CHARACTERIZING THE 2015 INDONESIA WILD FIRE EVENT USING MODIFIED MODIS AEROSOL RETRIEVALS

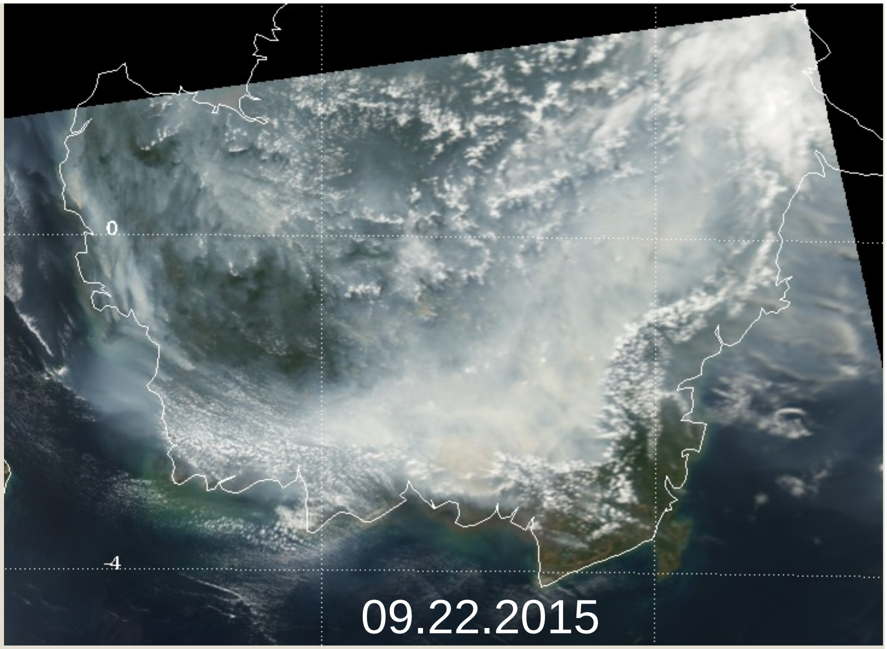
Yingxi Shi[1,2], Robert Levy[2], Shana Matoo[2,3], Lorraine Remer[4], Jianglong Zhang[5], and Ilya Slutsker[2,3]

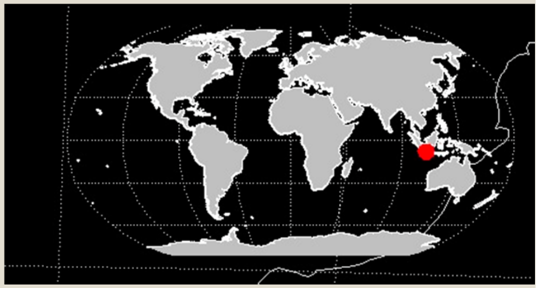
[1] GESTAR-Universities Space Research Associations,
[2] NASA Goddard Flight Center,
[3] Science Systems and Applications, Inc. Center,
[4] UMBC Joint Center for Earth Systems Technology,
[5] University of North Dakota

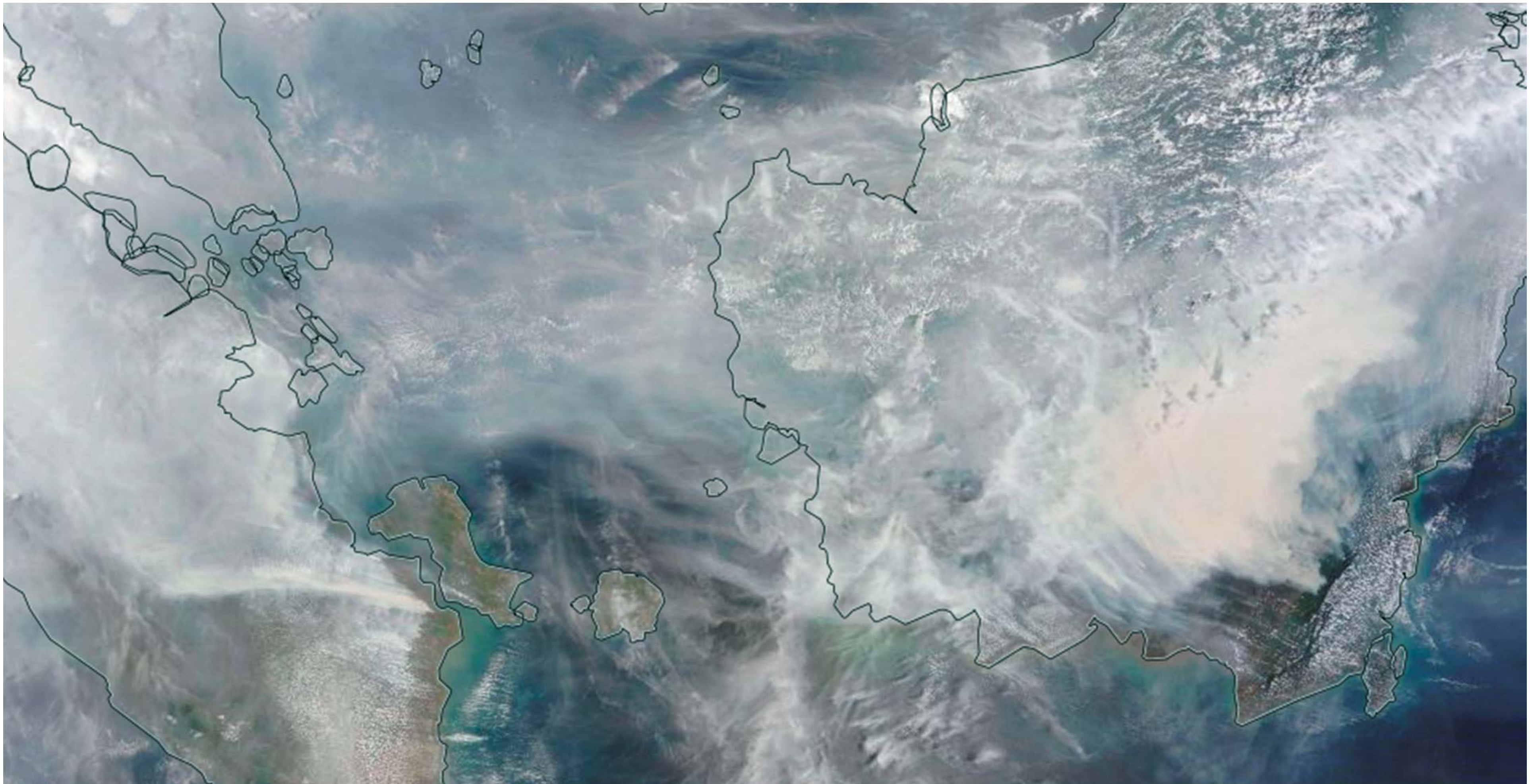
ICAP, Lille France, June 26-28, 2017

Outline

- Motivation
- Methodology
  - Case Study
  - Research Algorithm
  - Evaluation of Research Product
- Impacts of Research Product
  - Regional Aerosol Climatology
  - Influence on lower stratosphere heating rate
- Conclusion







according to satellite derived data the 2015 Indonesian fires contributed about 1750 million metric tons of carbon dioxide equivalent (half of global emissions in 2014).

