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TITLE:

GMES SERVICE ELEMENT
PROMOTE 2

C6 Validation Report

DESERT DUST AWARENESS SERVICE
Version 2

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BT	Brightness Temperature
BTD	Brightness Temperatures Difference
CGS	Carlo Gavazzi Space
CNR	Consiglio Nazionale delle Ricerche
CTM	Chemical Transport Model
DCW	Digital Chart of the World
DVB	Digital Video Broadcasting
GEOS(x)	Geostationary projection with sub-satellite point located at x degrees
GMV	Grupo de Mecánica de Vuelo
GRASS	Geographical Resources Analisys Support System
HRIT	High Rate Information Transmission
ISAC	Institute of Atmospheric and Climatic Sciences
MSG	Meteosat Second Generation
SAF	Satellite Application Facility
SEVIRI	Spinning Enhanced Visible and Infra-Red Imager
INM	Instituto Nacional de Meteorología
UML	Unified Modelling Language
TS	Technical Specification

N/A	Not Available
n.a.	not applicable
n.s.	not specified

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1 DESERT DUST AWARENESS

1.1 Service Summary

The desert dust awareness service is based on measurements of SEVIRI instrument on board MSG-1 and MSG-2 satellites. The service uses infra-red bands and visible bands. In particular, visible bands can provide quantitative information on parameters such as Aerosol Optical Depth and Angstrom Coefficient. Infra-red bands, on the other hand, can be adopted to enhance the presence of a desert dust transport towards the regions of interest. The repetition cycle of SEVIRI measurements allows the tracking of desert dust outbreaks.

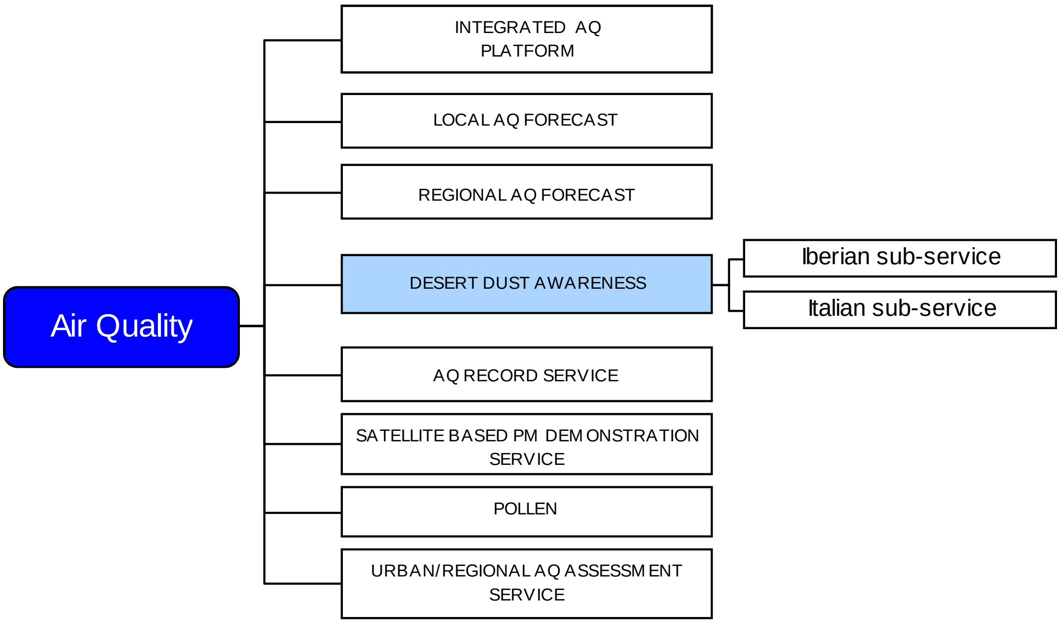

Figure 1.1-1 Structure and position of the Desert Dust Awareness Service within PROMOTE 2 Air Quality.

1.2 Product characterization

The products consist of retrieved estimates of aerosol optical depth (AOD) at 0.55 and 0.87 µm. IGAPs are individual sensor products for each day in which the "best" type has been selected from the 5 types considered by the algorthim (MARITIME, URBAN, DESERT DUST, BIOMASS, CONTINENTAL). The Angstrøm coefficient derived from these two optical depths is also reported.

Desert dust indicator	
Parameter	n.a.
Typical range	n.a.
Determination of the typical range (Method, criteria)	n.a.
Maximum range	n.a.
Units	n.a.
Standards	n.a.
Speciation	
Parameter	Speciation
Typical range	0-4
Determination of the typical range (Method, criteria)	0 Continental 1 Desert Dust 2 Maritime 3 Urban 4 Biomass
Maximum range	n.a.
Units	n.a.
Standards	*n.s.*
Aerosol Optical Thickness 550 nm	
Parameter	AOD550
Typical range	0-1.3

Determination of the typical range (Method, criteria)	n.a
Maximum range	n.a.
Units	[-]Dimensionless
Standards	*n.s.*
Aerosol Optical Thickness 870 nm	
Parameter	AOD870
Typical range	0-1.3
Determination of the typical range (Method, criteria)	n.a.
Maximum range	n.a.
Units	[-]Dimensionless
Standards	*n.s.*
Angstrom Coefficient	
Parameter	Angstrom Coefficient
Typical range	0-1
Determination of the typical range (Method, criteria)	n.a.
Maximum range	n.a.
Units	[-] Dimensionless
Standards	*n.s.*

Table 1.2-1 Desert Dust Awareness products characterization

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1.3 Iberian sub-service

Service is/will be operational since/after: May 2007

Research partners: Within validation phase will collaborate: Miguel Ángel Martínez (INM), Emilio Cuevas (Instituto Izaña).

Provider(s): GMV

Validation contact: Oscar Perez Navarro (e-mail: operez at gmv.com)

1.3.1 Validation plan and validation data

It is important to highlight that the validation has been performed using mainly the thresholds on effective radii and they are set as follows:

- Continental: 0 ≤ re ≤ 0:4µm.
- Desert: 0:1 ≤ re ≤ 8µm.
- Maritime: 0 ≤ re ≤ 8µm.
- Biomass: 0 ≤ re ≤ 0:2µm
- Urban: Thresholds are set so this type is never selected (the number of cases where this
- type is expected to be realistic dominate is too small to attempt to include it in the automatic speciation scheme).

It has to be noted that as much of the comparison are with AERONET data, then agreement with AERONET is likely to be poor if the assumed aerosol type is incorrect. Results for the merged products therefore depend on the assignment of type which is known to be problematic in many cases

1.3.1.1 Development and testing of a validation tool

This sub-service was validated in 2006 but due to a change in user requirements a new validation plan is currently in progress. As a consequence, the service is at the moment in an improvement phase (development status).

A visualization tool has been developed allowing the user inspecting data produced, defining validation parameters and obtaining graphical displays of validation results. The interface developed allows saving test configuration parameters and generation of log files containing all steps followed by the users during the validation process. Outputs are saved and can be displayed graphically using a range of colours to designate error ranges, allowing users to pick a general idea about the overall quality of the comparison. In addition, dump parameters can also be defined and invoked by specific dump command lines. Dump definitions and outputs can be saved, loaded and displayed as well.

The performance of this visualization tool is evaluated by means of traceability matrices allowing for the verification of design requirements: Each software component (basically objects, with associated functions and timing) identified and described in the Design shall be traceable from (forwards traceability) and to (backwards traceability) the requirements of the TS. Furthermore, UML rules and conventions shall apply to the production and verification of the models.

A set of tests has been defined to verify the suitability of this tool as a guarantee of the coverage of the PROMOTE functionality and to set and verify the validation and quality control procedures to be applied to the products. As a first step, the test data selected for this purpose is used as an input and as a reference.

Therefore, a Unit Testing (UT) approach is taken in order to check the conformance of each software operation with its detailed design. The expected result is that each individual software module behaves according to its detailed specification and, therefore, that each operation provides the expected outputs for different sets of inputs, calls expected subprograms, etc.

Unit tests are built following a black box approach (i.e. the module is tested seeing its interface and not its internals) but assuring a full coverage as in white box testing: all code lines of the module under test have been executed at least once and in reasonable combinations.

In every validation-test phase it is needed to define Item pass/fail criteria in order to detect whenever a test is successfully executed. Consequently, each test procedure will have an outcome, which should be clearly identifiable as a pass or a fail.

1.3.1.2 Validation by means of the visualization tool

Every time a validation is started a set of risks is assessed. Unit testing can be performed independently for each software module, so that the risk of global testing suspension is very low, i.e. when an error is found just the suspension of testing for this module would normally be required. This allows the possibility of reducing the time spent for unit testing by allocating more people to this task.

Making parallel unit and integration testing compatible could also shorten scheduled time. Modules used for integration should have been previously tested at unit level, so that those modules early required for integration are suggested to be unit tested first. The best approach will be to carry out unit tests in the same order as modules are required for integration

Testing tasks have been described in previous sections. They can be summarised as follows:

- Test design, test cases specification and test procedures determination. Document them in this document.
- Review this document for suitability of test cases for their intended purpose.
- Set up necessary files needed for test execution (e.g. test drivers and simulators, scripts, makefiles…).
- Execute the tests (compile necessary components, link to an executable file, download it to the target hardware, examine test results…) and document test results.
- Updates in source/test files and documents due to tests results.
- Execute regression test cases after software updates. Regression testing shall be automated as far as possible to minimise effort in repeating tests.
- Progress revisions are planned as both the development (basically coding) and UT evolves, to assess the status of activities, but not formal reviews are planned until the end of the tests.

Automated testing execution should be achieved in a very high degree. This will provide easy execution and repetition of tests, especially important for regression testing.

1.3.1.3 Validation of SEVIRI data with AERONET and ADRIEX data

The preliminary inter-comparison has been done for the period 26th of August to the 30th of September 2004, for SEVIRI instrument.

The SEVIRI data used in this analysis was version 0100 of level 1b and version 0100 of the cloud flag. September 2004 has significant biomass burning at southern tropical sites, such as central Africa and Southern America. It is also within a period of significant desert dust plumes over the Atlantic, this data set was used in the Aeronet validation and monthly comparisons. The data from August 2004 was used in the case study comparison during the ADRIEX campaign and also to understand the variation of AOD with time. All the SEVIRI data presented in this validation report was processed at RAL. The data was produced at 10x10km resolution.

The September 2004 period was selected to provide over lap with the ADRIEX campaign, (27August - 6 September). The complete month of September was analysed for comparison with monthly composites from other satellite sensors. This late period in the GAP temporal coverage is also suitable for the preliminary GAP in that (a) in more recent years the coverage of Aeronet data has greatly increased (b) SEVIRI data is routinely available since operation of Meteosat-8 commenced on 29 January 2004. The number of ground-stations receiving data (and hence coverage) has increased. Algorithms to improve pointing knowledge have improved with time, but the issue may well mean there is little value in validating SEVIRI aerosol from the 2004 preliminary GAP. This will be investigated and if geo-location proves to be a severe limiting factor, then a second month, will be selected as preliminary GAP.

The preliminary inter-comparison has been done for the period 26th of August to the 30th of September 2004, for SEVIRI instrument.

VALIDATION DATA	
Ground based/in-situ/Remote Sensing (ADRIEX) observations	
AERONET stations Levels 1.0, 1.5, 2.0 Phase 1+2	http://aeronet:gsfc:nasa:gov. Data availability and access: All AERONET measurements for the given ground station are extracted with time ±DT of the satellite overpass. The baseline for DT is 30 minutes (which given a typical aerosol transport speed of 50km/hour is consistent with the 50km spatial distance sampled from the service GAP Data (measurements) were provided into binary files. Spatial coverage and resolution: Pixels are selected within a region on ±20 km from each station (from a 10km resolution grid). Temporal coverage and resolution: August-September 2004 Location(s) (coordinates): 36.48° lat 34.28° lon Accuracy: 0.02 over ocean and 0.05 over land

ADRIEX Campaign Phase 1+2	Data availability and access: Data is provided in binary files. Spatial coverage and resolution: 10 Km resolution grid Temporal coverage and resolution and resolution: 27-08-2004/6-09-2004 Location(s) (coordinates): Northern Italy, the Adriatic Sea and between Northern Italy and the West coast of the Black Sea Accuracy 0.02 over ocean and 0.05 over land
Model outputs	
N/A	
Other EO Data	
SEVIRI Version 0100 / level 01 Version 0100 of cloud flag Phase 1+2	Data availability and access: Images at 10:12 et 16:15 Spatial coverage and resolution: 10x10 Km2 Temporal coverage and resolution: 26-08/30-09 2004 Location(s) (coordinates)/computational domain: Whole SEVIRI image Accuracy: 0.02 over ocean and 0.05 over land
MODIS Phase 1+2	Data availability and access: N/A Spatial coverage and resolution:1°x1°. Temporal coverage and resolution: September 2004 Location(s) (coordinates)/computational domain: Full earth coverage Accuracy: 0.02 over ocean and 0.05 over land

Table 1.3-1 Data used for the validation of the Iberian Desert Dust Awareness sub-service

1.3.2 Validation of individual components

1.3.2.1 SEVIRI cloud screening

The Operational SEVIRI cloud flag was found at an early validation stage to underestimate the real amount of cloud in a pixel. Fortunately, the technique used to retrieve aerosol optical depth has a number of measures to identify cloud-contaminated pixels. The following extra quality control was applied to identify cloudy pixels:

- Retrieval must reach a proper convergence.
- Optical depth is less than 3.0.
- 'Cost', *i.e.* the measure of the fit to the aerosol model, is less than 10 over land and less than 5 over sea.
- More than one iteration of the retrieval is performed.
- The effective radius retrieved is less than the maximum defined for the selected aerosol type.

