European research efforts on ocean acidification and its consequences

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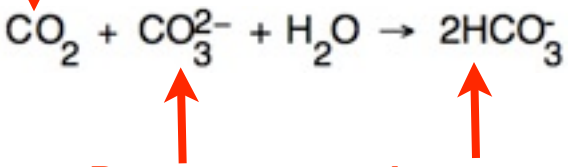
What is ocean acidification?

Increase in dissolved CO_2



$$CO_2 + CO_3^{2-} + H_2O \rightarrow 2HCO_3^-$$

Decreases carbonate

Increases bicarbonate

Redrawn from Körtzinger

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Acidity increases:
"*ocean acidification*"

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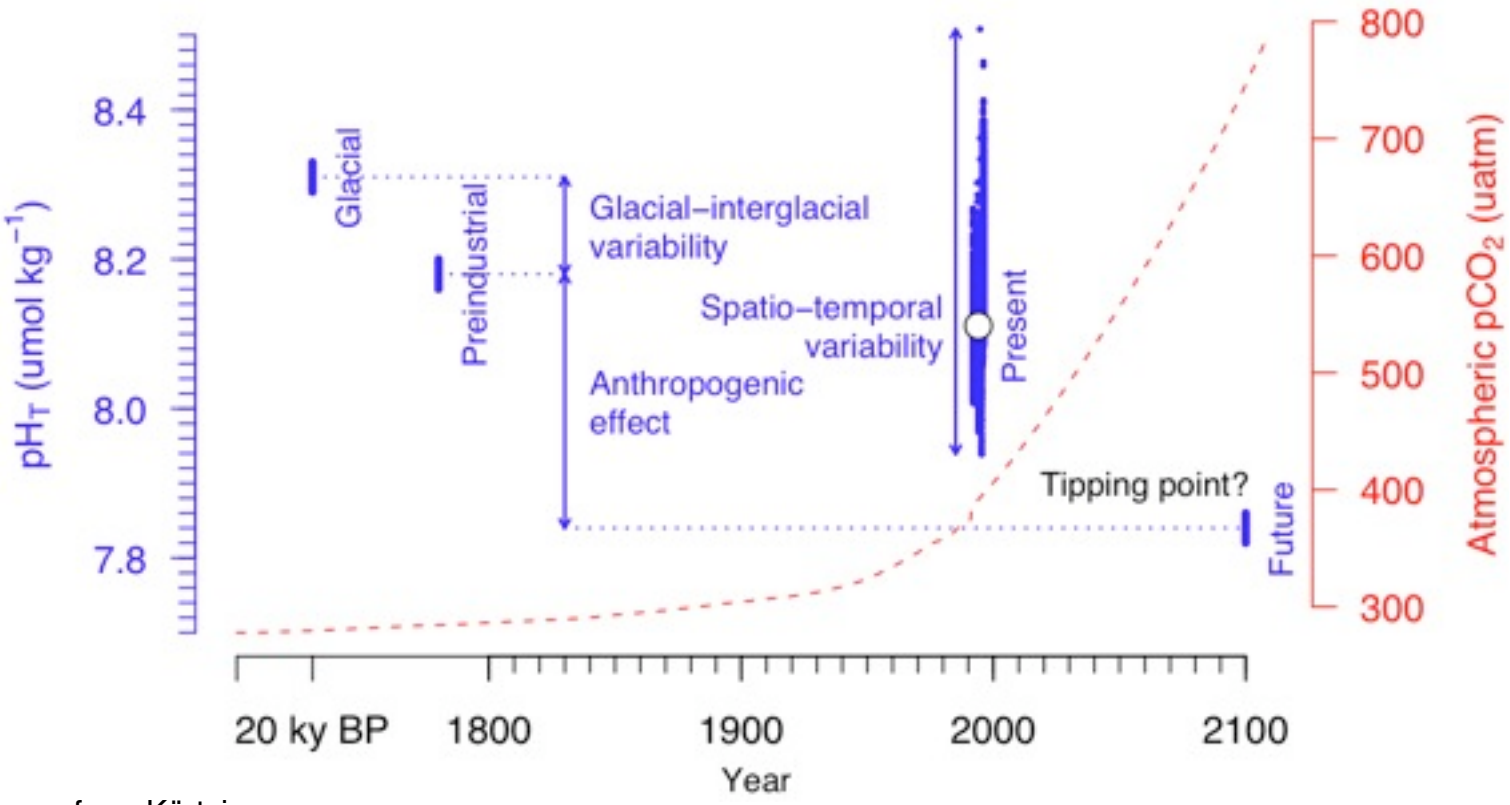
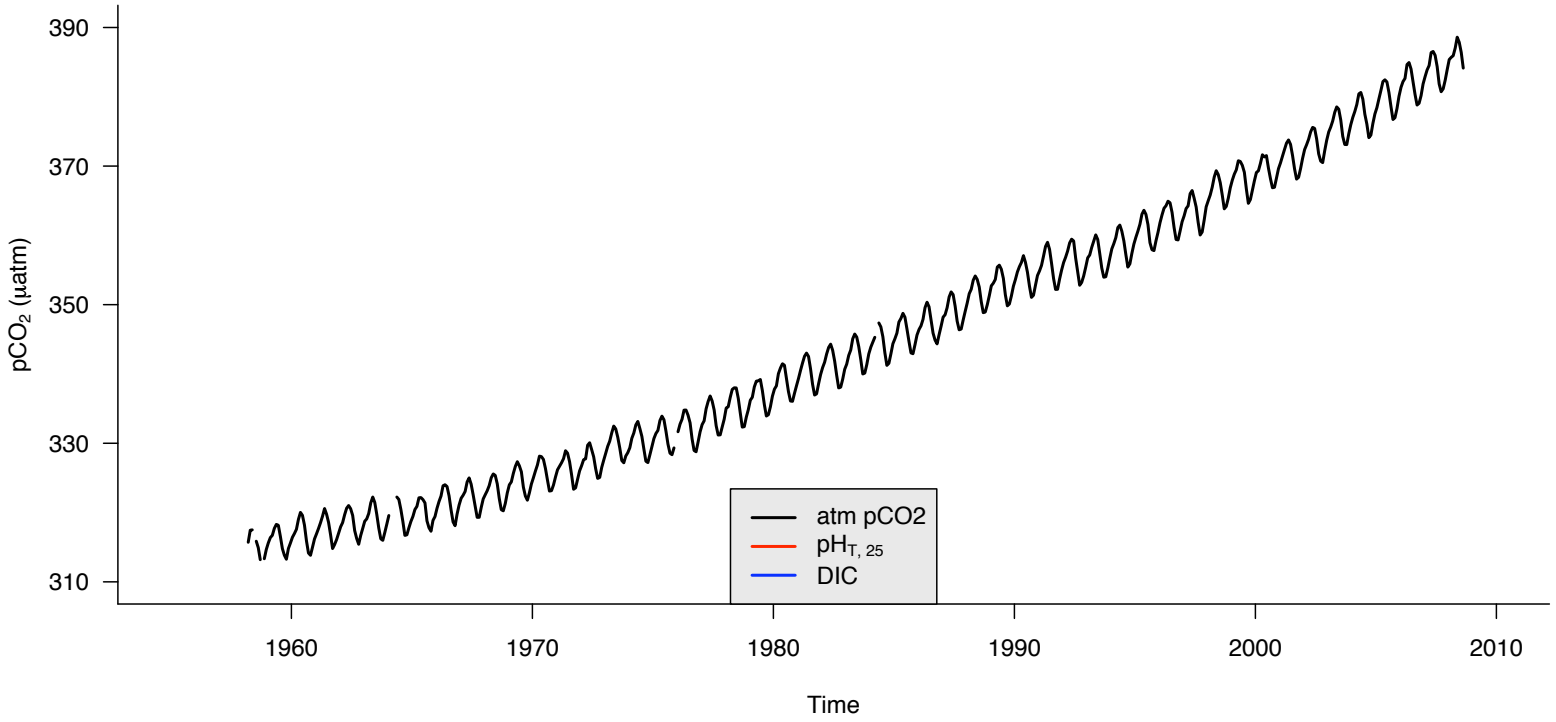


