2021 Report of the Section on *Carbon and Climate*

A virtual meeting of the Section on *Carbon and Climate* (S-CC) was held virtually from 17:00–20:00 on September 30, 2021 (US/Canada Pacific time) during PICES-2021. Drs. Alex Kozyr and Tsuneo Ono acted as meeting chairs. Fourteen members were present, representing Canada, China Japan, Korea, and the US (*S-CC Endnote 1*).

AGENDA ITEM 1
Confirmation of member exchange and adoption of agenda

Dr. Ono reported that Japanese member, Dr. Akihiko Murata, has stepped down and will be replaced by new member, Dr. Masahide Wakita, pending approval by Japan during the Governing Council meeting that will be held in October. The meeting agenda was slightly modified and adopted (S-*CC Endnote 2*). Prior to this web meeting, pre-discussions occurred from September 1 by e-mail. The meeting agenda was reviewed by members and accepted (*S-CC Endnote 2*).

AGENDA ITEM 2
S-CC new Terms of Reference

The Terms of Reference (TOR) of S-CC have been unchanged for many years, after the last modification in 2008, but this year we discussed modification of TOR to reflect the recent evolution of the Section. In new TOR, the scope of the section was expanded to more explicitly include cycles of oxygen and major nutrients in addition to that of carbon so that we can handle scientific issues related to ocean deoxygenation and nutrient cycle change. The list of collaborating organizations described within the TOR was updated. Finally, a new item was added to the TOR to further expand this Section's activity from biogeochemistry-based studies to ecological and fisheries impacts. The modified TOR were sent to Science Board and Governing Council for approval via the parent committees (POC and BIO).

AGENDA ITEM 3
Progress report of "inventory table" for coastal ocean acidification/deoxygenation monitoring sites

Dr. Ono reported current progress on the construction of an inventory table of domestic ocean acidification (OA) and deoxygenation monitoring sites in each PICES member country, a program launched in the last year as one of S-CC's new activities. The format of monitoring site reports was fixed and communicated to the members, but little information has been submitted so far. In parallel with encouraging submission of further monitoring site information, methods for publication of collected information were discussed. Dr. Ono proposed to upload collected information on each OA/deoxygenation monitoring site to the "PICES TCODE catalog" home page, so that people can access this information through this page. This proposal was accepted by the members after some discussion. Dr. Igor Shevchenko, the main administrator of the PICES TCODE catalog (https://sites.google.com/site/picestcodegeonetwork/home/pices-tcode-inventory), has agreed to upload S-CC data. Dr. Ono will consult with him soon after the business meeting to set specific procedures for information upload to this page.

AGENDA ITEM 4
Progress report of PACIFICA database update

Last year we found several inconsistencies in the contents of the PACIFICA database which is accessed via two international database repositories (MIRC PACIFICA and OCADS websites). Dr. Kozyr and Dr. Toru Suzuki (Japan) corrected these inconsistencies, adjusting the contents of OCADS to those of MIRC website. Dead links to an old CDIAC web address on the PICES web page were also corrected. Dr. Masao Ishii (Japan) emphasized that the PACIFICA database has its own unique value because it has data correction procedures independent of GLODAP, and hence S-CC should continue maintaining this database.

AGENDA ITEM 5
Reports of other S-CC activities in 2020

Dr. Ono gave a brief report on the ICES/PICES joint theme session K entitled "*Taking stock of ocean acidification research for provision of future efforts*" that was held at the ICES 2021 virtual Annual Science Conference. Due to the one-year postponement of this session, seven of the eight original presentations withdrew. The session was therefore structured as free-discussion following one original presentation and three brief presentations made by the conveners Silvana Birchenough (UK), Pablo Leon Diaz (UK), and Tsuneo Ono (Japan). Thirty-eight people participated to discuss multiple aspects of OA studies including chemistry, biology, policy, economics and social science.

A S-CC-proposed session at PICES 2021, entitled "*Connecting knowledge of ocean deoxygenation in coastal and offshore regions of the North Pacific*," and this will be held virtually at 17:00–19:00 October 27 (US/Canada Pacific time). Eight oral and one poster presentations are planned in this session.

Dr. Ono also reported on the GO2NE virtual meeting held on November 5–6, 2020. This meeting was held aiming to complete a white paper for the ocean oxygen data platform (GO2AT). Two S-CC members, Dr. Ono (Japan) and Dr. Hernan Garcia (US), participated in this meeting. Discussions were held on the required precision of oxygen data in each ocean region (oceanic and coastal) and measurement method (titration and several types of sensors), construction of regional hubs, economic value of the oxygen data platform products, *etc*. The finalized white paper was submitted to *Frontiers in Marine Science*, and is provisionally accepted for publication.

