surface ocean solas lower atmosphere study

Report for the year 2021 and future activities

SOLAS China

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This report has two parts:

- Part 1: *reporting of activities in the period of January 2021 - Jan/Feb 2022*
- Part 2: *reporting on planned activities for 2022 and 2023.*

The information provided will be used for reporting, fundraising, networking, strategic development and updating of the live web-based implementation plan. As much as possible, please indicate the specific SOLAS 2015-2025 Science Plan Themes addressed by each activity **or specify an overlap between Themes or Cross-Cutting Themes.**

1 Greenhouse gases and the oceans;
2 Air-sea interfaces and fluxes of mass and energy;
3 Atmospheric deposition and ocean biogeochemistry;
4 Interconnections between aerosols, clouds, and marine ecosystems;
5 Ocean biogeochemical control on atmospheric chemistry;
Integrated studies of high sensitivity systems;
Environmental impacts of geoengineering;
Science and society**.**

IMPORTANT*: This report should reflect the efforts of the SOLAS community in the* ***entire country*** *you are representing (all universities, institutes, lab, units, groups, cities).*

First things first…Please tell us what the IPO may do to help you in your current and future SOLAS activities. ?

PART 1 - Activities from January 2021 to Jan/Feb 2022

1. Scientific highlight

*Describe one scientific highlight with a title, text (**max. 300 words**), a figure with legend and full references. Please focus on a result that would not have happened without SOLAS, and we are most interested in results of international collaborations. (If you wish to include more than one highlight, feel free to do so).*

1) Title: Carbon Fluxes in the Coastal Ocean: Synthesis, Boundary Processes and Future Trends *(Theme 1)*

This review examines the current understanding of the global coastal ocean carbon cycle and provides a new quantitative synthesis of air-sea CO_2 exchange. This reanalysis yields an estimate for the globally integrated coastal ocean CO_2 flux of −0.25 ± 0.05 Pg C year^{-1}, with polar and subpolar regions accounting for most of the CO_2 removal (>90%). A framework that classifies river-dominated ocean margin (RiOMar) and ocean-dominated margin (OceMar) systems is used to conceptualize coastal carbon cycle processes. The carbon dynamics in three contrasting case study regions, the Baltic Sea, the Mid-Atlantic Bight, and the South China Sea, are compared in terms of the spatio-temporal variability of surface CO_2 partial pressure (pCO_2). Ocean carbon models that range from box models to three-dimensional coupled circulation-biogeochemical models are reviewed in terms of the ability to simulate key processes and project future changes in different continental shelf regions. Common unresolved challenges remain for implementation of these models across RiOMar and OceMar systems. The long-term trends in coastal ocean carbon fluxes for different coastal systems under anthropogenic stress that are emerging in observations and numerical simulations are highlighted. Knowledge gaps in projecting future perturbations associated with before and after net-zero CO_2 emissions in the context of concurrent changes in the land-ocean-atmosphere coupled system pose a key challenge.

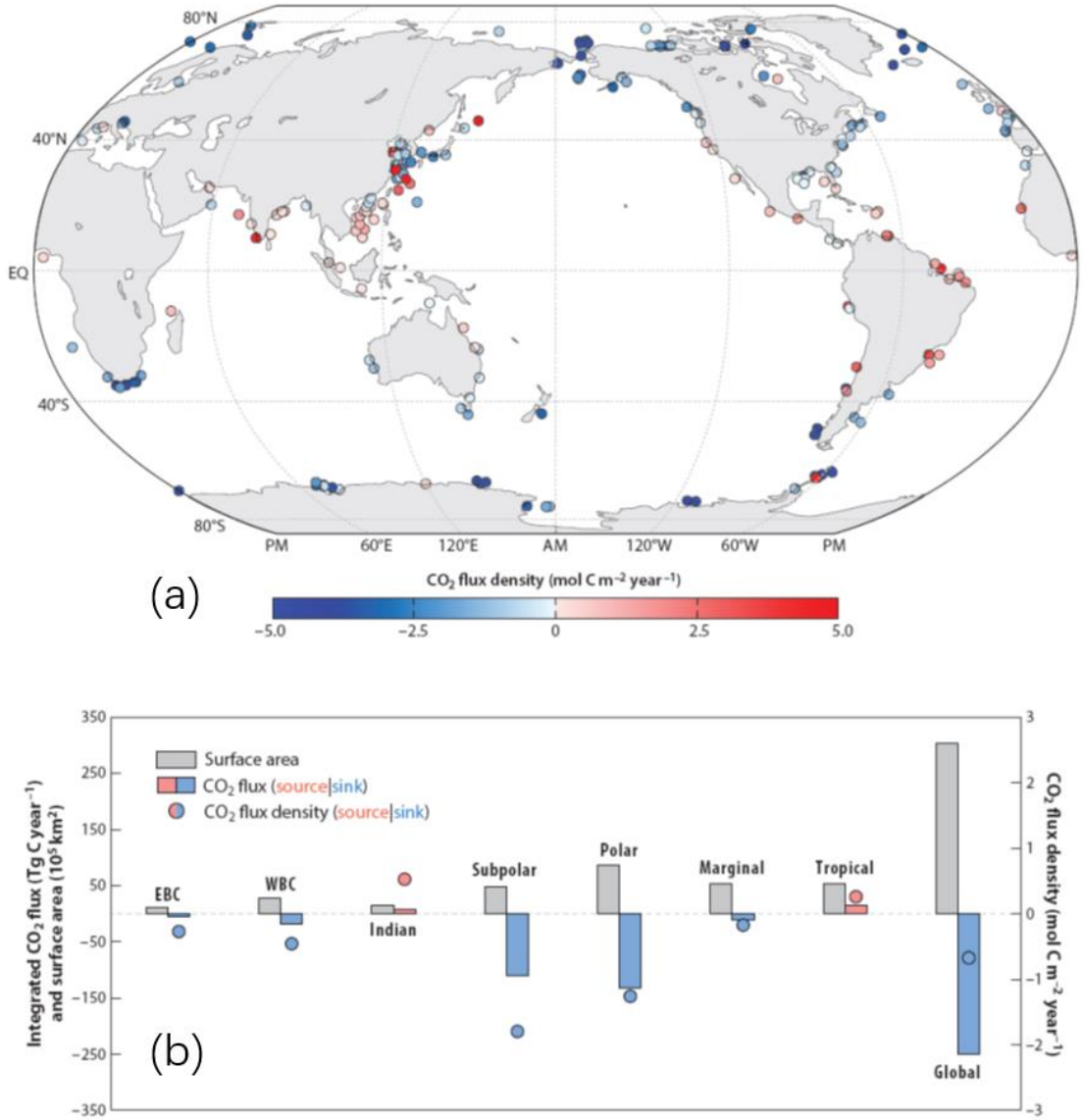

Figure: Updated sea-air CO_2 flux density (mol C m^{-2} year^{-1}) in the global coastal oceans (a); the shelf surface area (gray bars), CO_2 flux density (color circles), and spatially integrated CO_2 flux (red and blue bars) estimated for the seven shelf classes and global shelves (b). Abbreviations: EBC, eastern boundary current; Indian, Indian Ocean margins; marginal, marginal sea; WBC, western boundary current.

