# Drivers of summer oxygen depletion in the central North Sea
# +
# Recent developments from UEA

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# Basin-wide observations

First, a bit about the North Sea

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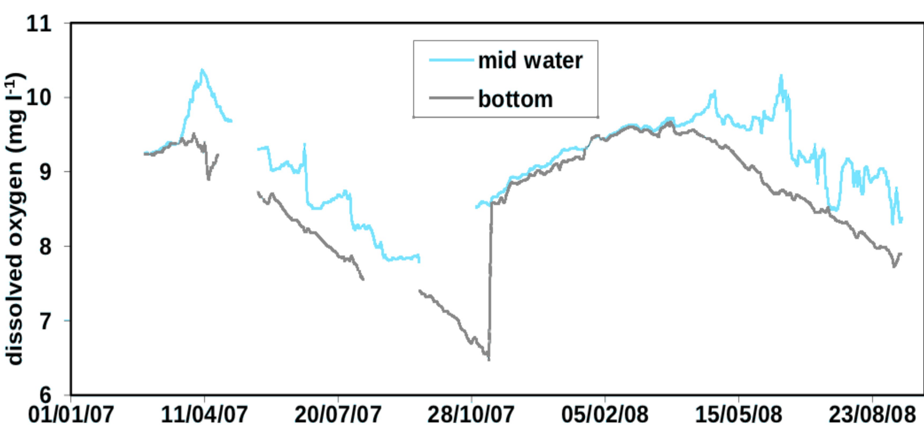
**North Dogger site:**

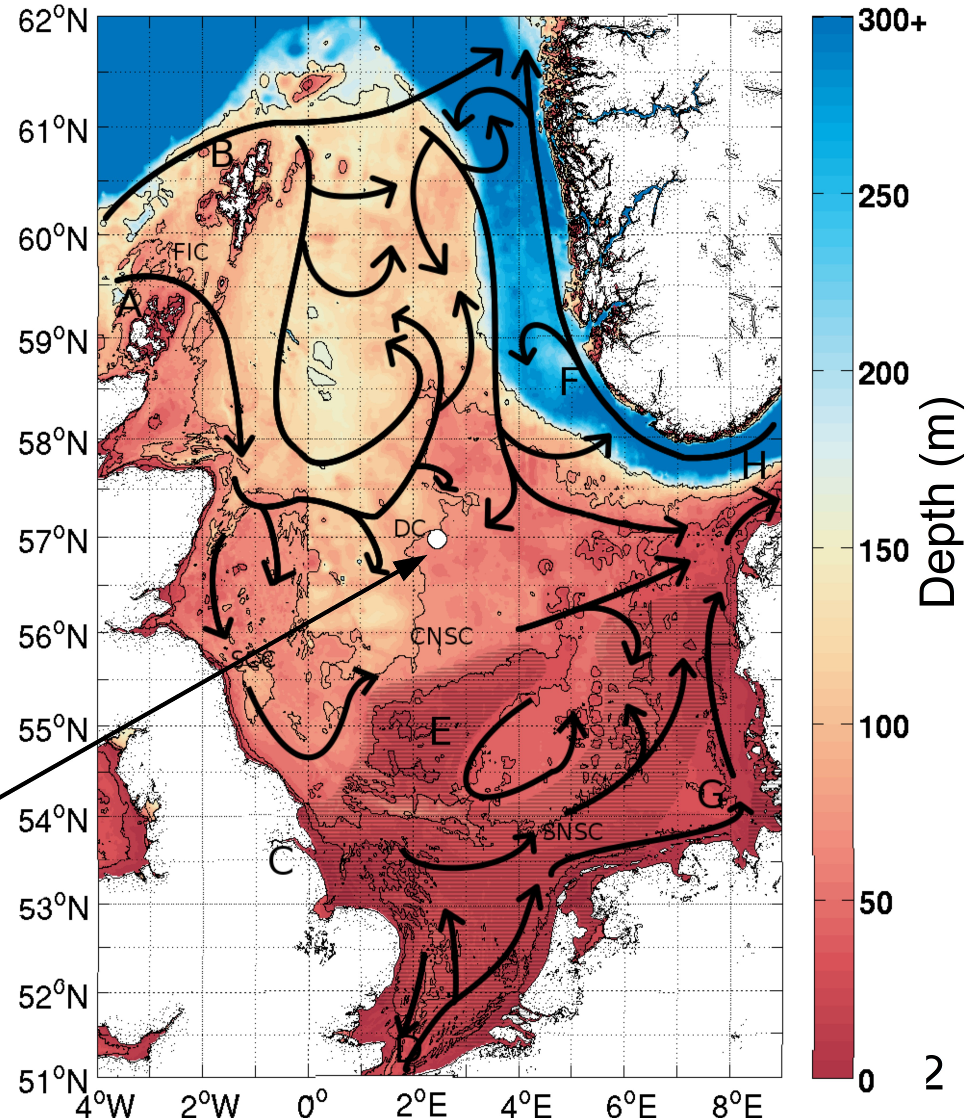
203 μmol $L^{-1}$

71% saturation

Important for:

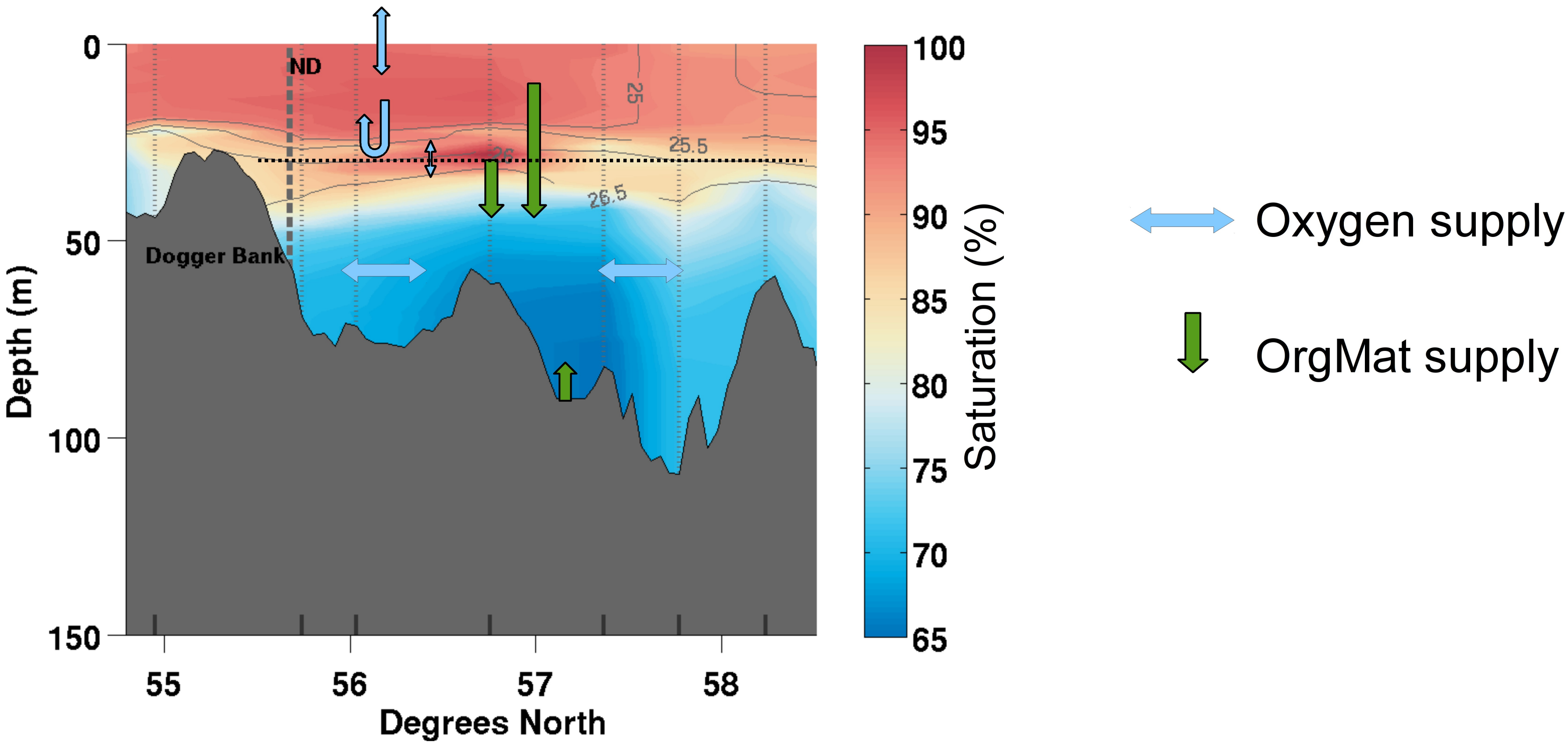
OSPAR + MSFD



# Mesoscale processes

## How does the oxygen depletion occur




Balance of oxygen consumption and supply:

Excessive consumption or limited reoxygenation leads to oxygen depletion

# Interannual variability

## Very large spatial variability

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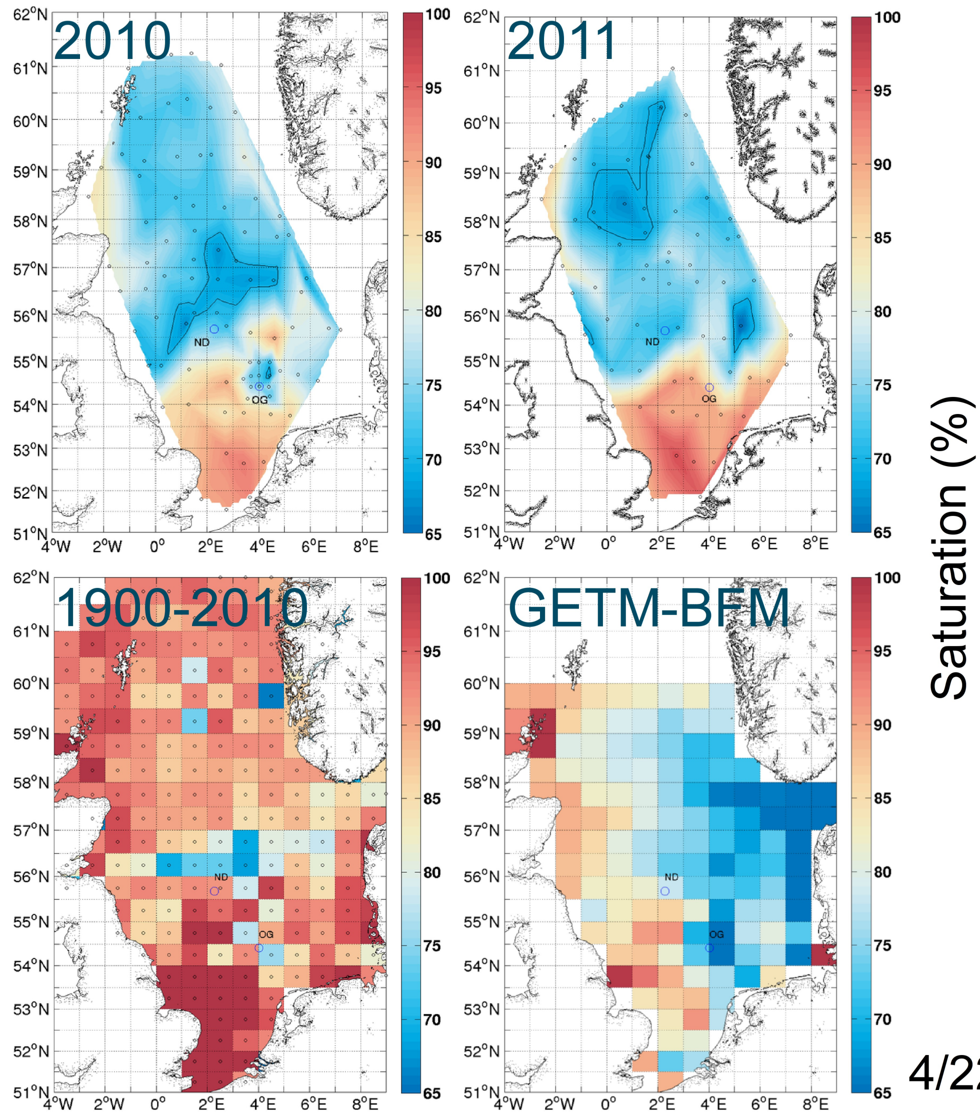
From left to right, top to bottom:

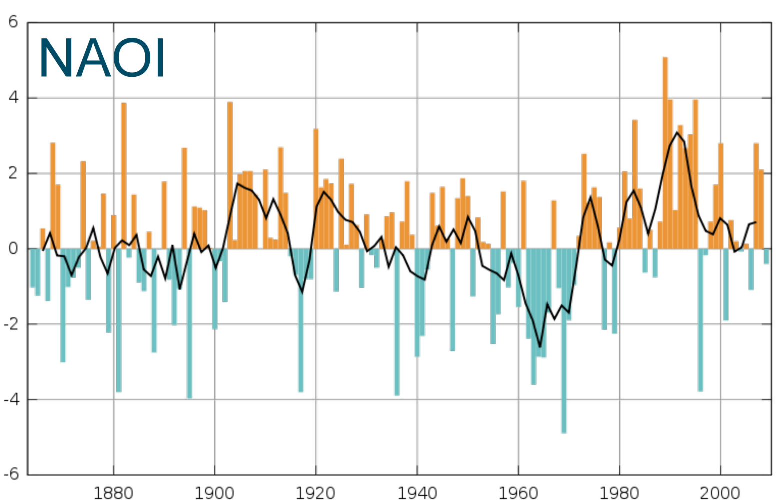
2010 cruise data

2011 cruise data

1900 – 2010 ICES average

1958 – 2008 model data



# Questions

Processes and timing the same across the north half so:

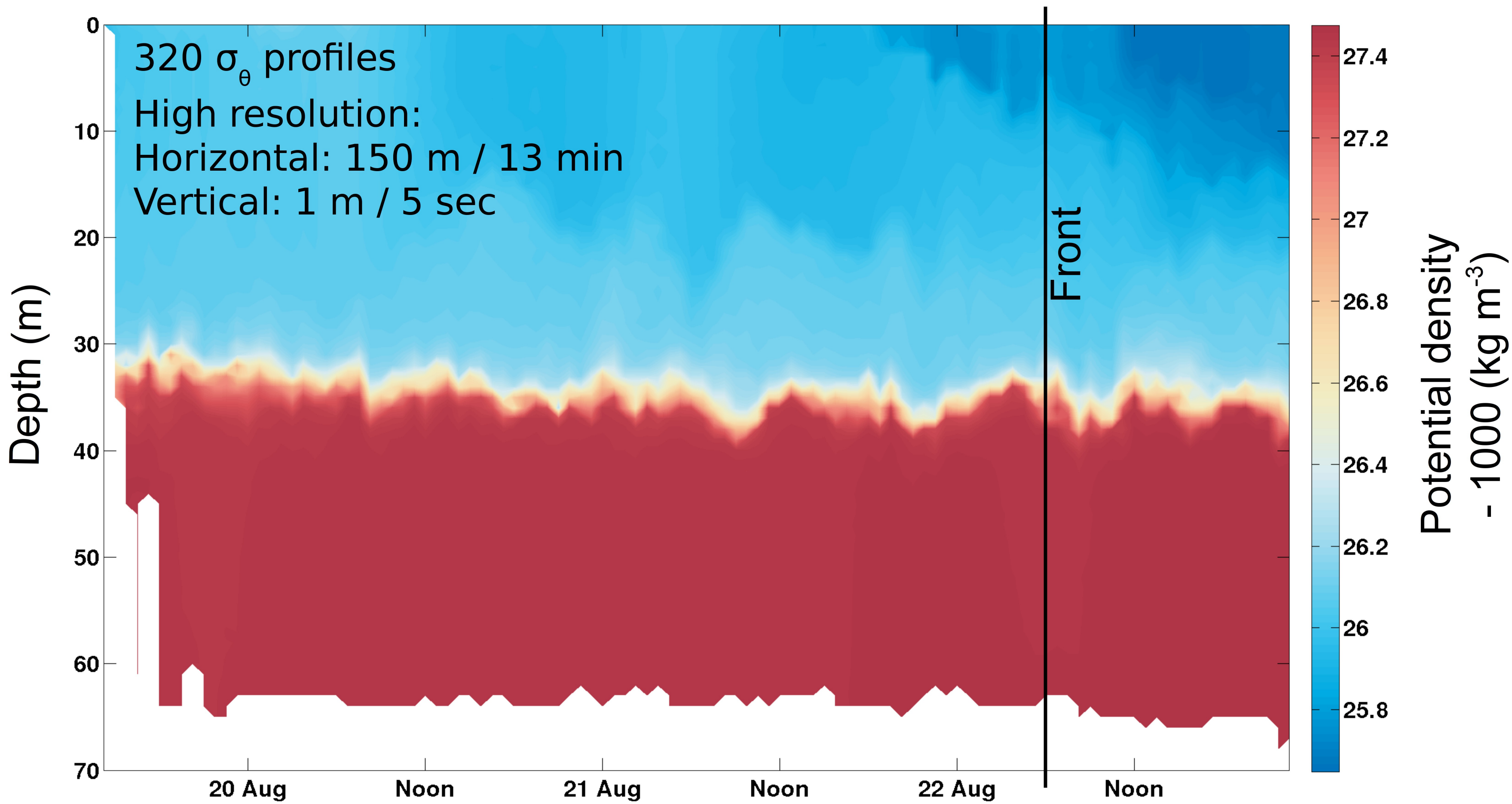
**Why such interannual spatial variability?**

