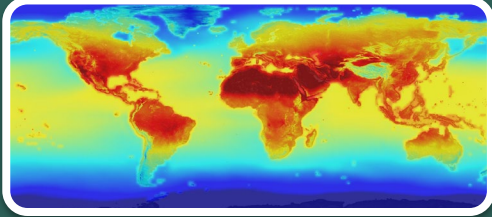


# Workshop Agenda



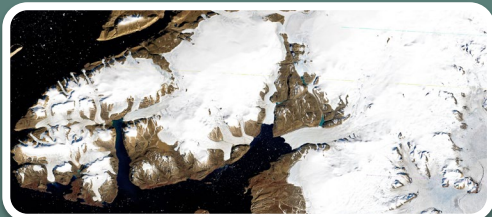
## Session I: Introduction to Climate Change

- Overview of climate change
- Monitoring climate change drivers using NASA data



## Session II: Earth observations for climate change impacts (Land & Atmosphere)

- Overview
- Focus area: Drought
- Focus area: Urban Heat Islands & Extreme Heat
- Focus area: Wildfires & Smoke



## Session III: Earth observations for climate change impacts (Ocean & Ice)

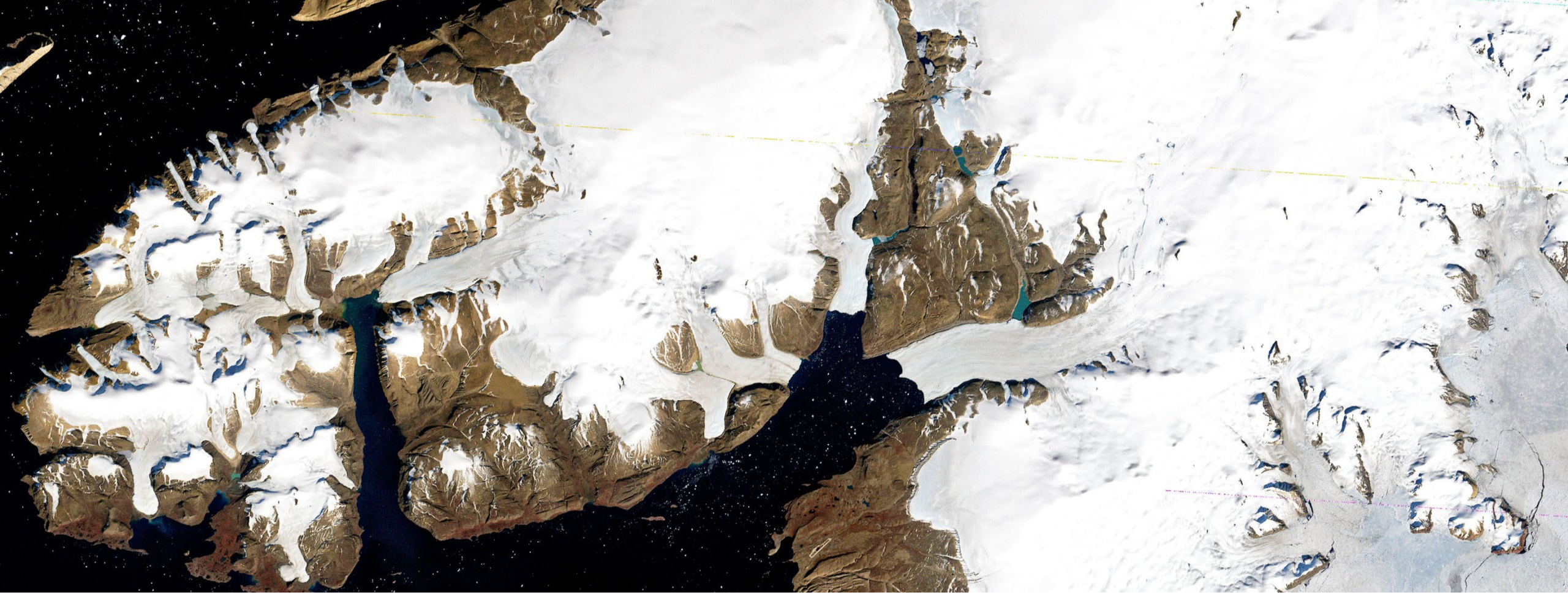
- Overview
- Focus Area: Sea Level Rise