Citation: Dai, M., J. Su, Y. Zhao, E. E. Hofmann, Z. Cao, W.-J. Cai, J. Gan, F. Lacroix, G. G. Laruelle, F. Meng, J. D. Müller, P. A. Regnier, G. Wang, and Z. Wang, 2022. Carbon fluxes in the coastal ocean: Synthesis, boundary processes and future trends. Annual Review of Earth and Planetary Sciences, 50, doi: org/10.1146/annurev-earth-032320-090746.

2) Title: High-frequency time-series autonomous observations of sea surface pCO_2 and pH *(Theme 1)*

With the aid of long-term high-frequency time-series observation, the changes detected in the coastal carbon cycle would be constrained more accurately; more importantly, it could provide opportunities to understand the impact of episodic events (e.g., typhoon) on seawater carbon chemistry and air-sea CO_2 exchange which are usually impossible to be captured by shipboard surveys. Using data from time-series observation by a moored buoy on the East China Sea shelf, this study investigated the seasonal dynamics of sea surface CO_2 partial pressure (pCO_2), pH, and air-sea CO_2 flux and their controlling mechanisms. The sea surface pCO_2 and its associated air-sea CO_2 fluxes had the largest temporal variations in summer and autumn due to the occurrences of frequent typhoon. The high wind stress and curl associated with the northward movement of typhoon induced complex sea surface water movement, vertical mixing, and subsequent biological drawdown, which differed in pre-, onset and post-typhoon stages. The lateral surface seawater movement was significant during pre- and post-typhoon periods when east and west wind prevailed, respectively, and vertical mixing was significant at the onset of typhoon. This study also suggest that typhoons could potentially dominate the seasonal CO_2 sink/source status although the period of typhoon perturbation was as short 4-5 days: the amount of CO_2 emitted to the atmosphere during typhoon was twice as much as the CO_2 uptake at the other time in summer.

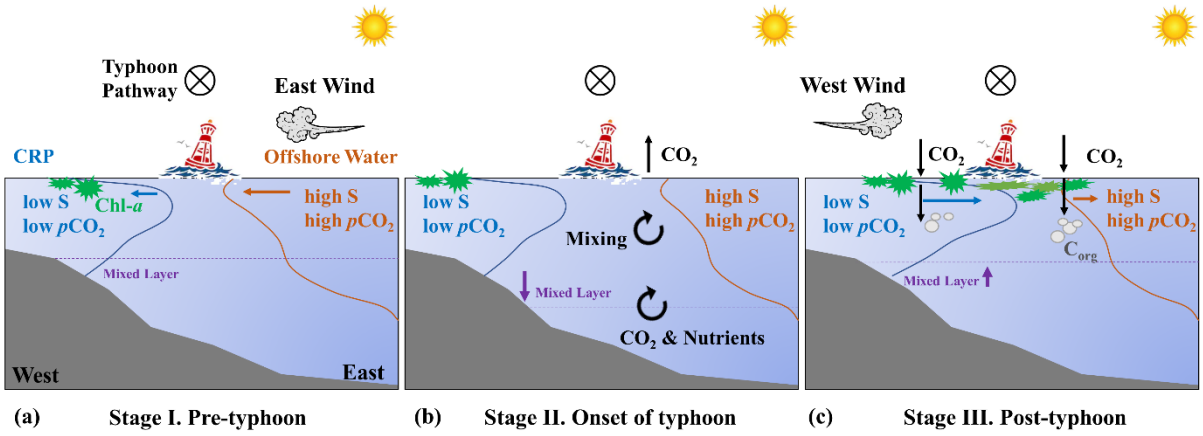

Figure: Dynamics of wind and surface ocean during three stages of typhoon at the buoy site. Circled cross denotes the direction (into the page) of typhoon pathway. Green shapes represent phytoplankton and Chl *a*, grey circles represent biological-sequestered organic carbon (C_{org}). Stage I: east wind prevails and drives the westward movement of offshore surface water; Stage II: strong wind promotes vertical mixing and hence CO_2 outgassing; Stage III: west wind prevails and drives the eastward movement of CRP, meanwhile, the reinvigoration of primary production drawdowns CO_2 from the atmosphere.

Citation: Wu, Y.X., M.H. Dai, X.H. Guo, J.S. Chen, Y. Xu, X. Dong, J.W. Dai and Z.R. Zhang, 2021, High-frequency time-series autonomous observations of sea surface pCO_2 and pH, Limnology and Oceanography, 66, 588-606. doi: 10.1002/lno.11625.

