

***Interactive comment on* “How relevant is the deposition of mercury onto snowpacks? – Part 1: A statistical study on the impact of environmental factors” by D. A. Durnford et al.**

Anonymous Referee #2

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Dear Editor and Authors- I am pleased to provide this review of: acp-2011-995 How relevant is the deposition of mercury onto snowpacks? Part 1: A statistical study on the impact of environmental factors D. A. Durnford, A. P. Dastoor, A. O. Steen, T. Berg, A. Ryzhkov, D. Figueras-Nieto, L. R. Hole, K. A. Pfaffhuber, and H. Hung

General Comments: This paper takes a wide array of data from numerous studies and locations in the arena of mercury and snow chemistry. The authors do a good job of collating the data and describing most of the specifics on the variety of statistical measurements they make. The paper will be of interest to snow chemistry and, specifically, mercury chemistry researchers.

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The work is solid enough to be published in ACPD but I recommend the following comments/ideas be addressed:

In the future PLEASE provide line numbers to make the Reviewer's job easier. The Journal should do this and if not then the Authors should. It is annoying to guide people to locations in the manuscript without line numbers. This turns off Reviewers.

The most tangible result from this paper, in my mind, is the fact that if you have greater halogen content you have higher Hg. This is likely because the HgX₂ (with X being a halogen) is likely one of the forms of AMDE Hg deposited to snow surfaces. And of the various forms postulated, perhaps it is least likely to be photo-reduced. The more this paper can speak to this the better. I like the idea of "less ice, more dynamic, more leads, more halogens, so likely more Hg scavenging or retention." This should be the focus of the paper. End the abstract with it and perhaps add a paragraph in the Introduction stating that the sea ice world is changing and this could alter Hg deposition or retention. The recent JGR papers on frost flowers and sea ice chemistry from OASIS speak to this. Mentioning this would strengthen the paper and add some needed context.

A final comment for the paper overall: I think you could say "taken in total, the results from this study suggest that the fate of Hg in snowpacks with low halogen concentrations is more predictable and thus more amenable to modelling application while the results from halogen rich snow are not as predictable and thus not as readily modelled. Due to the expected loss of sea ice and the various processes expected to increase the halogen content of snow the Hg content of coastal snow and snow on sea ice will become increasingly more heterogeneous and difficult to predict." ???

Abstract The last four sentences fall off into space. Why not lead to the "we find that the presence of" sentence as the final sentence? Or at least provide a summary of where you go and where you are at the end. The current abstract ends with mention of latitude, ventilation, and surface pressure which are not the most exciting results.

Introduction Page 2, paragraph 2 "This result is considered highly uncertain." This is

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a strong statement that is not borne out by any actual research and it should at least be weakened or some studies specific to this statement need to be provided. The references provided are focused on AMDEs and do not address the amount deposited due to AMDEs versus the potential links to the Ocean.

Last sentence in this paragraph: It might be good to say “many studies have tried to determine the fraction revolatilized, give some references, and then say that the studies do not provide substantial reasoning as to why some locations have higher values for loss than others.

The words “revolatilized, “re-emission,” and “emission” should be settled on as one word. The recent AMAP Report on Hg uses “re-emission” to designate Hg that was deposited to snow packs and then photochemically reduced back out to the air. The word “emission” is used for anthropogenic emissions from fossil fuels, coal, etc.

Page 3, top paragraph The results in Figure 1 are unclear. Are the blue data from Steen but the red calculated herein? If not the leave it be. If the data re all from Steen then put the Steen reference at the end of the caption.

Also I disagree that this Figure provides the “clearest result...” because numerous snow studies (many of which are the focus of this paper) show that Hg values go up in the surface snow during and after an AMDE and then the values decrease in snow while the GEM spikes above ambient background. These are real measurements not modelled results and provide ACTUAL confirmation of the process. Sentence should be weakened a bit in its boldness.

Same paragraph and Figure: since the data start on April 5 I would pose that pre-April 5 AMDEs (they typically start as early as February) could have loaded the snow pack so that the “first half” of the data show re-emission exceeding deposition. Without providing the whole season data for this location this statement is not accurate at all.

Page 4, paragraph starting with “The third” The sentence “The snowpack/meltwater is

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described and its performance evaluated in Durnford et al. (2011).” Should perhaps say “The snowpack/meltwater model is described and its performance evaluated in Durnford et al. (2011).”

Page 4, paragraph starting with “concerning” This should be a new section. We are no longer in an Introduction and the paper is moving into something like “Background on the deposition of Hg to Polar snowpacks during AMDEs.” The previous paragraph ends the Introduction in classic style of “this is what we do in this paper” so this should be a new section entirely.

Page 5, paragraph starting with “GEM” It should probably say “GEM is believed to be re-emitted” In this paragraph the word “emission” is used when I argue it is actually “re-emission.” “Emission” would be the “emission” of Hg from particles in the snow that is not AMDE related.

“effected” is used where “affected” should be

Page 7 In the sentence ending both paragraphs on this page close to the same sentence is repeated about “GEM is emitted...” Remove one of these or it is mundane repetition.

Paragraph beginning with “A smaller” Second to last sentence try “is produced within a shaded snowpack”

Page 8 Toward the end of first paragraph “this concentration and the extent of”

I think there should be another Section or topic break here before the paragraph beginning with “Concerning.” Perhaps it is called “Prior work modelling the fate of AMDE Hg in snowpacks” Paragraph beginning with “Concerning” I recommend putting a temperature values in C in parentheses after the 270 K to provide a more easily understood perspective.

