A spectral sorting approach for constraining coastal aerosol profile using OCO-2 O_2 A-band measurements

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IWGGMS-15, 2019, Hokkaido, Japan

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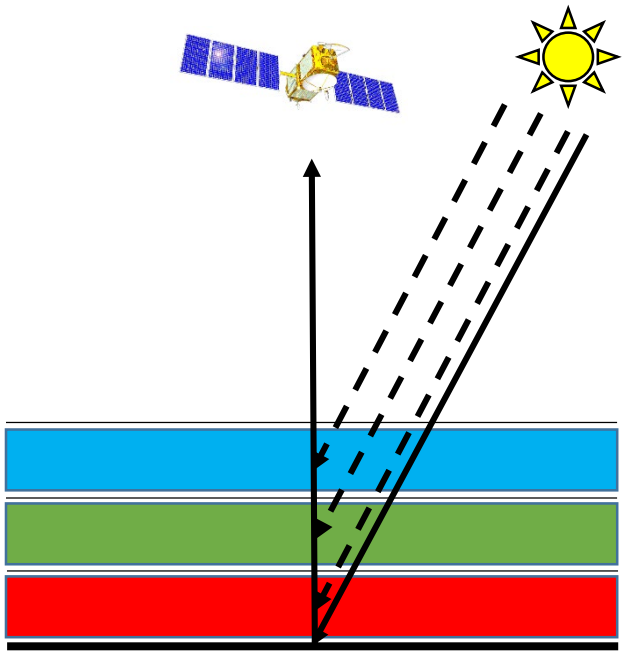
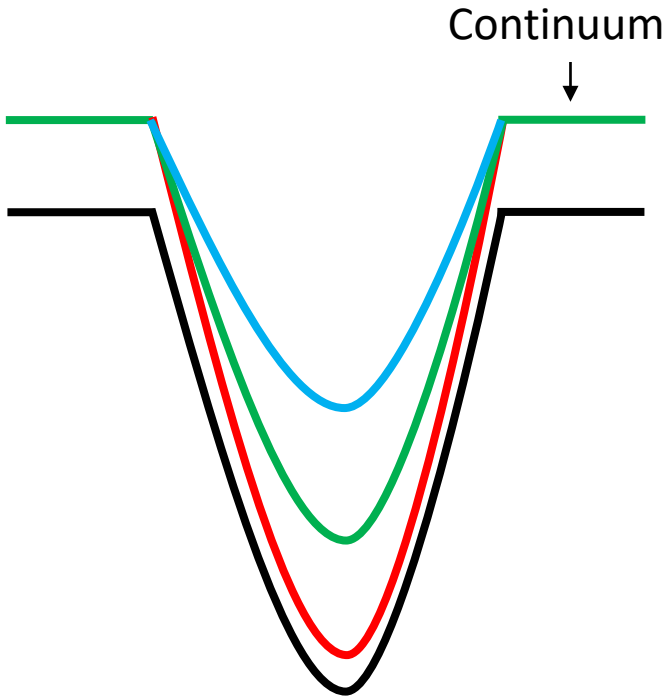
Why aerosol profile is important?



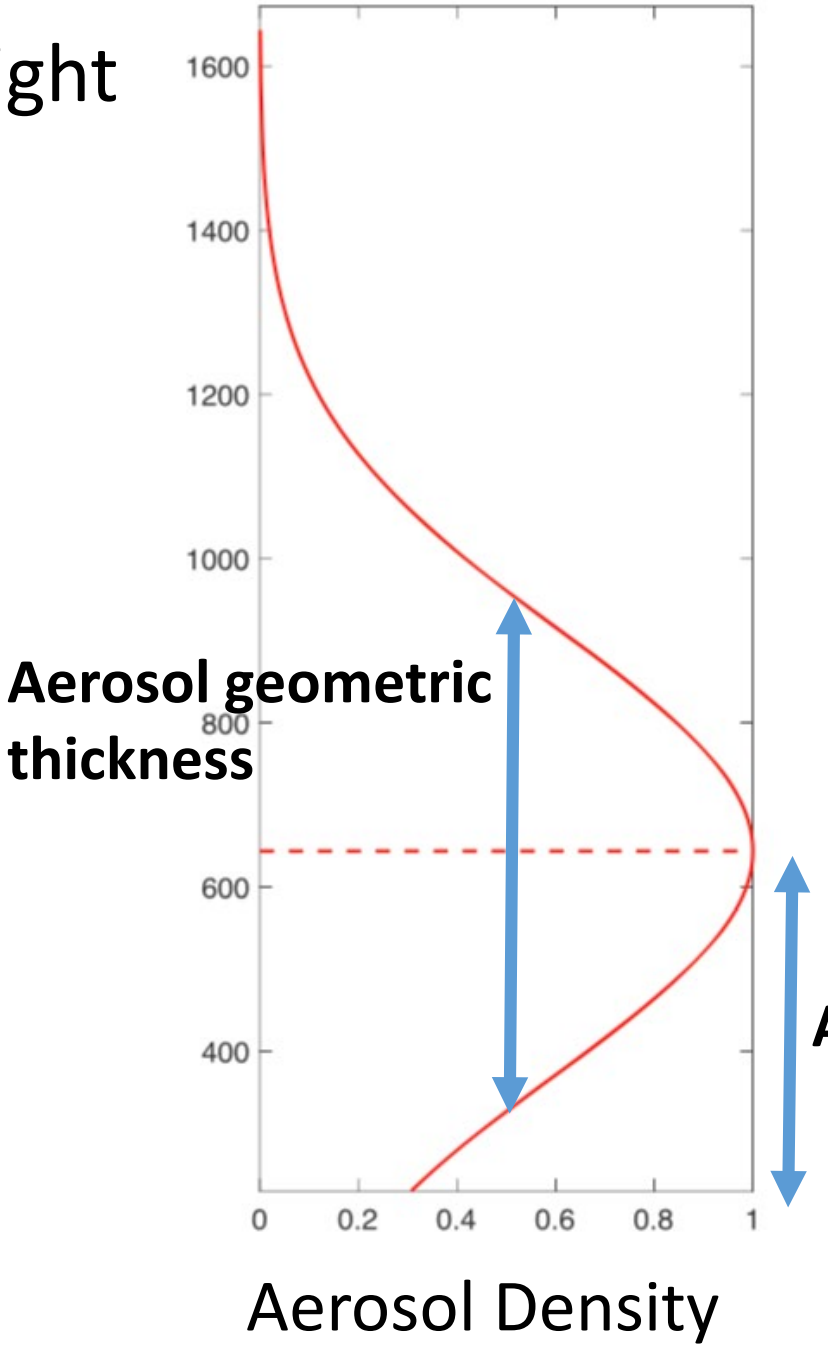
3 Scenarios:
Same amount of total AOD;
But at different altitudes.



gas absorption

1. Current passive remote sensing measurements provide little or no information on the vertical distribution of aerosols.

