Linking glaciers, ocean and atmospheric variability – lessons from marine sediment archives

Camilla S. Andresen, Andreea Elena Stoican, Kristian K. Kjeldsen, Kurt H. Kjær, Antoon Kuijpers, Jerry Lloyd and Anne Jennings

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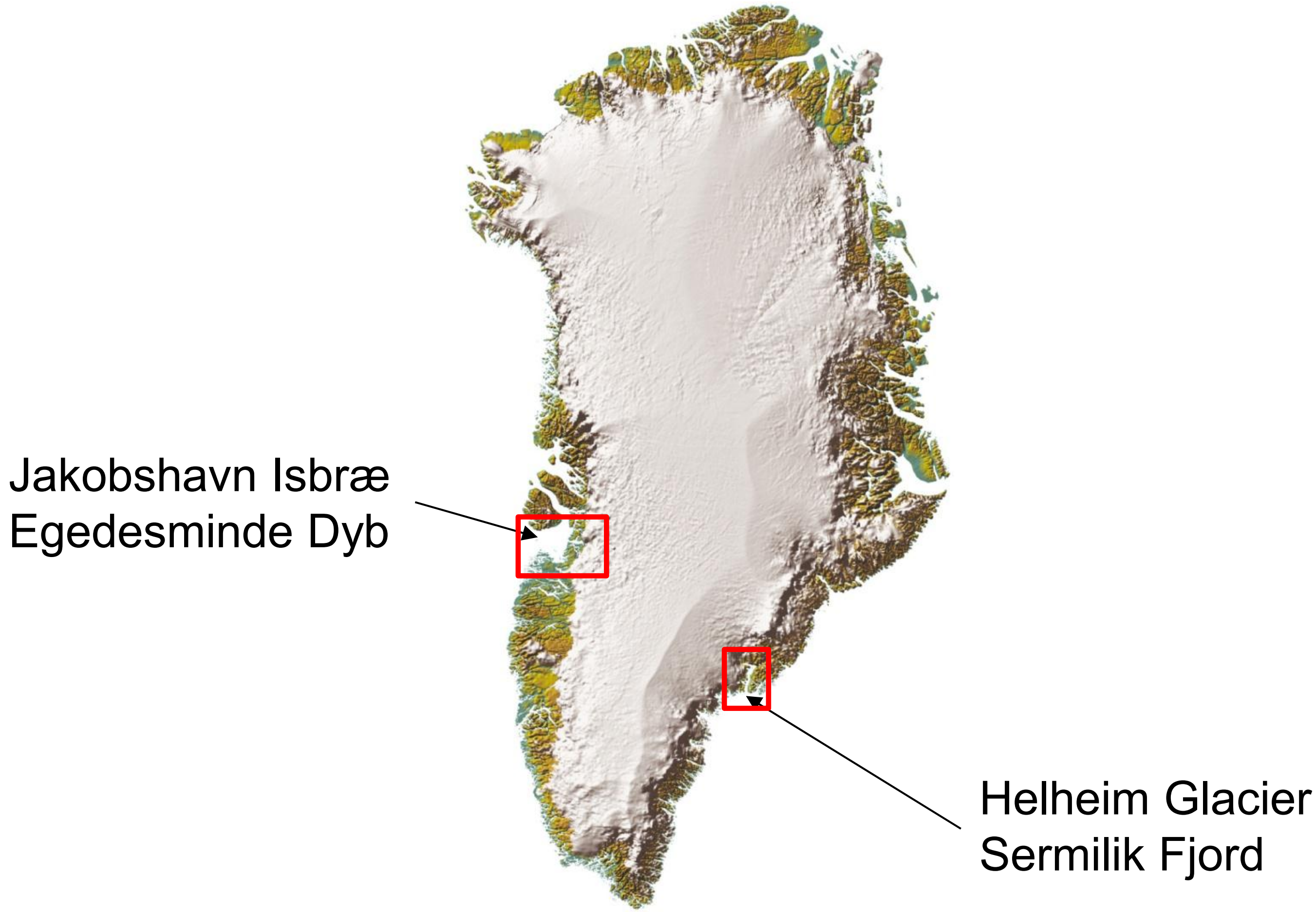
Greenland Ice sheet reconstructions

- and its interaction with ocean, sea ice and climate



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Findings

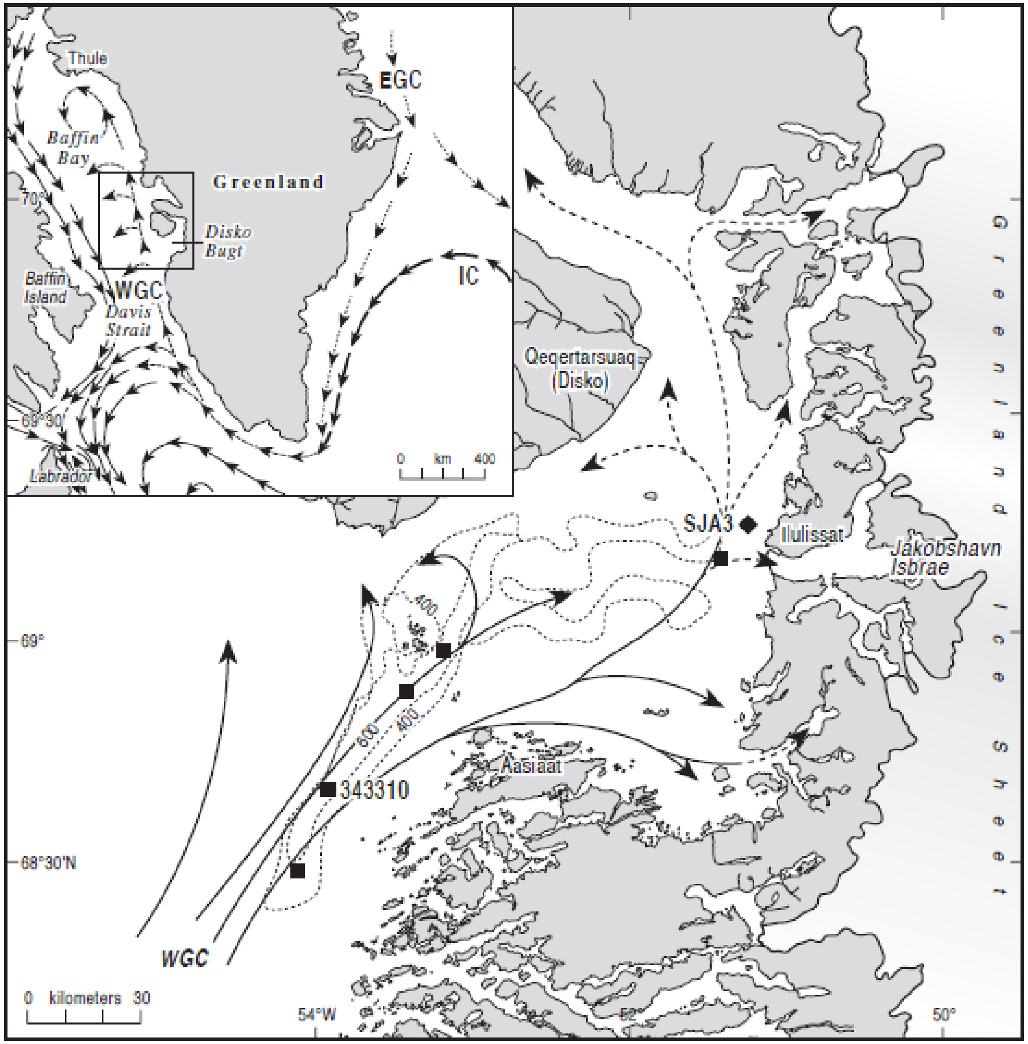
1. The climate drivers behind outlet glacier instability during the past 100 years

2. The late 1930s and early 2000s glacier retreat episodes

3. The potential effect on submarine glacier melt of ambient ocean water

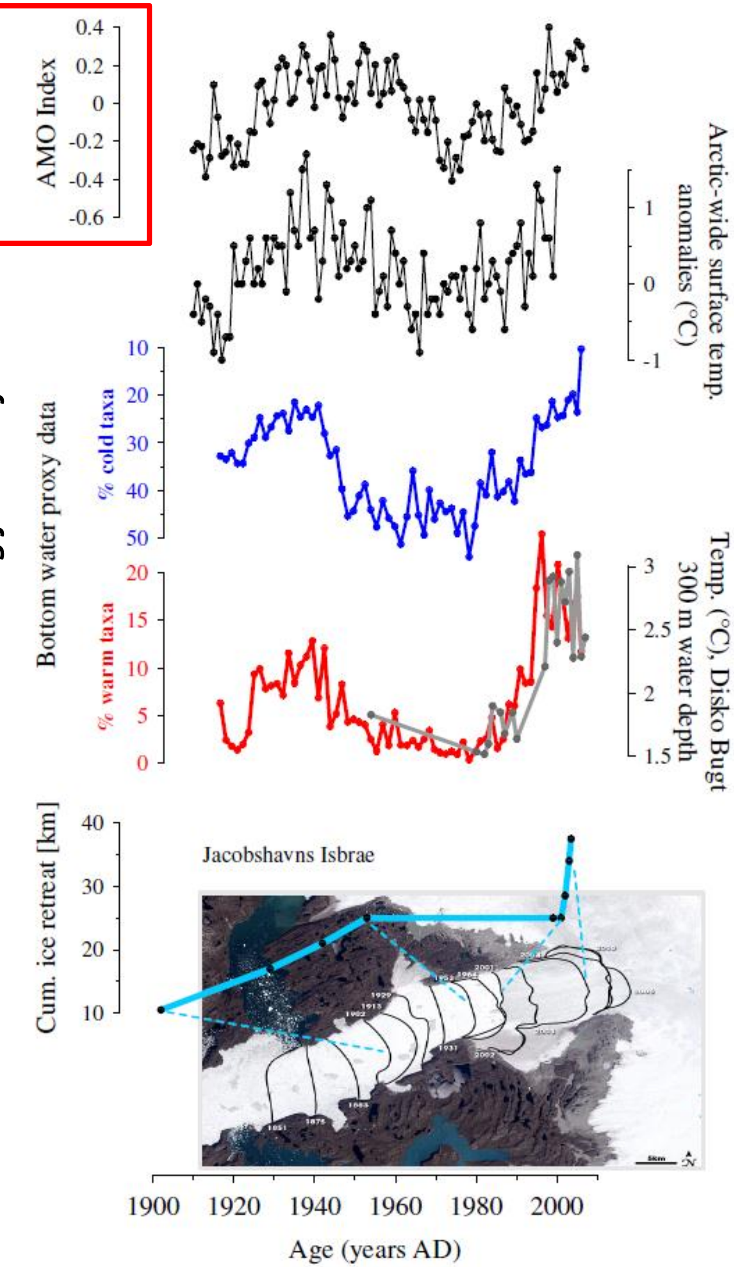
4. Fjord circulation intensity changes on inter-annual time scales

Subsurface water by Disko Bay



Lloyd et al. 2011

Subsurface water by Disko Bay



Bottom-living foraminifera

Lloyd et al. 2011

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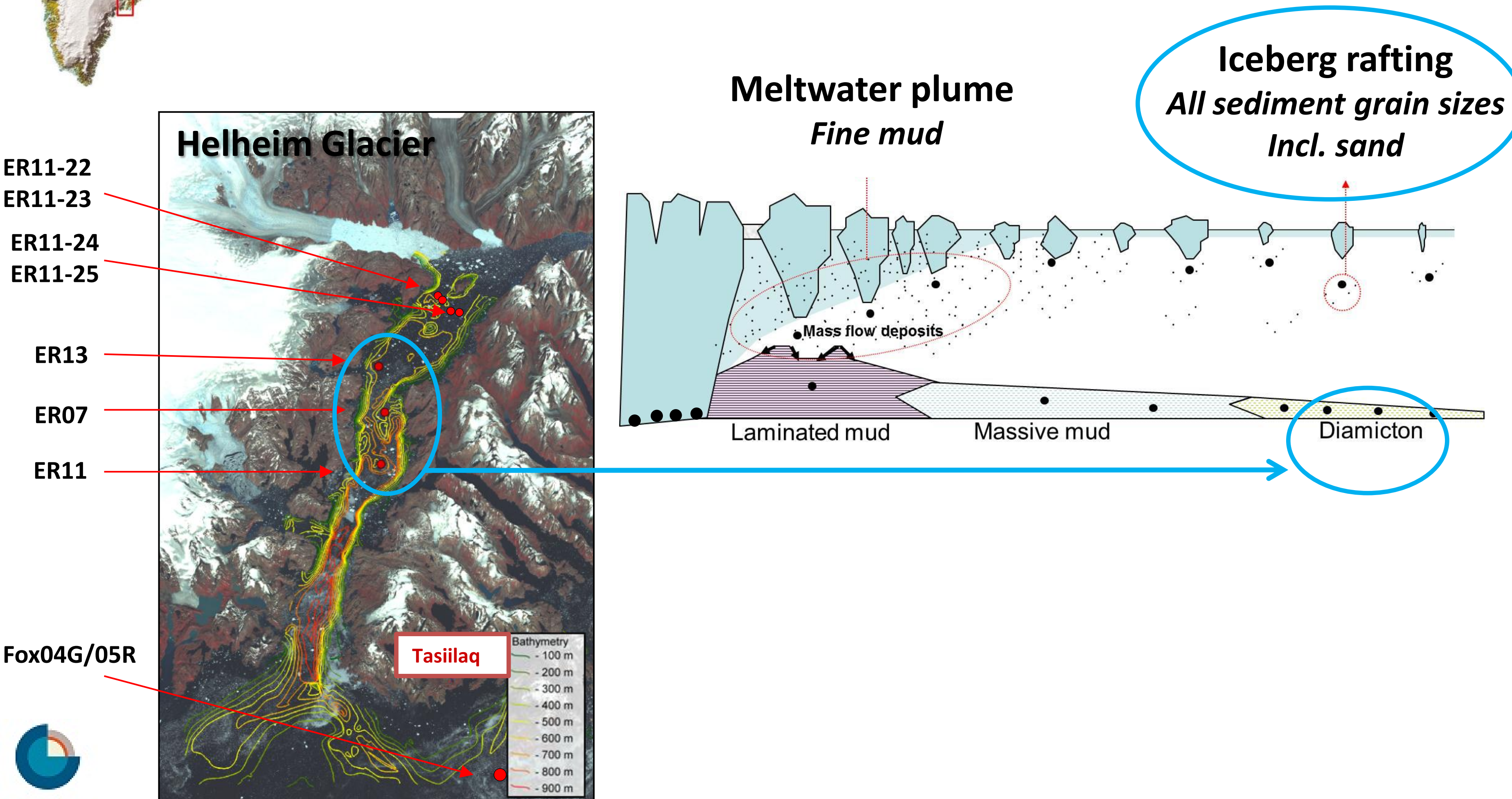

Helheim Glacier
ER11-22
ER11-23
ER11-24
ER11-25
ER13
ER07
ER11
Fox04G/05R
Tasiilaq
Bathymetry
- 100 m
- 200 m
- 300 m
- 400 m
- 500 m
- 600 m
- 700 m
- 800 m
- 900 m
Meltwater plume
Fine mud
Iceberg rafting
All sediment grain sizes
Incl. sand
Mass flow deposits
Laminated mud
Massive mud
Diamicton

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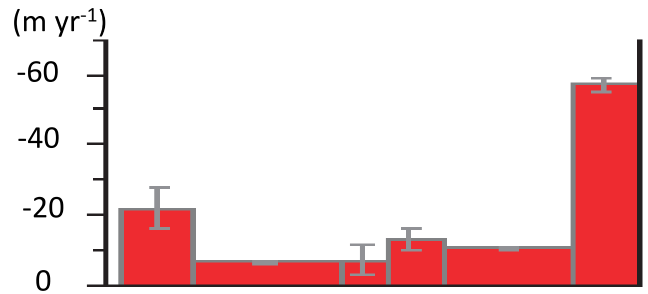
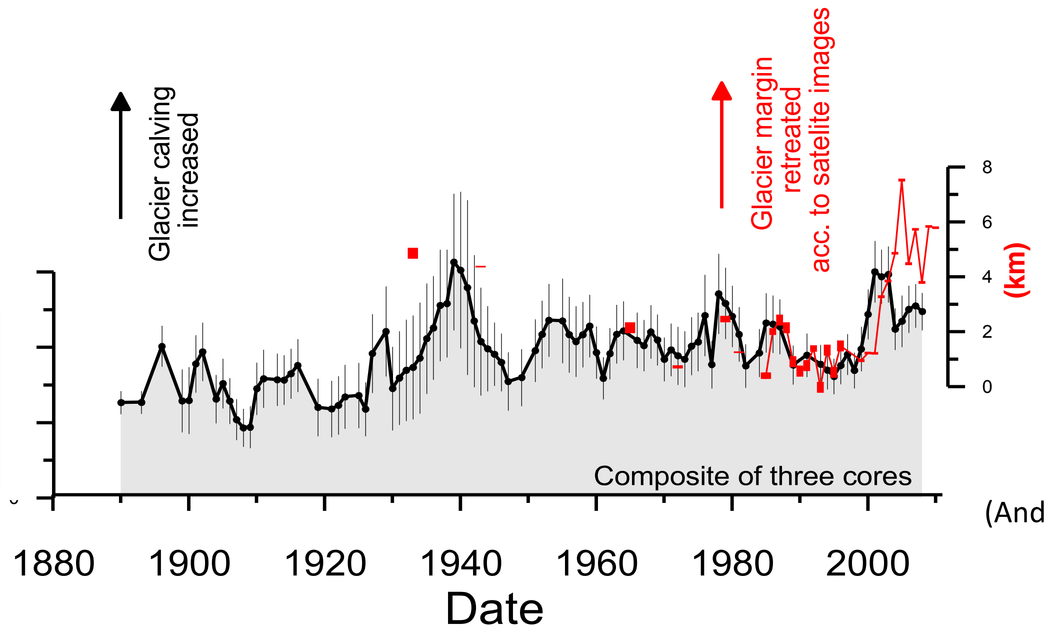
Retreat rate from marine-terminating glaciers in southeast Greenland increases



