DOSSIER: COMMON TASK: -2-

TITLE:

# GMES SERVICE ELEMENT

# PROMOTE 2

## C6 Validation Report
## SATELLITE-BASED PARTICULATE MATER DEMONSTRATION SERVICE
## Version 2

# DOCUMENT STATUS SHEET

| | FUNCTION | NAME | DATE | SIGNATURE |
|---|---|---|---|---|
| LEAD AUTHORS | editor | R. Delgado<br>J. C. Lambert | | |
| CONTRIBUTING AUTHORS | Service leader<br>Service providers | T. Holzer-Popp<br>W. Di Nicolantonio | | |
| REVIEWED BY | Reviewers | | | |
| APPROVED BY | Technical officer (ESA) | | | |
| ISSUED BY | Project manager | | | |

# DOCUMENT CHANGE RECORD

| Issue | Date | Modified Items / Reason for Change |
|---|---|---|
| **Version 1** | | |
| 0.1 | 22.02.2007 | Draft template created and distributed |
| 0.2 | 23.03.2007 | Integration of records sub service draft information in new document |
| 0.3 | 18.04.2007 | Integration of monitoring sub-service draft information in new document |
| 0.4 | 19.04.2007 | Draft template updated and distributed |
| 0.5 | 10.05.2007 | Update after input from service providers |
| 0.6 | 14.05.2007 | Update after input from service providers |
| 0.7 | 23.05.2007 | Document edited |
| 0.8 | 23.05.2007 | Document reformatted |
| 0.9 | 28.05.2007 | Document reviewed and links updated |
| 1.0 | 25.06.2007 | Document properties updated |
| **Version 2** | | |
| 1.01 | 10.04.2008 | C6 Pre-form integrated in draft |
| 1.05 | 21.04.2008 | S5 Specifications integrated in draft |
| 1.1 | 29.04.2008 | C6 Draft updated and sent |
| 1.2 | 30.05.2008 | update by thp for European records |
| 1.3 | 04.06.2008 | update by WDN for Regional monitoring |
| 1.8 | 20.06.2008 | Document edited and distributed for final review |
| | | |

# LIST OF TABLES

Table 1.2-1Characterization of the products of the European multi-year PM records service ..... 3
Table 1.2-2 Data used for validation of the European Satellite Based Particulate Matter multi-year records sub-service ..... 5
Table 1.2-3 Validation of individual components of the European Satellite Based Particulate Matter multi-year records sub-service..... 6
Table 1.2-4 Validation against specifications and user requirements of the European Satellite Based Particulate Matter multi-year records sub-service ..... 9
Table 1.3-1 Quality assessment and control procedures and service quality ..... 10
Table 1.4-1 Characterization of the products of the Italian Satellite Based PM monitoring sub-service ..... 12
Table 1.4-2 Data used for validation of the Italian PM monitoring service ..... 13
For Phase 2 validation of satellite derived PM2.5 linear regression parameters were calculated - on a monthly basis – between satellite estimated PM2.5 extracted in correspondence of the geo-location of the sampling sites and corresponding PM2.5 estimated at the ground. Taking into account both PM25 24-h average measurements and PM25 estimates at the ground as calculated from PM10 concentration in sites operated by ARPA Lombardia and Emilia Romagna, an overall number of 76 sampling sites were available (see table 1.4-3). ..... 16
Table 1.4-4 Validation of the individual components of the Italian PM monitoring service ..... 23
Table 1.4-1 Validation against specifications and against user requirements of the Italian monitoring service..... 25
Table 1.4-2 Quality control tools for the Italian PM monitoring service ..... 27

# LIST OF FIGURES

Figure 1.1-1 Position and structure of the Satellite-based Particulate Matter Service within PROMOTE 2 Air Quality Services. ..... 1
Figure 1.4-1 PM2.5 mass concentration sampled at the ground against spatio-temporal coincident satellite based PM2.5 concentration. ..... 14
Figure 1.4-2 PM2.5 concentration time series for June and July 2004 as sampled at the ground (grey bars) along with spatio-temporal coincident PM2.5 satellite estimated (orange bars). ..... 15

# LIST OF ACRONYMS

| | |
|---|---|
| AOD | Aerosol Optical Depth |
| EO | Earth Observation |
| EOS Data Gateway | Earth Observing System Data Gateway |
| GIS | Geographic Information System |
| GRASS | Geographical Resources Analisys Support System |
| HDF | Hierarchical Data Format |
| $PM_{XX}$ | mass concentration of particles with D < XX μm |
| SYNAER | SYNergetic Aerosol Retrieval |

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

# TABLE OF CONTENTS

**DOCUMENT STATUS SHEET ..... II**

**DOCUMENT CHANGE RECORD ..... III**

**LIST OF TABLES ..... IV**

**LIST OF FIGURES ..... V**

**LIST OF ACRONYMS ..... VI**

**TABLE OF CONTENTS ..... VII**

**1 SATELLITE-BASED PM DEMONSTRATION SERVICE ..... 1**

1.1 Service overview ..... 1

1.2 European multi-annual records ..... 2

1.2.1 Product characterization ..... 2
1.2.2 Validation plan and validation data ..... 3
1.2.3 Validation of individual components ..... 6
1.2.4 Validation against specifications and against user requirements ..... 7
1.2.5 Quality assessment and control procedures ..... 9

1.3 Service quality assessment and control procedures ..... 9

1.4 Regional monitoring for Italy ..... 11

1.4.1 Product characterization ..... 11
1.4.2 Validation plan and validation data ..... 12
1.4.3 Validation of individual components ..... 22
1.4.4 Validation against specifications and against user requirements ..... 23

June and july 2004 delivered (Phase 1) ..... **24**

1.4.5 Quality assessment and control procedures ..... 26

1.5 References ..... 28

1.5.1 Electronic references and data access paths ..... 28
1.5.2 Bibliographic references ..... 28

<PAGE INTENTIONALLY LEFT BLANK>

# 1 SATELLITE-BASED PM DEMONSTRATION SERVICE

## 1.1 Service overview

This service provides satellite based near surface concentrations of particulate matter (PM10, PM2.5, PM1) by exploiting statistical correlations, systematic conversion algorithms and auxiliary information (vertical profiles, meteorological patterns) to convert satellite AOD into PM values. This service consists in two sub-services, as shown in the figure below.

