Oceanographic time-series analysis during the ESONET demo-mission AOEM offshore Svalbard

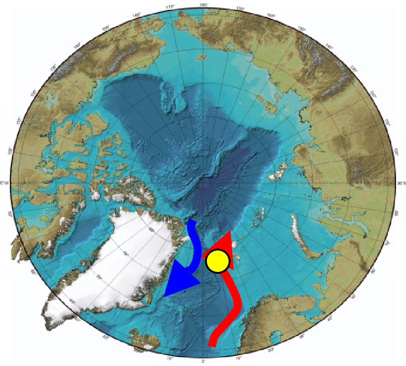
Bénédicte Ferré, Ian C. Wright, Rachael H. James, Doug P. Connelly, Veit Huhnerbach, Jürgen Mienert and Christian Berndt

benedicte.ferre@uit.no
University of Tromsø (Norway)

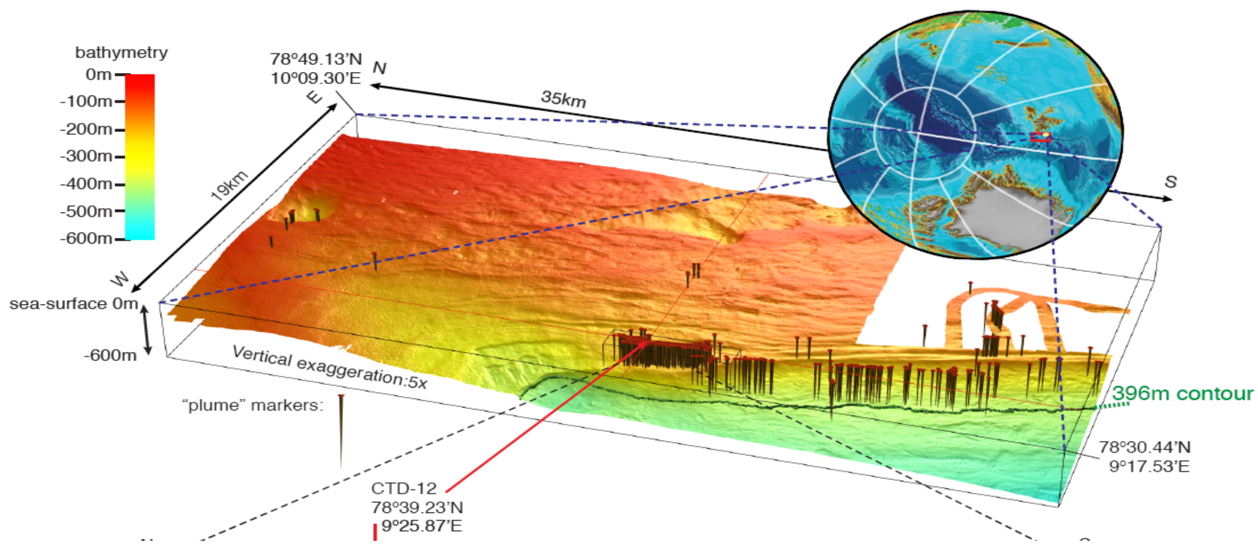
« Time-series analysis in Marine science and applications for industry »
Conference in Logonna-Daoulas, France, 17-22 sept. 2012

Time-series analysis in Marine science and applications for industry

Western Svalbard – Critical location



- Northward flowing filament of the North Atlantic Current, crucial "barometer" of global ocean warming
- Known methane venting with over 250 individual gas bubble plumes ascending through the water-column (majority at the immediate landward edge of the gas hydrate stability zone at ~400m water depth)



Arctic Ocean ESONET Mission

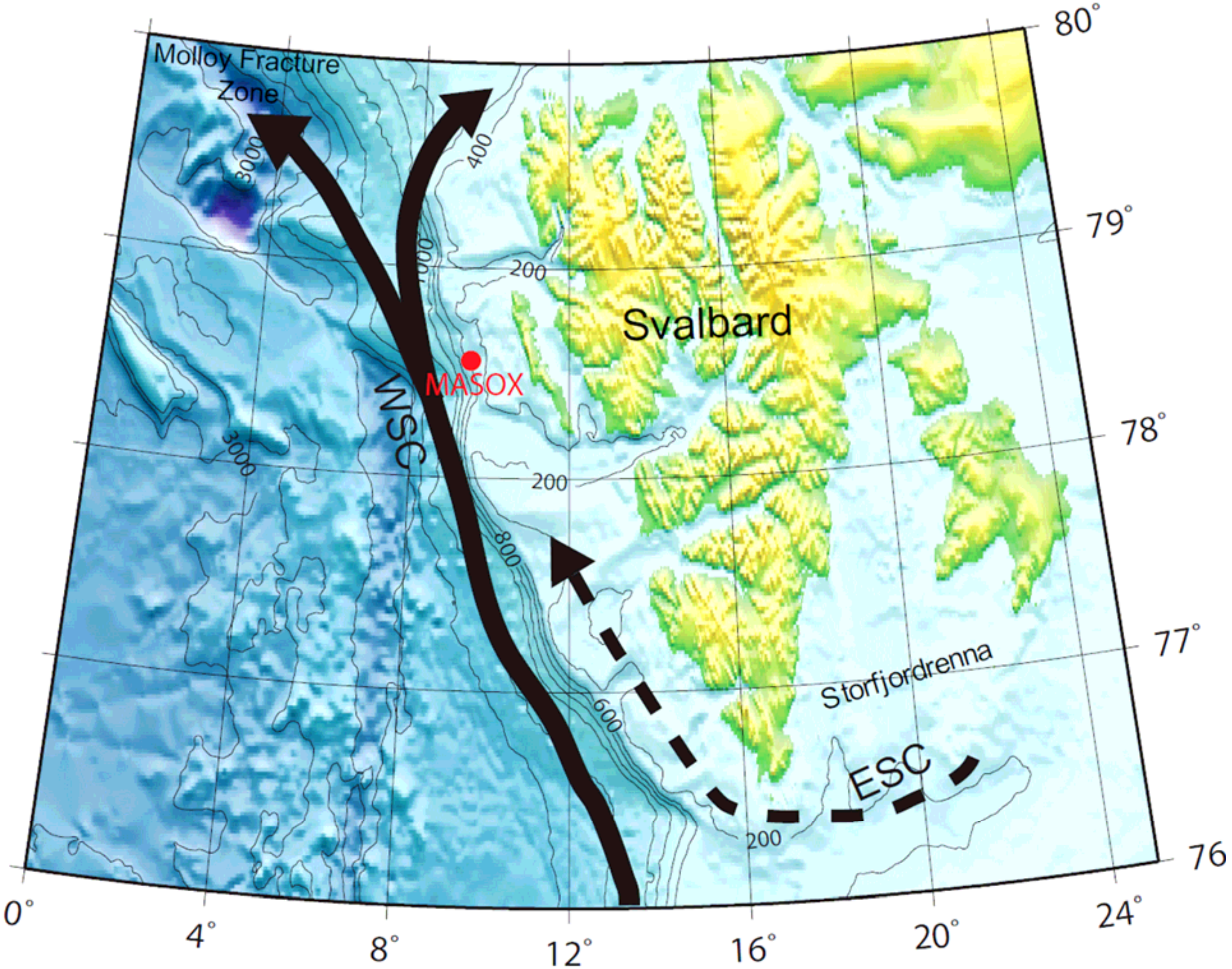
Logonna-Daoulas (France)

17-22 sept. 2012

Time-series analysis in Marine science and applications for industry

AOEM - Area

- RV Jan Mayen deployed lander in October 2010
- RRS James Clark Ross retrieved and deployed lander in August 2011

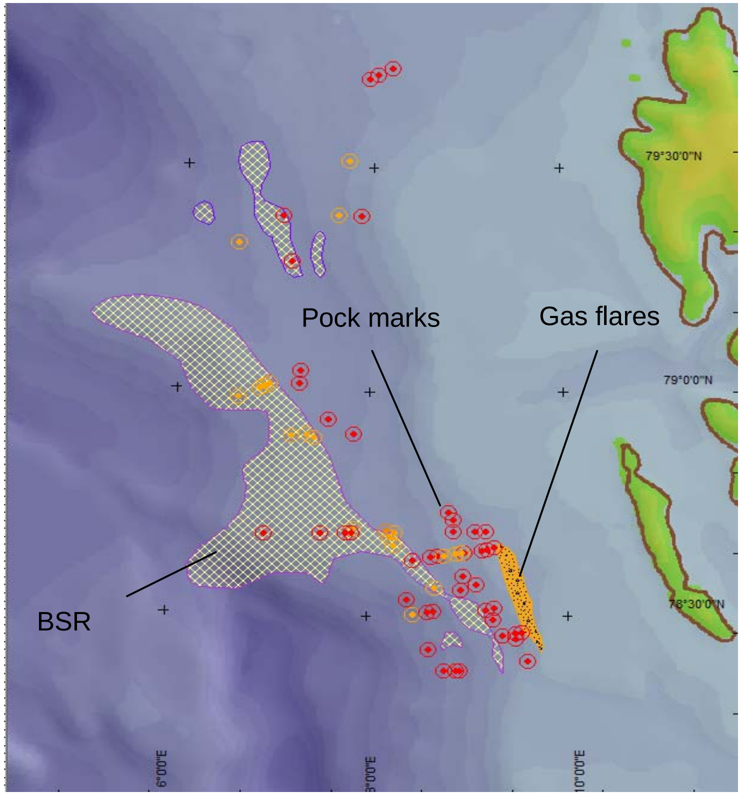


Logonna-Daoulas (France)

17-22 sept. 2012

Time-series analysis in Marine science and applications for industry

AOEM - Detailed area



BSR: Bottom Simulating Reflector, seismic reflection that parallels the seafloor, probably revealing the hydrate stability zone interface

