

Anonymous Referee #3

In this article the authors study the relationship between atmospheric rivers and explosive cyclogenesis through the objective identification of both large-scale features. The topic is interesting and within the scope of the journal. However, there are several details in the study and the interpretations of results that require attention before I can fully recommend the article for publication in ESD. These details are listed below in the specific comments followed by a list of purely technical correction.

Thank you for your valued time dedicated to reviewing this paper. We believe that these modifications will improve the manuscript. Here you can find the response to your comments, questions, and suggestions.

Specific comments

P1L14: I'm not convinced by the assertion that the occurrence of atmospheric rivers are characteristic features of baroclinic atmospheres. Are there atmospheric rivers on Mars?

We agree with the reviewer that the use of the word "atmospheres" is misleading since we are referring to the Earth atmosphere. Therefore we change the change it to: "The explosive cyclogenesis of extra-tropical cyclones and the occurrence of atmospheric rivers are characteristic features of a baroclinic atmosphere,.....".

P3L16-24: These lines are taken verbatim from Dettinger et al. (2015). Please rephrase or use quotation marks to indicate that you are using the words already published by another author. (To the editor: I didn't actively look for pieces of text taken without appropriate attribution from other sources.)

We are aware that these words were taken verbatim from Dettinger et al. (2015), but we didn't realize that quotation marks were needed, as we provided a clear reference to the author at the beginning of the lines "Recently, some agreement has been achieved (Dettinger et al., 2015) regarding the relationships between ARs, warm conveyor belts (WCBs), and tropical moisture exports (TMEs). The term WCB refers.....". And in addition, we repeated the reference to Dettinger et al. (2015) at the end of the paragraph. We will re-phrase the text in the revised manuscript and we apologize for the misunderstanding. There are no other pieces of the text being taken without the appropriate attribution from other sources as proven by the iThenticate.com Similarity Report provided by the Journal.

On the other hand, I don't agree with the clarification on the terms warm conveyor belt (WCB), tropical moisture exports (TME) and ARs made by Dettinger et al. (2015). The main drawback in Dettinger et al.'s clarification is the lack of an explanation as how ARs are formed. In my opinion, they are the footprint of WCBs and possibly other frontal jets, which extract moisture from wetter regions (originally the tropics) to moisten drier regions. From this point of view ARs are a consequence of frontal dynamics. Dettinger et al. state that "[water] vapour is often transported to the WCB by an AR". However, a WCB is an air stream that develops as a consequence of the baroclinic development of a cyclone and frontal structure. Being an air stream, it's the WCB itself the entity that transports the moisture. The moisture would be present or absent depending on whether previous WCBs or other frontal jets transported it.

We fully acknowledge that there is no consensual definition on how atmospheric

rivers relate to WCBs, TMEs, etc, and also on the controversial discussion on how atmospheric rivers are formed. There are some recent works that try to prove the origin of the moisture sources of the ARs by means of Lagrangian analysis:

a) Sodemann and Stohl (2013) showed that in December 2006 several ARs reached from the subtropics to high latitudes, inducing precipitation over western Scandinavia. The sources and transport of water vapour in the North Atlantic storm track during that month were examined, and they reveal that the ARs were composed of a sequence of meridional excursions of water vapour. Different moisture sources were found: (1) in cyclone cores, the rapid turnover of water vapour by evaporation and condensation was identified, leading to a rapid assimilation of water from the underlying ocean surface; (2) in the regions of long-range transport, water vapour tracers from the southern edges of the midlatitudes and subtropics dominated over local contributions.

b) Ramos et al., 2014 showed moisture sources for the major ARs affecting western European coasts between 1979 and 2012 over the winter half-year (October to March). The major climatological areas for the anomalous moisture uptake extend along the subtropical North Atlantic, from the Florida Peninsula (northward of 20° N) to each sink region, with the nearest coast to each sink region always appearing as a local maximum. In addition, during AR events the Atlantic subtropical source is reinforced and displaced, with a slight northward movement of the sources found when the sink region is positioned at higher latitudes. In conclusion, the results confirm not only the anomalous advection of moisture linked to ARs from subtropical ocean areas but also the existence of a tropical source, together with mid latitude anomaly sources (associated with convergence of moisture along the fronts).

c) More recently, Jorge Eiras-Barca et al. 2017, analysed two extreme ARs events by using a 3D Tracer tool coupled to the WRF model. Results show that between 80% and 90% of the moisture advected by the ARs, as well as 70% to 80% of the associated precipitation have a tropical or subtropical origin. Local convergence transport is responsible for the remaining moisture and precipitation.

