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

Dr Boris Kelly-Gerreyn

National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

EuroGOOS FerryBox Meeting, Goteburg 16-17 March 2010

Toby Tyrrell
Helen Smith
Laura Pettit
Anastasia Charalampopoulou

Cynthia Dumousseaud
Becky Garley
Eric Achterberg
David Hydes

Support

Special Acknowledgements:

Captains and crews of P&O and Swire ships

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

Timeline for operational FB system for carbonate system

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Two systems

Since 2002

MV Pride of Bilbao

Since 2007

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discovering the unknown

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Two systems

Since 2002

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

Since 2007

Vaisala
Atmos CO2
Met data

ProOceanus:
pCO2 & GTD
Aanderaa:
T, S, O2
Seabird
Hull T
Discrete samples
S, DIC and TA

Collected by ship's crew

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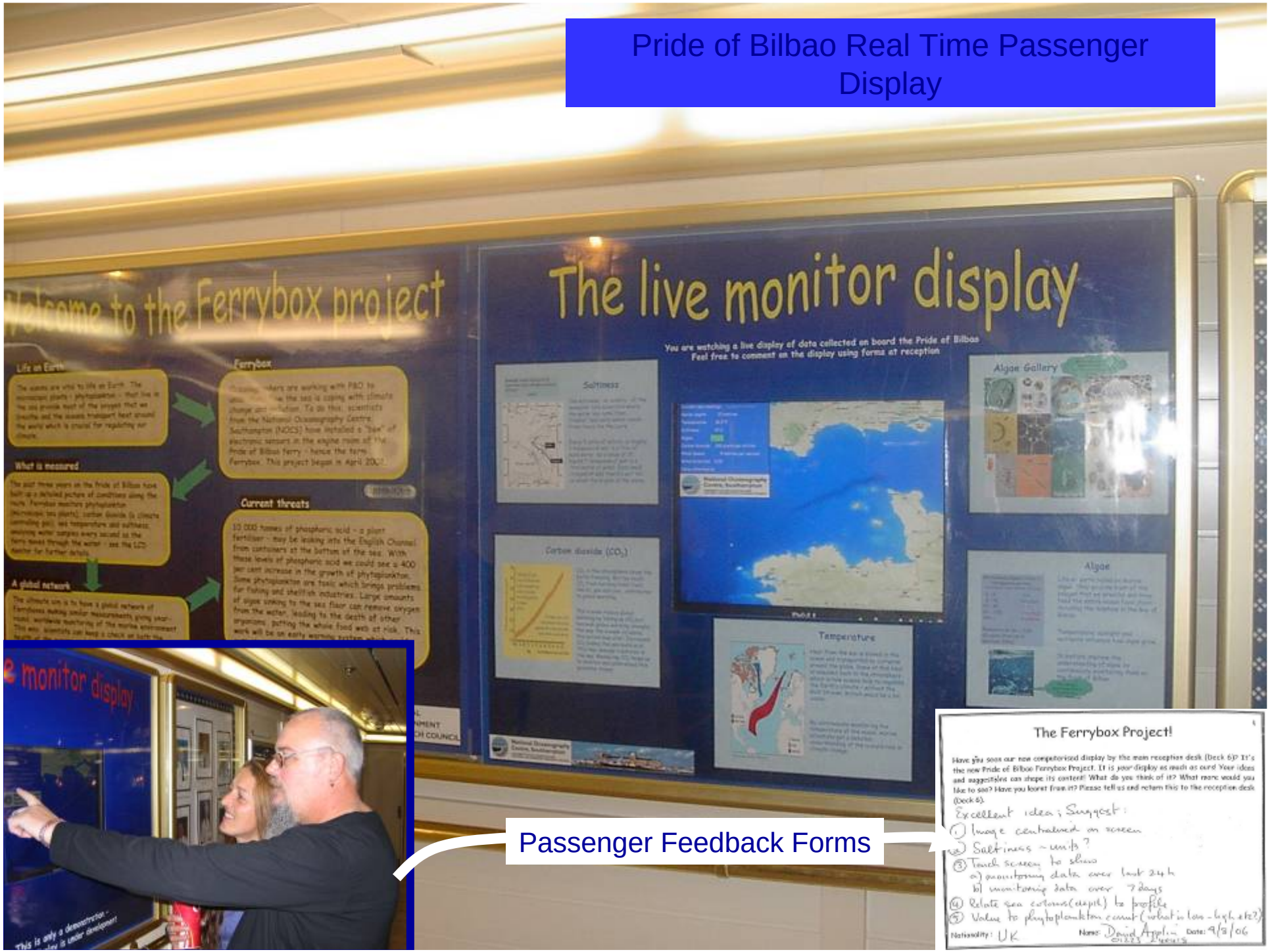
Pride of Bilbao Real Time Passenger Display



Passenger Feedback Forms

The Ferrybox Project!

Have you seen our new computerised display by the main reception desk (Deck 6)? It's the new Pride of Bilbao Ferrybox Project. It is your display as much as ours! Your ideas and suggestions can shape its content! What do you think of it? What more would you like to see? Have you learnt from it? Please tell us and return this to the reception desk (Deck 6).

Excellent idea; Suggest:
1) Image centralised on screen
2) Saltiness - units?
3) Touch screen to show
   a) monitoring data over last 24 h
   b) monitoring data over 7 days
4) Relate sea customs (depth) to profile
5) Value to phytoplankton count (what is low - high etc?)

Nationality: UK Name: David Appleton Date: 9/8/06

SNOMS tank and data logger in the machinery space on the MV Pacific Celebes

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Robust system serviceable by ships crew

Chief Engineer

Crew enthusiasm

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Motivational questions

- Oceans sequester ~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

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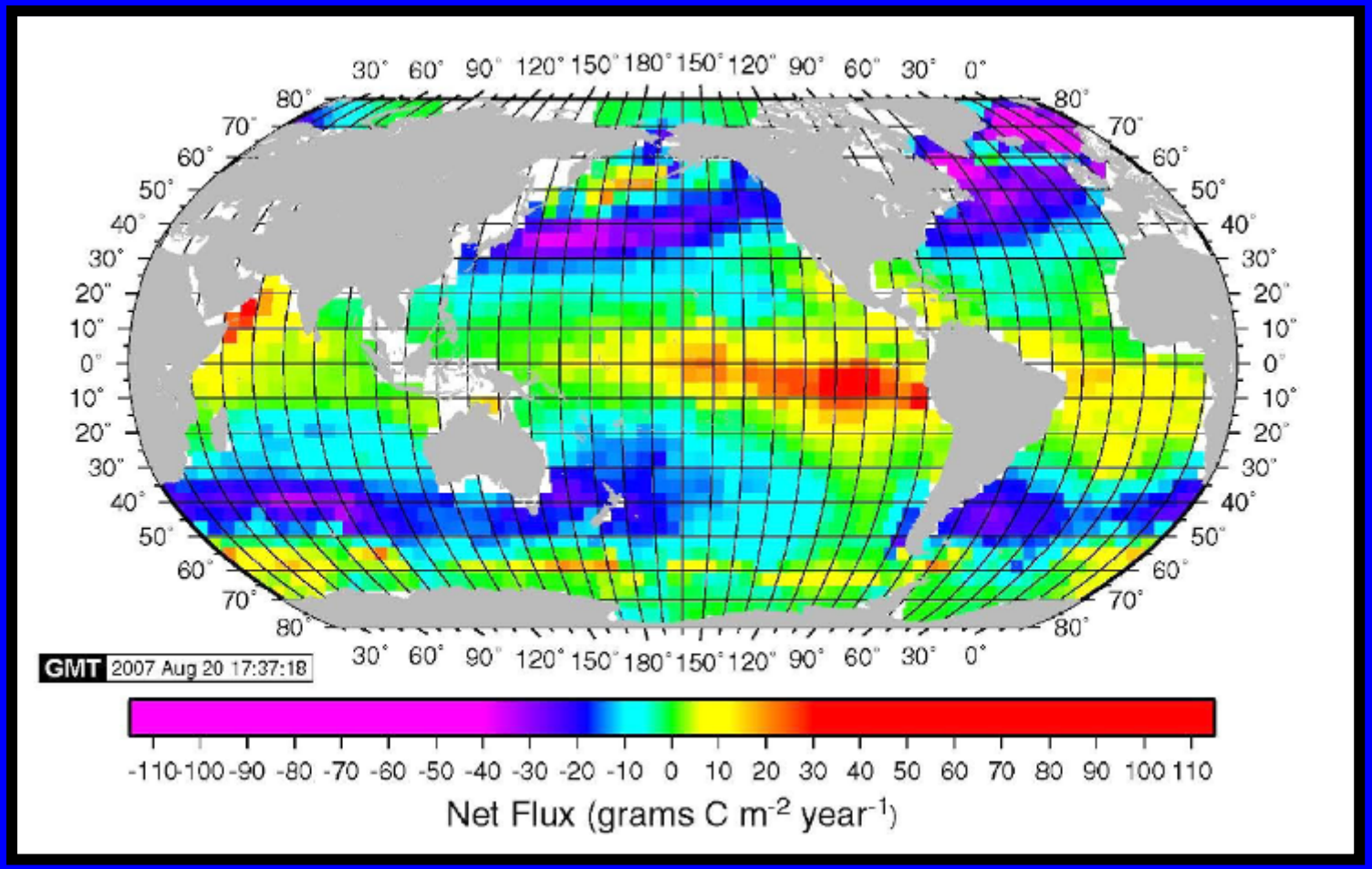
How much CO2 is removed by the oceans ?



