

## Report from the SMHI monitoring cruise with R/V Aranda



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**Survey period:** 2014-10-20 - 2014-10-28  
**Survey area:** Skagerrak, Kattegat, the Sound and the Baltic Proper  
**Principal:** SMHI and the Swedish Agency for Marine and Water Management

### SUMMARY

The expedition was part of the Swedish regular marine monitoring programme and covered Skagerrak, Kattegat, the Sound and the Baltic Proper. Data presented in this report have been subject to preliminary quality control procedures only.

Water temperature in the surface layer was slightly above normal in the whole investigated area. Nutrients in the surface layer showed normal concentrations, except for elevated silicate concentrations in the western and eastern Gotland basin. In the western part of Skagerrak a thin layer containing very high concentrations of nutrients was detected.

The Arkona Basin was well oxygenated, while in the Bornholm Basin and Hanö Bight acute hypoxia occurred from depths exceeding 60 to 70 metres. Oxygen conditions in the eastern Gotland basin had deteriorated in the central parts, where acute hypoxia ( $< 2\text{ml/l}$ ) was found from 70 to 80 metres depth and anoxia from 125 metres. Nevertheless, in the southern parts of the eastern Gotland basin bottom water containing relatively high oxygen content was registered. In the western Gotland basin hypoxia was found from 70 metres depth and anoxia from below 80 metres depth.

The next cruise is planned for week 46 (10-17 Nov) and will cover Skagerrak, Kattegat, the Sound and the Baltic Proper.

## PRELIMINARY RESULTS

The cruise was performed on board the Finnish research vessel Aranda, and began in Helsinki on 20<sup>th</sup> October and ended in the same port on the 28<sup>th</sup>. During the early part of the expedition winds were weak to moderate, coming mainly from east. After the first days the winds turned to westerly or south-westerly and increased to gale force. Air temperature varied between 10-13°C.

In order to get a better picture of the oxygen situation in the Eastern Gotland Basin an extra station, apart from the ordinary ones, was visited. A bottom-mounted rig with a recording oxygen sensor was deployed northeast of Öland's Southern Ground. The system will measure the oxygen level at a depth of 58 m, every 10 minutes, for about 5 months, in order to give a better picture of how fast the oxygen levels vary close to the halocline.

Two researchers from University of Helsinki took part in the expedition in order to study the formation of N<sub>2</sub>O in hypoxic waters, where this strong greenhouse gas is formed through a denitrification process. The goal was to study the formation of N<sub>2</sub>O following the inflow of water that took place in Feb-Mar 2014, and which oxygenated large parts of the Baltic Sea deep water – this subsequently led to widespread hypoxic conditions. In constant anoxia the accumulation of N<sub>2</sub>O ends, which is why the current situation of hypoxia is interesting to study.

### **The Skagerrak**

The thermocline was weakly developed close to the coast, while in the more central parts it was distinct and found at depths between 40 to 60 metres. Temperature in the upper layer was slightly above normal for the season, ca. 13 degrees. The halocline was also weakly developed in the coastal areas, where the salinity was around 33 psu in the surface water, which is higher than normal, while it was more distinct further west, where it was found at 10-20 metres depth. Nutrient levels in the surface layer had increased slightly since the previous survey. Phosphate concentrations varied between 0.10 and 0.33 µmol/l, silicate from 0.6 to 3.4 µmol/l, while concentrations of inorganic nitrogen (nitrite + nitrate) ranged between 0.25 and 1.16 µmol/l. All values normal for the season. At 15 m depth at station Å17, furthest west, a thin layer of water with extremely high nutrient concentrations was found, probably originating from the southern North Sea. Some plankton activity, based on fluorescence measurements, was recorded in the central regions, while the activity was low near the coast. The lowest oxygen value encountered in the bottom water was found at station Släggö, in the mouth of the Gullmar fjord, at 3 ml/l.

### **The Kattegat and the Sound**

The thermocline was located at a depth of about 15 metres, but was very weak. Temperature in the surface layer was slightly above normal, about 12.5°C. Surface salinity was normal, ca. 22 psu, in Kattegat and 17.5 psu in the Sound. The halocline was found at 15 metres depth in the Kattegat and at 7 metres in the Sound. Nutrients showed normal concentrations for the season, phosphate between 0.13 and 0.18 µmol/l, nitrite + nitrate from below detection limit (< 0.10 µmol/l) to 0.17 µmol/l, and silicate in the range of 1.9 to 3.3 µmol/l. In the Sound levels were generally higher, phosphate was at 0.42 µmol/l and silicate at 11 µmol/l. Fluorescence measurements indicated some plankton activity in the surface layer in the whole area. Oxygen concentrations in the bottom water were typical for the season and varied between 2.8 and 4.1 ml/l, lowest in the Sound.

## The Baltic Proper

The water temperatures were above normal in the whole area, varying from 11.4 to 14.3°C, and the thermocline was found at 30 metres depth. The salinity in the surface layer was normal in the major part of the area, at between 6.5 and 7.9 psu. In the Eastern Gotland Basin, however, surface salinity was clearly below normal, ca. 6.6 psu. The halocline was found at depths between 60 and 70 metres in the western and eastern Gotland Basins, while it was shallower located, between 35 and 50 metres, in the southern parts. All nutrients in the surface layer showed normal values for the season, silicate between 9 - 12 µmol/l, phosphate in the interval 0.15 to 0.30 µmol/l, while inorganic nitrogen (nitrite + nitrate) varied from below detection limit up to 0.6 µmol/l, highest in the Western Gotland Basin.

Effects of the inflow (25 km<sup>3</sup>) through the Sound that occurred in August were still obvious in the southern parts. In addition, during September and October two new inflows of ~20 km<sup>3</sup> and ~8 km<sup>3</sup> were registered through the Sound. The Arkona Basin was now well oxygenated, while acute hypoxia was present in the Bornholm Basin and Hanö Bight, at depths exceeding 60-70 metres. In the northern and central parts of the Eastern Gotland Basin acute hypoxia occurred from 70 - 80 metres, and hydrogen sulphide was found at depths exceeding 125-135 metres. In the southern parts of the basin (BY10 and BY9 W) an oxygen minimum (~1 ml/l) was detected at 90 to 100 metres, while oxygen concentrations close to the bottom, at 143 and 124 metres respectively, were about 2 ml/l. At station BCSIII-10 in the southeast an oxygen minimum (0.6 ml/l) was encountered at 80 metres, while at 90 metres depth the concentration was 2.4 ml/l.

In the western Gotland basin the oxygen situation was severe, as acute hypoxia was found from depths exceeding 70 metres and hydrogen sulphide from below 80 to 90 metres depths.

## PARTICIPANTS

Name		Institute
Lars Andersson	Chief Scientist	SMHI
Kristin Andreasson	Quality responsible	SMHI
Daniel Bergman-Sjöstrand		SMHI
Örjan Bäck		SMHI
Sofia Carlsson	(Lysekil – Helsingfors)	SMHI
Martin Hansson	(Helsingfors – Lysekil)	SMHI
Mikael Krysell	(Lysekil – Helsingfors)	SMHI
Vivi Månsson		SMHI
Susanna Hietanen		University of Helsinki
Petra Tallberg		University of Helsinki

## APPENDICES

- Track chart
- Table over stations, parameters and sampling depths
- Map showing bottom oxygen concentrations
- Monthly average surface water plots for selected stations
- Vertical profiles for selected stations

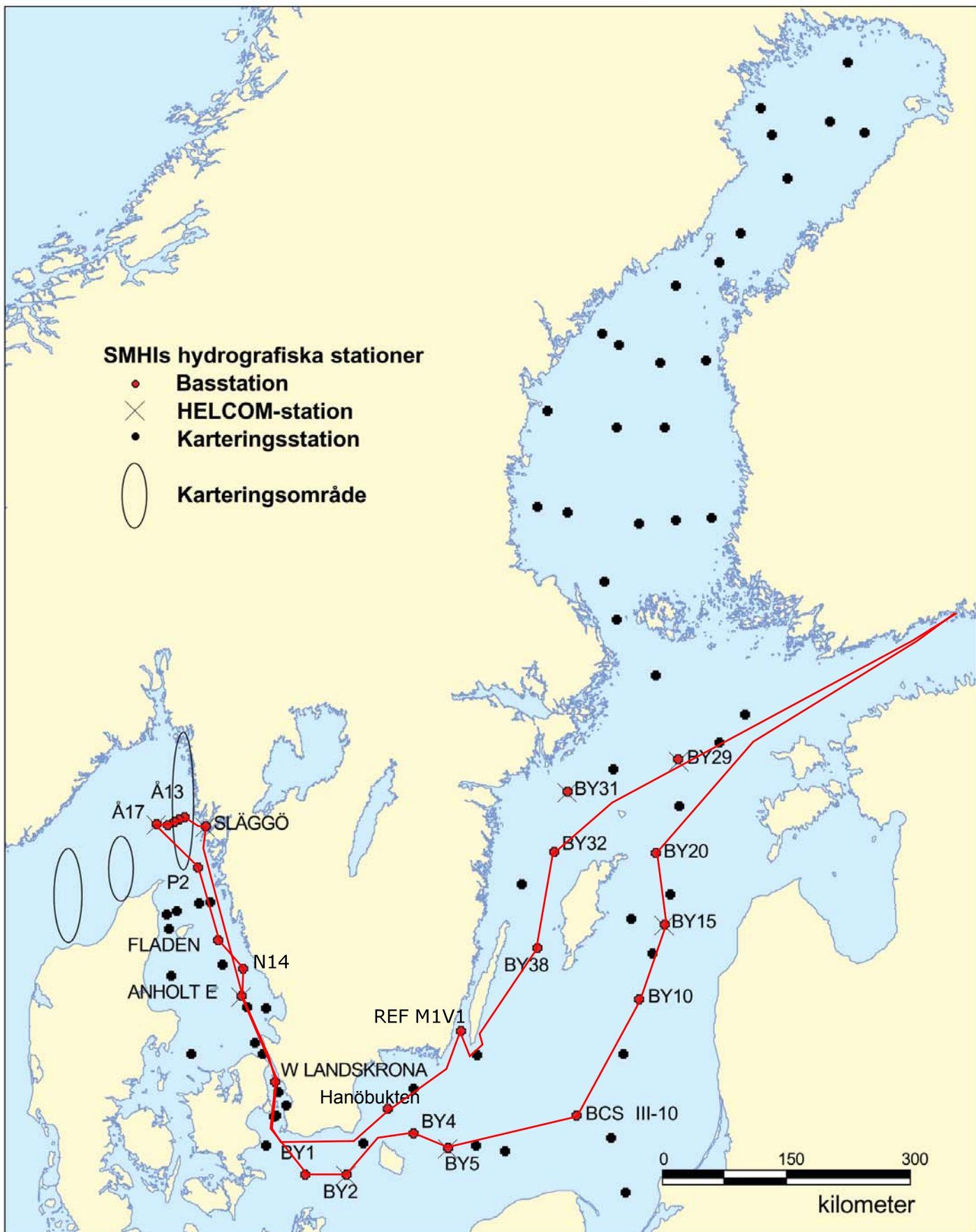
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Ship: R/V ARANDA

Date: 20141020-20141028

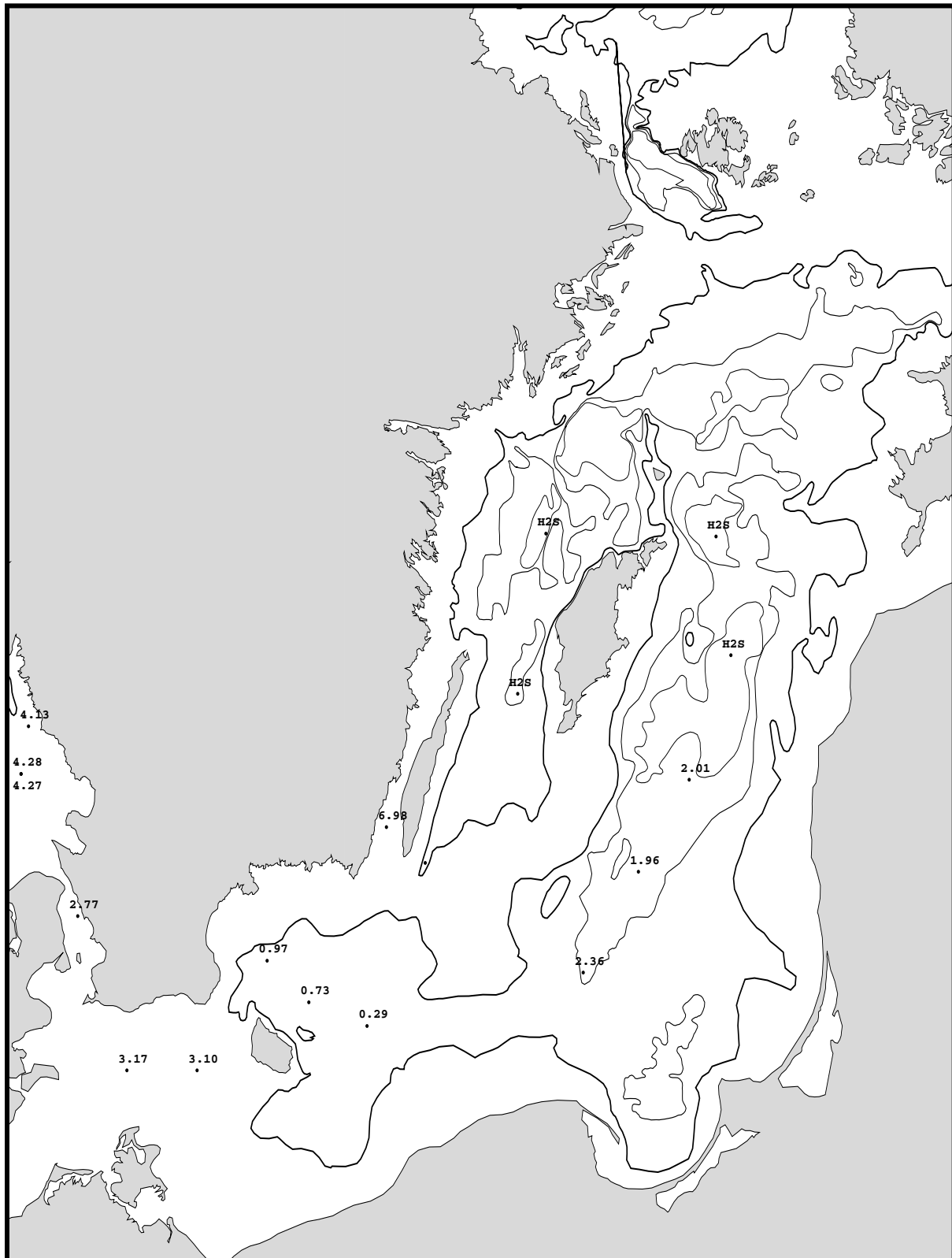
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# Bottom water oxygen concentration (ml/l)

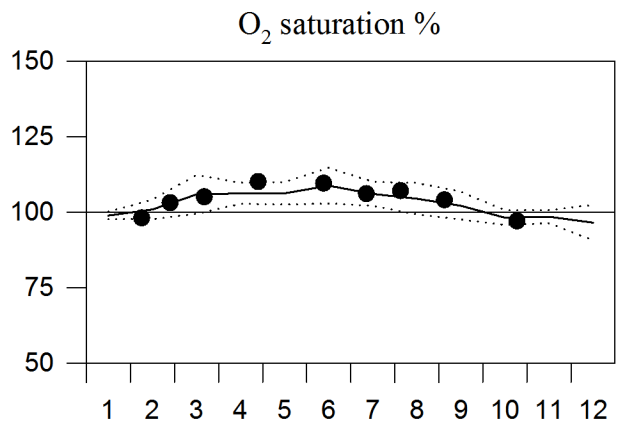
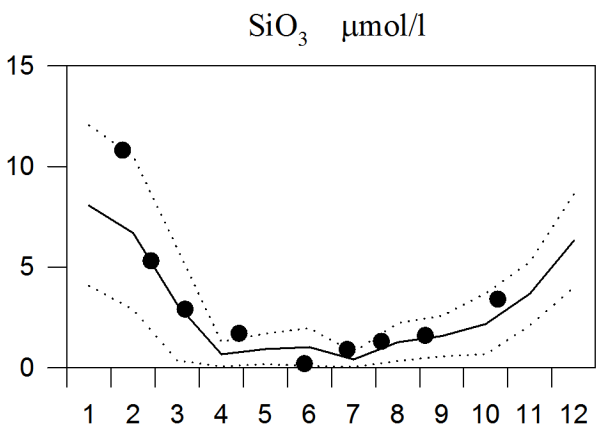
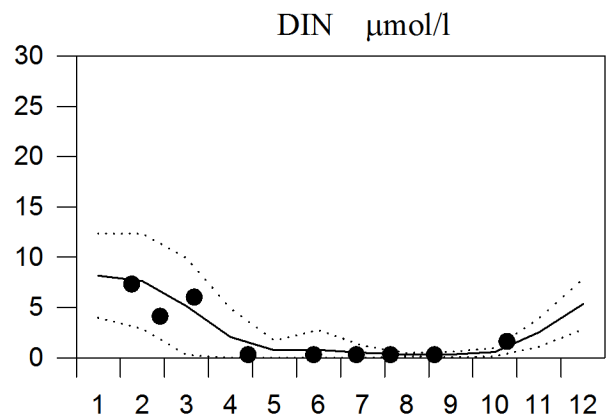
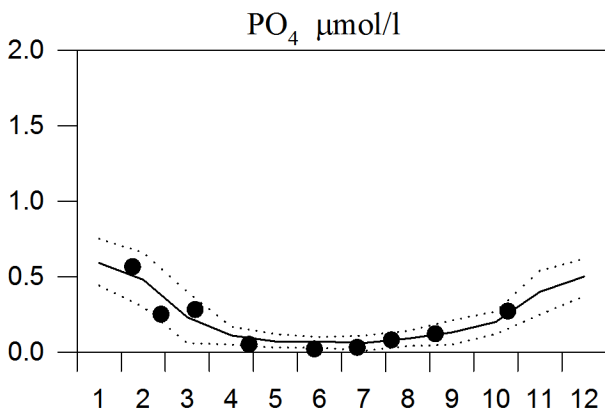
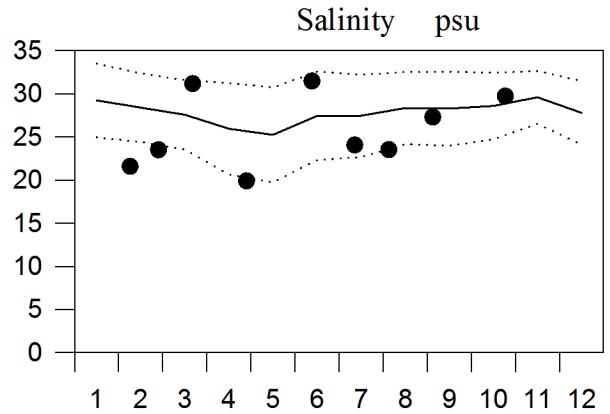
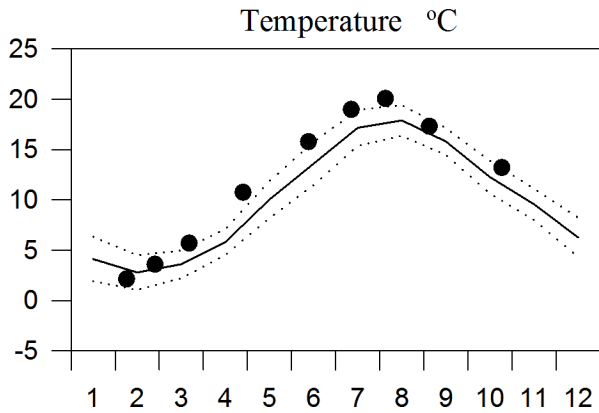
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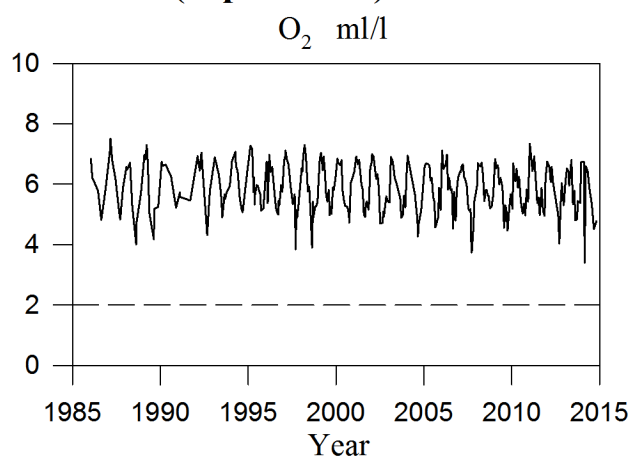
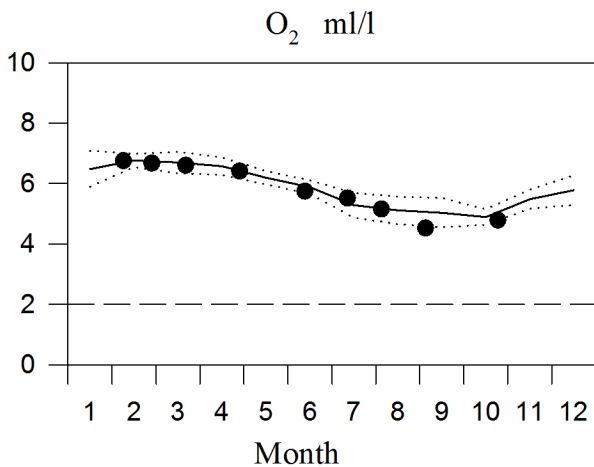
# STATION P2 SURFACE WATER

## Annual Cycles

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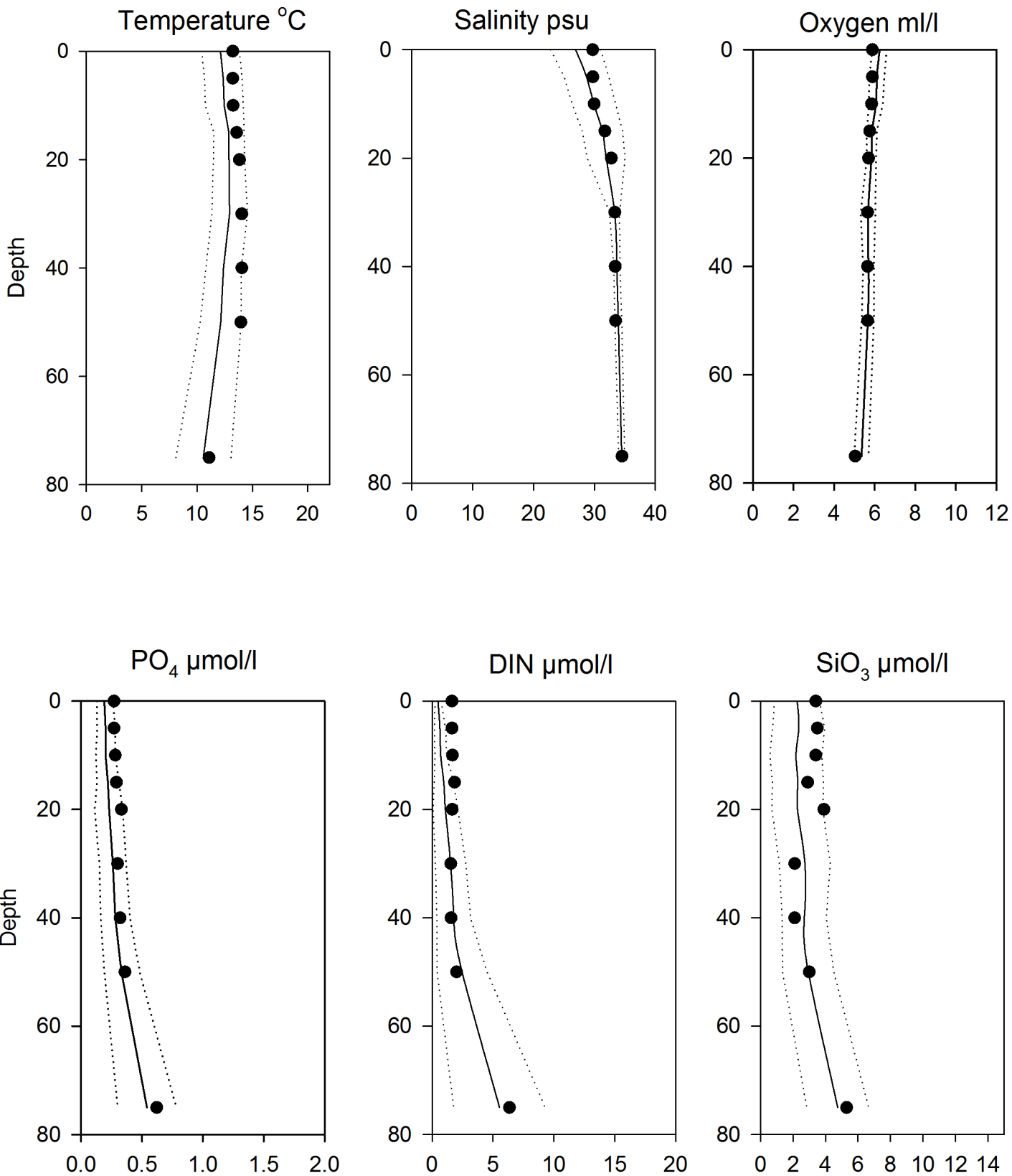


## OXYGEN IN BOTTOM WATER (depth >75m)



# Vertical profiles P2 October

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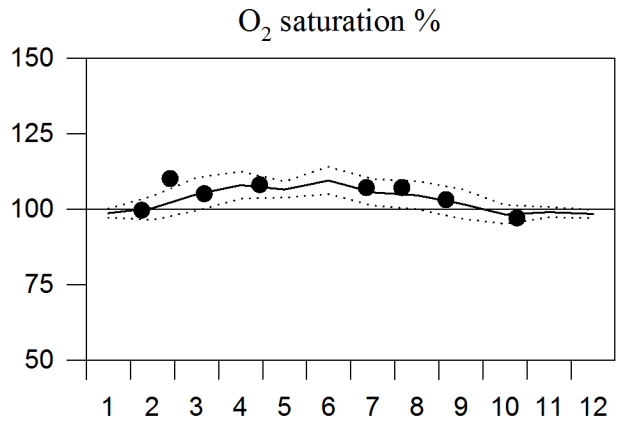
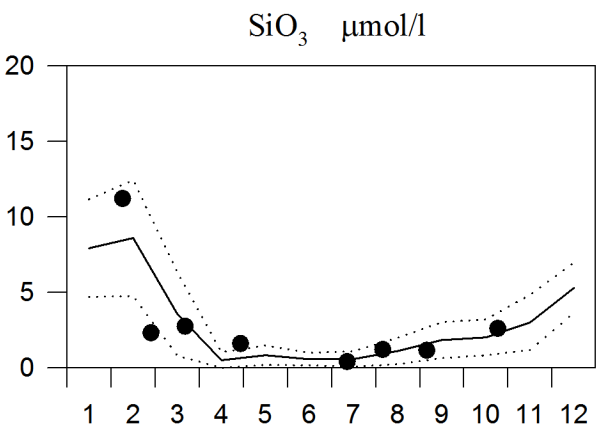
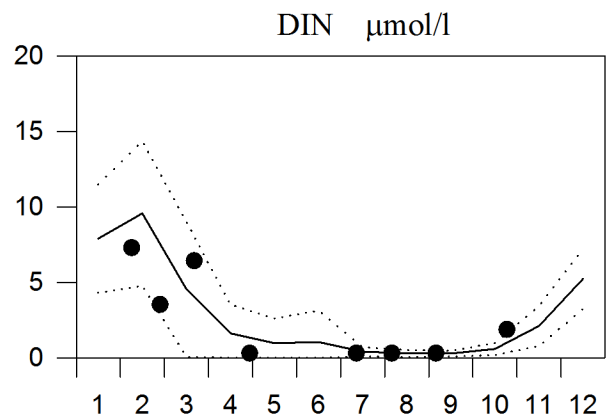
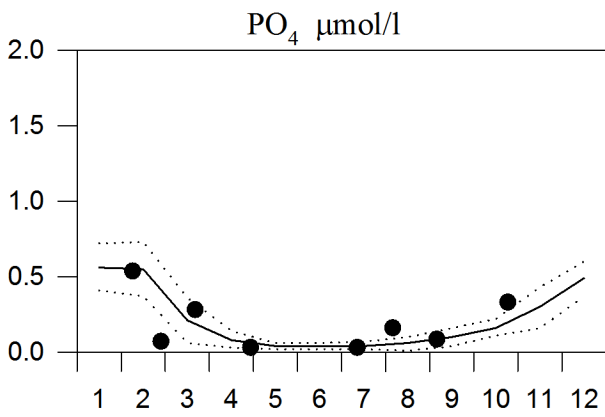
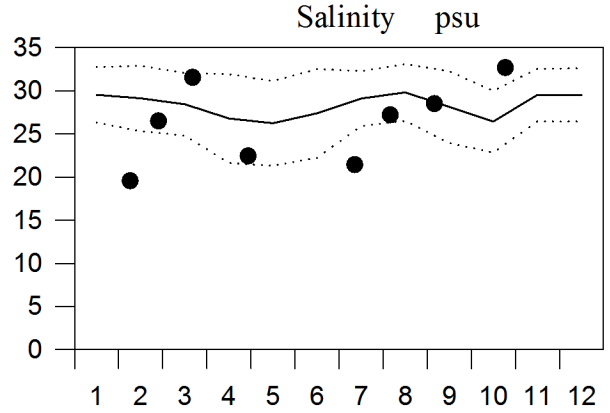
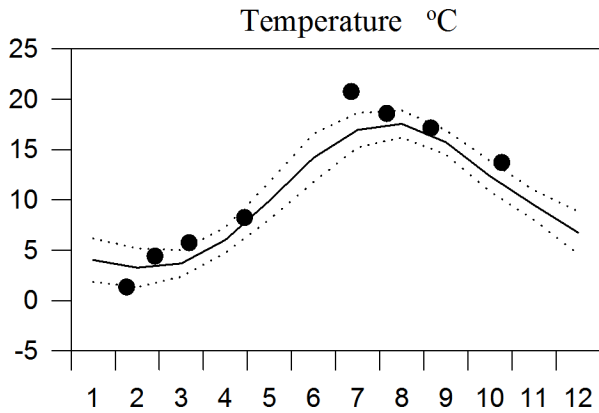




