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A statistical study of rainfall enhancement through an interplay of atmospheric rivers and cut off lows

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A rainfall event occurred in Hiroshima, Japan on 19 August 2014, which recorded over 200 mm accumulated rainfall during three hours and caused a disastrous flood. Recently, Hirota et al. (2016, MWR) analyzed this event with a piecewise potential vorticity inversion analysis as well as with sensitivity tests using a cloud resolving model. They suggested that an interplay of two factors related to middle to upper tropospheric phenomena, an atmospheric river (AR) which moisturizes free troposphere, and an upper tropospheric cut off low (COL) which induces dynamical ascent and destabilizes the atmosphere, enhances precipitation. However, in climatologically humid regions, such middle to upper tropospheric effects are often overlooked, and rather, boundary layer conditions and topographic effects are more emphasized as main factors for heavy rainfall events. Therefore, the mechanism of Hiroshima extreme event is also still under controversy. In this study, we statistically investigate the impact of an interplay of ARs and COLs upon rainfall enhancement.

Precipitation data are obtained from hourly Global Satellite Mapping of Precipitation (GSMaP) data (0.1 degree grid). Atmospheric rivers and COLs are detected using six-hourly JRA55 (1.25 degree grid) precipitable water and potential vorticity on 350 K isentropic surface, respectively. Then, to evaluate the effect of coexistence of AR and COL upon precipitation enhancement, COLs are classified into two categories named as “AR category” and “non-AR category” by the distance between AR and COL. The analyses are conducted over the western North Pacific region (100E-160W, 0-60N), for the period from March 2000 to February 2013.

The difference of composited precipitation between the AR category (112 cases) and the non-AR category (52 cases) showed a statistically significant enhancement of precipitation in the AR category is found in a region concentrated to the northwest of the COL. Notably, comparing the composite result in the AR category with the Hiroshima case, a very similar positional relationship among AR, COL, and enhanced precipitation region is confirmed. This similarity can also be confirmed for the vertical distribution of relative humidity, temperature anomaly, and unstable regions. In addition, since almost all COLs in this analysis are located over the ocean, we can emphasize that an enhancement of precipitation associated through an interplay of an AR and a COL can occur even without a topography, supporting Hirota et al.’s conclusion that such upper and middle tropospheric dynamical phenomena played a significant contribution to the Hiroshima event.

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