Authors response

First we thank the anonymous referee 1 and Oliver Bothe for their helpful and constructive comments, which helped us to improve the manuscript. We would like to apologize for the time needed to provide our answers and the revised version of the manuscript. We start with a general response relevant for both reviewers and later answer the reviewers point by point.

General response

Sources of uncertainty
Both reviewers asked for a more thorough discussion of uncertainty. We added a paragraph in the discussion section of the revised manuscript about the following points, and how these uncertainties may influence one core result of our study, the ratio of moisture coming from the outer TP (40%) to the total TP precipitation.

Precipitation accuracy:
Maussion et al. (2014) compared HAR precipitation with rain-gauge observations and the TRMM precipitation products 3B42 (daily), 3B43 (monthly) and 2B31 (higher resolution). They found an improvement when increasing the horizontal resolution from 30 km to 10 km in comparison to the gauges. A slight positive bias could be detected against the same stations (0.17 mm day^{-1} for HAR10 and monthly precipitation values, their Fig. 3), comparable to that of TRMM 3B43 (0.26 mm day^{-1}). Converted to annual values (62 mm yr^{-1}) and compared to the value of HAR precipitation averaged over the inner TP (544 mm yr^{-1}), this bias remains significant. In a simple first order approach, by assuming this bias to be constant over the region (and assuming that the rain gauges have no under-catch), this would increase the part of moisture needed for precipitation coming from the outer TP from 40% to 45%.

Position of the cross section:
As requested by reviewer 1, we replicated our budget analyses with the cross sections moved of around 60 km towards the center of the TP for the HAR10 dataset. Figure 1 below shows the map with the tested cross sections positions. This results in new budget values for net atmospheric water input of 202.6 mm yr^{-1} (220.5 mm yr^{-1} with the old cross sections), and 506.3 mm yr^{-1} (544.8 mm yr^{-1}) precipitation falling on the inner TP. These differences compensate each other and do not result in a change of the ratio of 40%.

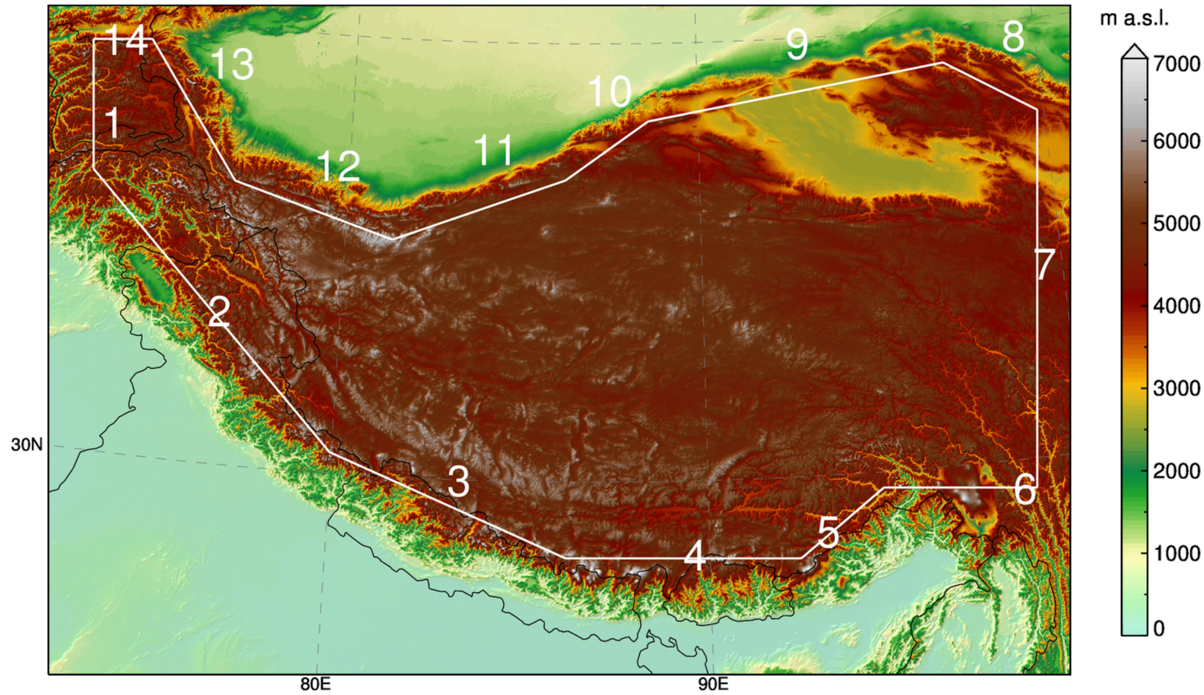

Figure 1: Map of HAR10 domain with cross sections (1-14) slightly moved towards the center of the TP (compare Fig. 1 in the manuscript).

Vertical resolution:
Referee Oliver Bothe asked the question whether the vertical resolution could have an influence on precipitation and moisture transport. We realized a new series of simulations for the whole year 2010 where we increased the number of vertical levels from 28 to 36 (all other settings kept equal).
Precipitation patterns in the HAR10 domain remain very similar. Figure 2 shows the precipitation for July 2010 for both resolutions (left: 36 levels, right: 28 levels). Large absolute differences are found in the monsoonal affected regions south of the TP and the Himalayas. The largest relative differences occur in regions with very low precipitation rates, the arid regions (e.g. Tarim Basin) north of the TP. Figure 3 shows the vertically integrated atmospheric water transport. The amounts and patterns match well to each other, relative differences are around +-5 % on the TP and just higher in small regions south and north of the TP. Table 1 and table 2 below show the values for the cross sections for the year 2010 for 36 and 28 vertical levels, respectively.
The computation of the water budget for the year 2010 for 36 (28) vertical levels, results in a net input of atmospheric water of 192.4 mm yr^{-1} (201.0 mm yr^{-1}), 622.8 mm yr^{-1} (621.4 mm yr^{-1}) precipitation falling on the inner TP and an annual ratio of 30.9% (32.3%) for 2010.