## Session IV: Climate Models, Policy & Decision making

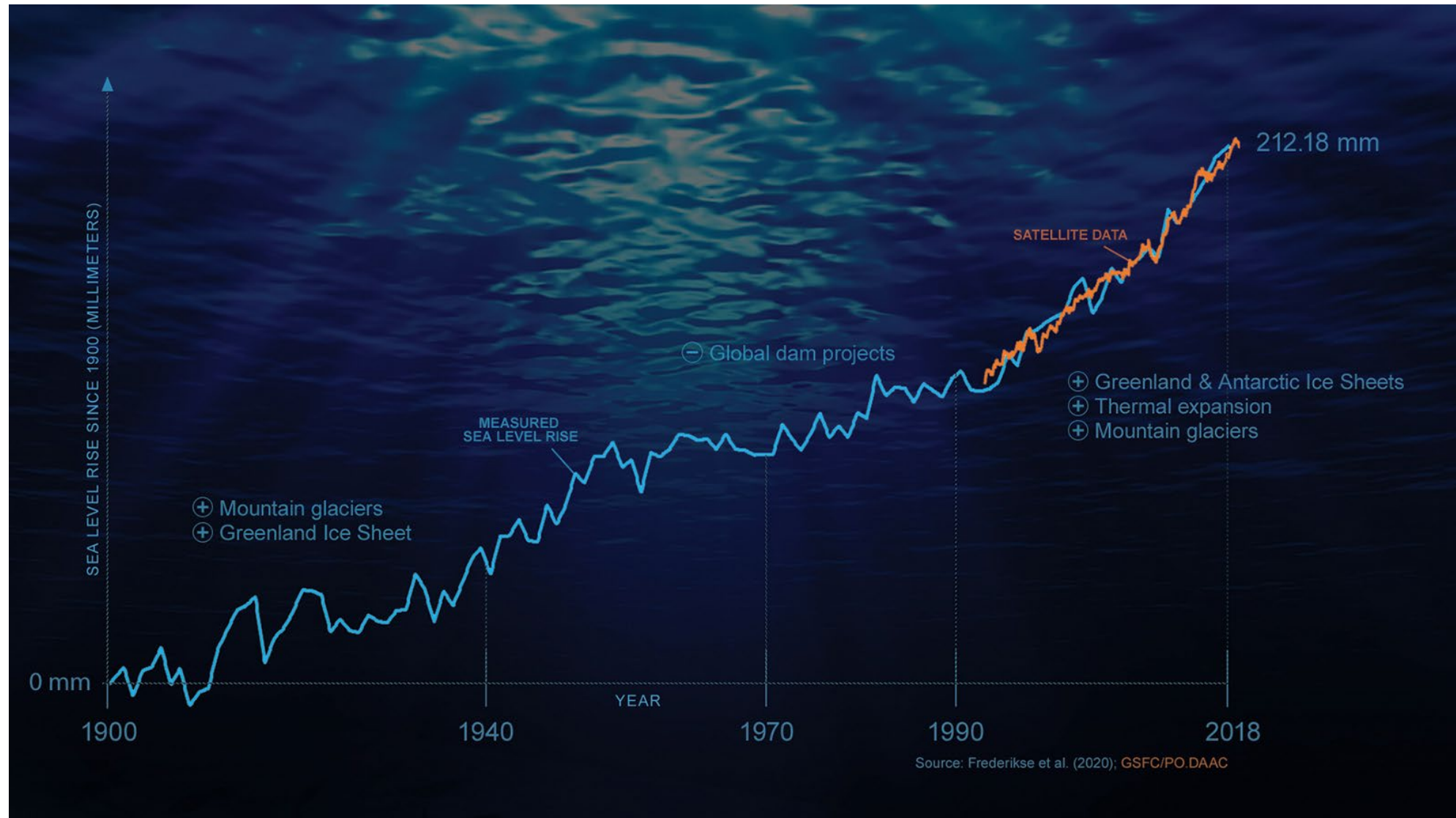
- Climate Modeling
- NASA ESO





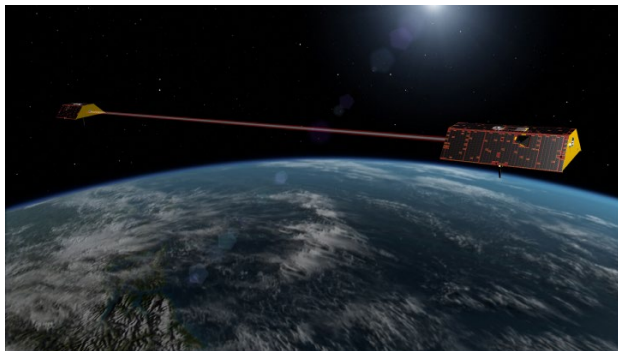
## Session III: Earth observations for climate change impacts (Ocean & Ice)

# Global Mean Sea Level



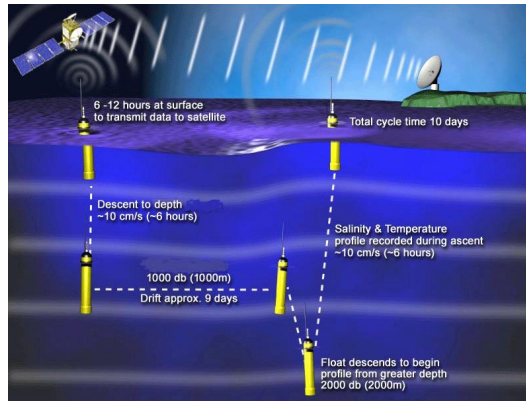
# Why is sea level rising globally?

## Ice (GRACE-FO)



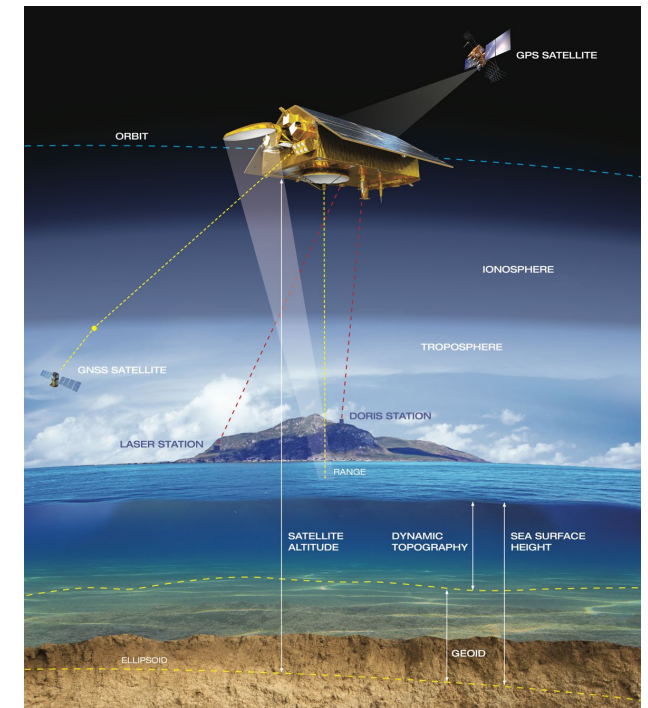
+

## Thermal Expansion (Argo)



=

## Total Sea Level (Altimetry)



# 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 across Earth's ice sheets and glaciers (e.g., Greenland & Antarctica)
  - They also tell us about the movement of water on Earth.



