New references (from both referee1 and referee#2 suggestions):

Devasthale, A. and Thomas, M. A.: A global survey of aerosol-liquid water cloud overlap based on four years of CALIPSO-CALIOP data, Atmos. Chem. Phys., 11, 1143–1154, doi:10.5194/acp-11-1143-2011, 2011.

Anderson, T. L., Charlson, R. J., Winker, D. M., Ogren, J. A., and Holmen, K.: Mesoscale variations of tropospheric aerosols, J. Atmos. Sci., 60, 119 – 136, 2003.

Torres, O., Jethva, H., and Bhartia, P.: Retrieval of aerosol optical depth above clouds from OMI observations: Sensitivity analysis and case studies, J. Atmos. Sci., 69, 1037–1053, 2012.

Bellouin, N., Boucher, O., Haywood, J., and Reddy, M. S.: Global estimate of aerosol direct radiative forcing from satellite measurements, Nature, 438, 1138–1141, 2005.

Peters, K., Quaas, J., and Bellouin, N.: Effects of absorbing aerosols in cloudy skies: a satellite study over the Atlantic Ocean, Atmos. Chem. Phys., 11, 1393–1404, doi:10.5194/acp-11-1393-2011, 2011.

Labonne, M., F.-M. Bréon, and F. Chevallier (2007), Injection height of biomass burning aerosols as seen from a spaceborne lidar, Geophys. Res. Lett., 34, L11806, doi:10.1029/2007GL029311.

Lohmann, U. and Feichter, J.: Global indirect aerosol effects: a review, Atmos. Chem. Phys., 5, 715–737, 2005.

Quaas, J., Ming, Y., Menon, S., Takemura, T., Wang, M., Penner, J. E., Gettelman, A., Lohmann, U., Bellouin, N., Boucher, O., Sayer, A. M., Thomas, G. E., McComiskey, A., Feingold, G., Hoose, C., Kristj´nsson, J. E., Liu, X., Balkanski, Y., Donner, L. J., Ginoux, P. A., Stier, P., Grandey, B., Feichter, J., Sednev, I., Bauer, S. E., Koch, D., Grainger, R. G., Kirkevåg, A., Iversen, T., Seland, Ø., Easter, R., Ghan, S. J., Rasch, P. J., Morrison, H., Lamarque, J.-F., Iacono, M. J., Kinne, S., and Schulz, M.: Aerosol indirect effects – general circulation model intercomparison and evaluation with satellite data, Atmos. Chem. Phys., 9, 8697–8717, doi:10.5194/acp-9-8697-2009, 2009.

de Graaf, M., Tilstra, L. G., Wang, P., and Stammes, P.: Retrieval of the aerosol direct radiative effect over clouds from spaceborne spectrometry, J. Geophys. Res., 117, doi:10.1029/2011JD017160, 2012.

van der Werf et al. (2010)

Coddington et al. (2010)

Wilcox et al. (2009)

Haywood et al. (2004)

Meyer et al. (2013)

Schutgens et al. (2013)

Bréon and Doutriaux-Boucher (2005)

Tanré et al. (1997)

Kaufman et al., 1997;

Remer et al., 2005

Remer et al., 2009

Twomey, 1977b; Atmospheric aerosols

Bréon et al. (2002)

Twomey, 1977a

Albrecht, 1989

AUTHOR'S RESPONSE TO REFEREE#2

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.

"A new estimate of
the aerosol effect is given and compared with existing estimates. It is well embedded in existing literature, but it is correctly noted that it is hard to compare because of the many different assumptions in the various estimates. However, for a complete review of the various DARE estimates and methods the comparison is too brief and a judgment of the improvement of the DARE estimates is not possible from the paper. And this is probably not the purpose of the authors. The authors claim that the purpose is to introduce a better estimate of the DARE using an improved representation of the SSA based on retrieved ANG and better relative position of clouds and aerosols. This would be a real contribution to the field. However, instead of a comprehensive study of the sensitivity of the DARE to the new assumptions (especially SSA), the mere result of the DARE is given and compared to a few different results. The paper would be greatly improved if a study of the sensitivity of the DARE to SSA were given, and a clear description of the MODIS retrieval of the ANG, which is missing at the moment. "

In this work we want to provide multi-annual monthly estimates of all-sky (divided in its two component in case of clear and cloudy scenes) DARE over South-East Atlantic, combining a large spectrum of information on clouds (cloud fraction, liquid water path, effective radius, altitude), aerosol (optical depth, angstrom coefficient, single scattering albedo, position with respect to cloud layer, asymmetry parameter) and other environmental variables (ocean albedo, solar zenith angle, day of the year) integrated in a radiative transfer model. The large number of uncertainties of different nature (e.g., satellite retrieval errors, aerosol daily cycle, exact solar zenith angle, single scattering albedo hypothesis) affects radiative calculations and make it difficult to systematically and quantitatively compare present results with previous estimates, that usually make use of other retrieval techniques and instrumentation and differs on temporal and spatial scales.