Summary:
There is no other possible way to estimate the uncertainty of the computed fluxes than the rough comparison with ERA-Interim provided in the manuscript. Certainly, the choice of the model set-up as well as the reinitialization strategy will also influence our results. Put together, we agree that we agree that these uncertainties are not negligible but there is no indication that our core conclusions would be affected significantly.

CS 36 lev 2010	1	2-3	4-5	6	7	8	9	10-11	12-14	1-14			
Month	West	SW 1-2	South 1-2	Brahmaputra	East	North-East	Qaidam	NW 5-4	NW 3-1	Sum	Inner TP Precipitation	Ratio to monthly (%)	Ratio to annual(%)
01	17.6	24.8	-3.3	3.0	-32.9	-3.0	6.4	9.6	-19.3	2.9	13.5	21%	0%
02	23.1	54.9	-4.4	4.1	-33.9	-4.5	5.8	10.8	-27.1	28.8	41.4	70%	5%
03	25.5	29.0	-9.8	8.9	-48.2	-3.8	14.1	18.4	-26.6	7.4	34.3	21%	1%
04	22.3	41.7	-11.4	6.6	-53.7	-3.8	16.1	18.4	-28.5	7.6	40.1	19%	1%
05	26.3	39.2	3.3	24.1	-57.9	-8.5	10.5	19.8	-30.8	26.0	69.0	38%	4%
06	13.7	41.7	20.7	23.7	-43.0	-4.6	3.9	1.3	-17.6	39.8	85.3	47%	6%
07	19.7	56.2	25.2	10.4	-0.6	-11.5	-11.7	-7.6	-38.6	41.4	108.8	38%	7%
08	15.2	35.5	25.0	16.5	-24.0	-11.4	18.4	7.7	-35.4	47.6	116.3	41%	8%
09	12.8	62.0	15.1	19.9	-53.7	-15.6	-0.4	3.7	-29.5	14.4	69.7	21%	2%
10	16.5	19.7	8.5	19.4	-58.9	-4.9	4.8	6.2	-17.2	-6.0	26.5	-23%	-1%
11	8.0	18.9	-11.0	6.2	-37.9	-1.3	7.0	7.8	-11.4	-13.7	8.3	-164%	-2%
12	5.5	20.8	-3.1	5.6	-33.7	-1.7	5.5	5.2	-7.8	-3.8	9.5	-39%	-1%
Sum (mm.yr-1)	206.1	444.3	54.9	148.3	-478.5	-74.6	80.3	101.5	-289.8	**192.4**	**622.8**		**31%**

Table 1: Decadal average of the atmospheric water flux for 36 vertical levels converted to a theoretical precipitation amount (mm month^{-1}) through vertical cross sections (slightly moved to the center of the TP) (1, 2-3, 4-5, 6, 7, 8, 9, 10-11, 12-14) for HAR10 (positive values denote transport towards the TP, negative values denote transport away from the TP). Decadal average of the precipitation (mm month^{-1}) on the inner TP and of the contribution (%) of the atmospheric water flux to the precipitation for HAR10.

CS 28 lev 2010	1	2-3	4-5	6	7	8	9	10-11	12-14	1-14			
Month	West	SW 1-2	South 1-2	Brahmaputra	East	North-East	Qaidam	NW 5-4	NW 3-1	Sum	Inner TP Precipitation	Ratio to monthly (%)	Ratio to annual(%)
01	17.7	25.2	-3.4	3.0	-33.0	-3.0	6.4	9.7	-19.5	3.1	13.8	23%	1%
02	23.3	55.4	-4.5	4-0	-33.9	-4.5	5.8	10.9	-27.3	29.1	41.9	70%	5%
03	25.6	29.0	-9.9	9.0	-48.3	-3.8	14.1	18.5	-26.7	7.6	34.8	22%	1%
04	22.6	42.1	-11.6	7.1	-54.0	-3.7	16.1	18.5	-28.6	8.5	41.0	21%	1%
05	26.6	39.9	3.5	24.3	-58.3	-8.5	10.7	19.9	-30.8	27.2	69.0	39%	4%
06	14.0	43.2	20.4	23.8	-43.3	-4.6	4.0	1.5	-17.9	41.0	84.5	49%	7%
07	20.2	56.2	25.5	10.5	0.2	-11.6	-11.6	-7.5	-39.1	42.9	107.2	40%	7%
08	15.7	36.4	25.5	16.9	-23.7	-11.4	18.8	8.2	-35.7	50.8	115.9	44%	8%
09	13.0	61.8	15.5	20.5	-54.0	-15.7	-0.3	3.8	-29.8	14.9	69.2	21%	2%
10	16.6	19.9	8.7	19.5	-60.0	-4.9	4.7	6.2	-17.2	-6.4	26.4	-24%	-1%
11	8.0	19.1	-11.3	6.2	-38.3	-1.2	7.0	7.9	-11.4	-14.0	8.2	-170%	-2%
12	5.5	21.0	-3.1	5.6	-34.0	-1.7	5.5	5.2	-7.7	-3.8	9.4	-41%	-1%
Sum (mm.yr-1)	208.8	449.3	55.4	150.5	-480.7	-74.7	81.3	102.7	-291.8	**201.0**	**621.4**		**32%**

Table 2: Decadal average of the atmospheric water flux for 28 vertical levels converted to a theoretical precipitation amount (mm month^{-1}) through vertical cross sections (slightly moved to the center of the TP) (1, 2-3, 4-5, 6, 7, 8, 9, 10-11, 12-14) for HAR10 (positive values denote transport towards the TP, negative values denote transport away from the TP). Decadal average of the precipitation (mm month^{-1}) on the inner TP and of the contribution (%) of the atmospheric water flux to the precipitation for HAR10.