It may also be useful in this context to emphasise that a new definition of ARs was recently included in the AMS glossary (http://glossary.ametsoc.org/wiki/Atmospheric_river) which states that: ARs are “a long, narrow, and transient corridor of strong horizontal water vapour transport that is typically associated with a low-level jet stream ahead of the cold front of an extratropical cyclone. The water vapour in atmospheric rivers is supplied by tropical and/or extratropical moisture sources. Atmospheric rivers frequently lead to heavy precipitation where they are forced upward—for example, by mountains or by ascent in the warm conveyor belt. Horizontal water vapour transport in the midlatitudes occurs primarily in atmospheric rivers and is focused in the lower troposphere.”

Therefore it is appropriate to state that the authors are particularly active (in other works) in trying to understand the origin of the moisture and how it is transported by the ARs to the mid latitudes. Nevertheless we partially agree with the reviewer that the definition provided by Dettinger et al., 2015 can be slightly misleading and further

studies need to be undertaken in order to better understand the connection between the TME and how is advected by the ARs to the mid-latitudes. However from our point of view this discussion is out of the scope of the present manuscript.

In the particular paragraph mentioned by the reviewer based on Dettinger et al. (2015) we choose to delete it and rephrase it as follows:

“According to the AMS glossary ARs are: “A long, narrow, and transient corridor of strong horizontal water vapour transport that is typically associated with a low-level jet stream ahead of the cold front of an extratropical cyclone”. The definition also affirms that the water vapour in ARs is supplied by sourced of both tropical and/or extratropical origin (e.g. Ramos et al.2016a; Eiras et al., 2017) and that ARs can lead to heavy precipitation whenever these systems are forced upward— either by mountains or by ascent in the warm conveyor belt. Horizontal water vapour transport in the midlatitudes occurs primarily in atmospheric rivers and is focused in the lower troposphere.”

Regarding TMEs, Knippertz and Wernli (2010, doi:10.1175/2009JCLI3333.1) explicitly included what was called AR in the set of TMEs. Therefore, all ARs are TMEs. The authors of the present paper seem to subscribe to this view at times: For instance, in P4L7-10, they seem to use the terms AR and TME as synonyms.

The authors do not agree that the term ARs and TME are synonyms. It was our mistake to include TME on that particular sentence therefore we have replaced TME by ARs in this sentence.

From our understanding of the study from Knippertz and Wernli, 2010 you can have TME but not necessarily the formation of ARs.

All this is not to say that the authors should not be studying ARs. They provide a good definition of ARs (P3L11-13, however see also the comment to P7L20). However, if the authors are willing to enter the debate, this is a good opportunity to provide a better clarification of terms.

Please see the previous comments. We agree with reviewer that the exact mechanism leading to how the ARs are formed is still an open topic for some authors however this debate is out of the scope of the present manuscript.

P5L16-17: Whether a trigger happens just prior to its effect or long before it is not something that can be guaranteed. Please rephrase.

We agree with the reviewer that the sentence was misleading, therefore the sentence was re-written.

P7L20: I'm not convinced there is a region with high IVT values extending from the Caribbean to the British Isles. This is precisely where the confusion in the interpretation of ARs arise as it is not IVT, but IWV what extends between these two locations in Fig.1. Even the two AR-detection methods show that strong IVT is confined in its most southern and western extreme to 30° – 35°N and about 30°W, whereas the Caribbean is a long way from this (around 20°N, 60°W). Please, rewrite this description.

In this particular example the reviewer is right that the IVT does not extend back till the Caribbean region due to the presence of a high pressure system that was located East of Florida. That high pressure location hampered the supply of water vapour to the ARs

(since the IVT is southwards). Therefore the text was changed accordingly to the following:

“The overall IWV pattern is clearly compatible with the presence of an AR-like structure located in the North Atlantic Ocean, showing an extensive region with high IWV values extending from the Caribbean to the British Isles (Fig. 2a). In this case, the IVT preferred direction along the high IWV region is directed from SW to NW between the sub-tropic and the cyclone center. However it seems that for these particular time steps the supply of water vapor from the tropics is cut off by the presence of high pressure system located East of Florida that make the IVT direction from the sub-tropics to the tropics.”