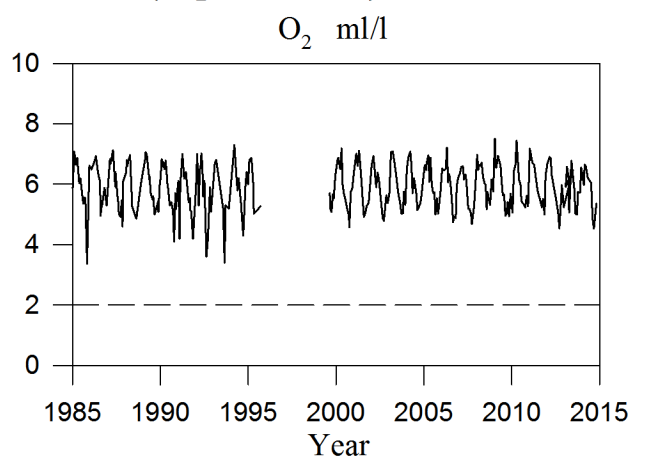
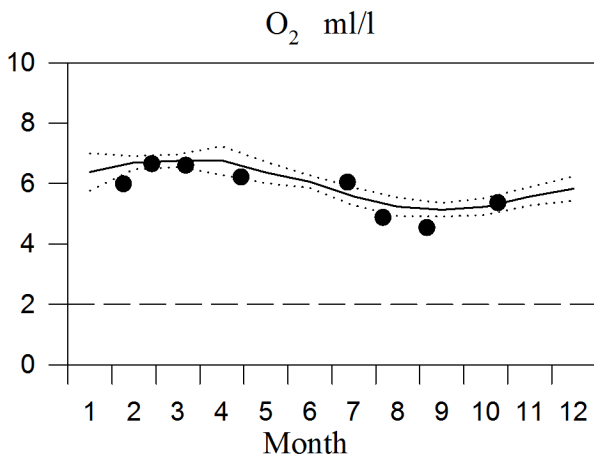
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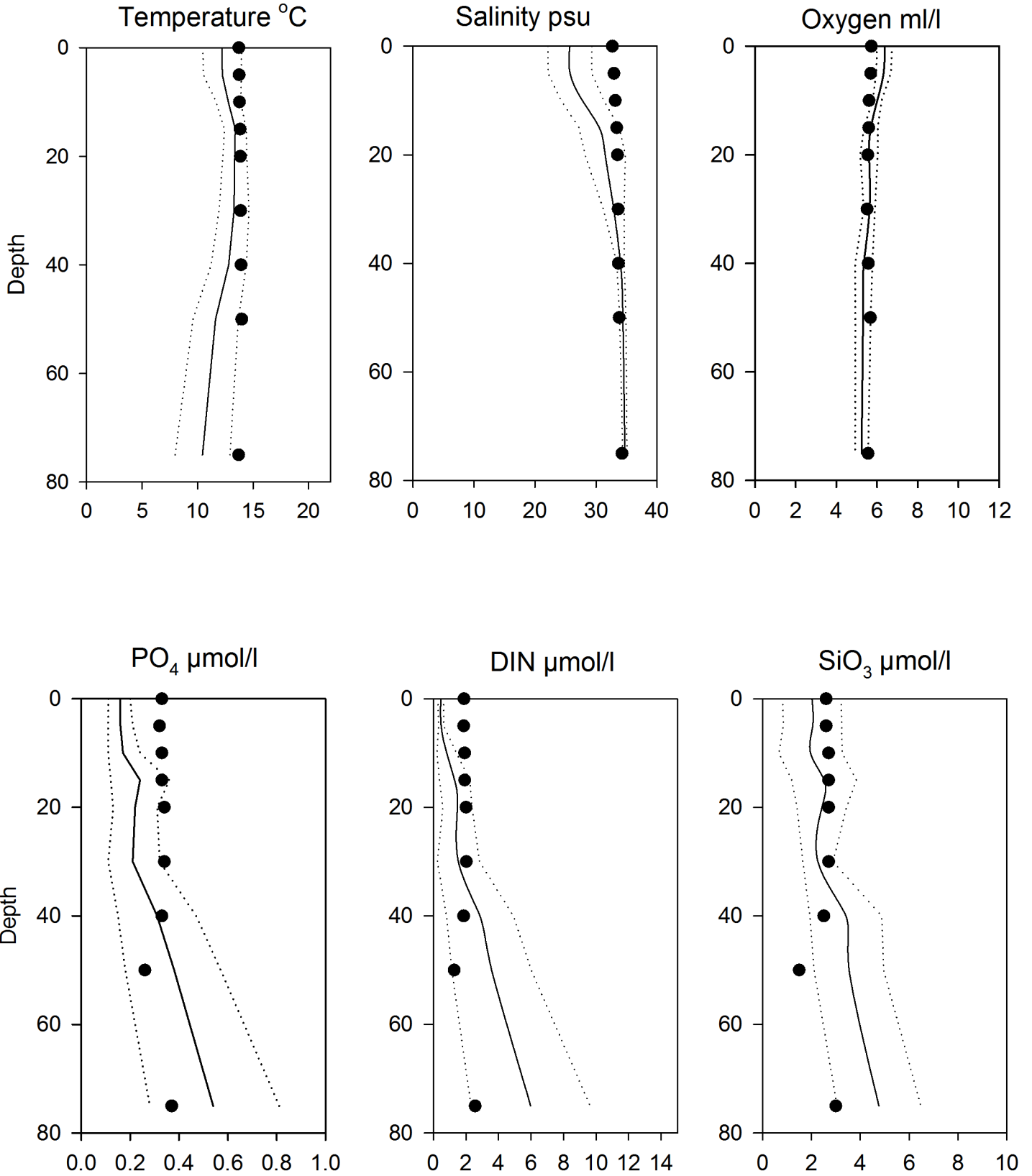


## OXYGEN IN BOTTOM WATER (depth >=75m)



# Vertical profiles Å13 October

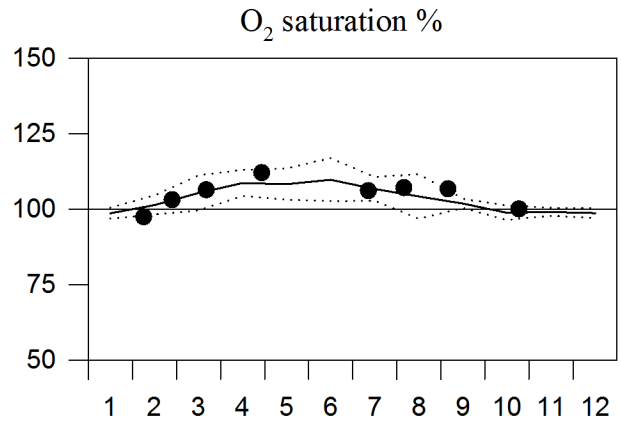
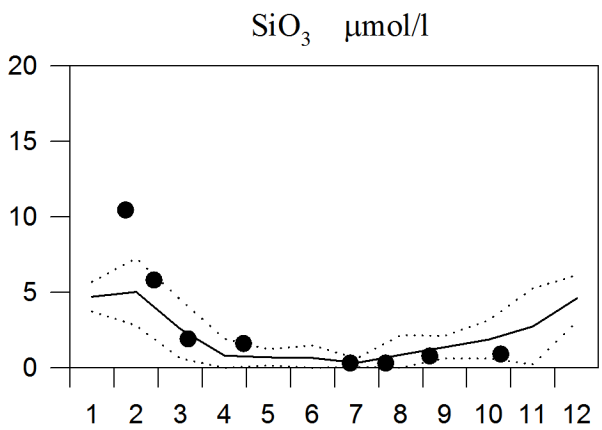
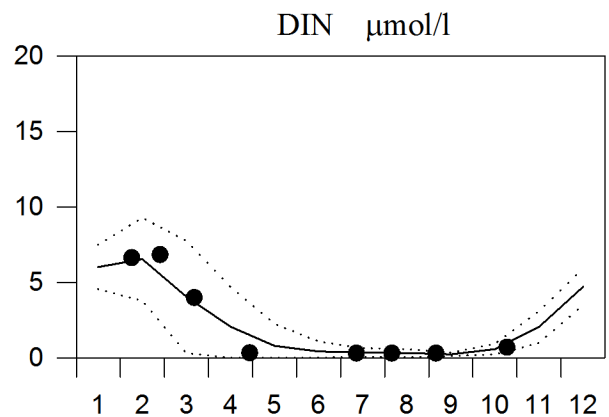
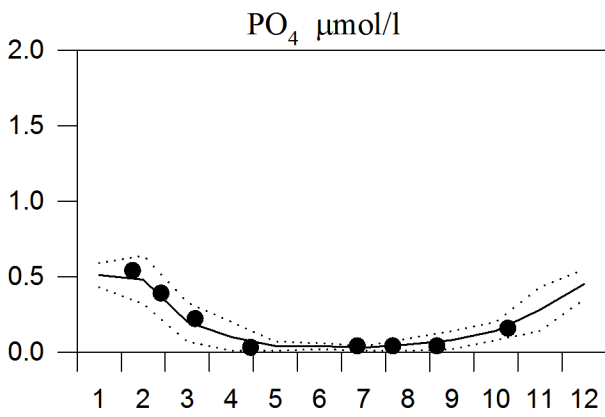
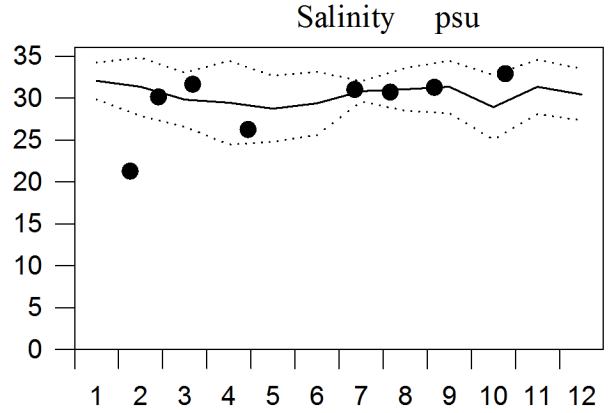
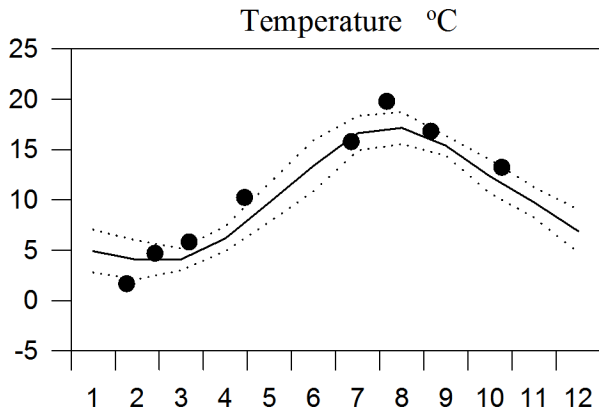
— Mean 1996-2010      ..... St.Dev.      ● 2014



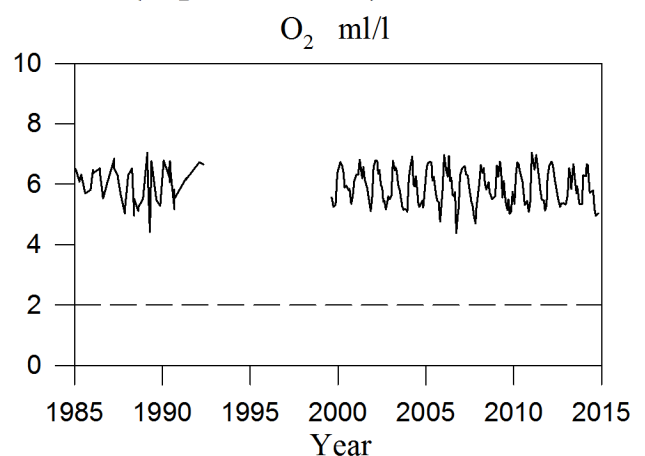
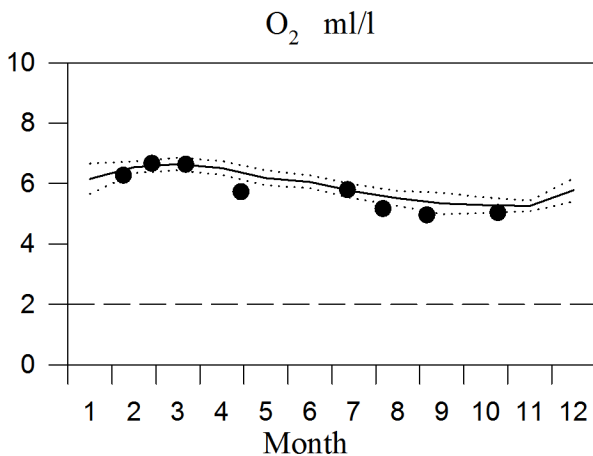
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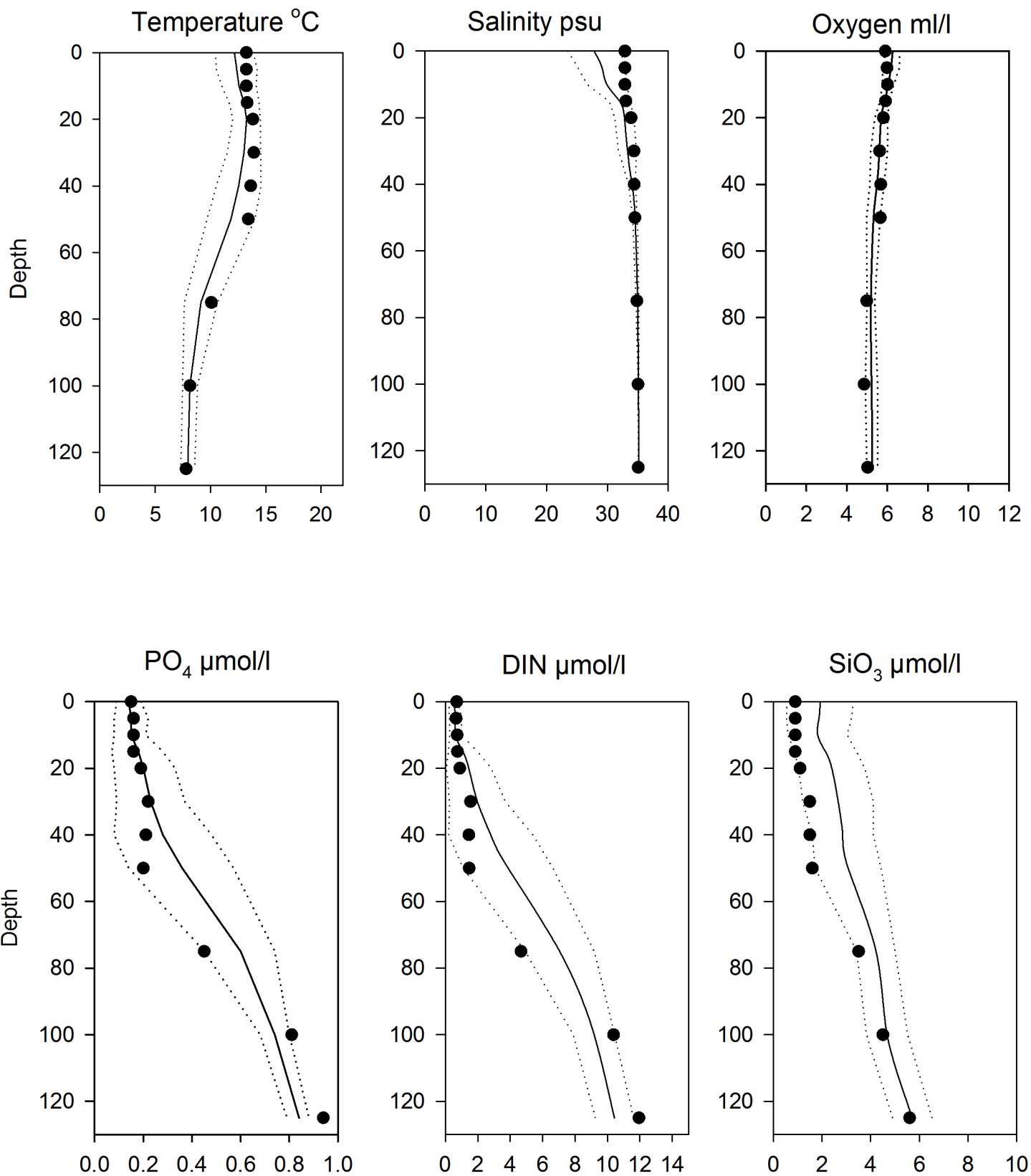


## OXYGEN IN BOTTOM WATER (depth >=125m)



# Vertical profiles Å15 October

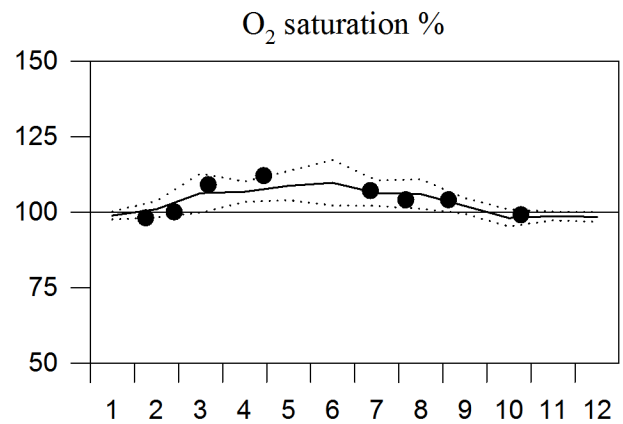
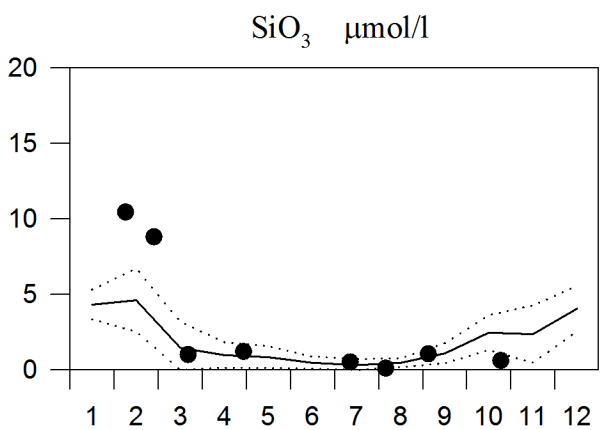
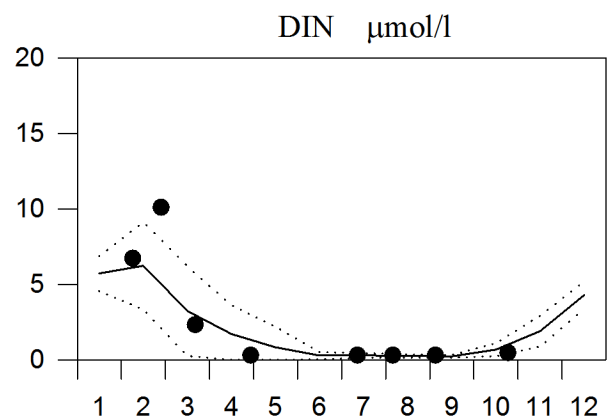
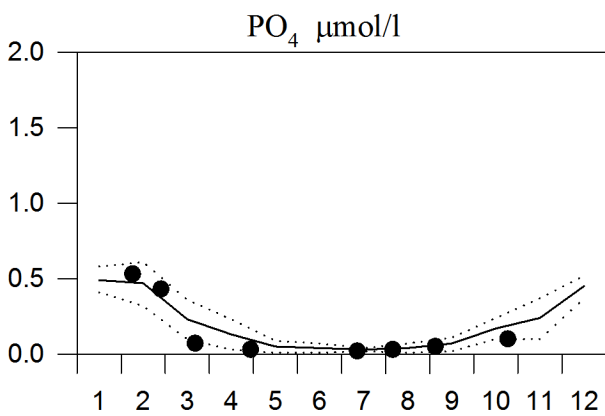
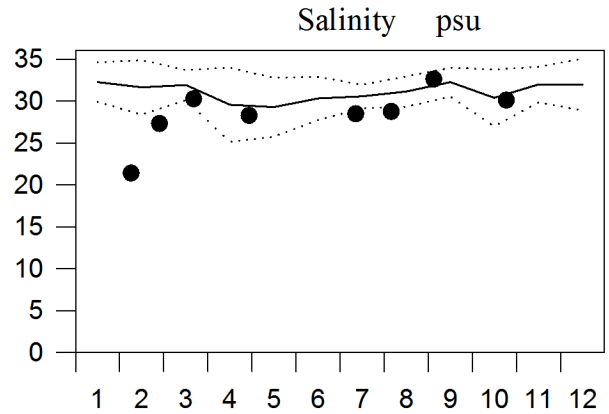
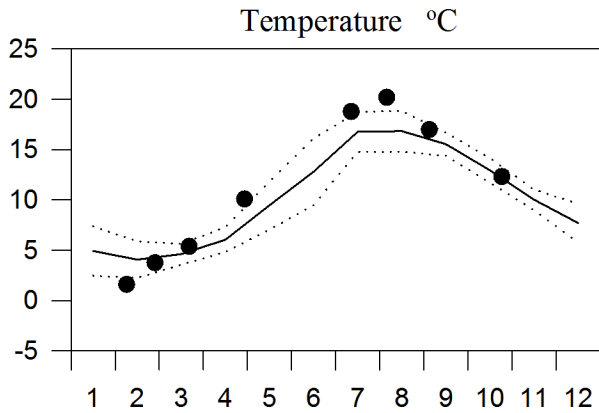
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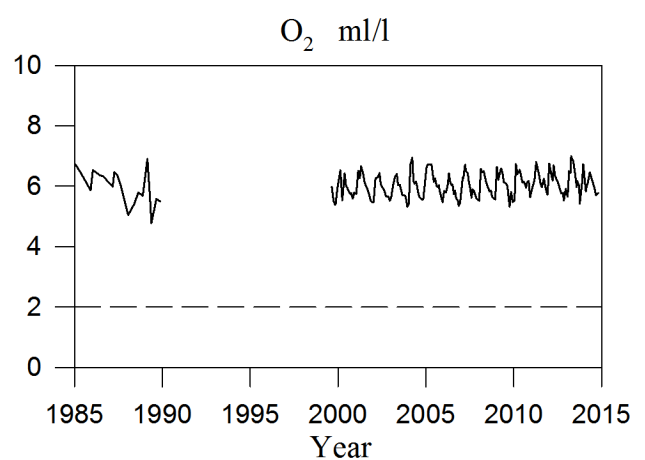
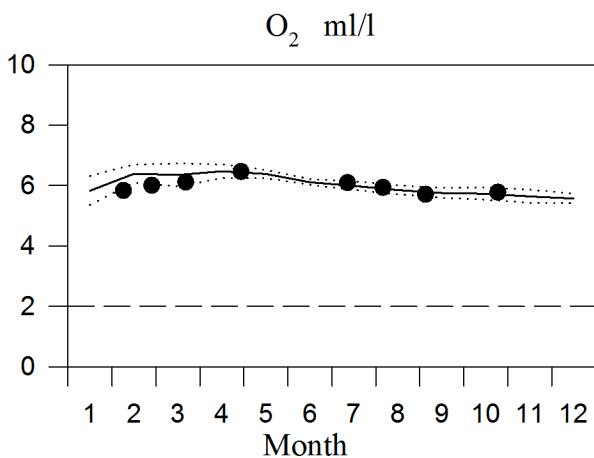
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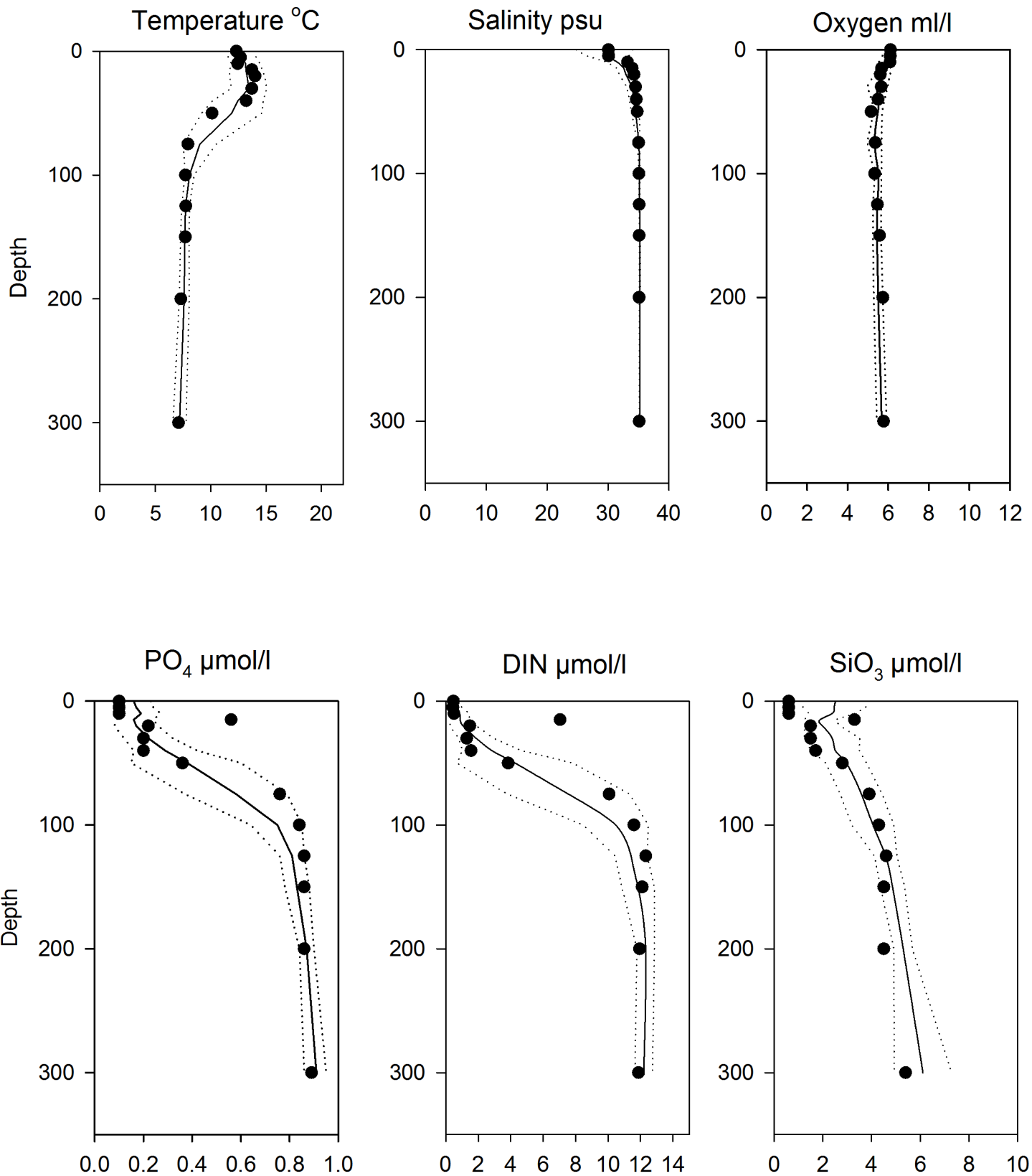