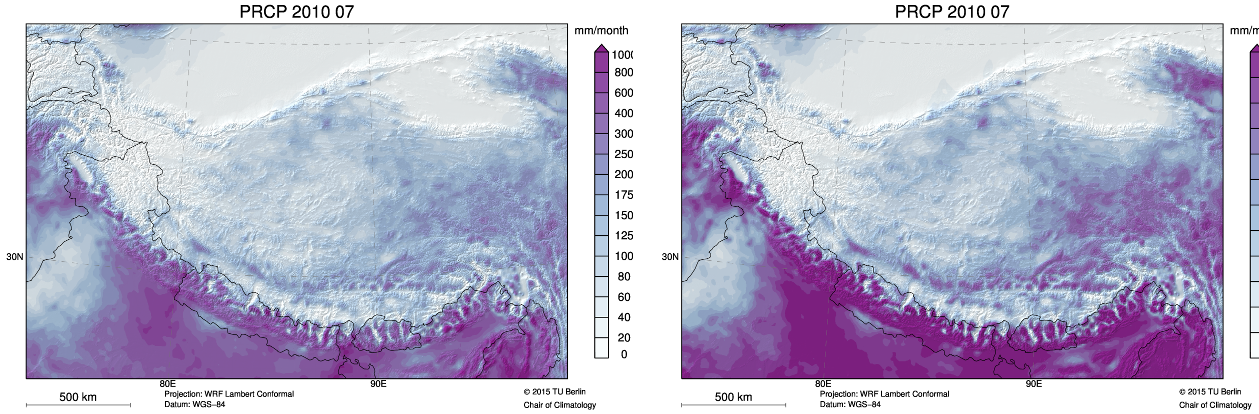

Figure 2: HAR10 precipitation for July 2010 for the vertical resolutions with 36 levels (left) and 28 levels (right) in mm month^{-1}.

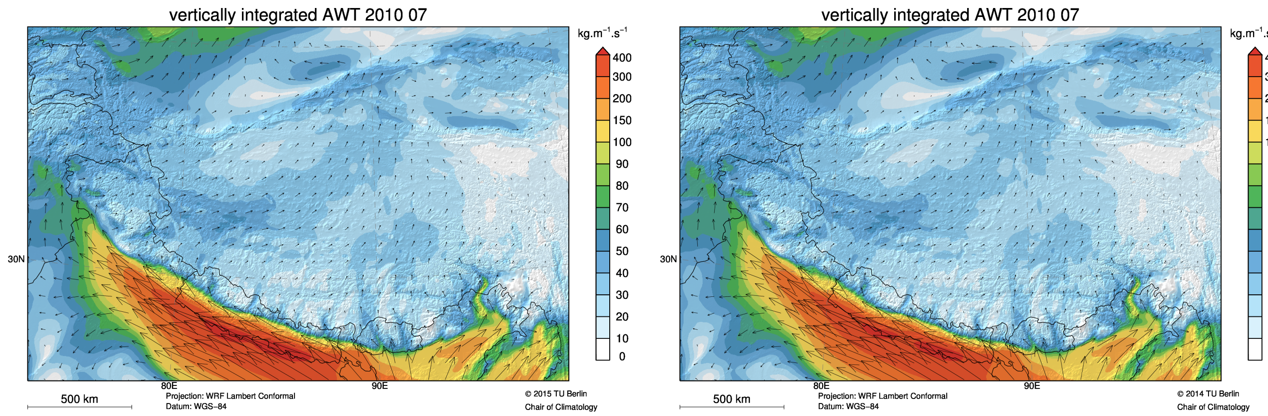

Figure 3: HAR10 vertically integrated atmospheric water transport for July 2010 for the vertical resolutions with 36 levels (left) and 28 levels (right) in kg m^{-1} s^{-1}.

Other changes

Other changes relevant to both reviewers include the change of the HAR name to “High Asia Refined Analysis”, as explained by the dataset providers here: http://www.klima-ds.tu-berlin.de/har/namechange.html

Interactive comment on “A twelve-year high-resolution climatology of atmospheric water transport on the Tibetan Plateau” by J. Curio et al.
Anonymous Referee #1
Received and published: 6 October 2014

RC: The atmospheric water vapor transport is crucial to understand the water and energy cycle between the Tibetan Plateau (TP) and its adjacent regions. Previous studies investigated the water vapor budget over the TP with coarse-resolution reanalysis data that are not able to resolve topography, whereas the present study uses a new high-resolution reanalysis data. It is well known that the vapor transport from south along Yarlong Zhangpo valley is a major water source of the TP, but the quantification of the vapor transport from southwest slope of Himalayas is quite uncertain. The major finding of this study is that the water vapor inflow from west and southwest is even larger than the well-known transport along the Yarlong Zhangpo valley from the south Asian monsoon. The results are quite new and well documented. As far as I know, someone has addressed *the importance of the southwest transport with AIRS satellite data, but no publication is seen. I would like to recommend the publication of this paper, subject to reasonable response to the following major and minor comments.*

Reply to specific comments

Major comments:

RC: 1. Water vapor flow around mountains depends on the velocity along the slope that has both horizontal and vertical components, but Eqs. (1) and (3) only takes the horizontal transport.

