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Supplement of

Dynamical drivers of Greenland blocking in climate models

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Table S1: Resolution and number of member for the HAPPI models. Further information can be found in Mitchell et al. (2017) and Li et al. (2018).

Model	Horizontal grid	lat × lon	Vertical levels	Members
CAM4-2degree	$1.9° \times 2.5°$	64×128	26	501
CanAM4	T63	96×192	35	100
ECHAM6.3-LR	T63	96×192	47	100
MIROC5	T85	128×256	40	100
NorESM1-HAPPI	$0.94° \times 1.25°$	192×288	26	125

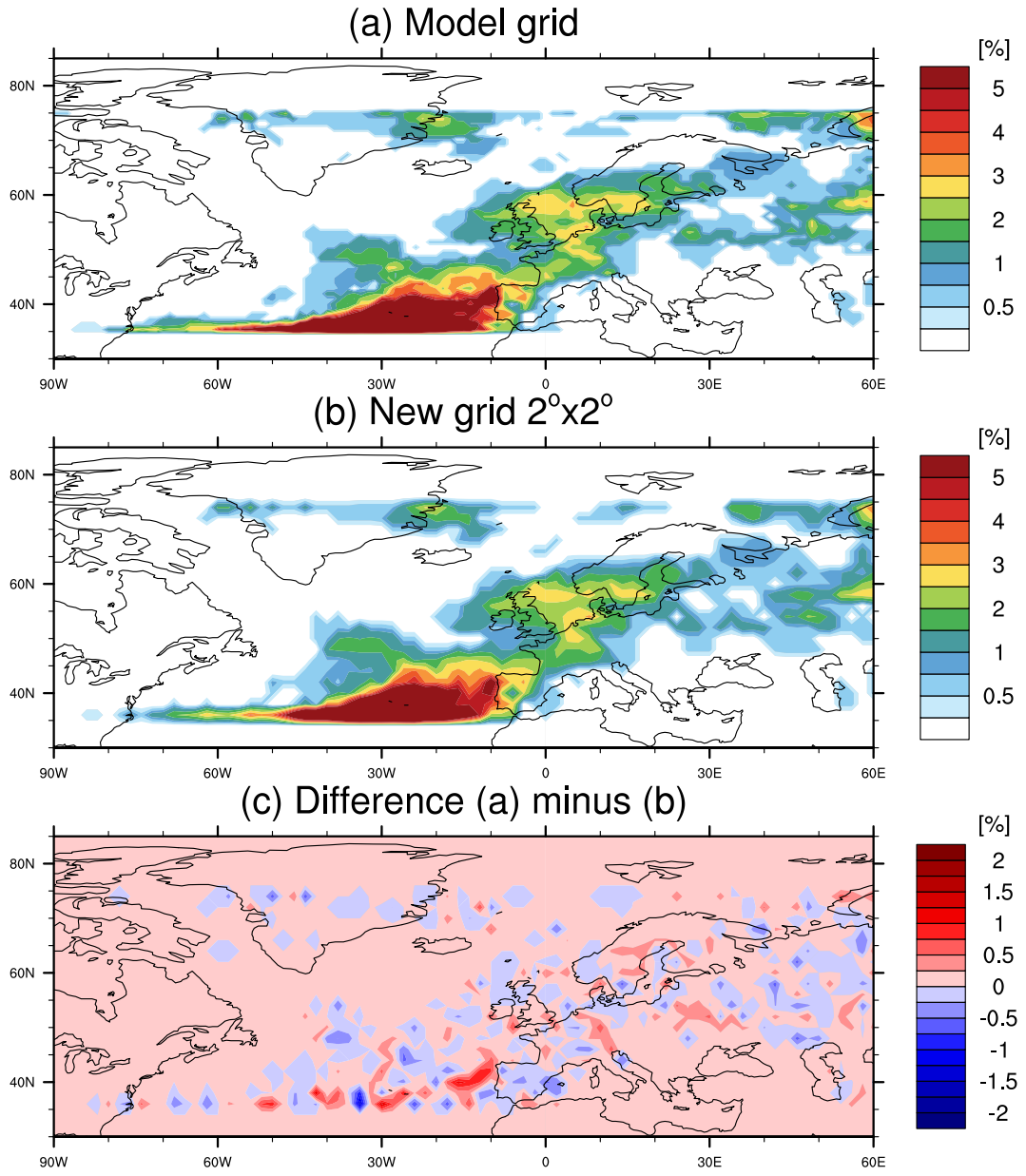

Figure S1: DJF mean blocking frequency (unit: % of winter days) for member 1 of the NorESM1-HAPPI ensemble, with blocking detected using the 500-hPa geopotential on (a) the model grid and (b) a grid of $2^\circ \times 2^\circ$. (c) Difference between the two mean frequencies (a) minus (b) where (a) has been remapped on the same $2^\circ \times 2^\circ$ grid as (b).

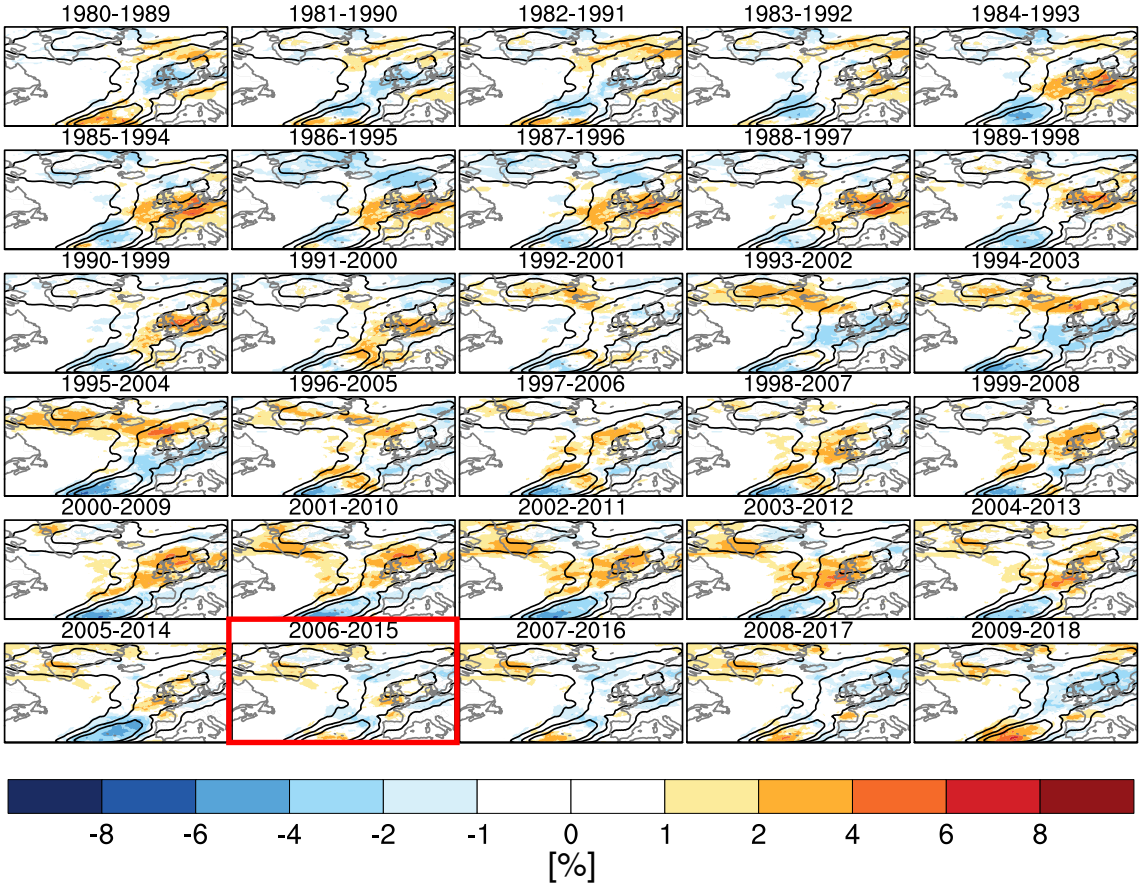

Figure S2: Differences between 9-winter blocking frequency climatologies and the 40-year (39-winter) climatology using ERA-Interim over the period 1979-2018 (shading, unit: % of winter days). Black lines show the 2, 4 and 6% contours for the 40-year DJF ERA-Interim climatology. The decade of each climatology is given above each panel and the red frame shows the 2006-2015 period (i.e. December 2006 to February 2015) used in the main paper. None of the 9-year climatologies are in any regions statistically different (t-test at 0.1 level) from the 40-year mean.

