Form 3

Annual Report

LaMer, Ehime University

Date (23 , 2 , 2017)

To Director of LaMer

Principle Investigator:

Affiliation Ocean University of China, OUC

Position Professor

Name in print Huiwang Gao

Include the report on the result of the project/meeting in a separate sheet.

1. Project / Meeting title

Contrasting effects of Asian dust and haze on dynamics of phytoplankton growth in the Northwest Pacific and Yellow Sea

2. Members of project / meeting

Name	Affiliation	Position	Contribution part
PI			
Huiwang Gao	Ocean University of China, OUC	Professor	Important idea; Make plan; Beneficial discussion
Members			
Chao Zhang	Ocean University of China, OUC	PHD candidate	Data processing; Paper writing
Xiaohong Yao	Ocean University of China, OUC	Professor	Beneficial discussion
Xinyu Guo	Ehime University	Professor	Beneficial discussion

Title

Contrasting effects of Asian dust and haze on dynamics of phytoplankton growth in the Northwest Pacific and Yellow Sea

Members' names and affiliations

Name	Institution and Department	Employment position	E-mail
Chao Zhang	Ocean University of China, OUC	PHD candidate	llyz_c3911@163.com
Xiaohong Yao	Ocean University of China, OUC	Professor	xhyao@ouc.edu.cn
Xinyu Guo	Faculty member of LaMer	Professor	guoxinyu@sci.ehime-u.ac.jp

Aim

This project aims to carry out cooperative research with Prof. Guo Xinyu of Ehime University on improving the studies of on-board microcosm experiments and marine ecosystem dynamics of regional seas, especially in the Northwest Pacific, and promoting cooperation and students exchange between the College of Environmental Science and Engineering of OUC and the Center for Marine Environmental Studies (CMES) of Ehime University.

Procedure

The principal investigator (PI) has first made an oral presentation "Contrasting effects of Asian dust and haze on dynamics of phytoplankton growth in the Northwest Pacific and Yellow Sea" and showed the recent studies including:

1. The stimulation effect of dust on phytoplankton growth was more pronounced in oligotrophic waters than in upper trophic waters.
2. Additions of dust and lower haze particles led to a shift in phytoplankton size towards larger cells over the duration of the experiments due to their dissolved bioavailable nutrients, while treatment with higher haze particles towards smaller size due to its toxic effect.
3. The possible toxic threshold of haze in seawater was 0.4 mg/L~2 mg/L, suggesting different haze weather conditions could induce different responses of phytoplankton size structures and primary productivity.

Moreover, the PI visited the laboratory of the Center for Marine Environmental Studies and discussed the idea about on-board microcosm experiments and marine ecosystem dynamics with scholars. From the discussions, we understand the study areas on each side (OUC and CMES of Ehime University) and reach an agreement that we will carry out further research with Prof. Guo Xinyu at CMES on the subject "The analytical solution of nitracline with the evolution of subsurface chlorophyll maximum in stratified water columns."

Results

On-board microcosm experiments were conducted in different oceanic regions including the Northwest Pacific Ocean (NWPO), Yellow Sea (YS) and Eastern China Sea (ECS) during the spring cruise by R/V *Dongfanghong* 2 in 2014 and 2015 (Fig. 1). Chl *a* and nutrient data demonstrated that the trophic levels decreased from seawaters at PN3 in ECS, to B7 and H10 in YS, to K4 and A1-b in the *Kuroshio* Extension, and to Ar4 and G7 in the subtropical gyres of NWPO. Besides, through the nutrient enrich experiments, we concluded that phytoplankton were primarily co-limited by NP at Ar4 and G7, limited by N at K4, A1-b and H10, limited by P at B7 and PN3, respectively (Fig. 2&3).

The addition of dust increased Chl *a* increases more significantly at Ar4, G7 than K4, H10 and B7 (Fig. 2). The maximum Chl *a* concentrations through the incubation experiments at Ar4 and G7 were 1.7-fold and 2.8-fold higher than those in the controls, respectively. While less than 1.3-fold increases compared to control in the maximum Chl *a* were observed at K4, H10 and B7. In oligotrophic waters of Ar4 and G7, the addition of dust provided considerable N, P and Fe to support phytoplankton growth relative to the nutrient stocks in the seawaters. However, the contribution of the nutrients provided by dust decreased with increasing trophic levels. As a result, the effects of dust deposition on phytoplankton growth were larger in oligotrophic waters than in upper trophic waters. Besides, compared to the controls, increased contributions of micro-sized Chl *a* to total Chl *a* as well as abundance of large sized phytoplankton (>5 μm) were observed in dust treatments at all stations, suggesting the addition of dust led to a shift in phytoplankton size towards larger cells (Liu et al., 2013).

