Supplemental material

1 Match statistics

A track from a PL list has a match, if a cyclone track is located within 150 km for at least half of the time steps of the PL track. This ensures a reasonable good spatio-temporal agreement in the tracks, which respects for some inaccuracies in the subjective PL lists, the reanalysis product and the cyclone tracking algorithm to detect or produce the PL center. Different merging distances were tested and compared in Table S1. A distance of 250 km results in only slightly higher detection rates than 150 km, but is more prone to false positive matches. A distance of 100 km significantly reduces the detection rate as compared to 150 km distance, especially for the PL lists from Rojo and Smirnova. Hence, the choice for a 150 km distance in the track matching.

PL list	cases $>$ 3 steps	detect 250km	%	detect 150km	%	detect 100km	%
Noer	162	138	85	131	81	119	73
Rojo	391	285	73	255	65	214	55
Smirnova	251	181	72	153	61	116	44
Golubkin	123	85	69	80	65	74	60
Yanase	(19)	13	68	13	68	11	58
Verezemskaya	1139	542	48	361	32	202	18

Table S1: Match statistics of the derived tracks in the different PL lists. A match is obtained if the track is in the vicinity of the PL for at least half of the time steps of the PL. Distances of 250, 150 and 100 km are compared.

2 Parameter correlation

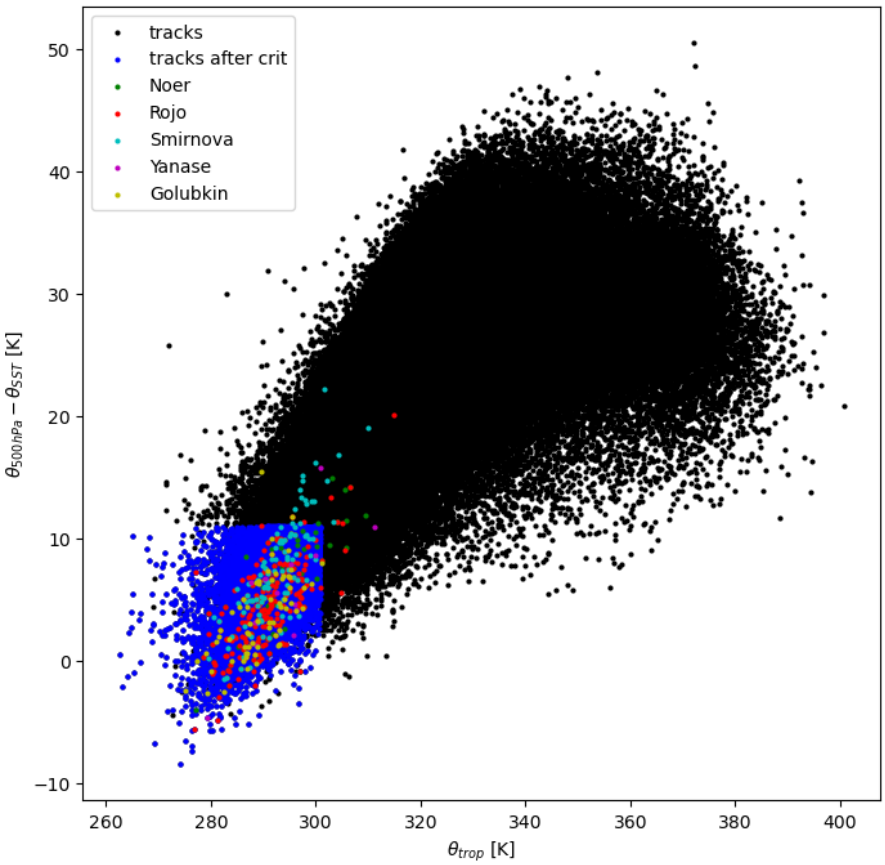

Figure S1: The potential temperature at the tropopause plotted against the static stability, $\theta_{500hPa} - \theta_{SST}$, for all tracks of the NH (black), the tracks satisfying all polar-low (blue), and the PLs from the different lists (other colors).

3 Sensitivity climatologies

3.1 Near land

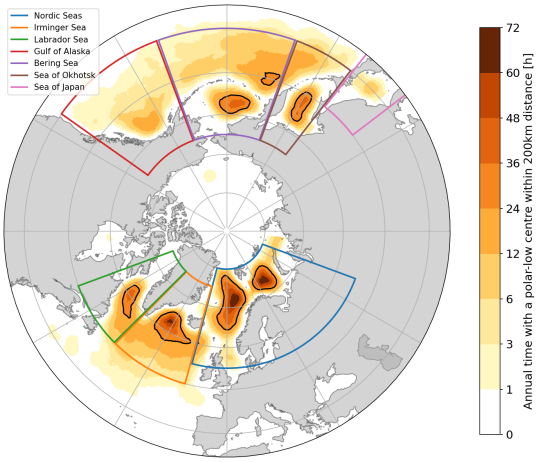

Figure S2: As Figure 3 from the article, but only including PL time steps with a distance more than 200 km from land.

