Comments of Reviewer 3 (Anonymous Referee) and responses

We really appreciate your suggestions to improve the manuscript. Below you can find the according revisions and comments.

Major comments

Comment 1: From my point of view the manuscript is not very well balanced with respect to the initial goal to transfer damage models to other regions. While the majority of the literature cited is dealing with flood damage (and consequently corresponding depth-damage functions), there should at least be a discussion on the differences of flood risk assessment in lowland rivers (such as Elbe, Mulde, Rhine mentioned in the cited studies) and mountain streams such as the branch of the Lech river the authors were studying[1]. The flood characteristics, and consequently the incurring damages or at least damage patterns are highly variable between lowland rivers (static inundation) and mountain rivers (dynamic inundation). This should be discussed in the respective introductory part of the paper. Moreover, since this study has been conducted in the Eastern European Alps, more efforts should be undertaken to describe the current research gap here: there are some studies around related to the application of different flood damage models in Europe, but none of these studies approached mountain rivers so far. The authors may also wish to refer to Totschnig et al. (2011) and Totschnig and Fuchs (2013) with respect to vulnerability functions to be used for mountain streams (this also corresponds to the results presented in Table 4: none of the German loss estimates was within the 95% interval – different process dynamics? Different building types? Different land-use characteristics?).

Response 1: Even if the mentioned studies of Totschnig et al. (2011) and Totschnig and Fuchs (2013) focus on torrent processes like fluvial sediment transport and debris flows, we refer to these studies in a new paragraph in the introduction (after the listing of a variety of damage models and their differences). There, we introduced the general differentiation in static and dynamic floods. In this context we also highlighted the questionable model transfer from lowland areas to mountainous regions such as the investigated area. However, as pointed out in Sect. 2, the study area in the lower Lechtal Valley is limited to the region of Reutte where the valley is very flat and the Lech River has hardly a downward slope. We described now in more detail that the flood event of 2005 in this area was not characterized by large flood velocities with associated material deposits as the widening and renaturation of the Lech River in the upstream part counteracted sediment transport in the flooded area of Reutte which is described by Habersack et al. (2004), for instance. Due to these descriptions and analysis of photographic records of 2005 we argue in Sect. 2.3.2 (where we introduce the applied or derived models) that the use of models for lowland rivers might be (at least partly) justified, even if this study area is rather characterized by a mix between both flood types (dynamic <-> static). In contrast to the three standard functions, the newly derived loss models are also based on loss data which were collected in mountainous areas like in the Erzgebirge (Ore Mountains) or in the foothills of the Alps (Bavaria). Thus the database for the

[1] Moreover, most of the citations originate from one „group“ working on flood risk management, while those working on flood risk in mountain catchments are by chance not considered (with the exception of Papathoma- Köhle et al. (2011)) – it would have been worth to perform a proper literature research on studies related to flood depth-damage/vulnerability functions in the European Alps, since the test site clearly shows characteristics of mountain rivers.

German-wide and Bavarian functions contains also loss cases where not only the static flood type occurred. Of course, none of the areas in the Erzgebirge etc. has an alpine character, but these data also do not represent solely loss data from flat areas affected by slowly-rising river flooding in the lowland. This information is also added now in Sect 2.3.1 where the data basis for the loss functions is described. Thus our approach should be justified as the dynamic flood type occurred only in the headwater of the Lech River like at the towns of Lech and Zürs where the flood in 2005 was characterized by large sediment deposits and high flow velocities (see detailed descriptions of BMLFUW 2006).

Comment 2: Similarly, the item “private precaution” may be tricky to implement since the dynamics of the two process groups (mountain rivers versus lowland rivers) are highly variable: what may be appropriate with respect to lowland river flooding (sand bags) may be not sufficient to resist the high erosive forces in mountain rivers (you may wish to see Holub et al. (2012) for details).

Response 2: As discussed in the previous comment we think that the flat mountain basin of Reutte is not characterized by a high dynamic flood impact like torrent processes. As pointed out by BMLFUW (2006) and identifiable in the photographic records of 2005 the area of Reutte remained free of larger sediment deposits and erosion processes. Nevertheless, you might be right that other protection measures like reinforcement of the buildings etc. are also very promising particularly in mountain regions (e.g. Holub et al. 2012) while others (e.g. sandbags) may fail, particularly in case of torrent processes. Therefore we introduced the importance of specific structural protection measures in mountainous regions (Sect. 2.3.2) as investigated by Holub et al. (2012). However, as we only considered the effect of “flood-adapted building use” and “flood adapted interior fitting” (and no sandbags for instance) which was surveyed in the German surveys (where the new models are based on) as well as in the Tyrolean survey (Raschky et al., 2009) we assume that the loss mitigation effect of these very effective measures is also justified in a mountainous region like Reutte with a rather mixed flood type. Even in the results section (Sect. 3.2) we refer now to the findings of Holub et al. (2012) regarding the loss mitigation effect of structural protection measures particularly in mountainous areas.

