Correction of Data Handling Error for the paper

Deficient feedbacks constrain NAO prediction

by Erik W. Kolstad

I identified a data-handling error in the processing of the model data, related to the incorrect chronological sorting of years when concatenating files. I have now corrected this issue and re-run the analysis. Overall the results have changed slightly but the main conclusions remain qualitatively the same. The text below summarises the updated findings, and the updated figures are included in the following pages.

Two additional changes were made: individual ensemble members were used instead of ensemble means, and November initialisations were used (instead of October). The latter change makes the last paragraph of Section 4.1 obsolete (starting with "While this may seem unfavourable").

The chronology error affected the calculation of the indirect (mediated) effects, particularly for the baroclinicity (Eady growth rate) pathway. The most consequential correction related to Figures 3–5. In short, Figures 3 and 4 illustrate that the SEAS5 model yields an indirect effect which is more in line with the indirect effect in ERA5. This is particularly evident for the baroclinicity parameter in Figure 4d. The summary graphs in Figure 5 change the most. In the new version of Figure 5, the clue point cloud in panel (b) is much more aligned to the diagonal line than in the erroneous first version. However, the mediation by the baroclinicity parameter is now inconsistent. This made it necessary to update the accompanying text. This is the new text for Section 4.4 (the direct effect τ' is renamed as τ_Z):

4.4 Relating feedbacks to skill

This section examines whether the strength of the indirect effect $\hat{\alpha}\hat{\beta}$ scales with $\hat{\tau}$, the strength of the SST–NAO relationship. Section 4.1 revealed that $\hat{\tau}$ is 0.60 in ERA5 and only 0.19 in SEAS5. Figures 3a and 4a demonstrated that the indirect effect in ERA5 is substantial within the outlined reference domains. Area-averaged values of $\hat{\alpha}\hat{\beta}$ within these boundaries amount to 0.34 for fluxes and 0.41 for σ_E, corresponding to 57% and 69% of $\hat{\tau}$, respectively.

In SEAS5, although $\hat{\tau}$ = 0.19 for the interannual ensemble mean (see Figure 1c), $\hat{\tau}$ is only 0.06 when sampling all the individual members. For the fluxes, the indirect effect is 64% of this, a comparable fraction to the one in ERA5. For the baroclinicity parameter σ_E, however, $\frac{\hat{\alpha}\hat{\beta}}{\hat{\tau}} > 1$. It follows from Equation 4 that the direct effect τ_Z and the total effect τ have opposite signs (in

this case $\tau_Z = -0.05$). As mentioned in Section 2.4, this scenario is referred to as inconsistent mediation. In other words, SEAS5 reproduces a positive mediated influence of σ_E on the NAO, but it also triggers an opposing pathway that suppresses the SST–NAO relationship.

Figure 5 explores the relationship between the total and indirect effects more systematically. Bootstrap resampling was used to generate ensembles of 1000 ($\hat{\tau}$, $\hat{\alpha}\hat{\beta}$) pairs for both datasets and both mediators. Each point was calculated for a set of resampled X, Y, and Z series with length 43, i.e. the number of years in the study period. This was done to make the point clouds comparable for both datasets.

The dashed ovals enclose the approximate 95% confidence regions, computed as two-dimensional covariance ellipses of the bootstrap samples. The minimal overlap between the two point clouds for both fluxes and baroclinicity highlights fundamental differences between the observational and model-based feedback structures. Before interpreting these results, it is useful to consider what the structure of such point clouds reveals about feedback processes.

If a feedback pathway is physically meaningful and consistently represented, the point cloud is expected to show a positive correlation between $\hat{\tau}$ and $\hat{\alpha}\hat{\beta}$. This implies that stronger total SST–NAO relationships tend to coincide with enhanced indirect effects. Such a cloud will be tilted towards the diagonal. In contrast, if the indirect effect is weakly linked to $\hat{\tau}$, the cloud will be oriented along the y-axis, reflecting that some samples may exhibit a strong total effect without any associated change in the indirect effect.