Best estimate from Takahashi et al., 2009

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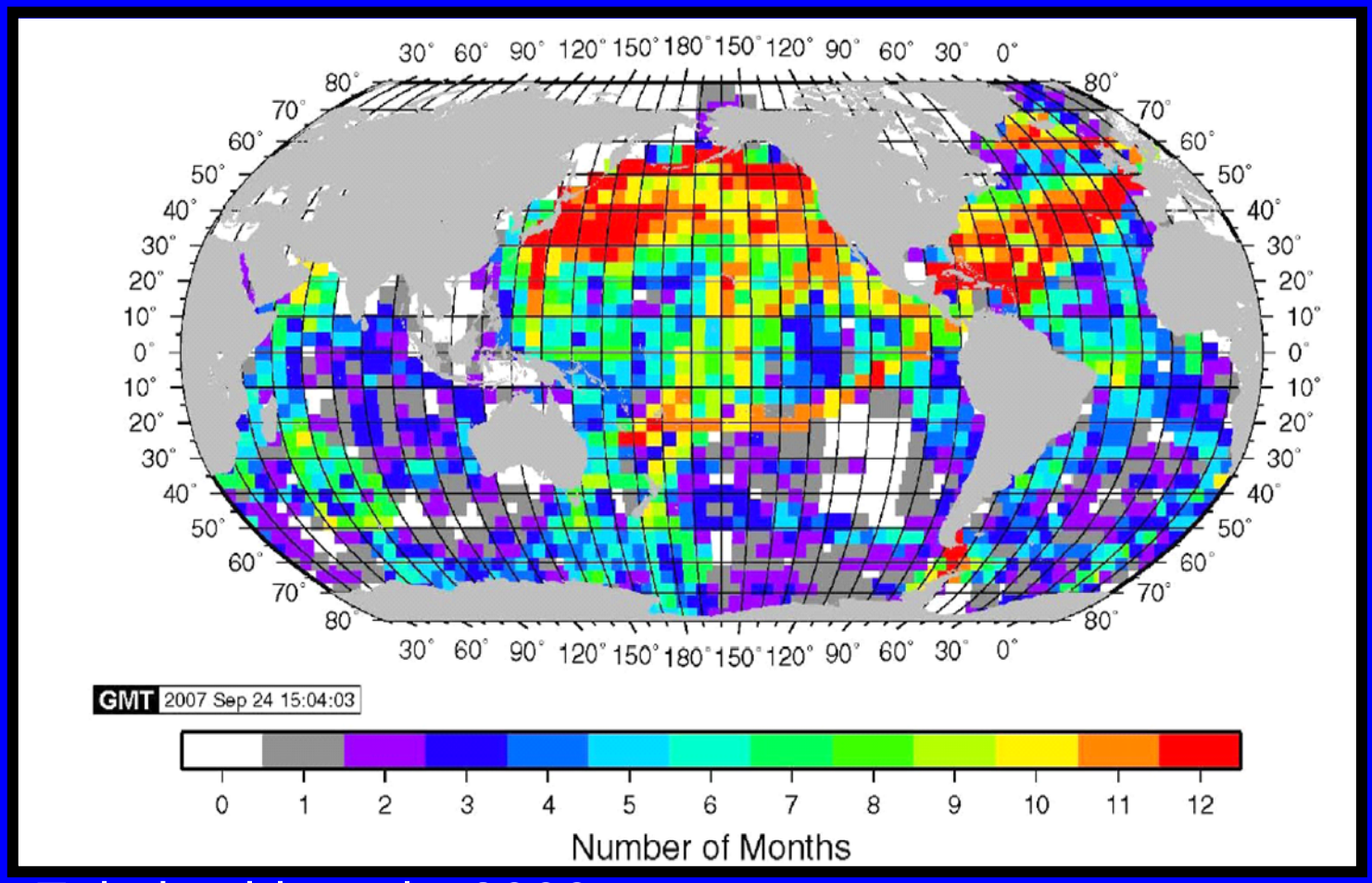
The global database for CO2 is full of holes



Takahashi et al., 2009

No year to year information either

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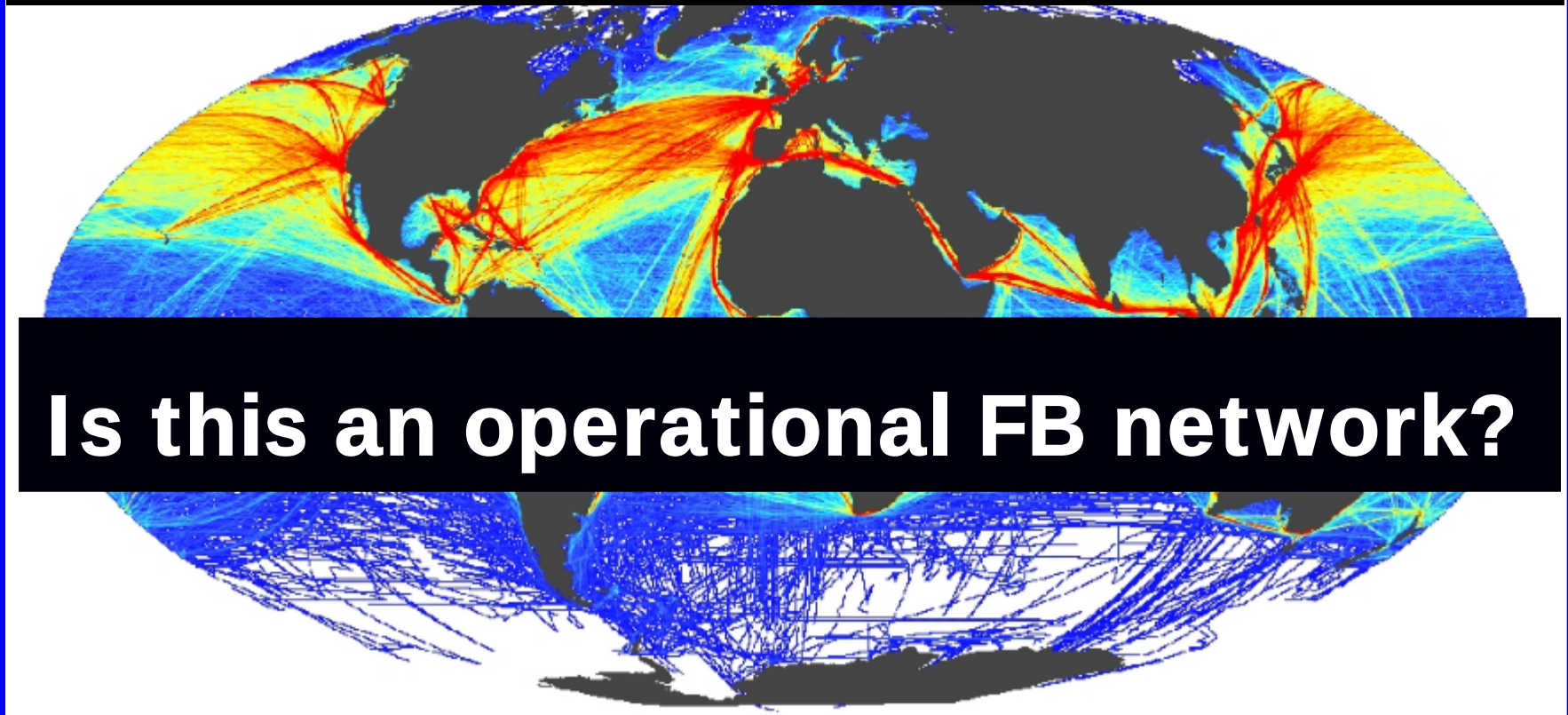
Commercial ships can fill the holes

Oceanography all day everyday AND everywhere



Is this an operational FB network?

FB partnership is leading the way in how best to do this

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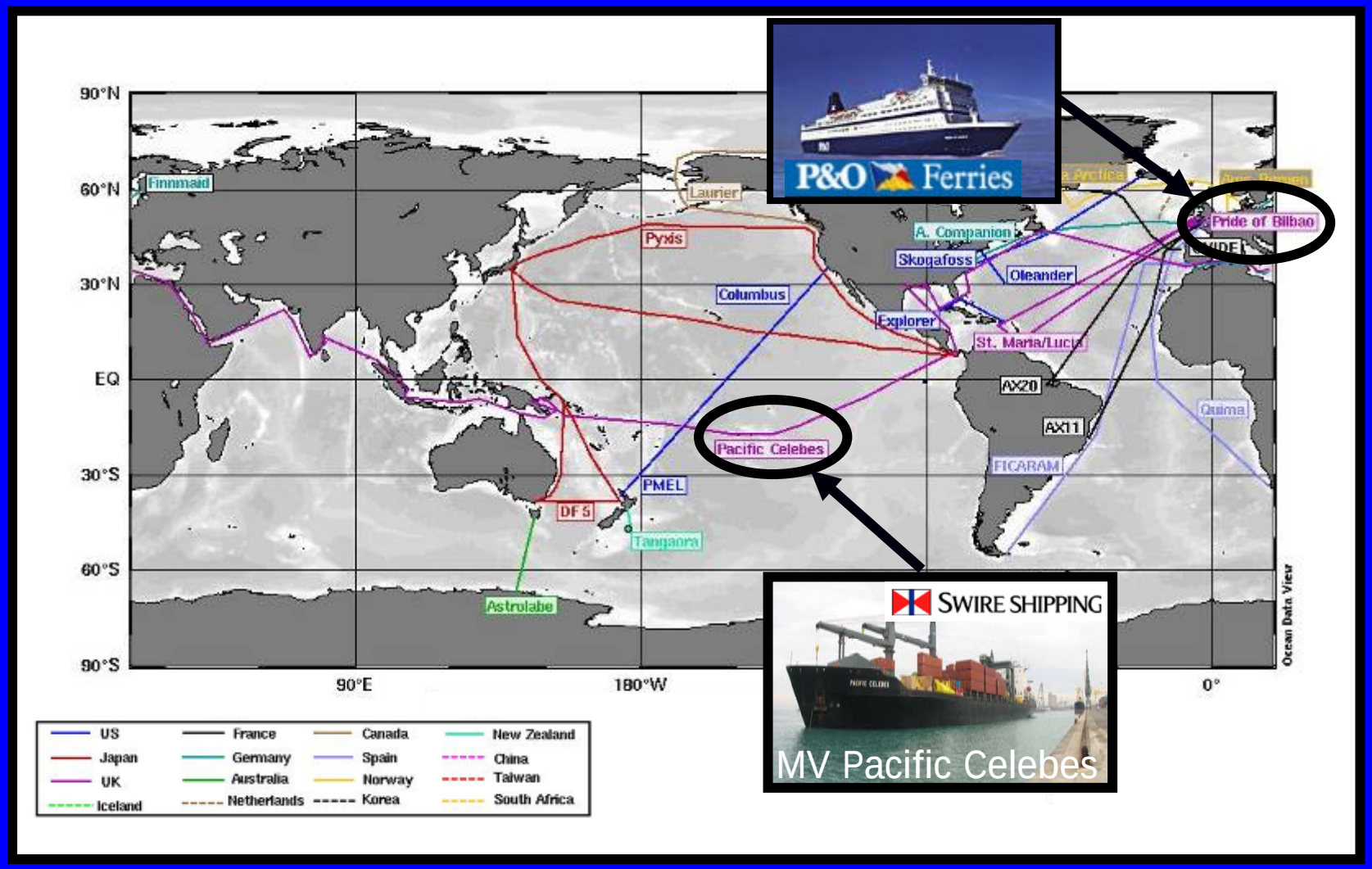
The current global network is small



