Impact of Atmospheric Input on Marine Phytoplankton

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Abstract

The goal of this study is to analyze the impact of East Asian dust on the primary production over the Northwestern Pacific Ocean (NWPO). We compared monthly mean chlorophyll-a concentration observed from SeaWifs and dust deposition simulated from a regional atmospheric dust model, and found the correlation between them is high (0.6~0.8) over 30~40°N of NWPO. This result shows that dust deposition maybe a key factor for primary production in that area. Form event study we found some dust events (with deposition more than 1 $mg/m^2/day$) correspond well with phytoplankton bloom episodes with fast response time.

Introduction

Marine phytoplankton is the basis of ocean ecosystem. It can absorb carbon dioxide and release DMS [Dacey et al., 1986], both of which can bring up negative feedbacks to climate forcing. The main nutrient sources of phytoplankton come from river, bottom of the ocean due to mixing, as well as atmospheric inputs from aerosols and trace gases. Martin [1988] proposed the famous Iron Hypothesis, which pointed out that iron is the limiting nutrient of phytoplankton growth in some marine regions. Later, a few iron experiments, such as SEEDS [Tsuda et al., 2003], supported that the increase of iron input in those regions may indeed enhance phytoplankton growth.

In natural environment, iron input to the ocean mostly comes from the deposition of atmospheric dust [Duce, 1986; Fung et al., 2000]. Therefore, the goal of this study is to analyze the impact of East Asian dust on the marine phytoplankton over the NWPO.

Method

We used a dust deflation and transport model to simulate dust deposition onto the oceans, and then compared simulation results with the phytoplankton concentration (in chlorophyll-a) observed by the NASA/SeaWiFS (Sea-viewing Wide Field of view Sensor) Satellite for the period of January 2001 to December 2005. At the same time, we also used aerosol optical depth (AOD) observation from MODIS (Moderate Resolution Imaging Spectroradiometer) to verify the model results and compare with the observed phytoplankton concentration. In addition, as anthropogenic pollutants are not only potential nutrient sources but may also transform Fe(III) into Fe(II) that can be utilized by phytoplankton. So we also applied a regional air pollution model to simulate the deposition of air pollutants, nitrate in particular, in the event study.

Results and Discussion

From the analysis of monthly data, we found high correlations between chlorophyll-a and dust deposition (correlation CA) over 30~40^{o}N of NWPO. But correlations between chlorophyll-a and AOD (correlation CD) is high over somewhat lower latitudes of 25~35^{o}N (Figure 1). Form the time series of monthly-averaged AOD, chlorophyll-a, and dust deposition shown in Figure 2, we found the following.

(A) Correlation CA and correlation CD are mostly lower than 0.3 in 40~50^{o}N. This indicates that other factors such as ocean mixing may be important in this area.

(B) The high correlation CD over the region 30-40^{o}N indicated that dust may be a key factor for the growth of phytoplankton in this area. On the other hand, discrepancies between correlations CA and CD over this area may result from the fact that AOD is a column property, cannot represent well the real dust deposition.

(C) Because AOD included air pollution, so the differences between correlation CA and correlation CD over 20~30^{o}N are possibly resulted form the air pollution which raises AOD and provide nutrient to phytoplankton.

(D) Low correlation over 10~20^{o}N may result form low values of both chlorophyll-a and dust deposition (shown in Figure 2).

Through event studies we also found phytoplankton blooms (Figure 6) happen quickly after the passage of dusty air masses (Figure 5). We show 3 events of dust arrival following the cold front massage (high pressure, decreasing SST) on Feb. 27 (event A), Mar. 5 (event B) and Mar. 14 (event C) in 2004 (Figure 3 and Figure 5). In event A, phytoplankton bloomed at the same time that nitrate and dust arrived; In event B, phytoplankton bloomed sometimes after the arrival of nitrate and dust; where as in event C, nitrate arrives first then dust and chlorophyll-a rise together. There are two possible reasons for the time lag in event B and C. The first is that nitrate do provide necessary nutrient (for low nutrient zone) but the biological response time is slow, and the other reason is that nitrate is not a limiting nutrient (for high nutrient zone).

Conclusion

Correlations between dust deposition and chlorophyll-a is high (0.6~0.8) over 35^{o}N~40^{o}N region of NWPO, which indicates the influence of dust deposition on phytoplankton bloom. Through event studies we found dust events seem to correspond well with phytoplankton bloom episodes with fast response time, and significant increase of chlorophyll-a occurs when the dust deposition is more than 1 mg/m^2/day. Moreover, anthropogenic pollutants may play an important role in phytoplankton bloom.

