

Response to referees' comments on "Southern Annular Mode Persistence and Westerly Jet: A Reassessment Using High-Resolution Global Models" by Chen et al.
MS No.: egusphere-2025-666
MS type: Research article

Reviewer 2

The revised manuscript makes a number of important changes: 1) the analysis of surface friction is more thorough, 2) the choice of model simulations to analyze are refined, with many simulations running for longer, 3) the manuscript is better situated in the literature, 4) its conclusions follow in a more logically-consistent manner from the results, with better discussion of relevant limitations, 5) the figures include more relevant information in regards to uncertainty and less extemporaneous information, 6) the narrative has a tighter focus on the SAM timescale across the different simulation types, and 7) general improvements to the writing quality. With these revisions, my previous major concerns regarding the manuscript are satisfied, and I find the paper to be generally acceptable for publication, with some minor corrections. The figures in particular are of high quality. I also suggest a general edit of the manuscript to tighten the language, which will improve clarity.

We appreciate reviewer 2's positive feedbacks. For the remaining comments and suggestions, please see our responses below in blue.

Scientific Comments

Lines 241-245: What is the filter being used here? Adding this would help align with the stated goal of reproducibility. Additionally, you might add a brief summary for the motivation for the double filtering (60-day then 30-year, which technically overlap). I think this procedure is not intuitive and currently requires readers to reference Gerber et al. (2010) to understand that this is a regularization technique. I think it would help the description to make it more explicit that the 30-year filter is being applied to the 60-day filtered data (at first I thought both were derived from the original time series, although the text does not say that. Mostly I find the text a bit ambiguous). I had to read the description several times to pick up on this subtlety. I understand this is a complex technique which is generally following previous literature, and the authors are doing quite well already, but a little further revision would help.

We applied the discrete Fourier transform (DFT) on the time series and filters out signals with a frequency higher than the cutoff frequency of 60 days. The double-filtering procedure follows exactly Gerber et al. (2010). We have clarified the procedure (and their reasoning) in the revised manuscript:

"Such $\Phi(\lambda, t)$ field is derived in two steps following Gerber et al. (2010). To avoid overfitting high-frequency noise, a 60-day low-pass filter is first applied to the detrended $\Phi(\lambda, t)$ along the t axis to retain only seasonal-scale variability. Specifically, we apply the discrete Fourier transform to the time series and filter out components with frequencies higher than $1/60$ days⁻¹. The resulting smoothed time series is then reindexed by calendar day (d) and year (y). For each calendar day (e.g., Jan 1st, Jan 2nd, etc.), a 30-year low-pass filter is subsequently applied along the y axis to extract long-term variations."

Lines 320-321: "Assuming that at sufficiently large positive lags, the feedback component dominates the eddy forcing," -> "Assuming that the random component of the eddy forcing is uncorrelated at sufficiently large positive lags,". I personally find that the decorrelation between the stochastic forcing and the original anomalies is a clearer explanation (since truly random forcing should not be state-dependent), but disagreeing would be reasonable. Some slight rephrasing may still be worthwhile.

Thank you. We agree to change the sentence as suggested.

Line 383: The timescale is lower with 9km, but you might recognize this may not be due to the change in resolution since the error bars overlap with the 28km ones, especially for the annual case.

We have decided to keep the sentence but add a short clause about the overlapping error bars to acknowledge the uncertainty: "Refining the atmospheric resolution from 28 km to 9 km suggests a lowering of the SAM decorrelation timescale, with τ of 8 days annually and 10 days in NDJ. However, the difference may not be robust, as the bootstrapped error bars of both resolutions overlap."

Line 402: You might add a brief statement before "A potential dependency on resolution...", referring to the previous result that EERIEE models have higher resolution and lower persistence. Just to help your audience understand why we may expect such dependence. Or you could discuss part of Gerber et al. (2008), currently in Lines 407-410, which suggests higher resolution may reduce persistence biases (but then wait to talk about the plateau effect until later).

Thank you for the good advice. We have modified the paragraph as "As EERIE results suggest that higher resolution may reduce persistence biases, we examine the model resolution of each CMIP6 simulation. However, there appears no strong or clear relationship between the model resolution and the model biases in either τ or λ (the conclusion holds for both latitudinal and longitudinal resolutions and for both atmospheric and oceanic components, although only the atmospheric latitudinal resolution is expressed in Fig. 3). A potential dependency on resolution could be obscured in the CMIP6 ensemble by other compensating factors arising from different model configurations and system designs."

Line 534: I wouldn't describe these mechanisms as competing. The effect of jet latitude on SAM is generally argued to be related to the eddy feedback, with more poleward jets requiring stronger wave breaking and larger feedbacks. Of course jet latitude isn't the only factor affecting the feedback, as this work indicates. I'd search for a different word to describe their relationship.

By "two competing dominant mechanisms", we meant the eddy momentum flux convergence (as measured in our diagnostic eddy feedback) and the surface friction. We have removed that term to avoid confusion: "Indeed, we find that the metrics of atmospheric eddy-mean feedback strength, surface friction and their joint effect correlate more strongly with τ than with λ_0 in the AMIP configurations, highlighting the importance of these mechanisms on SAM persistence."

