Comment on section "9. Reanalysis data" by Michael Mayer, Leopold Haimberger, Susanna Winkelbauer, and Hamish Prince (University of Vienna)

The first part of this section discusses the approach to infer ocean heat transport (OHT, which is closely linked with AMOC strength) using net surface energy flux (F_S) based on atmospheric reanalyses. The accuracy of this approach critically depends on the bias and temporal stability of the employed F_S data. The authors cite studies using two different approaches to quantify F_S, namely a "direct" and an "indirect" approach, which exhibit very different levels of accuracy and are outlined in the following:

i) the "direct" approach [as employed by the cited Terhaar et al. (2025)] uses fluxes output by the atmospheric models used for producing the reanalyses. These fields are results of short-term forecasts of the underlying weather models, i.e. they are not directly constrained by observations via data assimilation. This fact has been acknowledged already by Kalnay et al. (1996) who classified $F_{s,direct}$ as one of the reanalysis output fields which have the weakest observational constraint. Indeed, past studies found substantial biases and temporal inconsistencies in $F_{s,direct}$: The global average $F_{s,direct}$ bias is oftentimes on the order of 20 W/m2 (e.g., Mayer et al. 2024 or Wild and Bosilovich 2024) and exhibit large spurious shifts in time (e.g., Mayer et al. 2022). These biases inevitably project on OHT since accurate inference of OHT requires a global balance between surface flux and d/dt OHC. Trenberth and Fasullo (2017) proposed a global mean adjustment of the net surface flux that forces consistency with d/dt OHC, but the magnitude of the bias implies that a large adjustment is required. Moreover, it is unlikely that the fields have a globally uniform bias, i.e. the required adjustments will introduce large uncertainties to inferred OHT and hence reconstructed AMOC. We note that there exist attempts to constrain $F_{s,direct}$ using ocean subsurface measurements (e.g., Sohail and Zika 2025) but these suffer from discontinuities of the ocean observing system questioning the temporal stability of such adjustments.

ii) An alternative way to infer F_S is from the atmospheric energy budget, where only strongly constrained quantities from reanalyses (the divergence of atmospheric energy transports and atmospheric energy storage) are combined with observational data for the top-of-the-atmosphere net radiative flux [such as CERES-EBAF (Loeb et al. 2018)]. Mayer et al. (2024) demonstrated that both global and regional biases of $F_{s,inferred}$ are smaller by roughly an order of magnitude compared to $F_{s,direct}$ (compare their tables 4 and 5). Moreover, Mayer et al. (2022) demonstrated much improved temporal homogeneity of $F_{s,inferred}$ compared to $F_{s,direct}$. The superiority of $F_{s,inferred}$ over $F_{s,direct}$ for climate applications related to the Earth's energy budget has also been acknowledged by the expert community (Meyssignac et al. 2023). Thus, although not perfect, much smaller global mean corrections need to be applied to $F_{s,inferred}$ to obtain budget closure. Studies such as Trenberth and Fasullo (2017), Liu et al. (2020), Mayer et al. (2022), Meyssignac et al. (2024), and Pan et al. (2026) employed inferred $F_{s,inferred}$ for their OHT estimates. All these studies used $F_{s,inferred}$ (estimated with slightly varying methodological choices) to obtain OHT estimates which are in excellent agreement with independent observation-based OHT estimates such as those from the RAPID array, demonstrating the robustness of this approach. Finally, we note that the relatively short observational record of top-of-atmosphere fluxes potentially limits the backward extension of $F_{s,inferred}$. However, since atmospheric divergence is the main driver of $F_{s,inferred}$ in the North Atlantic on decadal time scales, there can be reasonable confidence in the evaluation of this quantity for the full period of the employed reanalysis.

Based on the evidence in the literature referenced above, we emphasize that OHT and AMOC estimates based on $F_{s,direct}$ and $F_{s,inferred}$ should not be treated as equally plausible reconstructions of these quantities. Hence, we urge a more nuanced discussion of reanalysis-based OHT and AMOC reconstructions. In particular, the authors should highlight the fact that the direct approach used by Terhaar et al. (2025) (suggesting no AMOC trends) is associated with high uncertainties both in terms of bias and stability.

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