Review of manuscript number os-2021-37

Regional Imprints of Changes in the Atlantic Meridional Overturning Circulation in the Eddy-rich Ocean Model VIKING20X

by Arne Biastoch et al.

General impression

The paper discusses a suite of hindcast simulations at varying resolution and atmospheric forcing. It systematically describes the key features of the AMOC and the boundary currents contributing to it, and as such is a valuable benchmark for follow-up studies.

I only have a few minor comments on the text and figures (mostly requests for clarification) and a list of text suggestions / typos. I therefore recommend **minor revisions** before publication in Ocean Science.

Minor comments

Writing style:
The authors sometimes have a tendency to make long sentences with several clauses, combining a lot of information for a reader to digest in one go. Often, such sentences also contain information on more than one subject / topic. Splitting them is usually easy, and will certainly improve the readability of the paper. Some examples are listed below, but I urge the authors to review the entire paper with this in mind.

Examples: 17-20; l.31-35; l.49-52, l.96-102, l.166-168, l.221-223, l.515-519

Detecting AMOC changes in regional current systems:
Besides a systematic description of the various numerical simulations, the authors also present an analysis of the modelled trends in the AMOC and in its current components at various latitudes, to address at which latitudes one can expect to see changes if these occur. I like that aim and the outcomes, but I find it not carefully and clearly phrased in the manuscript. Places where this needs some attention:

Abstract l.9-10: *"Regional observations in western boundary current systems at 53N, 26.5N and 11S are explored in respect to their ability to represent the AMOC and to monitor the temporal evolution of the AMOC"*

This can be misread as id the authors are solely analyzing observations. In stead, using the outcomes of the various model simulations, they explore if observations at these locations have the ability to give us a good view on / quantification of potential AMOC changes.

l.86-90: *A particular emphasis of the study is on the imprints of AMOC variability and trends on WBC systems which, in turn, contributes to exploring the capability of regional observation systems to capture changes in the basin-scale AMOC. Using the different evolution of the experiments in respect to the long-term evolution of the AMOC, we turnaround the question and ask which regional observations are able to capture changes in the AMOC.*

In the final sentence, it can be made more explicit that the authors analyze the features of the model simulations at the locations where long-term observations exist

L.621 *"our main objective is to test whether regional current systems are able to detect AMOC changes."*

I find this is oddly phrased, as the AMOC at a certain latitude is by definition (the net effect of) what happens in regional current systems. In my view, the key aspect addressed here is if an AMOC change would appear as a clear signal or not at these locations

Questions

l.260: I do not understand the statement that is made here: do the authors claim that the features of the horizontal circulation are less important for the AMOC than forcing / thermohaline drivers? And that this is because horizontal circulation = set by grid resolution? [which I would find a strange reasoning – one could argue that if it is key to get certain features horizontal circulation correctly represented then this implies using a certain minimal resolution is crucial]. Please elaborate / rephrase

L.409-413: The conclusion that the reduction in MLD_a has to be due to model drift confuses me, as convective activity in itself does not necessarily represent a changing contribution to the AMOC [in theory, as long as the dense water is not exported, the contribution of convection to the AMOC is zero].
Yet the authors apparently not only expect a one-to-one connection between convection and the AMOC strength, as they are suprised this is not happening (l.410) , but for these two specific experiments this one-to-one connection can also act in the reverse direction? (AMOC reduction yields convection reduction l. 412).
To me, this comes across as a too simplified view of a highly complex current system in which the AMOC, convection regions and the subpolar gyre interact, i.p. in eddy-rich models. Please elaborate / clarify

l.690
It probably helps that all currents are cyclonic at 53N so no compensation effects between upper and deep ocean that potentially confound signals? (unlike f.ex 11 S – Fig 16)

