The NO 2 Algorithm for GeoXO-ACX and Application to GEMS and TEMPO

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Overview of GeoXO ACX

- GeoXO is NOAA's geostationary constellation
- ACX is the atmospheric composition instrument on board GeoXO Central, to be launched in 2030s

ACX

Attribute	What	Why
Coverage	CONUS, southern Canada, northern Mexico, Caribbean	Hourly inputs to national air quality, hazard and fire forecasting capabilities and warnings.
Spatial Resolution	8x3 km² @ nadir	Resolve sources, including cities, highway corridors, airports, oil/gas fields, large point sources like fires and power plants.
Temporal Resolution	60 min	Capture diurnal variations in pollution emissions, photochemistry, and exposure. Detect episodic events like wildfires and volcanoes. Select for cloud-free conditions. Increase geographic coverage compared with LEO or surface observations.
Spectral Coverage / Resolution	UV: 300-500 nm Vis: 540-740 nm Both @ 0.6 nm	UV: ozone, nitrogen dioxide, formaldehyde, sulfur dioxide, absorption aerosol optical depth. Vis: cloud/aerosol layer height, PBL ozone, vegetation.

Abstract

NOAA includes an atmospheric composition instrument (ACX) for the planned GeoXO mission to advance NOAA's capabilities of air quality monitoring over North America. Similar to its geostationary predecessors, GEMS and TEMPO, the ACX provides hyperspectral coverage from ultraviolet (UV) to visible, allowing high-cadence and high spatial resolution observations of air pollutants such as O_3, NO_2, HCHO, SO_2, and particulate matter (PM) during the day. In this poster, we present an advanced algorithm for NO_2 retrieval from the visible (405 - 465 nm) spectrum and its application to the GEMS radiance measurements. We describe the technique for instrument characterization and identification of instrument artifacts for improving retrieval precisions, soft calibration approach for removing systematic biases in NO_2 retrieval, algorithm physics implementations to achieve high accuracy retrieval, and method for effective stratosphere-troposphere separation. Comparisons of NO_2 with polar-orbiting instruments (such as S5P TROPOMI) as well as the GEMS standard NO_2 product to demonstrate high-quality retrievals are achieved with the GeoXO NO_2 algorithm.

NO_2 Algorithm for GeoXO ACX

Direct Vertical Column Fitting (DVCF) Algorithm for NO_2 Retrievals

$$\ln I_m(\lambda) - \ln I_{TOA}(\lambda) = V \int_0^\infty \frac{\partial \ln I_{TOA}(\lambda)}{\partial \tau_z} S_z \sigma(\lambda, T_z)\, dz - \sum_i^m \xi_i \sigma_i(\lambda, T_i) + \sum_{k=0}^n \frac{\partial \ln I_{TOA}(\lambda)}{\partial R} \Delta R_k (\lambda - \lambda_0)^k + \varepsilon$$

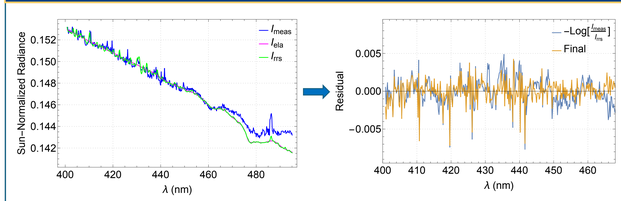
- λ : wavelength
- I_m : measured radiance
- I_{TOA} : radiative transfer simulation
- σ : gas absorption cross sections
- R : reflectivity or cloud fraction
- NO_2 vertical column : V
- NO_2 Shape factor : S_z
- Gas absorber slant columns : ξ_i
- Aerosol Index : R_1
- Altitude-resolved AMF: $-\frac{\partial \ln I_{TOA}}{\partial \tau_z}$