Comment 3: The approach to work on a grid-based information of values at risk exposed (section 2.2.3) is one possibility. How do these values correspond to the object-based values published by Keiler et al. for Western Austria (1,900-600 €/m² depending on the building category), since the suggested range (€224-353/m²) seems quite rough in comparison to object-based data here. Please see again my concerns of applying information from lowland rivers to mountain catchments. The authors were stating to assess uncertainties in the assessment, so why not also comparing results from similar studies? So far, some of these studies are just mentioned in the introductory part, which makes it also difficult to assess the “added value” of this NHESSD contribution to the scientific field of flood risk management.

Response 3: In the studies of M. Keiler for Western Austria only average values per whole residential buildings are published like within different hazard zones to summarize the overall damage potential in different hazard zones (see Keiler, 2004; Keiler et al., 2006a). The only specific values of Keiler et al. (2006b) for different building categories are indicated for the building volume, i.e. in cubicmeters (e.g. 350

€/m³ for one-family houses) but not for the building surface, i.e. in square meters like in our case. Your mentioned range of values (600-1900€/m²) were not findable in the literature of M. Keiler for Austria. Similarly, published average reinstatement values for residential buildings in Western Austria in the studies of S. Fuchs are also only available for whole buildings like in Fuchs et al. (2005; 2007) applied in frame of avalanche risk and debris flow risk assessments, respectively. The studies of R. Totschnig are one of the few examples for Austria where object based unit prices in €/m² for dwellings were published. In the work of Totschnig et al. (2011) object-based values for dwellings amount to 1,670 €/m² based on an average value of the Austrian building insurers. In a subsequent study of Totschnig and Fuchs (2013) further but different unit prices are used for residential buildings in Austria. Here the authors differentiate the unit price (€/m²) by the type of storey per building, i.e. living space (with different state of maintenance), attic and basement since they derived these information by fieldwork. Their values ranged from 308 €/m² (attic) to 1904 €/m² (living space, good state).

However, an object-based study is not comparable with a grid-based approach since the work of Totschnig and Fuchs (2013) uses footprints of the single buildings in contrast to our study dealing with grid-based land use and asset information. Therefore other studies convert object-based information to area-specific information by means of building densities and building surface derived from building cadastre like in the study of Jongmann et al. (2012). In that study they found out that the object-based information (€/m²) of discontinuous urban fabric land use/cover (CLC code 112), for example, is 3-6 times higher than the area-specific information (€/m²) in both study areas (Germany and UK). When these conversion factors would be used for our specific values (€ 224-353/m²), the object based values would result in a comparable range like those of Totschnig et al. (2011) for example.

Comparing our results with other grid-based studies like the one of ICPR (2001), for instance, our values are also in the range of these findings. In that study, specific asset values (building fabric) for residential areas range from 181 €/m² (Federal state of Rhineland-Palatinate) to 268 €/m² (Federal state of Baden-Württemberg) in Germany (not indexed to 2006). Even for other Alpine countries like Switzerland the specific values in that study amount only to 275 €/m² (not indexed to 2006).

Nevertheless, to mention also other studies in Austria where asset values for buildings were calculated (even it is object-based) we integrated and opposed the mentioned studies now in the section where the derivation of the asset values is explained (Sect. 2.2.3).

Comment 4: How representative is your result provided by the adapted FLEMOAT in comparison to the three other models mentioned? Here it would be good to see a more balanced comparison between “your” model and those of other scholars. Please do also properly introduce your applied model variations – it is not clear to me how many variations or model runs were performed with which parameter variations. Moreover, when comparing Table 4 to the statements made in section 3.3 (comparison…, pages 3505 ff.) it seems a bit unclear which results are compared to what – it would be probably good to see the reported loss data here. Please be also aware that the figures reported by Habersack et al. (2004) may be not representative for your catchment – your damage data collected is not only marginally higher but almost one third higher, which may be attributed to the “extreme hydrological impact” – see my remarks above: I highly doubt that it is really possible to adapt vulnerability curves from lowland rivers to those from highland rivers.