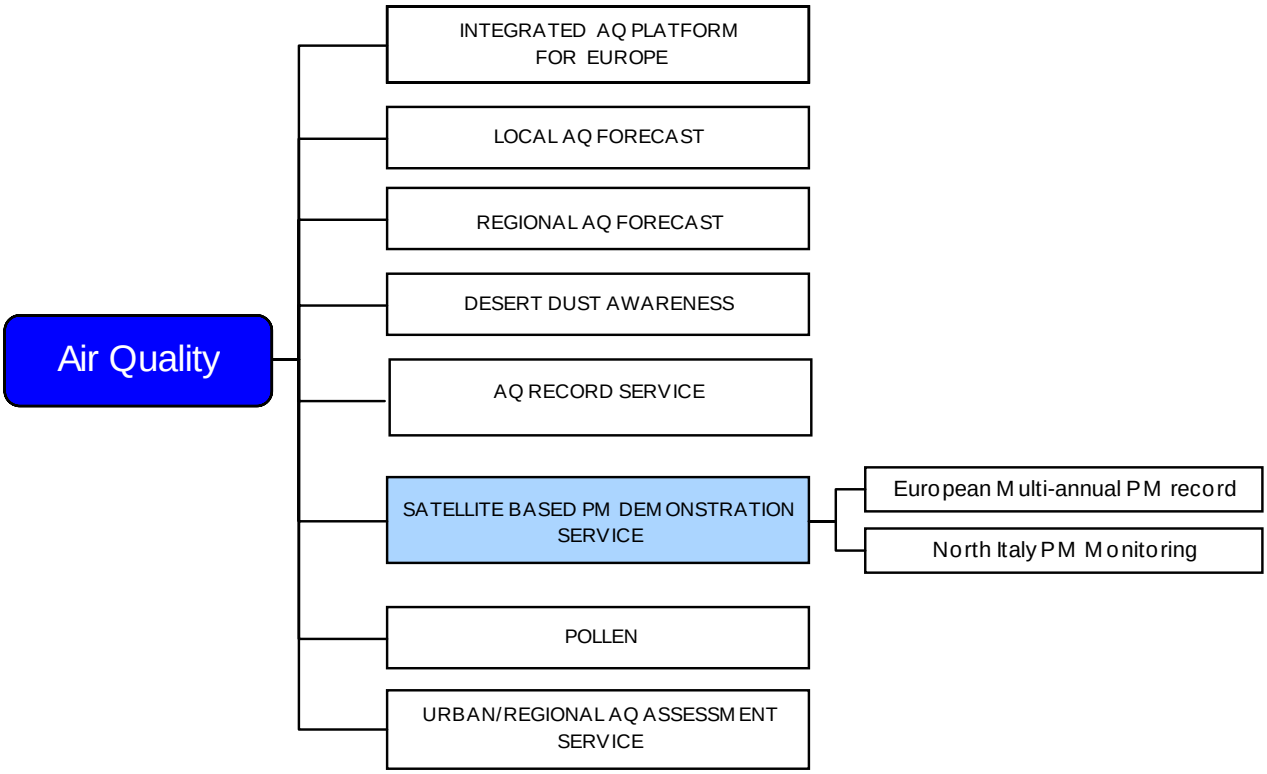


**Figure 1.1-1 Position and structure of the Satellite-based Particulate Matter Service within PROMOTE 2 Air Quality Services.**

## 1.2 European multi-annual records

ENVISAT daily aerosol parameters (aerosol optical depth and type from the Aerosol Records Service) on a 60x30 $km^2$ resolution provided in near-real time (approximately 12 hours after acquisition) over Europe and Africa (Asia) are used to estimate near-surface particulate matter concentrations (PM10, PM2.5m PM1.0) together with auxiliary information on vertical profiles from the EURAD model.

**Service is/will be operational since/after:** 7/2006

**Service Provider(s):** DLR

**Research partners:** RIU

**Valdiation contact:** T. Holzer-Popp, DLR

### 1.2.1 Product characterization

The products delivered are European Multi-annual Records (Eur-satPM-AQ-GSE-PRO2): Satellite particle mass concentration records: PM10, PM2.5, PM1.

| **PM10 concentration records** | |
|---|---|
| Parameter | Mass concentration |
| Typical range | 0-250 |
| Maximum range | 250 |
| Determination of the typical range (Method, criteria) | In-situ, Europe |
| Units | µg $m^{-3}$ |
| *Standards* | *Adjusted to PM In-situ* |
| **PM2.5 Concentration records** | |
| Parameter | Mass concentration |
| Typical range | 0-100 |
| Maximum range | 100 |
| Determination of the typical range (Method, criteria) | In-situ, Europe |

| | |
|---|---|
| Units | µg $m^{-3}$ |
| *Standards* | *Adjusted to PM In-situ* |
| **PM1 Concentration Records** | |
| Parameter | Mass concentration |
| Typical range | N/A |
| Determination of the typical range (Method, criteria) | In-situ, Europe |
| Maximum range | n.s. |
| Units | µg $m^{-3}$ |
| *Standards* | *Adjusted to PM In-situ* |

**Table 1.2-1Characterization of the products of the European multi-year PM records service**

### 1.2.2 Validation plan and validation data

Since Phase 1 the foillowing validation activities have been performed:

a) Method demonstration PM10, PM2.5: ERS-2 (GOME+ATSR-2)

Was carried out in 2004. As a result, a qualitative agreement of PM10 with 2001 EMEP report (e.g. gradient from Alps to Po basin) was found.

b) Method transfer to ENVISAT (SCIAMACHY+AATSR)

This method transfer was done in 2005 with data obtained during the period 7-10/2003. The validation was performed with data from selected stations by EMEP. The results indicated an overall good agreement between ENVISAT and EMEP data. However, over-estimations of PM concentrations near semi-arid regions and under-estimations near mountains (both most likely due to AOD error) were found. Detailed information regarding this validation has been published in EMEP Assessment Report 2006.

c) Method revision to version 1.8:

An AOD correction consisting in a vertical profile correction with EURAD model PM2.5 profile (form only!) was performed. Details are given in the Validation Report for Greenhouses and Aerosols Service.

In Phase 2, this new method version 1.8 was validated against selected EMEP data in phase 1 by NILU. The validation proved a significant improvement

d) Method revision to version 2.0:

In Phase 2, the dark field method and cloud screening of the AOD retrieval was improved – validation against AERONET data showed clear further improvement.

e) Method transfer to METOP:

The method transfer to METOP (GOME-2 + AVHRR) allows for a better coverage. As a result, data is now obtained over Europe daily – this transfer is almost completed and a delivery of a 1 month demonstration dataset is done in phase 2.

A separate validation of first METOP results against AERONET measurements has been started and will be reported in phase 3.

f) A series of activities are planned to provide an extended validation and to evaluate the long-term consistency of this sub-service during phase 2 of the project. Among the tasks foreseen, the following can be anticipated:

- Further PM validation against more EMEP stations (ENVISAT, METOP) by NILU using 1 year dataset
- Inter-comparison with Northern Italian Sat-PM sub service

Table 1.2-2 summarizes basic information regarding the datasets used for the validation of this sub-service.

| **VALIDATION DATA FOR MULTIYEAR PARTICULATE MATTER RECORDS** | |
|---|---|
| ***In-situ* observations** | |
| Offshore measurements | See Myhre *et al.*, ACP, 2005 |
| **VALIDATION DATA FOR MULTIYEAR PARTICULATE MATTER RECORDS** | |
| ***In-situ* observations** | |
| AERONET multi-spectral AOD data | Data availability and access: http://aeronet.gsfc.nasa.gov/<br>Spatial coverage and resolution: global<br>Temporal coverage and resolution: different per station, generally continuous and since 1997<br>Trajectories(s) (coordinates): multiple<br>Accuracy: multi-spectral AOD 0.01 |
| EMEP Data | Data availability and access: http://www.emep.int<br>Spatial coverage and resolution: Europe<br>Temporal coverage and resolution: 2003<br>Location(s) (coordinates): selected stations in semi arid and mountain environments<br>Accuracy: N/A |
| Other Airborne data | Data availability and access: N/A |

| | |
|---|---|
| sources<br>(For algorithm tuning only) | Spatial coverage and resolution: Germany, Namibia, Spain, others…<br>Temporal coverage and resolution: multiple<br>Trajectories(s) (coordinates): multiple<br>Accuracy: N/A |
| **Satellite outputs** | |
| SYNAER | Data availability and access: PROMOTE web portal<br>Spatial coverage and resolution: MSG FOV (starting May 2005: global)<br>Temporal coverage and resolution: 2003 - 2007<br>Location(s) (coordinates)/computational domain: n.a.<br>Accuracy: AOD 0.1 |
| **Other data** | |
| GOME+ATSR (ERS-2) | 1997-1998, Global (15 coincindences over different climate areas) See JGR, 2002 |
| SCIAMACHY+AATSR<br>(ENVISAT) | Data availability and access: -<br>Spatial coverage and resolution: -<br>Temporal coverage and resolution: 7-10/2003<br>Location(s) / Orbits: -<br>Accuracy:- |
| GOME-2+AVHRR<br>(METOP) | Data availability and access: -<br>Spatial coverage and resolution: Europe, 24 h<br>Temporal coverage and resolution: 7-10/2003<br>Location(s) / Orbits: -<br>Accuracy:- |
| EMEP Data | Data availability and access: http://www.emep.int<br>Spatial coverage and resolution: Europe<br>Temporal coverage and resolution: 2003<br>Location(s) (coordinates): selected stations in semi arid and mountain environments<br>Accuracy: N/A |