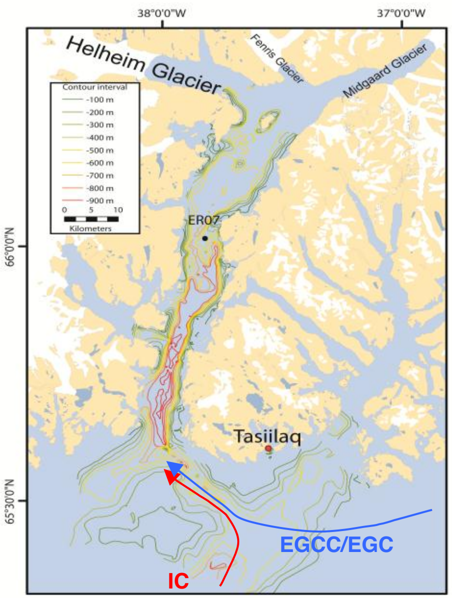
(Bjørk et al. 2012)

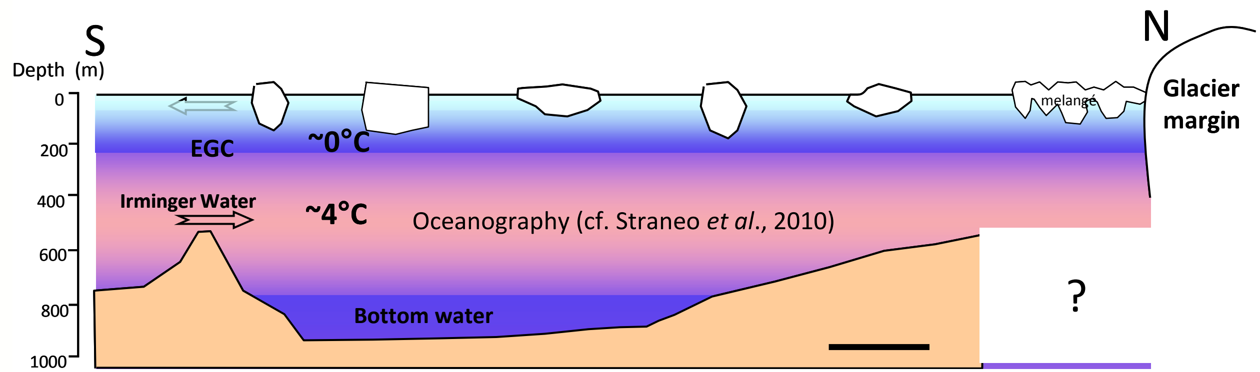
Calving from Helheim Glacier increases

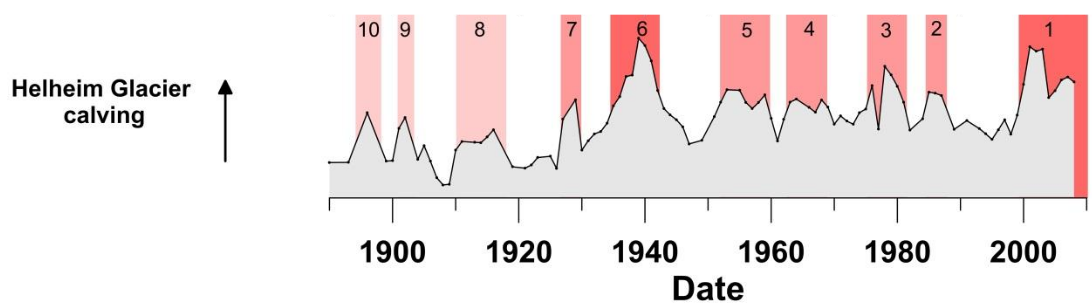


(Andresen et al. 2012)

Comparing the calving record with climate indices

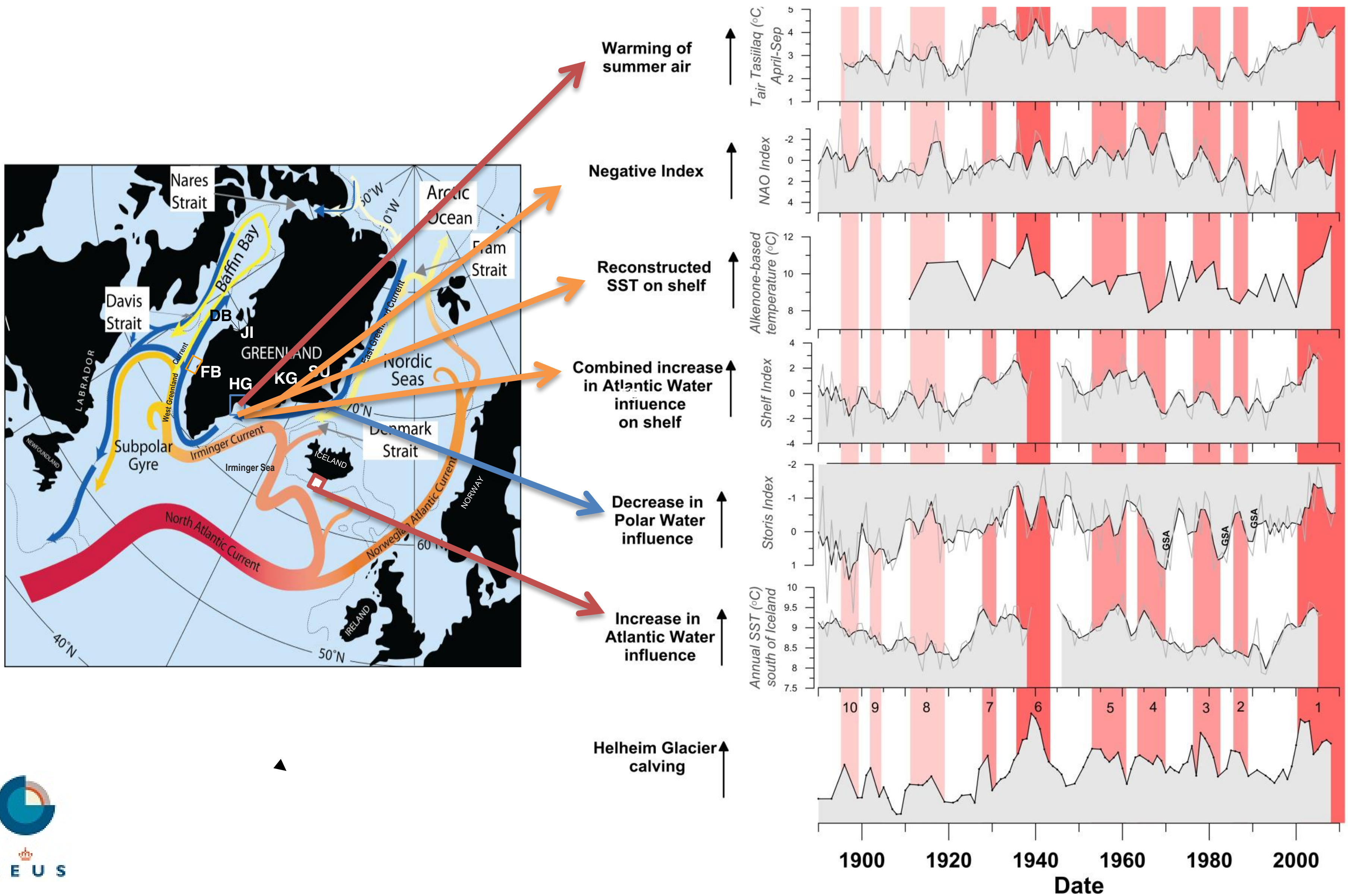






(Andresen et al. 2012)

Comparing the calving record with climate indices



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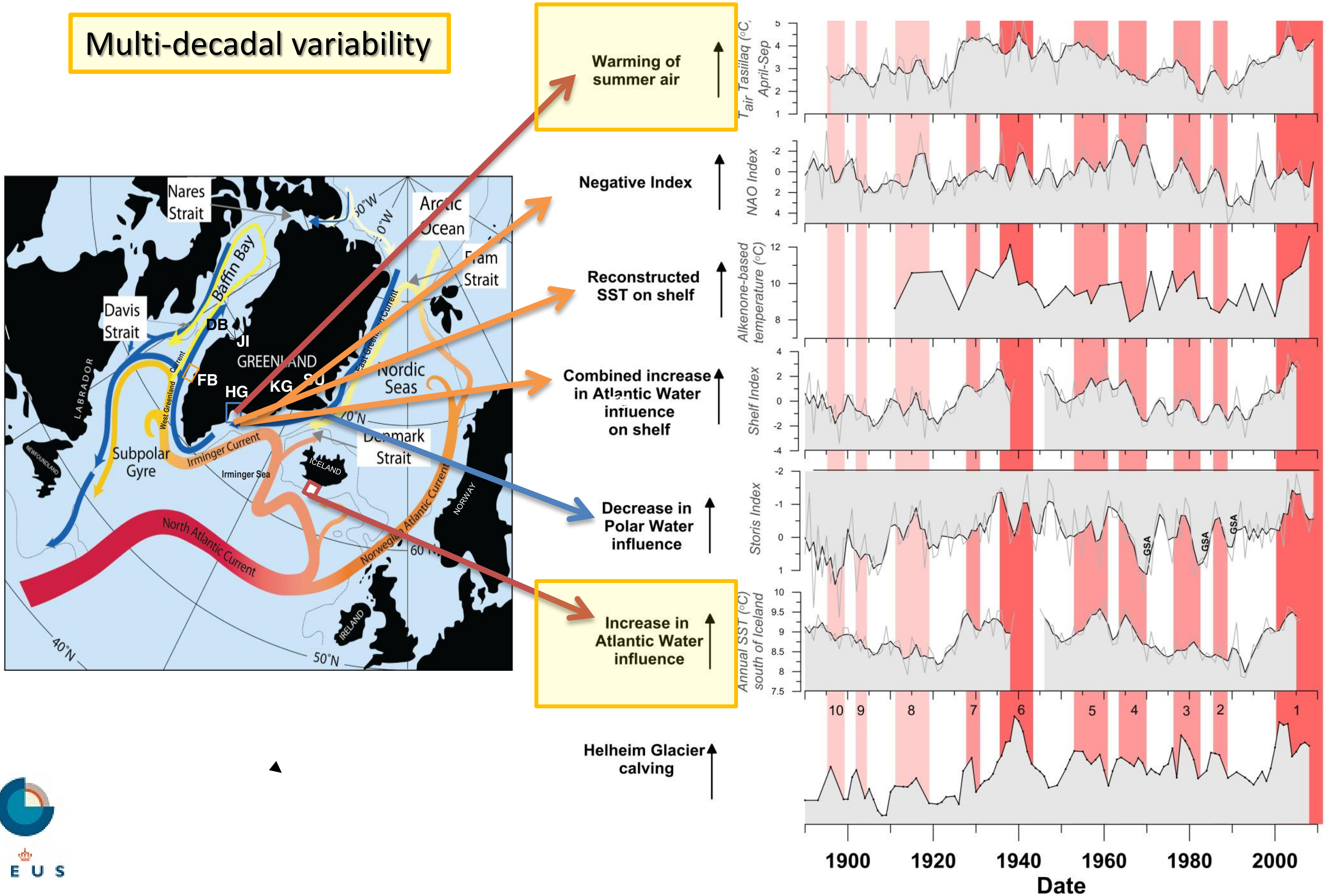
Comparing the calving record with climate indices

Multi-decadal variability



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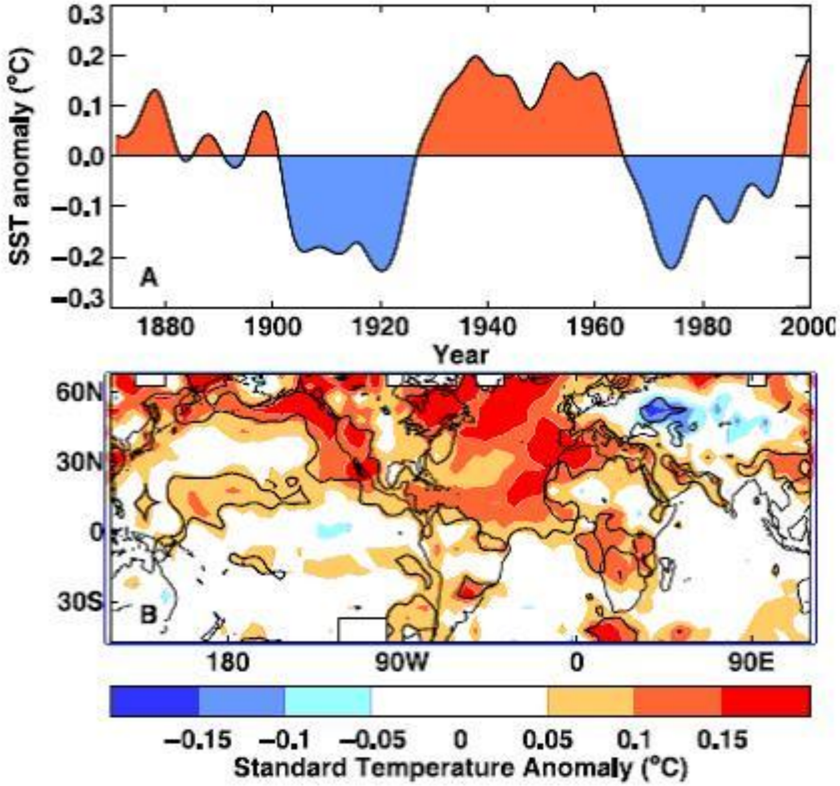
AMO
Atlantic Multidecadal Oscillation



(From Knight *et al.,* 2005)

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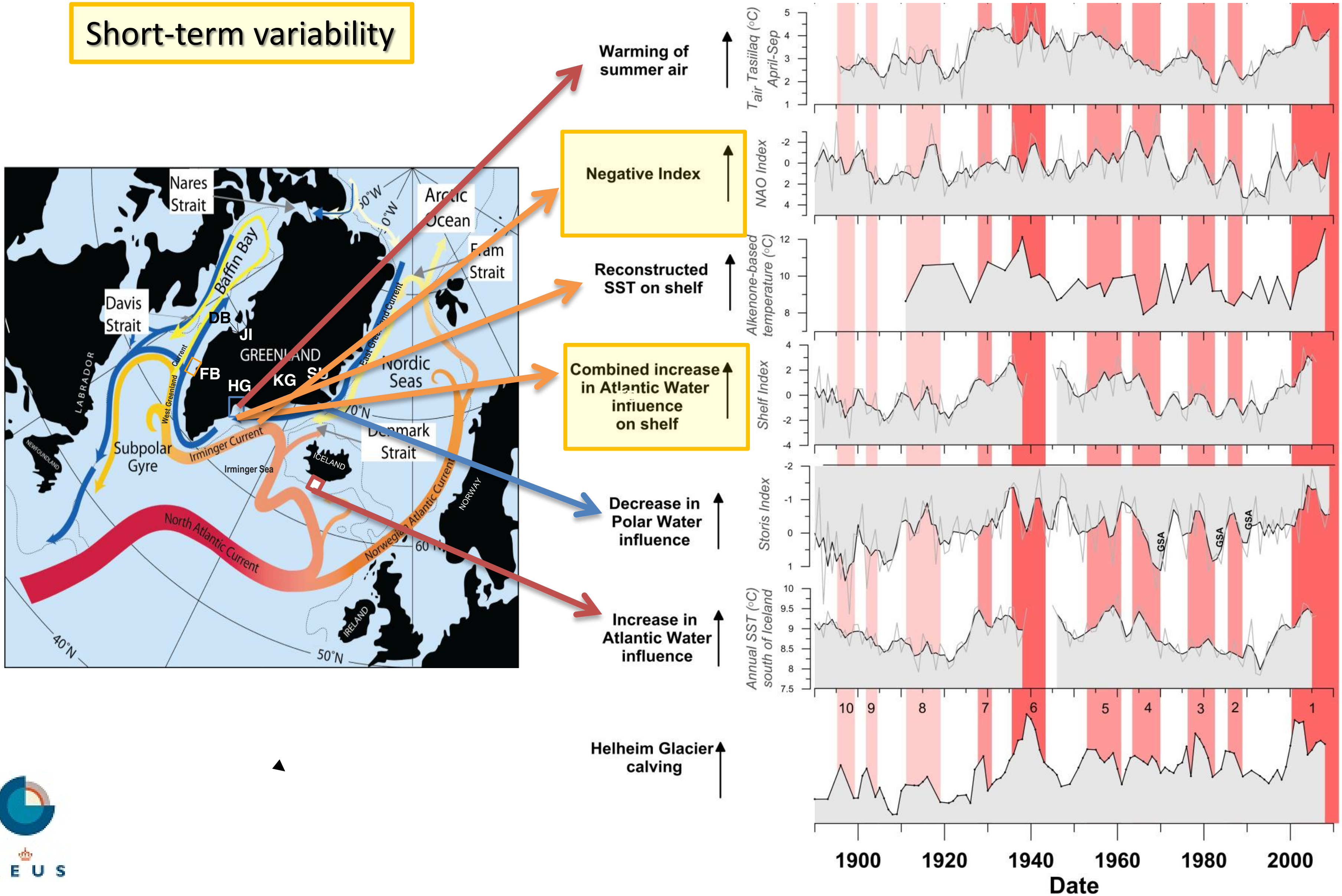
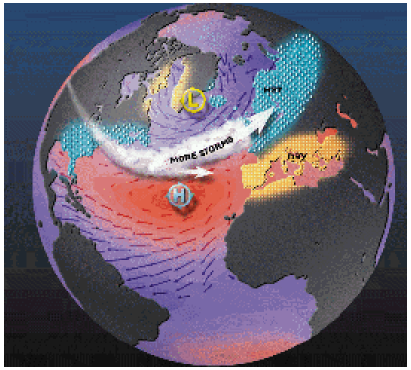
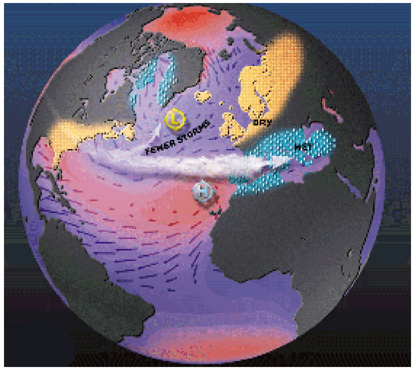
Short-term variability



