Report of the oceanographic cruise

"STEP"

(STorfjorden Polynya multidisciplinary study)

on board Research Vessel

"L'Atalante"

Tromsø, 10 July 2106 – Tromsø, 21 July 2106

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STEP website: http://ilsremontentletemps.inflexion.info/?q=node/10

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Acknowledgments :

On behalf of the Shipboard Scientific Party, we thank all the persons and committees who have contributed to the organization and the success of the STEP cruise on board R/V "L'Atalante".

We gratefully acknowledge the support of the Atalante crew for the preparation, their kindness and commitment, which contributed to the success of the numerous and varied operations at sea.

We dedicate this oceanographic cruise to the memory of Nicolas Martin who should have been with us...

The STEP cruise has been approved by the call offer INSU LEFE and accepted and scheduled by the French National Fleet Committee (CNFH). We benefited almost all along the cruise from a fair weather and calm seas. These conditions allowed us to conduct not only about the complete program (except for only a few stations for which the VMP/SCAMP operations were cancelled because of wind speeds above 20 knots) but also to add a few more stations closer to the coast, in order to compare the measurements to regional model simulations of Storfjorden.

English abstract:

The formation of dense brine-enriched water associated with ice formation is a key compartment of the global thermohaline circulation, which might have been even more active during the last glacial period. From the test case of an Arctic polynya, the STeP (STorfjorden Polynya multidisciplinary study) project is designed to improve our knowledge on polynya dynamics and processes associated with brine-enriched water formation, as well as on the impact of brine on the oceanic circulation and Greenhouse Gases (GHG) cycles through a multi-disciplinary physical-biogeochemical approach. This program will strengthen an on-going effort to build a team including physical, biochemical, paleo-oceanographers and modellers that formed within the French Arctic workshop project (`Chantier Arctique'). This French consortium has teamed-up with Belgian, German and Norwegian colleagues to promote Storfjorden as an observatory region to investigate processes specific to polynyas, which may ultimately fit within the Svalbard integrated Observing System (SiOS), a European Infrastructure under construction (ESFRI). Storfjorden, Svalbard, is of particular interest with this respect as it hosts a relatively accessible latent heat polynya where dense water forms through brine rejection. Previous and on-going studies have shown high inter-annual variability in the properties of the dense brine-enriched shelf water (BSW) formed there, depending in particular (but not exclusively) on the intensity of ice production over the previous winter. This impacts the capacity of the BSW overflow to feed intermediate or deep layers through cascading, a poorly understood process. Because of the availability of observations, Storfjorden is being used as a test case to assess the capability of state of the art coupled ocean-sea ice models (NEMO 3.4 + LIM3) to depict the process of dense water formation within polynya regions. The first cruise of this project allowed 1) pursuing the continuous collection of physical parameters (T, S and currents) started in 2011 with a mooring in the heart of the polynya equipped with autonomous CTD sensors and an ADCP, 2) adding $p\mathrm{CO_2}$, dissolved O_2, pH sensors, an automated water sampler and a trap to the mooring in order to register year round carbon cycle, CH_4 and N_2O changes and analyse changes in deep water and DIC isotopes composition, as well as analysing particle fluxes, and organic matter origin, 3) analysing hydrography, currents, turbulence, the carbonate chemistry parameters, the concentrations of GHG in the water column, bottom water, sediment pore waters and complementing the trap samples with multinet and multicore sampling. Ultimately, we expect this project to contribute to improve future climate simulations, by providing a better understanding and representation of possible feedbacks, both from the ocean circulation and the GHG cycle, associated with the rapid warming of the Arctic.

French abstract :

La formation des eaux denses enrichies en saumures lors de la formation de glace joue un rôle important dans la circulation océanique profonde, rôle très certainement renforcé pendant les périodes glaciaires. A travers l'étude d'une polynie arctique, le projet STeP (Storfjorden Polynya multidisciplinary study) vise une meilleure compréhension de la dynamique des polynies et des processus associés à la formation des eaux denses ainsi que de leur impact sur le cycle des gaz à effet de serre. Pour cela nous proposons une approche pluridisciplinaire physique et biogéochimique.

Ce programme s'appuie sur une équipe comprenant des océanographes physiciens, biologistes et chimistes ainsi que des paléo-océanographes et des modélisateurs. Cette équipe, qui s'est constituée à l'occasion du chantier Arctique français, collabore avec une équipe européenne (collègues belges, norvégiens et allemands) en vue d'améliorer nos connaissances concernant les processus spécifiques aux polynyies. Pour cela, nous proposons le Storfjorden, Svalbard, comme zone d'étude, qui pourrait, à terme, faire partie du « Svalbard integrated Observing System (SiOS). En effet cette région abrite une polynie relativement accessible, où se forment annuellement des eaux denses enrichies en saumures (BSW). Les études précédentes et en cours de cette polynie ont souligné l'importante variabilité interannuelle de la salinité des eaux denses, en fonction notamment (mais pas exclusivement) de la quantité de glace de mer formée au cours de l'hiver précédent, ce qui affecte leur capacité à s'insérer dans les masses d'eaux intermédiaires ou profondes en mer de Norvège au terme d'une cascade gravitaire dont le détail est mal compris. Grâce au suivi réalisé jusqu'à présent, cette zone est utilisée comme région test pour vérifier la capacité du modèle régional couplé océan-glace de mer (NEMO 3.4 +LIM3) à reproduire la formation des eaux denses dans une polynie. La première campagne de ce programme a permis : i) de prolonger le suivi temporel continu des paramètres physiques (température, salinité et courants) commencé en 2011 avec une ligne de mouillage équipée de CTDs autonomes et ADCP, ii) d'ajouter à ce mouillage des capteurs de pCO_2 (CARIOCA), d'oxygène dissous et de pH ainsi qu'un piège à sédiment et un échantillonneur automatique d'eau pour une suivi annuel du cycle du carbone, du méthane et du N_2O, de la composition isotopique de l'oxygène des eaux profondes et du carbone de leur DIC ainsi que des flux particulaires, iii) de mesurer les courants, la turbulence et les paramètres hydrologiques ainsi que la chimie des carbonates dans la colonne d'eau, les eaux de fond et les eaux interstitielles des sédiments.

Une meilleure compréhension des phénomènes de formation d'eaux denses enrichies en saumures et de leur impact sur les cycles des gaz à effet de serre et sur la circulation profonde devrait permettre d'améliorer les simulations futures du climat par une meilleure représentation de ces processus et des rétroactions qu'ils entrainent dans les modèles climatiques. Cela est particulièrement important dans le contexte actuel du réchauffement rapide de l'Arctique et de la disparition de la glace de mer.

Laboratories involved in this program :
FRANCE :
-LSCE (Laboratoire des Sciences du Climat et de l'Environnement, GIf/Yvette)
-LOCEAN (Laboratoire d'oceanographie et du Climat : Experimentation et Approches Numériques, Université Pierre et Marie Curie, Paris)
- LPG-BIAF, Université d'Angers
-CEFERM, Perpignan

BELGIUM :
- Univeristé de Liège, Liège
- Université Libre de Bruxelles, Bruxelles.

NORWAY :
-University of Tromsø, Troms
-UNIS (Longyearbyen, Svalbard)
-NPI, Bergen
-IMR, Bergen
-UNI, Bergen

GERMANY :
-AWI, Bremerhaven

1.1. Scientific context and objectives of the program STEP

Polar regions exert a major influence on oceanic circulation and carbon cycle through deep-water formation and atmosphere - deep ocean carbon exchange. Past and present climate changes are amplified in polar regions (Masson et al., 2006, Vaughan et al., 2003, Holland and Bitz, 2003) and the feedbacks of polar climate changes on the carbon cycle are not fully understood yet (Bates and Mathis, 2009; McGuire et al., 2009). These issues are particularly timely and pressing, since arctic sea-ice cover quickly diminished over the last decade (Overland and Wang, 2013) with potentially important consequences on deep-water formation and carbon cycle, and on their retroaction on the changing climate.

Each winter residual sea ice thickens and new, thinner ice is formed, leading to the release of brine. Sea ice is believed to specifically affect ocean-atmosphere CO_2 exchanges (Vancoppenolle et al, 2013) and deep-water formation partly results from brine rejection during sea-ice formation, primarily in confined polynya regions both in the Arctic Ocean and over Antarctic continental shelves (Ivanov 2004). However, processes linked to brine rejection and their impact on the carbon cycle are not fully understood yet (Miller et al., 2011). Improving the representation of physical, biological and chemical processes of polynya regions in numerical models is currently an essential requirement for forming deep and bottom waters with correct properties, and for a better representation of ocean –atmosphere carbon exchanges.

The rejection of brine from sea-ice is known to contribute to the CO_2 solubility pump (Bates and Mathis, 2009; Rysgaard et al. 2011). Indeed, recent studies of first-year Arctic sea-ice revealed that total alkalinity (TA) and dissolved inorganic carbon (DIC) are released from growing sea ice to the underlying water column (Anderson et al., 2004; Papadimitriou et al., 2007; Rysgaard et al. 2011; Miller et al., 2011). In addition, the precipitation of calcium carbonate within the ice changes the DIC/TA ratio in sea ice, which may affect the atmosphere-ocean CO_2 flux (Rysgaard et al, 2011, Geilfus et al. 2013). These components of the carbonate system may be transported into intermediate and deep waters with the high-density brine, as was reported from the Storfjorden in Svalbard (Anderson et al., 2004), the Okhotsk Sea (Shcherbina et al., 2003) and the Canada Basin in the Arctic Ocean (Yamamoto-Kawai et al., 2008).

Measurements of the oxygen isotopic signature ($\delta^{18}O$-H_2O) of brine waters in the Arctic seas (Bauch et al., 2011) and the Weddell Sea (Mackensen et al., 1996) have indicated low oxygen isotopic values in agreement with the small enrichment of oxygen isotopic composition during sea-ice formation (Melling and Moore, 1995). Unpublished oxygen isotopic data for the Storfjord waters also indicate a low oxygen isotopic composition of brine-enriched shelf waters (Dokken and Osterhus, and Michel, personal communications).

Thus, low oxygen isotopic values of benthic foraminifers picked from glacial sections in sediment cores retrieved in the northern North Atlantic and Nordic Seas have been interpreted as the signature of enhanced brine formation (Vidal et al., 1998, Dokken and Jansen, 1999; Waelbroeck et al., 2006, 2011). However, very cold temperatures of brine waters counteract the low isotopic values of brines as foraminifera incorporate more ^{18}O in their test when they develop in cold waters. Low oxygen isotopic values of benthic foraminifers could thus be also interpreted as a warming of deep water due to Atlantic water influence (Bauch and Bauch, 2001). These low oxygen isotopic values of the benthic foraminifera can be coeval with low carbon isotopic values of their test. Low carbon isotopic values have also been interpreted as a signature of important brine formation (Dokken and Jansen, 1999, Waelbroeck et al., 2006, 2011). Brine formation might have been far more prevalent during the last glacial period, modifying greatly the deep ocean circulation. It is one of the processes that, during the last glacial maximum, could have maintained a 30% reduced atmospheric CO_2 concentration and could explain the very low carbon isotopic composition of the Southern Ocean deep waters (Bouttes et al., 2012). However, Rasmussen et al. (2009) conducted isotopic analyses on Holocene foraminifers collected from sediment cores retrieved in Storfjorden in the vicinity of brine influence and did not find a specific isotopic signature. Mackensen (2012) suggests an enriched carbon isotopic composition ($\delta^{13}C$) of brines in the Southern Ocean associated to enriched surface waters DIC, the carbon isotopic composition of cold surface water DIC being enhanced by important air-sea exchange under strong winds. On the opposite, A. Mackensen (personal communication) measured low carbon isotopic composition for benthic foraminifera *Cibicidoides* sampled form a multicore retrieved in the deep basin of the Storfjorden. Thus no clear answer emerges from the few Storfjorden benthic foraminifera analyses. Moreover, processes associated with sea-ice formation (brine transport of nutrient, primary production under/within sea-ice, atmosphere-water gas exchange and ikaite precipitation) will modify locally the isotopic composition of brine's DIC (Papadimitriou et al., 2007, 2009; Munro et al., 2010) and so far, carbon isotopic analyses have been made within the sea-ice but not on the DIC of the brine dense water formed.

Storfjorden, Svalbard (Fig. 1), is of particular interest as it hosts a relatively accessible latent heat polynya. Brine-enriched shelf waters (BSW) formed there are dense enough to sink and accumulate at the bottom of the fjord before spilling toward the deep ocean. The presence of a sill at ~120 m depth at the entrance of the fjord allows to sample BSW all year round in the deep basins inside the fjord, down to 170 m.

Brine formation in Storfjorden has been studied over the last 20 years by several authors (Quadfasel et al., 1988, Schauer, 1995, Haarpaintner et al., 2001, Skogseth et al., 2004, 2005, 2007, 2008, Anderson et al., 2004), and in particular through scientific programs led by LOCEAN laboratory in the last years (BRINES and DAMOCLES, J.-C. Gascard, ICE-Dyn and OPTIMISM, F. Vivier; see Jardon et al., 2011; Jardon et al., 2014). BSW there reach high salinities ranging from 34.8 up to 35.8 (Skogseth et al., 2005), depending on the year. This large range of inter-annual variations is governed by a variety of factors including the surface water origin (Atlantic or Arctic) from which brine forms (Skogseth et al. 2008), and the intensity of ice production in the polynia (Skogseth et al., 2005). This temporal variability is not fully understood yet, although exceptionally salty BSW appears to coincide with outstanding ice production in the polynya during the previous winter (e.g. Jardon et al., 2014).

From 2011 to 2013, within the OPTIMISM project (http://optimism.locean-ipsl.upmc.fr), a mooring line equipped with autonomous CTD sensors throughout the water column and an upward looking ADCP (Acoustic Doppler Current Profiler) at the bottom has been deployed in the heart of the Storfjorden polynya area (Fig. 1). This continuous 2-year series of hydrographic observations in the heart of the polynya is highly valuable, and shows remarkable contrasts between the winter seasons of 2011-2012 and of 2012-2013. Anomalously fresh BSW formed over the season 2011-2012, with salinity barely exceeding 34.8, consistently with the extremely low ice coverage in Storfjorden during winter, coincident with the historical 2012 record low in arctic sea ice extent. Moreover, the 2011-2012 record reveals intriguing, unusual, intrusions of warm and salty waters of North Atlantic origin. By contrast the 2012-2013 record displays vigorous episodes of BSW formation with salinity culminating at 35.9 mid-March, due to very different sea-ice conditions in the Arctic (Parkinson and Comiso, 2013), although BSW salinity decreased to ~35.5 by the end of the freezing season (late April/early May). The BSW found in the deep pools of the fjord in summer time during deployment/servicing cruises, 4 months after formation, consistently reflects the properties of the BSW formed over the preceding winter season, suggesting a complete ventilation on these deep reservoirs on a yearly basis (Fig.1). A mooring with minimal equipment (1 autonomous C/T recorder) was redeployed at the same location in August 2013 with a two-year autonomy, in anticipation of this future cruise.

