Dear Editor Prof. Ying Fan and Reviewers,

Thank you very much for your comments on our manuscript entitled “The role of the Amazon Basin moisture in the atmospheric branch of the hydrological cycle: A Lagrangian analysis” (hess-2013-613). We have studied your comments carefully and made corresponding changes in the revision, and replied as follows. Revised portion are marked in blue in the following responses.

Following the Reviewers’ suggestions, the principal modifications in the manuscript were:

- Expansion of the background discussion with the inclusion of bibliographical references.
- Two new sections were incorporated in the “Results” to investigate possible changes in the role of the Amazon basin during flood and drought years (section 3.2), as well as during extreme Atlantic Meridional Mode years (section 3.4)
- Inclusion of the vertically integrated moisture fluxes fields to help the understanding of the lagrangian analysis

Moreover, there are language changes in the revision for better expression. These changes will not influence the content and framework of the paper. We did not list these changes below.

Best regards,
Anita Drumond and Co-Authors

REVIEWER 1

Specific comments

1024-L17 Precipitation is a flux and should be presented as indicated in the manuscript preparation guide "manuscript preparation" under the heading "Physical dimensions and units"

- Thank you. We corrected it in the text:

"The precipitation is approximately 2,300 mm/year"

1024-L21 "of anthropogenic origin" can be removed as this is quite obvious with deforestation.

- We agree with the reviewer that the information is redundant, and have removed the expression "of anthropogenic origin" from the sentence.

1025-L5-7 The Eulerian methodologies mentioned here seem to be studies that analyse wind fields without performing any type of tracking of moisture or any moisture recycling calculation. If their main conclusion is just that Amazonian moisture comes with trades winds from the Atlantic (as indicated by L8-9) it seems quite exaggerated to refer to 7 studies. Besides these studies, it would make sense to report on the findings of early studies on the Amazon that made use of an analytical framework (e.g., Brubaker et al., 1993; Eltahir and Bras, 1994; Burde et al., 2006). More recent numerical Eulerian methodologies and their results are relevant to mention as well (e.g., Yoshimura et al., 2004; van der Ent et al., 2010; Goessling and Reick, 2011; Keys et al., 2012).

and

1025-L20 Some other relevant literature is still missing. No reference is giving to studies that link moisture sources of the Amazon to the isotopic composition of rainfall and atmospheric moisture (Salati et al., 1979; Gat and Matsui, 1991; Risi et al., 2013). Moreover, the paper of Dirmeyer et al. (2009) published alongside the paper itself an extensive database of moisture sources and their variability for each nation and basin (http://www.iges.org/wcr/), which seems relevant to cite.

- We agree that relevant literature was missing in the original version of the manuscript. We incorporated these in the revised version of the introduction and throughout the manuscript.

  Please, see the text added in the Introduction:

“The role of Amazonian forest in the hydrological cycle of the region has received a fair amount of attention in recent decades. The ratio of the amount of precipitation that comes from a local region through evaporation to how much comes from advection into the region is known as the “recycling” ratio, and has been the subject of study since the mid-1970’s (see Molion [1975] and Salati et al [1987] and the references therein). This ratio varies substantially, assuming a generally lower value in winter and a generally higher value in summer, when large-scale transport diminishes in importance. Precipitation recycling is the contribution of evaporation from within a region to precipitation in that same region. The recycling rate is a diagnostic measure of the potential interaction between land surface hydrology and regional climate. The recycling of local evaporation and precipitation by the forest accounts for a sizable portion of the regional water budget, and because large areas of the basin are sensitive to the effects of deforestation there are grave concerns about how such disruptions to the land surface may affect the hydrological cycle in the tropics. Eltahir and Bras (1994), Brubaker et al., (1993), Costa and Foley (1999), Trenberth (1999), Nobrega et al (2005), Marengo et al (2006), Silva (2009), Van der Ent et al. (2010), and Satyamurty et al (2013), among others have estimated an annual mean recycling rate of about 20% to 35%, less than the previous estimates made by Molion. Dirmeyer et al (2009) combines the characteristics of persistence of soil moisture anomalies, strong soil moisture regulation of evaporation rates, and reinforcement of water cycle anomalies through recycling, and they demonstrated that there are signs of land–atmosphere feedback throughout most of the year in the Amazon region. More recently, in their study of the role of land surface processes and land use changes in regional circulation, Angelini et al. (2011) found that rain in Amazonia comes primarily from large-scale weather systems from the tropical Atlantic that do not rely on local evaporation. Previous studies by Gat and Matsui (2012) and references quoted in investigate the

> moisture recycling in the Amazon region using the isotopic composition of precipitation over the region. Their results suggest that an isotopically fractionated evapotranspiration flux contributes to the atmospheric water balance over the region, and they show that 20–40% of the total evapotranspiration flux is accompanied by an isotopic fractionation, such as by evaporation from an open water surface."

…

"Bosilovich et al (2006) suggested that evaporation from the Amazon River basin exhibits slight interannual variations, and in turn the interannual variation of precipitation recycling is therefore related to atmospheric moisture transport from the tropical South Atlantic Ocean."

…

"More recently, Makarieva et al. (2013) suggested that the water vapour delivered to the atmosphere via evaporation from forests represents a store of potential energy available to accelerate air and drive winds. This implies that changes in precipitation over Amazonia are due to a combination of different regional processes and interactions that are partly influenced by large-scale circulation and partly influenced by local water sources from forests and soil moisture."

- Angelini, I. M., and Coauthors, 2011: On the coupling between vegetation and the atmosphere. Theor. Appl. Climatol., 105, 243–261, doi:10.1007/s00704-010-0377-5.
- BRUBAKER, K.L.; ENTEKHABI, D.; EAGLESON, P.S.: Estimation of continental precipitation recycling, J. Climate, v.6, p. 1077-1089, 1993.
- ELTAHIR, E. A. B.; BRAS, R. L.: Precipitation recycling in the Amazon Basin. Quart. J. Roy. Met. Soc. v. 120, p. 861-880, 1994.
- Gat, J. R., Matsui, E.: Atmospheric water balance in the Amazon basin: An isotopic evapotranspiration model, J. Geophys. Res., 96(D7), 13179–13188, doi:10.1029/91JD00054, 1991.
- Makarieva, A. M., V. G. Gorshkov, D. Sheil, A. D. Nobre, and B. L. Li, 2013: Where do

winds come from? A new theory on how water vapor condensation influences atmospheric pressure and dynamics. Atmos. Chem. Phys., 13, 1039–1056, doi:10.5194/acp-13-1039-2013.