The Application of this quality control remove approximately extra 20% of pixels previously deemed clear.

VALIDATION OF INDIVIDUAL COMPONENTS	
Best stimator	
n.s.	
Screening procedures	
Identification of outliers	AOD550, AOD870. The way to identify out of range values is fixing a threshold that has been established on 3.0 as maximum and 0.0 as minimum (by definition). So the procedure is comparison against a fixed value.
Bad retrievals	Parameters checked for bad retrievals are exactly the same ad the ones considered for outliers: AOD550, AOD870. We apply the following quality checks: Cloud Fraction set to 0. Sun glint Effective radius < 3Mm Surface albedo < 0.12 Cost function <3 for continental over sea. Cost function <10 for desert over sea Cost function <30 for maritime over sea Cost function <1 for biomass over sea Cost function <30 for continental over land Cost function <1 for desert over land Cost function <1 for maritime over land Cost function <2 for biomass over land
Quality checks	Cloud Fraction set to 0 Sun-glint Effective radius < 3Mm Surface albedo < 0.12 Cost function <3 for continental over sea Cost function <10 for desert over sea Cost function <30 for maritime over sea Cost function <1 for biomass over sea Cost function <30 for continental over land Cost function <1 for desert over land Cost function <1 for maritime over land Cost function <2 for biomass over land
Accuracy/error	0.02 Over ocean and 0.05 over land.

Cross-correlation	With Aeronet: Cost < 10 Number of iterations > 1 AOD < 3 Cloud fraction = 0.0
Validation pass/fail criteria (Regression testing)	0.02 over ocean and 0.05 over land
Cloud screening quality control	See figure 1.3
Aeronet data manual inspection	n.a
Model/algorithms	
SEVIRI Cloud Screening (SEVIRI Cloud Mask v1)	SEVIRI Cloud flag needs a correction that can be done for Optical Depths of less than 3 and when the retrieved aerosol effective radius is smaller than 10 over land and smaller than 5 over sea. See 1.3.2.2 and Smirnov, 2000
	The validation parameter is the standard deviation
AERONET Cloud Screening (v2.0)	See Section 1.3.2.2 and Smirnov, 2000
	See Figure 1.3-1
SKYNET vs AERONET ()	Only Cloud free data is used for validation
	The validation is done by mean of a cross-correlation
DISORT Model ()	Only Cloud free data is used for validation.
	The validation is done by mean of a cross-correlation
Sunglint Correction (3rd SEVIRI Slot)	Sunglint calculated using ECMWF winds using the Cox and Monk formulation and an under light and foam contribution
	Not final parameter stored. It is intermediated data used for the final process.
Other	
1x1 AOD Monthly averages	Creation of Weekly or monthly products containing minimum, maximum, average and standard deviation of AOD and Angstrom Coefficient. The bin size may be selected for 1 kmX1 Km or 1°x1°
	AOD averaged Angstrom Coefficient Averaged

Table 1.3-2 Validation of individual components of the Iberian Service

1.3.2.2 Screening procedures

Measurements, which are contaminated by cloud, are identified by a screening procedure, Smirnov 2000, based on the assumption that large, rapid variations in retrieved AOD are caused by clouds. The flowchart for this screening process is shown in Figure 1.3-1.

Filters are applied to the triplet of observations upon which a single AOD measurement is based, and over all observations on a given day. Only data, which is known to be cloud free will, be used for validation of PROMOTE products. The screening procedure (which also includes a number of other quality control tests is illustrated schematically in Figure 3) In addition to the automatic cloud screening and quality assurance procedure, data are also manually inspected at Aeronet to further ensure a consistent data quality (level 2 data). Only Level 2 data is used in this project.

For each daily product a separate ”coincidence file” containing all information required to perform the validation was generated as follows:

For each of the selected Aeronet stations :

- The closest ”ground-pixel” (i.e. 10x10km grid box) is identified.
- AOD and Angstrom coefficient are extracted within a region on ±ΔP pixels from this pixel. The baseline value of ΔP is 2 from, Ichoku 2003.

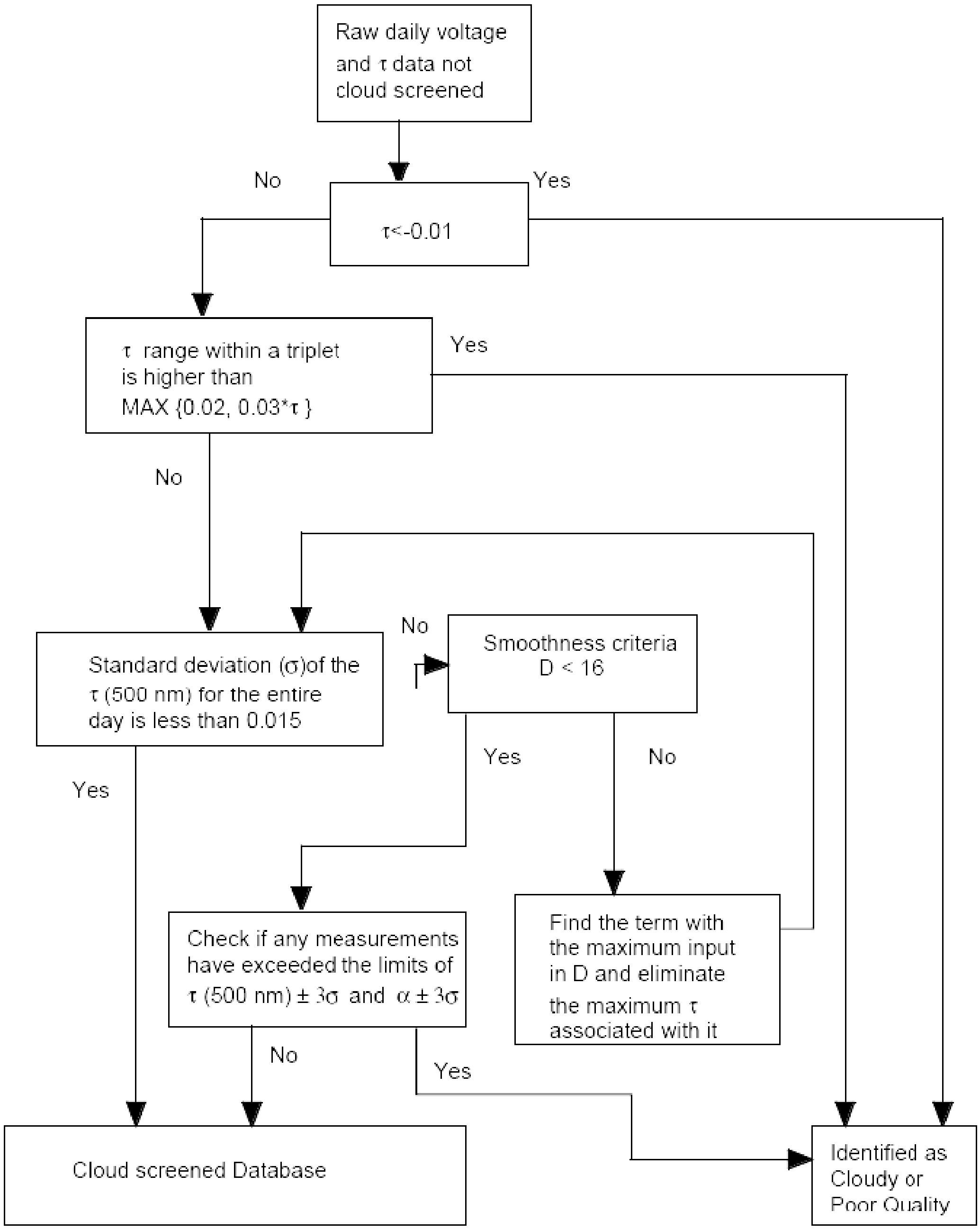


Figure 1.3-1 Schematic of the Aeronet cloud screening procedure from, Smirnov, 2000.

- The number of valid PROMOTE retrievals, mean and standard deviation of τA and σA from this spatial sample are determined and stored as NG, μτG, στG, μαG, σαG, respectively. The estimated accuracy of the mean quantities is also estimated and stored based on the error diagnostics provided with the retrieval (taking into account approximately whether these errors are expected to be random or systematic over the relevant spatial scale): ΔμτG, ΔμαG.
- All Aeronet measurements for the given ground station are extracted with time ±ΔT of the satellite overpass. The baseline for ΔT is 30 minutes (which given a

typical aerosol transport speed of 50km/hour is consistent with the 50 km spatial distance sampled from the PROMOTE product if ΔP is 2).

- The number of valid retrievals, mean and standard deviation of τA and σA from this temporal sample are determined and stored as NA, μτA, στA, μαA, σαA, respectively.
- There was no Earlinet lidar data provided that was time coincident with SEVIRI satellite retrievals.
- For SEVIRI a separate file is produced for each time-step.

For the extraction of coincident measurements the following validations and inter-comparisons were undertaken:

- Comparison with Daily Aeronet measurements of optical depth at 0.87nm and 0.55nm.
- Inter-comparison with MODIS 1x1o monthly averaged optical depth.

1.3.2.3 Fits of Aeronet site measurements to coincident SEVIRI retrievals

SEVIRI optical depths are compared with the Aeronet retrieved optical depths. A comparison is made assuming 6 different aerosol types and then with the merged data set, which selects the optimal aerosol type based on cost. The quality control applied in the first scenario is

1. Cost < 10
2. Number of iterations > 1
3. AOD < 3
4. Cloud fraction = 0.0

In the merged data set after careful analysis of the data the selection criteria was biased to prefer continental or biomass aerosol over land and maritime or desert over sea. The quality criteria applied in this case was

1. Cost < 3 for continental over sea
2. Cost < 10 for desert over sea
3. Cost < 30 for maritime over sea
4. Cost < 1 for biomass over sea
5. Cost < 30 for continental over land
6. Cost < 1 for desert over land
7. Cost < 1 for maritime over land
8. Cost < 2 for biomass over land
9. Number of iterations > 1
10. AOD < 3
11. Cloud fraction = 0.0

It must be noted that before the aerosol types are merged the appropriate bias correction must me made to the aerosol type selected.

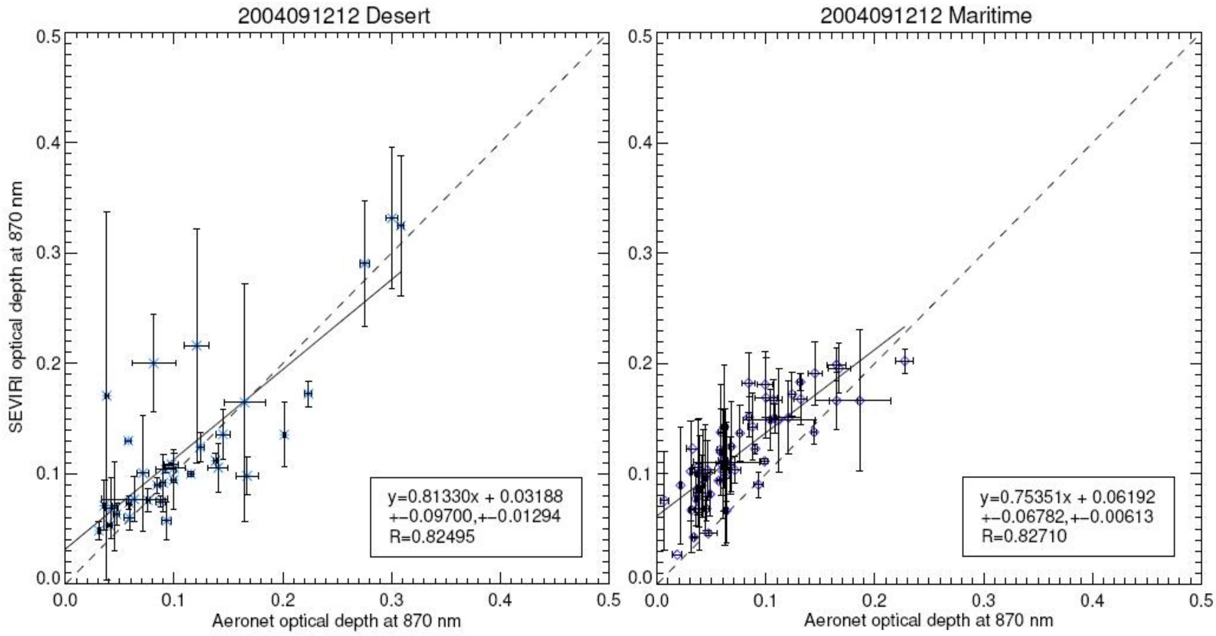


Figure 1.3-2 Comparison of 0.87 m Aeronet site measurement with SEVIRI measurements.

