



Supplement of

The interaction of warm conveyor belt outflows with the upper-level waveguide: a four-type climatological classification

Selvakumar Vishnupriya et al.

Correspondence to: Selvakumar Vishnupriya (vishnupriya.selvakumar@env.ethz.ch)

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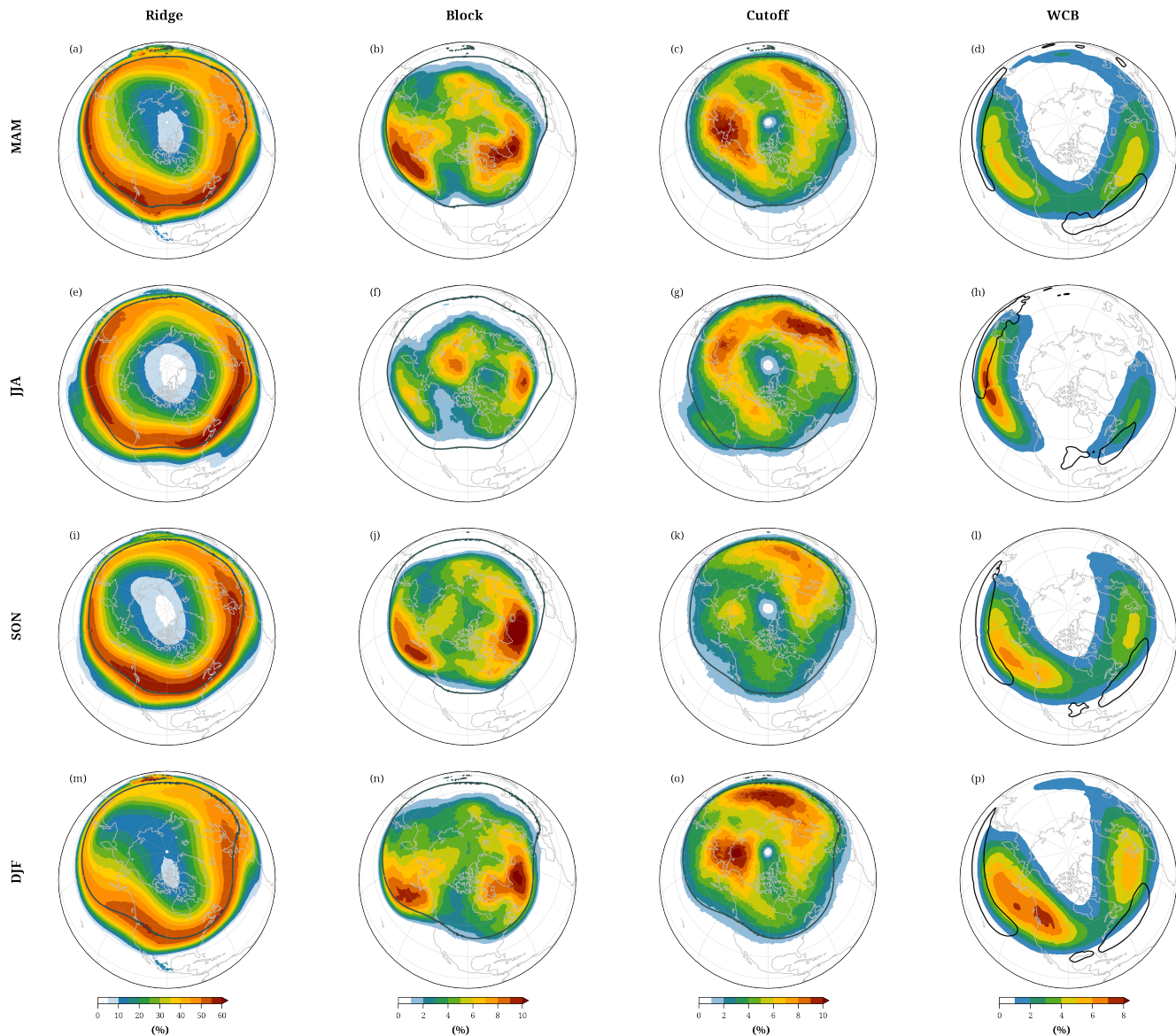


Figure S1. The climatological frequency of occurrence of weather features for different seasons in NH: **(a-d)** MAM, **(e-h)** JJA, **(i-l)** SON, and **(m-p)** DJF, showing **(a,e,i,m)** ridges, **(b,f,j,n)** blocks, **(c,g,k,o)** tropospheric cutoffs, and **(d,h,l,p)** WCBs at end-of-ascent. Note the different contour values in the four panels. The black contours illustrate in **(d,h,l,p)** the 95th percentile of the WCB start-of-ascent frequency and, in others, the climatological mean waveguide (i.e., the 2 PVU contour averaged for the four isentropes selected).

