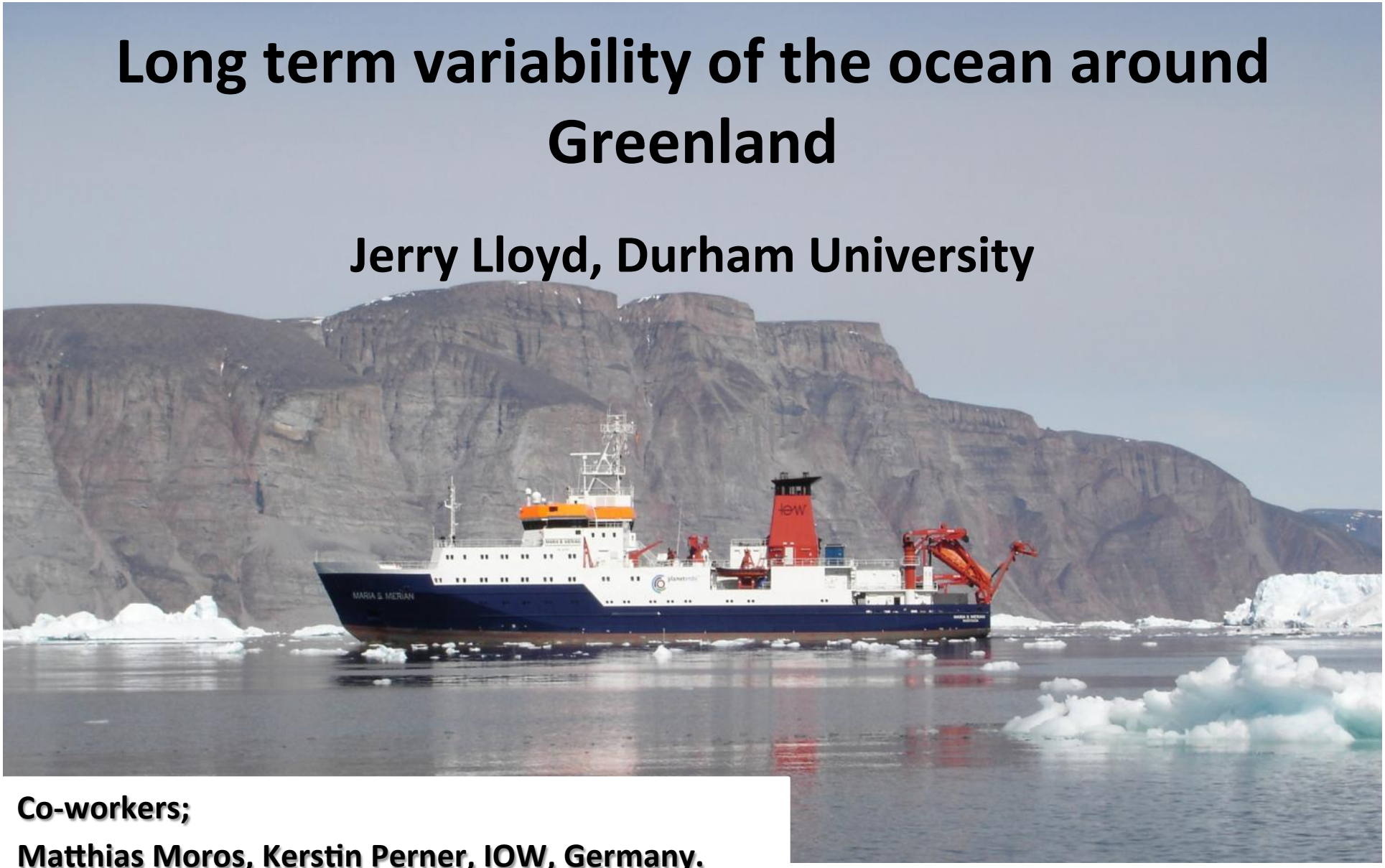
Long term variability of the ocean around Greenland

Jerry Lloyd, Durham University



Co-workers;

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David McCarthy, Durham University, UK.

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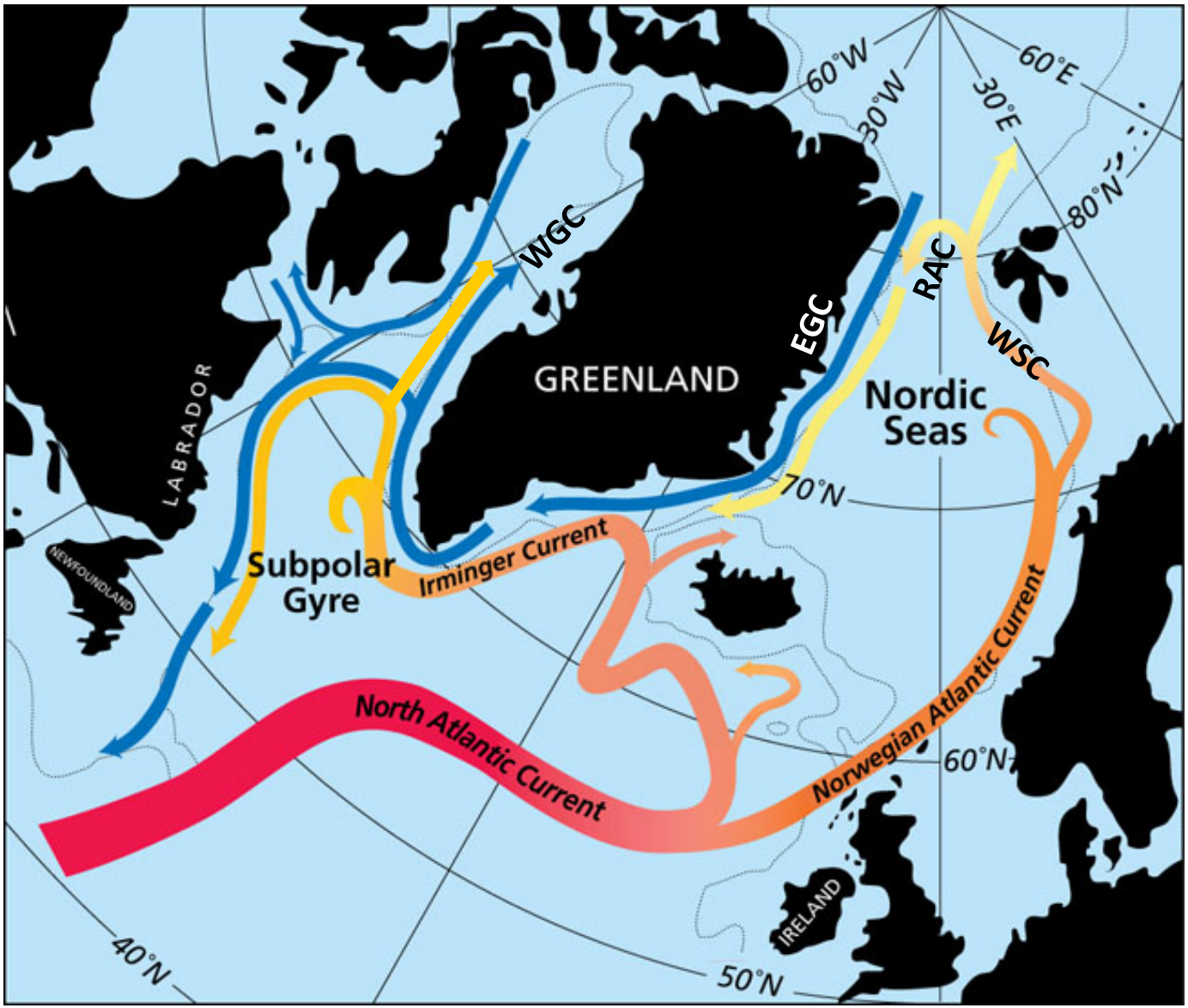
Durham University

Outline

- Overview of modern circulation system
- Long term perspective – proxy reconstructions
- Examples from around Greenland margins
- Time-slice summary of ocean changes
- Issues for discussion….

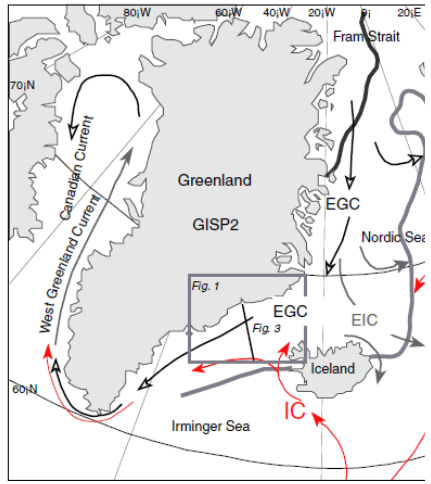
Modern Oceanographic context

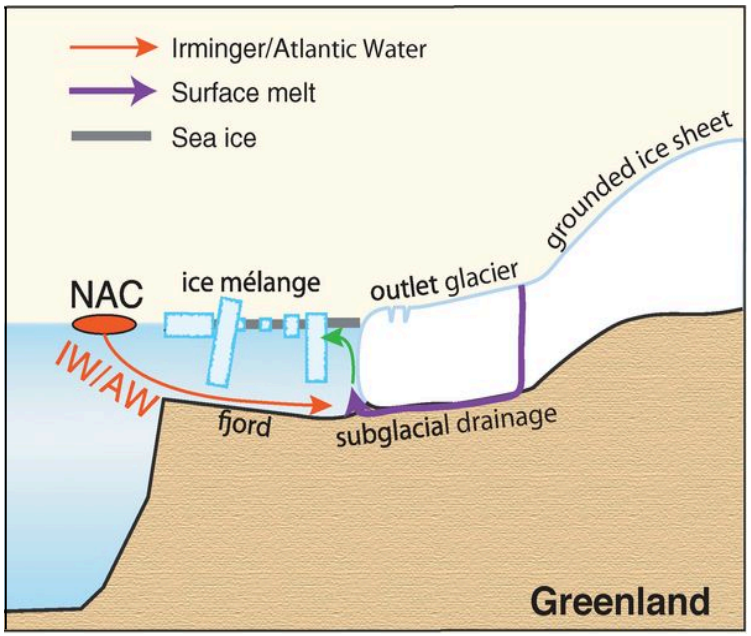


WSC: West Spitsbergen Current
RAC: Return Atlantic Current
WGC: West Greenland Current
EGC: East Greenland Current

