Press Releases

August 31, 2016
JAMSTEC

Significant Correlations between Wet Removal Rates of Black Carbon and Accumulated Precipitation

- New findings for more accurate evaluation of black carbon impacts on global warming -

Overview

A research team led by Dr. Yugo Kanaya at Department of Environmental Geochemical Cycle Research, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC: Asahiko Taira, President) carried out long-term observation of atmospheric black carbon (BC)[*1] mass concentrations at Fukue Island, Nagasaki Prefecture in Japan (Figure 1), using a continuous soot-monitoring system for six years from 2009 to 2015. Detailed analysis of these data presented significant correlations between wet removal rates of BC and accumulated precipitation. This work was carried out in collaboration with Institute of Atmospheric Physics in China, Kyushu University and National Institute of Polar Research.

BC, a component of PM2.5 aerosols[*2], is regarded as a major contributor to global warming. It is originally hydrophobic when emitted but then converts to hydrophilic particles by coagulation with other particles during atmospheric transportation ("aging" effect as shown in Figure 2). By accumulating long period data for the first time, the research team's analysis found that 1) the "aging" process of BC rapidly progresses over the East China Sea immediately after emission from source regions such as China and Japan, and completes before reaching Fukue, and 2) the removed fraction could be predicted as a function of the accumulated precipitation. These new findings, brought by examining BC concentrations with carbon monoxide (CO), which is not removed by rainfall (Figures 3-5), will be used to test and improve chemistry and climate models. They will also contribute to more accurate assessment of the impact of BC on global warming by the Intergovernmental Panel on Climate Change (IPCC).

More data will be collected using JAMSTEC's research vessel, *Mirai*, to further verify how far BC particles and PM2.5 aerosols will reach from China and other major sources, particularly whether they are transported to the Arctic regions or not, as has been pointed out by recent studies.

This work was supported by the Environmental Research and Technology Development Fund (S-7, 2-1403,2-1505) of the Ministry of the Environment, Japan, KAKENHI grant numbers 16H01770 and 25220101, and by the ArCS (Arctic Challenge for Sustainability) Project of the Ministry of Education, Culture, Sports, Science and Technology of Japan.

The above results were published in *Atmospheric Chemistry and Physic* issued by the European Geosciences Union on August 30, 2016 (JST).

Title: Long-term observations of black carbon mass concentrations at Fukue Island, western Japan, during 2009–2015: Constraining wet removal rates and emission strengths from East Asia

Authors: Yugo Kanaya[1], Xiaole Pan[2,3], Takuma Miyakawa[1], Yuichi Komazaki[1], Fumikazu Taketani[1], Itsushi Uno[3], Yutaka Kondo[4]
1 JAMSTEC
2 Institute of Atmospheric Physics, Chinese Academy of Sciences
3 Kyushu University
4 National Institute of Polar Research

*1 Black carbon (BC) particles are formed through incomplete combustion of fossil fuels, biofuel, and biomass. BC particles strongly absorb light and convert the energy to heat the atmosphere. Their deposition on the snow/ice surface reduces the Earth's reflectivity and thereby accelerates warming.

*2 Aerosol particles are solid particles or liquid droplets suspended in the atmosphere. PM2.5 (PM stands for particulate matter) is the fraction of the particles whose diameters are less than 2.5 micrometers (μm).

