VIIRS aerosol algorithm and products.
Report to AEROCOM, September 2013.

Lorraine A. Remer
JCET UMBC
Suomi-NPP satellite launched 28 October 2011
**VIIRS:** Visible-Infrared Imager/Radiometer Suite

**CrIS:** Cross-track Infrared Sounder

**CERES:** Cloud and Earth Radiant Energy System

**ATMS:** Advance Technology Microwave Sounder

**OMPS:** Ozone Mapping and Profiler Suite
VIIRS: Visible-Infrared Imager/Radiometer Suite

CrIS: Cross-track Infrared Sounder HIRS

CERES: Cloud and Earth Radiant Energy System CERES

ATMS: Advance Technology Microwave Sounder AMSU

OMPS: Ozone Mapping and Profiler Suite OMI
VIIRS: Visible-Infrared Imager/Radiometer Suite
MODIS/AVHRR/ SeaWIFS
CrIS: Cross-track Infrared Sounder HIRS
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<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Major Task</th>
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<tr>
<td>Kurt F. Brueske</td>
<td>IIS-Raytheon</td>
<td>Code testing support within IDPS</td>
</tr>
<tr>
<td>Ashley N. Griffin</td>
<td>PRAXIS, INC/NASA</td>
<td>JAM</td>
</tr>
<tr>
<td>Brent Holben</td>
<td>NASA/GSFC</td>
<td>AERONET observations for validation work</td>
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<tr>
<td>Robert Holz</td>
<td>UW/CIMSS</td>
<td>Product validation and science team support</td>
</tr>
<tr>
<td>Nai-Yung C. Hsu</td>
<td>NASA/GSFC</td>
<td>Deep-blue algorithm development</td>
</tr>
<tr>
<td>Ho-Chun Huang</td>
<td>UMD/CICS</td>
<td>SM algorithm development and validation</td>
</tr>
<tr>
<td>Jingfeng Huang</td>
<td>UMD/CICS</td>
<td>AOT Algorithm development and product validation</td>
</tr>
<tr>
<td>Edward J. Hyer</td>
<td>NRL</td>
<td>Product validation, assimilation activities</td>
</tr>
<tr>
<td>John M. Jackson</td>
<td>NGAS</td>
<td>VIIRS cal/val activities, liaison to SDR team</td>
</tr>
<tr>
<td>Shobha Kondragunta</td>
<td>NOAA/NESDIS</td>
<td>Co-lead</td>
</tr>
<tr>
<td>Istvan Laszlo</td>
<td>NOAA/NESDIS</td>
<td>Co-lead</td>
</tr>
<tr>
<td>Hongqing Liu</td>
<td>IMSG/NOAA</td>
<td>Visualization, algorithm development, validation</td>
</tr>
<tr>
<td>Min M. Oo</td>
<td>UW/CIMSS</td>
<td>Cal/Val with collocated MODIS data</td>
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<tr>
<td>Lorraine A. Remer</td>
<td>UMBC</td>
<td>Algorithm development, ATBD, liason to VCM team</td>
</tr>
<tr>
<td>Andrew M. Sayer</td>
<td>NASA/GESTAR</td>
<td>Deep-blue algorithm development</td>
</tr>
<tr>
<td>Hai Zhang</td>
<td>IMSG/NOAA</td>
<td>Algorithm coding, validation within IDEA</td>
</tr>
</tbody>
</table>
Heritage Capabilities

From Ed Hyer, NRL

Credit: Northup Grumman & Raytheon
VIIRS is a multiwavelength imager, like MODIS with similar wavelength bands in the aerosol range.

