GEOTRACES-CHINA GPpr15-winter Process Study
Cruise Report

R/V Tan Kah Kee (KK2007)

December 23, 2020 - February 07, 2021

Chief Scientists: Zhimian Cao[1], Kuanbo Zhou[1], and Ruifeng Zhang[2]

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1. Summary

The GEOTRACES GPpr15-winter/KK2007 Cruise was conducted on board R/V TAN KAN KEE from December 23th, 2020 to February 7th, 2021 in the western North Pacific. The cruise was organized by the State Key Laboratory of Marine Environmental Science of Xiamen University (MEL) and scientists from Xiamen University, Ocean University of China (OUC) and Shanghai Jiaotong University (SJTU) joined. It was supported by a "Ocean Desert" Major Project sponsored by the National Natural Science Foundation of China (No. 41890800; PI: Minhan Dai).

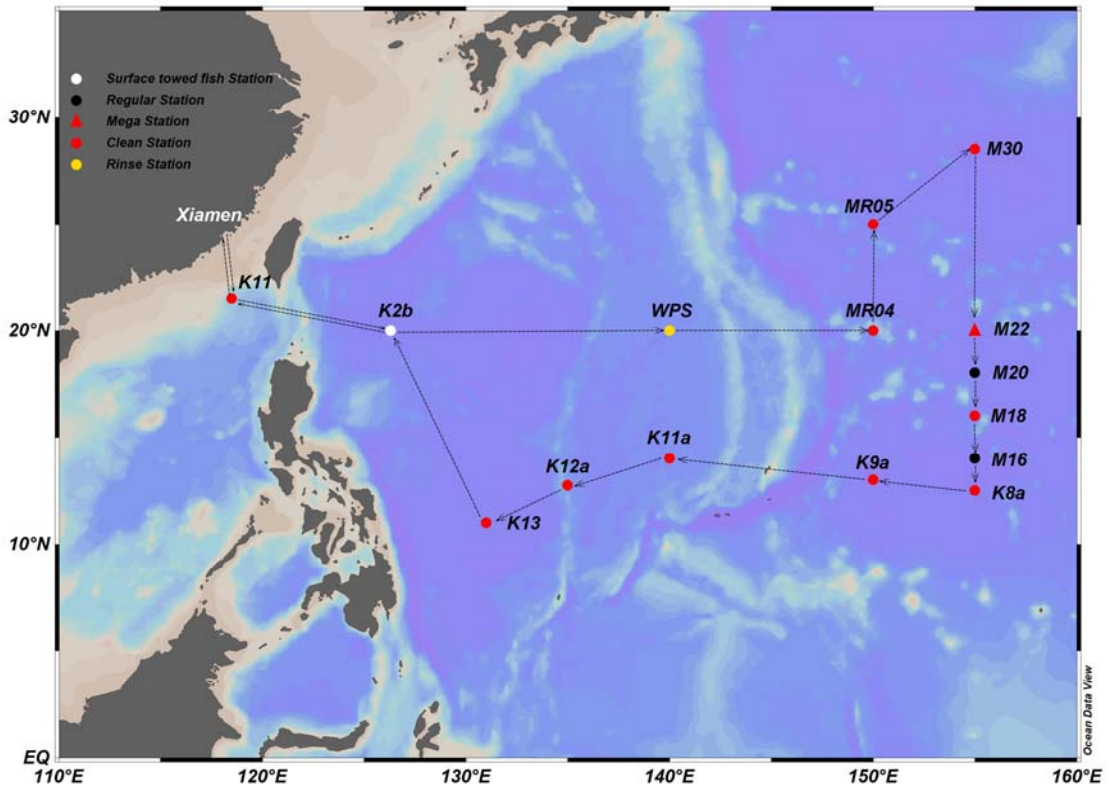

Figure 1. GPpr15-winter/KK2007 cruise map

The oligotrophic ocean occupies about 30% of the ocean surface and has been conventionally regarded as ocean deserts. It is characterized by nutrient depletion in the surface waters and extremely low net biological production and hence, per unit area, contributes little to carbon export from surface to deep waters. Emerging evidence, most notably based on ocean time-series studies such as the HOTS program, has shown a wider than previously assumed dynamic range of nutrient inputs and biological responses in this oceanic system. The "Ocean Desert" project selects the North Pacific Subtropical Gyre (NPSG), one of the world's largest oligotrophic regimes, as the study site 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).

In 2019, the first GEOTRACES-CHINA cruise (GP09/KK1903) was conducted from April 25 to June 13 in the western North Pacific (wNP). In 2020, the GEOTRACES-GPpr15-summer cruise

(KK2003) was conducted from July 3 to August 20 in the wNP. The GEOTRACES-GPpr15-winter cruise (KK2007) was further designed to explore the biogeochemistry of trace elements and isotopes (TEIs) in the wNP, covering a study area between 10-30°N and 118.5-155°E with 13 sampling stations including 1 Mega Stations, 10 Clean Stations, and 2 Normal Stations.

During the 47 days cruise, seawater samples were collected with a regular CTD and a trace metal clean CTD, respectively, and underway near-surface seawater samples were collected from a towed fish sampling system for TEIs, nutrients, pigments, and on-deck incubations. Particle samples for trace metal concentration measurements were also collected using McLane In-Situ Pumps with a SBE37IM CTD attached to each pump. Seawater, particles, and aerosol samples were collected in this cruise for the determination of TEIs. GEOTRACES key trace elements and isotopes, as well as some other elements and isotopes, e.g., REEs, ^{234}Th, ^{210}Pb-^{210}Po, and silicon and barium isotopes, will be analyzed after the cruise in shore-based laboratories.

Regular CTD casts at 13 stations were deployed to collecting others physical (salinity, currents, turbulence, etc), chemical (DO, DIC, POC, macro-nutrients, etc), and biological (chlorophyll *a*, pigments, flow cytometry and molecular samples, etc) parameters. Turbulence dissipation rate, hydrological parameters (T, S, Turbidity, etc), and meteorological parameters were measured at stations and/or underway. Nutrient profiles, including nanomolar level phosphate and nitrate in the surface water were analyzed aboard. A series of on-deck incubation experiments were also conducted with emphases on the interactions between ecosystem functions and macro- and micro-nutrient supply. These incubation experiments were conducted for phytoplankton primary production, nitrogen fixation, bacterial production and respiration, zooplankton grazing rates, etc.

We sincerely acknowledge Captain Long Yin, the crew, and the marine technical support team of the R/V Tan Kah Kee for their invaluable and successful support of all shipboard operations. Sincere thanks are also given to the Office for Research Vessel Operation Center of Xiamen University for its flawless logistic support to the cruise. We specially thank Liping Zhou (Peking University) and the whole international GEOTRACES community for their continual scientific advices and technical instructions to make the cruise possible.

2. Basic Information

Table1. KK2007/GPpr15-winter Cruise Data Inventory

Parameters	In-charge Person	PI Name	Submission Date
Trace metals			
FIA Fe	Yongming Huang	Yihua Cai	2022-12
Fe (ICP-MS)	Nan Zhang	Yihua Cai	2022-12
Cu, Zn, Cd, Ni, Pb, Co	Junbo Yang	Yihua Cai	2022-12
Dissolved and particle ^{210}Po	Jiaxu Li	Yihua Ca	2023-01
Dissolved and particle ^{210}Pb	Jiaxu Li	Yihua Ca	2023-01
Nd	Wanyang He	Jin Zhang	2022-12
Fe isotope	Ruifeng Zhang	Ruifeng Zhang	2022-12
Particle trace metal	Kan Zhang	Minhan Dai	2022-12
Total Hg/CH_4-Hg	Wanyang He	Jin Zhang	2022-12
REEs	Wanyang He	Jin Zhang	2022-12
Al	Jing Chen	Jinling Ren	2022-12
DIC-^{13}C	Liguo Guo	Minhan Dai	2022-08
BSi/PBa Trap&pump	Xinyuan Zhang	Zhimian Cao	2022-12
DSi/DBa	Xinyuan Zhang	Zhimian Cao	2022-12
BSi/PBa	Xinyuan Zhang	Zhimian Cao	2022-12
Total ^{234}Th	Kuanbo Zhang	Minhan Dai	2022-12
Particle ^{234}Th, POC	Kuanbo Zhang	Minhan Dai	2022-12
Trap POC/PN	Kuanbo Zhang	Minhan Dai	2022-12
Hydrography			
CTD	Fangtao Zhang	Zhiyu Liu	Submitted
ADCP	Fangtao Zhang	Zhiyu Liu	Submitted
MVP	Fangtao Zhang	Zhiyu Liu	Submitted
Underway T and S, AWS	Fangtao Zhang	Zhiyu Liu	Submitted
Underway Chl *a*	Ruotong Jiang	Dalin Shi	2021-12
Optics			
Phytoplankton pigment absorption coefficient(a_{ph})	Yongchao Wang	Shaoling Shang	2022-02
Absorption coefficient of colored dissolved organic matter(a_g)	Yongchao Wang	Shaoling Shang	2022-02
Remote sensing reflectance (R_{rs})	Yongchao Wang	Shaoling Shang	2022-02

