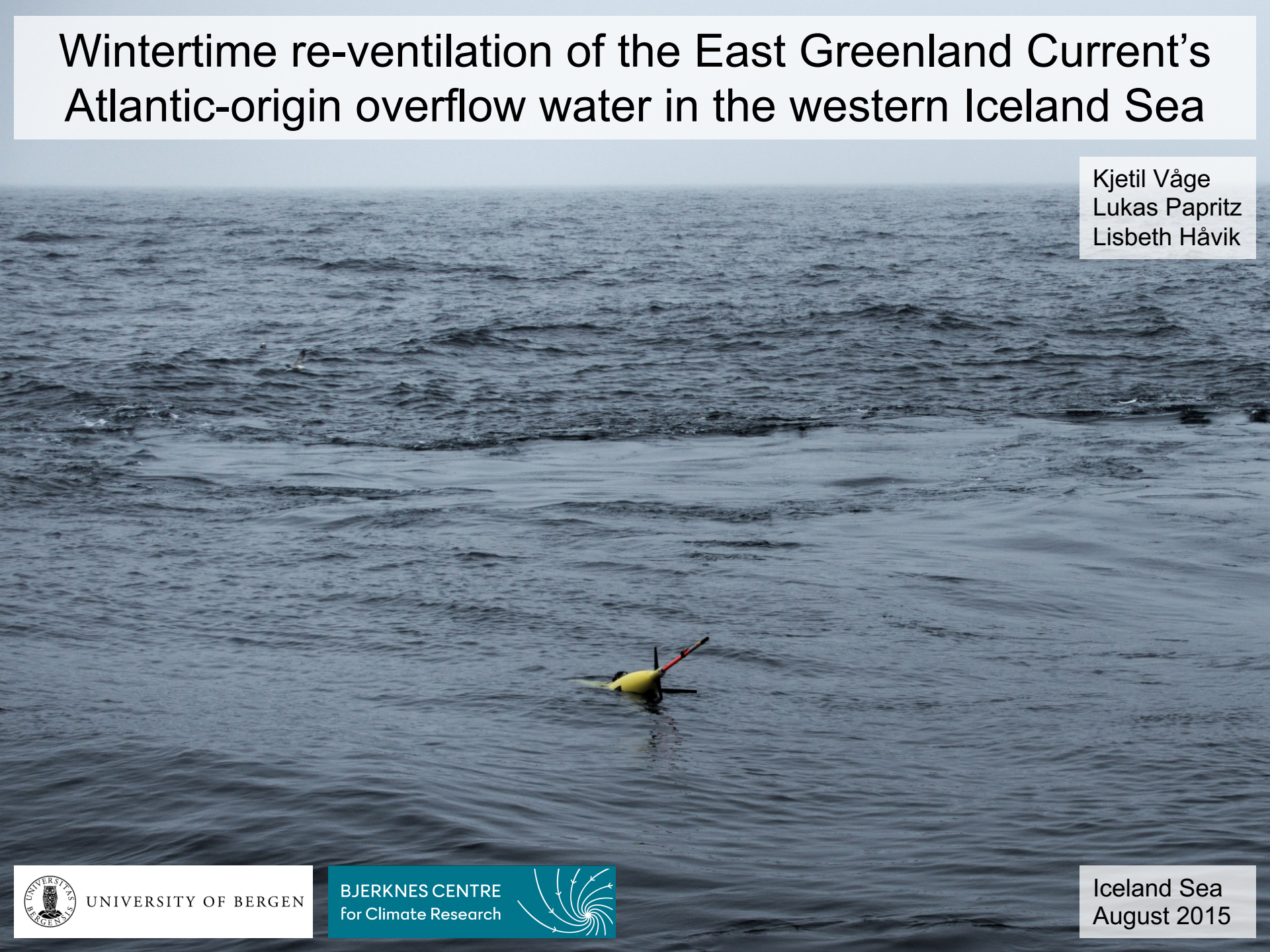
Wintertime re-ventilation of the East Greenland Current's Atlantic-origin overflow water in the western Iceland Sea

Kjetil Våge
Lukas Papritz
Lisbeth Håvik



UNIVERSITY OF BERGEN

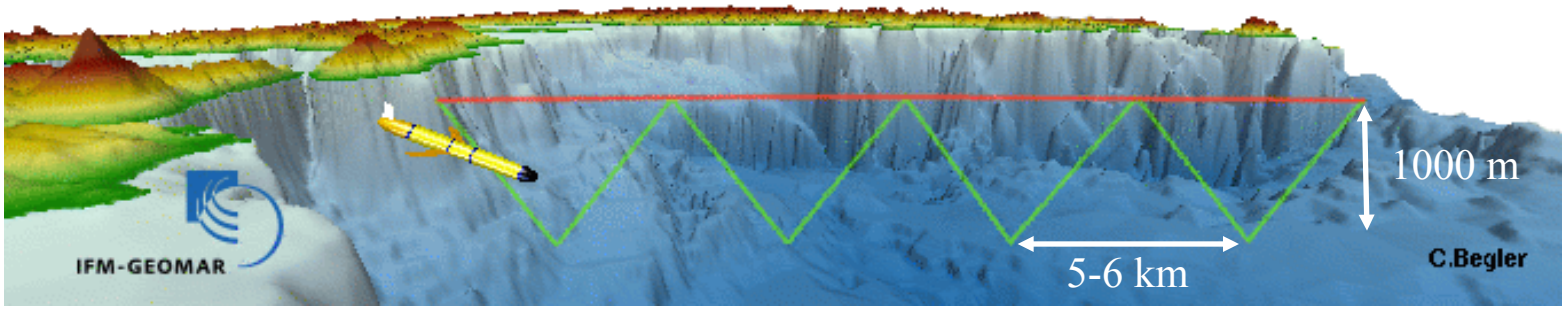
BJERKNES CENTRE
for Climate Research

Iceland Sea
August 2015

Underwater gliders

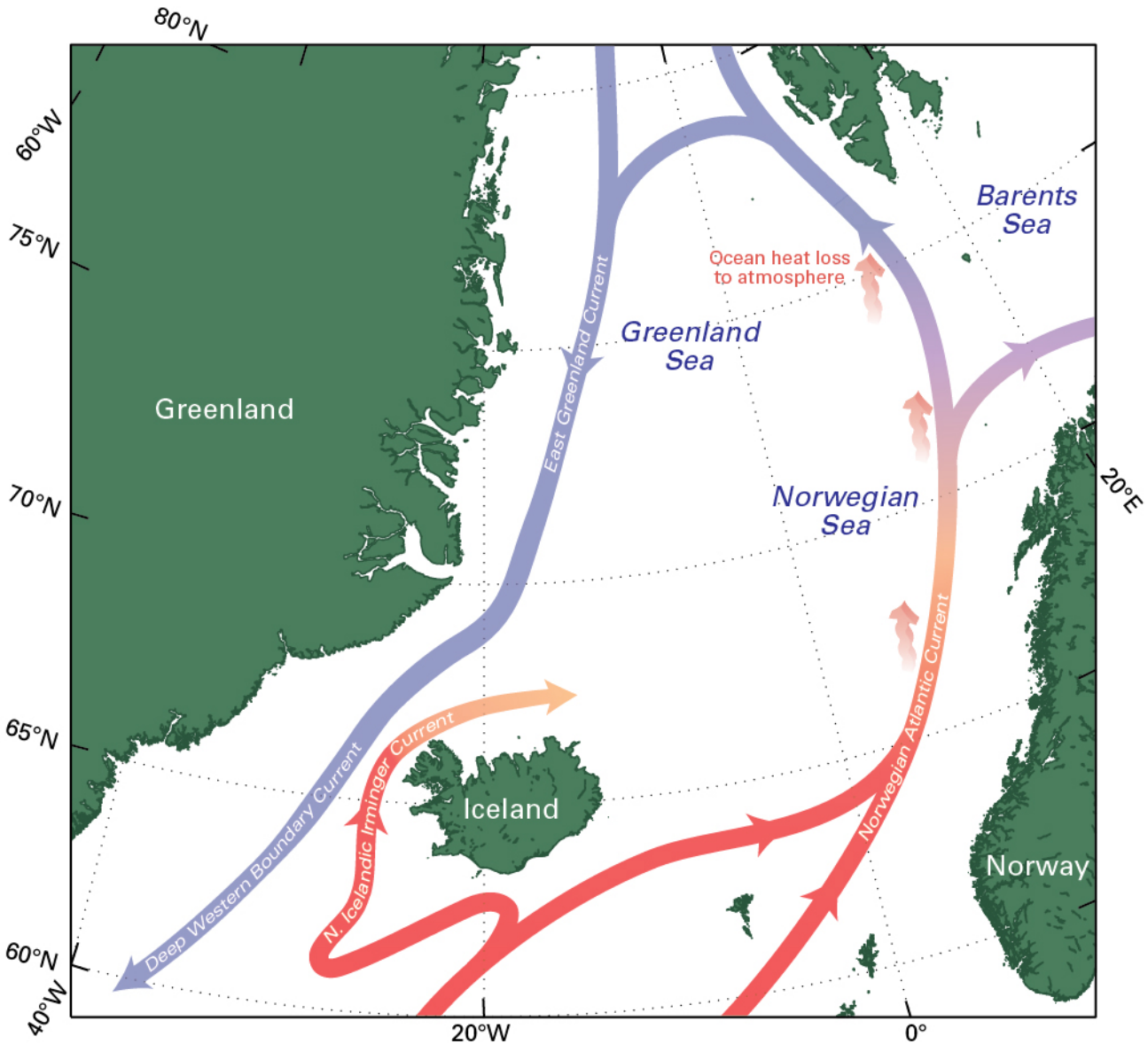
- Change buoyancy to dive or ascend
- Move batteries to control glider attitude, pitch, and roll
- Wings project vertical motion to horizontal
- Time per dive: 8-9 hours; velocity: 15-20 km/day

3 Seagliders deployed from fall 2015 to spring 2016



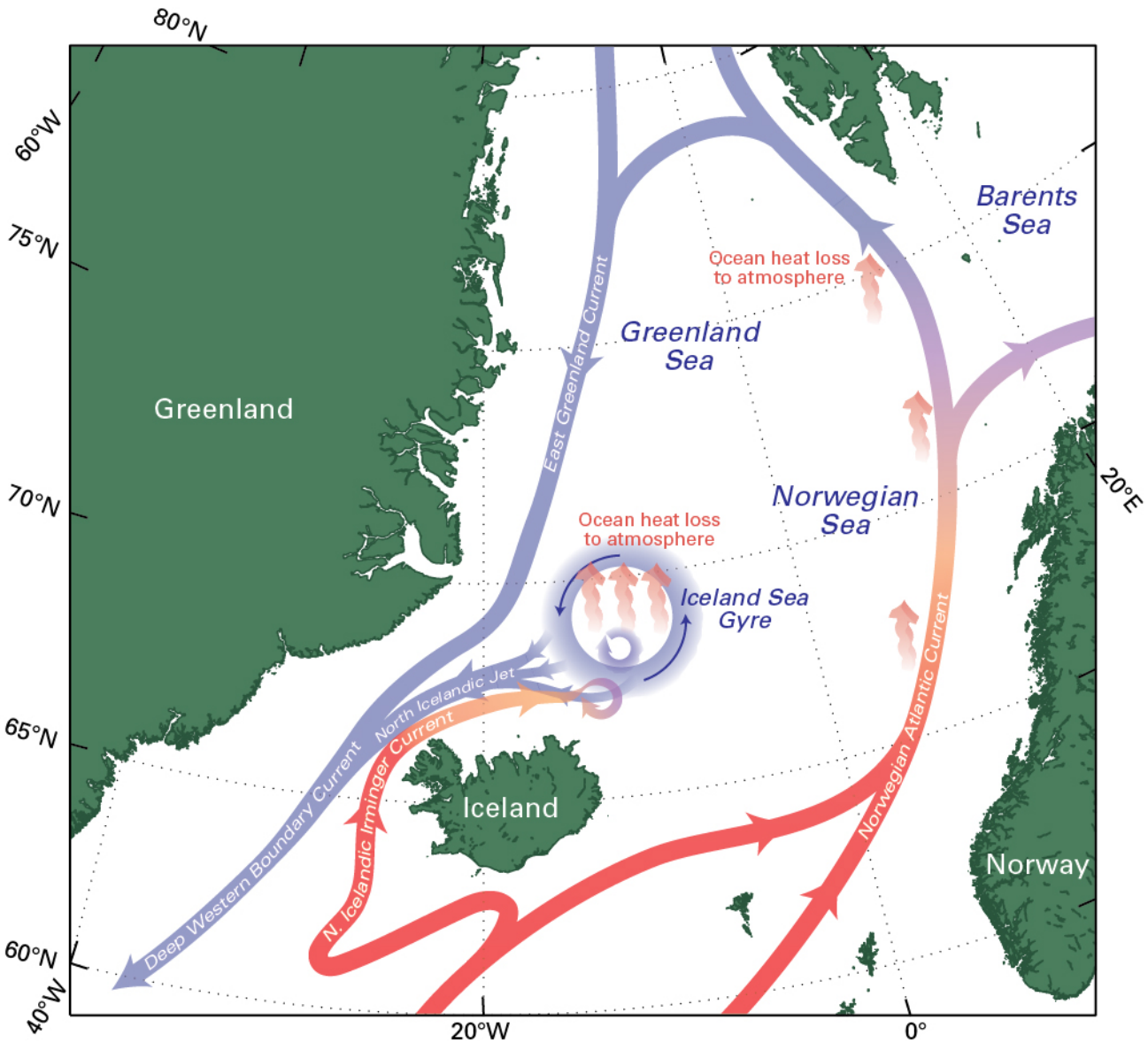
from IFM-GEOMAR

Overturning circulation schemes in the Nordic Seas



Transformation along the margins of the Nordic Seas

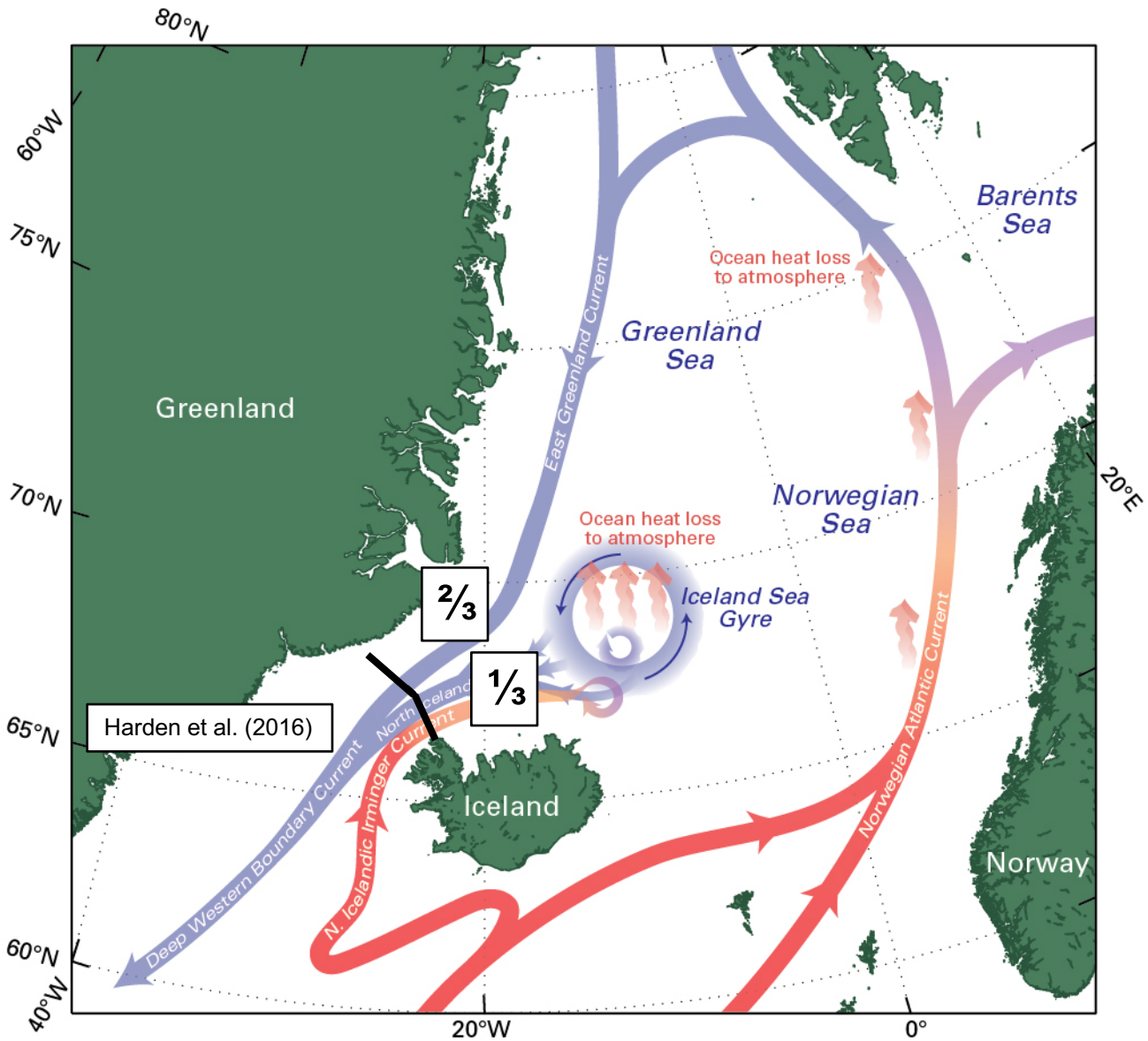
Overturning circulation schemes in the Nordic Seas