Page 9 The Paragraph “In the remainder” is not needed. As stated before- the end of what I would deem the Introduction provides the roadmap for the paper. Either move

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some of this info up there or delete it all together. Otherwise it comes totally out of place.

First sentence in “2. Methodology” No comma needed after “from surface snow”

Page 10, top I do not understand this “a seasonal snow pack lasting for no more than two years” information. By definition, the seasonal snow pack does not last more than one year. This is confusing.

Next paragraph The data is not from “all regions of the globe” as obviously tropical, ocean based, and other locations are exempt. Add “Polar” or “Temperate and Polar” to clarify this.

Next paragraph I do not totally buy the “arbitrarily set to five” call How many of the samples sizes out of what total did this include. If the sample set was “arbitrarily” set to 1 or 10 did this change the outcome substantially?

Page 12 First paragraph “fully integrated in GRAHM because at each”

Last paragraph Comma not needed after “in the gas phase”

Page 13, first paragraph, last sentence I would urge the authors to add “and time of year” to the end of this sentence.

Second paragraph Could you provide a sentence on how the sea surface temperature-emissions relationship is made?

Page 15 Last paragraph By looking from 1971 to 2010 in one set of data and then 2005 to 2009 in another do you assume that Hg deposition between 1971 and 2010 is stable? Is this true? There should be sentence with a reference or two to address this here.

Page 16 First paragraph “two sets of calculations”

“Set 1” instead of “Set1” be consistent

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Second paragraph First sentence: no comma needed after “Set2”

End of this paragraph To distinguish between on sea ice or on land would be a strength of this modelling. Dramatic differences in the amount of halogens (salts) in snow pack hundreds of meters apart but on sea versus land have been reported (Krnavek et al., 2012 Atmospheric Environment, Figure 4 and references therein; numerous other studies). Also- the “on sea ice” versus “on land” aspect would add to the halogen story that I think is the strongest outcome of this paper.

Page 17, top “significant deposition” is perhaps strong or biased. What amount of deposition are we talking?

Sentence “There is no guarantee” “be transported and deposited in an identical”

Sentence “Thus, halogens” “necessarily deposited to the same locations or at the same time.”

Page 18, last sentence in first paragraph: This is in my mind the most important part of the paper.

Page 19 Second paragraph “This average of the absolute values are no higher”

Third paragraph” To show somewhat reasonable” is vague. Do you mean “expected based on the processes involved”?

Page 20 After “(Garbarino)” reference How about a sentence right here saying “This hints at the role of halogens in decreasing the re-emission of Hg from coastal or sea ice-based snow packs”?

Last paragraph “or the four greatest observed concentrations represented by green circles are outliers.”

Page 21, middle paragraph I have no idea what “somewhat horizontal line” is mentioned. Neither the blue nor black circles do this.

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Page 22 End of first paragraph “impact on the retention of snowpack-related mercury.”
“control on decreasing the re-emission of snowpack-related mercury.”

Page 23, top Are there any percentages re-emitted” from any of these studies? Ie comparing halogen rich from halogen poor locales?

Page 24, bottom paragraph Do you mean the fractional loss over time or over wind speed? Somehow this is confusing.

Page 26 I would like to see a reference or two that say Hg values are depressed in high latitudes during the season. On a local scale for a few days, for sure, but at a regional scale through the winter I am not so sure.

Page 27, top Any chance that the snow fall itself is a scavenger of Hg? Ie particles associated with Hg provide nucleation sites or as crystals fall the Hg is sorbed/scavenged? I understand the idea here is more snow means less photochem and less re-emission but what if the snowfall itself was an Hg source?

Page 28 LAI could be a latitudinal aspect or the more shade the less photochem and the less Hg re-emission (as with the previous statements by me and the paper on fresh snow). Might not be ONLY latitude.

Page 28, bottom paragraph Melt water and snow depth This one is hard. More snow means more precip events so perhaps less photochem and less re-emission? More snow could also be a simple dilution. Also- the timing of the snow is key. Places that receive the majority of the snow pack in Oct-Feb will have a large amount of pre-AMDE snow that is definitely a diluter. Places with even or lots of late season snow may have the elevated Hg associated with the photochem “prevention” mentioned previously. I agree that dilution makes the most sense but the seasonal timing of the snow fall might be something in some locations?

Page 29, top For sure the deeper snow packs will take longer to get isothermal and the lower layers will not respond as readily to temperature fluctuations in deeper snow

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packs. The melt freeze cycles likely allow the Hg to be increasingly pooled at the base of the snow pack and this can lead to elevated Hg once the water starts to pool and move downslope.

Page 32, second and third paragraphs Again- what about dry deposition being associated with Hg-bound particles? And likely at coastal locations these are more commonly associated with halogens compared to far from the coast stations?

Bottom paragraph Cool idea about the condensation/nucleation sites. Any references for this? Any more to say about it? Another potential key result from this study if it can be explained in slightly greater detail.

Figures 2 and 5- Add a legend to explain what the various names/symbols mean. It could perhaps be equal in size to one of the plots and could become a 2 by 3 sized plot?

Figures 3 and 4- parentheses are off in the b to e access labels

Figure 3e: The green values really do support the potential that higher halogen concentrations are associated with lower Hg re-emission.

Table with Hg content values: I note that the location, type of snow, and time since AMDE are generally ignored in this modeling and these parameters may be major controls on Hg values measured from snow collected at a given date or time or location or type. Powder versus blowing snow versus surface wind slab. Immediately following an AMDE versus a week after one versus during one. This may be difficult to address with the Tables or modeling but should be stated in the text in at least one location. There is the possibility that apples and oranges are being compared and the results shield this fact.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 387, 2012.

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