

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



**Survey period:** 2016-10-10 to 2016-10-17

**Principal:** Swedish Meteorological and Hydrological Institute, the Swedish Agency for Marine and Water Management and Finnish Environment Institute

### SUMMARY

The cruise, which is part of the Swedish marine monitoring programme, covered the Skagerrak, the Kattegat, the Sound, the Gulf of Finland and the Baltic Proper.

The temperature in the surface water was now normal and the cooling of the surface water had started. This was clearly seen in the Skagerrak and Kattegat. The salinity showed normal values in the whole investigated area.

Generally, the nutrient concentrations in the surface water had increased since the last cruise in September, which is normal for the season. Though, high concentrations of inorganic nitrogen and phosphate were found in certain parts of the Baltic Proper. The silicate concentration in the whole Baltic Proper continued to be highly elevated.

Acute hypoxia ( $O_2 < 2$  ml/l) was found at some stations in the Kattegat and the Sound already from 20 meters depth. In the Baltic Proper and the Gulf of Finland acute hypoxia was found from depth exceeding 60-70 meters depth. Anoxia ( $O_2 = 0$  ml/l) was found in the Western and Northern Gotland basin and outer Gulf of Finland from depth over 80-90 meters, in the Eastern Gotland basin at intermediate depth and at the bottom. Due to a longer period with strong northerly/easterly winds and high air pressure over the Baltic, the water level is now low in the whole Baltic Sea. This provides favourable conditions for a new large inflow to the Baltic Sea, which is needed to improve the oxygen situation in the Baltic Proper.

Next regular cruise is scheduled to start 14<sup>th</sup> of November.

## RESULTS

The cruise was conducted aboard the Finnish research vessel Aranda and started in Helsinki on the 10<sup>th</sup> of October and ended in the same port on 17<sup>th</sup> of October. The winds during the cruise were fresh to strong, mainly from northeast to east. Due to the strong winds and rough seas the stations Hanöbukten and REF M1V1 could not be visited.

During the expedition extra zooplankton samples were taken at the stations; BY15, BY5, BY2, Anholt E and Släggö, on behalf of Umeå University for future analysis of mercury.

At N Midsjöbanken two hydrophones were deployed for the Swedish Defence Research Agency. The instruments will measure marine noise and register “click” sounds from harbour porpoise.

This report is based on data that have passed a first quality control. When data are published at the SMHI data centre some values might have changed after further quality controls have been performed. Preliminary data from this cruise are published as soon as possible on the data centres webpage, normally within one or two weeks after a cruise.

Download data here: <http://www.smhi.se/klimatdata/oceanografi/havsmiljodata>

### **The Skagerrak**

The temperature in the surface water was normal for the season and varied around 11-12°C. The cooling of the surface water had started and a shallow thermocline was found between 5-15 meters depth, while another thermocline was found deeper at 40-60 meters depth. The surface salinity was lower than normal in the outer and southern parts, while normal in the remaining areas. The lowest salinities were found at the station P2, ~21 psu and highest at Å15, ~33 psu. The halocline coincided with the upper thermocline and was weakly developed at the deeper thermocline.

All nutrients in the surface layer showed increasing concentrations compared to the previous cruise in September. However, the concentrations were lower than normal in the same areas as low salinities were found. The concentration of phosphate varied between 0.04-0.09 µmol/l and inorganic nitrogen (nitrite, nitrate and ammonia) had increased and varied around 0.32-1.71 µmol/l. The silicate concentrations showed values between 0.3 and 2.2 µmol/l.

The fluorescence from the CTD was low at all stations but some phytoplankton activated could be seen in the surface layer.

The bottom water was well oxygenated, even at the coastal station; Släggö.

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

The temperature of the surface water was now normal again and around 12°C. The cooling of the surface water had started also here and a thermocline at 10-20 meters depth separated the cooler surface water from the somewhat warmer water at intermediate depths. The surface salinity was generally lower than normal, due to a long period characterized by strong outflow from the Baltic Sea, and varied between 17 and 22 psu. In the Sound the salinity was around 9 psu. The halocline and thermocline coincided.

Similar to the conditions in Skagerrak, all nutrients had increased since the visit in September and the concentrations were overall normal for the season. The phosphate concentration was 0.1-0.4  $\mu\text{mol/l}$ , silicate 2-12  $\mu\text{mol/l}$  and the inorganic nitrogen varied between 0.3 and 0.8  $\mu\text{mol/l}$ . The concentrations were highest in the Sound. The nutrient concentrations increased below the halocline and showed generally higher values than normal in the deep water.

The oxygen concentrations in the deep water were lower than normal in the whole Kattegat. Acute hypoxia ( $\text{O}_2 < 2 \text{ ml/l}$ ) was found in the Sound and at the coastal station; N14 already from 20 meters depth. Hypoxia was also found at the bottom at Anholt E.

The phytoplankton activity was low in the whole investigated area.

## **The Baltic Proper**

The water temperature had decreased since the previous cruise in September and was now normal in the whole Baltic Proper. Surface temperatures were 9-14 °C, lowest in the Gulf of Finland and highest in the Arkona Basin. The salinity was just below normal in the Eastern Gotland Basin and normal or just over normal in the remaining areas. The lowest salinity was found in the Gulf of Finland, ~5 psu and highest in the Arkona Basin, ~8 psu. The halocline and the thermocline followed each other at about 60-70 meters depth in the Eastern Gotland Basin and in the Gulf of Finland. In other areas the stratification was found at 30-40 meters depth.

The concentrations of inorganic nitrogen was just over normal in the southeast, south and western Baltic Proper and varied between 0.7 and 1.0  $\mu\text{mol/l}$ . In the Eastern Gotland Basin lower concentrations were found, around 0.4  $\mu\text{mol/l}$ . The phosphate concentration was normal in the whole area, except from higher than normal concentrations in the Western Gotland Basin. The concentration of phosphate varied between 0.2-0.4  $\mu\text{mol/l}$ . Silicate continued to be higher than normal in the whole Baltic Proper and concentrations ranged between 11 and 16  $\mu\text{mol/l}$ . Below the halocline the concentrations of nutrients increase in the whole area, while lower concentration than normal of phosphate and inorganic nitrogen was found in the deeper parts of the Eastern Gotland Basin, probably due to the influence of oxygenated water that was found at those depths.

In the Western Gotland Basin the oxygen situation was still severe. Anoxic conditions were found already at depth exceeding 80-90 meters. In the Eastern Gotland Basin anoxic conditions was found at intermediate depth and at the bottom while anoxia was found from 80 meters in the Northern Gotland Basin and the outer parts of the Gulf of Finland. However, the deep water in the central parts of the Gulf of Finland, at LL7 was still oxygenated. Acute hypoxia was found from 60-80 meters depth in the whole Baltic Proper.

Due to a longer period of strong easterly and northerly winds and high air pressure over the Baltic Sea the water level in the whole area is low. This provides favourable conditions for a new large inflow to the Baltic Sea this winter, which is needed to improve the oxygen situation in the Baltic Proper.

The fluorescence measurements from the CTD showed low phytoplankton activity in the whole investigated area.

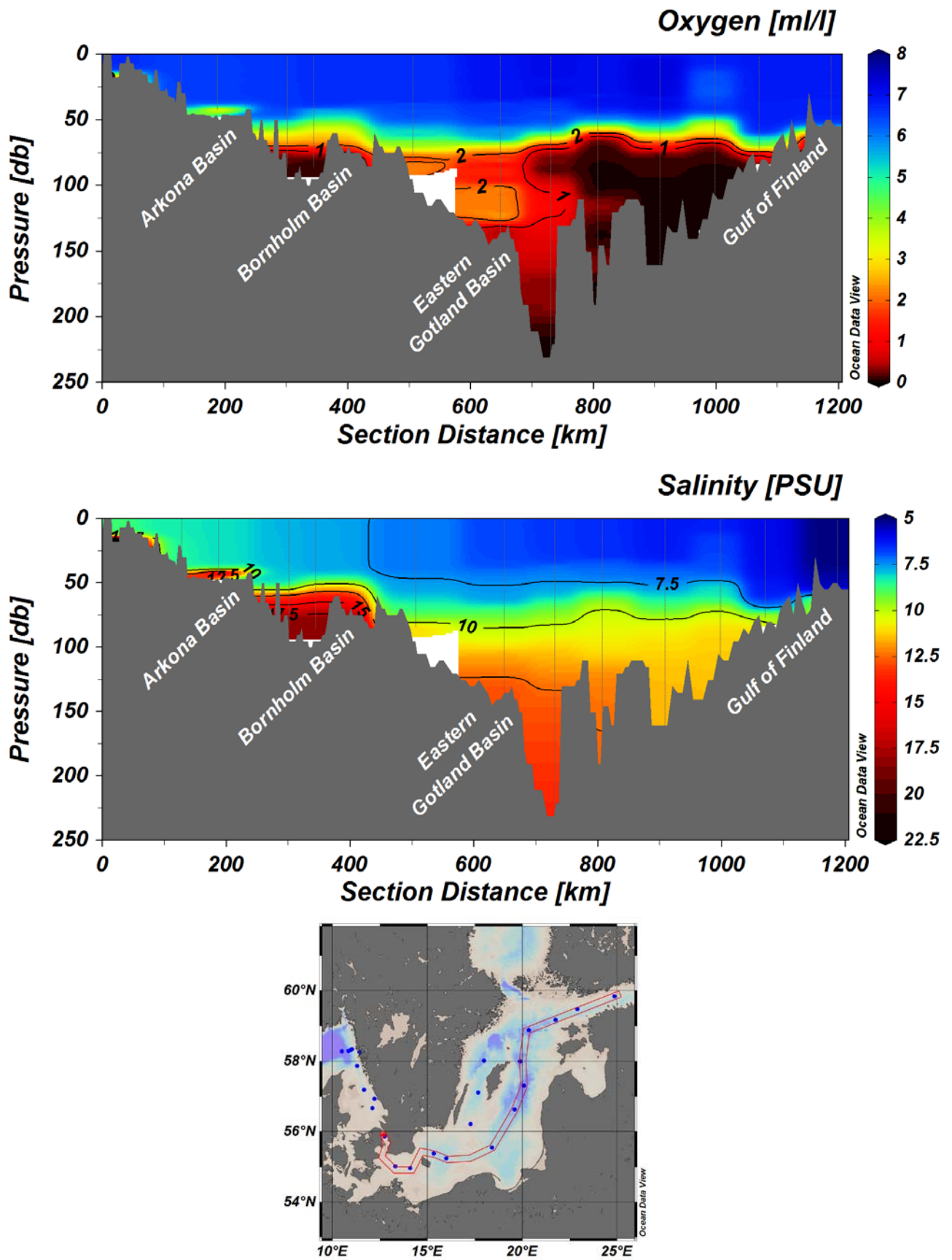


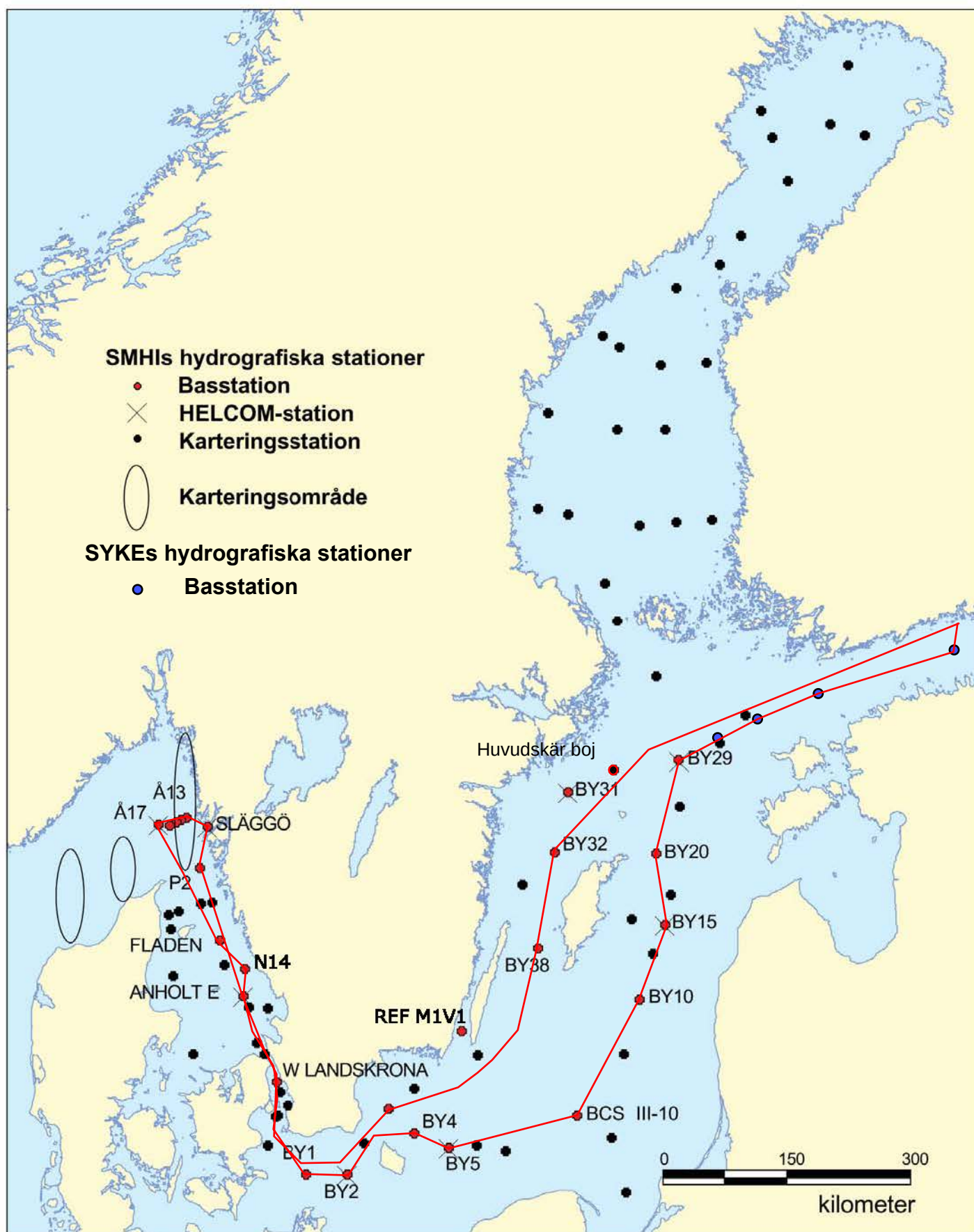
Figure 2. Transect showing oxygen and salinity through the Baltic Proper, from the Sound to the Eastern Gotland Basin.

## PARTICIPANTS

| Name             |                 | Institute                             |
|------------------|-----------------|---------------------------------------|
| Martin Hansson   | Chief Scientist | SMHI                                  |
| Örjan Bäck       |                 | SMHI                                  |
| Jenny Lycken     |                 | SMHI                                  |
| Johanna Linders  |                 | SMHI                                  |
| Daniel Simonsson |                 | SMHI                                  |
| Emilia Lalander  |                 | Swedish Defence Research Agency (FOI) |

## APPENDICES

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





Year: 2016

[illegible]

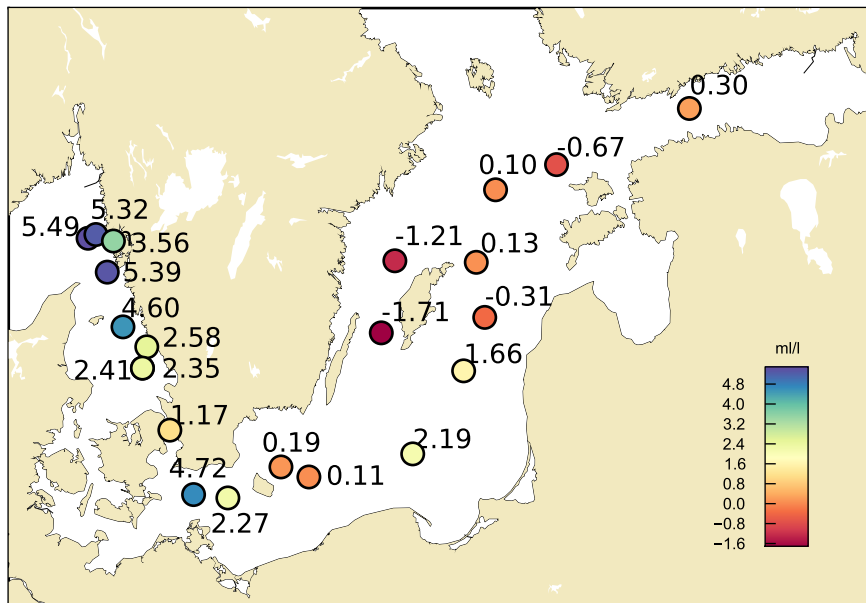
## Bottom water oxygen concentration (ml/l)

Country: Finland

Ship: Aranda

Date: 20161010-20161016

Series: 0544-0570





# STATION P2 SURFACE WATER (0-10m)

Annual Cycles

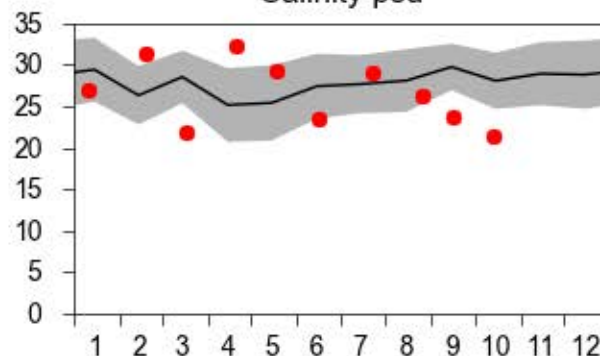
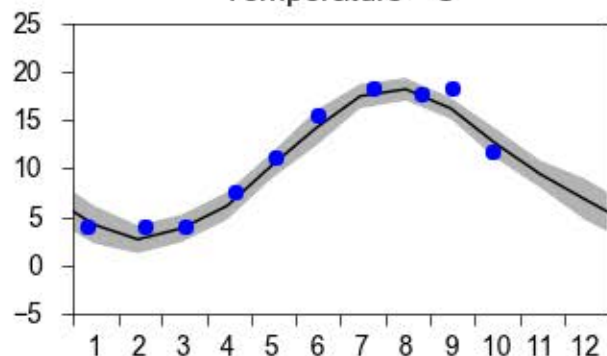
— Mean 2001-2015

■ St.Dev.

● 2016

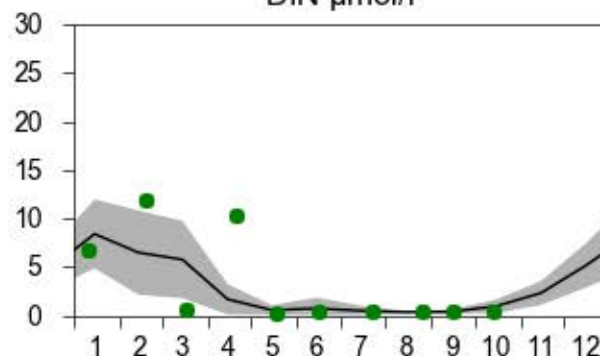
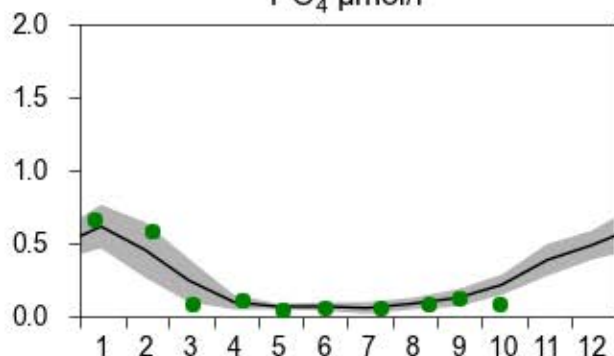
Temperature °C

Salinity psu



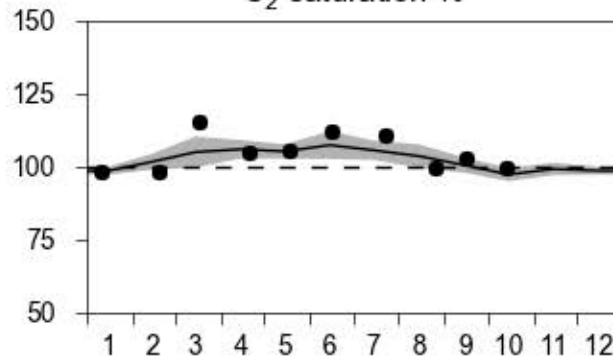
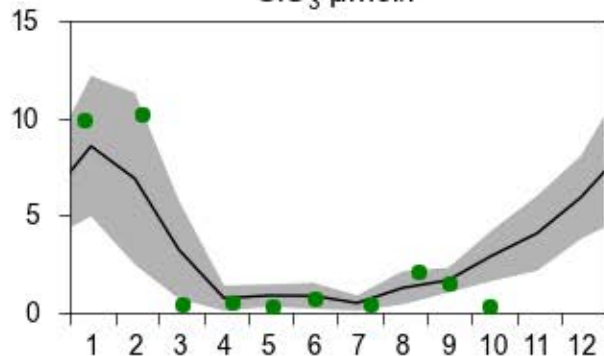
PO<sub>4</sub> µmol/l

DIN µmol/l



SiO<sub>3</sub> µmol/l

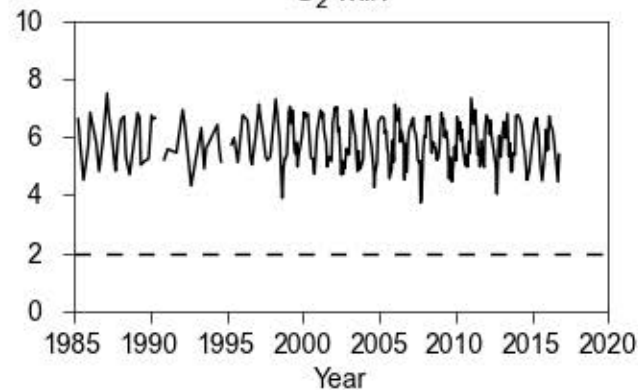
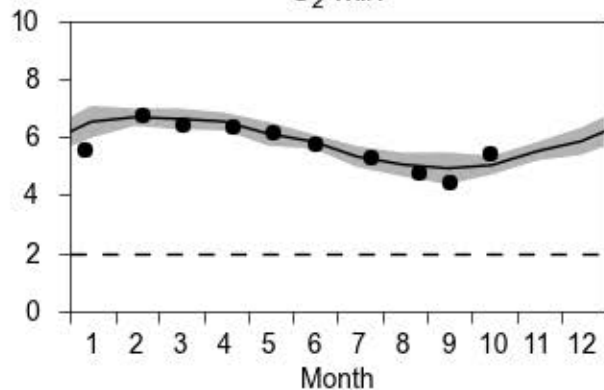
O<sub>2</sub> saturation %



