# Aerosol Layer Height from multiple sensors

**Jun Wang**
**Xi Chen**
Chemical & Biochemical Engineering
College of Engineering
University of Iowa

**Xiaoguang Xu**

**Omar Torres**

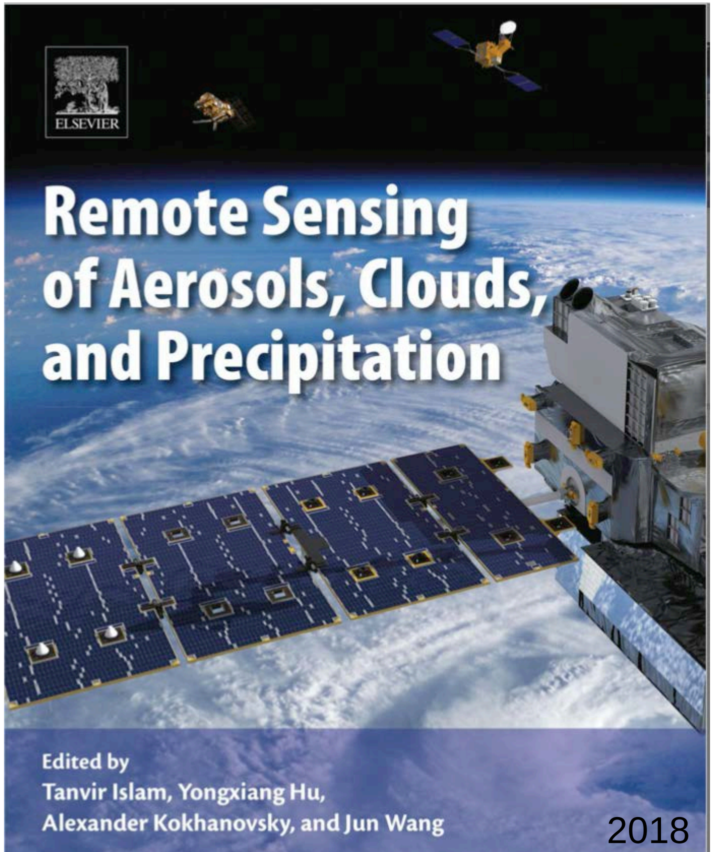
**Special thanks to:**
Folkert Boersma
Martin de Graaf
Pepijn Veefkind
Piet Stammnes
Ben Veihelmann

Jhoon Kim
Chris McLinden

Kelly Chance
David Diner
Shobha Kondragunta
Xiong Liu
Jeffrey Reid
Jay Al-Saadii
John Yorks

**CEOS Atmospheric Composition Virtual Constellation AC-VC-16**
**June 2020**

# For a literature survey, please refer to:




CHAPTER

1

## Passive Remote Sensing of Aerosol Height

*Xiaoguang Xu**, *Jun Wang**, *Yi Wang**, *Alexander Kokhanovsky*†,‡
*The University of Iowa, Iowa City, IA, United States †EUMETSAT, Darmstadt, Germany
‡National Research Nuclear University, Moscow, Russia

Diurnal variation
Global converge

**Active**

-*Lida*r such as CALIOP and CATS

**Passive**

- *Limb/ occultation* : SAGE, OMPS
- *Stereo photogrammetry* : ATSR, MISR
- *UV, Deep Blue + Polarization* : OMI, POLDER
- *Oxygen absorption spectroscopy:* POLDER and MERIS, EPIC/DSCOVR, OMI, TROPOMI, SCIAMACHY; EPIC/DSCOVR
- *Infrared:* dust and smoke, MODIS, AIRS

