An Operational Aerosol Data Assimilation System (NAVDAS-AOD)

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Three Year Project summary

(1) Proposed: An operational aerosol assimilation package.

Accomplishment: Developed an operational aerosol assimilation package NAVDAS-AOD [Zhang et al., 2008, JGR]. Run daily in semi-operational (research) mode. In transitioning to FNMOC.

(2) Proposed: Understand the uncertainties in the operational MODIS aerosol product.

Accomplishment: Developed QA and QC processes for both over ocean and over land MODIS aerosol product. Develop a new level 3 MODIS aerosol product that is suitable for aerosol data assimilation [e.g. Zhang and Reid. 2006 JGR]. Run daily in semi-operational (research) mode. In transitioning to FNMOC.
NRL aerosol data assimilation system (NAVDAS-AOD) includes:

**Model:**
Navy/NRL Aerosol Analysis and Prediction System (NAAPS), the world’s only truly operational global aerosol model.

**Observations:**
Newly derived Level 3 AOD product based on NRPTTE MODIS level II data stream. Later, MISR, MODIS Deep Blue.

**The assimilation system:**
NRL Atmospheric Variational Data Assimilation System (NAVDAS)
Background (NAAPS)

- Operational at FNMOC, twice-daily, 6-day forecasts of SO$_2$, sulfate, dust, sea salt, and smoke concentration
- Grid: 1X1 degree; 30 levels to 100 mb
- Operational global weather model (NOGAPS) provides forecasts of P, T, q, u, v, w, $K_z$, cloud parameters, precip., stress, and ground wetness at 6-hour intervals
- SO$_2$ emission inventory; oceanic DMS emission
- Dust deflation depends on threshold velocity, forecasted stress, rain, and ground wetness
- **Smoke emission** based on satellite detection of fires
- Linear gas-phase chemistry
- Dry deposition: function of specie, stress, stability, surface type
- Wet removal: function of precipitation rate, specie, cloud type
Background (NAVDAS)

- Using 2-D var version of NAVDAS
- Error variance terms were estimated using AERONET data
- No error correlation for satellite observations
- Horizontal background error correlation model (SOAR)
- Background error correlation length was found to be ~200 km

\[
x_{a} = x_{b} + P_{b} H^{T} [HP_{b} H^{T} + R]^{-1} [y - H \{x_{b}\}]
\]
We begin with NRTPE Collection 4 MOD04 AOT data. Shown is 2004 annual average.

QA: Data are screened using spatial tests and thresholds. Empirical corrections are made based on satellite and NOGAPS environmental data.

End result, more than 50% correction in southern oceans and Asian outflow to the north Pacific. 15-20% reduction in error globally.

Single sensor over water aerosol data assimilation & validation
Single sensor over water aerosol data assimilation

Application of modified collection 4 MODIS AOD

MODIS AOD (March-May, 2006, notice the difference to the standard MODIS L3 product)

NAAPS AOD, no assimilation (March-May, 2006)

NAAPSAOD analysis (March-May, 2006)

NAAPS AOD 6 hour forecast (March-May, 2006, with assimilation)
Summary for single sensor over water aerosol data assimilation

Five month evaluation vs. AERONET of NAVDAS-AOD using MODIS level 2 (Terra+Aqua) with additional screening and corrections.

- Can reproduce observation at the analysis fields.
- NAAPS mean bias reduced by nearly 1/3 for 48-hour forecast
- Currently in transition to 6.2 daily runs

Independent evaluation of NAVDAS-AOD
(Kalashnikova et al., 2008)

- All plots from Kalashnikova et al., 2008.
- NAAPS AOD agrees well with MISR and AERONET for June and July of 2000.

