

# Multi-Faceted Science Enabled by the Airborne Glaciological and Oceanographic Observations during NASA's 5-year Oceans Melting Greenland Mission

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07:54 - 08:02 PST

**AGU** FALL  
MEETING

**SCIENCE**  
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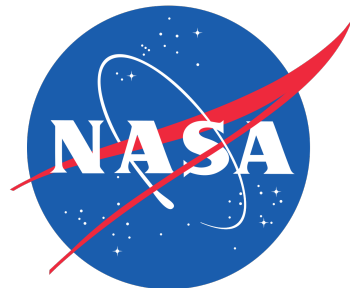
# IAN FENTY

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SCIENTIST

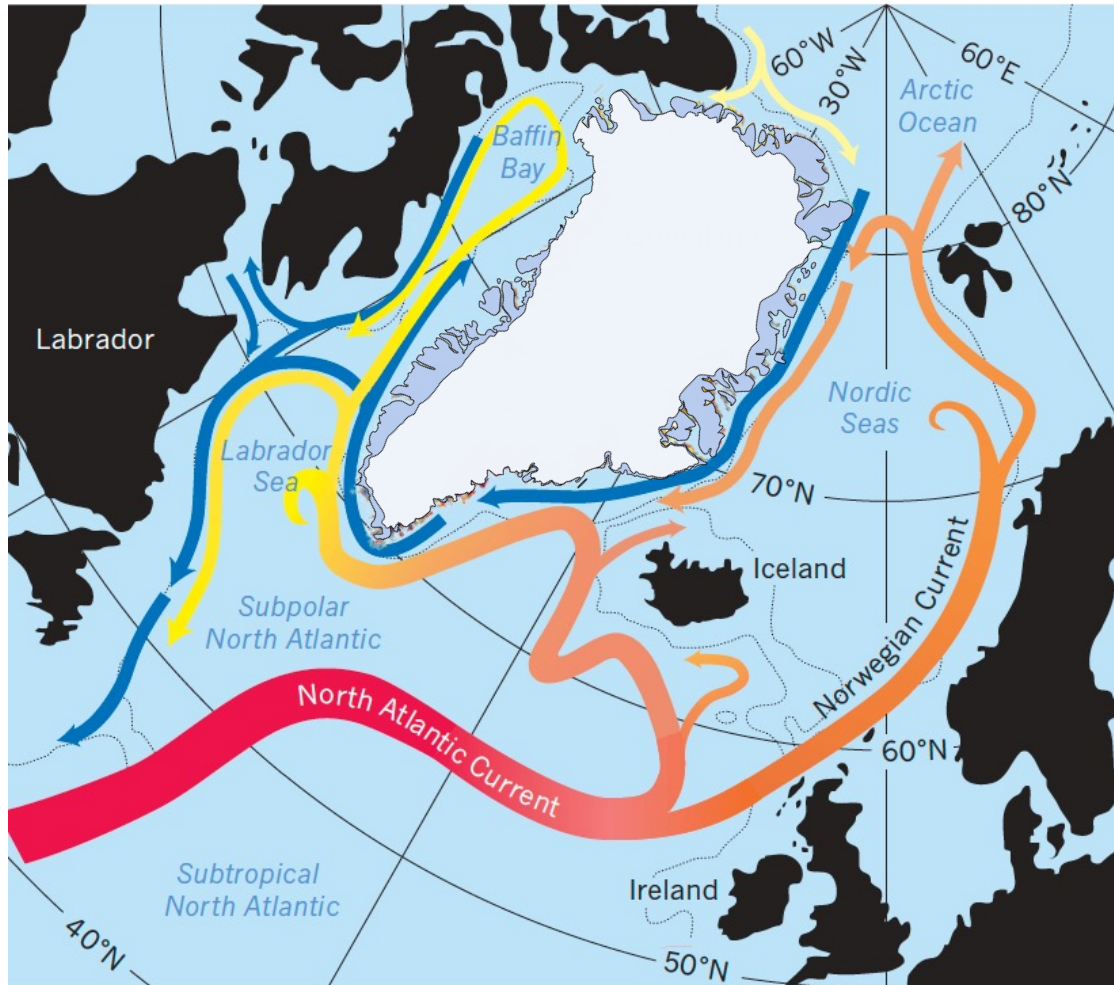


**JPL**  
Jet Propulsion Laboratory  
California Institute of Technology



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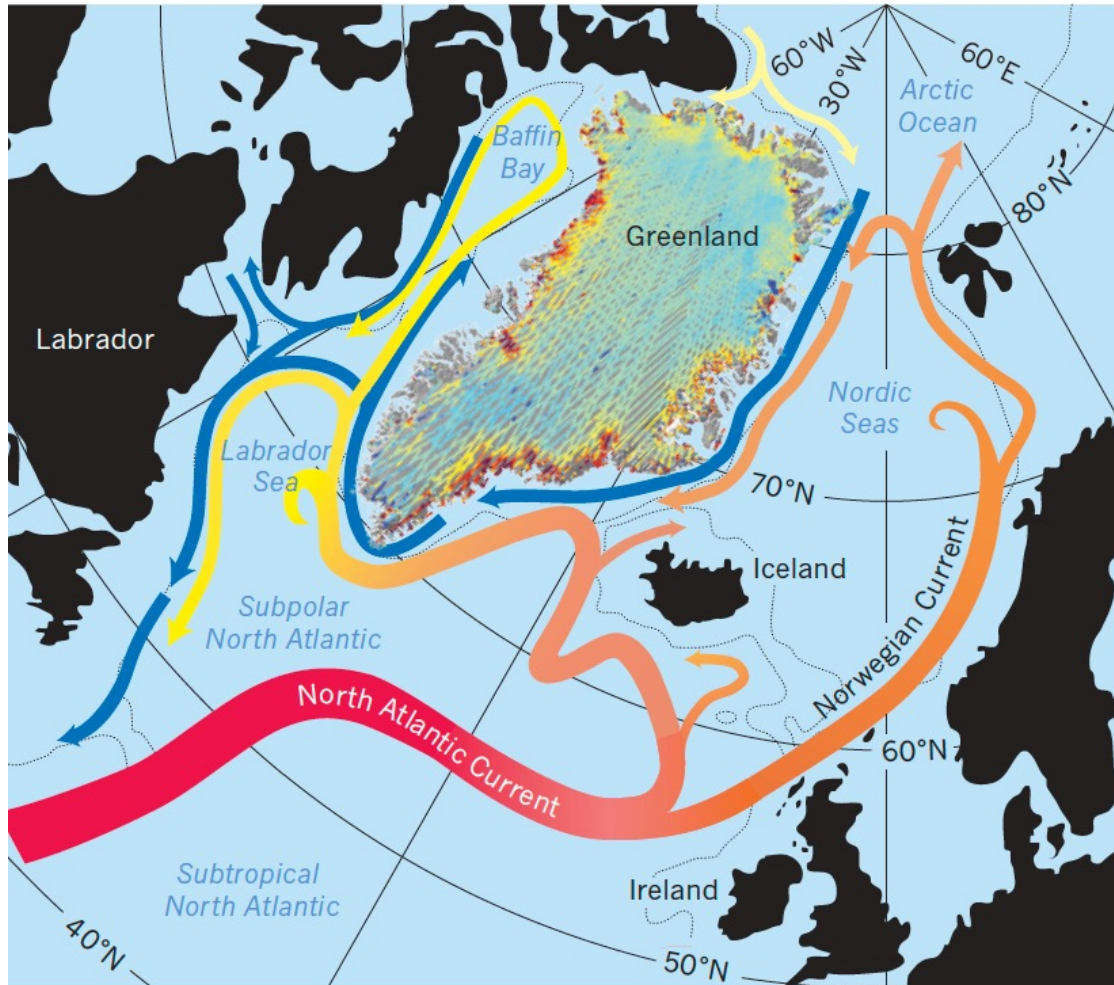




Warm waters from the tropics and sub-tropics are carried poleward on the North Atlantic Current and flow clockwise around the **Greenland Ice Sheet**.

In the late 1990's oceanographers detected **a warming signal** in some of these waters while also observing changes in many glaciers that flow into the ocean: frontal retreat, thinning, and accelerating.

When glaciers accelerate, more grounded ice is evacuated to the ocean, **contributing to global sea level rise**.



By the early 2010's satellite remote sensing of the ice sheet (e.g., ICESat, GRACE, Landsat, Radarsat-1/2, Cryosat-2), was showing the **greatest ice mass loss along the periphery of the southeast and northwest sectors.**

Interestingly, both sectors have:

- 1) Many marine-terminating glaciers.  
(glaciers that flow into the ocean)
- 2) relatively warm offshore waters

However, at that time there were **extremely few in-situ ocean measurements** near the glaciers and **limited measurements of glacier elevation change**

- no ICESat and pre-ICESat-2





Warm waters circulating around Greenland are generally found beyond the continental shelf, at depths of 350m to 600m, much deeper than the shallow continental shelf (50m to 100m).