Parameters	In-charge Person	PI Name	Submission Date
PAR and R_{rs}	Yongchao Wang	Shaoling Shang	2022-02
Inherent optical profile	Yongchao Wang	Shaoling Shang	2022-02
Aerosol thickness (AOT)	Yongchao Wang	Shaoling Shang	2022-02
Biogeochemistry			
Macronutrients and low lever nutrients	Zhongwei Yuan Tao Huang	Minhan Dai	2021-06
DO, DIC, TA, pH	Liguo Guo	Minhan Dai	2022-08
DOC	Lusong Zhang	Minhan Dai	2022-12
DON，DOP	Lusong Zhang	Xiaolin Li	2022-12
N_2O	Xianhui Wan	Shuji Gao	2022-09
Chlorophyll *a*	Feipeng Xu	Xin Liu	2021-12
Phytoplankton pigment	Feipeng Xu	Xin Liu	2021-12
Primary production	Hao Hu	Xin Liu	2021-12
Chl *a*（discrete samples）	Ze Chen	Dalin Shi	2022-08
FCM	Ruotong Jiang	Dalin Shi	2022-06
FCM (Macro omics)	Ruotong Jiang	Dalin Shi	2022-06
DNA/RNA	Ruotong Jiang	Dalin Shi	2023-12
Community Structure	Ruotong Jiang	Dalin Shi	2023-12
Functional gene analysis	Ruotong Jiang	Dalin Shi	2023-12
Zooplankton multinet	Feipeng Xu	Xin Liu	2022-09
Bacterial respiration	Yuchen Zhang	Xin Liu	2022-09
Bacteria abundance	Yuchen Zhang	Xin Liu	2022-09
Bacterial diversity	Yuchen Zhang	Xin Liu	2022-09
On-deck Incubation			
FCM (on-deck incubation)	Benben Du	Dalin Shi	2022-12
Chl *a* (on-deck incubation)	Xiaohua Hu	Dalin Shi	2022-12
Chl *a*（OA incubation）	Ze Chen	Dalin Shi	2022-12
DDN (on-deck incubation)	Xianhui Wan	Shuji Gao	2022-12
Nitrogen fixation rate（on-deck incubation）	Hui Shen	Shuiji Gao	2022-12
Nitrogen fixation rate (+nutrients)	Ruotong Jiang	Dalin Shi	2022-12
Carbon fixation rate (+nutrients)	Ruotong Jiang	Dalin Shi	2022-12
DNA/RNA(+nutrients)	Ruotong Jiang	Dalin Shi	2023-02
N_2O rate (on-deck incubation)	Hui Shen	Shuji Gao	2022-12
NP and RPP (on-deck incubation)	Hui Shen	Shuji Gao	2022-12
Surface Photosynthesis	He Li	Kunshan Gao	2022-04

Parameters	In-charge Person	PI Name	Submission Date
sequesters carbon			
Surface NPSi	He Li	Kunshan Gao	2022-04
Surface community structure	He Li	Kunshan Gao	2022-04
Rate			
Phytoplankton growth rate and microzooplankton grazing rate	Feipeng Xu	Xin Liu	2022-9
Nitrogen fixation rate	Ruotong Jiang	Dalin Shi	2022-9
Carbon fixation rate	Xiaohua Hu	Dalin Shi	2022-9
Nitrogen fixation rate(underway)		Dalin Shi	2022-9
Carbon fixation rate(underway)		Dalin Shi	2022-9
Others			
Aerosol	Jing Chen	Jin Zhang	2022-12
Rain	Wanyang He	Jin Zhang	2022-12

3. Cruise Participants

Table 2. Participants in KK2007/GPpr15-winter cruise

Name	Email	Organization	Shipboard Duties	Subprojects
Zhimian Cao	zmcao@xmu.edu.cn	Xiamen University	Chief scientist	Subproject 4
Wanyang He	21190311024@stu.ouc.edu.cn	Ocean University of China	Nd isotope, REEs et al.	Subproject 1
Jing Chen	1920359105@qq.com	Ocean University of China	Al, Mn	Subproject 1
Fangtao Zhang	zft@xmu.edu.cn	Xiamen University	Turbulence	Subproject 1
Zhongwei Yuan	zwyuan@stu.xmu.edu.cn	Xiamen University	Macronutrients	Subproject 1
Tao Huang	ht@xmu.edu.cn	Xiamen University	Low level NH_4, SUNA, sampling	Subproject 1
Lusong Zhang	1906255976@qq.com	Xiamen University	DOC	Subproject 1
Yongming Huang	yongminghuang@xmu.edu.cn	Xiamen University	FIA	Subproject 1
Liping Ye	lpye@xmu.edu.cn	Xiamen University	TMC CTD Supertech	Subproject 1
Junbo Yang	junbo@xmu.edu.cn	Xiamen University	Dissolved and particulate trace metal	Subproject 1
Chengwang Wang	649816726@qq.com	Xiamen University	Trace metal sampling	Subproject 1
Jinchang Yang	154793841@qq.com	Xiamen University	Trace metal sampling	Subproject 1
Ruifeng Zhang	ruifengzhang@sjtu.edu.cn	Shanghai Jiaotong University	Chief scientist, clean CTD, underway clean parameter	Subproject 1
Ruotong Jiang	249671581@qq.com	Xiamen University	Iron, phosphorus addition, on-deck incubation	Subproject 2
Xiaohua Hu	2582374088@qq.com	Xiamen University	Nitrogen fixation rate, carbon fixation rate	Subproject 2
Ze Chen	chenze300@163.com	Xiamen University	nifH gene abundance, activity	Subproject 2
Benben Du	benbendu@stu.xmu.edu.cn	Xiamen University	Metagenomic and transcriptome	Subproject 2
Hui Shen	shenhui@stu.xmu.edu.cn	Xiamen University	High resolution surface nitrogen fixation rate and	Subproject 2

Name	Email	Organization	Shipboard Duties	Subprojects
			biological	
			Nitrogen fixation DDN transmission culture at key	
Xianhui Wan	wanxh@xmu.edu.cn	Priceton University	stations	Subproject 2
Feipeng Xu	xufeipeng@xmu.edu.cn	Xiamen University	Chla/Pigment/FCM, trap	Subproject 3
Hao Hu	2366140825@qq.com	Xiamen University	PP	Subproject 3
Yuchen Zhang	langyami@qq.com	Xiamen University	Bacteria production, bacteria respiration	Subproject 3
He Li	lihe3717@163.com	Xiamen University	Photosynthetic carbon fixation	Subproject 3
Yuming Rao	55741943@qq.com	Xiamen University	trap, multi-net	Subproject 3
	yongchaowang@stu.xmu.edu.	Xiamen University		
Yongchao Wang	cn		Lw, Ed, c， bb， ap, ad, aph, ag, chl *a*, PFT	Subproject 3
Kuanbo Zhou	kbzhou@xmu.edu.cn	Xiamen University	Chief Scientist, Th234, in-situ pump	Subproject 4
Yuye Han	yuyehan@stu.xmu.edu.cn	Xiamen University	POC, PIC	Subproject 4
Kan Zhang	zhangkan@xmu.edu.cn	Xiamen University	Particulate Fe， trap, in-situ pump	Subproject 4
Liguo Guo	glg@xmu.edu.cn	Xiamen University	DO, carbonate, O_2/Ar， pCO_2 underway	Subproject 4
Xinyuan Zhang	zzzxy@stu.xmu.edu.cn	Xiamen University	Si, in-situ pump	Subproject 4
Jiaxu Li	136685330@qq.com	Xiamen University	^{230}Th-^{232}Th/^{210}Po-^{210}Pb	Subproject 4

4. Sampling and Parameters

4.1. Physical Oceanography

4.1.1. CTD Information

Two CTD profilers (Seabird 911) were used during the cruise, regular CTD and clean CTD, serial numbers 1181 and 1290. The instruments belong to R/V “Tan Kah Kee”. Sensors attached to the regular CTD include temperature, salinity, Chlorophyll, DO, PAR, SUNA, etc. The supporting water extractor is 24 Niskin bottles with volumn of ~12 L. The clean CTD has no PAR and SUNA sensors and other configurations are the same as the regular CTD. A total of 129 casts were done by CTD. Meanwhile, Acoustic Doppler Current Profiler (ADCP), Turbulence dissipation rate (VMP), Automatic Weather Station, underwater CTD, and Moving Vessel Profiler (MVP) were also applied during the cruise.

Table 3. CTD stations

No.	Station	Arrival Time	Lat (°N)	Long (°E)	Bottom (m)
1	WPS	2020-12-31 06:50	20	140	4877
2	MR04	2021-01-02 09:39	20	150	2417
3	MR05	2021-01-04 21:09	25	150	5761
4	M30	2021-01-07 18:05	28.5	155	6031
5	M22	2021-01-10 21:07	20	155	5703
6	M20	2021-01-14 16:16	18	155	5779
7	M18	2021-01-15 06:32	16	155	4783
8	M16	2021-01-16 18:18	14	155	6049
9	K8a	2021-01-17 06:15	12.5	155	6001
10	K9a	2021-01-19 09:19	13	150	6025
11	K11a	2021-01-21 21:51	14	140	5083
12	K12a	2021-01-23 09:17	12.75	135	4405
13	K13a	2021-01-25 15:26	11	131	5831
14	K11	2021-02-04 23:49	21.5	118.5	2743

4.1.2. Hydrography

Surface temperature was overall lower in winter than in summer, in paritular in the northern section the seasonal difference is more distinguished. Surface salinity showed minor variation between summer and winter in the northern section, whereas in the southern section the surface salinity was significantly higher in winter than in summer (Fig. 2).