It is obviously that additions of high haze (2 mg/L) inhibited phytoplankton growth in term of Chl *a* and large phytoplankton abundance, especially in micro-sized phytoplankton (Fig. 2&4). Moreover, after 5 days of the incubation experiments, an increased contribution of pico-sized Chl *a* were observed at Ar4, G7, H10 and B7, indicating the addition of high haze led to a shift in phytoplankton size towards smaller cells. Haze particles contain high soluble heavy metals such as Cu, which may cause an inhibition effect on phytoplankton growth. The ratios of added Cu (from haze particles)/total Chl a (μg $μg^{-1}$) concentration were 0.48, 0.16, 0.04 and 0.05 for the station Ar4, G7, H10 and B7, respectively. The ratio at station Ar4 was higher than the Cu toxic threshold, 0.2-2 μg Cu/μg Chl *a* indicated by *Paytan* et al. (2009). The opposite was true for other stations. Moreover, we also added Cu (comparable to dissolved Cu from high haze particle treatment) and N to the seawater at A1-b with the calculated Cu to initial Chl a ratio of 0.23μg μg-1, reaching the Cu toxic threshold. But we did not see an inhibition effect of Cu (Fig.2). These results suggest that the toxic effects of haze particles under high mass loading in seawater may be not directly originated from Cu. Considering substantial contents of heavy metals and organic compounds in haze particle, the toxicity of haze on phytoplankton prefers to be a combined function resulted from various toxic substances e.g. Cu, Pb, Cd (Miao et al., 2005) and some toxic organic compounds such as phenanthrene and pyrene etc (Echeveste et al., 2010), which needs to be further investigated. In addition, note that the inhibition effect on phytoplankton growth at Ar4 was larger than that at K4, H10 and B7 (Fig.2&4). The higher substantial dissolved organic compounds indicated by high Chl a concentrations at K4 and H10 might have a mediating effect on the toxicity of haze particle to phytoplankton.

The addition of low haze (0.4 mg/L) stimulated phytoplankton growth at A1-b (Fig. 2). This is because the added haze provided considerable N nutrients to relieve the N limiting condition of phytoplankton. Combined with the results of high haze additions, we concluded that the toxicity threshold of haze to phytoplankton growth fell in between 0.4 mg/L and 2 mg/L.

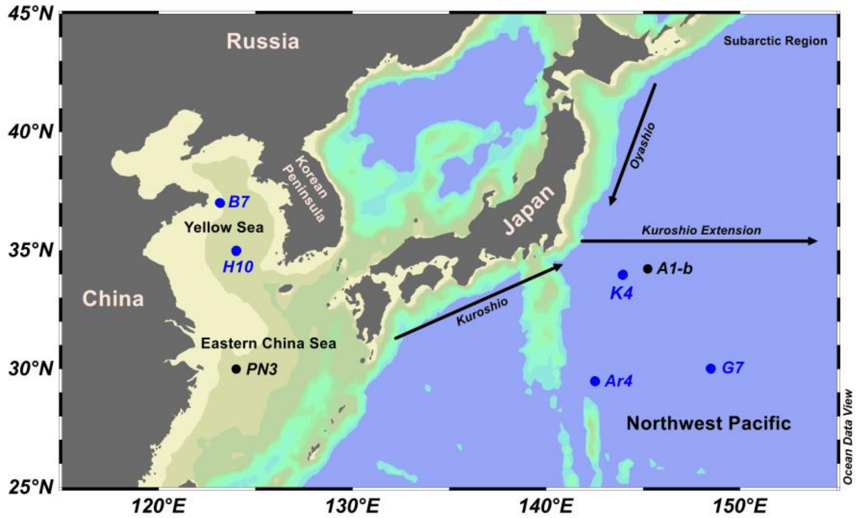

Figure 1 Maps of the sampling stations used for microcosm incubation experiments. Blue dot means stations carried out in 2014, black dot means stations carried out in 2015.

