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Joint Polar Satellite System (JPSS) VIIRS Suspended Matter Algorithm Theoretical Basis Document (ATBD)

For Public Release

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

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Joint Polar Satellite System (JPSS) VIIRS Suspended Matter Algorithm Theoretical Basis Document (ATBD)

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Preface

This document is under JPSS Ground AERB configuration control. Once this document is approved, JPSS approved changes are handled in accordance with Class I and Class II change control requirements as described in the JPSS Configuration Management Procedures, and changes to this document shall be made by complete revision.

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Change History Log

Revision	Effective Date	Description of Changes (Reference the CCR & CCB/ERB Approve Date)
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NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

VIIRS Suspended Matter
Algorithm Theoretical Basis Document (ATBD)

CDRL No. A032

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D43315
Rev D

NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

VIIRS Suspended Matter

Algorithm Theoretical Basis Document (ATBD)

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Revision/Change Record

Document Number D43315

Revision	Document Date	Revision/Change Description	Pages Affected
---	1/18/2007	Initial PCIM Release to bring document into Matrix Accountability. Reference original document number: Y2390 delivered in 2005	All
A	8/15/2007	Updated for changes to the science code baseline implemented by SPCR ALG00001205	All
B	11/20/2008	Updated in response to RFA's from NPOESS CDA	1, 7, 12-14
C	12/10/2008	Updated for changes to the science code baseline implemented by SPCR ALG00001387	15, 16
D	3/17/2010	In preparation for Public Release of this ATBD, the following administrative changes were made: all ITAR markings were removed, and Distribution Statement F added. Reference ECR A-184A Approved for Public Release per Contracts Letter 100730-1.	All

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GLOSSARY OF ACRONYMS

AERONET	Aerosol Robotic Network
ATBD	Algorithm Theoretical Basis Document
AVHRR	Advanced Very High Resolution Radiometer
BT	Brightness Temperature
CCN	Cloud Condensation Nuclei
CMIS	Conical Scanning Microwave Imager/Sounder
DLI	Dust Loading Index
EDR	Environmental Data Record
FOV	Field of View
GOES	Geostationary Operational Environmental Satellite
IPO	Integrated Program Office
IR	Infrared
LIDAR	Light Detection and Ranging
MODIS	Moderate Resolution Imaging Spectroradiometer
MODTRAN	Moderate Resolution Model for Atmospheric Transmittance/Radiance
NIR	Near Infrared
NPOESS	National Polar-orbiting Operational Environmental Satellite System
OMPS	Ozone Mapping Profiling Suite
QA	Quality Assurance
SDM	Smoke Detection Module
SeaWiFS	Sea-viewing, Wide-field-of-view Sensor
SRD	Sensor Requirements Document
TBD	To Be Determined
TBR	To Be Reviewed
UV	Ultraviolet
VIIRS	Visible/Infrared Imager/Radiometer Suite
WMO	World Meteorological Organization

ABSTRACT

Suspended matter is defined as dust, sand, volcanic ash, sea salt, and smoke, in the atmosphere. These materials have an important impact on climate change, aviation and military operations, and human health. The VIIRS Suspended Matter EDR provides information that will improve detection of pollution hazards and reduce the risk to military operations and human life. This information is not currently available on an operational basis. Additionally, this product will provide information for climate change research. The algorithm presented in this document uses the unique spectral signatures of each aerosol type. Volcanic ash displays a characteristic increase in radiometric emissivity from 11 μm to 12 μm due to the sulfuric acid present within the ash cloud which is detected and differentiated from clouds by tests in the VIIRS Cloud Mask. The remaining suspended matter types are identified by the aerosol model selected by the AOT inversion. Smoke is dominated by fine mode particles and has a lower single scattering albedo than other aerosol types. Sea salt is the dominant aerosol type over ocean and can be identified by low values of AOT and a mid-range value for the fine mode fraction. Dust is dominated by coarse mode particles and has a low albedo in the UV.

1.0 INTRODUCTION

Suspended matter plays an important role in climate change and can have a major impact on human health and military operations. Aerosols affect the Earth's radiative balance (Charlson *et al.*, 1992; Bolin *et al.*, 1994) directly and indirectly. Aerosol forcing is opposite in magnitude to the forcing of greenhouse gases. The uncertainty in aerosol forcing is considered to be one of the largest uncertainties in modeling climate change because of the shortage of global aerosol distribution information. This is true especially for those aerosols with large spatial and time variability, such as smoke, sand storms, and dust. Detection of these highly variable aerosols is challenging because of their short lifetime, small scale, and strong interactions with surface albedo and local meteorological conditions.

