Response to comments of Anonymous Referee #2

Comment 1
When the OMI albedo climatology exceeds the actual surface albedo a strong bias between ground-based and satellite data is observed due to two effects that go in the same direction. It would be very interesting to quantify the relative contribution of each effect over the bias in those stations with complementary ground-based data. For instance, could the authors select cloud-free cases as seen by the ground-based instruments as from the satellite?. Thus, this bias could be exclusively related to the overestimation of the clear-sky irradiance. The average of the bias for these selected cases would give an idea of the relative contribution of that effect. The bias for the remaining cases would be due to the sum of the two effects, so the determination of the contribution of the effect associated with the underestimation of attenuation by clouds could be easily derived from the subtraction of the other contribution.

Response:
We had considered this idea but have not implemented it because only the ground-based datasets for Summit and Barrow include flags indicating clear-sky conditions. Since the OMI albedo climatology for Summit is appropriate, exploring data from this site is of little value. However, data from Barrow are potentially suitable: as shown in Section 5.1.6, the albedo assumed by OMI is too large in September and October (Case 1), and data from these months should be appropriate to look into this suggestion. Unfortunately, clear-sky conditions are very rare in September and October: we found only three clear-sky spectra that were measured at the time of the OMI overpass. Hence, data from Barrow cannot be used after all.

To address the reviewer's comment, we have developed a simple, yet accurate method to determine periods of clear-sky for sites that use multifilter instruments, have performed the suggested analysis, and will add the following to subsection 5.1.9 (Trondheim). (We chose Trondheim because the Case 1 mechanism is most obvious at this site.)

"A large part of the observed bias must therefore be caused by the Case 1 mechanism discussed earlier. To provide further evidence that this is indeed the case, we filtered the ground-based measurements for clear-sky conditions and re-calculated the bias between OMI overpass data (DP (1)) and ground-based measurements. The clear-sky filter exploits the temporal variation in the measurements and takes advantage of the fact that the multi-channel radiometer used at Trondheim provides a measurement every minute. Data were considered clear-sky when the following two conditions were met: (1) The UVI at a given time must deviate by less than 1% from measurements performed one and two minutes before and after this time. (2) Condition (1) must be met for consecutive 15 minutes before and after the time of interest. Periods of constant cloudiness may meet condition (1), but are removed by condition (2).

The OMI dataset does not include overpass data without the CMF applied. We therefore calculated the CMF from the EDRate and CSEDRate data products and divided the overpass erythemal dose rate (OPEDRate) by the CMF to reconstruct the clear-sky overpass erythemal dose rate (CSOPEDRate).

Figure x compares box-whiskers calculated from the ratio of CSOPEDRate and the filtered clear-sky ground data (blue) with box-whiskers calculated from OPEDRate and "all-sky" ground data. The bias and variability of the clear-sky subset are much smaller than the corresponding values for all-sky data. For clear-sky data, the bias ranges between 16% in August (when SufAlbedo has an appropriate value of 0.04) to 44% in March and April, when SufAlbedo is 0.62. According to Fig. 2, an albedo of 0.62 enhances the clear-sky UVI by 30%. This theoretical value is consistent with the albedo effect derived from the measurements (44% - 16% = 28%), assuming that the observed summer-time bias of 16% — which results from unknown causes — also applies to winter months. This analysis suggests that the actual UV albedo at Trondheim during winter is similar to that in summer, which is not surprising considering the location of the instrument close to the center of a large city.

During summer months, the biases of the clear- and all-sky data sets agree to within 5%, while in March and April, the all-sky bias exceeds the clear-sky bias by 15 and 28%, respectively. Furthermore, the distributions of ρ_1 for the all-sky dataset are much more skewed towards larger values compared to those of the clear-sky dataset because attenuation by clouds is underestimated by OMI as a result of the large value of SufAlbedo used by the OMI UV algorithm. For example, the OMI data files indicate clear-sky conditions (i.e., CldOpt = 0) in 65% of data records for March and April. This percentage is far too large considering that the median cloud cover for these months is about 87% according to weather data from the Trondheim airport (https://weatherspark.com/averages/28896/Stj-rdal-Nord-Trondelag-Norway). Our analysis confirms that the Case 1 mechanism that leads to the overestimate by OMI is indeed composed of two components, one affecting the computation of clear-sky data and one affecting the calculation of cloud modification factors."