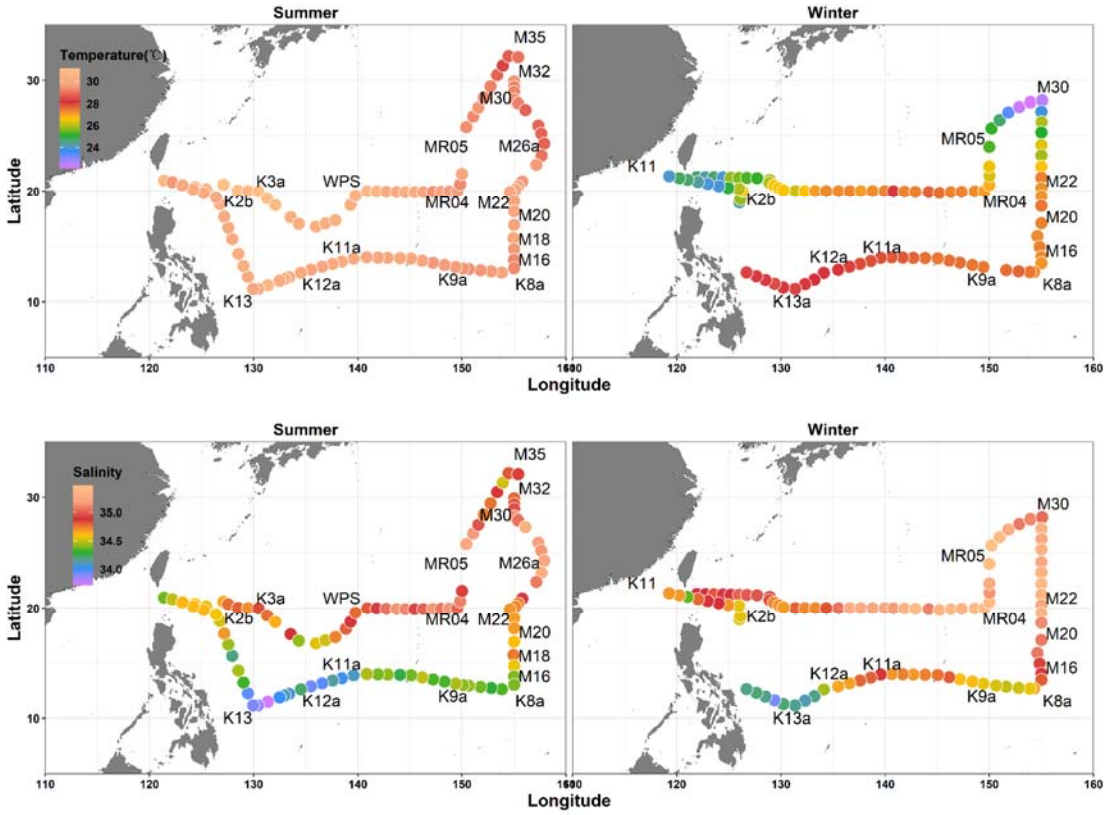

Figure 2. Surface distribution of temperature and salinity (KK2003 summer vs. KK2007 winter).

The T-S distribution pattern observed in the western North Pacific generally displayed an inverse S shape in both summer and winter. In subsurface and intermediate waters, a salinity maximum and minimum were distinguished (Fig. 3), which are influenced by advection of North Pacific Tropical Water sourced in the subtropical region and North Pacific Intermediate Water sourced in the subpolar region, respectively.

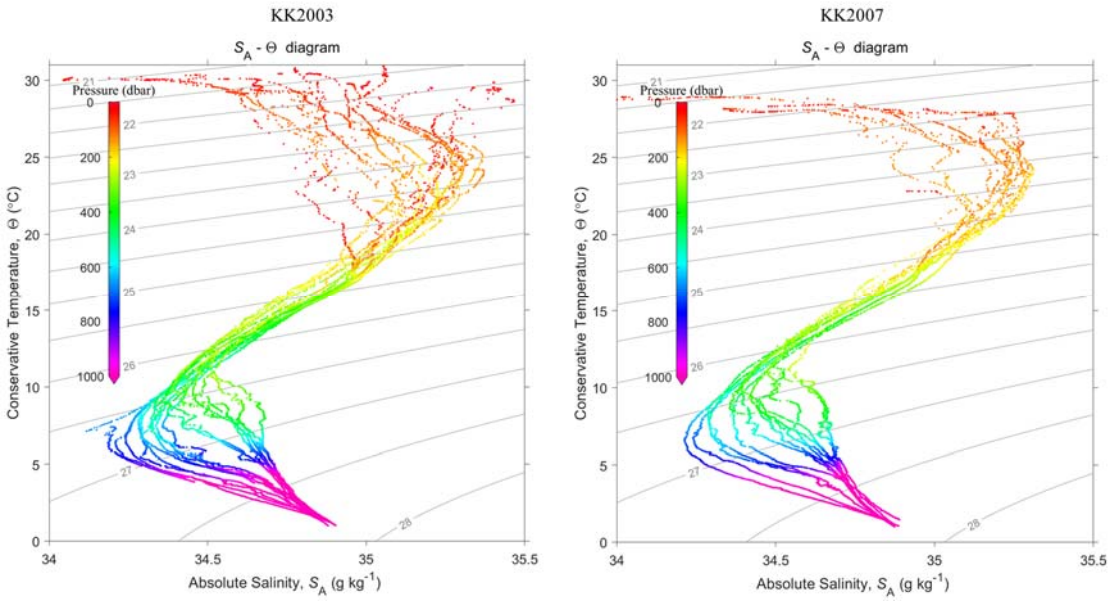

Figure 3. T-S diagram (KK2003 summer vs. KK2007 winter)

4.2. Apparent and Inherent Optical Properties

Mission: Measuring the inherent optical property (IOP) and appearance optic property (AOP) of Ocean Deserts

Parameter: R_{rs}, PAR, a, c, aph, ag, Zsd, AOT.

Station: 11 CTD stations (MR04, MR05, M30, M22, M18, K8a, K11a, K12a, K13,K2b,K11) and 19 underway stations (Z1, Z3, Z5, Z7, Z9, Z11, Z13, Z15, Z16, Z19, Z20, Z22, Z24, Z25, Z27, Z30, Z32, Z33, Z35, Z37)

The description of each parameter and the number of samples are shown in the table 4.

Table 4. The description of each parameter and the number of samples

Parameter	Number of samples	Instrument /Method	Remarks
a_{ph}	112	Filter ，GF/F (0.7 μm）	Including total particulate absorption coefficient and non-pigment particulate absorption coefficient.
a_g	112	Filter，Millipore(0.2 μm)	Light absorption capacity of dissolved substances in seawater.
R_{rs}	8	FOBY	Optical signal from seawater. On-Water measurement (the instrument floats on the water).

R_{rs}	30	Spectral Evolution	Above-Water measurement (the instrument is placed on deck).
R_{rs}	NA	HyperSAS	Underway observation (record data from sunrise to sunset).
PAR and R_{rs}	10	Profile II	In-Water measurement (depth profile data).
IOPs	21	Ac-s，bb9,bb3	Depth profile of water absorption, attenuation, scattering and backscattering coefficients.
AOT	510	Microtops	Attenuation coefficient of solar energy in the atmosphere to indicate the amount of aerosol.
Zsd	15	Secchi Disk	Characterize the clarity of seawater.

4.3. Chemical Oceanography (Trace Metal Clean CTD)

4.3.1. Trace Metal

Objectives: To explore the biogeochemistry of trace elements and isotopes (TEIs) and the control mechanism of key trace elements to N_2 fixation and carbon fixation in the western North Pacific.
Sampling information: TEIs samples were collected at 1 Mega Station (M22), 7 Clean Stations (MR04, MR05, M30, M18, K8a, K9a, K11a, K12a, K13a, K11) and 66 underway stations including 1707 profile samples and 132 underway samples. Parameters are listed in Table 5.

Table 5. Sampling information

Bottle	Unfiltered (L)					Filtered (L)					
number	TEIs	Hg	Ca&Sal	Low N&P	Nutrient	REEs	Al/Mn	Hg	Fe (FIA)	Fe/Zn/Cd isotopes	Fe (ICP MS)/Cu/Zn/Cd/Ni/Co
1	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
2	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
3	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
4	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
5	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
6	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
7	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
8	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
9	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25

10	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
11	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
12	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
13	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
14	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
15	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
16	0.5	0.5	0.125		0.125	0.5	0.25	0.25	0.125	2	4.25
17	0.5	0.5	0.125	0.25	0.125	0.5	0.25	0.25	0.125	2	4.25
18	0.5	0.5	0.125	0.25	0.125	0.5	0.25	0.25	0.125	2	4.25
19	0.5	0.5	0.125	0.25	0.125	0.5	0.25	0.25	0.125	2	4.25
20	0.5	0.5	0.125	0.25	0.125	0.5	0.25	0.25	0.125	2	4.25
21	0.5	0.5	0.125	0.25	0.125	0.5	0.25	0.25	0.125	2	4.25
22	0.5	0.5	0.125	0.25	0.125	0.5	0.25	0.25	0.125	2	4.25
23	0.5	0.5	0.125	0.25	0.125	0.5	0.25	0.25	0.125	2	4.25
24	0.5	0.5	0.125	0.25	0.125	0.5	0.25	0.25	0.125	2	4.25

Instrument information: The clean sampling system includes Niskin-X bottles, CTD &Water sampler (SBE 911plus), clean sampling van, clean analysis van, ultra-clean CTD winch and its control command container (Table 6).

Table 6. Instrument information

Instrument	**Information**	**Manufacturer**
Clean sampling bottle	Niskin-X, 12L	General Oceanics
CTD&Water sampler	SBE 911Plus, 32G-24P; water sampler with 24-position for use with 12-liter sampling bottle; integrated 2 sets of temperature-conductivity sensor, SBE43 dissolved oxygen sensor, WET Labs C-Star, WET Labs ECO-FLrtd, VA-500 altimeter	SeaBird
Ultra-clean CTD winch	2550*2350*1950 mm; contain cable	Kleyfrance
Winch control command container	3000*2450*2850 mm; contain portable control console, cardboard of bolting, carboard of 8 cables, carboard of FO components	Kleyfrance
Sampling van	Custom, 606*244*259cm, Class1000	GeOceanTech Co., Ltd.
Analysis van	Custom, 606*244*259cm, Class1000	GeOceanTech Co., Ltd.

Preliminary results: The clean sampling sytem was rinsed twice before sampling, while the rinse blank was determined on board using the FIA method (Figure 4). Also shown are selected profiles

of dissolved Fe (Figure 5) and surface distributions of dissolved Fe determined by the FIA method (Figure 6).