Redrawn from Körtzinger

Ocean acidification is detectable: Time-series



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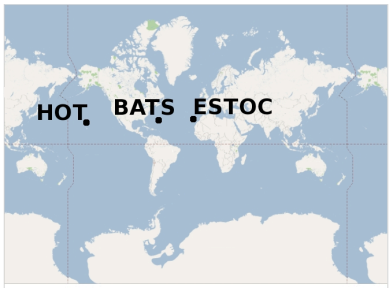
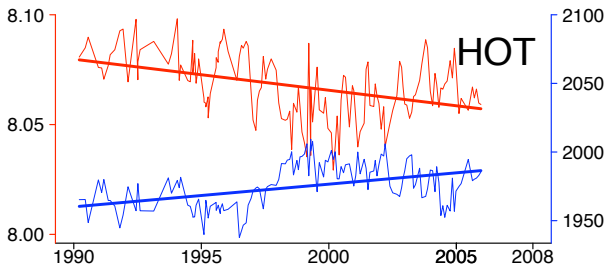
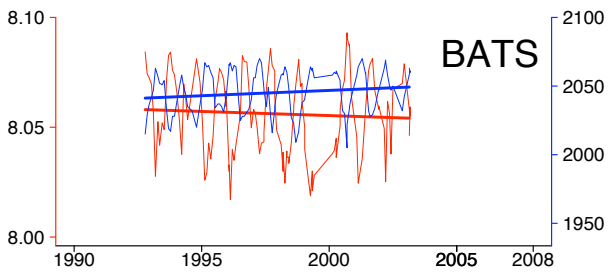
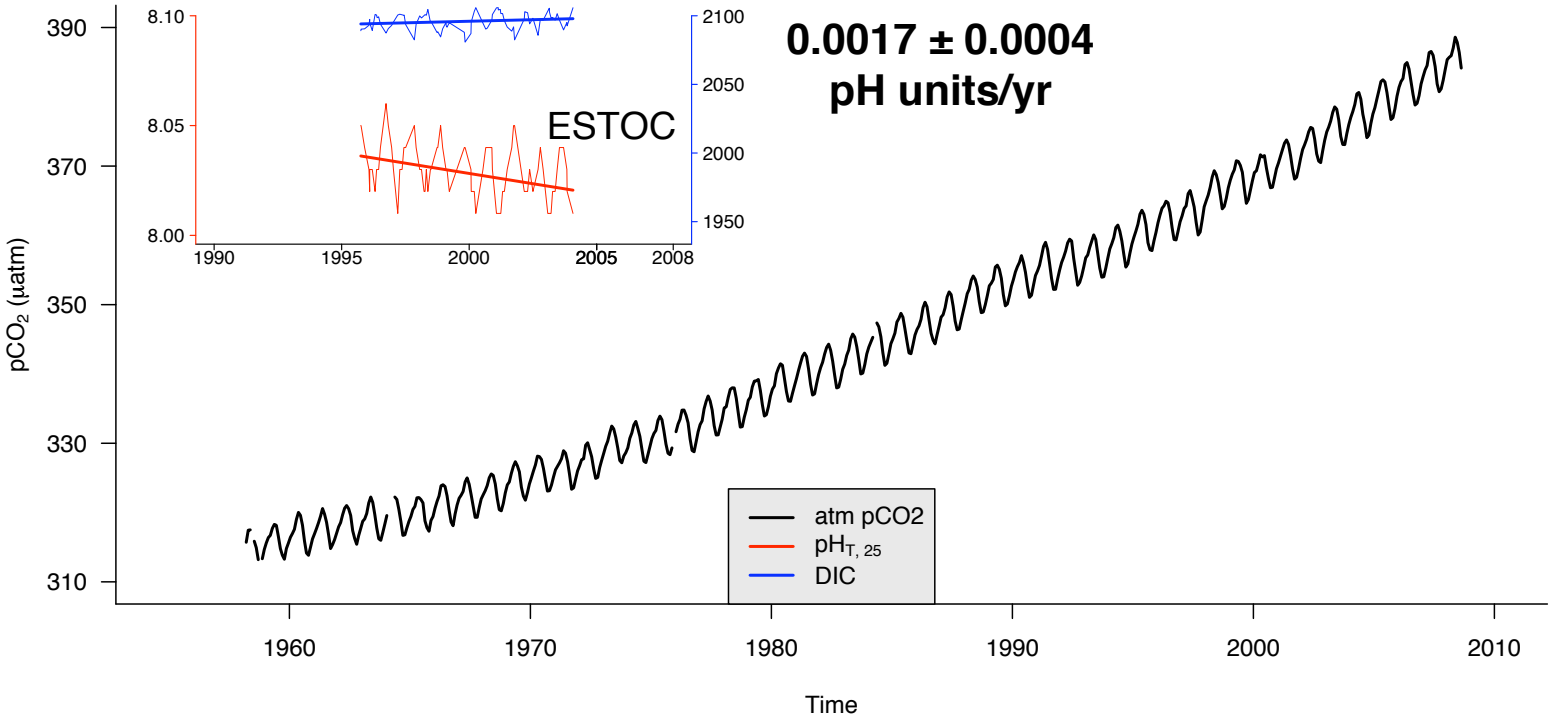








