

Report of the Section on *Carbon and Climate*

The meeting of the Section on *Carbon and Climate* (S-CC) was held from 09:00-18:00 on October 17, 2015 at the PICES Annual Meeting in Qingdao, China. Drs. James Christian and Tsuneo Ono acted as meeting Chairs. Eleven members were present, representing Canada, China, Japan, Korea, and the United States (*S-CC Endnote 1*). The meeting agenda (*S-CC Endnote 2*) was adopted unanimously (Agenda Item 1). The morning session was given over to discussion of the planned basin-wide acidification synthesis activity (Agenda Items 2 and 3), and the regular business meeting was conducted in the afternoon.

AGENDA ITEMS 2 AND 3

Individual country reports on acidification synthesis and discussion of plans for completion of synthesis

A full ½-day was devoted to reviewing progress toward the basin-wide acidification synthesis. Each national delegate gave a brief report and plans and strategies for Year 2 were discussed. The activity appears to be proceeding on schedule. Each national contingent will consult with biologists and other experts on particular local impacts in their own countries. Some members will be attending the 4th International Symposium on “*The ocean in a high-CO₂ world*” Conference (May 3–6, 2016, Hobart, Tasmania) and the SOLAS/IMBER Carbon Working Group will meet there as well. It is important to build on what this group achieves and not duplicate it.

The final structure of the synthesis report was discussed with the following conclusions:

- The report should start with a synthesis of open ocean data, *e.g.*, JMA, Line P, HOT. We will begin with what is well known and then proceed to what is more uncertain, especially the impacts on coastal zones and marginal seas.
- The second chapter will be an inventory of each member country’s observing programs and systems, and will identify gaps in current capabilities. Technology issues will be examined, *e.g.*, how low salinity affects the performance of pH sensors, and how correlated errors among different sensors affect our ability to close the carbon system. These are not Pacific-specific issues but it is important to document how they affect our efforts and what we are doing about it.
- The coastal regions will be broken down into the main regimes in terms of what environmental factors drive elevated variance and deviations from global patterns, *e.g.*, river dominated, upwelling dominated, or eutrophied. We have examples of each within our domains of interest and the emphasis will be on identifying the differences and what can be done to deploy resources most effectively in the context of diverse regional influences.
- Additional chapters will identify points of greatest vulnerability, either biological vulnerabilities, *e.g.*, aquaculture, spawning or nursery areas, or areas particularly vulnerable to acidification due to biogeochemical state, *e.g.*, eutrophication, large freshwater inputs, upwelling of undersaturated subsurface water.

AGENDA ITEM 4

Reports of collaborating organizations and agencies

Reports were given on several national and international programs relevant to the mandate of S-CC, including SOLAS (Dai), CLIVAR/GO-SHIP (Ishii), and IOCCP (Ishii). Dr. Akihiko Murata gave a presentation on the SCOR Working Group on Towards Comparability of Global Oceanic Nutrient Data (COMPONUT). Dr. Alex Kozyr reported on the progress of SOCAT and GLODAP (v2) and Dr. Toru Suzuki presented updates to the

PACIFICA data base. Dr. Steven Bograd, representing the FUTURE Scientific Steering Committee (SSC), gave a brief presentation on the current status of FUTURE and expectations regarding expert groups' contributions to it.

Prof. Minhan Dai has now rotated off the SOLAS SSC after serving two terms. One S-CC member (Dr. Lisa Miller) remains on the SSC. New members have been appointed from Canada, the US, India, France, and Italy. Of these Dr. V.V.S.S. Sarma (India) and Prof. Maurice Levasseur (Canada) probably have the closest connection to PICES. The new SOLAS Science Plan was submitted in December 2014. There are five “Core Themes” (including “Greenhouse gases and the oceans”, “Ocean biogeochemical controls on atmospheric chemistry”, and “Atmospheric deposition and ocean biogeochemistry”) and three “Integrated Topics”. An Open Science Conference was held in Kiel, Germany September 7–11, 2015, with keynote presentations and discussion sessions on some of the Core Themes and Integrated Topics. SOLAS is reorienting its goals around those of Future Earth and is a Future Earth Core Project as of September 2015 (IGBP will end this year). SOLAS is sponsoring a Short Course on Ocean Acidification at Xiamen University October 19-25.