Both visible and infrared (IR)-based techniques have been applied for detection of suspended particles in the atmosphere (Kaufman *et al.*, 1997; Tanre and Legrand, 1991; Ackerman, 1997). Visible techniques derive aerosol loading from path radiance, which is obtained by subtracting the surface contribution from the apparent reflectance measured by the sensor. IR detection techniques are based on the facts that aerosols display strong spectral variations in IR regions and that the atmosphere is fairly transparent in these spectral regions. If aerosol loading is thin, transmitted surface emissions become the major component of the detected signal. If aerosol loading is thick, aerosol emissions account for a major part of the measurement. In practice, the analysis is based on brightness temperature rather than radiance. The magnitude of the difference in brightness temperatures in selected IR channels can be used to infer the signature of aerosol loading. Our detection algorithms for suspended matter combine aerosol model information, aerosol optical thickness and particle size parameter information with visible and IR techniques, which will be described in detail in this document.

1.1 PURPOSE

This Algorithm Theoretical Basis Document (ATBD) describes the algorithm used to retrieve the Suspended Matter Environmental Data Record (EDR) for the Visible/Infrared Imager/ Radiometer Suite (VIIRS) on the National Polar-orbiting Operational Environmental Satellite System (NPOESS). This product is summarized in Table 1. Specifically, this document identifies sources of input data, both VIIRS and non-VIIRS that are required for retrieval; provides the physical theory and mathematical background underlying the use of this information in the retrievals; provides implementation details; and describes assumptions and limitations of the proposed approach.

Table 1. Summary of suspended matter product.

Parameter Name	Horizontal Cell Size	Comments
Suspended Matter	0.75 km (Nadir) 1.6 km (EOS)	• Will flag cells containing suspended matter in the atmosphere • Will type aerosol within horizontal cell • Will be retrieved globally • Will derive smoke concentration

1.2 SCOPE

This document covers the algorithm theoretical basis for retrieval of the suspended matter product of VIIRS on NPOESS.

Section 1 describes the purpose and scope of the document. Section 2 provides a brief overview of the suspended matter retrieval. The theoretical description and implementation of the algorithm are described in Section 3, and the assumptions and limitations of the approach are summarized in Section 4. References for citations in the text are listed in Section 5.

1.3 VIIRS DOCUMENTS

Reference to VIIRS Project or reference documents is indicated by a number in italicized brackets as follows, e.g., *[V-1]*.

[V-1] Visible/Infrared Imager/Radiometer Suite (VIIRS) Sensor Requirements Document (SRD) for National Polar-orbiting Operational Environmental Satellite System (NPOESS) Spacecraft and Sensors.

[V-2] VIIRS Aerosol Optical Thickness and Size Parameter Algorithm Theoretical Basis Document, Doc. # D43313, Revision A.

[V-3] VIIRS Cloud Mask Algorithm Theoretical Basis Document, Doc. # D43766, Revision A.

[V-4] VIIRS System Validation and Verification Plan, Doc. #Y3270.

[Y3257] VIIRS Computer Resources Requirements Document

1.4 REVISIONS

This is the first revision of the sixth version of this document and is dated August 2007. There are several changes from the previous version due to code changes required so that this module is compatible with the new design of the AOT algorithms. The first version of this document was dated October 1998.

2.0 EXPERIMENT OVERVIEW

2.1 OBJECTIVES OF VIIRS SUSPENDED MATTER RETRIEVALS

Suspended matter is defined as dust, sand, volcanic ash, sea salt, and smoke located in the atmosphere. These materials have an important impact on climate change, flight operations, and human health. The VIIRS Suspended Matter EDR will use the VIIRS Cloud Mask and Aerosol Optical Thickness IPs in combination with the properties of the types to classify aerosols globally at a horizontal resolution of 1.6 km.

