GFIT3: A full physics retrieval algorithm for remote sensing of greenhouse gases in the presence of aerosols

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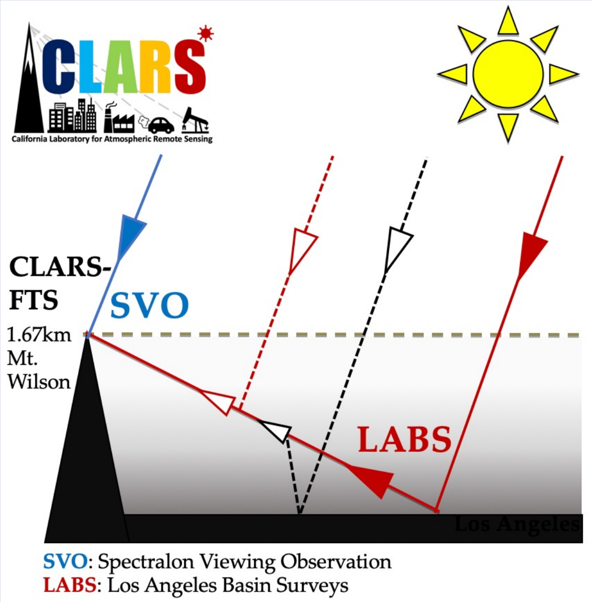
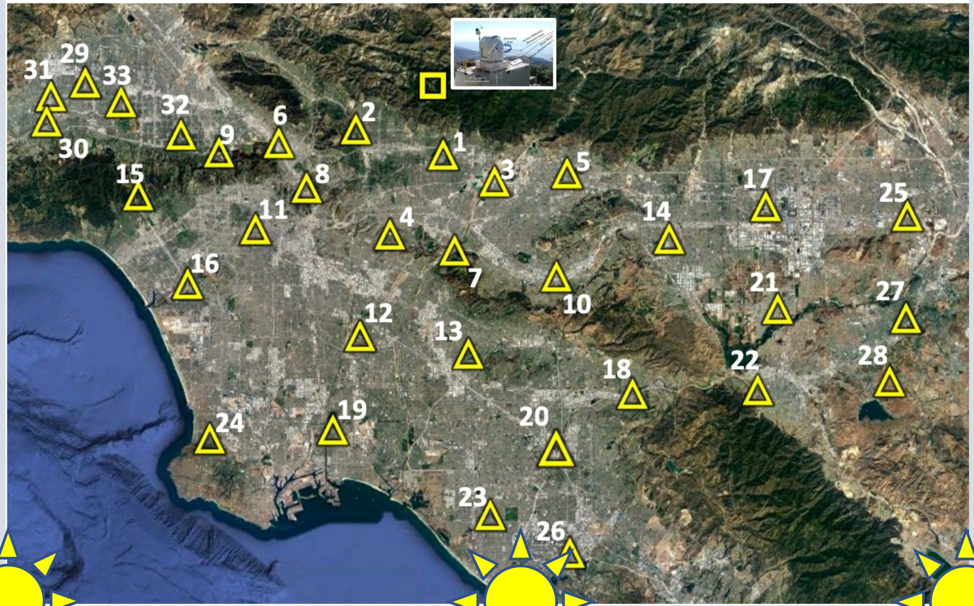
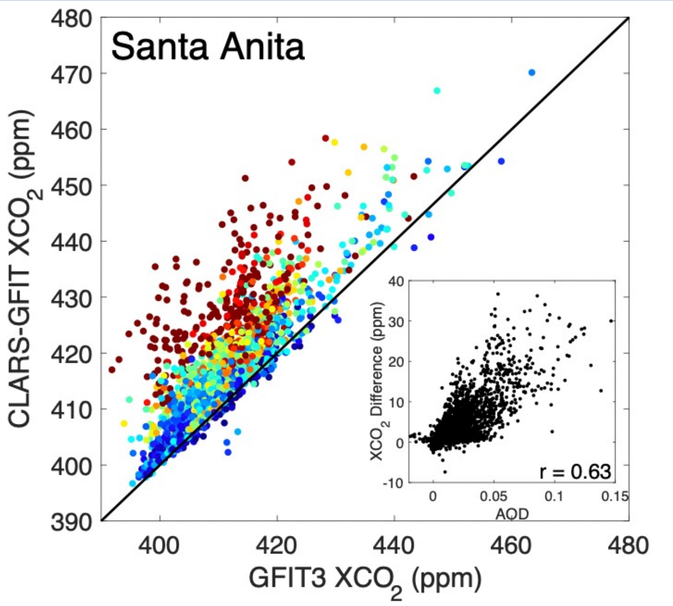
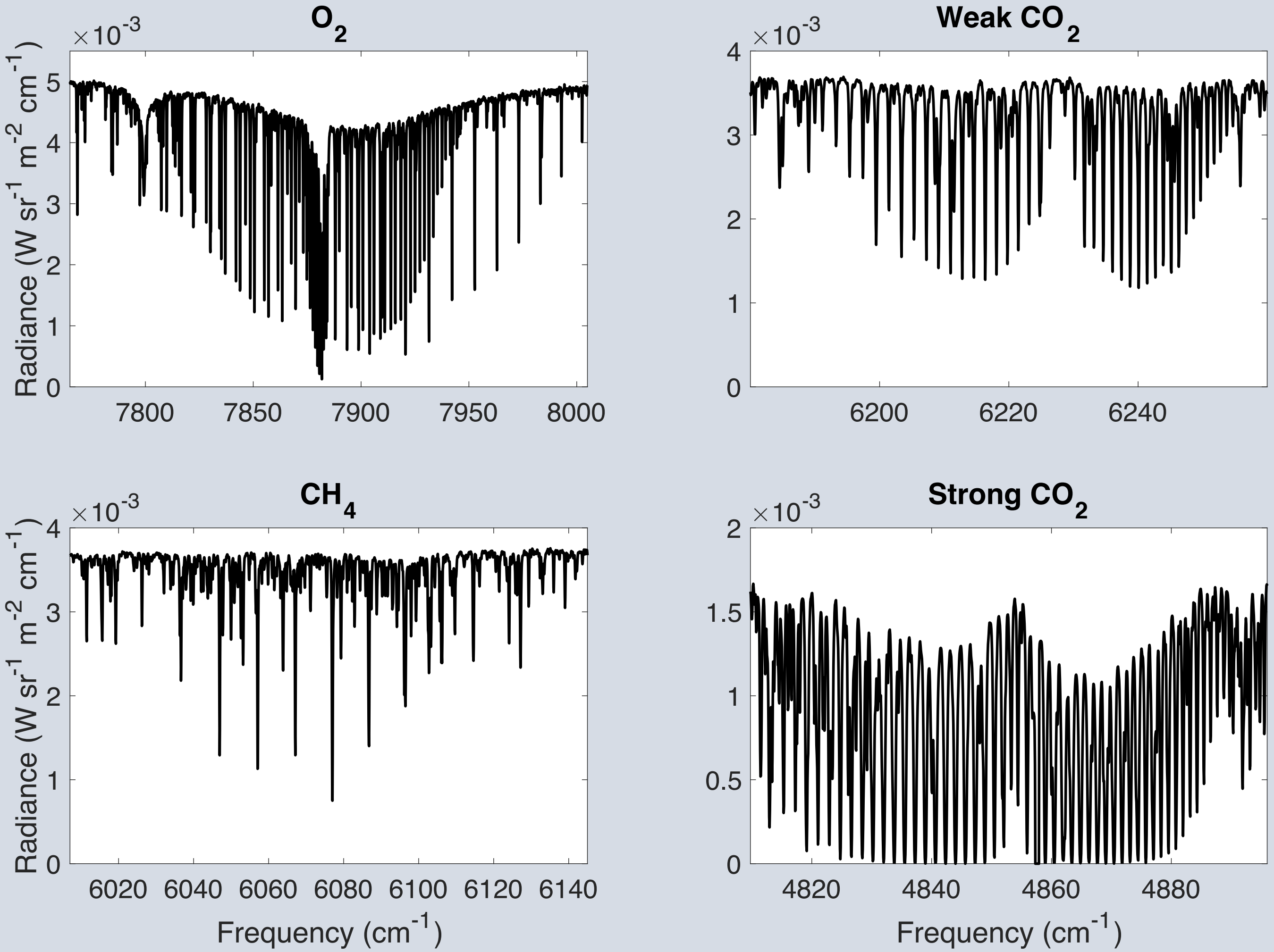






