Aerosol Optical Thickness (AOT), Aerosol Particle Size Parameter (APSP) and Suspended Matter (SM) EDR Overview

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and the Aerosol Cal/Val Team

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Cal/Val Team Members

Team Members	Organization	Roles and Responsibilities
Pubu Ciren	IMSG/NOAA	SM algorithm development and product validation
Bigyani Das	IMSG/NOAA	Algorithm integration
Ashley N. Griffin	PRAXIS, INC/NASA	JAM
Brent Holben	NASA/GSFC	AERONET observations for validation work
Jingfeng Huang	UMD/CICS	AOT Algorithm development and product validation
Edward J. Hyer	NRL	Product validation, assimilation activities
Shobha Kondragunta	NOAA/NESDIS	Co-lead
Istvan Laszlo	NOAA/NESDIS	Co-lead
Hongqing Liu	IMSG/NOAA	Visualization, algorithm development, validation
Chris van Poollen	Raytheon	Support code testing in IDPS
Lorraine A. Remer	UMBC	Algorithm development, ATBD, liason to VCM team
Hai Zhang	IMSG/NOAA	Algorithm coding, validation within IDEA
Stephen Superczynski	IMSG/NOAA	Product evaluation, data management

Instrument Overview

- Aerosol EDRs are derived from VIIRS

Visible Infrared Imaging Radiometer Suite (VIIRS)

- **cross-track scanning radiometer with ~3000 km swath – full daily sampling**
- **7 years lifetime**
- **22 channels (412-12,016 nm)**
  - 16 of these are M bands with 0.742 x 0.776 km nadir resolution
  - **aerosol retrieval is from M bands** ➡
- **high signal-to-noise ratio (SNR):**
  - M1-M7: ~200-400
  - M8-M11: ~10-300
- **2% absolute radiometric accuracy**
- **single look**
- **no polarization**

Band name	Wavelength (nm)	Bandwidth (nm)	Use in algorithm
M1*	412	20	L
M2*	445	14	L
M3*	488	19	L, T_L, T_O
M4*	555	21	T_O
M5*	672	20	L, O, T_O
M6	746	15	O
M7*	865	39	O, T_L
M8	1,240	27	O, T_L, T_O
M9	1,378	15	T_L
M10	1,610	59	O, T_L, T_O
M11	2,250	47	L, O, T_L, T_O
M12	3,700	191	T_L
M13	4,050	163	none
M14	8,550	323	none
M15	10,763	989	T_L, T_O
M16	12,016	864	T_L, T_O

*dual gain, L: land, O: ocean; $T_{L,O}$: internal test land/ocean

S-NPP Product Overview

Attribute	AOT	APSP
Applicable Conditions	Clear, daytime only, zenith angles ≤80^{o}	same
Vertical Coverage	Total column	same
Horizontal Cell Size	6 km (nadir), 12.8 km (Edge of Scan)	same
Vertical Cell Size	Total column	same
Mapping Uncertainty, 3 σ	4 km	same
Measurement Range	0 to 2	-1 to +3 alpha units
Measurement Accuracy		
Over Ocean	0.08 (Tau < 0.3) 0.15 (Tau ≥ 0.3)	0.3 alpha units
Over Land	0.06 (Tau < 0.1); 0.05 (0.1 ≤ Tau ≤ 0.8) 0.20 (Tau > 0.8)	n/a
Measurement Precision		
Over Ocean	0.15 (Tau≤ 0.3) 0.35 (Tau ≥ 0.3)	0.6 alpha units
Over land	0.15 (Tau < 0.1) 0.25 (0.1 ≤ Tau ≤ 0.8) 0.45 (Tau > 0.8)	n/a
Refresh	At least 90% coverage of the globe every 24 hours (monthly average)	same

Products are generated in IDPS

S-NPP Product Overview

Attribute	SM
Applicable Conditions	Clear, daytime, for AOTs >0.2; SM includes dust, volcanic ash, and smoke at any altitude
Vertical Coverage	Total column
Horizontal Cell Size	3 km
Vertical Cell Size	Total column
Mapping Uncertainty, 3 σ	3 km
Measurement Range	Type: dust, volcanic ash, smoke. Smoke concentration: 0 to 150 µg/m^3
Measurement Accuracy (Probability of Correct Typing)	Land: 80% (dust and smoke); 60% (volcanic ash) Water: 80% (dust), 70% (smoke); 60% (volcanic ash)
Measurement Precision	N/A
Refresh	At least 90% coverage of the globe every 24 hours (monthly average)