- Marengo, J.A.: ON THE HYDROLOGICAL CYCLE OF THE AMAZON BASIN: A HISTORICAL REVIEW AND CURRENT STATE-OF-THE-ART, Revista Brasileira de Meteorologia, v.21, n.3, 1-19, 2006

- MOLION, L. C. B.: A climatonomic study of the energy and moisture fluxes of the Amazon basin with considerations of deforestation effects. Ph. D. thesis. University of Wisconsin, Madison, 1975.

- NÓBREGA, R.S.; CAVALCANTI, E.P.; SOUZA, E.P. Reciclagem de vapor d'água sobre a América do Sul utilizando reanálises do NCEP-NCAR. Revista Brasileira de Meteorologia, v.20, n.2, p.253- 262, 2005.

- SALATI, E.: The Forest and the Hydrological Cycle, J. H. Gash, C. A. Nobre, J. M. Roberts, and R. L. Victoria, editors. Amazonian deforestation and climate. John Wiley and Sons, Chichester, UK, p. 273-296, 1987.

- SILVA, A.E. Variabilidade da Circulação e Transporte de Umidade no Regime de Monção da América do Sul. 2009. 137f. Tese (Doutorado) – Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Universidade de São Paulo, São Paulo, 2009.

- TRENBERTH, K.E. Atmospheric Moisture Recycling: Role of Advection and Local Evaporation. J Climate, v.12, n.5, p.1368-1381, 1999.

1026-13 I am not really seeing this contrast so much. When talking about Lagrangian and Eulerian numerical moisture tracking, both can yield similar results (see van der Ent et al., 2013)

- Thank you for your commentary. We eliminate the sentence

"and believing that a Lagrangian approach may complement the Eulerian analysis of moisture transport due to the tracking of air parcels and consequent links between evaporation and precipitation regions," from the manuscript and we included a paragraph introducing the different methodologies in the section 2. Please, see the text added below:

"A detailed intercomparison of the different methods used to establish source-sink relationships for atmospheric water vapor is given by Gimeno et al. (2012). There are different methods, namely ''analytical and box models'', ''physical water vapor tracers'' (isotopes), and "numerical water vapor tracers" (including the Lagrangian and Eulerian approaches). All of them provide useful and interesting information that aids the analysis and the results are subject to assumptions made and to the type and accuracy of the data used. The ''box models'' allow the identification of the moisture inflow and outflow given defined lateral boundaries, but they give no information about the physical processes that occur within the box itself. The use of isotopes depends on the sensitivity of the isotopic signal. The Eulerian methodology is widely used due its simplicity but it is not simple to extract the link between the precipitation over a region and the moisture source using this method. The Lagrangian approach provides realistic traces of air parcels, enabling the trajectories to be followed and source-receptor relationships to be established. In that way, the most recently developed Lagrangian techniques are being extensively applied for evaluating the origin of the water that precipitates over a continental area (e.g., Stohl and James, 2005; Dirmeyer and Brubaker, 2007; Gimeno et al., 2013; Knippertz et al., 2013)."

- Dirmeyer, P. A., and Brubaker, K. L.: Characterization of the global hydrologic cycle from a back-trajectory analysis of atmospheric water vapor, J. Hydrometeorol., 8(1), 20–37, 2007.

- Knippertz, P., Wernli, H., Glaser, G.: A global climatology of tropical moisture, J. Clim., 26, 3031–3045, doi:10.1175/JCLI-D-12–00401.1, 2013.

1026-25 What is an inedited way?

- We apologize for the incorrect use of English. We mean “novel way”. This has been corrected in the text.

1027-25-27 I find the average residence time of an atmospheric particle a rather weak argument to track the particle only for 10 days, as average indicates that it can also be much longer!

- Thank you for your commentaries. We agree with the Reviewer that the residence time can be different from 10 days, and we think that the period would be shorter in tropical rainy regions. If the backward tracking is extended much longer than 10 days, we believe that there is the possibility of finding “spurious” moisture sources in the air particle trajectories that would contribute to precipitation in other areas before they reach the target region. We therefore prefer to standardise all our studies of moisture transport through FLEXPART considering the same residence time as that adopted in the seminal works of Stohl and James (2004, 2005). Also, in a similar work, Stohl and James (2005) studied the moisture transport between different ocean basins and river catchments throughout the world using 10-day trajectories. We have clarified this in the revised manuscript. Please, see the text added below:

“Following the seminal works of Stohl and James (2004, 2005) and the subsequent studies based on the same lagrangian methodology (e.g., Nieto et al., 2008, Drumond et al., 2008, Gimeno et al., 2013), we limited the transport time to 10 days. While the 10-day period of tracking is somewhat arbitrary, it is about the average residence time of water vapour in the atmosphere (Numaguti, 1999). ”

1028-24 More information on the ONI is needed. Is this based on sea surface temperatures, pressures, exactly which area, and how do yielded El Niño and La Niña years compare to other standards (e.g., Trenberth, 1997)?

- We rewrote the paragraph in order to provide more information about ONI. Please see the new version below:

“The events were obtained from the NOAA/CPC Oceanic Niño Index (ONI) (www.cpc.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml). The index values were calculated as the 3-month running mean of ERSST.v3b SST anomalies (Smith et al. 2008) in the Niño 3.4 region (5ºN – 5ºS, 120ºW – 170ºW) referred to by Trenberth (1997), and the ONI is based on the 1981-2010 climatology. According to CPC, extreme ENSO episodes occur when the threshold of +/- 0.5ºC for the ONI is exceeded on a minimum of five consecutive overlapping seasons. Therefore, in order to select a whole year as El Niño or La Niña, we considered those years when the threshold was exceeded a minimum of five times consecutively from June in year 0 to May in year 1 (for a given ENSO cycle).”

- Smith, T.M., Reynolds, R.W., Peterson, T.C., Lawrimore, J.: Improvements to NOAA's Historical Merged Land-Ocean Surface Temperature Analysis (1880-2006), Journal of Climate,21, 2283-2296, 2008.
- Trenberth, K. E.: The Definition of El Niño, Bulletin of the American Meteorological Society, 78(12), 2771-2777, 1997.

1029-12 What is the average E - P over the Amazon? This is important while interpreting the results.
“Figure 1 shows the monthly averages of 10 day (E−P) backward trajectories from Amazon Basin along 33 yr period (June 1979–May 2012).”
We apologize for the improper use of English. We mean the monthly values of the 10-day integrated atmospheric moisture budget (E−P) obtained from backward trajectories in the Amazon Basin. This has been corrected in the text.

