— GROUP 7 REPORT —

SPATIAL DISTRIBUTION OF AIR-BORNE FE DEPOSITION INTO THE NORTHERN NORTH PACIFIC

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INTRODUCTION

Mineral dust containing Fe from the Asian continent is transported eastward over the North Pacific, especially in spring (Uematsu et al., 1983). The air-borne Fe is considered to be the only one source of input in the central part of the northern North Pacific. In fact, it was found that a near doubling of biological productivity was observed in the mixed layer in the North Pacific over a 2-week period after the passage of a cloud of Gobi desert dust (Bishop et al., 2002). The Amur-Okhotsk Project proposes that main source of dissolved Fe in the Sea of Okhotsk and Oyashio region associated with bio product is the Amur River. However, the contribution of the air-borne Fe to the biological productivity in the Sea of Okhotsk cannot be negligible. Therefore, we have to precisely evaluate the contribution of air-borne Fe deposited on the Sea of Okhotsk. In order to estimate flux of air-borne Fe transported from the Asian continent to the Sea of Okhotsk, we have carried out aerosol sampling at Oktyabr'sky, Kamchatka, Russia, and Toikanbetsu, Kushiro at Hokkaido, Japan. Here we report the spatial variation of Fe deposition into the Sea of Okhotsk and Oyasho region, and evaluate the impact of the air-borne Fe on biological productivity at Oyashio region.

AEROSOL SAMPLING

Aerosol sampling at Oktyabr'sky

Oktyabr'sky is in the southwestern part of the Kamchatka Peninsula (Fig1). It is in a middle of sandspit which faces the Sea of Okhotsk on the west side, and the Bolshaya River and wetland on the east side. A high volume aerosol sampler system (ACS-21: Kimoto Electric Co., LTD.) was installed in a small house facing the Sea of Okhotsk in the middle of Oktyabr'sky in October 2005. The sampler was established on the 2nd floor of the house, and connected a polyvinyl chloride pipe which was penetrated through a roof of the house. Ambient air was inhaled through the pipe by a pump. Aerosol in air was aerodynamically classified into coarse particle (>2.5μm) and fine particle (<2.5μm) by an impactor attached onto the filter unit, and was collected on Teflon filters (PF040, 90mm diameter: Toyo Roshi Kaisha , Ltd). Coarse particle and fine particle were concentrically collected on the central part and outer part of the filters, respectively. The filter was settled in a plastic cassette case.

The cassette case was automatically changed once every one week. The filters was refrigerate after sampling

The sampler system has a computer to record data of sampling condition (flow rate, running time and so on) and meteorological conditions which are monitored by an aerovane and a thermometer installed on the roof of the house during sampling. The sampler also has a control unit to confine the meteorological condition when the sampler runs. We could saw two chimneys of factories or power stations in Oktyabr'sky from the roof of the house. To prevent from contaminating emission from their chimneys, aerosol was sampled only when wind direction was within 170-340° and wind speed was more than 1.0m·s^{-1}. The aerosol sampling was conducted from 19 October 2005 to 15 May 2006. During the sampling period, electric power failure sometimes occurred, and the plastic cassettes were not exchanged in scheduled date. The aerosol sampler was damaged by 300V of electrical current when electrical surging occurred at Oktyabr'sky on 15 May. The sampler has not been repaired yet, though we tried to repair it at several times. The aerosol sampling was managed by Institute of Volcanolgy and Seismology, FEB-RAS (Far East Branch, Russian Academy of Science), and ROSHYDROMET (Russian Federal Service For Hydrometeorology and Environmental Monitoring).

