Towards understanding potential atmospheric contributions to abrupt climate changes: Characterizing changes to the North Atlantic eddy-driven jet over the last deglaciation by Andres and Tarasov.

In this manuscript the Authors describe a suite of experiments that show how the North Atlantic jet may have evolved over the last deglaciation. The Authors present results from simulations in which individual boundary conditions are changed in order that their effect on the circulation can be described. Such an approach is to be applauded as it makes clear the role that the various boundary conditions play overcoming the hand-waviness that exists in the analysis of many paleoclimate model simulations. Furthermore, the Authors compare their results directly with other model simulations to highlight the role that model physics might play. Overall it is a very thorough study.

The authors show that the evolution of the eddy driven jet is different on the eastern and western side of the Atlantic, with changes on the western side caused by the ice sheet topography, and changes on the eastern side influenced by all glacial forcings.

Overall I learned a lot from this paper and it is a great addition to the paleoclimate literature. It was, however, let down by some rather weak analysis in parts. There are also a number of sections that would be well to be rewritten as it was only possible to get the meaning on the third or fourth reading.

I detail below some specific comments and suggestions.

Introduction

The Introduction is quite variable. The description of the North Atlantic jet is great, and gives a reader unfamiliar with the topic a good start. I don't understand why there's an extensive description of the mechanisms for abrupt change in the climate during the deglaciation, because much does not appear to be relevant for the subsequent analysis. For example, it's only in the Introduction that changes in the AMOC are mentioned - why include this? I suggest focussing the Intro only on information that is pertinent for the paper itself.
The Intro, as written, just stops. It lacks a clear statement of the problem that this paper addresses. It conveys much information but doesn't link it together: how does jet variability have the potential to impact the climate during the deglaciation, especially abrupt changes? How is the paper going to answer this question?

Section 3.2
What is the point in this section? At the end of this section I don't konw what I am supposed to have learned. It would help to have a clear finishing paragraph to summarise this section. At present it is a selection of disparate facts. If you focus on the observations which support you summary, noting any discrepancies it may help add a narrative structure. It would help if you were to link the discussion here with the discussion comparing the jet in the east and west to the discussion of tilt - how do the changes at either end affect tilt?

Tilt v east/west changes
Reading the manuscript one gets a sense that the tilt of the jet and the changes in the jet in the east and west are two separate entities, which they evidently aren’t. Historically, the focus has been on tilt, so it makes sense to at least look at this. However, I really like the description of how the east and west vary as this adds nuance to the very simplistic view of tilt. What’s lacking the manuscript though is much of a bridge between the two. How can we interpret the previous discussions about tilt in the context of your results?

General comments

I'm not sure “oscillation” is a useful term to describe periods like the Younger Dryas. Oscillation implies some set of physics that gives a distinct cycle, and it's not clear to me that any changes which occur over the last deglaciation can be described as cycles. A better term would be “variability”, which encapsulates the fact that there are changes without implying any cyclical physics. You even make this point on page 2 line 28. The presence or absence of cycles is not important for the interpretation in the paper so I’d suggest the less loaded term “variability”|.

p3 l5 - “*During the deglaciation, changes to the variability of low-level winds can alter gyre transports (and to a lesser degree, wind position and strength”* Not sure I understand this, surely variability of the low level wind ***is*** changes in the wind position and strength?

p3 l27 - jet not yet.

p5 l29 - how many ensemble members are there?

p5 l30 - “*Gaussian grid that is then used for diabatic calculations”* not sure what diabatic calculations are.

p8 l22 - You don't mention anything about model spin up? How is the model initialized?

p9 l7 - I'm not sure what “*peak zonal winds”* means. Perhaps just say strongest winds?

p9 l16 “*the pattern of wind changes from the LGM to the past1000 are similar in both CMIP5 and PlaSim runs (including during JJA, not shown) even though the differences are stronger in the PlaSim transient simulations.”* Saying transient simluations at the end of this sentence makes it sound like there's an extra set of simulations - “the transient simulations” - as well as the normal “runs”. This is not the case?

p10 l9 - I'm not sure how you get from *“10 consecutive DJF periods”* to the histogram on figure 6. 10 DJF periods surely gives 30 months, yet the frequencies on Fig 6. show 100s of months. Is this due to all the ensemble members?

p12 l6 - “*tilt .. shifts slightly higher”* - better as tilt becomes steeper.

p12 l7 - It would be interesting to compare the spread in histograms between Trace21ka and PlaSim. You discuss spread for PlaSim on p11, why not Trace21ka too?

p12 l14 - There needs to be a discussion of “abrupt”. What constitutes abrupt: changes over what timescale? When looking at jet shifts in a coarse resolution model, a movement from on one grid box to the next come across as abrupt, tipping point like, but is actually just a smooth rapid change. To be abrupt suggests some set of non-linear feedbacks giving a larger response than the input would suggest. A linear response to a large change to me is not abrupt, just rapid. This is totally personal, but to avoid anyone misinterpreting what ***you*** mean by abrupt you need to define it.