International Ocean Carbon Coordination Project

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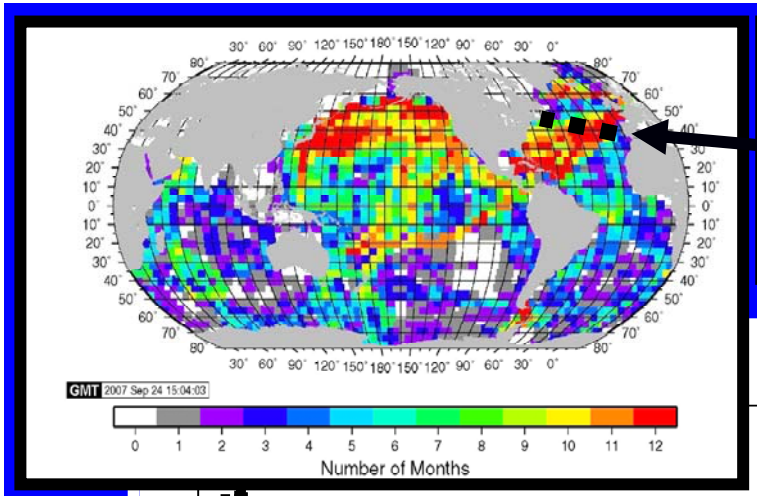
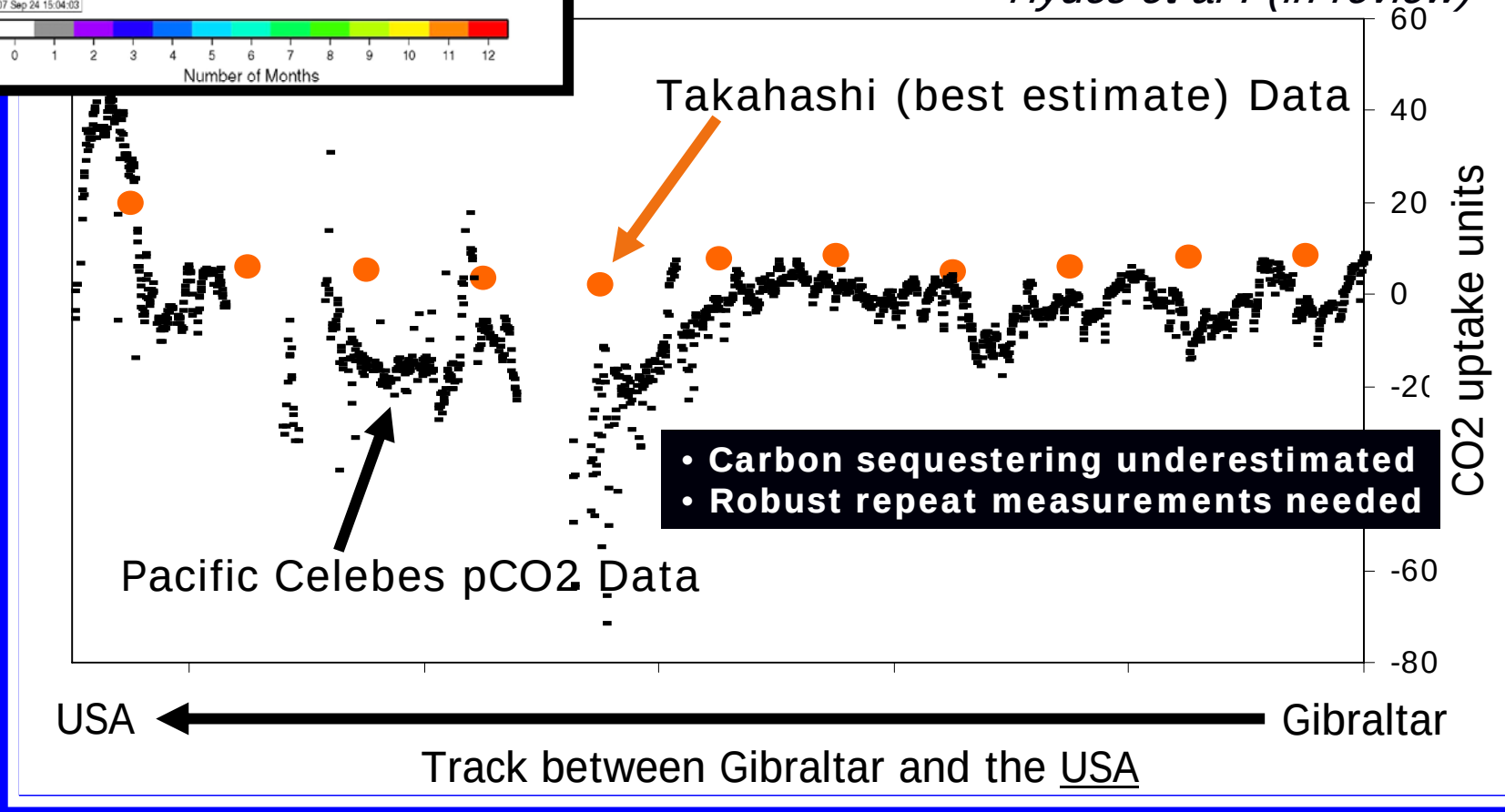


Filling the holes and improving the information

Hydes et al . (in review)



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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

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Ocean Acidification
More CO2 in the oceans = lower pH

Chemistry is well understood

Biological response not well understood

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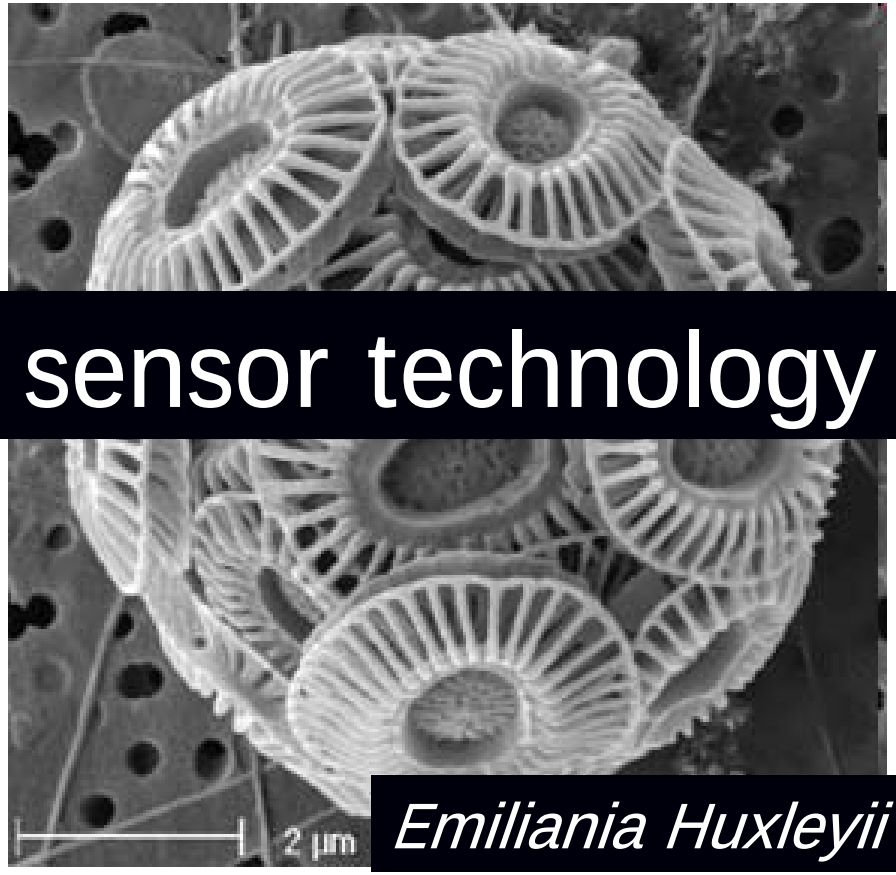
Impact of OA on Marine Ecosystem



No sensor technology exists

Emiliania Huxleyii

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

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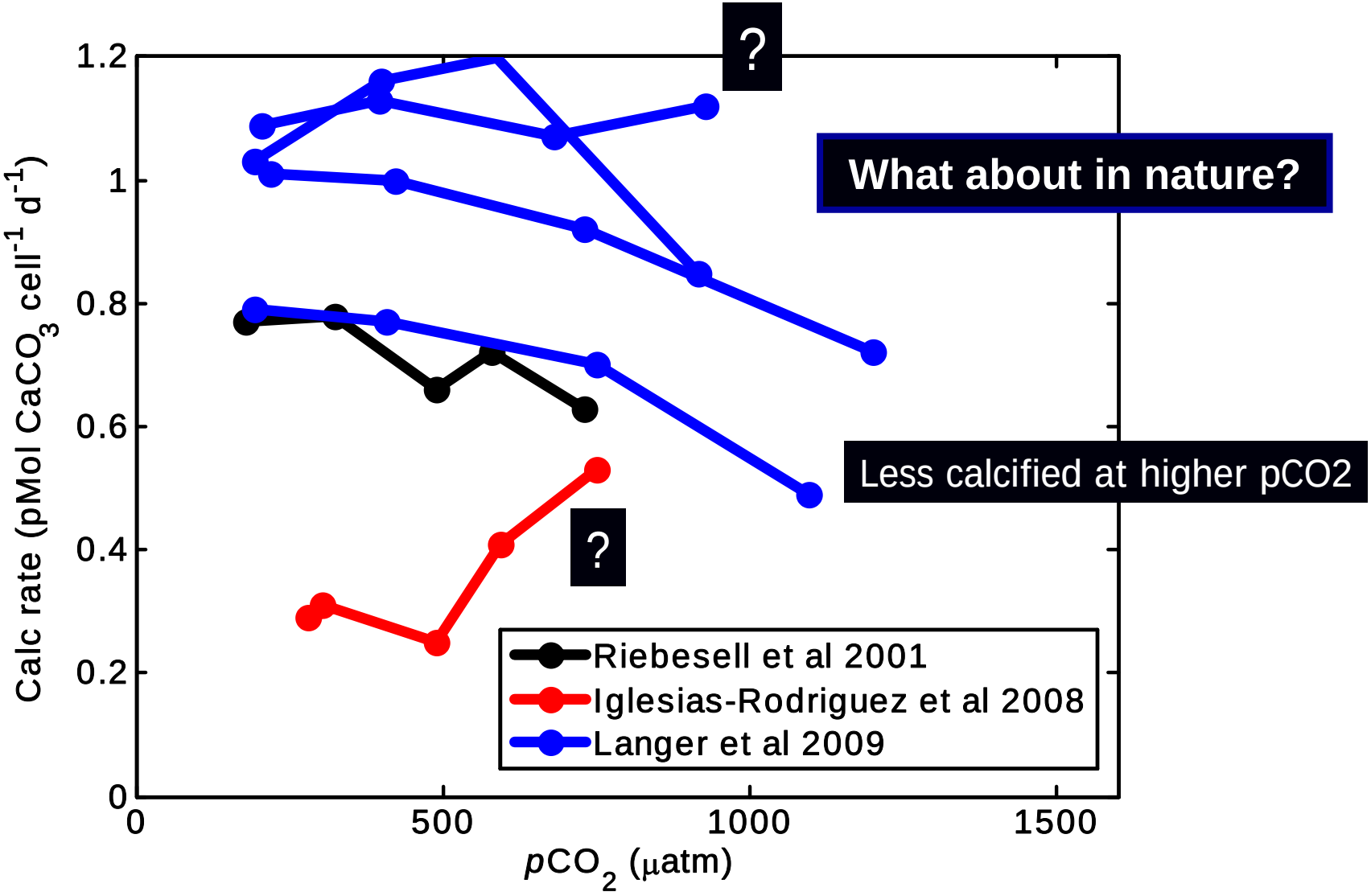
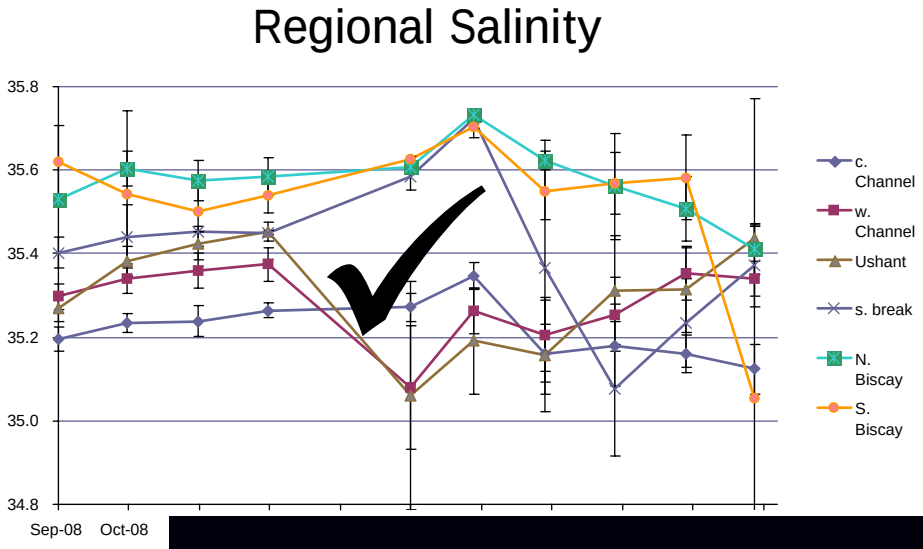
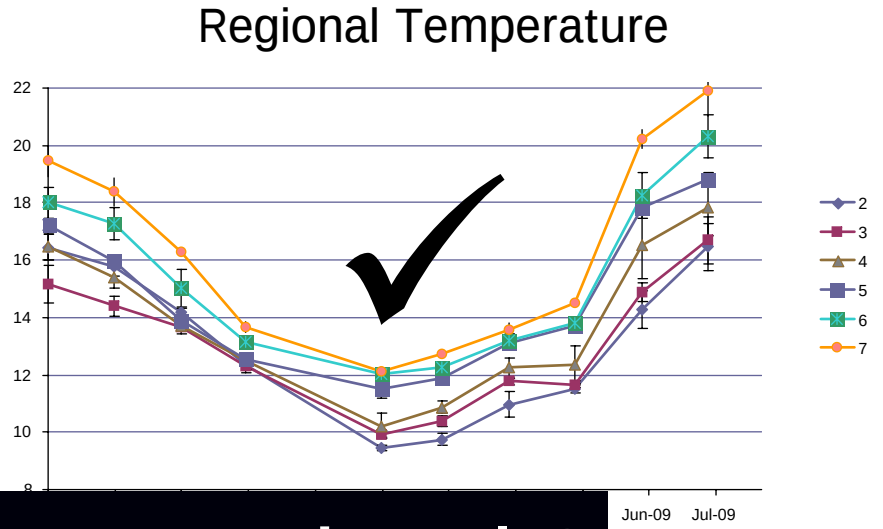
Conflicting Results from key Lab Studies

