Ocean Acidification & pCO2 Research with FerryBox
- Progress towards operational capability -

Dr Boris Kelly-Gerreyn

EuroGOOS FerryBox Meeting, Goteburg 16-17 March 2010

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Special Acknowledgements:
Captains and crews of P&O and Swire ships
Timeline for operational FB system for carbonate system
Two systems

Since 2002

MV Pride of Bilbao

Since 2007

Dr Boris Kelly-Gerreyn bag@noc.soton.ac.uk
Two systems

**MV Pride of Bilbao**

**Aanderaa**
- T, S, O2

**Seabird**
- Hull T

**Turner C3**
- Chl-Fluorescence
- CDOM
- Turb

**Discrete samples**
- S, Nutrients, Chl,
- DIC and TA

**Robotic Sampler**
- Pigments

**ProOceanus:**
- pCO2 & GTD

**Aanderaa**
- T, S, O2

**Seabird**
- Hull T

**Discrete samples**
- S, DIC and TA

**Vaisala**
- Atmos CO2
- Met data

Collected by ship’s crew

Since 2002

Since 2007

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Welcome to the Ferrybox project

Life on Earth

The oceans are vital to life on Earth. They provide food and oxygen, they regulate the climate and they are home to an incredible diversity of life. The Ferrybox project is exploring the marine environment in the North Sea and its impact on the biological processes that affect the climate.

Current threats

10,000 tonnes of phosphates a day - a plant accelerator - may be entering the English Channel from farmers at the bottom of the sea. These levels of phosphates, if we could see it, we’ve never seen before. What do you think of? What more would you like to see happening here? How could we change it?

The live monitor display

You are watching a live display of data collected in support of the Pride of Bilbao ferry project. The data is being transmitted in real-time to the control room on board the ferry. The data is used to monitor the vessel’s performance and to make decisions about its operations.

Passenger Feedback Forms

The Ferrybox Project

Diane Gold, Chief Executive

The Pride of Bilbao Ferry Project

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SNOMS tank and data logger in the machinery space on the MV Pacific Celebes
Robust system serviceable by ships crew

Chief Engineer
Crew enthusiasm
Motivational questions

- Oceans sequester $\sim 1/4$ of our CO2 emissions

- This reduces the potential rate of climate change

BUT

- how long will this keep going on for and
- what impact on marine ecosystems (services)?

Moving from a science understanding to operational oceanography
How much CO2 is removed by the oceans?

Best estimate from Takahashi et al., 2009
The global database for CO2 is full of holes

Takahashi et al., 2009

No year to year information either
Commercial ships can fill the holes

Oceanography all day everyday AND everywhere

Is this an operational FB network?

FB partnership is leading the way in how best to do this
The current global network is small

International Ocean Carbon Coordination Project

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Filling the holes and improving the information

Hydes et al. (in review)

Takahashi (best estimate) Data

Pacific Celebes pCO2 Data

- Carbon sequestering underestimated
- Robust repeat measurements needed

Track between Gibraltar and the USA

National Oceanography Centre, Southampton
Dr Boris Kelly-Gerreyn bag@noc.soton.ac.uk
How good are pCO2 sensors

ACT Trials: Intercomparison of the major players has just been completed in Hawaii

Results are pending, so the jury is currently out

• SAMI pCO2
• ProOceanus pCO2
• Contros pCO2
• Others, including General Oceanics
Ocean Acidification
More CO2 in the oceans = lower pH

Chemistry is well understood

Biological response not well understood
Impact of OA on Marine Ecosystem

Emiliania Huxleyii

No sensor technology exists

How does OA affect its ability to produce coccoliths
- a process called calcification

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Conflicting Results from key Lab Studies

What about in nature?

Less calcified at higher pCO₂

Calc rate (pMol CaCO₃ cell⁻¹ d⁻¹)

pCO₂ (μatm)

Riebesell et al 2001
Iglesias-Rodriguez et al 2008
Langer et al 2009
FerryBoxes provide seasonal cycles of ancillary data

Regional Salinity

Regional Temperature

Regional O2 Anomaly

Regional Nutrients

How close to being operational?

On trial
Discrete sampling gives carbonate data

DIC

pH

Alkalinity

Discrete sampling gives carbonate data
CaCO$_3$ Saturation Lowest in Winter in all regions

Expectation is less calcified Ehux in winter

From measurements of DIC and alkalinity on PoB ferry crossings

(Dumousseaud et al. 2009. *Biogeosciences Discuss.*, 6: 9701-)

But overcalcified in Winter!

% E. huxleyi coccospheres overcalcified

>95% overcalcified in Winter!

<5% overcalcified
Anticorrelation of $\Omega$ and Calcification

In-situ data DOES NOT suggest a lowering of calcification on *Emiliania huxleyi* due to OA
Summary

1. Straightforward lab to nature studies on OA.

2. Manual discrete sampling (probes?)

3. *Emiliania huxleyi* calcification found to vary with season in nature.