The mass of the Greenland ice sheet has rapidly declined in the last several years due to surface melting and iceberg calving. Research based on observations from the GRACE satellites (2002-2017) and GRACE-FO (since 2018) indicates that between 2002 and 2020, Greenland shed approximately 280 gigatons of ice per year, causing global sea level to rise by 0.8 millimeters (0.03 inches) per year. Credit: [NASA and JPL/Caltech](#)



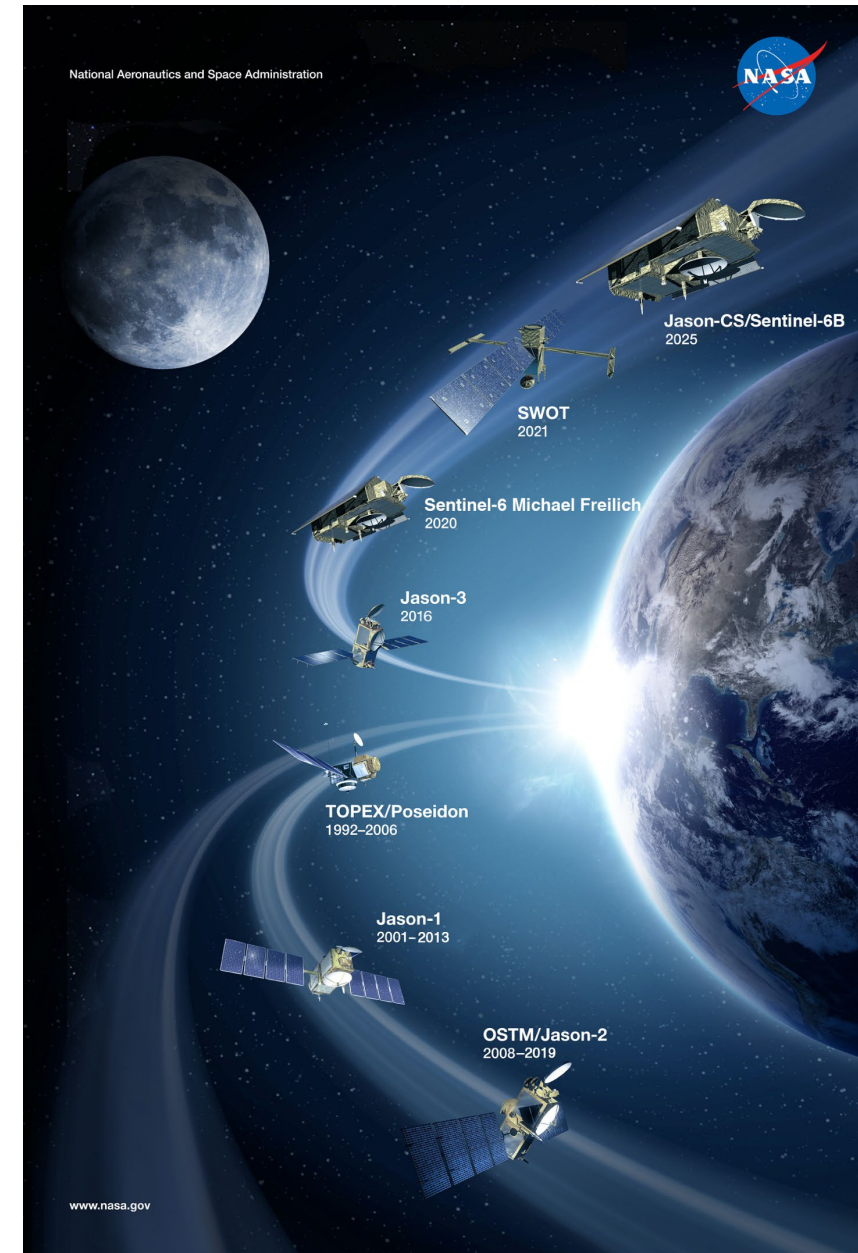
# NASA Missions for Climate

## Jason-3

- Jason-3 is the fourth mission in a U.S.-European series of satellite missions that measure the height of the ocean's surface using radar altimetry going back to 1992.
- The measurements provide scientists with critical information about circulation patterns in the ocean and both global and regional changes in sea level and the climate implications of a warming world.
- For nearly three decades, satellite altimeters have provided a precise, continuous record of global sea level with excellent spatial and temporal resolution.

<https://sealevel.jpl.nasa.gov/missions/jason-3/summary/>

NASA's Applied Remote Sensing Training Program



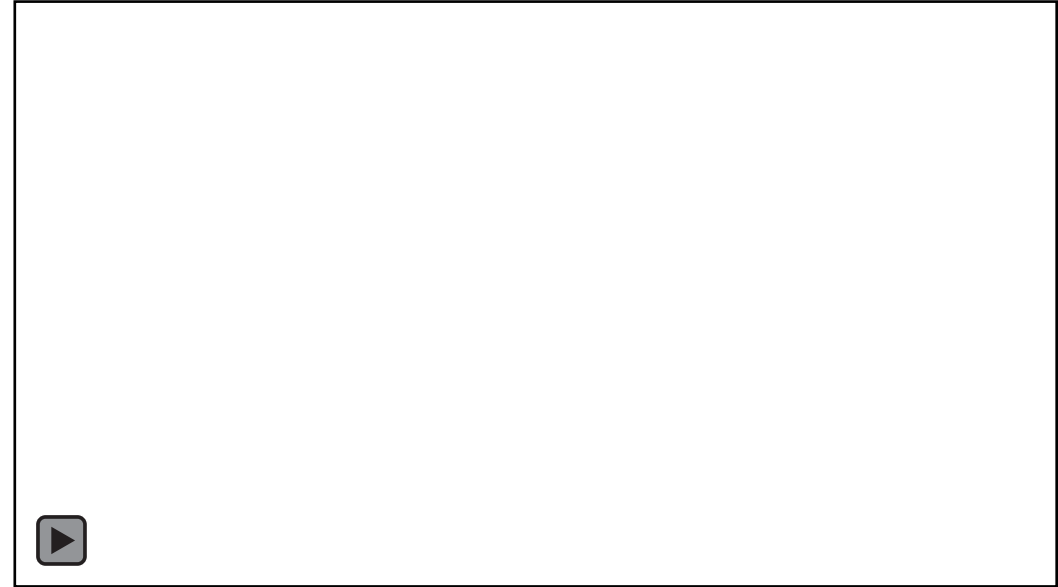
Past, present, and future NASA altimetry missions.  
Credit: NASA



# NASA Missions for Climate

## Sentinel-6 Michael Freilich

- A joint U.S.-European effort to collect the most accurate data yet on sea level and how it changes over time.
- The mission consists of two identical satellites that will be launched five years apart (Sentinel-6 Michael Freilich launched on Nov. 21, 2020).
- Both satellites use a radar altimeter to measure sea level down to the centimeter for more than 90% of the world's oceans. The data they collect will add to a long-term dataset that began with a joint U.S.-French effort called TOPEX/Poseidon in 1992.