Scattering aerosols: Most aerosols fall into this category. In this category the extinction is mainly a result of molecular (Rayleigh) scattering. The aerosol types that fall into this category are the continental, desert and maritime aerosols. At small effective radius, (re), the signal from these aerosols is almost identical, only as the effective radius changes do the aerosol properties change

- Absorbing aerosols: The urban and biomass aerosols fall into this category. These aerosols, which may be composed of soot, are strong absorbers, and a considerable part of their reddening is due to the increase in their absorption at short wavelengths..
- All the aerosols types in the model used here are spherical.
- Ideally we would like to include many more aerosol types in particular mixed aerosols in the retrievals as theses are probably more realistic than some of the single aerosol types used here, this is reserved for future investigations

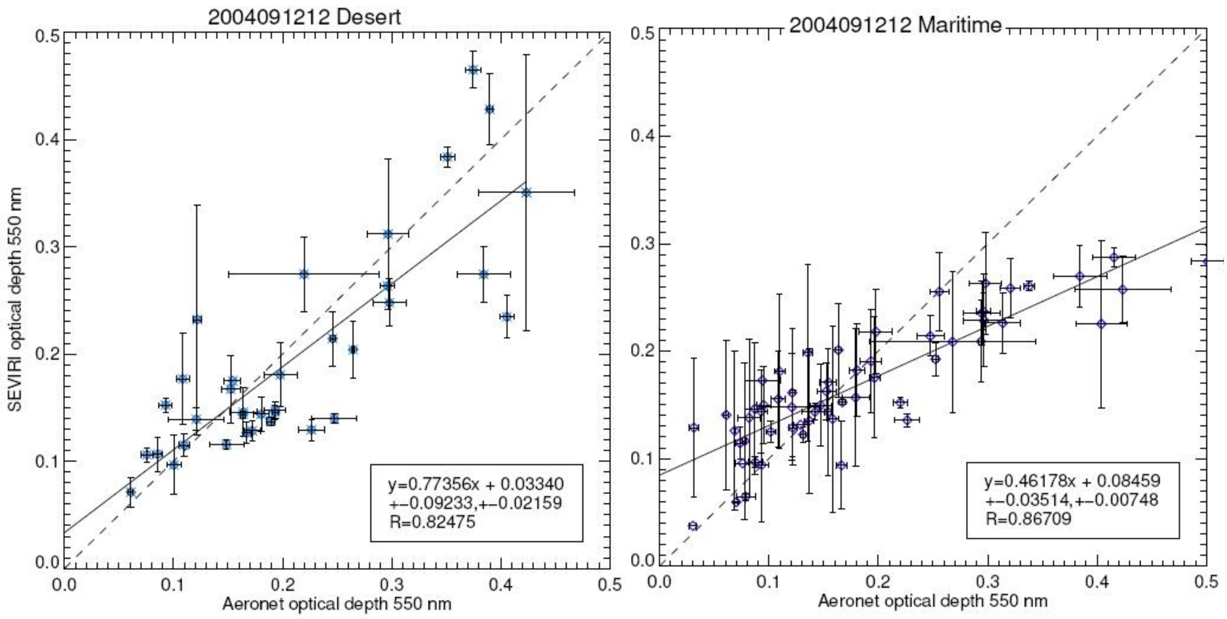


Figure 1.3-3 Comparison of 0.55 m Aeronet site measurement with SEVIRI measurements.

and show that most of the retrievals fit a scattering aerosol in preference to an absorbing aerosol type. The Aeronet retrievals in these figures are over sea, land and coastal areas. The 0.87nm channel has optical depths that are consistently smaller than the 0.55nm channel optical depths the 0.87nm AOD shows the best correlation, over 80channel so this result is interpolated. The comparisons with the 0.55nm channel show a positive bias at low AOD and a negative bias at high AOD. The underestimation of AOD at high values has been noticed before in comparisons of MODIS data with Aeronet site. In that paper they comment that the underestimation may be due to insufficient light absorption in aerosol models. Perhaps a better channel to measure optical depth for SEVIRI would be the 0.67nm channel.

1.3.2.4 Results

and show the comparison of each individual SEVIRI aerosol type with Aeronet 0.87 nm and 0.55nm channels respectively. The error bars indicate the standard deviation of the AOD used over the ±30 minutes of Aeronet data and ±20 km of SEVIRI data to create the match up. The line of best fit and correlation coefficient for each graph is calculated using the SEVIRI and Aeronet error bars. It should be noted that we do not expect to see good agreement for all the measurements as clearly if the aerosol type used to retrieve the optical depth is the wrong type of aerosol then the optical depth retrieval will be incorrect. In the simplest characterisation the aerosol types can in general be divided into 2 separate categories:

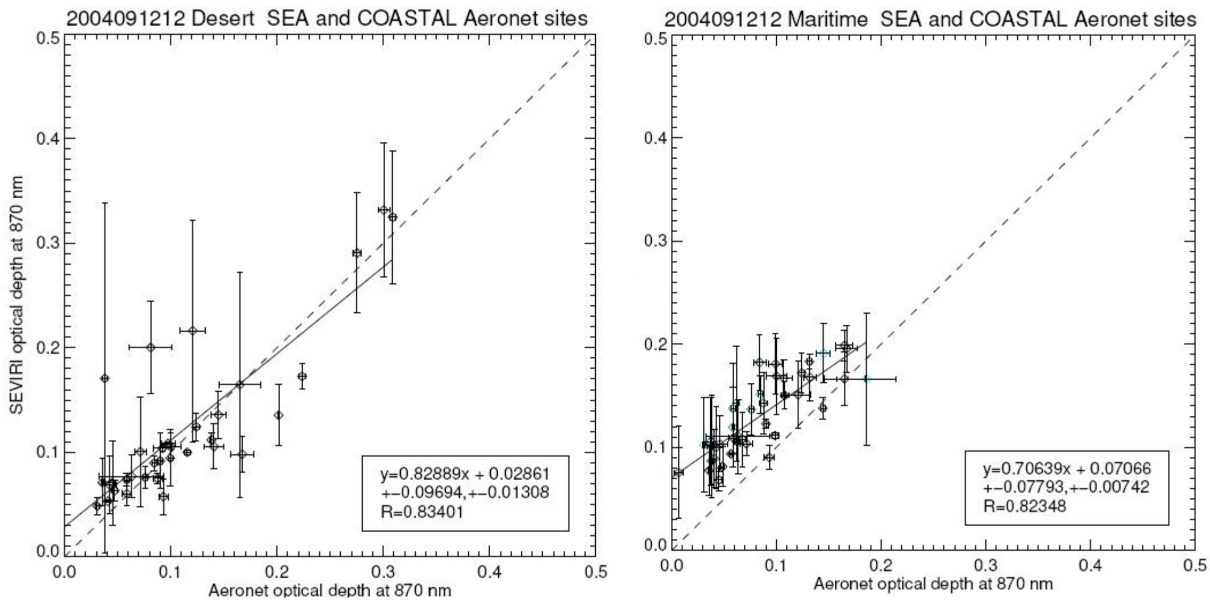


Figure 1.3-4 Comparison of sea and coastal 0.87 m Aeronet site measurement with SEVIRI measurements.

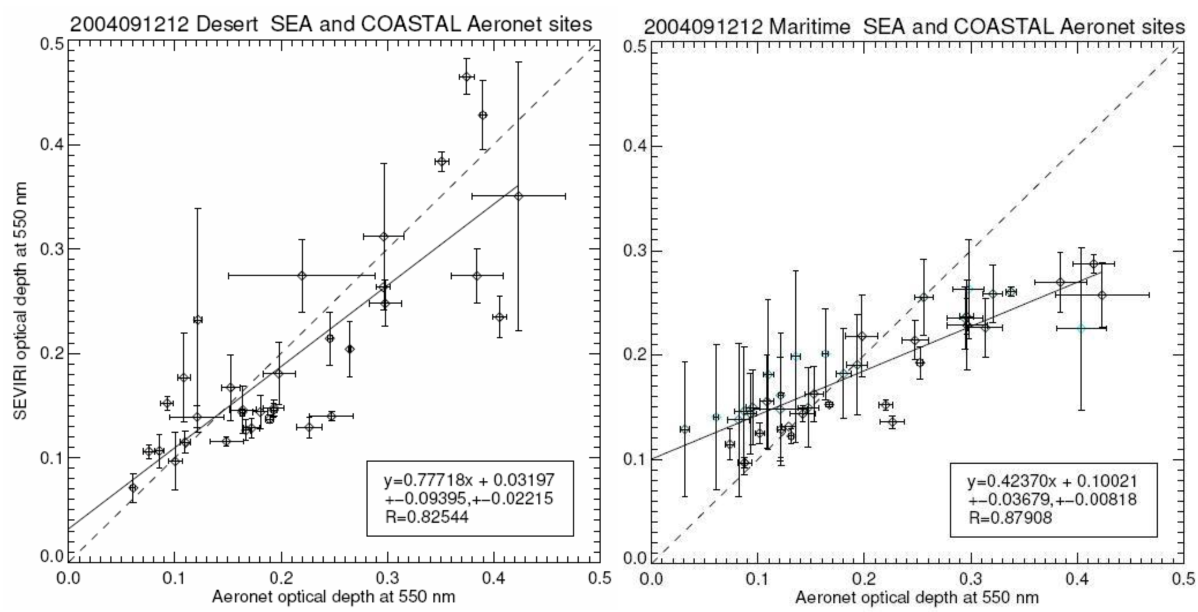


Figure 1.3-5 Comparison of sea and coastal 0.55 m Aeronet site measurement with SEVIRI measurements.

In and only the Aeronet sites, which are sited on the coast, are considered i.e the SEVIRI retrieval in these cases had a land fraction ranging from 0 to 0.99. The comparison with Aeronet observations in these cases is much better. This reflects that it is generally easier to retrieve the properties of bright aerosols over dark surfaces. At low optical depths there is a slight positive bias consistent with that seen by other remote sensing instruments such at MODIS. This is most likely due to incorrect modelling of the ocean surface. This is particularly a problem in coastal regions where the ocean colour can vary substantially from the default Cox and Munk (with wind correction) calculation due to the presence of brighter, 'type 2' coast waters. At high optical depths there is a slight negative bias. Interestingly for maritime aerosols there is a slight overall positive bias. This could also be due to the difference in viewing geometry between the Aeronets cimel photometer and the geostationary SEVIRI instrument. The Cimel photometer views pointing straight up while SEVIRI has a view angle that varies with latitude. The SEVIRI measurement therefore has a longer path length that will intercept more aerosol. The bias is relatively constant in the match ups identified in September 2004, nearly all of the match ups where in the European region.

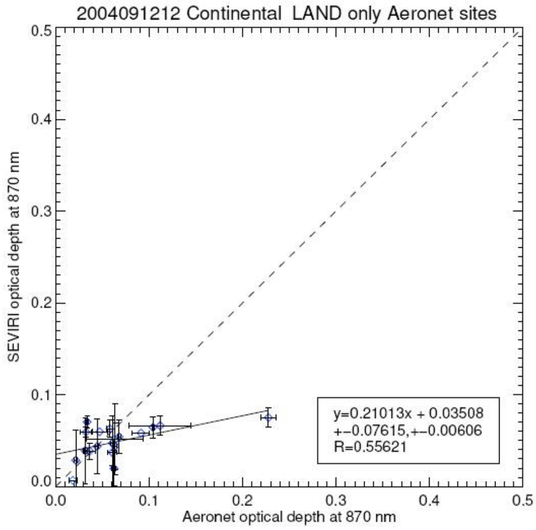


Figure 1.3-6 Comparison of land 0.870nm Aeronet Site measurements with SEVIRI Measurements.

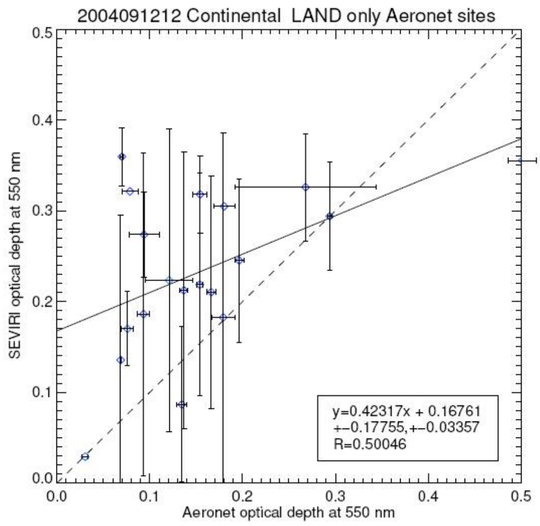


Figure 1.3-7 Comparison of land 0.550nm Aeronet Site measurements with SEVIRI Measurements.