The purpose of the suspended matter algorithm is to classify observed aerosol by type. This will be accomplished by looking for the spectral signatures unique to the types in conjunction with the aerosol model selection from the aerosol optical thickness inversion. The importance of classifying the suspended matter varies by type. For example, the detection of volcanic ash is very important for several reasons. Two of the most powerful eruptions of the century have occurred within the past 20 years: El Chichón in 1982 and Mt. Pinatubo in 1991 (Bredow *et al.*, 1995). Eruptions of volcanoes eject aerosols and fine ash into the atmosphere where they stay for extended time periods. In the atmosphere, they act as additional scatterers and absorbers, thus affecting the Earth’s radiation budget. It has been estimated that the Mt. Pinatubo eruption in June 1991 reduced the average net radiation at the top of the atmosphere by 2.5 W/m^2 for 2 to 4 years, yielding 0.5°C cooling regionally, and 0.2-0.3°C cooling globally (Simarski, 1992; Stowe *et al.*, 1992; Ardanuy *et al.* 1986). In addition to increasing the concentration of scattering and absorbing particles in the atmosphere, the volcanic gases emitted may react with anthropogenic CFC’s to accelerate the destruction of stratospheric ozone. One data set credits the Mt. Pinatubo eruption with a 15-20 percent loss of ozone at high latitudes (Bredow *et al.*, 1995). One of the most important reasons for a satellite ash detection product is the hazard posed to aviation. Jet engines have failed after flying through ash clouds, as the hot ash damages the engine by eroding moving parts and accumulating on surfaces of the engine (Bredow *et al.*, 1995).

Another reason for classifying suspended matter is the diverse effects suspended matter may have on clouds in the area. The different kinds of suspended matter can interact with the background cloud condensation nuclei (CCN) according to their size, and increase or decrease the amount and size of clouds in the area, thus altering the amount of solar radiation received.

The overall objectives of the VIIRS suspended matter retrieval are:

1) To flag cells containing suspended matter in the atmosphere.

2) To determine the type of suspended particles in an area from their optical thickness, size parameter, radiance and reflectance measurements, brightness temperature, and other available information.

3) To obtain smoke concentration when smoke is present.

2.2 BAND CHARACTERISTICS

The narrow band measurements of the VIIRS sensor in the 0.4 to 3.70 μm range are used to derive aerosol optical thickness. The aerosol algorithm uses a dynamic aerosol model for aerosol inversion selecting the model that better fits the signal observed at specific wavelengths (412nm, 445nm, 488nm, 672nm over land; 865nm, 1240nm, 1610nm, 2250nm over Ocean). The inversion maps directly to the smoke, dust and sea salt suspended matter categories. In case the inversion fails, the angstrom exponent, optical thickness and spectral indices are used for identification of suspended matter. In the case of volcanic ash, since no specific aerosol model has been defined so far, only spectral methods can be used for inversion. The visible and near-IR channels used to derive optical thickness are all within window regions, and their bandwidths are narrow, so that the contamination of gas (such as O_2, O_3, H_2O) absorption is minimized in direct measurements. The suspended matter algorithm uses techniques involving not only visible and near-IR channels, but also four IR channels (3.70, 8.55, 10.8, and 12 μm). Aerosols display strong spectral variations in these thermal spectral regions, and the atmosphere is also fairly transparent here. Thus, the signature of the aerosol emissions will be detectable by the sensor, especially when the aerosol loading is thick.

Table 2. VIIRS Band Characteristics

Band Name	Wavelength (μm)	Bandwidth (μm)
M1	0.412	0.0200
M2	0.445	0.0180
M3	0.488	0.0200
M4	0.555	0.0200
M5	0.672	0.0200
M6	0.746	0.0150
M7	0.865	0.0390
M8	1.240	0.0200
M9	1.378	0.0150
M10	1.610	0.0600
M11	2.250	0.0500
M12	3.700	0.1800
M13	4.050	0.1550
M14	8.550	0.3000
M15	10.7625	1.0000
M16	12.0125	0.9500

2.3 SUSPENDED MATTER RETRIEVAL STRATEGIES

The classification obtained by the model inversion can be used to classify all aerosol types except volcanic ash which requires thermal IR spectral tests which are performed by the VIIRS Cloud Mask. The objective requirements for this EDR listed in the SRD *[V-1]* specify the classification of aerosols within layers of the atmosphere. It is impossible using VIIRS channels alone, but the UV bands from the Ozone Mapping Profiling Suite (OMPS) may be used synergistically for additional information on absorption of the aerosols and the vertical profile once technical details of the sensor and EDR specifications are released.

2.3.1 Volcanic Ash

Volcanic ash is identified by the VIIRS Cloud Mask using tests developed by Prata (1989a; 1989b) and Pavolonis et al. (2006). See the VIIRS Cloud Mask (VCM) Algorithm Theoretical Basis Document (D43766, Revision A, Section 3.4.5.3) for additional details.

