Retrieval of desert dust from visible and infrared SEVIRI data.

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ABSTRACT: Different algorithms retrieve aerosol over land using visible and near infrared spectral regions, but frequently they fail over bright surfaces where it is not easy to distinguish the aerosol signal from the surface. Extending the retrieval to use also the mid-infrared adds significant information for large aerosols (effective radius –> 1um) e.g. desert storm events. The model presented here includes both visible and infrared components and it is used to analyze data from SEVIRI (Spin-ning Enhanced Visible and Infra-red Imager), on board Meteosat Second Generation. This work is based on the ORAC aerosol retrieval algorithm, developed at Oxford University and Rutherford Appleton Laboratories for the visible and near infrared channels, with the extension to the two SEVIRI infrared channels centred at 10.8 and 12.1 microns.

The radiative transfer model used for the vis/nir channels takes into account atmospheric scattering and absorption using DISORT (DIScrete Ordinate Radiative Transfer) code. For the IR channels DISORT is used to parameterize the aerosol scattering, absorption and emission terms which are combined with the clear-sky and surface contributions (themselves based on ECMWF data and RTTOV optical depth computations). The forward model uses an aerosol database of macro-physical optical properties computed from different sets of published aerosol microphysical properties.

Results for desert events in March 2006 in areas with high surface reflectance (like desert) will be shown. Not all the aerosol models which result in reasonable fits to the measurements in vis/nir range are capable of simultaneously fitting IR radiances. The major uncertainty is related to the not well known spectral refractive index in the IR region. This emphasises the importance of the aerosol optical properties used in radiative transfer calculations and especially on the consistency from UV to IR which is needed to accurately estimate the aerosol radiative effect in both the short and longwave.

Oxford-RAL retrieval of Aerosol and Clouds (ORAC)

http://www.atm.ox.ac.uk/project/orac

The Oxford-RAL retrieval of Aerosol and Clouds (ORAC) scheme was developed to retrieve aerosol properties from satellite borne radiometers such as SEVIRI and (A)ATSR instruments. The ORAC forward model is sensitive to aerosol size, chemical composition, and shape, as these characteristics determine aerosol radiative behavior. The addition of the 2 infrared channels add sensitivity to aerosol vertical distribution, surface temperature and atmospheric profiles.

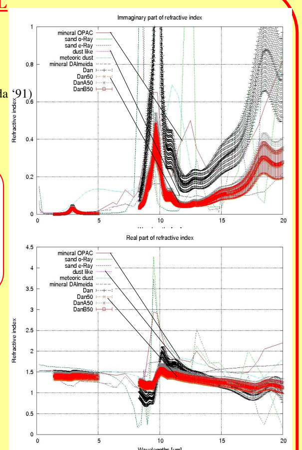
AEROSOL OPTICAL PROPERTIES

Every component is characterized by:

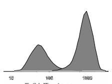
(1) Mode radius r_m and spread s log normal size distribution by number

(2) Spectral refractive index

3 models assumed below:
- OPAC (*Hess M. et al.* 1998)
- Dust-like (MODTRAN/D'Almeida '91)
- Oxford (Dan Peters, pri. comm.)



Approx: we consider up to components, external mixing, Mie spheres.

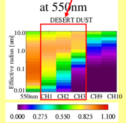


Changing the mixing ratio between components we obtain the optical properties corresponding to different effective radii

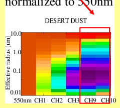
$K_{ext}(\lambda)$
$0 < \omega(\lambda) < 1$
$P(\theta, \lambda)$

Nadir satellite signals are influenced predominantly by scattering, in visible and near infrared spectral region (first 3 SEVIRI channels), and by total extinction in the infrared (ch 9 and 10)

Scattering coefficient normalized to extinction at 550nm



Extinction coefficient normalized to 550nm



Uncertainties in literature IR spectral refractive index for desert dust → Uncertainties in aerosol optical properties and difficulty fitting observations

We need a better aerosol characterisation in the IR spectral region

SEVIRI

http://www.atm.ox.ac.uk/project/seviri

Spinning Enhanced Visible and Infra-Red Imager. On board of Meteosat Second Generation (MSG) geostationary satellite. Spatial resolution 3 Km. 15 min time resolution.
SEVIRI has 12 channels in the 0.6-14µm range. In this study we use 3 VIS-NIR + 2 IR channles centered at 0.640,0.809,1.64, 10.78, 11.94 [um]

