Dynamics of the Denmark Strait Overflow Pathways

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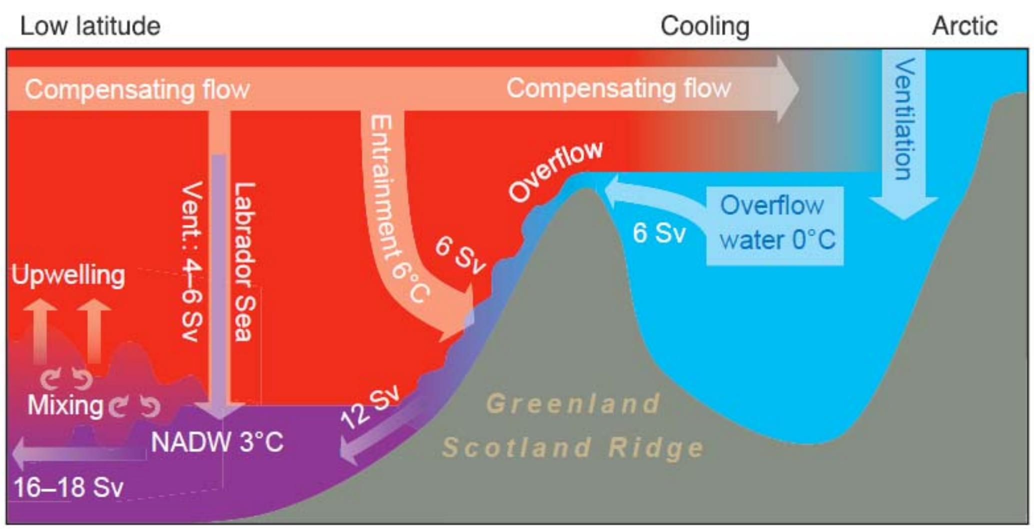
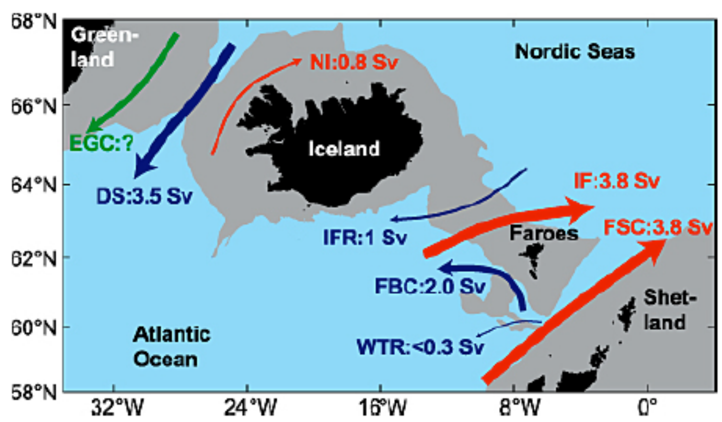
Why do we care about the Denmark Strait Overflow Pathways?

- The Nordic Sea Overflow is a major driver for the lower limb of the AMOC;
- Denmark Strait Overflow (DSO) contributes about 50% to total overflow transport;
- Variations in DSO are linked to alternation of the upstream pathways