**Active + Passive:** OMI, MODIS, and CALIOP

# A rising trajectory of geostationary satellites for air pollution

**GEMS 2020; TEMPO & Sentile-4, 2022/23**

Imager → Spectrometer



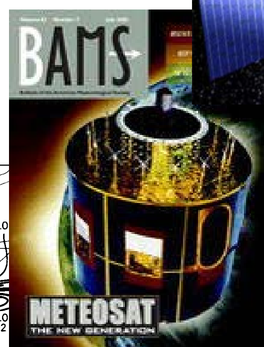
Chance et al., 2019
Zoogman et al, 2017

Fishman et al., 2012


Lahoz et al., 2012

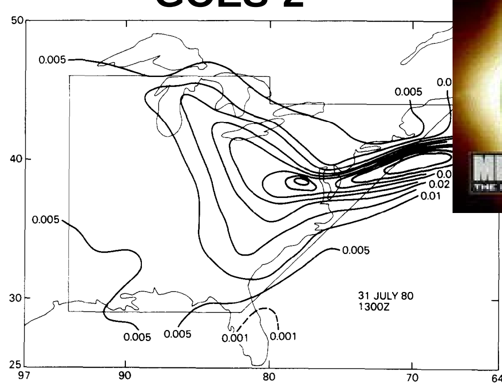

Schmit et al., 2017


Lee et al., 2010. RSE
6 visible
2 NIR

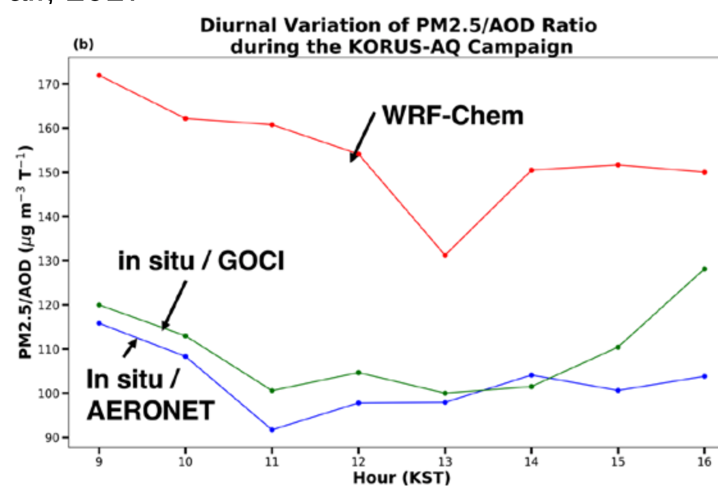



MSG, 8/28/2002
12 channels
2 visible

**GOES-2**



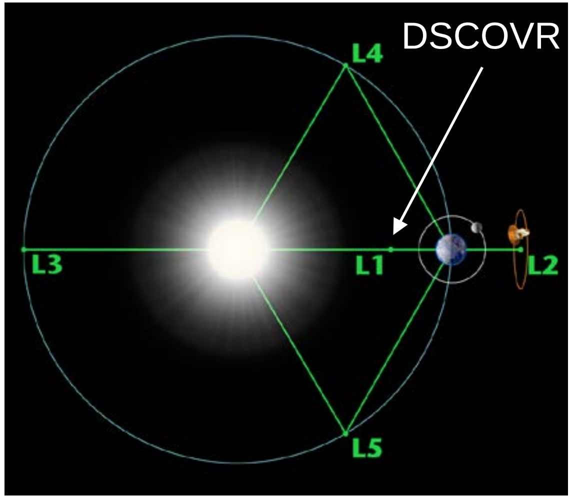

Fraser et a., 1984, AE

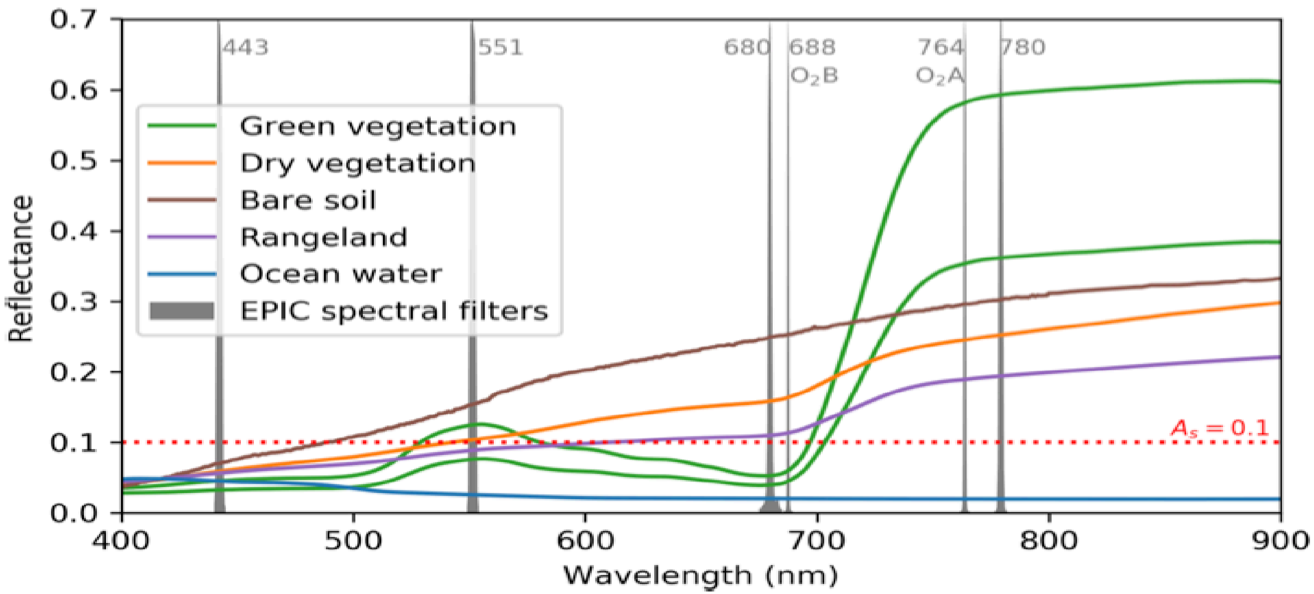