2. Aerosol profile affects gas retrievals: scattered sunlight by higher aerosol layers undergo shorter absorption paths, thereby less absorption.



Aerosol profile includes:

(1) Aerosol Optical Depth (AOD)

(2) Aerosol Layer Height (ALH)

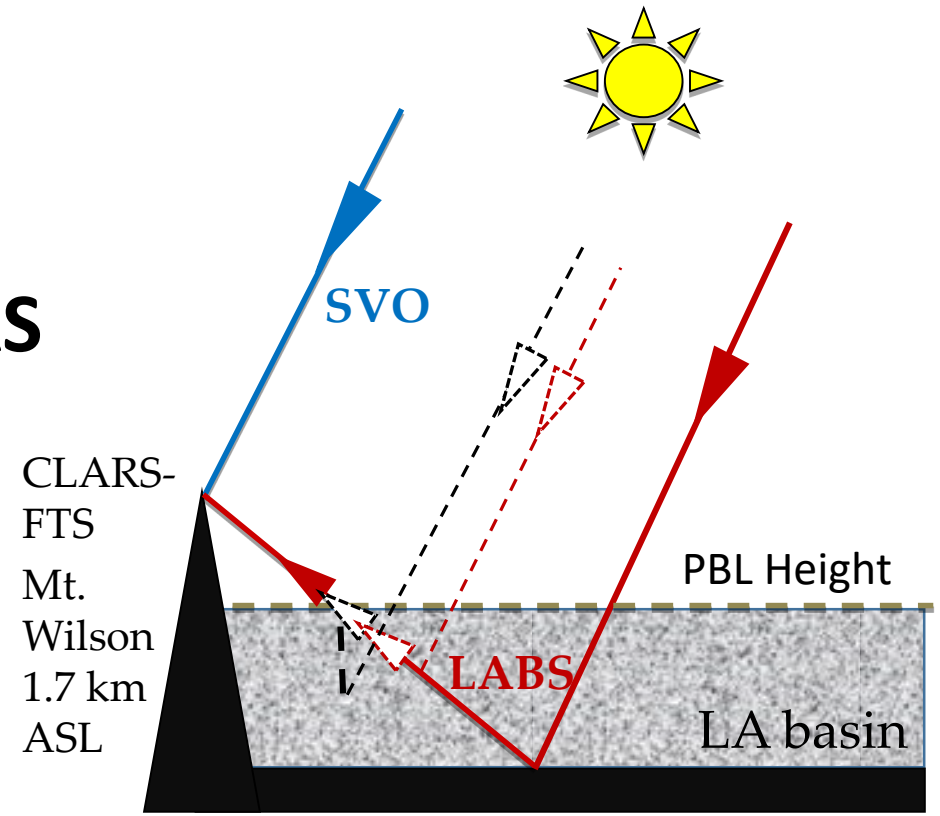
(3) Aerosol Geometric Thickness

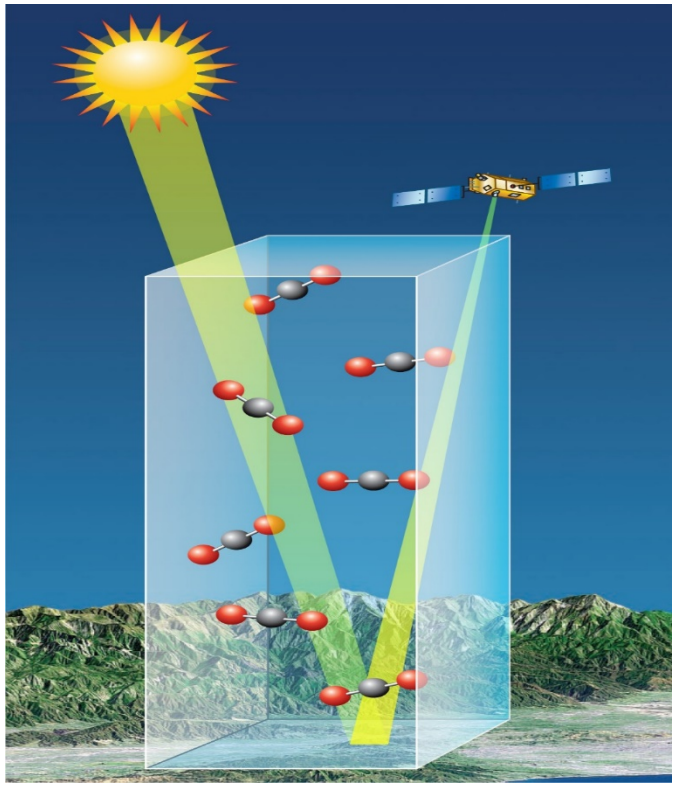
This study will focus on ALH and AOD.