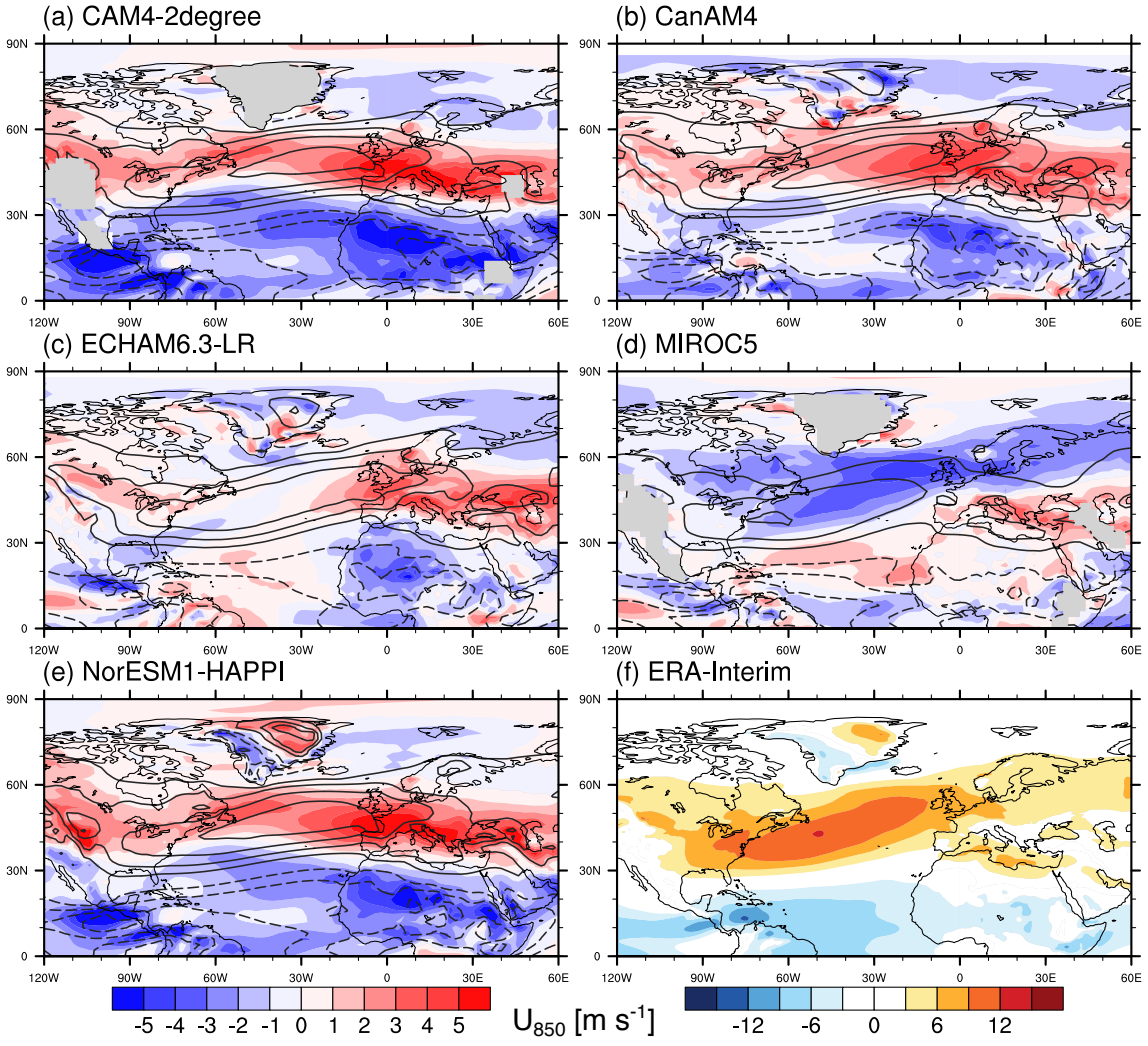

Figure S3: Bias in winter zonal wind at 850 hPa (shading, in m s^{-1}), overlapped by the model climatology (contours, interval: 3 m s^{-1}, zero-contour omitted, negative values with dashed lines). Bias are computed with respect to ERA-Interim (2006-2015) shown in panel (f).