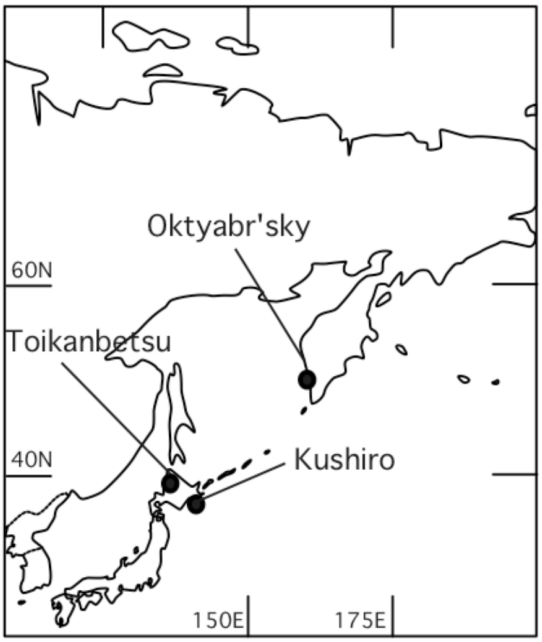

Figure 1 Location of the aerosol sampling sites

Aerosol sampling at Toikanbestu

Toikanbetsu is in the northern part of Hokkaido (Fig.1). A high volume aerosol sampler system (TE-PMD: Kimoto Electric Co., LTD.) was installed in an observation field in front of Teshio Field Science Center for Northern Biosphere, Hokkaido University. The aerosols were collected in the same way at Oktyabr'sky, but control system of wind sector was not used. A filter is changed once every one week by hand. The aerosol sampling was carried out from September 2007 to February 2008. The aerosol sampling was managed by Teshio Field Science Center for Northern Biosphere, Hokkaido University.

Aerosol sampling at Kushiro

Kushiro is in the eastern part of Hokkaido (Fig.1). A high volume aerosol sampling was installed on the loaf of Hokkaido National Fisheries Research Institute, Fisheries Research Agency which is in Katurakoi and faces Pacific Ocean. Aerosol was collected on Teflon filters (PF040, 200x250mm: Toyo Roshi Kaisha, Ltd) by a high volume aerosol sampler (SIBATA Co., LTD) without aerodynamically classification and wind sector control.

In addition to aerosol sampling, total deposition sampling was also carried out. Total deposition was collected by buckets filled by water (Fig. 2). The aerosol samplings were carried out from September 2007 to February 2009. The samplings were managed by Hokkaido National Fisheries Research Institute, Fisheries Research Agency, and W-PASS (Western Pacific Air-Sea Interaction Study).

Figure 2 Total deposition sampler at Kushiro.
Two Buckets filled by water were set in 1.8m heights on the roof of Hokkaido National Fisheries Research Institute, Fisheries Research Agency in Kushiro.

CHEMICAL ANALYSIS

The filters were divided into several fragments for chemical analysis of water-soluble substances and of total amount of chemical substances. To facilitate the measurement of the total component, the samples were digested in heated mixed acid (HNO_3, HF, $HClO_4$). The samples of deposition flux were added by 0.1% HCl, and leave at rest for more than 1 month before chemical analyses. The concentrations of chemical elements (Al, Fe, Ca, Mg, Mn, Na, Ti, Zn, Sr, Cr, Ba for Oktyabr'sky and Toikanbetsu; Al, Fe, Ca for Kushiro) were determined by an inductively coupled plasma atomic emission spectrometry and an atomic absorption spectrometry. Water-soluble components in the aerosol were extracted by 10 min ultrasonication with ultra pure water. The concentration of chemical component (Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, SO_4^{2-}) was determined by an ion chromatography. All chemical analysis was done in Tokai University and Institute of Low Temperature Science, Hokkaido University. In this study, we used only Fe data for results and discussions

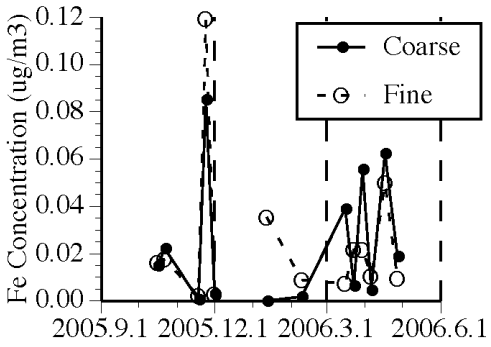

Figure 3 Temporal variation of concentration of Fe at Oktyabr'sky.

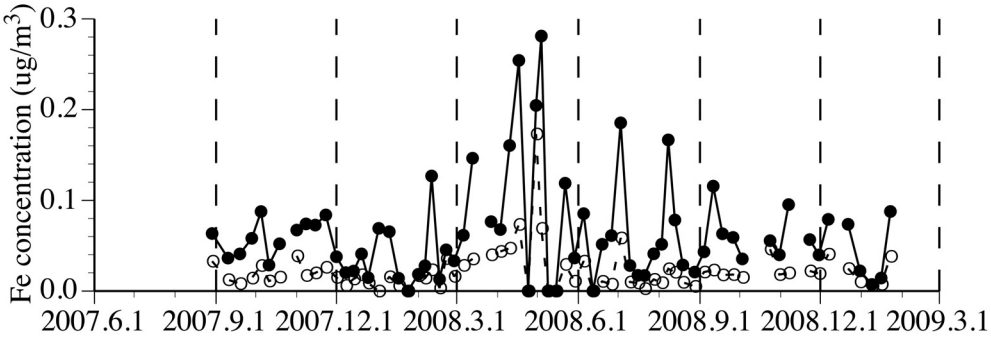

Figure 4 Temporal variation of concentration of Fe at Toikanbetsu.

