Interactive comment on "Bipolar long-term high temporal resolution broadband measurement system for incoming and outgoing solar UV radiation, and snow UV albedo, at Sodankylä (67^{o}N) and Marambio (64^{o}S)" by O. Meinander et al.

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Authors' response to the review of the Anonymous Referee #1

The Authors appreciate and fully agree to all of the constructive comments of the Referee #1. We also agree with the Referee that the comments of the Referee#1 will significantly improve the quality of the revised version of our manuscript. Our respond to each remark is given here below. (The language check will be made only to the final revised version of the manuscript.)

A) General comments

Referee #1 comment:
"The manuscript is divided into two parts. First it presents the bipolar UV albedo monitoring station at Sodankylä and Marambio. It explains in full details the setup and the challenges operating these polar stations. The second part tries to give an extensive overview over albedo measurements, analysis and modeling of these kinds of data. The later chapters are defined as literature review by the authors. The first part is a fundamental manuscript which could be used a master reference not only for further work related to the two measurements station but also to similar projects.

The second part summarizes resent albedo studies. It references to already published work. Although the reader gets a nice overview over these works this section is strongly questionable. Does this literature review fit to the more technical section in the beginning of the paper? These summaries of many publication do not enhance the readability of the manuscript. Thus, on the one hand the reader gets a nice overview of the past studies but on the other hand – without reading the actual papers – it is difficult to grab the paragraphs of this literature review."

Authors' reply
We thank the Referee#1 for this general comment and fully agree. We are also thankful for the sentence describing our paper as *"…master reference not only for further work related to the two measurements station but also to similar projects"*. This is exactly the motivation of the paper. We suggest to use this Referee's sentence in our revised manuscript, as indicated here below.

Our manuscript was originally planned to contain both the technical description, and thereafter a summary (which we called "review" in the original manuscript) showing what has been found in these measurement data so far. Based on the comments of all the three reviewers we suggest to use the word *"summary*" instead the word *"review"*. In addition we suggest to shorten the summary, and move it into the Introduction-section. These literature references are given for the benefit of any future data user. This we suggest to be more clearly stated in the revised version.

Suggested changes in the manuscript:

1) to add the following new sentences: *"The aim of this paper is to serve as a master reference not only for further work related to the two measurements stations, but also to similar projects by others".*
2) use *"summary*" instead of "review" when referring to our earlier results
3) shorten this literature summary from the original literature review (of our own previous results)
4) move the literature summary to the Introduction section.

B) Specific scientific comments

Referee #1 comment 1:
"The following comments should be taken into consideration to improve the quality of the manuscript.
1.) The setup in Marambio is fixed to a container which affects the snow deposition around it depending on the wind direction. How is this effect handled?"

Authors' reply
We fully agree that the Referee#1 detailed comments can be used to improve (and have improved) the quality of the manuscript. Our specific replies, point by point, are given here.

1)The Referee brings out an important question here. We fully agree that the wind can highly affect the snow deposition in Marambio. The effect is taken into consideration by taking photos of the snow surface on a weekly basis. Another solution could be a web camera showing the snow surface more frequently, and placing permanent snow height sticks (still avoiding to disturb the snow surface). Using the existing photographs we know the circumstances at the same moment as the photograph was taken. On the other hand, between the photos, snow surface conditions are unknown. Here clearly exists an improvement possibility for the future for Marambio work, or any snow albedo measurement setup. As a result of this Referee comment, an outdoor IP camera (pointing at the same view of the sensor), has actually been agreed to be installed besides the measurement. Marambio personnel will take the responsibility of installing the camera and programming it to run automatic a photo routine for a timelapsed, while FMI will provide the camera.

Suggested changes in the manuscript (also shown in the revised ms prepared using "track changes")
We suggest to add the following new sentence:

"The setup in Marambio is fixed to a container which affects the snow deposition around it depending on the wind direction. This effect is taken into consideration by snow surface photographs taken on a weekly basis. An alternative solution for the problem is a web camera documenting the snow surface more frequently. This has recently been agreed to be installed besides the measurements. Currently, the Marambio SL501 measurement data are uploaded by automatic routine once per hour to the ftp site and also stored in FMI data base."

Referee #1 comment 2:

"2.) Measuring height of 2m: If the snow accumulation around the setup is more than 1m than the distance between the snow surface and the instrument is below the recommended standard height. Does this never occur at both stations?"

