Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)


ACG37-P17 Room:Convention Hall Time:May 22 17:15-18:30

# Anthropogenic impact on spring precipitation over Eurasian continent in the late 20th century

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Global warming due to anthropogenic greenhouse gases (GHGs) causes an increase in mean and extreme precipitation. It also causes a decrease in snow cover duration and snow water equivalent (SWE) in mid-latitude and lower altitudinal area, whereas it causes an increase in SWE in high-latitude and high altitudinal area. On the other hand, anthropogenic emissions of aerosols have decreased over European countries, the U.S., Japan, etc., although they are still increasing in China, India, and developing countries. Changes in the anthropogenic aerosols alter the surface radiation fluxes through the scattering and absorbing processes of aerosols. These changes in surface radiation fluxes affect the surface energy budget; that is latent and sensible heat fluxes. Recently, it is pointed out that 'dimming and brightening' associated with aerosol changes affect regional and global climate changes. Decrease in anthropogenic aerosols induces brightening over Europe, which resulting in an increase in evaporation. The increase in evaporation contributed to the increase in precipitation via the water budget relationship.

Here, we investigate the impact of changes in GHGs and aerosols on precipitation over the Eurasian continent in the late 20th century using historical simulations performed by a coupled general circulation model generally known as the medium-resolution version of the Model for Interdisciplinary Research On Climate (MIROC). The atmospheric component of MIROC includes an explicit representation of the first and second kinds of indirect effects induced by soluble aerosols as well as the direct effects of all aerosols. We look into the relative contribution of individual anthropogenic forcing factors by analyzing datasets of several experiments forced with different combinations of external climate forcing factors. We focus on the changes in surface radiation and heat budgets which affect the evaporation and precipitation statically.

The historical simulation by MIROC can simulate the observed precipitation trend over high-latitudinal area in the late 20th century. Significant increase in precipitation was observed and simulated during spring. Moistening trends are significant over the western part of Eurasia (Europe) during all season. The annual drying trend can not be simulated over the eastern parts of Eurasian continent. According to an analysis using an approximated atmospheric moisture budget equation, we find that the increase in precipitation is caused by the increase in evaporation and advection over the western and eastern parts of Eurasian continent, respectively. The change in evaporation is thought to be related to the surface radiation changes, hence, we investigate the changes in surface shortwave and longwave radiation. Change in net surface shortwave radiation (SSR) controlled the changes in net radiation. The net SSR increases over central and western parts of Eurasian continent not only in the all-sky situation but also in the clear-sky situation. The downward SSR shows an increase over Europe. In contrast, the upward SSR shows a decrease, which means the increase in net radiation at the surface, over the central part of Eurasia. According to an analysis of several experiments forced with individual forcing factors, it is speculated the change in downward SSR is associated with the changes in aerosols, while the changes in upward SSR is associated with the snow cover change. The increase in downward SSR over Europe was caused by the decreases in aerosols. The decrease in upward SSR over the central part of Eurasian continent was caused by the increasing concentrations of GHGs; the decrease in upward SSR is strongly associated with the surface albedo reduction which is caused by the decrease in snow cover due to global warming.

Keywords: global warming, anthropogenic, greenhouse gases, aerosols