## OXYGEN IN BOTTOM WATER (depth = 300m)



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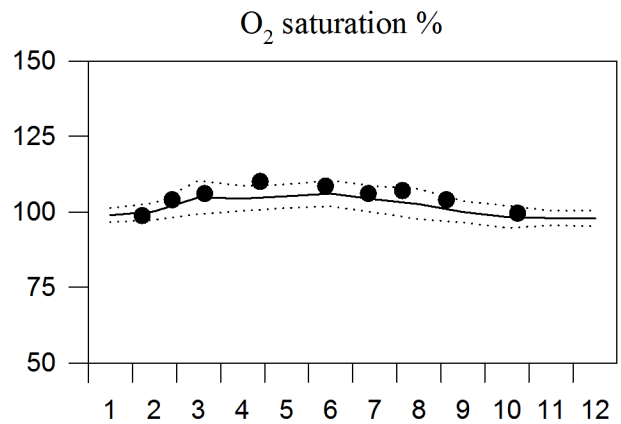
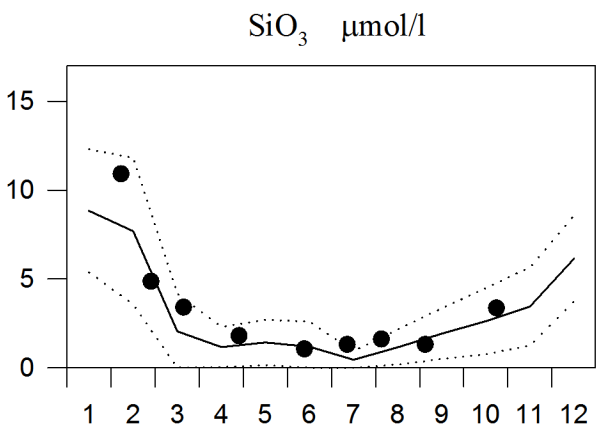
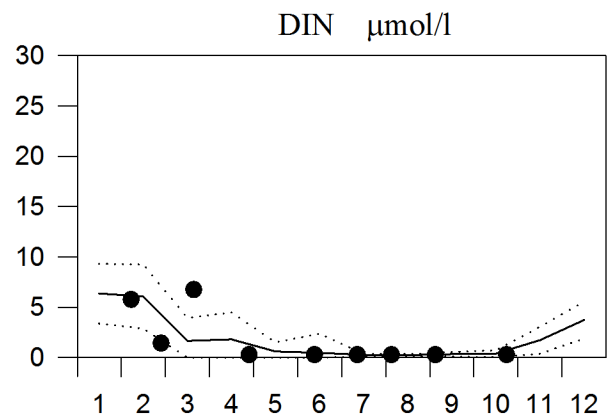
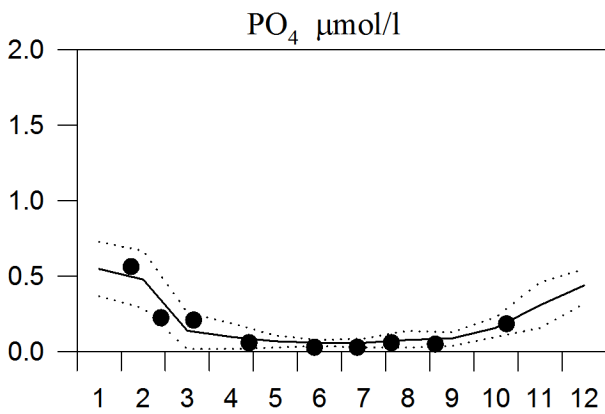
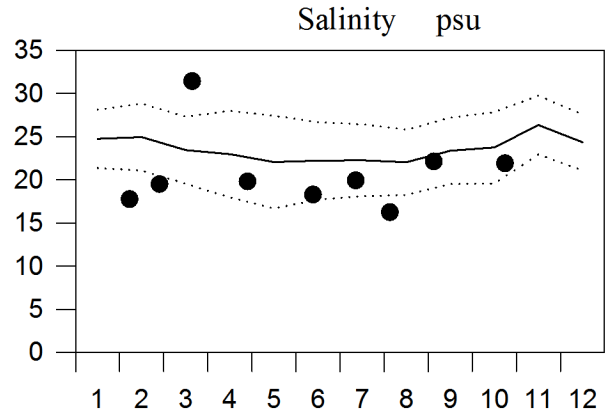
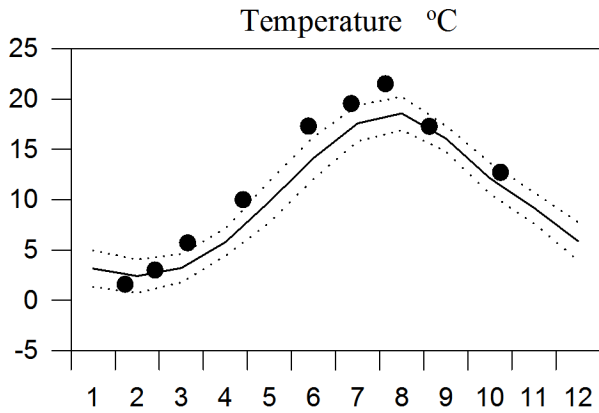
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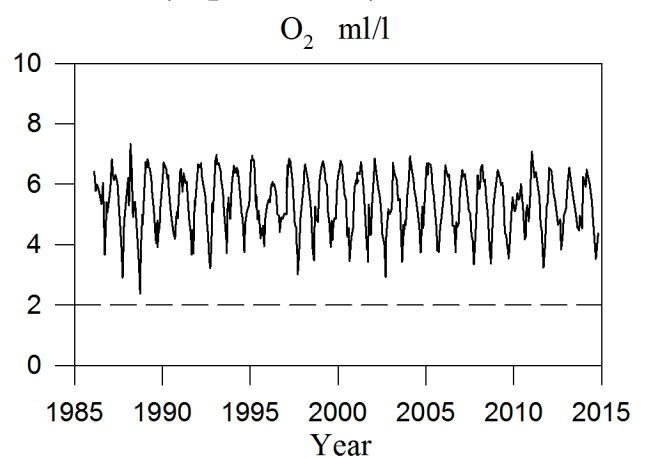
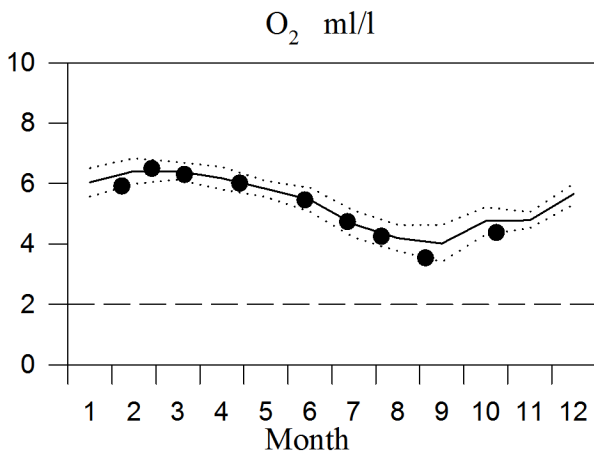
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## Annual Cycles

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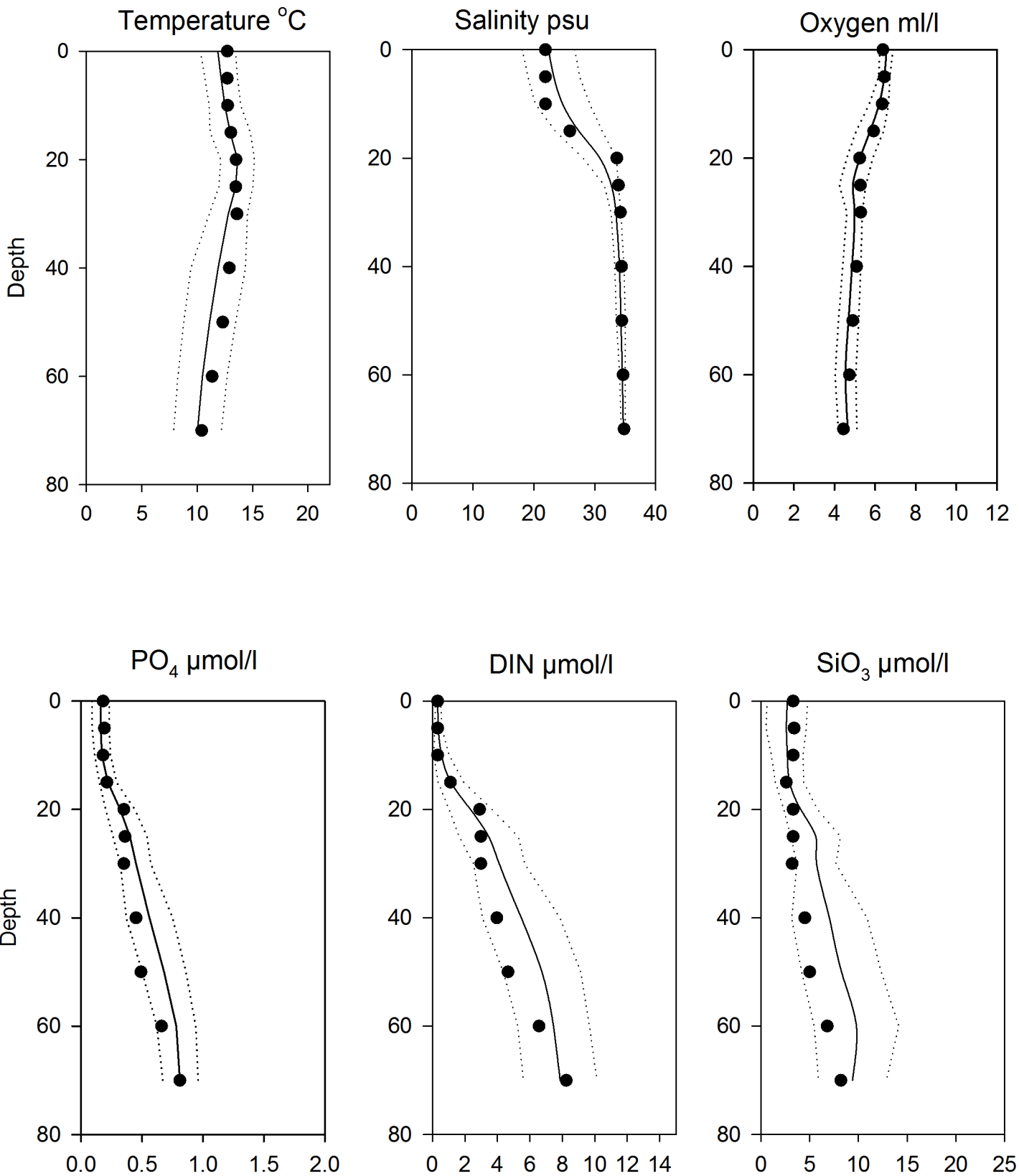


## OXYGEN IN BOTTOM WATER (depth > 70m)



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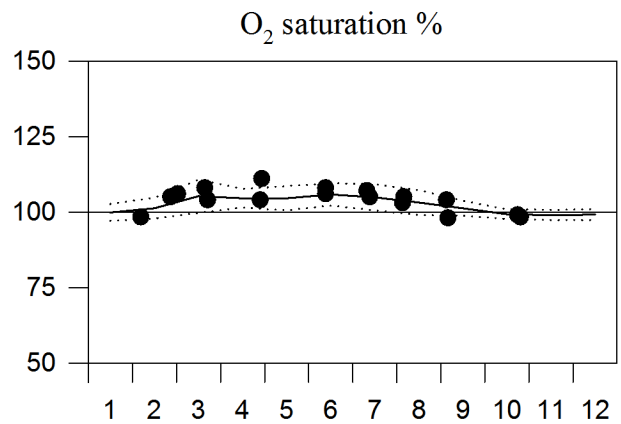
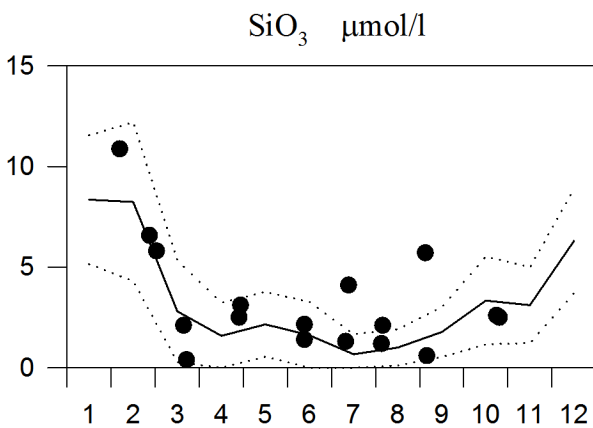
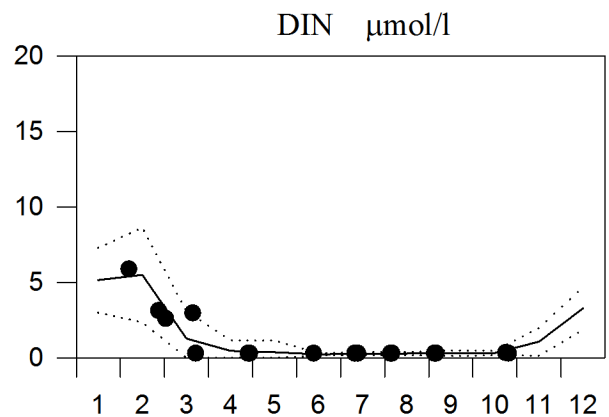
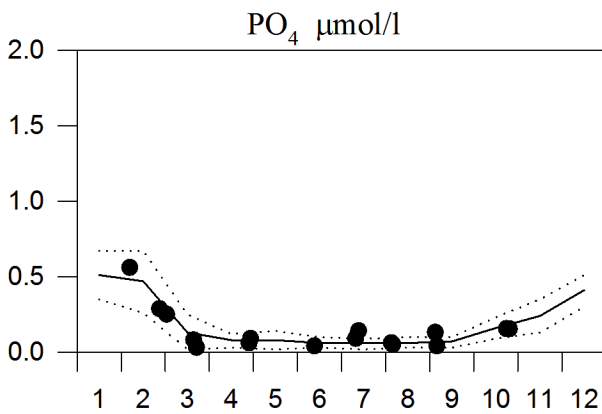
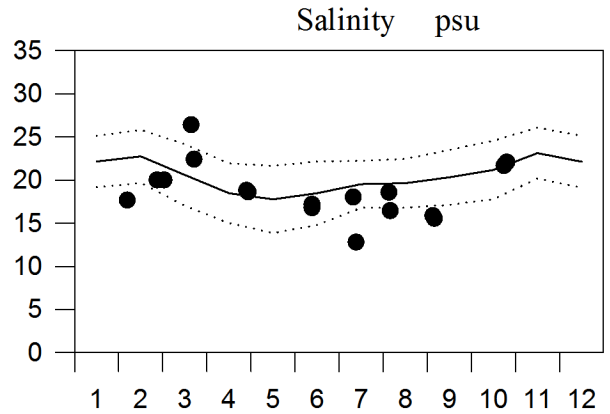
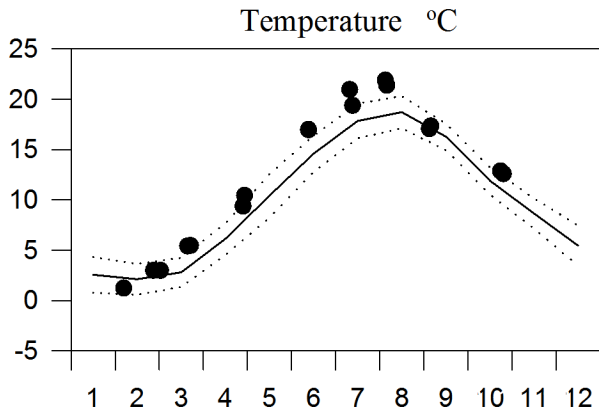




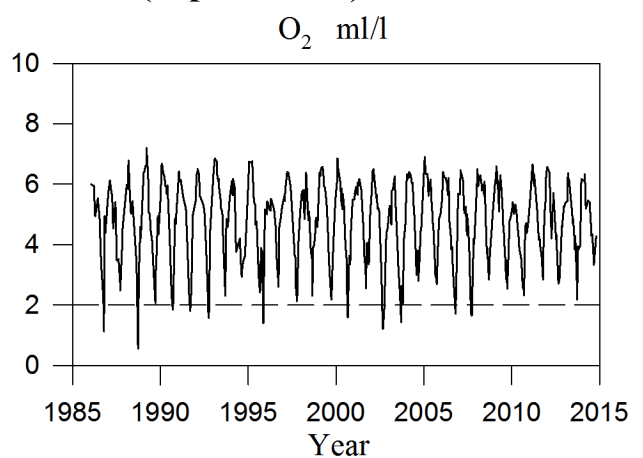
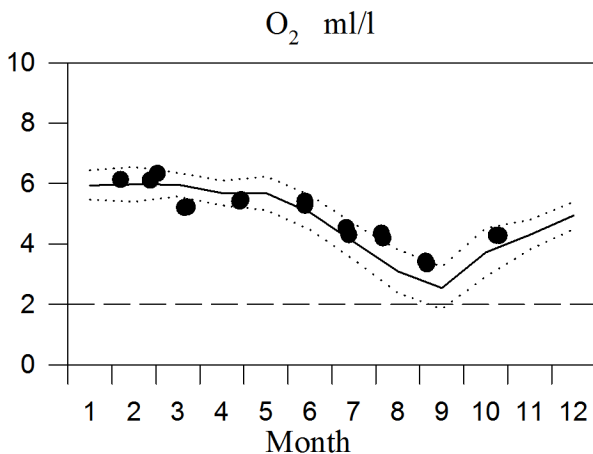
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## Annual Cycles

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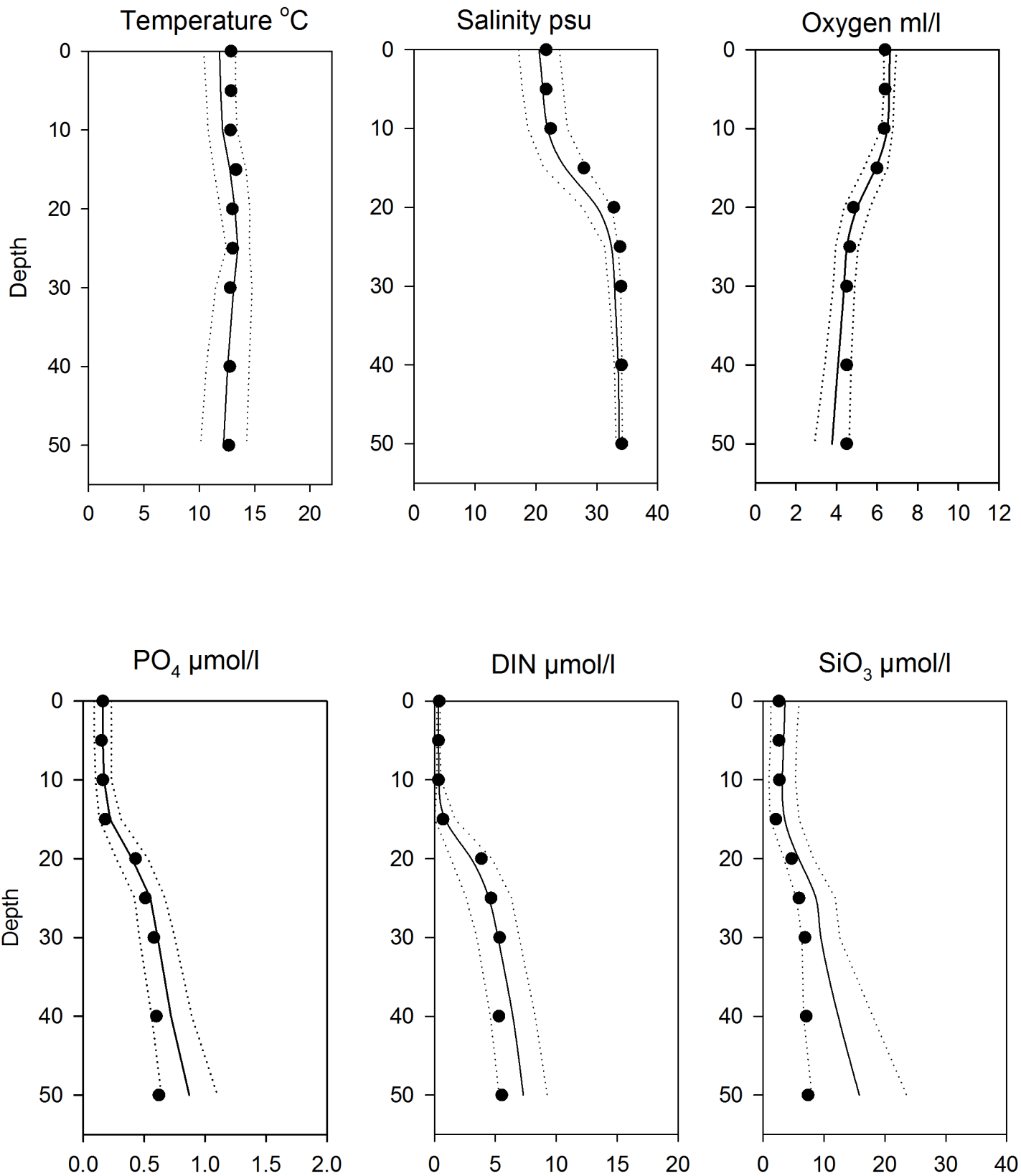


## OXYGEN IN BOTTOM WATER (depth > 50m)



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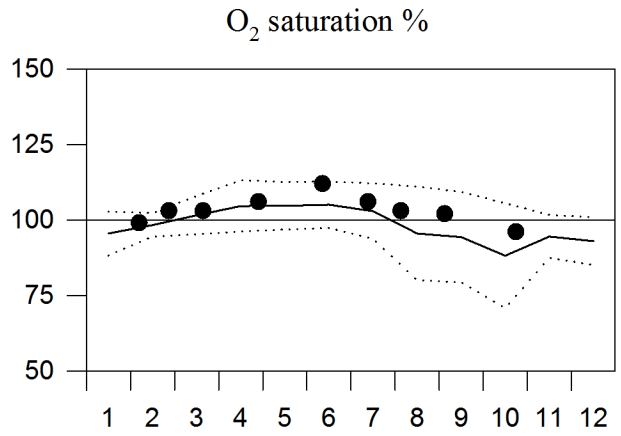
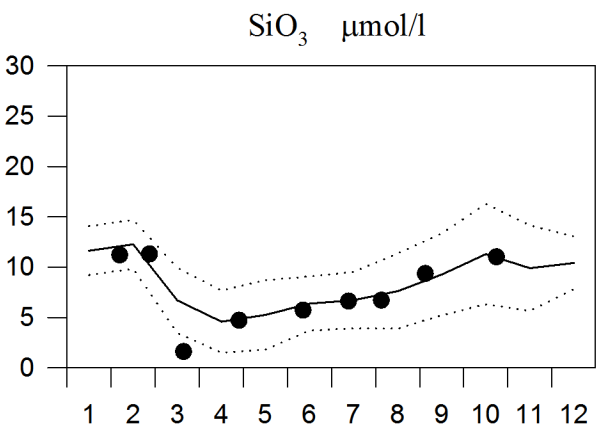
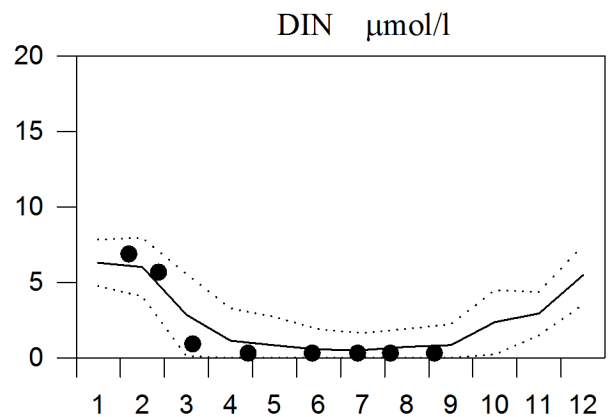
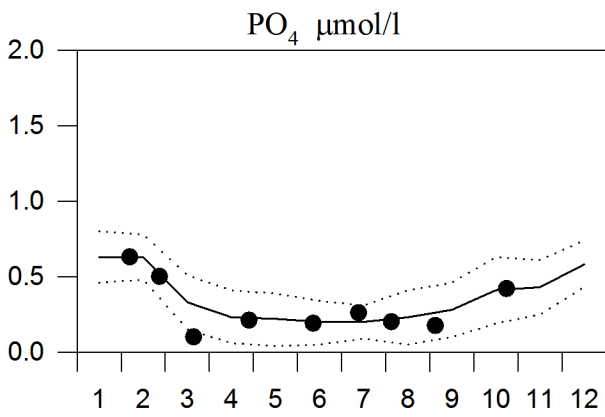
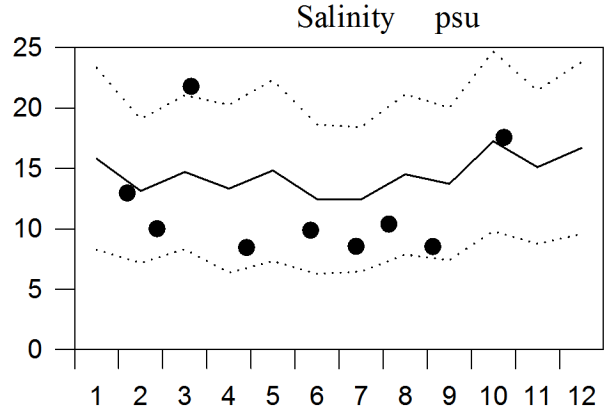
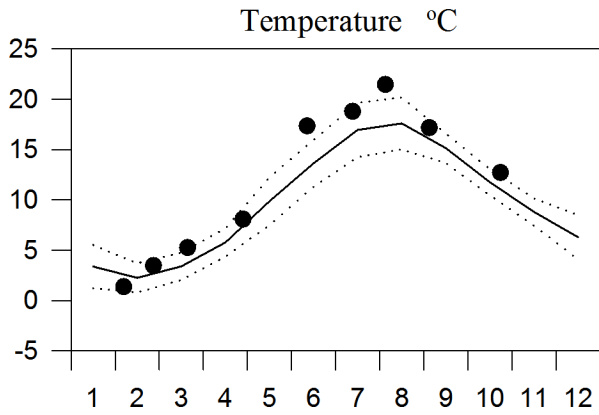
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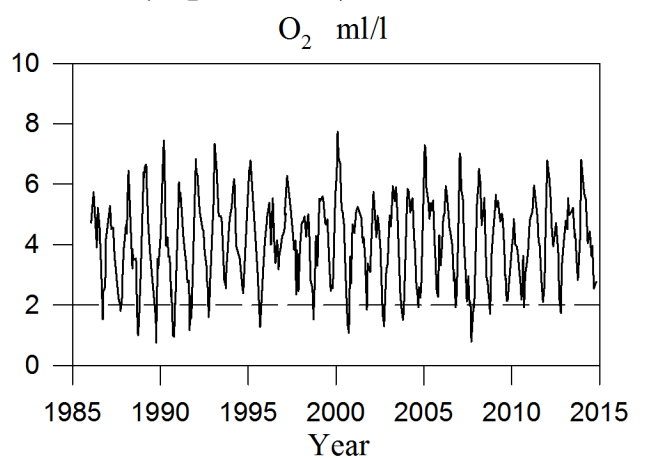
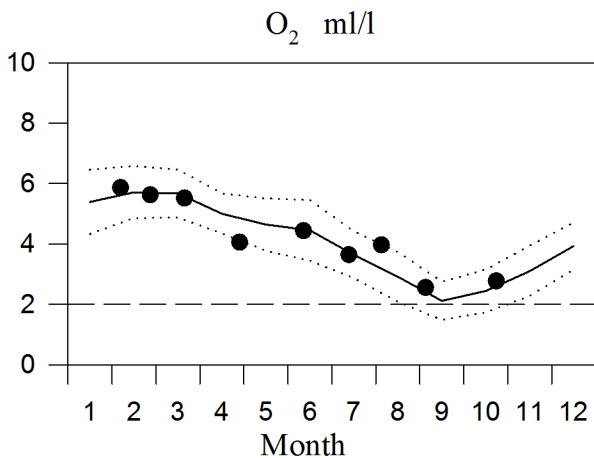
# STATION W LANDSKRONA SURFACE WATER

## Annual Cycles

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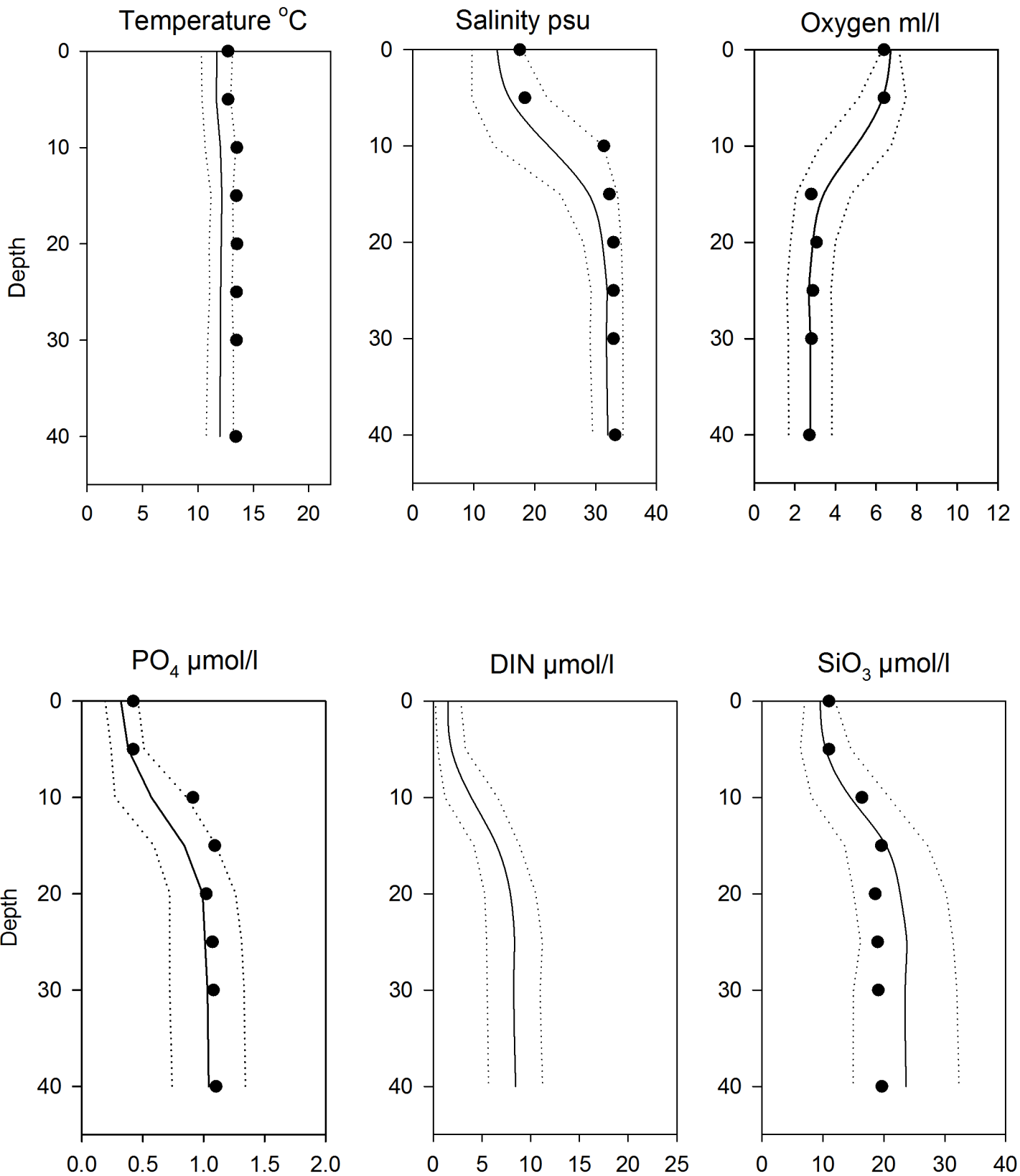