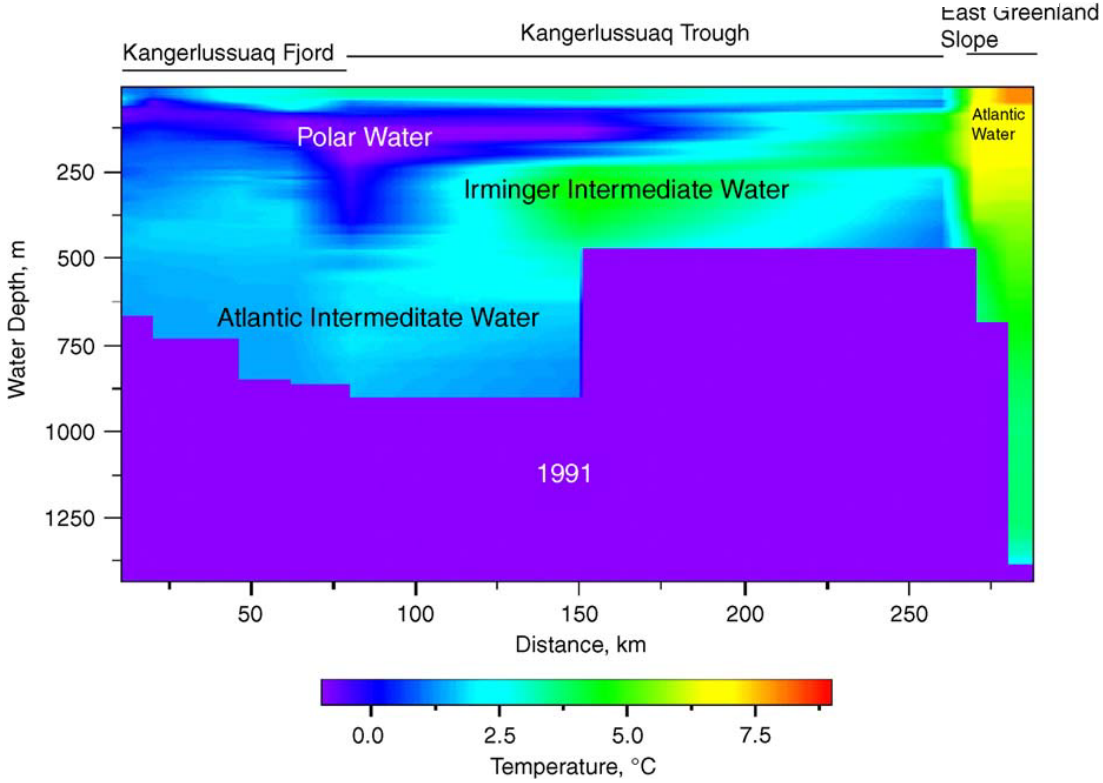
Link to ice sheet

Atlantic sourced water more saline – subsurface flow
Melting at grounding line of tidewater glaciers/ice shelves





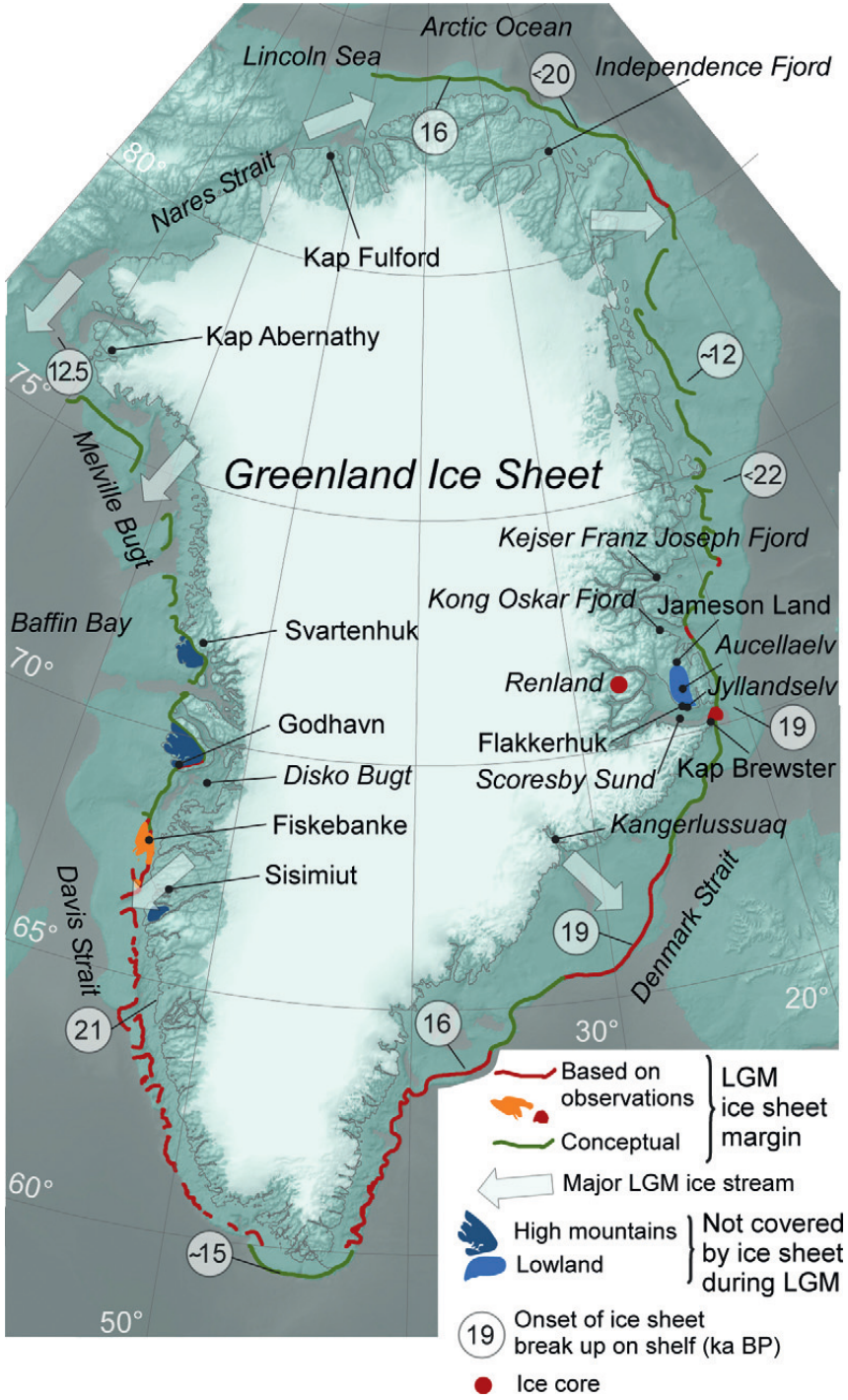
Source: Joughin et al., 2012



Source: Jennings et al., 2006

GIS perspective

- **LGM ice margin limits (Funder et al., 2011)**
- **Significant advance onto shelf areas**
- **Interaction with ocean potentially important**
- **Initial deglaciation varies from *c.* 20 to 11.5 ka**



Reconstructions based on Proxies

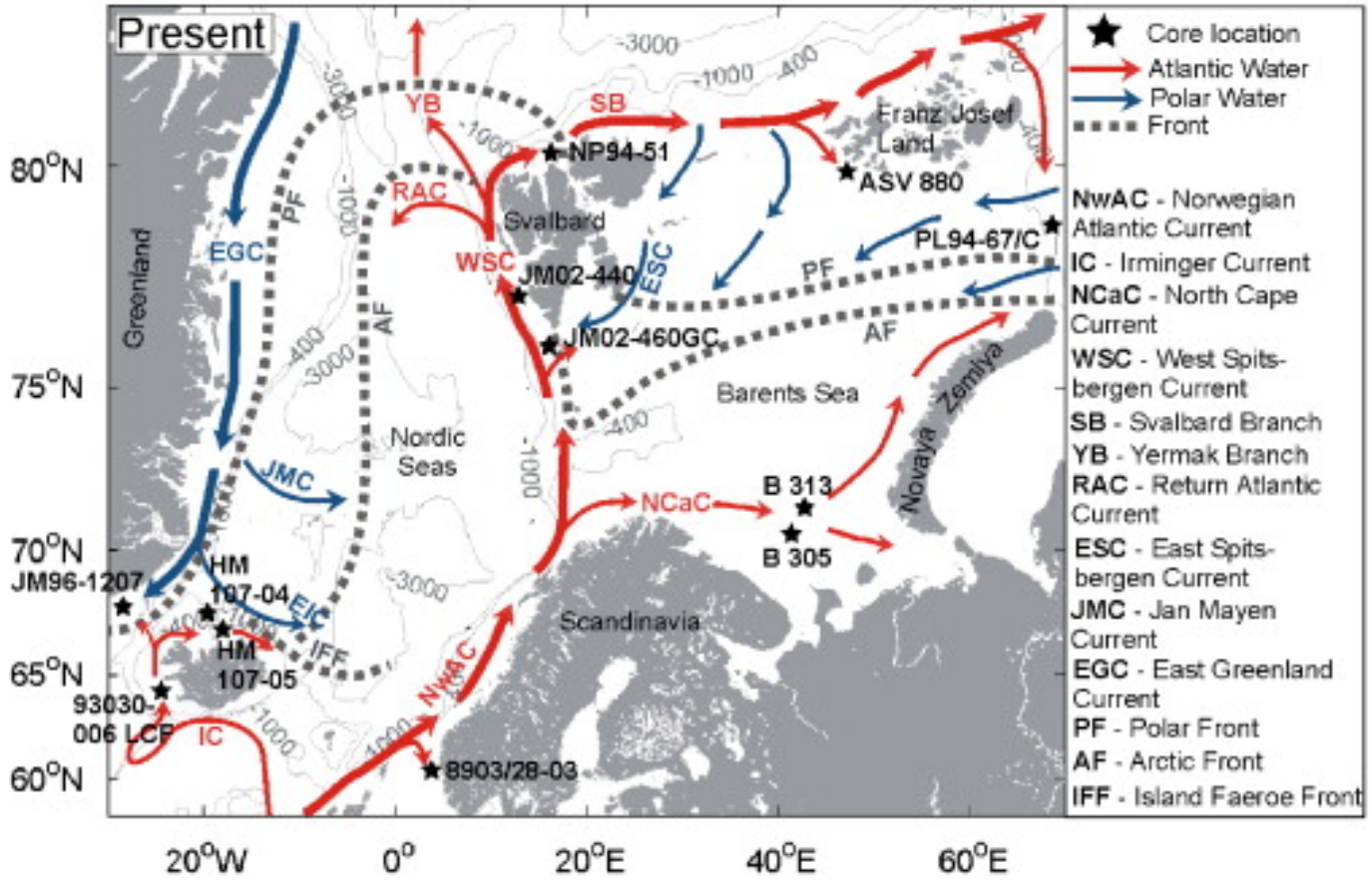
- Key issue – spatial / temporal extent of records
- Depo-centre, no erosion
- Availability of proxy
  - Preservation of biogenic material

- Examples of ocean circulation proxies:
  - Surface waters – diatoms, dinoflagellates, planktic forams, $\delta^{18}O$, organic geochemistry
  - Bottom waters – benthic foram fauna, $\delta^{18}O$, Mg/Ca