Response 4: In Sect. 3.3 we compared the results provided by the adapted $FLEMO_{AT}$ extensively with the results of the other models. However, due to the variety of employed loss models we do not discuss each result for each subset in the text as all results are shown in Table 4. In the description we focused only on those functions which performed well or best in the corresponding subset. For example, it has been shown that the polynomial function worked best (in case of the Bavarian subset) followed by the FLEMO model. The results show, however, that a multi-factorial model is not necessarily "better" than simpler stage damage curves which is also pointed out now in more detail at the end of Sect. 3.3. In Table 4 we also inserted now the reported loss data, i.e. the confidence interval between the 2.5th and 97.5th percentile, in the lowest line to make the model results more comparable.
Of course, the figures of Habersack et al (2004) may not be representative for our catchment as the long-term average damage to buildings based on a large number of flood events is considerably lower (not marginally). However, this average value gives a rough comparison about the average damage on buildings in Austria even if the catchment specific loss characteristic disappeared in this figure.
In Sect. 3.4 as well as in the introductory part we clarified how the model variations were performed for the flood risk analysis. Thus it should be more evident now how the 57 model combinations were developed and which of them belong to the "plausible" and "non-plausible" models.

Smaller comments

Comment 5: Page 3488: It is not true that indirect costs only occur outside of inundated areas, they can (and do) also occur as a direct result of the contact with the water body.

Response 5: Thanks for this hint.

Comment 6: Page 3488: Also intangibles can be monetized, they just do not have a market price and therefore evaluation techniques have to be applied (see the works from Andrea Leiter and Magdalena Thöni, both originally from Innsbruck University – you may know them).

Response 6: We included a new sentence to explain that different methods for the valuation of intangible costs exists as pointed out by Meyer et al. (2013), for instance.

Comment 7: Page 3491, line 16: remove 1971-2006, already stated in line 14

Response 7: Done.

Comment 8: Page 3492, line 4: please explain Bebbers Vb here, since this is very specific and may not be known to the international readers of NHESS

Response 8: We added now a few sentences two explain the importance and specific genesis of this weather situation.

Comment 9: Page 3492, line 23: breach

Response 9: Done.

Comment 10: Page 3494, line 12: what precisely is the added value of information here if the data is not shown???

Response 10: By this hint we only wanted to clarify that these hydraulic simulations are not shown on a map. As reviewer #1 criticized (small comment no. 4) that this paragraph contains too much results in advance we already deleted the whole last sentence as this one does not belong to this section.

Comment 11: I did not get the difference between the official and new categorization of buildings in Austria (two-family houses versus semi-detached house etc. -> needs more explanation)

Response 11: Indeed, it was not clear before what the difference between the official and new categorization is. Therefore we added shortly how residential buildings are classified in the official statistical data for Austria to understand the differentiation between the two terms. As two-family houses are not directly the same as semidetached houses we introduced this term for the following reasons:
1) A semidetached houses is a more technical term and refers particularly to houses which are joined on one side by a common wall and are based on two different land parcels
2) A two-family house, in contrast, is a more general and vague term which may include semi-detached houses but also two-storey houses (vertical division) lived in by two families.
From the official statistics it is not clear whether the building is semi-detached or not. We only derived this type by the number of apartments per building. Thus this term fits more in this context even it sounds equal.

Comment 12: Page 3504, lines 16ff.: Should go to conclusion section

Response 12: That's right. We moved now these statements to the conclusion section.

Comment 13: Page 3510, lines 16ff: I am wondering whether the homogenous means in terms of building types, in terms of process patterns or triggering processes, or a combination from them – probably this is one of the core challenges throughout the entire paper. What does make the Austrian sample similar to the Bavarian, and why there is the difference to the study from Saxony?

Response 13: As already replied to the comments no. 10 and 15 of reviewer #2 we added new information in Sect. 2.3.1 to explain in more detail how the Bavarian and Saxon samples differ (e.g. in regard to the flood impact). In the conclusion section (antepenultimate paragraph) we discussed that similar building characteristics as well as the flood characteristics of the single events may play an important role for the similar flood loss relationship. Since the mean flood losses on buildings in Saxony were considerably higher it is expected that also the extreme event character of the flood (in the year 2002) lead to a different damage figure, apart from differences in the building characteristics.

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