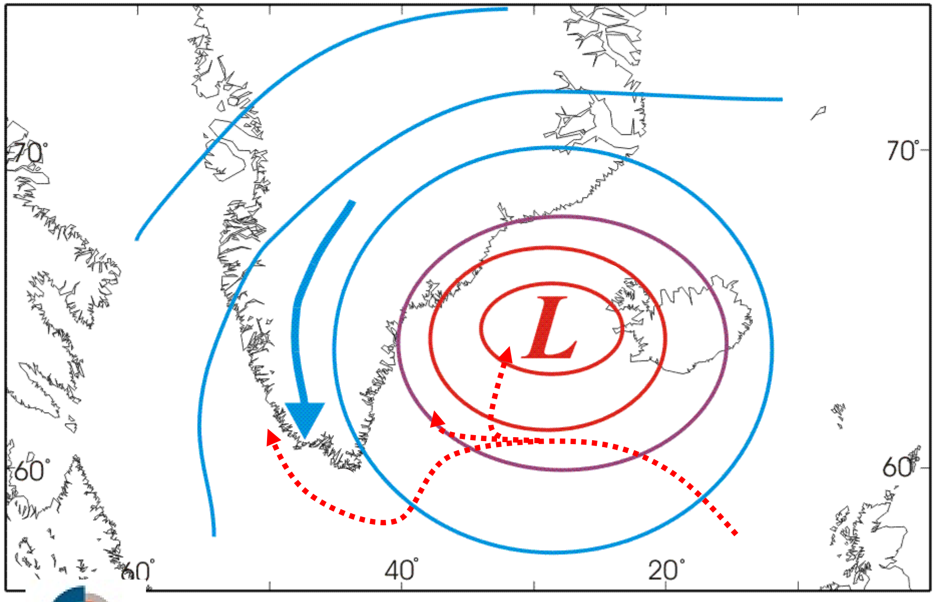
North Atlantic Oscillation

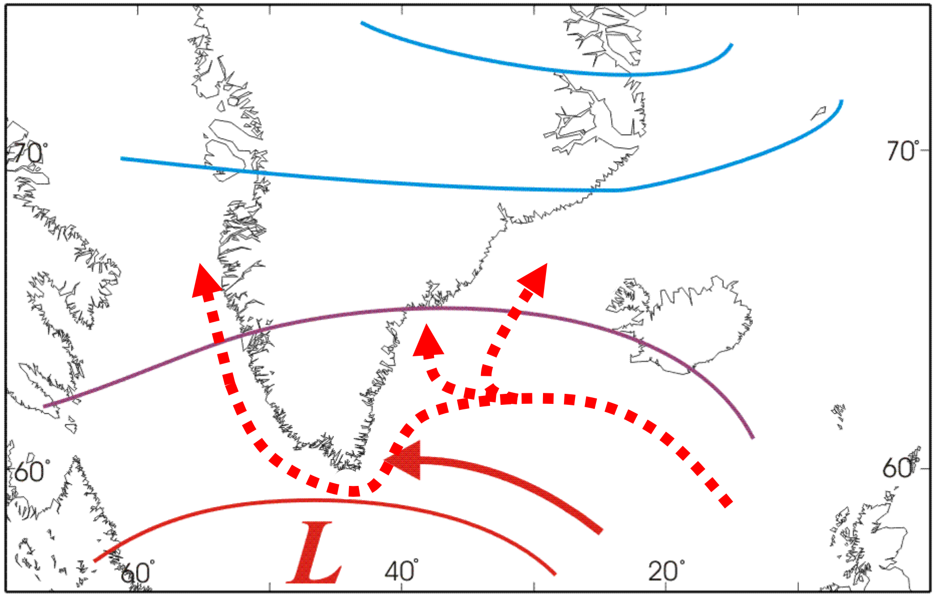


Positive index



Negative index





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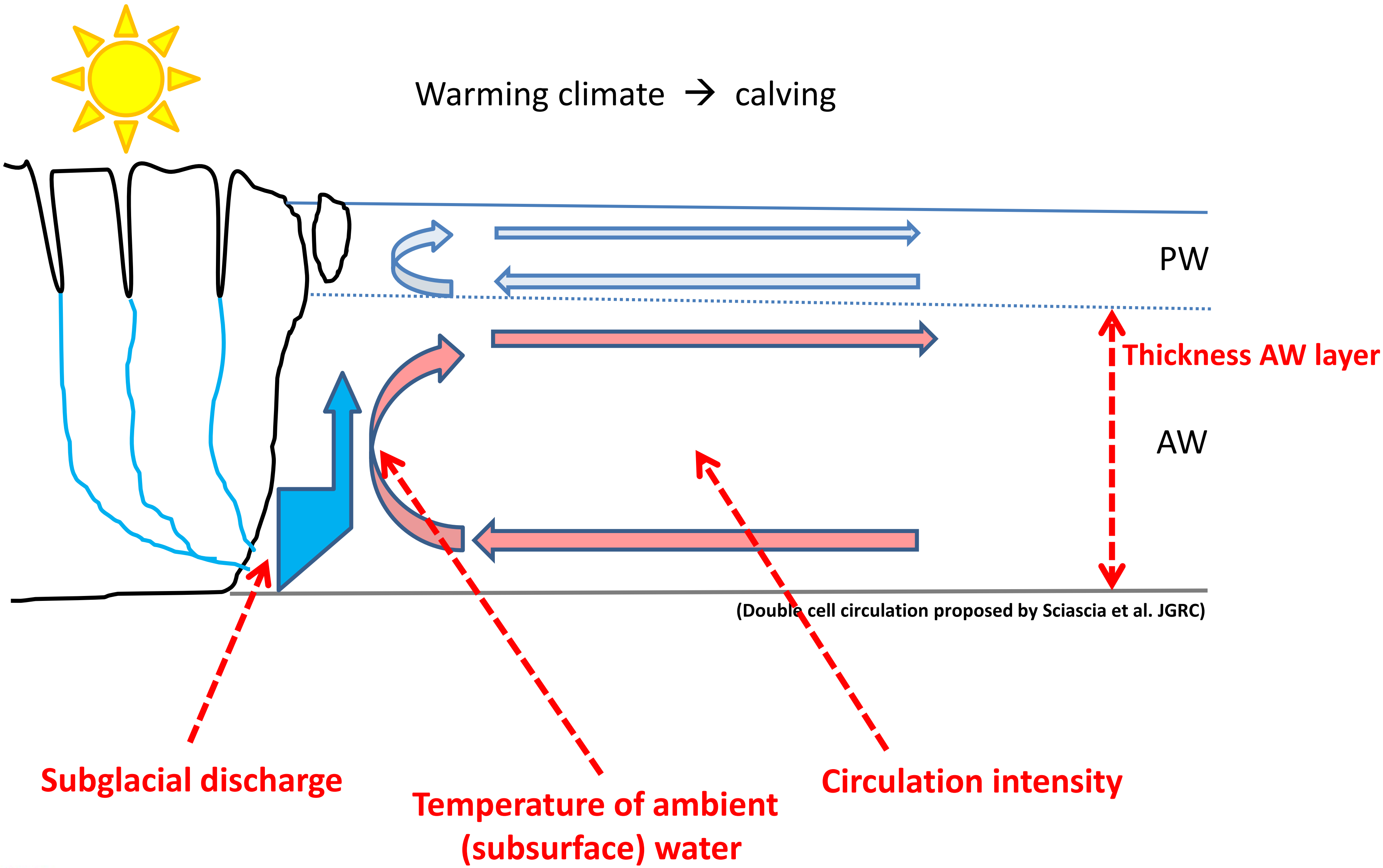

Warming climate → calving
PW
Thickness AW layer
AW
(Double cell circulation proposed by Sciascia et al. JGRC)
Subglacial discharge
Temperature of ambient (subsurface) water
Circulation intensity

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Timing of instability of Jakobshavn Isbræ and Helheim Glacier concurs with:

- a positive Atlantic Multi-decadal Oscillation
- a negative North Atlantic Oscillation index
- changes in sea ice occurrence around Greenland

GEUS

Findings

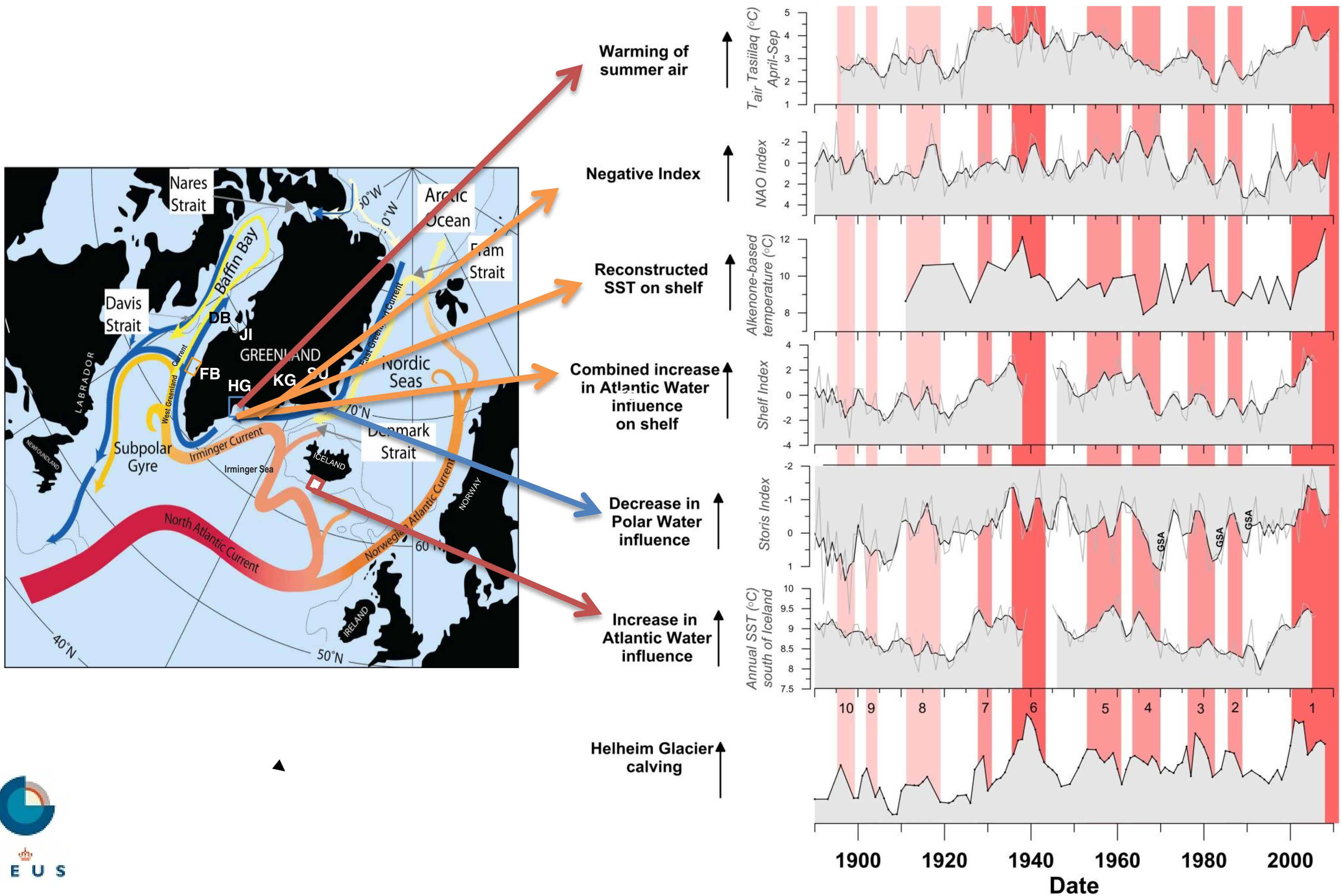
1. The climate drivers behind outlet glacier instability during the past 100 years

2. The late 1930s and early 2000s glacier retreat episodes

3. The potential effect on submarine glacier melt of ambient ocean water

4. Fjord circulation intensity changes on inter-annual time scales

The late 1930s and early 2000s marked glacier retreats



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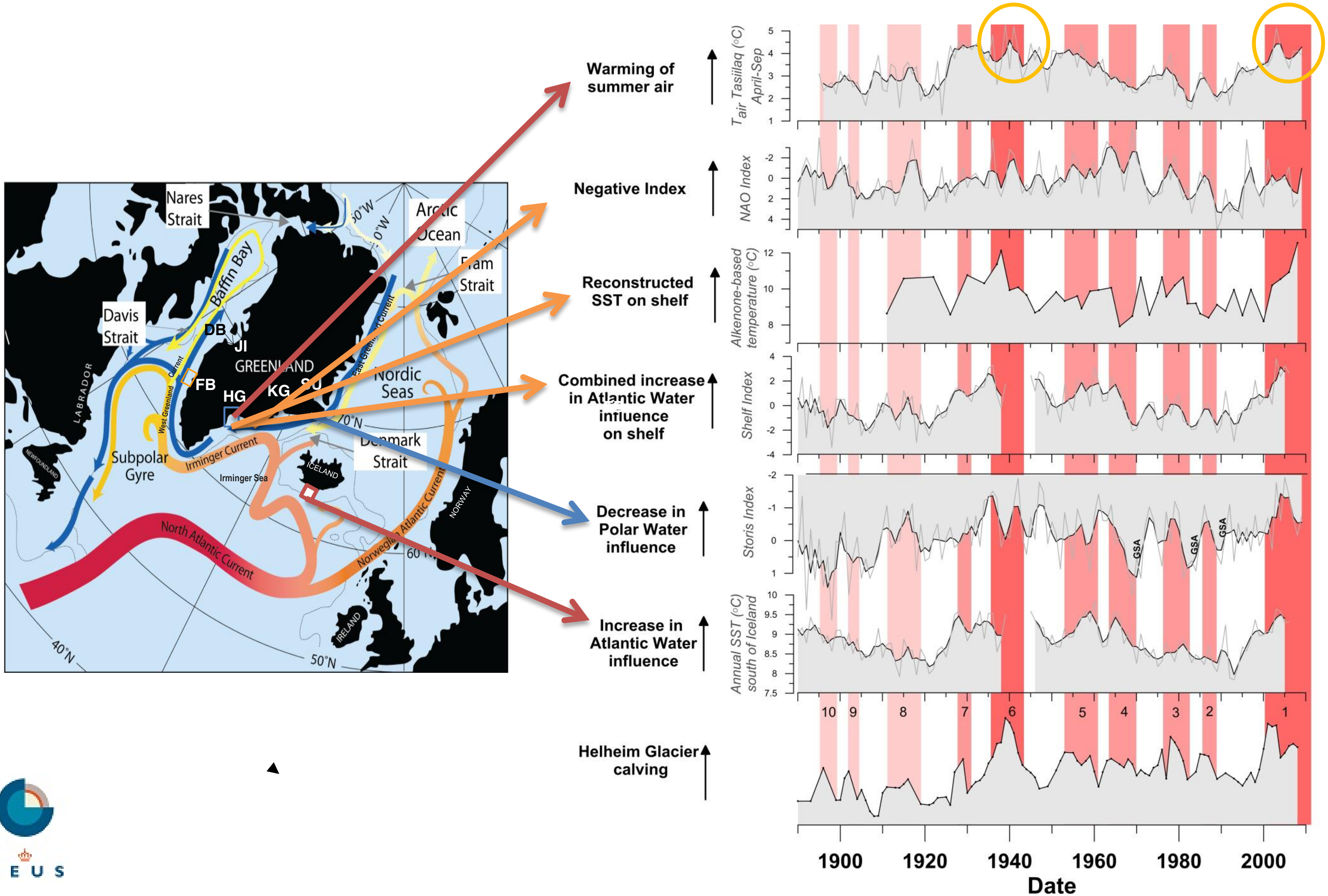

