Statistical Study of MODIS Algorithms in Estimating Aerosol Optical Depth over the Czech Republic

A Study By: Ing. Saleem Ibrahim

Supervised By: Dr. Lena Halounová

SVK - workshop moderních technologií geomatiky, Telč 2019

Introduction

Aerosol Optical Depth (AOD)

* **AOD is a measure of the columnar atmospheric aerosol content, these particles could absorb or scatter the sunlight and prevent it reaching the ground.**

* **High concentrations of AOD may cause serious problems to our health like infect the respiratory system, lung cancer, and cardiovascular diseases.**

* **AOD led to 4 million deaths worldwide in 2016 according to the Global Burden of disease study.**

Telč 2019

Introduction

Moderate Resolution Imaging Spectroradiometer (MODIS)

* **The first satellite plan that can provide an accurate information of aerosol optical characteristics.**

* **Both the Terra and Aqua satellite platforms are carrying MODIS instrumentations in a sun-synchronous polar orbits, since the year 1999 and 2002, respectively.**

* **They are able to record earth's surface with 2330 km viewing swath width every 1 to 2 days, MODIS measures 36 spectral bands between 0.4 and 14.4 μm wavelengths at many different spatial resolutions that provides a great opportunity to study aerosols thickness.**

Telč 2019

MODIS Algorithms

* **Dark Target (DT) algorithm. There are two distinct DT algorithms for retrieving AOD, one for retrieving AOD over ocean and the second for retrieving AOD over land.**

* **Deep Blue (DB) was developed in order to retrieve AOD over bright surfaces like deserts and arid areas.**

* **The merged DT/DB algorithm (DTB). It works based on the Normalized Difference Vegetation Index (NDVI).**

Telč 2019

Data description

MODIS Collection 6.1

Product	(SDS) name	Contents	Spatial resolution
MOD04-L2 C6.1	Optical-Depth-Land-And-Ocean	DT over land (QA=3)	10 Km
	Deep-Blue-Aerosol-Optical-Depth-Land-Best-Estimate	DB over land (QA ≥2)	
	AOD-550-Dark-Target-Deep-Blue-Combined	DTB over land and ocean	

Data description

AERONET data

* The AERONET (AErosol RObotic NETwork) is one of the most common and reliable aerosol networks.
* AERONET takes observations of the solar radiation at seven wavelengths (380, 440, 500, 675, 870, 936 and 1020 nm) around every 15 minutes with low uncertainty ranging between (0.01-0.02) under cloud-free conditions.
* In this study, we present data from level 2.0 of the data quality assurance. AERONET AOD measurements at 440 μm and 675 μm from Brno Airport station during the period (June of 2017 – December of 2018).

Telč 2019

Data description

AERONET data

These observations were interpolated to 550 μm, in order to compare it with MODIS retrievals, using the Angstrom exponents (a440 – 675 μm) provided in the AERONET datasets according to the Angstrom's turbidity equation:

$$\tau_a(\lambda) = \beta\lambda^{-\alpha}$$

The AOD values at two different wavelength values λ1, λ2 are related by:

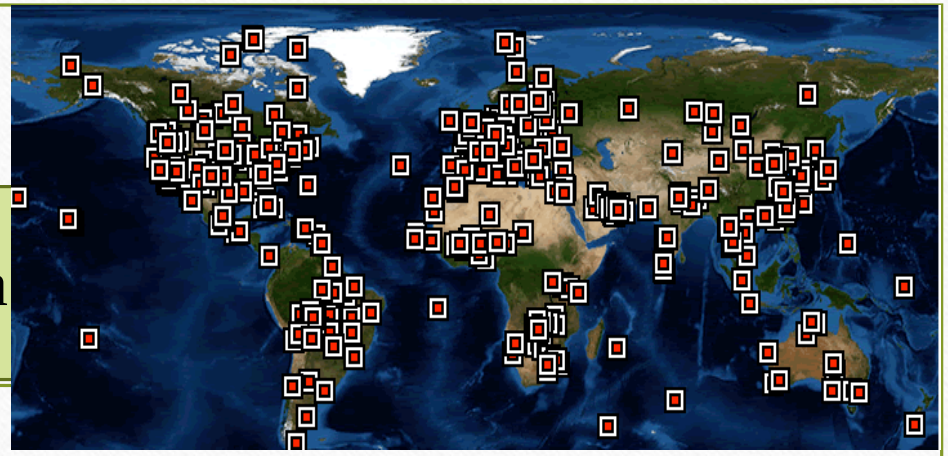
$$\tau_a(\lambda_1) = \tau_a(\lambda_2) * \left(\frac{\lambda_1}{\lambda_2}\right)^{-\alpha}$$

