

Interactive comment on “Reconciling the signal and noise of atmospheric warming on decadal timescales” by Roger N. Jones and James H. Ricketts

Anonymous Referee #2

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1. Does the paper address relevant scientific questions within the scope of ESD? Yes.
2. Does the paper present novel concepts, ideas, tools, or data? Yes.
3. Are substantial conclusions reached? Yes
4. Are the scientific methods and assumptions valid and clearly outlined? Yes, but some clarification needed in places, due to the complexity of the subject covered and to make the text more readable for a general rather than specialist audience.
5. Are the results sufficient to support the interpretations and conclusions? Yes
6. Is the description of experiments and calculations sufficiently complete and precise

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to allow their reproduction by fellow scientists (traceability of results)? Yes

7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution? Yes
8. Does the title clearly reflect the contents of the paper? Yes, but see my comments on 'decadal'.
9. Does the abstract provide a concise and complete summary? Yes
10. Is the overall presentation well structured and clear? Yes, and could be largely maintained in the current format with changes to the last sections including the conclusions. I suggest separating the manuscript into two related papers one that largely addresses the philosophy and statistical approach behind the study and another that reports and discusses the results and their significance.
11. Is the language fluent and precise? Yes mostly.
12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used? Yes
13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? Yes see comment 10.
14. Are the number and quality of references appropriate? Yes, a broad and comprehensive coverage of the literature.
15. Is the amount and quality of supplementary material appropriate? Yes. I am content with the supplementary material as presented.

General comments

This is an important paper and one of very few that challenges the conventional view that global warming is progressing in a gradual fashion. It proposes instead that warming has a step-like development with at times trends between each step. It backs up

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the challenge with significant statistical analyses of many different global and regional temperature time series, plus the same for the time series temperature products of CMIP 3 and 5 models. A large volume of data has been processed in a comprehensive way using a standard and tested procedure.

I have minimal problems with the scientific results and feel that they are the main issue that should be focussed on. My concern in this context is that the current manuscript tries to do two things: 1) expound the philosophy behind the two different approaches to the way global warming has developed in the past and is likely to progress in the future plus how this can be tested statistically; and 2) present the results of the applied statistical analyses of measured regional and global temperature time series plus the same for modelled temperature products from CMIP 3 and 5 to the end of the 21st century. The audiences for these two different themes is likely to be different. Also, the debate at the beginning of the manuscript on the two hypotheses and on the need for severe testing before the reader gets to the meat of the ms might put off some researchers reading the paper. A secondary consequence is that the manuscript is long and needs breaking up with headings into more sub-sections than at present.

I acknowledge the importance of the philosophical debate and for section 2.2. I leave it up to the Editor to decide, but one way of proceeding would be to redraft the current ms into two associated papers, the first outlining the philosophy behind the two opposing views of global warming and its history and why severe testing is needed to address this issue and the second presenting the results with a brief account of the methods (that are backed up by the supplementary information) and the consequences of the analyses presented in the present paper. Some of the early text in the paper might be better placed in the discussion. When I started to read the paper I was keen to see the scientific results and spent much time trying to understand the complexities of the philosophy first. I think many researchers might be turned off from reading the paper by the long debate that is presented at the beginning and thus not discover the key findings that are included.

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The current ms outlines a need for severe testing without summarising in more detail what 'severe testing' is, how this differs from other statistical approaches and what its advantages are, in language that is understandable to a general reader. The sentence that includes: "conditions for severe testing should be probative, rather than relying on a particular probability threshold" is relevant here. Severe testing proves or demonstrates that a particular hypothesis is accepted or rejected. The authors back up many of their statements throughout the ms and in the Supplementary Material by citing other papers that are in preparation that are led by one or other of the present authors. Only papers that have been published or are 'in press' should be cited. If more information is needed to back up a point it should be presented in the ms or if two, mss.

Most of my subsequent comments apply whether the Editor and authors decide to proceed with a revised version of the current ms or a revision that splits the contents into two related papers published at the same time, one after the other.

Specific comments

Abstract: I like the Abstract and the way it is organised and numbered against each of the six tests. To make it clearer refer to Test 1 rather than (1) and the same for the remainder unless this breaks the word count. If brevity is needed put the brackets and numbers in bold. It would be helpful if the results section could be organised in the same way. Introduction.