Issues and objectives:

Neither the physical processes linked to the formation of brine-enriched dense water, neither their precise contribution to the atmosphere-ocean exchange of greenhouse gases (GHG) are yet fully known. The understanding of physical, chemical and biological processes, during sea-ice formation and melt is therefore of utmost interest regarding the past, present and future climatic changes, owing to the role of brine-enriched dense water in deep ocean circulation and GHG cycles. This project aims at increasing our current knowledge on the formation of brine-enriched shelf water (BSW) and its impact on ocean circulation and GHG cycles through the solubility and biological ocean pumps. To do so, we will gain new insights into processes governing the inter-annual variability of the physical and chemical properties of the newly formed BSW within a polynya, through a multidisciplinary approach, combining observations and high-resolution regional modeling, with the prospect of a better representation of these confined regions in Earth system models. Ultimately, we expect that this project will improve future climate simulations by providing a better representation of possible feedbacks involving ocean circulation and GHG cycles, in the context of rapid warming of the Arctic.

Studies of the Storfjorden polynya and Storfjorden outflow have shown the large inter-annual variability of the BSW properties. However, issues concerning the physical processes leading to the BSW formation and their physicochemical properties are still poorly known. The different factors that may influence the properties and volume of the BSW needs to be investigated (atmospheric forcing, ice production intensity, origin of the water present in the fjord during the freezing season). The production of sea ice itself depends on the wind intensity and on the advection of sea ice from the Barents Sea, on the salinity of the source water, Atlantic or Arctic, and on vertical mixing within the polynya that may impact the upper ocean heat budget. Mixing is also crucial regarding the fate of the newly formed dense water exported towards the deep ocean as a gravity driven plume. Investigation of mixing requires in particular studying the generation/ propagation of internal waves (from tides or atmospheric forcing origin) and vertical energy flux associated with inertia-gravity wave breaking.

The biological and solubility pumps, associated with brine formation, have been evaluated in Storfjorden by Anderson et al. (1988, 1998 and 2004), over discrete periods of the year. We propose to analyse the balance between the biological and solubility pumps, with a year round monitoring of the physical parameters and associated pCO_2 changes. This will enable us to fully capture the seasonal amplitude and the inter-annual variability of the analysed processes (atmosphere-ocean GHG exchange during brine rejection, brine transport of nutrient, primary production under/within sea-ice). Thanks to the year round trap sampling, it will be possible to separate biological from physical processes acting on pCO_2. We will monitor year round changes for CH_4 and N_2O and take into account the water-sediment exchanges through sediment multicore analyses.

Physics: from sea ice to ocean dynamics, including formation of brine-enriched shelf waters

On all stations, high resolution profiles of temperature and conductivity (hence, salinity) have been measured with a CTD mounted on a rosette. It provides a sketch of the hydrographic situation throughout the fjord before and after the winter season. Currents over the whole water column have been measured with a L-ADCP mounted on the rosette-CTD-SBE 911. The network of station provides a picture of the different water masses present in Storfjorden and allow defining their hydrological and geochemical properties, as well as the vertical turbulent fluxes of these properties along the water column. Measurements of the microstructure have been performed with a SCAMP (Self-contained autonomous micro-structure profiler, a VMP has been used on the two first stations) to infer dissipation rate of turbulent kinetic energy and turbulent mixing, expanding previous estimates mostly based on observations near the fjord's exit (Fer et al., 2004; Fer, 2006).

The mooring's observations, providing times series of both currents and hydrography throughout the water column, will document water mass transformation in the polynya, and will enable in particular to detect BSW formation and intrusion of North Atlantic Water. The salinity and $\delta^{18}O$ of brine dense waters of the Storfjorden are significantly influenced by source water entering the fjord and sea-ice processes. The year round monitoring of both salinity and $\delta^{18}O$ of the water at the mooring line and the analyses of the network of stations samples, during the cruise, that will document waters entering from the North and South sills in the Storfjorden, will allow to establish the relationship between salinity and oxygen isotopes linked to source water on one hand and brine dense water formation on the other hand (Bauch et al., 2010, 2011). Furthermore, we will analyse the carbon isotopic composition ($\delta^{13}C$ and $\Delta^{14}C$) of the DIC. Carbon isotopic analyses will help to distinguish between Atlantic and Arctic origin of the water (Schlosser et al., 1997). Mooring and hydrographic station data all together will provide physical and geochemical properties as well as an estimate of the volume of the newly formed BSW.

Greenhouse gases fluxes (CO_2, CH_4, N_2O): from the atmosphere to the sediment

The freezing and melting of sea ice strongly influence the CO_2-system of the underlying water column and thus also the air-sea exchange of GHG. We will investigate the air-ice-sea exchange with respect to two different mechanisms: downward direct transport by brine rejection and through chemical composition of sea-ice and, thus, melt water.

Water samples have been collected from the CTD-rosette (24×12-L Niskin bottle) and from sediment pore water for the analyses of the various parameters of the seawater CO_2-system (DIC, TA and pH), GHG concentrations (CH_4 and N_2O) and their isotopes. Seawater carbonate parameters (DIC, TA and pH) and GHG concentrations (CH_4, N_2O) and their isotopes will be also monitored year-round thanks to an automatic water sampler fixed to the mooring. A Remote Access Sampler (RAS-500, McLANE) has been deployed on the mooring line, close to the seafloor in order to collect a time-series (48 samples) of brine-enriched shelf waters.

The biological and solubility pumps, associated with BSW formation, have been evaluated by Anderson et al. (1988, 1998 and 2004) in Storfjorden, over discrete periods of the year. We propose to analyse the balance between the biological and solubility pumps, capturing the seasonal amplitude of these processes. seawater samples (collected with the CTD-rosette), have been filtered with 0.45µm filters for subsequent chlorophyll measurements in order to calibrate the fluorometer vertical profiles from the rosette's CTD-SBE 911. Dissolved oxygen, by Winkler titration has been measured on board from the water samples to calibrate the O_2 sensor and the ISUS profiler. In addition, and in order to constrain the carbon budget, $\Delta^{14}C$-POC and $\Delta^{14}C$-DIC will be determined for surface water and BSW samples using the new Echo-MICADAS or/and the Artemis accelerator mass spectrometry (AMS facilities at LSCE).

Local biological productivity will be derived from day-to-day pCO_2 (CARIOCA and SAMI sensors) and oxygen measurements, during events when biological production is the main process affecting pCO_2 (Boutin et al., 2009; Lefèvre et al. 2012) and from the trap data samples. The mooring of the trap in Storfjorden will provide the opportunity to link biological and geochemical data from the surface production with hydrodynamic, biological and geochemical data from sediments. The trap will collect the downward fluxes originated from the surface production (in spring) and from the aerial deposition. It might collect also hyperpycnal flows from glacial rivers in summer, advected materiel, such as sediments along the shoreline eroded during storms or deeper sediments resuspended and flushed by dense shelf-water cascading. Damm et al., (2007) interpreted high methane measurements in the Storfjord water column during early spring as high accumulation rates of organic matter associated with submarine discharge from resuspension of sediments by the cascading dense bottom water. A turbidimeter is installed close to the trap, on the mooring line. We can assume that the quantity and quality of the settling material and therefore the fate of the deposited material may change according to the seasons and the meteo-climatical conditions.

We will also investigate the distribution and fluxes of O_2 and CO_2 at the sediment-water interface: ex situ profiles of O_2 and pH have been measured at the sediment-water interface on sediment from multicores, retrieved at 7 stations, using microelectrodes (vertical resolution 100-200 µm). Dissolved oxygen concentration and pH in the overlying water have been determined by Winkler titration and spectrophotometry, respectively to calibrate the signals of O_2 and pH microelectrodes. The vertical distribution of the carbonate parameters (DIC and TA) in pore water samples have been measured onboard. Porewater samples have also been collected to measure their oxygen and carbon isotopic composition later on land. The sediment porosity has been determined at a 0.5 cm vertical resolution. Analysis of particulate organic carbon (POC), particulate organic nitrogen (PON) and carbonate in the sediment will also be performed. Sediment core incubation experiments have been performed on three stations to give insights on benthic activity: respiration rates, O_2 and CO_2 benthic fluxes, bioturbation…

We will thus account for the chemical processes within the sediments and their impact on the oceanic carbon cycle. Gazeau et al. (2014) found a low impact of ongoing ocean acidification on sediment processes of the Arctic Ocean. We proposed to investigate the local impact of brine formation and its associated carbon solubility pump on the biological pump through local ocean acidification. On top of giving access to the annual productivity, sediment trap and multicore analyses will give access to the impact of acidification on organic matter and biogenic carbonate fluxes linked to foraminifer and pteropod production (see next §). Detailed faunal and biogeochemical analyses of planktonic foraminifers and pteropods sampled from the water column, from sediments and sediment trap will provide information on the physical changes and biological turnover, as well as on the pelago-benthic coupling at Storfjorden.

The responses of key marine calcifying organisms

The STeP cruise will allow to assess the responses of some key marine calcifying organisms, foraminifera and pteropods, in the water column, sediment trap and sediment core samples. Living planktonic foraminifera (LPF) are considered as major producers of calcareous shells (Schiebel and Hemleben, 2005) that are eventually preserved in the underlying marine sediments. The links between LPF standing stock, distribution pattern, and hydrographic conditions have been applied to paleoclimatic reconstructions since the 1960s (e.g. Kucera, 2007, and references therein). LPF shell production and deposition are key components of the marine calcite budget (Schiebel, 2002). Few studies on LPF were conducted in (sub-) polar regions, and these were concentrated in the Arctic region, mainly in Fram Strait (e.g. Pados and Spielhagen, 2014).

Basically, LPF population dynamics is strongly related to food availability. However, ecological factors controlling LPF production and species distribution in neritic environments are more complex than in open-marine waters. When offshore high LPF abundances are linked to seasonally enhanced primary production, i.e. phytoplankton bloom events, onshore LPF production may indirectly benefit from nutrients/organic matter supplied to coastal waters from the watershed. Under the influence of mid-latitude river plumes, LPF population dynamics proved to be negatively affected by seawater turbidity whereas low surface salinity seems to have low impact on the distribution of LPF (Retailleau et al., 2012). Yet, the LPF response to salinity is not well identified (Katz et al., 2010). In addition, strong water column stratification may affect the LPF population dynamics. At the western entrance of the Barents Sea, LPF production and species distribution are strongly connected to the water column stratification due to the Norwegian Coastal Current, and to the mixing occurring above the southern Svalbard plateau (work in progress at the LPG-BIAF.

Multinet samples (MULTINET HYDRO-BIOS, type midi), have been taken on 10 stations. Samples will be analysed on a species-specific scale in combination with co-registered CTD data and Chlorophyll-a satellite images. Living planktonic foraminifera have been collected and analysed for species, shell size, shell weight and TOC and will be further analysed for isotopes and trace elements. LPF population dynamics and depth of calcification need to be clarified to improve proxies of paleoclimatology based on the geochemistry of the foraminiferal tests. In the same time, sampling of pteropods (ex Limacina helicina) has been performed for analyses of “fitness” and genetics.

Shells of planktonic foraminifera from plankton net, sediment trap and surface sediments and sediment cores will be measured, weighed and visually analysed to establish their dissolution/preservation stage. Geochemical analyses ($\delta^{11}B$, B/Ca, Mg/Ca, Li/Ca, Sr/Ca, U/Ca) on shells from plankton net, sediment trap and surface sediments will follow. Calcifying pteropods will be also collected within sediment trap samples. We will investigate the temporal evolution of sinking pteropods in term of the shell thickness, density and overall fitness. This data set will be compared with parameters of the carbon system in the water column. Sediment cores will be used for both, planktonic and benthic, foraminiferal analyses in order to assess the carbonate dissolution in the past.

The vertical export of particulate inorganic carbon (PIC) by calcifying organisms and their contribution to PIC will be estimated. Changes in living planktonic foraminifera fluxes to the sea floor should reflect changes in the seasonal production of LPF, and are closely coupled to seasonal changes in trophic conditions at the sea surface. The sediment trap sampling will allow accurate estimates of export production throughout the year of this representative zooplankton group, in response to seasonal/annual changes. Fluxes of LPF species (tests >150 μm) are analysed for temporal dynamics by means of the sediment trap deployment. Carbon budget due to LPF production and sedimentation (C-organic : cytoplasm and C-inorganic: shell) can be calculated based on automatically measured size distributions for the various species (method developed at LPG-BIAF-Angers University, Movellan et al., 2012). Correlation curves, calibrated with LPF from the Southern Ocean (Meilland et al., 2016), give C-organic and C-inorganic masses in function of foraminiferal test size. Benthic foraminifera (BF) are strongly influenced by the downward flux of organic matter to the sea floor. Past changes in this flux should be also reflected by shifts in BF accumulation rate (BFAR), and species composition.

Vertical fluxes and benthic-pelagic coupling

Over the last two decades, knowledge on the present export of shelf particulate matter to the slope is essentially derived from measurements of downward particle fluxes by sediment traps (e.g., Heussner et al., 1999; McCave et al., 2001; Fabres et al., 2002; Iseki et al., 2003). Such observations allowed building a picture of horizontal and vertical gradients and seasonal variability of flux characteristics (intensity and composition). Investigating the fate of river-borne, ice-borne, air-borne and re-suspended sediments that is transported across continental margins is a fundamental task for i) our understanding of the dispersal and sequestration of chemical elements (e.g. carbon, contaminants…), ii) the factors impacting benthic habitats and ecosystems, and, in the long term, iii) the construction of sedimentary strata and evolution of continental margin morphology.

Sediment transport on continental margins depends on a wide variety of processes, including river floods, marine storms, and dense water formation. In the Arctic Ocean, continental inputs are mainly occurring in summer with the formation of turbid melting freshwaters delivered by Arctic rivers and the numerous tidal glaciers (pink sediments). While storms are a ubiquitous driver of sediment transport in continental margins, dense shelf-water formation in arctic environments are mainly due to the formation of brine-enriched water masses through surface cooling and freezing (Skogseth et al., 2008). The year round samples from the sediment trap will allow:

- to describe the seasonal variability of downward particle fluxes (total mass fluxes) and the seasonal variability in the geochemical composition (carbon, nitrogen, trace elements) of this trapped material. What is the period when the maximum total mass fluxes are measured? Is there a large shift in the quality of the trapped material between seasons and between low and high total mass fluxes?
- to assess the physical, chemical and biological forcing parameters responsible for the major flux events. What are the physical, chemical and biological processes that affect the total mass fluxes and the quality of these downward fluxes?
- to determine the benthic responses to these downward fluxes. Is the geochemical composition of surface sediments collected at the mooring station similar to the one of the trapped material? Do the benthic activities transform the deposited material? Are the benthic activities raised with the increase of the total mass fluxes or with the settling of organic-rich

material from surface waters?

In complement to the study of downward fluxes, investigations will be carried out on the multicore sediments collected during the cruise in order to determine the potential links between the benthic activities and the quantity and quality of downward fluxes. Various geochemical analyses will be performed on trapped material and sediments in the laboratory: (i) Elemental (CHN) and isotopic (EA-IRMS) analyses : total carbon, inorganic carbon, organic carbon, $CaCO_3$, total organic nitrogen, $\delta^{13}C$-OC and $\delta^{15}N$-ON, (ii) Trace elements (ICPMS), (iii) Particle-size distribution (Laser diffraction methods) and (iv) Scanning Electron Microscopy (SEM).