Visualization of Sentinel-6 Michael Freilich collecting radar altimetry data over the Earth's oceans to monitor sea level down to the centimeter and how it changes over time. Credit: NASA's Scientific Visualization Studio

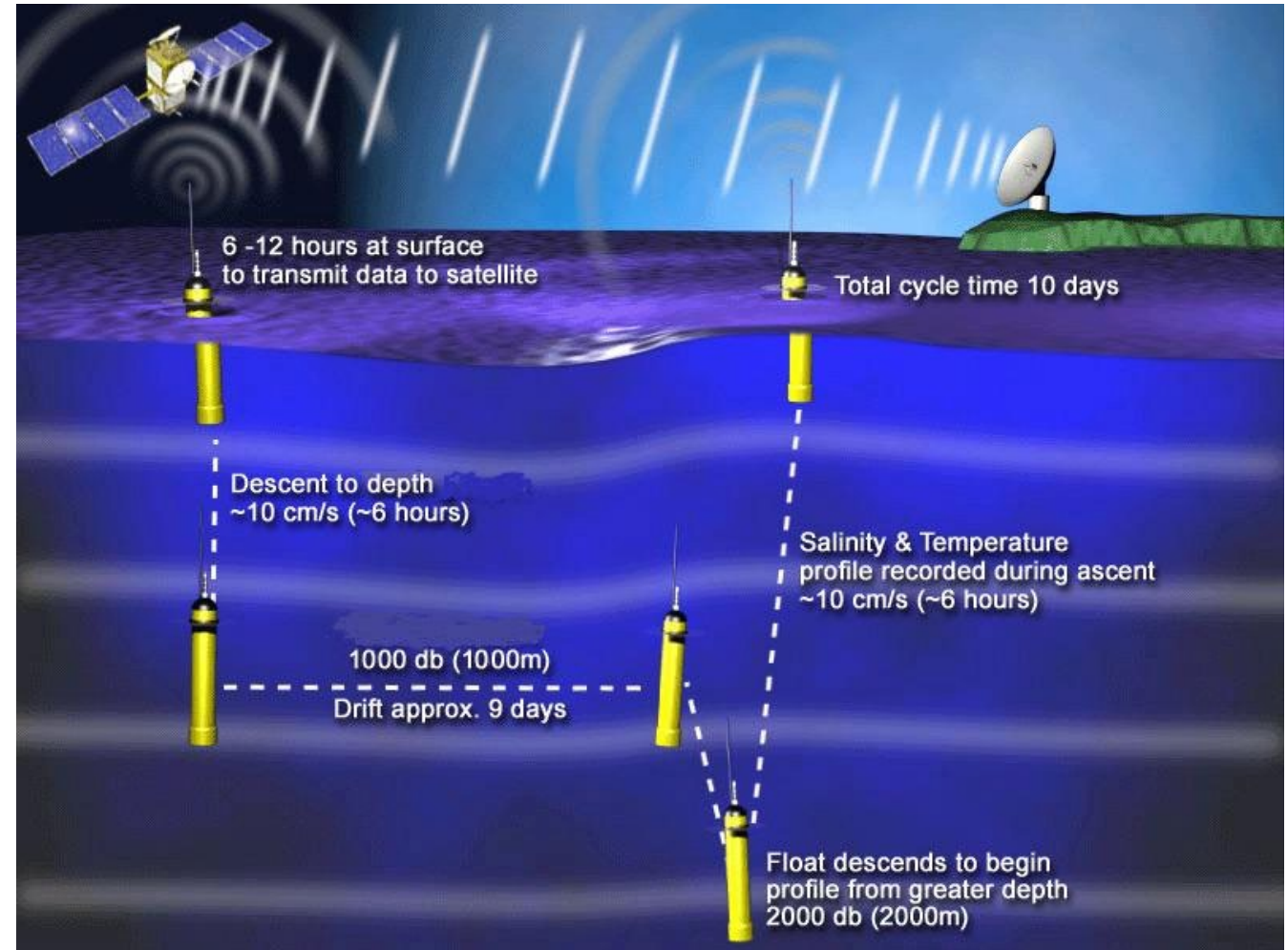
<https://www.nasa.gov/sentinel-6>

NASA's Applied Remote Sensing Training Program