AR: It is true that eqs (1) and (3) are based on the horizontal components of the total WV flow vector, which also has a vertical component. However, this vertical component has no influence on the numerical computation of the actual transport (it is, in a way, fully included in the WRF model physics. I.e, if the vertical component is very important at one place and one level, it would reduce the remaining horizontal components). We looked at the vertical vapour transport separately, but its magnitude is much smaller than for the horizontal transport in average.

RC: 2. Water vapor inflow budget is critical and its estimation is a major contribution of this study. I am wondering the sensitivity of the budget to the location of the cross-sections. The present cross-sections are exactly defined at the edge of the TP, which may cause the following problems: (1) transport along slopes may be important but not be estimated well (see comment 1); (2) plentiful precipitation forms along the edge and the water vapor is not really transported into the Plateau. The second one is more concerned when we discuss the water budget over the TP. So, I like to see what the water budget is if we move all cross-sections slightly (for example, by 50 km) toward the center of TP.

AR: Thanks for this suggestion. See the general response above.

RC: 3. Abstract: "Our results show that 40% of the atmospheric moisture needed for precipitation comes from outside the TP, while the remaining 60% are provided by local moisture recycling". HAR30 and HAR10 show quite different ratios of the water recycling, and thus this statement should have an uncertainty description or at least you should mention that the uncertainty is large.

AR: This is true and now better discussed in the revised manuscript (see general comment above).

Minor comments:
RC: 4.
P3L13: the period in Lu N. et al. (2014) is short (2000-2010) and should be mentioned here to avoid misunderstanding. I suggest mentioning that specific humidity increased since 1970 (Lei Y. et al., 2014, Clim. Change., 125:281–290), as the decadal variability is more concerned in terms of lake area changes.
AR: We added the time period for Lu et al. (2014). In Lei et al. (2014) we read that precipitation increased on the TP interior since the late 1990s. Lei et al. (2013) found increased lake levels since the 1970s, which they connect with decreased lake evaporation and increased precipitation and runoff.
Added on page 1161, line 13: for the relatively short period 2000-2010

(Lei Y. et al, 2013, Journal of Hydrology, 483: 61-67)

RC: 5.
P3L15: Gao Y. et al. (2014) did not show evidence to support the intensification of the monsoon. Instead, Yao T. et al. (2012, Nature climate change, 2, 663–667) shows the monsoon was weakened, which is more consistent with observed wind stilling and precipitation decreasing in the monsoon-impacted regions (southern and eastern TP).

AR: We add a sentence about the monsoon weakening found by Yao et al. (2012). Also we slightly changed the sentence about Gao et al. (2014) to make their findings more clear.

RC: 6.
P7L11-13: Please extend slightly to describe the HAR precipitation accuracy.

AR: Thanks for this suggestion. See the general response above.

RC: 7.
P11L21: you have high-resolution data, which provides the possibility to confirm "sub-sidence or high wind speeds"
AR: Agreed, but looking for the reasons of the Qaidam Basin dryness still requires a more profound analysis, which we would prefer not to realize here. We would like to keep the sentence as is if possible.

RC: 8.
P11L23: "In September we have the highest WV transport amounts over the TP." I guess there might be a result of wind speed recovery after the monsoon withdraw in September. The wind speed recovery will facilitate both more evaporation and larger water vapor transport.
AR: Thank you for this very plausible explanation. We added a sentence in the revised manuscript.
Added sentence (page 1169, line 28ff): Another reason for higher transport amounts is the wind speed recovery after the withdraw of the monsoon, which is visible in the 500 hPa wind field (Maussion et al., 2014), and facilitates higher evaporation rates and therefore higher transport amounts.

RC: 9.
P13L5: give the height of Level 12
AR: The height of level 12 is ~ 3200 m above ground in Tibet. At the beginning of section 3.3 (page 1170, line 25 – page 1171, line 1) we give the heights for all mentioned levels. For more readability, we also added the level heights to the legend of Figure 8.

RC: 10.
P18: The work by Yang M. et al. (2007. Arctic, Antarctic, and Alpine Research, 39, 694-698) may support your results of water recycling over the TP.
AR: Thank you for this suggestion. We added a sentence about the findings of Yang et al. (2007).
added sentence (page 1176, last paragraph): Yang et al. (2007) show for two flat observation sites in the central eastern part of the TP that the evaporation is 73% and 58% of the precipitation amount, respectively.

Interactive comment on "A twelve-year high-resolution climatology of atmospheric water transport on the Tibetan Plateau" by J. Curio et al.

O. Bothe (Referee)
ol.bothe@gmail.com
Received and published: 8 October 2014

AC: Curio, Maussion and Scherer describe the climatology for atmospheric water transport on/off the Tibetan Plateau for the High Asia Reanalysis (HAR) of Maussion et al. (2014). HAR provides high resolution data and in turn allows a much more detailed description of the atmospheric water inflow to the Tibetan Plateau and its water budget. The HAR water transport provides a major step for our understanding of the Tibetan Plateau water budget and its influence on regional and large scale climate. The authors pose three objectives, the spatial climatology, the effect of topography on blocking and channeling moisture and the influence of model resolution. They deal with the first two topics convincingly but from my point of view they do not really address the last one.
Any conclusions suffer from the short period of available data and the lack of appropriate validation data. I am not convinced that the authors sufficiently discuss the relation between their work and the literature on the water cycle of High Asia. While the language is good, the manuscript could still benefit from clarifying and simplifying some of the more complex sentence structures in later sections. Nevertheless, from my point of view the manuscript requires no major changes. I only give some suggestions below. Additionally, I endorse the comments by Anonymous Referee 1.

