RGC Ref.: N_HKUST627/13 NSFC Ref. : 41361164001
(please insert ref. above)

The Research Grants Council of Hong Kong
NSFC/RGC Joint Research Scheme
Joint Completion Report

(Please attach a copy of the completion report submitted to the NSFC by the Mainland researcher)

Part A: The Project and Investigator(s)

1. Project Title

Response of air-sea CO2 fluxes in the northern South China Sea to the carbon and nutrient export associated with the Pearl River plume (PRP). 南海北部海-氣二氧化碳通量對珠江沖淡水輸出的碳和營養鹽的響應

2. Investigator(s) and Academic Department/Units Involved

	Hong Kong Team	Mainland Team
Name of Principal Investigator *(with title)*	Prof. Jianping Gan	Prof. Minhan Dai
Post	Chair Professor	Chair Professor
Unit / Department / Institution	Department of Mathematics & Division of Environment, Hong Kong University of Science and Technology	State Key Laboratory of Marine Environmental Science (Xiamen University)
Contact Information	magan@ust.hk (852)2358-7421	mdai@xmu.edu.cn (592)2182132
Co-investigator(s) *(with title and institution)*		

3. Project Duration

	Original	Revised	Date of RGC/ Institution Approval *(must be quoted)*
Project Start date	01/01/2014		
Project Completion date	31/12/2017		
Duration *(in month)*	48		
Deadline for Submission of Completion Report	31/12/2018		

Part B: The Completion Report

5. Project Objectives

5.1 Objectives as per original application

1. Study the inherent hydrodynamic and biogeochemical processes and their coupled effects that control the carbon and nutrient export associated with the Pearl River plume.
2. Quantify the response of air-sea CO_2 fluxes in the northern South China Sea shelf to the carbon and nutrient export from the Pearl River Plume based on both field observation and three-dimensional coupled physical-biogeochemical numerical modelling.

5.2 Revised Objectives

Date of approval from the RGC: _____

Reasons for the change: _____

_____

1.
2.
3. ....

6. Research Outcome

Major findings and research outcome
(maximum 1 page; please make reference to Part C where necessary)

By adopting advanced research approach of observational-modeling study, we conducted comprehensive, and novel interdisciplinary study on the response of air-sea CO2 fluxes in the northern South China Sea (NSCS) to the carbon and nutrient export associated with the Pearl River plume (PRP). The major findings are underlined.

We started with background investigation of ocean physical transport in the broad continental shelve in the northern South China Sea, where PRP located. We identified the unique hydrodynamics associated with local flow-topography interaction maintains the persistent upwelling circulation over the NSCS shelf. This enriches the upwelling coastal circulation dynamics and provides new understanding for the PRP motion off the Pearl River Estuary (PRE) (**Gan et al., 2014, *Deep Sea Res.*** in Part C). Relevant physical forcing on the shelf circulation and transport by topography was investigated (**Liu and Gan, 2015, *J. Geophys. Res.*** in Part C).

The ocean circulation in the PRE over the broad NSCS has its own dynamics characteristics. We found that the mean (sub-tidal) circulations in the PRE and over the adjacent shelf are interactive, and multi-forcing of winds, tides, and the buoyancy of river discharge drive them based on both field data and numerical ocean modeling. In this study, we advanced the numerical model scheme by developing a new open boundary condition (OBC) for limited-area simulation that overcome dynamic inconsistencies in the tidally and subtidally forced PRE ocean circulation. This OBC better resolves the condition of PRP (**Liu and Gan, *J. Geophys. Res.*, 2017** in Part C). The circulation of the PRE regulated the critical upstream condition for PRP and thus has a strong impact on its biogeochemical response (**Zu and Gan, 2014, *Deep Sea Res.*** in Part C).

This result was further expanded to investigate the coupled physical-biological effect on biological blooms. We find that joint controls by freshwater residence time, water column stability, and light limitation associated with river discharge, vertical mixing, and turbidity determines the spatiotemporal variability of biological bloom in PRE (**Lu and Gan, 2014, *Deep Sea Res.*** in Part C).

The effect of phosphorus limitation is unique characteristic in PRP ecosystem. We developed a new nitrogen, phosphorus, phytoplankton, zooplankton, and detritus (NPPZD) ecosystem model to investigate the effect of P-limitation in the PRP, in which a noticeably reduction of the total phytoplankton production and shorter downstream excursion of phytoplankton bloom in PRP were found due to P-limitation (**Gan et al., 2014, J. *Geophys. Res.*** in Part C).

By conducting collaborative research with the mainland group, we conducted intensive field and modeling study on the dynamics of *p*CO2 and the associated biogeochemical processes.

