Passive Remote Sensing of Aerosol Height

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Active
- **Lidar** 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

Diurnal variation
Global converge
A rising trajectory of geostationary satellites for air pollution

Fraser et al., 1984, AE

MSG, 8/28/2002
12 channels
2 visible
Lee et al., 2010.
RSE
6 visible
2 NIR

GOES-R
2016

GOCI, 6/10/2010

Schmit et al., 2017

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

Chance et al., 2019
Zoogman et al., 2017

Fishman et al., 2012

Lahoz et al., 2012

Lennartson et al., 2018, ACP
EPIC/DSCOVR

- 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

- O₂ A band pair and O₂ B band pair to retrieve ALH over both land and ocean
- Blue + O₂ 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)**

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

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
R²: > 0.63-0.68;

AOD: 0.2 – 0.36
R²: 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
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
Preliminary results. Please don’t cite/quote!

08-16-2018  08-17-2018  08-18-2018

- 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
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 Sentinel-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