- To investigate the impact of aerosol scattering on remote sensing of GHGs in cities, we developed GFIT3, a full physics algorithm to retrieve GHGs (CO_2 and CH_4) by accounting for aerosol scattering effects in polluted urban atmospheres.
- CLARS–FTS is an ideal testbed for GHG remote sensing algorithms because (1) the LA basin's high GHG emissions are associated with its heavy aerosol loading; (2) the aerosol scattering angle changes from forward (~20 degrees) to backward (~140 degrees).
- When aerosols are not accounted for in the retrieval, the XCO_2 and XCH_4 are overestimated. The bias can be up to about 10% for both XCO_2 and XCH_4.

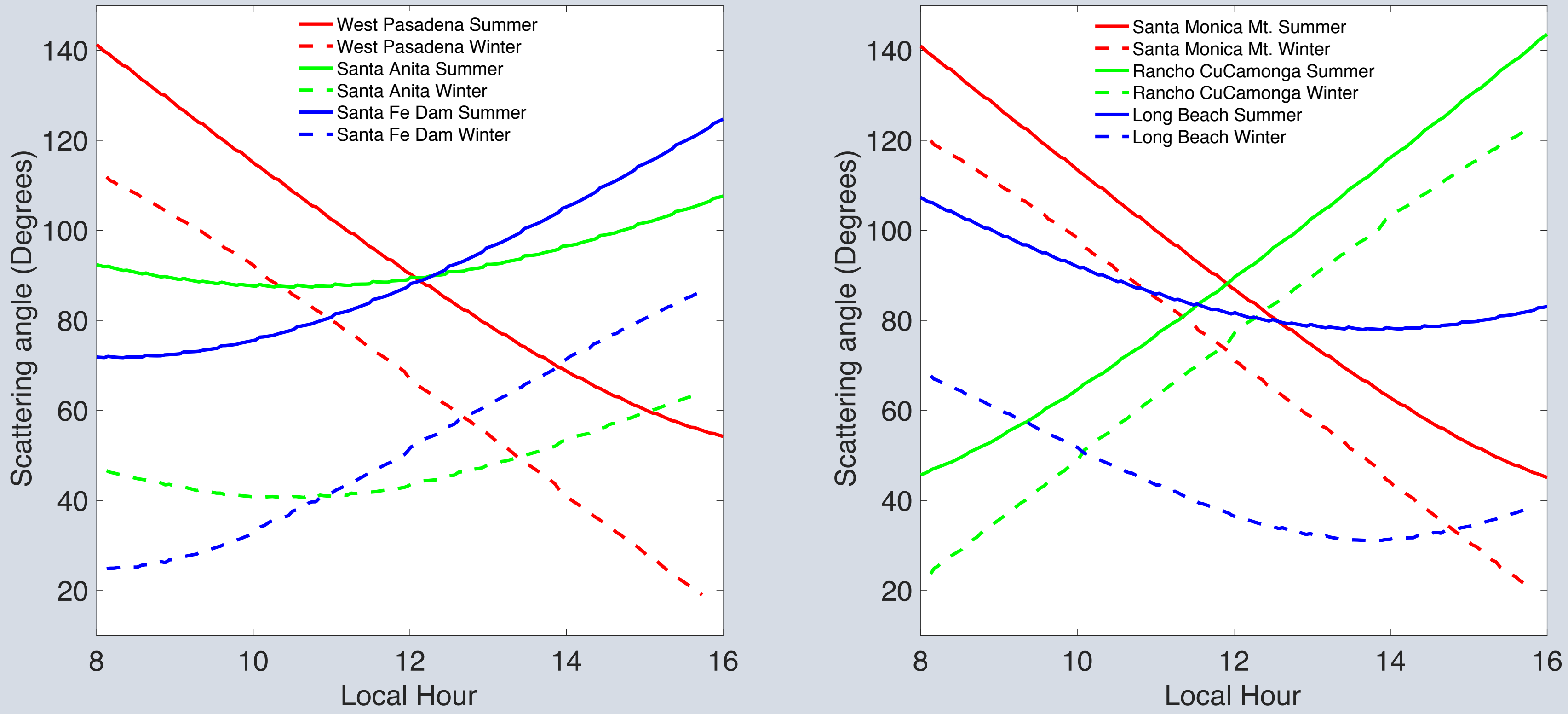
Observed spectra for O_2 $^1\Delta$, CO_2, CH_4, and SCO_2 bands