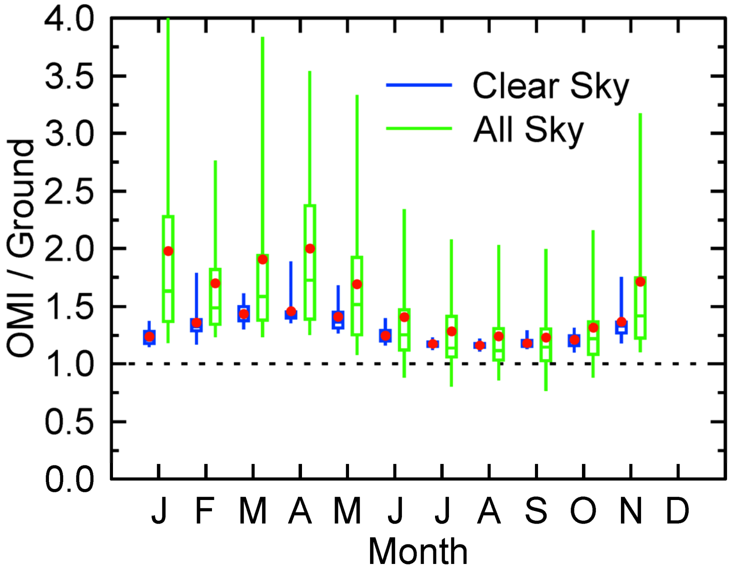

Figure x: Ratio of overpass erythemal dose rate (DP (1)) measured by OMI and the radiometer at Trondheim. Box-whiskers represent the distribution of ratios filtered for clear-sky (blue, left of month marker) and all-sky (green, right of month marker), and indicate the 5th and 95th percentile (whisker), the interquartile range (box), median (line), and average (red dot). Match-up data were filtered for SZA < 84° and Dis < 12 km.

Comment 2
When the surface albedo is correctly specified by the OMI albedo climatology, the results reported in the manuscript show that OMI data tend to exceed ground-based data up to 11 %. The authors should indicate that this bias is in accordance with previous inter-comparison papers using ground-based stations with snow-free conditions throughout the year. Please reference at least the following articles:

— Buntoung, S. and A. R. Webb (2010), Comparison of erythemal UV irradiances from Ozone Monitoring Instrument (OMI) and ground-based data at four Thai stations, J. Geophys. Res. 115, D18215, doi:10.1029/2009JD013567.

— Anton, M., V. E. Cachorro, J. M. Vilaplana, C. Toledano, N. A. Krotkov, A. Arola, A. Serrano, and B. de la Morena (2010), Comparison of UV irradiances from Aura/Ozone Monitoring Instrument (OMI) with Brewer measurements at El Arenosillo (Spain) – Part 1: Analysis of parameter influence, Atmos. Chem. Phys., 10, 5979 – 5989, doi:10.5194/acp-10-5979-2010.

— Mateos, D., J. Bilbao, A.I. Kudish, A.V. Parisi, G. Carbajal, A. di Sarra, R. Román, A. de Miguel (2013), Validation of OMI satellite erythemal daily dose retrievals using ground-based measurements from fourteen stations, Remote Sensing of Environment, 128, 1 - 10, ISSN 0034-4257, http://dx.doi.org/10.1016/j.rse.2012.09.015..

Response:
We will add the following:

“These positive biases are quantitatively consistent with systematic differences between OMI and ground-based measurements that have been observed at unpolluted, snow-free mid- and low-latitude locations (e.g., Anton et al., 2010; Bais et al., 2014; Cordero et al., 2014; Buntoung and Webb, 2010; Mateos et al., 2013). Several studies have shown that the bias in OMI UV data increases with increasing aerosol optical depth, in particular for absorbing aerosols (Arola et al., 2009; Cachorro et al., 2010; Ialongo et al., 2008), and can reach over 40% in highly polluted areas (Cabrera et al., 2012). We did not address the effect of aerosols because our study focuses on pristine high latitude sites with generally low aerosol optical depth.”

The references suggested by the reviewer plus the following references will be added:

Bais, A. F., McKenzie, R. L., Bernhard, G., Aucamp, P. J., Ilyas, M., Madronich, S., and Tourpali, K.: Ozone depletion and climate change: Impacts on UV radiation. Photochem. Photobiol. Sci., 14(1), 19-52, 2015.

Cachorro, V. E., Toledano, C., Antón, M., Berjón, A., Frutos, A. D., Vilaplana, J. M., Arola A., and & Krotkov, N. A.: Comparison of UV irradiances from Aura/Ozone Monitoring Instrument (OMI) with Brewer measurements at El Arenosillo (Spain)–Part 2: analysis of site aerosol influence. Atmos. Chem. Phys, 10(23), 11,867-11,880, 2010.

Cabrera, S., Ipiña, A., Damiani, A., Cordero, R. R., and Piacentini, R. D.: UV index values and trends in Santiago, Chile (33.5 S) based on ground and satellite data. J. Photoch. Photobio. B, 115, 73-84, 2012.

Cordero, R. R., Seckmeyer, G., Damiani, A., Riechelmann, S., Rayas, J., Labbe, F., and Laroze, D.: The world's highest levels of surface UV. Photochem. Photobiol. Sci, 13(1), 70-81, 2014.

Ialongo, I., Casale, G. R., and Siani, A. M.: Comparison of total ozone and erythemal UV data from OMI with ground-based measurements at Rome station. Atmos. Chem. Phys, 8(12), 3,283-3,289, 2008.

Comment 3
P. 8939, L. 5: “throughput” by “throughout”

Response:
The typo will be corrected.