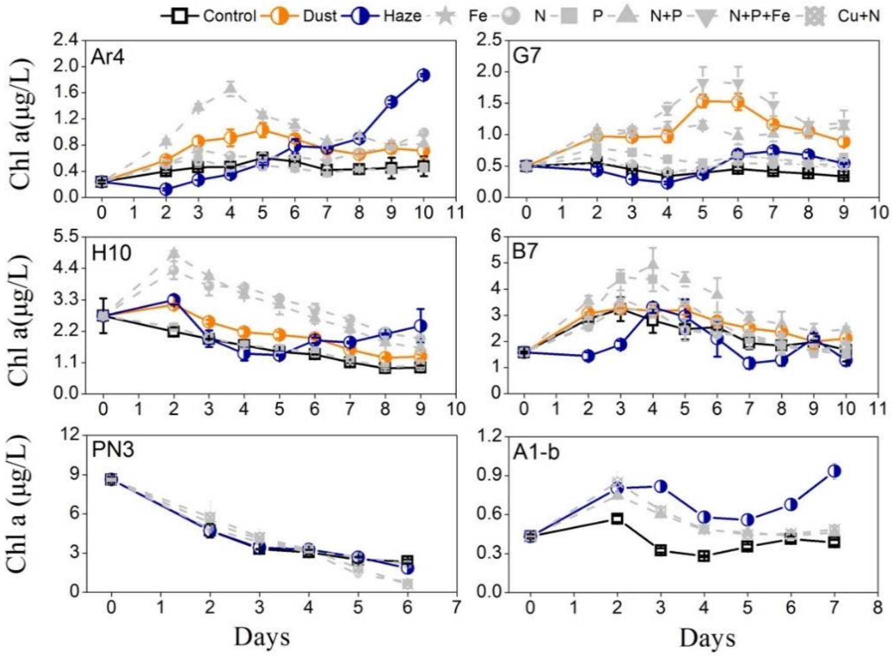

Figure 2 Changes of Chl *a* concentrations in control, dust, haze and various nutrient treatments during the incubation experiments

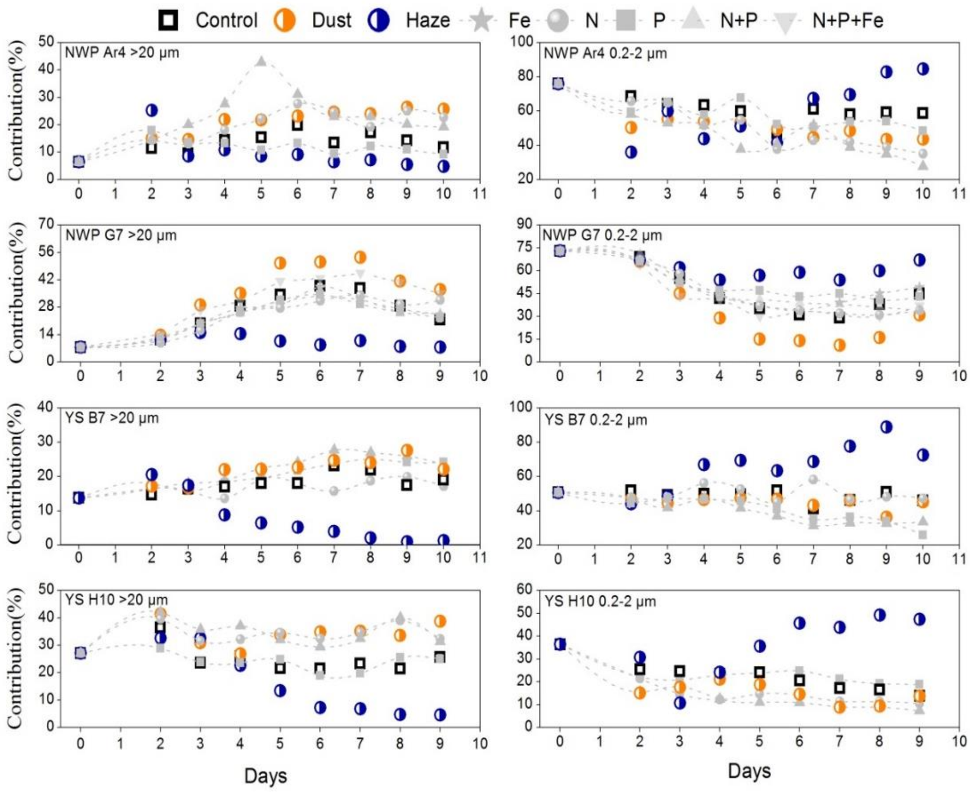

Figure 3 Contributions of micro-(>20 μm) and pico- (0.2-2) sized Chl *a* to total Chl *a* at Ar4, G7, H10 and B7.