**Table 1.2-2 Data used for validation of the European Satellite Based Particulate Matter multi-year records sub-service**

### 1.2.3 Validation of individual components

| VALIDATION OF INDIVIDUAL COMPONENTS | |
|---|---|
| **Quality assessment** | |
| Ambiguity test | Least square fit: those aerosol types are ambiguous, which fit better than 3% noise with the best fit spectrum |
| Fit error test | Least square fit: fit of best simulated spectrum with measured spectrum better than 0.01 |
| Exceedance control of method limitations | Surface albedo brighter than 0.1 at 670 nm<br><br>Cloud fraction in SCIAMACHY pixel larger than 0.35 |
| AOD pixel-wise Error estimate | mean bias and stdv between SYNAER and insitu PM values for selected EMEP stations |
| **Model/algorithm/retrieval** | |
| APOLLO Cloud detection | 1/8 cloud fraction accuracy |
| | against synoptic observations from ground |
| EURAD PM2.5 vertical profile correction | N/A |
| | - |
| AOD-PM Conversion factors | depends on vertical profile correction and selected aerosol type |
| | - |
| **SYNAER** | Large errors in AOD near deserted areas |
| Method demonstration: Case study SYNAER vs. AERONET [Holzer-Popp, et al., JGR 2002] | 15 cases against ERS-2 distributed over many climate zones |
| | Indirect indication of correct aerosol type through multi-spectral AOD agreement |
| | Standard deviation (1 sigma) of errors 0.10 (440nm) and 0.06 (670nm) |
| Selected PM Retrievals vs. EMEP data [PROMOTE-2 utility report phase 1] | Overall reasonable agreement with over-estimation in semi-arid and under-estimation near mountainous areas.<br>RMS : N/A |

**Table 1.2-3 Validation of individual components of the European Satellite Based Particulate Matter multi-year records sub-service**

### 1.2.4 Validation against specifications and against user requirements

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

| **VALIDATION AGAINST SERVICE SPECIFICATIONS** | | | |
|---|---|---|---|
| A processing delay for 2006 data of about 2 weeks occurs due to unforeseen hardware overload; up to the deadline 31 May about 35% of the data are processed. However, additional coverage for 2003 (7 months) is provided (and will be completed for entire year in June/July) | | | |
| **VALIDATION AGAINST USER REQUIREMENTS** | | | |
| **SPECIFICATION** | **S5** | **REQUIRED*** | **ACTUAL** |
| Products | PM10, PM 2.5, PM1 and AOD at 550 nm (PM0.5 instead PM1) | | |
| Accuracy (or best estimator) | mean bias and stdv | n.s. | AOD 20%<br>PM n.s. |
| Accuracy minimum | n.s. | *30%* | n.s. |
| Accuracy target | n.s. | *5%* | 20% for PM demo |
| Spatial coverage | Swath 480 Km, 14 Orbits/day; i.e. Global coverage in approx 2 weeks<br><br>Europe, MSG FOV | Europe, Africa<br><br>*Global* | Europe |
| Horizontal resolution | n.s. | *Min. 10x10 Km$^2$*<br>*target 1x1 Km$^2$* | 60x30 km$^2$ |
| Vertical resolution | n.s. | n.s. | N/A. |
| Grid/Projection | Orbit geometry; gridded data sets (monthly mean) | *Orbits, UTM or EMEP grid 50x50 or finer Km$^2$* | orbit geometry |
| Temporal coverage | 2003-2006 | 3 months 2005 in the warm season+1 year for Europe and Africa<br><br>*Minimum 3 years global* | 6-9 / 2005 (v1.8)<br><br>4, 7-12 / 2003 (completed)<br><br>1-12 / 2006 (about 50% completed) |
| Temporal resolution | 24 h + monthly means | 24 h – *1 h* | re-visit cycle (cloud free): 12 days |
| **User Interfaces** | | | |

| | | | |
|---|---|---|---|
| PROMOTE Web | n.s. | Operational, complete and up to date | Operational, complete and up to date |
| SYNAER Web Site | n.s. | Daily operational update of the SYNAER Website including PM Datasets | Daily operational update of the SYNAER Website including PM Datasets |
| ftp | n.s. | n.a. | n.a. |
| **Data formats and data delivery** | | | |
| Data availability | ENVISAT 2003-2006 (Partly, PROMOTE 1)<br><br>3 months warm season 2005 (PROMOTE 2 Phase 1) | 3 months warm season 2005+1 year for Europe and Africa | 3 months warm season 2005<br><br>1 year 2006<br><br>Additional to SLA: 1 year 2003 |
| Data access | n.s. | Any time of the day, through PROMOTE web portal | Any time of the day, through PROMOTE web portal (v0.9) |
| Delivery Mode | Offline (Online no NRT) | n.s. | Offline (Online no NRT) |
| Delivery frequency | Month 9 of every phase plus daily update | Daily operational update of the SYNAER Website including PM Datasets Month 9 of every phase plus daily update | Delivery during May 2005 and continued<br><br>Daily operational update of the SYNAER Website including PM Datasets<br><br>Month 9 of every phase plus daily update |
| Data Format | HDF, GIF | HDF, GIF | HDF, GIF |
| Historical archive | Europe/Africa 04/2003-11/7/2006 (with gaps) | *2003-2005* | 2003-2007 (v1.0) |
| Visualization | HDF Viewer, idl routines | n.s. | HDF Viewer, idl routines, GIF Quick looks |

| REMARKS |
|---|
| An additional dataset is provided for 2003 in phase 2. |

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

**Table 1.2-4 Validation against specifications and user requirements of the European Satellite Based Particulate Matter multi-year records sub-service**

### 1.2.5 Quality assessment and control procedures

## 1.3 Service quality assessment and control procedures

| **Service delivery start date: operational since 1 March, update 8 June** | | | | |
|---|---|---|---|---|
| **SPECIFICATION** | **S5** | **REQUIRED*** | **ACTUAL** | **N checks/Delivery period**<br><br>**Continuous** |
| Quality checks | Internal for SYNAER. Pixel-wise AOD error estimate<br><br>External to be defined | *yes* | See Table 1.2-3 | automatic for each pixel, reported in hdf<br><br>External: will be defined in phase 3 after current user evaluation and final method upgrade |
| Product confidence interval | n.s. | *95% Confidence limits to be given* | n.s. | n.s. (ongoing validation by user NILU in June/July) |
| Error bar definition and representation | 1 sigma | *2 Standard deviations* | n.s. | n.a. |
| Representation of missing data | The number of orbits processed per day, month and year, are documented in a separate file, which is made available on the webportal. | *-99.99 or similar value <0* | not included in HDF and GIF files | 1 summary file provided 30 May 2008, upgrade after each completing of a reprocessing effort or on annual basis |

| | | | | |
|---|---|---|---|---|
| Documentation of process failure | Summary of process failure is reported in the S6 document | *Available in background* | File not processed | Between 1st of March and May the 20th. NRT failure for few short periods of few days. Reprocessing failure during May 9-26<br><br>(orbit number file shows also failure periods) |
| Version control mechanisms and representation | Changes between software versions are documented in a dedicated word file which is available on the web portal.<br><br>Data products are stored in subdirectories (each month) with naming specifying the product version. | *Processing version number in product. Good documentation on processor version included.*<br><br>*References to QC procedures; product version number and last date of modification to be available in background* | separated sub directories | version document is provided at 30 May and updated for each new version |

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

**Table 1.3-1 Quality assessment and control procedures and service quality**

## 1.4 Regional monitoring for Italy

The Aerosol Optical Depth fine-mode fraction and PM content service is based on aerosol optical depth (AOD) and fine-mode fraction (η) of tropospheric aerosol as retrieved from MODIS radiances - both Terra and Aqua platforms - and provided by NASA EOS Data Gateway.