## OXYGEN IN BOTTOM WATER (depth >40m)



# Vertical profiles W Landskrona October

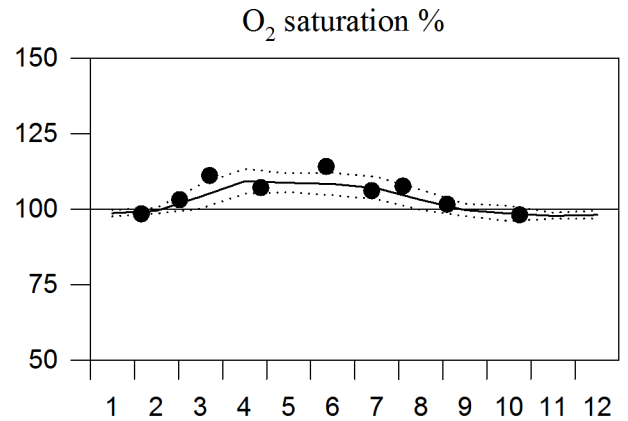
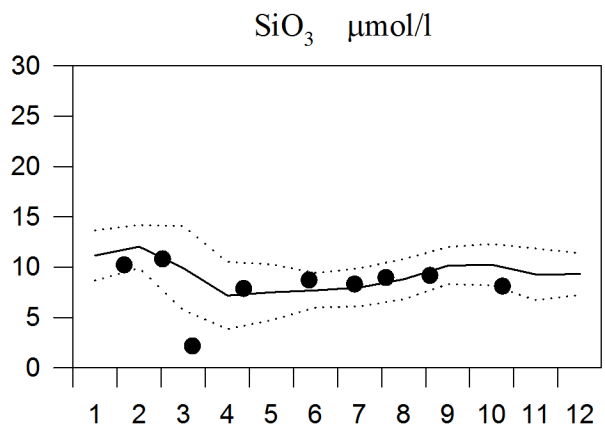
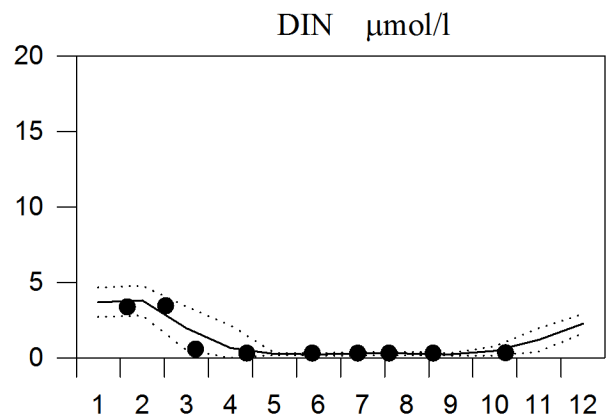
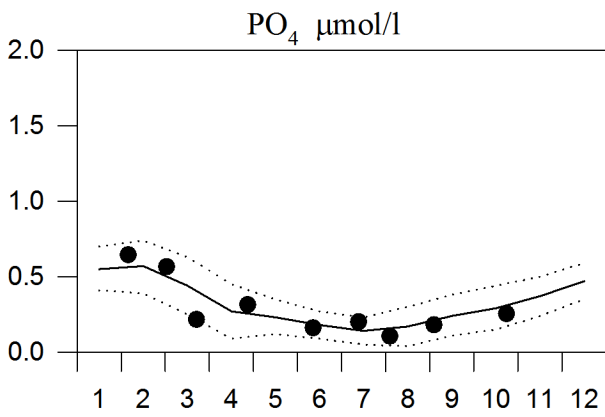
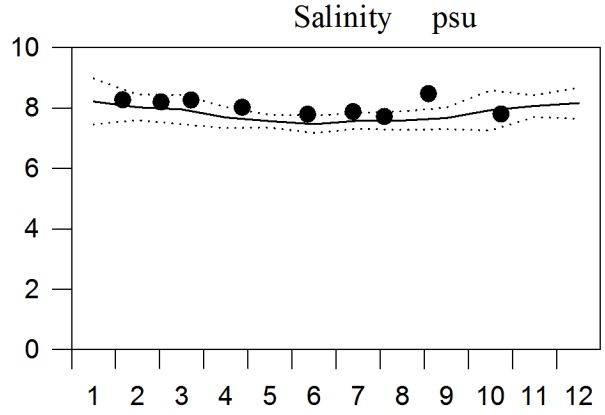
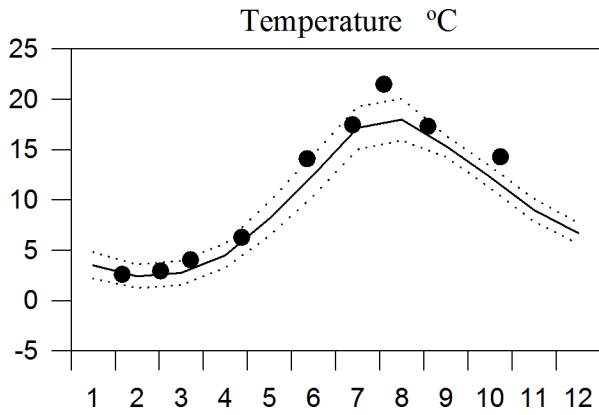
— Mean 1996-2010      ..... St.Dev.      ● 2014



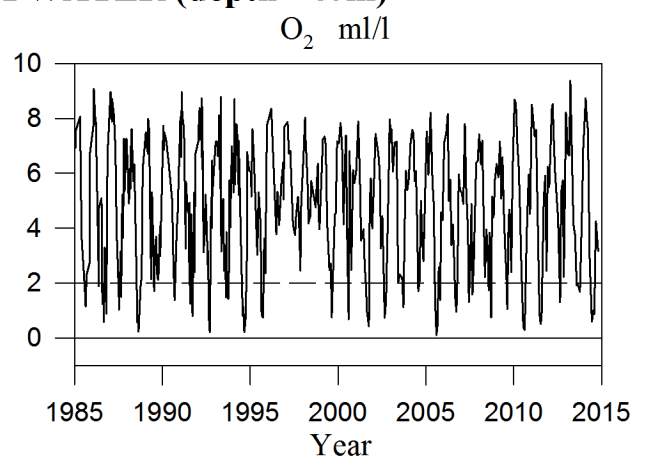
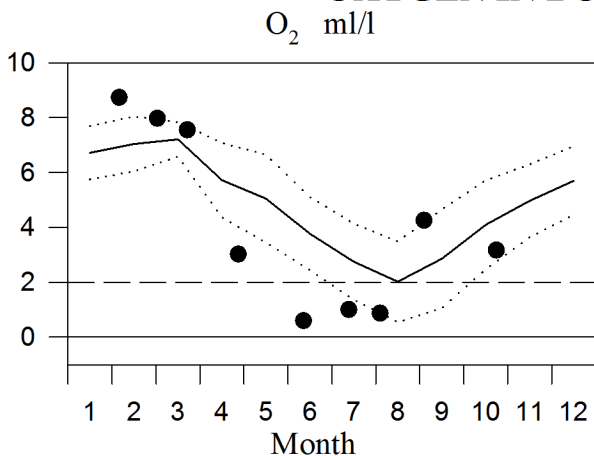
# STATION BY1 SURFACE WATER

## Annual Cycles

— Mean 1996-2010      ····· St.Dev.      ● 2014

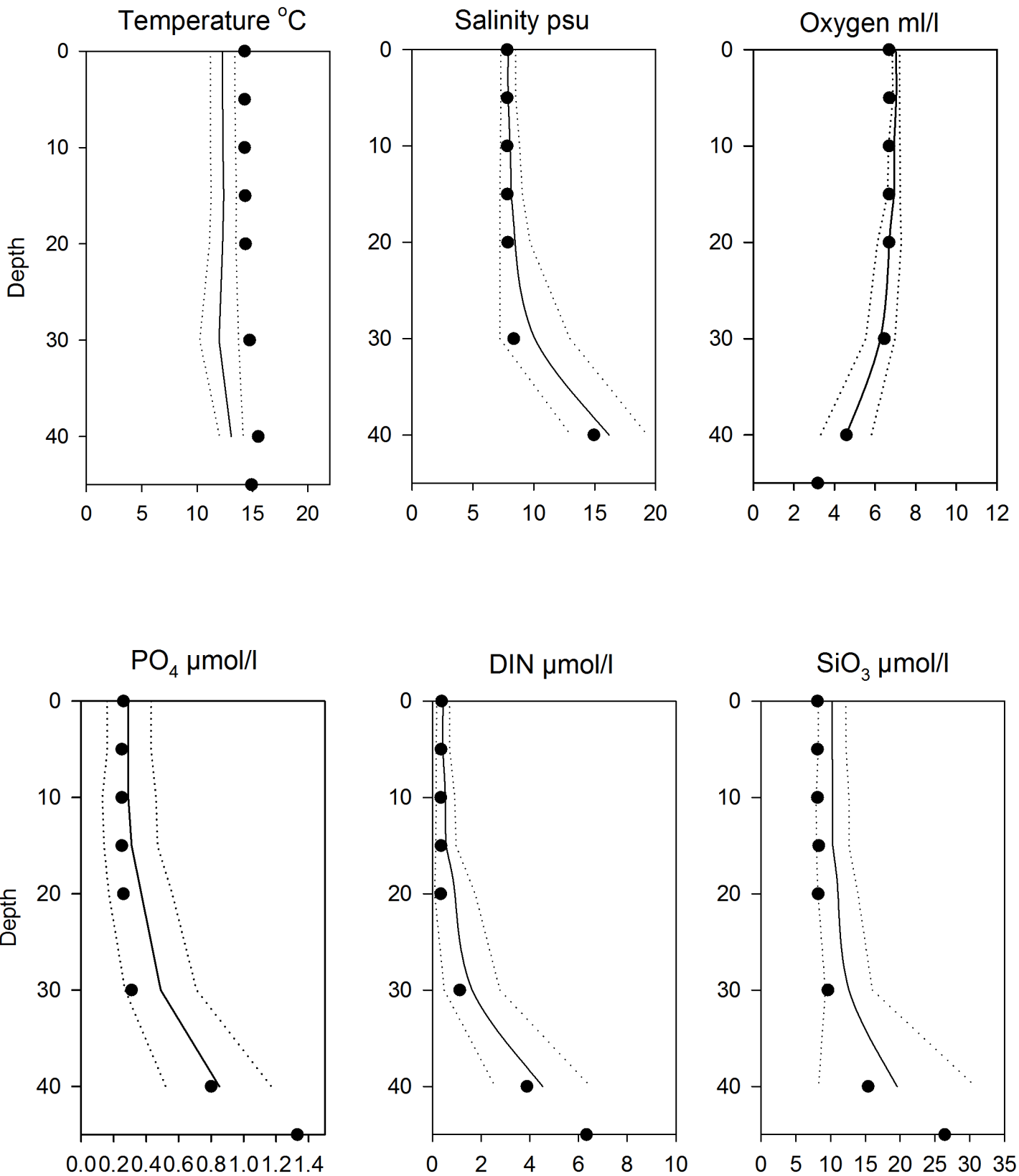


## OXYGEN IN BOTTOM WATER (depth >40m)



# Vertical profiles BY1 October

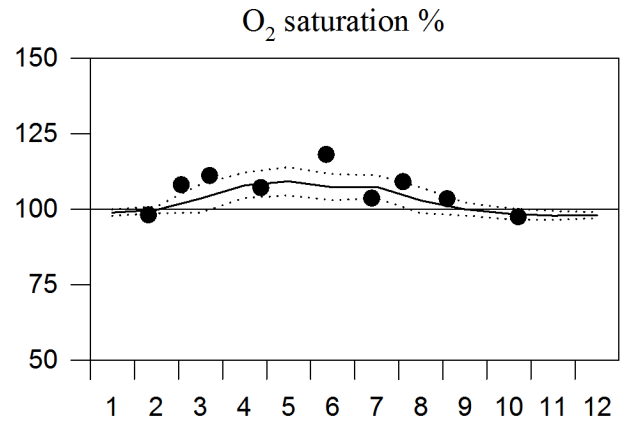
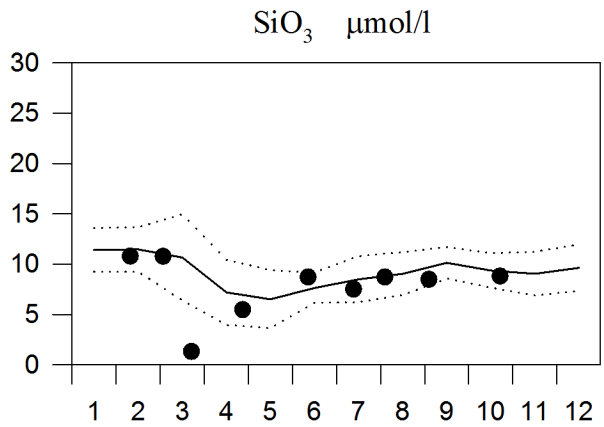
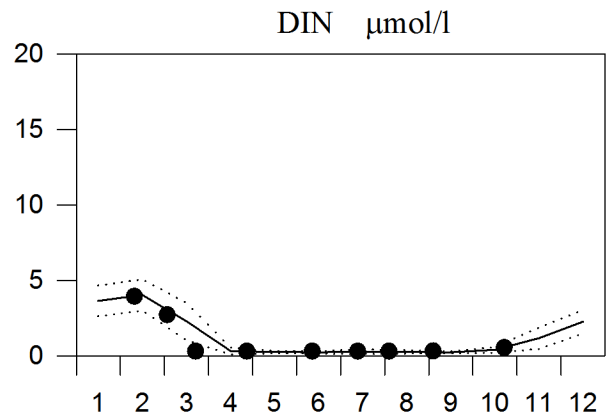
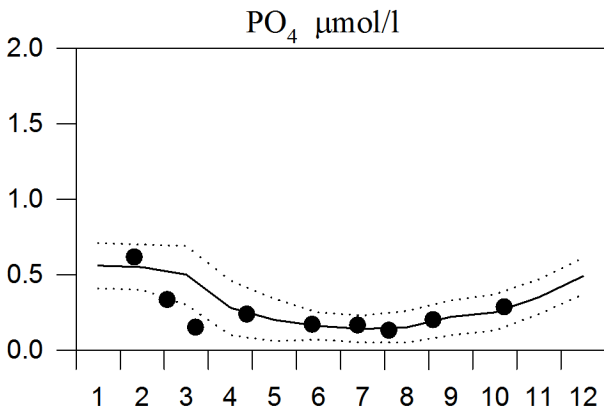
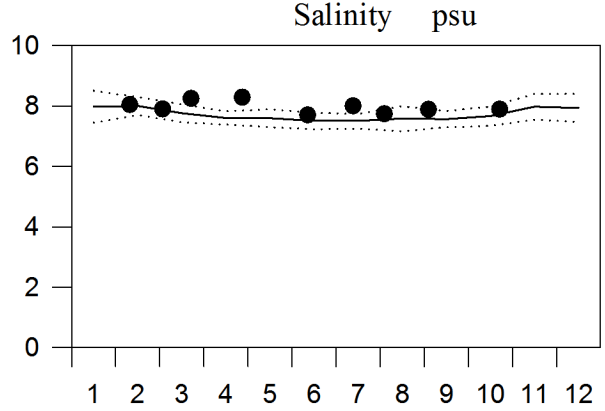
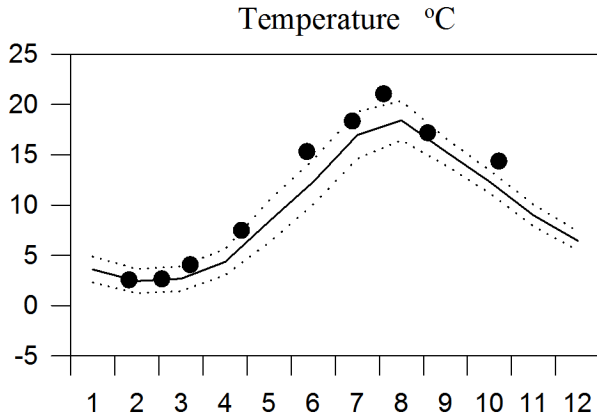
— Mean 1996-2010      ..... St.Dev.      ● 2014



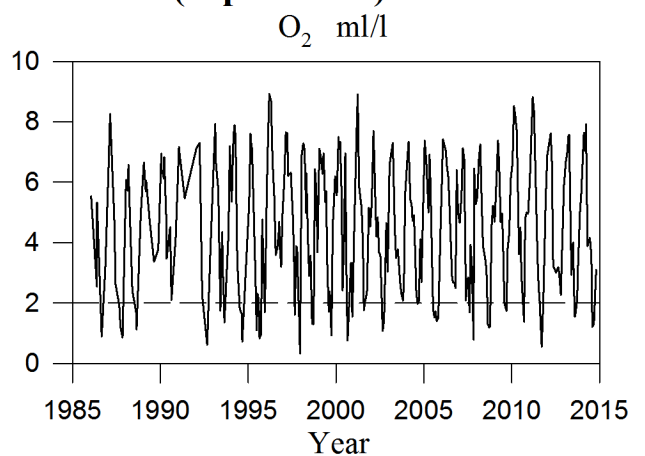
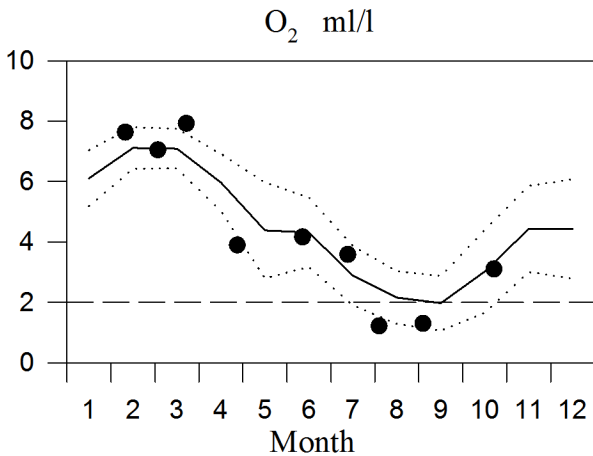
# STATION BY2 SURFACE WATER

## Annual Cycles

— Mean 1996-2010      ····· St.Dev.      ● 2014

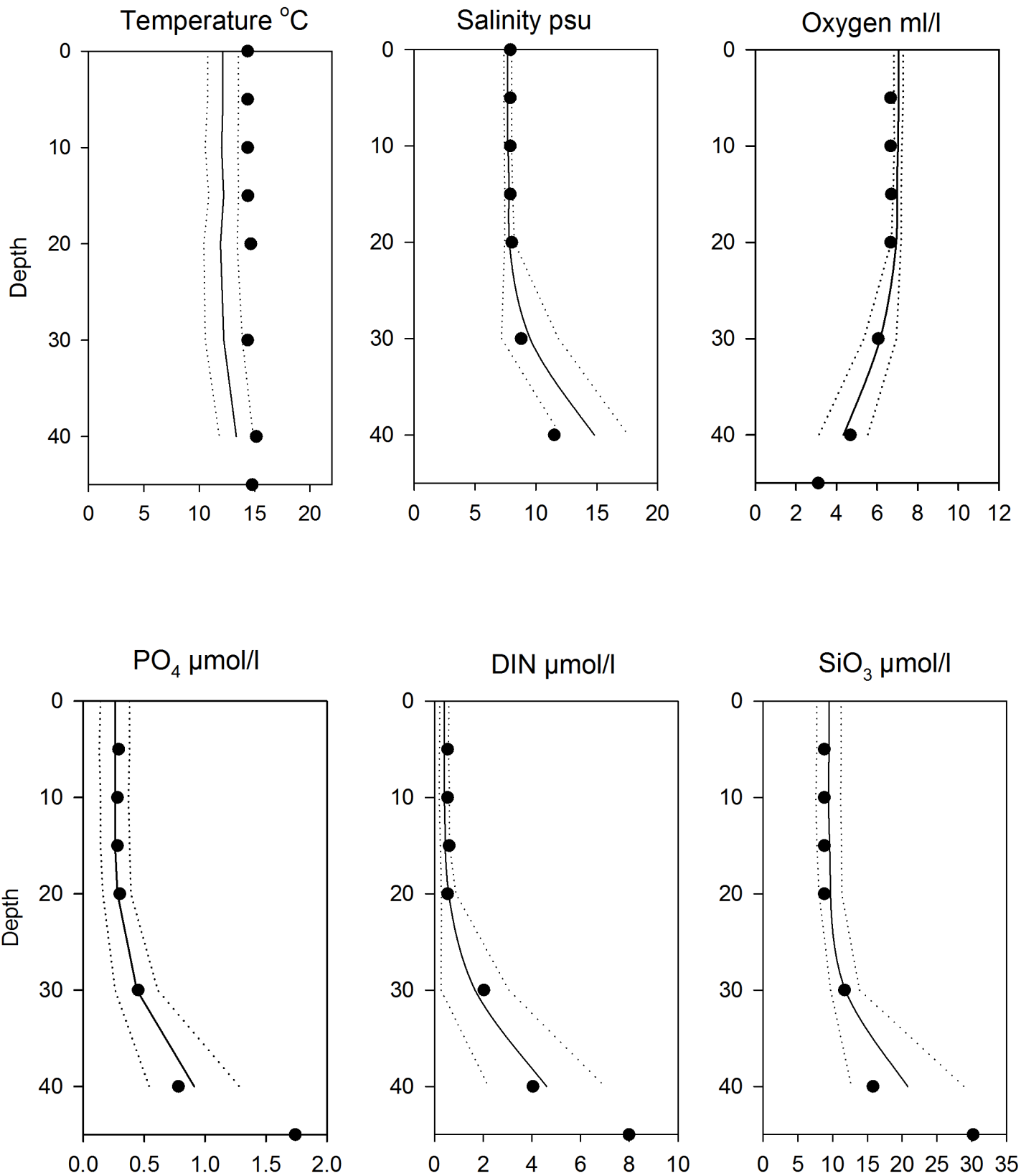


## OXYGEN IN BOTTOM WATER (depth >40m)



# Vertical profiles BY2 October

— Mean 1996-2010      ····· St.Dev.      ● 2014

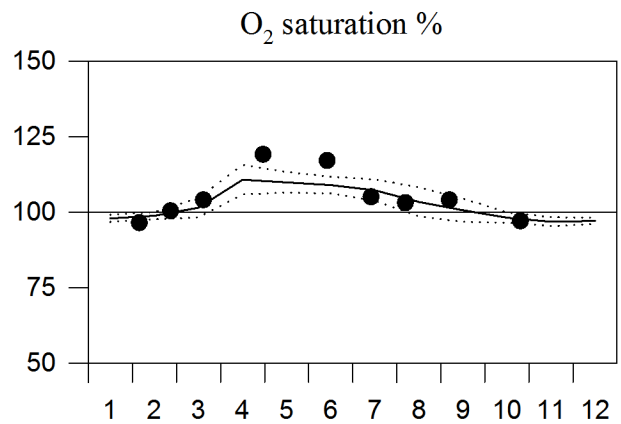
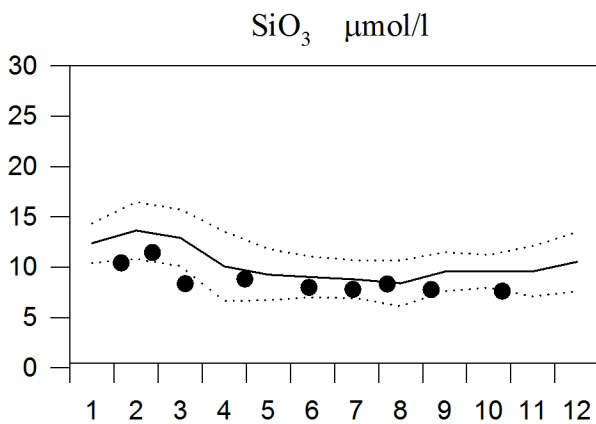
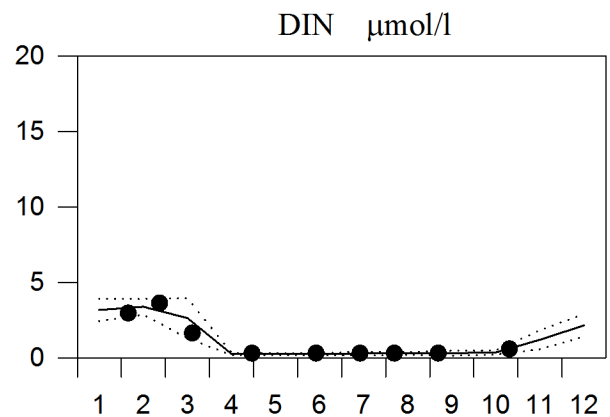
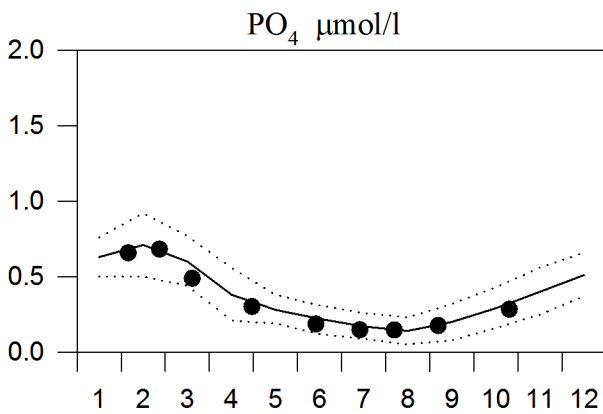
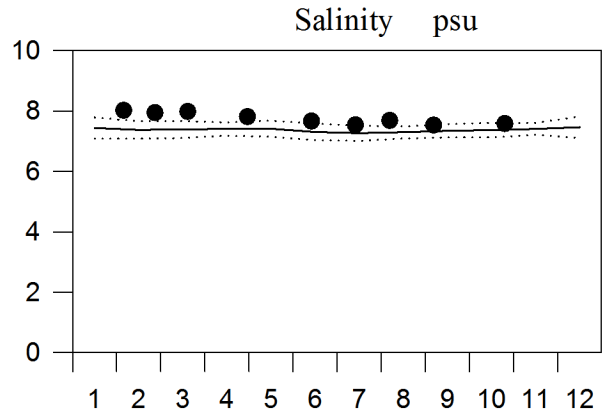
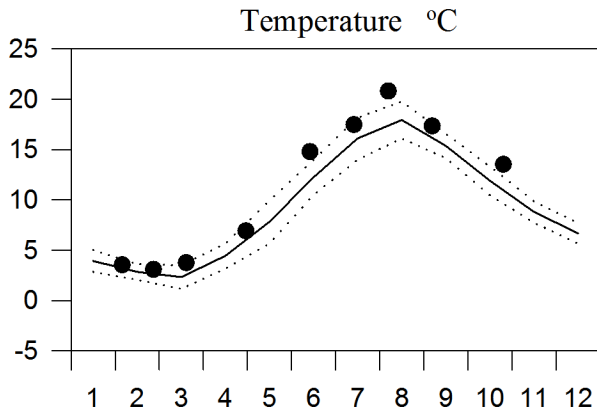




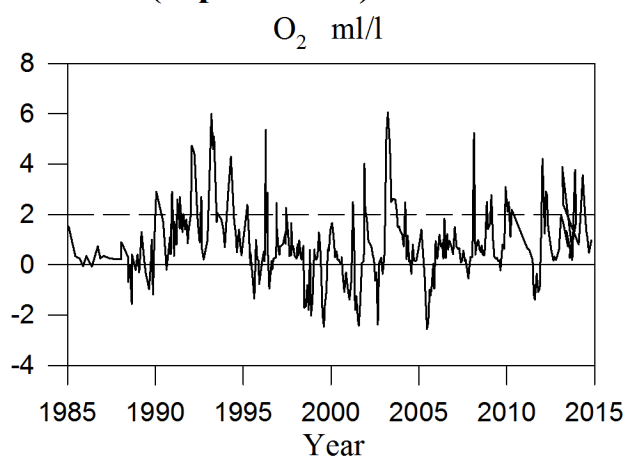
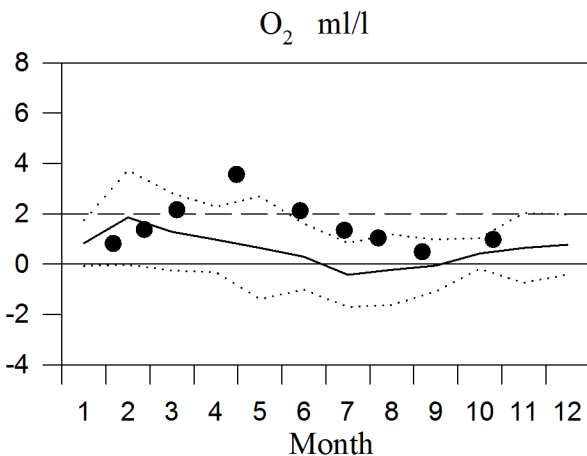
# STATION HANÖBUKTEN SURFACE WATER