4. Reason for the seasonal shift is not at all understood.

5. Expected sensitivity to OA is not observed.

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• Oceanic CO2 uptake currently undersampled – CC is a major driver for this to be overcome

• Appropriate monitoring of CO2 sequestration by the ocean can be achieved with FBs / SOOs

• Encouraged collaboration with other CO2 groups (Canada, New Zealand, USA)

• Some work needed before such work is operational i.e.

When autonomous pCO2, DIC and pH measurements become the norm and we’ve worked out optimal data processing.
Timeline for operational FB system for carbonate system

Science Questions/Policy drivers → Biology

Development & testing

Chemistry

Operational
Future

• SCIENCE
  • Extend the studies to high latitudes and Pacific ocean-shelf regions
    - is the response the same?
  • Impacts on coral reefs?

• ASSESSMENTS
  • Intercomparison of pCO2 measurements in Pacific region for community
    synthesis into 5th IPPC Report

• DEVELOPMENT
  • Ongoing testing of reliability and robustness of pCO2 sensors.
  • Development, deployment and testing of pH and DIC sensors (JERICO)
  • Continue working out how best to QC the data (JERICO + MyOcean input)
  • Enhance passenger display for user interactivity and web access (JERICO)

• FIND A NEW SHIP: Brittany Ferries? Or move to Hebridean Shelf or ?????
Invading CO2 is Reducing Carbonate Ion Concentration

Aragonite Saturation
Calcite Saturation

[Jim Orr]
As pCO2 increases, pH decreases.
CO2 Influx is Altering Carbon Chemistry

(Doney, March 2006, Scientific American, 38-45)
Inorganic Calcification dependent on Saturation State

$$\Omega = \frac{[\text{CO}_3^{2-}] \times [\text{Ca}^{2+}]}{K_{sp}'}$$

Undersaturation

Dissolution

Super-saturation

Precipitation

Ω numberline
Robust Results

Cynthia's paper shows between years: temperature is dominant signal in differences in air-sea exchange of pCO2.

But seasonality of DIC dominated by biology.
Impact of OA on Marine Ecosystem

Emiliania
Sediment Trap Samples Suggest Less Calcified in Winter

‘closed’ morphotype
heavily calcified
Type A overcalcified

‘open’ morphotype
lightly calcified
Type A

Coccolithophores collected from sediment trap at 1900m water depth, possible lateral transport

Robust Results

1. Based on direct sampling of surface water
2. Straightforward and reliable method (appearance of cells in SEM images)
3. Pattern is repeating this winter (shift to overcalcified again)
4. Dominance of normal Type A is also seen in previous summers (2006 and 2007)
5. 22 crossings in total, >300 sampling stations
6. ~60,000 SEM images studied in total
7. Statistics support a highly significant trend (p ≪ 0.01)
Cause of Phenomenon is Unclear

1. High $\Omega$ (CaCO$_3$ saturation)  
2. Low [PO$_4$]  
3. High temperature  
4. Low temperature (Sorrosa et al., 2005)  
5. High light intensity  
6. Slow growth (cf. diatoms)  
7. Overwintering resting stage

Is it a genotypic or a phenotypic shift?
How good are pCO2 sensors

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• SAMI pCO2
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• Contros pCO2
• Others?
Several Lab Studies of *E. huxleyi* response to OA

**letters to nature**

**Reduced calcification of marine plankton in response to increased atmospheric CO₂**

Ulf Riebesell *et al.*

*Alfred Wegener Institute for Polar and Marine Research, P.O. Box 120161, D-27515 Bremerhaven, Germany*

**RESEARCH ARTICLES**

**Phytoplankton Calcification in a High-CO₂ World**

M. Debora Iglesias-Rodriguez,†† Paul R. Hallinnas,‡‡ Rosalind E. M. Rickaby,‡ Ian R. Hall,‡ ila Colmenero-Hidalgo,*† John K. Gittins,† Caryn E. B. Green,* Toby Tyrrell,* Samantha J. Gilks,* Peter von Dassow,* Eric Behrens,* E. Virginia Aramant,* Kari P. Boeschekolb*

Ocean acidification in response to rising atmospheric CO₂ partial pressures is widely expected to reduce calcification by marine organisms. From the mid-Mesozoic, coccolithophores have been major calcium carbonate producers in the world's oceans, today accounting for about a we present laboratory evidence that coccolithophore species *Emiliania huxleyi* are. Field evidence from the deep ocean is that over the past 2.2 Ma there has been data show that coccolithophores are already to rising atmospheric CO₂ partial pressures, al modeling of future ocean and climate.

**Strain-specific responses of *Emiliania huxleyi* to changing seawater carbonate chemistry**

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Definitions

“Operational Oceanography can be defined as the activity of systematic and long-term routine measurements of the seas, oceans and atmosphere, and their rapid interpretation and dissemination.”

EuroGOOS

Requires pull through of science

Learning from science driven questions involving sensor technology

Policy driver: Carbonate data are specified in European Marine Strategy Framework Directive