Lennartson et al., 2018, ACP

# EPIC/DSCOVR

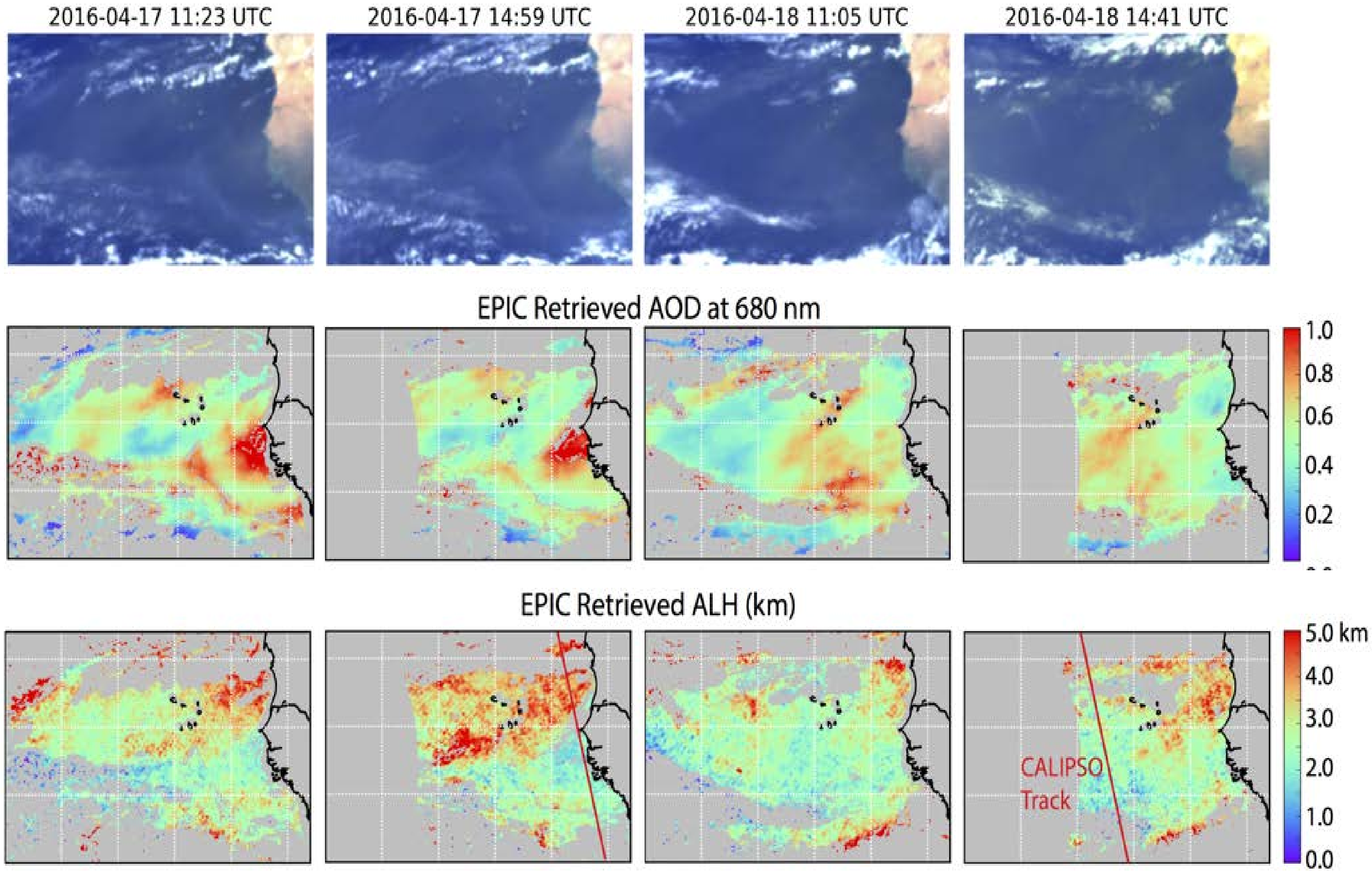
- Launched, 11 Feb. 2015.
- 1st image, 15 June 2015.
- Parked at L1 point: 1.5 million kilometers from Earth, enabling 24/7 observation of sunlit portion of Earth's surface every hour.
- 18-24 km/pixel, every hour
- It has 10 channels
  - 4 UV: 371, 325, 340, and 388 nm
  - 6 Vis as in below



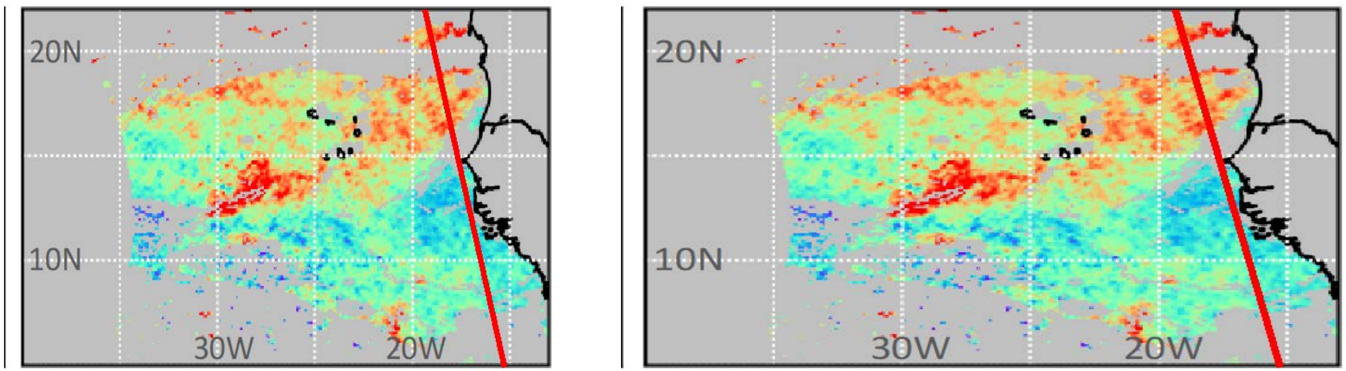

- $O_2$ A band pair and $O_2$ B band pair to retrieve ALH over both land and ocean
- Blue + $O_2$ B band pair are most suitable for ALH retrieve over land