“Figure 1 shows the monthly values of 10-day integrated atmospheric moisture budget (*E-P*) obtained via backward trajectories from the Amazon Basin for the 33-year period June 1979– May 2012”

Figure 1: These type of figures seem quite standard for publications using FLEXPART, however I think that they are not self-explanatory and need more explanation in the

caption. My main concern is how to interpret the numbers of E - P . Is the area weighted sum over the entire figure always zero? It also seems that interpretation depends very much on the chosen scale, this is the case because it does not become clear how much of Amazon's moisture all red areas together contribute. And what kind of physical meaning do the blue values over the Pacific have?

- We totally agree that the interpretation of the *(E-P)* figures may be the cause of some misunderstanding. Following the Reviewer's suggestion, we included some explanation of how to interpret Figure 1 both in the text and in the captions. In response, the (*E-P*) values represent the net atmospheric moisture budget for each grid point considering only the air particles located within the respective vertical column travelling towards the target area. The area weighted sum over the entire figure is therefore not necessarily zero. The scale is adjusted in order to provide evidence of the regions of maximum (*E-P*) absolute values and to show the preferred regions of gain or loss of moisture of the tracked air particles. It is important to clarify that our methodology does not guarantee that the moisture gained by an air particle when crossing a source reaches the target region. It depends on the interaction with all particles present in the atmospheric column along its trajectory to the Amazon. In addition, the water may precipitate if the air particle crosses a sink region before reaching the target. For us, a sink region occurs where the (*E-P*) values are negative (blueish colours in the figure), i.e., where the atmospheric moisture budget of the tracked particles is characterised by a loss of moisture. Therefore, summing up all positive (*E-P*) values will not necessarily indicate the remote moisture contribution for the Amazonian moisture budget. This explanation was also included in the methodology section of the revised manuscript.

- Please, see the modifications included in the revised manuscript below (2.Data and Methods):

In the text:

… "a forward analysis may identify all trajectories crossing the basin, and if we follow them we will find where they lose moisture. In this case, the (E-P < 0) values indicate the most important sinks of moisture, i.e., where the atmospheric moisture budget of the tracked air particles is characterised by a loss of moisture. All figures show E-P integrated over the whole tracking period (10 days) at the monthly scale, allowing us to study the annual cycle. It is important to clarify that the applied methodology does not guarantee that the moisture gained by an air particle when crossing a source will reach the target region. This depends on the interaction with all air particles present in the atmospheric column. In addition, the water may precipitate if the air particle crosses a sink region before reaching the target." …

…

"Figure 1 shows the monthly values of 10-day integrated atmospheric moisture budget (*E-P*) obtained via backward trajectories from the Amazon Basin for the 33-year period June 1979– May 2012. The backward experiment allows us to identify where the tracked particles gain humidity along their trajectories towards the target area. The areas characterised by reddish colours represent regions where (*E-P*) > 0, meaning that evaporation exceeds precipitation in the net moisture budget considering only those air particles located within that vertical column and travelling towards the target area, and these regions act as moisture sources for the tracked particles. In the opposite sense, the blueish colours represent areas where (*E-P*) < 0, which are those regions where precipitation exceeds evaporation in the net moisture budget of the tracked air particles (moisture sinks)."

New caption Figure 1: (left-hand column) Climatological monthly 10-day integrated (E-P) values observed for the period June 1979 – May 2012, for all the particles bound for the Amazon basin, determined from backward tracking. Reddish (blueish) colours represent regions acting as moisture sources (sinks) for the tracked particles. Black contour line indicates the basin area.

1029-17-19 incomprehensible sentence

"The figure suggests that part of the oceanic region increase its moisture contribution during the corresponding hemisphere's winter."

- We agree that the sentence was not clear. We have rewritten it as:

"It seems that there is an increase in the moisture contribution from the Northern or Southern TA during the respective winter associated with the intensification of the hemispheric trade winds."

1029-10-12 If you look at Fig. 5 in the paper by van der Ent and Savenije (2013), you will see that they got exactly the same results, which should clearly be mentioned.

And

1029-14 Besides the study by (Bosilovich and Chern, 2006), other studies seem relevant here as well (Dirmeyer et al., 2009; Spracklen et al., 2012; van der Ent and Savenije, 2013)

- We thank the Reviewer for providing these references. The work of Van der Ent and Savenije (2013) is now mentioned in the revised text.

Revised text:

"The negative (E-P) values characterising the NA from June to September suggest that this region does not act as a moisture source for the Amazon basin during these months. In our methodology, this means that precipitation prevails over evaporation in the atmospheric moisture budget integrated over NA during this period. This may be the case because the positioning of the VIMF convergence associated with the Atlantic ITCZ in these months (Figure 1, right-hand column) coincides with the NA box. On the other hand, the contribution of the SA (traced black line) occurs all year and reaches its maximum during the austral winter, when the VIMF divergence over the South Atlantic is greater and expands into the tropical continent, enhancing the moisture flux towards the Amazon (Figure 1, right-hand column). Our results compare well with those of Bosilovich and Chern (2006) and of Van der Ent and Savenije (2013). Bosilovich and Chern (2006) made use of a 50-year atmospheric general circulation model simulation including water vapour tracers to investigate the water budget for the Amazon River and its respective sources of water. These authors also noted the importance of the South Atlantic ocean in providing moisture to the Amazon Basin throughout the year, except during the austral summer when the contribution of the tropical North Atlantic dominates. Using a different methodology from that applied in the present study to identify the oceanic sources based on an atmospheric backtracking analysis of continental precipitation, Van der Ent and Savenije (2013) also verified not only the importance of the TA in providing moisture to South American precipitation, but also a similar variability of the contributions from the northern and southern TA throughout the year."

- Bosilovich, M.G., Chern, J.-D.: Simulation of water sources and precipitation recycling for the MacKenzie, Mississippi, and Amazon river basins, J. Hydrometeor., 7, 312-329, 2006
- Van der Ent, R. J., Savenije, H. H. G.: Oceanic sources of continental precipitation and the correlation with sea surface temperature, Water Resour. Res., 49 (7), 3993-4004, doi:10.1002/wrcr.20296, 2013.

- Concerning the works of Dirmeyer et al (2009) and Spracklen et al. (2012), we think it would be more appropriated to cite these in the discussion of the results about the transport from the Amazon towards the La Plata basin. If the Reviewer agrees, these references will be included in the review of lines 1030-23-26.

1030-23-26 Incomprehensible sentence. Besides that the authors overlook again some relevant moisture tracking studies (Dirmeyer et al., 2009; van der Ent et al., 2010; Keys et al., 2012; Spracklen et al., 2012; Bagley et al., 2014).
"Agreeing with previous results obtained through different methodologies (e.g. Roads et al., 2002; Marengo, 2005; Drumond et al., 2008; Arraut and Satyamurty, 2009), contribution from the basin occurs toward southeastern South America (including La Plata Basin, hereafter LP) predominantly.
Thank you. Please, see the revised text including the bibliography suggested by the Reviewer:

“in view of previous results obtained using different methodologies (e.g., Roads et al. 2002; Marengo, 2005, 2006; Drumond et al., 2008; Arraut and Satyamurty, 2009; Dirmeyer et al., 2009; Van der Ent et al., 2010; Keys et al., 2012; Spracklen et al. 2012; Bagley et al., 2014), the contribution from the basin predominantly extends towards southeastern South America (including the La Plata Basin, hereafter LP).”