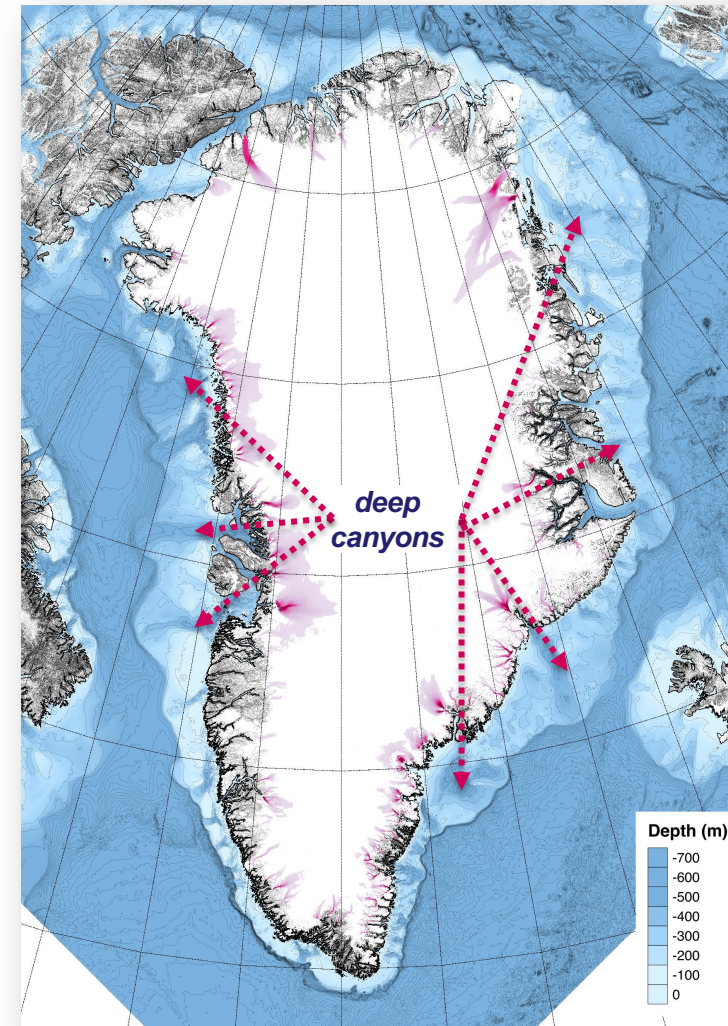
However, many deep canyons cut across the continental shelf and provide a pathway for warm subsurface waters to reach the glaciers.

In the mid 2010's these deep canyons had been identified **but not mapped close to shore**.

- icebergs, navigation hazards

***Were there deep connections all the way to the glaciers?***

## Seafloor Depth (Bathymetry)



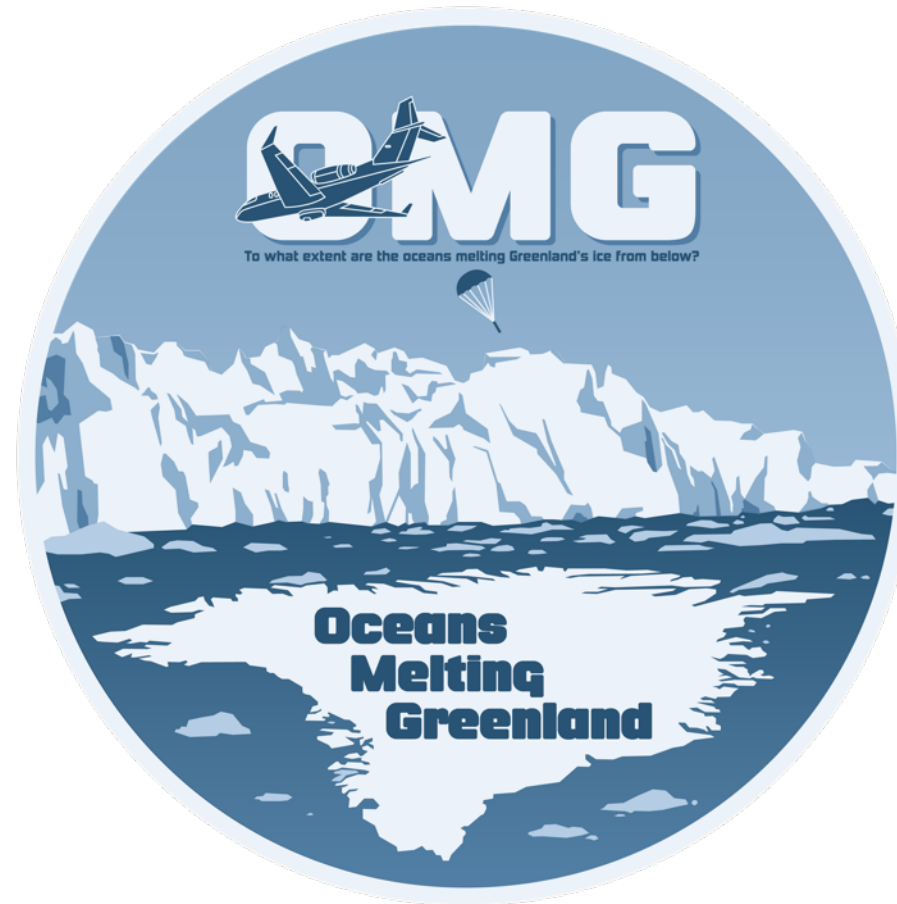


The Oceans Melting Greenland (OMG) mission was motivated by the question:

***To what extent are the oceans melting Greenland's ice from below?***

*Three observational objectives:*

1. **Ocean Campaign:** Annual surveys of ocean temperature and salinity around the ice sheet.
2. **Ice Campaign:** Annual surveys of the ice surface elevation of nearly all marine-terminating glaciers
3. **Bathymetry Campaign:** One-time surveys of seafloor geometry in fjords and on the continental shelf







## Ocean campaign (annual)

The **A**irborne **eX**pendable **C**onductivity, **T**emperature and **D**epth (**AXCTD**) probes

Measures vertical profiles of ocean temperature and salinity (via conductivity)

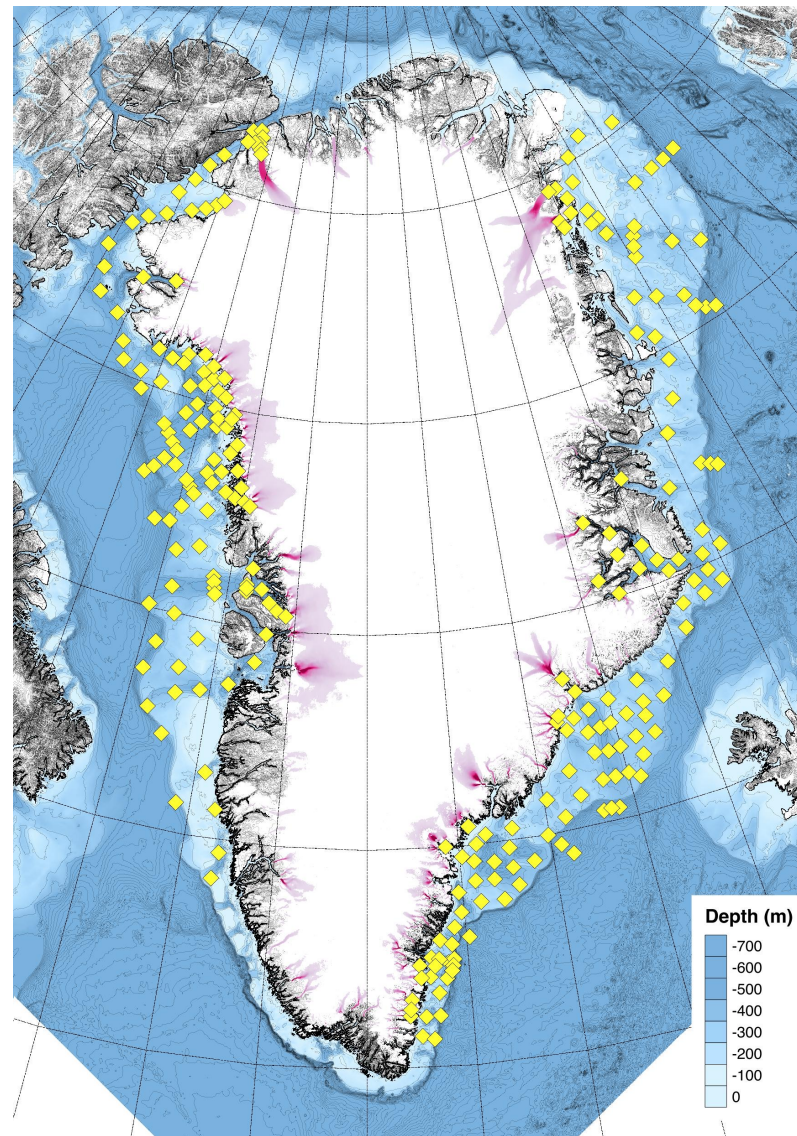
- 1000m maximum depth



**Basler BT-67 (DC-3)**  
Kenn Borek Air Ltd.



**AXCTD**



- 250 sites







## Glacier campaign (annual)

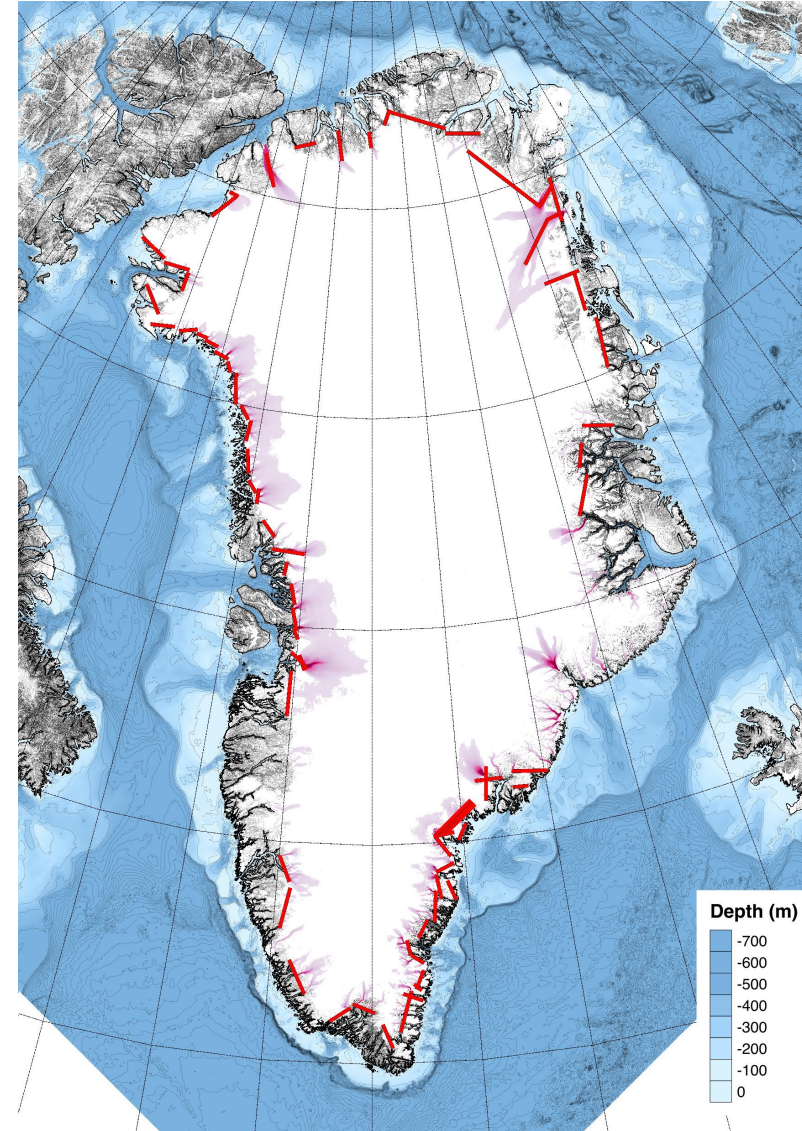
Airborne synthetic aperture radar altimeter  
**GL**acier and Ice **S**urface Topography  
**IN**terferometer (**GLISTIN-A**)