## Annual Cycles

— Mean 1996-2010      ..... St.Dev.      ● 2014

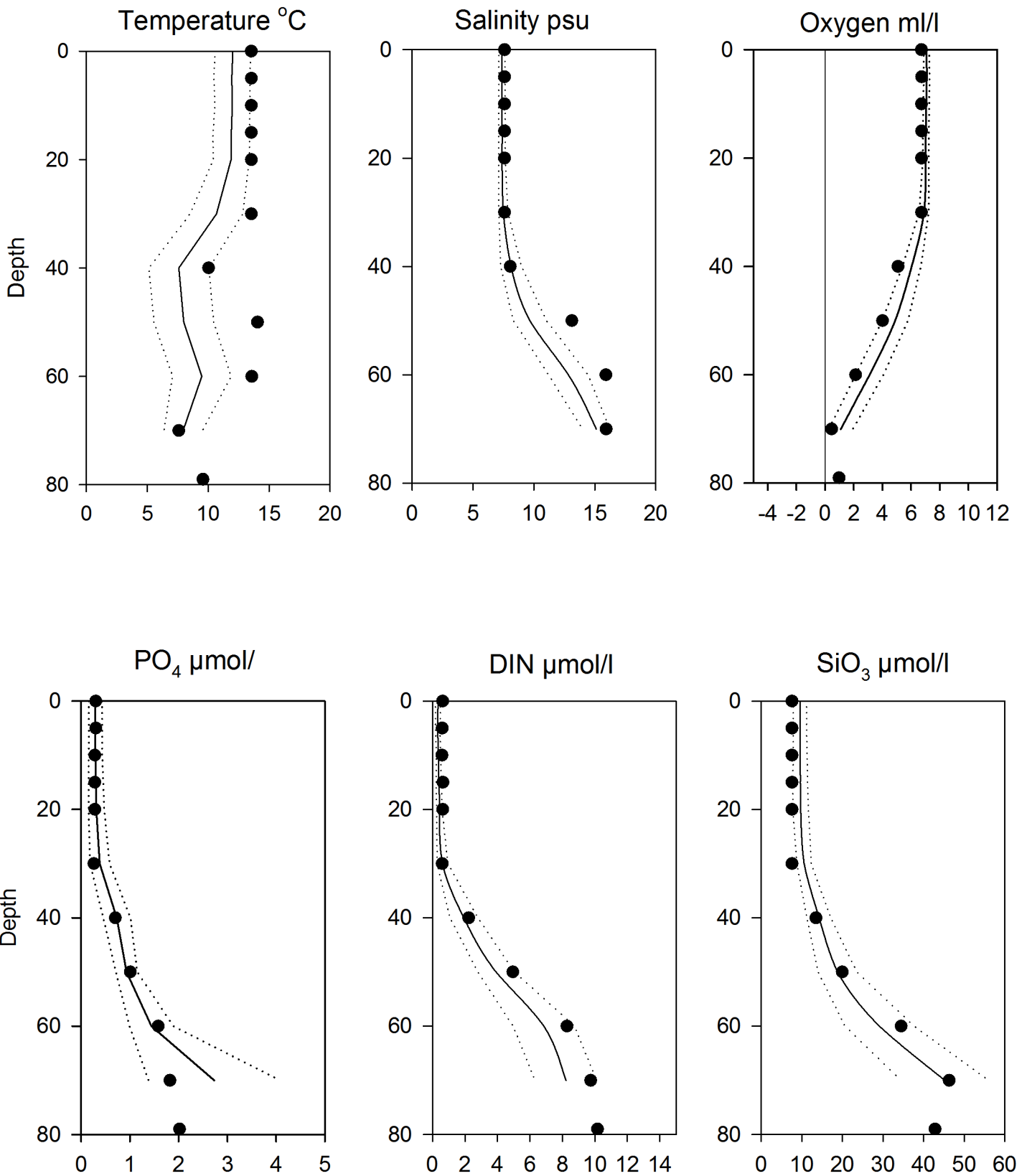


## OXYGEN IN BOTTOM WATER (depth > 70m)



# Vertical profiles Hanöbukten October

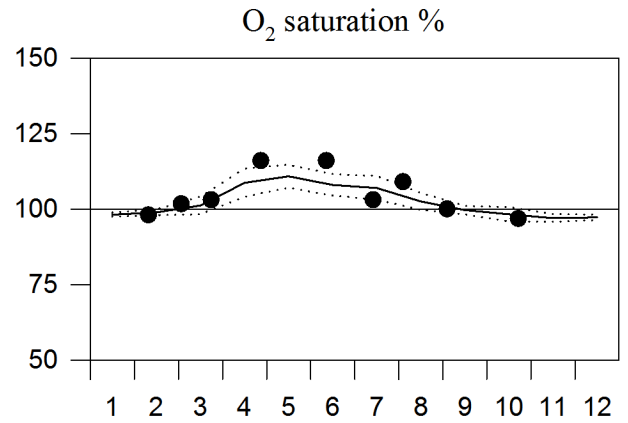
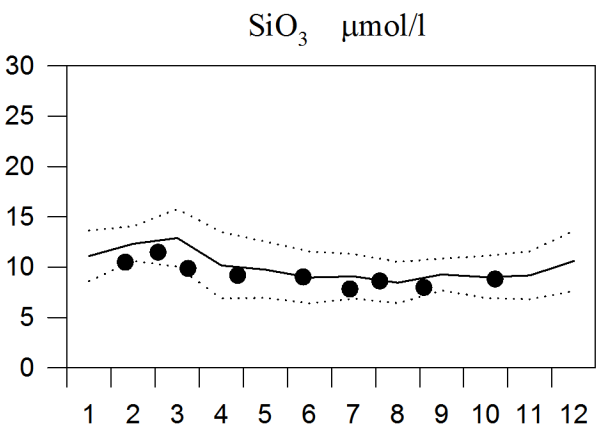
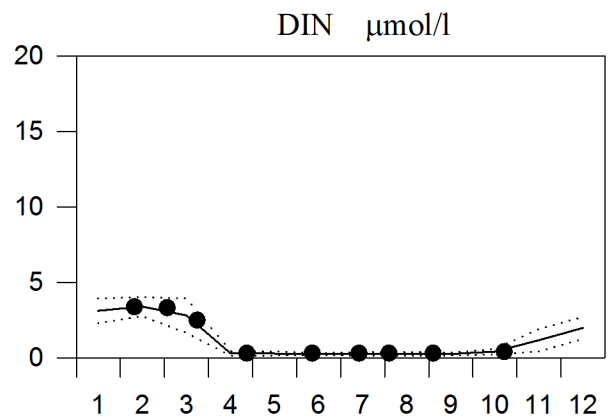
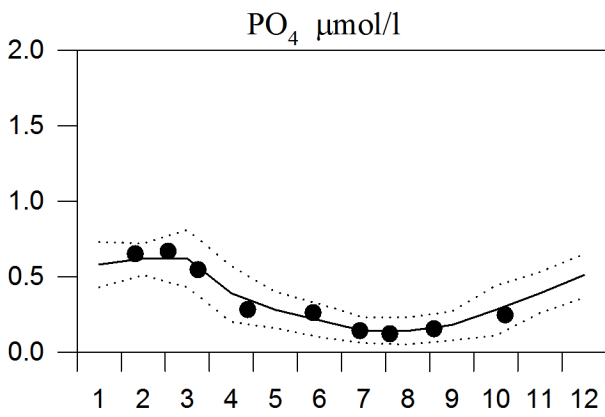
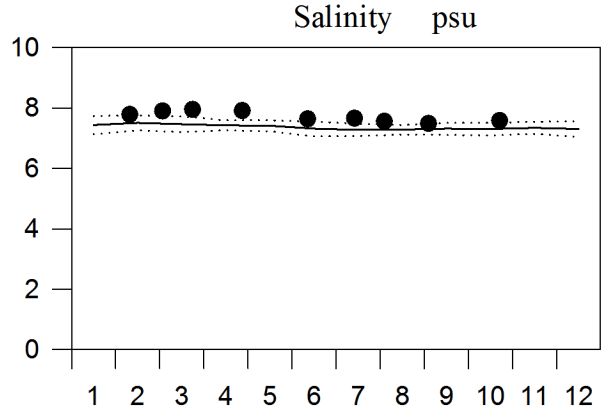
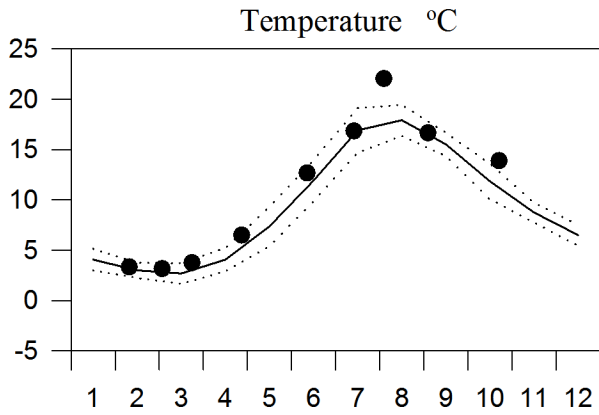
— Mean 1996-2010      ····· St.Dev.      ● 2014



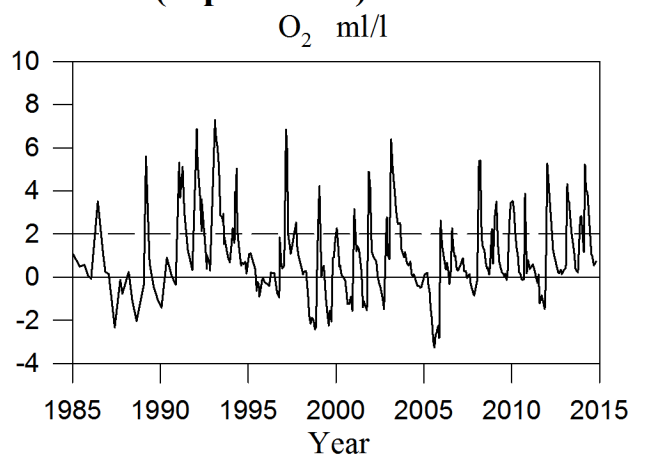
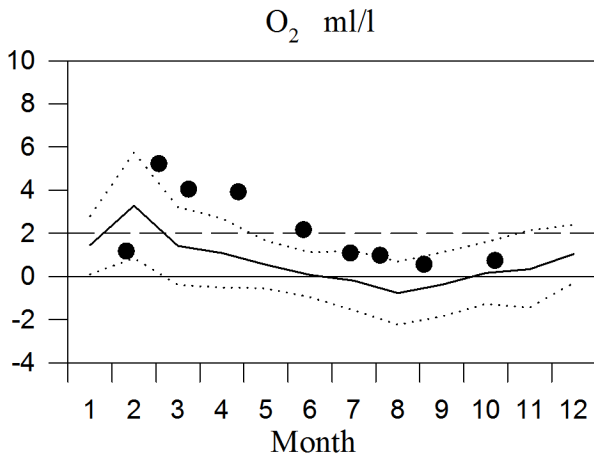
# STATION BY4 SURFACE WATER

## Annual Cycles

— Mean 1996-2010      ..... St.Dev.      ● 2014

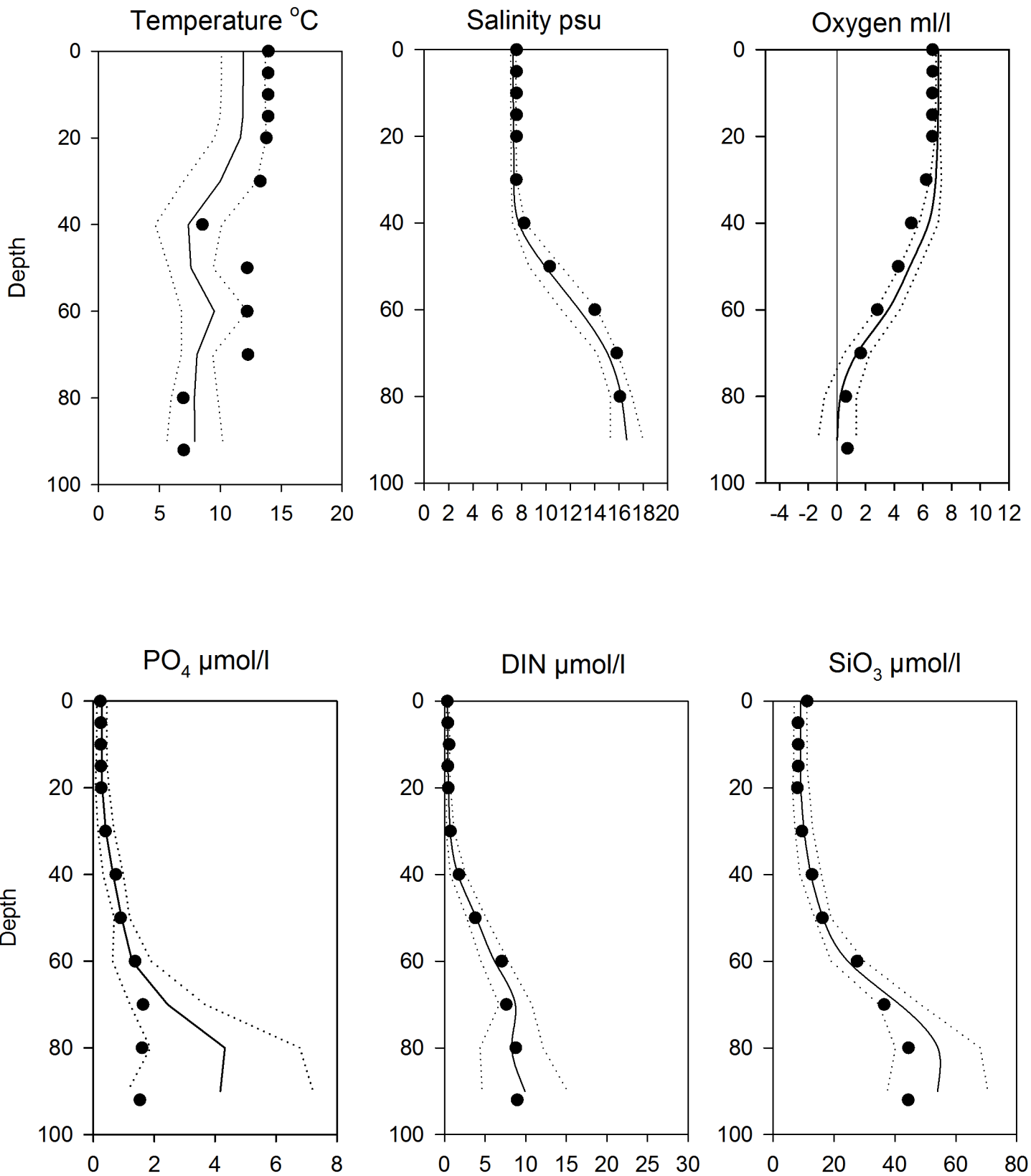


## OXYGEN IN BOTTOM WATER (depth >80m)



# Vertical profiles BY4 October

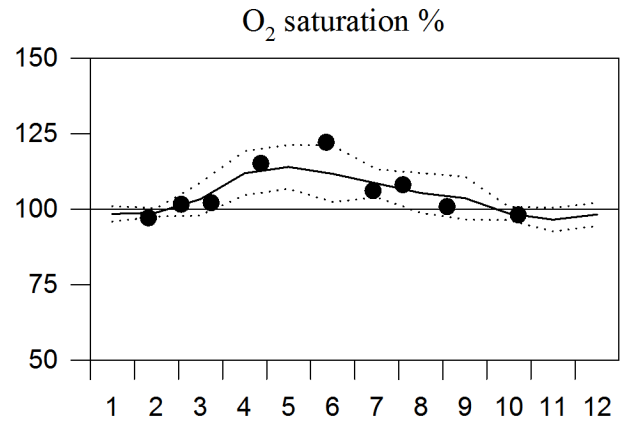
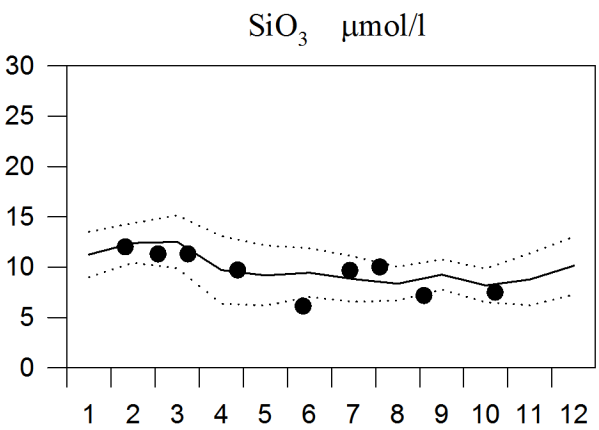
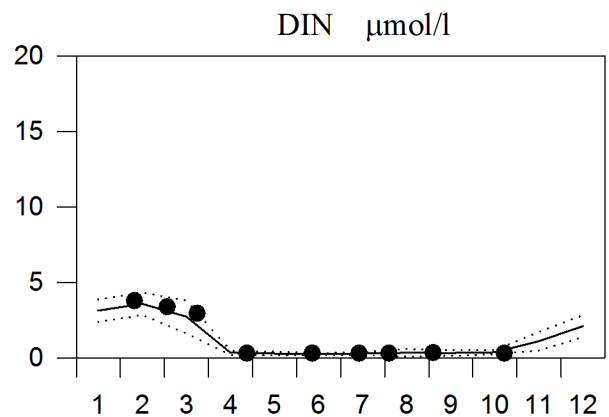
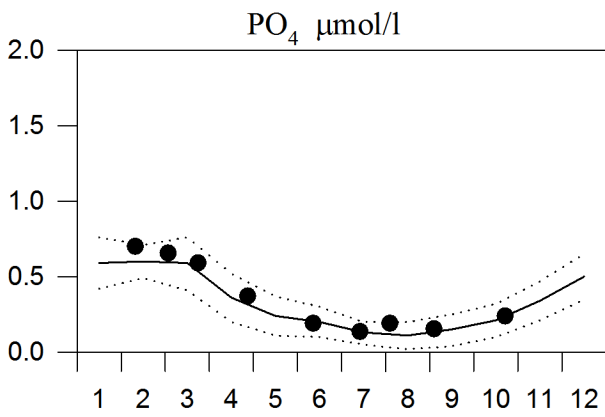
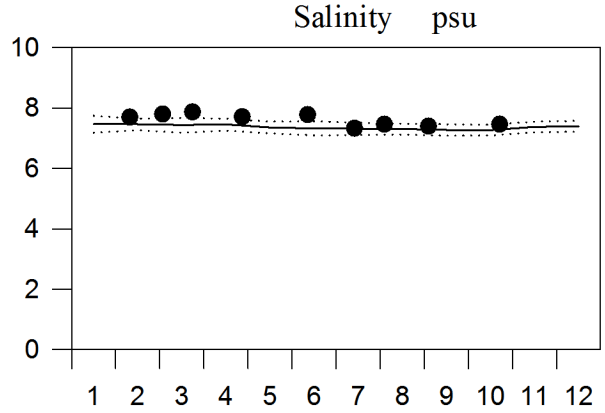
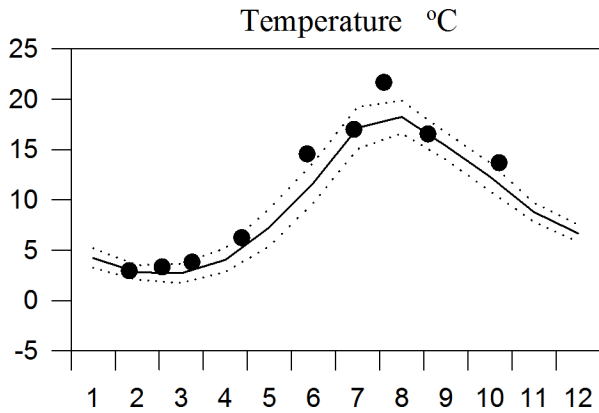
— Mean 1996-2010      ····· St.Dev.      ● 2014



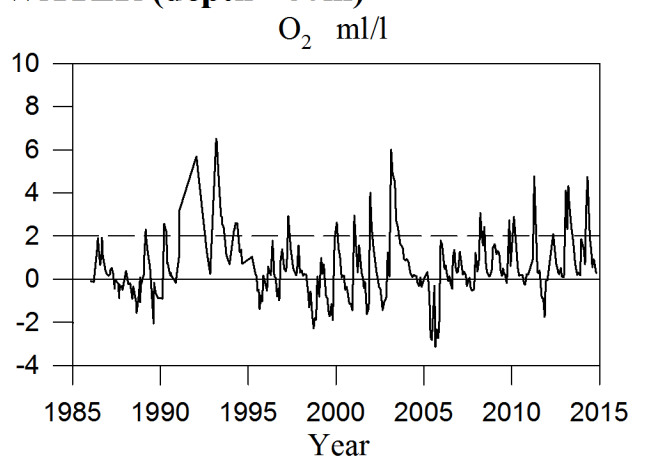
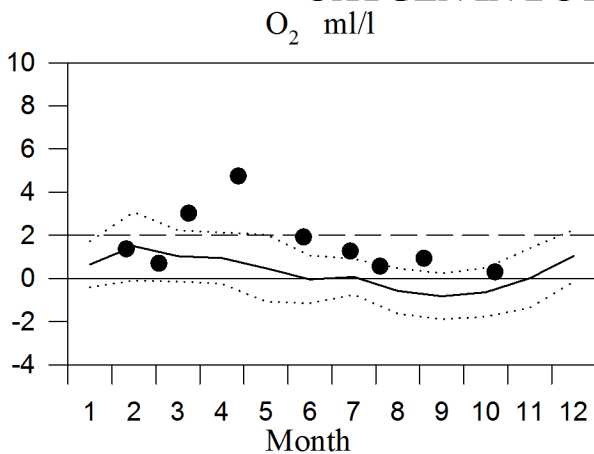
# STATION BY5 SURFACE WATER

## Annual Cycles

— Mean 1996-2010      ..... St.Dev.      ● 2014

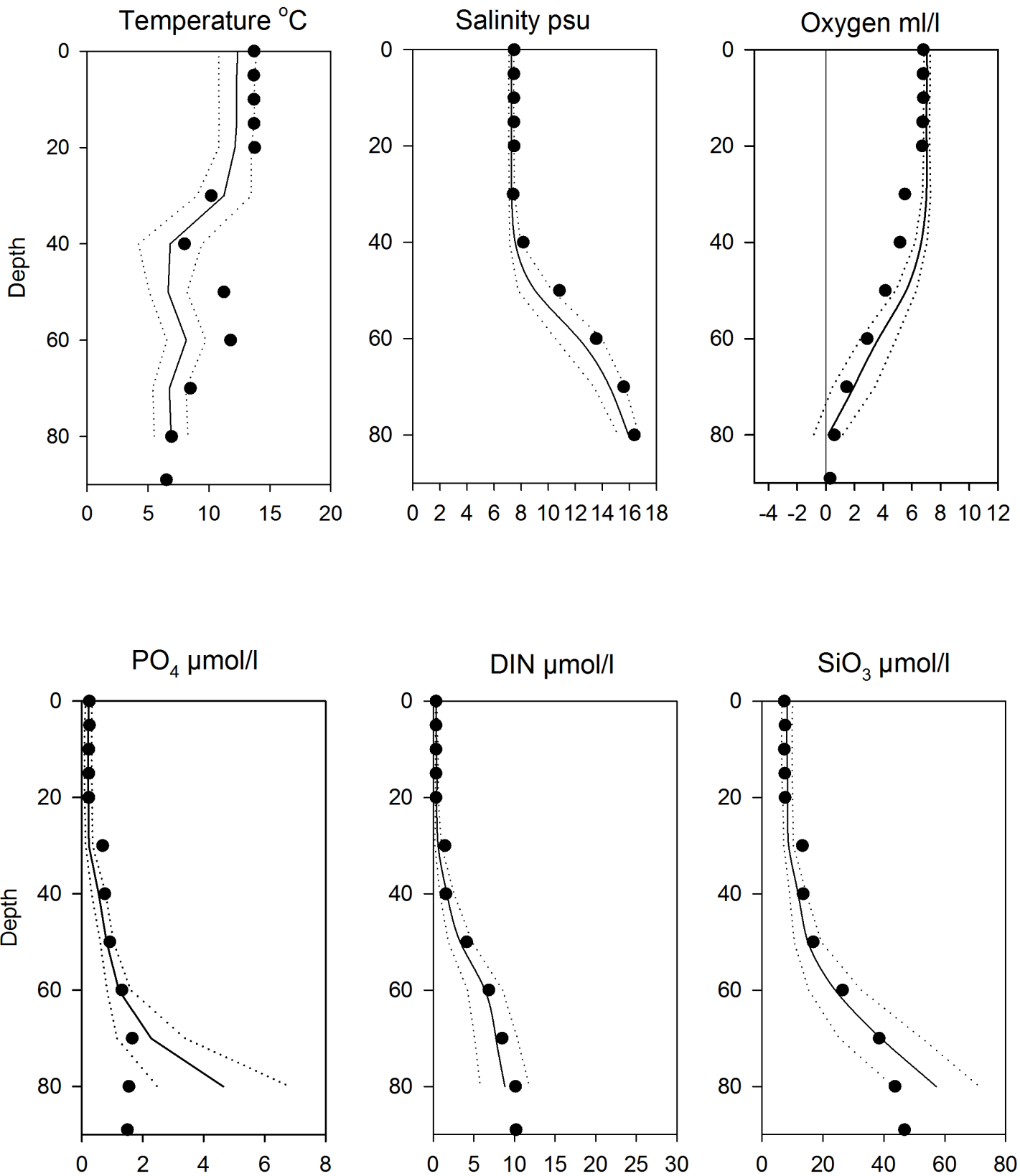


## OXYGEN IN BOTTOM WATER (depth >80m)



# Vertical profiles BY5 October

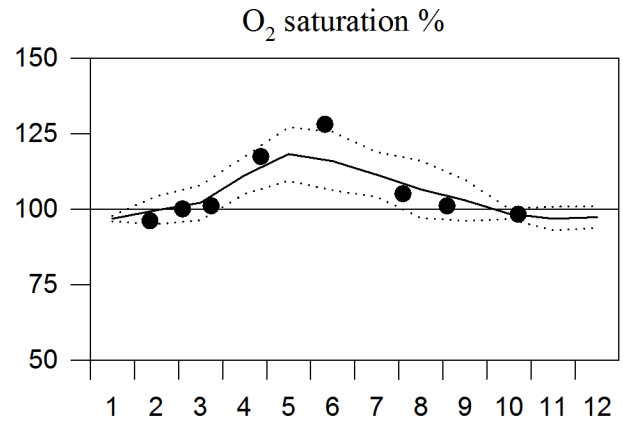
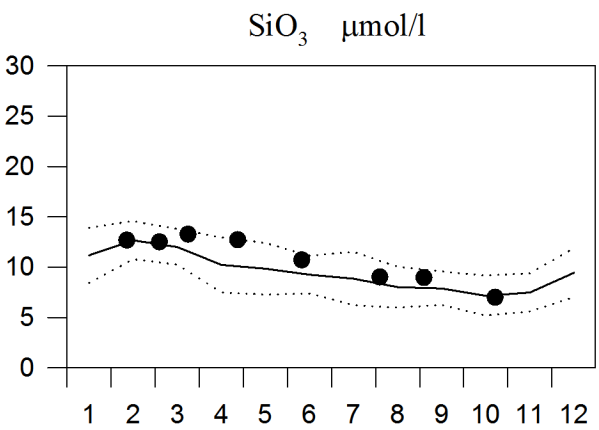
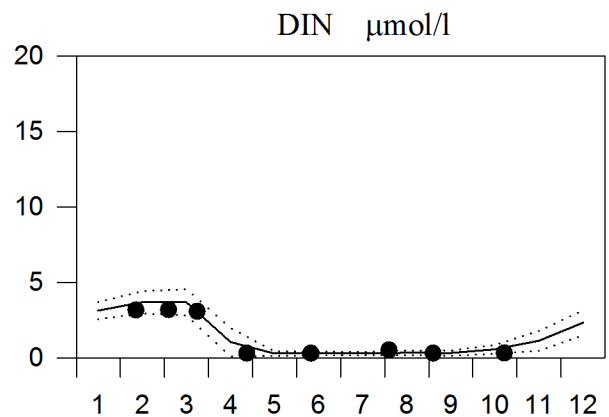
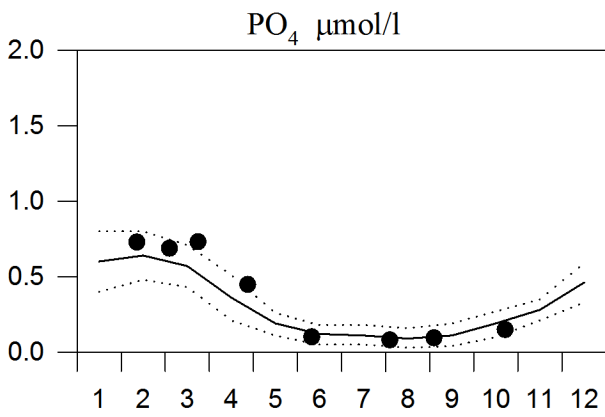
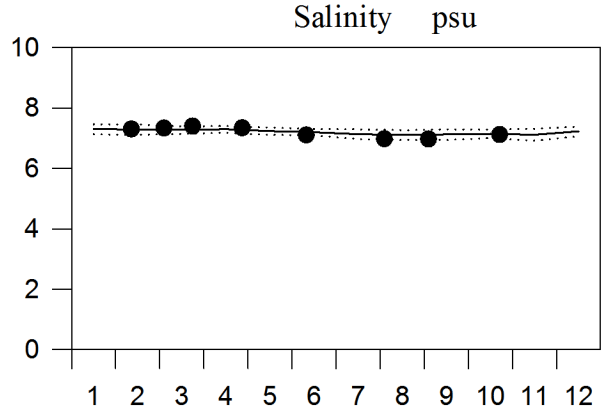
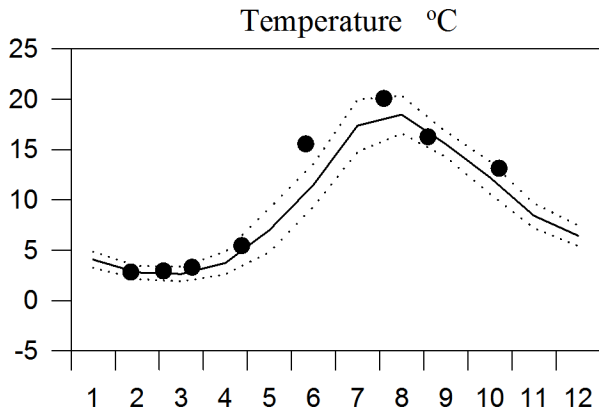
— Mean 1996-2010      ····· St.Dev.      ● 2014