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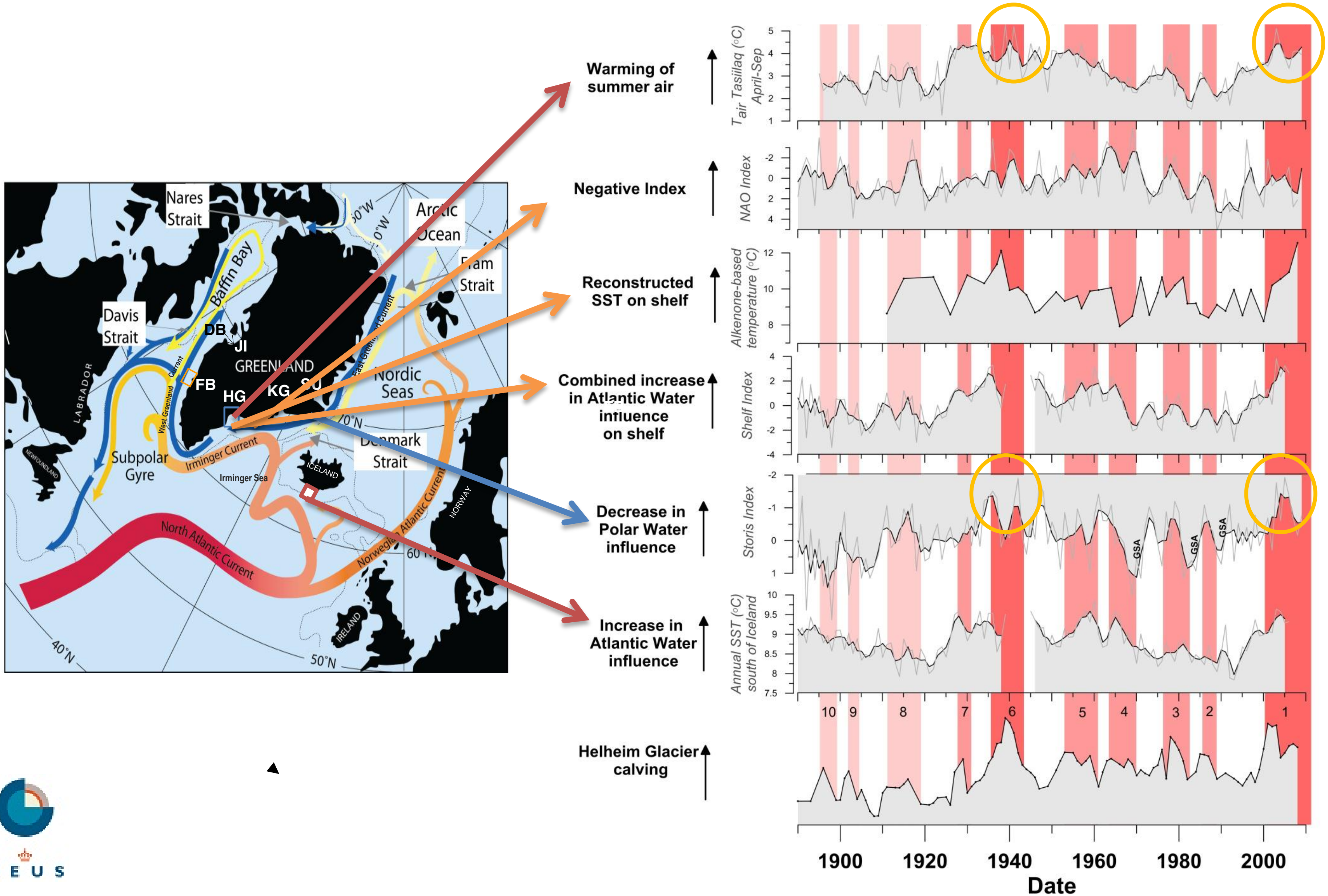
The late 1930s and early 2000s marked glacier retreats



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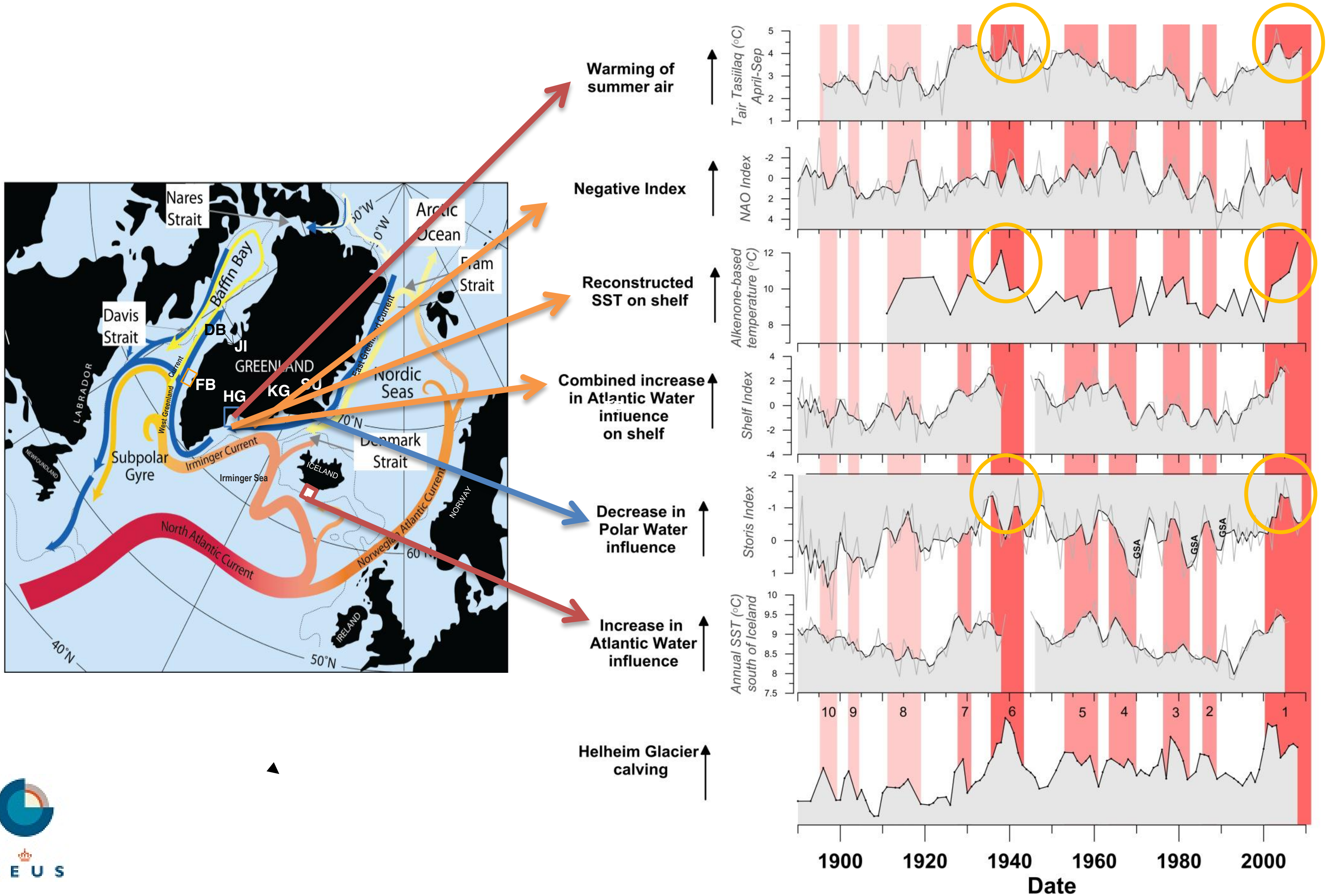
The late 1930s and early 2000s marked glacier retreats



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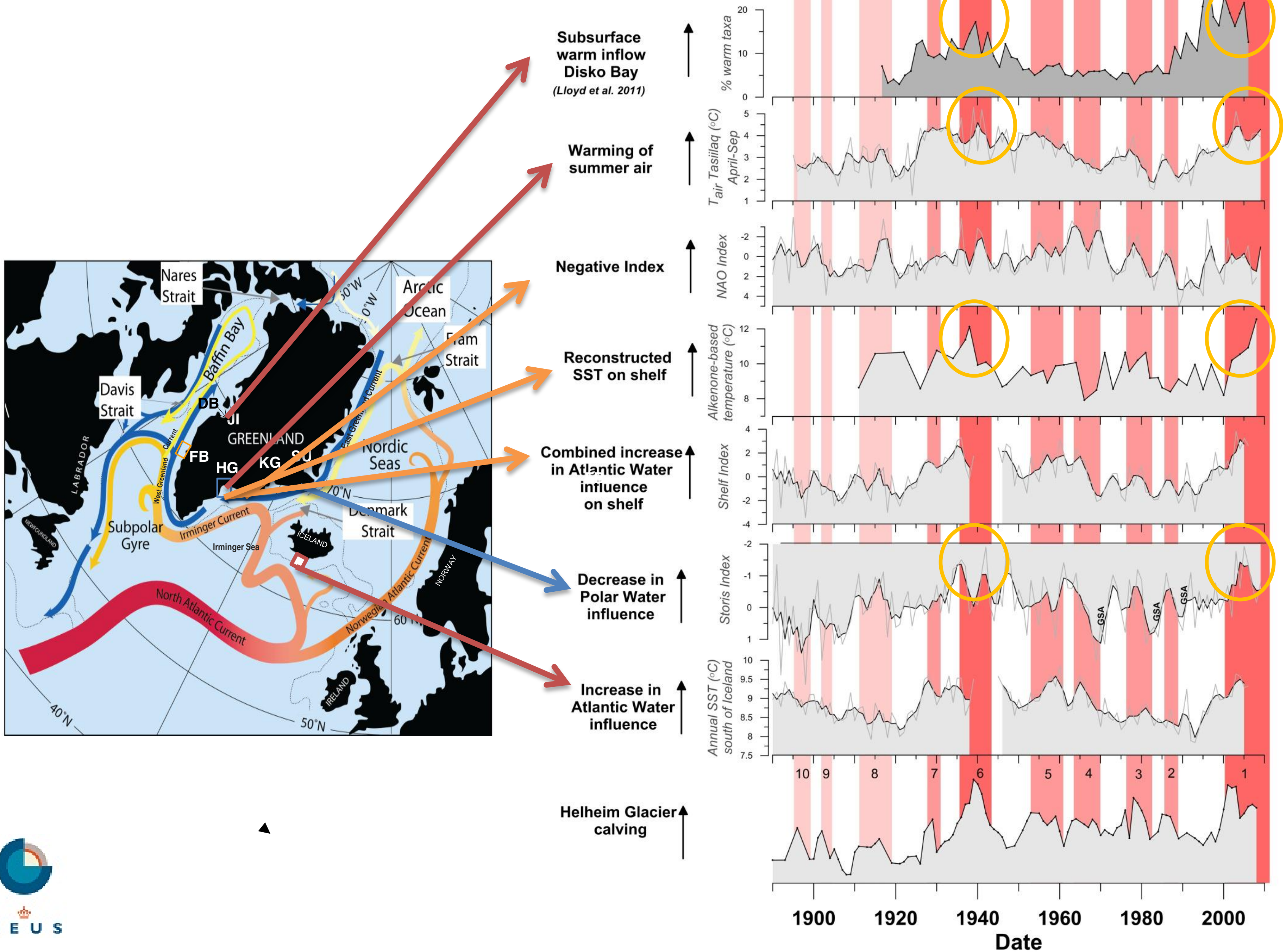
The late 1930s and early 2000s marked glacier retreats



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The late 1930s and early 2000s episodes of marked glacier retreat of Jakobshavn Isbræ and Helheim Glacier may stand out due to the coincidence of:

Subsurface warming of the ocean around Greenland
Record low sea ice occurrence
Record warm summer air

GEUS

Findings

1. The climate drivers behind outlet glacier instability during the past 100 years

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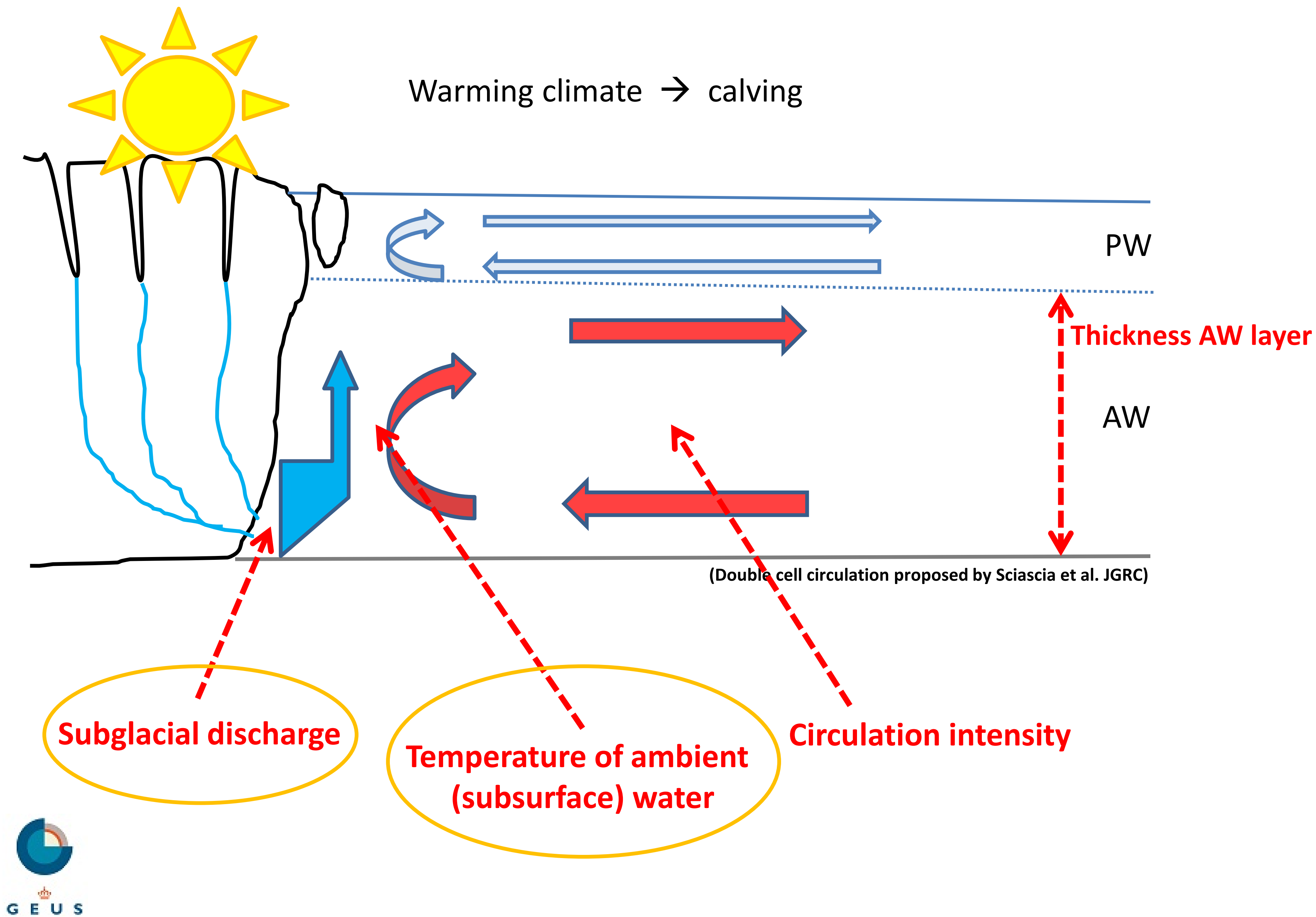
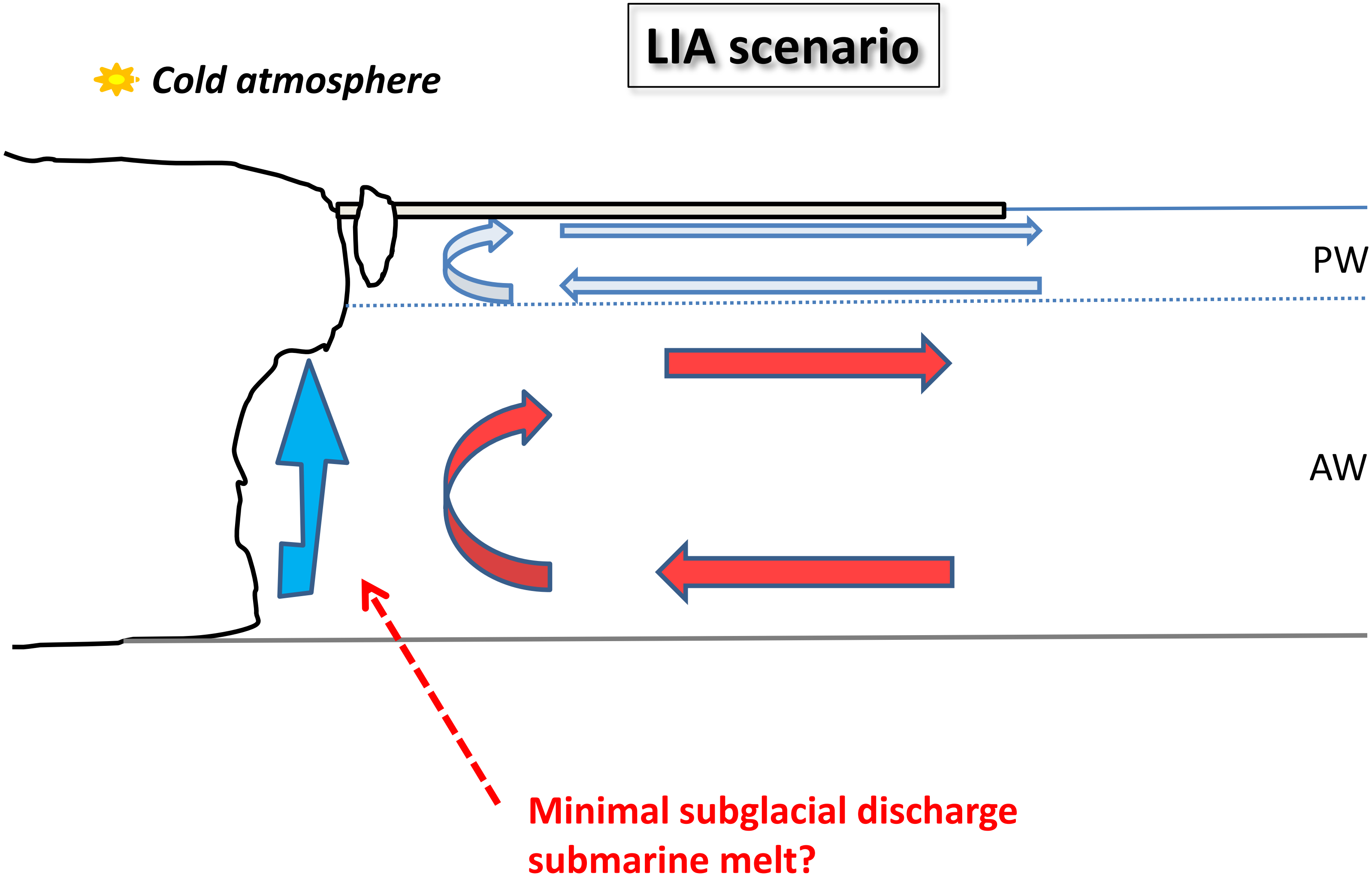