AGENDA ITEM 6
Reports from collaborating organizations and agencies

Dr. Kozyr reported on the recent publication of GLODAPv2.2021 at OCADS. GLODAPv2.2021 now consists of 989 cruises, appending 43 new cruises to GLODAPv2.2020. Because of the COVID-19 pandemic situation, the number of new cruises is low compared to GLODAPv2.2020. However, several new cruises are ongoing this year, and they expect to publish GLODAPv2.2022 next year.

Dr. Kozyr also reported that a new carbon dataset, Coastal Ocean Analysis Product in North America (CODAP-NA v.2021, https://www.ncei.noaa.gov/data/oceans/ncei/ocads/metadata/0219960.html) was published this year. This new dataset is composed of synthesized, and quality-controlled coastal carbon data around North Pacific. Four S-CC members, Dr. Richard Feely, Dr. Simone Alin, Dr. Kozyr, and Prof. Burke Hales were among the investigators involved (see paper in *Earth System Science Data*, 13, 2777–2799, 2021). Dr. Ishii mentioned that the method of quality control applied to coastal carbon data in this dataset is quite

informative for other coastal carbon monitoring groups. Dr. Kozyr also introduced a new numeric data package from OCADS titled "Compilation of dissolved organic matter (DOM) data obtained from global ocean observations from 1994 to 2020) (NCEI Accession #0227166).

Dr. Shin-ichiro Nakaoka (Japan) reported on the recent publication of SOCAT v.2021. This dataset contains pCO_2 data from 6752 transects of the global ocean, with 961 in the North Pacific. The number of new transects added from SOCAT v.2020 is 350 in total, with 44 in the North Pacific. SOCAT is now in the phase of new data submission for SOCAT v.2022, which will end on January 14, 2022. SOCAT has changed its metadata format so that contributors can submit more detailed information. Although data submission with the old metadata format is still allowed, Dr. Nakaoka strongly recommended that members submit their data with the new format. SOCAT is discussing inclusion of carbon parameters other than pCO_2 (*e.g.*, surface pH) in the dataset, and the result of this discussion will be opened soon.

Dr. Ishii introduced recent activities of Integrated Ocean Carbon Research (IOC-R). IOC-R is a formal working group of UNESCO-IOC that was formed in 2018 in response to the UN Ocean Decade. Its objective is to identify critical knowledge gaps in the ocean carbon cycle, as well as research activities to close these gaps. This program also aimed to bridge between science and policy through the programs such as UN Ocean Decade, UN Framework Convention on Climate Change (UNFCCC) and Intergovernmental Panel on Climate Change (IPCC). In 2021, IOC-R released a report in which four fundamental and emerging research questions are raised as follows:
(1) Will the ocean uptake of anthropogenic CO_2 continue as primarily an abiotic process?
(2) What is the role of biology in the ocean carbon cycle and how is it changing?
(3) What are the exchanges of carbon between the land-ocean-ice continuum?
(4) How are humans altering the ocean carbon cycle and resulting feedbacks?

Approaches to address these research questions are also discussed. Two S-CC members, Dr. Ishii and Dr. Feely, contributed to this report as co-authors.

Dr. Ishii also gave a brief introduction of IPCC WG1 AR6 that was released on August 9, 2021. In this latest IPCC Assessment Report, occurrence of acidification in the present surface open ocean is evaluated as "virtually certain," while declining oxygen concentrations in many upper ocean regions were evaluated to be ongoing with "high confidence." This report also predicted that acidification (virtually certain) and deoxygenation (high confidence) in the upper open ocean will continue to increase in the 21st century, at rates dependent on the level of emissions. It also assessed that the changes are irreversible on centennial to millennial time scales in global ocean temperature (very high confidence), deep ocean acidification (very high confidence), and deoxygenation (medium confidence).

Dr. Ishii mentioned that oxygen decline has still not been fully documented in some part of ocean regions, and that has kept the confidence of deoxygenation "medium" in expert judgement. Dr. James Christian (Canada) mentioned that extreme events are an important issue in the AR6 reports, and that will be relevant to PICES WG 49 (Working Group on *Climate Extremes and Coastal Impacts in the Pacific*) which is expected to be approved soon. Dr. Christian suggested that S-CC should contribute to this new working group. Dr. Samantha Siedlecki (US) is a co-convener of Topic Session S7 of this year's PICES meeting "*Predictions of extreme events in the North Pacific and their incorporation into management strategies*", and further discussions on the impact of ocean extremes on biogeochemical cycles will occur there.

Dr. Christian reported that ISO (International Organization for Standardization) has prepared ISO/DIS 5667-26 "Guidance on sampling for the parameters of the oceanic carbon dioxide system", which reproduces parts of

PICES Special Publication 3 "Guide to Best Practices for Ocean CO_2 Measurements." Previous practice has been to permit reproduction of the Best Practices Guide as long as it is reproduced accurately. Concern was raised that this document would involve substantial changes to the method, such as not poisoning samples with $HgCl_2$, which is acceptable as long as these are clearly indicated and not inadvertently represented as following the Best Practices Guide. Potential influences of these methodology changes to ocean carbon monitoring were discussed. S-CC member Prof. Andrew Dickson (US) is involved in the publication team for this SIO/DIS, and he will monitor the final text. Dr. Ono proposed that we should review how this new SIO/DIS is accepted by the community at next year's S-CC meeting, in accordance with Item 4 of our new TOR (Periodic review of methodology).

