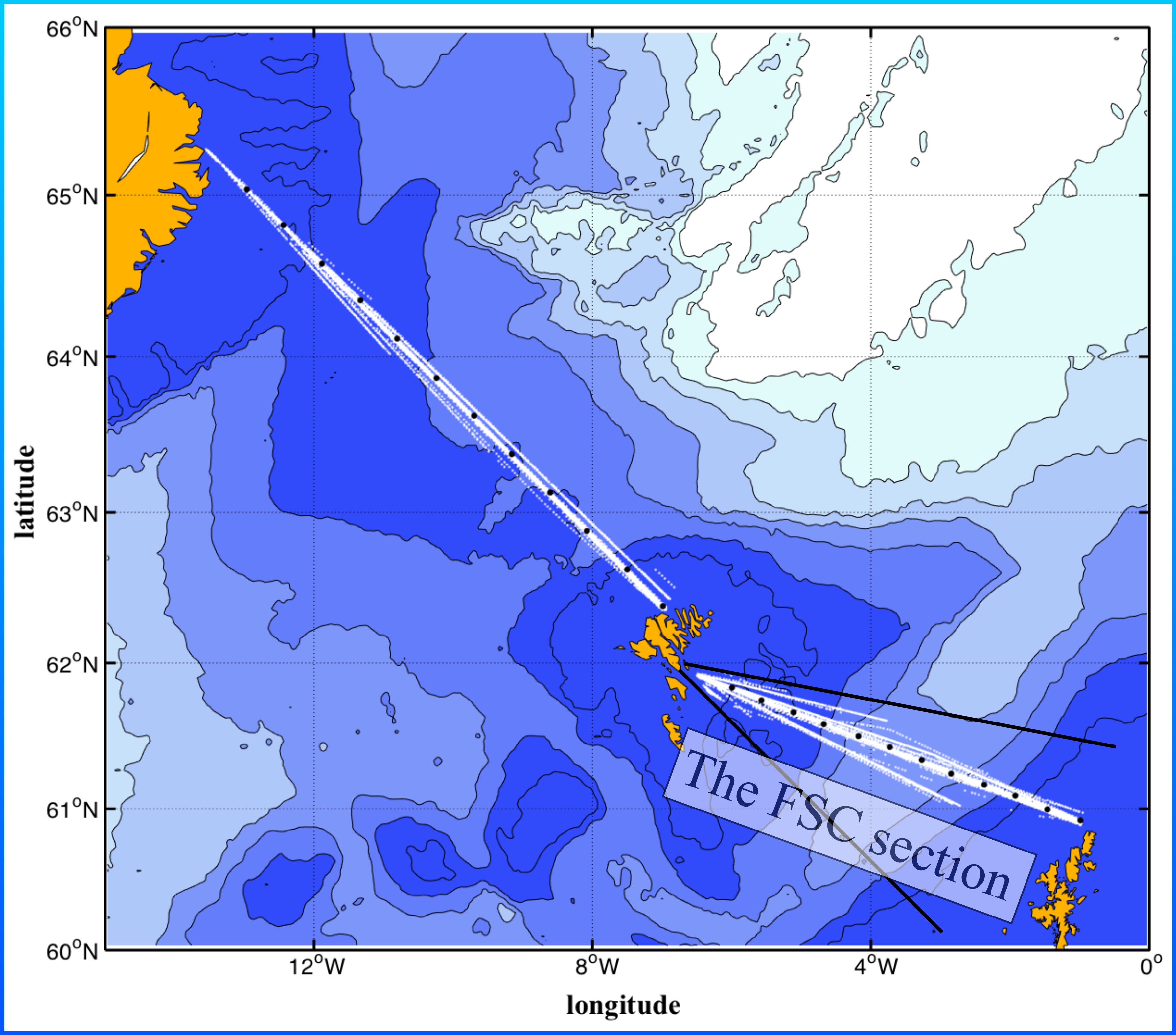
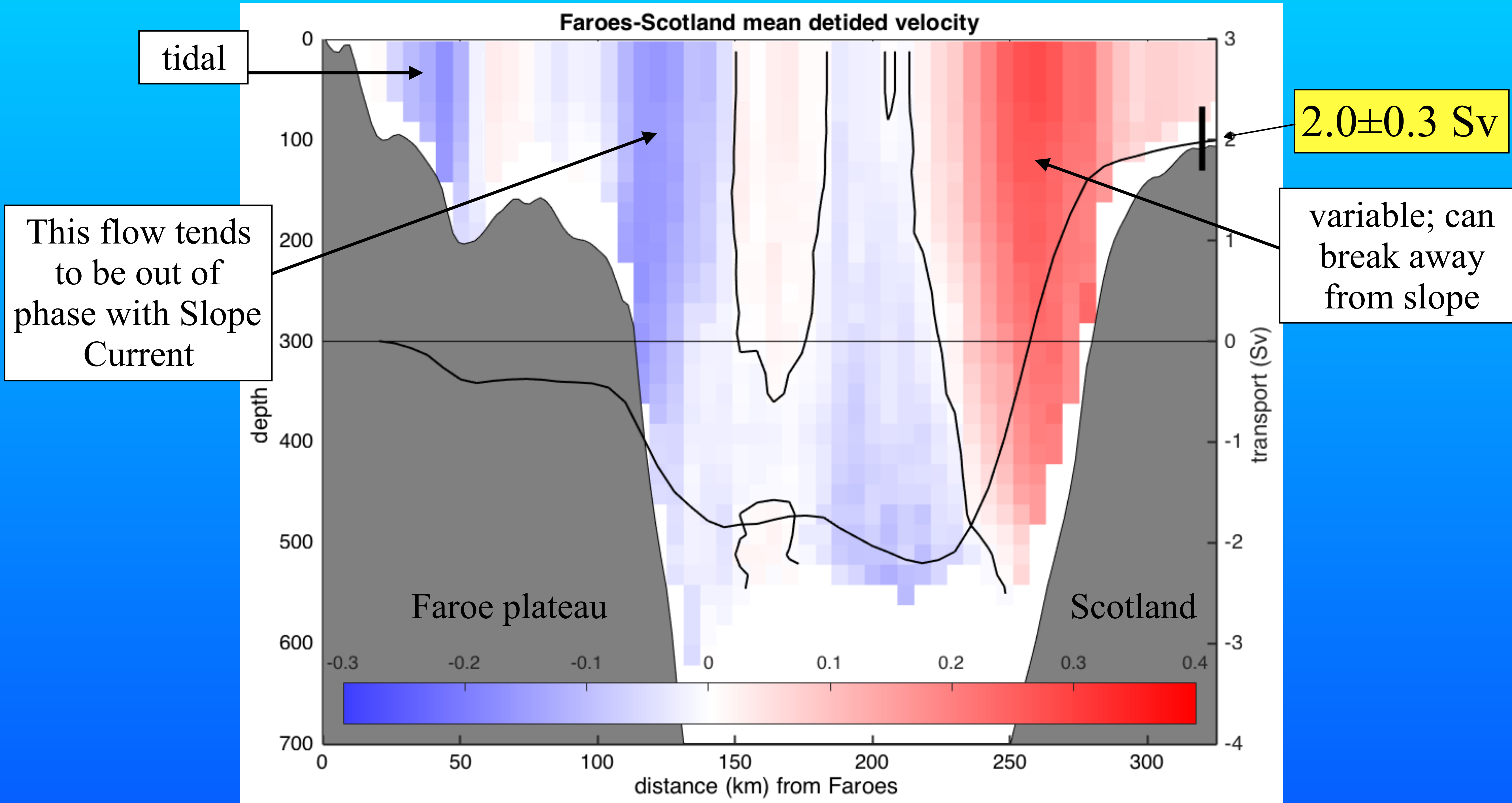
The Norröna project

Since 2008 Charlie Flagg and I have been operating an ADCP on the Norröna, a high-seas ferry that operates weekly from the Faroes to Denmark and Iceland. This route spans almost all water flowing towards the Nordic Seas. We give here improved estimates of volume, heat and (fresh water) transport. With an XBT launcher we also routinely sample thermal structure along both sections.