- IRD – Ice Rafted Detritus – evidence ice break-up

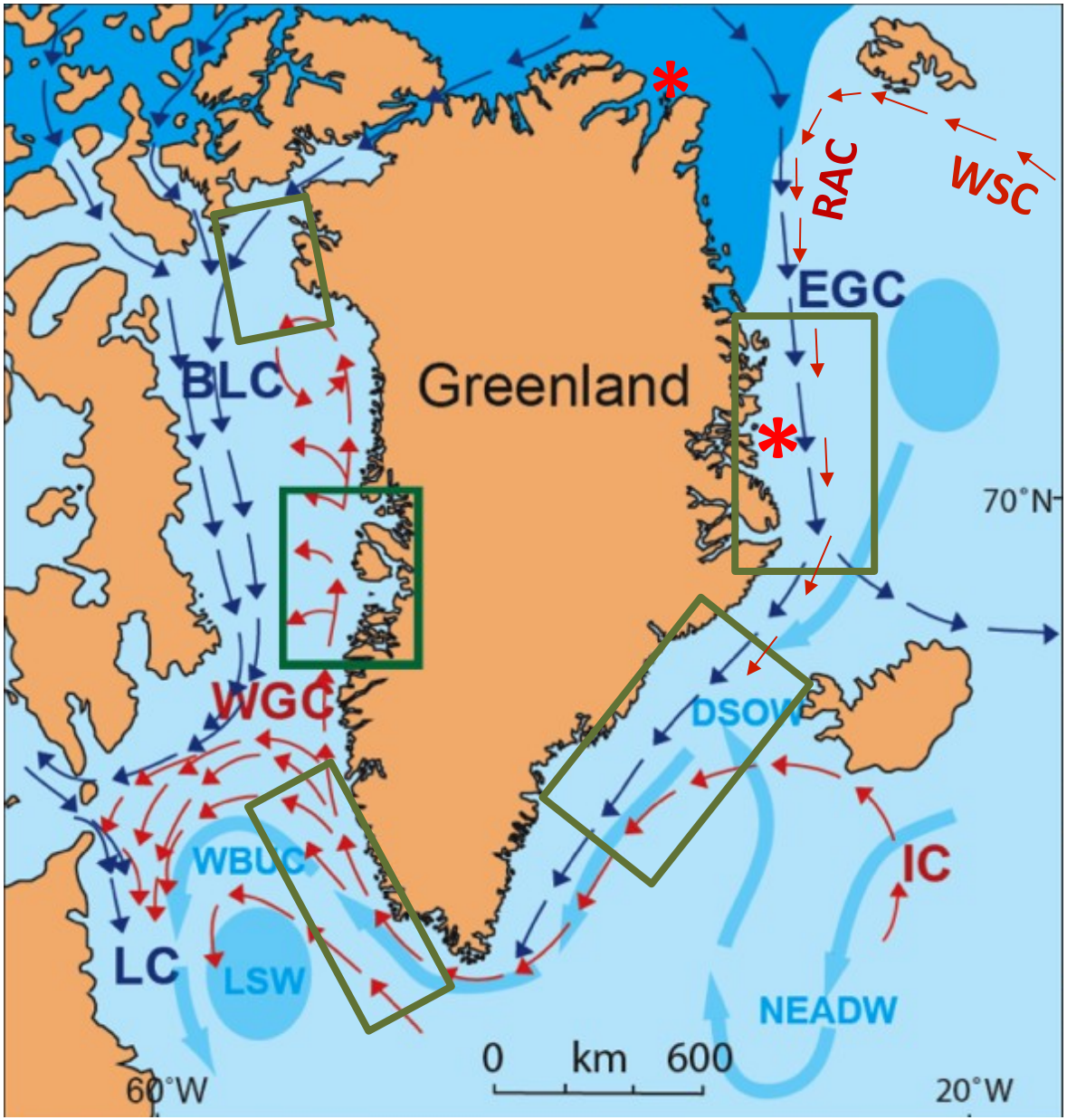
Atlantic Water inflow to Nordic Seas

- SST reconstructions – diatoms (e.g. Koç et al., 1993)
- Sub-surface conditions – benthic forams – compilation from shelf areas by Slobowska-Woldengen et al., (2008)

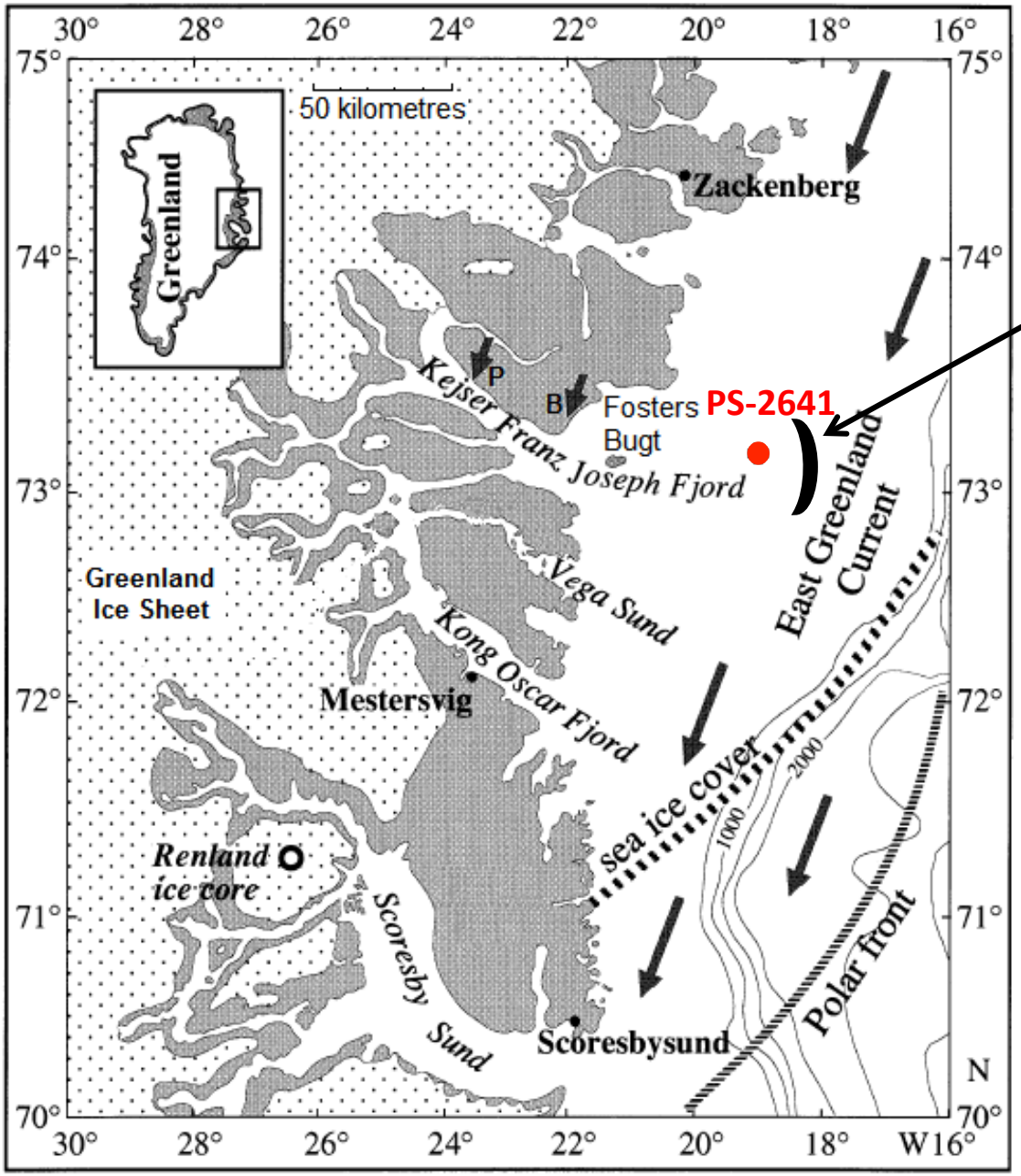


Ocean circulation changes around Greenland margin

- Limited evidence from East Greenland margin
- Planktic foram δ18O and IRD – deglaciation started *c.* 20 -18 ka (e.g. Nam et al., 1995)
- Nørgaard-Pedersen et al., 2008
- Benthic forams Independence Fjord
- Chilled AW 10 – 8.9 ka cal BP
- New data from Fosters Bugt



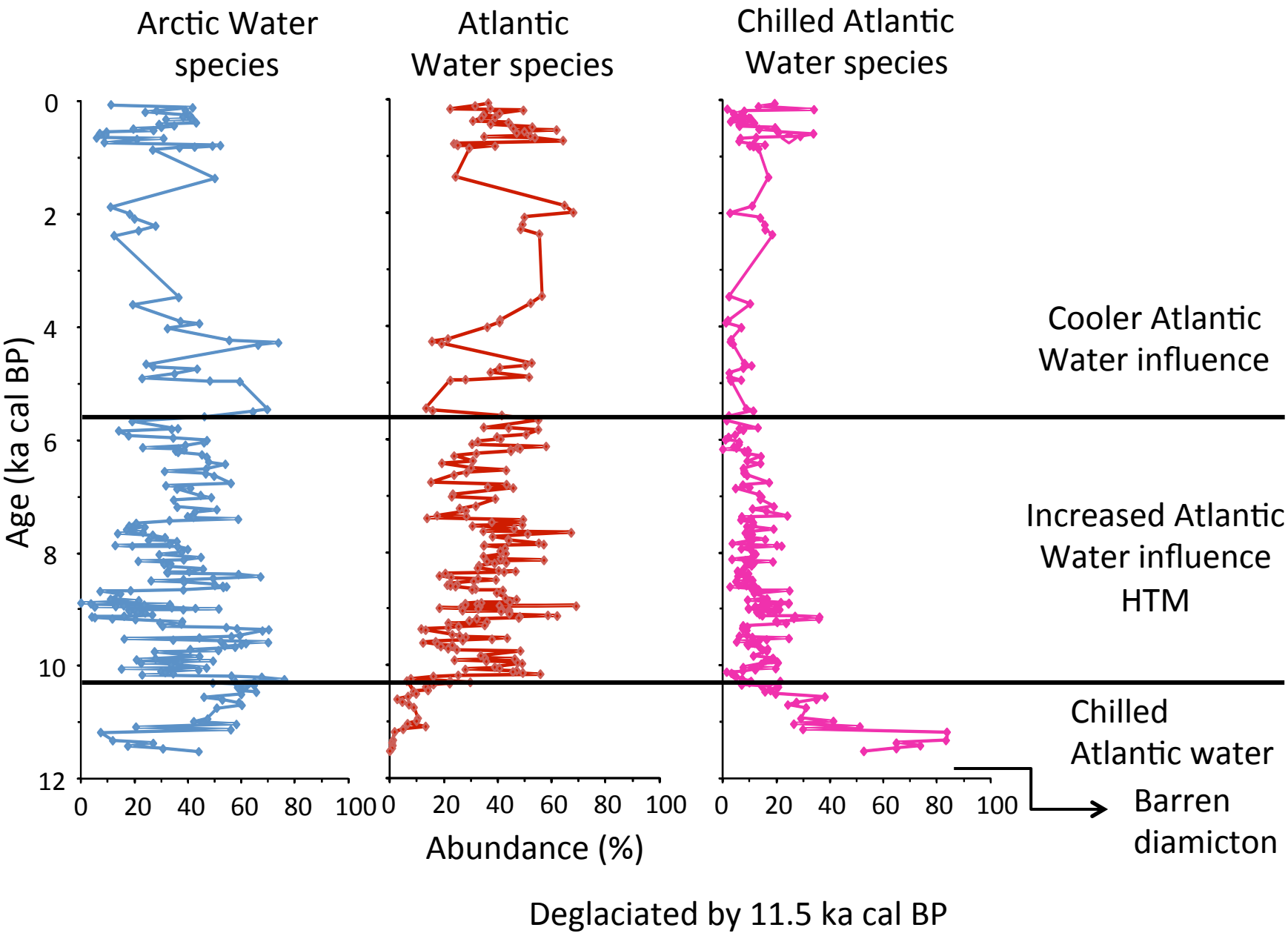
East Greenland – Fosters Bugt



Mid-shelf moraine
Retreat from moraine *c.* 14 ka cal BP (Evans et al., 2002)