Dr. Masao Ishii gave a brief presentation on IMBER. He is now an IMBER SSC member. The seventh China-Japan-Korea IMBER Symposium will be held March 24–26, 2016, in Jeju, Korea. IMBER is also transitioning from IGBP to Future Earth sponsorship, and expects to become a Future Earth Core Project. A new Science Plan is currently open for discussion (draft dated May 12, 2015). IMBER has a Carbon Research Working Group with three subgroups: surface ocean, interior ocean carbon, and ocean acidification. The Surface Ocean $p\text{CO}_2$ Mapping intercomparison (SOCOM) held meetings in February and September; a Discussion Paper has been submitted (Rödenbeck *et al.*, Data-based estimates of the ocean carbon sink variability – first results of the Surface Ocean $p\text{CO}_2$ Mapping intercomparison (SOCOM), *Biogeosciences Discuss.*, doi:10.5194/bgd-12-14049-2015). Another paper in preparation (Gruber *et al.*) estimates an annual mean ocean CO_2 uptake of 2.3 ± 0.5 PgC/y since the Sabine *et al.* (2004, *Science* 305: 367) (cumulative) estimate of 118 PgC.

Dr. Ishii also gave a brief presentation on GO-SHIP. A joint GO-SHIP/Argo/IOCCP conference on “*Sustained ocean observing for the next decade*” was held in Galway, Ireland on September 14-18, 2015. Korea is now a member of GO-SHIP (Dr. Jae Hak Lee from KIOST is their representative). Korea is building a new vessel (~100 m long, 5900 tons, berths for 38 scientists) which is expected to be operational in 2016. Underway $p\text{CO}_2$ and DIC/TA/pH (2 of 3) are now considered Level 1 core measurements. Some GOOS “Essential Ocean Variables” are Level 1 GO-SHIP variables while others are Level 2. A review paper summarizing changes observed during the first 10 years is in press at the *Annual Review of Marine Science* (Talley *et al.*, Changes in ocean heat, carbon content, and ventilation: A review of the first decade of GO-SHIP Global Repeat Hydrography).

COMPONUT held its first meeting in April at the European Geosciences Union General Assembly (April 12–17, 2015) in Vienna, Austria. The first international intercomparison experiment involved 58 laboratories in 28 countries. Reference materials from the National Metrology Institute of Japan (NMIJ), KANSO and KIOST were used. Homogeneity was estimated at 1% and the standard deviations of reported data were 1–2% (note that 2% was the benchmark in PACIFICA). Another experiment is planned for 2016–2017, and a training course is planned for November 2017 in Texel, The Netherlands. JAMSTEC plans to produce certified reference materials and sell them at cost (estimated as 6000–7000 JPY per sample); these samples will be labelled as SCOR certified. There was considerable discussion around the issue of what exactly constitutes “certified” reference material (CMR) and who does the certification. In Japan JAMSTEC is cooperating with KANSO to produce reference materials traceable to those certified by NMIJ (which are considered too expensive for routine use). In Korea KIOST certifies their own CRMs using real seawater, whose homogeneity is within 1%; they are stable within their homogeneity for at least 6 months. Although there does not yet appear to be an internationally agreed upon standard, it is recommended to use CRM materials where available. The latest questionnaire regarding client needs received replies from 67 laboratories in 28 countries for a total estimated demand of 2800 samples per year across five sample types (CRMs are regionally specific to reflect the different nutrient ratios in different oceans, e.g., Atlantic surface, Atlantic deep, Pacific deep: demand is divided about equally between Pacific and Atlantic users).

Dr. Ishii gave a brief presentation on IOCCP. IOCCP has nine Theme Leaders including S-CC members Dr. Ishii for Ocean Interior Observations and Dr. Richard Feely (USA) for Ocean Acidification. The IOCCP Steering Group met on April 14–16, 2015, in Sendai, Japan, in parallel with the Ocean Observations Panel for Climate (OOPC); they will meet again in February 2016 at the AGU Ocean Sciences Meeting in New Orleans, USA. The Sendai meeting reviewed readiness of some Essential Ocean Variables including N₂O (Bange), DOC (Hansell) and particulates (Church).

Dr. Alex Kozyr gave a brief presentation on GLODAP (v.2), which is expected to be released soon. Unlike v.1 it will include the Arctic Ocean. A gridded CFC product will likely be created as there is demand from the climate modelling community. Dr. Ishii thinks that the adjustment table for PACIFICA is more reliable than that derived for the same cruises in GLODAP2 because GLODAP2 solved the optimization problem globally, and did so without designating specific cruises as “core” cruises known to have high data quality. Dr. Suzuki is working on an updated version of PACIFICA; it contains 377 cruises vs. 306 for the original PACIFICA data set. A large number of the new cruises are in high-latitude regions of the Southern Ocean.