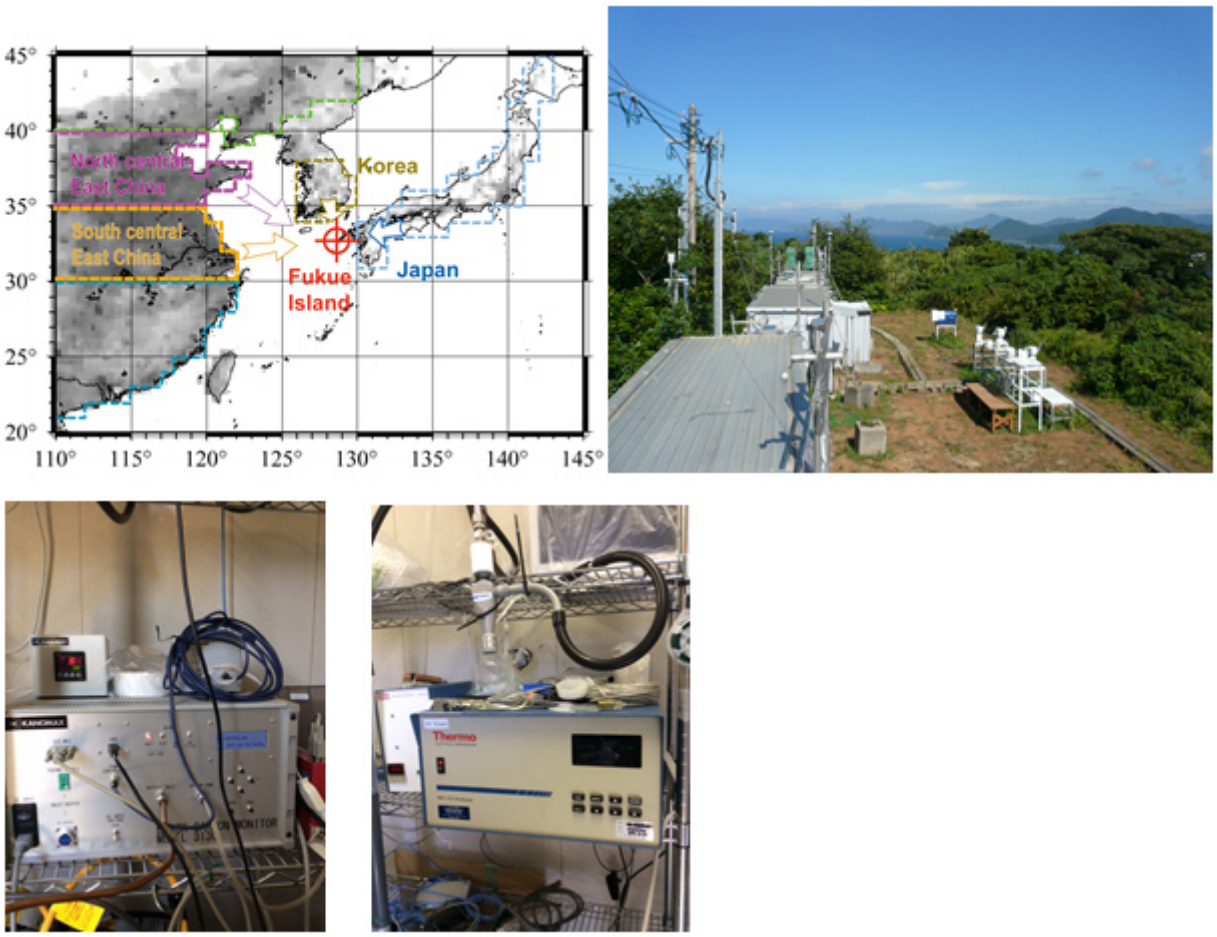

Figure 1. Location of the observatory in Fukue Island, where air masses from China, Korea, and Japan arrive with typical travelling time of 6 to 46 hours. The gray scales in the map indicate estimation of BC emission rates. The two bottom photos show the instruments for measuring BC (left) and CO (right).

