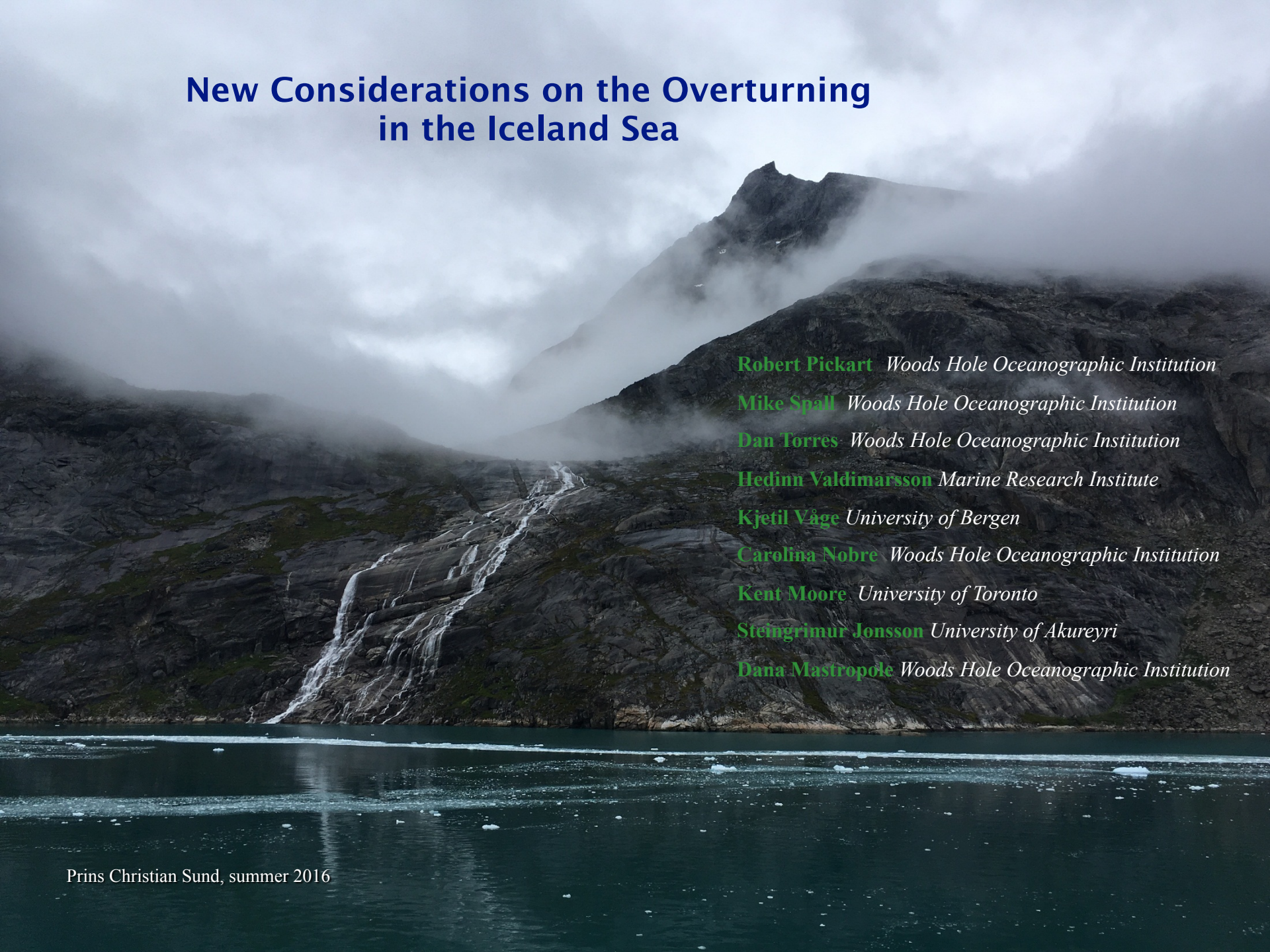
New Considerations on the Overturning in the Iceland Sea



Robert Pickart *Woods Hole Oceanographic Institution*

Mike Spall *Woods Hole Oceanographic Institution*

Dan Torres *Woods Hole Oceanographic Institution*

Hedinn Valdimarsson *Marine Research Institute*

Kjetil Våge *University of Bergen*

Carolina Nobre *Woods Hole Oceanographic Institution*

Kent Moore *University of Toronto*

Steingrimur Jonsson *University of Akureyri*

Dana Mastropole *Woods Hole Oceanographic Institution*

Prins Christian Sund, summer 2016

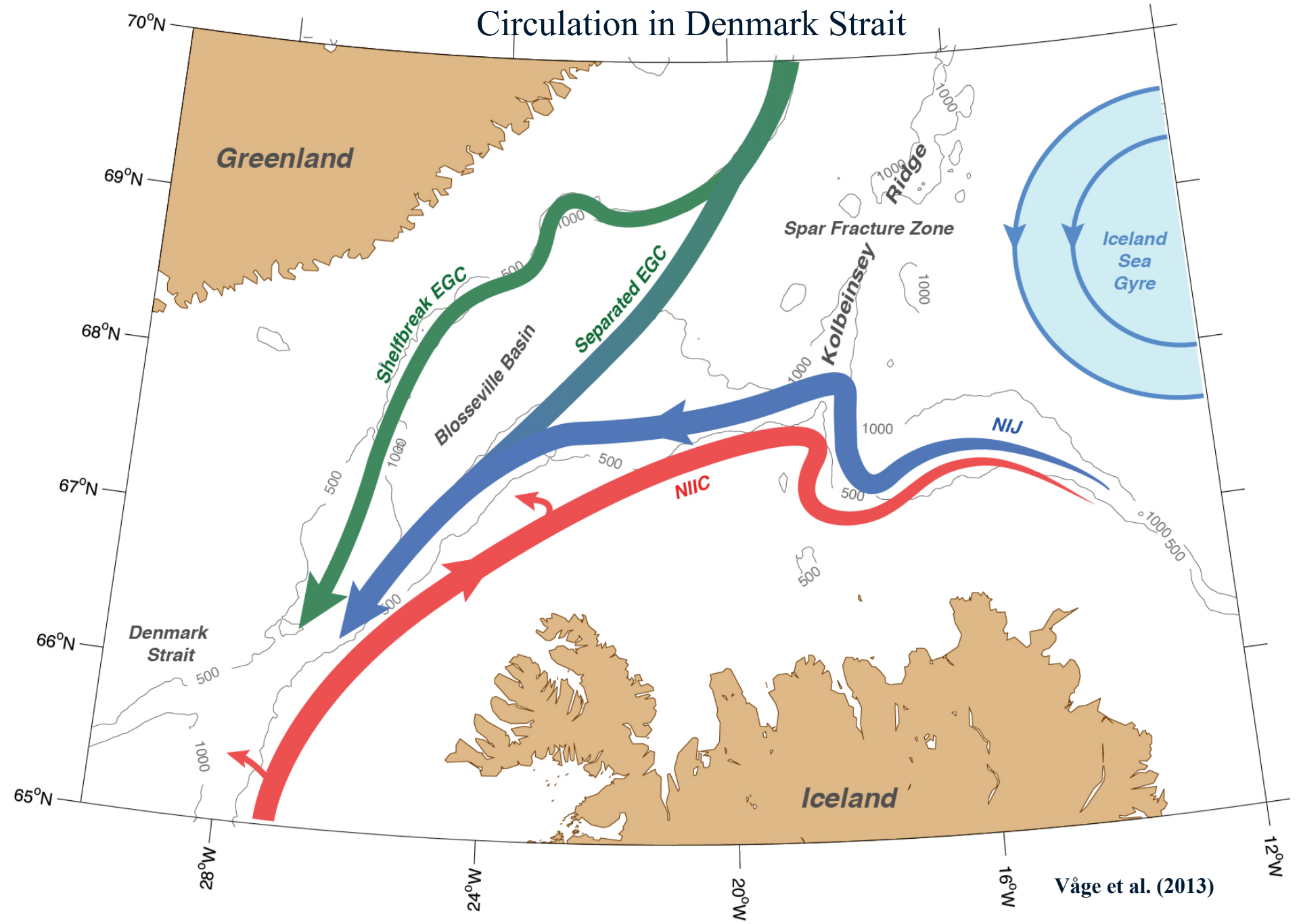
Outline

Brief overview of the circulation in the vicinity of Denmark Strait and the shipboard data used in the study

Aspects of the densest overflow water exiting the strait and its relationship to the subtropical inflow

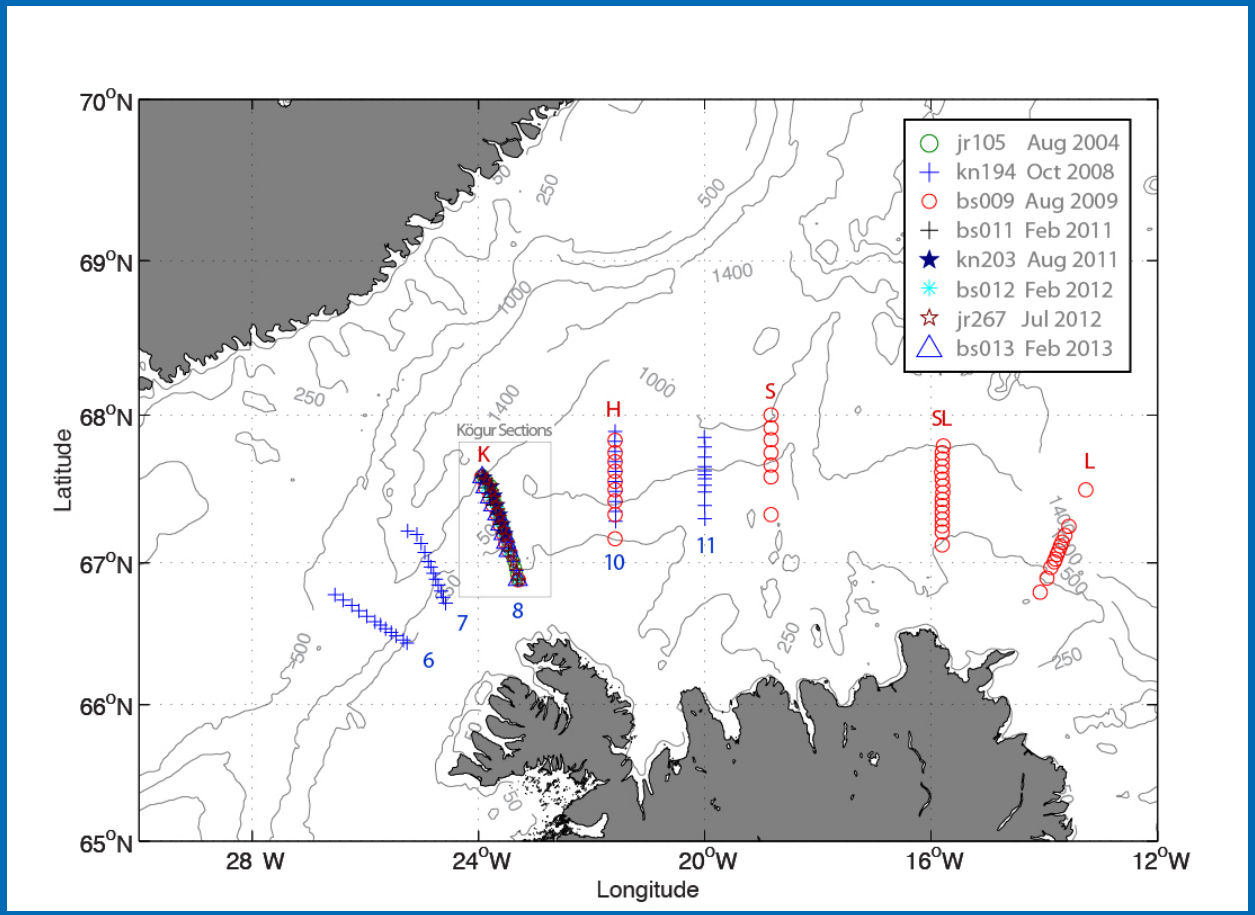
Interannual variability of the exchange

Circulation in Denmark Strait

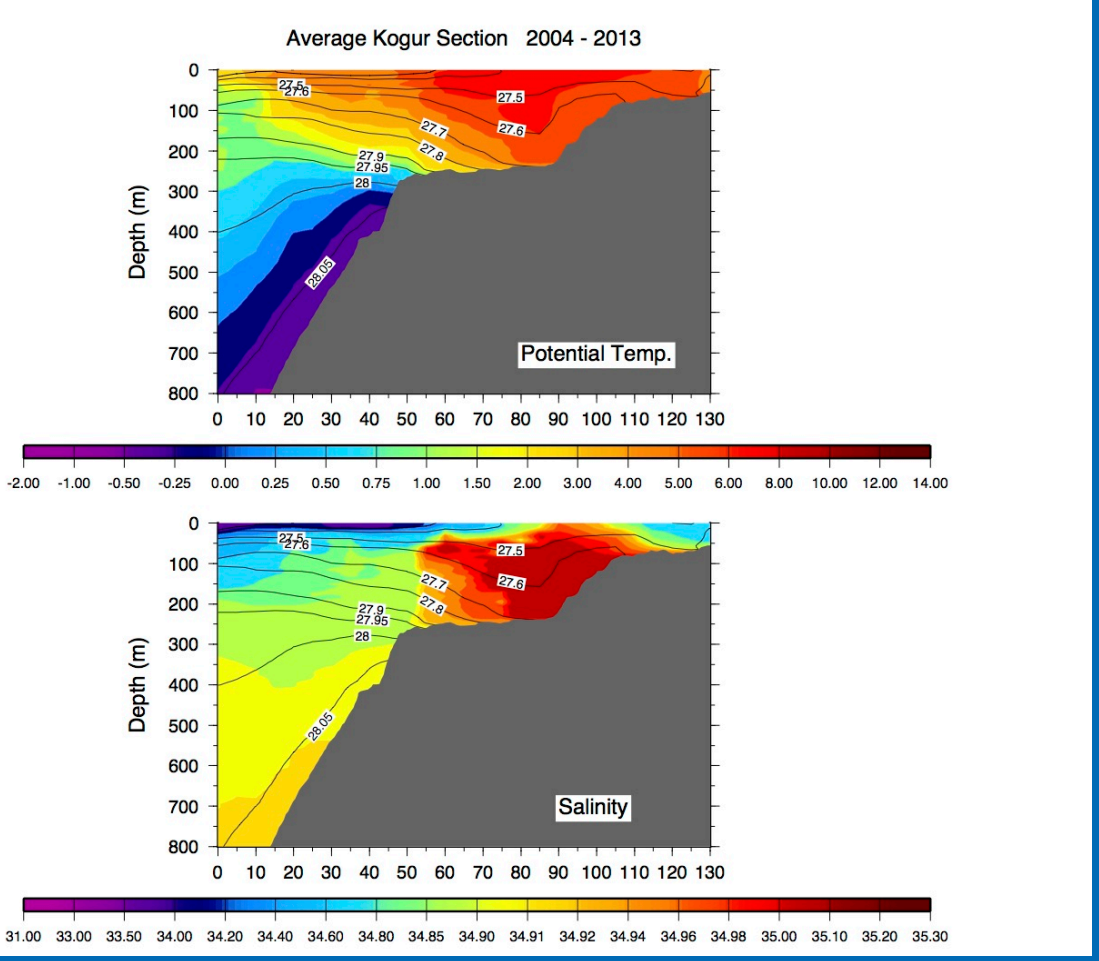


Våge et al. (2013)

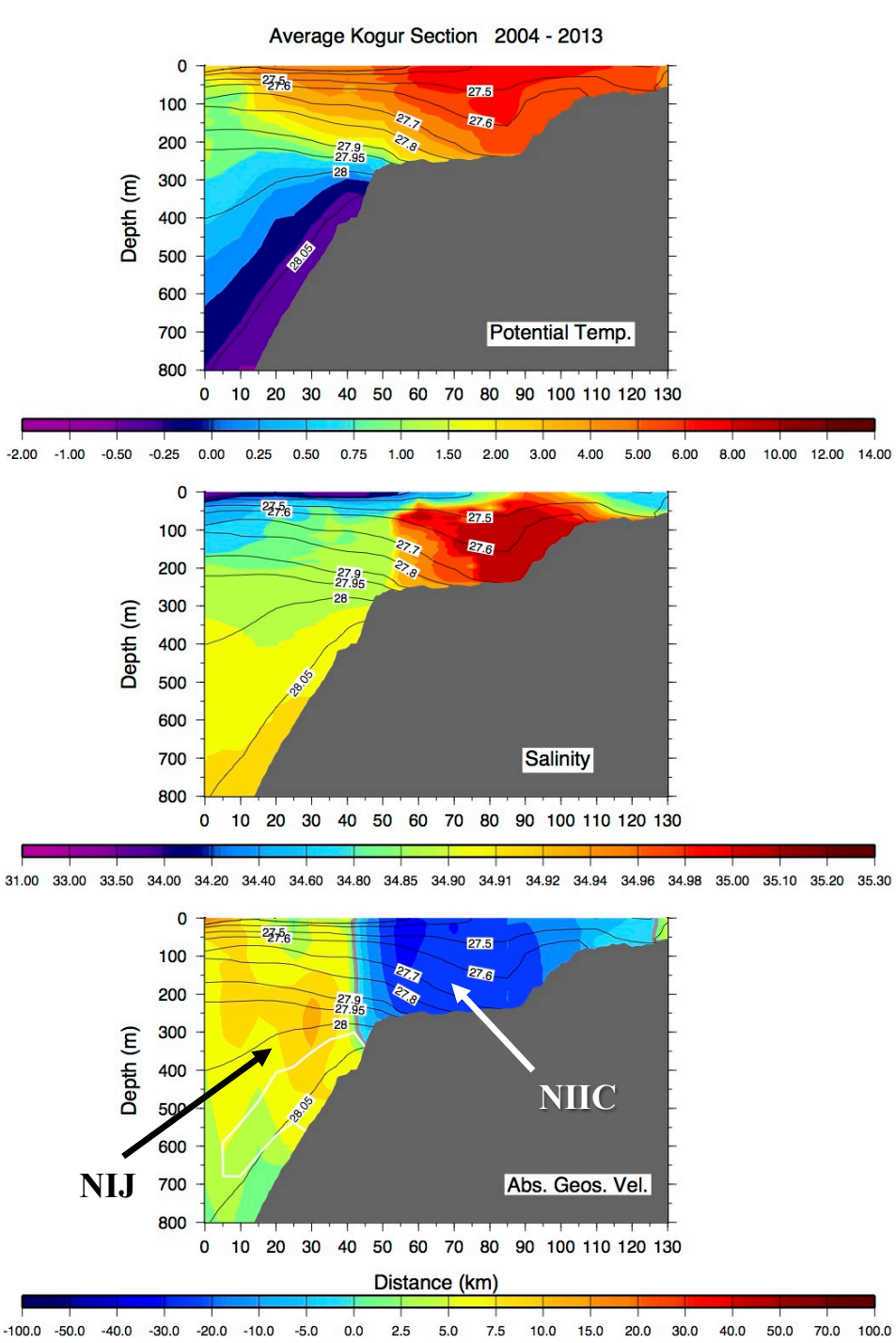
Shipboard data used in the study (2004-2013)