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

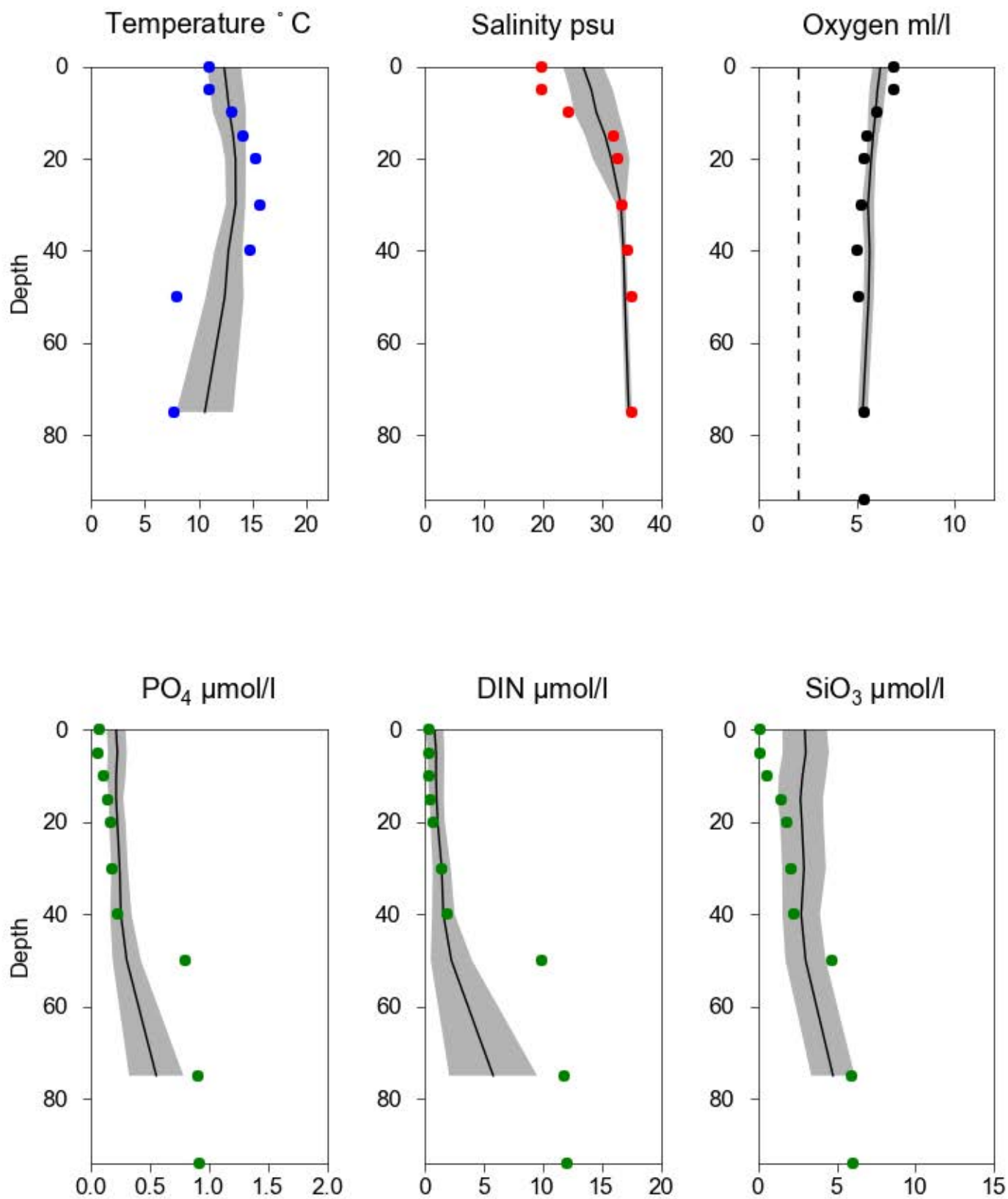
O<sub>2</sub> ml/l

O<sub>2</sub> ml/l



## Vertical profiles P2 October

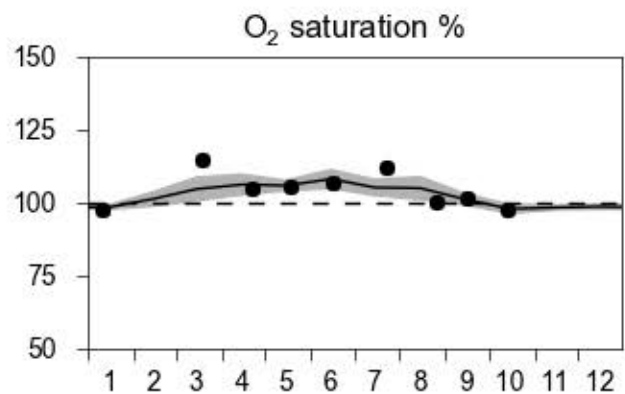
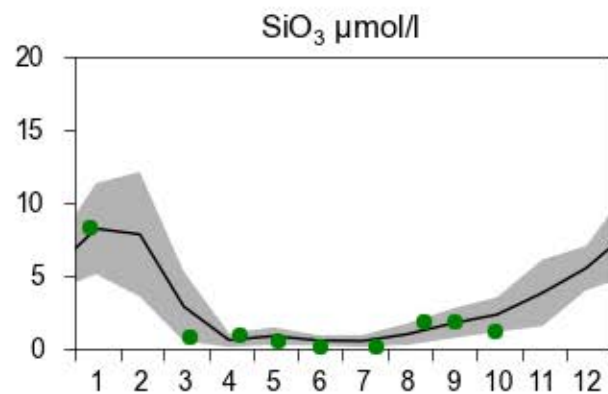
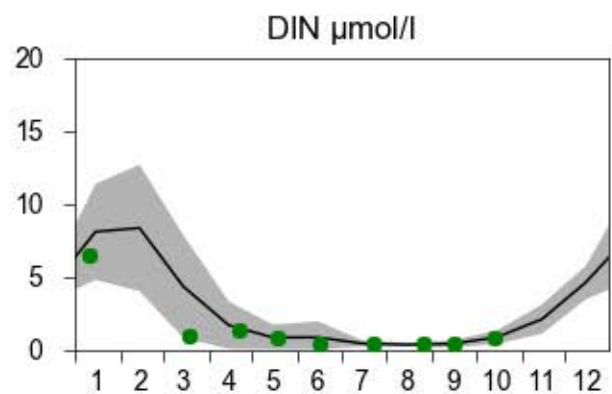
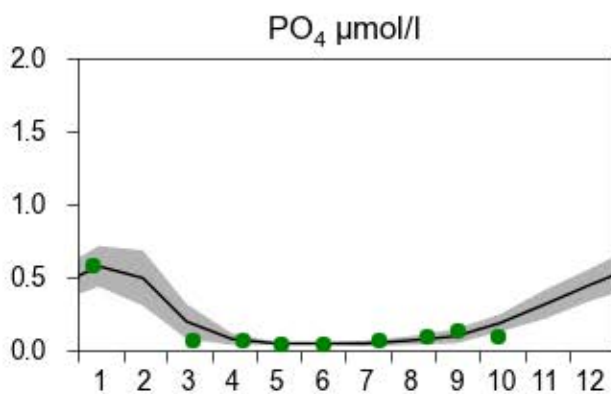
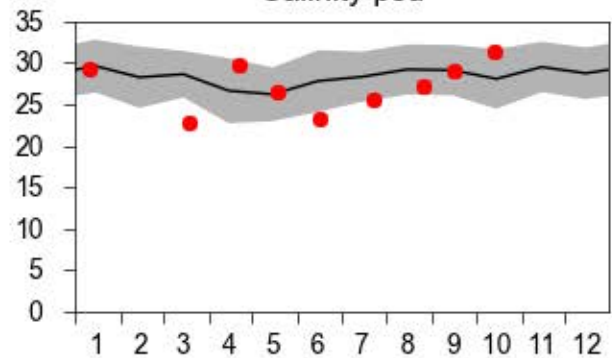
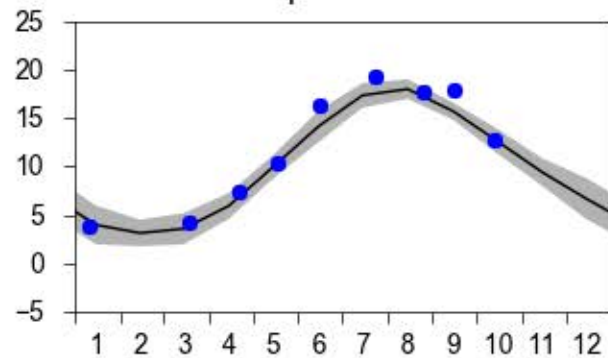
Mean 2001-2015    
  St.Dev.    
  2016-10-14



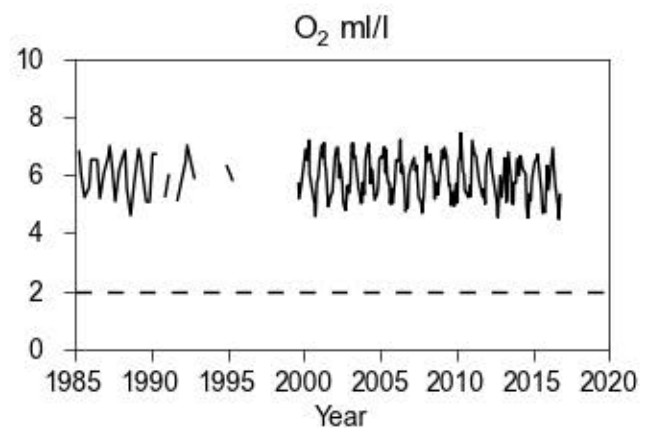
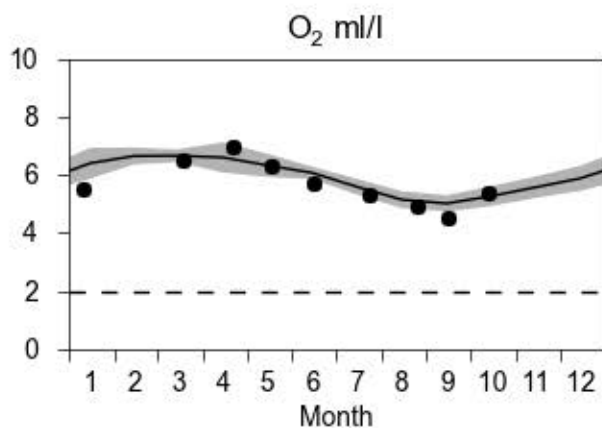
# STATION A13 SURFACE WATER (0-10m)

Annual Cycles

— Mean 2001-2015    St.Dev.    • 2016

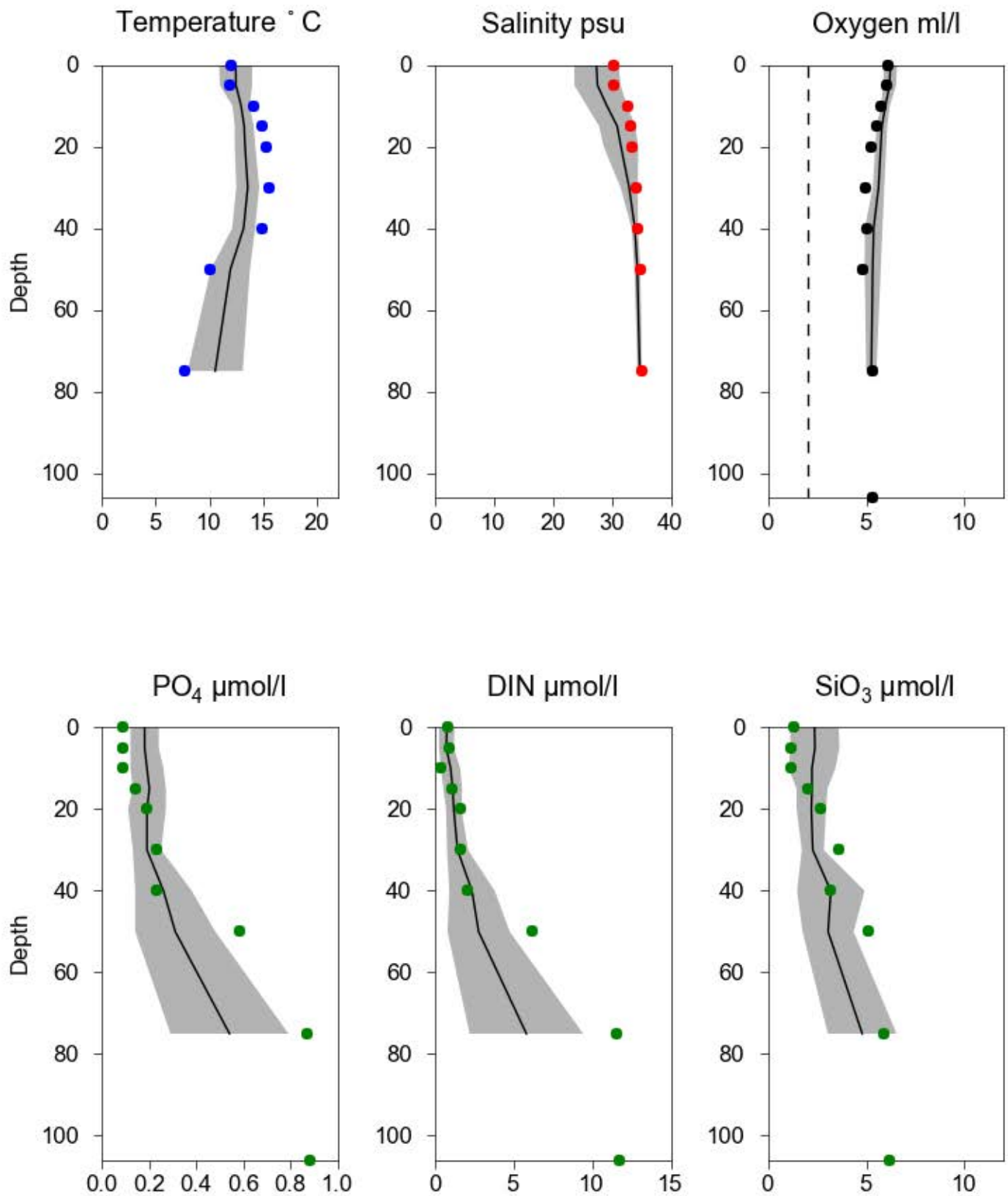


## OXYGEN IN BOTTOM WATER (depth >= 75 m)



## Vertical profiles A13 October

— Mean 2001-2015    St.Dev.    • 2016-10-14

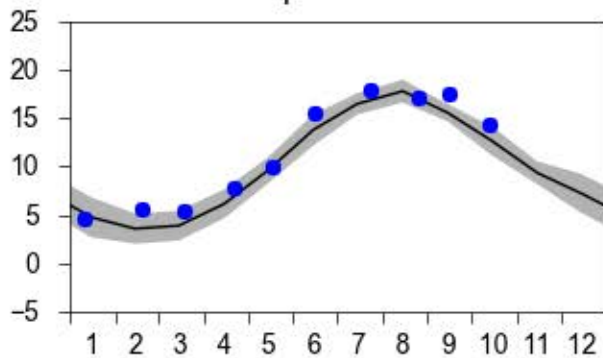


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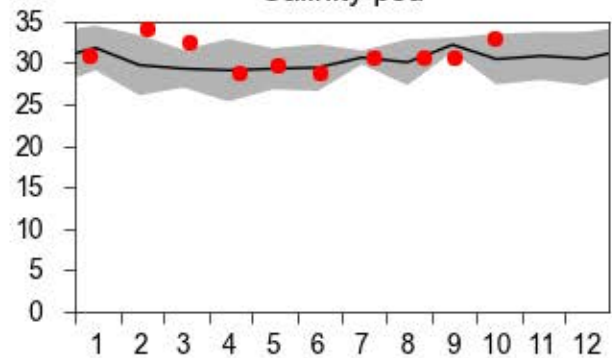
Annual Cycles

