GeoXO Atmospheric Composition Instrument Simulations: Polarization Sensitivity Impacts on Trace Gas Retrievals

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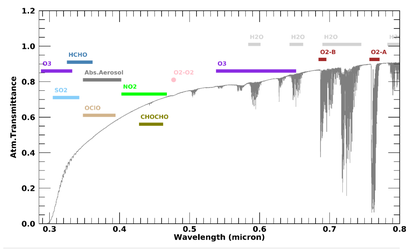
GeoXO and the Atmospheric Composition Instrument

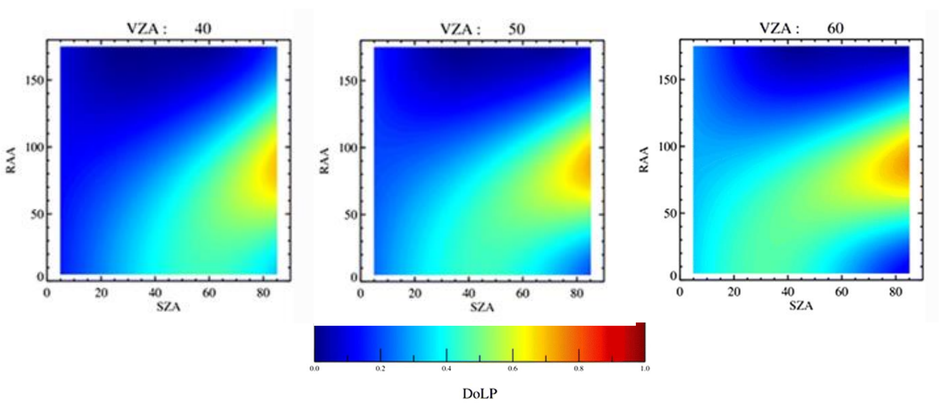
- NOAA's GeoXO initiated the development of an atmospheric composition instrument (ACX) to monitor and forecast air quality to help reduce the adverse impacts of poor air quality, enhance the protection of ecosystems, and improve human health.
- In support of its development, we are assessing requirements to estimate the resulting potential product quality within a modeling and simulation framework that accounts for the instrument response and retrievals of total column trace-gas amount based on the differential optical absorption spectroscopy (DOAS) technique [1]
- We analyze NO_2 retrievals and assess polarization sensitivity (PS) – both its magnitude and potential spectral variation – to estimate trace gas retrieval impacts for NO_2. PS corrections are introduced and their uncertainties estimated to show potential mitigation effects.



Planned ACX Instrument	
Spectral Resolution	0.6 nm
Spectral Sampling	0.2 nm
Spectral Range	300 – 500 nm; 540 – 740 nm
Temporal Revisit	60 min
Spatial Resolution	25 km² at nadir

Polarization

- The degree of linear polarization (DOLP) describes the amount of linear polarization incident on the sensor. Its values are highly dependent on the solar and view geometry.
- The example below, taken from Choi et al. 2021 [2], shows this dependence on relative azimuth angle (RAA) and solar zenith angle (SZA) for three different view zenith angles (VZA) at 440 nm.