**Why is this not resolved in models of the North Sea?**

**Can gliders provide new information on these processes?**

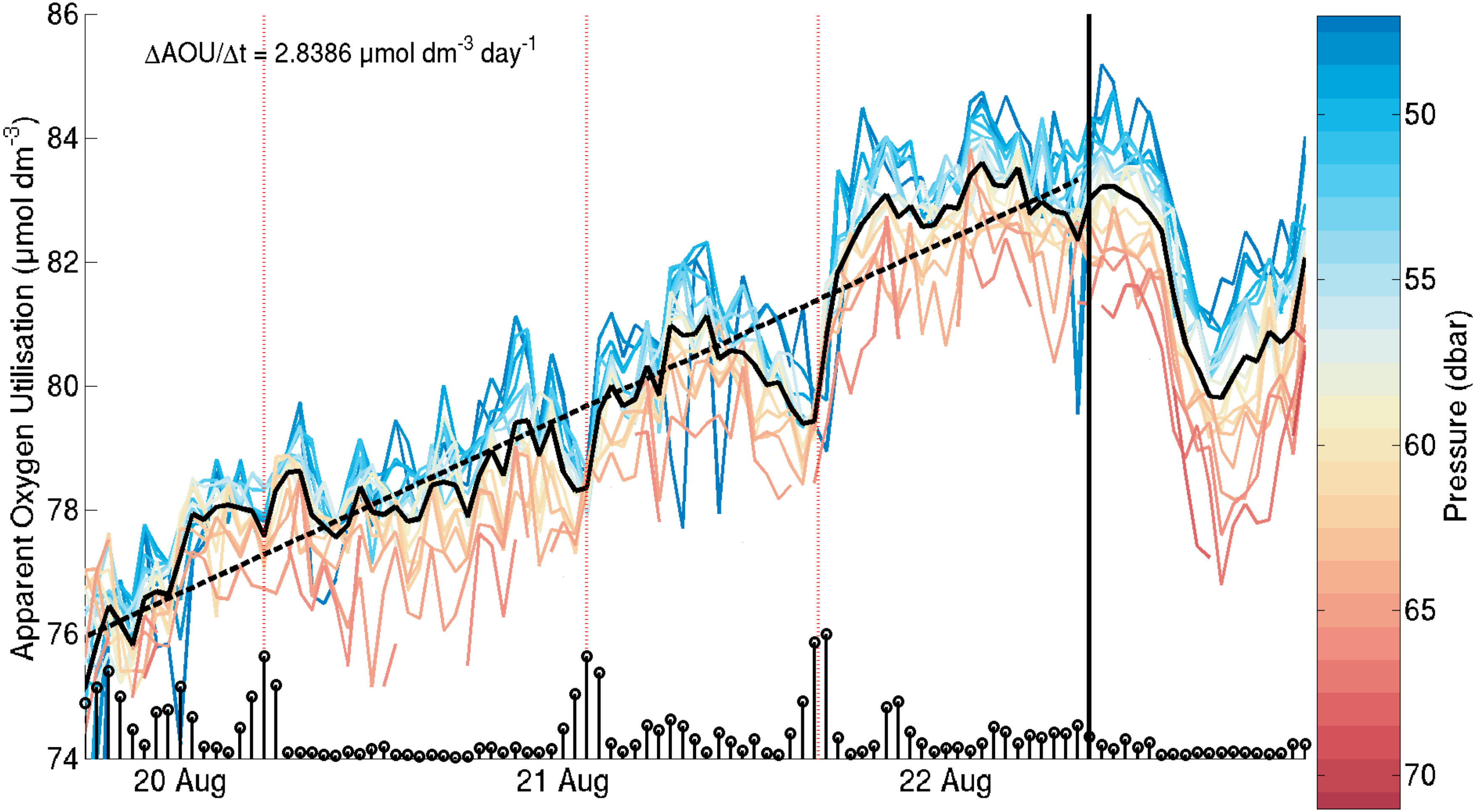
# Submesoscale processes

## How does the oxygen depletion occur




Two layer system – both layers well mixed/uniform

# Submesoscale processes
: : Current balance




ROU: 2.84 μmol $L^{-1}$ $day^{-1}$

# Submesoscale processes

## Resupply : : Vertical mixing

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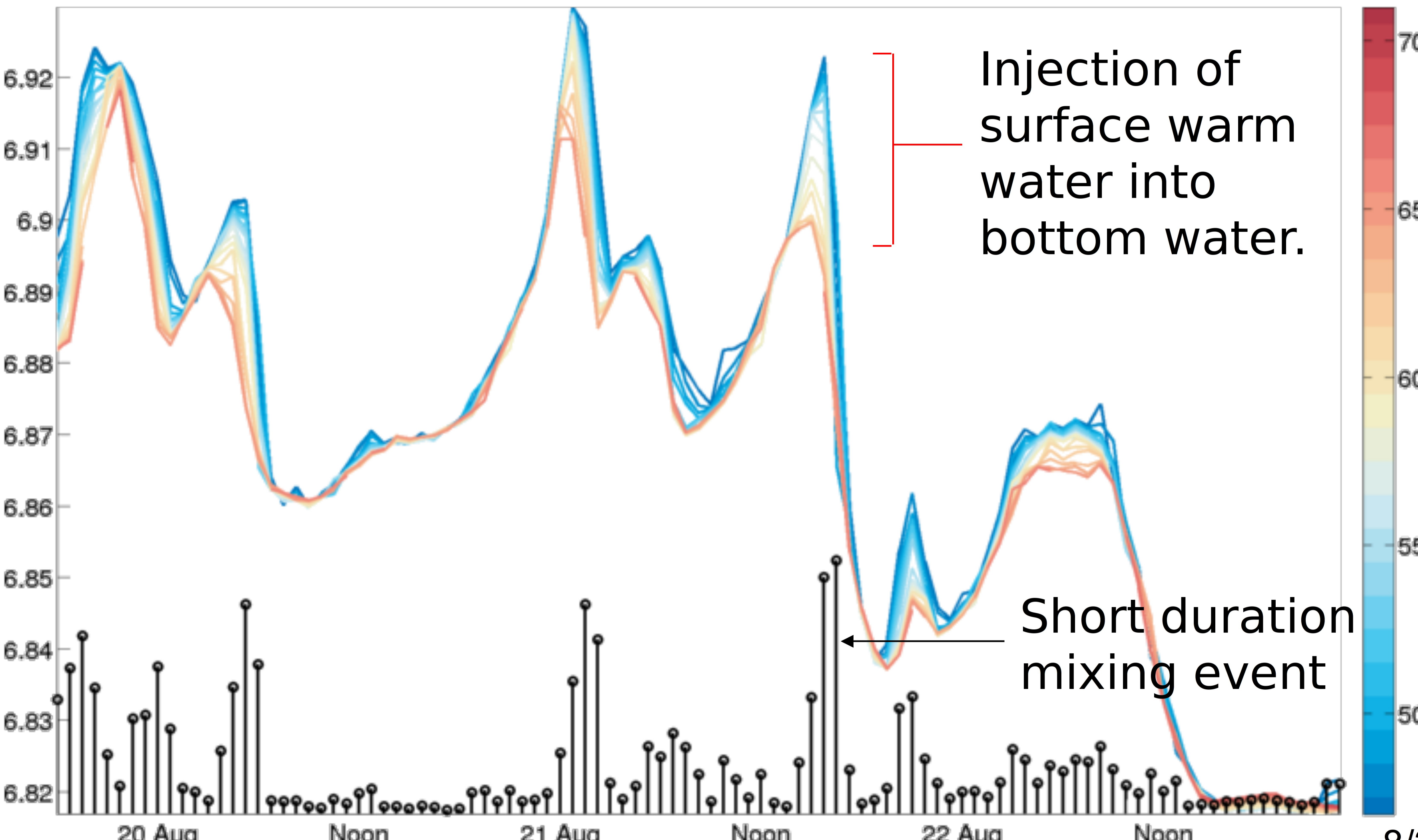
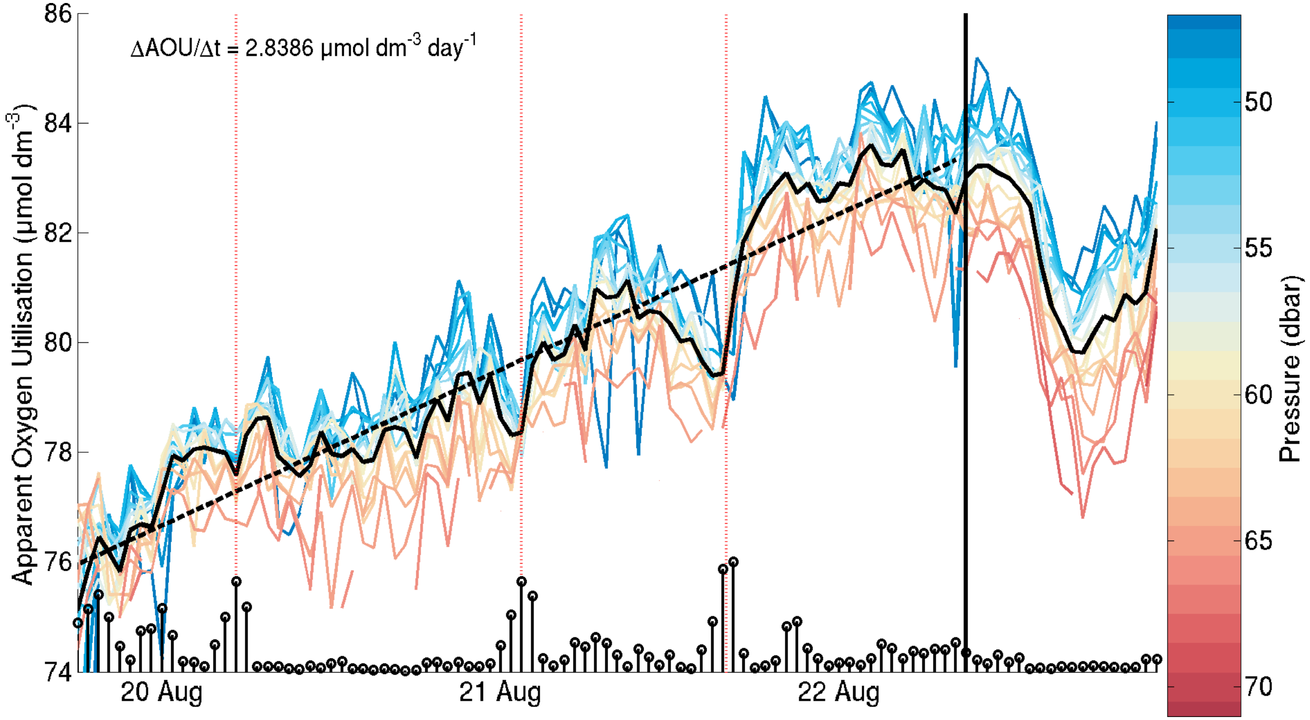


