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著者	Hatsushika Hiroaki, Yamazaki Koji, Kim Yong-Won
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Long-range Transport of Gaseous and Particulate Materials by Forest Fire (Extended Abstract)

HIROAKI HATSUSHIKA[1], KOJI YAMAZAKI[1,2] and KIM YONG-WON[2]

[1] Graduate School of Environmental Earth Science, Hokkaido University, Kita-10, Nishi-5, Kita-ku, Sapporo, Hokkaido 060-0810
[2] International Arctic Research Center, Frontier Research System for Global Change, SEAVANS-N 7F, 1-2-1 Shibaura, Minato-ku, Tokyo 105-6791

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Abstract: The Frostfire Experiment was performed between July 8th and 15th at Little Poker Creek in the suburb of Fairbanks in 1999. The fire emitted carbon dioxide, methane, and many particulate materials. A trajectory calculation is used to study how and to where the gaseous and particulate materials emitted from the fire were transported.

The particles were spread to the wide area of North American continent within a week and the some were transported to the Arctic Polar region by a strong southern wind and deposited onto the sea ice by gravity effect and by precipitation. This suggests that boreal forest fires may affect to the climate change of the Arctic region through reduction of surface albedo.

Body

The Frostfire Experiment was planned at Little Poker Creek in the suburb of Fairbanks for investigating the impacts of forest fire on the boreal ecosystem and the feedback to the climate system. The experiment was performed between July 8th and 15th in 1999. The fire emitted carbon dioxide, methane, and many particulate materials.

The objective of this study is to simulate how and to where the gaseous and particulate materials are transported by using trajectory calculation. The data set used in this study is ECMWF/TOGA objective analysis data (4 times per day, 0.5×0.5 degrees horizontal resolution, 15 pressure levels) during the period from July 8th to 19th in 1999. Material either gas or charcoal is transported by interpolating the three dimensional wind (Yamazaki, 1992).

Figure 1 shows the releasing time of particles from the fire experiment site. Shaded circles denote releasing time and strength of the fire and shaded rectangles indicate the duration of precipitation which is judged by video observation from Poker Flat (provided by M. Fukuda). Taking into account the uncertainty of wind data, 716 (26×26) particles are released from one pressure level and pressure interval of initial location of particles is set to 10 hPa. The number of particles released in strong, moderate and weak smoke cases is 16,224, 11,494 and 6,084, respectively. In total, 295,412 particles are released in the simulation.

In the simulation of charcoal ash, we assume that the particle falls with its terminal velocity as a function of its diameter (Kasten, 1968) and it is deposited by precipitation. For a gaseous particle, neither effect is considered. In the ECMWF data used in this study, precipitation is not included. Therefore, we deduce the occurrence of precipitation and washout rate by cloudiness which was estimated by relative humidity and pressure (Hatsushika *et al.*, 2000). We estimate the distribution of particles under certain conditions, such as size of the particles (0.4, 1, 2, 5, 8, 10, and 20 micron in diameter) and effect of the wet deposition.

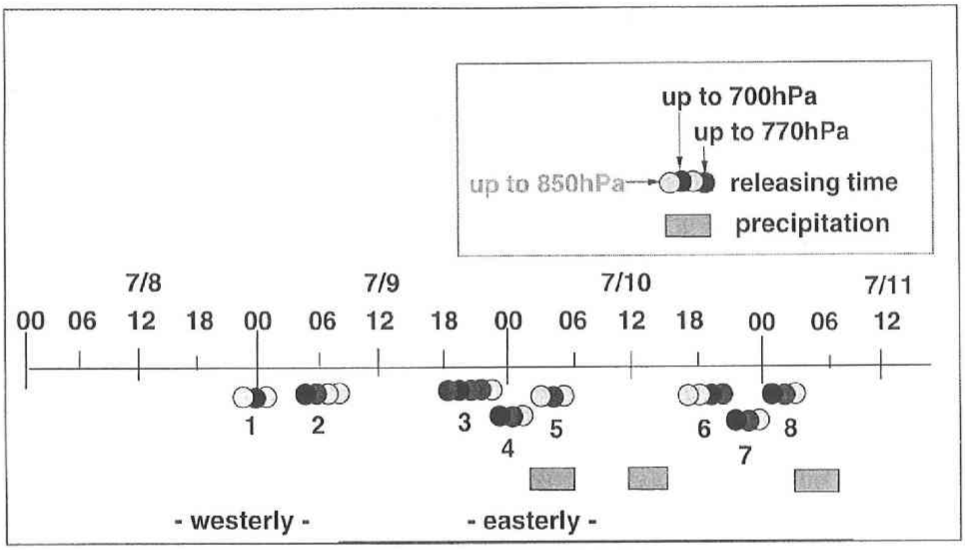

Fig. 1. Releasing time of particles in trajectory calculation. Position and shading of circles denote the releasing time in UTC and fire strength (height of smoke top). Shaded rectangles denote the precipitation periods estimated by examining the video observation.