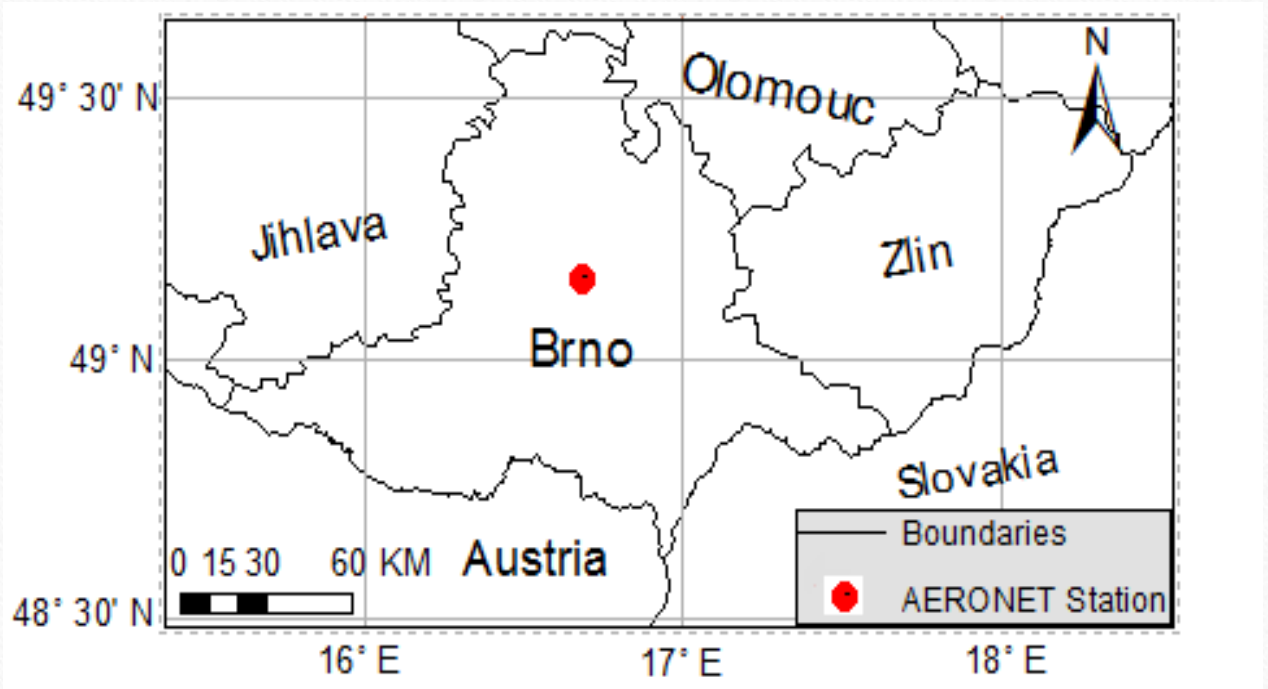
where $\tau_a(\lambda)$ is the AOD at a wavelength λ in microns, α is the Angstrom wavelength exponent, and β is the Angstrom's turbidity coefficient.