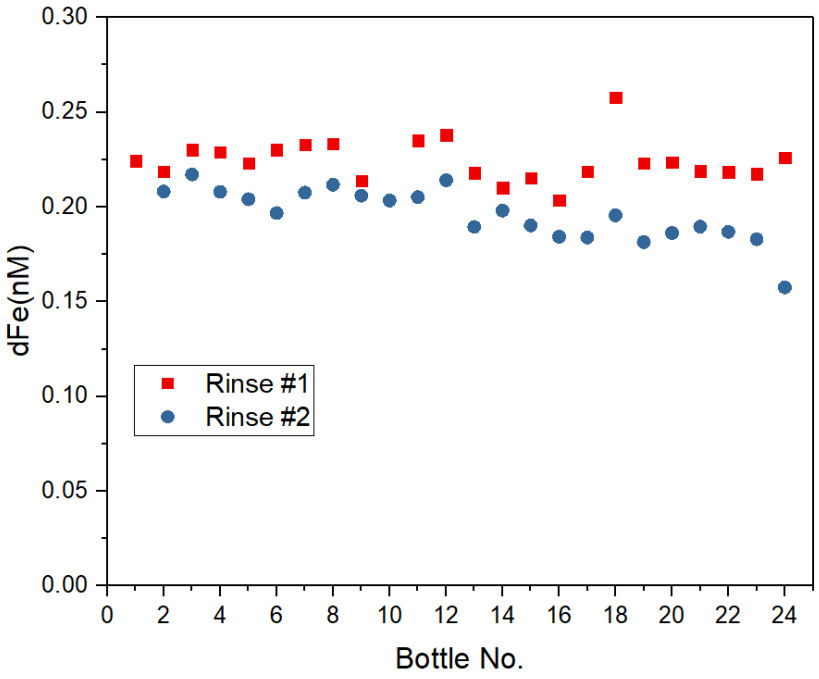

Figure 4. Rinse blank results for dissolved Fe.

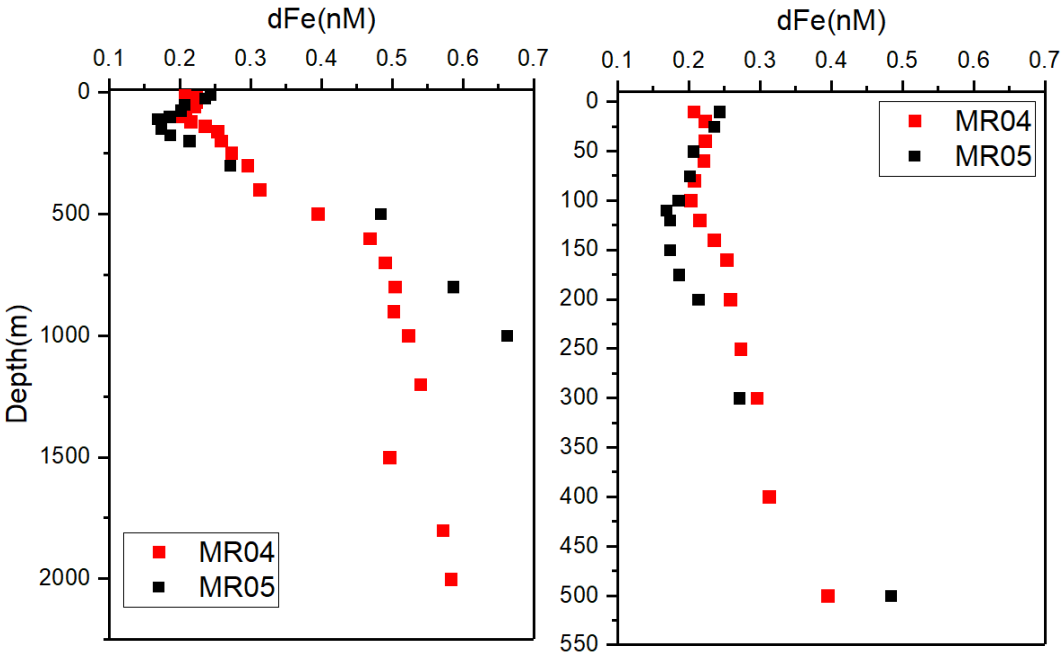

Figure 5. Vertical distributions of dissolved Fe at stations MR04 and MR05.

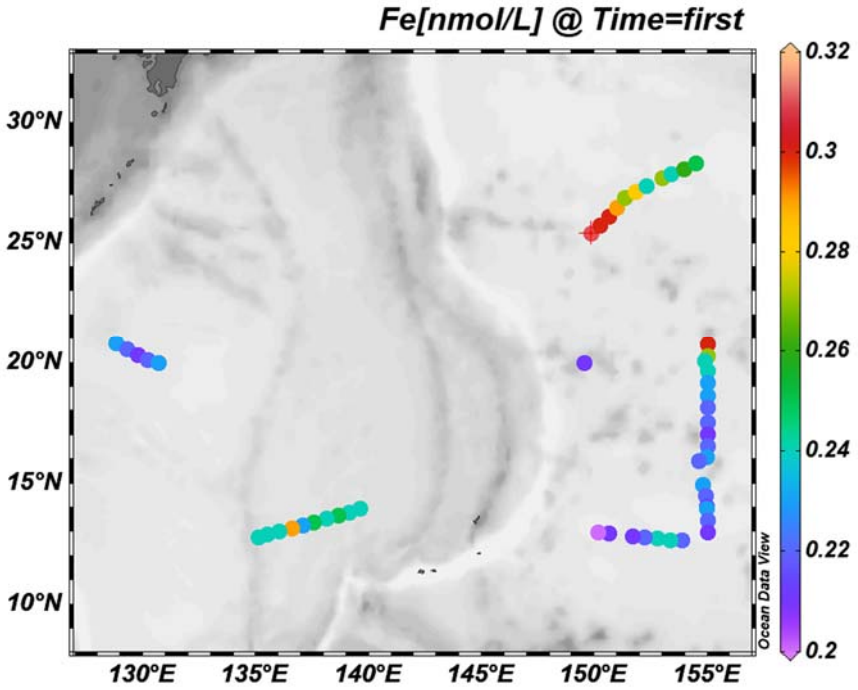

Figure 6. Distributions of dFe in the surface seawater.

4.3.2. Incubations

Parameters: In addition to the routine sampling for trace metals analysis, the other task is to investigate the limiting nutrients in the North Pacific Subtropical Gyre by nutrient addition experiments. Chlorophyll and 18s will be analyzed for the incubation experiments.

Methods: At stations MR04, M30, M22, M18, and K8a, seawater from towed fish was used for incubation experiment. Each treatments has 3 replicates, after nutrients were amend, the 1 L bottles will be incubated in a seawater flow incubator. 300 ml from each 1 L bottle was filtered for Chl-a measurement. The rest sample were collected for 18s analysis for community compositions.

Preliminary results: As shown in Figure 7, similar to the previous study, our preliminary results suggested that nitrogen is the key limiting nutrient in the North Pacific subtropical gyre. However, our results showed different response to the nutrient addition. For example, at station MR04, Fe was the secondary limiting nutrient after nitrogen; while at station M18, P was the secondary limiting nutrient after nitrogen.

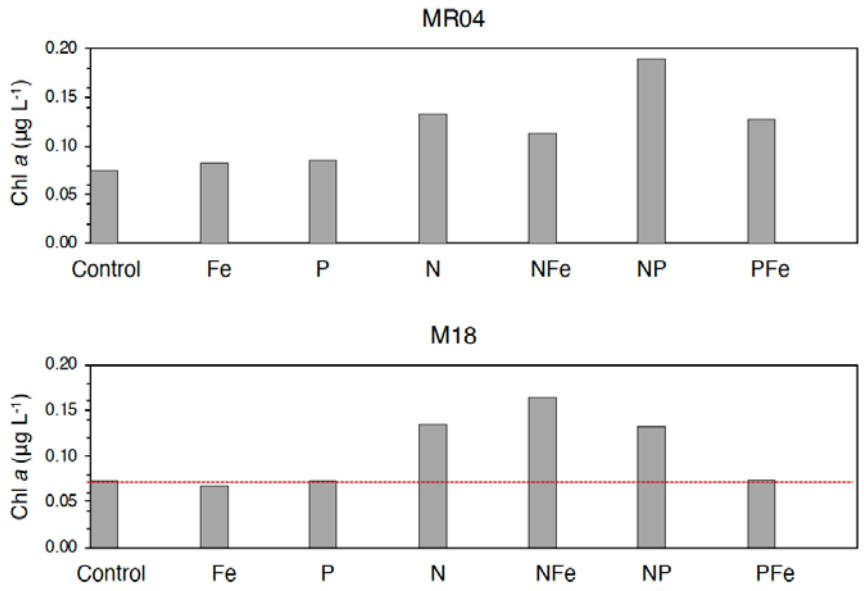

Figure 7. Chl a response to the nutrient addition after 48 hours incubation

4.4. Chemical Oceanography (Regular CTD)

4.4.1. Nutrients

Nutrient samples were collected at 13 stations including 680 normal concentration nutrient samples, 412 ammonium samples, and 300 samples for surface low-level P and N. Meanwhile, we also collected 176 underway samples with 3-h interval.

Nutrient samples were immediately analyzed onboard using a Four-channel Continuous Flow Technicon AA3 Auto-Analyzer (Bran-Lube GmbH). The detection limits for NO_3^-, NO_2^-, DIP, and $Si(OH)_4$ were 0.03 μmol L^{-1}, 0.02 μmol L^{-1}, 0.03 μmol L^{-1}, and 0.05 μmol L^{-1}, respectively, and the analytical precision was better than 1% for NO_3^-, 1% for NO_2^-, 2% for DIP, and 2.8% for $Si(OH)_4$ (Du et al. 2017; Han et al. 2012). Ammonium was measured on board using a solid phase extraction combined with fluorescence detection (SPE-Flu) method. The detection limit was 1.2 nmol L^{-1} and the analytical precision was 3.5% in the shipboard laboratory (Zhu et al. 2013; Zhu et al. 2018). In addition, samples including NO_3^- and DIP within nanomolar levels were collected and frozen separately at -20 ℃ until analysis in a shore-based laboratory.