3) Title: Mapping gaseous dimethylamine, trimethylamine, ammonia, and their particulate counterparts in the marine atmosphere of China's marginal seas *(Theme 4, 5)*

To study sea-derived gaseous amines, ammonia, and primary particulate aminium ions in the marine atmosphere of China's marginal seas, an onboard URG-9000D Ambient Ion Monitor-Ion Chromatograph (AIM-IC, Thermo Fisher) was set up on the front deck of the R/V Dongfanghong-3 to semi-continuously measure the spatio-temporal variations in the concentrations of atmospheric trimethylamine (TMA_{gas}), dimethylamine (DMA_{gas}), and ammonia ($NH_{3,gas}$) along with their particulate matter ($PM_{2.5}$) counterparts. The data obtained from the cruise and coastal sites demonstrated that the

observed TMA_{gas} and protonated trimethy-lamine ($TMAH^+$) in $PM_{2.5}$ over the Yellow and Bohai Seas overwhelmingly originated from marine sources. The observed $TMAH^+$ in $PM_{2.5}$ was overwhelmingly derived from primary sea-spray aerosols. Using TMA_{gas} and $TMAH^+$ in $PM_{2.5}$ as tracers for sea-derived basic gases and sea-spray particulate aminium ions, the values of non-sea-derived DMA gas, NH_3 gas, and non-sea-spray particulate $DMAH^+$ in $PM_{2.5}$ were estimated. The estimated average values of each species contributed 16%, 34%, and 65% of the observed average concentrations for non-sea-derived DMA gas, NH_3 gas, and non-sea-spray particulate $DMAH^+$ in $PM_{2.5}$, respectively. Uncertainties remained in the estimations, as $TMAH^+$ may decompose into smaller molecules in seawater to varying extents. The non-sea-derived gases and non-sea-spray particulate $DMAH^+$ likely originated from long-range transport from the upwind continents based on the recorded offshore winds and increased concentrations of non-sea-salt SO_4^{2-} ($nss\text{-}SO_4^{2-}$) and NH_4^+ in $PM_{2.5}$. The lack of a detectable increase in particulate $DMAH^+$, NH_4^+, and $nss\text{-}SO_4^{2-}$ concentrations in several SO_2 plumes did not support the secondary formation of particulate $DMAH^+$ in the marine atmosphere.

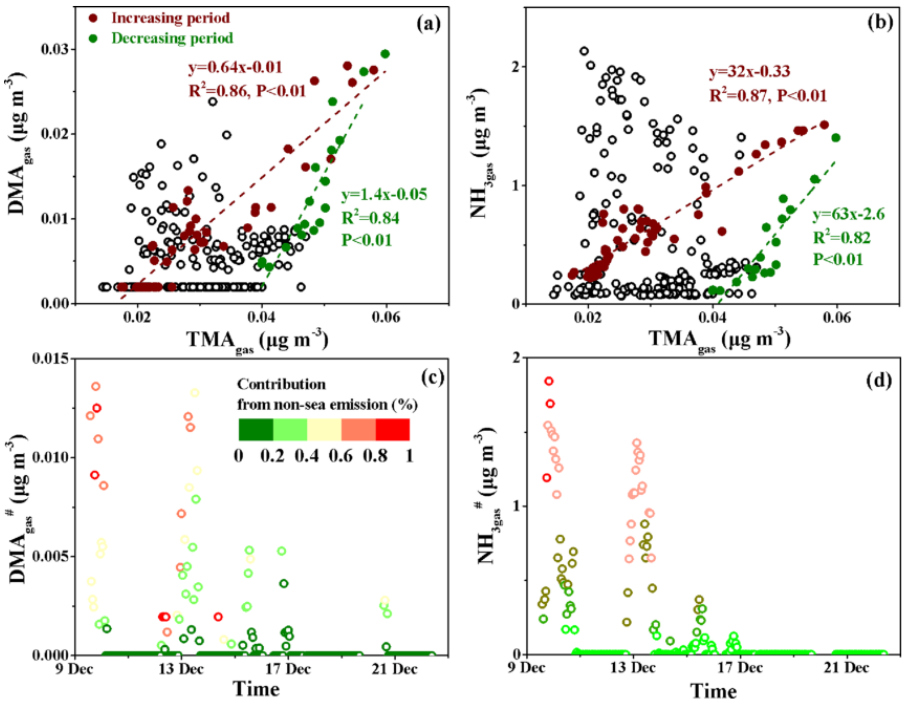

Figure: Correlations of DMA_{gas} and NH_{3gas} with TMA_{gas} and time series of the calculated $DMA_{gas}^{\#}$ and $NH_{3gas}^{\#}$. (a) DMA_{gas} vs. TMA_{gas}; (b) NH_{3gas} vs. TMA_{gas}; (c) $DMA_{gas}^{\#}$; (d) $NH_{3gas}^{\#}$. The color bars in panels (c) and (d) represent the percentages of transported $DMA_{gas}^{\#}$ and $NH_{3gas}^{\#}$ in each corresponding observed value.

Citation: Chen, D.H., Y.J. Shen, J.T. Wang, Y. Gao, H.W. Gao and X.H. Yao, 2021. Mapping gaseous dimethylamine, trimethylamine, ammonia, and their particulate counterparts in marine atmospheres of China's marginal seas–Part 1: Differentiating marine emission from continental transport. Atmospheric Chemistry and Physics, 21(21), 16413-16425, doi: 10.5194/acp-21-16413-2021.

4) **Title: Atmospheric deposition promotes relative abundances of high-DMSP producers in the western North Pacific** *(Theme 3, 4)*

Haptophytes and Dinoflagellates are two cosmopolitan algae associated with dimethylsulfoniopropionate (DMSP) synthesis, which regulates the marine biogenic flux of dimethyl sulfide (DMS) to the atmosphere with potential effects on global climate. Attempting to reveal the potential impact of atmospheric deposition on the growth of high-DMSP producers, four bioassay experiments were conducted in the western North Pacific (WNP) by adding aerosols, nutrients, and trace metals. Our results showed that the percentage of high-DMSP producers increased substantially from coastal seas (<1%) to the open ocean (~17%) with the dominance of Dinophyceae and Haptophyceae, respectively. Aerosol additions largely increased the percentage of high-DMSP producing species in the subtropical gyre of WNP. Specifically, atmospheric dissolved inorganic nitrogen, soluble Cu and Fe promoted Dinophyceae taxa, *Chrysochromulina*, and *Phaeocystis* and *E. huxleyi*, respectively. It is very likely that atmospheric deposition could lift the relative abundance of high-DMSP producers in the vast oligotrophic oceans and potentially contribute to the climate change.