# Submesoscale processes
## : : Effects of mixing




Net balance: -2.84 μmol $L^{-1}$ $day^{-1}$

Have yet to quantify resupply – very difficult to do with current data. However, vertical mixing has a **strong** effect on AOU.

# Submesoscale processes

## Sinks : : Deep chlorophyll maximum

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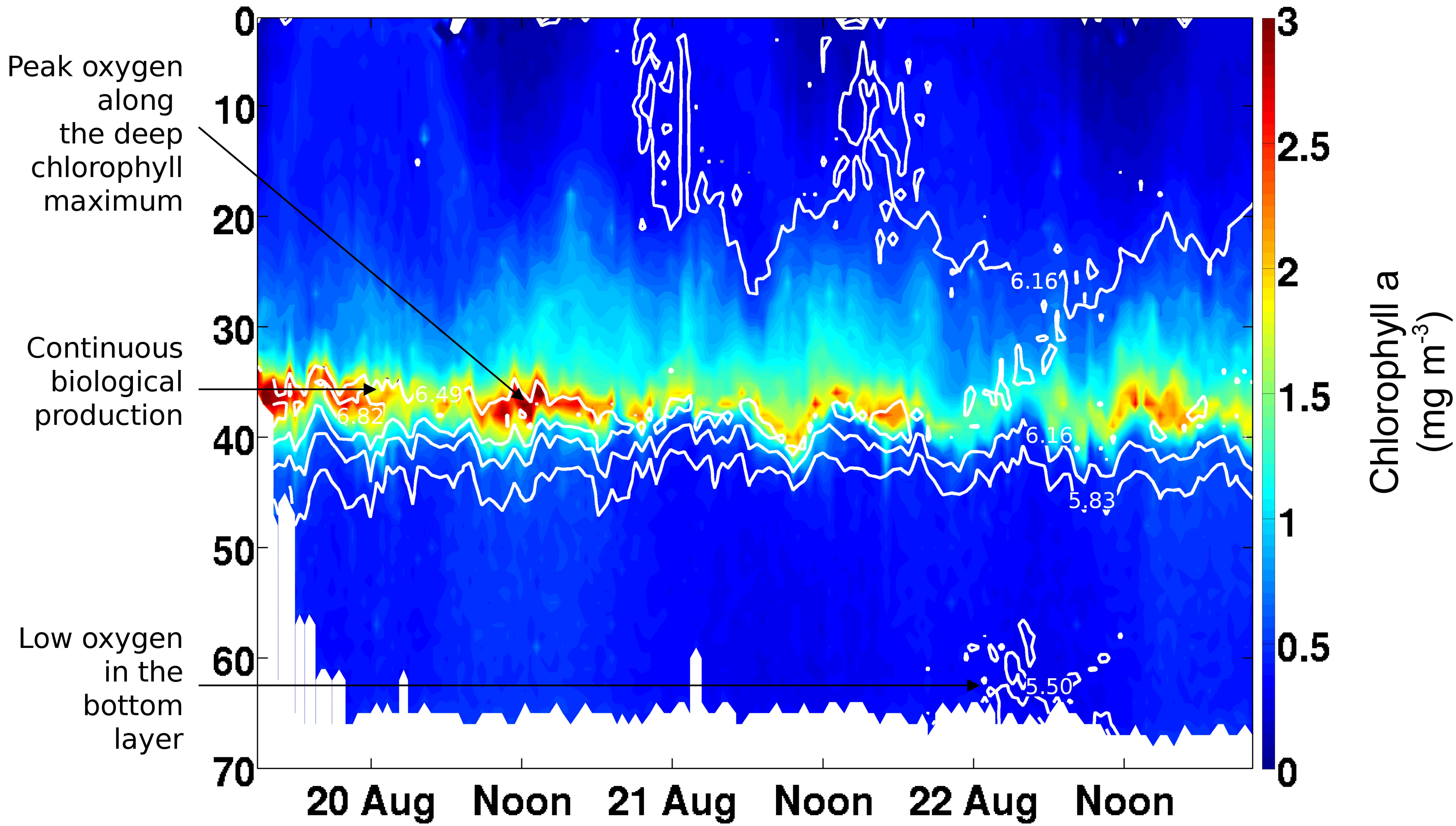