The World Bank *The Cost of Fire: An Economic Analysis of Indonesia's 2015 Fire Crisis* (Indonesia Sustainable Landscape Knowledge, 2016)

Koplitz, Shannon N., et al. "Public health impacts of the severe haze in Equatorial Asia in September–October 2015: demonstration of a new framework for informing fire management strategies to reduce downwind smoke exposure." *Environmental Research Letters* 11.9 (2016): 094023.

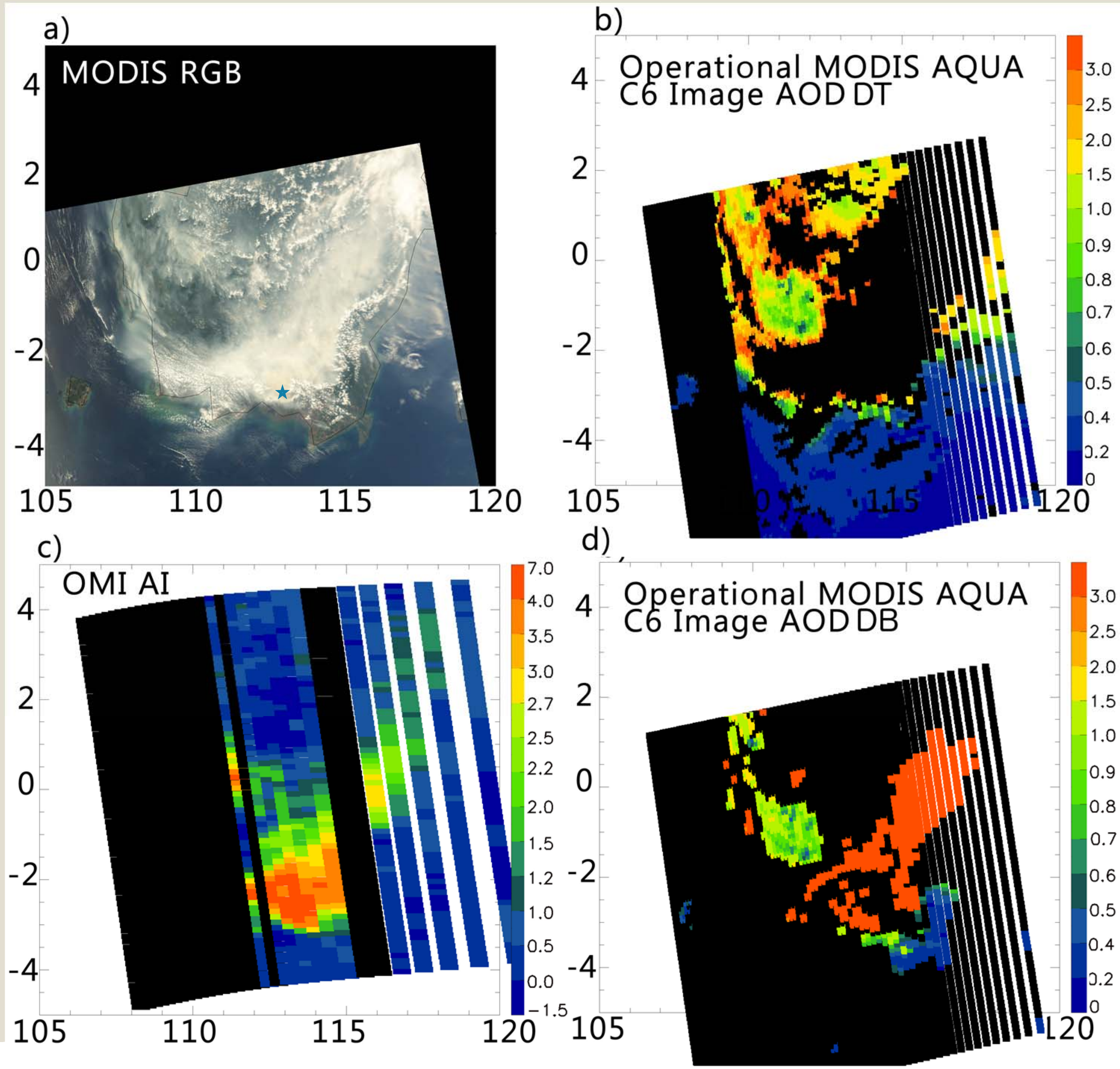
Crippa, P., et al. "Population exposure to hazardous air quality due to the 2015 fires in Equatorial Asia." *Scientific Reports* 6 (2016).

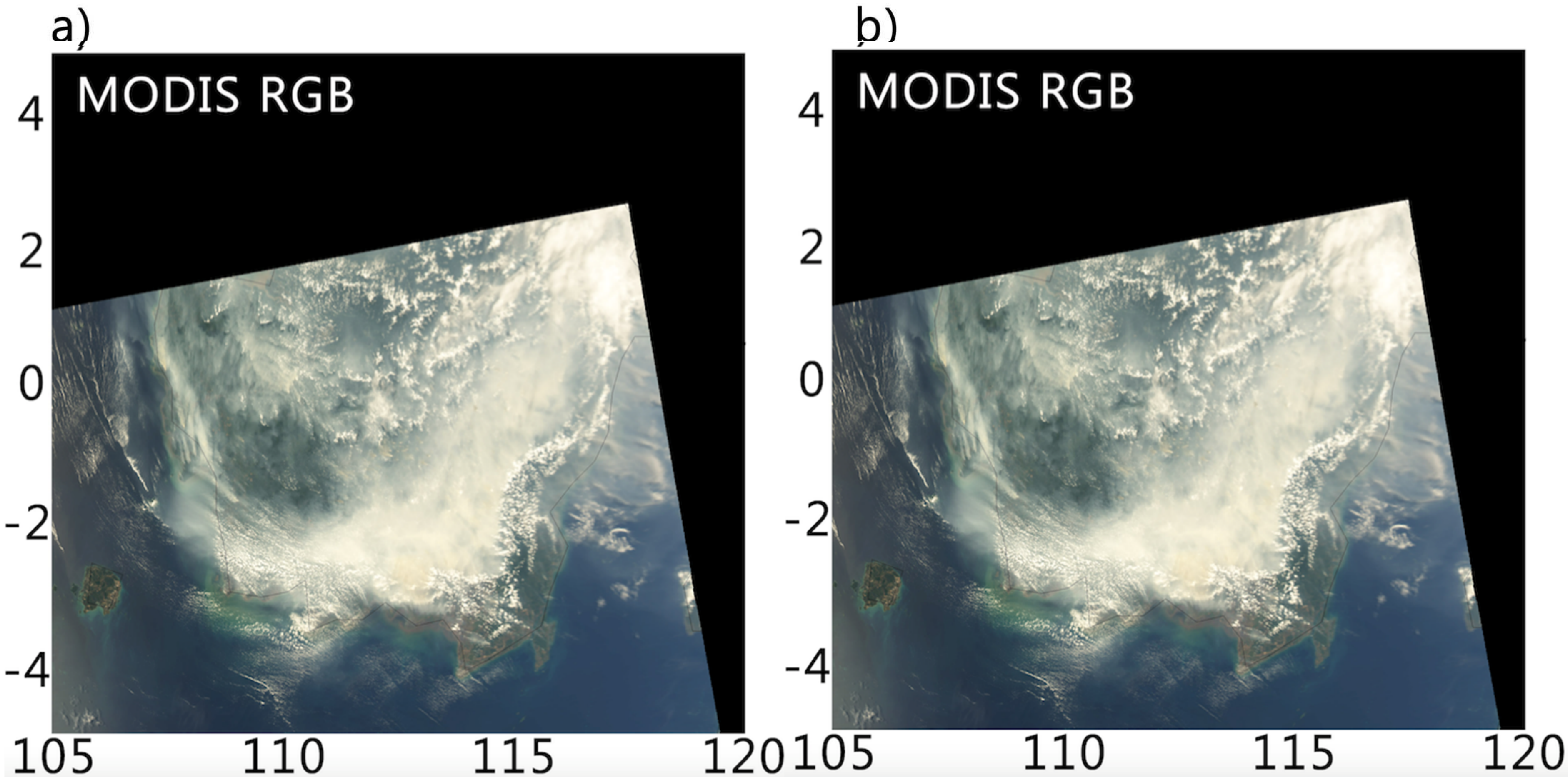
Trends in global CO2 emissions 2015 report, PBL Netherlands Environmental Assessment Agency

