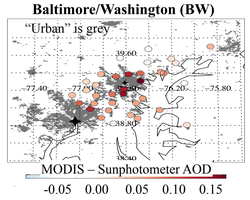
Aerosol Retrieval over Urban Area in MODIS Dark Target Land Algorithm

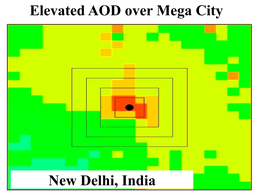
Pawan Gupta[1,2], Rob Levy[2], Shana Mattoo[2,3], and [4]Lorraine Remer

[1]GESTAR-Universities Space Research Associations, [2]NASA Goddard Space Flight Center, [3]Science Systems and Applications, Inc., [4]JCET/UMBC

Introduction

- In many parts of the globe, particulate matter concentrations can be 5 to 10 times higher than the World Health Organization's air quality guidelines, especially in urban regions where most people live.
- Ground monitors are sparse in many global regions, so using satellite-derived aerosol properties can help to quantify global exposure to poor air quality.
- The new version (C6) of the MODIS Dark Target (MDT) over-land aerosol algorithm retrieves aerosol optical depth (AOD) at 10km and 3km spatial resolutions over global dark targets (Levy et al., 2013).
- Large cities appears as hot spot in MDT AOD maps (Gupta et al., 2013) and comparison with ground-based sun photometer over the cities in the USA show that MDT-retrieved AOD may be biased high (Munchak et al., 2013).





Approach

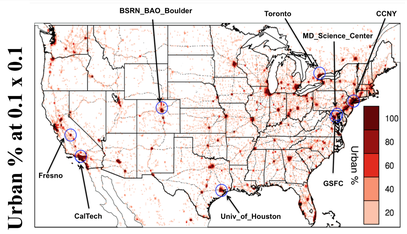
- MDT assumes a relationship between the visible (VIS) and shortwave-IR (SWIR) surface reflectance, based on statistics of dark-target (primarily vegetated) surfaces. $NDVI_{SWIR}$ is Normalized Difference Vegetation Index (1.24, 2.1 µm).

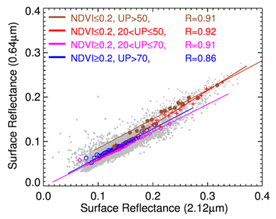
$$R_{VIS} = f(R_{SWIR}, Angles, NDVI_{SWIR})$$

- Over brighter and more variable surfaces (e.g. urban), the assumed VIS/SWIR relationship breaks down.
- Here, we use MODIS Land surface product ("MOD09", Vermote et al.) to derive a new VIS/SWIR surface relationship for urban areas where urban percentage is greater than 20% (MCD12). Using data from the US, from 2010-2011, we derive:

$$R_{VIS} = f(R_{SWIR}, Angles, NDVI_{SWIR}, Urban\%)$$

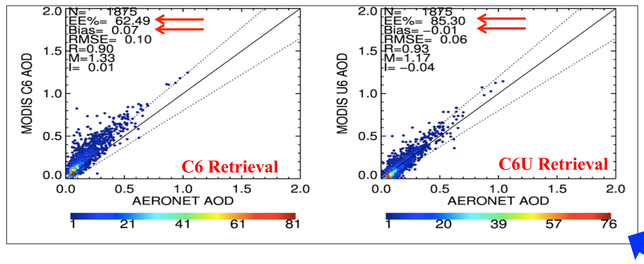
R: Surface Reflectance, UP or Urban %: Urban Percentage from MODIS land classification product.