2.3.2 Dust/Sand

Dust/sand is identified by the selection of the dust aerosol model over land. See the VIIRS Aerosol Optical Thickness and Particle Size Parameter Algorithm Theoretical Basis Document (D43313, Revision A, Section 3.2.2.1) for details of the dust model. Over ocean, dust is identified by a fine mode fraction of less than 20%.

2.3.4 Sea Salt

Due to the difficulty in performing aerosol inversions over coastal region, sea salt is only identified over ocean. Sea salt will be identified by a fine mode fraction of between 20% and 50% and an AOT of less than 0.3 τ.

2.3.4 Smoke

Smoke detection is an important product for identifying areas of biomass burning. Part of the interest in smoke detection comes from its potential role in monitoring forest fires, which is a priority of the U.S. Department of Commerce. However, biomass burning is also important for the global environment due to the emission of trace gases and organic hygroscopic particles (Kaufman *et al*., 1992). Some of the trace gases emitted are greenhouse gases (e.g., CO_2, CH_4, and CH_3Cl) that directly contribute to global warming. Others are chemically important in the troposphere (e.g., NO_x and CH_4) and are involved in reactions producing increased levels of ozone and acid precipitation. The organic particles introduced into the troposphere indirectly affect the radiation budget by altering cloud microphysics.

Smoke is identified by the selection of either of two smoke or two pollution aerosol model over land. See the VIIRS Aerosol Optical Thickness and Particle Size Parameter Algorithm Theoretical Basis Document (D43313, Revision A, Section 3.2.2.1) for details of the smoke and pollution models. Over ocean, smoke is identified by a fine mode fraction of greater than 50%.

3.0 ALGORITHM DESCRIPTION

3.1 PROCESSING OUTLINE

The suspended matter type is identified by two functions called from the main pixel loop of the VIIRS Aerosol Algorithm. One function identifies the suspended matter type over land and the other identifies the suspended matter type over ocean. Both modules use the VCM Volcanic Ash flag to identify volcanic ash.

3.2 ALGORITHM INPUT

The algorithm has been combined with the Aerosol Optical Thickness and Aerosol Particle Size Parameter algorithms into a single VIIRS Aerosol Algorithm module. The inputs to the module are described in the VIIRS Aerosol Optical Thickness and Particle Size Parameter Algorithm Theoretical Basis Document (D43313, Revision A, Section 3.1).

3.3 THEORETICAL DESCRIPTION OF SUSPENDED MATTER RETRIEVALS

3.3.1 Quality Check of the Input Data

The AOT IP quality flags computed in the main pixel loop of the VIIRS Aerosol Products code will be used to set the Suspended Matter EDR Quality Flags described in Table 3.

3.3.2 Physics of the Problem

The VIIRS Cloud Mask provides the spectral tests to differentiate clouds from aerosol and to identify volcanic ash. The aerosol inversion provides the aerosol model information required to differentiate between the remaining aerosol types. The AOT value obtained by the aerosol inversion differentiates heavy aerosol which should be flagged as suspended matter from background aerosol loading. Therefore, the detailed description of the relevant physics is fully described in the VCM and AOT/APSP ATBDs.

3.3.3 Mathematical Description of the Algorithm

3.3.3.1 Determining Suspended Matter Type over Land

The land aerosol models (AMI) are mapped to suspended matter type as follows: Dust AMI is mapped to Dust SM Type. Smoke High Absorption, Smoke Low Absorption, Urban Clean and Urban Polluted AMI are mapped to Smoke SM Type as indicated in Figure 1 below..

3.3.3.2 Determining Suspended Matter Type over Ocean

The dynamic ocean aerosol models consisting of Small Mode Model (SMM), Large Mode Model (LMM) and Small Mode Fraction (CM) are mapped to suspended matter type as indicated in Figure 1 below.

