Genesis and spatial extension of a 1000m deep convection event in the Irminger Sea in 2011-2012

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Summary

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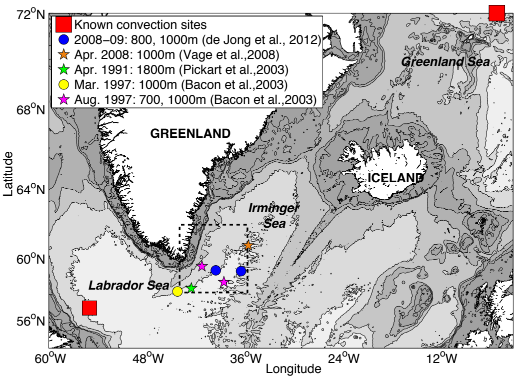
Bibliographic context



Convection sites in the North Atlantic Ocean and observations of deep mixed layers in the Irminger Sea

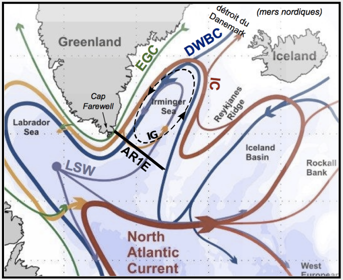
Past observations of convection in the Irminger Sea are **limited in space and time**

- Lack of data, especially during wintertime
- Focus on the Labrador site

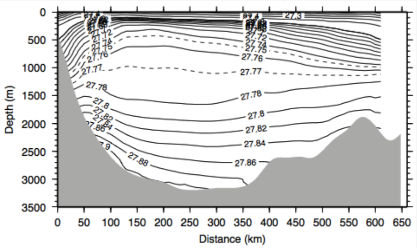
Mechanisms of convection in the Irminger Sea

1. Preconditioning

- Cyclonic circulation : Irminger Gyre [Lavender et al., 2000]
- Doming of isopycnals [Pickart et al., 2003]
- LSW in the Irminger intermediate layers [Pickart et al., 2003]



Irminger Sea circulation [P. Lherminier, LPO]



Vertical section (AR1E) of potential density [Pickart et al., 2003]

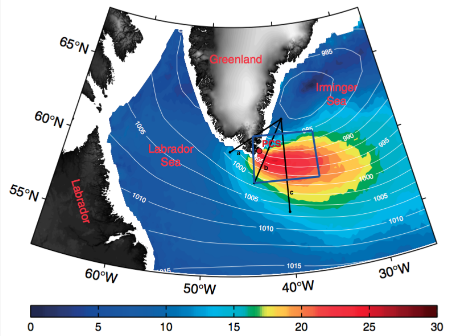
Mechanisms of convection in the Irminger Sea

2. Atmospheric forcings

Greenland relief influence : formation of Greenland Tip Jet events

Greenland Tip Jets :

- regional-scale atmospheric events
- high wind speed (westerly)
- duration < 1 day
- induce heat loss that can reach 1000 $W.m^{-2}$ locally



*Mean (1999-2002) Tip Jet QuikSCAT winds ($m.s^{-1}$) and ERA 40 sea level pressure (hPa) [Vage et al., 2009]; Blue box : '**TJ box**'*

Questions

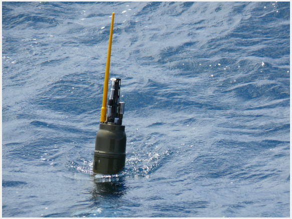
ARGO data, sampling the Irminger Sea all year (especially during winters) give informations about the ocean AT BASIN SCALE, DURING the convection event.

ARGO data permit to identify a deep convection event during the 2011-2012 winter.

- What is the spatial extent of deep convection in the Irminger Sea ?
- Can we identify the sequence of atmospheric forcings responsible for convection ?
- Can we use the 2011-2012 event to have a better understanding of the past events that could not be observed because of the lack of data ?

