Response to comments from Reviewer 3:

We thank the reviewer for the useful comments and remarks, and hope to address main concerns. We humbly apologize for the inconvenience caused by repeated delays in our response since the publication of reviews.

Background

The study is in the framework of the development of the HeliosatV method for estimating downwelling solar irradiance at the surface from satellite imagery. It is claimed that a new way to retrieve a cloud index from a large variety of satellite instruments on geostationary and non-geostationary platforms was developed. The method uses simulations from a fast-radiative transfer model to estimate overcast (cloudy) and clear-sky (cloud-free) satellite scenes of the Earth's reflectance. An implementation of the method is applied to the visible imagery from a Meteosat Second Generation satellite. Results from preliminary implementation of Heliosat-V and ground-based measurements show a correlation coefficient reaching 0.948, for 15-minute means of downwelling surface radiation, similar to operational and corrected satellite-based data products (0.950 for HelioClim3 version 5 and 0.937 for CAMS Radiation Service).

General Comments

1. It was difficult to read the paper due to lack of transparency caused by following:

a) Superfluous information dominates the text.

b) This is not a review paper so there needs to be a strong focus on the objective of the paper.

We modified in depth the structure of the paper to make it easier to read, in particular the introduction and the results section, and removing information of secondary importance. We also rewrote the objective of the paper in the introduction as :

"In this paper, we propose a cloud-index method based on radiative transfer modeling as an alternative to the archive-based approach. This exploratory direction aims at reproducing the satellite measurements of reflectances in both clear-sky and overcast conditions based on description of surface, clear atmosphere and cloud properties. Radiative transfer simulations are able to reproduce how TOA reflectances depend on viewing and solar geometries, with also their spectral distribution. In addition, it is possible to provide to the radiative transfer model input data that describes variations in space and time of clear atmosphere composition and of surface properties. Thus, our approach is useful to identify and quantify sources of errors in cloud-index methods. With a spectral and angular description, our method is also able to extend the application field of the cloud-index approach to a wider variety of orbits and optical shortwave sensors. In order to limit the effects of molecular scattering, ozone absorption and polarization present in the ultraviolet, and of the absorption of radiation by clouds in the near infrared, the method focuses on satellite imagery in the spectral range 400-1000 nm (λ< 1000 nm). This range is wide enough to consider imagers on many meteorological satellites launched since the beginnings of spaceborne Earth observation."

c) Many statements were repeated several times in the text.

d) There was a frequent jump from one topic to another.

Thanks for noting these, the text has been modified keeping these remarks in mind.

2. The discussion in many instances went into detail on a special topic (like aerosols) that were not utilized in implementing the methodology. One wonders why dwell on it.

Aerosols are an important topic for the Heliosat-V cloud-index: we use aerosol data as input to simulate the clear-sky reflectances at the top of the atmosphere. We add a short discussion and the figure below on the effect of aerosols on TOA clear-sky reflectances in the Results section:

"For CAM, some higher values of ρ_{clear} are observed in January. This can be attributed to high aerosol optical depth during this period, as illustrated in Figure 9. It shows that ρ_{clear} is not only sensitive to time variations of surface properties but also to atmospheric composition changes."

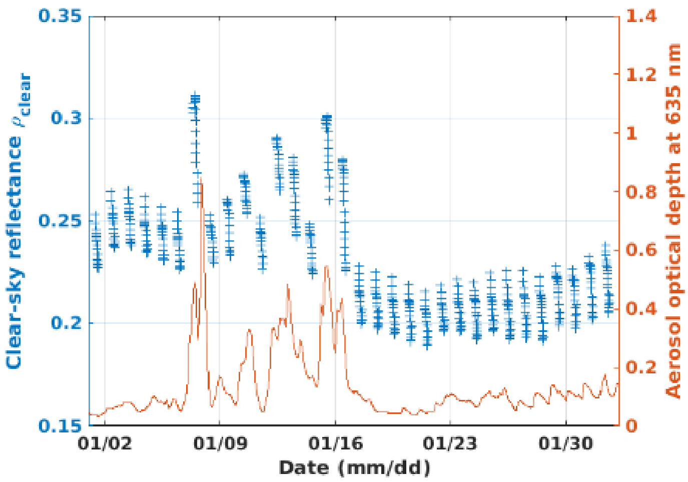

Figure 8. Blue plus signs: simulated reflectances at the top of the atmosphere in clear-sky conditions ρ_{clear} in January 2011 at Camborne station (CAM) and for MSG 0.6 μm. Red line: aerosol optical depth at 635 nm used for simulations.

3. If a new methodology is proposed there is a need to demonstrate that it is better than anything else that is available. The Authors state in the Abstract: *Results from our preliminary implementation of Heliosat-V and ground-based measurements show a correlation coefficient reaching 0.948, for 15-minute means of DSSI, similar to operational and corrected satellite-based data products (0.950 for HelioClim3 version 5 and 0.937 for CAMS Radiation Service).* Since improvement was not demonstrated (against an earlier version of their methodology or any other methodology) why would one be interested in the described approach?

In the current version of our method, we did not show improvement in terms of accuracy and precision in the validation results compared to HelioClim3, but our method provides others advantages.

Developing this new method aims at extending the cloud index concept to a broad range of satellite imagers of different sensitivities on different orbits. The way chosen for that is to use radiative transfer simulations instead of archives of satellite imagery. This paper is a first step: we are able to produce DSSI estimates with a similar quality compared to operational products including HelioClim3 which is based on a cloud index method. The extension of the validation to other satellites including non-geostationary is an ongoing work that we aim to submit in the near future.