Pock marks: indicators of seabed fluid flow expression

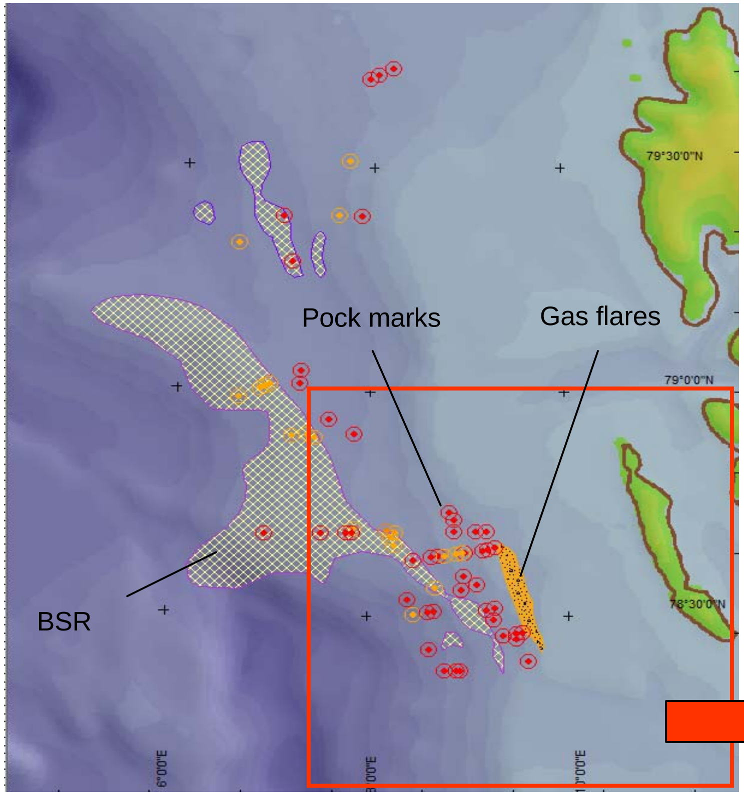
Gas flares: acoustic expression of methane bubbles emanating from the seabed

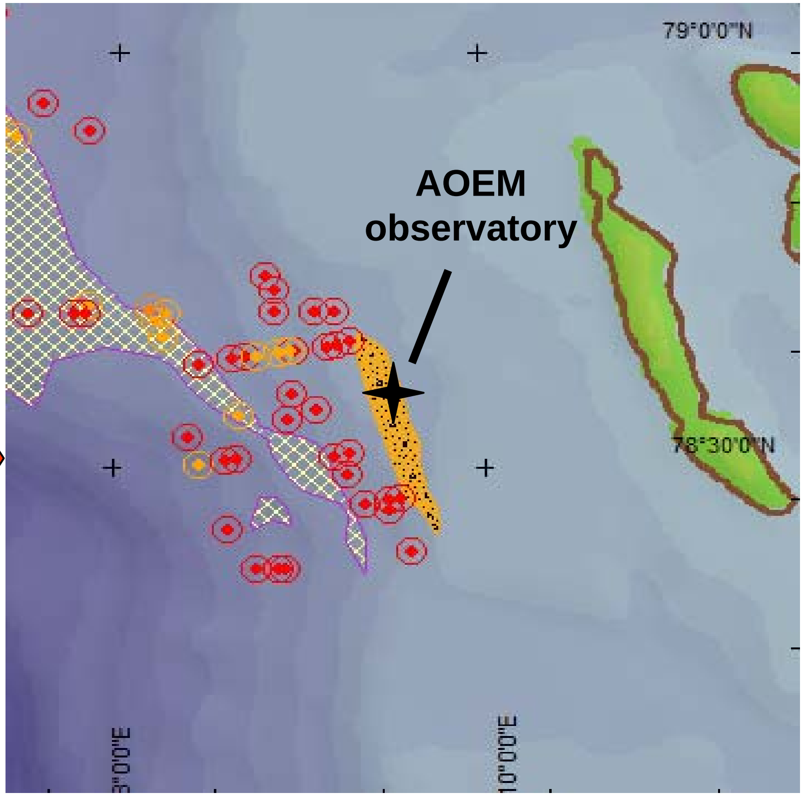
Logonna-Daoulas (France)

17-22 sept. 2012

Time-series analysis in Marine science and applications for industry

AOEM - Detailed area





Arctic Ocean ESONET Mission

Logonna-Daoulas (France)

17-22 sept. 2012

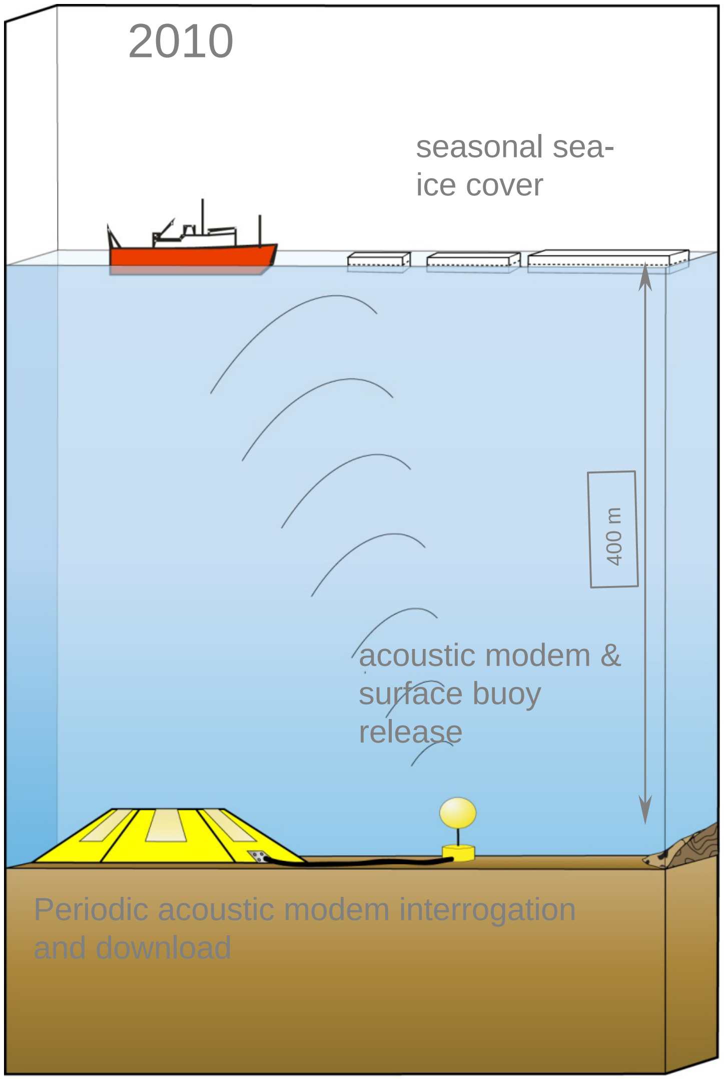
Time-series analysis in Marine science and applications for industry

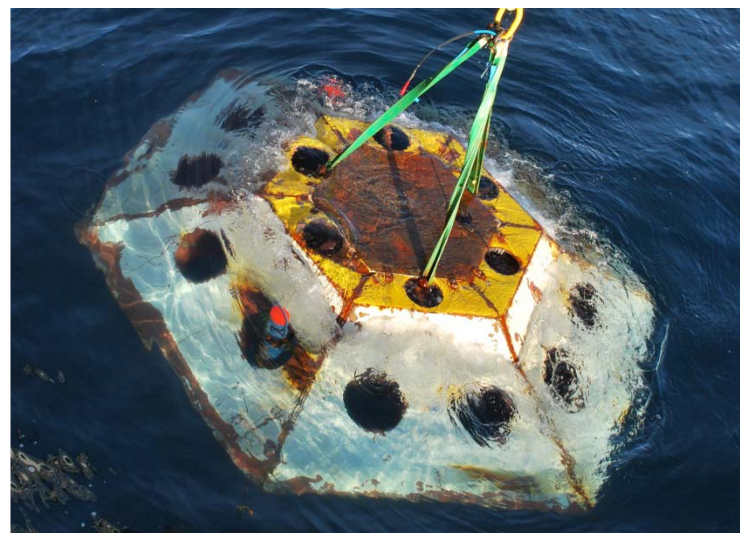
Arctic Ocean ESONET Mission

Logonna-Daoulas (France)

17-22 sept. 2012

The lander





The Experiments

Geophysical Experiments:

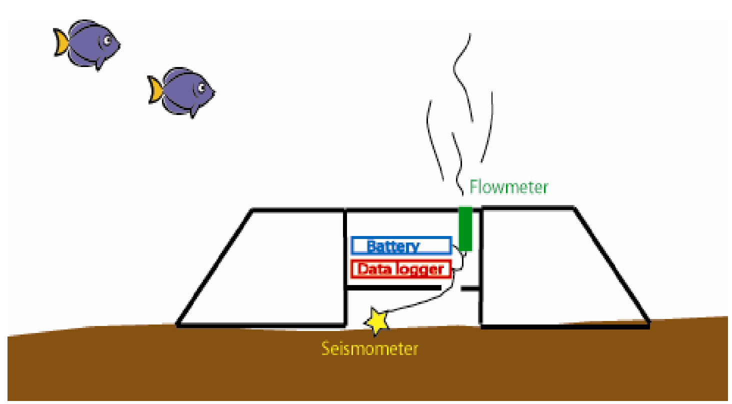
- Measure temperature profiles, surface temperature and heat-flow in the water column;
- Monitor the thermal signal of fluids expelled from the sediment;
- Monitor micro-seismicity expression of hydrate dissociation and fluid escape, and possible trigger events that initiate episodic fluid flow from deeper sources.
- Monitor flow of free gas bubbles from seafloor.

Geochemical Experiments:

- Assess whether methane comes from just dissociating gas hydrate, or includes deeper (thermogenic) source;
- Quantify how much methane is chemically transformed via redox and anaerobic oxidation reactions;
- Biogeochemical sensors (e.g., dissolved oxygen, and Ph sensors) integrated with bubble measurements to determine geochemical fluxes across seafloor-sediment interface.