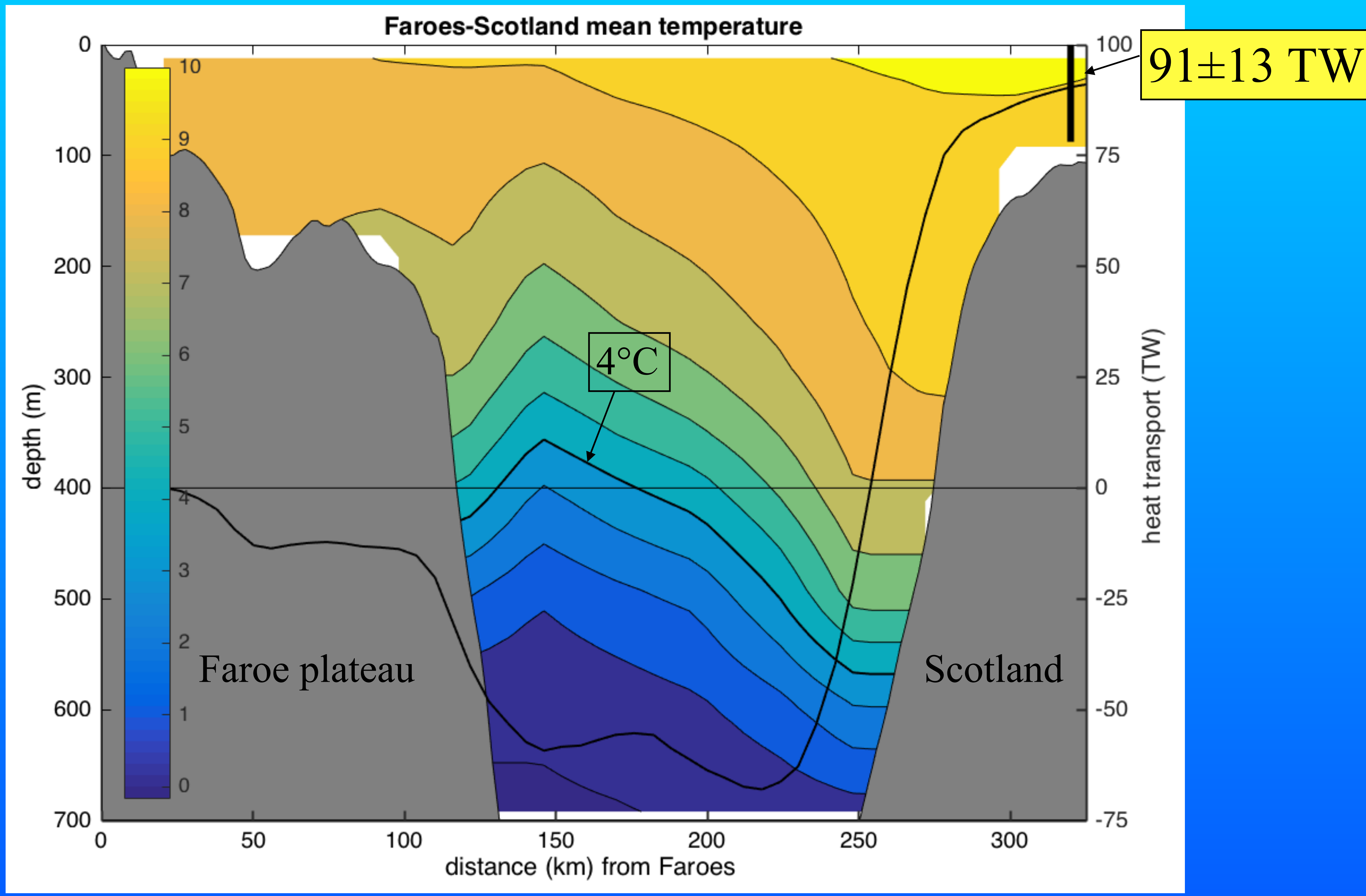
Outline:
the Faroe-Shetland Channel (FSC)
the Iceland Faroe Ridge (IFR)
Fluxes (Norröna) and Budgets (Nuka Arctica - Norröna)



The FSC section. The two black lines are earlier routes. Black dots are XBT sites.

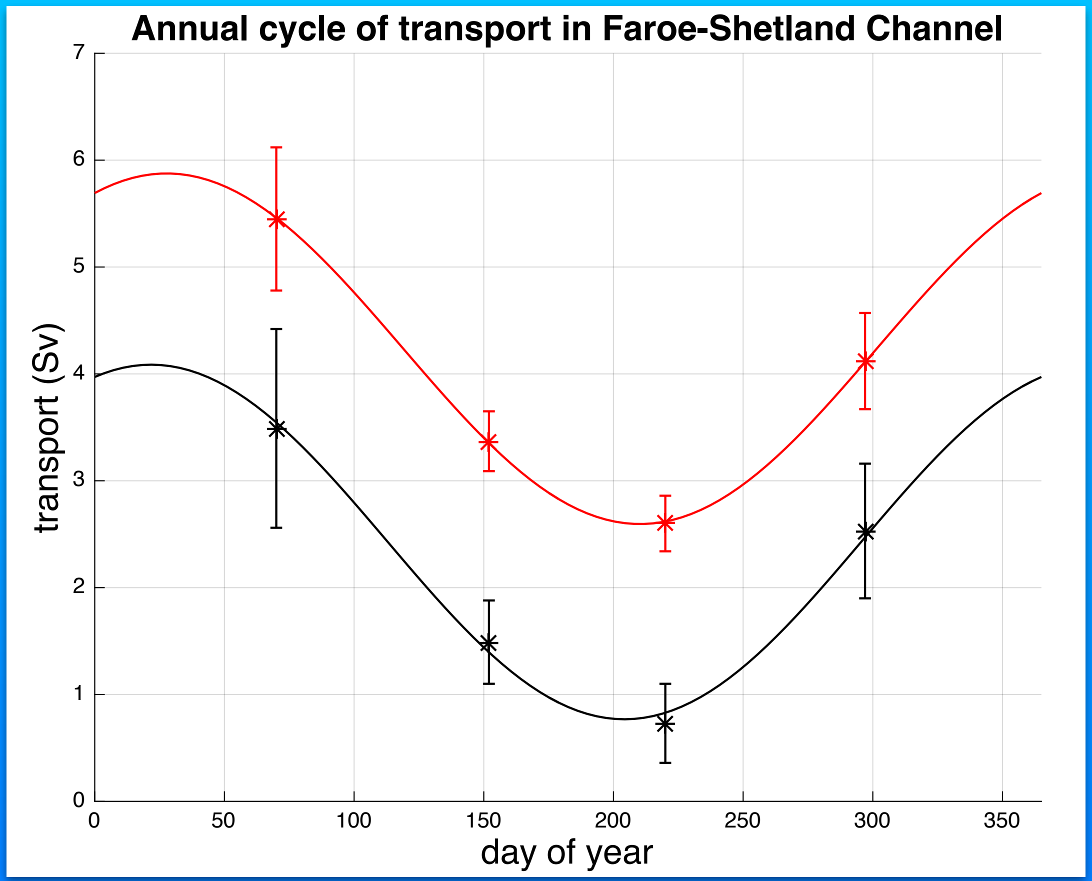


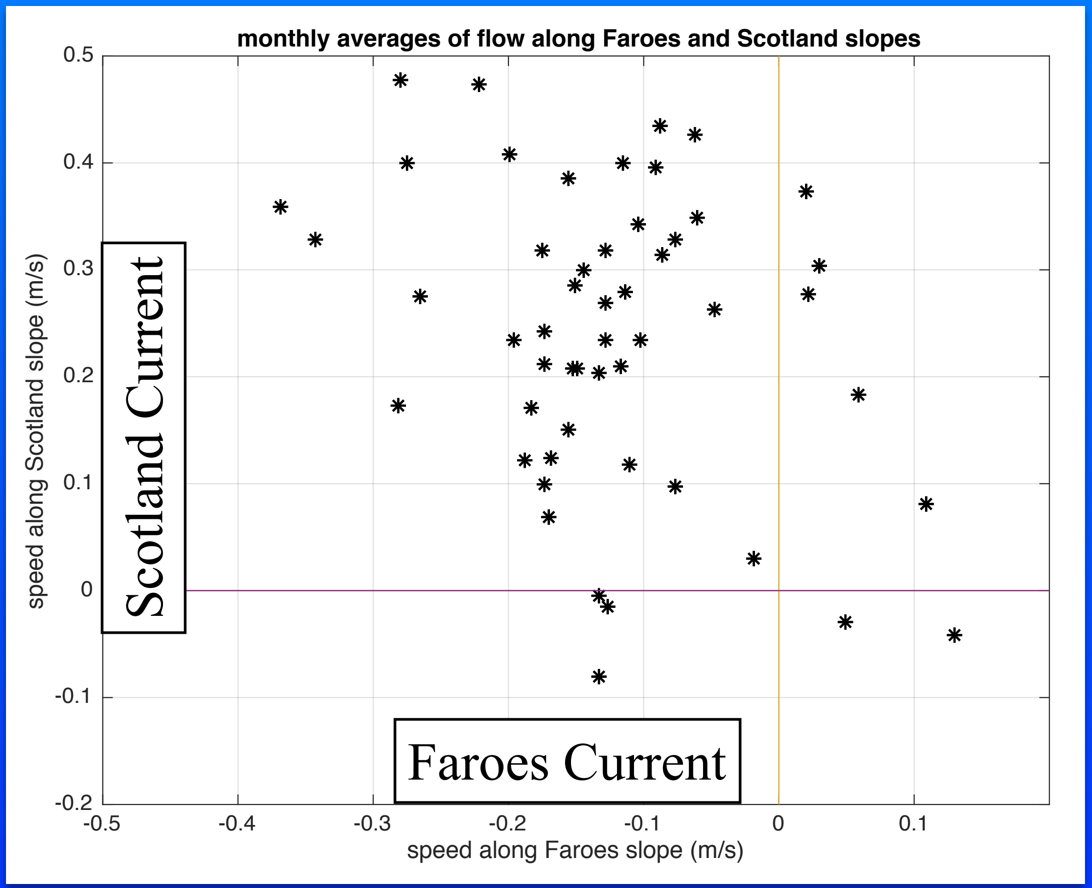
Mean velocity in ms^{-1} in the Faroe-Shetland Channel. Red colors indicate flow to the northeast, blue to the southwest. Black line integrates velocity warmer than 4°C ($\sim\sigma_\theta<27.8$) flowing north, the total is 2.0 ± ~0.3 Sv.