<table>
<thead>
<tr>
<th></th>
<th>MODIS</th>
<th>VIIRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit altitude</td>
<td>690 km</td>
<td>824 km</td>
</tr>
<tr>
<td>Equator crossing</td>
<td>13:30 LT</td>
<td>13:30 LT</td>
</tr>
<tr>
<td>time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granule size</td>
<td>5 minutes</td>
<td>86 seconds</td>
</tr>
<tr>
<td>swath</td>
<td>2330 km</td>
<td>3000 km</td>
</tr>
<tr>
<td>Pixel nadir</td>
<td>0.5 km</td>
<td>0.75 km</td>
</tr>
<tr>
<td>Pixel edge</td>
<td>2 km</td>
<td>1.5 km</td>
</tr>
</tbody>
</table>
MODIS
0.66 – 0.55 – 0.47 µm
2 Sep 2012
21:40 UTC

VIIRS
0.67 – 0.55 – 0.49 µm
2 Sep 2012
20:24:27.8 UTC
MODIS swath edge ‘bowtie’ effect

VIIRS doesn’t have this

From NASA LANCE
<table>
<thead>
<tr>
<th></th>
<th>MODIS</th>
<th>VIIRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product resolution nadir</td>
<td>10 km and 3 km</td>
<td>6 km and 0.75 km</td>
</tr>
<tr>
<td>Product resolution edge</td>
<td>40 km and 12 km</td>
<td>12 km and 1.5 km</td>
</tr>
<tr>
<td>Products land</td>
<td>AOT</td>
<td>AOT, (suspended matter)</td>
</tr>
<tr>
<td>Products ocean</td>
<td>AOT, fine mode fraction</td>
<td>AOT, Angstrom exponent, (suspended matter)</td>
</tr>
</tbody>
</table>

Suspended matter is a *qualitative* index designating aerosol type.

It has no MODIS heritage, and is currently under development with no access to users.
EDR is Environmental Data Record (Think Level 2 data product)

SDR is Sensor Data Record (Think Level 1b)

IP is Intermediate Product (No MODIS counterpart).

IP AOT is at 0.75 km nadir, no aggregation

EDR is the aggregation of 8x8 IP retrievals
35 individual 0.75 km AOT retrievals

1 value of AOT to represent the entire box
EDR product is aggregated from IP product, using complex decision tree involving QA. Not from original radiances.
Ocean algorithm differences from MODIS

No 550 nm channel in the retrieval

Dynamic glint mask

Variable wind speed

But otherwise every inch a Tanré ocean retrieval, just like MODIS
Land algorithm differences from MODIS

VIIRS retrieval is NOT a Kaufman retrieval, and NOT a Levy retrieval

VIIRS: 0.412 µm, 0.444 µm, 0.486 µm, 0.672 µm, 2.257 µm
MODIS: 0.466 µm, 0.665 µm, 2.13 µm

VIIRS: Chooses from 5 discrete aerosol models
MODIS: mixes two assigned models

VIIRS: does atmospheric correction and solves for $\rho_{surf}(\lambda)$
MODIS: that’s crazy!

VIIRS: fits to expected spectral shape of $\rho_{surf}$
MODIS: assumes spectral shape and fits to $\rho_{TOA}$
Kondragunta
NASA MODIS Atmospheres

MODIS AOT 550 nm 4 July 2012
Aqua L2 Col51 10 km
Important Dates:

- **Initial instrument check out.**
- **Tuning cloud mask parameters.**

- **Aerosol product at Beta status.**
- **Beta status.**
- **Aerosol product candidate provisional status.**

**Software production error.**

---

**Red periods:** DO NOT USE the product.

**Beta:** Use with caution. Known biases. Frequent changes.

**Provisional:** Improved from Beta. Still under close scrutiny.
Daily global mean AOT550 and standard deviation.
NOT collocated: both algorithm and sampling differences

VIIRS AOT550 – MODIS AOT550

VIIRS team is attacking this problem now by linking surface assumptions to NDVI_SWIR
VIIRS AOT vs. AERONET

Ocean
VIIRS R=0.91  MODIS R=0.92
65% within expected error
(same as MODIS)

Land
VIIRS R=0.80    MODIS R=0.91
71% within expected error
MODIS only 65%
VIIRS vs. MAN