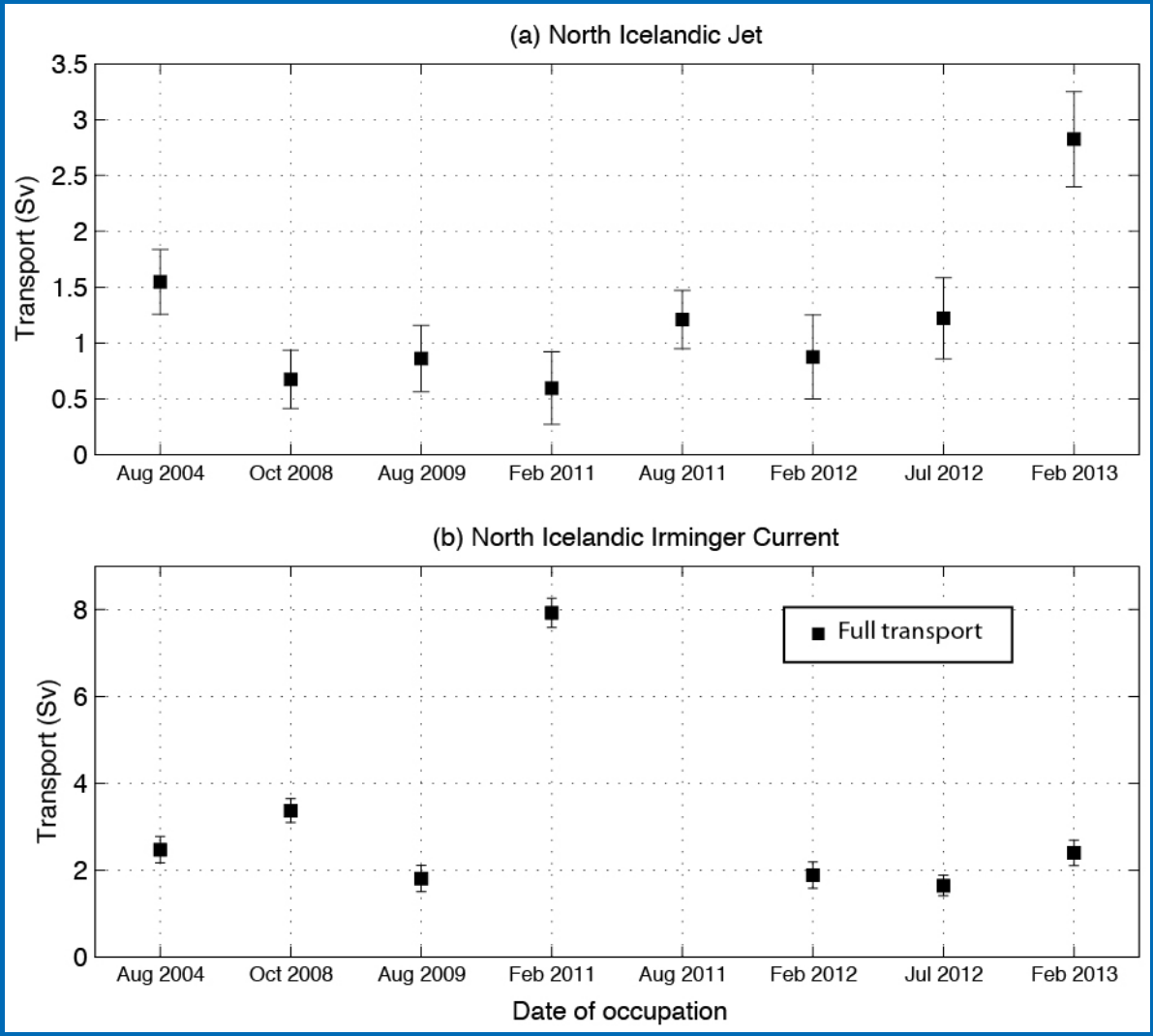
Mean Kögur Sections



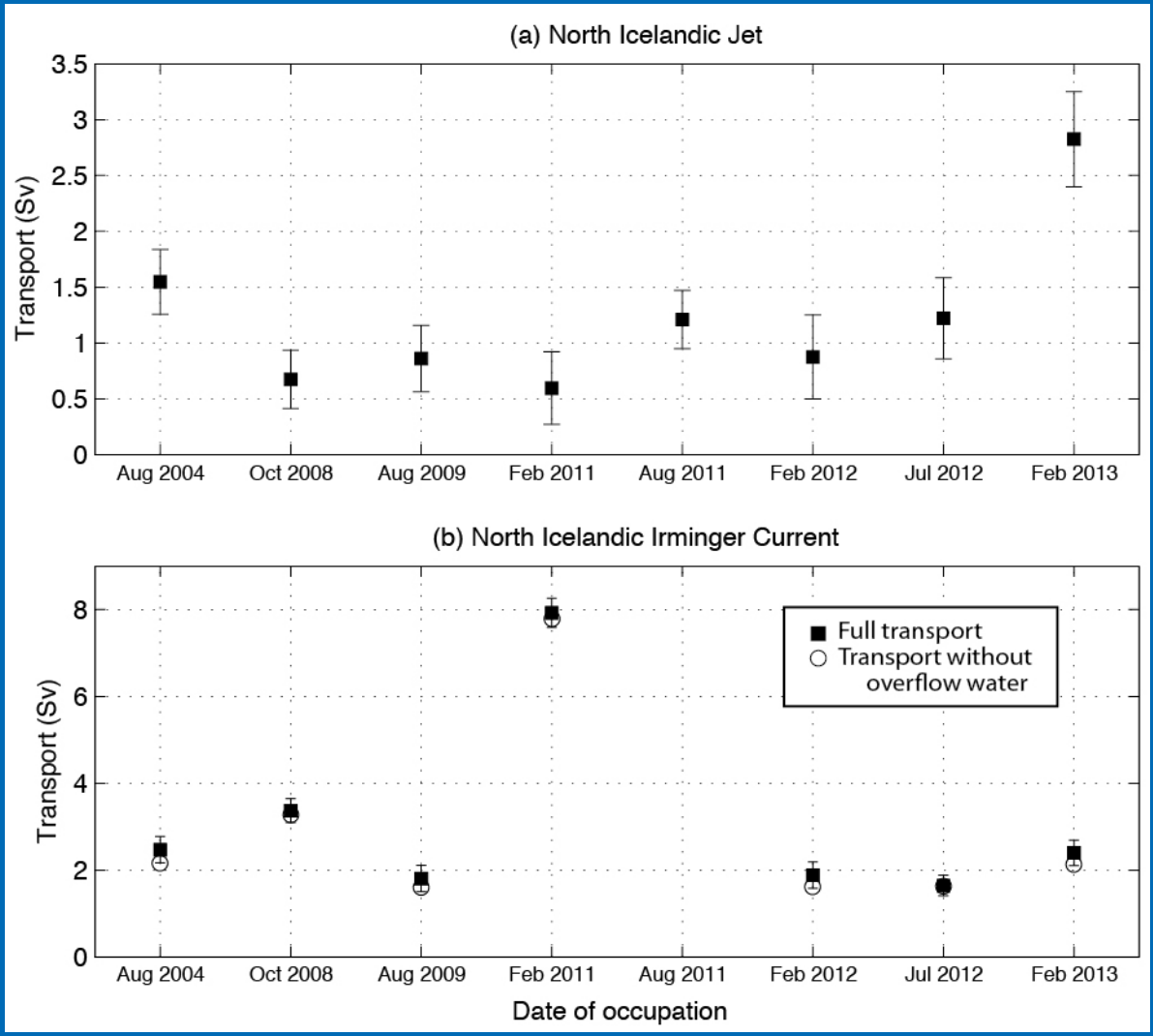
Mean Kögur Sections



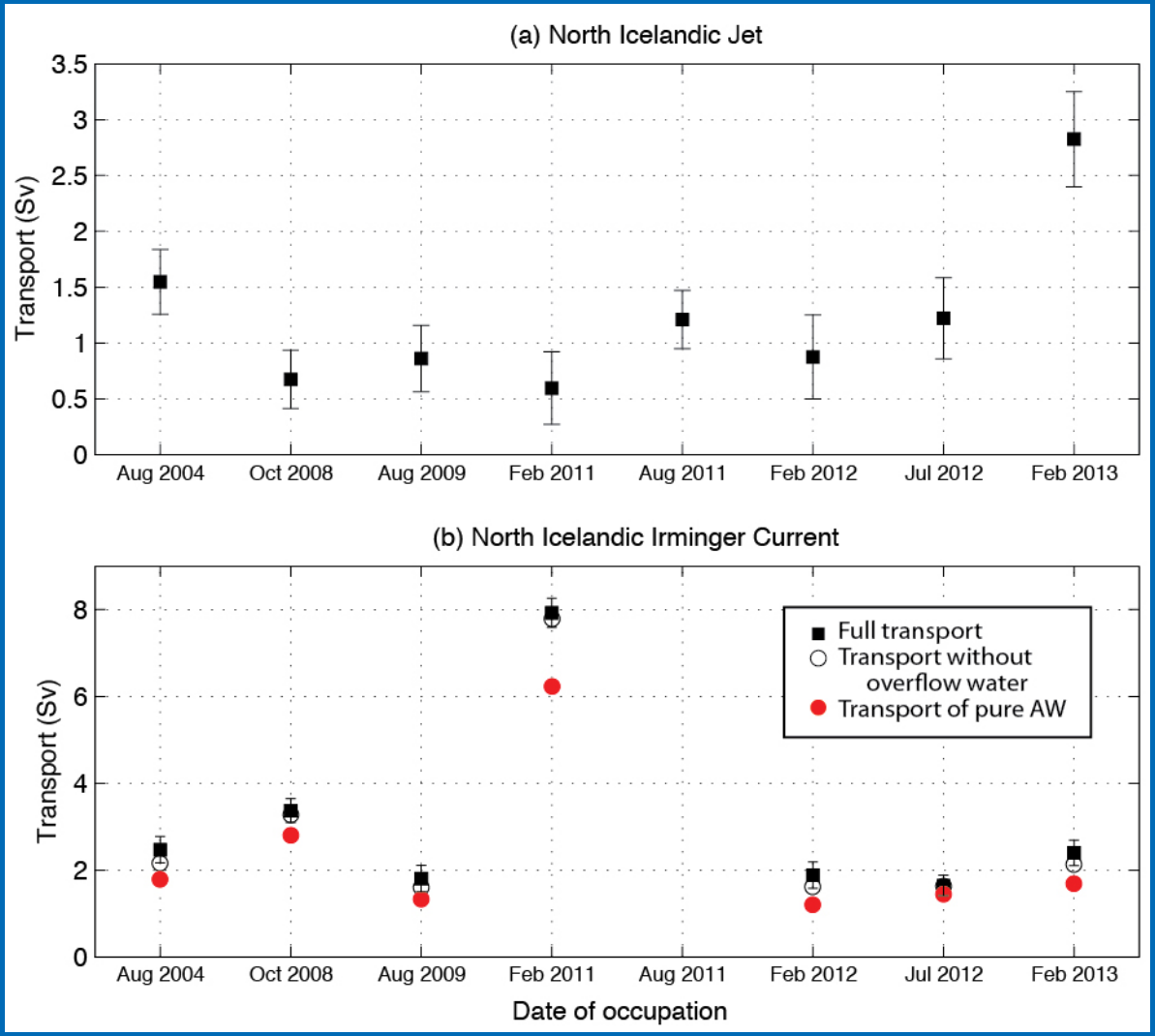
Transports at the Kögur line



Transports at the Kögur line



Transports at the Kögur line



NIJ 1.3±0.33 Sv

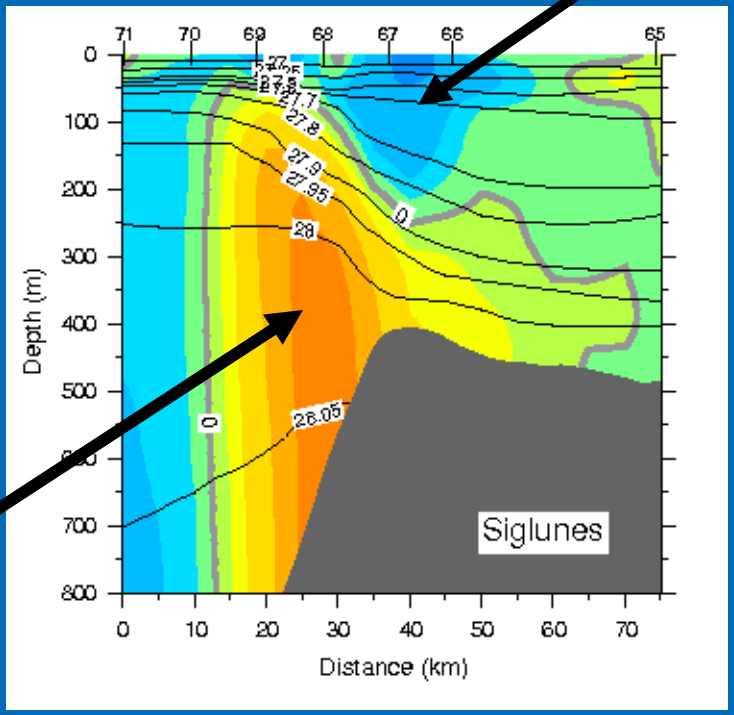
NIIC 1.7±0.22 Sv

Pathway of the NIJ and NIIC

Absolute geostrophic velocity (cm/s, color)
overlain by potential density (kg/m^3, contours)