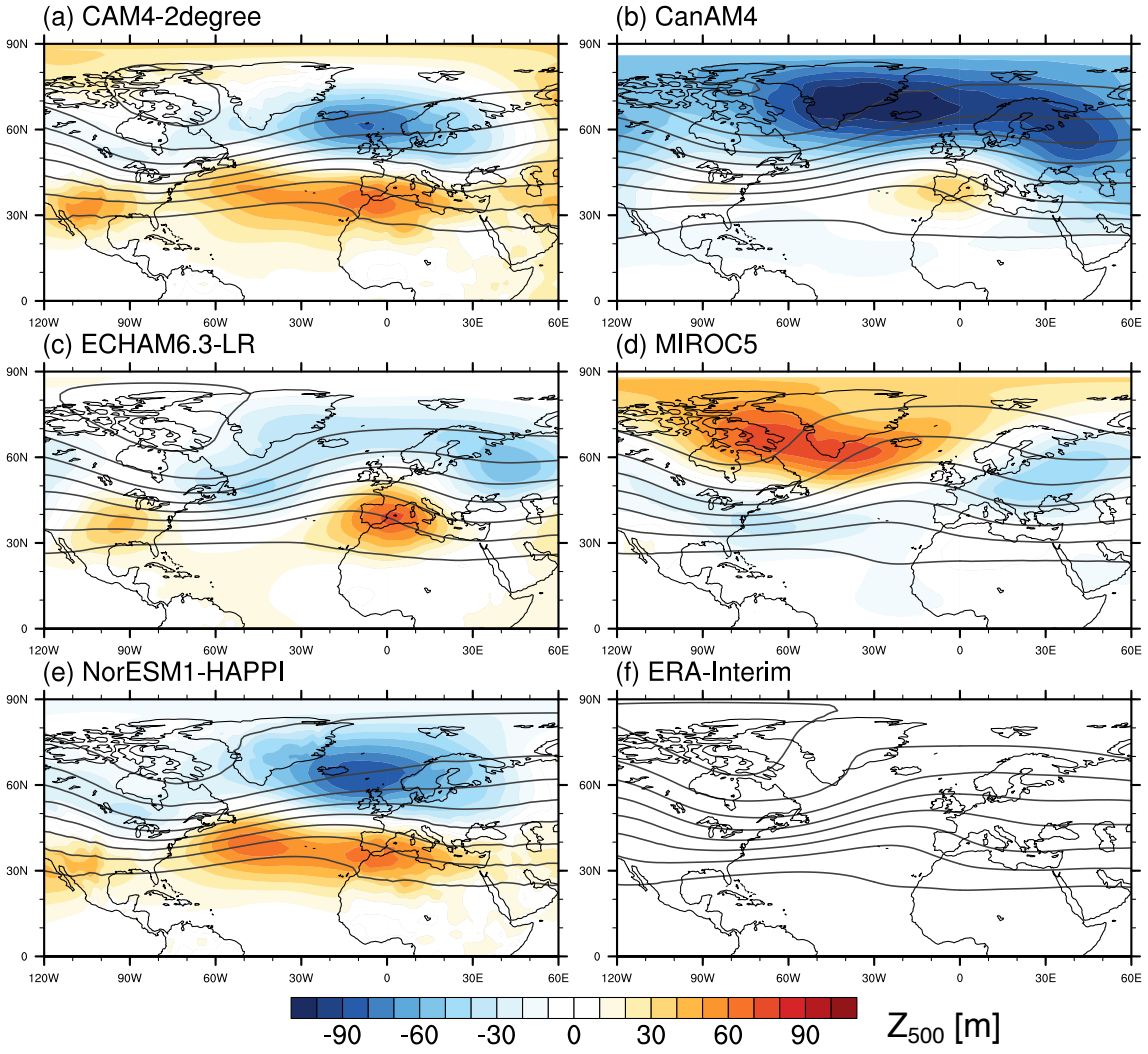

Figure S4: Bias of the ensemble mean 500-hPa geopotential height (shading, unit: m) and ensemble mean of the 500-hPa geopotential height (contours, interval: 100 m). Bias are computed with respect to ERA-Interim (2006-2015) shown in panel (f).

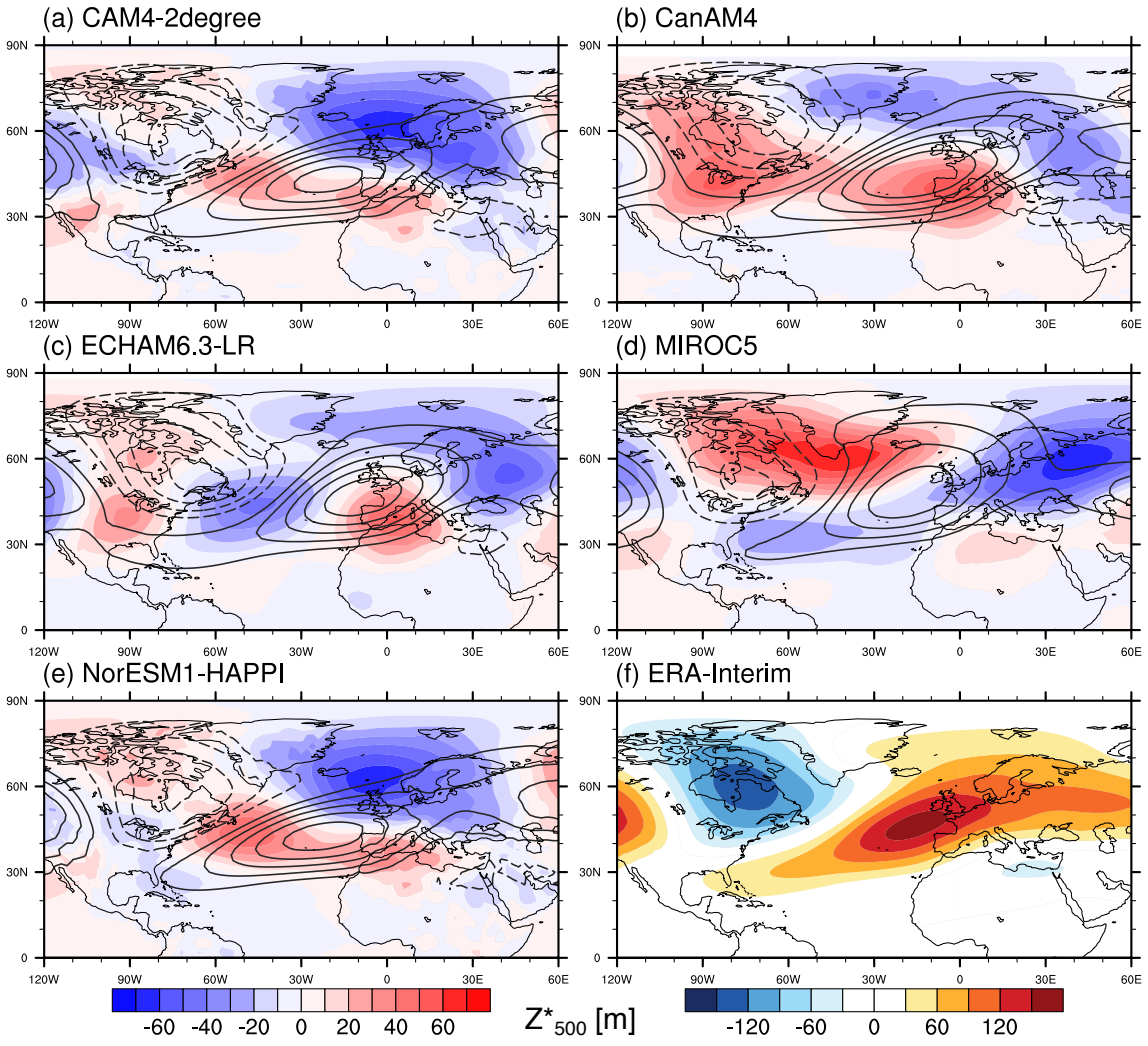

Figure S5: (a-e) Bias in winter stationary waves at 500 hPa defined as the deviation from the zonal mean geopotential (shading), overlapped by the model climatology (contours, interval: 30 m, zero-contour omitted). Bias are computed with respect to ERA-Interim (2006-2015) shown in panel (f).

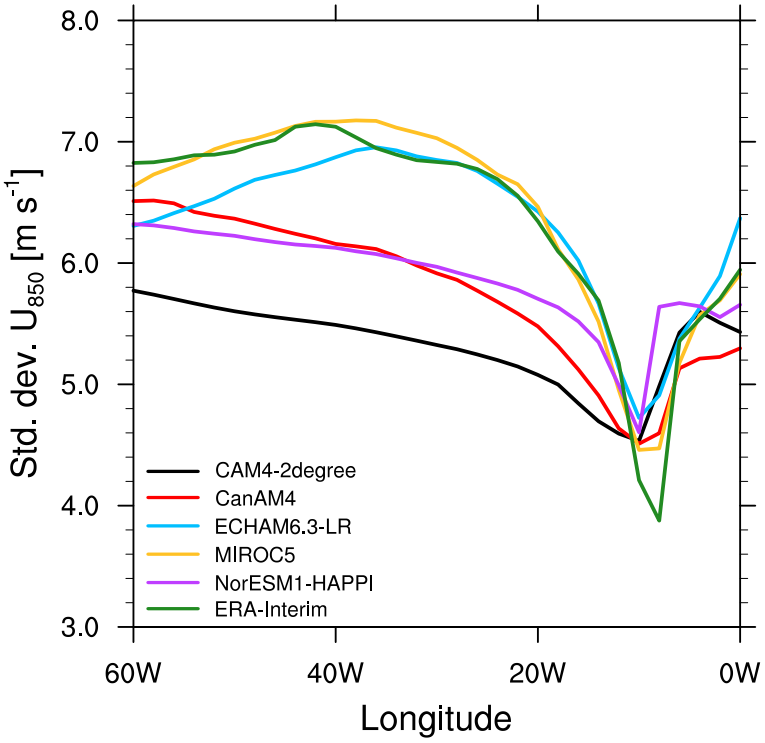

Figure S6: Ensemble mean of the DJF mean daily standard deviation of the 850-hPa zonal wind at 30°N (units: m s^{-1}) as a function of the longitude (covering the North Atlantic domain, here from 60°W to 0°W) for every HAPPI ensemble. The green line shows the DJF mean daily standard deviation for ERA-Interim (2006-2015).