Overarching questions

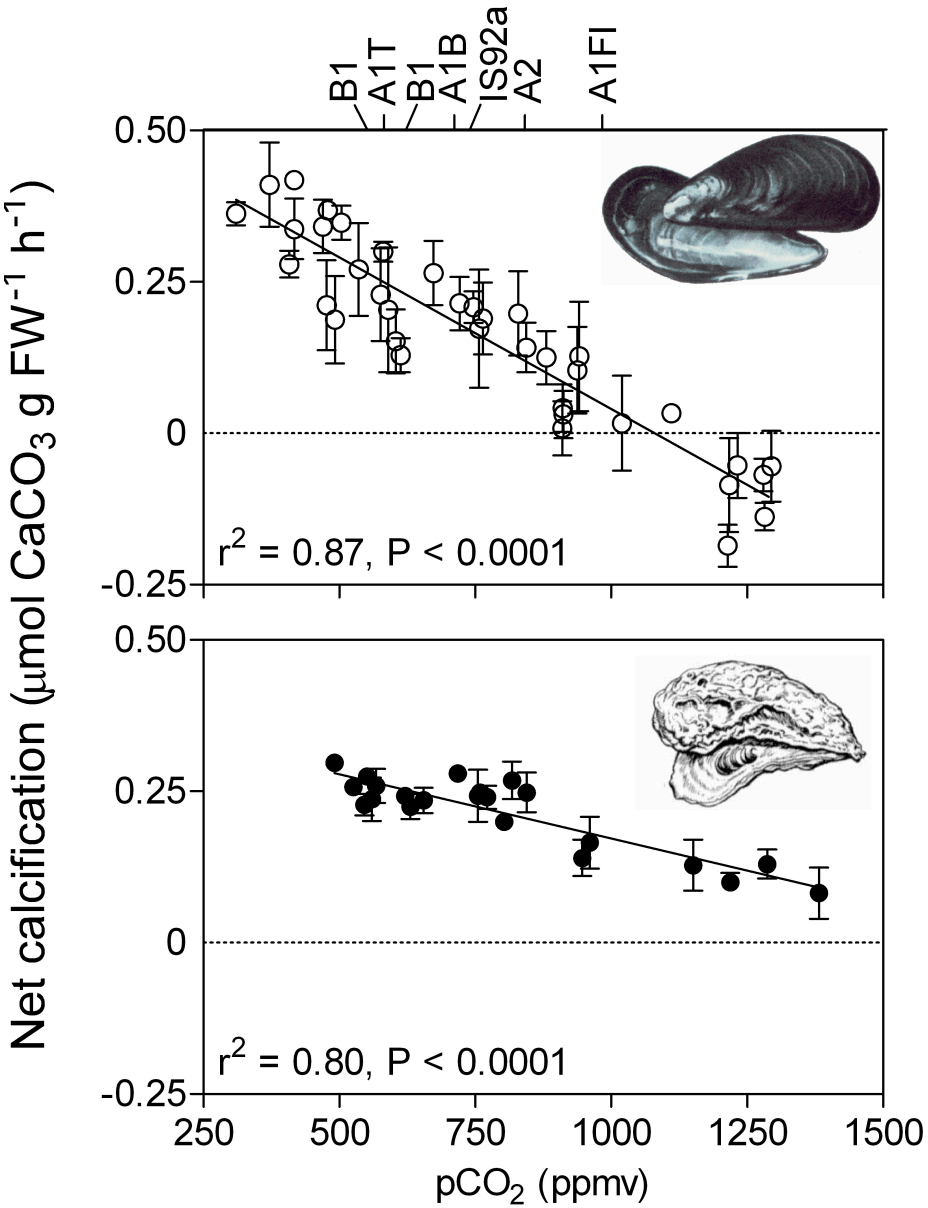
- Improve the understanding of the past and present changes of ocean acidification
- Determine the impacts of ocean acidification on marine biota
- Improve understanding of future changes in ocean chemistry and biogeochemical feedbacks
- Synthesize information on tipping points