The sediment compartment: connecting actual to paleoceanography

Multicores have been retrieved from 7 stations (6 within the Storfjorden and one station in the Storfjorden Trough) and kullenberg cores from 5 stations (4 within the Storfjorden and one in the Storfjorden Trough). These stations have been chosen in order to cover different water depths below and above the sill depth and to compare different deep basins north of the sill within the fjord with the southern flank of the sill, outside the fjord. The study of the multicores will allow understanding how the physical and chemical conditions within the Storfjorden are registered within the sedimentary archive and particularly by planktonic and benthic foraminifera assemblage and within their tests. The assemblages and geochemical properties (weight, carbon, oxygen and boron isotopes) of the planktonic foraminifera picked from the top cm of the multicore will be compared with the results from the multinet and trap samples to evaluate how the water column signal is preserved within the sediment.

Usually, BF assemblage characteristics (density, diversity, composition) are mainly determined by the organic flux to the sea floor. In the highly specific context of Storfjorden, brine injection into the basinal areas will probably be a major secondary factor. Recently, in a paleoceanographic study of the last deglaciation and Holocene in Storfjorden, Rasmussen and Thomsen (2014, 2015) observed systematically increases of the ratio between agglutinated and perforate calcareous BF taxa during colder periods. They mainly ascribe these shifts to a selective taphonomic loss of the calcareous tests, and suggest that the greater tolerance of agglutinant taxa to corrosive bottom waters could also have modified the past living BF faunas.

For a correct interpretation of the fossil record, it is essential to deconvolve the impact of the downward organic flux and brine injection. It will be partly solved with a spatial study of the fluctuations of the living and sub-recent BF, in response productivity in the surface waters and the redox conditions on the sea floor. The temporal response to the different inter-annual properties of brine formation requires pluri-annual sampling. Whole test stable carbon isotopes and single chamber (laser ablation ICPMS of successive chambers of single individuals) trace metal ratios (Mg/Ca, Sr/Ca, Ba/Ca, Mn/Ca) will be used to see how the temporal variability of the main controlling factors is registered in the geochemical composition of the BF shells. Furthermore, to know whether the changes in the ratio between agglutinated and calcareous BF are only due to preservation changes or are partly a primary signal, a detailed study of the dead BF assemblages will be done for the top 10 to 20 cm of the sediment, that represent the last 200-500 years (Rasmussen and Thomsen, 2014), in order to obtain a better insight in the changes of the fossil assemblage during early diagenesis. The carbon and oxygen isotopic composition of live benthic foraminifera will be analysed and compared to their bottom water/pore waters and DIC counterpart to verify that the benthic foraminifera isotopes register the variability observed on the water samples.

Within the Storfjorden the kullenberg cores should cover the last twelve thousands years as the inner basin of the Storfjorden was filled with continental ice earlier in the last glacial period and deglaciation (Rasmussen and Thomsen, 2014). From the Storfjorden Trough, unfortunately the core was bended and we might not have recovered older sediment than within the Storfjorden. Benthic and planktonic foraminifera isotopes and trace element ratios will be studied downcore. Taking advantage of the results obtained on the multicores, we might be able to reconstruct the past intensity of brine dense water production as well as their chemical properties. Scanning electron microscope (SEM) analyses will be undertaken to observe changes in shell preservation and will be linked to foraminifera weight analysis and fragment number to estimate changes in calcium carbonate preservation. It will then be the first tentative for a quantitative reconstruction of brine dense water formation, since the last glacial period, and an estimate of the associated impact on local ocean acidification.

1.2 Map of the cruise

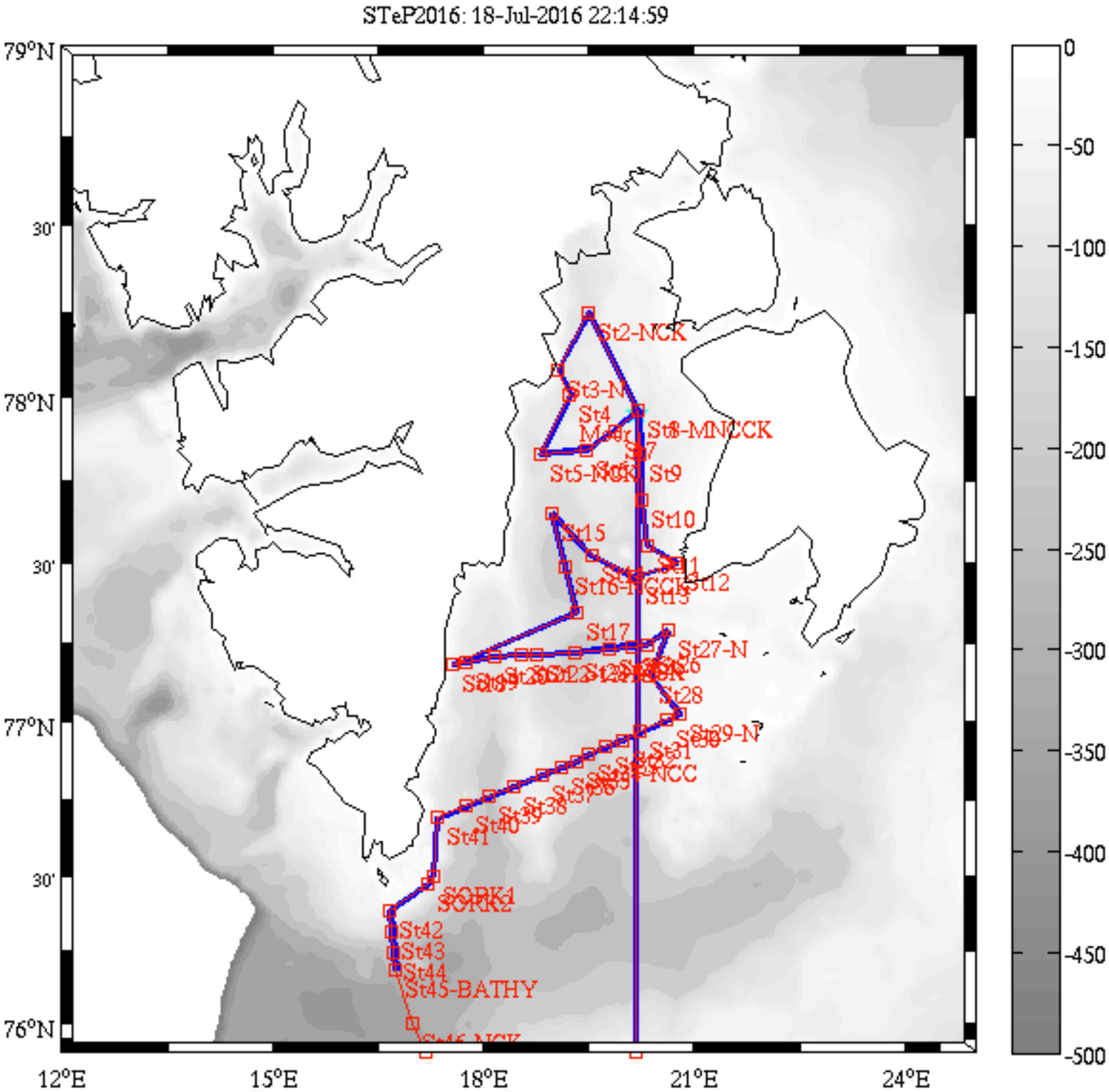


Figure 1. Map of the STEP cruise, position and number of the different stations

1.3 Scientific Participants

Table of participants

Surname	Name	Specialty	On board :	Institute	country
Michel	Elisabeth	Paleoceanography	Co-chief scientist , CTD, multicores, kullenberg	LSCE	France
Vivier	Frédéric	Physical Oceanography	Co-chief scientist, CTD, Mooring	LOCEAN	France
Lansard	Bruno	Chemical Oceanography	CTD, Multicores	LSCE	France
Boutin	Jacqueline	Physical Oceanography	CARIOCA, mooring, CTD	LOCEAN	France
Lourenço	Antonio	Physical Oceanography	Mooring, SCAMP	LOCEAN	France
Le Goff	Hervé	Physical Oceanography	ADCP, Mooring	LOCEAN	France
Vancoppenolle	Martin	Oceanography modelling	CTD, GHG	LOCEAN	France
Kerhervé	Philippe	Bio-geochemistry	Sediment trap, multicore	Perpignan University	France
Rousset	Clément	Oceanography modelling	CTD, Mooring, GHG	LOCEAN	France
Madec	Gurvan	Oceanography modelling	CTD, ADCP	LOCEAN	France
Cuypers	Yannis	Physical Oceanography	SCAMP	LOCEAN	France
Ofstad	Siri	Paleoceanography	Kullenberg, multinet	Tromsø University	Norway
Mc Govern	Maeve	Bio-geochemistry	Multicores	Tromsø University	Norway
Bombled	Bruno	Chemical Oceanography	Multicores	LSCE	France
Howa	Hélène	Planktic Foraminifera	Multinet, multitubes	Angers Uiversity	France
Meilland	Julie	Planktic foraminifer, carbon cycle	Multinet	Tromsø University	Norway
Dausse	Denis	Physical Oceanography	Mooring, CTD	LOCEAN	France
Crispi	Olivier	Bio-geochemistry	CTD, mooring (RAS500)	Perpignan University	France
Isguder	Gulay	Micro-paleontology	Multinet, multitube, CTD	LSCE	France
Guillaumin	Xavier	Artist	Outreach	Théâtre du grain	France
Vanderlinden	Fanny	Chemical Oceanography	CTD, GHG	Liege University	Belgium
Pang	Xiaolei	Paleoceanography	CTD, Multicore	LSCE	France


Antonio Lourenço


Bruno Bombled

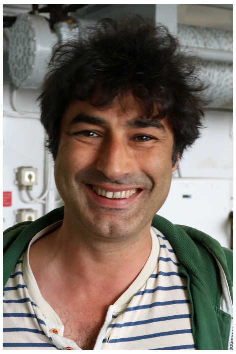

Bruno Lansard


Clément Rousset


Denis Dausse


Elisabeth Michel


Fanny Vanderlinden

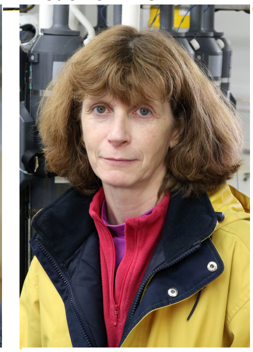

Frédéric Vivier


Gulay Isguder


Gurvan Madec


Hélène Howa


Hervé Legoff


Jacqueline Boutin


Julie Meilland


Maeve Mc Govern


Martin Vancoppenolle


Michel Boutbien


Olivier Crispi

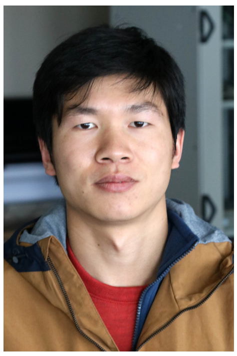

Philippe Kerhervé


Pierre Guyavarch


Serge Louzaouen


Siri Ofstad 1


Xavier Guillaumin


Xiaolei Pang


Yannis Cuypers

1.4 Time Log of the cruise

(local time GMT+2)
All time in GMT

11th July 2016

(GMT)	
06h15	Start of cruise , out of Tromsø, transit to Storfjørden
15h35	Test boat ADCP 150, ADCP 38 with sediment sounder, synchronous mode with ADCP lead
15h54	File ADCP 150001
16h33	End of test Files ADCP 150002, ADCP38001

12th July 2016

16h38	Start registering: ADCP 150 (leader), multibeam EM170, sediment echosounder

13th July 2016

07h39	Arrival **Station 1. 77°5 8.62'N, 20°13.54'E**
	sediment echosounder, EM170, ADCP 38k stopped
	No response of the mooring
08h30	ADCP150, EM170 on. Mooring detected 12kHh, grapnels
10h50	preparation
13h00	Starting grapnel operation
13h30	Mooring on board, full success
15h46	CTD (without water sampling), VMP
17h40	End of Station 1, transit to station 2
18h25	Arrival **Station 2. 78°14.99'N, 19°30.03'E**
19h15	CTD on board
19h25	VMP at sea
19h40	VMP on board
19h50	Multinet at sea
20h00	Multinet on board
20h17	Multinet at sea
21h05	Multinet on board
21h51	Multitube at sea
	Multitube on board**. STEP16_2_MC1**. **78°15'N, 19°30'E**

14th July 2016

0h55	Kullenberg at sea
01h06	Kullenberg triggering, **STEP16_2_K01. 78°15'N, 19°29.97'E**
01h31	End of station, transit to station 3
02h38	Arrival **Station 3. 78°05.16'N, 19°04.07'E**
	CTD, SCAMP
04h50	Start Multinet
05h33	End of station 3, transit to station 4
06h20	**Station 4. 78°00.51'N, 19°13.73'E**
06h34	CTD at sea
07h15	CTD on board, SCAMP
07h40	End of station 4, transit to station 5
08h55	**Station 5 77°49.8'N, 18°47.85'E**
09h00	CTD at sea
09h30	CTD on board, SCAMP
10h45	Multinet at sea
11h10	Multinet on board

12h00	Multicore at sea
12h15	Multicore on board, **STEP16_5_MC2**. **78°50'N, 18°48'E**
12h16	End of station 5, transit to station 6
13h18	**Station 6 77°50.63'N, 19°28.47'E**
13h28	CTD at sea
14h00	CTD on board, SCAMP
14h29	End of station 6, transit to station 7
15h12	**Station 7 77°54.18'N, 19°51.66'E**
15h15	CTD at sea
15h50	CTD on board, SCAMP
16h26	End of station 7, transit to station 8
16h40	**Station 8 77°57.83, 20°12.23'E**, start of bathymetric survey
18h10	Start of first mooring at sea
18h26	**Mooring 1 77°57.83'N, 20°12.24, 98 m** depth checked on multibeam
19h15	Start of second mooring at sea
19h50	**Mooring 2 77°57.77'N, 20°12.23'E 98 m** depth, checked on multibeam, ~150 m from mooring I
20h35	North to the moorings, Multinet at sea
20h45	Multinet on board
21h50	First Multicore at sea
22h10	Multicore on board, **STEP16_8_MC3**. **77°58.7'N, 20°14.5'E**
23h33	2nd Multicore on board, **STEP16_8_MC3b**. **77°58.7'N, 20°14.6'E**

15th July 2016

00h29	Kullenberg at sea
00h37	Kullenberg triggering, **STEP16_8_K02. 77°58.54'N, 20°14.25'E**
01h16	Transit for CTD closer to moorings
01h40	CTD at sea
02h00	CTD on board, SCAMP
03h11	End of station 8, transit to station 9
04h06	**Station 9 77°50.03'N, 20°13.72'E**
04h27	CTD at sea
04h50	CTD on board, SCAMP
04h24	End of station 9, transit to station 10
06h27	**Station 10 77°41.58'N, 20°15.52'E**
06h35	CTD at sea
07h05	CTD on board, SCAMP
07h50	End of station 10, transit to station 11
08h55	**Station 11 77°33.42'N, 20°19.72'E**
09h05	CTD at sea
09h30	CTD on board
09h42	SCAMP at sea
10h03	SCAMP on board
10h06	End of station 11, transit to station 12
10h54	**Station 12 77°31.00'N, 20°44.92'E**
10h55	CTD at sea
11h15	CTD on board, SCAMP
11h38	End of station 12, transit to station 13
12h40	**Station 13 77°27.38'N, 20°09.90'E**
12h42	CTD at sea
13h10	CTD on board, SCAMP
13h40	End of station 13, transit to station 14
14h34	**Station 14 77°31.41'N, 19°33.36'E**