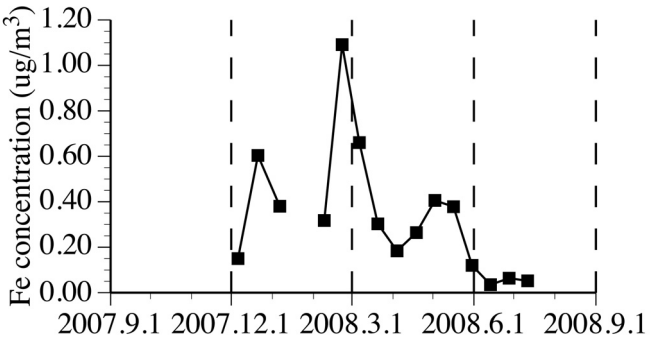

Figure 5a Temporal variation of concentration of Fe at Kushiro.

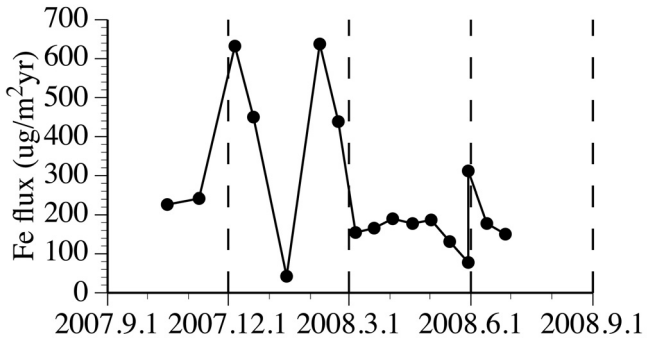

Figure 5b Temporal variation of flux of Fe at Kushiro.

RESULTS

Fig. 3, 4 and 5a show the temporal variations of Fe concentration of aerosols at Oktyabr'sky, Toikanbetsu, and Kushiro, and Fig. 5b shows the temporal variation of Fe deposition flux at Kushiro. The concentration of Fe in Oktyabr'sky was rather high from March to May, and showed sporadic peaks on 18-24 November, 5-12 April and 24 April to 3 May. In the beginning of April, and end of the April, low atmospheric pressures moved from Asian continent to Kamchatka peninsula. It seems that Asian dust was transported along the cold front with the traveling lows from Asian continent to Kamchtka. At Toikanbetsu, any significant dust events were not observed through the observation period, but the average of Fe concentration in spring was two times higher than the other seasons. At Kushiro, chemical analyses have not been finished yet. Fig 5 shows the data from October 2007 to June 2008. Fe concentration shows significant peaks in December 2007 and March 2008 corresponding to those of Fe deposition.

The concentration of Fe and the deposition of Fe at Kushiro are correlated with an r-value of 0.81 ($p<0.01$) (Fig. 6). The relation is presented as total deposition velocities of 2.2cm·s^{-1}. The value of 2.2cm·s^{-1} is comparable to those reported by several papers (e.g. Uematsu et al., 2003). We use this value to estimate the deposition flux of Fe from the concentration of Fe at Oktyabr'sky and Toikanbetsu, and obtained spatial variation of annual deposition flux of Fe (Fig. 7).

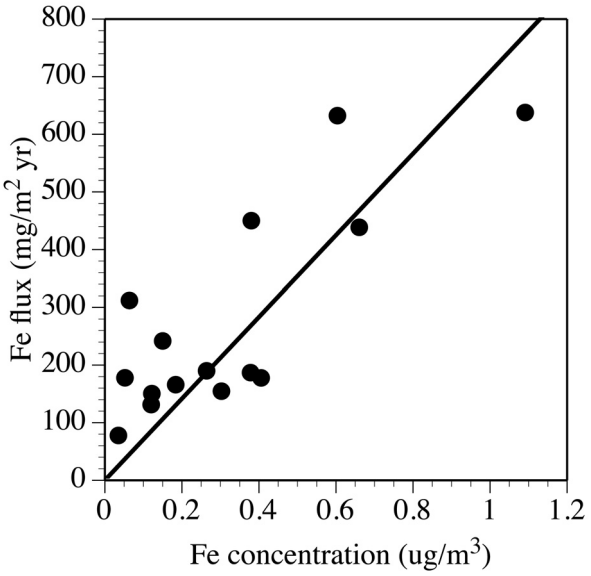

Figure 6 Relationship between Fe concentration and Fe flux at Kushiro.