Technical Corrections

Line 41: "inferred" -> "implied"

Corrected

Lines 64-70: This is a good summary of the relevant mechanisms. I suggest restructuring the writing to improve clarity.

We have rewritten the section to: "Several mechanisms may contribute to the eddy–mean flow feedback that reinforces the shifted jet. These include barotropic processes, such as anomalous wave propagation and breaking, and baroclinic processes related to enhanced eddy generation and increased lower-tropospheric baroclinicity in response to shifts in the westerly winds (e.g., Robinson 2000, Lorenz and Hartmann 2001, Zurita-Gotor et al. 2014, Hassanzadeh and Kuang, 2019). Westerly flow anomalies also induce changes in the diabatic heating and cooling—through latent heat release and cloud radiative effects—which alter temperature gradients and, in turn, affect SAM persistence (Xia and Chang 2014, Smith et al. 2024, Vishny et al. 2024)."

Line 76: "Skills" -> "Skill"

Corrected

Line 137-138: "the ocean eddies" -> "mesoscale eddies"

Changed

Line 148: "are conducted" -> "were conducted" or "are being conducted" (if ongoing)

Changed to "are being conducted"

Line 150: "similar as" -> "similar to"

Corrected

Lines 160-170: Well said.

Thanks

Line 192: "conditions with the a spatial" -> "conditions with a spatial"

Corrected

Line 195: "their relative winds-currents effects" -> "their mechanical effects"

The sentence has been rephrased to "We emphasize that such a design only allows us to test ocean eddies' direct thermodynamic impact (as reflected in SSTs) but not their mechanical influence (through the so-called wind stress feedback or relative winds-currents effects)"

Line 198: "spatially varying climatological" -> "spatially varying, climatological"

Added

Line 304: "zonal momentum tendency equation" -> "zonal momentum equation"

Changed

Line 327: "However, although the PCs are uncorrelated by construction on short timescale," -> "While the PCs are uncorrelated on short timescales (by construction),"

Modified as suggested. Thanks.

Line 426: Nice transition.

Thanks

Figure 4 (caption): I think the marker shapes are just individual ensemble members (only the star is discussed), but you might mention their significance (or lack thereof). I would also suggest using one legend for the whole figure since the color scheme seems to imply some of the simulations are ObsSST and some NoEddies, but I don't find this explicitly stated anywhere. Right. We have modified the caption for figure 4 to provide clearer explanation about the shown components:

"Figure 4. Analysis of the IFS-AMIP idealized experiments (black for ObsSST and red for NoEddies; yellow for ERA5 as reference): (a) SAM decorrelation timescale (τ) as a function of

month for 28km simulations (dashed for individual ensemble members and solid for ensemble means). (b) Similar to (a) but for 9 km experiments (shades for the ± 1 standard deviation of τ from the 1,000 bootstrap resampling). (c) Scatter plot of τ (days; y-axis) and westerly jet latitude (x-axis; filled-color markers for 28 km; hollow stars for 9 km simulations). (d)–(e) Similar to (c) but with x-axis variable replaced with the eddy feedback strength and frictional impact, respectively. In (b)–(d), the same marker shape indicates the same ensemble member. The gray dotted line represents the linear regression fit, and the correlation coefficient and p-value are indicated in the top-right corner.”

Figure 4e: Perhaps my eyes are seeing what they want, but it seems the frictional impact is lower in the NoEddies during DJF, consistent with the lower persistence. It seems unlikely to be a robust relationship, but maybe it is worth quantifying?

While three NoEddies members do show lower frictional impact, consistent with their lower persistence, the strongest frictional impact (red square) also occurs in one of the NoEddies members. This variability makes it challenging to conclude a systematic shift between ObsSST and NoEddies. Nonetheless, we agree that this potential relationship is interesting and merits further investigation in future work.

Lengthy Phrases

I suggest the following phrases/sentences be made more concise. Ellipsized sentences refer to the entire sentence. The list is not exhaustive. I provide a few sample rewrites as suggestions.

We have taken the following editorial suggestions or rewritten the marked sentences to improve readability. We’ve also re-read the manuscript and made a few more changes to avoid lengthy phrases.

Line 26-27: "results in reduced tau" -> "reduces tau"

Changed accordingly

Line 62: "act to counteract" -> "counteract"

Changed accordingly

Lines 63-64: "Several mechanisms can be at the origin of this eddy-mean flow feedback that reinforces the shifted jet..."

Modified. See our response above.

Lines 81-84: "Many studies have found a strong dependency... tropospheric westerly jet." -> "GCM biases in SAM persistence are correlated with biases in Southern Hemisphere jet persistent models simulating tropospheric jets which are too far equatorward (citations)."

We have changed to "Overly persistent SAM in GCMs is correlated with a common bias in the climatological jet position, whereby the simulated tropospheric jets are placed too far equatorward (citations)". Thanks.

Lines 84-86: "A possible explanation for... maintain SAM."