Authors' reply

In Sodankylä the maximum snow height measured during 1911-2016 has been measured to be 119 cm in winter 1999-2000 (ref, http://ilmatieteenlaitos.fi/lumitilastot). Hence, in Sodankylä it is possible to happen. Snow albedo changes according to snow properties, of which the grain size the most critical. On the other hand, albedo is a quantity that also changes according to the measurement height. Therefore, a change in the snow depth also has the potential to affect the measured albedo. It is however currently practically impossible to change manually the albedo measurement height often enough to keep a fixed distance between the downward looking sensor and the snow surface, without disturbing the albedo field. Automatical height change for the albedo sensors would be ideal, but not available. Therefore, we handle this by: automatically measuring the snow height closeby the Sodankylä albedo measurement field, and albedo is measured in a fixed position.

In Marambio, this amount of snow does not occur. In the surrounding area of the Marambio shelter, after the event that heavy snow and/or blizzard, some 10- 30 cm of snow during winter or spring time could collected.

Suggested changes in the manuscript (also shown in the revised ms prepared using "track changes")

We suggest to add the following text:

"The WMO defined albedo measurement height is 1-2m. If the snow accumulation around the setup is more than 1m, the distance between the snow surface and the instrument is below the recommended standard height. This can sometimes happen in Sodankylä, where the maximum snow height ever measured (1911-2016) is 119 cm on 6 April 2000 (ref, http://ilmatieteenlaitos.fi/lumitilastot). Albedo is a quantity that changes according to the measurement height, although snow grain size is the most critical parameter to determine snow albedo. Therefore a natural change in the snow depth also has the potential to affect the measured albedo. As a result, we measure automatically the snow height closeby the Sodankylä albedo measurement field, while albedo is measured in a fixed height. Alternatively, the measurement height could, if possible in practice, automatically changed to keep a fixed distance between the downward looking sensor and the snow surface. A manual change in adjusting measurement height to achieve a fixed distance between snow surface and the sensor can be considered if it is possible without disturbing the measurement or destroying the snow surface.In Marambio, this much snow is not an issue"

Referee #1 comment 3:

"3.) It is unclear what the cleaning frequency of the entrance domes actually is."

Authors' reply

First we need to consider that any visit to manually clean the domes disturbs the measurement and the snow surface. On the other hand, if the dome is dirty, we can't rely on the data. Manual cleaning is therefore done when needed but as seldom as possible to avoid disturbing the measurements. The automatical blowing and sensor temperature regulating systems (a Peltier

element to keep the sensor temperature at 25 deg Celsius; this temperature is measured and reported together with the data at 1 min intervals) partially help to keep the domes cleaner.

In the FMI Sodankylä Arctic Research Center, all the radiation sensors are cleaned always when needed, which means minimum of once a week during snow time. The best estimate is 5 times/month. Sodankylä sensor domes have blowing systems which keep them free of falling snow, and also the blowing dries water droplets away from the domes.

In Marambio, the domes are cleaned once per week. This depends of the weather conditions, which can extend the length of time, that can elapse in some cases between two visits to the shelter (up to 10 days). In fact, the heating system can also clean the domes a bit in certain conditions, but the domes usually gets dirty when it snowing and the permafrost is driven with the wind. The heating system is not so powerful to remove this particles. The upper dome usually is more dirty than the other one. Sometimes there are a little snow (or piece of ice) in the upper dome accumulate. The position of this piece of ice (or snow) cover a small part of the North-East dome sector.

Hence, all the sensors both the Marambio and Sodankylä have blowers on the domes and the sensors have Peltier elements for temperature regulation for 25 deg Celsius.

Suggested changes in the manuscript (also shown in the revised ms prepared using "track changes")
We suggest to add the following new sentence:
"The temporal frequency of the manual cleaning of the entrance domes balances between the facts that manual cleaning disturbs the measurement and changes the surface snow (in the North direction) and that there is a need to clean the domes from dirt to gain as reliable data as possible. In Sodankylä and Marambio the domes are manually cleaned once per week, or when needed."

<u>Referee #1 comment 4</u>
"4.) Is there any kind of ventilation and heating systems (VHS) around the devices? If not, how many measurements are affected by snow accumulated on the sensors?"

Authors' reply
Yes, both in Marambio and Sodankylä the sensors are heated (temperature regulated using a Peltier element to set the sensor temperature to 25 deg Celsius).

Suggested changes in the manuscript (also shown in the revised ms prepared using "track changes")

Instead of saying "temperature controlled", we will we use "*temperature regulated*".

<u>Referee #1 comment</u> 5
5.) In line 191 the life time of sensors is discussed. Do the author mean the lifetime of the calibration or the device itself? Sensitivity changes of this sensor type are mostly affected by the lake of maintenance (old desiccant). This is independent on the light exposure and sensitivity changes happen most frequently in the storage rooms.

Authors' reply

In line 191 we refer to the lifetime of the sensors. We fully agree that sensitivity changes occur even when storing the sensors.