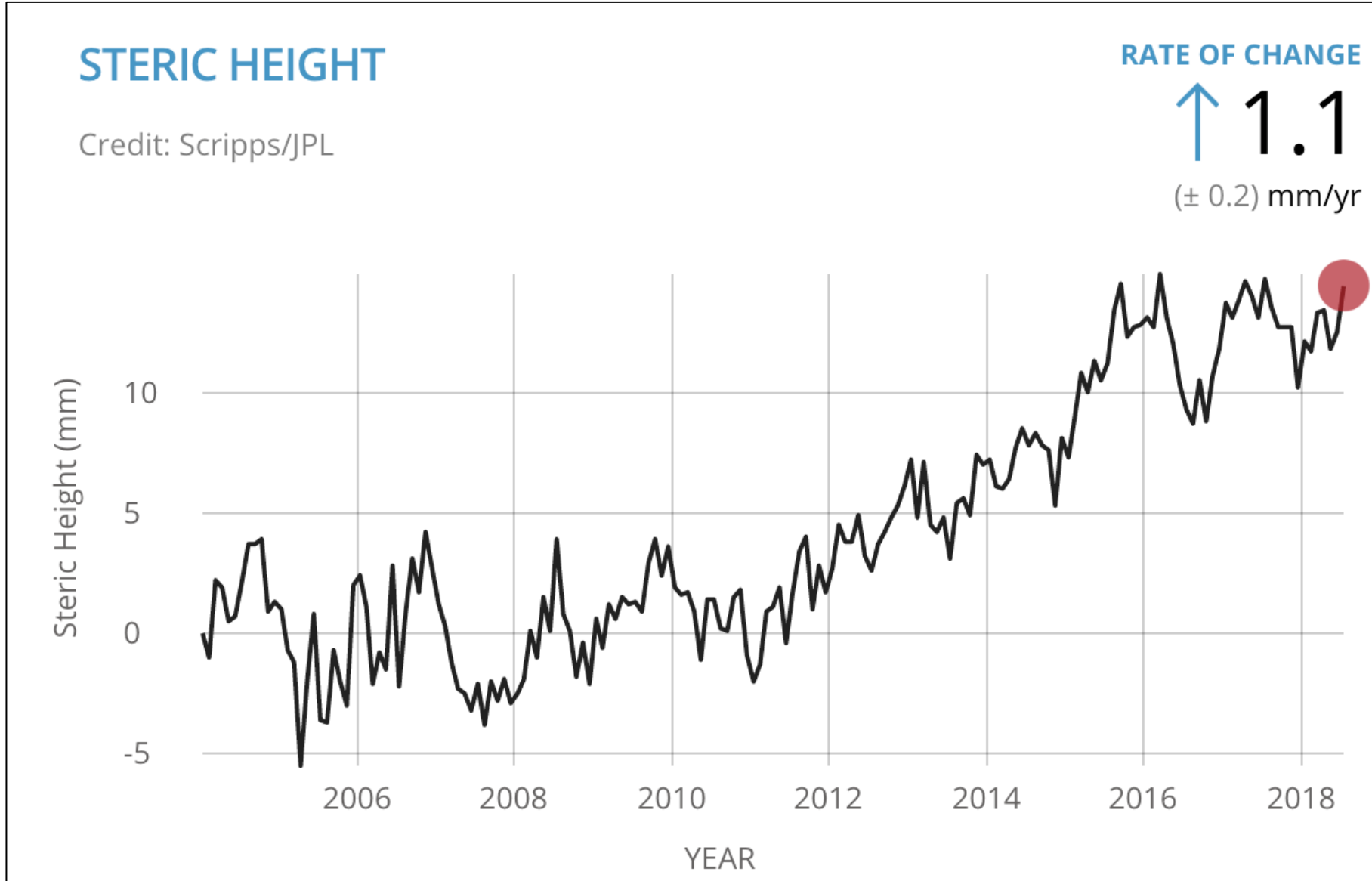
# Argo Profiling Floats

- 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



# Closing the Sea Level “Budget”



# Regional Sea Level Change

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

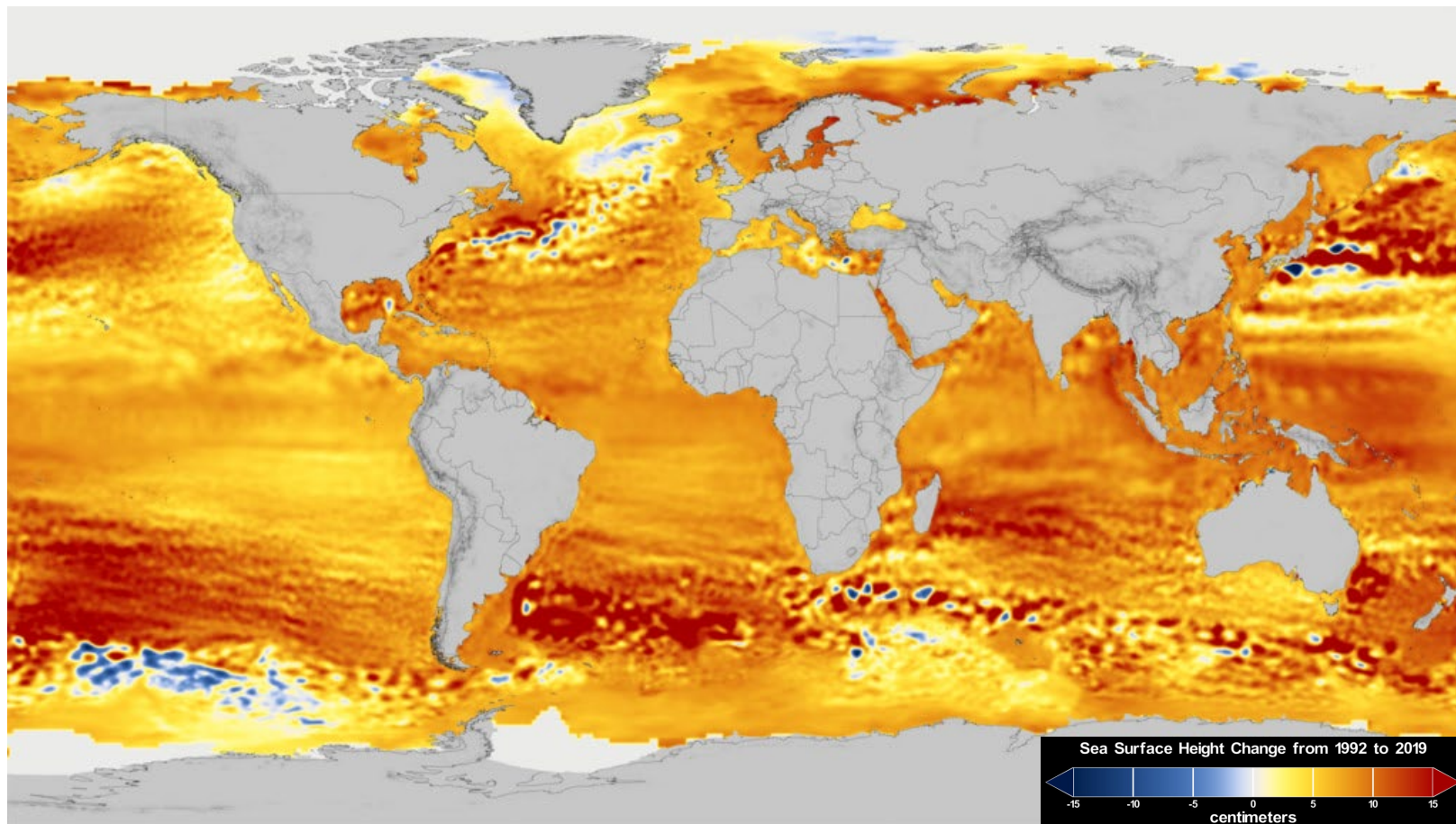
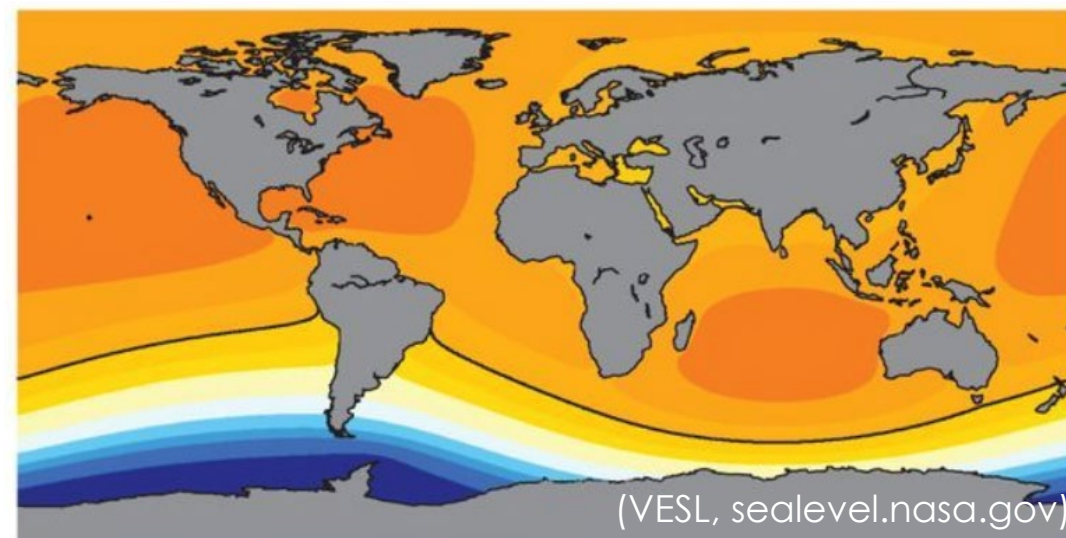
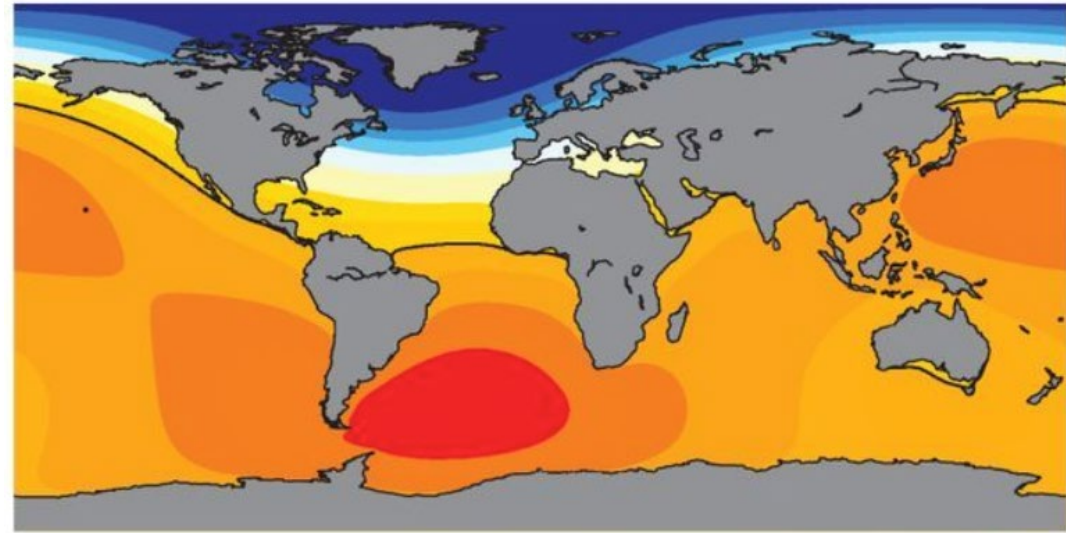


