Level-2 AOD median from multiple satellite sensor retrievals
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GEOS5 nature run for a given time, depicting different aerosol types with different colors
Outline

- Spatio-temporal Challenges of Aerosol Inter-comparison between Satellite observations and Model simulations
- The MAPSS aerosol data sampling/analysis system
- Lessons from Multi-sensor Coherent Uncertainty Analyses
- Toward Multi-sensor Data Synergy: Level 2 AOD Median
- Future Possibilities (Suggestions very welcome)
±30 minute MODIS Terra swath cutouts for evaluation of 3-hour model snapshots on 2008-08-22

Single product poor coverage, even whole day is not optimal spatially/temporally
Combined swath cutouts from MODIS Aqua&Terra, MISR, OMI, SeaWiFS, and POLDER

Combined product, a little improved, but still same issues, plus sampling dilemma
Global monthly AOD for August 2007

GOCART

MODIS Terra

MISR

MODIS Aqua

Monthly averages, improved coverage, but less useful for diagnosing models
Aerosol data are available from different sensors:
- AERONET
- MODIS
- MISR
- OMI
- POLDER
- CALIOP
- SeaWiFS
- VIIRS

It is hard to compare and inter-validate:
- Different spatial and temporal resolution
- Different data access strategies

MAPSS uniformly samples Level-2 aerosol products and stores resulting statistics in simple CSV files.

Giovanni-based WEB interface for MAPSS provides convenient customized access to the data, with on-line plotting and data export capabilities.

Petrenko et al., 2012, AMT
MAPSS (Multi-sensor Aerosol Products Sampling System)

http://giovanni.gsfc.nasa.gov/mapss/

This user interface is used to obtain selected parameter statistics from the MAPSS database for a chosen location and time period. Time Series Plot is the available service. Plot output is rendered as a graph and is also available in ASCII format.
Comparative Accuracy of spaceborne AOD retrievals

- Satellite data sampled within 55-km diameter circles centered over AERONET stations
- AERONET data sampled within ±30 minutes of each overpass of the satellites
- Space-borne AOD uncertainty metrics computed on the basis of comparison with AERONET data

MAPSS-Explorer

http://giovanni.gsfc.nasa.gov/mapss_explorer/
Relative Performance of Satellite Aerosol Products at AERONET locations

Sensors providing the best $R^2$ of AOD over land at 382 AERONET stations, at all seasons (outliers removed)

Relative Performance of Satellite Aerosol Products by Landcover Type

Measures of accuracy (e.g. $R^2$) by Land-cover Type

Lessons from coherent uncertainty analysis

### Results and Summary

<table>
<thead>
<tr>
<th>IGBP land cover type</th>
<th>Most adapted products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>MODIS, MISR, and SeaWiFS</td>
</tr>
<tr>
<td>Evergreen needleleaf forest</td>
<td>MODIS and MISR</td>
</tr>
<tr>
<td>Evergreen broadleaf forest</td>
<td>POLDER, MISR, and MODIS</td>
</tr>
<tr>
<td>Deciduous broadleaf forest</td>
<td>MODIS and MISR</td>
</tr>
<tr>
<td>Mixed forests</td>
<td>MODIS and MISR</td>
</tr>
<tr>
<td>Closed shrubland</td>
<td>MISR, CALIOP, MODIS Deep Blue</td>
</tr>
<tr>
<td>Open shrublands</td>
<td>All sensors have $R^2 &lt; 0.7$</td>
</tr>
<tr>
<td>Woody savannas</td>
<td>MODIS Dark Target, MODIS Deep Blue, MISR, SeaWiFS</td>
</tr>
<tr>
<td>Savannas</td>
<td>MODIS, SeaWiFS, MISR, POLDER</td>
</tr>
<tr>
<td>Grasslands</td>
<td>All sensors have $R^2 &lt; 0.7$</td>
</tr>
<tr>
<td>Permanent wetlands</td>
<td>MODIS and MISR</td>
</tr>
<tr>
<td>Croplands</td>
<td>MODIS and MISR</td>
</tr>
<tr>
<td>Urban and built-up</td>
<td>MISR</td>
</tr>
<tr>
<td>Cropland / natural veget. mosaic</td>
<td>MODIS, MISR, and SeaWiFS</td>
</tr>
<tr>
<td>Snow and ice</td>
<td>MISR</td>
</tr>
<tr>
<td>Barren or sparsely vegetated</td>
<td>MISR</td>
</tr>
</tbody>
</table>

- Accuracy varies with land-cover type, but no product is accurate across all regions.
- Each product has unique features that make it advantageous in certain regions.
- Certain land-cover types are problematic for all products, e.g., open shrublands and grasslands.

What satellite aerosol product to use for modeling and other Applications?

One that combines the best of all available aerosol products wherever and whenever they occur.

**Challenge**

How to derive a unique product that is an embodiment of the best the satellites can offer?
Exploring AOD Median at Selected Locations
Preliminary Method for Median Estimation

• Step 1: Extract spatial mean or median of each satellite product from MAPSS:
  This is mean or median of pixels within the 55-km diameter sample space centered at each AERONET station.