— Mean 2001-2015    St.Dev.    • 2016

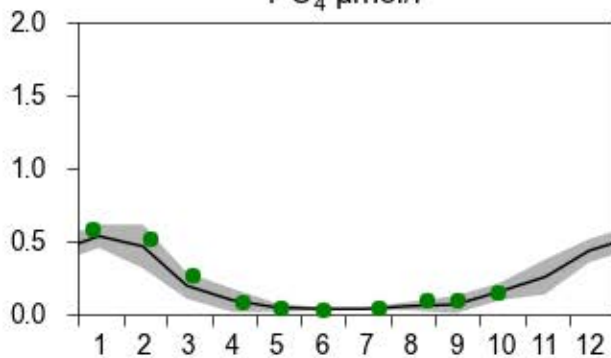
Temperature °C



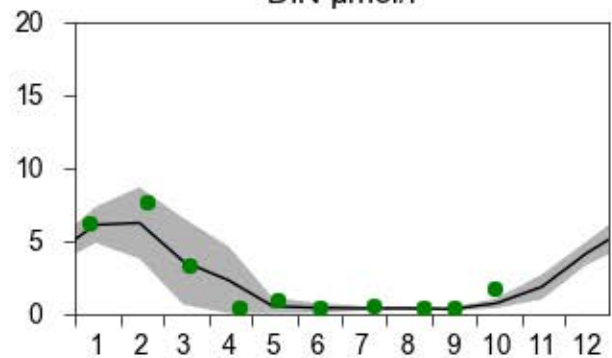
Salinity psu



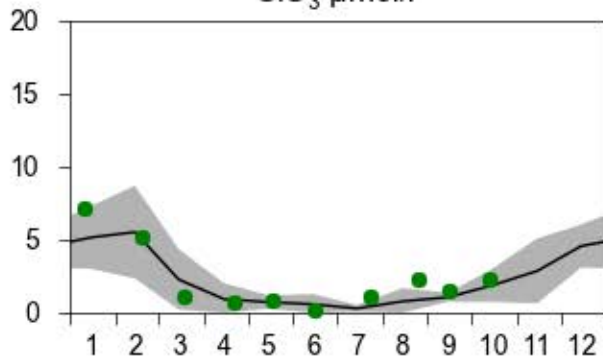
PO<sub>4</sub> µmol/l



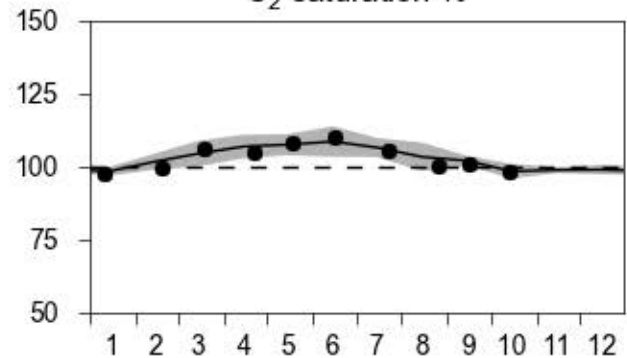
DIN µmol/l



SiO<sub>3</sub> µmol/l

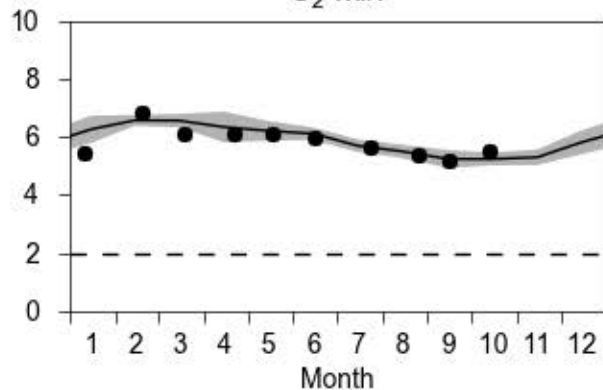


O<sub>2</sub> saturation %

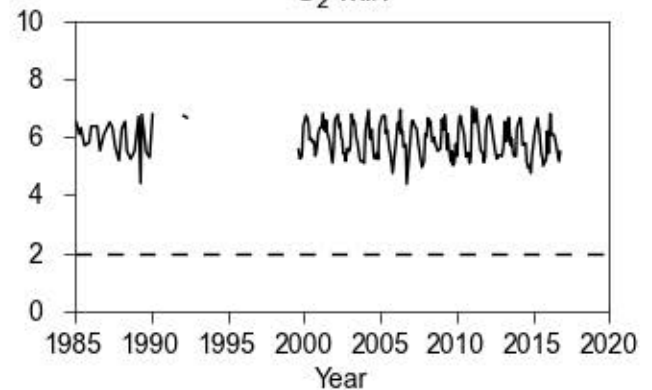


## OXYGEN IN BOTTOM WATER (depth >= 125 m)

O<sub>2</sub> ml/l



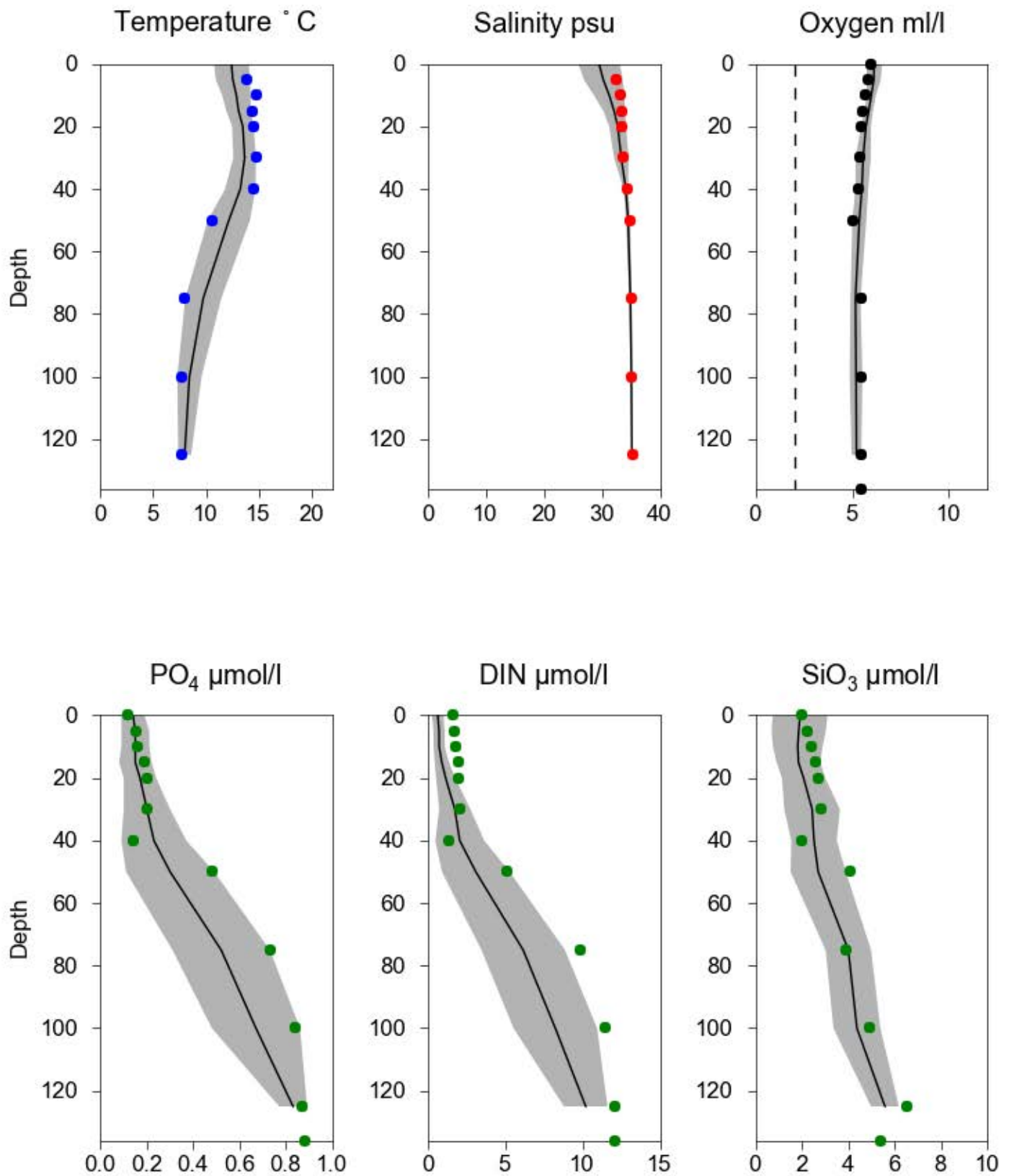
O<sub>2</sub> ml/l





## Vertical profiles A15 October

— Mean 2001-2015    St.Dev.    • 2016-10-14

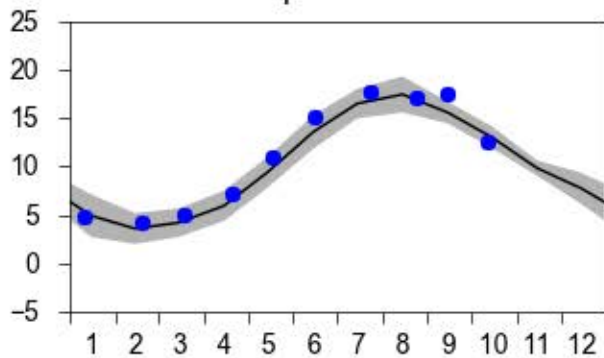


# STATION A17 SURFACE WATER (0-10m)

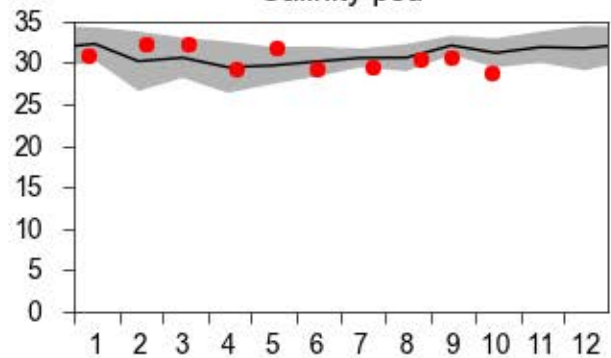
Annual Cycles

— Mean 2001-2015    St.Dev.    • 2016

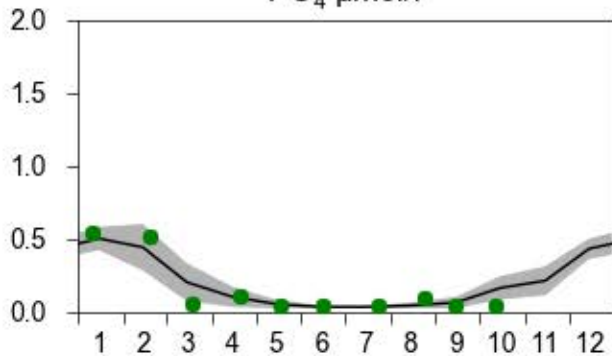
Temperature °C



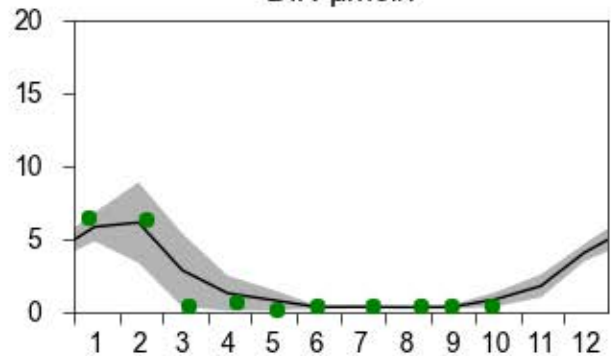
Salinity psu



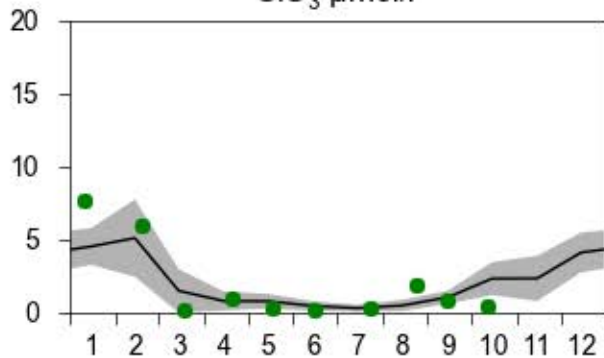
PO<sub>4</sub> µmol/l



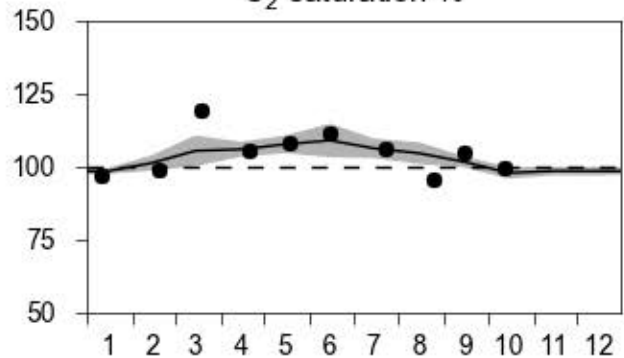
DIN µmol/l



SiO<sub>3</sub> µmol/l

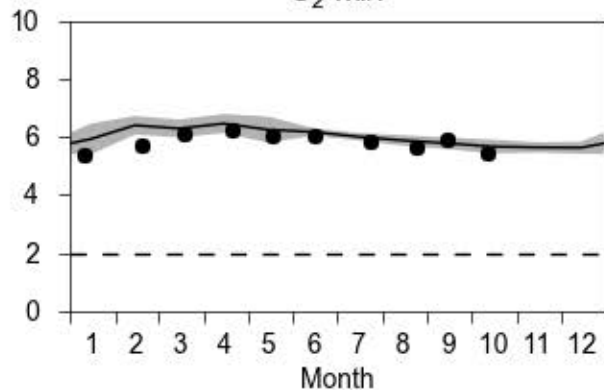


O<sub>2</sub> saturation %

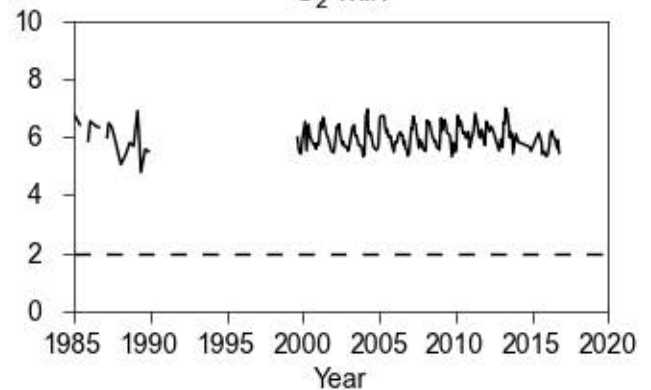


## OXYGEN IN BOTTOM WATER (depth ≥ 300 m)

O<sub>2</sub> ml/l



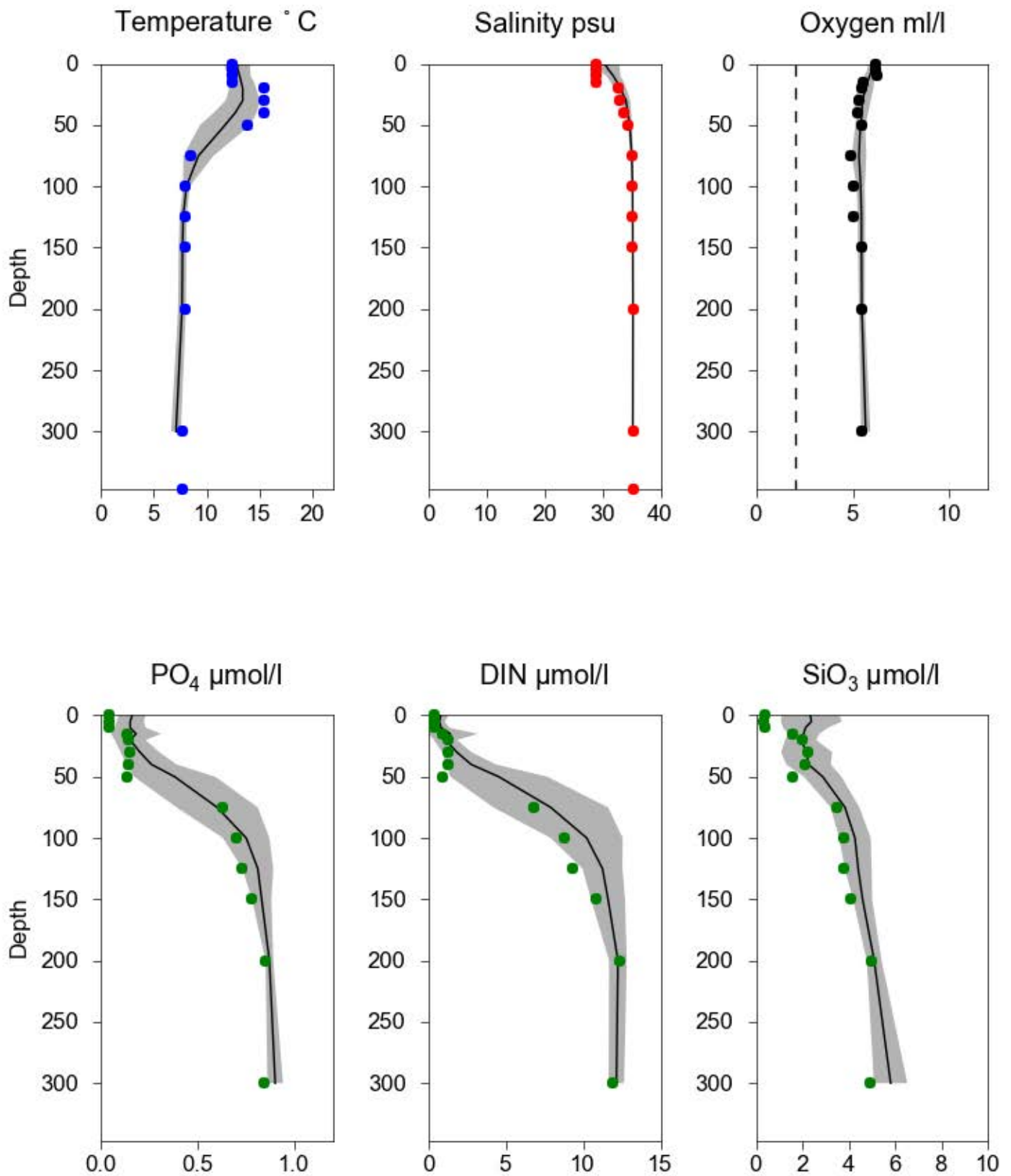
O<sub>2</sub> ml/l





# Vertical profiles A17 October

— Mean 2001-2015    ■ St.Dev.    ● 2016-10-13



# STATION FLADEN SURFACE WATER (0-10m)

Annual Cycles

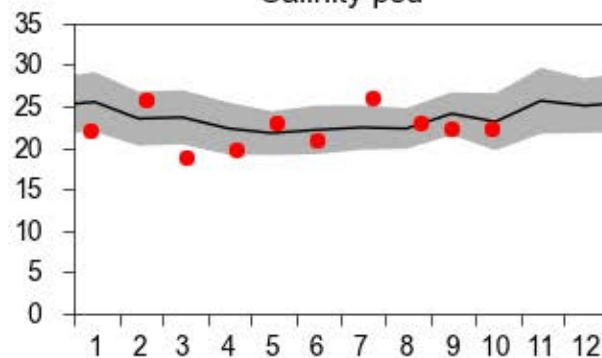
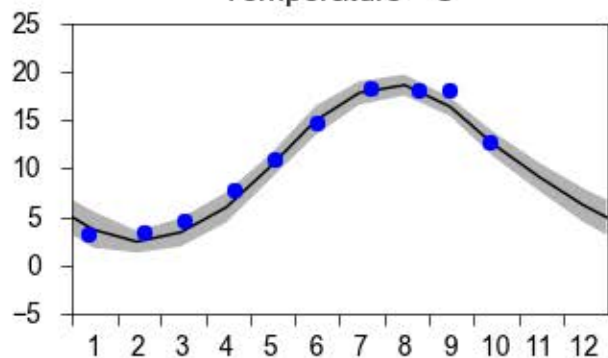
— Mean 2001-2015

■ St.Dev.

● 2016

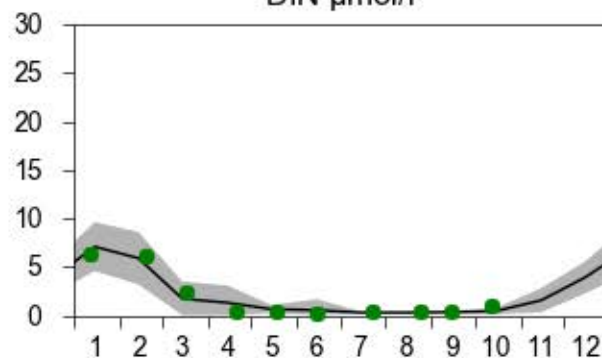
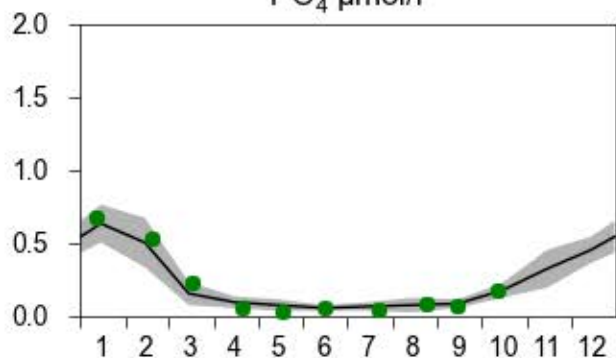
Temperature °C

Salinity psu



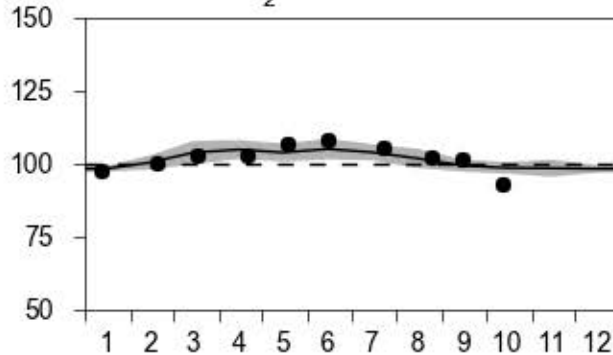
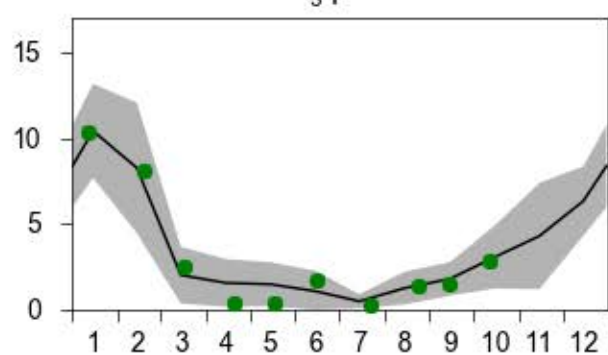
PO<sub>4</sub> µmol/l

DIN µmol/l



SiO<sub>3</sub> µmol/l

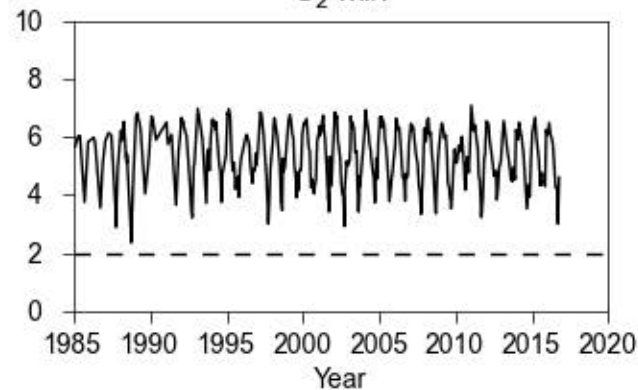
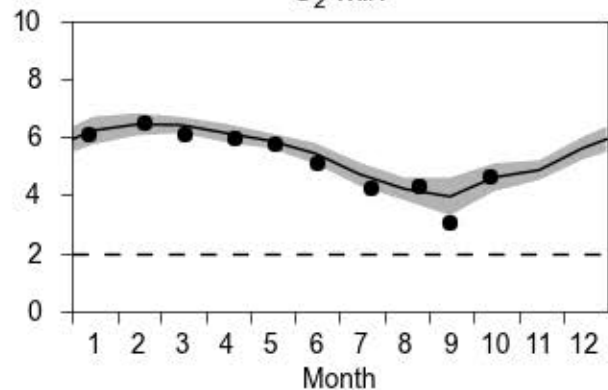
O<sub>2</sub> saturation %



## OXYGEN IN BOTTOM WATER (depth >= 65 m)

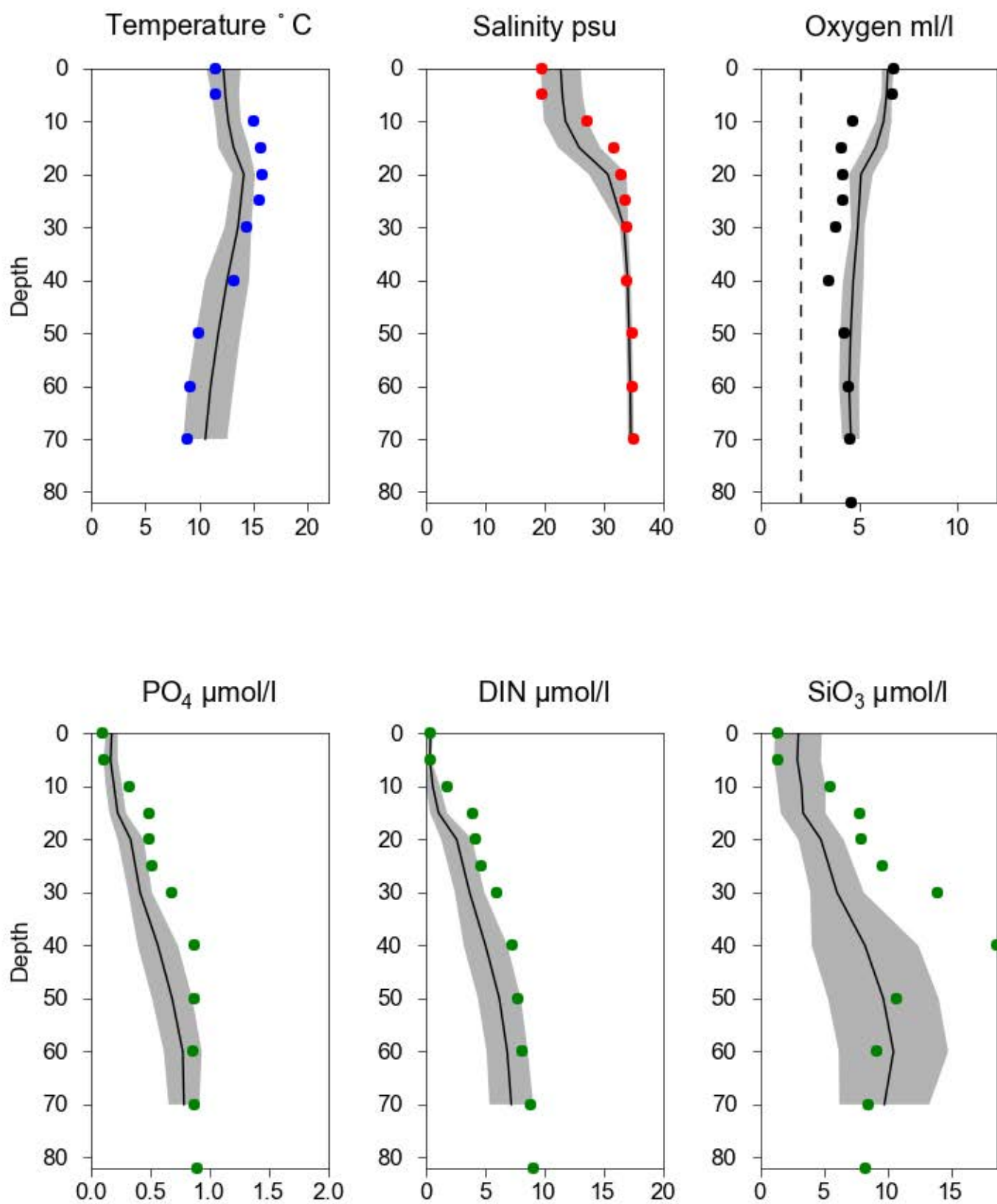
O<sub>2</sub> ml/l

O<sub>2</sub> ml/l



# Vertical profiles FLADEN October

— Mean 2001-2015    St.Dev.    • 2016-10-13



# STATION ANHOLT E SURFACE WATER (0-10m)

Annual Cycles

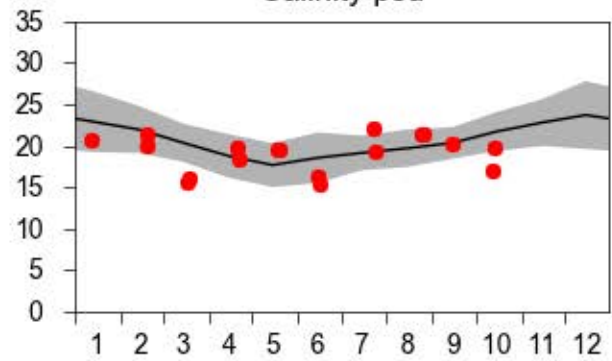
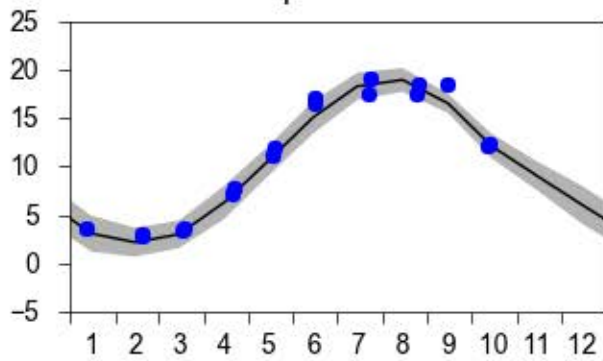
— Mean 2001-2015

■ St.Dev.

● 2016

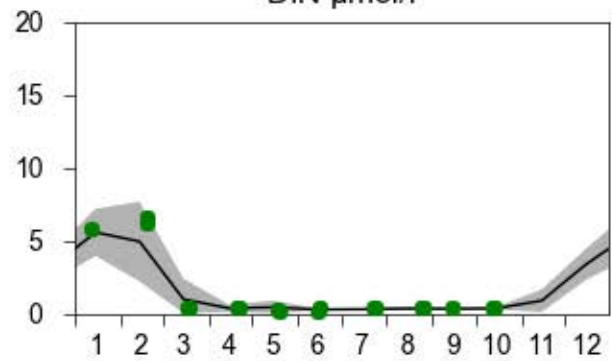
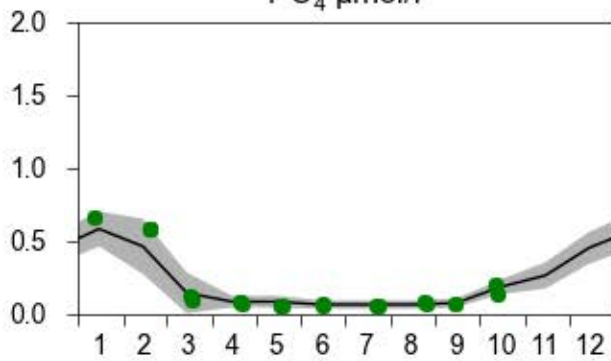
Temperature °C

Salinity psu



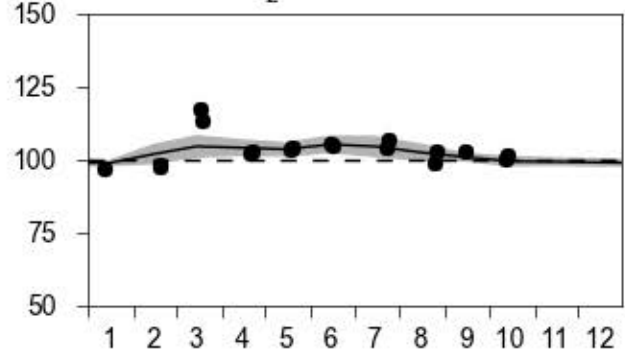
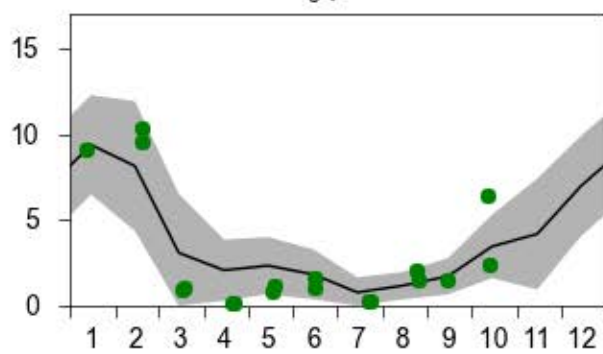
PO<sub>4</sub> µmol/l

DIN µmol/l



SiO<sub>3</sub> µmol/l

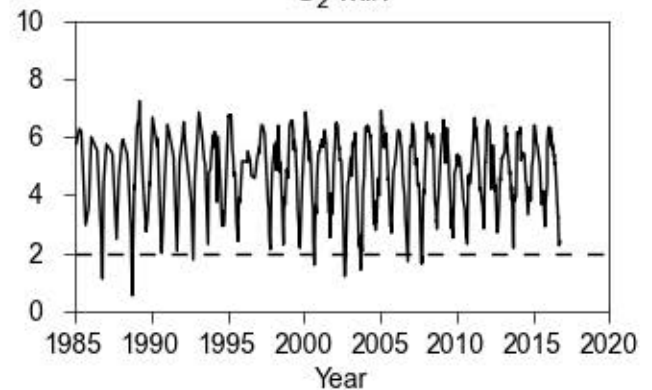
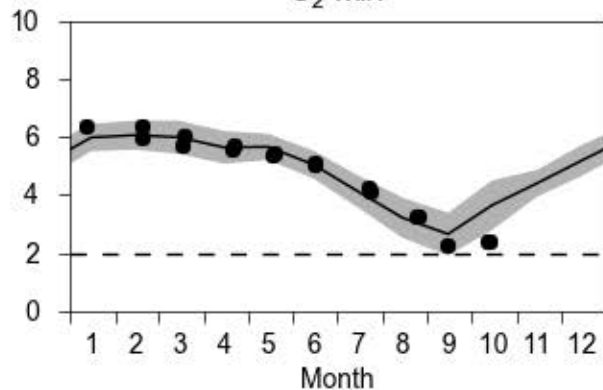
O<sub>2</sub> saturation %



## OXYGEN IN BOTTOM WATER (depth >= 45 m)

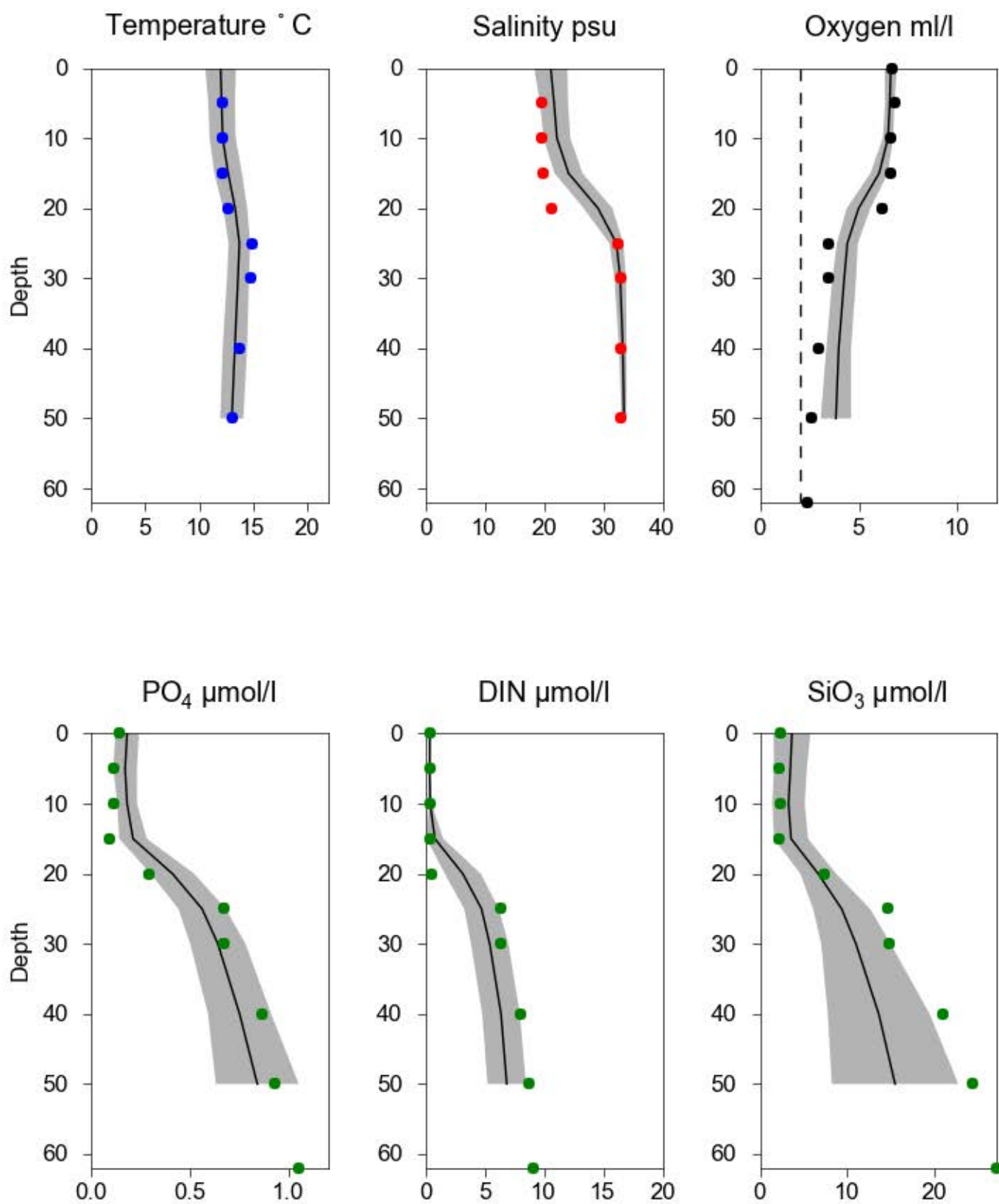
O<sub>2</sub> ml/l

O<sub>2</sub> ml/l



## Vertical profiles ANHOLT E October

— Mean 2001-2015    St.Dev.    • 2016-10-14





# STATION W LANDSKRONA SURFACE WATER (0-10m)

Annual Cycles

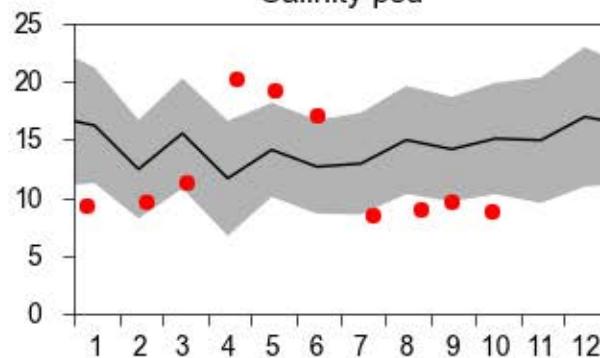
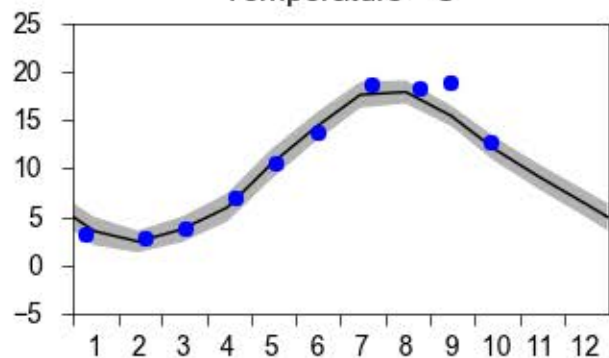
— Mean 2001-2015

■ St.Dev.