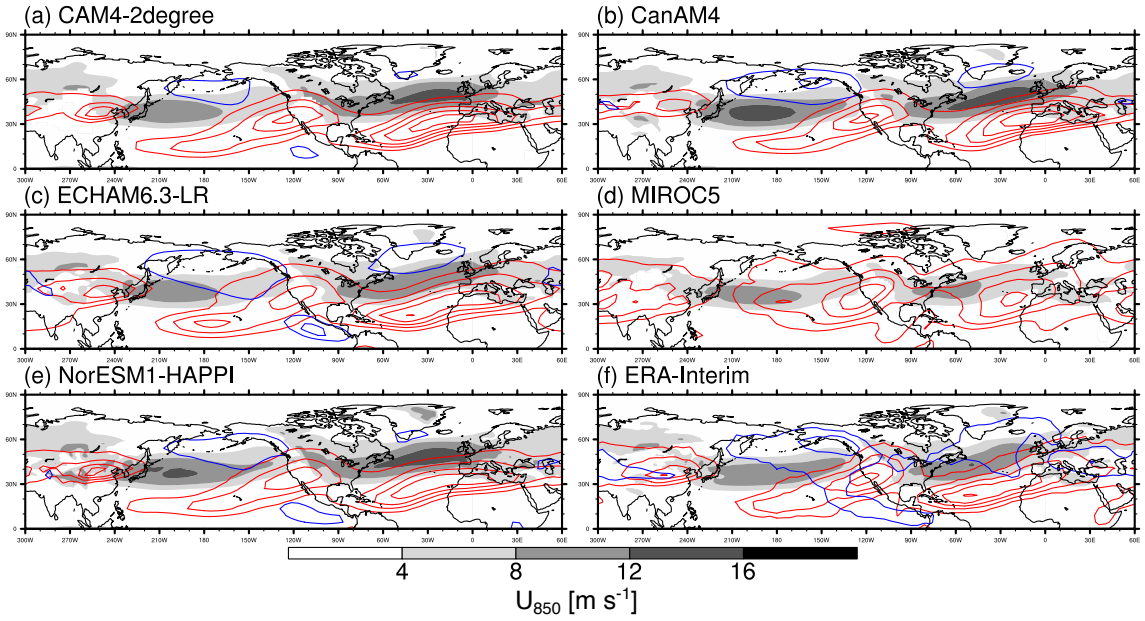

Figure S7: Ensemble mean of DJF Rossby wave breaking frequency for (a-e) the five HAPPI models and (f) ERA-Interim (blue (red) contours for CWB (AWB), first contour: 0.1 day^{-1} and interval: 0.05 day^{-1}) superimposed to the ensemble mean zonal wind at 850 hPa (shading, in m s^{-1}).

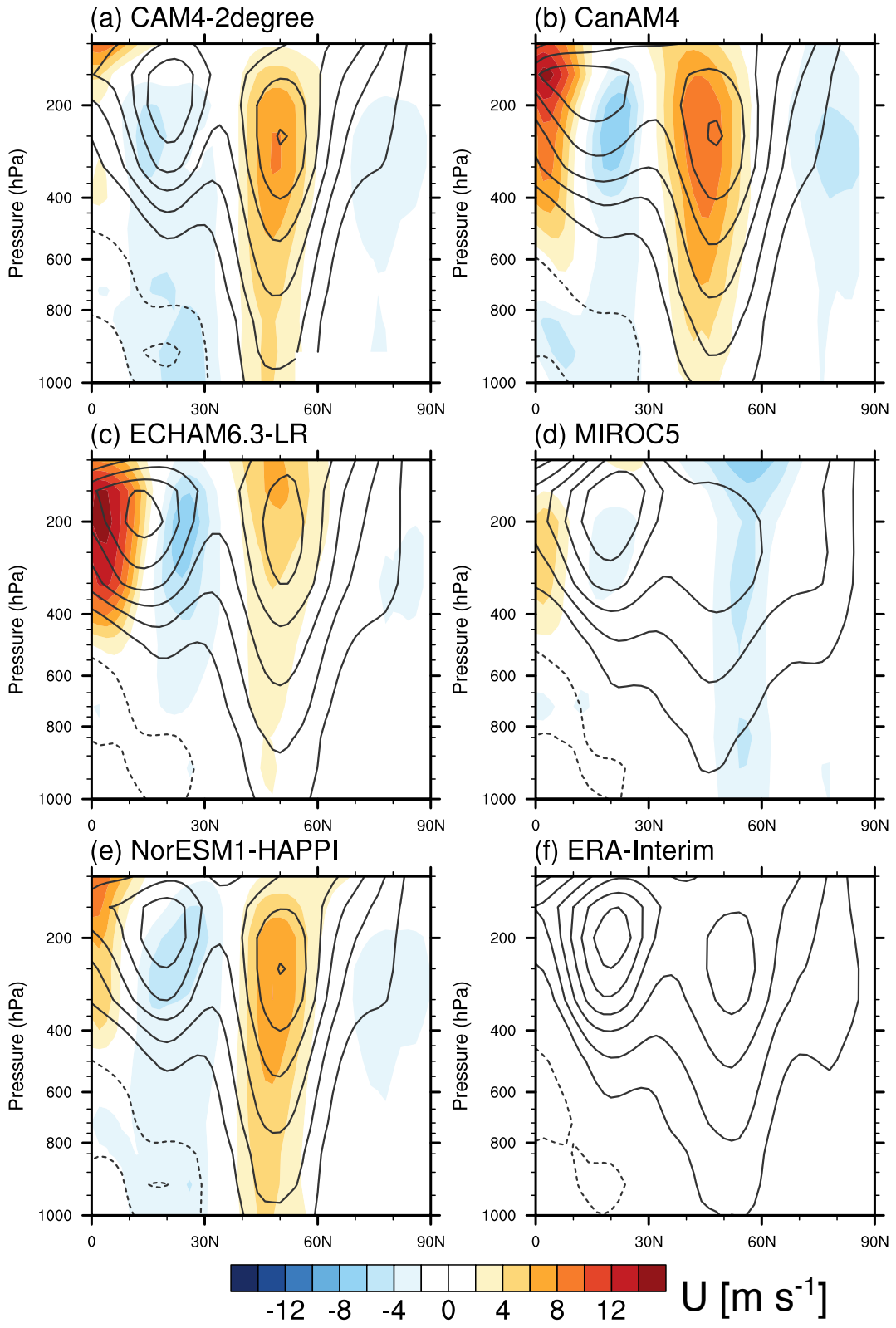

Figure S8: Cross-sections of the bias of the DJF ensemble mean of the zonal mean zonal wind (shading, unit: m s^{-1}) overlapped by the ensemble mean zonal mean zonal wind (contours, interval: 5 ms^{-1} , zero-contour omitted) for (a-e) the five HAPPI models. The bias is computed with respect to ERA-Interim (2006-2015) shown in panel (f). The zonal mean is taken between 30°W-0°, that is the eastern half of the North Atlantic.

