TMP 18/19-09

Exploit TROPOMI Sensor

OPPA TMP 2019

End-Of-year (EOY)

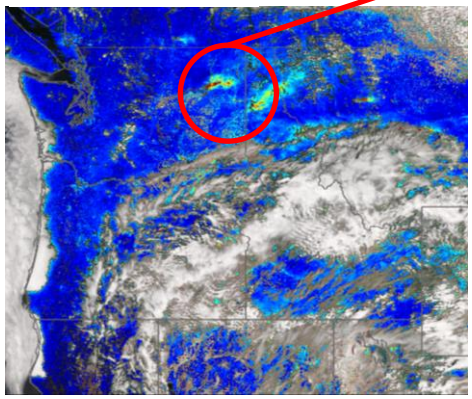
Report Presentation

NOAA

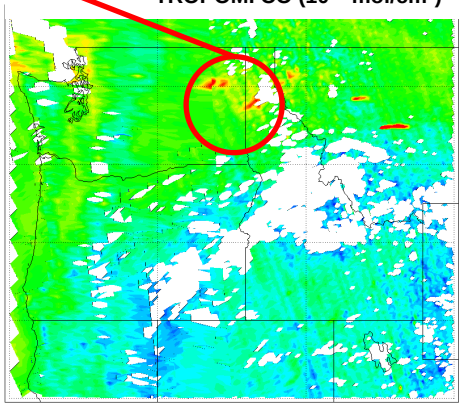
10/15/2020

Williams Flats Fire August 06, 2019

NOAA-20 VIIRS AOD



TROPOMI CO (10^{18} mol/cm^2)



Presented by:

R. Bradley Pierce
UW-Madison Space Science and Engineering Center

PI: Tim Schmit, Col's: Allen Lenzen, Tommy Jasmin, Collaborator Brad Pierce

Project Summary:

- Exploit composition retrievals from the TROPOspheric Monitoring Instrument (TROPOMI) to *improve air quality forecasts* through better constraints on long-range pollution transport and timely updates of global NOx emission inventories.

- Air quality forecast improvements are *realized through chemical data assimilation* using the TROPOMI carbon monoxide (CO) and nitrogen dioxide (NO2) retrievals within the Next Generation Global Prediction System (NGGPS) Unified Forecast System (UFS) with Real-time Air Quality Modeling System (RAQMS) chemistry.

- Supports *situational awareness* for NWS Incident Meteorologists (IMET) through *better estimates* of the vertical distribution of pollution from wildfires. This is accomplished by combining the NOAA Unique Combined Atmospheric Processing System (NUCAPS) and TROPOMI CO retrievals to constrain boundary layer CO concentrations.

Project Objective(s):

- Combining NUCAPS and TROPOMI CO retrievals to constrain boundary layer CO concentrations within UFS.
- Utilizing TROPOMI tropospheric NO2 retrievals to constrain UFS global nitrogen oxide (NOx) emission inventories.
- Developing a multi-sensor level 3 (L3) boundary layer CO product by combining NUCAPS and TROPOMI CO retrievals.

Strategic Alignment Discussions:

- NOAA & NESDIS Strategic Plan
  - The NOAA Satellite Observing System Architecture (NSOSA) study prioritized *atmospheric composition measurements* as one of the future product needs for National terrestrial and ocean observation objectives.
  - Exploitation of TROPOMI atmospheric composition measurements aligns with NESDIS's Mission to provide global environmental data from satellites to *protect the Nation's environment and quality of life through improved air quality forecasts*.
- NWS Strategic Plan
  - Annex 10 "Aerosols and Atmospheric Composition" of the Strategic Implementation Plan for Evolution of NGGPS to a National Unified Modeling System outlines the need for *including aerosol and chemistry within the UFS*.
  - Project 10.2 of Annex 10 "Data Assimilation for Atmospheric Composition" identifies *essential chemical data assimilation (CDA) and emission data assimilation (EDA) capabilities* needed to accomplish these goals
- World Meteorological Organization (WMO) 2025 Vision
  - A *constellation of atmospheric composition instruments* "including high spectral resolution UV sounder on geostationary orbit and at least a UV sounder on am + pm orbit" for "greenhouse gas monitoring, ozone/UV monitoring, *air quality monitoring*".