Image showing sea surface height changes from 1992 to 2019 in cm using satellite altimetry data.  
Credit: NASA GSFC Visualization Studio

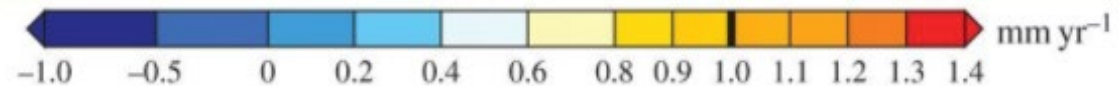


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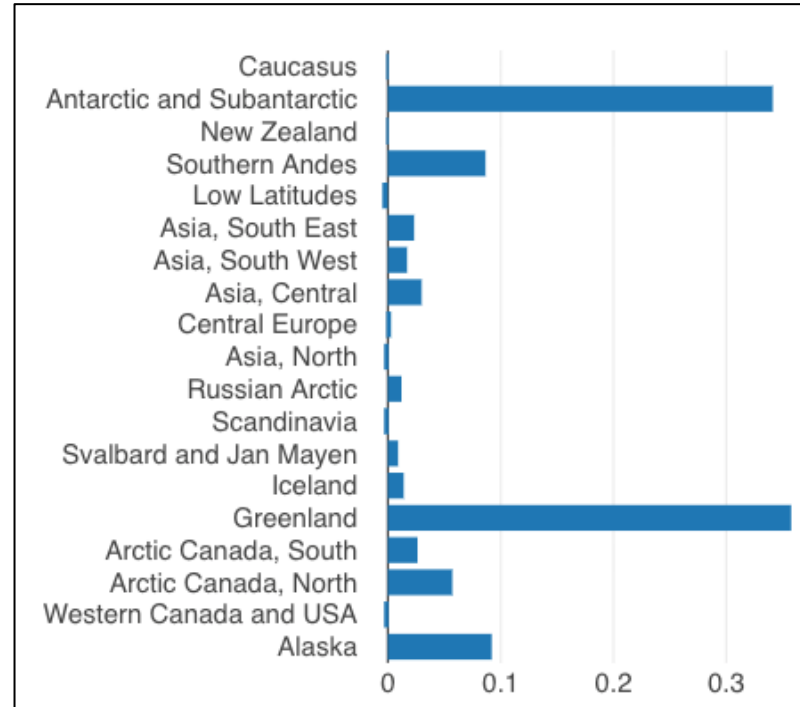
(VESL, [sealevel.nasa.gov](http://sealevel.nasa.gov))