Case Study

09.22.2015 over Kalimantan.

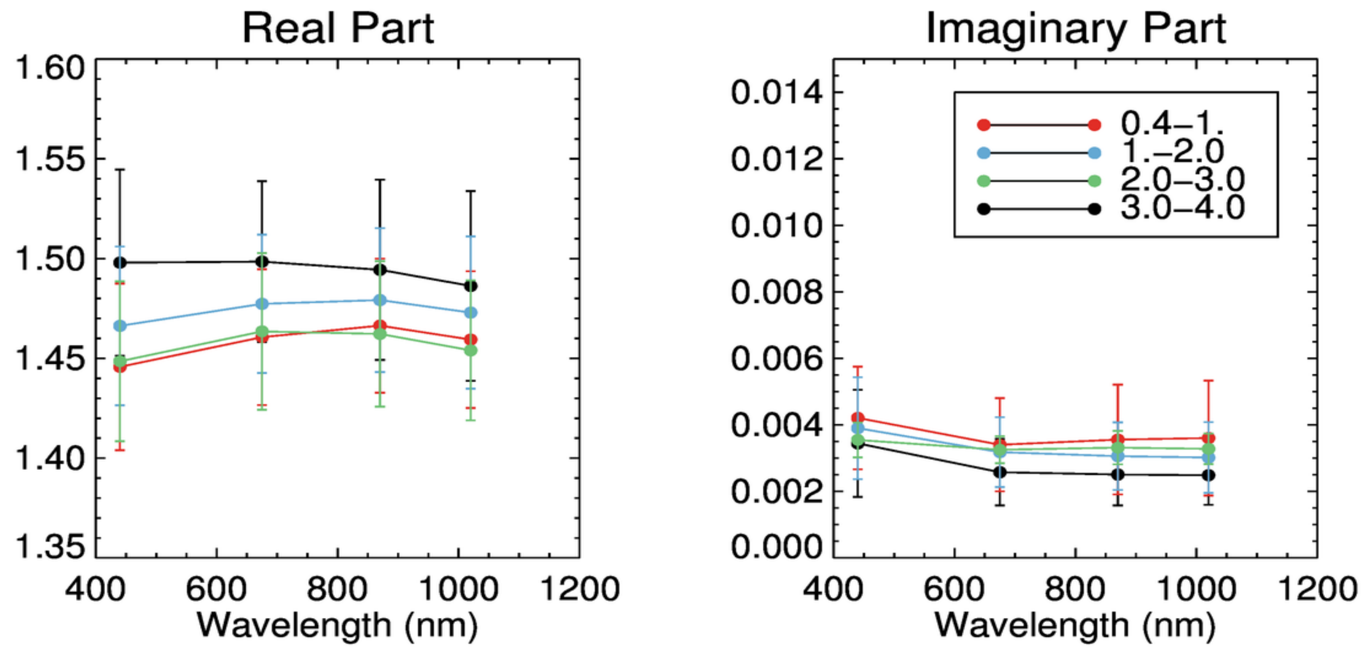
- Moderate Resolution Imaging Spectroradiometer (MODIS) C6 Dark Target (DT) and Deep Blue (DB) products both missed part of the plume.
- Ozone Monitoring Imager (OMI) UV Aerosol Index (AI) shows strong absorption.
- Aerosol Robotic Network (AERONET) Palangkaraya site recorded AOD_{500} is 5.15 and 6.7 the day before and after at 4-6 UTC.



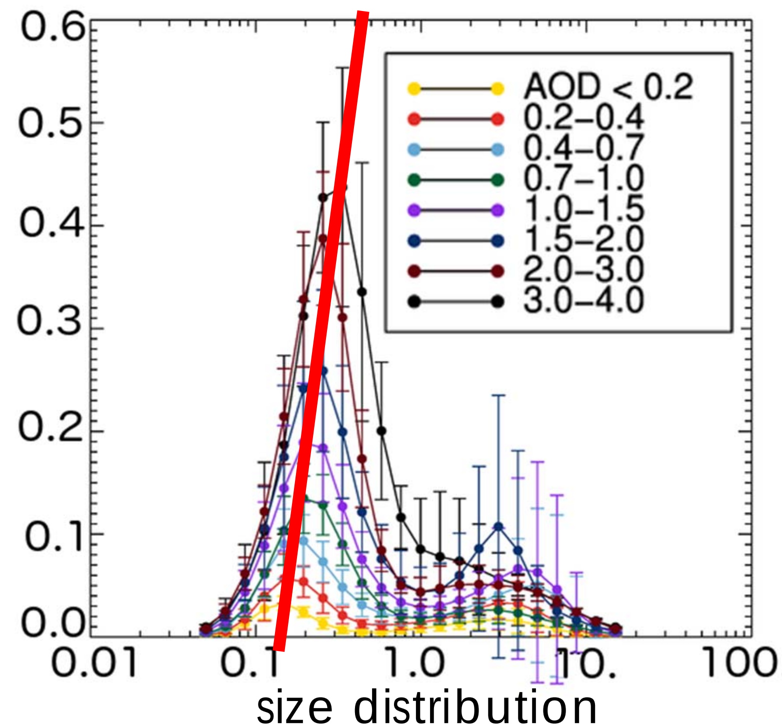


- Inland water mask (NDVI of 0.87, 0.66) < 0.1 and operational DT low cloud mask (TOA $R_{0.46}$ and the standard deviation of $R_{0.46}$) block retrievals within the center of the plume.
- Aerosol particle size are much smaller than cloud
- MODIS cloud product cloud effective radius failure metrics in 1.6, 2.1 and 3.7 micron separate aerosols from clouds

Derived Aerosol Model



- Averaged aerosol models based on AERONET inversion data from Aug. to Oct. 2015. (Jambi, Kuching, Palangkaraya, Pontianak, and Singapore)
- Size distribution is a function of AOD, which shows positive trend in particle size versus AOD.
- Refractive index is calculated using $AOD_{675} > 0.4$.