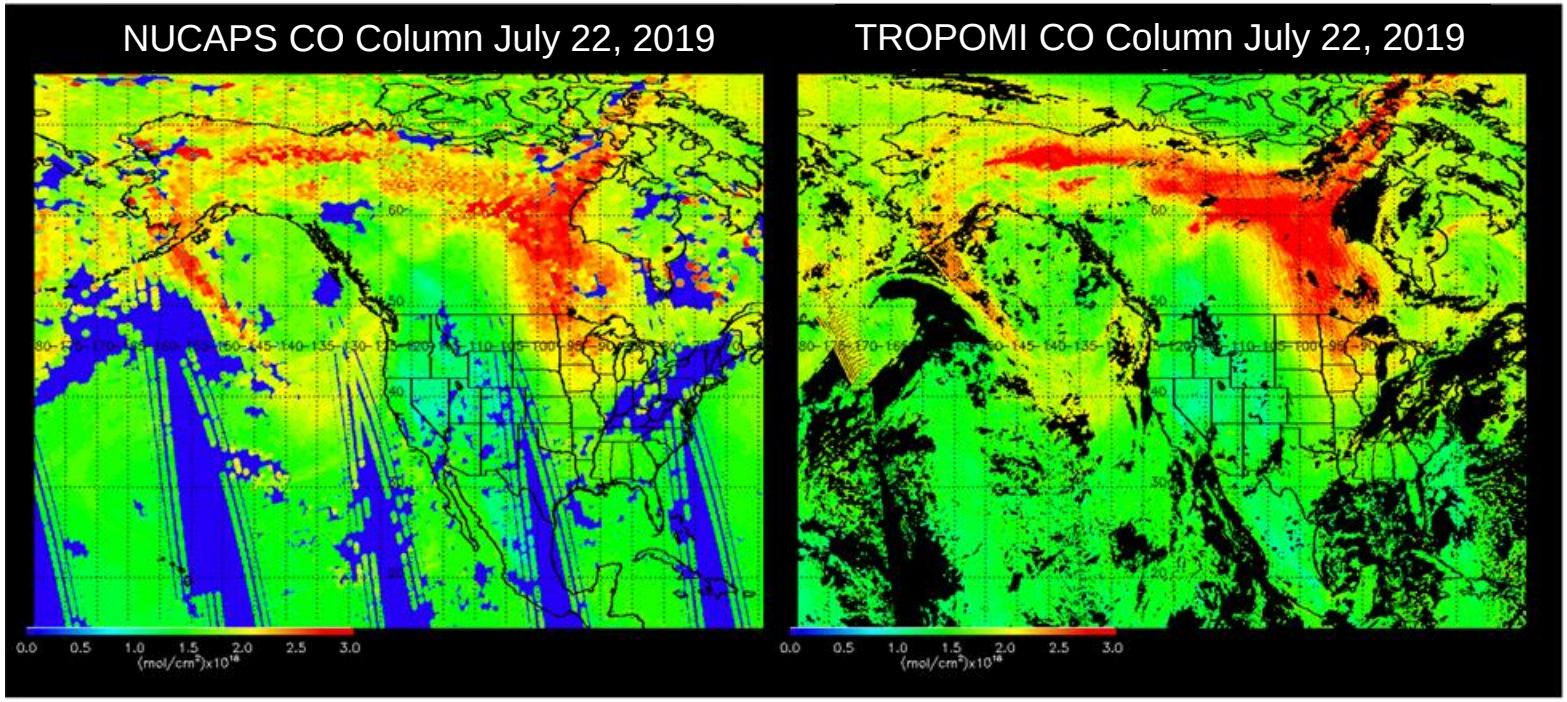
FY2019 Accomplishments:

- The project milestones and status are listed in the table below.

Milestone	Description	Status
1	Project Start	Sept, 2019
2	Collect July-September 2019 NUCAPS and TROPOMI retrievals. Develop and test L3 multi-sensor boundary layer CO retrieval	Complete
3	Conduct UFS-RAQMS Baseline and 15% wildfire and anthropogenic emissions reduction forecast experiments	Complete
4	Generate CO and NO_2 background error covariances and NO_X wildfire and anthropogenic Jacobians	Complete
5	Conduct UFS-RAQMS/GSI TROPOMI NO_2 data assimilation experiments and off-line wildfire/anthropogenic NO_X emissions adjustments	Complete
6	Conduct FV3-RAQMSCHEM adjusted NO_X emission experiment to assess impact of TROPOMI NO_2 assimilation	Complete
7	Conduct FV3-RAQMSCHEM NUCAPS, TROPOMI, and NUCAPS+TROPOMI CO assimilation experiments	Partially Completed (TROPOMI CO DA)
8	Prepare final report	Completed