Examples of observed high resolution (0.06 cm^{-1}) spectra for the O_2 $^1\Delta$ absorption band centered at 1.27μm (7885 cm^{-1}), the weak CO_2 absorption band at 6220 cm^{-1}, the CH_4 absorption band at 6076 cm^{-1}, and the strong CO_2 absorption band at 4852 cm^{-1}.

- A scientifically unique feature of CLARS–FTS, among instruments that measure surface reflected sunlight, is that it uses the O_2 $^1\Delta$ band at 1.27 μm instead of the O_2 A band at 0.76 μm that is traditionally used by spaceborne instruments to constrain surface pressure and aerosols.
- In the GFIT3 algorithm, the aerosols are primarily constrained by the O_2 and the SCO_2 bands.

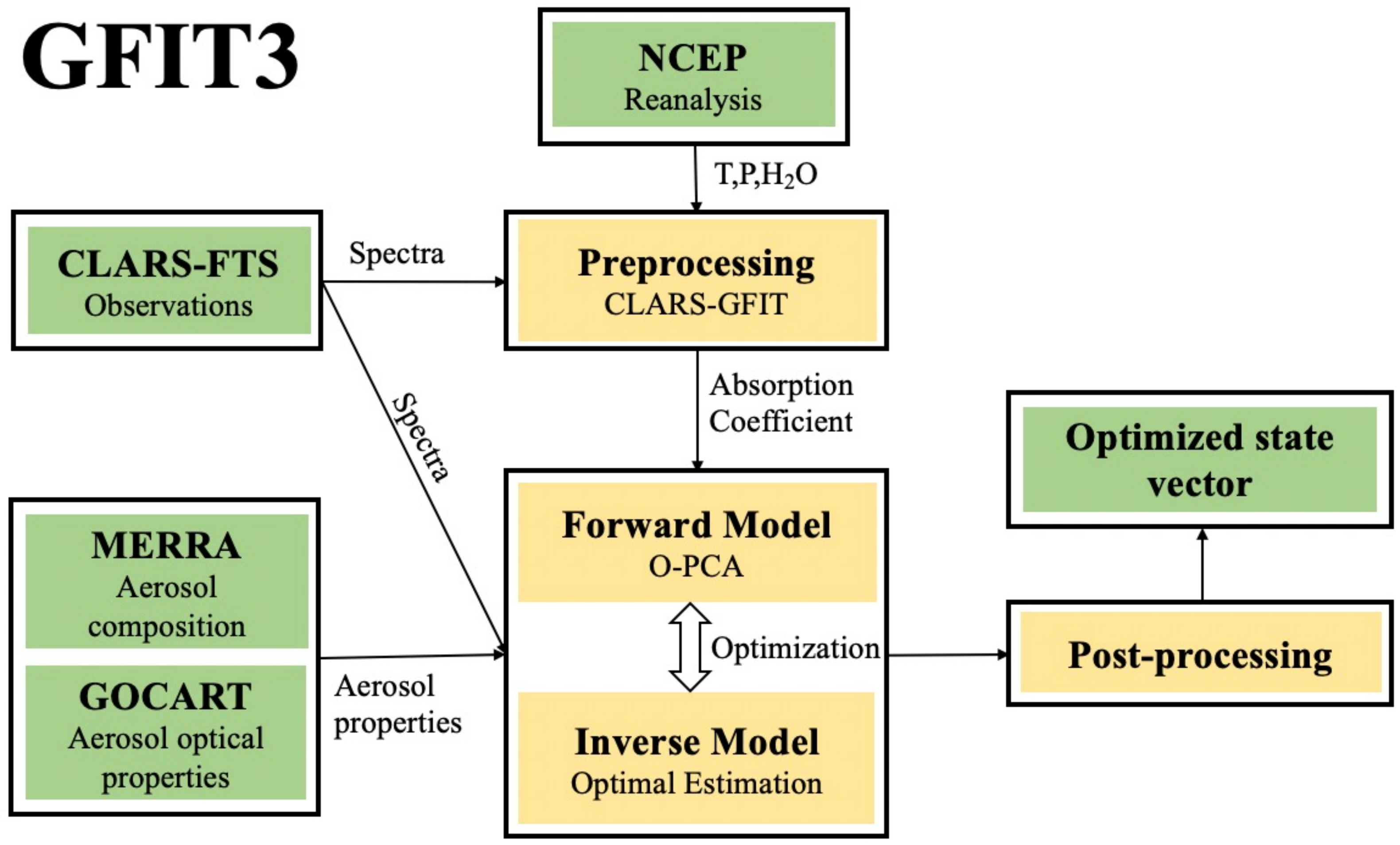
Aerosol scattering angles: diurnal change