**Service is/will be operational since/after (indicate date):** January 2007

**Product Name:** Daily AOD and derived PM Concentration (Demo)

**Service Provider(s):** CGS

**Research partners:** Milano Bicocca University (Prof. E. Bolzacchini), Brescia University (Prof.ssa M. Volta)

**Validation contact:** Walter Di Nicolantonio, CGS

### 1.4.1 Product characterization

| **Aerosol Optical Depth AOD at 550 nm** | |
|---|---|
| Parameter | Optical depth |
| Typical range | AOD (500nm) = 0 – 1 |
| Determination of the typical range (Method, criteria) | For AOD the range is a typical range for tropospheric aerosol content. |
| Maximum range | 2 |
| Units | [-] |
| *Standards* | - |
| **Small to total number particles ratio (η)** | |
| Parameter | Ratio |
| Typical range | 0 – 1 |
| Determination of the typical range (Method, criteria) | |
| Maximum range | 1 |
| Units | [-] |
| *Standards* | - |

| **Satellite derived PM content at the surface** | |
|---|---|
| Parameter | PM2.5 mass concentration |
| Typical range | 0 – 100 μg $m^{-3}$ |
| Determination of the typical range (Method, criteria) | The iupper limit is seldom reached in the current in-situ measurements within of region of interest. |
| Maximum range | 100 |
| Units | [μg $m^{-3}$] |
| *Standards* | - |

**Table 1.4-1 Characterization of the products of the Italian Satellite Based PM monitoring sub-service**

### 1.4.2 Validation plan and validation data

The Regional Monitoring (Northern Italy) sub-service is part of the Satellite-based Particulate Matter Demonstration Service. The aim of this sub service is to provide daily maps of AOD - from MODIS - and the related PM2.5 estimated content at the ground over Northern Italy.

Aerosol optical properties retrieved from MODIS measurements (collection 005) are freely available via LAADS Web (Level 1 and Atmosphere Archive and Distribution System). Their validation is not the main focus for this service. Comparisons between MODIS AOD and AERONET AOD are available in literature also for the new operational algorithm (Levy et al., 2007). A further comparison with data recorded in four AERONET sites located in the Po valley throughout 2004 will be done.

Within this service, validation is focused on the PM2.5 content as derived from the AOD to PM conversion. Correlative data sets are represented mainly by PM2.5 concentration measurements at the ground. Since these measurements are not yet required by Air Quality control laws, there is a lack of this kind of data.

Table 1.4-2 summarizes basic information concerning the datasets used for validation. Gravimetric measurements of the 24h-average PM2.5 concentrations are available through a dedicated field-campaign and provided by Milano Bicocca University, from March to October 2004 in 6 measurements sites in Lombardia region.

In Phase 1, validation was made with gravimetric measurements of the 24h-average PM2.5 concentrations in one site of the Po Valley, as it will be described next.

| VALIDATION DATA FOR SATELLITE BASED PARTICULATE MATTER | |
|---|---|
| **Ground based observations** | |
| AERONET AOD observations (Phase 1) | See Holben *et al.*, 1998 |
| **Ground based observations** | |
| Name<br>AERONET AOD observations<br>Phase: ( 2 ) | Data availability and access: AERONET data are freely available via web: aeronet.gsfc.nasa.gov<br>Spatial coverage and resolution: Northern Italy<br>Temporal coverage and resolution: whole 2004<br>Location(s) (coordinates): Ispra (45N,8E) Modena (44N,10E), Venezia (45N, 12E)<br>Uncertainty quantification (e.g. Accuracy): 0.01 for AOD |
| | |
| | |
| ***In-situ* observations** | |
| Po Valley (Brescia)/gravimetric PM2.5<br>Phase 1 | Data availability and access: data provided by Milano Bicocca University<br>Spatial coverage and resolution: in situ measurements; March-October 2004<br>Temporal coverage and resolution: June-July 2004<br>Location(s) (coordinates):10:12:00E ; 45:32:00N<br>Accuracy: <10% |
| Name<br>24-h averaged<br>PM25 gravimetric<br>concentrations at the ground<br>Phase: (1+2) | Data availability and access: data provided by Milano Bicocca University<br>Spatial coverage and resolution: NA<br>Temporal coverage and resolution: March- October 2004<br>Location(s) (coordinates): Bosco Fontana (45:12N,10:42E,), Brescia (45:32N 10:12E), Cantù (45:45N, 09:07E), Milano (45:29N, 09:10E), Mantova (45:09N, 10:47E), Varese (45:50N, 08:49E)<br>Uncertainty quantification (e.g. Accuracy): <10% |
| Name<br>24-h averaged PM10 concentrations at the ground by ARPA Lombardia and ARPA Emilia Romagna<br>Phase: (2) | Data availability and access:<br>PM10 Data available from ARPA web sites<br>Spatial coverage and resolution: NA<br>Temporal coverage and resolution: whole 2004, 24h averaged measurements<br>Location(s) (coordinates): 70 sites in Lombardia and Emilia Romagna regions<br>Uncertainty quantification (e.g. Accuracy): < 5 μg $m^{-3}$ |

**Table 1.4-2 Data used for validation of the Italian PM monitoring service**

Satellite estimated PM2.5 concentration - derived from satellite AOD measurements provided by MODIS - was compared to in-situ mass concentration measurements of PM2.5. For the first year, product should be referred to two months in warm season. June and July 2004 were selected as period for the product generation and are already available on the subservice web site, both in terms of daily maps of AOD and PM2.5 satellite estimates.

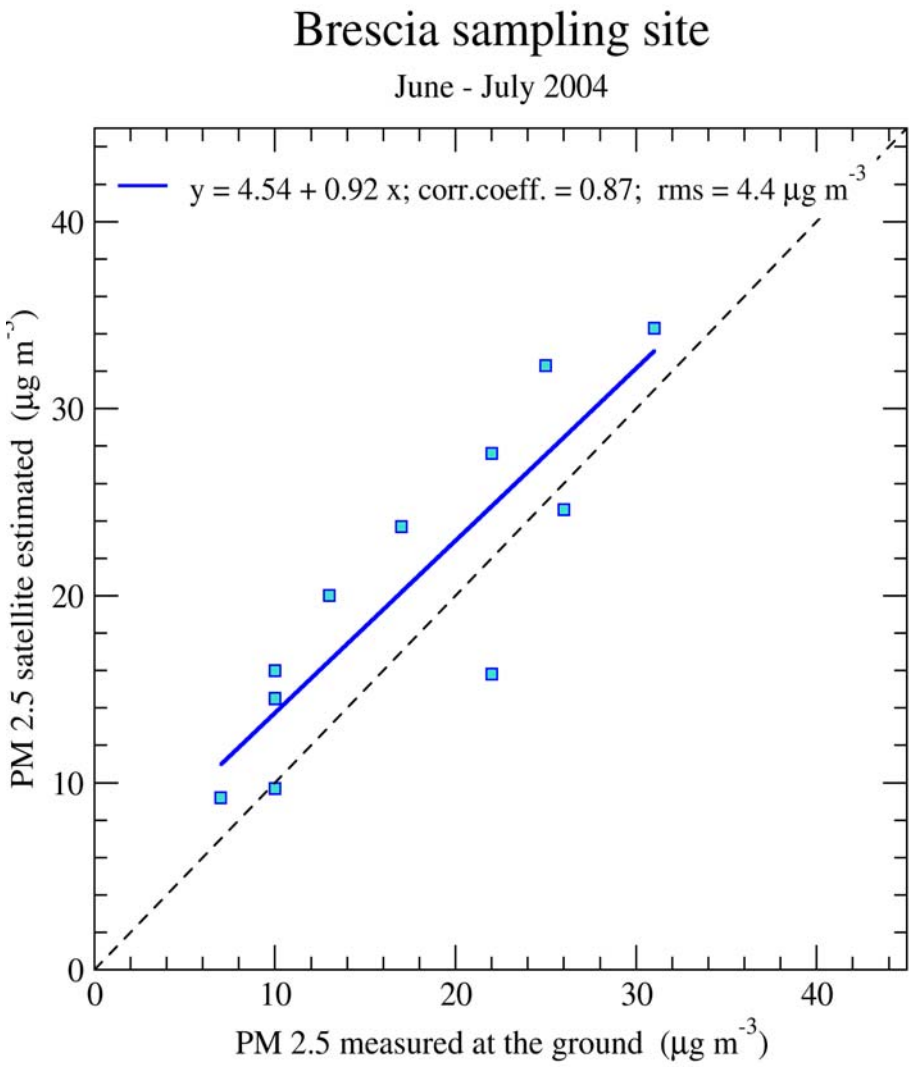


**Figure 1.4-1 PM2.5 mass concentration sampled at the ground against spatio-temporal coincident satellite based PM2.5 concentration.**