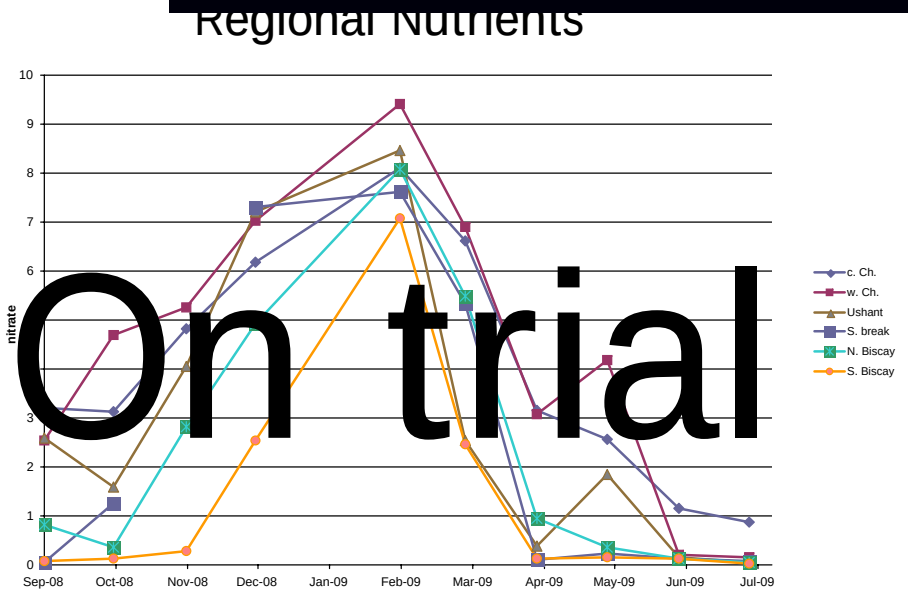


FerryBoxes provide seasonal cycles of ancillary data

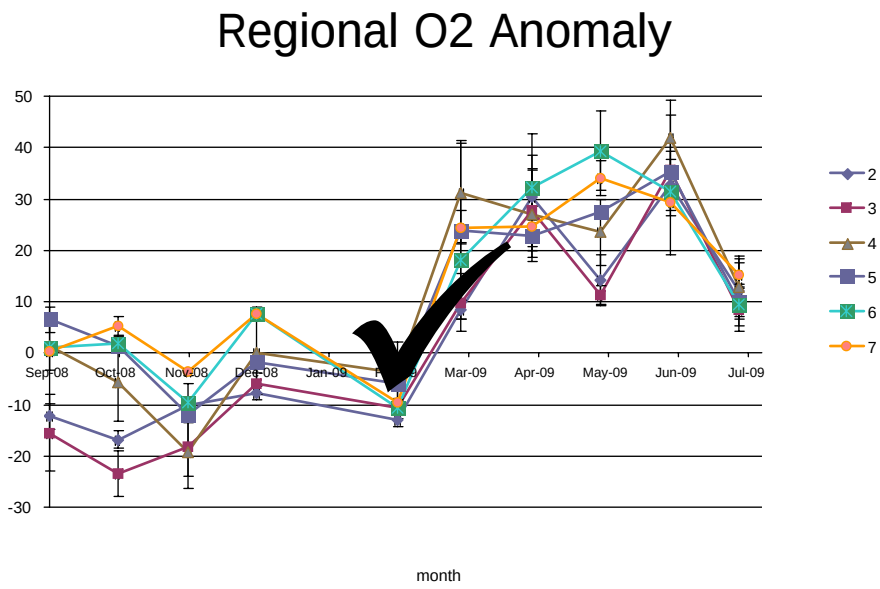




How close to being operational ?