14h37	CTD at sea
15h05	CTD on board, SCAMP
15h48	End of station 14, transit to station 15
16h55	**Station 15 77°39.29'N, 18°58.87'E**
17h02	CTD at sea
17h25	CTD on board, SCAMP
17h58	End of station 15, transit to station 16
19h02	**Station 16 77°29.27'N, 19°10.55'E**
19h08	CTD at sea
19h45	CTD on board, SCAMP
20h33	SCAMP on board
20h40	Multinet at sea
21h08	Multinet on board
21h48	First Multicore at sea
22h20	Multicore on board, **STEP16_16_MC4**. **77°29.3'N, 19°10.4'E**
23h13	2nd Multicore at sea
23h40	2nd Multicore on board, **STEP16_16_MC4b**. **77°29.3'N, 19°10.4'E**

16th July 2016

00h30	Kullenberg at sea
00h44	Kullenberg triggering, **STEP16_16_K03. 77°29.21'N, 19°10.64'E**
01h15	
02h11	End of station 16, transit to station 17
02h19	**Station 17 77°20.96'N, 19°18.88'E**
02h45	CTD at sea
03h35	CTD on board, SCAMP
05h57	End of station 17, transit to station 18
06h00	**Station 18 77°11.06'N, 17°33.71'E**
06h20	CTD at sea
06h25	CTD on board, SCAMP
06h55	End of station 18, transit to station 19
07h00	**Station 19 77°11.54N, 17°45.46'E**
07h30	SCAMP at sea
07h57	CTD at sea
08h40	End of station 19, transit to station 20
09h03	**Station 20 77°12.50'N, 18°09.73'E**
09h30	CTD at sea
10h06	CTD on board, SCAMP
10h43	End of station 20, transit to station 21
10h49	**Station 21 77°12.89'N, 18°32.61'E**
11h07	CTD at sea
11h33	CTD on board, SCAMP
11h53	End of station 21, transit to station 22
12h04	**Station 22 77°12.86'N, 18°45.92'E**
12h28	CTD 22A at sea
13h00	CTD 22A on board, SCAMP
13h24	SCAMP on board
13h45	CTD 22B at sea
14h20	CTD 22B on board, SCAMP modified
14h37	CTD 22C at sea
14h46	CTD 22C on board
15h00	SCAMP at sea
15h06	SCAMP on board

15h23	CTD 22D at sea
15h48	CTD 22D on board
16h02	SCAMP on board
16h20	CTD 22E at sea
16h28	CTD 22E on board
16h43	SCAMP at sea
17h03	SCAMP on board
17h25	CTD 22F at sea
17h30	CTD 22F on board
17h51	SCAMP at sea
18h07	SCAMP on board
18h25	CTD 22G at sea
18h57	CTD 22G on board
19h05	SCAMP on board
19h20	CTD 22H at sea
19h30	CTD 22H on board
19h50	SCAMP at sea
20h00	SCAMP on board
20h20	CTD 22I at sea
20h20	CTD 22I on board
20h45	SCAMP at sea
21h15	SCAMP on board
21h30	CTD 22J at sea
21h37	CTD 22J on board
21h55	SCAMP at sea
22h04	SCAMP on board
22h20	CTD 22K at sea
22h28	CTD 22K on board
23h00	SCAMP at sea
23h14	CTD 22L at sea
23h29	CTD 22L on board
23h47	SCAMP at sea
23h56	SCAMP on board
	CTD 22M at sea

17th July 2016

00h09	CTD 22M on board
00h30	SCAMP at sea
00h48	SCAMP on board
01h05	CTD 22N at sea
01h21	CTD 22N on board
01h45	SCAMP on board
01h49	End of station 22, transit to station 23
02h37	**Station 23 77°13.23'N, 19°18.06'E**
02h40	CTD at sea
03h10	CTD on board
03h29	SCAMP at sea, SCAMP wet ->repair
	Electrocable connexion for multinet broken, ->repair
04h30	Multicore at sea
05h00	Multicore on board, **STEP16_23_MC5 77°13.2'N, 19°17.9'E**
06h18	Kullenberg at sea
06h54	Kullenberg triggering **STEP16_23_K04 77°13.2'N, 19°17.9'E**
07h55	Multinet at sea
08h10	Multinet on board

08h17	End of station 23, transit to station 24
09h09	**Station 24 77°14.09'N, 19°46.70'E**
09h10	CTD at sea
09h48	CTD on board
09h55	End of station 24, transit to station 25
10h31	**Station 25 77°14.45'N, 20°06.98'E**
10h37	CTD at sea
11h01	CTD on board
11h04	End of station 25, transit to station 26
11h40	**Station 26 77°14.67'N, 20°19.84'E**
11h42	CTD at sea
12h00	CTD on board
12h04	End of station 26, transit to station 27
12h46	**Station 27 77°17.53'N, 20°37.83'E**
12h52	CTD at sea
13h14	CTD on board
13h45	Multinet a sea
14h05	Multinet on board
14h25	SCAMP at sea
14h40	SCAMP on board
14h42	End of station 27, transit to station 28
15h40	**Station 28 77°09.05'N, 20°22.35'E**
15h45	CTD at sea
16h13	SCAMP at sea
16h28	SCAMP on board
16h31	End of station 28, transit to station 29
16h34	**Station 29 77°01.61'N, 20°47.86'E**
17h36	CTD at sea
17h52	CTD on board
18h09	SCAMP at sea
18h20	2nd SCAMP at sea
18h35	SCAMP on board
18h50	Multinet a sea
19h00	Multinet on board
19h01	End of station 29, transit to station 30
19h30	**Station 30 77°00.44'N, 20°35.52'E**
19h33	CTD at sea
19h50	CTD on board
20h01	SCAMP at sea
20h16	SCAMP on board
20h17	End of station 30, transit to station 31
20h57	**Station 31 76°58.20'N, 20°13.36'E**
21h02	CTD at sea
21h18	CTD on board
21h38	SCAMP at sea
21h58	SCAMP on board
21h59	End of station 31, transit to station 32
22h38	**Station 32 76°56.21'N, 19°58.13'E**
22h41	CTD at sea
22h59	CTD on board
23h22	SCAMP at sea
23h24	SCAMP on board
23h25	End of station 32, transit to station 33
23h56	**Station 33 76°55.20'N, 19°43.56'E**

18th July 2016

00h04	CTD at sea
00h19	CTD on board, too much wind for SCAMP
00h23	End of station 33, transit to station 34
00h58	**Station 34 76°53.86'N, 19°29.99'E**
01h04	CTD at sea
01h36	CTD on board, wind>22nds, no SCAMP
02h02	Multinet a sea
02h12	Multinet on board
02h28	Less wind, SCAMP at sea
02h50	SCAMP on board
03h34	First Multicore at sea
03h51	Strong swell when Multicore on the sediment
04h10	Multicore did not trigger
04h30	Second multicore at sea
04h52	Multicore on sediment floor
05h08	Multicore on board, **STEP16_34_MC6 76°53.87'N, 19°30.25'E**
05h55	Third Multicore at sea
06h15	Multicore on the sediment
06h25	Multicore on board, **STEP16_34_MC6 76°53.89'N, 19°30.32'E**
06h33	End of station 34, transit to station 35
07h01	**Station 35 76°52.50'N, 19°20.69'E**
07h11	CTD at sea
07h35	CTD on board, too much wind for SCAMP
07h37	End of station 35, transit to station 36
08h09	**Station 36 76°51.36'N, 19°07.15'E**
08h12	CTD at sea
08h23	CTD on board, too much wind for SCAMP
08h27	End of station 36, transit to station 37
09h05	**Station 37 76°49.80'N, 18°50.40'E**
09h09	CTD at sea
09h20	CTD on board, too much wind for SCAMP
09h23	End of station 37, transit to station 38
10h05	**Station 38 76°47.64'N, 18°25.94'E**
10h13	CTD at sea
10h42	CTD on board, too much wind for SCAMP
10h45	End of station 38, transit to station 39
11h21	**Station 39 76°45.51'N, 18°04.56'E**
11h25	CTD at sea
11h50	CTD on board, SCAMP
12h45	End of station 39, transit to station 40
13h00	**Station 40 76°43.74'N, 17°44.78'E**
13h08	CTD at sea
13h27	CTD on board,
13h33	End of station 40, transit to station 41
14h15	**Station 41 76°41.44'N, 17°20.25'E**
14h17	CTD at sea
14h42	CTD on board,
14h45	End of station 41, transit to station 42
16h45	**Station 42 76°23.04'N, 16°40.75 'E**
16h46	CTD at sea
17h08	CTD on board,
17h14	End of station 42, transit to station 43

17h50	**Station 43 76°18.82'N, 16°41.99'E**
17h52	CTD at sea
18h06	CTD on board,
18h14	End of station 43, transit to station 44
18h43	**Station 44 76°14.59'N, 16°43.19 'E**
18h45	CTD at sea
19h06	CTD on board,
19h08	End of station 44, transit to station 45
19h38	**Station 45 76°11.01'N, 16°44.71'E**
19h45	CTD at sea
20h18	CTD on board,
20h20	End of station 45, transit to station 46, search for sediment
23h38	**Station 46 76°00.92'N, 17°03.33'E**
23h43	CTD at sea

<u>19th July 2016</u>

00h28	CTD on board
00h39	First Multinet a sea
01h05	Multinet on board
01h20	2nd Multinet at sea
01h35	Multinet on board
02h10	Multicore at sea
02h27	Multicore on sediment floor
02h58	Multicore on board, **STEP16_46_MC7 76°00.92'N, 17°03.39'E**
	Kullenberg at sea
05h34	Kullenberg triggering
	Kullenberg bended, **STEP16_46_K5 76°00.94'N, 17°03.34'E**
08h35	End of station 46, transit to Tromsø

<u>20th July 2016</u>

Transit to Tromsø
Arrival Tromsø

1.5 Operations and summary tables

Following are short reports/tables for the different operations

1.5.1. Moorings

On the 13th of July, the mooring line, deployed in August 2013, has been successfully retrieved. This line (see schematics) has recorded temperature and salinity evolution within the Polynya for 3 years.

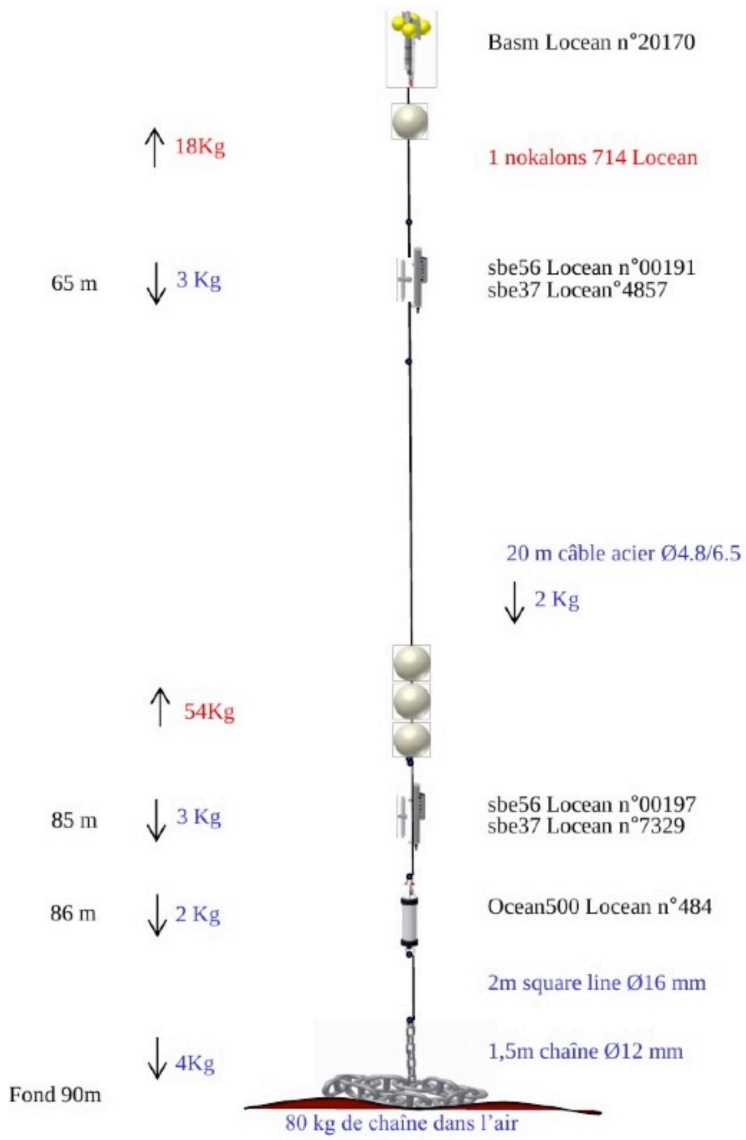


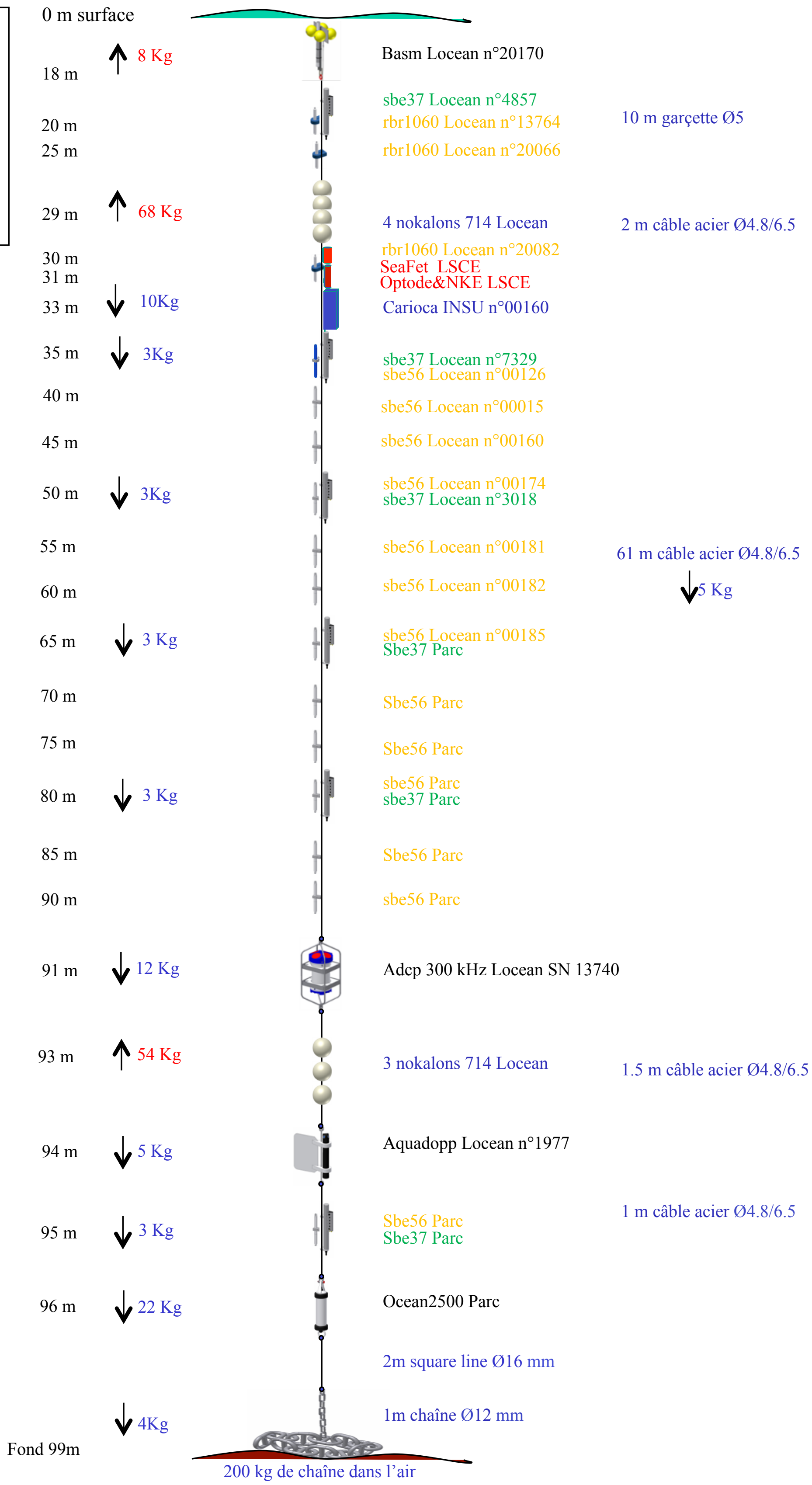
Figure 2. Schematics of the mooring deployed the 23/08/2013

On the 14th of July, two mooring line have been deployed to monitor year round physical and chemical waters characteristics in the polynya of the Storfjorden. The second mooring line is equipped with an autonomous water sampling and a sediment trap (see schematics).

