

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 November 4, 2016 at the PICES-2016 in San Diego, USA. Drs. James Christian and Tsuneo Ono acted as meeting Chairs. Nine members were present, representing Canada, China, Japan, Korea, and Russia (*S-CC Endnote 1*). The meeting agenda (*S-CC Endnote 2*) was adopted unanimously.

AGENDA ITEM 2

Acidification synthesis workshop

The previous day's workshop (W1; *Acidification of the North Pacific Ocean: A basin-wide assessment*) was briefly discussed. All members present except one had attended the workshop, so an extensive rehash was not considered necessary. The workshop was generally regarded to have achieved its goals and the assessment is on track for completion in 2017. A key decision was to broaden the scope of the assessment to include deoxygenation as well as acidification, as the two issues are closely intertwined. A request will be made to the parent committees for PICES financial support in editing and collating the report.

AGENDA ITEM 3

Report to FUTURE mini symposium

A brief presentation to the FUTURE Mini-Symposium on the day following the business meeting was presented, and members provided their input. The S-CC content changed little from the previous year, as the key objective remains the completion of the acidification assessment, which was explicitly conceived as a product (Outlook) that would be a central S-CC contribution to the FUTURE Science Plan.

AGENDA ITEM 4

Three-year report and activities for 2016–2019

S-CC was given a 3-year reauthorization in 2013, following a change to the Rules of Procedure that reduced the reauthorization interval from 5 years to 3. A list of accomplishments for 2013–2016 and objectives for 2016–2019 (see *S-CC Endnote 3*) were discussed.

AGENDA ITEM 5

Reports of collaborating organizations and agencies

Dr. Masao Ishii gave a brief report on IMBER. IMBER is preparing a new Science Plan for 2016–2025. This has been reviewed by SCOR and Future Earth, but is not final yet. There will be five core working groups and four regional programs. There is a need to coordinate carbon research with SOLAS, as these two programs have had several carbon-related joint working groups, but the structure of these may be reorganized in cooperation with CLIVAR and IOCCP. Regional programs such as ESSAS will continue. A China-Japan-Korea regional symposium was held in Jeju, Korea in March 2016. The next one will be in China in 2018. IMBIZO V on “*Marine biosphere research for a sustainable ocean: Linking ecosystems, future states and resource management*” will be held at Woods Hole, USA, October 2–6, 2017.

Dr. Ishii also reported on GO-SHIP. A WebEx meeting was held on July 13; minutes are available at www.go-ship.org/GO-SHIPmeeting_13July2016final.pdf. Several Pacific lines have recently been completed, but no recurring long-line programs are in the Pacific, and only two of the cruises planned for the next four years are in the Pacific. Pacific lines no one is yet planning to do during 2012–2023 are P14N, P03

and P01E. Line P is now a GO-SHIP-associated line. A review article (Talley *et al.*, 2016. *Ann. Rev. Mar. Sci.* 8: 185) summarizing the first decade of GO-SHIP results (several S-CC members are co-authors) has been published. Some chapters of the GO-SHIP methods manual need updating (*e.g.*, DOM, ADCP); the manual will be moved to IOC's International Oceanographic Data and Information Exchange (<http://www.iode.org/>) page for greater visibility beyond the GO-SHIP community.

Dr. Christian presented on GLODAP on behalf of Dr. Alex Kozyr who was not able to attend. The release of the GLODAPv2 data product has been completed. Documentation can be found in Olsen *et al.* (2016 *Earth Syst. Sci. Data* 8: 297) and Lauvset *et al.* (2016 *Earth Syst. Sci. Data* 8: 325), which also have multiple S-CC co-authors. The new data product contains a total of 775 cruises of which 280 are from PACIFICA. Also see GLODAPv2 article, pp. 36–38 in [PICES Press, Vol. 24, No. 2](#).

Dr. Akihiko Murata gave a brief overview of COMONUT. COMONUT met in September 2016 in association with the CLIVAR Open Science Conference in Qingdao, China, and presented a cluster of 14 posters at the conference. Samples for the next intercalibration exercise are scheduled to be distributed in September 2017. [Results](#) of the previous exercise have been published. Use of Certified Reference Materials (CRMs) can reduce the spread of values across different laboratories analyzing the same reference sample by an order of magnitude. New JAMSTEC CRMs (<http://www.jamstec.go.jp/scor/>) will cost only about 6700 JPY (about US\$65) vs 11,000 JPY for the KANSO version. There will be five distinct water types; three have already been completed.