(1) Vertical distributions of N, P, and Si at a selected station of MR04

The nutrient concentrations in the upper 200 m water column in winter are generally higher than those in summer. There is no obvious seasonal variation in nutrient concentration below the depth of 1000 m, where the nutrient concentrations are relatively constant (Figure 8).

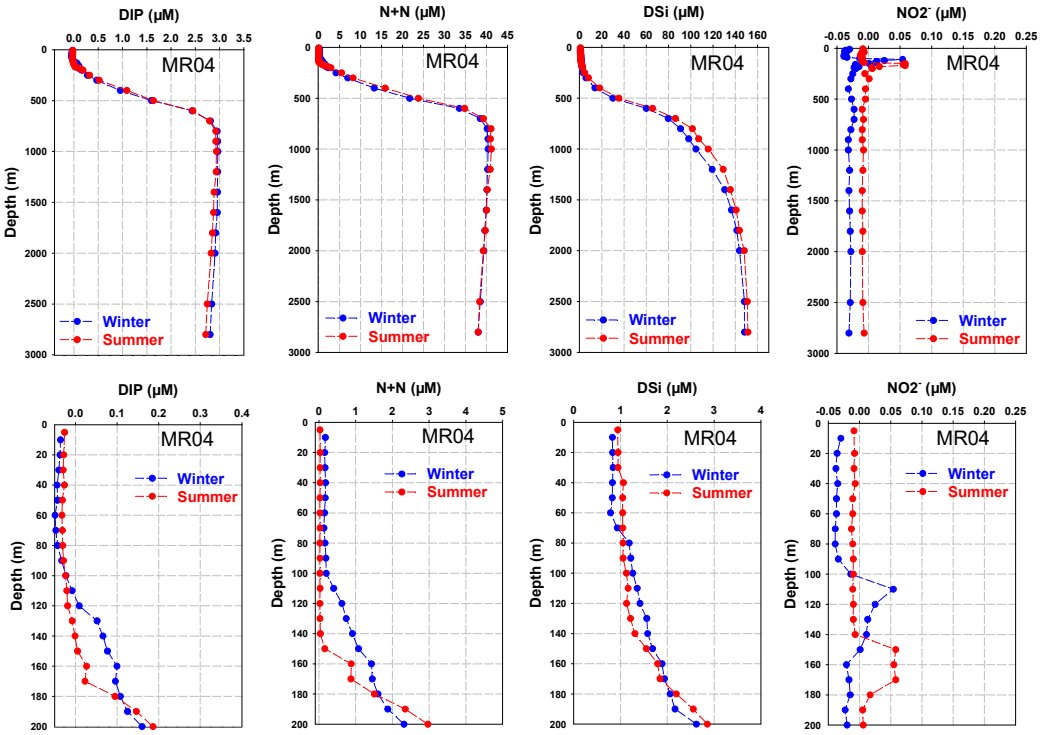

Figure 8. Nutrient distributions at station MR04.

(2) Vertical distributions of NH_4 at stations MR04 and MR05

At station MR04, NH_4 concnetrations were higher in winter than in suumer throughout the water column. At station MR05, the NH_4 maximum value around 100 m was markedly higher in summer than in winter (Figure 9).

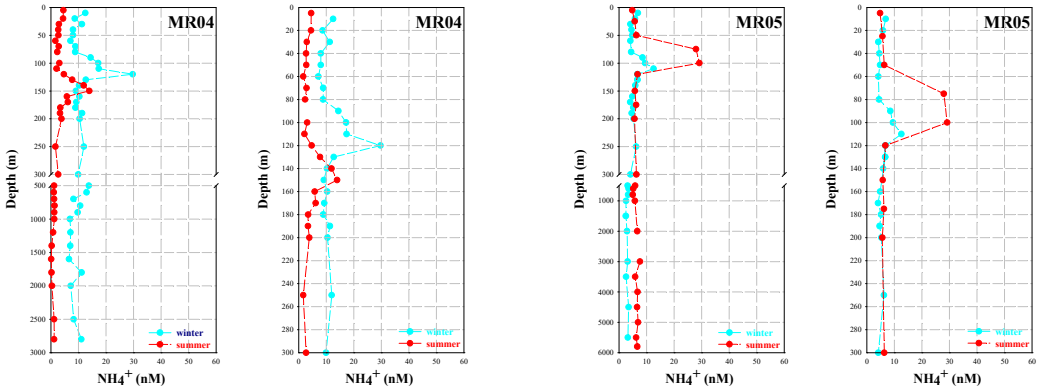

Figure 9. Ammonium distributions at stations MR04 and MR05.

Reference

Du, C., Z. Liu, S. J. Kao, and M. Dai. 2017. Diapycnal Fluxes of Nutrients in an Oligotrophic Oceanic Regime: The South China Sea. *Geophysical Research Letters* **44:** 11,510-511,518.

Han, A. Q., M. H. Dai, S. J. Kao, J. P. Gan, Q. Li, L. F. Wang, W. D. Zhai, and L. Wang. 2012. Nutrient dynamics and biological consumption in a large continental shelf system under the influence of both a river plume and coastal upwelling. *Limnology and Oceanography* **57**: 486-502.

Zhu, Y., D. X. Yuan, Y. M. Huang, J. Ma, and S. C. Feng. 2013. A sensitive flow-batch system for

on board determination of ultra-trace ammonium in seawater: Method development and shipboard application. *Anal Chim Acta* **794**: 47-54.
Zhu, Y. F., J. Liu, T. Huang, L. F. Wang, T. W. Trull, and M. H. Dai. 2018. On the fluorometric measurement of ammonium in oligotrophic seawater: Assessment of reagent blanks and interferences. *Limnol Oceanogr-Meth* **16**: 516-524.

4.4.2. Dissolved Organic Carbon, Phosphorus and Nitrogen

Objective:

(1) Clarifying the source, flux and temporal and spatial concentration distribution of organic nutrient in the euphotic layer to improve the understanding about the controlling mechanisms of the biological pump in the NPSG;
(2) Quantifying the output flux of DOC in the NPSG and its contribution to the carbon sink by biological pump;
(3) Exploring the stoichiometric change of DOM and its response to and regulation of the nitrogen fixation;
(4) finding out the possible supply relationship between DOM and inorganic nutrients in the NPSG.

Sampling:

1. CTD: discrete samples of DOC, DON and DOP were collected in the whole water column at all stations. A total of 411 samples from 13 stations were collected.
2. Underway: 176 surface samples of DOC, DON and DOP were collected every 3h in a clean container during sailing.

4.4.3. Inorganic Carbon System

Sampling:

At each station, seawater samples were collected with 12 L Niskin bottles mounted to a CTD rosette (Seabird SBE 911). Dissolved oxygen (DO) samples were taken with 60 mL BOD (biological oxygen demand) bottles. First, BOD bottles were rinsed 3 times and Tygon tubing was inserted to the bottom of bottles. Then overflowed at least 3 times of BOD bottle volume and avoided turbulence before tubing was bring out of sampling water. And then reagents of 0.5 mL manganese chloride and 0.5 mL alkaline iodide were added. Finally the stopper was inserted and the bottles were shaken upside down at least 30 times. Samples for pH, dissolved inorganic carbon (DIC) and total alkalinity (TA) were taken with Tygon® tubing free of air bubbles into 250 mL corning borosilicate bottles with grounded stoppers, overflowed 1 time of bottle volume and poisoned with 125 μL of saturated $HgCl_2$ solution. DO samples were measured onboard within 24 hours. Samples of DIC/pH/TA were stored in the dark until analysis.

Methods:

DO samples were measured spectrophotometrically at 466 nm on onboard within 24 hours of sample collections (Labasque et al., 2004). The samples were placed in a constant temperature bath at 25±0.02°C for about 1 hour before measurement.

Analyses of DIC and TA followed the methods in Cai et al. (2004). DIC was measured by collecting and quantifying the CO_2 released from the sample upon acidification with a

non-dispersive infrared detector (Li-Cor 7000) using a DIC Analyzer (Apollo SciTech model AS-C3) with a precision of better than ±2 μmol kg^{-1}. TA was determined by a Gran titration with hydrochloric acid using an automated Alkalinity Titrator (Apollo SciTech model AS-ALK1+) with a precision of better than ±2 μmol kg^{-1}. Both DIC and TA were calibrated with the certified reference materials (CRM) provided by Dr. A. G. Dickson (Scripps Institution of Oceanography).

Samples for pH measurements were placed in a constant temperature bath at 25±0.01 ºC for about 1 hour before their pH values were measured spectrophotometrically at the same temperature (Dickson et al., 2007). The precision of the measurement was better than ±0.0005.