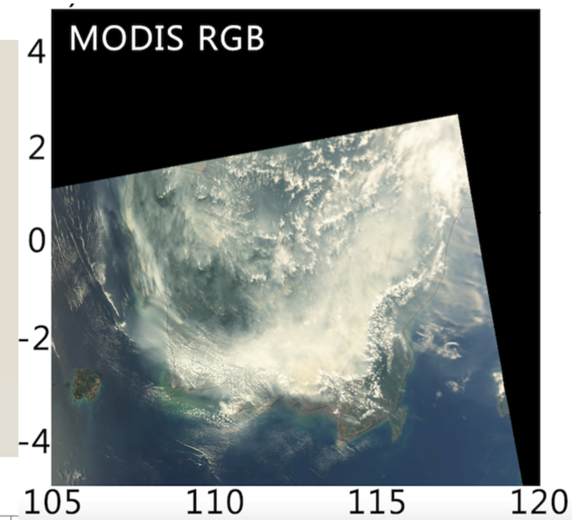


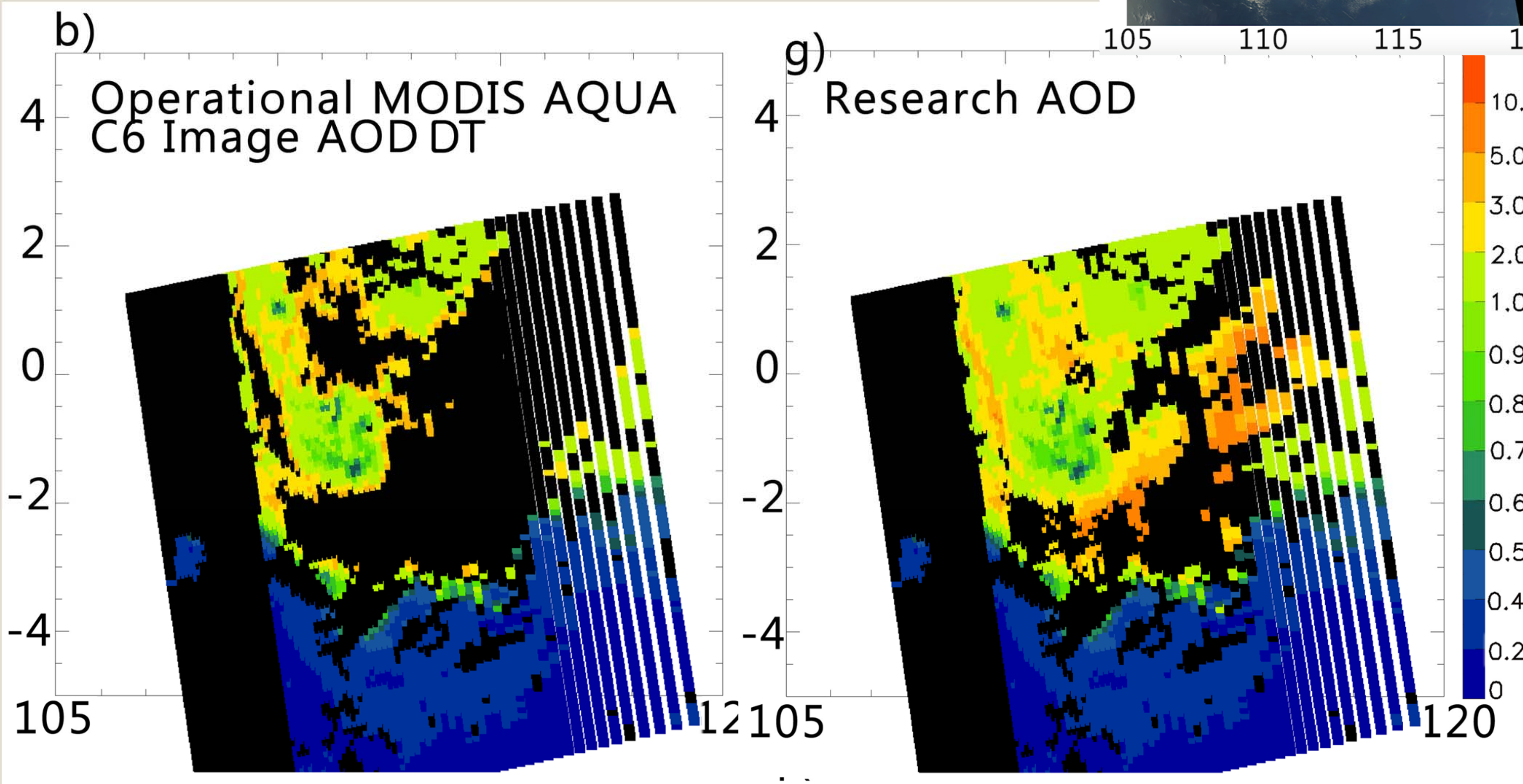
Research Algorithm

Model	R_{v}, μm	σ	V_{0}, $\mu m^3/\mu m^2$	Real part of Refractive Index	Imaginary part of Refractive Index
Moderate absorbing	$0.020\tau + 0.145$	$0.1365\tau + 0.374$	$0.1642\ \tau^{0.775}$	$1.43+0.05\tau$	$-0.002\tau-0.008$
Regional smoke	$0.047\tau + 0.160$			$1.43+0.03\tau$	$-0.00025\tau-0.0045$

- Tuned NDVI threshold from 0.1 to 0.01 to include heavy smoke
- Combined DT cloud mask with failure metrics from MODIS cloud product to "recover" the misidentified smoke.
- Removed upper AOD retrieval cap in algorithm
- Used regional AERONET derived smoke model
- This research algorithm is applied on MODIS granules Aug-Oct over Indonesia region when
  - OMI UV Aerosol Index (AI) > 2 AND
  - MODIS C6 AOD > 2.5 for at least 5 pixels.
- Total of 80 granules are selected to run the research algorithm.