Step M1
Storfjord
Depth : 98 m

Deployed : 14/07/2016
Time :
Lat: 77°57.83'N
Long: 020°12.24'E

Recovered :



Step M2
Storfjord
Depth : 98 m

Deployed : 14/07/2016
Time :
Lat: 77°57.77'N
Long: 020°12.23'E

Recovered :

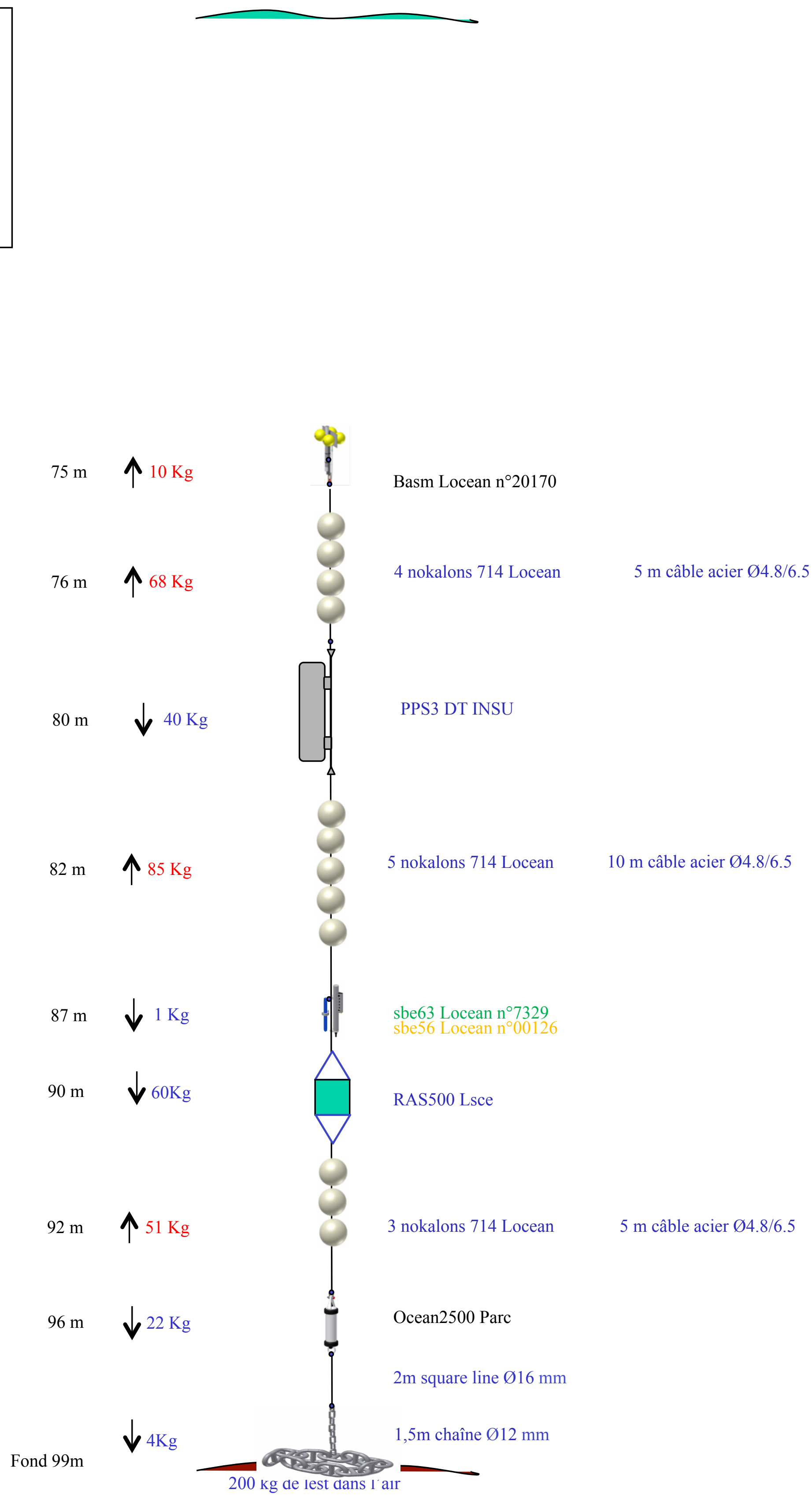


Figure 3. Schematics of the two mooring lines deployed the 14/07/2016

1.5.2 LADCP and SADCP data (Lowered /Shipborne Acoustic Doppler Current Profiler).

Current profiles from LADCP/SADCP during the cruise. (H LeGoff, LOCEAN). A preliminary processing of SADCP and LADCP data was carried out during the cruise. The onboard instrumentation is first introduced together with the processing methodology; results are presented in the form of graphics and their statistical quality is discussed. A provisional dataset of the currents in Storfjorden based on the 150 kHz LADCP and SADCP is provided. Its quality will have to be refined during the post-processing phase back at the lab. The 2 transits Tromsø-Spitzbergen remain to be processed, including profiles from the 38kHz SADCP. The near real time processing of LADCP and SADCP data has enabled us to track, day by day, the quality of data acquisition, to detect (and solve) some instrumental issues, and to provide a provisional dataset for the Storfjorden stations.

<u>I- Instrumentation and processing chain</u>

Two 300kHz ADCPs (down and up-looking) are deployed on the 24 bottle CTD – Rosette. The ship is equipped with two ADCP (SADCP) OS 150 et OS38 that were continuously working on transit (figure 4).

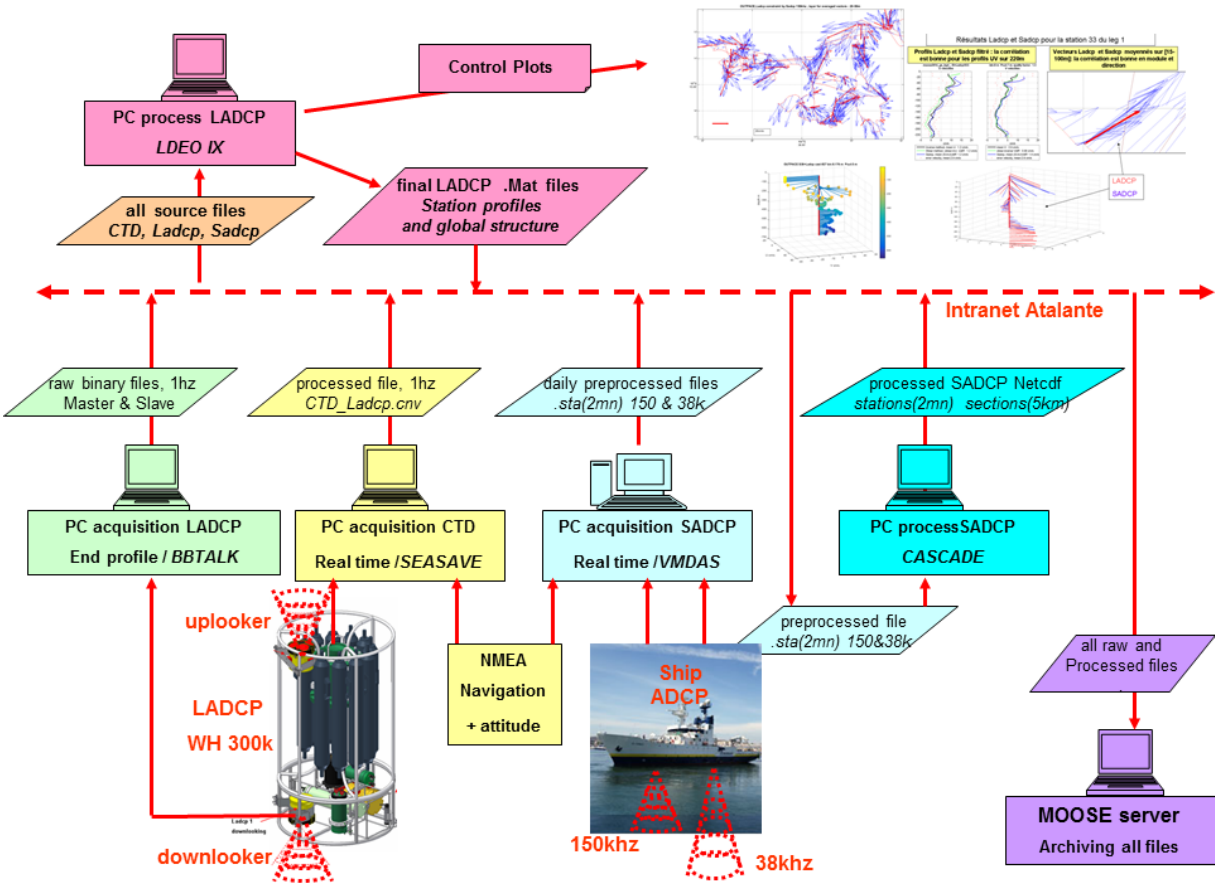


Figure 4. Schematics of ADCP processing

Onboard processing : After each CTD/LADCP station, LADCP profiles are processed with the LDEO IX program [ref 2], to validate the proper functioning of instruments. Raw SADCP files from the past 24h are provided each morning by the electronician from the board. Those are processed in NRT with the Cascade V7 [ref 1] program. The SADCP (150 kHz) profile at each station is used for comparison with LADCP profiles and upon this comparison, the SADCP constraint may or may not be applied on LADCP profiles.

II- Presentation of the results in Storfjorden

Figures 5 and 6 present final results of the processing, based on 150kHz LADCP and SADCP :

- SADCP vectors averaged in successive 30m-thick layers between the surface and 120m, at a 2km step along the ship track.

-The position of CTD/LADCP stations together with LADCP vectors constrained by SADCP data and averaged in the same layers. Please note that no tide correction was applied to the dataset. The tide vector obtained by the barotropic model (Tpxo7) along the ship track is displayed in Fig 3; the amplitude is small in the northern part of Storfjorden but gradually increases to the South, towards the Barents Sea. The anticlockwise general circulation in the fjord distinctly appears in the surface layer. The strong coastal current at the western boundary is apparent. As discussed in the appendix, LADCP data processing for shallow regions (bathymetry < 50m) is not satisfactory at the moment. Optimal parameters for the inversion process, which enable to apply the SADCP constraint on LADCP profiles, remain to be tuned. An accurate bathymetry is also needed in the processing (e.g. ETOPO1).

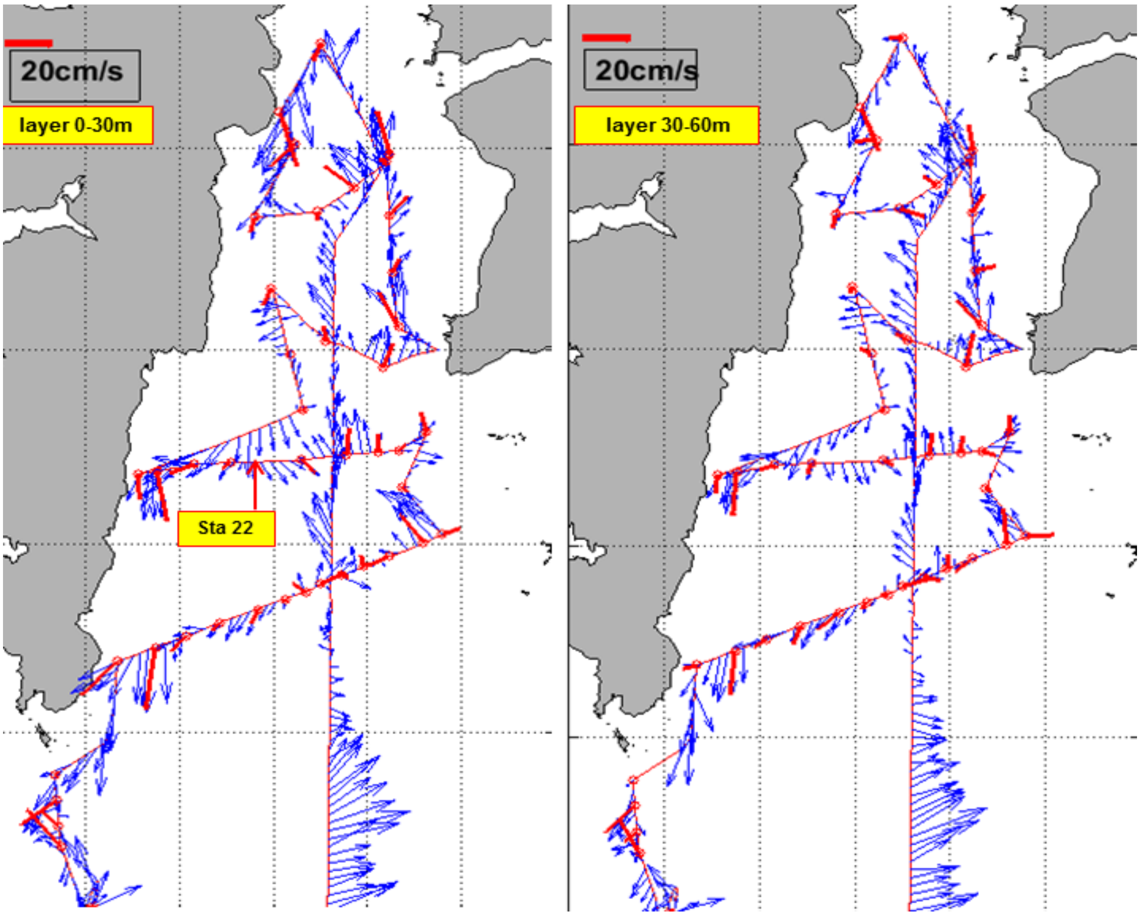


Figure 5 SADCP and LADCP vectors at each station averaged in the 0-30m (left) and 30-60m (right) layers

