

## ***Interactive comment on “Isotopic composition of daily precipitation along southern foothills of the Himalayas: impact of marine and continental sources of atmospheric moisture” by Ghulam Jeelani et al.***

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Reply to interactive comments by Anonymous Referee #1

We appreciate very much the comments of Anonymous Referee #1. They allowed us to improve the overall shape of the MS and forced us to formulate our reasoning more clearly.

1. General comment As a general comment to the content of the MS, Referee #1 wrote: “This MS presented isotopic composition of precipitation in the Himalaya region.

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The isotope data were analysed using a backward trajectory analyses. The authors suggest that ISM evolution results in gradual decrease in isotope value, while WD period generally shows gradual increase in isotope value. The sampling locations are quite unique and important. Although this MS describe the data in detail, interpretation of the data is qualitative and descriptive. It is not clear the motivation of this MS and/or what is new and interesting in term of Atmospheric chemistry and physics. In addition, the data selection criteria must be justified more clearly (see below). I feel that the content is more suitable for hydrological or meteorological journals rather than ACP”.

Reply: Referee #1 suggests that interpretation of the data is qualitative and descriptive. The way of discussing isotopic composition of individual rainfall events from six stations extending over the distance of almost 3000 km and covering 3-year period (548 isotope data in total), presented in the MS, is in our opinion the only feasible way of gaining deeper insight into mechanisms and parameters controlling isotopic composition of precipitation in the important region of southern foothills of the Himalayas. Fully fledged modelling of isotope cycles in the regional atmosphere of Himalayas, with daily resolution and well represented continental feedback, would require vast amount of data not available to date and is beyond the reach of current crop of global general circulation models. Instead, the art of discussion presented in the MS and supported by extensive backward trajectory modelling provides in our view valuable, general understanding of physical factors controlling isotopic composition of precipitation in the Himalaya region. As to the appropriateness of publishing the MS in ACP we refer to the webpage of the ACP (Aims and Scope section, [https://www.atmospheric-chemistry-and-physics.net/about/aims\\_and\\_scope.html](https://www.atmospheric-chemistry-and-physics.net/about/aims_and_scope.html)) where subject ‘precipitation’ and ‘isotopes’ is explicitly mentioned: “The main subject areas comprise atmospheric modelling, field measurements, remote sensing, and laboratory studies of gases, aerosols, clouds and precipitation, isotopes, radiation, dynamics, biosphere interactions, and hydrosphere interactions (for details see journal subject areas). The journal scope is focused on studies with general implications for atmospheric science rather than investigations that are primarily of local or technical interest”. Therefore, we leave the question of

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appropriateness of the MS to the judgement of the editors of the ACP.

## 2. Specific comments

P 4, L5-8 “A station, Srinagar, shows almost no rain during the ISM season (July-September) (Figure 2). There is no reason to assign the Srinagar station as a ISM affected station. Backward trajectory and isotope data at this station (in L11-13) should not be used as a reason because they are the data of this study which will be shown in Section 4.”

Reply: In the revised MS we have made reference to Section 4.1 (Fig.3 and Table 3) and Section 5.1 (Fig. 7) to support the statement. In fact, in our view, the characteristic decline of  $\delta^{18}\text{O}$  ( $\delta^2\text{H}$ ) values at the onset of ISM period (cf. Srinagar  $\delta^{18}\text{O}$  record in Fig. 3) is a powerful tool to identify arrival of monsoonal air masses even in situations when precipitation amount does not indicate this. We underlined this fact in the conclusions.

P5, L6-9 “negative d-excess value were not considered in subsequent evaluation: : :in total, 35 isotope records were marked as locally affected: : :for Jammu station (19 out of 98)” This is the most fundamental problem in this paper. How can you prove that there is no negative d-excess value in this region? Minima of d-excess values in Figure 3(b), Figure 5, and Figure 6 are zero. This is very unnatural. There should be many negative value data of d-excess, which did not show in the MS. The authors should justify this data selection criteria. For example, an data set of African monsoon event shows negative d-excess data (e.g., Risi et al., 2008) In addition, I suggest that all the data should be published as Supplementary data”

Reply: Isotopic composition of maritime water vapour is formed in the process of evaporation of surface ocean water. This process is well described by Craig and Gordon model (see for instance review paper by Horita et al. 2007) where two fractionations steps are postulated: (i) equilibrium fractionation between liquid and vapour phase of water, and (ii) kinetic fractionation step, which is linked with transport of water vapour

