

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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Laura Pettit

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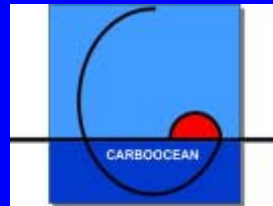
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discovering the unknown

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

Support

P&O  **Ferries**



PROTOOL



Special Acknowledgements:

Captains and crews of P&O and Swire ships



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Timeline for operational FB system for carbonate system



Two systems

Since 2002



MV Pride of Bilbao



Since 2007



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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

Welcome to the Ferrybox project

Life on Earth
The oceans are vital to life on Earth. The microscopic plants - phytoplankton - that live in the sea provide most of the oxygen that we breathe and the oceans transport heat around the world which is crucial for regulating our climate.

What is measured
Over just three years on the Pride of Bilbao have built up a detailed picture of conditions along the route. Parameters measured: phytoplankton (microscopic sea plants), carbon dioxide (climate warming gas), sea temperature and salinity; measuring water samples every second as the ferry sails through the water - see the LCD screen for further details.

A global network
The ultimate aim is to have a global network of Ferryboxes making similar measurements giving year-round, worldwide monitoring of the marine environment. This way, scientists can keep a check on such things as:

Ferrybox
Scientists around the world are working with F&O to help monitor how the sea is coping with climate change and pollution. To do this, scientists from the National Oceanography Centre, Southampton (NOCES) have installed a 'box' of electronic sensors in the engine room of the Pride of Bilbao ferry - hence the term 'Ferrybox'. This project began in April 2007.

Current threats
10 000 tonnes of phosphoric acid - a plant fertilizer - may be leaking into the English Channel from containers at the bottom of the sea. With these levels of phosphoric acid we could see a 400 per cent increase in the growth of phytoplankton. Some phytoplankton are toxic which brings problems for fishing and shellfish industries. Large amounts of silt settling to the sea floor can remove oxygen from the water, leading to the death of other organisms - putting the whole food web at risk. This work will be an early warning system which

The live monitor display

You are watching a live display of data collected on board the Pride of Bilbao
Feel free to comment on the display using forms at reception

Salinity
Sea salinity is the amount of dissolved salts in the water. The average salinity of the world's oceans is 35 parts per thousand (ppt). This means that for every 1000g of water there are 35g of salt. Salinity affects the density of the water and is a key factor in determining ocean circulation.

Carbon dioxide (CO₂)
CO₂ is the greenhouse gas that is most responsible for global warming. It is taken up by the oceans and stored in the water. The amount of CO₂ in the atmosphere is increasing rapidly and this is causing the oceans to become more acidic. This is a problem for many marine organisms, particularly those with shells or skeletons made of calcium carbonate.

Temperature
The temperature of the sea is a key indicator of climate change. The oceans absorb most of the heat from the sun and this causes the water to expand and rise. This is what causes sea level rise. The oceans also transport heat around the world, which helps to regulate our climate.

Algae Gallery
Algae are microscopic plants that live in the sea. They are the base of the marine food web and produce most of the oxygen that we breathe. There are many different types of algae and they play a vital role in the health of the oceans.

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Passenger Feedback Forms

The Ferrybox Project!

Have you seen our new computerised display by the main reception desk (Deck 6/P 1)? 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 looked from it? Please tell us and return this to the reception desk (Deck 6).

Excellent idea; suggest:

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

Nationality: UK Name: David Appleby Date: 9/3/06

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



Robust system serviceable by ships crew



Chief Engineer



SNOMS

SWIRE NOCS Ocean Monitoring System

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Southampton



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SWIRE SHIPPING

SWIRE
TRUST



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)?

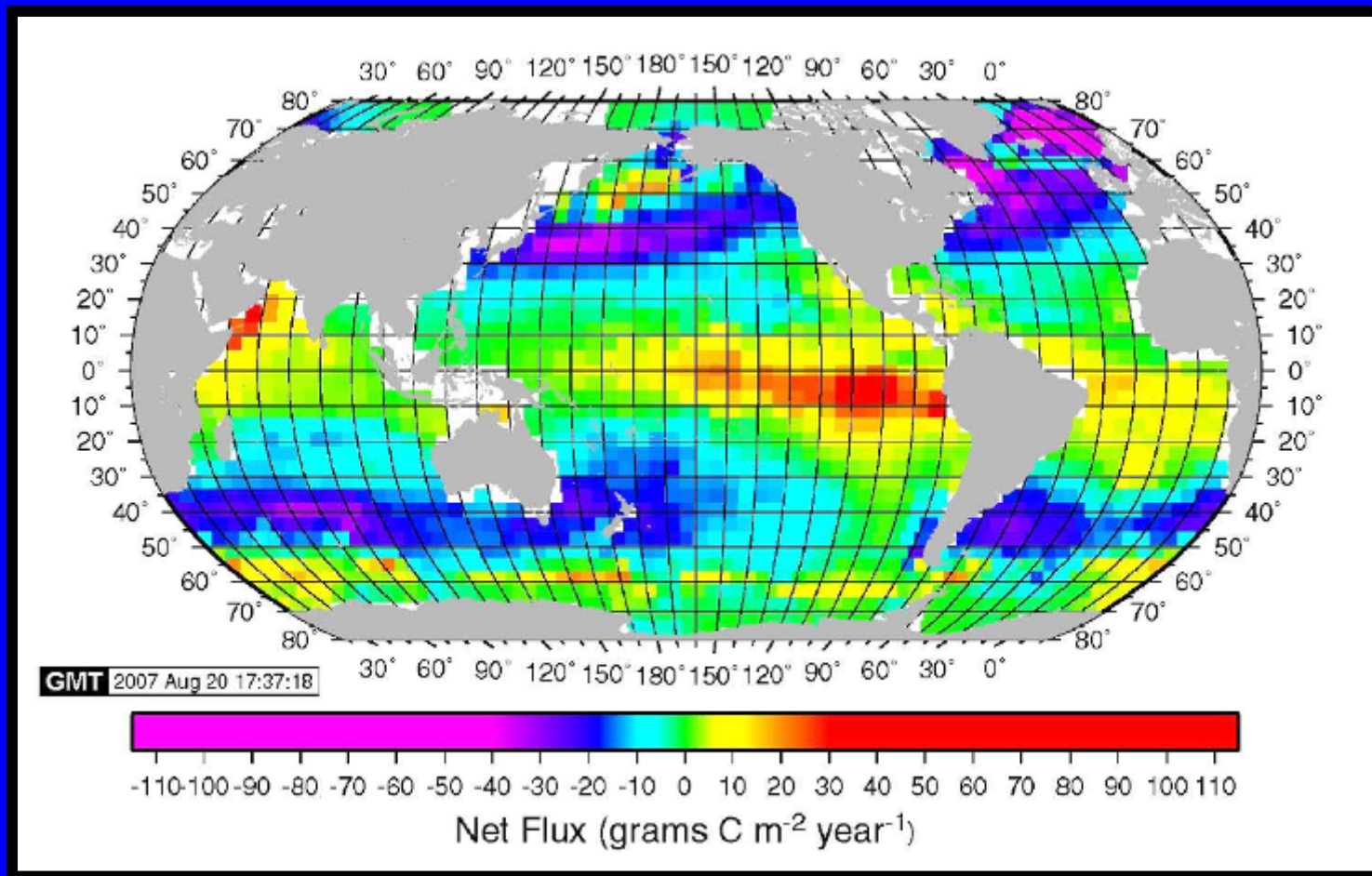
Moving from a science understanding to operational oceanography



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How much CO₂ is removed by the oceans ?



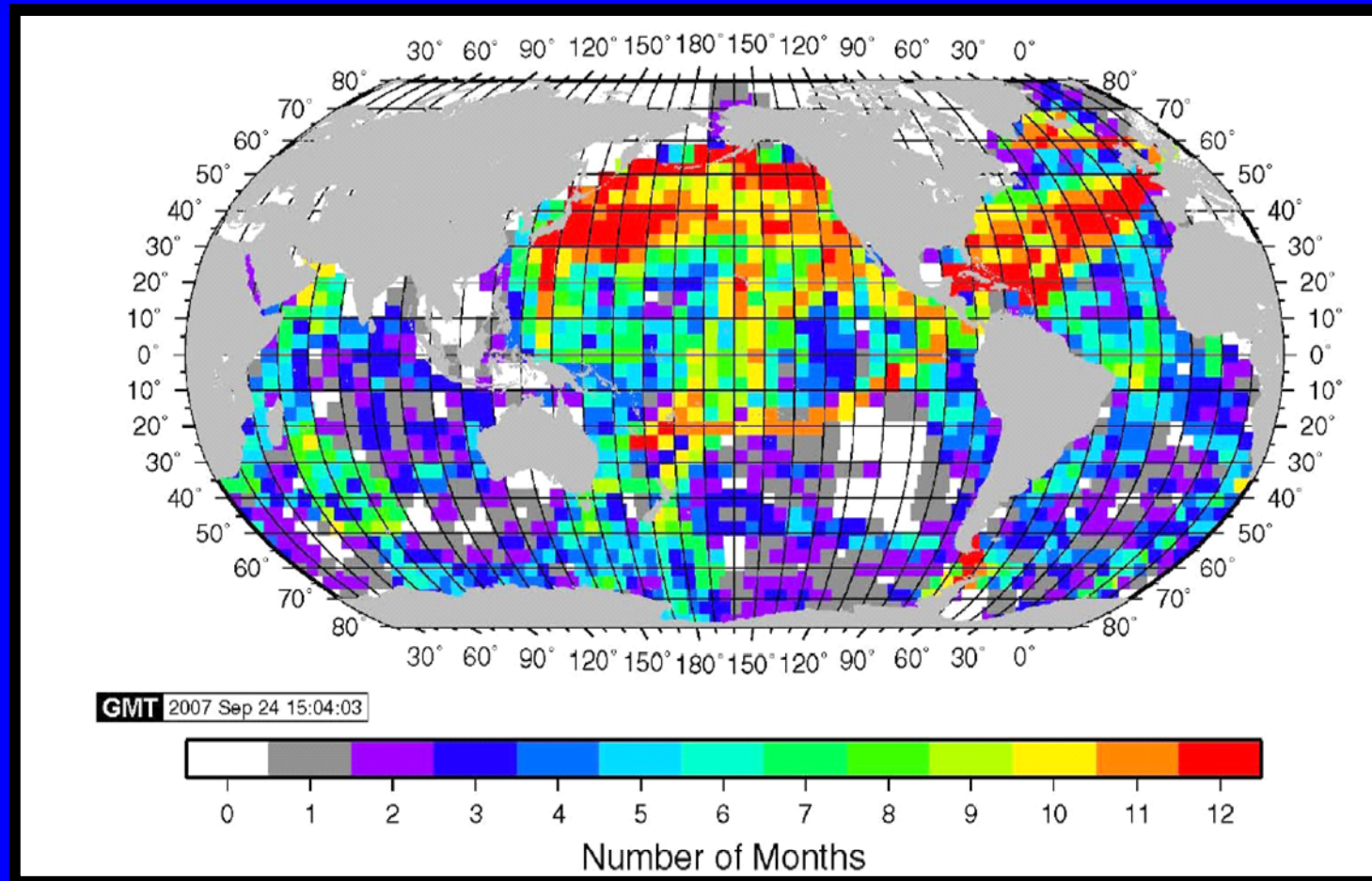
Best estimate from Takahashi et al., 2009