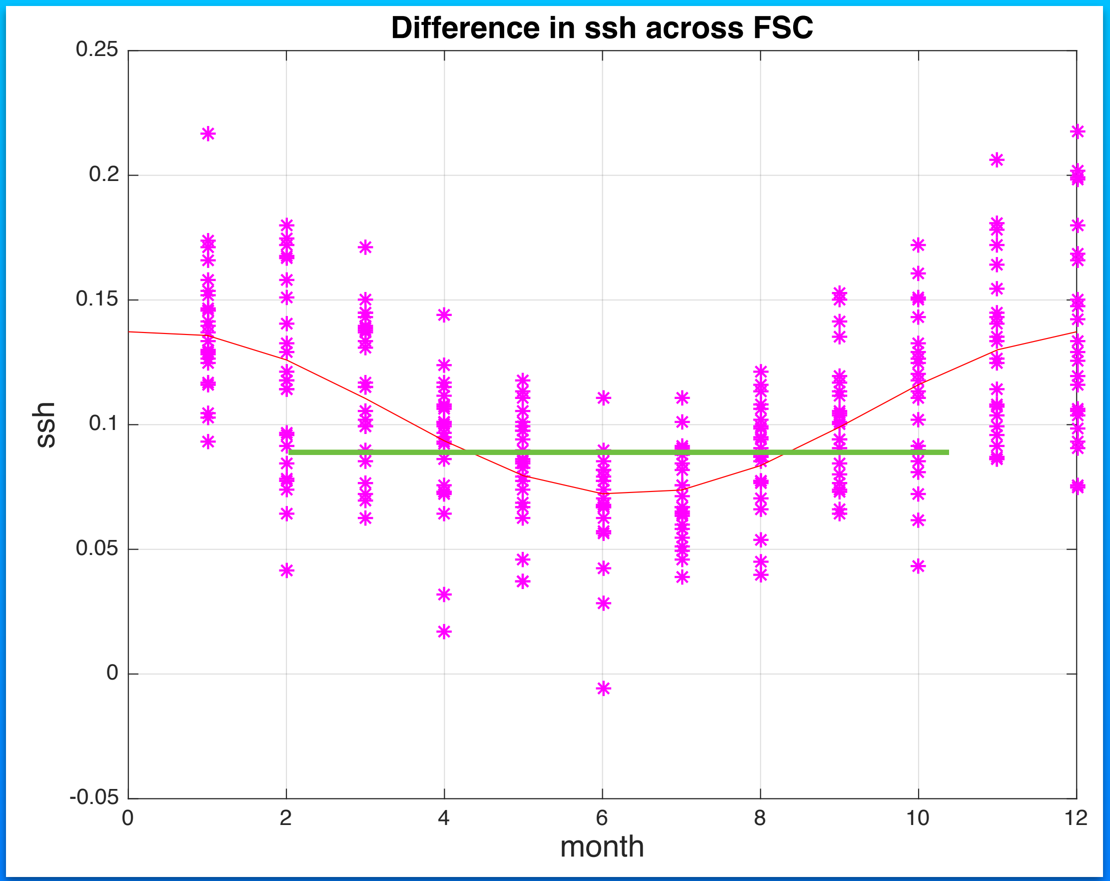
Mean annual temperature (°C) in the Faroe-Shetland Channel. The solid line shows temperature flux integral for water T>4°C (highlighted). The total is 91 TW.

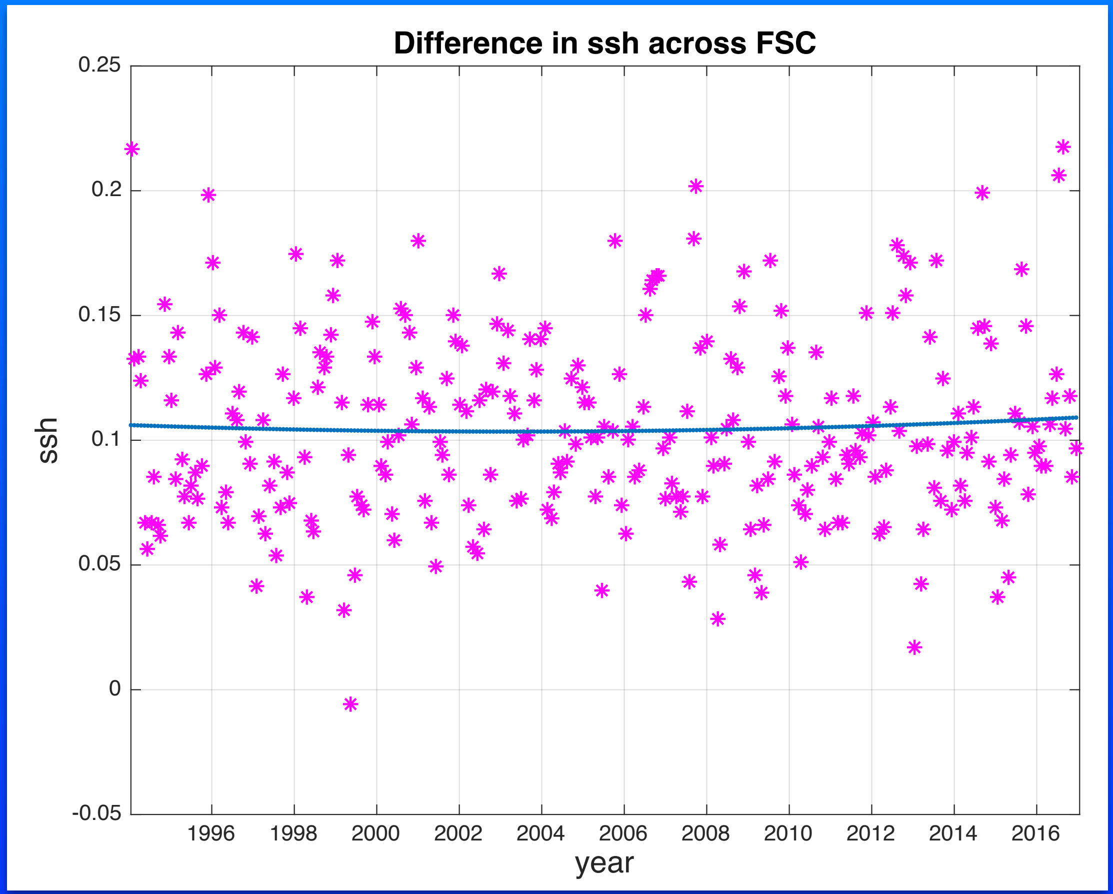
ADCP transport in FSC:

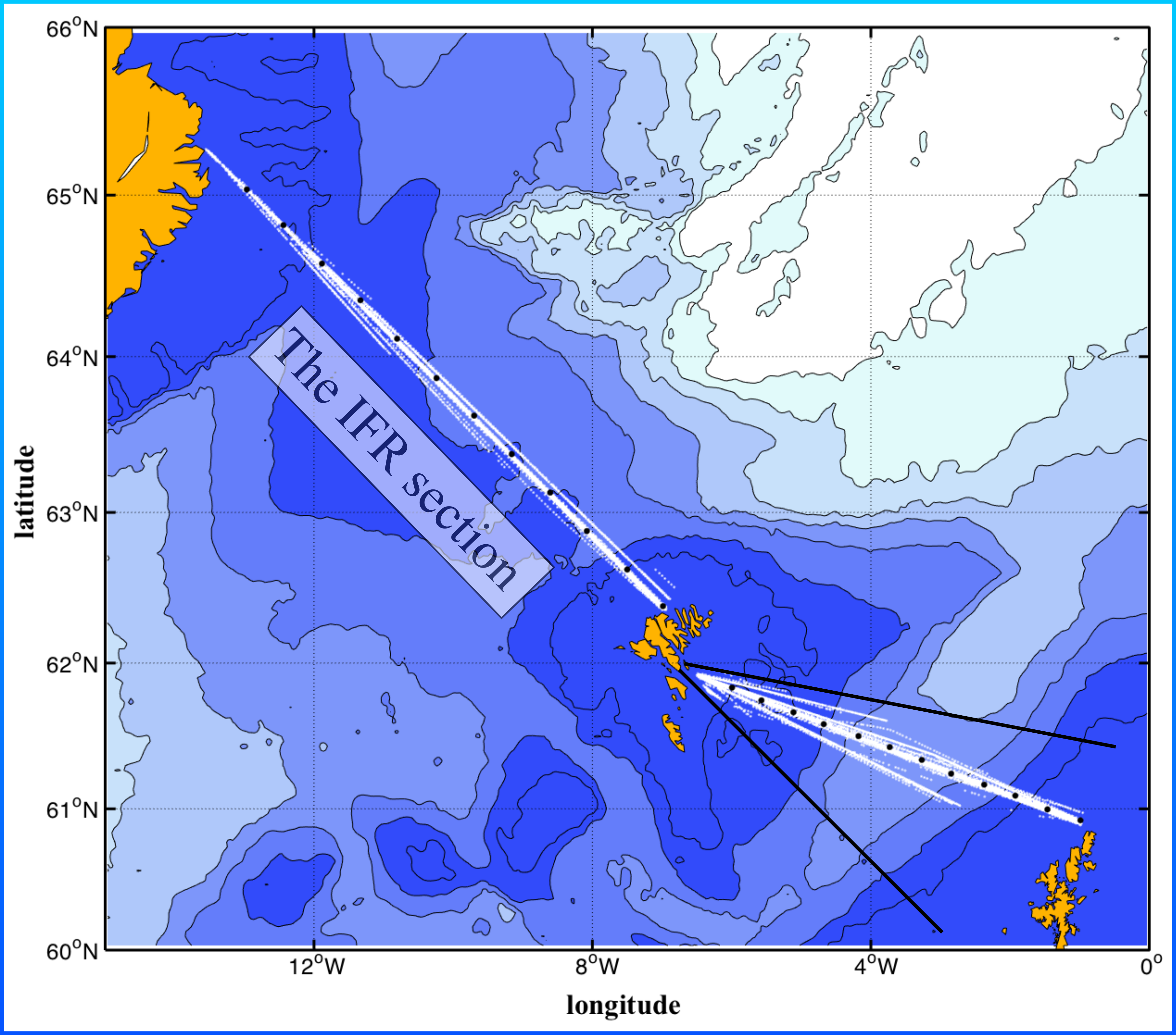




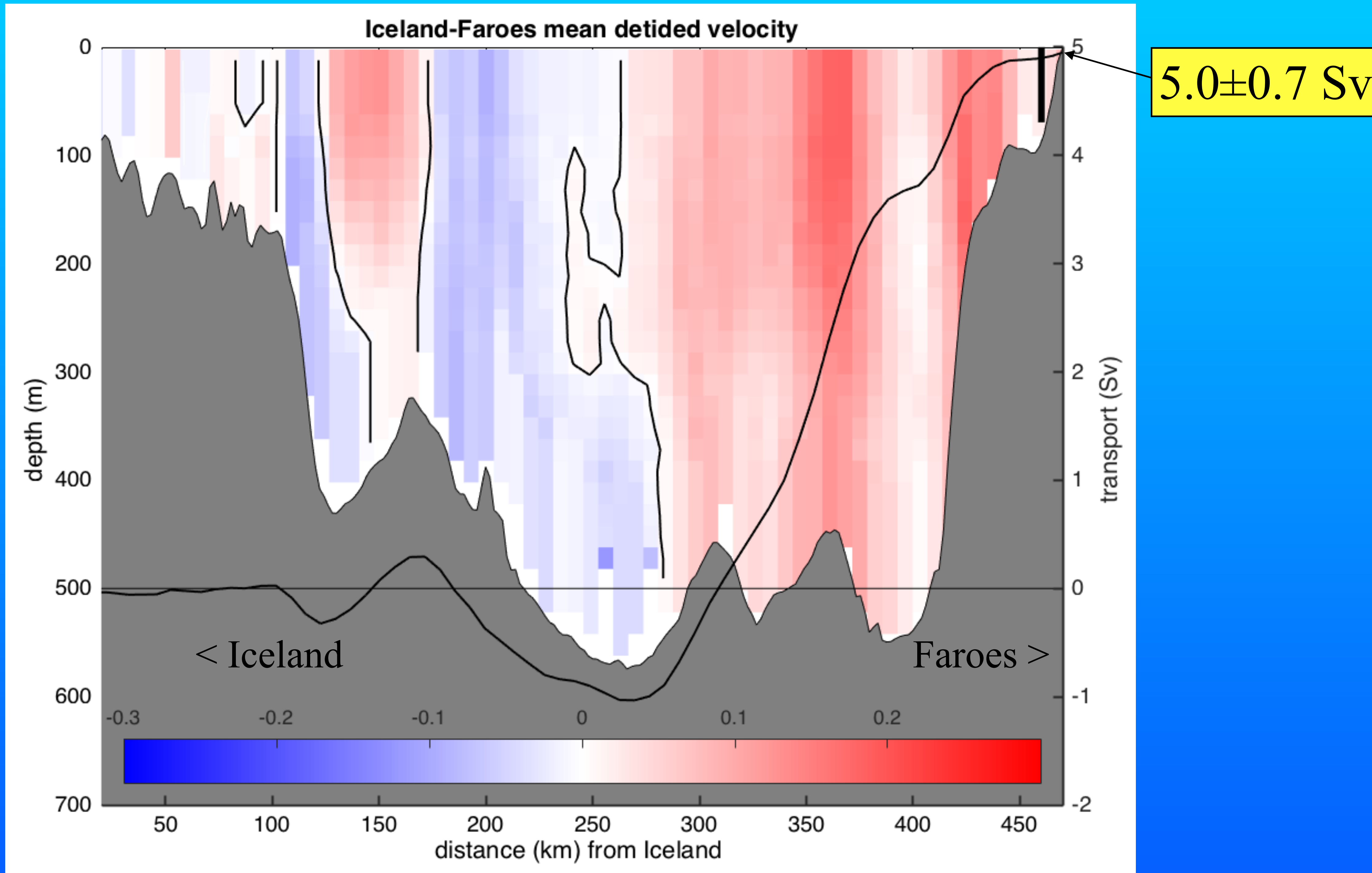
SSH difference across FSC:



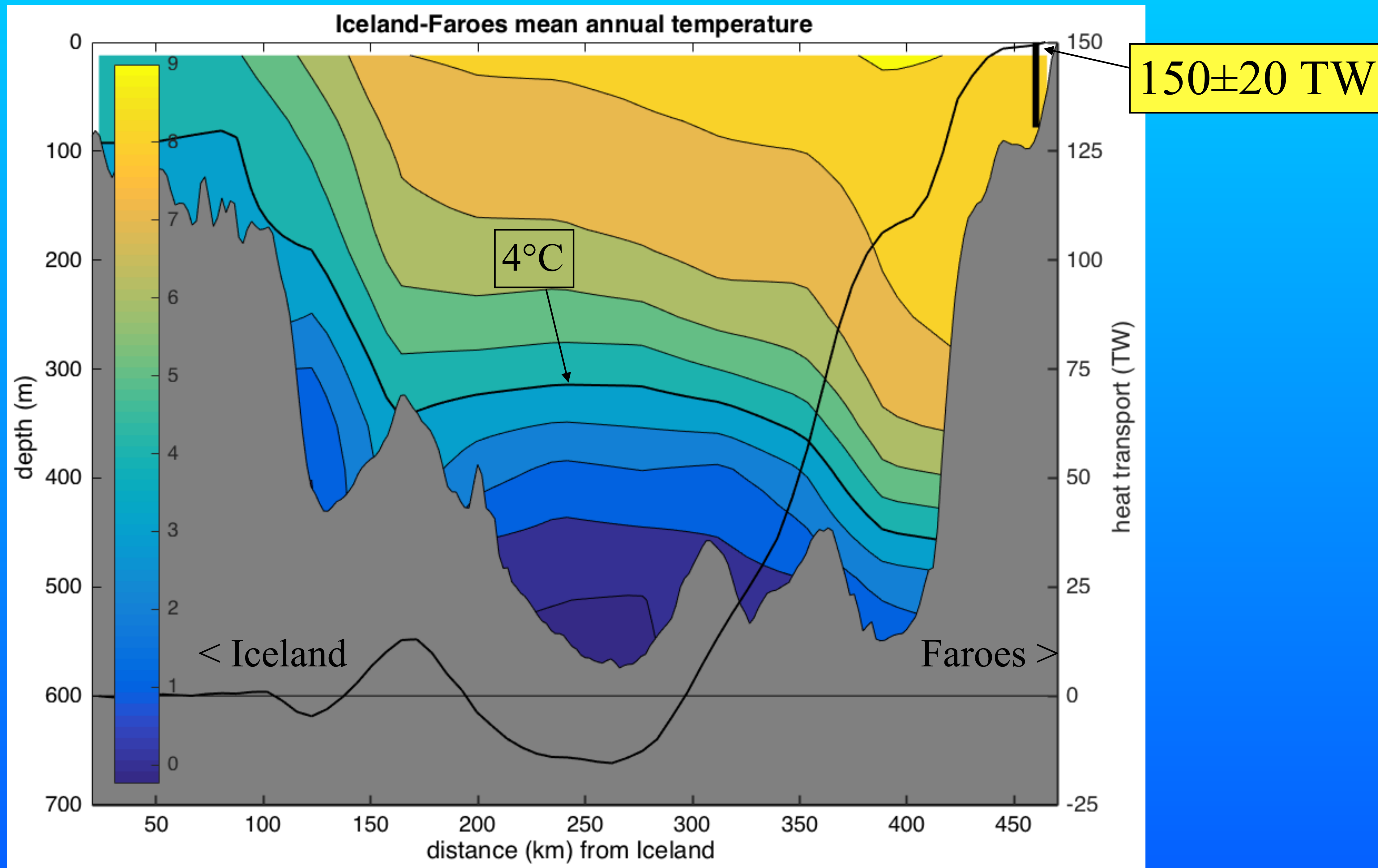




The IFR section. The two black lines are earlier routes. Black dots are XBT sites.

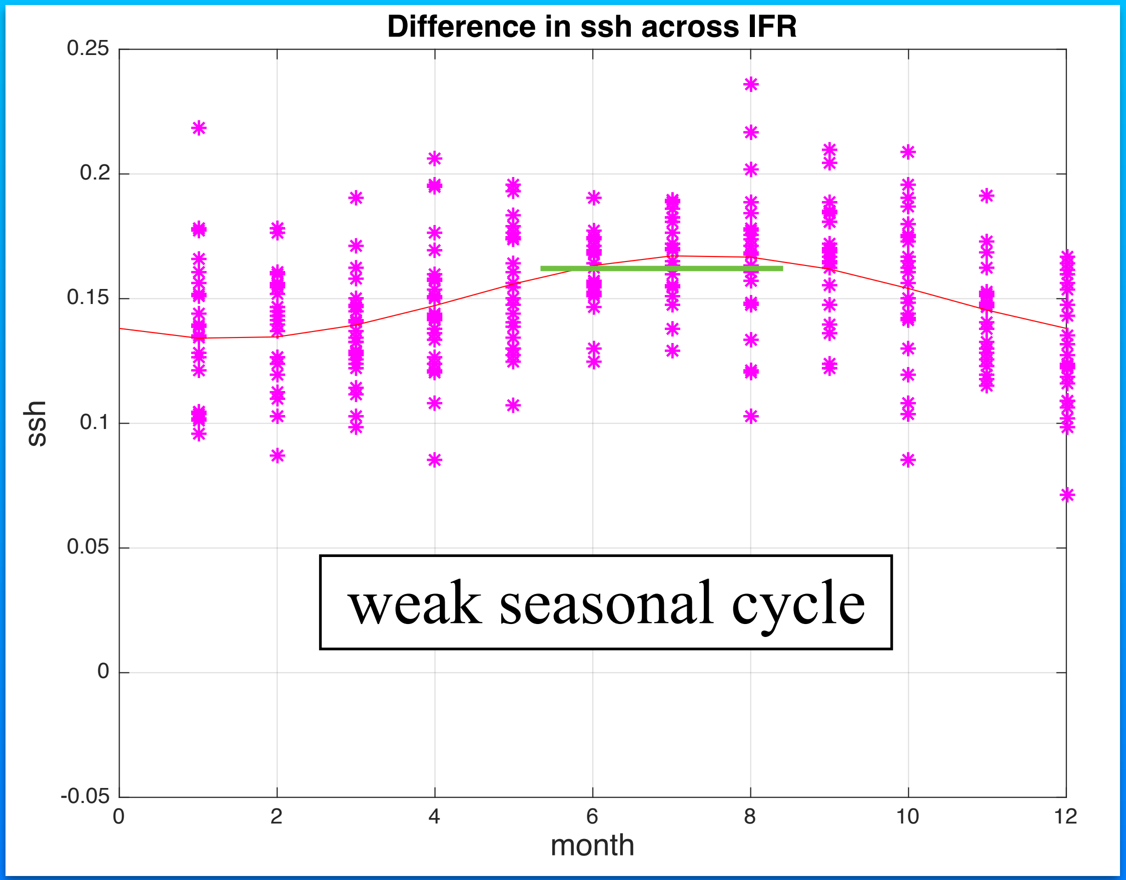


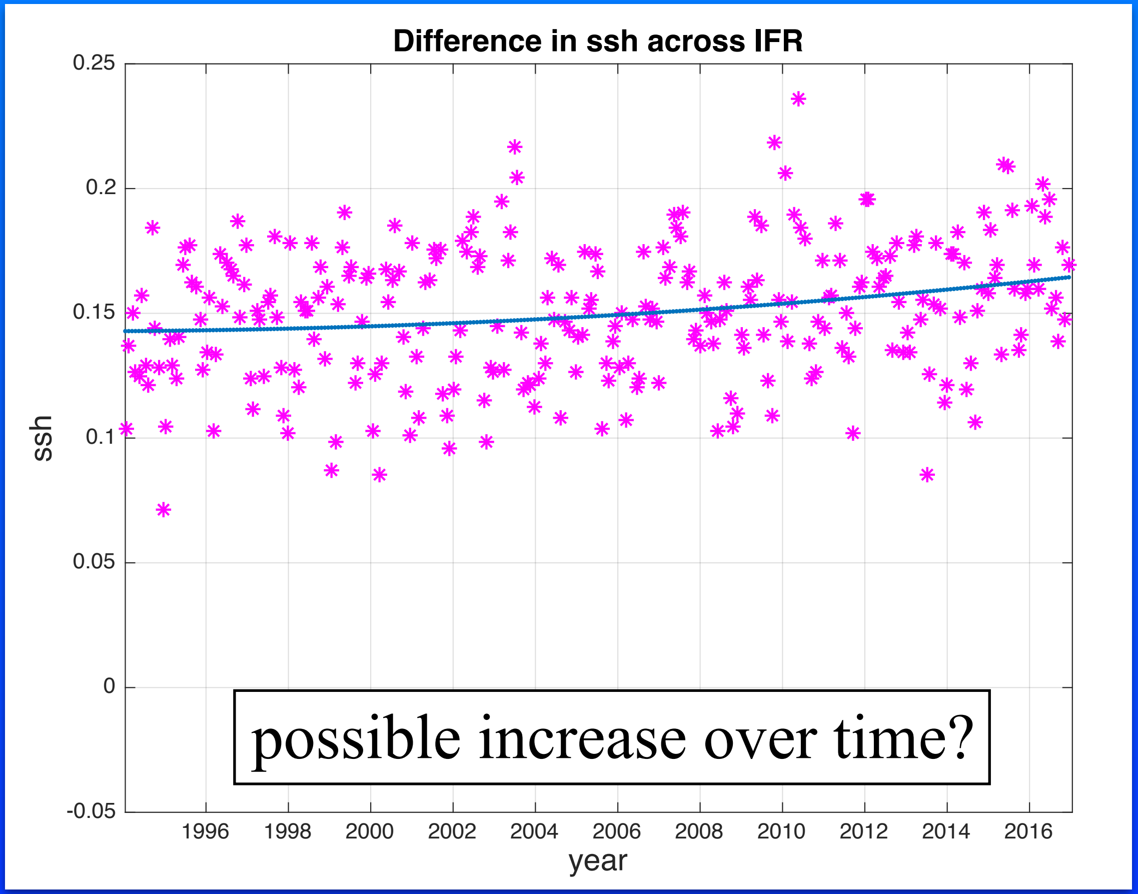
Summer mean velocity in ms-1 between Iceland and the Faroes. Red colors indicate flow to the northeast, blue to the southwest (black contour = zero velocity). Black line integrates the top-to-bottom velocity flowing NE.



