Regional Climate Change in Korea: Current Status and Future Projection

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The global mean air temperature has been increased gradually since the end of nineteenth century (IPCC 2001), which is very likely related to the increase of atmospheric concentration of greenhouse gases, including carbon dioxide and methane. The evidences of global warming in the climate system are found in mountain glaciers, lower stratosphere, and ecosystems as well as in surface and meteorological variables. The climate of Korea also shows similar trends with the global environmental change. We have better understanding of global changes than ten years ago but the regional aspects of climate change over Korea or any other area, need to be better assessed.

The climate of East Asia is characterized by the large variability both in space and time scales. Thus, it is very difficult to derive any solid conclusion on impact assessment for regional climate change without appropriate climate information. The objectives of this study are to understand the trends of the frequency and/or severity of extreme climate events in relation with global climate change and to understand the past and future climate changes in Korea based on observations and model simulations.

We used the observation data of KMA for the period of 1904 to 2000. The mean annual temperature of Korea has been increased by 1.5℃ during the 20th century. The frequencies of frost day ($T_{min} < 0$℃) and winter day ($T_{max} < 0$℃) show significant decrease throughout the whole country and the winter period ($T_{mean} < 5$℃) also was shortened by about one month. The indices for the warm climate were increased, including the frequencies of tropical nights ($T_{min} > 25$℃), the number of heating day, and the summer period ($T_{mean} > 20$℃). A systematic increase in the 90th percentile of daily minimum temperatures throughout most of the analyzed areas over Korea has been observed. This increase is accompanied by a similar reduction in the number of frost days and a significant lengthening of the thermal growing season. Although the inter-annual extreme temperature is based on only two observations, it provides a very robust and significant measure of declining extreme temperature variability.

The mean annual precipitation was increased about 10% but the number of rainy day was decreased; therefore the average precipitation intensity has been decreased.

There is a tendency of more drought and flood, indicating the increase of natural disaster frequencies. The five precipitation-related indicators show no distinct changing patterns for spatial and temporal distribution except for the regional series of maximum consecutive dry days. Changes in the ecosystem also are observed.

The global climate projections based on the IPCC SRES A2 and B2 scenarios have been produced using dynamical downscaling nested in ECHAM4/HOPE-G model for 241 years (1860-2100) in collaboration with Max Planck Institute for Meteorology and University of Bonn. The model simulation shows about 6C warming and 10-15% precipitation increase by the year 2100. These simulations include GHGs only referred to as A2G and B2G, which represent pessimistic and optimistic scenarios, respectively. In the A2G [B2G] scenario, for example, CO2 concentration increases up to 821 [606] ppm by 2100.

East Asian (domain of 80E-180 and 20N-60N) climate changes in A2G and B2G are analyzed focusing on the changes of near surface temperature and precipitation. The results show that East Asia is likely to experience warmer and wetter climate than present with larger amplitude than global mean. The A2G [B2G] result shows 6.5 [4.5] ℃ increase of temperature and 10.5 [6.0] % increase of precipitation over East Asia by 2100. However, it should be noted that precipitation projection has a large uncertainty from the dominant interannual and decadal variability, which cannot be reliably estimated from a single realization. Spatial pattern of climate change over East Asia shows that northern continental area has larger warming than southern oceanic area, while the precipitation change is dominant over the coastal area of East Asia. Local climate change over the Korean Peninsula are projected as about 5~7 [3~5]℃ and 10~30 [10~20]% increase in A2G [B2G] by 2100, but large uncertainty should also be taken into account. There is seasonal dependencies of climate change over East Asia: surface temperature increases in cold season (SON, DJF) are 0.5℃ larger than in warm season (MAM, JJA), while precipitation increase in summer (JJA) is dominantly larger than other seasons which might be related to the strengthening of East Asian summer monsoon system. A detailed investigation on the seasonal dependency of climate change might be necessary in the future.

Although the resolution of AOGCMs is still coarse, simulations of present day climate with the AOGCMs agree with the observed atmospheric general circulation features in general. It is not feasible to use high resolution AOGCMs for long-term simulation; therefore, Regional Climate Models (RCMs) can be used for regional purposes (IPCC, 2001). For a regional climate simulation, MM5 (version 3.4) with 27 km horizontal resolution and 18 layers in vertical is nested within the output of IPCC

SRES A2 experiment provided by the ECHO-G for the period of model year 1951 to 2100.

The temperature and precipitation simulated by MM5 for the model domain indicate very strong dependency on those of ECHO-G simulation. RCM produces surface air temperature at mountainous region more realistically than AOGCM, therefore, we think this is an encouraging feature for the studies on the regional impact assessment for climate change. We may reach to the same conclusion with precipitation simulations. For all seasons, the development of monsoon by RCM is well organized in the RCM simulation compared to that in AOGCM.

By combination of global climate projection and dynamic downscaling, we may provide reasonable future regional climate information for impact assessment. The final output of temperature is quite adequate for regional assessment studies since there are distinguished variation modes influenced by land and ocean. Precipitation, however, needs to be improved. There are some disagreements in dominant modes of real world and model world. This may be caused not only from the fact that precipitation is local phenomena and less systematic than temperature but also the model has still treated the precipitation processes inadequately. This might be one of important tasks of future studies to overcome to provide reasonable regional climate change information.

As a pilot application of high-resolution projection data to water resource management, we calculated the Palmer Drought Severity Index (PDSI) over Korea. The result indicates a very pessimistic future for Korea. It is because evapotranspiration increases faster than precipitation, due to the fact that water vapor holding capacity of the air increases exponentially rather than linearly. We can also compute the spatial patterns of PDSI for different time periods.

It is not necessary to emphasize the importance of understanding the characteristics of regional climate change. The global warming is not just a global issue. It is a regional issue and we experienced warming and impact of warming during the 20th century. It is also evident that the concentration of GHGs will increase in the future, thus the surface temperature and the variability of precipitation. We have to put more emphasis on the researches on impact assesment of global/regional warming for human society and natural ecosystem as well as the adaptation measures.