Comments on "An assessment of uncertainties in using volume-area modelling for computing the twenty-first century glacier contribution to sea-level change", by A.B.A. Slangen and R.S.W. van de Wal, *The Cryosphere Discussions*, 5, 1655-1695 (2011):

Graham Cogley, June 2011

General Comments

This paper has a self-explanatory title. It addresses several, but not all, of the uncertainties that are likely to affect projections of sea-level changes due to glacier mass loss over the 21st century. The leading sources of uncertainty are found to be the specification of mass-balance sensitivity to climatic forcing, the inadequacy of basic information about individual glaciers, and (potentially) failure to allow for the fact that glacier responses lag behind the forcing. Lesser contributions are made by the volume-area scaling factor (the scaling exponent not being considered) and by discrepancies between the climate models from which the forcing is taken. Sources of uncertainty that the paper does not consider, although they are mentioned in the Conclusion, include "scenario uncertainty", the behaviour of tidewater glaciers, and "measurement uncertainty" in a sense broader than that implied by the paper's comparison of two different glacier inventories. The authors estimate that the sources that they study combine to give a total uncertainty of about ±30% for the glacier contribution to sea-level rise over the period 1990-2090.

I found the paper to be well written and well executed, interesting and valuable. I recommend that it be accepted for publication subject to revision by the authors in light of the detailed comments below.

Substantive Comments

P1656

L7 Clarify. Most volume-area formulations have two parameters (sometimes three). "scaling constant" should be something like "fitted parameters". We learn later that in fact only one of these parameters is being investigated, however; perhaps change "scaling constant" to "scaling factor", although not all readers will grasp that a factor is a number that multiplies another number.

L14 Give the total sea-level contribution, perhaps by adding "or ...%" after "0.027 m".

L16-23 The paper might be strengthened by adopting a more general classification of the sources of uncertainty: glaciological measurement uncertainty; glaciological analytical uncertainty; climate-model uncertainty, measured by the spread of outputs from different models; and scenario uncertainty, measured by the spread of outputs from different runs of the same model. Reasonably enough, the paper does not consider scenario uncertainty, but it should at least be mentioned as a part of the larger picture. Of more concern is the lack of explicit treatment of measurement uncertainty, other than through the comparison of inventories.

P1659

L17 Parameters held constant for ice caps: perhaps this is reasonable, but surely most of the mass will be lost from the ice caps, which hold most of the initial mass, rather than from the smaller glaciers? See comment on P1663 L20 below.

P1660

L8-9 There are problems here. What are the standard errors of the five parameters in equations 3 and 4? Are these uncertainties factored into the assessment of other uncertainties? Is P to be understood as P_s and P_{ns} in 3 and 4 respectively?
The description leading up to the equations is puzzling, because it says that the sensitivities are functions of the temperatures but the equations say that they are functions of the precipitation alone.

L16 How many samples are there in the ensemble? 144?

P1662

L19 Model outputs are not "data".

P1663

L20 The figure of 90% surprises me. Presumably it derives from the V-A scaling calculations, but we are not told what proportion of the total area is accounted for by ice caps or what

their mass balances are. Over 100 years, I would expect the ice caps to account for much more than 10% of the contribution to sea-level rise.

P1664

L23-24 It is technically correct that Cogley (2009b) adopted 785 000 km^2 for total glacierized area, but Leclercq et al. (2011) used 704 000 km^2 (see last paragraph of their section 2), the result of an update of the Cogley estimate for glacierized area in the periphery of Antarctica.

P1665

L3-7 I do not understand this reasoning. It seems to be over-interpreting uncertain numbers, and adds little to the argument of the paper.

L10 "in the lower range": not an accurate summary of Figure 2, in which R10 and W01 start higher than Leclercq, are lower from about 1920 to 1990, and end somewhat higher.

P1666

L5 "to relate mass-balance sensitivity to precipitation".

L12-13 Delete "for the future scenarios". All the scenarios in the SRES sense are the same, and the sensitivity does not vary with time within each simulation.

P1667

L15-21 The time scale is usually understood as the time for $1 - 1/e$ of the total change to be realized; "hundreds of years" sounds like the time for a much larger fraction. And I do not understand why any size class should reach a new equilibrium before 2100, unless by complete disappearance as in Figure 4b; this point should be made more accurately.

L24 Give the calendar date at which $t = 0$.

L26 Equation 5 suggests that the units of V are radians. Presumably this V is a fraction of some reference value, which should be stated. It would also be prudent to use a distinct symbol, say V^*.

P1668

L5 The paper switches indiscriminately between V as glacier volume, as in Figure 4, and V as sea-level contribution, as in equation 6. One of the definitions should be chosen and adhered to. At what date, if any, does the $\delta V/\delta t$ of eq.6 pass through a maximum? This question is of some interest in the context of water resources, because the answer represents "peak meltwater".

