Response to reviewer 1.

I thank the referee for another review and for spotting some remaining mistakes. All the comments were included as recommended.

COMMENTS

Reviewer: *L. 237 (Fig. 1 ⇒ (Fig. 1)*

Response: Thanks.

Reviewer: *Figure 1. How about adding a vertical red dashed line indicating the threshold value?*

Response: Vertical red dashed lines were added as suggested.

Reviewer: *L. 405-407 The same sentences are repeated.*

Response: Thanks.

Reviewer: *L. 573 remove "," after "Note"*

Response: Thanks.

Reviewer: *L. 604 Both in accordance with ⇒ Both are in accordance with*

Response: Thanks.

Response to reviewer 2.

I thank the referee for another review.

Specific comments

Reviewer: *P. 2 L. 54: A quick sentence should be added in the text on why those criteria differ from the ones used in previous studies.*

Response: Following the advice, I added the following: "Numerous criteria for the detection of PLs from modelled datasets have been suggested (Zahn et al.,2008; Bracegirdle and Gray, 2008; Zappa et al., 2014; Michel et al., 2018; Stoll et al., 2018, e.g.), however, only two of them compared the success of the criteria (Bracegirdle and Gray, 2008; Stoll et al., 2018). This study derives a set of criteria successful to detect PLs by an updated approach of the latter two studies."

And removed: "Despite these challenges, this study provides a set of criteria successful to detect PLs."
Reviewer: *P. 3. L. 66: Maybe a quick definition of the shear could be added into parenthesis.*

Response: I added a footnote: "A definition is provided in Section 2.4.".

Reviewer: *P. 4 L. 92: It should be noted that, although band-pass filtered approaches may include synoptic-scale cyclones, spectral filtering can be used to only retain the wave-numbers equivalent to mesoscale features with similar scales as PLs. This has been successfully done for PLs using spectral filtering to the vorticity field by previous studies such as Zappa et al. (2014), Yanase et al. (2016), Smirnova and Golubkin (2017) and Stoll et al. (2018).*

Response: I agree with the reviewer that the studies of Zappa et al. (2014), Yanase et al. (2016), Smirnova and Golubkin (2017) and Stoll et al. (2018) have applied the spectral filtering with success, and added Smirnova and Golubkin (2017) to the manuscript. However, the first sentence of the reviewer captures the problematic by pointing into two directions simultaneously (i) "may include synoptic-scale cyclones" versus (ii) "only retain ... mesoscale features". My experience also in the study Stoll et al. (2018) is that higher harmonics of the circulation variable of the synoptic cyclones are still present after the application of spectral filtering, hence option (i). This is communicated in the manuscript, whereas I do not want to state that any of the previous attempts to detect PLs were non-successful even though they have some drawbacks.

Reviewer: *P. 10 L. 292-293: This sentence is a bit confusing. Maybe rephrase it by stating "criterion" after the "first/second/etc.".*

Response: Thanks for the suggestions. I reformulated the sentence to: "A track that satisfies criterion 1 in the mean of the lifetime, the criterion 2 as the minimum and criterion 3 and 4 as maximum is defined a PL track."

Reviewer: *P. 11 L. 302: A sentence could be added on the fact that these criteria, although relatively efficient, do not detect all observed PLs from the previous lists.*

Response: It seems to me that the formulation "most" with the specification "(68 - 89%)" is clear enough in communicating that not all are included. Hence, opt for the option "could."

Reviewer: *P. 14 L. 337-340: This is an interesting suggestion: has it been verified for some PLs of this study or in other studies?*

Response: This is a hypothesis to explain why some PLs in the Sea of Japan feature a considerable jet poleward of the system as measured along the same longitude. Future studies can test it.

Reviewer: *P. 15 L. 378-379: Instead of "punishing" the region, how about decreasing the SST-T500 criterion for the Southern Hemisphere then? Have you tried different thresholds/criteria for SH PLs and if so, would using different thresholds/criteria for NH and SH PLs be more beneficial (since SH PLs seem less "responsive" to your criteria than NH PLs)? Maybe a word on this could be added.*

Response: The aim is to derive criteria that are universally applicable, instead of different thresholds depending on the area or season. Of cause one could fiddle around with the threshold, but it is more convenient to use $\theta_{500hPa} - \theta_{SST}$ since is not dependent on different background SLP and hence not regional dependent. The manuscript was apparently not very clear on this point and therefore changed with the attempt to include the comment from the reviewer.

