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Interactive comment on "The role of precipitation for high-magnitude flood generation in a large mountainous catchment (upper Rhône River, NW European Alps)" *by* Florian Raymond et al.

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The authors would like to warmly thank the anonymous reviewer for his.her useful comments and suggestions which will help to significantly improve the manuscript. Please find below our answers to the reviewer comments:

*)The manuscript is difficult to follow. The flow data are first described as coming from three catchments, then two, and finally one catchment, being runoff from a heavily regulated catchment where the considered flow is the combined flow from two of the smallest catchments.

C1

response:

Sorry for the confusion probably due to the lack of details when using the discharge dataset. The study focuses on the upper Rhône River catchment, for which the Rhône@Bognes gauge station records daily mean discharges at the outlet of the catchment (10 900 km2). To study the flood dynamic within this catchment, three sub-catchments have been also considered: (i) the Geneva catchment (8 000 km2) with the Rhône@HDI gauge station at the outlet of this sub-catchment, (ii) the Arve catchment (1 900 km2) with the Arve@BDM gauge station at the outlet of this sub-catchment, and (iii) the Valserine catchment (1 000 km2). For this latter sub-catchment, no gauge station is available, the daily mean discharge is thus estimated as follow: discharge of the Valserine catchment = Rhône@Bognes – (Rhône@HDI + Arve@BDM).

*)The data are described as being adjusted for seasonal variation, but all results are reported as flow values.

response:

In fact, we display deseasonalised anomalies evolutions of the discharge for the 4 flood-types in Figs. 5, 7 and B1, to capture how abnormal were the discharges during the floods. In this study, when we talk about "anomalies" of discharge, it always refers to the "deseasonalised anomalies".

However, we also show the daily flow values associated with the 28 flood events in the Fig. 6, this is not "anomaly" but the observed daily mean discharge values associated with the 28 floods, to identify the strongest floods of our sample of high-magnitude flood events.

The manuscript will be changed to avoid the confusion; we will clarify this point from the beginning.

*)With respect to the precipitation two sources are available, station data and ERA-20. I have not worked with ERA-20, but I expect that it - like the other ERA reanalysis

products - to some extend are based on measured station data for precipitation, at least for some of the years. Hence the study most likely uses and compares different data products on which on is based on the other. Please clarify what data sources are used in the study and how they are used.

response:

The gridded ERA-20C reanalysis are indeed used as daily precipitation dataset over the 1923-2010 period. The full description of the ERA-20C reanalysis is given in Poli et al. (2016), where the authors explained the data assimilation procedure. The observations assimilated in the ERA-20C reanalysis are:

- the marine wind;

- the surface pressure;

- the sea ice concentration;

- the sea surface temperature;

- the solar radiation;

- the tropospheric and stratospheric aerosols;

- ozone;

- and the greenhouse gases.

No precipitation observation is assimilated in the ERAC-20C building process. Hence, the ERA-20C precipitation dataset is independent from the weather station data we used for the evaluation.

Poli, P., Hersbach, H., Dee, D.P., Berrisford, P., Simmons, A.J., Vitart, F., Laloyaux, P., Tan, D.G.H, Peupley, C., Thépaut, J.N., Trémolet, Y., Holm, E.V., Bonavita, M., Isaksen, L., Fischer, M.: ERA-20C: An Atmospheric Reanalysis of the Twentieth Century, J. Clim., 29, 4083-4097, https://doi.org/10.1175/JCLI-D-15-0556.1, 2016.

*)I don't understand how Figure 2 can be used to deduct exactly which data are used in the cluster analysis and how.

response:

This point has been also highlighted by Reviewer 1. The text will be changed in order to better describe our methodology and to avoid the confusion.

Fig.2 is indeed a bit difficult to understand.

To capture the main flood characteristics (i.e. as proposed by Merz and Blöschl, 2003, short-rain or long-rain floods), we tested different time sequences of precipitation occurring prior to the floods. This allows to highlight the time sequences that have the main influence on the 28 observed flood events.

