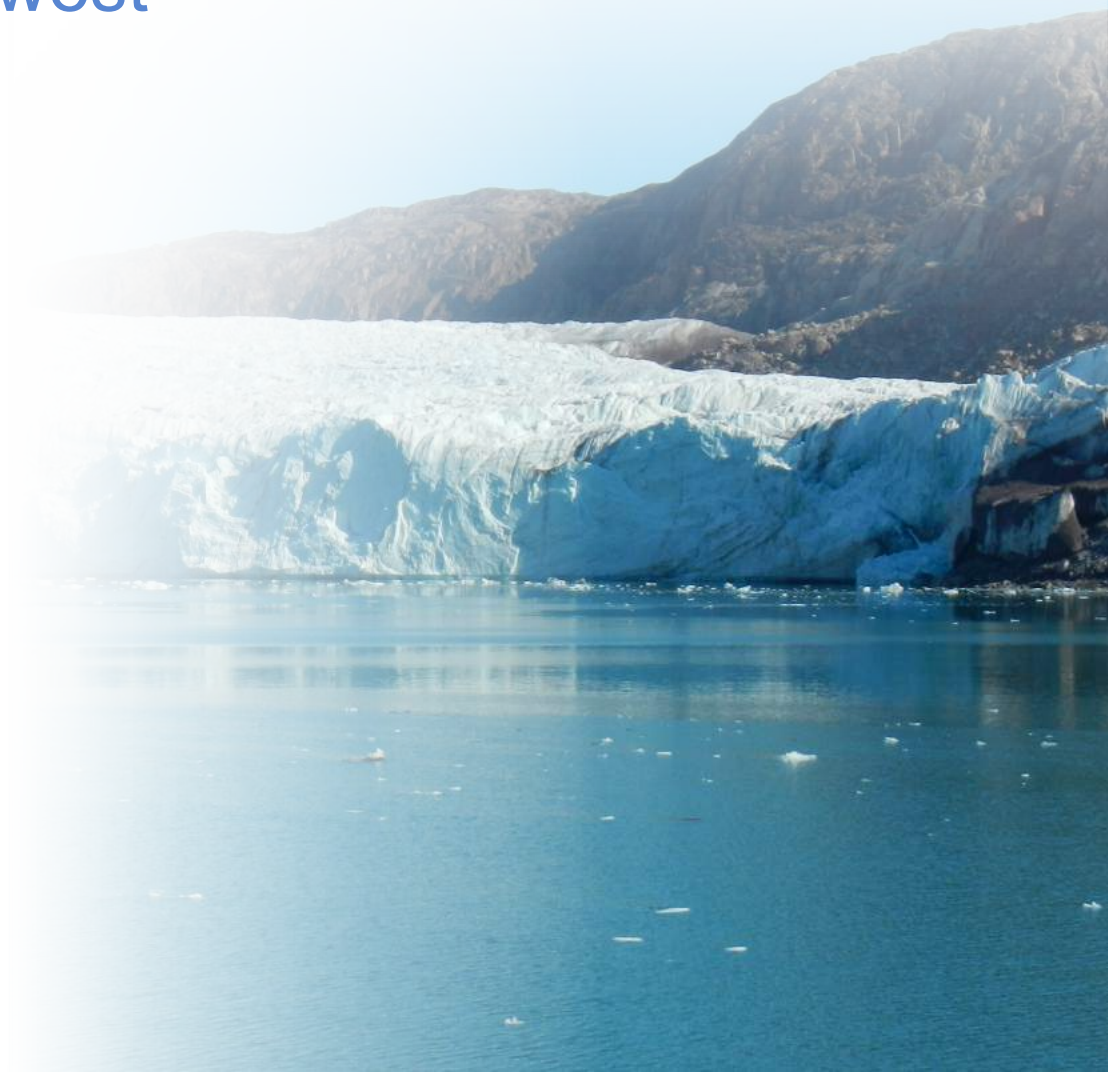
# Ocean-induced melt triggers glacier retreat in Northwest Greenland

October 30, 2018

Michael Wood

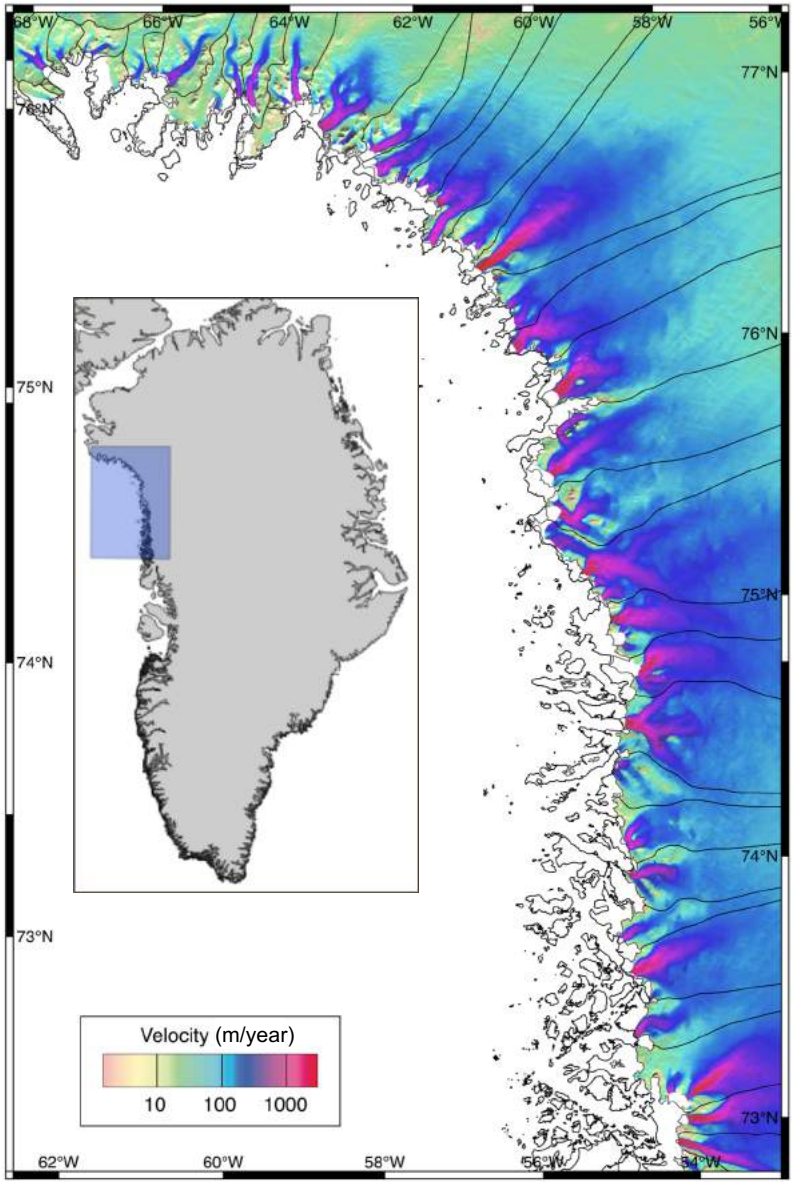
Eric Rignot, Romain Millan, Lu An
Jeremie Mouginot, Mathieu Morlighem,
Ian Fenty, Dimitris Menemenlis



# Overarching Questions

1) To what extent does ocean-induced undercutting influence the evolution (retreat) of NW Greenland's tidewater glaciers
2) How do recent ECCO solutions compare around Greenland?

