Response to referee #1 for manuscript:

X. Ceamanos, D. Carrer, and J.-L. Roujean, Improved retrieval of direct and diffuse downwelling surface shortwave flux in cloudless atmosphere using dynamic estimates of aerosol content and type: application to the LSA-SAF project, Atmos. Chem. Phys. Discuss., 14, 8333-8392, doi:10.5194/acpd-14-8333-2014, 2014

Dear Editor,

Please find below the response to all the concerns raised by referee #1. We have addressed the main points (P1-P9) by detailing several aspects of the proposed method SIRAMix and by clarifying some information given in our manuscript. Also, we have run additional sensitivity studies to answer the question of referee #1 regarding the impact on the DSSF estimation of the vertical profile assumed for aerosol particles (see P6). We propose to add some of this additional information in the revised version of the article. Finally, we explain how minor comments made by referee #1 (see P10) will be addressed in the improved version of the manuscript.

Best regards,

The authors

Interactive comment on "Improved retrieval of direct and diffuse downwelling surface shortwave flux in cloudless atmosphere using dynamic estimates of aerosol content and type: application to the LSA-SAF project" by X. Ceamanos et al.

Anonymous Referee #1
Received and published: 7 April 2014

"Improved retrieval of direct and diffuse downwelling surface shortwave flux in cloudless atmosphere using dynamic estimates of aerosol content and type: Application to the LSA-SAF project" describes and assesses in detail a novel algorithm to derive surface shortwave radiation parameters from satellite observations, taking into account a combination of aerosols. This work is very significant, as direct and diffuse down-welling surface radiation fluxes are very useful in a number of meteorological and climate modelling activities. The method presented here appears to bring a large improvement in the quality of remotely observed DSSF, and the distinction between direct and diffuse fluxes, even though it is more sensitive to the aerosol load and errors are thus higher, are a definite plus. These results will be useful and used in a number of observing and modelling activities. They are also a novel and intelligent way of making use of the MACC-II reanalysis and near-real time aerosol products. The new products that are proposed (direct and diffuse surface down-welling fluxes, atmospheric radiative forcing of specific gases or aerosol species) are extemely appealing.
The SIRAMix algorithm is clearly explained, and the paper is overall well organized and easily readable. No major scientific shortcoming were spotted. The validation method (vs simulated observations, observations and state of the art algorigthms) is sound. The sensitivity study brings more insight to the product and also to its limitations. A few remarks, comments and questions are listed below. A (non-exhaustive) list of minor corrections is also added.

Dear Referee #1,

Thank you for your constructive comments and sensible suggestions. Please find our response to your comments below.

P1 - The proximity of this work to the modelling of the aerosol direct effect could be mentioned or discussed somewhere. This could place this work in a broader perspective and make more explicit the link between aerosol modelling and the method presented here. This could also provide more validation tools.

Thanks for your comment. This suggestion is partly addressed in Section 4.3 of the original manuscript, which investigates the capabilities of SIRAMix to monitor the direct radiative forcing (or direct effect) caused by aerosols and other atmospheric components. The physical parameterization at the core of SIRAMix provides the means to quantify this radiative quantity at the surface level given a set of atmospheric inputs. According to the suggestion of referee #1, we propose to complete this part of our study by adding a more complete discussion on this complementary asset of SIRAMix. This will place our work in a broader perspective. It is important to notice that the validation of the direct forcing products has not been carried as comprehensively as it has been done for the DSSF estimates since we wanted to emphasize the main objective of the paper: the estimation of diffuse and direct DSSF.

P2 - Line 27 : "This outcome (ie the fact that the MACC-II aerosol forecasts are less accurate than the analysis) will be taken into account in the forthcoming implementation of SIRAMix in the operational production chain of the LSA-SAF project". How do the authors propose to address this issue?

As we state at the end of the conclusions of our manuscript: "*While forecasted MACC-II data will be used for the operational LSA-SAF chain, a second run will be performed when reanalyzed MACC-II data will become available (similar to what is done for the operational McClear DSSF product).*". The LSA-SAF products are associated to a timeliness of three hours, meaning that all land surface products are generated three hours after a given SEVIRI/MSG observation is acquired. In this context, we will firstly use forecasted MACC-II data to generate the DSSF products in an operational manner. On the other hand, periodical reanalysis are carried out in the LSA-SAF project to update existent surface products, either using new versions of the algorithms or improved inputs. The use of reanalyzed MACC aerosol data will be considered in this case. We believe that this way of proceeding provides a good trade-off between accuracy and the near real time constrain required by the LSA-SAF project. We propose to make this matter clearer in the improved version of the manuscript.