Biological processes potentially affected

- Calcification (needs carbonate)
- Dissolution of calcium carbonate
- Photosynthesis (needs CO_2 or bicarbonate)
- Nutrient uptake (availability depends on pH)
- ...

Impact on shellfish calcification

- At 740 μatm: -25% for mussels and -10% for oysters
- Mussels dissolve at pCO_2 > 1100 μatm
- Global shellfish production: 11.7 million tons, a commercial value of US$10.5 billion
- Pacific oyster most cultivated species (4.2 millions tons or 10.8% of the total world aquaculture)
- Mussel production: 1.4 million tons (3.6% of total production)
- Predicted decrease of calcification likely cause a severe economic loss



Gazeau et al. (2007)

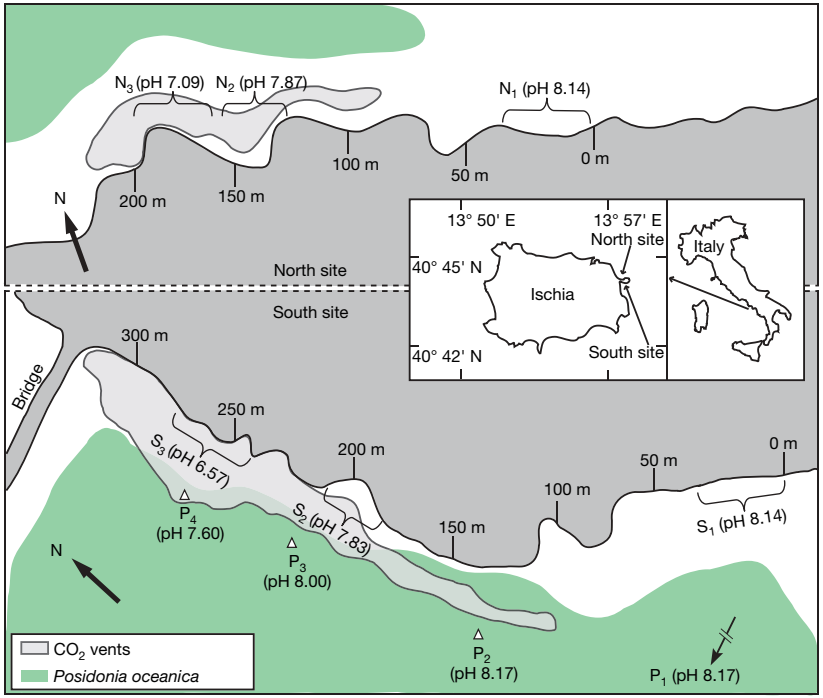
Biological reponses

Physiological response	Major group	Species studied	Response to increasing CO_2 a	b	c	d
Calcification						
	Coccolithophores[1]	4	2	1	1	1
	Planktonic Foraminifera	2	2	–	–	–
	Molluscs	4	4	–	–	–
	Echinoderms[1]	3	2	1	–	–
	Tropical corals	11	11	–	–	–
	Coralline red algae	1	1	–	–	–
Photosynthesis[2]						