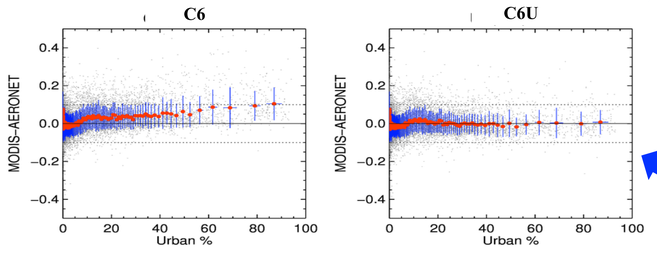


Inter-Comparison with AERONET

Over AERONET with Urban >20%

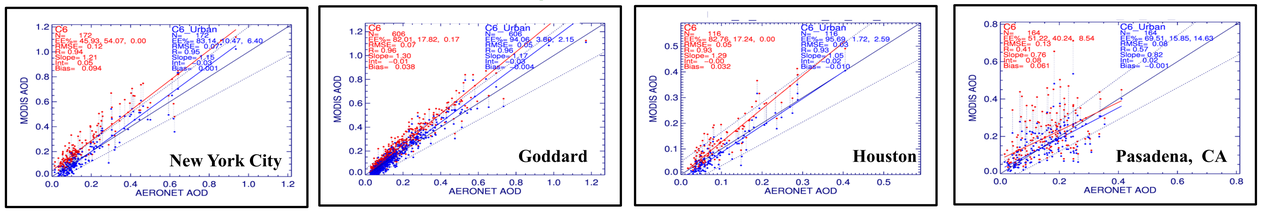


- MDT (C6) and new C6U compared to AERONET (USA, AQUA-MODIS, 2003-2012).
- All comparisons are made at λ =0.55 µm
- For Quality Confidence flag (QC ≥ 1)
- "Expected Error" (EE) envelope is ±(0.05 + 15%).
- EE % refers to percentage of retrievals falling within EE
- Note that "urban" retrieval applied when urban % ≥ 20%.

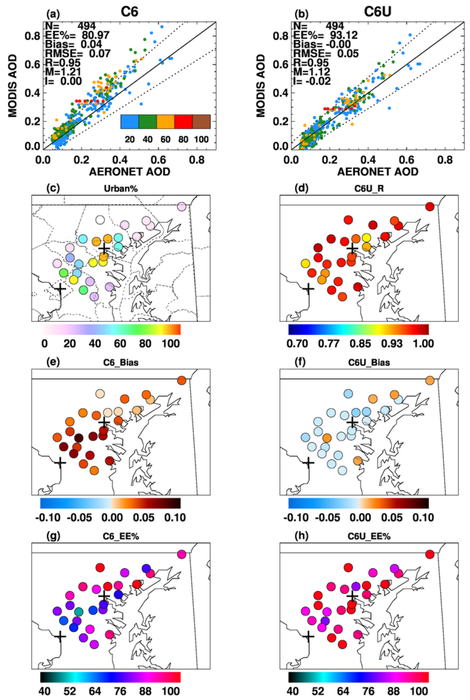


- Inter-comparison over all the AERONET sites in USA located in urban area. MDT retrievals with highest quality flag and urban % >20 % are considered in the comparison. The new retrieval (C6U) removes some of the high bias and produced more AOD retrieval within EE%.
- The C6 retrieved AODs show increase in bias as a function of urban %, which is corrected in C6U retrieved AODs over urban areas.

Comparison over Individual Sites

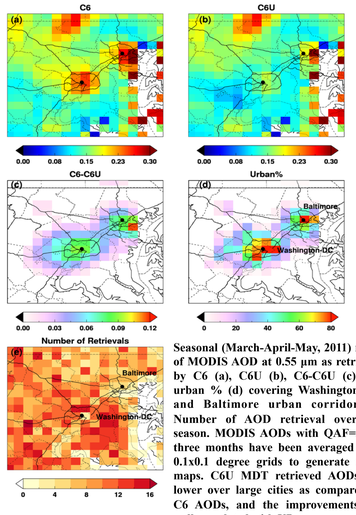


DISCOVER-AQ, Baltimore-DC Corridor



Inter-comparison statistics of MODIS-AERONET AODs over DRAGON network during DISCOVER-AQ field campaign (Jun-July 2011) in the Washington DC – Baltimore area. This analysis used data from AERONET stations operated as part of DRAGON network. Scatter plot between AERONET and MODIS for C6 (a), C6U (b), and each collocated point is color coded with UP corresponding to AERONET site. Other statistical parameter for each AERONET stations are mapped in following order: c) Linear correlation coefficient (R) for C6 and UP, d) R for C6U, e) mean bias in C6 AODs, f) mean bias in C6U AODs, g) EE% from C6, and h) EE% from C6U.