● 2016

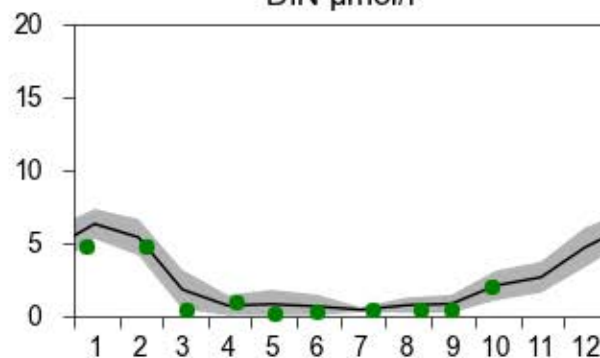
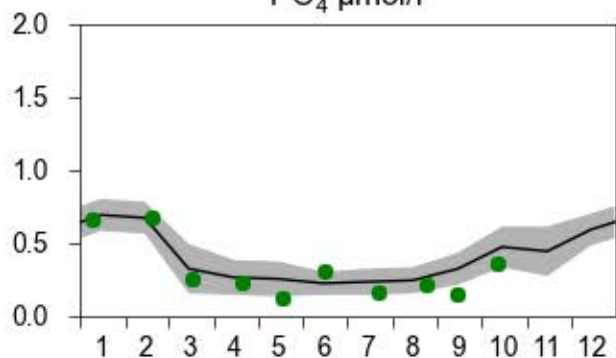
Temperature °C

Salinity psu



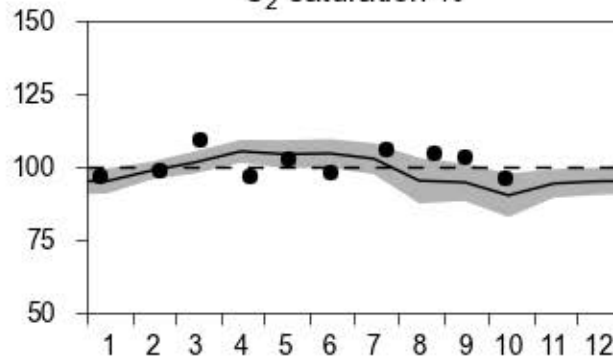
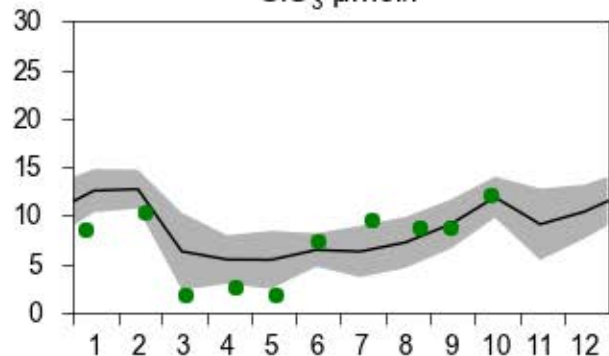
PO<sub>4</sub> µmol/l

DIN µmol/l



SiO<sub>3</sub> µmol/l

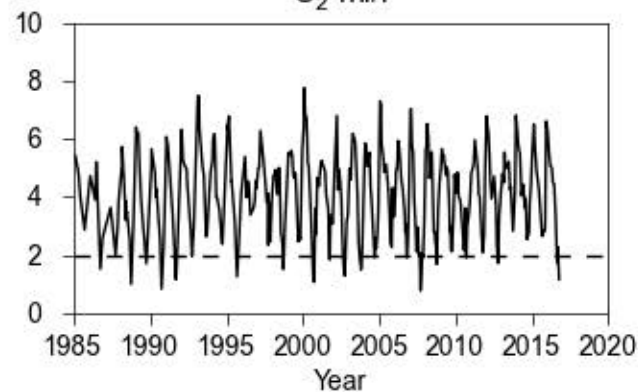
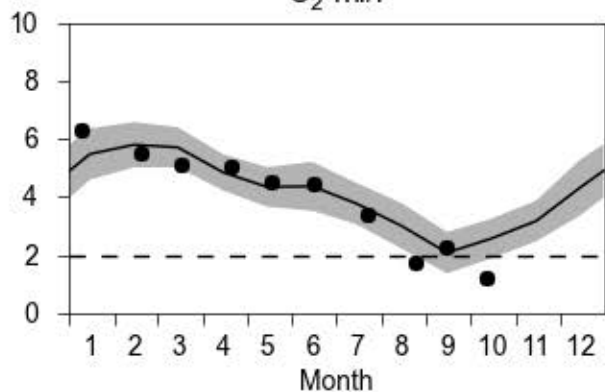
O<sub>2</sub> saturation %



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

O<sub>2</sub> ml/l

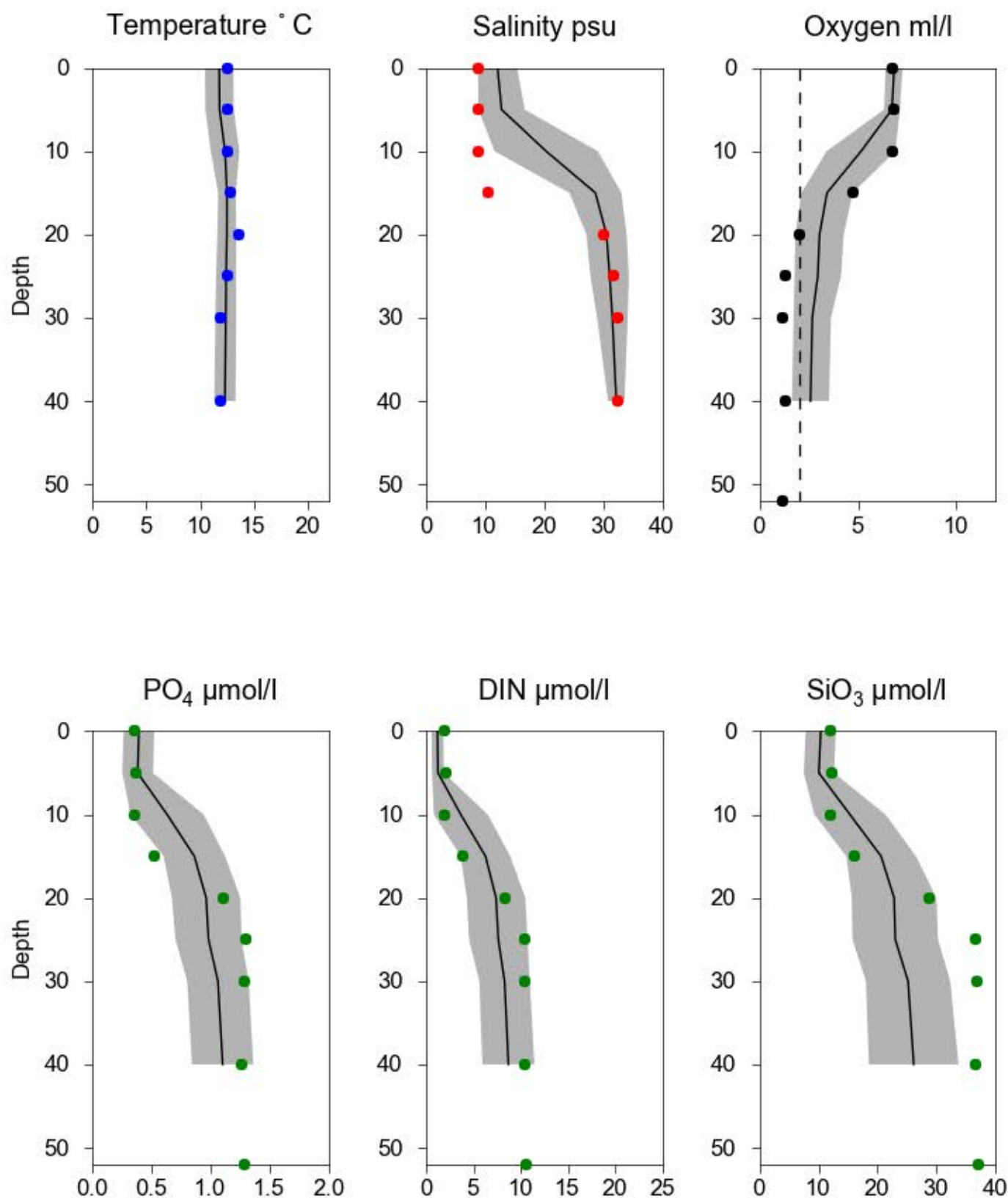
O<sub>2</sub> ml/l





# Vertical profiles W LANDSKRONA October

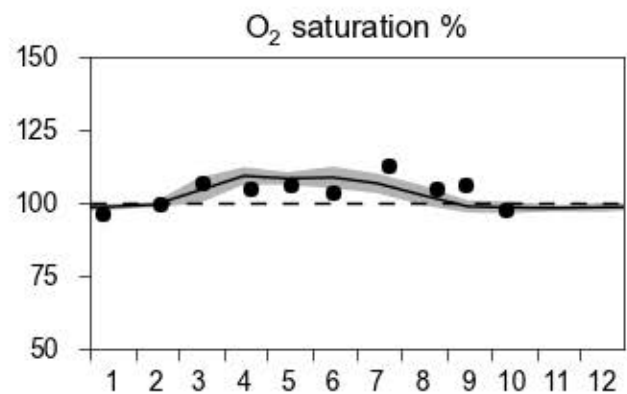
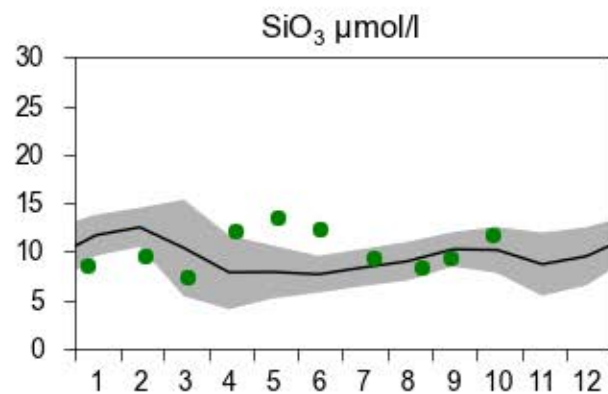
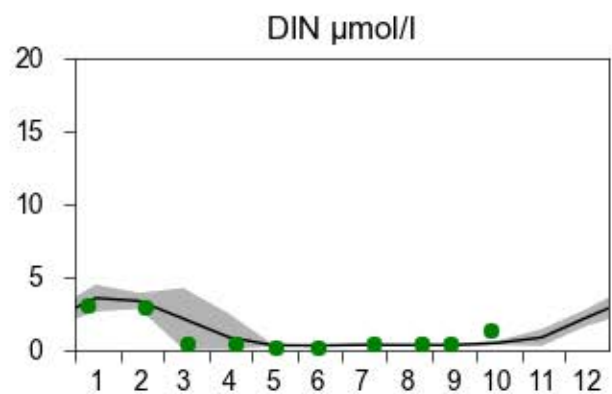
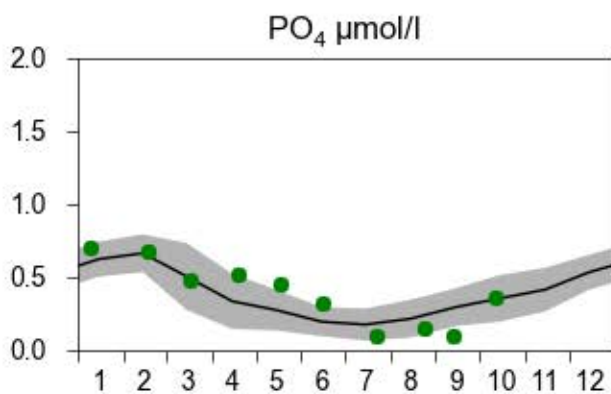
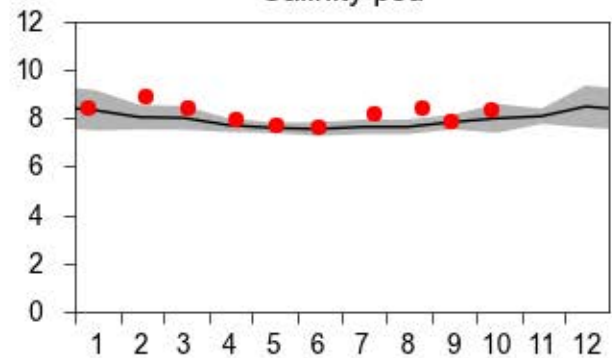
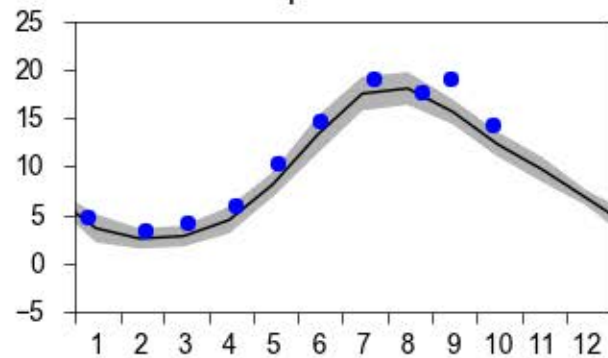
— Mean 2001-2015    St.Dev.    ● 2016-10-13



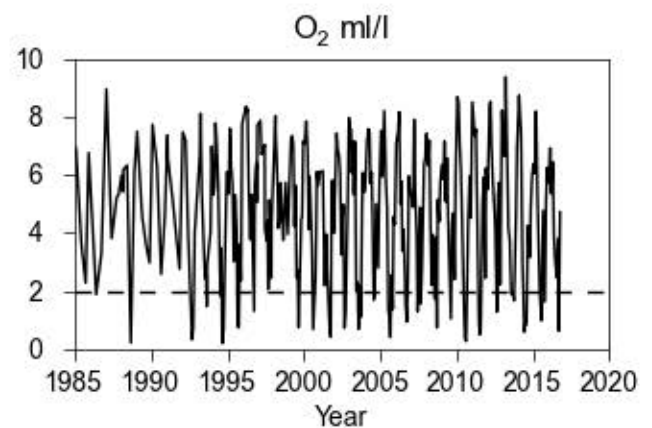
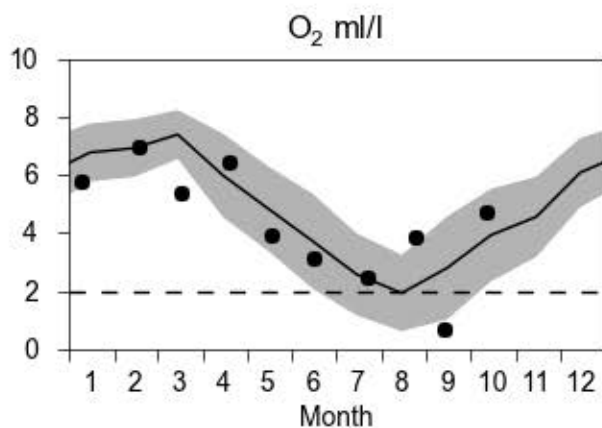
## STATION BY1 SURFACE WATER (0-10m)

Annual Cycles

— Mean 2001-2015    St.Dev.    • 2016

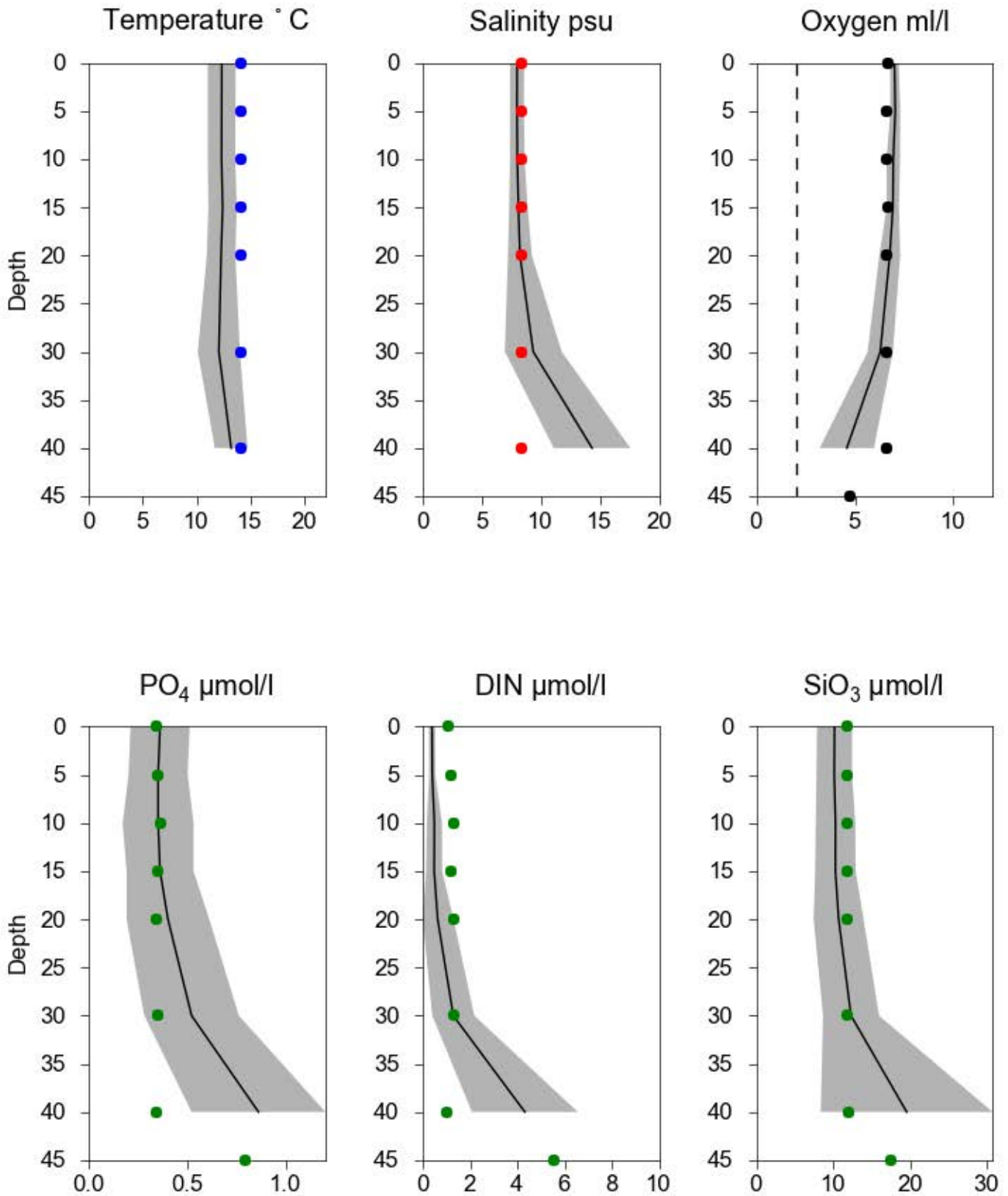


## OXYGEN IN BOTTOM WATER (depth >= 40 m)



## Vertical profiles BY1 October

— Mean 2001-2015    ■ St.Dev.    ● 2016-10-12



# STATION BY2 ARKONA SURFACE WATER (0-10m)

Annual Cycles

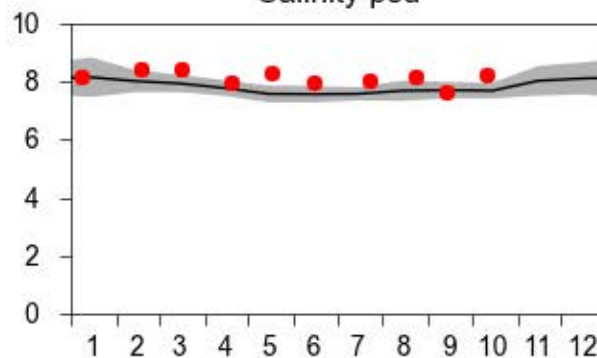
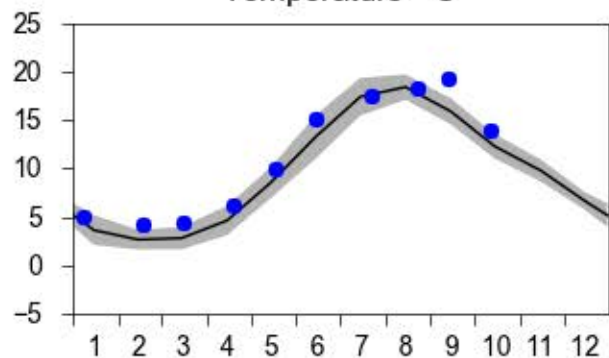
— Mean 2001-2015

■ St.Dev.