The instruments

- K/MT Seismometer (4.5-200 Hz)
- HTI-04 Hydrophone;
- SENS Geolon-MLS data logger (14 Gb)
- Lithium battery packs;
- **Aanderaa Seaguard Recording Current Meters (RCM's);**
- **CTD sensors including oxygen, using the fast response optodes, and turbidity;**
- TriTech underwater video camera.



Time-series analysis in Marine science and applications for industry

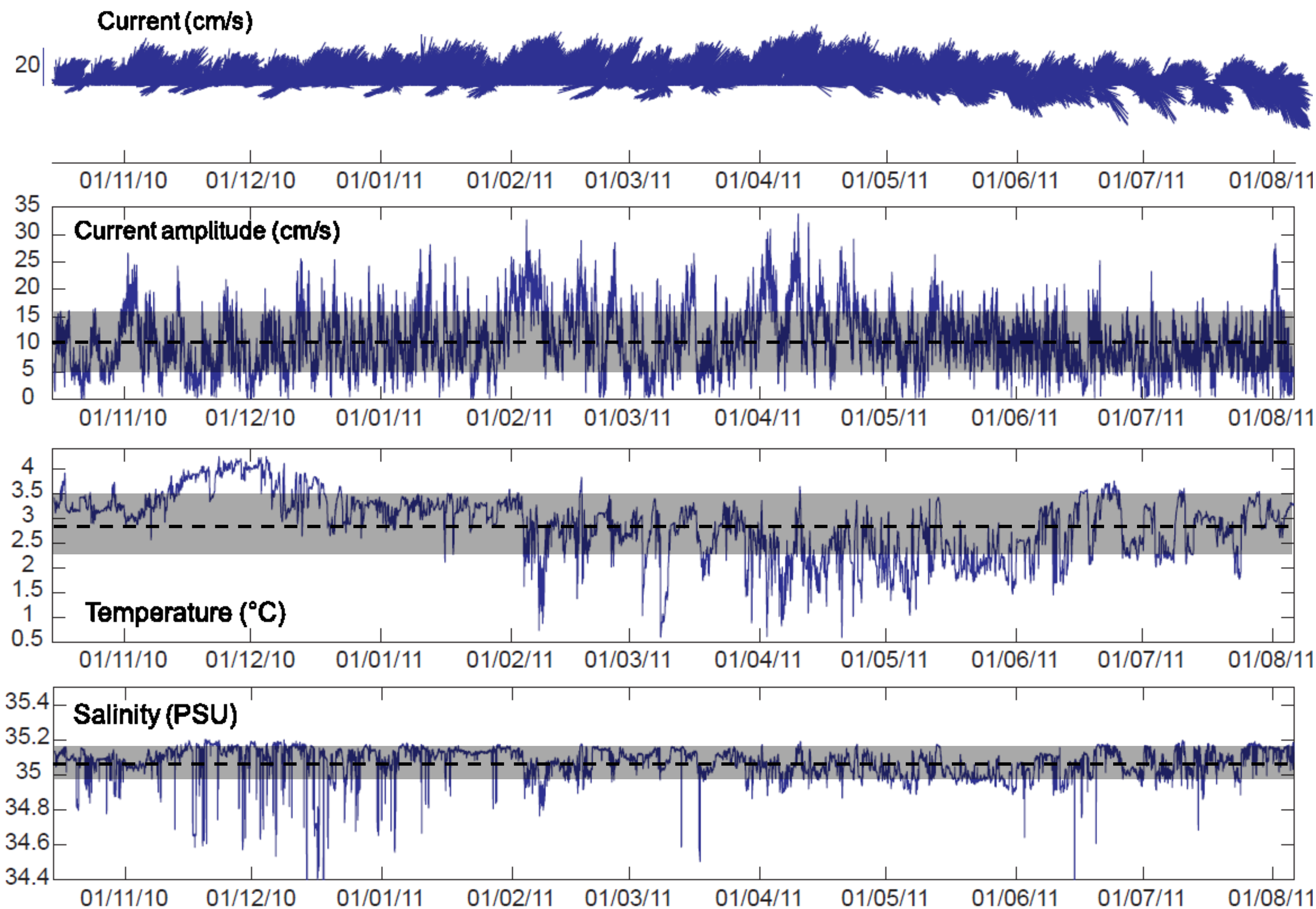
Results – RCM9

Logonna-Daoulas (France)

17-22 sept. 2012

Time-series analysis in Marine science and applications for industry

The time-series

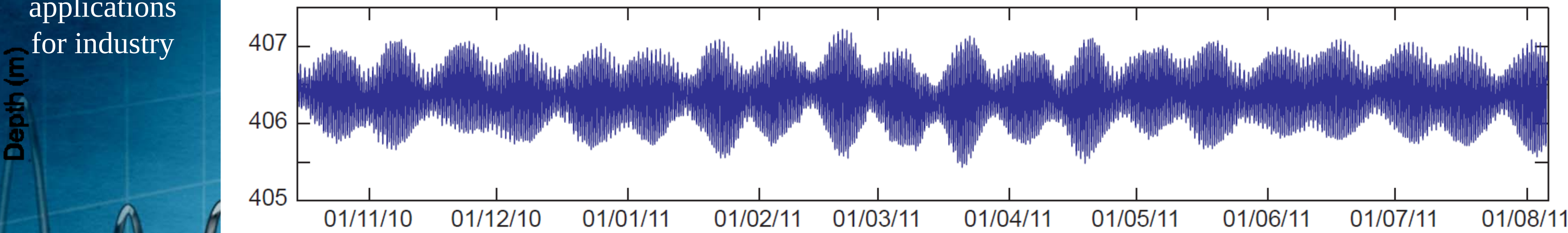


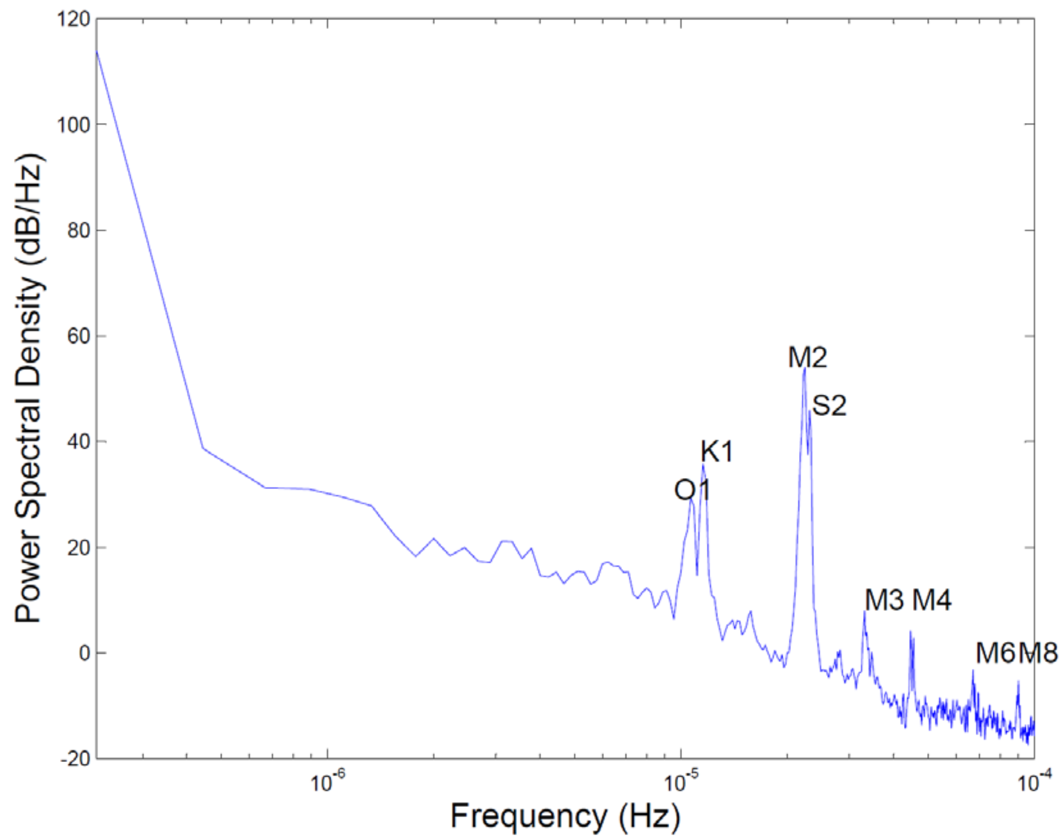
Logonna-Daoulas (France)

17-22 sept. 2012

Time-series analysis in Marine science and applications for industry

Pressure – Spectral analysis (m)





Logonna-Daoulas (France)