Thus, for June and July 2004, in-situ samplings at the Brescia site were singled out as a correlative data set to be compared with the spatio-temporal coincident satellite based PM2.5 concentration. Validation has been carried out in terms of regression fit of satellite based PM concentration versus in-situ measurements. As reported in Figure 1.4-2 , the spatial temporal coincidence over the two month period turned out to provide 11 points. For these coincident points, the correlation coefficient was found to be equal to 0.87 and the r.m.s. was equal to 4.4 μg $m^{-3}$.

In Figure 1.4-2 the time series of PM2.5 measured at the ground is reported (grey bars) along with the spatio-temporal coincident satellite estimated values (orange bars). In most cases, satellite estimated values seem to be amplified with respect to the ground measured values.

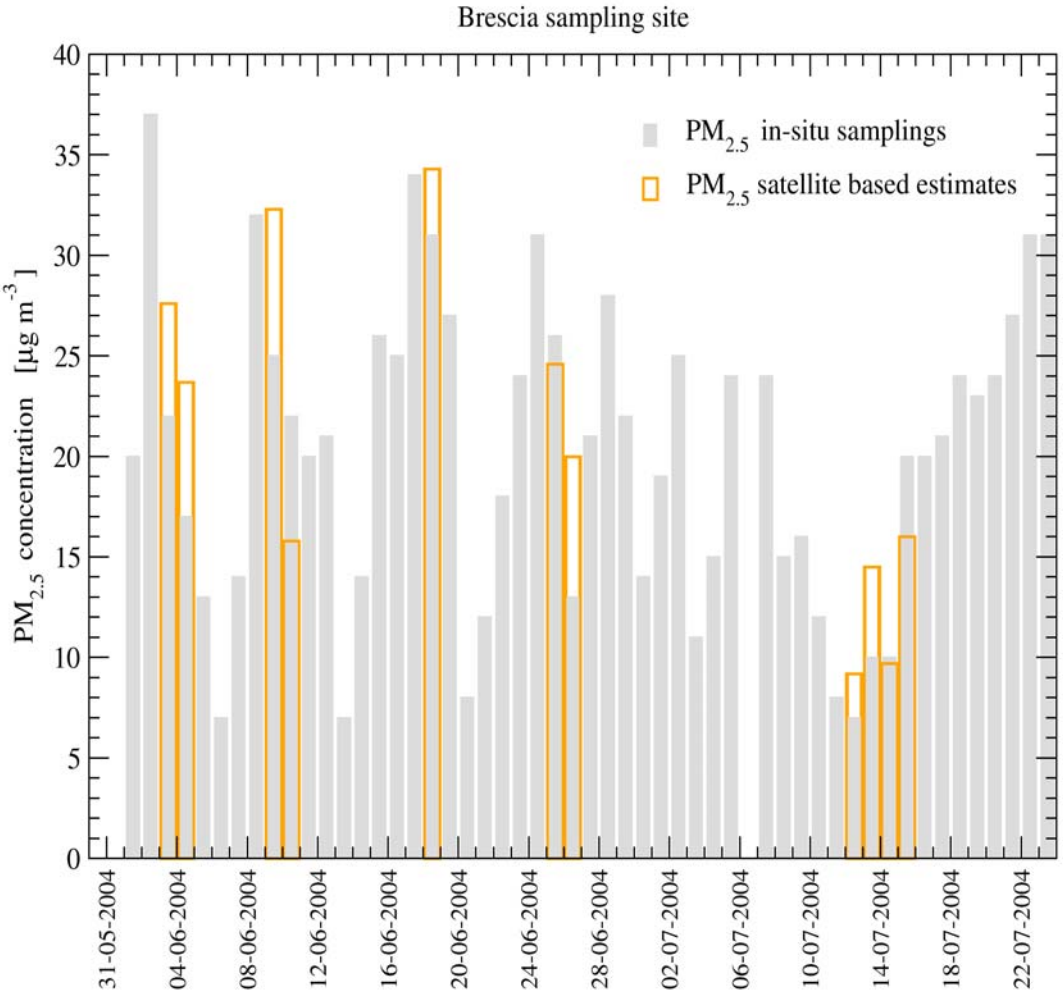


**Figure 1.4-2 PM2.5 concentration time series for June and July 2004 as sampled at the ground (grey bars) along with spatio-temporal coincident PM2.5 satellite estimated (orange bars).**

.Validation is made against PM2.5 concentrations derived from 24h-averaged PM10 concentrations routinely measured in different sites located in Emilia Romagna and Lombardia regions by ARPA. On the basis of the ratio PM10/PM2.5 determined on a monthly base for the Po valley area, PM2.5 estimates at the ground are calculated from PM10 concentration measured at the ground in the 70 sampling sites operated by ARPA Lombardia and Emilia Romagna.

Linear regression will be calculated between satellite estimated PM25 extracted in correspondence of the geolocation of the sampling sites and corresponding PM2.5 estimated at the ground as it has been done in Di Nicolantonio et al., (2007).

For Phase 2 validation a comparison of AOD data from MODIS have been made – taking advantage of the sinergy with the QUITSAT project (www.quitsat.it). Comparison of AOD data from MODIS for 2004 related to Terra(MOD) and Aqua(MYD) platform to AERONET data has been made for 3 station loacted in the Po Valley: Ispra, Venezia-ISGDM, Modena.

| Platform \ Station | Ispra | Venezia – ISDGM | Modena |
|---|---|---|---|
| MOD | y = 0.971 x – 0.015 | y = 1.238 x – 0.083 | y = 0.789 x – 0.140 |
| MYD | y = 0.880 x – 0.017 | y = 0.815 x – 0.171 | y = 0.807 x – 0.087 |

**Table 1.4-3 Best-fit resulted from the MODIS to AERONET AOD comparison**

For Phase 2 validation of satellite derived PM2.5 linear regression parameters were calculated - on a monthly basis – between satellite estimated PM2.5 extracted in correspondence of the geo-location of the sampling sites and corresponding PM2.5 estimated at the ground. Taking into account both PM25 24-h average measurements and PM25 estimates at the ground as calculated from PM10 concentration in sites operated by ARPA Lombardia and Emilia Romagna, an overall number of 76 sampling sites were available (see table 1.4-3).