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The global database for CO₂ is full of holes



Takahashi et al., 2009

No year to year information either

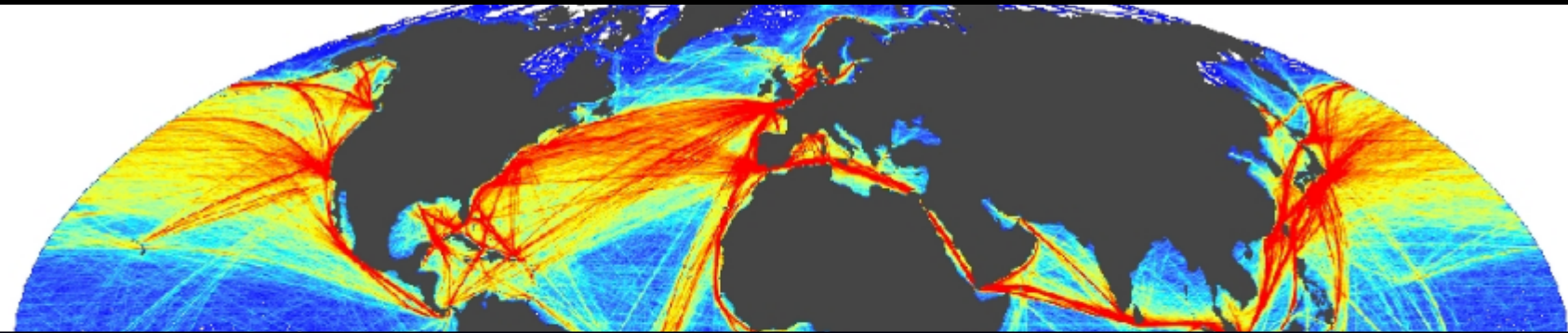


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Commercial ships can fill the holes

Oceanography all day everyday AND everywhere



Is this an operational FB network?

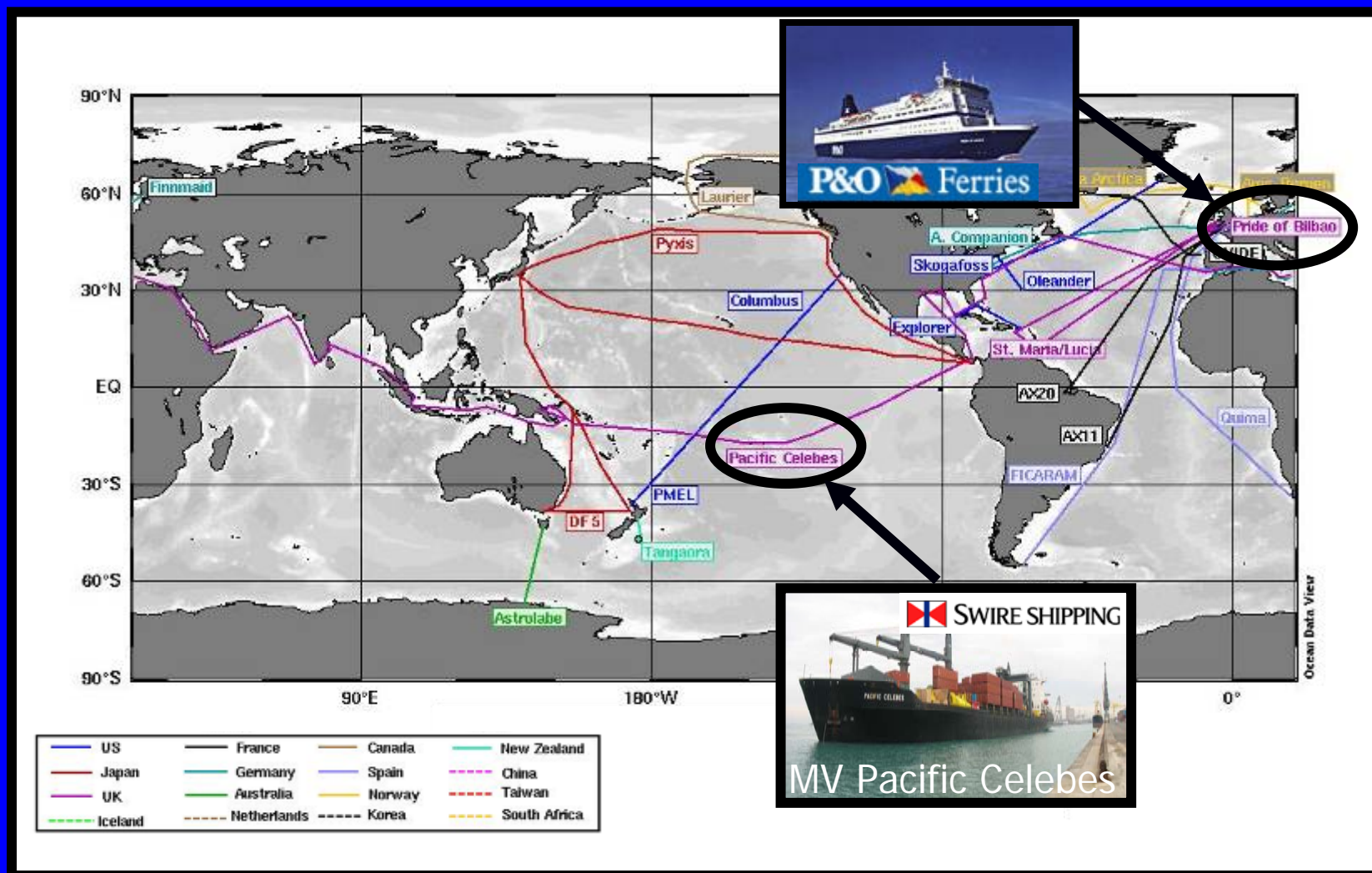
FB partnership is leading the way in how best to do this



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The current global network is small



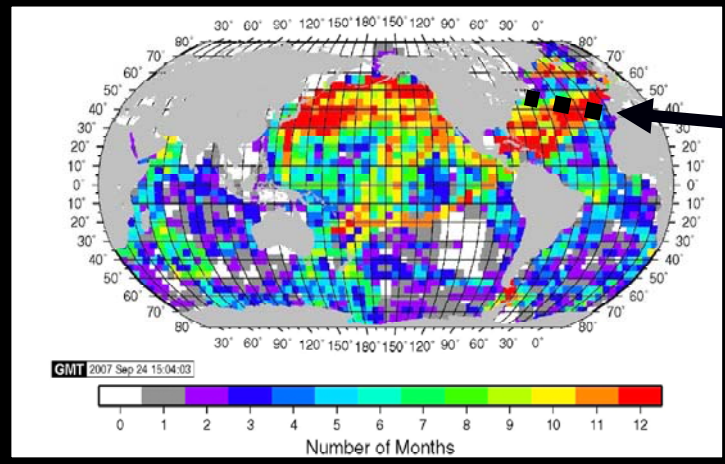
International Ocean Carbon Coordination Project



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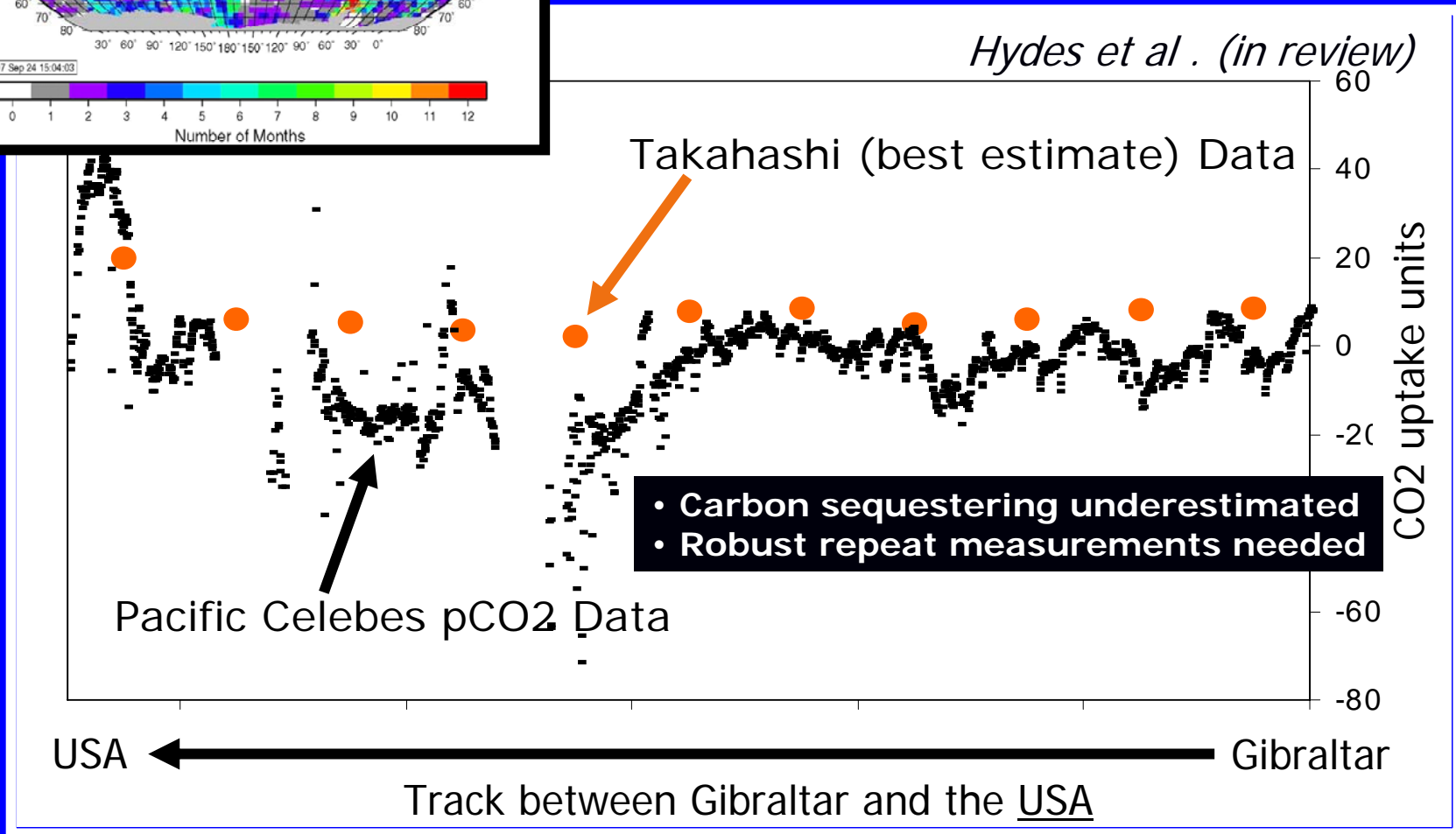
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Filling the holes and improving the information

