The Detection and Distribution of Atmospheric Rivers in the South Polar Region

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Atmospheric River (AR), is defined as a narrow, filamentary structure of water vapor flux, playing a significant role in moisture transport from mid to high latitude regions. In this study, we will focus on AR in the south polar region which are considered to be related with extreme snow accumulation events (Gorodetskaya et al., 2014) and even with the Antarctic Ice Sheet discharge (Wille et al., 2019). It should be noted that the geographical distribution of AR occurrence has yet to be examined in detail, while it may be important for understanding the zonally asymmetric changes of Antarctic ice sheet (Wingham et al., 2006).

In many previous studies, AR is defined as an event in which water vapor flux exceeds some threshold as determined at each grid point from long-term record. Such AR detection method, however, is not suitable for examining the geographical distribution of AR since AR is more difficult (easier) to detect in the region where AR tend to appear more (less) frequently. In this study, we use a method using a threshold based on the anomaly from zonal mean at each time step for the vertical integrated water vapor flux (IVT) (Zhu and Newell., 1998). That is, the threshold is common for all grids (on a particular latitude band at one time) so that the zonally asymmetric distribution can be detected. With this procedure, we aim at revealing the regional features of AR activity including their underlying mechanism.

The data set we used is the Japanese 55-year Reanalysis (JRA-55) data (Kobayashi et al., 2015), which provides global, 6-hourly atmospheric fields with a longitude-latitude resolution of 1.25° × 1.25° . Data over seven years between 2013 and 2019 are analyzed. The AR detection is based on IVT that is calculated with specific humidity and horizontal winds at 17 pressure levels from surface to 300hPa. First, some AR-like objects are detected in the case that the zonal anomaly of IVT has values above the maximum zonal anomaly multiplied by a factor of 0.3. These objects may have not only filamentary structures, but also spiral structures like a tropical cyclone. So, only the objects whose length is longer than 2000km and whose aspect ratio exceeds 2 are finally defined as AR. We investigate the geographical distribution of AR occurrence and AR-related meridional moisture transport (MMT) including their seasonal variations.

Figure 1a and 1b show the horizontal distribution of AR frequency and AR-related MMT, respectively. We find that the AR frequency has a zonally asymmetric structure around the Antarctica (Figure. 1 (a)). Between 40° S to 50° S, ARs appear more frequently in the Eastern Hemisphere than in the Western Hemisphere, while they tend to occur more frequently in the Western Hemisphere for the region southward of 50° S including the Antarctica. AR occurs only less than 10 days per year on the east Antarctica. Such geographical dependency has never been reported in previous studies as far as the authors know. The distribution of AR-related MMT is similar to that of AR frequency: large (small) moisture transport is observed in high (low) AR-frequency area (Figure. 1 (b)).

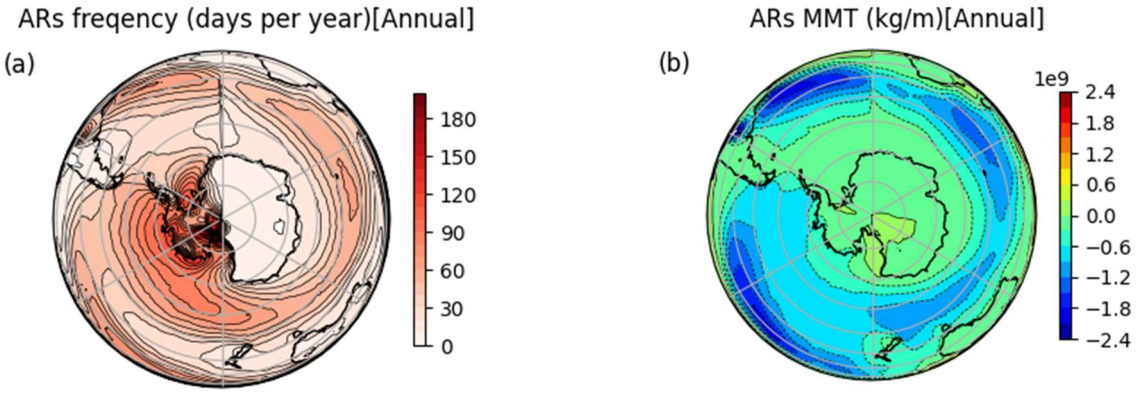

Figure 1. (a)Annual frequency of ARs and (b)Annual ARs-related meridional moisture transport (units: kg/m, poleward values are negative) in southern hemisphere for the years 2013-2019. ARs = Atmospheric rivers

The zonally asymmetric AR activity is likely related to the geographical pattern of storm tracks and the zonal jet streams in the Southern Hemisphere. In fact, the annual-mean eddy kinetic energy and zonal wind at 500 hPa have zonally asymmetric structures similar to the AR frequency distribution. The AR frequency shows a marked seasonal variation with maxima twice in

April and September; this seasonality is also found in zonal-mean zonal wind at 60° S. The observed geographical dependency of AR activity might be a key for understanding the zonal asymmetry in Antarctic Ice Sheet discharge because high frequency area of AR occurrence is corresponding to the area where ice sheet significantly discharges in the west Antarctica (Wingham et al., 2006).

References

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