DTU Aqua

Cruise report 09A12, R/V Dana, Hirtshals-Reykjavik, 27/8-2/9 2012
Oceanography at Sea DTU course 25501.
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Scientific Participants

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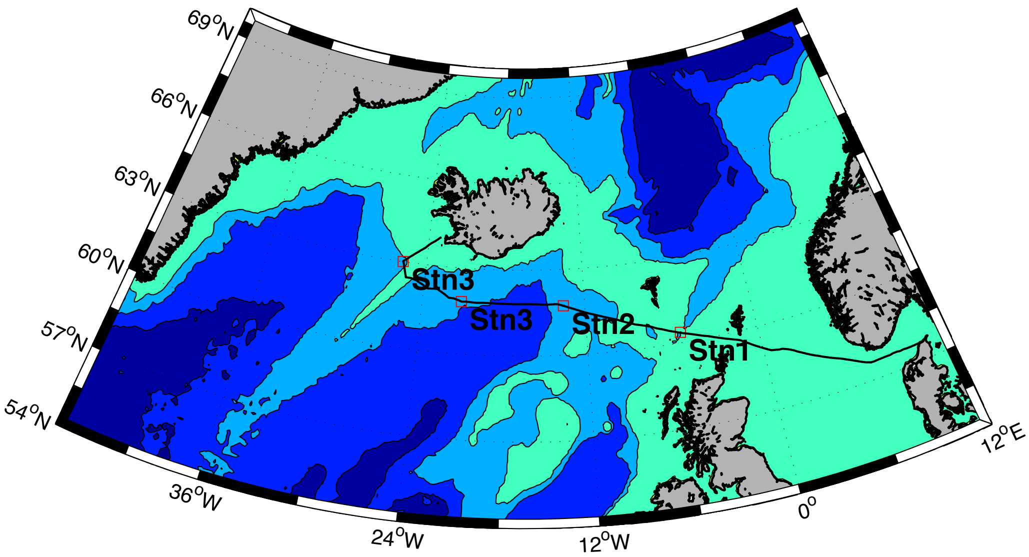
Cruise Objective

This cruise was the focus of a university course (5 ECTS) in oceanographic research techniques on board R/V Dana, sponsored by the Danish Centre for Marine Research. The course was designed to give students sea-going experience and a practical introduction to ocean sampling. The learning objectives of the course were:

- Identify common pitfalls and necessities with organizing oceanographic sampling
- Use a conductivity-temperature-depth (CTD) probe for measuring the physical properties of seawater
- Conduct measurements of underwater light penetration and assess the contribution of different water constituents to light attenuation.
- Quantify phytoplankton biomass distribution using chlorophyll a measurements and assess phytoplankton productivity.
- Conduct measurements of chemical properties of seawater (concentrations of oxygen and selected nutrients)
- Use ODV for processing and presenting oceanographic data.
- Integrate and interpret the oceanographic data collected.
- Relate the data collected during the cruise to regional oceanographic phenomena.

Figure 1: The route sailed and the location of the stations visited. At each station CTD (+light) profiles and water samples were collected.



Nature of work carried out on board.

The course was designed to have four oceanographic sampling themes: biological; physical; chemical and optical. The students were split into four groups and rotated between each theme each day. Biological oceanographic theme covered sampling for phytoplankton and measuring chlorophyll concentrations using a spectrophotometer and carrying our Winkler oxygen measurements. Physical measurements included operating the CTD, coordinating water sampling between the groups, communicating with the bridge, and sampling for salinity calibrations. The chemical oceanography components covered sampling and analysis of pH, Alkalinity, phosphate and silicate concentrations, and the optical theme covered measurements of the attenuation of broadband light (PAR) in the surface waters and comparing these with the optical properties of particles and dissolved organic matter measured from water samples.

Cruise log

27th August,

All arrived in Hirtshals and boarded Dana. Equipment set up and secured in the laboratories. Sailed from Hirtshals around 14:00 (UTC) in good weather.
Course started with a brief introduction and outline by Colin. After dinner, Andy gave a talk introducing some of the fundamentals of ocean physics. At around midnight the sea state began roughen and winds picked up.