## Submesoscale processes
Sinks : : Deep chlorophyll maximum

Pulses of approx +0.15 mg $m^{-3}$ Chl during mixing events
= export 5.7 mg $m^{-2}$ $day^{-1}$ Chl a

↓ POC/Chl = 50:1

0.285 g $m^{-2}$ $day^{-1}$ C

Equivalent in dissolved oxygen consumption potential:
33.58 mmol $m^{-2}$ $day^{-1}$ or ***0.8 µmol $L^{-1}$ $day^{-1}$***

# Submesoscale processes

## Sinks : : Spring bloom

**Highly productive region.**

GPP 40 to 300 g $m^2$ $yr^{-1}$ of carbon
NPP 150 to less than 15 g $m^2$ $yr^{-1}$ of carbon
with **maximum in the central North Sea area** (north of Dogger Bank).

DCM summer contribution estimated between 58% and 60% of total production in this region (Fernand et al., 2013; Weston et al., 2005).

Most deposited/remineralised already and included in benthic rate, but if we aim for a high end estimate:
***0.6 μmol $L^{-1}$ $day^{-1}$***

# Submesoscale processes

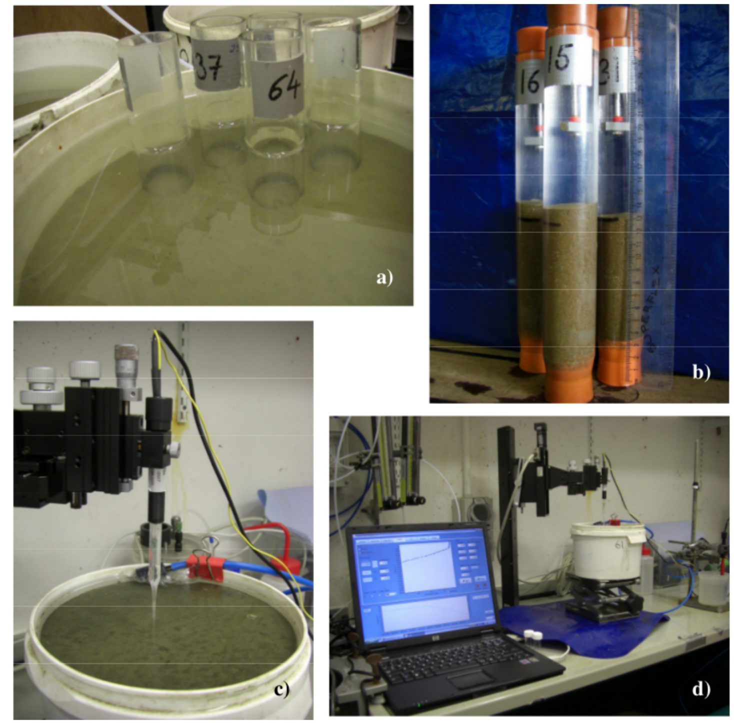
## Sinks : : Benthic processes

17 to 45% of primary production is remineralised in the sediments (*Van Raaphorst et al. 1998*)

DO uptake by the sediment around

250 μmol $m^{-2}$ $hr^{-1}$ (Neubacher, 2009)

**Equivalent to 1.58 μmol $L^{-1}$ $day^{-1}$**




Neubacher (2009)

Oxygen and nitrogen cycling in sediments of the southern North Sea. PhD Thesis.

# Submesoscale processes

## Sinks : : Current balance

DCM = 0.8 μmol $L^{-1}$ $day^{-1}$
Spring bloom = 0.6 μmol $L^{-1}$ $day^{-1}$
Benthic = 1.6 μmol $L^{-1}$ $day^{-1}$
***But these overlap... therefore:***

Benthic + DCM + Spring Bloom << 2.9 μmol $L^{-1}$ $day^{-1}$

Net balance ≈ 2.84 μmol $L^{-1}$ $day^{-1}$

## So where does that leave us?
### Sinks : : Current balance

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Either resupply is **very** small → **FALSE**

*or*

Estimates are wrong:
- temporal variability, delayed response, decoupling

*or*

There exist oxygen sinks which are not resolved here:
- Temporary depocentres (Tyson et al., Van Raaphorst et al.)
- *Pelagic* nitrification/bacterial cycling (*+23%? Johnson, pers comm*)

***Both are very dependent on resuspension events and neither are well represented in North Sea models***

## Recent developments from UEA:

## Ocean2Ice Mission (Amundsen Sea)

## REP14 sensor trials

## New facility under construction

# Since then...
# OCEAN2ICE Mission

3 gliders in the Amundsen Sea, integrated with AutoSub, moorings, ship ADCP and CTD data

Temperature of -15ºC and winds > 60 $km.h^{-1}$ (gusts > 100 $km.h^{-1}$)

The result =

# REP14 Mission

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Includes Seagliders, SLOCUMS, and SeaExplorer instruments.

