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RESPONCE TO REFEREE#1

We provide here our response to referee's questions/comments. The text of the following answers will be inserted, if positively judged by the referee, in the final manuscript.

"My main issue with the present manuscript is that the authors have failed to adequately address one very important uncertainty of their method which derives from using MODIS retrieved values of cloud optical thickness (COT) in conditions of overlying absorbing aerosols"

MODIS uses six spectral channels in VIS and NIR at 0.66, 0.86, 1.24, 1.63, 2.12, 3.75 µm wavelengths (King et al., 1998). The non-absorbing channel at 0.86 µm (over ocean) is used to minimize the surface contribution together with the base radiance at 2.12 µm and eventually at 1.64 or 3.75 µm. For each measurements, the retrieved reflectance pair is compared with a pre-computed Look Up Table (LUT) to estimate CDR and COT.

In this spectral region, reflectance measurements are strongly sensitive to the absorption properties of aerosol. Therefore, one of the most important and debated uncertainties in MODIS cloud retrievals is the error associated to CDR and COT estimates in the presence of biomass burning particles overlying a cloud field. The quantification of this potential bias on cloud optical properties is a very difficult issue. At the stare of the art, the impact of overlaying aerosols is not still clearly quantified, remaining somewhat controversial. However, this is a critical point to understand as an error in CDR and COT may largely affect LWP values and, hence, DARE estimates.

It has been show that this error can be aerosol and wavelength dependent. Haywood et al. (2004) analyse the Namibian/Angolan stratocumulus region and compare simulated bi-spectral measurements of CDR and COT (using the MODIS look-up tables) with in-situ observations collected during the SAFARI 2000 campaign, with and without an overlying aerosol. In case of biomass burning aerosols, they find that CDR is very little underestimated (with an error l smaller than 1 µm) using the 0.86/2.1 µm couple of wavelengths, while COT can be low biased up to 17%-22%. Using the 0.86/3.7 and 0.86/1.63 radiance pairs, the low bias in CDR increases up to slightly less than 2 µm and 3 µm (respectively), while the error in COT remains mostly unaltered. For Saharan dust, biases are somewhat smaller as the aerosol effect on 0.86 µm radiance is less important because of the smaller SSA (less absorption) and higher asymmetry factor (less scattering in the backscatter direction). However, they find a large bias on CDR (up to 6 µm) using the 0.86/3.7 µm radiance pair, because dust extinction coefficient of is still important at 3.7 µm.

Other studies seem to show that the overlying aerosol error on MODIS cloud retrievals may depend on the geographical region and cloud field variability. Wilcox et al (2009) analyse marine boundary layer clouds off the coast of Western Africa and over South-East Pacific, during July-August 2005-2006. MODIS retrievals at 0.86/2.13 μm are used to derive LWP and compare with AMSR-E estimates. Off the Western African sub-continent, MODIS LWP agrees on average within ±10g/m² with AMSR-E, while a systematic low bias is found in MODIS values over the South-East Pacific (because of a low bias on COT). One year after, Coddington et al. (2010) find similar results comparing MODIS measurements with those collected during INTEX-A (Intercontinental Chemical Transport Experiment) study from the Solar Spectral Flux Radiometer (SSFR). SSFR was on board of an aircraft frying between the absorbing aerosol layer (from industrial outflow) and extended stratocumulus clouds off the northeast coast of United States. In case of reduced cloud variability (as for the South-East Atlantic region), they find a small high bias in MODIS CDR of about 1-2 μm, with respect to the estimates obtained using SSFR albedo measurements, while values of COT and LWP agree within the uncertainty of each instrument. For very heterogeneous cloud scenes, with a large variability of cloud optical properties, CDR and COT errors are shown to largely increase and the difference between SSFR and MODIS values can reach 10 μm and 10, respectively.