28th August,

The main plan for the day was lectures while we steamed across the North Sea towards the first sampling station south of the Faroe Islands. There were high winds and 5 m swells making for challenging teaching conditions. During the day the conditions improved. During the morning introductory lectures on aspects of biological, chemical and optical oceanography where given by Katherine, Colin and Stiig, respectively. After lunch an introduction to the oceanography software Ocean Data View was given and the students carried out some exercises with the software.

29th August,

Swells picked up again a little in the night but by morning returned to relatively calm and overcast conditions. The morning was used to prepare for the first sampling in groups. We arrived at Station 1 in the Faroe-Scotland Channel at about 13:30 and started with a shallow CTD cast, collecting water for phytoplankton abundance and primary production, and bio optics measurements. Then carried out a deep CTD cast down to 1100 m, collecting water for water chemistry. Students worked on the samples and data collected while the ship then continued to steam west towards the Iceland Basin. It was a late night in the lab for some and a long night processing CTD data for others.

30th August,

Sea state fine, only a gentle swell, and the clouds where clearing. Arrived at Station 2 in the Iceland Basin at around 9 am. Carried out two casts again, a deep and a shallow. Students worked on their samples and data during the rest of the day. After dinner two Ph.D. students, Areif (DTU) and Ciaran (AAU) gave talks presenting their PhD projects.

31st August,
Arrived early in the morning at the third station south of Iceland. First cast with the CTD started at 6 am down to approximately 1000 meters. Followed by a shallow cast for phytoplankton samples and light measurements. Students busy the rest of the day in the lab although we were finished earlier due to the early start. Before dinner Nikolaj Sørensen (KU) gave a presentation of his PhD and after dinner Stavroula (DTU) presented her project. A whale was spotted in the distance at about 8 o'clock in the evening and everyone was up in the bridge on the look out. It did not come too close and it was difficult to sea its body or tail as there was quite a swell. In the evening the weather turned bad again with high winds and swell. A gentle reminder for the students that anything not strapped down or correctly stowed away goes flying!

1st September
Arrived on station southwest of Iceland at 5:30 in the morning. Same sampling plan carried out as the day before. In the afternoon, whilst steaming to Reykjavik, the students were then reorganized into the groups they will be working up data in, and began discussing with the teachers how to present and interpret the data and plans for eventually making a poster. After dinner, Stiig gave a short talk that he was preparing for the Danish parliament on the status of nitrogen loadings to Danish coastal waters. After the talk we arrived in Reykjavik. The students continued in their groups working on the data collected from the cruise. Andy Visser disembarked.

2nd September
After breakfast, a short meeting and group picture, the students disembarked, tired but happy. The teaching cruise appeared to have been a success, with the students grasping the realities of sampling at sea and obtaining hands on experience with a range of techniques.

Findings.
To document the findings of the work the four posters created by students are in the appendix of this report.

Concluding remarks.
The course was a great success. The crew of Dana, the teachers and the students all enjoying the experience. I would like to take the opportunity to thank all involved and especially the Danish Centre for Marine Research for providing the funds to support the course. The teaching on board worked well and I highly recommend that this is repeated in the future. Dana and its crew provide an inspirational teaching and learning environment.

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Biological *oceanography* at Sea

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Dansk Center for Havforskning
DTU Aqua National Institute of Aquatic Resources
AARHUS UNIVERSITY

Aim

The aim of this cruise was to learn to organize biological oceanography data sampling. A conductivity-temperature-depth (CTD) probe measured physical, chemical, optic and biological properties of North Atlantic water and we used the sampling results to quantify phytoplankton biomass distribution and productivity. Some CTD-plots are presented in the software program OceanDataView (ODV). We focus on the different factors influencing phytoplankton productivity and distribution and in addition discuss the changing conditions in the world´s oceans.

Figure 1. Surface irradiance on a sunny (orange) and cloudy (blue) day.

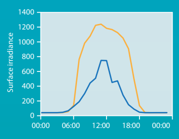


Figure 2. Chlorophyll *a* profile.

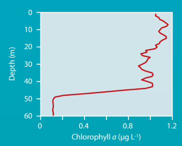
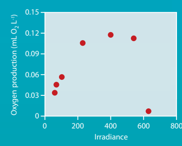


Figure 3. Oxygen production as function of light intensity in live sea water samples incubated under *in situ* conditions.