The new method also aims at investigating on the origin of cloud index uncertainties. Using simulations of TOA reflectances integrating surface, clear atmosphere, and cloud properties provides flexibility for future improvements and sensitivity analyses. We also consider that the development of an alternative method to compute the cloud index with different assumptions is useful to assess, for example, the robustness of DSSI time variations within multi-model comparison exercises. This work is exploratory, and our publication comes as a first version showing encouraging results. Several significant sources of errors are identified (source of calibration gains, spectral interpolation of MODIS BRDF data, cloud properties used in the ρ_{ovc} Look-Up Table, angular description of the LUT). These errors will be further considered in future works (including on-going works), and their treatment is likely to improve results. Please also note that, as the paper focuses on the computation of the cloud index, the clear-sky index/cloud-index relationship is not investigated, and may also improve the quality of future results.

The aim of the method is clarified in the introduction (see answer to general comment 1.b.)

Moreover, why do they provide information on the correlation only?

We add in the abstract information on bias and RMS

4. Something is amiss in the logic of the approach: the Heliosat idea is to use a cloud index to get Downwelling surface solar irradiance (DSSI). This, for simplicity of the process and contrary to the LUP table approach that is based on simulations. In order to use the LUP tables one needs to know the parameters used in the simulations to do the matching with the observed TOA radiance/albedo. Not clear what is the benefit in doing the simulations that are not appropriately utilized?

The simulations are made to estimate reflectances as would be measured by a sensor at the top of the atmosphere in boundary cases clear-sky and overcast conditions. LUT are not used to estimate directly the DSSI. We use the radiative transfer simulations to compute a cloud index to estimate the attenuation of solar irradiance by clouds. Please also refer to the answer to the comment n°3 for more explanations on the objectives of the method.

5. The argument that the simulated SAL is better than the library of min SALs or that it can be used with every satellite, is weak. To estimate the DSSI for each case using the Heliosat approach one needs the SAL at the time of the observation. How is such matching achieved?

Our current version of the method deals only with historical time series of input data. A near real time version of the method could also be developed based on alternative datasets describing surfaces and clear atmosphere (e.g. climatologies, forecasts…)

Some misleading and unsubstantiated statements:

It is stated: "*the lower boundary is "archive-based", in most literature we reviewed: it is a minimum based on a time series of past satellite imagery. Such an approach is hardly applicable to non-geostationary satellites due to variable viewing geometries and a low* *revisit time In this paper, we aim at finding an alternative to the need for archives of satellite imagery. It would then be easier to consider imagery from non-geostationary spaceborne platforms and produce a worldwide coverage.*

It was not shown how the simulated albedo is used in the context of geostationary satellites and/or polar orbiters.

We changed this part in the Introduction. To make it clearer, we mentioned the use of radiative transfer model to estimate the TOA clear-sky reflectance.

Stated:

Heliosat-V is a method approximating the attenuation of DSSI radiation by clouds with a cloud index, n. We aim at developing an alternative "stateless" method to extend the application field of the cloud-index approach to a wider variety of orbits and optical shortwave sensors What is “stateless”? How was it extended to polar orbiters? The paper deals only with SEVIRI. Briefly, in addition to the lack of clarity of the text it seems that it was not demonstrated that the stated objectives of improvement and generalization have been achieved.

We removed the expression “stateless”. Our concept of simulating cloud index is able to be used on polar orbits, but as we explain in our answer to comment n°3, this paper is a first step: we are able to produce DSSI estimates with a similar quality compared to operational products including HelioClim3 which is based on a cloud index method. The extension of the validation to other satellites including non-geostationary is an ongoing work that we aim to submit in the near future.

In the section between lines 245-250 the following statements are made:

1. *The use of optimal calibration is out of the scope of our work. Still, we compared gains coefficients proposed by EUMETSAT gEUM with those provided by Doelling et al. (2018) gD2018 for the measurements produced by the Meteosat-9 250 0.6 and 0.8 µm channels in 2011.*

2. *They show a mean disagreement, calculated as (gEUM − gD2018)/gD2018, of about -9 % for 0.6 µm and -8 % for 0.8 µm during this period (also illustrated on Fig. A1). Such errors will affect with the same magnitude the agreement between numerical simulations and measurements of clear-sky TOA reflectances, underlining the importance of absolute calibration for the Heliosat-V method.* Not obvious what is the message of the Authors here: on one hand, the calibration is out of the scope of their work. Then they report on the evaluation of different gains which show large differences (-9 %).

The identification of optimal calibration is not our purpose, but we emphasize the fact that different sources of calibration are different enough to cause errors on the cloud index computation depending on the calibration used.

They continue to state: *Such errors will affect with the same magnitude the agreement between numerical simulations and measurements of clear-sky TOA reflectance, underlining the importance of absolute calibration for the Heliosat-V method.* Which is it? Is it important or not?

We clarify by reformulating “This underlines that an accurate source of absolute calibration is important for the Heliosat-V method.”

In Figure 6 provided are:

Simulation of clear-sky reflectances at the TOA (ρclear) for MSG 0.6 µm (left panel) and 0.8 µm (right panel) spectral channels compared with actual satellite measurements. The comparison is done for all 11 locations, for the year 2011. How was this comparison done? At each of the 11 locations, the atmospheric conditions are different. The atmospheric correction would be different. Not clear how the comparison was performed.

Figure 6 shows 2D histograms merging all clear-sky simulations and measurements. We clarify this point with “Represented data include simulations and measurements for all 11 locations, for the year 2011.” We also add a description of statistics on STD for stations with best and worst results: “When studying station by station, the highest absolute standard deviation of the difference between simulations and measurements is reached for Sede Boker with 0.03, while the lowest is reached for Tamanrasset with 0.008.”

In summary, this manuscript is not ready for publication.