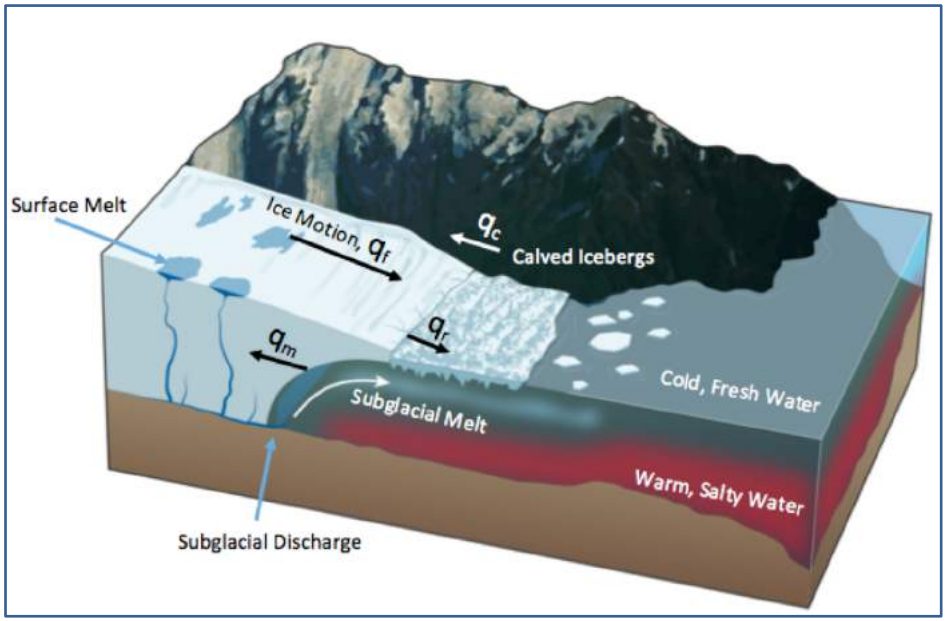
# Northwest Greenland Overview



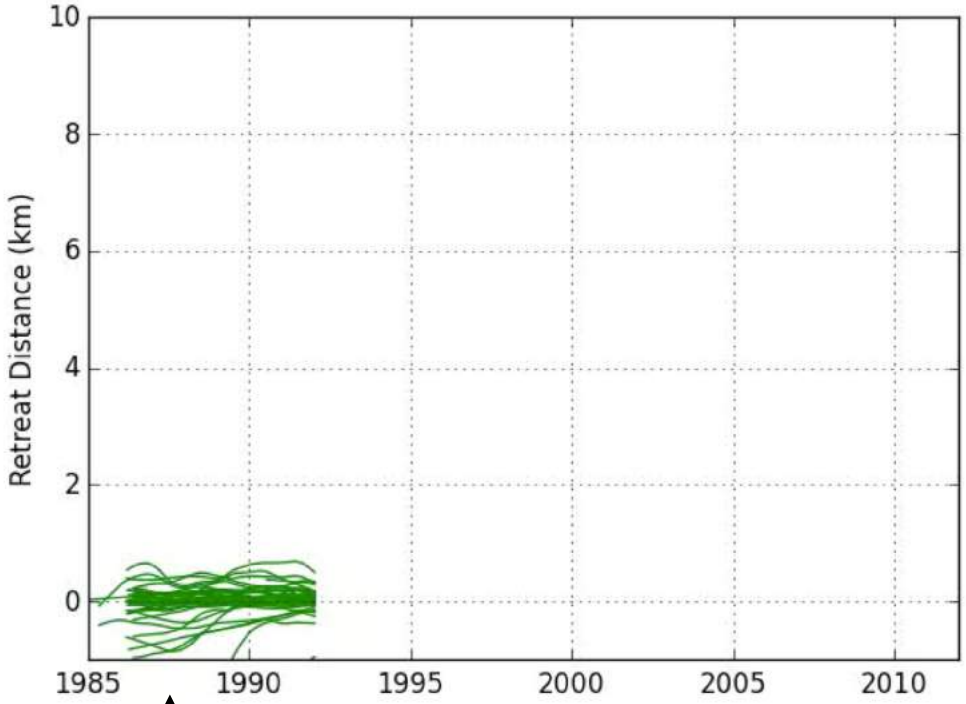

37 (of 200+) Marine-Terminating Glaciers

- 21% of discharge from the Greenland Ice Sheet
- 1.27 m SLE in Drainage Basin

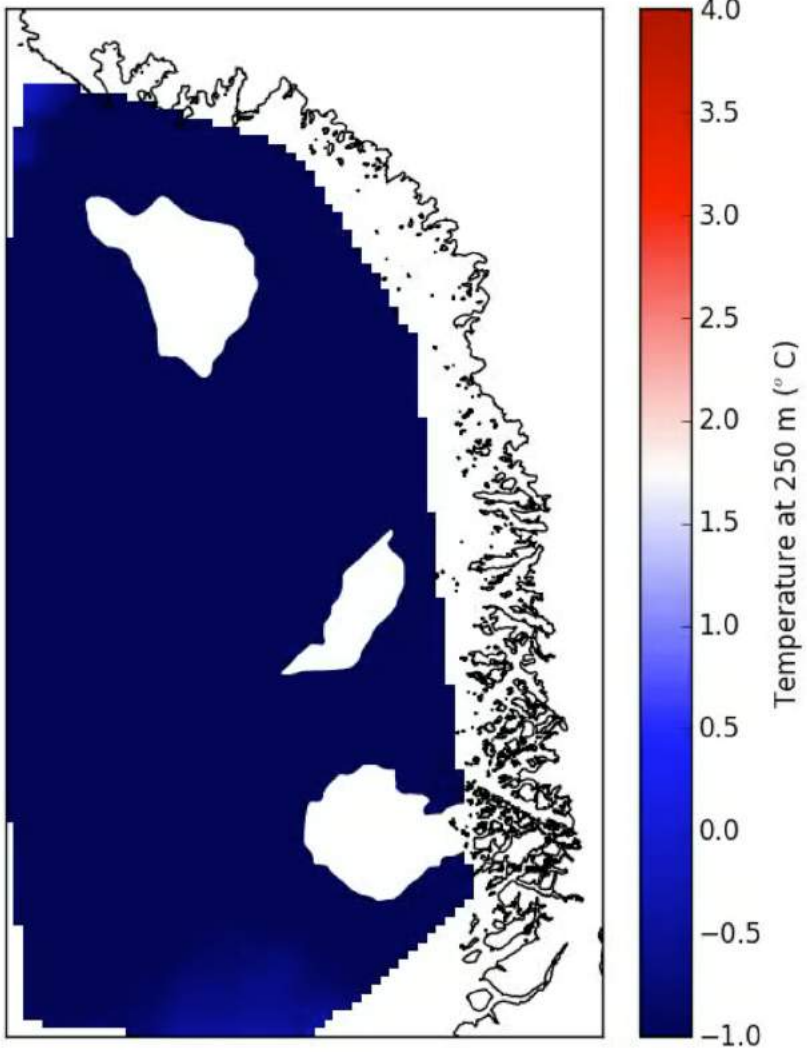
Adapted from Straneo and Heimbach 2013



# Motivation: NW Glaciers and Simulated Ocean Temperature



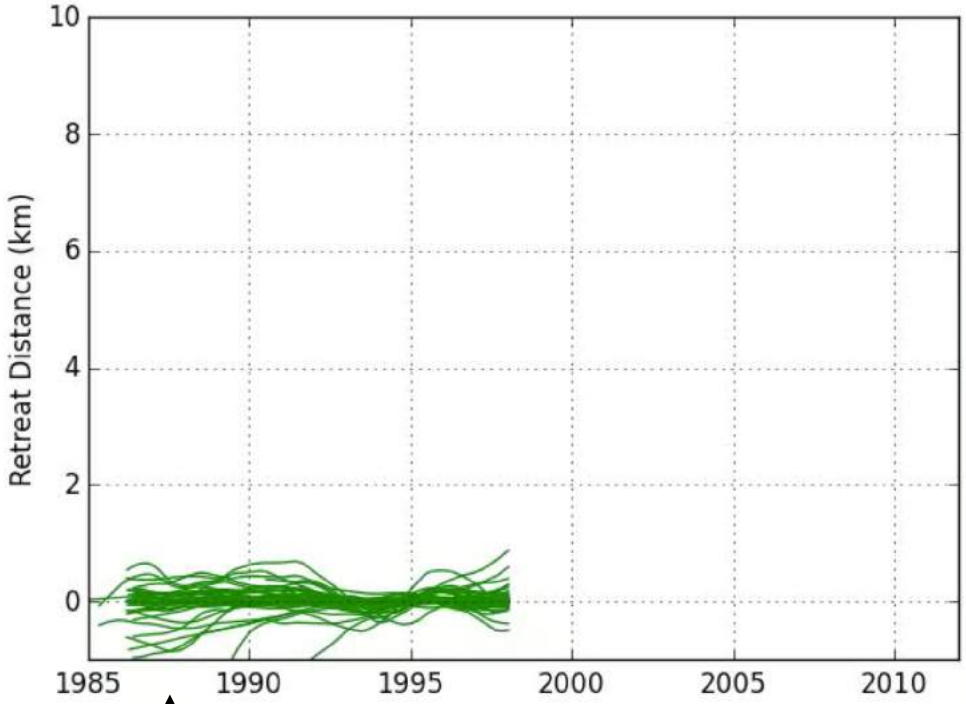

Landsat-derived ice front retreat



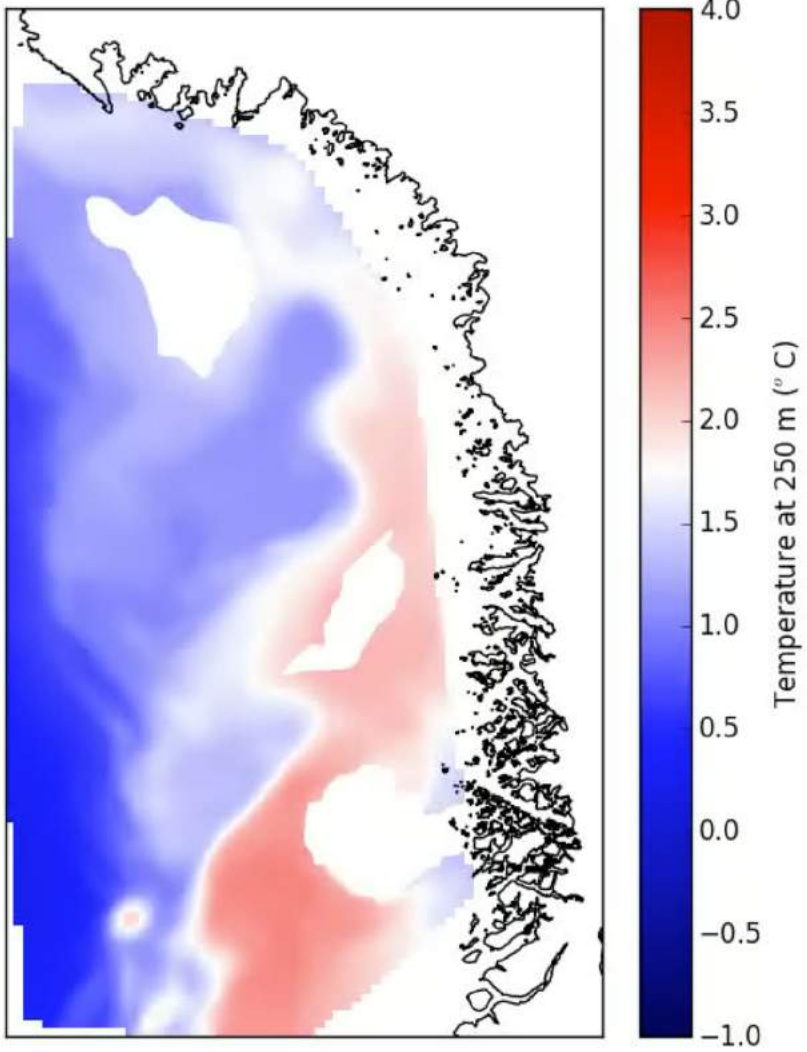

4km Arctic/N. Atlantic output ➤
1992-1997

Rignot et al 2012

# Motivation: NW Glaciers and Simulated Ocean Temperature




Landsat-derived ice front retreat

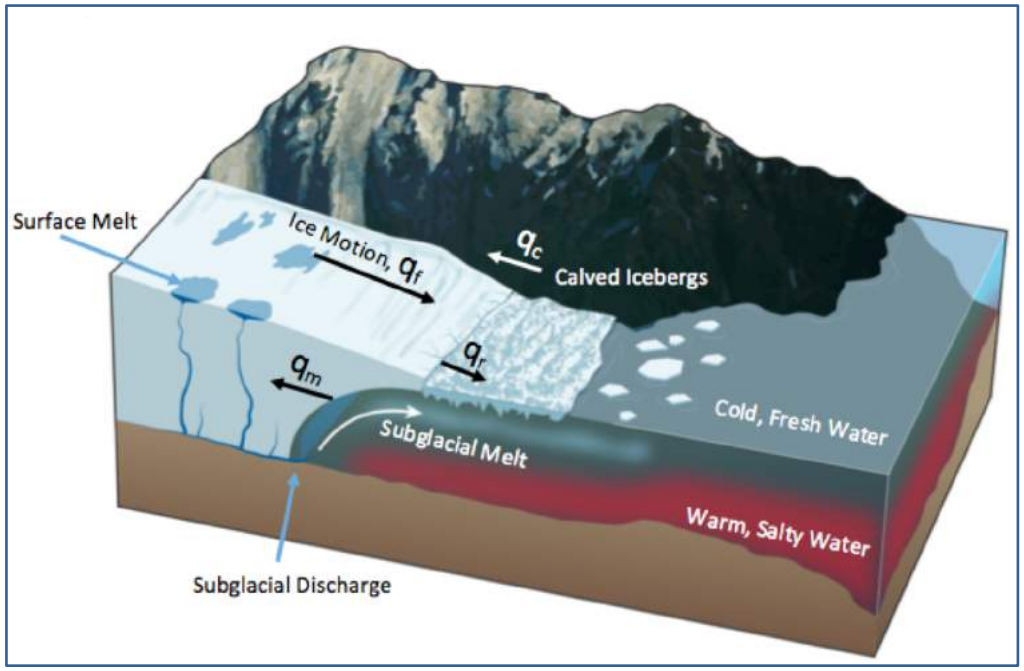



4km Arctic/N. Atlantic output ➤
1998-2011

Rignot et al 2012

# Mass Balance at the Ice Front

Adapted from Straneo and Heimbach 2013



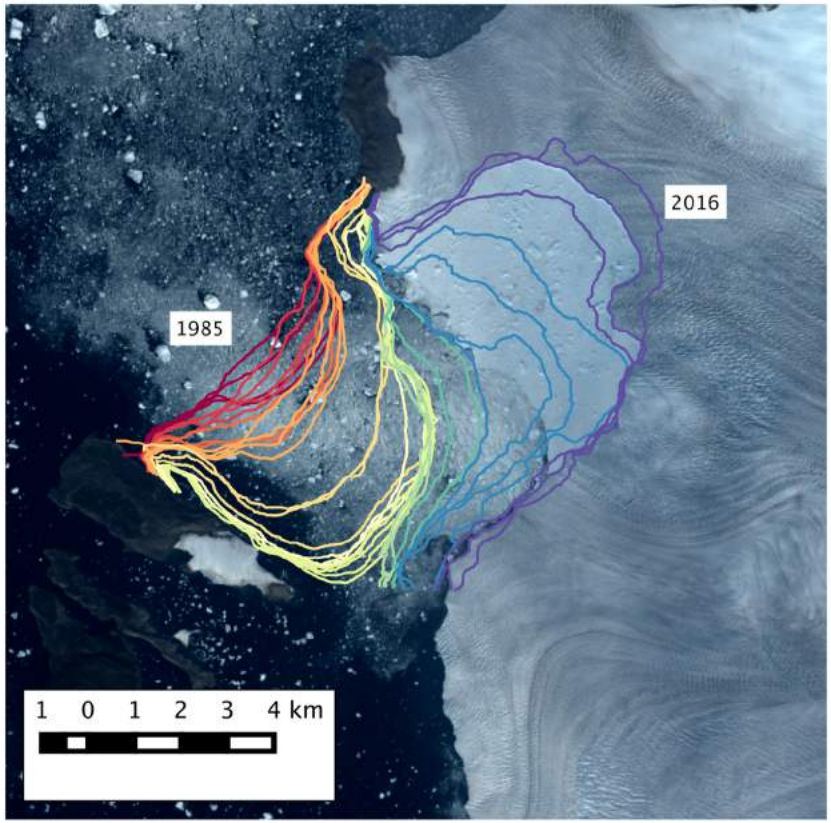

- Change in Ice Front, $q_r$
- Ice Velocity, $q_f$
- Ocean-induced undercutting, $q_m$
- Dry Calving, $q_c$
- Expressed as flux per unit area → m/day