Dr. Bograd gave a brief presentation on FUTURE and its recent reorganization and revised structure. The FUTURE SSC was formed in 2014 with a mandate to develop links to existing expert groups to facilitate implementation of the Science Plan. The SSC held its first meeting in La Jolla, USA, in March 2015. The SSC can recommend the establishment of new expert groups as needed. Dr. Bograd and Dr. Fangli Qiao (China) are the SSC liaisons to S-CC.

Dr. Dong-Jin Kang gave a brief update on the work of the Study Group on the *North Pacific Ecosystem Status Report* (SG-NPESR3). The NPESR has been published every 5 years, but the second report fell behind its intended schedule. The Study Group is tasked with defining a protocol for updating the reports. An inter-sessional workshop is planned for June 2016 at which a new Working Group will be launched which will carry out the actual work of synthesizing the relevant observations. Expert groups are invited to nominate data time series or ‘snapshots’ to be featured in the report. SG-NPESR3 is to present its work at PICES-2016, with the NPESR to be presented at PICES-2017.

Prof. Nianzhi Jiao (China) presented his proposal for a joint PICES/ICES Working Group on *Climate Change and Biologically-driven Ocean Carbon Sequestration*. This proposal grew out of a workshop on “*Effects of climate change on the biologically-driven ocean carbon pumps*” at the PICES/ICES/IOC 3rd International Symposium on “*Effects of Climate Change on the World’s Oceans*” in Santos, Brazil, March 21–27, 2015 (see pages 9–11, [PICES Press, Vol. 23, No. 2](#)). A conclusion of the workshop was that there was a need to “build a team to work closely on integrating the studies of the three ocean carbon pumps (solubility pump, biological pump and microbial carbon pump), and to find a way to deliver our scientific findings to policy makers”. This working group would likely focus more on the microbial carbon pump (sequestration in refractory DOC) than previous efforts, but would address all three pumps in an integrated fashion. There is a strong will to deliver results to the policy arena; it was noted that coastal eutrophication, for example, affects marine microbiota in ways that can, in turn, affect both carbon sequestration and production of non-CO₂ greenhouse gases. S-CC members generally supported the Working Group proposal.

AGENDA ITEMS 5 AND 6

Science topics

Dr. Sayaka Yasunaka (Japan) gave a presentation on ship-of-opportunity sampling for surface nutrient concentrations. These observations are far more spatially extensive than the data in PACIFICA and represent the majority of data archived by the U.S. National Ocean Data Center since about 1995. JAMSTEC made continuous underway measurements aboard the R/V *Mirai* from 1998–2004 and since 2014 is making continuous measurements using an optical sensor. Scientists from the National Institute of Environmental Studies (NIES, Japan) and Fisheries and Oceans Canada (DFO) have collected large amounts of data aboard commercial vessels on trans-Pacific routes. Self-organizing maps constitute a method of interpolating and

extrapolating these data to make continuous maps without assuming *a priori* physical or statistical relationships with other variables. These maps were used to conduct an EOF analysis that shows a distinct Pacific Decadal Oscillation signature in the variability of surface nutrient concentrations.

A suggestion was made that, following the completion of the acidification assessment, a worthwhile activity for S-CC would be to prepare a “rescue” data base of historical nutrient data not included in PACIFICA or archived by national data centres (*e.g.*, shallow hydrocast, surface-only sampling, sensor data) and encourage analyses using this data set, such as temporal changes in surface nutrient inventory or changes in nutrient ratios.

Dr. Katsunori Kimoto (Japan) gave a presentation on new methods to measure dissolution of calcium carbonate minerals using Microfocus X-ray Computer Tomography. This instrument was acquired by JAMSTEC in May 2015 and provides submicrometre 3D imaging of objects opaque to visible light. X-ray attenuation was shown to be linearly related to the density of carbonate shell samples (μg of mineral per μm^3 total volume), and attenuation was shown to be lower in partially dissolved samples of pteropod and foraminiferan shells collected below the saturation horizon.