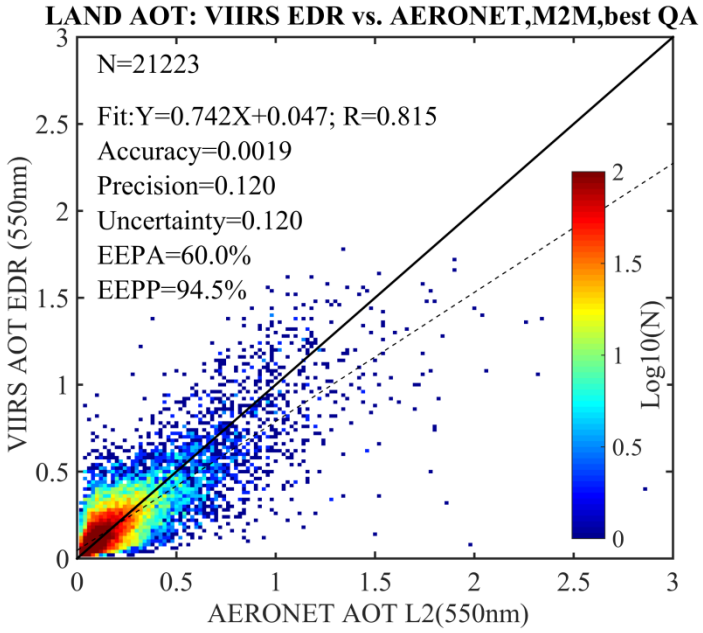
Product generated in IDPS is Beta.
New algorithm to become operational in NDE in January 2016.

S-NPP Product Overview

- **S-NPP Cal/Val Status**
  - AOT: Validated Stage 2
  - APSP: Validated Stage 1
  - SM: Beta in IDPS.

AOT/APSP Product Status

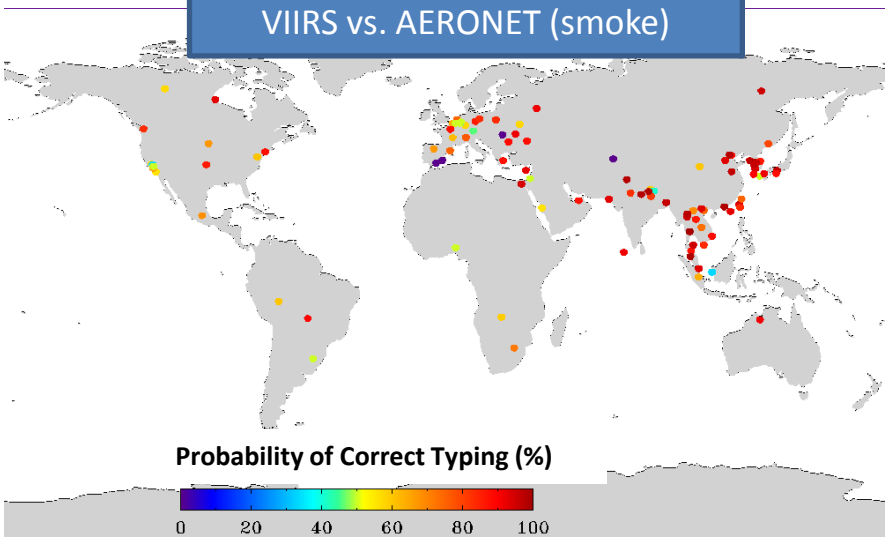
- **Accomplishments: AOT/APSP**
  - Enhanced internal tests to flag pixels that are not ideal for AOT retrieval (snow/ice, ephemeral water, bright pixel)
  - New evaluation with AERONET and established expected error of VIIRS AOT