3.2 Strong criteria

Parameter	Threshold	excluded polar lows [%] N/R/S/Y/G/V	excluded cyclones NH/SH [%]	excl. cyclones after other crit. NH/SH [%]
Polar-front criterion				
θ_{trop}	$< 300.8\,\mathrm{K}$	9/4/5/8/2/40	76/ 65	14/ 14
	$< 295\,\mathrm{K}$	30/21/33/54/12/61	86/ 75	43/ 43
Static-stability criterion				
$\theta_{500hPa} - \theta_{SST}$	$< 11.0\,\mathrm{K}$	7/4/17/8/3/56	80/ 74	34/ 55
	$< 7.0\,\mathrm{K}$	35/22/49/31/14/74	89/ 80	70/ 87
Intensity criterion				
$\xi_{smth,850}$	$> 20.0 \times 10^{-5}\mathrm{s}^{-1}$	0/1/9/8/5/5	19/ 19	20/ 20
	$> 30.0 \times 10^{-5}\mathrm{s}^{-1}$	30/28/55/23/34/49	64/ 67	65/ 79
Meso-scale size criterion				
vortex diameter	$< 430\,\mathrm{km}$	9/8/9/8/5/44	25/ 34	22/ 32
	$< 350\,\mathrm{km}$	28/28/31/23/20/62	40/ 51	43/ 55

Table S2: As Table 3 from the article. Statistics of the strict thresholds for the sensitivity climatologies as compared to the polar-low criteria. The first row within each criterion repeats the polar-low criteria, the second row depicts the stricter threshold, that excludes 20 - 30% of the PLs from the Noer, Rojo, Yanase and Golubkin lists.

Intense PLs need to exceed an intensity criteria of $\xi_{smth,850} > 30.0 \times 10^{-5}\mathrm{s}^{-1}$ instead of $20.0 \times 10^{-5}\mathrm{s}^{-1}$. This criteria excludes additional 56% of the PL time steps from the Northern Hemisphere and 74% from the Southern Hemisphere. Hence, considerably less intense PLs occur in the Southern Hemisphere (Fig. S3). In the Northern Hemisphere, the intense PLs develop in the same regions as general PLs, however, more constraint to regions in the vicinity of land masses.
Small PLs are defined by a threshold on the vortex diameter of below 350 km, instead of 430 km. This excludes additional 27% and 34% of the PLs from the Northern and Southern Hemisphere, respectively. The spatial distribution of small PLs is quite similar to the one of all PLs (Fig. S3).