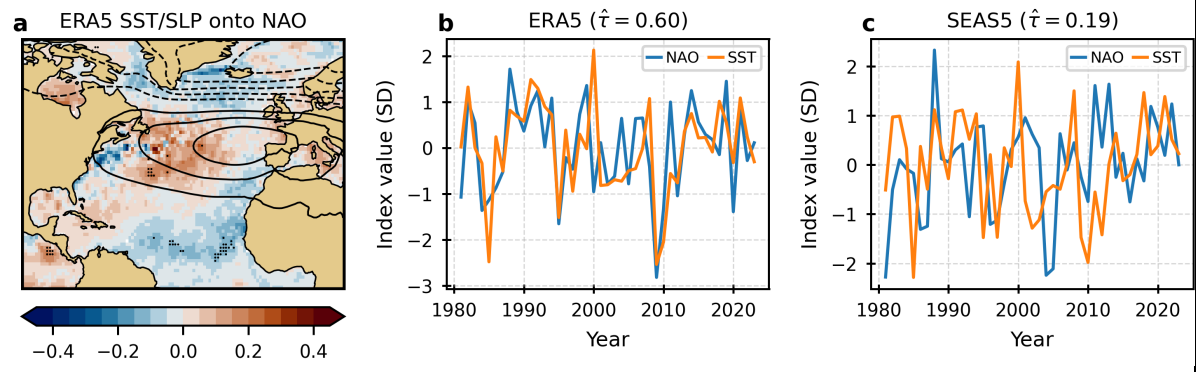
Starting with the flux pathway in Figure 5a, the ERA5 point cloud shows a modest diagonal tilt, and the correlation between $\hat{\tau}$ and $\hat{\alpha}\hat{\beta}$ is 0.49 ($p \ll 0.05$), indicating that the indirect effect explains roughly a quarter of the variance in the SST–NAO correlation. Almost all ERA5 samples (orange points) lie in the upper half of the upper-right quadrant, labelled “correct mediation” because $\hat{\tau}$, $\hat{\tau}_Z$, and $\hat{\alpha}\hat{\beta}$ are all positive.

The blue SEAS5 point cloud presents a clear contrast: the correlation between $\hat{\tau}$ and $\hat{\alpha}\hat{\beta}$ is higher ($r = 0.73$), implying that flux-mediated feedbacks explain more than half of the variance in $\hat{\tau}$. This indicates that the feedback mechanism is important for the SST–NAO relationship, but unfortunately this mechanism is not adequately represented. A large part of the SEAS5 samples fall outside the proper area representing correct mediation, spanning in a clockwise direction inconsistent mediation, wrong (negative) total effect, mediation of wrong total effect, and suppression.