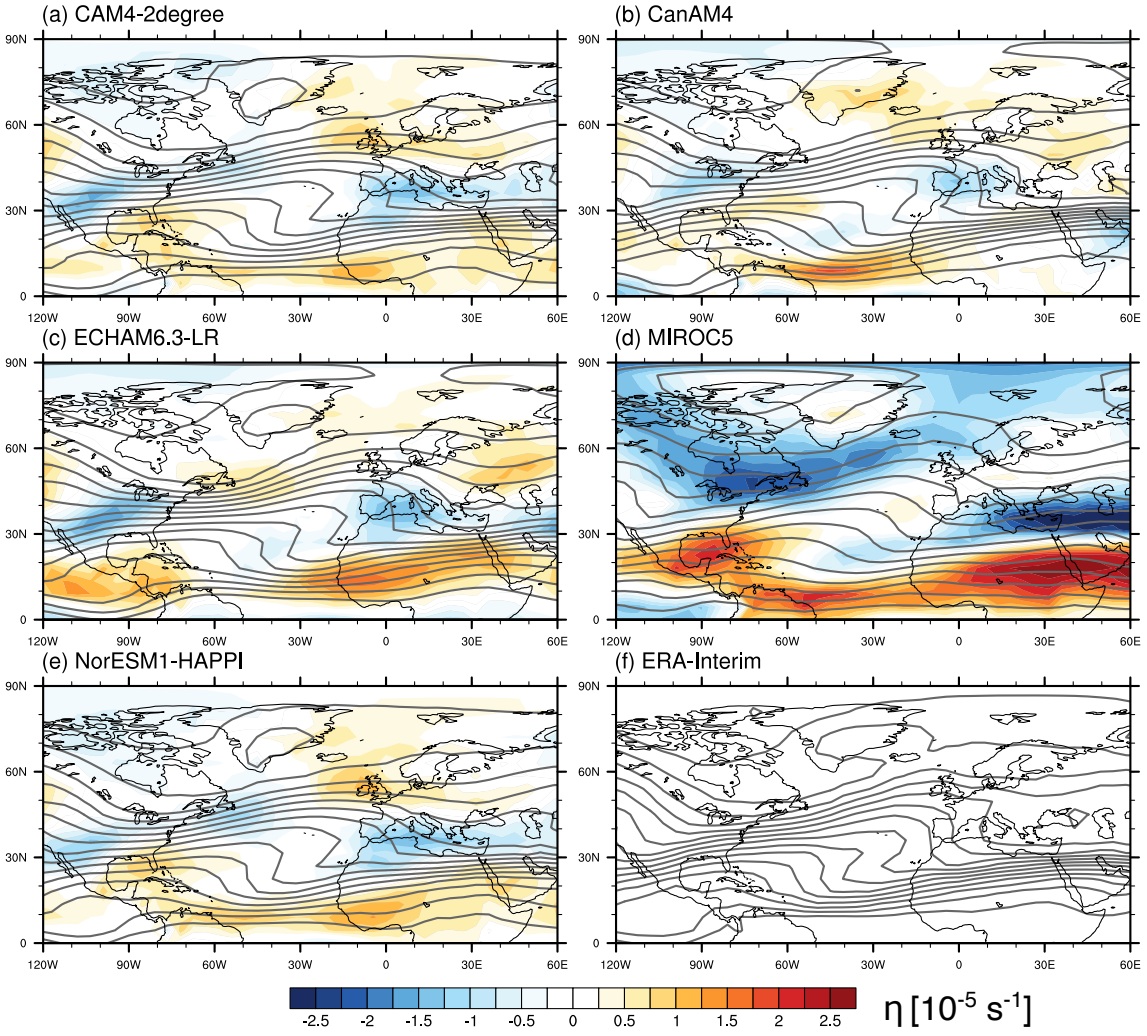

Figure S9: Bias of the ensemble mean 250-hPa absolute vorticity (shading, unit: 10^{-5} s^{-1}) and ensemble mean 250-hPa absolute vorticity (contours, interval: 10^{-5} s^{-1}). Bias are computed with respect to ERA-Interim (2006-2015) shown in panel (f).

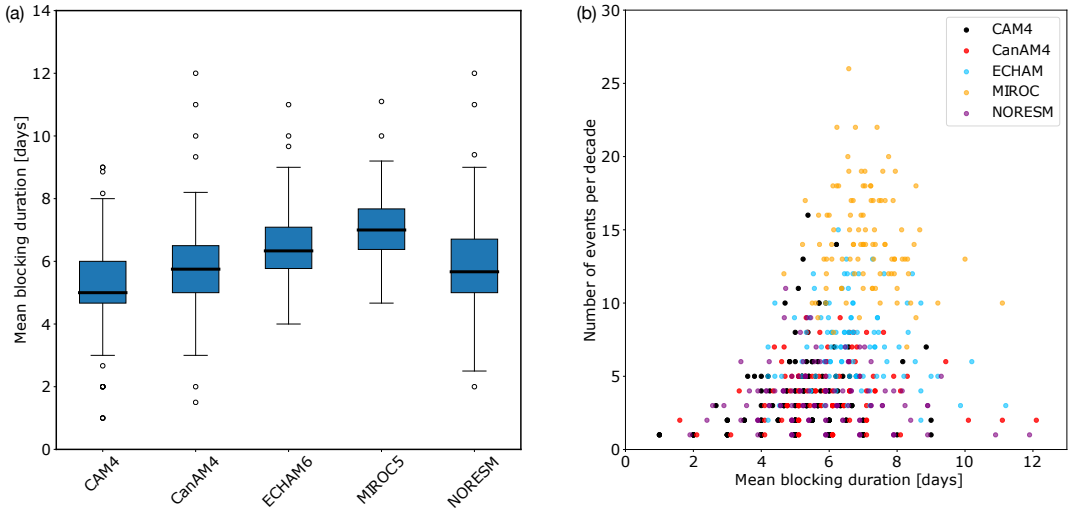

Figure S10: (Left) Ensemble distribution of the mean blocking duration (in days) for each member. The boxes show the interquartile range (IQR) and the dots represent values lower (greater) than 1.5 IQR represented by the whiskers. (Right) Number of Greenland blocking events as a function of their mean duration (in days) for each member (dots) of each model (colors).