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



Ocean Acidification

More CO₂ in the oceans = lower pH

Chemistry is well understood

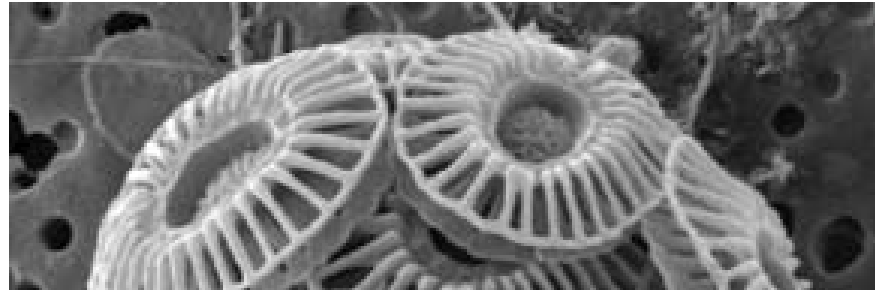
Biological response not well understood



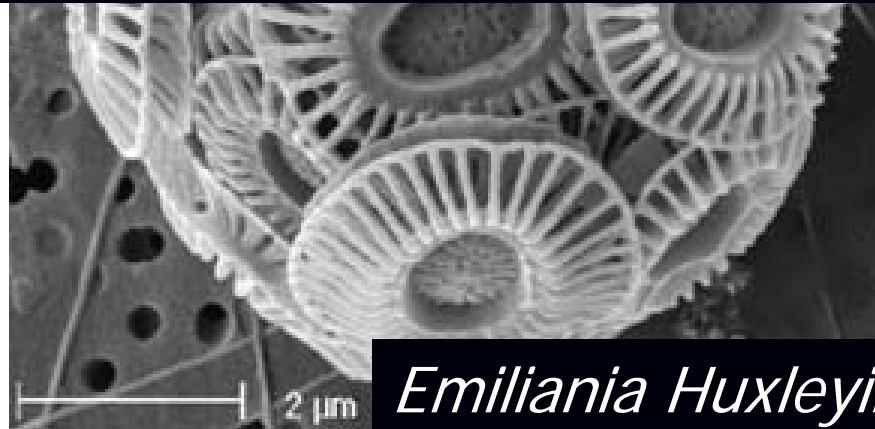
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Impact of OA on Marine Ecosystem



No sensor technology exists



Emiliana Huxleyii

How does OA affect its ability to produce coccoliths

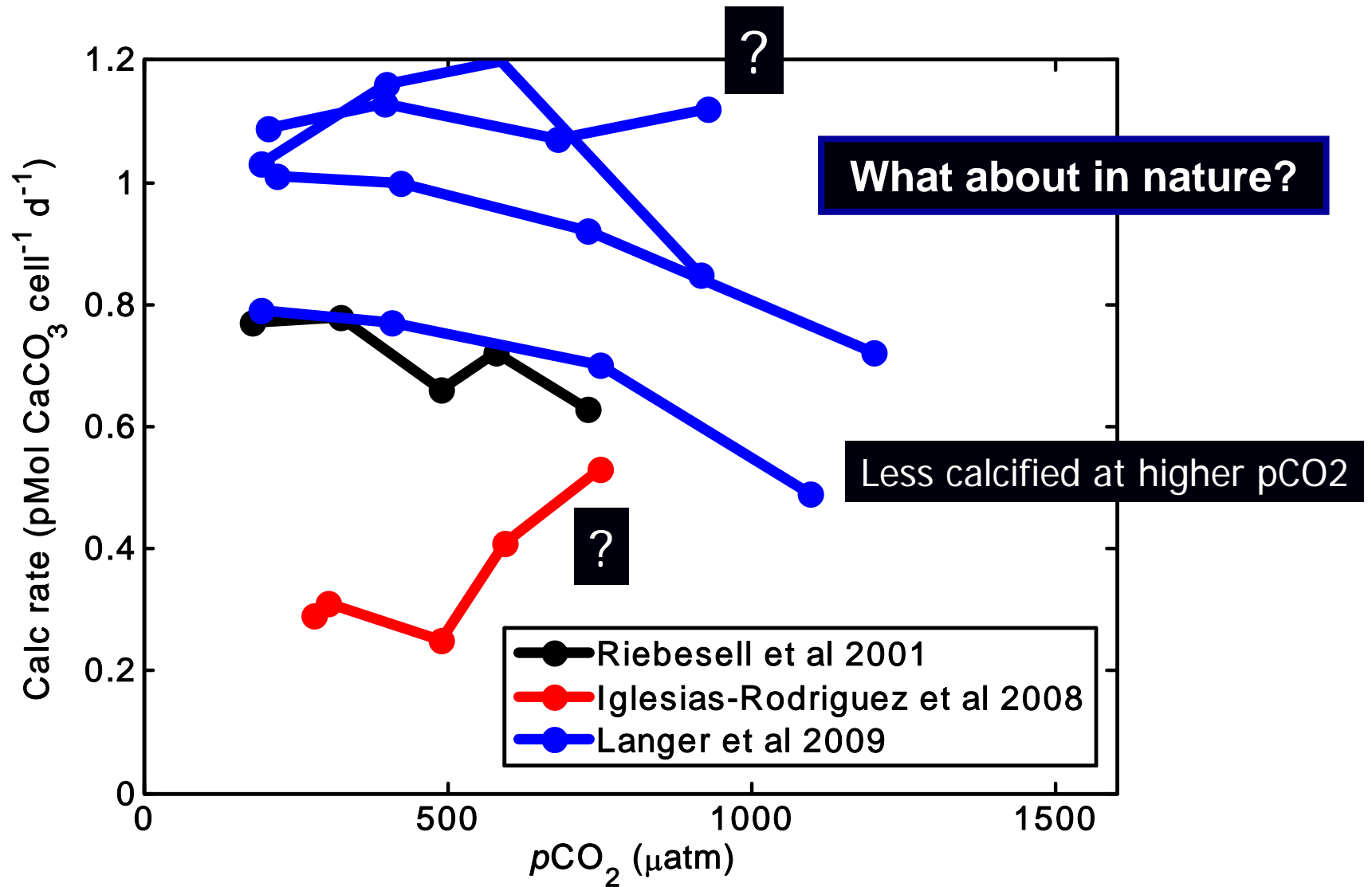
– a process called calcification



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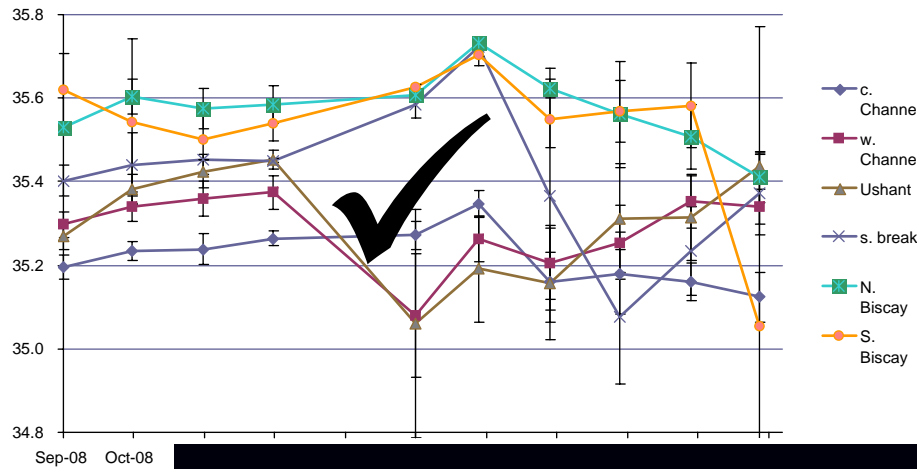
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Conflicting Results from key Lab Studies