- Bagley, J.E., Desai, A.R., Harding, K.J., Snyder, P.K., Foley, J.A.: Drought and deforestation: Has land cover change influenced recent precipitation extremes in the Amazon?, J. Climate, 27, 345-361, DOI: 10.1175/JCLI-D-12-00369.1, 2014.

- Dirmeyer, P. A, Schlosser, C. A., Brubaker, K. L.: Precipitation, Recycling, and Land Memory: An Integrated Analysis, J. Hydrometeor., 10, 278-288, DOI:10.1175/2008JHM1016.1, 2009.

- Keys, P.W., van der Ent, R.J., Gordon, L.J., Hoff, H., Nikoli, R., Savenije, H.H.G.: Analyzing precipitationsheds to understand the vulnerability of rainfall dependent regions, Biogeosciences, 9, 733-746, DOI: 10.5194/bg-9-733-2012, 2012.

- Spracklen, D.V., Arnold, S.R., Taylor, C.M.: Observations of increased tropical rainfall preceded by air passage over forests, Nature, doi: 10.1038/nature11390, 2012.

- van der Ent, R. J., Savenije, H. H. G. , Schaefli, B. , Steele-Dunne, S. C.: Origin and fate of atmospheric moisture over continents, Water Resour. Res., 46, W09525, doi:10.1029/2010WR009127, 2010.

1031-13 What is exactly meant here? The contour line of -0.4 mm day-1 corresponds to how much of the Amazon’s moisture?

“The LP box (67–50_ W; 20–34_ S) was defined over southeastern South America based on the contour line of −0.4mmday−1 observed in the annual average of 10 day (E −P) forward trajectories from Amazon Basin along 33 yr period (Fig. 4a).”

- In the map of the 33-yr annual average of the 10-day integrated (E −P) values obtained via forward analysis (figure 4a), the contour of -0.4 mm day^{-1} corresponds to the 95% percentile of all negative values observed. In the backward experiment, 0.4 mm day^{-1} represents the 96% percentile of all positive values obtained in the 33-year annual average of the 10-day integrated (E −P) (Fig. 2a). This information is included in the new version of the manuscript.

We apologise for our inappropriate use of English. Please see the corrected sentence:
"The limits of the LP box (67–50_ W; 20–34_ S) were defined according to the contour line of −0.4 mm day^{-1} configured in the 33-year annual average of the 10-day integrated (E −P) values of the forward trajectories from the Amazon Basin (Fig. 4a). In Figure 4a, -0.4 mm day^{-1} corresponds to the 95% percentile of all the negative values obtained."

We have also included this explanation in the revised version:
"The technique of percentiles was applied to the annual averages of (E-P) for both the backward and the forward experiments (Figures 2a and 4a, respectively), in order to determine the boundaries of the areas of interest. Although the definition of the threshold was arbitrary, we believe that this statistical procedure is valid for identifying the regions of maximum absolute (E-P) values. To provide a standardised analysis, we chose the contour line of 0.4 mm/day, which corresponds to the 96% percentile of all positive values shown in Figure 2a, as well as to the 95% percentile of all negative values configured in the (E-P) annual average from the forward experiment (Figure 4a), which we discuss later."

1031-22 I completely disagree with this so-called unknown variability. According to me it is simple the ITCZ that is migrating and causes different wind patterns.
"Figure 4b shows maxima contributions during June (a secondary maximum), October and January, and minima in August, December (a secondary minimum) and March. The causes of this quite seasonal variability are unknown and deserve further attention in a future work."

- Again, we apologise for possible misunderstandings due to an inappropriate use of English. Figure 4b suggests a higher frequency of variability (presenting a near-seasonal signal) of the moisture contribution superimposed on an annual cycle with maxima during the extended austral summer and minima in the extended winter. Agreeing with the reviewer, the migration of the ITCZ and its association with the development of the South American Monsoon System may explain the annual cycle. According to previous work, the Atlantic Inter Tropical Convergence Zone (AITCZ) (e.g. Moura and Shukla, 1981; Folland et al., 1986) presents a seasonal latitudinal migration coupled with the annual cycle of the spatial distribution of the maximum sea surface temperature (SST) observed over the Tropical Atlantic (TA), reaching its maximum northward (southward) displacement during austral spring (autumn). However, we are not able to explain the near-seasonal variability of the Amazonian contribution of the LP through the ITCZ migration; its causes remain unclear to us. The sentence has been rewritten in order to include this discussion, as follows:

"Figure 4b suggests a higher-frequency variability of the moisture contribution (presenting something like a seasonal cycle) superimposed on an annual cycle with maximum values during the austral spring/summer and minima during autumn/winter. It shows maximum contributions during June (a secondary maximum), October and January, and minima in August, December (a secondary minimum) and March. The migration of the ITCZ associated with the development of the SAMS may explain the annual cycle of the moisture contribution from the Amazon for LP. According to previous studies (e.g., Moura and Shukla, 1981; Folland et al., 1986), the Atlantic ITCZ presents a seasonal latitudinal migration coupled with the annual cycle of the spatial distribution of the maximum SST observed over the TA, and it reaches its maximum northward (southward) displacement during austral spring (autumn). However, the causes of this near-seasonal variability remain unclear and merit further attention."

- Folland, C, Palmer, D Parker, 1986: Sahel rainfall and worldwide surface temperatures: 1901-1985. Nature, 320, 602-606.

- Moura, AD, J Shukla, 1981: On the dynamics of droughts in northeast Brazil: observations, theory and numerical experiments with a general circulation model. JAS, 38, 2653-2675.

Moreover, van der Ent and Savenije (2013) did relevant ENSO analysis as well which should be referred to in Section 3.2.

Thank you. The main findings of van der Ent and Savenije (2013) concerning the importance of ENSO and South Atlantic SST in modulating the interannual variability are now compared with our own results in two new sections, "3.3 Role of ENSO in the moisture transport over the Amazon basin" and "3.4 Role of the AMM in the moisture transport over the Amazon basin". Also, some additional discussion between the relationship of ENSO and AMM was included in the new version of the paper based on the work of Souza et al (2005).