Warming climate → calving
PW
Thickness AW layer
AW
(Double cell circulation proposed by Sciascia et al. JGRC)
Subglacial discharge
Temperature of ambient (subsurface) water
Circulation intensity
G E U S


LIA scenario
Cold atmosphere
PW
AW
Minimal subglacial discharge
submarine melt?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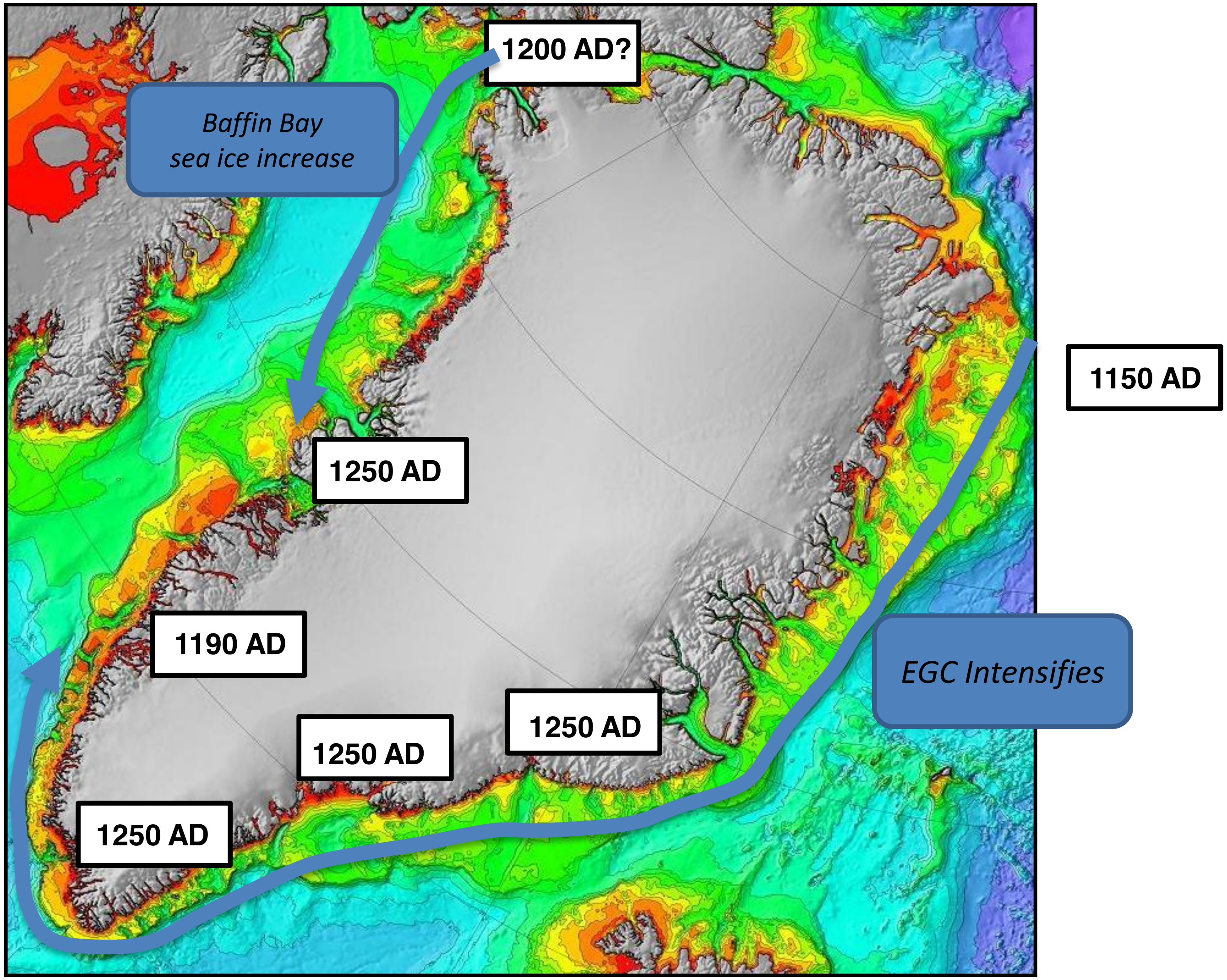
Onset LIA
Associated oceanographic change



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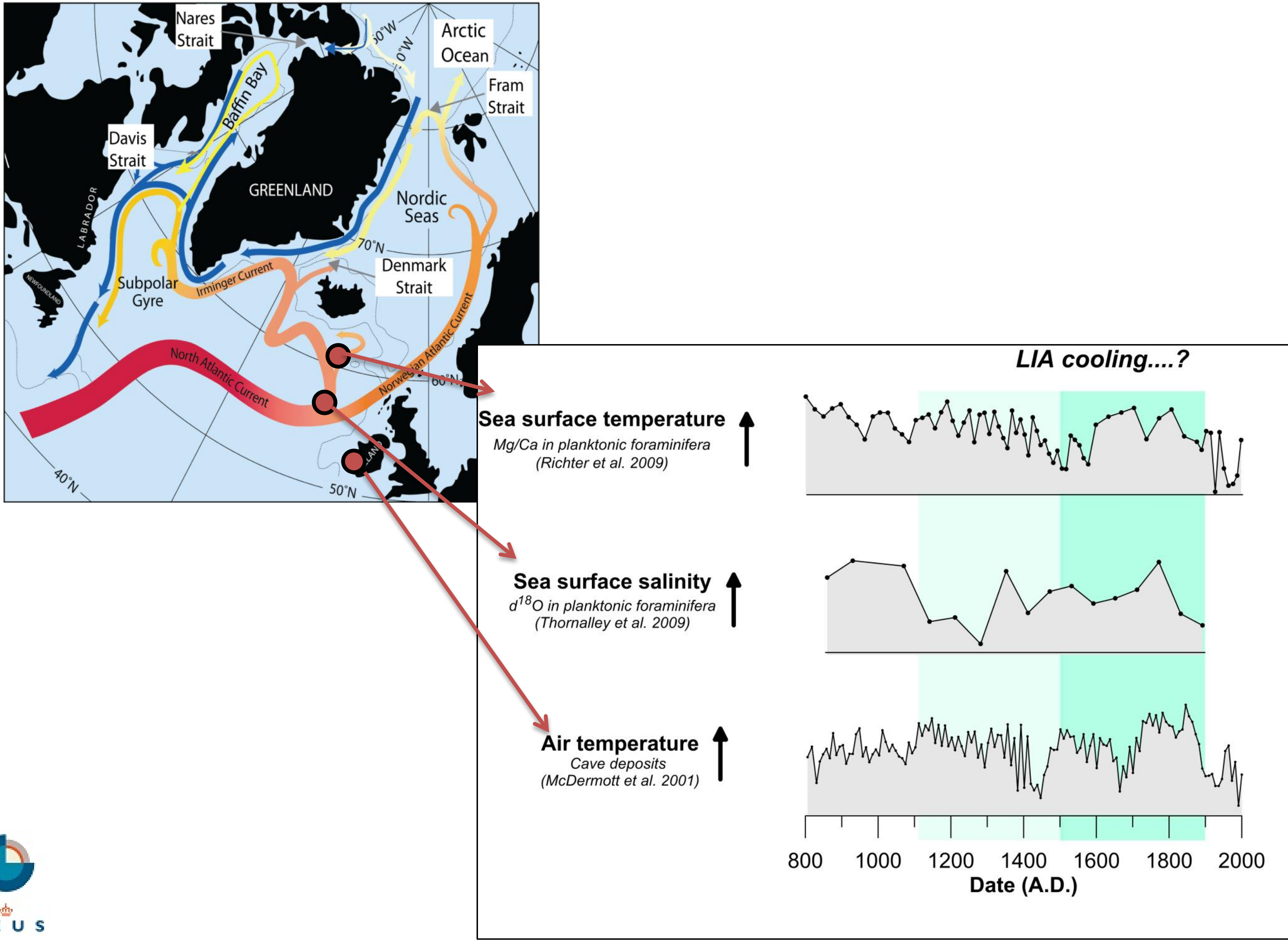
Nares Strait
Arctic Ocean
Fram Strait
Baffin Bay
Davis Strait
GREENLAND
Nordic Seas
LABRADOR
70°N
Denmark Strait
Irminger Current
Subpolar Gyre
NEWFOUNDLAND
North Atlantic Current
Norwegian Atlantic Current
60°N
40°N
50°N
LIA cooling....?
Sea surface temperature
Mg/Ca in planktonic foraminifera
(Richter et al. 2009)
Sea surface salinity
d18O in planktonic foraminifera
(Thornalley et al. 2009)
Air temperature
Cave deposits
(McDermott et al. 2001)
800
1000
1200
1400
1600
1800
2000
Date (A.D.)

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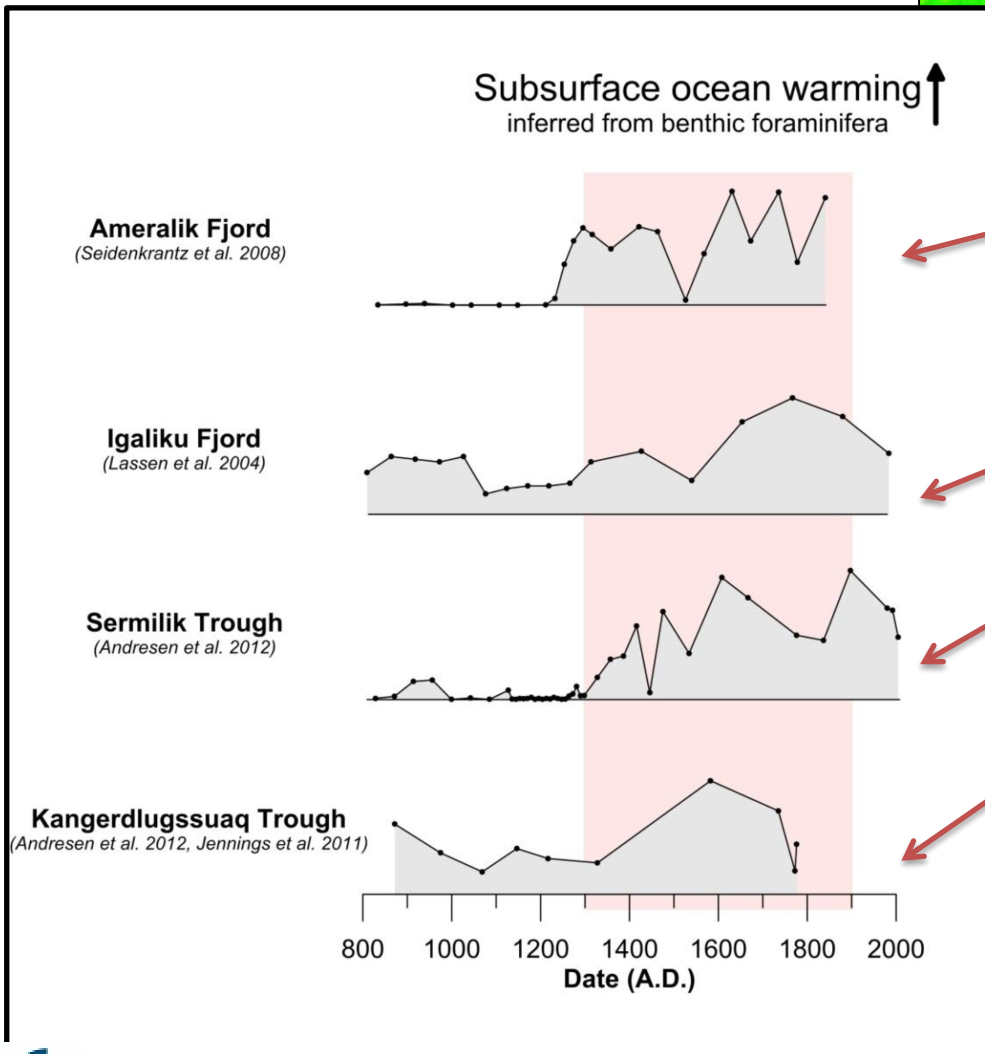
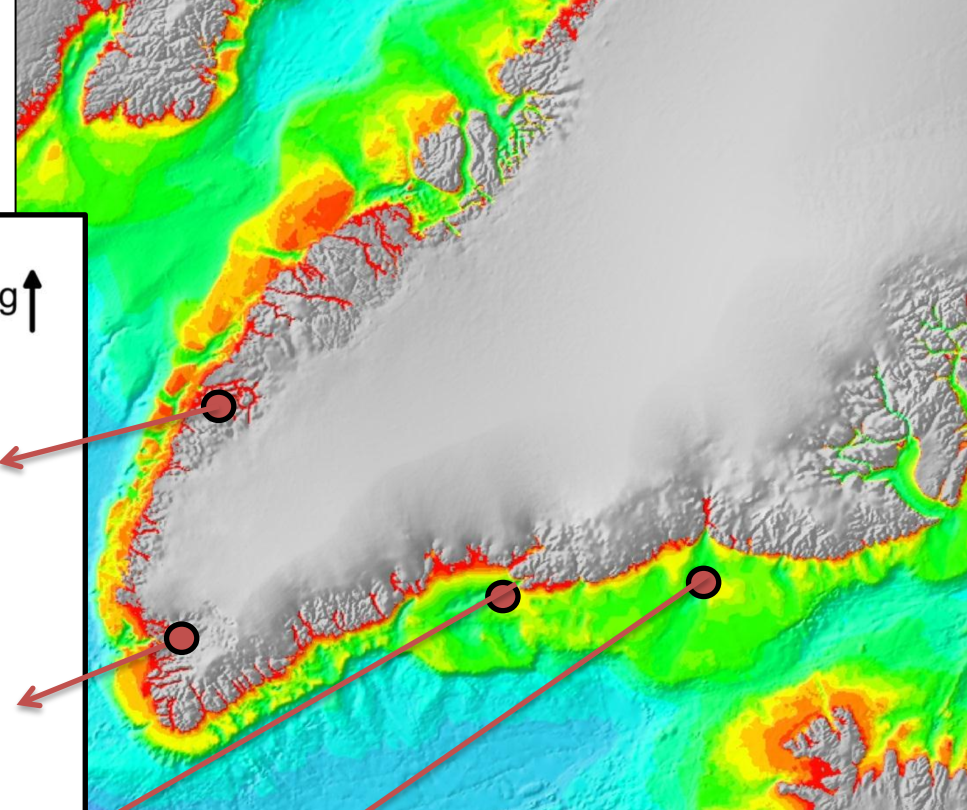
Little Ice Age submarine melt