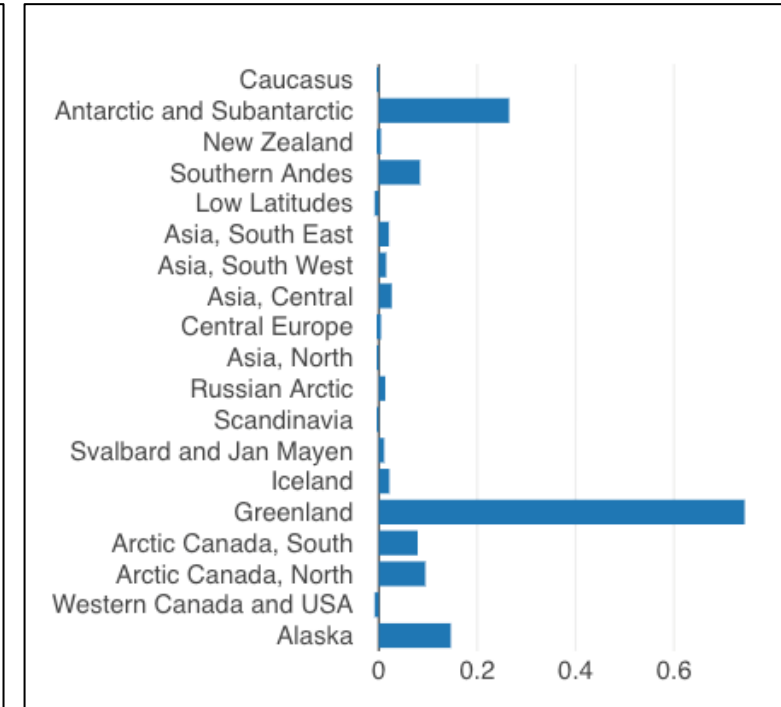
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New York City: 1.06 mm/yr



Sydney: 1.50 mm/yr

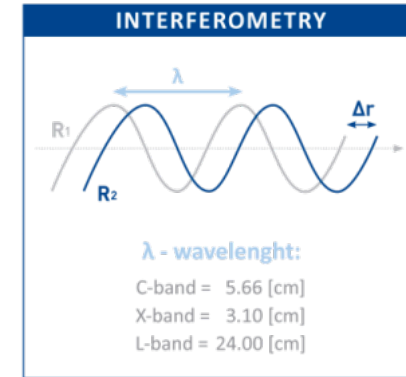
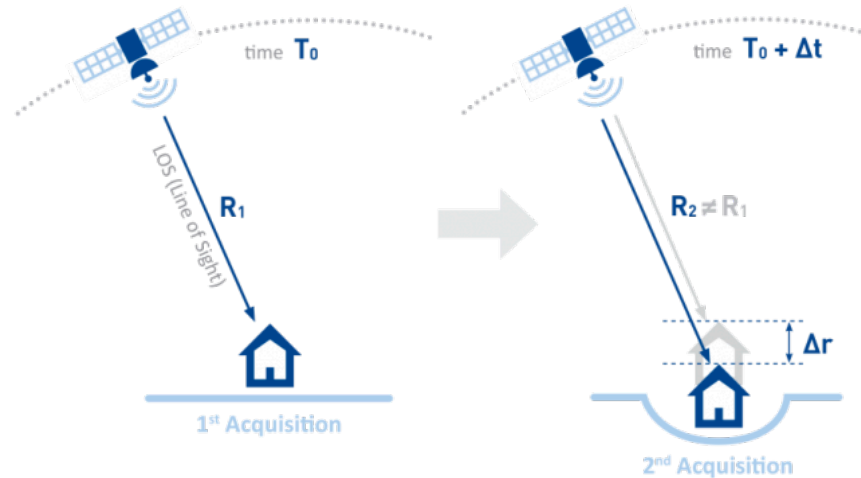


Credit: VESL, [sealevel.nasa.gov](http://sealevel.nasa.gov)



# 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/>

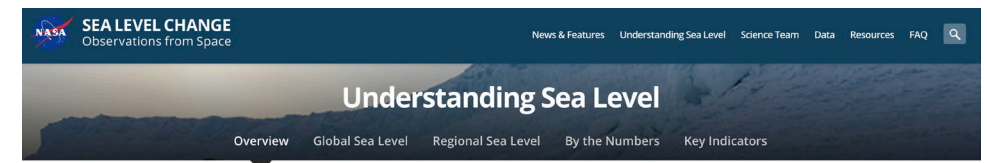


# NASA Sea Level Change Team

- Satellites will play a critical role in monitoring these processes and provide 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.
  - [sealevel.nasa.gov](https://sealevel.nasa.gov) was created as part of this effort.
  - 70+ scientists from government and academia.

## 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.



ON THIS PAGE  
Introduction  
Contributing Factors  
Ice Loss Versus Precipitation

Earth's seas are rising, a direct result of a changing climate. Ocean temperatures are increasing, leading to ocean expansion. And as ice sheets and glaciers melt, they add more water. An armada of increasingly sophisticated instruments, deployed across the oceans, on polar ice and in orbit, reveals significant changes among globally interlocking factors that are driving sea levels higher.