3 Seagliders piloted by UEA with different aims:

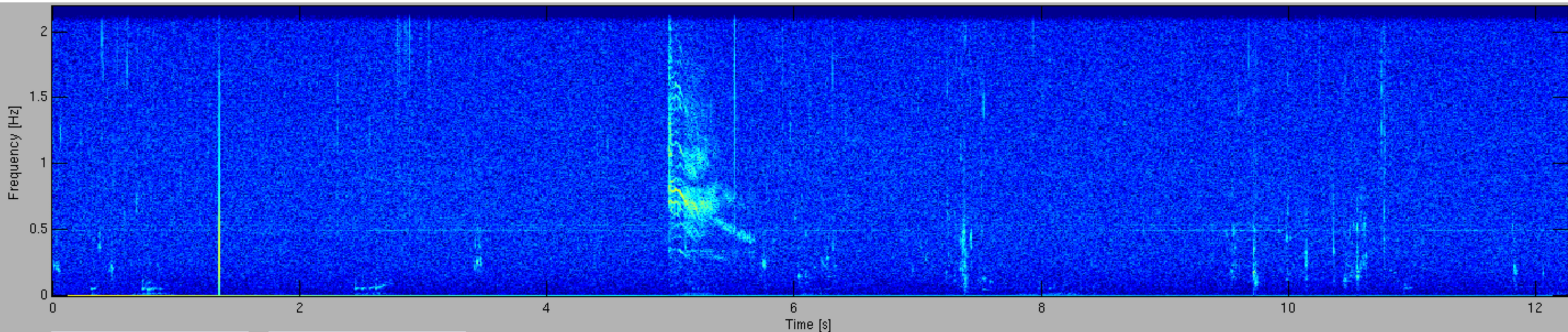
- Improve ogive flight
- Test passive acoustic sensor
- Trial pH/p$CO_2$ sensor

# REP14 Mission:
# Passive acoustic sensor

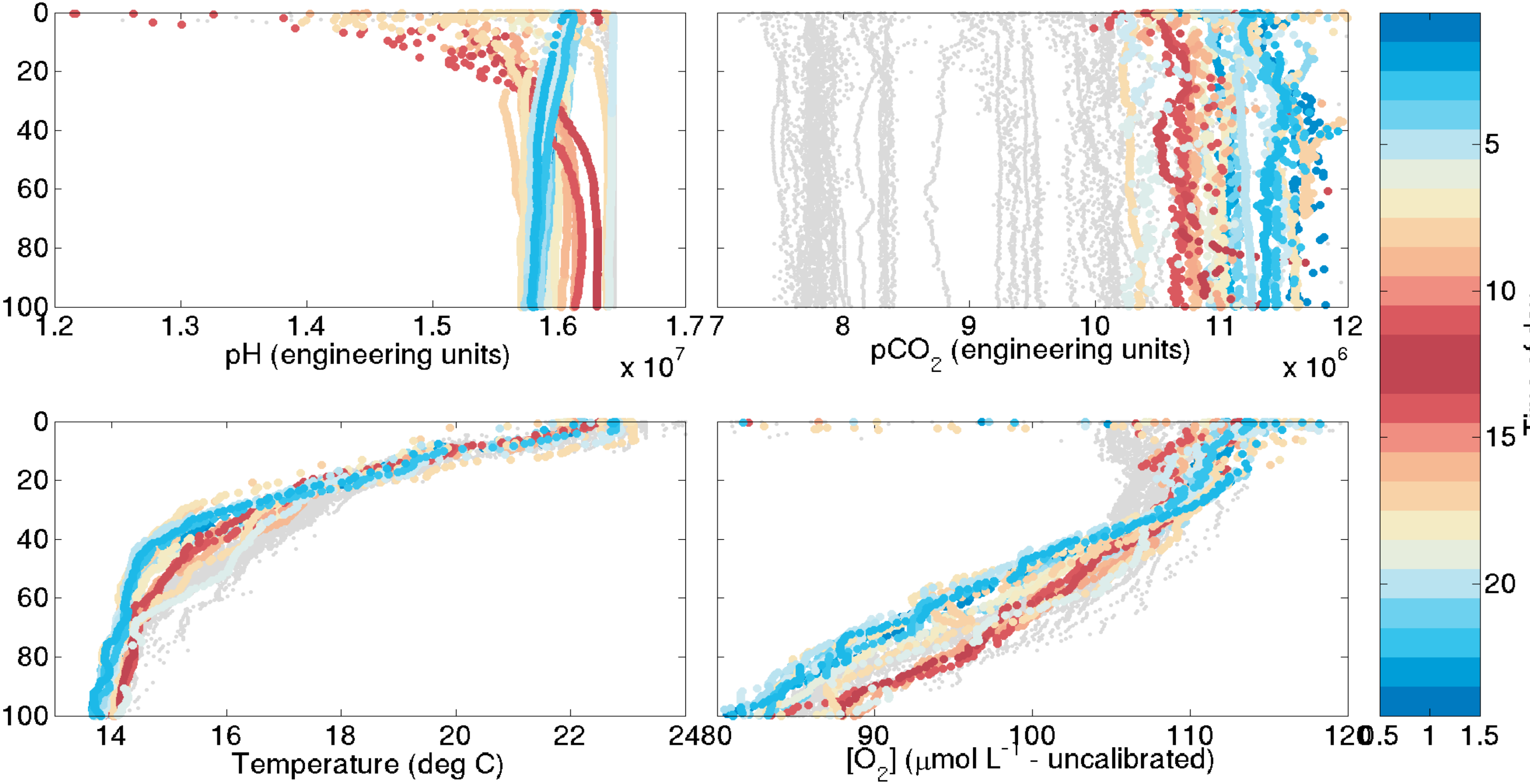
New *integrated* passive acoustic monitoring (PAM) sensor

The broad spectrum (2-50 Hz) WISPR BOARD package includes the following components:

- High Tech, Inc HTI-92-WB Hydrophone
- Embedded Ocean Systems HM1 Wideband Preamplifier
- Embedded Ocean Systems WISPR V1.0 digital signal processing board with Analog Devices BF537E Blackfin CPU



