The East Greenland Current and its impact on the Nordic Seas

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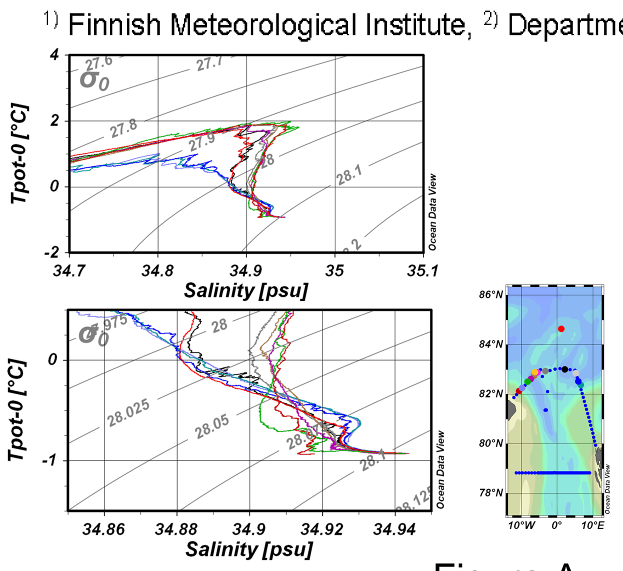


Figure A

The East Greenland Current exports low salinity polar waters and sea ice but also denser waters created or transformed in the Arctic Ocean. This influences the hydrographic conditions in the Nordic Seas and ultimately in the North Atlantic. The Arctic Atlantic Water (AAW) in the East Greenland Current exhibits a bimodal structure. One mode is characterised by a warm temperature maximum that is often overlying a salinity minimum deriving from the Barents Sea inflow. This part originates from the Eurasian Basin. The AAW from the Canadian Basin is cooler and does not display any salinity maxima or minima. In the deeper layers the Canadian Basin water column is warmer and more saline. The presence of the Canadian Basin deep water and the inflow of less saline Nordic Seas deep water create a salinity maximum at ~1700m and a salinity minimum at ~2300m in the Eurasian Basin water column above the salinity increase in the deepest layers (Fig. A).

In Fram Strait the East Greenland Current is augmented by Recirculating Atlantic Water (RAW) (Fig. B). The intensity and extent of recirculation vary. In e.g. 1988 AAW dominated in the western part of the strait while in 2010 warm and saline RAW extended over the entire Fram Strait almost reaching the Greenland continental slope (Fig. C).

