Aerosol Retrieval over Urban Area in MODIS Dark Target Land Algorithm

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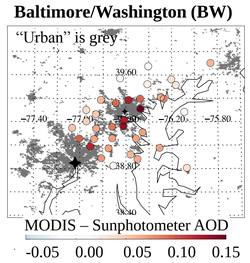
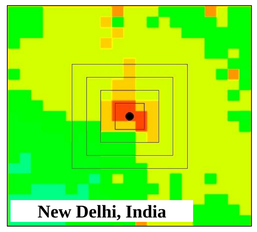
Introduction

- 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).

Baltimore/Washington (BW)



Elevated AOD over Mega City



Approach

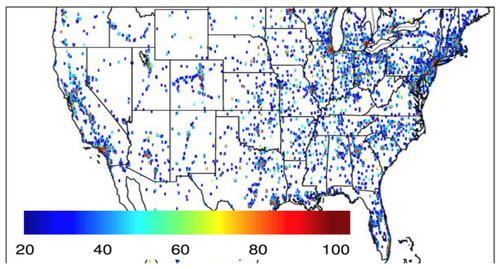
- MDT assumes a relationship between the visible (VIS) and shortwave-IR (SWIR) surface reflectance, based on statistics of dark-target (primarily vegetated) surfaces. $NDVI_{SWIR}$ is Normalized Difference Vegetation Index (1.24, 2.1 µm).

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

- 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:

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

Urban % at 0.1°

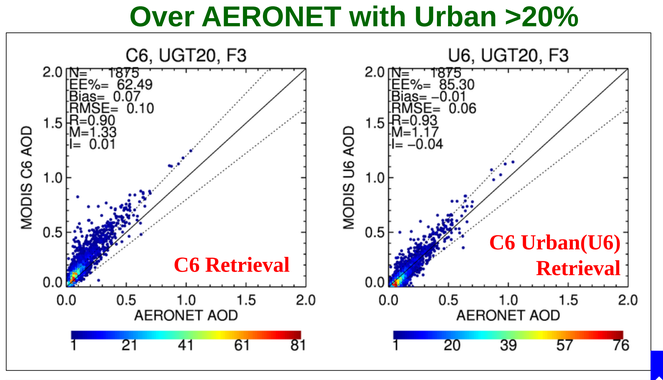


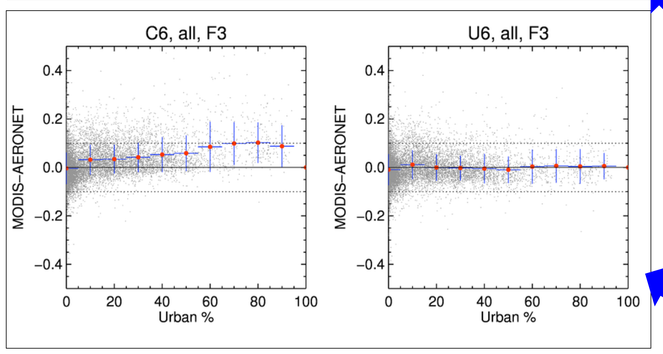
Surface Type	NDVI <0.2 & UP > 50		NDVI<0.2 & 20<UP<50		NDVI>0.2 & 20<UP<70		NDVI >0.2 & UP > 70	
→	M	I	M	I	M	I	M	I
$R_{red} = M*R_{nir} + I$	0.66	0.02	0.78	-0.02	0.62	0.00	0.65	0.00
$R_{blue} = M*R_{red} + I$	0.52	0.0	0.51	0.0	0.47	0.01	0.48	0.01

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

Inter-Comparison with AERONET

Over AERONET with Urban >20%

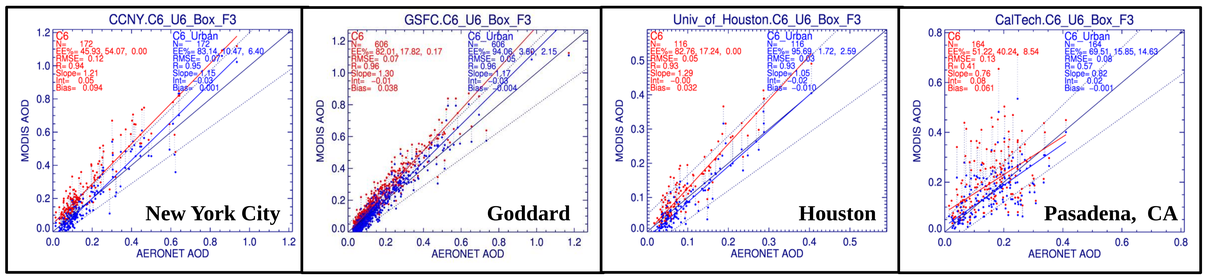




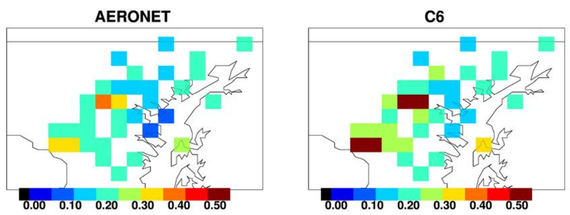
- MDT (C6) and new C6 URBAN (U6) compared to AERONET (USA, AQUA-MODIS, 2003-2012).
- All comparisons are made at λ =0.55 µm
- For Quality Confidence flag (QC ≥ 1)
- "Expected Error" (EE) envelope is ±(0.05 + 15%).
- EE % refers to percentage of retrievals falling within EE
- Note that "urban" retrieval applied when urban % ≥ 20%.