Transformation along the margins of the Nordic Seas

Transformation in the interior of the Nordic Seas

Overturning circulation schemes in the Nordic Seas



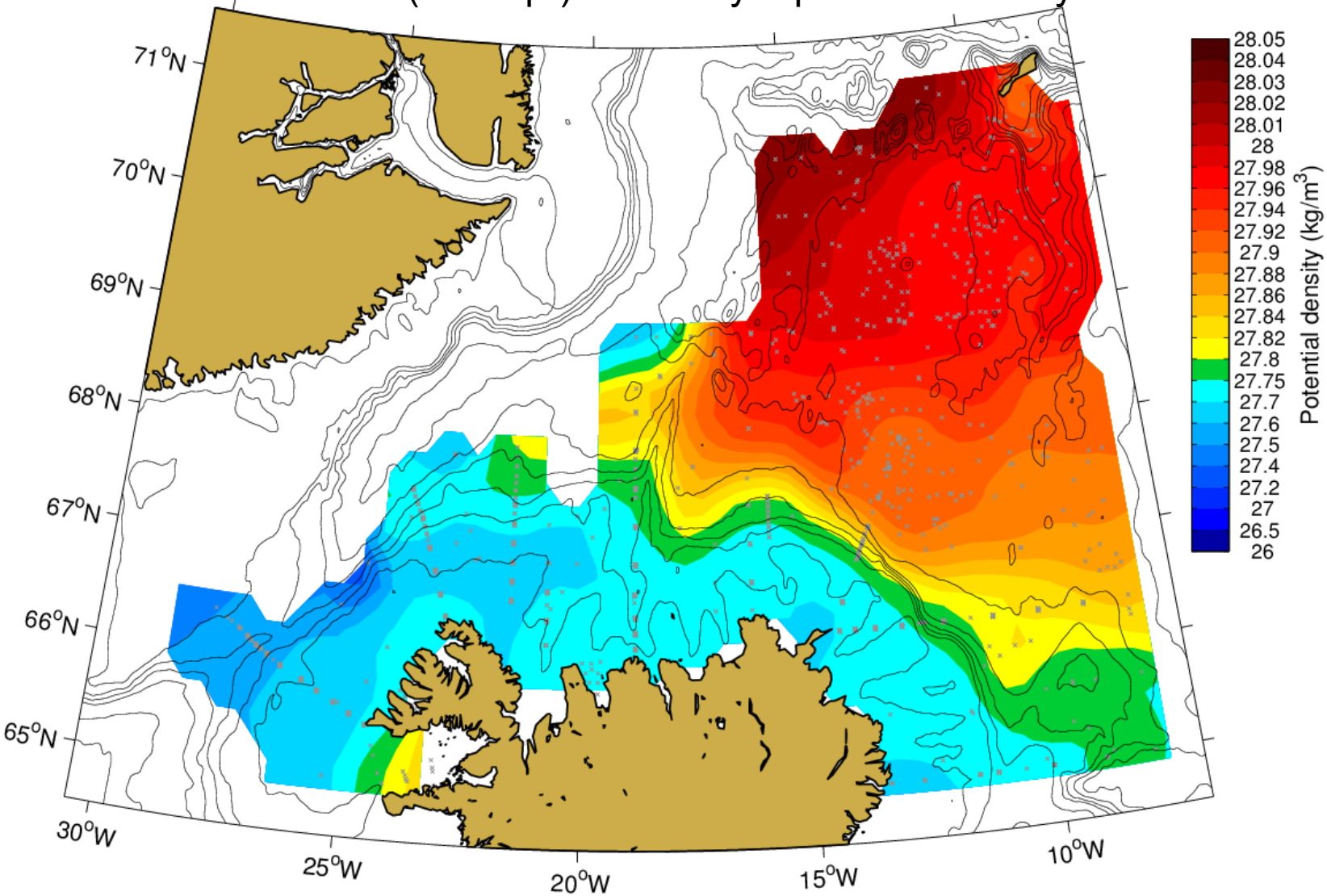
Transformation along the margins of the Nordic Seas

Transformation in the interior of the Nordic Seas

Water mass transformation in the Iceland Sea

Historical data (1980 – 2014)

Late-winter (Feb-Apr) mixed-layer potential density



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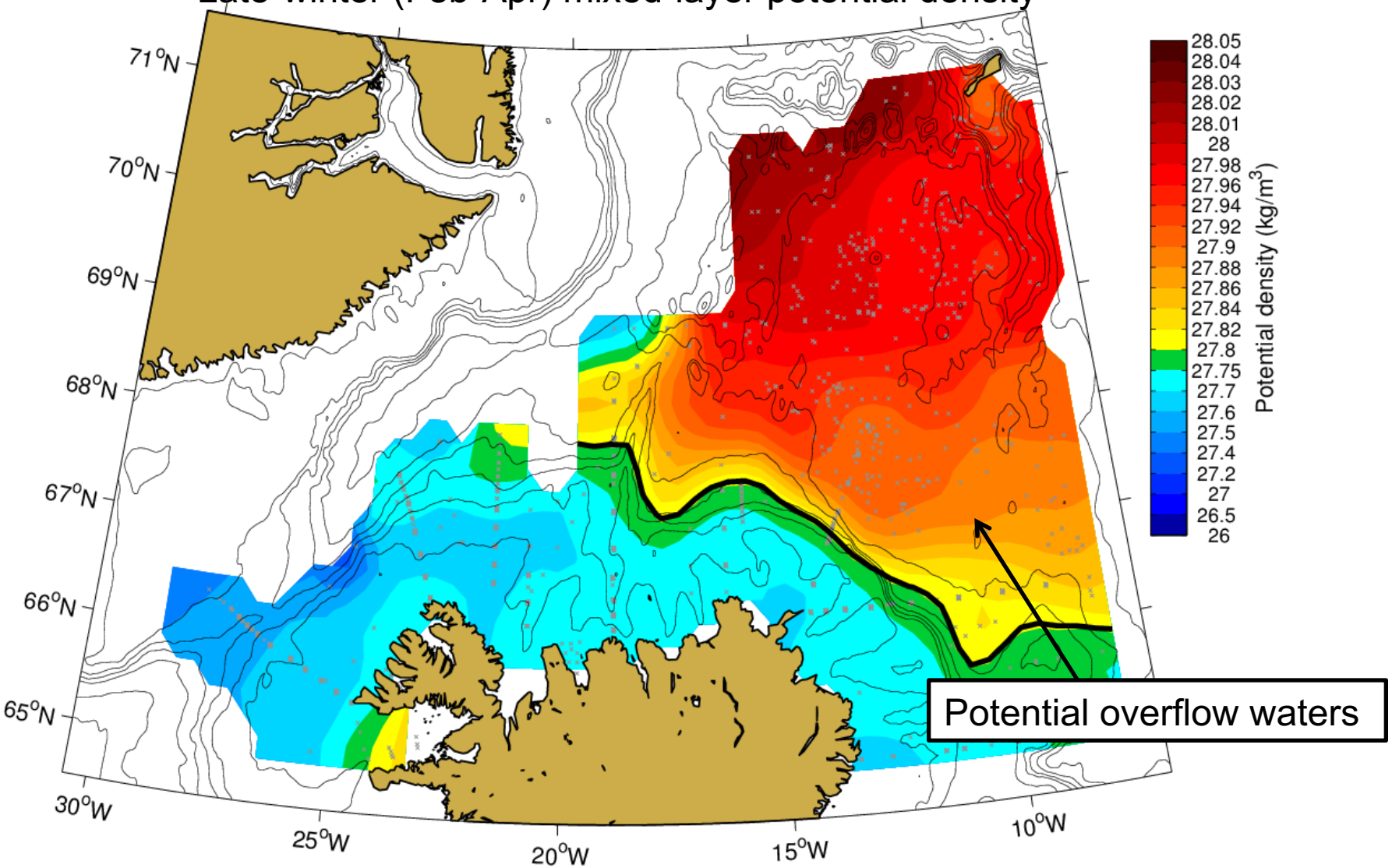

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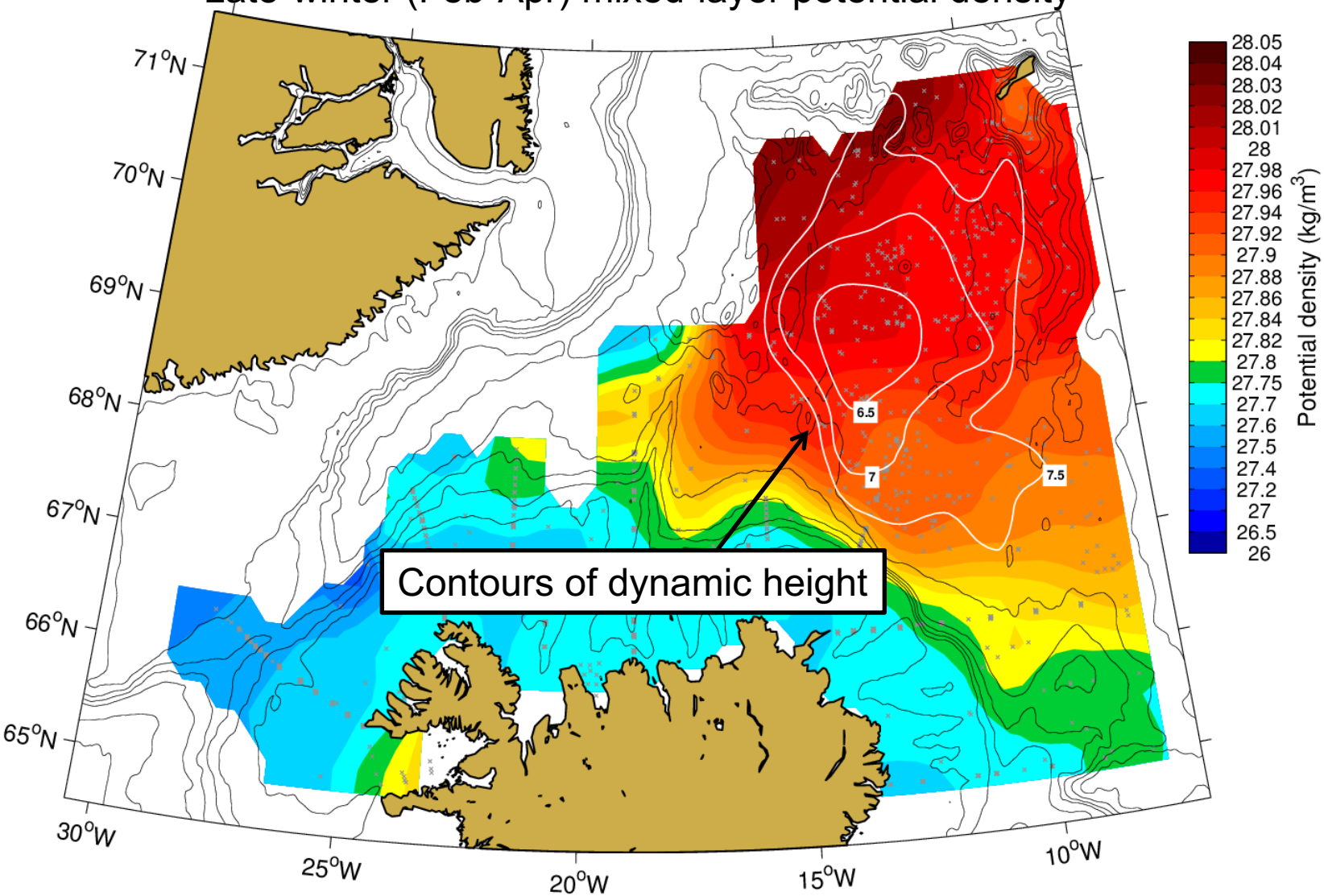

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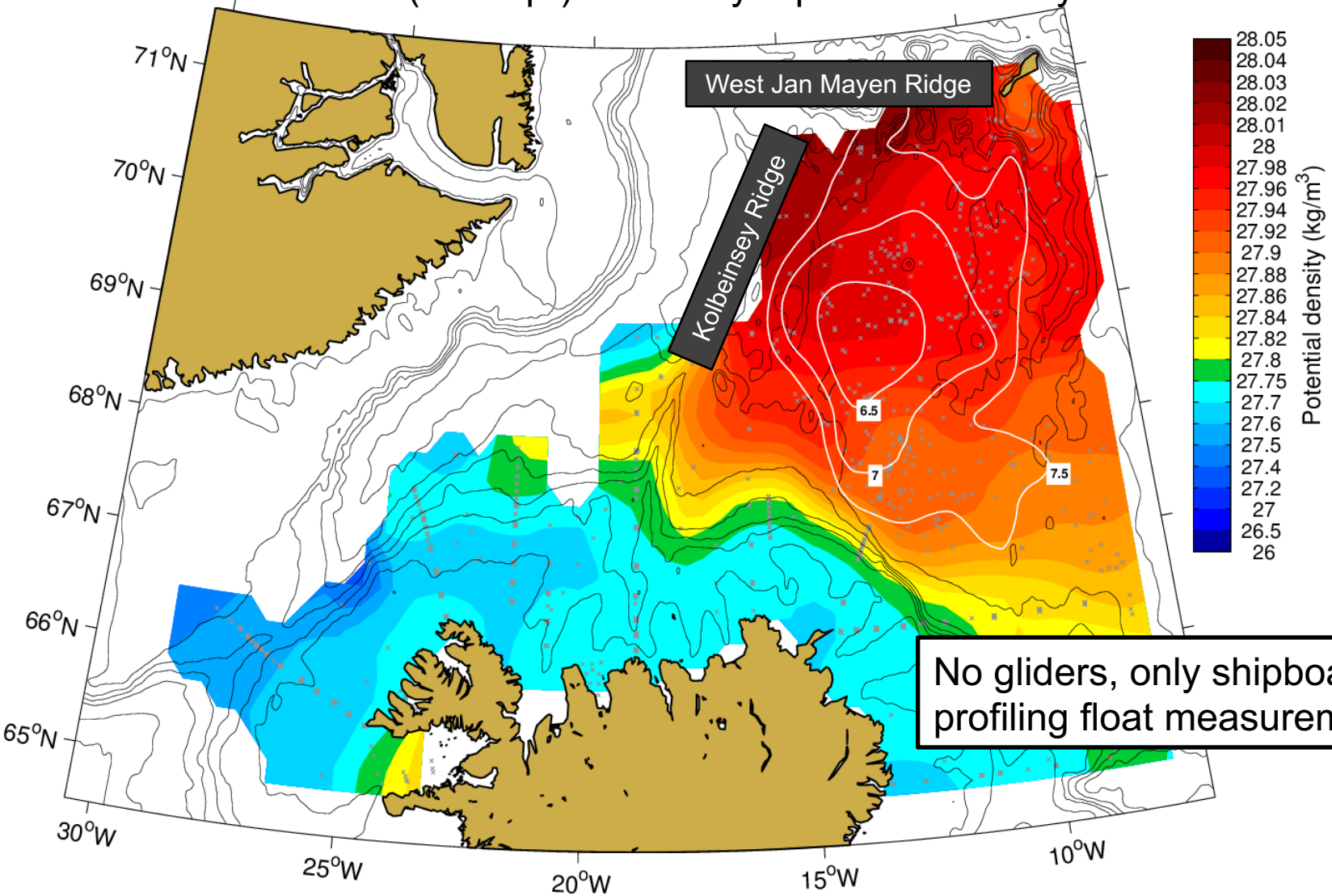
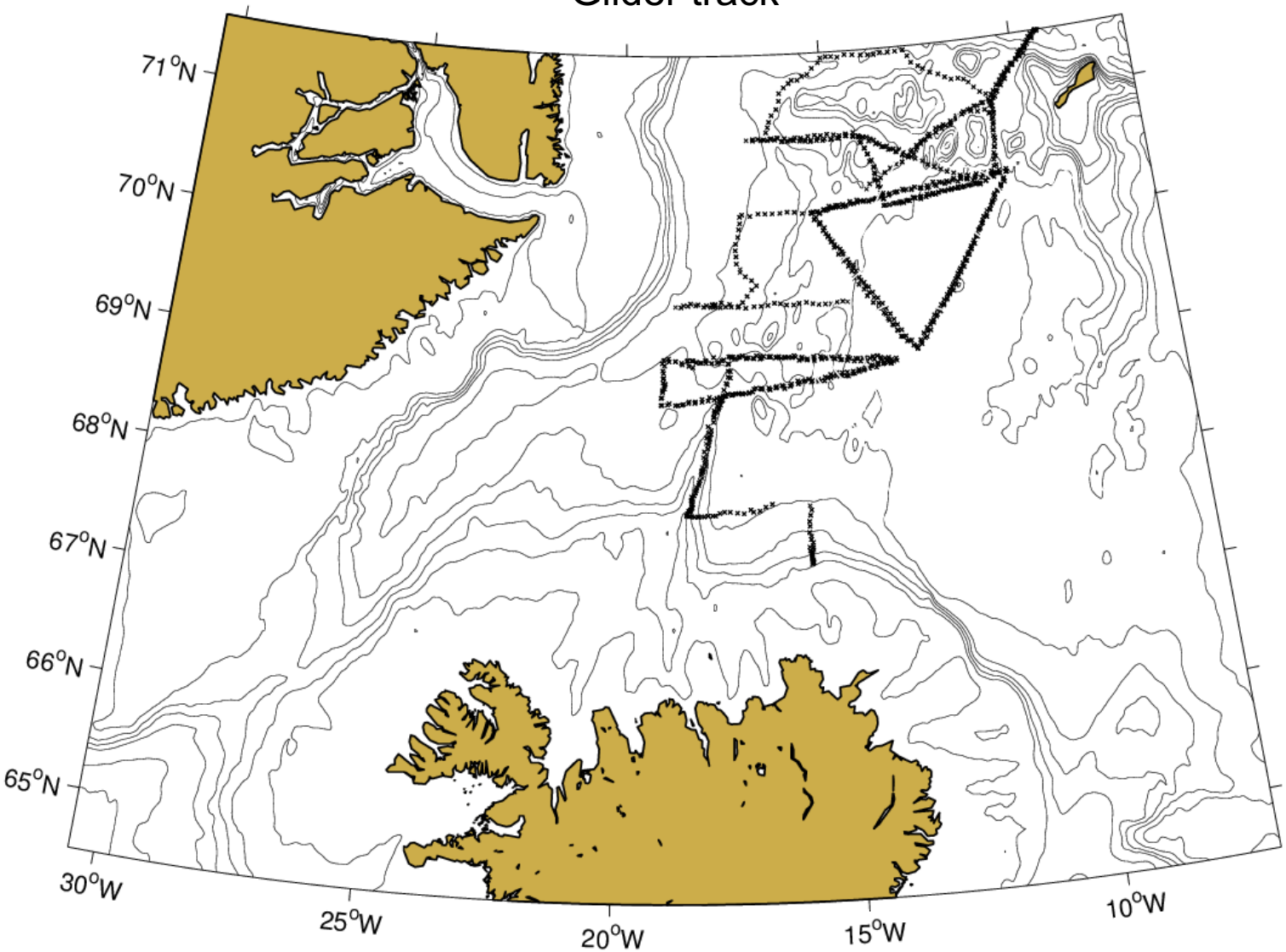