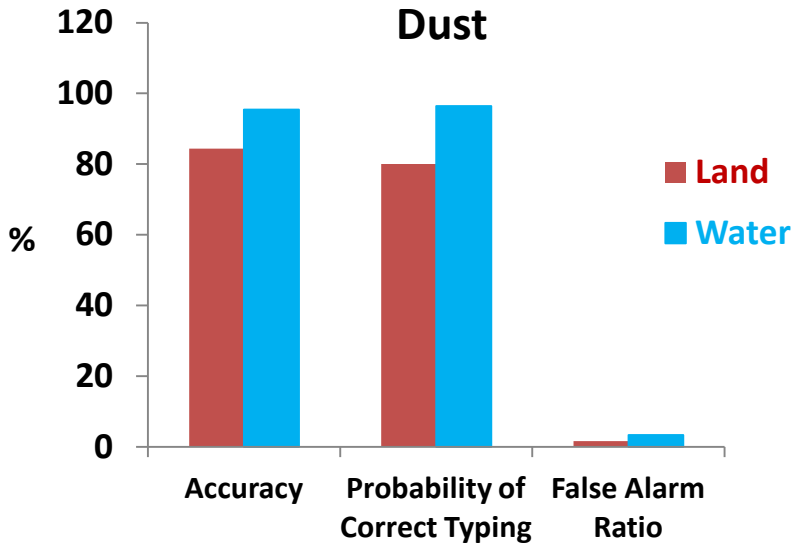
S-NPP Product Overview

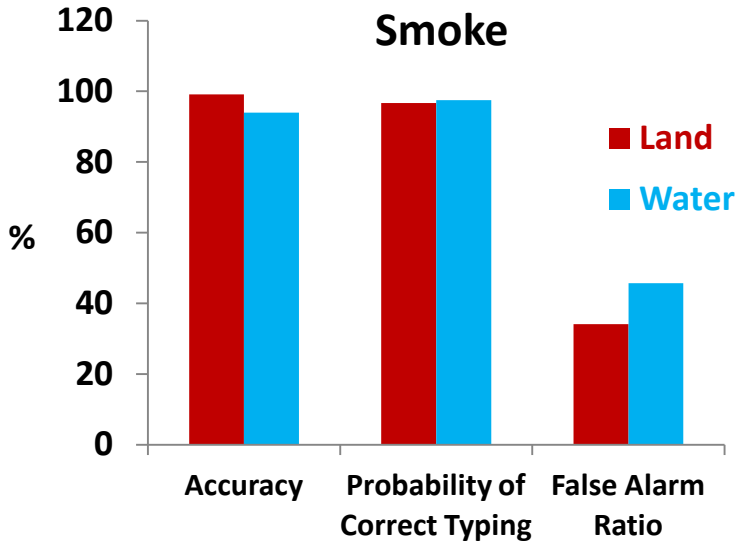
- **Accomplishments: SM**
  - Running J1 algorithm routinely on SNPP VIIRS direct broadcast data over CONUS. Smoke and dust only. *Volcanic ash information flows from an independent algorithm*
  - Working with users on feedback of the product.
  - Two years of SM product validated against CALIPSO, MISR, and AERONET.

VIIRS vs. AERONET (smoke)



VIIRS vs. CALIPSO





S-NPP Product Overview

- **Product Deficiencies**
  - **AOT**
    - ✓ AOT range restricted to 0-2
    - ✓ No retrieval over bright surface and inland water bodies
    - ✓ Globally constant surface reflectance ratio
  - **SM**
    - ✓ Smoke/haze discrimination
    - ✓ Preliminary approach to derive smoke concentration: scaling of AOD
    - ✓ False detections over bright surfaces (e.g., white sands)
    - ✓ Cirrus flag interference