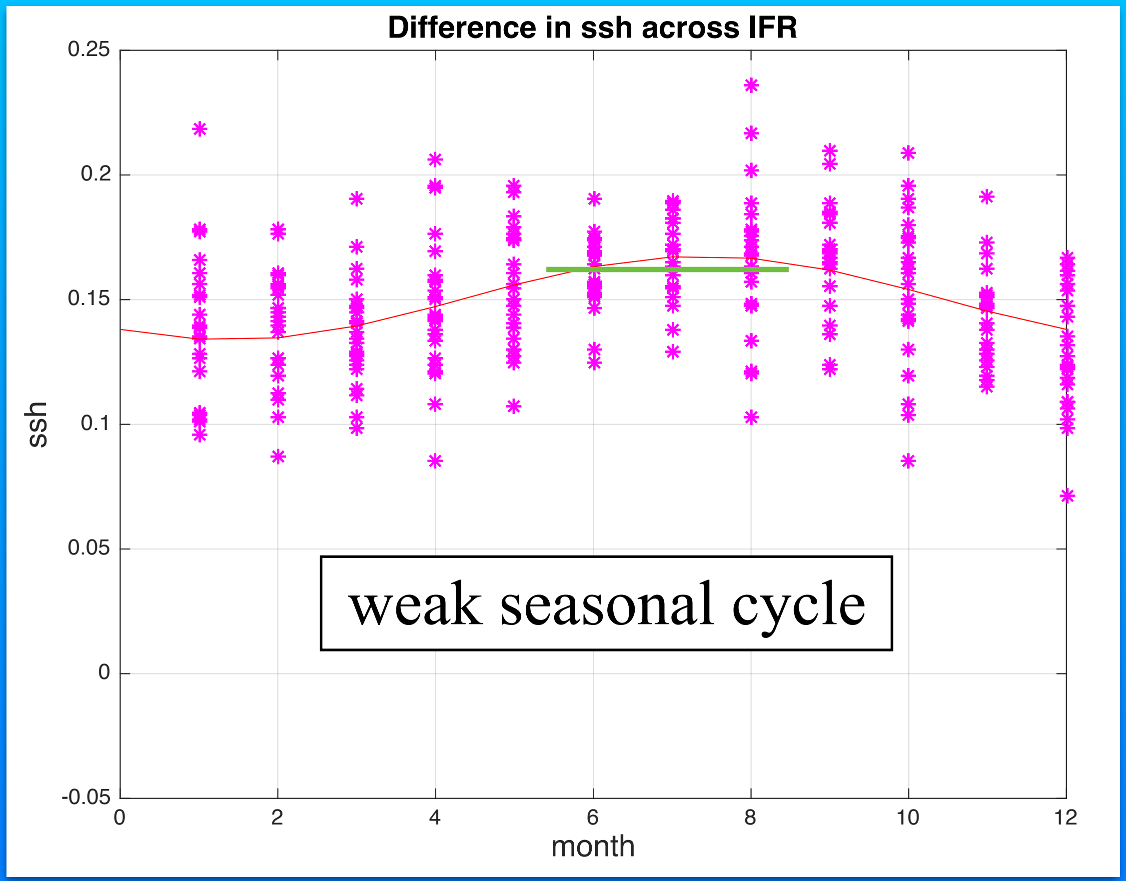
Annual mean temperature between Iceland and the Faroes. The solid line shows temperature flux integral from Iceland to the Faroes.

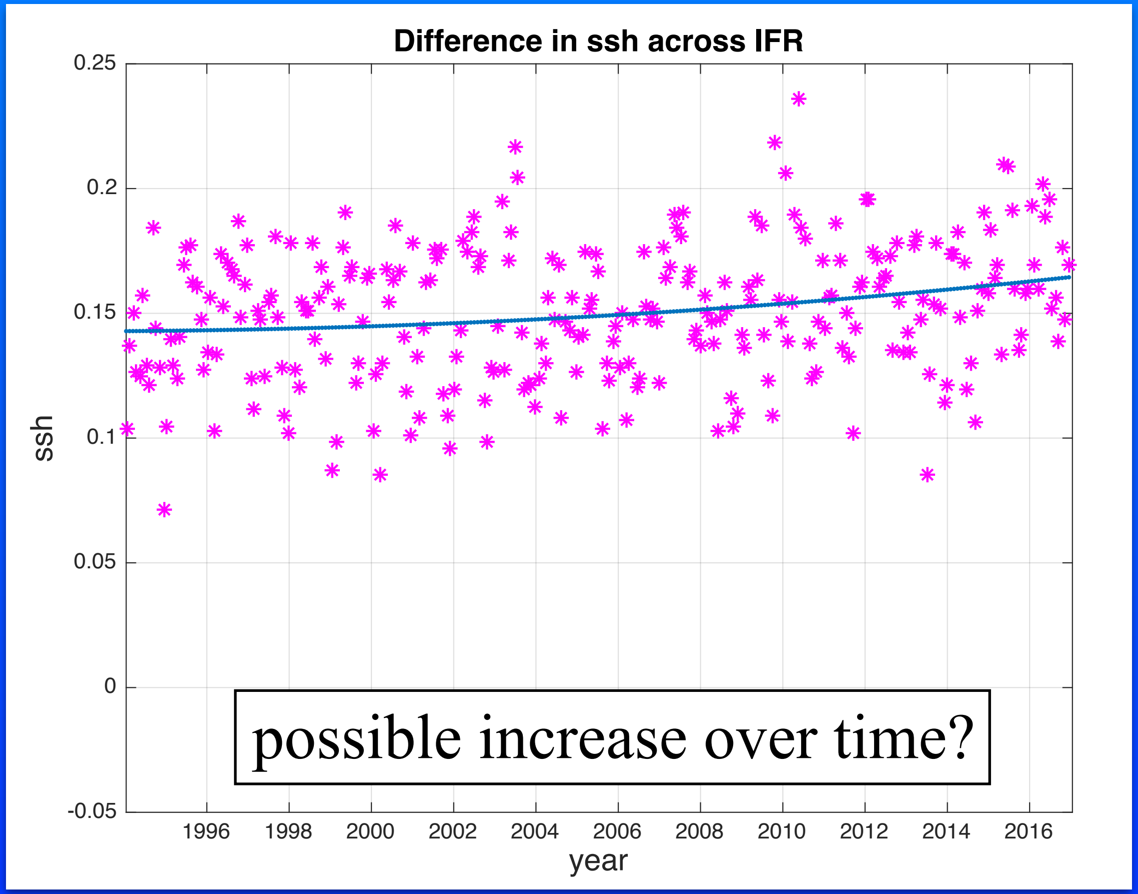
SSH difference across IFR:



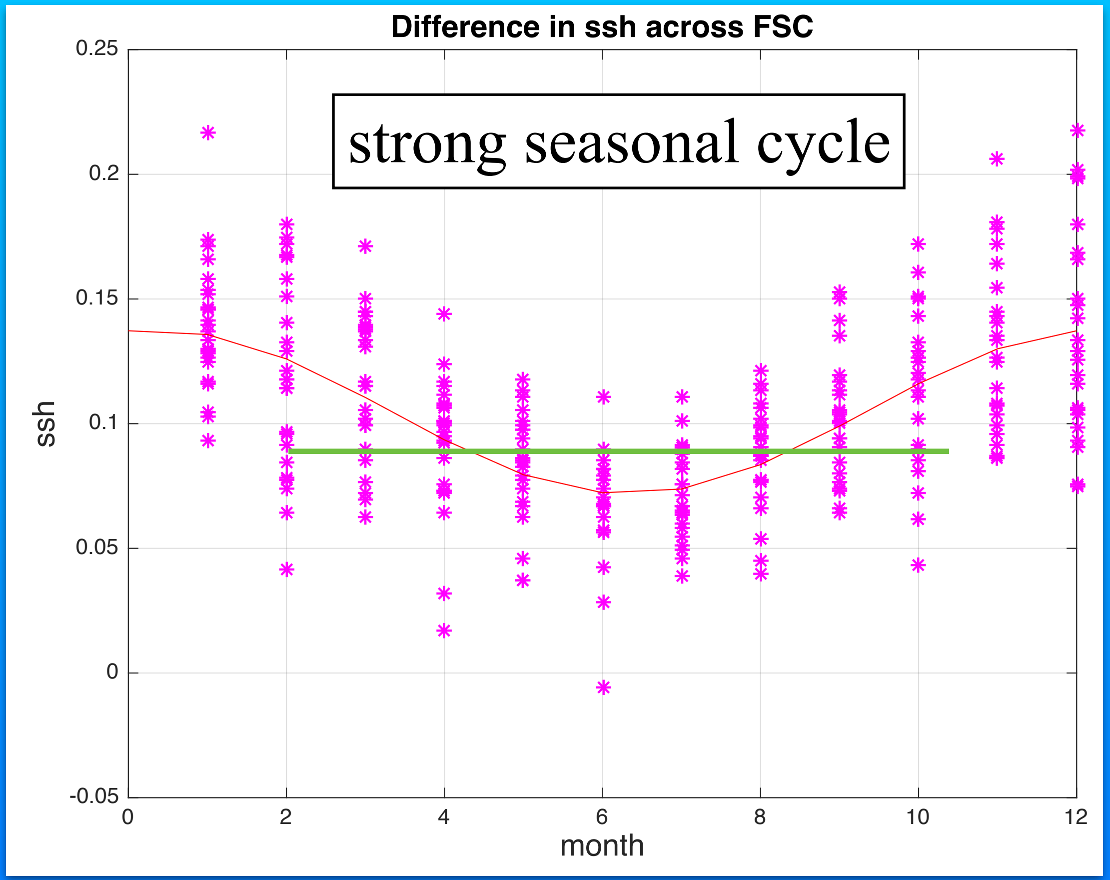


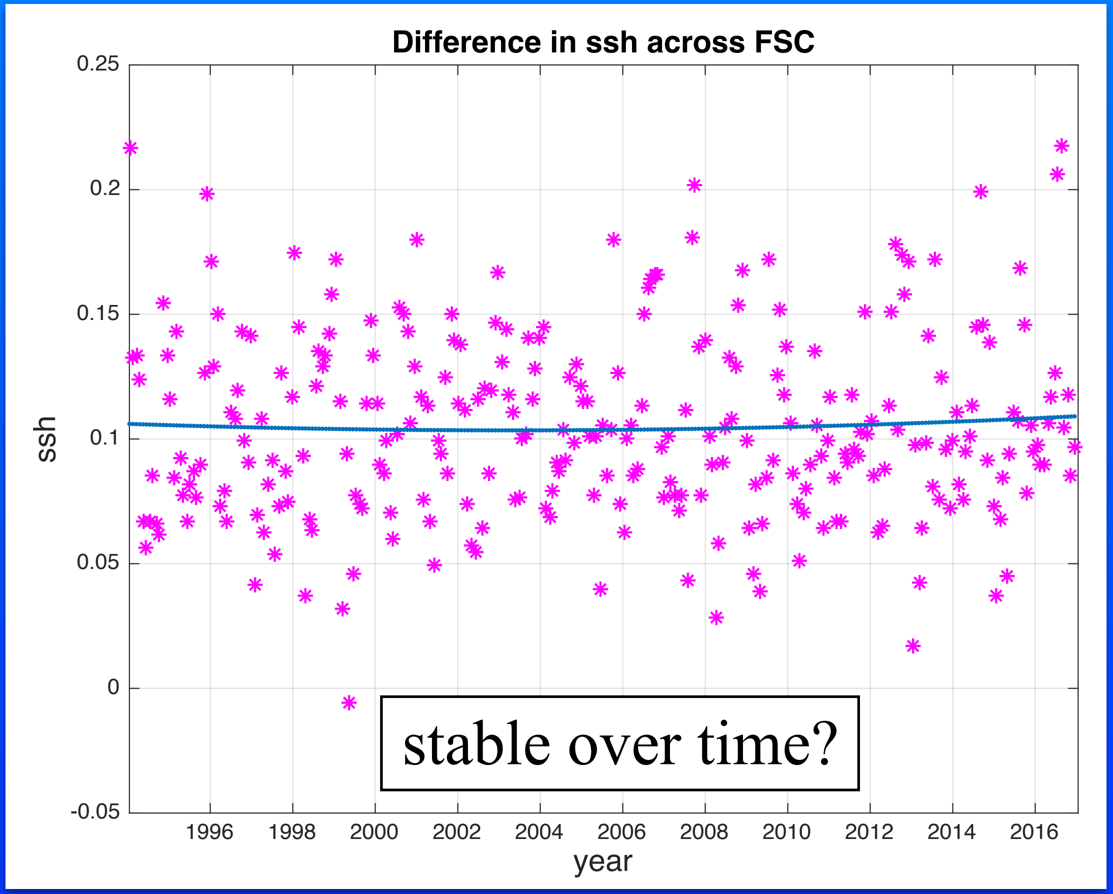
SSH difference across IFR:





SSH difference across FSC:





G-I-F-S volume and temperature fluxes:

Denmark St.

$\sigma_\theta < 27.8$:
V = -2.4 Sv.
Q = 3.5 TW

$\sigma_\theta > 27.8$:
V = -3.2 ± 0.5 Sv.
(Q = 2 ± ? TW)

Iceland-Faroe R.

To bottom:
V = 5.0 ± ~0.7 Sv.
Q = 150 ± 20 TW

$\sigma_\theta > 27.8$:
V = 0.3 ± 0.3 Sv.
Q = 3 ± 9 TW

Faroe-Shetland Ch.

$\sigma_\theta < 27.8$:
V = 2.0 ± ~0.3 Sv.
Q = 91 ± 13 TW

$\sigma_\theta > 27.8$:
V = -1.9 ± ~0.3 Sv.
Q = -2 ± 0.3 TW

$\sigma_\theta < 27.8$ numbers based on Harden et al. (2016). $\sigma_\theta > 27.8$ numbers from Jochumsen et al. (2017).

V and Q sums:

V = -2.4 +0.9 -3.2
+5.0 +2.0 -1.9
= 0.4 ± 0.8 Sv. ← Ideally = 0 Sv

Q = 3.5 +24 +2 +150
+ 91 -2
= 269 ± 40(15%) TW ← Net heat flux into Nordic Seas

$\sigma_\theta > 27.8$ numbers from Hansen - Østerhus (2007).

West Iceland Curr.
V = +0.9 Sv.
Q = +24 TW

Jónsson and Valdimarson (2013)

Summary I:

Direct measurement (scanning) of currents has led to improved estimates of currents and transports (and tides and EKE, not shown).

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The IFR is the larger entry to the Nordic Seas; weak seasonal cycle; eddy-rich with mean velocity field defined by topography.

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The FSC exhibits a much stronger seasonal cycle (wind-driven) and is subject to large flux disturbances (adjustments between N.A. and N.S.).

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Program is ongoing. Henrik Søiland at the Institute of Marine Research will take over in the coming two years.

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Two int’l workshops, last January, and this coming September.

Heat (and later fresh water) budgets:

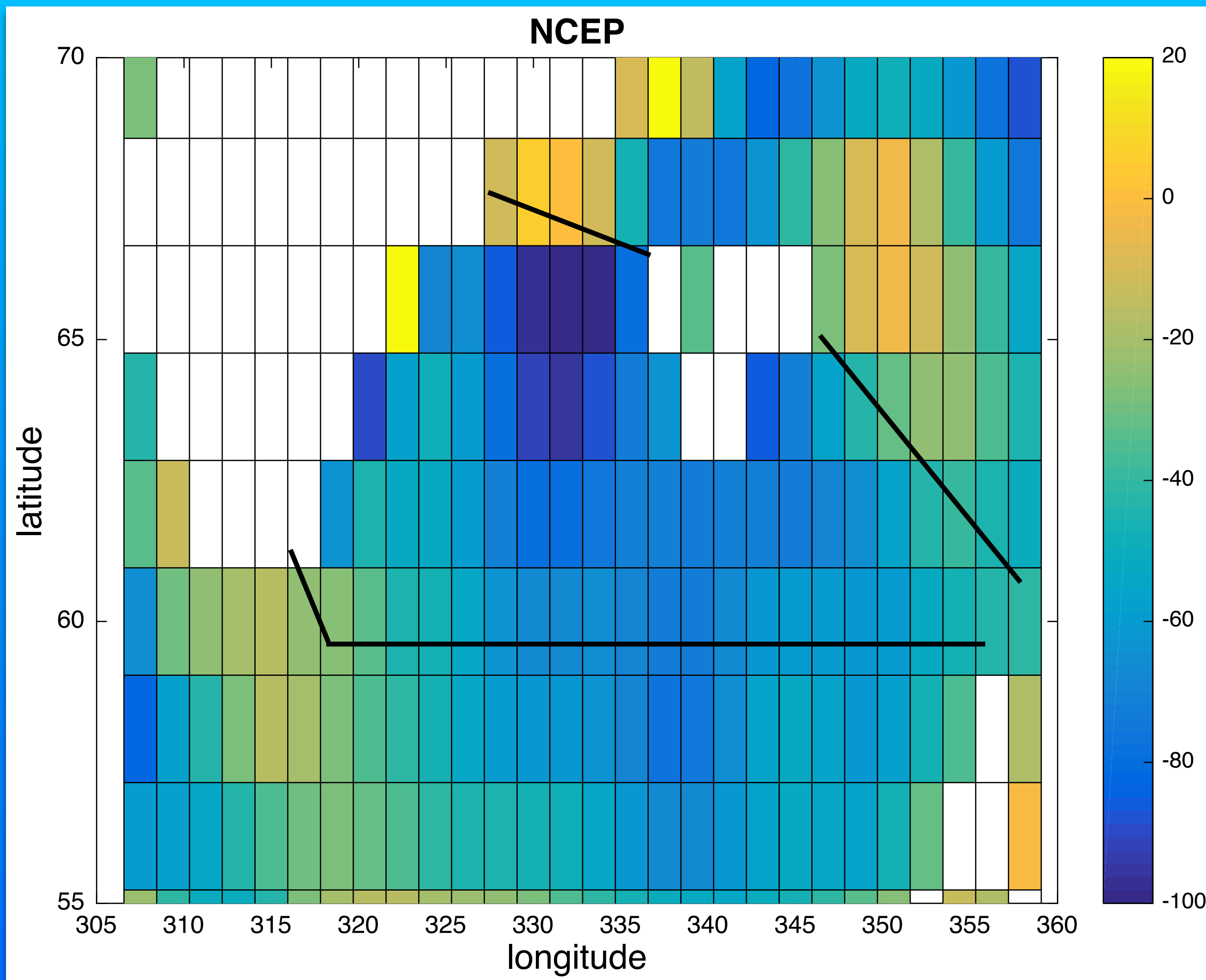
We recently completed a study of the MOC, heat and fresh water fluxes between Greenland and Scotland at 59.5°N. This permits us to estimate heat flux convergence between this and the Norröna sections.