Figures 2 and 3 show the distributions of particle density for each size. The darker shading denotes higher density. In Figure 2, the upper panels show that the particle's diameter is 10 micron and the lower panels show that the particle's diameter is 0.4 micron. In each case, precipitation effect is not included. Large particles ((a) in Fig. 2) are confined below 700 hPa, while small particles exist around 700 hPa ((b) in Fig. 2). In both cases, particles are transported to the Arctic region.

Figure 3 shows the column number density of floating particles (left-hand side) and deposition density (right-hand side). The upper panels of Fig. 3 (A-U, G) are for 10 micron in diameter case and the same as the upper panels of Fig. 2. In the case shown at the lower panels of Fig. 3 (B-U, G), the precipitation effect is included and the particle size is 0.4 micron.

In the case for 10 micron without wet deposition, a majority of particles are transported to the Arctic region and significant particles are deposited on the sea ice of Arctic Ocean. An aerosol sampler measurement in the Caribou-Poker watershed has revealed a size distribution of aerosol that is significantly narrower than the typical log-normal distribution and the mean diameter is around 0.4 micron (C.F. Cahill and R.L. Collins with personal communications). Therefore, the case for 0.4 micron is close to the reality. In the case for 0.4 micron with wet deposition, which is considered to be close to the real situation, a majority of particles are deposited over Alaska, but some are deposited on the sea ice of Arctic Ocean.

Figure 4 also shows the number densities of particles. They are divided into 4 groups by its latitudinal position, *i.e.*, poleward of 73N or equatorward of 73N, and whether deposited or not. These graphs show that moderate size and precipitation effect bring particles to the Arctic sea ice region. All particles, of which size is 20 micron in diameter, fell on the inland of Alaska before July 14th. They couldn't be affected by the strong northward wind from 15th to 17th. Other particles have a possibility to go into the Arctic region. They are deposited to the Arctic

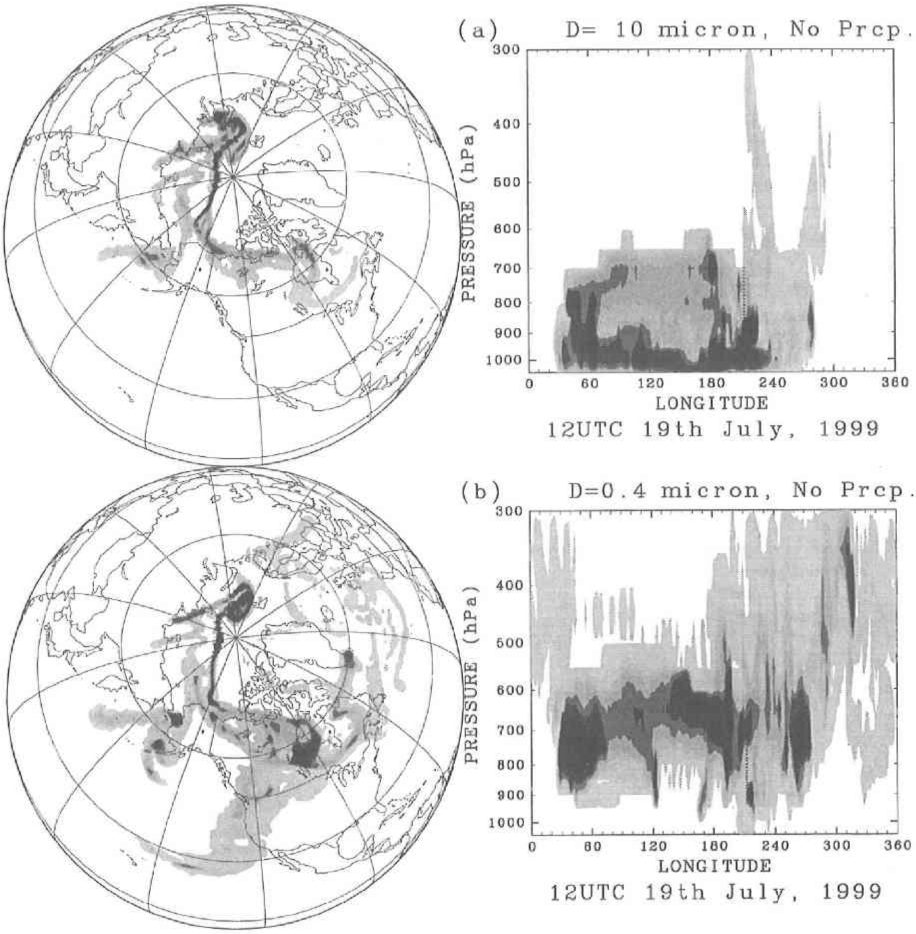

Fig. 2. Left: Column number density of floating particles at 12UTC, 19 July 1999. Right: Longitude-pressure (height) cross section of latitude-mean particle density at the same time. The deposited particles are included in the right panels. Precipitation effect is not included.
The particle's diameter in the upper map is 10 micron and that in the lower map is 0.4 micron.

region by gravity effect and precipitation. It is clearly seen that the particles of 10 micron can be deposited to the sea ice region than any other size and also seen that much of smaller particles can remain in the Arctic air.