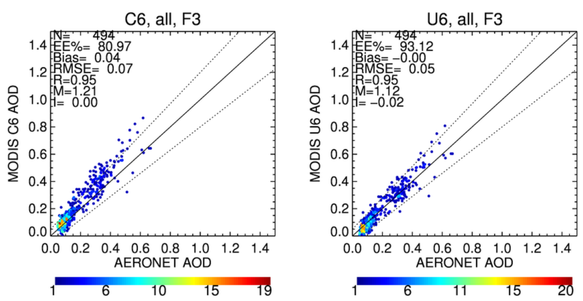
- F3: Quality Flag =3, UGT20: Urban > 20%
- Inter-comparison over all the AERONET sites in USA located in urban area. MDT retrievals with highest quality flag and urban % >20 % are considered in the comparison. The new retrieval (U6) removes some of the high bias and produced more AOD retrieval within EE%.
- The C6 retrieved AODs show increase in bias as a function of urban %, which is corrected in U6 retrieved AODs over urban areas.

Comparison over Individual Sites



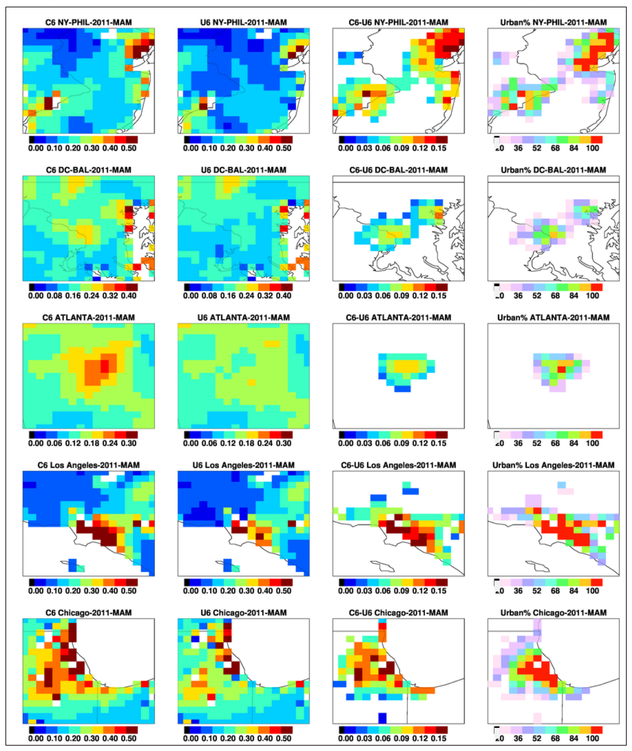
DISCOVER-AQ, Baltimore-DC Corridor



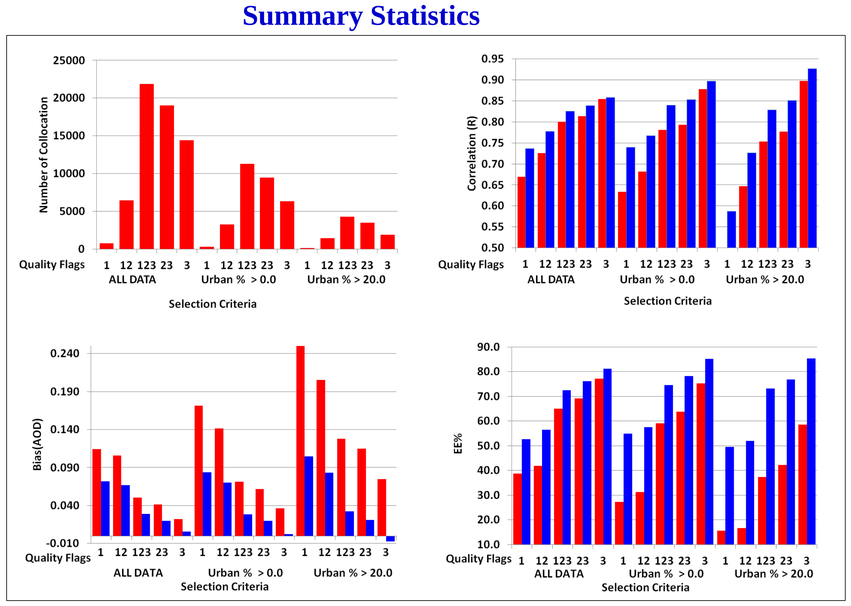


- Maps show time (June-July 2011) averaged AODs during Baltimore-DC DISCOVER AQ field campaign over AERONET DRAGON network. C6 show elevated AODs near cities as compared to U6. The scatter plot represents comparison of C6 and U6 with AERONET AODs.

Spatial Distribution of Aerosols over Large Cites



Summary Statistics



- 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 U6 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).

References

Levy, R. C., Mattoo, S., Munchak, L. A., Remer, L. A., Sayer, A. M., Patadia, F., and Hsu, N. C.: The Collection 6 MODIS aerosol products over land and ocean, Atmos. Meas. Tech., 6, 2989-3034, doi:10.5194/amt-6-2989-2013, 2013.

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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 U6 algorithm was applied to MODIS-Aqua data from 2003-2012 over the U.S.
- Reduced AOD is seen over urban areas in U6 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%.

Ongoing/Future Work

- Evaluating the urban surface relationship over other parts of the world and testing the retrieval over AERONET sites.
- Exploring the idea of optimizing surface characterization to work over global regions.
- Exploring impacts of new AOD retrieval on regional and global studies of air quality, PM2.5 and health.

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