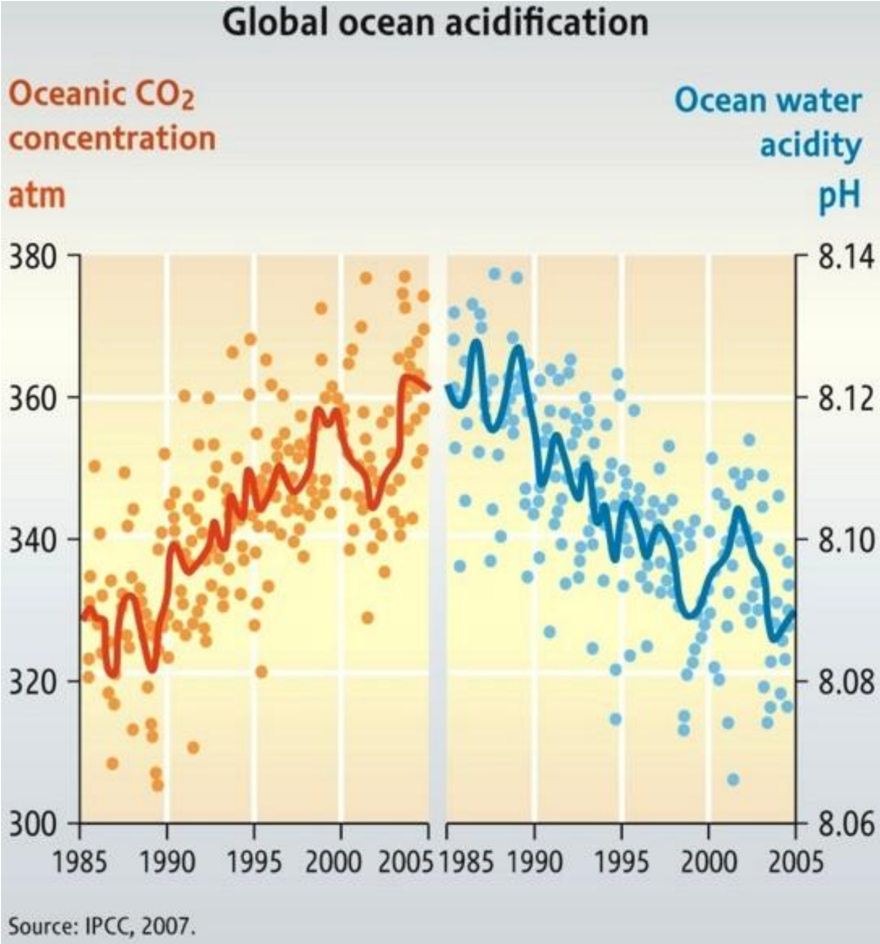

GIFT – 2011
Ocean Acidification

Geosciences Information for Teachers Workshop

Penang, Malaysia, June 23-24 2011

European Geosciences Union

GEOPHYSICAL INFORMATION FOR TEACHERS (GIFT) WORKSHOP

Penang, Malaysia,

June 23-24, 2011

Dear Teachers,

Welcome to this GIFT workshop on Ocean Acidification!

This is the 11th workshop of this kind, but only the second to be organized outside the General Assemblies of EGU, and in connection with an Alexander von Humboldt Topical Conferece on Ocean Acidification.

Together with Climate Change, Ocean Acidification is a major threat on our environment. Since 1800, about one third of CO2 emissions linked to human activities has been absorbed by the Ocean, which amounts to about 1 ton of CO2 per person and per year. This has had a positive impact by reducing the amount of CO2 (a green-house gas) in the atmosphere and thus mitigate climate changes. However, when carbon dioxide reacts with water it produces carbonic acid, so when more CO2 is taken up by the ocean, the ocean pH decreases (pH is a measure of acidity). The pH of surface ocean has already decreased by 0.1 units since pre-industrial times, and it is estimated that it will decrease by 0.4 units by 2100. This corresponds to an increase by a factor of 3 in the acidity of the Oceans, and it is happening at a rate that has not been experienced for at least 800,000 years and maybe for the last 20 million years.

The impact of this acidification is huge on sea organisms building a carbonate skeleton, such as pteropoids or coral reefs, because changes in CO2 concentration in sea water result in a decrease in the amount of carbonate ions, which are used by calcifying organisms. With increasing acidification, it will be harder for these organisms to make their shells or skeletons.

Although the effect of ocean acidification on marine ecosystems and organisms has only recently been recognized, many studies and programs already exist worldwide taiming to the study of this phonomen. One such program, the European Project EPOCA (European Project on Ocean Acidification) was launched in June 2008 for 4 years. The overall goal is to advance our understanding of the biological, ecological, biogeochemical, and societal implications of ocean acidification, with specific goals to:

- document the changes in ocean chemistry and biogeography across space and time
- determine the sensitivity of marine organisms, communities and ecosystems to ocean acidification
- integrate results on the impact of ocean acidification on marine ecosystems in biogeochemical, sediment, and coupled ocean-climate models to better understand and predict the responses of the Earth system to ocean acidification

- assess uncertainties, risks and thresholds ("tipping points") related to ocean acidification at scales ranging from sub-cellular to ecosystem and local to global

The EPOCA consortium brings together more than 160 researchers from 32 institutes and 10 European countries (Belgium, France, Germany, Iceland, Italy, The Netherlands, Norway, Sweden, Switzerland, United Kingdom), which gives a clear idea of how important this environmental threat is. A documentary “Tipping Ponts” will be shown to inform you on the progress and achievements of this international program.

In the one and a half day of the workshop we can only address a small number of the different aspects of the study of Ocean Acidification, but we hope that you will acquire some basic information and ideas on this environmental threat, and that you will transmit this to your students, our ambassodors to the future. The speakers who will address you are internationally known scientists or economist who participate to the AvH7 conference and who have kindly accepted to address you. At the end of each of their conferences, we have scheduled 15 minutes for questions and observations. Please don’t be shy in asking questions to our speakers! Showing your interest is the best way to thank them for taking their time to address you in this workshop!

Also, please take a look to our web pages on the EGU web site, where you can find the brochures and the pdf presentations corresponding to the 10 GIFT workshops which we have organized so far. Since 2009, we have implemented an activity called GIFT Web Conferences, by which selected talks at GIFT workshops are recorded and made available for download or streaming in the classroom via the internet. We encourage you to use this tool in the classroom and share them with your students, train them to listen to a talk in English language, and discuss the content of the talk. Previous years conferences are accessible through the EGU GIFT Workshop web pages: http://www.egu.eu/webtv/2010/gift/ and http://www.egu.eu/webtv/2009/gift/

It is very important for us to understand whether this workshop has been useful to you in your classroom activity. Therefore, we ask you 1. to fill out the evaluation forms as soon as possible and send them back to us as well as 2. make a presentation of your experiences at GIFT to a group of your teaching colleagues sometime after you return from EGU, and 3. Later in the year send us reports and photographs about how you have used the GIFT information in your classrooms.

Information on past and future GIFT workshop is available on the EGU homepage. Look a http://gift.egu.eu where you can find the brochures (pdf) and also the slides of the different presentations given at the GIFT workshops for the last 7 years.

We hope that you enjoy and learn during your time at the 11th GIFT workshop!

Carlo Laj
On behalf of the Committee on Education of EGU

European Geosciences Union
Committee on Education

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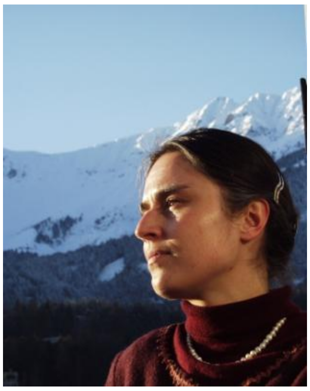
European Geosciences Union

Committee on Education



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GEOSCIENCE INFORMATION FOR TEACHERS (GIFT) WORKSHOP

Penang, Malaysia June 23 - 24, 2011

Ocean Acidification

Programme

Thursday, June 23, 2011

09:00 – 9:20	**WELCOME !** **PRACTICAL INSTRUCTIONS FOR THE WORKSHOP** Carlo Laj EGU Committee on Education
09:20– 10:00	**OCEAN ACIDIFICATION – A BIOGEOLOGICAL PERSPECTIVE** Jelle Bijma Marine Biogeosciences Alfred Wegener Institute for Polar and Marine Research Bremerhaven Germany
10:00 – 10:40	**OCEAN ACIDIFICATION: THE BASIC CHEMISTRY** Richard E. Zeebe School of Ocean and Earth Science and Technology, Department of Oceanography, University of Hawaii at Manoa, Honolulu, HI 96822. USA
10:40 – 11:00	**COFFEE BREAK**
11:00– 11:20	**QUESTIONS TO** Jelle Bijma and Richard Zeebe
11:20– 12:00	**THE CORAL REEF STORY: CLIMATE CHANGE AS MAJOR THREAT THE WORLD'S MOST BIOLOGICAL DIVERSE ECOSYSTEM. (VIDEO)** Ove Hoegh-Guldberg, Global Change Institute, University of Queensland, Australia
13:00 – 14:00	**LUNCH**
14:00 –14:40	**OCEAN ACIDIFICATION: BACK TO BASIC(S)** R.D. Schuiling Institute of Geosciences University of Utrecht Holland
14:40 –14:50	**QUESTIONS TO** R.D. Schuiling

14:50 –15:30	**The Richness and Splendors of the Malaysian Seas** Zulfigar Yasin Marine Science Laboraotry Universiti Sains Malaysia, Penang, Malaysia
15:30 – 15:40	**Questions** to Zulfigar Yasin
15:40 - 16 :00	**Coffee Break**
16:00 – **17:00**	**Inquiry-to-Insight: Digital Education Project conveying Scientific Ocean Acidification Data to High-School Students** Sam Dupont Department of Marine Ecology Göteborg University Sweden