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through laminar layer of the atmosphere adjacent to the interface. Whereas the ratio of equilibrium fractionations for  $^2\text{H}$  and  $^{18}\text{O}$  isotopes is approximately 8 and causes the equilibrium vapour to be located in the  $\delta^2\text{H} - \delta^{18}\text{O}$  space on the line with the slope 8 and intercept zero, the kinetic fractionation step which is characterized by the ratio of kinetic  $^2\text{H}$  and  $^{18}\text{O}$  fractionations equal ca. 0.9, moves this vapour to the line with the slope equal 8 and intercept equal 10. Since subsequent in-cloud condensation is considered to be equilibrium process, the rainfall, which is leaving the cloud base will stay on this line with the slope of 8. This is why the Global Meteoric Water Line is described by the equation  $\delta^2\text{H} = 8\delta^{18}\text{O} + 10$  (see for instance seminal paper by Merlivat and Jouzel, 1979). If rainfall is formed from continental moisture sources under transient conditions, the isotope mass balance considerations suggest that it should have generally higher d-excess values than the original water because vapour generated in such processes will have d-excess values higher than 10. From the above discussion it is clear that it would be virtually impossible to generate negative d-excess values in typical regional rain-forming processes. As we were interested in such processes, we decided to remove from the discussion all the data for daily rainfall events exhibiting negative d-excess values. We did not said in the MS that “there is no negative d-excess value in the region”. We only stated that those are most probably locally influenced data (below cloud base evaporation of rain drops and/or evaporation of collected rainfall in the rain gauge). As our focus in the MS was clearly on regional processes, such decision was in our view justified. In the section 7 (Data availability) we will mention that all data, including those, which were not considered in the discussion, will be available on request.

P5, L17-19, “ensemble members released at 12:00 LT on the days with precipitation sample collection” The backward trajectory may change significantly before and during precipitation events. Thus, the fixed release time may cause some bias.

Reply: Good point. Unfortunately, we had no information about exact timing of precipitation events (except of the date). Thus, we were left with two options. One was

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to calculate a single release starting on a given hour (midday was selected), which has the potential problem of representativeness that Referee #1 mentioned. The other option was to calculate several releases during the selected day and use them all in the analyses. For footprint analyses, the timing of release has little significance, as we used 3 years of daily releases. We wanted to represent large scale transport patterns here, and there is no reason to expect that night-time releases would show a different pattern. In case of individual rainfall events, adding additional trajectory ensembles would be most meaningful in case of frontal passages. However, one has to remember the resolution of meteorological data driving Hysplit analysis (3h temporal, 1deg x 1deg spatial), which already added uncertainty to the transport analysis. We have considered and estimated this uncertainty by using the ensemble analysis. Even if a strong frontal system would be passing over the station on a given day, it is likely that the ensemble scheme would capture at least part of the variability of the transport patterns. In fact we took a closer look at the events presented in Fig.7 and Fig.8, generating the trajectories for the whole given day (every three hours). The results did not display significant changes in ensemble patterns – neither in terms of trajectory source areas, nor in the behaviour of presented meteorological variables. In the revised manuscript we will include the paragraph discussing the question of representativeness of backward trajectory analysis for individual rainfall events.

Figure 5 (bottom) “ Why you plotted (1-RH) not simple (RH)? Then, the dxs-RH regression line can be compared and discussed with the similar secondary evaporation effect found in African Monsoon region (Landais et al., 2010)”Discussion paper

Reply: In the framework of Craig-Gordon evaporation model the actual magnitude of kinetic fractionation is controlled by humidity deficit (1-RH), not by RH. Therefore, we considered it more appropriate to relate the d-excess of individual rainfall events to 1-RH. In this representation the d-excess values tend to drop with increasing humidity deficit, as one would expect it for partial evaporation of raindrops.

3. Technical corrections

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P7, L1-20, “These paragraphs appear to be simple description of the result. In fact, Fig. 3-5 were already described in Result section (4.1.). I feel that other paragraphs in discussion section are somewhat lengthy”

Reply: We tried to be rigorous and separate the presentation of the generated data in the form of Tables and Figures from the discussion of those. We feel that this way makes the text and the overall appearance of the MS more transparent and digestible. In the Discussion section we tried to be as comprehensive as possible, and explain all aspects of the presented data in sufficient detail. In our view, significant shortening of the Discussion section would have a negative impact on the overall value of the MS.

Table 1. “The number of samples” differs significantly in each station. I guess number of rain event differs. Thus, please add “number of precipitation day”.

Reply: Labelling of last column in Table 1 will be modified accordingly.

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