Telč 2019

Data description

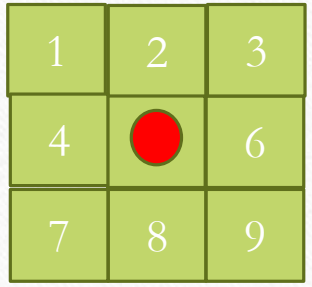
AERONET data





Methodology

The comparison takes place between the average of Brno AERONET observations in the period (± 30 minutes) of the Terra satellite passing over this station (approximately 10:30 am), and the mean value of AOD retrievals at 550 μm of nine-pixel sample centered on this AERONET station, at least three pixels should be available and have the required quality assurance, QA=2,3 for DB, and QA=3 for DT and DTB. Considering that $AOD_{AERONET}$ represents the true value.



Telč 2019

Methodology

List of equations

Root Mean Square Error: $RMSE = \sqrt{\frac{1}{N} \sum (AOD_{AERONET} - AOD_{MODIS})^2}$

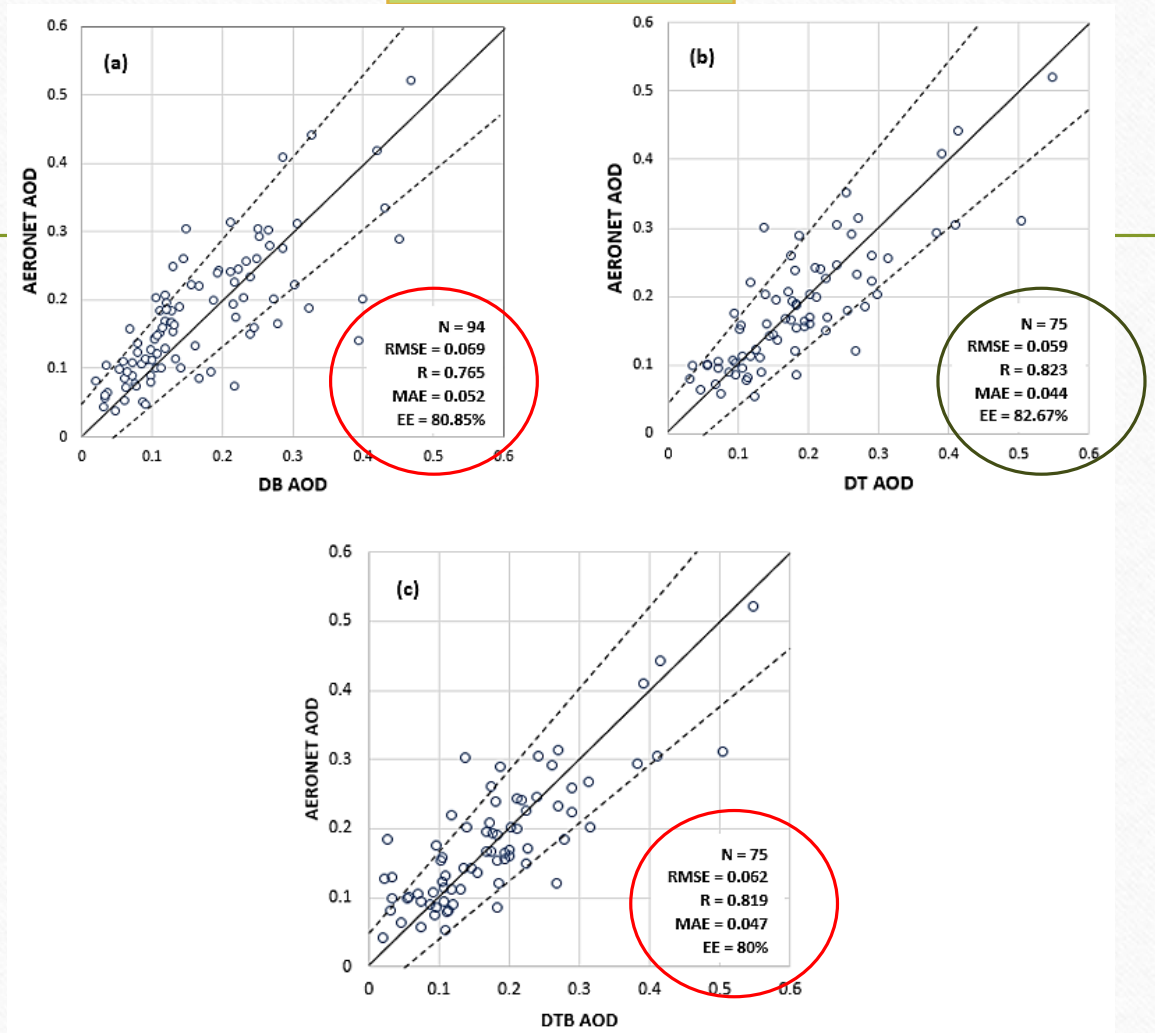
Mean Absolute Error: $MAE = \frac{1}{N} \sum | AOD_{AERONET} - AOD_{MODIS} |$