No gliders, only shipboard and profiling float measurements

Water mass transformation in the Iceland Sea

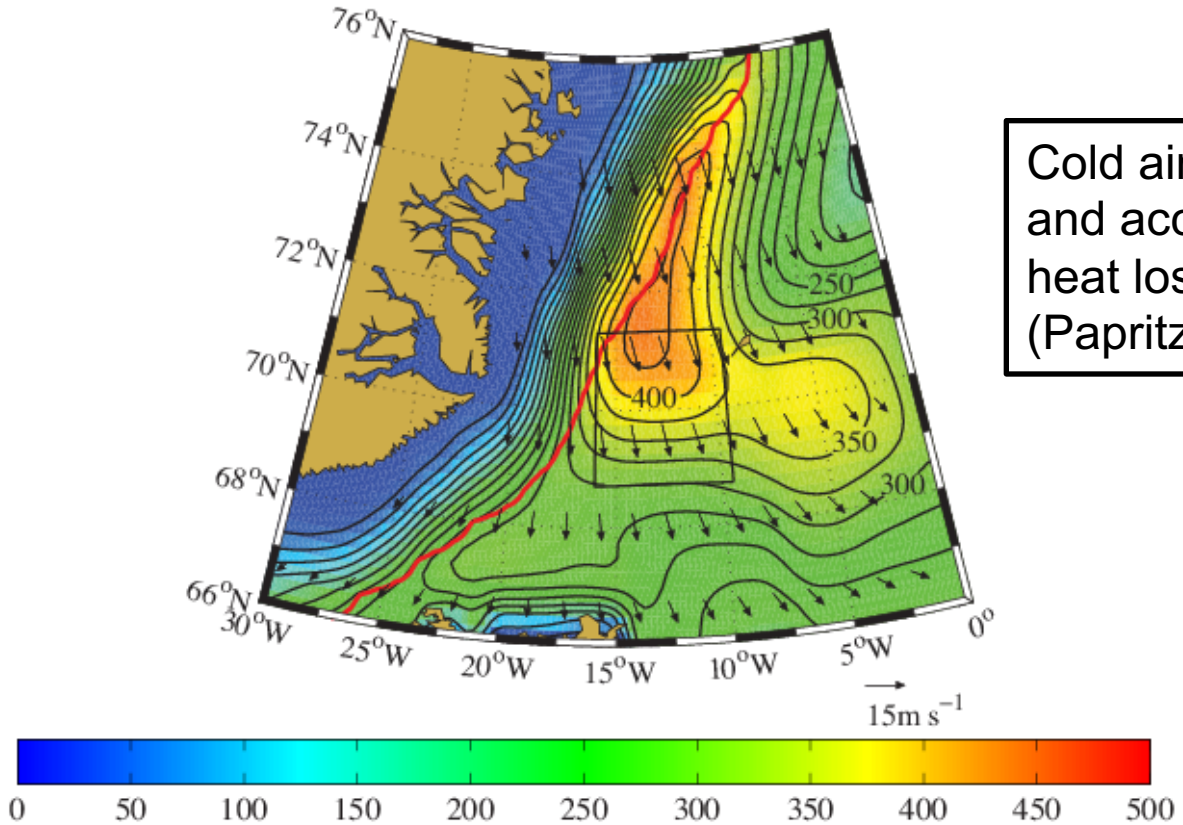
Glider measurements (2016)

Glider track



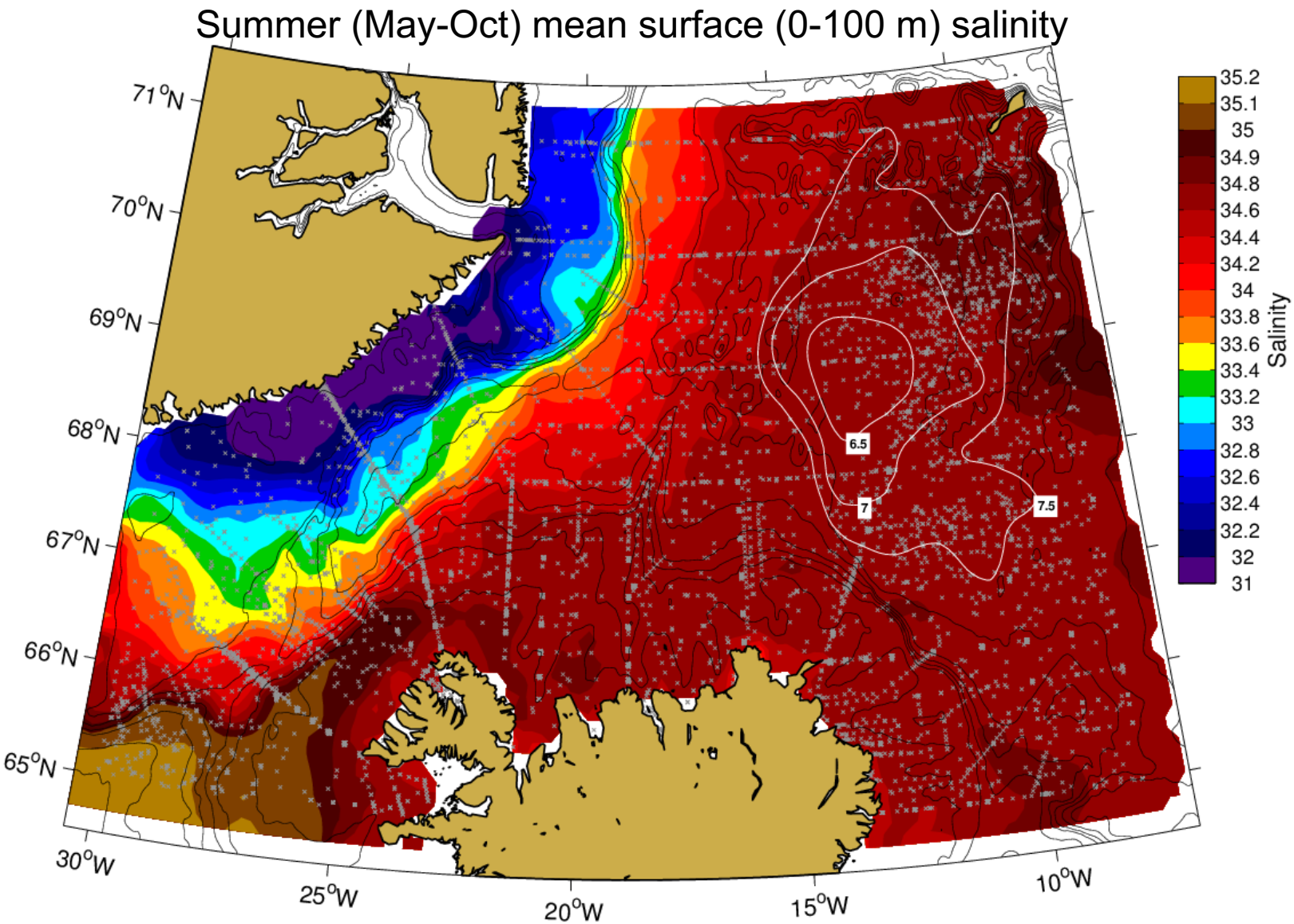
Strongest atmospheric forcing near the ice edge

Composite high heat flux event (W/m^2)



Cold air outbreaks are prevalent and account for 60-80% of the heat loss in the Iceland Sea (Papritz and Spengler, 2017)

Low surface salinity in the western Iceland Sea



Low surface salinity in the western Iceland Sea

Summer (May-Oct) mean surface (0-100 m) salinity

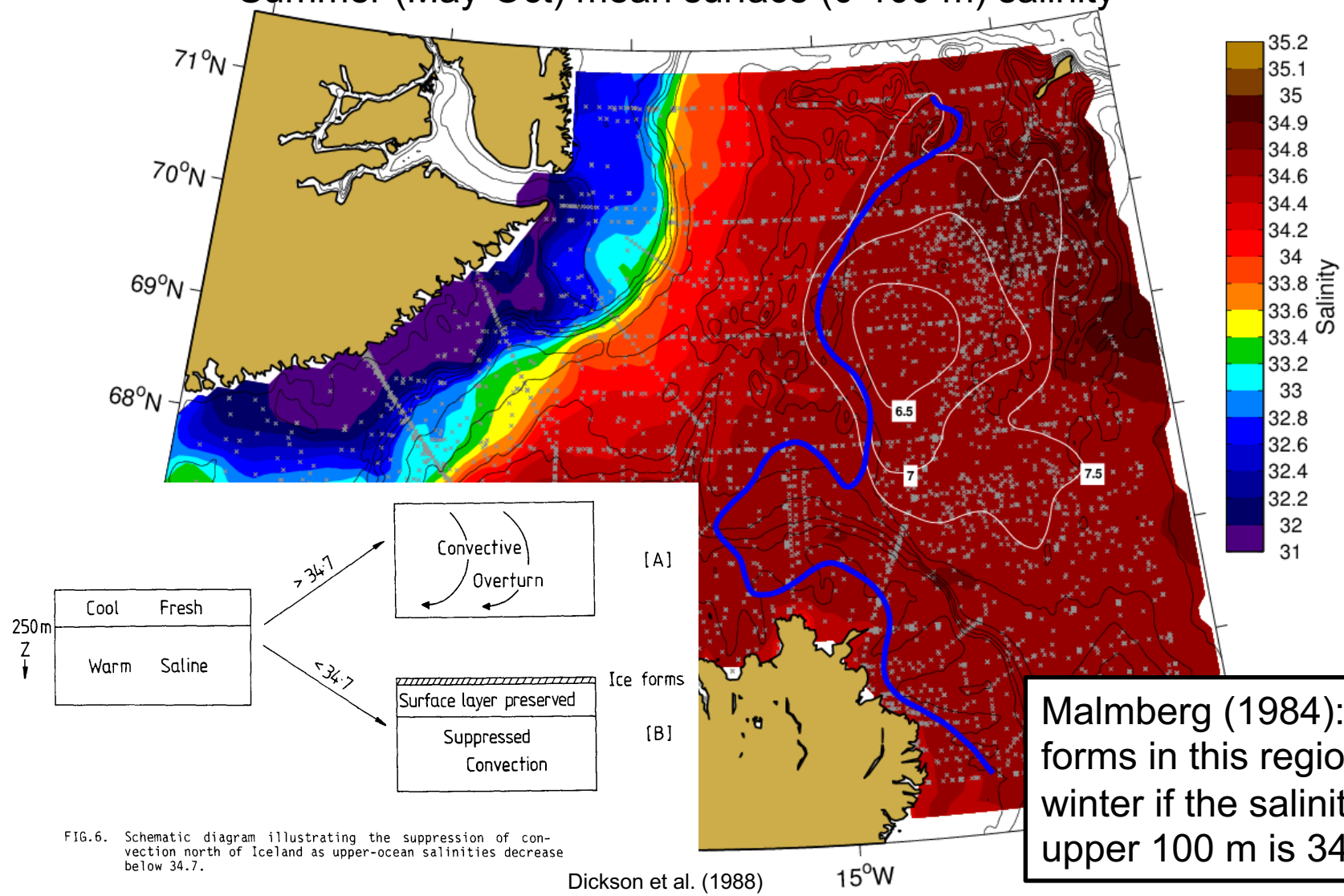


FIG.6. Schematic diagram illustrating the suppression of convection north of Iceland as upper-ocean salinities decrease below 34.7.