The land only matches ups shown in Figures 1.2.7 and 1.2.8 have considerably worse agreement between satellite and sun photometer retrievals. This result suggests problems retrieving aerosol over highly reflective surfaces. The worst retrievals were over desert surfaces. In the absence of an operational SEVIRI surface reflectance product we have used the MODIS 16 day averaged albedo for the land surface reflectance that correspond to the SEVIRI channels. While we allow the retrieval to adapt within errors to a different land surface reflectance, this product could be improved.

1.3.2.5 Merging the aerosol types

After studying the retrieval accuracy as a function of aerosol type, it was decided to amalgamate only the continental, maritime, desert and biomass retrievals. The urban and polluted maritime results gave misleading results when included in the amalgamation. The validation plots and maps are still included for completeness and for further future flexibility. Figure 1.2.9 shows the results of the retrievals that have been selected as the best match on the basis of cost. The retrievals show a mix of aerosol types including some absorbing types that would be expected to be associated with urban areas. The results are better for the 0.87nm channel than the 0.55nm channel. There is a positive bias at low optical depth and a negative bias at high optical depths, which is consistent with the individual aerosol comparisons. This bias and slope will be corrected for in the merging algorithm. Figures 1.2.10 and 1.2.11 show the comparison broken into sea and land sites.

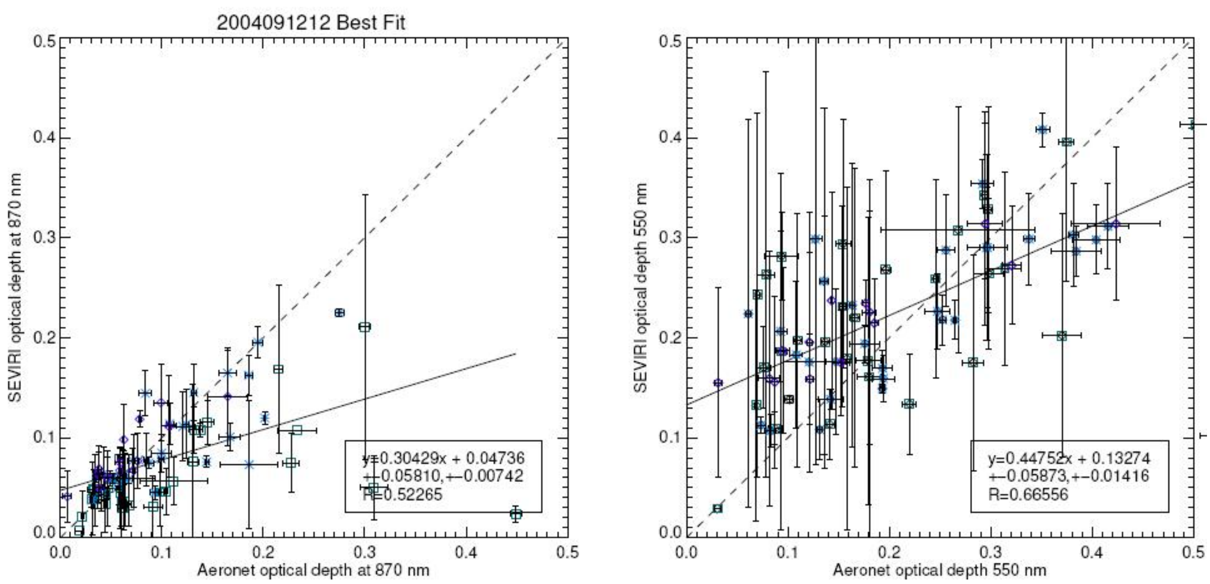


Figure 1.3-8 Amalgamated results for September 2004, 1212 UTC. The individual aerosol types were combined according to quality control and cost, over land and sea.

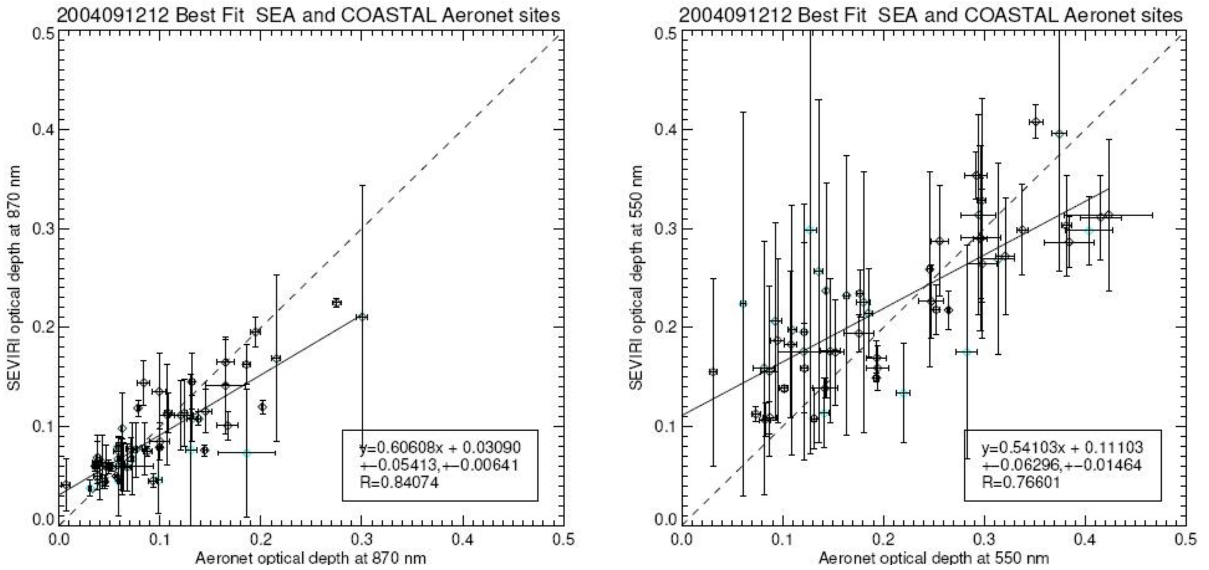


Figure 1.3-9 Amalgamated results for September 2004, 1212 UTC. The individual aerosol types were combined according to quality control and cost, over land and sea.

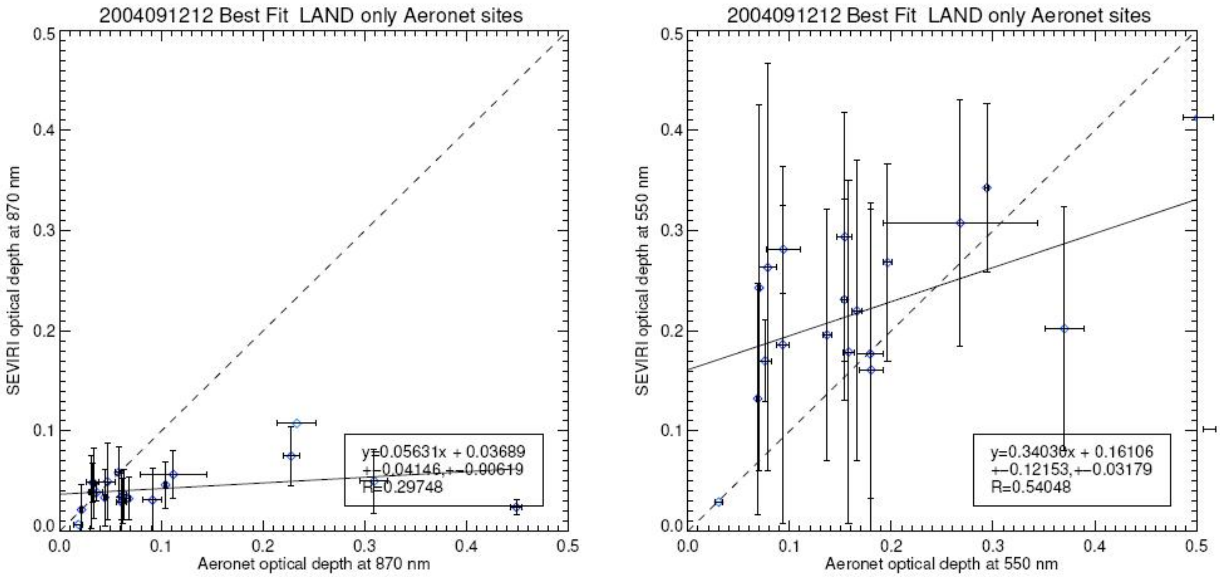


Figure 1.3-10 Amalgamated results for September 2004, 1212 UTC. The individual aerosol types were combined according to quality control and cost, over land and sea.

1.3.2.6 Comparisons with other Satellite Platforms

It have been also compared the service retrievals with MODIS and MISR. Over sea the correlation with MODIS (0.61) is better than that between MISR and MODIS (0.48). Over land the correlation of SEVIRI with MISR (0.45) is better than that with MODIS (0.33), though not as good as the correlation between MISR and MODIS (0.62). It should however be noted that the region of the globe observed by SEVIRI omits Asian regions responsible for much of the global variability (i.e. there is less variability to be observed over the SEVIRI disk than globally so one might expect less correlation).

The following points relating to the SEVIRI AOD distribution are noted:

- The field is a daily product generated from individual retrievals from radiances observed at 10:12 and 16:12 UT. No-data is acquired off the coast of southern Africa because this region is flagged as sun-glint in the 10:12 image and has solar zenith angle greater than 70 at 16:12. Apart from this feature however, the "join" between the regions sampled by one or both of the two radiance products is gratifyingly difficult to discern.
- Some of the high AODs off the north coast of South America are due to an underestimation of the spatial extent of sun-glint at 16:12 (in turn due to probably erroneously low winds in the ECMWF analyses used to predict the glint area).
- There appears to be some shift to the north of the high aerosol load over central / southern Africa (which is mainly due to biomass burning) as observed by SEVIRI compared to MISR or MODIS (and compared to the associated plume off the east coast). This structure is likely to be due to problems modelling the surface reflectance over land in this region, and is connected to the discrepancies found between SEVIRI AODs and those observed at the Mongu station.

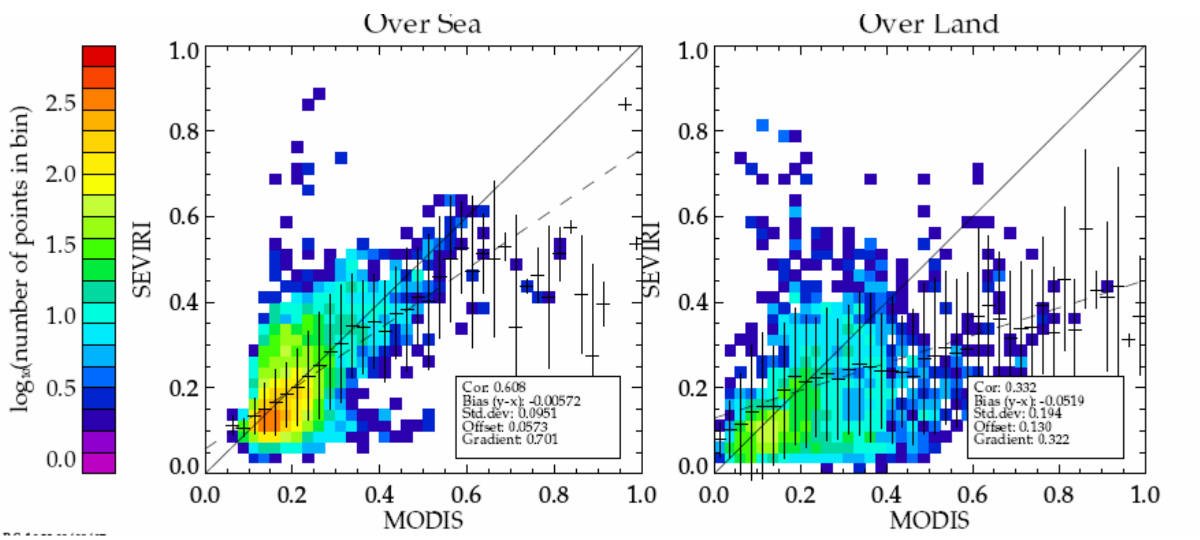


Figure 1.3-11 the right show scatter density distributions of the monthly mean value over sea and land separately. "+" symbols indicate the mean over all SEVIRI points within the indicated range of MODIS values. Error bars indicate the corresponding standard deviation