Figures

- Fig A1: a difference plot would help to support the statement on l.251
- Fig 3 – why in black and white? Hard to see the differences
- Fig 10 – consider adding the zero-line in the plot for clarity
- Fig 11 grey density lines hardly contrast with blue colors
- Fig 14 authors never refer to this figure
- Fig. 17d-e appear very cluttered, impossible to distinguish lines

Text suggestions & typos

- l.4-6: re-order sentence: The representation of the Atlantic Meridional Overturning Circulation (AMOC), and in particular its long-term temporal evolution, strongly depends on numerical choices for the application of freshwater fluxes.
- l.8 – pointing at a dominant role of the forcing – this is an important remark, which is now presented in passing. In my view, it could use a half sentence explanation
- l.11 if → provided
- l.22 I find this sentence oddly phrased (order of words is not grammatically correct, also why most difficult?). Please rewrite
- l.23 attempts aim -very vague
- l.26 This is an "apples & oranges" list: some items mention the current that is observed, some just the name / location of the array but not what is measured there. Please make consistent
- l.58 odd sentence, please rephrase [I think my confusion comes from the use of "integrated" here as "performing a numerical calculation" rather than as "unified"]
- l.63 not clear to me what "these" refers to in this sentence
- l.64 the use of "thermohaline events" is unclear to me – what is meant with that? Why not simply the thermohaline circulation?
- l.82 improve, compared to what? VIKING20X versus VIKING20? Or compared to older / lower resolution models?
- l.84-86 Not clear to me what is meant; what exactly is exploited / explored. Please rephrase
- l.86-88 sentence not clear / grammatically not correct: "WBC systems, which… contribute" [but is that what the authors want to say?]
- l.89 turn around / reverse
- l.93 results
- l.95 start the section with some guidance for the reader what is coming; after this intro text the section header of 2.1 seems incomplete / not covering the content
- l.98 features
- l.102 the successful representation of the physical circulation
- l.111 strangely phrased with 2x compare and 2x AMOC in the sentence
- l.124 remove "to"; with → at
- l.130 an → a
- l.134 damped by applying
- l.144 sentence unclear
- l.165 add comma after level
- l.188 represented differently on the two ocean model grids
- l.190 In section 2.2 acronyms are used distinguishing the various model experiments (VIKING20X-JRA-OMIP, ORCA025-JRA-OMIP, VIKING20X-JRA-short, VIKING20X-JRA-long) but the list of experiments is only given in section 2.3.
- Table 1 - not sure why the long names are given? Seems only relevant to the modellers?
- l.222 unclear, something is missing? – with a piston velocity of 50 m 4.1 yr^{1}
- l.223 – In…. suppressed: unclear to me what is meant here
- l.235 2x systematic in one sentence
- l.240 repeats l.216; it is unclear to me what point the authors want to make in l.240-243
- l.244/246 is focus is on basin-scale AMOC then title section 3 should reflect that
- l.251 explain what aspect is improved [basically the text on l.256-259, as this is about the mean and not about the variability / Fig 2]
- l.255 remove "at" or "around"
- l.265- are → is