Diurnal change of aerosol scattering angle for six selected surface reflection points, separated into two groups.

- This large range of angles, from forward scattering (<90 degrees) to backward scattering (>90 degrees), means that a majority of the change in aerosol scattering comes from angular variations.
- This also indicates that the aerosol scattering phase function is a key parameter that needs to be accurately modelled in order to obtain high fidelity RT calculations.
- GFIT3 algorithm includes coarse (including sea salt and dust) and fine (including organic carbon, black carbon, and sulfate) mode aerosols in the radiative transfer model.

Workflow



There are four major components:

(1) a pre-processing step to identify soundings free of clouds and heavy aerosol loading;

(2) a forward RTM to generate synthetic spectra in order to simulate observed CLARS-FTS measurements;

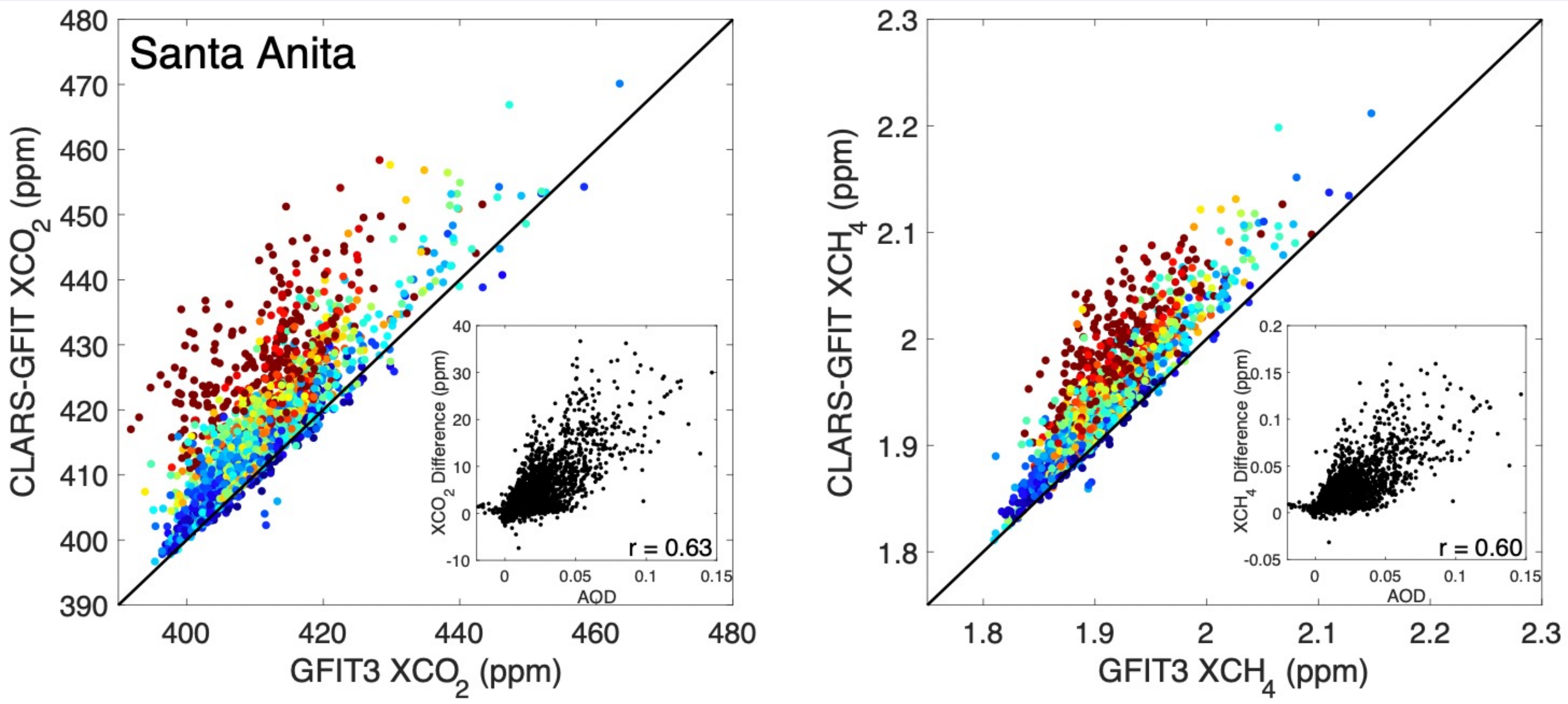
(3) an inverse model based on optimal estimation to update the surface and atmosphere states to minimize the difference between model and observation; and