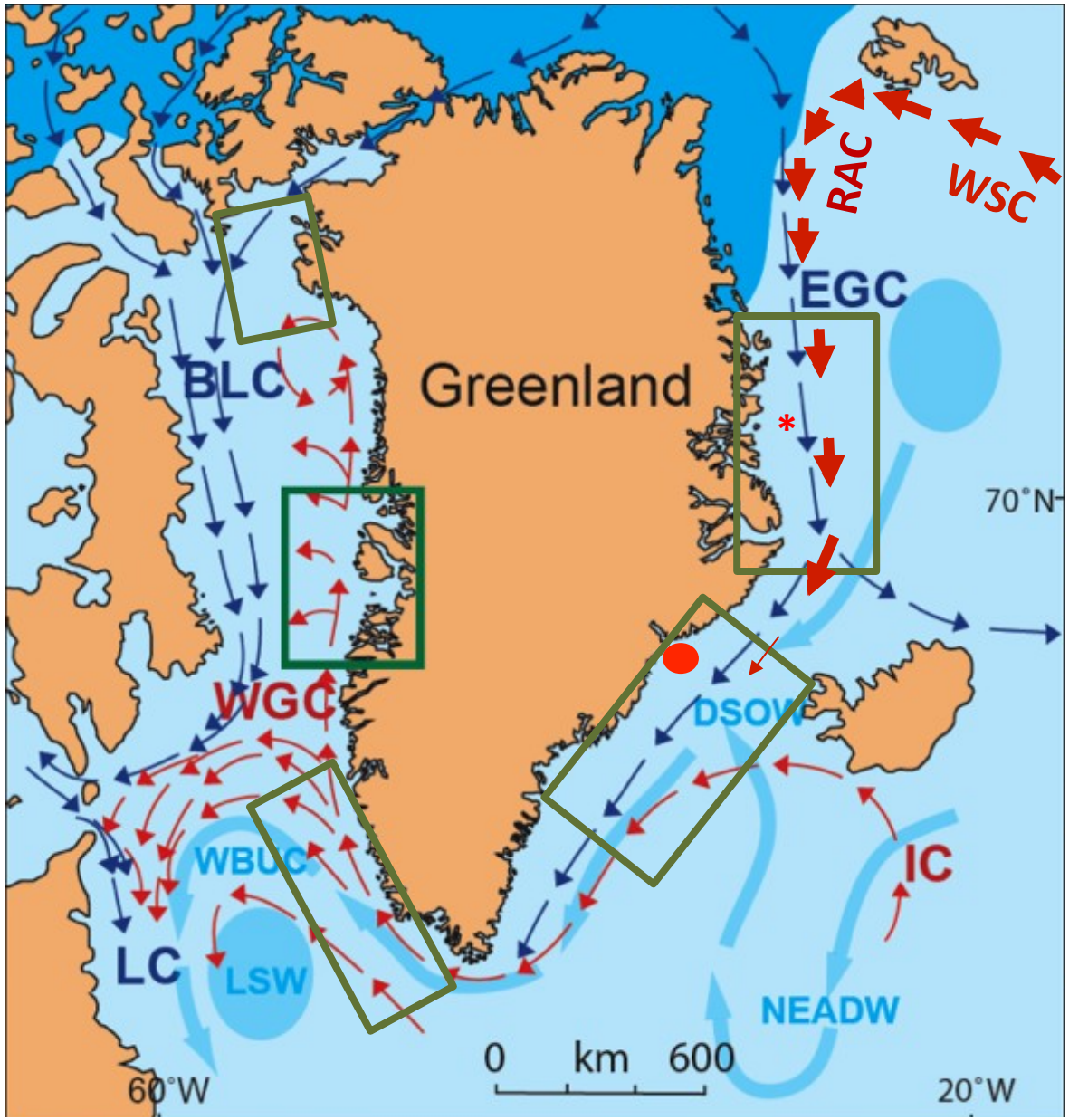
Core PS-2641
Sedimentary basin behind moraine

Benthic foraminifera assemblage East Greenland, core PS-2641 –

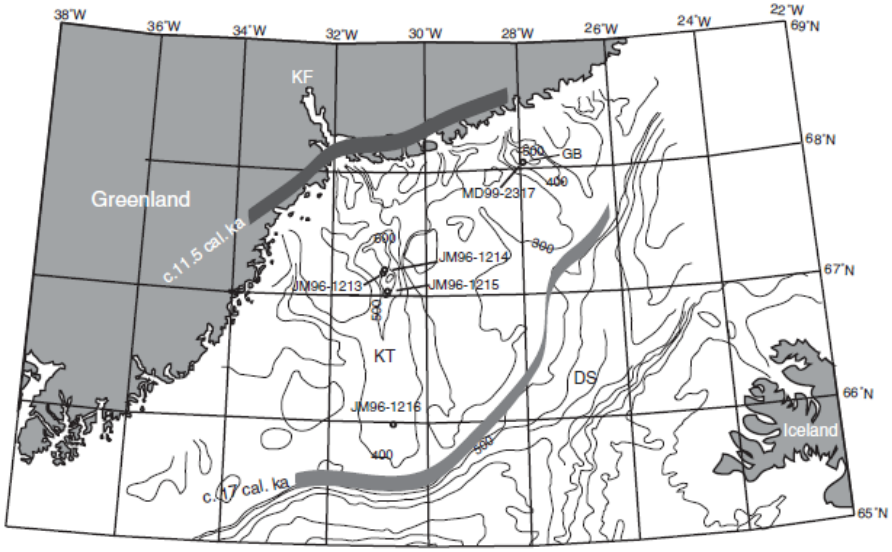


East Greenland Margin

- Return Atlantic Current
- Chilled AW by 11.5 ka (post YD)
- Warm AW from *c*. 10 ka – HTM suggested *c.* 10 – 6 ka
- Southeast margin

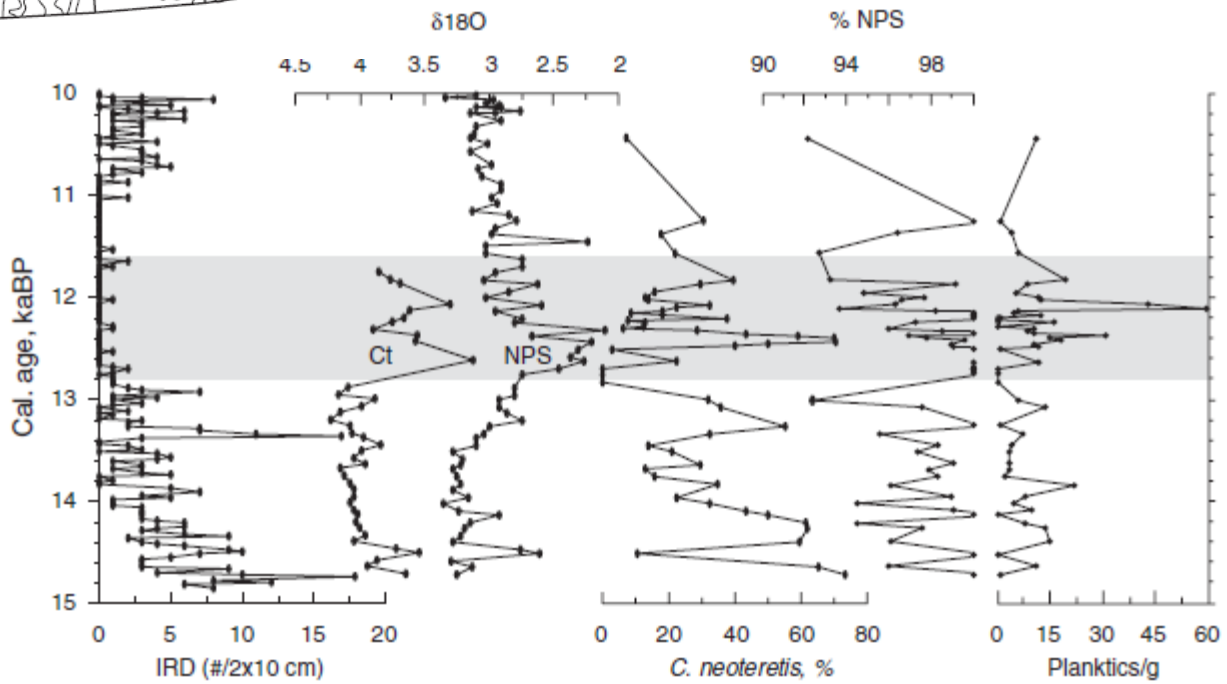


Southeast Greenland shelf



- Kangerlussuaq Trough, benthic foraminifera, $\delta^{18}O$
- Atlantic Intermediate Water from *c.* 14.5 ka, through YD
- AW promoted melting and retreat of GIS

- Holocene Thermal Maximum: *c.* 8.1 – 3.5 ka
- Neoglacial cooling from *c.* 5 ka
- Warm intervals *c.* 2 – 1.5 ka



From Jennings et al., 2002, 2006, 2011

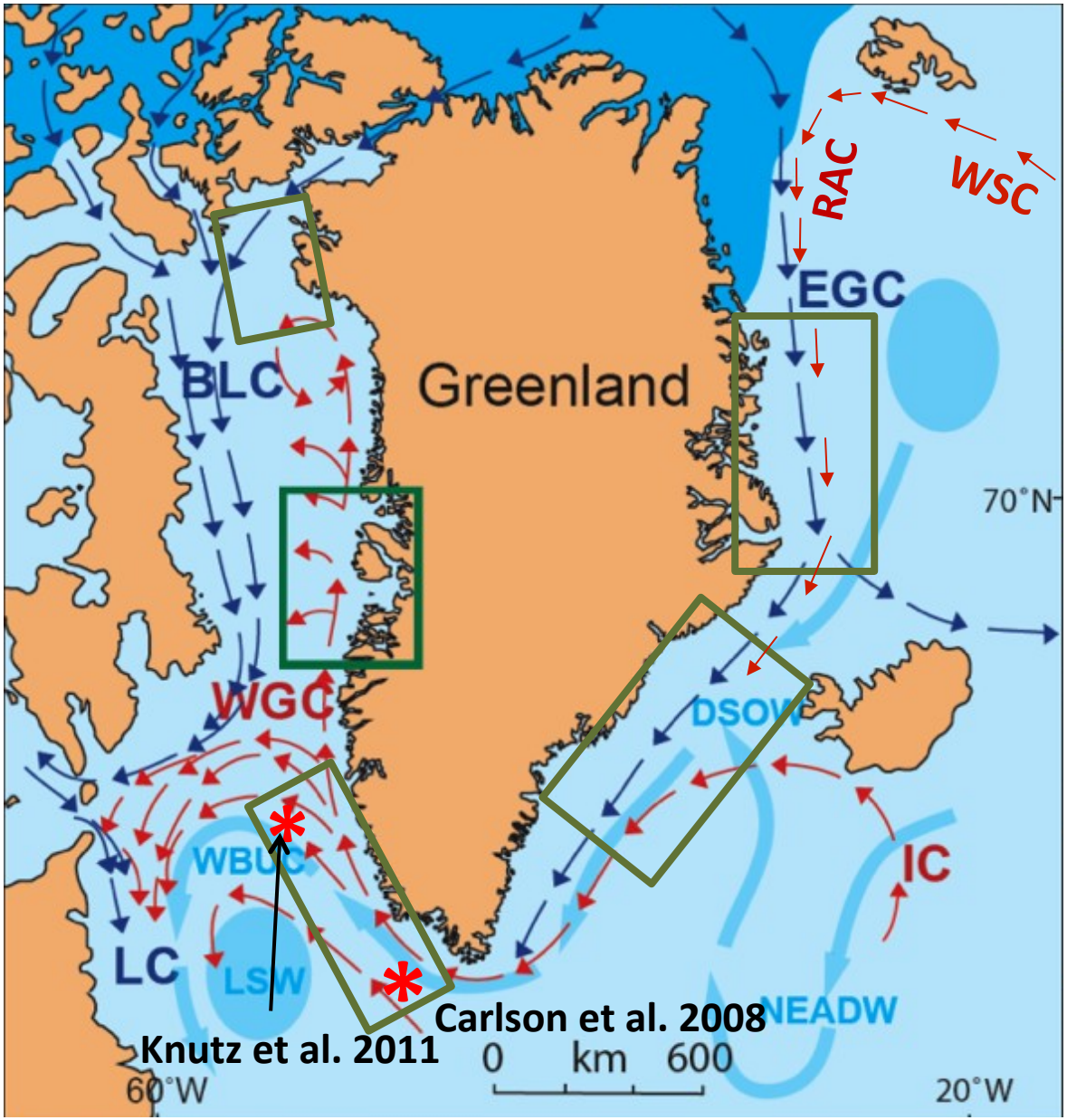
South and Southwest Greenland Margin

- Two records beyond shelf
- Broader deglaciation – ocean links

- Carlson et al. (2008)
- Ti and Fe – terrestrial input

- Peak in Ti and Fe *c.* 19 - 18 ka – initial southern GIS deglaciation
- Insolation increase, ocean warming + RSL rise