- l. 267 re-order sentence for clarity: The strength of the NADW cell in ORCA025-JRA is quite different from that in VIKING20X-CORE, with 1990-2009 average values at 26.5N ranging from 10.9 Sv to 20.4, respectively (Table 2).
- Table 2 note on *: rephrase; values indicated by * denote a shorter averaging period … due to the limited length of the CORE forcing and RAPID data sets
- L.273 – does the statement belong here, if it is discussed later, and no reference is given to a figure supporting it? Or specify where "below" is?
- L.277 specify where "below" is
- L.293 add "in the various experiments"
- L.304 robust in the models and compares well to / in good agreement with observations?
- L.306 1980-2009
- L.309 variability of the AMOC strength
- L.309-311 connection between the different statements can be clarified / made more explicit [now it reads as a loose set of statements]. Guess the point is to discuss the differences in variability on various timescales between RAPID and the models. Also: what do the authors conclude from the fact that these differ?
- L.317 trend in …
- L.321 indicate how you define "Arctic FWC " – which latitudes; in text and caption of Fig 6; same for subpolar FWC – l.326
- L.322 the trend … is stable → that does not seem correct – looks like there is no trend; the FWC is stable
- L.322 … and increasing..: not sure one can say the trend in increasing based on just the figure, but the FWC itself certainly is. Please clarify what is meant
- L.325 maybe add the trends in km^3 /yr that emerge from the models for comparison
- l.326 as l.321 - indicate how you define "subpolar FWC " – which latitudes; in text + caption of Fig 6
- l.335 sentence unclear – needs a comma after 'correction' ?
- l.339 capable of
- l.345 indicate which experiment; indicate how this pathway is deduced/defined [referring to it as a pathway to me suggests something Lagrangian, which is not the case]
- l.346-7 oddly phrased - the path is broken into eddies… and reconfigures..
- l.355 remove brackets
- l.355 statement is a loose end, any attempt to explain? Van Sebille uses Lagrangian techniques – can this be relevant?
- L.355 A concluding statement on section 3 is missing
- L.356 title not very informative – regional imprints of what?
- L.358-365 could use some references to review papers…
- L.366-370 missing discussion on densities in 1/20deg versus 1/4deg – linking this to the resolution / mixing argument presented earlier
- L.383-385: not clear what statement the authors want to make – please elaborate why is this is noteworthy
- L.386 "additional deepwater is added to the system" - please rephrase – additional to what? Which system?
- L.390 mention criterium used to define the bottom boundary of the MLD
- L.402 unclear which experiment 'former' refers to
- L.430 similar to above remark: "the AMOC… 1990s" – this seems to suggest the authors expect a one-to-one connection between the AMOC and gyre strength. Is that indeed the author's statement? If so then explain why
- L.486 are → is
- L.486 the availability of long-term observations for comparison?

- L. 488 modelled transports agree; but statement based on Table 6 seems at odds with curves shown in Fig 14
- L.505-this needs some more specific guidance for the reader what to look for; what exactly is "indicating" and "suggesting" this underlying physical explanation in terms of a connection to NBC rings
- L. 513 figure domain ends before that latitude
- L.527 provide overestimate in % is more common?
- L.534 last
- Fig 17 – The text only refers to Fig 17a – l.537, and to 17e (as a sidestep on l.534). Fig 17b-c-d are never mentioned
- L.556 this → these
- L.567 signal,
- L.562 indicate how one can see this from ssh (variance)
- L.566 19a
- L.580-582 I understand what the authors mean, but I find the sentence not very clear (probably because it starts with "depending on" after which I expect something like "you may either see A or B"
- L.587 "forcing comes an important change" - unclear what is meant here
- L.589 could → can?
- L.591 "as well as its regional components' – unclear what is meant here
- L.597 / 593 – not clear if the authors make the connection here between SPG transport and AMOC strength? Please clarify what point authors want to make on l.592-599
- L.599 ability to simulate
- L.601 features of dc regions
- L.630 and l. 635 explain how you know what the forcing mechanism is in this simulation (or is this an assumption? Then rephrase)
- L.634 We identify – explain how & where / indicate in plot
- L.638 only slightly slanted – they look quite straight to me – so why not an explanation in terms of surface forcing?
- l.639 Only or Besides
- l.640 give latitude
- l.654 in principle – I'd say it is really a matter of trend amplitude versus variability? Of does 'in principle' imply 'if the timeseries is sufficiently long' ?
- l.559- the transport … AMOC – something is missing in this sentence
- l.673 bracket missing
- l.674 "At 11S, the WBC system is more exposed to the open ocean": not sure what is meant here
- L.694 add reference to Moat et al 2020 - https://doi.org/10.5194/os-16-863-2020
- L.705 "An important factor could be the 5th cycling of the simulations through the forcing period" – please rephrase / explain what this means for readers not familiar with the procedure
- L.727 concentrate on
- Typos in references - author names l.824, 873, 965