From CLARS to OCO-2

CLARS: California Laboratory for Atmospheric Remote Sensing

CLARS





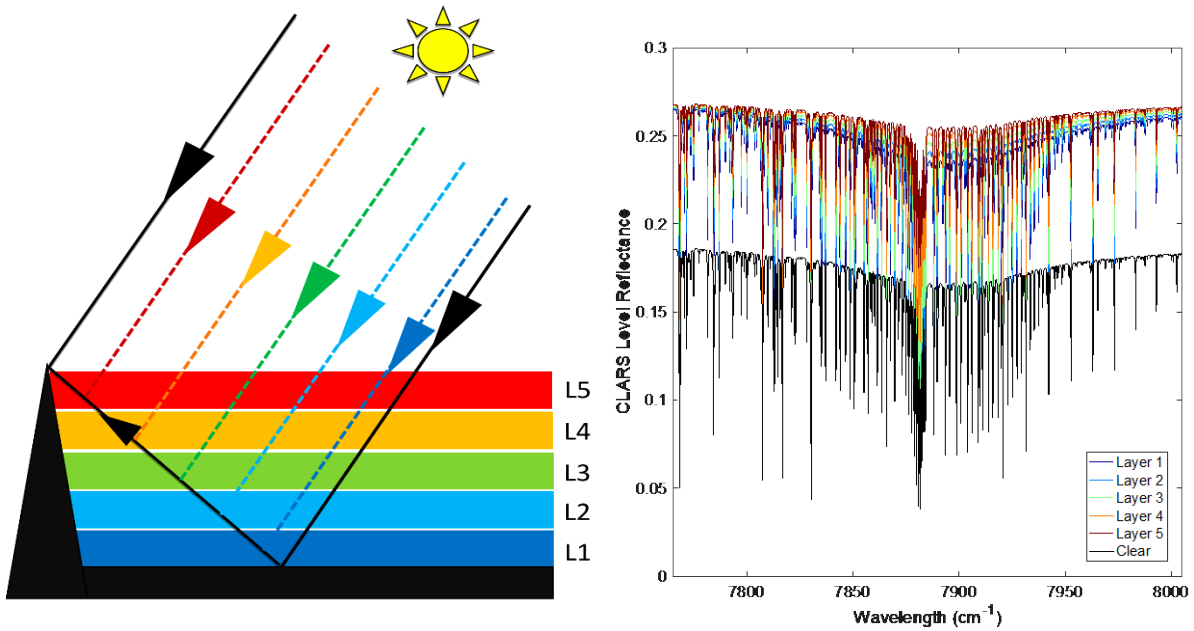
OCO-2

- CLARS mimics LEO/GEO satellite observations. Its large viewing zenith angle amplifies the effects of aerosol scattering;
- **A spectral-sorting algorithm developed for CLARS O2 measurement to constrain the aerosol profile in the LA basin can be applied to OCO-2 data (We will focus on coastal dust plume here).**

Spectral-sorting approach for retrieving aerosol layer height

1. Same amount of aerosol at different layers (black: clear case);

2. We see difference in simulated O2A spectra;



For more details:

Zeng, Z.C., et al. 2018. **Constraining Aerosol Vertical Profile in the Boundary Layer Using Hyperspectral Measurements of Oxygen Absorption**. *Geophysical Research Letters*, *45*(19), pp.10-772.

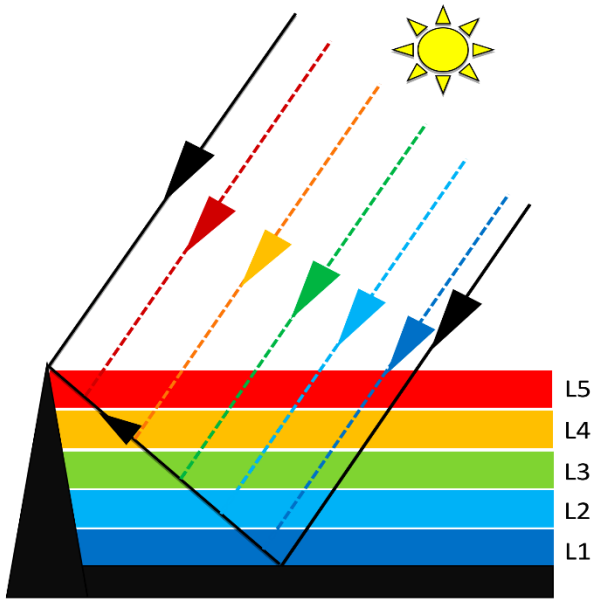
Spectral-sorting approach for retrieving aerosol layer height

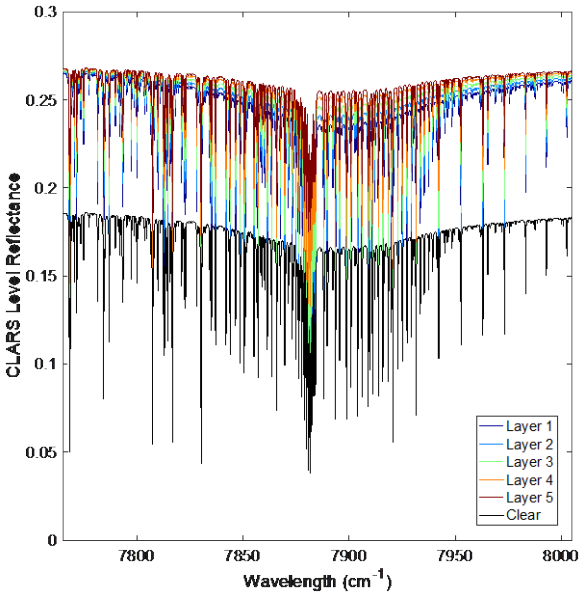
1. Same amount of aerosol at different layers (black: clear case);

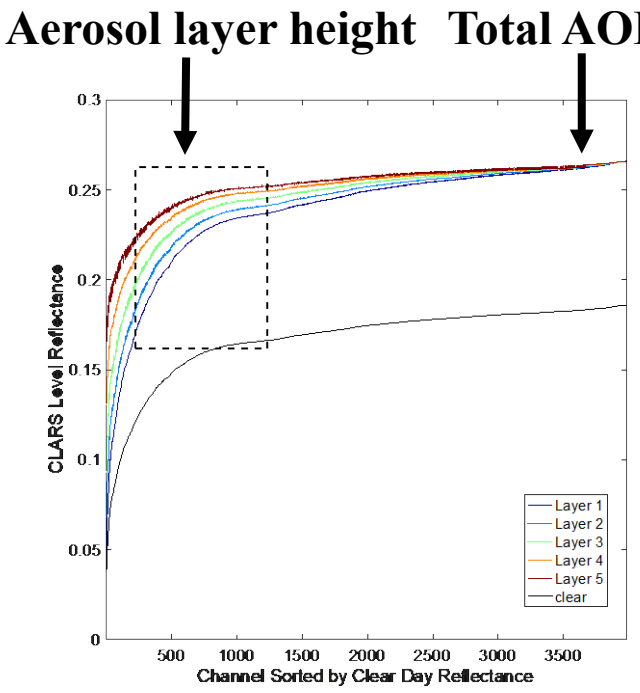
2. We see difference in simulated O2A spectra;