In the tables reported below the frequency distribution of the values of the regression parameters (correlation coefficient, regression coefficient, regression constant [µg m-3] and RMS [µg m-3]) - related to the whole set of 76 sampling sites - are presented.

| R [range] | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -0.8 | 4 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| -0.6 | 0 | 2 | 4 | 0 | 0 | 2 | 0 | 0 | 0 | 3 | 2 | 3 |
| -0.4 | 0 | 2 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 9 | 1 |
| -0.2 | 1 | 4 | 3 | 8 | 3 | 4 | 1 | 0 | 3 | 1 | 7 | 1 |
| 0 | 0 | 7 | 6 | 12 | 7 | 5 | 3 | 2 | 1 | 1 | 5 | 4 |
| 0.2 | 2 | 10 | 4 | 10 | 8 | 11 | 10 | 2 | 5 | 2 | 6 | 8 |
| 0.4 | 6 | 11 | 5 | 7 | 16 | 12 | 13 | 10 | 24 | 6 | 2 | 4 |
| 0.6 | 3 | 5 | 14 | 15 | 11 | 24 | 24 | 13 | 25 | 7 | 3 | 3 |
| 0.8 | 7 | 6 | 11 | 7 | 11 | 3 | 17 | 16 | 13 | 7 | 10 | 7 |
| 1 | 11 | 8 | 2 | 7 | 12 | 3 | 1 | 28 | 1 | 9 | 10 | 4 |

**Table 1.4 -4 Frequency distribution number of correlation coefficients as results of the regression of Satellite estimated PM2.5 from Terra (MOD) against corresponding in-situ measurements**

| R [range] | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -0.8 | 0 | 0 | 3 | 0 | 0 | 2 | 1 | 0 | 1 | 4 | 5 | 1 |
| -0.6 | 0 | 0 | 9 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 |
| -0.4 | 0 | 3 | 2 | 4 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 0 |
| -0.2 | 0 | 4 | 4 | 4 | 3 | 0 | 0 | 1 | 0 | 1 | 4 | 0 |
| 0 | 1 | 6 | 4 | 4 | 6 | 7 | 5 | 1 | 3 | 2 | 1 | 0 |
| 0.2 | 0 | 10 | 8 | 9 | 16 | 10 | 8 | 8 | 12 | 4 | 2 | 0 |
| 0.4 | 0 | 9 | 10 | 13 | 15 | 16 | 18 | 3 | 25 | 5 | 2 | 0 |
| 0.6 | 0 | 2 | 9 | 14 | 20 | 22 | 18 | 9 | 18 | 4 | 4 | 0 |
| 0.8 | 0 | 11 | 8 | 10 | 6 | 10 | 18 | 23 | 8 | 6 | 7 | 0 |
| 1 | 6 | 4 | 6 | 7 | 2 | 1 | 2 | 25 | 3 | 6 | 9 | 1 |

**Table 1.4 -5 Frequency distribution number of correlation coefficients as results of the regression of Satellite estimated PM2.5 from Aqua (MYD) against corresponding in-situ measurements**

| B [range] | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -2 | 4 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| -1.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -1.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -1.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -1.2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -0.8 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| -0.6 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -0.4 | 0 | 2 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 3 | 0 | 0 |
| -0.2 | 0 | 3 | 3 | 5 | 0 | 1 | 0 | 0 | 1 | 2 | 1 | 0 |
| 0 | 0 | 7 | 14 | 15 | 8 | 7 | 4 | 2 | 3 | 4 | 23 | 9 |
| 0.2 | 4 | 10 | 11 | 15 | 9 | 36 | 19 | 14 | 20 | 6 | 24 | 17 |
| 0.4 | 3 | 15 | 7 | 14 | 16 | 11 | 25 | 10 | 40 | 8 | 4 | 4 |
| 0.6 | 5 | 5 | 9 | 6 | 9 | 4 | 18 | 14 | 8 | 5 | 2 | 0 |
| 0.8 | 5 | 5 | 3 | 5 | 10 | 2 | 2 | 21 | 0 | 7 | 1 | 2 |
| 1 | 4 | 1 | 4 | 2 | 6 | 0 | 1 | 7 | 0 | 2 | 0 | 3 |
| 1.2 | 3 | 3 | 1 | 0 | 4 | 0 | 0 | 2 | 0 | 2 | 0 | 0 |
| 1.4 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1.6 | 2 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -2 | 4 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

**Table 1.4 -6 Frequency distribution number of regression coefficients (slope) as results of the regression of Satellite estimated PM2.5 from Terra (MOD) against corresponding in-situ measurements**

| B [range] | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -2 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -1.8 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| -1.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -1.4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| -1.2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| -1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| -0.8 | 0 | 0 | 3 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| -0.6 | 0 | 1 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 |
| -0.4 | 0 | 0 | 1 | 0 | 1 | 1 | 16 | 0 | 0 | 0 | 0 | 0 |
| -0.2 | 0 | 4 | 5 | 4 | 1 | 1 | 34 | 2 | 0 | 0 | 4 | 0 |
| 0 | 0 | 8 | 12 | 5 | 5 | 7 | 12 | 1 | 5 | 10 | 5 | 1 |
| 0.2 | 2 | 20 | 11 | 17 | 18 | 11 | 1 | 9 | 35 | 24 | 18 | 1 |
| 0.4 | 4 | 6 | 7 | 13 | 15 | 10 | 0 | 14 | 29 | 1 | 5 | 0 |
| 0.6 | 1 | 3 | 3 | 7 | 8 | 17 | 0 | 19 | 3 | 0 | 0 | 0 |
| 0.8 | 0 | 3 | 6 | 3 | 7 | 8 | 0 | 10 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 4 | 3 | 3 | 6 | 0 | 11 | 0 | 0 | 1 | 0 |
| 1.2 | 0 | 2 | 1 | 3 | 3 | 4 | 0 | 3 | 0 | 0 | 0 | 0 |
| 1.4 | 0 | 0 | 3 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 |
| 1.6 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1.8 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -2 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 1.4 -7 Frequency distribution number of regression coefficients (slope) as results of the regression of Satellite estimated PM2.5 from Aqua (MYD) against corresponding in-situ measurements**

| A [range] | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -70 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| -55 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -50 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -45 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| -40 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -35 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -30 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| -25 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -20 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| -15 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -10 | 0 | 2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| -5 | 2 | 3 | 4 | 1 | 2 | 0 | 0 | 4 | 0 | 3 | 0 | 4 |
| 0 | 4 | 1 | 6 | 2 | 7 | 9 | 0 | 8 | 0 | 6 | 0 | 2 |
| 5 | 2 | 5 | 8 | 7 | 19 | 14 | 3 | 19 | 7 | 5 | 4 | 7 |
| 10 | 2 | 6 | 9 | 14 | 21 | 19 | 13 | 22 | 24 | 4 | 16 | 8 |
| 15 | 2 | 6 | 11 | 25 | 8 | 19 | 16 | 13 | 30 | 4 | 18 | 7 |
| 20 | 2 | 6 | 5 | 8 | 4 | 0 | 14 | 5 | 8 | 8 | 11 | 4 |
| 25 | 2 | 2 | 4 | 3 | 2 | 1 | 14 | 0 | 1 | 1 | 4 | 1 |
| 30 | 0 | 5 | 0 | 2 | 0 | 1 | 7 | 0 | 1 | 1 | 0 | 0 |
| 35 | 3 | 2 | 0 | 2 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 |
| 40 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 45 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 50 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 55 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 1.4 -8 Frequency distribution number of regression constant (offset) as results of the regression of Satellite estimated PM2.5 from Terra (MOD) against corresponding in-situ measurements**

| A [range] | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -55 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -50 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| -45 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -40 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -30 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -25 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -20 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -10 | 0 | 1 | 3 | 0 | 1 | 3 | 0 | 2 | 0 | 0 | 0 | 0 |
| -5 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 2 | 2 | 1 | 4 | 0 | 8 | 0 | 0 | 0 | 0 |
| 5 | 1 | 4 | 4 | 1 | 9 | 11 | 5 | 23 | 8 | 0 | 6 | 0 |
| 10 | 1 | 8 | 6 | 6 | 12 | 16 | 25 | 24 | 20 | 6 | 7 | 0 |
| 15 | 1 | 5 | 9 | 17 | 25 | 13 | 25 | 8 | 30 | 17 | 12 | 0 |
| 20 | 2 | 6 | 17 | 12 | 8 | 10 | 12 | 1 | 10 | 8 | 4 | 0 |
| 25 | 0 | 3 | 2 | 16 | 2 | 8 | 2 | 0 | 4 | 4 | 3 | 1 |
| 30 | 1 | 3 | 4 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 1 | 1 |
| 35 | 0 | 6 | 1 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| 40 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 45 | 0 | 0 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 55 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 65 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 1.4 -9 Frequency distribution number of regression constant (offset) as results of the regression of Satellite estimated PM2.5 from Aqua (MYD) against corresponding in-situ measurements**