VIS-NIR FORWARD MODEL

Radiances are modelled by combining the spectral surface reflectance with pre-computed LUTs of the atmospheric reflectances and transmittances

$$R = R_{BD} + T_B T_D R_S \left[1 + R_S R_{FD} + (R_S R_{FD})^2 + (R_S R_{FD})^3 + \ldots\right]$$

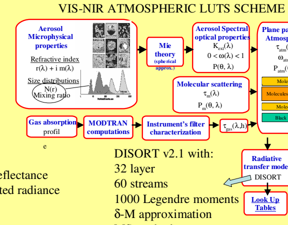
$R_{BD}(\theta_0, \theta_v, \phi)$ = direct bidirectional reflectance of the atmosphere
$T_B(\theta_0)$ = atmospheric transmission of the incoming beam
$T_D(\theta_v)$ = atmospheric transmission of the diffuse reflected radiance
R_S = surface reflectance
R_{FD} = atmospheric reflectance of the diffuse reflected radiance

Approx: plane parallel atmosphere $R_S R_{FD} < 1$

$$R = R_{BD} + \frac{T_B T_D R_S}{1 - R_S R_{FD}}$$

LUTs

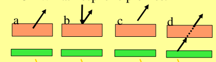
VIS-NIR ATMOSPHERIC LUTS SCHEME



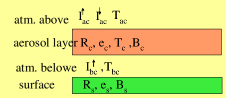
DISORT v2.1 with:
32 layer
60 streams
1000 Legendre moments
δ-M approximation
MS methods

IR FORWARD MODEL

We need to divide the contributions between atmosphere and aerosol layer components.
Aerosol layer optical properties are precompiled in LUTs.
Other atmospheric parameters (radiances above/below aerosol layer going up/down) are computed with RTTOV using ECMWF atmospheric profiles.



LUTs for aerosol layer optical properties



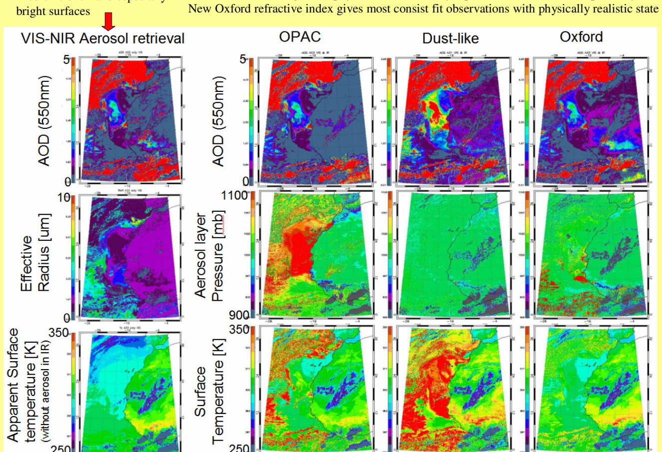
The suffix 'c' refers to aerosol layer, 'c' is to maintain the same notation as for ORAC cloud retrieval

FM extended to IR is a function of 5 parameters:
Aerosol optical depth (AOD),
Aerosol effective radius (Re)
Surface reflectance at 550nm (Rs)
Surface temperature (Ts)
Aerosol effective height (H)

CASE STUDY: DESERT PLUME (8 March 2006)

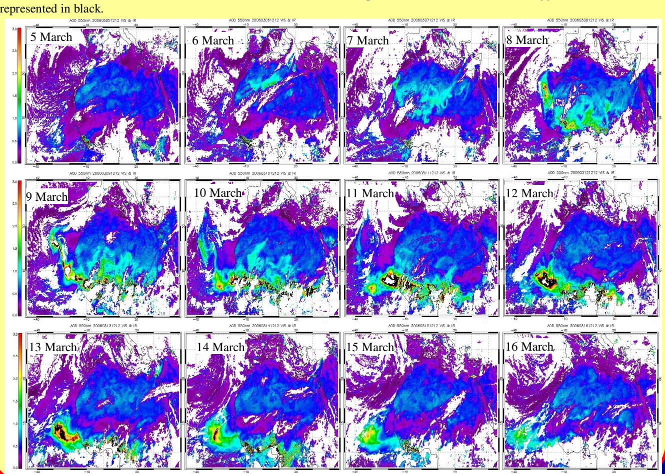
Results from VIS-NIR retrieval
Problems over land especially bright surfaces