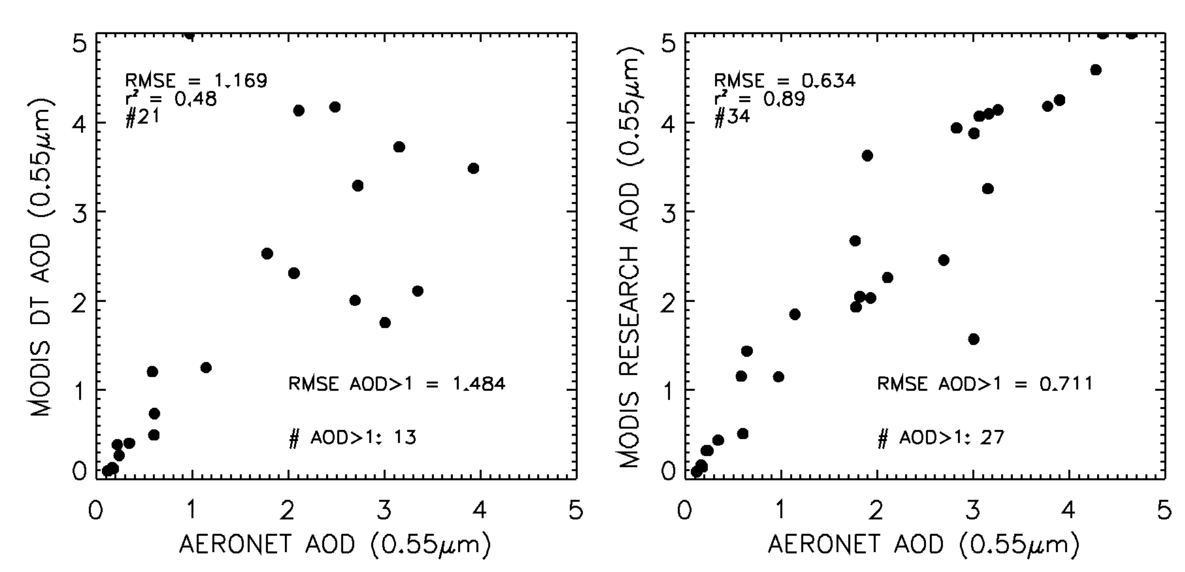
- More data retrieved **within the center of the smoke plume** and **near source regions**.
- Cloud features are identified.
- AOD values extend beyond what DT algorithm retrieves (AOD above 5.)