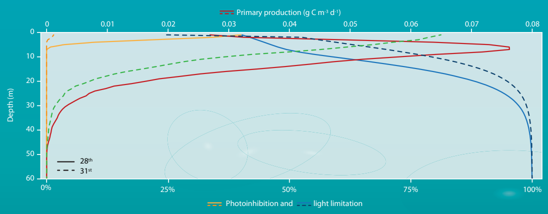


Figure 4. Primary production (red) in the water column on a cloudy and sunny day, and the relative importance of photoinhibition (orange) and light limitation (blue), over a 24 hour period.

Changing ocean conditions

When ocean conditions are changed, by natural or anthropogenic causes it has an effect on the biological pump and the organisms that are part of it.

Increasing atmospheric concentrations of carbon dioxide is reducing the pH of the oceans (by increasing hydrogen ion concentrations), making the sea more acidic. The concentration of calcium carbonate is also decreasing, and this could potentially be detrimental to calcifying organisms, such as corals and some forms of plankton, making them particularly vulnerable to climate change. Because these organisms are part of the biological pump and because $CaCO_3$ acts as ballast to sinking material, this could potentially have a large impact on primary production and deep-sea export of DOM.

Warmer temperatures will limit the supply of nutrients in the surface layers, and that will decrease primary production in the euphotic zone. Often, production in surface layers are limited by nutrient supply from below and an increase in surface layer stratification will have a negative effect on nutrient supply.

Our growing understanding of how our world and seas is working, needs to be passed on to the people who live here, without whom we have no chance of stopping this potentially detrimental effect.

Acknowledgement

This work is part of the marine field course Oceanography at Sea launched by Dansk Center for Havforskning. Associate Professor Colin A. Stedmon (DTU-Aqua), Professor André Viser (DTU-Aqua), Professor Katherine Richardson (Copenhagen University) and Professor Stiig Markager (Aarhus University). Thanks to the Crew at Dana for taking such good care of us!

References

Falkowski, P.G. (2007). Photosynthesis and Primary Production in Nature. In: Aquatic Photosynthesis (Second edition), pp. 319-363. – Princeton University Press.
Sabine, C.L. & Tanhua, T. (2010). Estimation of Anthropogenic CO_2 Inventories in the Ocean. – Annual Review of Marine Science 2:175-198.
Sverdrup, K.A. & Armbrust, E.V. (2009). The Chemistry of Seawater. In: An introduction to The Worlds Oceans 10th, pp. 148-165. – McGraw-Hill Custom Publishing.
Varney, M. (1996). The Marine Carbonate System. In: C.P. Summerhayes & S.A. Thorpe. Oceanography, An illustrated Guide, pp. 182-194. – London: Manson Publishing Ltd.

Primary production

The light regime may change considerably on a small scale time. The surface irradiance measured on a cloudy and sunny day here are only three days apart in the North Atlantic (fig. 1).

Recent windy conditions had likely mixed the upper layer, removing any spatial variation with depth but also between stations. There was still stratification however, ensuring a lower layer with few to no algae (fig. 2).

As irradiance increases, so does primary production. If the light intensity becomes too high however, the algae will take damage, severely reducing their photosynthesis; this is called photoinhibition (fig. 3).

Based on light profiles from a sunny and cloudy day, incubation experiments at different light intensities and a chlorophyll a profile (to determine the autotrophic biomass), the primary production at each depth could be calculated over a 24 hour period (fig. 4).

Photoinhibition only plays a role in the uppermost layer on a sunny day. Light limitation is most pronounced at depths, but also plays a role in the upper layers due to low light at night. Highest primary production is found on sunny days (1.01 g C m^{-2}) compared to cloudy days (0.69 g C m^{-2}).

On sunny days, highest primary production is seen at some depth due to photoinhibition. On cloudy days, irradiance is not sufficient to cause photoinhibition why light is almost always limiting. Here, highest primary production is seen at the surface (fig. 5, 6 and 7).

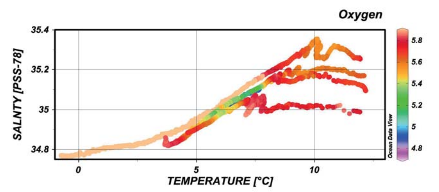


Figure 5. Salinity, temperature and oxygen plot.

