Estimates of global radiative forcing derived from the GlobAEROSOL dataset

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Introduction

As part of the NERC ADIENT project, the GlobAEROSOL aerosol optical depth product, derived from the Advanced Along Track Scanning Radiometer (AATSR) instrument on Envisat, formed the basis of a new estimate of clear-sky direct aerosol radiative forcing. The Edwards and Slingo (1996) broadband radiation code was used to perform the radiative transfer calculation, with the AEROCOM "Pre" model experiment providing the pre-industrial (1750) aerosol loading. Calculations are being done for each month of 2006.

AERONET AOD measurements, along with perturbed radiative transfer model runs are being used to provide a comprehensive characterisation of the uncertainty of the radiative forcing.

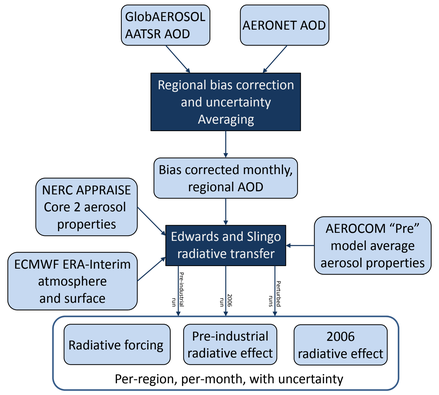

Fig.1. Flow diagram of the aerosol radiative forcing calculation and uncertainty characterisation .

Radiative code

The radiative transfer programme used in this study is Edwards and Slingo (1996) model, which is a fast, broad band two-stream model, developed for use with the Met Office models. It was run with five broad bands from 0.2 – 10 µm, driven by ECMWF ERA-Interim reanalysis data (temperature/pressure, water vapour, O_3, surface albedo) over 36 vertical levels.

GlobAEROSOL

GlobAEROSOL (http://www.globaerosol.info) AOD retrieved from AATSR using the dual-view Oxford-RAL Aerosol and Cloud retrieval scheme forms the basis for the radiative transfer estimate. The full GlobAEROSOL AATSR dataset has been compared to AERONET measurements on a regional basis, providing a bias and 1σ uncertainty estimate for each region.

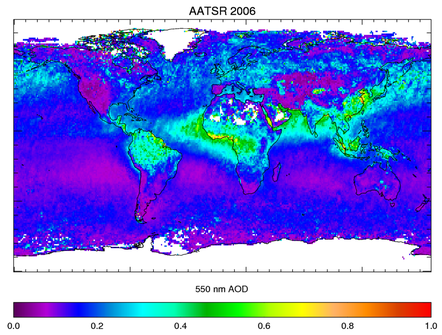

Fig.2. AATSR GlobAEROSOL mean 550 nm AOD for 2006.

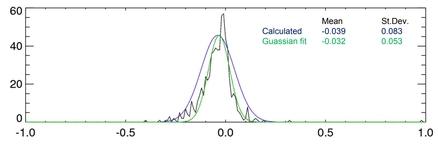

Fig.3. PDF of AATSR-AERONET AOD for the AL05 region (see Fig.4). Gaussian fits provide error statistics

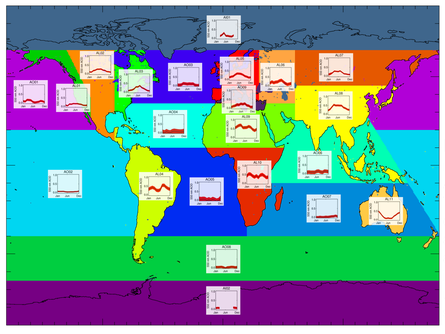

Fig.4. Monthly and regionally averaged AOD from AATSR. The values are corrected for bias against AERONET and the red shading indicates the 1σ uncertainty, including sampling error.

Aerosol properties

The aerosol properties used in the radiative transfer calculations originate from the NERC APPRAISE Core 2 project, undertaken at Reading, to improve the description of aerosol properties within global models. Errors arising from the use of different aerosol properties to those assumed in the GlobAEROSOL retrievals are included in the overall uncertainty.