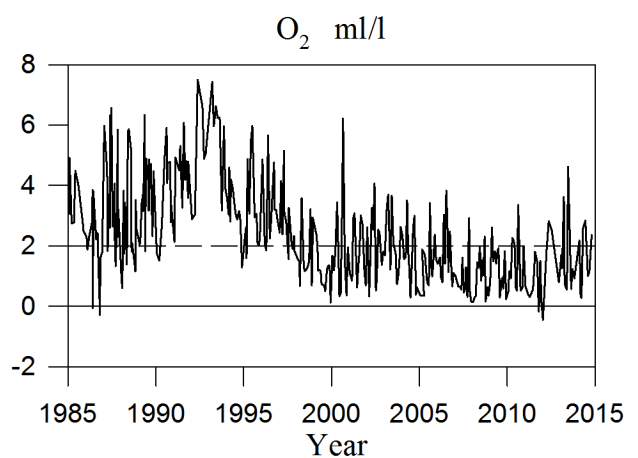
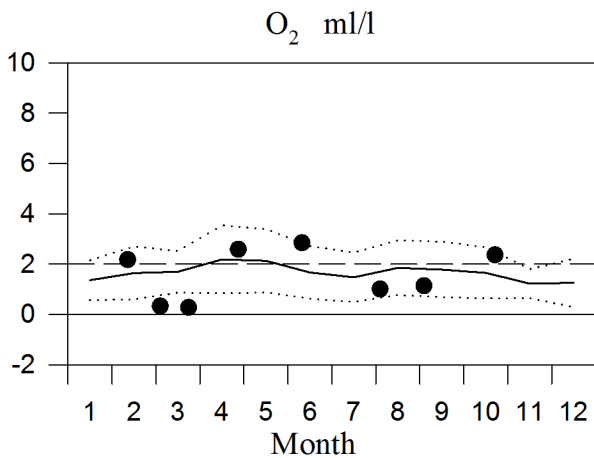
# STATION BCS III-10 SURFACE WATER

## Annual Cycles

— Mean 1996-2010      ····· St.Dev.      ● 2014

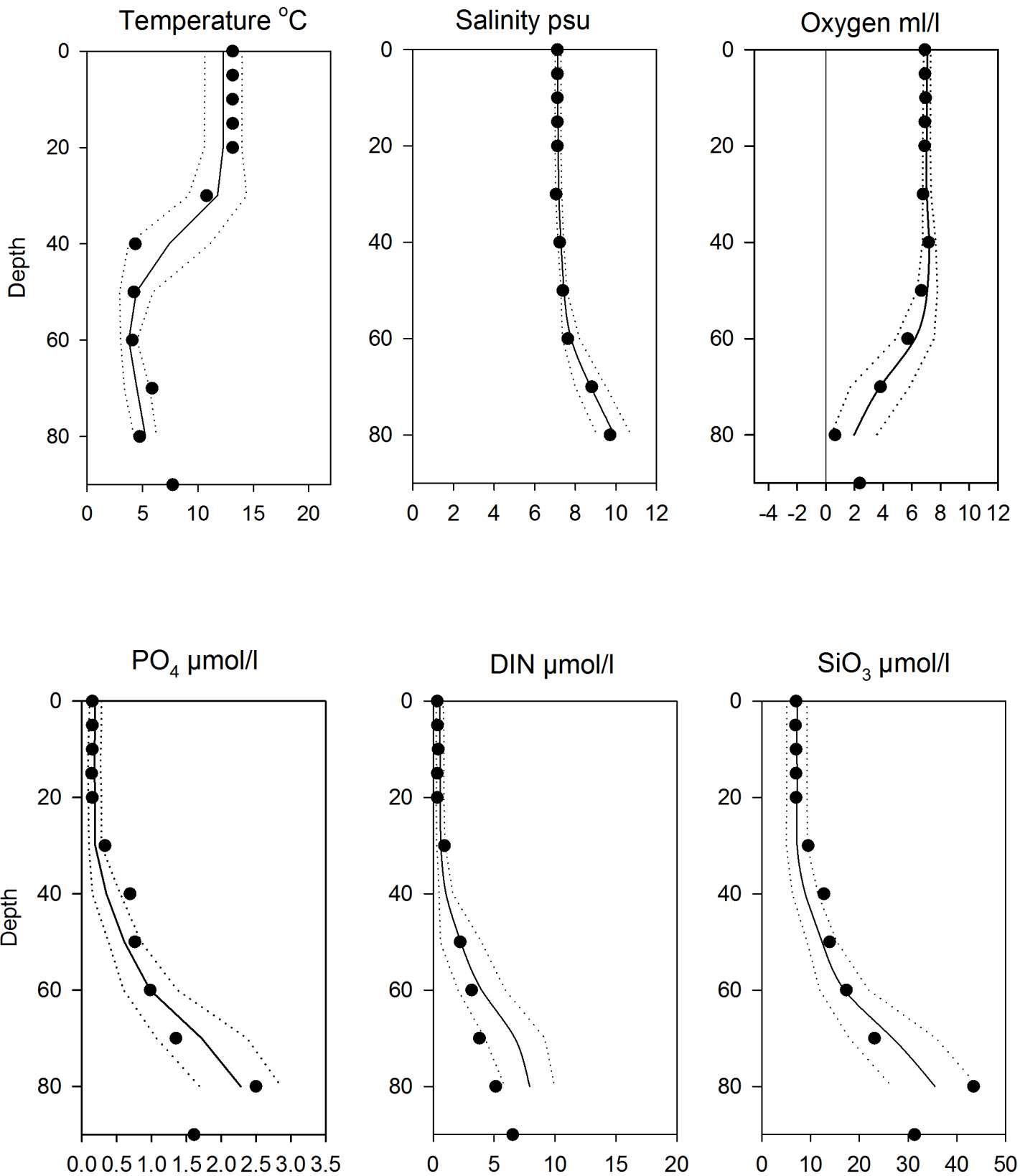


## OXYGEN IN BOTTOM WATER (depth > 80m)



# Vertical profiles BCS III-10 October

— Mean 1996-2010      ····· St.Dev.      ● 2014

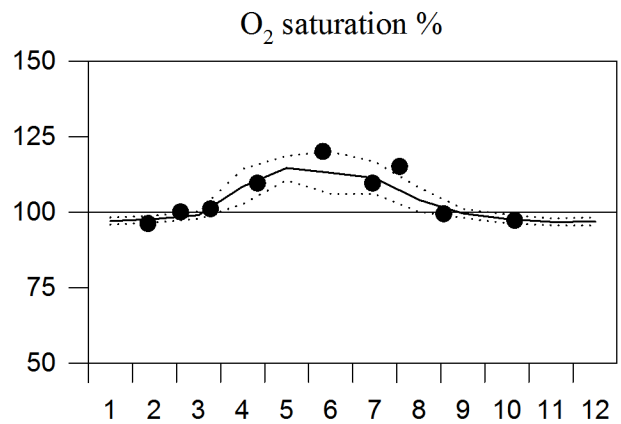
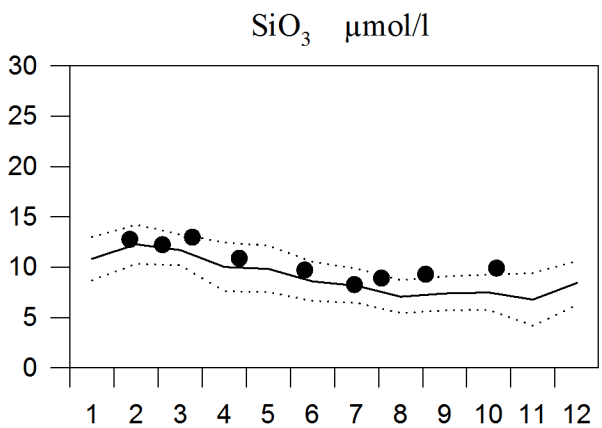
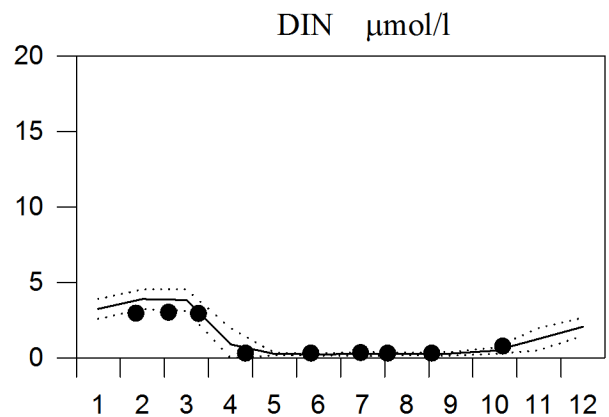
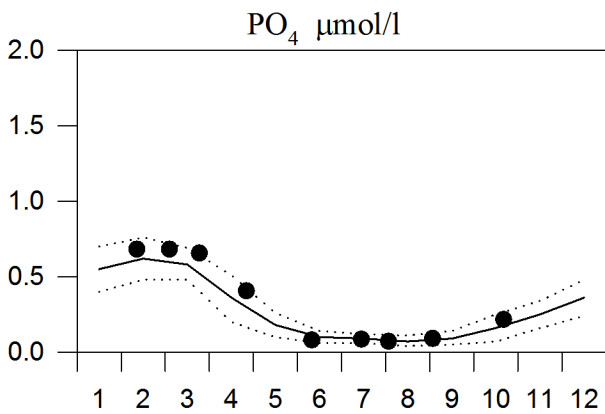
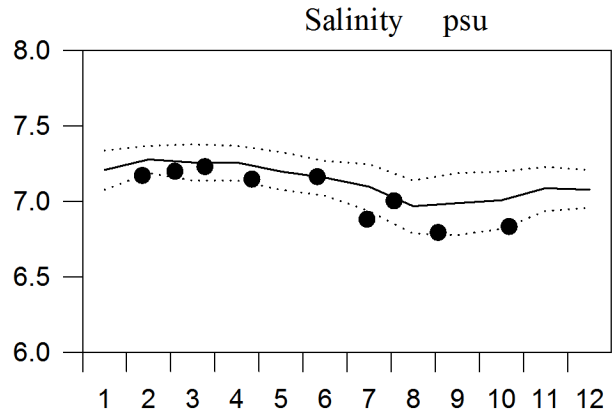
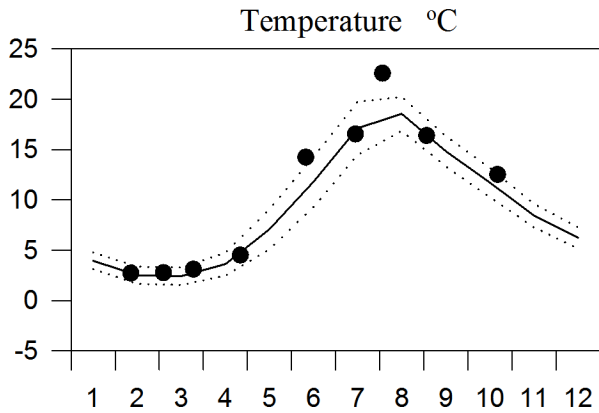




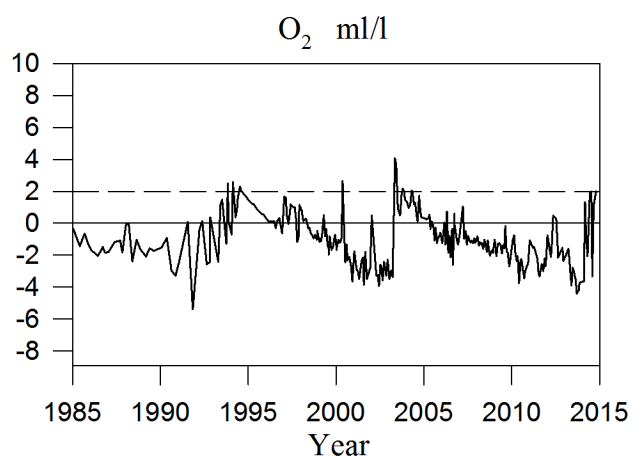
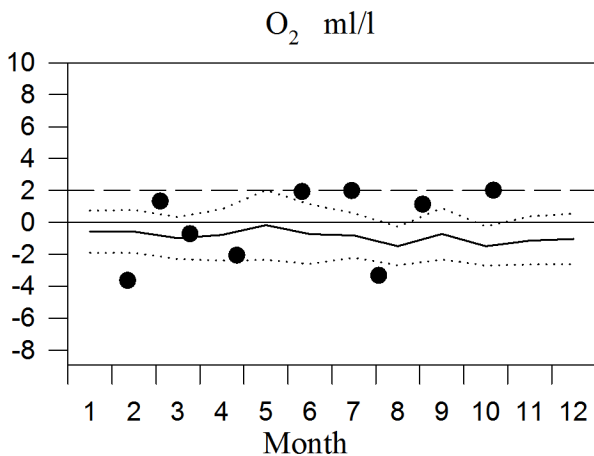
# STATION BY10 SURFACE WATER

## Annual Cycles

— Mean 1996-2010      ····· St.Dev.      ● 2014

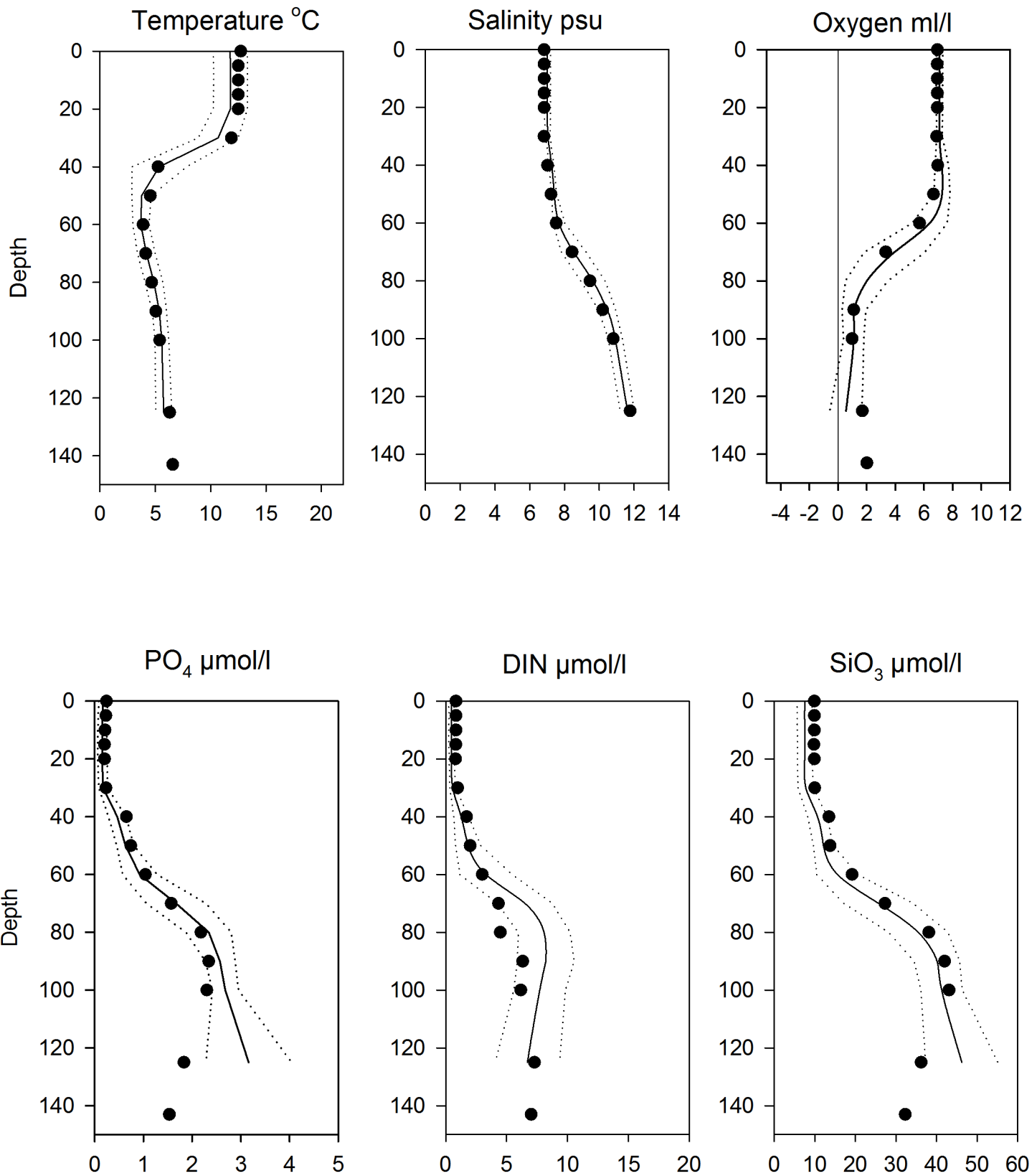


## OXYGEN IN BOTTOM WATER (depth >125m)



# Vertical profiles BY10 October

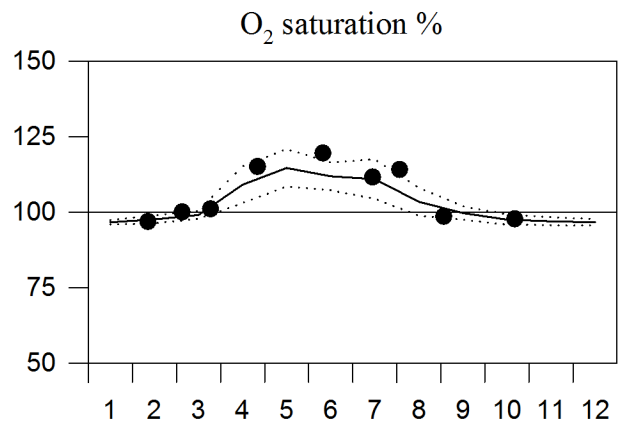
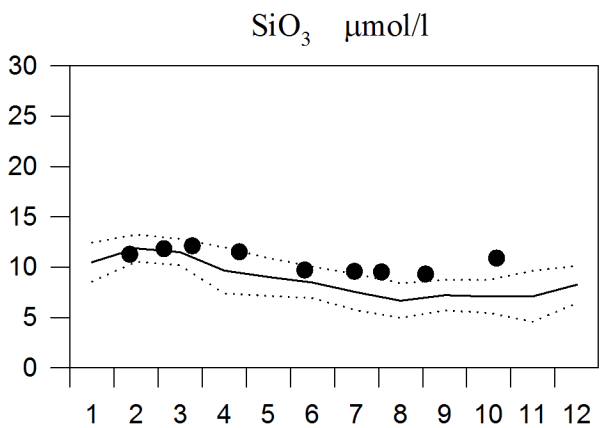
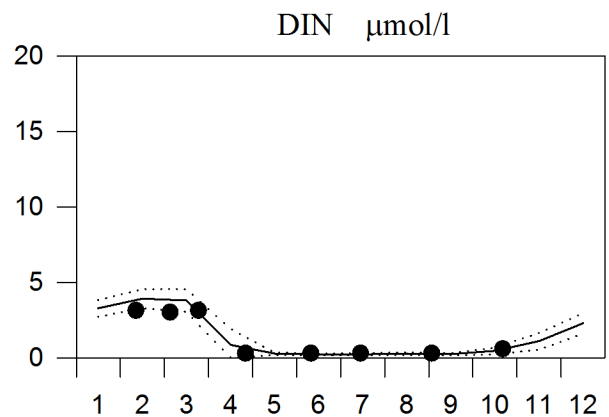
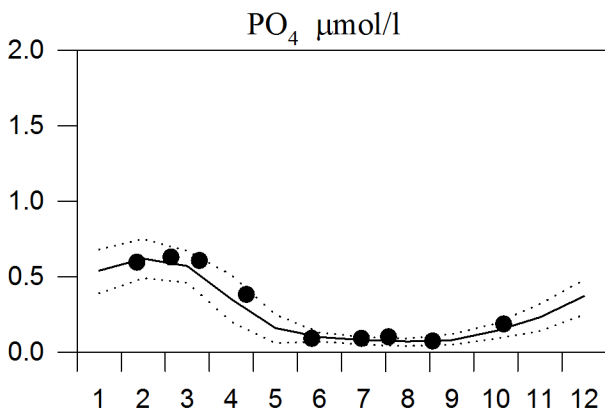
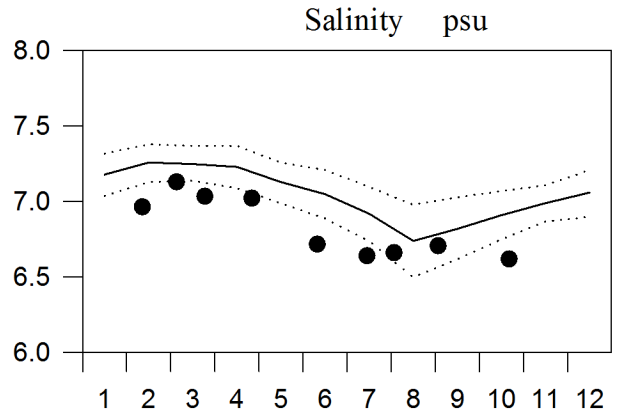
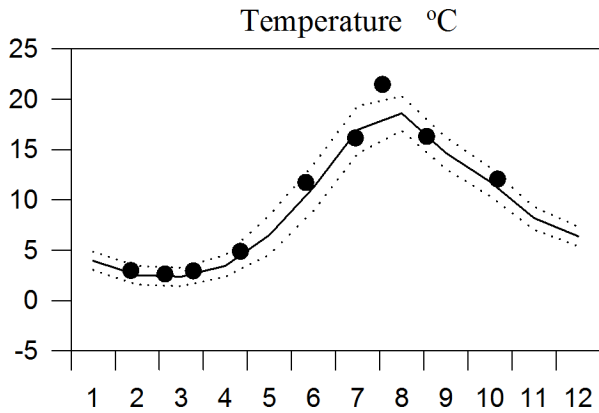
— Mean 1996-2010      ····· St.Dev.      ● 2014



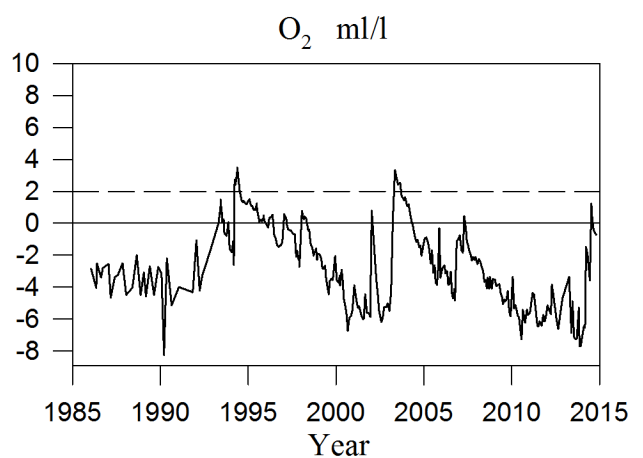
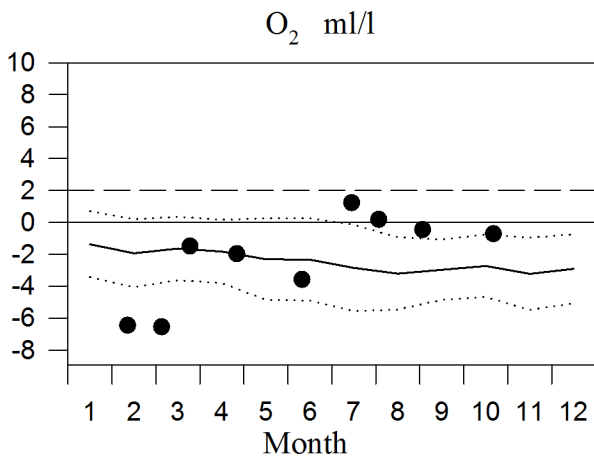
# STATION BY15 SURFACE WATER

## Annual Cycles

— Mean 1996-2010      ..... St.Dev.      ● 2014

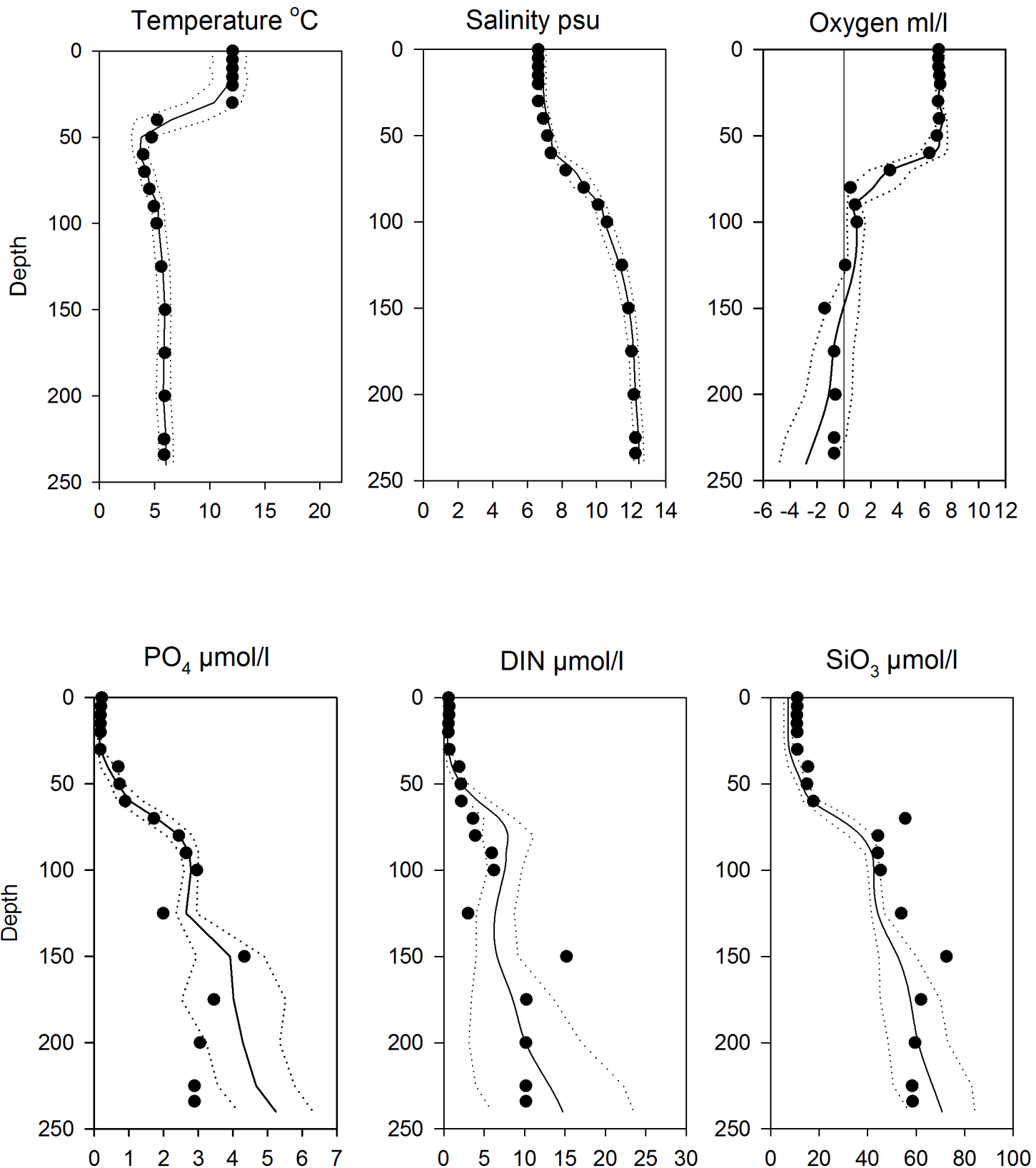


## OXYGEN IN BOTTOM WATER (depth >225m)



# Vertical profiles BY15 October

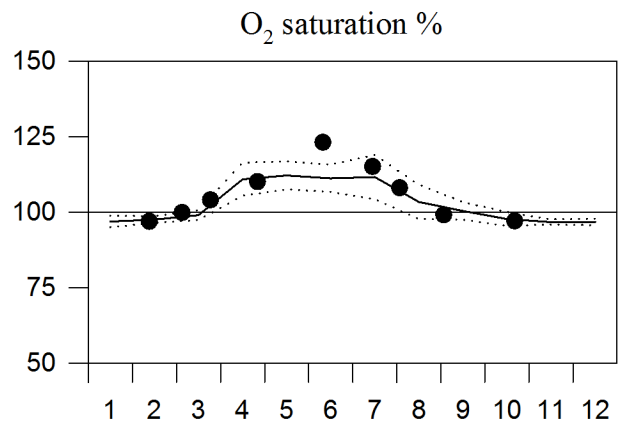
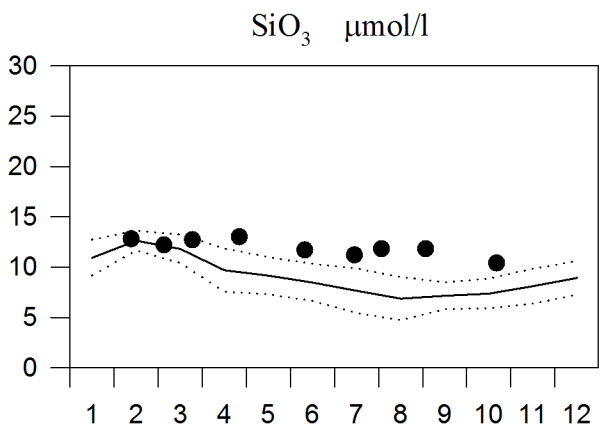
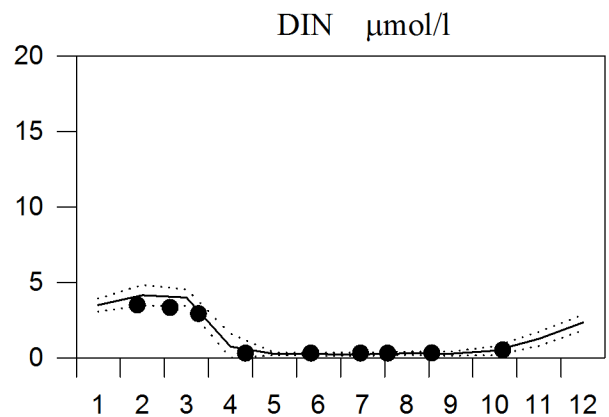
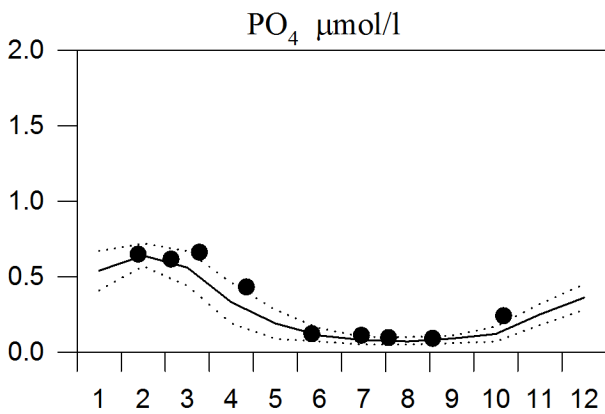
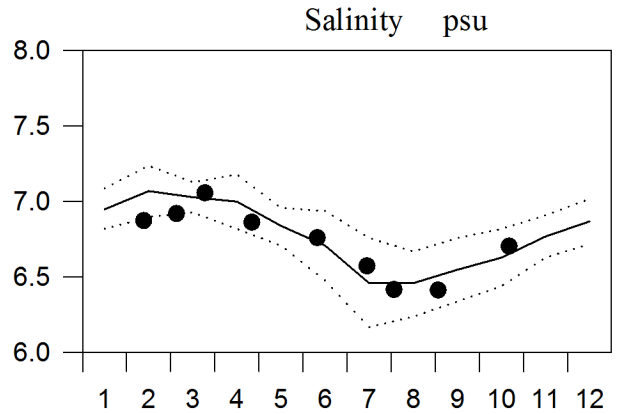
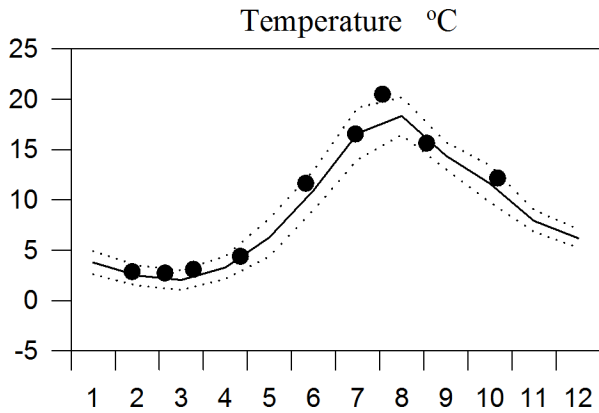
— Mean 1996-2010      ····· St.Dev.      ● 2014