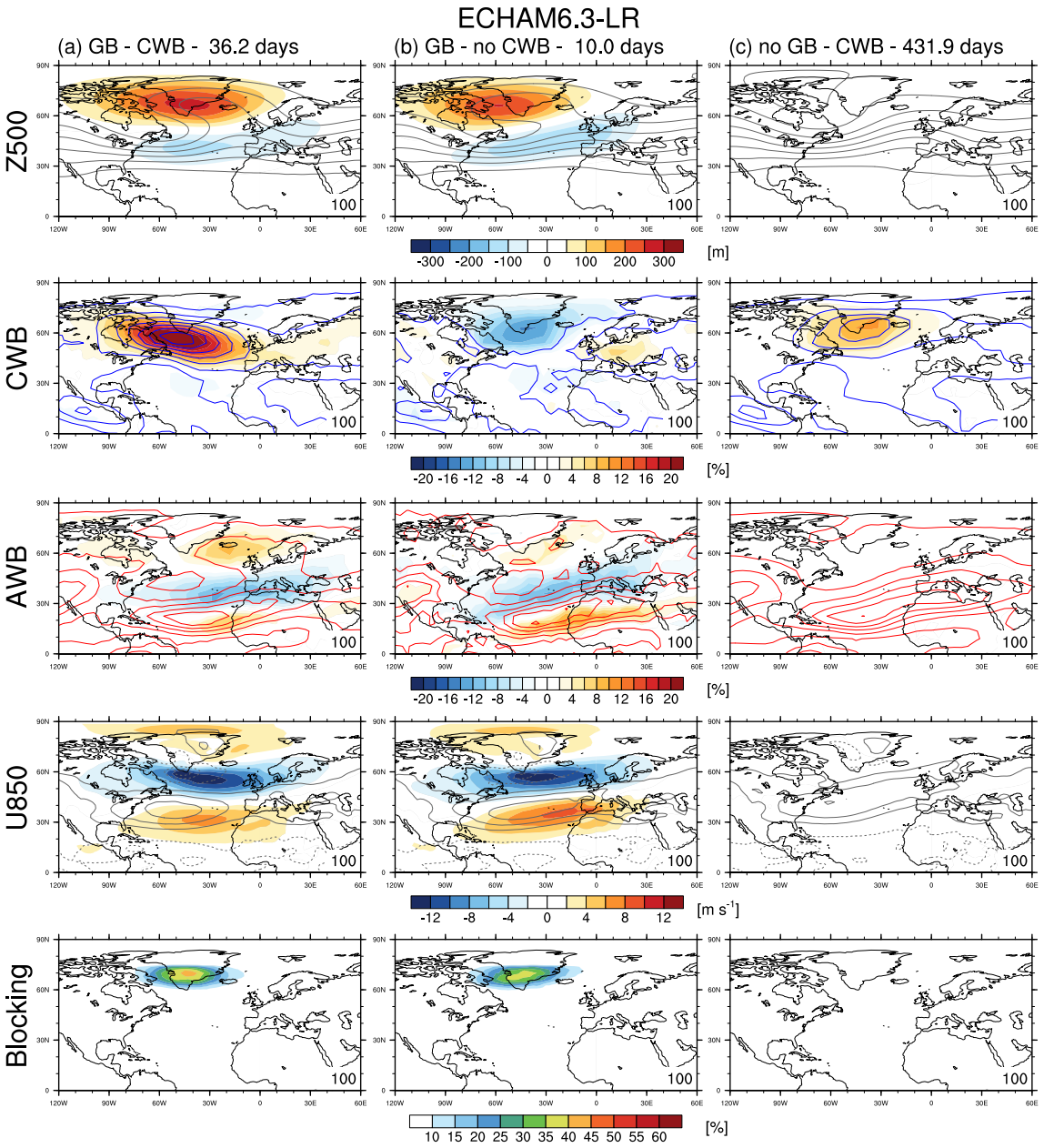

Figure S11: Ensemble mean of the composites of the 500-hPa geopotential (Z500), AWB, CWB, 850-hPa zonal wind (U850) and blocking for three categories (GB - CWB, GB - no CWB, and no GB - CWB) whose mean numbers of days are found in Table 2 for ECHAM6.3-LR. The first four top rows shows the anomalies in shading and the total field in contours and the bottom row shows the blocking frequency in shading. The numbers in the bottom right corner of each panel show the number of members that have days in the category. Here all members have at least one day in all categories. GB stands for Greenland Blocking.

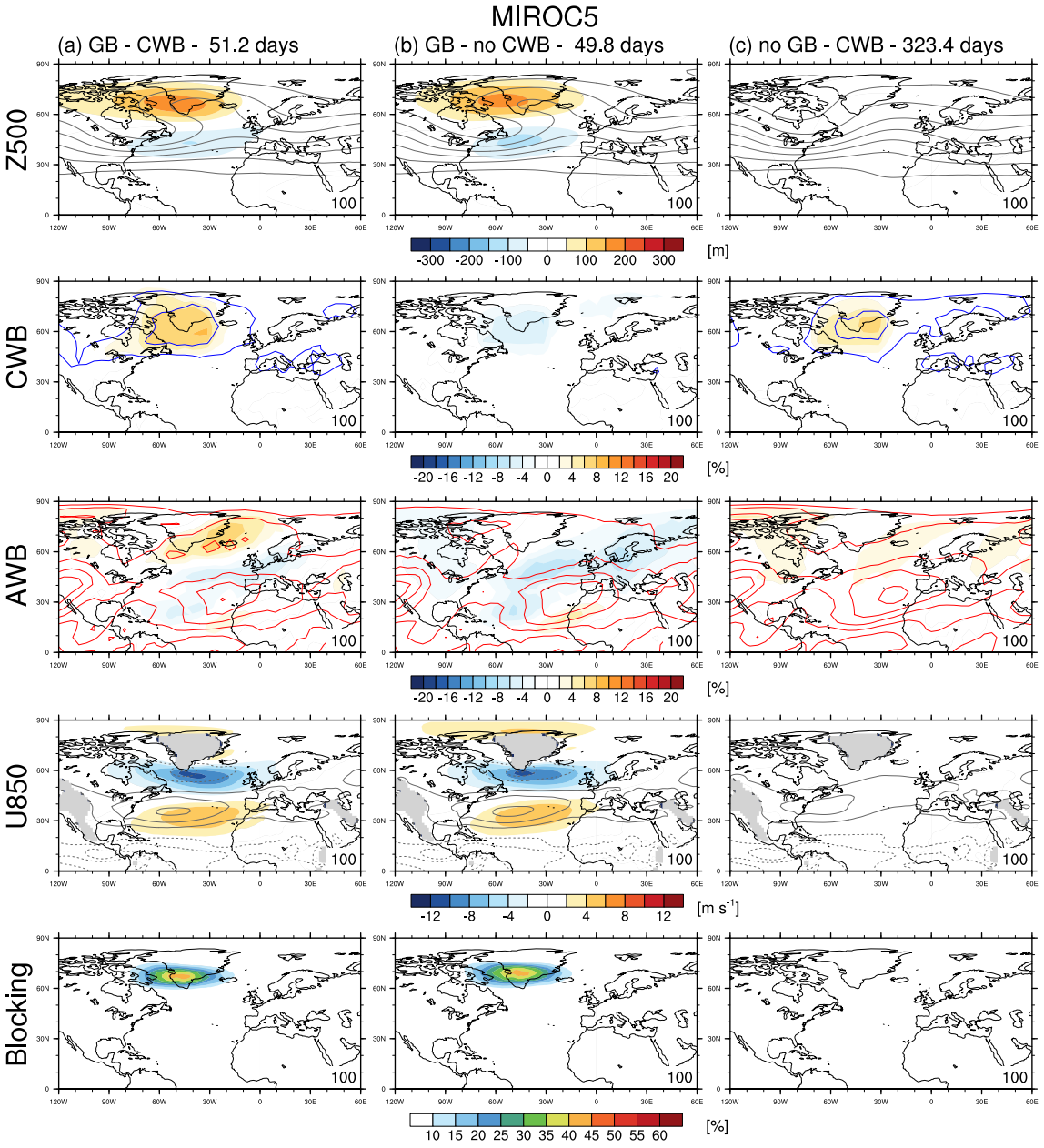

Figure S12: As Fig. S11 but for MIROC5.