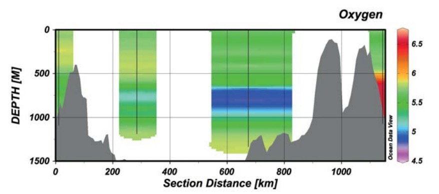


Figure 6. Oxygen profile as a function of distance.

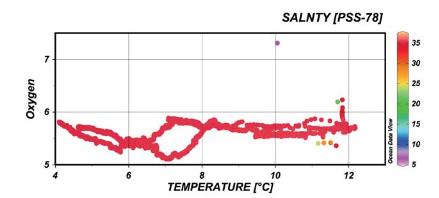
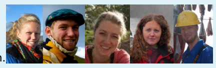


Figure 7. Oxygen, temperature and salinity plt.

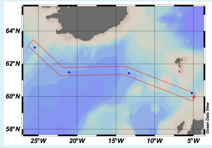
Estimation of Anthropogenic CO_2 in the North Atlantic

Dansk Center for Havforskning, Dana, summer 2012,
Christina Søegren, Nikolaj Thyessen Dam, Sanne Høj Andrén, Stavroula Tsoukali, Thomas Bech-Thomassen.



Introduction

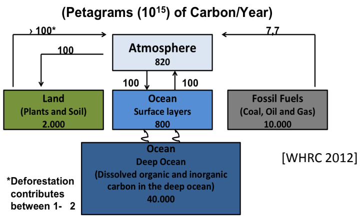
During the course *'Oceanography at sea'* on board Dana, we examined different chemical properties at four different station in the North Atlantic. We measured the pH, alkalinity, phosphate and silicate. We used these measurements to estimate the anthropogenic CO_2 in the water column.



Section of the four stations

Global flows of carbon

The ocean plays a dominant role in the Earth's carbon cycle. The figure shows the global carbon cycle, which involves the carbon in and exchanging between the Earth's atmosphere, fossil fuels, the oceans (the surface layers and the deep ocean), the vegetation and soils of the terrestrial ecosystems. The oceans constitute the largest active pool of carbon at the Earth's surface. The total amount of carbon in the ocean is about 50 times greater than the amount in the atmosphere, and is exchanged with the atmosphere on a time-scale of several hundred years.



[WHRC 2012]

Anthropogenic Carbon calculations

In order to reconstruct the anthropogenic part (C_{ant}) of the observed Dissolved Inorganic Carbon (DIC_{obs}) in the water samples, it is necessary to derive how much of the carbon/CO_2 has been removed by primary production (DIC_{bio}), and how much of the DIC has a natural/preindustrial source (DIC_{pi}).

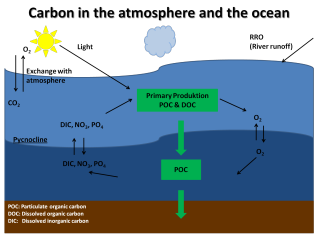
$$C_{ant} = DIC_{obs} - \Delta DIC_{bio} - DIC_{pi}$$

DIC_{obs} is calculated from the chemical parameters Alkalinity, pH and different physical factors and with an atmospheric CO_2-concentration of 380 ppm. In order to calculate the DIC_{pi} we used the atmospheric CO_2-concentration of 280 ppm, which corresponds to preindustrial values, assuming that the physical characteristics (T, S, nutrients) were the same.

DIC_{bio} is an estimation of how much CO_2 has been removed by primary production. This is calculated indirectly by estimating how much oxygen has been used by organisms since the last time the water mass was at the surface, under the assumption that the oxygen saturation of surface water is 100%.

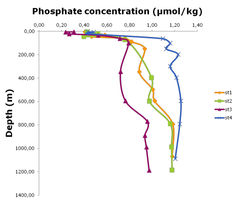
In small timescales DIC_{bio} is insignificant, because the amount of CO_2 that is removed by water is much larger. In a larger timescale however the DIC_{bio} has an important role, because the water bound CO_2 returns to the surface again at some time, but some of the DIC_{bio} will sediment, bury and thereby be removed from the system. [Sarmiento & Gruber, 2006]