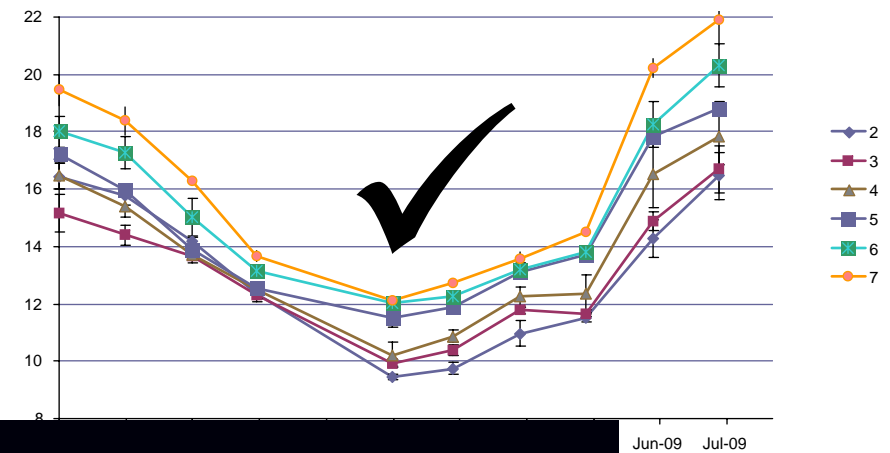


FerryBoxes provide seasonal cycles of ancillary data

Regional Salinity



Regional Temperature

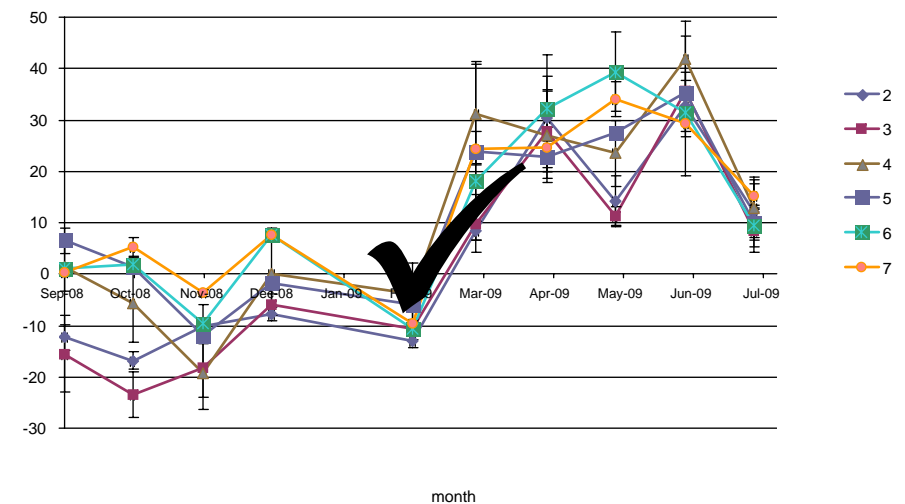


How close to being operational ?

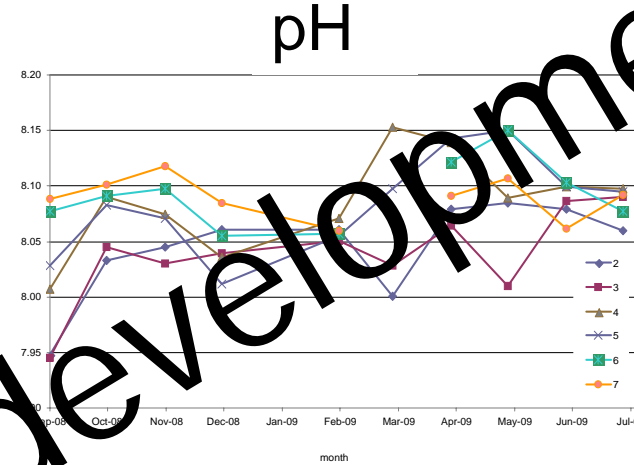
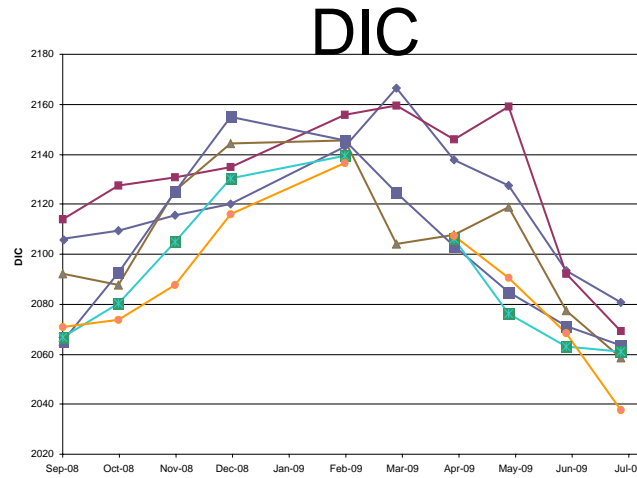
Regional Nutrients