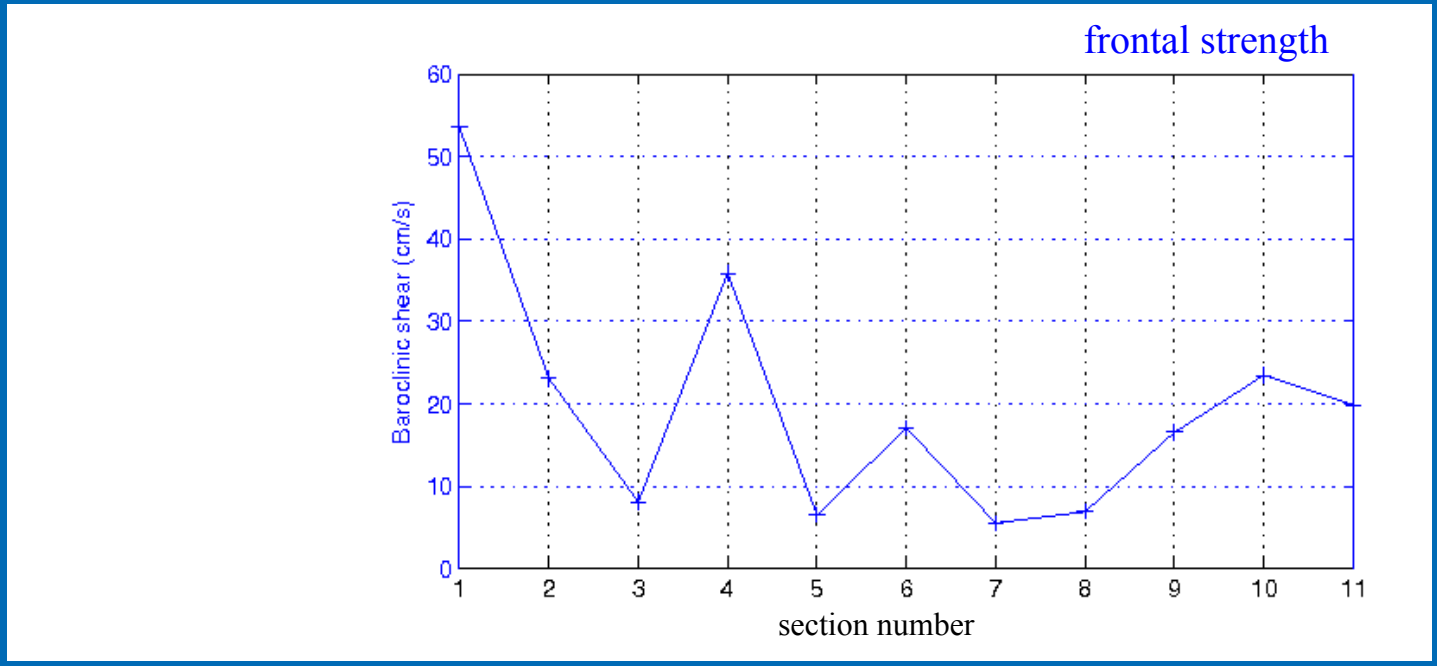
August 2009

Poleward flow

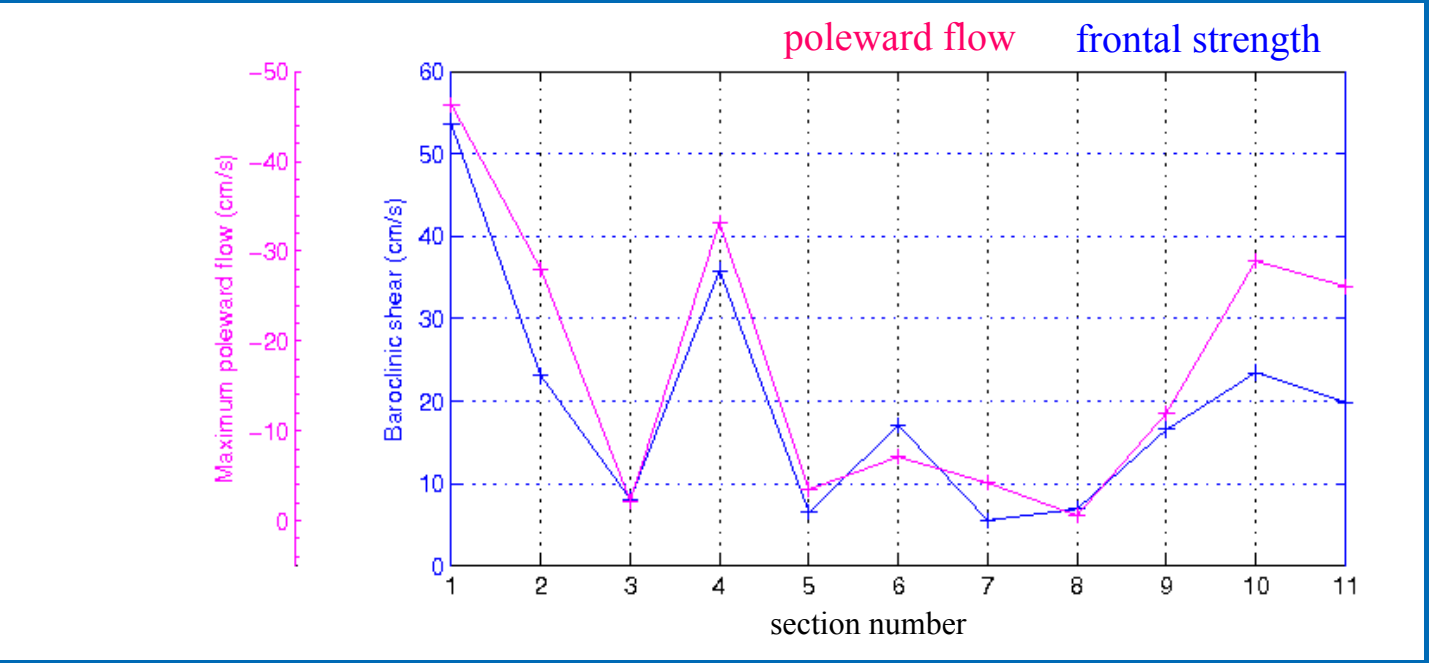


Equatorward flow

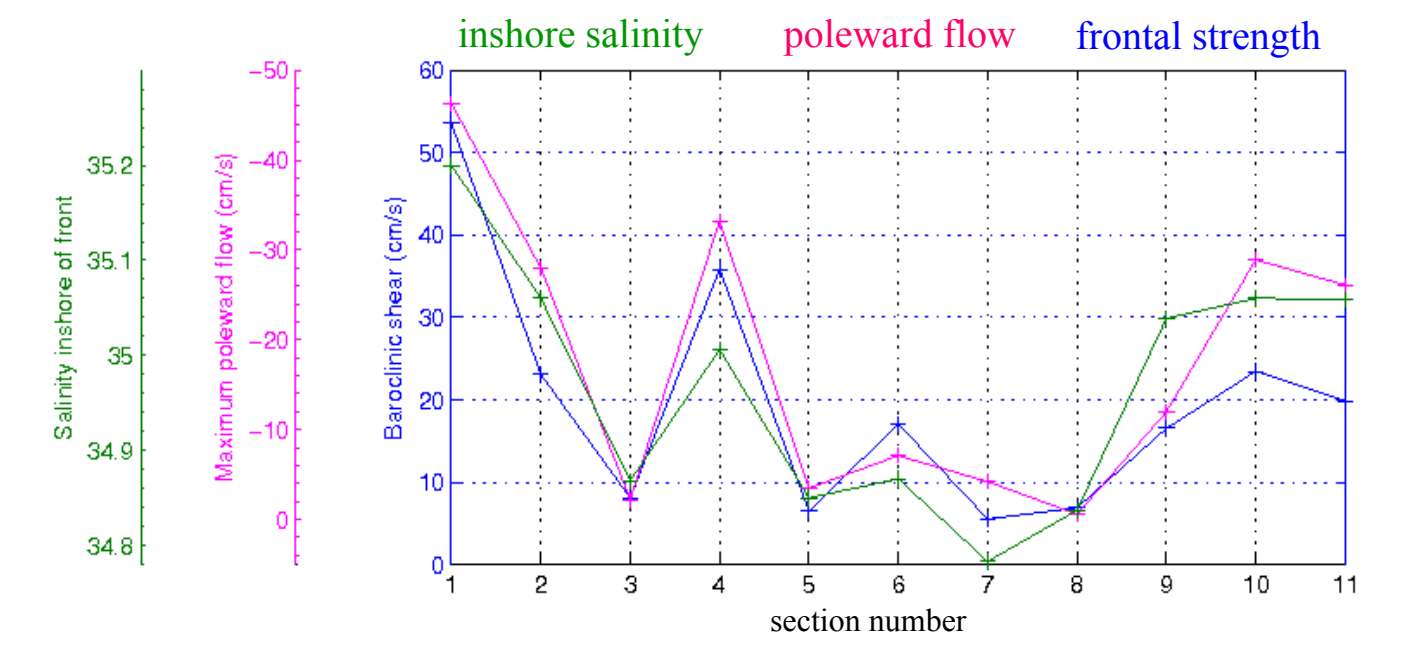
Metrics


frontal strength
Baroclinic shear (cm/s)
0
10
20
30
40
50
60
1
2
3
4
5
6
7
8
9
10
11
section number

Metrics

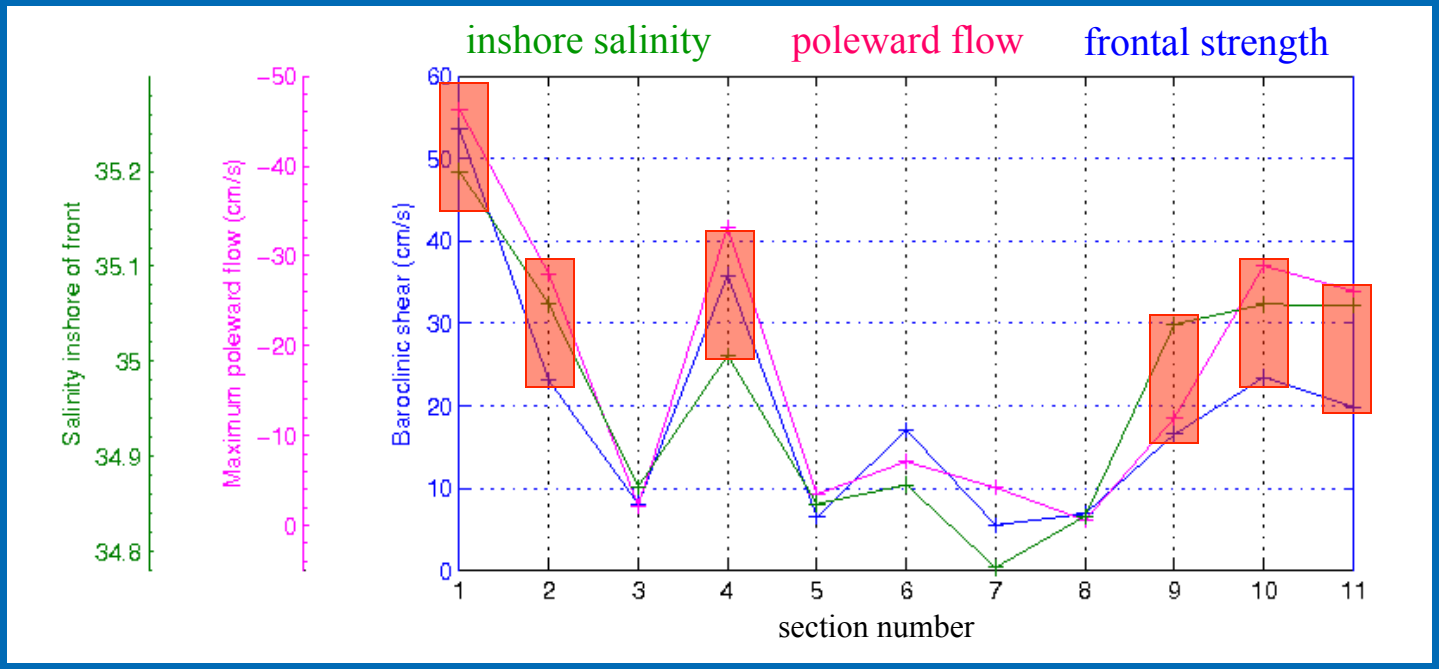

poleward flow
frontal strength
Maximum poleward flow (cm/s)
−50
−40
−30
−20
−10
0
Baroclinic shear (cm/s)
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
section number

Metrics


inshore salinity
poleward flow
frontal strength
Salinity inshore of front
35.2
35.1
35
34.9
34.8
Maximum poleward flow (cm/s)
−50
−40
−30
−20
−10
0
Baroclinic shear (cm/s)
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
section number