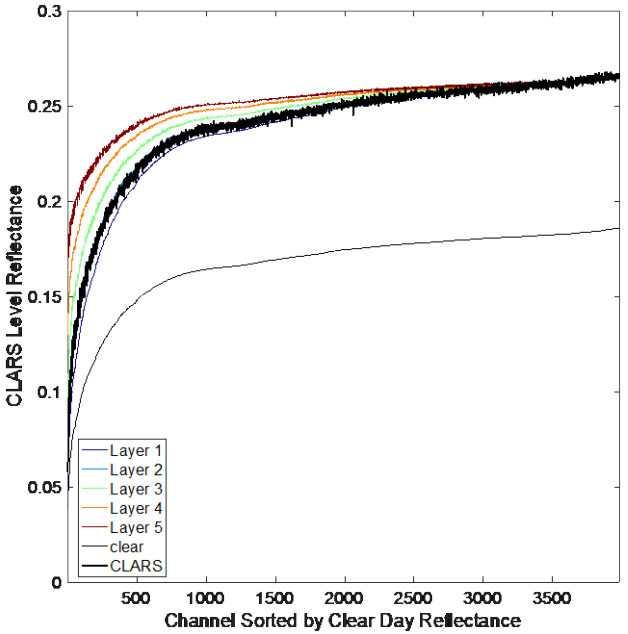
3. By sorting the spectra, we get the continuum region that is sensitive to total AOD, and the median-absorption part that is sensitive to ALH;

4. By overlaying the real measurement, we can retrieval both AOD and ALH.









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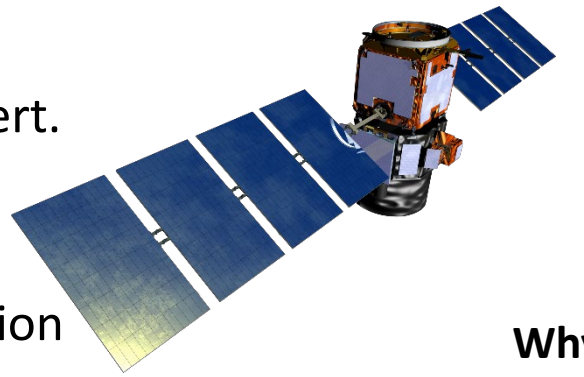
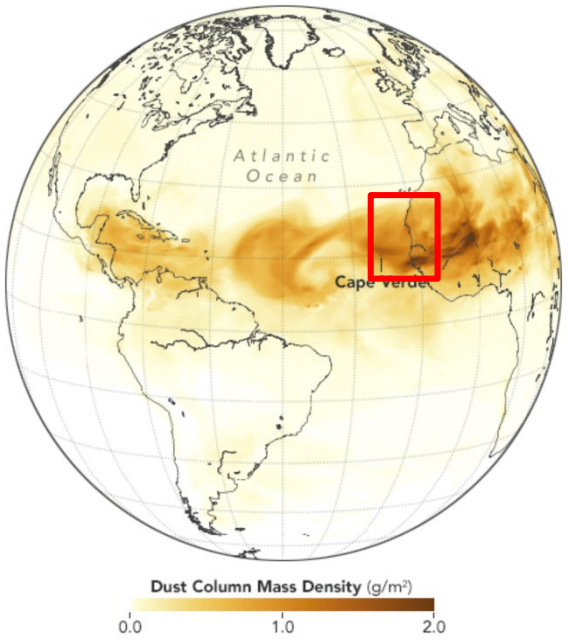
Constraining aerosol profile using O_2A band at west coast of Sahara

OCO-2 tracks (Nadir mode)
over the coastal region of Sahara desert.