Uncertainty characterisation

An important element of this work is an attempt to identify all significant sources of error in the measurements and calculations used, quantify them and propagate the resulting uncertainty through to the final radiative forcing estimates. The errors investigated are:

- Error in satellite AOD (see Fig.3).
  AERONET used as ground truth.
- Sampling error due to relatively poor AATSR spatial coverage (~6 days for global coverage).
  Monthly composites of MODIS data with full spatial coverage and AATSR-like sampling compared.
- Spatial error due to performing radiative transfer on regional average aerosol loading.
  1x1° radiative transfer performed for April 2006 .
- Temporal error due to using monthly average aerosol loading.
  Daily radiative transfer performed for April 2006.
- Uncertainty in aerosol properties.
  Radiative transfer repeated for a range of assumed aerosol properties including those used in GlobAEROSOL retrievals.
- Surface albedo uncertainty.
  Radiative transfer repeated using surface reflectance retrieved in GlobAEROSOL.

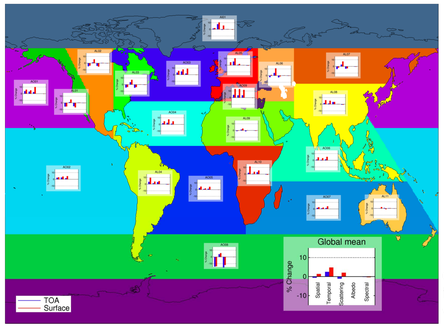

Fig.5. Percentage change in broadband flux corresponding to various uncertainties.

All uncertainties, except for that due to surface albedo (which is assumed to be independent of the atmospheric radiative fluxes), are expressed as relative errors in TOA or surface flux and added in quadrature, to produce a uncertainty in radiative effect.
Due to the unknown error in the pre-industrial aerosol loading, these uncertainties must be considered a lower limit on the radiative forcing uncertainty.

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GlobAEROSOL was an ESA Data User Element project

Results

Fig.6 shows radiative transfer results for the twelve months of 2006, using bias corrected GlobAEROSOL AODs. The aerosol radiative forcing at TOA and the surface is shown for each region. Note worthy features of the results include:

- The global forcing is poorly constrained, whereas many regions show clear signals.
- The largest forcings are found over land regions, where the largest anthropogenic aerosol loadings are found.
- The forcing tends to mirror and accentuate the seasonal pattern in AOD, especially in regions with a wide seasonal variation in solar elevation.
- Some regions show physically unreasonable forcings – such as the strong positive forcing seen in the Southern Ocean – which are almost certainly due systematic biases in between the models and measurements.

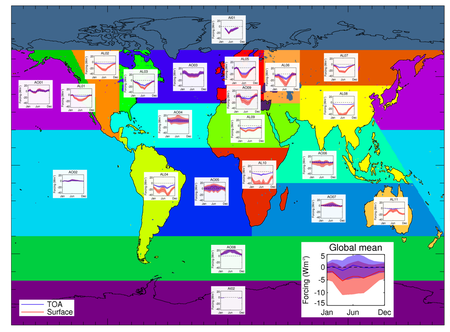

Fig.6. Aerosol radiative forcing for 2006. The width of the shaded areas indicates the 1-sigma uncertainty.

Conclusions

The global, annual average clear-sky TOA radiative forcing estimate from this analysis is (-0.15 ± 3.5) Wm^{-2}, which becomes (-1.6 ± 2.5) Wm^{-2} if the unreasonable positive forcing found in the Southern Ocean is neglected. Previous satellite based estimates of this quantity range between (-1.4 ± 0.9) to (-1.3 ± 0.2) Wm^{-2} (Bellouin et al. 2008; Forster et al. 2007), with a model ensemble approach producing (-0.66 ± 0.24) Wm^{-2} (Schulz et al. 2006).
The attempt to represent and propagate all of the most significant uncertainties in the radiative transfer problem in this study suggests that the radiative impact of aerosols is perhaps significantly less well constrained than other studies have suggested.

References

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