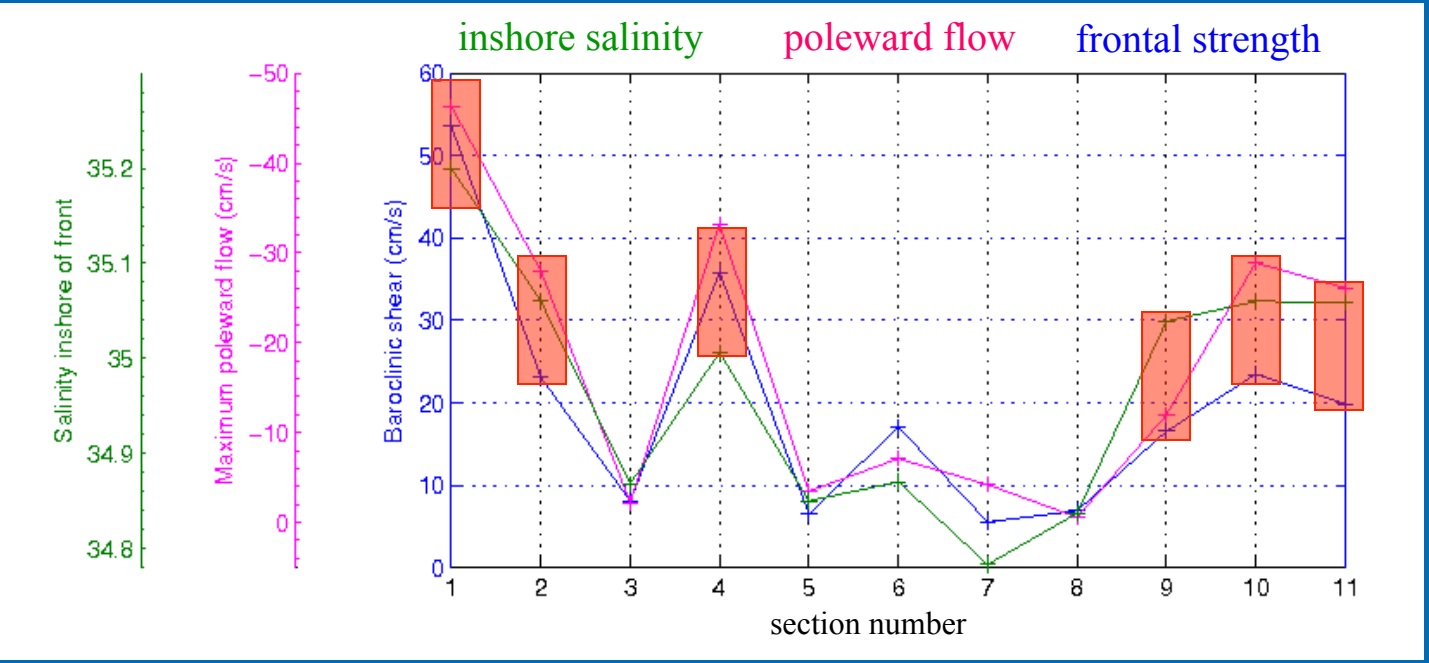
Metrics

= NIIC



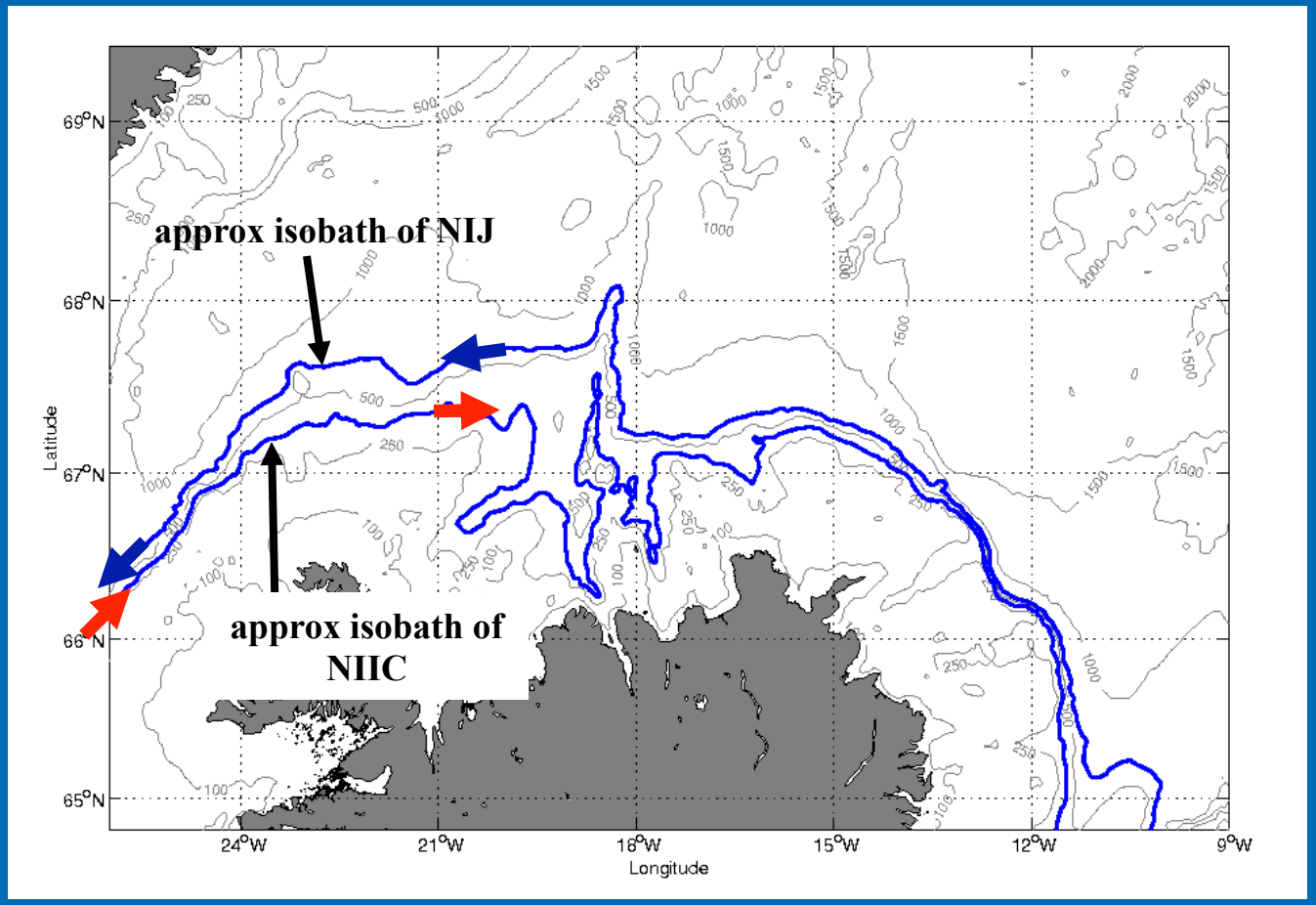
Metrics

= NIIC

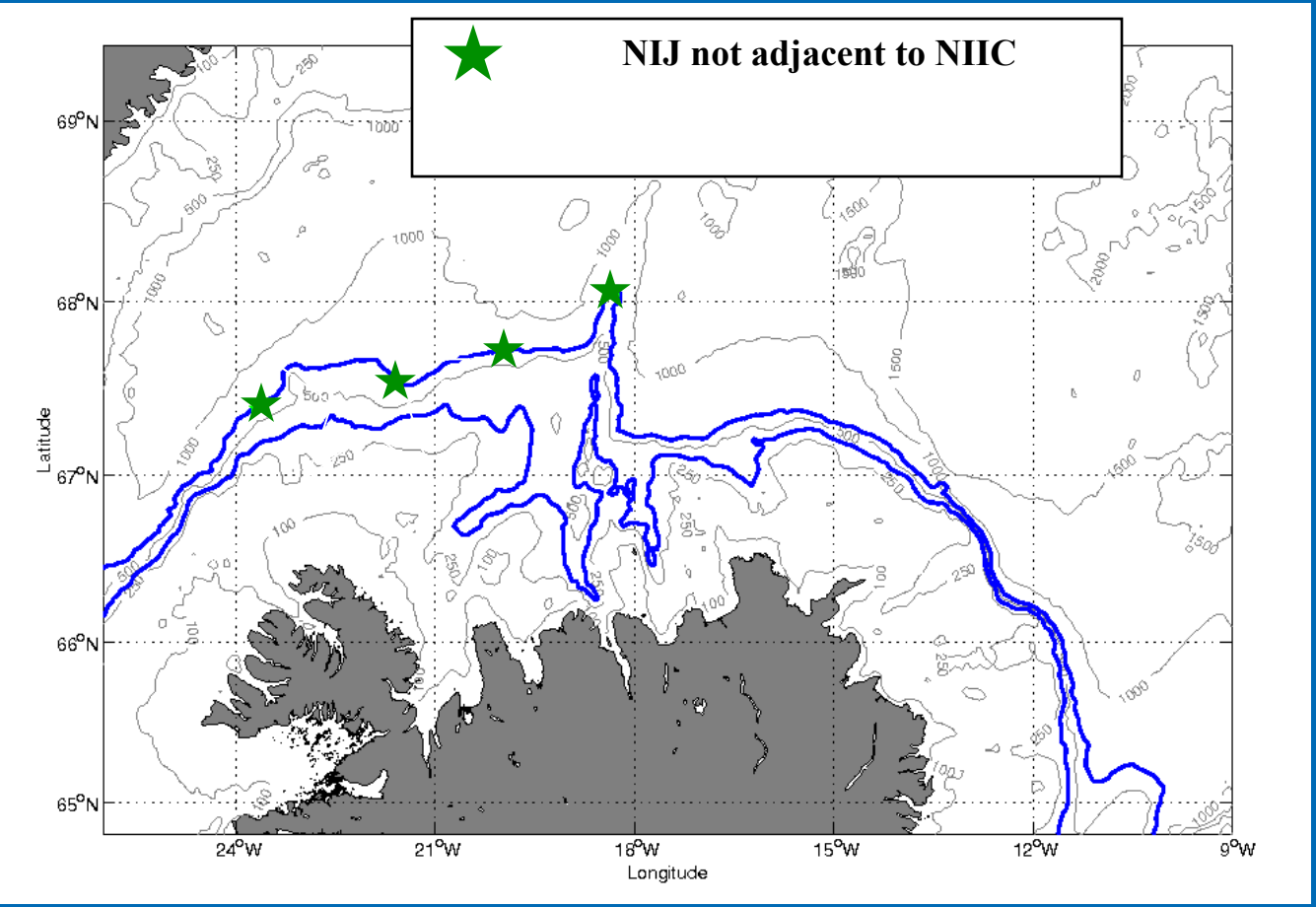


Sometimes the NIJ is associated with the NIIC, sometimes it isn't

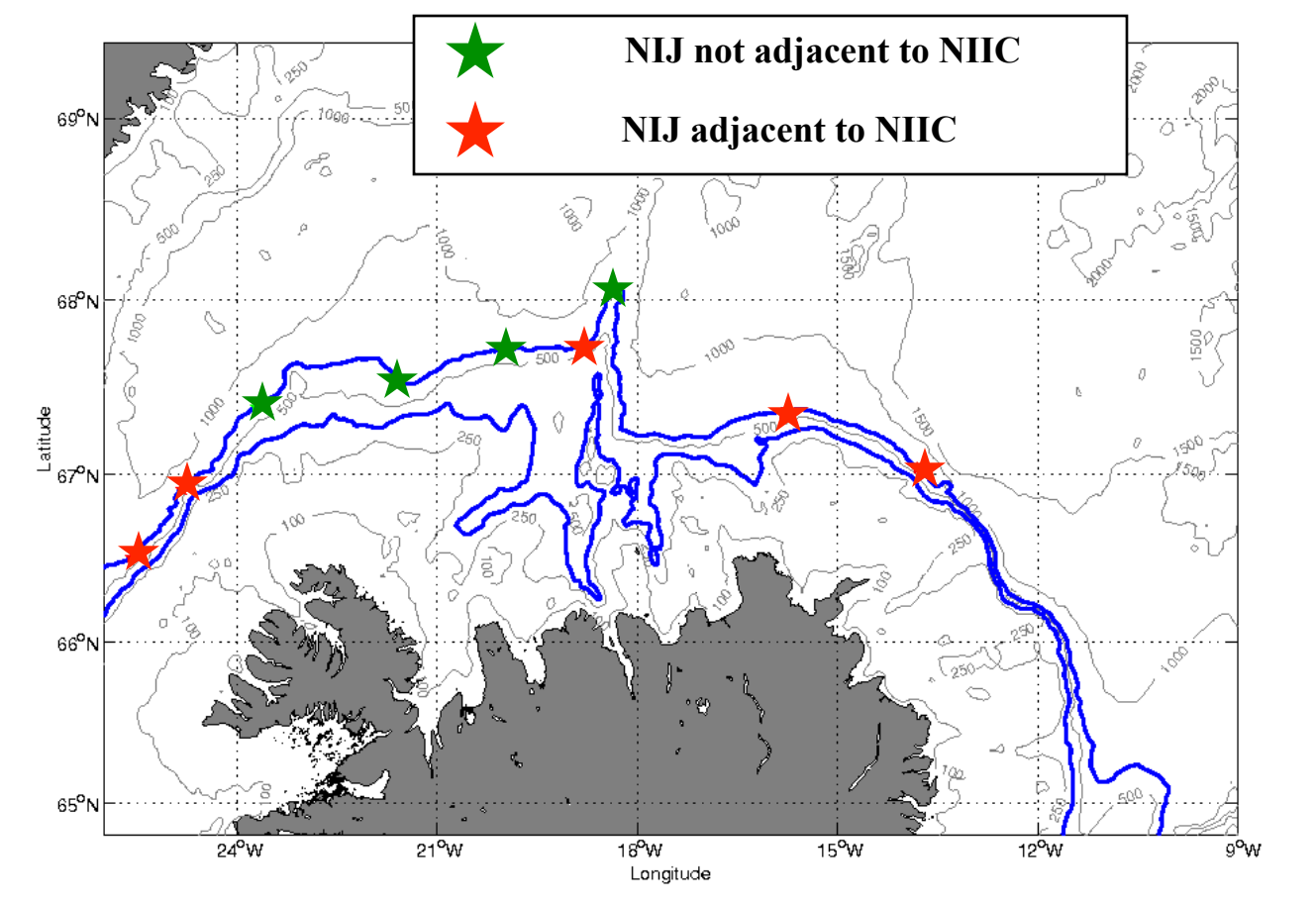
Bathymetric considerations



Bathymetric considerations



Bathymetric considerations



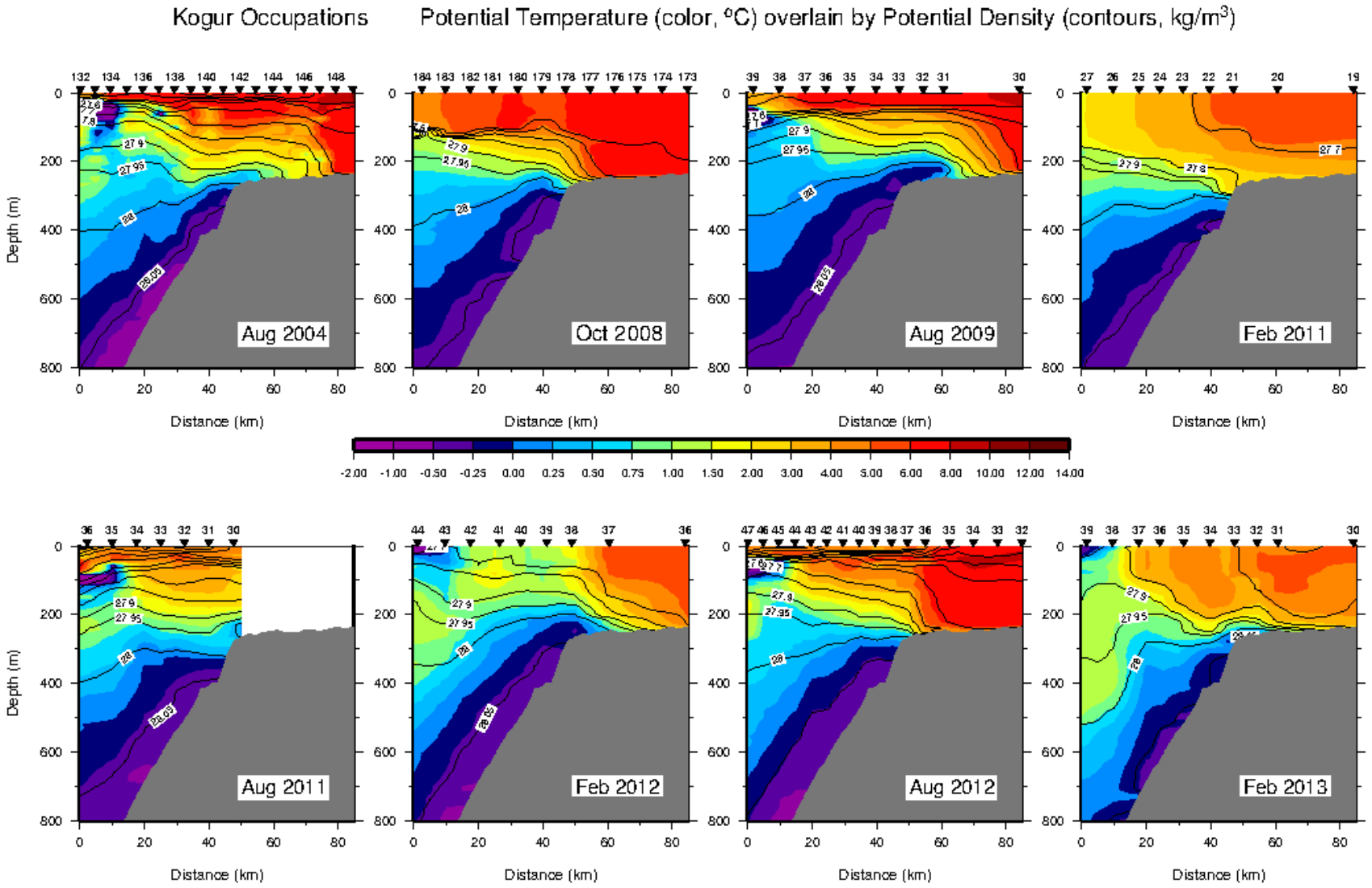
Overall impression:

The NIJ appears to be coupled to the NIIC when the two are in close geographical proximity to each other.

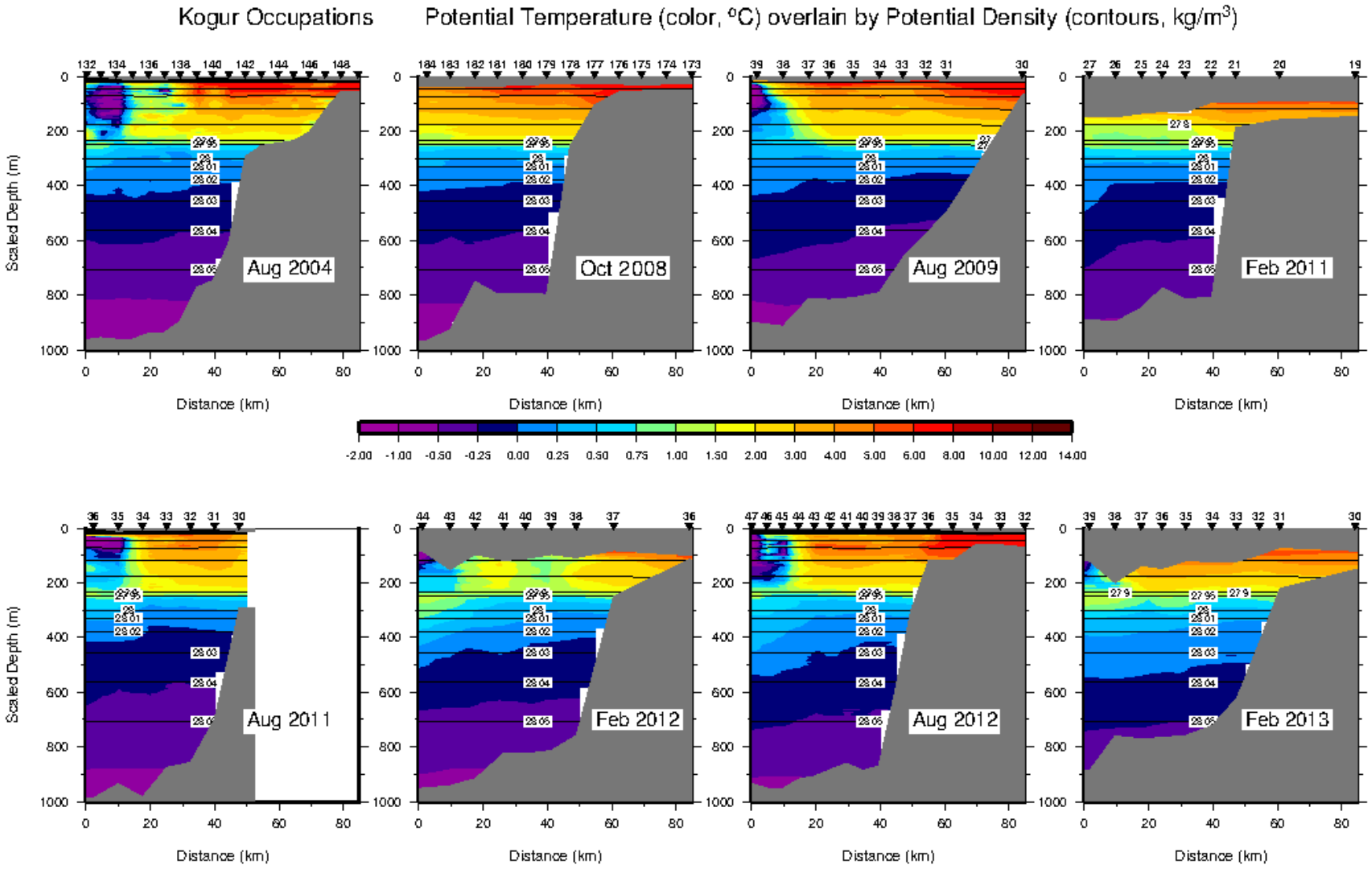
Even when they are de-coupled, the NIJ is flowing adjacent to a (weaker) inflow of warm water.