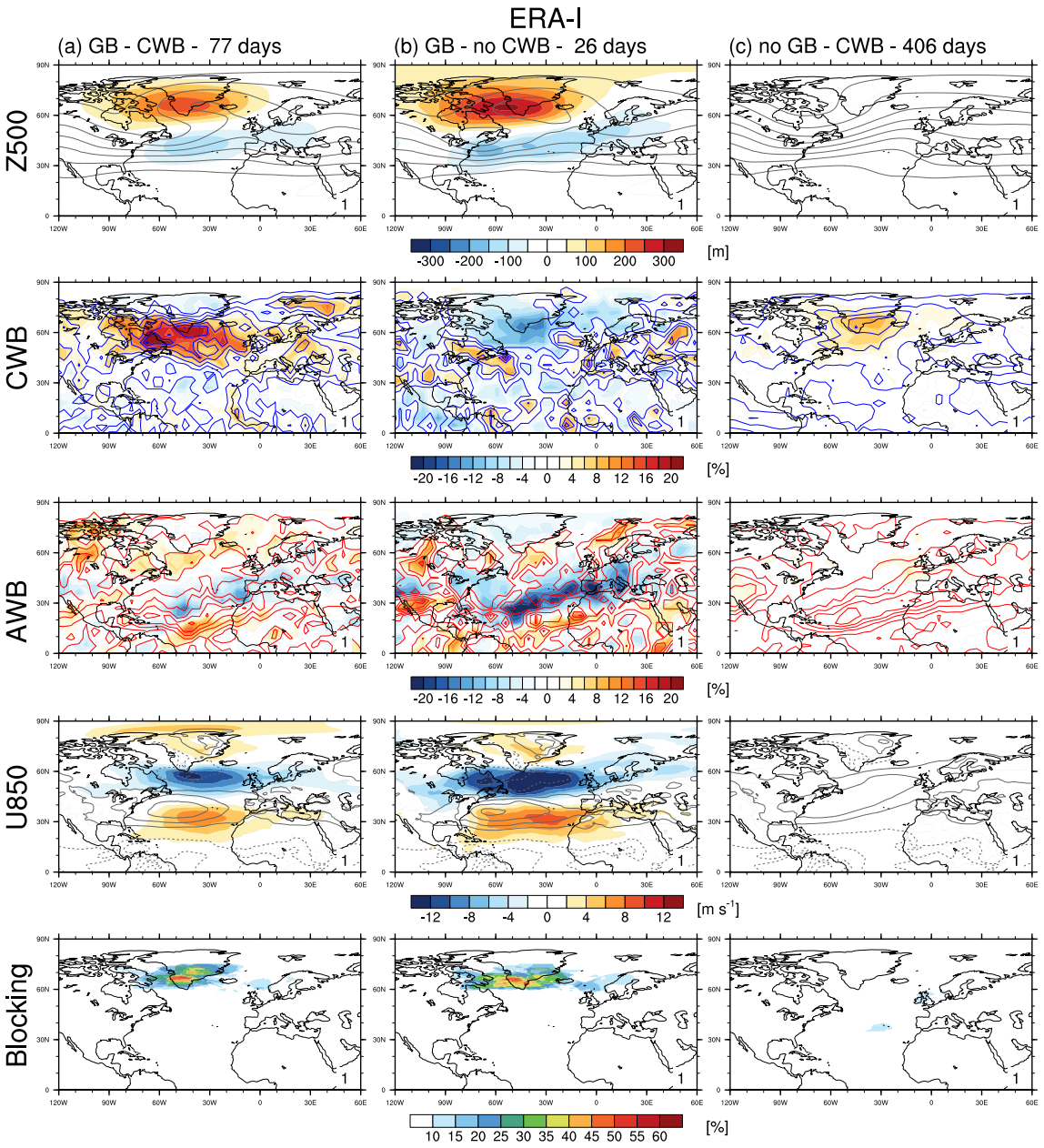

Figure S13: Composites of the 500-hPa geopotential (Z500), AWB, CWB, 850-hPa zonal wind (U850) and blocking for three categories (GB - CWB, GB - no CWB, and no GB - CWB) whose numbers of days are found in Table 2 for ERA-Interim. The first four top rows shows the anomalies in shading and the total field in contours and the bottom row shows the blocking frequency in shading. The number 1 in the bottom right corner of each panel points out that this is ERA-Interim and not an ensemble. GB stands for Greenland Blocking.

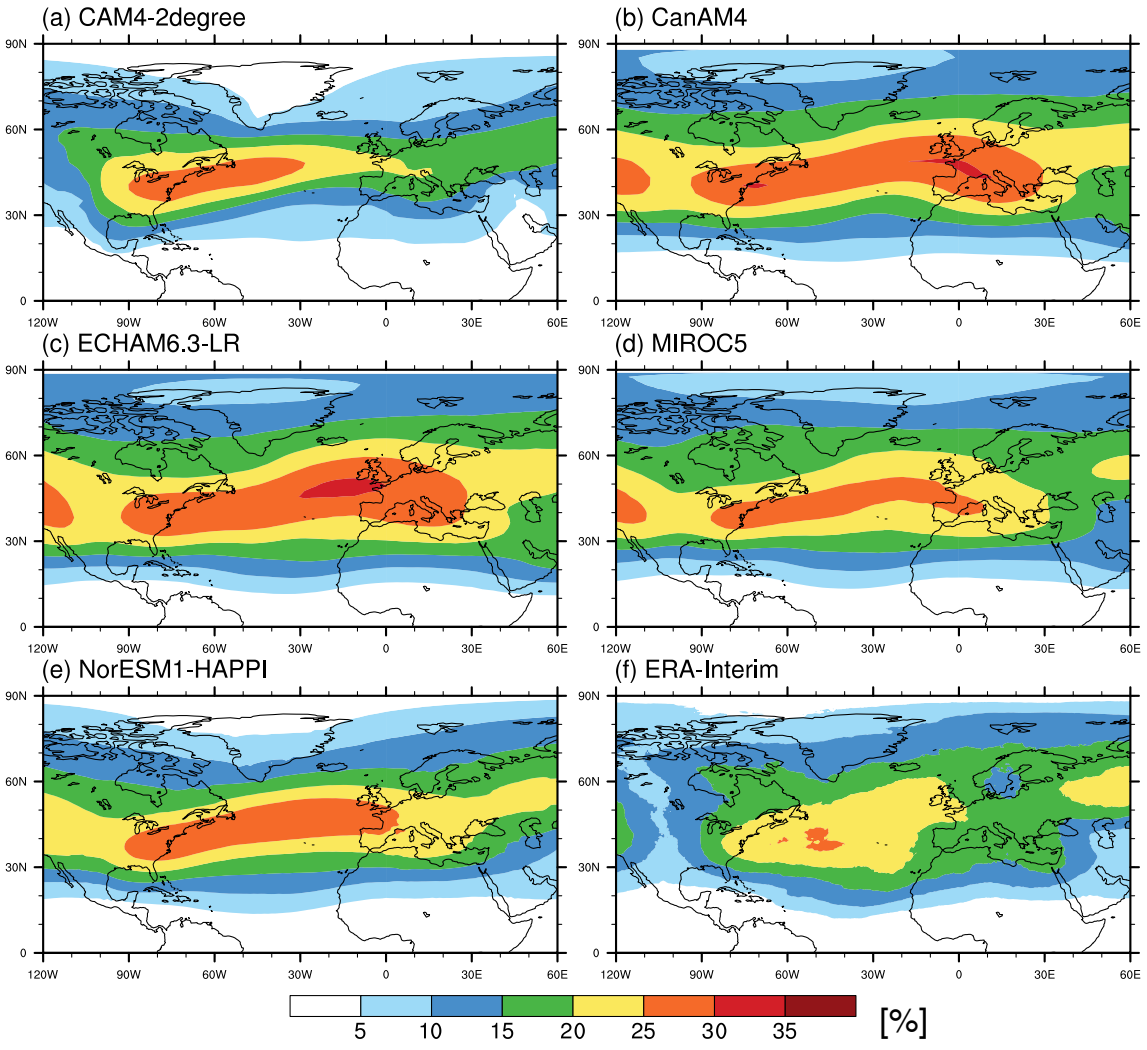

Figure S14: Ensemble mean of the DJF mean anticyclone frequencies for (a-e) the five HAPPI models and (f) ERA-Interim. Unit: percentage of the winter days.