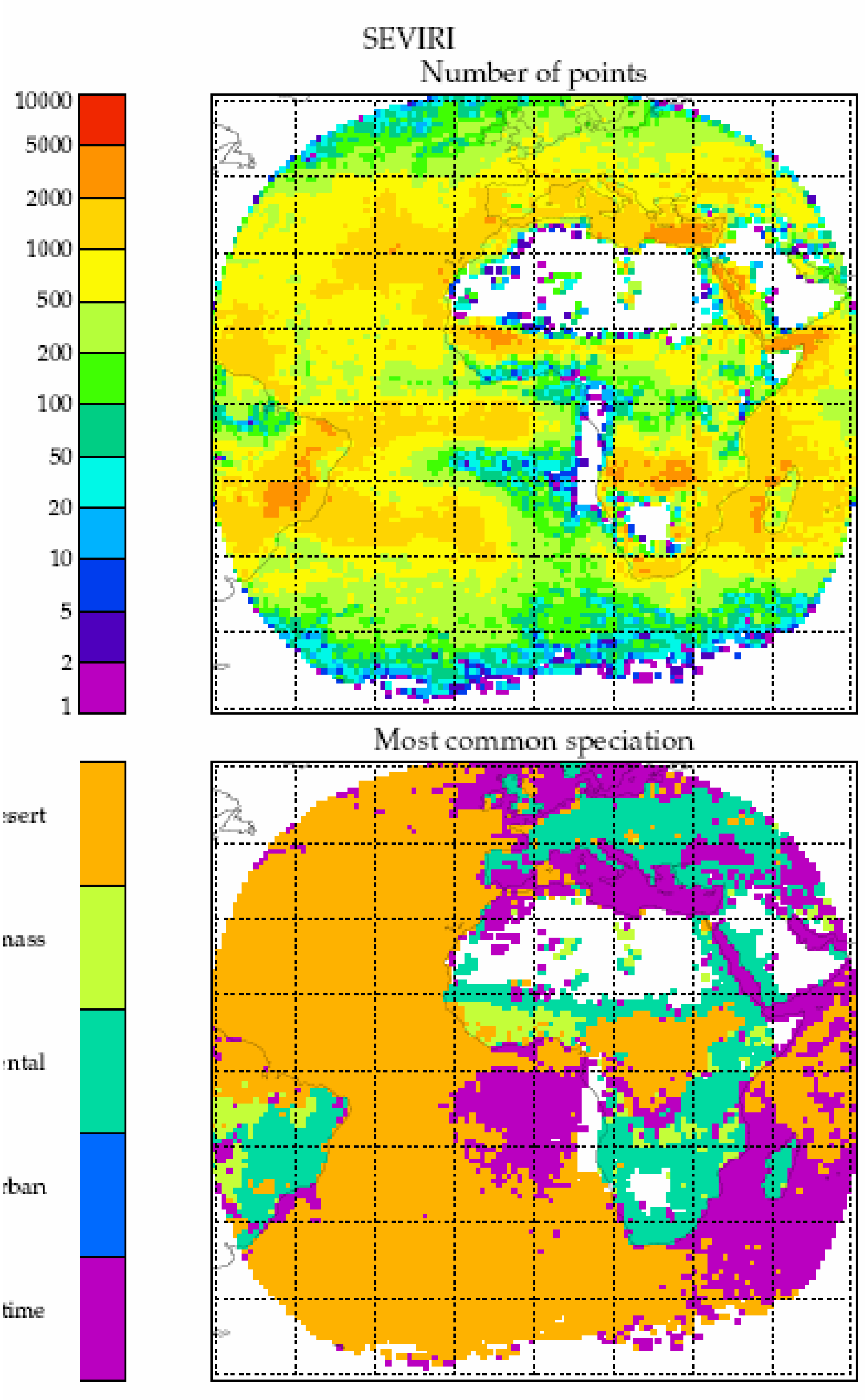


Figure 1.3-12 Number of data points in each bin of the of 1 degree gridded monthly statistical product and the most common aerosol speciation identied

1.3.2.7 Conclusions

Before discussing these results further it is worth noting that all aerosol retrieval schemes based on passive nadir visible / near-infrared satellite imagery are subject to the following fundamental problems:

1. Discrimination of aerosol from cloud: The signal from most types of cloud is generally

much stronger than from aerosol. Consequently, even a relatively small amount of undetected cloud in a scene can cause large biases in retrieved AOD. For this reason cloud masks are used to select only radiances which are cloud-free. However, care is required to avoid wrongly flagging cases of high aerosol load, thereby omitting these potentially important events from the retrieved dataset and introducing a low bias into statistical analyses. More fundamentally, many clouds have aerosol as condensation nuclei and the point at which the "aerosol" becomes "cloud" through growth of water droplets around the aerosol particle is ambiguous.

2. Unknown aerosol composition: The back-scattered signal observed by the satellite depends not only on the amount of aerosol present but crucially also on the phase function and single scatter albedo, which in turn are dependent on the aerosol refractive index, size distribution and particle shape. There is generally insufficient information in remote measurements (even ground-based) to fully constrain the optical properties and, as a consequence, retrieved optical depths are quite strongly dependent upon a priori assumptions about the aerosol type.

3. Surface reflection: Over much of the land surface (and glint regions of sea), the signal from direct and diffuse reflection of radiation from the surface is much stronger than that from aerosol. The sign of the aerosol effect on measured radiances changes depending on the surface reflectance and aerosol single scattering albedo, so conditions exist in which radiances are insensitive to aerosol perturbations. Relatively small errors in modelling the interaction of light with the surface can therefore cause significant error in aerosol retrieval. For this reason, retrieving aerosol over the (dark) ocean is relatively straightforward. Retrievals over bright land surfaces are particularly challenging.

The validation and inter-comparison results presented here demonstrate that all the products perform well over ocean, yielding correlations with AERONET in the region of 0.8 (despite most stations being near the coast rather than open ocean) and correlations with the MODIS monthly mean distribution which are comparable or better than found between MODIS and MISR.

Where problems exist these are almost exclusively related to retrievals over land. The most positive results from the current official product set have been obtained for SEVIRI, the AERONET correlation over land being 0.82 at 0.55μm, without significant bias over many regions including Europe. This leads to a number of impressive time-series comparisons with individual AERONET stations. The SEVIRI agreement with MISR over land is also comparable to that between MISR and MODIS. The benefit of geostationary observations in obtaining good sampling of the cloud-free atmosphere is clear from the number of good observations acquired even from the two observations per day that are analysed in the current set of products, leading to a relatively large number of AERONET coincidences and a well sampled monthly mean field.

The following recommendations are made based on the validation results and the considerations outlined above:

- There are indications of errors due to modelling of the surface reflectance in the SEVIRI retrieval (e.g. over central and southern Africa). These may be attributable to channel spectral response function difference compared to MODIS (use to define the a priori BRDF). Methods to correct for such systematic errors are being studied at the moment and could lead to a useful improvement in the short-term. It is however noted that in the long-term it would be highly desirable to use surface BRDF information from SEVIRI itself.
- Some residual effect of sun-glint are evident in the SEVIRI product partly due to apparently underestimated wind-speeds in ECMWF. Use of a minimum assumed wind speed to remove this effect is being considered.
- It would of course be desirable to process as many SEVIRI scenes in a single day as possible within available computing resource (SEVIRI acquires a scene every 15 minutes). Use of at least one additional time e.g. 13:12 to complement the existing slots of 10:12 and 16:12 would be particularly desirable to eliminate the current data gap off eastern Africa which is contaminated by glint at 10:12 and has too high a solar zenith angle at 16:12. As noted above, observing aerosol at different scattering angles can yield information on the phase function (and hence type). While multi-time observations cannot yet be directly exploited by the products scheme, post analysis of retrievals at as many different time of day could help to improve the speciation (and hence estimated AOD). Multiple-time observations are of course also valuable for tracking the evolution of specific events.
- There is evidence of over-zealous cloud flagging, leading to events of high aerosol load being omitted. While the long-term aim would be to by-pass this issue altogether using a joint aerosol-cloud scheme, for the current products more pragmatic measures to improve the current status would be desirable in the short-term. For SEVIRI the cloud mask is not useful as a means of generating cloud-free radiances for partially cloudy scenes all partially cloud scenes are currently flagged as unreliable. It would therefore make sense to process all scenes without regard to the Eumetsat cloud mask, then rely (as is the case at the moment) on quality control criteria (including the Eumetsat cloud fraction) to screen cloud post-hoc..
- The assumed aerosol models (refractive indices, size distribution, assumed particle shape) do not of course perfectly represent the true aerosol conditions and improvements / additions to the set of models used may well be worthwhile and are the subject of continuing research and development.

1.3.3 Validation against specifications and against user requirements

*Requirements written in *Italics* are only recommended and not compulsory for Phase 2

VALIDATION AGAINST SERVICE SPECIFICATIONS			
No limitations/delays for compliance between theoretical and actual service specifications reported			
VALIDATION AGAINST USER REQUIREMENTS			
SPECIFICATION	**S5**	**REQUIRED***	**ACTUAL**
Parameters	Latitude, longitude, Speciation, Aerosol Optical Thickness 550nm, Aerosol Optical Thickness 870nm, Cloud Pixel Flag, Land / Sea Flag, Sun Zenith Angle, Sun Azimuth Angle, View Zenith Angle, Julian Date, Effective Radius, Angstrom Coefficient, Angstrom Coefficient		
Accuracy minimum	n.s.	n.s.	AOD: ± 0.02 over ocean and ± 0.05 over land
Accuracy target	n.s.	15%	n.s.
Spatial coverage	South Europe (Spain, Portugal and Italy)	South Europe (Spain, Portugal, Macaronesia)	South Europe (Spain, Portugal, Macaronesia)
Horizontal resolution	10x10 Km^2	n.s.	10x10 Km^2
Vertical resolution	n.s.	n.s	n.s
Grid/Projection	Sinusoidal	n.s	Sinusoidal
Temporal coverage	24 h	n.s.	24 h
Temporal resolution	15 minutes	n.s.	45 min
User Interfaces			
PROMOTE Web	n.s.	Complete, operational up-to-date	Incomplete, no operational not up to date
ftp	n.s.	n.s.	n.s.
On demand	n.s.	n.s.	n.s.
Data formats and data delivery			
Data availability	n.s.	Specific test periods in Phase 1	n.s.

Data access	Online	online	Online
Delivery Mode	Offline/NRT	Phase 1: NRT for a specific test period to be defined. Phase 2: NRT For the available SEVIRI slots	NRT
Delivery frequency	n.s.	Daily	Daily
Data Format	IDL custom tool, NetCDF	netCDF, HDF	netCDF, HDF
Historical archive	None	n.s.	None
Visualization	IDL custom tool, NetCDF	netCDF, HDF	n.s.
REMARKS			
No Remarks			

*Requirements written in *Italics* are only recommended and not compulsory for Phase 1

Table 1.3-3 Validation of the Iberian Sub-service against specifications and against user requirements

1.3.4 Service quality assessment and control procedures

Service delivery start date: The service was available from August 2007, but due to some problems found in the last validations, the website was disabled due to user request (until products have the quality expected). It has been foreseen to open the site again in August 2008.				
SPECIFICATION	**S5**	**REQUIRED***	**ACTUAL**	**N checks/Delivery period**
Quality checks	See Table 1.3-2	n.s.	n.s	N/A
Quality flags	n.s.	n.s.	n.s	N/A
Product confidence data	n.s.	n.s.	n.s	N/A
Error bar definition and representation	N/A	N/A	N/A	N/A

Representation of missing data	n.s.	n.s.	n.s	**N/A**
Documentation of process failure	A control function which checks for the presence/absence of implemented product/auxiliary data. It is split by input data.	n.s.	n.s	**N/A**
Version control mechanisms and representation	Version control process is enabled; Current version is 1.1. Version number follows S5 upgrades: 1.0-Pahse 1 1.1- Phase 2	n.s.	n.s	**N/A**

*Requirements written in *Italics* are not compulsory for Phase 2

Table 1.3-4 Validation of quality assessment and control procedures for the Iberian Sub-service

1.4 Italian sub-service

Service is/will be operational since/after: January 2007

Research partners: ISAC-CNR

Provider(s): CGS

Validation contact: W. Di Nicolantonio

Satellite desert dust detection is based on the radiances and Brightness Temperature (BT) sampled by the imaging radiometer SEVIRI (Spinning Enhanced Visible and InfraRed Imager) on board MSG-1 (Meteosat-8) meteorological satellite. The high temporal (15 min) and spatial (about 4x4 km^2 over the Mediterranean area) resolutions of MSG images in the IR channels allow to follow the evolution of dust transport towards the Italian region and may permit a link with threshold exceeding of PM concentrations measured in situ. Desert Dust indicator maps are obtained by analyzing 8.7, 10.8, and 12.0 µm SEVIRI IR channels.