Interannual variability:
subtropical inflow vs. dense outflow

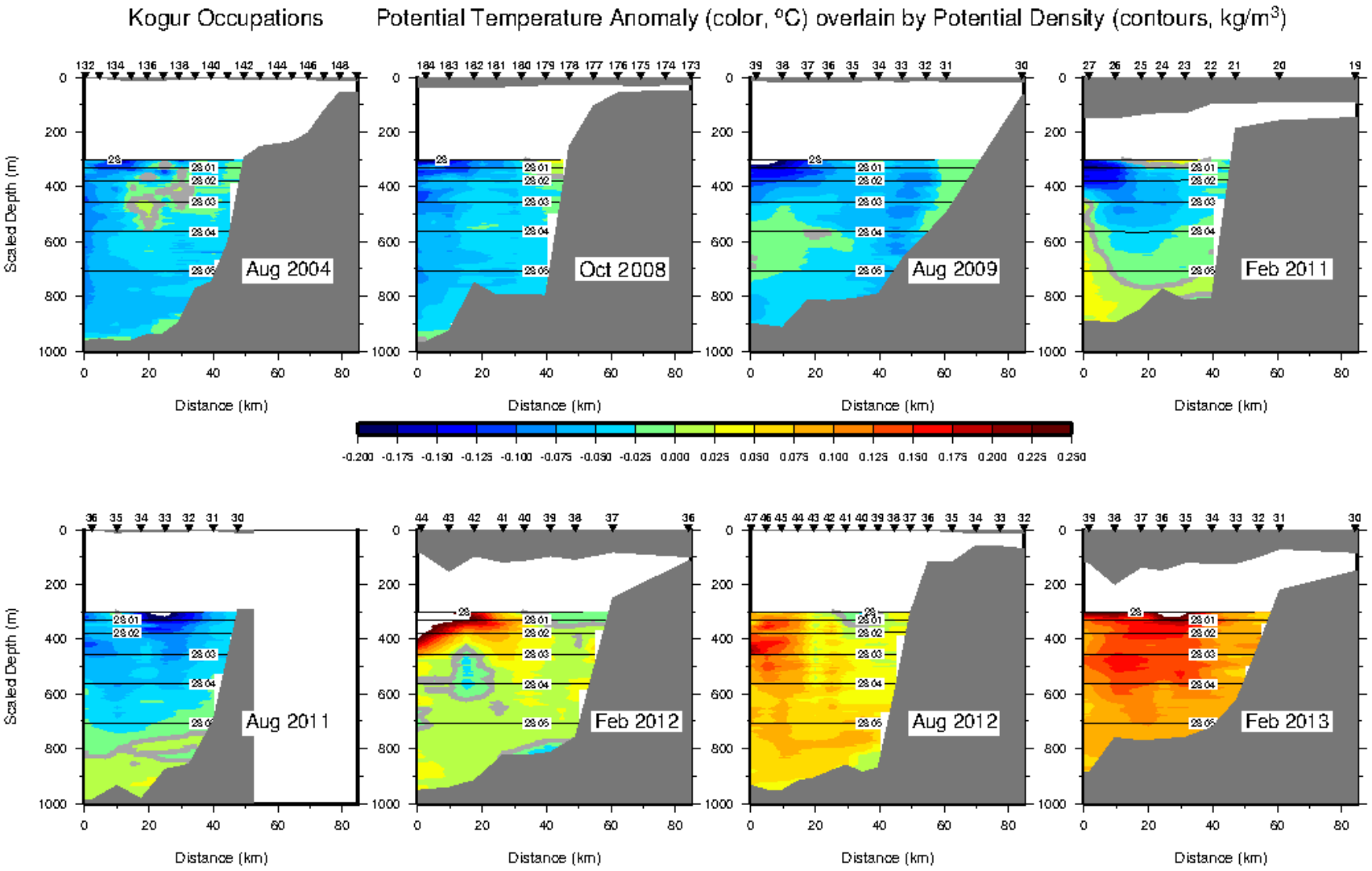
Depth-space

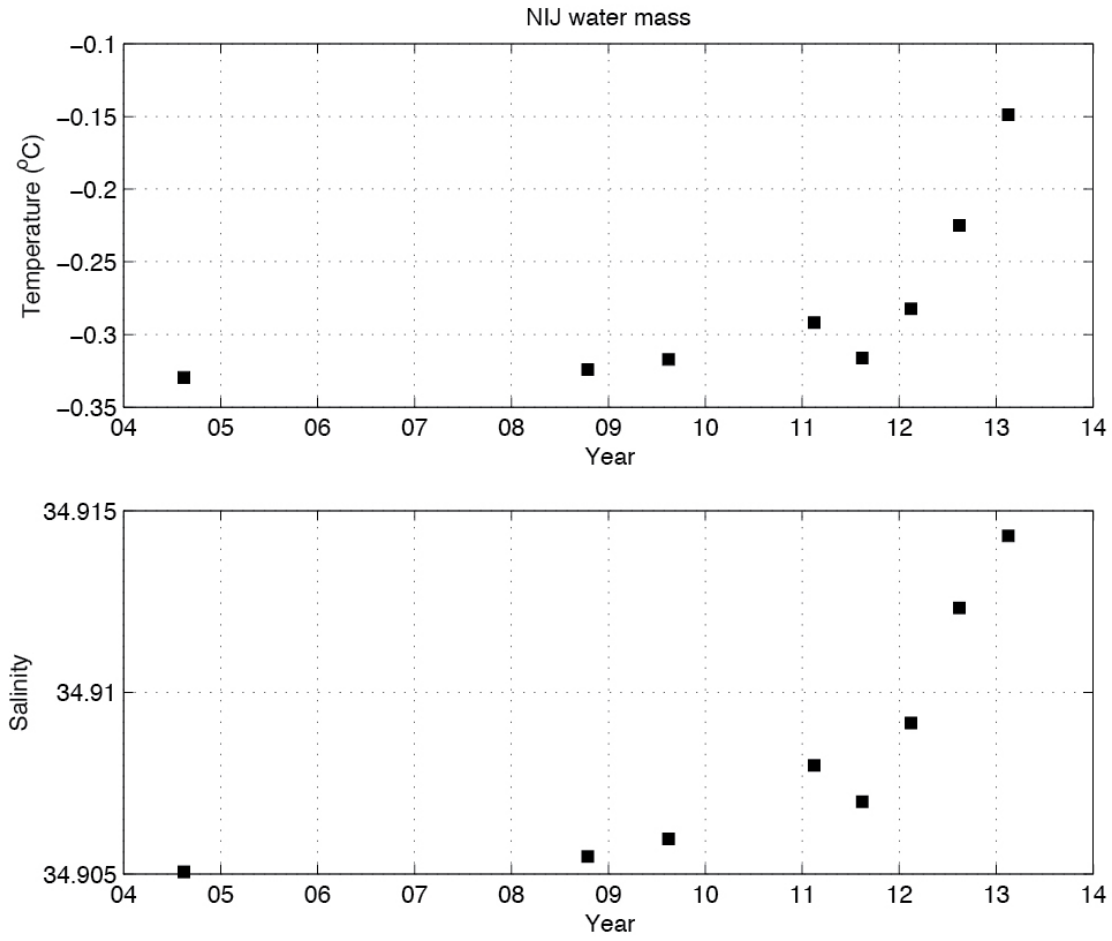

Kogur Occupations
Potential Temperature (color, °C) overlain by Potential Density (contours, kg/m3)
Aug 2004
Oct 2008
Aug 2009
Feb 2011
Aug 2011
Feb 2012
Aug 2012
Feb 2013
Depth (m)
Distance (km)

Density-space



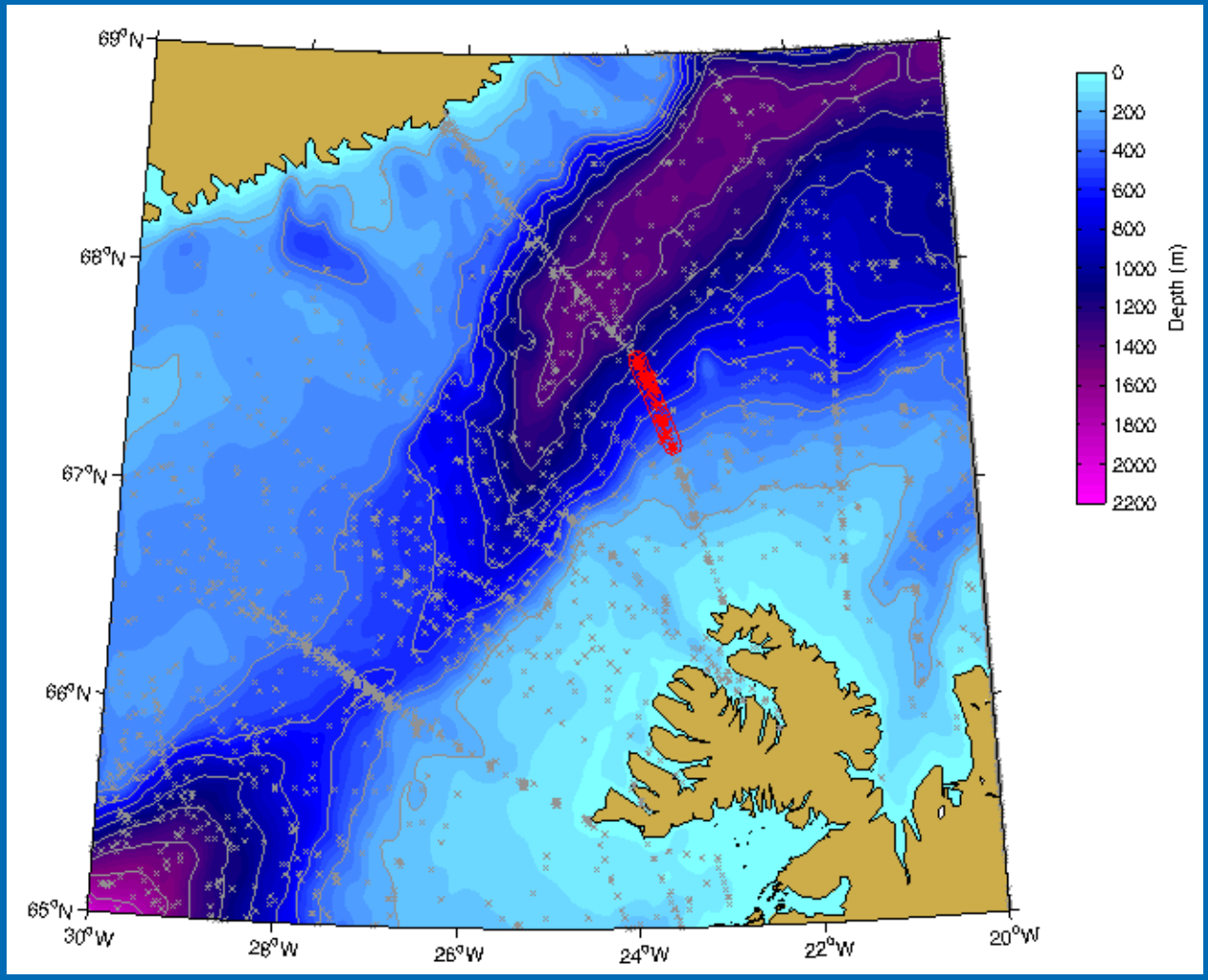
Anomaly in density-space



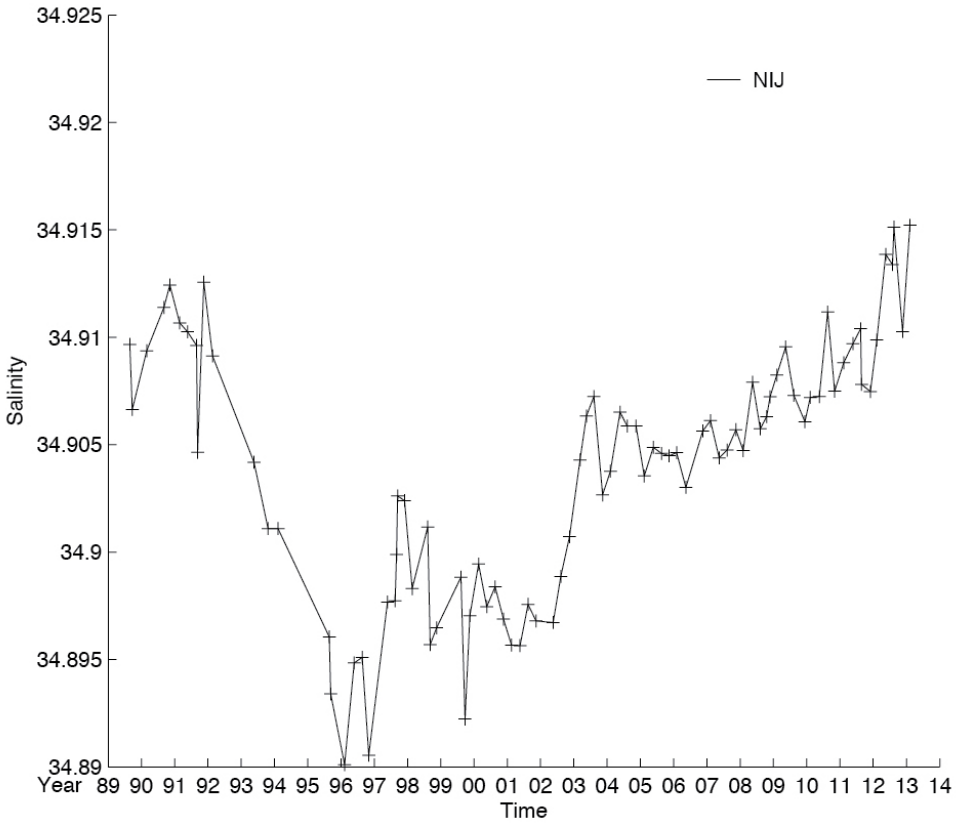


For the densest component of the NIJ ($\sigma_\Theta > 28.035$)