	Coccolithophores[3]	2	–	2	2	–
	Prokaryotes	2	–	–	1	–
	Seagrasses	5	–	–	–	–
Nitrogen Fixation						
	Cyanobacteria	1	–	1	–	–
Reproduction						
	Molluscs	4	4	–	–	–
	Echinoderms	1	1	–	–	–

1) Increased calcification had substantial physiological cost; 2) Strong interactive effects with nutrient and trace metal availability, light, and temperature; 3) Under nutrient replete conditions.

Doney et al. (2009)

Naturally acidified site: Ischia island (Italy)



Hall-Spencer et al. (2008); Martin et al. (2008)

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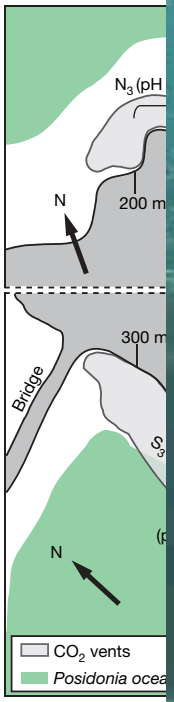

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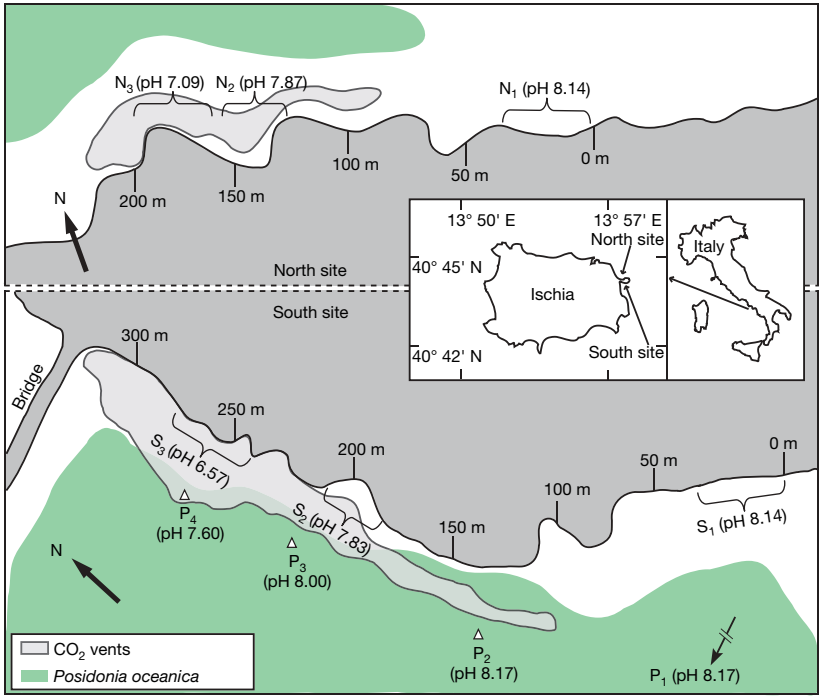


30% reduction in biodiversity at mean pH 7.8

Algae	**pH 8.2**	**pH 7.8**	**pH 6.6**
Green	15	12	4
Red	20	11	3
Brown	17	13	11
Total	**52**	**36**	**18**
Fauna			
Sponges	8	7	1
Cnidarians	8	4	2
Annelids	4	3	0
Crustaceans	5	3	2
Molluscs	29	17	6
Echinoderms	6	6	0
Fish	9	9	0
Total	**69**	**49**	**11**

Hall-Spencer et al. (2008); Martin et al. (2008)

Unknowns are numerous...

