Comments on "Extrapolating glacier mass balance to the mountain range scale: the European Alps 1900–2100", by M. Huss, *The Cryosphere Discussions*, 6, 1117-1156 (2012):
J. Graham Cogley, May 2012

General Comments
This paper addresses the problem of estimating mass balance for whole mountain ranges, given a substantial number of single-glacier measurements of diverse kinds. Several ways of extrapolating from the single glaciers are investigated, and the best results are found for multiple regression on geometric and physiographic attributes of the measured glaciers, extended to the same attributes for glaciers without mass-balance measurements (but included in an inventory). Validation against independent estimates shows good agreement. The computed mass balance of glaciers in the European Alps is found to have a confidence range of 40 mm w.e. a^{-1}, with a similar uncertainty for modelled mass balance over 1900–2011. Projections for the 21st century suggest that depending on the chosen climatic scenario the glaciers of the Alps will have shrunk to between 18% and 4% of their 2003 extent by 2100.

I found this study to be very interesting and very thoroughly and competently conducted. Most of my substantive concerns, detailed below, are minor. The most substantial relates to inadequate treatment (in fact, possibly neglect) of collinearity of the independent variables of the multiple regression that is at the core of the preferred extrapolation method. Subject to the author's consideration of this and other concerns, and to his making some fairly minor stylistic improvements, I see no reason why this paper should not become a welcome addition to the literature.

Substantive Comments
P1118
L23   "eustatic" is better avoided. It refers to the globally averaged total sea-level change, not to the component due to ocean mass change. It can simply be omitted.
P1119
L13   I do not understand this. Does it mean that time series from different glaciers tend to be well correlated?
L20-24 The accuracy of extrapolation from centreline traverses has been questioned by Berthier, E., E. Schiefer, G.K.C. Clarke, B. Menounos and F. Rémy, 2010, *Nature Geoscience*, **3**(2), 92–95.
P1123
L21   Detrended data: if they were also normalized, say so.
L23   Clarify by ending the sentence at "2100", then saying "The combination of RCPs and individual GCMs yielded a total of 35 such series."
P1127
L7   These citations are rather odd because, although the sources present arithmetic averages, those averages are not the basis of the large-scale balance estimates.
P1128
L1   Mention the effect on the 100-year mean of *including* the debris-covered glaciers.
L21-25 But it is also true that a rising ELA has less far to go to reach the maximum elevation of most smaller glaciers.
L27-28 The Lliboutry model (1974, *Journal of Glaciology*, **13**(69), 371-392) almost qualifies as multiple regression. (See also Letréguilly, A. and L. Reynaud, 1990, *Arctic and Alpine Research*, **22**(1), 43-50.)
P1129
L16   Something has gone wrong with Table 2, in which the sum of entries in the R_{var} column is 104.9% and the variance explained by easting seems improbably large (it contradicts the "slight decrease" mentioned at L21).
L1-22   This discussion needs further work. Nothing is said about the collinearity (i.e. non-independence) of the supposedly independent variables. For example I would expect easting and median elevation to be well correlated for reasons to do with continentality.

There should also be some discussion, if only brief, of the suitability of linear as opposed to nonlinear regression models.

P1130

L23   Should "distribution" be "distributions"? That is, are the distributions those of the glaciers individually, or of the two variables over all the glaciers?

P1134

L14-15 Logically it seems that layers 2 and 3 ought to be transposed.

P1135

L2   Change "normally" to "independently". Normality is not required as a justification of the upcoming calculation, but independence is.

P1137

L21-24 This remark is entirely accurate, but not very helpful when (as is true of most of them) your mountain range has fewer than 5-10 series. Say something to indicate that help is coming (e.g. on P1139).

L28-29 The mass balance of Stubacher Sonnblickkees has been reported for the past decade or more by relying on measurements of the accumulation-area ratio, the latter variable being calibrated against early glaciological mass-balance measurements.

Stylistic Comments

P1117

Title   "mountain-range" should be hypenated here and in most occurrences in the body of the paper (wherever it is an adjective).

P1118

L2   "single-glacier".

P1119

L7   "than by regional" would be clearer.