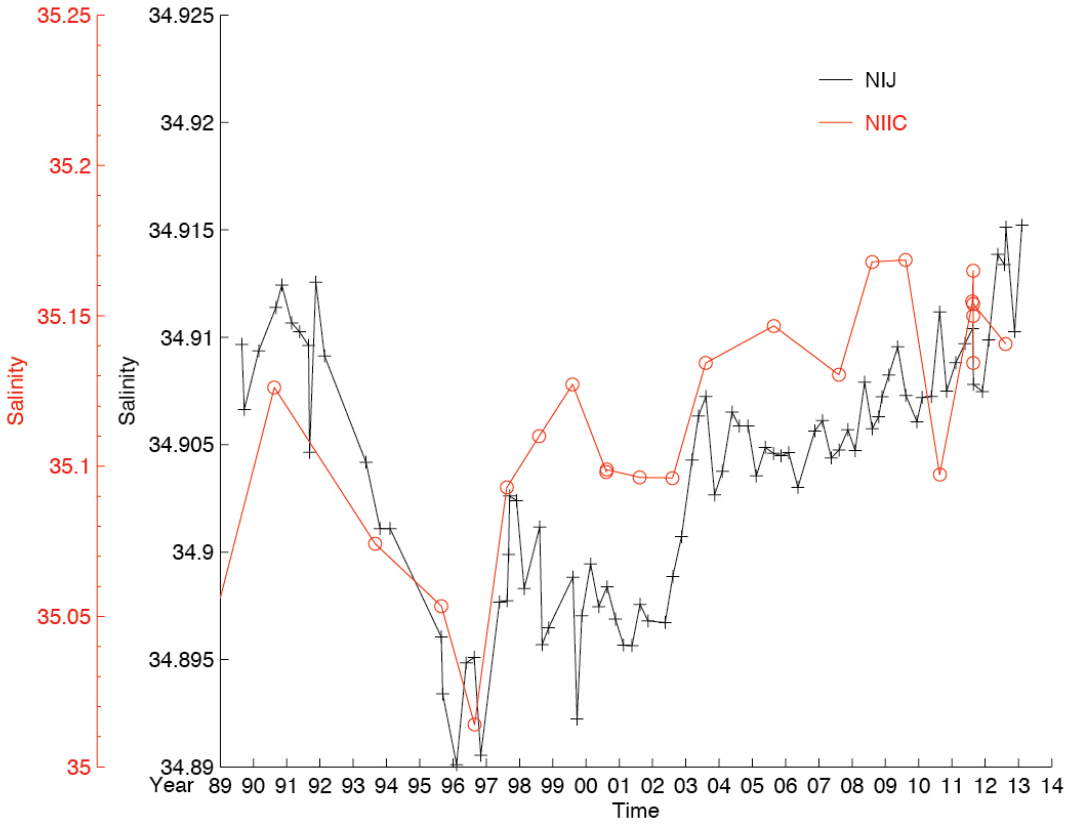
Changes in the NIJ water



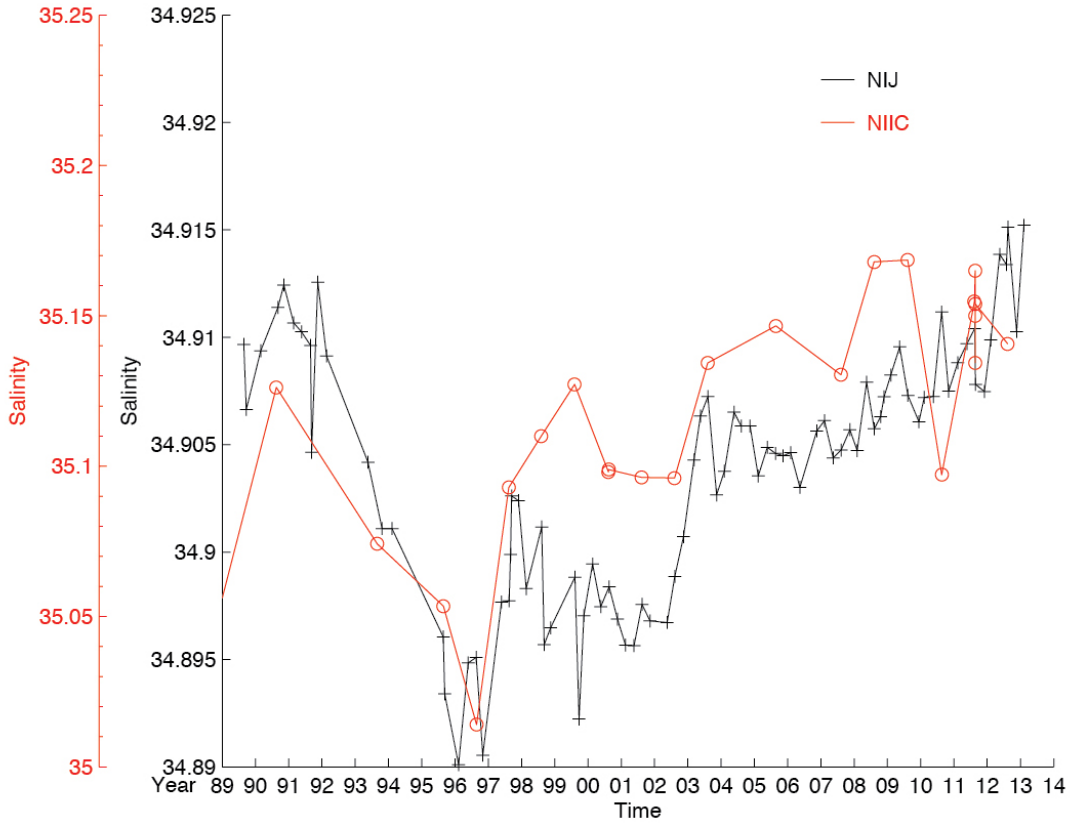
Longer term interannual variability



Longer term interannual variability



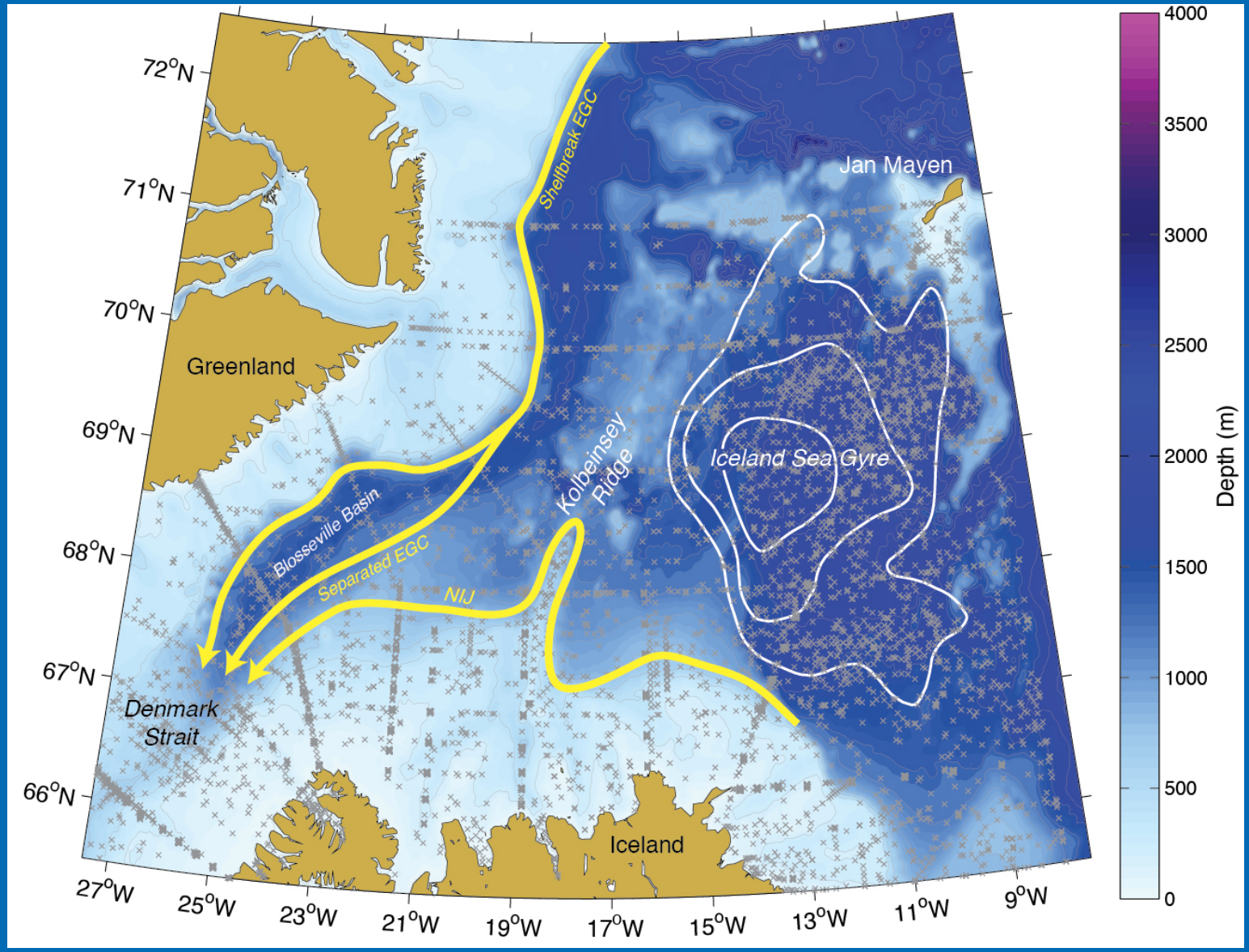
Longer term interannual variability



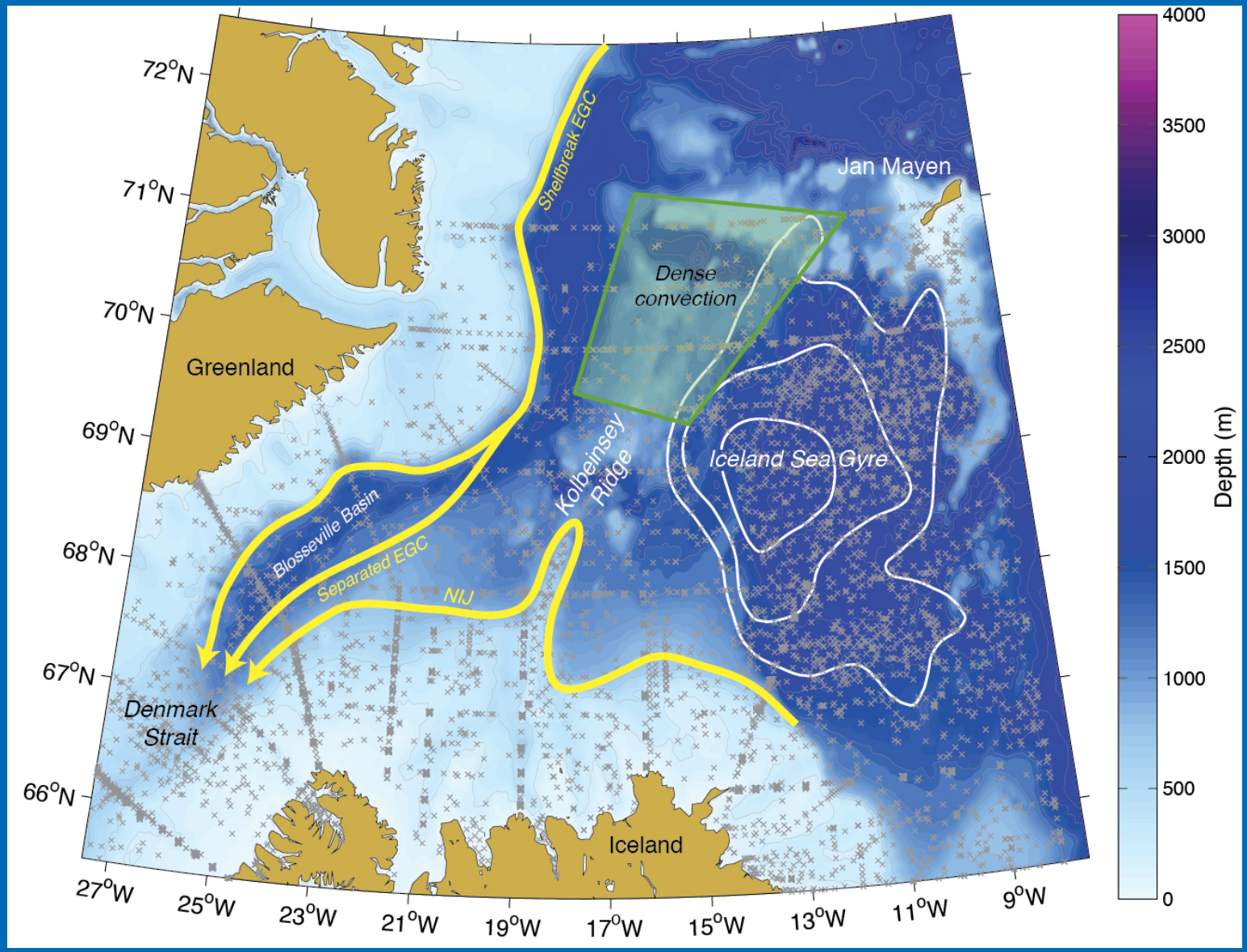
Aspects to consider:

1. The curves are nearly in phase
2. The outflowing salinity is ~0.2 fresher
3. The salinity fluctuations of the inflow are much greater than the outflow

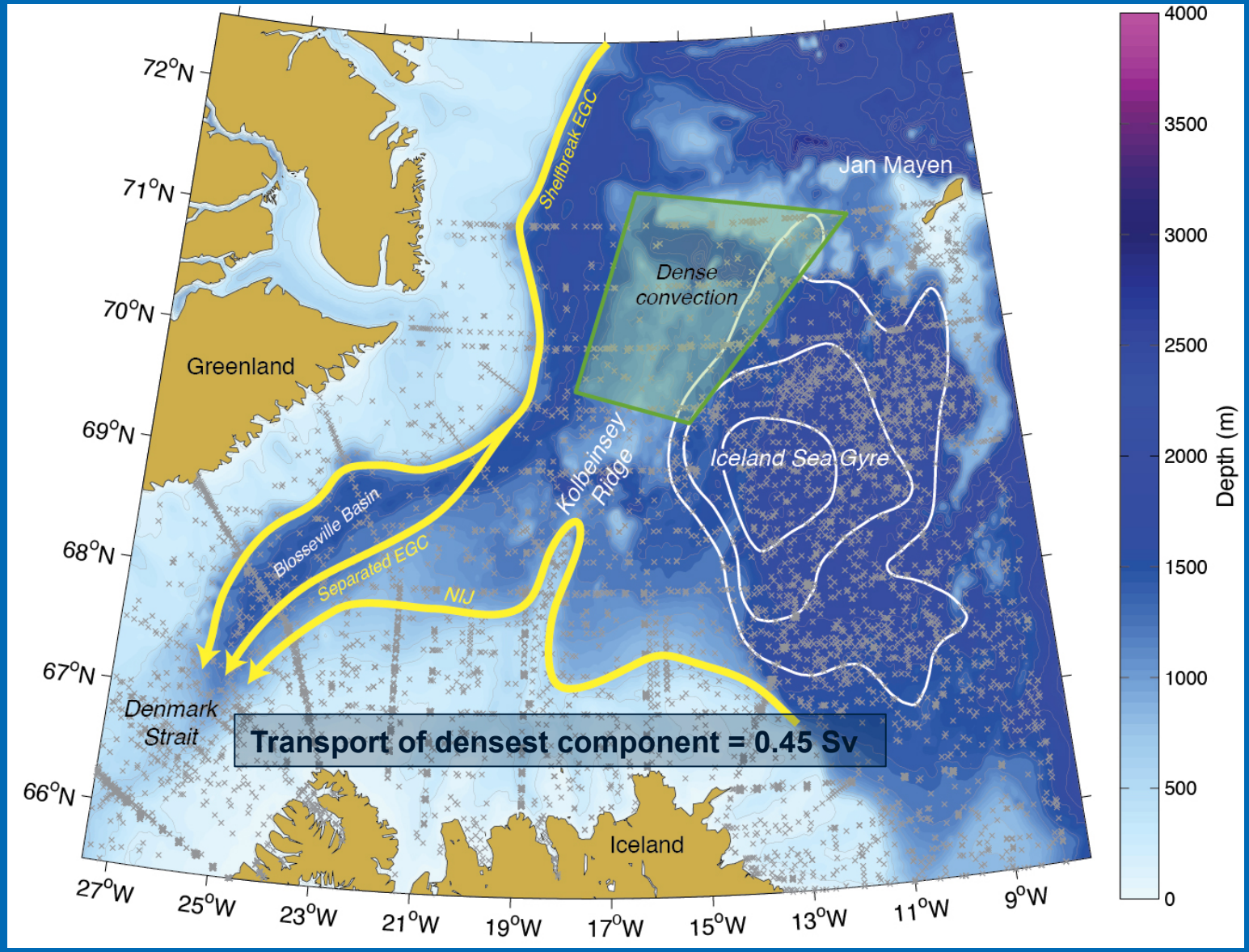
1. Variations of the inflow and outflow are in phase



1. Variations of the inflow and outflow are in phase



1. Variations of the inflow and outflow are in phase



2. Need to freshen ~0.5 Sv of inflow by 0.2

2. Need to freshen ~0.5 Sv of inflow by 0.2

This requires approximately 100 mSv of freshwater to mix with the inflowing salinity

Possibilities:

1. **Precipitation**
2. **Liquid freshwater flux from EGC**
3. **Solid freshwater flux from EGC**

2. Need to freshen ~0.5 Sv of inflow by 0.2

This requires approximately 100 mSv of freshwater to mix with the inflowing salinity

Possibilities:

1. **Precipitation**
2. **Liquid freshwater flux from EGC**
3. **Solid freshwater flux from EGC**

1. **Precipitation an order of magnitude too small**

2. Need to freshen ~0.5 Sv of inflow by 0.2

This requires approximately 100 mSv of freshwater to mix with the inflowing salinity

Possibilities:

1. **Precipitation**
2. **Liquid freshwater flux from EGC**
3. **Solid freshwater flux from EGC**

1. **Precipitation an order of magnitude too small**
2. **Offshore flux of liquid freshwater is O(50 mSv) (Håvik et al., 2017)**
3. **Offshore flux of solid freshwater is O(50 mSv) (Dodd et al., 2009)**

3. Salinity fluctuations of NIJ much smaller than NIIC

3. Salinity fluctuations of NIJ much smaller than NIIC

Possibilities:

1. **Precipitation**
2. **Liquid freshwater flux from EGC**
3. **Solid freshwater flux from EGC**

3. Salinity fluctuations of NIJ much smaller than NIIC

Possibilities:

1. **Precipitation**
2. **Liquid freshwater flux from EGC**
3. **Solid freshwater flux from EGC**

Cannot evaluate this

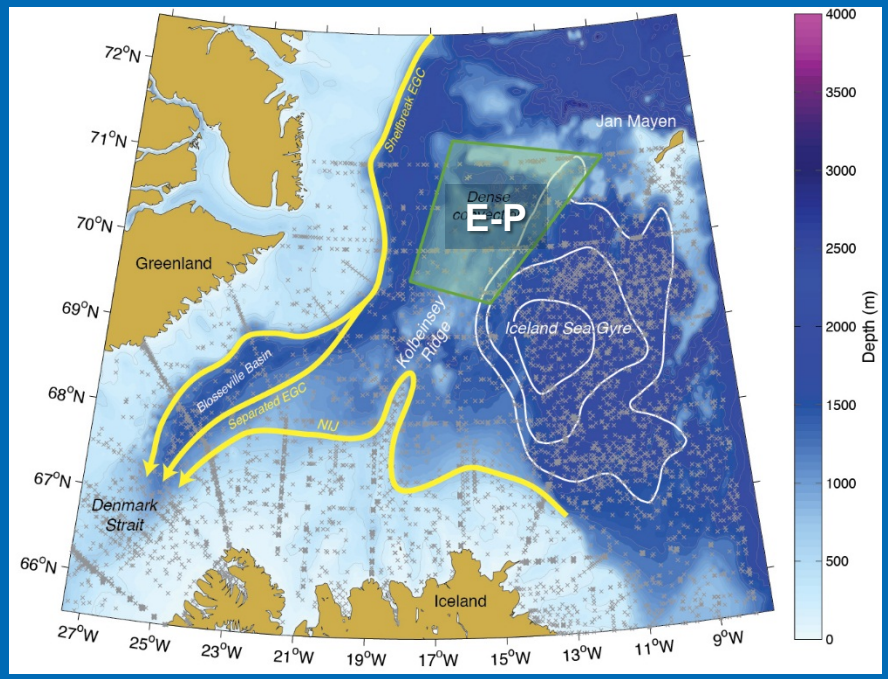
3. Salinity fluctuations of NIJ much smaller than NIIC

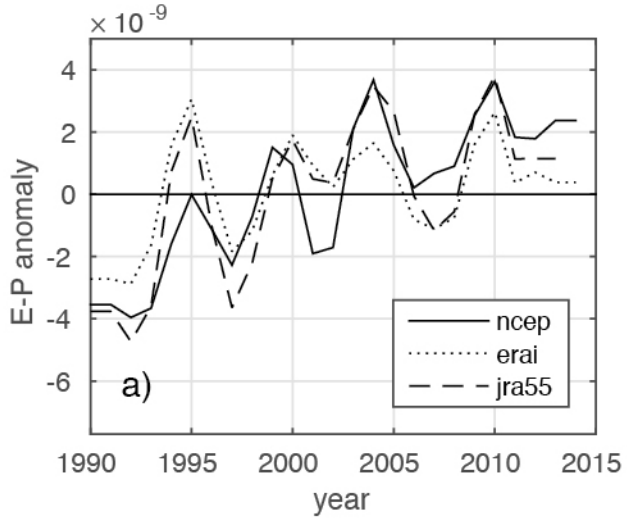
Possibilities:

1. Precipitation
2. Liquid freshwater flux from EGC
3. Solid freshwater flux from EGC

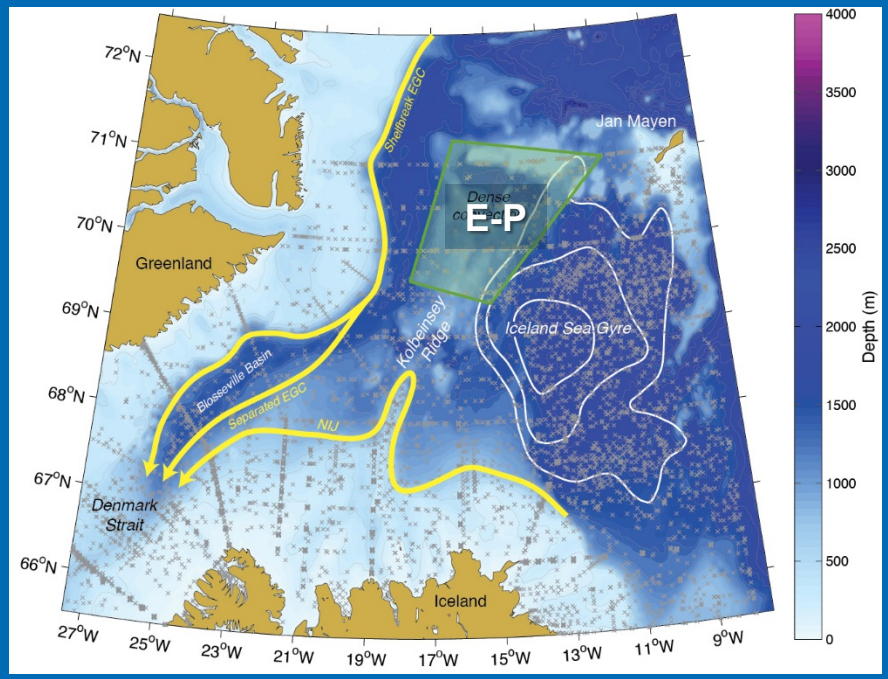
What about this?