- Increased again 14.7 – 10 ka
- Increased AMOC



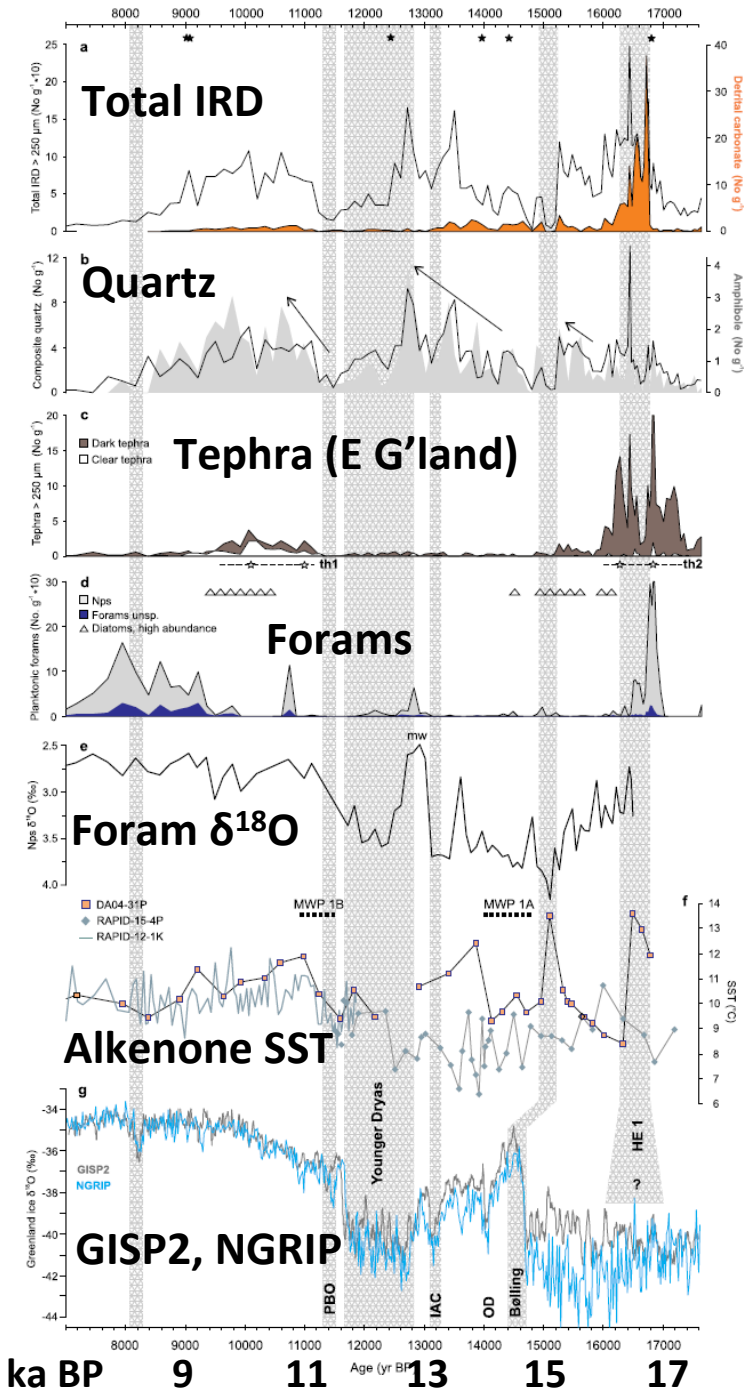
Knutz et al., 2011

- IRD and tephra geochemistry
- Foram $\delta^{18}O$
- Alkenone SST

- Peak east Greenland sourced IRD *c.* 17 – 16 ka – deglaciation

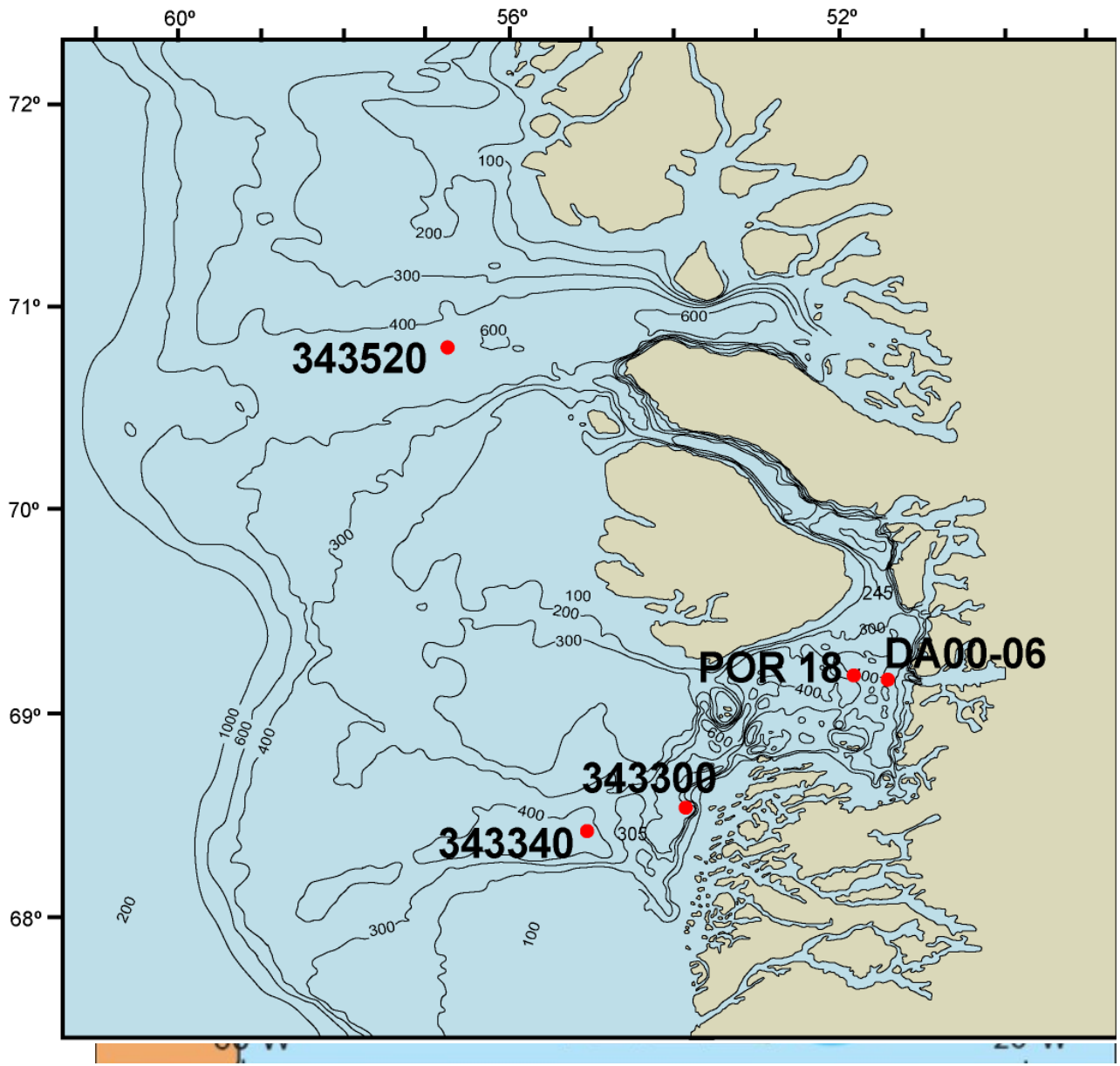
- IRD peak from general GIS 14 ka
- Final deglaciation 9 – 11 ka

- Alkenone SST – advected from IC
- Sustained warming from 14 ka
- Earlier isolated incursions

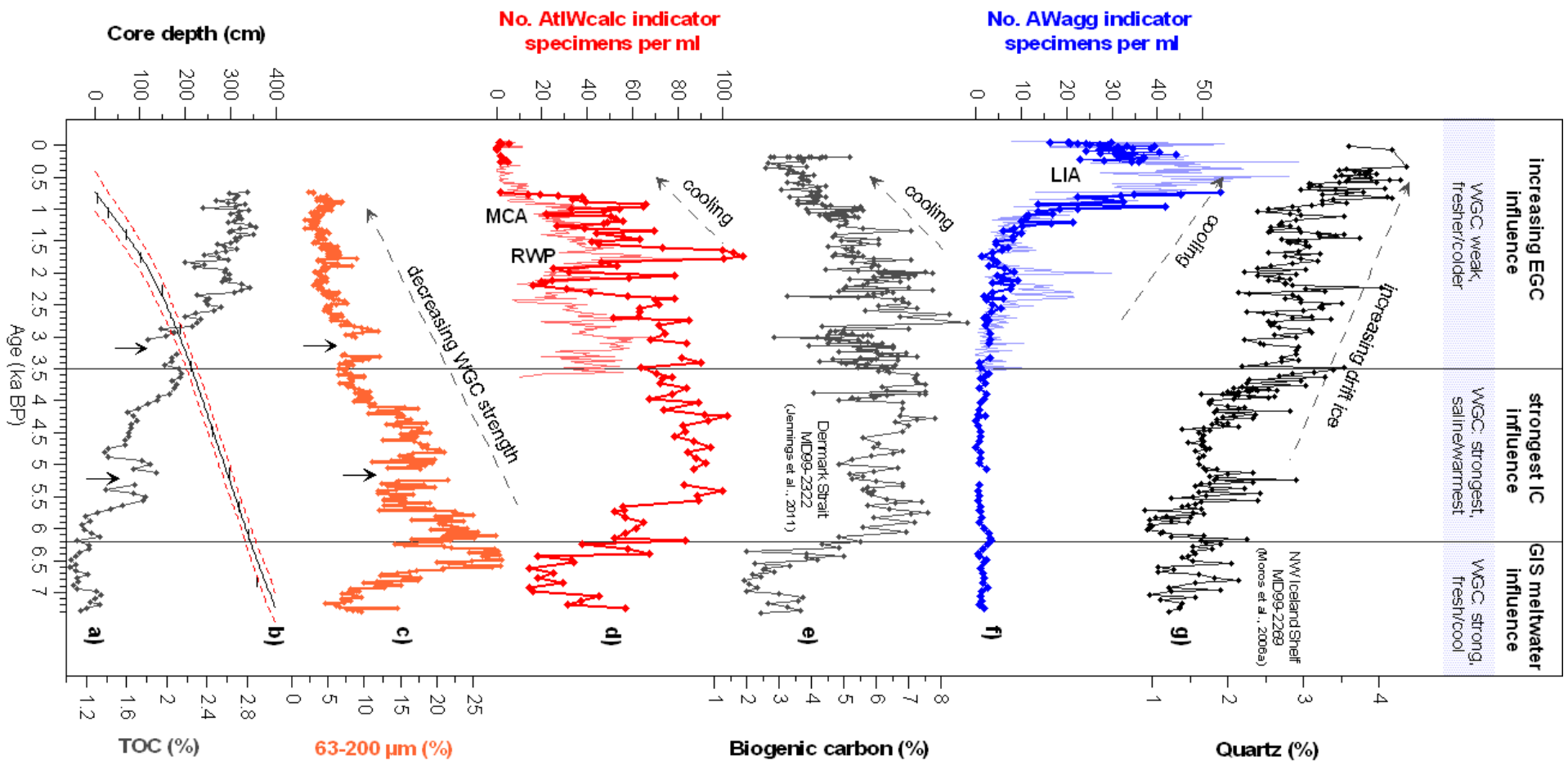


Central West Greenland Margin

- McCarthy 2011, Perner et al., 2013)
- Two major troughs – Disko Trough and Uummanaq Trough
- 343340
  - Chilled AW from *c.* 11 ka
  - Warmer AW from *c.* 8 ka