Reference

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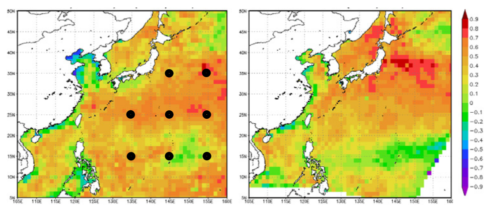

Figure 1: Correlation of monthly mean AOD and chlorophyll_a (left) is high over 25~35oN of NWPC; but the correlation of dust deposition and chlorophyll_a (right) is high over 30~40 oN of NWPC

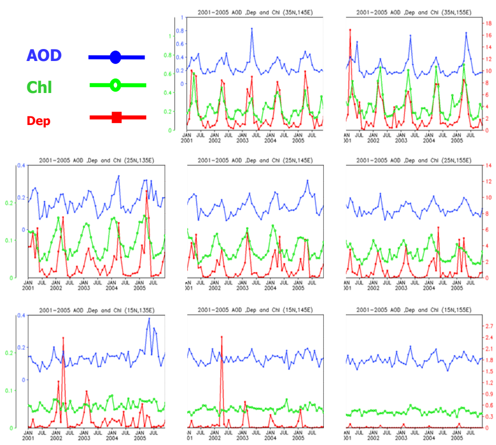

Figure 2: Monthly mean of dust dep., AOD and Chl_a. Locations of these panels are indicated by the black circle in Figure 1

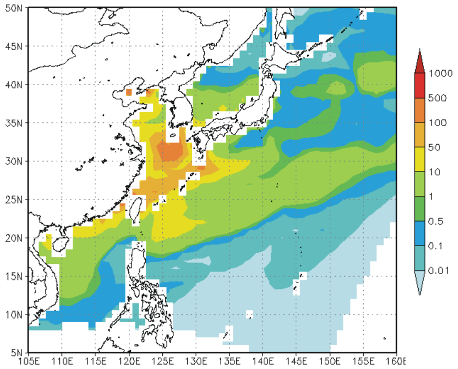

Figure 3: 2004/03/05 dust deposition (unit: mg/m2/day)

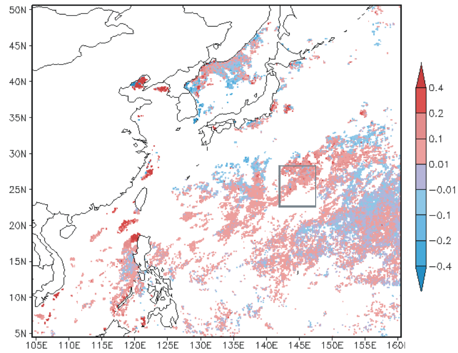

Figure 4: Increase of weekly mean chlorophyll-a after the dust event on 2004/03/05 (unit: mg/m3)

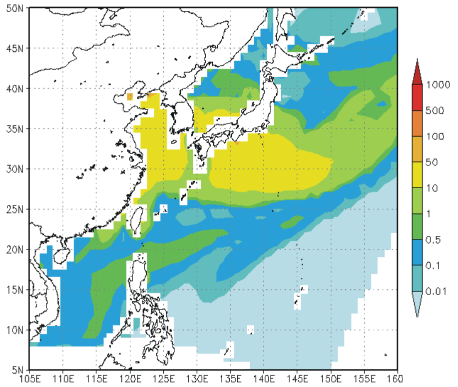

Figure 5: Same as Figure 3 but for 2004/03/14

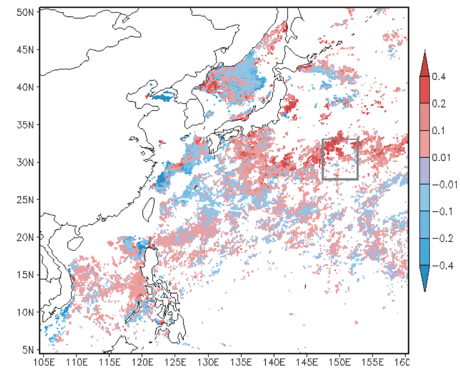

Figure 6: Same as Figure 4 but for 2004/03/14

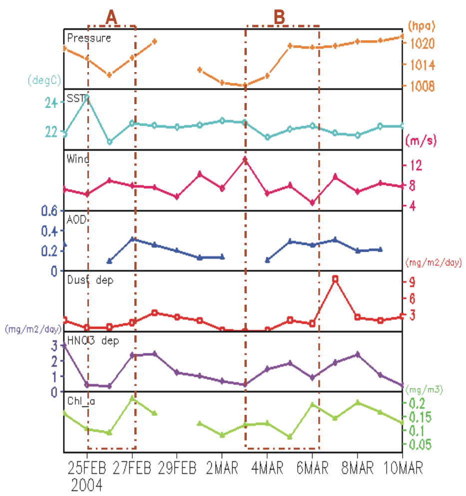

Figure 7: Time series of sea surface pressure (NCEP FNL), SST (TRMM), Wind (Qscat) , MODIS-observed AOD (MODIS), dust dep. (TAQM/kosa), nitrate (TAQM) and chl-a (SeaWiFS) for event A and B at 25 °N,145 °E (grey square in Figure 6)

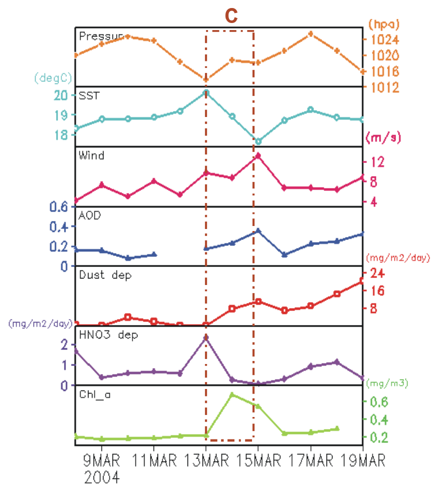

Figure 8: Same as Figure 7 but for event C at 30 °N,150 °E (grey square in Figure 6: Same as Figure 4 but for 2004/03/14)