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UNIVERSITY OF BERGEN
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Water mass transformation in the Greenland Sea during the period 1986-2016

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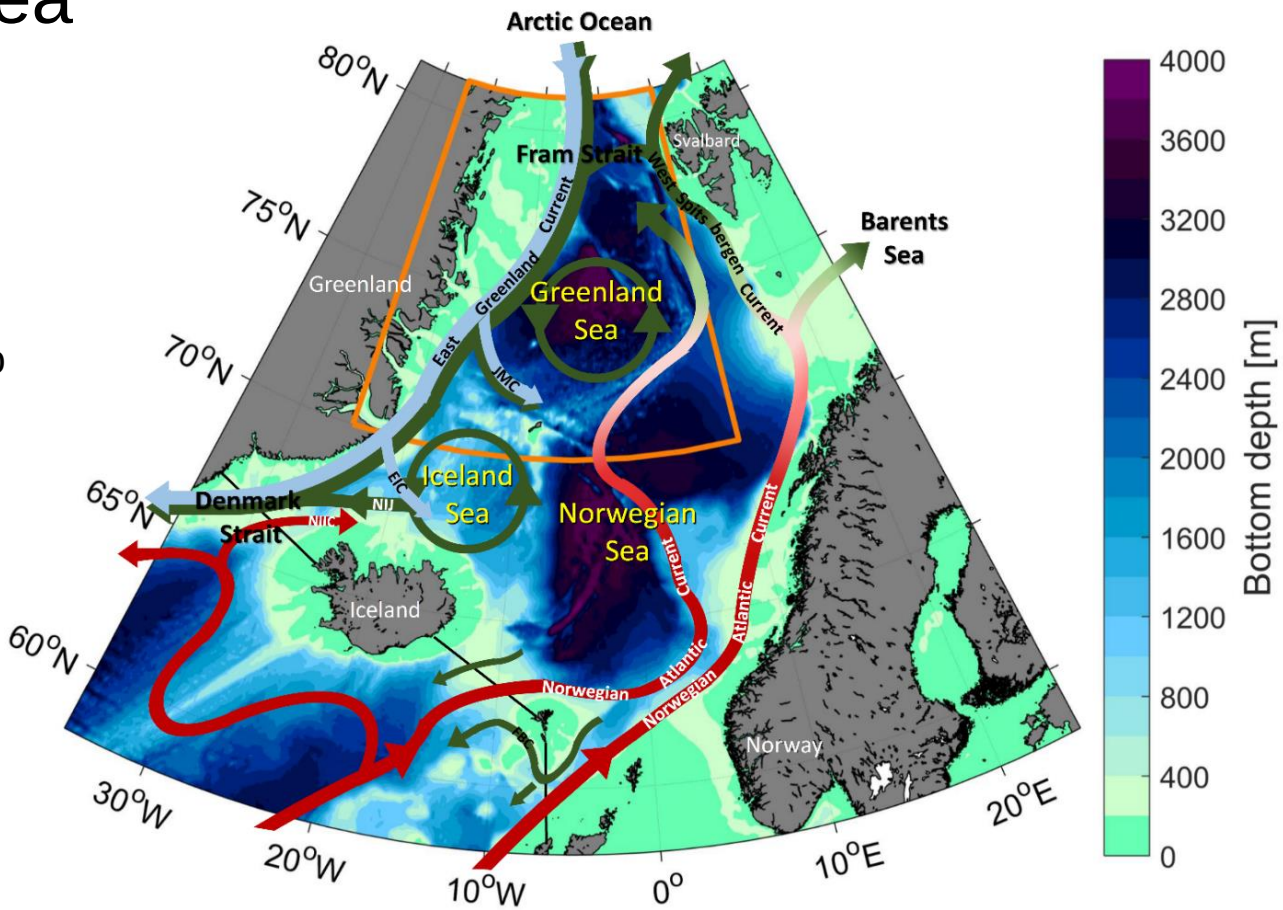
The Greenland Sea

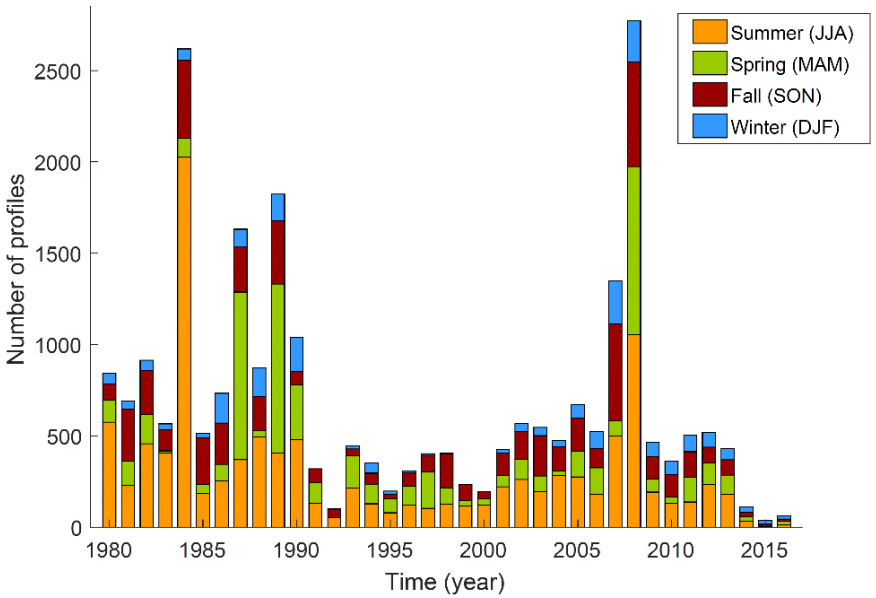
- One of few regions in the World Ocean where dense water is formed.
- Convection has been limited to < 2000m since the 1980s.
- Air-sea heat fluxes has reduced by 20% since 1979 (Moore et al., 2015)
- Several studies suggest significant contribution to the Nordic Seas overflow waters