● 2016

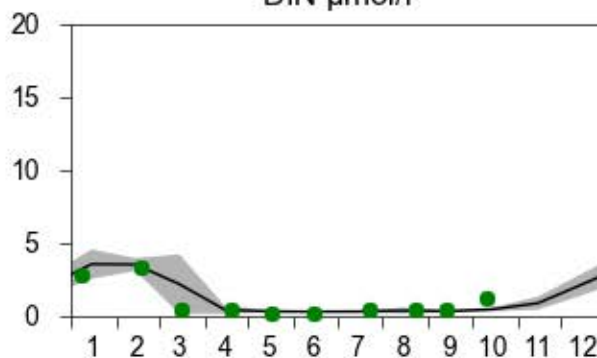
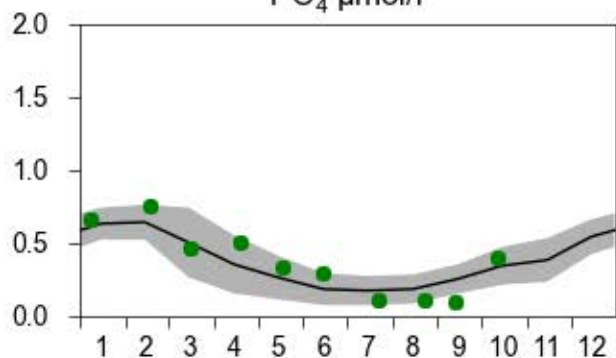
Temperature °C

Salinity psu



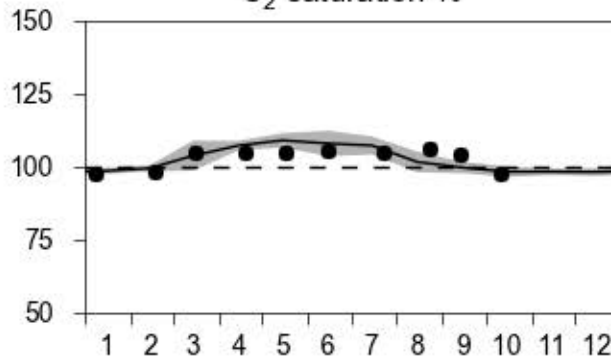
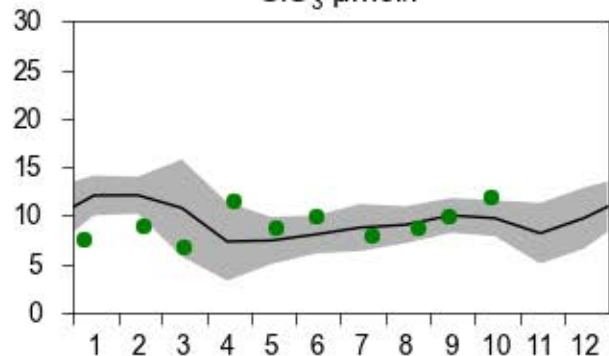
PO<sub>4</sub> µmol/l

DIN µmol/l



SiO<sub>3</sub> µmol/l

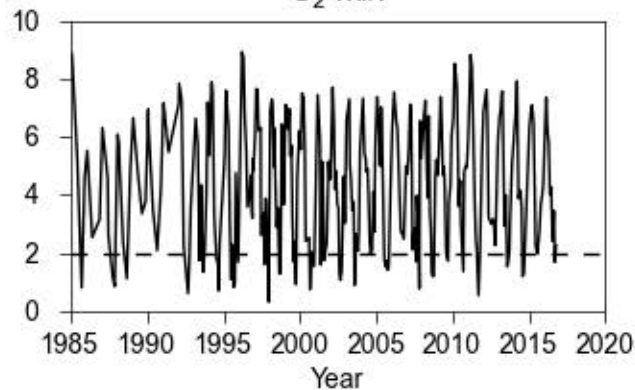
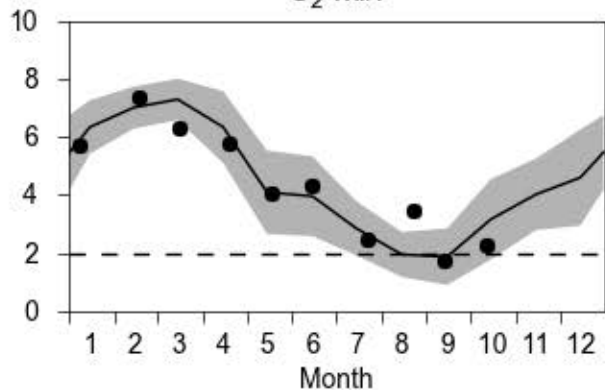
O<sub>2</sub> saturation %



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

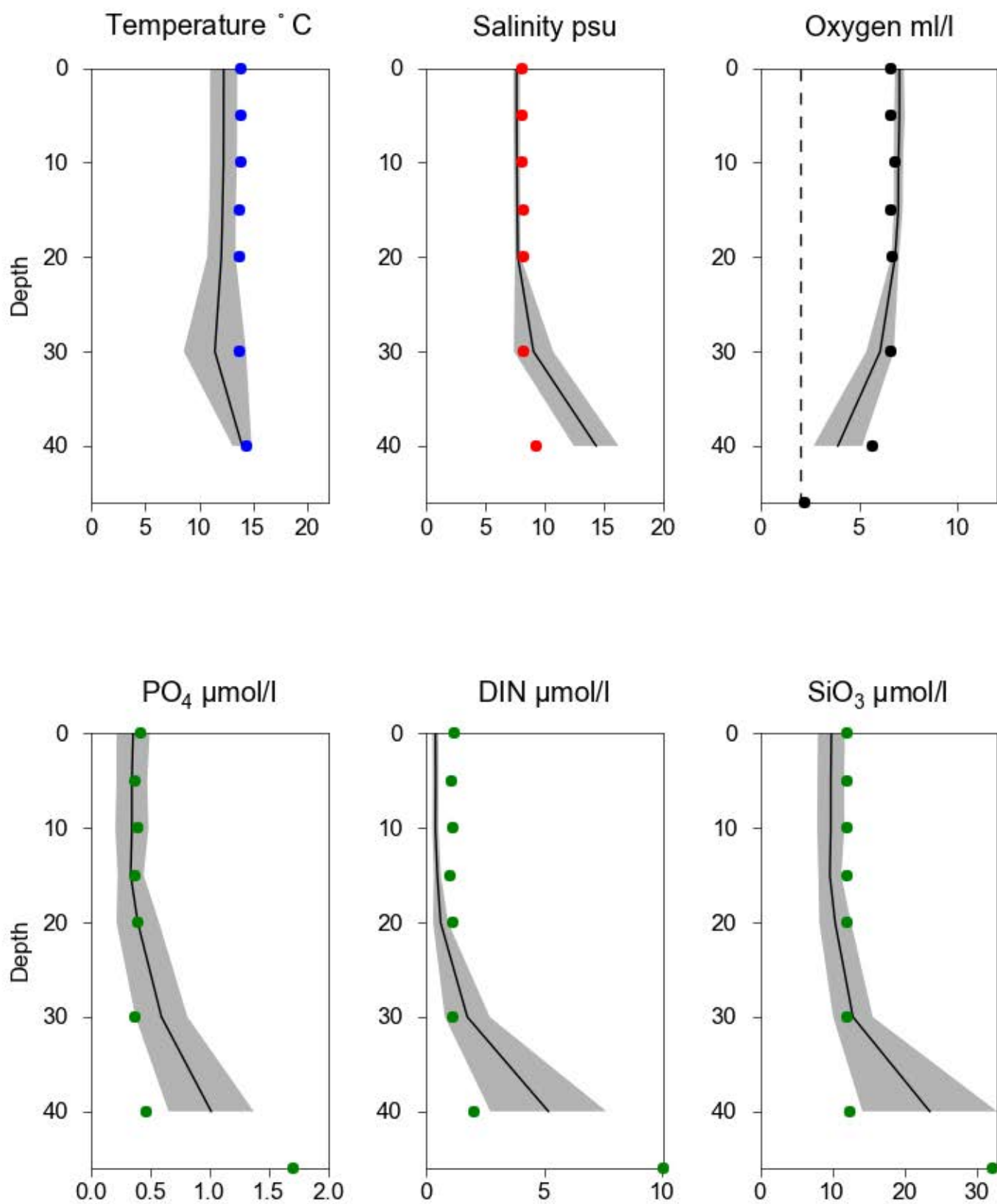
O<sub>2</sub> ml/l

O<sub>2</sub> ml/l



## Vertical profiles BY2 ARKONA October

— Mean 2001-2015    St.Dev.    • 2016-10-12

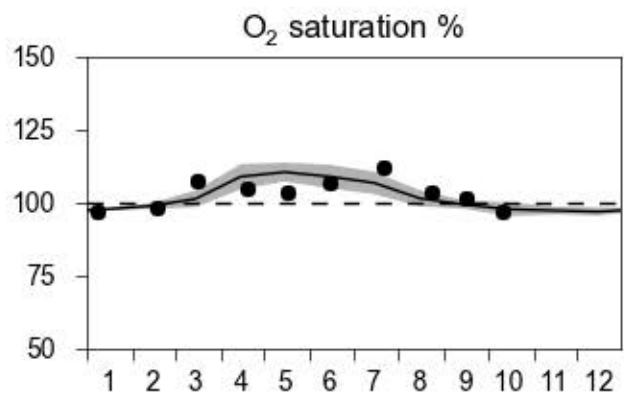
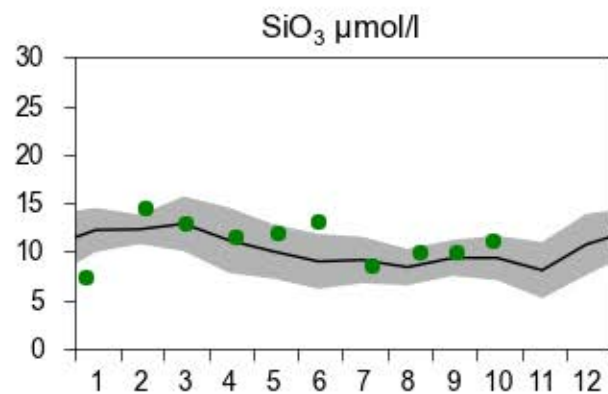
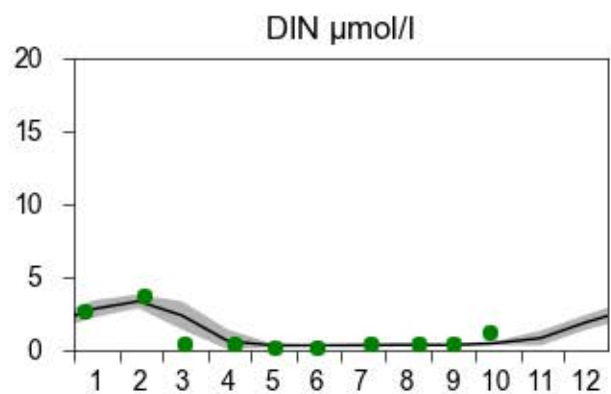
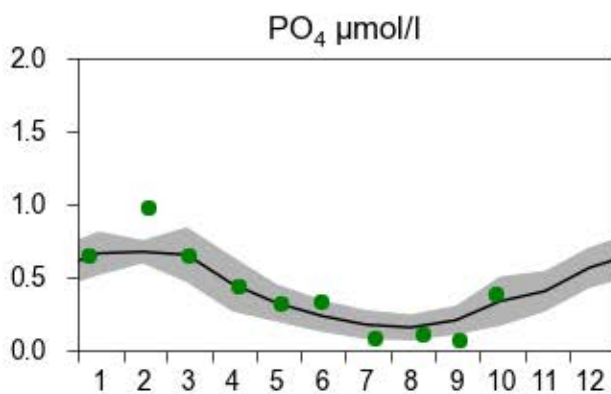
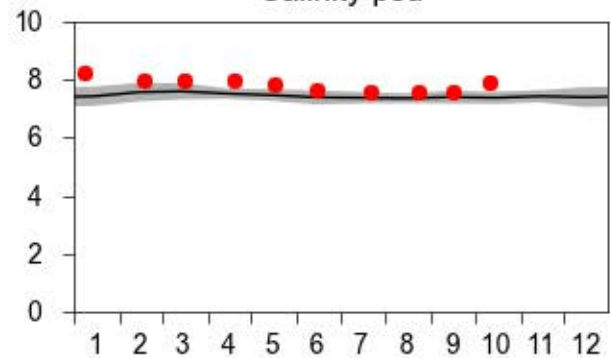
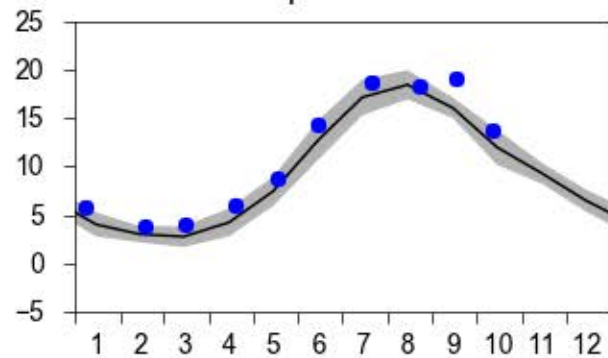




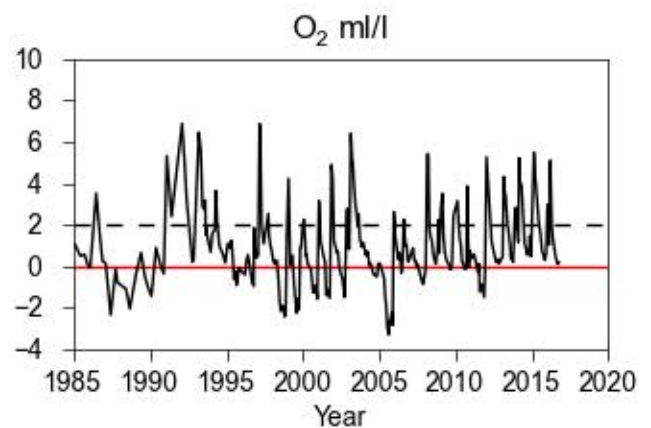
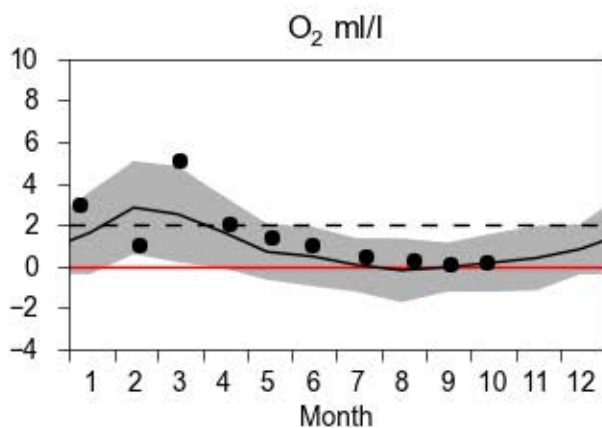
# STATION BY4 CHRISTIANSÖ SURFACE WATER (0-10m)

Annual Cycles

— Mean 2001-2015    St.Dev.    • 2016

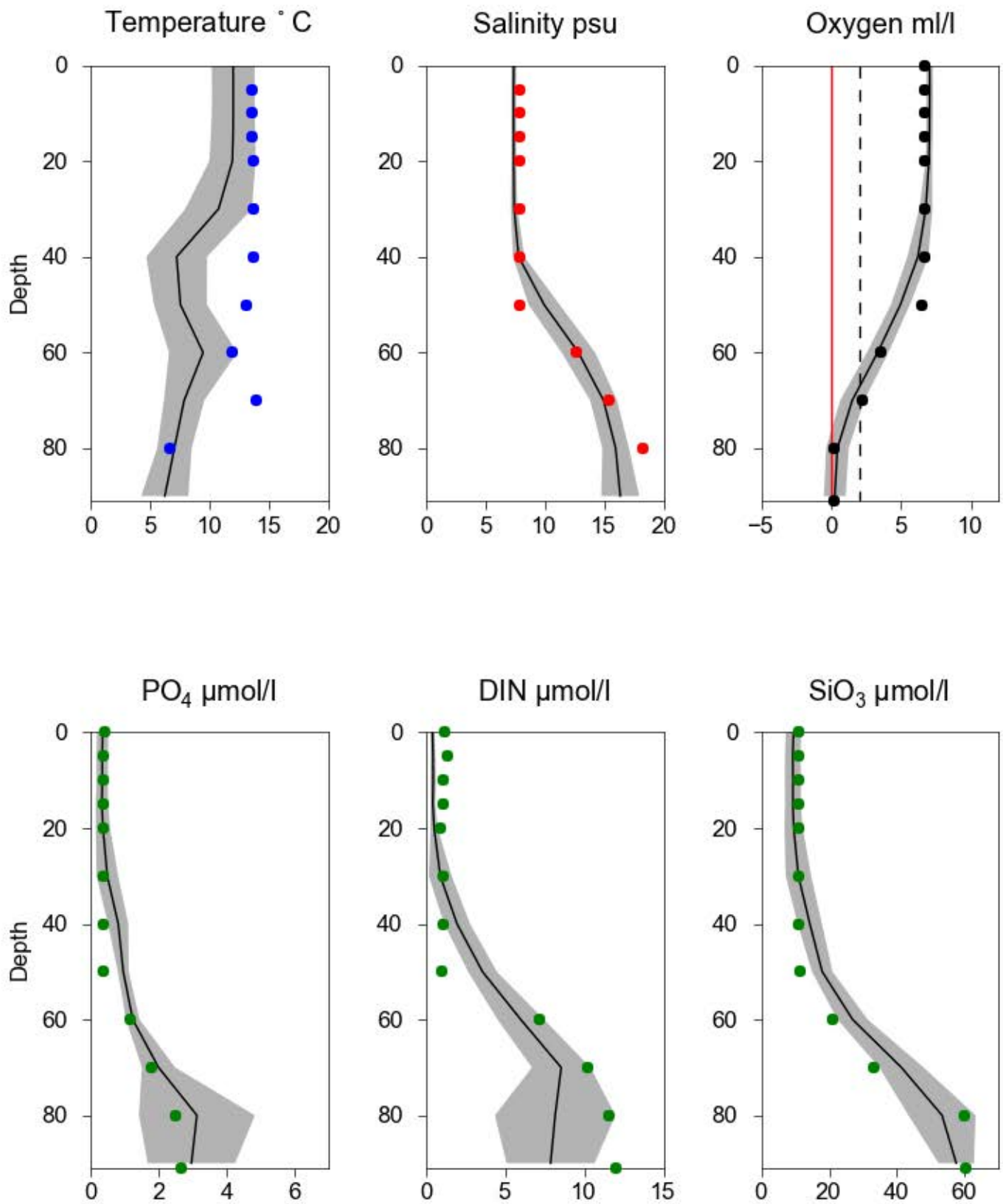


## OXYGEN IN BOTTOM WATER (depth >= 80 m)



## Vertical profiles BY4 CHRISTIANSÖ October

— Mean 2001-2015    St.Dev.    • 2016-10-12



# STATION BY5 BORNHOLMSDJ SURFACE WATER (0-10m)

Annual Cycles

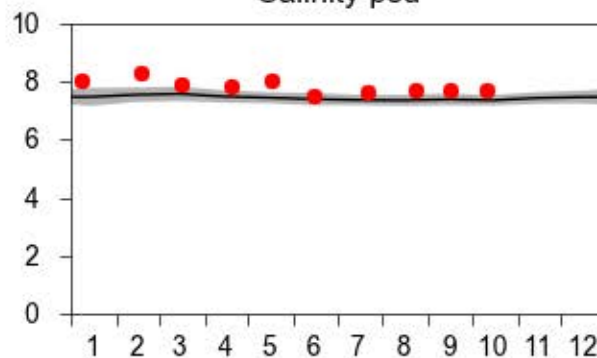
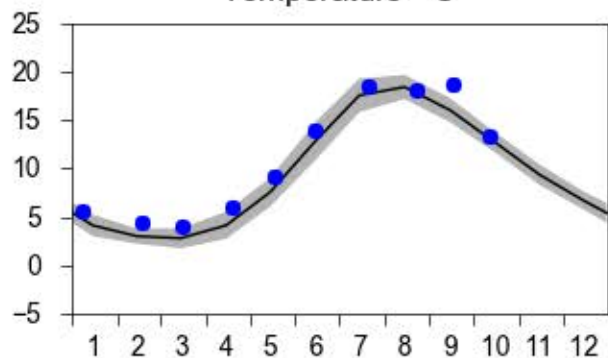
— Mean 2001-2015

■ St.Dev.

● 2016

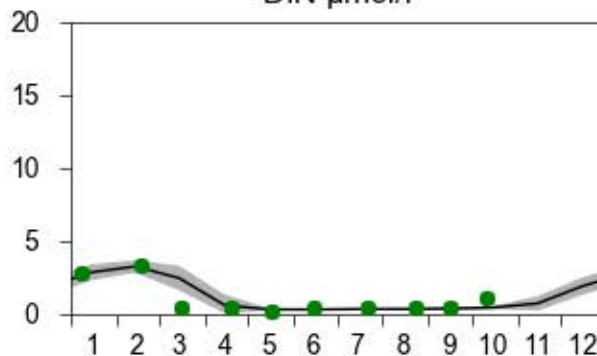
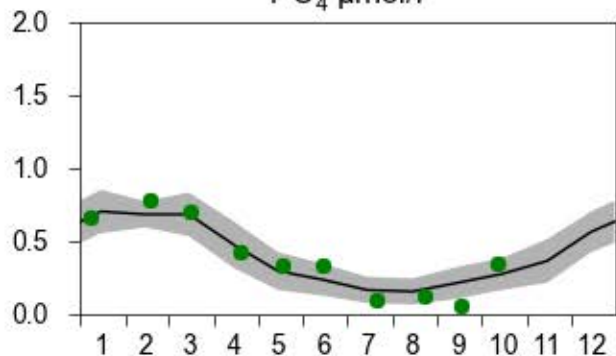
Temperature °C

Salinity psu



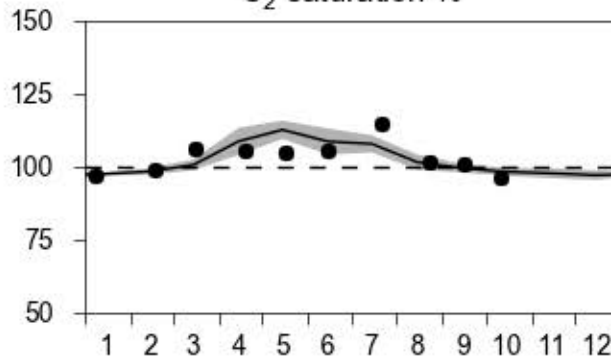
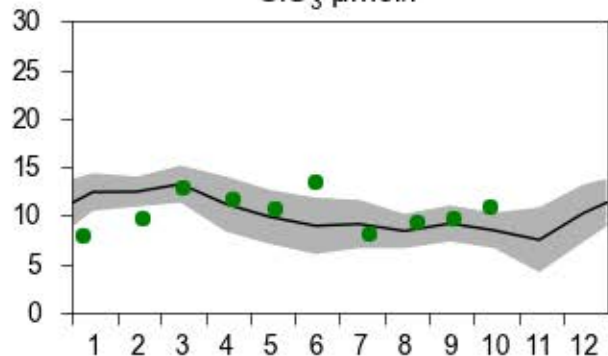
PO<sub>4</sub> µmol/l

DIN µmol/l



SiO<sub>3</sub> µmol/l

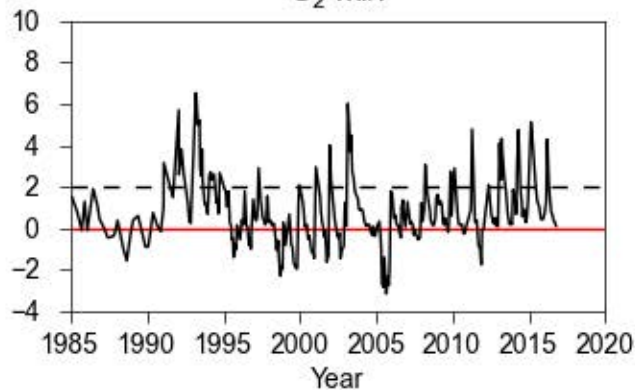
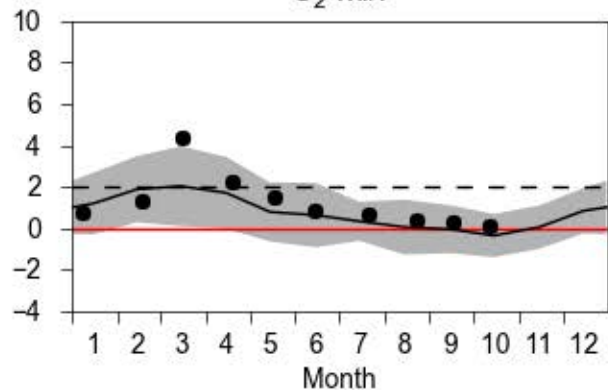
O<sub>2</sub> saturation %



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

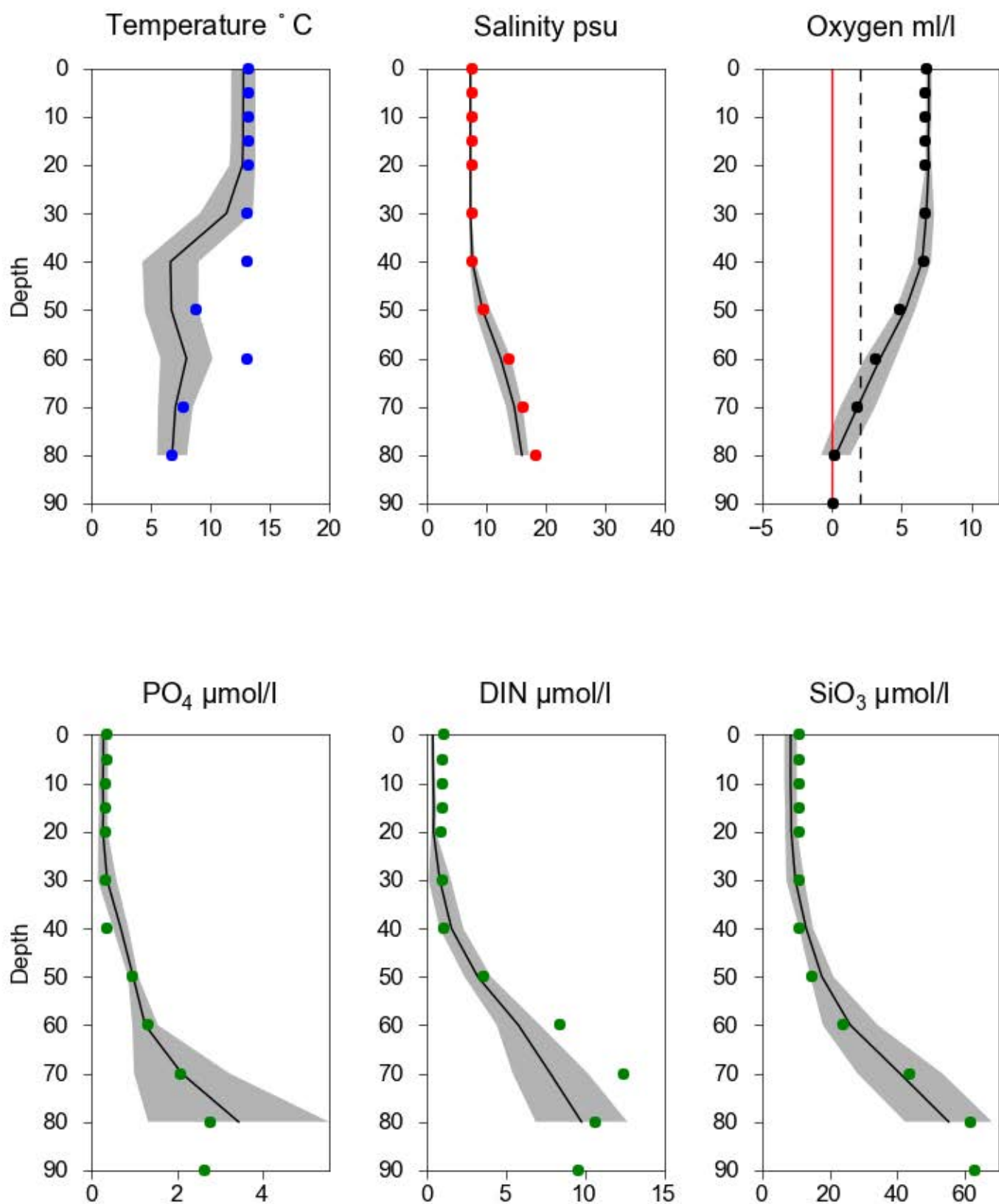
O<sub>2</sub> ml/l

O<sub>2</sub> ml/l



## Vertical profiles BY5 BORNHOLMSDJ October

— Mean 2001-2015    St.Dev.    • 2016-10-12



# STATION BCS III-10 SURFACE WATER (0-10m)

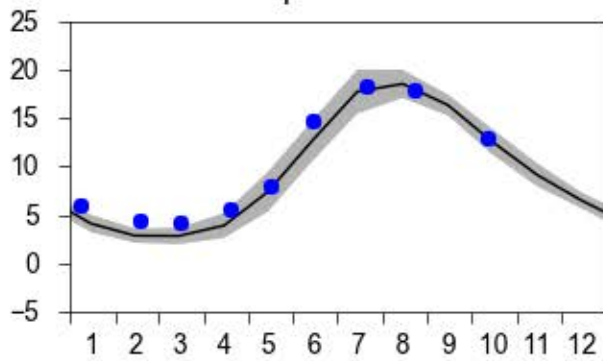
Annual Cycles

— Mean 2001-2015

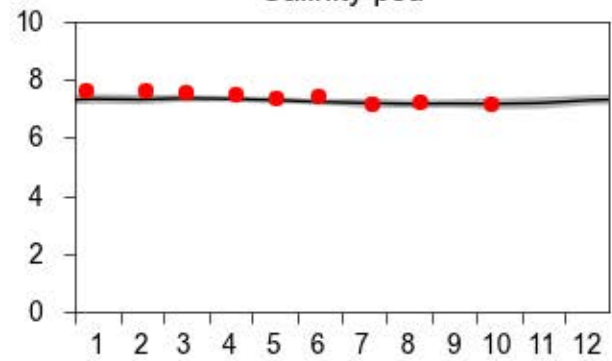
■ St.Dev.