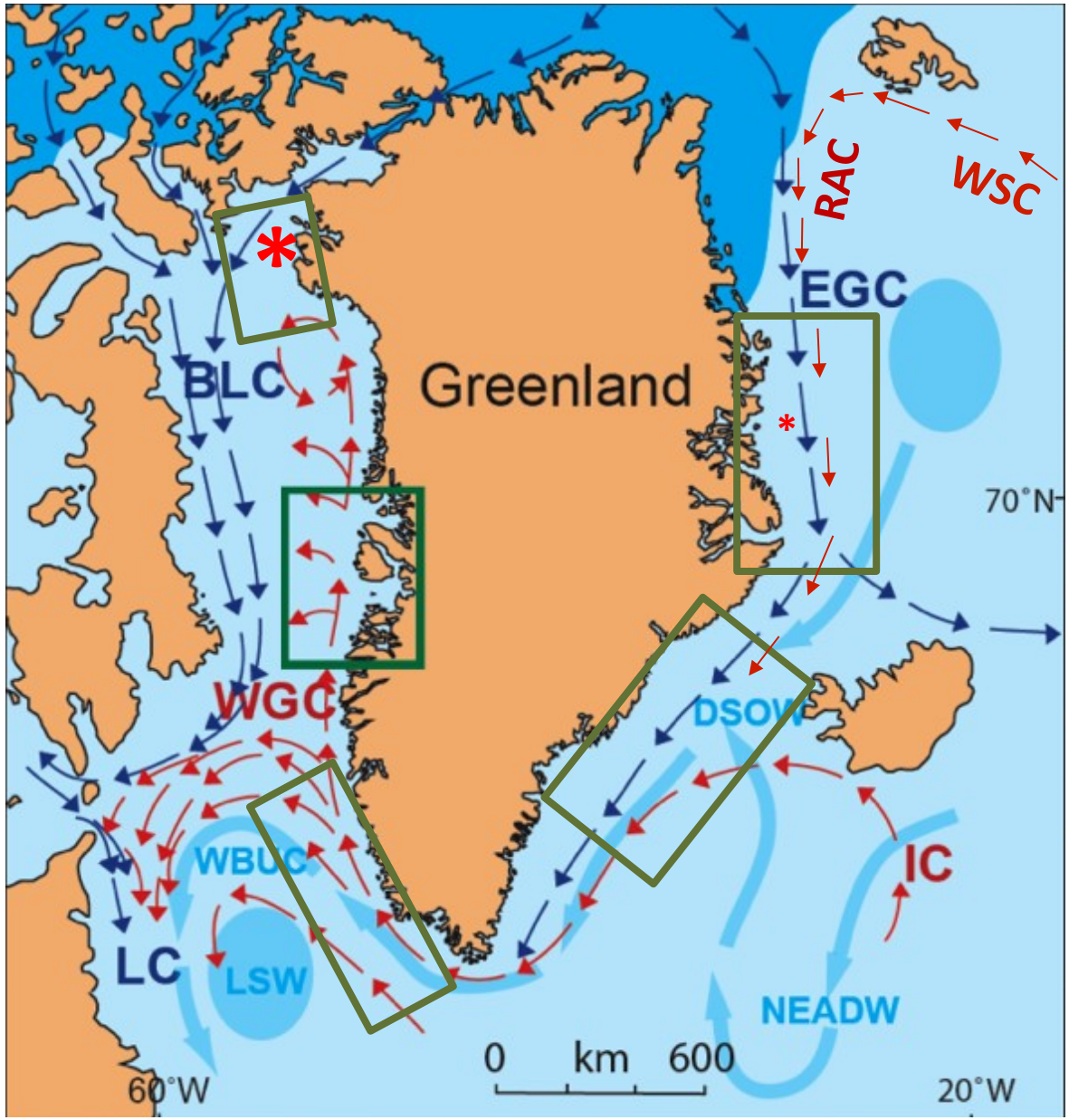
MSM343300 – benthic foram, (Perner et al., 2013)



- Relatively warm AW from *c.* 7.5 – 6.2 ka
- Warm AW *c.* 6.2 – 3.5 ka – Holocene Thermal Maximum
- Neoglacial cooling from 3.5 ka
- Millennial/centennial cycles visible

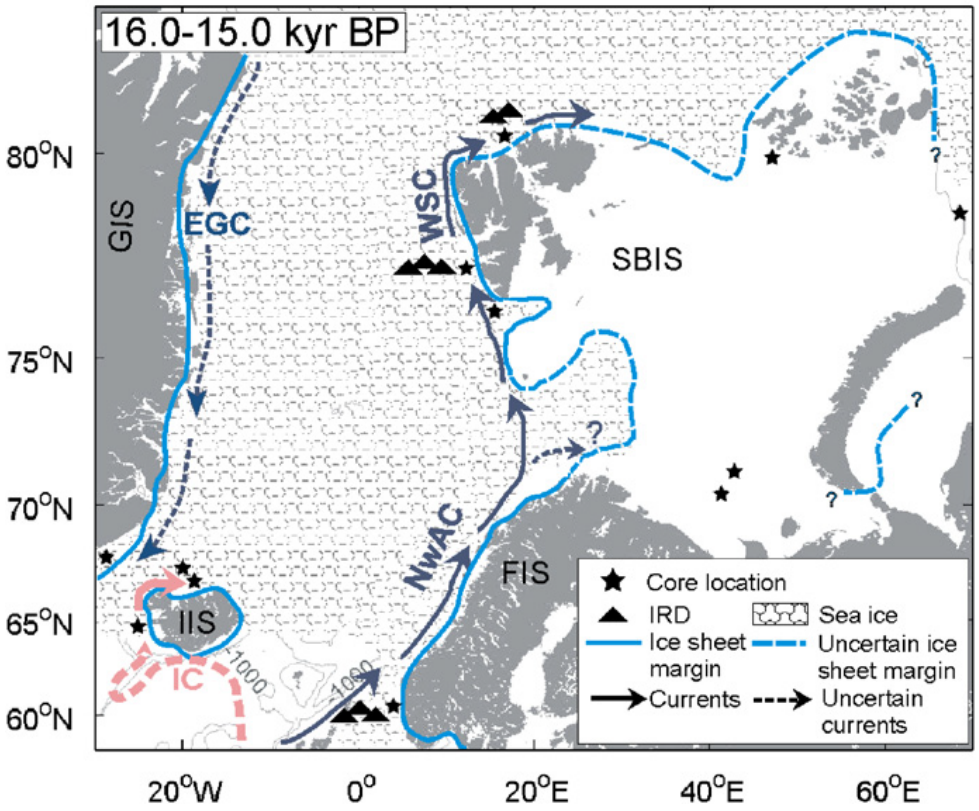
Northwest Greenland Margin

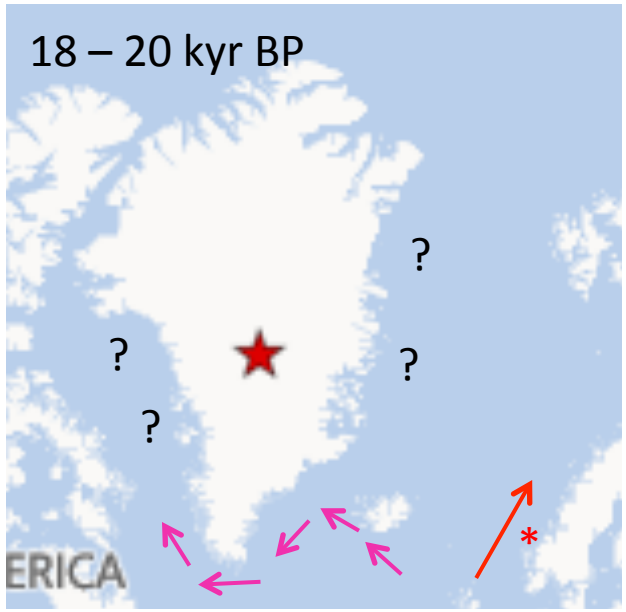
- Knudsen et al., 2008
- Benthic forams
- Till at base of core
- From 12.3 ka cal BP – chilled Atlantic Water influence
- Strongest Atlantic Water influence 10.9 – 8.2 ka cal BP



Time slice summary of ocean circulation

Initial deglaciation – Older Dryas





Slobowska-Woldengen et al., (2008)

Blue – cold Atlantic or Polar Water

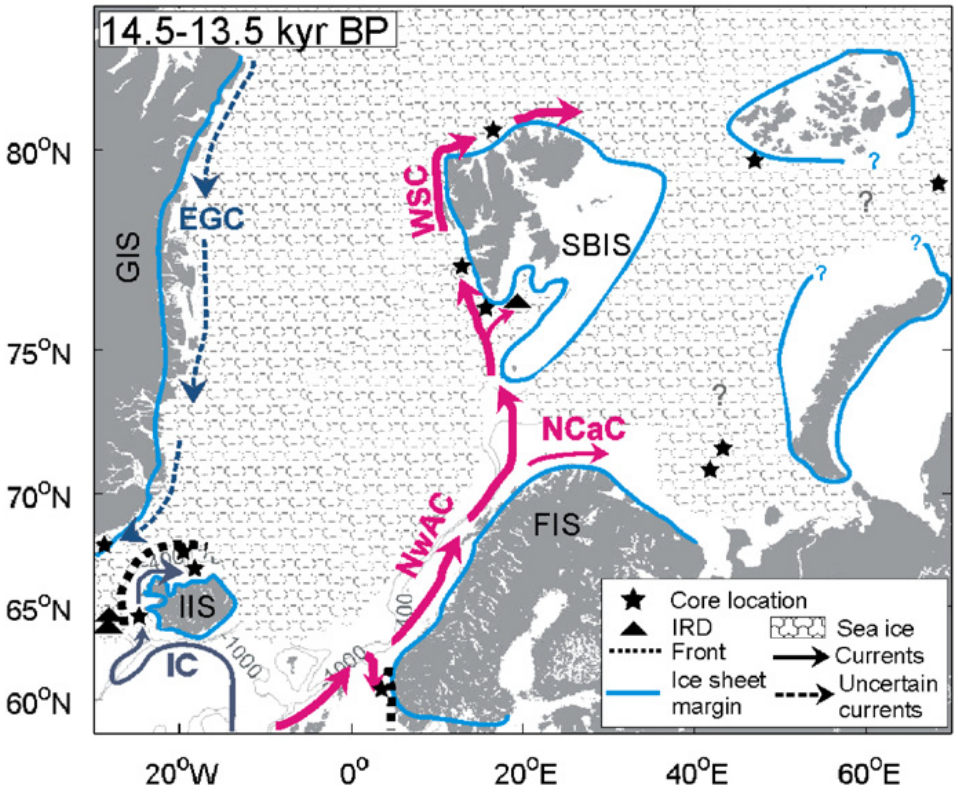
Light pink – relatively cold Atlantic Water