Advanced Algorithm Features

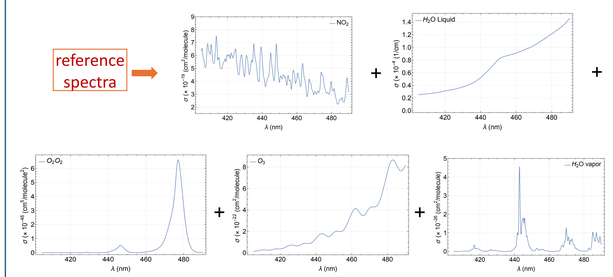
- Allow accurate algorithm physics: explicit treatment of aerosol and surface BRDF to provide accurate representation of spectral and altitude variations of measurement sensitivities (DOAS's equivalent is the improved AMF).
- Allow more accurate stratosphere-troposphere separation by combining retrievals from UV and VIS spectra
- Allow soft calibration to correct biases in radiometric calibration and instrumental features that interfere with the interpretation of molecular absorptions.

References:
Yang et al., 2014, DOI: 10.1002/2014GL060136
Huang et al., 2022, DOI: 10.1016/j.atmosenv.2022.119367

Illustration of DVCF retrievals



- Information + error are contained in spectral residual: - Log[I_{meas}/I_{rrs}]
- Fitting of residual with reference spectra to extract slant (or vertical) columns

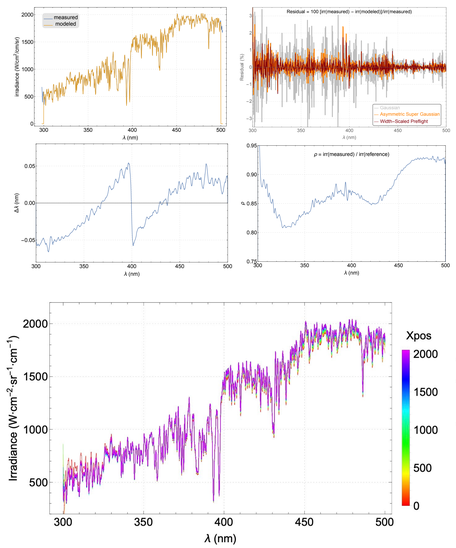


Objectives

In preparation for GeoXO ACX, we apply the ACX NO_2 algorithm to proxy data (such as GEMS. TEMPO, and TROPOMI) to develop and perfect techniques for handling measurement characteristics:

- wavelength registrations
- instrument spectral responses
- anomalous pixels
- calibration biases
- common mode spectra

Directing Fitting of GEMS Irradiance and Composite



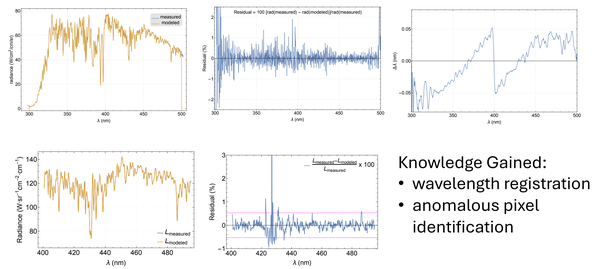
Knowledge Gained:

- wavelength registration
- more accurate ISRF
- calibration biases and their spectral dependence

Monthly Irradiance Composite

- Noise reduction
- Anomalous pixels removal
- Wavelength corrections and interpolation (under-sampling) error elimination

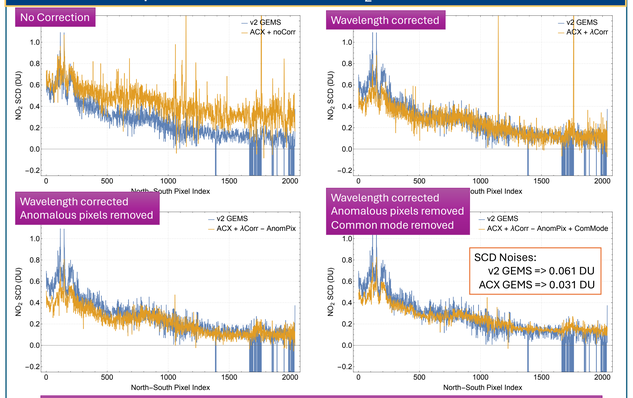
Directing Fitting of GEMS Radiance and Identification of Anomalous Pixels