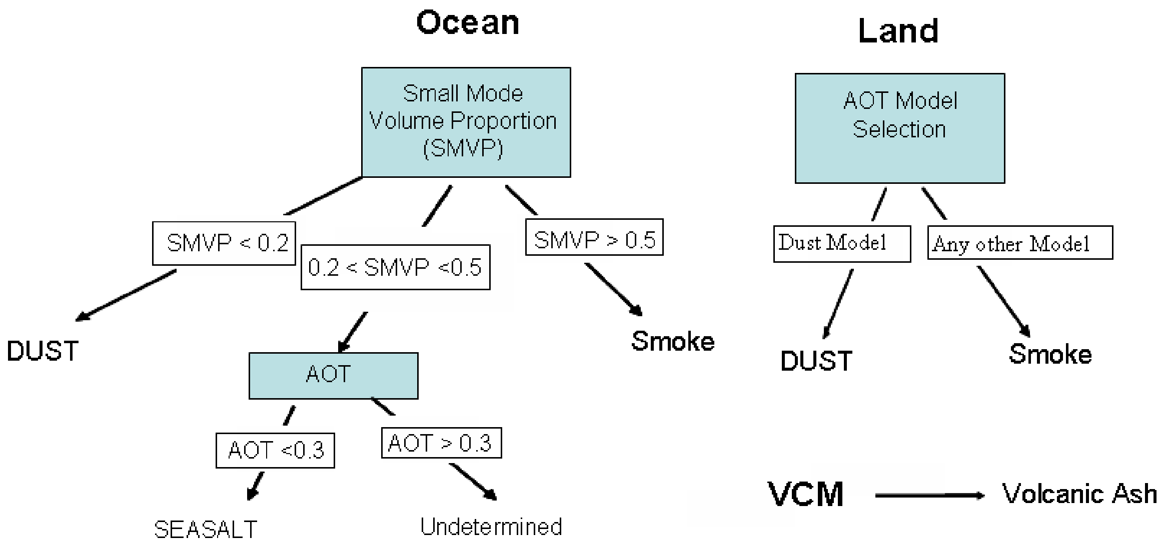

Figure 1. Suspended Matter Type Flow Diagram.

3.3.4 Volcanic Ash Detection

The results of the VCM volcanic ash tests are passed to both the land and ocean suspended matter functions. If the VCM indicates volcanic ash, then the suspended matter type is set to volcanic ash, the quality is set to good and no further processing is done for that pixel.

3.3.9 Smoke Concentration

One of the objective requirements in the VIIRS SRD is to measure smoke concentration in micrograms per cubic meter ($\mu g/m^3$). In this section we describe two methods of achieving this goal. The initial accuracy is expected to be of the order of 50% for these methods, but can potentially be improved with more surface measurements and with additional theoretical and experimental work. These techniques for deriving smoke concentration are only valid over dark surfaces where aerosol optical depths can be derived. Only the first method has been implemented in the code.

3.3.9.1 Use of Aerosol Optical Thickness Measurements

A number of studies (d'Almeida et al., 1991) have shown that aerosol concentration C can be related to visibility (V). In general, the concentration is inversely proportional to visibility and according to the Auburn University Private Forest Management Team, can be expressed as follows:

$$C = 1000/V \tag{1}$$

where V is the visibility in kilometers and C is the smoke concentration in $\mu g/m^3$. This approximate expression is accurate to about 50% and needs to be refined. The visibility is horizontal visibility and VIIRS is responding to vertical visibility, so there probably will be no one expression that is always applicable due to the complex structure associated with smoke plumes.

Visibility can also be related to aerosol optical thickness. From Iqbal (1983) the relationship for low visibilities can be written as:

$$V = 3.9449 / (\beta/0.55^{\alpha} - 0.08498) \qquad (2)$$

where α and β are the Angstrom coefficients, V is the visibility in kilometers, and 0.55 is the wavelength at which visibility is measured, namely 0.55 microns (or 550nm).

The previous expression can be written in terms of the aerosol optical thickness at 550 nm (τ_{550}) as follows:

$$V = 3.9449 / (\tau_{550} – 0.08498) \qquad (3)$$

The first and third equations above can be combined to give the smoke concentration C as follows:

$$C = 253.5\ \tau_{550} –21.5 \qquad (4)$$

A plot of this relationship is shown in Figure 10:

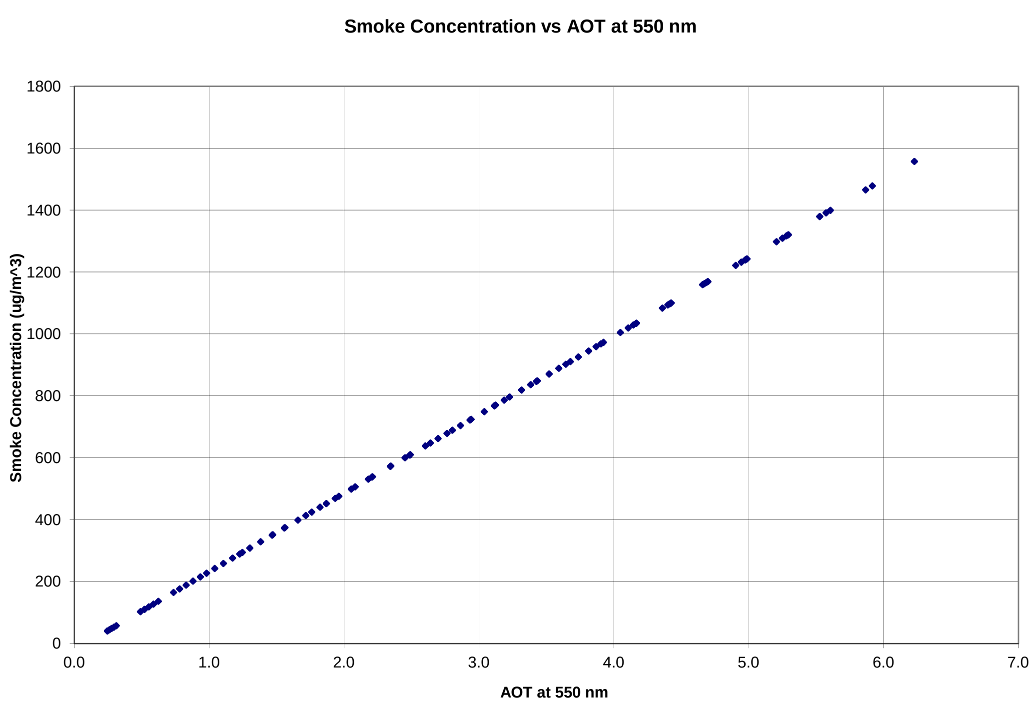

Figure 2. Smoke concentration ($\mu g/m^3$) vs aerosol optical thickness at 550 nm.

As mentioned above this approach is expected to be accurate to within about 50% because of limitations on the accuracy of relating visibility to smoke concentration.

3.5 PRACTICAL CONSIDERATIONS

3.5.1 Numerical Computation Considerations

Requirements on processing speed and data storage are described in the VIIRS Computer Resources Requirements Document *[Y3257]*.

3.5.2 Programming and Procedural Considerations

The procedural outline has been described in section 3.1.

3.5.3 Configuration of Retrievals

To avoid "hard-wiring" specific values into the operational software, a retrieval configuration file can be adopted in which the numerical values of adjustable parameters used within the retrievals (e.g., thresholds establishing whether a successful retrieval occurred) are stored.

3.5.4 Quality Assessment and Diagnostics

We have introduced a quality assurance (QA) flag which is stored at the resolution of the output EDR.

Table 3. Summary of Suspended Matter Quality Flags.

Byte	VIIRS SM EDR Quality Flag	Result	Bits
0	SM Detection Product Quality	11 = High 10 = Medium 01 = Low 00 = Not retrieved	2
	SM Typing Product Quality	11 = High 10 = Medium 01 = Low 00 = Not retrieved	2
	Smoke Concentration Product Quality	11 = High 10 = Medium 01 = Low 00 = Not retrieved	2
	Land / Ocean / Not Produced	11 = Not Produced 01 = Ocean 00 = Land	2
1	Cloud Contamination in Cell	1 = Yes 0 = No	1

Byte	VIIRS SM EDR Quality Flag	Result	Bits
	Cloud Adjacent to Cell	1 = Yes 0 = No	1
	Cirrus Contamination in Cell	1 = Yes 0 = No	1
	Bad SDR	1 = Yes 0 = No	1
	Sun Glint in Cell	1 = Yes 0 = No	1
	Cloud Shadow in Cell	1 = Yes 0 = No	1
	Snow / Ice in Cell	1 = Yes 0 = No	1
	Fire Detected in Cell	1 = Yes 0 = No	1
2	Smoke Concentration Out of Spec Range	1 = Yes 0 = No	1
	Excluded, Typing for AOT at 550 nm < 0.5	1 = Yes 0 = No	1
	Excluded, Detection for AOT at 550 nm < 1.0	1 = Yes 0 = No	1
	Low Sun, Excluded, SZA > 65	1 = Yes 0 = No	1
	Bright Surface in Cell (Land) / Shallow or Turbid Water in Cell (Ocean)	1 = Yes 0 = No	1
	Spare Bit		1
	Spare Bit		1
	Spare Bit		1

3.5.5 Exception Handling

Retrieval applicability is tested either on the pixel level or on a horizontal cell size level depending on the type. If a pixel or a cell is found to be unusable or contaminated according to a certain test, the remaining tests are not performed and the pixel or cell is discarded and flagged.