$$\underbrace{q_r}_{\text{Change in Ice Front}} = \underbrace{q_f}_{\text{Source}} - \underbrace{q_m - q_c}_{\text{Sink}}$$

Rignot et al 2016

# Methods: Ice Front Retreat

## Annual Ice Front Digitization

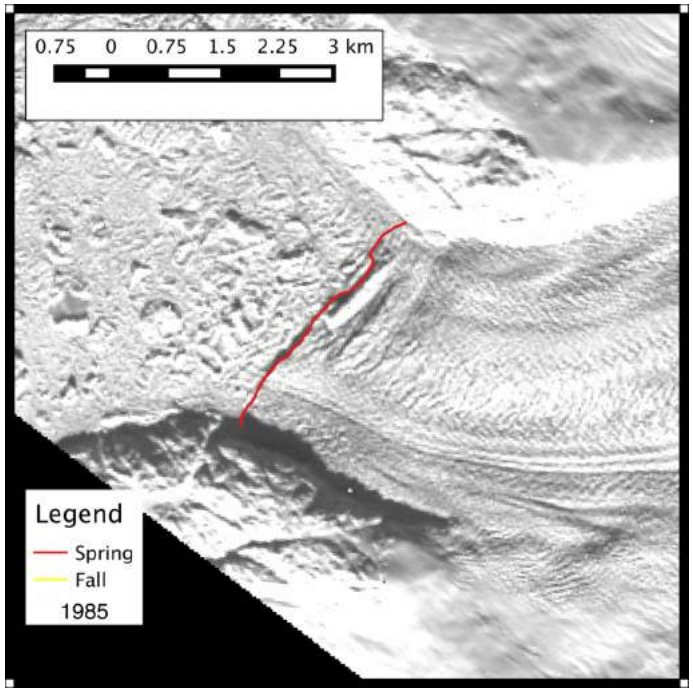



Kjer Gletscher Retreat
1985 - 2016

- Ice fronts digitized annually
  - Derived from Landsat 4,5,7,8
  - 1985-present, when scenes are available
  - 37 glaciers along NW coast

# Methods: Seasonal Front Fluctuations

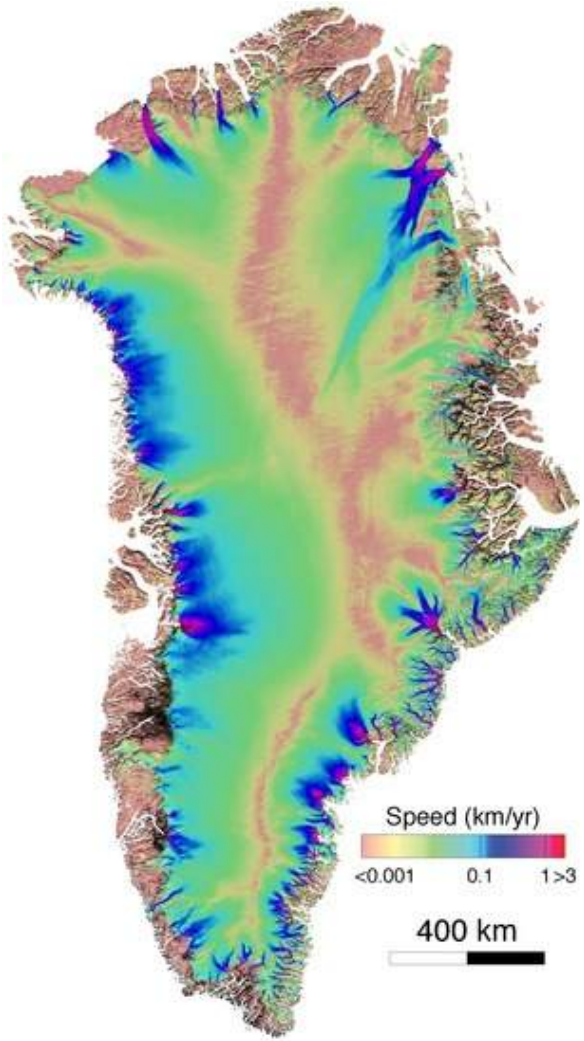
## A baseline for long-term retreat




Upernavik Isstrøm: Central Branch Seasonal Variability

- Seasonal fronts digitized
  - 1985-1997
- Establish natural variability of ice front position
- Investigate change in ice front position relative to this range
  - $\mu + 1\sigma$

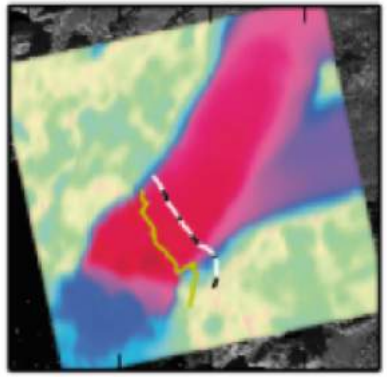
# Methods: Ice Velocity




Mouginot et al 2015

- Velocity averaged annually from various sources, e.g.
  - MEaSURES (Joughin and Moon)
  - Rignot et al 1996, 2011
  - Mouginot et al 2015
- Sampled on a line 1km upstream:

Sverdrup Velocity: 2014-2015



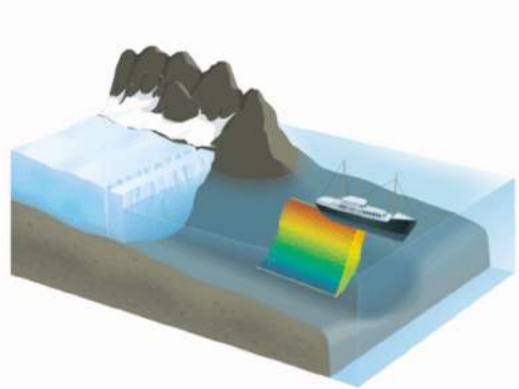
# Methods: Ice Front Undercutting

$$q_m = (0.0003 h q_{sg}^{0.39} + 0.15) T F^{1.18}$$

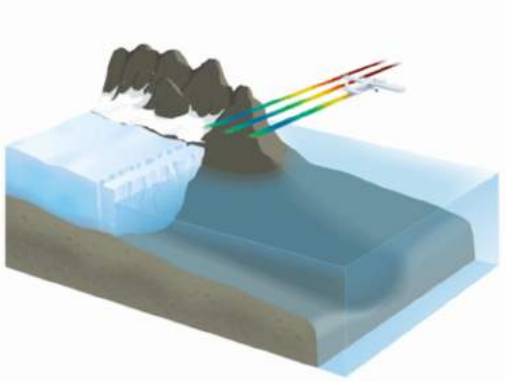
Rignot et al 2016

## Mean Water Depth

- BedMachine Version 3
  - Sampled with Ice front Position
  - Includes both MBES and Inverted Gravity from OMG within the fjords



MBES



Gravity

# Methods: Ice Front Undercutting

$$q_m = (0.0003 h q_{sg}^{0.39} + 0.15) TF^{1.18}$$

Rignot et al 2016

## Subglacial Discharge

- Downscaled RACMO 2.3 Runoff
- ISSM for Basal Melt
- Integrated over the drainage basin

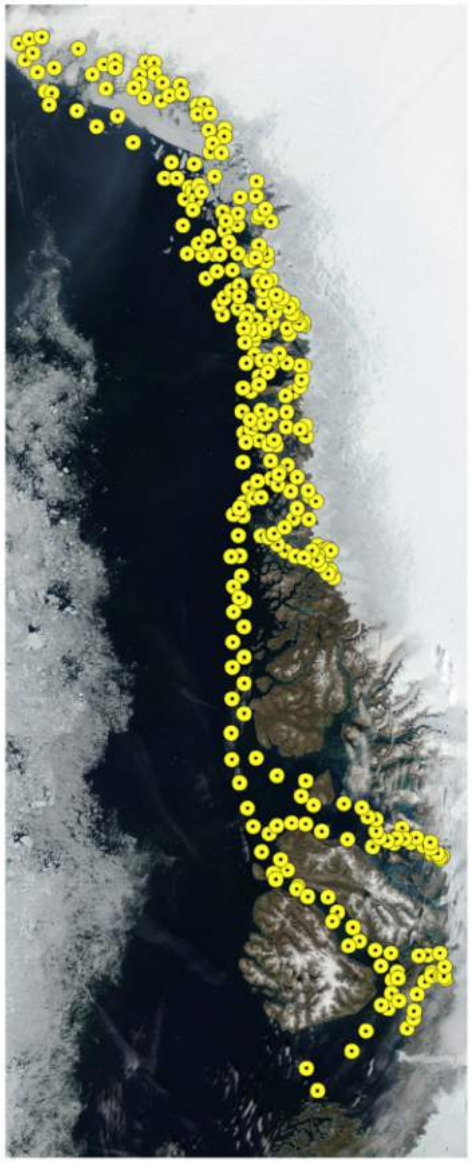
# Methods: Ice Front Undercutting

$$q_m = (0.0003 h q_{sg}^{0.39} + 0.15) T F^{1.18}$$

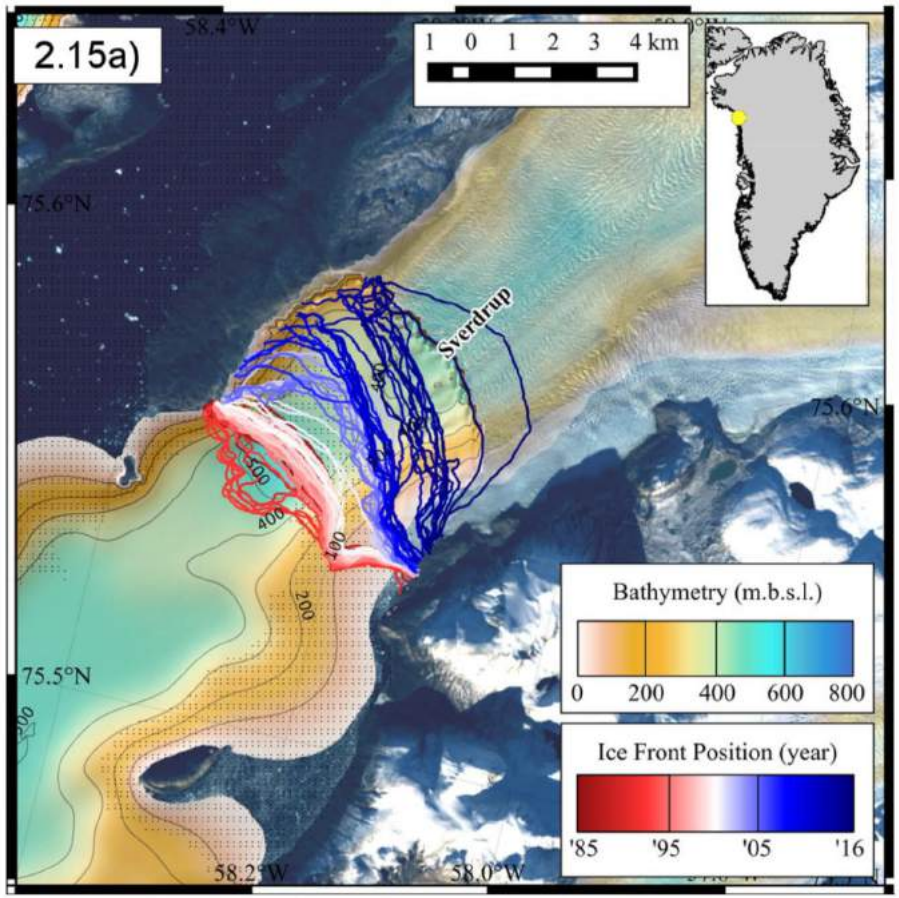
Rignot et al 2016

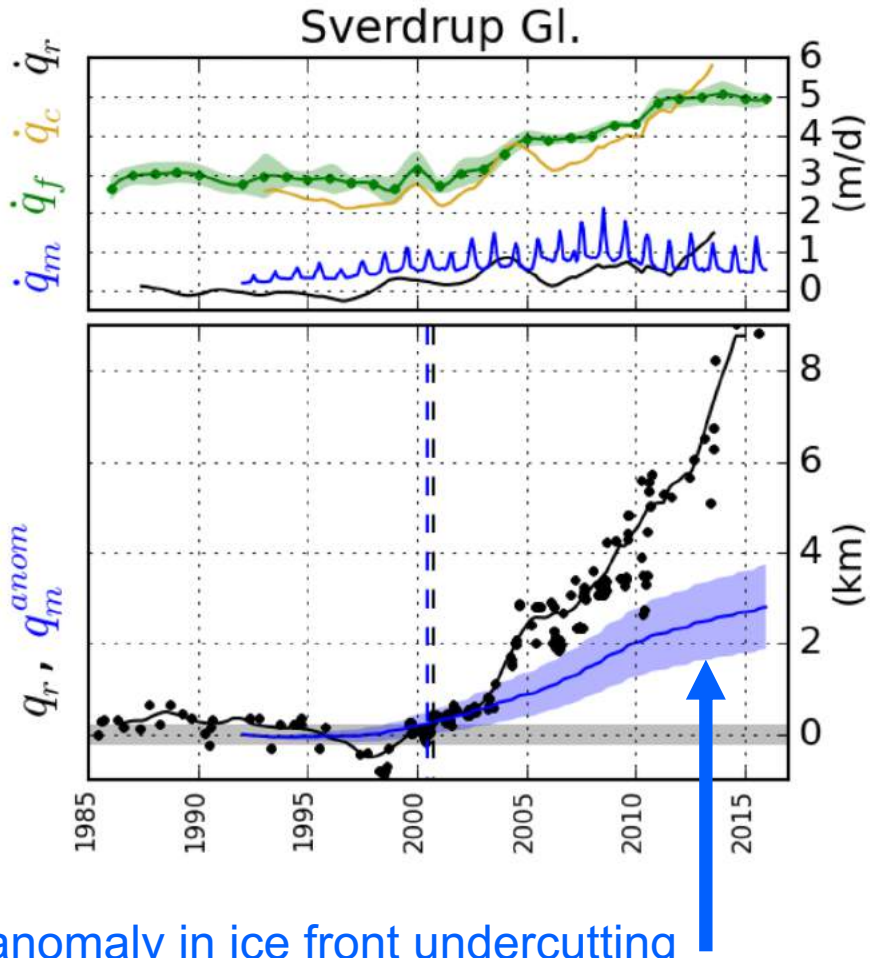
## Thermal Forcing

- $= T + 0.0575S - 0.0901 + 0.000761P$
- Two Models Employed:
  - 4-km Arctic/N. Atlantic Solution 1992-2011
  - LLC270 Solution 2009 - 2015
    - Model adjusted with OMG CTDs
      - Bias of 1.68 ± 0.32 °C (too cold)
- Models merged with linear weighting 2009-2011:
- CTDs used to quantify a transfer function between the shelf TF and the fjord TF