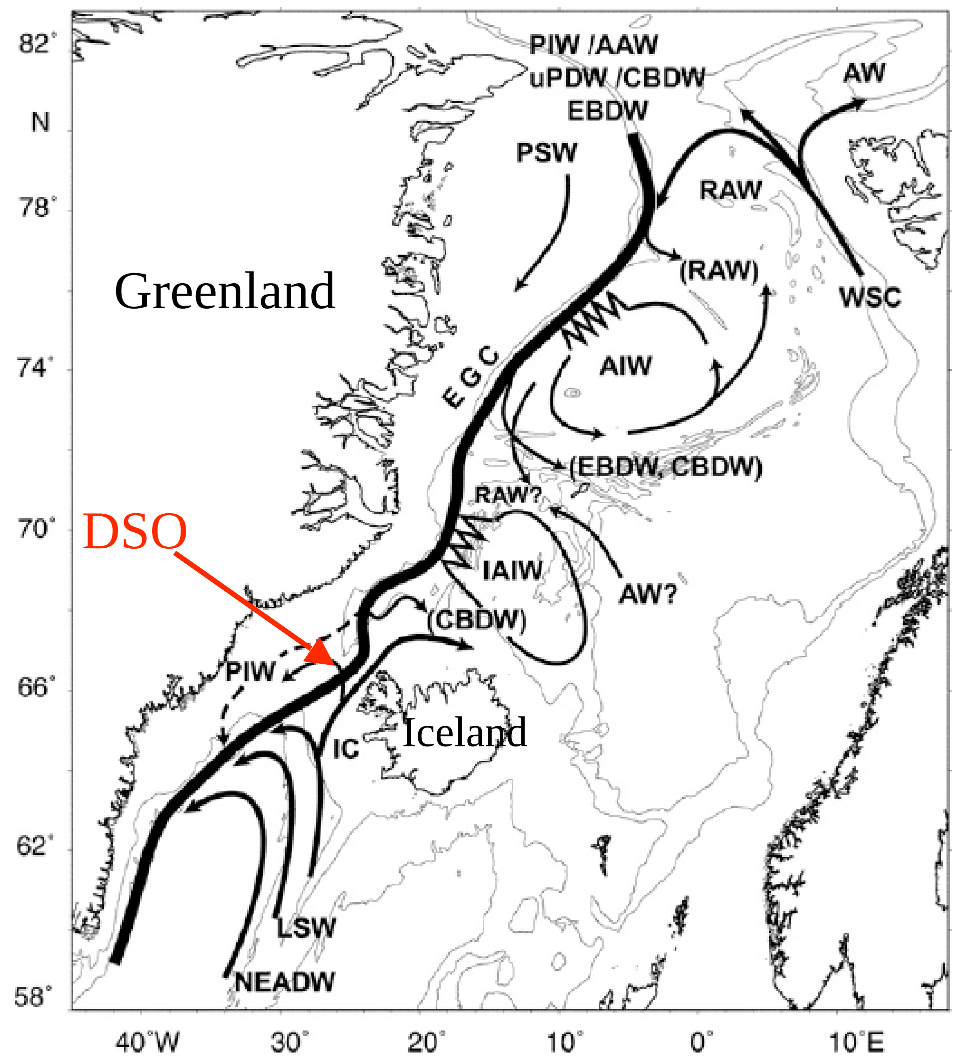




From: Hansen et al. (2010)

According to hydrochemical analyses, the DSO water mass has multiple origins, especially from regions along Greenland (Tanhua et al, 2005; Jeansson et al., 2008);

This supports a long held view that the East Greenland Current (EGC) is the pathway for the DSO (Rudels, et al., 2002)



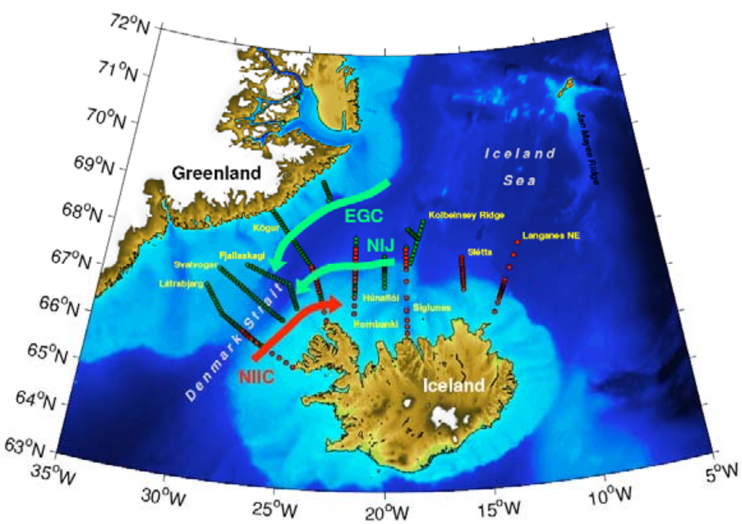
Rudels et a. (2002); Jeansson et al. (2008)

A new DSO pathway - the North Icelandic Jet (NIJ)

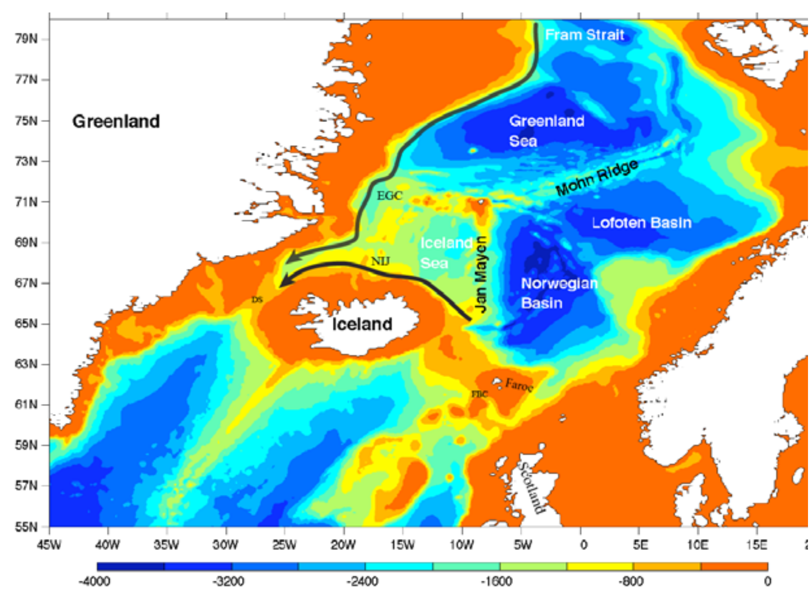
Jonsson and Valdimarsson (2004, *GRL*) found a new pathway along the northern Icelandic shelf;

Våge et al. (2011, *Nature Geosciences*) unambiguously proved the existence of the NIJ as a major DSO pathway;

Kohl et al. (2010) suggested that the observed DSO variation were due to a NAO-forced alternation between the EGC and NIJ