AGENDA ITEM 7

Future goals and objectives

Workshop and Topic Session for 2016

S-CC members proposed a Workshop and Topic Session for the 2016 Annual Meeting to present the final results of our acidification assessment activity. “Acidification of the North Pacific Ocean: A basin-wide assessment” (workshop) was proposed by Drs. Christian and Ono (*S-CC Endnote 3*) and “New stage of ocean acidification studies: Responses of oceanic ecosystem including fisheries resources” (Topic Session) by Drs. Ono, Jun Kita (Japan), and Debby Ianson (Canada) (*S-CC Endnote 3*). ICES is expected to co-sponsor the latter; an ICES co-convenor will be identified. These events are expected to be important fora for presentation and discussion of the results of the acidification assessment. A special journal issue is also planned to document key findings in the peer-reviewed literature.

S-CC Endnote 1

S-CC participation list

Members

Liqi Chen (China)
James Christian (Canada, Co-Chair)
Minhan Dai (China)
Zhongyong Gao (China)
Masao Ishii (Japan)
Dong-Jin Kang (Korea)
Alex Kozyr (USA)
Kitack Lee (Korea)
Akihiko Murata (Japan)
Tsuneo Ono (Japan, Co-Chair)
Toru Suzuki (Japan)

Observers

Steven Bograd (USA)
Masahiko Fujii (Japan)
Deborah Iglesias-Rodriguez (USA)
Nianzhi Jiao (China)
Sejong Ju (Korea)
Jamyung Kim (Korea)
Katsunori Kimoto (Japan)
Yawei Luo (China)
Shin-ichiro Nakaoka (Japan)
Angelica Peña (Canada)
Hiroaki Saito (Japan)
Yi Xu (IMBER)
Sayaka Yasunaka (Japan)
Rui Zhang (China)

S-CC Endnote 2**S-CC meeting agenda**

1. Opening (Christian, Ono)
 - Review and adopt agenda
2. Individual country reports on acidification synthesis
3. Discussion of synthesis report and 2016 workshop format
4. Reports of collaborating organizations and agencies
 - SOLAS (Dai)
 - IMBER (Ishii)
 - CLIVAR/GO-SHIP (Ishii)
 - GLODAP/SOCAT (Kozyr)
 - COMPONUT (Murata)
 - IOCCP (Ishii)
5. Introduce nutrient activities (Yasunaka) / discussion of post-2016 activities
6. quantifying CaCO₃ dissolution (Kimoto)
7. Further discussion of Section business (membership, publications); further discussion of acidification synthesis and 2016 workshop

S-CC Endnote 3

**Proposal for a 1-day Workshop on
 “Acidification of the North Pacific Ocean: a basin-wide assessment” at PICES-2016**

Convenors: James Christian (Canada), Tsuneo Ono (Japan)

Ocean acidification has been proceeding for a century, at an accelerating rate, and its impacts are beginning to be felt in many corners of the North Pacific. This workshop will bring together scientists from all of the PICES countries to synthesize our observations and projections of acidification processes and impacts in our respective countries' waters and adjacent international waters. This workshop is the culmination of a two-year long process of collation of relevant information, and synthesis of data collected in each of the countries of the North Pacific basin. The workshop proceedings will form the basis for subsequent assessments, with improved understanding of which ocean regions are most vulnerable to acidification impacts, and how additional resources might best be deployed to predict or detect changes likely to produce significant impacts.

Proposal for a 1-day Topic Session on “New stage of ocean acidification studies: Responses of oceanic ecosystem including fisheries resources” at PICES-2016

Convenors: Tsuneo Ono (Japan), Jun Kita (Japan), Debby Ianson (Canada), TBD (ICES)

Suggested Co-sponsor: ICES

Passing over 20 years of progress on ocean acidification studies, our knowledge on biological responses against acidified ocean environment has accumulated to some extent. WGII report of IPCC IR 5 illustrates sensitivity matrix of ocean life against the acidification among wide range of species and *p*CO₂ level, showing our present terminus of this scientific topic. However, our progress simultaneously awakes various new questions, such as response of biology against temporally-varied *p*CO₂, inter-species interaction under acidified environment, and biological adaptation. Also, we have gradually realized existence of ocean acidification by eutrophication, as well as anthropogenic CO₂, in coastal regions. Emergence of these new questions reveals that we are now moving into new stage of understanding on ocean acidification problem, in

which we may be able to make more realistic and quantitative prediction about future biological/ecological responses to acidified ocean, and socio-economic response of humans against these changes. In this session we recruit wide area of studies on biological/ecological responses against ocean acidification, including fisheries resources, both in coastal and open ocean. We particularly welcome reports from advanced issues on this field, including response of biology against temporally-varied $p\text{CO}_2$, inter-species interaction under acidified environment, and biological adaptation.