Dr. Maciej Telszewski reported on the IOCCP. IOCCP may be merged into GOOS as “GOOS-Biogeochemistry” and its focus expanded beyond carbon. SOCAT v.4 has been released. Data upload is now automated and the software automatically checks for impossible combinations of values. There is still complete seasonal coverage only in the northern hemisphere mid-latitudes. GLODAPv3 is not expected until 2025; v.2 will be updated periodically.

Dr. Toshiya Nakaoka gave a brief update on SOCAT. As noted above, v.4 has been released; v.4 includes a new flag for sensor data. It is also possible to submit calculated $p\text{CO}_2$ in cases where *e.g.*, only DIC and alkalinity were measured. pH estimated from SOCAT data does not show a significant trend in the Subarctic Pacific over 1991–2011 (Lauvset *et al.* 2015, *Biogeosciences* 12: 1285). Data submission for SOCAT v.5 closes in January 2017 and release is expected in summer 2017.

AGENDA ITEM 6

Further section business

Changes in membership were briefly discussed. Prof. Yutaka Watanabe (Japan) will likely rotate off and Dr. Shin-Ichiro Nakaoka (who was present) was suggested as a replacement. Turnover in the U.S. and Canadian delegations is also likely, but the exact individuals involved are still to be decided. There will also probably be some turnover in *ex-officio* members, as IGBP, in which Prof. Chen-Tung Arthur Chen represents in S-CC, ended in 2015. Dr. Maciej Telszewski and Dr. Gro van der Meeren have expressed interest in joining as *ex-officio* members, representing IOCCP and IMBER, respectively.

Objectives for post-2017 were discussed, centering around emerging technologies used to measure ocean carbon chemistry parameters (*e.g.*, sensors). Members plan to seek funding from national agencies to conduct intercomparison experiments with these technologies. The Canadian members have already received some funds for this purpose. Another objective is to develop new data products related to oxygen and nutrient concentrations for (*e.g.*, coastal) regions and data types (*e.g.*, volunteer observing ships) excluded from PACIFICA and GLODAPv2. These are detailed more fully in the 3-year report and extension proposal (*S-CC Endnote 3*).

S-CC Endnote 1**S-CC participation list**Members

Andrey Andreev (Russia)
 James Christian (Canada, Co-Chair)
 Zhongyong Gao (China)
 Masao Ishii (Japan)
 Dong-Jin Kang (Korea)
 Akihiko Murata (Japan)
 Tsuneo Ono (Japan, Co-Chair)
 Jeong Hee Shim (Korea)
 Toru Suzuki (Japan)

Observers

Simone Alin (US)
 Masahiko Fujii (Japan)
 Toshiya Nakano (Japan)
 Shin-ichiro Nakaoka (Japan)
 Maciej Telszewski (IOCCP)

Members unable to attend

Canada: Sophia Johannessen, Lisa Ann Miller
 China: Liqi Chen, Minhan Dai, Liyang Zhan, Yumei Zhao
 Chinese-Taipei: Chen-Tung Arthur Chen
 Japan: Yutaka Watanabe
 Korea: Kitack Lee
 Russia: Pavel Ya. Tishchenko
 USA: Richard A. Feely, Hernan Eduardo Garcia, Burke Hales, Alexander Kozyr

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

1. Opening (Christian, Ono)
 - Review and adopt agenda
2. Further discussion of acidification synthesis workshop W1 (Christian, Ono)
3. Discussion of report to FUTURE mini symposium
4. Discussion of 3-year report and activities for 2016-2019
5. Reports of collaborating organizations and agencies
 - SOLAS (Miller, Dai)
 - IMBER (Ishii)
 - CLIVAR/GO-SHIP (Ishii)
 - GLODAP (Kozyr)
 - COMPONUT (Murata)
 - IOCCP (Ishii)
 - SOCAT (Nakaoka)
6. Further discussion of Section business (Membership, Publications, future activities)
7. Further discussion of acidification synthesis and steps towards completion
8. Adjourn