Våge et al., 2011, *Nature Geosciences*



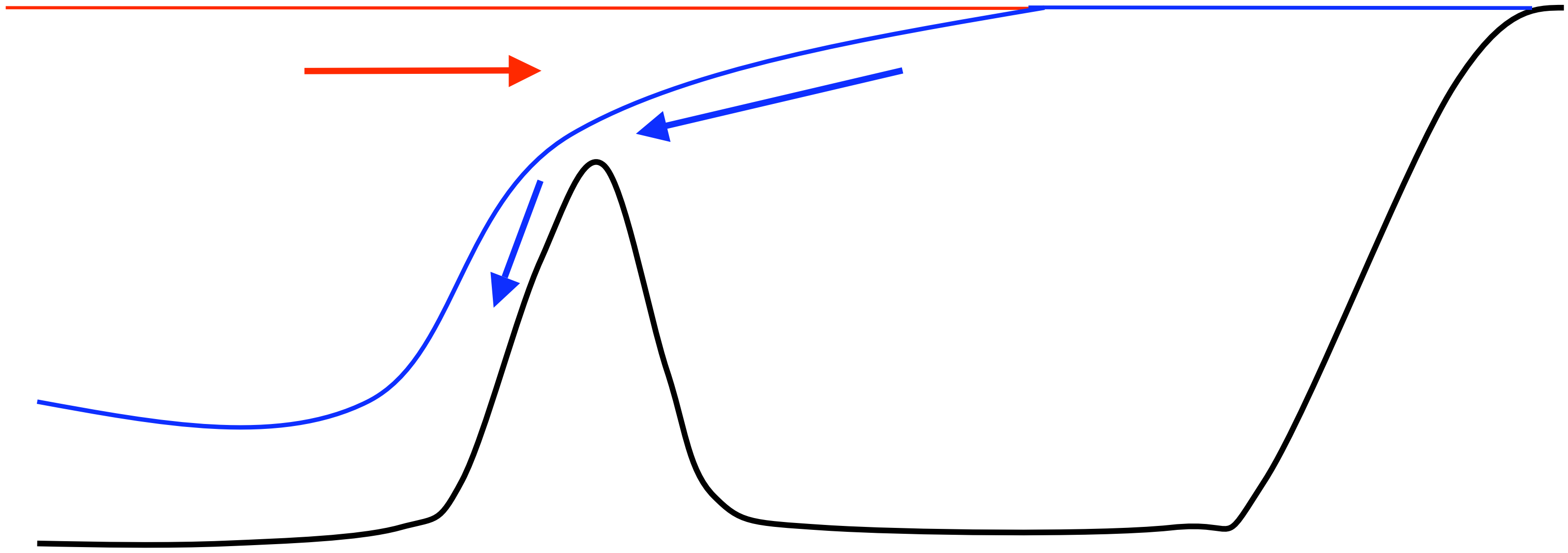
From Observations:

Hydrochemical data analyese indicate that the DSO water mass have multiple origins and the major components are from regions along Greenland
(Jeansson et al., 2008; Tanhua et al., 2005);

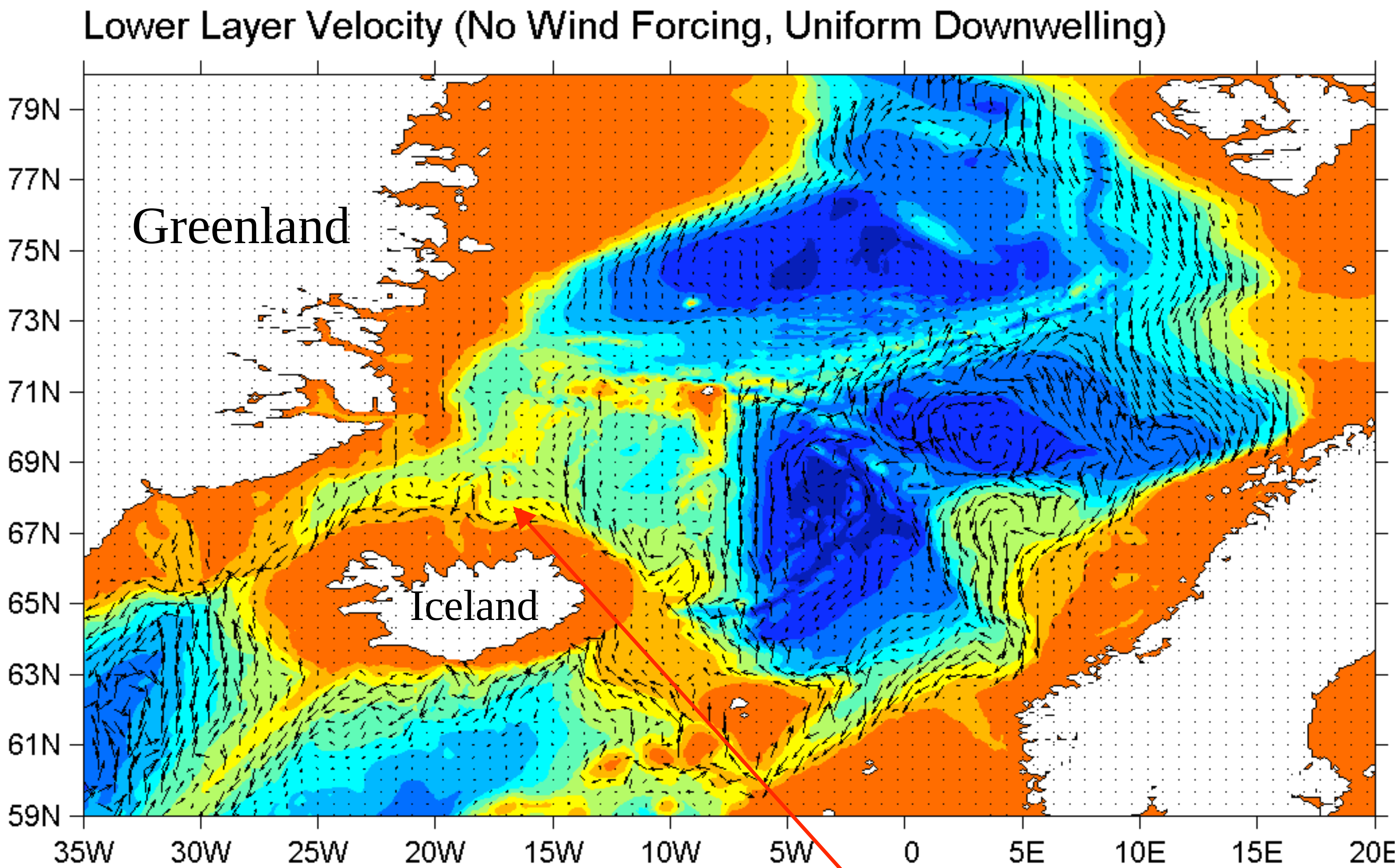
Direct observations showed that North Icelandic Jet is a main pathway for the DSO.