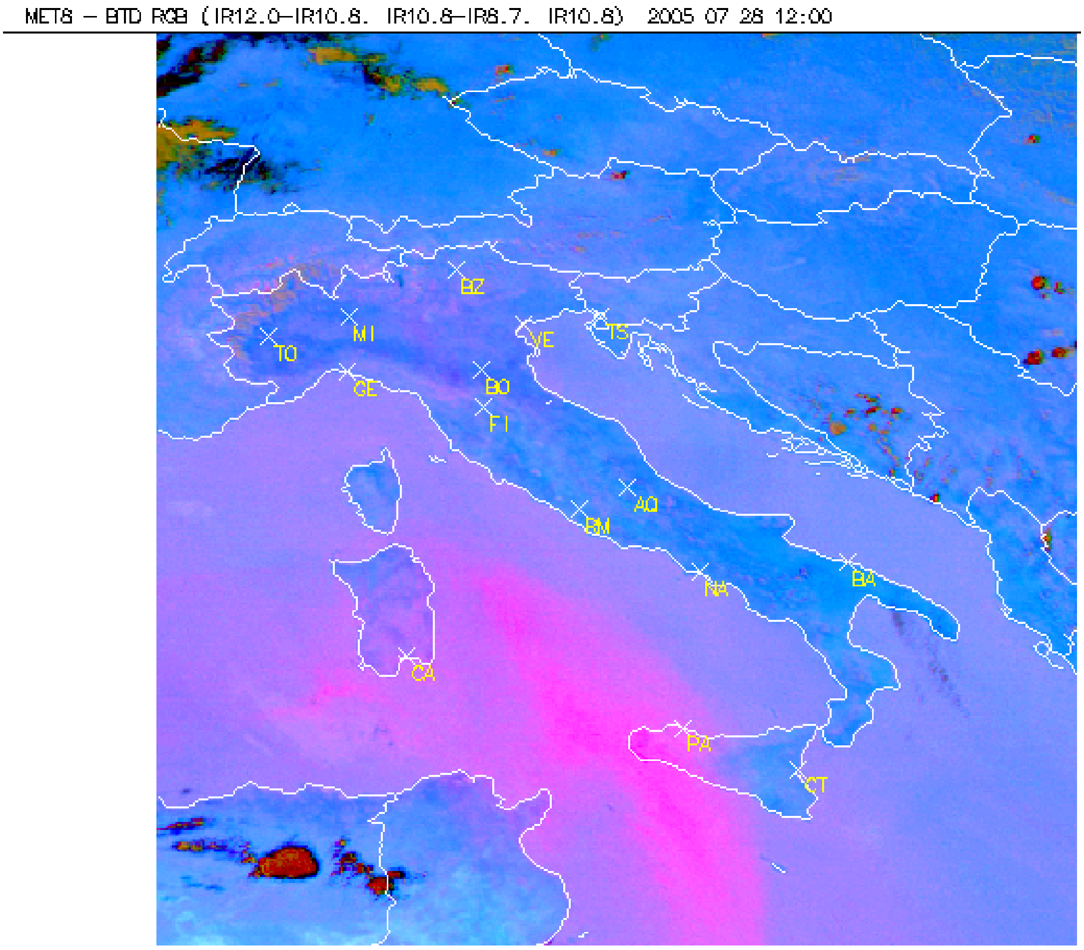
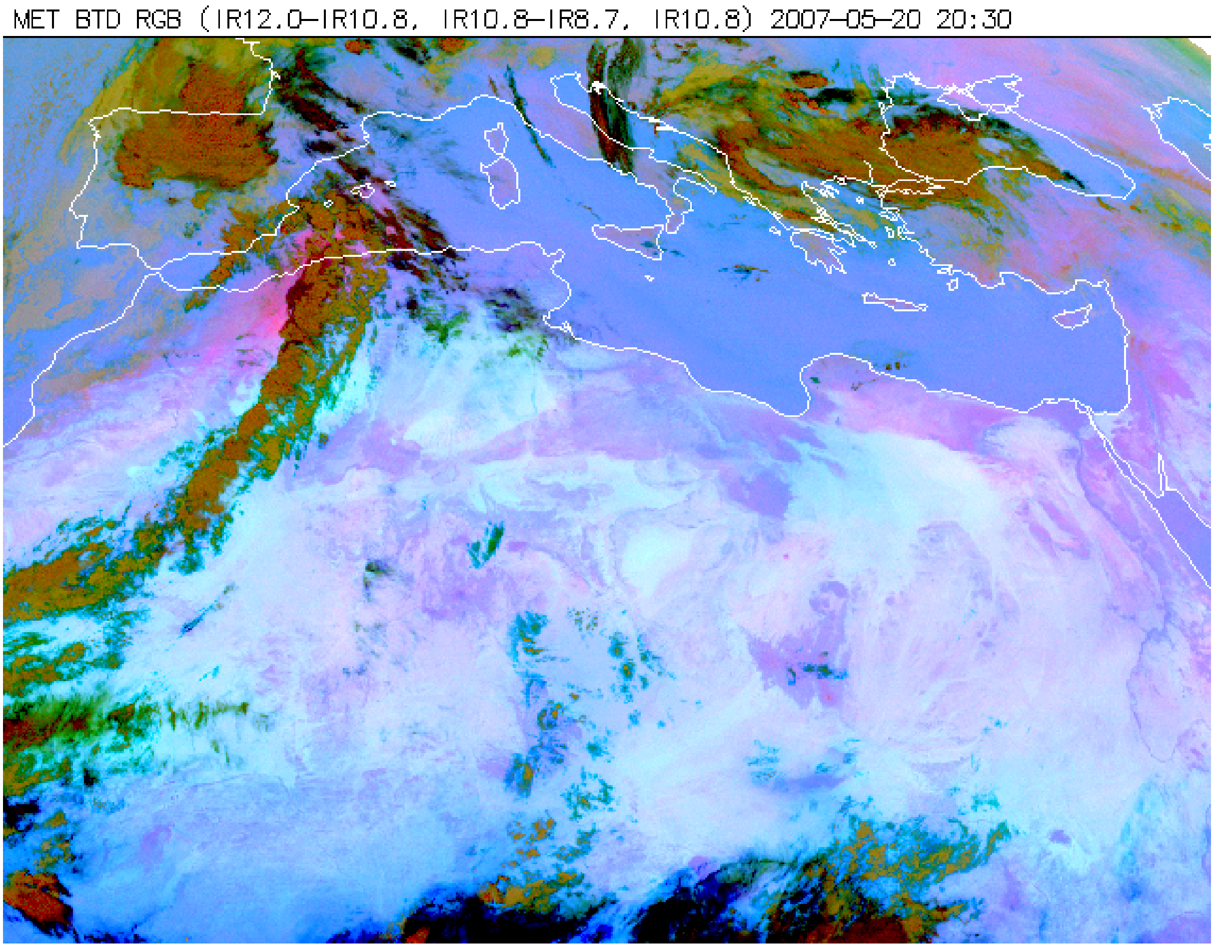


Figure 1.4-13 Desert dust transport highlighted in magenta as detected through the RGB BTD technique applied to SEVIRI IR channels, as available for Phase 1.



. Figure 1.4-2 Desert dust transport highlighted in magenta as detected through the RGB BTD technique applied to SEVIRI IR channels, for the Mediterranean area monitored in Phase2.

From the IR SEVIRI channels the two Difference of BT, (BT12.0 – BT10.8) and (BT10.8 – BT8.7), needed to enhance the presence of desert dust, are derived. For sequence of RGB composite images, where R=(BT12.0 – BT10.8), G=(BT10.8 – BT8.7), B=BT10.8, dust appears pink or magenta, while, for instance, thick high-level clouds turn out red-brown and thin high-level clouds appear very dark. In Figure 1.4-13 is reported a snapshot of the dust transport as detected by SEVIRI on 28 July 2005 at 12 a.m.

1.4.1 Validation Plan and Validation Data

For phase 1 validation, dust transport events taking place in summer 2005 and detected by SEVIR/MSG were compared to Lidar observation, which are routinely carried out in Rome by ISAC-CNR.

Lidar observations allow detection of events of Saharan dust transport over Italy. Dust particles are tipically non-spherical, then Aerosol Depolarization level, Da, from Lidar measurements is a good indicator of the presence of mineral dust in the atmosphere. Comparison have been made reporting time evolution of dust Aerosol Optical Depth, minimum and maximum heights related to dust particles are recorded, in order to classify the magnitude of the dust events, as can be seen in Figure 1.4-.

During the second phase of PROMOTE2, Lidar observations will be again employed for the comparison with time corresponding SEVIRI data for events from 2005 up to now.

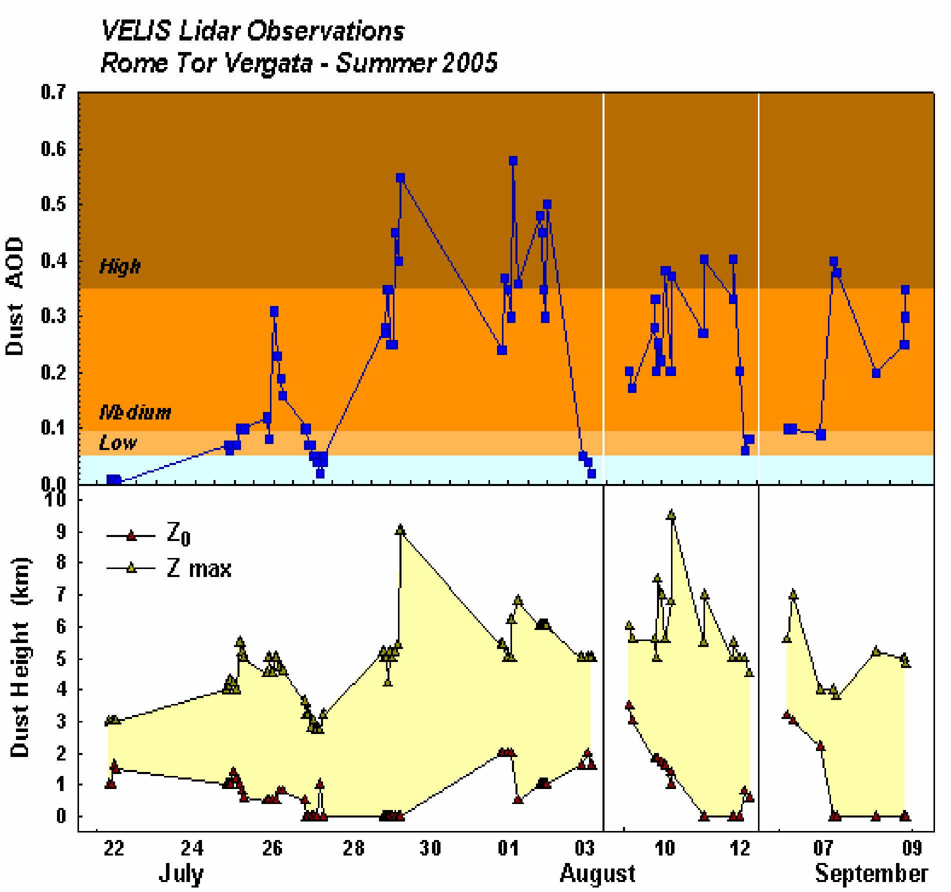


Figure 1.4-3 Lidar observations in Rome for three selected events in Summer 2005.

A further indirect comparison about the presence of desert dust detected by SEVIRI was planned starting from the second phase of PROMOTE2 taking advantage of the several AERONET routine measurements carried out in the South Italy area. In particular, time patterns of Aerosol Optical Depth, AOD, and Ångström parameter, α, in the visible wavelength range will be employed to highlight the presence of dust in terms of small values of parameter α accompanied by significant AOD. Measurements since 2005 up to now will be analysed for the sites of Lampedusa (35N,12E), Potenza (40N,15E), Messina (38N,15E), Lecce(40N,18E), Tor Vergata (41N,12E). Moreover, to confirm the dust transport to the northern region of Italy, AOD and α from Ispra (45N,8E), station will be also examined.

For Phase 2 validation, focus is on Spring 2007, for which 3 main events were detected analysing SEVIRI/MSG data in terms of RGB-BTD:

1. March 9, 2007
2. April 8 – 18, 2007
3. May 20, 2007

and (for the AERONET comparison) on Summer 2005 for which 3 main events were detected analysing SEVIRI/MSG data in terms of RGB-BTD:

4. July 22 – August 08 , 2005
5. around August 10, 2005
6. September 4 – 9, 2005

As stated above, lidar observations in Tor Vergata (Rome) [see Table 1.4-5] were employed. In particular, Figure 1.4-4 and Figure 1.4-5 show the time-patterns of dust AOD (AOD due only to the Saharan dust contribution to aerosol extinction) and corresponding minimum and maximum height of the dust layer. Significant values of dust AOD are present around March 9, April 10 and May 20, together with layer heights ranging between 200 m to 7 km.

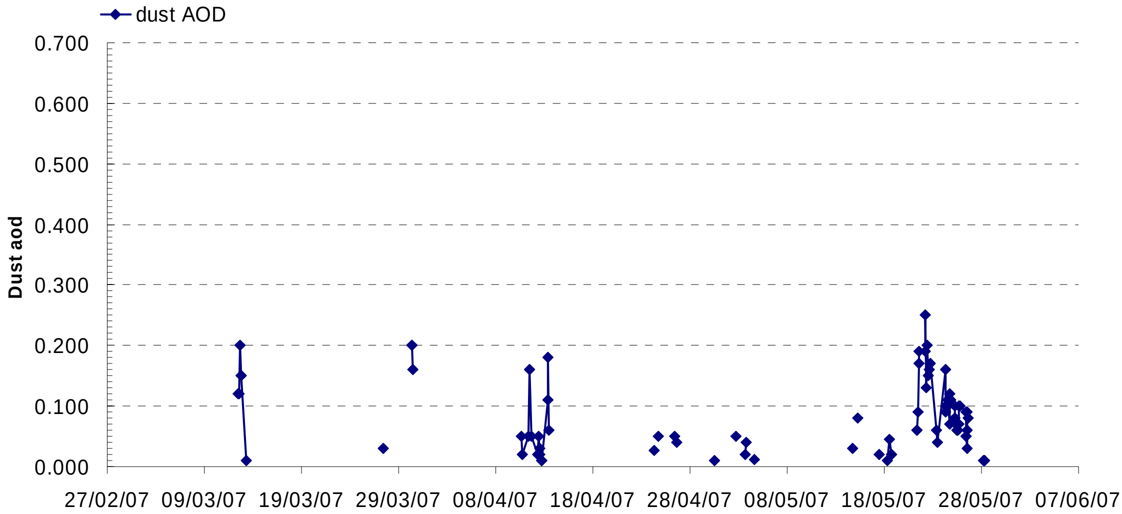


Figure 1.4-4 Time-pattern of the Aerosol Optical Depth only due to the saharan dust contribution (dust AOD) in the period March – May 2007 as recorded at Roma tor Vergata.