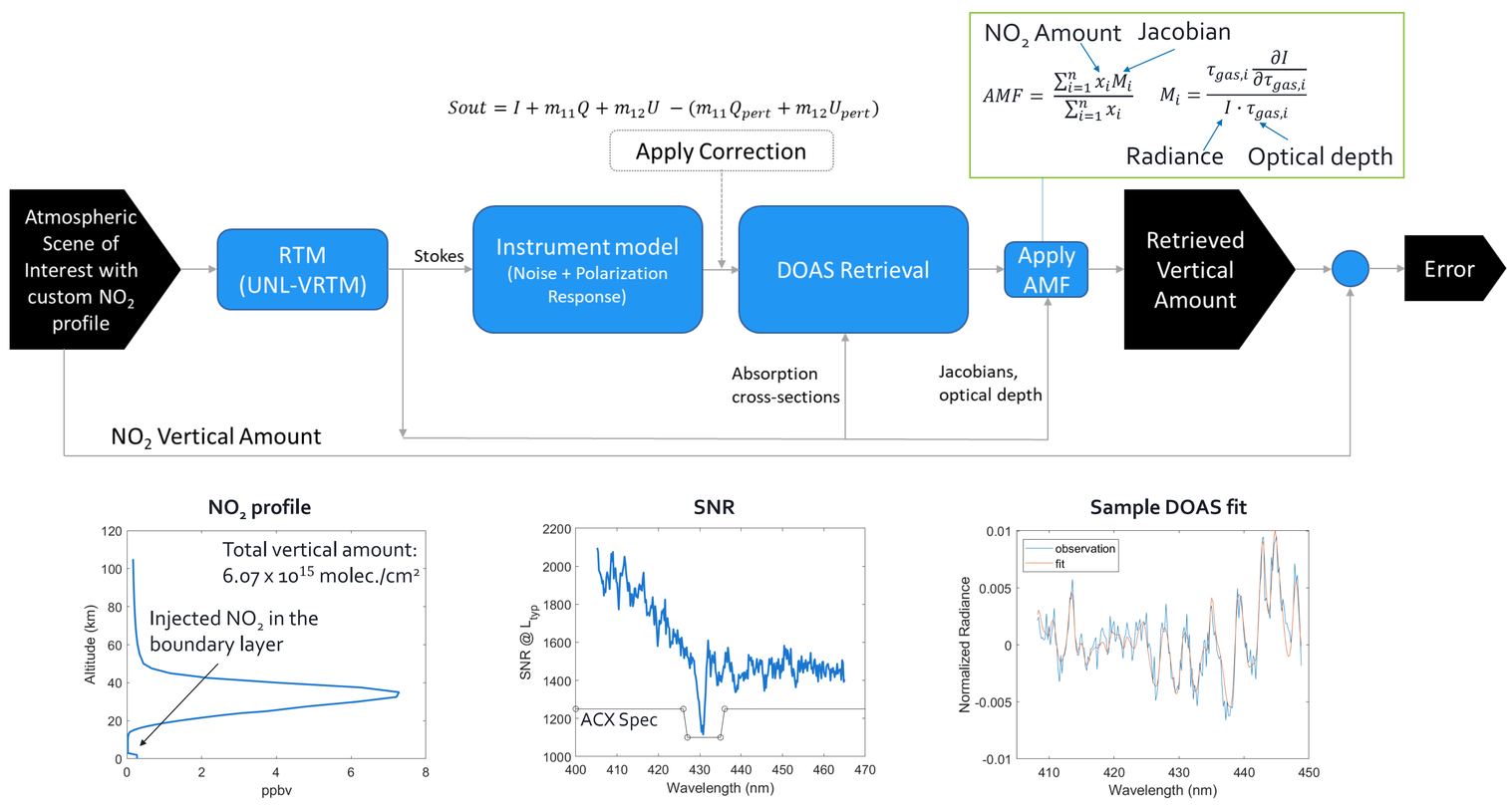


Methodology

- A scene of interest with a custom gas profile is supplied to a VLIDORT-based radiative transfer model, the Unified Linearized Vector Radiative Transfer Model (UNL-VRTM), to generate Stokes parameters to represent the incident light. [3-4]
- The ACX polarization response is applied as represented by a Mueller matrix with non-zero linear response terms (vertical orientation is assumed here).
- To derive polarization sensitivity corrections that account for the aerosol knowledge uncertainties, we use Stokes parameters derived from the same scene with no aerosol and assume perfect knowledge of the polarization sensitivity.
- Other instrument parameters – set to be consistent with our current knowledge of ACX and consistent with its requirements [5] – are used to apply the noise and spectral parameters.
- The differential optical absorption spectroscopy technique (DOAS) is used, where the cross-sections and air mass factors (AMFs), used to convert observed slant column amounts to vertical column are calculated using Jacobians produced by the radiative transfer code.