Results with VIS-NIR + IR channels assuming 3 different spectral refractive indices
OPAC and dust-like give unphysical results (for layer pressure & surface T, respectively)
New Oxford refractive index gives most consist fit observations with physically realistic state



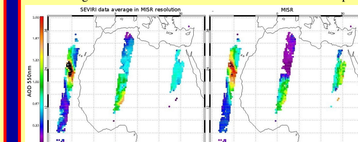
DESERT DUST EVENT: 5th-16th March 2006

Aerosol optical depth (AOD) at 550nm from 5th to 16th March 2006 (from right to left and top to bottom), retrieved using both visible and infra-red channels. SEVIRI data at 12:12 UTC. Colour-bar represent AOD from 0 to 3, AOD bigger then 3 are represented in black.



COMPARISON WITH MISR DATA

A preliminary comparison between MISR AOD and SEVIRI AOD retrieved with IR channels.
We average the SEVIRI retrieved AOD to match the MISR spatial resolution for the period 5-10 March 2006.



Example of SEVIRI data re-sampled at MISR resolution (left), compared with the MISR data (right) for 8 March 2006.

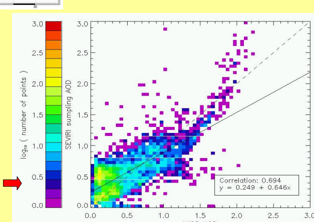
MISR data from NASA Langley Research Center web site: http://eosweb.larc.nasa.gov/

Similar features over ocean and over desert seen by MISR & SEVIRI !

SEVIRI overestimates the AOD over north Africa (presumably still affected by some error in modelling the surface reflectance)

Quality control of SEVIRI data:
Cost function < 15
0.01 < AOD < 4.99
Reff < 7 um
N.B. No cloud screening applied to SEVIRI!!

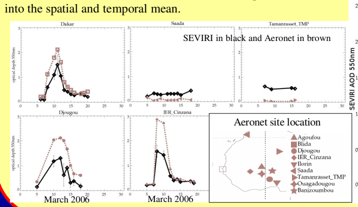
Density plot of AOD SEVIRI vs. MISR region 0:40 Lat. and -30:40 Lon.

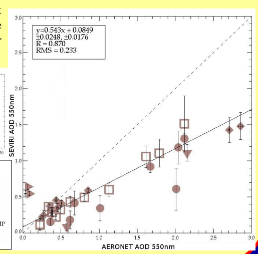


COMPARISON WITH AERONET DATA

For the period 5-20 March 2006 we made a comparison with AERONET lev.2 ground data.
Criteria: SEVIRI measurements within 20km from the Aeronet site. Aeronet measurement within 30min. from the satellite measurement. AOD standard < 0.15. At least 4 points must enter into the spatial and temporal mean.

AERONET data http://aeronet.gsfc.nasa.gov/





CONCLUSIONS:

Results have been presented from new optimal estimation retrievals which simultaneously fit SEVIRI visible, near-ir and mid-ir radiances. The analysis is focused on a desert dust case-study for which the IR channels are expected to add useful information to the solar channels, by adding sensitivity over the bright desert surface and information on aerosol layer height.

It has been shown that results are dependent upon the assumed spectral refractive index of desert dust. Indeed the optimal estimation method is confirmed to be a valuable tool for testing the consistency of aerosol optical models and observations. Two of the three aerosol models chosen are shown to be incapable of fitting the SEVIRI measurements with a physically realistic aerosol plus surface state. Of the models used, the new refractive indices measured by Oxford in the RAL molecular spectroscopy facility, provide the most consistent representation.

Using this set of optical properties it is possible to follow and quantify the desert dust event over bright surface with SEVIRI data.

The comparison with others satellite (MISR) and ground (Aeronet) data show the success of the method (quantified with the high correlation coefficient). However there remain discrepancies that show the need of future improvement for the characterization of the surface and of aerosol in the infared region.

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