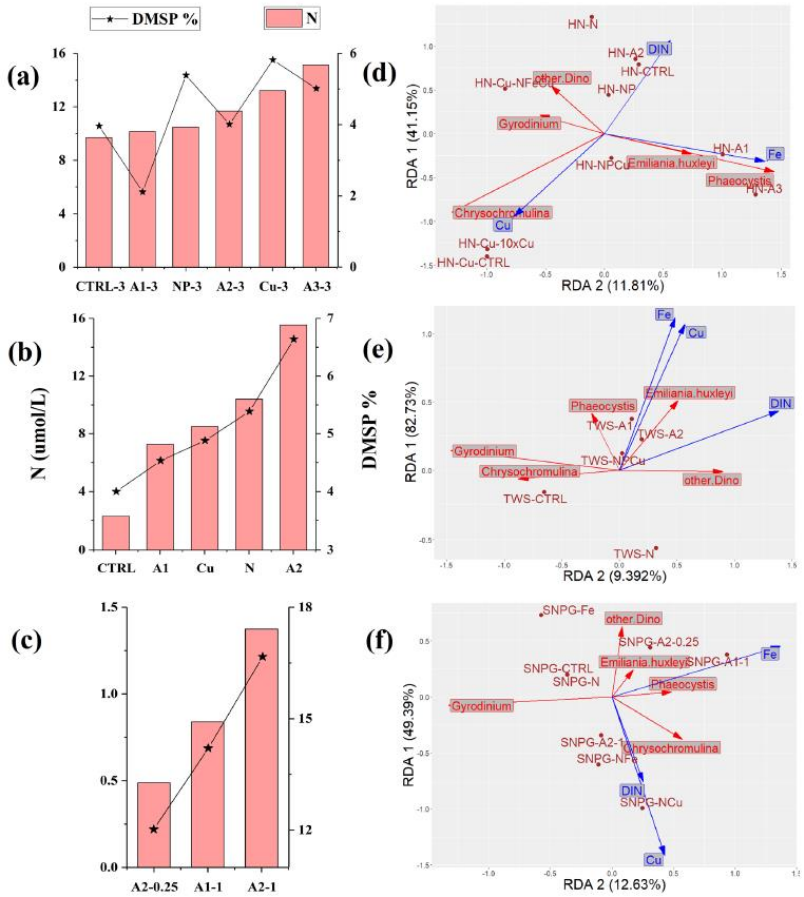

Figure: Increase of percentages of high-dimethylsulfoniopropionate (DMSP) producers with the increasing dissolved inorganic nitrogen concentrations in the late period (Day 3) of Huaniao Island (HN) (a), on the Chl-a peak days in Taiwan Strait (TWS) ; (b), and North Pacific Subtropical Gyre (NPSG) (c); RDA plots of high-DMSP producing species, nutrients/metals and treatments in HN (d), TWS (e) and NPSG (f). * as high-DMSP producing species struggled in the coastal HN, unlike relatively oligotrophic TWS and extreme sterile NPSG, we chose the late period of HN incubation to ensure their proportion. Three sites were illustrated separated because of their discrepant biomass and algae composition.

Citation: Li, H.W., S.Q. Zhou, Y.C. Zhu, R.F. Zhang, F.H. Wang, Y. Bao, and Y. Chen, 2021. Atmospheric Deposition Promotes Relative Abundances of High-Dimethylsulfoniopropionate Producers in the Western North Pacific. Geophysical Research Letters, 48 (15), e2020GL092077, doi: 10.1029/2020GL092077.

5) Title: Non-marine sources contribute to aerosol methanesulfonate over coastal seas *(Theme 4)*

Methanesulfonate (MSA) in the marine boundary layer is commonly considered to be solely contributed by the oxidation of ocean-derived dimethyl sulfide (DMS) and often used as an indicator of marine biogenic sources. But whether this judgment is valid in coastal seas and how the validity is affected by air mass transport history have been less discussed. Based on multi-year observations of aerosol MSA in the coastal East China Sea (ECS) and the Gulf of Aqaba (GA), as well as the analysis of air mass transport pattern and exposure to ocean surface phytoplankton biomass, we found that terrestrial sources made a non-negligible contribution to MSA over the ECS but not over the GA. The abundant MSA in winter over the coastal ECS was likely associated with substantial emissions of volatile organic sulfur compounds from both anthropogenic and natural sources in eastern China and significant terrestrial transport influenced by the East Asian Monsoon. Good correlations between aerosol MSA and air mass exposure to surface phytoplankton biomass were established by removing the influence of terrestrial transport and confining the air transport height within boundary layer, which makes it possible to construct parameterizations for obtaining the spatiotemporal distributions of marine biogenic aerosol components using satellite ocean color datasets.