Minor comments:
RC: 1. As already noted by Anonymous Referee 1, please give a short assessment of the quality of HAR precipitation.

AR*:* See the general response above.

RC: 2. Could the vertical resolution have an influence on transport and precipitation estimates?
AR*:* Thanks for the suggestion. See the general response above.

RC: 3. Could precipitation suppression be an HAR/WRF-artefact rather than a dynamical plausible feature?

AR: We do not think that the precipitation suppression is an artefact. The large-scale circulation is given by the forcing dataset in the initial conditions. The flow dynamic in the HAR in the upper atmosphere, where the anticyclonic movements described in the manuscript arise, will not differ much to the dynamic in the FNL dataset. Reason for that is the daily reinitialization strategy used in the HAR dataset. So there is not much time for the model dynamic created in the boundary layer to propagate in the upper atmosphere.

RC: 4. A question with respect to the assessment of import and local sources of precipitable water: I assume the model-setup behind HAR has a locally closed water balance and no artificial sources and sinks? This may sound ridiculous but if I recall correctly there are (mainly older) models for which this is not guaranteed.

AR: We do not know if the WRF internal physics have a closed budget, and this might even be parameterization specific. However, we use a daily reinitialization strategy to generate the HAR, indeed resulting in artificial sources and sinks. The problem is similar to that of global reanalyses (e.g. Lorenz and Kunstmann, 2012; Trenberth and Guillemot, 1998), and impossible for us to quantify here. The spin-up time of 12 hours given to the WRF model as well as the realistic representation of the atmosphere in the HAR are indicators, but no guarantee, that the water budget should be approximately closed.

RC: 5. a) Although you frequently mention the East Asian (summer) monsoon, I cannot identify to which studies you refer. As you see the lack of an influence as an important finding (and I agree) I would appreciate a pointer which findings you challenge.

AR: On page 1162 in line 21ff we give Araguás-Araguás (1998) as reference for the East Asian Monsoon to be a major moisture source for summer precipitation on the TP. With this comment we refer to the general agreement (albeit rarely proven, as you mention) that the EASM is a driver of climate variability on the TP. For example, the recent high-impact studies of Yao et al. 2012 and Bolch et al 2012 both list the EASM as driver in their Fig. 1. While these studies do not address this topic specifically, we find it important to challenge this Fig. 1. Recent studies (including Bothe et al BLABLA and the present manuscript) are further steps in this direction. We also found it difficult to find real references for the EASM influence on the TP and revised our introduction to better explain what we mean.

b) As a side note, I wonder whether the disagreement on East Asian moisture inflow is due to differing definitions. Günther et al. (2011) present a borderline for the Pacific monsoon and some definitions assume both NWP and East Asian monsoons to be part of the same monsoonal circulation. Considering Günther et al.'s definition the south-east inflow is more due to the NWP-EA-monsoon than due to the Indian monsoon. Compare e.g. WMO TD report "Global Monsoon System: Research and Forecast". Third International Workshop on Monsoon (IWM-III) (Hangzhou, China, November 2004) (WMO TD 1266) http://www.wmo.int/pages/prog/arep/tmrp/documents/global_monsoon_system_IMW3.pdf

AR: You are right, their seem to be problems with the definition and naming convention of the different monsoon systems. Günther et al. (2011) present a borderline for the Pacific monsoon in their figure 1. This presented borderline is not a result of their own work, they reference to Winkler and Wang (1993) and Morrill et al. (2003). In these references the borderline is presented for the East Asian Monsoon.

RC: c) There is apparently on average no inflow from the East. However based on your current analyses, you cannot exclude this for individual years.

AR: Correct. We do not see a contribution of the EASM in the averages, but at the same time we expect it to be visible if significant. Our hypothesis is that transient weather systems could bring moisture from the east to the Tibetan Plateau but that they are not visible in our averages. It will be the goal of a further study to examine these weather systems more in detail. Another important aspect of your question is the very basic role of averaging in our analyses, since we do not separate transport during precipitation from other transient transport. Our approach is very common (e.g.: Feng and Zhou, 2012), and it is required to realize the budget presented in our study, but it does hide some of the details. We added a paragraph in the discussion to reflect your question.

RC: 6. While I agree with your general description of the on average major influences (page 1161 bottom and 1162 top), it may confuse prior findings on climatological influences and anomalous influences in individual years.

AR: We added a passage to make clear that we focus on the mean climatology during our

period of investigation and that the picture can be different for individual years and single events. See also comment above.
Due to the temporal averaging of the model results to monthly data we get the mean climatology for out period of investigation but loose the ability to analyze the data process based. The processes will be analyzed in a subsequent study on a higher temporal resolution, e.g. daily. In the monthly data we cannot proof when transport of moisture and precipitation occurs exactly and in which way they are connected to each other. Due to the vertical integration of the atmospheric water transport over the whole atmospheric column, we cannot make statements about which part of the atmospheric column is responsible for precipitation.

RC: 7. In Figure 2c, the comparison between HAR30 and ERA-Interim shows large differences in the South Asian Monsoon, which are likely of interest to the present study and should be addressed. Less prominent are differences in northern latitudes of the domain.