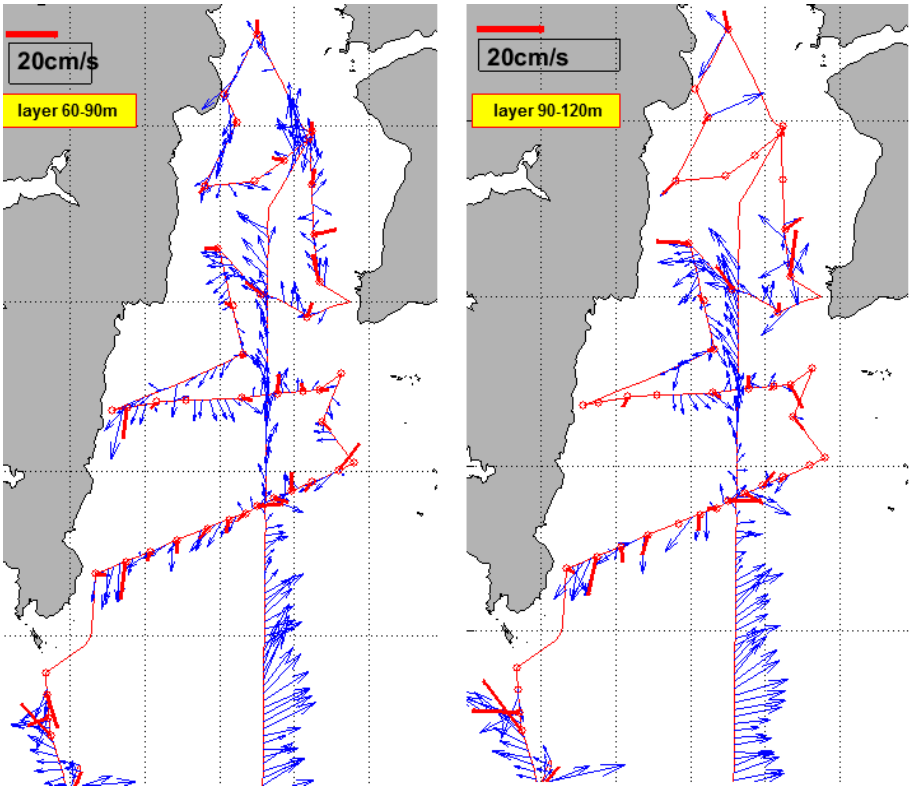


Figure 6 : SADCP and LADCP vectors averaged at each station in the 60-90m and 90-120m layers, respectively.

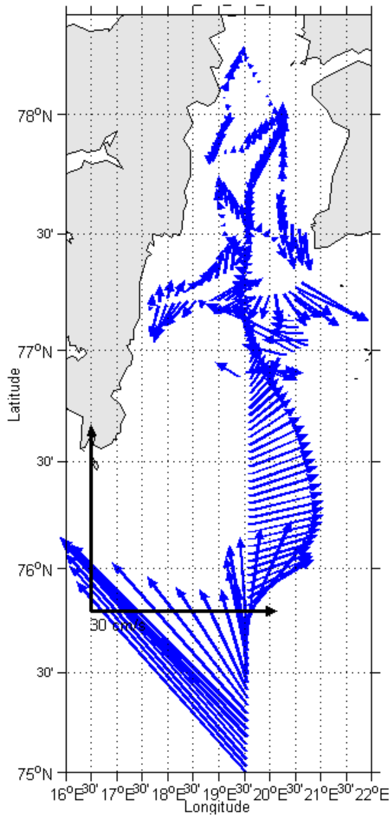
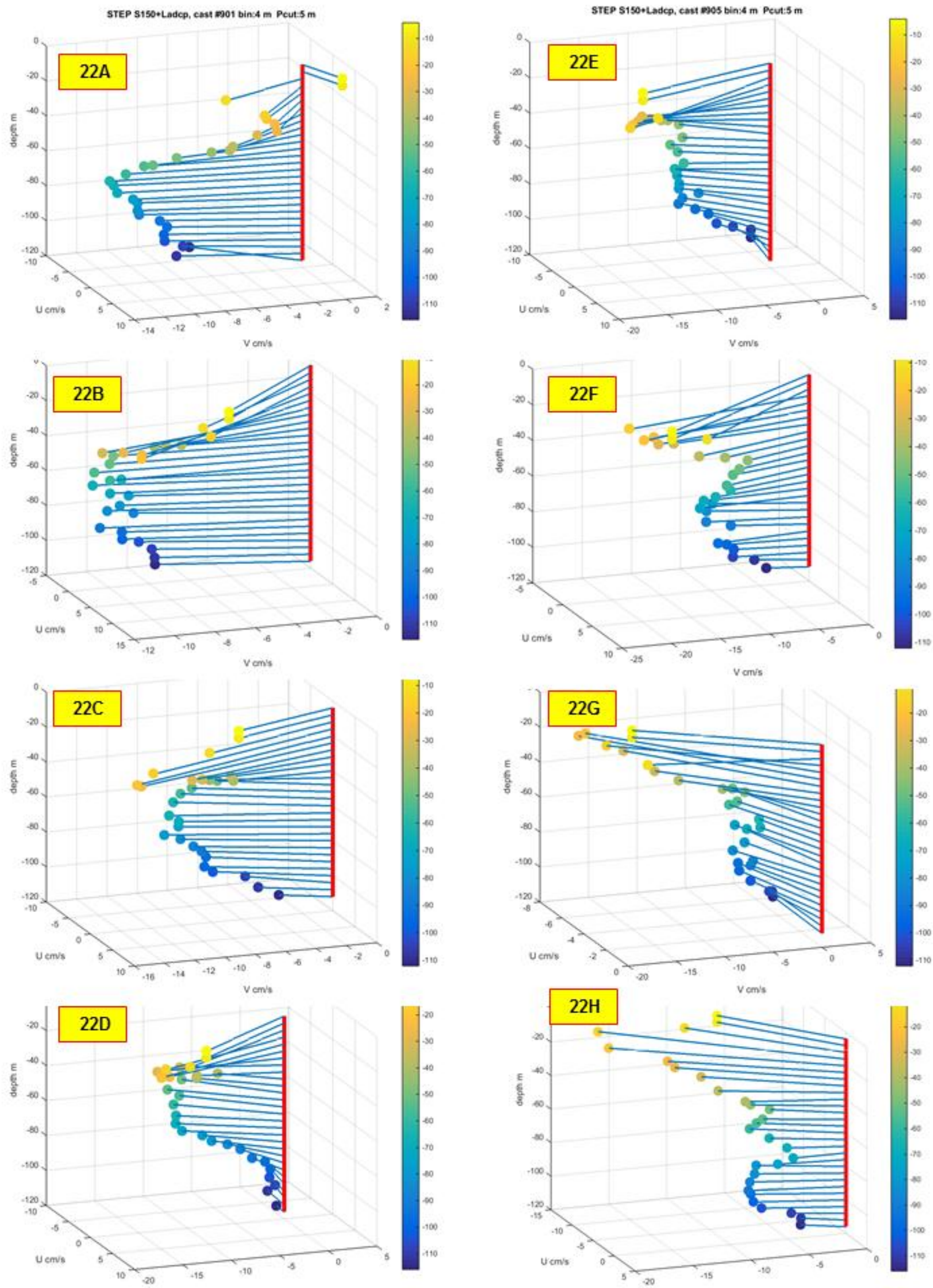


Figure 7 : Barotropic tide velocity vector from the Tpxo7 model along the vessel track.

III- Results from the « long » station (22A through 22N)

A fixed point station was held during 14h (st 22 A-22N) with repeated CTD/LADCP casts . The 150 kHz SADCP was acquiring data during the entire duration of station 22 Current profiles thus collected are displayed as 3D view in Fig 8. The median of the error on horizontal velocities (4.9 cm/s) is correct according to the criteria discussed in the appendix. However the constraint provided by the SADCP is not optimal (offsets are important) ; the processing of this long station therefore needs to be replayed.


STEP S150+Ladcp, cast #901 bin:4 m Pcut:5 m
22A
STEP S150+Ladcp, cast #905 bin:4 m Pcut:5 m
22E
22B
22F
22C
22G
22D
22H
depth m
U cm/s
V cm/s

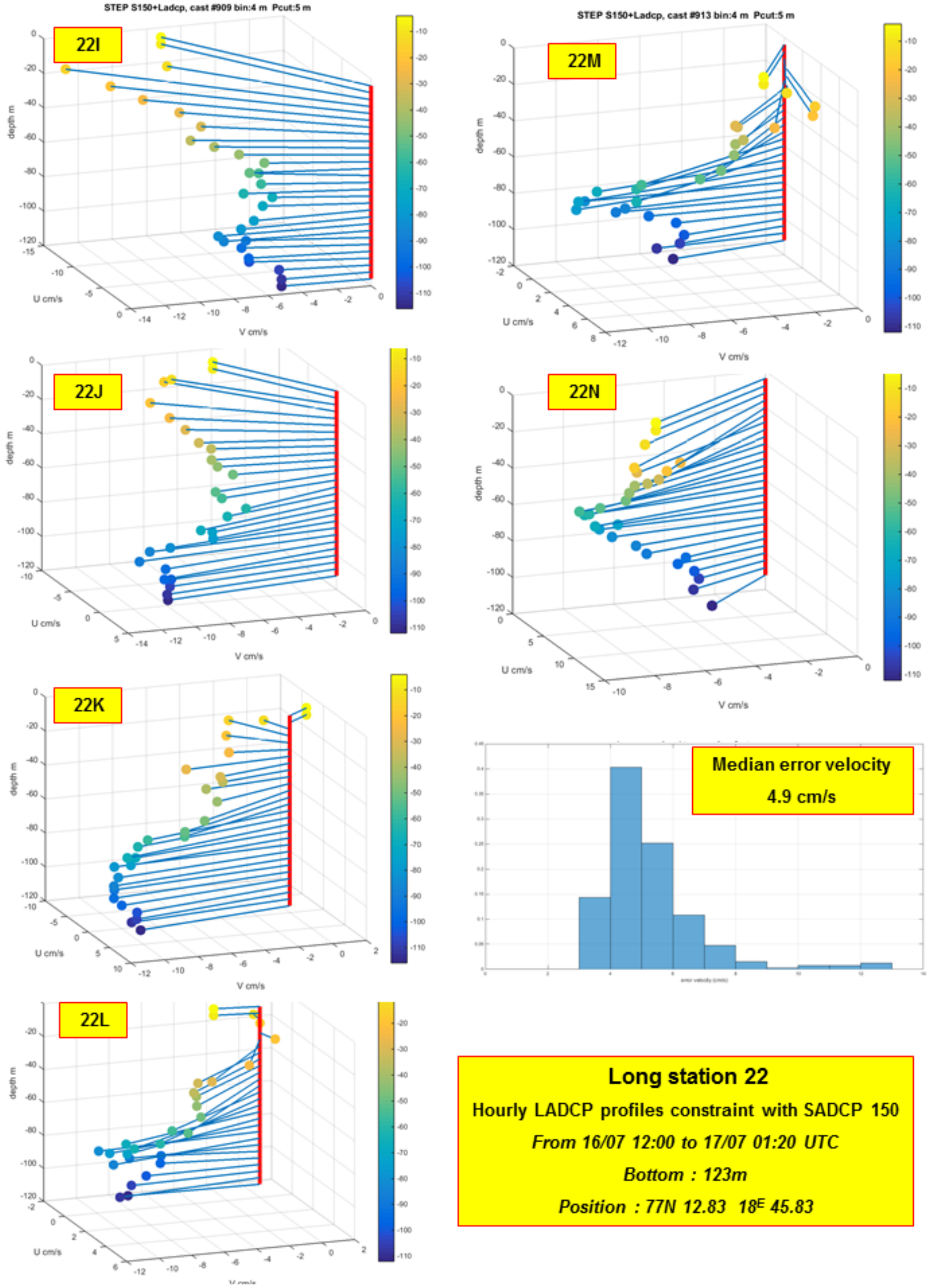


Figure 8 : Series of 14 LADCP profiles from the « long » station (st 22A through 22N)

1.5.3. VMP and SCAMP operations

On the two first stations, the VMP was deployed. On the following stations SCAMP profiles were done. For stations 23 to 26 there has been no SCAMP profile (it was on repair) and for stations 33 and 35 to 46 there was too much wind (>20nds) to try SCAMP profiles.