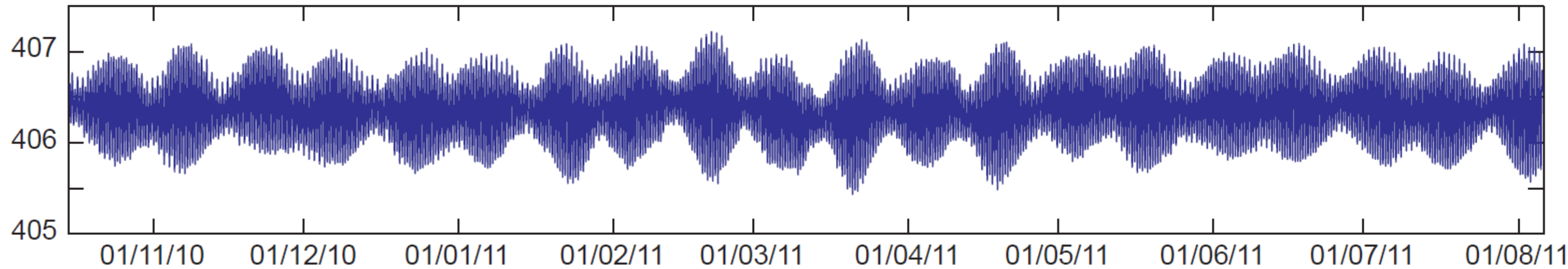
17-22 sept. 2012

Welch's method

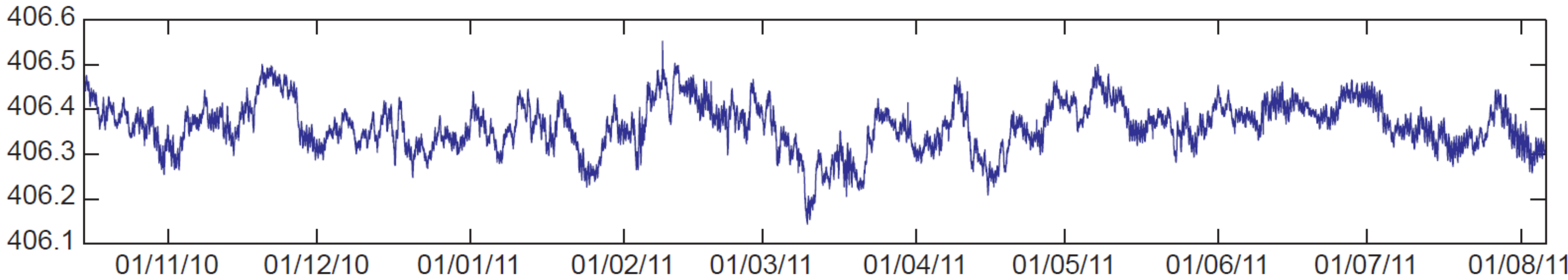
- Calculate the Power Spectral Density (PSD) from overlapped and windowed segments
- Reduces the noise in the estimated power spectra
- *Calculation*:
    1. Signal is divided into K segments of length N, overlapping by D points
    2. Each overlapping segment is windowed
    3. Individual PSD calculated using the discrete Fourier transform
    4. Individual PSD are averaged
    - Here: function PWELCH in matlab, dividing the 28273 points using Hanning window, overlapping by 2500 points.

Time-series analysis in Marine science and applications for industry

Pressure – Spectral analysis



Detided signal



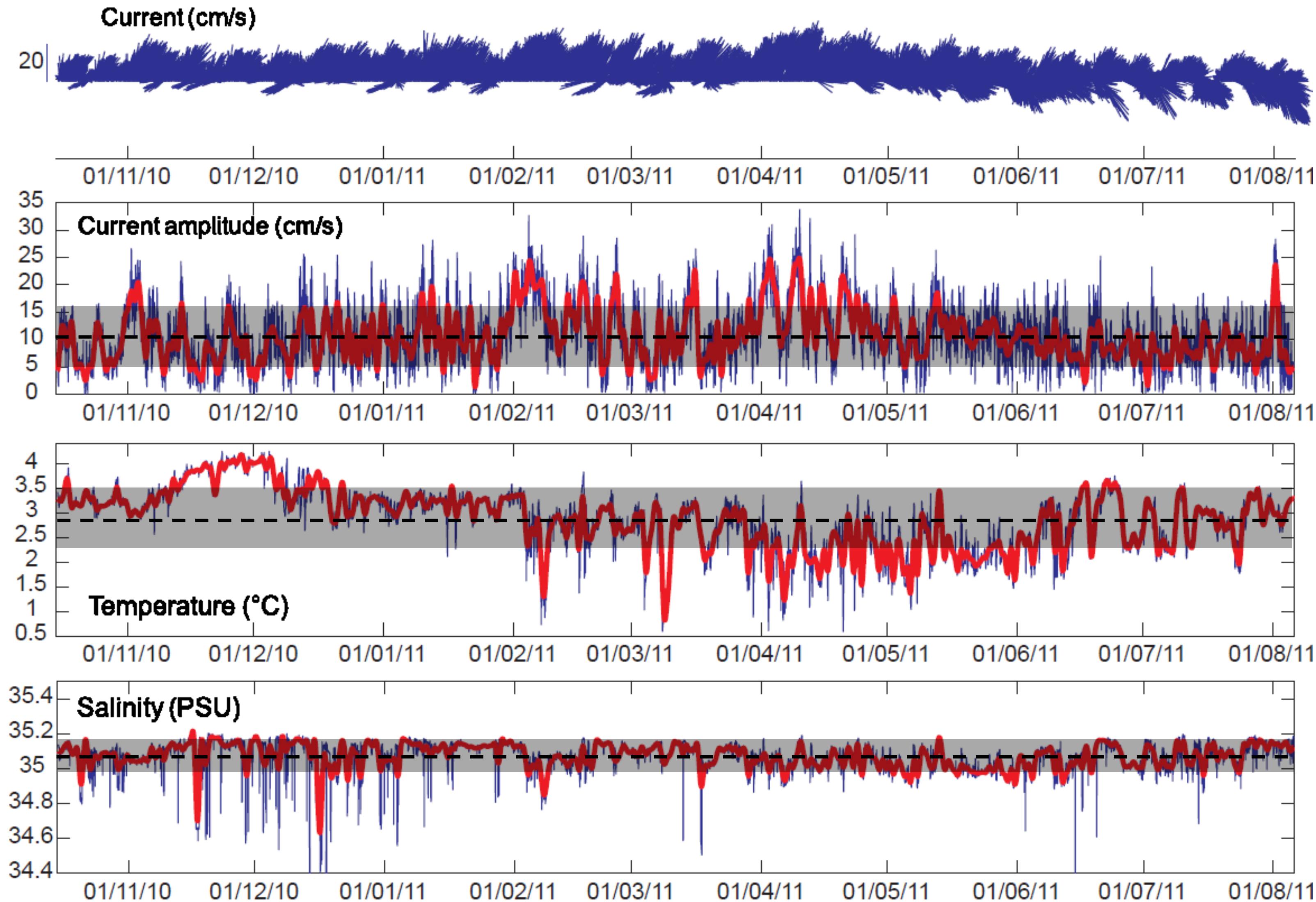
Logonna-Daoulas (France)

17-22 sept. 2012

Filter applied

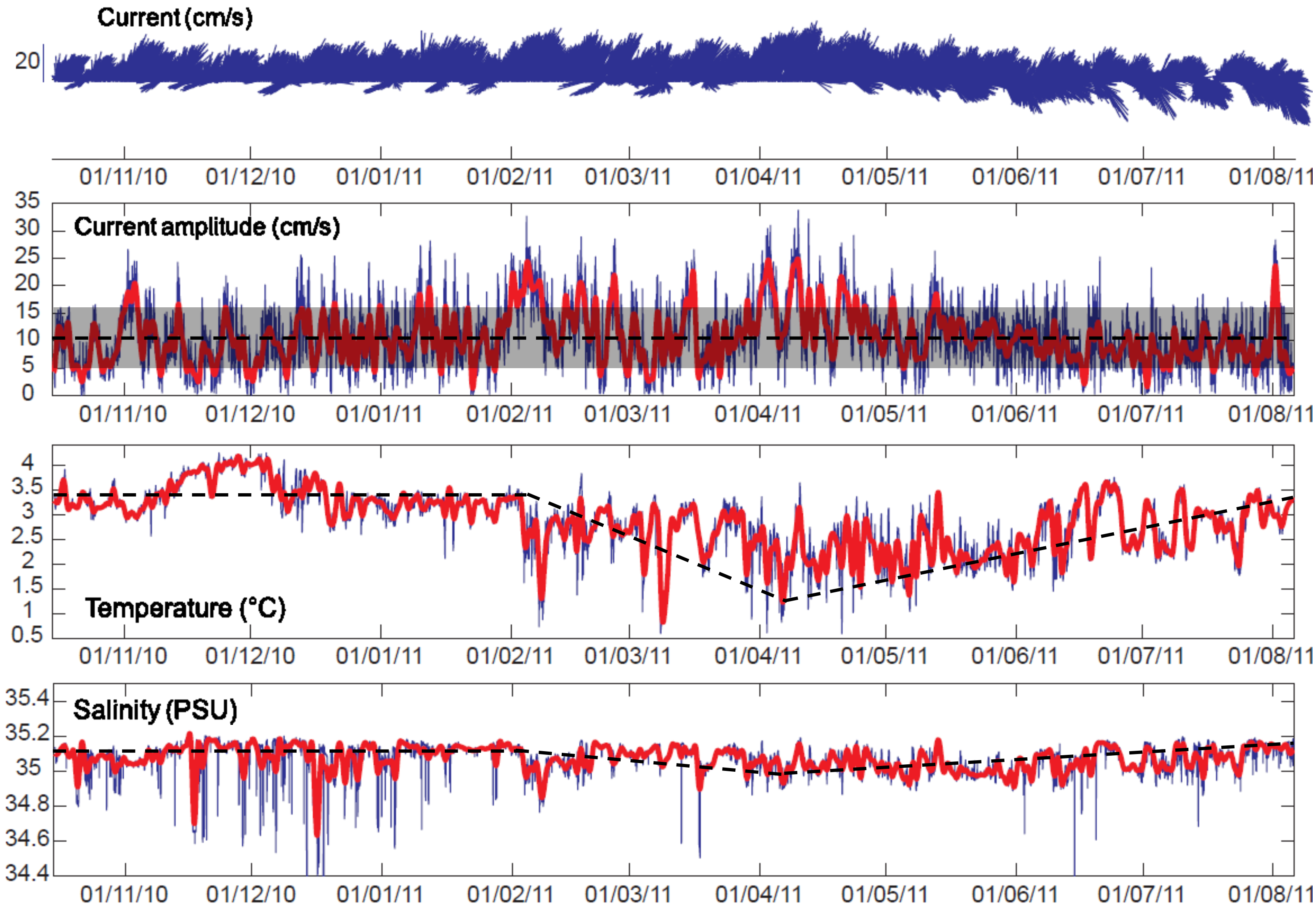
- *Low-pass filter*: passes low-frequency signals but attenuates signals with frequencies higher that the cutoff frequency
- *Cutoff frequency*: maximum frequency that will remain entrapped
- Here: cutoff frequency chosen at 35h to remove the tide.