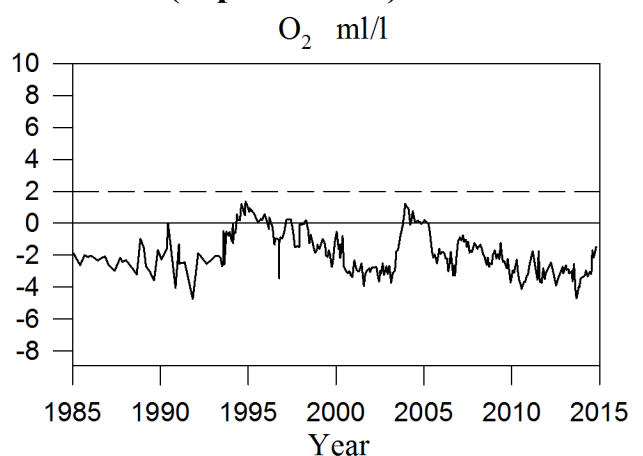
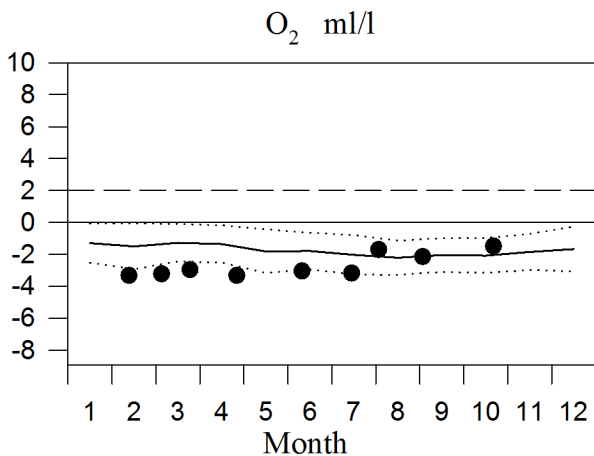
# STATION BY20 SURFACE WATER

## Annual Cycles

— Mean 1996-2010      ..... St.Dev.      ● 2014

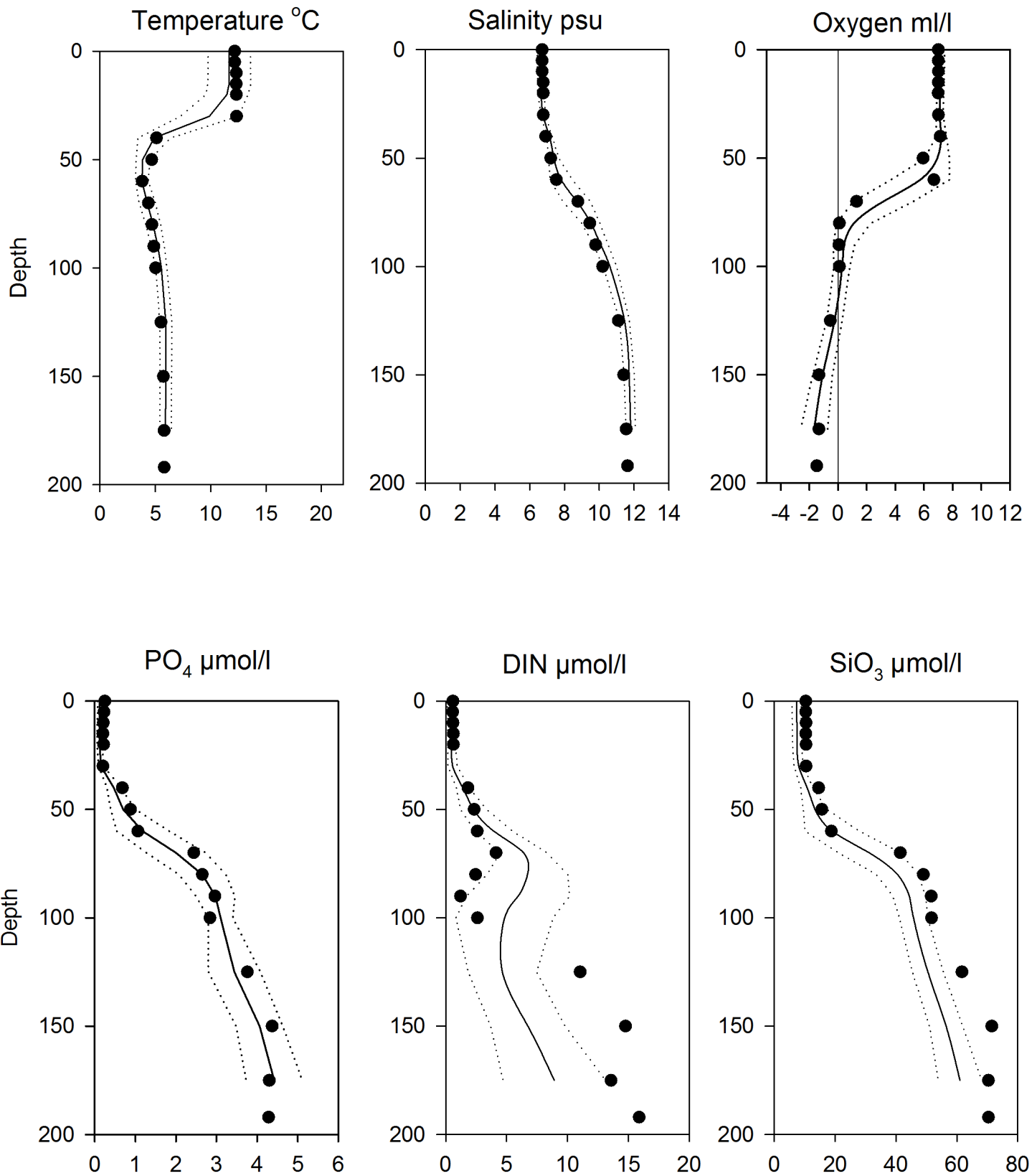


## OXYGEN IN BOTTOM WATER (depth >175m)



# Vertical profiles BY20 October

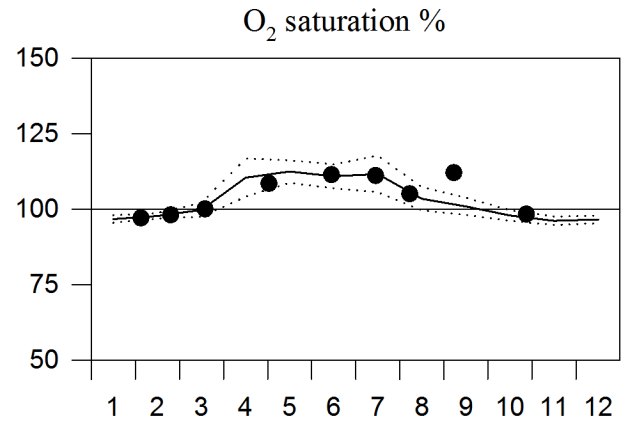
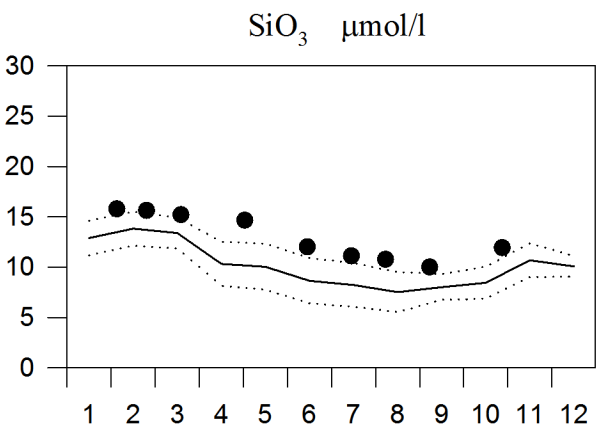
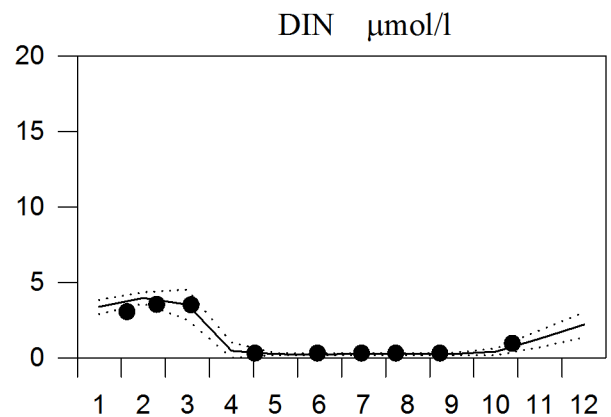
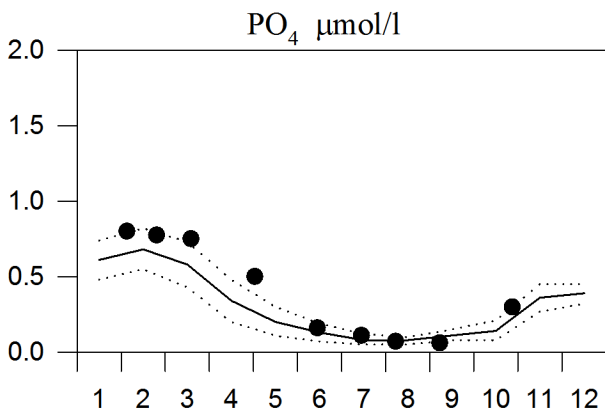
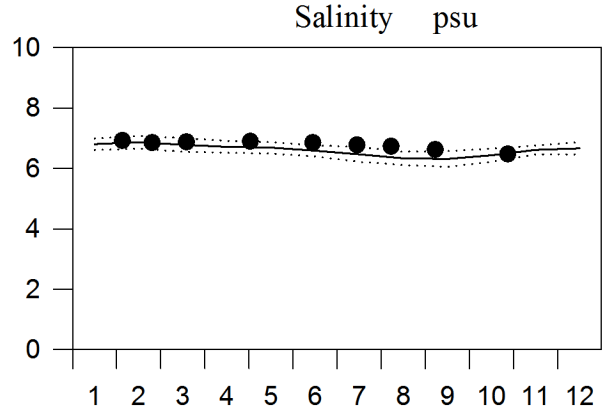
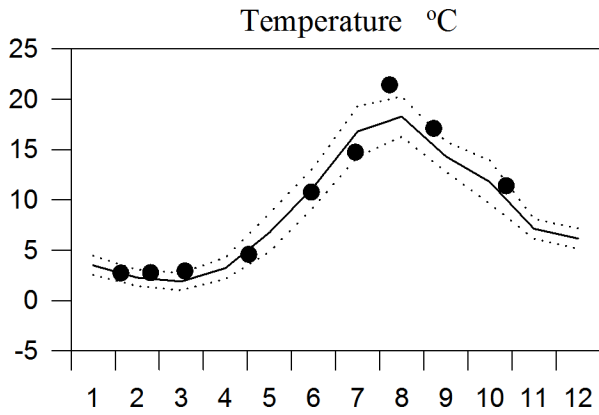
— Mean 1996-2010      ..... St.Dev.      ● 2014



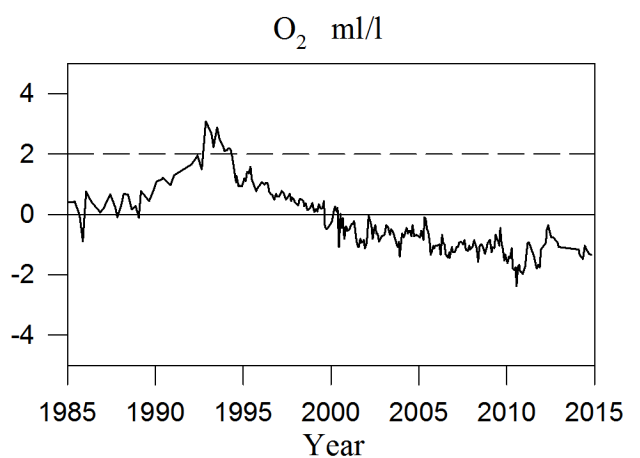
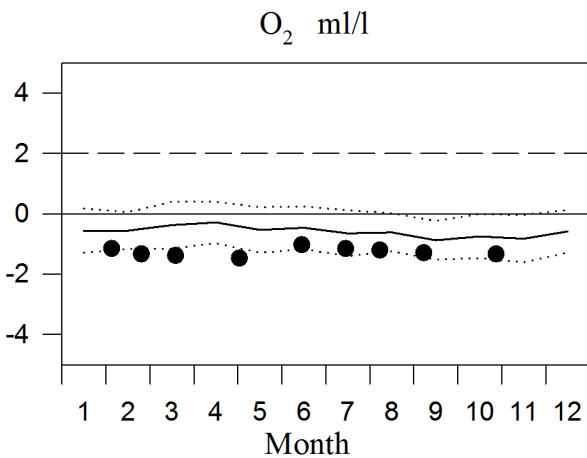
# STATION BY32 SURFACE WATER

## Annual Cycles

— Mean 1996-2010      ..... St.Dev.      ● 2014

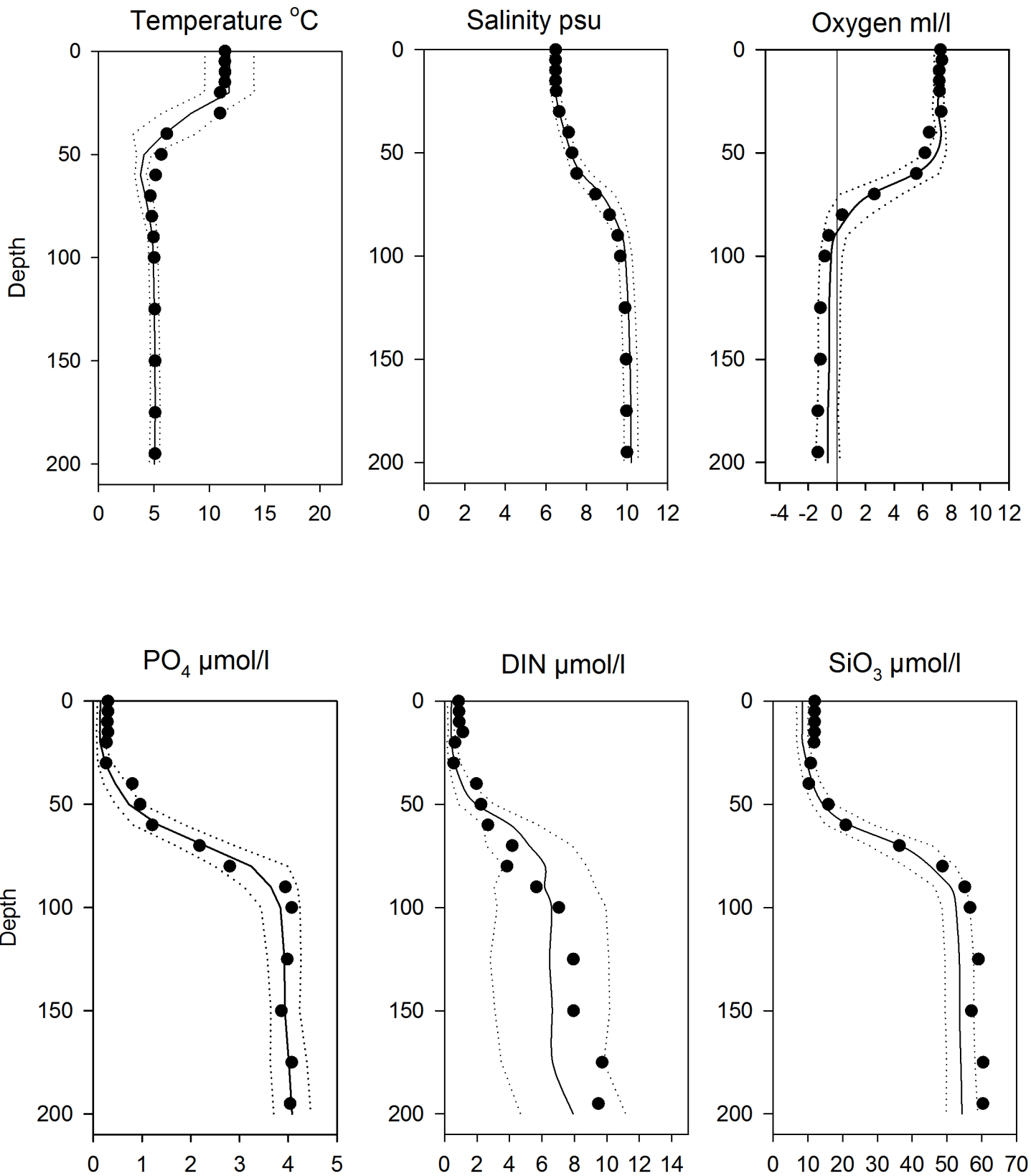


## OXYGEN IN BOTTOM WATER (depth > 175m)



# Vertical profiles BY32 October

— Mean 1996-2010      ····· St.Dev.      ● 2014

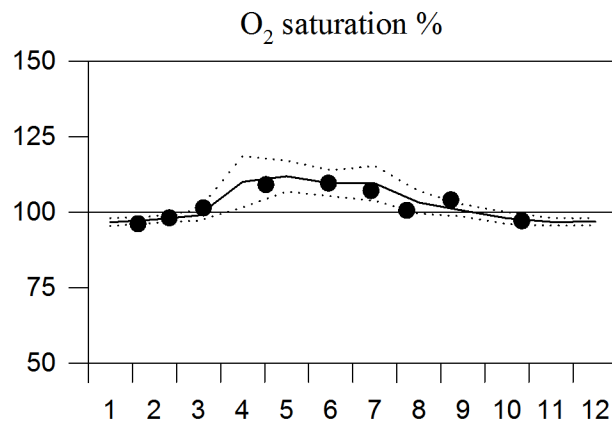
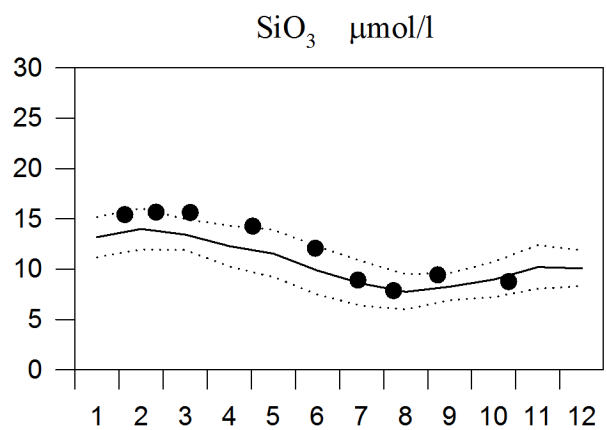
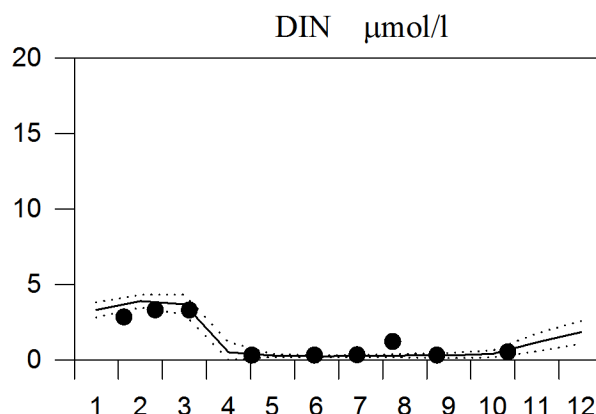
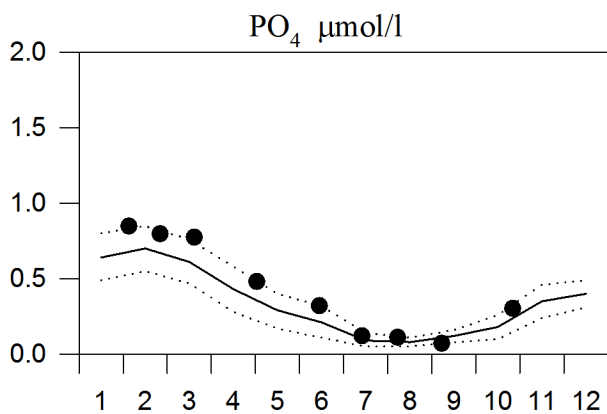
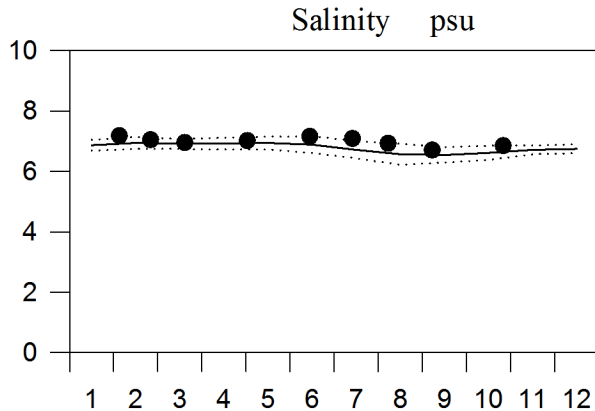
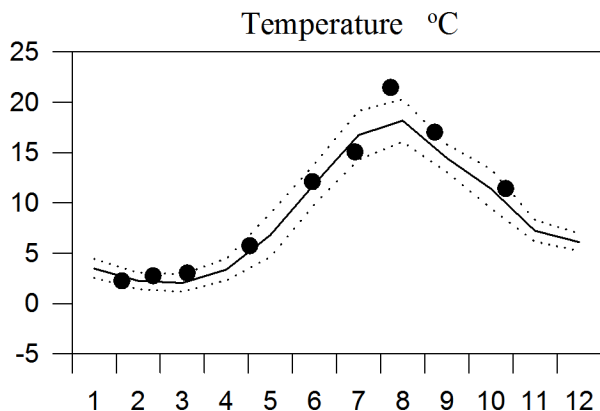




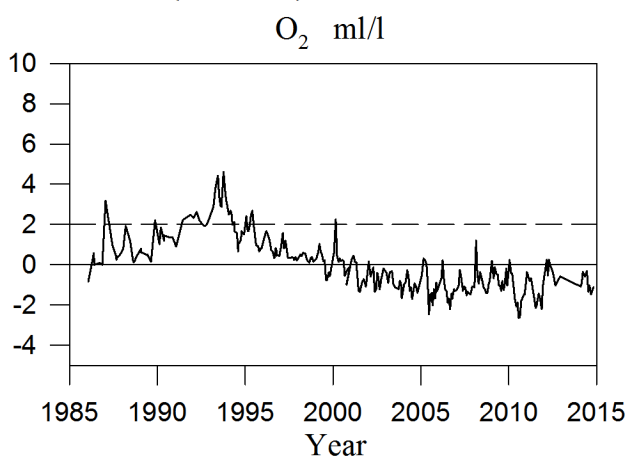
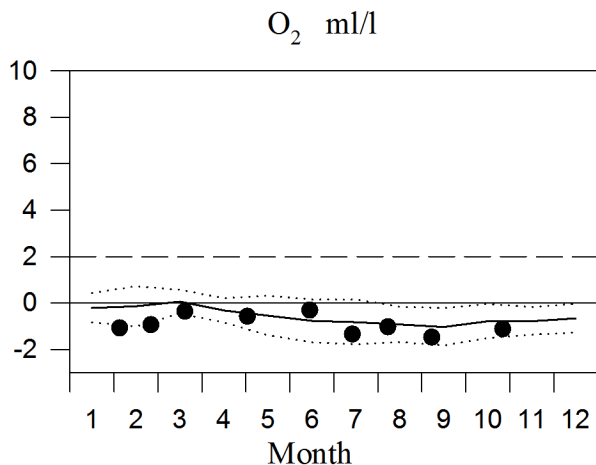
# STATION BY38 SURFACE WATER