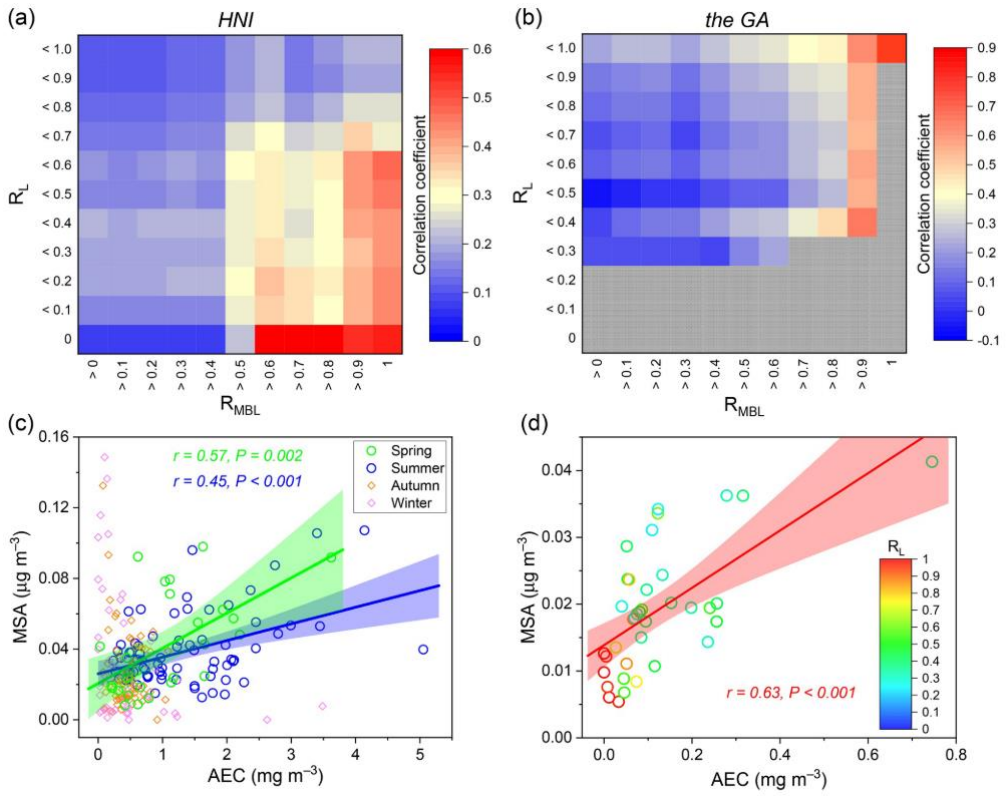

Figure: Correlation coefficient (Pearson's) matrix of MSA concentration and air mass exposure to Chl*a* (AEC) in different R_L and R_{MBL} ranges for (a) Huaniao Island (HN) and (b) the Gulf of Aqaba (GA). The gray grids represent that the valid data numbers are less than nine. The scatter plots show the relationships between MSA concentration and AEC when marine air masses were mainly under the boundary layer (R_{MBL} > 0.9) in different seasons for (c) HN and (d) the GA. The lines and shaded regions show the linear regressions and 95% confidence intervals.

Citation: Zhou, S.Q., Y. Chen, A. Paytan, H.W. Li, F.H. Wang, Y.C. Zhu, T.J. Yang, Y. Zhang, and R.F. Zhang, 2021. Non-Marine Sources Contribute to Aerosol Methanesulfonate Over Coastal Seas. Journal of Geophysical Research: Atmospheres, 126 (21), e2021JD034960, doi: 10.1029/2021jd034960.

2. Activities/main accomplishments in 2021 (e.g., projects; field campaigns; workshops and conferences; model and data intercomparisons; capacity building; international collaborations; contributions to int. assessments such as IPCC; collaborations with social sciences, humanities, medicine, economics and/or arts; interactions with policy makers, companies, and/or journalists and media).

- **Cruises and field experiments**

1) Time-Series

Time	Location	Parameters investigated	Theme
May 13-June 3, 2021	Huaniao Island (122.67°E, 30.86°N)	Aerosol chemical compositions, aerosol optical properties, trace gases, airborne microorganisms.	3-5

2) Cruises

Time	Location	Activities	Theme

Spring, 2021	East China Sea and Yellow Sea	The biogeochemical cycle and climate effects of DMS, CH_4 and N_2O were systematically studied.	1, 3
April, 2021	Bohai and Yellow Seas	Parameters investigated include chemical compositions of aerosols, POC and marine phytoplankton.	3-5
April 17-May 5, 2021	East China Sea and Yellow Sea	Parameters investigated include aerosol chemical compositions, airborne microorganisms, phytoplankton and marine bacteria species. The response of seawater bacteria to atmospheric deposition was studied by onboard mesocosm experiments.	3-5
May 13-Jun. 11, 2021	Western North Pacific	The distributions, air-sea fluxes and biogeochemical cycles of trace gases (i.e. CH_4, N_2O, DMS, Halogens), chemical compositions of aerosols, alkaline phosphatase activities and marine phytoplankton were studied.	1, 3-5

- **Selected Projects**

1) National Key Research and Development Program of China: Biogeochemical Processes and Climate Effect of Marine Biogenic Trace Gases in the East Marginal Seas of China (2016-2021), Leading PI: Guipeng Yang at Ocean University of China. (Theme 1)
2) National Key Research and Development Program of China: The Migration and Transformation of Marine Biogenic Active Gases in the Atmosphere and Their Climate Effects (2016-2021), Leading PI: Ying Chen at Fudan University. (Theme 3, 4)
3) National Key Research and Development Program of China: Vertical Observation of Aerosol Particles and their Characteristics at Single Particle Level within Marine Boundary Layer at Coastal Areas (2018-2021), Leading PI: Bingbing Wang at Xiamen University. (Theme 4)
4) National Nature Science Foundation of China (NSFC) General Project: Effects of Multiphase Reactions for Atmospheric Organic Acid on Deposition Ice Nucleation Efficiency of Particles (2018-2021), Leading PI: Bingbing Wang at Xiamen University. (Theme 3)
5) NSFC General Project: Variation of Abundance and Community Structure of Airborne Microorganisms and Affecting Mechanism over the East China Sea (2018-2022), Leading PI: Ying Chen at Fudan University. (Theme 3, 4)
6) NSFC Innovative Research Group: Nitrogen Cycle under Global Change (2018-2023), Leading PI: Shuh-Ji Kao at Xiamen University. (Theme 1)
7) NSFC General Project: Characteristics of Atmospheric Deposition Dominated by Haze Weather and Its Effect on Phytoplankton Growth in the Bohai and Yellow Sea (2019-2022), Leading PI: Huiwang Gao at Ocean University of China. (Theme 3)
8) NSFC Key Project: Source and Sink of Volatile Halogenated Organic Compounds in the East China Sea and the Yellow Sea and Their Influences on the Environment (2019-2023), PI: Guipeng Yang at Ocean University of China. (Theme 1)
9) NSFC Major Project: CARBON Fixation and Export in the Oligotrophic Ocean (Carbon-FE) (2019-2023), Leading PI: Minhan Dai at Xiamen University. (Theme 1, 3 & Environmental impacts of geoengineering). This is a SOLAS endorsed project.
10) NSFC Youth Project: Impact of Atmospheric Deposition on the Utilization of Dissolved Organic Phosphorus by Phytoplankton in the Yellow Sea (2020-2022), Leading PI: Chao Zhang at Ocean University of China. (Theme 3)
11) NSFC-Shandong Joint Fund Project: Impacts of Atmospheric Deposition on Water Quality and

Ecosystem in the Coastal Waters of Shandong Province (2020-2023), Leading PI: Huiwang Gao at Ocean University of China. (Theme 3)

12) NSFC General Project: Study on the Source, Distribution, Transformation and Removal of COS and CS2 in the Continental Shelf Seas of Eastern China (2020-2024), PI: Guipeng Yang at Ocean University of China. (Theme 1)

13) NSFC Key Project: Source and Flux of N_2O in the Euphotic Zone of the Northwestern Pacific (2021-2024), Leading PI: Shuh-Ji Kao at Xiamen University. (Theme 1)

14) NSFC General Project: Physicochemical Characterization and Depositional Ice Nucleation Efficiency of Atmospheric Particles over South China Sea (2021-2024), leading PI: Bingbing Wang at Xiamen University.

