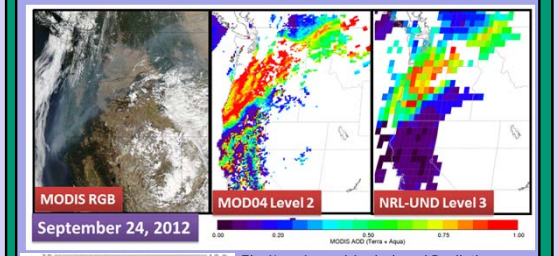
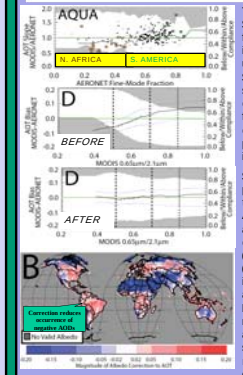
Operational Assimilation of Aerosol Optical Depth from Suomi NPP VIIRS in a Global Aerosol Model

Edward J. Hyer[1], Jianglong Zhang[2], Jeffrey S. Reid[1], Walter Sessions[3], Cynthia Curtis[1], Douglas L. Westphal[1]
1)Naval Research Laboratory, Marine Meteorology Division, Monterey, CA, USA
2) Department of Aerospace, University of North Dakota, Grand Forks, ND, USA
3) Computer Science Corporation, Monterey, CA, USA
Email: edward.hyer@nrlmry.navy.mil

1. NAVDAS-AOD: Assimilation of global aerosol optical depth for forecasting





The Navy Aerosol Analysis and Prediction System is the Navy's operational aerosol forecasting system. The NAAPS analysis cycle includes assimilation of AOD data from MODIS using the Navy Variational Data Assimilation System for AOD (NAVDAS-AOD). In the process shown at left, radiance data from MODIS are converted to AOD retrieval data, which is then further processed into a form where it can be combined with a NAAPS model forecast to produce an analysis, which then serves as the initial condition for the next forecast step.

Starting with the NASA Level 2 AOD data, NRL performs filtering, correction, and aggregation to prepare the data for assimilation into NAAPS. After extensive filtering for cloud contamination and other data issues, the most important corrections are for land surface characteristics (left), and for aerosol microphysical properties (above left). These corrections reduce outliers in the data, improve the error characteristics, and increase the global consistency of the data, but impose a large cost in data volume. This reflects a key difference between data assimilation and other applications, in that the sensitivity of assimilation to outliers justifies far more stringent filtering than other applications demand.

The NRL/UND Level 3 AOD product is now produced in near real time at NASA LANCE. You can find more information about this product at the EOSDIS webpage: https://earthdata.nasa.gov/about-eosdis/news/nrt-value-added-modis-aerosol-optical-depth-product-available or search the WWW for "MCDAODHD."

6. Relevant Papers and Resources

NRL Aerosol webpage: http://www.nrlmry.navy.mil/aerosol_web

References Related to NAVDAS-AOD and NAAPS:
Zhang, J., Campbell, J. R., Reid, J. S., Westphal, D. L., Baker, N. L., Campbell, W. F., and Hyer, E. J.: Evaluating the impact of assimilating calipo-derived aerosol extinction profiles on a global mass transport model, Geophys. Res. Lett., 38, L14801 doi:10.1029/2011gl047737, 2011.
Zhang, J. L., Reid, J. S., Westphal, D. L., Baker, N. L., and Hyer, E. J.: A system for operational aerosol optical depth data assimilation over global oceans, J. Geophys. Res.-Atmos., 113, D10208, D10208 doi:10.1029/2007jd009065, 2008.