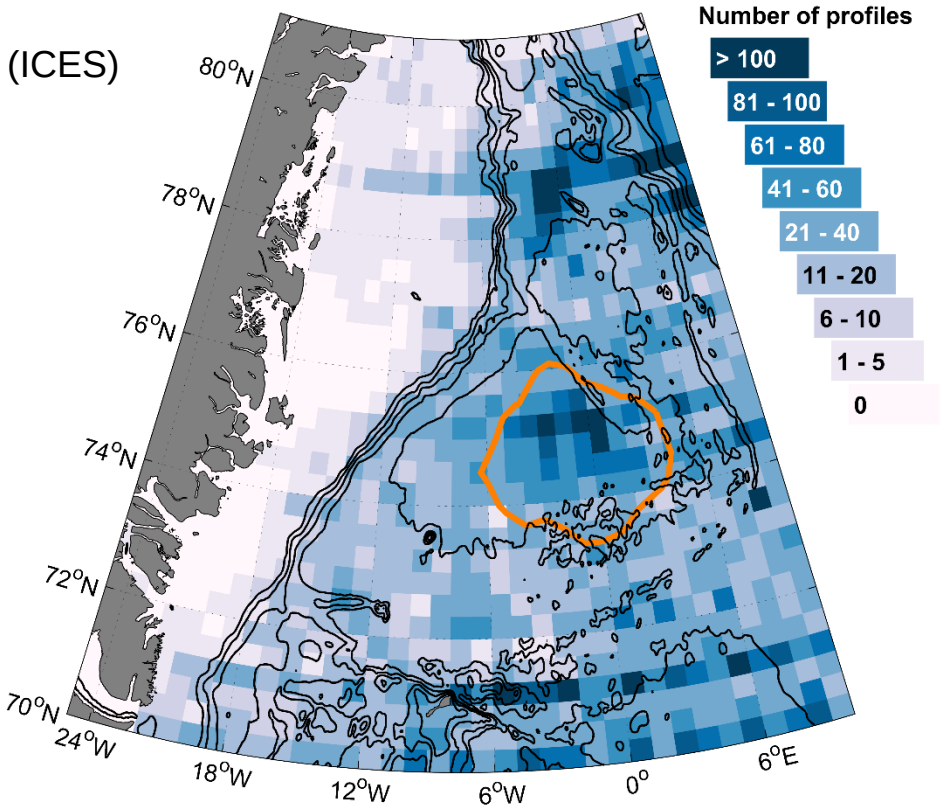


(Jeansson et al., 2008; Våge et al., 2015; Eldevik et al., 2009).

Data sources

- International Argo Program
- Norwegian Iceland Seas Experiment (NISE)
- International Council for the Exploration of the Seas (ICES)
- World Ocean Database (WOD)
- Marine Research Institute (MRI) of Iceland
- Instrumented seals (IPY-MEOP)





Definition of the gyre (orange) adopted from Moore et al. (2015)

Mixed-layer depths

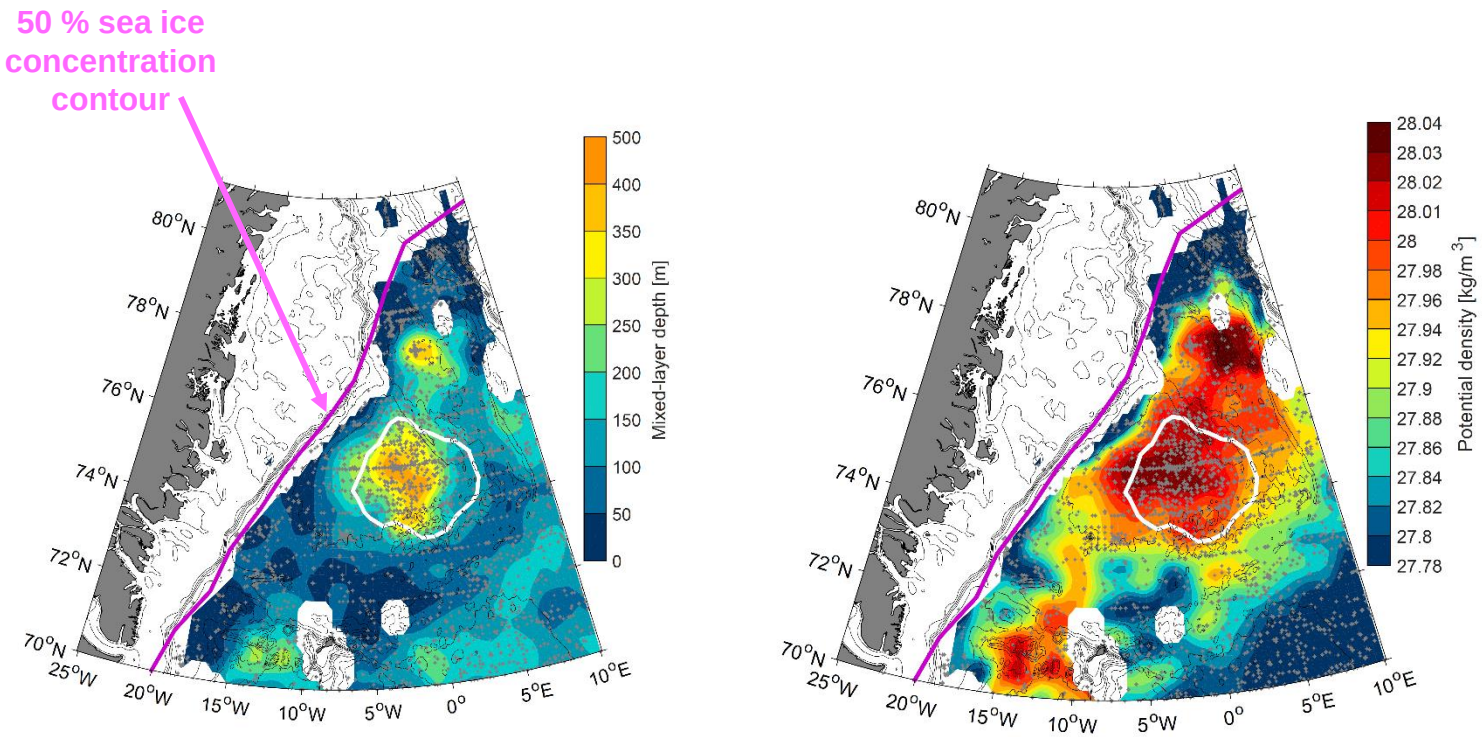
- Two independent automated routines:

Density difference criterion (Nilsen and Falck, 2006)

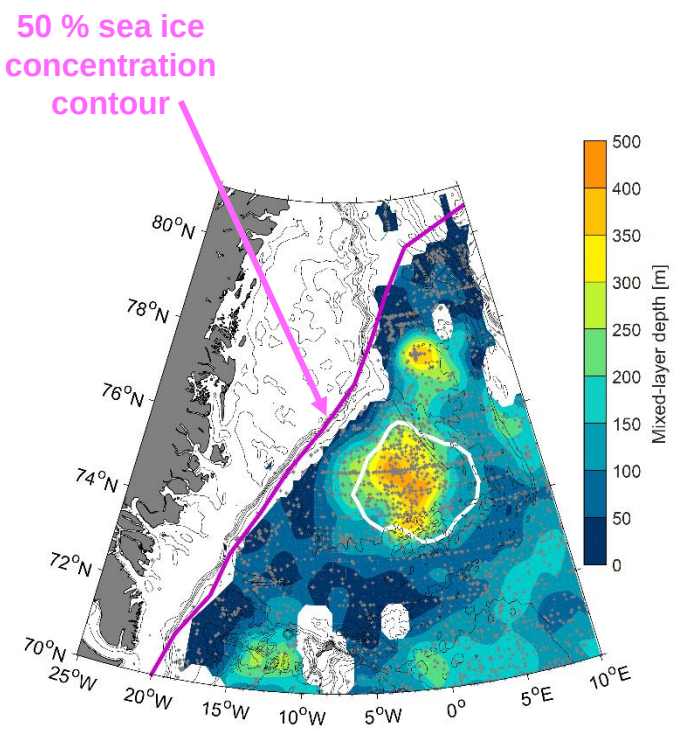
Shallowest extremum in curvature (Lorbacher et al., 2006)

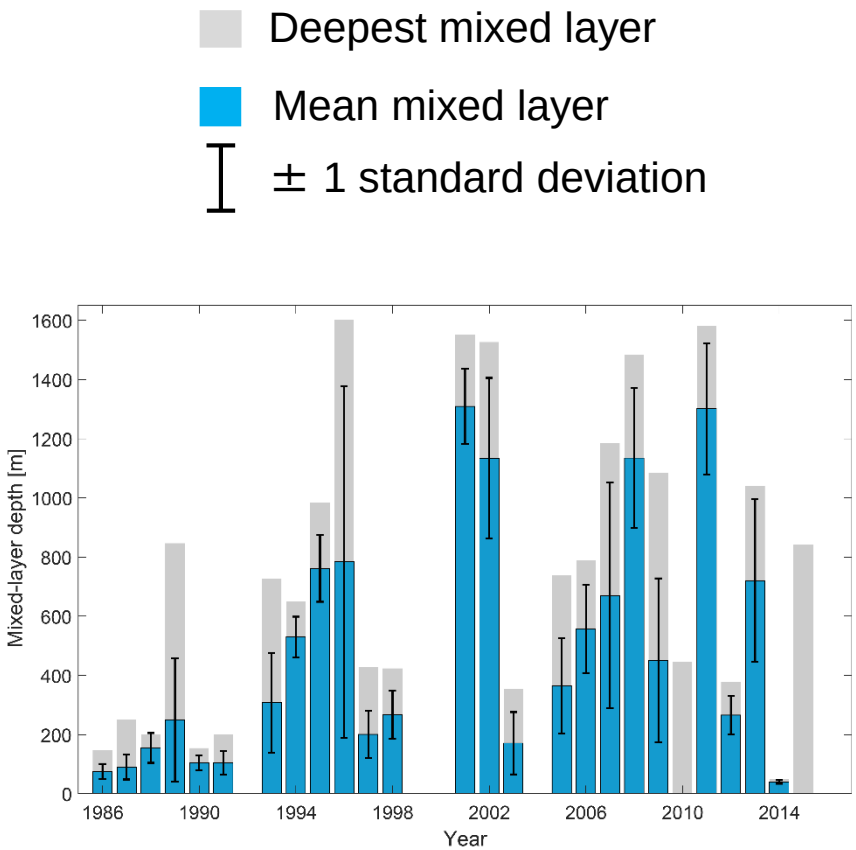
- Manual procedure (Pickart et al., 2002)