Friday, June 24, 2011

09:00 – 09:40	**Ocean Acidification, Marine Organisms and the Marine Carbon Cycle** Uta Passow Marine Sciences Institute University of California, Santa Barbara, USA
9:40 – 9:50	**Questions** to Uta Passow
9:50 – 10:30	**Confronting the Challenges of Ocean Acidification: Linking Potential Socio-Economic Impacts and Economic Valuation Towards Appropriate Policies** Rodelio Subade Institute of Fisheries Policy and Development Studies University of the Philippines Visayas (UPV) Miagao, Iloilo, Philippines
10:30 – 10:40	**Questions** to Rodelio Subade
10:40 – 11:00	**Coffee Break**
11:00 – 11:30	**Educational Activities at the European Geosciences Union** Carlo Laj Chair, EGU Committee on Education
11:30 -12:40	**Showing of "Tipping Points" Movie on EPOCA achievements**
12:40 – 13:00	**Joined AOGS, JpGU & EGU statement on Ocean Acidification**
13:00 - 13:30	**Lunch and Goodbye**

Teachers

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23-24 Jun 2011 (Khamis-Jumaat)

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Speakers

Prof. Dr. Jelle Bijma

Marine Biogeosciences
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Am Handelshafen 12
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My university training is in biology and geology at the State University of Groningen, The Netherlands (1979-1985). After my MSc (marine biology and actuopaleontology) I accepted a position as research assistant at the University of Tübingen (Germany). In 1991 I received my Doctor of Science with a thesis "On the biology of tropical spinose Globigerinidae (Sarcodina, Foraminiferida) and its implications for paleoecology" at the State University of Groningen (The Netherlands). In 1993 I moved to the Alfred-Wegener Institute for polar and marine research (AWI) as a post-doc where I initiated the interdisciplinary Carbon Working Group. After a two-years post-doc at the department of geology at the University of Bremen (1997-1999), I was offered a permanent position at the AWI. The Carbon Working Group became the section Marine Biogeosciences and this is where I still am. In 2004 I became adjunct professor of marine geosciences at the International University Bremen (Jacobs University Bremen as of spring 2007). In 2008, I successfully launched the HGF Graduate school for Polar and Marine Research, POLMAR", which currently counts over 100 PhD students.

My research interests focus on process-oriented studies of the incorporation of isotopes and (trace) elements ("proxies") into biogenic carbonates, biomineralisation, global biogeochemical cycles (specifically the carbon cycle) and processes of modern and past climate change including ocean acidification.

I have been President of the Biogeosciences devision at EGU from 2004 through 2010 and still act as editor of the EGU open access journal "Biogeosciences". I am coordinator of several EU, EGS, bi-national and national projects and serve on several national and international scientific committees and programmes dealing with biogeology, paleoceanography, modern and past climate and global change in research, ocean acidification, training and outreach. I am speaker of the HGF Graduate school for Polar and Marine Research, POLMAR".

Ocean acidification – a biogeological perspective

Jelle Bijma

Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
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When CO_2 is absorbed from the atmosphere into the ocean, it forms carbonic acid and lowers pH. This process is commonly referred to as ocean acidification (OA). On geologic timescales, the CO_2 concentration in the atmosphere and the carbonate chemistry of the oceans are constantly changing and adjusting to forcing through tectonics, volcanism, weathering, biology and currently, the human race.

Relationships between the elemental and isotope composition of fossil remains and environmental parameters, so called proxy relationships or "proxies" for short, allow to reconstruct climates of the past. Proxy evidence suggest that atmospheric CO_2 concentrations have been much higher than today during long warm intervals in Earth's history and that those conditions were not harmful to e.g. calcifying organisms. In fact, the name Cretaceous with its high atmospheric pCO_2 was coined because of its massive limestone deposits from e.g coccolithophores that build the cliffs of Dover in the UK. Hence, it is a common misconception that high atmospheric pCO_2, *per sé*, goes hand in hand with reduced biocalcification. In fact, for most calcifying organisms the saturation state of the ocean with respect to calcium carbonate is more important than its pH.

If a carbon perturbation is slow enough, surface waters will remain supersaturated because dissolution of deep sea sediments and weathering of rock on the continent, can keep pace with the perturbation and the saturation state of the ocean with respect to calciumcarbonate is well regulated. As a consequence, calcifying organisms continue to form their skeletons in a well buffered ocean even when pH is low. On the other hand, organisms that actively regulate their acid-base balance will still be under pressure at a lower pH even though the saturation state of the ocean remains high, simply because they have to spend more metabolic energy on their pH regulation at the expense of other processes.

There have been periods in Earth's history where we have indications that the ocean has been acidified, in terms of a lower pH than today. For instance, at the end of the Permian, ca. 251 Myr ago or at the Paleocene-Eocene Thermal Maximum (PETM), 55 Myr ago. These acidification events were also triggered by a carbon perturbation but had a different origin (volcanism and methane clathrates, respectively) than today. Nevertheless, all are characterized by catastrophic extinctions and biodiversity loss. Importantly, it should be noted that OA (lowering of pH) is only one consequence of a carbon perturbation. These events are usually accompanied by global warming, stronger stratification of the ocean and a decrease of the oxygenation of the deep sea (so called "Ocean Anoxic Events" or OAE's). As such, it is difficult to de-convolve the consequence of decreased pH from the plethora of associated impacts.

It is important to keep in mind that the climatic conditions prior to the above mentioned geologic events were vastly different from today. The atmospheric pCO_2 was high to start with, the oceans were warmer and had a different chemistry, which, by itself, had a considerable impact on the saturation state with respect to calciumcarbonate. However, the most important difference between all previous geological events compared to today is the rate at which the human induced carbon perturbation proceeds.

Hence, even though we do not seem to have a perfect analog to the present day carbon perturbation, we can only expect that the consequences of manmade OA are worse than those recorded in the geological records, simply because the rate of change is unprecedented in the Earth's history and the marine ecosystem as we know it today has mainly evolved in a time where atmospheric CO_2 has been low and oceans were well buffered. The detailed PETM record, which is probably the best analog, teaches us, that it might take about 100kyr for a full chemical recovery of the ocean and that biological recovery takes millions of years.

Ocean acidification is occurring today and will continue to intensify, closely tracking global CO_2 emissions. Given the potential threat to marine ecosystems and biodiversity and, its ensuing impact on human society and economy, especially as it acts in conjunction with ocean warming, there is an urgent need for immediate action. This "double trouble" is probably the most critical environmental issue that humans will have to face in their immediate future and it might become the major socio-economic challenge of this century.

The impacts of ocean acidification are global in scope and yet some of the least understood of all climate change phenomena. Given that its effects are already measurable and that biological impacts may become dramatic within only decades, we must now accept the challenge to better coordinate and stimulate research on ocean acidification if we are to fully understand the consequences of and eventually help mitigate ocean acidification.

Understanding the risks and consequences of OA and recognising that both OA and global warming are caused by anthropogenic CO_2 emissions will hopefully help to set in motion a stringent climate policy worldwide. The only solution to neutralize OA and global warming is a long-term mitigation strategy to limit future release of CO_2 to the atmosphere and/or enhance removal of excess CO_2 from the atmosphere.

Dr. Richard E. Zeebe

Professor in the Department of Oceanography
University of Hawaii at Manoa.

Richard E. Zeebe received his PhD in Physics from the University of Bremen in Germany and worked at Columbia University in New York as a post-doctoral scholar. His research focuses on the global carbon cycle, biogeochemistry and paleoclimatology. This includes a broad spectrum of topics, ranging from physico-chemical properties of molecules and the biogeochemistry of tiny marine organisms to climate change and ocean acidification at the global scale. He has authored and co-authored more than fifty publications in peer-reviewed international journals and has published a book on the CO2 chemistry in seawater. He is also an editor of the international journals 'Climate of the Past' and 'Paleoceanography'.

A few publications

Zeebe, R. E. and A. Ridgwell, Past changes of ocean carbonate chemistry, in Ocean Acidification, ed. J.-P. Gattuso and L. Hansson, Oxford University Press, in press 2011.

Zeebe, R. E.. On the molecular diffusion coefficients of dissolved CO2, HCO3-, and CO32- and their dependence on isotopic mass. Geochim. Cosmochim. Acta, 2011.

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Riebesell, U., I. Zondervan, B. Rost, P. D. Tortell, R. E. Zeebe, and F. M. M. Morel, Reduced calcification of marine plankton in response to increased atmospheric CO2. Nature, 407, 364-367, 2000.

Zeebe, R. E., D. A. Wolf-Gladrow, and H. Jansen, On the time required to establish chemical and isotopic equilibrium in the carbon dioxide system in sea water. Mar. Chem., 65, 135-153, 1999.

Ocean acidification: the basic chemistry

Richard E. Zeebe

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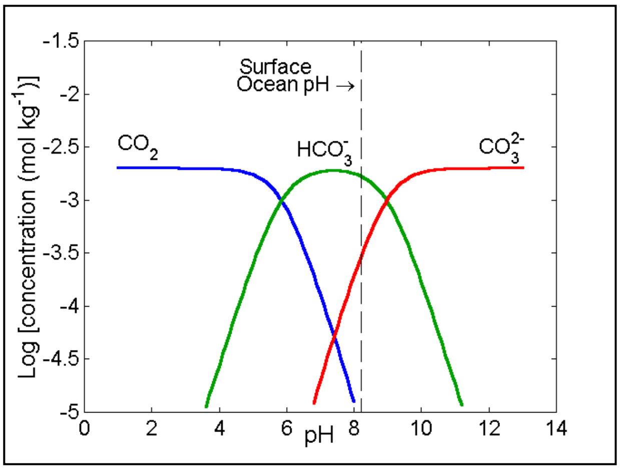
Abstract. Since the industrial revolution, humans have released about 500 billion metric tons of carbon dioxide into the atmosphere. This is equivalent in weight to about 28 inches of water (ca. 70 cm) across the whole State of Texas. This has not only consequences for atmospheric greenhouse gases and climate but also for ocean chemistry. The oceans have absorbed about one third of the released carbon dioxide, which makes the seawater less alkaline - a process termed 'ocean acidification'. As a result, surface ocean pH has already dropped by 0.1 units relative to preindustrial levels and is expected to drop by 0.3 units until year 2100 under business as USual scenarios. In this presentation, I will explain the basic chemistry of ocean acidification and the role the oceans plays in the global carbon cycle. Furthermore, I will describe the human impact on the carbon cycle since the preindustrial revolution and will present future projections of man-made carbon dioxide emissions. If time permits, I will illustrate the consequences of those emissions for marine life in the open and coastal ocean, including prospects for coral reef habitats.