3.6 ALGORITHM VALIDATION

Modules of the retrieval algorithm will be verified pre-launch using data from existing satellite systems, such as Advanced Very High Resolution Radiometer (AVHRR), SeaWiFS, and Moderate Resolution Imaging Spectroradiometer (MODIS). We have successfully detected the smoke related to the large forest fires in Brazil and Indonesia during the summer of 1997 using the SeaWiFS data, and volcanic ash clouds using AVHRR data. More pre-launch validation will be performed along with the update of detection modules. Post-launch verification will involve intercomparisons between VIIRS observations, ground-based measurements (e.g., Aerosol Robotic Network [AERONET]), and special airborne campaigns.

The required validation data for suspended matter will consist of data that describe as much as possible the aerosol layer much more than the optical thickness itself which is representative of the loading. The aerosol size distribution, which is inverted routinely for AERONET sites, will be a critical part of characterizing the aerosol type. The information provided by AERONET, provided its reliability has been established, can be directly translated in most cases in one of the suspended matter category because they provide in addition to the size distribution, the absorption (single scattering albedo) and real refractive index at several wavelengths (0.45μm to 1.02μm). Other measurements typically taken during validation campaign, will help augment or validate the AERONET measurements, typically independent estimation of aerosol size distribution (through particle counters), electronic microscopy analysis of particle size and shape deposited on filters, chemical characterization, independent measurements of absorption properties, aerosol profiles by Light Detection and Ranging (LIDARs).

4.0 ASSUMPTIONS AND LIMITATIONS

4.1 ASSUMPTIONS

Assumptions in the retrieval of aerosol optical thickness and size parameter are applicable to the retrieval of suspended matter (VIIRS Aerosol Optical Thickness and Size Parameter Algorithm Theoretical Basis Document [V-2]). As the types of suspended matter are not completely defined within the SRD, we have stated our own definitions of the suspended matter types within this document.

4.2 LIMITATIONS

The suspended matter SRD requirements call for a threshold of typing within the atmosphere total column, and an objective of typing the suspended matter within specified 0.2 km layers of the atmosphere. Determining the amount of suspended matter within layers will be difficult to achieve, and impossible with VIIRS data alone. We may utilize the OMPS UV radiances for absorbing aerosols to determine their vertical distribution. We could use the OMPS limb-scanning information to determine vertical distribution, but this data would only be useful down to the cloud tops. One potential problem in using the OMPS data is the 50 km horizontal resolution of the OMPS aerosol index and ozone products. The suspended matter horizontal cell size is required to be 3 km or smaller. All the retrievals will be performed under clear conditions.

5.0 REFERENCES

Ackerman S.A. (1997). Remote sensing of aerosols using satellite infrared observations. *Journal of Geophysical Research-Atmospheres*, 102: (D14) 17069-17079.

Ackerman S.A. (1989). Using the radiative temperature difference at 3.7 and 11μm to track dust outbreaks. *Remote Sensing of Environment*, 27: (2) 129-133.

Ackerman S.A., and K.I. Strabala (1994). Satellite remote-sensing of H_2SO_4 aerosol using the 8μm to 12 μm window region - application to Mount Pinatubo. *Journal of Geophysical Research-Atmospheres*, 99: (d9) 18639-18649.

Ardanuy, P. E., and H. L. Kyle (1986). Observed Perturbations of the Earth's Radiation Budget: A Response to the El Chichón stratospheric Aerosol Layer, *J. Climate Appl. Meteor.*, 25, 505-516.

Barton I.J., A.J. Prata, I.G. Watterson, and S.A. Young (1992). Identification of the Mount Hudson volcanic cloud over SE Australia. *Geophysical Research Letters*, 19: (12) 1211-1214.

Bolin, B., J. Houghton, and L. G. M. Filho; ed. (1994). Radiative Forcing of Climate Change, Intergovernmental Panel on Climate Change (IPCC), UNEP, World Meteorol. Organ., Geneva.

Bredow, J., R. Proco, M. Dawson, C. Betty, S. Self, and T. Thordarson (1995). A multifrequency laboratory investigation of attenuation and scattering from volcanic ash clouds. *IEEE Trans. Geosci. Remote Sens.*, 33, 1071-1081.

Charlson, R. J., S. E. Schwartz, J. M. Hales, R. D. Cess, J. A. Coackley Jr., J.E. Hansen, and D. J. Hofman (1992). Climate forcing of anthropogenic aerosols. *Sciences*, 255, 423-430m.

d'Almeida, G.A., P. Koepke, and E.P. Shettle (1991). Atmospheric aerosols: Global climatology and radiative characteristics. A. Deepak Publishing, Hampton, Virginia.