The time-series



Time-series analysis in Marine science and applications for industry

The time-series



Arctic Ocean ESONET Mission

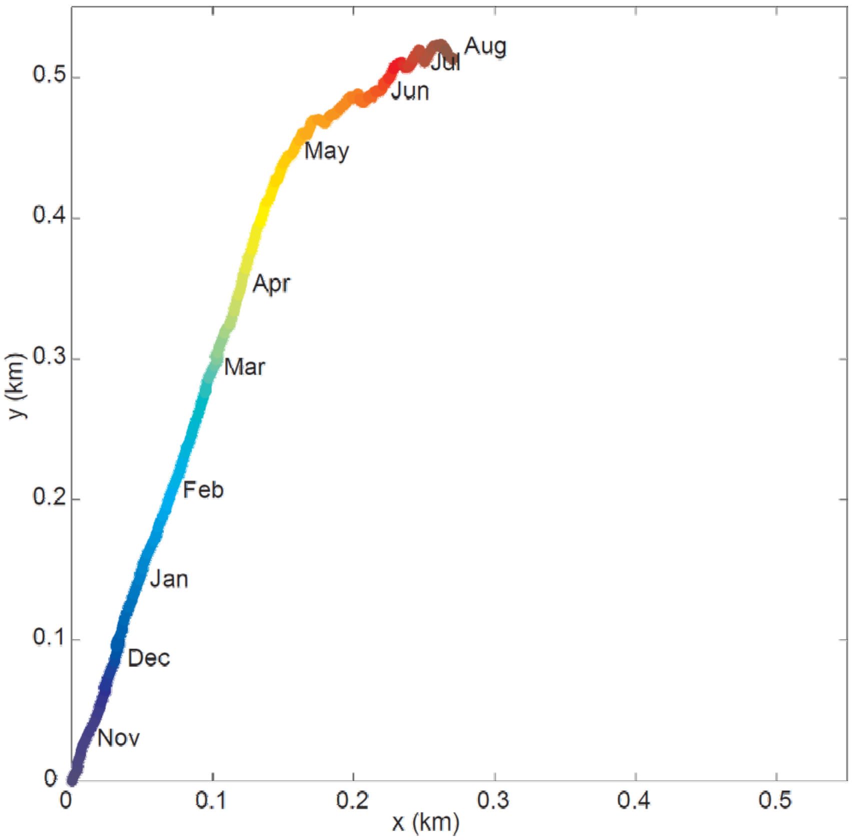
Logonna-Daoulas (France)

17-22 sept. 2012

Time-series analysis in Marine science and applications for industry

Progressive Vector Diagram

- General direction of the current
  - Northeastward until May
  - Variable in summer
- Variability of amplitude
  - Regular until February and in March
  - Stronger in February and April
  - Weaker in summer months (June to August)



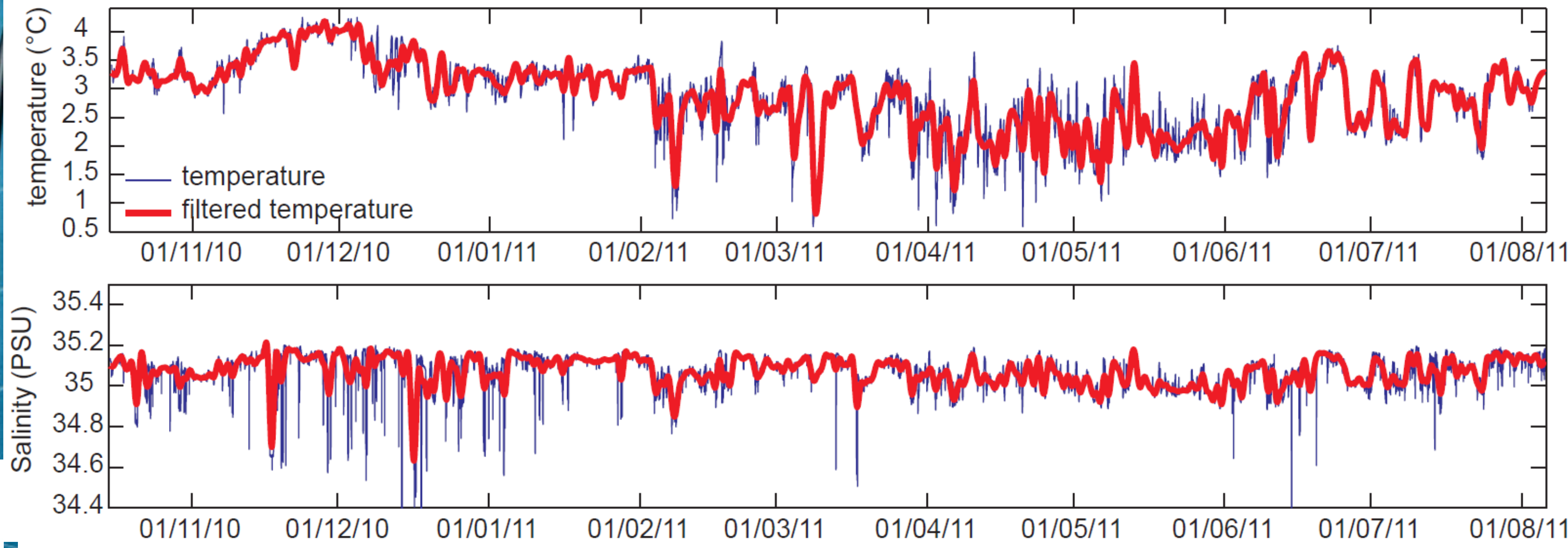
Arctic Ocean ESONET Mission

Logonna-Daoulas (France)

17-22 sept. 2012

Time-series analysis in Marine science and applications for industry

Temperature and salinity

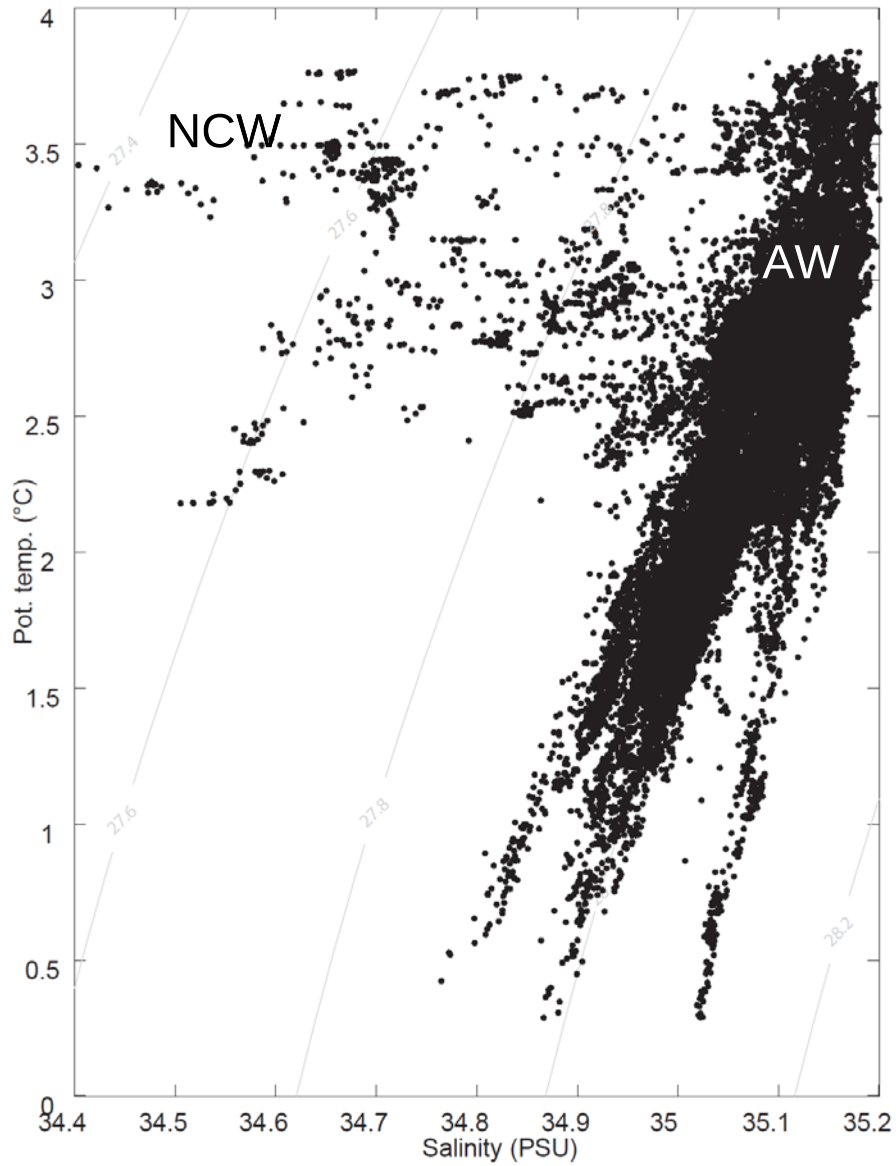


Logonna-Daoulas (France)