Identify & quantify uncertainties in collection 5 over ocean MODIS AOD
Identify & quantify uncertainties in collection 5 over ocean MODIS AOD
• Biases due to lower boundary condition still exist
• Biases due to cloud contamination and cloud artifacts still exist
• 20% reduction in absolute errors

In progress: for QC and QA of collection 5 over ocean MODIS AOD

a) Terra+Aqua MODIS AOD (Level 3 daily average), before QA and QC, Jan. – Dec. 2006

b) Terra+Aqua MODIS AOD (Level 3 daily average), after QA and QC, Jan. – Dec. 2006
In progress: for QC and QA of collection 5 over ocean MODIS AOD

a) Terra+Aqua MODIS AOD, before QA and QC, Jan 2007

b) Aqua MODIS AOD, Jan 2007 [Vaughan et al. 2007]

c) Terra+Aqua MODIS AOD, After QA and QC, Jan 2007

d) CALIPSO AOD, Jan 2007 [Vaughan et al. 2007]

Figures b and d are from Mark Vaughan and co-authors, CALIPSO Aerosol Backscatter and Extinction Characterization Using the MODIS and OMI Products, *Eos Trans. AGU*, 88(52), Fall Meet. Suppl., Abstract A23A-0882.
Identify & quantify uncertainties in collection 5 over land MODIS AOD
QC and QA processes for the collection 5 over land MODIS AOD

- With albedo filter, numbers approach ocean values
- Ocean numbers from Zhang & Reid, *JGR* 2006
QC and QA processes for the collection 5 over land MODIS AOD

• c5 is a Huge Improvement over c4 over-land AOD
• Modest Gains from filters using MOD04 metadata
  – Reduce data volume by 50%, reduce RMSE by 16%
• Better gains eliminating high-albedo areas
  – Data volume = 30%, RMSE reduction = 36%
  – At this time, no albedo product for real-time use
• AOD CV + Coverage not as good as ocean product, but getting there
Applications

(1) Multi-sensor fusion
(2) Aerosol forcing
(3) Nighttime aerosol detection
(1) Using aerosol assimilation for data fusion

- Combined the strength of Satellite aerosol studies and aerosol modeling studies.
- High temporal resolution, weight averaging based on data error statistics.
- Aerosol optical property estimates over cloudy regions, useful for studies like aerosol indirect forcing studies.
- Directly applicable to operational aerosol forecast.
(1) Data fusion, simple multi-sensor case (06-08, 2005)

Monthly (June- Aug, 2005)

Daily

Combined daily product-near total global coverage

Aqua MODIS

Deep Blue

MISR
(1) Inter-comparisons among satellite aerosol products
(1) Analysis versus forecast (AOD) (June-Aug, 2005)

MISR+MODIS

NAAPS Analysis

Natural run (land + ocean)

Natural run

6h forecast

NAAPS Analysis
• MODIS/MISR data have finer spatial resolutions that can be used in detecting aerosol and cloud properties within a CERES footprint.

(2) Hope: Aerosol forcing studies, approaches from combining satellite and MODEL

Smoke
(2) Potential application: LW forcing over Saharan region
(2) Potential application: LW forcing over Saharan region

MODIS + MISR

NAAPS + MODIS + MISR

NAAPS + MODIS + MISR + DEEPBLUE

LW forcing (Wm\(^{-2}\))
(3) Night-time aerosol observations

- Aerosol retrieval using city lights
- Use the Operational Linescan System (OLS) data
- Problems
- Hopes

FY 08 Milestones

1. Continue test and validate over-water aerosol assimilation.
   - Accomplishment #1 Full-scale validation.

2. Over ocean aerosol data assimilation.
   - Accomplishment #1 QA and QC collection 4 (C4) over-water MODIS aerosol product.
   - In Progress Update and re-validate QA/QC for the over water MODIS collection 5 (C5) AOD data.

3. Over land aerosol data assimilation.
   - Working on #1 QA and QC MODIS C5 over-land aerosol product.
   - In Progress Construct over-land MODIS level 3 aerosol product.

4. Scientific applications.
   - Accomplishment #1 Test the possibility of multi-sensor data fusion.
   - Accomplishment #2 Nighttime aerosol study.
1. Peer reviewed journal, published or accepted


2. Conference Proceedings & Other