CALIPSO:
Aerosol backscatter profile for validation





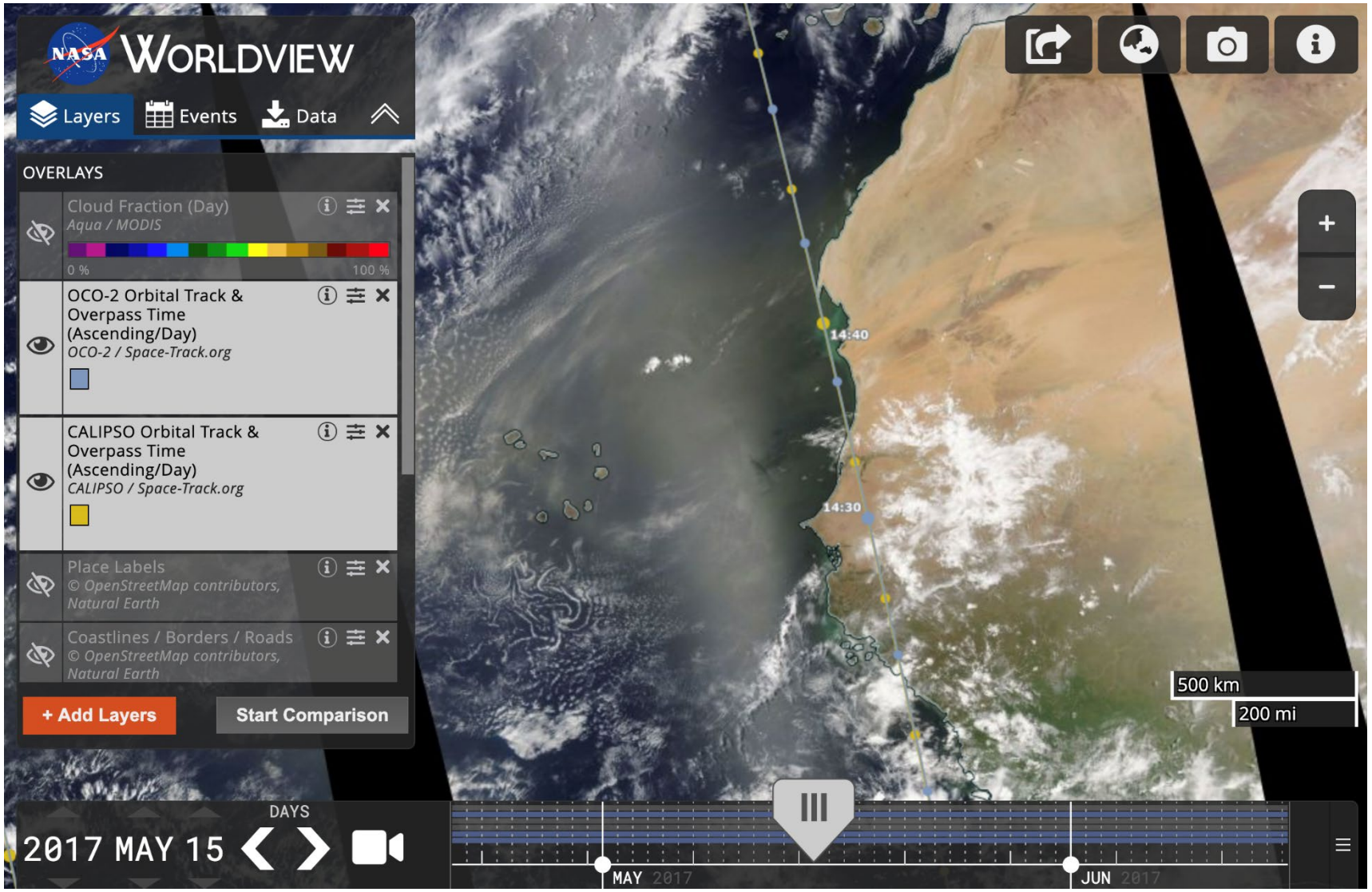
source: earthobservatory.nasa.gov

Why coastal ocean?
Close to plume source;
Ocean surface is relatively dark and well known BRDF.

How many data?
There are 45 tracks from 2014 to 2018, and after excluding clouds and collocating with CALIPSO, there are 25 scenes available for this study;

Zeng et al., 2019, in prep.

Example: Dust plume out of Sahara

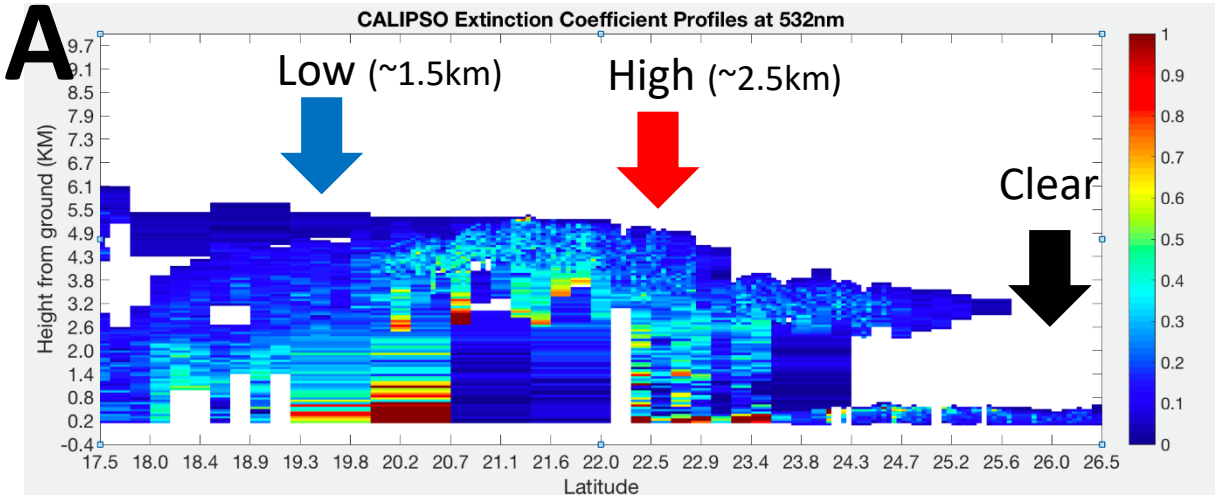


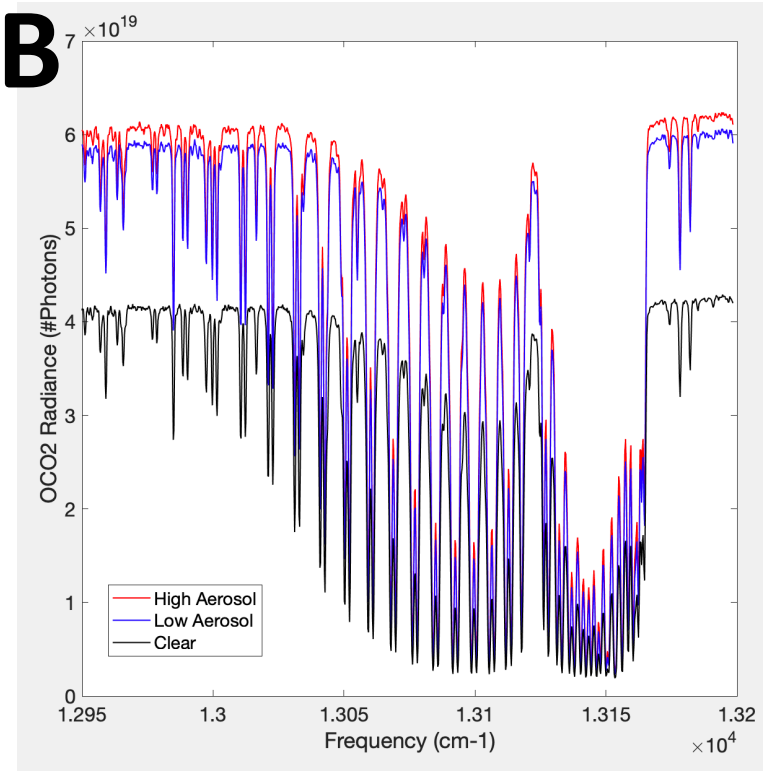
MODIS/Aqua images with OCO2 and CALIPSO tracks on May 15, 2017.