Results:

(1) Vertical distributions of DO

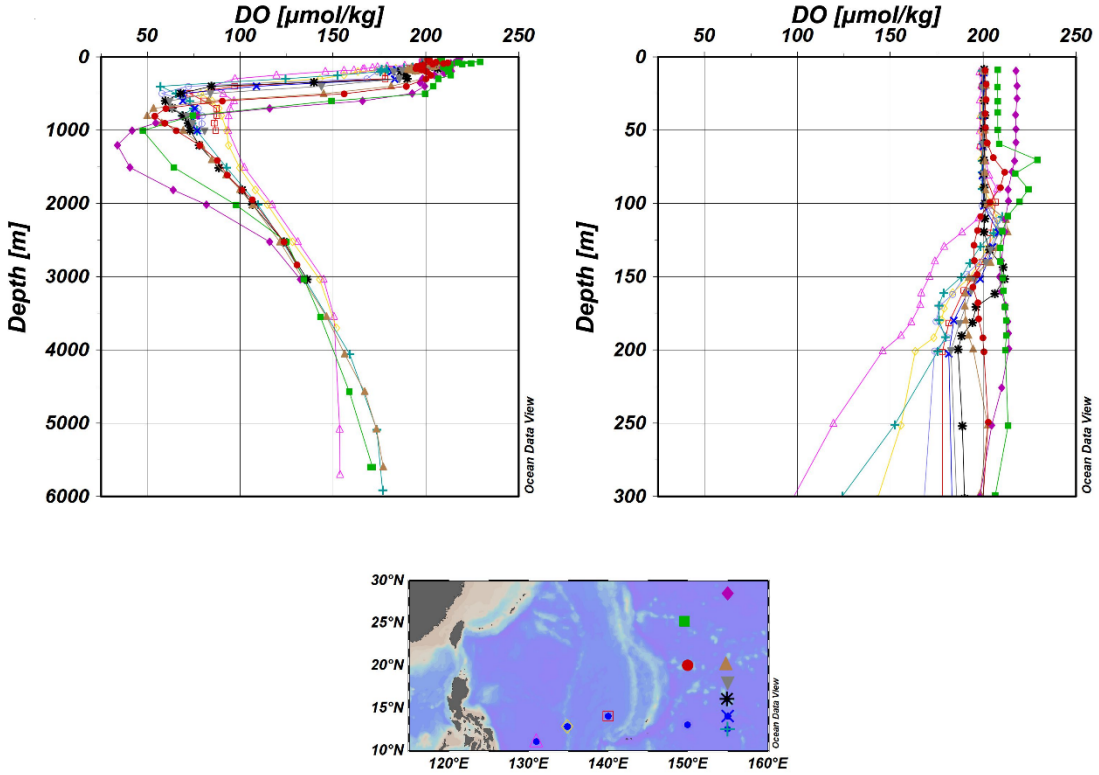

Figure 10. Vertical distributions of DO.

(2) Section distributions of DO along 155°E

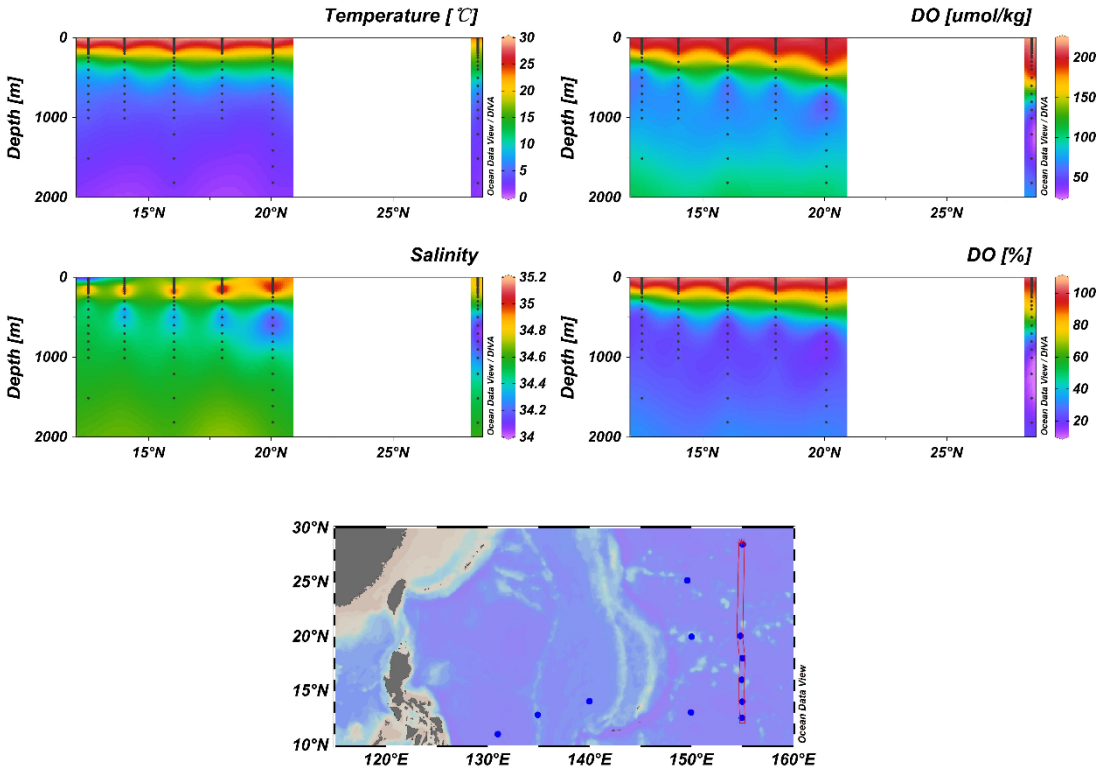

Figure 11. Section distributions of DO along 155°E

4.4.4. ^{234}Th, POC, BSi and PBa

Objectives:

1. To examine the spatial variability of the particle fluxes in the North Pacific Subtropical Gyre (NPSG) during winter;
2. To examine the vertical variability of the particle fluxes at the export horizon of Nutrient Depleted Layer (NDL) and Nutrient Replete Layer (NRL), and identify their major biogeochemical control;
3. To study the coupling and decoupling between different bio-limiting elements and their fluxes, e.g., C, N and Si;
4. To investigate the particle remineralization rate using a new tracer Ba and its isotope in the twilight zone.

Sample strategy and collection:

1. Sampling Station: 13 stations (MR04, MR05, M30, M22, M20, M18, M16, K8a, K9a、K11a, K12a, K13a, K11) have been sampled during the cruise;
2. Sampling depths: For station MR04&M22, 19 depths have been covered, i.e. 10, 20, 40, 60, 80, 100, 120, 140, 160, 180, 200, 300, 400, 500, 600, 700, 900, 1000 m; For other stations: 12 depths have been sampled, i.e. 10, 20, 40, 60, 80, 100, 120, 140, 160, 180, 200, 300 m

Sample numbers and statistics:

1. Dissolved Barium/Silica and their isotopes: 13 stations and 429 samples;
2. Biogenic Silica: 13 stations and 169 samples;

3. Particulate Barium and its isotopes: 3 stations and 48 samples;
4. Total ^{234}Th: 13 stations and 170 samples;
5. Particulate ^{234}Th and POC: 13 stations and 158 samples;
6. Particulate Inorganic Carbon: 13 stations and 158 samples.

Methods:

1. Total thorium-234 analysis: 4L seawater sample was collected and Spiked with Th-230. Thorium isotopes was co-precipitated with MnO2 formed by adding $MnCl_2$ and $KMnO_4$ solutions. The Mn precipitates was then filtered and beta counted. The thorium-234 recoveries will be done 6 months after sampling using ICP-MS method. For the method detail, please check in Buesseler et al., 2001 and Pike et al., 2005.
2. Particulate Th-234 and POC analysis: 8L seawater sample was collected and filtered on a 25mm, QMA filter. The sample was first beta counted for particulate Th-234. Then it will be measured for POC using a CHN analyzer.
3. BSi analysis: BSi will be measured with a Technicon AA3 auto-analyzer (Bran-Lube, GmbH) after double-wet alkaline (NaOH) digestion (Cao et al., 2012).

Reference:

1. Buesseler, K.O. et al., 2001. An intercomparison of small- and large-volume techniques for thorium-234 in seawater. Mar. Chem., 74(1): 15-28.
2. Pike, S. M., K. O. Buesseler, J. A. Andrews, and N. Savoye (2005), Quantification of 234Th recovery in small volume sea water samples by inductively coupled plasma mass spectrometry, J. Radioanal. Nucl. Chem., 263, 355– 360.
3. Cao, Z. M., Frank, M., Dai, M.H., Grasse, P. & Ehlert, C. (2012). Silicon isotope constraints on sources and utilization of silicic acid in the northern South China Sea. Geochim. Cosmochim. Acta, 97, 88-104.

4.4.5. ^{210}Po-^{210}Pb, D-^{230}Th, D-^{231}Pa, D-^{232}Th

(1) Particulate ^{210}Po-^{210}Pb, Dissolved ^{210}Po-^{210}Pb

Objectives:

Tracing the export flux of biogenic particles out of the euphotic zone with the disequilibria between^{210} Po and ^{210} Pb and particle dynamics in mesopelagic and bottom waters.

Analytical Methods:

Dissolved: For operationally defined dissolved Po and Pb, the water samples were filtered through the PC membrane with a pore size of 0.4 μm and acidified immediately after filtration with reagent grade 6M HCl to pH<2. ^{209}Po, Stable Pb($PbCl_2$) and $FeCl_3$ were added and after equilibration, Pb and Po were simultaneously co-precipitated with $Fe(OH)_3$. The $Fe(OH)_3$ precipitate was collected by decanting and centrifuging and dissolved in HCl, and ^{210} Po and ^{209} Po were spontaneously plated onto silver plates.

Particulate: The particulate samples collected on the PC membrane were dried in a desiccator and weighed to estimate the concentration of total suspended matter. After adding ^{209}Po, the filter was decomposed and digested by HNO_3/HCl/$HClO_4$. ^{210}Po and ^{209}Po were plated onto silver plates following the same procedures as for dissolved samples.

Both dissolved and particulate ^{210}Po and ^{210}Pb in seawater were measured using alpha spectroscopy. All activities of ^{210} Po were corrected back to the sampling time after the ingrowths from parent radionuclides were subtracted.

Sampling Information:

All particulate and dissolved ^{210}Po-^{210}Pb samples were collected at 12 layers above 1000 m (10 liters per layer) at regular clean stations. A total of 24 layers throughout the whole water column

were collected at the mega station.

(2) Dissolved ^{230}Th, ^{231}Pa, ^{232}Th

Objectives:

Studying particle dynamics and water mass mixing. ^{230}Th, ^{231}Pa, and ^{232}Th in seawater can also calculate the average sinking rate and residence time and trace the cycling of Fe and other elements in deep waters.

Analytical Methods:

The water samples were filtered with capsule filters (0.8 μm/0.45 μm Acropak ® 500 filters) and acidified immediately with optima HCl to a pH<2.0. After weighting, spiking and pre-concentration with Mg hydroxide, seawater Pa and Th concentrations and isotope ratios were measured using HR MC-ICP-MS.

Sampling information:

All samples were collected at 12 layers throughout the whole water column (10 liters per layer) at regular clean stations. A total of 24 layers throughout the whole water column were collected at the mega station.