15) NSFC Special Project: Air-sea carbon fluxes, budget and uncertainties in China Seas (2022-2025), leading PI: Xianghhui Guo at Xiamen University.

- **Infrastructure**

National Observation and Research Station for the Taiwan Strait Marine Ecosystem (T-SMART) has been approved as a national station of the Ministry of Science and Technology of the People's Republic of China in 2021. Mission of T-SMART: Its primary goals are to clarify long-term changes in marine ecosystems and its driving mechanisms, integrated monitoring of the structure and function of coastal upwellings, subtropical bay and coastal wetland ecosystems in the Taiwan Strait and analyze the processes and responses of the ecosystems under the impact of global climate change and human activities; to provide important scientific and technological support to ensure the health of marine ecosystems and the environment, and promote sustainable economic development.

New deep-sea research vessel (Dong-Fang-Hong 3, delivered to Ocean University of China in 2019) with the capacity of SOLAS researches has carried out scientific expeditions in the western Pacific ocean in 2021.

- **International interactions and collaborations**

1) Conference presentations

Minhan Dai. Potential synergies between mitigation and adaptation for the ocean sink and how to evaluate opportunities and tradeoffs. 13th Meeting of the United Nations Framework Convention on Climate Change (UNFCCC) Subsidiary Body on Scientific and Technological Advice (SBSTA) Research Dialogue. June 1-2, 2021. Online (Invited talk)

Shengqian Zhou. The spatiotemporal distributions and future changes of global sea surface dimethyl sulfide. The 7th Youth Scientist Forum of Earth Science. July 10, 2021.Guiyang, China (Oral talk)

Minhan Dai. Coastal zones under intensifying human activities and changing climate: A regional programme integrating science, management and society to support ocean sustainability (Coastal-SOS). Life Science Across the Globe. September 1, 2021. Online (Invited talk)

Minhan Dai. Carbon fluxes in the coastal ocean: Synthesis, boundary processes and future trends. 3rd International Workshop on Surface-Earth System Science. September 27-28, 2021. Tianjin, China. Online (Plenary talk)

Minhan Dai. Carbon fluxes in the coastal ocean: Synthesis, boundary processes and future trends. 7th International Conference on Estuaries and Coasts. October 18-21, 2021. Shanghai, China. (Plenary talk)

Shijie Jia. The distribution and diversity of antibiotic resistance genes in aerosols between a coastal site and marine sites. PICES-2021 Annual meeting. October 25-29, 2021. (Recorded oral)

Qing Wang, The response of phytoplankton in the oligotrophic and eutrophic waters of the Yellow Sea to the addition of haze in spring. PICES-2021 Annual meeting. October 25-29, 2021. (Recorded oral)

Jiao Wang. The concentrations and depositions of atmospheric particles nutrient into the China adjacent seas. PICES-2021 Annual meeting. October 25-29, 2021. (Recorded oral)

Minhan Dai. Ocean-based Carbon Dioxide Remonal (CDR): Techniques, potentials and research needs. UN Climate Change Conference (COP 26) Side Event – Carbon conservation and sequestration in ocean: nature based solutions and other marine processes. November 6, 2021. Glasgow, Scotland. Online.

Shengqian Zhou. The contribution of non-marine sources to aerosol methanesulfonate over coastal seas. The 27th Conference on Atmospheric Environmental Science and Technology of China, Session 10 – Marine aerosol. November 17, 2021. (Live oral)

2) Conference & meetings organized

Initiated and organized by MEL since 2014, the serial international conference, the Xiamen Symposium on Marine Environmental Sciences (XMAS) celebrated its fifth iteration from January 11-14, 2021 online and offline. The theme of the conference was "How Multidisciplinary Sciences Can Serve a Sustainable and Healthy Ocean". In response to the UN Decade's call, XMAS set up a special forum, the "UN Decade of Ocean Science for Sustainable Development", discussing how to achieve the goals outlined under the UN Decade. Chief Engineer Zhanhai Zhang, Director of the Department of International Cooperation, Ministry of Natural Resources of China, IOC Executive Secretary Vladimir Ryabinin, and other experts held fruitful discussions in the forum. The experts shared related scientific projects to support the implementation of the UN Decade and discussed how stakeholders can effectively participate in and address the challenges they face. The forum was reported on by National Science Review, a top academic journal.

Huiwang Gao and Guiling Zhang along with other three scholars from different countries convened the topic session "Atmospheric Nutrient Deposition and Microbial Community Responses, and Predictions for the Future in the North Pacific Ocean" in PICES-2021 Annual Meeting.

3) Contribution to international initiatives

The Surface Ocean-Lower Atmosphere Study (SOLAS) International Project Office – China was officially launched in Xiamen. Minhan Dai was elected as Co-Chair of the SOLAS Scientific Steering Committee.

Minhan Dai is one of the major authors of the report *Integrated Ocean Carbon Research: A Summary of Ocean Carbon Research, and Vision of Coordinated Ocean Carbon Research and Observations for the Next Decade* which was published by the Intergovernmental Oceanographic Commission of UNESCO (UNESCO-IOC) in April 2021.

Minhan Dai is engaged in REgional Carbon Cycle Assessment and Processes-2 (RECCAP2) which is an activity of the Global Carbon Project with a number of partners. The objectives of RECCAP2 are: 1) to quantify anthropogenic greenhouse gas (GHG) emissions, 2) to develop robust observation-based estimates of changes in carbon storage and greenhouse gas emissions and sinks by the oceans and terrestrial ecosystems, distinguishing whenever possible anthropogenic vs. natural fluxes and their driving processes, 3) to gain science-based evidence of the response of marine and terrestrial regional GHG (CO_2, CH_4, N_2O) budgets to climate change and direct anthropogenic drivers. To address these objectives, RECCAP2 will design and perform a set of global syntheses and regional GHG budgets of all lands and oceans, and explore mechanisms by which to deliver regular updates of these regional assessments based on scientific evidence, considering uncertainties, understanding of drivers, and retrospective analysis of recent trends.

Minhan Dai as a member of the Expert Group of the High Level Panel for a Sustainable Ocean Economy (HLP) endorsed the Statement by the High Level Panel for a Sustainable Ocean Economy at COP26 (https://www.oceanpanel.org/news/hlp-cop-leaders-statement). The statement spoke to both the urgency of action as well as the opportunity that exists within the ocean economy to reduce emissions and improve resilience.