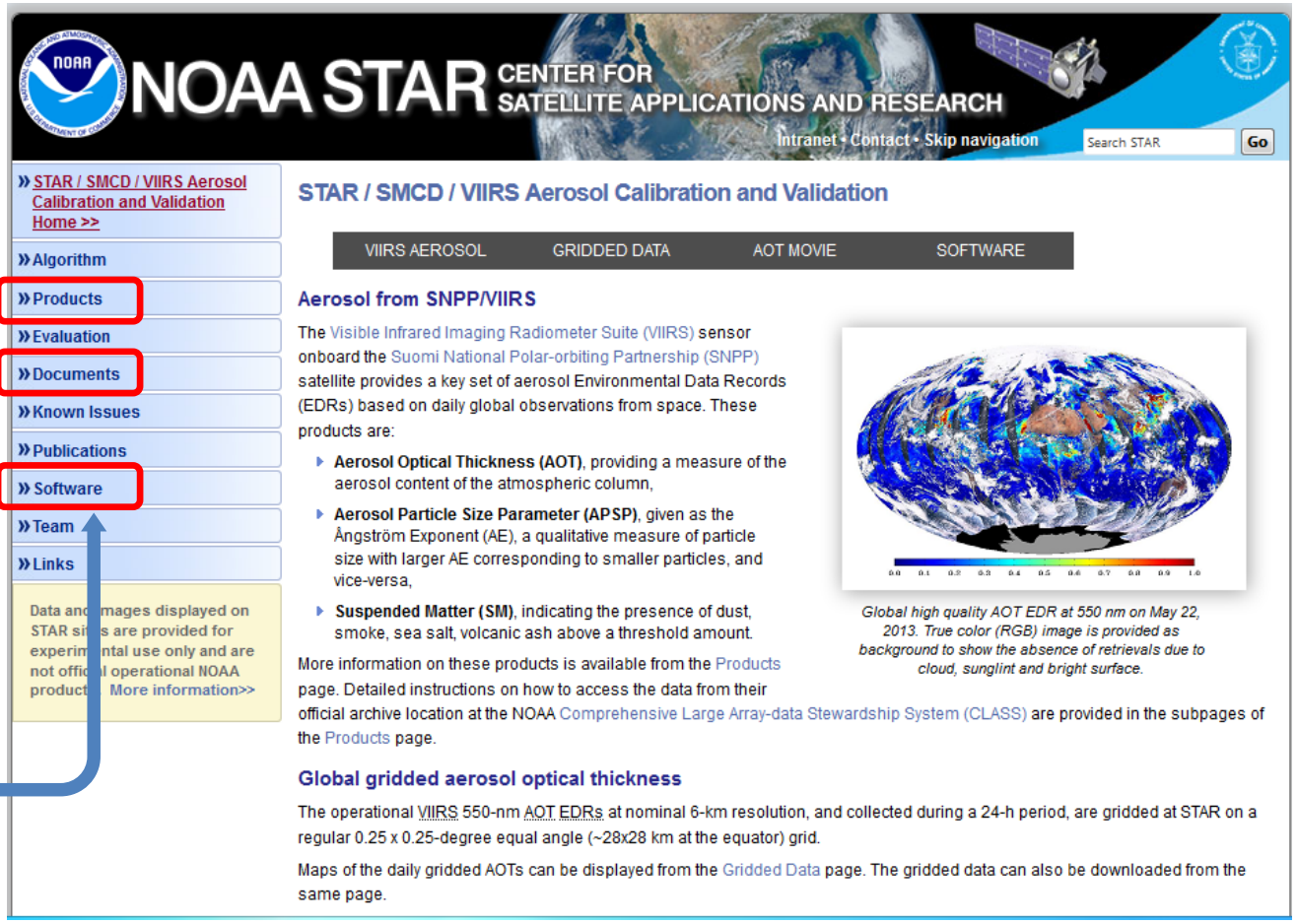
S-NPP Product Overview

- VIIRS Aerosol Calibration and Validation website http://www.star.nesdis.noaa.gov/smcd/emb/viirs_aerosol/index.php

Products page has links to CLASS and STAR FTP site for data download

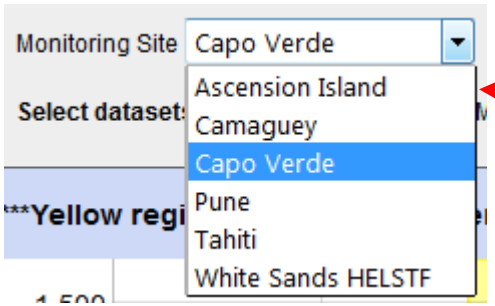
Links to ATBD, user's guide, product ReadMe, etc.

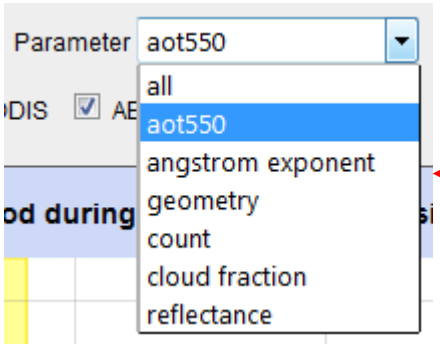
Software to display VIIRS aerosol products and convert data to MODIS-like EOS HDF format are available for download