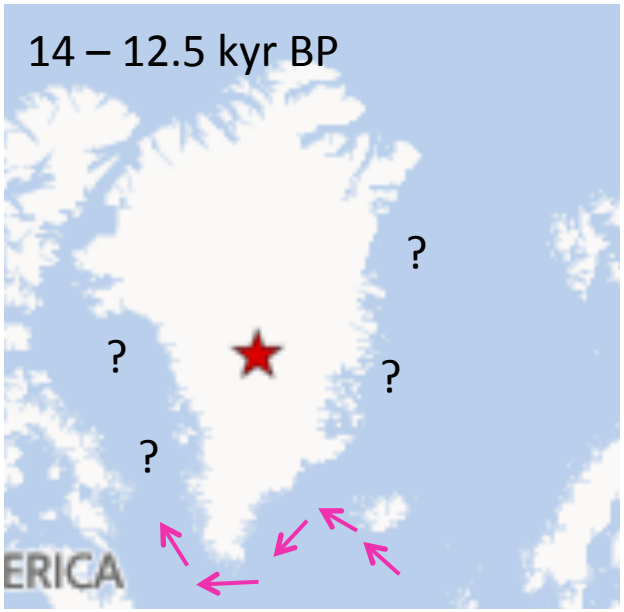
Dark pink – chilled Atlantic Water

Red – warm Atlantic Water

- Benthic foram Mg/Ca – subsurface warming from *c.* 19 – 17 ka (Marcott et al., 2012)
- Chilled AW through IC periodically

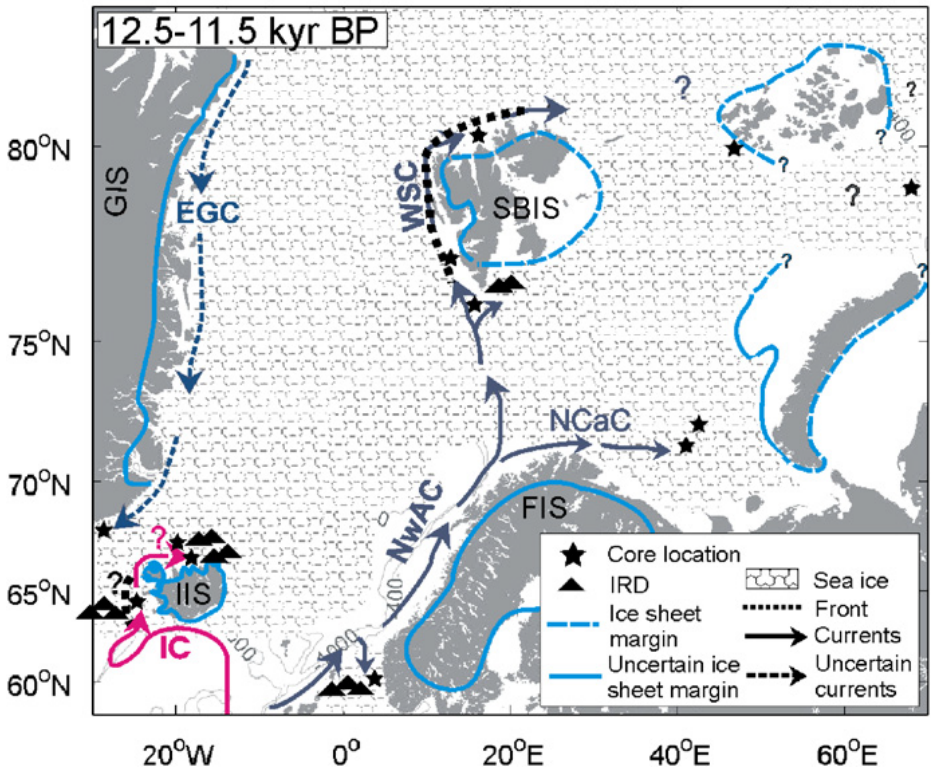
Bølling - Allerød

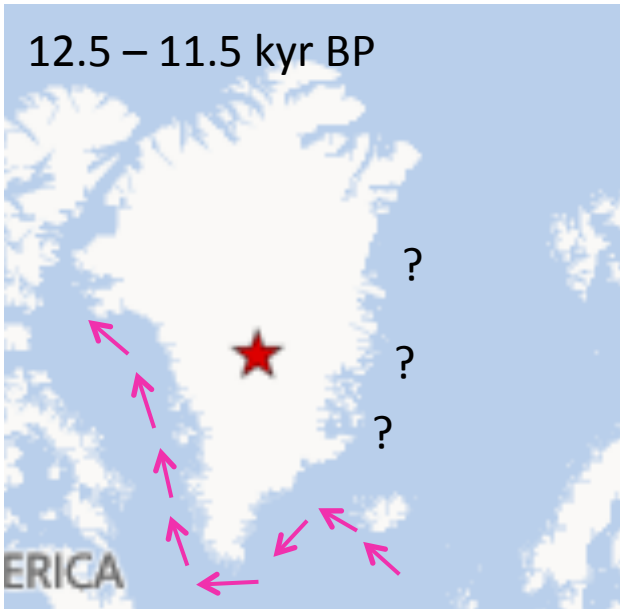




- Chilled AW through IC into SE shelf
- Relatively warm AW via IC to SW of Greenland

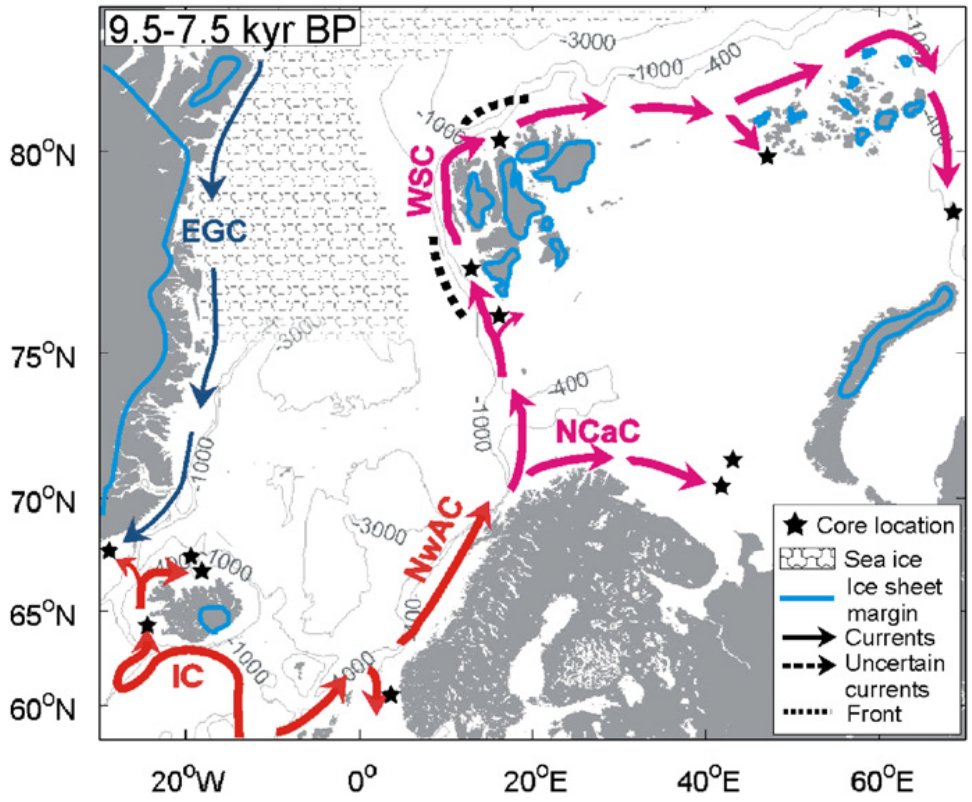
Younger Dryas

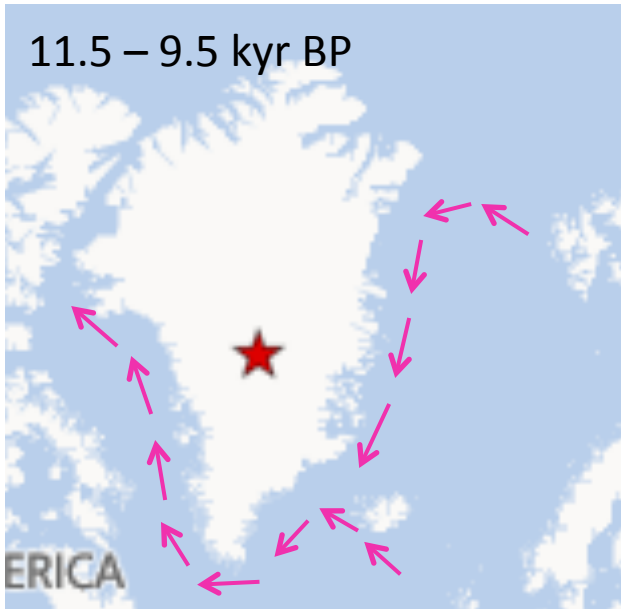


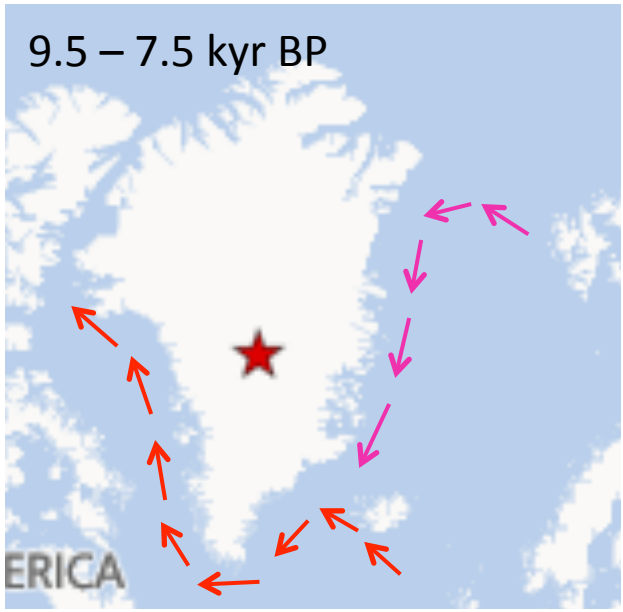


- Chilled AW through IC into SE shelf
- Chilled AW via WGC to northern Baffin Bay

Early Holocene (HTM)