Suggested changes in the manuscript (also shown in the revised ms prepared using "track changes")

The revised version to clarify to what the term "lifetime" refers:

"To prolong the lifetime of the sensor devices, they are not kept outside when the Sun is at lowest. Sensitivity changes are expected to occur also independent on the light exposure. Therefore the responses of the sensors need to be measured on a regular basis. In our case, It means before and after each measurement season of less than 6 months in Sodankylä and one year in Marambio (up to 2 years)."

Referee #1 comment 6

6.) The sensors of Marambio are calibrated in Finland which includes long distance transportation. Sensitivity changes are thus detected after the arrival in Finland. Air travel can strongly affect the sensitivity of the sensor by the lower pressure present during the transport (humidity can enter the device). This can be tested during the calibration period at the calibration facility. Could the authors comment on this point?

Authors' reply

The Referee makes an important note on the air travel affecting the sensors, which we had not included in the original manuscript . For Sodankylä, air travel does not affect, since the sensors are transported by car. For Marambio, the sensors air travel from Finland to Antarctica. After calibration, the calibrated sensors are transported to Marambio

Suggested changes in the manuscript (also shown in the revised ms prepared using "track changes")

To be added: "The sensors of Marambio are calibrated in Finland. The calibrated sensors are then transported to Antarctica in airplanes with long distance transportation. Air travel can in principle strongly affect the sensitivity of a sensor by the lower pressure present during the transport or changes in the humidity entering the devices. Any sensitivity changes are detected and corrected during the calibrations in Finland. As the SL501 sensors are pressurized with nitrogen, the air pressure changes during air travel are not assumed to affect the sensors, and we have not detected any indications of that. For Sodankylä sensors, air travel does not affect, since the sensors are transported by car.

C.) Presentation

Referee #1 comment:

"First of all it should be considered to either move section 3 and 4 to a separate manuscript. Alternatively these to sections could by shortened to one section "Albedo literature review" with a few paragraphs listing the literature references. The emphasis of the paper as indicated by the title should be on the "measurement system" of the

two stations. Currently the paper is divided approx. 60/40. Otherwise the manuscript is clearly structured."

Authors' reply

We fully agree to the Referee comment that the emphasis of this paper should be, "*as indicated by the title, on the "measurement system" of the two stations".* We also agree to the alternative solution suggested by the Referee for better re-organizing the manuscript: i) we agree to the Referee suggestion that sections 3 and 4 could be moved to a separate manuscript. ii) Also we agree that alternatively a shortened section on albedo literature review could be a good idea. To have the focus on the main task of the paper (measurement system) we suggest to shorten the review, and name it a summary, and give the references in the introduction section.

Suggested changes in the manuscript (also shown in the revised ms prepared using "track changes")

We refer here to our reply in A).

<u>Referee #1 comment:</u> "Minor modifications are recommended to improve the quality of the paper:"

1.) Throughout the paper abbreviation are used either without declaration or they are multiple times declared. In addition, no common declaration style is used or late declarationsare used. Consider using the standard style: "first use, first declaration".
Examples without claiming to be complete: line 53 "RT", line 107 "SMN", line 217 "SZA", line 285 "VIS", ...,line 31 and 94 "IPY", line 44 and 59 "UV", line 29 and 77 WMO and (WMO), line 290 – first late declaration of "BC

- ***Authors' reply:*** *We agree that these need to be corrected in the way suggested by the Referee.*

2.) The statement "first time" is used in line 24, 57, 69 and 332. As this is intrinsic for a novel manuscript it is not needed.

- ***Authors' reply:*** *We agree and remove multiple "first times".*

3.) Line 110: "The measurements" change to "The measurement devices" (or similar)

- ***Authors' reply:*** *We agree to change "the measurements" to "the measurement devices".*

4.) Typo line 136: 2pi -> 2_

- ***Authors' reply:*** *Agree, this needs to be corrected.*

5.) Paragraph line 154 to 160 is essentially a copy of the former (146-153). Both paragraphs could be merged together.

- ***Authors' reply:*** *Agree, these paragraphs need to be merged together.*

6.) Equation 2 (if the paragraph remains in the paper) should be written as: A=c*SZA, with A being the albedo decline, c the fit constant and the solar zenith angle SZA (if not previously defined!). In the Neumeyer data c found out to be -0.024 or -0.0024 (line 266 and 268)?

- ***Authors' reply:*** *Agree on the Eq 2, where A is for albedo decline.*

Figure 3: The location of the radiometers at the container is not visible.

- ***Authors' reply:*** *Agree, the photo only shows the surroundings of the containor prior to adding the measurement devices.We will add a new figure (below) showing the pole where the sensors will be (are) attached.*

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Figure 5: Copy of Meinander, 2013. This meaning is only understandable in the context of the original publication.

- ***Authors' reply:*** *Agree that the parameter values need to be given in the revised paper in addition to the literature reference.*