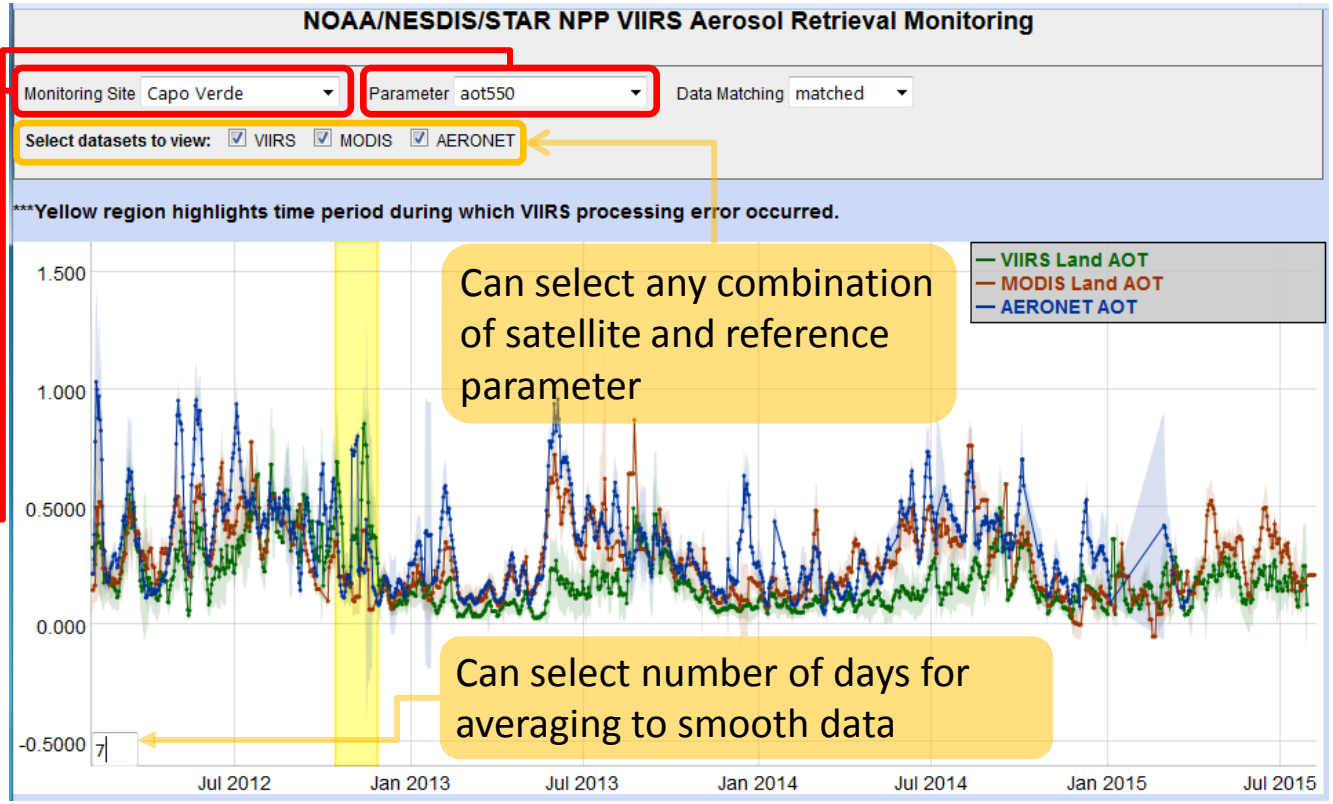


S-NPP Product Overview

- Interactive (JAVA-based) LTM Website: http://www-dev.star1.nesdis.noaa.gov/smcd/spb/stephens/monitoring/WEB/monitoring_NEW.html (internal to STAR for now!)