We have shortened it to "A possible explanation is that models with lower latitude jets exert stronger eddy-mean flow feedback to maintain SAM (Codron, 2005; Simpson and Polvani, 2016)."

Lines 96-99: "Simpson et al.... the summer season."

We have removed this sentence as it’s a repetition in Section 3.3.

Line 109: "has reached beyond a sufficiently high level" -> "is sufficiently high"

Changed as suggested

Lines 110-112: "The potential role... (EERIE)."

Shortened to "Here we revisit this issue using new experiments from the Horizon Europe project European Eddy-Rich Earth System Models (EERIE)".

Lines 124-126: "In addition to the development... SST biases."

Shortened

Line 189: "To enable exploration of the response of the atmosphere to the extratropical SST ocean mesoscale features," -> "To explore the atmospheric response to extratropical ocean features,"

Changed

Lines 201-203: "The latter consequence...teleconnections."

Combined with the previous sentence and thus overall shortened to "The filter with a smaller L_R at high latitudes effectively removes the smaller oceanic eddies there. However, it also removes the larger-scale tropical instability waves near the equator as when L_R reaches its maximum. This potentially obscures the impact of targeted extratropical ocean mesoscales due to tropical-extratropical teleconnections."

Lines 277-279: "We apply...of the model."

Modified to "We first identify the latitude ($\lambda_{\max}$) of the maximum monthly zonally averaged 850-hPa zonal wind between 75°S and 10°S. Then, we apply a quadratic fit to the zonally averaged zonal wind at $\lambda_{\max}$ and at the two adjacent latitudes to the north and south. The latitude corresponding to the maximum value of this quadratic fit defines the position of the tropospheric westerly jet."

Lines 284: "showed a high correlation" -> "is highly correlated"

Changed

Line 302: " $\cos(\lambda)$ weighting when defining the EOF in Simpson et al. (2013b)" -> " $\cos(\lambda)$ -weighting (Simpson et al. 2013b)"

Changed

Lines 312-313: "While this assumption...their simulations." -> "Simpson et al. (2013b) demonstrate the validity of this assumption."

Changed

Lines 324-325: "In Simpson...of the models (Fig. 1f)."->"Following Simpson et al. (2013b), b is averaged over lags 7 to 14 days (Fig. 1f)."

Changed

Lines 330-331: "in our analysis of the model spread in simulated SAM persistence." -> "in our analysis."

Changed as suggested

Line 339-340: "it is counteracted by the negative impacts, predominantly by the surface friction, which acts to dissipate the SAM anomalies." -> "the SAM anomalies are primarily dfriction."

Modified to "While eddy momentum flux convergence primarily supports the persistence of SAM, surface friction predominantly acts to dissipate SAM anomalies."

Lines 404-406: "However, it is also possible...(e.g., CMIP6)."

Shortened to "However, it is also possible that resolution-driven improvements have plateaued within the typical grid size range of current GCMs (e.g., CMIP6)."

Lines 414-416: "For NDJ, ... jet location."

Shortened to "For NDJ, the spread of EERIE clearly shifts toward a lower τ , closer to ERA5's τ compared to other CMIP6 exhibiting a similar jet location."

Lines 420-423: "Still, well represented...jet location." The first part of the sentence reads well, maybe splitting would help.

Split into two sentences.

Lines 446-449: "To explore...controlled framework."

Shortened to "To explore these possibilities within a controlled framework, this section focuses on EERIE atmosphere-only sensitivity experiments with and without SST eddies (ObsSST vs. NoEddies) at two model resolutions."

Lines 476-479: "We found that...dominant mechanisms."

Shortened to "This metric correlates with τ more strongly than b or $[\bar{f}]_s$ ($[\bar{F}]_s$) alone, showing a higher correlation coefficient of 0.61 and a lower p-value of 0.03 (Fig. S1d). This result points to the importance to assess the joint/net impact of the competing dominant mechanisms."

Lines 513-515: "However, the outperformance... at play."

Rewritten for clarity: "However, some CMIP6 models capture jet locations similar to EERIE, yet still perform worse for τ , suggesting other factors are at play."

Lines 518-519: "by other factors varying in CMIP6 simulations incorporating different configurations and model systems"

Split into two sentences to improve clarity: "It is possible that the impact of resolution is outweighed by other varying factors in CMIP6, or that resolution-driven benefits have plateaued within the grid-size ranges in current CMIP6 and require more substantial resolution refinement to emerge."

Lines 551-553: "Between EERIE coupled...mesoscale features."

Shorten it to "The superior performance of the AMIP compared to coupled simulations might suggest that model skill in representing SAM persistence gains little from two-way ocean-atmosphere coupling or explicit resolving ocean mesoscale features."

Lines 559-562: "The large variability...outstanding questions." This sentence could be stronger as well as shorter.

Shorten and modified to "The large variability among ensemble members highlights the intricate mechanisms behind SAM persistence in GCMs, urging deeper investigation and alternative approaches to resolve outstanding questions regarding the atmospheric variability in the Southern Hemisphere."