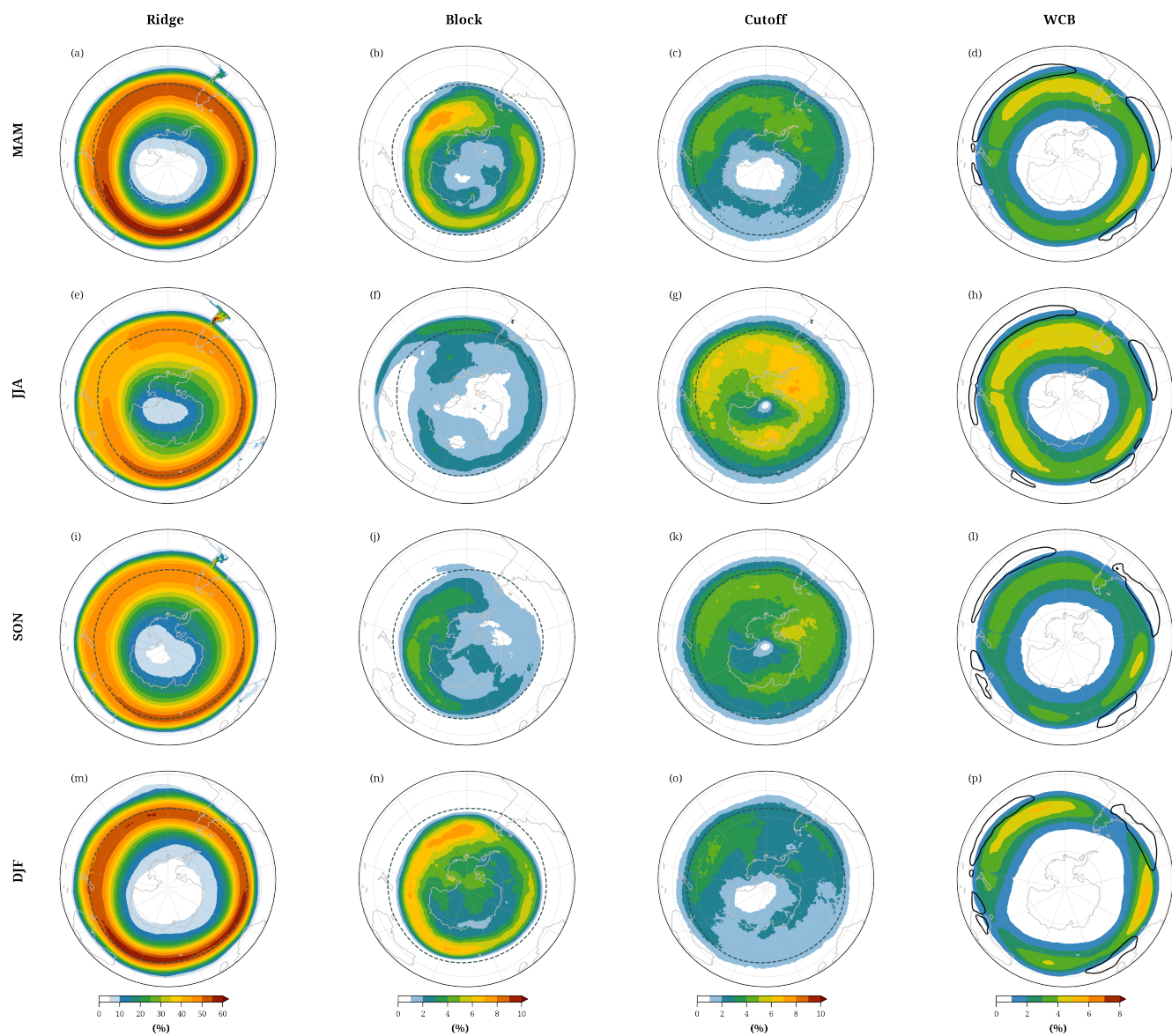


Figure S2. As Fig. S1, but for SH

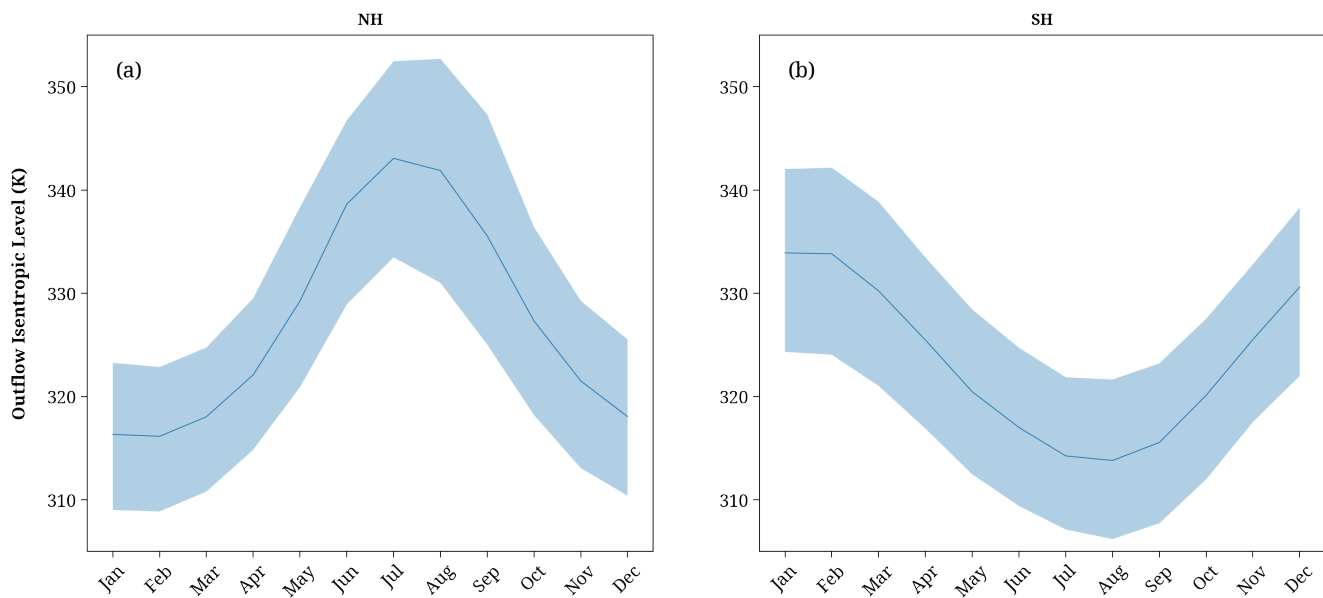


Figure S3. The monthly distribution of isentropic level reached by WCB outflow at the minimum pressure level for (a) NH and (b) SH. The solid line denotes the median, and the shaded region is the interquartile range.

Month	$\theta^*(\text{NH})$	$\theta^*(\text{SH})$
1	315	335
2	315	335
3	320	330
4	320	325
5	330	320
6	340	315
7	345	315
8	340	315
9	335	315
10	325	320
11	320	325
12	320	330

Table S1. The median isentropic levels selected for each month and hemisphere according to the distribution in Figure. S3

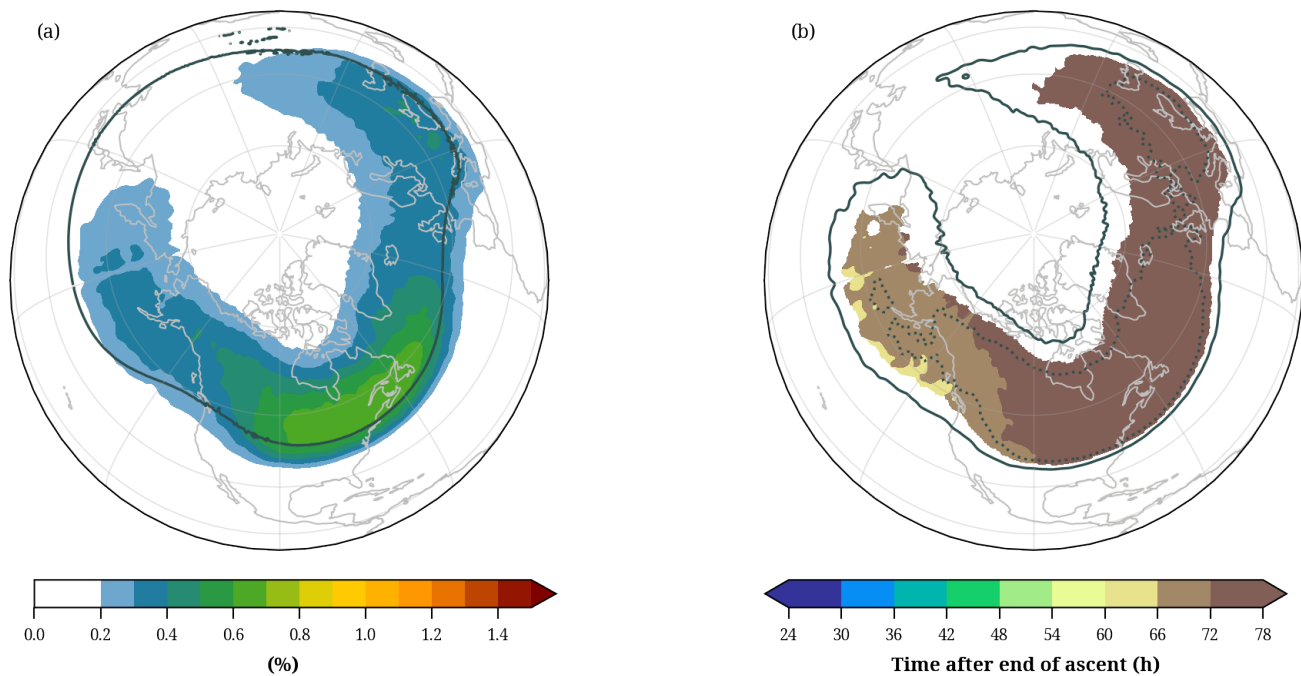


Figure S4. (a) Climatological frequency of occurrence of stratospheric WCB trajectories at their point of interaction (colors, in %) during DJF 1980–2022. Black contours indicate the climatological mean position of the waveguide (2 PVU). (b) Corresponding climatological mean outflow age at the point of interaction (colors, in hours). Black contours indicate the 80th (solid) and 95th (dotted) percentiles of WCB interaction frequency from panel (a).