In Section 3.3 (ENSO):

"The known importance of the ENSO in modulating South American precipitation (e.g., Chavasse and Seoane, 2009) through its associated changes in atmospheric circulation (Rahmstorf, 2002) was also reported in a correlation analysis by Van der Ent and Savenije (2013)."

- Chavasse, D. I., Seoane, R. S.: Assessing and predicting the impact of El Nino southern oscillation (ENSO) events on runoff from the Chopim River basin, Brazil, Hydrological Processes, 23(22), 3261-3266, doi:10.1002/hyp.7392, 2009.
- Rahmstorf, S.: Ocean circulation and climate during the past 120,000 years, Nature, 419(6903), 207-214., 2002.

In Section 3.4 (AMM):

"It is interesting to note that the correlation analysis of Van der Ent and Savenije (2013) did not reveal any clear significant relationship between the continental precipitation and the SST in the tropical South Atlantic. The authors could not identify any obvious positive feedback between SST and evaporation there. From our results, however, the correlation coefficients between the time series of the AMM index and the evaporation and SST averaged over the NA and SA boxes (Table 2) suggest some opposite behaviour in the interannual variability of SST and evaporation associated with AMM during FMAM. During an extreme AMM episode, it seems that the warmer (colder) SST anomalies in either of the boxes are associated with decreased (increased) evaporation in the same area. This could explain the existence of a variability of opposite sign between SST and evaporation over the oceanic moisture sources studied over the tropical Atlantic during these months. These variations could probably be explained through the occurrence of the local Wind-Evaporation-SST mechanism (WES) reported by other authors, particularly over the equatorial North Atlantic (e.g., Chang et al., 2001; Czaja et al., 2002). According to them, the WES feedback can be understood in the following way: SSTs over the weak (strong) wind zone increase (decrease) and a lower (higher) amount of evaporation is released. Of course, a more conclusive analysis would be needed to understand the joint variability of oceanic evaporation over these moisture source regions, the wind, and the continental precipitation, but such an analysis is beyond the scope of the present study."

Correlation AMM x	NA		SA	
	Ev	SST	Ev	SST
Feb	-0.31 *	0.53 *	0.06	-0.50 *
Mar	-0.1	0.45 *	0.24	-0.45 *
Apr	-0.55 *	0.61 *	0.45 *	-0.40 *
May	-0.37 *	0.65 *	0.33 *	-0.44 *

Table 2: Correlation coefficients between the monthly time series of AMM and: evaporation and SST averaged over the NA and the SA source regions. All time series cover the 33-year period. Values statistically significant at the 90% level according to T-Test are denoted *. The one-degree monthly ocean evaporation dataset comes from the OAFlux project (Yu et al., 2008).

- Chang, P, L Ji, R Saravanan: A hybrid coupled model study of tropical Atlantic variability. J Clim, 14, 361-390, 2001.

- Czaja, A, P van der Vaart, J Marshall: A diagnostic study of the role of remote forcing in tropical Atlantic variability. J Clim, 15, 3280-3290, 2002.
- Souza, E. B.; Kayano, M. T.; and Ambrizzi, T.: Intraseasonal and submonthly variability within autumn rainy regime over the Eastern Amazon/Northeast Brazil and associated atmospheric mechanisms.. Theoretical And Applied Climatology, Austria, v. 81, n.3-4, p. 177-192, 2005.
- van der Ent, R. J., Savenije, H. H. G.: Oceanic sources of continental precipitation and the correlation with sea surface temperature, Water Resour. Res., 49 (7), 3993-4004, doi:10.1002/wrcr.20296, 2013.

Section 3.2: Some nice plots are shown in this section, but it would be relevant to know how ENSO and its relation to moisture sources could be linked to drought as well. Now this is not investigated in depth.

- In an attempt to provide additional information concerning the transport of moisture, the Era-Interim vertically integrated moisture flux (VIMF) and its divergence fields were provided together with the lagrangian backward analyses. Although not shown together, the VIMF fields presented with the backward figures may be useful to interpret the forward analyses as well. We believe that the VIMF analysis will contribute to a better understanding of the links between sources and sinks of moisture. Moreover, two new sections were included in the manuscript. The first one investigates changes in the moisture transport during flood and drought episodes over the Amazon Basin, and the other reports what happens in years of extreme of the Atlantic Meridional Mode. Following the Reviewer's suggestion, our aim in this new version is to identify some relationship between years characterized by extreme water-availability conditions in the basin and two important climatic variability modes configured over the Pacific and the Atlantic oceans.

1031-25-26 June/year 0 and May/year 1. This looks quite strange and I hope the authors can come up with a nicer way of expressing these periods.

- We agree that the expression looks strange. In the new version of the figures these periods are expressed as June/0 and May/1.

1032-6 Why is Fig. 2b introduced only after Fig. 5?

- In order to summarize the graphical representation of the results and to help the comparison of the ENSO analyses with the climatology, In the original version of the manuscript Figure 2b showed the annual cycle of the climatological values of (E-P) integrated over the SA and NA source areas (black lines), as well as the (E-P) values obtained through the ENSO composites (pink and green lines). We apologise for this mistake, but in the original version Fig 2b was introduced in Section 3.1 (1030L4), and was referred to again in topic 3.2 after Fig. 5. In the new version of the manuscript three more graphs were added in Figures 2 and 4, each illustrating the changes in moisture transport over the areas of interest in the three sections studied. Please let us know if the Reviewer does not consider this version to be appropriate.

1033-25-26 What is exactly the definition of the South Atlantic Convergence Zone?

- According to Kodama (1992) the South Atlantic Convergence Zone (SACZ) is a large subtropical frontal zone of cloudiness and precipitation oriented from northwest South America to southeast Brazil (and the Atlantic ocean), and is more commonly observed during the austral spring and summer.

We rewrote the sentence including this brief description to clarify the system to the reader. Please, see below:

"From the austral spring onwards for La Niña events, the moisture transport was enhanced towards the tropical latitudes including the region of occurrence of the South Atlantic Convergence Zone (SACZ), particularly up till March. According to Kodama (1992) the SACZ is a large subtropical frontal zone of cloudiness and precipitation oriented from northwestern South America to southeastern Brazil (and the Atlantic ocean), and is more commonly observed during the austral spring and summer."

- Kodama, Y. M. (1992), Large-scale common features of subtropical precipitation zones (the Baiu frontal zone, SPCZ, and the SACZ). part I: Characteristics of subtropical frontal zones, J. Meteorol. Soc. Jpn., 70, 813–835.

Section 4 Summary: The summary says pretty much the same thing as the abstract. Why are there no discussions and conclusions sections?

- Section 4 was renamed "Conclusions". In an attempt to emphasise the main findings in the revised version, the section was rewritten and the conclusions obtained through the analyses of drought/flood years, and the roles of the ENSO and AMM variability modes were also included.