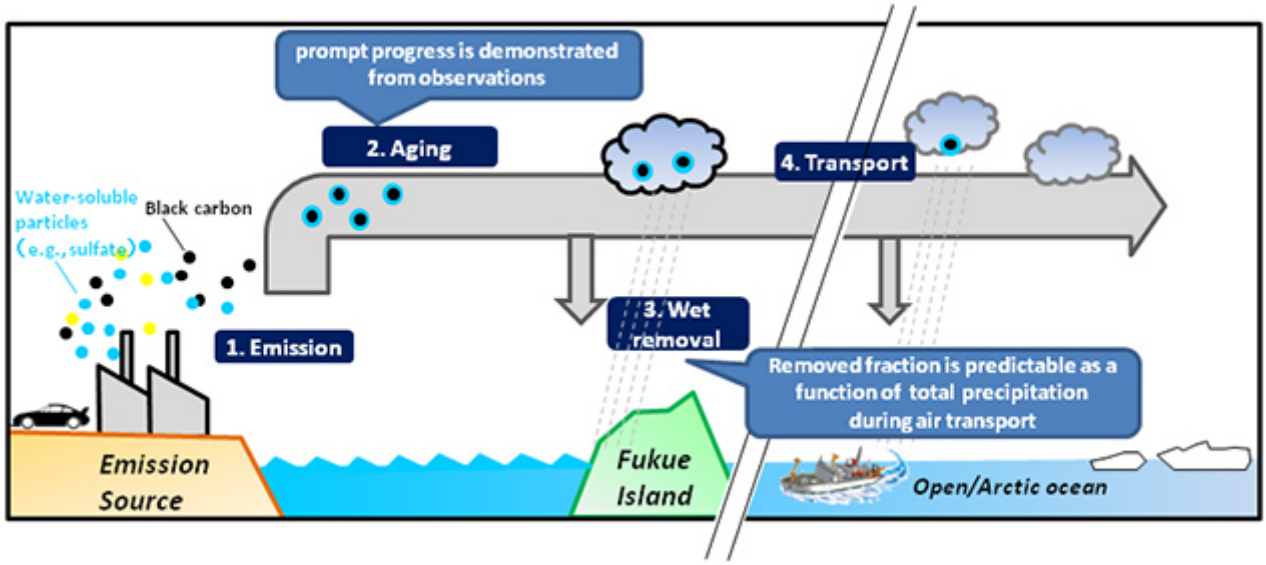

Figure 2. Schematic diagram of black carbon life cycle
BC particles are originally hydrophobic when emitted and then become hydrophilic by coagulation with other water-soluble particles such as ammonium sulfate. These particles are transported under the influence of wet deposition processes due to rainfall. This study clearly demonstrated that the aging processes occur promptly before pollution plume reaches Fukue Island. The team also found that the BC fraction removed from the atmosphere could be expressed as a function of accumulated precipitation during the air transportation. It helps better understand how far the BC particles could travel, as it is determined in a balance between wet deposition and transport.

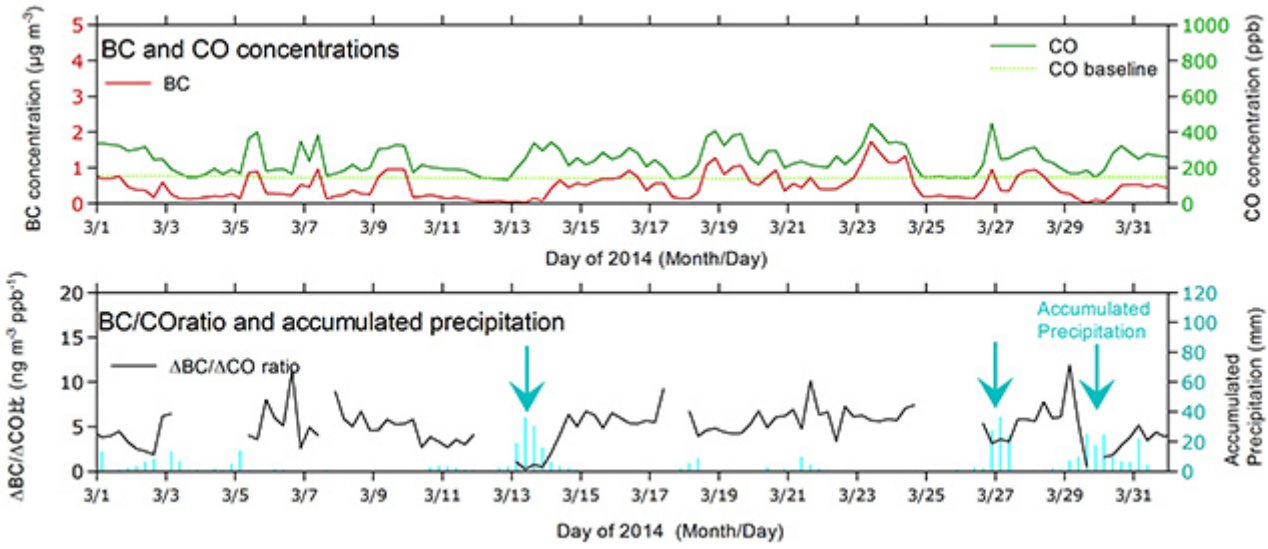

Figure 3. (Top) Time-series of BC and CO concentrations (e.g., March, 2014)
BC and CO shows very similar variation patterns. ΔCO was calculated by subtracting the baseline level (determined as a 14-day moving 5th percentile level) from the observed CO mixing ratio. (Bottom) Time-series of the observed BC/CO ratio. The ratio clearly decreased when APT (accumulated precipitation along backward trajectory for the last 3 days) increased. Typical cases are indicated with arrows: March 13, 27, and 29-31.

* Δ(Delta) indicated the increment from the baseline concentration in a hemispheric scale. The baseline concentration for BC was assumed to be zero.