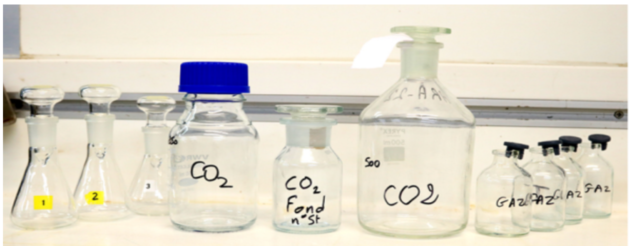
SCAMP LOG							
Station #	Profile #	# casts	file	Lat	Lon	depth	Remarque (meteo etc..)
3	1	2	14JUL2016 043250	78°04.199	19°04.073	49m	tirage sur ligne 2nd profil
4	2	1	14JUL2016 071819	78°.00.51	19°13.73	103m	
5	3	1	14JUL2016 100113	77°49.81	18°47.85	117,5m	
6	4	1	14JUL2016 141135	77.50.632	19.28.741		
7	5	1	14JUL2016 154730	77.54.174	19.51.586	79m	
8	6	1	15JUL2016 024258	77°57.952	20°12.177	99m	touche fond?
9	7	1	15JUL2016 050141	77°50.03	20°13.179	87m	
10	8	1	15JUL2016 072829	77°41.581	20°15.508	120m	
11	9	1	15JUL2016 093939	77°33.420	20°19.722	125m	
12	10	1	15JUL2016 112218	77°30.995	20 42.200	47m	
13	11	1	15JUL2016 131747	77°27.331	20°10.10	120 m	
14	12	1	15JUL2016 151948	77°31.410	19°33.433	157 m	
15	13	1	15JUL2016 173035	77°39.297	18°58.811	127 m	
16	14	1	15JUL2016 201358	77°29.278	19°10.316	180m	
17	15	1	16JUL2016 031127	77°20.93	19°.19.06	146m	
19	16	1	16JUL2016 070244	77°11.503	17°45.594	84m	
20	17	1	16JUL2016 093929	77°12.532	18°13.542	107m	
21	18	1	16JUL2016 111948	77°11.027	17°.33.654	63m (50m??)	déploie, nœud en surface, mise à bord, puis deploie 5'30''
22	19	1	16JUL2016 123720	77°12.860	18°45.960	122.9m	
22	20	1	16JUL2016 134841	77°12.860	18°45.960	122.9m	
22	21	1	16JUL2016 135721	77°12.860	18°45.960	122.9m	
22	22	1	16JUL2016 144615	77°12.860	18°45.960	122.9m	
22D	23	1	16JUL2016 152832	77°12.860	18°45.960	122.9m	Concerto On
22E	24	1	16JUL2016 162436	77°12.860	18°45.960	122.9m	
22F	25	1	16JUL2016 173025	77°12.860	18°45.960	122.9m	
22G	26	1	16JUL2016 183523	77°12.860	18°45.960	122.9m	
22H	27	1	16JUL2016 192725	77°12.860	18°45.960	122.9m	
22I	28	1	16JUL2016 202241	77°12.860	18°45.960	122.9m	capteur AccCT marche plus sur C (cassé)
22J	29	1	16JUL2016 213622	77°12.860	18°45.960	122.9m	
22K	30	1	16JUL2016 223025	77°12.860	18°45.960	122.9m	
22L	31	1	16JUL2016 232544	77°12.860	18°45.960	122.9m	
22M	32	1	17JUL2016 002557	77°12.860	18°45.960	122.9m	
22N	33	1	17JUL2016 012640	77°12.860	18°45.960	122.9m	scamp innondé rincage séchage changement capteur fastT0

23	No scamp					171 m	Scamp wet, no profile obtained
28	35	1	17JUL2016 161148	77°09.57	20°22.348	108.5m	
29	36	1	17JUL2016 180852	77°01.592	20°.47.902	46m	
30	37	1	17JUL2016 200042	77°00.413	20°.35.69	71m	(vent plus fort ~20 nœuds) pas de concerto?
31	38	1	17JUL2016 213845	76°58.205	20°13.544	122m	pas de concerto?
32	39	1	17JUL2016 230507	76°53.881	19°30.324	156.7m	
34	No scamp					155.6 m	concerto seulement pas de scamp

1.5.4 Water profile and sampling: CTD and GHG, thermosalinometer calibrations

The CTD rosette bottles have been sampled for oxygen, pH, water carbon chemistry, water oxygen and DIC carbon isotopes, GHG (CH_4 and isotopes, and N_2O) and volatile organic compound, Chlorophyll, nutrients and for salinity control. The samples for GHG and DIC isotope were poisoned with $HgCl_2$. (sea picture for the conditioning). Between 2 to 3 litres were filtered with 0.45µ filters that were frozen for future chlorophyll measurements. Water samples for nutrients were also frozen at -80°C.

The following table indicates the different sampling at each station.



	empoisonné HgCl2													
O2	CO2			GAZ		13C		18O		nut	Chloro	Salinity	pH
3 x 60ml	250 ml	fond 100 ml	500 ml	4 x 60 ml	250 ml	10 ml	30 ml	10 ml	30 ml	80 ml	2 btl 1,5l	125 ml	50 ml
3 flac Flac déjà n°	Flac déjà n°	n° station	Flac déjà n°	*4 flac*			*verre brun*			Flac déjà n°	Flac déjà n°	Flac déjà n°	Flac déjà n°
indiquer le n°flac sur feuille prélèvement				*Marquer Btle: STEP16-n°station-n°Niskin*						*indiquer le n°flac sur feuille prélèvement*			

		O_2	CO_2			GAH	N_20	^{13}C		^{18}O		nut	Chlor	sal	pH
station	**depth**		v250ml	fond	SNAPO	4x v60ml	v250ml	v10ml	v30ml	v10ml	v30ml	p80ml	x 2btl	v125ml	P50ml
N°	**m**				n°							n°	n°	n°	n°
2	**109**	x	x	x		x	x	x		x		x		x	x
3	**49**	x	x			x	x							x	x
4	**103**		x											x	
5	**118**	x	x	x		x		x		x		x		x	x
6	**67**		x												
7	**79**		x											x	
8	**99**	x	x	x	x	x	x	x	x	x	x	x		x	x
9	**87**		x											x	
10	**120**		x			x									
11	**125**		x												
12	**47**		x			x	x								

13	**135**		x												
14	**157**		x											x	
15	**128**		x											x	
16	**194**	x	x	x	x	x	x	x	x	x	x	x	x	x	x
17	**146**		x											x	
18	**49**		x			x	x								
19	**84**		x												
20	**108**		x											x	
21	**61**		x												
22A	**123**		x		x	x	x							x	
23	**171**	x	x	x	x	x	x	x	x	x	x	x	x	x	x
24	**126**		x												
25	**147**		x												
26	**105**		x												
27	**50**		x												
28	**109**		x										x		
29	**46**		x			x	x					x			
30	**74**		x												
31	**123**		x												
32	**154**														
33	**151**														
34	**156**	x	x	x	x	x	x	x	x	x	x	x	x	x	x
35	**155**														
36	**122**														
37	**90**														
38	**99**		x									x			
39	**205**														
40	**162**														
41	**122**														
42	**34**		x									x			x
43	**89**														
44	**238**														
45	**311**													x	
46	**322**	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Water samples have also been sampled close to the SCAMP or the boat TSG for future comparison. Those samples are indicated in the following table.

#canette	date	heure TU	lat	lon	Tcuv °C)	Tship (°C)	S	Commentaires
224	14/07/16	02:11	78°08.700	19°13.911		3.8		Prélèvement TSG
223	14/07/16	15:53	77°54.202	19°51.636		4.3		Prélèvement TSG
232	15/07/16	05:30	77°50.00	20°13.550	5.25	4.83	33.811	Prélèvement TSG
240	15/07/16	15:34	77°31.517	19°33.263	5.043	4.615	34.445	Prélèvement TSG
103	16/07/16	10:00	77°12.523	18°10.057	4.363	3.79	34.446	Prélèvement seau à côté du SCAMP -
104	16/07/16	10:00	77°12.523	18°10.057	4.363	3.79	34.446	Prélèvement seau à côté du SCAMP
102	16/07/16	10:00	77°12.523	18°10.057	4.363	3.79	34.446	Prélèvement TSG - Station 20
111	16/07/16	12:43	77°12.891	18°46.070	3.891	3.438	34.504	Prélèvement seau à côté du SCAMP
112	16/07/16	12:43	77°12.891	18°46.070	3.891	3.438	34.504	Prélèvement seau à côté du SCAMP
110	16/07/16	12:43	77°12.891	18°46.070	3.891	3.438	34.504	Prélèvement TSG - Station 22A
108	16/07/16	15:43	77°12.795	18°45.982	4.635	4.094	34.498	Prélèvement seau à coté bathysonde
109	16/07/16	15:43	77°12.795	18°45.982	4.635	4.094	34.498	Prélèvement seau à coté bathysonde-

105	18/07/16	02:43	76°53.910	19°30.557	4.75	4.247	34.465	Prélèvement TSG
117	19/07/16	03:01	76°00.912	17°03.356	6.95	6.516	35.052	Prélèvement TSG
70	20/07/16	08:13	73°03.12	19°12.972	9.068	8.632	34.968	Prélèvement TSG
67	20/07/16	18:13	71°43.618	18°19.436	10.075	9.613	34.613	Prélèvement TSG
64	20/07/16	21:36	71°21.114	19°51.306	10.18	9.742	34.738	Prélèvement TSG

Data treatment of the CTD data has taken into account the fact that T and S sensors were not correctly connected on the CTD. Salinity has been measured on board on 33 discrete samples taken from the rosette bottles with an autosalinometer. Following is the comparison between the thermosalinometer and the CTD salinity measurements.

Assessment of the accuracy of salinity data from the bathysonde.

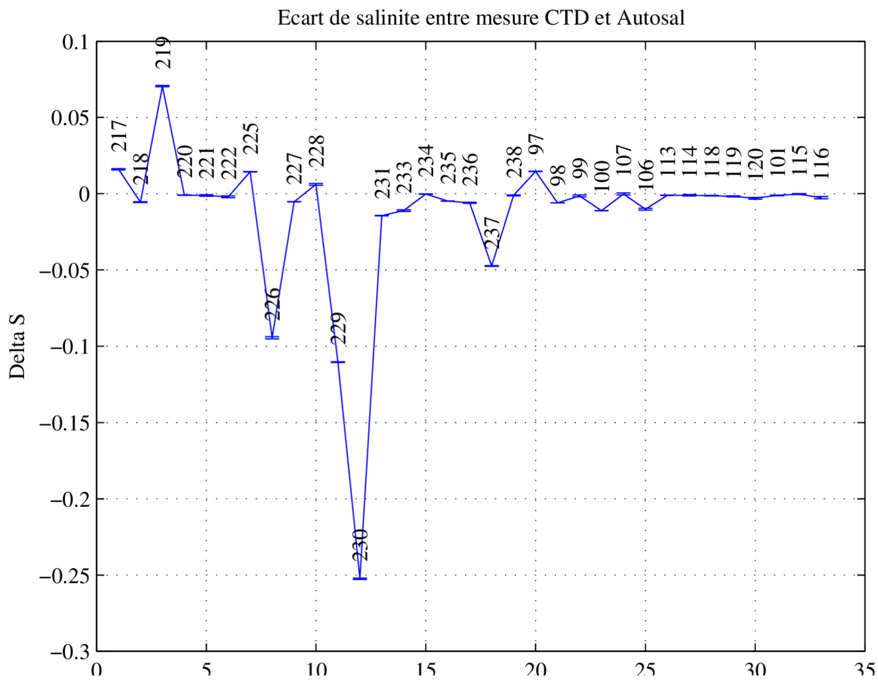
A total of 33 samples were collected on the rosette for salinity calibration ; those were regularly spaced in time between stations 2 et 46. (cf table CTD stations)

The 2 salinity sensors of the bathysonde deliver consistent data for the 33 points measured, the observed differences are consistent with the expected accuracy : the salinity bias (sal0-sal1) is -3.8 1e-4 and the RMS error is 0.003. Comparisons with Autosal measurements will therefore only be carried out for only one sensor of the bathysonde (sal0).

The difference between Autosal and CTD measurements for the all samples is sometimes large, reaching 0.05, and even 0.25 (figure 9), with therefore relatively poor statistics (bias -0.0145, error 0.052 RMS). However, largest errors correspond to samples taken near the surface, where a larger variability is expected. On exception to this is the sample taken near the bottom for station 3, at a depth of 43m (can #219).

After removal of the most problematic samples (219 226 229 230 237), statistics improve considerably (bias -0,0015, error 0,0072 RMS)(figure 10).

Largest errors correspond to samples taken in the surface layer, and also in the bottom layer (a



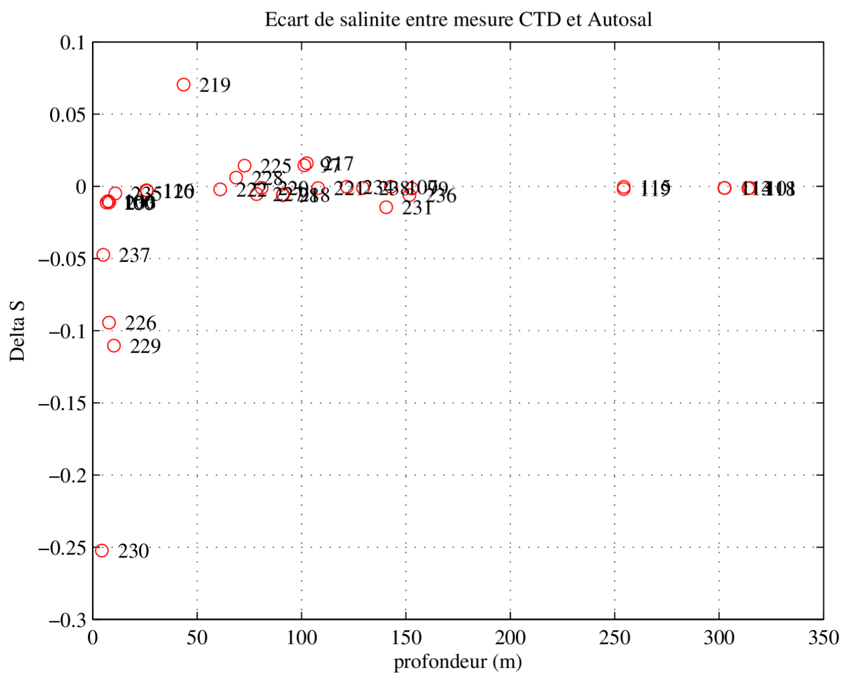


Figure 9 salinity difference betwwen CTD and Autosal measurements bottom boundary layer is clearly observed for some stations). The cleanest comparison is probably to be expected for the very homogeneous NAW layer that spans almost the entire depth of the water column for stations 45 and 46.

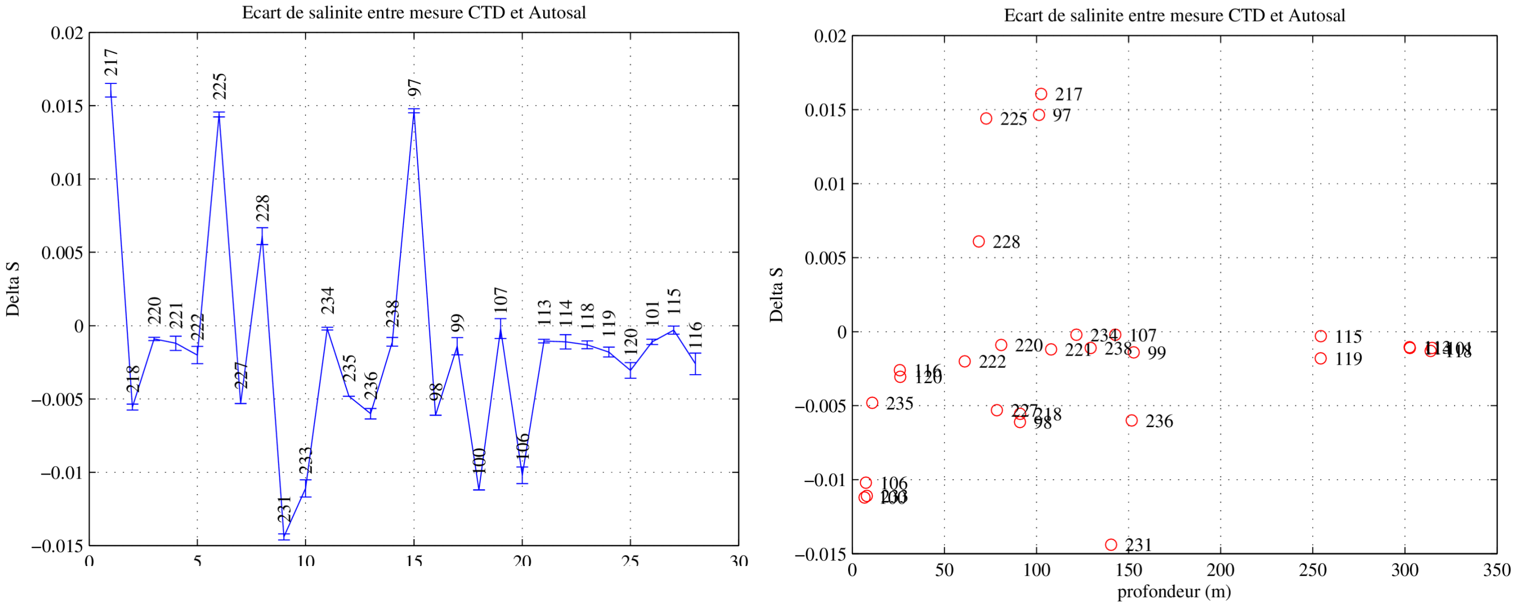


Figure 10. Salinity difference betwwen CTD and Autosal measurements after excluding 5 problematic samples

Retaining only these 8 measurements, we get a bias of -0.0015 and a RMS error of 9x1e-4 RMS, totally consistent with the sensor accuracy. <u>There is therefore no need for a correction to CTD data regarding salinity</u> (except perhaps for the small low bias of 1.5/1000 that could be corrected).