S-CC Endnote 3

Report of the Section on *Carbon and Climate* for 2013-2016

The Section on *Carbon and Climate* (S-CC) was created in the fall of 2005 the PICES Annual Meeting in Vladivostok, Russia, following discussions to the effect that a more permanent body was needed to carry on the work of the disbanded Working Groups 13 (*Carbon Dioxide in the North Pacific*) and 17 (*Biogeochemical Data Integration and Synthesis*). At the 2010 Annual Meeting the Section was reauthorized for a further five years. Subsequent changes to the Rules of Procedure reduced the reauthorization period to three years. The Section was reauthorized for a further three years at the 2013 Annual Meeting.

The S-CC has two parent committees, POC and BIO. Drs. James Christian (Canada) has been North American Co-Chair of the section since its inception; Dr. Tsuneo Ono (Japan) has been Asian Co-Chair since 2014.

Membership

S-CC has members from all PICES nations, in addition to an *ex-officio* member representing IGBP (Prof. C.T.A. Chen). Current membership is 22; national complements range from 2 to 5 (see *Annex I*).

S-CC achievements in the past 3 years

Topic Sessions at PICES Annual Meetings

At the 2016 Annual Meeting in San Diego, USA, POC, TCODE, and MEQ convened a joint ICES/PICES topic session entitled “*New stage of ocean acidification studies: Responses of oceanic ecosystem including fisheries resources*”. S-CC Co-Chair, Dr. Tsuneo Ono, was convenor. At the 2015 Annual Meeting in Qingdao, China, POC, BIO, MONITOR, and TCODE convened a topic session entitled “*Ocean Acidification Observation Network for the North Pacific and adjacent areas of the Arctic Ocean*”. S-CC members Drs. Li-Qi Chen (China), Kitack Lee (Korea) and Toru Suzuki (Japan) were convenors, and Dr. Richard Feely (USA) was an invited speaker.

Both sessions drew large audiences and large numbers of presenters. This attests to widespread interest in these topics at PICES Annual Meetings and the need for the continued presence of a formal body dedicated to these topic areas.

PACIFICA and GLODAPv2 data synthesis

The most significant undertaking of S-CC over 2005–2013 was the data synthesis project known as PACIFICA (PACIFic ocean Interior Carbon). PACIFICA collected biogeochemical data (DIC, TA, nutrients, oxygen, salinity) from more than 200 cruises in the Pacific and implemented a set of algorithms for crossover analysis that permit the construction of a basin-wide, consistently calibrated data set. The PACIFICA algorithms were adapted from CARINA and implemented by Dr. Toru Suzuki (Japan). The data product was published in 2013 as [NDP-092](#).

GLODAP was the original data synthesis arising from the Global Ocean Survey of ocean CO₂ in the 1990s. GLODAPv2 is a new data product incorporating the original GLODAP as well as CARINA, PACIFICA, and additional cruises subsequent to PACIFICA. GLODAPv2 also covers areas of the North Pacific marginal seas and the Pacific Arctic that GLODAPv1 excluded. PACIFICA is the largest component of GLODAPv2 (280 of 775 cruises) and its excellent coverage in large areas of the North Pacific is a direct result of S-CC activities. GLODAPv2 was published in January 2016 and is freely available to all users. It has had nearly 3000 users as of mid-October, with 5 of the 6 PICES countries being in the top 10 data downloading countries.

Contribution to RECCAP

RECCAP (Regional Carbon Cycle Assessment and Processes) project is an international effort to develop a global carbon budget, synthesizing ocean, terrestrial, and atmospheric carbon studies. S-CC members Drs. Masao Ishii and Richard Feely are leading the air–sea carbon flux synthesis effort for the Pacific (<http://www.globalcarbonproject.org/reccap/syntheses.htm>). There are several RECCAP-related publications listed in *Annex 2* (e.g., Ishii *et al.*, 2014).