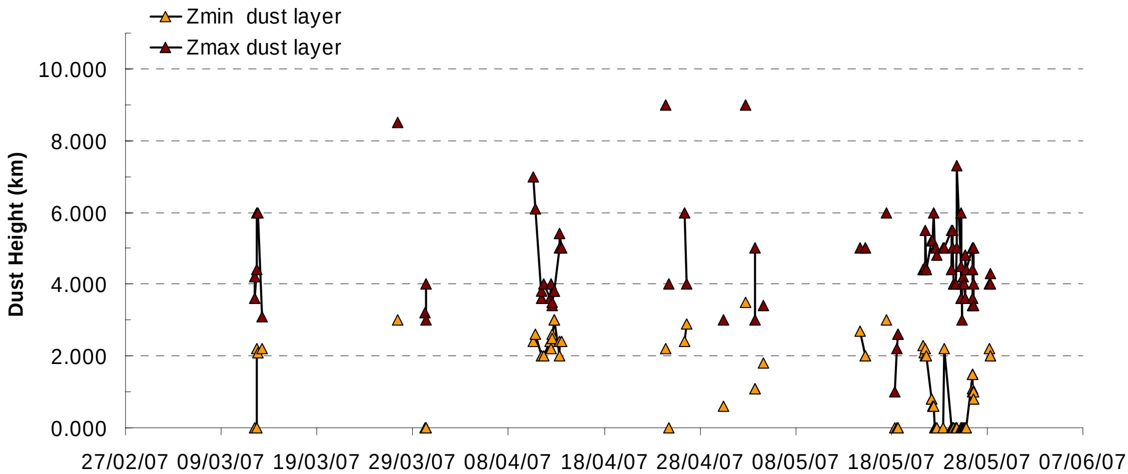


Figure 1.4-5 Time-pattern of the minimum and maximum height of the dust layer (Zmin dust layer, Zmax dust layer) in the period March – May 2007 as recorded at Roma tor Vergata

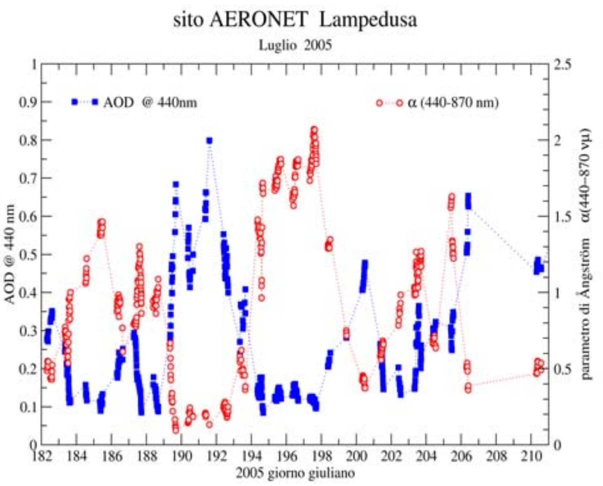
Furthermore, the indirect comparison against AERONET data [see table 1.4-1] has been made both for the events highlighted in Phase 1 validation (Summer 2005) and Phase2 validation (Spring

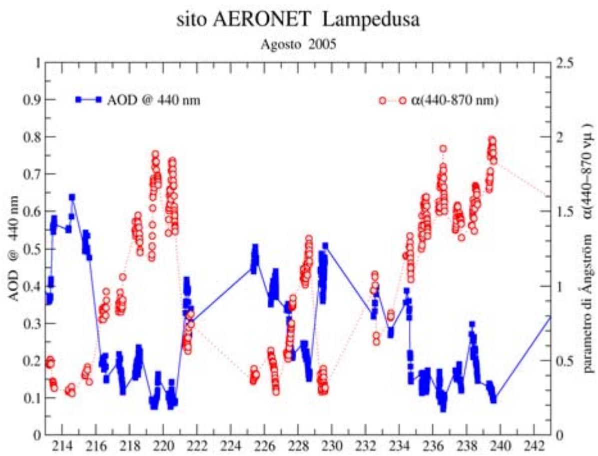
2007). AERONET Level2 data (i.e.quality assured) for the Lampedusa and Lecce sites were available only for July-September 2005 period , while Potenza and Messina data were available only for April-May 2007.
Time patterns of Aerosol Optical Depth, AOD, at 440 nm and Angström parameter, α, relative to the visible wavelength range [440-870]nm are presented in the Figures below to highlight the presence of dust in terms of small values of parameter α accompanied by significant AOD.

Concerning Lampedusa site in summer 2005 (see Figure 1.4-6), an increase in AOD can be seen in correspondance of the decrease in parameter α for 2-4 August (214-216 julian day). AOD presents values lower than 0.2 at mid-July then undergoes to an increase up to 0.6 together with a decrease in α from 0.7 to almost 0.1. A similar behaviour can be recognized at the end of the event on 12-13 August (225-226 julian day), while in the period before a lack of data prevents further analysis.

Analysing time-patterns relative to Lecce AERONET site (Figure 1.4-7), AOD and α inversions are present around August 2 (214 julian day), August 12 (224 julian day) and from September 7 to 11 (250 – 254 julian day).

Dust events in Spring 2007 did not significatively reach Messina and Potenza, as can be seen in Figure 1.4-8 and Figure 1.4-9.





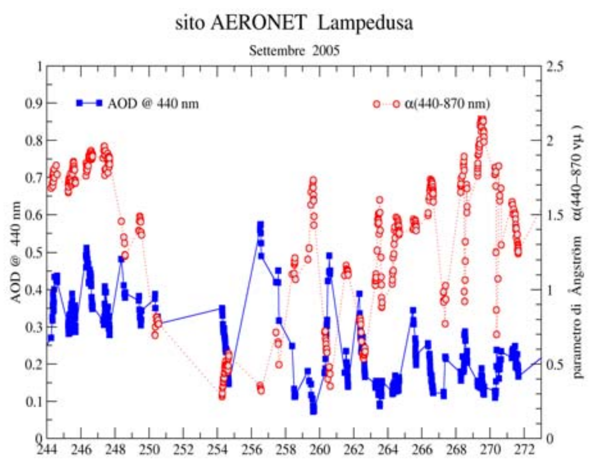


Figure 1.4-6 Time-pattern of AOD @ 440 nm and Ångström parameter, α, for July, August and September 2005 at Lampedusa AERONET sites.

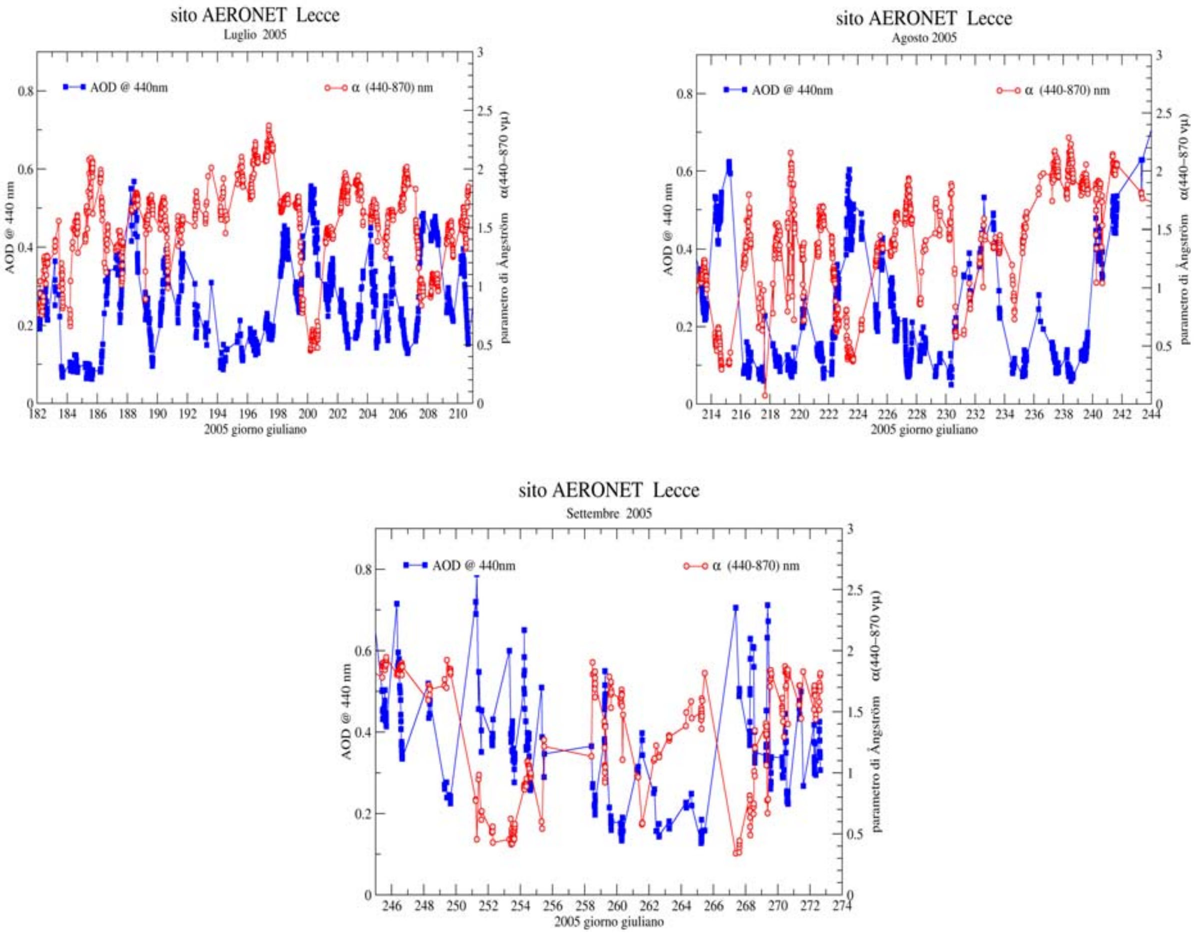


Figure 1.4-7 Time-pattern of AOD @ 440 nm and Ångström parameter, α, for July, August and September 2005 at Lecce AERONET sites.

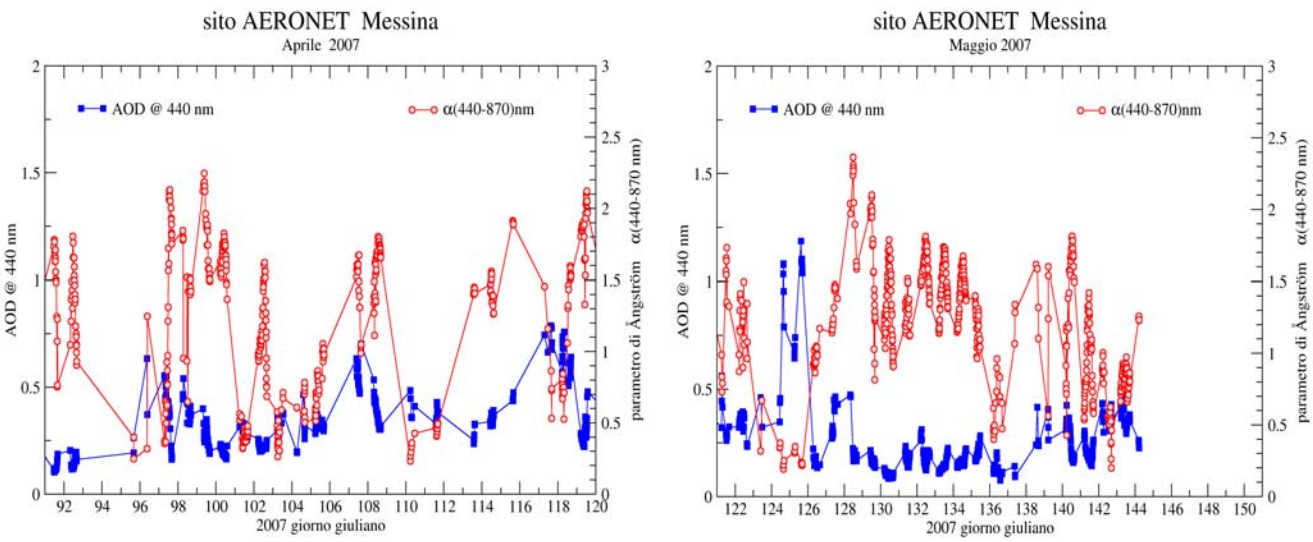


Figure 1.4-8 Time-pattern of AOD @ 440 nm and Ångström parameter, , for April and May 2007 at Messina AERONET sites.