1035-1-2 incomprehensible sentence

"This assessment was undertaken for a 33 yr period (from June 1979 to May 2012) and has focused on the climatological annual cycle and the modulation of ENSO, one of the climatic variability modes with impacts over South America more extensively investigated, on the hydrological budget over Amazon."

- The sentence was rewritten taking into account the new sections incorporated in the revised version. Please see below:

"The climatological annual cycle of the main moisture sources and sinks of the Amazon was characterised for the period June 1979 to May 2012. The large temporal domain (33-year) allowed the investigation of some aspects of the interannual variability of the moisture transport over the basin, such as the changes observed during years characterised by flood and drought conditions in the Amazon, as well as the role of the anomalous SST conditions in the Pacific and the Atlantic on the Amazonian hydrological budget."

1035-20-24 I suggest the authors take that into account in their current work instead

- Following the Reviewer's suggestions, we included two new sections: 3.2 on changes in moisture transport in extreme drought and flood years in the Amazon basin, and 3.4 on the possible impacts of extreme Atlantic Meridional Mode (AMM) episodes on moisture transport in Amazonia. In the new version we intend to place more emphasis on the interannual variability of precipitation in the basin from a Lagrangian perspective. After a climatological introduction in Section 3.1, we discuss changes in moisture transport observed during years characterised by severe drought and flood conditions in Section 3.2. Our aim in Sections 3.3 and 3.4 is to investigate how two climatic modes of variability with known impacts over the Tropical South America (ENSO and AMM) can affect the moisture transport over the Amazon basin, as well as how these modes were related to the severe years discussed in Section 3.2. Please see the new structure in the new version of the manuscript.

Fig. 2b and 4b: Is the "100 mm/day" really correct? This seems very unlikely. Why are not all indicated lines in the legend?

- We apologise for this mistake. The correct units on the y axis are (E-P) /100 mm/day. We have corrected these figures. We rewrote the legend in order to clarify the figure. The line styles and the colours are also referenced in the graph. Please see the new version of the legend below:

"b: The annual cycle of the monthly values of 10-day (E-P) shown in Fig.1 and integrated over the NA (continuous line) and SA (traced line) source areas indicated in a). Black lines represent the 33-year average values, while pink and green lines indicate the average of the drought and flood years, respectively."

Fig. 1,3,5,6 Why is there some kind of technical experiment title above these figures?

- Because these figures are quite similar, we included a short title in each one to facilitate their identification by the reader. We preferred to keep them in the revised version to differentiate the three composite analyses presented. We think the titles will help the reader to identify the figures.

Technical corrections

Only for the abstract I list all my spotted language and grammar mistakes, but there are many more throughout the rest of the paper.

1024-L6 Missing "the" before Amazon

1024-L7 Missing "The" before Northern

1024-L7 “Austral” and “Summer” should not be capitalized

1024-L9 Missing “the” before Amazon

1024-L10 “for” should be “to”

1024-L10 “over” should be “of”

1024-L10 “inter annual” should be “interannual”

1024-L9-10 “slightly” should be after “increases” instead

1024-L11-12 Missing “the” before NA and SA

1024-L14 “Austral” and “autumn” should not be capitalized

- We thank the author for pointing out some of the grammatical mistakes in the original version. Following the reviewer’s suggestions, we have engaged the services of a professional editing company to revise the manuscript.

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REVIEWER 2

Major Concerns

1a) There is a lack of a rigorous interpretation of the results in light of large-scale circulation patterns and previous results in the literature. This is true in the climatological analysis, but particularly in the interpretation of El Nino and La Nina. As it stands right now, the authors are showing the reader their results without a physical interpretation. For example, the “Walker Circulation”, a critical physical mechanism to explain their findings with respect to ENSO analysis, is not mentioned anywhere in the manuscript. In particular, the decrease in the transport from NA to the Amazon during El Niño is related to the weakening of the Atlantic Walker circulation and the increase in the transport towards La Plata coincides with a stronger subtropical jet during El Niño. See for example

Kousky et al, 1984, A review of the Southern Oscillation: oceanic-atmospheric circulation changes and related rainfall anomalies, Tellus, 36A, 490-504.

Ropelewski and Halpert, 1987, Global and Regional Scale Precipitation Patterns Associated with the El Niño/Southern Oscillation. Monthly Weather Review, 115, 1606-1626.

General features of the climate of La Plata (see e.g. line 20, page 1031) and the corresponding variability associated with ENSO. See for example Garreaud et al. 2009, Present-day South American Climate, Paleo3, 281, 180-195.

1b) Related to my concern above, there are several key papers that the authors have not mentioned in their background section. This tells me that the authors must first go through some fundamental reading of the papers that have studied this issue, so that they can show their true (very interesting) contributions to the field. For example, there is one study that quantifies the exchanges of moisture between the Amazon and other sources. In that study, annual cycles and inter-annual time series for a period of 25 years is available for comparison and further analysis.

See Dirmeyer and Brubaker, 2007. Characterization of the Global Hydrological Cycle from a Back- Trajectory Analysis of Atmospheric Water Vapor. Journal of Hydrometeorology, 8, 20- 37

- We totally agree with the commentaries of the Reviewer. Some additional information about ENSO, Walker and Hadley circulation and their impact on the Amazon precipitation was included in the new version of the manuscript as well as references. A vertically integrated moisture flux analysis was also included in order to illustrate the physical mechanisms associated with the lagrangian analysis. Please, see our answers to the Reviewer 1's questions "1025-L5-7" and "section 3.2".

Please, see the text introduced in the manuscript:

"As mentioned by Grimm and Ambrizzi (2009, and references therein), during El Niño episodes the tropical convection is shifted from western Pacific towards central and east Pacific. Consequently, the Pacific Walker cell is weakened, because the induced anomalous circulation along the equator is opposite to the climatological circulation. As the anomalous subsidence in the Walker cell associated with anomalous convection over the eastern Pacific occurs over northern South America and Atlantic Ocean, the two smaller cells connected with the continent are strongly affected, especially by the weakening of the ascending branch over the Amazon region. The reduction of the convection over this region also reduces the regional Hadley circulation. On the other hand, the Hadley circulation is strengthened over the central/eastern Pacific. During La Niña episodes the changes are nearly opposite.”

2a) The FLEXPART results are unique in this type of literature because they don’t actually quantify mass (as for example the quasi-isentropic back trajectory algorithm). The results are difficult to interpret because you are showing maps of E-P. In particular, Figure 2b shows negative values of (E-P) associated to NA: does this mean that moisture is transported from the Amazon to NA or that moisture coming from the eastern Atlantic is lost in NA before reaching the Amazon? The authors clearly state that NA is not a source for the Amazon during June to September, which suggests that Figure 2b should be interpreted as follows: moisture coming from other places to the Amazon is lost in NA during June to September. It would be helpful for the reader to state this clearly (e.g. near line 12, page 1030), and clarify what this other sources are.