References related to NRL/UND Level 3 MODIS product:
Hyer, E. J., Reid, J. S., and Zhang, J.: An over-land aerosol optical depth data set for data assimilation by filtering, correction, and aggregation of modis collection 5 optical depth retrievals, in: Atmospheric Measurement Techniques, European Geophysical Union, 379-408, 2011.
Shi, Y., Zhang, J., Reid, J. S., Holben, B., Hyer, E. J., and Curtis, C.: An analysis of the collection 5 MODIS over-ocean aerosol optical depth product for its implication in aerosol assimilation, Atmos. Chem. Phys., 11, 557-565, doi:10.5194/acp-11-557-2011, 2011.
Zhang, J. L., and Reid, J. S.: MODIS aerosol product analysis for data assimilation: Assessment of over-ocean level 2 aerosol optical thickness retrievals, J. Geophys. Res.-Atmos., 111, D22207, doi:10.1029/2005JD006898, 2006.
Related AMS93 Papers (this is a small sample, there are many more):
#659 (Wednesday 9 January, Exhibit Hall 3): Validation of the NPP/VIIRS Operational Aerosol Products Through Multi-Sensor Intercomparisons. **Jingfeng Huang**, UMD/ESSIC, NOAA/NESDIS/STAR, College Park, MD;
#670 (Wednesday 9 January, Exhibit Hall 3): Suomi NPP Intensive Cal/Val Over Tropical Ocean: Results from the 2012 NOAA Aerosols and Ocean Science Expedition (AEROSE). Nicholas R. Nalli, NOAA/NESDIS, College Park, MD;
Session 4.1 (Tuesday 8 January, Ballroom G, 15:30): The Suomi National Polar-Orbiting Partnership (NPP) Cal/Val Overview. **Fuzhong Weng**, NOAA/NESDIS, College Park, MD

For more information on VIIRS: http://npp.gsfc.nasa.gov/viirs.html

2. MODIS and VIIRS Aerosol Product Differences

	Aqua-MODIS	Suomi NPP-VIIRS
Swath Width	2330 km	3000 km
Sensor bands used for aerosol retrieval.	0.411, 0.466, 0.554, 0.646, 0.856, 1.242, 1.629, 2.114 µm	0.412, 0.445, 0.488, (0.550), 0.555, 0.672, 0.746, 0.865, 1.24, 1.61, 2.25 µm
Pixel size, nadir	0.5 km	0. 75 km
Pixel size, edge of scan	2 km	1.2 km
Product resolution, nadir	10x10 km (20x20 500m pixels)	6x6 km (8x8 750m pixels) (AOT and Angstrom exponent)
Product resolution, edge of scan	40x20 km	12.8x12.8 km

The VIIRS sensor on Suomi NPP has technical heritage from MODIS and AVHRR sensors flown by NASA and NOAA, and the OLS sensor from the Defense Meteorological Satellite Program.

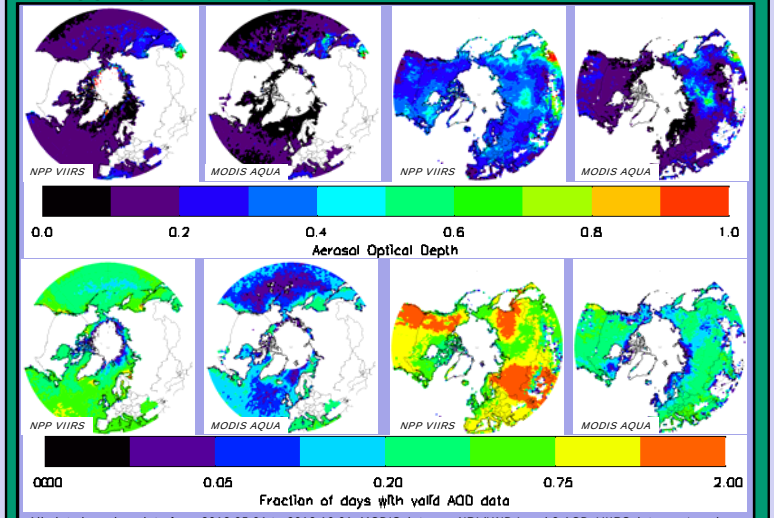
Compared with MODIS, VIIRS has:

- Improved coverage, with gap-free daily observation around the globe, enabled by the wider swath
- Improved spatial characteristics across the swath: VIIRS uses a subpixel averaging scheme to limit pixel size expansion to a factor of 2 from nadir to the swath edge.

