Mineral Aerosol Profiling from Infrared Radiances (MAPIR)

File content and user information

We request that any potential user read this document to avoid misuse or misinterpretation of the data and especially its information content. We highly recommend to also reading the reference publication. Profile comparison with reference data and profile assimilation should be done according to the state-of-the-art literature on the subject and usually involves using the averaging kernels.

The user interested only in level 3 (average on a grid, daily and/or monthly, morning, evening or all day) dust AOD and/or dust mean altitude can find the data in the Climate Data Store (cds.climate.copernicus.eu) - search term "aerosol" then in the data set containing all aerosol data, select the MAPIR algorithm to access our data. The user interested in level 2 (at satellite resolution) dust AOD and/or dust mean altitude and/or the full vertical profiles of dust concentration should use the data set available here.

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Reference publication

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The Mineral Aerosol Profiling from Infrared Radiances (MAPIR) algorithm: version 4.1 description and evaluation, Sieglinde Callewaert, Sophie Vandenbussche, Nicolas Kumps, Arve Kylling, Xiaoxia Shang, Mika Komppula, Philippe Goloub, and Martine De Mazière, Atmos. Meas. Tech., 12, 3673–3698, 2019

Short algorithm description

The MAPIR algorithm retrieves **dust aerosols vertical profiles** (**7 layers** centred at 0.5km to 6.5km by steps of 1 km) following the well-known **Optimal Estimation** (OE) method with **Levenberg Marquardt** implementation (on the **logarithm** of the dust concentration), using three spectral windows in the so-called atmospheric window (800-1250cm-1). The surface temperature is also adjusted in the retrieval process as it is a very important parameter in the thermal infrared, but it is not considered a product and therefore not included in the files. Currently MAPIR is applied to data from **IASI/Metop-A** (sun-synchronous polar orbit with local solar time of about **9h30 and 21h30**).

The retrievals are done only for **cloud clear spectra** (<10% cloud cover in the IASI cloud data). This cloud cover data is of course not perfect: it misses some clouds (for which we have an additional filter after the retrieval) and it **mis-flags intense or unexpected dust** as cloud. The latter are therefore excluded from our retrievals, unfortunately.

For the parts of the globe **where dust is not frequent**, retrievals are attempted only when a **plausible dust signature** is detected in the spectra. That filter also flags a significant amount of non-dusty scenes, and **misses small events** in unexpected dusty places when their signature is not clear enough. Details on the filter can be found in the reference publication's section 4. IASI measurements at latitudes higher than 60° N and S are always rejected. Indeed at those high latitudes, dust events strong enough to be detected are scarce and the temperature conditions often unfavourable for that observation in the TIR.

Quality of the retrieval is assessed based on the root mean square of the spectral residuals (RMSSR). Retrievals with RMSSR lower than 1K, identical to the defined spectral noise for the MAPIR retrievals (about 5 times the IASI spectral noise), are considered good.

Uncertainty estimations are provided, but they do not yet contain the uncertainty due to uncertainties on the ancillary parameters (not retrieved, including aerosol optical properties). They are therefore most probably underestimated.

Information content and averaging kernels

The sensitivity of a vertical profile retrieval is characterized by the **Averaging Kernel** (AK), which is calculated during the retrieval. The AK is a **square matrix of the size of the state vector** (all retrieved parameters). In our case, we remove the parts linked to the surface temperature retrieval, leaving the AK to be a matrix of 7*7 linked to the vertical profile of dust in 7 layers.

The **diagonal** elements represent the specific **sensitivity** of the retrieval to **each layer**, while the **other** elements represent the **cross-sensitivity** between the different layers (i.e. AK_{ij} is the effect of "real" dust in layer j on the retrieved dust in layer i).

The **trace** (sum of diagonal elements) of the averaging kernel is called the "**Degrees Of Freedom**" (DOF) of the retrieval. For MAPIR, the DOF is **usually about 2** in good conditions (temperature not too low, and reasonable amount of dust aerosols).

Given that the DOF is about 2 while the number of retrieval layers is 7, it is obvious that **the precise dust concentrations retrieved in each layer are partly depending both on the a priori** (when the diagonal AK for that layer is significantly lower than 1) **and on the dust in other layers** (when the cross-diagonal elements are significantly higher than 0). Each layer's retrieved concentration is not independent, as only 2 independent pieces of information are available.

Note: The common assumption that those 2 pieces of information are the total AOD and the mean altitude is wrong here, as those are correlated in the case of Thermal Infrared aerosol retrievals. Therefore 2 DOF means that 2 independent layers can be retrieved.