(4) a post-processing screening step to filter out bad retrievals.

GFIT3 is an extension of the widely used GFIT model, to retrieve GHGs in polluted urban atmospheres from spectra of reflected solar radiation. GFIT is a state-of-the-art profile scaling algorithm to retrieve gas concentrations and related atmospheric and instrumental parameters from absorption spectra.

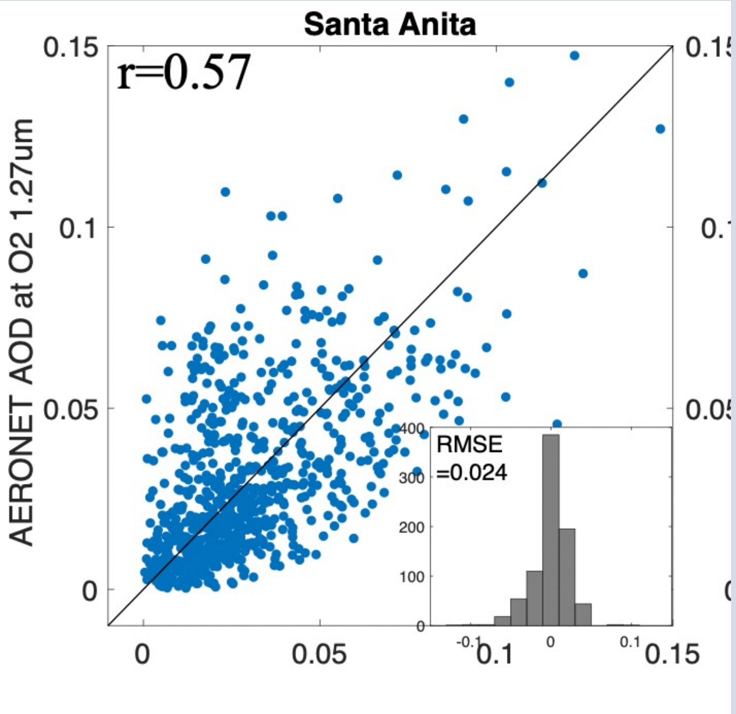
Retrieval results

Retrieved CO_2 and CH_4 (with and without aerosols)



In general, when aerosols are not accounted for in the retrieval, as in CLARS-GFIT, XCO_2 and XCH_4 are overestimated. The bias can be up to about 10% for both XCO_2 and XCH_4. The scatter plots indicate that the differences in XCO_2 and XCH_4 are significantly correlated with AOD.

Retrieved AOD vs AERONET



The retrieved AOD is in good agreement with AERONET-Caltech AOD

Future work

Future research will focus on developing a "divide and conquer" algorithm for retrieving aerosol properties and GHGs in order to further improve the accuracy of GHG retrievals. The basic idea is to use a two-step procedure. First, O_2 absorption lines will be used to constrain the AOD and ALH based on a spectral sorting technique (Zeng et al., 2018). These values will then provide constraints for AOD and ALH (with uncertainty estimates) for the retrieval of GHGs.

References:

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