• Step 2: Determine the median of the above parameters for all available satellite AOD products:
  This is median of all available satellite AOD spatial mean or median values within a pre-determined sample bin size (e.g. 20), which is adjustable.
GSFC

GSFC 2008(mean,best-QA,filter=20)

<table>
<thead>
<tr>
<th>corr</th>
<th>1.00</th>
<th>0.95</th>
<th>0.97</th>
<th>0.95</th>
<th>0.97</th>
<th>0.70</th>
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<tr>
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<td>0.07</td>
<td>0.08</td>
<td>0.11</td>
<td>0.04</td>
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<td>141</td>
<td>232</td>
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<td>141</td>
<td>117</td>
<td>167</td>
<td>15</td>
<td>78</td>
<td>0</td>
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</tbody>
</table>

corr: correlation
bias: relative bias. Σsatellite > ΣAERONET, if > 1.
rmse: root mean square error
#all: number of points with valid data
#match: number of points when both satellite and AERONET have valid data
Using MAPSS median, bin size = 20

GSFC

GSFC 2008(median,best-QA,filter=20)

corr: 1.00 0.95 0.97 0.95 0.96 0.71 0.75
bias: 1.00 1.21 1.31 1.48 1.03 1.54 1.37
rmse: 0.00 0.07 0.08 0.11 0.05 0.09 0.12
#all: 790 182 142 232 16 86 2 1531
#match: 790 141 118 167 15 78 0 790

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Using MAPSS mean, bin size = 20

**Bratts_Lake**

Bratts_Lake 2008(mean,best-QA,filter=20)

<table>
<thead>
<tr>
<th>corr</th>
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<th>0.82</th>
<th>0.73</th>
<th>0.95</th>
<th>0.57</th>
<th>0.90</th>
<th>0.49</th>
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<tbody>
<tr>
<td>bias</td>
<td>1.00</td>
<td>2.26</td>
<td>1.98</td>
<td>2.22</td>
<td>1.31</td>
<td>1.65</td>
<td>0.81</td>
<td>2.02</td>
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<tr>
<td>rmse</td>
<td>0.00</td>
<td>0.15</td>
<td>0.13</td>
<td>0.16</td>
<td>0.06</td>
<td>0.10</td>
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<td>0.13</td>
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<tr>
<td>#all</td>
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<td>137</td>
<td>104</td>
<td>172</td>
<td>19</td>
<td>81</td>
<td>22</td>
<td>1400</td>
</tr>
<tr>
<td>#match</td>
<td>1102</td>
<td>123</td>
<td>99</td>
<td>150</td>
<td>18</td>
<td>79</td>
<td>6</td>
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</tr>
</tbody>
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Bratts_Lake

Bratts_Lake 2008(median,best-QA,filter=20)

corr: 1.00 0.78 0.83 0.74 0.96 0.55 0.90 0.50
bias: 1.00 2.27 1.98 2.18 1.30 1.60 0.78 1.99
rmse: 0.00 0.15 0.12 0.15 0.05 0.10 0.04 0.13
#all: 1102 137 104 172 19 81 22 1400
#match: 1102 123 99 150 18 79 6 924

corr: correlation
bias: relative bias. Σsatellite > ΣAERONET, if > 1.
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Using MAPSS mean, bin size = 20

Monterey

Monterey 2008(mean,best-QA,filter=20)

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Using MAPSS median, bin size = 20

Monterey

Monterey 2008(median,best-QA,filter=20)

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<th>corr</th>
<th>1.00</th>
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<th>0.63</th>
<th>0.75</th>
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<tr>
<td>bias:</td>
<td>1.00</td>
<td>0.83</td>
<td>0.92</td>
<td>0.99</td>
<td>0.51</td>
<td>1.45</td>
<td>0.87</td>
<td>0.84</td>
</tr>
<tr>
<td>rmse:</td>
<td>0.00</td>
<td>0.10</td>
<td>0.09</td>
<td>0.09</td>
<td>0.42</td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
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<tr>
<td>#all:</td>
<td>1027</td>
<td>264</td>
<td>277</td>
<td>337</td>
<td>27</td>
<td>130</td>
<td>24</td>
<td>1607</td>
</tr>
<tr>
<td>#match:</td>
<td>1027</td>
<td>174</td>
<td>184</td>
<td>221</td>
<td>14</td>
<td>107</td>
<td>5</td>
<td>1027</td>
</tr>
</tbody>
</table>

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Conclusions

- There is considerable disagreement in AOT (level 2) between different satellite sensors/algorithms.

- Multi-sensor synergy can help restore harmony and improve understanding in aerosol loading and impacts.

- We are currently evaluating viable options for combining different products to get the best consensus satellite-based AOT.

- Such consensus product can be of significant benefit for model evaluation, and hopefully provide a consistent satellite-based long-term aerosol climate data record across multiple satellite generations.
Acknowledgement

- NASA HQ Program Managers:
  - Hal Maring
  - Martha Maiden
  - Steve Berrick
  - Kevin Murphy
  For tag-team Funding support of this series of aerosol projects.

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  - AERONET: Brent Holben, David Giles, Ilya Slutsker
  - MODIS: Lorraine Remer, Rob Levy
  - MISR: Ralph Kahn
  - OMI: Omar Torres
  - POLDER: Didier Tanre, Fabrice Ducos, Jacques Descloitres
  - CALIOP: Dave Winker, Ali Omar
  - SeaWiFS: Christina Hsu
  - GOCART Model: Mian Chin
  - GEOS-5: Arlindo da Silva
Functions and Web Sites

GIOVANNI — Level 3 Earth Science Data Visualization and Analysis
http://giovanni.gsfc.nasa.gov/giovanni/

MAPSS — Level 2 Aerosol Point Sampling: Timeseries & Spreadsheet
http://giovanni.gsfc.nasa.gov/mapss/

MAPSS_Explorer — Level 2 Aerosol uncertainty analysis over AERONET sites
http://giovanni.gsfc.nasa.gov/mapss_explorer/

AeroStat — Level 2 Aerosol Point Sampling: Scatterplots & Statistics
http://giovanni.gsfc.nasa.gov/aerostat/