.

| RMS | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 0 | 0 | 1 | 0 |
| 2.5 | 1 | 4 | 10 | 3 | 7 | 20 | 1 | 13 | 4 | 4 | 30 | 19 |
| 5 | 4 | 5 | 21 | 5 | 21 | 22 | 12 | 22 | 6 | 5 | 16 | 4 |
| 7.5 | 3 | 9 | 11 | 15 | 16 | 11 | 15 | 15 | 11 | 16 | 5 | 2 |
| 10 | 4 | 7 | 1 | 11 | 3 | 3 | 18 | 5 | 14 | 10 | 1 | 2 |
| 12.5 | 4 | 8 | 3 | 6 | 5 | 2 | 9 | 10 | 14 | 1 | 1 | 2 |
| 15 | 3 | 5 | 0 | 12 | 1 | 3 | 7 | 2 | 10 | 2 | 1 | 2 |
| 17.5 | 4 | 3 | 3 | 4 | 0 | 0 | 2 | 1 | 9 | 2 | 0 | 0 |
| 20 | 1 | 3 | 0 | 5 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| 22.5 | 0 | 0 | 1 | 0 | 4 | 0 | 2 | 1 | 1 | 0 | 0 | 2 |
| 25 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| 27.5 | 0 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 30 | 2 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32.5 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 1 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37.5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 42.5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 45 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 47.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 1.4 -10 Frequency distribution number of RMS as results of the regression of Satellite estimated PM2.5 from Terra (MOD) against corresponding in-situ measurements**

| RMS | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.5 | 3 | 3 | 10 | 5 | 3 | 5 | 5 | 9 | 7 | 22 | 24 | 2 |
| 5 | 1 | 12 | 7 | 9 | 18 | 6 | 13 | 20 | 18 | 12 | 9 | 0 |
| 7.5 | 3 | 13 | 13 | 9 | 12 | 13 | 9 | 18 | 18 | 1 | 0 | 0 |
| 10 | 0 | 4 | 3 | 7 | 9 | 14 | 15 | 5 | 15 | 0 | 1 | 0 |
| 12.5 | 0 | 3 | 9 | 5 | 3 | 9 | 5 | 4 | 7 | 0 | 1 | 0 |
| 15 | 0 | 2 | 6 | 4 | 2 | 8 | 2 | 5 | 4 | 0 | 0 | 0 |
| 17.5 | 0 | 1 | 2 | 2 | 6 | 6 | 8 | 1 | 1 | 0 | 0 | 0 |
| 20 | 0 | 0 | 1 | 4 | 3 | 4 | 2 | 1 | 1 | 0 | 0 | 0 |
| 22.5 | 0 | 2 | 1 | 2 | 2 | 1 | 2 | 0 | 1 | 0 | 0 | 0 |
| 25 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 |
| 27.5 | 0 | 0 | 1 | 2 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 30 | 0 | 1 | 0 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32.5 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37.5 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 42.5 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 45 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 47.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 1.4 -11 Frequency distribution number of RMS as results of the regression of Satellite estimated PM2.5 from Aqua (MYD) against corresponding in-situ measurements**

As expected, a better agreement is found on summer months, in particular August, both for Aqua and Terra platform in terms relatively high values of correlation coefficient and relatively small values of the offset and RMS. An overestimation of at maximum 10 μg m-3 is resulted for summer months.

In winter months, higher values of the offset are present together with relatively low values of the slope, leading to an overestimation of low values of PM2.5 concentration while significant concentration of particulate matter at the ground are better represented.

### 1.4.3 Validation of individual components

Being PM concentration derived from satellite retrieved AOD, it can be affected by the *a priori* employed in the AOD retrieval, both for aerosol optical properties and vertical distribution and surface reflectance parameterization. Furthermore, for the AOD-to-PM conversion, PM2.5 measurements at the ground are needed for the determination of the conversion parameters. Since these samplings are not yet routinely performed, it turns out to be difficult to find correlative data set for validation and measurements at the ground for widening the area over which providing PM concentration maps.

| **VALIDATION OF INDIVIDUAL COMPONENTS** | |
|---|---|
| **Quality assessment** | |
| Quality checks | Reliable values of PM-sat must be greater than 8 μg $m^{-3}$; |
| Best estimator: | Linear regression parameters.<br>Correlation coefficient ,Regression coefficient, regression constant,<br>calculated through least square fit |
| Regression | MODIS PM vs Brescia Correlative in-situ data : Correlation coefficient = 0.87; linear best fit: PM-sat = 0.92PM-situ + 4.54 ; r.m.s. = 4.4 μg $m^{-3}$; (Di Nicolantonio *et al.*, 2007) |
| Error bar | RMS= SQRT [( 1/Nobs-2) Σ (PMsat – regression constant – regression coefficient * PMsitu) **2] |
| Fit error test | N/A |
| **MODELS/ALGORITHMS/RETRIEVALS** | |
| AOD-PM Conversion factors | Depends on aerosol type, if the mixing layer results well-mixed, surface meteorological characterization |
| **Output validation against in-situ PM Measurements** | |
| PM2.5 | |

| | |
|---|---|
| | Linear regression parameter<br><br>(Reasonable agreement, as shown by the results presented in the Tables above). |

**Table 1.4-4 Validation of the individual components of the Italian PM monitoring service**

### 1.4.4 Validation against specifications and against user requirements

**NRT Implementation**

Despite this sub-service is intended as a demonstration service during Phases 1 and 2 of the project, the whole processing chain for the AOD-to-PM conversion was designed taking into account a potential NRT requirement.

In particular, concerning this issue, the Regional Monitoring sub-service takes advantage of the QUITSAT ASI project, which aims at providing a NRT processing chain to estimate PM2.5 from AOD satellite measurements. It has to be pointed out that for this processing chain AOD values over the region of interest should be already available.$µ

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

| **VALIDATION AGAINST SERVICE SPECIFICATIONS** | | | |
|---|---|---|---|
| PM1 data were not used since there are no available mesurements in the region of interest up to now. PM10 data have been employed to estimate PM2.5 concentrations | | | |
| **VALIDATION AGAINST USER REQUIREMENTS** | | | |
| **SPECIFICATION** | **S5** | **REQUIRED*** | **ACTUAL** |
| Product | Aerosol Optical Depth at a 550 nm; η; Satellite derived PM content at the surface | | |
| Accuracy | AOD: 0.05+0.2*AOD<br>H: N/A<br>PM: N/A | n.s. | AOD: 0.05+0.2*AOD<br>η : N/A<br>PM2.5 : r.m.s. = 4.4 $\mu gm^{-3}$ |
| Accuracy minimum | n.s | *30%* | N/A |
| Accuracy target | n.s. | *5%* | 20% |
| Spatial coverage | Northern and Central Italy with focus on Po Valley area | North Italy<br><br>*Italy* | Northern Italy with focus on Po Valley area |