- We agree that the interpretation of (E-P) results can be very confusing, and apologise for this. Following the Reviewer´s suggestions, we included an additional explanation in Figure 2. Please, see the revised version below:

“Figure 2b shows the monthly averages of the 10-day (E-P) backward trajectories calculated in Figure 1 and integrated over both source areas. Recalling that we define a region as a moisture source when it presents positive (E-P) values, it seems that the NA (continuous black line) contributes moisture from October to May. During this period, the convergence of VIMF associated with the ITCZ migrates southwards, and the northern trade winds carrying moisture reach the southern American coast (Figure 1, right-hand column). The negative (E-P) values characterising the NA from June to September suggest that this region does not act as a moisture source for the Amazon basin during these months. In our methodology, this means that precipitation prevails over evaporation in the atmospheric moisture budget integrated over NA during this period.”

In general, in your Data and methods please be clearer about the following aspects - In the back trajectory analysis, what does negative E-P indicate? - In the forward trajectory analysis, what does positive E-P indicate? - If I understand correctly, you are doing BOTH *forward and backward analysis. . .correct? If so, paragraph 10 and 15 are misleading, because you say "A forward analysis may identify all trajectories. . .." But you never actually say that you did both.*

- Again, we apologise and completely agree that more information is necessary for the correct interpretation of the figures, as also pointed out by Reviewer 1. We detailed the explanation of how to interpret the results in the new version of the manuscript. Please see our answer to Reviewer 1's comments concerning Figure 1.

*2b) Related to my concern above, when looking at figures 2b and 4b, the units on the y axis are (E-P)*100 mm/day. This means that you are getting peak values of around .025 mm/day for these source regions. . ..can we interpret these as mass? They seem awfully low. Please interpret these physically.*

- We apologise for this mistake. The correct units on the y axis are (E-P) /100 mm/day. The figures have now been corrected. Thank you.

3) Figure 4b is presented in a very strange way (focusing on points of inflection, as opposed to the seasons where there is large or small contribution), also, paragraphs 20 is very awkward. I think that after the authors have read the references mentioned above they can say a bit more about this point.

- As per our response to Reviewer 1, in our opinion Figure 4b suggests a higher-frequency variability (presenting a near-seasonal period) of the moisture contribution superimposed on an annual cycle with maxima during the extended austral summer and minima in the extended winter. The migration of the ITCZ and its association with the development of the South American Monsoon System may explain the annual cycle. However, we are not able to explain this near-seasonal variability of the Amazonian contribution to LP. The sentence was rewritten in order to include this discussion. Please see the revised text in Reviewer 1's question 1031-22.

4) In many cases the figures are presented for all months of the year, but there is minimal discussion. The authors should either a) remove the panels that are not discussed b) *include a discussion of every panel or c) not show every month, but a subset (one in each season). In any case, please discuss all figures/panels that are presented.*

- Thank you for your suggestions. Because our aim is to investigate the temporal evolution of the moisture transport over the Amazon Basin and how this may affect the Amazonian rainy season, we think it would be more appropriate to show the figures for all months of the year. Although we define the rainy season from February to May, the configuration of the rainy season is not homogeneous over the Basin, and the monthly figures may illustrate the changes inside the region. We believe that monthly figures may also reveal more information concerning the role of Amazonia on the active phase of the South American Monsoon that occurs during the extended austral summer. In addition, we believe that the inclusion of an analysis of the ENSO impacts over the Amazon would be more complete if the whole of the ENSO cycle is considered (from June in year 0 to May in year 1). Thus, we preferred to standardise the presentation of the figures according to the ENSO cycle. We agree that we should detail the discussion of the temporal evolution observed in each figure, and this has now been incorporated in the revised text.

Figure 1:

"We now describe the temporal evolution of the distribution of the moisture sources for the Amazon basin throughout the year. The reddish colours configured during the period June-August in Figure 1 suggest the predominance of the contribution from the southern Atlantic ocean, compared with those from northeastern Brazil, the southern Amazon, and the La Plata Basin. It seems that tropical and subtropical South America provide some moisture during the austral winter. Apart from the La Plata basin, the evaporative sources described above coincide quite well with the areas of divergence of the vertically integrated moisture flux (herein VIMF; right-hand column). One can identify some predominantly evaporative sources over the Northern Atlantic (yellow colours, left-hand column), but our methodology cannot be used to check whether the moisture received by the particles crossing this region will precipitate when crossing the ITCZ (blueish equatorial areas) before reaching their target. From September onwards, the moisture sink areas (left-hand column) and the convergence of the VIMF observed over the northwestern Amazon expand towards southeastern Brazil and the La Plata Basin, and persist until March. The persistence of these moisture sink regions through the extended austral summer coincides with the active phase of the SAMS. From November to April, the evaporative sources and the divergence of the VIMF intensify over the tropical North Atlantic ocean and reach the northern boundary of the basin, accompanied by a moisture flux from the northern hemisphere towards the target region. The displacement northwards of the equatorial sink during May is accompanied by a weakening of this evaporative region."

Figure 3:

"We will now briefly describe the temporal evolution. During the austral winter months the major moisture sinks of the air particles that leave the basin are located over southeastern South America and over northern South America and adjacent equatorial regions. These sinks coincide with two regions of convergence of VIMF over the continent: one over the subtropics, and another associated with the ITCZ (Figure 1, right-hand column). From September to January, the moisture transport towards the equatorial latitudes weakens in association with the weakening of the convergence of the VIMF (Figure 1, right-hand column), while the moisture sinks and the convergence of the VIMF areas expand over tropical and subtropical South America. During the austral autumn, the convergence of the VIMF and the sink regions reduce again towards both the subtropics of the continent and the equatorial band"

Figure 5:

"During flood years, moisture contribution prevailed from a region extending from central Brazil towards the Southern Atlantic from June/0 to October/0 (green colours). In these months, moisture transport analysis (Figure 5, right-hand column) suggests the predominance of higher VIMF divergence over central South America and the southwestern South Atlantic ocean accompanied by a weakening of the moisture flux from the Amazon basin towards the subtropics of the continent in flood-years compared with drought ones. From November (year 0) onwards for flood-years, the anomalous moisture transport from the Southern Atlantic reduced in intensity, while the contribution from the tropical North Atlantic was enhanced, which can be understood in terms of the differences in the VIMF of both composites. This analysis reveals the predominance of higher divergence conditions over the North Atlantic from September (year 0) onwards for flood years, culminating in an anticyclonic structure (perhaps associated with a probable intensification of the Azores high) and intensified northerly trade winds that could transport more moisture towards the Amazon basin during the austral winter. In comparison with flood years, it seems that the moisture contribution was confined to the equatorial/tropical South Atlantic region during years dominated by drought conditions."