Contribution to SOCAT

SOCAT ([Surface Ocean CO₂ Atlas](#)) is “a collection of underway ocean CO₂ observations quality controlled by the science community”. Eight S-CC members contributed to SOCAT as data contributors and/or participants in data quality control and the development of the data product (L. Chen, R. Feely, Z. Gao, B. Hales, A. Kozyr, A. Murata, T. Ono, T. Suzuki, <http://www.socat.info/credits.html>). Publications describing several updates to SOCAT are listed in *Annex 2*.

Scientific publications

Annex 2 provides a list of sample publications for the years 2014–2016, emphasizing those that involve multiple S-CC members from different PICES countries (and a few that include multiple S-CC members within the same country but from different institutions). There are numerous additional publications not listed here that represent, for example, member collaborations with members of other PICES expert groups or with non-member scientists in other PICES countries.

Participation in international symposia

S-CC members Drs. Feely, Ishii and Murata attended the GO-SHIP/Argo/IOCCP Conference on “*Sustained ocean observing for the next decade*” September 14–18, 2015 in Galway, Ireland. Dr. Feely was on the Science Program Committee. S-CC members Drs. Dai, Ishii, Kozyr, Miller, and Ono attended or co-authored presentations at the SOLAS Open Science Conference September 7–11, 2015 in Keil, Germany. S-CC member Dr. Dai was a Plenary Speaker at the 4th International Symposium on the “*Ocean in a High-CO₂ world*” May 3–6 2016 in Hobart, Australia. S-CC member Dr. Miller was also a co-author on a presentation at this conference. S-CC member Dr. Shim attended the IOC WESTPAC Workshop on “*Research and monitoring of the ecological impacts of ocean acidification on coral reef ecosystems*” January 19–21, 2015 in Phuket, Thailand. S-CC Co-Chair Dr. Christian attended the Joint DFO-NOAA Workshop on Ocean Acidification September 19–20, 2016 in St. Andrews, NB, Canada.

Future plans

The FUTURE Science Plan notes that “natural and anthropogenic pressures are causing the oceans to acidify, while pollution, extirpations, invasive species, anoxia, habitat loss, and exploitation affect the coastal zones”, and suggests that “Region-specific assessments of topical issues” (e.g., harmful algal blooms, eutrophication, native and alien species range changes, anoxia, and ocean acidification) will be one of the key “anticipated benefits and products” of FUTURE. It is clear that ocean acidification, deoxygenation, and productivity are key issues for FUTURE; in PICES, much of the scientific expertise on these issues resides within S-CC.

We have oriented our activities to the FUTURE Science Plan by conducting an assessment of the state of ocean acidification and deoxygenation in the North Pacific. Our plan, as stated in the previous 3-year report (2013), was to “Develop data syntheses or products related to ocean acidification and deoxygenation and their biological and ecosystem impacts in support of FUTURE objectives, in consultation with FUTURE APs and other expert groups.” The Advisory Panels have been phased out, but we have pursued this activity and have regularly briefed the parent committees and the FUTURE SSC on its progress. At the 2016 Annual Meeting, we hosted a workshop entitled “*Acidification of the North Pacific Ocean: A basin-wide assessment?*” at which progress was reviewed and plans for completion made; the assessment is scheduled to be finished by the 2017

Annual Meeting although it will be subject to future revisions (see objectives listed below). In addition, at the 2016 Annual Meeting, we discussed other objectives that we will pursue over 2017–2019, with a focus on data from new technologies that are being widely adopted but still require rigorous evaluation, and data sets ‘orphaned’ in previous syntheses. The Canadian and Japanese members have already had some success in obtaining funds from national sources for these activities.

Objectives for 2017–2019

- 1) Complete acidification/deoxygenation synthesis and finalize plans for making it a “living document” that can be updated as needed and linked to relevant data sets as they emerge;
- 2) Develop data syntheses or meta-analyses for emerging technologies used to measure ocean carbon chemistry parameters (*e.g.*, sensors);
- 3) Seek funding from national agencies to conduct intercomparison experiments with these technologies;
- 4) Develop new data products related to oxygen and nutrient concentrations for (*e.g.*, coastal) regions and data types (*e.g.*, volunteer observing ships) excluded from PACIFICA and GLODAPv2.