$\Rightarrow$ The NIJ should exist even if the water mass is not formed locally in the Icelandid Sea

A Two-Layer Marginal-Sea Overflow Model (Yang and Pratt, 2012) is used to explore the DSO pathways

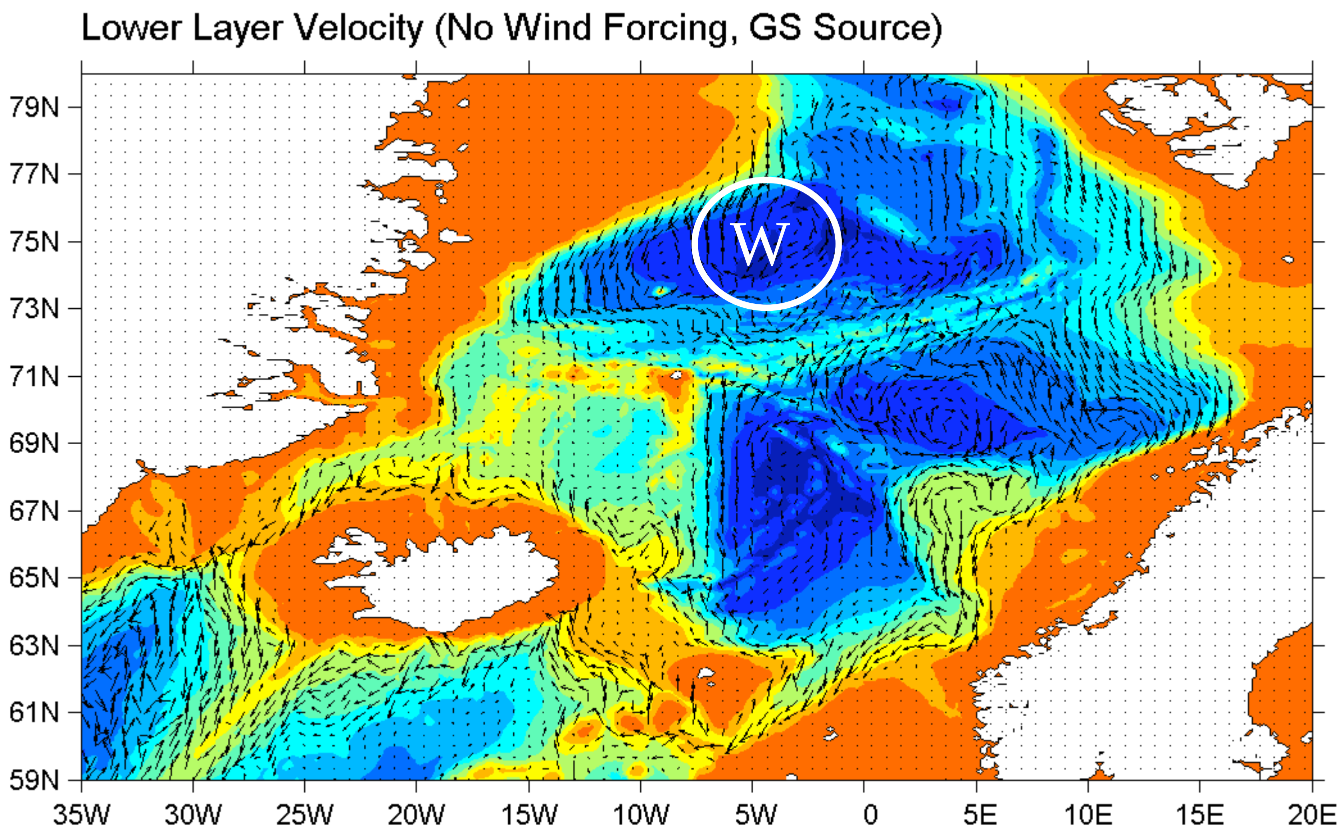


First experiment: uniform downwelling from top to bottom layer in the Nordic Seas