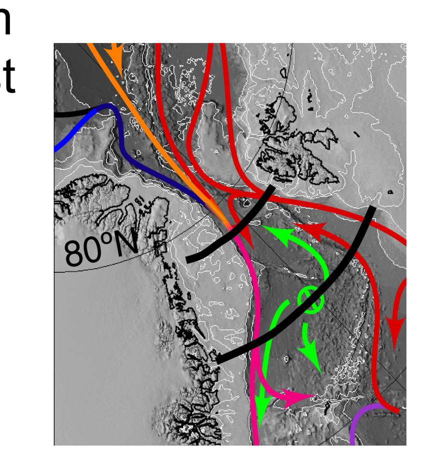


Figure B. Black lines denote sections

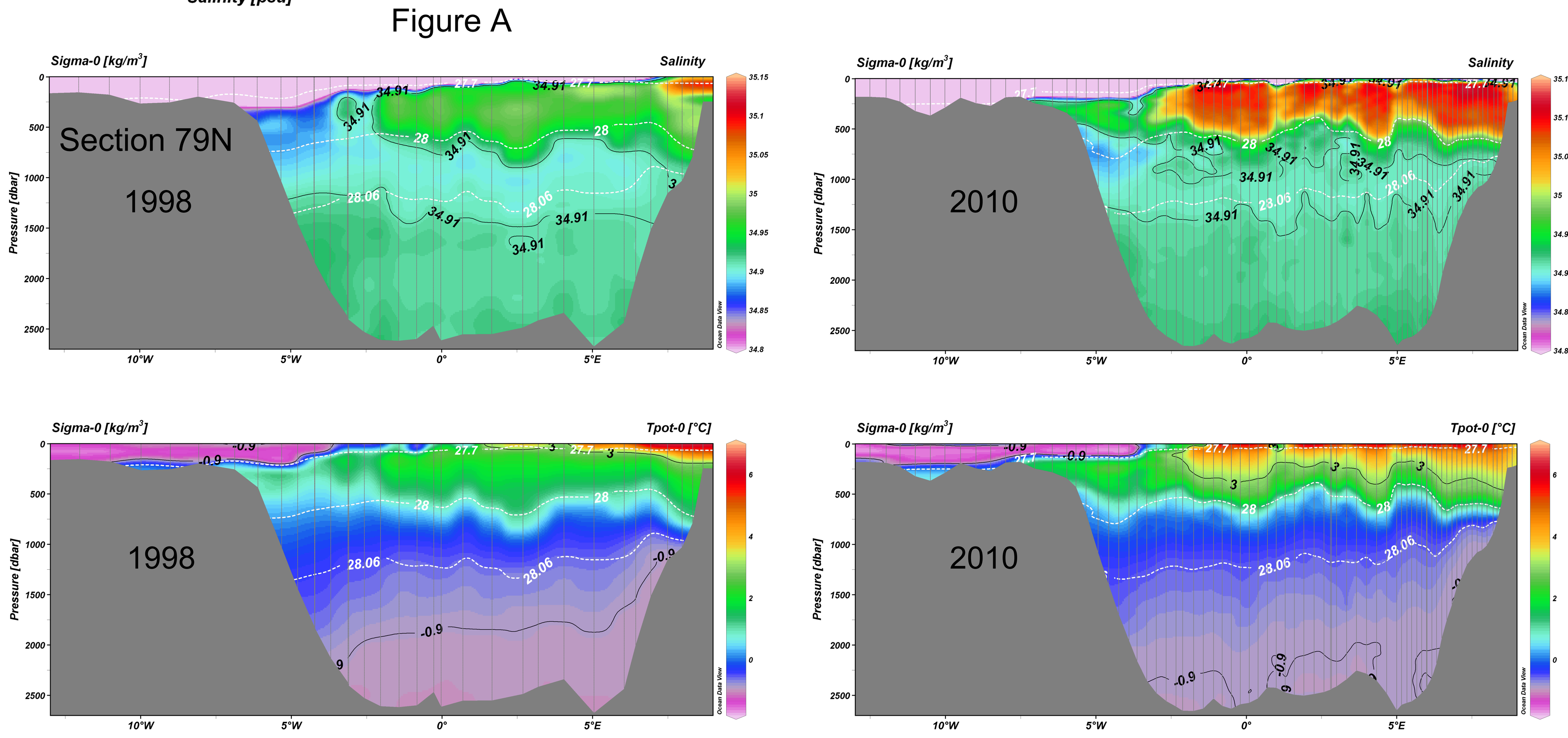


Figure C

Variations in the deeper layers are less clearly seen on the sections but the TS diagrams show that the deeper layers have become warmer and more saline indicating a stronger presence of Arctic Ocean deep waters (Fig. D). Also the salinity of the Arctic Intermediate Water (AIW) formed in the Greenland Sea has increased. This suggests that changes in the open ocean deep convection in the Greenland Sea are visible in Fram Strait (Fig. C).