Cannot evaluate this





three different reanalysis products



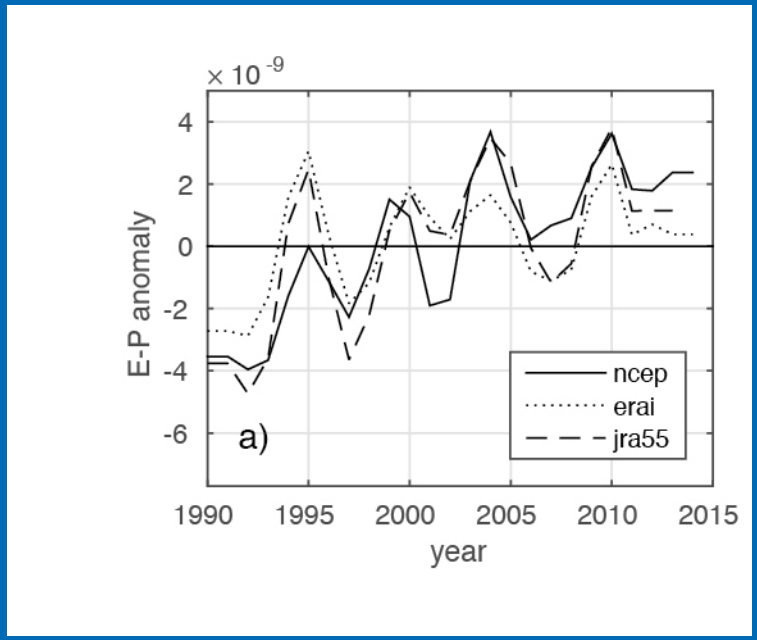
1-D mixing model

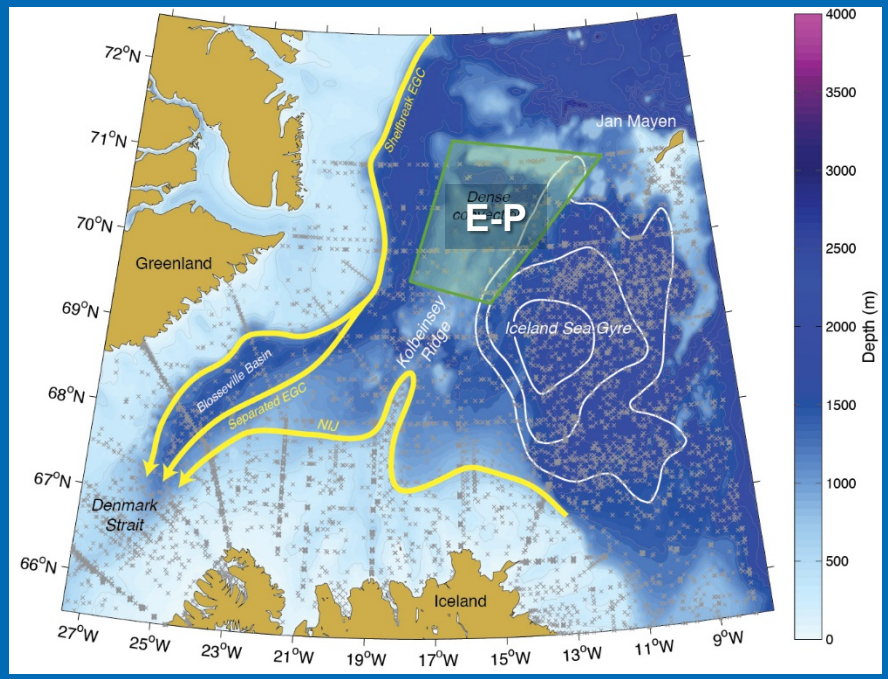
$$\partial S/\partial t = SrE/H$$

S_r = reference salinity

E = anomaly of E-P

Assume H = 500m





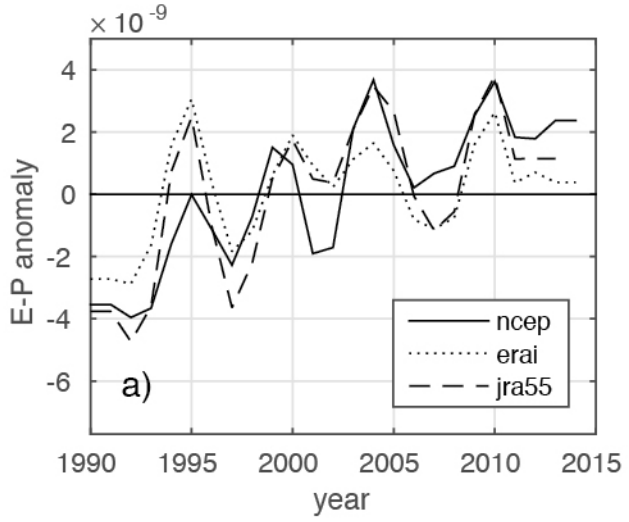
1-D mixing model

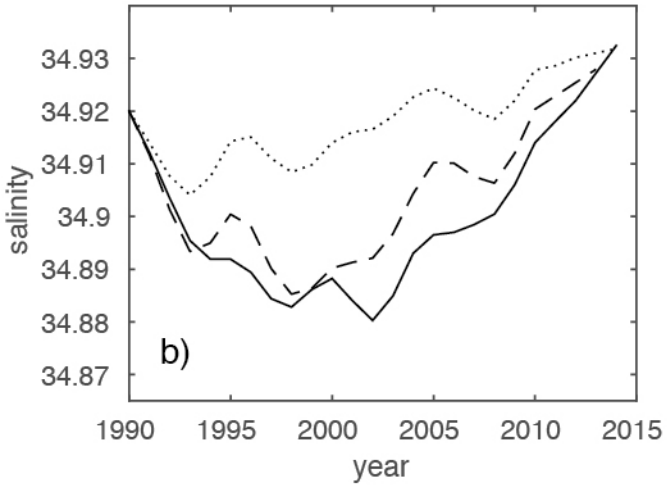
$$\partial S/\partial t = SrE/H$$

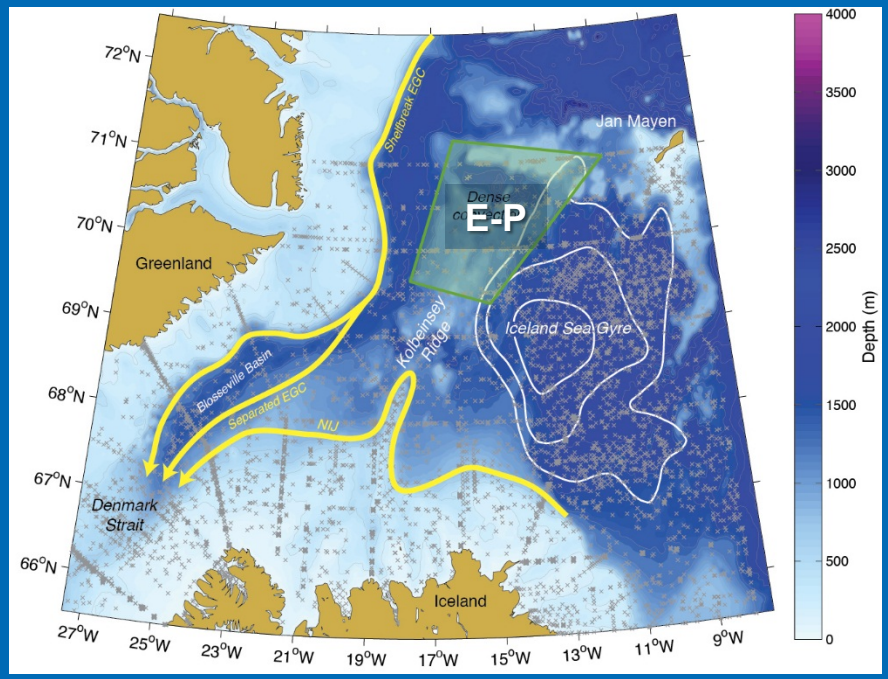
S_r = reference salinity

E = anomaly of E-P

Assume H = 500m







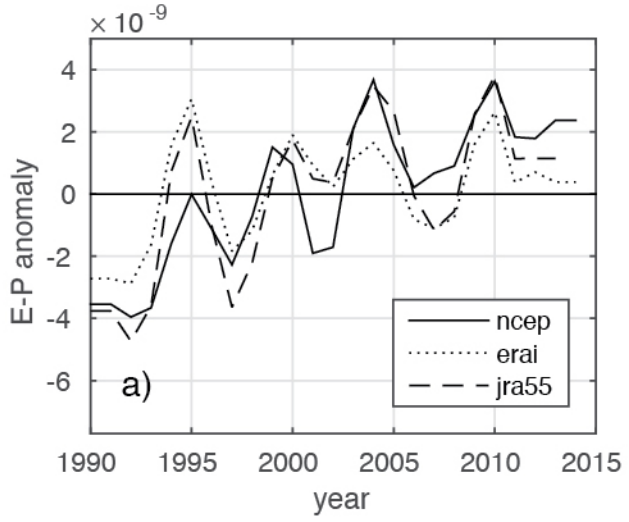
1-D mixing model

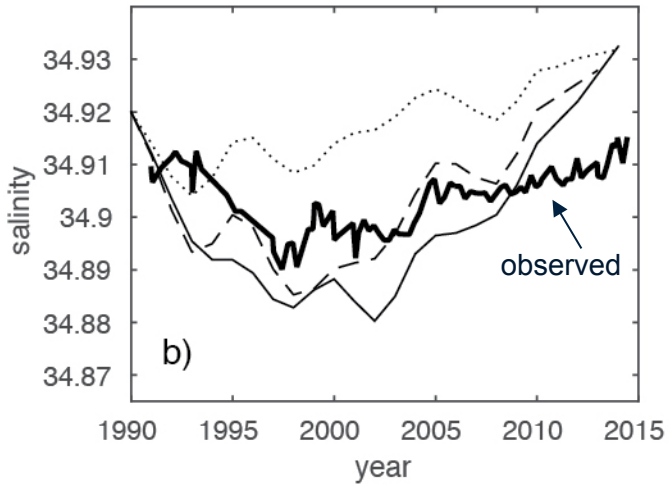
$$\partial S/\partial t = SrE/H$$

S_r = reference salinity

E = anomaly of E-P

Assume H = 500m





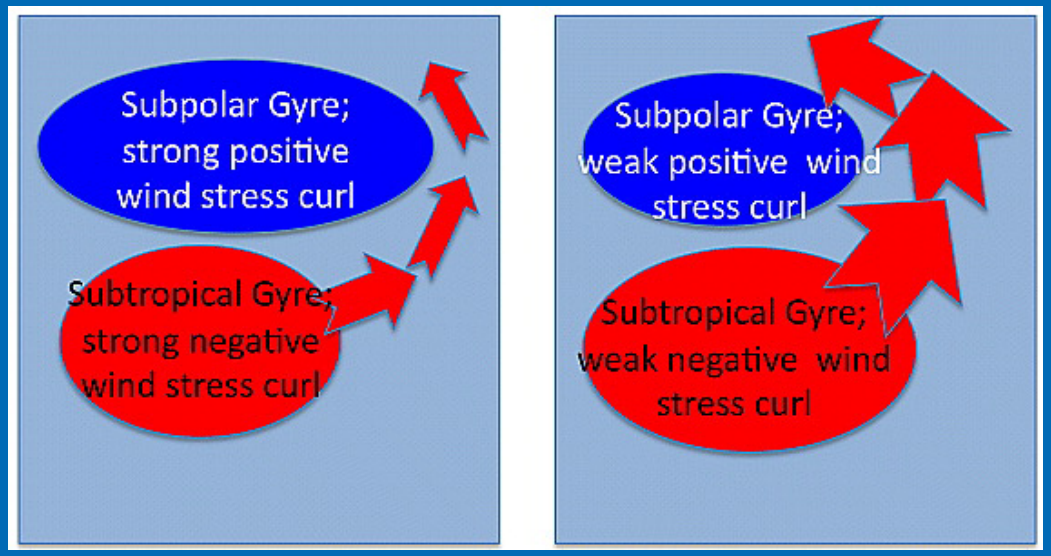
If E-P determines the outflow salinity variations, what determines the inflow salinity variations?

And why are the inflow and outflow in phase?

If E-P determines the outflow salinity variations, what determines the inflow salinity variations?

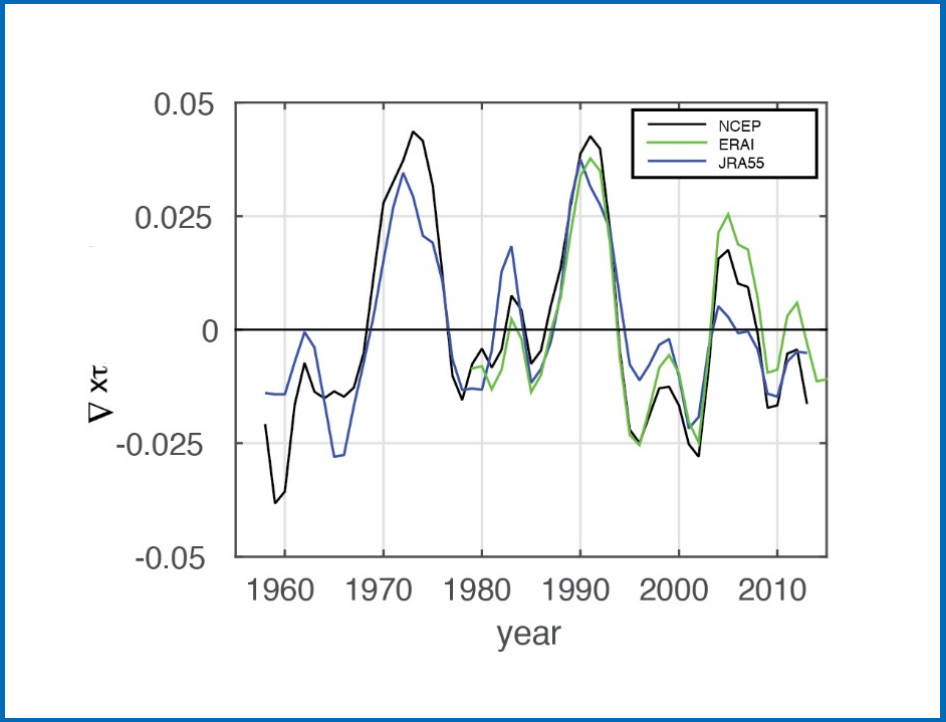
And why are the inflow and outflow in phase?

As demonstrated by previous studies, the wind stress curl over the subpolar gyre helps dictate the supply of subtropical water into the Nordic Seas

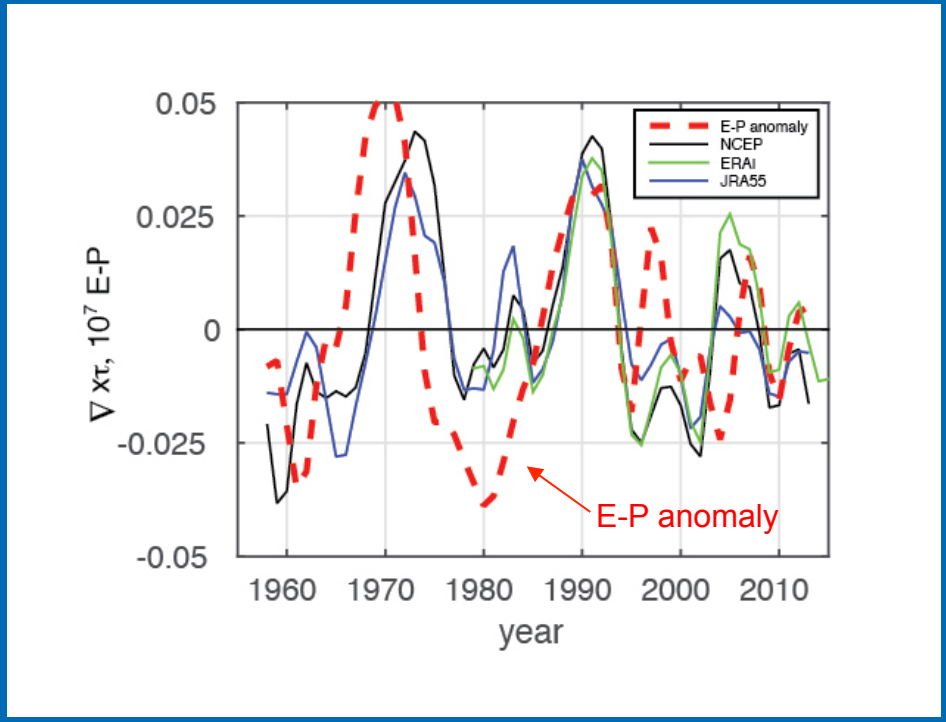


Hakkenin et al. (2011)