Ocean carbonate chemistry

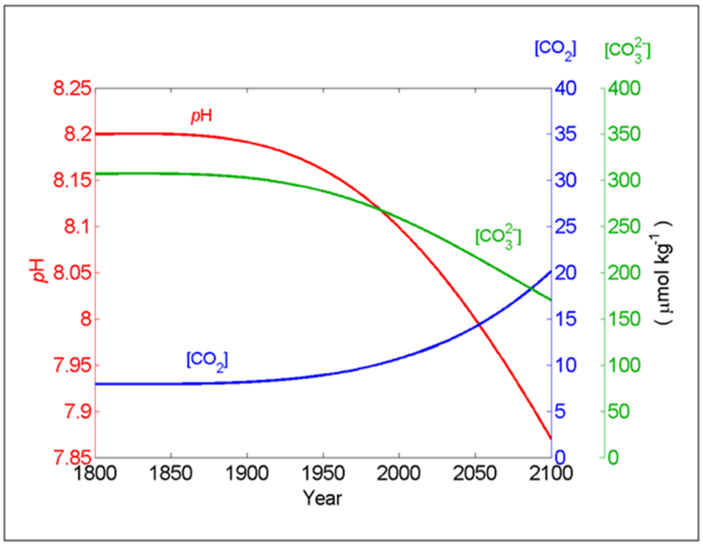
Dissolved carbon dioxide in the ocean occurs mainly in three inorganic forms (see Fig. 1): free aqueous carbon dioxide (CO_2(aq)), bicarbonate (HCO_3^-), and carbonate ion (CO_3^{2-}). A minor form is true carbonic acid (H_2CO_3) whose concentration is less than 0.3% of [CO_2(aq)]. The sum of [CO_2(aq)] and [H_2CO_3] is denoted as [CO_2]. The majority of dissolved inorganic carbon in the modern ocean is in the form of HCO_3^- (>85%), for more details, see Zeebe and Wolf-Gladrow (2001).

Fig.1



Between 1750 and 2000, anthropogenic CO2 emissions have led to a decrease of surface ocean pH by ~0.1 units from ~8.2 to ~8.1. If anthropogenic carbon dioxide emissions continue unabated, surface ocean pH will drop below 7.9 in year 2100 (see Fig. 2). By year 2300, surface ocean pH will fall to 7.5 (Zeebe et al., 2008). Note that surface ocean pH has probably not been below ~8.1 during the past two million years. With increasing CO_2 and decreasing pH, carbonate ion (CO_3^{2-}) concentrations decrease and those of bicarbonate ($HCO3^-$) rise (Fig. 2). With declining CO_3^{2-} concentration ($[CO_3^{2-}]$), the stability of the calcium carbonate ($CaCO_3$) mineral structure, used extensively by marine organisms to build shells and skeletons, is reduced. Other geochemical consequences of CO_2 invasion into the ocean include changes in trace metal speciation and even changes in sound absorption.

Fig. 2



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Prof. Ove Hoegh-Guldberg

Director, Global Change Institute,
University of Queensland

In addition to his role as the inaugural Director of The University of Queensland's Global Change Institute, Ove leads an active research program involving over 30 researchers and students who are focused on the influence of global climate change and ocean acidification on marine ecosystems such as coral reef ecosystems (www.coralreefecosystems.org). This research spans molecular, ecological and socio-economic studies of coral reef processes and services.

Ove was recognised with the Eureka Prize in 1999 for his work on climate change impacts on coral reefs, and the Queensland Smart State Premier's Fellowship in 2009. He has worked extensively with the World Bank, Royal Society, NASA, NOAA and other international scientific organisations, and is currently coordinating lead author of the Chapter 30 ('Oceans') for the 5th Assessment Report of the IPCC. Ove has published over 200 refereed publications and book chapters, and is one of the most cited authors within the peer-reviewed literature on climate change and its impacts on natural ecosystems.

Ove has published works that include over 200 refereed publications and book chapters and is one of the most cited authors within the peer-reviewed literature on climate change and its impacts on natural ecosystems. Ove is also a regular contributor to the media, with his work featuring on the ABC (Catalyst), BBC (with Sir David Attenborough) and NBC (with Tom Brokaw) in his role as Deputy Director of the ARC Centre of Excellence for Coral Reef Studies, and working group chair within the World Bank-Global Environment Facility Coral Reef Targeted Research (CRTR) project (www.gefcoral.org). He runs the scientific blog site, www.climateshifts.org, which explores the science and politics of climate change as it relates to natural ecosystems such as the coral reefs.

Ove was born in 1959 in Sydney, Australia, and undertook studies at The University of Sydney and The University of California, Los Angeles (PhD, UCLA). He was appointed the Professor of Marine Studies at University of Queensland 1999, during which time he initiated and directed programs such as Stanford University's Australia program and more recently, the Australian Sea Level Rise Project (ASLRP).

The Coral Reef Story: Climate change as major threat the world's most biological diverse ecosystem.

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Coral reef ecosystems are peculiar in a number of aspects. Firstly, while they only occupy 0.1% of the surface yet they are the richest biological habitats within the world's oceans. Estimates of the biological diversity of coral reefs put the number of species is somewhere between 1 and 9 million species. Consequently, from a purely scientific perspective, coral reefs are extremely important to the biological heritage of our planet. In addition to this, however, coral reefs are also critically important to the stability of tropical coastlines - providing a barrier against the impact of wave stress which would otherwise impact vulnerable coastal areas. In all of this, coral reefs provide food and income to a large number of people who live along coastlines in the tropical regions of the world. Estimates of the number of people that are directly or indirectly supported by coral reef ecosystems range from 100 to 500 million people.

Unfortunately, coral reefs appear to be under threat from human activities, with the distribution and abundance of coral reefs contracting across many parts of the world over the past 30 years. Data from John Bruno and Liz Selig for example, found that coral reefs across the Asia-Pacific had almost twice as much coral on them than they had in the 1980s (Bruno and Selig, 2007). Other studies such as the recent update by the World Resources Institute Study (Burke et al., 2011) found that 75 percent of the world's coral reefs are currently threatened by local and global pressures. Careful scientific and geographic analysis reveals that the major drivers of change on coral reefs are as follows:

a. **Water quality:** The water quality along coastlines is declining due to unsustainable management coastlines, agriculture and river catchments. Deforestation is a major driver of these changes.
b. **Overfishing:** The removal of ecologically important groups such as grazing fish results in the ecological balance of reef systems shifting towards macro algae and other non-coral organisms. Removing these species essentially removes organisms play a crucial role within reef ecosystems.
c. **Coastal development:** The expansion of ports and urban centres has led to the destruction of linked ecosystems such as mangroves, seagrass and coral reefs. This has resulted in a direct loss of coral reefs from many parts the world.
d. **Climate change:** Rapidly changing sea temperatures and alkalinities as a result of rising concentrations of atmospheric carbon dioxide are resulting in impacts are shifting the ecological and carbonate balance of reef systems.

All of these factors are driving rapid changes to coral ecosystems. Most of these changes are be irreversible on the time scale of human lives and livelihoods. These changes have huge implications for the many millions of people that live along tropical coastlines.

Climate change is considered to be the major driver threat to coral reef ecosystems. One of the clearest signs of change within coral reef ecosystems is that of mass coral bleaching. Mass coral bleaching arises when the symbiosis between corals and dinoflagellate breaks down (Hoegh-Guldberg, 1999). This can occur as a result of a large range of stresses such as hot and cold temperatures, low and high light, reduce salinity and pollutants. The net effect of coral bleaching is that the brown dinoflagellates normally live in the tissues of the coral leave, turning coral tissues a brilliant white colour (in hence the term "bleaching").

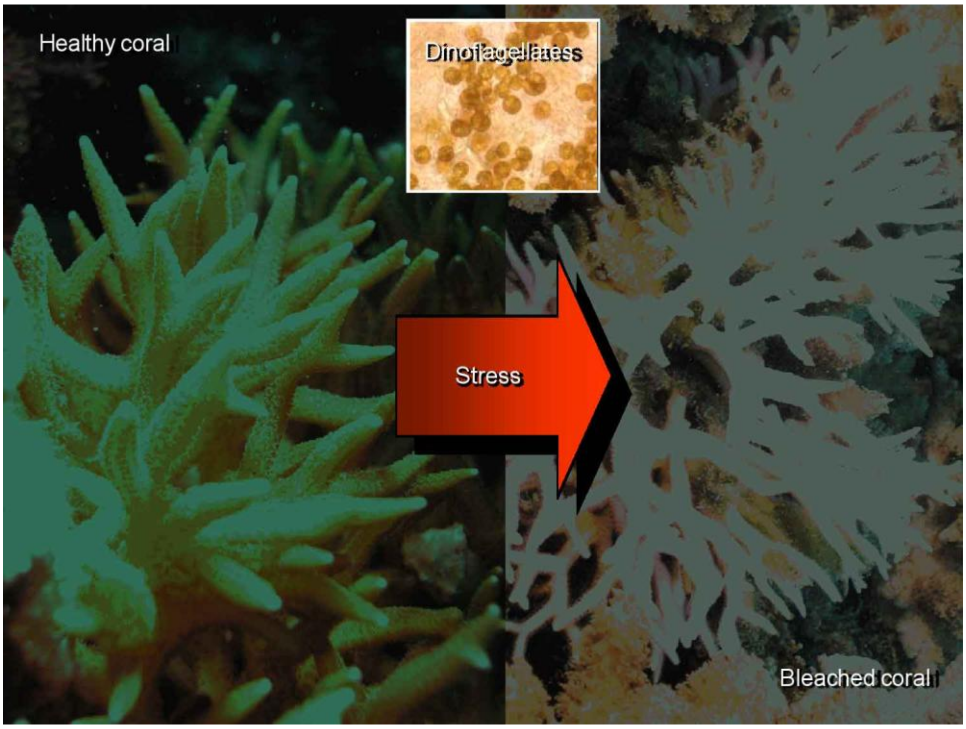

Figure 1. Coral bleaching involves the loss of the brown dinoflagellate symbionts and occurs as a result of environmental stresses such as changing temperature, light or pollution. The dinoflagellates are a crucial to the success of reef-building corals, allowing them to grow and calcify in the otherwise nutrient poor waters of the tropics.