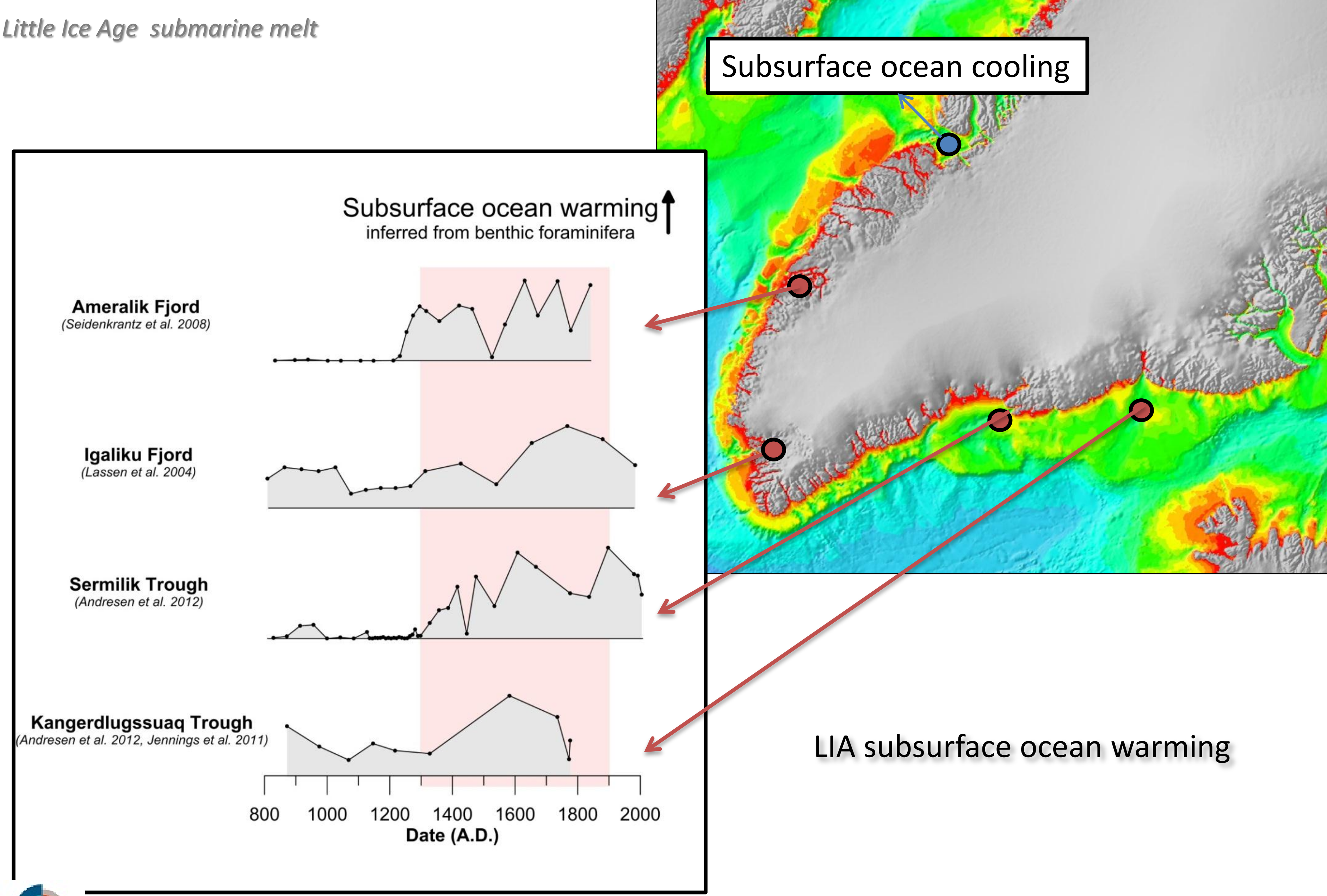




LIA subsurface ocean warming

GEUS

Little Ice Age submarine melt



LIA subsurface ocean warming

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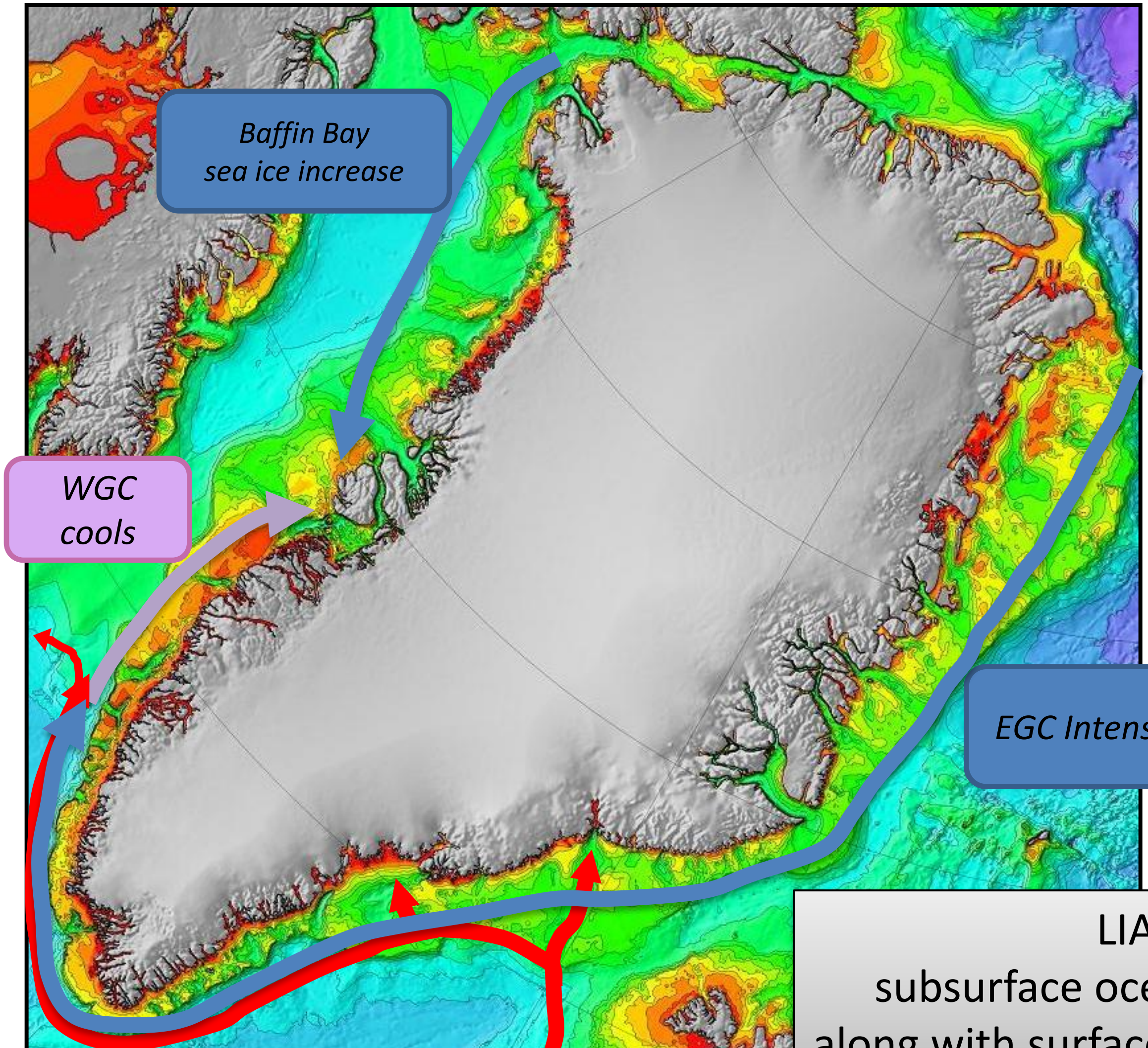
Onset LIA
Associated oceanographic change



LIA:
subsurface ocean warming
along with surface ocean cooling

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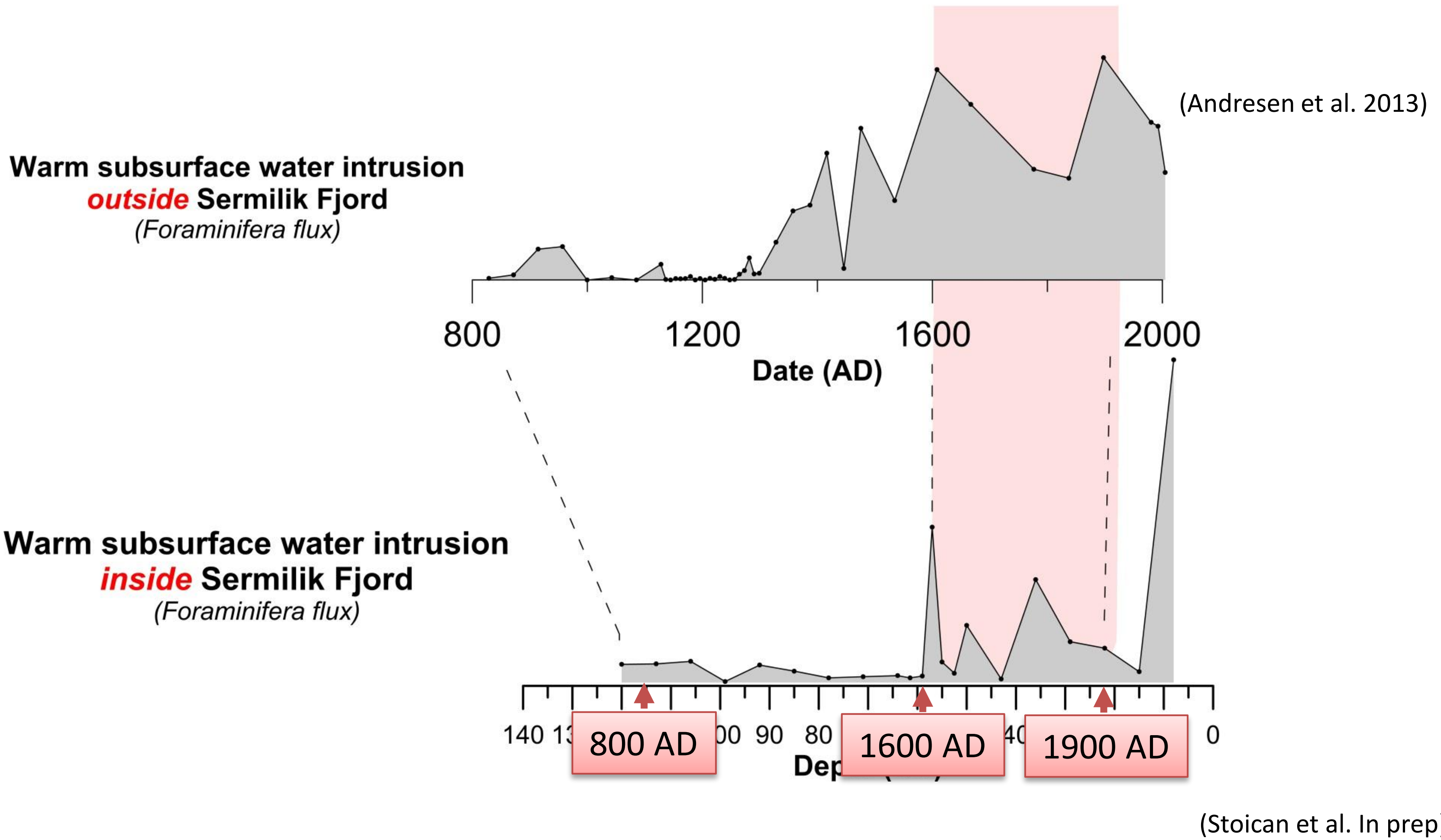
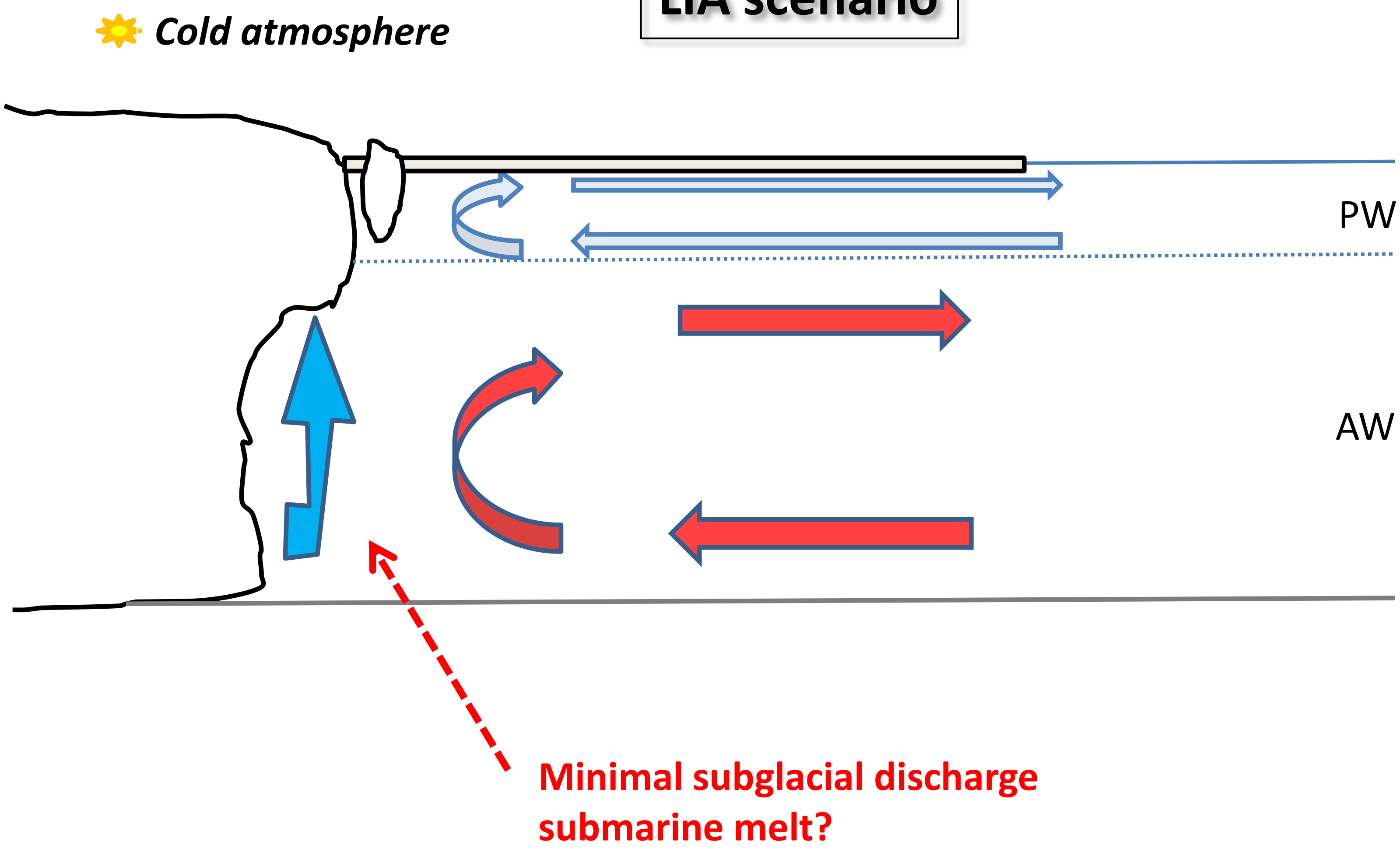
Little Ice Age submarine melt



LIA scenario



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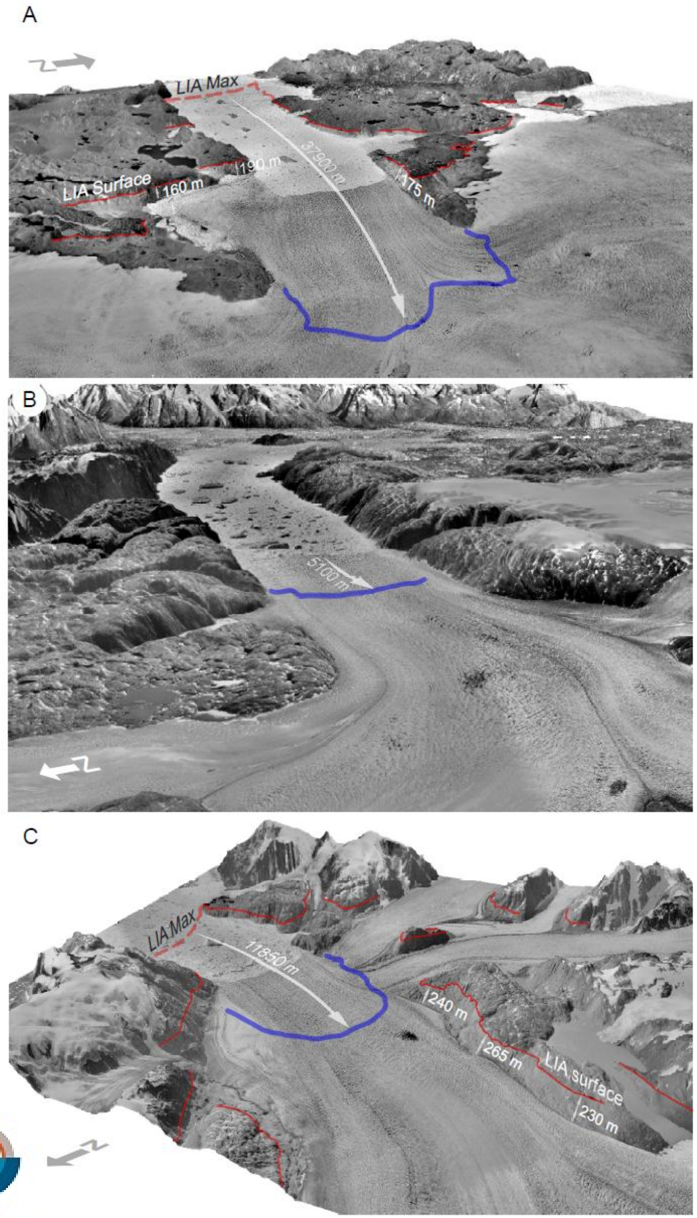
What happened to the large outlet glaciers during the LIA?