Because the albedo of sea ice is decreased with the contamination of aerosols and melting of sea ice is promoted, the transport of the emitted materials from the forest fire might be important for the Arctic climate. Nevertheless to say that the particles floating in the air are also important, for they affect the albedo of atmosphere and act as condensation nuclei which change the precipitation behavior. We need to investigate the behavior of emitted particles in more detail, because the particles affect directly and indirectly to environment of the Arctic region.

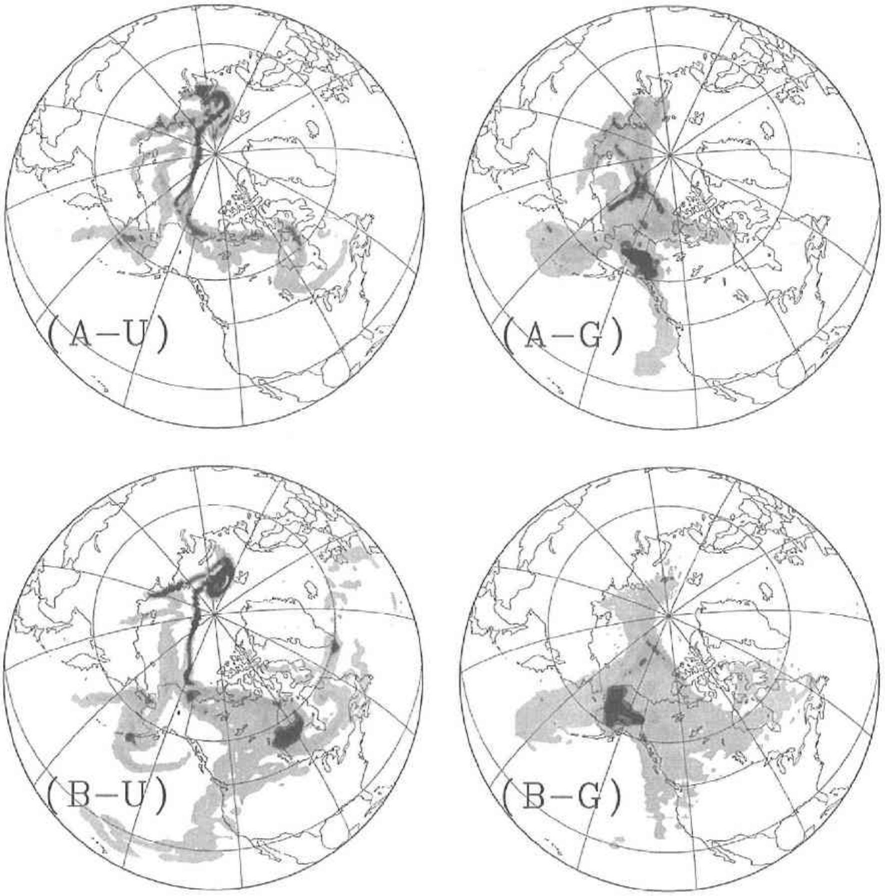

Fig. 3. Left (U): Column number density of floating particles at 12UTC, 19 July 1999.
Right (G): Density of deposited particles at the same time.
Top (A): Particles of 10 micron in diameter without precipitation.
Bottom (B): Particles of 0.4 micron in diameter with precipitation.

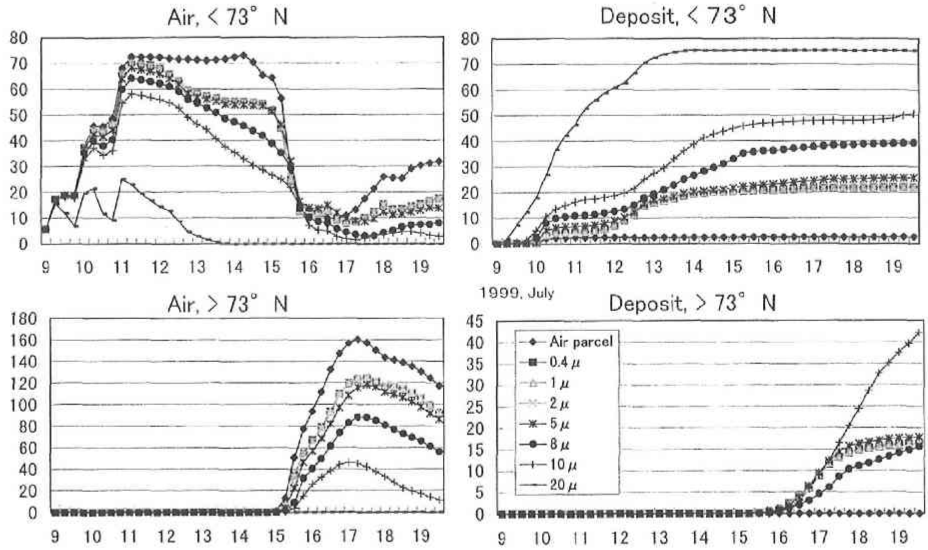

Fig. 4. Left : Time variation of column number density of floating particles located poleward of 73N (top) and equatorward of 73N (bottom) for each particle size. Right : Same as left panels but for deposited particles.

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