Slightly expand in the statistical analysis ms if the 2 paper route is chosen by incorporating some of the material from Sections 2.1, 2.2 and 2.3, but most of this text would I expect be transferred to the 'Philosophy ms'. I think the latter would be an important paper in its own right as it could include some of the history behind the two views of global warming as well as emphasising that the risks from global warming are possibly greater if the second hypothesis is what is really happening. Include the text on page 5 lines 16 to 19 and perhaps expand on this reason for rejection by the scientific community of a nonlinear pattern to global warming here or in the discussion of the statistical

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analysis paper. This discussion should be included in both ms.

Two hypotheses H1 and H2 and even $-H1$ and $-H2$ are used throughout the paper, but are not clearly defined early on. Do the authors consider that the two hypotheses outlined at the top of page 3 are equivalent to H1 and H2. If so this should be clearly stated in the Introduction.

2.3 Line 23. I do not understand what you mean by “is an inverse, ill-posed mathematical problem”. I realise that the phrase has been quoted from Serban and Jacobsen. Please clarify for the non-mathematical general reader. Further down I do not see why “external forcing” need always be linear; please clarify. The development of this section comes back to the use of the word decadal in the title. My understanding of decadal is based on data averaged by decade. Most of the data used in the ms is based on annual averages and the step changes take place within a year so I don’t think the word decadal should be used; long-term would be better although I realise that decadal is used widely in time series literature. Serban above distinguishes between annual, decadal and centennial averages. Later in the paper I believe the CMIP time series are based on 5 year averages.

Page 6. I can see why radiative forcing and its interactions is additive, but again, I do not see why entrainment of heat energy into the various heat reservoirs of the Earth and especially the hydrothermal system need always be nonlinear. This is likely to vary with the area defined and the time taken, for example heat release from the ocean to the atmosphere. Lines 2 to 6 outline a number of alternative approaches to determine ‘shifts’, ‘change points’, ‘step changes’, but there is no discussion of the advantages/disadvantages of these different approaches and why they were not used in this study. See also: Drijfhout et al. (2015) and Reid et al. (2016) Reid PC, Hari RE, Beaugrand G et al. (2016) Global impacts of the 1980s regime shift. *Global Change Biology*, 22, 682-703.

Page 7 line 21. First mention of ECS without identifying what the acronym stands for.

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There is no summary of the source of the data or how it is derived/measured other than from Table S3 in the Supplementary Information (ECS is taken from Sherwood et al. (2014) unless otherwise noted). Nor is there any explanation of why ECS is compared to the CMIP time series. Page 8 MYBT. Many acronyms are used throughout the paper. It would be helpful to provide these as a list with the full name at the beginning of the paper as searching for them in the text is onerous.

Page 9 lines 22 to 28. A diagrammatic representation of the different terms used for the analyses is needed. A descriptive expansion of what is meant by each of the terms would be helpful. The word ‘shift’ has been used in a different way in previous papers and a different word would be more appropriate here for this characteristic. Is the text in brackets at the end of the last bullet correct? Page 18 line 4. Lack of predictability. How can the author’s be so definite that this might be due to aerosols?

Page 23 Section 5.1. This section would be better drafted as the conclusions of the paper rather than as a summary of severe testing. Combine the first two paragraphs with the current conclusions, which are similar in part if worded slightly differently. Ensure that all the observations highlighted in yellow above are covered in the bulleted summarised conclusions.

I don’t think it is necessary to repeat the ratio numbers or r^2 values from the results in this section. It should instead just give a verbal summary of the main conclusions reached.

Page 25 line 2. Again I do not like the use of the word decadal here. Table 6 does not show that hstep is better at a decadal scale the steps are occurring within a year, but may continue at a new level or develop a trend afterwards for more than a decade. Decadal data is usually averaged and smoothes out any signal from a step change. e.g. Figure SPM 1 in the 2013 IPCC Summary for Policy Makers.. Longer term (> 50 year) warming is also smoothed out and here there may also be issues with the quality of the data, so while it may seem to be proportional to forcing, steps may also have

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occurred in this data.

Page 27 line1-2. The hiatus is now thought to be due to an increased storage of heat deeper in the ocean and is not a continuing event considering the warming of the last few years. See Reid 2016 and references included.