AR: We added a description about the differences in the South Asian Monsoon.
Added sentences (page 1167, line 19ff): Additionally, there are differences in the Arabian Sea and the Bay of Bengal. Over the Arabian Sea more water vapour is transported further to the south in the HAR30 dataset. The transport direction in the Era-Interim dataset is more from south-west to north-east. Therefore, the transport amount over the southern part of the Indian peninsula is also higher for HAR30. Because of that southward shift, the transport amount over the southern part of the Bay of Bengal is higher for HAR30 than for ERA-Interim and then has a stronger northward component in the eastern part of the Bay. So the South Asian Monsoon circulation has a modified shape in the HAR, maybe due to the influence of the southern branch of the mid-latitude westerlies, which is more pronounced in HAR30.

RC: 8. You mention in passing work on drought and wetness on the Tibetan Plateau but don't give references. It is not necessary to add more references, but it could help to more highlight the interannual variability. Figure 5 indicates the strong interannual variability and I appreciate that you wish to discuss this in more depth in a subsequent study. However, the reader would benefit in her/his understanding by some information visualising the variations around the mean climatology. Standard deviations for some measures presented in the tables could provide this information. Additionally one or two individual cases added to Figure 3 could also be valuable.

AR: Thank you for this comment. We add references for drought and wetness on the TP (e.g. Bothe et al., 2009; Liu and Yin, 2001). In a revised version we add standard deviations in the tables, thank you for this idea. But we do not want to add individual cases in the study because they are not the focus of the current study.

RC:
9. a) Section 3.3: Could you check the description of the results for consistency? For example: You write "above these levels [15,16]" and "Level 10 which lays between".

AR: We checked the description for consistency. Maybe is was formulated a bit ambiguous because the word "between" for Level 10 refers to the cyclonic (level 1 and 5) and anticyclonic (level 12 and 15) circulation features. So level 10 lays between these lower and upper levels. We slightly changed the sentence and inserted the corresponding levels in brackets to avoid misunderstanding.
Changed sentence: Level 10, which lays between the cyclonic (levels 1 and 5) and

anticyclonic (levels 12 and 15) circulation features, could be called the equilibrium level.

b) I also miss the Tibetan anticyclone (compare the work of, e.g., Flohn) in your descriptions.

AR: We already mention the anticyclonic circulation in the manuscript and now expanded the description by the fact that this is the Tibetan anticyclone and added a reference. Modified sentence (page 1171, line 14ff): Level 12 and 15 (and levels in between) show an anticyclonic circulation around a centre at the southern TP, directly north of the Himalayas. This is the high-tropospheric Tibetan anticyclone that forms during May or early June (Flohn, 1968).

c) The mixing of water sources is, from my point of view, a major results which should be discussed later with its implications.

AR: Thank you for the remark that we should highlight this finding. We added a paragraph concerning this result in a revised version of the manuscript.

d) In the last paragraph of Section 3.3, you are basically describing the features of the heat low over Pakistan and the elevated anticyclone. It may be appropriate to give a reference. That is, your final sentence is not necessarily something new. Furthermore, I wonder to what extent the work of Sajjad Saeed on the heat low may be relevant.

AR: You are totally right that this is not really something new, we just wanted to highlight regions where we have atmospheric water transport which does not lead to precipitation. We modified the paragraph under consideration of your helpful remarks.

Modified paragraph (page 1172, line 17ff): In the lower levels the heat low over Pakistan (Bollasina and Nigam, 2010) is visible in the transport patterns (Fig.8) and in the 10 m wind field (Fig. 6). Saeed et al. (2010) point out that the heat low over Pakistan connects the mid-latitude wave train with the Indian Summer Monsoon. In the surrounding region where we do not see this anticyclonic movement in the levels above the boundary layer, the large amounts of transported WV result in high amounts of precipitation. This result can provide an indication of the processes, which lead to the risk of droughts and floods (e.g. in July 2010) in Pakistan, like already analysed by Galarneau et al.(2012).

Technical comments:

RC: 1. I would like to ask you to reconsider the use of the rainbow palette (even if the Figures appear to be already colorblind safe). See e.g.: http://geog.uoregon.edu/datagraphics/EOS/ http://www.poynter.org/uncategorized/224413/why-rainbow-colors-arent-always-the-best-options-for-data-visualization

AR: We aware of this problem and know that we do not have the perfect solution. We experimented a long time to find color palettes which are easy to read and so we rather want to keep our selected color schemes.

RC: 2. I seem not to be able to find information about the top of the atmosphere in HAR, i.e. where the top level is approximately.

AR: The top of the atmosphere in the HAR is 50hPa. This is the default value of the WRF model.

RC: 3. I propose to put Figures 9-12 as four panels of one new Figure.
AR: Good idea, we do that in the revised version of the manuscript.

RC: 4. Generally, I am confused by your description of prior results. It would help to just give a general summary of moisture paths to the TP and then discuss the different approaches and studies.
AR: Thank you for this remark. In a revised version of the manuscript the description of prior findings is restructured to ease the understanding for the reader.

RC: 5. You appear to focus on very recent studies and to more or less ignore older studies. The Tibetan Plateau and its moisture and heat balance are a topic of intense research for 30 years now. Since the HAR data provides a new and improved perspective on the topic, it is valuable to discuss very thoroughly how the new findings challenge or complement previous assessments and conclusions. The works of, among others, Akiyo Yatagai, Tetsuzo Yasunari, or Michio Yanai may (or may not) be relevant.

AR: Thank you very much for the remark and the literature suggestions. We consider this in the revised version of the manuscript.

RC: 6. Your discussion section is more a summary of your results and not a discussion of them with respect to the literature. For example, if HAR10 and HAR30 differ by 60mm per year in AWT input, how do they compare to, e.g., ERA-I. Generally, it is necessary to more clearly discuss how your results add to or contradict works presented in motivating the study.

AR: We expand the discussion in a revised version of the manuscript.