- Why some calcifiers seem to be resistant? Adaptation possible?
- Impact on fisheries:
  - almost certain on shellfish
  - unknown on fish industry (salmon industry in North Pacific?)
- Ecosystem responses (including biodiversity)
- Consequences for ocean carbon cycle (primary production, export to the deep-sea, feedback to ocean CO_2 uptake)

European Project on Ocean Acidification

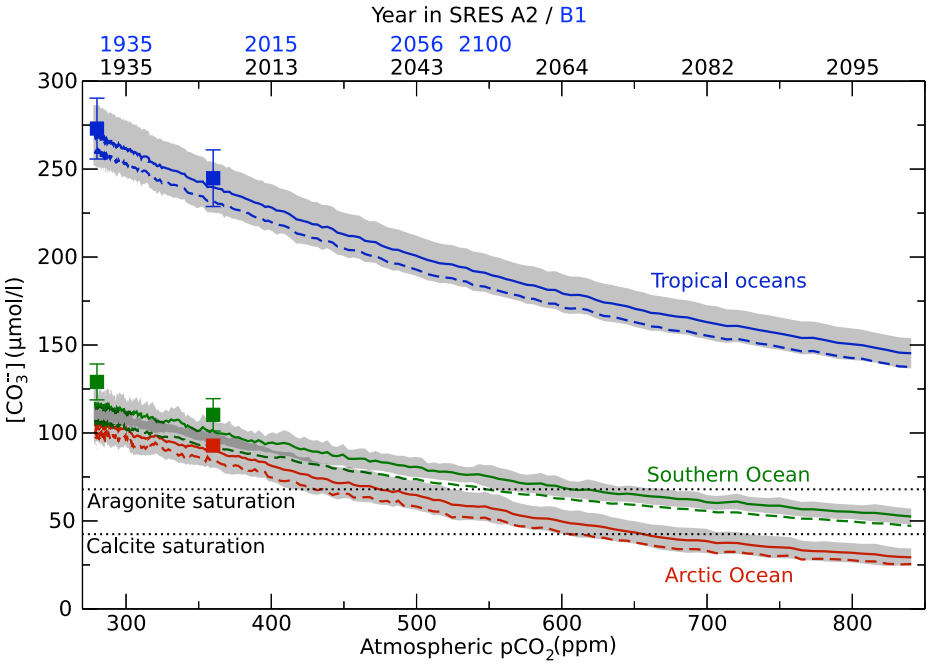
- A large-scale integrating project of the European Union which investigates ocean acidification and its consequences
- More than 100 scientists from 27 institutions and 9 countries
- Total budget of 16 M€, including 6.5 M€ from the EU (2008-2011)

EPOCA

epoca-project.eu

One of EPOCA's target regions: Arctic. Why?

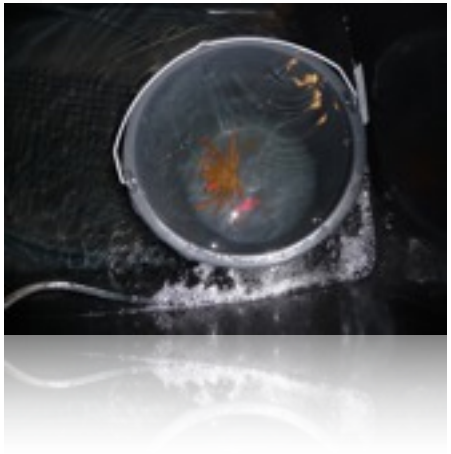
- The colder the water, the more gases it absorbs
- Polar regions will be the first places where surface seawater will become undersaturated (=corrosive) with respect to calcium carbonate
- Since millions of years until today all surface and near subsurface waters were super-saturated. In 2008, near-subsurface waters in the Canada Basin have become undersaturated
- If CO_2 emissions continue to rise as today (Orr et al.):
  - 10% of Arctic surface waters will be undersaturated already by 2018
  - 50% by 2050
  - 100% by the end of the century



Steinacher et al. (comm. pers.)