Expected Error: $EE = \pm (0.05 + 0.15 \times AOD_{AERONET})$

$AOD_{AERONET} - |EE| \leq AOD_{MODIS} \leq AOD_{AERONET} + |EE|$

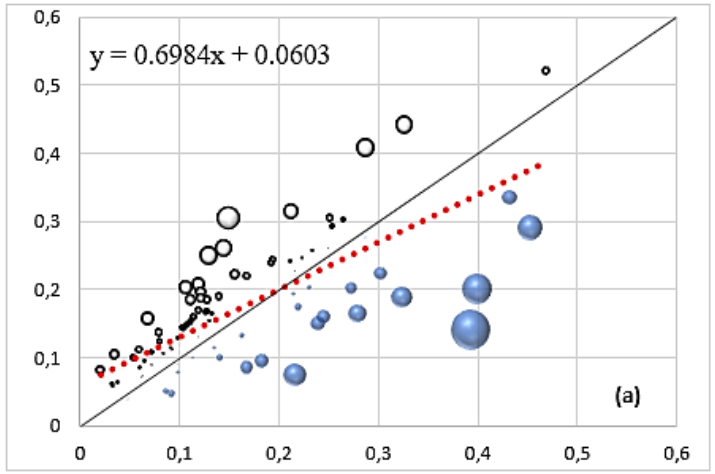
Telč 2019

Results & Discussions

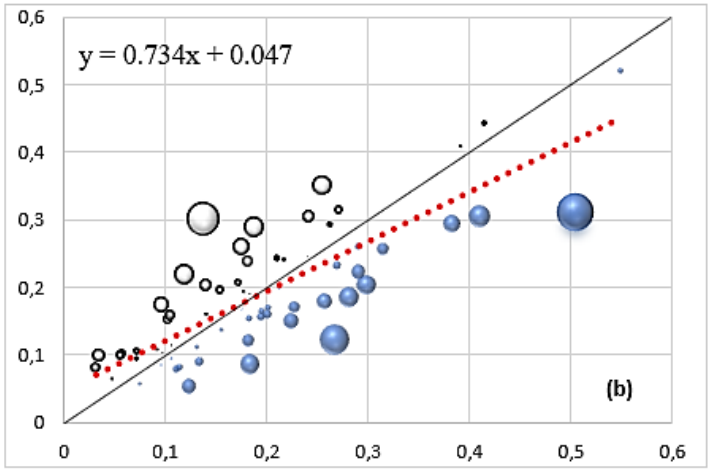


Results

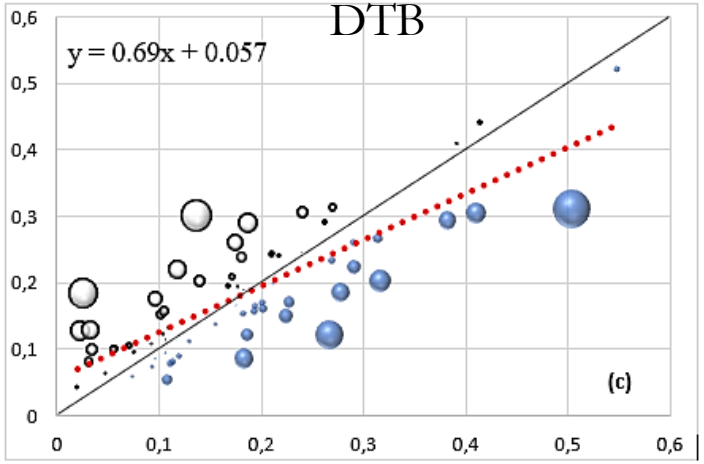
DB



DT



DTB



Summary

1. The DT algorithm gave the closest estimations to the real AOD values observed at Brno AERONET station, with a correlation coefficient (R = 0.823), root mean square error (RMSE = 0.059), and with a high percentage of retrievals falling within the EE envelope (EE = 82.67%).
2. We also found that the MODIS coverage is highly affected by NDVI, among other factors like snow and cloud density, and thus we recommend testing the coverage of the three MODIS algorithms above all the Czech Republic first and then use the results of the current study to reach an optimal methodology to estimate the AOD over the whole country.

Telč 2019

Summary

3. Using the AERONET data of 2019 when it is fully available to investigate whether a longer period influences the results of the current statistics study.

Telč 2019

Limitations

* The fact that there is only one AERONET station in the Czech Republic and Even this station was under calibration and data from three months (June – August, 2018) were missing.

Telč 2019

References

[1] Zhang, L., M. Zhang, and Y.B. Yao., 2019. Multi-Time Scale Analysis of Regional Aerosol Optical Depth Changes in National-Level Urban Agglomerations in China Using Modis Collection 6.1 Datasets from 2001 to 2017. Remote Sensing, 11(2).

[2] Kaufman, Y.J., et al., 1997. Passive remote sensing of tropospheric aerosol and atmospheric correction for the aerosol effect. Journal of Geophysical Research-Atmospheres, 102(D14): 16815-16830.