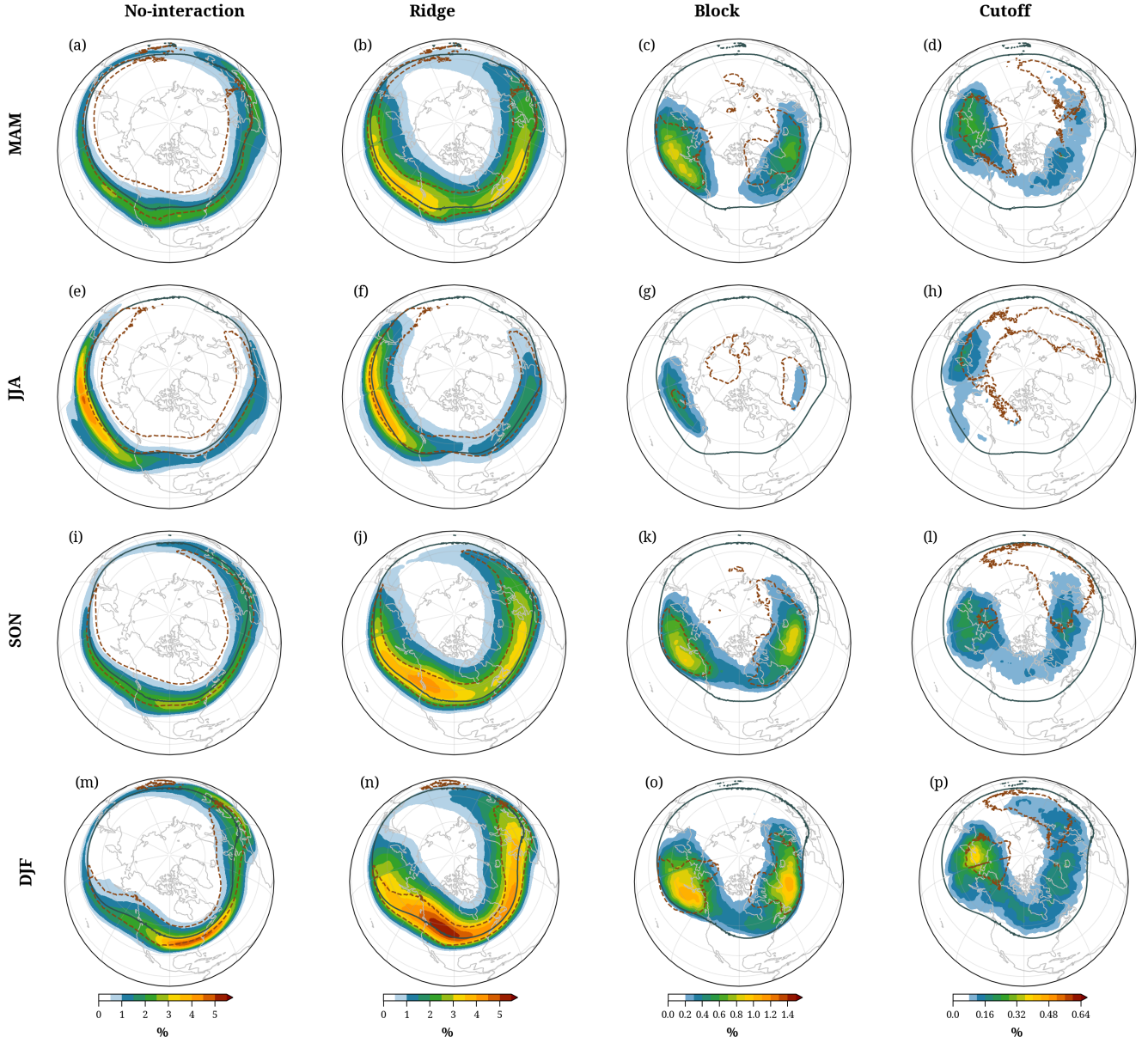


Figure S5. The climatological frequency of occurrence of WCB trajectories at their point of interaction (colors, in %), for different seasons in NH: **(a-d)** MAM, **(e-h)** JJA, **(i-l)** SON, and **(m-p)** DJF, showing the four interaction types (a,e,i,m) no-interaction, (b,f,j,n) ridge, (c,g,k,o) block, and (d,h,l,p) cutoff interactions. Note the different contour values in the four panels. The black contours illustrate the climatological mean waveguide in the particular season (2 PVU), and the dashed red contours show the 95th percentile regions of the associated weather features (a,b,e,f,j,i,m,n) ridges, (c,g,k,o) blocks, and (d,h,l,p) cutoffs.