Assessment of oxygen data from the bathysonde.

O_2 measurements from the rosette are performed with a Seabird SBE43 sensor (membrane). These are compared with measurements obtained with the Winkler method (Bruno Bumbled, LSCE).

Measurements from the Winkler method are in µmol/l, while those from the SBE43 are in µmol/kg ; the following conversion is applied : O_2(µmol/kg)=O_2(µmol/l)/1.027

(NB : at 11.5bar, T=-1.8°C, S=34, the factor would be 1.028, we neglect the difference between 1.027 and 1.028)

No Station	No Btl	Prof(m)	O_2(µmol/l) Winkler	O_2(µmol/kg) Winkler	O_2(µmol/kg) SBE43	SBE43-Winkler	std Winkler	Remarques
2	1	66	341.1	332.1	329.0	-3.2	0.4	! La SBE43 mesure 333. à fond-1m, fond-2n fond-3m lors de l descente
2	*fond-2m,-3m*	*63-65*	*341.1*	*332.1*	*333.6*	*1.5*	*0.4*	*Les valeurs des station 2,3,5 sont cohérentes ave un décalage a 1.5*mmol/kg de la SBE 4
3	1	43	336	327.2	328.5	1.4	0.2	
5	1	107	317.2	308.9	310.4	1.5	0.4	
8	6	95.4	350.1	340.9	336.4	**-4.5**	1	!la SBE43 mesure un variabilité de ~15µmol/k entre btl 1 et btl claquées au fond=> o prend la moyenne de mesures au dessus d fond (95-96.4m)
8	10	30.5	360.3	350.8	350.2	-0.6	0.5	
8	12	27.6	360.5	351.0	350.4	-0.6	0.2	
8	18	7.8	346.9	337.8	328.0	**-9.8**	0.1	Variabilité due à l surface?
16	1	185	319.4	311.0	312.387	1.4	0.2	
16	12	35	322.5	314.0	316.389	2.4	0.2	
16	19	5	346.9	337.8	334.659	-3.1	0.1	
23	1	161.3	317	308.7	309.496	0.8	0.1	
23	17	6	339.3	330.4	328.429	-2.0	0.0	
34	1	149	317.1	308.8	310.368	1.6	0.1	
34	10	107	326.2	317.6	321.645	**4.0**	0.1	Variabilité~3µmol/kg vu par la CTD
34	19	8	343.6	334.6	334.603	0.0	0.2	
46	1	315	305.2	297.2	297.018	-0.2	0.6	
46	17	25	319.8	311.39	311.667	0.3	0.5	

Mean (CTD-O_2-Winkler)= -0.5µmol/kg (std=3.2µmol/kg)

removing the large difference at the surface, one gets : Mean (CTD-O_2-Winkler)= 0.2µmol/kg (std=2.1µmol/kg)

In conclusion, we get a very good consistency between CTD-O_2 and Winkler measurements. No drift of CTD- O_2 measurements is observed during the cruise.

1.5.5 Multinet operations and sampling

Multinet samples have been taken on 10 stations. Few planktic foraminifera have been found within the Storfjorden with the largest abundance on the East part within the surface current entering from the Barents Sea. Pteropods have been retrieved and calibrated for their organic content.

For the assemblages, the samples are under the responsibility of BIAF (University of Angers) possibly in collaboration with Tromsø University.

The following table summarizes the different depth for the net samples at the different stations.

n° Multinet	N°Station (CTD)	Date	depth (m)	Lat (S -)		Long (W -)		Météo				CTD	Multinet H TU	
				deg	min	deg	min	T°C	clouds	wind	wave h		Cast	début/fin
MTN 1	BTS 2	13/07/2016	109	78	15	19	30	T° air: 3,4 T°eau: 3,1 P : 1012 hPa	ciel: clair couvert: 90 % nuage: -- brume: -- soleil: --	Force: 19 nds Dir :	calme/~~peu agitée~~/agitée ~~houle~~-mer du vent h (m) < 0,5	Pic Chloro: étalé 0 - 25 m à 0,005 mg/m^3 Couche mélange: 30 m; dessalée 34,3	0-20m 20-40m 40-60m 60-80m 80-95m	19z40-20z17 autres obs : couche fond (<60m), plus turbide (1,6) et plus froide (-1,75)
MTN 2	BTS 3	14/07/2016	48	78	5.143	19	4.154	T° air: 2,5 T°eau: 4 P : 1010 hPa	ciel: -- couvert: 100 % nuage: -- brume: épaisse soleil: --	Force: 17 nds Dir :	calme/~~peu agitée~~/agitée ~~houle~~-mer du vent : frissante h (m) < 0,5	Pic Chloro : rond 5 - 6 m à 0,015 mg/m^3 Couche mélange : 5-7m; dessalée 33,2	0-10m 10-20m 20-30m 30-40m 80-100m	04z50-05z33 autres obs : couche fond (<35m), MOINS turbide (2,8), plus salée (34,25) et plus froide (2,7)
MTN 3	BTS 5	14/07/2016	118	77	49.8	18	48	T° air: 4,1 T°eau: 3,7 P : 1009 hPa	ciel: voilé, gris couvert: 95 % nuage: haut, fin brume: qq bancs soleil: --	Force: 20 nds à 9h puis 12 n à 13h Dir :	calme/~~peu agitée~~/agitée ~~houle~~-mer du vent : frissante h (m) < 0,5	Pic Chloro: étalé 0- 50 m à 0,015 mg/m^3 Couche mélange : 30m; dessalée 34,3	0-20m 20-40m 40-60m 60-80m 80-100m	10z45-11z10 autres obs : couche fond (<60m), plus turbide (3,4) et plus froide (-1)
MTN 4	BTS 8	14/07/2016	99	77	58.66	20	14.55	T° air: 5,4 T°eau: 4,6 P : 1007 hPa	ciel: gris/blc/bleu couvert: 95 % nuage: haut brume: -- soleil: --	Force: 14,5 nds Dir :	calme/~~peu agitée~~/agitée ~~houle~~-mer du vent : frissante h (m) < 0,5	Pic Chloro :étalé 0- 15 m à 0,005 mg/m^3 Couche mélange : 17m; dessalée 34,2	0-20m 20-40m 40-60m 60-80m 80-90m	20z35-20z45 autres obs : couche fond (<60m), plus turbide (4) et plus froide (1-2)
MNT 5	BTS 16	15/07/2016	192	77	29.39	19	10.06	T° air: 4,7 T°eau: 3,9 P : 1008hPa	ciel: total gris fer couvert: 100 % nuage: -- brume: épaisse soleil: --	Force: 8 nds Dir :	calme/~~peu agitée~~/agitée ~~houle~~-mer du vent à peine risée h (m) < 10cm	Pic Chloro :pointu 10-15 m à 0,065 mg/m^3 Couche mélange : 15m; dessalée 34,5	0-20m 20-55m 55-90m 90-125m 125-150m	20z40-21z08 autres obs : Visi proche 0 !! (en état d'alerte => corne de brumme) couche fond (<100m), plus turbide (1,6) et plus froide (-1,75) !!! même eau qu'en St.2

n° Multinet	N°Station (CTD)	Date	depth (m)	Lat (S -)		Long (W -)		Météo				CTD	Multinet H TU	
MNT 6	**BTS 23**	17/07/2016	171	77	13.22	19	17.86	T° air: 7,1 T°eau: 4,8 P : 1010 hPa	ciel: gris/blc/bleu couvert: 100 % nuage: haut brume: -- soleil: --	Force: 5,2 nds Dir :	~~calme/peu agitée~~/agitée Mer d'huile ~~houle-mer du vent~~ h (m) : 0	Pic Chloro :pointu à 20 m à 0,06 mg/m^3 Couche mélange :15m; Dessalée	0-20m **20-55m** **55-90m** **90-125m** **125-150m**	07z55-08z10 autres obs : corne de brume de temps en temps !! couche fond (<100m), plus turbide (2,254), plus salée (35) et plus froide (-1.75)
MNT 7	**BTS 27**	17/07/2016	53.8	77	17.58	20	37.63	T° air: 5,1 T°eau: 3,4 P : 1010 hPa	ciel: gris couvert: 100 % nuage: -- brume: haute soleil: --	Force: 6,8 nds Dir :	~~calme/peu agitée~~/agitée Mer d'huile, frisottante ~~houle-mer du vent~~ h (m) : 0	Couche mélange :7 m; peu déssalée 34,2	**0-10m** **10-20m** **20-30m** **30-40m** **80-100m**	13z45-14z05 autres obs : couhce fond peu marquée < 40m
MNT 8	**BTS 29**	17/07/2016	45.8	77	1.62	20	48.29	T° air: 3,7 T°eau: 2,7 P : 1009 hPa	ciel: gris/blc couvert: 100 % nuage: -- brume: légère soleil: --	Force: 15 nds Dir :	~~calme~~/peu agitée/agitée ~~houle~~-mer du vent h (m) : < 0,5		**0-10m** **10-20m** **20-30m** **60-80m** **80-100m**	18z50-19z00autres obs : colonne d'eau homogène FILM gopro d'Olivier (Perpignan) depuis
MNT 9	**BTS**	18/07/2016	156.7	76	53.87	19	30.23	T° air: 5,4 T°eau: 4,2 P : 1006 hPa	ciel: gris uniforme couvert: 100 % brume: haute	Force: 23 nds Dir :	peu agitée ~~houle~~-mer du vent h (m) : 0,7 m	Pic Chloro: pointu à 25 m à 0,09 mg/m^3	0-20m 20-40m 40-60m 60-**90m**	2z02-2z12 autres obs : couche fond > 130 m; turbide (1,3) et froide (-1), le
MNT 10	**BTS 46**	19/07/2016	321	76	0.931	17	3.378	T° air: 5 T°eau: 6,5 P : 999 hPa	ciel: gris uniforme couvert: 100 %	Force: 20-25 nds Dir :	~~calme/peu agitée~~/agitée houle-mer du vent 1 m - <0,5m h (m)	Pic Chloro: étalé entre 0 - 40 m à 0,2 mg/m^3 Couche mélange: 40m, + chaude, dessalure en surf	**0-60m** **60-80m** **80-100m** **100-200m** **200-300m**	00z39-01z05
								autres obs					0-20m 20-40m 40-60m	01z20-01z35

1.5.6 Multicore operations and sampling

Multicores have been retrieved on 7 stations at different depths and location of the Storfjorden and on the Storfjorden Trough. The oxygen, pH and porosity profiles have been measured for each station. Samples have been taken for benthic foraminifera fauna on each station and treated with Rose Bengal. Incubation experiment has been conducted on 3 stations. When enough cores have been retrieved non disturbed at all, sampling was done for pore waters. The following table summarizes the experiment and the slices samples and their storage.

Station	Depth (m)	Latitude (°N ',00)	Longitude (°W ',00)	Date	Name	R-B	Measurements/samples Destination
2	108.5	78°15	19°30	13/07/16	**STEP16-st2-MC1**		O_2, pH, porosity profiles
							pore water sampling, LSCE
							LSCE archive
						x	Faune foraminifères - BIAF
						sac	Repliquat-Faune foraminifères - BIAF
5	117	77°50	18°48	14/07/16	**STEP16-st5- MC2**		O2, pH, porosity profiles
							pore water sampling, LSCE
						sac	LSCE archive
						x	Faune foraminifères - BIAF
						sac	Repliquat-Faune foraminifères - BIAF
8	98.8	77°58,7	20°14,6	15/07/16	**STEP16-st8-MC3**	x	Faune foraminifères - BIAF
							O_2, pH, porosity profiles
							pore water sampling, LSCE
8	98.8	77°58,7	20°14,6	15/07/16	**STEP16-st8-MC3bis**		incubation
							incubation
							incubation
							incubation
							incubation
							slice for organic matter, Tromsø
							slice for organic C, Tromsø
16	192.4	77°29,2	19°10,6	16/07/16	**STEP16-st16-MC4**	x	Faune foraminifères - BIAF
							O_2, pH, porosity profiles
							pore water sampling, LSCE
							pore water sampling, LSCE
							incubation
							incubation
						sac	Archives LSCE

						sac	Repliquat-Faune foraminifères - BIAF
16	192.4	77°29,2	19°10,6	16/07/16	**STEP16-st16-MC4bis**		incubation
							incubation
							incubation
						sac	slice for organic matter, Tromsø
						sac	slice for organic C, Tromsø
						sac	sliced 1cm , Archive Tromsø
						sac	sliced 1cm , paleo, LSCE
23	172	77°13,2	19°17,9	17/07/16	**STEP16-st23-MC5**	x	Faune foraminifères - BIAF
							O_2, pH, porosity profiles
							pore water sampling, LSCE
						sac	Archives LSCE
						sac	Repliquat-Faune foraminifères - BIAF
34	157	76°53,9	19°30,3	18/07/16	**STEP16-st34-MC6**	x	Faune foraminifères - BIAF
							O_2, pH, porosity profiles
							pore water sampling, LSCE
						sac	Archives LSCE
						sac	slice for organic matter, Tromsø
						sac	slice for organic C, Tromsø
						sac	Repliquat-Faune foraminifères - BIAF
34	157	76°53,9	19°30,3	18/07/16	**STEP16-st34-MC6**		incubation
							incubation
							incubation
							incubation
						sac	incubation
						sac	sliced 1cm , Archive Tromsø
46	322	76°0,9	17°3,4	19/07/16	**STEP16-st46-MC7**	x	Faune foraminifères - BIAF
							O_2, pH, porosity profiles
							pore water sampling, LSCE
						sac	Archives LSCE
						sac	Repliquat-Faune foraminifères - BIAF

1.5.7 Kullenberg operations

Kullenberg coring has been done at five stations. The cores are stored frozen at Tromsø University. Along the cores, benthic assemblages will be studied at Tromsø University while their isotopes will be measured at LSCE. The following table summarize the core position and length.

Station	Name	Latitude (°N)	Longitude (°E)	water depth (m)	length (m)	number of sections	comments
2	STEP16_2_K1	78°15.0	19°29.97	109	9.6	8 (1A and 1B)	Bag 4cm between IA and IB
8	STEP16_8_K2	77°58.54	20°14.25	99	9.6	7	
16	STEP16_16_K3	77°29.21	19°10.64	192	9.51	7	
23	STEP16_23_K4	77°13.2	19°17.9	171	9.01	6	
46	STEP16_46_K5	76°00.94	17°03.34	322	8.2	7 (IVA and IVB)	tube bended core in two pieces

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