# Retrieval of diurnal variation of plume height and AOD from EPIC's $O_2$ A and B bands



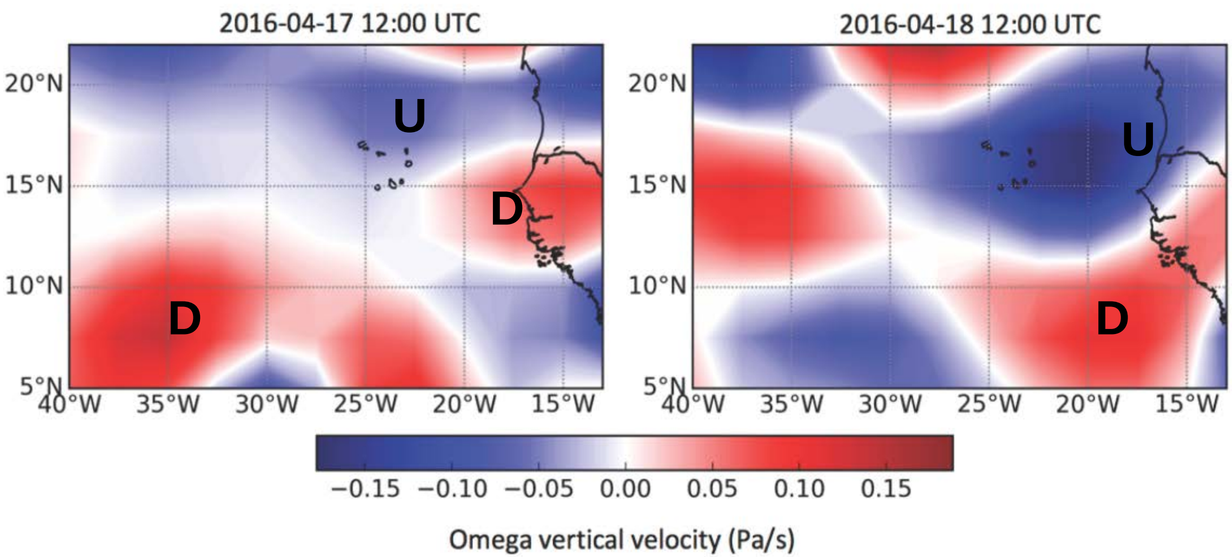

- AOD field clearly indicates mass continuity; high close to the source, and low in downwind.
- ALH shows no relationship with AOD
- ALH varies 1 – 5 km.

# Evaluation of Aerosol Layer height (ALH)




$$\text{ALH} = \frac{\sum_{i=1}^{n} \beta_{\text{ext},i}\, Z_i}{\sum_{i=1}^{n} \beta_{\text{ext},i}}$$

**Vertical velocity**




ALH varies from 1 – 5 km

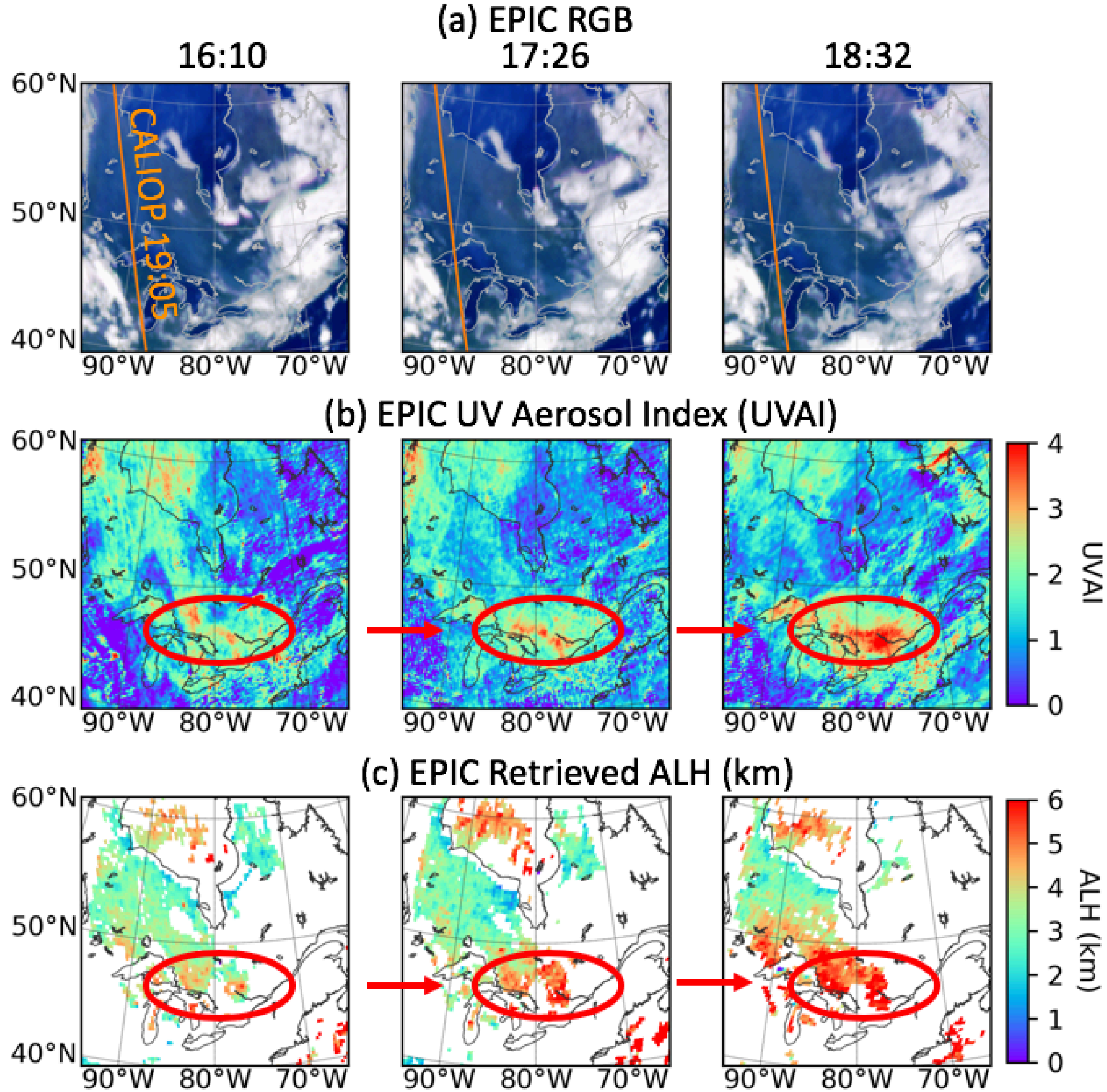
Resonates with vertical velocity field well