Xianghui Guo is a member of Session of Carbon and Climate (S-CC), North Pacific Marine Science Organization (PICES)

Minhan Dai is a member of GOOS Task Team ocean indicator framework which is an activity support the GOOS Expert Panels (lead: GOOS Physics and Climate Panel) to develop a global ocean monitoring indicator framework to serve as a standardized means of monitoring global ocean changes and trends, identifying knowledge gaps and observations needs, and facilitating communication on the state of the ocean.

Gui-Peng Yang is full member of International SCOR Sea Surface Microlayer Working Group.

4) International collaborations

Ocean University of China and University of East Anglia have established a sustained and stable relations of collaborations, covering the exchange of undergraduate and graduate students.

- **Research Front in Environmental Chemistry**

Ying Chen at Fudan University and Honghai Zhang at Ocean University of China organized a Research Front entitled 'Fluxes and Chemistry of Marine Biogenic Volatile Organic Compounds' in the scientific journal Environmental Chemistry.

- **Human dimensions (outreach, capacity building, public engagement etc.)**

The 10th XMU Ocean Science Day was held virtually in 2021, targeting different groups through several short films and courses, allowing the general public a glimpse of what life is like as an ocean scientist.

3. List SOLAS-related publications published in 2021 (only PUBLISHED articles). If any, please also list weblinks to models, datasets, products, etc.

Selected Publications

Chen, X.L., X. Ma, X.J. Gu, S.M. Liu, G.D. Song, H.Y. Jin, and G.L. Zhang, 2021. Seasonal and spatial variations of N_2O distribution and emission in the East China Sea and the South Yellow Sea. Science of the Total Environment, 775, 145715, doi: 10.1016/j.scitotenv.2021.145715.

Dai, M., J. Su, Y. Zhao, E. E. Hofmann, Z. Cao, W.-J. Cai, J. Gan, F. Lacroix, G. G. Laruelle, F. Meng, J. D. Müller, P. A. Regnier, G. Wang, and Z. Wang, 2022. Carbon fluxes in the coastal ocean: Synthesis, boundary processes and future trends. Annual Review of Earth and Planetary Sciences, 50, doi: org/10.1146/annurev-earth-032320-090746.

Gao, X.X, H.H. Zhang, S.H. Mao, and G.P. Yang, 2021. Responses of biogenic sulfur compound production to dust aerosol enrichment and seawater acidification in the Western Pacific Ocean. Geophysical Research Letters, 48, e2021GL095527.

Gao, X.X., H.H. Zhang, and G.P. Yang, 2021. Springtime spatial distributions of biogenic sulfur compounds in the Yangtze River Estuary and their responses to seawater acidification and dust. Journal of Geophysical Research – Biogeosciences, 126, e2020JG006142.

Gu, X.J., F. Cheng, X.L Chen, G.X. Du, and G.L. Zhang, 2021. Dissolved nitrous oxide and hydroxylamine in the South Yellow Sea and the East China Sea during early spring: Distribution, production and emission. Frontier Marine Science, 8, 725713, doi: 10.3389/fmars.2021.725713.

Han, Y., Z. He, and G.P. Yang, 2021. Distributions of volatile halocarbons and impacts of ocean acidification on their production in coastal waters of China. Science of the Total Environment, 752, 141756.

Li, C.X., K. Chen, X. Sun, B.D. Wang, G.P. Yang, Y. Li, and L. Liu, 2021. Occurrence, distribution, and sea-air fluxes of volatile halocarbons in the upper ocean off the northern Antarctic Peninsula in summer. Science of the Total Environment, 758, 143947.

Li, G.L., Y. Chen, G.P. Yang, and Z. He, 2021. Distributions of volatile halocarbons in the marine atmosphere and seawater of the northern South China Sea. Marine Chemistry, 229, 103912.

Li, H.W., S.Q. Zhou, Y.C. Zhu, R.F. Zhang, F.H. Wang, Y. Bao, and Y. Chen, 2021. Atmospheric Deposition Promotes Relative Abundances of High-Dimethylsulfoniopropionate Producers in the Western North Pacific. Geophysical Research Letters, 48 (15), e2020GL092077, doi: 10.1029/2020GL092077.

Li, H.W., Y. Chen, S.Q. Zhou, F.H. Wang, T.J. Yang, Y.C. Zhu, and Q.W. Ma, 2021. Change of dominant phytoplankton groups in the eutrophic coastal sea due to atmospheric deposition. Science of the Total Environment, 753, 141961.

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Links to models and datasets

1. An artificial neural network (ANN) model for sea surface DMS simulation: https://github.com/SQZhou95/Sea_surface_DMS_simulation_using_neural_network.
2. Global sea surface DMS concentration and flux gridded datasets (1850 to 2100) simulated by ANN model: https://doi.org/10.5281/zenodo.5062438.

4. Did you engage any stakeholders/societal partners/external research users in order to co-produce knowledge in 2021? If yes, who? How did you engage?

Led by Xiamen University, the joint initiative of “Coastal Zones Under Intensifying Human Activities and Changing Climate: A Regional Programme Integrating Science, Management and Society to Support Ocean Sustainability” (COASTAL-SOS) has been endorsed by the UN Decade as a decade project in Oct., 2021. The official COASTAL-SOS launch session was held on 26 Nov, 2021, during the UN Ocean Decade Kickoff Conference for the Western Pacific and its Adjacent Seas. The International Project Office was officially launched in Xiamen.

COASTAL-SOS partners cross-sectorial stakeholders, including leading academic institutions, industrial enterprises, foundations, and nongovernmental /intergovernmental organizations (NGO/IGOs) non-profit and non-governmental organizations from Eastern Asian countries, to enable the advancement of scientific understanding of critical coastal ocean health issues. The aim is to transform this scientific knowledge to provide solutions, including improved and integrated management strategies, and to empower industry towards adopting best practices in ocean usage.

PART 2 - Planned activities for 2022 and 2023

1. Planned major national and international field studies and collaborative laboratory and modelling studies (incl. all information possible, dates, locations, teams, work, etc.).