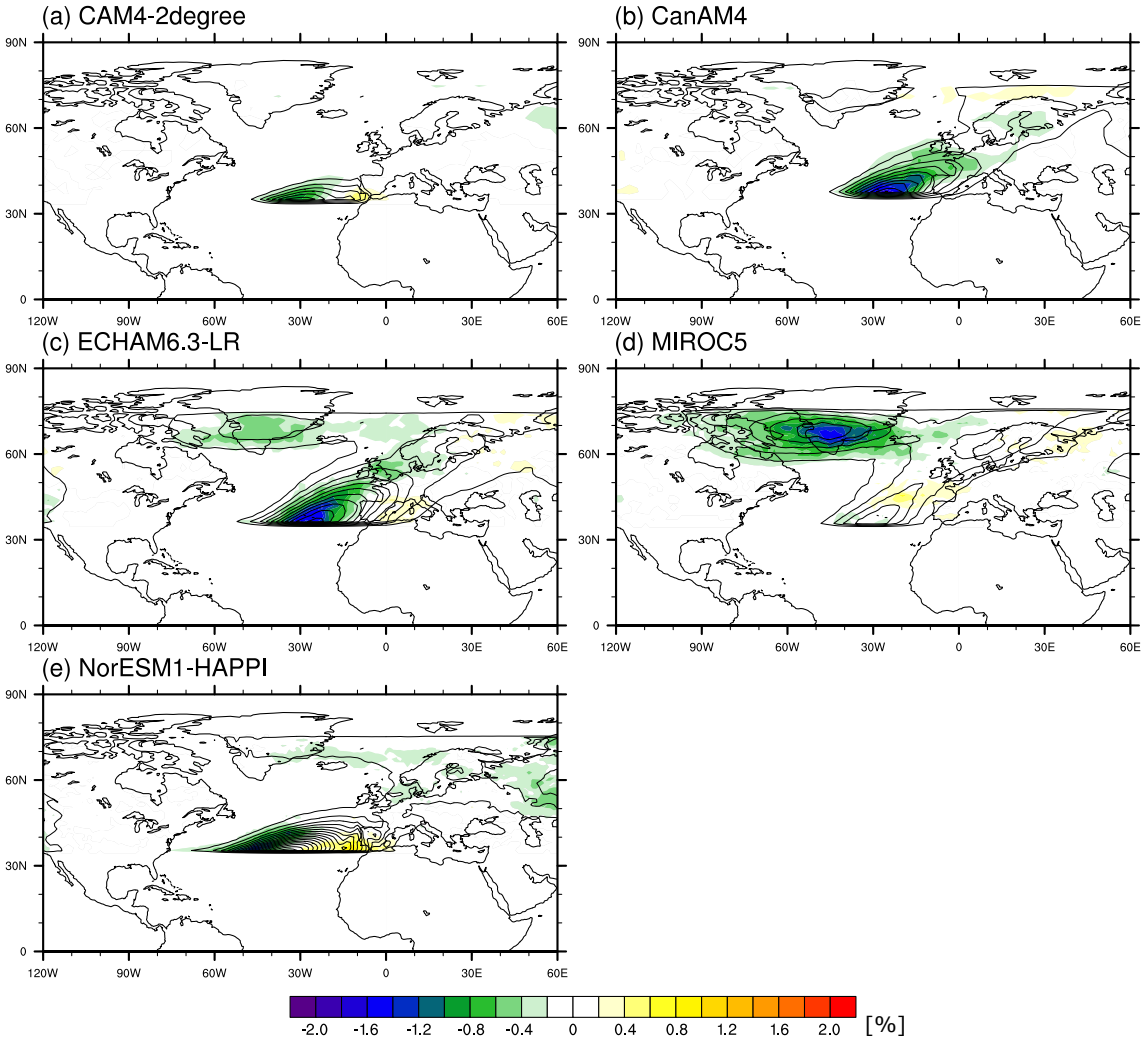

Figure S15: Ensemble mean response (shading, difference between the future and present experiments) of the DJF mean blocking frequency (percentage of blocking days relative to the total number of winter days, in %) for the five HAPPI models. The contours show the ensemble mean DJF mean blocking frequency (first contour and interval: 1%).

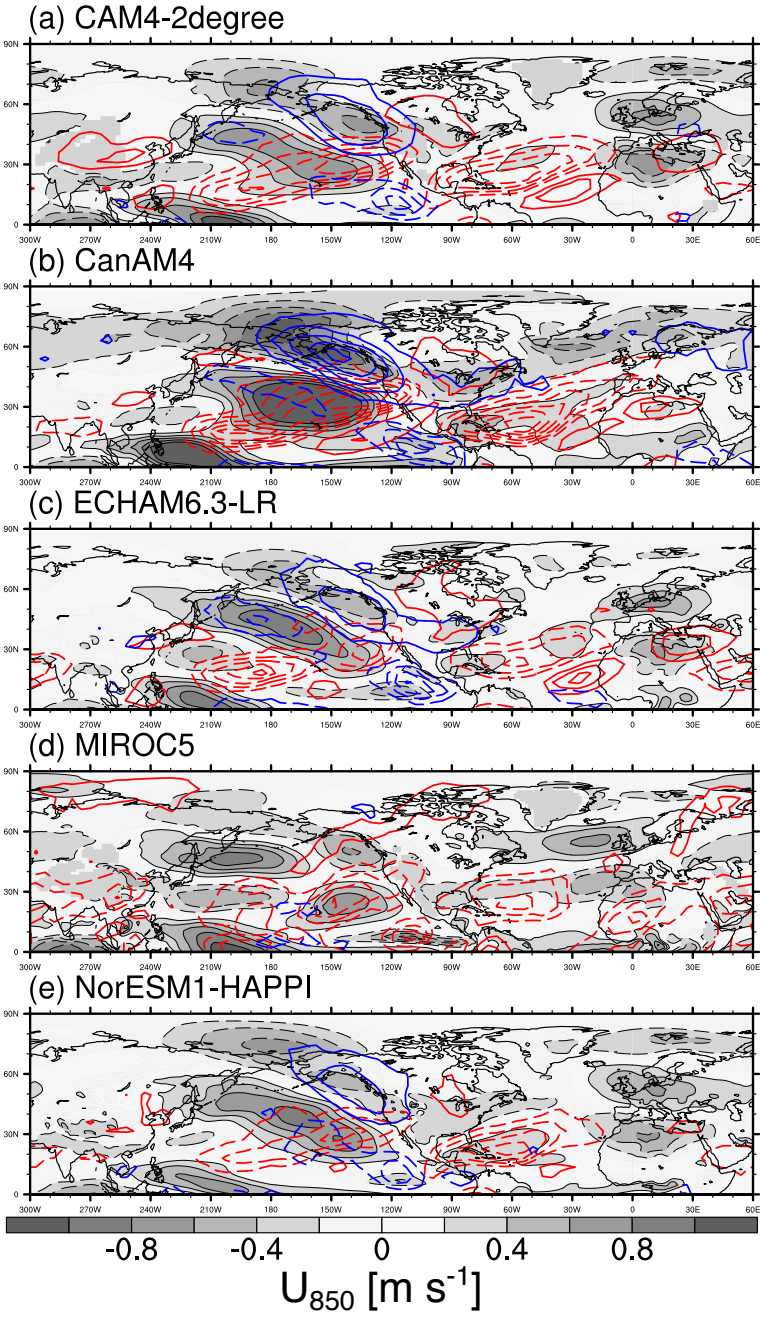

Figure S16: Ensemble mean responses (difference between the future and present experiments) of Rossby wave breaking frequency (blue contours for CWB and red contours for AWB, solid lines for positive values and dashed lines for negative values, zero-contour omitted, interval: 0.5%) and 850-hPa zonal wind (black contours and gray shading, unit: m s^{-1}) for DJF for the five HAPPI models.