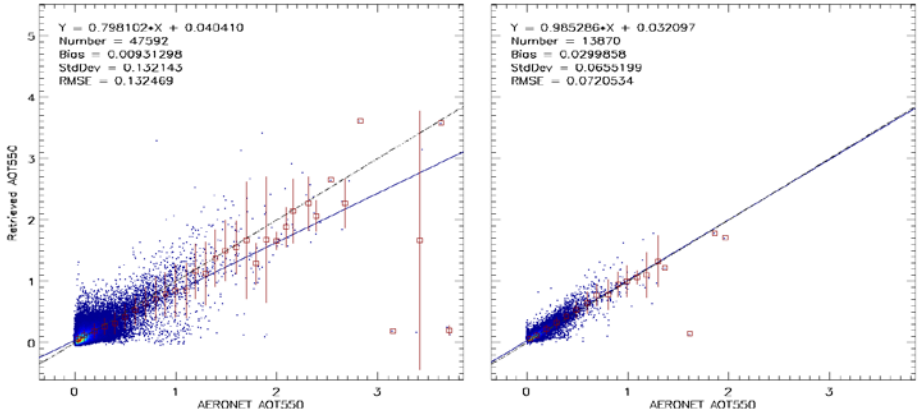


Can zoom in to select time period of interest

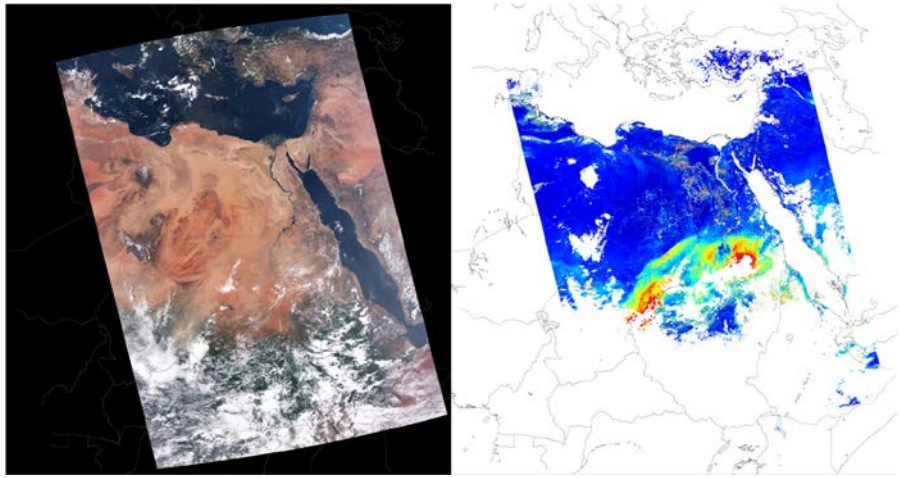
JPSS-1 Readiness

Major Accomplishments Moving Towards J1

- **Improved JPSS AOT/APS RR algorithm**
  - Pixel-level, dual scheme for better retrieval of high AOT; extended AOT range [-0.05, 5]; better screening for snow/ice/cloud; heavy aerosol detection; MODIS aerosol model with non-spherical dust; NDVI & redness dependent ratios
  - Successful Test Readiness Review
- **Developed global surface reflectance database**
  - Accounts for changes in surface reflectance ratio with location and scattering angle; 0.1x0.1 degrees
- **Developed Bright-surface algorithm**
  - Same method as in IDPS but uses global database of ratios of bright surface reflectances



Performance of JPSS Aerosol Algorithm



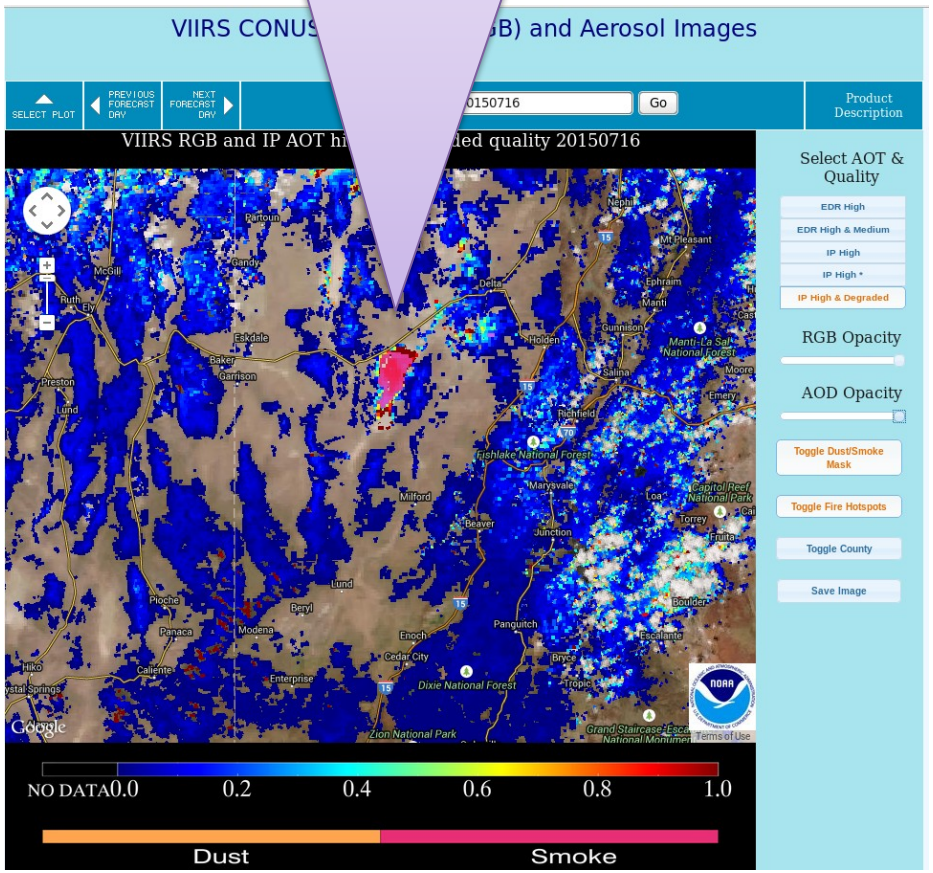
VIIRS RGB (left) and JPSS bright-surface AOT (right).

