Did the Great Salinity Anomaly really prevent deep convection in the Labrador Sea from 1969 to 1971?

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In the winters of 1969 to 1971 deep convection in the Labrador Sea was entirely shut down. It is commonly assumed that the low surface salinity, brought about by the Great Salinity Anomaly, was the cause of this remarkable event. It seems however that we cannot neglect a sizeble influence of the unusually mild winters in these years. Furthermore, lateral ocean fluxes seem to play a vital role in the mixed layer properties in all years.

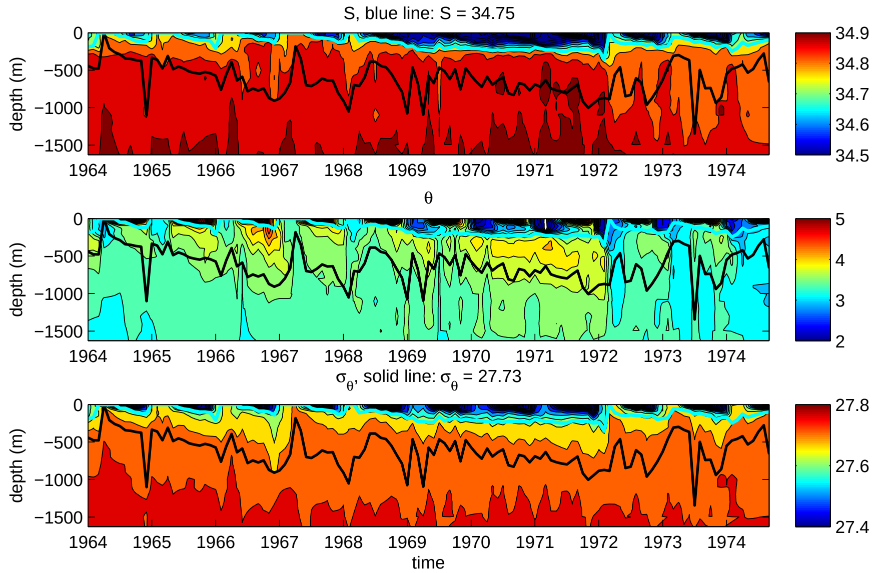

Figure A. *Time series of the oceanographic measurements at Ocean Weather Station Bravo [1]. Upper: Salinity [psu]; the blue line is the S = 34.75 psu isohaline. Middle: Potential temperature. Lower: Potential density [kg/m^3]; the thick solid line is the σ_θ = 27.73 kg/m^3.*

1. The Problem

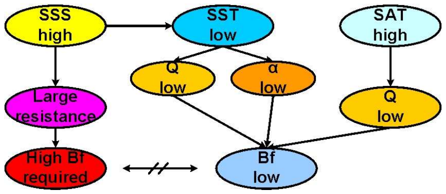

Figure B. *Overview of the factors at play. Bf is buoyancy flux.*

The Great Salinity Anomaly [2], visible as the low SSS in Fig A, is commonly recognized as the cause for the shutdown of deep convection in the winters of 1969 to 1971. Fig B shows that other factors could also be at play here.

2. Atmosperic forcing

Both a high surface air temperature (SAT) and a low sea surface temperature (SST) can cause a low heat flux:

$$Q = f(SST - SAT)$$

Fig C shows that in winter any variation in Q is mainly due to variations in SAT. Fig D shows a remarkable correlation between Q and mixed layer depth (MLD). **Atmopheric forcing (Q) was very low from 1969-1971, coinciding with the shallow mixed layers.**

3. Oceanic resistance

Fig E shows the buoyancy required to remove for deep convection per year as a measure for the resistance of the ocean to convection. **In 1969 the resistance was not unusually high, but it was concentrated in the upper (cold and fresh) layer.** A surface feedback through the thermal expansion coefficient α therefore decreased the buoyancy flux by 10-20%, **which made it more difficult to remove the required amount of buoyancy.**

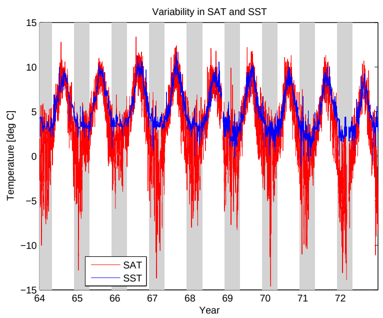

Figure C. *Time series of 3-hourly measurements of Sea Surface Temperature and Surface Air Temperature at OWS Bravo. Q mainly depends on the SAT.*

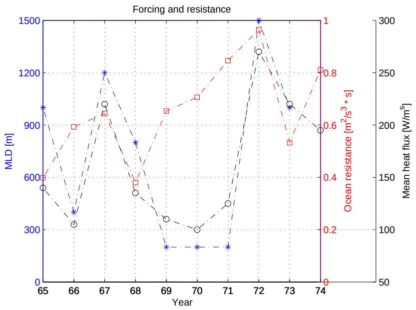

Figure D. *Winter mean heat flux (black), MLD (blue), and oceanic resistance (red).*

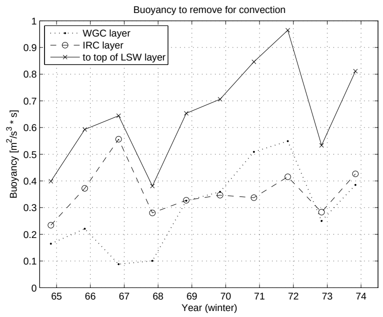

Figure E. *Excess buoyancy stored in the cold and fresh West Greenland Current layer (above the thick blue line in Fig A), in the Irminger Current layer (between the thick blue and the thick black line), and in the two layers together.*

4. 1D Mixed Layer Model Results

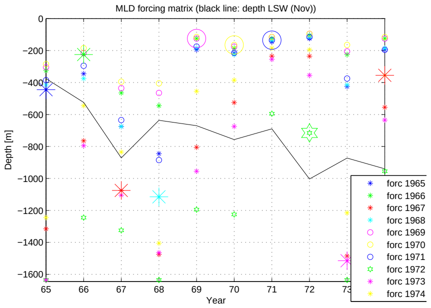

Figure F. *1D mixed-layer model MLD results for 10 initial profiles (of all 10 winters and 10 forcings (of all 10 winters).*

Quantification of the relative influence of the ocean and atmosphere requires a model. **A 1D mixed layer model (Fig F) underestimates the MLD because of the lack of lateral fluxes.** Including them will be done shortly.

5. Conclusions

- **The lower SSS during the GSA increased the resistance of the ocean to convection.**
- **The atmospheric forcing was unusually low, which likely played a significant role as well.**
- **Lateral ocean fluxes are very important for the mixed layer properties in all the simulated winters.**

References

[1] Lazier (1980), Atmosphere-Ocean, 18(3), 227-238.
[2] Dickson (1988), Progress in Oceanography (20), 102-151.
[3] Straneo (2006), J. Phys. Oceanogr., 36, 606-628.

This research was in part funded by a grant from the NWO/SRON User Support Programme Space Research.

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