P12 - I don't see a figure which shows the temperature over Greenland. Why are you showing the temperature over Greenland, anyway. What does it represent in this study looking at jet shifts.

p13 l5 - What exactly are you saying in this paragraph? I don't see what the point is.

p14 - Transition seems to be used to describe two different things here. From line 8 there are the three events called transitions then on l10 transition is used to describe the way things change. It doesn't help that on l10 it says "*A second type of transition"* without ever being clear what the first type of transition is. This whole paragraph l2 onwards is really difficult to understand. I'm struggling to be more helpful and think of suggestions to improve it, but a reader is really going to struggle with this.

p15 l4 - This seems to contradict p11 l5 which says that the jet tilt doesn't change much from LGM to past 1000.

p15 l13 - "*The preferred latitude shifts northward twice within a single decade of simulation, at 19.3ka BP and 14.6ka BP. The timing of these transitions match the more gradual shifts in the jet as a whole and two occasions when the tilt is reduced. They are also consistent with the historical timing of the start of the OD and B-A."* I do not understand this pair of sentences.

p16 l14 "*This separation makes it much easier to identify what changes are occurring and attribute their causes than examinations of the mean jet position over the entire range or its tilt.. "* This is an awkward sentence.

p17 l4 - this is an interesting point, any conjecture as to why orbit and GHG matter?

p18 l10 - "*Yet, the jet does not always move to the latitude of the jet"* Is an odd sentence.

p19 l3 - "*The consequences of this restriction are that the western end of the jet is more focussed relative to the eastern side, particularly when the NAIS extends well into the midlatitudes, and that the northern range of the western side of the jet increases much more over the deglaciation than its southern range"*
Perhaps rewrite as: "There are two consequences of this restriction. First the western end of the jet is more focussed relative to the eastern side, particularly when the NAIS extends well into the midlatitudes. Second, the northern range of the western side of the jet increases much more over the deglaciation than its southern range"

p19 l10 - "*The preferred tilt in the PDTopo experiment is near zero"*. The tilt doesn't change much in this simulation and stays at its past1000 value, which you show and argue does have a tilt, 5 degrees in Fig. 8. I agree that the ***change*** is near zero, but not that there is no tilt.

p19 l15 - *"In contrast, the shift in latitudes occurs earlier on the eastern side of the jet, and no further change to the preferred range of jet latitudes occurs following this."* This sentence exemplifies why, I think, this paper is so confusing. What is important in this sentence is *"the eastern side of the jet":* this is what is being compared to the preceding sentence. Yet the way that this sentence is structured puts this midway through the sentence, slightly buried. Thus it takes very careful reading to parse the sentence. If you wrote it as: "In contrast, on the eastern side of the jet the shift in latitudes occurs earlier..." it would be much more obvious what's going. It may be that this reviewer is a bit stupid, but with the long sentences that you use any help that a reader can get would be good. I'd have a look through the paper for more instances of this inverting of sentences. Given the quality of the English in this review you may, however, choose to ignore the stylistic recommendations of this reviewer.

p22 l1 - This section of the conclusions relates to the weakest part of the main text, much of what is in this part of the conclusions was not clear from the preceding sections.

p22 l10 colon inappropriate here.

p22 l21 - it would be clearer to say “through two phenomena: first, ... second ....” the two descriptions are so long you need to make it clear where one stops and the other starts.

p23 l7 - “*Conversely, the sensitivity of the jet position on the eastern side of the North Atlantic to the background climate state implies that it would be difficult to estimate historical changes to the jet in this region from model simulations, since estimates would vary between models and between simulations with different boundary conditions.*” Need to explain this more. Surely, because the orbit and GHG are better constrained than ice sheets, this response will be better simulated?

p23 l12 - I disagree. The assumption here is that the surface temperature response is linear with respect to the jet latitude: as jet latitude increases so will temperature in direct proportion. But, if there are non-linear feedbacks it could be that when the jet reaches a certain latitude abrupt changes in temperature are possible. For example, imagine the jet is well south of the sea ice margin but gradually moves north due to a slow retreat of the ice sheet. At some point the jet will be over the sea ice margin and a different set of feedbacks become possible. Thus you can get abrupt changes in temperature from a smoothly varying jet/ice sheet.

Figure 1(a) - There's an enormous remnant ice sheet over NAm: 1.7km at 0ka. What is this?

Figure 5 - Its hard to judge in this figure how the amplitude of the jet changes. If you highlight one isotach, 20m/s, in both the contours and colours it would make it simpler to see how the structure of the jet differs.