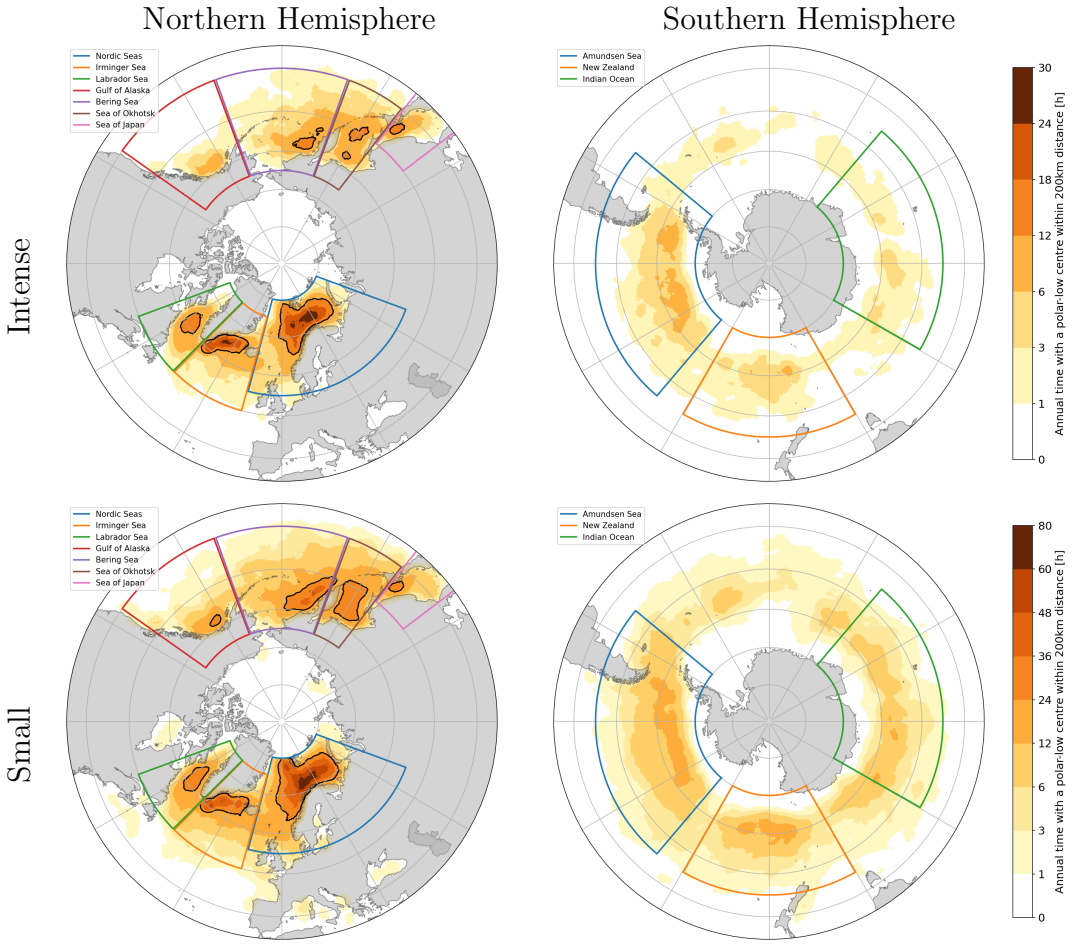

Figure S3: As Figure 3 from the article, but for sensitivity climatologies with stricter criteria. Top panels for the intense PLs, satisfying $\xi_{smth,850} > 30.0 \times 10^{-5}\mathrm{s}^{-1}$. Bottom panels for the small PLs with a vortex diameter$<$ 350 km.

PLs occurring at a low static stability are found by a threshold of $\theta_{500hPa} - \theta_{SST} <$ 7.0 K, instead of 11.0 K. A low static stability is reached by strong heating from the sea surface and favors a fast growth rate of PLs. The stricter criteria excludes additional 55% and 71% of the PLs from the Northern and Southern Hemisphere, respectively. Hence, the spatial distribution of PLs occurring at a low static stabil-

ity features considerably less PLs in the Southern Hemisphere and the North Pacific (Fig. S4). The North Atlantic is less influenced by the stricter static stability criterion.

Polar lows with a low potential temperature at the tropopause are identified by a threshold of $\theta_{trop} < 295\,\mathrm{K}$, instead of 300.8 K. This criteria excludes additional 34% of the PL time steps from both hemispheres. The PLs satisfying the stricter criteria are developing deeper in the polar air masses. Hence, the spatial distributions feature less PLs at lower latitudes, whereas the higher latitudes are less effected (Fig. S4).