Glacier elevations are mapped using single-pass interferometry

- 10-km wide swath
- 20 cm vertical precision
- 3 m horizontal resolution



Gulfstream III  
NASA



- 82 swaths
- 100 km length (avg)
- 85,000 km<sup>2</sup>





## Seafloor campaign (one time)

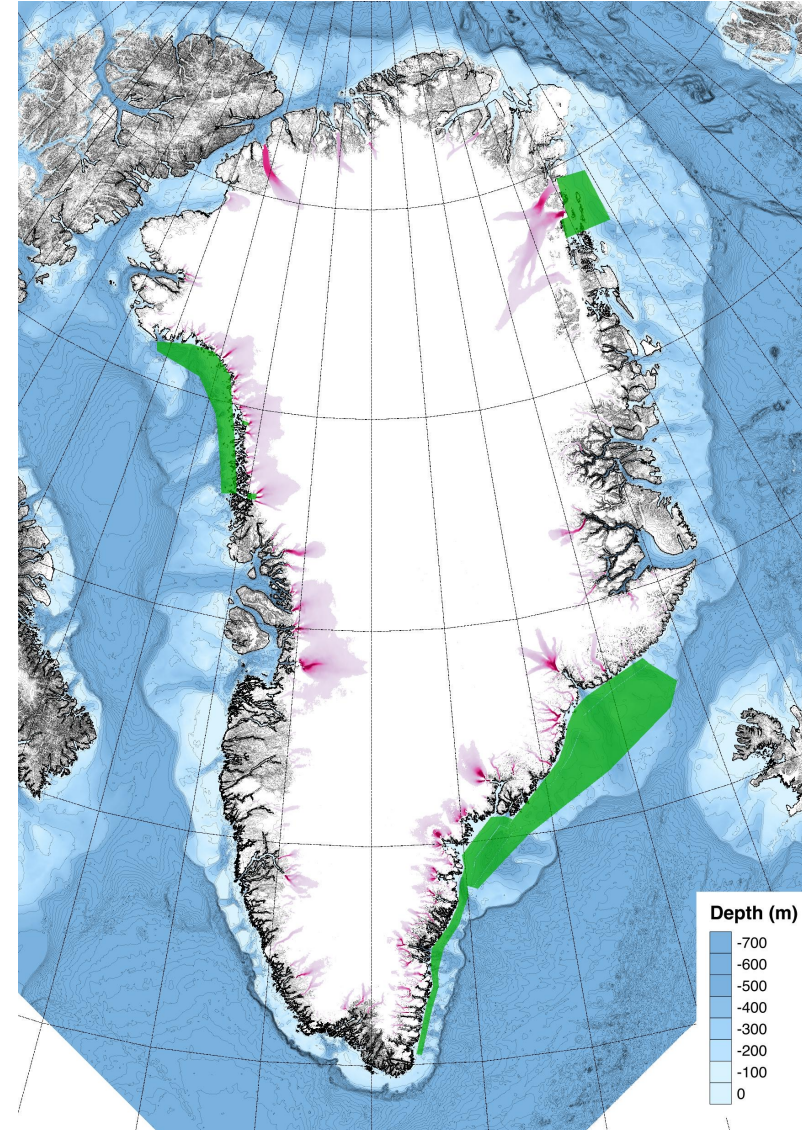
A **one-time** survey of seafloor bathymetry using **airborne gravity (AIRGrav)**

Seafloor depth is calculated by inverting free-air gravity anomalies related to varying proportions of seawater to rock

- 2-4 km spacing parallel flight lines
- Vertical precision ~100m
- Horizontal resolution ~1.5 km



**Cessna 208B Grand Caravan**  
Sander Geophysics Limited (SGL)  
<http://www.sgl.com/qaanaaq.html>



- Total ~140,000 km<sup>2</sup>



# WHY DID WE DESIGN THE MISSION TO INCLUDE EXTENSIVE AIRCRAFT-BASED MEASUREMENTS?

Earth System Science Pathfinder (ESSP) Venture-class Science Investigations:  
Earth Venture Suborbital-3