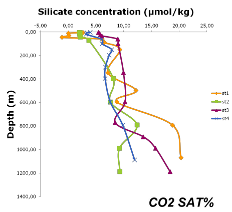
Carbon in the atmosphere and the ocean

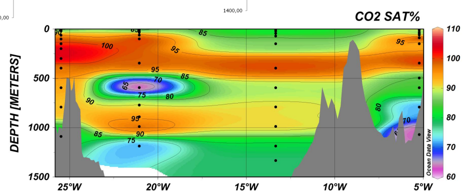


The different Carbon fluxes in the ocean

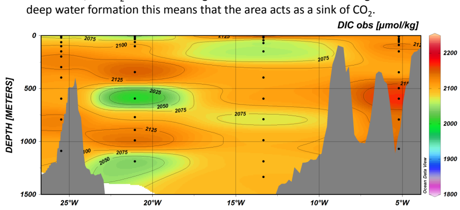
Results



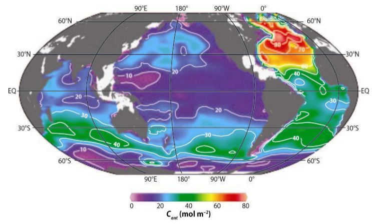




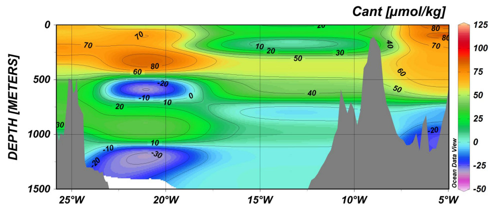
CO_2-saturation: In the figure it can be seen that surface waters aren't in equilibrium with the air, so CO_2 will be diffusing from the air into the water. Together with the deep water formation this means that the area acts as a sink of CO_2.



DIC_{obs}: The figure shows DIC_{obs} (DIC observed), which is higher than the DIC_{pi}. The difference between the two is around 55-65 µm kg^{-1}.



Sabine and Tanhou (2010) estimated the oceans anthropogenic carbon. In the North Atlantic they calculated a C_{ant} of 80 mol m^{-2}.



C_{ant}: The figure shows C_{ant} (the anthropogenic carbon).

➢The anthropogenic CO2 values (in Table) that we measured are close to the values that Sabine & Tanhua (2010) presented for the N.Atlantic Ocean, although our values may be underestimated due to the assumptions that we made during our calculations.
➢The negative C_{ant} values that we observe are due to some extreme values in the physical and chemical measurements (e.g. temperature bellow 0°C at the first station)

CO_2 anthropogenic	
Station	TCO2, mol/m²
St1	31,16
St2	24,28
St3	25,11
St4	40,89

Conclusion

✓The silicate and phosphate vertical profiles show a depletion of nutrients at the surface waters, as expected, due to biological activity.
✓From our CO_2 %-saturation plot we see that the eastern part of the study area is not saturated yet, which means the ocean acts as an sink. On the western part (station 4), however, we observed highly saturated water masses.
✓We also estimated higher DIC concentration today (DIC_{obs}) compared to the preindustrial period (DIC_{pi} , plot not shown here). We can hence see that anthropogenic CO_2 emission have increased oceanic carbon levels.
✓By comparing our results with results in the literature [Sabine & Tanhua 2010, Gruber 1996] we can see that our values are close to already published data.

References

Gruber N., Sarmiento J.L & Stocker T.F. (1996), *An improved method for dectecting antropogenic CO2 in the oceans*, Global Biogeochemical cycles, vol 10, no. 4
Sabine, C. L. & Tanhua T. (2010), *Estimation of Anthropogenic CO2 Inventories in the Ocean*, Annual Reviews.
Sarmiento, J. L. & Gruber N. (2006), *Ocean Biochemical Dynamics*, Princeton University Press
Woods Hole Center Resarch Center (WHRC)
http://www.whrc.org/global/carbon/index.html (last viewed 14th September 2012)

Oceanography at Sea: Optics

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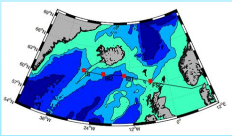
Introduction

The aim of our work was to investigate the optical properties of the North Atlantic Ocean. During a cruise in August and September 2012, measurements were made and water samples were taken from 4 stations: a station in the Faroe Scotland Channel (FSC), 2 stations in the Iceland Basin (IB1, IB2) and a station in the Irminger Sea (IS).