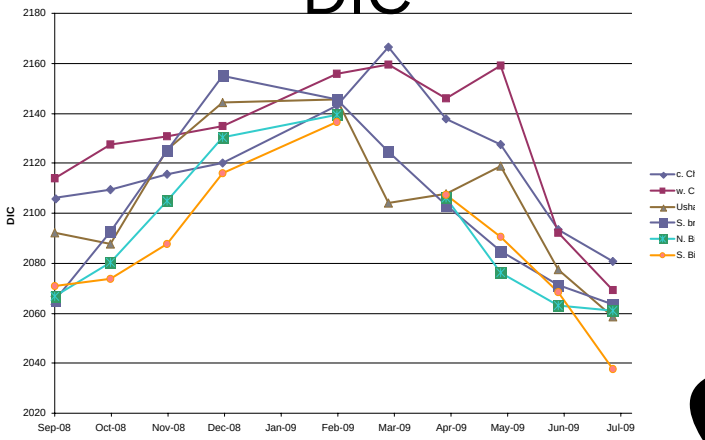


On trial

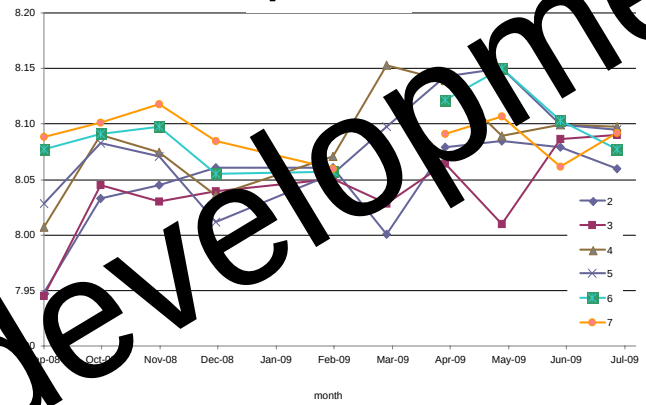


Discrete sampling gives carbonate data

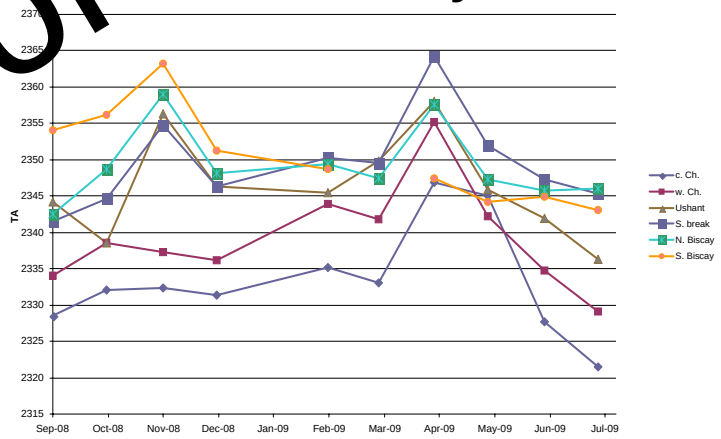
DIC



pH



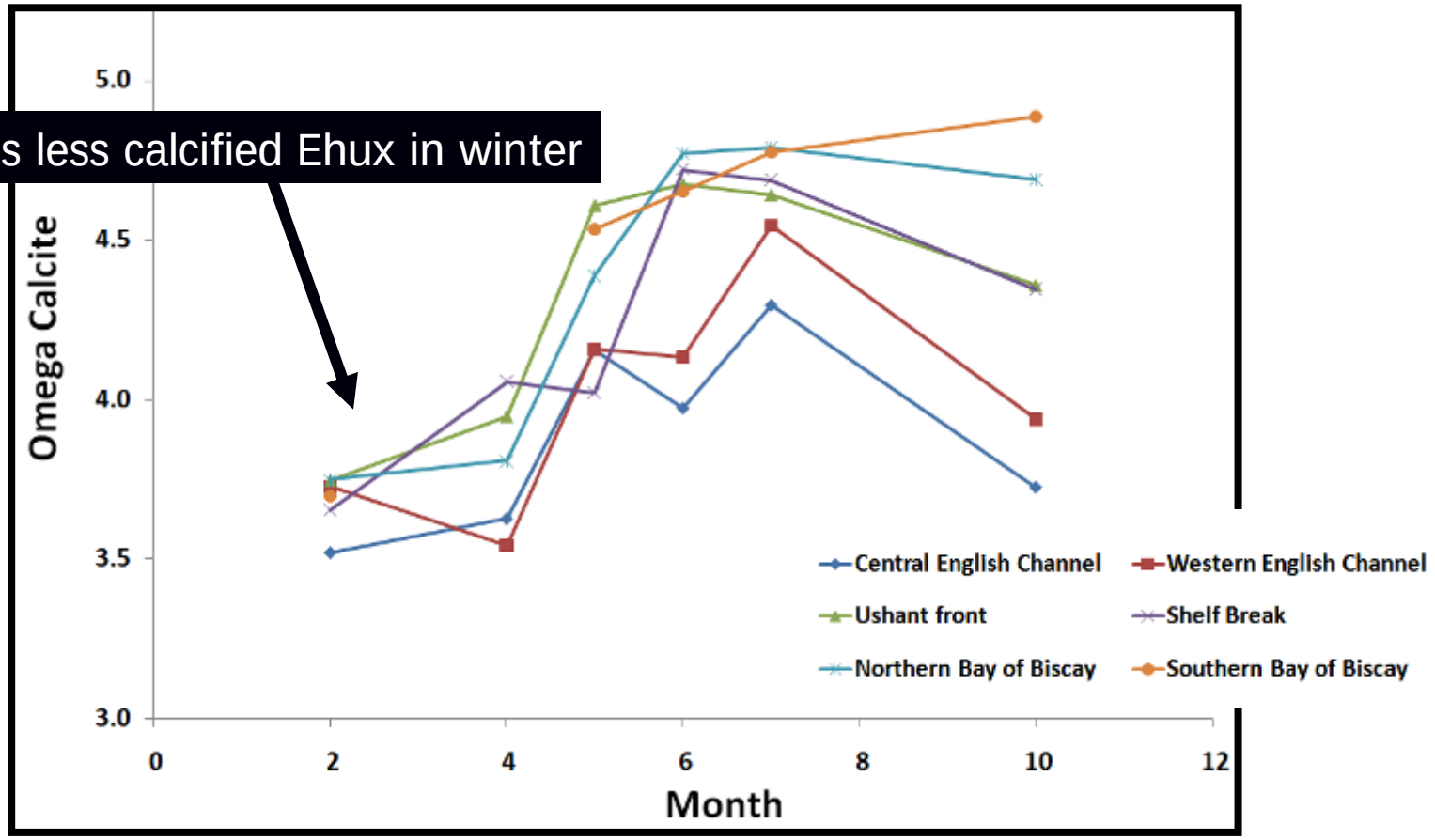
Alkalinity



Sensors in development

$CaCO_3$ Saturation Lowest in Winter in all regions

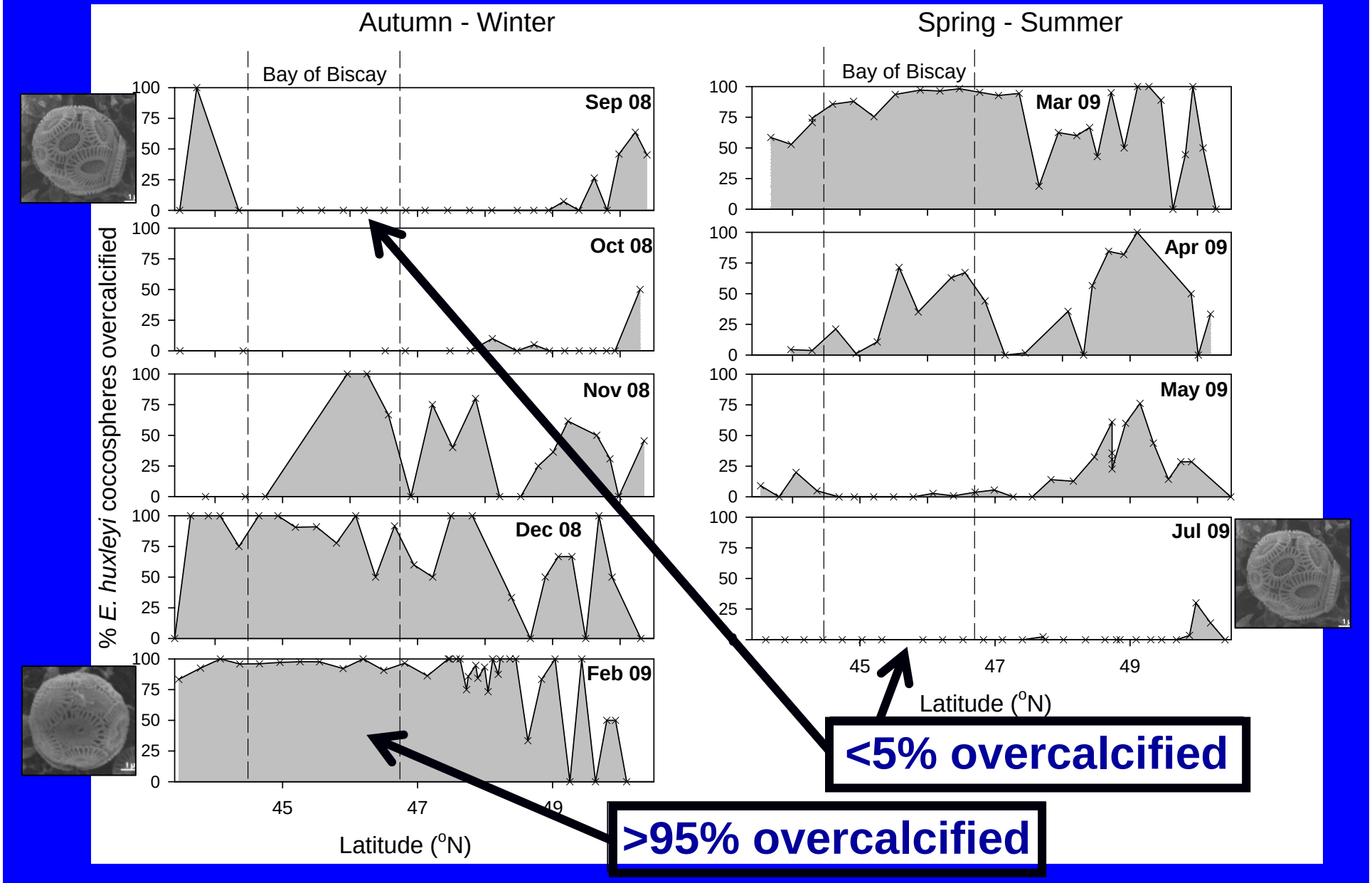
Expectation is less calcified Ehux in winter



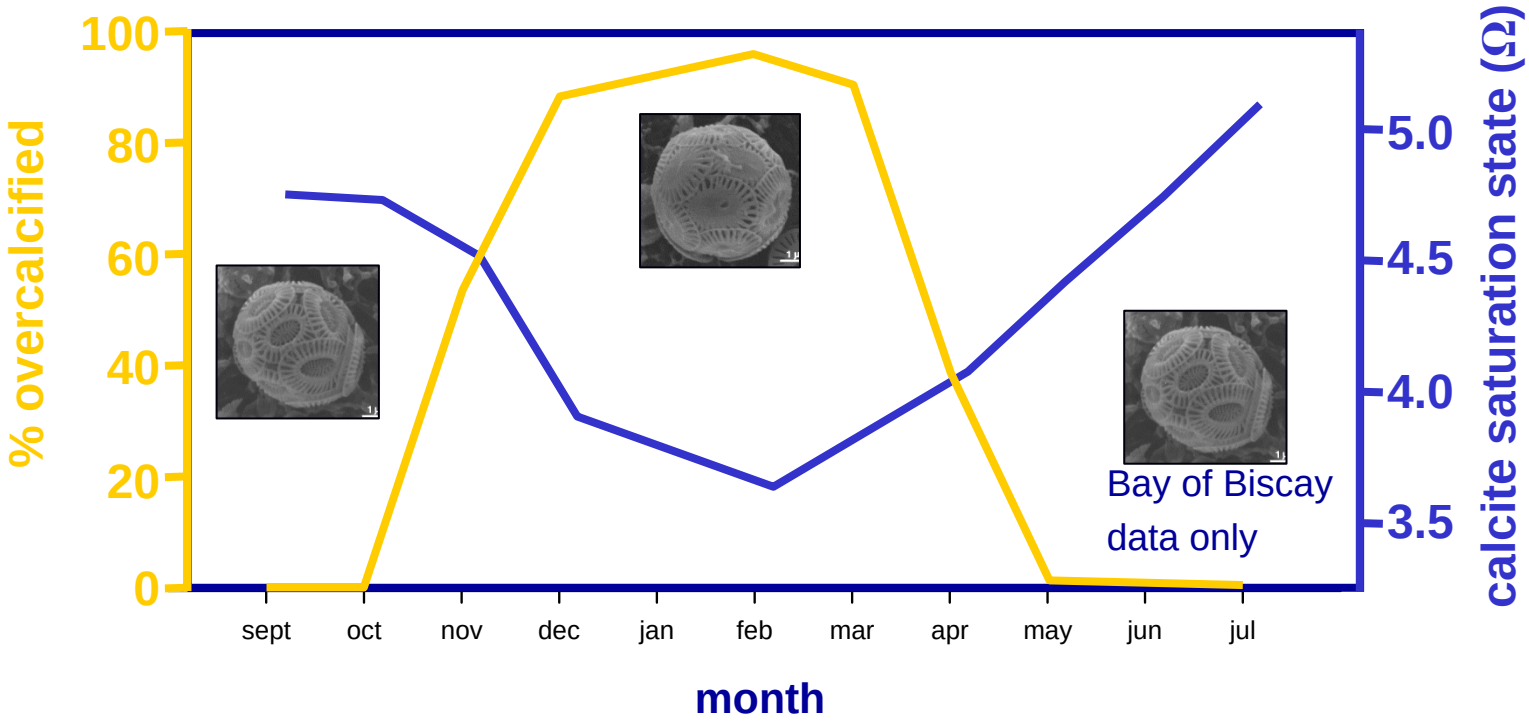
From measurements of DIC and alkalinity on PoB ferry crossings

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

But overcalcified in Winter!



Anticorrelation of Ω 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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Summary cont/d

- 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 collobaoration 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.