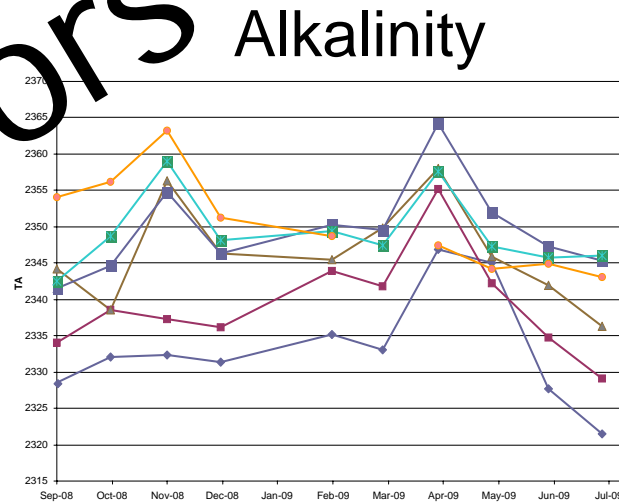
Regional O2 Anomaly



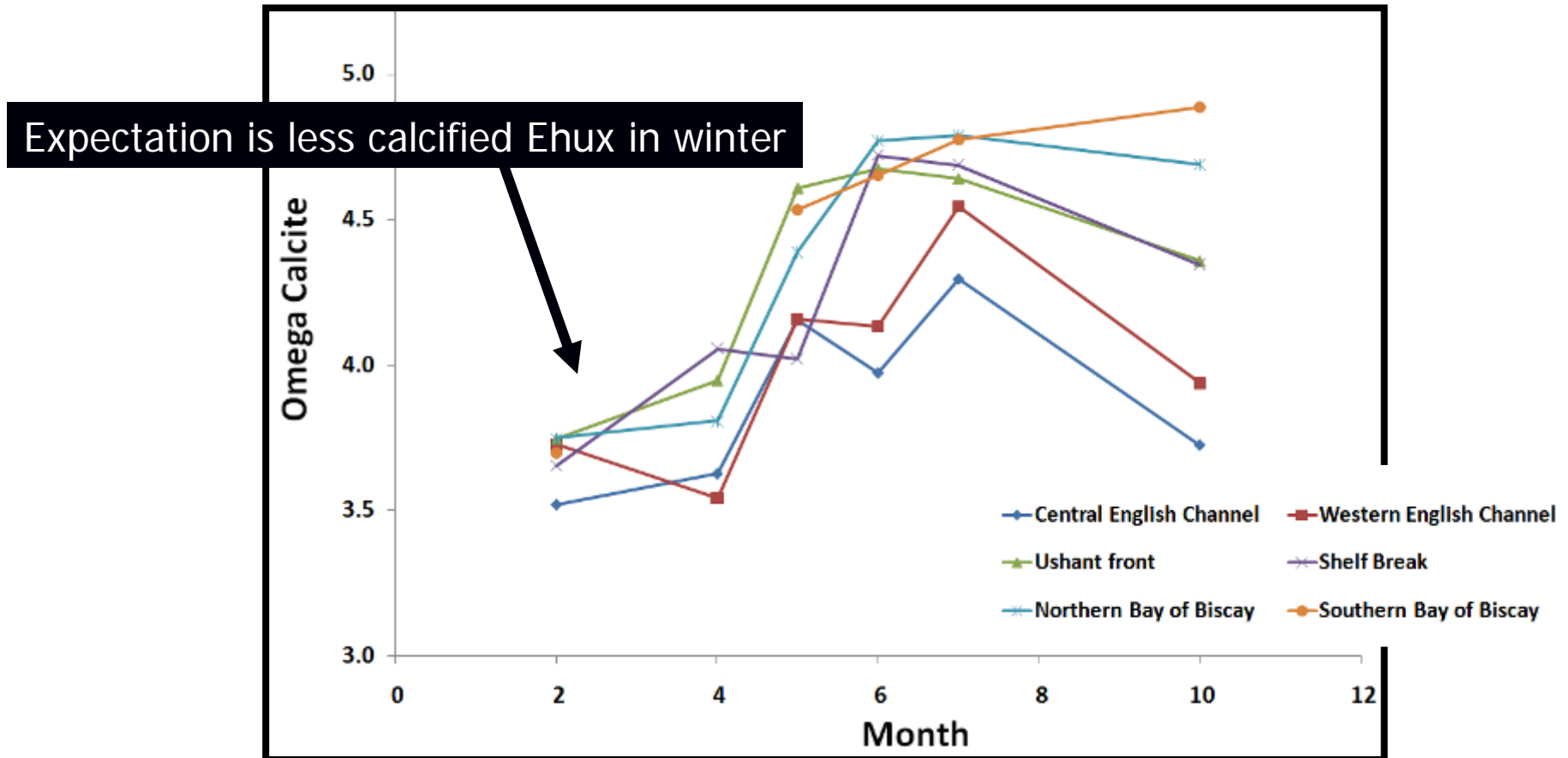
Discrete sampling gives carbonate data



Sensors in development



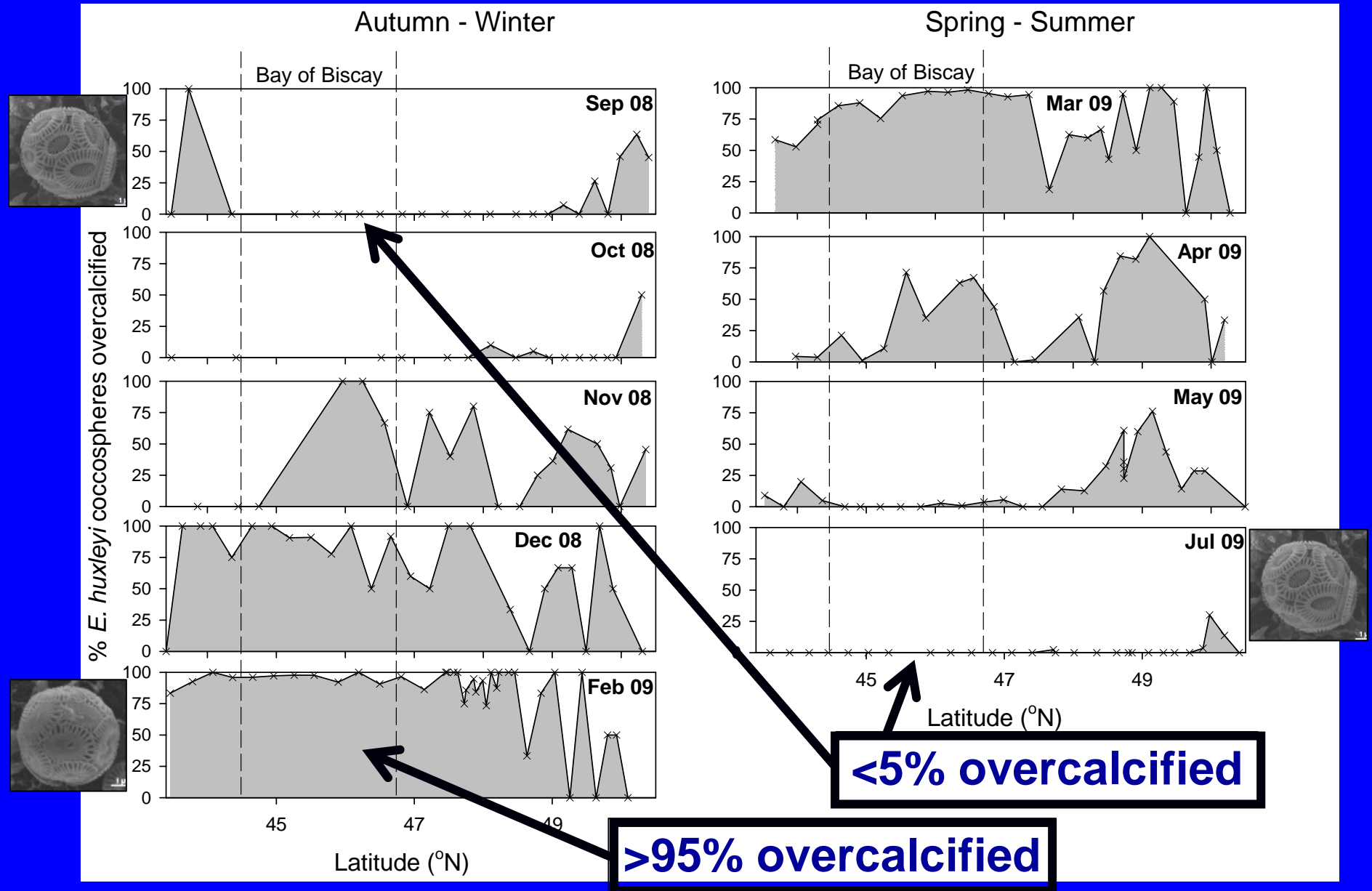
CaCO₃ Saturation Lowest in Winter in all regions



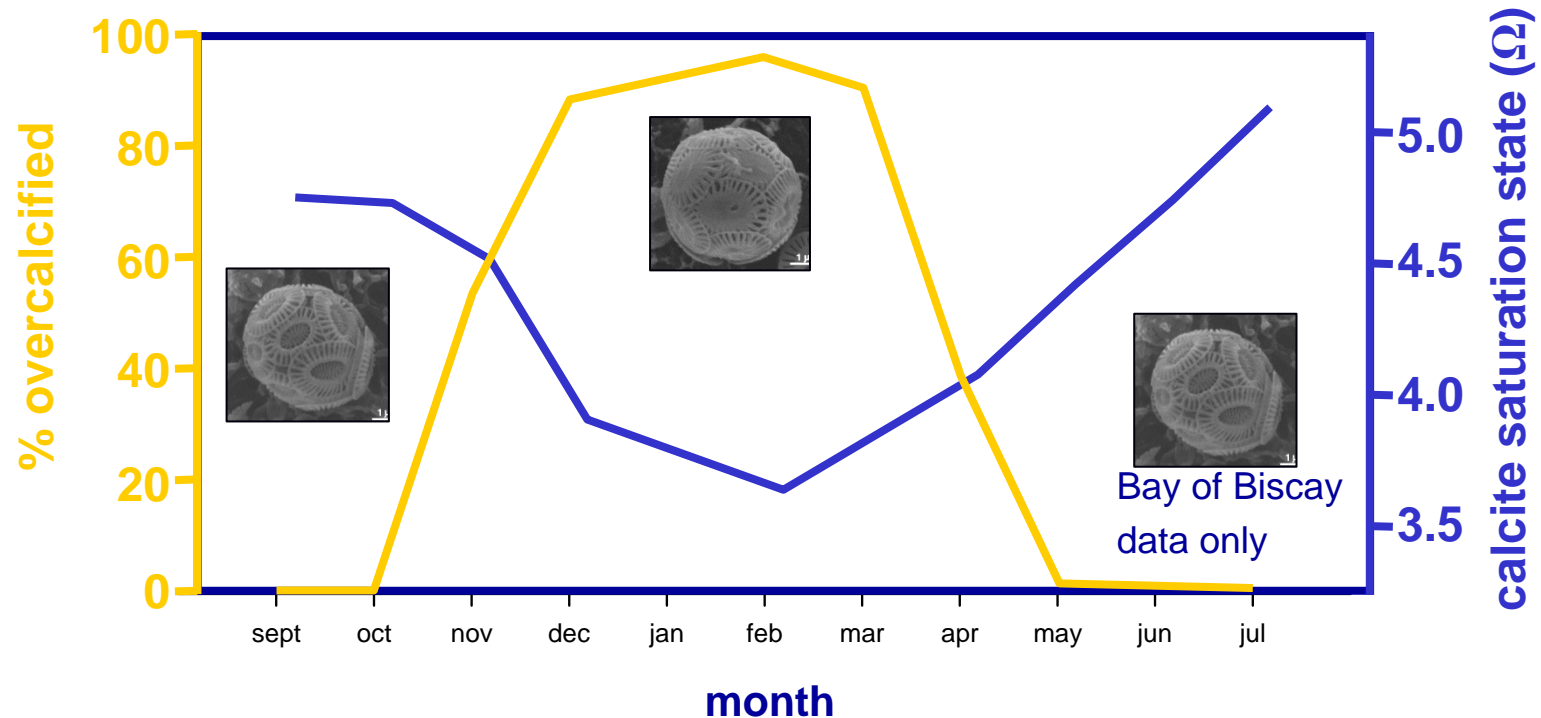
From measurements of DIC and alkalinity on PoB ferry crossings

(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 *Emiliana huxleyi* due to OA

Summary

1. Straightforward lab to nature studies on OA.
2. Manual discrete sampling (probes?)
3. *Emiliana 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.



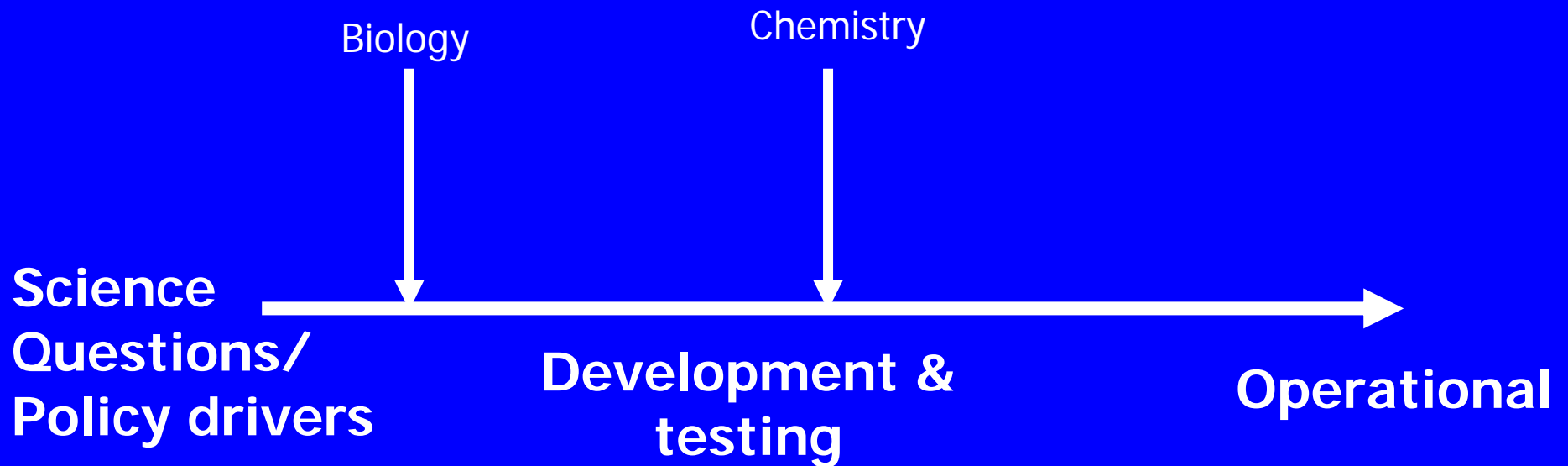
Summary cont/d

- 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 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



