Long-term observations of the impacts of global warming on air quality and marine deposition in Asia and the Pacific
（**Abstract of the Final Report**）

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1. Introduction

Some of air pollutants including tropospheric ozone and black carbon have positive radiative effects. Hence, they are collectively called "short-lived climate forcers (SLCFs)" in contrast to long-lived greenhouse gases (LLGHGs) such as carbon dioxide. Owing to its short lifetime in the atmosphere, great attention has been paid to the reduction of SLCFs emissions, in response to the urgency of climate change mitigation. Not only climate impacts, tropospheric ozone and aerosols have strong detrimental effects on human health. The negative effects of tropospheric ozone are not limited to those on human health, but also on forest trees and agricultural crops.

By contrast, climate change has substantial impacts on air quality. The concentration of air pollutants, both gaseous and particulate pollutants, is affected by meteorology including temperature, wind, precipitation, and solar radiation. Hence, changing climate affects the levels, variabilities and trends of air pollutants. Nitrate, one of air pollutants, can act as nutrient, once it is deposited onto the ocean surface. Therefore, the impacts of climate change on air pollutants can be further connected to the marine biogeochemistry.

Many of these SLCFs, key species controlling air quality, are emitted into the atmosphere from the combustion sources, including anthropogenic, biomass burning and biofuel burning emissions. East and Southeast Asia are thought to be a large source region of these species, and the emissions have been increasing due to expanding human dimensions and developing socioeconomic activities.

2. Research Objectives

In contrast to modeling studies, the observational studies of SLCFs in the atmosphere over the open oceans have been very limited, because of limited availability of the observing capability. Therefore, long-term, systematic observations are needed to obtain observational evidence of the levels, variabilities and trends for the SLCFs. Here, we utilize three cargo-ships in operation between Japan and any of Oceania, North America, or Southeast Asia, as volunteer observational ship (VOS) platforms. The VOS observations have an advantage to achieve wide coverage over the open oceans with relatively high frequency for the target observation areas. We aim to fill the gap in the global observing system of atmospheric composition by making regular observations in the Asia-Oceania regions using the VOS platforms.

3. Research Methods

(1) Volunteer Observational Ship Platform

Figure 1 illustrates the standard routes of the three cargo-ships. For the Southeast Asian route, the ship ships depart Japan and makes every 4-week cruise, visiting Hong Kong, Thailand, Singapore, Malaysia, Indonesia and Philippines. For the Oceania route, the ship ships depart Japan and makes every 6-week cruise, visiting Australia and New Zealand. For the North America route, the ship ships depart Japan and makes every 8-week cruise, visiting Canada and the East Coast of the United States.

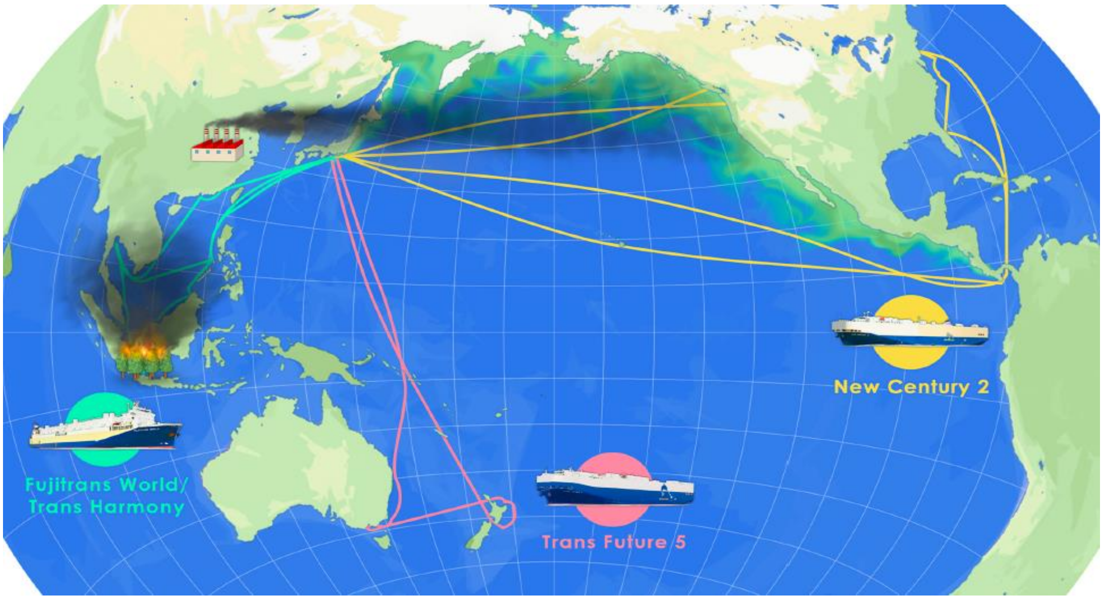

Figure 1. Standard routes of the cargo-ships between Japan-Oceania, -North America, and -Southeast Asia.

(2) Measurement and Sampling System

Onboard the three cargo-ships, we install atmospheric measurement systems for SLCFs as well as LLGHGs. The instrument system includes continuous monitors of ozone, carbon monoxide, carbon dioxides, methane, nitrogen oxides, sulfur dioxides, and aerosols. For the analysis of nutrients and chlorophyll, seawater samples are collected at the frequency of 2–3 times each day. These samples are transported to the laboratory for the subsequent analysis.