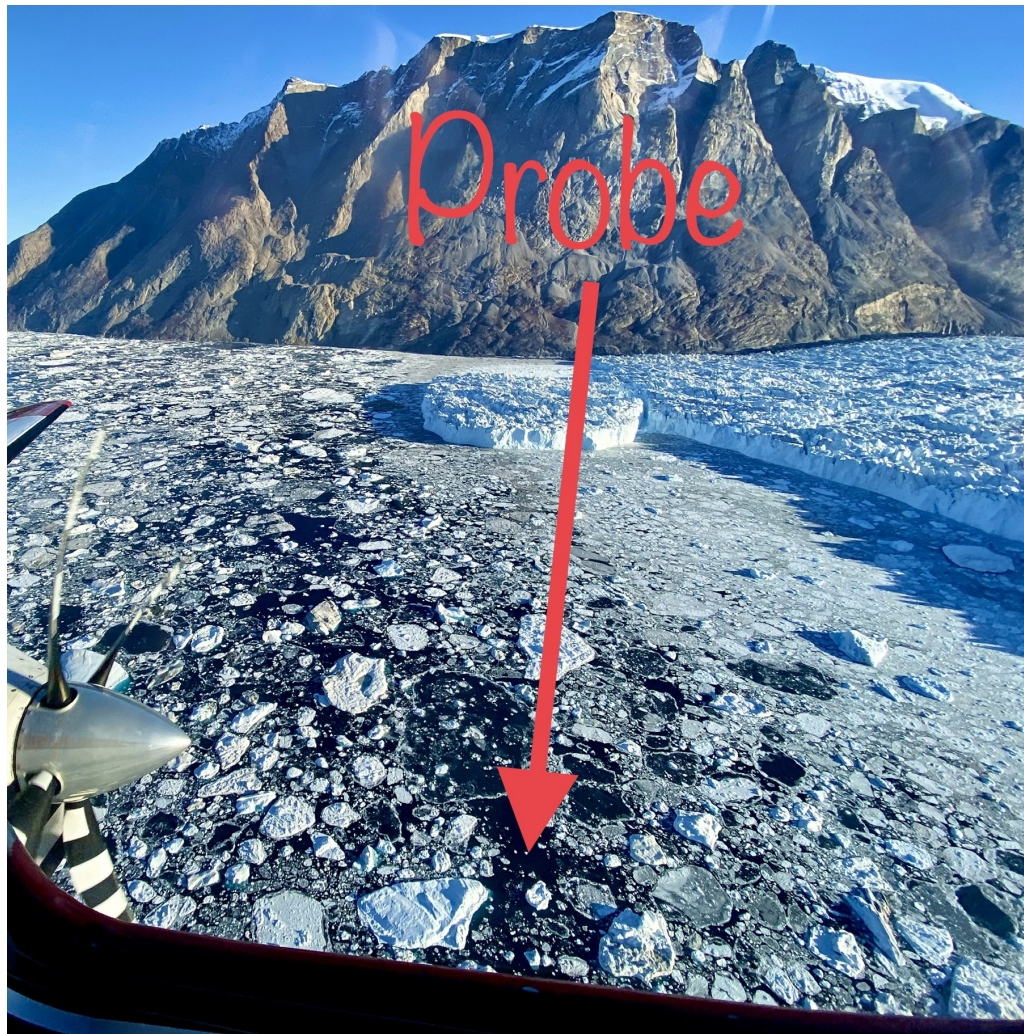
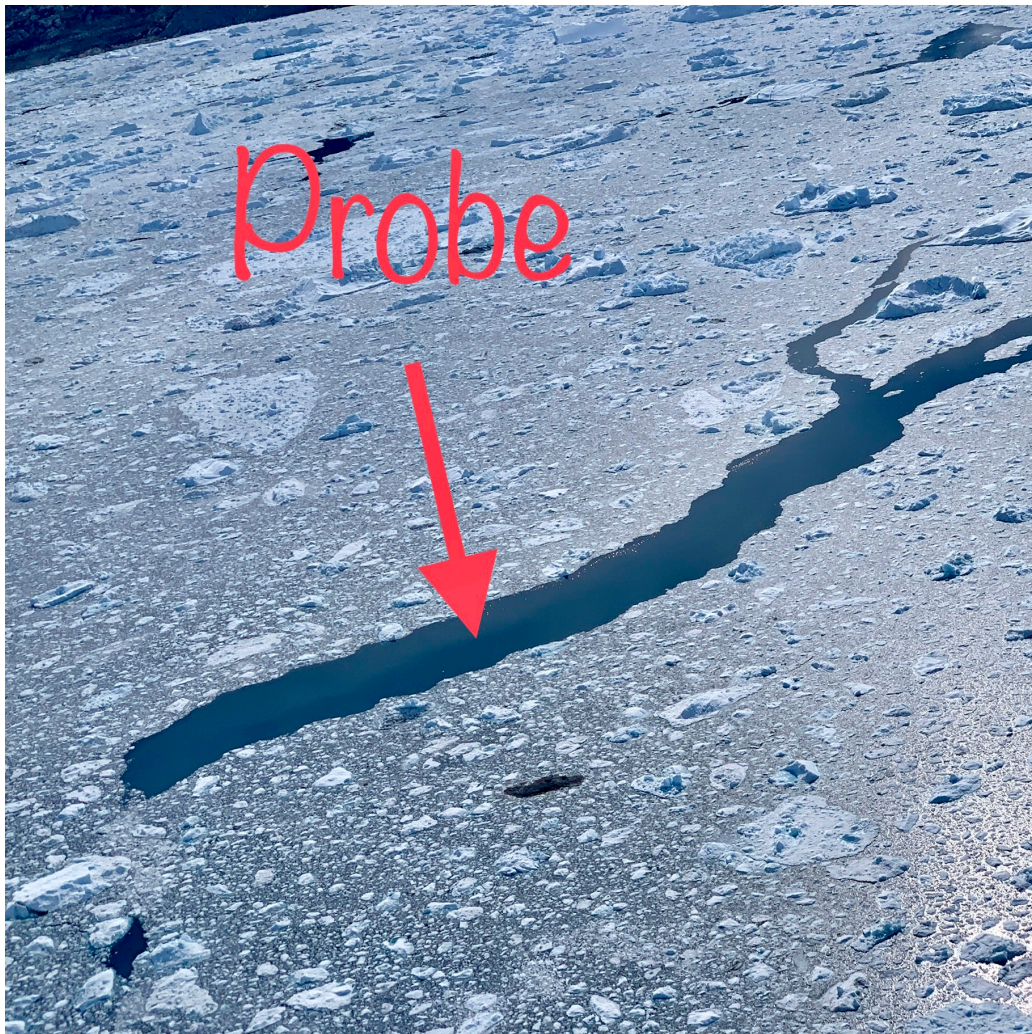
“Earth Venture Suborbital-3 (EVS-3) program element solicits science proposals for multi-year, Principal Investigator-led, **suborbital** campaign-based investigations to advance Earth system science objectives in order to better understand the current state of the Earth and to predict future change.”