Figure 6:

"Analysing Figure 6 and the VIMF fields (Figure 5, right-hand column) jointly, from June (year 0) to August (year 0) the moisture contribution increased towards the northwestern Amazon and the Pacific ITCZ (pink colour) during drought years, and the difference in the VIMF divergence analysis suggests the predominance of more convergent patterns over these regions compared with flood years. On the other hand, the moisture transport was enhanced towards northern South America and the Atlantic ITCZ (green colours) during flood years, in agreement with the VIMF flux, as well as with its convergence over the sink areas mentioned (Figure 5, right-hand column). During the flood years considered, the transport of moisture was increased, but confined, over the Amazon and Tropical Brazil from September (year 0) onwards. Nevertheless, it seems that the transport from the Amazon was enhanced towards southeastern South America during all months in the drought years. The difference between the flood- and drought-year VIMF composites confirms these preferred transport paths described through the sink analysis, and reveals the predominance of a dipolar structure in the VIMF divergence: convergence was enhanced over the tropics and inhibited over the subtropics during flood years. Moreover, the VIMF differences show a cyclonic structure over southeastern Brazil in November (year 0) that was probably associated with this dipolar structure. The variability of the contribution from the Amazon basin towards LP, the major climatological sink region, is quantified in Figure

4b, where the green and pink lines indicate the contribution during flood and drought years, respectively. In general terms, the contribution towards LP increased (reduced) during drought (flood) years, particularly during the periods September (year 0) to January (year 1) and March (year 1 to May (year 1).”

Figure 7:

“From the results it is clear that the moisture contribution from the equatorial Atlantic was enhanced during all months of an El Niño cycle. In comparison to La Niña episodes, it seems that the contribution from the Tropical and Subtropical Atlantic was weakened during an El Niño cycle. The differences in the VIMF from both composites (Figure 7, right-hand column) show enhanced VIMF divergent conditions over the equatorial Atlantic during the El Niño episodes selected, accompanied by an intensified moisture transport from there towards the basin. However, the enhanced VIMF divergence expanding towards tropical South America probably inhibited the precipitation of the moisture carried from the ocean to the Amazon. We believe that the configuration of these patterns may be understood through the displacement of the Walker cell eastwards as observed during an El Niño cycle, favouring subsidence over tropical South America. As a probable consequence of the presence of this intensified subsidence over the continent, the VIMF differences suggest the displacement of the moisture flux convergence associated with the Atlantic ITCZ northwards during April and May (year 1), probably associated with the inhibition of the latitudinal ITCZ migration southwards.”

Figure 8:

“It seems that the transport from the Amazon was enhanced towards southeastern South America (particularly the La Plata Basin) during the beginning of the El Niño phase, and this anomalous sink is displaced northwards during the cycle. The VIMF differences (Figure 7, right-hand column) reveal the predominance of intensified moisture transport towards the subtropics and enhanced moisture flux convergence over southeastern South

America during an El Niño cycle. During the onset of El Niño events (from June to August in year 0), the moisture contribution increased towards the northwestern Amazon and the Pacific ITCZ (pink colour), and this last region acted again as an anomalous sink from February to April (year 1). Again, the VIMF differences suggest some moisture transport towards the Pacific ITCZ, particularly from November (year 0) onwards. This might be understood via the eastward displacement of the Walker cell, increasing precipitation over the eastern equatorial Pacific. Instead, moisture transport is enhanced towards northwestern South America and the Atlantic ITCZ during the onset of La Niña events (from June to September in year 0, green colour). From the austral spring onwards for La Niña events, the moisture transport was enhanced towards the tropical latitudes including the region of occurrence of the South Atlantic Convergence Zone (SACZ), particularly up till March."

Figure 9:

"When we compare the two cases, it seems that an anomalous see-saw structure of the moisture sources prevailed during FMAM (year 1), with the South (North) Atlantic region increasing its contribution towards the Amazon during AMM+(-) episodes. Considering the VIMF differences for the two composites (Figure 9, right-hand column), a cyclonic structure configured over the northern hemisphere suggests the weakening of the Azores High from December (year 0) onwards for AMM+ episodes. VIMF convergence was then favoured over an area covering the eastern and tropical North Atlantic, and from January (year 1) onwards a dipolar structure was configured over the tropical Atlantic, increasing convergent conditions over NA and divergence over SA. This pattern agrees with the source analysis discussed above, and suggests the displacement of the Atlantic ITCZ northwards during the AMM+ events studied. From the same figure it is possible to identify the intensification of the moisture transport from SA towards the Amazon, probably due to enhanced VIMF convergent conditions configured over the Eastern Equatorial Pacific and the north of the continent during the AMM+ phase. In April (year 1) of the same episodes, an anticyclonic structure was favoured over central South America, and this probably reinforced the moisture transport from SA towards the Amazon, as well as the transport from the basin towards the subtropics. Considering only the AMM- years, the results suggest changes in the structure of the anomalous moisture sources over the months of interest. While the moisture contribution prevailed from the equatorial and southern tropical Atlantic regions from June to November (year 0; green colours), anomalous transport was displaced towards the North Atlantic region from December (year 0) onwards. During AMM+ years, it seems that some moisture was contributed by the basin itself from June to October (year 0). Afterwards, the anomalous source extended its domain towards northern South America, as well as to the equatorial and the southern tropical Atlantic regions. A similar evolution in the enhanced VIMF divergence extending from eastern Amazon basin towards the tropical Atlantic during the AMM+ phase agrees with the enhanced importance of these areas as moisture sources for our target area."

Figure 10:

"These results suggest some monthly variability in the preferred sinks. Nevertheless, it seems that moisture transport intensified towards the subtropical South America (the Amazon and northeastern Brazil) during the AMM+ (-) phase, particularly from October (year 0) onwards. From June to September (year 0) the anomalous patterns were mixed, but they suggest some presence of anomalous sinks over the western (eastern) Amazon and subtropical (extratropical) South America during AMM+(-) events. Transport was also favoured towards northwestern South America and the Pacific ITCZ during the austral spring of each AMM+ episode. All these patterns may also be identified via the VIMF analysis (Figure 9, right-hand column): during the AMM+ phase, VIMF convergent conditions predominated over the subtropical South America (with some temporal variation in the spatial domain), and over the eastern equatorial Pacific and northwestern continental areas"