The VIIRS aerosol EDR algorithm produced by the JPSS Independent Data Processing system is also different from the MODIS aerosol products:

- Retrieval of AOD is done at the pixel level, aggregation of AOD values is done to produce the EDR product.
- Over-land algorithm (like MOD09 atmospheric correction) retrieves a single aerosol model, a mix of fine and coarse; over-ocean algorithm (like MOD04) retrieves fine and coarse mode properties separately.

3. Aggregate Comparison of VIIRS and MODIS AOD



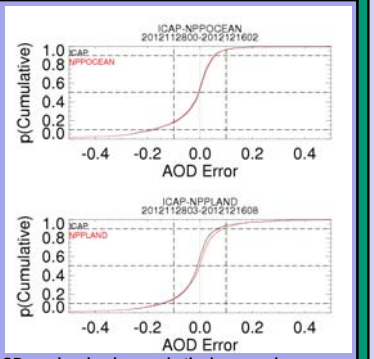
All plots based on data from 2012.05.01 to 2012.10.01. MODIS data are NRL/UND Level 3 AOD, VIIRS data are 'good QA' only with additional filtering based on in-granule quality flags. For a more detailed comparison of VIIRS AOD to MODIS and AERONET, see Jingfeng Huang's poster #659.

4. VIIRS AOD Assimilation Results

Using the filtered VIIRS AOD data as shown in panel 3, we conducted assimilation experiments using NAAPS and NAVDAS-AOD as follows:

Starting with the operational NAAPS analysis (including assimliation of global MODIS from Terra and Aqua), this analysis was combined with VIIRS AOD to make a combined MODIS+VIIRS analysis. This was then used to initialize a NAAPS forecast. One forecast per day was created using the VIIRS over-ocean data from 21Z-03Z (Pacific quadrant), and another using the over-land data from 09Z-15Z (Europe-Africa quadrant).

The outputs from this system were compared with AOD reference data from AERONET to evaluate model performance. The results at right show cumulative distribution of errors vs AERONET for the NAAPS(MODIS+VIIRS) and NAAPS(MODIS) analyses for the period 2012.11.28 – 2012.12.16.



The positive bias in the over-land NPP VIIRS AOD can be clearly seen in the increased occurrence of positive errors in the NAAPS(MODIS+VIIRS) analysis. The analysis also has slightly increase occurrence of negative errors, compared with the operational system. The over-ocean analysis shows very little difference with AERONET in this limited sample, reflecting the sparse nature of the AERONET data over the open ocean. Qualitative comparison of NAAPS(MODIS+VIIRS) to NAAPS(MODIS) indicates that the higher VIIRS AOD values over ocean are passed into the analysis.

5. Conclusions and Outlook for Assimilation of VIIRS Aerosol Optical Depth

Aerosol optical depth data from NPP VIIRS are currently assigned 'Beta' status. Upgrades to these data are in process, originating with requests from the Cal/Val teams:

- Recalculation of EDR lookup tables (LUTs) to reflect post-launch spectral response functions
- Recalculation of base surface reflectance ratio used in over-land AOD retrieval

These upgrades do not represent a complete solution to all the problems identified, but the Cal/Val teams continue to search for the most effective means to modify the IDPS processing to produce the most accurate product possible.

Priorities for more detailed examination of this product include:

- Examination of high AOD values at high latitudes, including examination of snow/ice masking
- Evaluation of cloud clearing over ocean
- Evaluation of regional biases over land after implementation of LUT and algorithm revisions

Based on the current EDR product, significant additional filtering and correction of VIIRS AOD data will be required to achieve an improvement in operational NAAPS analyses and forecasts.