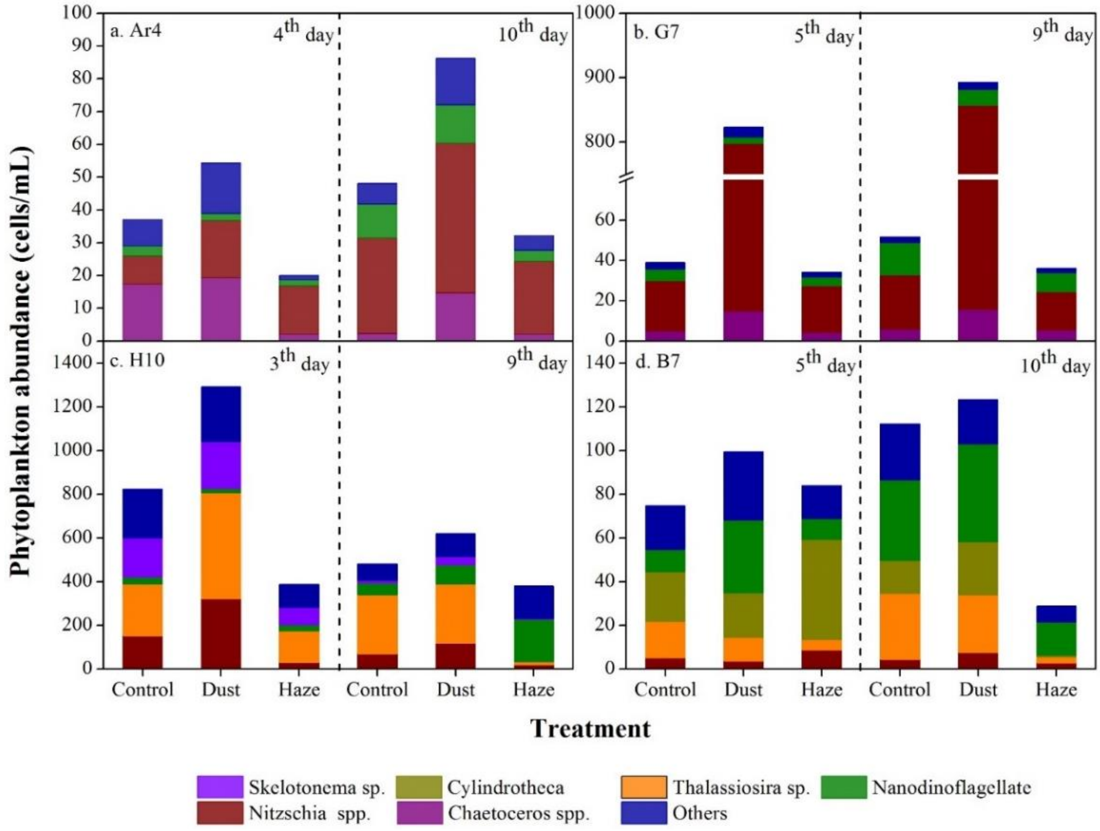

Figure 4 Changes in taxonomic structure of large phytoplankton community during the incubation experiments.

References:

Echeveste, P., Dachs, J., Berrojalbiz, N. & Agustí, S. Decrease in the abundance and viability of oceanic phytoplankton due to trace levels of complex mixtures of organic pollutants. Chemosphere 81, 161-168 (2010).

Liu, Y., Zhang, T., Shi, J., Gao, H. & Yao, X. Responses of chlorophyll a to added nutrients, Asian dust, and rainwater in an oligotrophic zone of the Yellow Sea: Implications for promotion and inhibition effects in an incubation experiment. Journal of Geophysical Research: Biogeosciences 118, 1763-1772 (2013).

Miao, A. J., Wang, W. X. & Juneau, P. Comparison of Cd, Cu, and Zn toxic effects on four marine phytoplankton by pulse‐amplitude‐modulated fluorometry. Environmental toxicology and chemistry 24, 2603-2611 (2005).

Paytan, A. et al. Toxicity of atmospheric aerosols on marine phytoplankton. Proceedings of the National Academy of Sciences 106, 4601-4605 (2009)

Publication/conference presentation

Conference:

1. The Surface Ocean- Lower Atmosphere (SOLAS) Open Science Conference 2015, Kiel, Germany, 2015.9.7 - 2015.9.11
   Poster: Nutrients-oriented fertilization effects of Asian dust on surface phytoplankton in Northwestern Pacific ocean
2. The Surface Ocean- Lower Atmosphere (SOLAS) in Asia: a Future SOLAS Symposium, Qingdao, China, 2016.10.27 - 2016.10.28
   Presentation: Contrasting effects of Asian dust and haze on dynamics of phytoplankton growth in the Northwest Pacific and Yellow Sea

Oral presentation (LaMer):

Title: Contrasting effects of Asian dust and haze on dynamics of phytoplankton growth in the Northwest Pacific and Yellow Sea
Lecturer: Huiwang Gao.
Time: December 26, 2016.
Location: Ehime University.

Perspectives in future

We will investigate the analytical solution of nitracline with the evolution of subsurface chlorophyll maximum in stratified water columns and to estimate the nutrients fluxes across the nitracline, which will deepen our understanding on the variations of primary production. We will enhance the cooperation researches and exchanges of faculties and students between the Ocean University of China and CMES of Ehime University.