# egusphere-2025-2074

## 1 Summary

The manuscript *The effect of noise on the stability of convection in a conceptual model of the North Atlantic subpolar gyre* explores the sensitivity of the subpolar gyre (SPG) convection to noise by adapting and building on the conceptual model of Born and Stocker (2014, hereafter BS14). The BS14 model is non-dimensionalized and made autonomous in order to perform a bifurcation analysis. In addition, stochastic noise is added to represent variability in surface current's salinity and in freshwater forcing. The bifurcation analysis shows two stable states in the system: convective and non-convective, where the non-convective state is defined by the total non-dimensional volumetric transport in the gyre $M \leq 22$ Sv. The stability of the model is explored by analysing the sensitivity of convection to noise in salinity and freshwater forcing. It is found that the salinity noise impacts convection in the gyre significantly more than the noise in freshwater forcing. Additionally, it is found that the SPG recovers from the non-convective state across all tested parameters, a result which is not commonly found in Earth System Model (ESM) studies.

The quality of the scientific analysis in the manuscript is good and the topic is both important and thematically suitable for the Earth System Dynamics Journal. However, the study could go further in terms of the impact of the results. In the present form, the novelty of the research presented in the manuscript is questionable. This review presents some suggestions as to how the authors could push their study further.

## 2 General comments

The current description of the conceptual model is lacking. At multiple instances, the authors provide citations to previous work without outlining how these choices fit into the current model (for example, ll. 125-127: how is the value for $\tau_X$ picked?; ll. 445-448 what is the effect of picking $k \gg 1$ on the model?). BS14 provide an extensive discussion on the origin and physical meaning of the conceptual model parameters. Since this model is adapted in the current work, such in-depth discussion is not necessary - but sentence summary for different model parameters would greatly improve the transparency and clarity of the text. For example, mentioning that $U_{btp}$ corresponds to the volumetric transport of 20 Sv would be useful.

The choices made in connection with extending the BS14 model should also be clarified. On which basis were the values for $\tau_S$ and $\tau_F$ picked? What is the relation between parameters $c^*$ in BS14, and $c_1$ and $c_2$ in the adapted version of the model? An alternative mechanism for convective mixing is introduced without sufficient justification or description. How is the value for $c_2$ chosen?

The discussion about the realism of the model is somewhat contradictory throughout the text. In the model description, the amplitude of the noise is described as unrealistic and the choice is motivated by exploring the mechanistic aspects of the system (ll. 136-140). In the discussion, the noise values are instead described as "on the high end of realistic values" (ll. 355-356). I agree with the authors that the realistic frequency of the non-convective state under the current oceanographic conditions can be seen as an argument for the robustness of the model and the magnitude of the noise parameters used. The discussion on this aspect of the model could be streamlined throughout the text.

Section 4 does not convey that the results contribute significantly to the understanding

of the dynamics of the SPG. It is not obvious to me that the study goes far enough beyond the analysis of the conceptual model dynamics in the BS14 paper. One of the main results of the study is that the SPG convection is more sensitive to noise in the gyre salinity compared to freshwater forcing. However, as the authors themselves point out, this may be due to the structure of the conceptual model (ll. 339-340). Could the robustness of this result be tested in additional experiments? Another main result of the study is the resilience of the SPG convective state. The collapse and recovery of the SPG has been observed in at least one ESM study (Jochum et al. 2012). The physical mechanism which allows SPG to recover in the ESM is the freshwater flux through the Bafflin Bay. This and other ESM studies of the SPG dynamics could serve as a basis for a more exhaustive discussion on the physical meaning of the results in the present manuscript, and perhaps aid to design additional experiments that push the exploration of the idealized BS14 model with the inclusion of noise tipping further.

# 3 Minor comments

Larger figure labels would improve readability.

Punctuation should be edited throughout the text.

ll. 69-71: Why is it worrisome? Clarifying the magnitude of the SPG effect on the AMOC here would strengthen this statement.

l. 311: influence $\rightarrow$ influences

ll. 325-326: Is this not just due to the form of the equation of state ($\beta > \alpha$)?

Table A1: $r$ as a symbol for radius of the inner box and ratio of the surface and deep box heights should be distinguished; $S_4$ is the salinity of the deep gyre box.

# 4 References

Jochum, Markus, et al. "True to Milankovitch: Glacial inception in the new community climate system model." Journal of Climate 25.7 (2012): 2226-2239.