However, we believe that it is important to have long-period estimates of DARE over this particular region, where the cooling effect due to the presence of largely reflecting aerosol (such as desert dust), during December-February, may (at least partly) compensate on yearly basis the warming effect due to absorbing aerosols (smoke) transported during July-September over a semi-permanent stratocumulus deck. From 1997 to 2009, the sub-equatorial African continent contributed to approximately 28% of global biomass burning carbon emissions (van der Werf et al., 2010). It has been show in several works that at local scale the instantaneous TOA DARE off the coast of Angola can reach very strong values during the biomass burning season, larger than a hundred of W m^{-2} (e.g., de Graaf et al., 2012, with a spatial resolution of 60x30 km^2 and a peak DARE value of 132±8 W m^{-2}). The aim of this work is to then provide an overall DARE estimate, starting from daily satellite observation, to quantify in first approximation the regional energy balance between cooling and warming over the whole year, taking into account (even roughly) temporal variations of local meteorology and aerosol climatology.

In conclusion, the results presented in this paper confirm the strong positive radiative effect of BB above clouds and are substantially consistent with previous DARE estimates, that are mostly focused on the ocean area off the coast of Angola during the SH winter months/days but also show a substantial difference in absolute DARE values when different assumptions are made on SSA and aerosol vertical position. Because of the large number of uncertainties and error sources liked to each retrievals techniques and radiative transfer calculation, we believe that exact absolute DARE values can be considered (to a certain extent) as meaningless. On the other hand, we believe that a reliable estimation of the energy budget between positive and negative aerosol effects is fundamental to asses the climate impact of this region at global scale. Further research work is needed to provide sensitivity studies for a better understanding of the radiative impact dependence on each cloud and aerosol parameter, and in particular of the SSA.

"A brief
discussion of the parameters of MODIS is necessary, because the DARE estimates will
be rather dependent on the correct MODIS retrievals, which are not guaranteed. E.g.
the MODIS COT retrieval will be biased for a retrieval with overlying absorbing aerosols
(Haywood, 2004; Coddington et al., 2010) so these cannot be used without correction
for a claimed improved estimate of the DARE. Similarly, one would like to know how
the ANG is determined, what the retrieval uncertainties of this parameter are, and how
they would affect the DARE estimates"

For what concerns ANG:

MODIS aerosol retrieval algorithm over ocean (Tanré et al., 1997; Kaufman et al., 1997; Remer et al., 2009) uses six spectral channels in the 0.55 – 2.1 μm spectral range. Aerosol index is calculated as the product of AOD (retrieved at 0.55 μm) and the Angstrom coefficient, ANG. The latter parameter describes the spectral dependence of AOD on the retrieval wavelength and is generally larger for smaller the particle . It is calculated as

$$ANG = \frac{-\log(\tau_{\lambda_2}/\tau_{\lambda_1})}{\log(\lambda_2/\lambda_1)} \quad (1)$$

where τ represents the AOD retrieved at λ1=0.55 and λ2=0.86 μm. If MODIS AOD over ocean has been extensively validated through in-situ AERONET measurements (e.g., Demeret et al., 2005). Its random error has been shown to be relatively small, equal to 0.03±0.05τ with very little bias (e.g. Remer et al., 2005). An estimation of ANG error sources and bias magnitude is provided by Schutgens et al. (2013), that validated Level 2 MODIS collection 5 Angstrom coefficient, by comparison with AERONET coastal and island stations. They find that MODIS ANG shows no significant bias, which hardly depends on AOD, cloud fraction and other parameters. This is probably because of a balance of AOD errors in eq. (1). ANG random error is shown to be dependent from AOD but it is smaller than it might be expected, because of a substantial correlation of AOD errors at different wavelengths.

For what concerns MODIS COT:

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/m^2 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.

Either the comparisons of different DARE estimates should be complete, or preferably and probably the intention of the authors, the new ideas should be explored and described more extensively. Furthermore, the paper could be structured better and the use of a spell checker might have avoided a sense of haste and carelessness.

I changed the organization of the paper with one paragraph with only the analysis of satellite aerosol and cloud "climatology" and the model results, called "3. Results". In another paragraph, called "**4. Discussion**", I analyse error sources and uncertainties (paragraph 4.1) of our study and I try to compare our results with some of those studies mentioned, underlying discrepancies and trying to understand where the strongest differences come from (in paragraph 4.2).

Textual issues:

We tried to correct all textual issues proposed by referee#2. New text and correction are reported in red.