4. Results and Discussions

Figure 2 shows the seasonal maps of tropospheric ozone observed by the three ships. The concentration levels of tropospheric ozone show clear enhancements in the northern mid-latitudes, in particular, in winter and spring, and to some extent, in autumn. It is also noted that the mid-latitude enhancement is seen over the wide area from west to east of the North Pacific. Also, the ozone enhancements are seen along the subtropical Asian continental rim regions, indicating active photochemistry in the presence of substantial amounts of ozone precursors emitted from the continental sources. In tropical Asia, the ozone levels are typically lower than in the subtropical regions.

Since the atmospheric lifetime of aerosols is very short, the distributions and variabilities of aerosols are larger than those of tropospheric ozone. The PM2.5 concentration levels are enhanced near the Asian continent, in particular, close to the large cities, while the levels are near zero over the open oceans. Figure 3 shows the seasonal variations of PM2.5 and black carbon concentrations obtained by the Southeast Asian cruises, for the areas of South China Sea and Thailand Bay. In general, both PM2.5 and black carbon aerosol show the winter-spring maximum and the summer minimum. It is interesting to note that the concentration levels are higher in Thailand Bay than in South China Sea, for both PM2.5 and black carbon, suggesting substantial emission sources of particulate matters in Southeast Asia.

Figure 4 depicts the latitudinal distributions of chlorophyll and nutrients (i.e. nitrates and nitrites) by the Oceania cruises. They show episodic enhancements over the general latitudinal features having small enhancements in the subtropics. It is remarkable to see large enhancements in the southern mid-latitude for both chlorophyll and nutrients, possibly due to the influence from the Southern Ocean.

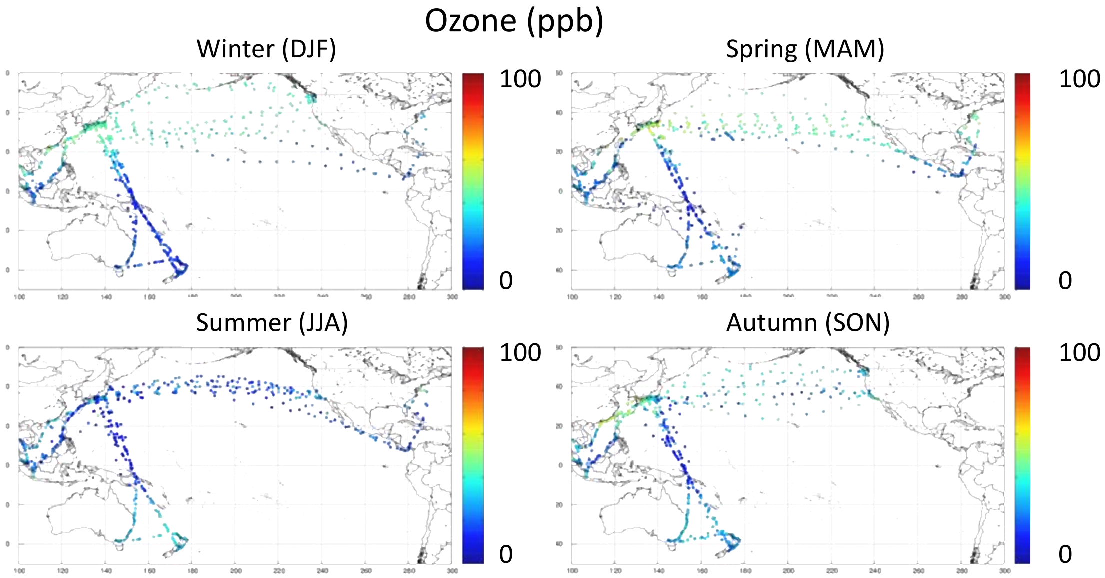

Figure 2. Seasonal climatology of tropospheric ozone over the open oceans.

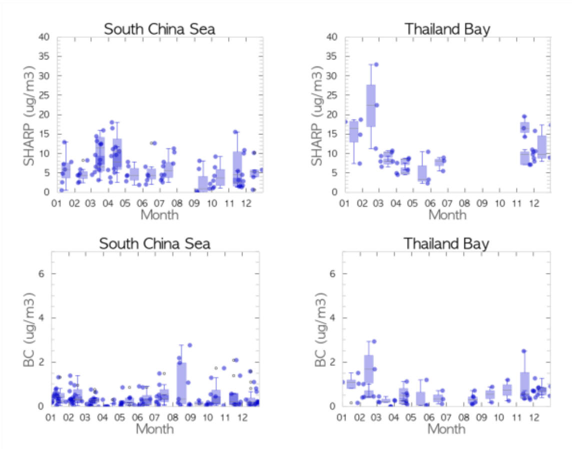

Figure 3. Seasonal variations of PM2.5 (as the SHARP method, top) and black carbon aerosol (bottom) in South China Sea and Thailand Bay.

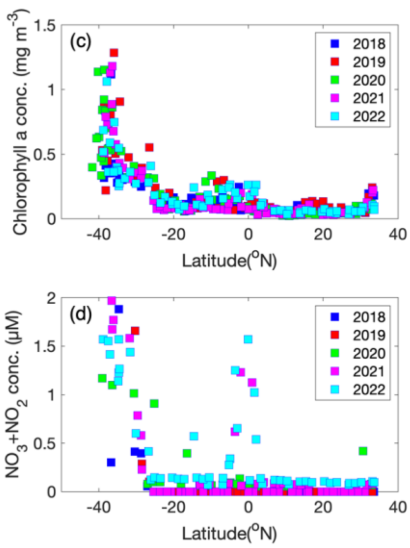

Figure 4. Latitudinal distributions of chlorophyll and nutrients (nitrates and nitrites) by the Oceania cruises.