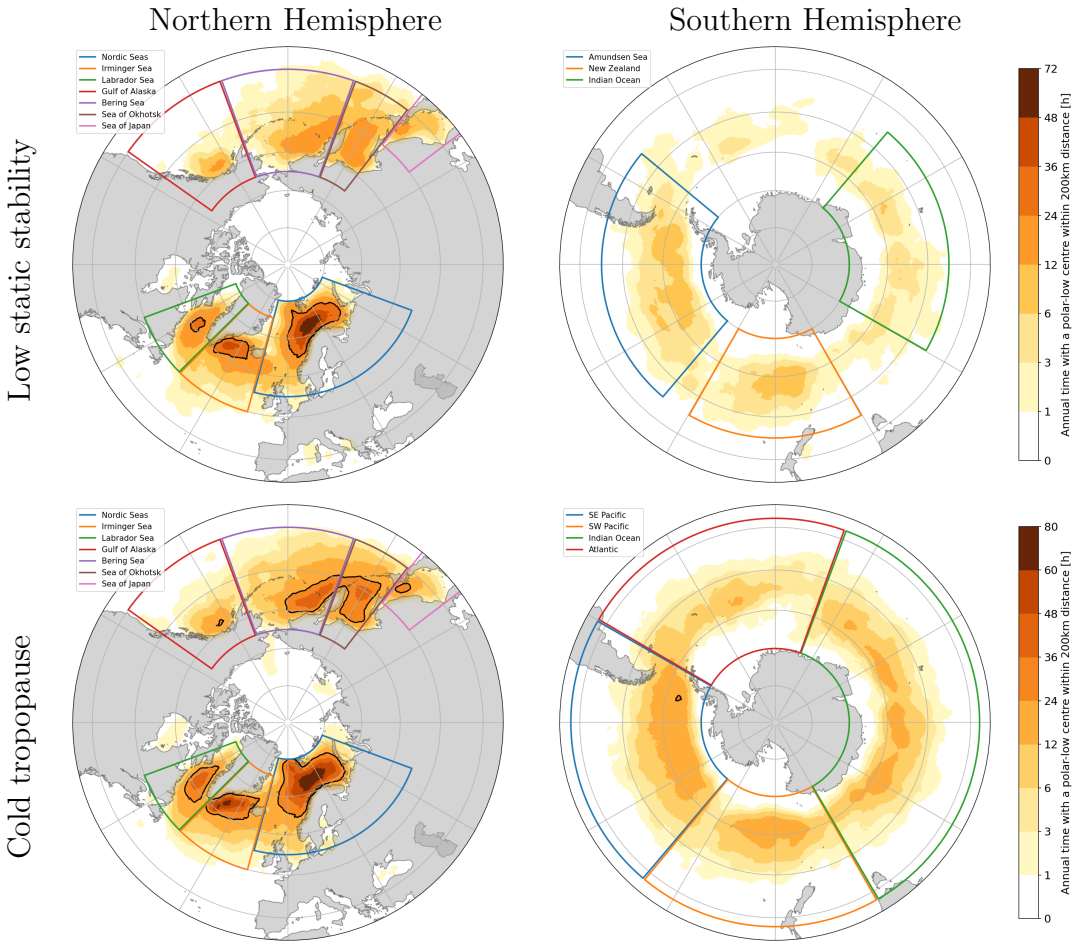

Figure S4: As Figure 3 from the article, but for sensitivity climatologies with stricter criteria. Top panels for the PLs developing at low static stability, $\theta_{500hPa} - \theta_{SST} < 7.0\,\mathrm{K}$. Bottom panels for PLs occuring within air masses of low potential temperature at the tropopause, $\theta_{trop} < 295\,\mathrm{K}$.

4 Similarities across the shear categories

PLs of the different shear categories are rather similar in the parameters displayed in Figure S5.

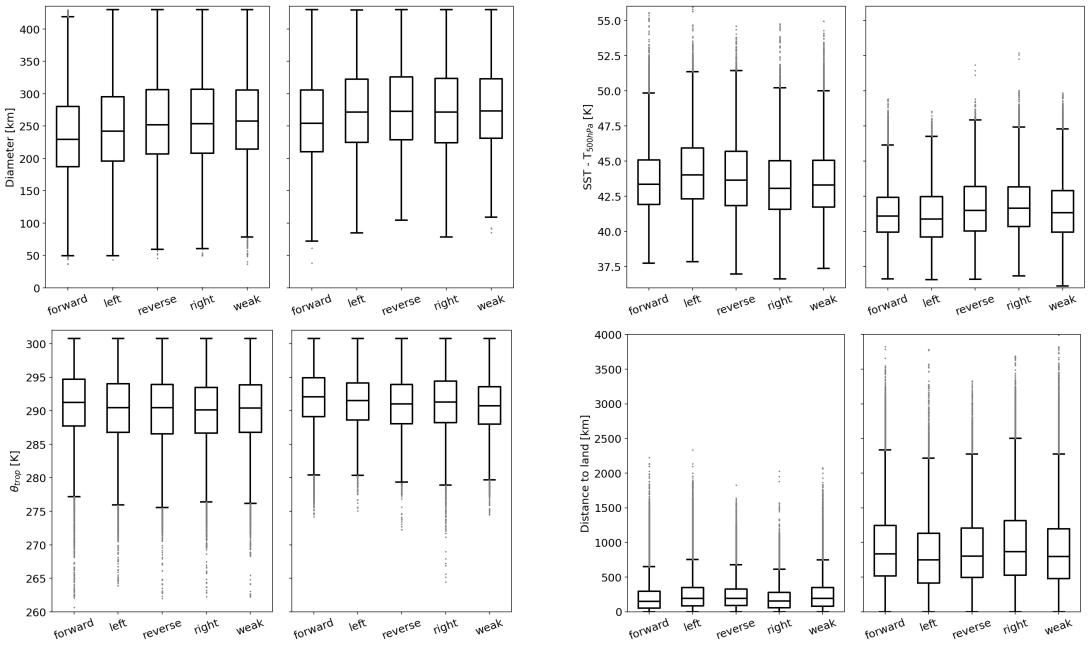

Figure S5: As Figure 10 of the article. Distributions for the different shear categories for the Northern (left) and Southern Hemisphere (right).