[3] Cheng, A.Y.S., M.H. Chan, and X. Yang., 2006. Study of aerosol optical thickness in Hong Kong, validation, results, and dependence on meteorological parameters. Atmospheric Environment, 40(24): 4469-4477.

[4] IPCC (2007), Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by S. Solomon et al., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[5] Poschl, U., 2005. Atmospheric aerosols: Composition, transformation, climate and health effects. Angewandte Chemie-International Edition, 44(46): 7520-7540.

[6] Remer, L.A., et al., 2005. The MODIS aerosol algorithm, products, and validation. Journal of the Atmospheric Sciences, 62(4): 947-973.

[7] Sun, L., et al., 2016. A Universal Dynamic Threshold Cloud Detection Algorithm (UDTCDA) supported by a prior surface reflectance database. Journal of Geophysical Research-Atmospheres, 121(12): 7172-7196.

[8] Tanre, D., M. Herman, and Y.J. Kaufman., 1996. Information on aerosol size distribution contained in solar reflected spectral radiances. Journal of Geophysical Research-Atmospheres, 101(D14): 19043-19060.

[9] Tanre, D., et al., 1997. Remote sensing of aerosol properties over oceans using the MODIS/EOS spectral radiances. Journal of Geophysical Research-Atmospheres, 102(D14): 16971-16988.

[10] Kaufman, Y.J., D. Tanre, and O. Boucher., 2002. A satellite view of aerosols in the climate system. Nature, 419(6903): 215-223.

References

[11] Li, Z., et al., 2009. Uncertainties in satellite remote sensing of aerosols and impact on monitoring its long-term trend: a review and perspective. Annales Geophysicae, 27(7): 2755-2770.

[12] Bilal, M., et al., 2013. A Simplified high resolution MODIS Aerosol Retrieval Algorithm (SARA) for use over mixed surfaces. Remote Sensing of Environment, 136: 135-145.