Dr. Ishii asked the members about existing or planned activities on making CRM (Certified Reference Material) for carbon parameters in each PICES member country. In Japan, a private company, KANSO, has prepared and distributed RM, but still needs SIO-CRM for certification of its DIC and TA values. Several groups in the US have started making high-level CRMs, but have had difficulty in getting low-nutrient seawater consistently. Dr. Wiley Evans (Canada) mentioned that if we can make secondary standards in each country, it will significantly reduce the burden on SIO to make large amount of CRM. Prof. Kitack Lee (Korea) agreed with this proposal, but pointed out the importance of keeping a reliable primary person or company to keep this system consistent. All members noted the importance of keeping systems of world-wide CRM distribution, and S-CC will continue reviewing progress on this issue at next year's meeting.

AGENDA ITEM 7
Discussion for 2021–2022 Section business plans

No sessions/workshops are planned for PICES-2022.
Members will collect information on domestic monitoring sites that include carbon and/or oxygen in each member country. Dissemination of the new SIO/DIS will be monitored and reviewed at the S-CC meeting in 2022. S-CC will also interact with WG 49 if it is approved.

S-CC Endnote 1

S-CC participation list

Members

Alexander Kozyr (USA, Co-Chair)
Tsuneo Ono (Japan, Co-Chair)
James Christian (Canada)
Wiley Evans (Canada)
Liqi Chen (China)
Zhongyong Gao (China)
Masao Ishii (Japan)
Shin-ichiro Nakaoka (Japan)
Toru Suzuki (Japan)
Kitack Lee (Korea)
Geun-Ha Park (Korea)
Jeong Hee Shim (Korea)
Simone Alin (USA)
Samantha Siedlecki (USA)

Members unable to attend

China: Xianghui Guo, Liyang Zhan, Yumei Zhao
Russia: Andrey Andreev, Pavel Ya. Tishchenko
USA: Andrew Dickson, Richard A. Feely, Hernan Eduardo Garcia, Burke Hales

Observer

Masahide Wakita (Japan)

PICES

Lori Waters (Administrative Assistant)

S-CC Endnote 2

S-CC meeting agenda

1. Confirmation of member exchange and adoption of agenda
2. Discussion for S-CC new Terms of Reference
3. Progress report of "inventory table" for coastal OA/deoxygenation monitoring cites (Ono)
4. Progress report of PACIFICA database update (Kozyr)
5. Reports of other S-CC activities in 2020 (Ono)
   - ICES/PICES joint OA session in ICES 2021
   - PICES-2021 session on deoxygenation
   - discussion with GO2NE
6. Reports from collaborating organizations and agencies
   - GLODAPv.2021 (Kozyr)
   - SOCAT (Nakaoka)
   - IOC-R & IPCC IR6 (Ishii)
   - ISO/DIS 567-26 (Andrew)
7. Discussion for 2021–2022 section business plans

S-CC Endnote 3

S-CC Terms of Reference
(bold indicates 2021 revisions**)**

1. Coordinate and encourage ongoing and planned national and international syntheses of ~~**carbon cycle**~~ research studies **regarding biogeochemical cycles of carbon, oxygen, and nutrients** 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**-related biogeochemical** studies, such as the International Ocean Carbon Coordination Project (IOCCP), **Ship of Opportunity Project (SOOP/VOS),** ~~**CLIVAR/CO_2**~~ **GO-SHIP/CO_2** Repeat Hydrography and the SOLAS/IMBeR implementation group for carbon research;
3. Review the existing information on **biogeochemical cycles of** carbon, **oxygen, and nutrients** in the North Pacific, including anthropogenic carbon, the biological pump, impacts of ocean acidification and deoxygenation 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 ~~**CO_2**~~ measurements **for the ocean carbon system, oxygen and nutrients**, including the preparation of standards and reference materials, **and sensor development**, and advise on inter-calibration and quality control procedures;
5. Identify suitable data sets on the oceanic ~~**CO_2**~~ **biogeochemical system, including carbon, oxygen and nutrients** in the Pacific region as they become available, and recommend mechanisms of data and information exchange;
6. Carry out and publish basin-scale syntheses of ~~**carbon cycling**~~ **biogeochemical cycles of carbon, oxygen, and nutrients** 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,**~~ **biogeochemical cycles of carbon, oxygen, and nutrients,** ocean acidification, **ocean deoxygenation, and other** climate studies in the North Pacific.
8. **Enhance cross-disciplinary collaboration across climate, ocean biogeochemistry, biology and fisheries on issues such as the biological effects of ocean acidification and deoxygenation.**