Little Ice Age submarine melt

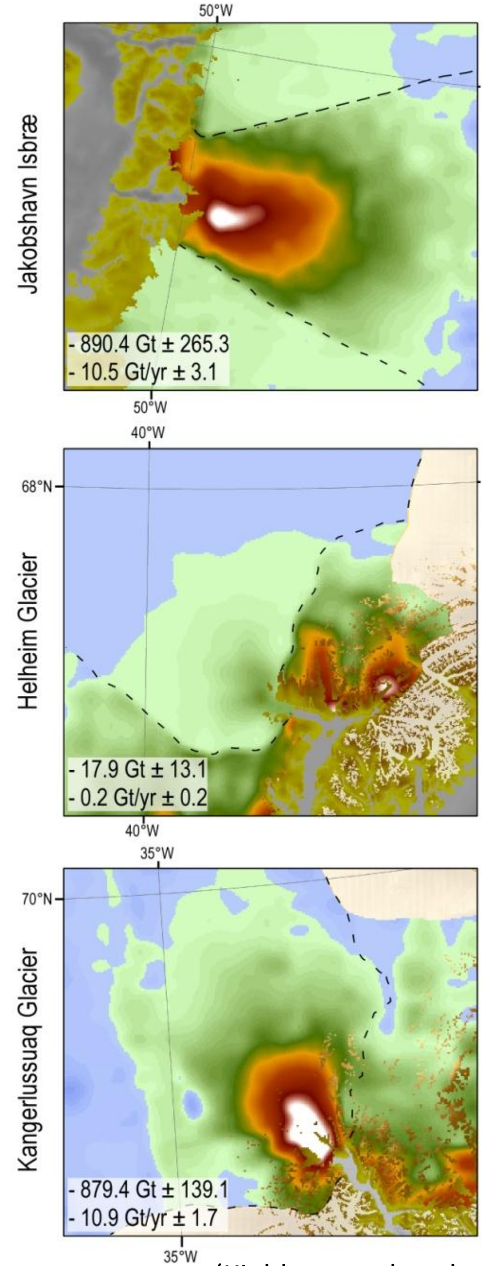
Mass loss since the LIA (1900 AD) untill 1980s



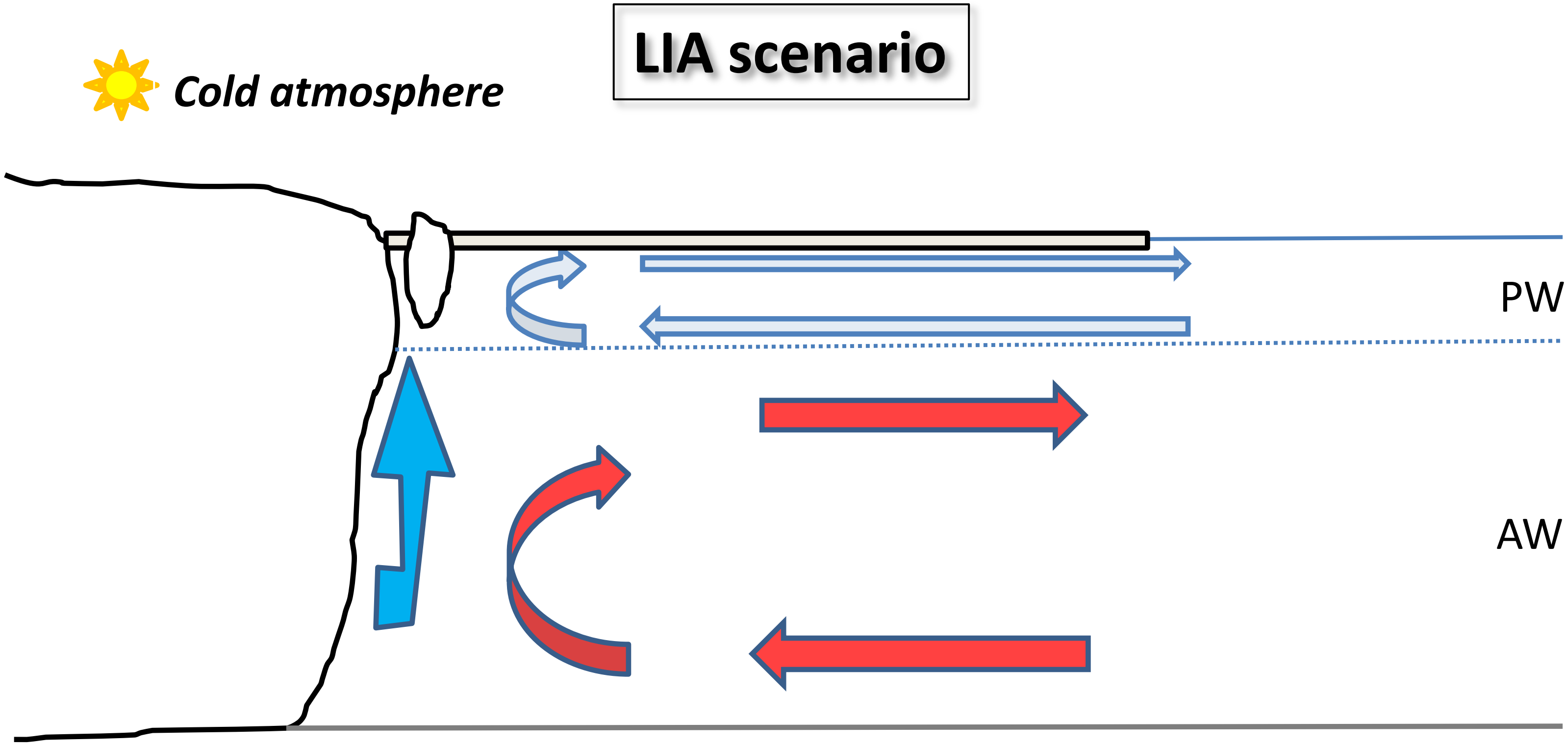
Jakobshavn Isbræ

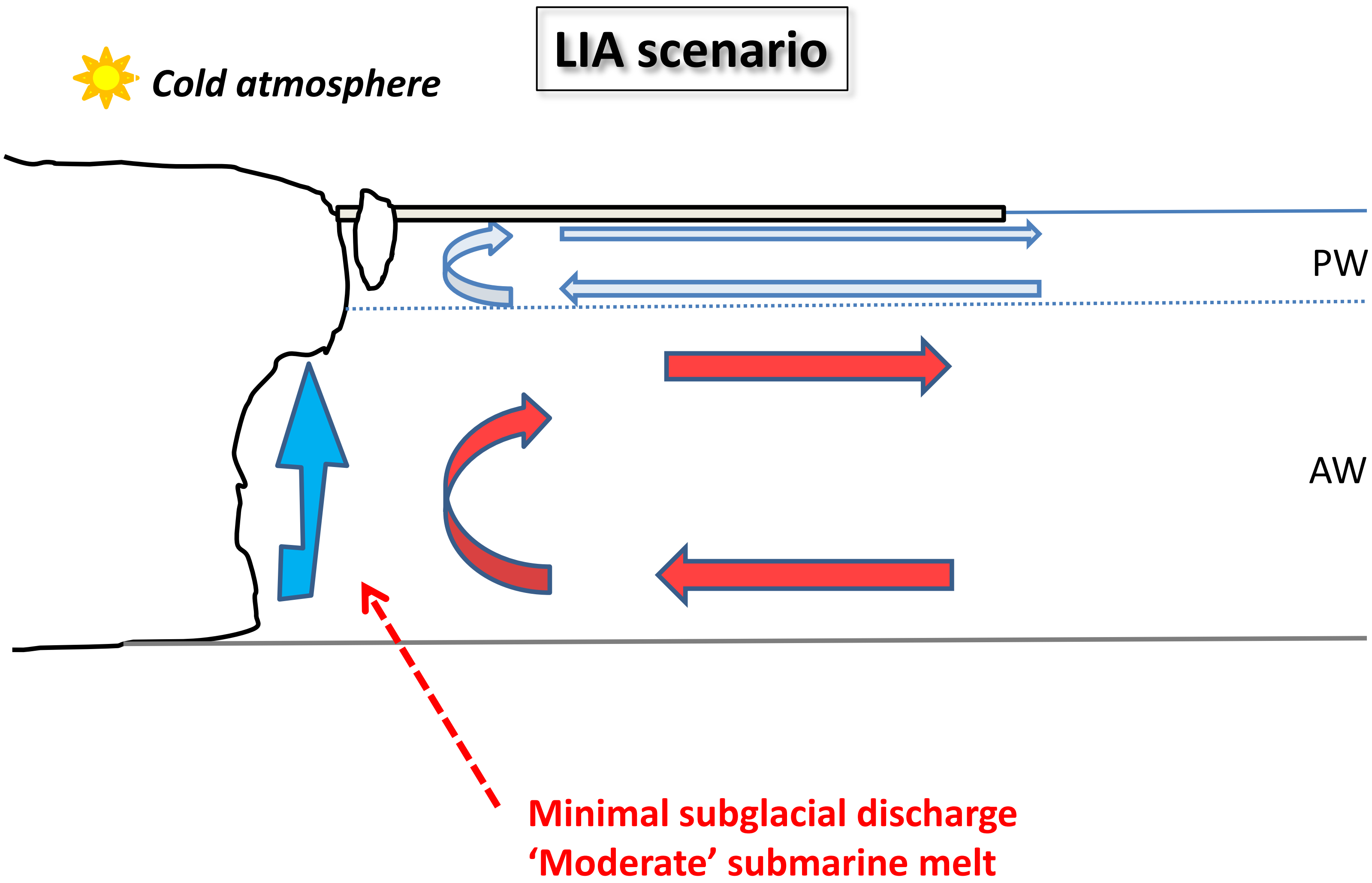
Helheim Glacier

Kangerdlugssuaq Glacier



(Kjeldsen et al., submitted)


LIA scenario
Cold atmosphere
PW
AW


LIA scenario
Cold atmosphere
PW
AW
Minimal subglacial discharge
'Moderate' submarine melt

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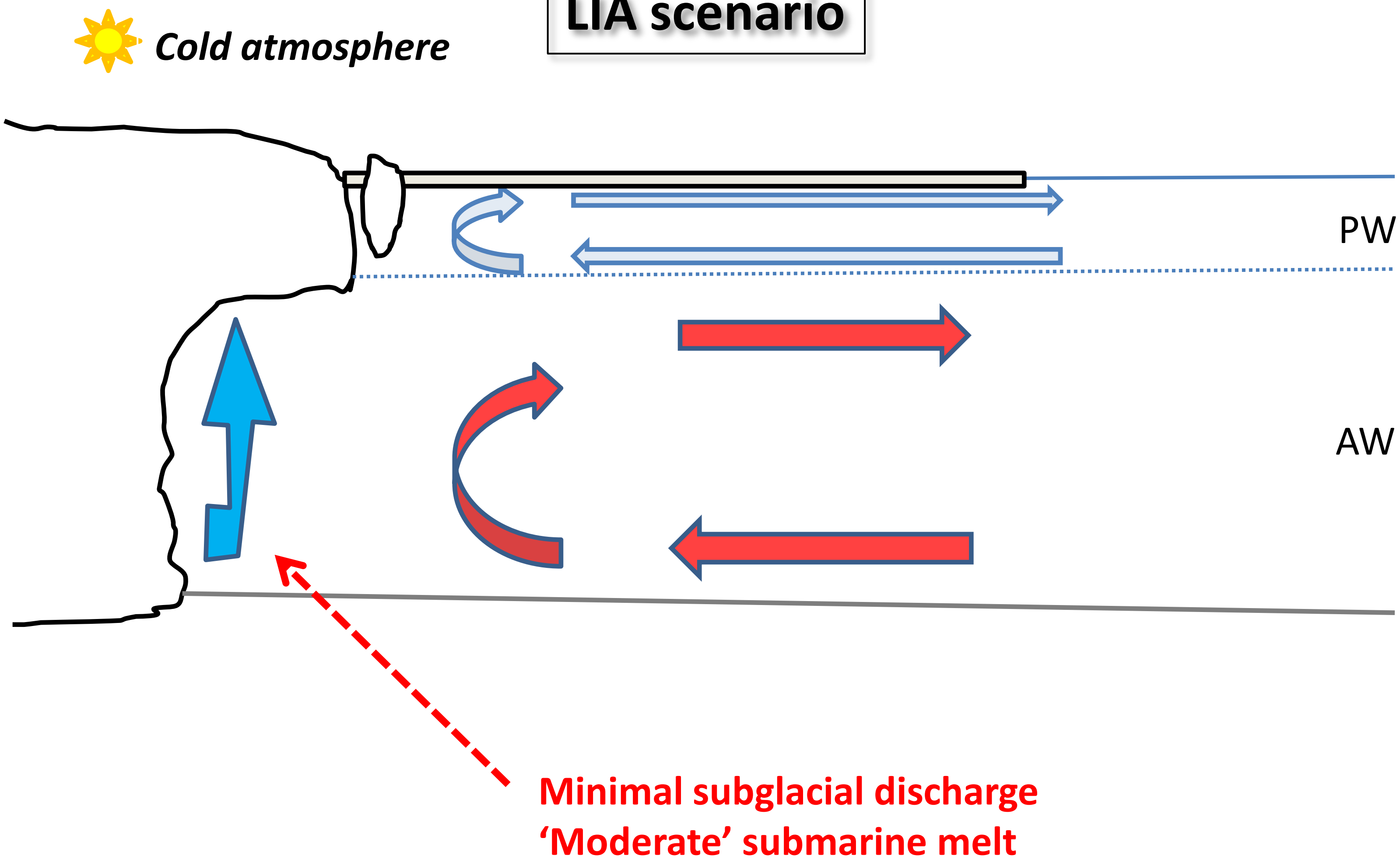
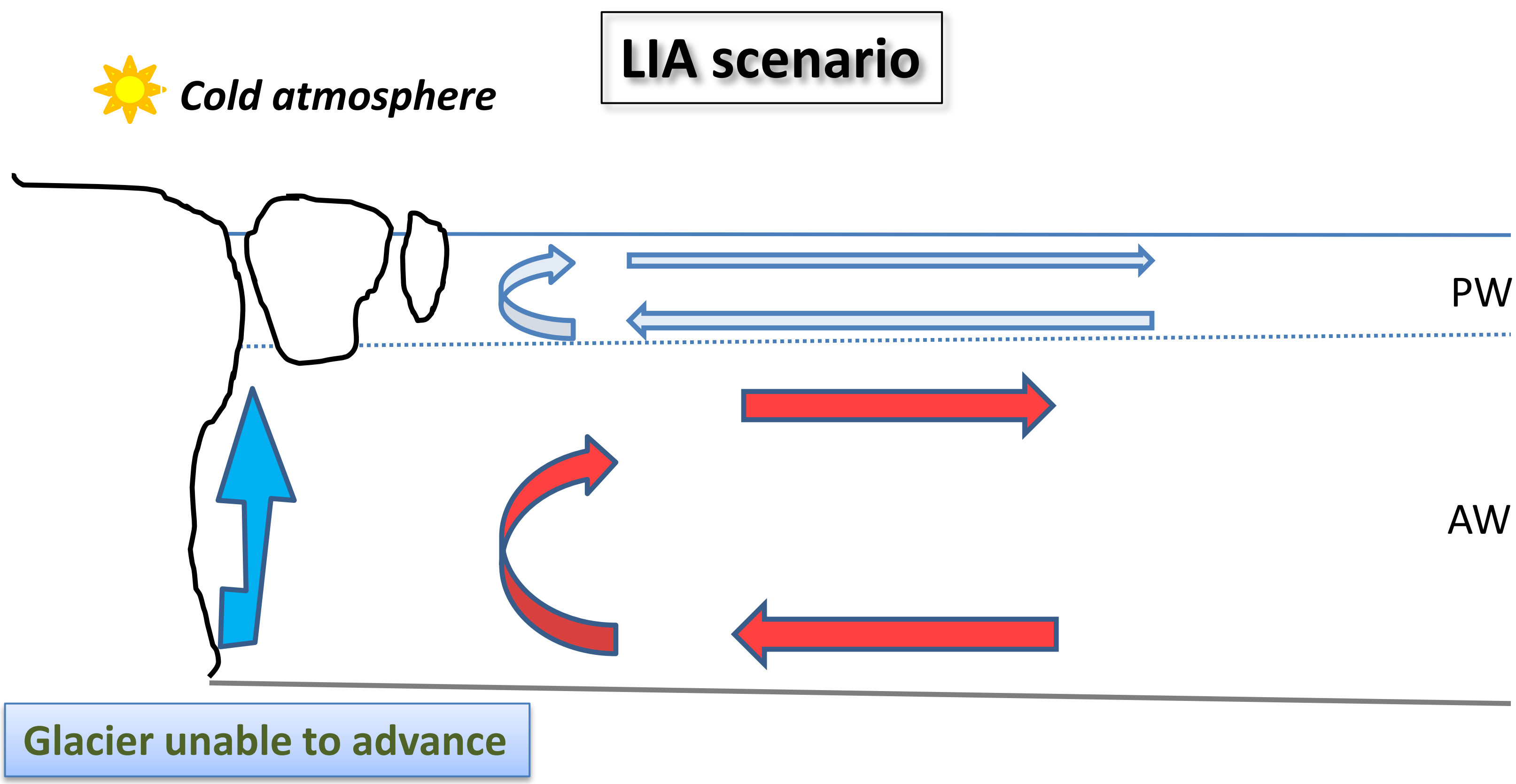
LIA scenario