# Sverdrup Glacier

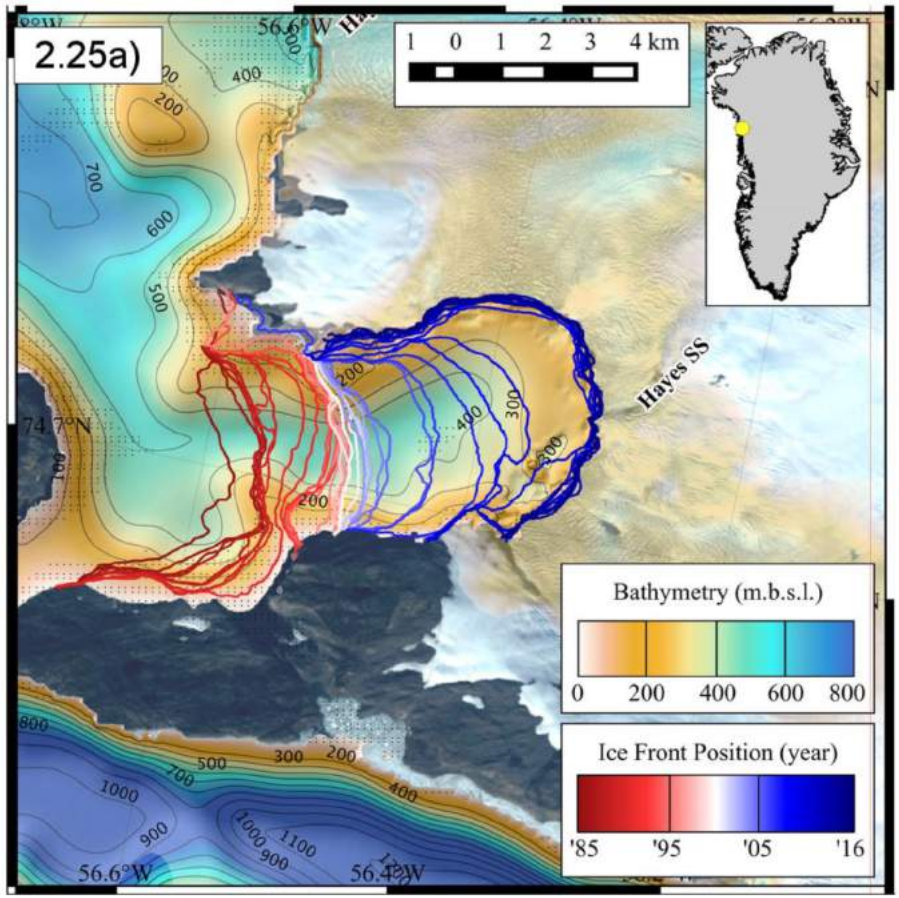


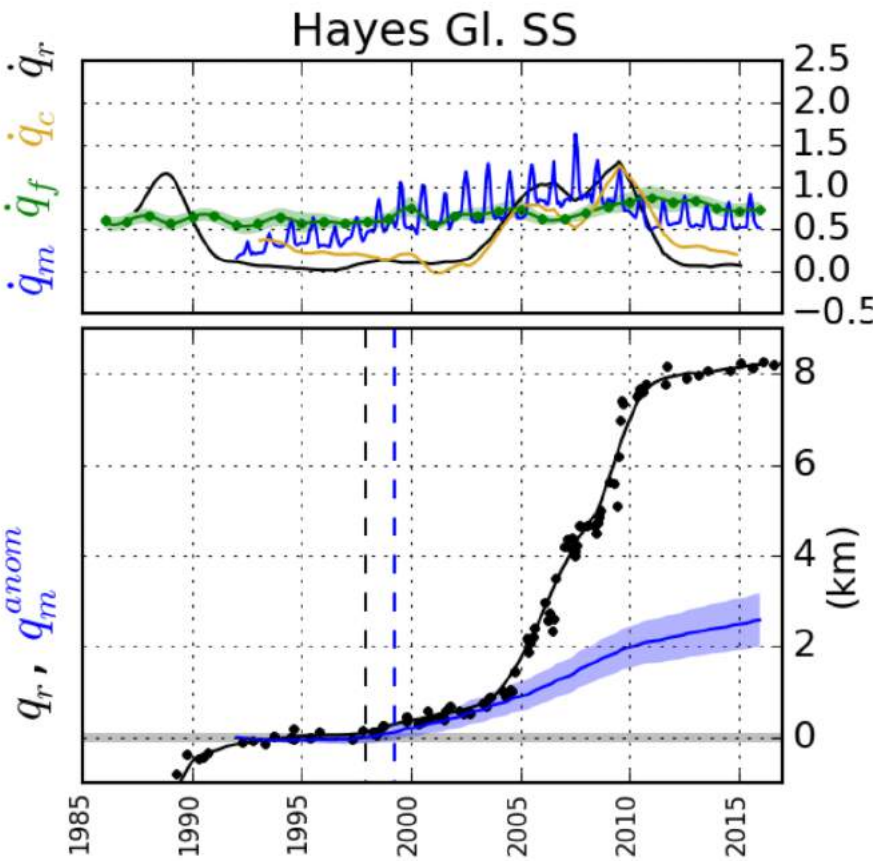




Integrated anomaly in ice front undercutting
(relative to 1992-1997)

