Refining aerosol optical depth retrievals over land by constructing the relationship of spectral surface reflectances through deep learning: Application to Himawari-8

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Main Objectives

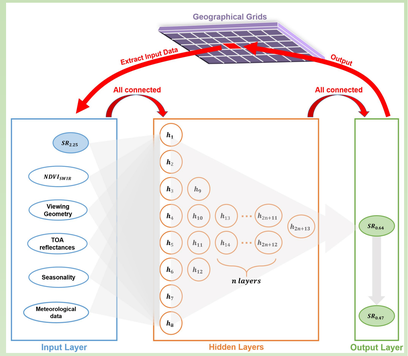
- Retrieve the AOD from Himawari-8 with relatively high accuracy and under different environmental conditions and underlying surfaces.
- Explore the application of artificial intelligence for AOD retrieval techniques from multi-spectral satellite observations.

Dark-Target Algorithm

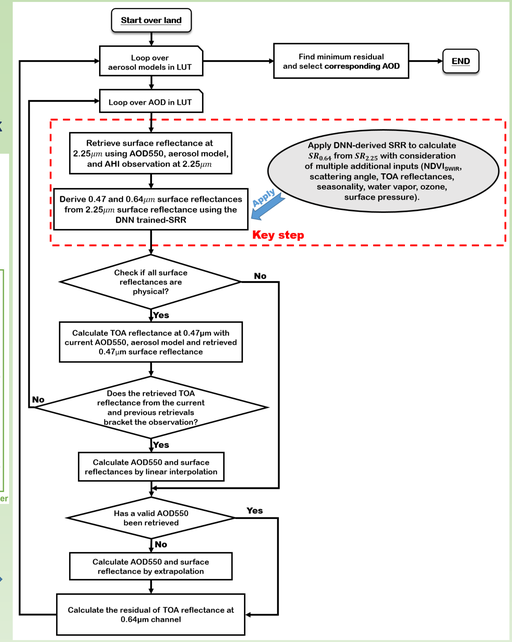
- DT (Dark-Target) is one of the most popular methods to retrieve AOD over land, and its products are widely used in numerous studies. (Levy et al., 2007)
- To retrieve AOD, there is need to estimate the contribution of the land surface to the radiation observed at TOA.
- The Dark-Target method estimates this contribution (simultaneously with AOD) using pre-determined relationships between surface reflectances in three spectral bands.
- The pre-determined surface reflectance relationships are strongly subjected to entangled factors, such as scattering angle, vegetation state, liquid water absorption, chlorophyll, etc.
- Traditional linear regressions of surface reflectance relationships usually lead to relationships characterized by large standard deviation, which in turn serves as one of the major sources of uncertainties in AOD retrievals.

Dark-target – Deep-learning (DTDL) algorithm

Diagram describing the deep neural network

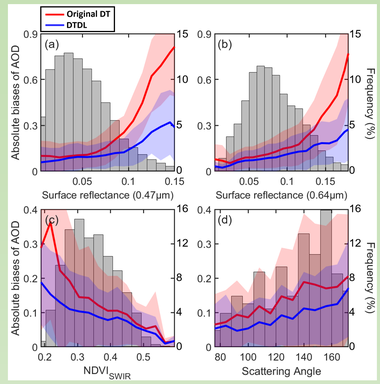


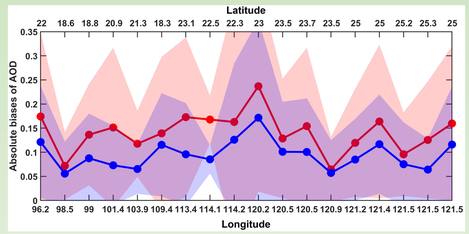
Flowchart of the DTDL algorithm



Biases related to various factors

Absolute biases of AOD retrievals under different conditions





Spectral surface reflectance relationships (SRR)

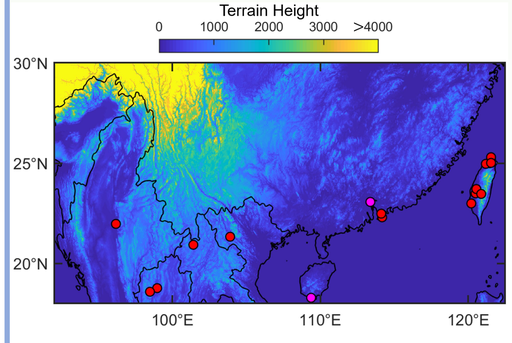
- **Specifications**

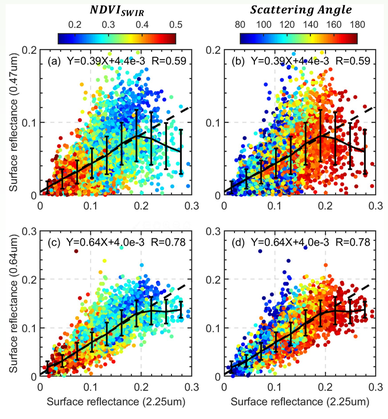
	Band #	Central wavelength (μm)	Spatial resolution (km)
Visible	#1	0.47	1
	#2	0.51	
	#3	0.64	0.5
Near-infrared	#4	0.86	1
	#5	1.6	2
	#6	2.3	
Infrared	#7	3.9	
	#8	6.2	
	#9	6.9	
	#10	7.3	
	#11	8.6	
	#12	9.6	
	#13	10.4	
	#14	11.2	
	#15	12.4	
	#16	13.3	