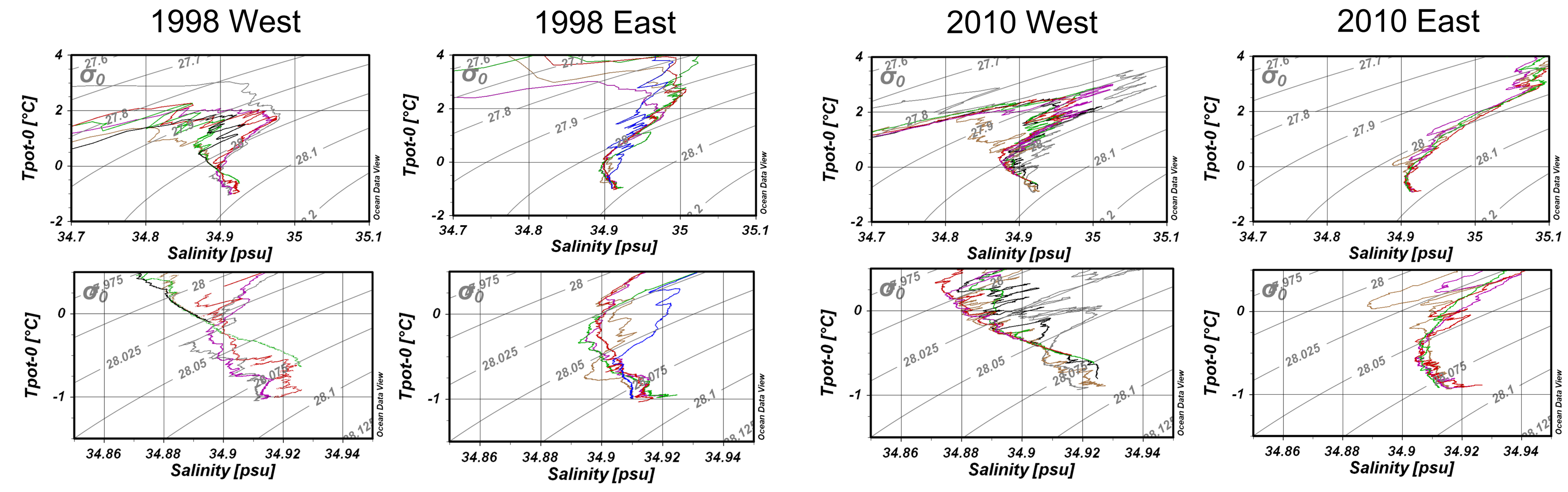


Figure D

The water column in the Greenland Sea was in the late 1990s and early 2000s characterised by a temperature minimum around 1500m overlying a temperature maximum at ~2000m and a deeper salinity maximum above the cooler and less saline bottom water. The temperature and salinity maxima derive from the East Greenland Current and can be traced back to the Canadian Basin and the Eurasian Basin deep waters. The temperature minimum is created locally by cooling and convection during winter and is characteristic of the AIW (Fig. E&F).

During the last decade the temperature of the AIW has increased, likely due to higher temperatures in the RAW. It is no longer a temperature minimum and the input from the Canadian Basin is only noticed by its higher salinity. The salinity of the deep salinity maximum has increased and the bottom water has become warmer, more saline and reduced in the volume (Fig. E&F).

Between 1998 and 2010 the salinity has increased in the Greenland Sea but not in the Norwegian Sea (Lofoten Basin), and the deep water of the Lofoten Basin is now located within the bend of the Greenland Sea TS curve (orange circle in Fig. F). This implies that the Arctic Ocean deep waters that leave the East Greenland Current are confined to the Greenland Sea and do not cross the Mohn Ridge.