Annex 1 - S-CC members

Canada: Dr. James Christian (Co-Chair); Dr. Sophia Johannessen; Dr. Lisa Miller

China: Prof. Liqi Chen; Prof. Minhan Dai; Dr. Zhongyong Gao

Japan: Dr. Masao Ishii; Dr. Akihiko Murata; Dr. Tsuneo Ono (Co-Chair); Dr. Toru Suzuki; Prof. Yutaka Watanabe

Korea: Dr. Dong-Jin Kang; Prof. Kitack Lee; Dr. Jeong Hee Shim

Russia: Dr. Andrey Andreev; Dr. Pavel Tishchenko

United States: Prof. Andrew Dickson; Dr. Richard Feely; Dr. Hernan Garcia; Prof. Burke Hales; Dr. Alexander Kozyr

ex-officio member representing IGBP: Prof. Chen-Tung Arthur Chen

Annex 2 – Sample S-CC Publications

(S-CC authors in bold)

Bakker, DCE, B Pfeil, K Smith, S Hankin, A Olsen, SR Alin, C Cosca, S Harasawa, A **Kozyr**, Y Nojiri, KM O'Brien, U Schuster, M Telszewski, B Tilbrook, C Wada, J Akl, L Barbero, NR Bates, J Boutin, Y Bozec, W-J Cai, RD Castle, FP Chavez, L **Chen**, M Chierici, K Currie, HJW de Baar, W Evans, RA **Feely**, A Fransson, Z **Gao**, B **Hales**, NJ Hardman-Mountford, M Hoppema, W-J Huang, CW Hunt, B Huss, T Ichikawa, T Johannessen, EM Jones, SD Jones, S Jutterström, V Kitidis, A Körtzinger, P Landschützer, SK Lauvset, N Lefèvre, AB Manke, JT Mathis, L Merlivat, N Metzl, A **Murata**, T Newberger, AM Omar, T **Ono**, G-H Park, K Paterson, D Pierrot, AF Ríos, CL Sabine, S Saito, J Salisbury, VVSS Sarma, R Schlitzer, R Sieger, I Skjelvan, T Steinhoff, KF Sullivan, H Sun, AJ Sutton, T **Suzuki**, C Sweeney, T Takahashi, J Tjiputra, N Tsurushima, SMAC van Heuven, D Vandemark, P Vlahos, DWR Wallace, R Wanninkhof, and AJ Watson, 2014. An update to the Surface Ocean CO₂ Atlas (SOCAT version 2). *Earth System Science Data* 6: 69–90.

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Yamamoto-Kawai, M, Kawamura, N, Ono, T, Kosugi, N, Kubo, A, Ishii, M, and Kanda, J, 2015. Calcium carbonate saturation and ocean acidification in Tokyo Bay, Japan. *Journal of Oceanography* 71: 427–439.

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Annex 3 – S-CC Terms of Reference

(bold indicates 2008 revisions)

1. Coordinate and encourage ongoing and planned national and international syntheses of carbon cycle research studies in the North Pacific and, where necessary and appropriate, for the larger Pacific basin;
2. Ensure effective two-way communication with other international scientific groups that have a responsibility for the coordination of ocean carbon studies, such as the International Ocean Carbon Coordination Project (IOCCP), CLIVAR/CO₂ Repeat Hydrography and the SOLAS/IMBER implementation group for carbon research;
3. Review the existing information on carbon cycling in the North Pacific, including anthropogenic carbon, the biological pump, impacts of **ocean acidification** on marine biota, and possible feedbacks to atmospheric greenhouse gases; identify gaps in our knowledge, and make prioritized recommendations for future research;
4. Periodically review the status of the methodology of CO₂ measurements, including the preparation of standards and reference materials, and advise on inter-calibration and quality control procedures;
5. Identify suitable data sets on the oceanic CO₂ system in the Pacific region as they become available, and recommend the mechanisms of data and information exchange;
6. Carry out and publish (in the refereed literature) basin-scale syntheses of carbon cycling in the North Pacific, including new data whenever appropriate, and encourage scientific interpretation of these evolving data sets;
7. Organize symposia, workshops, or Annual Meeting sessions on **the carbon cycle, ocean acidification**, and climate studies in the North Pacific.