Summary

Data



ARGO data in the Irminger Sea

Between Sept. 2011 and Sept. 2012 :

- 574 vertical profiles from 51 different floats
- 4 floats have particularly been studied (4901163, 4901165, 4901166 and 5902298)
- 1 float with an O_2 sensor during convection

Model and satellite data

- ADT (Absolute Dynamic Topography) : AVISO (7 days ; 1/3°)
- SST, wind : ERA-Interim (12h ; 1/2°)
- Air-sea heat flux : ERA-Int. (12h ; 1/2°). NCEP (R-II) and ARPEGE (op. model) (1 day ; 1/2°)

Method of determining Mixed Layer Depths (MLD)

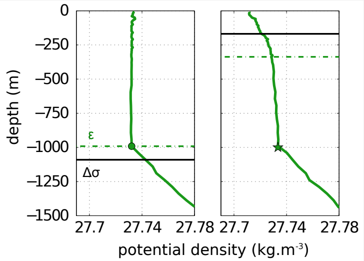
2 automatic methods

- the threshold method (de Boyer Montégut et al., 2004) : $\Delta\sigma = 0.01\ kg.m^{-3}$
- the split-and-merge method (Thomson and Fine, 2003) : $\epsilon = 0.003\ kg^{2}.m^{-6}$

Visual inspection of vertical profiles

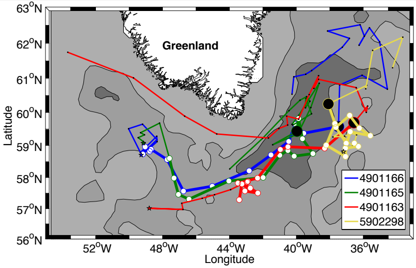
Check results of the 2 automatic methods and identify :

- homogeneous profiles from the surface (●)
- homogeneous below a stratified layer (⋆)



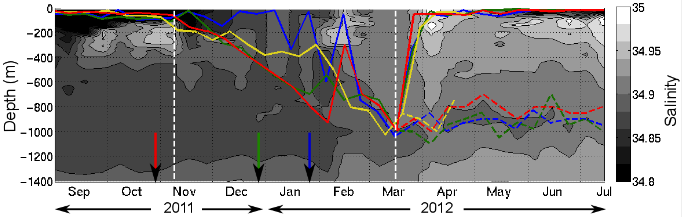
Summary

Deepening of the mixed layers along floats trajectories

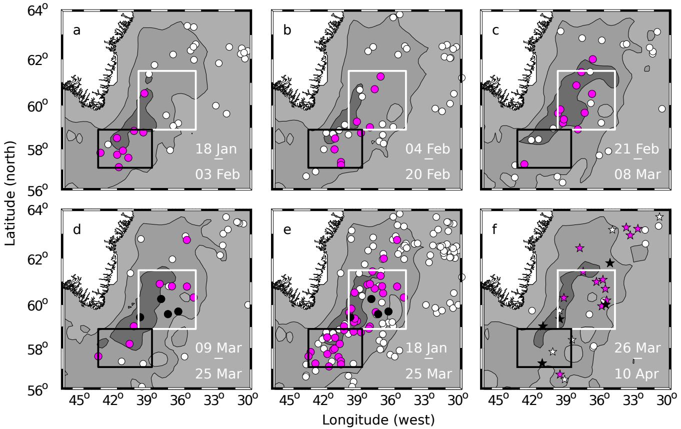


Left : floats trajectories between Sept. 2011 and Jul. 2012
- white dots : floats positions during deepening
- black dots : 1000m MLD

Bottom : MLD along floats trajectories
- white lines : delimit the deepening phase
- arrows : floats enter the Irminger Sea
- shade : float 4901163 salinity

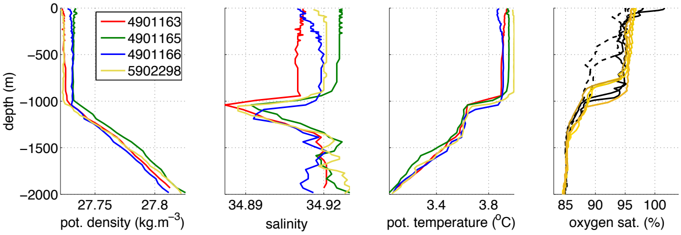


Spatial extent of the convection



***Symbols** : MLD (white : $<$ 680m - magenta : $\geq$ 680m - black : $\approx$ 1000m)*
***Shade** : dynamic topography (contours : -65, -55cm)*
***Boxes** : convection areas (white : north box - black : south box)*

Local formation of the convection



***Right panel** : oxygen profiles (every 10 days) of the 5902298 float*

- black dashed : 30 Jan. ; 9 Feb.
- yellow : 19 Feb. to 20 Mar.
- black : 30 Mar. ; 9 Apr.