Stn.	Date/ Time (2012)	Position
FSC	29 Aug 12:23	60° 21.59' N 5° 22.39' W
IB1	30 Aug 09:01	61° 43.99' N 13° 34.15' W
IB2	31 Aug 08:38	61° 50.66' N 21° 09.10' W
IS	01 Sep 07:41	63° 01.52' N 25° 46.76' W



Materials and Methods

I: During CTD casts, light intensity was recorded every 0.20 meters to give profiles of PAR (photosynthetically available radiation) through the water column. The diffuse light attenuation coefficient, K_d, was estimated for the surface waters (0-30m) by linear regression on the log-transformed light intensity.

II: To estimate chlorophyll specific absorption, water samples from 2 depths (surface and DCM) were filtered onto a Whatman GF/F filter. The optical density of the filters was measured with a Shimadzu UV-2500 spectrophotometer using an integrating sphere attachment. The absorption coefficients were calculated by the following equation: $a(\lambda)=2.3*OD(\lambda)*s/(V_f*\beta(\lambda))$ where β is a corrrection factor $\beta(\lambda) = 1.63 * OD(\lambda)^{-0.22}$ *(Bricaud & Stramski 1990)*

To calculate the chlorophyll specific absorption, the absorption coefficients were divided by the measured chlorophyll-a concentrations at the respective depths.

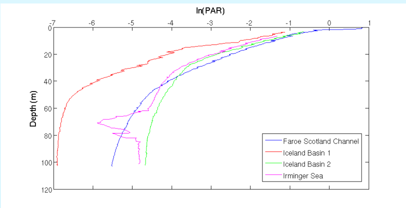
III: to investigate the origin of CDOM, water samples were collected from each station. Water was filtered through a 0.2 μm filter, and by using 10 cm quartz cuvettes the samples were analysed in a spectrophotometer. An exponential function was fitted to the observed absorption spectra to give estimates of spectral slope coefficient (S) and absorption coefficient at 375 nm (a_{375}):

$a(\lambda)=a(\lambda_0)*exp(S(\lambda_0-\lambda))$ *(Stedmon & Markager, 2001)*

IV: A photon budget was made for station FSC. Spectral attenuation was modelled by the sum of calculated absorption components and backscattering $K_d(\lambda)=(a_{water}(\lambda)+a_{CDOM}(\lambda)+a_{part}(\lambda)+b_b)/cos(\theta)$. The backscatter b_b and zenith angle θ were estimated by fitting the model to the observed PAR profile.

Results and Discussion

Light attenuation through the water column

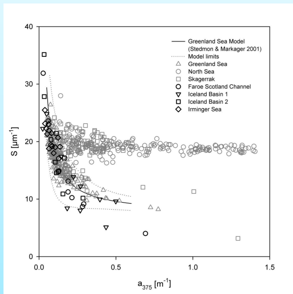


Light attenuation coefficient K_d (0-30m)

Stn	K_d [m⁻¹]
FSC	0.111
IB1	0.166
IB2	0.121
IS	0.126

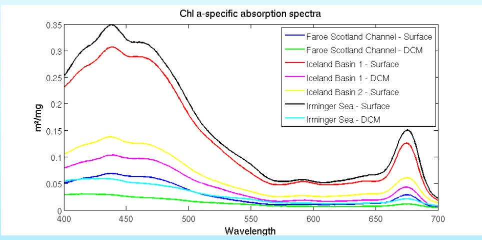
The data from the stations shows decrease in light intensity with depth is approximately exponential over the uppermost 30-40m of the water column. There is a clear reduction in attenuation below the pycnocline. The light attenuation is greatest at IB1.

CDOM pool comparison



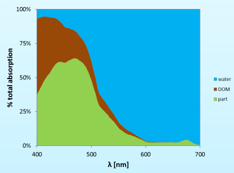
CDOM data from the four stations plotted with data from the Greenland Sea, the North Sea and Skagerrak *(Stedmon & Markager, 2001)*

The chlorophyll-a specific absorption spectra

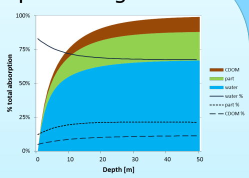


Chlorophyll a specific absorption at all stations. Peaks between 650-700 show absorption of visible red light and peaks around 450 absorption of visible blue light. Surface waters from Irminger Sea and Iceland Basin 1 were found to have the strongest chlorophyll specific absorption: the values are very high in comparison with oceanic (Greenland Sea) values observed by Stæhr et al (2004)

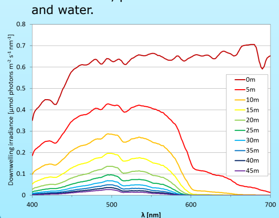
Where do the photons go?