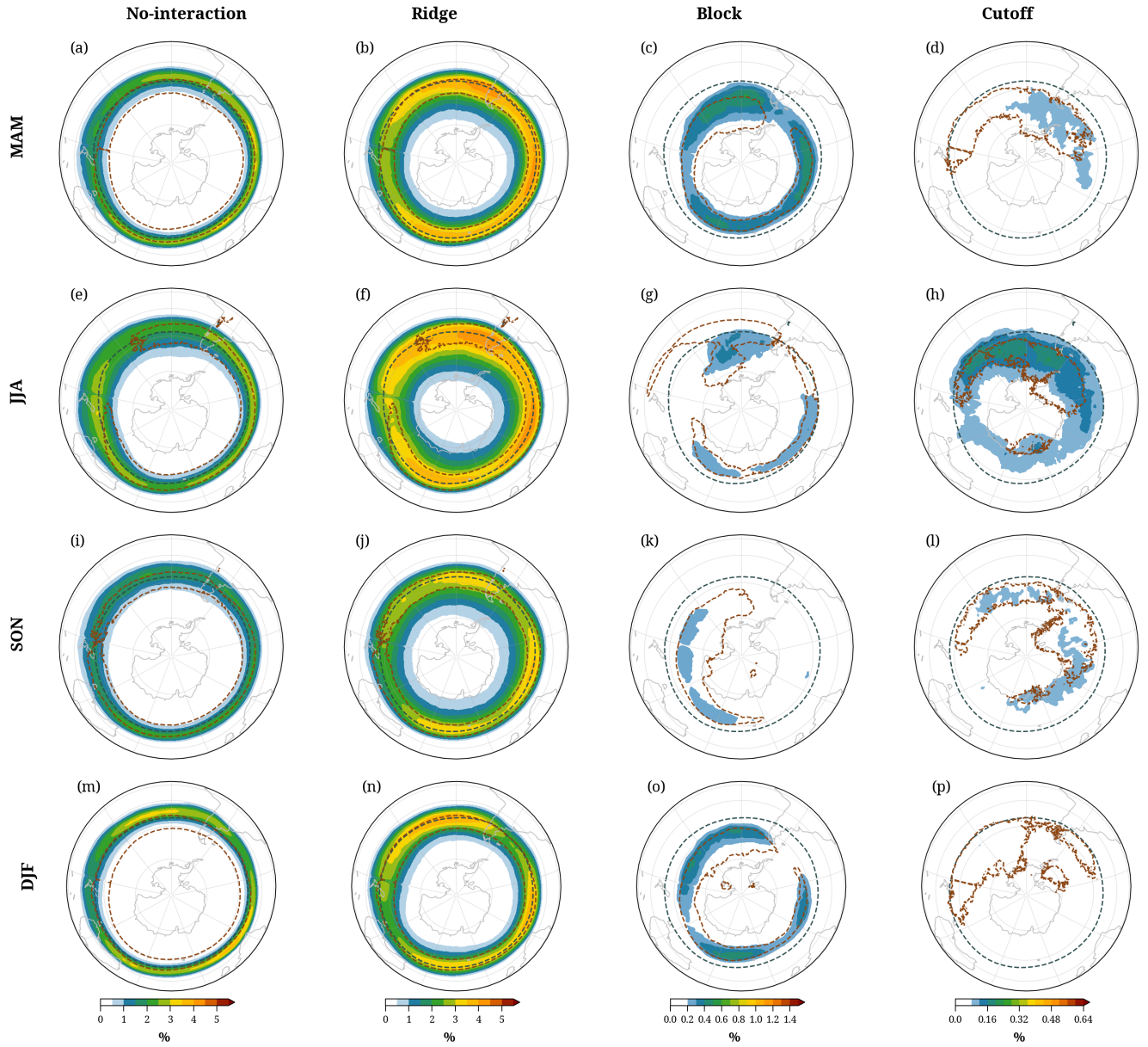


Figure S6. As Fig. S5, but for SH

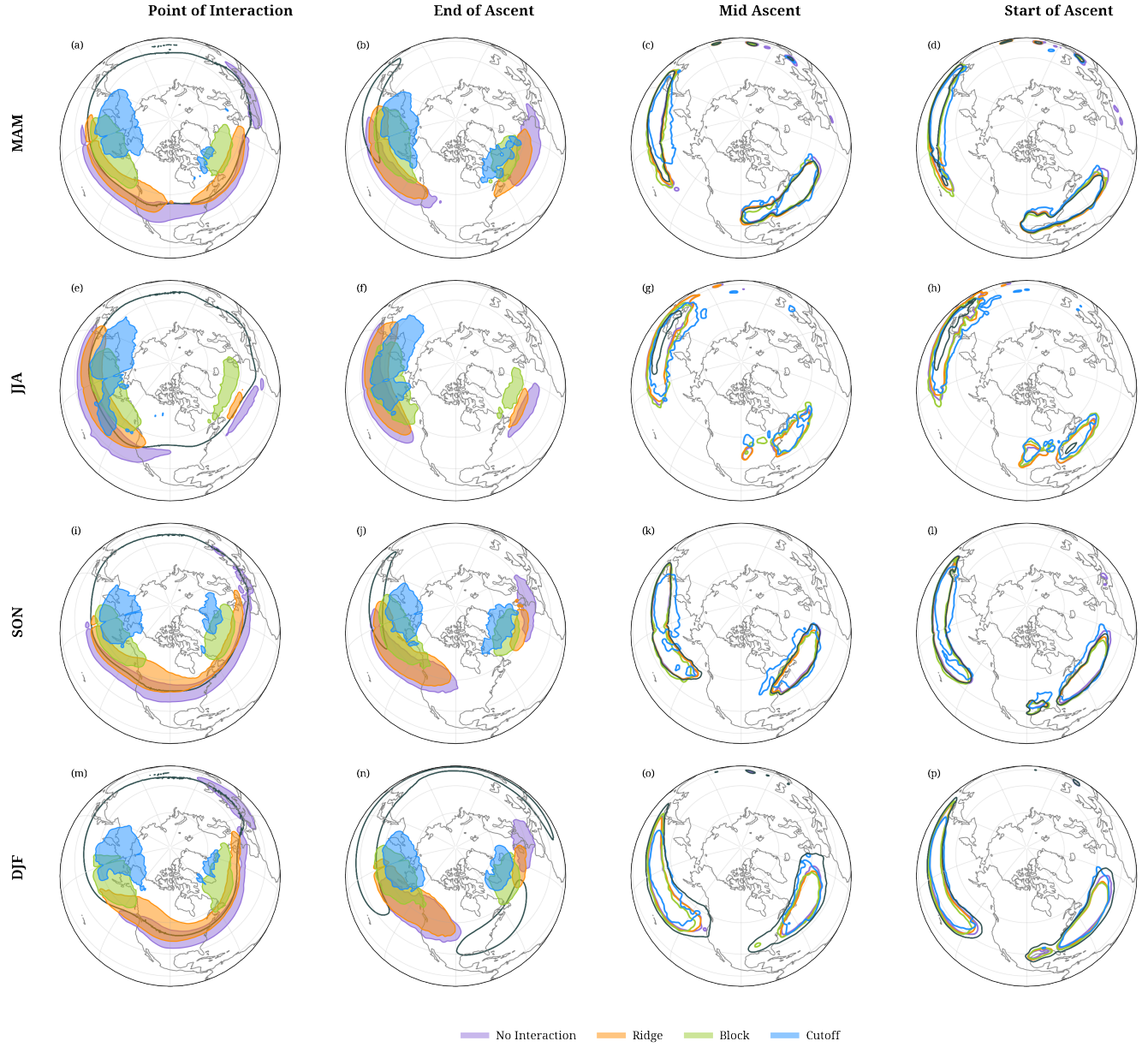


Figure S7. The main climatological frequency maxima (95th percentile regions) of WCB trajectories for: no-interaction (purple shading and contours, denoting the regions where the interaction type frequency exceeds the 95th percentile), ridge interaction (orange), block interaction (green), and cutoff interaction (blue) at the four trajectory phases for different seasons in NH: **(a-d)** MAM, **(e-h)** JJA, **(i-l)** SON, and **(m-p)** DJF, showing **(a,e,i,m)** point of interaction, **(b,f,j,n)** end-of-ascent, **(c,g,k,o)** mid-ascent and **(d,h,l,p)** start-of-ascent. In **(c,d,g,h,k,l,o,p)** shading is omitted to enhance readability. The black contours in **(a,e,i,m)** illustrate **(a)** the climatological mean waveguide and **(b,f,j,n)** the climatological jet stream indicated by a wind speed of 30 m s^{-1} , averaged over the four isentropic levels considered, and 95th percentile regions of total WCB **(c,g,k,o)** mid-ascent and **(d,h,l,p)** start-of-ascent.