P3 - In section 2 line 194 : does there exist any reference for this formula?

Equation number 16 is a classical formula used in atmospheric radiative transfer. The reference (Sobolev, 1972) will be added.

Sobolev, V. V.: Light scattering in planetary atmospheres (translated as Light scattering in planetary atmospheres, Pergamon Press, Oxford, 1975), Nauka, Moscow, 1972.

P4 - Line 293 : MACC-II provides forecasts up to 5 days ahead. There are 11 aerosol pronostic variables (and not 9) : for both OM and BC both the hydrophilic and the hydrophobic components are takin into

We agree with referee #1 and acknowledge our mistake. Indeed, the MACC-II system generates 11 AOD variables and not 9. We will correct this mistake in the new version of the manuscript.

In this matter, we would like to remark that the AOD for the different bins of DU, SS, OM, BC are not accessible from the MACC-II data server (or at least from the download website that we used: http://apps.ecmwf.int/datasets/data/macc_reanalysis/). Only the total AOD corresponding to each one of the five major aerosol species (i.e., Dust, Sea Salt, Organic Matter, Black Carbon and Sulphate) was available. This information will be included in the improved manuscript.

Also, we propose to perform the following modification concerning the nomenclature used to refer to the different aerosol species. First, the acronyms SU, DU, SS, OM, BC will be used only for MACC-II aerosol species, in agreement with the MACC-II paper (Morcrette et al., 2009). Second, the acronyms WASO, INSO, SOOT, SSALL, and MIALL will be used to refer to the GADS-based aerosol components defined in Appendix A and used by SIRAMix. The adoption of this new nomenclature is meant to avoid confusion, for example, between the sea salt components in MACC-II and GADS.

P5 - Lines 303-305 : the forecast time(s) concerned here should be mentioned

The following information will be included in the improved version of the manuscript:

"Cesnulyte et al., (2014) used forecasted MACC-II aerosol data from the *fdmj* experiment. To cover a full day of AOD values, Cesnulyte et al., (2014) took hourly forecasted AOD from time steps 1 to 12 h from forecast base times 00:00 UTC and 12:00 UTC".

P6 - Lines 318 - 325 : What is the impact of this height correction on AOD and on direct, diffuse and global DSSF? While this step is necessary due to the wide difference in resolution between the MACC-II products and the satellite pixel, the vertical repartition of aerosols that is used in this algorithm (ie exponential decrease with height), while certainly adequate on a climatolofical range, can at times differ a lot to the observed or analysed aerosol load. This height correction algorithm could be a source of errors for the whole proposed method, for regions with a marked orography, since it was shown in section 3 that results are very sensitive to AOD. As the authors already use MACC-II products in their algorithm, wouldn't it be possible to also use the same products to assess dynamically the aerosol decrease as a function of height above the ground? This point would perhaps deserve more discussion.

As explained in Section 2.3.3, the height of a given ground station may not be the same than the altitude considered in the corresponding MACC-II grid pixel. Since aerosols are not homogeneously distributed along the vertical, AOD values analyzed by MACC-II may not be adequate to be used directly in SIRAMix. In order to overcome this issue, SIRAMix adjusts the MACC-II AOD estimates to the station actual height. For that purpose, the vertical distribution profile of the aerosol particles must be known. In our study, we have assumed an exponential distribution of the aerosol concentration, with a concentration maximum at the surface level (see

Appendix B2). This simple yet realistic distribution is adopted from (Hess et al., 1998), who provides different vertical profiles for different aerosol species. A similar strategy is used in other DSSF retrieval algorithms such as the McClear method (Lefèvre et al., 2013).

Sensitivity studies were run to evaluate the impact on DSSF estimation of assuming an exponential vertical distribution under the occurrence of a different vertical profile. Figure A shows two different aerosol vertical profiles that have been used in SIRAMix to simulate DSSF. The red line corresponds to a classical exponential vertical profile used for continental aerosols (Hess et al., 1998) while the black line assumes the presence of an aerosol cloud between 1 km and 2 km.

