Aerosol Layer Height from Spectrometers

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CEOS Atmospheric Composition Virtual Constellation AC-VC-16
Aerosol Vertical Information Applications

- Long range transport of aerosol plumes
  - desert dust, biomass burning, volcanic ash, pollution
- Climate change by absorbing aerosols
- Aerosol correction for trace gas satellite observations
Aerosol Observations of Aerosol Vertical Distribution

ACTIVE

› LIDAR (Caliop, Aeolus, Earthcare)
› Pro: Vertical profiles
› Pro: Day and night observations
› Con: limited swath

PASSIVE

› VIS-NIR spectrometry using oxygen absorption.
› Multi-angle radiometry/polarimetry (MISR, POLDER/3MI, Spex)
› IR spectrometry (IASI, ..)

› Pro: wide swath
› Pro: large number of sensors
› Con: limited vertical information
› Con: Only daytime, except for IR observations of dust
Aerosol Layer Height from Oxygen Bands

- Physical principle is that the atmospheric oxygen profile is well-known.

- Usable oxygen absorptions are in the VIS (O$_2$-O$_2$ dimer weak absorptions) and in the NIR (O$_2$ A and B band strong absorption)

- Method is limited to moderate to strong aerosol loading under cloud-free conditions.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Oxygen Bands</th>
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</thead>
<tbody>
<tr>
<td>OMI</td>
<td>O$_2$-O$_2$</td>
</tr>
<tr>
<td>S5P/TROPOMI</td>
<td>O$_2$-O$_2$, O$_2$ A, O$_2$ B</td>
</tr>
<tr>
<td>GEMS</td>
<td>O$_2$-O$_2$</td>
</tr>
<tr>
<td>S4/UVN</td>
<td>O$_2$-O$_2$, O$_2$ A</td>
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<tr>
<td>S5/UVNS</td>
<td>O$_2$-O$_2$, O$_2$ A</td>
</tr>
<tr>
<td>TEMPO</td>
<td>O$_2$-O$_2$, O$_2$ B</td>
</tr>
<tr>
<td>CO2M</td>
<td>O$_2$-O$_2$, O$_2$ A</td>
</tr>
</tbody>
</table>

Synthetic oxygen A-band spectra for a cloudless atmosphere containing aerosols over a surface with an albedo of 0.03. **Left:** Aerosol layer is fixed at a height of 900 hPa - 950 hPa, for two scenes are different aerosol optical thicknesses. **Right:** Aerosol vertical distribution is varied for an aerosol optical thickness of 1.0 at 760 nm.
Operational ALH Retrieval Algorithm for O₂ A Band

- Optimal estimation algorithm with AOT and ALH as fitting parameters.
- Aerosol model is fixed and uses Henyey-Greenstein phase function.
- Online Radiative transfer uses a neural network approach.
- Currently the surface albedo is based on a monthly climatology.
- Requirement for ALH 1 km threshold, 0.5 km goal

ALH Saharan Dust, 2018-06-08

ALH Biomass Burning, 2018-11-09

ALH Biomass Burning, 2020-01-09
Validation Examples

Biomass Burning N-America

Comparison to MISR over continental N-America. Griffin et al. [www.atmos-meas-tech.net/13/1427/2020/]

Saharan Dust, Atlantic Ocean

Nanda et al: [https://doi.org/10.5194/amt-2019-348]
Planned Algorithm Improvements

› Co-fit the surface reflectance.
› Increase the number of retrievals.
› Expand the vertical range.
› Explore the O$_2$ B band for Tropomi.
› Improving the cloud clearing.
Conclusion

› Current and planned spectrometers allow for retrieval of aerosol layer height.
› The S5P/TROPOMI ALH product is the first operational data product.
  – For S4 and S5 operational products are in development.
› Validation is performed with CALIOP.
  – Results are good over the ocean, but over high-reflective surfaces retrievals are more challenging.
› ALH is a new product, further developments are foreseen.

More Information:
https://s5phub.copernicus.eu/dhus/#/home