● 2016

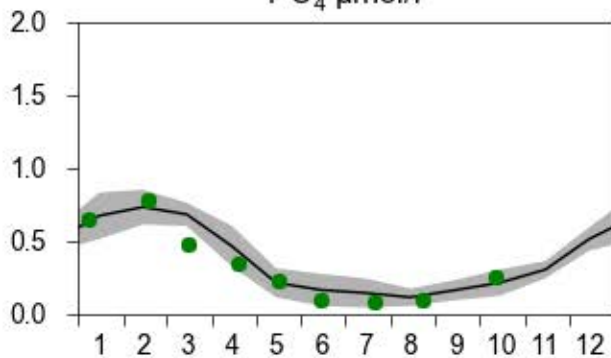
Temperature °C



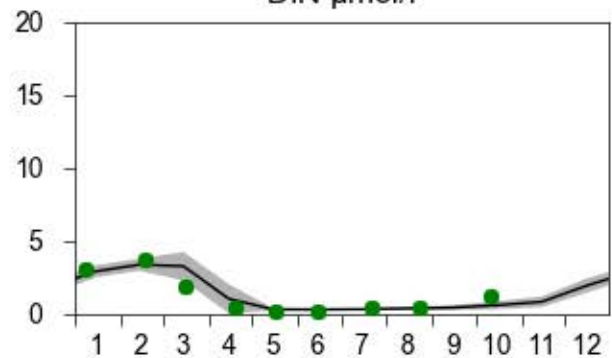
Salinity psu



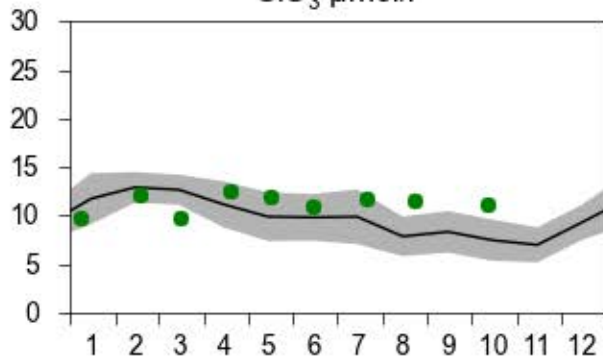
PO<sub>4</sub> µmol/l



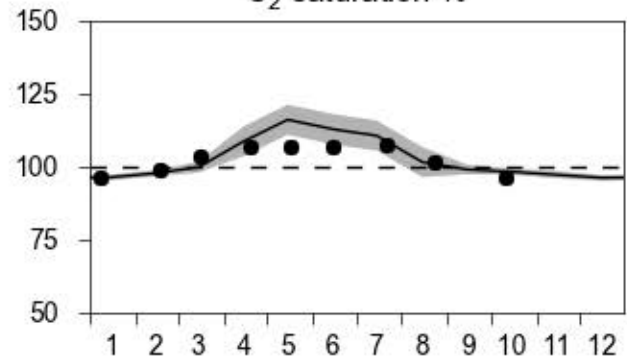
DIN µmol/l



SiO<sub>3</sub> µmol/l

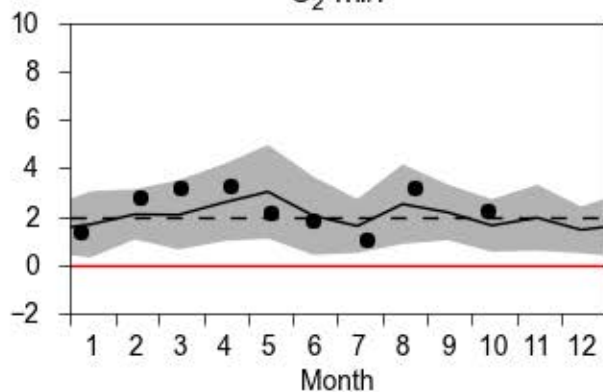


O<sub>2</sub> saturation %

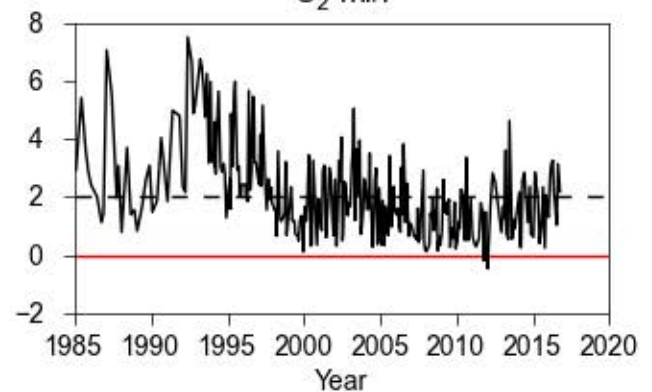


## OXYGEN IN BOTTOM WATER (depth >= 80 m)

O<sub>2</sub> ml/l



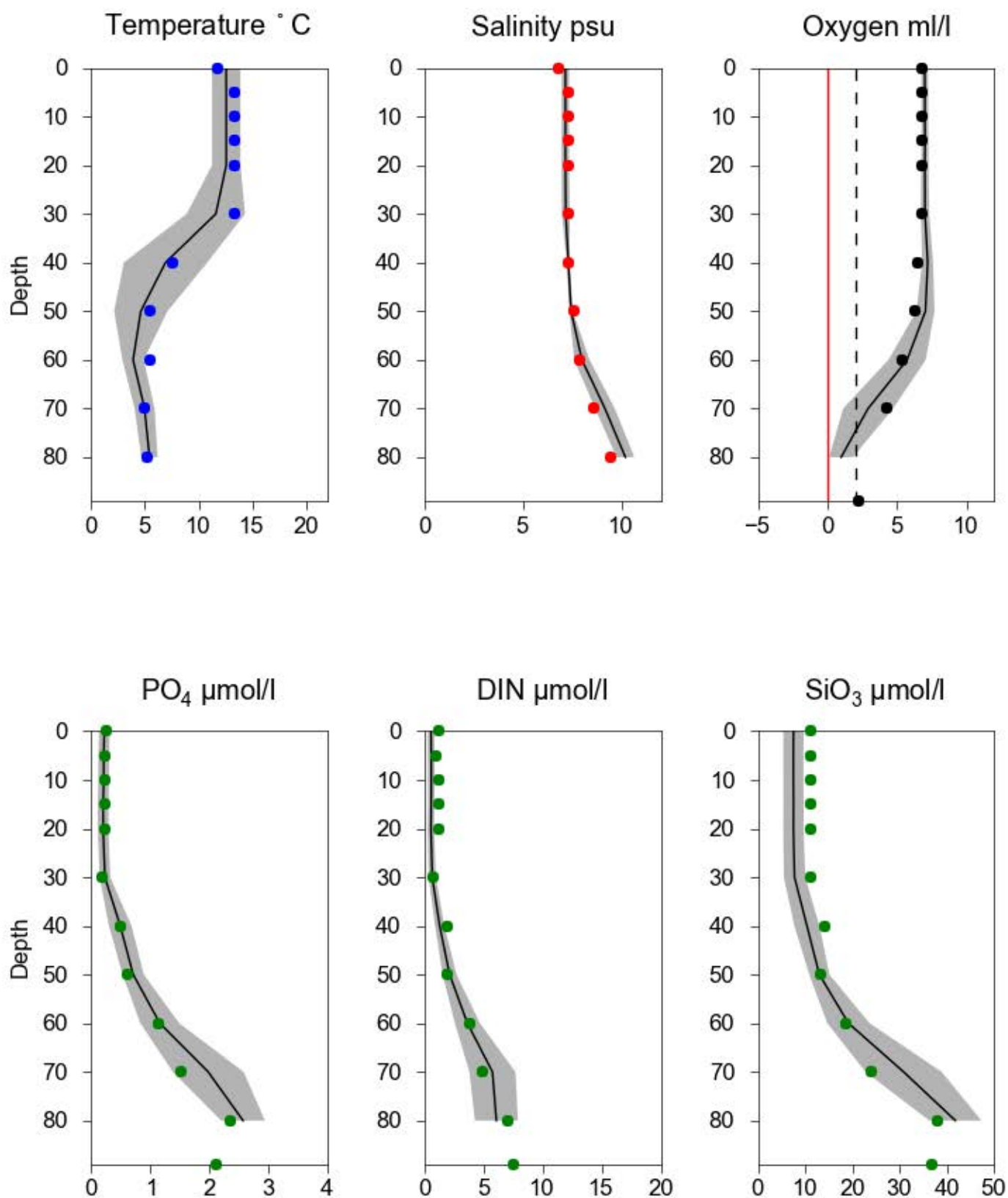
O<sub>2</sub> ml/l





# Vertical profiles BCS III-10 October

— Mean 2001-2015    St.Dev.    • 2016-10-12



# STATION BY10 SURFACE WATER (0-10m)

Annual Cycles

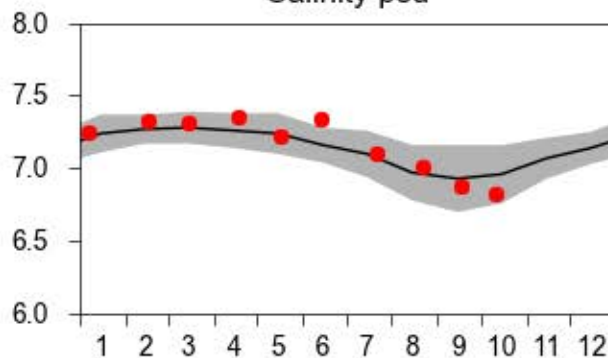
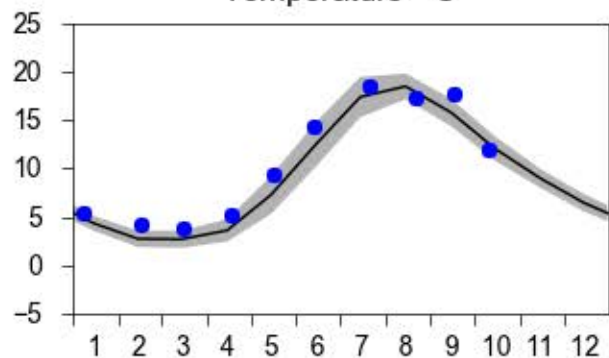
— Mean 2001-2015

■ St.Dev.

● 2016

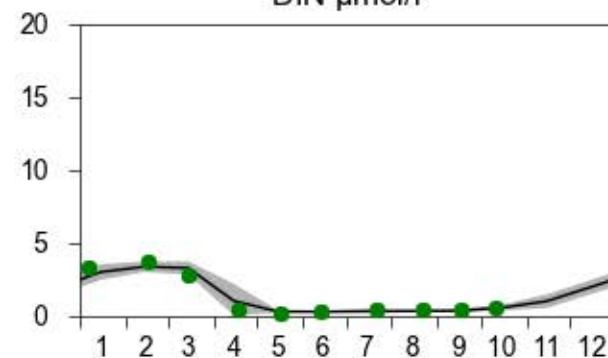
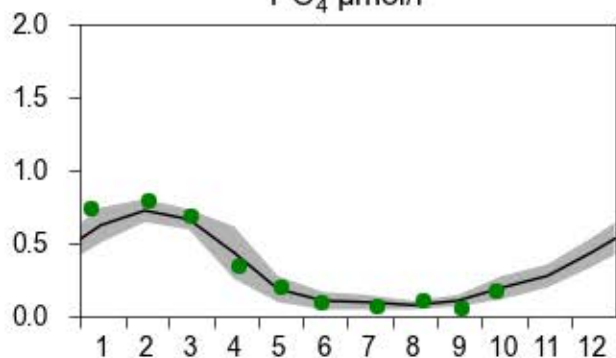
Temperature °C

Salinity psu



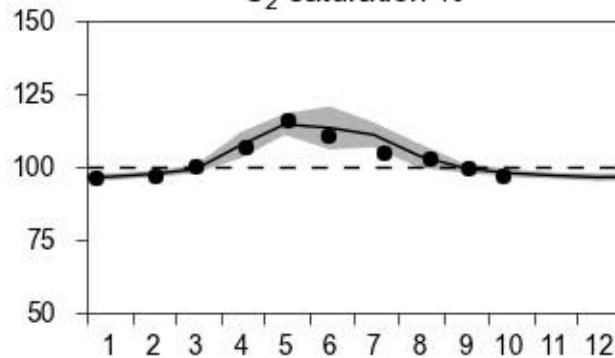
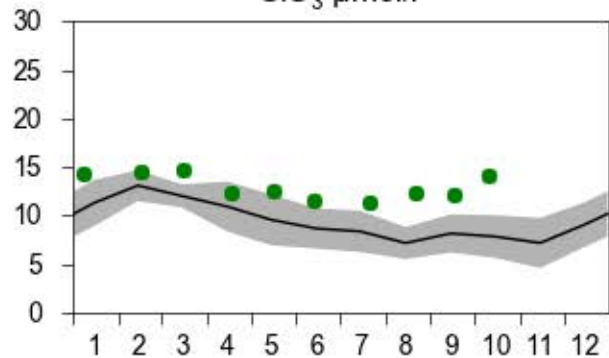
PO<sub>4</sub> µmol/l

DIN µmol/l



SiO<sub>3</sub> µmol/l

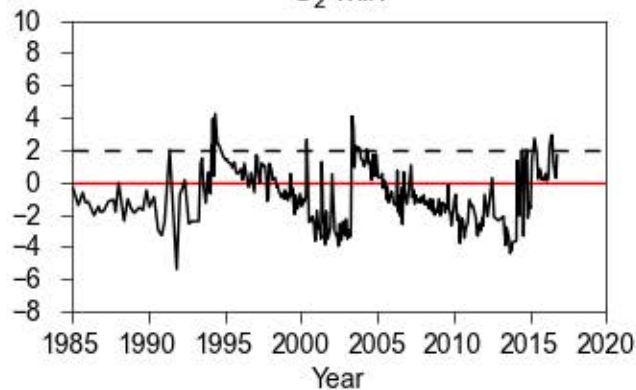
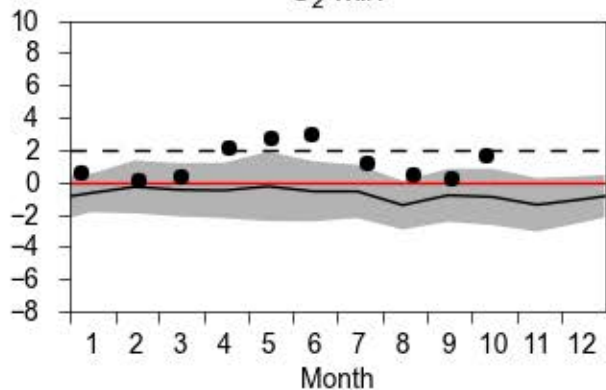
O<sub>2</sub> saturation %



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

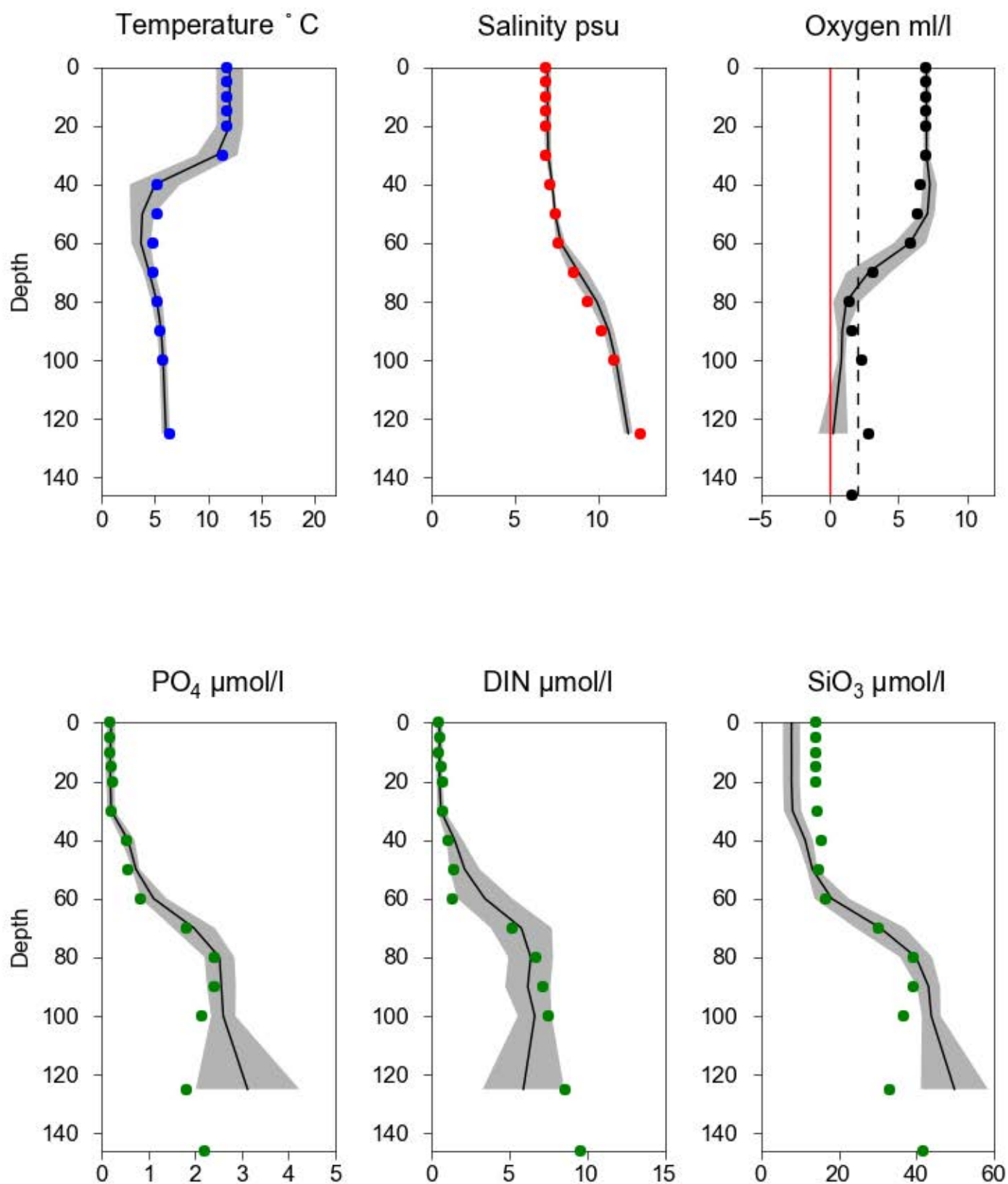
O<sub>2</sub> ml/l

O<sub>2</sub> ml/l



# Vertical profiles BY10 October

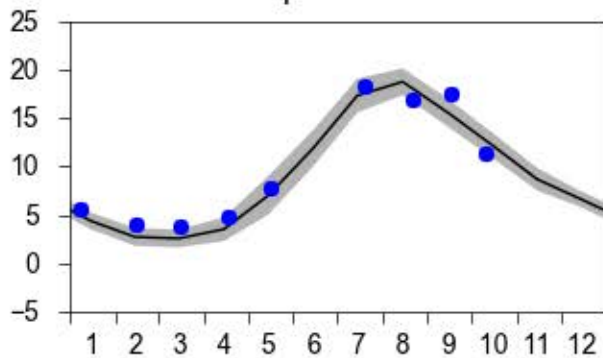
— Mean 2001-2015    ■ St.Dev.    ● 2016-10-11



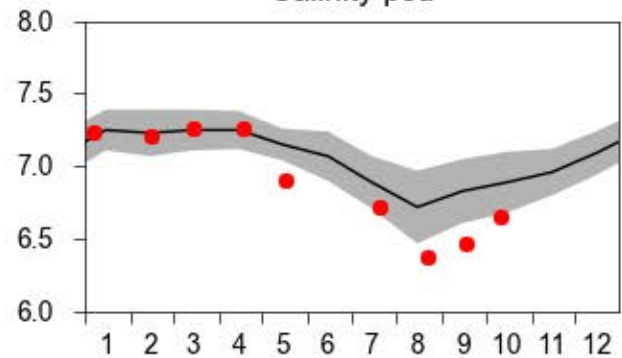
# STATION BY15 GOTLANDSDJ SURFACE WATER (0-10m)