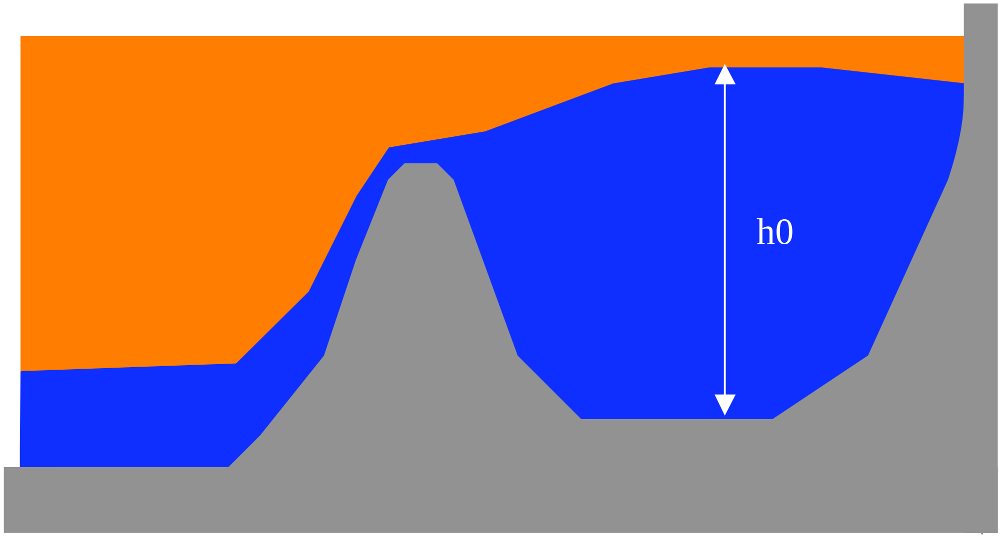
NIJ-like current along 600-800m isobaths

<u>2nd Experiment</u>: A source in the Greenland Sea



We conducted several additional source- and sink-driven experiments with different locations of deep-water sources. The NIJ always exists. The flow around the Greenland-Iceland-Scotlant Ridge is insensitive to where the source is located.

First mechanism: PV modification



In the upstream deep basin, the PV is near zero $q = \dfrac{f+\zeta}{h_0} \approx 0$

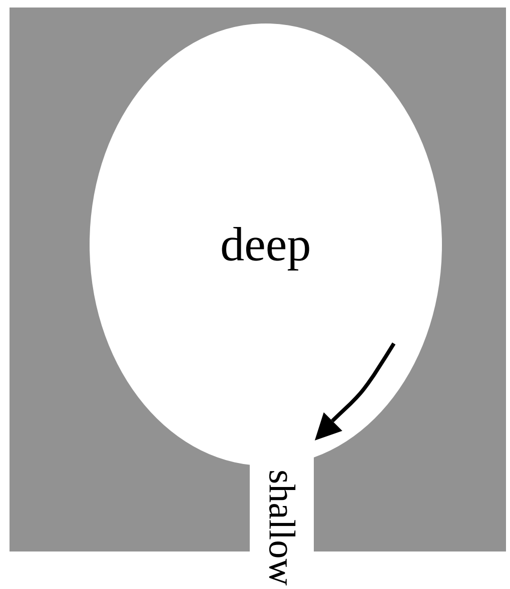
Observation shows that the PV is large at the sill

$$q = \frac{f+\zeta}{h_{sill}} \approx \frac{0.8f}{h_{sil}} \text{ to } \frac{0.9f}{h_{sil}}$$