Wood et al 2018

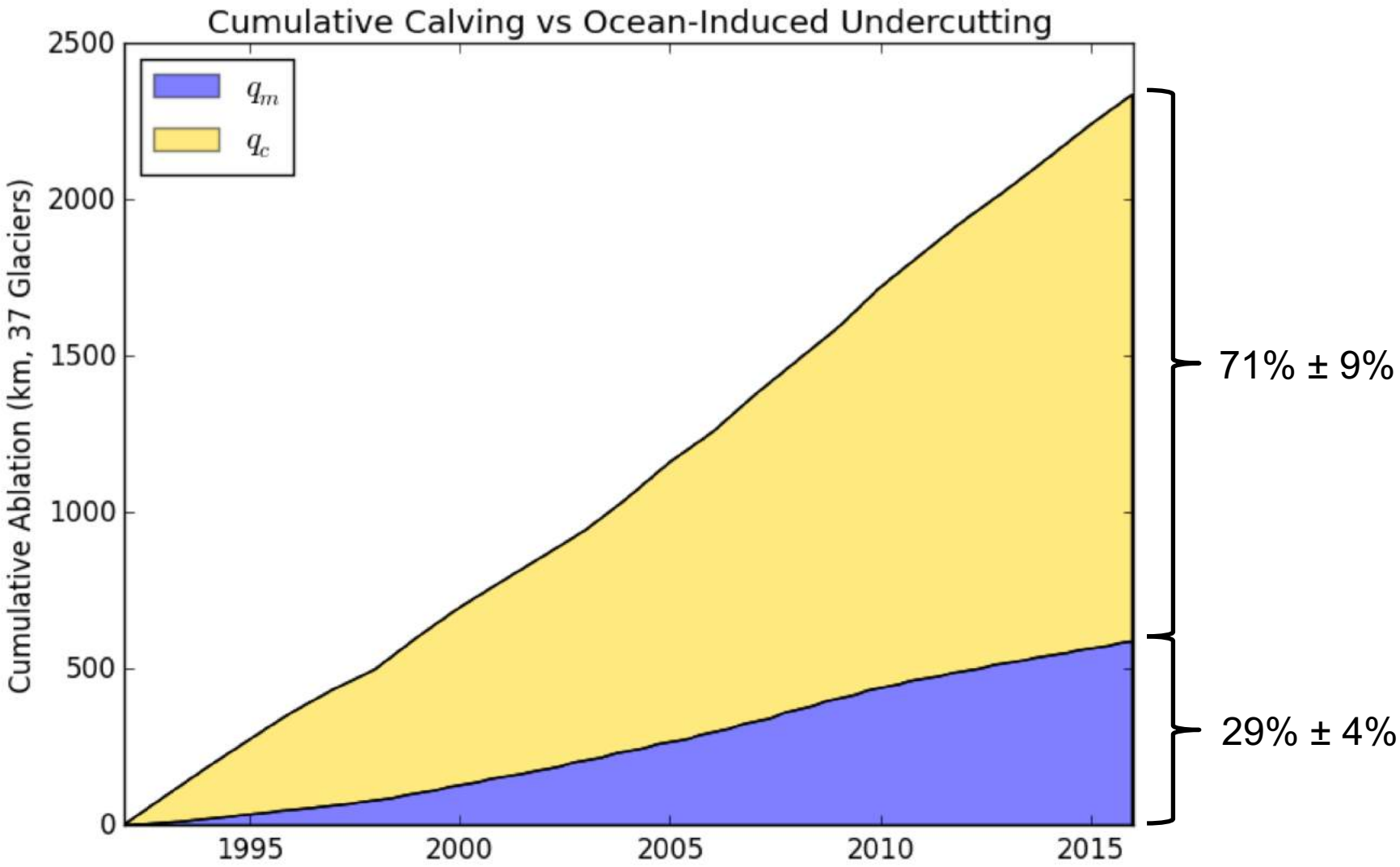
# Hayes Glacier South




Wood et al 2018

# Total Ablation: $q_m$ vs $q_c$



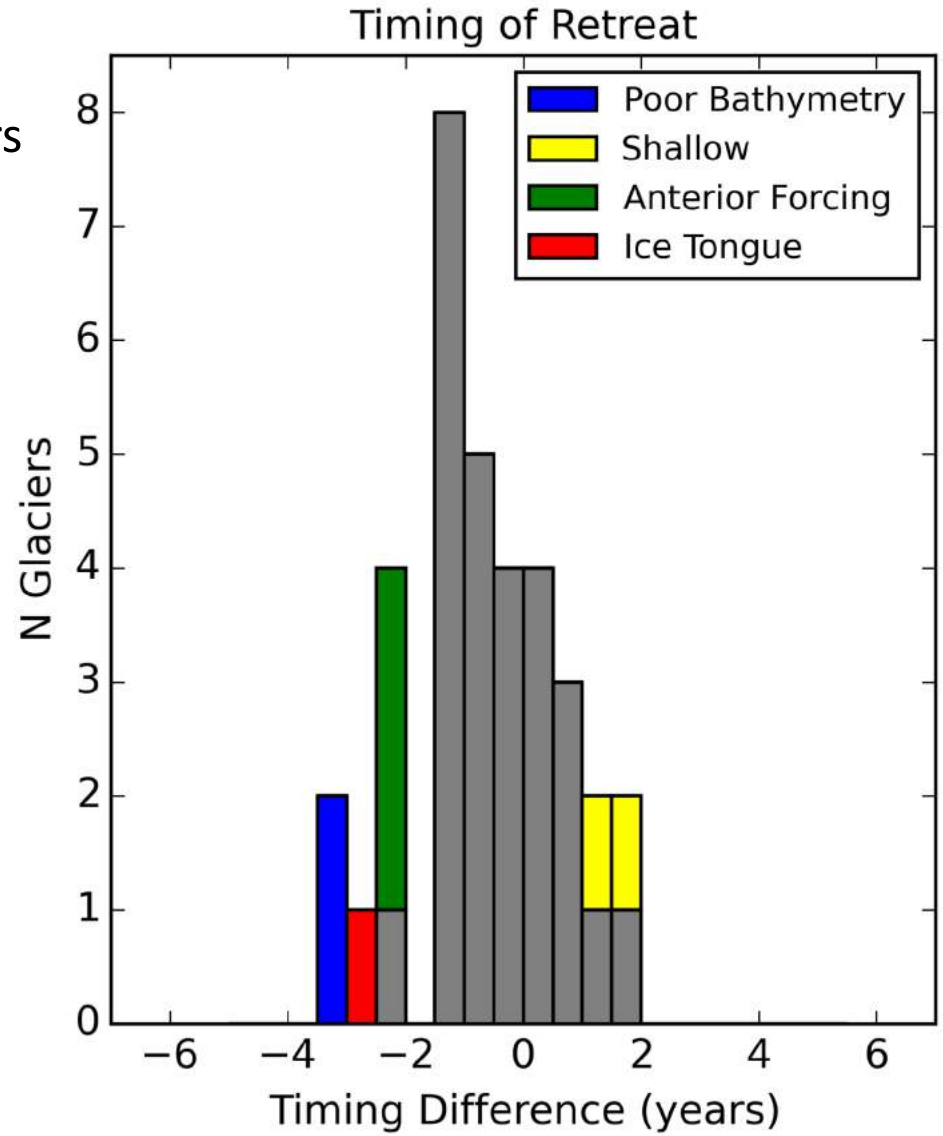

Wood et al 2018

# Timing of $q_r$ vs $q_m^{anom}$

- Timing agreement of -0.9 ± 2.6 yrs
  - Negative: $q_r < q_m^{anom}$ timing
- Either:
  - $q_r^{ref}$ underestimated
  - $q_m^{anom}$ overestimated

## Highlighted Glaciers

- Alison Glacier
- Upernavik Isstrom S
- Qeqertarsuup
- Kjer
- Kjer North
- Upernavik Isstrom NW
- Illullip
- Cornell



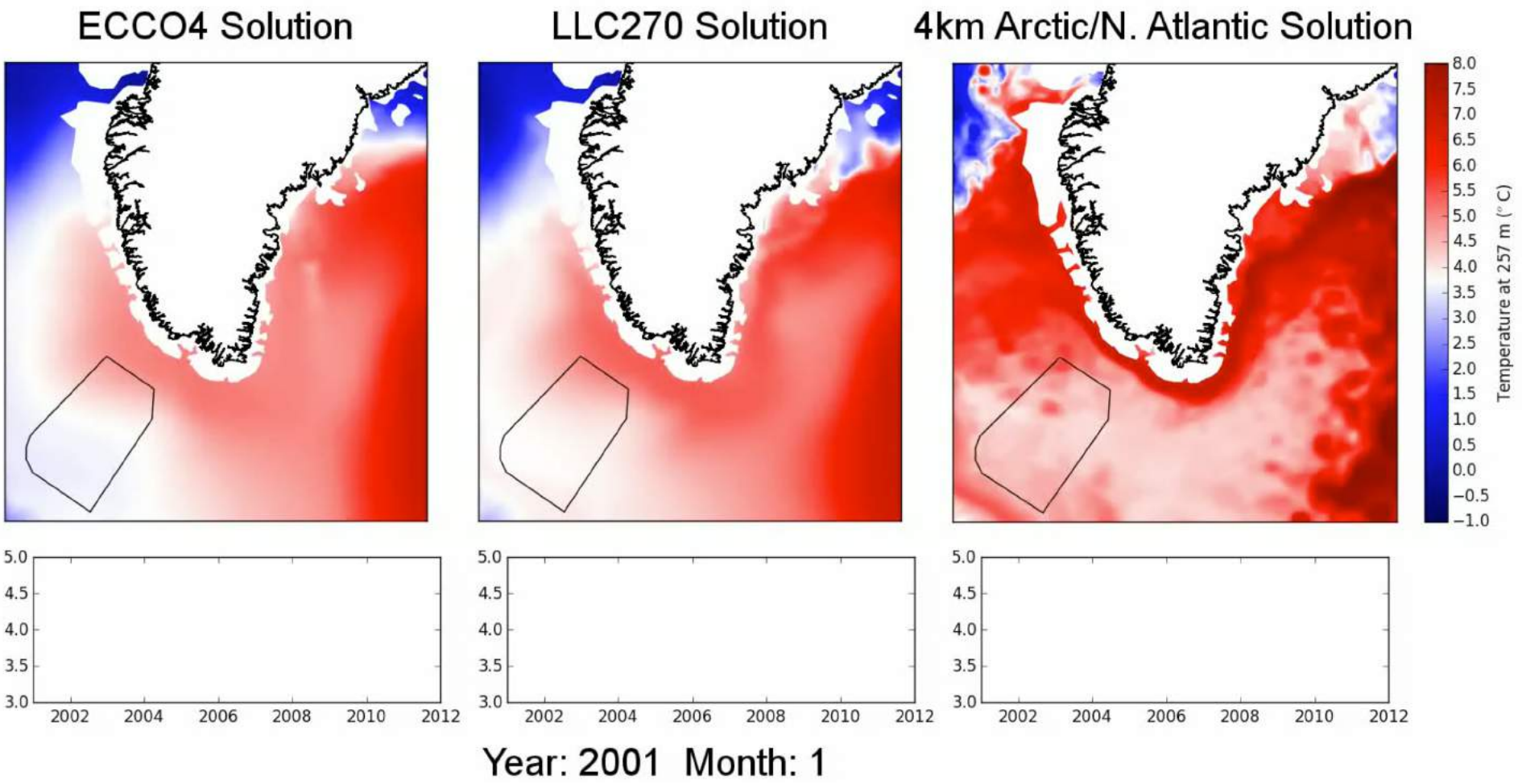

Wood et al 2018

# Conclusions, Round 1

1. ECCO Model output and CTDs indicate that ocean-induced undercutting triggered widespread retreat in NW Greenland
    - Retreat triggered around 1999 ± 2 years
2. But ice front ablation is dominated by calving processes

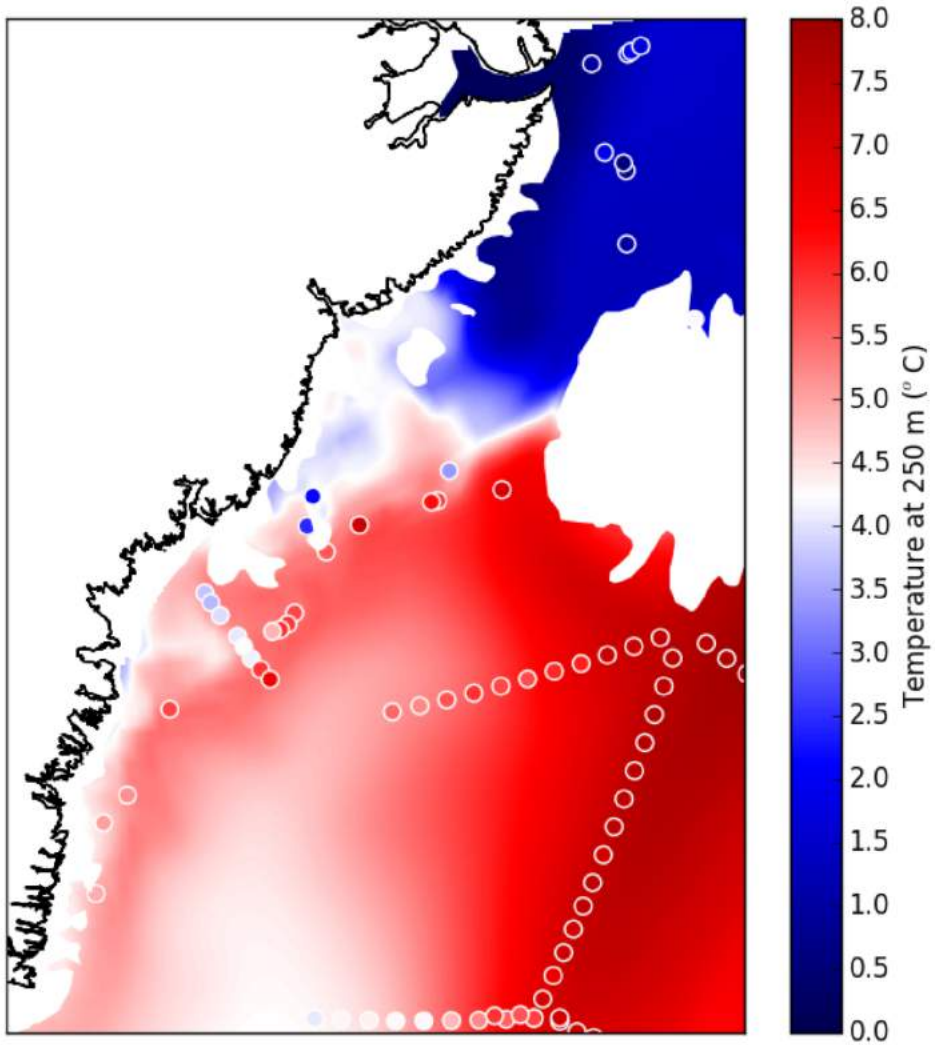
# Moving Forward:
# ECCO Solutions around Greenland