Knowledge Gained:

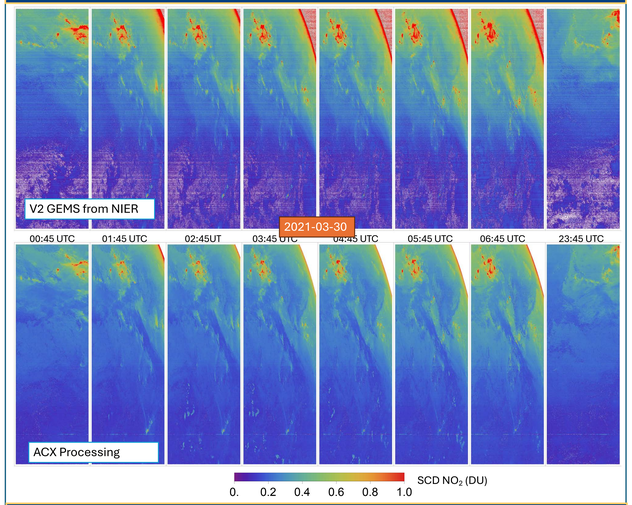
- wavelength registration
- anomalous pixel identification

Improvement of GEMS NO_2 Slant Columns

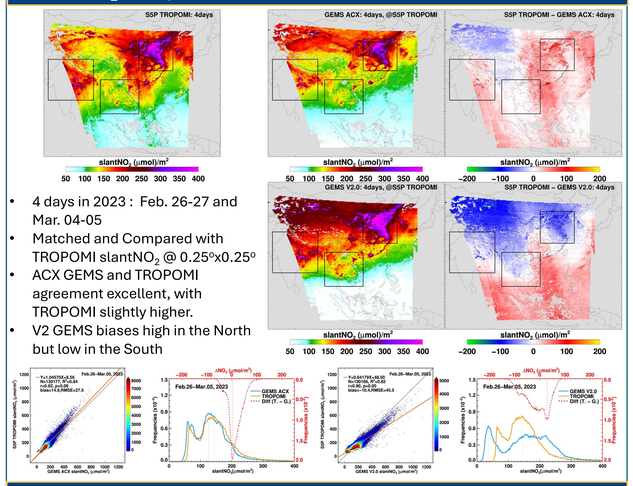


Improved NO_2 slant columns from GEMS are achieved through successive corrections of measurement spectra.

GEMS Slant NO_2 Columns: v2 GEMS vs ACX Algorithm

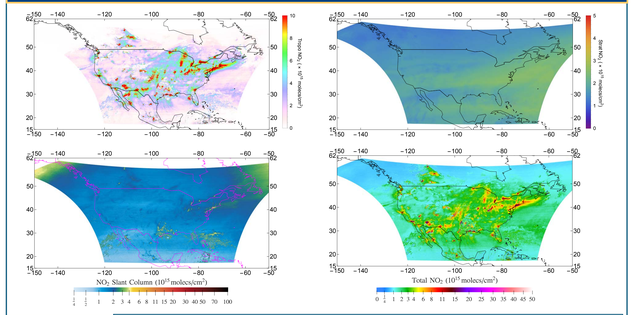


Slant NO_2 Comparisons: v2 GEMS vs TROPOMI vs ACX GEMS



- 4 days in 2023 : Feb. 26-27 and Mar. 04-05
- Matched and Compared with TROPOMI slantNO_2 @ 0.25°x0.25°
- ACX GEMS and TROPOMI agreement excellent, with TROPOMI slightly higher.
- V2 GEMS biases high in the North but low in the South

ACX Algorithm on TEMPO: 2023-11-16 Scan 8



Summary Rapid production of high quality NO_2 data is successfully demonstrated by the application of GeoXO ACX algorithm to GEMS and TEMPO observations.