We focus on two aspects: the precipitation duration (number of consecutive days) and the occurrence of the precipitation sequence (with respect to the flood day). In total, we studied 10 precipitation durations (from 1 to 10 consecutive days). The mean percentile is thus computed for these 10 durations. Then, to analyse the signature of the occurrence of the precipitation sequence on the flood day, we compute the mean percentile of the 10 precipitation sequences for 11 ending times (from 10 to 0 days prior to the flood).

To illustrate this approach, Fig. 2 is proposed as a conceptual graphic illustrating the 10 precipitation sequences, i.e. from 1 to 10 consecutive days (y-axis) which end from 10 days to 0 day before the flood day (x-axis).

The selections of the precipitation durations and the ending times are based on the analyses of Fig.3 and 4, respectively. Fig.3 displays the mean percentile values associated with each of the precipitation duration (colours) and for each ending time (Up to...). It aims at identifying the durations that have the greatest influence on the 28 flood events. The higher the percentile value is, the more the precipitation duration is related to high precipitation accumulation, compared to the entire period studied. From

Fig.3, the following comments can be made: the precipitation accumulation has the greatest influence on the floods when we consider the precipitation sequences until the day before the flood (D-1) whatever the duration.

Fig.4 displays the distribution of percentile values for the 10 precipitation sequences ending at D-1. The selection of the best duration related to the high precipitation accumulation is based on precipitation sequences that present the highest mean percentile values and a weakest dispersion within the 28 flood events. The 2-day and 8-day durations are thus selected based on Fig.4.

*)I also find it questionable that the author selects as a proxy for flood the maximum daily flow rates from a catchment that has a concentration time of about 1 day (line 193), after which they conclude that the main type of flood generation mechanism is precipitation. This seems to follow from the design of the study rather than a finding. The delayed response is hence more likely a result of the operation of the dams in the catchment.

response:

We are really sorry but we do not fully understand the meaning of your comment.

Since our introduction was not clear enough to present our objectives (see the last point below), there is probably misunderstanding on the basic assumption of this study.

*)There may be value in the manuscript that I overlook. But in its present form I cannot recommend publication, nor can I give good guidance on how the authors should improve the paper.

response:

According to your feedbacks as well as those from the 2 other reviewers, we realize that the objectives were probably not stated clearly enough in the first version of the manuscript. Please find below the clarified question, motivations and objectives of this study. In the revised manuscript, the introduction will be thoroughly modified to make

these points clearer.

A set of previous studies based on data series starting from the 1960s have shown that regular alpine floods (with annual/sub-annual occurrence) are complex events resulting from numerous processes in interaction like rain variability, snow/ice-melt dynamics, and soil moisture evolution (e.g. Merz and Blöschl, 2003; Sikorska et al., 2015; Brunner et al., 2017; Keller et al., 2018). On another hand, a set of studies focused on single flood cases seen as the largest historical floods and showed that these "extreme" floods mainly result from heavy precipitation accumulations (e.g. Blöschl et al., 2013; Ruiz-Bellet et al., 2015; Brönniman et al., 2018; Stucki et al., 2018).

As stated by Alfieri et al. (2015), "the assessments of the future flood hazard are commonly performed by coupling atmospheric climate projections with land-surface schemes and hydrological models". Accurate flood hazard projections are required by the decision makers in charge of flood risk reduction and water resources management at local to regional scales (Kundzewicz et al., 2016). However, expected changes in the magnitude and frequency of floods are highly uncertain, mainly due to i) the large uncertainties of extreme precipitation projections by the global and regional climate models (Sillmann et al., 2013; Kundzewicz et al., 2014; Mehran et al., 2014) and ii) the uncertainties of hydrological modelling (Dankers et al., 2014).