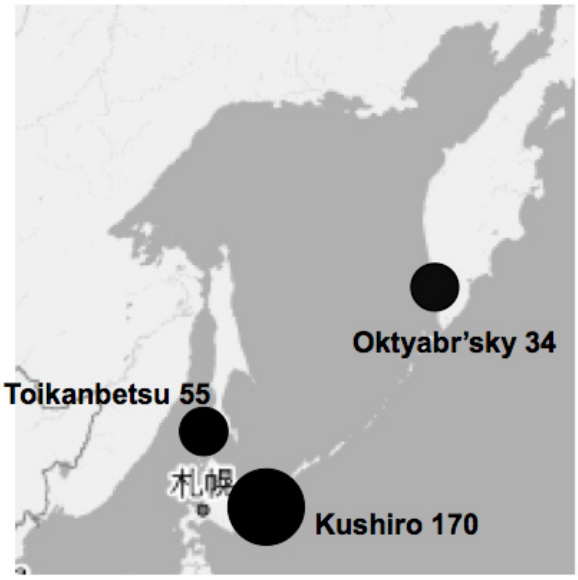

Figure 7 Spatial variation of annual air-borne Fe flux (mg/m^{2}yr).

EVALUATION OF AIR-BORNE FE IMPACT ON THE BIOLOGICAL PRODUCTIVITY IN OYASHIO REGION

In order to evaluate the impact of air-borne Fe on biological productivity, we compare air-borne Fe deposition flux to dissolved Fe flux supplied by ocean circulation at Oyashio region. Not all air-borne Fe can be soluble in seawater and available for phytoplankton. Most considerable factor is solubility of air-borne Fe in seawater. Solubility of air-borne Fe suggested by various kinds of studies ranged from 0.1 to 10%. We assume that reliable value of solubility ranges from 0.4 to 2.0 % (e.g. Ooki et al., 2008). Therefore, deposition flux of dissolved air-borne Fe at Toikanbestu is estimated to be 0.26-1.30 μmol/m^2·month in winter, summer, and autumn, and 0.52-2.60 μmol/m^2·month in spring.

Nishioka (personal communication) estimated Fe flux from deeper part to mixing layer to Oyashio region from seasonal variation of dissolved Fe in surface water. The fluxes are estimated to be 1.25 μmol/m^2·month caused by vertical mixing from December to April when mixing layer is formed, and 0.44 μmol/m^2·month caused by vertical advection from May to November when ocean stratifies. Schematic of seasonal variation of fluxes into mixing layer from atmosphere and deeper part Oyashio region is shown in Fig.8. In brief, main source for the increase of dissolved Fe in surface water of Oyashio region is vertical mixing in winter when vertical mixing is dominant, and is both of vertical advection and air-borne dust after stratification of Oyashio region. We should notice that the estimated flux from deeper part of ocean is net value taking into account of scavenging process of dissolved Fe. On the other hand, estimated flux from atmosphere is actual gross value without any consideration of the behavior of air-borne dust and Fe in seawater. In order to quantify the contribution of air-borne Fe precisely, we should consider residence time of air-borne dust, residence time and scavenging rate of dissolved Fe as well as solubility of air-borne Fe. These factors remain largely unknown and require more research including the studies of aerosol chemistry and marine chemistry.

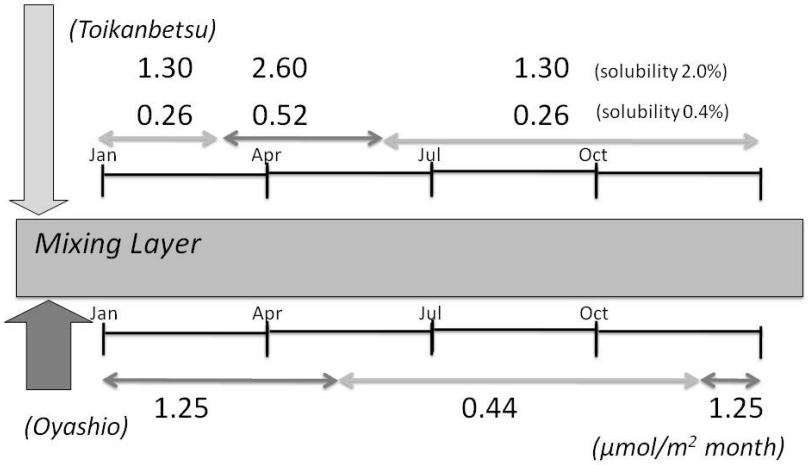

Figure 8 Schematic of Fe flux from atmosphere and deeper part of ocean to the mixing layer at Oyashio region

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