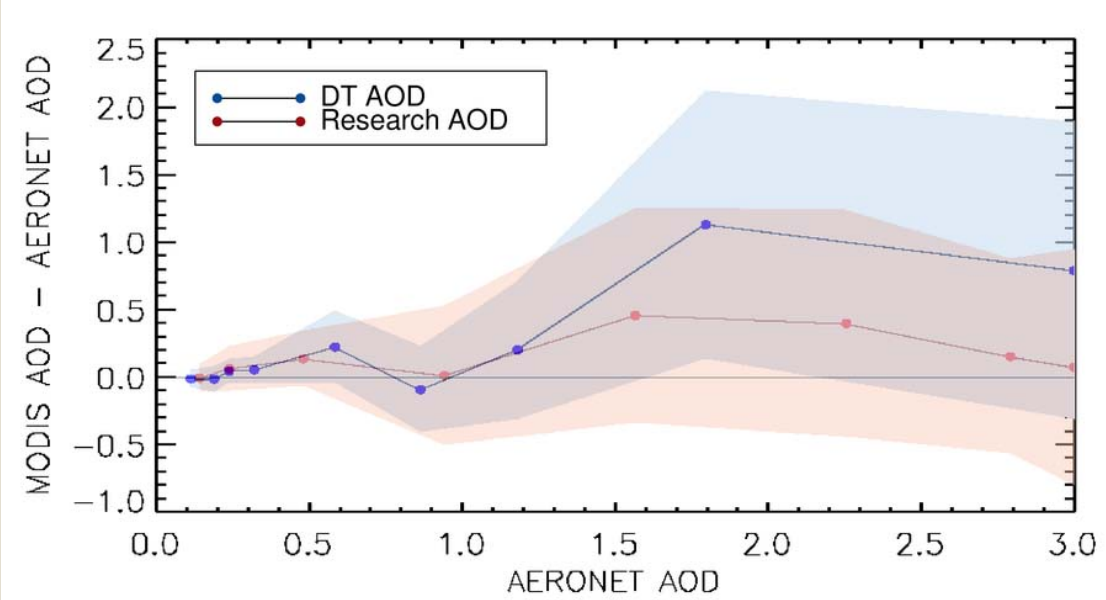


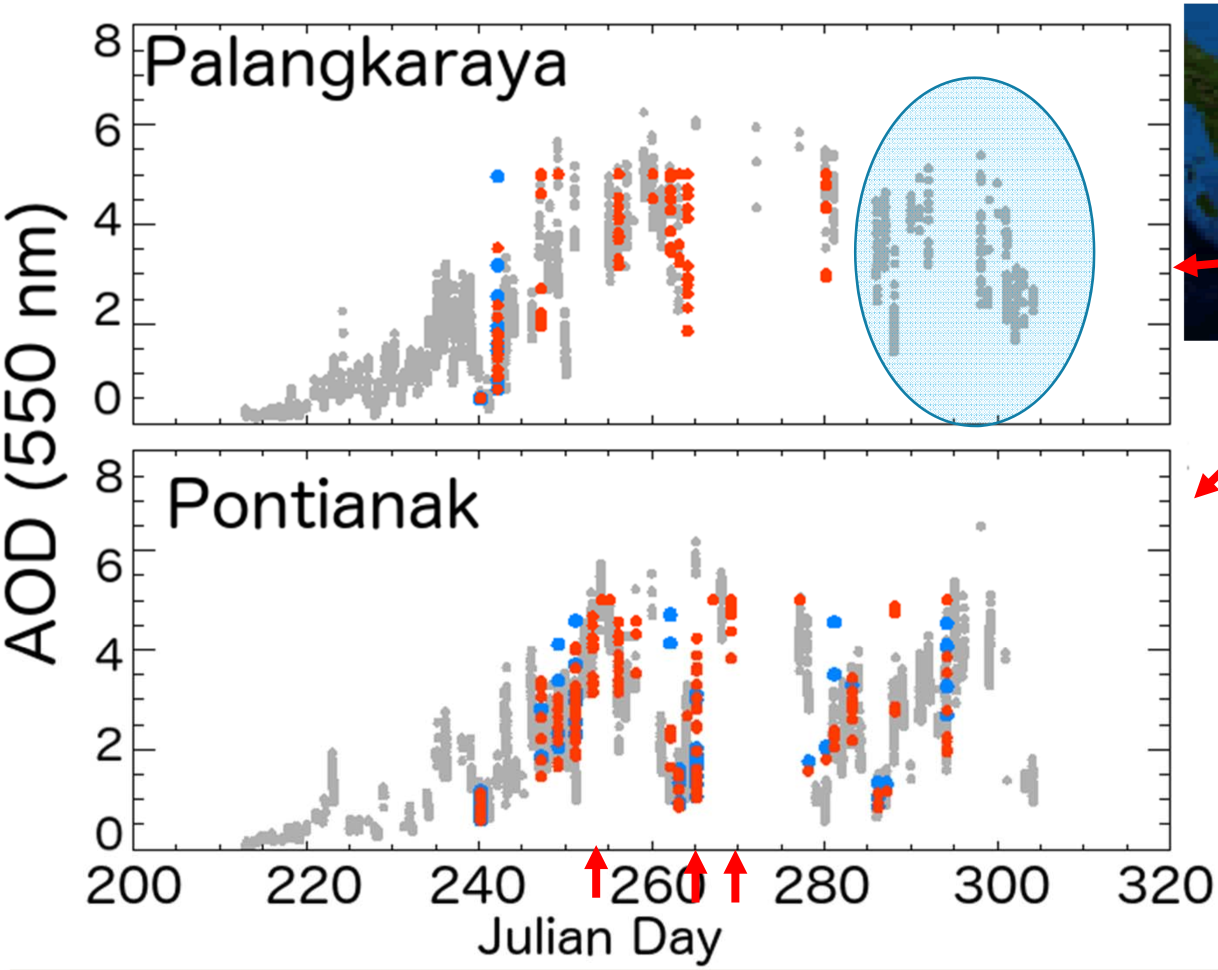
Validation

MODIS vs AERONET version 3 level 1.5 AOD Collocation: 0.3° spatial and 30 mins temporal

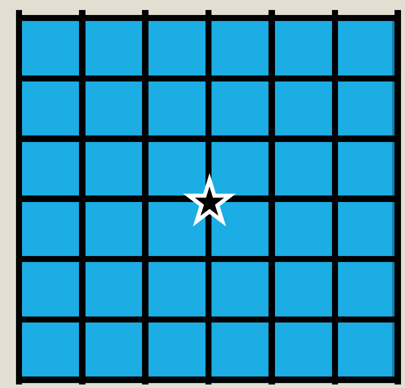


- The number of retrievals when AOD > 1 are **doubled**.
- Less scattering is found for higher AOD regime (AOD > 1) in research product.
- RMSE is reduced.
- Bias reduced to half at high AOD regime.





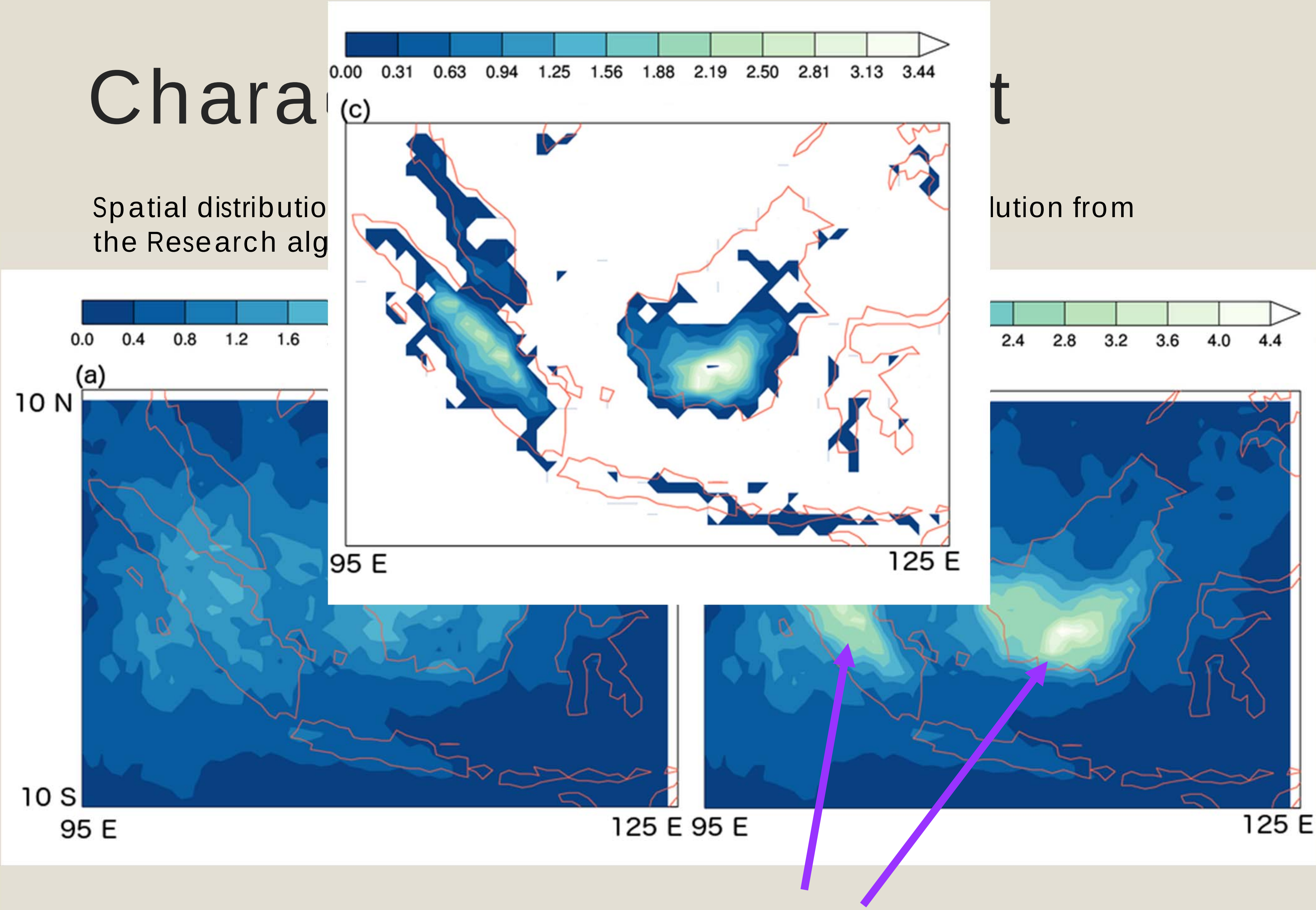
All MODIS retrievals within ±30° & ±30 mins of AERONET retrieval are included.