Harris, D., and W. Rose (1983). Estimating particle sizes, concentrations, and total mass of ash in volcanic clouds using weather radar. *J. Geophys. Res.*, 88, pp. 10,969-10,983.

Iqbal, M. (1983). An Introduction to Solar Radiation. Academic Press, New York

Kaufman, Y.J., A. Setzer, D. Ward, D. Tanre, B.N. Holben, P. Menzel, M.C. Pereira, and R. Rasmussen (1992). Biomass burning Airborne and Spaceborne experiment in the Amazonas (BASA-A). *J. Geophys. Res.*, 97, pp. 14, 581-14,599.

Kaufman, Y. J., D. Tanre, L. A. Remer, E. F. Vermote, A. Chu, and B. N. Holben (1997). Operational remote sensing of tropospheric aerosol over land from EOS moderate resolution imaging spectroradiometer. *J. Geophys. Res.*, 102, 1,6971-1,6988.

Legrand M., J.J. Bertrand, M. Desbois, L. Menenger, and Y. Fouquart (1989). The potential of infrared satellite data for the retrieval of Saharan-dust optical depth over Africa, *Journal of Applied Meteorology*, 28: (4) 309-319.

Longtin, D.R., E.P. Shettle, J.R. Hummel, and J.D. Pryce (1988). A wind dependent desert aerosol model: Radiative Properties, AFGL-TR-88-0112.

Morales, C., ed. (1979). Saharan Dust: mobilization, transport, deposition: papers and recommendations from a workshop held in Gothenburg, Sweden, 25-28 April 1977, pp. 297.

Péwé, T. L. (1981). Desert Dust: Origin, Characteristics, and Effect on Man, Geological Society of America, Special Paper 186.

Prata, A.J. (1989). Infrared radioactive transfer calculations for volcanic ash clouds. *Geophy. Research Letters,* 16, 1293.

Private Forest Management Team, Auburn University, Alabama, (1999). (http://www.pfmt.org /standman/smokeman.htm)

Rose, W., A. Kostinski, and L. Kelley (1995a). Real time C-band radar observations of 1992 eruption clouds from Crater Peak/Spurr volcano, Alaska. U.S. Geol. Surv. Bull., 2139, pp. 19-26.

Shenk W.E., and R.J. Curran (1974). Detection of dust storms over land and water with satellite visible and infrared measurements, *Monthly Weather Review,* 102: (12) 830-837.

Simarski, L. (May 1992). Volcanism and climate change. *Amer. Geophys. Union.*

Stowe, L., R. Carey, and P. Pellegrine (Jan 24, 1992). Monitoring the Mt. Pinatubo aerosol layer with NOAA/11 AVHRR data. *Geophys. Res. Lett.*, 19, no. 2, 159-162.

Tegen I. and I. Fung (1995). Contribution to the atmospheric mineral aerosol load from land-surface modification, *Journal of Geophysical Research Atmospheres*,100:(D9) 18707-18726.

Tanré, D., and M. Legrand (1991). On the satellite retrieval of Saharan dust optical thickness over land: two different approaches, *J. Geophys. Res.*, 96, 5221-5227.

Tanre D., P.Y. Deschamps, C. Devaux, and M. Herman (1988). Estimation of Saharan aerosol optical thickness from blurring effects in Thematic Mapper data, *Journal of Geophysical Research-Atmospheres*, 93: (D12) 15955-15964.

Vermote, E., C. O. Justice, J. Descloitres, N. El Saleous, J. Ray, D. Roy, B. Margerin, and L. Gonzalez (2001). A Global Monthly Coarse Resolution Reflectance Data Set from SeaWiFS for use in Land, Ocean, and Atmosphere applications, *International Journal of Remote Sensing,* 22: (6) 1151-1158.

Vermote, E., D. Tanre, J. L. Deuze, M. Herman, and J. J. Morcrette (1997). Second Simulation of the Satellite Signal in the Solar Spectrum (6S). 6S User Guide Version 2, 217 pp.

Wald, A.E., Y.T. Kaufman, D. Tanré, and B.C. Gao (1998). Daytime and nighttime detection of mineral dust over desert using infrared spectral contrast. *J. Geophys. Res.*, 103, 32307-32313.

Wen S. and W.I. Rose, Retrieval of particle sizes and total masses in volcanic clouds using AVHRR bands 4 an 5, Poster presented at AGU 1993 Fall Meeting.