- Cruises for the investigation of seasonal variations of DMS, CO, volatile halocarbons, and non-methane hydrocarbons are planned in the Yangtze River Estuary.
- There will be a cruise in May to the Northwest Pacific, which aims to examine carbon fixation and export, or the biological pump in general, regulated by differently sourced nutrients including macronutrients (i.e., N, P, Si) and micronutrients (e.g., Fe).
- There will be a regular spring cruise to the Northwest Pacific conducted by R/V Dongfanghong-3 in the next few years, which is closely related to themes 3-5 of SOLAS.
- NSFC Shiptime Sharing Project including four seasons will be carried out in China coastal seas, which covers five themes of SOLAS.

2. Events like conferences, workshops, meetings, summer schools, capacity building etc. (incl. all information possible).

- The 6th Xiamen Symposium on Marine Environmental Sciences (XMAS-VI) will be held in Xiamen from January 9 to 12, 2023. XMAS-VI will focus on Multidisciplinary and Solution Sciences for a Sustainable and Healthy Ocean.

3. Funded national and international projects/activities underway.

- NSFC Innovative Research Group: Nitrogen Cycle under Global Change (2018-2023), Leading PI: Shuh-Ji Kao at Xiamen University. (Theme 1)
- NSFC General Project: Characteristics of Atmospheric Deposition Dominated by Haze Weather and Its Effect on Phytoplankton Growth in the Bohai and Yellow Sea (2019-2022), Leading PI: Huiwang Gao at Ocean University of China. (Theme 3)
- NSFC Key Project: Source and Sink of Volatile Halogenated Organic Compounds in the East China Sea and the Yellow Sea and Their Influences on the Environment (2019-2023), PI: Guipeng Yang at Ocean University of China. (Theme 1)
- NSFC Major Project: CARBON Fixation and Export in the Oligotrophic Ocean (Carbon-FE) (2019-2023), Leading PI: Minhan Dai at Xiamen University. (Theme 1 & 3 & Environmental impacts of geoengineering). This is a SOLAS endorsed project.
- NSFC Youth Project: Impact of Atmospheric Deposition on the Utilization of Dissolved Organic Phosphorus by Phytoplankton in the Yellow Sea (2020-2022), Leading PI: Chao Zhang at Ocean University of China. (Theme 3)
- NSFC-Shandong Joint Fund Project: Impacts of Atmospheric Deposition on Water Quality and Ecosystem in the Coastal Waters of Shandong Province (2020-2023), Leading PI: Huiwang Gao at Ocean University of China. (Theme 3)
- NSFC General Project: Influences of Hydrodynamics on the Spatial Distribution and Long-term Variations of Persistent Halogenated Hydrocarbons in the Bohai, Yellow, and East China Seas (2020-2023), Leading PI: Xinyu Guo at Ocean University of China. (Theme 1)
- NSFC General Project: Study on the Source, Distribution, Transformation and Removal of COS and CS2 in the Continental Shelf Seas of Eastern China (2020-2024), Leading PI: Guipeng Yang at Ocean University of China. (Theme 1)
- NSFC Key Project: Source and Flux of N_2O in the Euphotic Zone of the Northwestern Pacific (2021-2024), Leading PI: Shuh-Ji Kao at Xiamen University. (Theme 1)
- NSFC General Project: Physicochemical Characterization and Depositional Ice Nucleation Efficiency of Atmospheric Particles over South China Sea (2021-2024), Leading PI: Bingbing Wang at Xiamen University.
- NSFC General Project: Temporal and spatial variations and regulating mechanism of distribution and air-sea fluxes of dissolved methane in the western North Pacific" (2022-2025), Leading PI: Guiling Zhang at Ocean University of China. (Theme 1)
- NSFC Basic Science Center Program: Research center for marine carbon sequestration and

biogeochemical processes (2022-2027), Leading PI: Nianzhi Jiao at Xiamen University. The center will focus on the international frontier of marine carbon sequestration processes and their control mechanisms. The center is also a platform for collaborations with intellects both domestic and abroad, creating a plateau of scientific innovation and development. (Theme 1 & 3)

4. Plans / ideas for future national or international projects, programmes, proposals, etc. (please indicate the funding agencies and potential submission dates).

The proposal of integrated research on sustainability of the coastal ocean is to be submitted to NSFC for Major Project in September and Ocober. 2022. The prospective proposal aims to address how land-sea-ocean-atmosphere/ecosystem-resource-environment-social economic system is coupled in the coastal ocean under dual stresses of climate change and human activities.

5. Engagements with other international projects, organisations, programmes, etc.

- Minhan Dai is engaged in REgional Carbon Cycle Assessment and Processes-2 (RECCAP2) which is an activity of the Global Carbon Project with a number of partners. The objectives of RECCAP2 are: 1) to quantify anthropogenic greenhouse gas emissions, 2) to develop robust observation-based estimates of changes in carbon storage and greenhouse gas emissions and sinks by the oceans and terrestrial ecosystems, distinguishing whenever possible anthropogenic vs. natural fluxes and their driving processes, 3) to gain science-based evidence of the response of marine and terrestrial regional GHG (CO_2, CH_4, N_2O) budgets to climate change and direct anthropogenic drivers. To address these objectives, RECCAP2 will design and perform a set of global syntheses and regional GHG budgets of all lands and oceans, and explore mechanisms by which to deliver regular updates of these regional assessments based on scientific evidence, considering uncertainties, understanding of drivers, and retrospective analysis of recent trends.
- Xianghui Guo is a member of Session of Carbon and Climate (S-CC), North Pacific Marine Science Organization (PICES)
- Minhan Dai is a member of GOOS Task Team ocean indicator framework which is an activity support the GOOS Expert Panels (lead: GOOS Physics and Climate Panel) to develop a global ocean monitoring indicator framework to serve as a standardized means of monitoring global ocean changes and trends, identifying knowledge gaps and observations needs, and facilitating communication on the state of the ocean.
- Minhan Dai is the co-chair of Organizing Committee of OceanObs'29 which will be organized in Qindao, China. The OceanObs conferences are held once every 10 years for the scientific, technical, and operational communities involved in the planning, implementation, and use of ocean observing systems.
- Huiwang Gao is the chair of Sino British Joint Research Center, which aims to develop the collaboration between Ocean University of China and University of East Anglia.
- Gui-Peng Yang is full member of International SCOR Sea Surface Microlayer Working Group.

Comments