In very recent times, Meyer et al. (2013) analyzed the case of marine stratocumulus clouds topped by an aerosol layer, over South-East Atlantic. Their results suggest that the overlying aerosol bias on MODIS cloud retrievals may depend on the pollution level of underlying cloud. They use a research level version of MODIS collection 6 algorithm to retrieve CDR and COT, from August to September 2006-2011. They modified the MOD06 reflectance look-up tables to account for the effect of overlying aerosols detected by co-located CALIOP measurements. The standard MODIS retrieval algorithm seems to underestimates CDR and COT up about 6% and 18%, for polluted clouds topped by an aerosol layer. In case of clean and polluted clouds, the underestimation is reduced on average to 2.6% and 11%, respectively. Accounting for these errors, the corrected DARE efficiency increases by 21%. We can then argue that MODIS low bias seems to be smaller when underlying clouds are cleaner.

In the present study we use the MODIS 0.86/2.1 μm radiance pair, which seems to be the best suited over South-East Atlantic area to retrieve CDR with very small errors. For what concerns COT estimates, the reduced cloud heterogeneity above the selected area seems to provide a favorable condition for insignificant retrieval bias. The little cloud optical properties variability over

South-East Atlantic is confirmed by the large availability of PARASOL measurements (Costantino and Bréon, 2010), that are only possible in case of a fairly homogeneous cloud field over a spatial scale of at least 100 km (Bréon and Doutriaux-Boucher, 2005). In addition, Costantino and Bréon (2001) analyse the CDR and COT dependence on AI over South-East Atlantic in case of clean clouds topped by aerosol. They find on average no significance variations of both parameters as AI increases from 0.02 to 0.5. We are then positive that our MODIS estimates of CDR, COT and then LWP are little affected by presence of above aerosol, even in case of absorbing particles. However, in the present study we are very close to the scenario studied by Meyer et al. (2013), with clean but also polluted clouds eventually topped by absorbing aerosols and potentially affected by a 2.6% and 6% low bias in CDR and COT (with a consequent low bias in LWP of slightly less than 9%). If the results of Meyer et al. (2013) are confirmed, DARE estimates provided in the present study should be considered as lower bounds, as contribution of overlying aerosols to the total energy budget would result underestimated.

Minor points:

We tried to correct all minor points raised by referee#1. Corrections are reported in blue in the revised version of the paper. In particular, we want to explicitly answer here to the following comments (that we found the most “relevant”):

P23296, line 19 (and elsewhere in the manuscript): The authors often speak of their results in terms of mean and standard deviation. However, this may lead to substantial confusion because it seems that the calculated distributions of DRE shown in Fig. 4 of the manuscript are heavily skewed towards values of large positive DRE. Perhaps this is just an artefact of the log-linear presentation. How close to Gaussian are the distributions of calculated DRE ? If the distributions are considerably non-Gaussian, it would make more sense to speak of the variability in calculated DRE in terms of percentiles or quartiles.

Effectively there are very large values of DRE and probably it would be useful to speak of the variability in calculated DRE in terms of percentiles or quartiles. We tried to quantify the DRE in terms of mean (median) values for a matter of consistency with other previous studies that quantify the DARE in terms of mean ± stddev.

Sadly, I have no more access to data (as this work has been done many months ago, and I am currently working on other subjects in a different institution). It would be impossible for me to statistically re-analyses the data.

P23297, line 19: By definition, the term "radiative forcing" is only applicable to the radiative effect brought about by anthropogenic substances in the atmosphere. True, both natural and anthropogenic aerosols may have a cooling effect on the Earth System, but only the anthropogenic ones can be considered as "forcing". The authors often confuse this throughout the manuscript. In fact, because their methodology generally considers all aerosols, the derived DRE should not be termed as "forcing" anywhere in the paper.

Aerosol Direct Radiative forcing has been everywhere replaced by Direct Aerosol Radiative Effect (DARE).

• P23299, lines 1–5: The review of studies focusing on the DRE of absorbing aerosols above clouds from observations is incomplete. Numerous studies have produced such estimates and their contribution to the field should at least be mentioned if not shortly reviewed and contrasted (Peters et al., 2011; Wilcox, 2012; de Graaf et al., 2012; Meyer et al., 2013).