“The overall objective of this EVS-3 program element is to substantially advance Earth system science and NASA’s Earth science goals through **innovative science investigations** involving sustained aircraft and/or other suborbital data acquisition campaigns.”















# MID-MISSION AIRCRAFT CHANGES IMPROVED OUR OCEAN SCIENCE DATA RETURN



**2016: NASA GIII**

**pros:** fast

**cons:** fast, airport  
restrictions, small  
storage capacity



**2017: NASA C-130**

**pros:** huge storage capacity, long  
range, fast

**cons:** not very maneuverable



**2018-21: Basler BT-67 (DC-3)**

**pros:** good storage capacity, very  
maneuverable, few airport  
restrictions

**cons:** relatively slow

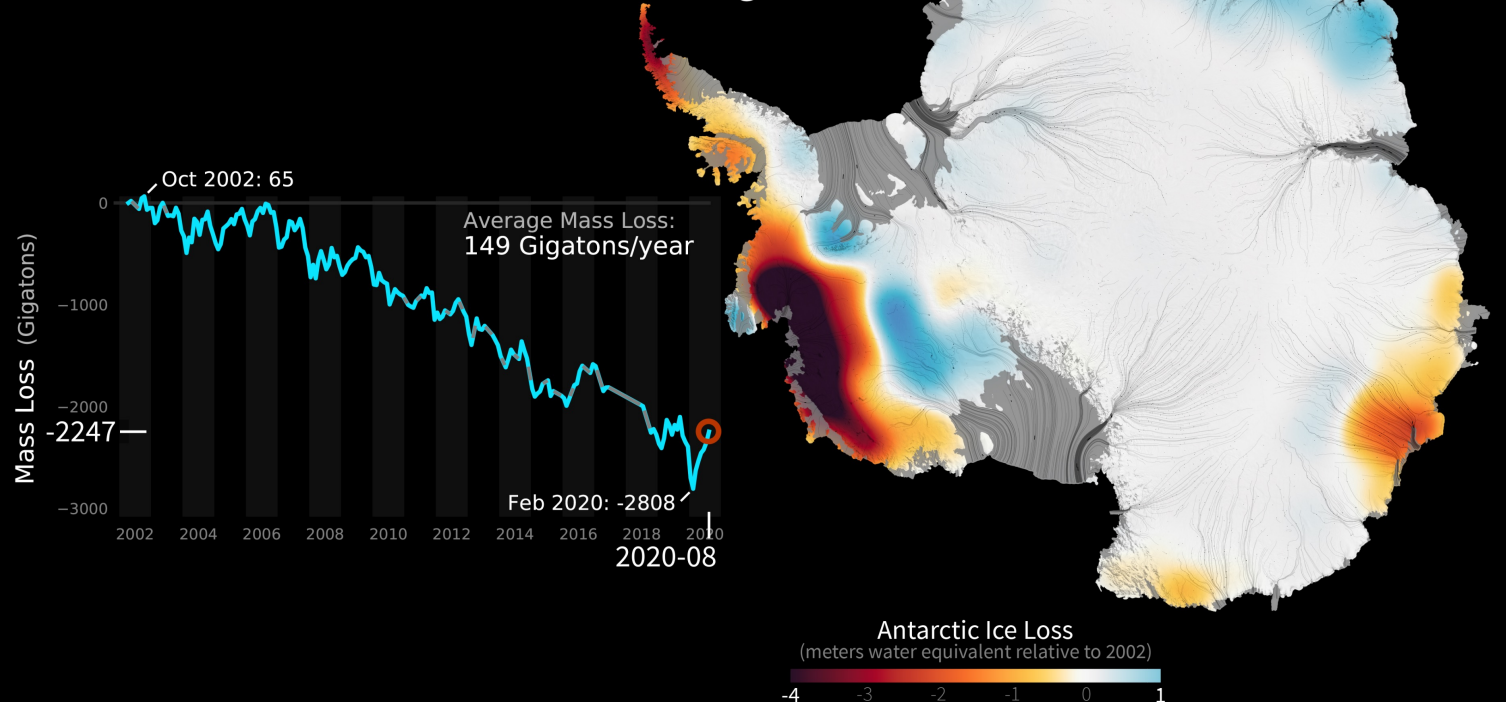






# AIRCRAFT SHOULD BE USED TO HELP MEASURE OCEAN CHANGES AROUND ANTARCTICA

## GRACE AND GRACE-FO Observations of Antarctic Ice Mass Changes



Many of the same challenges that apply in Greenland apply for Antarctica:

- 1) Very large and varied area
- 2) Extensive sea-ice & icebergs
- 3) Expensive to operate ships
  - Icebreaker class
  - short operating season



# THANK YOU

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