4.4.6. Nitrogen Fixation

(1) N_2 fixation and DDN release rate: N_2 fixation rate was measured at 9 stations during the cruise by using the $^{15}N_2$ labeling incubation. Light manipulation experiments were performed to investigate the effect of light on N_2 fixation. Samples for determining the release rate of DDN to the DON pool and the non-diazotroph plankton were also collected. Results of these experiments are expected to disclose the rate, release and transfer of DDN and their environmental determinants in the NPSG.

(2) Nitrification and N_2O production: Nitrification and N_2O production rate were measured using multiple ^{15}N labeling incubation at 5 stations during the cruise.

Analytical Methods:

N_2 fixation rate will be measured following the $^{15}N_2$ gas bubble method (Montoya et al., 1996) and isotope composition of PN and DON by alkaline persulfate oxidation method (Knapp et al., 2005) combined to the bacterial method for nitrate isotope analysis (Sigman et al., 2001).

DDN transfer rate will be measured using the combined flow cytometry sorting and N isotope measurement (Fawcett et al., 2011).

N_2O isotope will be measured according to Mcllvin and Casciotti 2010.

Reference

Casciotti, K. L., D. M. Sigman, M. Galanter Hastings, J. K. Bǒhlke, A. Hilkert Measurement of the Oxygen Isotopic Composition of Nitrate in Seawater and Freshwater Using the Denitrifier Method. *Anal. Chem.* **74,** 4905-4912 (2002).

Fawcett, S. E.,, M. W. Lomas, J. R. Casey, B. B. Ward, D. M. Sigman, Assimilation of upwelled nitrate by small eukaryotes in the Sargasso Sea. *Nat. Geosci.* **4**, 717-722 (2011).

Mcllvin, M. R., K. L. Casciotti. Fully automated system for stable isotopic analyses of dissolved nitrous oxide at natural abundance levels. *Limnol. Oceanogr. Methods.* **8,** 54-66 (2010).

Montoya, J. P., M. Voss, P. Kahler, and D. G. Capone. 1996. A Simple, High-Precision, High-Sensitivity Tracer Assay for N_2 Fixation. Appl. Environ. Microbiol., 62(3): 986-993.

Knapp, A. N., D. M. Sigman, and F. Lipschultz. 2005. N isotopic composition of dissolved organic nitrogen and nitrate at the Bermuda Atlantic Time-series Study site. Global Biogeochemical Cycles, 19, GB1018, doi:10.1029/2004GB002320.

4.5. In-situ Pump

Samplimg strategy:
Modified in-situ pump system was used to collect particle samples based on the GEOTRACES cookbook. It has two pump heads (Figure 12): for one pump head, seawater sequentially passes through a 142mm 51μm polyester prefilter (acid cleaned) and 142mm 0.8 μm PES membrane (acid cleaned) for trace element and BSi analysis; for the other pump head, seawater also passes through a 142mm 51μm polyester prefilter (acid cleaned) and 150mm 1.0 μm QMA filter (400 ºC combusted) for POC/PN, ^{234}Th and biological paremeter (e.g. 16S, 18S, HPLC) analysis. One-way valves were used to prevent the back flow of seawater to the pump heads which may induce contamination.

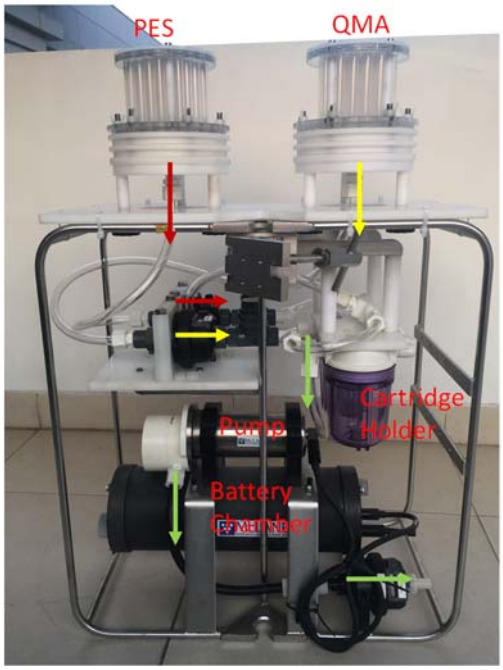

Figure 12. The new design of in-situ pump with two pump heads

Deployment information:
In-situ pump deployment was performed at 8 clean stations with 9 casts in total, including Station MR05, M30, M22, M18, K8a, K12a, K13a and K11. 8-10 pump systems were deployed during each cast. Two casts were performed at Station M22 till the depth around 3000m. At other stations one cast was performed till the depth around 1000m. About 1000-2000L seawater was filtered during 3-5h pumping time, and the volume ratio between PES and QMA pump head were around 1:2.

Sample processing:
1. 1/4 51μm polyester prefilter and 1/16 0.8μm PES membrane from PES pump head were used for particulate trace element (PTE) analysis. The polyester prefilter samples were firstly washed with clean filtered seawater onto a 25mm 0.8μm PES membrane. Both PES membranes were dried under room temperature in a clean flow bench (better than class 100).
2. 1/4 51μm polyester prefilter and one punch of 23 mm diameter QMA filter from QMA pump head were used for POC, PN and particulate ^{234}Th analysis. The polyester prefilter samples were firstly washed onto a 25 mm diameter 1.0μm QMA filter. Both QMA membranes were dried in an oven at 50 ºC.

3. 1/4 51μm polyester prefilter and two punches of 23 mm diameter QMA filters from QMA pump head were used for particulate inorganic carbon (PIC) analysis. The polyester prefilter samples were firstly washed onto a 25 mm diameter 1.0μm QMA filter. Both QMA membranes were dried in an oven at 50 ºC
4. 1/16 51μm polyester prefilter from QMA pump head and 1/16 0.8μm PES membrane from PES pump head were dried under room temperature in a clean flow bench (better than class 100) for biogenic silica analysis.
5. 1/8 51μm polyester prefilter and one punch of 47 mm diameter QMA filter from QMA pump head were used for 16S, 18S and HPLC analysis. The polyester prefilter samples were firstly washed onto a 47mm diameter 0.2μm PC filter. The filters were then preserved at -80 ºC.

4.6. Trace Elements and Aerosol Sampling

4.6.1. Trace Elements and Isotopes (Ocean University of China)

(1) From clean CTD

Analytical Methods:

Seawater REEs samples will be treated using NOBIAS resin and then measured by ICP-MS.

The concentrations of dAl and dMn will be analyzed by the flow injection analysis methods with on-line preconcentration following the protocol described in Brown and Bruland (2008) and Aguilar-Islas and Bruland (2006). The detection limits for dAl and dMn are 0.18 nmol L^{-1} and 0.2 nmol L^{-1}, respectively. The analytical precision is better than 4% for dAl and 5% for dMn.

Total Hg samples will be oxidized with 0.05% bromine monochloride (BrCl) solution or equivalent for at least 1 hour. Then excess halogens will be removed by mixing with 0.05% v/v hydroxylamine hydrochloride (NH_2OH•HCl) solution for at least 5 minutes, and final reduction will be conducted with 0.05% v/v stannous chloride ($SnCl_2$) solution. Hg^0 in solution will be purged and trapped on gold or gold-coated sand (or the equivalent). Purging should proceed at a volumetric flow rate of no more than 1 L min^{-1} (we recommend 0.5 L min^{-1}) until a volume of gas of at least 15 times the volume of liquid has been sparged. Then the gold will be detected by AFS.

The MeHg samples will be first neutralized with 6 mL of 50% KOH, and then buffered to pH=5 with 1.8 mL of 2 M Na-Acetate/Acetic buffer, the pH should be checked and adjusted as necessary with small additions of strong acid (H_2SO_4) or strong base (KOH). 0.18 mL of 1% NaTEB will be added to the buffered 250 ml sample, allowing each sample to react for at least 15 minutes, and then sparging the formed MeHgEt from the sample to a Tenax trap. MeHgEt on the trap will then be detected by a packed column GC (OV-3)-AFS.

Sampling information:

Samples were collected by 12-liter Niskin-X bottles mounted onto a clean rosette sampling assembly, equipped with a CTD recorder (Sea-Bird SBE911Plus). Unfiltered and filtered seawater samples were subsampled for each depth. To obtain filtered samples, seawater was filtered in-line from Niskin-X bottles in the clean van through AcroPak 1000 cartridges (pore size of 0.8/0.45 μm) into pre-cleaned LDPE bottles. The samples were acidified to a pH of ~1.8 with ultra-clean HCl in a 100-class clean bench in the laboratory and stored for more than one month before analysis. More detailed sampling information is given in Table 7.

Table 7. Sampling information from clean CTD

Parameter	Sample station	Sample Volume	Sample counts
Filtered-REEs	MR04, MR05, M30, M22, M18, K8a, K9a, K11a, K12a, K13a，K11	500 ml	269
Unfiltered- REEs	M22, K8a, K13a, K11	500 ml	114
Filtered-Al/ Mn	MR04, MR05, M30, M22, M18, K8a, K9a, K11a, K12a, K13a，K11	250 ml	269
Unfiltered-Al/ Mn	M30, M22, M18, K8a, K13a, K11	250 ml	162
Unfiltered-THg	MR05, M30, M18	250 ml	36
Unfiltered-MeHg	MR05, M30, M18	250 ml	36

(2) From regular CTD

Analytical Methods:

Nd isotopes will be analyzed using MC-ICP-MS in the laboratory on land.

Sampling information:

Unfiltered and filtered seawater samples from surface to bottom were taken from 12 L Niskin bottles mounted on a Rosette sampler equipped with a calibrated CTD recorder.

For Nd isotopes, seawater was filtered on board in a clean bench with 0.45 μm Polyethersulfone membrane filter into pre-cleaned LDPE cubitainers. The filtrate was acidified to a pH of ~2 with ultra-clean 6 N HCl (self-distilled or trace metal grade).