Starting in 1979, however, coral reefs across entire reef systems began to bleach (and often die) simultaneously. Evidence of mass coral bleaching events prior to 1979 is entirely missing from the scientific literature and it appears that they were rare or non-existent before that time. After a decade of research, it became clear that these events are being driven by short periods of anomalously high sea temperatures. Mass coral bleaching events have increased in frequency and severity over the past several decades (Hoegh-Guldberg 1999; Hoegh-Guldberg et al. 2007). Examples of recent mass coral bleaching events are those which have occurred across large parts of the Caribbean in 2005 and across large parts of Southeast Asia, the Indian Ocean and Middle East in 2010. Currently, in Western Australia, coral reefs are facing some of the warm sea temperatures they have ever seen. This is being accompanied by major coral bleaching event.

The behaviour of corals with respect to sea temperature allows us some ability to project how coral reefs might change as sea temperatures increase across the tropics due to global climate change. This fairly straightforward approach compares known thermal thresholds for coral bleaching and mortality with projections with sea temperatures that are projected to occur as atmospheric carbon dioxide levels increase. As can be seen from Figure 1, the threshold above which coral bleaching and mortality is exceeded by projected future sea temperatures on a yearly basis by 2030 to 2050. This study was published in 1999 (Hoegh-Guldberg 1999) and attracted a lot of attention from the scientific and policy communities. Ten years later, the majority of coral reef scientists have come to the same conclusion which is that coral reef ecosystems are likely to be irreparably changed if we continue on current business-as-usual pathway, emitting extremely large amounts of carbon dioxide from fossil fuels into the Earth's atmosphere.

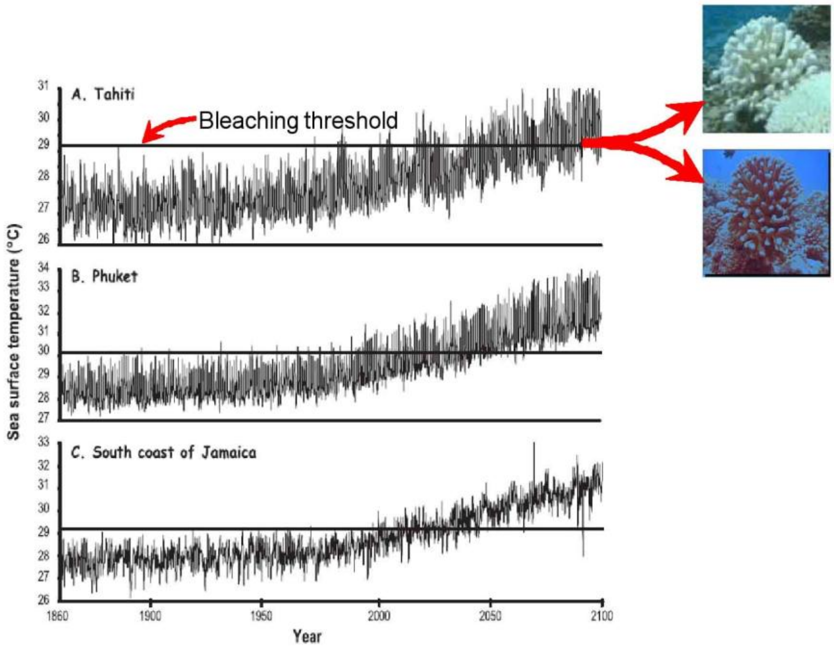

Figure 2. Projected sea temperature in tropical regions over the coming century will exceed the temperature threshold known to cause coral bleaching and mass mortality of reef-building corals. Adapted from Hoegh-Guldberg (1999).

One of the possible responses to this situation is that corals might be able to evolve quickly enough to counter the impacts of rising sea temperatures. Alternatively, corals might also be able to rapidly migrate to cooler locations at higher latitudes. Looking at both these options, reveals the problem that the environment around coral reefs is changing so rapidly that evolution and migration away from hot areas is not occurring at a fast enough of a rate. These issues will be explored in the GIFT lecture. The other problem facing corals is that warming oceans is not the impact of carbon dioxide on the world's oceans.

As carbon dioxide has built up in the atmosphere as a result of human activities, an increasing amount has gone into the world's oceans. Once in the ocean, carbon dioxide reacts with water to create a dilute acid called carbonic acid. The production of this acid results in a steady decrease in ocean pH. This steady acidification of the ocean is referred to as 'ocean acidification'. The steady acidification of the world's oceans has resulted in a chemistry that is very different to any conditions seen for millions of years, and is already resulting in an impact on the ability of corals to form their skeletons. And as corals struggle to form their skeletons, reefs struggle to maintain themselves in these warming and acidifying conditions (Hoegh-Guldberg et al., 2007). This has a huge impact on the number of species living in and around reefs, which all that often depend on corals directly for their habitat and food. Recent research that we have done on Australia's Great Barrier Reef has revealed that corals bleach at lower temperatures when they are exposed to more acidic conditions. That is, the two big effects of carbon dioxide and the world's oceans are interacting to make effect of each other worse.

There is also some compelling evidence from field studies that these changes are occurring. A study by the Australian Institute of Marine Sciences led by Dr Glenn D'eath, for example, has shown that the deposition of calcium carbonate by long-lived corals such as *Porites* across much of the Great Barrier Reef has declined by 14% since the 1990s (De'ath et al., 2009; Figure 3). Perhaps the most compelling part of the story is that similar decline in calcification was not seen anywhere else in the 400 years of record examined. While it is not possible in this study to attribute the decline in calcification solely to ocean acidification, the changes are consistent with the idea that changing sea temperatures and acidity are already beginning to impact the ability of reef building corals to maintain the carbonate structures that are so important to the biodiversity and productivity of coral reef ecosystems.

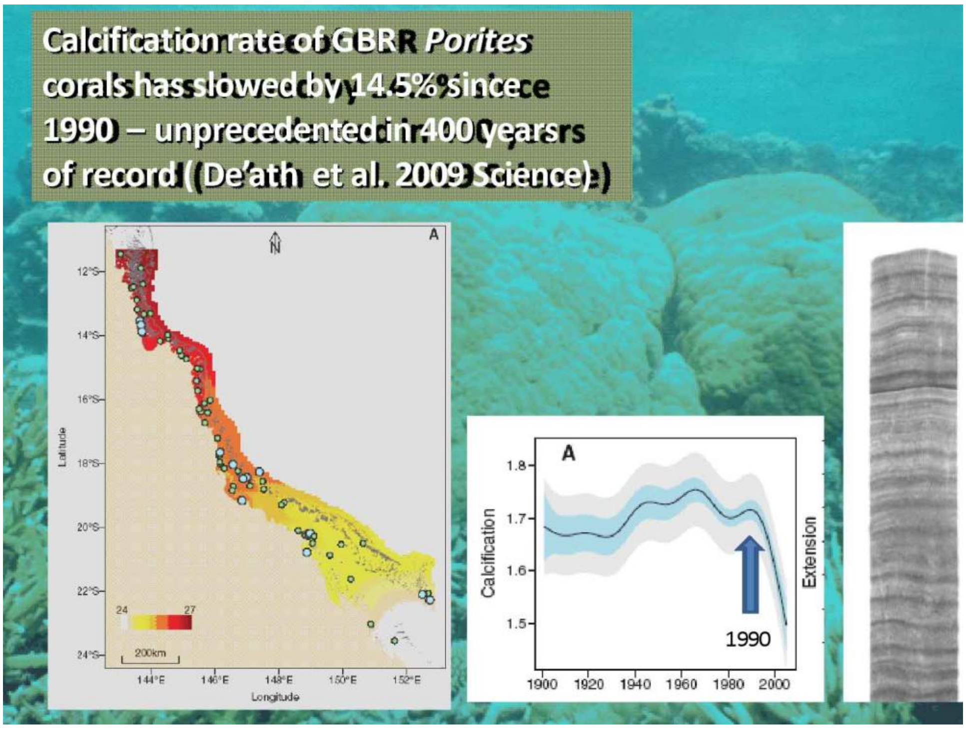

Figure 3. The calcification rate of long-lived corals in the Great Barrier Reef has declined by 14.5% since 1990.

In the last part of this talk, the future of coral reefs is discussed; particularly the actions we need to take if we are to preserve these important tropical ecosystems. In this respect, we need to know that at what concentration of carbon dioxide in the atmosphere conditions become untenable for coral reefs. In this respect, there is now considerable evidence that concentrations of carbon dioxide rise above 450 ppm will see the complete demise of coral dominated reef ecosystems within tropical waters. This will essentially push coral reefs from the left-hand side of Figure 4 to the right-hand side. These changes to coral reefs will have significant decrease their ability to provide the ecosystem services that are important to hundreds of millions of people throughout the world's tropical coastal areas. The important issue here is that we will reach these concentrations within the next 30 years if we continue to release carbon dioxide at the current rate (over 2 ppm per year).

Figure 4. What will future reefs look like if we exceed 450 ppm. These photos taken from different parts of the Great Barrier Reef are analogous to the state of ecosystems expected, if we continue to increase atmospheric carbon dioxide over the next few decades and century. Adapted from Hoegh-Guldberg et al. (2007).

This leads to the question: How much do we need to reduce our carbon dioxide emissions in order to stabilise the Earth's climate at or below 450 ppm (which is also required if we are to constrain the heating of the oceans to less than +2°C over the preindustrial ocean temperatures)? The answer to this question is provided in a paper by Meinshausen et al. (2009) from the internationally respected Potsdam Institute for Climate Change Adaptation Research in Germany. This analysis which relates global emissions to the concentration of carbon dioxide in the atmosphere reveals an important and critical number. This is that we have around 700 Gigatons of carbon dioxide left to emit to the atmosphere if we are to have a 60% chance of staying below 450 ppm and a +2°C rise in global temperature above the preindustrial value. Given that we emit somewhere around 30 Gigatons of carbon dioxide across the globe each year, we will need to reduce global emissions starting today by around 3-4 % per annum. If we delay action by another five years, global emissions will need to be reduced by 5-6% per annum. This is a tall order but one which we must achieve if we are to preserve coral reefs for the future.