Based on the TOA reflectances from AHI, we can derive the spectral surface reflectance by using radiative transfer model with inputs of AERONET AOD. We use the data during 2017 over Eastern Asia.

$$SR_{0.64} = m + n \times SR_{2.25}$$
$$m = a + b \times \Theta;\ n = c + d \times \Theta$$
$$SR_{0.47} = 0.86 \times SR_{0.64} - 0.02$$

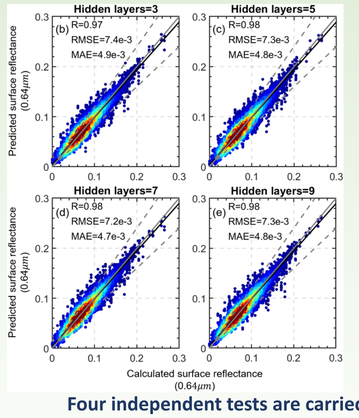
$NDVI_{SWIR}$ range	a	b	c	d
$NDVI_{SWIR} < 0.2$	-0.0416	0.00058	0.68	-0.00095
$0.2 \le NDVI_{SWIR} < 0.3$	-0.038	0.00060	0.9	-0.0036
$0.3 \le NDVI_{SWIR} < 0.4$	-0.026	0.00026	1.21	-0.0045
$0.4 \le NDVI_{SWIR} < 0.5$	-0.0147	0.000067	1.32	-0.0048
$0.5 \le NDVI_{SWIR}$	0.0077	-0.00011	0.91	-0.0019

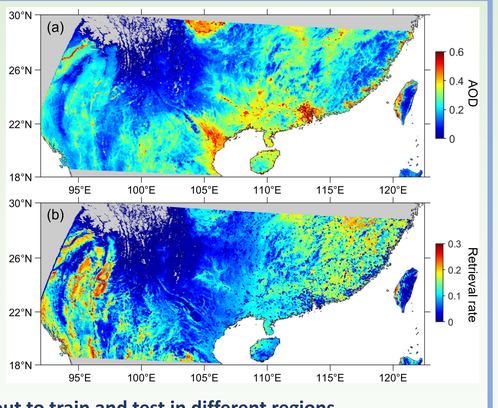




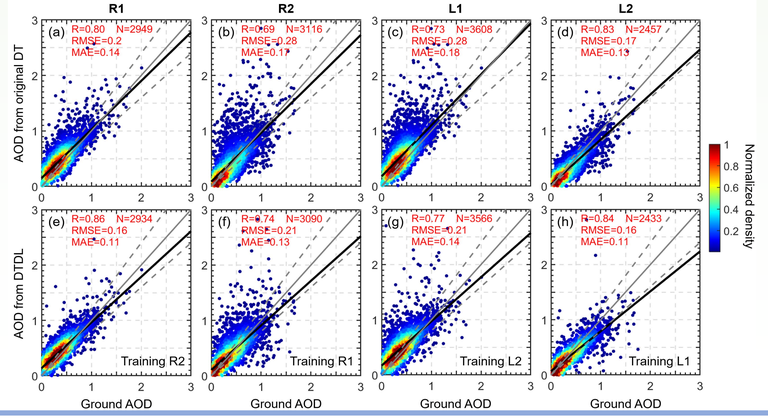
Evaluation of algorithm

- SRR derived from DNN





Four independent tests are carried out to train and test in different regions



Take home message

- A scheme is developed to construct surface reflectance relationships (SRR) through deep learning techniques.
- The AOD algorithm combines dark-target method and deep learning techniques.
- There are considerable reductions in the biases of AOD, especially for low NDVI and high surface albedo cases.
- Independent tests indicate the algorithm can be applied for untrained regions as well.

References

Levy, R.C., Remer, L.A., Mattoo, S., Vermote, E.F. and Kaufman, Y.J., 2007. Second-generation operational algorithm: Retrieval of aerosol properties over land from inversion of Moderate Resolution Imaging Spectroradiometer spectral reflectance. Journal of Geophysical Research: Atmospheres, 112(D13).

Su, T., Laszlo, I., Li, Z., Jing, W., Kalluri, S., 2020. Refining aerosol optical depth retrievals over land by constructing the relationship of spectral surface reflectances through deep learning: application to Himawari-8. Remote Sensing of Environment, 251, 112093.