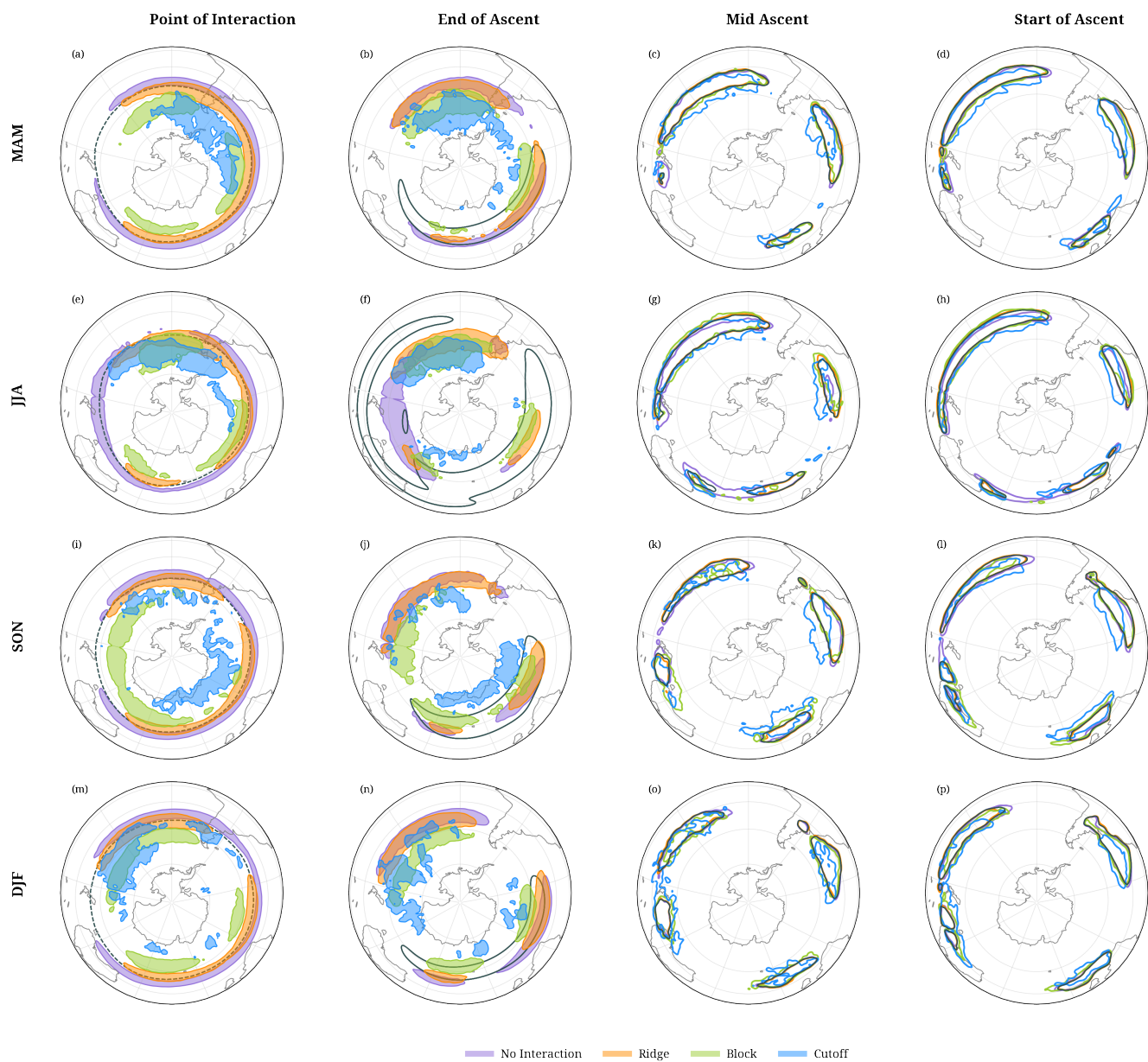


Figure S8. As Fig. S7, but for SH

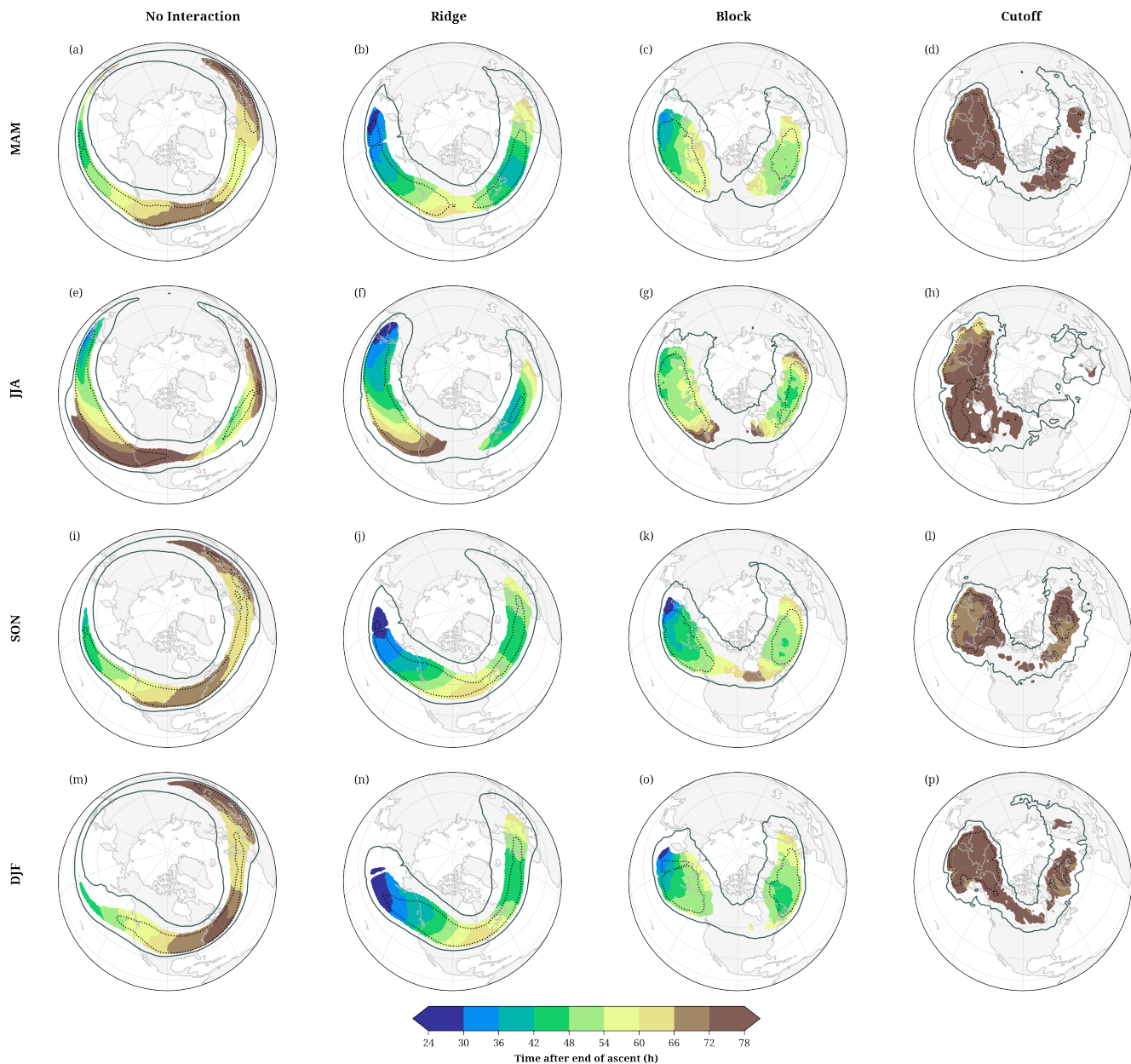


Figure S9. The climatological mean outflow age at the point of interaction (colors, in h) for different seasons in NH: **(a-d)** MAM, **(e-h)** JJA, **(i-l)** SON, and **(m-p)** DJF, showing **(a,e,i,m)** no-interaction, **(b,f,j,n)** ridge, **(c,g,k,o)** block, and **(d,h,l,p)** cutoff interaction categories. The black contours show the 80th (solid) and 95th (dotted) percentiles of WCB frequencies at the point of interaction for the respective interaction types.