For Al and Mn, seawater was filtered on board in a clean bench with 0.4 μm polycarbonate filter into pre-cleaned LDPE bottles.

For the total Hg concentration analysis, HCl (conc.) was added to form a final concentration of 0.5%. For MeHg analysis, H_2SO_4 (conc.) was added to form a final concentration of 1%. The samples were stored at -20 ºC before analysis.

More detailed sampling information is given in Table 8.

Table 8. Sampling information from regular CTD

Parameter	Sample station	Sample Volume	Sample counts
Filtered-Nd isotopes	MR04, MR05, M30, M22, M18, K8a, K12a, K13a, K11	20 L	109
Filtered-Al/ Mn	M22, M18, K8a	250 ml	72
Unfiltered-THg	MR04, M22, M18, K8a, K12a, K13a, K11	250 ml	78
Unfiltered-MeHg	MR04, M22, M18, K8a, K12a, K13a, K11	250 ml	78

(3) Underway sampling

In this cruise, the underway surface seawater samples were taken by Towed fish. Seawater was filtered in a trace metal clean van through AcroPak 1000 filters (pore size of 0.8/0.2 μm) into pre-cleaned LDPE bottles. For REEs, 59 samples were acidified to pH<2 with 1 ml ultra-clean 6

N HCl (optima grade). For dissolved Al and Mn, 67 samples were acidified to a pH of ~1.8 with ultra-clean HCl (Merck) in a 100-class clean bench in the laboratory and stored for more than one month before analysis.

(4) Aerosols

Parameters:

Trace elements (Al, Ti, Fe, V, Zn, Pb, Mn, Ni, Cu, Hg), REEs (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu), major anions (SO_4^{2-}, Cl^-), and nutrients (NO_3^-, PO_4^{3-}).

Sampling Information:

Aerosol samples were collected using a high-volume (1000 L/min) air sampler on the compass deck with Whatman 41 membrane filter (low ash cellulose esters, PN 1441-047) during this cruise. The samples were preserved at -20ºC on board. Rainwater samples were collected by rainwater sampler and stored in LDPE bottles. In this cruise, 44 aerosol samples were collected with cellulose filter including 16 underway sampling samples and 28 samples at stations, while the number of rainwater samples were 6.

4.6.2 High-resolution atmospheric aerosol metal monitoring

Analytical Methods:

Twenty-three trace elements in PM10 including K, Ca, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Pd, Ag, Cd, Sn, Sb, Ba, Au, Hg, Tl, and Pb were measured by the Xact 625 Ambient Metal Monitor. Trace elements on the filter were automatically detected using the standard method of USEPA with X-ray fluorescence (XRF) analysis.

Sampling Information:

With Xact, ambient air was introduced through a PM10 cyclone inlet at a constant flow rate of 16.7 L/min and collected on the reel-to-reel Poly tetrafluoroethylene (PTEE) filter type. Sampling and analysis of trace elements were performed alternatively and continuously, except for a 20-s requirement to advance the tape.

Marine aerosol single particles

The sampling time of the single particle sampler is 15 minutes, and the sampling flow rate is 0.8 L/min. Currently, 49 single-particle samples have been collected, covering 23 days of the voyage.

4.7. Biological Oceanography

4.7.1. Phytoplankton, Multinet, Primary Productivity

(1) Phytoplankton

Sampling parameters:

Phytoplankton biomass and community structure

Methods:

Chlorophyll-a concentrations: 500 mL seawater (5m, 25m, 50m, 75m, 100m, DCM, 150m，200m) was filtered onto Machery Nagel GF/F filter papers and extracted for 16-20 hours in 10 mL 90% analytical reagent acetone in a -20 °C freezer in the dark before measurement on a Turner

Designs fluorometer following the method of Welschmeyer (1994).

High Performance Liquid Chromatography (HPLC): 4-6 L seawater per sample (5m, 25m, 50m, 75m, 100m, DCM, 150m，200m) was filtered onto Machery Nagel GF/F filter papers and placed directly into a -80 °C freezer. These will be analysed using the method of e.g. Gibb et al. (2000). Chlorophyll-a concentrations determined by HPLC will be used to verify those determined by fluorimetry.

Analytical flow cytometry: 1.8 mL of seawater was mixed with 20 uL 16% paraformaldehyde yielding a final paraformaldehyde concentration of 1%. Samples were mixed by hand and left for 10 minutes at room temperature in the dark before transfer to a –80°C freezer. Samples will be analysed on a FACSort flow cytometer following the method of e.g. Davey et al. (2008), with the intention of analysing for nanophytoplankton, picophytoplankton, and total bacterial cell counts.

(2) Multinet

130 mesozooplankton samples were collected at 5 layers (50m, DCM, 200m, 400m and 700m) at 8 stations (K2b, M35, M30, WPS, M18, MR04, K8a, And M22) during this cruise. Four trawling operations were conducted at the Mega station, and two trawling operations were conducted at other key stations close to noon or midnight. Motoda sampler was used to divide the collected medium-sized zooplankton on the research ship. Half of the samples were put into 200mL plastic bottles, and 5% neutral formaldehyde solution was added for fixation and preservation. ZOOSCAN was used to analyze the samples in the laboratory. The other half of the sample was frozen in a 200ml plastic bottle.

(3) Phytoplankton growth rate and microzooplankton grazing rate: dilution method
Methods:

The growth rate of phytoplankton and the grazing rate of microzooplankton were determined by dilution method (Landry & Hassett, 1982). We collected surface layer and DCM layer water through CTD, as well as surface water between stations into PC bucket.

The non-particle seawater was prepared by gravity filtration using a 0.2 um diameter membrane capsule filter. The non-particle seawater was first injected into 2.4L incubation flask according to the proportion of natural seawater 16.7% , 37.5% , 62.5% and 100% , each dilution gradient set two parallel, then slowly fill the natural seawater culture bottle with silicone tube, tighten the cap, up and down slowly invert several times to make the incubation water well mixed; The incubation bottle containing surface seawater was placed in the deck incubator for 24 h. The temperature was controlled by surface flowing water and the incubation bottle containing DCM layer seawater was placed in the laboratory. All treatments were completed within 1 hour after water extraction.

Before incubation, one sample of chlorophyll a (0.7-2um, 2-20um, >20 um), two samples of pico-phytoplankton (FCM) and one sample for lugols' microscopic examination were collected. At the end of incubation, samples of chlorophyll a, two samples for pico-phytoplankton (FCM) and lugols' microscopic examination were collected from each incubation bottle. The fractionated chlorophyll a samples were filtered, extracted and determined by Turner Trilogy Fluorimetry, and one sample for FCM was determined by Cytosub on board. The remaining samples were taken back to the land-based laboratory for analysis.

(4) Bacteria Respiration

Methods:

Size fractionated respiration was estimated based on in vitro INT reduction rates as described by Elena et al (2019). Sampling was done at 8 layers in the euphotic zone. Four 100 mL polypropylene plastic bottles were filled with seawater. One bottle was immediately fixed by adding formaldehyde (2% final concentration) as a blank. Fifteen minutes later, the four replicates were inoculated in the dark by addition of 2-para (iodophenyl)-3(nitrophenyl)-5(phenyl) tetrazolium chloride tetrazolium salt (INT) at a final concentration of 0.8 mM. The INT samples were incubated at the in situ temperature. After incubations of 1.5 h, the reactions were stopped by adding formaldehyde. All samples were sequentially filtered after 15 min through 0.8 and 0.2 μm pore size polycarbonate filters and stored frozen until further processing. The INT_f reduction rates were measured using a SP 8001 UV/Vis Spectrophotometer at 485 nm.

(5) Primary Productivity

Methods:

Water samples were collected at 8 layers according to the CTD's PAR data, which were spiked by ^{14}C. After incubation on the board, the water sample was filtered onto filter membranes, which were then stored at -4°C in dark. The radioactivity of ^{14}C was measured using liquid scintillation counting to get DPMs, which were used to calculate the primary productivity.

4.7.2. N_2 Fixation Rates and Diazotroph Compositions

Introduction:

The N_2 fixation is a key process which provides bioavailable nitrogen for the growth of phytoplankton that lives in the euphotic zone. In some area of the oligotrophic open ocean, the flux of such "new nitrogen" from N_2-fixers equals that by diffusion from deep waters, substantially supporting the primary production and subsequently the export production. In this context, N_2 fixation rates as well as the diazotroph composition were measured during this cruise. In addition, deck-based incubation experiments were conducted by adding Fe and P alone or simultaneously to understand the limiting nutrient of N_2 fixation across the NPSG.

Objectives:

(1) Determining spatial distribution of N_2 fixation rates and diazotroph in the western NPSG.

(2) Exploring response of N_2 fixation to the addition of Fe and P alone or simultaneously.

Sampling and Parameters:

Regular CTD Sampling System: At each station, seawater from 6 layers in the upper DCM was collected to measure the N_2 fixation rate, primary production, Diazotroph composition, Chl-a and POC/PON.

Underway Sampling: Surface seawater was collected at 109 sites to measure the N_2 fixation rates, primary production, diazotroph composition and POC/PON.

Deck Incubation (including Turner Design & FRRF): 7 Fe and/or P addition experiments were conducted at selected stations. Subsamples for N_2 fixation rates, primary production, diazotroph composition and POC/PON were collected.

4.7.3 UV Effects on Primary Productivity

To investigate the effects of ultraviolet radiation on primary production of phytoplankton community, two treatments (PAR or PAR+UV-A+UV-B) were applied by covering different light filters. Surface seawater was collected before sunrise, filtered (180 μm) to remove large grazers and dispensed into quartz tubes. Temperature was controlled using the surface seawater. Photosynthetic carbon fixation was determined by inoculating 10 μCi $NaH^{14}CO_3$ in 50 ml samples, incubating for several hours and measuring the incorporated radioactivity by liquid scintillation counting. 878 samples were harvested up during the cruise.