17-22 sept. 2012

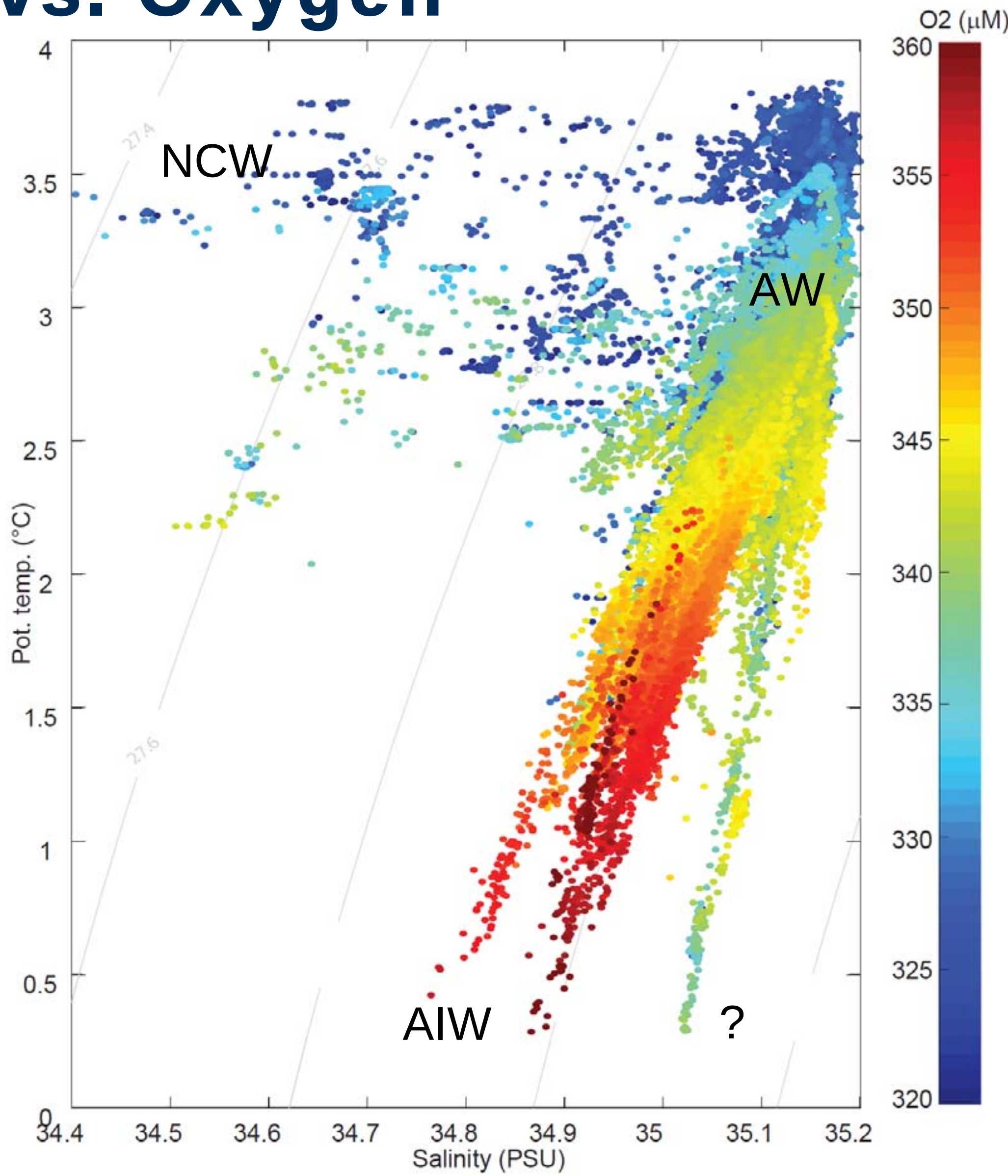
TS – diagram

- Potential temperature vs. salinity
- Identify the presence of different water masses and mixing between those water masses
- Has to be interpreted according to the water depth and the location of the station
- In WSC, Atlantic Water (AW) has T>2°C and S>35 PSU
- NCW: T>2°C and 32<S<35 PSU



TS – diagram vs. Oxygen

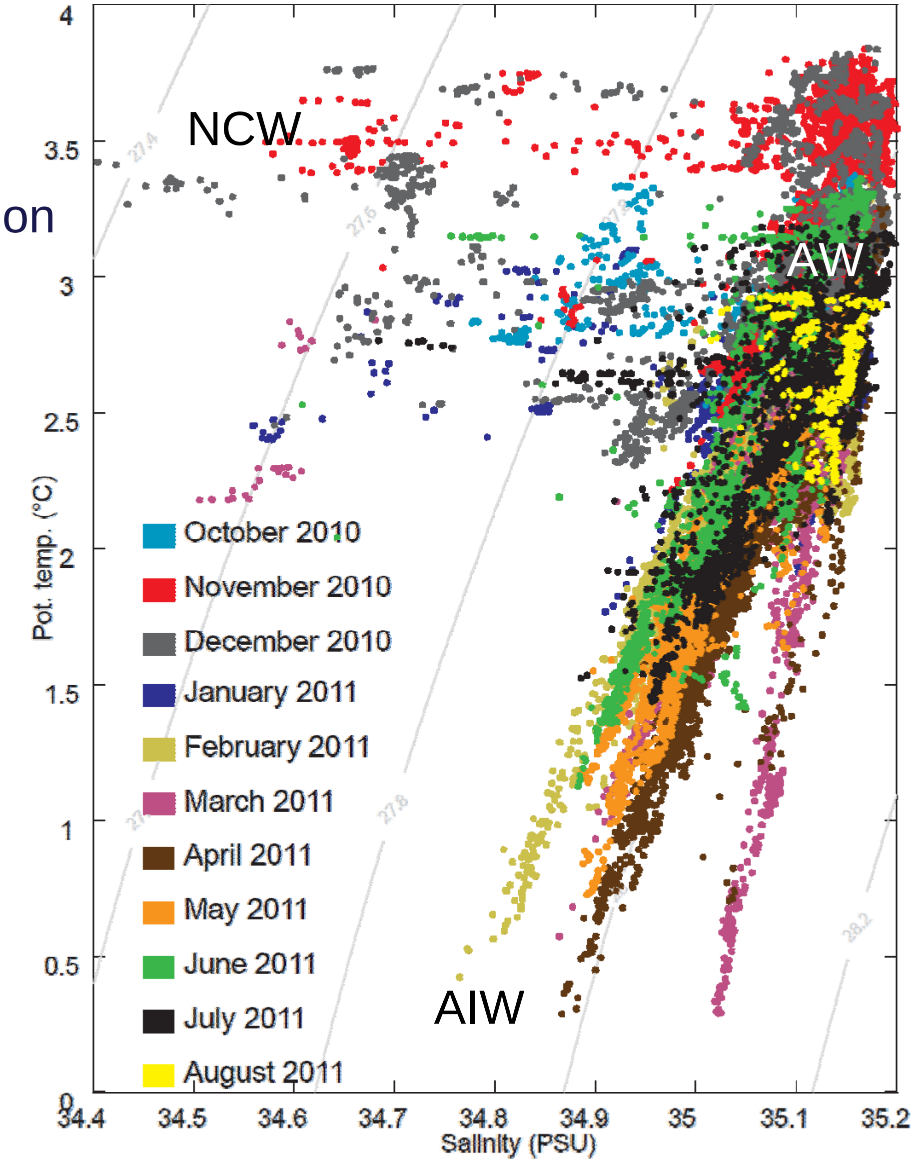
- Leinebø (1969) showed Arctic Intermediate Water (AIW) associated with salinity minimum and maximum in Oxygen content
- Coloration of TS diagram by Oxygen reveal maximum
- Consistent with Swift and Aagaard (1981) where AIW has T<2°C and 34.7<S<34.9 PSU



Arctic Ocean ESONET Mission

TS – diagram month by month

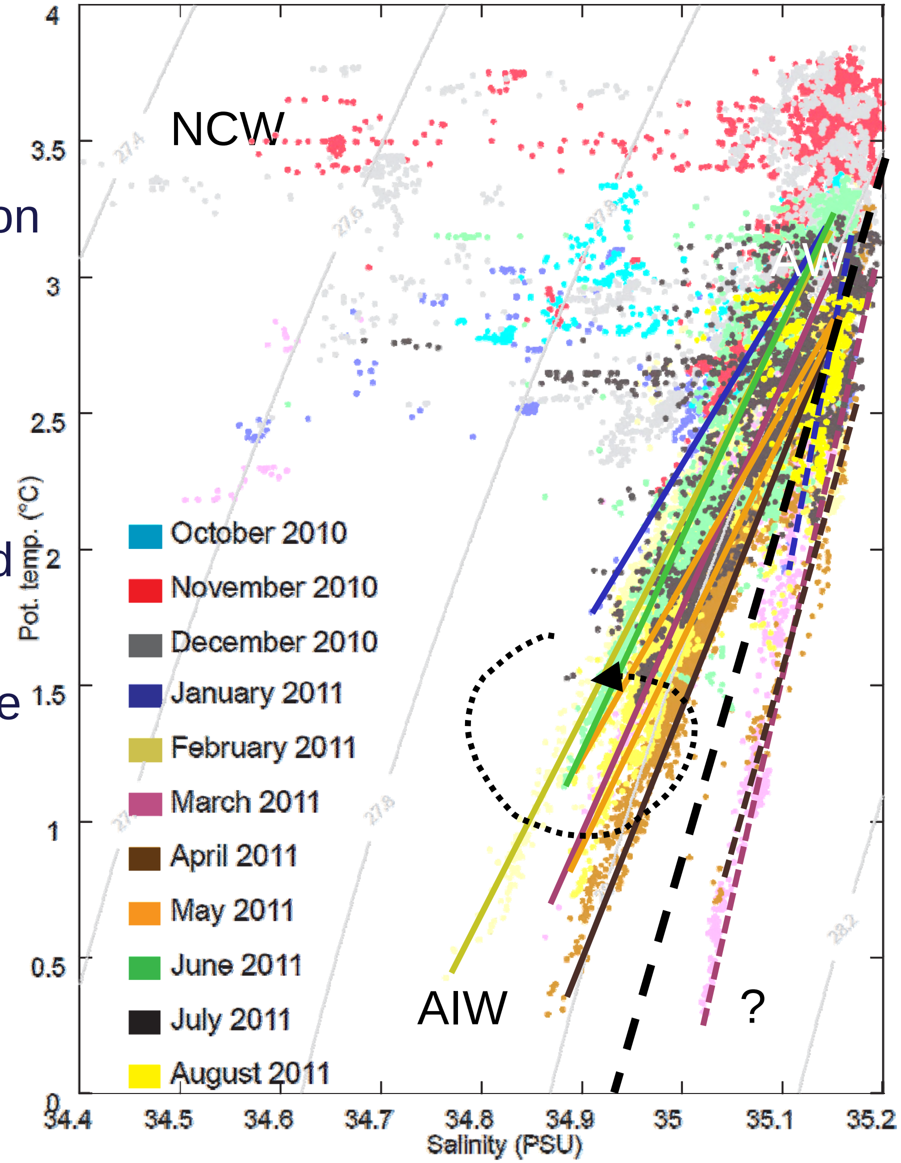
- Focus on monthly evolution of the water masses



Time-series analysis in Marine science and applications for industry

TS – diagram month by month

- Focus on monthly evolution of the water masses
- Separation between AIW and unknown water mass
- Cycle from January to June with an increase and a decrease of salinity
- Influence from more saline water mass in March and April?