Similar to physical part, we conducted the biogeochemical study over the NSCS where PRP locates. We investigated distribution and seasonality of dissolved organic carbon (DOC) based on a large data set collected from the northern South China Sea (NSCS) shelf under complex circulation schemes influenced by river plume, coastal upwelling, and downwelling. We demonstrated that the NSCS shelf had various origins of DOC including riverine inputs, inter-shelf transport and in situ production. The accumulated DOC would be exported to and stored in the deep ocean, suggesting that continental shelves are a potentially effective carbon sink (**Meng, et al., 2017, *J. Geophys. Res.*** in Part C). We then investigated the relative contributions of different sources of organic matter in PRE. We estimated that ~65% of the oxygen-consuming organic matter was derived from marine sources, and the rest ~35was derived from the continent (**Su et al., *Biogeosciences*** in Part C).

We modelled carbonate system based on the relationships between salinity and total alkalinity (TA) as well as the dissolved inorganic carbon (DIC). The overall biological effect on partial pressure of carbon dioxide (*p* O 2) pl m e w e w s e o of <15% (o 60 µ m). We proposed that the river input nutrients and the mismatch of the timescale between plume current and buffer effect of the carbonate system are the fundamental for the RiOMar system being as atmospheric CO2 sink (**Zhao at l., *to be submitted*** in Part C).

Potential for further development of the research and the proposed course of action *(maximum half a page)*

In 2016, we conducted a cruise over entire northeast South China Sea (NSCS) by joint effort from South China Sea Institute of oceanography, Xiamen University and HKUST. This data (see example in Figure 10) is under processing and analyzing. This is the potential further development and expansion of the research that can be built upon the findings from this NSFC-RGC project.

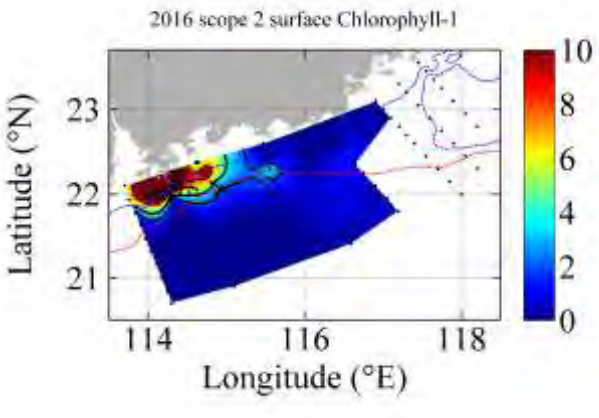

Figure 10. Surface chlorophyll-a (mg/m^3) in NSCS during the cruise in 2016 summer. The dot points are the sampling stations.

7. The Layman's Summary

(describe in layman's language the nature, significance and value of the research project, in no more than 200 words)

The air-sea CO2 fluxes have a significant impact on global carbon budget, since the ocean ove s ~71% of he e h's s f e , and has an averaged depth of 4000 m. Ocean has huge capacity for depositing the CO2 in atmosphere. Although the coastal ocean occupies only a very small po o of e h's o e , el s ~40 % olog l p o v , s es l of e input from terrestrial source. Therefore, the coastal ocean, particularly in the waters linked with larger river such as the Pearl River, can serve as a carbon sink for atmosphere.

The air-sea CO2 fluxes are controlled by nutrient dynamics of chemical oceanography, biological productivity associated food web dynamics through photosynthesis and utilization of the nutrients of biological oceanography and physical forcing to disperse, transport and mix the biogeochemical substances of physical oceanography. We conducted advanced coupled physical-biogeochemical study, based on both *in situ* measurements and cutting-edge technology of numerical ocean modeling. We collected valuable physical and biogeochemical data, and developed a novel numerical simulation to fill the spatiotemporal gaps of field measurements, in order to conduct holistic investigation of the concerned scientific questions in the project. Our results revealed that the sink of CO2 varied along the Pearl River Plume (PRP) in the near-, mid- and far-field as a results of coupled biophysical processes under the controls of winds, tides, freshwater, and fluxes of biogeochemical substances.

Part C: Research Output

8. Peer-reviewed journal publication(s) arising directly from this research project

(Please attach a copy of each publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				Author(s) ***(bold** the authors belonging to the project teams and denote the corresponding author with an asterisk*)*	Title and Journal/ Book *(with the volume, pages and other necessary publishing details specified)*	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of this Joint Research Scheme *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*
Year of publication	Year of Acceptance *(For paper accepted but not yet published)*	Under Review	Under Preparation *(optional)*						
2018			x	Huade Zhao, **M. Dai***, **J. Gan**, L. Liang and X. Zhao	River-dominated *p*CO2 dynamics in the 1 northern South China Sea: modeling study	Dec. 31, 2018	Yes	Yes	