Old version: "The two measures for the potential static stability, $\theta_{500hPa} - \theta_{SST}$ and $SST - T_{500hPa}$, are quite similar in the success of excluding cyclone tracks. However, the following consideration leads to the choice for the former: $\theta_{500hPa} - \theta_{SST}$ corrects the potential static stability for pressure variations at sea level, which is ignored by $SST - T_{500hPa}$. High values in $SST - T_{500hPa}$ are supported by a high sea-level pressure, when the vertical distance between the sea surface and the 500 hPa level is large.
The primary characteristics of PLs appear to be the low potential dry-static stability, whereas the environmental-mean in the sea-level pressure, a synoptic-scale parameter, does not have a direct physical impact on PL development (Section 3.4). Monthly mean values in the sea-level pressure are varying between seasons and ocean basins. For example, the wintertime high latitudes are rather of low sea-level pressure, a reason why $\theta_{500hPa} - \theta_{SST}$ in isolation is slightly more successful for detection of PLs than $SST - T_{500hPa}$. However, the polar-front criterion is mainly satisfied within the winter season, making for the Northern Hemisphere

both criteria equally successful in excluding cyclones remaining after application of the other three PL criteria (Tab. 2, Col. 6). Differently, in the Southern Ocean, $SST - T_{500hPa}$ excludes considerably more remaining cyclones than $\theta_{500hPa} - \theta_{SST}$, since it is the area of globally lowest sea-level pressure, contributing to lower values in $SST - T_{500hPa}$, such that a $SST - T_{500hPa}$ criteria is less frequently satisfied in the Southern than the Northern Hemisphere.

and hereby "punishing" this region if a criterion with $SST - T_{500hPa}$ is used. Hence, it appears that $\theta_{500hPa} - \theta_{SST}$ is less prone to induce seasonal and regional biases than $SST - T_{500hPa}$."

New version: "The two measures for the potential static stability, $\theta_{500hPa} - \theta_{SST}$ and $SST - T_{500hPa}$, are quite similar in the success of excluding cyclone tracks. However, $\theta_{500hPa} - \theta_{SST}$ is the more universal parameter since the environmental sea-level pressure appears to be physically irrelevant for PL development (Section 3.4) and $\theta_{500hPa} - \theta_{SST}$ corrects the static stability for pressure variations at sea level.Differently, $SST - T_{500hPa}$ is prone for seasonal and regional biases by a varying sea-level pressure, as high values are supported by a high sea-level pressure, when the vertical distance between the sea surface and the 500 hPa level is large and the lapse rate contributes to the large temperature contrast. When $SST - T_{500hPa}$ is used such biases occur in the Southern Ocean, the area of globally lowest sea-level pressure. Here, $SST - T_{500hPa}$ excludes considerably more remaining cyclones (Tab. 2: 46%) than $\theta_{500hPa} - \theta_{SST}$ (33%), since the lower sea-level pressure contributes to lower values in $SST - T_{500hPa}$, such that the $SST - T_{500hPa}$ criterion is less frequently satisfied in the Southern than the Northern Hemisphere. Hence, for the Southern Ocean a lower threshold should be applied if $SST - T_{500hPa}$ is utilised, which can be alleviated by using $\theta_{500hPa} - \theta_{SST}$."

It was a mistake that the sentence "and hereby "punishing" this region if a criterion with $SST - T_{500hPa}$ is used." was in the previous version of the manuscript. It should have been removed following a response on page 6 of reviewer 1.

Reviewer: *P. 24 Section 5.2: It would be interesting to know if trends appear in the different PL shear distributions (in the global of each shear distributions and the distributions for each region). If you already calculated it (or if it's not too much work) a sentence or two on this would be appreciated.*

Response: I performed some additional analysis as suggested and added a paraph at the end of that section:
The observed increase in PL activity of 7.5 days per decade in the Northern Hemisphere discussed in Section **??** is mainly due to a significant increase of weak-shear (3.2 days per decade), forward-shear (2.8) and reverse-shear PLs (1.0), whereas the number of left and right-shear PLs is not changing significantly. In the Southern Hemisphere, the PL activity in all shear classes remains constant.

Technical comments

Reviewer: *P. 1 L. 18: I think references to books should contain the page numbers corresponding to the citation.*

Response: I generally agree. However, here the book of Rasmussen and Turner is cited as a whole to provide literature on general background information about polar lows.

Reviewer: *P. 11 L. 300: I think "Furthermore" might be more appropriate than "Further".*

Response: Thanks.

Reviewer: *A few typos (misplaced coma/point/capital letter/e.g.) are found along the text (ex: L. 120, 397).*

Response: Thanks. I went through the whole manuscript to spot some remaining typos.