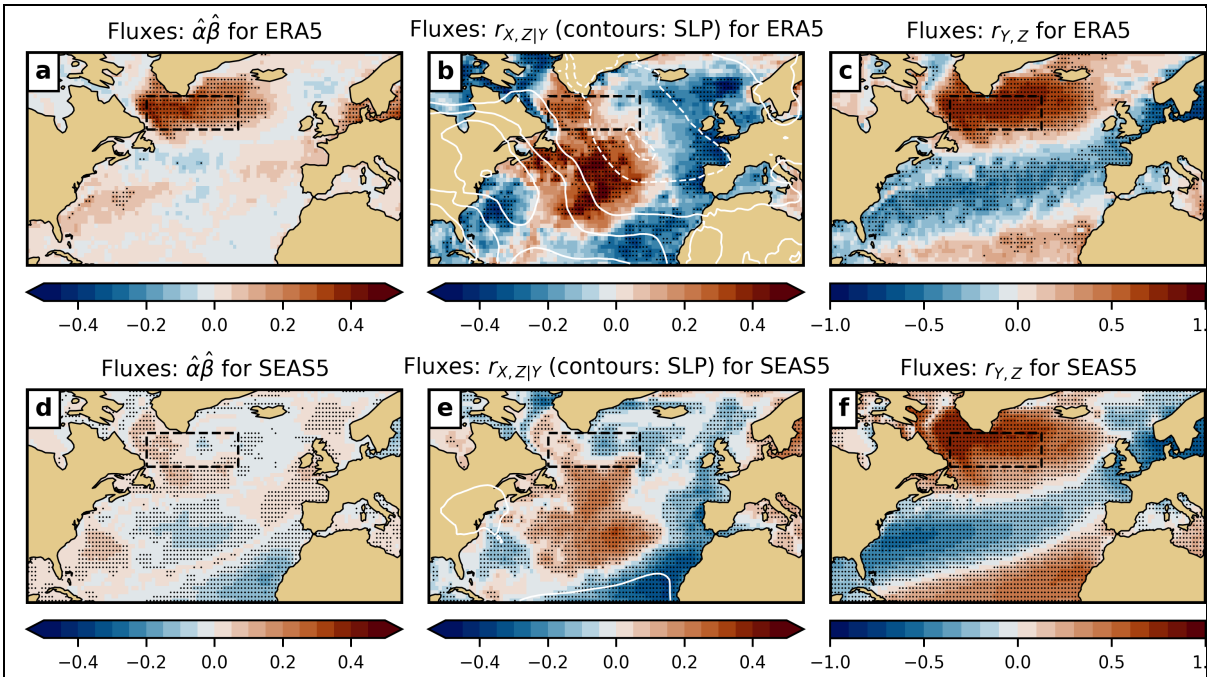
The contrast between SEAS5 and ERA5 is sharp for the baroclinicity pathway as well, where inconsistent mediation was revealed for the total sample (Figure 5b). In ERA5, the correlation between $\hat{\tau}$ and $\hat{\alpha}\hat{\beta}$ is 0.66, with the indirect effect accounting for 44% of the variance in $\hat{\tau}$. This

is higher than what was found for the flux pathway. In SEAS5 the correlation is comparable to this ($r = 0.70$), which is similar to the correlation for the flux mediation and reflects an important role of the baroclinicity feedback in the forecast model as well. Yet, it is obvious that an even smaller fraction of the blue points are located in the correct area than for the flux pathway. This again demonstrates that there is a mechanism in SEAS5 which offsets the indirect effect via σ_E, resulting in a lower SST–NAO correlation.