To overcome the uncertainties in the high-magnitude floods hazard projections, and as proposed by Farnham et al. (2018), a complementary approach that would rely on direct links between atmospheric processes and flood occurrences is used in this study. This approach assumes that i) flood events mainly result from "extreme" precipitation and ii) that atmospheric features resulting in "extreme" precipitation can be used as predictors of such events directly from climate projections (e.g. Farnham et al., 2018; Schlef et al., 2019). In this study, we explore the first point, i.e. in what extent the generation of high-magnitude flood events in a large mountainous catchment can be explained by precipitation only. We also analyse the features of precipitation, i.e. its duration and its accumulation, associated with such natural hazard.

To reach this objective, we propose a new approach, at the intersection between the study of regular alpine floods and of largest historical floods, discussed above. We study historical floods that occurred in a given large mountainous catchment and we use long discharge and precipitation datasets (almost a century) to get a "robust" sample of high-magnitude flood events.

Our key results are:

- Precipitation alone seems sufficient to explain 13 of 28 flood events (types 2 and 4). Conversely, precipitation alone is not sufficient to explain the onset of flooding of types 1 and 3, possibly associated with other processes such as snow or ice melting.

- The largest flood events (return time period > 20 years) clearly result from precipitation accumulations only.

- Precipitation accumulations resulting in these flood events are characterized mostly by the 2-day and secondly by the 8-day accumulation, all ending 1 day before the events.

- In this given catchment, only flood events with return time period > 20 years or types 2 and 4 flood events could be associated with atmospheric features. - To link these flood events to atmospheric features, a link between atmospheric processes and 2 and 8-day precipitation accumulations.

We achieve promising results since part (13 of 28 flood events) of the high-magnitude floods seem mainly associated with "extreme" precipitation accumulations only. Interestingly this includes the strongest flood events (return period > 20 years) that have the potential of greatest impacts on societies. Hence, this opens a promising avenue for complementary flood hazard projections if robust links can now be found between atmospheric processes and 2 and 8-day precipitation accumulations.

Since this approach mainly relies on the global gridded ERA-20C reanalysis, it can be applied in any part of the world. The main limitation is the need of a long flow series

to get a large sample of high-magnitude flood events. A second limitation may relies on the need of meteorological station data to evaluate the precipitation series from the ERA-20C since they might encompass large biases (as suggested by the reviewer). We trust that this approach could be successfully applied in many parts of the world since we have shown that it can work for high-magnitude events in a mountainous catchment, where the flood-induced hydrometeorological processes are made even more complex by the topography, the presence of snow and ice, etc.

Alfieri, A., Burek, P., Feyen, L., Forzieri, G.: Global warming increases the frequency of river floods in Europe, hydrology and earth system sciences, 19, 2247-2260, doi:10.5194/hess-19-2247-2015, 2015.

Blöschl, G., Nester, T., Komma, J., Parajka, J., Perdigão, R.A.P.: The June 2013 flood in the Upper Danube Basin, and comparisons with the 2002, 1954 and 1899 floods, Hydrol. Earth Syst. Sci., 17, 5197–5212, doi:10.5194/hess-17-5197-2013, 2013.

Brönnimann, S., Rohr, C., Stucki, P., Summermatter, S., Bandhauer, M., Barton, Y., Fischer, A., Froidevaux, P., Germann, U., Grosjean, M., Hupfer, F., Ingold, K., Isotta, F., Keiler, M., Martius, O., Messmer, M., Mülchi, R., Panziera, L., Pfister, L., Raible, C. C., Reist, T., Rössler, O., Röthlisberger, V., Scherrer, S., Weingartner, R., Zappa, M., Zimmermann, M., Zischg, A. P.: 1868 – Les inondations qui changèrent la Suisse : Causes, conséquences et leçons pour le futur, Geographica Bernensia, G94, 52 S., doi :10.4480/GB2018.G94.03, 2018.

Brunner, M.I., Viviroli, D., Sikorska, A.E., Vannier, O., Favre, A.C., Seibert, J.: Flood type specific construction of synthetic design hydrographs, Water Resour. Res, 53, 1390-1406, https://doi.org/10.1002/2016WR019535, 2017.