FY2019 Accomplishments:

- Develop and test L3 multi-sensor boundary layer CO retrieval

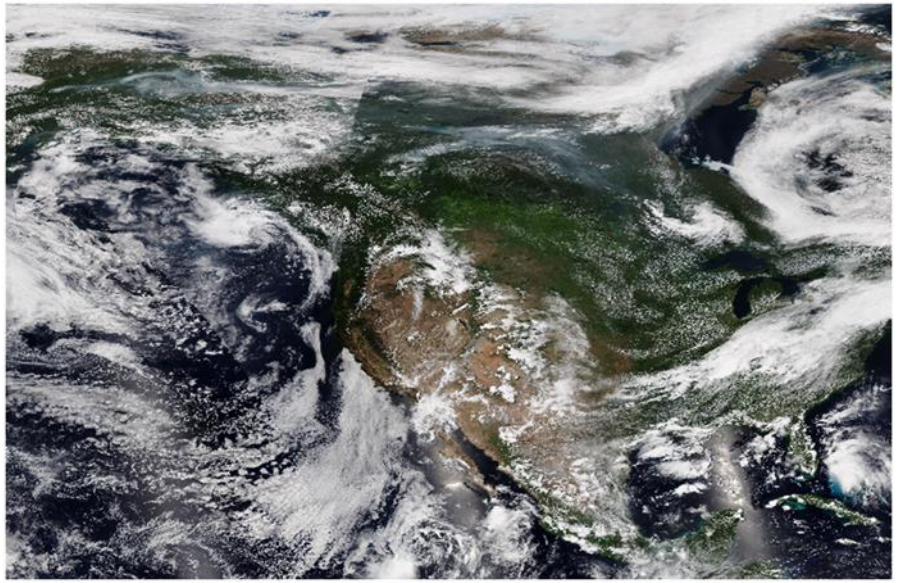


- TROPOMI SWIR retrieval uses reflected solar radiances and is sensitive to the total CO column
- NUCAPS TIR retrieval uses thermal emission and is most sensitive to mid tropospheric CO concentrations

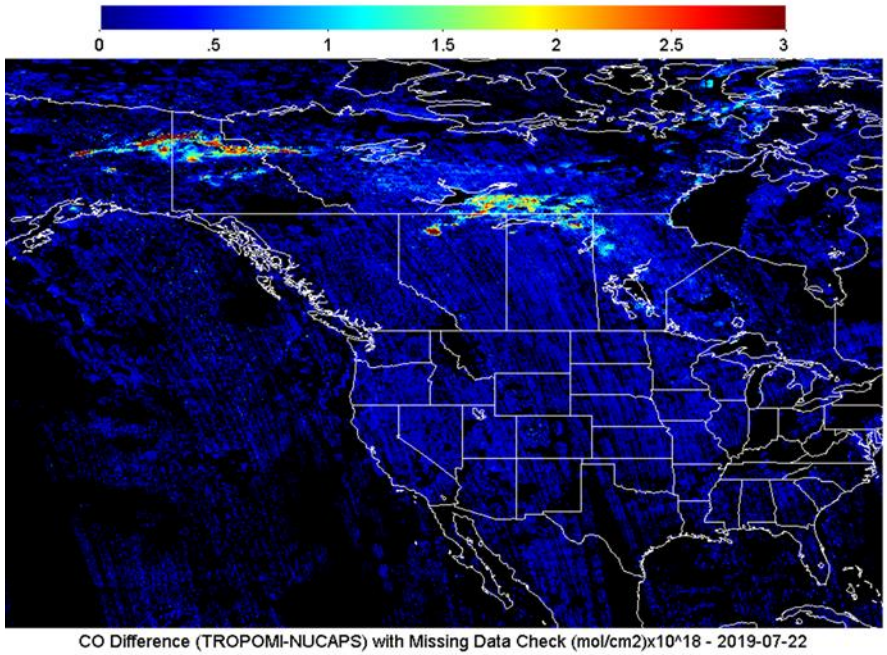
FY2019 Accomplishments:

- Develop and test L3 multi-sensor boundary layer CO retrieval

VIIRS True Color Imagery July 22, 2019



TROPOMI-NUCAPS CO Column July 22, 2019



- Difference (TROPOMI-NUCAPS) highlights boundary layer CO concentrations that show *where smoke is near the surface*

FY2019 Accomplishments:

- UFS-RAQMS TROPOMI NO2 off-line NOx emission adjustment experiments

1) Calculate monthly mean NO_2 Jacobian (β) from a 15% NO_X emission reduction perturbation experiment following *Lamsal et al.* 2011

$$\frac{\Delta E}{E} = \beta \times \frac{\Delta \Omega}{\Omega}.$$

2) Calculate monthly mean NO_2 analysis increment using UFS-RAQMS/GSI TROPOMI NO_2 assimilation
   a. NOx wildfire emission sensitive background errors (to correct UFS-RAQMS wildfire emissions)

$$\frac{\Delta E}{E} = \beta \times \frac{\Delta \Omega}{\Omega}.$$

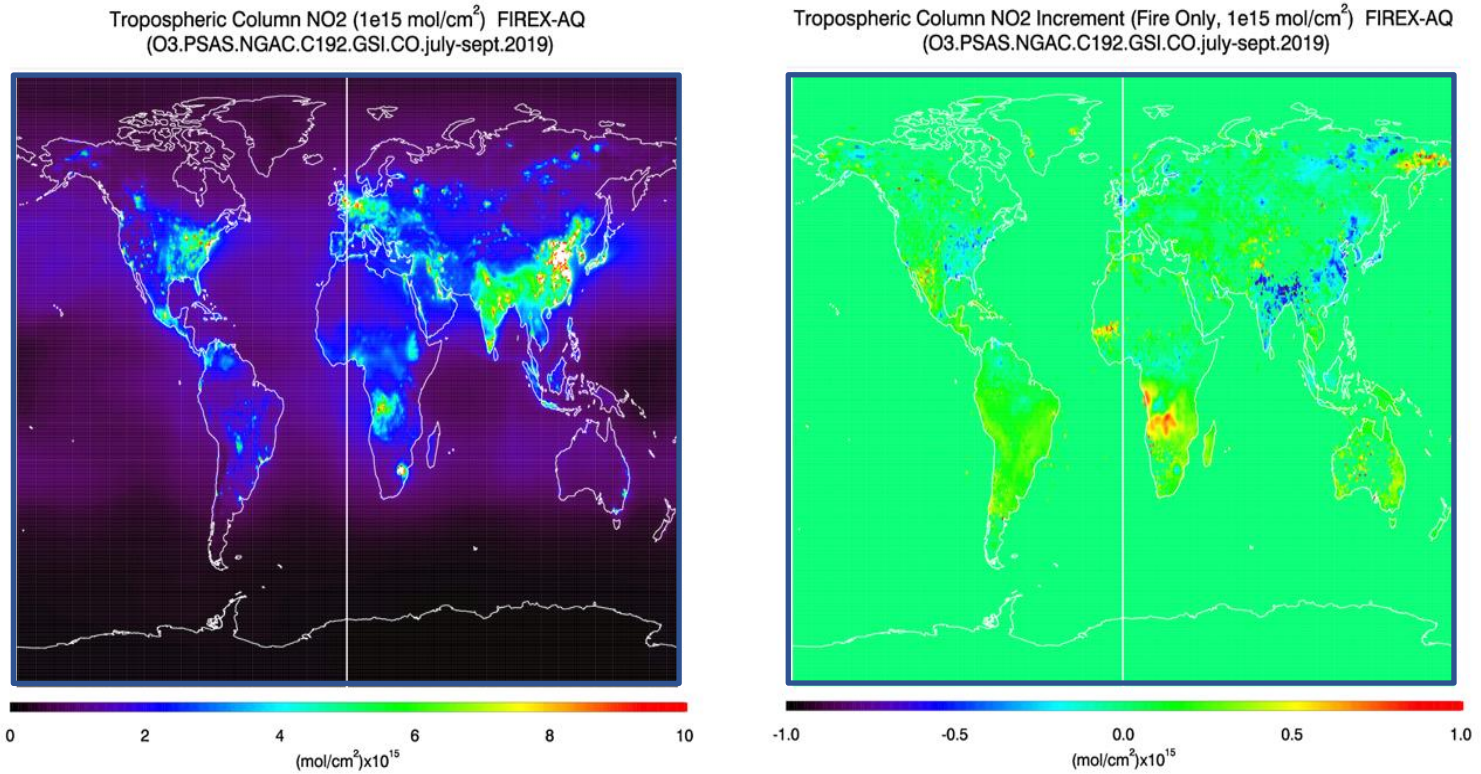
3) Adjust UFS-RAQMS NO_x wildfire emissions using Jacobian and average analysis increment

$$\frac{\Delta E}{E} = \beta \times \frac{\Delta \Omega}{\Omega}.$$

Lamsal, L. N., et al. (2011), Application of satellite observations for timely updates to global anthropogenic NOx emission inventories, Geophys. Res. Lett., 38, L05810, doi:10.1029/2010GL046476.