L10   "representative of".

L29   "large samples of glaciers".

P1120

L3   Change "strong variability" to "large difference".

L6   "uncertainty in accumulation,".

L8   Change "100" to "hundred".

L17   "used by".

P1121

L3   Change "data" to "information", and make the same change at L7.

L12   Delete the redundant "different".

L15   Delete "Digital Elevation Models (" (acronym defined on P1120).

L20   Change "totally >" to "more than".

L23   Insert "by interpolation" after "glacier size". "Thus conventional mass balance, that is referred to the actual glacier geometry, is evaluated".

P1122

L20   Most people think of sensors as having "wavelength bands" rather than "frequency bands".

P1123

L1-2   "By using them as a mask for terrain …".

L16   Delete "respective".

L18   "as averages within the perimeter".

L26   "by 2100".

L26-27 "to drier conditions and warming greater than the annual average in summer".

P1124

L8-9   Delete either "e.g." or "etc.".

P1125

L1-2   "Four regions for the study of … are defined by the drainage divides of …".

L17   Delete "subsequent" (it should be "sequential", but even then it would not be doing any useful work).

P1126

L3   Delete "Relative".

L6   "percentage".

L7-8   Change "not covered" to ". Glaciers not covered", and "based on" to "were grouped into".

L11   Delete "Whereas,".

L14   Insert "of" after "suitability".

L16   "balances to those of the same 38".

L24-25   "of the difference \bar B^{ex} – \bar B^{obs} between … B^{ex} is evaluated.".

P1128

L2   Change "implicitly assumes" to "implies".

L13   Change "compared to" to "than those for".

L28   "foundation" would be better than "basis".

P1129

L4   "Multiple linear regression".

L7   Change "multiplicators" (no such word) to "factors", or more accurately to "parameters".

L24   Change "a better" to "better agreement".

L27-28   "for extrapolating mass balance to the mountain-range scale from an imperfectly representative sample …".

P1130

L11   "in part to the considerable".

L15-16   Delete "can be explained and" and change "when accounting for" to "by taking into account".

L23   "are crucial".

P1131

L6   Delete "individual".

L15   "two dozen large".

L22   "on the four RCPs".

P1132

L3   "which are assumed to be representative in both …".

L19   "in 1900 to less than 1900 km^2 at present". ("presently" means "soon".)

L23   Change "maximal" to "greatest".

L24   Commas around "1977".

L25   Comma after "1900", and change "were subject to" to "have experienced".

P1133

L7   "comparatively".

L21   "The emission changes of RCP8.5 force a …".

L22   Delete "down wasting with".

L26   "remarkable also that even with".

P1134

L2   "mass balances".

L5   "widely" is unclear – "generally"?

L8   "comparatively".

L8-9   "Melting of valley glaciers, currently over 100 m thick, requires ...". ("several" is an exaggeration.)

L10   "progressively more negative".

P1135

L1   "volume change".

L9   Change "based on" to "measured by".

L16   "obtained by".

L19   "Merging evidence from all theses sources, …".

P1136

L2	Delete "local".
L3	Delete "sites".
L10	Comma before "which".
L14	"balances or time series".
L16	"The size of the sample of surveyed".
L17-18	Move "is" to follow "rarely". Change "poses" to "imposes".
L26	Change "Alps is" to "Alps, are".
L28	"poorer" would be better than "lower".
P1137	
L3	"fewer than", not "less than".
L26	"method and longer than".
P1138	
L10	"difficult to quantify".
L11	Delete the redundant "realistically". (Adverbs that split infinitives always obscure some semantic or syntactical problem, usually – as here – that the adverb itself is redundant.)
L14	Spell out "four".
P1139	
L4-5	"from the single-glacier scale to the mountain-range scale".
L7-8	Delete either "e.g." or "etc.".
L9	No comma after "Whereas".
L17	"with an error of".
L18	"fewer than".
L20	"balances".
L26	Comma after "volume", and change "was lost" to "has been lost".
P1140	
L13	Delete "be".
L14	"changes are based".
P1147	
Table 2	Caption, L4-5: "total variance" (delete "explained").