Spectral absorption. The fraction of absorption at each wavelength due to CDOM, particulate matter and water.



Solid curves show cumulative absorption of light with depth, and by which component. The lines show fraction of total light absorption at each depth by each component, weighted for the spectral composition of the light at that depth.



Modelled irradiance spectra by depth.

Conclusions

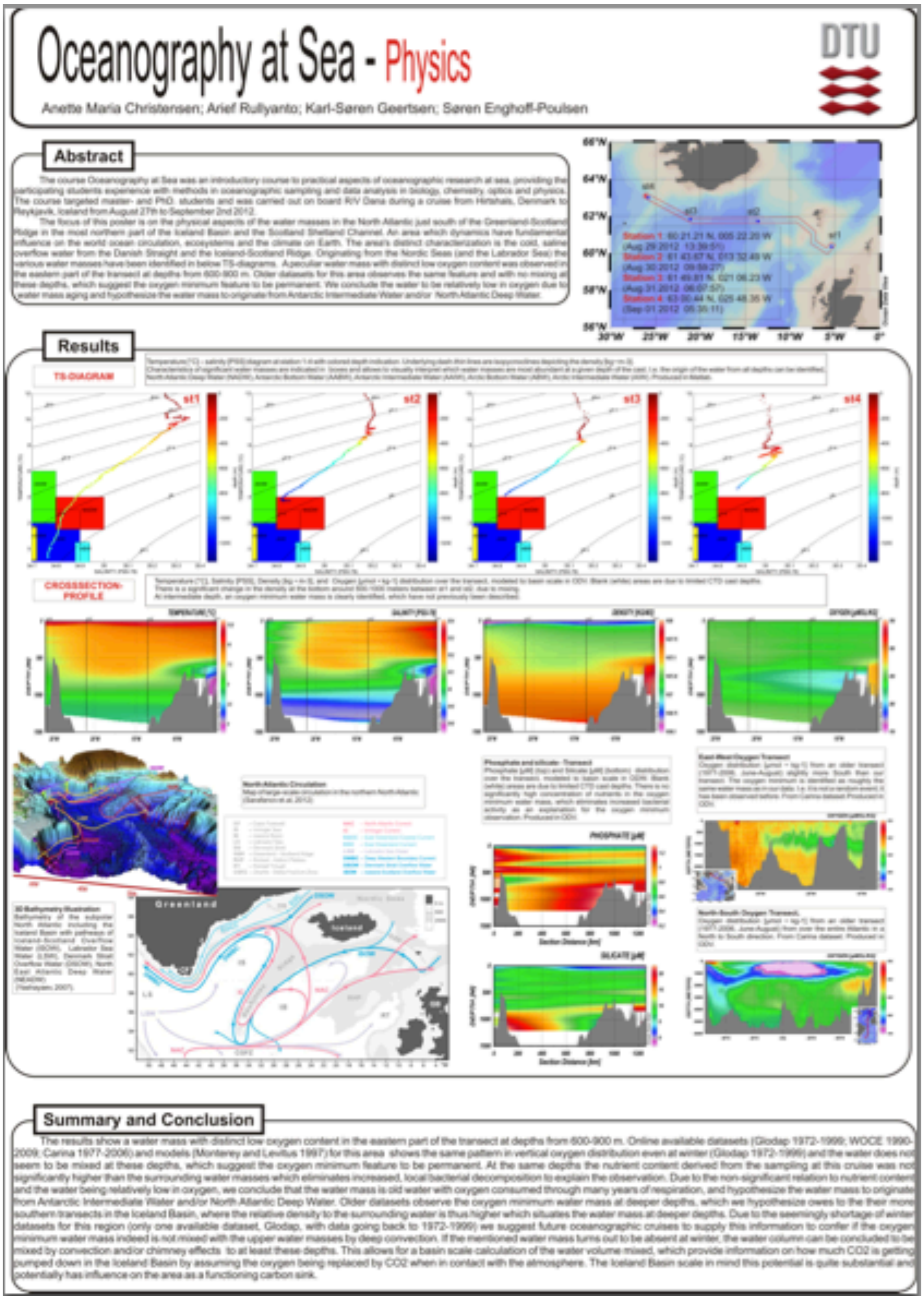
PAR attenuatedthrough the water column and the highest attenuation was seen at Iceland Basin 1.
There was no clear relation between chlorophyll-a specific absorption and depth or station, or to overall attenuation.
The CDOM seen in the four stations had similar optical charateristics to CDOM from the Greenland sea and most likely derives from in situ production in the ocean.