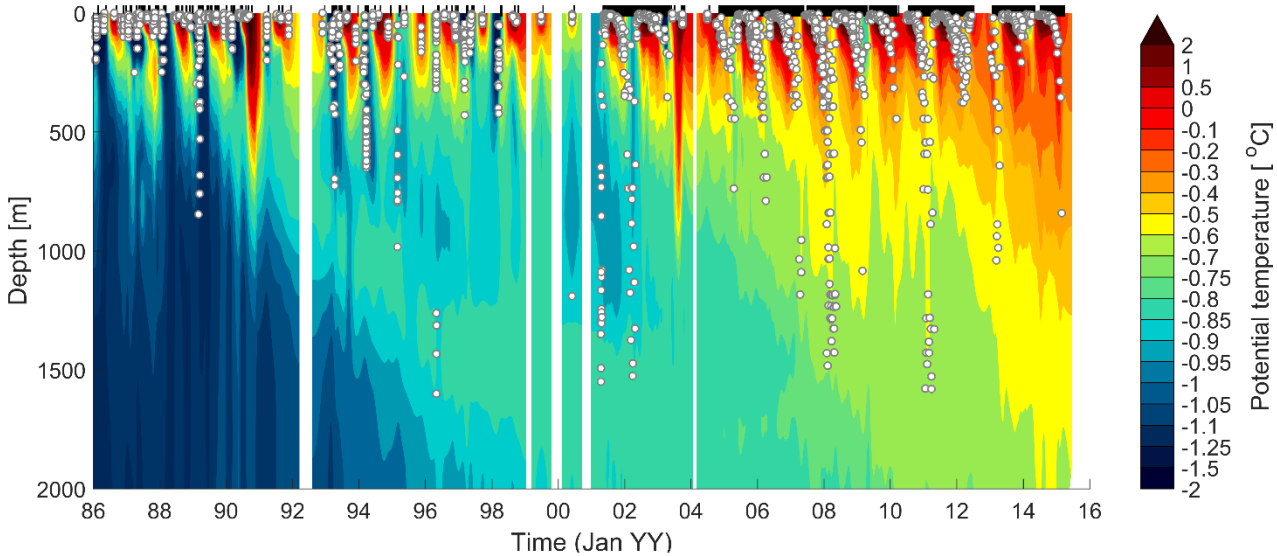
Mean late-winter (Feb-Apr) mixed-layer depth and density