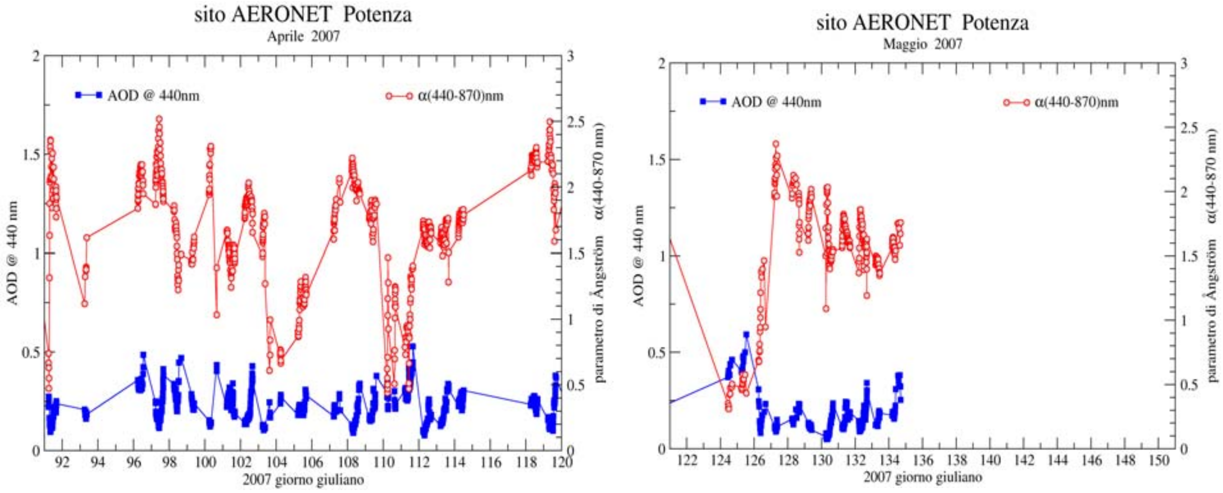


Figure 1.4-9 Time-pattern of AOD @ 440 nm and Ångström parameter, α, for April and May 2007 at Potenza AERONET sites.

VALIDATION DATA	
Ground based/in-situ observations	
Name AERONET observations - level 2 Phase: (2)	Data availability and access (include access details if data is freely available):AERONET data are freely available via web: aeronet.gsfc.nasa.gov Spatial coverage and resolution: NA Temporal coverage and resolution: summer 2005 to december 2007 Location(s) (coordinates): Lampedusa (35N,12E), Potenza (40N,15E), Messina (38N,15E), Lecce(40N,18E), Uncertainty quantification (e.g. Accuracy): 0.02 for AOD
Name Lidar observations Phase: (1+2)	Data availability and access (include access details if data is freely available): events since 2005, available through QUITSAT ASI project from ISAC-CNR Spatial coverage and resolution: NA Temporal coverage and resolution: events since 2005 Location(s) (coordinates):Roma Tor Vergata (41N,12E). Uncertainty quantification (e.g. Accuracy): TBD

Table 1.4-6 Data used for the validation of the Italian Desert Dust Awareness Sub-service

1.4.2 Validation of individual components

Following Ackermann (1997), the so-called trispectral method is applied to MSG data. In this approach, brightness temperature differences (BTD) between the 10.8 and 8.7 µm channels set against BTD between the 12 and 10.8 µm channels enables to discriminate dust from the clear-sky over both oceans and lands.

In Figure 1-3 is reported an example of trispectral diagram applied to SEVIRI BTD *Brightness Temperature* Difference pertaining to July 27, 2005. As can be seen in the figure, three different populations can be discriminated relative to clear sky (blue triangles), clouds (brown diamonds) and desert dust (pink squares) pixels.

BTD SEVIRI data in spatial and temporal coincidences with Lidar and/or AERONET sun-photometer observations will be analyzed for events in which all instruments detect dust presence: SEVIRI in terms of BTD, Lidar and sun-photometers in terms of Depolarization ratio, AOD, and Ångström parameter.

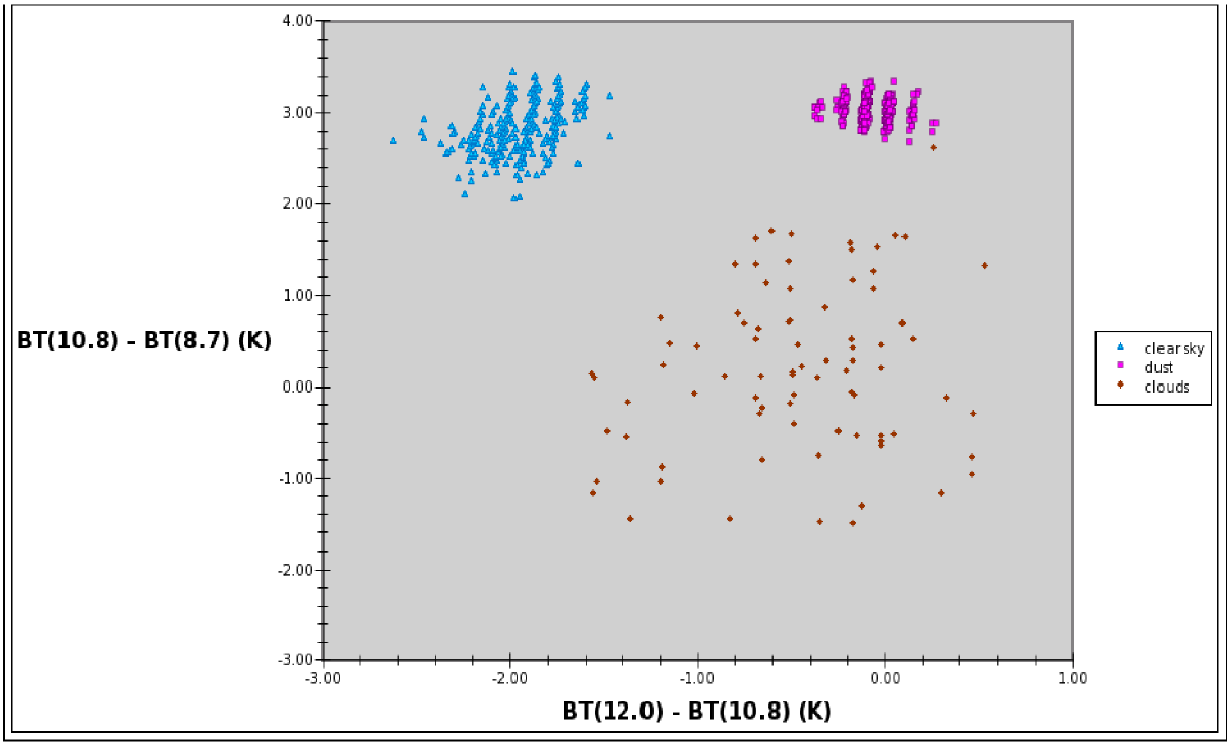


Figure 1.4-14 . Example of trispectral diagram of BTD from MSG-1/SEVIRI over the Mediterranean area related to July 27, 2005.

VALIDATION OF INDIVIDUAL COMPONENTS	
Best estimator	
n.s.	Detection of the same dust event
Coincidence check	Time-pattern diagrams for lidar data (dust AOD and dust layer height)
Quality assessment	
Identification of outliers	TBD
Quality checks	Events detected by both SEVIRI and lidar measurements in terms of : 1. Pixel magenta coloured for seviri (small values of the the differences BT(12.0-10.8) and positive small values of the differences of BT(10.8-8.7) and 2. Significatly high values of dust AOD as measured by the lidar.
Accuracy/error	no quantitative parameter defined , TBD
Cloud screening quality control	Not enabled
Model/algorithms	
BTD technique	Brightness Temperature Differences technique applied to 3 SEVIRI infrared bands IR8.7, IR10.8, and IR12.0 (Ackerman, 1997)
Composite RGB	RGB of BTD as false color composition http://www.eumetsat.int/en/dps/msg/channel_interp/index.html
	R=BT(IR12.0) –BT(IR10.8); G= BT(IR10.8)-BT(IR8.7) ; B=BT(IR10.8);
Consistency	
MSG data vs. LIDAR	in both period selected for validation with lidar measurements (Summer 05, Spring 07) events detected by MSG were detected in correspondance by lidar measurement in Roma Tor Vergata (see figs Figure 1.4-3, Figure 1.4-4 and Figure 1.4-5

MSG data vs. In-situ	
	For periods selected in Summer 2005, AERONET data shown the typical behaviour of dust aerosol loading (see figs Figure 1.4-6 , and Figure 1.4-7) . For period in spring 2007, AERONET sites providing level2 data are not reached by the dust transport as can be seen in the product available in the service web site and it is confirmed in figs Figure 1.4-8 Figure 1.4-9.

Table 1.4-7 Validation of individual components of the Italian Service

- **Validation against specifications and against user requirements**

*Requirements written in *Italics* are only recommended and not compulsory for Phase 1

VALIDATION AGAINST SERVICE SPECIFICATIONS			
variation has been made in the processing chain regarding data format conversion in the data import part, areas selection and data archiving			
SPECIFICATION	**S5**	**REQUIRED***	**ACTUAL**
Parameters	Desert dust indicator		
Accuracy minimum	N/A	n.s.	N/A
Accuracy target	n.s.	n.s.	TBD
Spatial coverage	10°N – 50°N lat.; 20°W – 50°E long.	Italy	Phase 1 : Italy Phase 2: Mediterranean area (see Figure 1.4-2)
Horizontal resolution	3x3 Km^2 (Ground pixel)	n.s.	3x3 km^2
Vertical resolution	n.s.	n.s	n.a.
Grid/Projection	MSG perspective	n.s	MSG perspective
Temporal coverage	transport events	n.s.	Phase 1: selected dust transport events Phase 2: NRT monitoring, with a delay of 24 hour
Temporal resolution	30 minutes	n.s.	15 minutes
User Interfaces			

PROMOTE Web	n.s.	Operational, complete and up to date	Operational, complete and not up to date Phase 2: operational, complete and updated
ftp	n.s.	n.s.	on demand
Data formats and data delivery			
Data availability	n.s.	Specific test periods in Phase 1 (agreed with users) In Phase 2: data from Saharian sources towards Italy	Phase1 Dust transport events detected since Summer 2005 Phase2: 2006 since May, whole 2007, and NRT monitoring for 2008
Data access	Online	online	Online
Delivery Mode	NRT	NRT	Phase 1: Offline Phase 2: through web-page
Delivery frequency	30 minutes	n.s.	60 minutes
Data Format	Png, image sequences, geotiff on demand		Png, image sequences
Historical archive	None	n.s.	None
Visualization	geoTIFF, png and gif viewers		geoTIFF, png and gif viewers
REMARKS			
] NRT service planned for phase 3 is started during the phase 2			

Table 1.4-8 Validation of the Italian Sub-service against specifications and against user requirements

1.4.3 Quality assessment and control procedures

Service delivery start date: n.s.				
SPECIFICATION	**S5**	**REQUIRED ***	**ACTUAL**	**N checks/Delivery period**
Quality checks	See Table 1.4-7	n.s.	detection of the same dust event by SEVIRI and lidar,	Once during validation phase for the whole data-set
Quality flags	n.s.	n.s.	N/A	NA
Product confidence data	n.s.	n.s.	N/A	N/A
Error bar definition and representation	N/A	N/A	N/A	N/A]
Representation of missing data	n.s.	n.s.	In the NRT chain, a log file is generated with the list of days for which no data are available.	Log file during processing
Documentation of process failure	Not enabled. No automatic reporting on process failure enabled. Only screen reporting available.	n.s.	not enabled	not enabled
Version control mechanisms and representation	Version control process is enabled; Current version is 1.1. Version number follows S5 upgrades: 1.0-Phase 1 1.1- Phase 2	n.s.	V 1.2 related to S5 April 08	n.s.

*Requirements written in *Italics* are not compulsory for Phase 2

Table 1.4-9 Validation of quality control procedures for the Italian Sub-service

1.5 References

1.5.1 Electronic references

http://aeronet:gsfc:nasa:gov

http://www.eumetsat.int/en/dps/msg/channel_interp/index.html

1.5.2 Bibliographic references

Ackerman, S., 1997, “Remote sensing of aerosols using satellite infrared observations”, J.Geophys. Res., 102, 17069-17079.

Gobbi G. P., F. Barnaba, and L. Ammannato, 2004, The vertical distribution of aerosols, Saharan dust and cirrus clouds in Rome (Italy) in the year 2001, Atmospheric Chemistry and Physics, Vol. 4, 351-359.