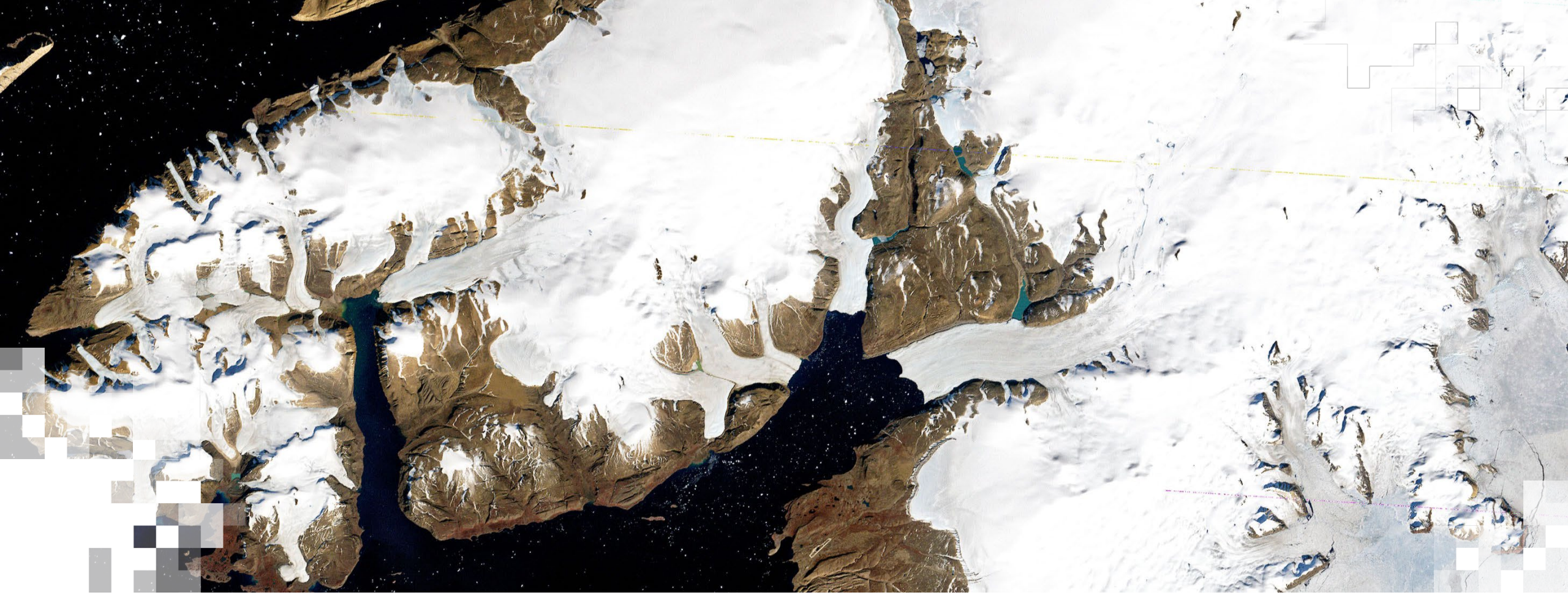


# Satellite and Integrated Products

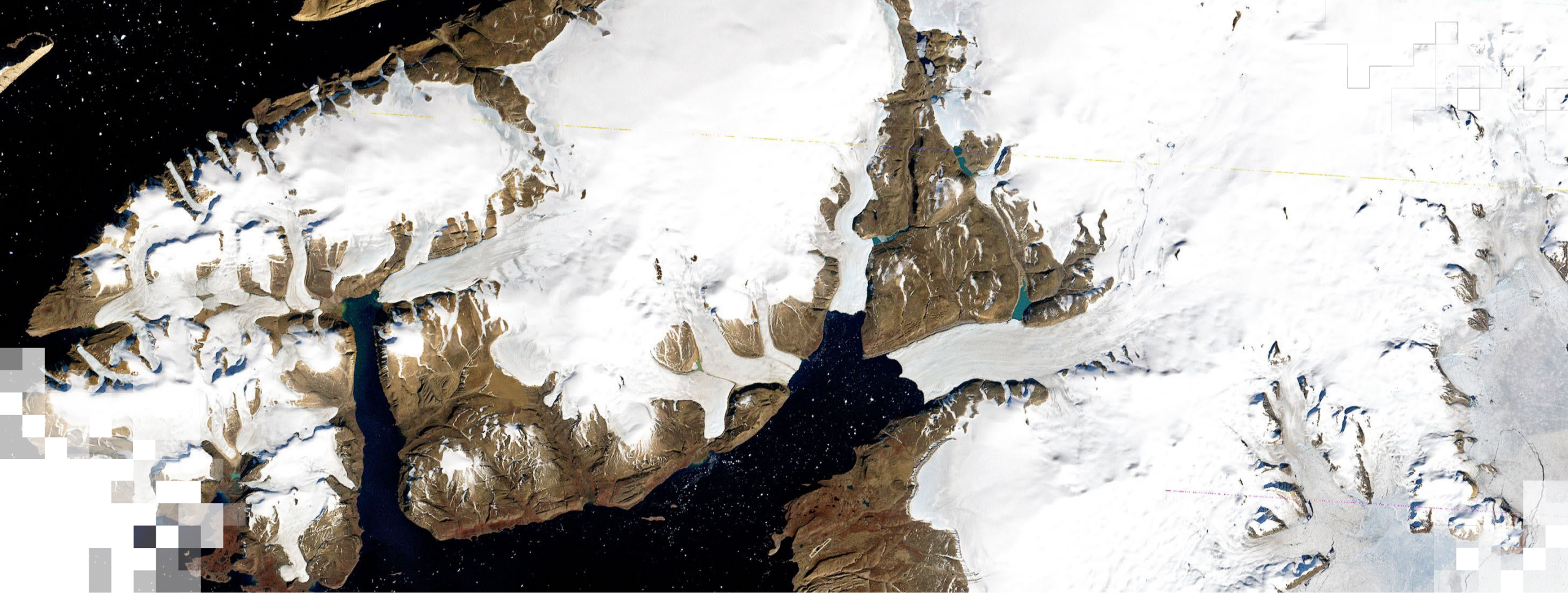
- A full list of data tools on NASA sea level portal can be found here: <https://sealevel.nasa.gov/data/tools>.
- As a demonstration of how these tools and data can be combined to understand past, present, and future sea level, refer to the links below:
  1. Data Analysis Tool: [https://sealevel.nasa.gov/data\\_tools/1](https://sealevel.nasa.gov/data_tools/1)
  2. Virtual Earth System Laboratory: [https://sealevel.nasa.gov/data\\_tools/2](https://sealevel.nasa.gov/data_tools/2)
  3. Sea Level Evaluation and Assessment Tool: [https://sealevel.nasa.gov/data\\_tools/16](https://sealevel.nasa.gov/data_tools/16)
  4. IPCC AR6 Sea Level Projection Tool: [https://sealevel.nasa.gov/data\\_tools/17](https://sealevel.nasa.gov/data_tools/17)
  5. Flooding Days Projection Tool: [https://sealevel.nasa.gov/data\\_tools/15](https://sealevel.nasa.gov/data_tools/15)







Demo: NASA Sea Level Portal



Exercise: NASA Sea Level Portal