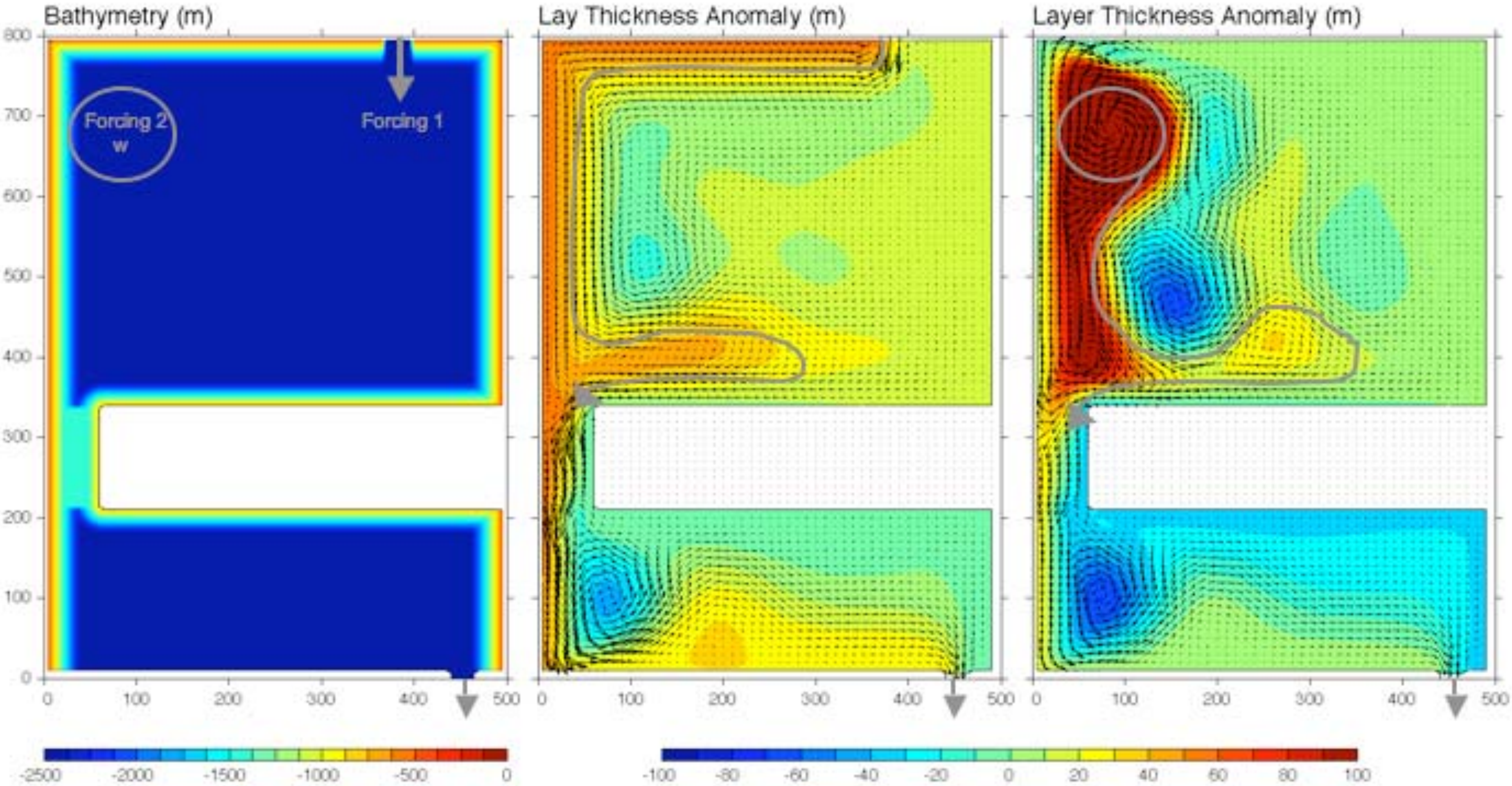
(Saunders, 1990; Lake, et al., 2005). J. Price (WHOI, personal comm.)

⇒Source water needs to increase PV from upstream basin to the sill;

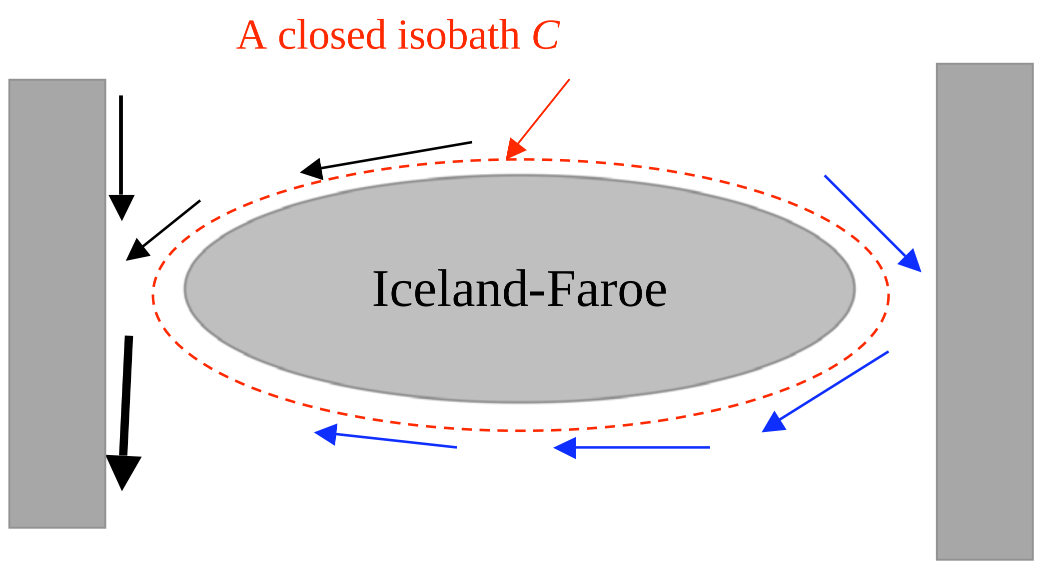
=>The source water approaches the sill as an anti-cyclonic current so the frictional torque is positive (Yang and Price, 2000; Helfrich and Pratt, 2003)