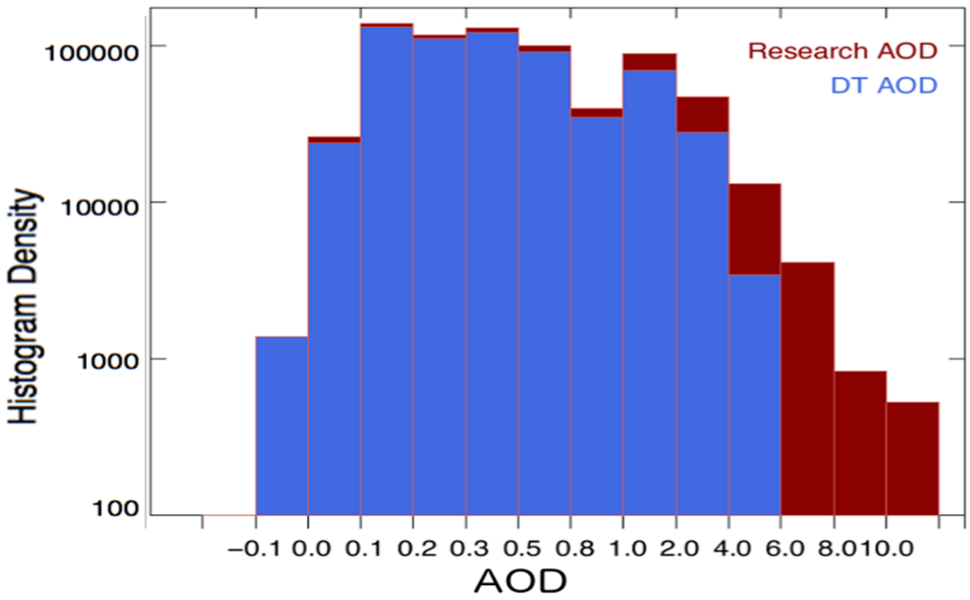
- Time series of MODIS C6 and Research AOD that collocated with AERONET versus all AERONET AOD at two AERONET sites over Indonesia regions. (AERONET, Research AOD, C6 AOD)
- The research product provides more retrievals than operational product when AERONET observes high AOD loading.
- The differences between AERONET observations and research product are due to sampling differences.

Chara t

Spatial distributio lution from
the Research alg



The differences in AOD at some regions are 2.0 to 3.5



The histogram of MODIS AOD Aug. to Oct. 2015 in a logarithmic scale.

Research product has much more data when AOD > 2.0, especially when AOD > 6.0.

- Monthly mean AOD averaged over the whole domain during the smoke season for Operational (C6) and Research algorithms are listed in the table.
- The differences in mean AOD over land are **~0.2** during Sept. and Oct.
- When compared with the C6 DT product, there is a higher frequency of large AOD occurrence in the new retrievals.

AOD	C6 Land	C6 Ocean	Research Land	Research Ocean
August	0.41	0.30	0.41	0.30
September	0.99	0.61	1.17	0.63
October	1.26	0.80	1.45	0.80

Aerosol related instantaneous SW radiative heating rate

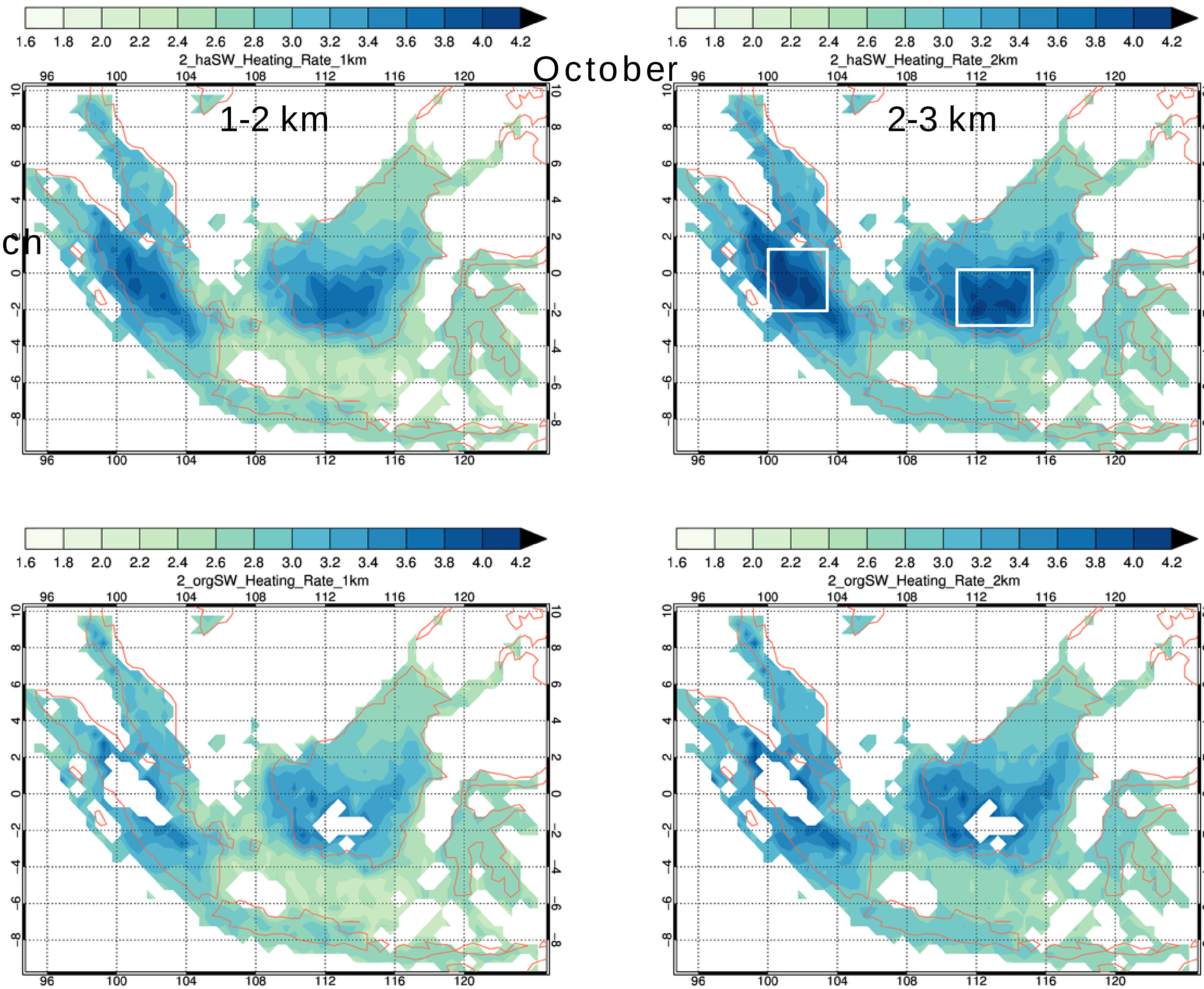
- Changing of the AOD distribution over Indonesia alters its local dynamics. Increased absorbing aerosol loading at lower stratosphere increases the local heating rate over this region.
- To estimate the influence of missing high AOD retrievals on radiation budget, we set up the Libradtran radiative transfer model (RTM) to simulate the change in broadband shortwave (SW) heating rate using this research product.
- The aerosol vertical distribution is generated from averaged CALIPSO aerosol profile Backscatter_Coefficient at 532 nm over land from Sept-Oct 2015 in Indonesia.