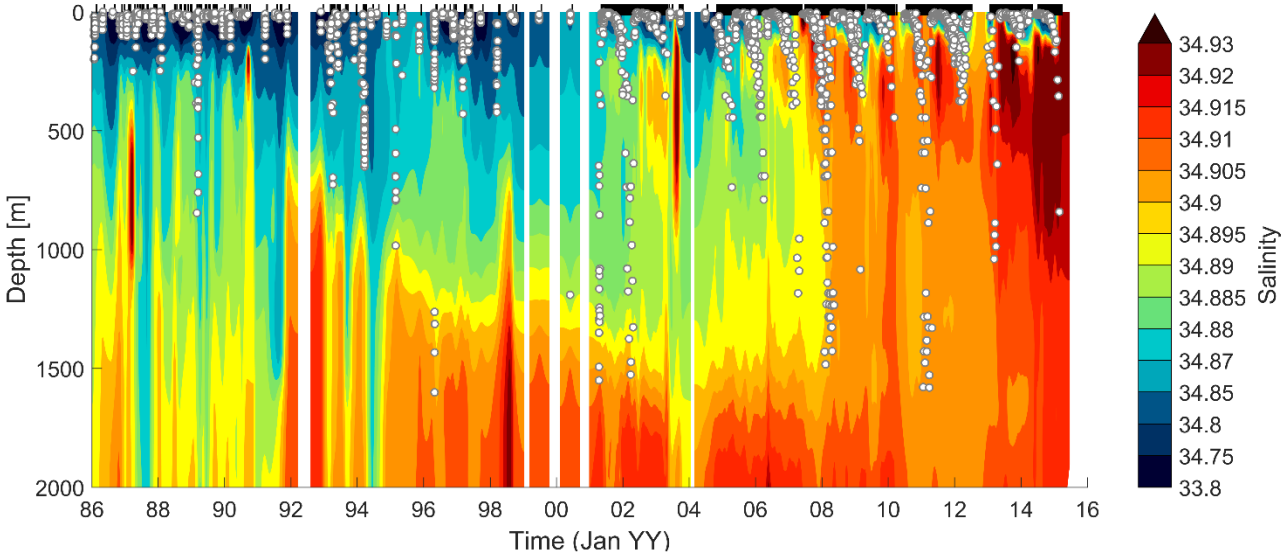


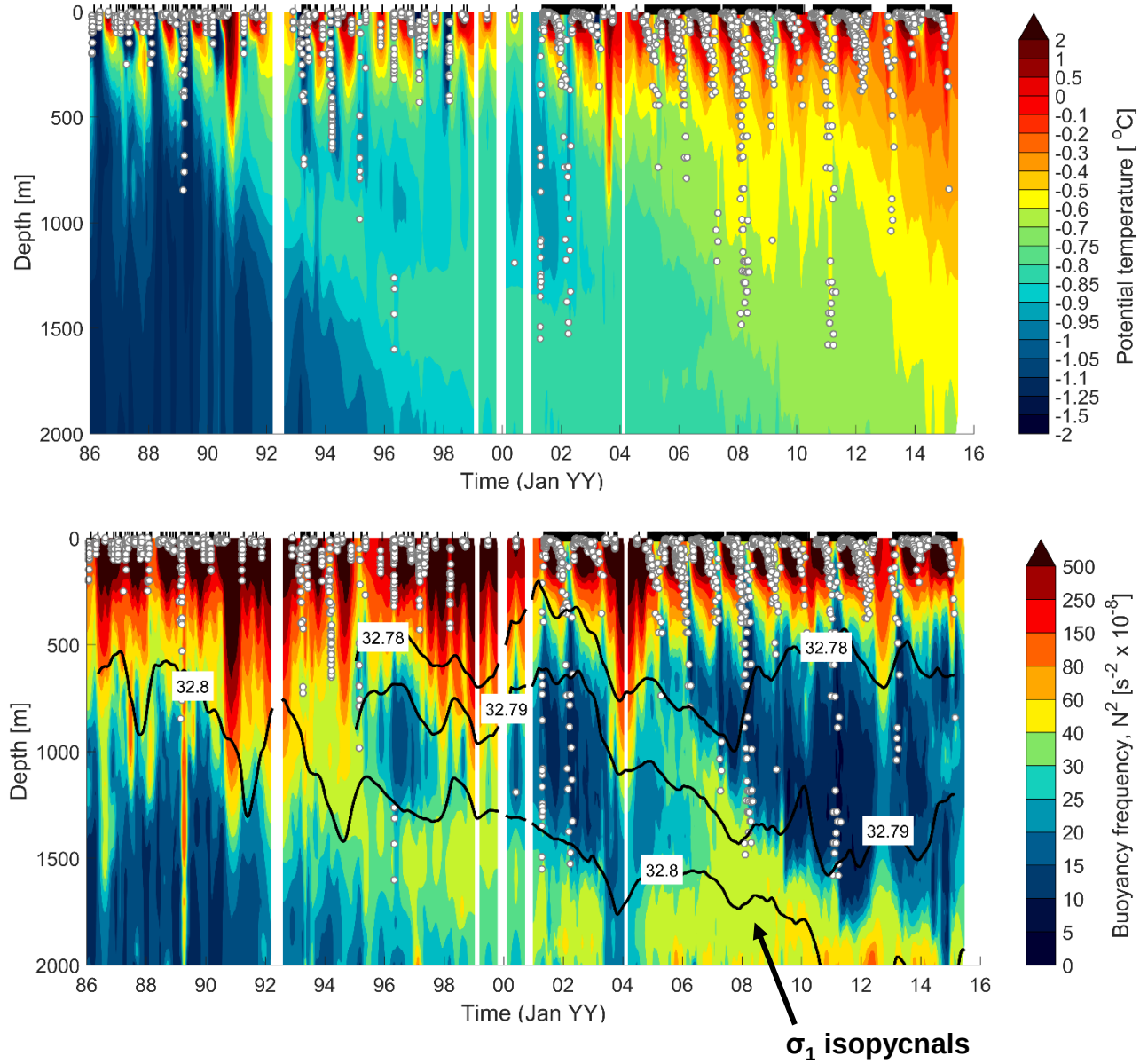
Mean late-winter (Feb-Apr) mixed-layer depth



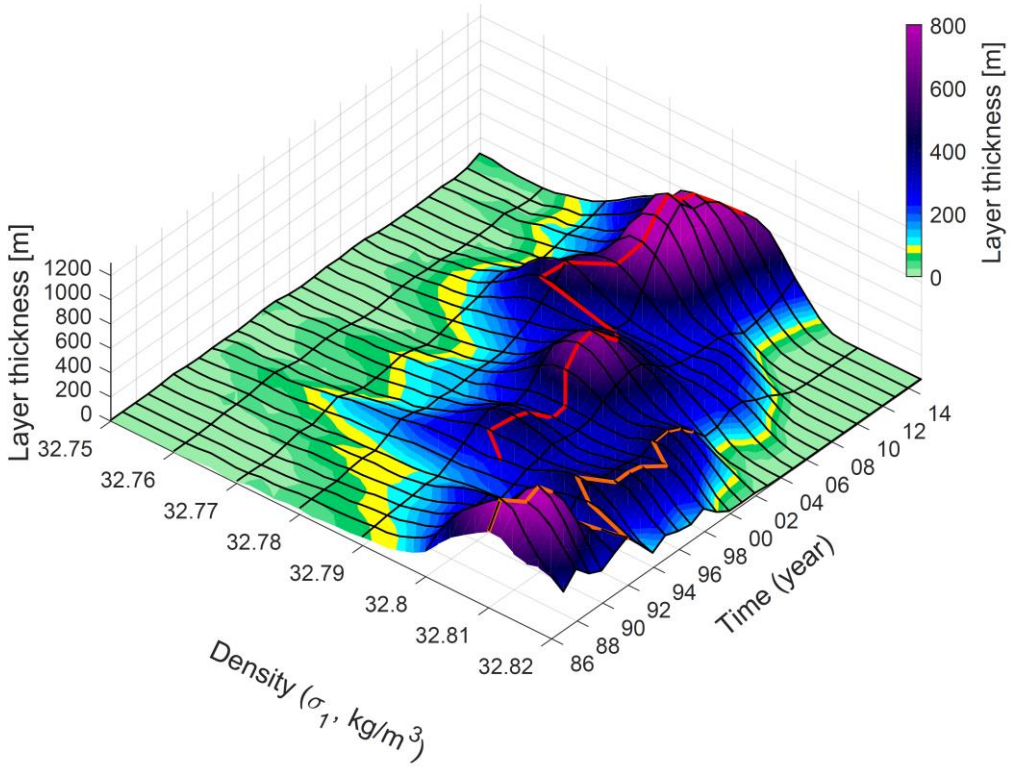



Depth [m]
0
500
1000
1500
2000
86 88 90 92 94 96 98 00 02 04 06 08 10 12 14 16
Time (Jan YY)
2
1
0.5
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.75
-0.8
-0.85
-0.9
-0.95
-1
-1.05
-1.1
-1.25
-1.5
-2
Potential temperature [°C]


Depth [m]
0
500
1000
1500
2000
86 88 90 92 94 96 98 00 02 04 06 08 10 12 14 16
Time (Jan YY)
34.93
34.92
34.915
34.91
34.905
34.9
34.895
34.89
34.885
34.88
34.87
34.85
34.8
34.75
33.8
Salinity