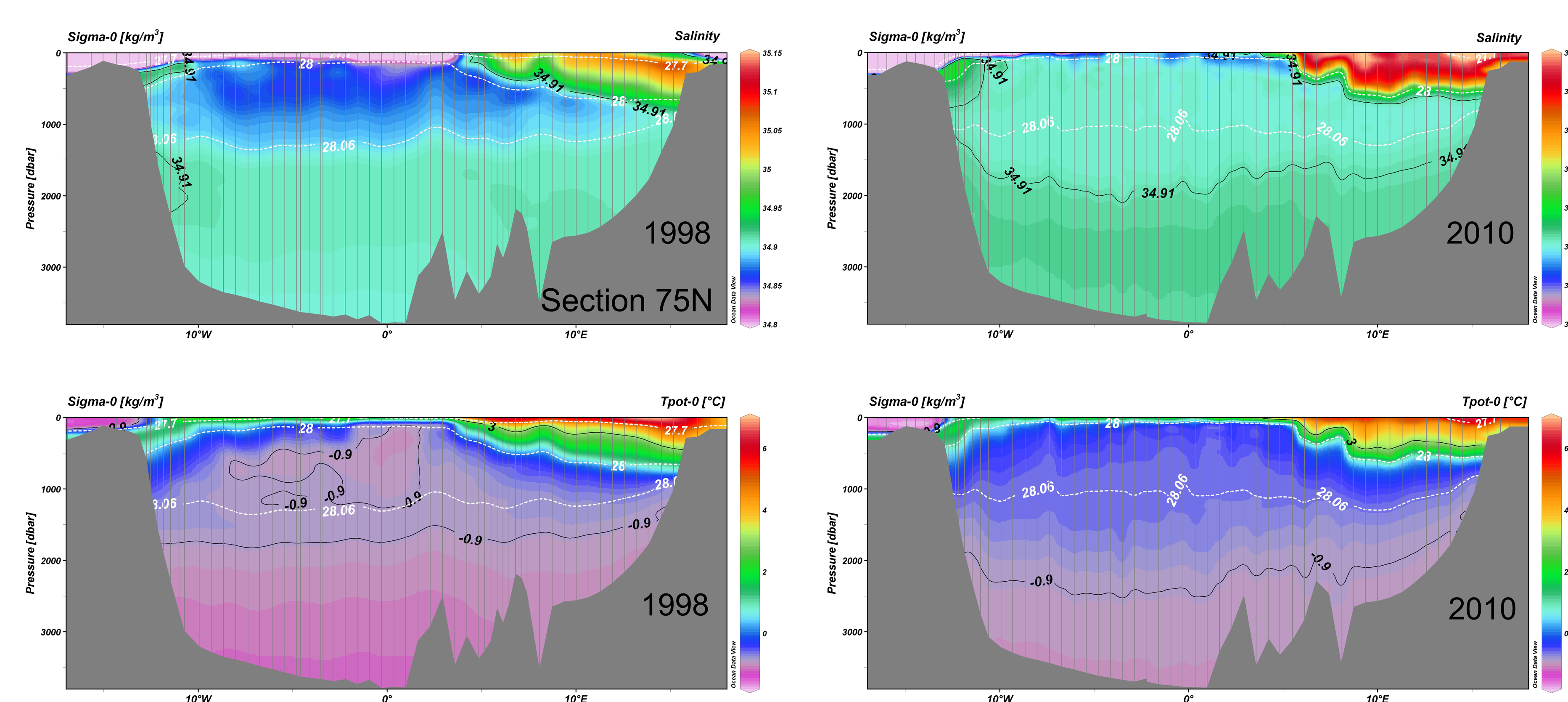


Figure E

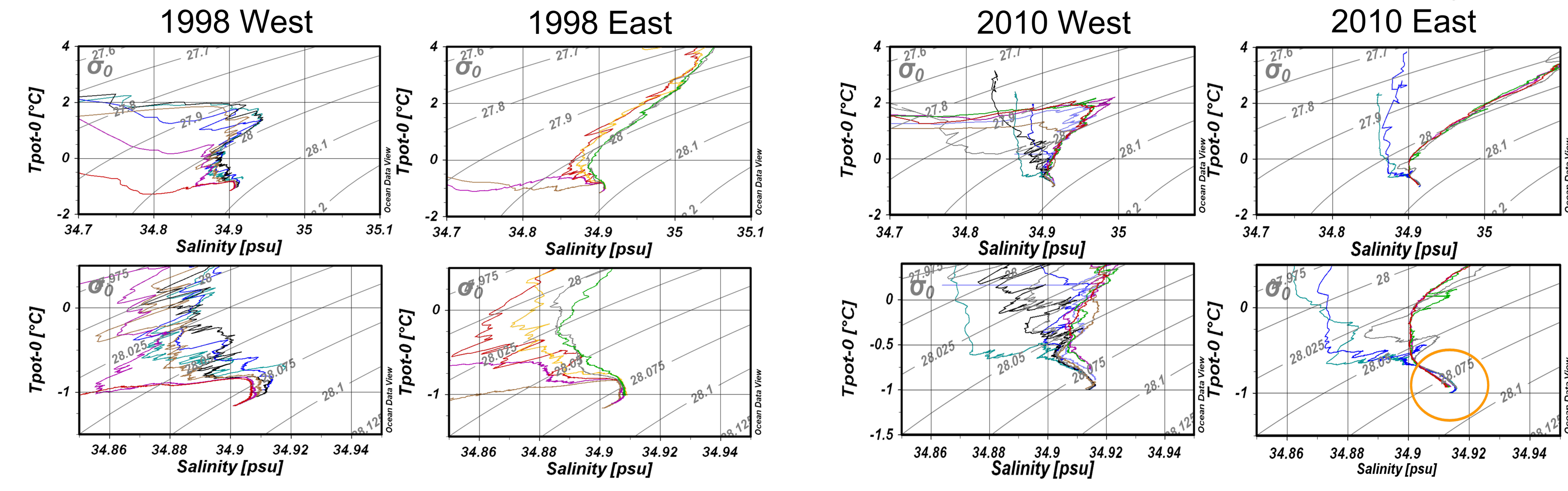


Figure F

The increase in temperature and salinity of the AIW and the Greenland Sea deep water weakens the Nordic Sea signal in Fram Strait. This will affect the deep inflow to the Arctic Ocean and the mixing with outflowing Arctic Ocean deep waters in the East Greenland Current. Their salinity and temperature will be less reduced before they enter the Greenland Sea and the changes in the deeper layers of the Greenland Sea are likely to speed up.

This change in the Greenland Sea deep water has been going on for more than 20 years in spite of some remarkable deep convection events in the late 1990s and early 2000s, when homogenous water columns were observed reaching down to almost 3000m and eroding the deep temperature maximum (Budéus et al., 2004). However, these were small-scale features on the scale of the Rossby radius (5km) and while the density in their upper part was higher than their surroundings it was lower in their deeper part. This indicates that these eddies were not buoyancy but rather dynamically driven (Fig. G).