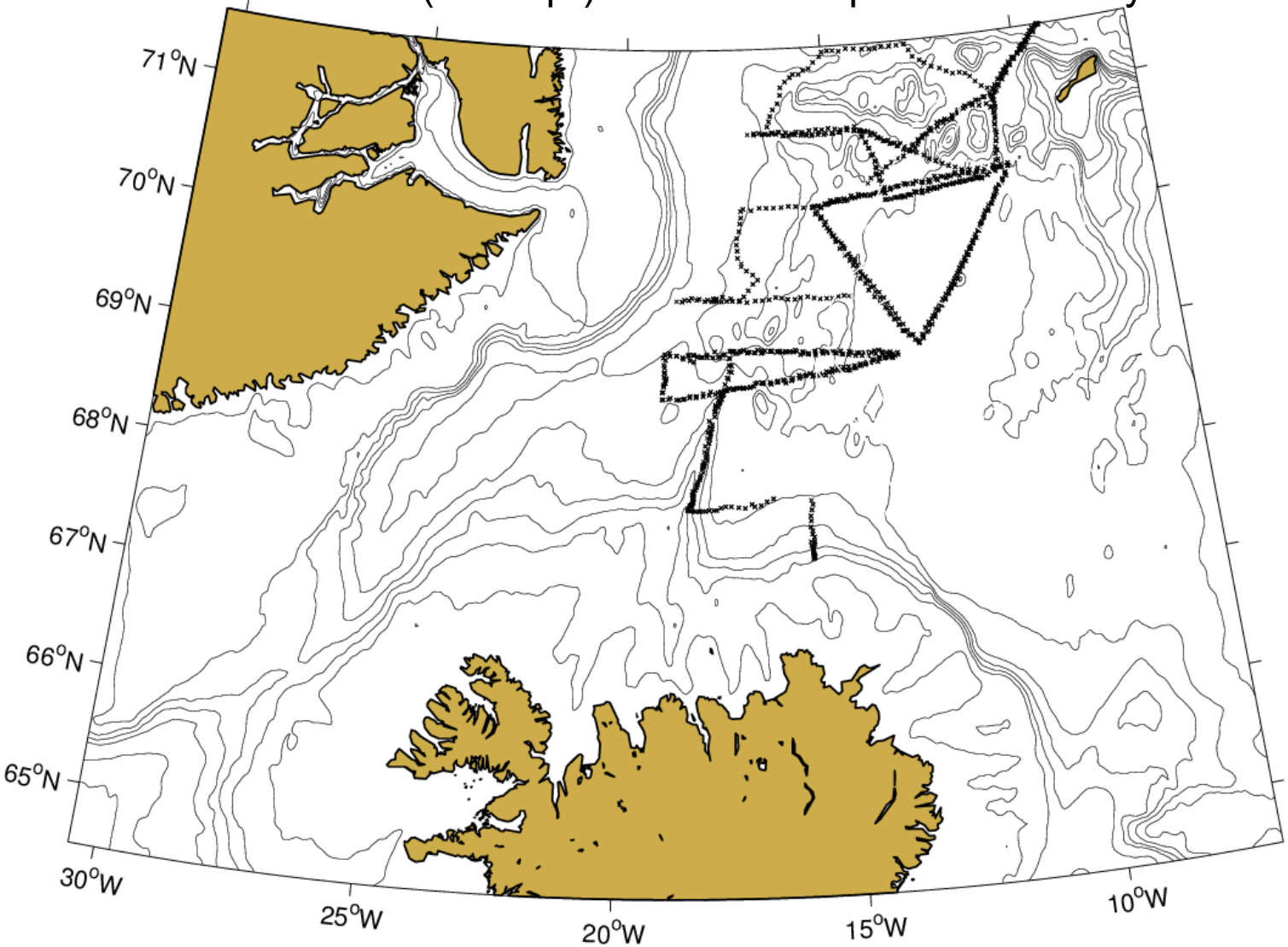
Dickson et al. (1988)

Malmberg (1984): Sea ice forms in this region in winter if the salinity of the upper 100 m is 34.7 or less

Water mass transformation in the Iceland Sea

Glider measurements (2016)

Late-winter (Feb-Apr) near-surface potential density



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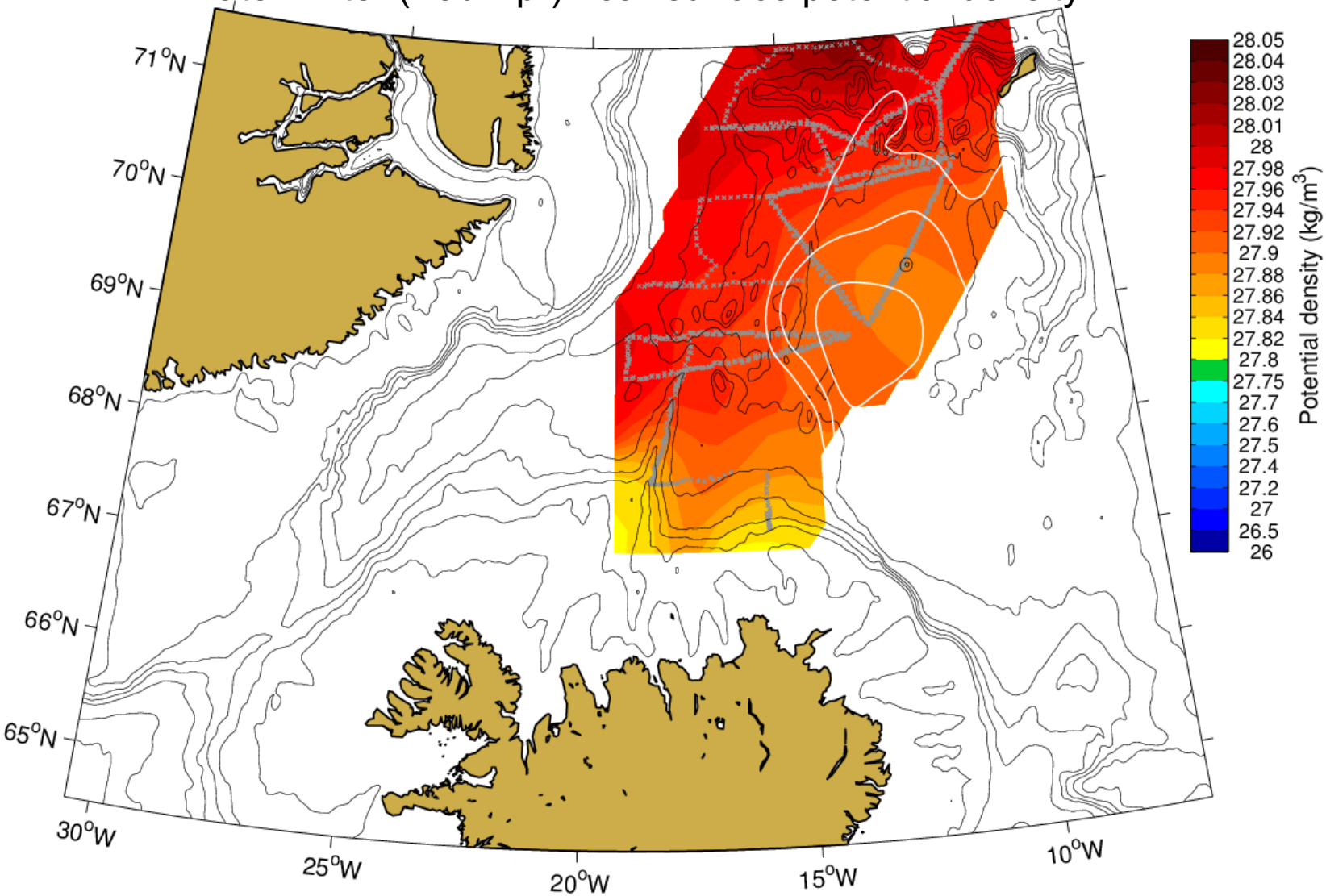

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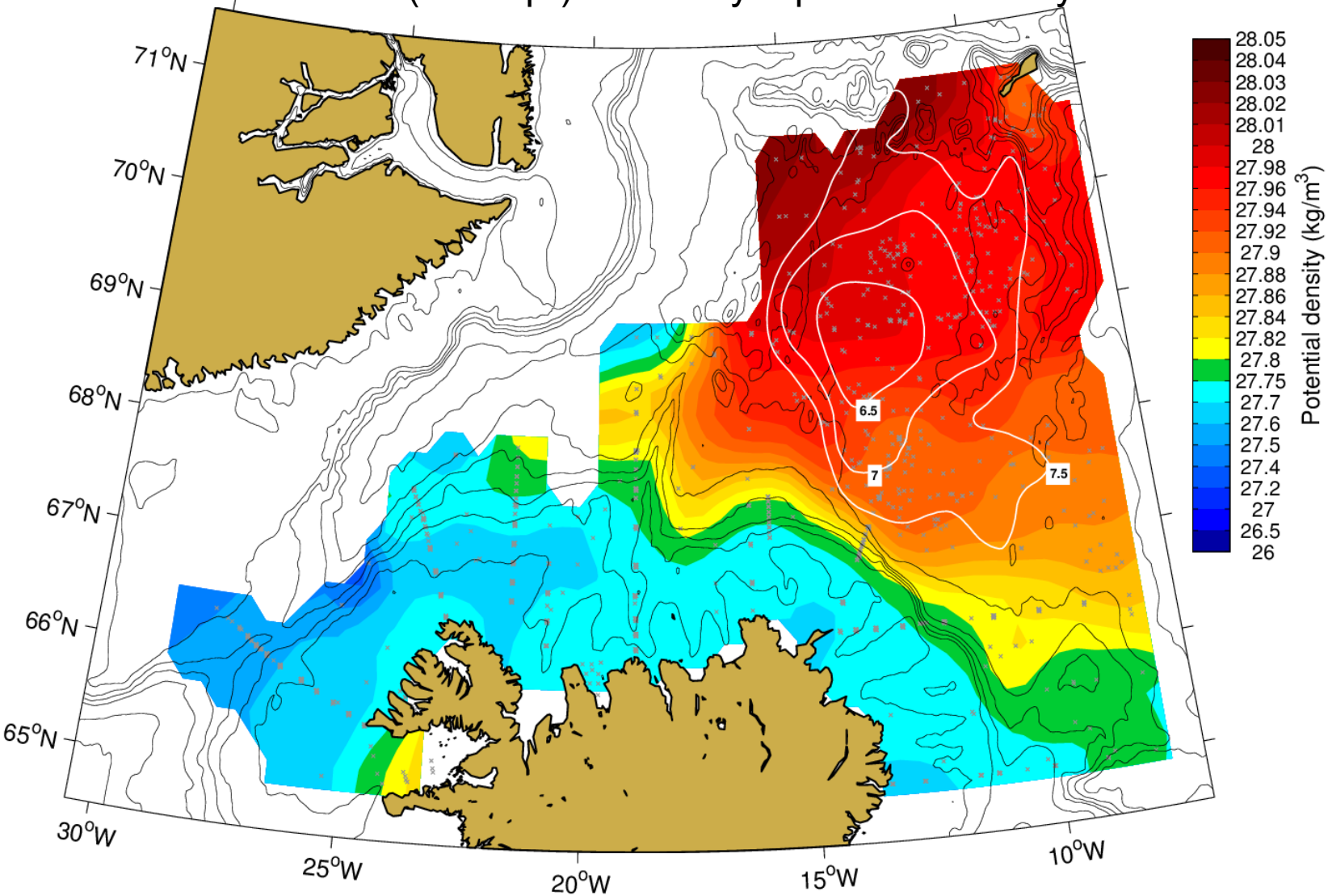
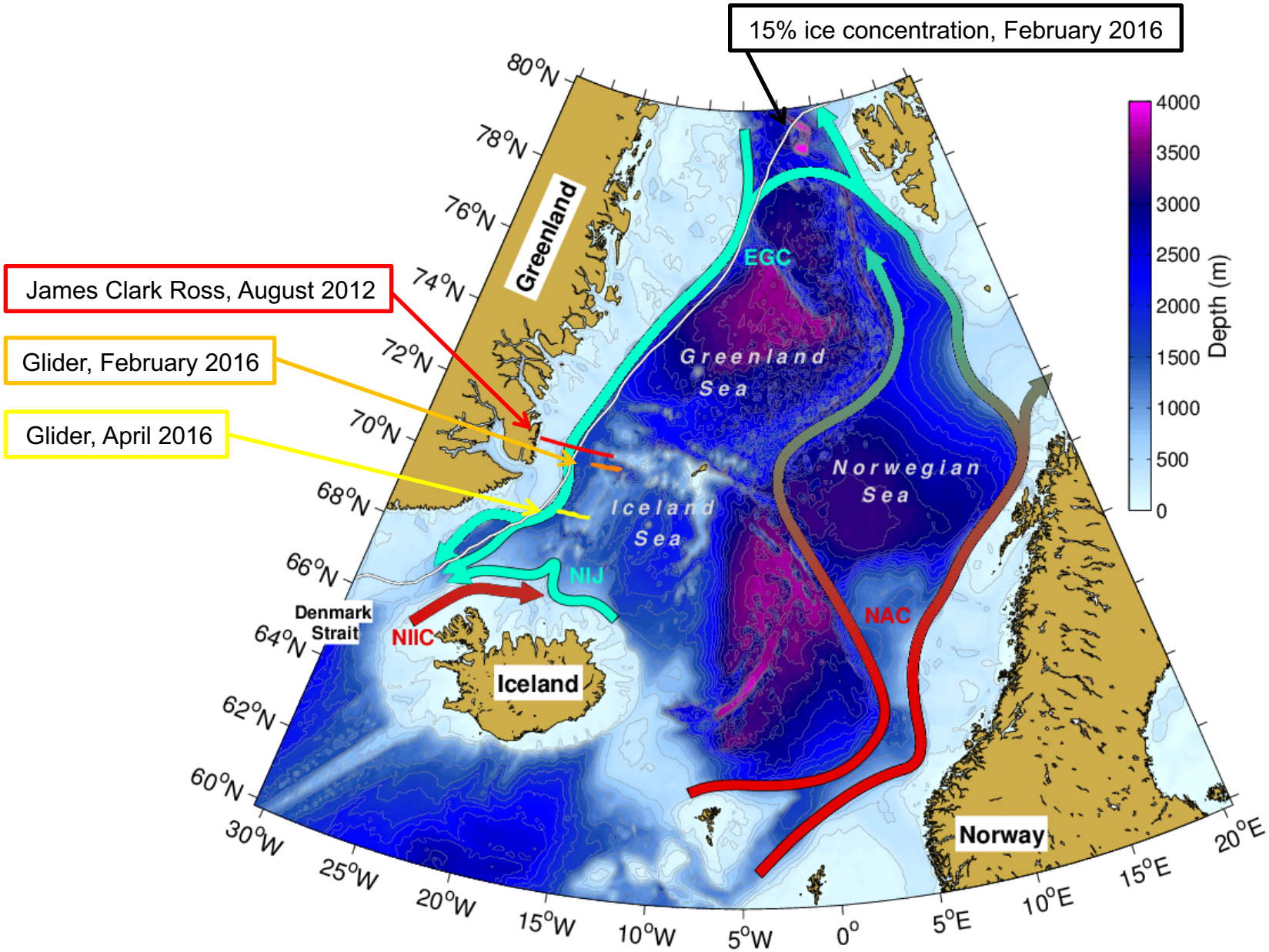
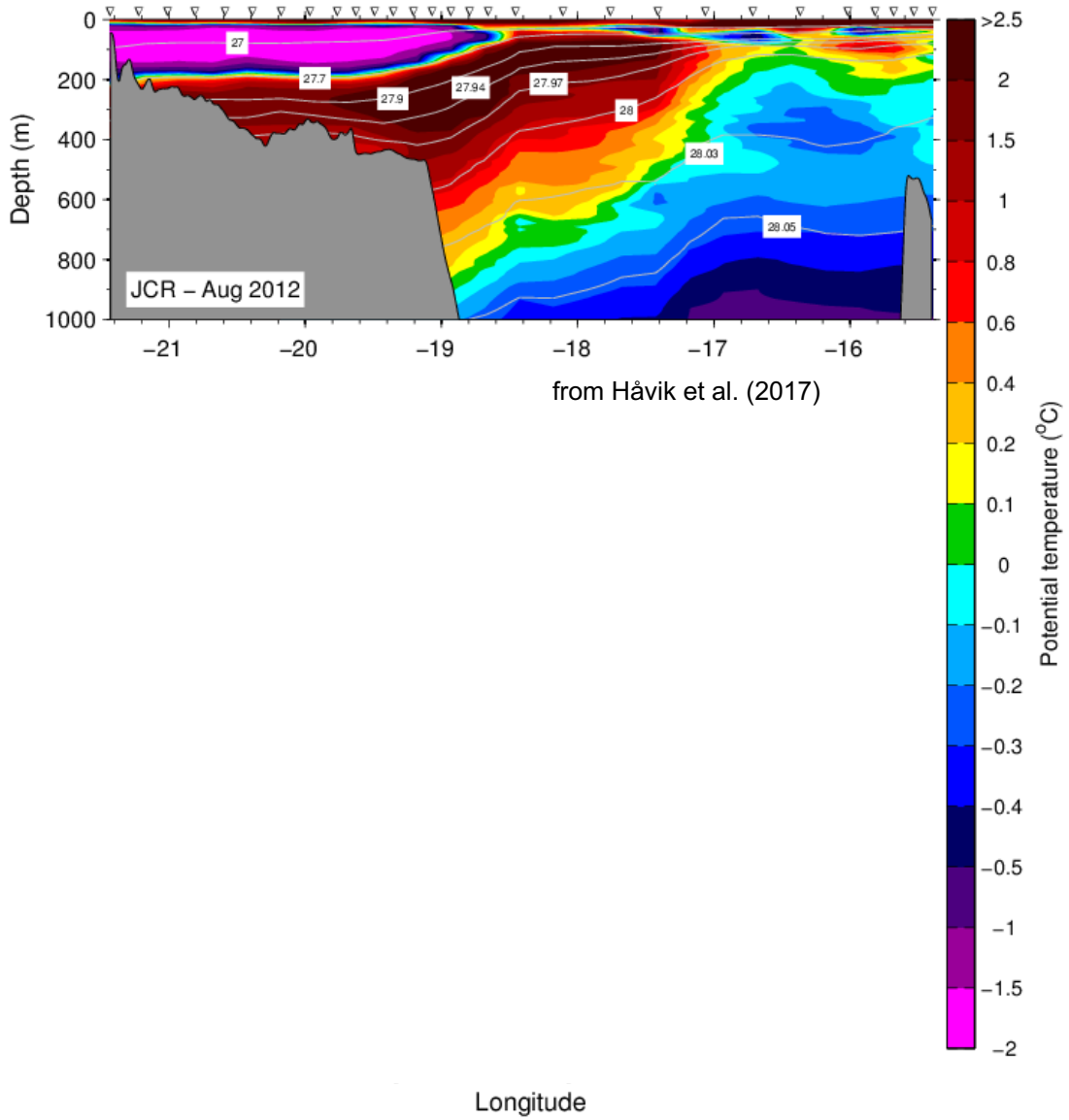