RC: 7. Similarly your conclusions are rather an outlook and not so much conclusions from your results. (As a sidenote: Is there a reference for the TP precipitaion variability? Analysing dry and wet episodes should not only be compared to Lu et al. who use a comparable time interval but also to studies dealing with other periods. These could potentially include Hahn and Shukla, 1976, Tang and Reiter, 1984, Luo and Yanai, 1984a,b, and especially Liu and Yin, 2001. But there are many more publications on dryness and wetness of the TP.)

AR: Thank you for the literature suggestions. We revise the conclusion section and expand the passage about the precipitation variability.

Annotations, questions, typos etc:
RC: I would suggest to slightly restructure the abstract to emphasize your main findings. For example, the larger than thought westerly contribution gets slightly lost.
AR: Since our main findings are the first thing we mention after the description of what we do in this study, we do not know how to highlight them more.

page 1160
RC: Line 16 (and elsewhere): extend (noun) -> extent
AR: OK
RC: Line18: Do you mean "needed" or do you mean "available"?
AR: Needed might sound misleading, but we want to highlight that a certain amount of precipitation falls on the inner TP and the atmospheric water for this precipitation must be supplied to the TP.

RC: Line 19ff: I would skip the outlook from the abstract.
AR: OK

page 1161
RC: Line 2: “water supply” where?
AR: The TP provides moisture for the downstream regions like Yellow and Yangtze River valleys. We added this information in the introduction.

page 1164
Line 14: “levels We” -> “levels. We”
AR: OK

Line 20ff: Please simplify this sentence.
AR: OK, done.

New: The HAR is the result of the dynamical downscaling of the global gridded dataset, the Operational Model Global Tropospheric Analyses (Final Analyses, FNL; dataset ds083.2). These final analyses are available every six hours and have a spatial resolution of one degree. The model used for this purpose is the advanced research version of the Weather and Research Forecasting model (WRF-ARW, Skamarock and Klemp, 2008) version 3.3.1.

page 1168
RC: Line 16: ? can just takes place through ?
AR: can just take place through
RC: Line 24: “in in” -> in
AR: OK

page 1170
RC: Line 1: the fluxes does -> the fluxes do
AR: OK

page 1172
RC: Line 5ff: Please clarify/simplify this sentence.
AR: new: Therefore, the air at this level tends to descent. This means that just below this level clouds in the boundary layer are possible. These clouds can provide just samll amounts of precipitation due to their low vertical extent.

page 1173
RC: Line 11/12: Can you give a reference here with respect to the Brahmaputra Channel as main input channel?
AR: OK, we added a reference and slightly modified the sentence.
Tian, L., V. Masson-Delmotte, M. Stievenard, T. Yao, and J. Jouzel (2001), Tibetan Plateau summer monsoon northward extent revealed by measurements of water stable isotopes, J. Geophys. Res., 106(D22), 28081–28088, doi:10.1029/2001JD900186.
New: CS 6 contains the Brahmaputra Channel, which is often referred to as one of the main input channels for atmospheric moisture (Tian et al., 2001).

RC: Line 22: The paragraph is about CS1 and CS6. I think the break should be before the mention of CS2-3?
AR: I do not think that we should make the brake before mentioning CS2-3, because this

sentence and CS2-3 belong to the statement that there input through the western boundary has a similar magnitude as the transport through the Brahmaputra channel. CS2-3 are important because the transport through them is also not only monsoon controlled but there is a large share of westerly air masses.

RC: Line 29: (Fig. 11) In -> (Fig. 11).
AR: OK

RC: In Generally Section 3.4: Especially here, I feel that less nested sentence structures could ease the understanding for the reader.
AR: We slightly reconstructed sentences in this paragraph which seemed to be too long or nested.

Changed sentences:
Page 1173, line 20: In July the ratio between CS 1 and CS 6 is 90.47 %. This means that the input through the western boundary is around 90 % of the transport through the Brahmaputra Channel region.

Page 1174, line 6f: However, if we look at the total of the AWT amount through the eastern boundary, we see that the transport from the Plateau towards the east is dominant also in summer.

Page 1174, line 8ff: The transport through the northern boundary (CS 14-8) towards the TP (input) is lower than from west and south in January and July (Fig. 11 & 12, Table 1), although the circulation is directed to the boundary of the TP especially in summer. There we have a strong gradient in altitude and fewer passages, through which the atmospheric water could enter the TP, than in the Himalayas. For the westernmost northern cross sections (14-12) the transport from the TP to the north is dominant. Reason for this is the north-eastward transport on the western TP, which also explains the lower transport amounts towards the TP. The AWT with the northern branch of the westerlies north of the TP is blocked by the high elevated TP. The AWT then follows the northern border of the TP to the east, where the elevation is lower in some regions (CS 9-11), e.g. at the border to the Qaidam Basin (CS 9).

page 1175:
Line 14: numerous and large? or just numerous? or numerous large? (also page 1176, line 25)
AR: numerous large, we changed this in both sentences.
RC: Line 19: what-> which
AR: OK
RC: Line 22/23: as found by . . . too. -> as also found by
AR: Ok
RC: Line 24: and so -> . Thus
AR: OK

page 1176
RC: Line 1: found out -> found
AR: OK
RC: Line 10: did not considered -> did not consider
AR: Ok
RC: Line 12: does not has -> does not have
AR: Ok

RC: Generally for these paragraphs: you may want to check the language.
AR: OK.

page 1178
RC: Line 6: skip “even”
AR: Ok
RC: Line 11: how and if -> maybe: if and how
AR: Ok
RC: Line 13: maybe could play -> could play
AR: Ok

page 1180:
RC: Line 1: Guenther -> Günther?
AR: I know that this is the same person. In the author list of the article her name is written with “ue” instead of “ü”, so I just wanted to be correct.