Future

- SCIENCE

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

- ASSESSMENTS

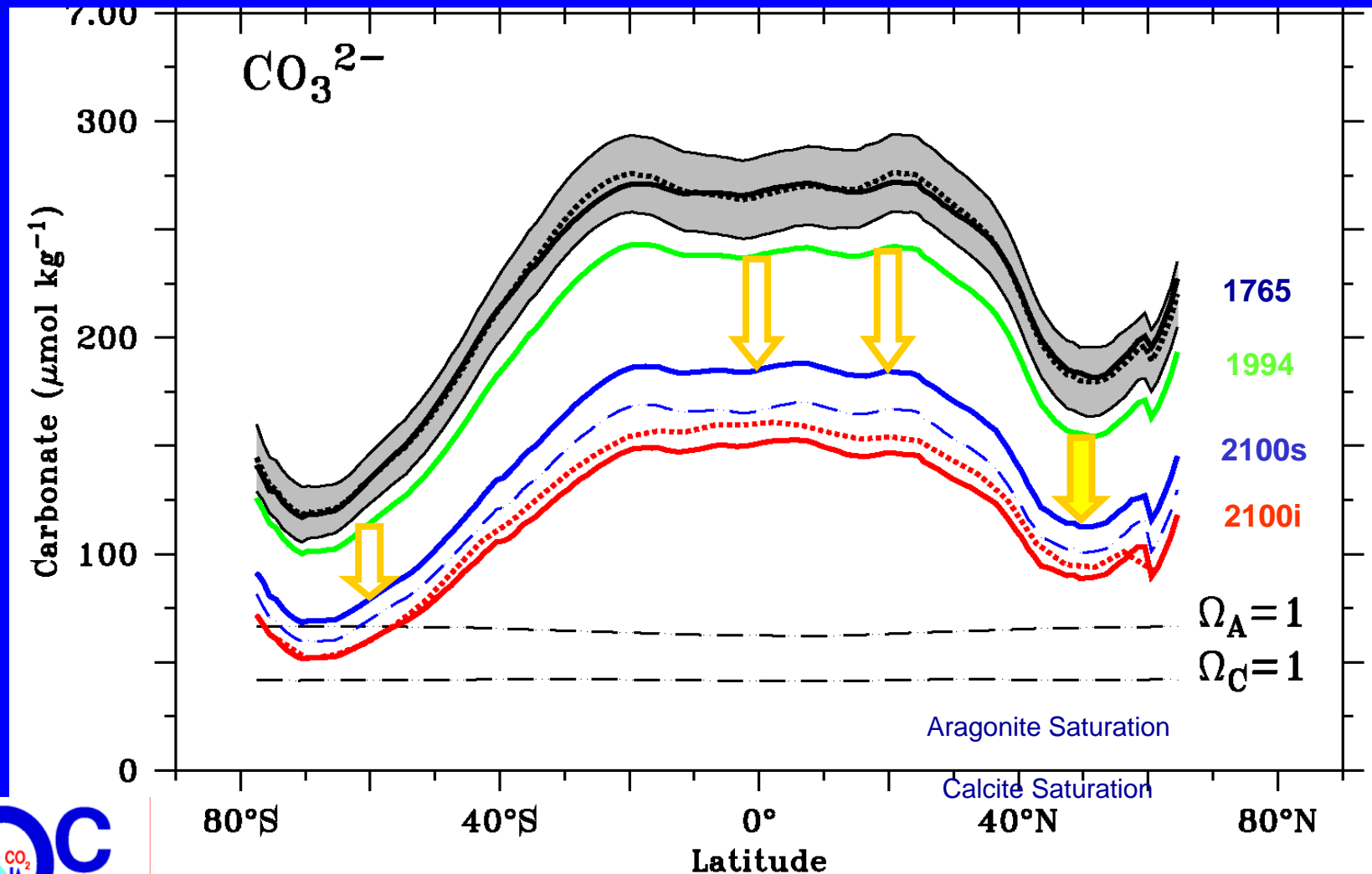
- Intercomparison of pCO₂ measurements in Pacific region for community synthesis into 5th IPCC Report

- 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)

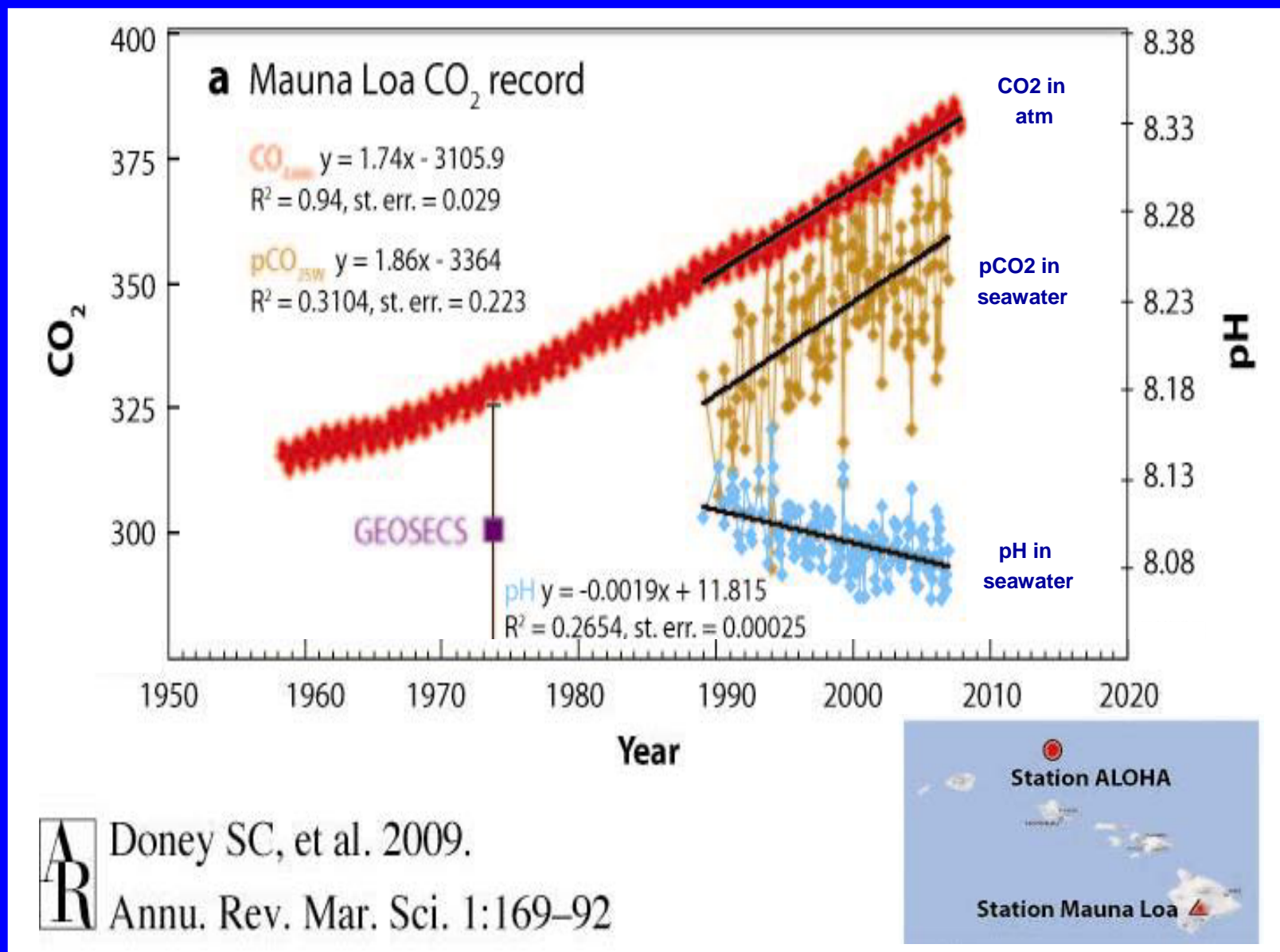
- FIND A NEW SHIP : Brittany Ferries? Or move to Hebridean Shelf or ??????

Invading CO₂ is Reducing Carbonate Ion Concentration

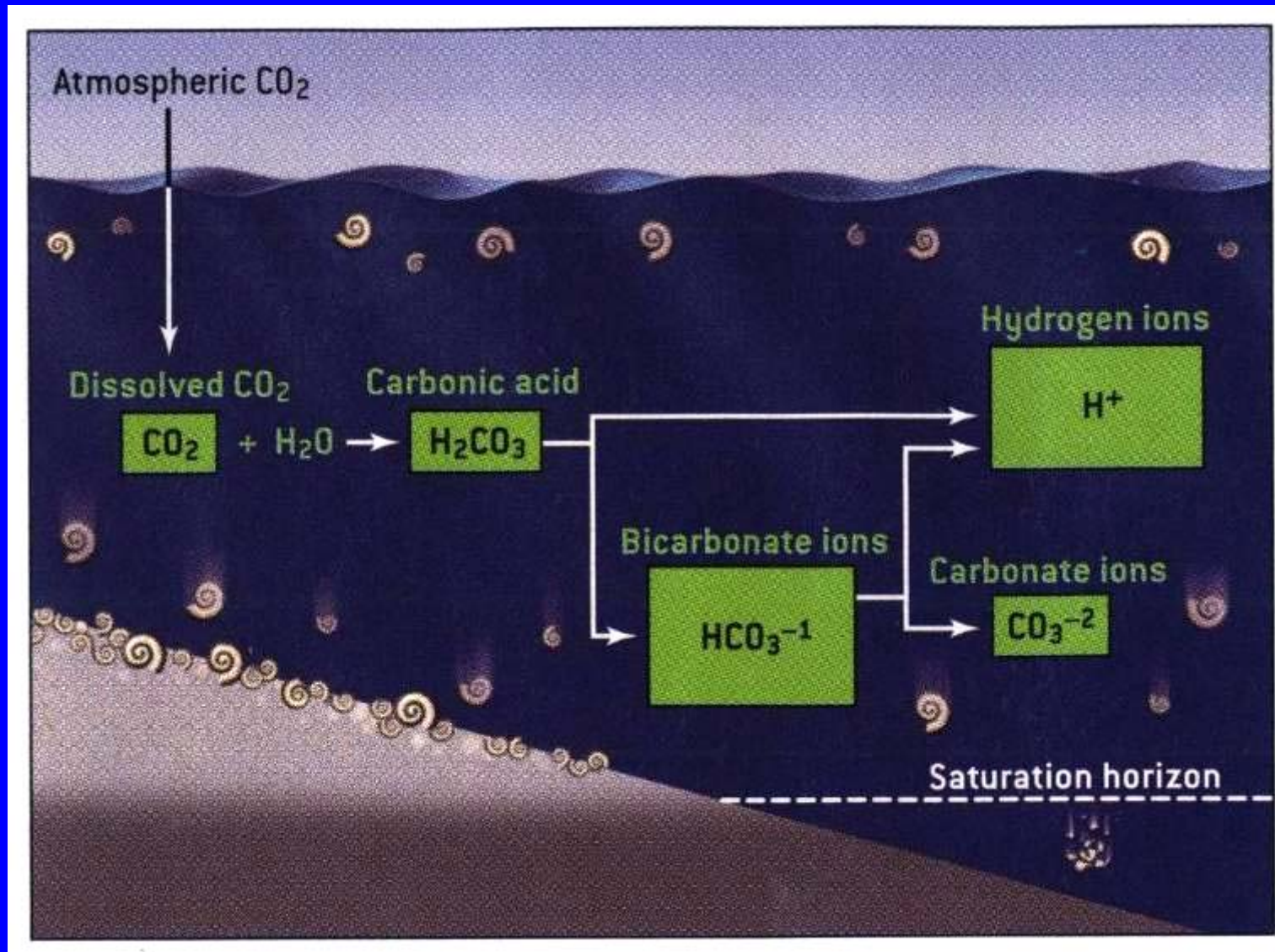


[Jim Orr]