2017				Z. Liu and **J. Gan***	Open boundary conditions for tidally and subtidally forced circulation in a limited-area coastal model using the Regional Ocean Modeling System (ROMS), *J. Geophys. Res (Oceans),* 121 (8), 6184-6203, doi:10.1002/2016JC011975.	Dec 31, 2018	Yes	Yes	Yes
2017				Su J.Z., **M.H. Dai*,** B.Y. He, L. Wang, **J.P. Gan**, X.H. Guo, H.D. Zhao, and F. Yu	Tracing the origin of the oxygen-consuming organic matter in the hypoxic zone in a large eutrophic estuary: the lower reach of the Pearl River Estuary, China, *Biogeosciences,* 14, 4085-4099	Dec. 31, 2018	Yes	Yes	Yes
2017				Meng F.F., **M.H. Dai*,** Z.M. Cao, K. Wu, X.Z. Zhao, X.L. Li, J.H. Chen and **J. Gan**	Seasonal dynamics of dissolved organic carbon under complex circulation schemes on a large continental shelf: the northern South China Sea. *J, Geophys. Res.* 122, 9415–9428. https://doi.org/10.1002/2017JC013325	Dec. 31, 2018	Yes	Yes	Yes

2015				Z. Liu and **J. Gan***	Upwelling induced by the frictional stress curl and vertical squeezing of the vortex tube over a submerged valley in the East China Sea. *J. Geophys. Res.* (*Oceans)*, 120 (4), 2571-2587, doi:10.1002/2015JC010715.	Dec 31, 2018	Yes	Yes	Yes
2014				**J. Gan***, Z. Lu, Anson Cheung, **M. Dai**, L. Liang, P. J. Harrison, and X. Zhao	Assessing ecosystem response to phosphorus and nitrogen limitation in the Pearl River plume using the Regional Ocean Modeling System (ROMS), *J. Geophys. Res.,* 119, doi: 10.1002/2014JC009951	Dec 31, 2015	No	Yes	Yes
2014				Z. Lu and **J. Gan***	Controls of seasonal variability of phytoplankton blooms in the Pearl River Estuary Deep-Sea Res. II (2014), http://dx.doi.org/10.1016/j.dsr2.2013.12.011	Dec 31, 2015	No	Yes	Yes

2014				T. Zu and **J. Gan***	A numerical study of coupled estuary-shelf circulation around the Pearl River Estuary during summer: Responses to variable winds, tides and river discharge. *Deep-Sea Res. II*.doi:10.1016/j.dsr2.2013.12.010	Dec 31, 2015	No	Yes	Yes
2014				**J. Gan***, J. Wang, L. Liang, L. Li and X. Guo	A Modeling study of the formation, maintenance, and relaxation of upwelling circulation on the northeastern South China Sea Shelf. Deep-Sea Res. II (2014), doi:10.1016/j.dsr2.2013.12.009.	Dec. 31, 2015	No	Yes	Yes

9. Recognized international conference(s) in which paper(s) related to this research project was/were delivered *(Please attach a copy of each delivered paper. All listed papers must acknowledge RGC's funding support by quoting the specific grant reference.)*

Month/Year/ Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of this Joint Research Scheme *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*
01/2014/ Puerto Rico	Circulation, biogeochemical and pCO2 trends in the Chian Sea from a scientifically-based numerical simulation	COSS-TT International Coordination Workshop	Dec. 31, 2015	No	Yes	Yes

07/2014/Sapporo	Circulation, biogeochemical and pCO2 trends in the China Seas from the China Sea Multi-Scale Ocean Modeling System (CMOMS)	11th Asia Oceania Geosciences Society (AOGS) Annual Meeting	Dec. 31, 2015	No	Yes	Yes
01/2015/Xiamen	Contrasting dynamics of cross-isobath transport over steep and concave shelves	Symposium on Marine Environmental Sciences	Dec. 31, 2015	No	Yes	Yes
07/2015/Singapore	A novel dynamic interpretation for cross-shelf transport	13th Asia Oceania Geosciences Society (AOGS) Annual Meeting	Dec. 31, 2015	No	Yes	Yes
09/2016/Guanzhou	Circulation and ecosystem responses to phosphorus/nitrogen limitation in the Pearl River plume	International Workshop on Turbulent Mixing and Sediment Transport in the Ocean	Dec 31, 2018	Yes	Yes	Yes

10. Student(s) trained *(Please attach a copy of the title page of the thesis.)*

Name	Degree registered for	Date of registration	Date of thesis submission/ graduation
Zhongya CAI	PhD	2013	2018
Serena McDonnell	MPhil	2015	2017
Ran Sun	MPhil	2013	2015
Chenmin Yu	MPhil	2015	2017
Haoshuo Liu	MPhil	2015	2017

11. Other impact *(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, etc.)*