201205–201210, N=172

Fit: $Y=0.814X+0.038$; $R=0.833$
Accuracy=0.006
Precision=0.086
Uncertainty=0.087
Angstrom Exponent Over Ocean

VIIRS vs. MODIS (AOT > 0.4)

MODIS & VIIRS (EDR)(VIIRS AOT >0.4) #collocated points= 29801

VIIRS vs. AERONET

Ocean AE: VIIRS EDR vs. AERONET,M2M,best QA

20120502–20130324, N=509
Fit: Y=0.434X+0.667; R=0.529
Accuracy=0.254
Precision=0.526
Uncertainty=0.585
VIIRS aerosol product is quickly progressing to MODIS level of validity

Needs Deep Blue.
In perspective

VIIRS vs. MODIS algorithm evolution

3 years after Terra launch

1 year after Suomi-NPP launch

Global validation heavily weighted to Eastern U.S. and western Europe, with Amazon also well-represented.

In time AERONET spread out to less desirable surfaces and MODIS retrieval “got worse”

VIIRS is facing a harder “audience”
In perspective
MODIS aerosol validation 2000-2002
(3 years after Terra launch)

0.06 high bias over land,
against “favorable” AERONET stations.
2 years later this bias was closer to 0.10
4 years after launch and still plagued by Spring thaw snow melt and artificial AOT of 0.2 to 0.3 over low NDVI areas and places with complex topography, which was finally eliminated in 2006 (6 years after launch)
In perspective
VIIRS vs. MODIS algorithm evolution

It’s only been 2 years since launch of VIIRS

- Already VIIRS is producing AOT and AE with accuracy equal to MODIS that took MODIS 4 to 6 years to accomplish!

From the MODIS perspective, VIIRS is advancing at light speed, and people need to be patient with their expectations.

The main obstacle to VIIRS aerosol success will be data dissemination, not data quality.
Obtaining VIIRS aerosol data and documentation

Data (not SM) are available through CLASS:
http://www.class.noaa.gov

A “back door” for data via the IDEA site:

Another back door to get gridded data (0.25 degree)

Users’ guide available at:
http://www.star.nesdis.noaa.gov/jpss/ATBD.php#S126472

README file under VIIRS aerosol (AOT) at:
http://www.nsof.class.noaa.gov/saa/products/welcome

Other documents are available at:
In addition...

2 papers in revision for publication in JGR

Jackson et al. To explain the algorithm

Liu et al. To demonstrate preliminary evaluation
From the Users Guide
Data are available through CLASS:
http://www.class.noaa.gov

AEROSOL EDR Product File
VAOOO_npp_d20120626_t1958134_e1959376_b03440_c20120627024612139725_noaa_ops.h5

HDF5 format

GAERO_npp_d20120626_t1958134_e1959376_b03440_c20120627021509002956_noaa_ops.h5

AEROSOL geolocation file
From the Users Guide
Data are available through CLASS:
http://www.class.noaa.gov

AEROSOL EDR Product File

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HDF5 format

GAERO_npp_d20120626_t1958134_e1959376_b03440_c20120627021509002956_noaa_ops.h5

AEROSOL geolocation file
Back door #1: U.S. real-time imagery/animations
Back door #2: Global gridded data
The VIIRS *sensor* is sufficient to match MODIS aerosol capabilities, but is not another MODIS.

The VIIRS aerosol *algorithms* are NOT the same as MODIS algorithms.

There is no Deep Blue.

VIIRS AOT product is good and is approaching MODIS accuracies. It will be VERY GOOD in about a year. Ocean is already very good.

VIIRS Suspended Matter is under development. (Aerosol type)

A back door to obtain GLOBAL GRIDDED (0.25 degree) AOT is available.

No plans for reprocessing and data record is not continuous. Know the timeline.

Read the documentation for caveats.
BACK-UP
CLASS will be unavailable 9/24/2013 from 1300-1900 UTC (9AM-3PM EDT):
On September 24, 2013, from 1300-1900 UTC (9AM-3PM EDT) CLASS will be conducting a system-wide maintenance, which will require all CLASS web services and subscription services to be off-line during the planned 6 hour maintenance window. However, ftp access to completed orders will still be available to users. If you have any questions, please contact CLASS Help Desk.