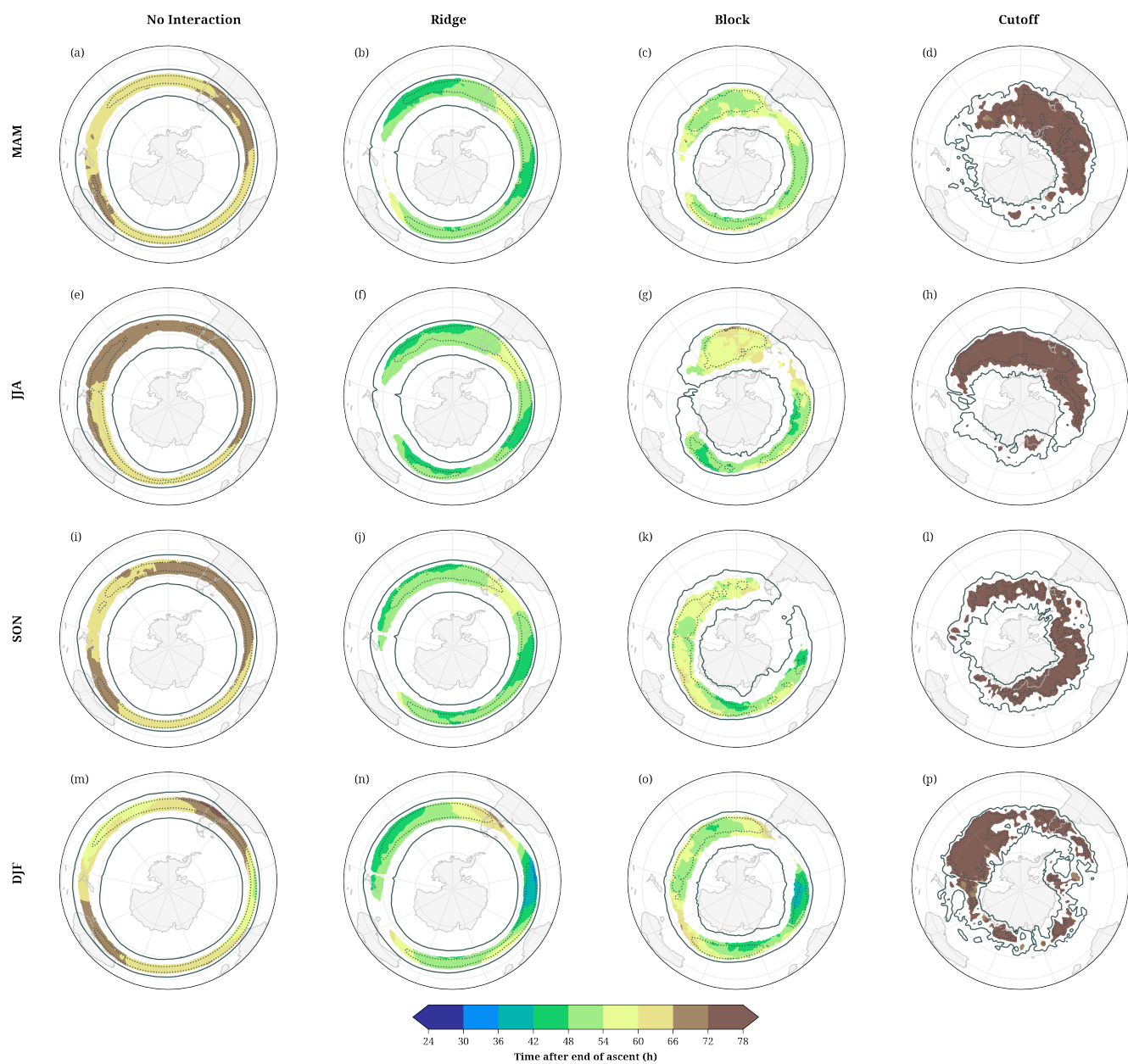


Figure S10. As Fig. S9, but for SH

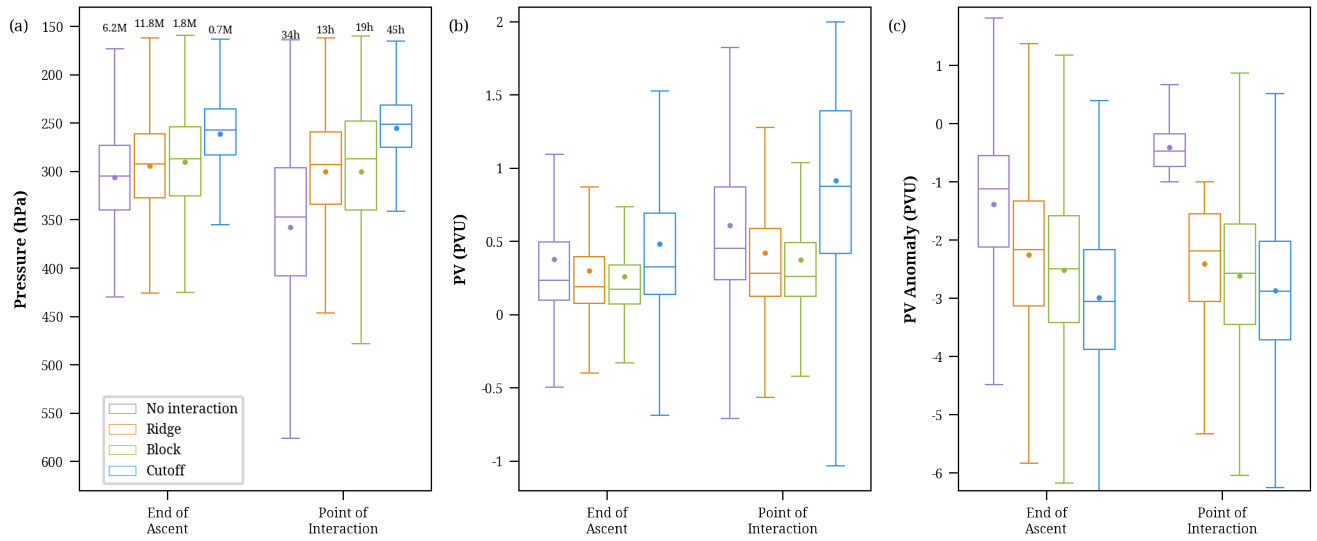


Figure S11. Characteristics of different WCB interaction types at the end-of-ascent and point-of-interaction for NH in MAM. Shown are box plots of (a) pressure (hPa), (b) absolute PV (PVU), and (c) PV anomalies (PVU). Indicated are the median (horizontal line), the mean (circular dot), the interquartile range (box), and the whiskers extending to the 5th and 95th percentiles; outliers are not shown. The numbers in (a) above the bars indicate (left) the total number of trajectories and (right) the median outflow age (M = million).

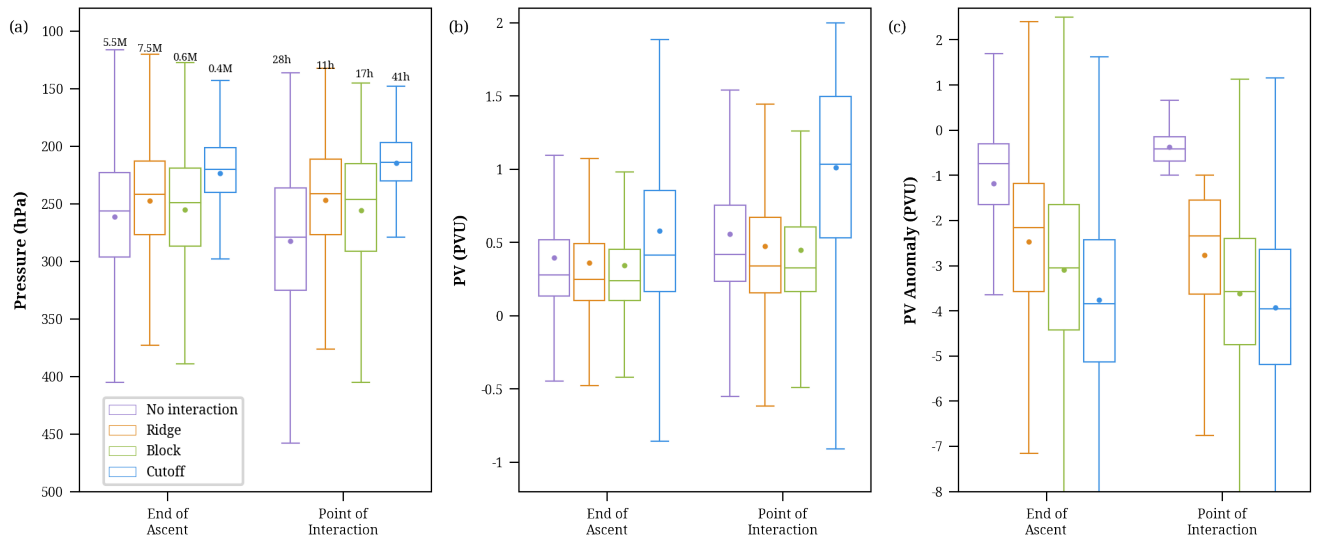


Figure S12. As Fig. S11, but for JJA

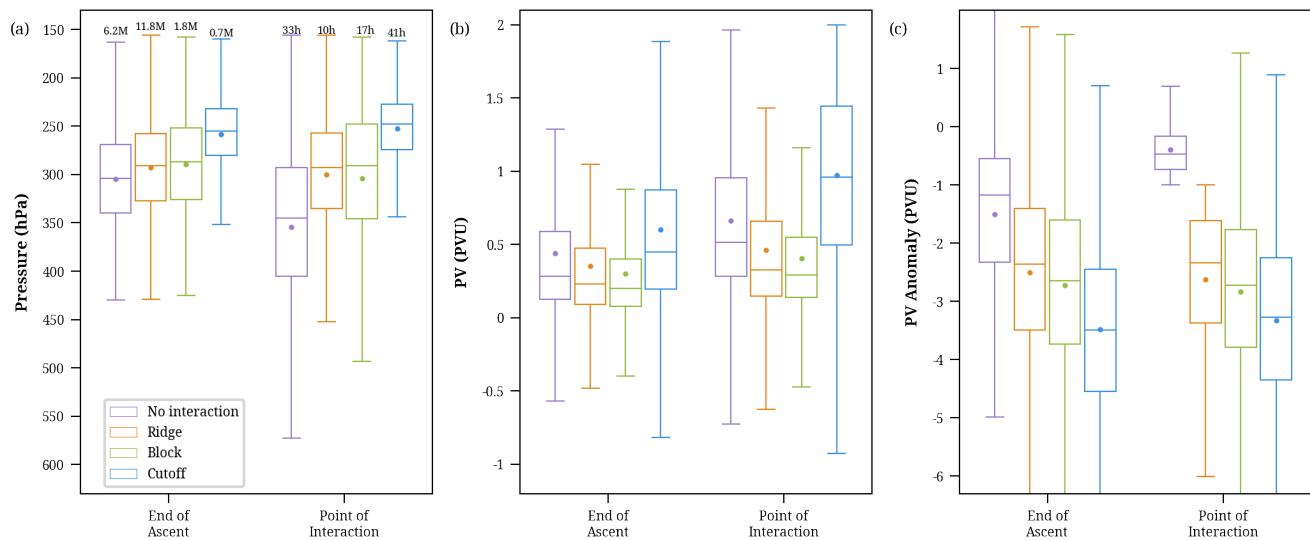


Figure S13. As Fig. S11, but for SON

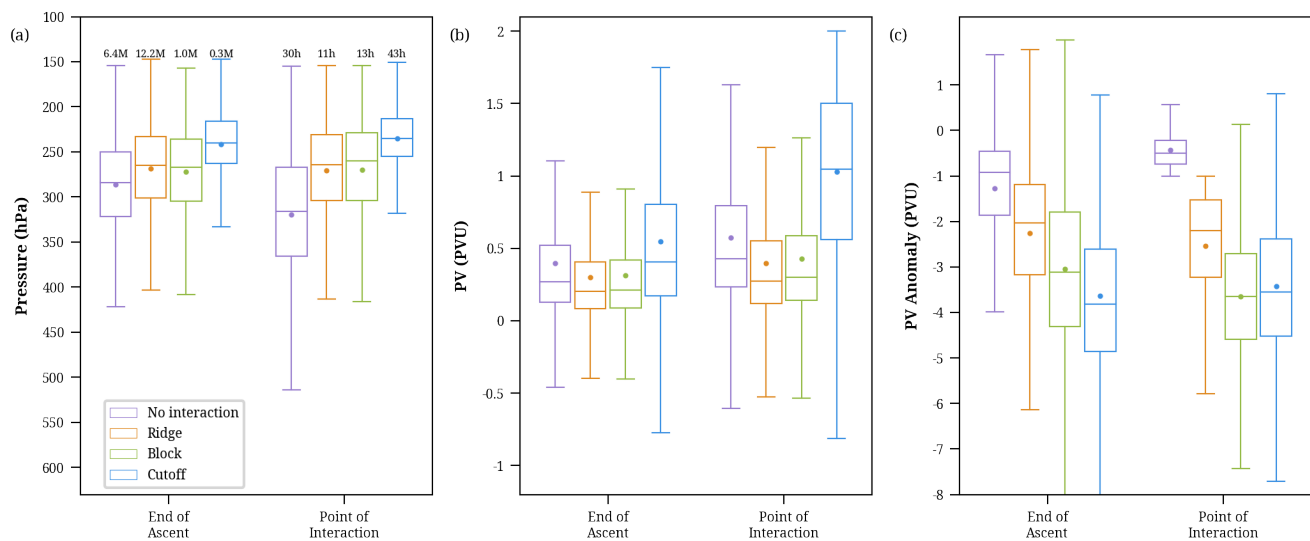


Figure S14. As Fig. S11, but for SH in JJA. PV values are multiplied by -1.

