

The authors wish to thank the reviewer for his/her critical comments that provided a constructive guidance to improve the manuscript. Please find our detailed response to the major comments below.

Tilt correction

There exist references which quantify the errors of a sensor tilt in high detail. e.g. Bannehr and Schwiesow (1993), Wendisch et al. (2001). Those are not included in the discussion of the manuscript but may easily point to the problem and magnitude of sensor tilt. Also common correction methods frequently applied to airborne radiation measurements are not compared to the method presented here, nor are these methods discussed (e.g., Bannehr and Schwiesow, 1993). Instead, a rather simplified approach is used to correct for the sensor tilt. This approach is not well explained in the manuscript. Details are missing and assumptions like neglecting diffuse radiation or assuming the diffuse radiation to be height independent are questionable. Additionally, Figure 4 seems to have a bug. At least it show larger tilt errors for high Sun (zenith position) which does not follow theory. So I had problems following the method.

- *Figure 4 shows the error in shortwave downward radiation as a function of sun zenith angle. It is delineated from the data fits displayed in figure 3 and further on it is assumed that based on such fits individual (scene dependent) functions can be obtained. Please consider that figure 4 is displaying absolute units in contradiction to the reference Bannehr & Schwiesow 1992, using percentage error. Recalculating data for figure 4 to percentage error would show an expected behavior: higher errors at low sun altitudes.*

Only one example of measurements at a different location is shown, which certainly does not cover all possible conditions for which the correction needs to be applied. In the end it also was stated, that simulated downward irradiance were used for the analysis of the examples. Finally, I completely lost track of what had been done with the measurements to correct for the sensor tilt and how large the remaining uncertainty is after the correct. Some detailed comments and questions are here and in the list of comments below.

L149: Neglecting uncertainties of a sensor tilt for terrestrial radiation and upward solar radiation might be not acceptable. There should be uncertainties for 10° , which at least need to be quantified. Or a reference needs to be given discussion this problem. Can you estimate what error a 10° tilt would cause if a bright surface and a dark sky would be assumed. Should be possible to calculate from geometry.

- *Mean misalignment for the cloud flights on May 12, 2015, is 1.8° . Saunders et.al. (1992) is stating that 'in diffuse radiation the attitude of the pyranometer is not critical since the measured flux does not vary significantly with the attitude of the pyranometer'. This is given with the cloud flights. It is agreed that bright surface/dark sky aspect might be an issue with the albedo flights. There are two things to consider, first to keep out data points obtained in large misalignments ($>10^\circ$), second the topography around Ny Alesund. It is not a sky flight, we do not exceed 2 km height – tilting the sensor will rather add minor contributions from the surrounding low mountains (thus, snow) and atmospheric scattering.*

L156, Figure 2: For what SZA this example holds? The effect of 5° tilt will be different if the Sun is in zenith. Therefore, I do not understand why this should be shown with a single measurement case. It is possible to calculate the effect from geometry for all possible geometries.

- *Fig 2 shows exemplary, based on measurement data obtained in Lindenberg on March 05, 2013, that a misalignment of the sensor, causing apparent sun zenith change from 65° to 70° , would lead to a loss in shortwave downward of 96 W/m^2 . It is agreed, that a more generalized statement, covering the range of expected SZA, matches better.*

L162: Calculation of individual solar zenith angle: How this transformation is calculated? Provide the equations or a reference. However, it will not help to calculate the individual solar zenith angle if you want to analyse vertical profiles and compare two measurements with different tilt. I do not understand this approach.

- *Equations are taken from https://en.wikipedia.org/wiki/Euler_angles. SZA and sun azimuth for a horizontal plane are calculated using 'zenith'-function come along with libradtran-package (Mayer*

and Kylling, 2005, should be cited too and added to the references). Polar coordinates are converted to Cartesian using

$$\begin{aligned}x &= r \cdot \sin(\text{SZA}) \cdot \cos(\text{azimuth}) \\y &= r \cdot \sin(\text{SZA}) \cdot \sin(\text{azimuth}) \\z &= r \cdot \cos(\text{SZA})\end{aligned}$$

Measured yaw angle (radiation sensors are mounted on a wind vane), pitch and roll from inclinometer provide the true 3d state of the sensor. Building the rotation matrix

$$\text{rotmat} = \begin{bmatrix} \cos(\theta) \cdot \cos(\psi) & \cos(\theta) \cdot \sin(\psi) & -\sin(\theta) \\ \sin(\phi) \cdot \sin(\theta) \cdot \cos(\psi) - \cos(\theta) \cdot \sin(\psi) & \sin(\phi) \cdot \sin(\theta) \cdot \sin(\psi) + \cos(\phi) \cdot \cos(\psi) & \sin(\phi) \cdot \cos(\theta) \\ \cos(\phi) \cdot \sin(\theta) \cdot \cos(\psi) + \sin(\phi) \cdot \sin(\psi) & \cos(\phi) \cdot \sin(\theta) \cdot \sin(\psi) - \sin(\phi) \cdot \cos(\psi) & \cos(\phi) \cdot \cos(\theta) \end{bmatrix}$$

and application on (x, y, z) gives (x', y', z') and converting back to polar coordinates the apparent SZA'. Following the idea introduced here the difference to SZA corresponds to a yield/loss in shortwave downward according to the daily data fit.

L167-169: This assumption is highly risky in my point of view. Especially, if vertical profiles are to be analysed. Direct/diffuse fraction will change in dependence of altitude. Therefore, I recommend to use the analytical equations that can be used to correct for the sensor tilt. Only the direct/diffuse fraction needs to be known. This can be estimated by radiative transfer simulations.

→ Agreed.

L174: Which day? Which solar zenith angle? Is this example comparable to Arctic observations? Are the conclusions transferable to the Arctic?

→ It covers the whole day of Jul 22, 2013. This approach is insensitive to changes in atmospheric composition during the day. This is more a general restriction than an Arctic issue.

Figure 4: I do not understand, why the misalignment error should be larger for low solar zenith angles (high Sun)? Cosine law tells, that changes for solar zenith angles of 0_ (sun in zenith) are way less than changes of low sun, e.g., solar zenith angles of 80_.

$$\begin{aligned}\cos(0_) \cdot 1000\text{Wm}^{-2} - \cos(3_) \cdot 1000\text{Wm}^{-2} &= 1\text{Wm}^{-2} \\ \cos(77_) \cdot 1000\text{Wm}^{-2} - \cos(80_) \cdot 1000\text{Wm}^{-2} &= 51\text{Wm}^{-2}\end{aligned}$$

To conclude: This correction scheme needs to be explained and tested in much more detail. In order to make the study shown in the manuscript more relevant, the correction approach needs to be explored for a general application to measurements in all potential conditions. Radiative transfer simulations are needed to support the approach. Two measurements at one location on a single can not be used to derive a parametrization for such a correction. Alternatively, the authors may apply common methods to correct for the sensor tilt.

→ Please see the first comment. After this discussion it is agreed that there are two strategies to go on concerning tilting: first is to more generalize the scheme introduced here (would be an own study), second is to apply a referenced scheme. We'll choose second and follow recommendation given in your comment L167-169.