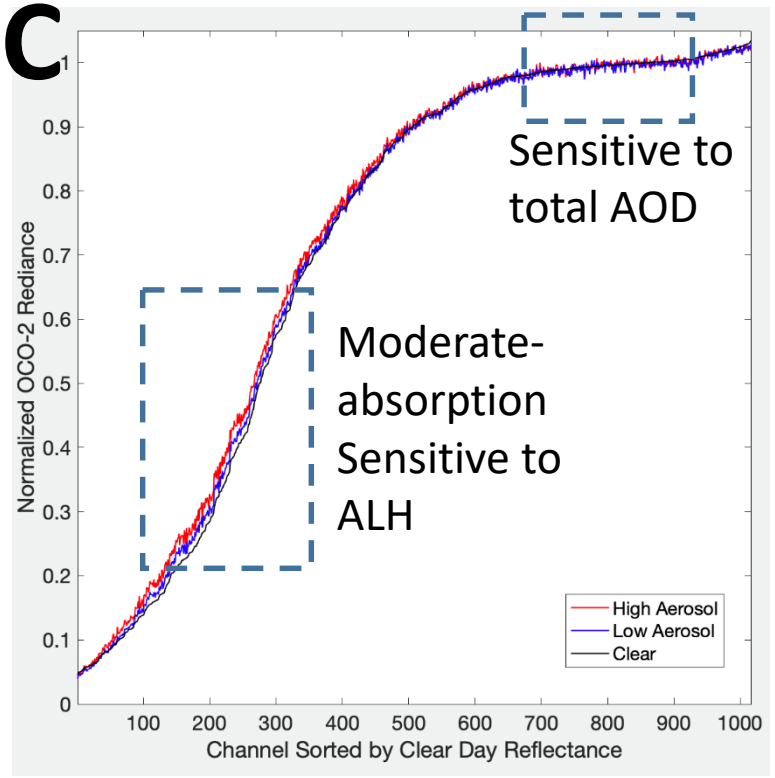
Zeng et al., 2019, in preparation.

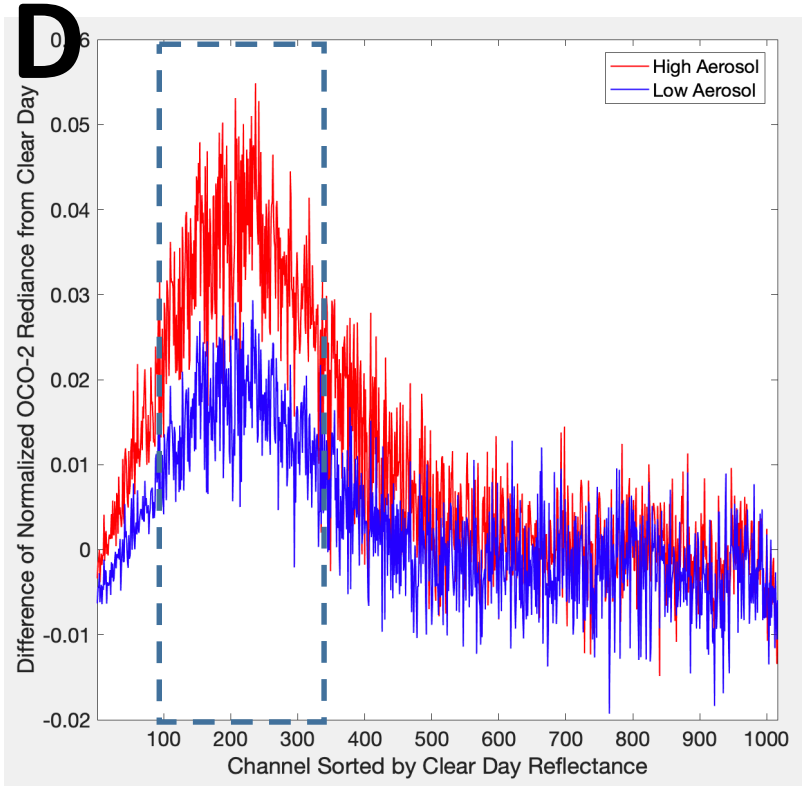
Spectral sorting for Aerosol Layer Height

A. Aerosol vertical profiles from CALIPSO;
   Low and high aerosol layer (same AOD~0.5; ALH diffs by 1km);
B. OCO-2 O2A radiance;
C. Spectral sorting technique (Zeng et al. 2018; Richardson et al. 2017)
   Identify the spectral regions with the largest sensitivity to ALH
D. The difference between high aerosol, low aerosol, and clear cases (in percentage)