Assuming that we do reduce the emissions of carbon dioxide from fossil fuels by 90% over the next 50 years, it will still be necessary to increase the protection of coral reefs against local stresses such as overfishing, pollution and physical destruction from human activities. This activity becomes even more important as corals enter a century in which they will also be facing enormous stresses from a global ocean which will still be warming and acidifying over this century as a result of the effects of CO_2 already in the system. Both local and global challenges will require real, immediate and major responses from all nations. However, given that coral reef ecosystems (and indeed many other natural ecosystems) are facing ecological extinction, there is no question that we must undertake a rapid implementation of the solutions to these challenges immediately.

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Prof. Olaf Schuiling

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The Netherlands
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Education
Obtained doctoral degree in 1957; majored in Petrology, with secondary subjects Geophysics and Structural Geology. Worked in 1954 3 months in a German lead-zinc mine, and took part in a geophysical expedition on board of a submarine of the Royal Dutch Navy.
PhD in 1961, with mention "cum laude"

Career
2002- present independent researcher (mainly environment and mining)
1996- March 2002
Part-time professor of geochemical engineering at IHE/Delft

1972-1997 (retired in 1997)
Full professor of geochemistry and experimental petrology at Utrecht University.Dean of the Faculty of Earth Sciences for 2 3-year periods

1973-1996
Part-time lecturer environmental geochemistry at IHE/Delft.

1979-1980
Senior officer of UNESCO, to give a course to geologists of the Geological Survey of Greece.

1961-1972
Scientist at Utrecht University, in charge of setting up and running a high pressure/high temperature laboratory

1964-1965 taking part in the NAVADO expedition (a combined Dutch-British expedition) across the Atlantic Ocean

1965-1966
NATO Research Fellow at Princeton University, USA

1957-1961
Exploration geologist with Maden Tetkik Arama Enstitüsü (Geological Survey of Turkey), with a 3 month interruption in 1961 as research fellow of the German Research Organisation.
Professional interests

Although the early scientific career was mainly directed towards (experimental) petrology, environmental geochemistry became increasingly more important from 1970 onwards. This has led to the development of a number of environmental technologies, based on optimization of natural geochemical processes. Some of the larger projects include:

- Development of a process for the neutralization of waste acids by olivine; initial development was supported by the Dutch Ministry of Environment and the titaniumdioxide industry. Further development took place in the framework of an EC project, and later by a large international chemical company.

The breakdown of asbestos is the complementary side of the neutralization of (waste) acids by olivine or other magnesium-silicates like asbestos

- Development of a process to break down jarosite by reaction with organic waste streams under moderately elevated temperatures and pressures in autoclaves, e.g. of the VERTECH type. Project supported by EC.
- Zeolitisation of coal fly ashes. Large project in collaboration with KEMA.
- Formation of self-sealing and self-healing isolations under toxic waste deposits, by the reaction between two contrasting waste types.
- Removal and Recovery of phosphate from calf manure. Pilot study financed by the Ministry of Agriculture. The process is applied full-scale in a calf manure treatment plant in Putten, the Netherlands. It operates without a hitch, and has led to a considerable cost reduction. The technology is now also used in several other plants.
- Lifting the ground. If low-lying areas are underlain by limestone formations, their ground-level can be raised by injecting sulphuric acid into these limestones. The reaction produces gypsum, which has twice the volume of the original limestone. Research was supported by the Foundation for Applied Research.
- Recovery of manganese from manganese tailings in the Nikopol area, Dnepropetrovsk Oblast, Ukraine.
- CO_2 sequestration by enhanced weathering of olivine

The application of natural processes to solve environmental problems has been defined as "**Geochemical Engineering**"; the subject was formalized in a paper by Schuiling in 1990 in Applied Geochemistry ("Geochemical Engineering; some thoughts on a new research field") and extended in a paper in the Journal of Exploration Geochemistry (Geochemical Engineering; taking stock)

59 PhD-students have obtained their degree under his supervision.

He is currently active in setting up a programme to export excess manure to nutrient-starved areas of the oceans, in order to fix CO_2 as biomass, and thus combat the greenhouse effect.

He spent several years in mining exploration and visited many mining districts all over the world (India, Philippines, Brazil, Canada, Russia, Ukraine, several countries of the EC). Noteworthy is a NATO-sponsored inspection tour of mining wastes in Southern Poland.

In March 2000 he was invited to Australia to give an independent evaluation of the newly developed bauxsol (seawater neutralized red mud) technology for the remediation of acid mine drainage.

Ocean acidification: back to basic(s)

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Abstract

Rising CO2 concentrations in the atmosphere will be a probable cause for climate change, and also affect the pH of ocean water. This, in turn, will have an impact on carbonate equilibria in the ocean, and thereby on important parts of ocean ecosystems (corals, shellfish). To restore the basicity of the oceans it is necessary to add alkalinity to the ocean system. This can be done by increasing the rate of weathering on land, thus increasing the flux of magnesium and calcium to the oceans. By the enhanced weathering of basic silicates, notably olivine, and the transport to the oceans of the resulting weathering solutions the acidification can be slowed down, and ultimately even reversed.

Enhanced weathering starts with the selection of abundantly available rock types that weather easily. Rocks containing high concentrations of olivine and/or its hydrated equivalent serpentine are obvious candidates. These must be mined and milled, and the grains spread on land, preferably in the wet tropics, where weathering proceeds fastest. Other suitable locations to spread these grains are beaches and tidal flats.

The rate of weathering on land is much higher than in abiotic laboratory experiments. This is due to the activity of mycorrhizal fungi, living in symbiosis with higher plants. They secrete organic acids that rapidly attack mineral grains in the soil, thereby releasing mineral nutrients, which are taken up by the plants. When the plants die, part of their mineral content is washed out and carried by rivers to the oceans. When applied to farmland an additional benefit is that the weathering products, especially Mg, serve as fertilizer.

On beaches the rate of weathering is accelerated because the sand grains are ground down by surf action. Small abraded mineral slivers weather quickly, adding alkalinity directly to the sea. On tidal flats, the mineral grains are ingested by lugworms. In their guts, mineral transformations proceed 700 to 1000 times faster than outside. These are major ways by which alkalinity can be added to the oceans. The silica released by olivine weathering will promote the growth of diatoms. When these die, their carbon will be carried to the deep ocean, and part of it is buried in ocean sediments.

Enhanced weathering is an acceleration of ongoing natural processes, making it a far cheaper and more effective process to counteract climate change and ocean acidification than any of the high tech solutions proposed so far.

Keywords: ocean acidification, alkalinity, olivine, enhanced weathering,

Introduction

Rising levels of CO_2 are considered by many to be a major cause for climate change. It is beyond doubt that CO_2 levels are rising, and that this is caused by the burning of fossil fuels. Mankind burns in a few hundred years the fossil fuels that have formed over hundreds of millions of years. The problem of the relation between CO_2 and climate is complex, however, as there are many variables and uncharted interactions. This gives room to a sizable number of skeptics. As far as the rising CO_2 levels affect the acidity of the oceans, there can be no doubt, as this is basic chemistry. The higher the CO_2 pressure in the air, the more acid becomes a solution that is in equilibrium with this air. So, even if it would turn out, against the expectations of the majority, that rising CO_2 levels are not the (major) cause of climate change, there still would be many good reasons to counteract them, as the effect of a pH drop on marine life is likely to be disastrous, in the first place for calcareous organisms, but also for life forms that depend on them, like most reef dwellers.

To counteract ocean acidification it is proposed to increase the alkalinity flux to the oceans by enhancing the process of weathering. This will restore the balance between the input of CO_2 from the degassing of the Earth, and its output as carbonate sediments, which represent the ultimate storage of CO_2 in the form of stable solids. There is more than 1.500 times more CO_2 stored in carbonate rocks than in the oceans, the atmosphere and the biomass together.

Enhanced weathering

The recipe is simple, but the scale of the operation is almost beyond imagination (fig.1)

This gigantic rock mass represents 1 week of the world's CO2 emission!

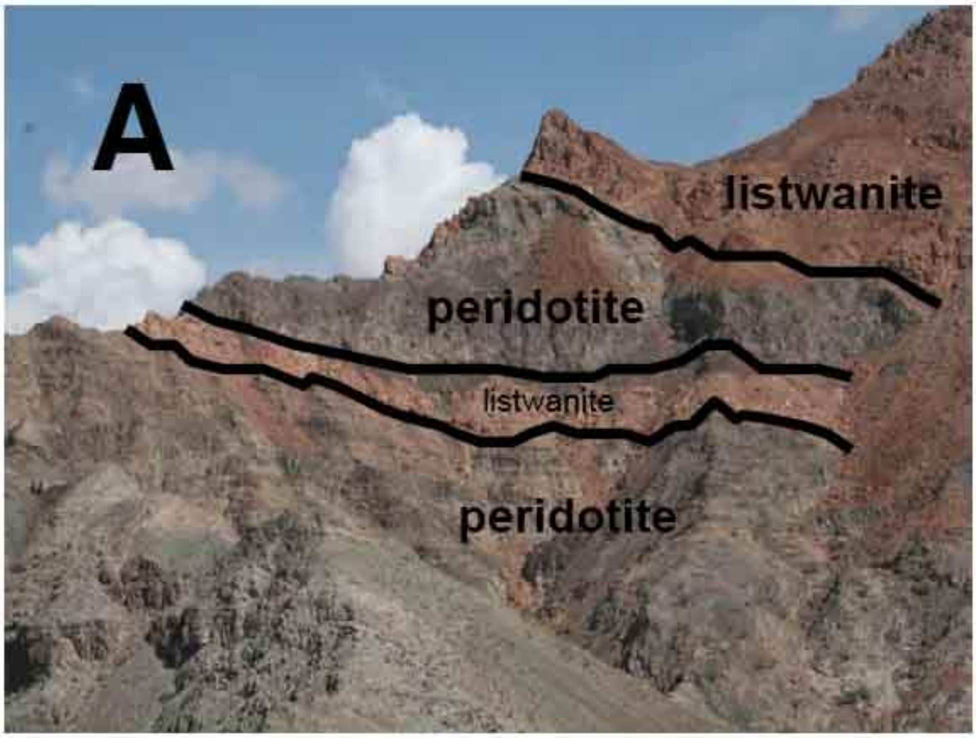

Figure 1: It is a sobering thought that the huge listvanite bands (completely carbonated olivine rocks) in this rock face in Oman are equal to only one week of the human emission of CO_2

In order to increase the rate of weathering to cope with man-made emissions, one must

- Select abundantly available rocks that weather easily
- Mine and mill these at a scale suitable to sequester 25 billion tons of CO_2
- Spread the grains over large areas in the wet tropics

From a survey of possible minerals that can capture CO_2 it is clear that olivine and its hydrated equivalent serpentine are the most suitable candidates. There are many large massifs of olivine rock in a number of countries on every continent (fig.2).