# ECCO Comparison in the North Atlantic



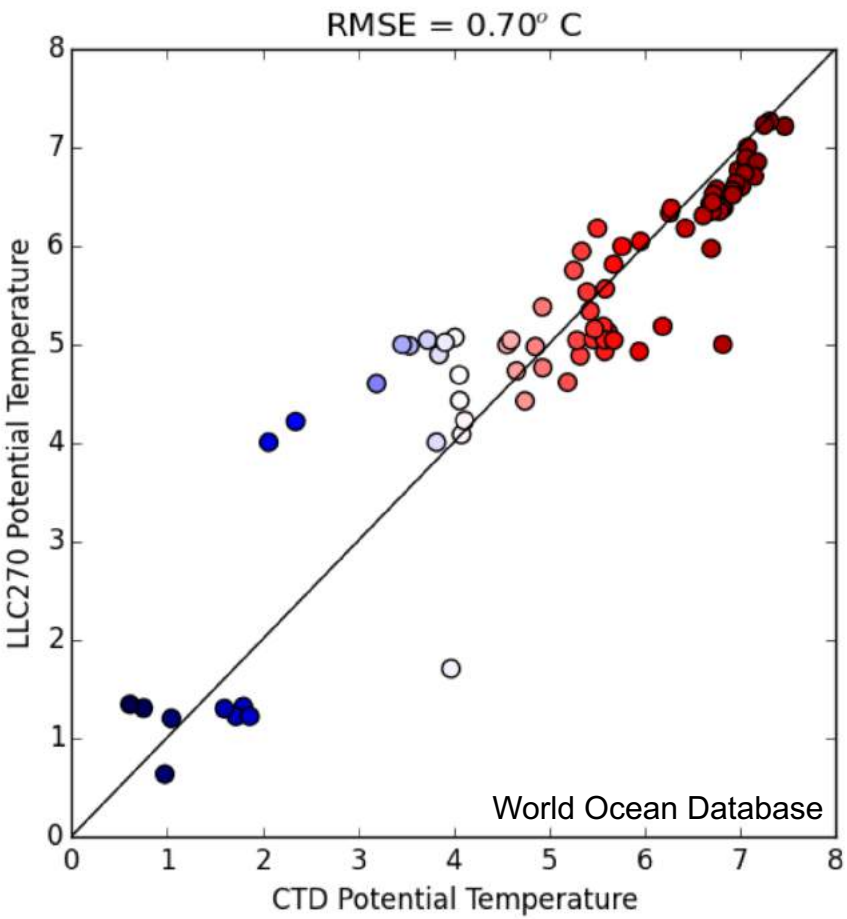

CTDs in Sample Box from the World Ocean Database

# ECCO Comparison in the North Atlantic

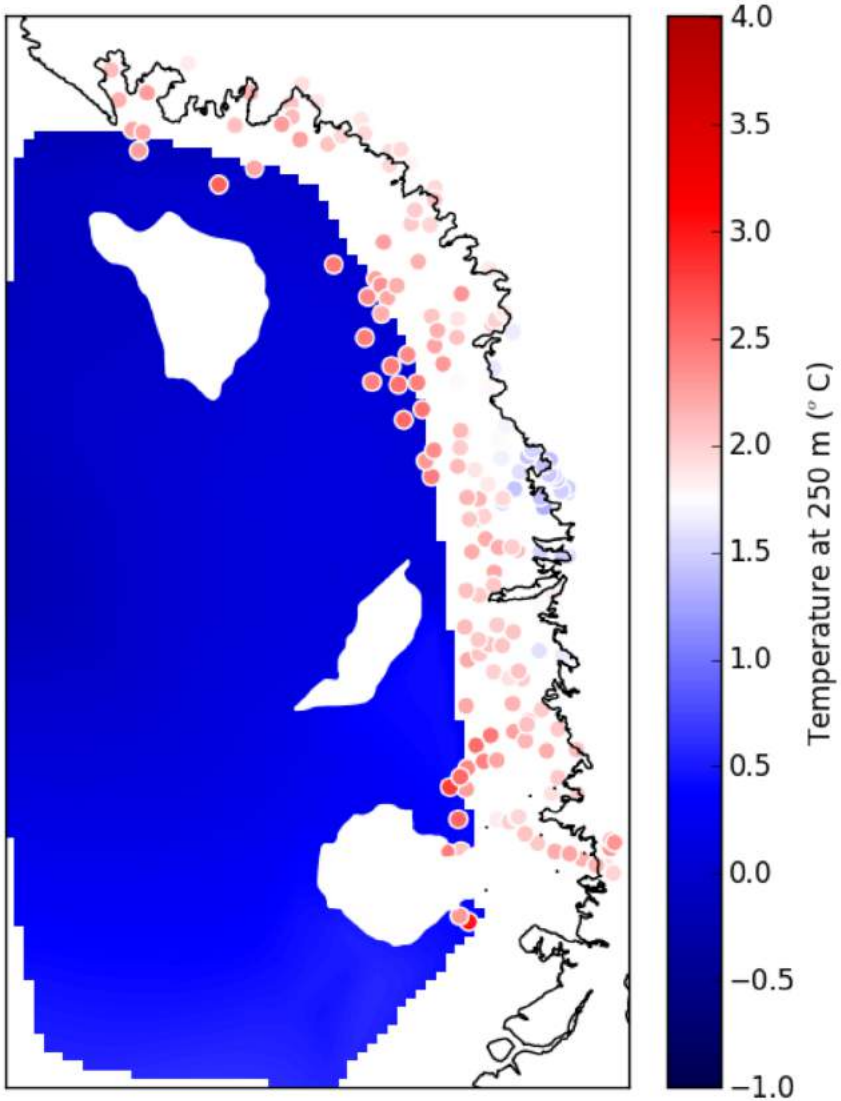



LLC270

June – October 2015

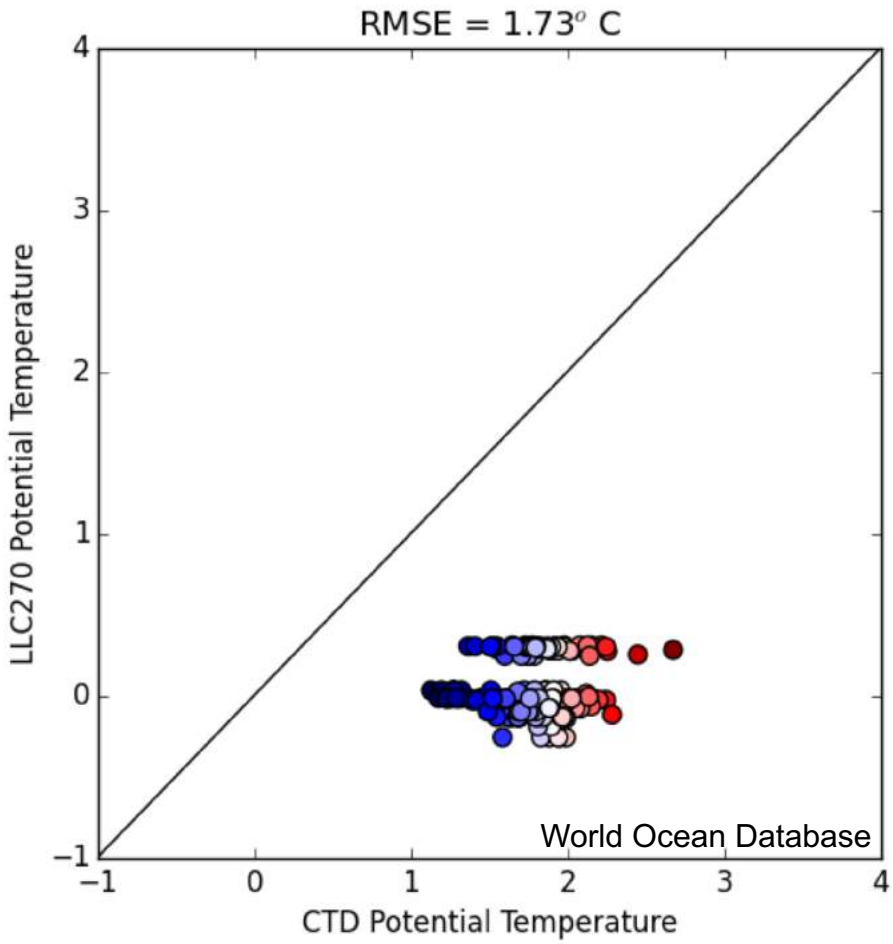


# ECCO Comparison in Baffin Bay



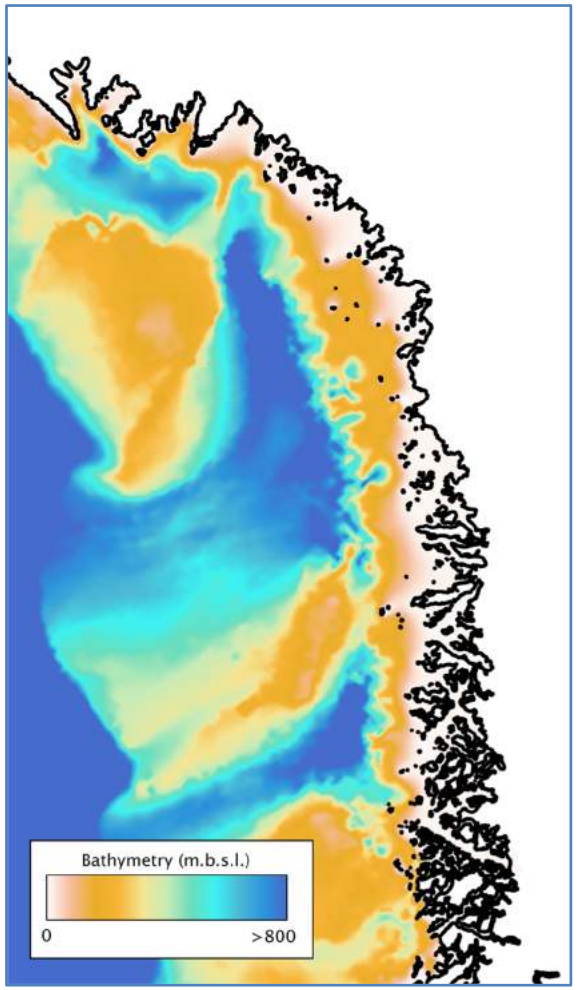

LLC270

June – October 2015

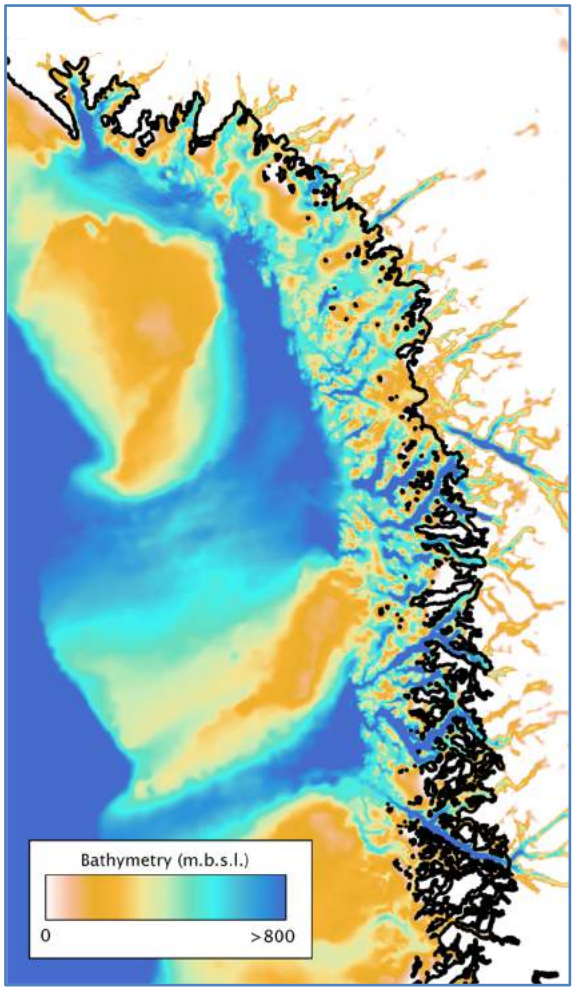



Difference from closest model domain point