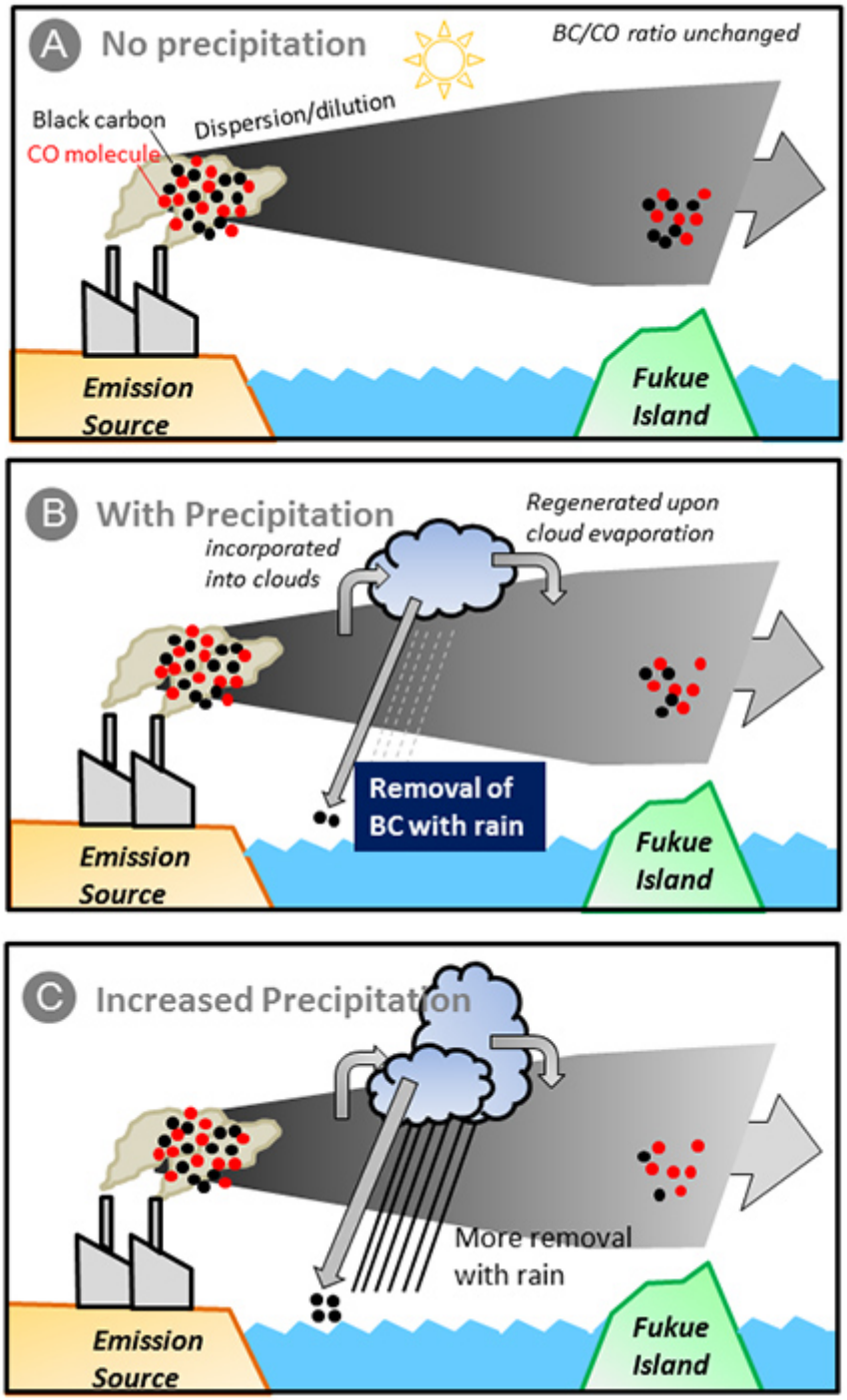

Figure 4. Schematic diagram showing changes in the BC/CO ratio due to wet removal of BC.
Panel (A) shows a case when there is no rainfall along the trajectory, in which the BC/CO ratio does not change, whereas both concentrations decrease due to atmospheric dilution and dispersion. In contrast, in panel (B), BC particles are lost additionally during transport due to rainfall along the trajectory, which reduces the BC/CO ratio. In panel (C), BC/CO ratio is further reduced as the BC particles are lost more significantly during travelling.