Spatial Distribution of Aerosols over Baltimore-DC Corridor



Seasonal (March-April-May, 2011) maps of MODIS AOD at 0.55 µm as retrieved by C6 (a), C6U (b), C6-C6U (c) and urban % (d) covering Washington DC and Baltimore urban corridor (e) Number of AOD retrieval over the season. MODIS AODs with QAF=3 for three months have been averaged over 0.1x0.1 degree grids to generate these maps. C6U MDT retrieved AODs are lower over large cities as compared to C6 AODs, and the improvements are well correlated with UP.

C6 show elevated AODs near cities as compared to C6_Urban.

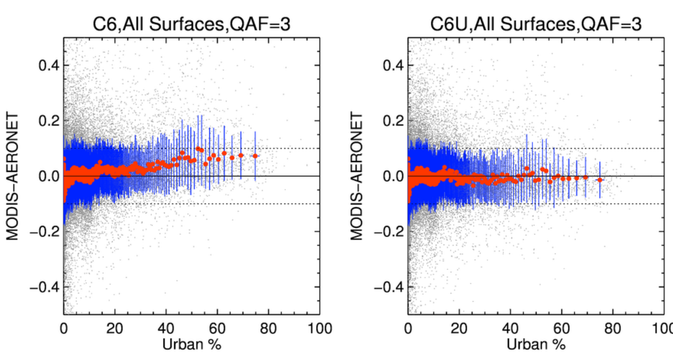
Summary Statistics

			R		Bias		EE%	
Data Set	QAF	N	C6	U6 Urban	C6	U6 Urban	C6	U6 Urban
All	1	723	0.67	0.74	0.114	0.072	38.8	52.6
	1, 2	6415	0.73	0.78	0.106	0.067	41.9	56.4
	1, 2, 3	21842	0.80	0.83	0.051	0.029	65.0	72.5
	2, 3	18995	0.81	0.84	0.041	0.020	69.1	76.0
	3	14402	0.85	0.86	0.022	0.006	77.1	81.1
Urban % >0.0	1	295	0.63	0.74	0.171	0.084	27.3	55.0
	1, 2	3269	0.68	0.77	0.141	0.070	31.3	57.5
	1, 2, 3	11258	0.78	0.84	0.071	0.028	59.1	74.6
	2, 3	9455	0.79	0.85	0.062	0.020	63.8	78.1
	3	6300	0.88	0.90	0.036	0.002	75.2	85.2
Urban % >20.0	1	109	0.50	0.59	0.259	0.105	15.5	49.5
	1, 2	1406	0.65	0.73	0.205	0.083	16.6	52.0
	1, 2, 3	4301	0.75	0.83	0.128	0.032	37.4	73.2
	2, 3	3451	0.78	0.85	0.115	0.021	42.2	76.8
	3	1875	0.90	0.93	0.075	-0.007	58.6	85.3

- ALL: Considering all AOD retrieval irrespective of surface type.
- Urban >0%: Considering AOD retrieval only over urban surfaces.
- Urban >20%: Considering AOD retrieval only over urban surfaces with urban % larger than 20%. This where C6_Urban algorithm has been applied.

Significant improvement in bias and EE% have been observed for all the quality flags and correlation show more improvement for lower quality AOD retrievals (QA=1,2).

Global Implementation & Challenges



References

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Munchak, L. A., Levy, R. C., Mattoo, S., Remer, L. A., Holben, B. N., Schafer, J. S., Hostetler, C. A., and Ferrare, R. A.: MODIS 3 km aerosol product: applications over land in an urban/suburban region, Atmos. Meas. Tech., 6, 1747–1759, 2013.

Summary

- MODIS land surface reflectance and land cover classification data sets have been used to define a VIS/SWIR surface reflectance relationship to be used over urban surfaces (urban percentage > 20%). The standard C6 MODIS Dark-Target surface reflectance relationship was replaced.
- The C6_Urban algorithm was applied to MODIS-Aqua data from 2003-2012 over the U.S.
- Reduced AOD is seen over urban areas in C6_Urban as compared to C6 retrieval. Compared to AERONET observations, these new retrievals reduced the bias by about 50% and increased the number retrievals within EE%.

pawan.gupta@nasa.gov