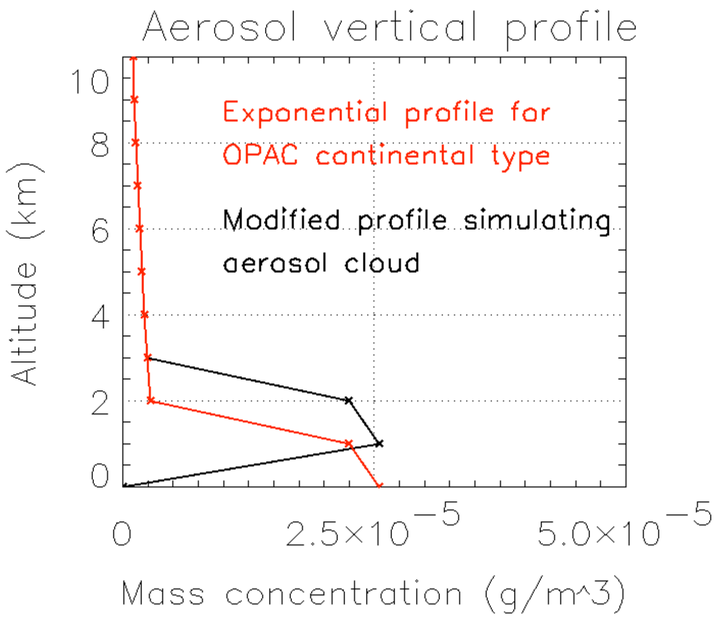

Figure A – Vertical profile of the mass concentration of aerosol particles considered to simulate DSSF with the proposed method SIRAMix. Red line corresponds to the vertical profile of a typical continental aerosol type (Hess et al., 1998). Black line is the result of modifying the previous profile to simulate an aerosol cloud not touching the ground.

Black lines in Figure B shows the diurnal evolution of the bias on global, direct, and diffuse DSSF calculated by SIRAMix due to the use of the exponential vertical profile (red line in Fig. A) instead of the configuration with the aerosol cloud (black line in Fig. A). Two aerosol contents (AOD=0.2 and AOD=1.0) are considered (see left and right columns in Fig. B, respectively). In addition, we have also plotted the bias resulting of using the correct vertical profile but an AOD that is affected by a ±10% bias (see red and blue lines). As it can be seen, results show that inaccuracies of using a wrong vertical aerosol profile are greatly lower (<5 W/m2) than those resulting from the AOD inaccuracies (up to 30 W/m2). This is especially true for standard aerosol conditions (AOD=0.2).

Given that MACC-II aerosol data may be biased by 10% or more, we concluded that the aerosol vertical profile is not a first-order parameter in the estimation of DSSF. In this context, we decided that the exponential vertical distribution was accurate enough for the purposes of SIRAMix. Besides this point, comprehensive experiments would be necessary to assess the use of MACC-II aerosol vertical profiles in SIRAMix, as uncertainties are supposed to exist in these analyzed data. This issue may be addressed in the future when MACC-II estimates will be improved.

The previous discussion will be partly included in the improved version of the manuscript.