Water mass transformation near the marginal ice zone

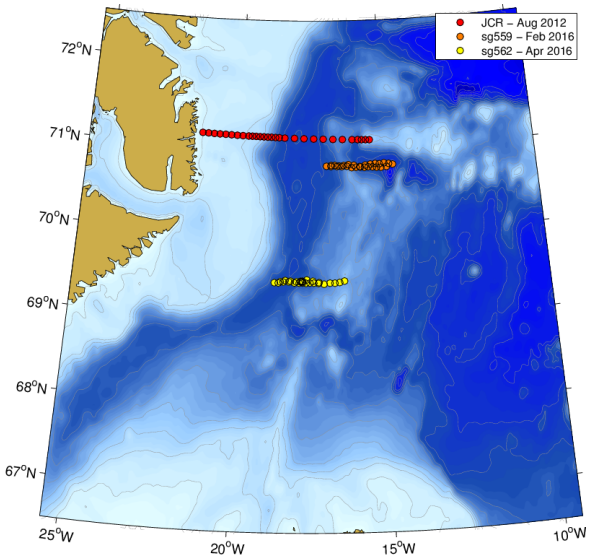


Hydrographic structure of the East Greenland Current

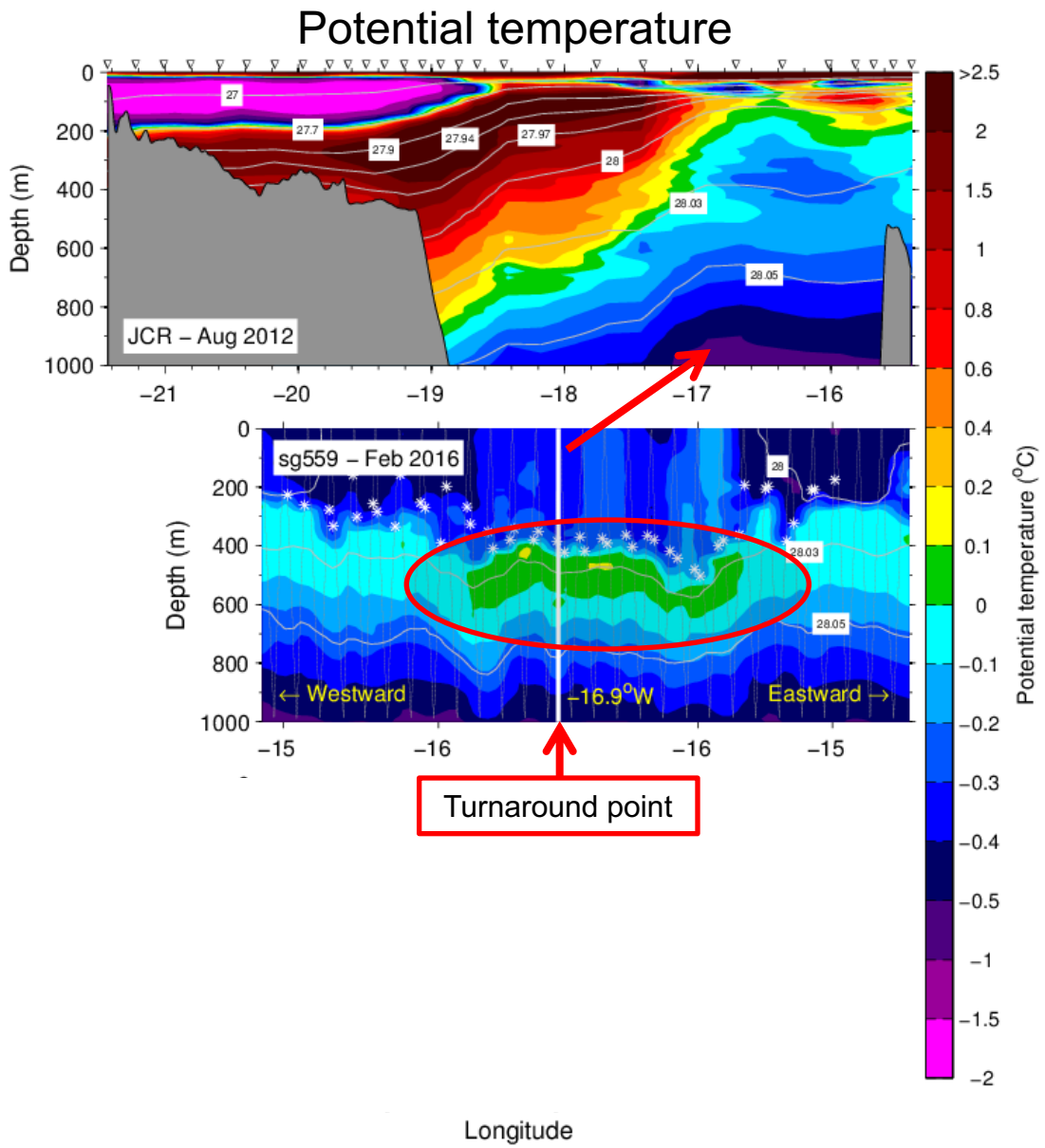
Potential temperature

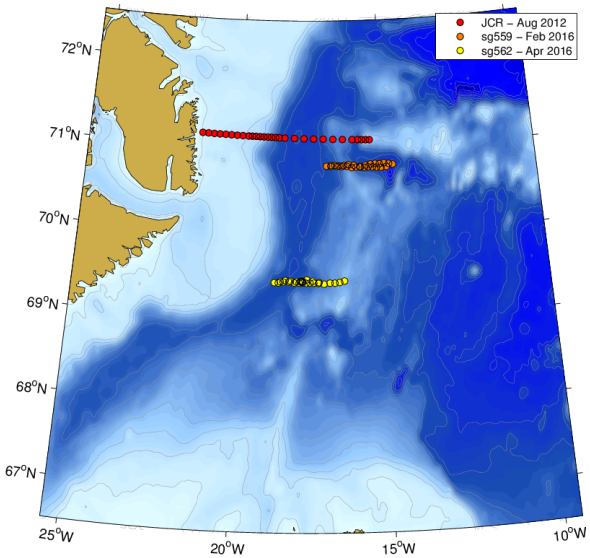


from Håvik et al. (2017)



Atlantic-origin water re-ventilated in the EGC





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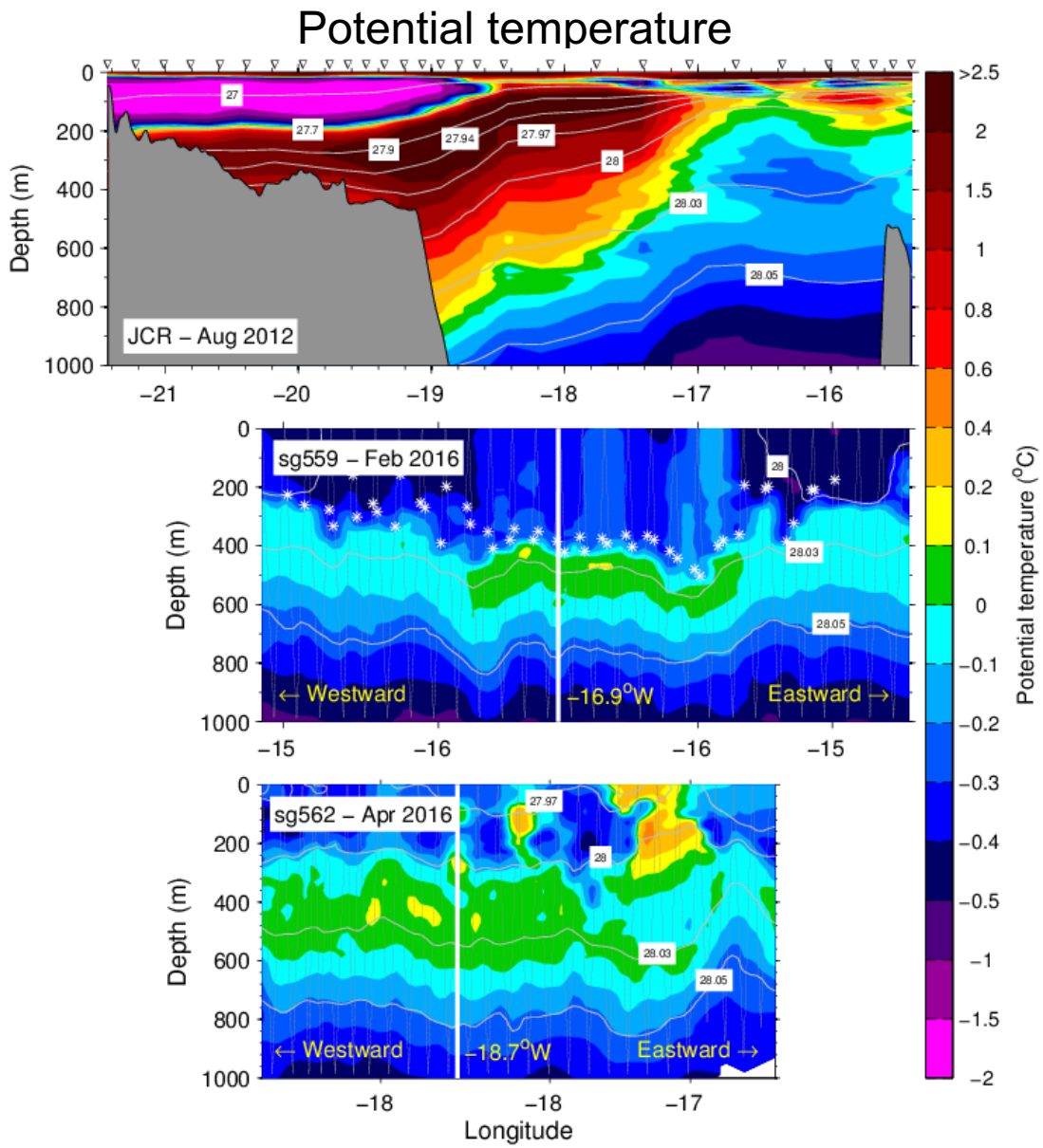

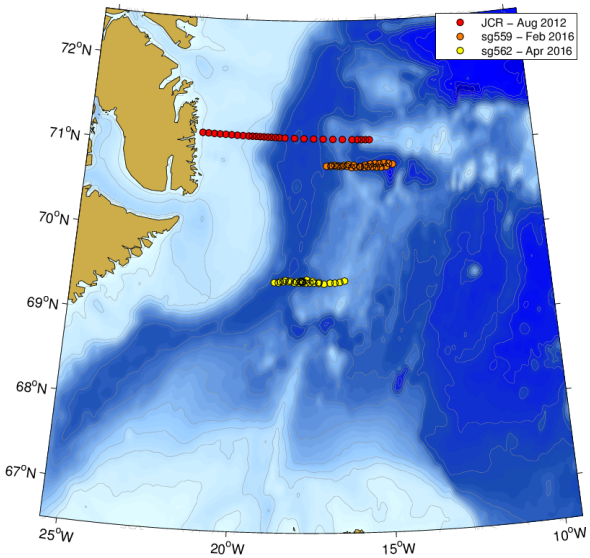

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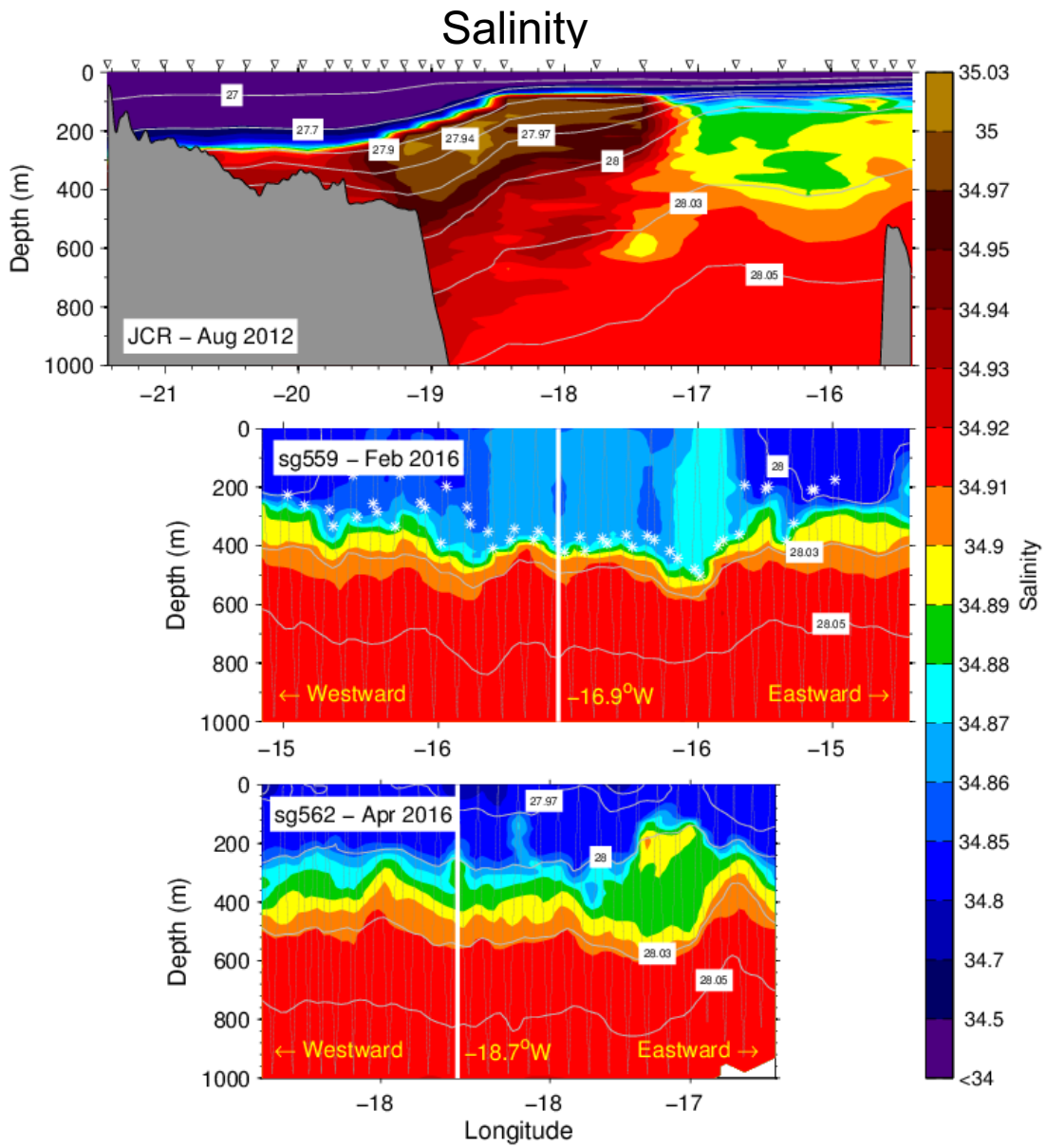