So in spite of atmospheric cooling Helheim Glacier did not advance during the LIA - maybe because of the warming subsurface layer in the fjord in relation to high SSTs in the Irminger Sea

In regions with quite warm subsurface waters these have the potential to trigger glacier instability even with minimal glacier discharge

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Findings

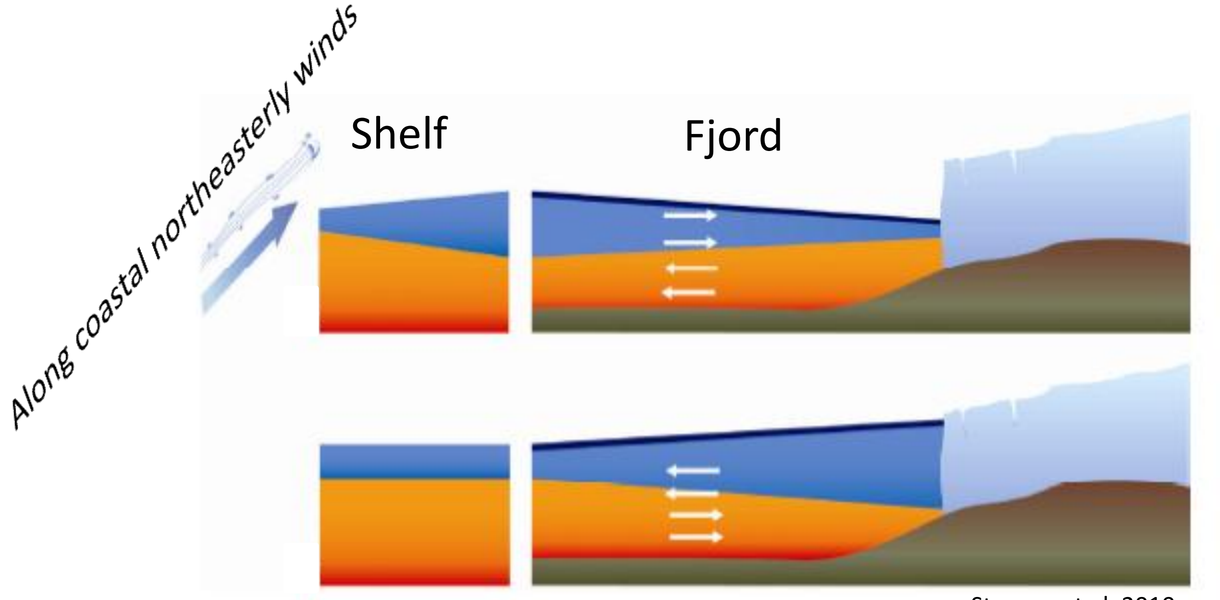
1. The climate drivers behind outlet glacier instability during the past 100 years

2. The late 1930s and early 2000s glacier retreat episodes

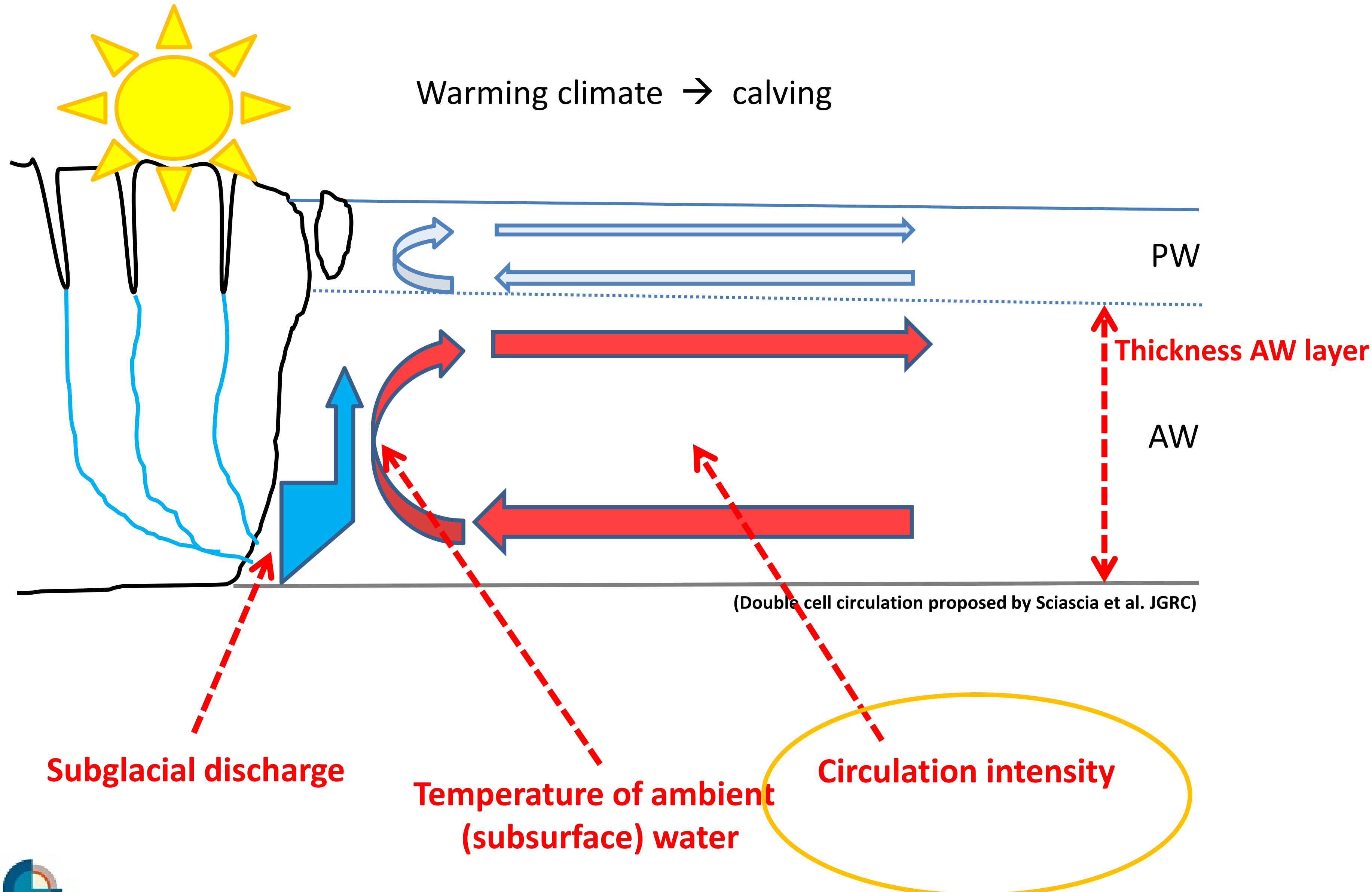
3. The potential effect on submarine glacier melt of ambient ocean water

4. Fjord circulation intensity changes on inter-annual time scales

Circulation intensity ?



Straneo et al. 2010



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Thickness AW layer
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(Double cell circulation proposed by Sciascia et al. JGRC)
Subglacial discharge
Temperature of ambient (subsurface) water
Circulation intensity

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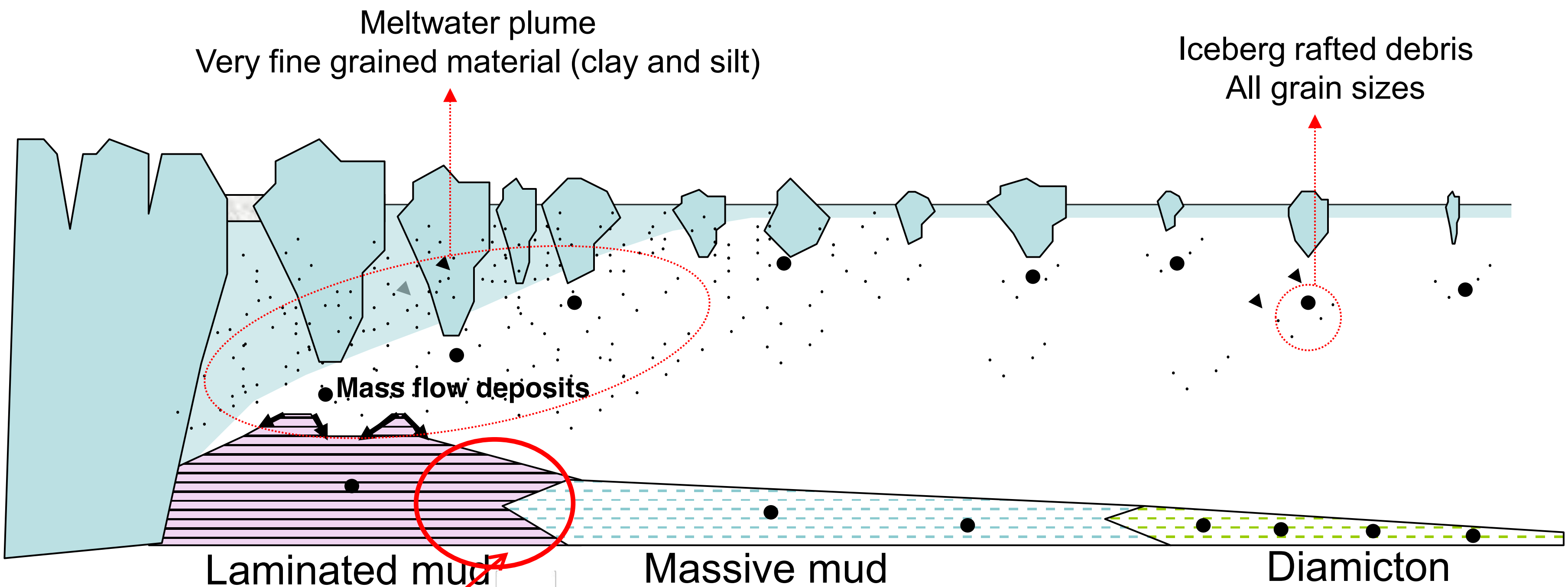
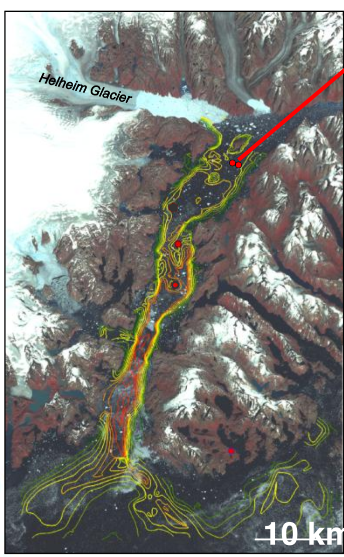
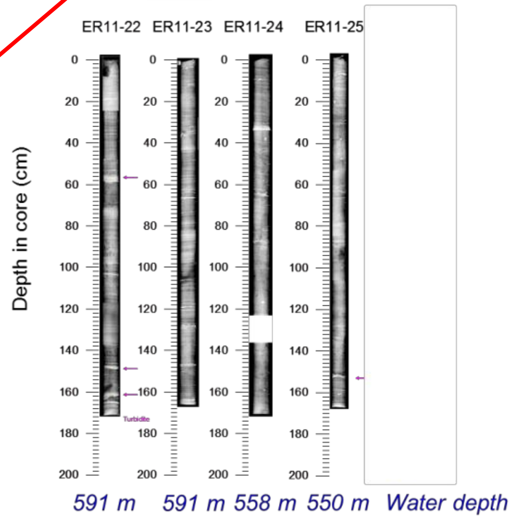
Circulation intensity – Sermilik Fjord







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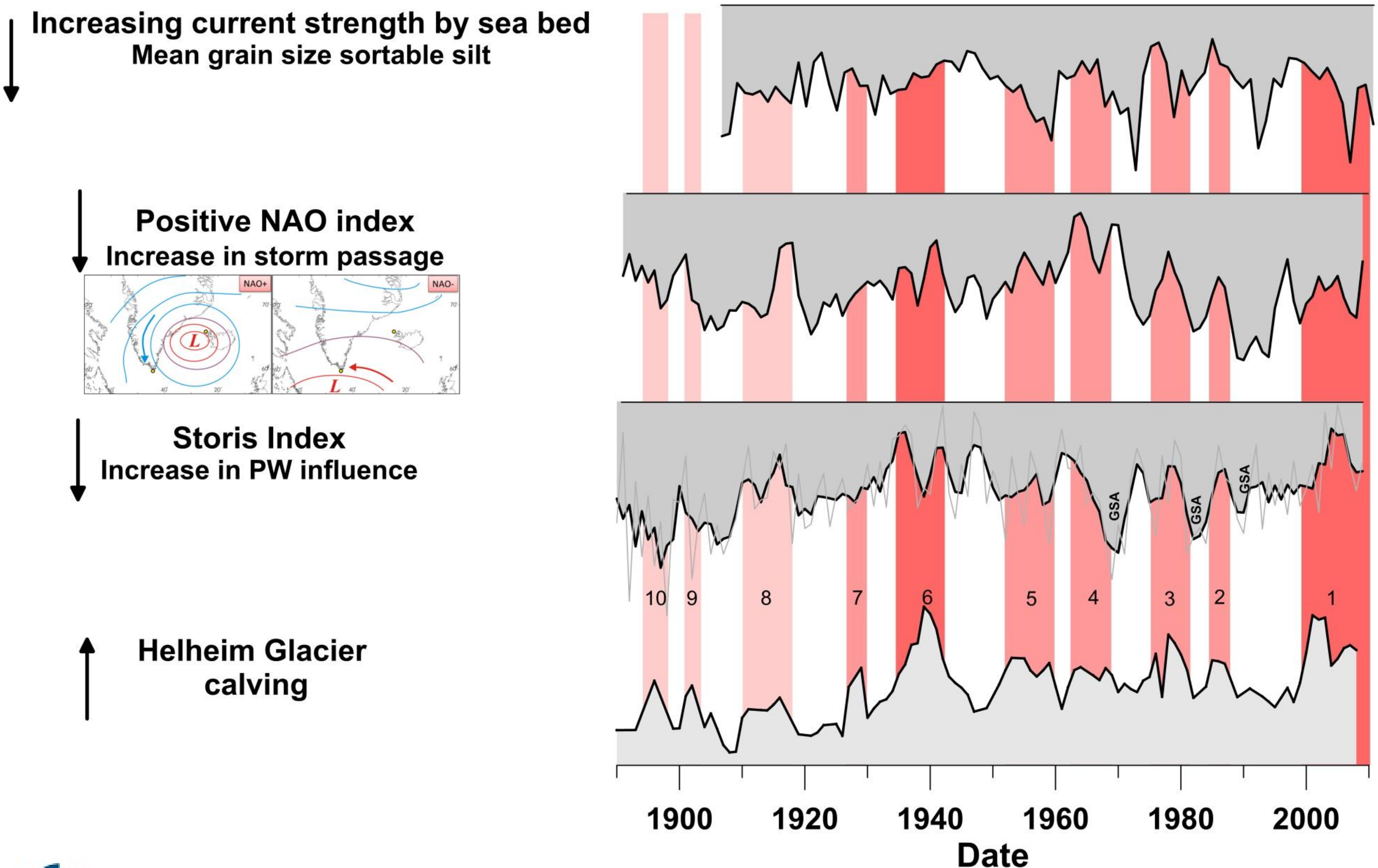
Circulation intensity – Sermilik Fjord



(Andresen et al. In prep)

On inter-annual time scales episodes of increased fjord circulation are linked with a positive NAO index and increased sea ice occurrence on the shelf - thus a climatic setting impeding calving rates in spite of marked renewal rate

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Summary of findings

1. Timing of instability of Jakobshavn Isbræ and Helheim Glacier concurs with:

- a positive Atlantic Multi-decadal Oscillation
- a negative North Atlantic Oscillation index
- decreased sea ice occurrence around Greenland

2. The late 1930s and early 2000s episodes of marked glacier retreat of Jakobshavn Isbræ and Helheim Glacier may stand out due to the coincidence of: Subsurface warming of the ocean around Greenland, record low sea ice occurrence and record warm summer air

3. In regions with quite warm subsurface waters these have the potential to trigger glacier instability even with minimal glacier discharge

4. On inter-annual time scales episodes of increased fjord circulation are linked with a positive NAO index and increased sea ice occurrence on the shelf - thus a climatic setting impeding calving rates in spite of marked renewal rate

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