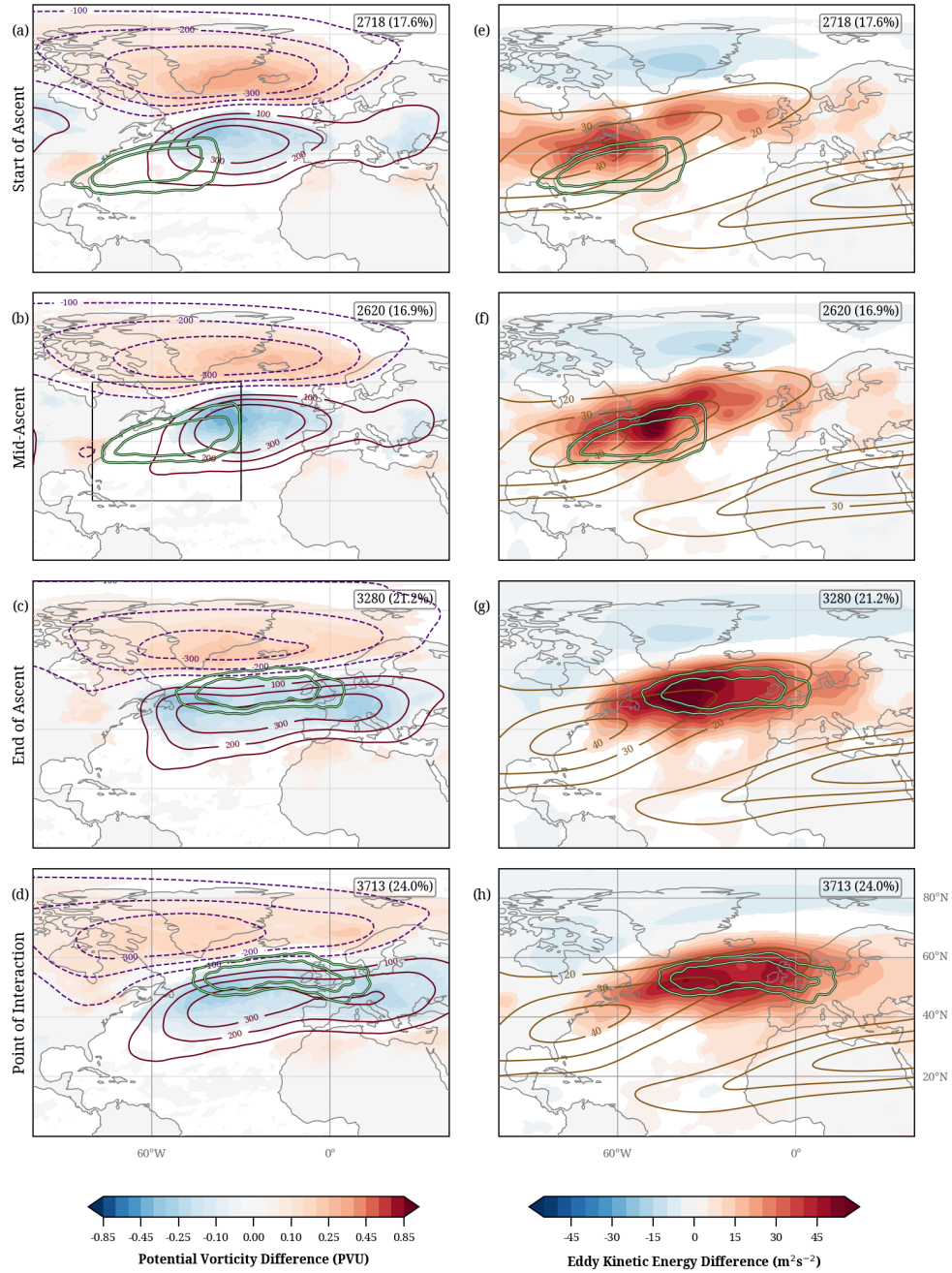


Figure S15. Composites of ridge time steps over North Atlantic for the four trajectory phases: start-of-ascent (a,e), mid-ascent (b,f), end-of-ascent (c,g), and point-of-interaction (d,h). (a-d) show PV at 320 K and geopotential anomalies at 250 hPa (solid and dashed lines for positive and negative values, respectively). (e-h) show 500 hPa EKE anomalies and low-pass filtered zonal wind at 250 hPa (brown lines). Grid points where PV and EKE anomalies fall within the 1st–99th percentile confidence interval are shown in white. The highlighted white-green contours in (a-h) show the 98th and 99th percentiles of occurrence frequency of the ridge-interaction WCB air parcels in the corresponding phases. Only the WCB air parcels that ascend within the rectangle (b,f) are selected for the analysis. The number of time steps included in each composite and the corresponding percentage w.r.t. all DJF time steps in the considered 43-y period are given in each panel.

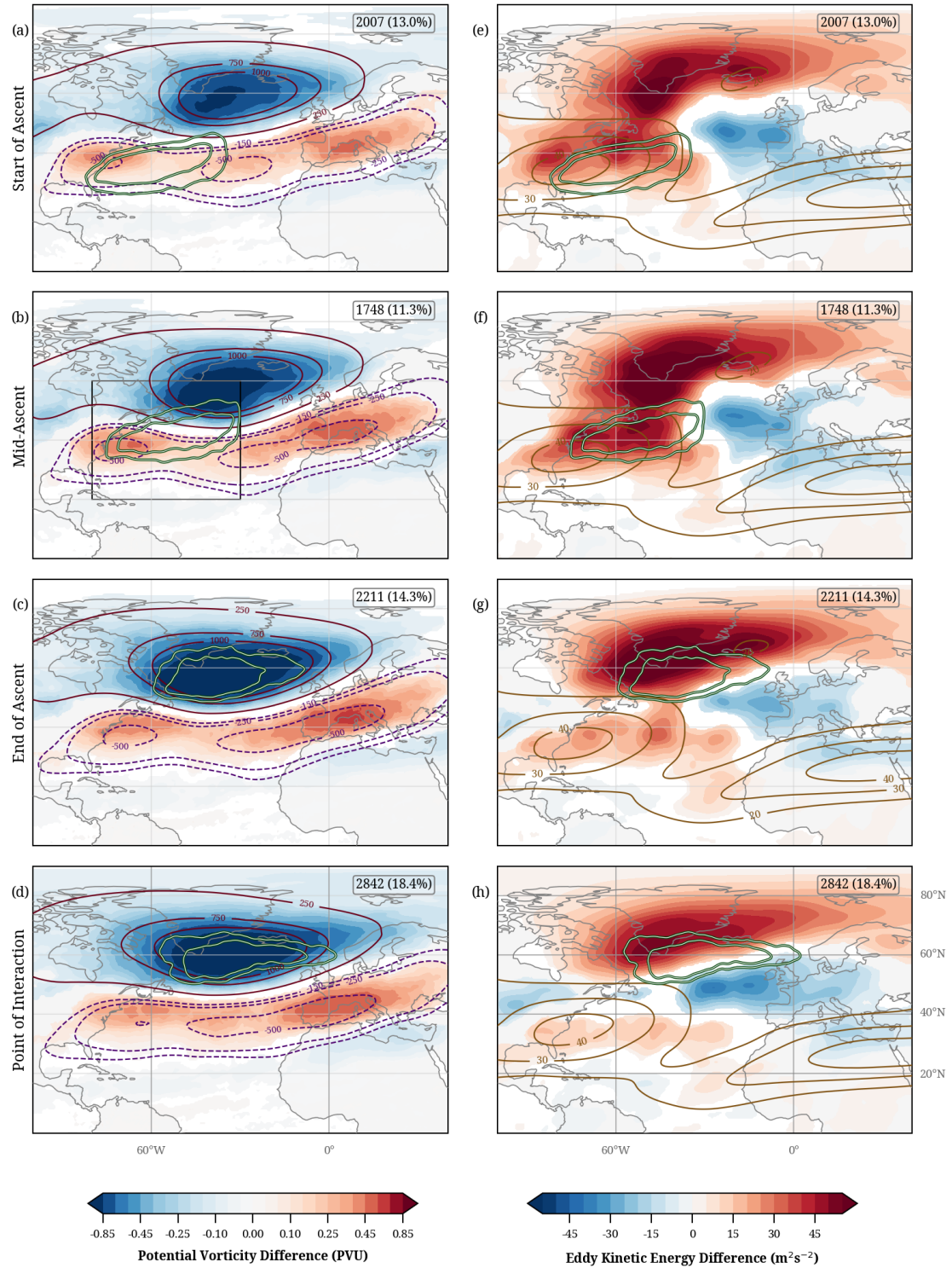


Figure S16. As Fig. S15, but for block interaction time steps.