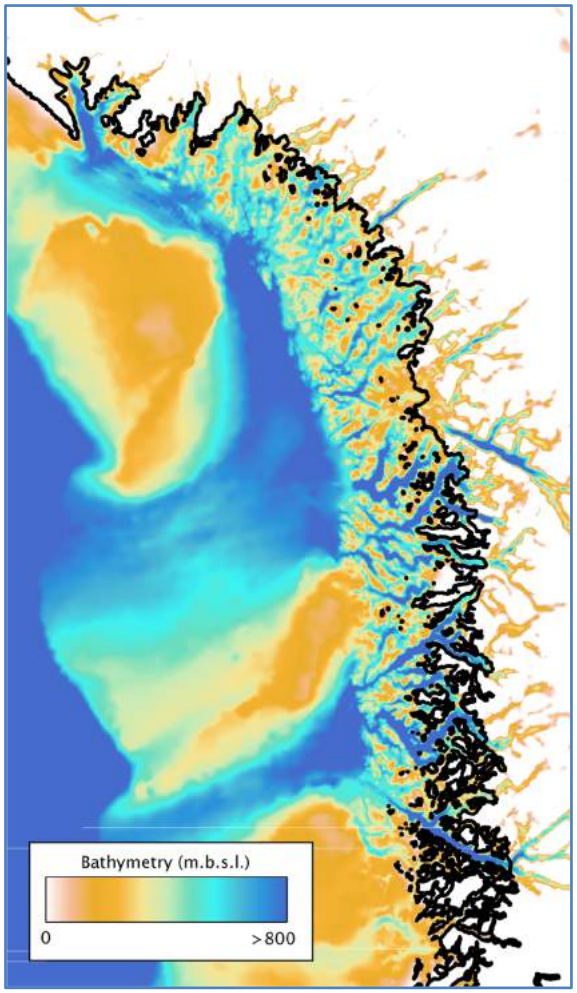
# Bathymetry in Baffin Bay




IBCAO V3




BedMachine V3



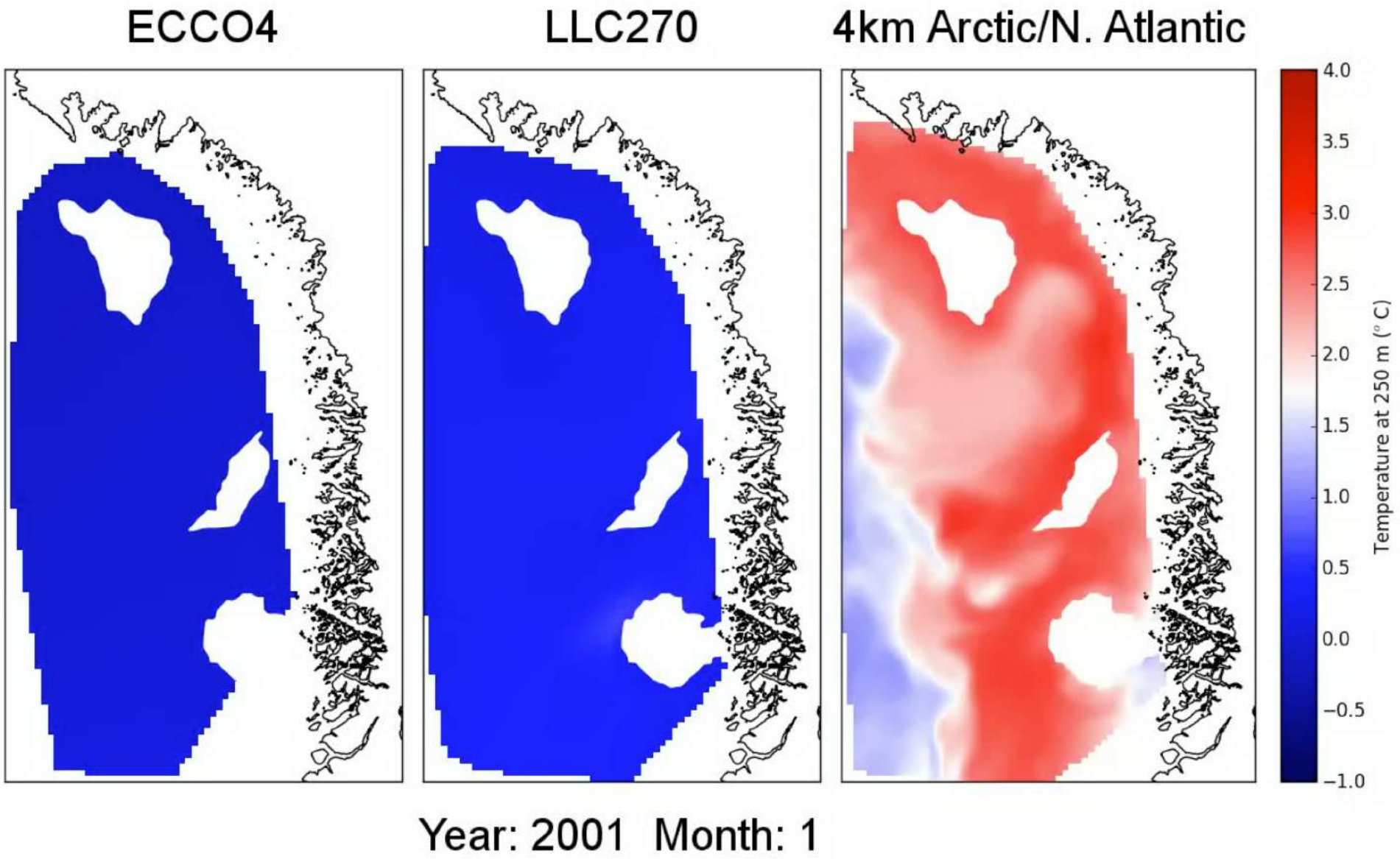

BedMachine V3
+ An et al 2018 (in review)

# Conclusions, Round 2

3. Ocean state estimate in the polar regions is critical to our understanding of ice-ocean coupling
    - Particularly as the ECCO community moves toward implementing ice front/shelf melt with `streamice` and `shelfice`

# Thank you

# ECCO Comparison in Baffin Bay



# ECCO Comparison in Baffin Bay