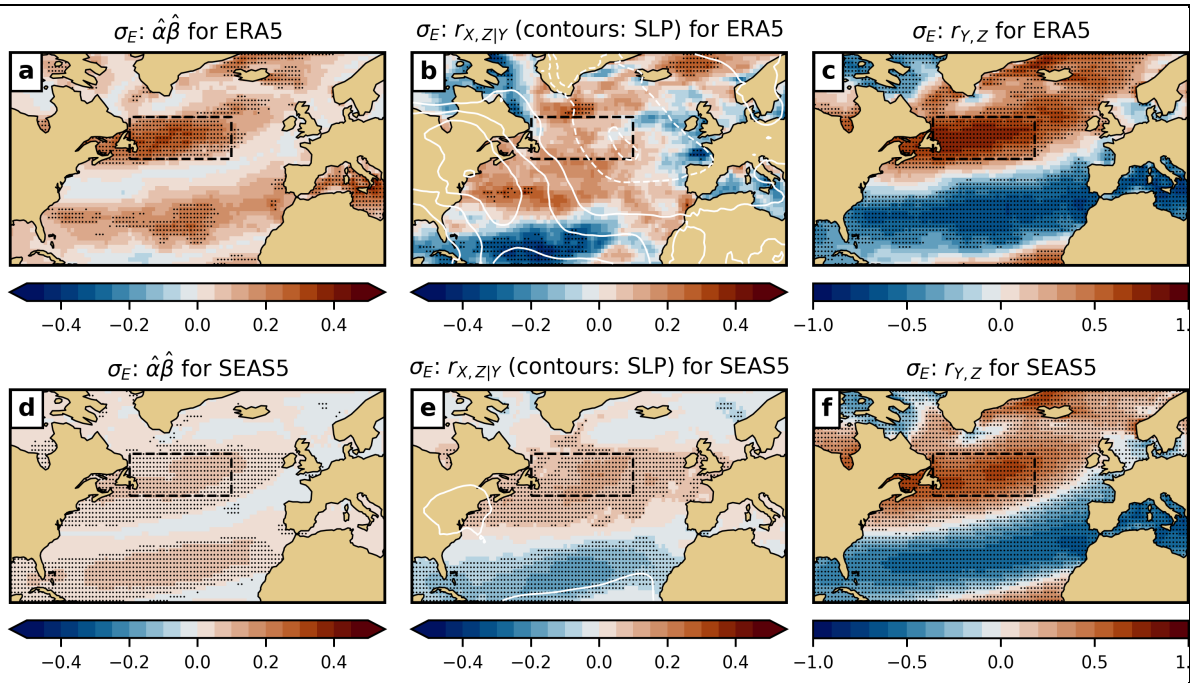
Updated figures



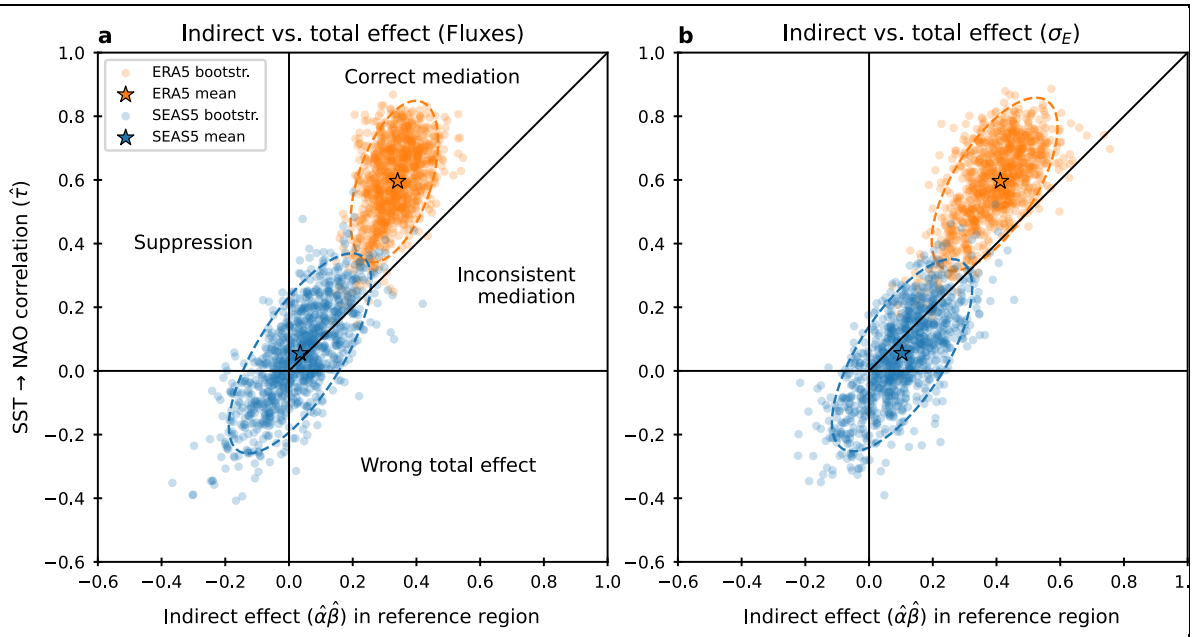
New Figure 1. Caption unchanged.



New Figure 3. Caption unchanged.



New Figure 4. Caption unchanged.



New Figure 5. Caption unchanged.