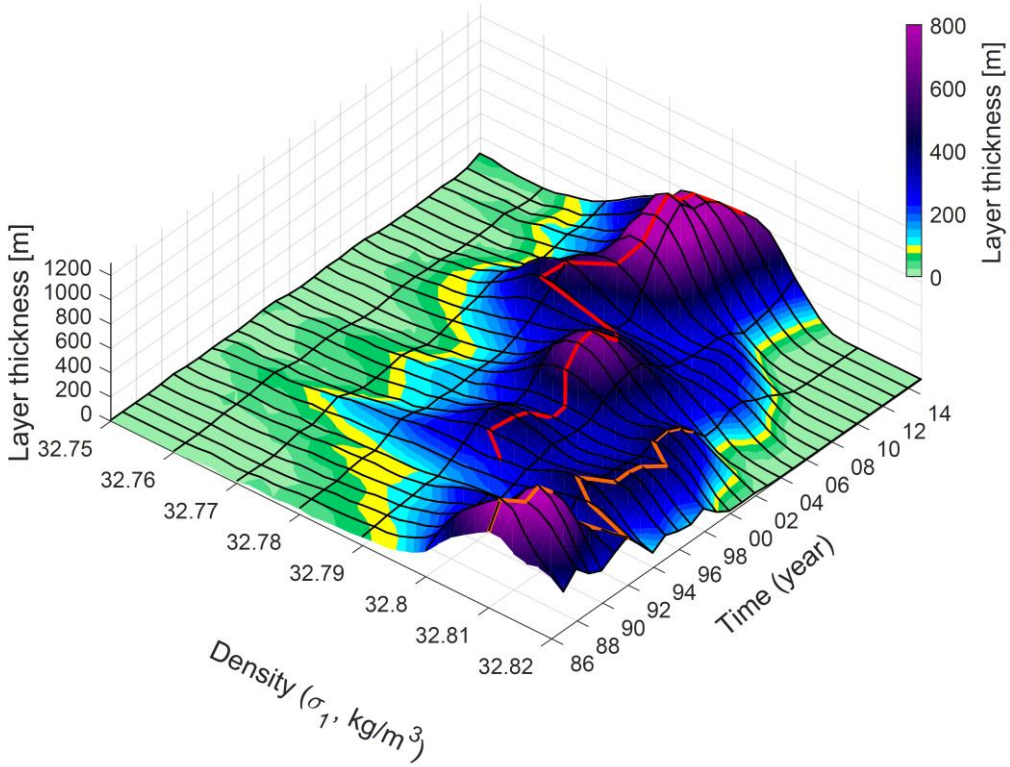

Depth [m]
Time (Jan YY)
Potential temperature [°C]
Buoyancy frequency, N² [s⁻² x 10⁻⁸]
32.8
32.78
32.79
σ₁ isopycnals

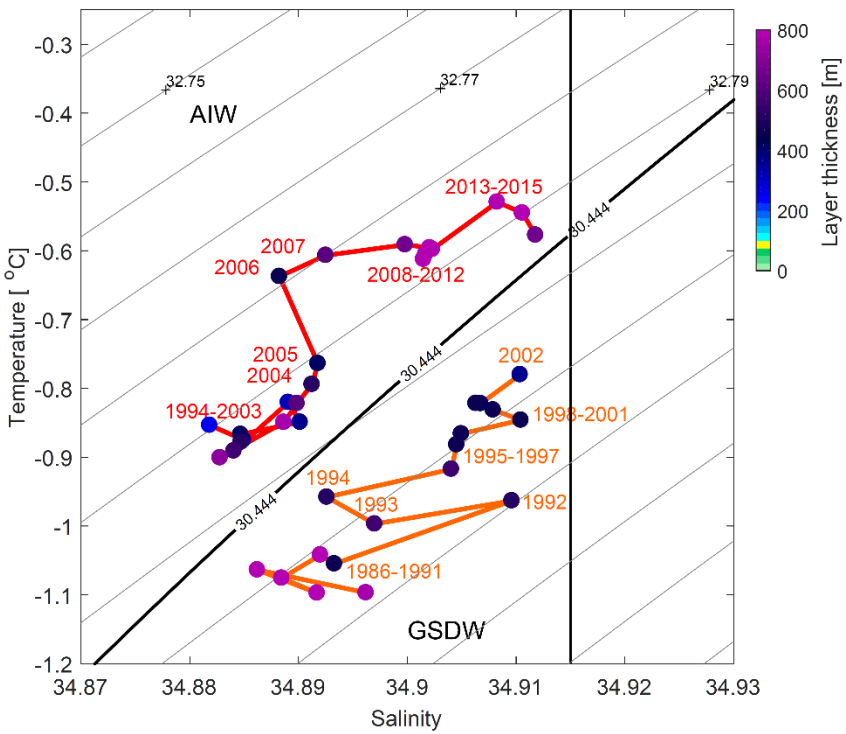
Thickness of density layers



$(\Delta\sigma_1 = 0.01 kg/m^3)$

Thickness of density layers





Water masses defined according to Rudels et al. (2005)

$(\Delta\sigma_1 = 0.01 kg/m^3)$

1-D Mixed-layer model

(Developed by Price et al., 1986)

Atm. forcing ERA-Interim

Mean fall (Oct-Nov) hydrographic profile

Input

Stability criteria:

$$\frac{\partial \rho}{\partial z} \geq 0$$

$$R_b \geq 0.6$$

$$R_g \geq 0.25$$

Output

Evolution of the mixed layer (Nov-Apr)

Lateral advection

Of heat (Moore et al., 2015) and salt based on budget calculations

Formation of sea ice not included

1-D Mixed-layer model

(Developed by Price et al., 1986)