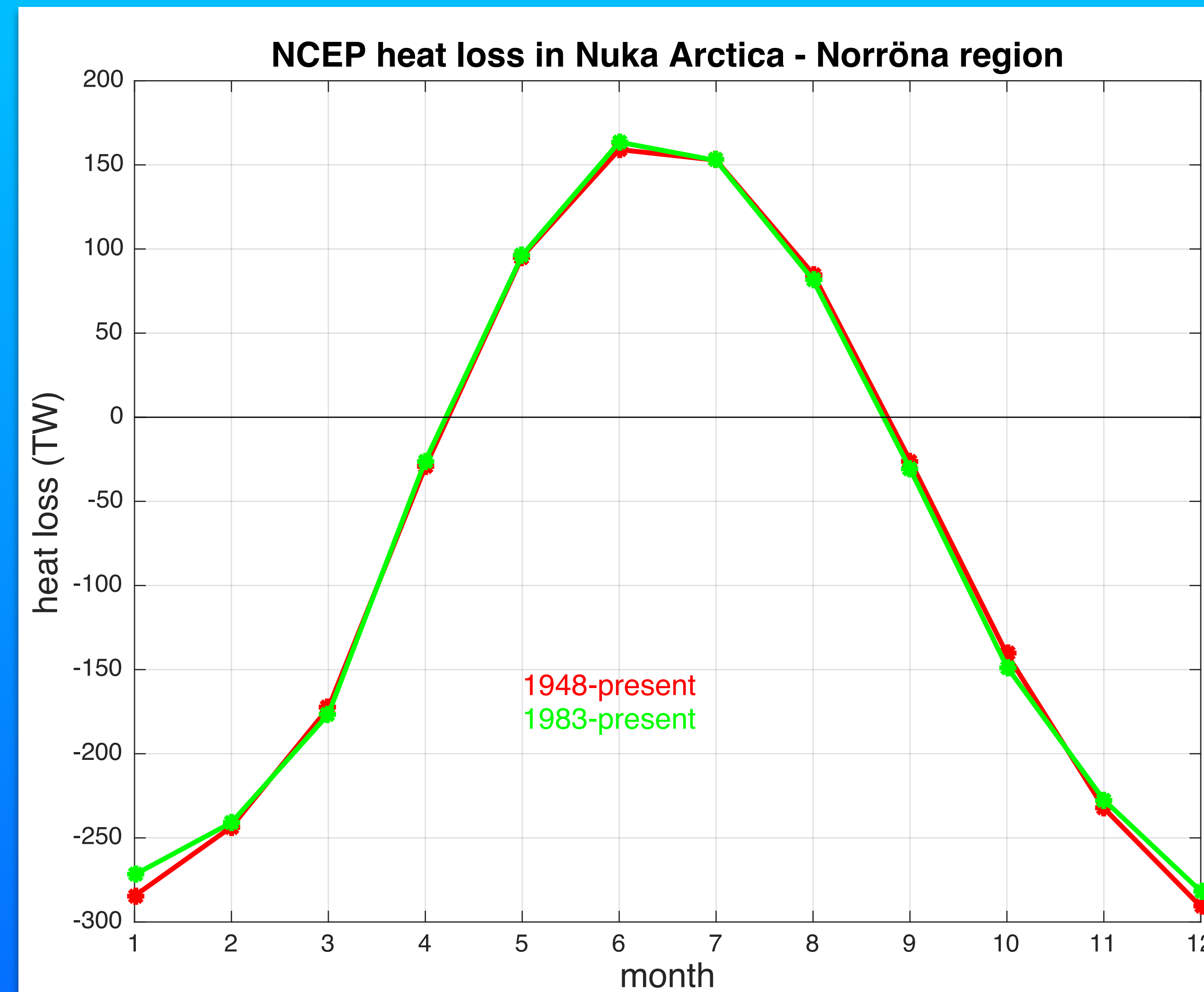
MOC:
18.4 ± 3.4 (18%) Sv to the $\sigma_\theta = 27.55$ kg m^{-3}
16.6 ± 0.1 (<1%) Sv (Sarafanov et al., 2012)
15.5 ± 2.4 (15%) Sv (Willis, 2010 at 41°N)

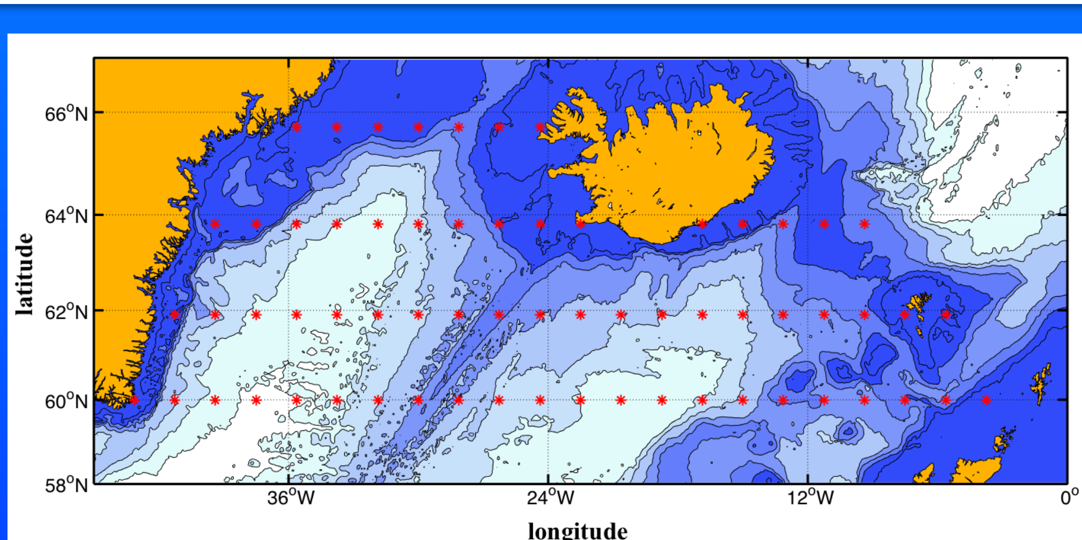
Net heat transport:
399 ± 74 (19%) TW
280 ± 60 (21%) TW (Bacon, 1997)

The heat flux convergence between the Nuka Arctica and Norröna lines =
399 ± 74 - 269 ± 40 = $\boxed{130 \pm 84 \text{ TW}}$.

NCEP reanalysis







Red dots indicate pixels used in area summation.

Annual average heat loss (NCEP): $\boxed{-77.2 \text{ TW}}$ (area 1.19×10^6 km^2 <=> -65 Wm^{-2}). This is quite a bit less than the $\boxed{130 \pm 84 \text{ TW}}$ heat flux convergence between the two sections. Is the difference significant?

Summary II (re heat fluxes):

While there may be some adjustment to the Norröna fluxes as we start writing these results, we think the estimates are solid.

Both the Nuka Artica and Norröna flux estimates are from recent years when the MOC appears to be a bit stronger.

Both ADCP and XBT programs are ongoing; they can with modest effort be significantly strengthened. The Norröna continues to have a severe bubble issue, but there are options. The Nuka Arctica sorely needs an AXIS for systematic temperature and salinity sampling.

Thank you!