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Contributing factors to the downward longwave radiation at surface

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Longwave radiation as well as shortwave radiation is a key issue to understand the climate change, energy budget, and water cycle of the Earth. Water vapor, clouds and greenhouse gases such as carbon dioxide are major contributing factors to the variation of longwave radiation. The downward longwave radiation at the surface can be estimated with some accuracy by applying parameterization formula of surface air temperature and surface water vapor pressure. However, the accuracy by using parameterization is limited and it is difficult to evaluate which factor contributes to the longwave radiation.

In the present study, the surface downward longwave irradiance at different climate regions is evaluated by comparing Baseline Surface Radiation Network (BSRN) observations and calculations with a two-stream radiative transfer code. The comparison was carried out for five BSRN sites, i.e. Sapporo (43.0600°N, 141.3283°E), Tateno (36.0546°N, 140.1221°E), Fukuoka (33.5817°N, 130.3750°E), Ishigaki-Island (24.3367°N, 124.1633°E), and Syowa-Station, Antarctica (69.0043°S, 39.5816°E), which are located at different climate regions. Vertical profiles of water vapor and cloud were obtained from radio-sonde observation. The observed longwave irradiance was reproduced by calculation with an accuracy of 4.5±6.2W/m2 under the clear sky conditions of all sites, while the accuracy was -4.2±18.5W/m2 under the overcast condition.

The individual contributions of water vapor, cloud and carbon dioxide to the downward longwave irradiance were evaluated by removing these factors one by one from the normal condition with all factors. The largest contribution of water vapor to the longwave radiation was estimated for Ishigaki-Island in summer, i.e. 73.8% and 50.2% for the clear sky and overcast conditions, respectively. The largest contribution of carbon dioxide was estimated for Syowa-Station in winter, i.e. 25.2% and 7.0% for the clear sky and overcast conditions, respectively. The largest contribution of cloud was estimated for Syowa-Station in winter, i.e. 36.9%. Hotter and warmer site showed larger contribution without water vapor. In regard to, larger contributions without carbon dioxide or cloud were showed at colder and drier site.

On the other hand, the individual contributions of water vapor, cloud, and carbon dioxide were evaluated by removing all factors except these factors one by one. The largest contribution of water vapor alone to the longwave radiation was estimated for Syowa-Station in winter, i.e. 68.1% and 91.3% for clear sky and overcast conditions, respectively. The largest contribution of carbon dioxide was estimated for Ishigaki-Island in summer, i.e. 21.9% and 46.9% for the clear sky and overcast conditions, respectively. The largest contribution of cloud was estimated for Ishigaki-Island in summer, i.e. 33.9%. The tendency of contribution of removing all factors except a single factor is opposite to the tendency of removing the single factor.