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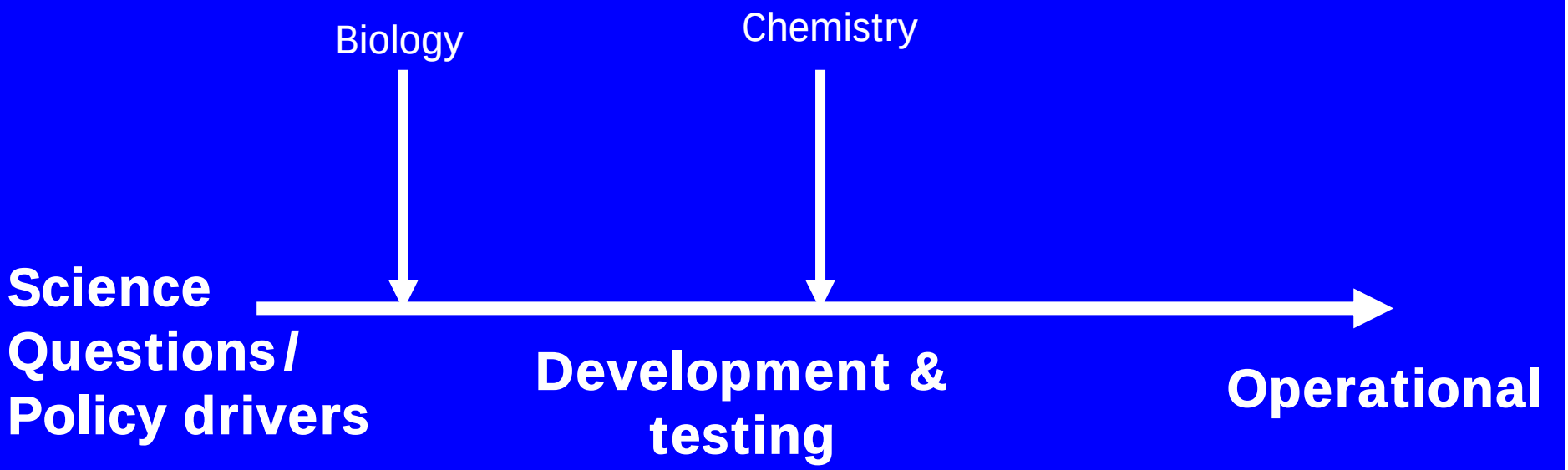
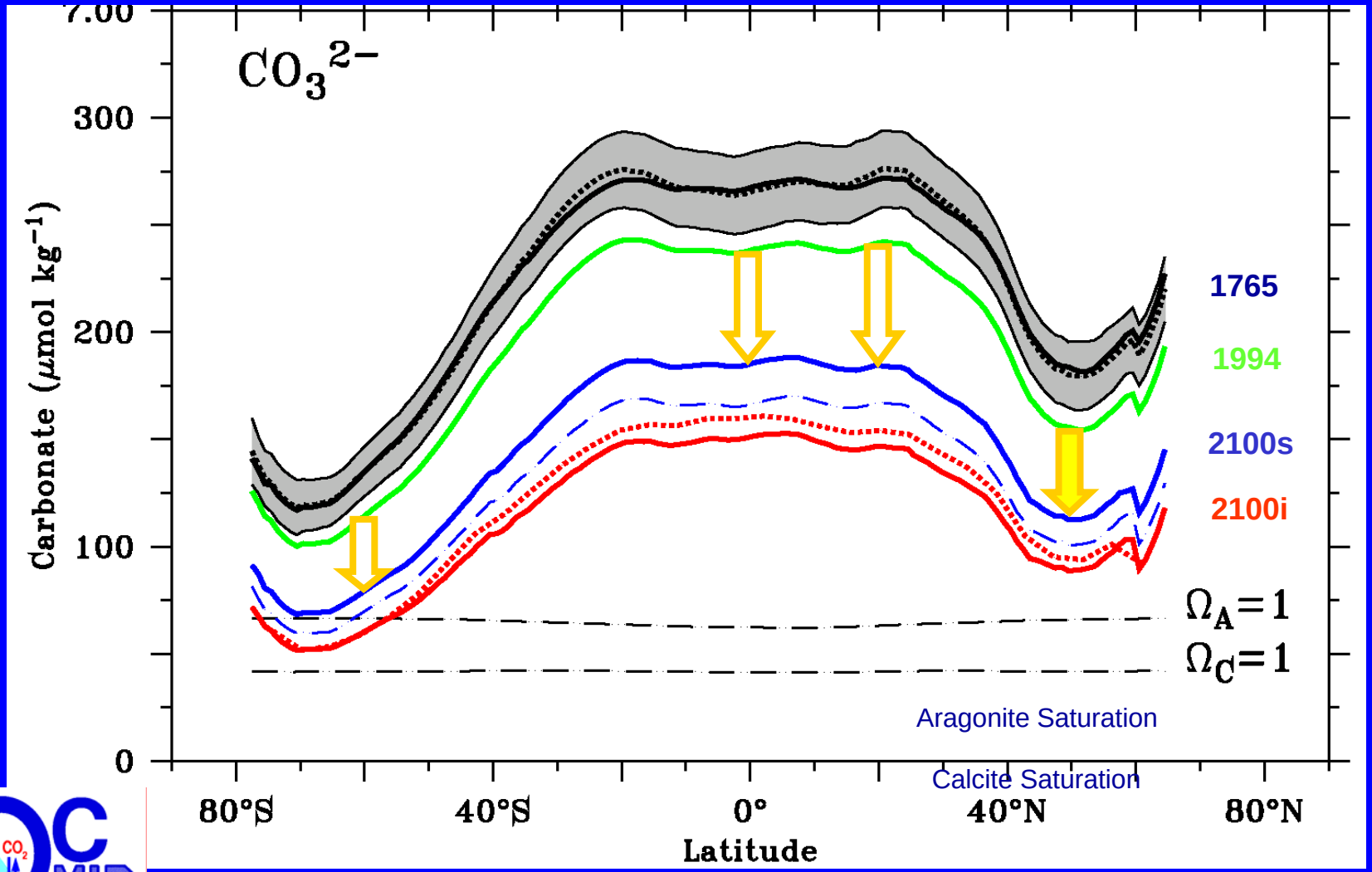
Timeline for operational FB system for carbonate system



Future

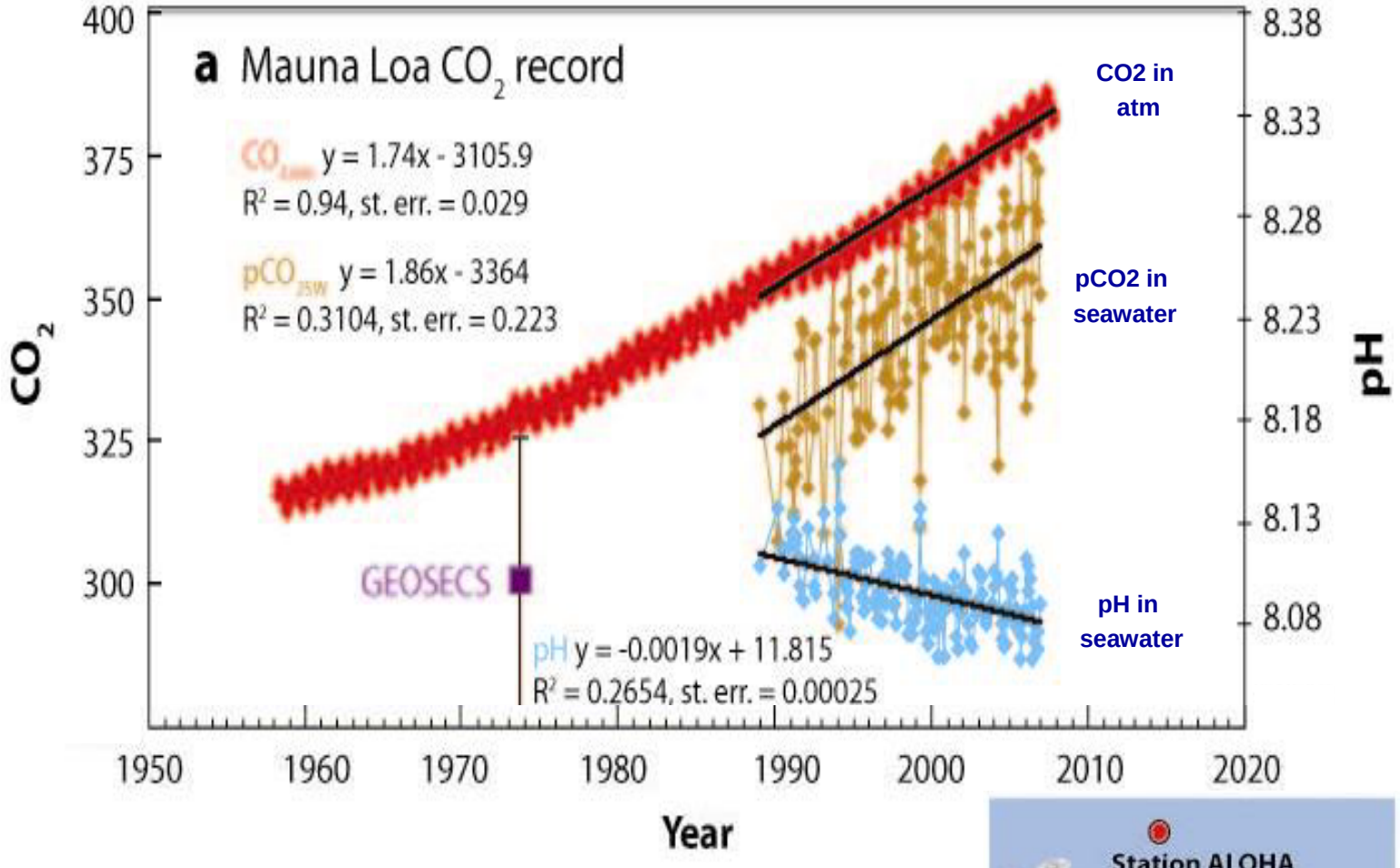
- SCIENCE
  - •Extend the studies to high latitudes and Pacific ocean-shelf regions - is the response the same?
  - • Impacts on coral reefs?
- ASSESSMENTS
  - • Intercomparison of pCO2 measurements in Pacific region for community synthesis into 5th IPPC Report
- DEVELOPMENT
  - • Ongoing testing of 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 : Britanny Ferries? Or move to Hebridean Shelf or ?????

