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

Harden et al. (2016)
Water mass transformation in the Iceland Sea

Historical data (1980 – 2014)

Late-winter (Feb-Apr) mixed-layer potential density
Water mass transformation in the Iceland Sea
Historical data (1980 – 2014)

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

Potential overflow waters
Water mass transformation in the Iceland Sea
Historical data (1980 – 2014)

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

Contours of dynamic height
Late-winter (Feb-Apr) mixed-layer potential density

No gliders, only shipboard and profiling float measurements
Water mass transformation in the Iceland Sea
Glider measurements (2016)
Strongest atmospheric forcing near the ice edge

Composite high heat flux event (W/m²)

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

Summer (May-Oct) mean surface (0-100 m) salinity
Low surface salinity in the western Iceland Sea

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

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
Water mass transformation in the Iceland Sea
Glider measurements (2016)
Water mass transformation in the Iceland Sea

Historical data (1980 – 2014)

Late-winter (Feb-Apr) mixed-layer potential density
Water mass transformation near the marginal ice zone

15% ice concentration, February 2016

James Clark Ross, August 2012
Glider, February 2016
Glider, April 2016
Hydrographic structure of the East Greenland Current

Potential temperature from Håvik et al. (2017)
Atlantic-origin water re-ventilated in the EGC
Atlantic-origin water re-ventilated in the EGC
Atlantic-origin water re-ventilated in the EGC
Atlantic-origin water re-ventilated in the EGC
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)
Pronounced seasonality in the western Iceland Sea

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

Mean $\theta$S properties of the upper 50 m in the western Iceland Sea
Use 1D mixed-layer model (PWP) to simulate convection
Use 1D mixed-layer model (PWP) to simulate convection.
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

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

Onshore Ekman transport

Total heat flux
Simulated mixed-layer development

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

Apply constant forcing of 120 W/m² from November to February
Simulated mixed-layer development

Reasonable agreement between observed (blue) and simulated (red) profiles
Northerly winds play a key role

**Onshore Ekman transport**

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

**Total heat flux**

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)