JPSS-1 Readiness

Major Accomplishments Moving Towards J1

- J1 Algorithm Summary
  - Algorithm is different from IDPS. Only smoke and dust in SNPP NDE algorithm. New volcanic ash algorithm for SNPP and J1 (Pavolonis).
  - Approach to derive smoke concentration is still in development. Preliminary approach involves simple scaling of AOT.
  - Preliminary version of SM cal/val website deployed (http://www.star.nesdis.noaa.gov/smcd/spb/aq/viirs_aqpg_2015/sdmask_monitor/index.php)
- Further Developments
  - Combined OMPS/VIIRS aerosol index approach.
  - Minimize false positives for dust and smoke over bright surfaces.
  - Develop a viable approach to derive smoke concentration.

Screenshot of IDEA website showing SNPP VIIRS AOT and smoke mask overlaid was sent to us as a feedback from NWS Western Region Incident Meteorologist. Area in pink shows false smoke over a dry lake bed in central Utah



JPSS-1 Readiness

- **J1 Cal/Val Overview**
  - *Timelines for Beta, Provisional and Validated Maturity*

Maturity	Time - AOT/APSP
Beta	3 months after data starts flowing from sensor
Provisional	6 months after VCM does initial tuning
Validated	19 months after VCM does initial tuning

  - *Pre-Launch Calibration/Validation Plans*
    - ✓ Year 1 (2015): Continue evaluation of Suomi-NPP VIIRS aerosol products.
    - ✓ Year 2 (2016): Modify validation software to ingest and to correctly interpret J1 data. Test impact of J1 instrument artifacts on aerosol products if needed.
  - *Post-Launch Calibration/Validation Plans*
    - ✓ Year 3 (2017): Inspect EOC data. Evaluate product for Beta level. Collect data (1 month) and perform ICV (2 months) to advance product to Provisional.
    - ✓ Year 4 (2018): 12 months of data collection and 4 months of analysis, documentation to advance product to Validated level.

JPSS-1 Readiness – Issues/Mitigation

- **Issue:** JPSS RR AOT algorithm and bright-surface retrieval module is not yet integrated.

  Mitigation: Integrate bright-surface retrieval module in RR AOT algorithm and test on global scale for extended period.

- **Issue:** Drift in SDR calibration affecting products, especially APSP

  Mitigation: Monitor time series of APSP. Requires 3-4 year time series!

- **Issue:** One or more of the primary data sources for evaluation (e.g. AERONET) are unavailable during JPSS-1 lifetime.

  Mitigation: Look for other sources, e.g., PHOTON (France), AEROCAN (Canada).

- **Issue:** Loss of independent satellite data.

  Mitigation: Rely on remaining sensors (MODIS/S-NPP-VIIRS) or switch to ground-based alternatives.

- **Issue**: A method to derive smoke concentration is not ready.

  Mitigation: Develop a method based on regression models developed from correlation between smoke/dust indices and surface PM2.5.