Libradtran Model Inputs

	Aerosol Model		Flux Calculation			
Input parameter	Refractive Index	Size Distribution	Aerosol Vertical Distribution	Solar Geometry	Atmospheric condition	Spectral Albedo
Source	AERONET Version 3 Inversion products		CALIOP / AOD from MODIS C6 operational and research products	MODIS aerosol product (MYD04)	Standard tropical profile	MODIS albedo product (MCD43GF) total albedo

- Two stream RTM solver with Lowtran molecular absorption to calculate integrated SW heating rate from 257 nm to 4 micron.
- Input aerosols are 21 total layer from 0.3 to 6.3 km every 0.3 km per layer. Output heating rate is from 0 to 5 km every 1km.
- Uncertainty Tests, total SW upward flux is compared with
  - AERONET version 3 Inversion products
  - CERES level2 Single Satellite Footprint (SSF) product after MODIS scene and cloud cleared.

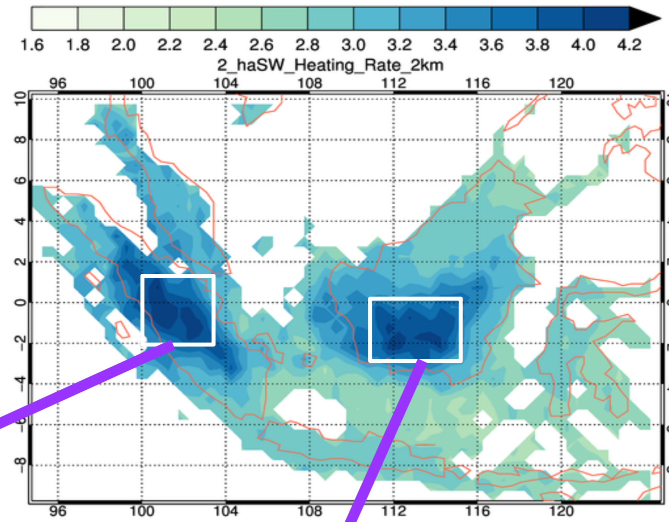
October

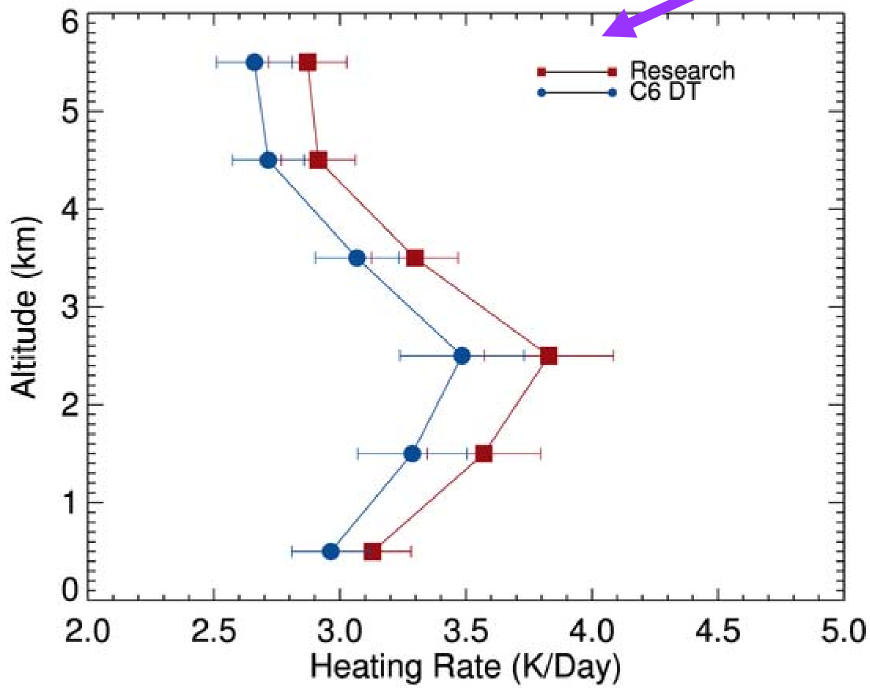


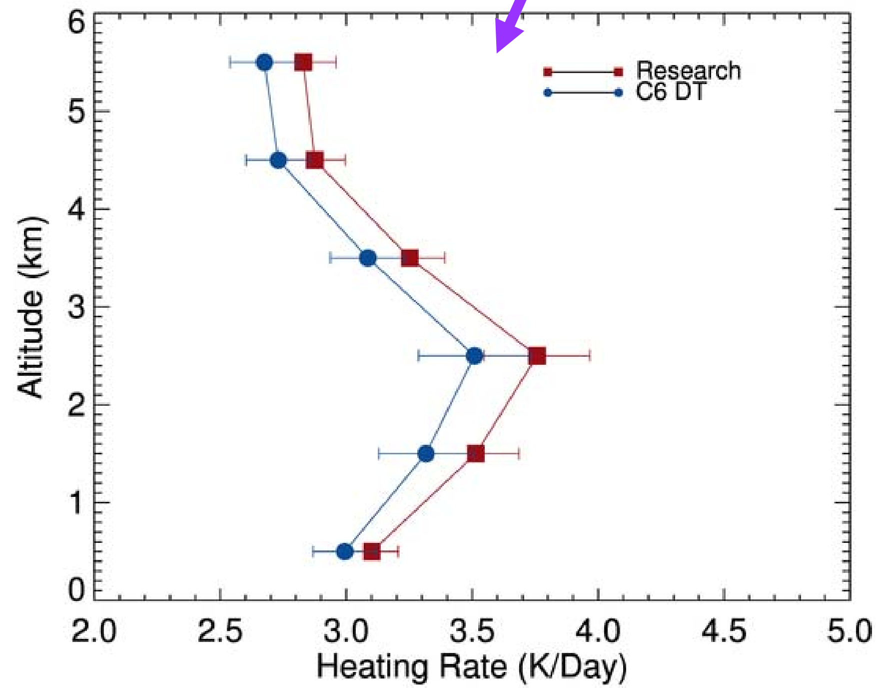
Research

C6 DT

- The largest change in heating rate occurs at 2-3 km altitude, where highest aerosol loading exist (10% to 15% change).
- The lapse rate changes as well due to the increased heating within the aerosol layer.







Conclusion

- An event based research product is generated over Indonesia region targeting the thick smoke plume during the burning season. This product is based on operational MODIS DT algorithm and utilized OMI AI.
- The research product double the number of AOD with AOD > 1 compared with the DT AOD product. The bias of AOD is reduced to half when AEONET AOD > 1.
- The research product captures the elevated instantaneous AOD that AERONET observed and provides a more complete picture of aerosol loading over the 2015 Indonesia wild fire.
- These “extra aerosols” change the regional shortwave radiative heating rate. There are regions where the instantaneous heating rate can change up to 0.4 K/day.
- This work will be extended globally over regions where optically thick aerosol plumes exist.

Thanks!

Email: Yingxi.shi@nasa.gov

MODIS DT website: https://darktarget.gsfc.nasa.gov

Aerosol vertical structure