As pCO₂ increases, pH decreases



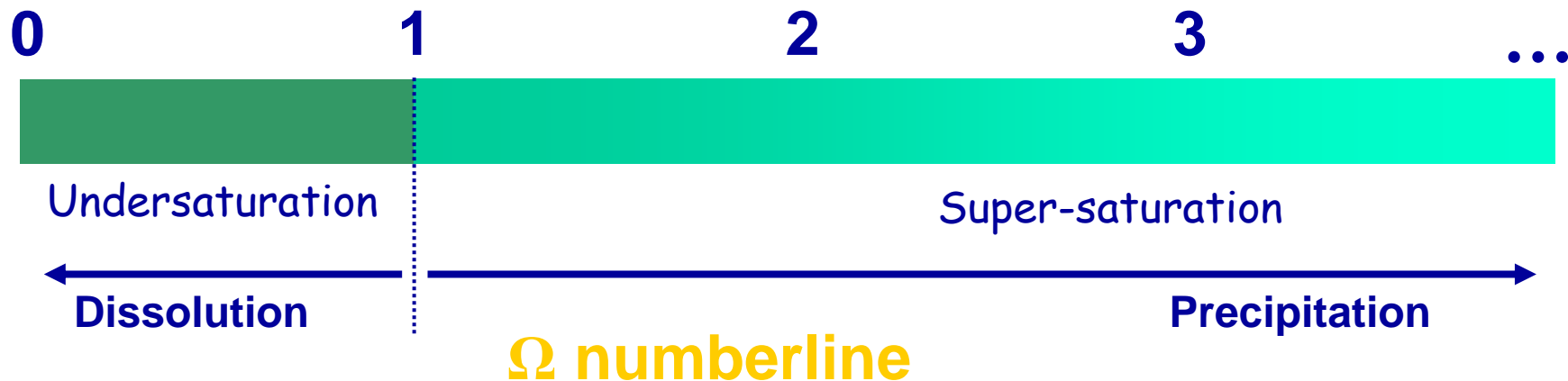
CO₂ Influx is Altering Carbon Chemistry



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

Inorganic Calcification dependent on Saturation State

$$\Omega = \frac{[\text{CO}_3^{2-}] * [\text{Ca}^{2+}]}{K'_{sp}}$$

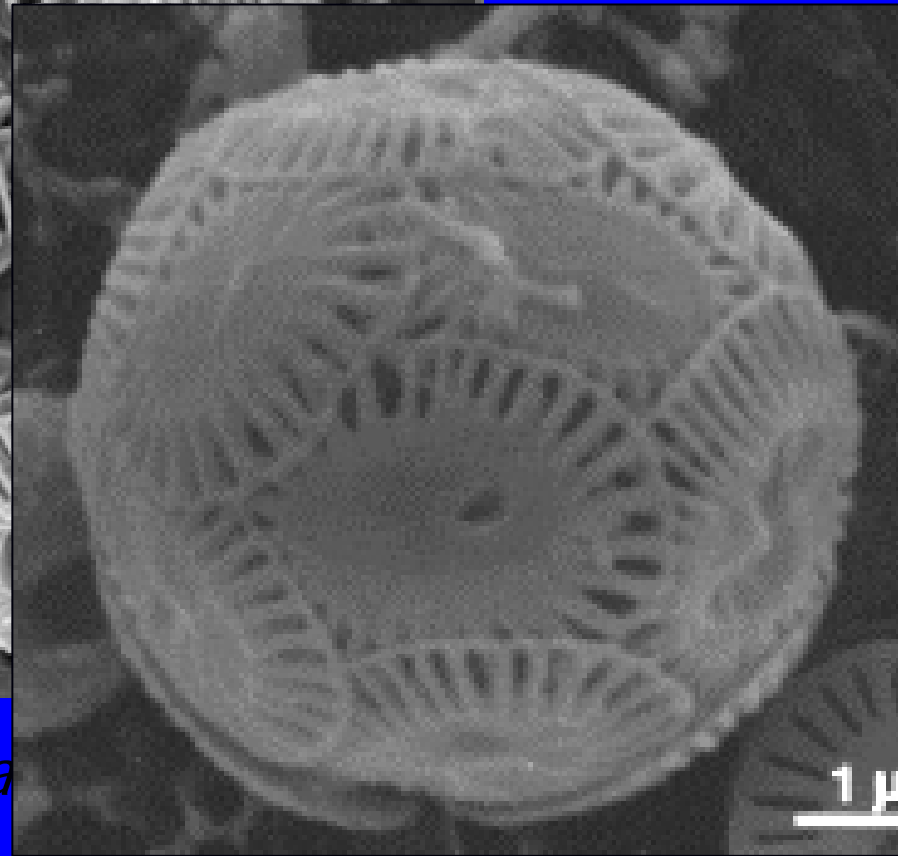
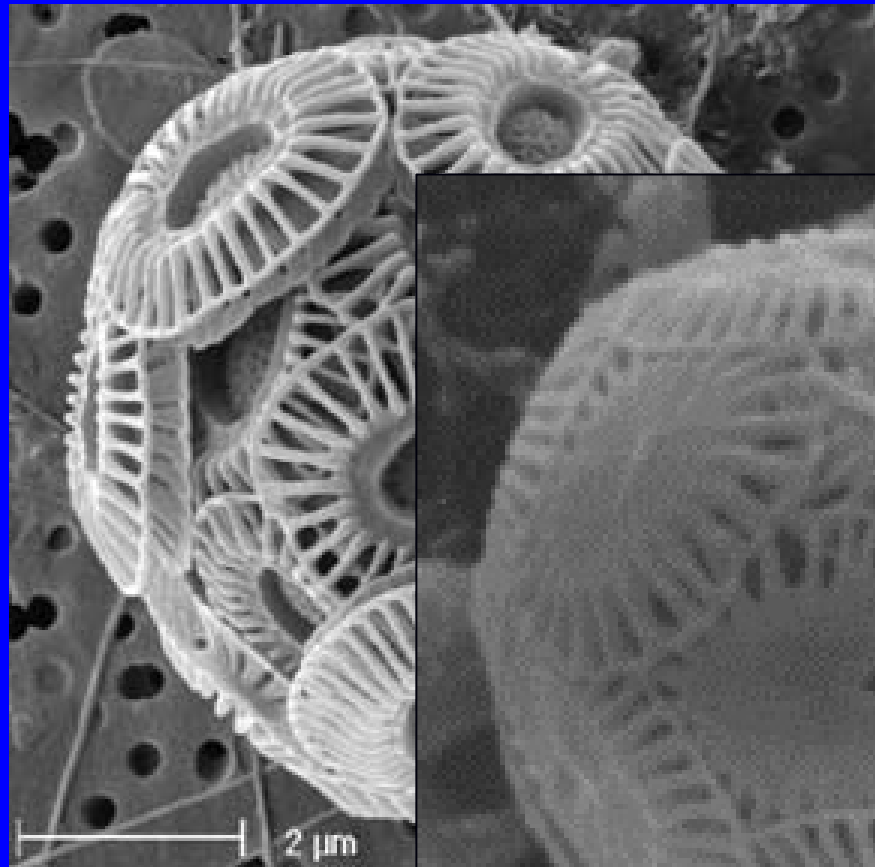