- Upward motion, high ALH up to 5 km
- Downward motion, low ALH down to 1-2 km

Xu et al., 2017, GRL

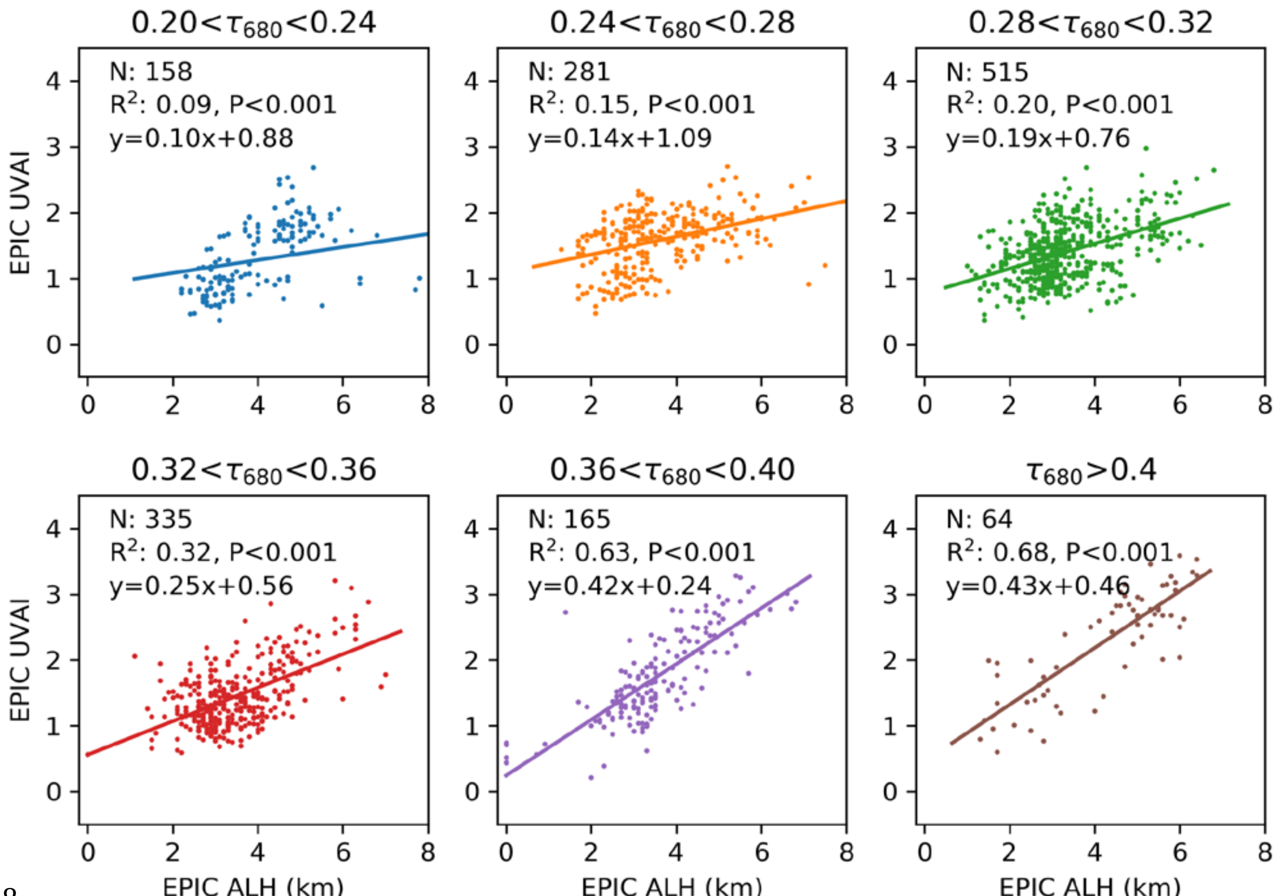
# Smoke ALHs over Canada
# Case I: Aug-25-2017

- Smoke layer is 3 – 5 km high over Hudson Bay
- ALHs are 2 – 4 km over land southeast of Hudson bay, increase to 4 – 6 km towards the Great Lakes
- Diurnal changes of UVAI and ALH appears to be qualitatively consistent, but quantitively different



# Comparison with UV aerosol index

- UVAI indicates composite effect of AOD, SSA and ALH
- UVAI and ALH correlation varies with AOD; Higher AOD, larger correction.