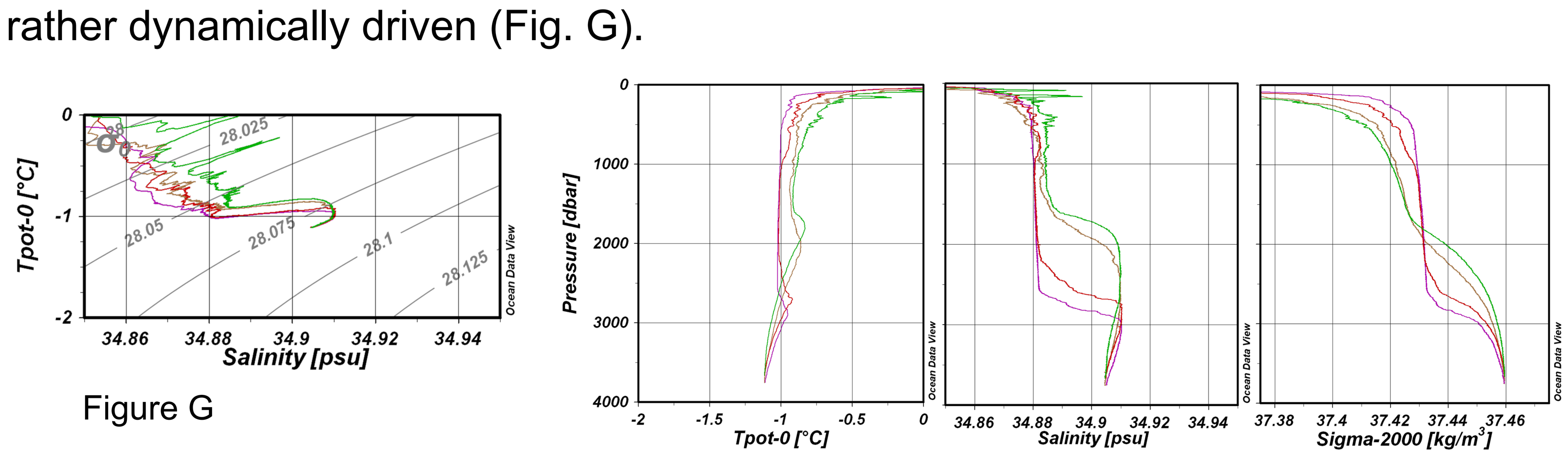
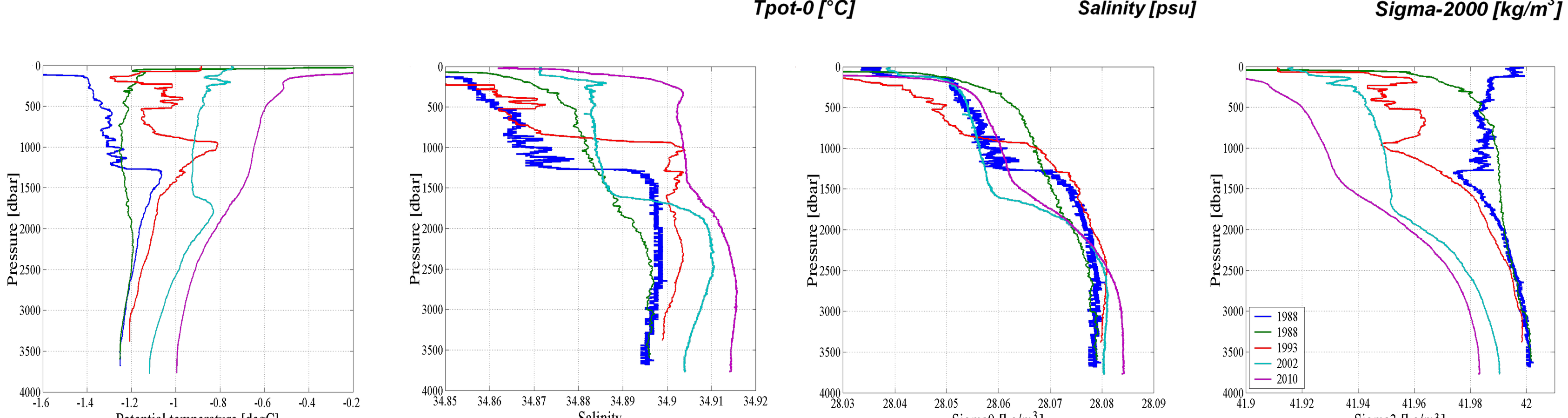


Figure G

The last observed deep (2500m) buoyancy induced renewal of the Greenland Sea deep water occurred in the late 1980s (Rudels et al., 1999) (Fig. H). After this first the salinity maximum of the Eurasian Basin deep water was reforming, then the temperature maximum deriving from the Canadian Basin deep water was created. The doming of the isopycnals in the central Greenland Sea, a feature noticed by Helland-Hansen and Nansen (1909), weakened (Meincke et al., 1997) and eventually changed to a depression (Budéus et al., 1998). This suggests that the doming observed earlier and considered a necessary preconditioning for deep convection was not caused by the prevalent cyclonic wind field but by the long established deep convection and deep water renewal, a process that might have involved ice formation and brine rejection in a shallow, less saline surface layer (Fig. H).



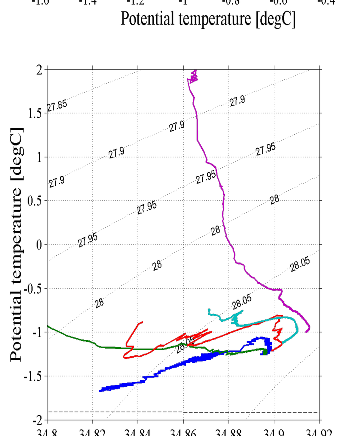


Figure H

Thermal convection now characterise the Greenland Sea as well as the Labrador Sea. The upper layers are ventilated by local convection, while the deeper layers are renewed from the East Greenland Current by deep waters from the Arctic Ocean. The RAW and AAW, the parent waters of the AIW, are presently so warm that a change into a period with local ice formation in the central Greenland Sea appears remote. A massive ice export in the East Greenland Current could, if it enters the central Greenland Sea create a less saline, less dense upper layer. However, the haline convection would still be limited to the AIW layer.

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