Invading CO2 is Reducing Carbonate Ion Concentration



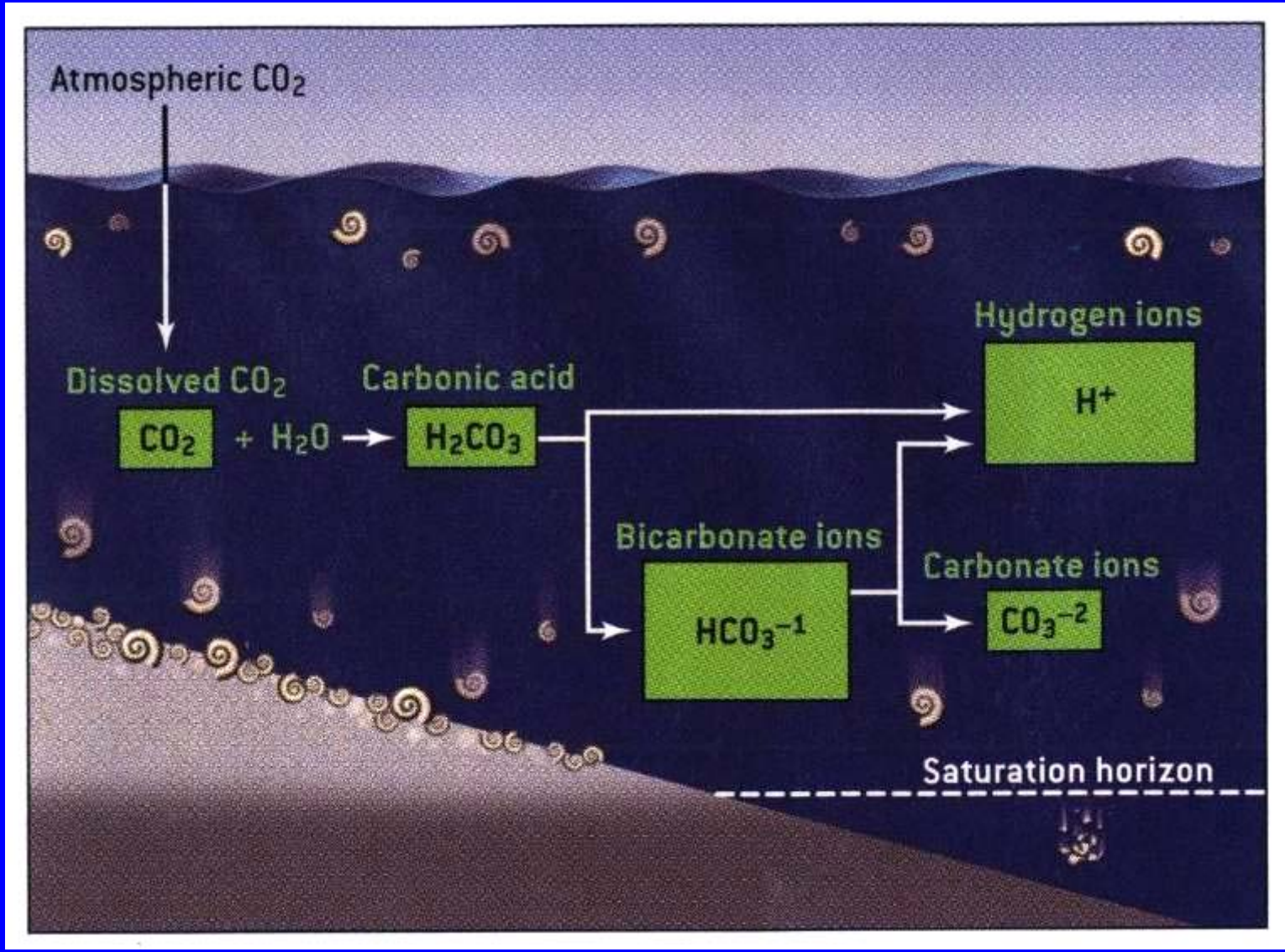
[Jim Orr]

As pCO2 increases, pH decreases



Doney SC, et al. 2009.
Annu. Rev. Mar. Sci. 1:169–92

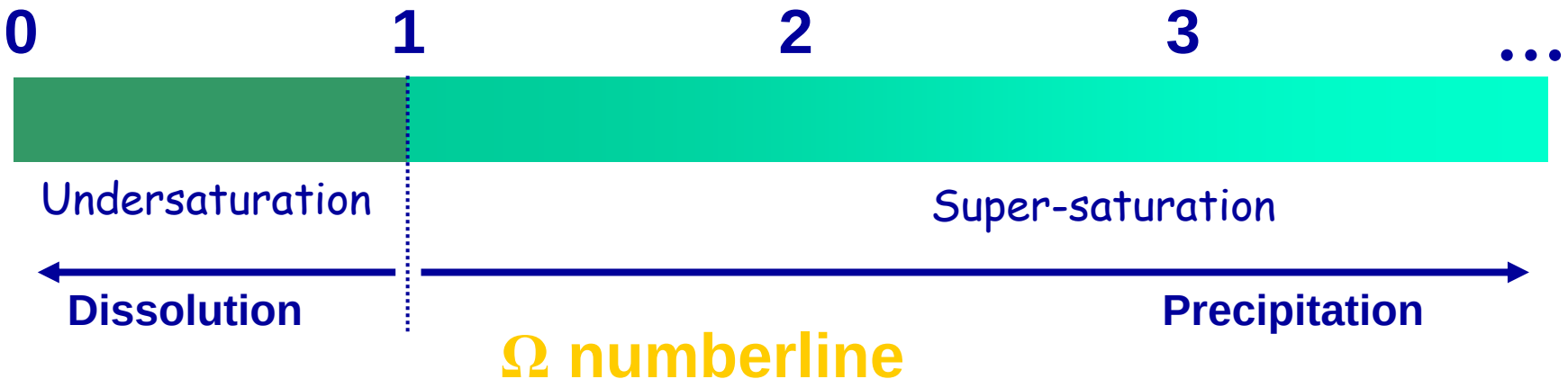
CO2 Influx is Altering Carbon Chemistry



(Doney, March 2006, *Scientific American*, 38-45)

Inorganic Calcification dependent on **Saturation State**

$$\Omega = \frac{[CO_3^{2-}] * [Ca^{2+}]}{K'_{sp}}$$

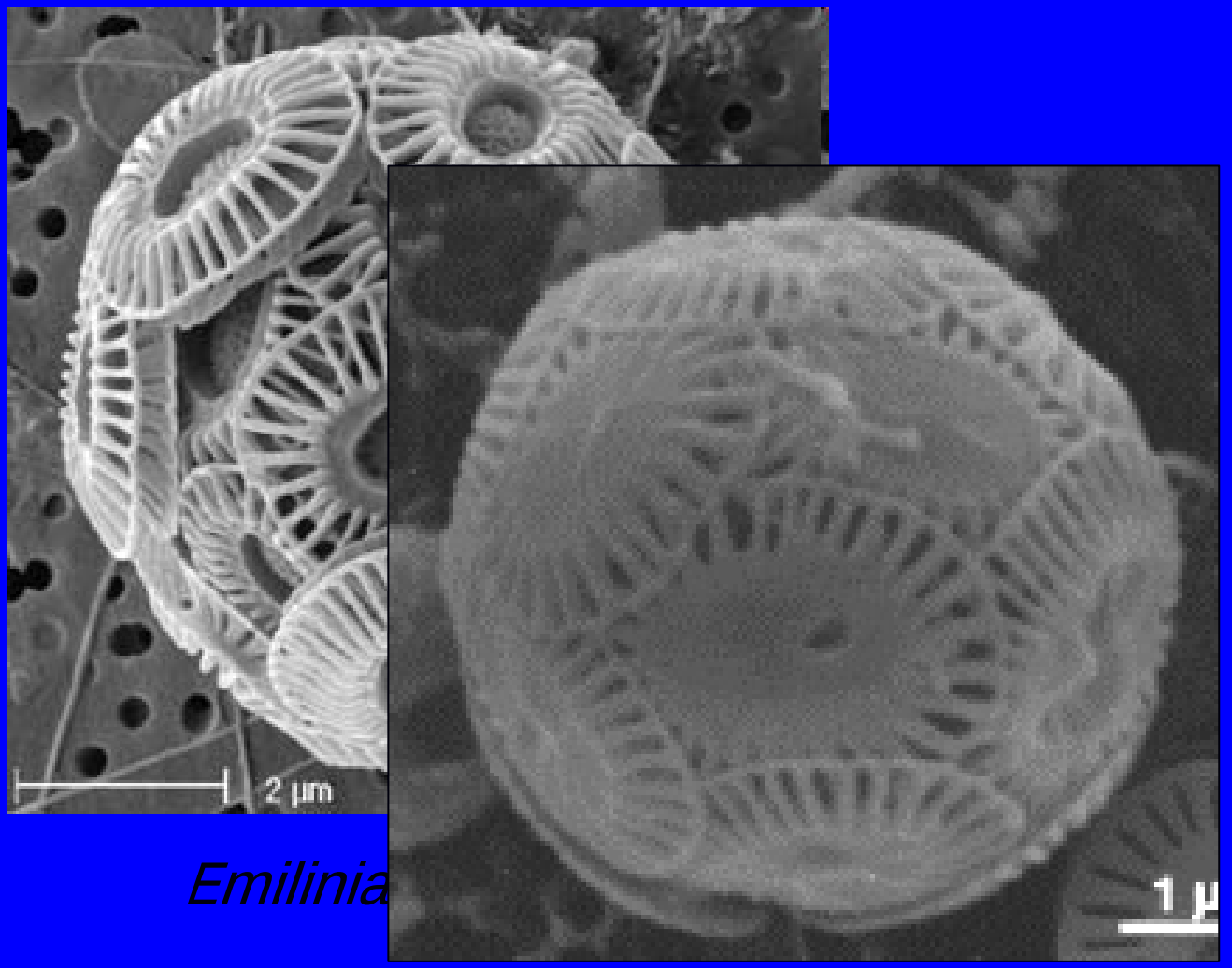


Robust Results

Cynthias paper shows between years : temperature is dominant signal in differences in air-sea exchange of pCO_2

But seasonality of DIC dominated by biology

Impact of OA on Marine Ecosystem

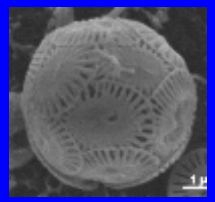


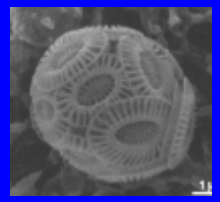
Emilinia

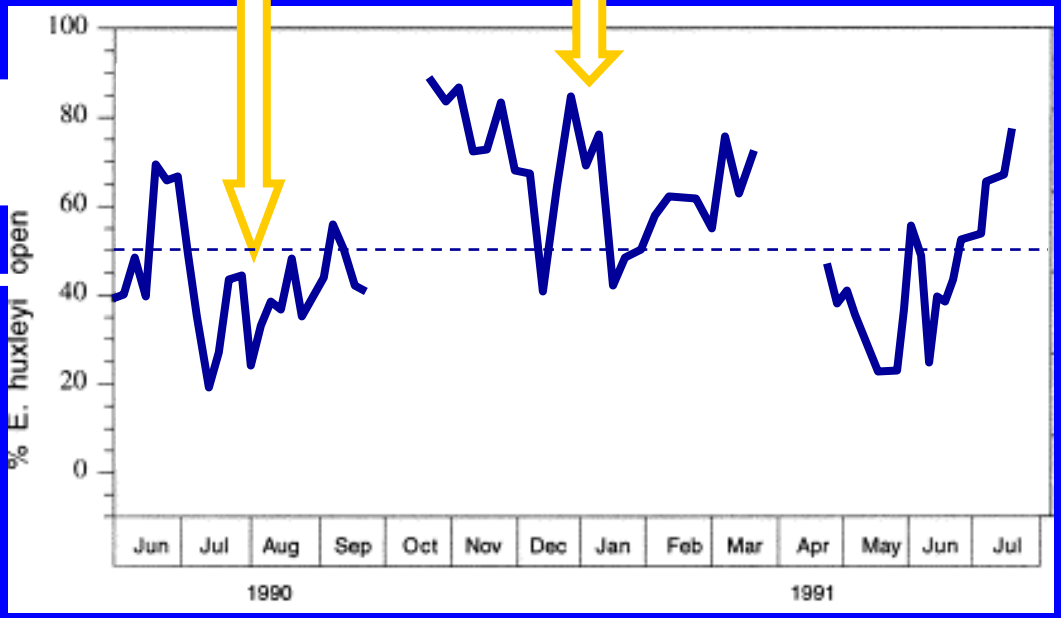
Sediment Trap Samples Suggest Less Calcified in Winter