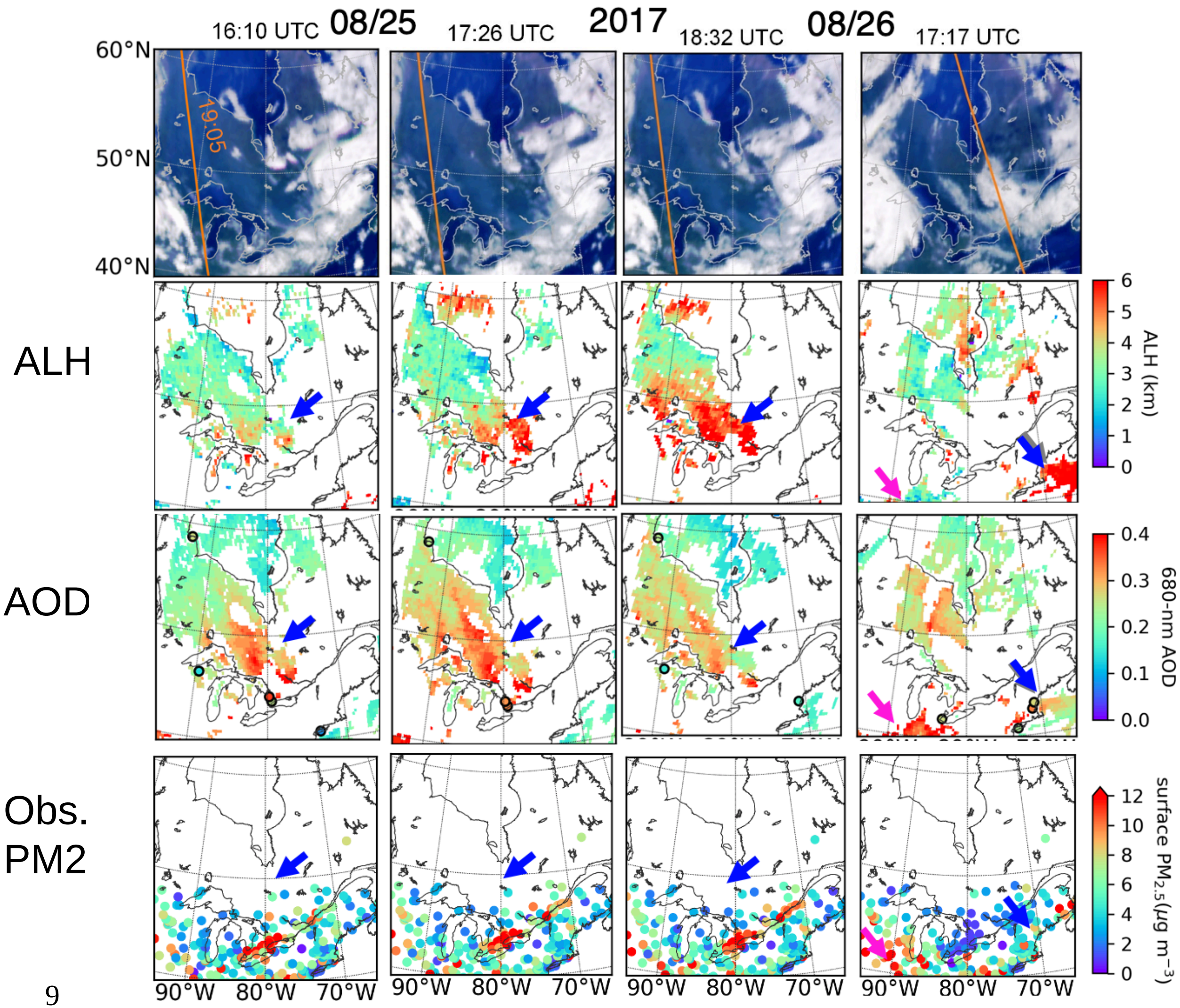



AOD: > 0.36
$R^2$: > 0.63-0.68;

AOD: 0.2 – 0.36
$R^2$: 0.09 – 0.32.

All correlations are statistically significant.