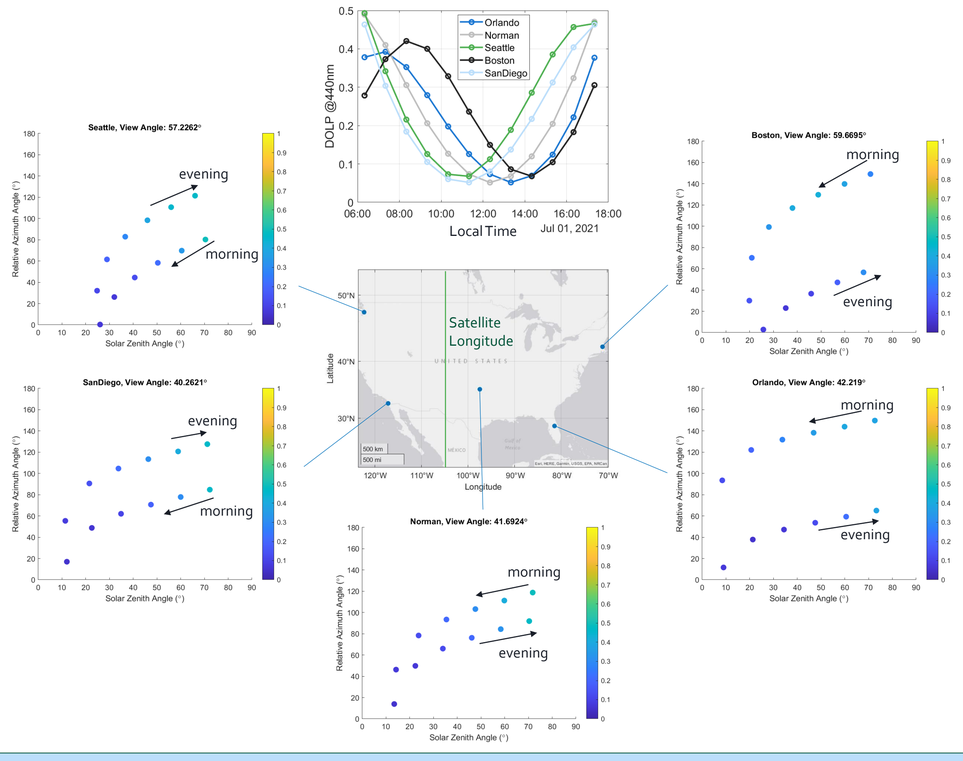
Scene and Instrument Parameters

- Atmospheric Profile: US Standard Atmosphere with modified boundary layer concentration amount of NO_2
- Aerosol model for an urban scene (soot and water-soluble) with 0.03 and 0.2 AOD, respectively
- Satellite Location: longitude = -105°
- Noise at the requirement level [5] with 1000 realizations for each simulation, spectral sampling/resolution: 0.2 nm/ 0.6 nm, polarization sensitivity: 0%, 5% constant, 5% spectrally- varying, with vertical orientation



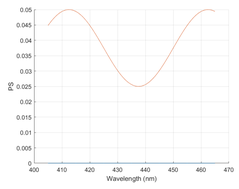
Results

(Top, center) The change in the degree of linear polarization as it changes throughout the day (July 1) is shown for several locations around the continental US. The remaining plots show more details on the geometrical dependence as discussed in the Polarization section.

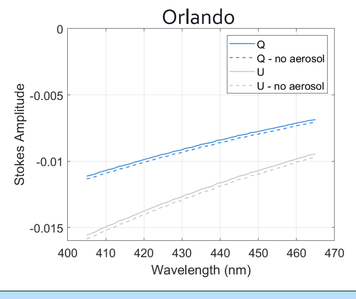


NO2 retrieval errors are shown for different instrument polarization values/spectral dependences for the locations

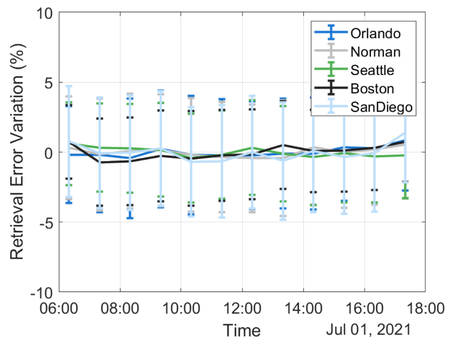
Spectrally-varying PS example



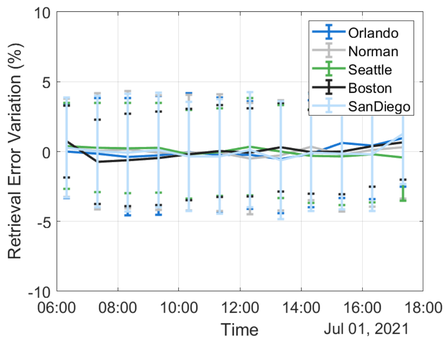
The Stokes parameters used for the observations and those derived neglecting the aerosol component (and used for the correction) are shown for a single location



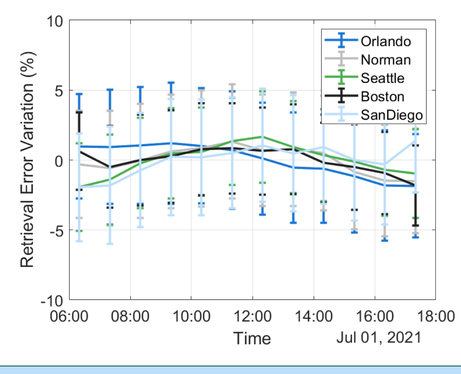
PS = 0



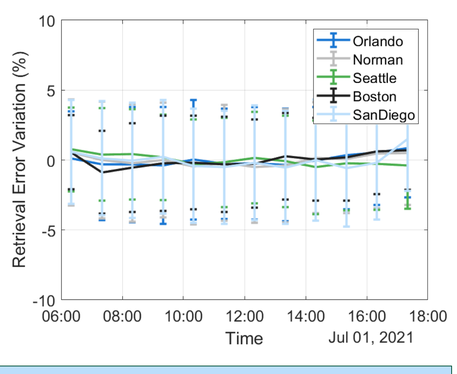
PS = 5% constant



PS = 5%, spectrally varying



PS = 5%, spectrally varying with a correction



Summary

- A modeling framework was developed that includes the impact of instrument noise, spectral sampling, and polarization impacts that can be used to understand instrument parameter impacts during ACX development.
- This study shows some potential ACX polarization diurnal impacts for NO2 retrievals:
  - A polarization sensitivity of 5 % has negligible impact on the retrieval error when it is spectrally constant across the NO_2 retrieval wavelength range.
  - Polarization sensitivity that is spectrally varying can increase its impact on the NO2 retrieval error.
  - Using a correction with Stokes parameters derived without aerosol impacts appears to mitigate the retrieval error assuming aerosol optical depth of 0.03 and 0.2 for soot and water-soluble aerosols, respectively.
- This study will be expanded to include additional uncertainties in the PS correction, other PS correction strategies, other trace gas retrievals, scene parameters including clouds, and updated instrument parameters to more closely reflect its design as it is being developed.

References

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