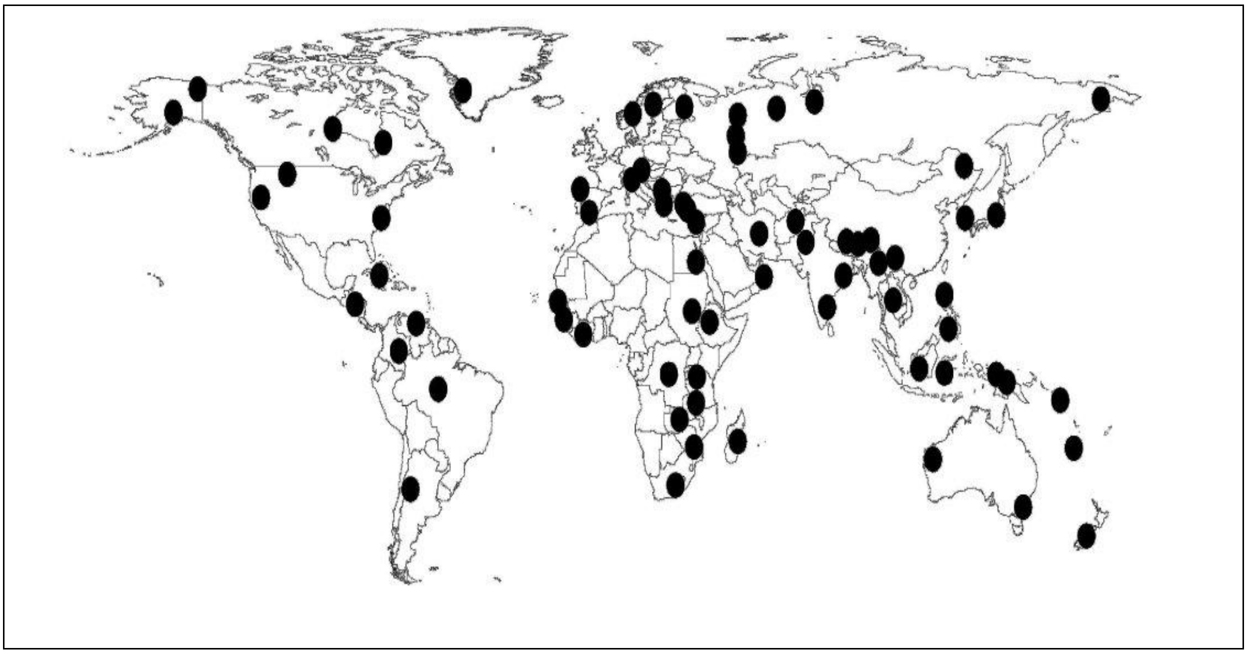

Figure 2: Distribution of dunites in the world. One dot in a country often represents several dunites

It is possible, therefore, to select a number of strategically located mine sites in the wet tropics in order to limit transport distances of the olivine grains to the point of use. Another selection criterion for mine sites is the following. By their very nature, most olivine deposits in the tropical zone are deeply weathered. Their weathering crust shields the rocks from interaction with the atmosphere, so at present they no longer play a role in CO_2 capture. This weathering crust, usually tens of meters thick, but sometimes even more than hundred meters is called a laterite. Olivine rocks are very poor in harmful heavy metals like lead, cadmium, mercury, arsenic, uranium, but they are richer in nickel than most other rock types. Major elements like magnesium and silicon, which make up 90% of the rock are removed during weathering, but nickel is not very mobile and is enriched in the residual laterite. These laterites thus become nickel ores and are exploited or explored in a number of countries (among others Cuba, Brazil, Columbia, Dominican Republic, Tanzania, Malawi, Madagascar, Philippines, Australia, New Caledonia, Papua New Guinea, Indonesia). Obviously, because these nickel laterite ores overlie fresh olivine rocks, it is advantageous to select these sites for mining. It saves the environmental impact of clearing a new mining site, the infrastructure for mining is in place, and a population depending on mining lives nearby. Mining companies must be persuaded not to stop when their nickel laterites are mined out, but to continue and mine the underlying olivine as well.
Mining and milling of bulk rock in large open pit mines costs around 6 US$/ton (Steen and Borg, 2002), and transport of the olivine to not too distant points of use may add another 5 to 10 $, making this way of carbon capture far cheaper than any of the proposed approaches so far.

CO_2, the long and the short cycle

The attention of most people is focused on the short cycle of CO_2, involving exchanges between atmosphere, hydrosphere and biomass. A typical example is the life and death of trees and plants. They grow by removing CO_2 from the atmosphere by photosynthesis, and when they die or drop their leaves they will be reconverted to CO_2. During the decay of the organic matter in the soil they cause the soil atmosphere to be considerably richer in CO_2 than the ambient air. This is important to note, because this increases considerably the rate of weathering of minerals in the soil. Soils, therefore, constitute a short-lived but important reservoir in the geochemical cycle of CO_2.

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ACADEMIC/PROFESIONAL QUALIFICATIONS

Year	Institution	Qualification/Discipline
1988	Salford University	PhD (Marine Biology)
1987	CMAS International (UK)	Scuba Diving Instructorship (BSAC/CMAS)
1987	British Sub-Aqua Club (U.K)	Scuba Diving Instructorship (BSAC/CMAS)
1986	British Sub-Aqua Club (U.K)	Coastal Navigation (BSAC)
1986	British Sub-Aqua Club (U.K)	Small Boat Handling (BSAC)
1982	Aston University (U.K)	BSc (Environmental Biology)

AREA OF EXPERTISE

Marine ecology, Biodiversity
Research on Invertebrates
Conservation and Coral Reef Studies
Environmental studies (Remote sensing & Environmental Impact Assessments)

RESEARCH, INNOVATIVE DESIGN AND DEVELOPMENT

1. *Malaysian Marine Science Expedition to Antarctic*
2. *The Roses Scientific Expedition to the South China Sea*
3. *Establishment of the National Marine Reference Collection*
4. *Establishment of Conservation and Research of Giant Clam – First Giant Clam Cultured In Malaysia*
5. *Creation of Mobile Plankton Production Kit for the Aquaculture Industry*
6. *Establishment of Social And Educational Programmes And Research into Marine Science*
7. Research on Marine Ecology and Conservation

The richness and splendors of the Malaysian Seas

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<u>Abstract</u>

Malaysia is a maritime nation surrounded by four seas – the Straits of Malacca, the South China Sea, the Sulu Sea and the Sulawesi Sea. Much of its food, wealth, tradition and livelihood is directly associated or derived from these seas. However discourses on the seas are few and far between and as is reflected in its school curriculum. This talk will focus on the richness and splendors of the Malaysian Seas hoping to promote the understanding and interest of these important water bodies.

The "Coral Triangle" bounded by the marine region from Malaysia to Papua New Guinea is characterized by the richest seas in the world from the perspective of marine biodiversity. Almost all the major tropical marine habitats are represented here which include the coral reefs, the sea grass beds, the mudflats, the mangrove forests, the continental shelf and the deep sea.

Figure 1 illustrates the areas where the highest numbers of coral species are found in the world as an example of the rich diversity of the seas around us. The rise and fall of sea levels in the past has isolated the land and sea - giving rise to forces driving evolution and extinction. Six hundred species of corals, three thousand species of fish and many more living species live here. Perhaps no other marine region on the planet is as rich as the one found here.

More than 1.1 million metric tones of fish are harvested annually from Malaysia coastal waters. Fishing and its related activities represent one of the major occupations of the dominantly coastal population. Malaysia, Thailand, Indonesia, Philippines and Vietnam harvest 8.5 million tones of fish from these seas to feed their population. All of these countries however have reached their maximum sustainable yield since statistics have shown that the annual landing tonnage of fish has reached a plateau in the past decade.

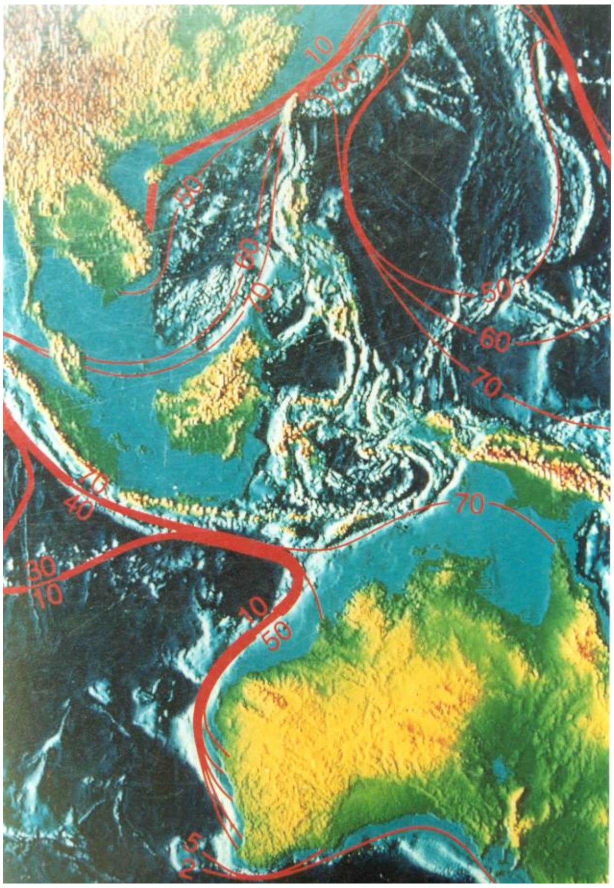

Figure 1. The map of coral diversity showing lines joining areas of equal coral genera. The highest diversity areas (70 genera of coral) encompass the Coral Triangle (from Veron, 1985).