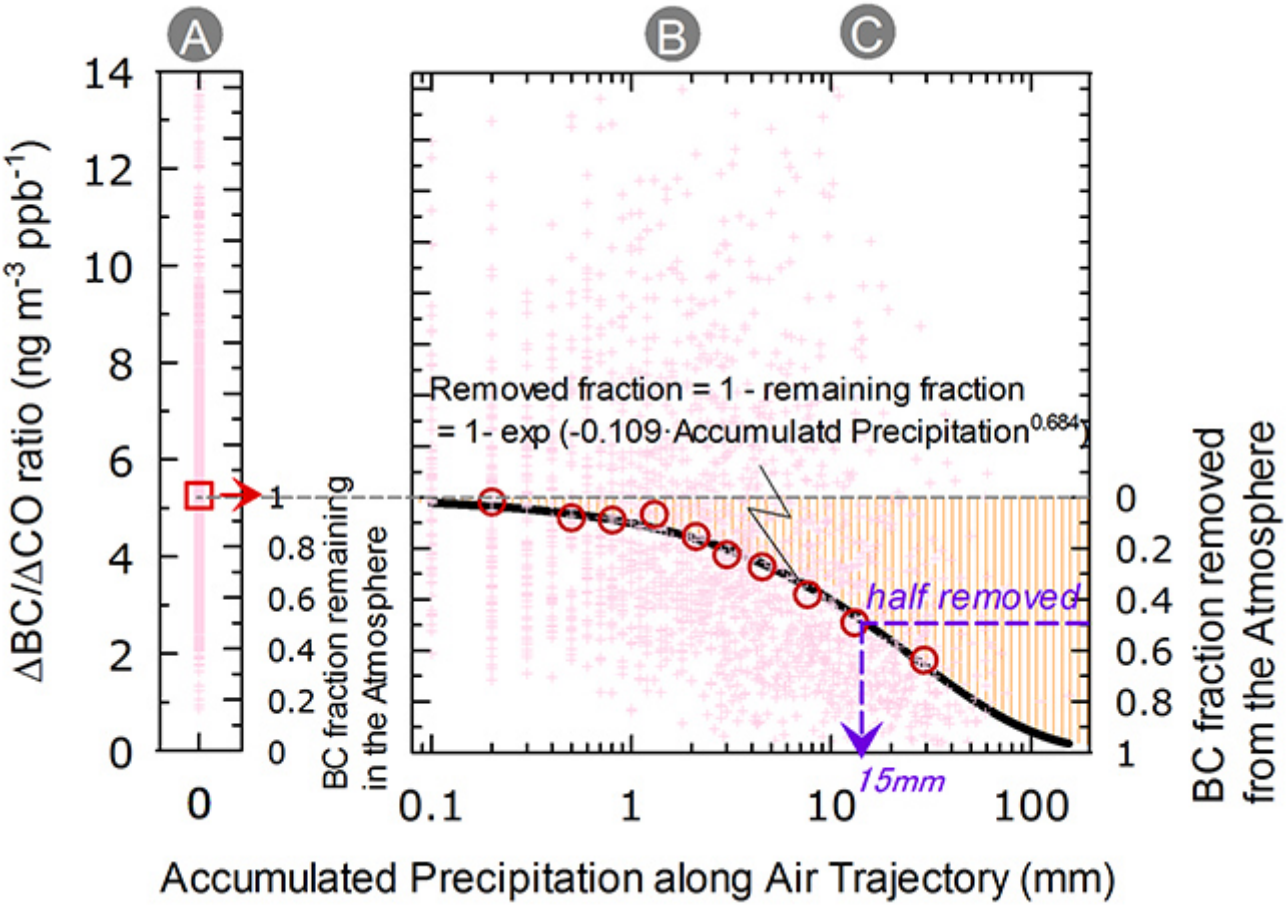

Figure 5. BC/CO ratios (red circles) decrease steadily according to accumulated precipitation, indicating that BC is removed by rain. The BC fraction remaining in the atmosphere, which is estimated by dividing the BC/CO ratios with that without precipitation (shown by the red square in the left panel), and the removed fraction defined as 1 minus (remaining fraction), are best represented by a stretched exponential decay function of the accumulated precipitation (formula as shown in the figure; the black curved line). Half of BC is removed when accumulated precipitation reaches 15 mm (as shown in purple).