Additional information on the averaging kernels, some examples and the implications of the OEM-LM implementation in the logarithmic mode retrieval are in the reference publication.

Additional information on how to **use dust concentration in a single layer** (for example, the layer closest to surface) are in another publication, in its section 3.1: doi.org/10.5194/acp-2020-130 [1]. One should **ensure a sufficient information content in the target layer**, using the corresponding **diagonal element from the AK**. If combining more than one layer in a partial column, again one should care that a sufficient amount of information is contained in those layers using the sum of the AK diagonal elements for those layers.

Data files content

The data is stored in **netcdf4** format. The data provided is the level 2 data, at satellite resolution. The files contain **only the cloud-free IASI scenes**. They do contain also results of dubious retrievals, which should be screened out using the **Post_quality_flag**, except for an expert specific use of the data.

Field name	**Short description**
Latitude	Latitude in degrees North, range -60 to 60
Longitude	Longitude in degrees East, range -180 to 180
Time	UTC Time in seconds since 01/01/1970, 0h
Vertical_scale	Mid-layer altitudes (km) for the dust vertical profiles (fixed)
D_vertical_profile	Retrieved dust vertical profile (concentration in particles / cm^3) on the vertical range given in "Vertical_scale")
D_vertical_profile_partial_uncertainty	Partial uncertainty on the dust vertical profile (concentration in particles / cm^3)
D_a_priori	A priori profile (particles / cm^3)
D_averaging_kernel	Full averaging kernels. See previous section.
D_AOD10000	Dust AOD at 10µm (column integration of the vertical profile, multiplied by the cross-section)

[1] North African mineral dust sources: new insights from a combined analysis based on 3D dust aerosols distributions, surface winds and ancillary soil parameters, Sophie Vandenbussche, Sieglinde Callewaert, Kerstin Schepanski, and Martine De Mazière, ACPD 2020

D_AOD10000_partial_uncertainty	Partial uncertainty on the dust AOD at 10µm
D_AOD550	Dust AOD at 550nm (D_AOD550= D_AOD10000 x 1.78)
D_ALT	Mean dust altitude (altitude at which half the dust column is below and half is above)
Dust_flag	Dust pre filter flag; 0 means the retrieval was not run and all dust values are set to 0, mean altitude and post quality flag are fill values
Surface_type_number	1 for land, 0 for sea
Satellite_zenith_at_center	Satellite viewing angle at the centre of the field of view (given with respect to the vertical at the ground)
Post_quality_flag	Flag referring to the post retrieval screening, ensuring good quality of the data. See next section.

Quality flags and data filtering

Two flags are available in the data files.

The "**Dust_flag**" is the a priori filter flag as explained in section 1 and is briefly described in the data content table. More information on how this flag is obtained can be found in the reference publication's section 4. When Dust_flag = 0, AOD = 0 and all dust concentration values in the vertical profile are equal 0. The uncertainty fields and the Post_quality_flag are set to the fill value.

The "**Post_quality_flag**" is obtained based on the Root Mean Square of Spectral Residuals (RMSSR, expressed in K) between the modelled spectrum after the retrieval and the observed spectrum. That value should remain below 1K for a reliable retrieval. In addition, there is a test to reject cloudy scenes undetected using the cloud screening before the retrieval: if the retrieved surface temperature is below 200K and the 10µm AOD higher than 5 the result is flagged as dubious/bad (value of 0)

- Post_quality_flag = **1**: the retrieval is considered reliable
- Post_quality_flag = **fill_value** (-9) : the retrieval was **not run** because the Dust_flag was not triggered (and the vertical profile and AODs are set to 0)
- Post_quality_flag **= 0**: the retrieval should be considered with caution; the retrieved dust profile might be good and the spectral error linked to an interfering species, but the retrieved dust profile might also be completely absurd; another reason for this flag value is when we suspect that the scene is cloudy instead of / in addition to being dusty

Known shortcomings of the algorithm / data set

- **Imperfect cloud filtering**: some intense dust plumes or smaller dust plumes but at unexpected places are erroneously flagged as meteorological clouds within the EUMETSAT IASI level 2 data; those are therefore unfortunately excluded from our retrievals
- **Imperfect dust presence pre-filter**: this filter exists for computational resources reasons. In the dust belt (defined in the reference publication) where the dust is most expected, all retrievals are undertaken. Outside that area, a pre-filtering on the spectral signature of dust is used. That pre-filtering misses small events and events at cold temperatures because their spectral signature is too small.
- **Uncertainties regarding the dust optical properties**: a generic set of dust optical properties is used, while in reality those may vary with time and space. The consequence is an increased uncertainty mostly on the vertical distribution of the dust aerosols.