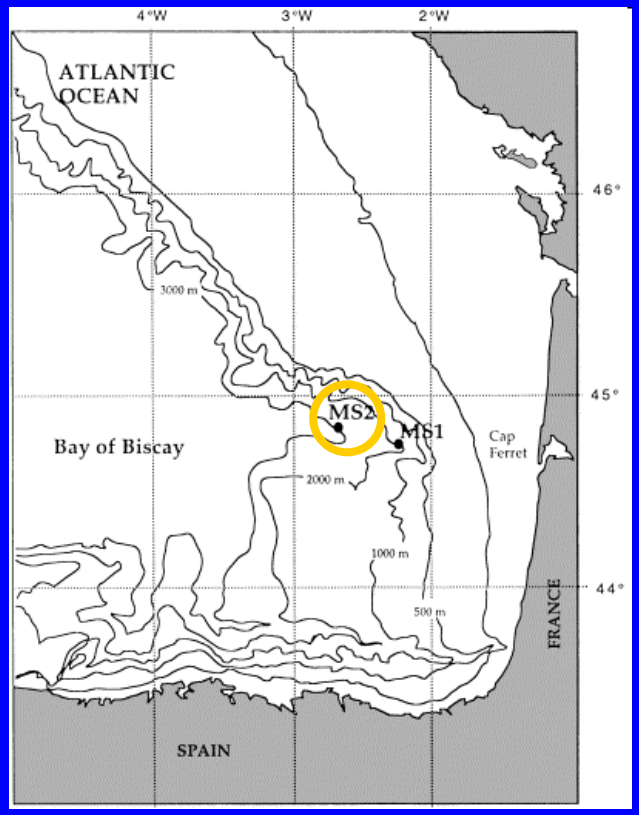
‘closed’ morphotype
heavily calcified
Type A overcalcified

‘open’ morphotype
lightly calcified
Type A









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

(Beaufort & Heussner. 2001. Marine Micropal., 43:27-55)

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 ($p \ll 0.01$)

Cause of Phenomenon is Unclear

1.	High Ω ($CaCO_3$ saturation)	X
2.	Low [PO_4]	X
3.	High temperature	X
4.	Low temperature (Sorrosa et al., 2005)	?
5.	High light intensity	X
6.	Slow growth (*cf.* diatoms)	?
7.	Overwintering resting stage	?

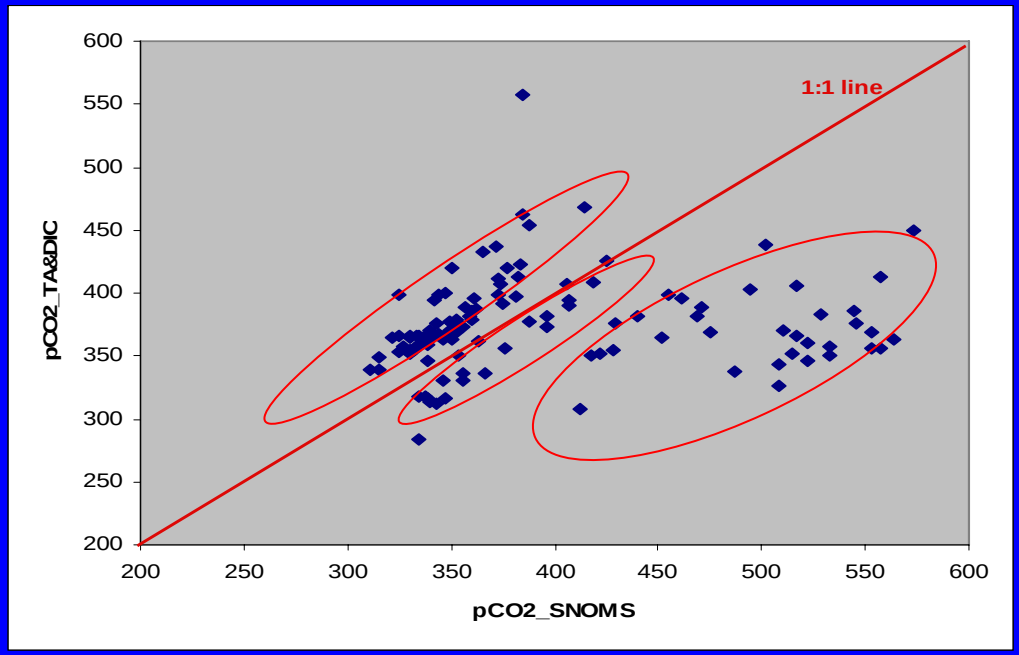
Is it a genotypic or a phenotypic shift?

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?



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Several Lab Studies of *E. huxleyi* response to OA

letters to nature

Reduced calcification of marine plankton in response to increased atmospheric CO_2

Ulf Riebesell *, Ingrid Zondervan*, Björn Rost*, Philippe D. Tortell†, Richard E. Zeebe*‡ & François M. M. Morel†

* *Alfred Wegener Institute for Polar and Marine Research, P.O. Box 120161, D-27515 Bremerhaven, Germany*
† *Department of Geosciences & Depar... Princeton University, Princeton, New*
‡ *Lamont-Doherty Earth Observatory, New York 10964, USA*

RESEARCH ARTICLES

Phytoplankton Calcification in a High-CO_2 World

M. Debora Iglesias-Rodriguez,[1]* Paul R. Halloran,[2]* Rosalind E. M. Rickaby,[2] Ian R. Hall,[3] Elena Colmenero-Hidalgo,[3]† John R. Gittins,[1] Darryl R. H. Green,[1] Toby Tyrrell,[1] Samantha J. Gibbs,[1] Peter von Dassow,[4] Eric Rehm,[5] E. Virginia Armbrust,[5] Karin P. Boessenkool[5]

Ocean acidification in response to rising atmospheric CO_2 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 ...colithophore species *Emiliania huxleyi* are ...s. Field evidence from the deep ocean is ...ting that over the past 220 years there has been ...dings show that coccolithophores are already ...to rising atmospheric CO_2 partial pressures, ...al modeling of future oceans and climate.

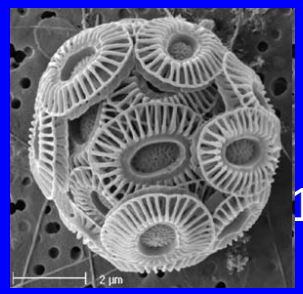
Biogeosciences, 6, 2637–2646, 2009
www.biogeosciences.net/6/2637/2009/

Biogeosciences

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

G. Langer[1,2], G. Nehrke[2], I. Probert[3], J. Ly[1,2], and P. Ziveri[1,4]
[1]ICTA, Autonomous University of Barcelona (UAB), 08193 Bellaterra, Spain
[2]Alfred Wegener Institute for Polar and Marine Research, 27570 Bremerhaven, Germany
[3]CNRS/UPMC, Station Biologique de Roscoff, 29682 Roscoff, France
[4]EALW, Vrije Universiteit Amsterdam, 1081HV Amsterdam, The Netherlands

Received: 27 March 2009 – Published in Biogeosciences Discuss.: 17 April 2009
Revised: 19 October 2009 – Accepted: 4 November 2009 – Published: 24 November 2009



1/600

Dr. Toby Tyrrell

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

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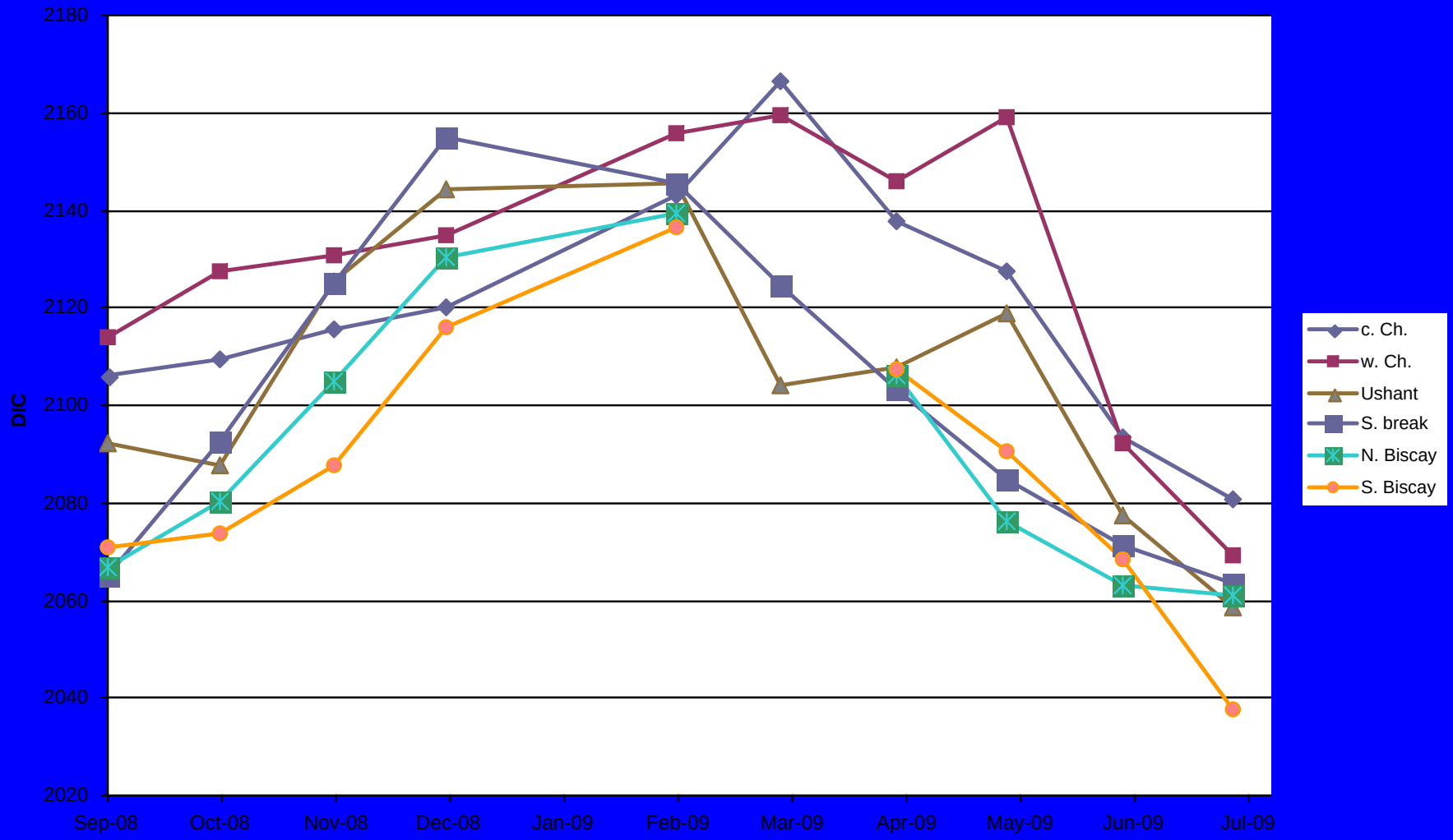
Seasonal DIC in regions along PoB track



Autumn-Winter

Spring-Summer