Attention CLASS users (09/10/13):
On September 19, 2013, one of the CLASS sites will change IP addresses for ftp.class.ncdc.noaa.gov from 152.53.15.180 to 204.62.251.180. If you have firewall rules including this IP address, please update them accordingly. If you have questions, please contact class.help@noaa.gov

Attention Suomi NPP Users:
The most recent global NPP operational products are now available in daily tar files for quick and easy downloads at ftp://ftp-npp.class.ngdc.noaa.gov. Please see the NPP help page for instructions. Up to the most recent 90 days of data will be available for direct online access.
NEWS

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Attention CORS users (07/2013):
The National Geodetic Survey's CORS data archived at the National Geophysical Data Center has been transitioned into CLASS. The data collections include RINEX since 1994 and raw GPS from selected CORS sites since 2004. The original at-sampling rate was retained except where it was only the 30-second decimated rate data. For more info see the CORS CLASS search page.

Attention Metop users (08/14/2013):
With the exception of GOME Level 2 data, all Metop-B level 1b and 1c satellite data is now available beginning January 15, 2013 (IASI L1c starts on May 16, 2013). Pre-operational data collected prior to those dates remains restricted. Please contact the CLASS Help Desk if assistance is needed.

Suomi NPP outgoing Longwave Radiation dataset is now available since July 31, 2013.

Suomi NPP data access status (09/06/13):
Below is a list of S-NPP products released to the public and now available through CLASS. The complete list of products along with the begin dates of product availability are located on the Suomi NPP FAQ page. The remaining NPP products will be released to the user community over a time frame of several months. Please note that all newly released products are at 'Beta' maturity level as defined in the Product Maturity Level page. Details of high priority issues related to the data quality are contained in the Readme files provided by the NPP Project Scientist. Please read these before ordering and using the data.
Data Description

Visible/Infrared Imager Radiometer Suite - The Visible/Infrared Imager/Radiometer Suite collects visible/infrared imagery and radiometric data. Data types include atmospheric, clouds, earth radiation budget, clear-air land/water surfaces, sea surface temperature, ocean color, and low light visible imagery. VIIRS contributes to 23 Environmental Data Records (EDRs) and is the primary instrument for 18 EDRs.

Details - Metadata, Documentation

Spatial

Note: XY Plane searches are resized to enforce a minimum lat/lon difference of 0.1 degrees.
### Temporal

(maximum range is 366 days)

| Start Date (format: YYYY-MM-DD) | 2013-09-22 |
| Start Time (UTC) (format: HH:MM:SS) | 00:00:00 |
| End Date (format: YYYY-MM-DD) | 2013-09-23 |
| End Time (UTC) (format: HH:MM:SS) | 23:59:59 |

Specify the range of the times for: 
- [ ] Each Day
- [ ] The Entire Range Of Days

### Advanced Search

**Datatype**

- Sensor Data Record
  - [ ] VIIRS Day Night Band SDR (public 02/07/2012)
  - [ ] VIIRS Imagery Band 01 SDR (public 02/07/2012)
  - [ ] VIIRS Imagery Band 02 SDR (public 02/07/2012)
  - [ ] VIIRS Imagery Band 03 SDR (public 02/07/2012)
  - [ ] VIIRS Imagery Band 04 SDR (public 02/07/2012)
  - [ ] VIIRS Imagery Band 05 SDR (public 02/07/2012)
  - [ ] VIIRS Moderate Resolution Band 01 SDR (public 02/07/2012)
  - [ ] VIIRS Moderate Resolution Band 02 SDR (public 02/07/2012)
  - [ ] VIIRS Moderate Resolution Band 03 SDR (public 02/07/2012)
  - [ ] VIIRS Moderate Resolution Band 04 SDR (public 02/07/2012)
  - [ ] VIIRS Moderate Resolution Band 05 SDR (public 02/07/2012)
  - [ ] VIIRS Moderate Resolution Band 06 SDR (public 02/07/2012)
  - [ ] VIIRS Moderate Resolution Band 07 SDR (public 02/07/2012)
  - [ ] VIIRS Moderate Resolution Band 08 SDR (public 02/07/2012)
  - [ ] VIIRS Moderate Resolution Band 09 SDR (public 02/07/2012)
  - [ ] VIIRS Moderate Resolution Band 10 SDR (public 02/07/2012)
  - [ ] VIIRS Moderate Resolution Band 11 SDR (public 02/07/2012)
  - [ ] VIIRS Moderate Resolution Band 12 SDR (public 02/07/2012)