[13] Wei, J., et al., 2019. MODIS Collection 6.1 aerosol optical depth products over land and ocean: validation and comparison. Atmospheric Environment, 201: 428-440.

[14] Jeong, M.J., et al., 2011. Impacts of Cross-Platform Vicarious Calibration on the Deep Blue Aerosol Retrievals for Moderate Resolution Imaging Spectroradiometer Aboard Terra. Ieee Transactions on Geoscience and Remote Sensing, 49(12): 4877-4888.

[15] Sayer, A.M., et al., 2014. MODIS Collection 6 aerosol products: Comparison between Aqua's e-Deep Blue, Dark Target, and "merged" data sets, and usage recommendations. Journal of Geophysical Research-Atmospheres, 119(24): 13965-13989.

[16] Levy, R.C., et al., 2010. Global evaluation of the Collection 5 MODIS dark-target aerosol products over land. Atmospheric Chemistry and Physics, 10(21): 10399-10420.

[17] King, M.D., et al., 2013. Spatial and Temporal Distribution of Clouds Observed by MODIS Onboard the Terra and Aqua Satellites. Ieee Transactions on Geoscience and Remote Sensing, 51(7): 3826-3852.

[18] Gupta, P., et al., 2016. A surface reflectance scheme for retrieving aerosol optical depth over urban surfaces in MODIS Dark Target retrieval algorithm. Atmospheric Measurement Techniques, 9(7): 3293-3308.

[19] Levy, R.C., et al., 2013. The Collection 6 MODIS aerosol products over land and ocean. Atmospheric Measurement Techniques, 6(11): 2989-3034.

[20] Hsu, N.C., et al., 2006. Deep blue retrievals of Asian aerosol properties during ACE-Asia. Ieee Transactions on Geoscience and Remote Sensing, 44(11): 3180-3195.

References

[20] Hsu, N.C., et al., 2006. Deep blue retrievals of Asian aerosol properties during ACE-Asia. Ieee Transactions on Geoscience and Remote Sensing, 44(11): 3180-3195.

[21] Hsu, N.C., et al., 2004. Aerosol properties over bright-reflecting source regions. Ieee Transactions on Geoscience and Remote Sensing, 42(3): 557-569.

[22] Chu, D.A., et al., 2002. Validation of MODIS aerosol optical depth retrieval over land. Geophysical Research Letters, 29(12).

[23] Remer, L.A., et al., 2002. Validation of MODIS aerosol retrieval over ocean. Geophysical Research Letters, 29(12).

[24] Holben, B.N., et al., 1998. AERONET - A federated instrument network and data archive for aerosol characterization. Remote Sensing of Environment, 66(1): 1-16.

[25] Holben, B.N., et al., 2001. An emerging ground-based aerosol climatology: Aerosol optical depth from AERONET. Journal of Geophysical Research-Atmospheres, 106(D11): 12067-12097.

[26] https://aeronet.gsfc.nasa.gov/.

[27] Dubovik, O., et al., 2000. Accuracy assessments of aerosol optical properties retrieved from Aerosol Robotic Network (AERONET) Sun and sky radiance measurements. Journal of Geophysical Research-Atmospheres, 105(D8): 9791-9806.

[28] Liu, Y., et al., 2004. Validation of multiangle imaging spectroradiometer (MISR) aerosol optical thickness measurements using aerosol robotic network (AERONET) observations over the contiguous United States. Journal of Geophysical Research-Atmospheres, 109(D6).

[29] Wei, J. and L. Sun, 2017. Comparison and Evaluation of Different MODIS Aerosol Optical Depth Products Over the Beijing-Tianjin-Hebei Region in China. Ieee Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 10(3): 835-844.

[30] Remer, L.A., et al., 2013. MODIS 3 km aerosol product: algorithm and global perspective. Atmospheric Measurement Techniques, 6(7): 1829-1844.