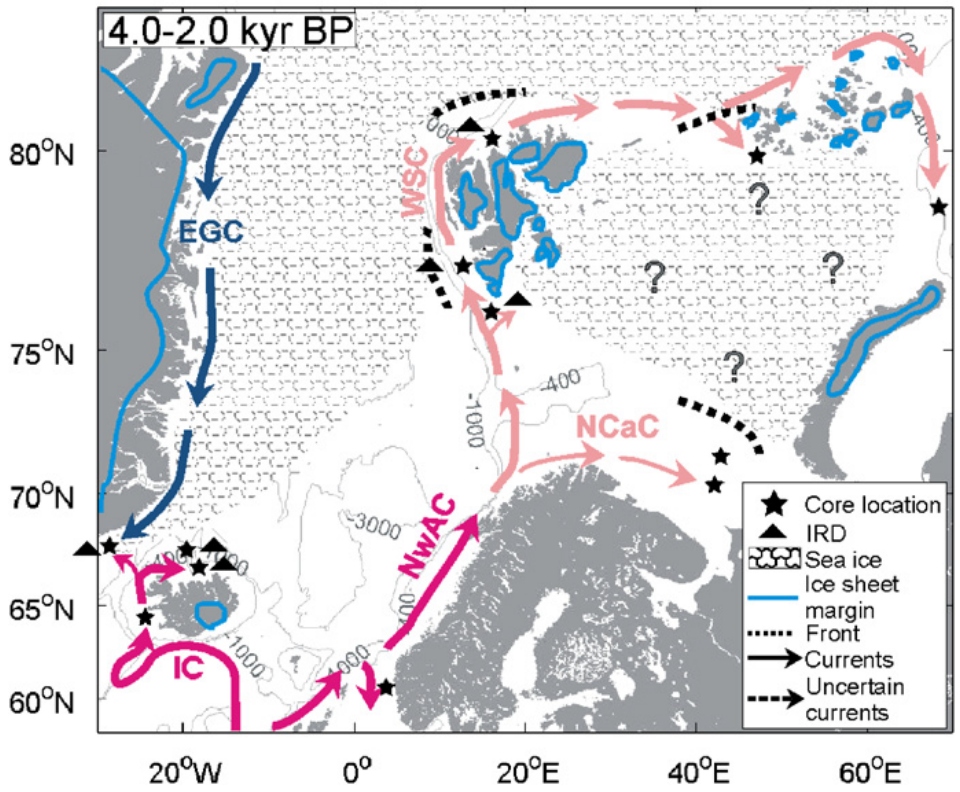


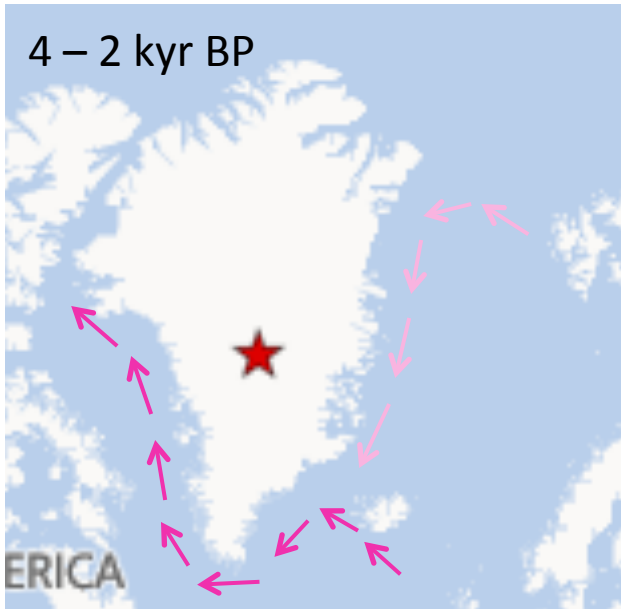




- Chilled AW east Greenland margin post YD
- Relatively warm AW via IC, SE margin and via WGC to SW and W margin
- HTM east: 10 – 6 ka; SE: 8 – 3.5 ka; west: 6.2 – 3.5 ka

Mid-Holocene (Neoglacial)





- Neoglacial cooling of AW:
  - East margin from 5.5 ka
  - SE margin cooling from 5 ka
  - West margin cooling from 3.5 ka

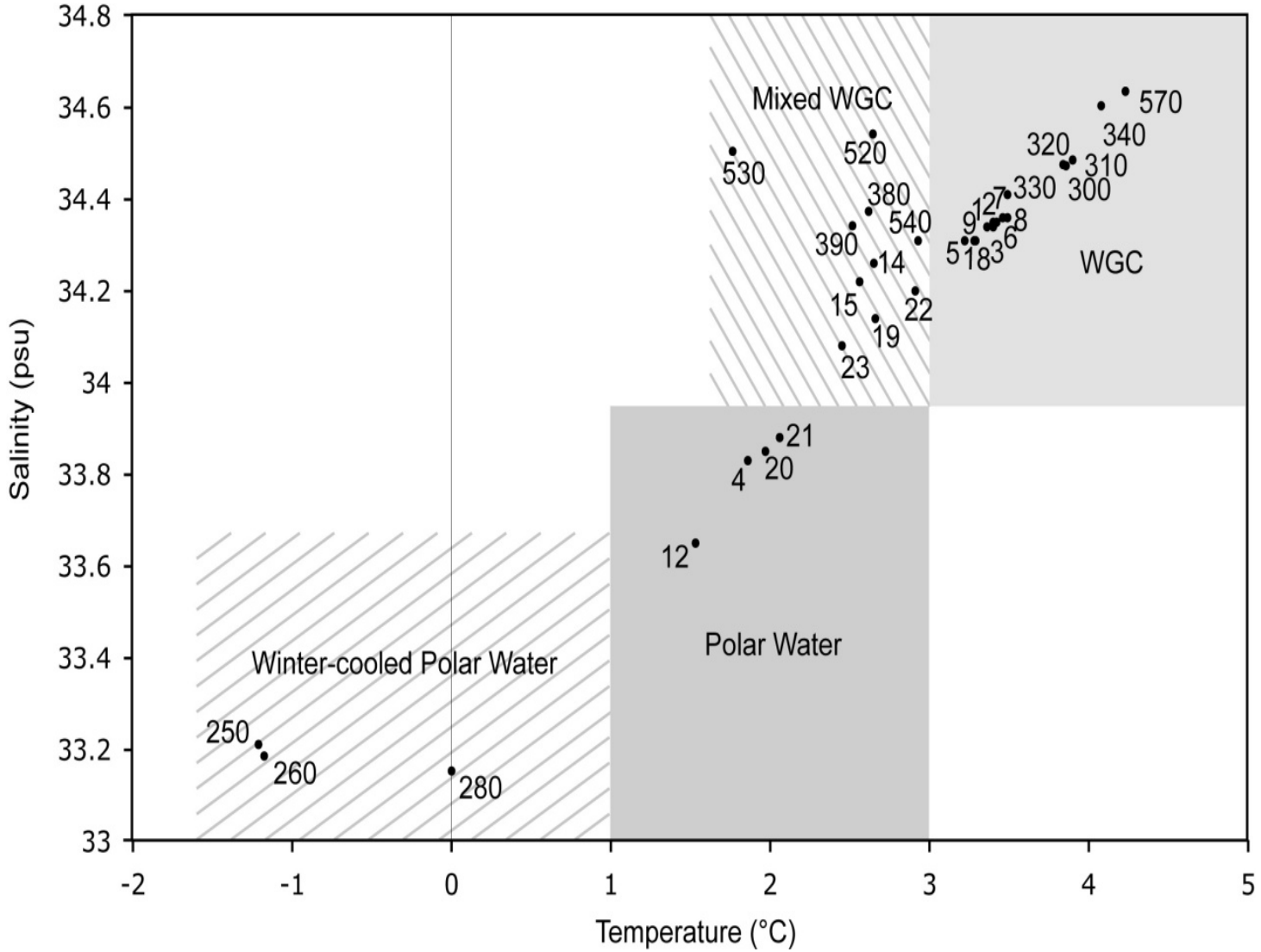
Palaeoceanography - future developments

- Quantitative temperature reconstructions (benthic foram transfer function, Mg/Ca)
- Spatial aspects – where are new records needed from?
  - Continental shelf outside LGM limit?
  - Continental slope?
  - Deeper water basins (Greenland Sea, Baffin Bay)?

Temperature – Salinity characteristics of bottom water

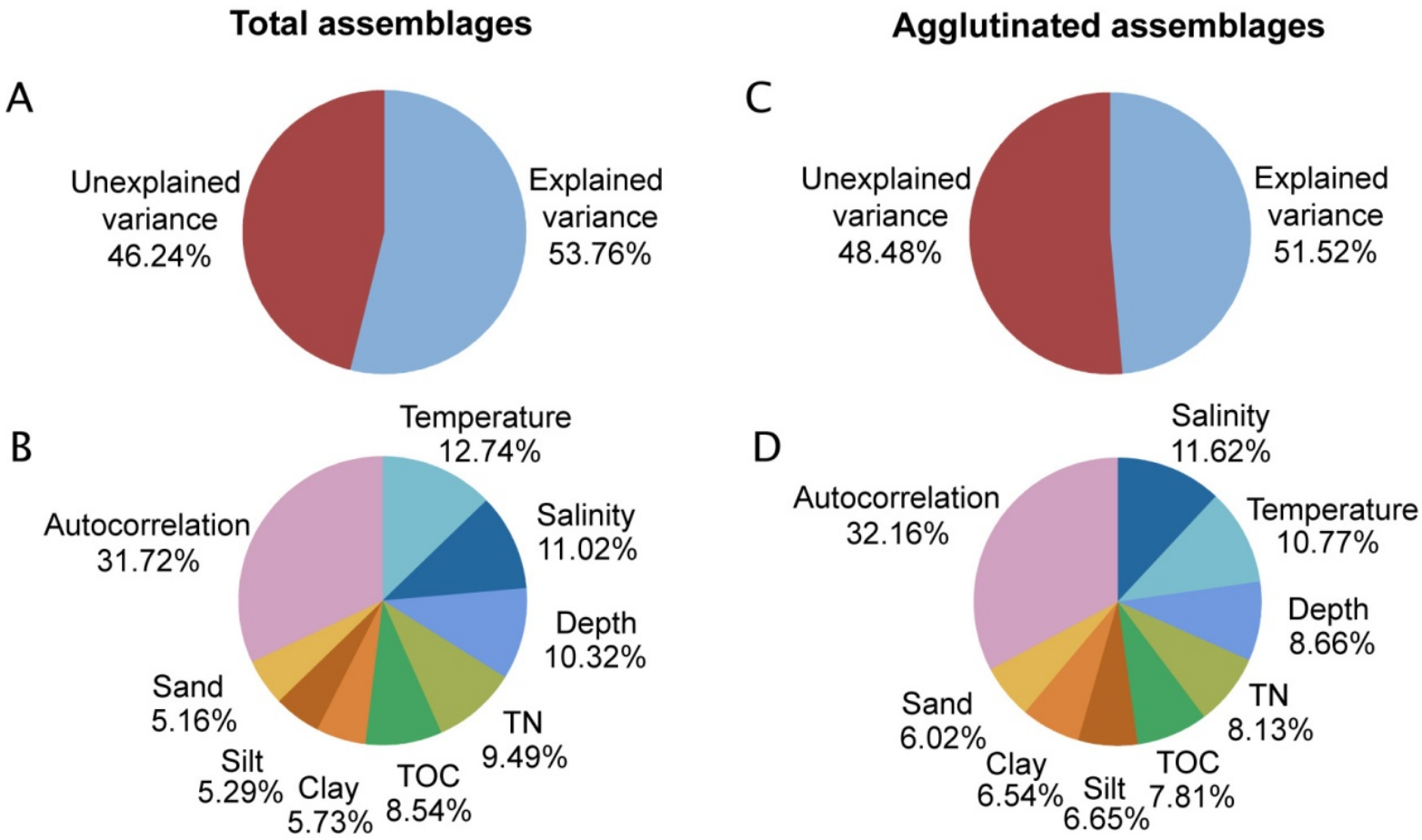
Modern dataset of 40 samples

- Water temperature and salinity
- West Greenland Current strength
- Meltwater flux from ice sheet



Benthic Foraminifera

Relationship with environmental variables (CCA)



Benthic Foraminifera

Modern distribution linked to temperature and salinity

Weighted average optima and tolerances