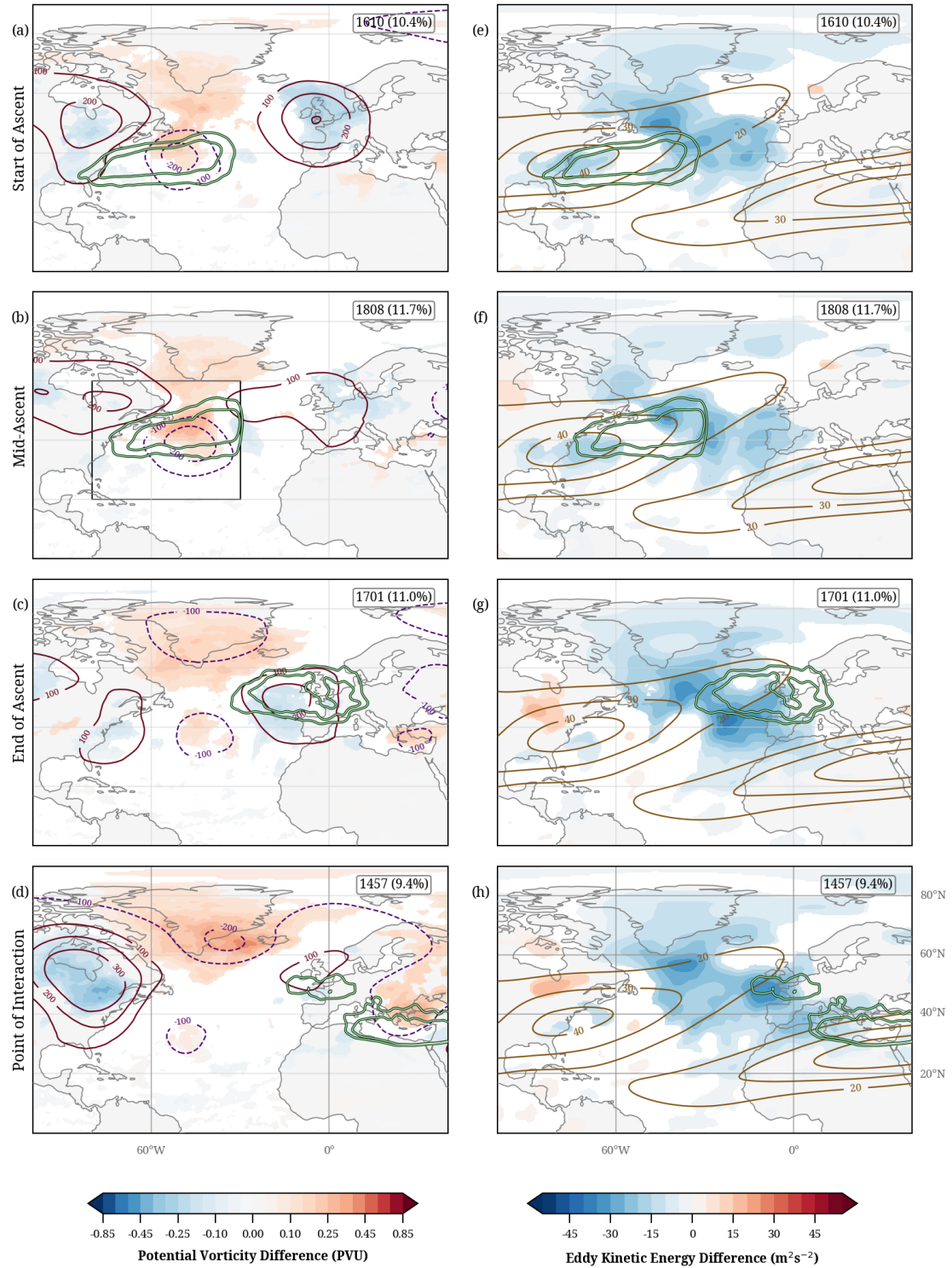


Figure S17. As Fig. S15, but for no-interaction time steps.

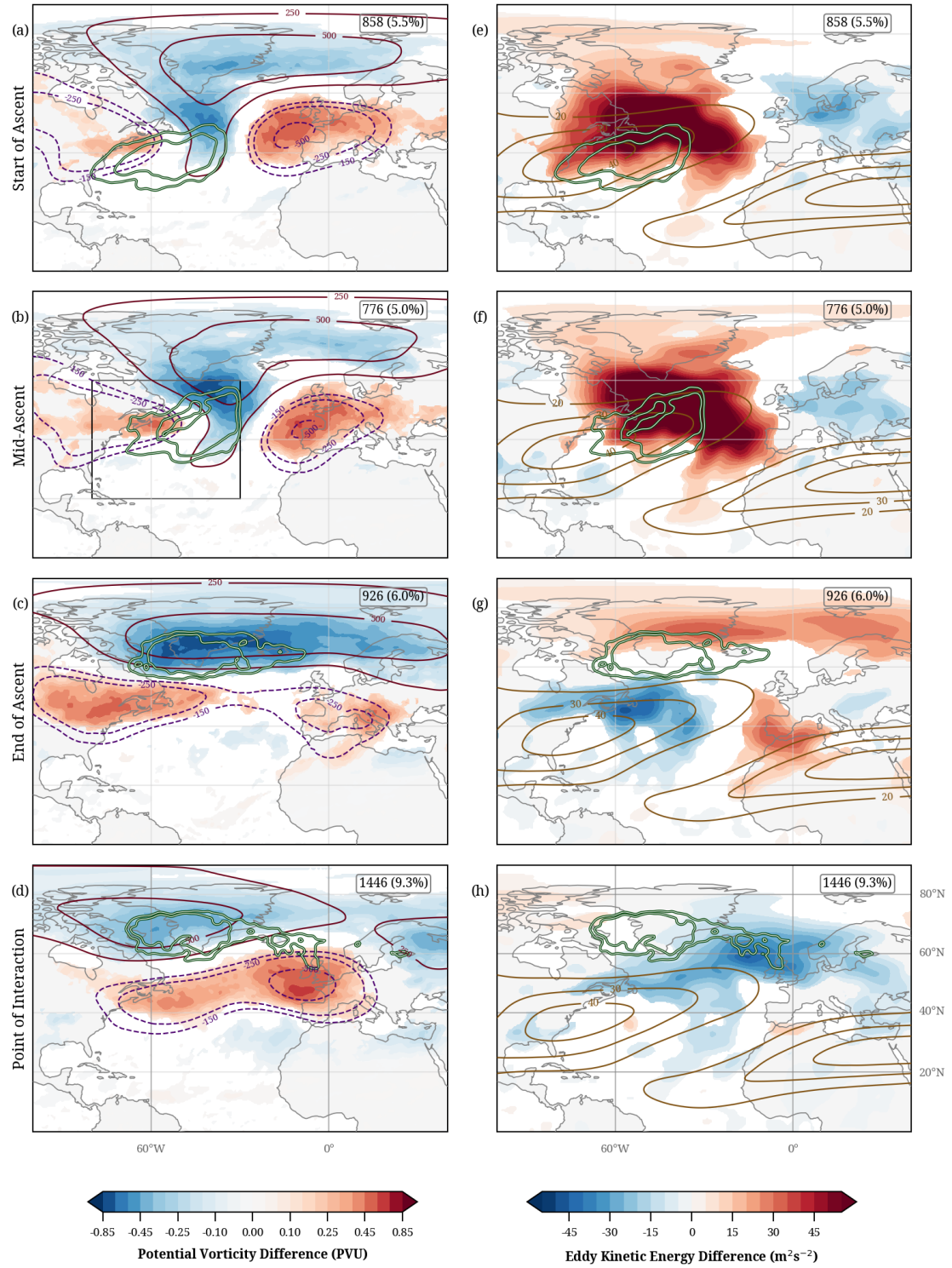


Figure S18. As Fig. S15, but for cutoff interaction time steps.