# REP14 Mission
# pH/$pCO_2$ sensor




**SHELF DATA**

# REP14 Mission
# pH/$pCO_2$ sensor

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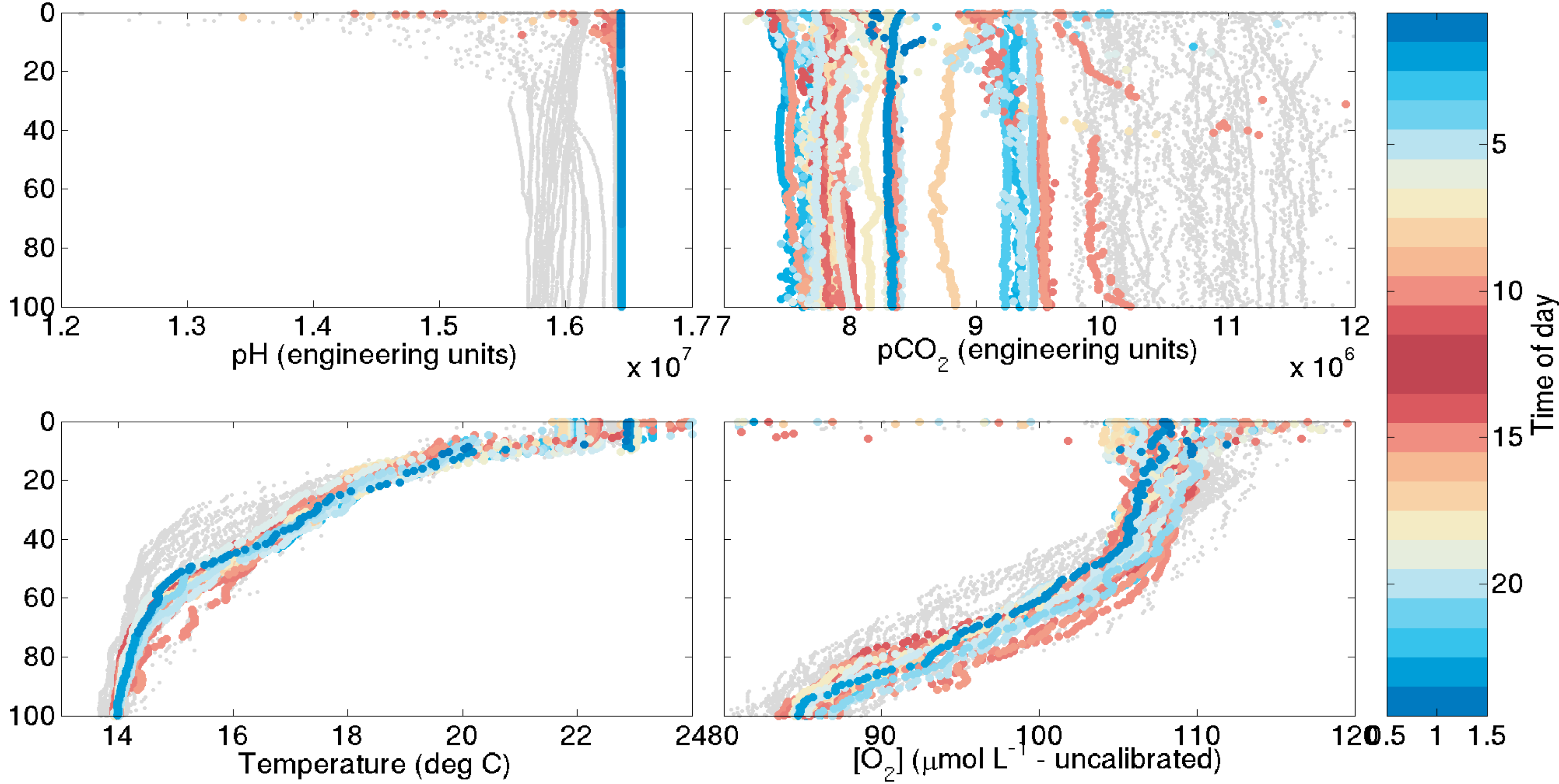
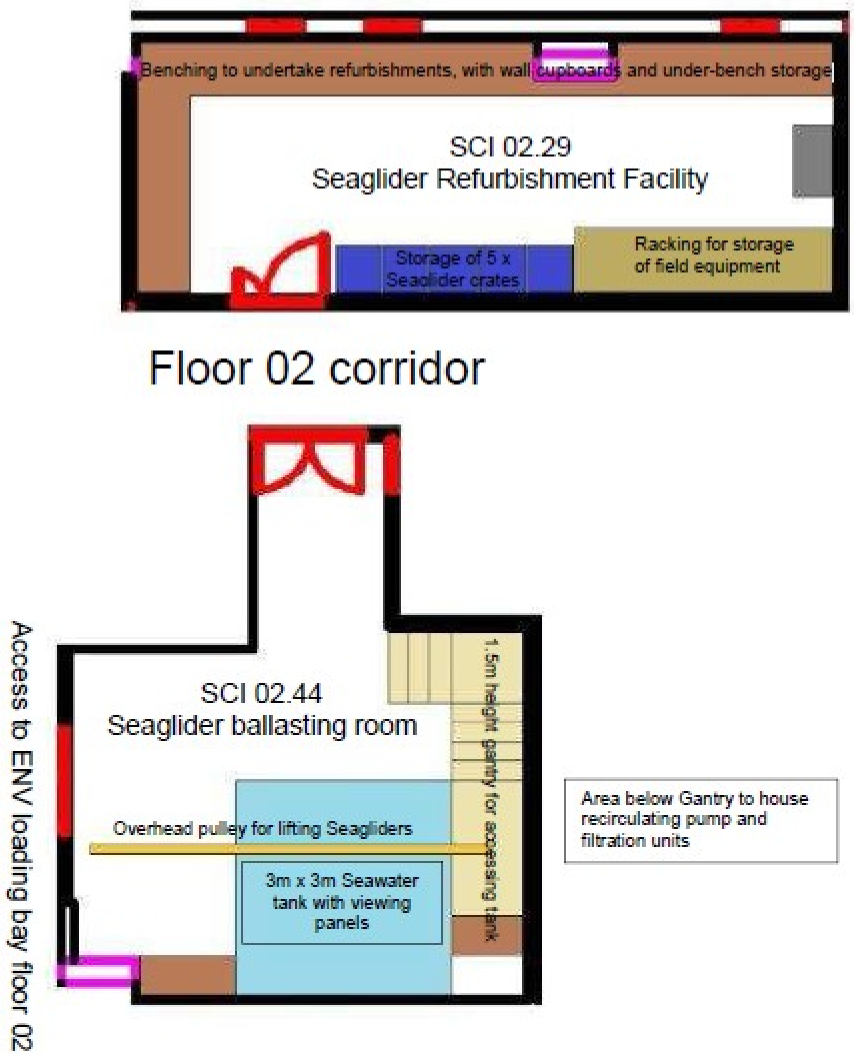



## OFF SHELF

# Proposed UEA Seaglider Facility

**A Plan of the new Seaglider facility incorporating benching, storage space and Seawater tank.**




## Features of the new facility include:

- A ballasting tank with 2 glass sides as a viewing window to showcase Seagliders
- An Iridium repeater to relay iridium communication into the laboratory
- A GPS repeater to relay GPS signals into the laboratory
- A Seabird CT sensor to accurately measure the salinity and thus seawater density for ballasting calculations
- Recirculating pump and filtration to clean and mix the seawater
- Installation of increased benching and storage for our growing fleet of Seagliders
- A presentation area for demonstrating PoS activities to students/VIP's
- An overhead pulley system for lifting Seagliders