EPOCA
epoca-project.eu

EPOCA Svalbard experiment May 2009: sea floor



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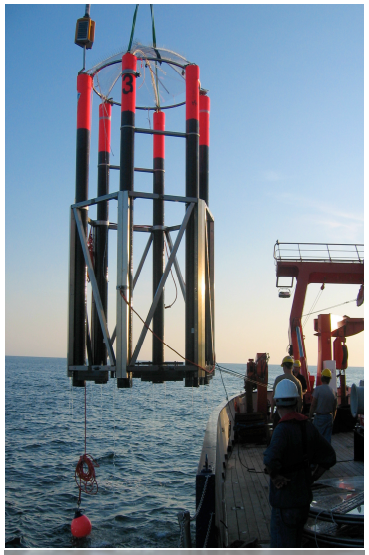
PML | Plymouth Marine Laboratory

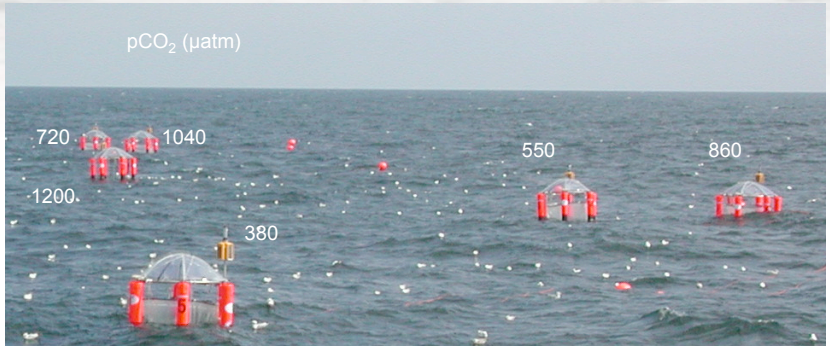
AWI

NIOO

EPOCA Svalbard expt June 2010: water column

Pelagic mesocosms





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Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

Photos: Andrea Ludwig

Contribution française

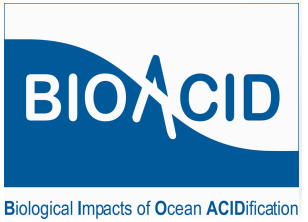
- Aucune structuration à l'échelle nationale
- Deux projets financés par CYBER (Douville, Leblanc)
- 4 labos français dans EPOCA (LOV, SBR, CEREGE et LSCE) et CARBOOCEAN (LSCE, LOV, UPERP)
- *Exemples* de projets passés, en cours ou en gestation:
  - Douville : paleo pH à partir de coraux
  - Goyet : documentation de l'acidification (DYFAMED, BIOSOPE)
  - Martin-Jézéquel : expériences de perturbation (Bergen et cultures diatomées labo)
  - Leblanc: perturbation phytoplancton en chémostats
  - Boye : impact sur spéciation métaux traces et phytoplancton
  - Gehlen et al.: Production, export et dissolution $CaCO_3$.

International activities

- **European Project on Ocean Acidification**
  - A large-scale integrating project of the EU (FP7)
  - 100+ scientists from 27 institutions and 9 countries
  - 16 M€, 6.5 M€ from the EU (2008-2011)

- **EU call** (FP7; July 2009): impacts of ocean acidification in the Mediterranean

- **BIOACID** (Germany): 18 partners, 9 M€ for 3 years
- **NERC** (UK): call in 2009; 11 M£ for 5 years



- **Federal Ocean Acidification Research And Monitoring Act** (US): passed in April 2009, US M$ 14-45 per year for 5 years (extension planned)
- **SOLAS-IMBER** working group on OA to be launched (i) synthesis and review activities and (ii) help coordinating international activities
- US Academy NRC panel on OA (2009)

Take home messages

- Ocean acidification is underway
- It is already detectable
- It is accelerating and severe damages are imminent
- It will have socio-economic impacts
- It is rapid but recovery will be slow (thousands of years)
- Ocean acidification can be controlled only by limiting future atmospheric CO_2 levels

Continuously updated information

- EPOCA ocean acidification blog: oceanacidification.wordpress.com
- Launched January 2007
- about 1000 posts published; 181 subscribers; 102000 pages viewed

Acknowledgements

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