Reid PC (2016) Ocean warming: setting the scene. In: Explaining ocean warming:causes, scale, effects and consequences. (eds Laffoley D, Baxter JM) pp Page. Gland, Switzerland, IUCN.

Technical corrections

Page 2 Line 2. Abstract. Change to: 'variations that extend over decadal scales of time'. See later comment on use of decadal.

Page 2 Line 13. 'the correlation'

2.2 Line 21. First mention of H1 and H2 together. They were used separately in the introduction.

Line 7. Start 'For H1...'.on a different line to make it comparable to H2 below. There are no citations to back up the statements made in the H1 section.

Line 18. Decadal again. The transfer from one regime to another is evident at an annual level and not decadal.

Line 17. Should not be numbered 3 or indented.

Lines 25 to 30. This text should be part of a discussion and not here.

Line 33. At the end it is important to note that regime change is precipitated, but to a new level or a trend.

Line 31 to Page 7 line 4 repeated below.

Page 7 line 12. –H1 and –H2 mentioned for the first time. Define what they mean in general language.

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Page 7 line 13 onwards. Six tests are identified. It is not clear if the first two are the same as the two tests mentioned on page 9 lines 31-32. Please make this section clearer.

Page 8 line 19/20 "MYBT is considered reliable". Is this remark necessary without some backup? You could refer to page 13 line 2 in the Supplementary Information.

Page 9 line 2. Put in a heading Data and distinguish between the observed and modelled time series by putting them in different paragraphs. It would have been helpful to leave a line space between each paragraph.

Page 9 line 13 Again provide a new sub-heading

Page 9 line 32. Again, does the reference to Test 1 and 2 refer to the first two tests of the six mentioned earlier?

Page 11 below line 13 put in a heading: Shift/Trend Ratios

Page 12 lines 1 and 2. An important result. Missing full stop after warming.

"The more steplike character of both the oceans and the mid-latitudes is consistent with those areas being the loci of change in terms of decadal regimes and nonlinear equator-to-pole transport. This is inconsistent with the hypothesis of gradual warming".

Page 12 line 7. Suggest change to "Annual and seasonal anomalies were investigated". And edit next sentence so not starting with Annual.

Page 12 line 12. Why are quarterly anomalies only examined for the satellite temperatures? This needs explaining.

Page 12 line 23. Confirmation of the results from Reid et al. 2016 that the 1987 regime shift is evident at a global scale and yet on the next line it is said to be only evident at a regional scale.

Page 12 line 25 and 26. An important result.

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“When all four records are plotted on a common baseline of 1979–1998, the surface and satellite temperatures display similar shifts but different internal trends (Fig. 3)”.

Page 12 lines 333-34. An important observation.

“Unless substantially contaminated by artefacts, these changes do not reflect gradual warming in the atmosphere, but instead may reflect regime-like change controlled from the surface”. As is the subsequent comment on heat release from the ocean during El Niño. See commentary in Reid 2016 on this issue.

Page 13 line 5. Which timescale?

Page 13 line 14. Insert ‘out’ after carried.

Page 14 line 18 An important observation.

“indicates that the onset of the warming signal in these broader regions is abrupt (Jones, 2012)”.

Page 14 line 21 Use year (2016) of hard copy publication for Reid et al. (2015).

Page 14 line 23. An important observation. “that shifts may be more distinct at regional scales, integrating into a more trend-like global average”.

Page 14 lines 23-25. Sea level steps are said to be ubiquitous in local tide gauge time series, Table 3 in Jones et al. 2013, but were not checked or analysed by Jones et al.

Page 14 line

Page 16 lines 20-21. An important observation.

“A simple linear trend measured over the entire period has the same correlation with steps (0.93, $p < 0.01$) but averages 0.76 °C, so underestimates total warming by 0.18 °C”.

Page 17 line 4. Why are 5 year averages used here, the first mention that the data has been treated in this way.

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Page 18 lines 7-8 and 12-13. Important observations.

“that the magnitude of 20th century warming in the models has little predictive skill and is not a reliable guide to potential future risk”.

“This strongly indicates that 20th century warming may not be a good guide to future warming, if observations are being affected in a similar way”.

Page 18 lines 19-21. An important observation.

“step changes clearly carry the greatest signal with respect to ECS over time”.

Page 18 line 33. Label bullet A1 and at top of next page the bullet A2.

