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Interactive comment on "The mechanisms of North Atlantic CO_2 uptake in a large Earth System Model ensemble" *by* P. R. Halloran et al.

Anonymous Referee #2

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The introduction to this manuscript is well written and compelling. It is a nice review of the state of understanding with respect to mechanisms of North Atlantic carbon uptake. Unfortunately, the remainder of the manuscript is a disappointment. The authors fail to adequately describe and justify their box model, or to illustrate that it can be used effectively as a mechanistic emulator of the ESMs. After the introduction, the manuscript is also poorly organized, overly terse and difficult to follow.

The conclusion that chemical change is to be the dominant mechanism of future CO2 uptake change in the North Atlantic appears to be a re-presentation of the results from Volker et al. (2002), but without any additional evidence that the mechanism is occurring in ESMs or in nature. The possibility that this may be just the behavior of this box model needs to be addressed carefully by the authors.

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Interactive Discussion
Discussion Paper

This manuscript is inadequate for publication and should be rejected.

If the authors will revise, they need to begin by (1) describing their box model in greater detail and (2) proving more convincingly that their method of emulation with this model is effective to capture the mechanisms. They might use the latitudinal distribution of CO2 flux as compared to the ESMs, as opposed to just the integrated flux, which can vary widely in space. Physical comparisons indicating that the model is reasonable would also be of use. (3) They need also to more carefully describe and justify their analysis via comparison back to the mechanisms occurring in the ESMs (not just the CO2 fluxes).

Major Comment Pg 14556 – 14557 "1. By using a single box model that replicates the behaviour of a wide range of Earth System Model formulations using only a single set of parameters (i.e. not retuning the simple model to emulate each different version of the more comprehensive model), one can be confident that the box model contains (and therefore that one has identified) the key processes important to the change of interest within those Earth System Model formulations." COMMENT: This statement is not adequately justified. It is not clear WHY a single box model emulator leads to confidence that all key processes are captured. If the CO2 flux is an emergent behavior of a complex ESM, how can one be so sure that a box model will capture it? Similarly, points #2 and #3 here need justification. The rest of the analysis hinges on these statements being carefully justified.

COMMENT: This box model is very simple. For example, the tropics extend 30S-48N. The authors should not be discussing "subtropical processes" in results. They should use the term "Tropical" to be consistent with their model setup and to clarify the very simple nature of their box model system to the reader.

Pg 14560: "This gives us confidence that the box model represents all of the 1st order processes involved in the ESM simulation of North Atlantic CO2 uptake, and provides us with a diagnostic tool to identify what drives CO2 uptake variability in the ESPPE."

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COMMENT: Similar to the comment above, there is insufficient support for this statement.

Pg 14561: "The "peak and decline" behaviour seen in the low-frequency air–sea CO2 flux signal is unlike the globally averaged signal (Fig. 2), which under a CO2 emission scenario like RCP8.5 (in which atmospheric concentrations are increasing throughout the 21st Century) would be expected to (and indeed does: Fig. 2) continue increasing, but at a progressively reduced rate. As long as the atmospheric CO2 concentration is increasing, assuming no dramatic changes in ocean circulation or biology, there will always be an air to sea CO2 concentration gradient, and therefore air-to-sea CO2 flux. The decrease in this flux through time reflects the changing speciation of carbon in seawater in response to the increase in carbonic acid concentrations – which partitions carbon progressively in the direction of CO2, elevating surface ocean CO2 concentrations, and reducing the air–sea CO2 concentration gradient (Zeebe and Wolf- Gladrow, 2001; Revelle and Suess, 1957)." COMMENT: Is there evidence that this is happening in the ESMs? Otherwise, this is simply re-presenting the work of Volker et al. (2002) from the same box model. Is there any evidence that this is not just a behavior of this very coarse model?

Minor comments Pg 14554, line 1 "Here we attempt to develop our understanding of the possible mechanisms controlling future subpolar North Atlantic CO2 uptake within Earth System Models." This sentence is overly caveat-ed, remove "attempt to" and "possible".

Pg 14557, line 7 "ESPPE" Acronym has not been defined yet .

Methods section

Pg 14559 Why don't the parameters listed in Table 1 correspond to the parameter values listed in Table 2?

Pg 14559 "Indeed the ability of the box model is relatively insensitive to the box model

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parameters (Fig. 4 and Table 1), suggesting that conclusions drawn on the drivers of the box model CO2 flux are unlikely to be strongly dependent on the exact choice of box model parameters." It is not clear how this conclusion is to be reached when given Table 1 that lists parameter names and whether they vary or not; and Figure 4 which does not offer any indication of the parameter values in the box model for each timeseries of flux. If the authors mean Table 2, they need to indicate how "Ranking" relates to the panels in Figure 4 more clearly. Are there only 6 in this ranking, or is it 1000 as indicated in the text? If 1000, Table 2 and Figure 4 do actually not correspond.

Pg 14559, Box model equations need to be presented. It is not possible to understand Table 1 or to begin to understand the parameter-setting process otherwise.

Pg 14560, line 18 and on – This methodological discussion belongs in Methods.

Pg 14560, line 21 "we high-pass" FILTER

Pg 14560. Line 24 "in a time-series THAT varIES"

Interactive comment on Biogeosciences Discuss., 11, 14551, 2014.