In Malaysia income from tourism, a significant portion of which is marine related tourism, is the second largest contributor to Malaysia's GDP. Apart from this the marine habitats perform important ecosystem services.

As life in the oceans is interlinked through biological and ecological relationships we begin to understand that protection of the seas needs an encompassing approach. Our current knowledge of the seas and their components, although significantly improved is still far from complete. It requires the application of the precautionary principle for effective conservation.

In Malaysia and its surrounding seas pollution from coastal areas, habitat destruction and disruption from coastal development are the major causes threatening biodiversity.

There are new emerging threats that are already shaping the future of our seas. Climate change and its associated repercussions will be the main threat. These include the rise in the sea surface temperature beyond the normal mean. Corals and other zooxanthellate species are sensitive to elevated sea temperatures for just a few days and may bleach and die. These bleaching phenomenons spreading over wide areas are becoming more frequent. The latest event in 2010 is particularly bad where in many places whole reefs have been wiped out. Another looming catastrophe is the lowering of the ocean pH caused by the increased input of carbon dioxide into the sea from the atmosphere – known as ocean acidification. As pH of seawater falls the ability of corals and animals to manufacture their shells and skeleton will be hampered (Figure 2). Existing reefs will erode and many scientists think that the coral reefs will be the first major marine ecosystem that will face extinction. Since climate change and its associated events are global in nature, efforts to mitigate against these should be too.

It is clear that the understanding and protection of the marine and coastal ecosystems should be highly prioritized. The role of education and awareness to the importance and plight of our seas will play an important part for the protection and wise use of the seas. It will also provide the necessary preparation to adapt to the changing future.

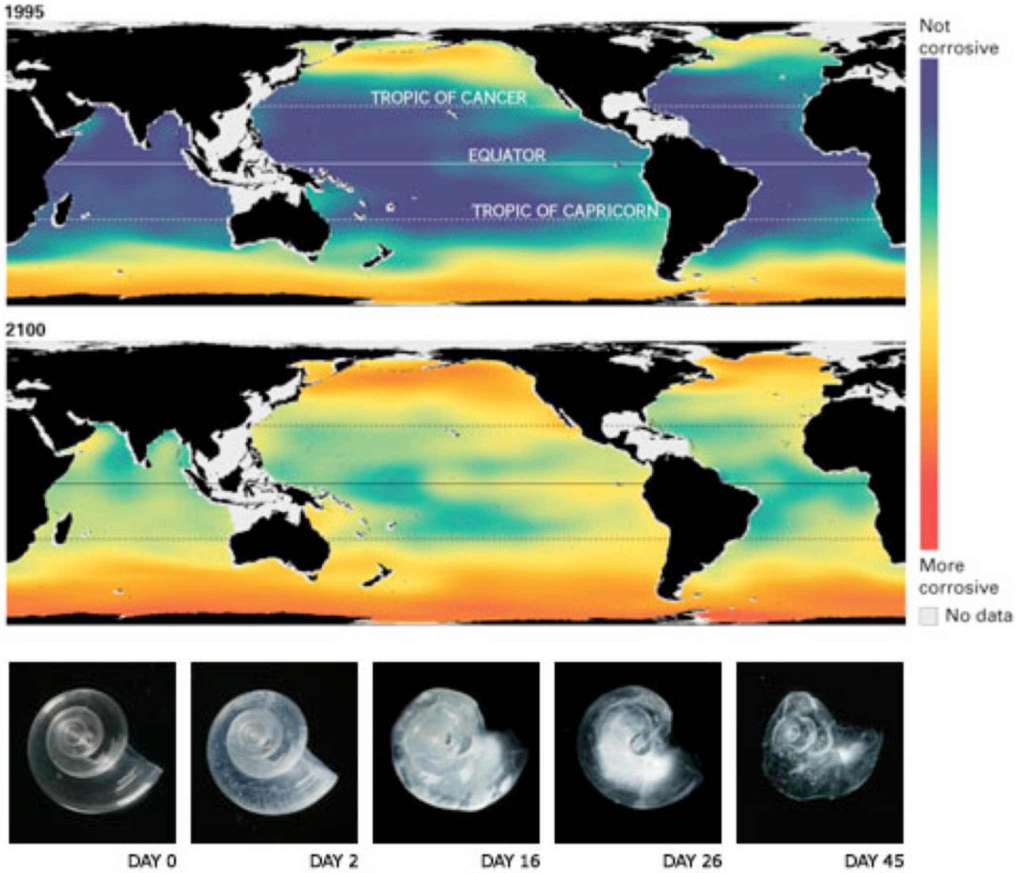

Figure 2. If CO_2 continues to rise unchecked, computer models show that acidification will deplete carbonate ions in much of the ocean by 2100, turning the waters corrosive for many shell-building animals (from National Geographic.com)

Dr. Uta Passow

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EDUCATION

2001 Habilitation (German degree for full professorship), University Kiel, Germany
1989 Ph.D in Biological Oceanography, Institut für Meereskunde, Kiel, Germany.
1985 Diplom (masters) in Biological Oceanography University Kiel, Germany.
1981 Vordiplom (BA) in Biology, University Freiburg, Germany.

EMPLOYMENT HISTORY

2008-present Professional Researcher. Marine Science Institute, University of California, Santa Barbara, USA
2000-2010 Tenured Research Oceanographer. Alfred-Wegener Institute for Polar and Marine Research, Bremerhaven, Germany.
1991-2000 Research Oceanographer. Marine Science Institute, University of California, Santa Barbara, USA.
1987-1991 Researcher. Institute für Meereskunde, Kiel, Germany.
1986-1987 Consultant. Howalds Deutsche Werke-Electronics, Kiel, Germany
1985-1986 Researcher. Institute für Meereskunde, Kiel, Germany

RESEARCH INTERESTS

Carbon cycling in a changing world: Increased CO_2 production by human activity result in changes of the global carbon cycle. The marine carbon cycle is an essential component of the global carbon cycle. For example one third of CO_2 generated by human activity has been taken up by the oceans, another fraction by terrestrial systems with the remainder increasing atmospheric CO_2 concentrations. I try to gain a mechanistic understanding of the processes which regulate the cycling of carbon in marine systems, now and in the future. Uptake of CO_2 by the ocean leads to a drop in the pH of seawater, termed ocean acidification. Ocean acidification is potentially changing the structure of pelagic ecosystems and the cycling of carbon. Predictions of future conditions require a *mechanistic* understanding. One of my research focuses is on ocean acidification how it effects the cycling of carbon. I study the factors and processes driving marine carbon cycling under ocean acidification conditions both in the surface ocean, where photosynthesis removes inorganic carbon and in the twilight zone, where loss of sinking particles due to dissolution, degradation or grazing is high. To this end I combine field work with simple laboratory or more complex mesocosm perturbation experiments.

CURRENT SYNERGISTIC ACTIVITIES

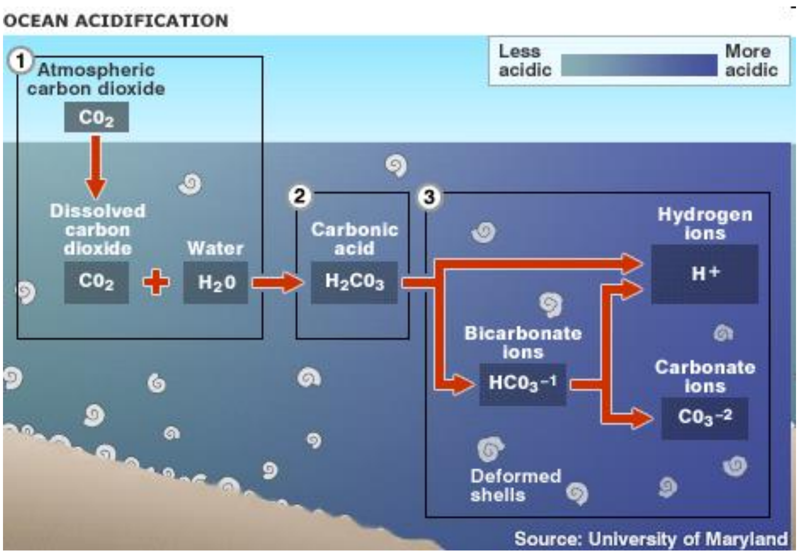
- Member *at Large* ASLO
- Outreach: Public Lectures on Global Change and the Ocean, The Oil Spill in the Gulf of Mexico, Ocean Acidification. Mentor for Junior High school Projects
- Reviewer: Several peer reviewed journals and international funding agencies
- NSF panelist

Ocean Acidification, Marine Organisms and the Marine Carbon Cycle

Uta Passow

Biological Oceanographer
Marine Science Institute, University of California Santa Barbara, CA 93106, USA

Burning of fossil fuels (coal, fuel, wood) is increasing concentrations of CO_2 worldwide. Increased CO_2 in the atmosphere results in increased concentrations of inorganic carbon in the surface ocean, as well as a shift in the speciation of carbon. This also leads to a decrease in pH of seawater. This process, the increase in inorganic carbon and the decrease in pH is termed *ocean acidification*. Ocean acidification will potentially impact marine organisms, both animals and plants. Primary production of many algae might be higher and nitrogen fixation also seems to increase, whereas other processes, e.g. the production of calcium carbonate shells, called calcification, will decrease. For some species reproduction will be less successful. Simultaneous changes in temperature of the surface ocean due to global warming complicate the responses of marine organisms. As a consequence the partitioning of primary produced organic matter between sedimentation, microbial turnover, and respiration within the food web will change. This presentation reviews some of our current knowledge of the effects of ocean acidification on different organisms and their activity and introduces some simple experiments that can be conducted in the classroom to teach some of these impacts more effectively.



Schematic of ocean acidification and the different carbon species: The addition of CO_2 results in an increase in the amount of inorganic carbon, as well as in an increase in H^+ ions, which lowers the pH.

