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Title: Multidecadal Polynya Formation in a Conceptual (Box) Model

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Additional revisions as a reply to reviewer #2

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1. *First, the authors now make the distinction between MRPs and WSPs. I'm a bit surprised that the authors present the box model as model for MRPs, whereas in my mind it is more appropriately applied to WSPs. WSPs are thought to be associated with convection due to large-scale instabilities of the water column, as modeled here. In contrast, MRPs appear to have a significant dynamic driver, namely the Taylor cap dynamics. It would be good to understand why the authors apply this model to MRPs, but not to WSPs. Besides, Martinson et al., Dufour et al. all consider WSPs.*

   Author's reply:
   As mentioned by the reviewer, stratified Taylor columns (Alverson and Owens, 1996, de Steur et al., 2007) contribute to the preconditioning of the Maud Rise region. There are still two distinct layers near Maud Rise in the presence of stratified Taylor columns (see Figure 3a). Taylor columns only reduce the stratification near Maud Rise and make this region more susceptible to convection compared to the surroundings. However, the stratified Taylor columns near Maud Rise are not sufficient to initiate convection (van Westen and Dijkstra 2020a). Most MRP literature (Kurtakoti et al., 2018; Campbell et al., 2019; Cheon and Gordon, 2019; Kaufman et al., 2020) consider positive salinity anomalies to initiate the convection near Maud Rise, similar as in WSP formation in the model of Martinson et al. (1981). This suggests that the Martinson model can still be used, but needs some adjustment for the Maud Rise region. For example, the total depth ($H = 2000$ m) is adjusted and we use different values for the subsurface temperature (T_2) and salinity (S_2) compared to Martinson et al. (1981). The effect of stratified Taylor columns are assimilated in the subsurface temperature and salinity time series (Figure 4). These values are retained from

model output of the Community Earth System Model (CESM). In this way, the basic set-up of the Martinson model can be used to study MRP formation.

Changes in manuscript:
The differences between this study (MRPs) and Martinson et al. (1981) are discussed in the revision. We motivate why the original model is still applicable, with some adjustments, to the Maud Rise region (pg. 2 lines 32, 33; pg. 3 lines 1-6).

2. *Also, there are still a few issues with the set of equations. For starters, Eq. 5b is missing the exchange term with the layer below. Second, there is still a problem with the freshwater flux. I now realize that my previous comment about F was ignoring a bigger issue with how the term F is treated and described; I realize that Martinson et al. (1981) are treating this term rather loosely, but it would be good to be consistent here. The simplest fix is to simply replace F by $F\ S_0$ in Eqs. 2b, 3b, 4b and 5b; as well as in 4c and 5c. Martinson et al. use a conversion factor of 35 g/kg. In that way, F still represent the freshwater flux (positive if into the ocean), with units of m/s (or similar); while $F\ S_0$ represents the associated virtual salt flux. Please verify that the code is correct, and that these issues are addressed in the manuscript.*

   Author's reply:
   This is not clearly documented in the revision and we follow the suggestion by the reviewer. The freshwater flux has been used correctly in the model code, i.e. as a virtual salt flux.

   Changes in manuscript:
   The term is added in equation 5b. S_0 is added to the equations, the discussion of the equations, and to Table 2. Transforming the freshwater flux to a virtual salt flux is also discussed in section 2.1.

3. *In the sections on p. 6 please be more consistent in the terminology: l. 12, ocean atmosphere heat flux is given by Q_{ia} –without the terms in the denominator, which convert the flux to a temperature change. Similarly in ll. 15, 17, 19, 22, 24, and 25.*

   Author's reply:
   The terminology was confusing and we aligned the terminology throughout the manuscript.

Changes in manuscript:
The terminology is aligned throughout the manuscript.