JPSS-1 Readiness

- Stake Holder Interactions, Users and Impact Assessment Plans
  - Users/Stake Holders, include:
    - Operational air quality forecasters
    - State and local environmental agencies
    - National Weather Service Weather Forecast Offices
    - National Weather Service global aerosol prediction system
    - Naval Research Laboratory (NRL)
  - How the products are being used by the users
    - Daily air quality forecasting
    - Exceptional events monitoring
    - Data assimilation to improve aerosol forecasting
  - User impact assessment
    - NRL (Ed Hyer): "*VIIRS+MODIS over MODIS only aerosol assimilation has a quantitative advantage in the Navy Aerosol and Analysis Prediction System (NAAPS)*"
    - Forecaster (Amy Huff): *see next slide*

JPSS-1 Readiness

- User impact assessment continued - Forecaster (Amy Huff):

"*I am an operational air quality forecaster for several areas of the Mid-Atlantic region, including the Philadelphia metropolitan area and the State of Delaware. My team and I use the VIIRS AOD and smoke/dust mask products routinely for forecasting of fine particulate matter (PM2.5). We work under many time constraints related to forecast deadlines, so having the AOD imagery available on IDEA in near real-time is invaluable. We would not be able to utilize VIIRS AOD products if we had to access them in their native format via CLASS. The high-resolution VIIRS AOD products (EDR and IP) provide information on the distribution of AOD on the urban scale that is not possible with other products, such as MODIS AOD. The interactive Google-maps based tool on the IDEA website makes it very easy to zoom into the city level, where we have the most interest, and identify areas of high AOD. The quality flag buttons allow us the flexibility to view high, medium, or degraded quality AOD, depending on the conditions. For smoke plumes, for example, it is frequently preferable to view the medium or degraded AOD pixels. Having the option to change the quality flags enhances our analysis, and is only possible through the IDEA website. Many of the other features of the tool, including the opacity slider bars, toggle fire hotspots, and toggle county boundaries, were added at the request of users, and make it easier for us to focus in on areas of interest. The smoke/dust mask is a relatively new feature that we are exploring. It is particularly helpful during haze events when smoke and occasionally dust are mixed in with urban haze. Overall, the VIIRS AOD and smoke/dust mask products are very useful for PM2.5 forecasting - the high resolution (6 km and 3 km) of the VIIRS AOD products allow us to track the variations in AOD on the urban/suburban scale, which is critical for air quality forecasting. And we can't praise the IDEA website too highly - it is essential for operational users, such as forecasters, to access the various aerosol satellite products, including VIIRS products. Thanks to Shobha and Istvan and their team for developing the tools on IDEA and for making the VIIRS data available in near real-time!*"

Summary & Path Forward

- S-NPP AOT and APSP products are at Validated Stage
- Internal tests in IDPS algorithm were updated to better detect pixels not suitable for AOT retrieval
- AOT and SM algorithms for J1 were developed, evaluated – passed TRR
- Capability to retrieve AOT over bright surface was developed
- FY16 Milestones:

Task/Description	Start / Finish	Deliverable
Development (D) 1) Adapt SNPP AOT and SM algorithms for J1 VIIRS 2) Build LUTs for J1 VIIRS 3) Build reprocessing capabilities	October 1, 2016 September 30, 2017	V1 algorithm LUTs for J1 VIIRS
Integration & Testing (I) 1) Enhancements to bright surface AOT algorithm in production phase 2) Enhancements to SM algorithm in production phase	October 1, 2016 September 30, 2017	N/A
Calibration & Validation (C) 1) Validation of reprocessed bright surface AOT and SM products 2) Final version of cal/val plan	Ongoing	Validation report Final version of J1 cal/val plan
Maintenance 1) IDPS and NDE algorithms and products	Ongoing	N/A
LTM & Anomaly Resolution (L) 1) Daily monitoring of product to diagnose instrument/algorithm artifacts	Ongoing	Report

Summary & Path Forward

- J2 and Beyond: Future Improvements

	S-NPP	JPSS-1	JPSS-2
FY17	(1) maintain algorithm and products (2) continue validation of AOT and SM product	(1) participate in launch preparation reviews, (2) participate in checkout phase and post-launch validation of products, (3) work towards beta release of products	Build LUTs for J2 VIIRS and participate in meetings related to instrument waivers etc.
FY18	(1) maintain algorithm and products (2) continue validation of AOT and SM product	Work towards provisional release of AOT/APSP and SM products	Participate in meetings related to J2 mission and VIIRS instrument
FY19	(1) maintain algorithm and products (2) continue validation of AOT and SM product	Work towards validated release of AOT/APSP and SM products	Algorithm readiness and reviews such as CDR etc.
FY20	(1) maintain algorithm and products (2) continue validation of AOT and SM product	(1) maintain algorithm and products and update algorithms based on new science as needed, (2) continue validation of AOT/APSP and SM product	Prepare for J2 launch