**Node**

- [ ] Ascending
- [ ] Descending
- [ ] Either

**Satellite**

- NPP
VIIRS Moderate Resolution Band 16 SDR (public 02/07/2012)

Raw Data Record
- VIIRS Diagnostic RDR (none available)
- VIIRS Memory Dump RDR (public 02/07/2012)
- VIIRS Science RDR (public 02/07/2012)
- VIIRS Telemetry Diagnostic RDR (none available)
- VIIRS Telemetry RDR (public 02/07/2012)

Intermediate Product
- VIIRS Cloud Mask Intermediate Product (public 05/02/12)
- VIIRS Quarterly Surface Type IP

Geolocation
- VIIRS Aerosol (aggregated) EDR Ellipsoid Geolocation (public 05/02/2012)
- VIIRS Cloud Aggregated EDR Ellipsoid Geolocation (restricted)
- VIIRS Day Night Band SDR Ellipsoid Geolocation (public 02/07/2012)
- VIIRS Image Bands EDR GTM Geolocation (public 02/07/2012)
- VIIRS Image Bands SDR Ellipsoid Geolocation (public 02/07/2012)
- VIIRS Image Bands SDR Ellipsoid Terrain Corrected Geolocation (public 02/07/2012)
- VIIRS Moderate Bands SDR Geolocation (public 02/07/2012)
- VIIRS Moderate Bands SDR Terrain Corrected Geolocation (public 02/07/2012)
- VIIRS Near Constant Contrast (NCC) EDR Ground Track Mercator (GTM) Geolocation (public 07/18/2012)
- VIIRS Net Heat Flux EDR Geolocation (restricted)

Environmental Data Record
- VIIRS Aerosol Optical Thickness (AOT) EDR (public 05/02/2012)
- VIIRS Cloud Base Height EDR (public 04/27/2013)
- VIIRS Cloud Cover Layers EDR (public 04/27/2013)
- VIIRS Cloud Effective Particle Size EDR (public 04/27/2013)
- VIIRS Cloud Optical Thickness EDR (public 04/27/2013)
- VIIRS Cloud Top Height EDR (public 04/27/2013)
- VIIRS Cloud Top Pressure EDR (public 04/27/2013)
- VIIRS Cloud Top Temperature EDR (public 04/27/2013)
- VIIRS Ice Surface Temperature EDR (public 03/14/2013)
VIIRS Sea Surface Temperature EDR (public 03/22/2012)
VIIRS Snow Cover/Depth Binary Map EDR (public 03/14/2013)
VIIRS Snow Cover/Depth Snow Fraction EDR (public 03/14/2013)
VIIRS Surface Albedo EDR (restricted)
VIIRS Surface Type EDR (public 01/29/2013)
VIIRS Suspended Matter EDR (public 05/12/2012)
VIIRS Vegetation Index EDR (public 05/02/2012)

Application Related Product

VIIRS Active Fires ARP (public 04/03/2012)

Search

Quick Search & Order

to place small order after reviewing inventory and granule metadata, including browse images when available.

Quick Search & Order

to place large order without reviewing inventory or granule (file) metadata.

Save Criteria  Load Criteria  Dataset Name/Granule ID/Beginning Orbit Number View  Reset