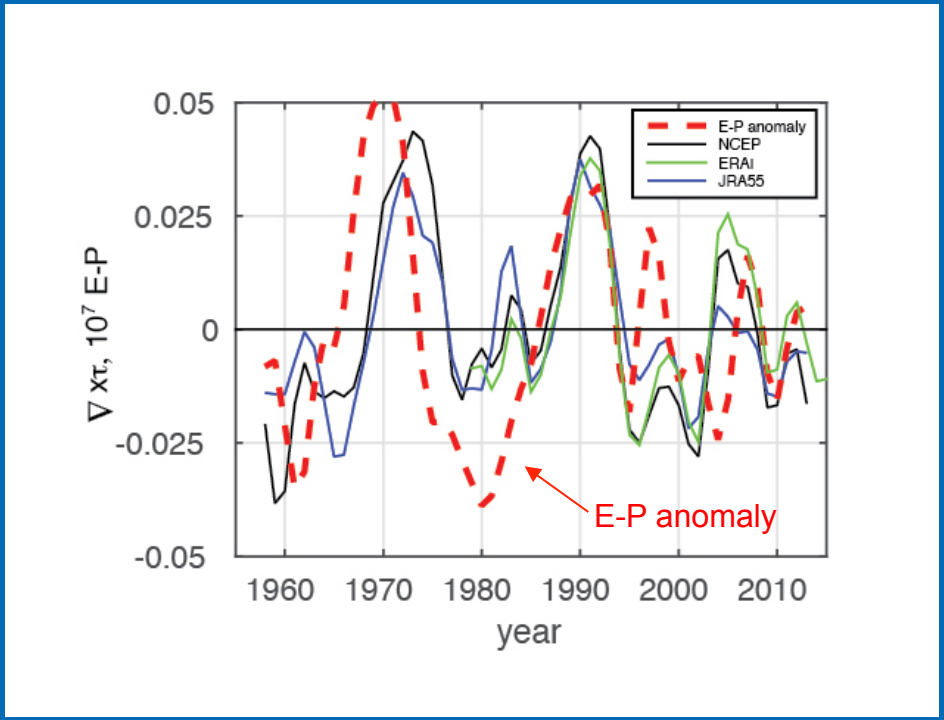
decreased inflow **increased inflow**



Wind stress curl anomaly averaged over the subpolar gyre

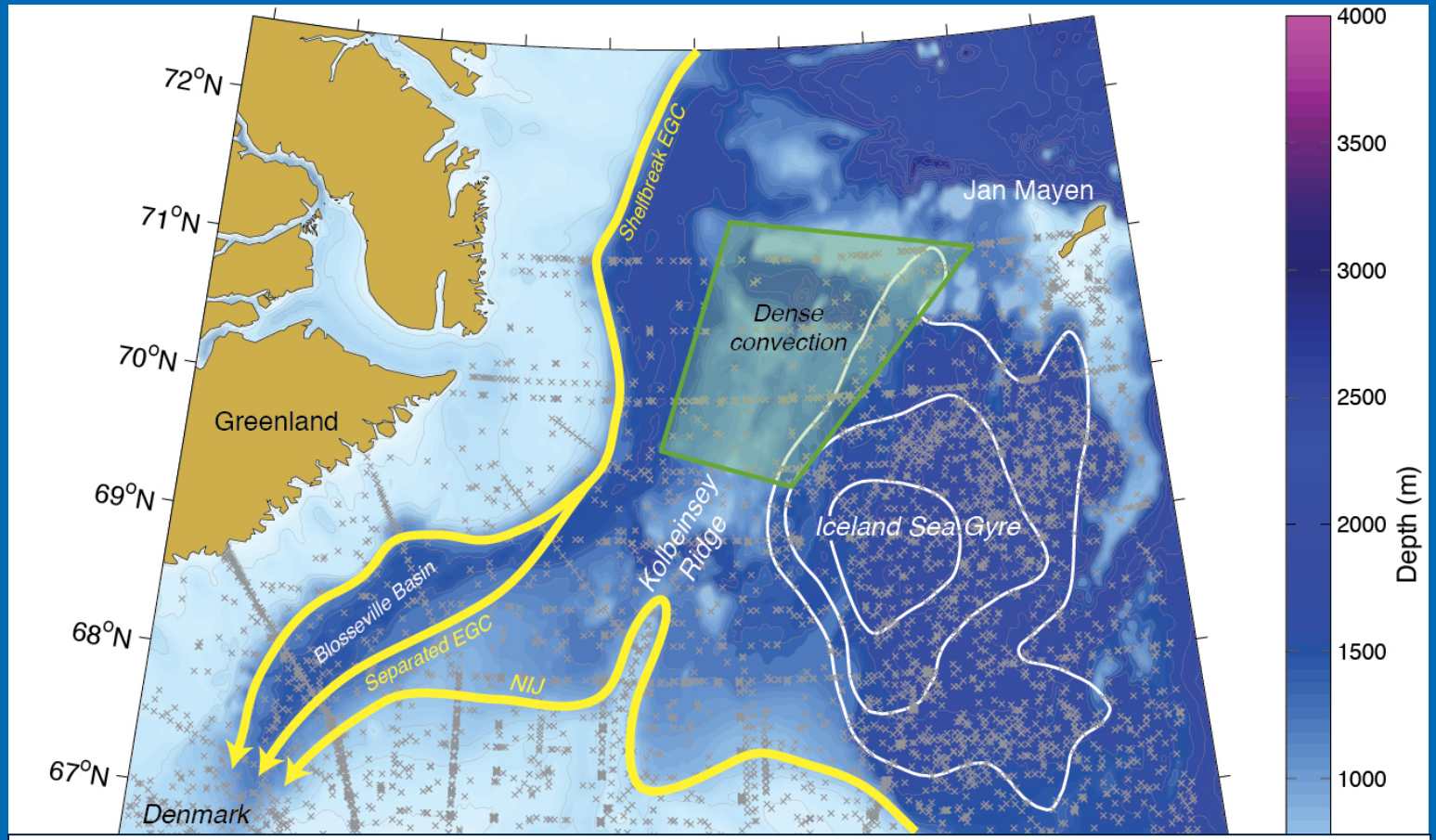


Wind stress curl anomaly averaged over the subpolar gyre

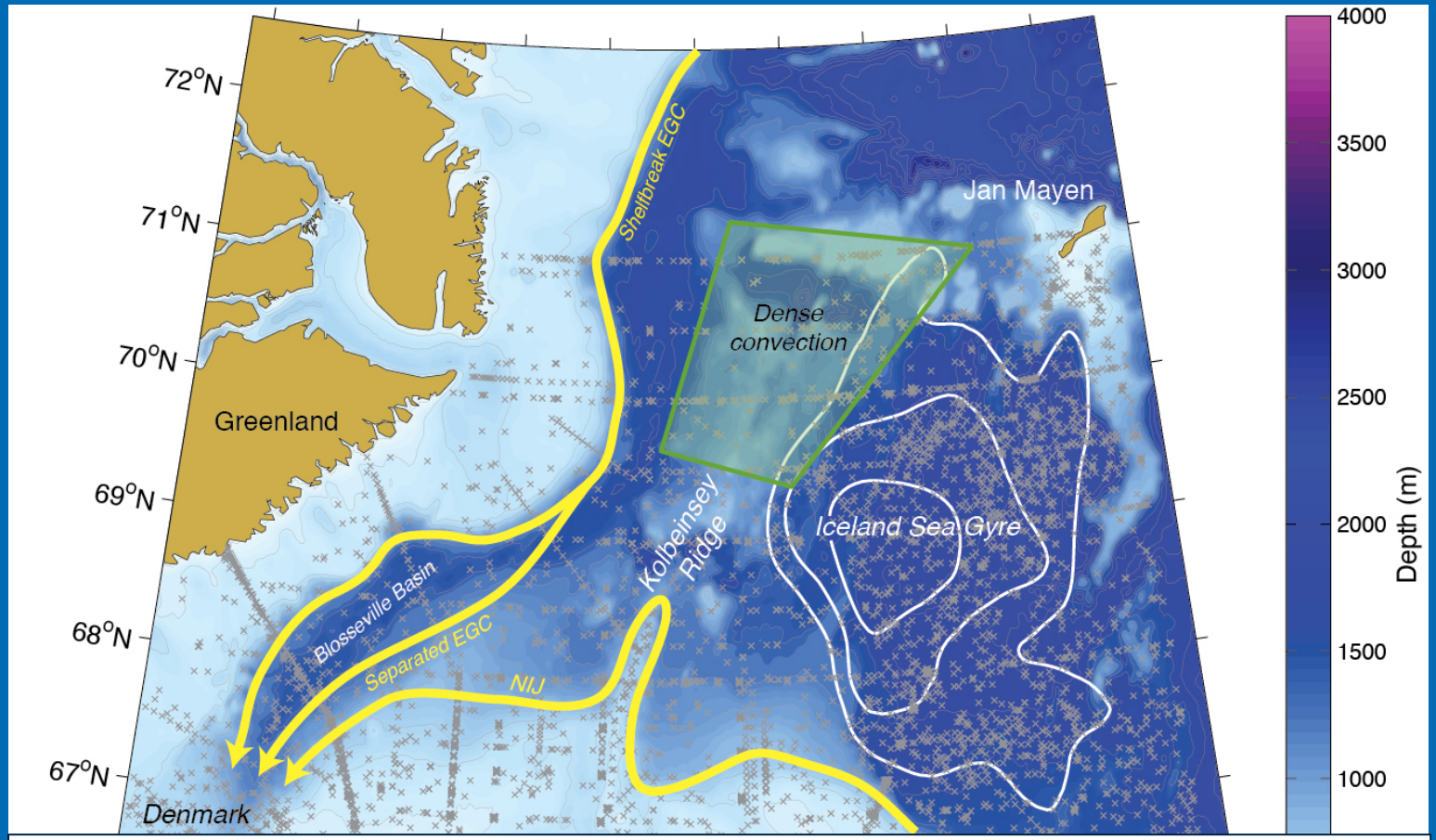


Wind stress curl anomaly averaged over the subpolar gyre

This implies that the large-scale weather patterns that control the low frequency variability of the wind stress curl over the subpolar North Atlantic also influence the E-P fields over the Iceland Sea

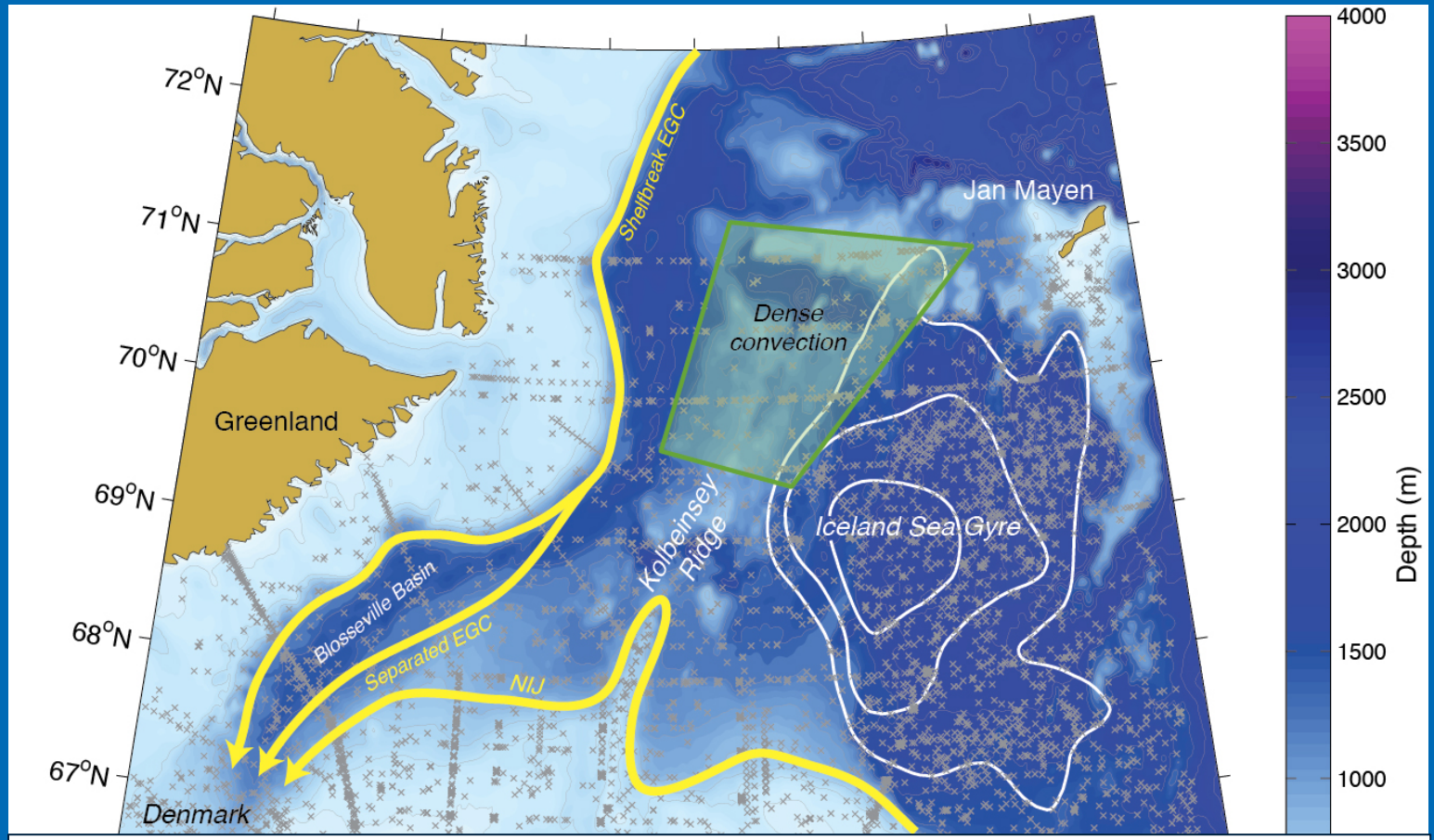


This does not tell us how fast the overturning loop is, but:



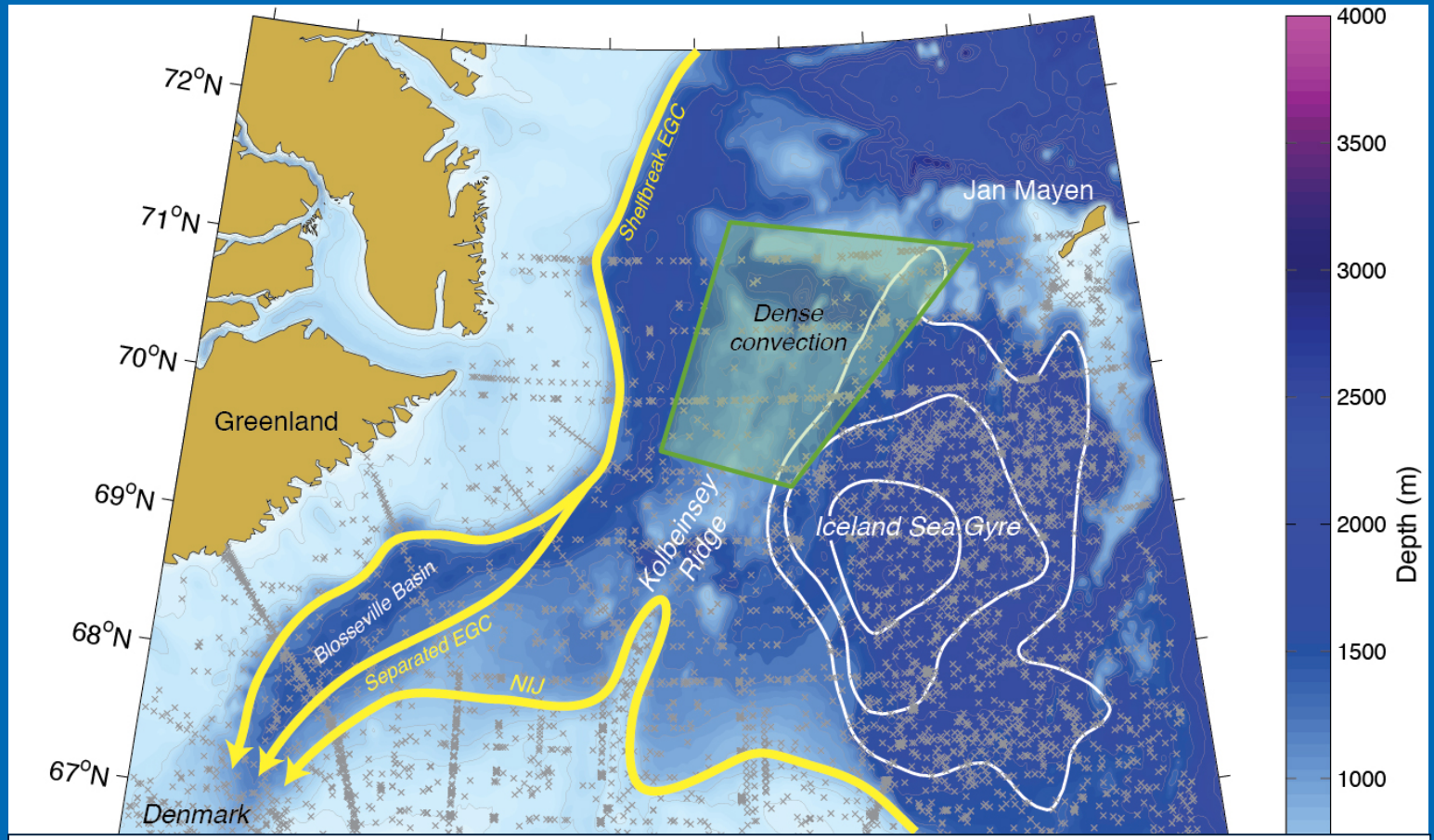
This does not tell us how fast the overturning loop is, but:

1. **The E-P imprint on the NIJ seems to happen within 1 year**



This does not tell us how fast the overturning loop is, but:

1. **The E-P imprint on the NIJ seems to happen within 1 year**
2. **The flushing time of the dense water reservoir for 0.5 Sv and 500m is 1 year**



This does not tell us how fast the overturning loop is, but:

1. **The E-P imprint on the NIJ seems to happen within 1 year**
2. **The flushing time of the dense water reservoir for 0.5 Sv and 500m is 1 year**
3. **With a modest advective speed of 1 cm/s the advective time from the dense water reservoir to the NIJ is less than 1 year**

Summary

As the NIJ and NIIC flow along the north side of Iceland they appear to “lock” to each other when the bottom topography steers them close together.
Even when they are separate, there is a poleward flow inshore of the NIJ.

Summary

As the NIJ and NIIC flow along the north side of Iceland they appear to “lock” to each other when the bottom topography steers them close together. Even when they are separate, there is a poleward flow inshore of the NIJ.

The combination of liquid and solid freshwater flux from the EGC can account for the net freshening of the NIIC to the NIJ as part of an overturning loop involving the densest NIJ water.

Summary

As the NIJ and NIIC flow along the north side of Iceland they appear to “lock” to each other when the bottom topography steers them close together. Even when they are separate, there is a poleward flow inshore of the NIJ.

The combination of liquid and solid freshwater flux from the EGC can account for the net freshening of the NIIC to the NIJ as part of an overturning loop involving the densest NIJ water.

The interannual variability of the inflow salinity is dictated by wind stress curl over the subpolar gyre; the variability of the outflow can be explained by in-phase changes in E-P over the Iceland Sea.