Dr. Rodelio Subade

Professor of Economics
Director of the Institute of Fisheries Policy and Development Studies
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Dr. Rodelio F. Subade is a Professor in Economics at the Division of Social Sciences, College of Arts and Sciences, and con-currently Director of the Institute of Fisheries Policy and Development Studies, College of Fisheries and Ocean Sciences, both of which are in the University of the Philippines Visayas (UPV), Miagao, Iloilo, Philippines.

He has been teaching and doing research, both unviversity- and externally-funded, in UPV for over twenty years. Areas of his interests and research range across various areas of environment and natural resource economics and policy --- such as economic valuation, conservation and biodiversity economics, fisheries and aquaculture economics, socio-economics, economics of climate change adaptation, fisheries co-management and others. He has been a researcher with the Economy and Environment Program for Southeast Asia (EEPSEA) and an alumni/ fellow of the Southeast Asian Regional Center for Graduate Studies and Research in Agriculture and Natural Resources (SEARCA). He is a member of the European Association of Environmental and Resource Economics, Asian Fisheries Society and the Philippine Economic Society, and former officer of the Philippine Association of Marine Sciences. He has published in national and international scientific peer reviewed journals, and has presented research/ scientific papers in various international conferences. He is happily married with Ana Liza Subade and has two children Rona Grace (13) and Daniel Rodfred (2).

Confronting the Challenges of Ocean Acidification: Linking Potential Socio-Economic Impacts and Economic Valuation Towards Appropriate Policies

Rodelio Fernandez Subade

Division of Social Science,
College of Arts and Sciences Institute of Fisheries Policy and Development Studies,
College of Fisheries & Ocean Sciences,

University of the Philippines Visayas, Miagao, Iloilo, Philippines

Ocean Acidification has emerged as major threat to marine ecosystems and species, as well as the communities that have depended on them for livelihood and food. If not addressed, various studies within the last decade shows that the effects may be enormously tremendous Linking this looming environmental reality with social and economic considerations will be crucial in soliciting corresponding urgent policy responses from various levels of policy makers. Studies and information on consequent threats to food security, the impact on poor and seafood-dependent peoples and communities, and the economic valuation of benefits and costs of policy actions may prove crucial in gathering concerted global and local efforts towards mitigating ocean acidification This paper plots a socio economic framework and research agenda that links geo-biological-physical aspects of ocean acidification to potential social impacts. Economic valuation of impacts and the attendant cost-benefit analysis may provide helpful inputs in the continuous efforts to address this “other CO2 problem”.

Dr. Carlo Laj

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Education:

Secondary school in Italy and the USA (American Field Service Exchange Student.)
University studies at the University of Paris, PhD in Solid State Physics.

Research Interests:

After my PhD in Physics I spent a few years working with critical phenomena (scattering of laser light by critical fluids) then moved into the field of geophysics.
My main interests in this new field has always been linked to the magnetic properties of sediments and igneous rocks (paleomagnetism), used with several objectives: geodynamical reconstructions (particularly in the Eastern Mediterranean and the Andean Cordillera), reconstruction of the history of the Earth's magnetic field (including the morphology of field reversals) and more recently reconstructions of environmental and climatic changes on a global scale.

I have published over 180 articles in international scientific journals and am a Fellow of the American Geophysical Union (AGU).

Educational activities:

Chairman, Education Committee of the European Geosciences Union
Member, Committee on Education and Human Ressources , AGU
Participant to different National and International Education Committees

Educational Activities at the European Geosciences Union

Carlo Laj

Committee on Education of EGU

The number of university students in geoscientific subjects has been in decline for several years now in many parts of the world, whereas disciplines like economics, medicine and law claim a steady increase. In order to ensure an adequate number of geoscientists in the future, several steps need to be taken. One of them is the strengthening of school teachers in their subjects (especially high school teachers, but also those at primary or intermediary level dealing with environmental topics in a broad sense). If school teachers are supported by lecturers at universities, scientific unions and other partners, such as sponsors, city councils, museums etc. their teaching may improve inasmuch as they get informed about the latest developments in science. Teachers then can contribute to discussions about current issues (like global change, recent earthquakes etc.), because they have more knowledge about the issue or have personal contacts with university lecturers in that field. They are then more likely to interest their students in science and thus contribute to a larger number of upcoming students and scientists at universities.
The European Geosciences Union (EGU), one of the biggest players in the field, attempts to contribute to this goal with different projects:

- The GIFT workshops
- Educational Sessions at EGU General Assemblies
- The GIFT Distinguished Lecture Series
- Teachers at Sea
- Fostering of International Collaboration between schools

<u>The GIFT Workshops</u>
The main program, the GIFT workshops series, was initiated in 2003. These workshops are two-and-a-half-day teacher enhancement workshops held in conjunction with EGU's annual General Assembly. The program of each workshop, focused on a unique general theme, combines scientific presentations on current research in the Earth and Space Sciences, given by prominent scientists attending those EGU General Assemblies, involving hands-on, inquiry-based activities that can be used by the teachers in their classrooms to explain related scientific principles or topics presented by science educators. Also, teachers are welcomed to present to their colleagues some aspects of their own hands-on classroom activities.
The main objective of these workshops is to spread first-hand scientific information to science teachers of primary and secondary schools, significantly reducing the time between discovery and textbook, and to provide the teachers with material that can be directly used in the classroom. In addition, the full immersion of science teachers in a truly scientific context (EGU General Assemblies with up to 9000 scientists attending each year) and direct contact with world leading geoscientists (Nobel Prize laureates among them) are likely to stimulate a curiosity towards scientific research, that the teachers can transmit to their pupils.
The value of bringing teachers from several nations together includes the potential for networking and collaboration, the sharing of experiences, and an awareness of science

education as it is presented outside their own countries. At all previous EGU GIFT workshops, teachers mingled with other teachers from outside their own country, had lunch together with the scientists, met in front of posters and during presentations and thus became involved in a lot of dialogues regarding ideas about learning, presentation of content material, curriculum ideas and the like. We, therefore, believe that, in addition to their scientific content, the GIFT workshops are also of high societal value. To determine the effectiveness of the GIFT workshop we require the participating teachers to provide immediate feedback at the end of the workshop. In addition, we follow up after six months and ask for a report on how and what they have implemented of the new concepts learned at the GIFT workshop in the classroom.

The dissemination of the information provided through GIFT workshops is done first by the teachers themselves: many of them are responsible for informing other teachers in their own country and have used this opportunity to spread the material and ideas gained at GIFT. A brochure is published for each workshop containing relevant information (biography of the speakers, abstracts…) and is distributed to the teachers and to different institutions and sponsors (130-150 brochures every year). A CD containing all PowerPoint presentations given by the lecturers is distributed to the teachers. These presentations are also posted on the EGU website in the year of the workshop (see http://gift.egu.eu). Small reports on the GIFT workshops are submitted regularly to EOS and to the EGU Newsletter. Starting in 2009, a selection of the conferences offered by speakers have been video and audio recorded and have been mounted for consultation via internet by the teachers with their students in the classroom.

The workshops so far have focused on “Climate and Natural Hazards” (2003 in Nice, France), “The Ocean” (2004, in Nice, France), “The History of the Earth” (2005 in Vienna, Austria), “The Polar Regions” (2006, in Vienna, Austria), “Geosciences in the City” (2007, in Vienna, Austria), “The Carbon Cycle” (2008, in Vienna, Austria), “The Earth from Space” (2009, in Vienna, Austria), “Energy and sustainable development” (2010 in Vienna Austria), “Evolution and Biodiversity” (2011, Vienna) and will continue next year with the topic “Water!”. In 2010, for the first time, a GIFT workshop has been organized in Merida, Mexico, in connection with the AvH6.

By their nature, the GIFT workshops are multinational, both with respect to the attending teachers and to the scientists addressing the teachers. Typically, between around 80 middle and high school teachers participate in the GIFT Workshops, with a limit of one per school and a teacher only being allowed to participate twice. The teachers are selected from about 200-300 applicants each year. Registration to GIFT workshops and to the General Assemblies of EGU is free for teachers and they receive travel and living grants. The organization of the workshop is done by the Committee on Education (CoE) of the EGU (for details on the members see http://gift.egu.eu/committee-on-education.html).

Educational Sessions at EGU General Assemblies

Traditionally the EGU Committee on Education organizes a poster session at the General Assembly, where teachers and scientists from all over the world relate their experiences in the classroom. In the last two years, this poster session has been one of the most attended of all the poster sessions at EGU.

The GIFT Distinguished Lecture Series

Starting this year, the Committee is going to inaugurate a new program, an annual series of Geosciences Information For Teachers (GIFT) Distinguished Lectures, to be given by top scientists who have previously participated as speakers in GIFT workshops during the EGU General assemblies.

High school teachers, high school directors, educators for teachers from the European area are welcome to request a lecture, for which the EGU Committee on Education will cover the travel and subsistence costs of the speaker.
Requisites for are posted on the EGU GIFT website.

Teachers at Sea

Already twice we have embarked a group of 5 teachers on board of the Research vessel Marion Dufresne of the French Polar Institute to participate to Oceanographic cruises.
The objective of the pedagogical action is to allow the embarked teachers, and through their daily reports to their fellow teachers on land, to meet internationally known scientists, engaged in paleoclimatic-paleoceanographic research, and to be able not only to ask them all the questions they wish, but also to fully participate to the scientific life on board. They are imbedded in Science, the way scientists do it!
The best way to evaluate the importance of this program for the high school teachers is given by this statement of one of the participant teachers:
"I truly think that this experience onboard R/V Marion Dufresne will change and improve my teaching strategies allowing me to take "real science" into the classroom. I would like to acknowledge the European Geosciences Union (EGU) and the French Polar Institute (Institut Paul-Emile Victor - IPEV) that have funded the «Teachers at Sea» educational program. And particularly I would like to thank Carlo Laj, coordinator of the program, for inviting me to take part in this magnificent experience. I can only hope that other fellow teachers will have the opportunity to participate and enjoy the great experiences this program provides (Hélder Pereira, Secondary School at Loulé, Portugal).

Fostering of International Collaboration between schools

Starting this year, the Committee has also helped in setting up a web site specifically aimed and run by teachers having participated to GIFT workshops, in order to exchanges experiences and develop collaborations between schools. Some collaborations are already under way.