Arctic Ocean ESONET Mission

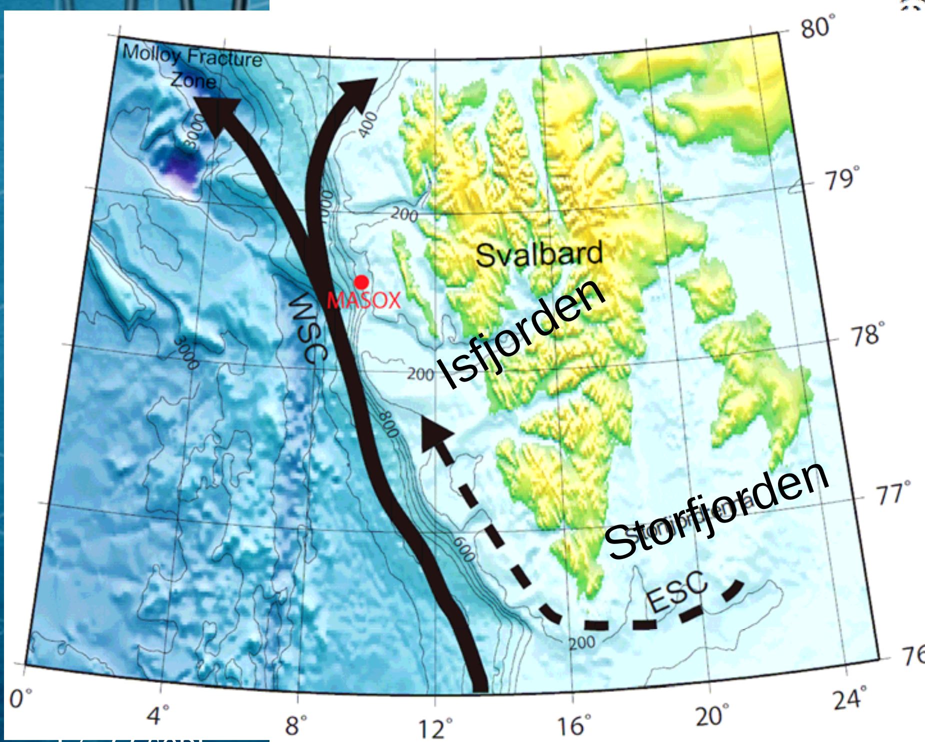
Logonna-Daoulas (France)

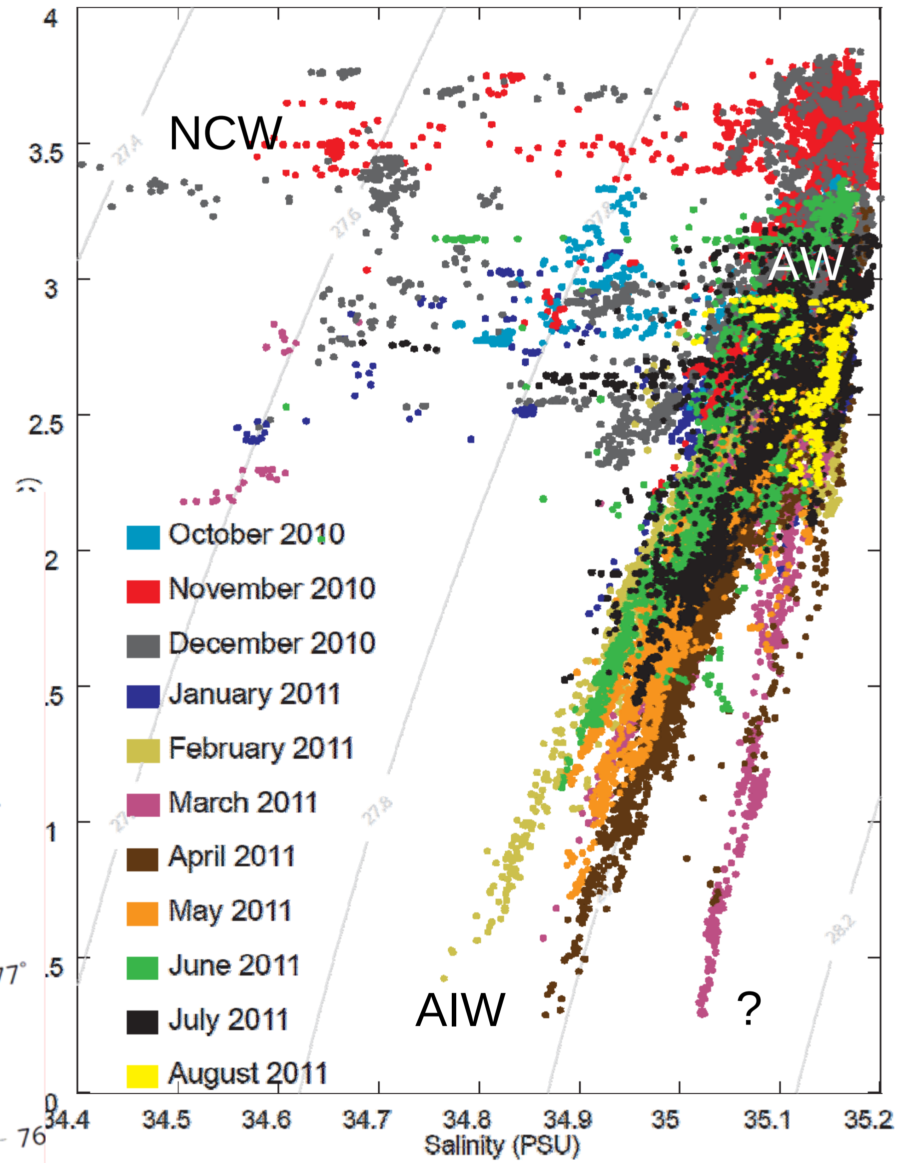
17-22 sept. 2012

Time-series analysis in Marine science and applications for industry

TS – diagram month by month

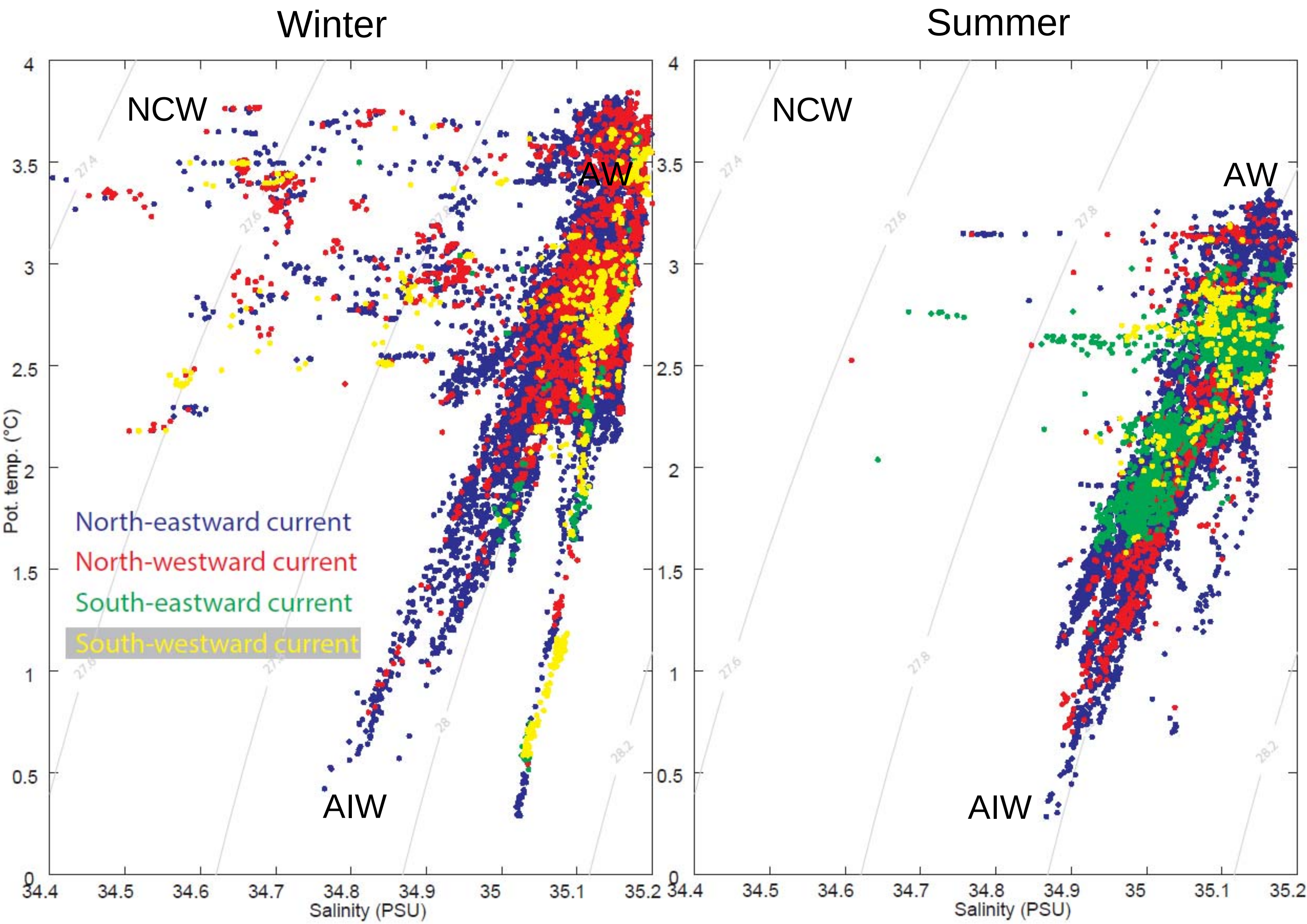
- Brine formation from Storfjorden?
- Local water due to brine formation from Isfjorden?
- Norwegian Sea Deep Water?