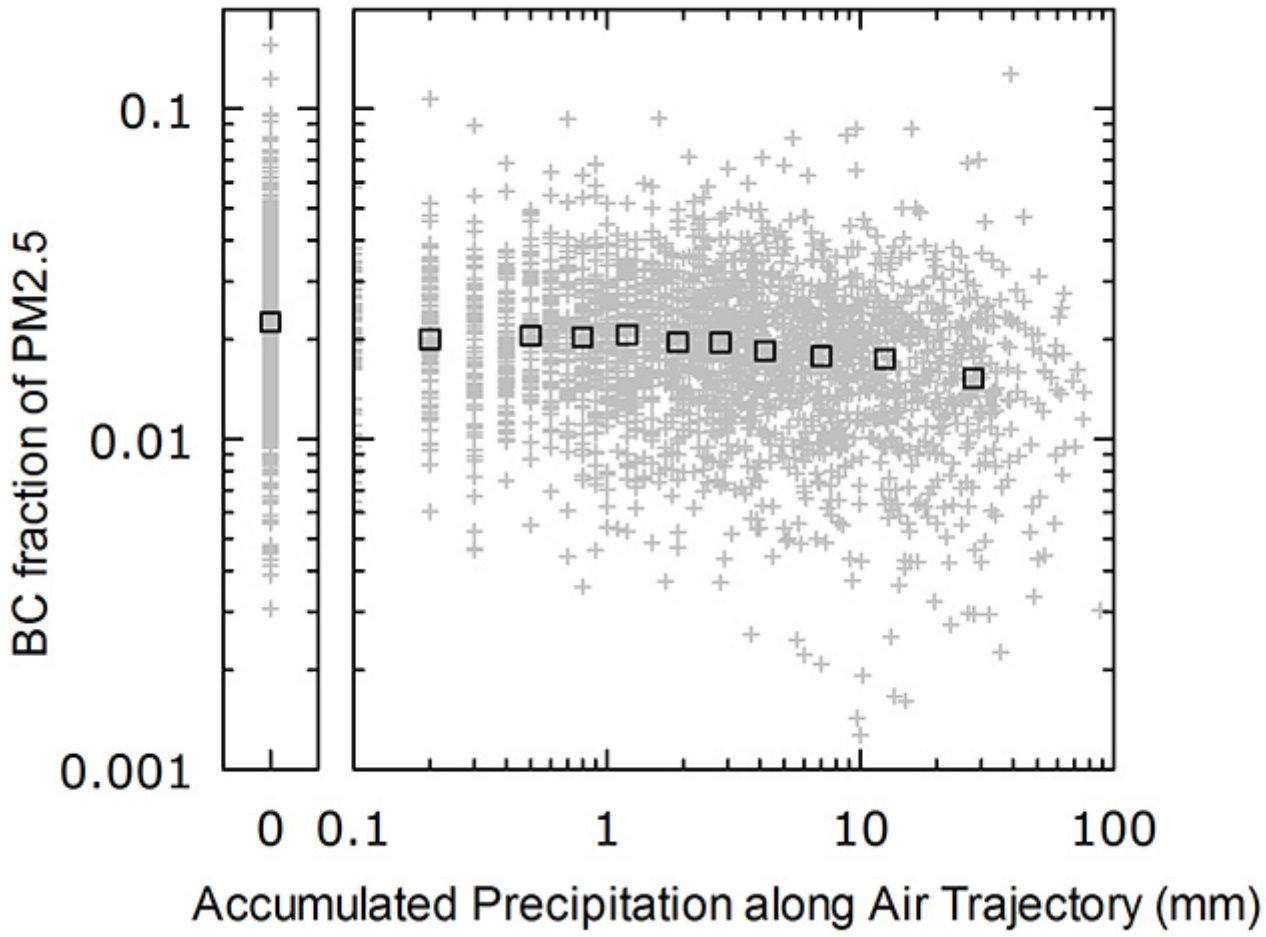

Figure 6. BC fraction of PM2.5 is almost constant (~2%) over the wide range of the accumulated precipitation; i.e., there is no evidence that BC particles are selectively left in the atmosphere as a result of wet removal. This fact implies that BC is hydrophilic like major components of PM2.5.

Contacts:
JAMSTEC
(For this study)
Yugo Kanaya, Deputy Director, Department of Environmental Geochemical Cycle Research
(For press release)
Tsuyoshi Noguchi, Manager, Press Division, Public Relations Department