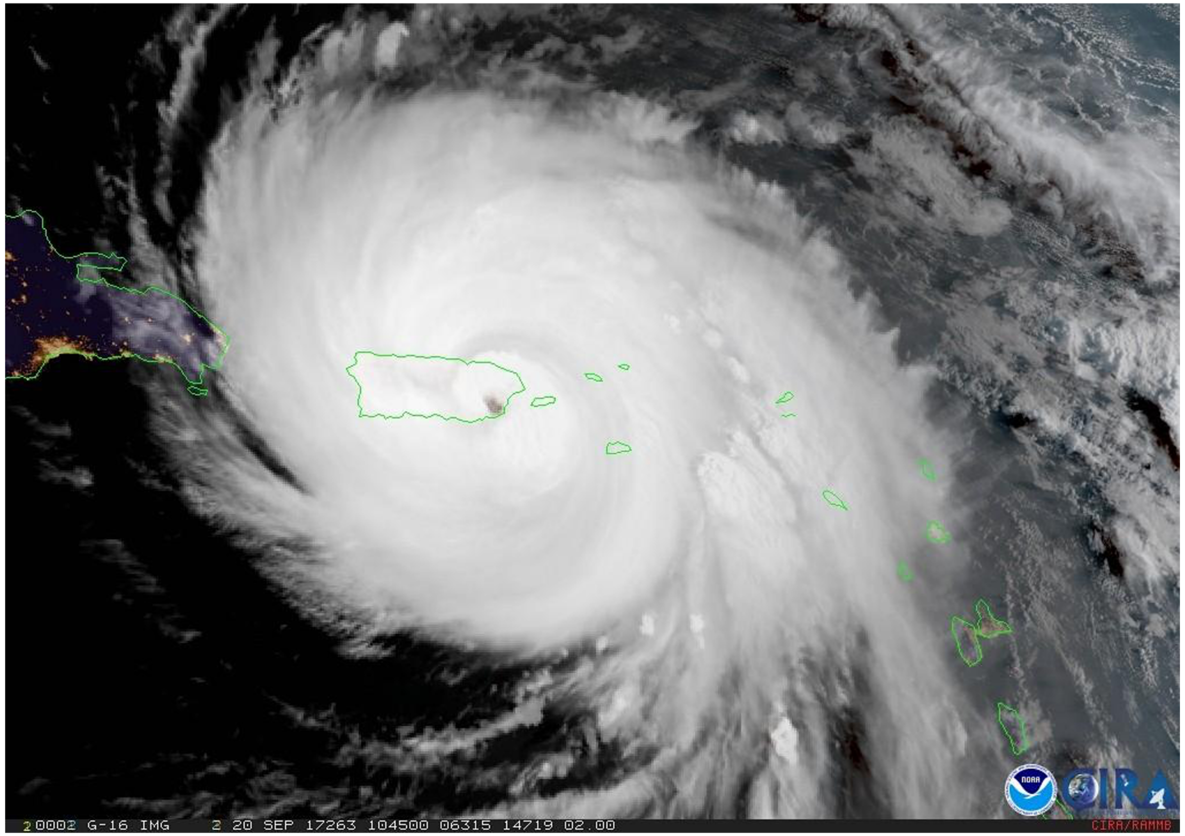


Image Credit: NOAA

# Thank You!