## Annual Cycles

— Mean 1996-2010      ..... St.Dev.      ● 2014

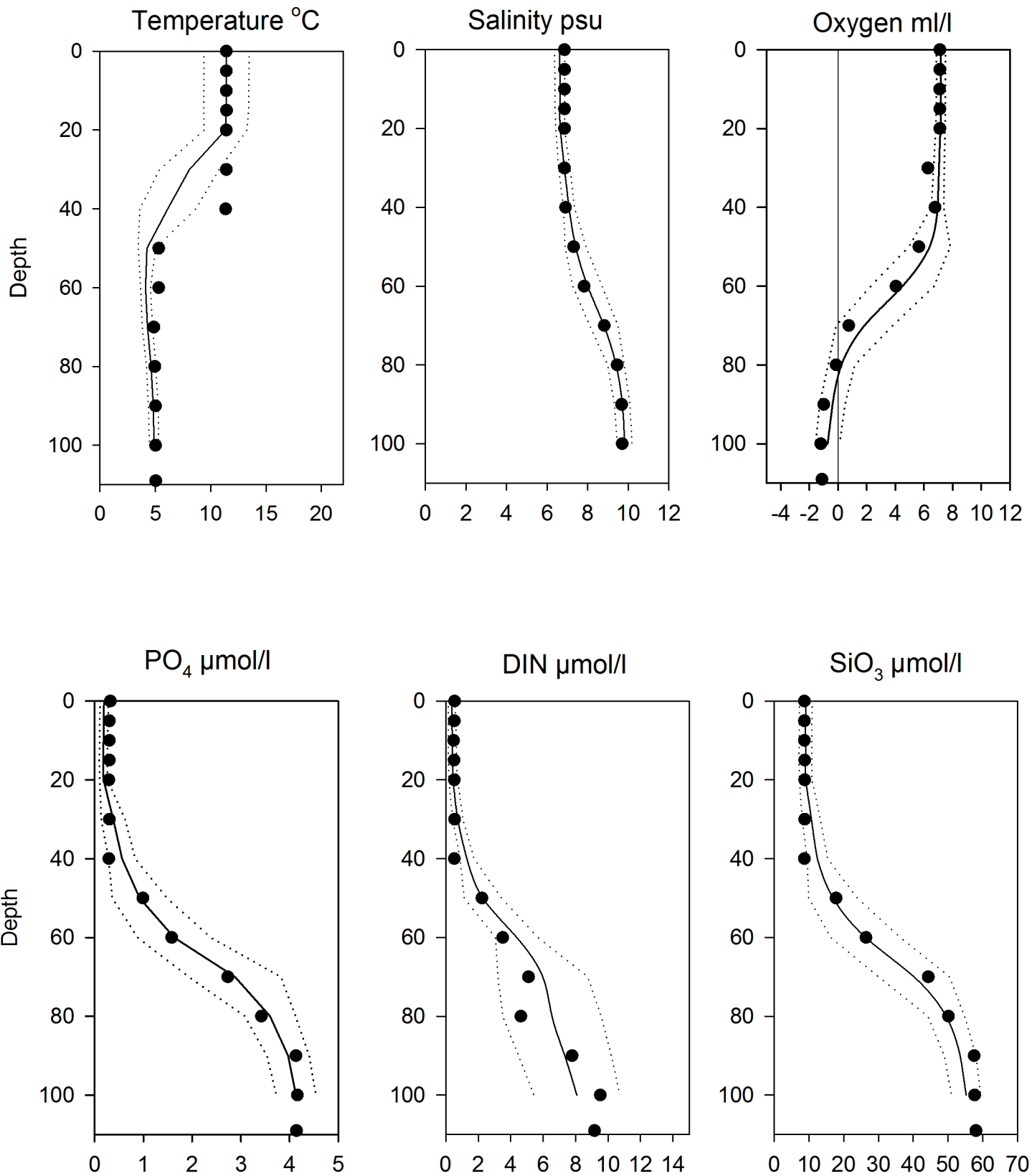


## OXYGEN IN BOTTOM WATER (> 100m)



# Vertical profiles BY38 October

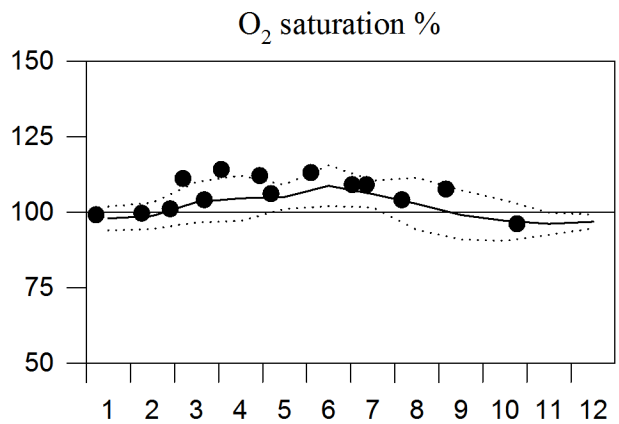
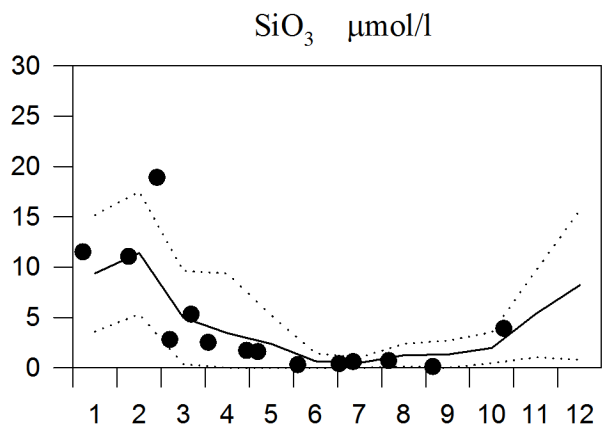
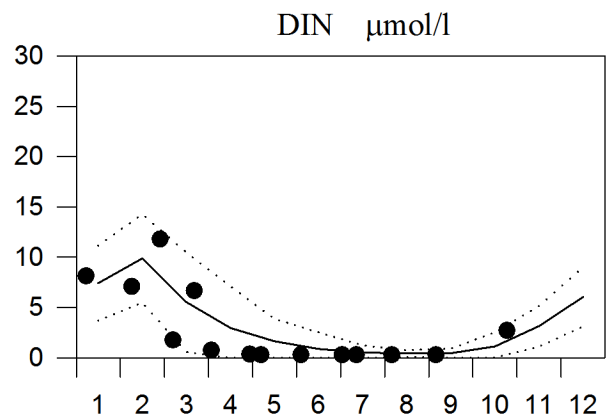
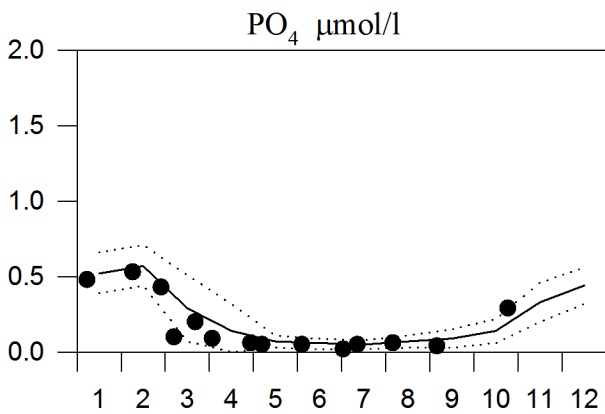
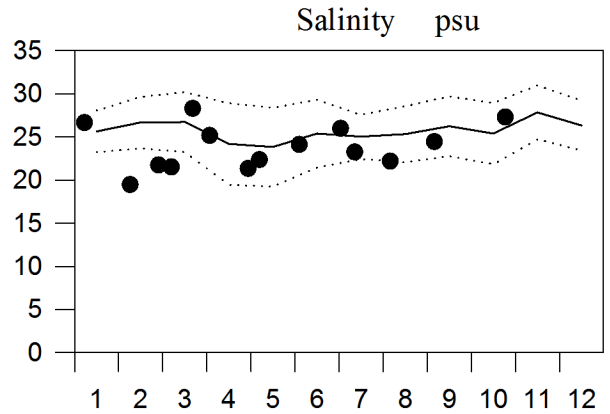
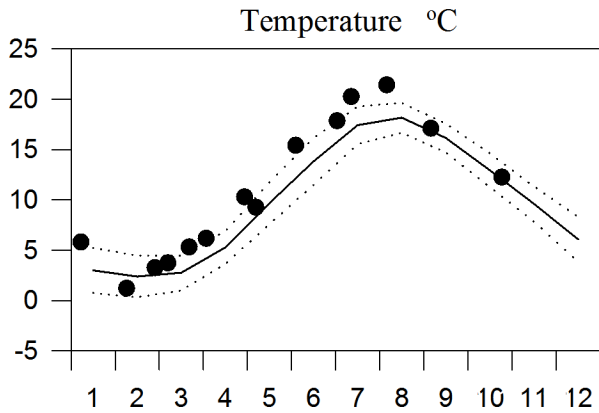
— Mean 1996-2010      ····· St.Dev.      ● 2014



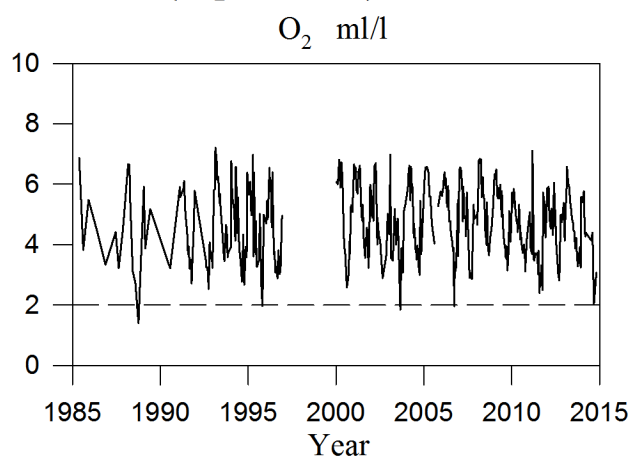
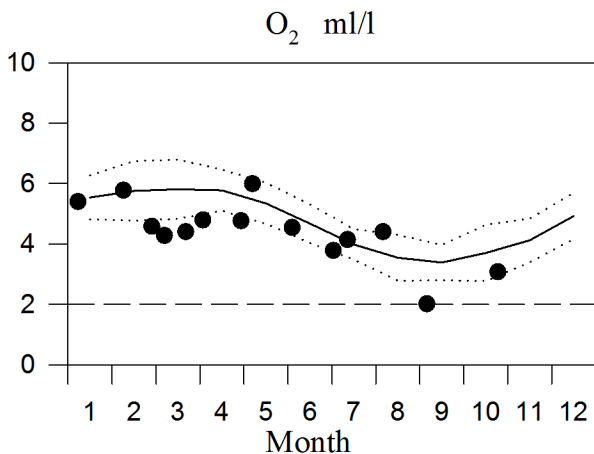
# STATION SLÄGGÖ SURFACE WATER

## Annual Cycles

— Mean 1996-2010      ..... St.Dev.      ● 2014

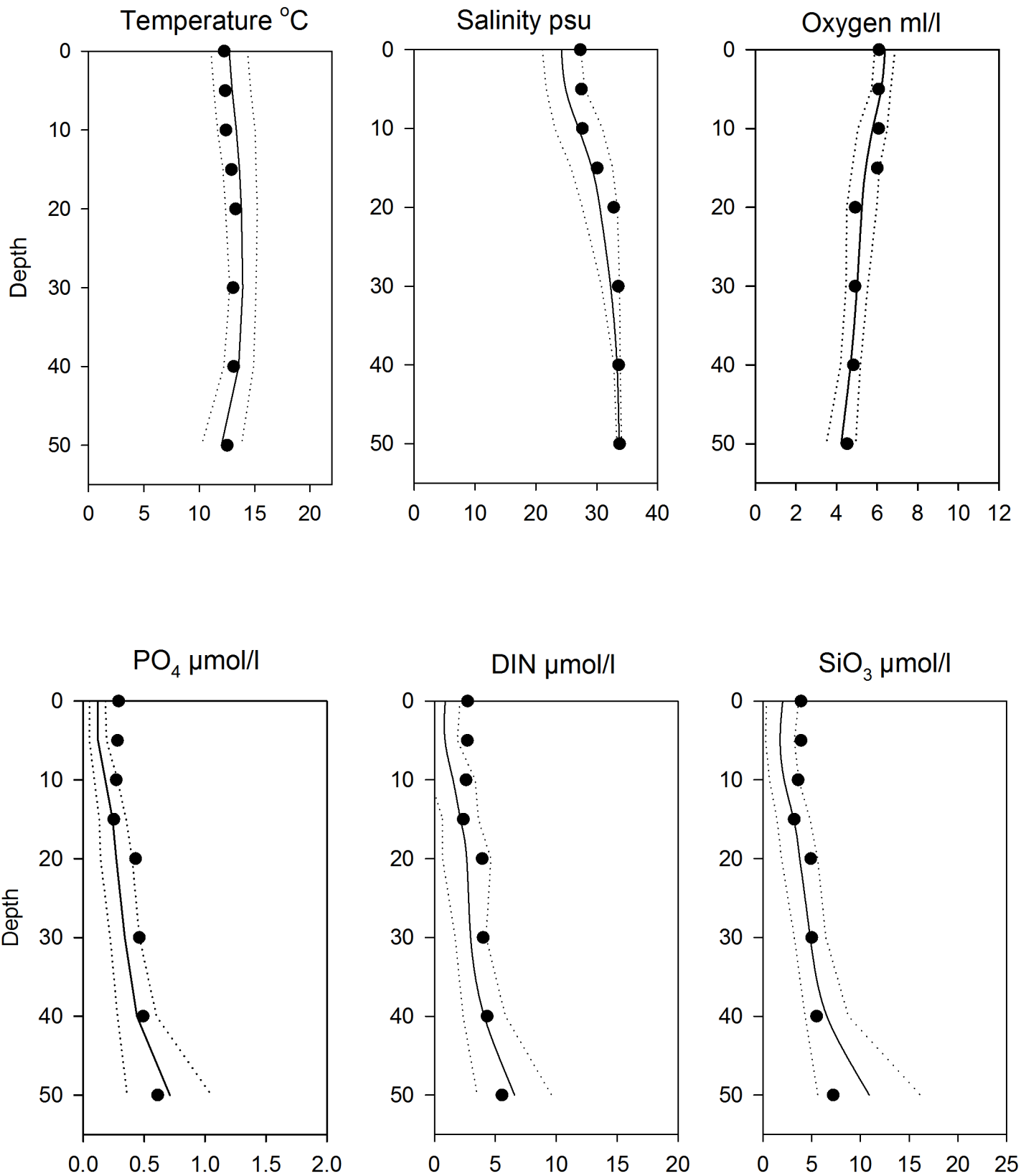


## OXYGEN IN BOTTOM WATER (depth >50m)



# Vertical profiles Släggö October

— Mean 1996-2010      ..... St.Dev.      ● 2014



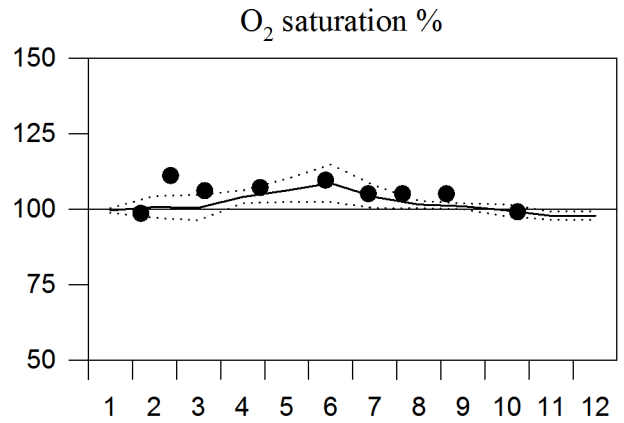
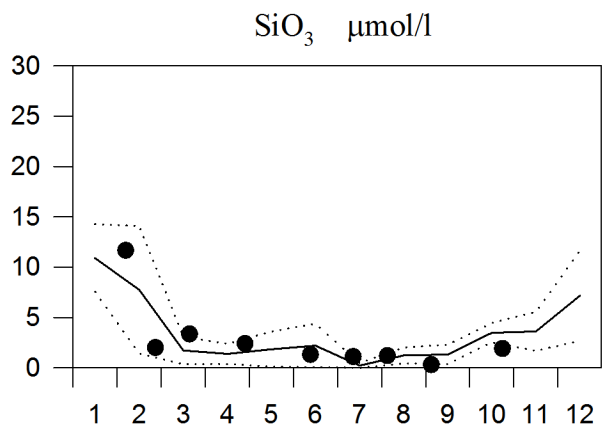
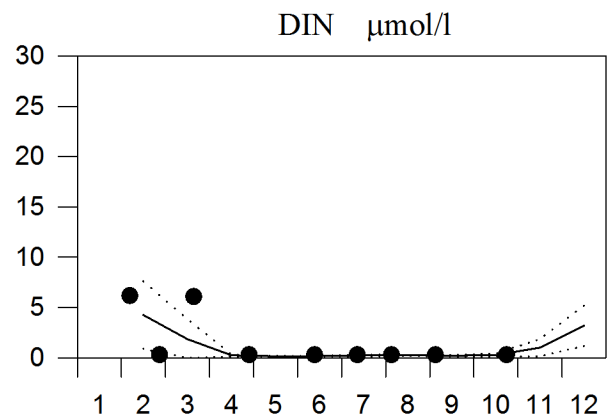
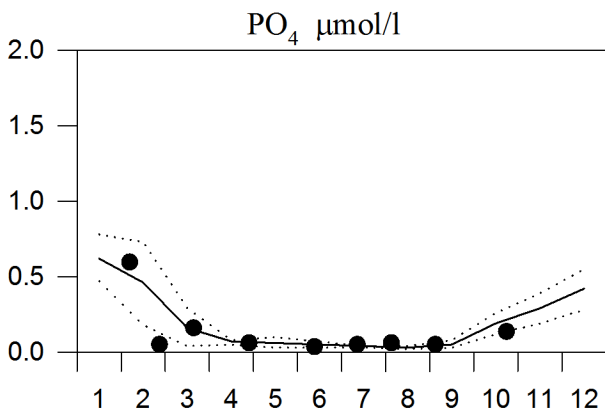
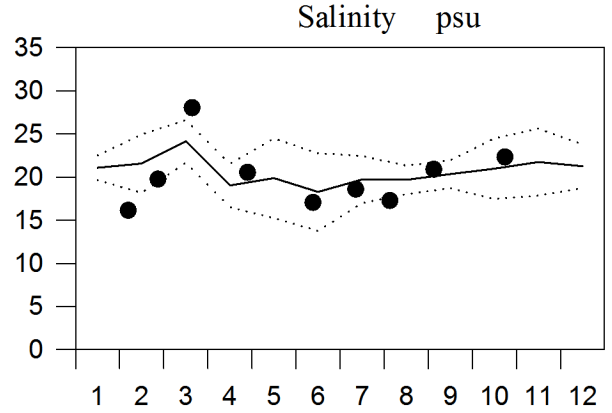
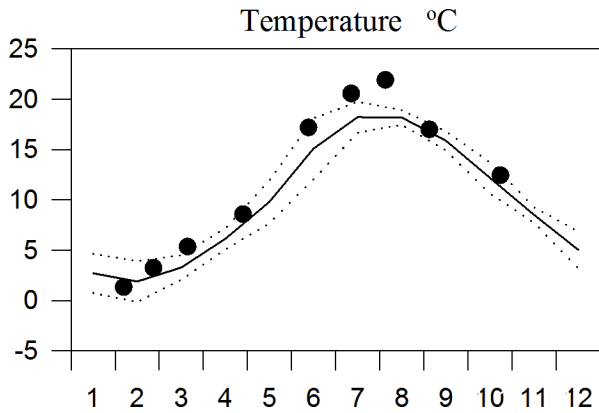
# STATION N14 Falkenberg SURFACE WATER

## Annual Cycles

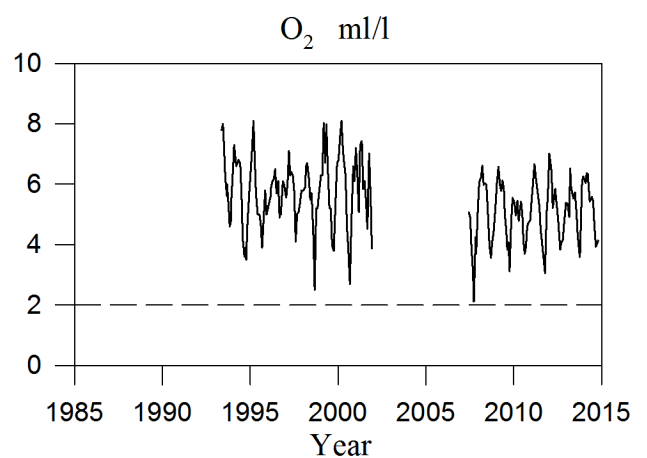
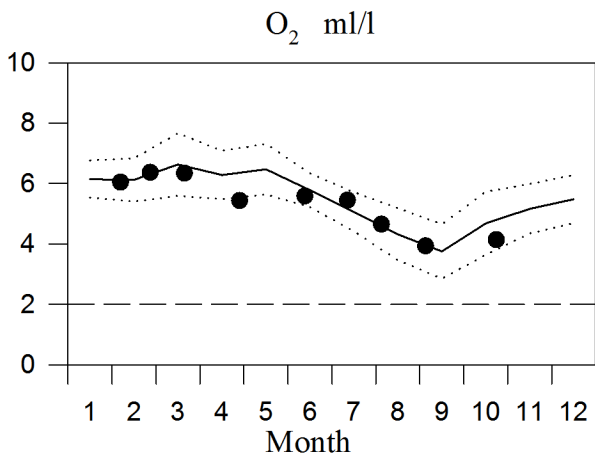
— Mean 2007-2010

..... St.Dev.

● 2014

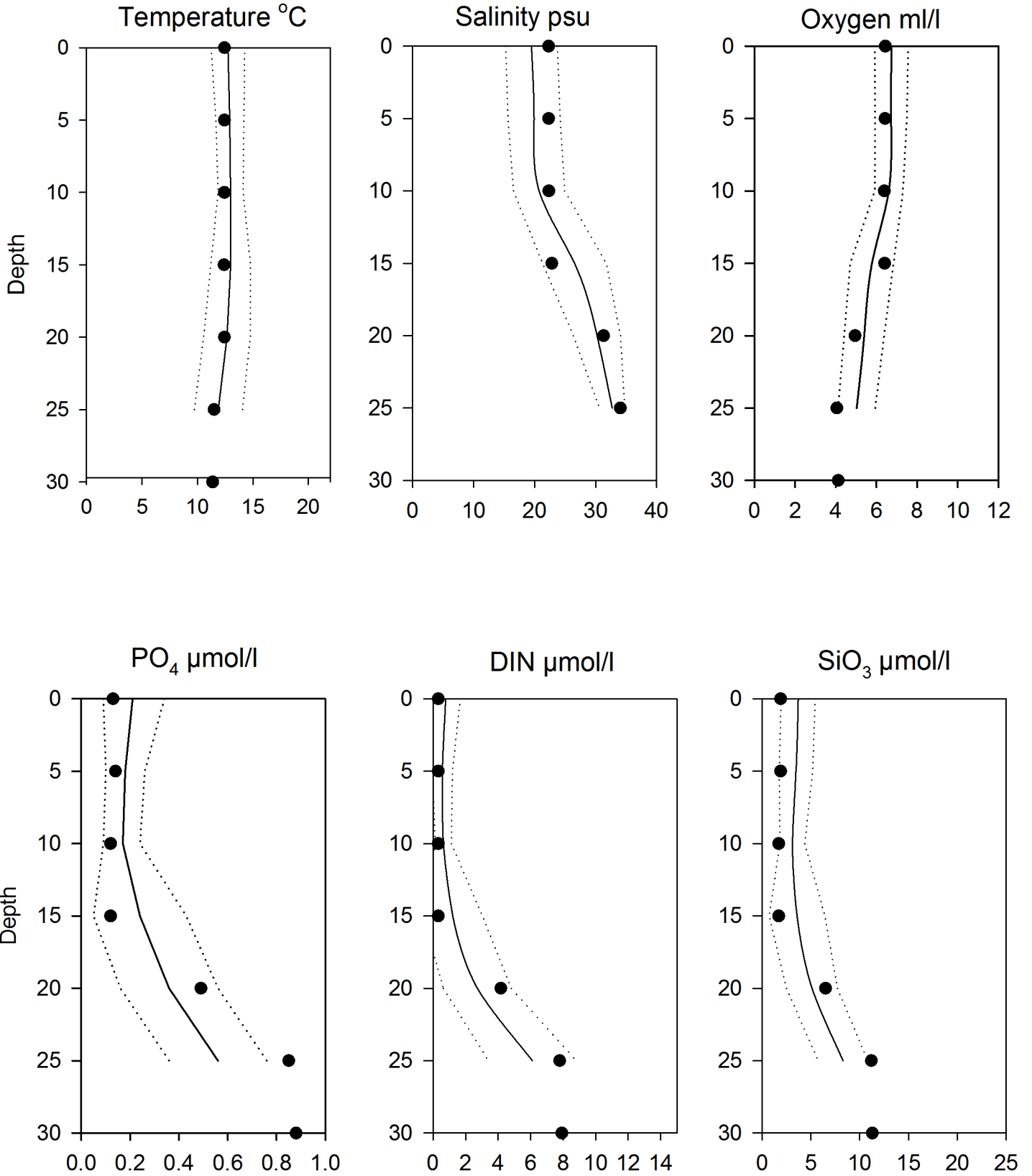


## OXYGEN IN BOTTOM WATER (depth > 25m)



# Vertical profiles N14 Falkenberg October

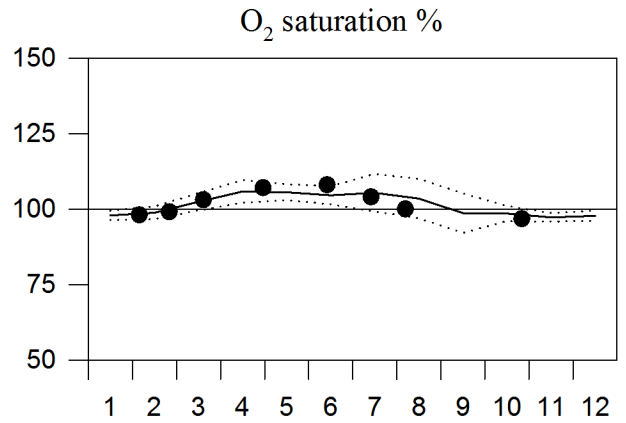
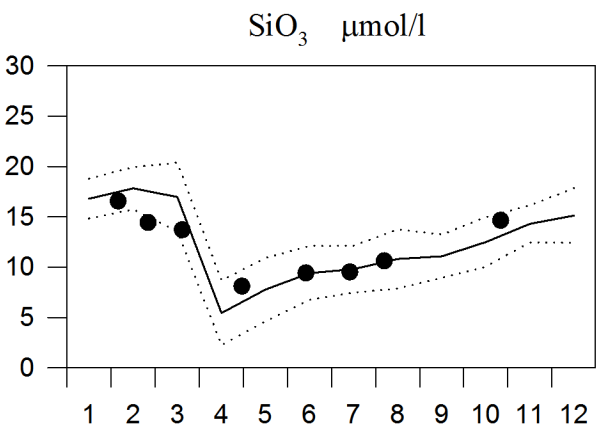
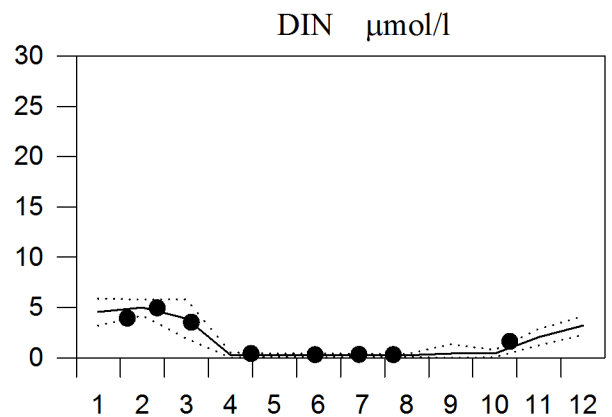
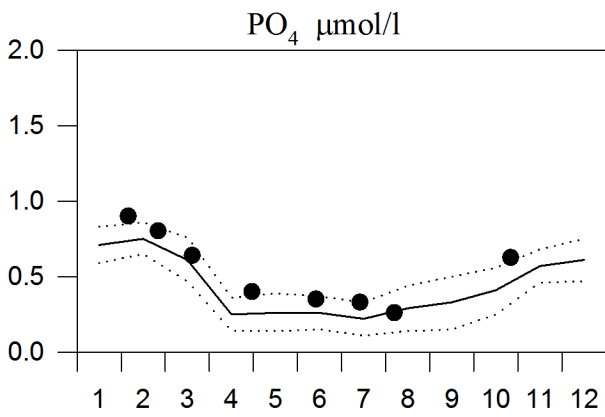
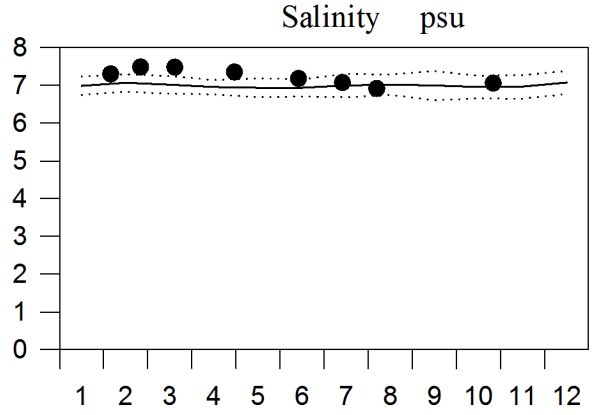
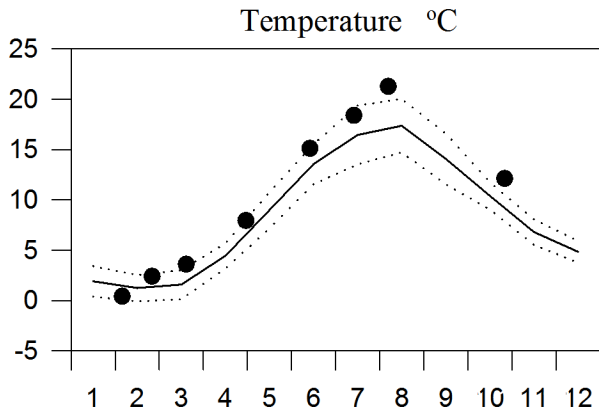
— Mean 1996-2010      ..... St.Dev.      ● 2014



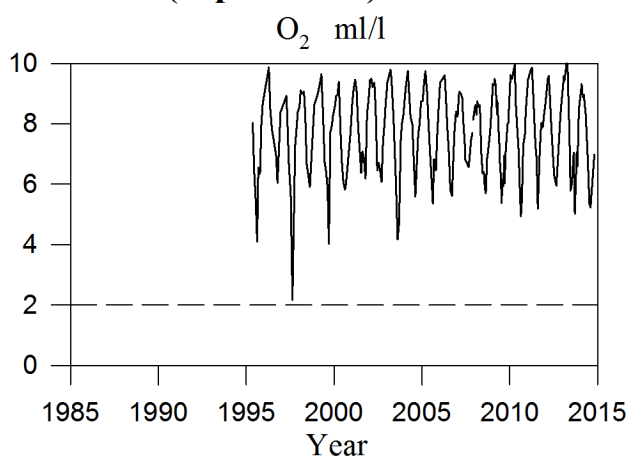
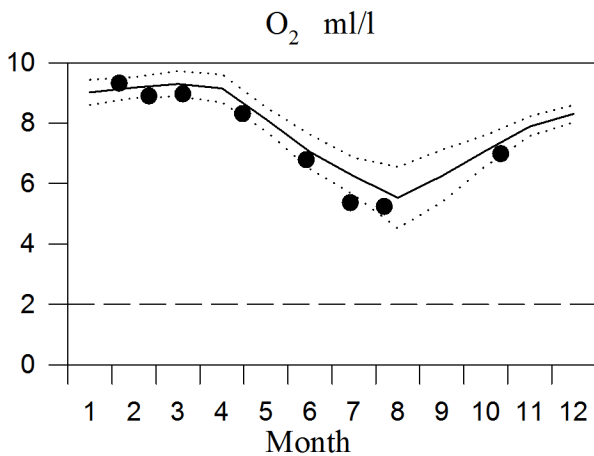
# STATION REF M1V1 SURFACE WATER

## Annual Cycles

— Mean 1996-2010      ..... St.Dev.      ● 2014



## OXYGEN IN BOTTOM WATER (depth >15m)



# Vertical profiles Ref M1V1 October

— Mean 1996-2010      ..... St.Dev.      ● 2014