Atm. forcing ERA-Interim

Mean fall (Oct-Nov) hydrographic profile

Input

Stability criteria:

$$\frac{\partial \rho}{\partial z} \geq 0$$

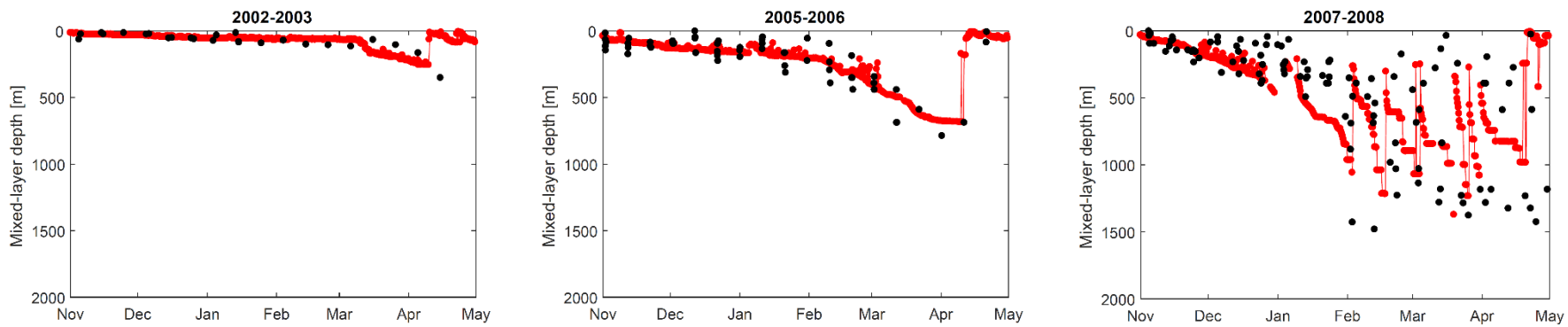
$$R_b \geq 0.6$$

$$R_g \geq 0.25$$

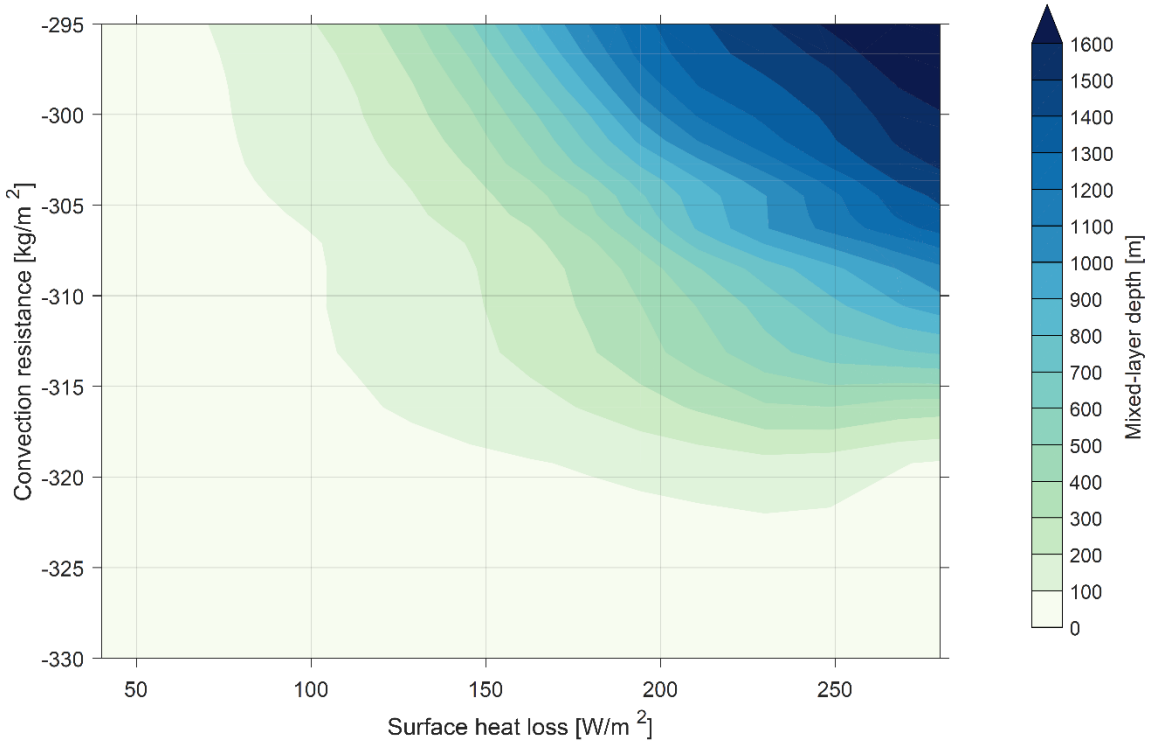
Output

Evolution of the mixed layer (Nov-Apr)

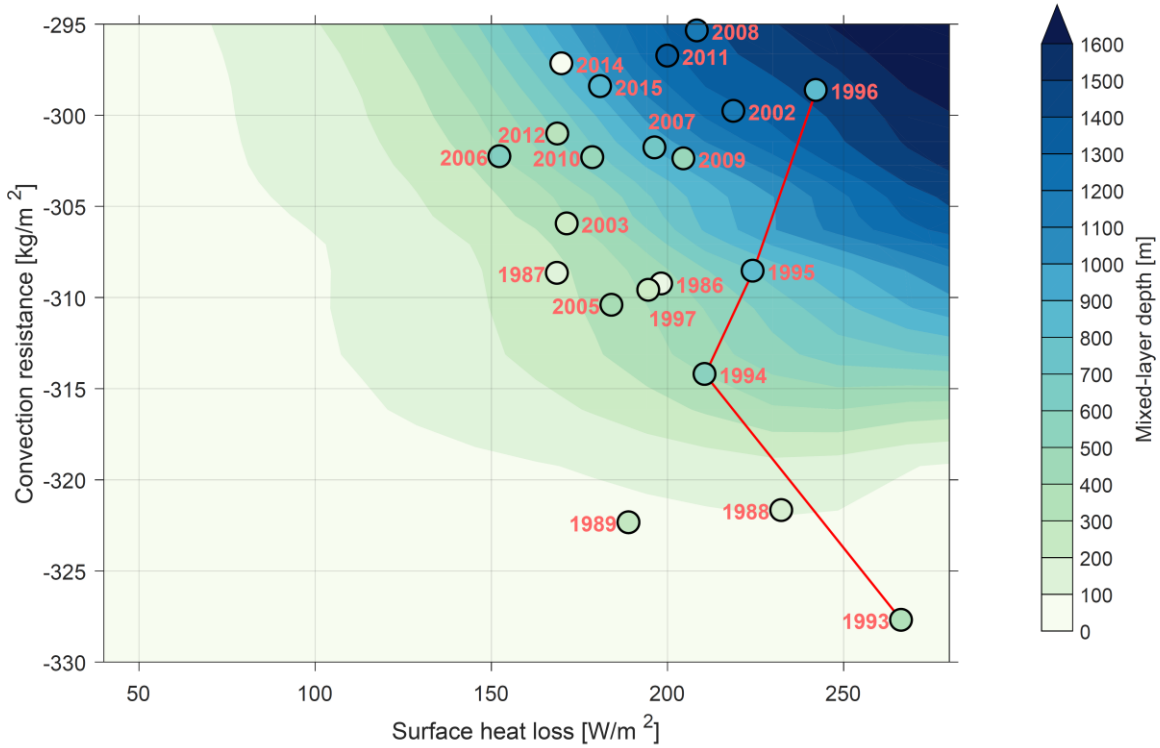
Simulated mixed-layer depth compared with **observations**