Idealized experiments:



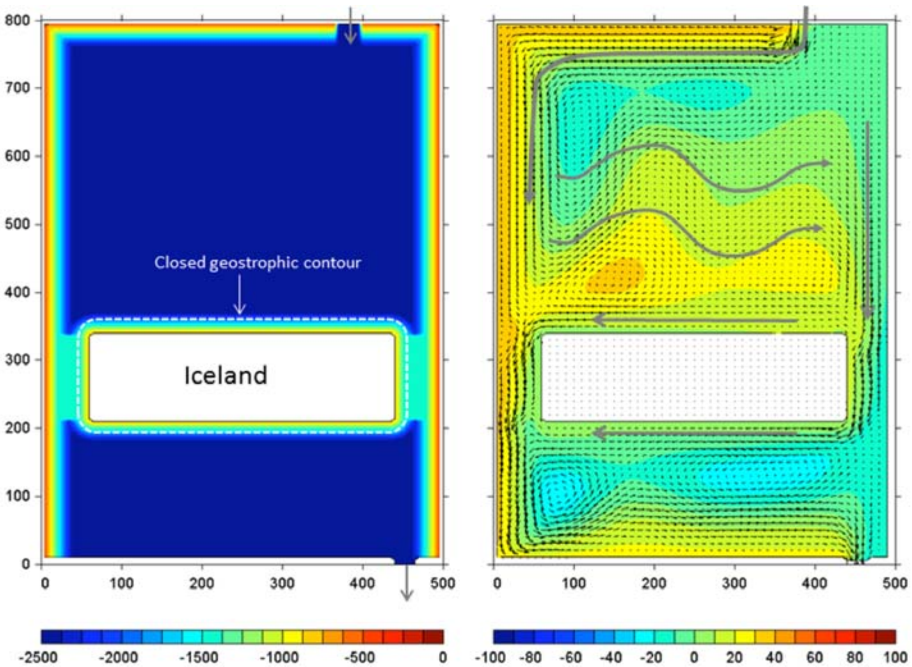
<u>Second mechanism</u>: A modified Kelvin theorem:



If there is no water-mass source and sink with a closed geostrophic contour, the integration of the tangential components of external forcing around this contour is zero (Pratt, 1998; Yang and Price, 2000):

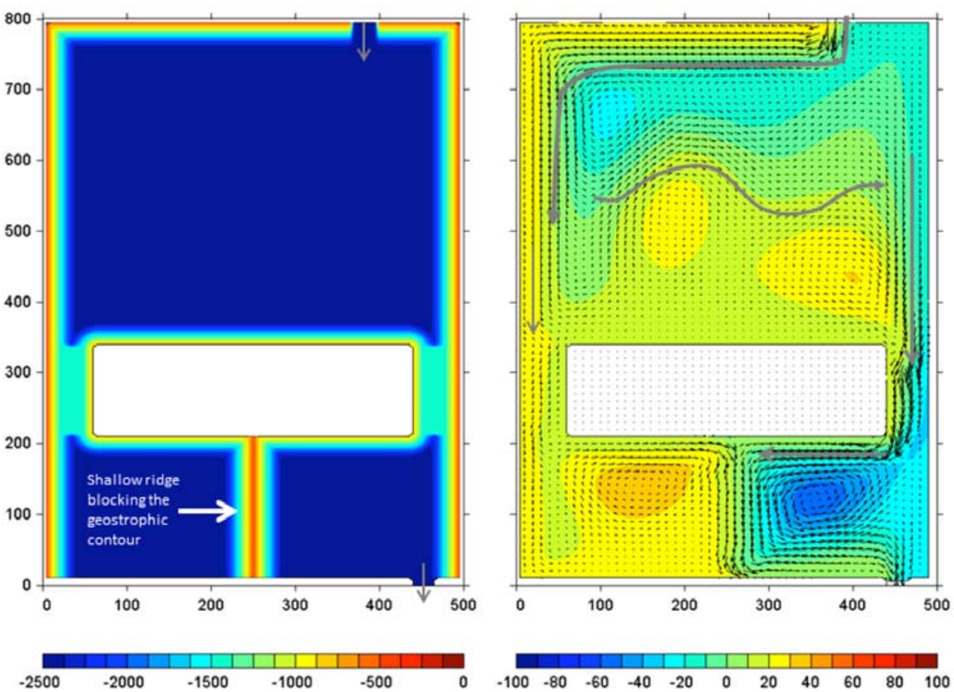
$$\oint_C \vec{\tau}_{friction} \cdot d\vec{l} = 0$$

A cyclonic NIJ must exist if there is an anti-cyclonic current along this contour (Faroe Bank Channel Overflow)