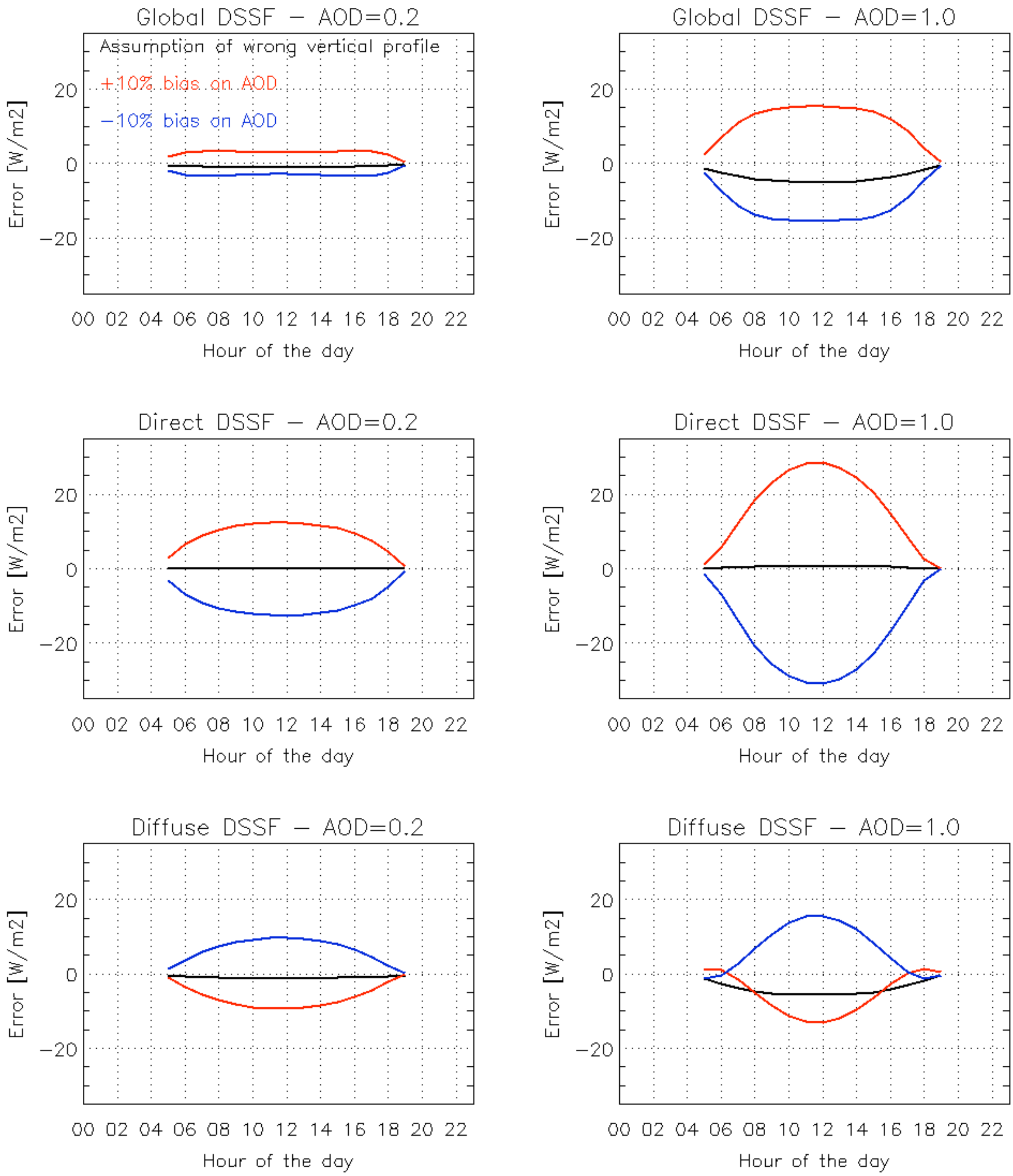

Figure B – Diurnal evolution of bias on global, direct, and diffuse DSSF when using (black line) a wrong aerosol vertical profile, (red line) a +10% biased AOD, or (blue line) a -10% biased AOD. For this experiment, we have selected the SZA corresponding to the station of Carpentras on June 21st and a typical mid-latitude continental atmosphere.

P7 - line 450 : the physical link between the errors on diffuse and direct fluxes should perhaps be more clearly explicited. Also, it appears that the positive bias (as compared to in situ observations and Mc Clear values) for the SIRAMix diffuse DSSF is more important than the negative bias of the SIRAMix direct DSSF, resulting in an overall small positive bias for the SIRAMix global DSSF. Is there any explanation for this?

First, we propose to add in the revised version of the manuscript a few sentences detailing the physical link between the errors on direct and diffuse DSSF in Section 4.1.2. For instance, we will explain the relationship among a higher AOD, the resulting scattering increase, the fall-off of direct radiation, and the increase of diffuse DSSF.

Second, Experiment 5 shows indeed an average positive error for global DSSF coming from (i) a moderate negative error affecting direct DSSF and (ii) a larger positive error from diffuse DSSF. Although this may be surprising given that diffuse DSSF is lower than direct radiation for average AOD values, we identify four reasons explaining this result:

1. Diffuse DSSF is more sensitive to inaccuracies affecting AOD when aerosol content is relatively small. This can be seen in Figure 5 middle-right (see plain line), which shows bias larger than ±10% for diffuse DSSF when AOD is 0.2 and the associated bias is ±25%. Under the same configuration, direct DSSF suffers only from a bias not greater than ±5%.
2. The physical parameterization used in SIRAMix is probably less accurate for diffuse DSSF, as the modeling of this radiation component has been historically more challenging than the direct one. However, experiments proved that it is more accurate than state-of-the-art methods such as McClear.
3. Likewise, the aerosol look up table generated with libRadtran is likely less accurate in terms of diffuse transmittances due to the same reasons given in point 2.
4. The accuracy of measurements taken by ground stations is generally lower for diffuse radiation, as the measuring technique is more complex than for the direct component.

The previous discussion will be included in sections 4.2 and 5 of the improved manuscript.

P8 - line 520 : a possible explanation of the higher RMSE for Tamanrasset and Sede Boqer (in addition to the fact that the aerosol load is generally much higher than other stations) is that the aerosol assimilation system of the MACC-II products uses MODIS observations of total AOD which are not available over deserts. This can affect the quality of the aerosol analysis over desertic areas.

Thank you for your comment. This suggestion will be included in the improved manuscript.