Convective response to various hydrographic and atmospheric conditions

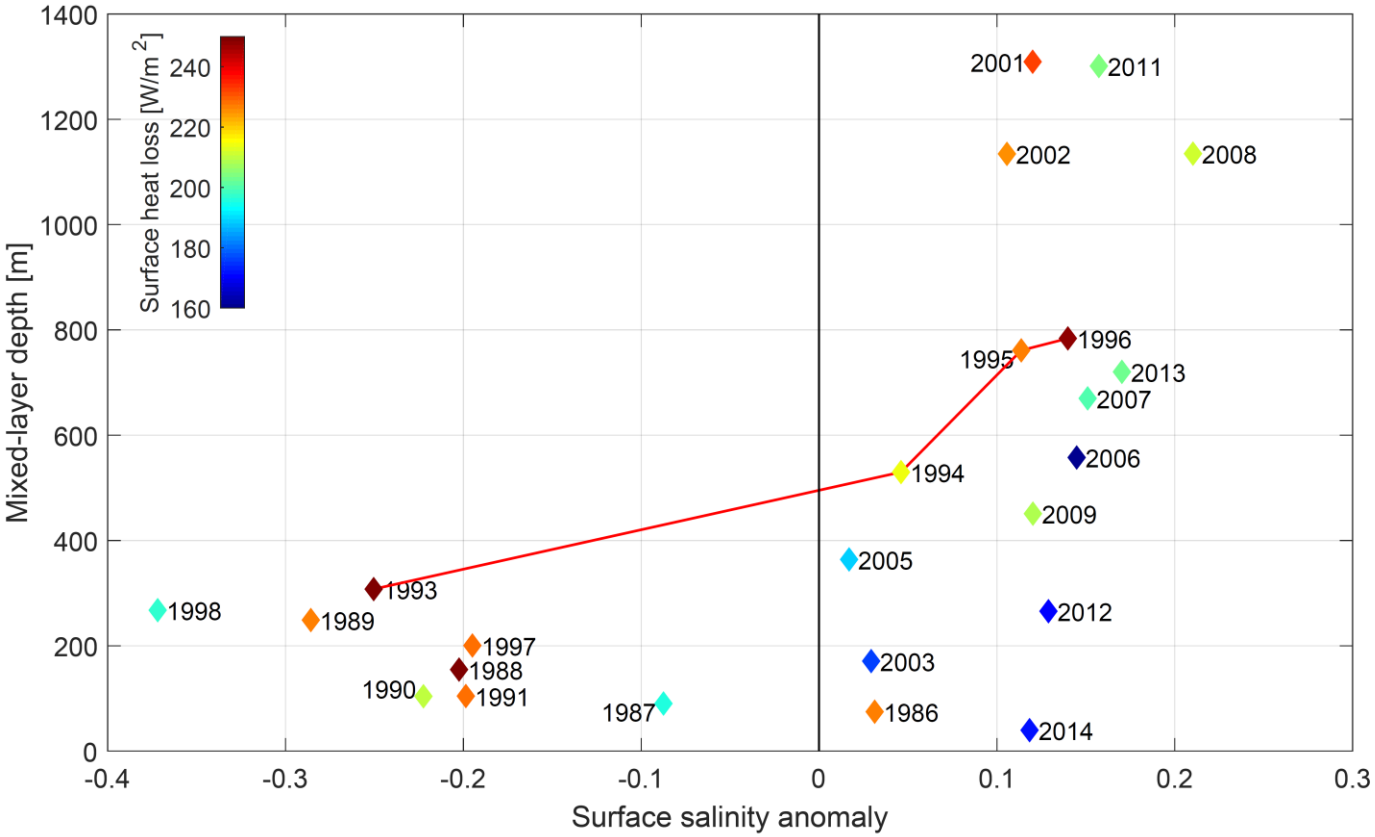


Convective response to various hydrographic and atmospheric conditions



Mixed-layer depth vs near surface salinity anomaly

Salinity anomaly relative to the mean (34.71) from 1986 - 2016



Concluding remarks

- Changes in stratification and surface heat loss can explain most of the evolution of convection and water masses in the Greenland Sea gyre from 1986 – 2016
- Increased near-surface salinities during winter 1994-95 resulted in the formation of a new, less dense class of intermediate water.
- Since it first started forming, this water mass has been the main product of convection in the Greenland Sea.
- The freshwater content near the surface has a great impact on the depth of convection. More work is needed to better understand the sensitivity of deep convection to the total content and distribution of freshwater.
- Increased salinities has decreased the water column stability and made the gyre more preconditioned for deeper convection.