We would like to show an example where we have an ARs clearly visible in the IVT field (values above 400kg/m/s), and thus the water vapour transport from the tropics is documented. This AR struck directly over the Iberian Peninsula for several time steps. Still, ARs do not need to be directly connected from the tropics to the mid-latitudes.

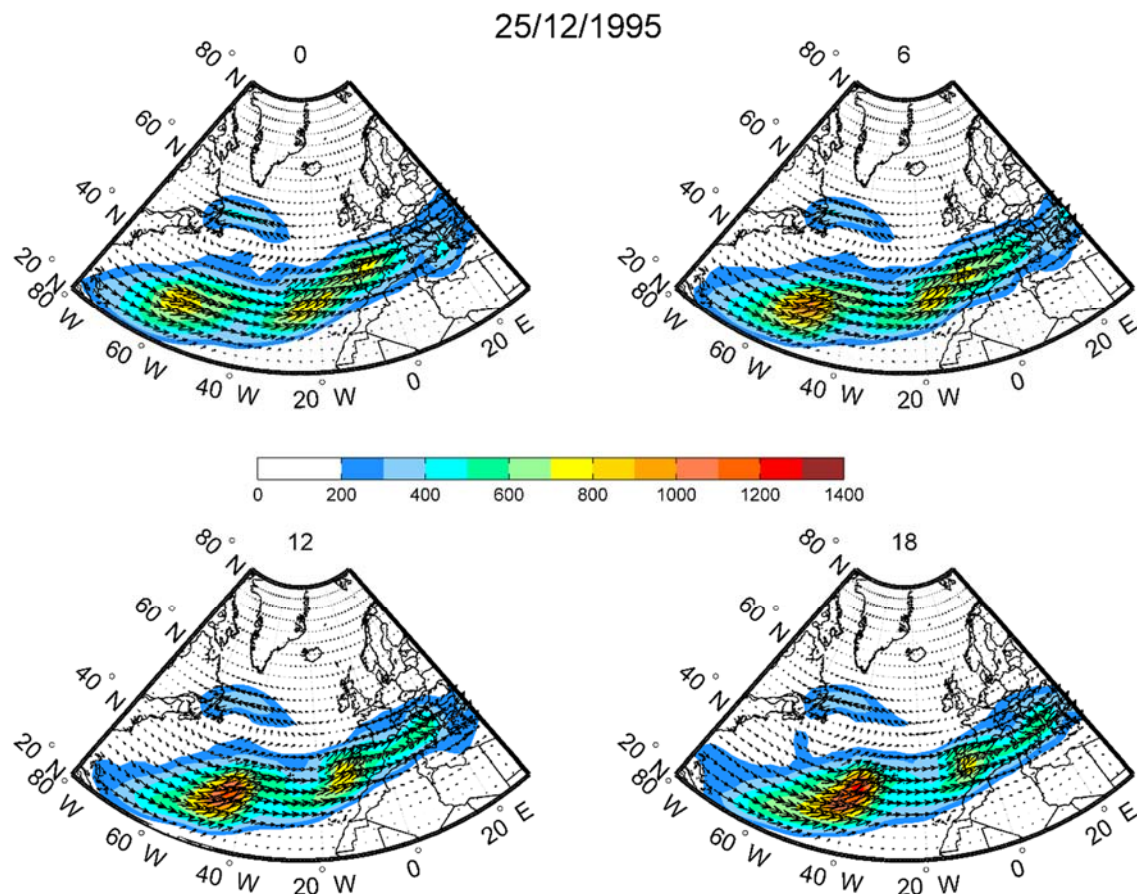
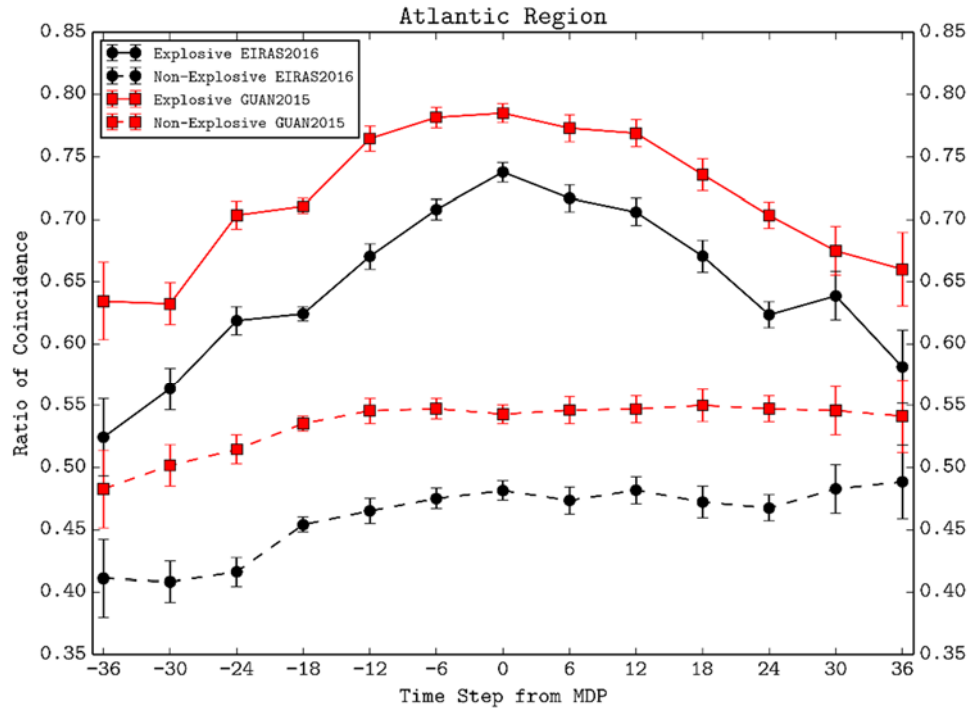
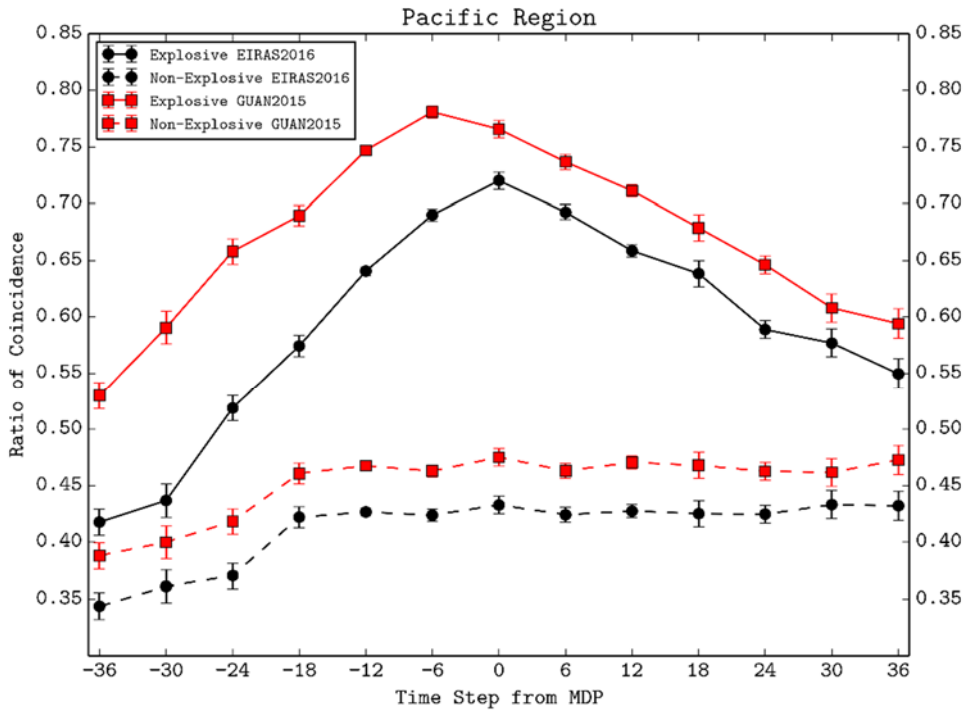