Preliminary conclusions :

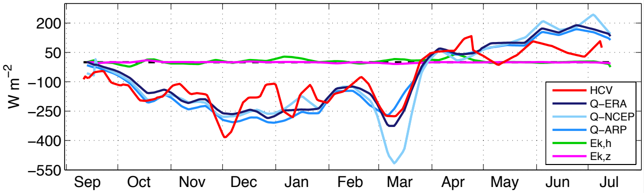
- The convection occurs at basin scale following different stages. The deepening :
  - was progressive until early February
  - slowed in February
  - strongly restarted, bringing MLDs at 1000m at mid-March
- The convection formed locally in the Irminger Sea

Summary

Heat bugdet along floats trajectories

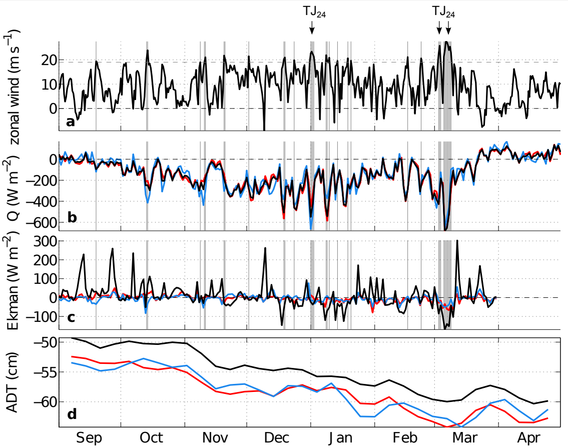
Equation of heat budget [de Boisséson et al., 2010]

$$h\delta_t < T > = \frac{F_{net}}{\rho_0 C_P} - U_{Ek}\delta_x T - V_{Ek}\delta_y T - [< T > - T(-h)]w_{Ek}$$



- Heat flux explain most of the mixed layer heat variation
- Ekman terms are weak
- Heat losses are exceptionally strong early March

Winter 2011-2012 Greenland Tip Jets



Black curves : TJ box

Red curves : north boxes

Blue curves : south box

Tip Jet criterion

zonal wind > 19 $m.s^{-1}$

Winter 2011-2012 inventory :

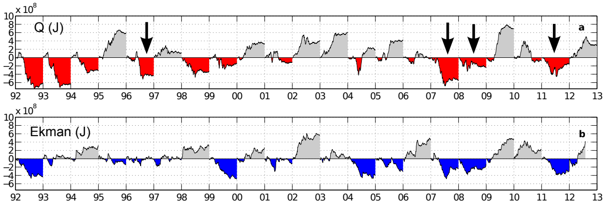
- Total : 18 TJ (Sep. - Mar.)
- 3 longer than a day
- 2 very exceptional early March

Preliminary conclusions

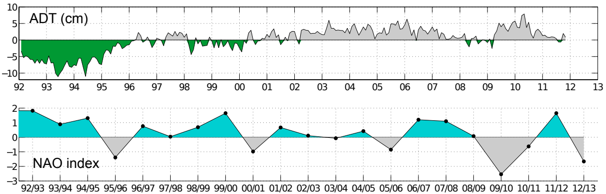
- Air-sea heat flux mainly explain the mixed layer heat content variation
- The heat loss events are concomitant with Greenland Tip Jets :
  - Number of Tip Jets reduced in February explain the slowing deepening during February
  - An event of strong heat loss, caused by 2 consecutive intense Tip Jets, explains the abrupt re-deepening of the mixed layers at mid-March
- Heat loss by Ekman terms are weak

Summary

Back to the early 1990s...



Anomalies of cumulated heat flux :
- at the surface (top)
- associated with Ekman transport (bottom)



- Anomalies of dyn. topography (top)
- Hurrel PC-based NAO wintertime (DJFM) index (bottom)

Summary

Conclusions

- Thanks to ARGO data, it is the first observation of Irminger Sea deep convection, at basin scale and during the whole period of convection
- Convection zone located east and south of Cap Farewell
- Deepening (2 months) : firstly progressive, then interrupted (Feb.), and finally strongly restarted bringing ML at 1000m. Fast restratification
- Heat budget along floats trajectories :
  - Air-sea heat flux are mainly responsible for the ML heat content variation
  - Role of Ekman terms is less important
- The TJ caused the heat loss
- Late intense TJ early March deepened the MLs up to 1000m. Without these late TJ, MLs would probably not reach 1000m and convection would have stopped in February : so, finally a local small-scale atmospheric event has influence on a larger scale oceanic event
- NAO, Ekman, Q, cyclonic circulation : indicators of deep convection for the Irminger Sea, for past years that have no observation

THANK YOU !

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