| | | | |
|---|---|---|---|
| Horizontal resolution | 10x10 $Km^2$ | *min. 10x10 $Km^2$ target 1x1 $Km^2$* | 10x10 $km^2$ |
| Vertical resolution | n.a. | n.a. | n.a. |
| Grid/Projection | Equal angle grid | n.s. | Equal angle grid |
| Temporal coverage | Sat_PM: selected months in 2002 and 2004;<br><br>AOD, η: selected months in 2002, whole 2004;<br><br>PROMOTE-2 / phase 1: 2 months in warm season (June, July 2004);<br><br>PROMOTE-2 / phase2: reprocessing of whole 2004 over a wider geographical domain (Northern Italy). | 2 months in the warm season (Phase 1)<br><br>4 selected moths in all seasons (Phase 2)<br><br>*Minimum 3 years (Since 2000 optimal)* | selected months in 2002 and whole 2004 and 2005 for AOD (phase1)<br><br>whole 2004 for satellite PM (Phase2) |
| Temporal resolution | 24 h | 24 h – *1 h* | 24 h |
| **User Interfaces** | | | |
| PROMOTE Web | Operational, complete and up to date | Operational, complete and up to date | Operational, complete and up to date |
| ftp | On event | On event | On demand |
| **Data formats and data delivery** | | | |
| Data availability | n.s. | 2 months in the warm season (Phase 1)<br><br>4 selected moths in all seasons (Phase 2) | June and july 2004 delivered (Phase 1)<br><br>Whole 2004 over whole Northern Italy, delivered by the end of May 08 (Phase2) |
| Data access | n.s. | On event | Png Images available on web, geotiff available via FTP |

| | | | |
|---|---|---|---|
| Delivery Mode | FTP | FTP<br><br>*NRT* | Offline, Via FTP on demand |
| Delivery frequency | n.s. | At the end of each month processed | On demand |
| Data Format | ASCII | ASCII | Geotiff, png,<br><br>ASCII on demand |
| Historical archive | Sat_PM Selected months 2002 and 2004<br><br>AOD, η: selected months in 2002 and complete 2004 | n.s. | selected months in 2002 and whole 2004, and 2005 for AOD<br><br>whole 2004 for PM_sat |
| Visualization | GEOTIFF and PNG on demand | n.s. | Standard GEOTIFF and PNG viewer |
| **REMARKS** | | | |
| 4 months of products relative to all seasons were planned for Phase 2, actually whole 2004 has been processed in terms of satellite estimated PM25, thus 12 months are available for users. | | | |

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

**Table 1.4-1 Validation against specifications and against user requirements of the Italian monitoring service**

### 1.4.5 Quality assessment and control procedures

| **Service delivery start date: [“Phase 1”, updated at May 30, 2008]** | | | | |
|---|---|---|---|---|
| **SPECIFICATION** | **S5** | **REQUIRED *** | **ACTUAL** | **N checks/Delivery period** |
| Quality checks | PM-sat values compared to PM ground data samples | *yes* | linear regression between PM-sat and PM ground data samples | Once during validation phase for the whole data-set |
| Product confidence interval | n.s. | *95% Confidence limits to be given* | n.a. | n.a. |
| Error bar definition and representation | RMS | *2 Standard deviations* | monthly averaged RMS calculated | n.a. |
| Representation of missing data | In GEOTIFF file with satPM data, null=-9999; Furthermore a log file is generated with the list of days for which no data are available. | *-99.99 or similar value <0* | In GEOTIFF file with satPM data, null pixels are represented by -9999; | For each null pixel in each GeoTIFF file |
| Documentation of process failure | At moment it is an off-line processing and the processing chain is not automatized. An eventually failure is reported on screen. | *Available in background* | eventual failure is reported on screen during data processing | n.a. |

| | | | | |
|---|---|---|---|---|
| Version control mechanisms and representation | current version in use is 1.2<br>Version numbering follows – up to now – S5 upgrades<br>V0.5 related to S5 - PROMOTE Stage1,<br>V 1.0 related to S5 - PROMTE Stage2, March 07<br>V 1.2 related to S5 - PROMTE Stage2, April 08 | *Processing version number in product. Good documentation on processor version included.*<br><br>*References to QC procedures; product version number and last date of modification to be available in background* | separated sub directories<br><br>current version is v.1.2 | Document describing actual processing version is available on the service web page since30 May |

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

**Table 1.4-2 Quality control tools for the Italian PM monitoring service**

## 1.5 References

### 1.5.1 Electronic references and data access paths

http://www.emep.int

### 1.5.2 Bibliographic references

*Commission Decision 2004/470/CE concerning guidance on a provisional reference method for the sampling and measurement of PM2.5, 29 04 2004.*

Di Nicolantonio W., Cacciari A., Bolzacchini E., Ferrero L., Volta M., Pisoni E., (2007) Modis aerosol optical properties over Noth Italy for estimating surface-level PM2.5, Proc. 'Envisat Symposium 2007', Montreux, Switzerland, 23-27 April 2007, ESA SP-636, July 2007.

Engel-Cox J.A., Hoff, R.M., Haymet, A.D.J. ,2004, "Recommendation on the use of satellite remore-sensing data for urban air quality", J.Air Waste Manag. Assoc., 54, 1360-1371.

Engel-Cox J.A., Holloman, C.H., Coutant, B.W., Hoff, R.M., 2004, "Qualitative and quantitative evalution of MODIS satellite sensor data for regional and urban scale air quality", Atm.Env. 38, 2495-2590.

Fahre Vik A., Fjaeraa A. M., Stiebel K., Yttri K. E., Torseth K., de Leeuw G., Scheomacher R., Holzer-Popp T., Schroedter-Homscheidt M., European aerosol measurements from space, in: Yttri K. E. and Aas W., Measurements of particulate matter: Status Report 2006, NILU, EMEP/CCC-Report 3/2006, pp. 81 – 98, 2006

Holben B.N., T.F.Eck, I.Slutsker, D.Tanre, J.P.Buis, A.Setzer, E.Vermote, J.A.Reagan, Y.Kaufman, T.Nakajima, F.Lavenu, I.Jankowiak, and A.Smirnov, 1998: AERONET - A federated instrument network and data archive for aerosol characterization, *Rem. Sens. Environ.*, **66**, 1-16.

Holzer-Popp, T., Monitoring of aerosol properties from space, in: C. A. Brebbia, J. F. Martin-Duque (eds.), Air Pollution X, WIT Press, Southampton, pp. 423 – 434, 2002

Holzer-Popp, T., Schroedter-Homscheidt, M., Satellite-based background concentration maps of different particle classes in the atmosphere, in: C. A. Brebbia, (eds.), Air Pollution XIII, WIT Press, Southampton, 2004

Kaufman, Y.J. *et al.*,1997, "Operational remote sensing of tropospheric aerosol over and from EOS moderate resolution imaging spectrometer" J. Geophys. Res. 102, No.D14, 17051-17067.

Levy R.C., Remer L.A., Mattoo S., Vermote E.F., and Kaufman Y.J., (2007), Second-generation , operational-algorithm: Retrieval of aerosol prioperties over land from inversion of moderate Resolution Imaging Spectroradiometer spectral reflectance,

Liu, Y., Sarnat, J.A., Kilaru, V., Jacob, D.J., and Koutraskis, P., 2005, " Estimating ground-level PM2.5 in the eastern United States using satellite remote sensing", Environ. Sci. Technol. 39, 3269-3278.

Remer L.A., Kaufman, Y.J., Tanrè D., Mattoo S., Chu D.A., Martins J.V., Li R.-R., Ichoku C., Levy R.C., Kleidman R.G., Eck T.F., Vermote E., and Holben B.N. (2005), The MODIS aerosol algorithm, products and validation , J. Atmos. Sci., 62, 947-973.

Sarigiannis, D.A., Soulakellis, N.A., and Sifakis, N.I. 2004, "Information Fusion for Computational Assessment of Air Quality and Health Effects", Photogrammetric Engineering & Remote Sensing, 70, No.2, 235-245.

Slater J.F. *et al.*, 2004, "Physical and chemical properties of surface and columnar aerosols at a rural New England site during MODIS overpass", Rem.Sens. of Env., 92, 173-180.

Wang, J., and Christopher, A., 2003, "Intercomparison betwenn satellite-deriverd aerosol optical thickness and PM2.5 mass:Implications for air quality studies", Geophys. Res. Letters, 30, No.21, 2095, doi: 101029/2003GLO18174