Page 19 lines 8-9. “peaking in the 2080s...” does not fit with the figure 5f. What should be Fig. 5f is a duplicate of Fig. 5d.

Page 20 line 16. Local changes. An important observation.

“significant increases in impact risks”. Is this statistically demonstrated. If not don’t use the word ‘statistically’.

Page 20 line 23. Is the first part of Section 5 essential to the paper? Would it be better to label it ‘Sensitivity testing’.

Page 20 line 25. Insert ‘and’ after ‘warming’?

Page 21. Line 30 change to: ‘performs the best’

Page 21 line 31-33. Duplication ‘into the’ and ‘test’. Change to: ‘at a global scale when each model is’

Page 22 line 30. ‘21st’

Page 24 line 9. Spelling ‘are’ not ‘area’

Page 24 line 18-19. Edit sentence beginning: ‘Warming is not...’

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Page 24 lines 24-25. Make sure this statement is backed up by appropriate citations in the results section

Page 24 lines 9-10 and 30-32 repetition. Is this necessary.

Page 25 lines 5 to 10. Delete 'In summary' and draft as the final paragraph of the conclusions.

Page 25 line 7 in situ in italics. And, 'or as a gradual'.

Page 25 lines 9-10. Edit to: 'where climate change and variability interact rather than varying independently.'

Page 25 line 13 Discussion. Include a discussion of how the results of Drijfhout et al. (2015) compare to those presented in this paper.

Drijfhout S, Bathiany S, Beaulieu C et al. (2015) Catalogue of abrupt shifts in Inter-governmental Panel on Climate Change climate models. Proceedings of the National Academy of Sciences, 112, E5777-E5786.

Page 25 line 15 change 'earlier' to 'before'?

Page 25 line 17. 'gradualism' and 'as a key tool to understand how'?

Page 25 line 23 'to explain climate'

Page 25 line 24. Change 'covering methods' to 'applying procedures'?

Page 25 line 25. Delete 'and its application to understanding climate processes'.

Page 26 line 5. 'analytical'.

Page 26 line 12 a priori Italics

Page 26 lines 13-14. Important observation that needs to be included in the conclusions. 'the processes involved are timescale invariant indicate that the meaning of seamless has not really been thought through'.

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Page 26 line 16. 'would likely be'. And change 'considerable' to 'sizeable' as repeated on the next line.

Page 26 line 17. Change 'under' to 'that have'.

Page 26 line 19. First sentence of bullet. Something is missing.

Page 26 line 20-21. 'physics, understood as being primarily linear and hydrometeorology with its substantial nonlinear behaviour; both remain largely unreconciled.

Page 27 line 9. 'stated'

Page 27 line 20. Somewhere in the text above it is worth stating that both Cahill and Foster consider that the hiatus was a non-event.

Page 27 line 26-7. Good point!

Page 28 lines 7-9. Delete: 'As we discussed in a related paper where H2 is examined in greater detail' and the reference to Jones and Ricketts, 2016 as this paper is only 'in preparation'. Edit the sentence without the above text except for H2.

Page 28 lines 11-18. An important paragraph. You might also cite Roemmich's recent papers and Reid 2016 to back up this paragraph.

Page 28 lines 19- 22 repeated below on lines 23-26.

Page 28 line 31, The word 'extraordinary' is perhaps a bit too strong.

Page 28 line 32. 'to either side'

Page 29 lines 1-2. Leave out the sentence: 'Elsewhere . . .', but, raise the possibility that we are undergoing another shift at present.

Page 29 lines 3-5. Poor ending to this section. Edit and improve as a statement to round off the discussion.

Page 29 line 13. See earlier comment on >50 year climate change.

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Page 29 line 17. Delete sentence beginning: 'We discuss this'

Page 46. Figure 4. I don't know what the journal policy is for sub-figures, but I prefer the lettering, a, b, c to be in the top left hand corner, inside the enclosing border of each sub-plot. It would also help if the respective sub-plots were labelled: England, Texas and Australia within the enclosing border. Insert at the beginning of the legend: 'Regional temperature change'.

Page 47. Same comment as for Figure 4. Label a, b, c, d, e, f in the top left corner of the subplots and in the top right in order: Add in sequence in the top right corner of a: 'observed', of b: simulated, of c: '2.6', of d: '4.5', of e: '6.0' and of f: '8.5'. In the legend add downward blue and upward red as for Figure 1.

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