Annual Cycles

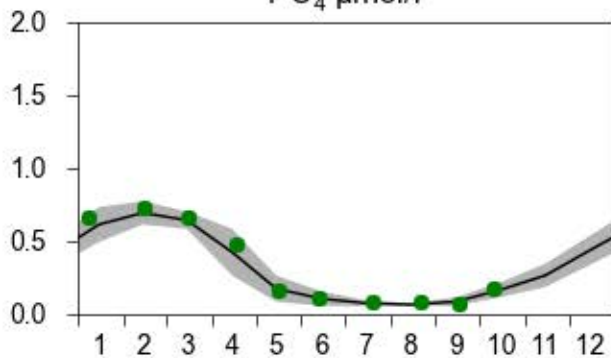
— Mean 2001-2015  
Temperature °C



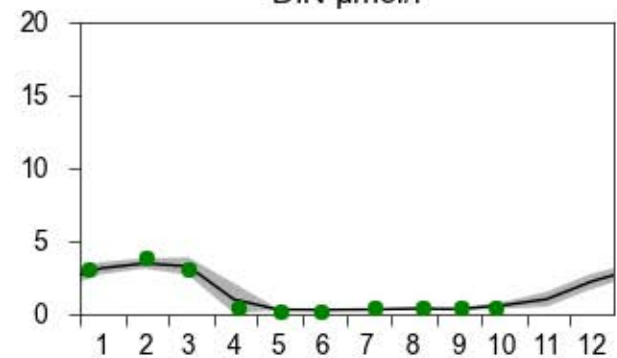
St.Dev. ● 2016  
Salinity psu



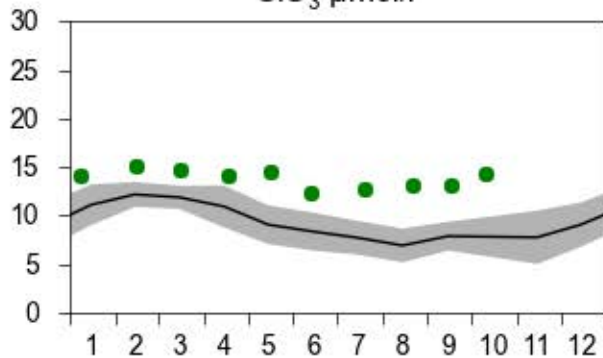
PO<sub>4</sub> μmol/l



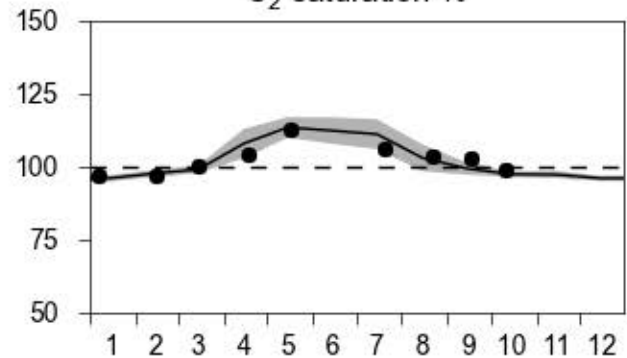
DIN μmol/l



SiO<sub>3</sub> μmol/l

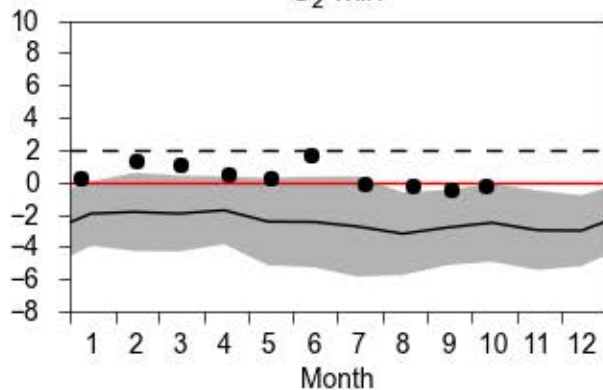


O<sub>2</sub> saturation %

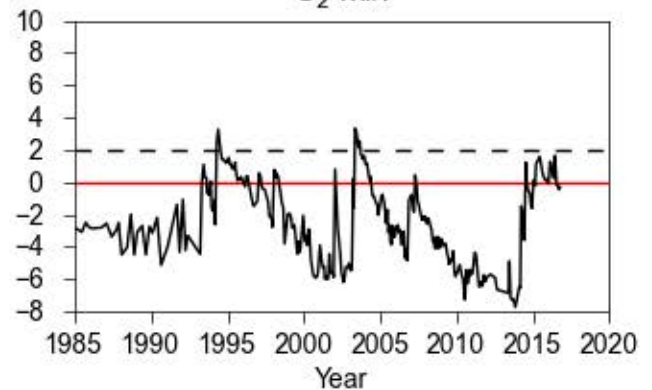


## OXYGEN IN BOTTOM WATER (depth ≥ 225 m)

O<sub>2</sub> ml/l

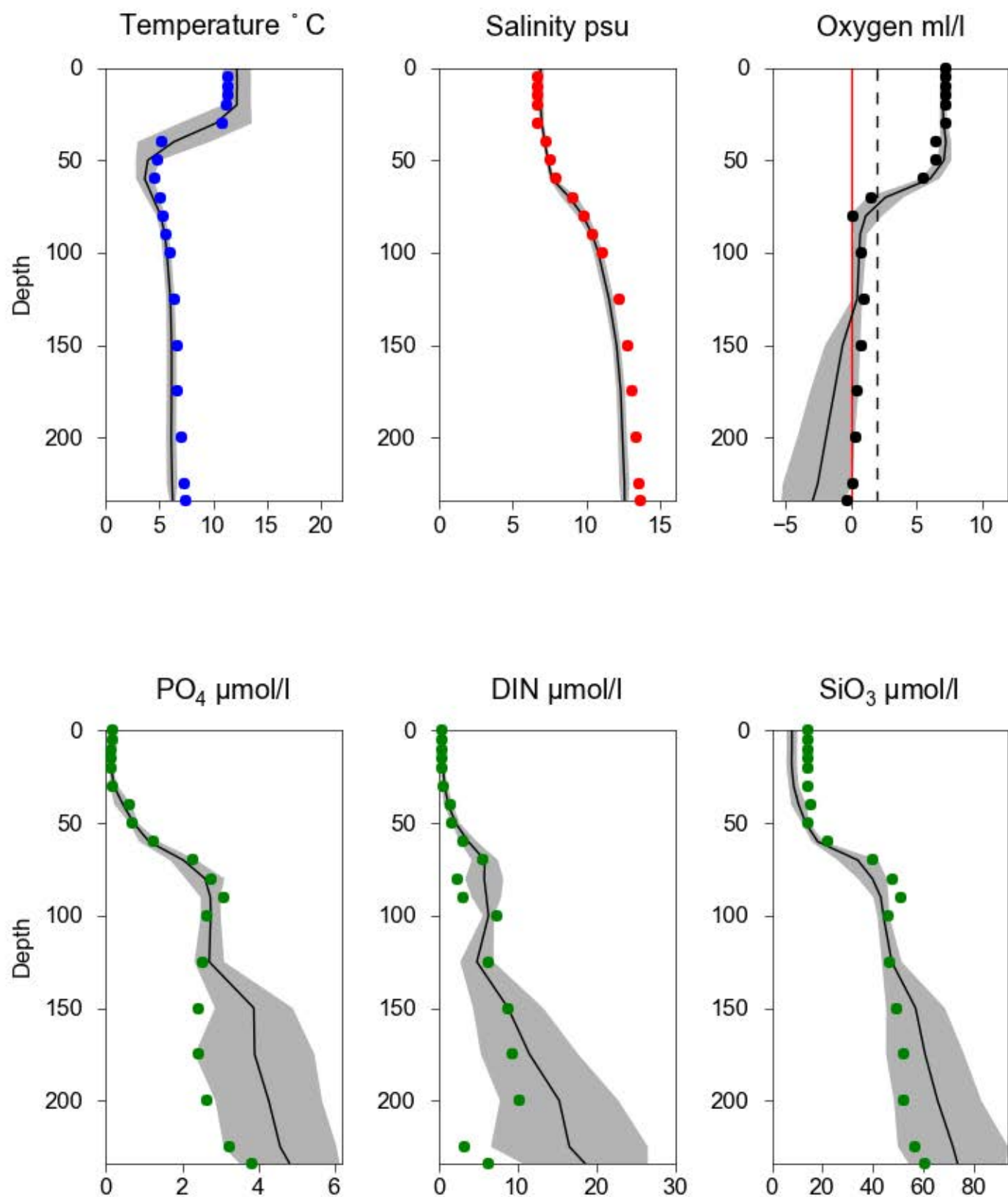


O<sub>2</sub> ml/l



## Vertical profiles BY15 GOTLANDSDJ October

— Mean 2001-2015    St.Dev.    • 2016-10-11



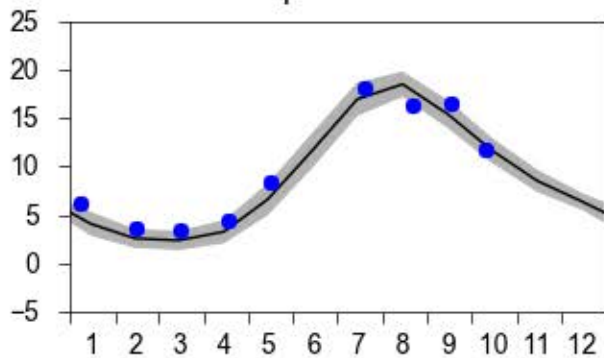


# STATION BY20 FÅRÖDJ SURFACE WATER (0-10m)

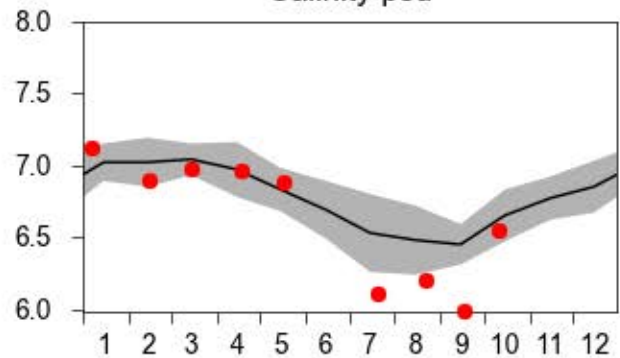
Annual Cycles

— Mean 2001-2015    St.Dev.    • 2016

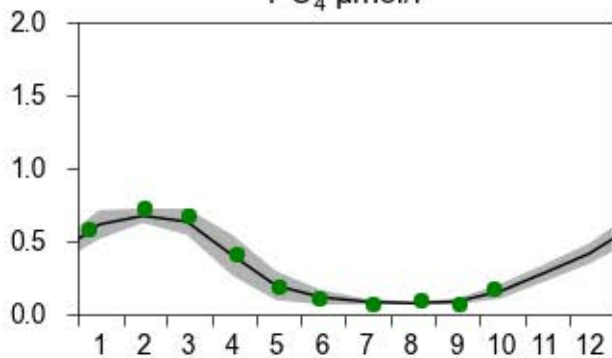
Temperature °C



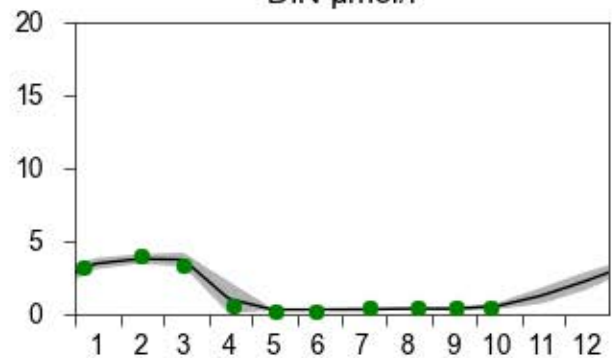
Salinity psu



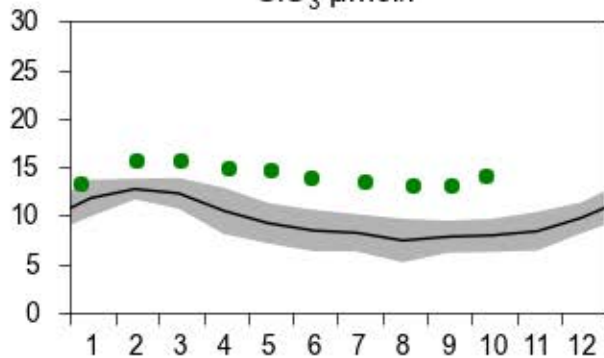
PO<sub>4</sub> µmol/l



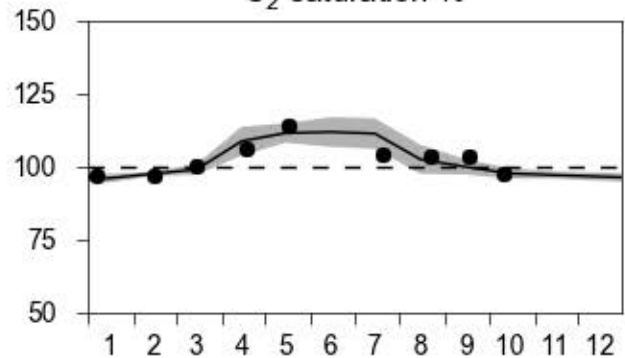
DIN µmol/l



SiO<sub>3</sub> µmol/l

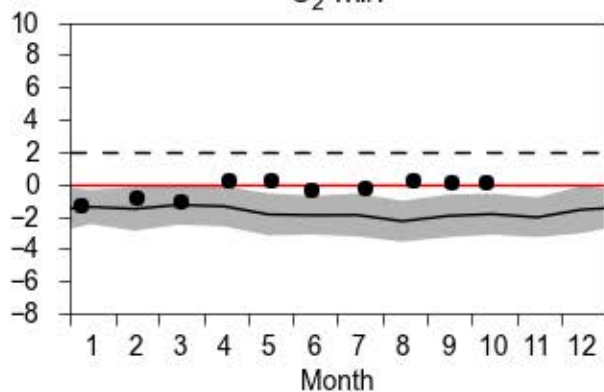


O<sub>2</sub> saturation %

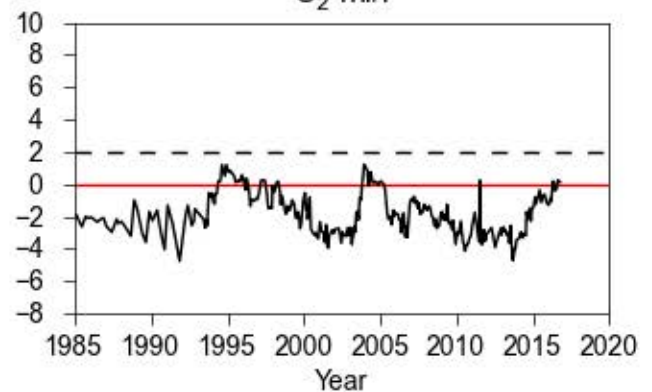


## OXYGEN IN BOTTOM WATER (depth >= 175 m)

O<sub>2</sub> ml/l

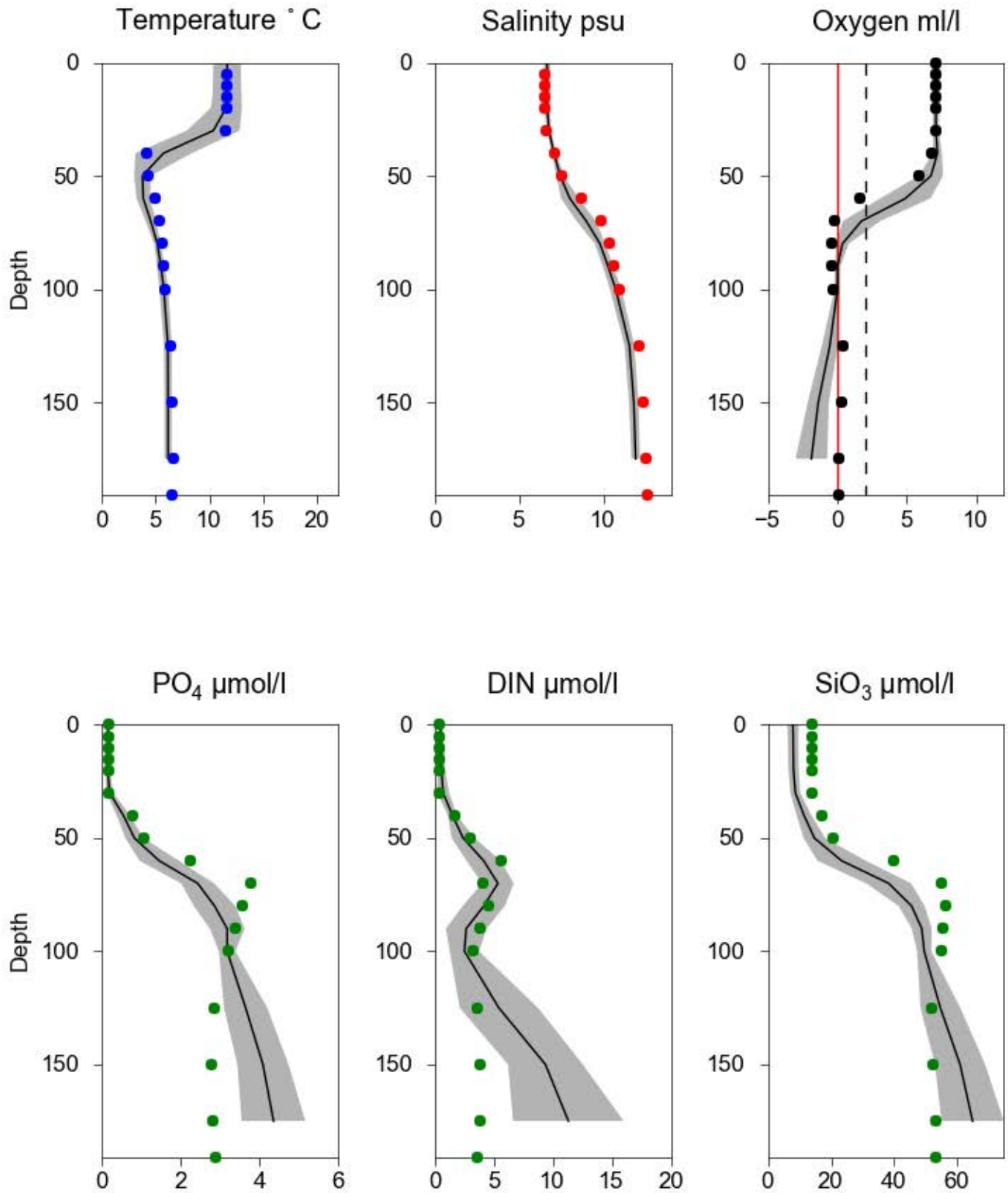


O<sub>2</sub> ml/l



# Vertical profiles BY20 FÄRÖDJ October

— Mean 2001-2015    St.Dev.    ● 2016-10-11



# STATION BY32 NORRKÖPINGSDJ SURFACE WATER (0-10m)

Annual Cycles

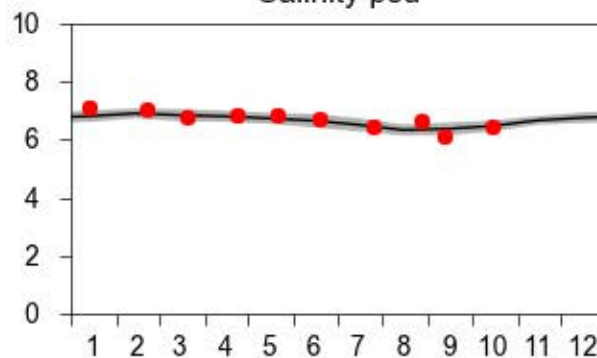
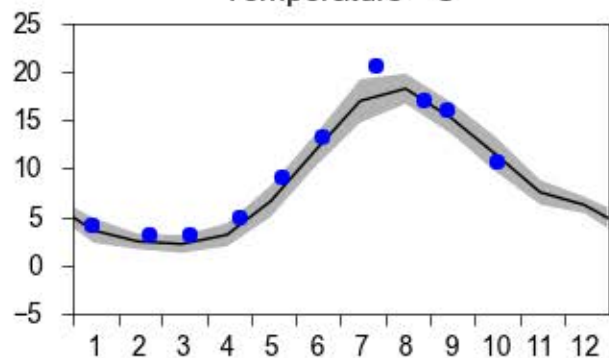
— Mean 2001-2015

■ St.Dev.

● 2016

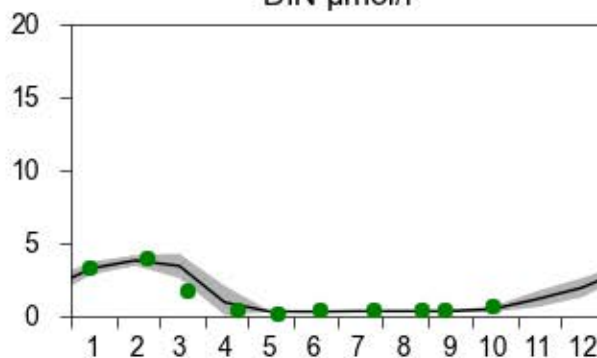
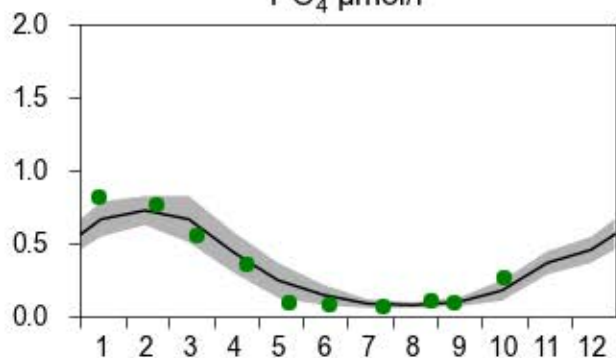
Temperature °C

Salinity psu



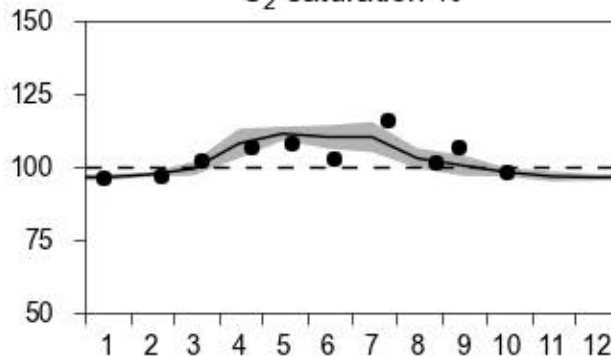
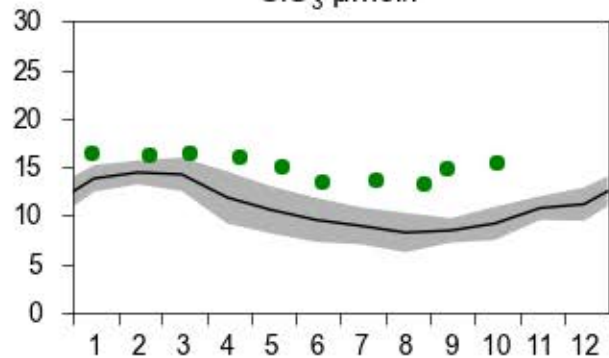
PO<sub>4</sub> µmol/l

DIN µmol/l



SiO<sub>3</sub> µmol/l

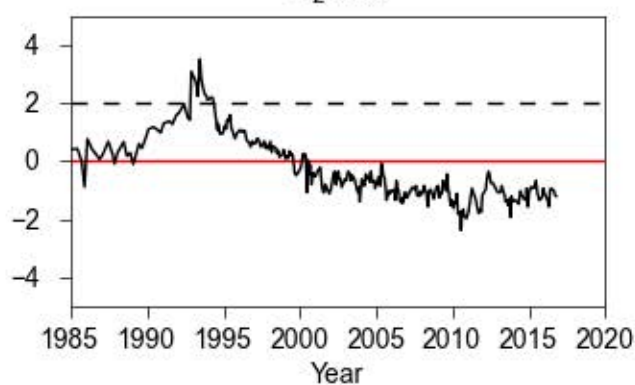
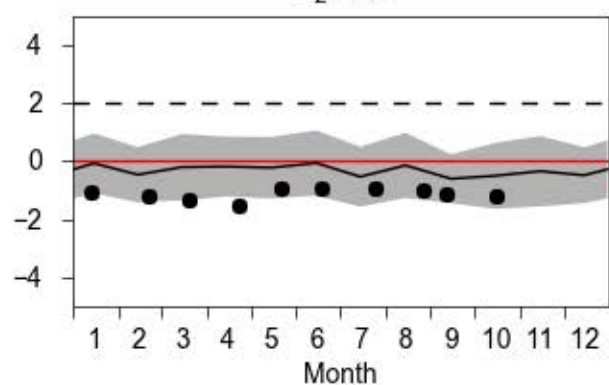
O<sub>2</sub> saturation %



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

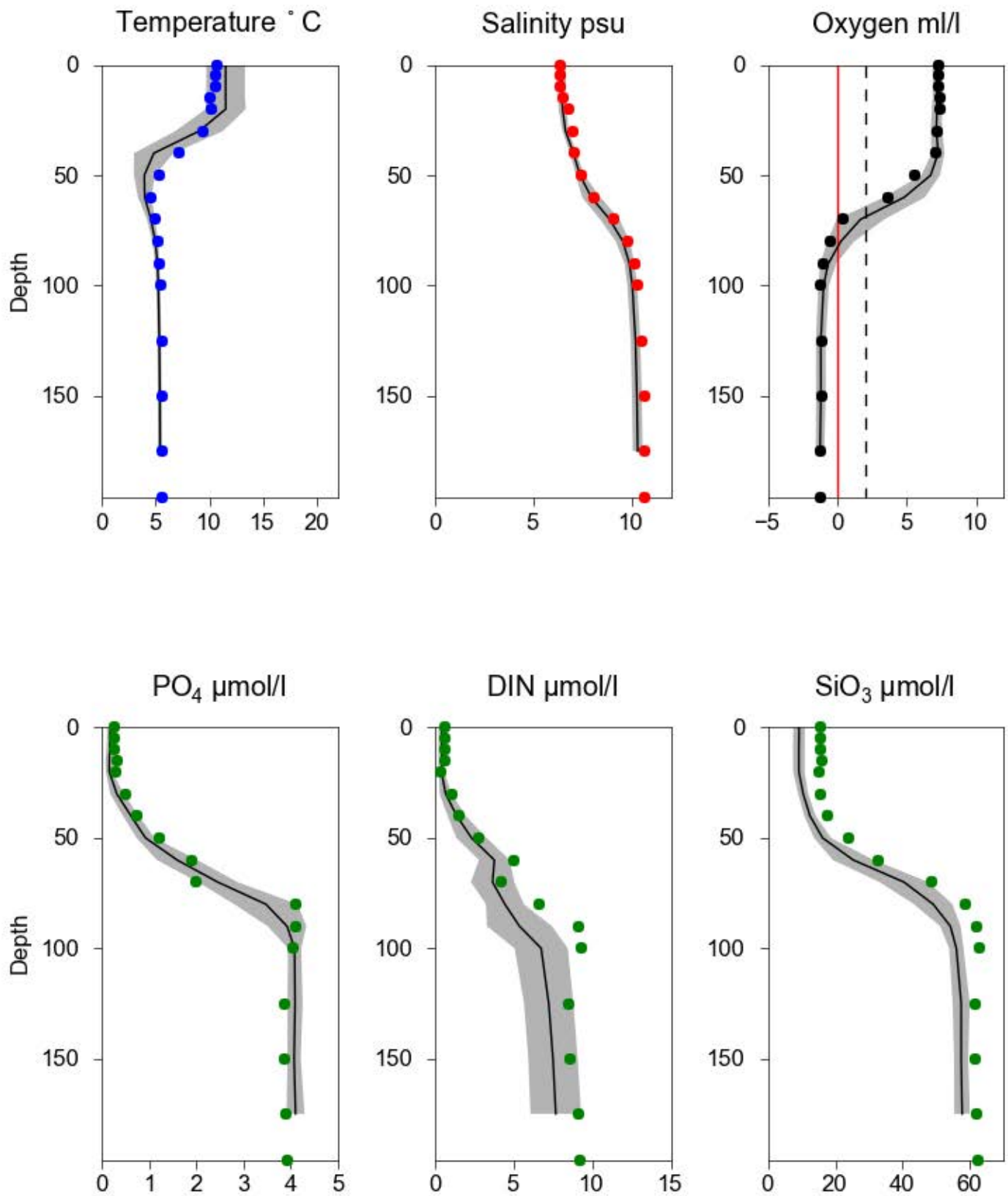
O<sub>2</sub> ml/l

O<sub>2</sub> ml/l



# Vertical profiles BY32 NORRKÖPINGSDJ October

— Mean 2001-2015    St.Dev.    ● 2016-10-16



# STATION BY38 KARLSÖDJ SURFACE WATER (0-10m)

Annual Cycles

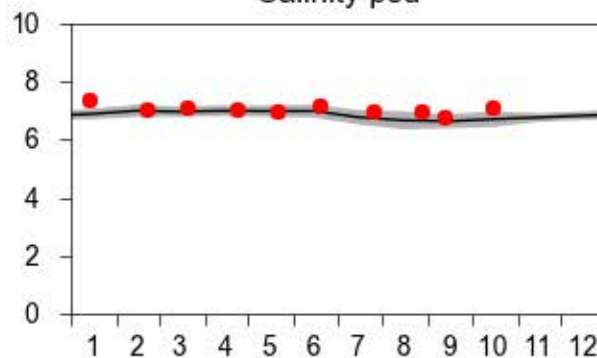
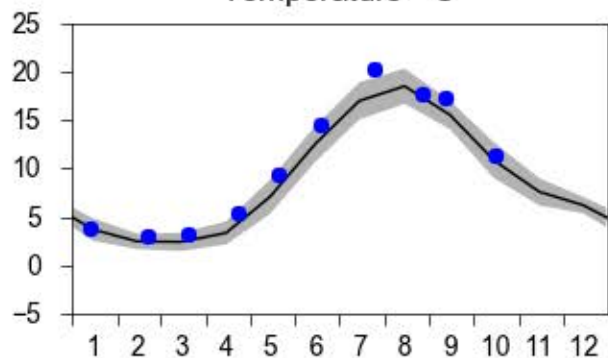
— Mean 2001-2015

■ St.Dev.