Figure R1. IVT direction (vectors) and intensity (kg/m/s; colour shading) fields at (a) 0000, (b) 0600, (c) 1200, and (d) 1800 UTC 25 December 1995.

P9L5-9: Is there really an increase? There is an increase between -36 h and -24 h but after that the lines are essentially flat. The lines in Fig. 3 must include error bars. This might reveal whether the increase is within the error or not. Also, please elaborate on the relationship of this increase and the frontal moisture convergence as it's not clear. We agree with the reviewer that Fig. 3 should display also the uncertainty range for each time step. Therefore we will include the *variance* as an error bar for each MDP time step. The new version of the Figure 3 is shown below:



(a)



(b)

P9L11: What is a quasi-linear relationship? Even if it was a line, I don't see how it helps in the interpretation of results. This term also appears in P11L1.

We agree with the reviewer that the use of the term quasi-linear relationship is not very clear. Therefore, in the new revised section 3 the text was changed to "While a clear peak is identified close to the MDP for EC, for NEC a stable relationship with the ARs is identified in both methodologies with almost no changes of the ratio of coincidence when analysing the different 6h time frames."

In the conclusion section it was changed to "While a clear peak is found for EC, a stable relationship is identified for NEC"

P9L20-26: This part of the study produced the expected results, which is good, but it can go beyond that. What the composites are showing are the 80

We believe that this comment by the reviewer was somehow cut in half. In the pdf of the revision (shown below) the sentence stops abruptly in "...are showing are the 80". Can the reviewer clarify it?

P9L20-26: This part of the study produced the expected results, which is good, but it can go beyond that. What the composites are showing are the 80

P10L17: I don't see how your description goes beyond a statistical relationship. This is also stated in P11L16. However, to truly remove the statistical character the evolution of whole ARs would need to be studied too so that changes in cyclones can be related to changes in ARs.

We agree with the reviewer this would be a very nice idea, but it is in our opinion out of scope for the present study. We aim to do additional analysis along this direction in a follow-up study, namely by using a high resolution RCM to model the effect of introducing (or removing) an AR in the evolution of different EC and NEC events.

Technical comments

P2L18: Delete 'that'.

The word has been deleted.

P2L21: Delete 'the most'. Or how are you measuring the quality of being maritime?

The words have been deleted.

P4L8: Delete 'the' in front of Ferreira et al.

We have deleted it according to the reviewer suggestion.

P5L7: Use period instead of colon in $0 : 75^\circ \times 0 : 75^\circ$.

The typo was corrected.

P5L9: It says '...lasting more than 24 hours'. Should it be less, i.e. '... lasting less than. . .'?

The text was corrected according to the reviewer suggestion.

P5L13: I don't understand what the authors meant by 'attained'.

We agree with the reviewer that "attained" was not the best choice of word. We have replace it by "was computed".

P5L14: Use 'rather than' instead of 'over'.
We have changed the text accordingly.

P5L26: 'For' should not start with capital.
The entire sentence was re-written in order to become clear. The new version is as follows: "Two wide domains over both ocean basins have been selected: for the Atlantic domains latitudes between 25°N and 65°N and longitudes between 80°W and 10°E are considered, while for the Pacific domain considered longitudes span between 120°E and 105°W."

P5L27-P6L2: There is no need to give approximate figures. Give the actual percentages.
The text was re-written for clarity.

P6L7: Change 'Whereas' for 'While' and delete 'has'.
The text was changed according to the reviewer's suggestion.

P6L12: Delete the second 'be'.
The "be" was deleted from the text.

P6L15: Delete 'For' and start the sentence with 'Methods'.
We have changed the text accordingly.

P6L16: Delete ', they'
The word was deleted.

P6L17: '... combination of IWV and IVT estimated reanalysis datasets' is not clear. Please rewrite.
The sentence has been re-written for clarity.

P6L23: Change 'cf.' to 'see'. Cf. indicates comparison, which is not the case here.
We have replaced the "cf" to "see".

P7L1-2: Plural of radius is radii
We have changed the text accordingly.

P7L4: Delete 'et al.'
The "et al." was deleted from the text.

P7L4-5: Are Guan and Waliser (2015) also studying ERA-Interim to produce their dataset?
Indeed, Guan and Waliser (2015) also used ERA-Interim in their algorithm. This information has been included in the text.

P7L7: Should it say 'world' rather than 'word'?
The typo was corrected.

P8L24: I'm not sure what 'temporal association' means. Change to 'temporal coincidence'.

We have changed the word according to the reviewer's suggestion.

P9L1: The verb 'reduce' implies that it was once high and now it's low. Perhaps change to 'smaller'.

We have changed the text accordingly.

P9L27-28: What is a 36h wind-frame?

We have replaced "wind-frame" to "time-frame".

P10L15: Delete 'of this'.

We have delete it according to the reviewer's suggestion.

P10L25: Delete 'reduced to'.

We have delete it according to the reviewer's suggestion.

P11L7: Should it say '-36 hours' rather than '-30 hours'?

The typo was corrected.

P11L8: Change 'Afterword's' to 'Afterwards'.

We have changed the text accordingly.