P9 - line 580 : the agreement between the global estimate of aerosol SRF provided by SIRAMix and study that provides local values over North Korea is not enough to validate the aerosol SRF product.There exists many papers and studies trying to quantify and model the aerosol direct effect that could help provide a broader validation.

We agree with referee #1. According to his/her suggestion, we will add some references giving average values of aerosol SRF (SARF) in different places across the world for different periods of time. For example, we suggest to cite the following works:

- di Sarra et al., (2013), who measured the average SARF on 7 September 2005 to be equal to -24 W/m2 in the Mediterranean station of Lampedusa during a Saharan dust event .
- The MILAGRO (Megacity Initiative-Local and Global Research Observations) campaign in March 2006 over Mexico (Schmidt et al., 2010), which resulted in average SARF values of -22 W/m2.
- The work of Péré et al., (2011) who used a chemistry-transport model coupled with a meteorological model for the period 7-15 August 2003 to determine a mean SARF ranging from -10 to -30 W/m2 over southeastern France and the Mediterranean Basin.
- Mallet et al. (2006) and Roger et al. (2006), who used measurements of microphysical and optical aerosol properties obtained during the ESCOMPTE (ExperimentS to COnstrain Models of atmospheric Pollution and Transport of Emissions) campaign to simulate average values of SARF equal to -(24-47) W/m2 for the southeast of France between 4th June and 13th July 2001.

P10 - Specific correction propositions (not exhaustive) :

- line 6 constant instead of unchanging

- line 10 : composed instead of constituted

These modifications will be done in the revised manuscript.

- line 11 : "real" is optimistic. Observed or analysed would maybe fit better?

We suggest to replace "to match real aerosol conditions" by "to reproduce real aerosol conditions as best as possible".

- line 19 : improve rather than decrease

- line 26 : issue instead of outcome

- line 35 : absence rather than lack

- line 36 : The latter particles

These modifications will be done in the revised manuscript.

- line 39-40 : "On the other hand" is not necessary

We will remove it from the revised article.

- line 59 : In particular usually doesn't start a sentence. "A static climatological aerosol load doesn't match the variability of aerosols in space and time"

- line 61 : "...doesn't describe accurately enough the usual mixture..." instead of "...is not correct in front of the usual mixture..."

These modifications will be done in the revised manuscript.

- line 66 "In front of" is not necessary. This sentence should be rewritten

Sentence "*In front of the poor knowledge on aerosols at broad scale, however, the description of aerosol properties had to be necessary simplified.*" will be replaced by "*However, the description of aerosol properties had to be necessary simplified due to the poor knowledge on aerosols at broad scale*".

- line 94 : existent instead of existing

- line 95 : "The upgrade consists of..."

- line 97 : "the abundance of which may vary with time and space". This part is not strictly necessary

- line 97 : "As explained"

- line 112 : Even though I see what you mean by "horizontally" (it refers to the surface and not the radiative flux), the term is misleading and should probably be removed.

- line 116-117 : this sentence should probably be move to the beginning of the section

These modifications will be done in the revised manuscript.

- line 132-133 : ", on mu0..., and on the factor v(t)". Why not write cos(theta0) in the formulae?

We prefer to keep using the Greek symbol *mu* for the cosine of the solar zenith angle for historical reasons.

- line 170 : computed instead of calculated, single scattering rather than singly scattered

- line 173 : idem

- line 269 : to monitor the aerosols

- line 291 : there was also the MACC project in between GEMS and MACC-II

- line 299 : made available

- line 301 : delayed mode

- line 350 : "minor" should probably be removed

These modifications will be done in the revised manuscript.

- lines 391-392 : "assesses the sensitivity of SIRMix to the variability of inputs" fits perhaps better

We would like to point out that Experiment 2 does not investigate the impact of the inputs variability but their uncertainties (or quality). The suggestion of referee #1 could make the reader think that we are considering the physical intra-variability of the inputs (the range of values within they naturally span), which is not the case. In this context, we prefer to keep the text as it is.

- lines 400-405 : while the difference between experiments 5 and 6 is clear when you go to the corresponding sections, it is not very clear as explained in these two bullet points. The sentence describing experiment 6 should probably be rewritten

We propose to further clarify this sentence by saying the following "*Experiment 6 in Sect. 4.3 investigates the additional capabilities of SIRAMix in quantifying the direct radiative forcing caused by aerosol and other atmospheric components*".

- line 413 : "shows a comparison" instead of "compares"

- line 460 : "As can be seen"

These modifications will be done in the revised manuscript.

Best regards,

The authors