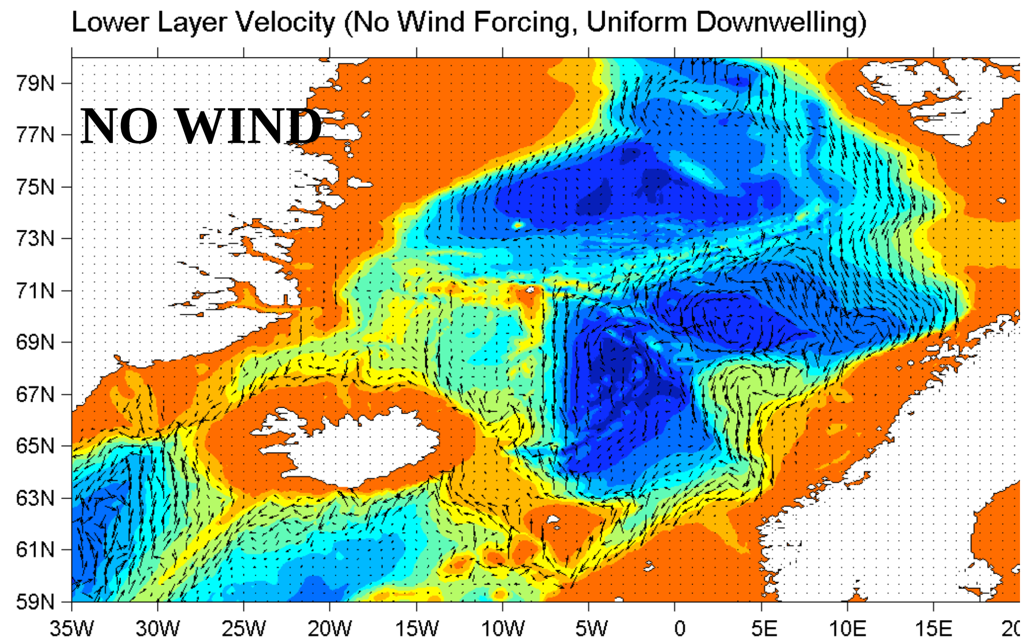


with a closed geostrophic contour
around Iceland-Faroe Ridge

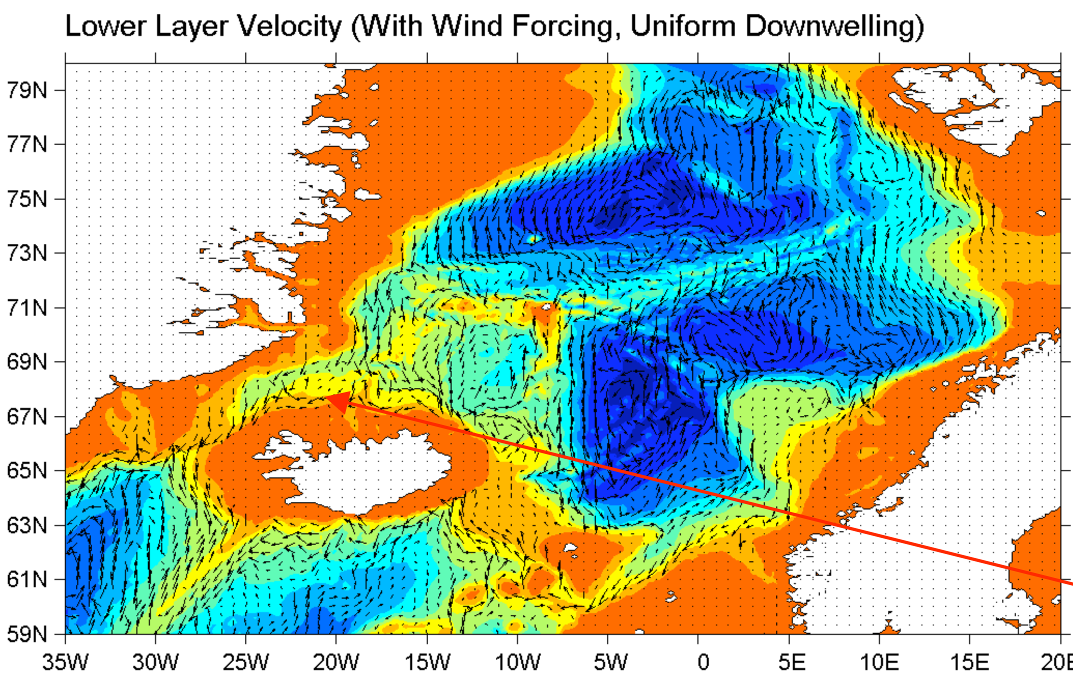
without a closed geostrophic contour
around Iceland-Faroe Ridge



Wind Forcing



Wind-stress forcing and
whe EGC pathway



The EGC pathway becomes much stronger with wind-stress Forcing. But the NIJ still persists!

NIJ along 600-800 isobaths

Summary:

The Northwest Icelandic Jet exists and does not depends on the location of the source water;

The existence of the NIJ is due to (at least) two dynamical constraints, the PV modification and circulation integral around a closed geostrohic contour;

Wind-stress forcing strengthens the EGC and weakens the NIJ

Some thoughts: Vage et al.'s observations were made in 2008, 2009 when NAO state was very low (wind-stress forcing is typically weak in low NAO). Would the NIJ be weaker in a high NAO state?