References:

Araguás−Araguás, L., Froehlich, K and Rozanski, K.: Stable isotope composition of precipitation over southeast Asia, J. Geophys. Res., 103(D22), 28721-28742, doi:10.1029/98JD02582, 1998.

Bolch, T., and Coauthors: The state and fate of Himalayan glaciers. Science, 336, 310–314, doi:10.1126/science.1215828, 2012.

Bollasina, M., & Nigam, S.: The summertime “heat” low over Pakistan/northwestern India: evolution and origin. *Climate Dynamics*, *37*(5-6), 957–970. doi:10.1007/s00382-010-0879-y, 2010.

Bothe, O., Fraedrich, K., & Zhu, X.: The large-scale circulations and summer drought and wetness on the Tibetan plateau. International Journal of Climatology, 855(May 2009), n/a–n/a. doi:10.1002/joc.1946, 2009.

Feng, L. and Zhou, T.: Water vapor transport for summer precipitation over the Tibetan Plateau: Multidata set analysis, J. Geophys. Res. Atmos., 117(D20), n/a–n/a, doi:10.1029/2011JD017012, 2012.

Flohn H.: Contributions to a meteorology of the Tibetan highlands. Atmospheric Science Paper No. 130, Department of Atmosphere Science, Colorado State University: Colorado, 1968.

Galarneau, T. J., Hamill, T. M., Dole, R. M., & Perlwitz, J.: A Multiscale Analysis of the Extreme Weather Events over Western Russia and Northern Pakistan during July 2010. Monthly Weather Review, 140(5), 1639–1664. doi:10.1175/MWR-D-11-00191.1, 2012.

Gao, Y., Cuo, L. and Zhang, Y.: Changes in Moisture Flux over the Tibetan Plateau during 1979–2011 and Possible Mechanisms, J. Clim., 27(5), 1876–1893, doi:10.1175/JCLI-D-13-00321.1, 2014.

Günther, F., Mügler, I., Mäusbacher, R., Daut, G., Leopold, K., Gerstmann, U. C., Xu, B., Yao, T. and Gleixner, G.: Response of dD values of sedimentary n-alkanes to variations in source water isotope signals and climate proxies at lake Nam Co, Tibetan Plateau, Quat. Int., 236, 82–90, doi:10.1016/j.quaint.2010.12.006, 2011.

Lei, Y., Yao, T., Bird, B. W., Yang, K., Zhai, J., & Sheng, Y.: Coherent lake growth on the central Tibetan Plateau since the 1970s: Characterization and attribution. Journal of Hydrology, *483*, 61–67. doi:10.1016/j.jhydrol.2013.01.003, 2013.

Lei, Y., Yang, K., Wang, B., Sheng, Y., & Bird, B.: Response of inland lake dynamics over the Tibetan Plateau to climate change. *Climatic Change*. doi:10.1007/s10584-014-1175-3, 2014.

Liu, X., & Yin, Z.-Y.: Spatial and Temporal Variation of Summer Precipitation over the Eastern Tibetan Plateau and the North Atlantic Oscillation. Journal of Climate, 14(13), 2896–2909. doi:10.1175/1520-0442(2001)014, 2001.

Lorenz, C. and Kunstmann, H.: The Hydrological Cycle in Three State-of-the-Art Reanalyses: Intercomparison and Performance Analysis. J. Hydrometeor, 13, 1397–1420.doi: http://dx.doi.org/10.1175/JHM-D-11-088.1, 2012

Maussion, F., Scherer, D., Mölg, T., Collier, E., Curio, J. and Finkelnburg, R.: Precipitation Seasonality and Variability over the Tibetan Plateau as Resolved by the High Asia Reanalysis*, J. Clim., 27(5), 1910–1927, doi:10.1175/JCLI-D-13-00282.1, 2014.

Morrill, C., Overpeck, J.T., Cole, J.E.: A synthesis of abrupt changes in the Asian summer monsoon since the last deglaciation. The Holocene 13, 465-476, 2003.

Saeed, S., Müller, W. a., Hagemann, S., & Jacob, D.: Circumglobal wave train and the summer monsoon over northwestern India and Pakistan: the explicit role of the surface heat low. *Climate Dynamics*, *37*(5-6), 1045–1060. doi:10.1007/s00382-010-0888-x, 2010.

Tian, L., V. Masson-Delmotte, M. Stievenard, T. Yao, and J. Jouzel: Tibetan Plateau summer monsoon northward extent revealed by measurements of water stable isotopes, J. Geophys. Res., 106(D22), 28081–28088, doi:10.1029/2001JD900186, 2001.

Trenberth, K. E., & Guillemot, C. J.: Evaluation of the atmospheric moisture and hydrological cycle in the NCEP/NCAR reanalyses. *Climate Dynamics*, *14*(3), 213–231. doi:10.1007/s003820050219, 1998.

Winkler, M.G. and Wang, P.K.: The late Quaternary vegetation and climate of China. In Wright, H.E., editor, Global climates since the last glacial maximum, Minneapolis: University of Minnesota Press, 221–61, 1993.

Yang, M., Yao, T., Gou, X., & Tang, H.: Water recycling between the land surface and atmosphere on the Northern Tibetan Plateau—A case study at flat observation sites. Arctic, Antarctic, and Alpine Research, 2007.

Yao, T., and Coauthors: Different glacier status with atmospheric circulations in Tibetan Plateau and surroundings. Nat. Climate Change, 2, 663–667, doi:10.1038/nclimate1580, 2012.