Dankers, R., Arnell, N.W., Clark, D.B., Falloon, P.D., Fekete, B.M., Gosling, S.N., Heinke, J., Kim, H., Masaki, Y., Satoh, Y., Stacke, T., Wada, Y., Wisser, D.: First look at changes in flood hazard in the Inter-Sectoral Impact Model Intercomparison Project ensemble, Proceedings of the National Academy of Sciences of the United States of

America, 111, 3257-3261, https://doi.org/10.1073/pnas.1302078110, 2014.

Farnham, D.J., Doss-Gollin, J., Lall, U.: Regional extreme precipitation events: robust inference from credibly simulated GCM variables, water resource research, 54, 3809-3824, https://doi.org/10.1002/2017WR021318, 2018.

Keller, L., Rössler, O., Martius, O., Weingartner, R.: Delineation of flood generating processes and their hydrological response, Hydrological Processes, 32, 228-240, https://doi.org/10.1002/hyp.11407, 2018.

Kundzewicz, Z.W., Krysanova, V., Dankers, R., Hirabayashi, Y., Kanae, S., Hattermann, F.F., Huang, S., Milly, P.C.D., Stoffel, M., Driessen, P.P.J., Matczak, P., Quevauviller, P., Schellnhuber, H.J.: Differences in flood hazard projections in Europe – their causes and consequences for decision making, hydrological sciences journal, 62, 1-14, https://doi.org/10.1080/02626667.2016.1241398, 2016.

Kundzewicz, Z.W., Kanae, S., Seneviratne, S.I., Handmer, J., Nicholls, N., Peduzzi, P., Mechler, R., Bouwer, L.M., Arnell, N., Mach, K., Muir-wood, R., Brakenridge, G.R., Kron, W., Benito, G., Honda, Y., Takahashi, K., Sherstyukov, B.: Flood risk and climate change: global and regional perspectives, Hydrological Sciences Journal, 59, 1-28, https://doi.org/10.1080/02626667.2013.857411, 2014.

Mehran A., AghaKouchak A., Phillips T.J.: Evaluation of CMIP5 continental precipitation simulations relative to satellite-based gauge-adjusted observations. J. Geophys. Res. Atmos, 119, 1695-1707, 2014.

Merz, R. and Blöschl, G.: Regional flood risk âĂŤ what are the driving processes?, Water resources research, 39 (12), 1340, doi:10.1029/2002WR001952, 2003.

Ruiz-Bellet, J.L., Balasch, J.C., Tuset, J., Barriendos, M., Mazon, J., Pino, D.: Historical, hydraulic, hydrological and meteorological reconstruction of 1874 Santa Tecla flash floods in Catalonia (NE Iberian Peninsula), Journal of Hydrology, 524, 279-295, http://dx.doi.org/10.1016/j.jhydrol.2015.02.023, 2015.

Schlef, K.E., Moradkhani, H., Lall, U.: Atmospheric circulation patterns associated with extreme United States floods indentified via machine learning, scientific reports, 9, first online published 9 may 2019, https://doi.org/10.1038/s41598-019-43496-w, 2019.

Sikorska, A.E., Viviroli, D., Seibert, J.: Flood-type classification in mountainous catchments using crisp and fuzzy decision trees, Water Resour. Res, 51, 7959-7976, https://doi.org/10.1002/2015WR017326, 2015.

Sillmann J., Kharin V.V., Zhang X., Zwiers F.W., Bronaugh D.: Climate extremes indices in the CMIP5 multimodel ensemble: Part 1. Model evaluation in the present climate. J. Geophys. Res. Atmospheres,118, 1716-1733, 2013.

Stucki, P., Bandhauer, M., Heikkilä, U., Rössler, O., Zappa, M., Pfister, L., Salvisberg, M., Froidevaux, P., Martius, O., Panziera, L., Brönnimann, S.: Reconstruction and simulation of an extreme flood event in the Lago Maggiore catchment in 1868, Nat. Hazards Earth Syst. Sci., 18, 2717-2739, https://doi.org/10.5194/nhess-18-2717-2018, 2018.