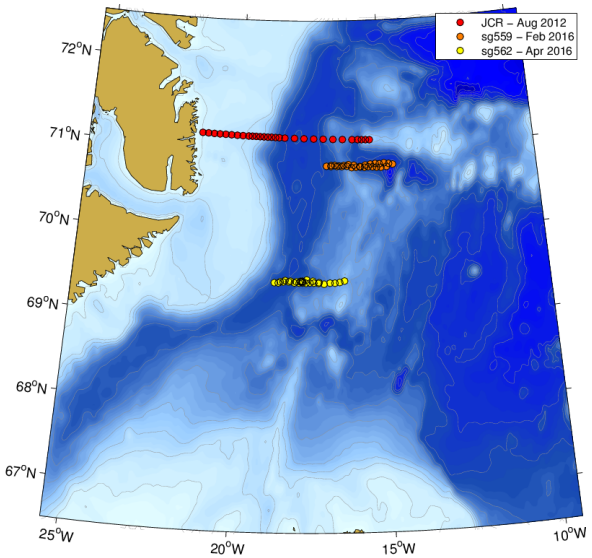

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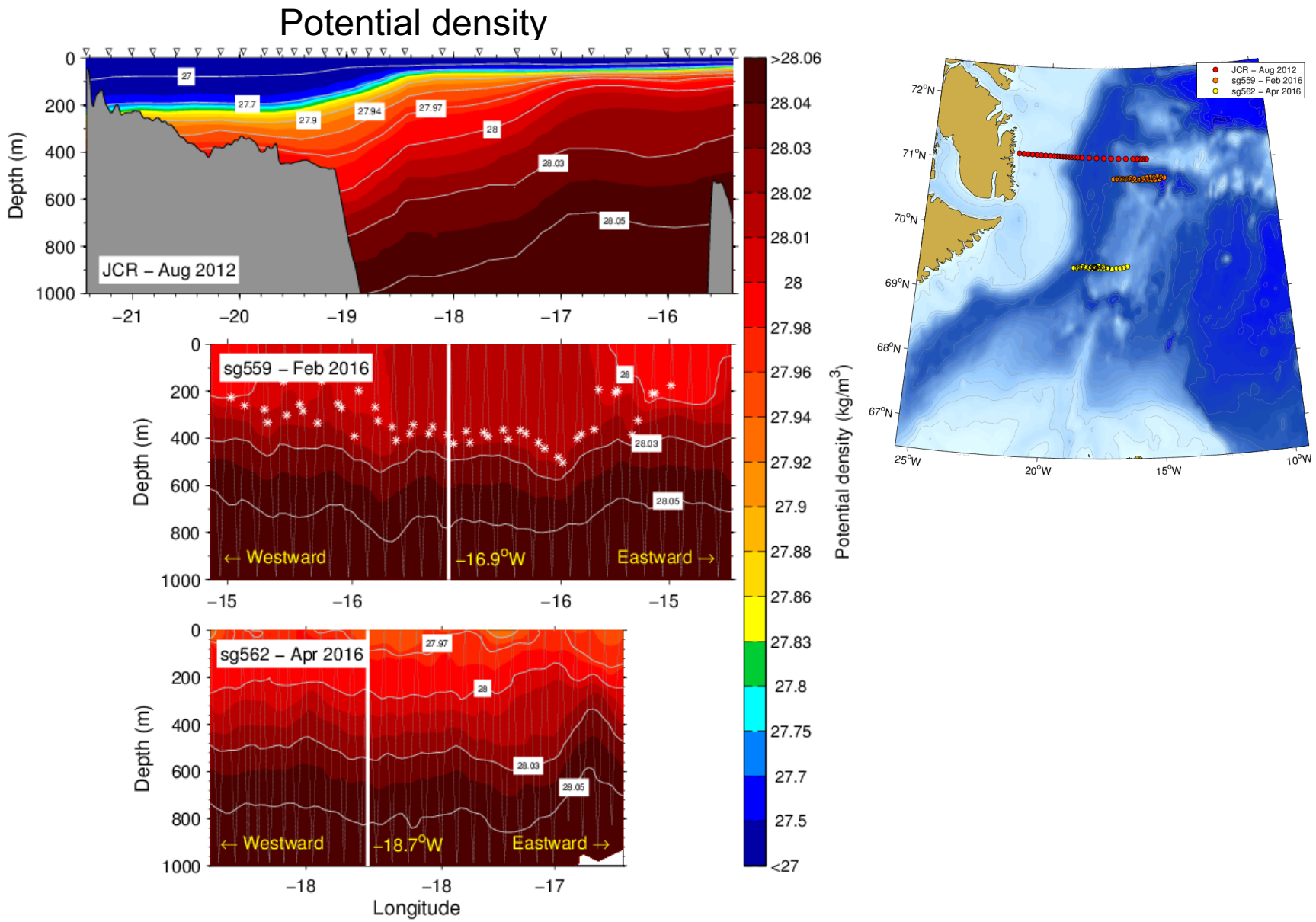
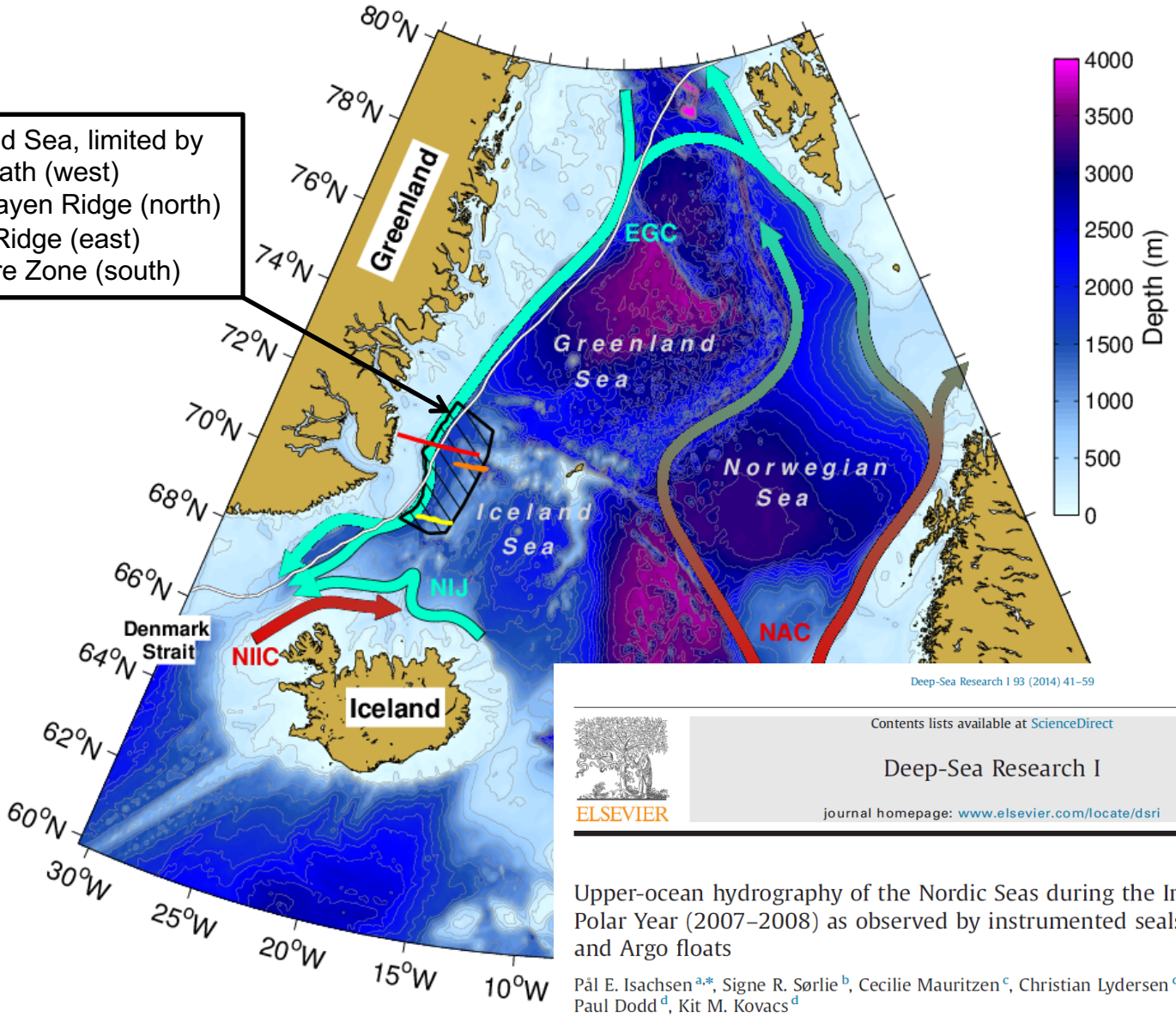


Use data from instrumented seals and hydrographic cruises

Western Iceland Sea, limited by
- 1000 m isobath (west)
- West Jan Mayen Ridge (north)
- Kolbeinsey Ridge (east)
- Spar Fracture Zone (south)



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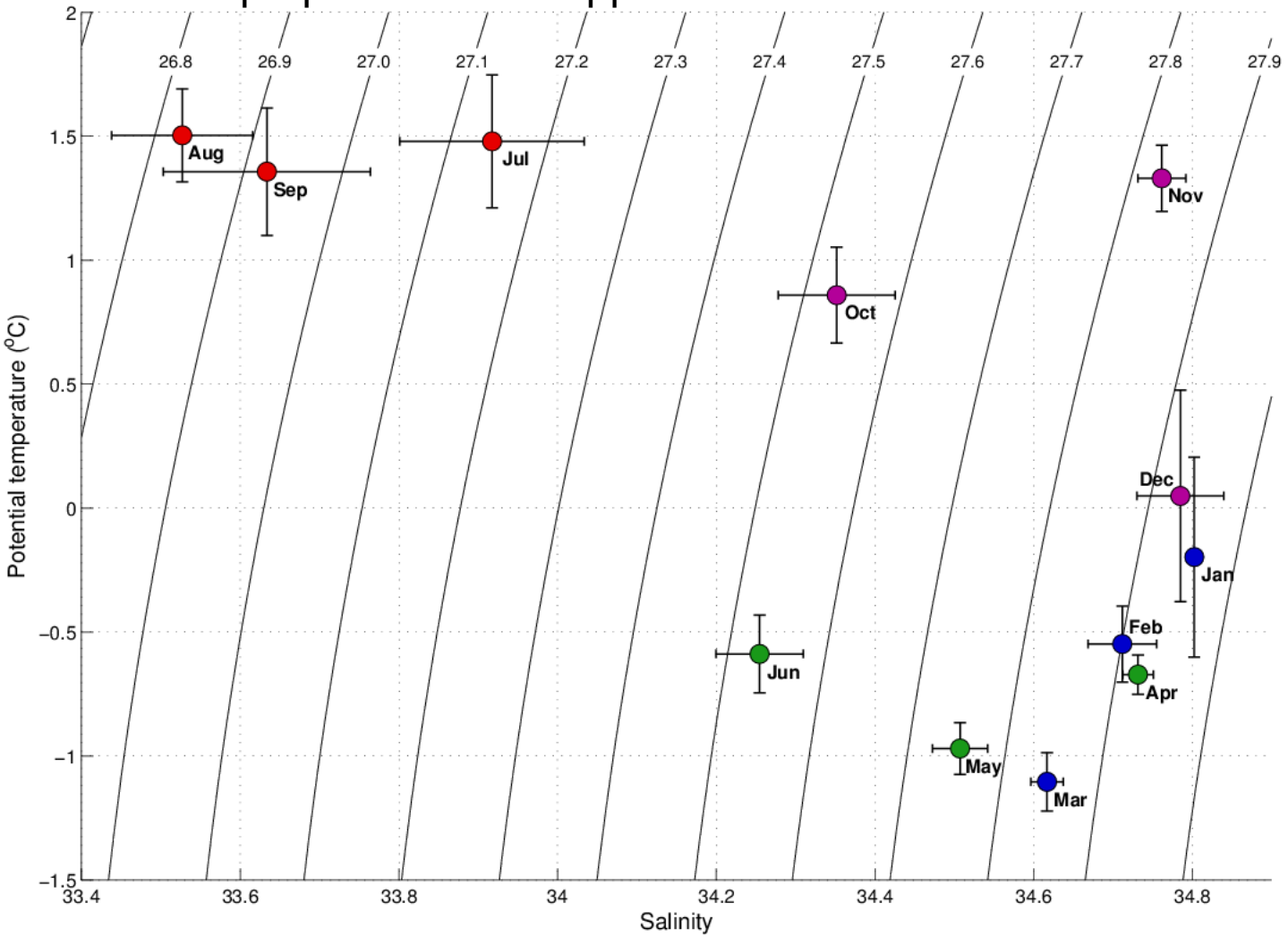
journal homepage: www.elsevier.com/locate/dsri

Upper-ocean hydrography of the Nordic Seas during the International Polar Year (2007–2008) as observed by instrumented seals and Argo floats

Pål E. Isachsen[a,*], Signe R. Sørlie[b], Cecilie Mauritzen[c], Christian Lydersen[d], Paul Dodd[d], Kit M. Kovacs[d]

Pronounced seasonality in the western Iceland Sea

Mean θS properties of the upper 50 m in the western Iceland Sea



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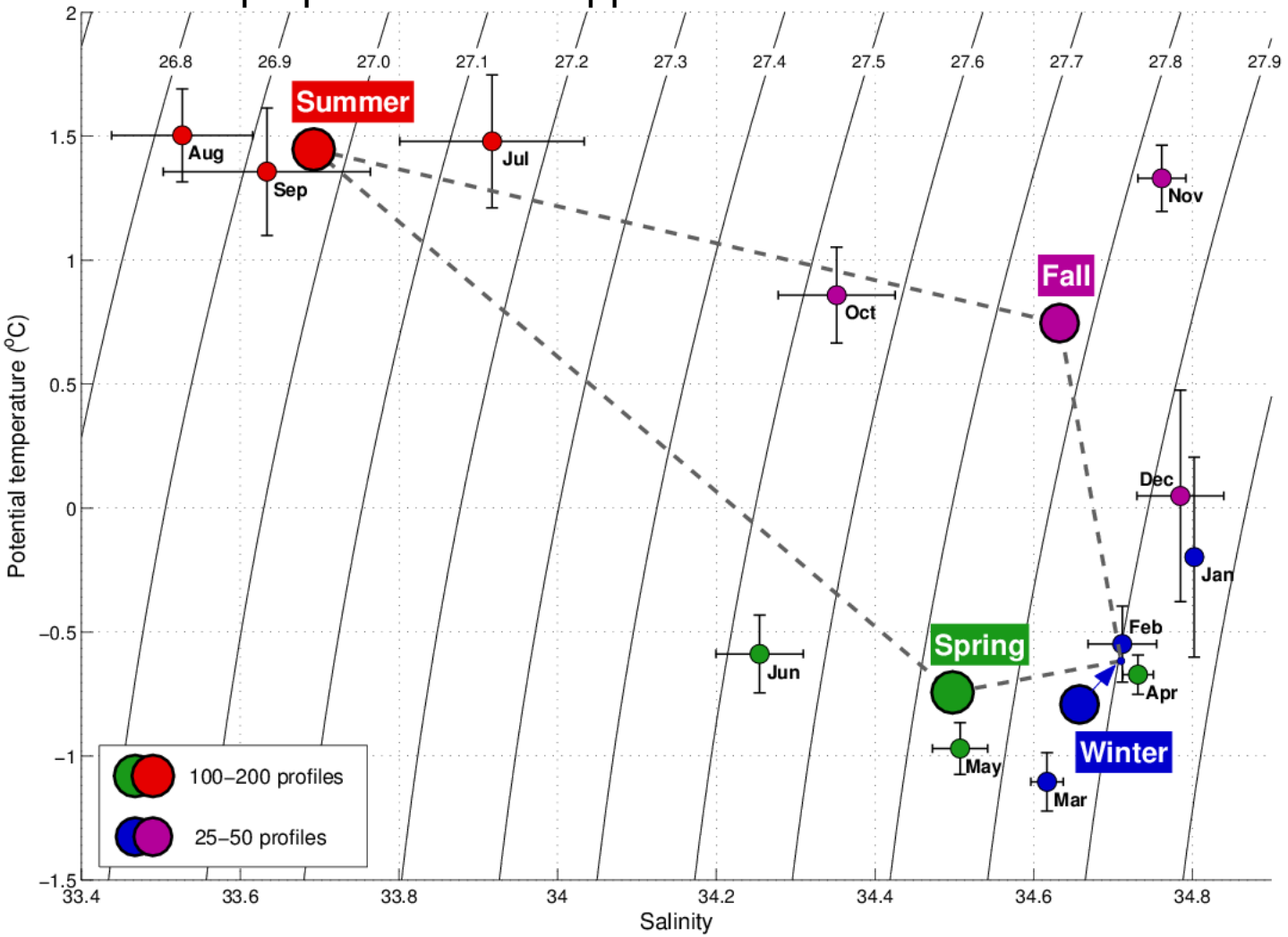
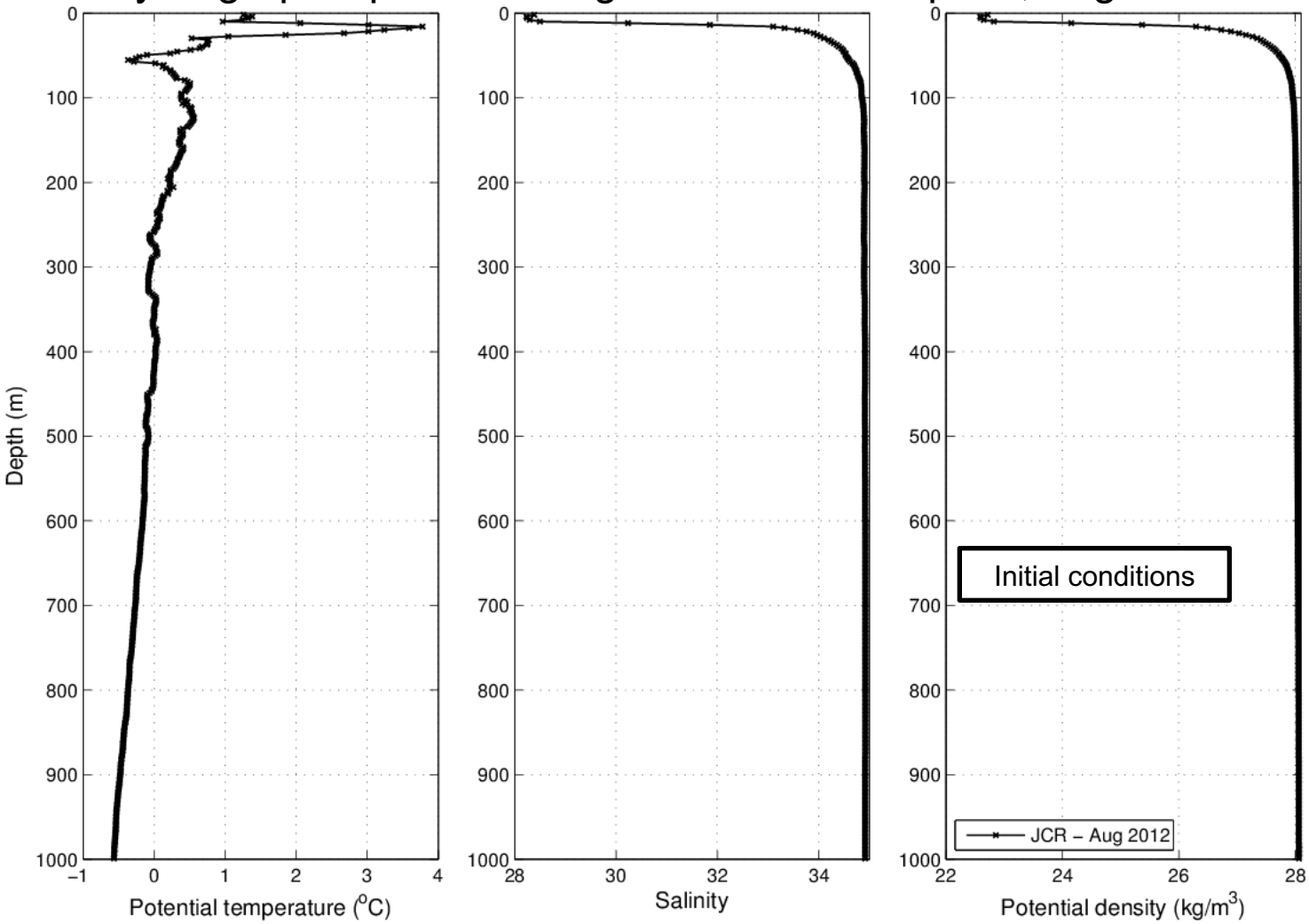