Robust Results

Cynthias 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

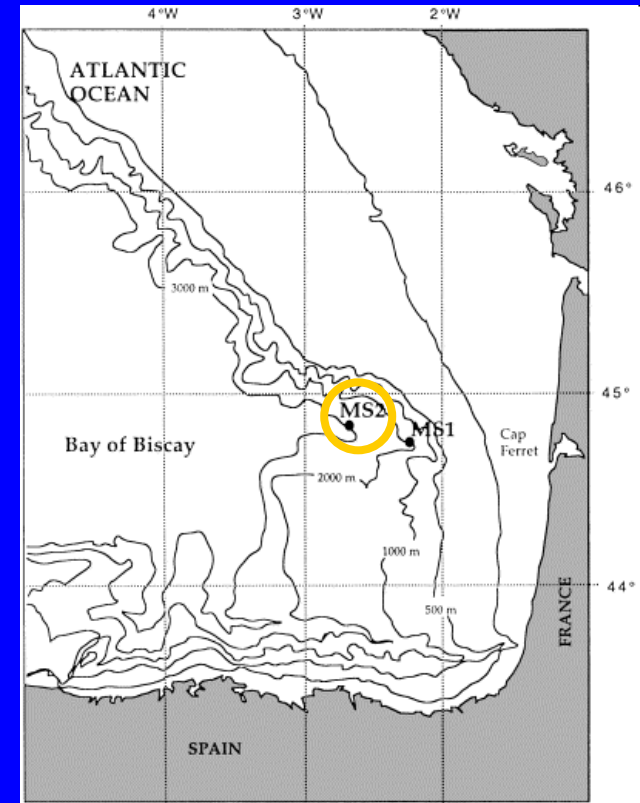
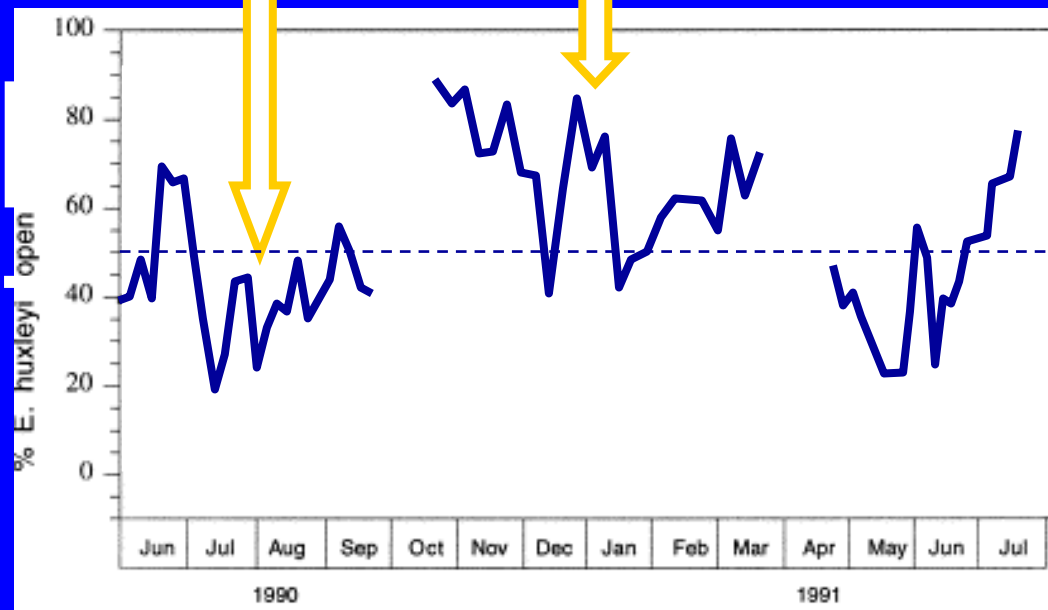
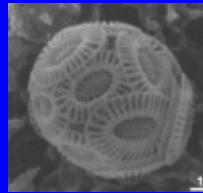
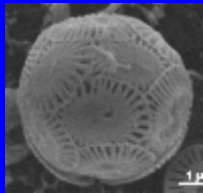


Emilinia

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 (<i>cf.</i> diatoms) | ? |
| 7. Overwintering resting stage | ? |

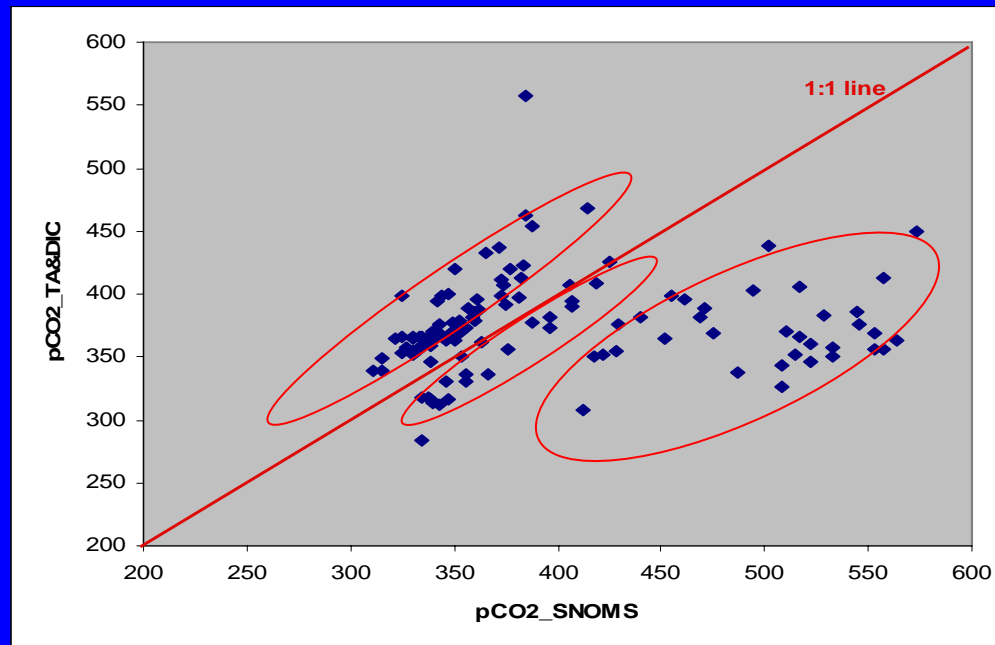
Is it a genotypic or a phenotypic shift?

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?



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^{*}, 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 & Department of Princeton University, Princeton, New Jersey, USA

[‡] Lamont-Doherty Earth Observatory, 61 Rte. 9W, New York, New York 10964, USA

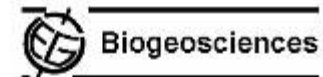
Biogeosciences, 6, 2637–2645, 2009
www.biogeosciences.net/92637/2009/
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RESEARCH ARTICLES

Phytoplankton Calcification in a High-CO₂ 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,² Peter von Dassow,⁴ Eric Rehm,⁵ E. Virginia Armbrust,³ Karin P. Boessenkool³

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 *Emiliana huxleyi* are less calcified under high CO₂ conditions. Field evidence from the deep ocean is consistent with our findings, showing that over the past 220 years there has been a decline in calcification. Our findings show that coccolithophores are already responding to rising atmospheric CO₂ partial pressures, and our modeling of future oceans and climate.

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

G. Langer^{1,2}, G. Nehrknecht², I. Probert³, J. Ly^{1,2}, and P. Ziveri^{1,4}

¹ICTA, Autonomous University of Barcelona (UAB), 08193 Bellaterra, Spain

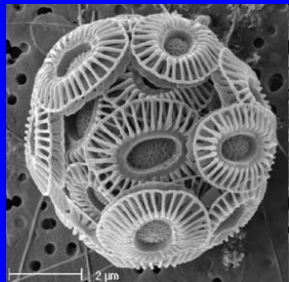
²Alfred Wegener Institute for Polar and Marine Research, 27570 Bremerhaven, Germany

³CNRS/UPMC, Station Biologique de Roscoff, 29682 Roscoff, France

⁴ALW, Vrije Universiteit Amsterdam, 1081HV Amsterdam, The Netherlands

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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

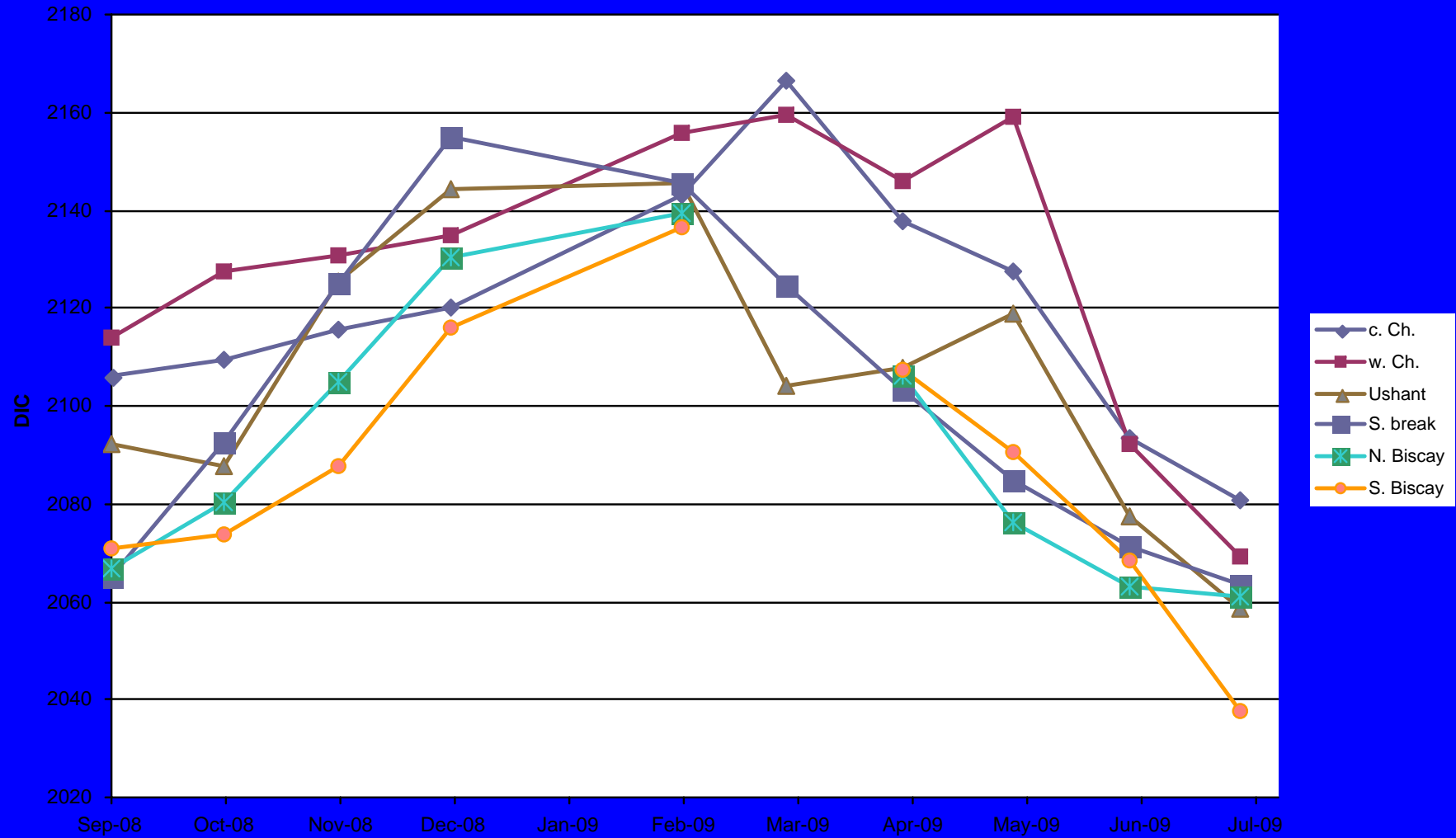
European Marine Strategy Framework Directive



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Seasonal DIC in regions along PoB track



Autumn-Winter

Spring-Summer