# Implication to Surface PM2.5 Air Quality Assessment

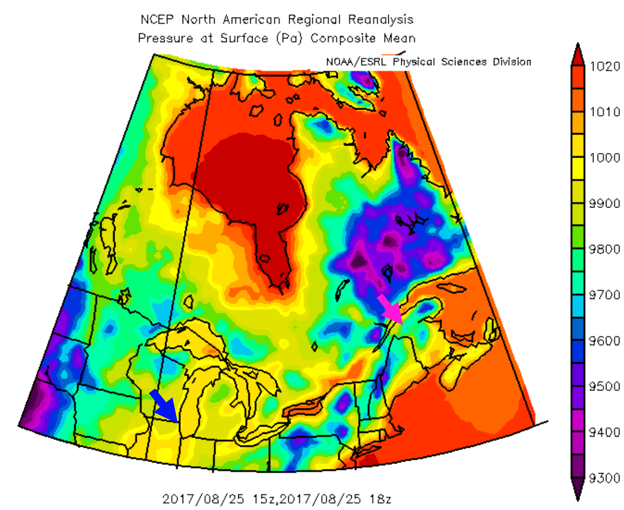



Location later affected by high AOD and descending layer of smoke

High surface PM2.5

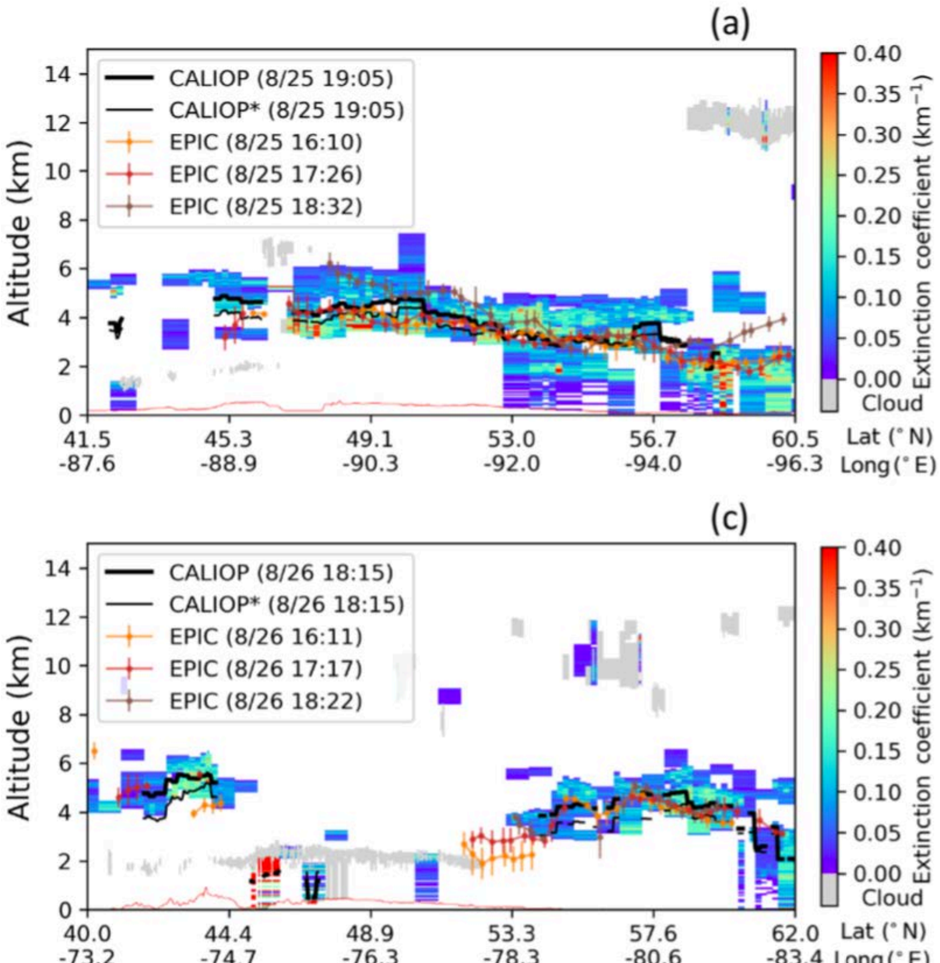
Location later affected by high AOD and lofted layer of smoke

Low surface PM2.5



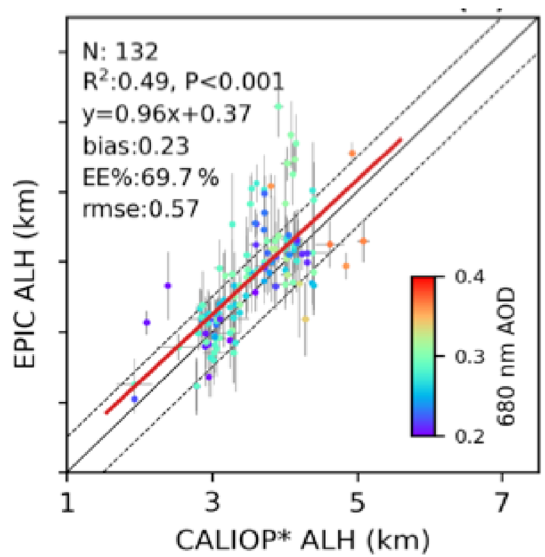

Surface pressure, Aug. 25

# EPIC ALH vs. CALIOP extinction profile




Retried ALH tracks CALIOP well. Overall:

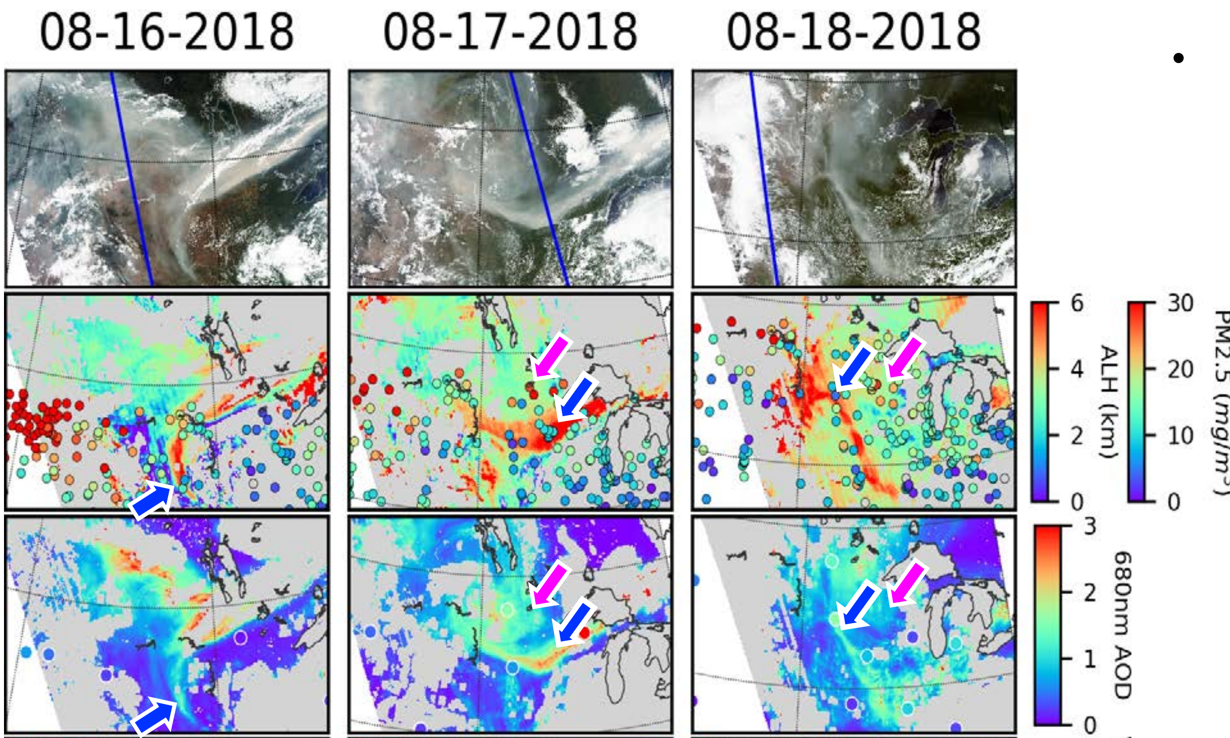
- 70% fall in the expected uncertainty envelope of 0.5 km
- Mean bias: 0.23 km
- RMSE: 0.57 km



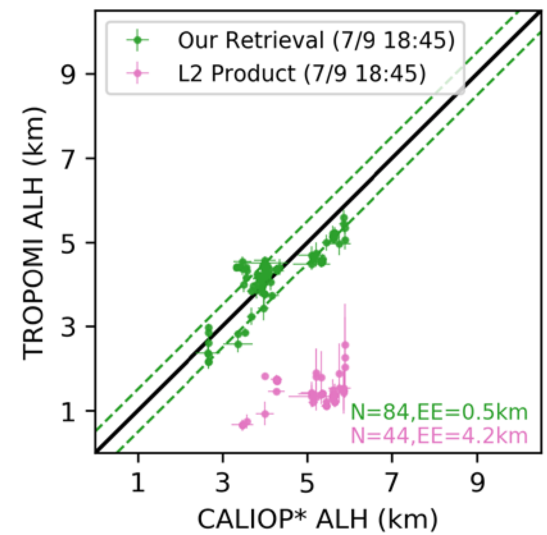

Xiaouang Xu et al., 2019, AMT

# Application to TROPOMI

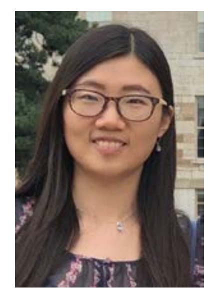
Preliminary results. Please don't cite/quote!




- ALH of this study agrees with CALIOLP with EE of 0.5 km
- TROPOMI level-2 ALH has significant high bias. 4.2 km




- ALH provides key information needed for mapping PM2.5 from AOD.
- High AOD up to 3 km, but ALH is also high to 6 km, no effect on AOD



Xi Chen
Univ. of Iowa

# Summary and outlook

- **Passive remote sensing of ALH has been made significant progress in the last decade. ALH can be retrieved over the ocean and the vegetated land with uncertainty envelope of ~ 0.5 km.**
- **Future retrieval of ALH can be enabled by TROPOMI and MAIA for global coverage, TMEPO and Sentitle-4  (and likely GEMS) for diurnal variation.**
- **Virtual constellation is on the rise to provide 3D description of aerosol pollutants, with good hourly spatial converge, especially from passive sensors on geo. platform.**
- **Detailed profiling or active sensing of the diurnal variation of aerosols, at both day and night, currently doesn't exit, and is strongly needed for bridging and validation of ALHs from multiple passive sensors.**

# Thank you !

Applied sciences, ACMAP,
MAIA, TEMPO, DSCOVR

MRUI: Multidisciplinary
University Research Initiative

# Back-up slides