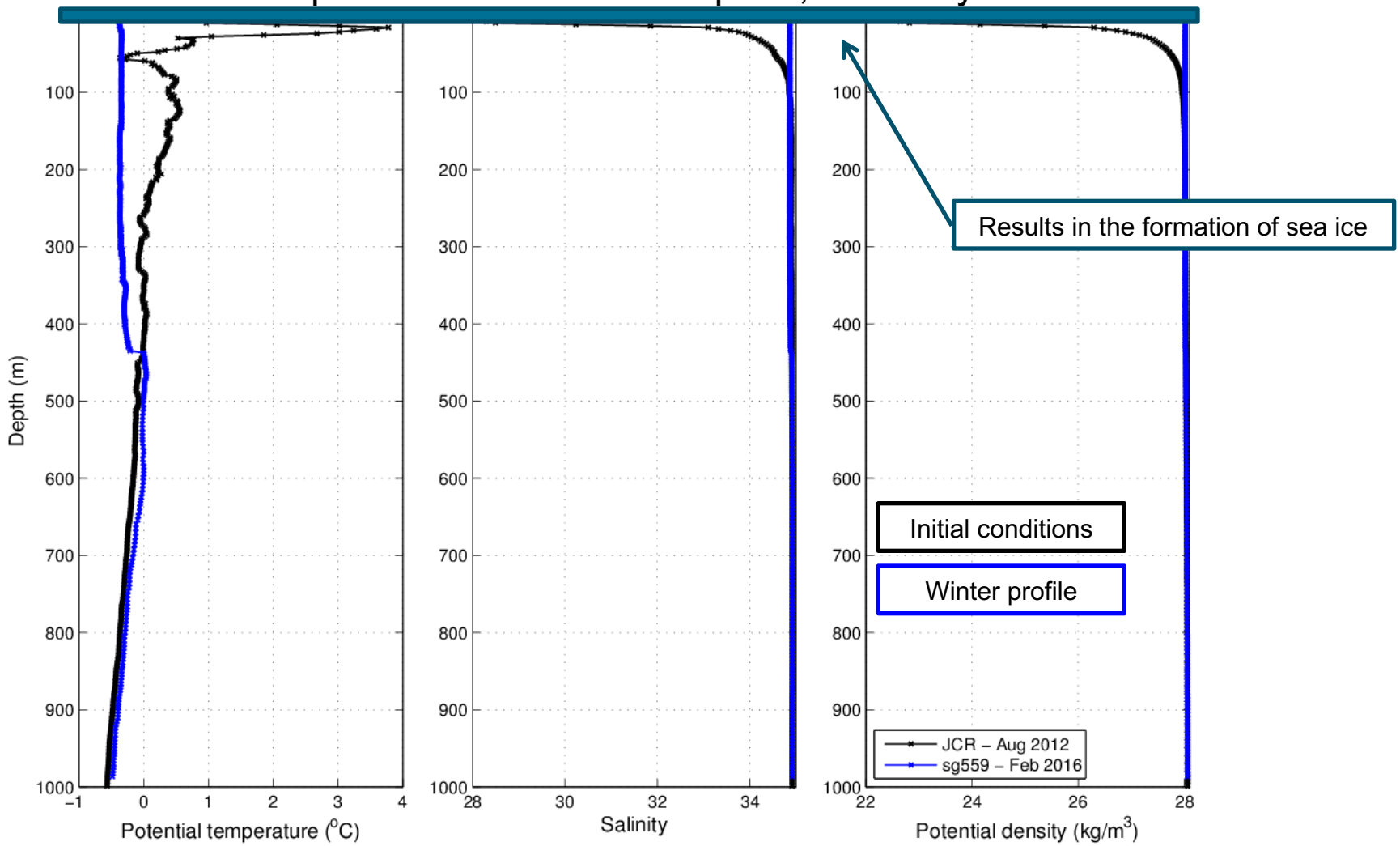
Use 1D mixed-layer model (PWP) to simulate convection

Hydrographic profile near glider turnaround point, August 2012

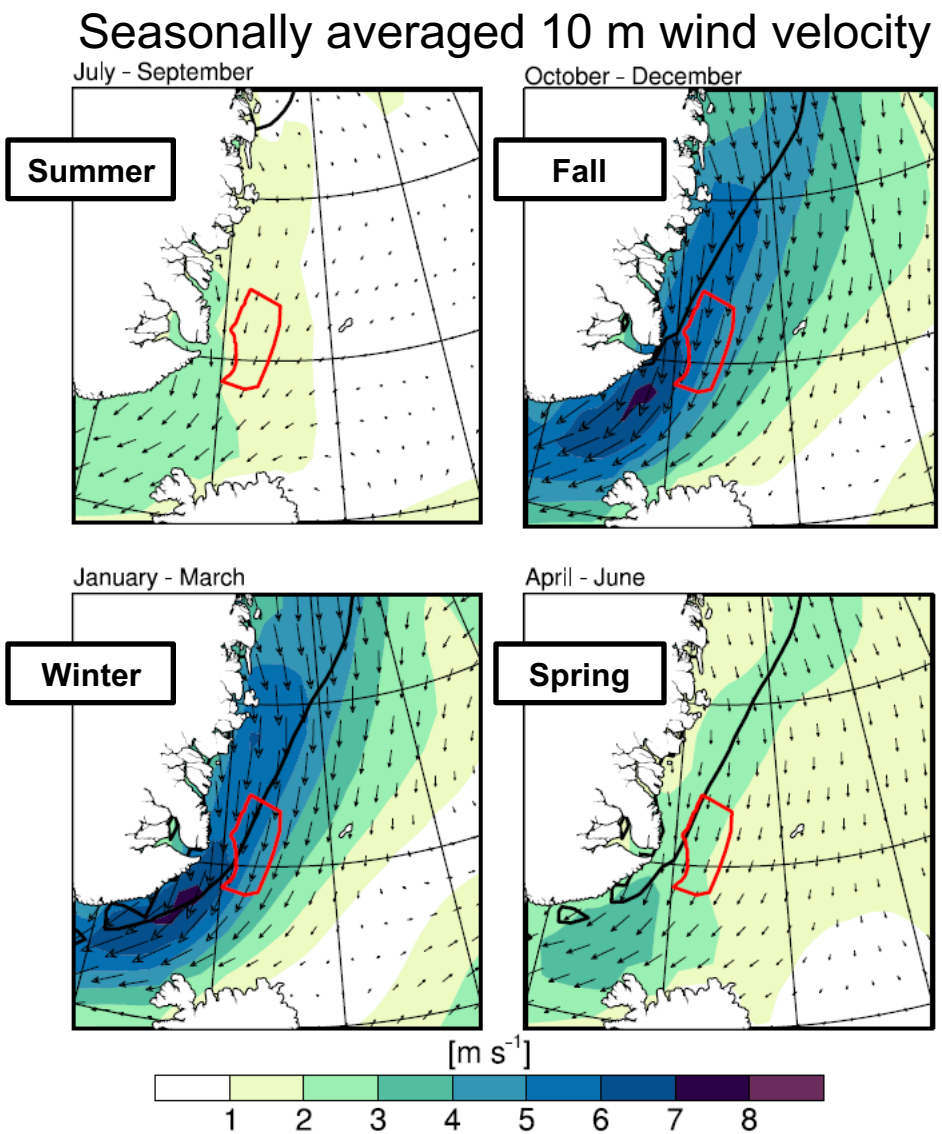


Use 1D mixed-layer model (PWP) to simulate convection

Glider profile near turnaround point, February 2016



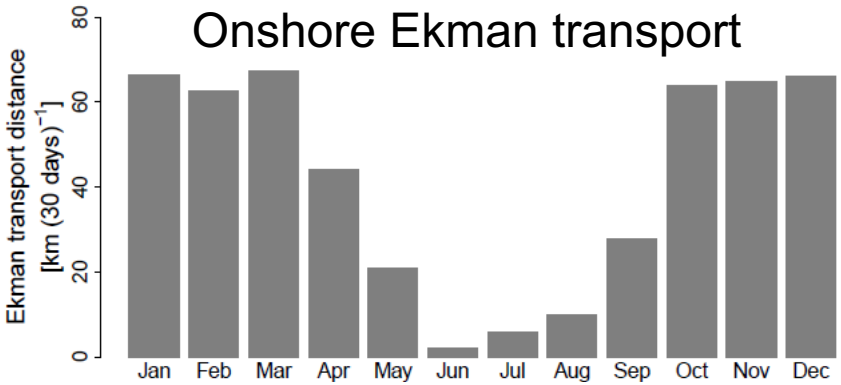
Northerly winds play a key role



- Enhanced northerly winds in fall and winter
- Barrier wind episodes are prevalent in these seasons
- Results in strengthened onshore Ekman transport

Northerly winds play a key role

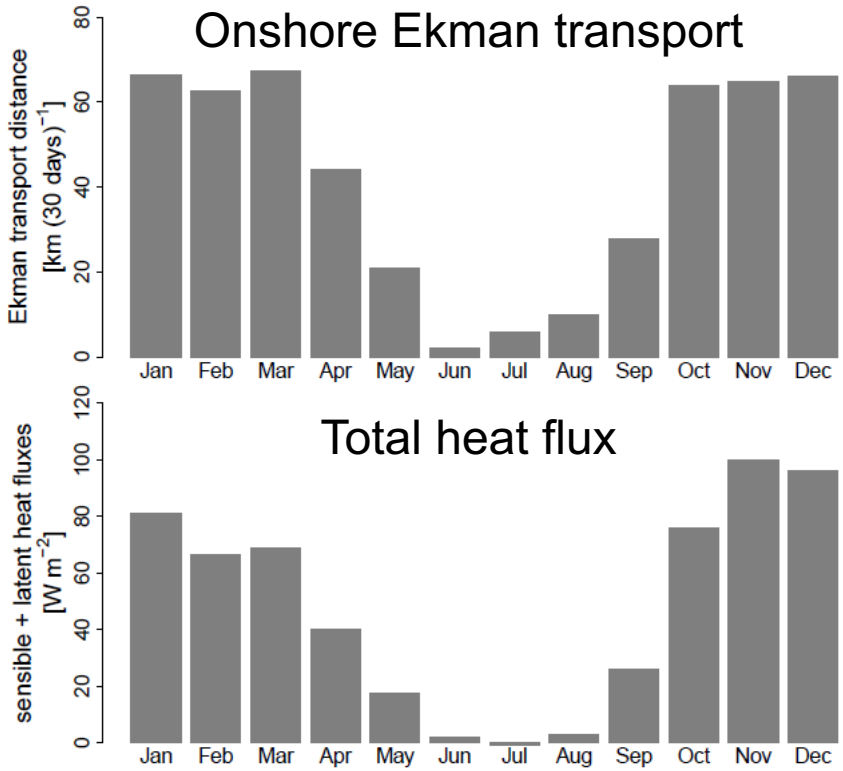
Assuming Ekman layer depth of 50 m



Onshore Ekman transport through fall is sufficient to flush the fresh layer onto the Greenland shelf

Northerly winds play a key role

Assuming Ekman layer depth of 50 m



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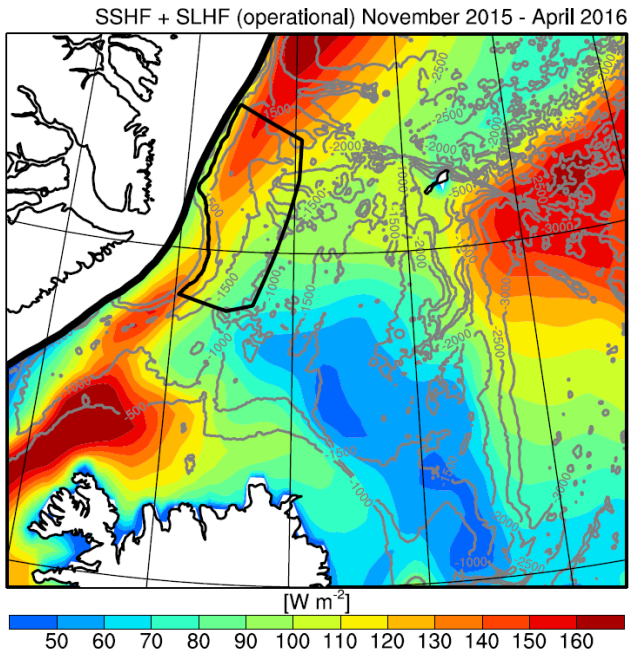
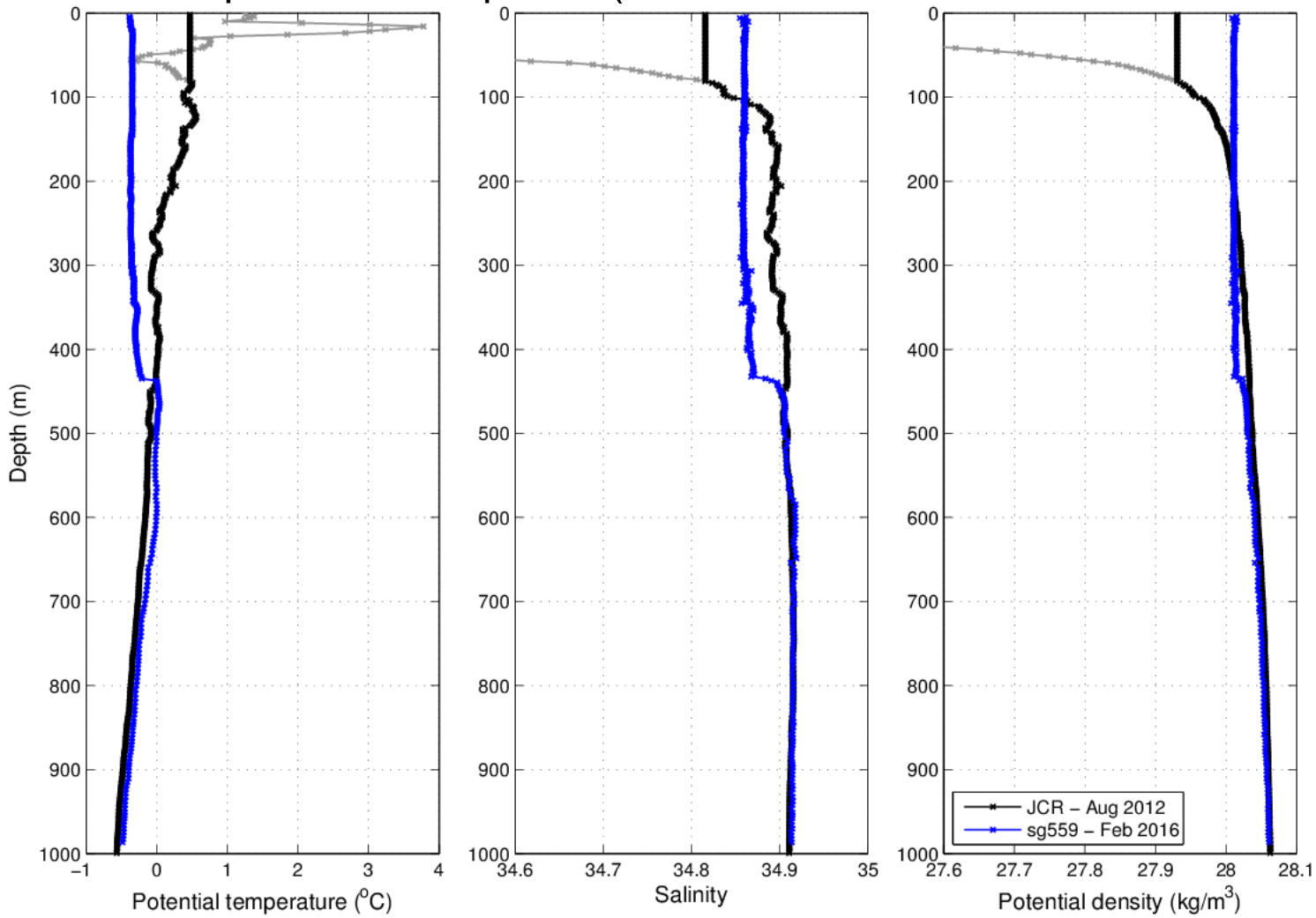