P1671

L1-6 This comparison of two inventories accounts well for the differences seen in Figure 6, but I am not sure of its relevance. The W01 inventory resolves the glaciers with the greatest areas only poorly, and is plainly rather unrealistic as a basis for estimating volumes. For example, it has about three quarters of the total Central Asia area (Figure 7) in glaciers with sizes of 512-1024 km^2, of which there are fewer than 10. I suspect that many of the glaciers in its bin 9 are in fact "glacier complexes" (patches of ice taken from small-scale maps?).

P1672

L5-10 This is not expressed accurately. Except for Patagonia, the Southern Hemisphere will see a sea-level rise *greater than average* and the Northern Hemisphere a rise less than average. According to Figure 10a, only the high Arctic will see an actual drop.

L8 Delete "and". This tends to contradict the claim at P1663 L20. Most of the Arctic ice, by area, is in ice caps.

L14-16 Again, not a very accurate description of Figure 10b. I would say that the differences are "moderate" in Pakistan and Bangladesh and "substantial" in Patagonia and the high Arctic.

P1673

L19 Table 4 would summarize the study better if it had a "No imbalance" row, perhaps below the Total uncertainty row.

P1674

L7-8 It should be mentioned somewhere that there are other ways of building the imbalance into projections, for example by modelling the equilibrium-line altitude and/or accumulation-area ratio explicitly.

P1675

L8-11 The text might also add that an elevation-dependent correction of the climate-model outputs would strengthen the volume-area scaling model. Such corrections are very uncertain for precipitation, but less so for temperature, for which they could be made glacier by glacier for most of the entries in WGI-XF.

L12-18 These numbers for "scenario uncertainty" are substantial with respect to those in Table 4, and reinforce my impression (P1656 L16-23) that the paper ought to say more about it. For example it could be mentioned near the last two sentences on P1676. In the same vein, I suggest also that it would be appropriate to add near this one a paragraph about "measurement uncertainty". Two inventories are better than one, but they do not amount to a systematic analysis of the shortcomings of the glacier database.

Stylistic Comments

P1657

L9 "microclimate" (one word).

P1658

L2 "two assumptions".

L8 Delete "volume".

L12 "into", not "in".

L13 The "Therefore" sentence simply repeats the preceding sentence.

L22 Delete hyphen before "study" (and before "data" at L24; this mistake appears at several places later in the paper).

L28 The "which" clause should follow "Sect. 4".

P1659

L1 Delete one "the".

L7 Delete this sentence and begin the next with "The volume-area scaling method ...".

P1660

L10 Capitalize "Coupled".

P1661

L11 "enlarged" or "augmented" rather than "upscaled".

L18-19 No hyphen before "data" in two places.

L27 "merged", not "divided".

P1662

L12 Delete "almost".

L14 "size distribution" rather than "size".

L20 No apostrophe in "AOGCMs".

L25 "Nakićenović" (two c-acutes).

P1663

L1 "bilinearly".

P1666

L15-21 In idiomatic English, "vary" requires the adverb "by", not "with". It would also be clearer to describe each of the variations as "±*X* %".

L18 Delete "the future". δV is defined on P1663 as the sea-level contribution for 1990-2090.

P1667

L11 "in the literature".

L16 "more quickly".

P1668

L19 Delete "effect".

L22 "green dashed line": the dashes are hard to see at screen magnification less than ~200%.

P1669

L3 "deviations of about ±1 cm" would be clearer, with "±0.5 cm" in the next line.

P1670

L7 The paper switches often between cm and m for the amount of sea-level change, which is rather distracting. Consistent use of one unit would promote readability.

L19 “investigate” rather than “establish”.
L25 The volume is proportional to the 11/8ths power of the area, which is not “exponential”.
P1671
L5 “number”, not “amount”.
P1673
L8-9 “The average absolute deviation”, presumably.
P1674
L13 Delete “sets”.
P1676
L8-9 Say “the uncertainty due to differences of analytical method”.
L12 Perhaps “foci” or “targets”, to avoid repeating “points”.
L16 “J.G. Cogley” or “G. Cogley”.

Table 1 “Russian Arctic” would be a more accurate name than “Franz Josef” (note, not “Jozef”).
Figure 3 Use the same number of decimal digits on each axis for each tick label. Change the vertical-axis title to “Scaled volume or volume change”.
Figure 11 In the caption, change “per climate model” to “for the 12 climate models and the two glacier inventories”, and “per data set” to “for each inventory”.
It occurs to me that this paper may be using “ensemble” in a sense different from that which is usual in climate modelling (a collection of runs from a single model).