References

Bricaud, A. and D. Stramski. 1990 . Spectral Absorption Coefficients of Living Phytoplankton and Nonalgal Biogenous Matter. Limnol. Oceaogr. **35:** 562-582

Stedmon, C.A. and S. Markager. 2001. The Optics of Chromophoric Dissolved Organic Matter (CDOM) in the Greenland Sea. Limnol. Oceaogr. **46:** 2087-2093

Stæhr et al. 2004. Pigment specific in vivo light absorption of phytoplankton from estuarine, coastal and oceanic waters. Mar. Ecol. Prog. Ser. **275:** 115-128


Oceanography at Sea - Physics
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Abstract
The course Oceanography at Sea was an introductory course to practical aspects of oceanographic research at sea, providing the participating students experience with methods in oceanographic sampling and data analysis in biology, chemistry, optics and physics. The course targeted master- and PhD. students and was carried out on board R/V Dana during a cruise from Hirtshals, Denmark to Reykjavik, Iceland from August 27th to September 2nd 2012.
The focus of this poster is on the physical aspects of the water masses in the North Atlantic just south of the Greenland-Scotland Ridge in the most northern part of the Iceland Basin and the Scotland Shetland Channel. An area which dynamics have fundamental influence on the world ocean circulation, ecosystems and the climate on Earth. The area's distinct characterization is the cold, saline overflow water from the Danish Straight and the Iceland-Scotland Ridge. Originating from the Nordic Seas (and the Labrador Sea) the various water masses have been identified in below TS-diagrams. A peculiar water mass with distinct low oxygen content was observed in the eastern part of the transect at depths from 600-900 m. Older datasets for this area observes the same feature and with no mixing at these depths, which suggest the oxygen minimum feature to be permanent. We conclude the water to be relatively low in oxygen due to water mass aging and hypothesize the water mass to originate from Antarctic Intermediate Water and/or North Atlantic Deep Water.
Results
TS-DIAGRAM
st1
st2
st3
st4
CROSSSECTION-PROFILE
PHOSPHATE [µM]
SILICATE [µM]
Section Distance [km]
Greenland
Iceland
Summary and Conclusion
The results show a water mass with distinct low oxygen content in the eastern part of the transect at depths from 600-900 m. Online available datasets (Glodap 1972-1999; WOCE 1990-2009; Carina 1977-2006) and models (Monterey and Levitus 1997) for this area shows the same pattern in vertical oxygen distribution even at winter (Glodap 1972-1999) and the water does not seem to be mixed at these depths, which suggest the oxygen minimum feature to be permanent. At the same depths the nutrient content derived from the sampling at this cruise was not significantly higher than the surrounding water masses which eliminates increased, local bacterial decomposition to explain the observation. Due to the non-significant relation to nutrient content and the water being relatively low in oxygen, we conclude that the water mass is old water with oxygen consumed through many years of respiration, and hypothesize the water mass to originate from Antarctic Intermediate Water and/or North Atlantic Deep Water. Older datasets observe the oxygen minimum water mass at deeper depths, which we hypothesize owes to the their more southern transects in the Iceland Basin, where the relative density to the surrounding water is thus higher which situates the water mass at deeper depths. Due to the seemingly shortage of winter datasets for this region (only one available dataset, Glodap, with data going back to 1972-1999) we suggest future oceanographic cruises to supply this information to confer if the oxygen minimum water mass indeed is not mixed with the upper water masses by deep convection. If the mentioned water mass turns out to be absent at winter, the water column can be concluded to be mixed by convection and/or chimney effects to at least these depths. This allows for a basin scale calculation of the water volume mixed, which provide information on how much CO2 is getting pumped down in the Iceland Basin by assuming the oxygen being replaced by CO2 when in contact with the atmosphere. The Iceland Basin scale in mind this potential is quite substantial and potentially has influence on the area as a functioning carbon sink.