17-22 sept. 2012

TS – diagram vs. current direction

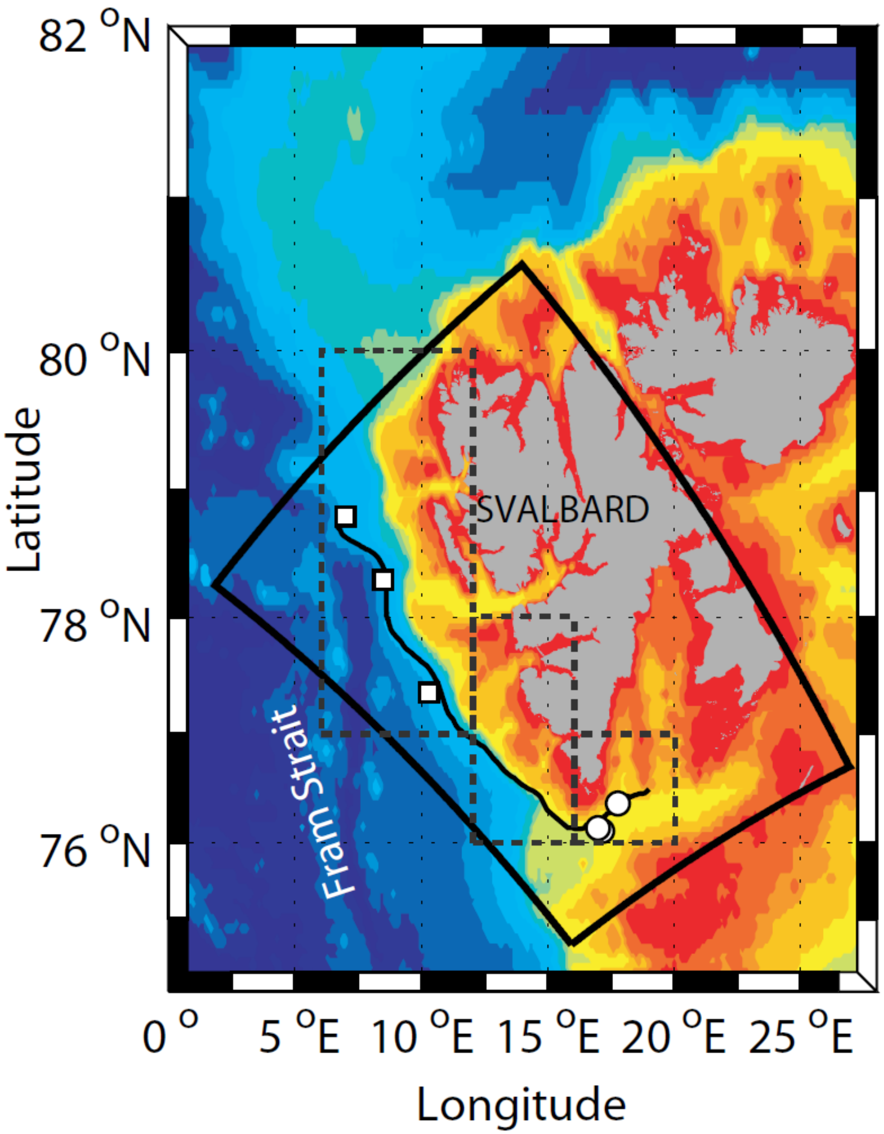


Arctic Ocean ESONET Mission

Time-series analysis in Marine science and applications for industry

Dense water from Storfjorden?

- Production of dense, brine-enriched shelf water (BSW) through ice-formation in winter in Storfjorden
- 34.8<S<35.8
- Temperature close to the freezing point on the shelf
- Can overflow the 120-m sill to flow northward along the continental slope
- Killworth model (2001) (black line) and observation of Storfjorden water(white squares) > 1000 m water depth



Fer et al., *Ocean Science.* 2008

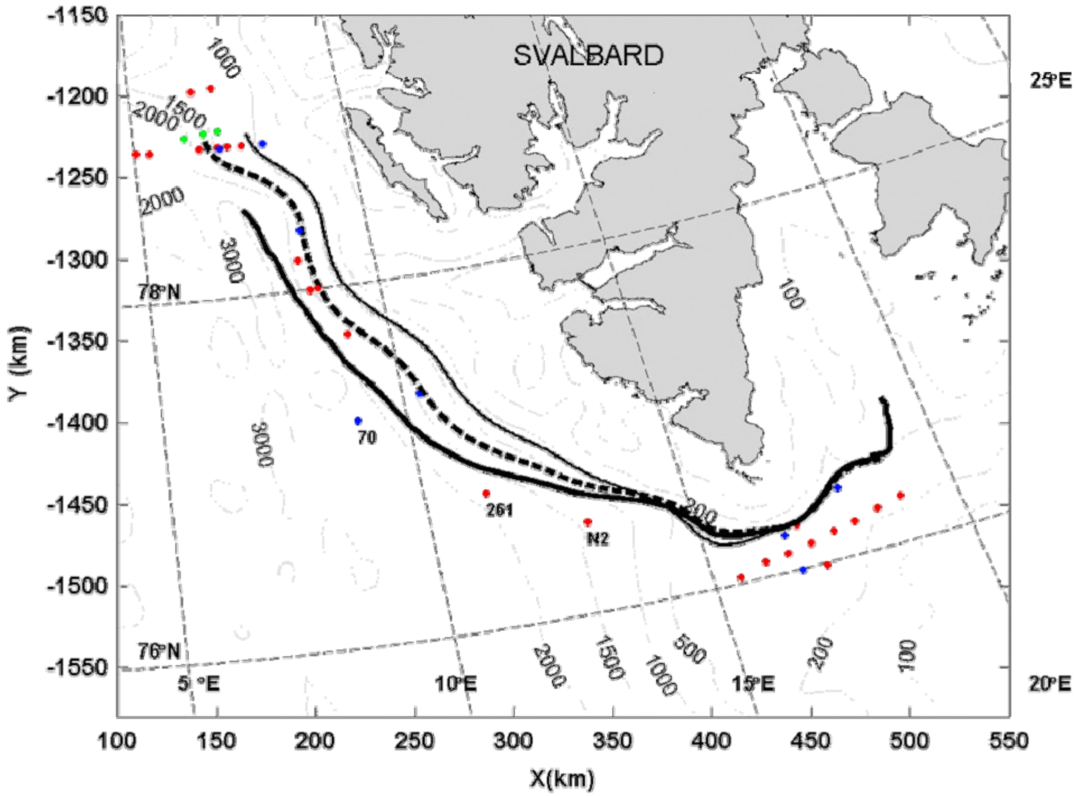
Arctic Ocean ESONET Mission

Logonna-Daoulas (France)

17-22 sept. 2012

Dense water from Storfjorden? (*cont.*)

- Plume spreads along continental slope over 600 km away from its formation and reaches 2000 m depth
- 30 to 80 m thick in the deep layer
- Almost 0.4°C warmer and 0.06 more saline than ambient water
- Signature only seen deeper than 1000 m depth



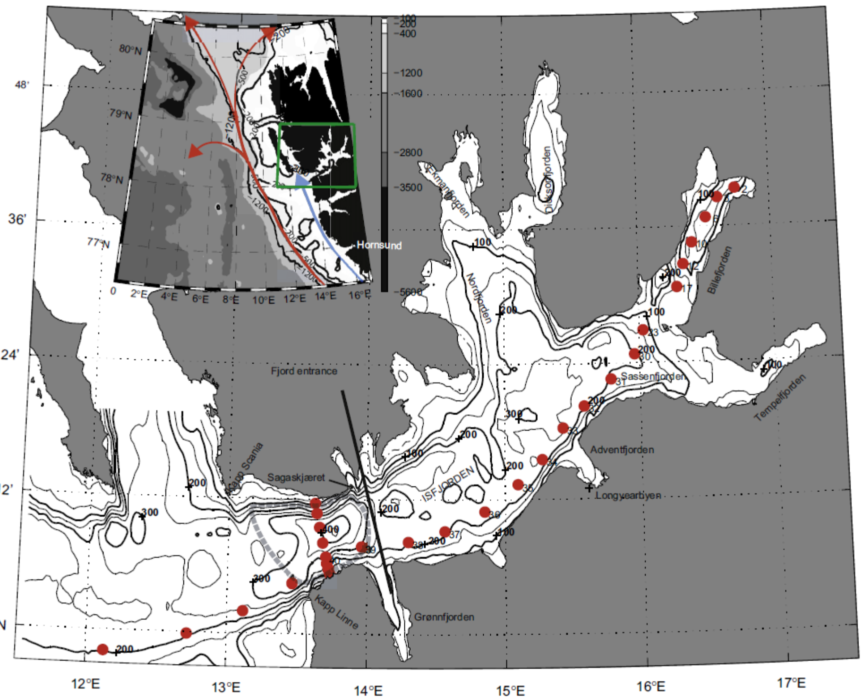
Akimova et al., *Deep Sea Res.* 2011

CTD stations where plume was observed: in 1986 (blue dots), 1988 (green dots) and 2002 (red dots)

Time-series analysis in Marine science and applications for industry

Dense water from Isfjorden?

- No sill: direct link to shelf and slope area
- Exchange with Atlantic Water
- Formation of brine-enriched water from late-Nov. to mid-May
- Critical parameter controlling fjord–shelf exchange: the density difference between fjord water masses and the Atlantic Water.



Nilsen et al., *Cont. Sh. Res.* 2008

- Winter cooled water (T < -0.5°C, 34.4 < S < 35 psu)
- Mixing between Arctic water, brine-enriched water and Atlantic water could explain the last water mass after being transported outside the fjord.

Logonna-Daoulas (France)

17-22 sept. 2012

Conclusions

- Strong seasonal variability of water masses
- Distinction between 4 main water masses
  - Norwegian Coastal Water
  - North Atlantic Water
  - Arctic Intermediate Water
  - Brine-enriched water from surrounding fjords ?
- Several origin possibilities for brine-enriched water
- Seasonal variability of methane release corresponding to water masses?
- New time series from August 2011 to August 2012