Simulated mixed-layer development

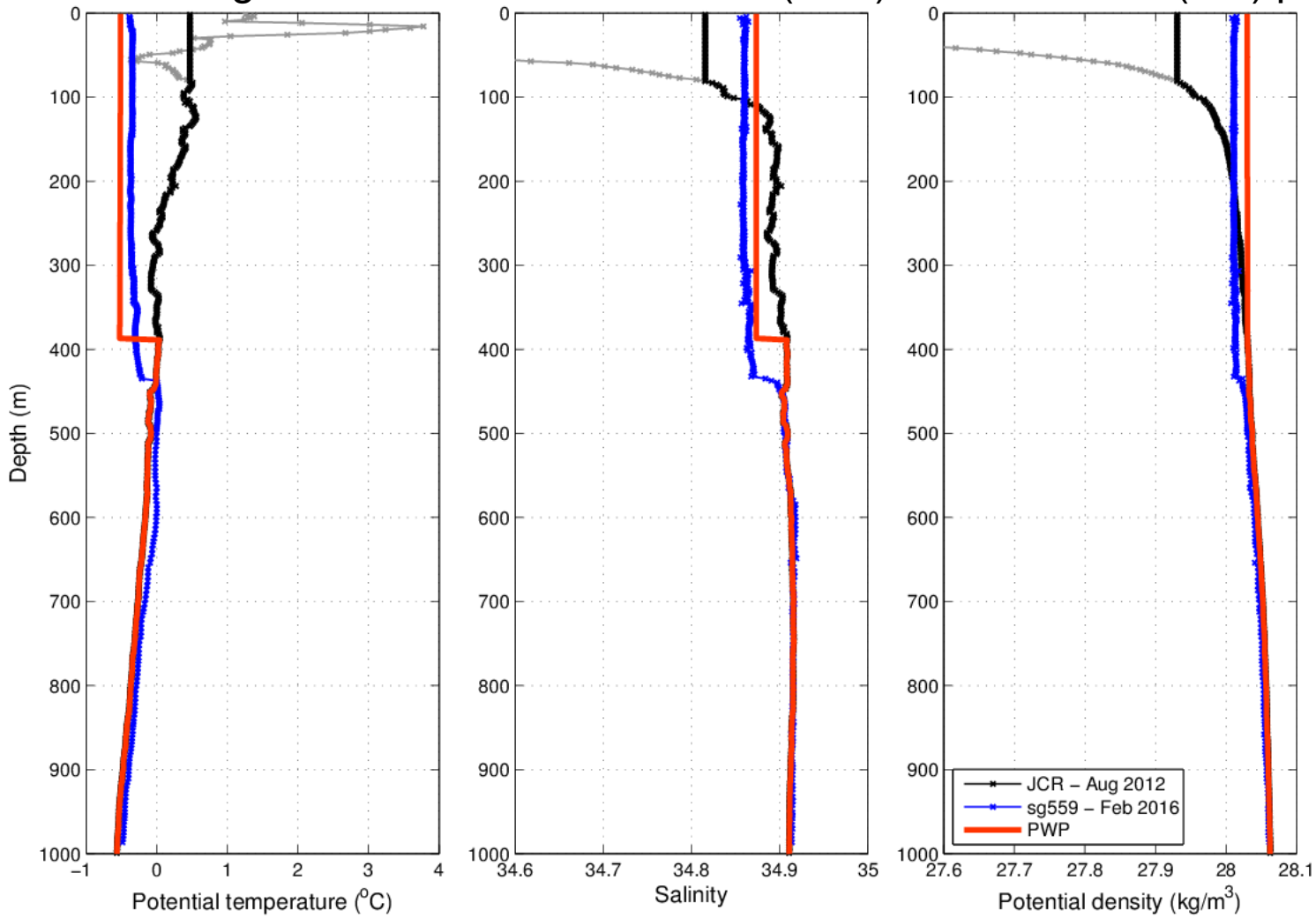
Apply constant forcing of 120 W/m^2 from November to February

Remove the top 80 m of the profile (assume effect of onshore Ekman transport)

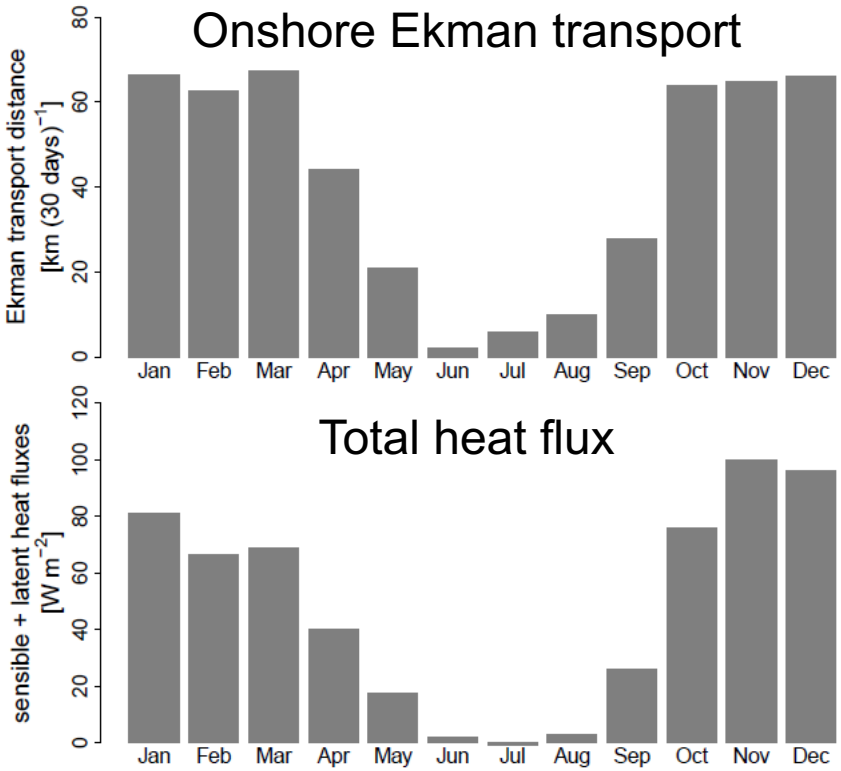


Simulated mixed-layer development

Reasonable agreement between observed (blue) and simulated (red) profiles



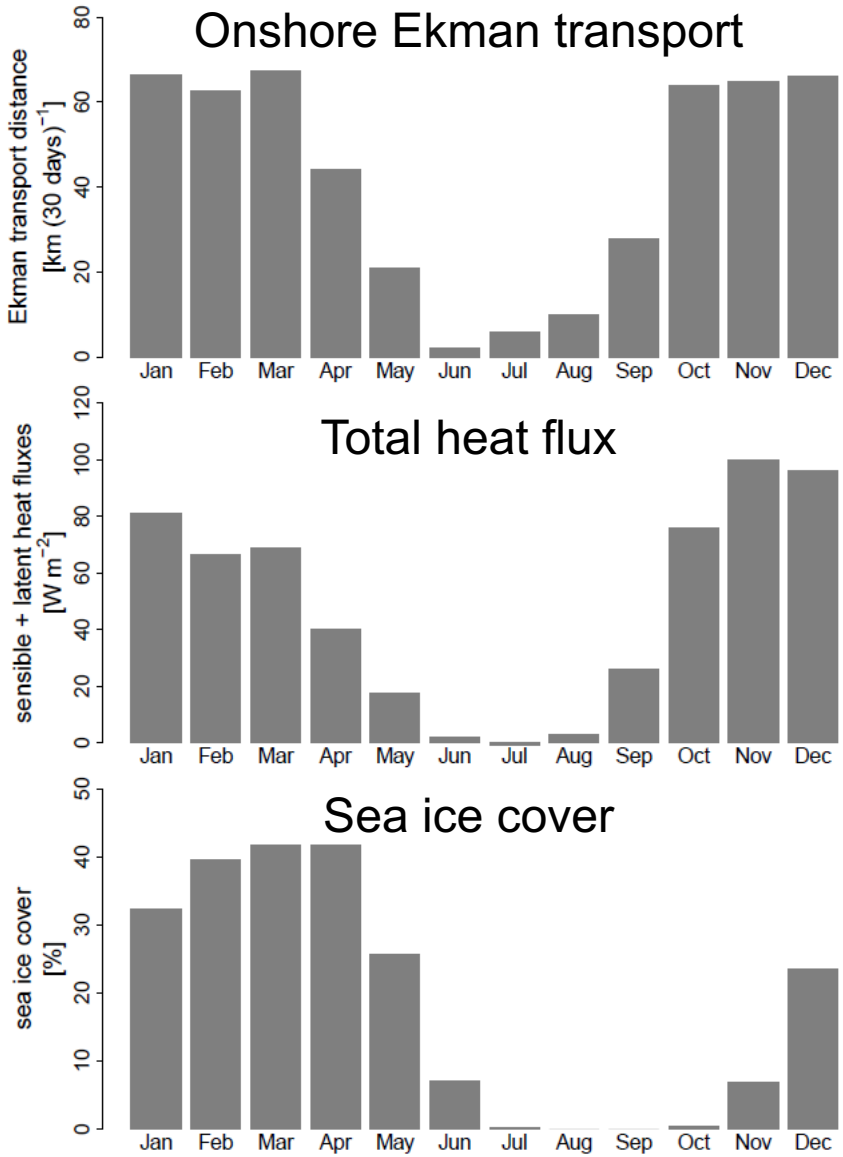
Northerly winds play a key role



Onshore Ekman transport through fall is sufficient to flush the fresh layer onto the Greenland shelf

Strong atmospheric forcing + preconditioning results in deep convection near the ice edge

Northerly winds play a key role



Onshore Ekman transport through fall is sufficient to flush the fresh layer onto the Greenland shelf

Strong atmospheric forcing + preconditioning results in deep convection near the ice edge

Melting of sea ice in summer replenishes the fresh surface layer (e.g. Dodd et al., 2009)

Summary

- Atlantic-origin water transported by the EGC toward Denmark Strait was re-ventilated while transiting the western Iceland Sea in winter
- Ekman transport induced by enhanced northerly winds in winter removed surface stratification that would otherwise inhibit convection
- Severe heat loss from the ocean to the atmosphere along the ice edge subsequently led to deep convection

Implications

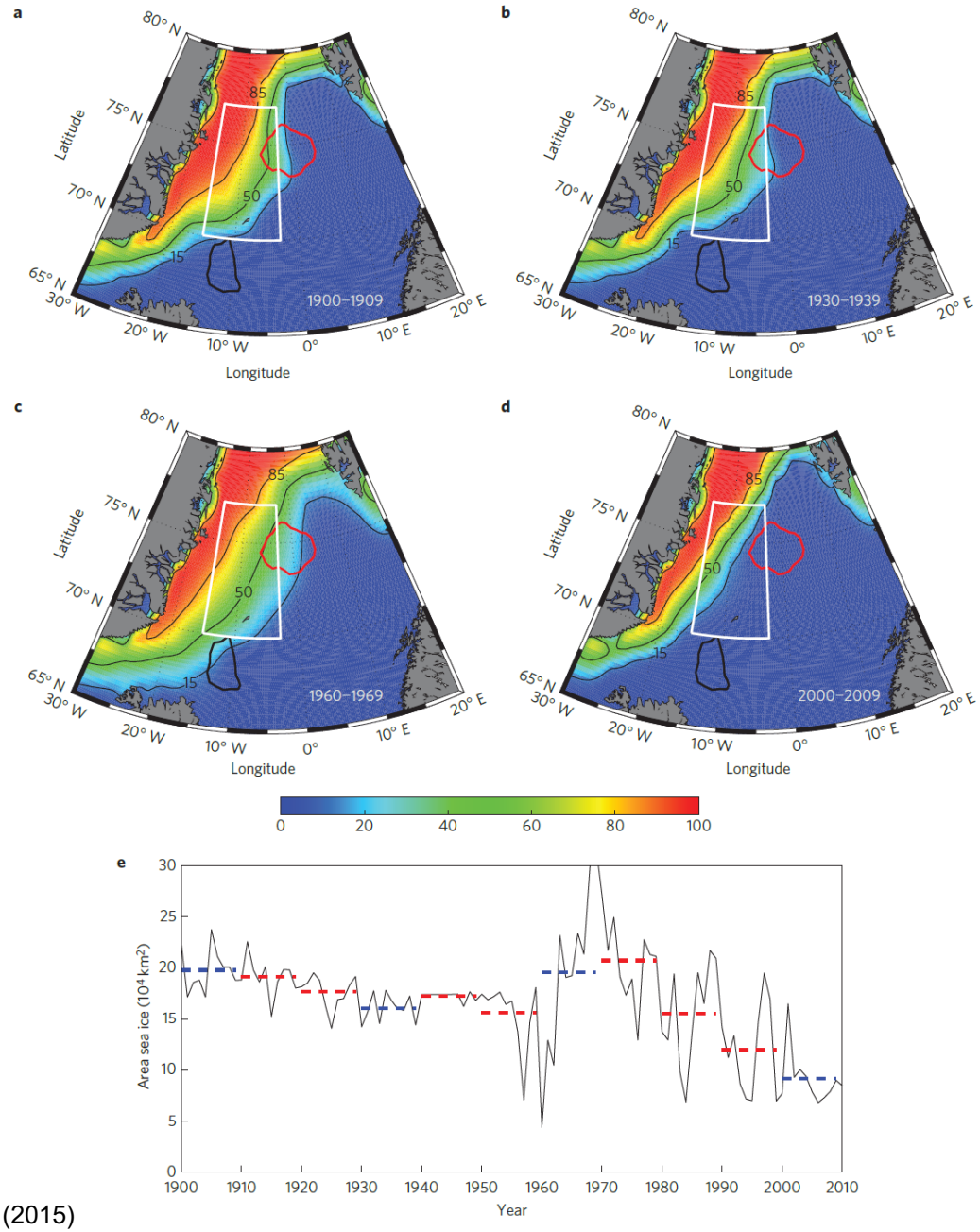
- May explain
  - Diapycnal mixing observed along the EGC (Håvik et al., 2017)
  - Significant seasonal cycle in temperature at the Denmark Strait sill of 0.09°C (minimum in September, Jochumsen et al., 2012)

- Re-ventilation of Atlantic-origin water along the ice edge off Greenland may impact the final properties of the Denmark Strait Overflow Water

- Retreat of ice edge toward Greenland (Moore et al., 2015) may leave more of the Atlantic-origin water in the EGC accessible to direct atmospheric modification

Implications

Retreat of ice edge toward Greenland may leave more of the Atlantic-origin water in the EGC accessible to direct atmospheric modification



from Moore et al. (2015)