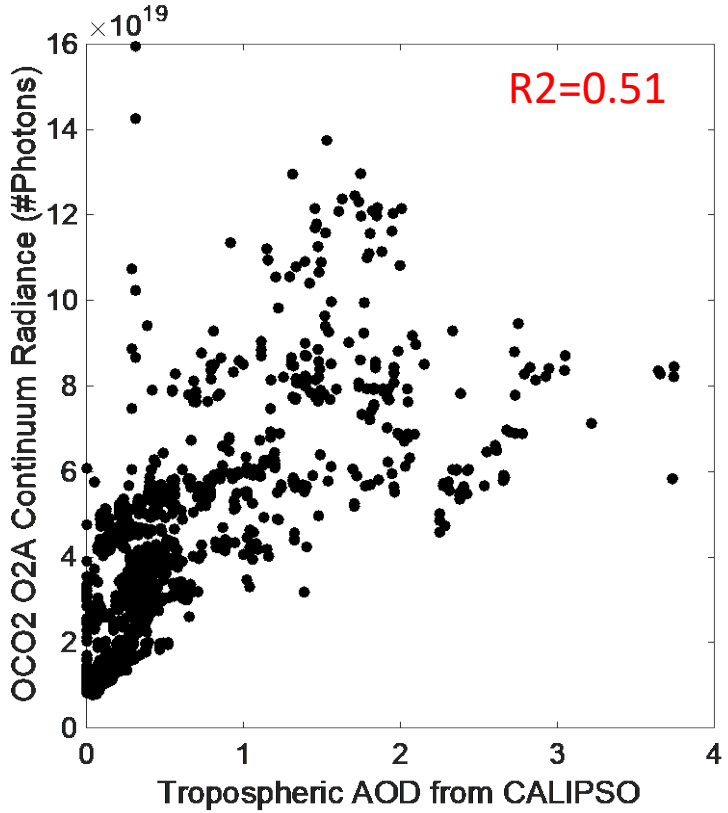


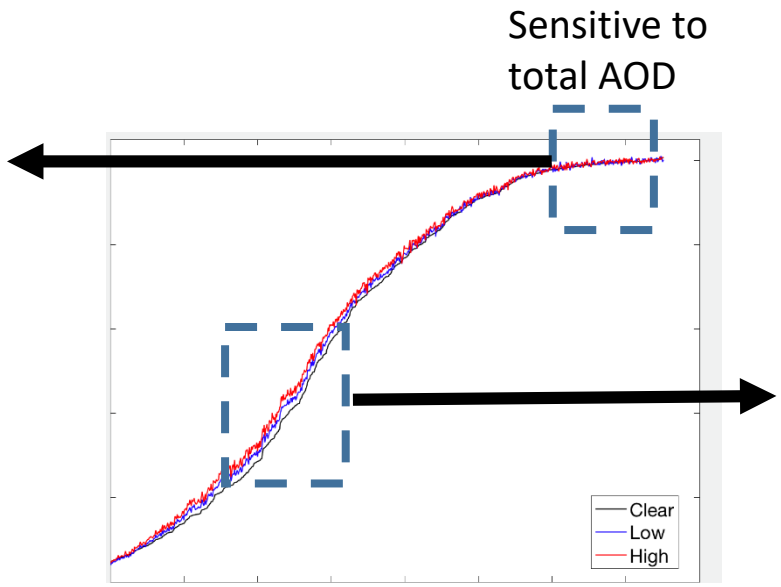


Zeng et al., 2019, in preparation.

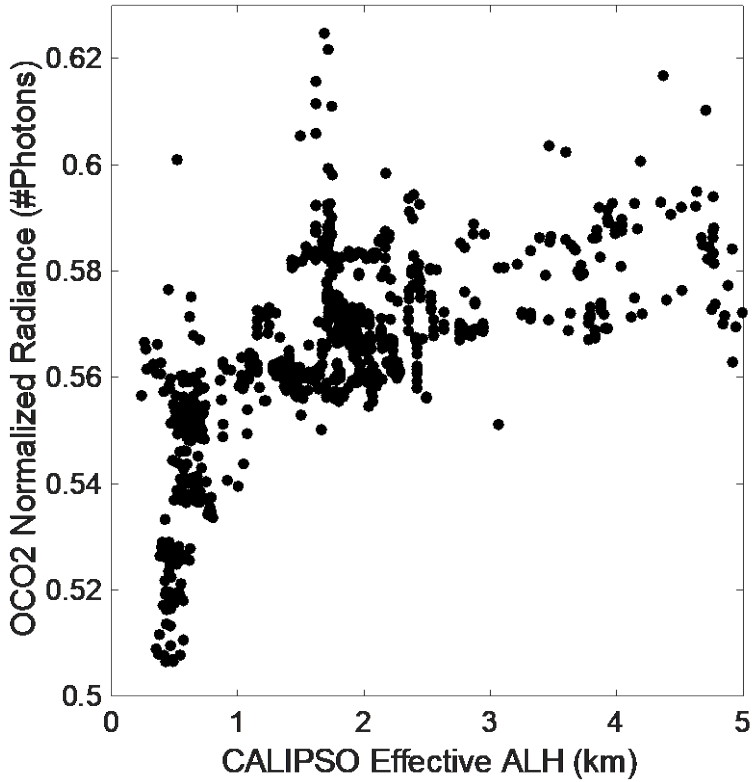
What original O2A Spectra is telling us (before RT modeling)?

AOD vs OCO-2 Radiance





ALH vs OCO-2 Radiance



1. Significant linear correlation between AOD and continuum radiance;
2. OCO2 radiance at moderate absorption lines increases as ALH increases in a non-linear way.

Zeng et al., 2019, in preparation.

Preliminary results:

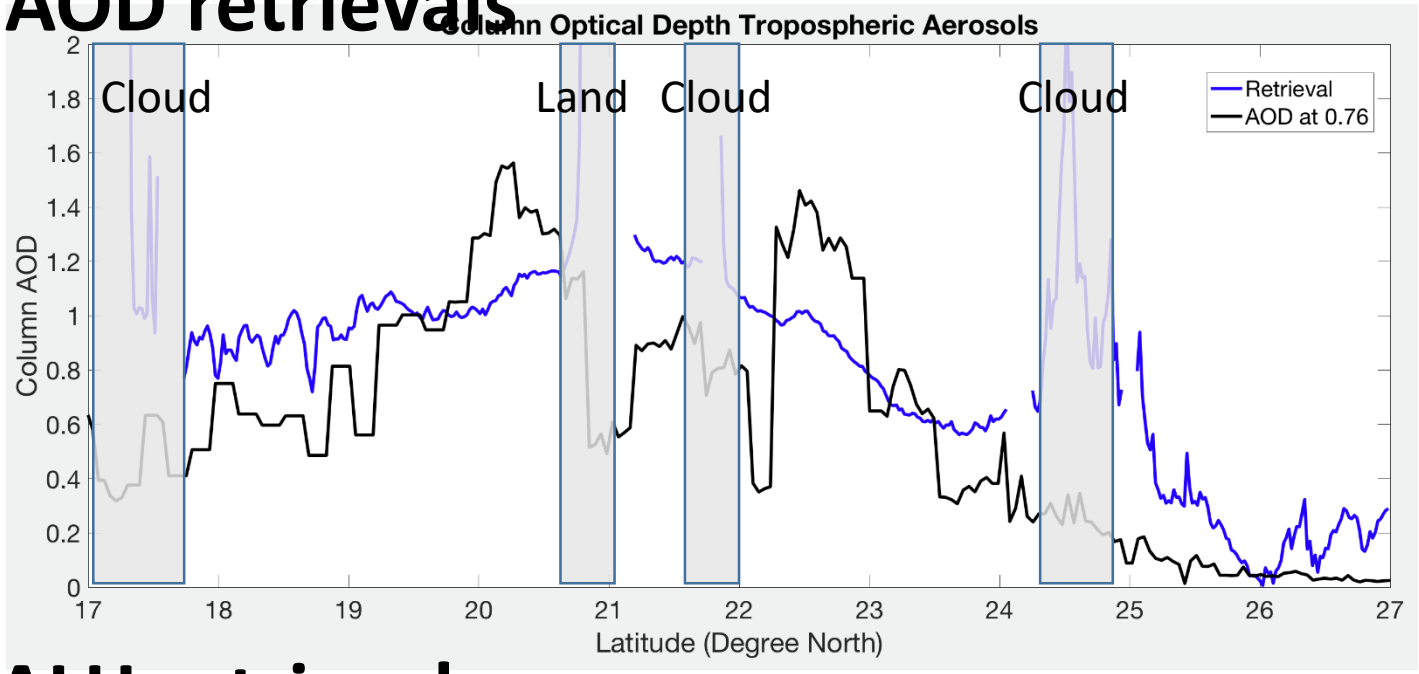
Retrieval of total AOD and ALH

1. Retrieval algorithm (Zeng et al., 2018, GRL)
(1) Look-up table based on the sorted spectra
(2) Simple assumption of dust optical properties (SSA=0.92; Phase function from GOCART) and ocean surface BRDF (Cox-Munk; constant wind speed of 10m/s);

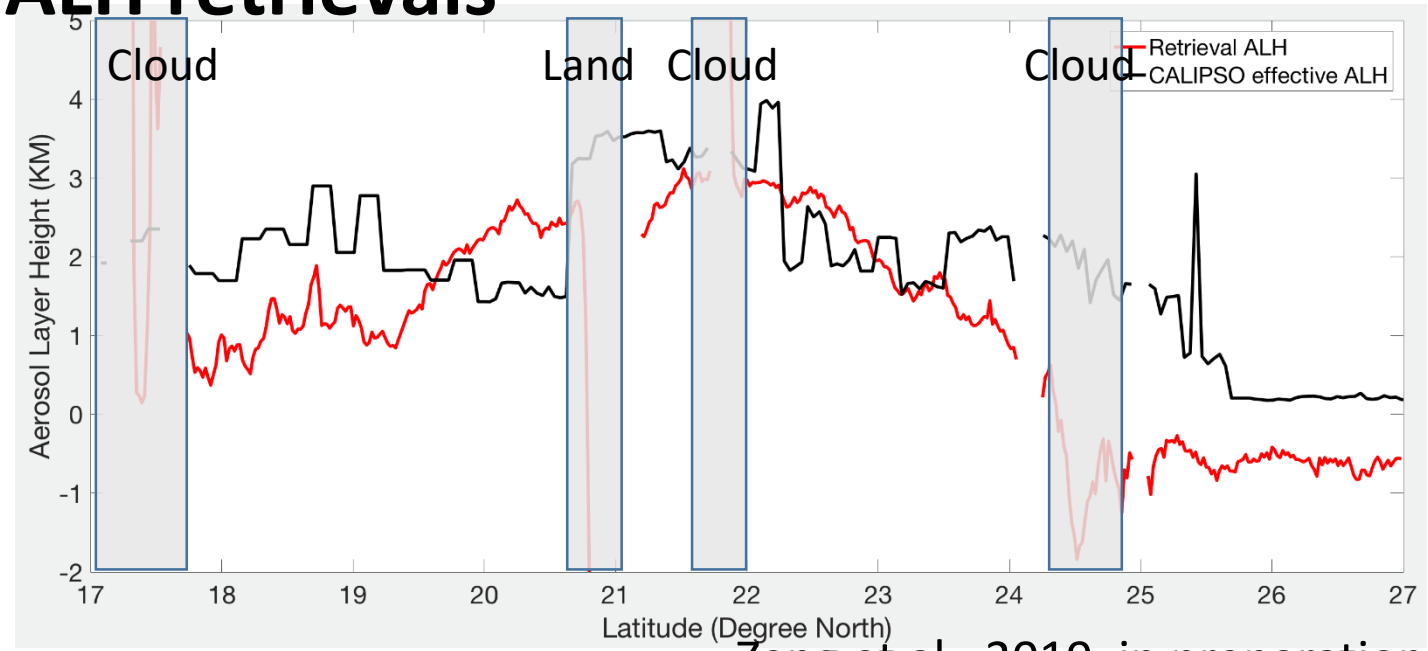
2. The total AOD and effective ALH can be constrained to the first order; Decreased accuracy for ALH retrieval with lower AOD.

3. Larger uncertainty around cloud regions.

AOD retrievals



ALH retrievals



Zeng et al., 2019, in preparation.

Conclusions:

1. OCO-2 O2A band nadir measurements show potential to constrain the aerosol vertical structure over the coastal regions

On land, especially over polluted urban areas, need further investigation(due to the complex BRDF effect)

2. A "Divide and Conquer" strategy for gas retrievals may worth testing:

(1) To constrain the aerosol vertical profiles using O2A band;

(2) To retrieve gas concentrations with the constrained aerosol inputs in RT.

3. Next Goal: Retrieval over Saudi Arabia

References:

Zhang, Q., V. Natraj, K. -F. Li, R.-L. Shia, D. Fu, T. J Pongetti, S. P Sander, C. M. Roehl, and Y. L. Yung, (2015), "Accounting for aerosol scattering in the CLARS retrieval of column averaged CO2 mixing ratios", *J. Geophys. Res.: Atmospheres*, 120, 7205–7218, doi:10.1002/2015JD023499

Zhang, Q., R-L. Shia, S. P. Sander and Y. L. Yung (2016), XCO2 Retrieval Error over Deserts near Critical Surface Albedo. *Earth and Space Science*, 3, doi:10.1002/2015EA000143.

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