● 2016

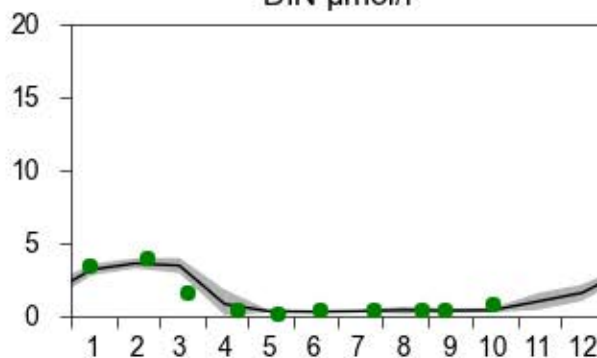
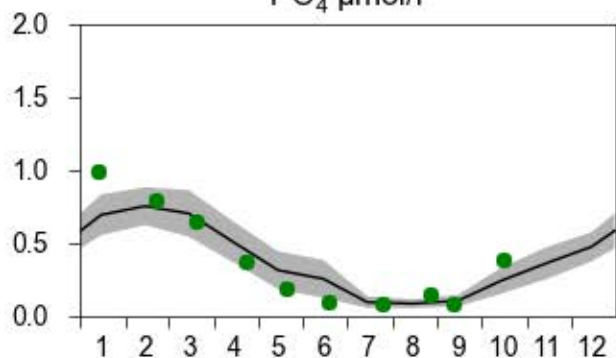
Temperature °C

Salinity psu



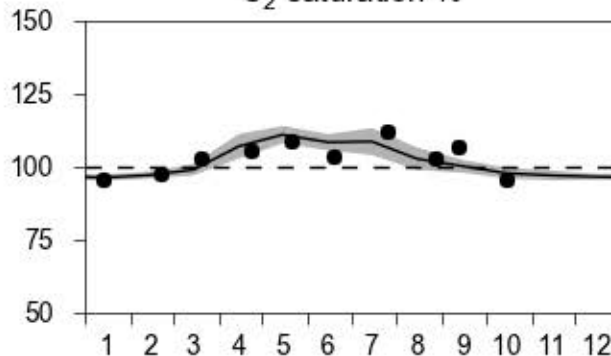
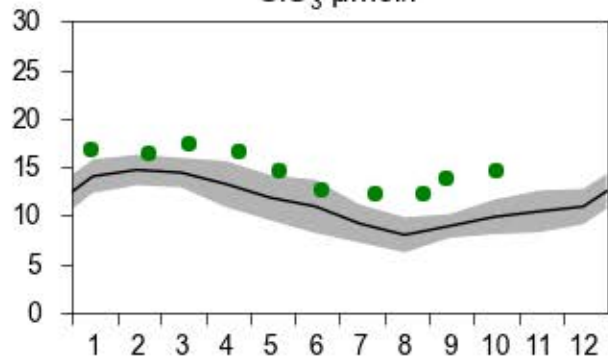
PO<sub>4</sub> µmol/l

DIN µmol/l



SiO<sub>3</sub> µmol/l

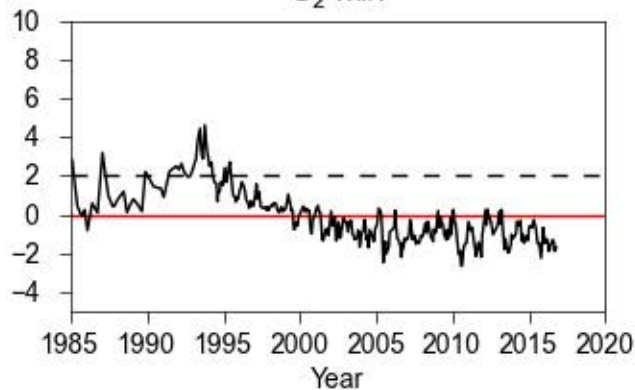
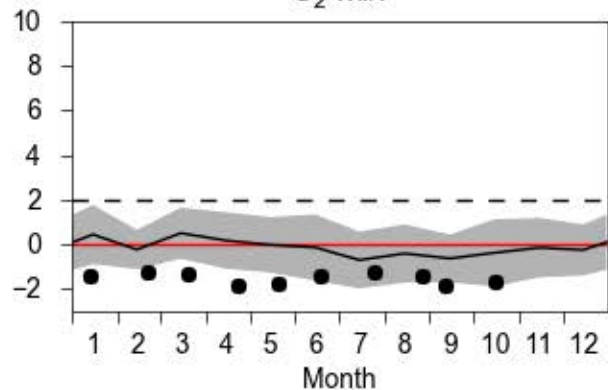
O<sub>2</sub> saturation %



## OXYGEN IN BOTTOM WATER (depth >= 100 m)

O<sub>2</sub> ml/l

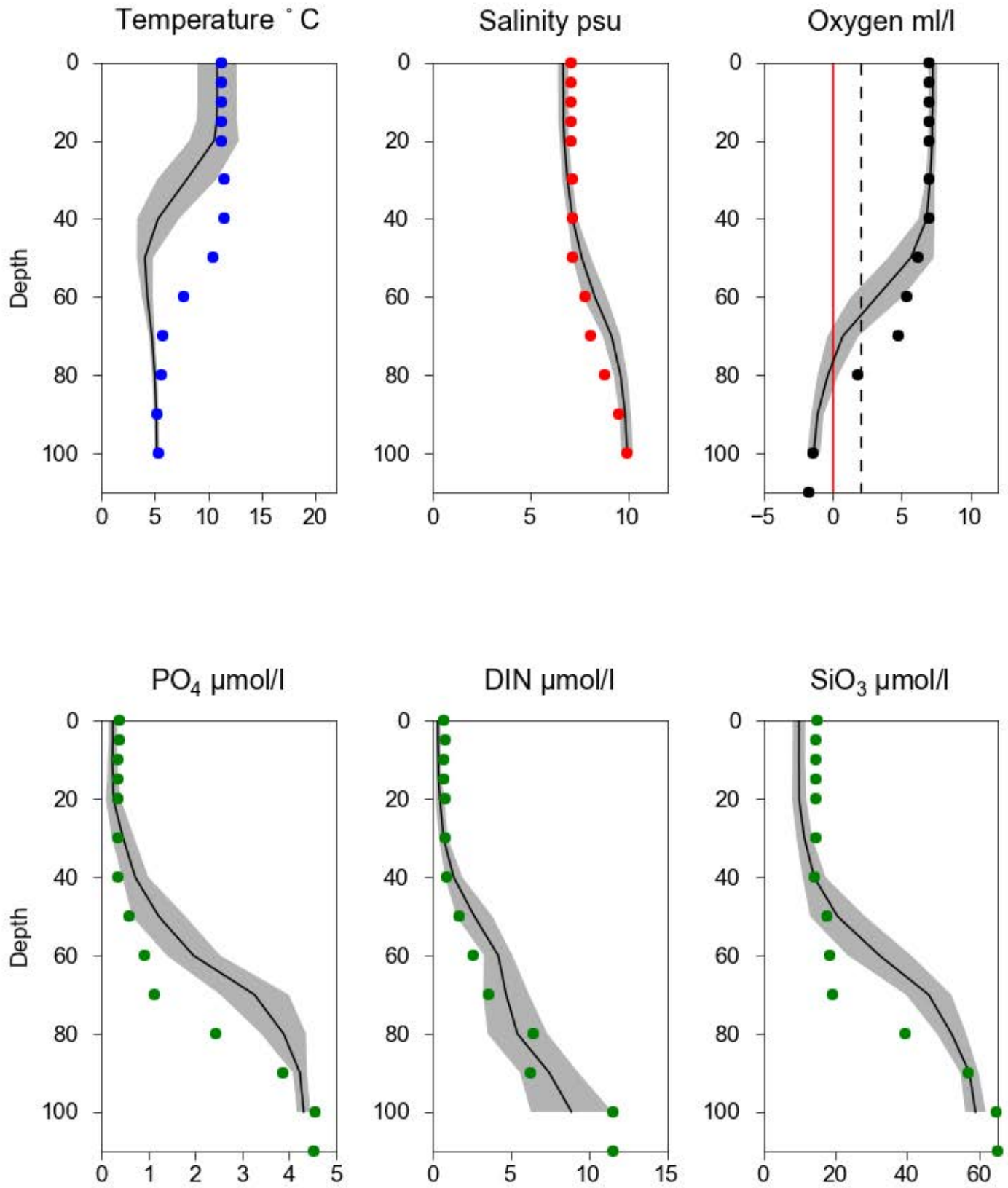
O<sub>2</sub> ml/l





## Vertical profiles BY38 KARLSÖDJ October

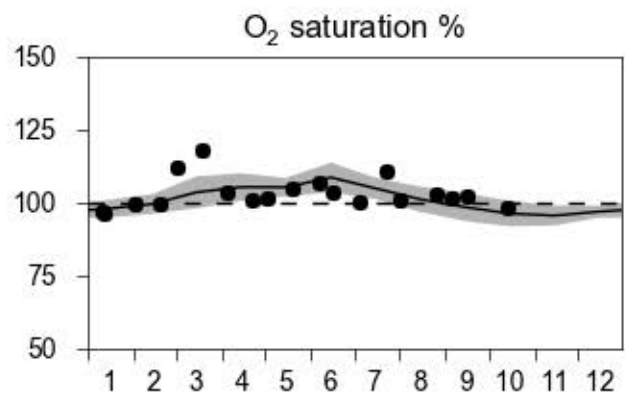
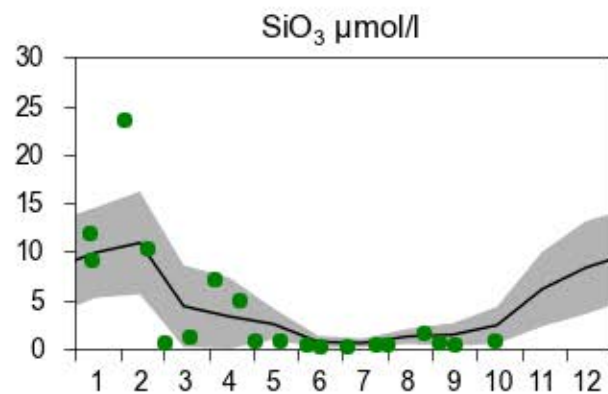
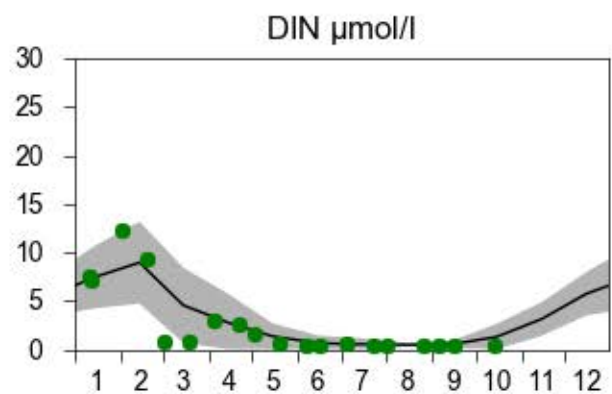
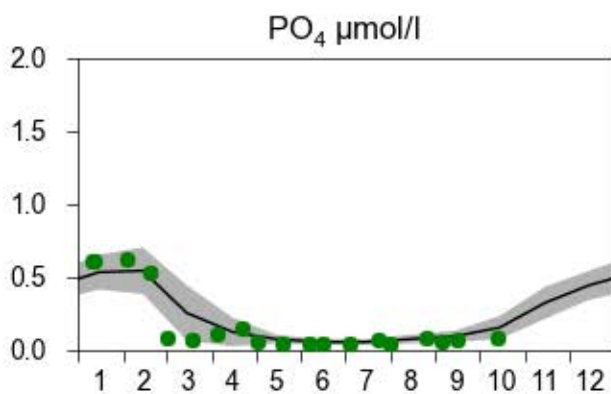
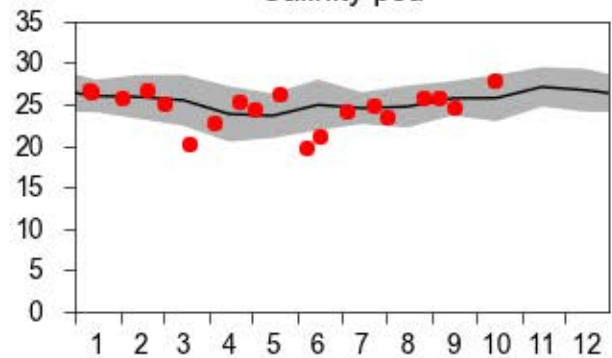
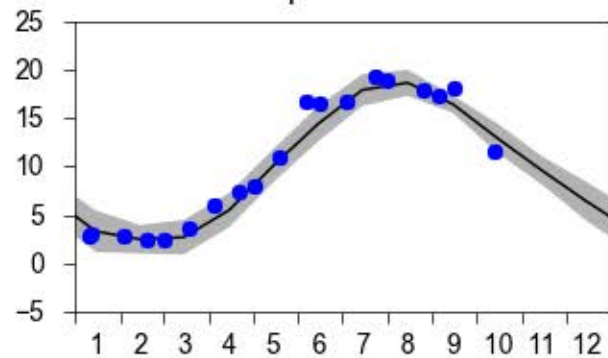
— Mean 2001-2015    St.Dev.    • 2016-10-16



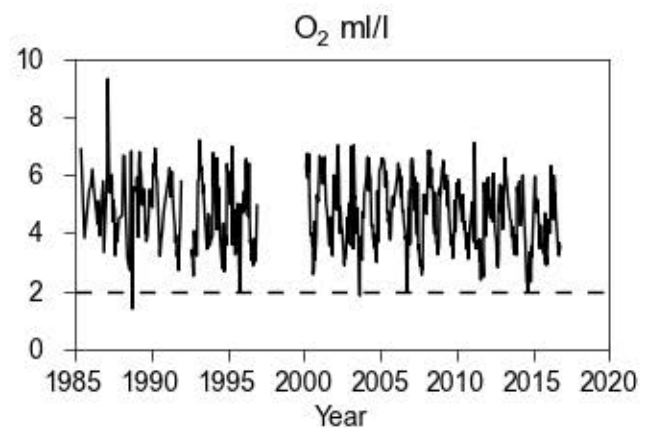
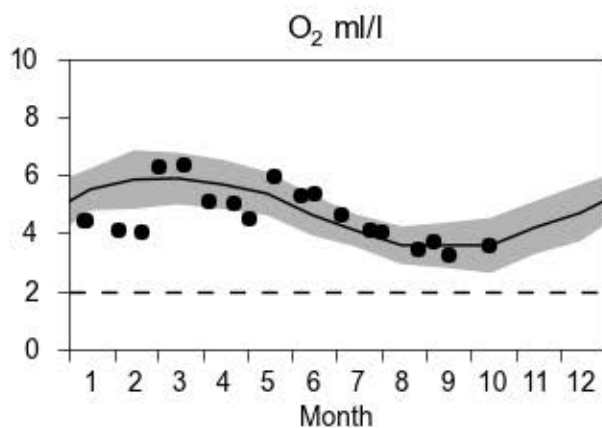
# STATION SLÄGGÖ SURFACE WATER (0-10m)

Annual Cycles

— Mean 2001-2015    St.Dev.    • 2016

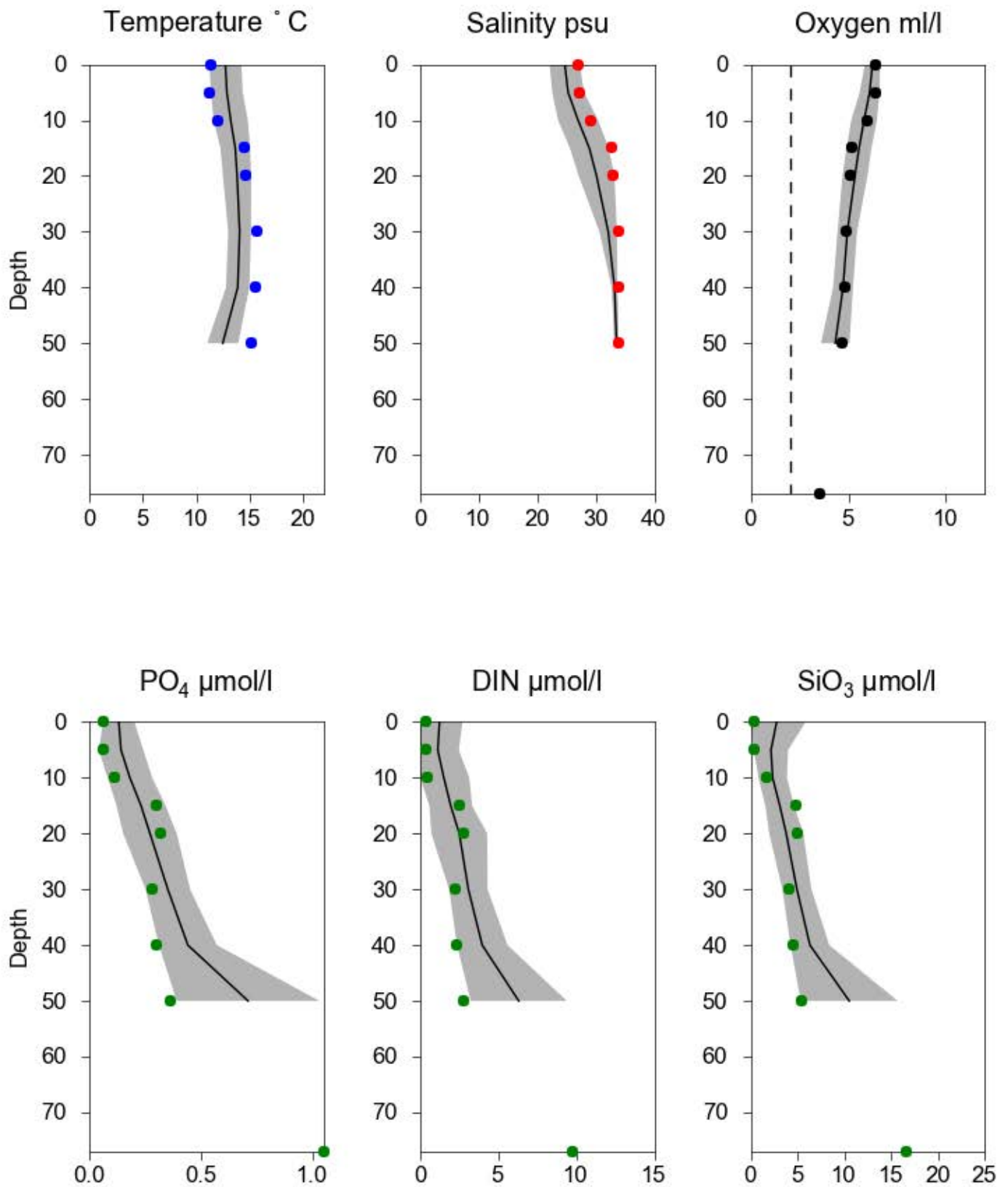


## OXYGEN IN BOTTOM WATER (depth >= 50 m)



# Vertical profiles SLÄGGÖ October

— Mean 2001-2015    St.Dev.    ● 2016-10-14



# STATION N14 FALKENBERG SURFACE WATER (0-10m)

Annual Cycles

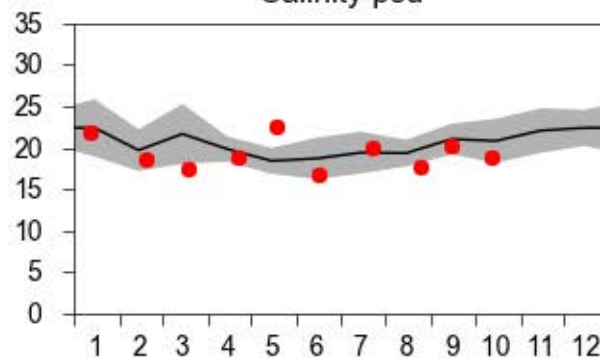
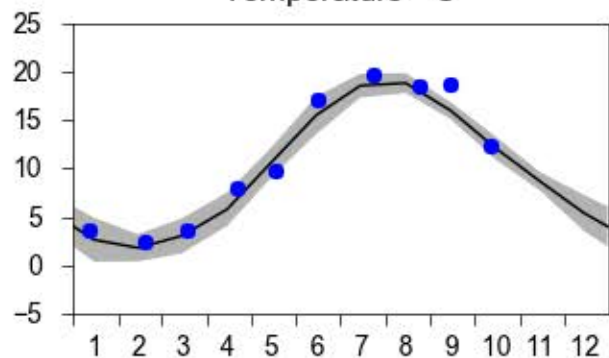
— Mean 2001-2015

■ St.Dev.

● 2016

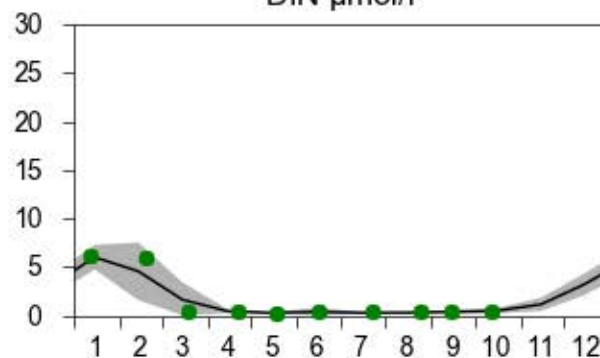
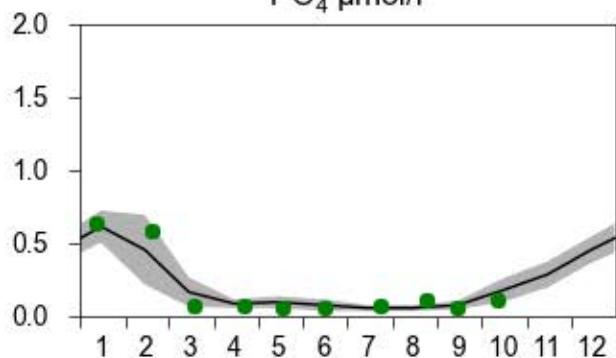
Temperature °C

Salinity psu



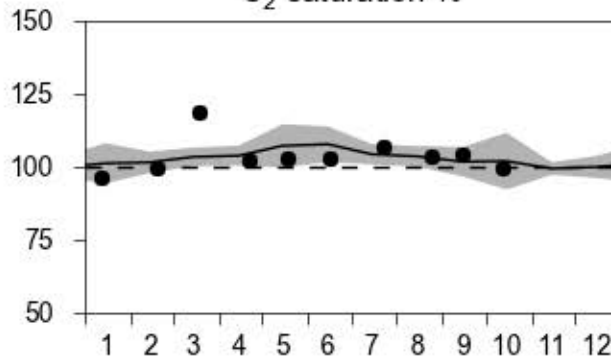
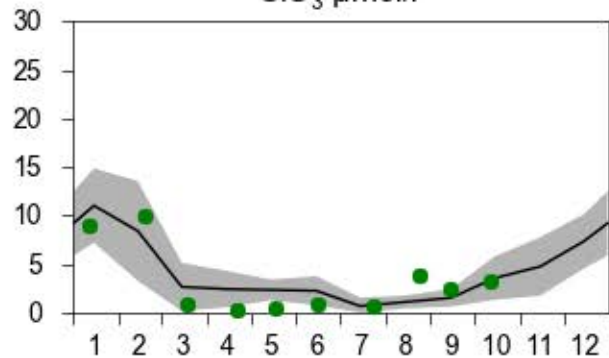
PO<sub>4</sub> µmol/l

DIN µmol/l



SiO<sub>3</sub> µmol/l

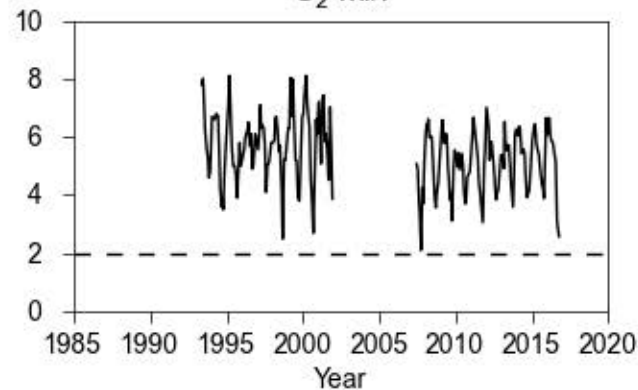
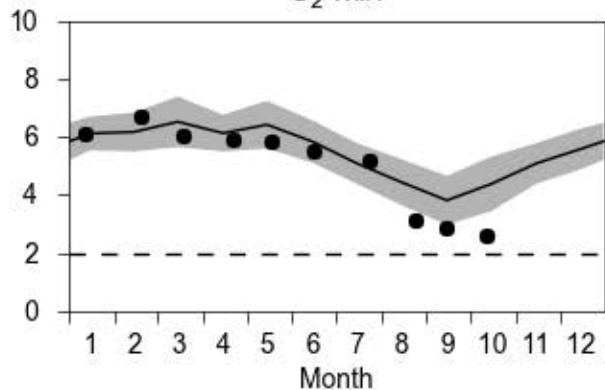
O<sub>2</sub> saturation %



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

O<sub>2</sub> ml/l

O<sub>2</sub> ml/l



# Vertical profiles N14 FALKENBERG October

— Mean 2001-2015    St.Dev.    • 2016-10-13

