Lifting and Transport of Saharan Dust

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Abstract. Tropospheric aerosols have a significant influence on climate and have been recognised by the Intergovernmental Panel on Climate Change as the biggest source of uncertainty in understanding future climate, yet the factors controlling their spatial distribution remain unclear. Despite new observations from the UK ATSR instruments and the MODIS and MISR instruments (on NASA's Terra satellite) there are still open questions about aerosol sources, sinks, microphysical properties and the aerosol vertical distribution. A three-dimensional dust lifting and transport model, using meteorological fields from ECMWF analyses, is used to compare predicted dust loading over the Sahara with observations from AERONET, SEVIRI, AATSR, and MISR. The model will be used to investigate the sensitivity of the predicted aerosol profiles to variations in model parameters. Processes included in the model include emission, advection, diffusion, gravitational settling, and turbulent deposition.

Large scale dust storms have been observed coming off the Sahara desert [*Slingo et al.*, 2006] by satellite instruments such as SEVIRI, but these instruments cannot accurately assess the spatial distribution of aerosol particle sizes. The aim of the current work is to predict the transport of desert aerosol using meteorological and soil data.

The 3D model is driven by meteorological data from the European Centre for Medium-range Weather Forecasting (ECMWF) operational data set (91 hybrid levels at a resolution of 1.125°) and by soil data from the International Satellite Land Surface Climatology Project (ISLSCP), which provides an estimate of the distribution of particle sizes, at a resolution of 1°.

Implicit within the model is the role that *saltation* and *sand-blasting* have in mobilising and emitting dust particles from the surface: saltation is a transport mechanism in which sand particles are ejected by impact of other particles, and when they strike the surface again they eject (sand-blast) more particles. The emission flux is described by *Miller et al.* (2006) using the semi-empirical formula:

$$emission(r) = C\,F(r) \int w^2 (w - w_{tr})\, p(w)\, dw \qquad (1)$$

C is a factor equal to 1 μg s^{2}m^{-5}, $F(r)$ is the source size distribution, r is the particle radius, w is the horizontal wind speed at 10 m altitude, $w_{tr}(r)$ is the threshold wind velocity, and p(w)dw is the Weibull distribution of wind speeds. The larger particles (> 10 μm) quickly drop back to the surface, while finer particles (with radii typically less than 1-2 μm) can be transported to higher altitudes (up to 8 km or so), and further.

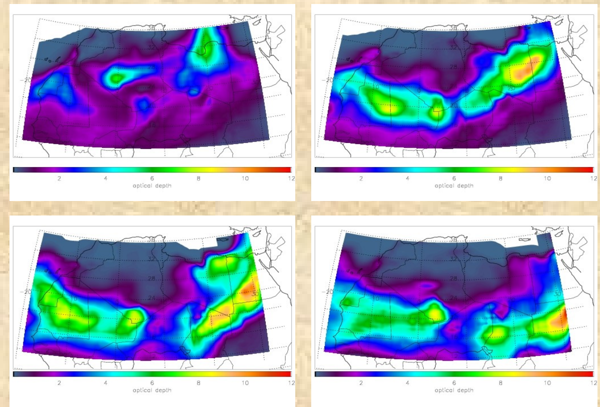

Figure 3: Maps of the model output optical depth fields, at a wavelength of 870 nm, from 6-9 March 2006.

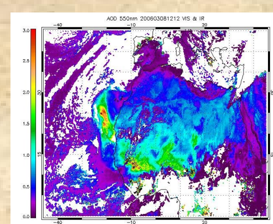

Figure 4:
SEVIRI AOD at 550 nm from Oxford-RAL retrieval algorithm (Elisa Carboni private communication). Data is taken from the SEVIRI instrument on Meteosat-8, on the 8/3/2006.

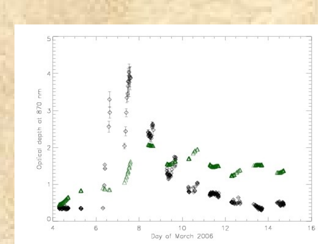

Figure 5: Inter-comparison between AERONET data from the Banizoumbou site in Niger (2.67°E, 13.54°N) and the corresponding model optical depth at 870 nm (white diamonds represent the AERONET data, and green triangles the model output). AERONET data courtesy of NASA (PI of the site is Didier Tanre).

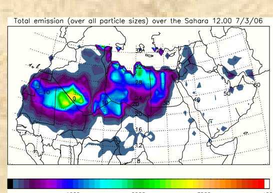

Figure 1: Plot of the total mass flux of particles being emitted from the surface of the Sahara at noon on 7/3/2006. This emission is due to saltation.

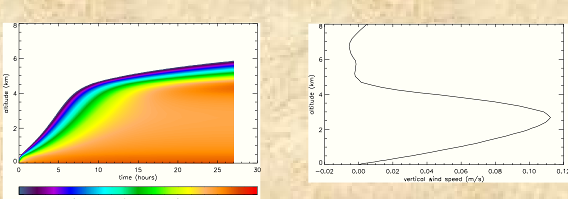

Figure 2: Model simulation of the evolution of particle number density for a 1D column, in the steady state. Conditions are at 12.00 on 16/5/2006, at 38.25°E, 28.125°N, in the north-west of Saudi Arabia. In terms of the size distribution, the number density peaks at r = 0.13 μm, while the concentration peaks at r = 1.0 μm. The vertical wind velocity profile is on the right.

The main source regions for mineral dust are those areas with a large amount of exposed fine particles. 'Hot spots' are regions which have been identified as particularly strong sources, these are generally dried lake beds or seasonal streams, which are regularly fed by fine silt particles, but which are dry, so that the particles do not stick to the surface as much as when it is wet. Rainfall is also a major factor in deposition, since raindrops are very efficient scavengers of mineral dust.

Output from the 3D model is a size distribution of particle concentrations, in 3 space dimensions and 1 time dimension, which can be easily translated into particle number density. Optical depth over each column can also be inferred, using Mie Theory: the assumed effective refractive index in the model is 1.5 + 0.004i [Munoz et al., 2007].

In order to validate the model results, the predicted optical depth can be compared against observations of optical depth. Instruments currently used include the AERONET network of ground-based sun photometers, the SEVIRI instrument on Meteosat 8 (ESA), the AATSR instrument on Envisat (ESA), and the MISR instrument on TERRA (NASA). Each instrument has their own advantages: AERONET can produce accurate values of optical depth in localised areas, SEVIRI can provide observations across the whole Sahara every 15 minutes, while AATSR and MISR can provide more resolved data than SEVIRI, and over a wider range than AERONET.

The model domain currently extends from -19.125 to 31.5°E, and from 11.25 to 36°N, at a resolution of 0.56° (~60 km); in the vertical, there are 18 layers, to a height of ~10 km. Within this domain there are 15 AERONET sites.

Further work will involve data assimilation, using observational data (from SEVIRI, etc.) to constrain the model parameters.

References

Miller R L et al. (2006). Mineral dust aerosols in the NASA Goddard Institute of Space Sciences ModelE atmospheric circulation model, *J. Geophys. Res.*, Vol. 111.

Munoz O et al. (2007). Scattering matrix of large Saharan dust particles: Experiments and computations, *J. Geophys. Res.*, Vol. 112.

Slingo A et al. (2006). Observations of the impact of a major Saharan dust storm on the atmospheric radiation balance, *Geophys. Res. Lett*, Vol. 33.