We added and commented the results of Peters et al. (2011), de Graaf et al. (2012) and Meyer et al. (2013).

• P23300, line 10: Please insert an appropriate reference here.

Labonne et al., (2007).

P23300, line 15: I partly disagree. Yes, dust generally has a higher SSA than biomass burning aerosol. However, dust still yields substantial absorption at visible wavelengths with SSA values spanning ≈0.82–0.97 in the range of ≈400–800 nm (PRIDE campaign, Bergstrom et al., 2007). This is confirmed by the results of Peters et al. (2011), who find a reduction of local planetary albedo (shortwave) in overcast scenes (positive direct radiative effect) everywhere over the tropical- and subtropical Atlantic Ocean. Over the tropical north-east Atlantic, this is attributable to dust aerosol.

Yes, we agree that the sentence is not completely corrected as it is. We reformulated this sentence in a more correct way.

P23300, lines 22–23: This applies only to those studies which applied radiative transfer modelling to derive the DRE. Observationally based studies that rely on measured radiances do not need to make such approximations (Peters et al., 2011; Wilcox, 2012; de Graaf et al., 2012).

Yes, we agree and specified this concept in the text.

• P23301, lines 4–6: The description of the data is confusing. The sentence suggests that the authors use the operationally derived Level3 product by the MODIS science team. However, when going through the publication describing the dataset (Costantino and Br´on, 2013), it is clear that the authors produce their own Level3 data from Level2 cloud retrievals. This should be made more clear at this point.

We use the standard MODIS L3 product as model input. The referee is right when he says that the dataset we use to derive CALIPSO statistics (Costantino and Bréon, 2013) is based on collocated measurements of MODIS L2 and CALIPSO L2 products. However, we never use this MODIS L2 information in here.

• P23302, line 15: If retrievals with COT<5 are excluded from the analysis, how can the authors produce the plots in Fig. 6 of the manuscript. These plots span the COT range down to values of 2.

In this paragraph I quickly describe the selection criteria of MODIS-CALIPSO coincidence dataset (L2 product) from Costantino and Bréon (2013). This section criterium does not apply to the L3 cloud product used as input in the radiative transfer model.

• P23302, line 21: Although used in almost every study using satellite data to quantify aerosol-cloud interaction, it should be mentioned that it is of course an approximation to assume that AOD measured in cloud-free scenes is also representative for the AOD in cloudy scenes (Anderson et al., 2003). This could be overcome by using AOD retrievals in cloudy scenes from e.g. OMI (Torres et al., 2012).

This comment has been added.

• P23304, lines 18–22: It should be noted that similar results are provided in Devasthale and Thomas (2011). Please compare shortly .

This reference has been added and they results are quickly stressed.

• P23305, lines 6–7: Compare to the results of Peters et al. (2011) who find the by far strongest positive DRE in the South-East Atlantic for the time period June – November.

I added this references to comment our results.

P23309, lines 12–29: I suggest the authors shift these three paragraphs upwards to directly follow the paragraph ending on "...clouds get involved". This way, a clear separation between results and the contrasting to previous studies would be achieved. This would make reading the paper easier.

We totally agree, the text has been reorganized and the comparison with some previous study has been moved to a specific chapter (as also suggested by referee#2).

P23311–P23312: The authors go very much into detail with a number of shortcomings, which is very nice. However, the possibly most critical one (Haywood et al., 2004; Meyer et al., 2013) is not mentioned (see above).

We add some considerations (see above). We hope we addressed this issue in this revised version.

• Summary and Conclusions: Maybe this is just me, but I like to see acronyms redefined in the summary section. Memory for acronyms may get lost along the way. Furthermore, some readers may want to look at the summary first before reading the whole paper. I leave it up to the authors to decide what to do.

We can easily add a memory for acronyms.