FY2019 Accomplishments:

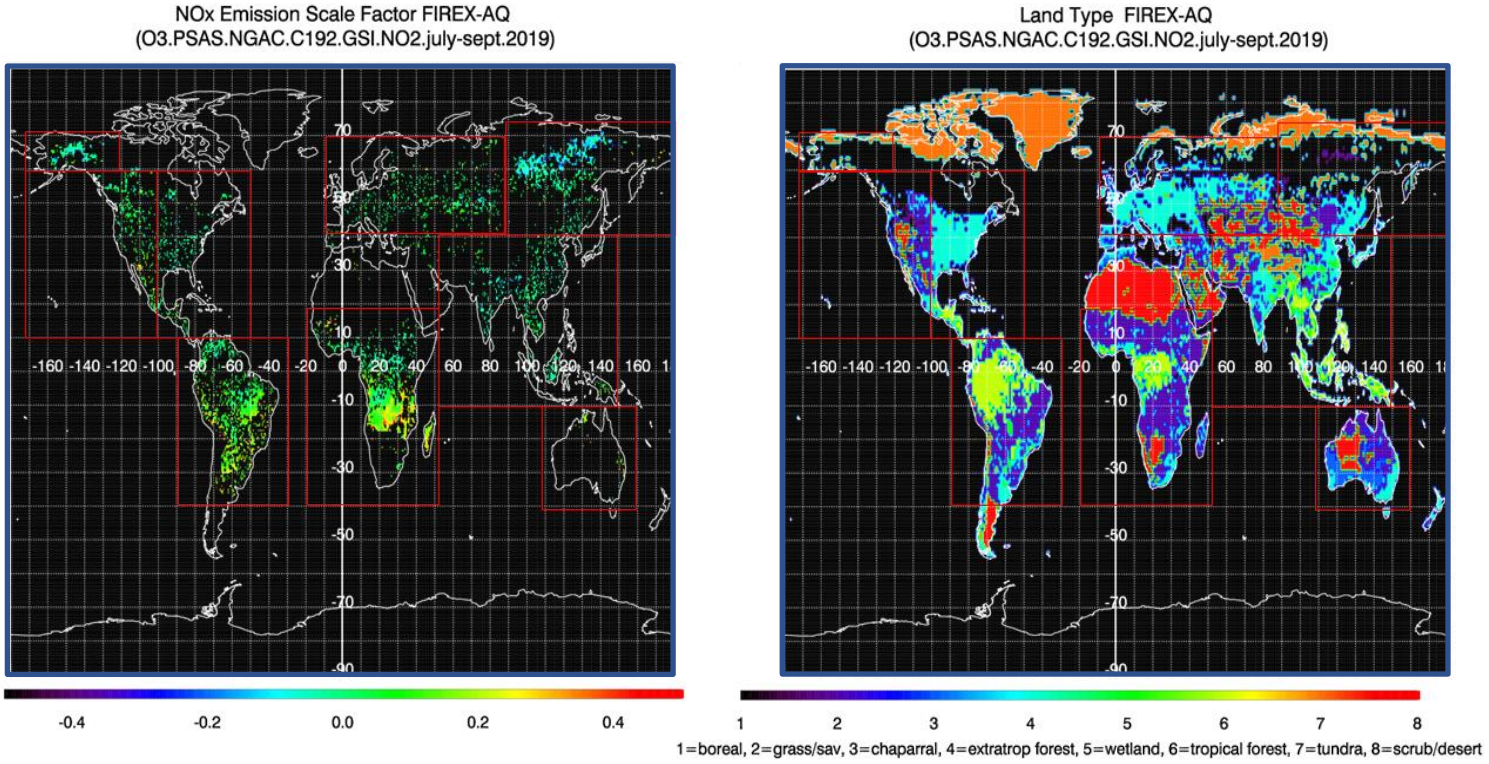
- UFS-RAQMS TROPOMI NO2 off-line NOx emission adjustment experiments



UFS-RAQMS Tropospheric column NO2 (left) and TROPOMI fire only analysis increment (right) for July-September, 2019. Units are 1e^{15} mol/cm^2

FY2019 Accomplishments:

- UFS-RAQMS TROPOMI NO2 off-line NOx emission adjustment experiments

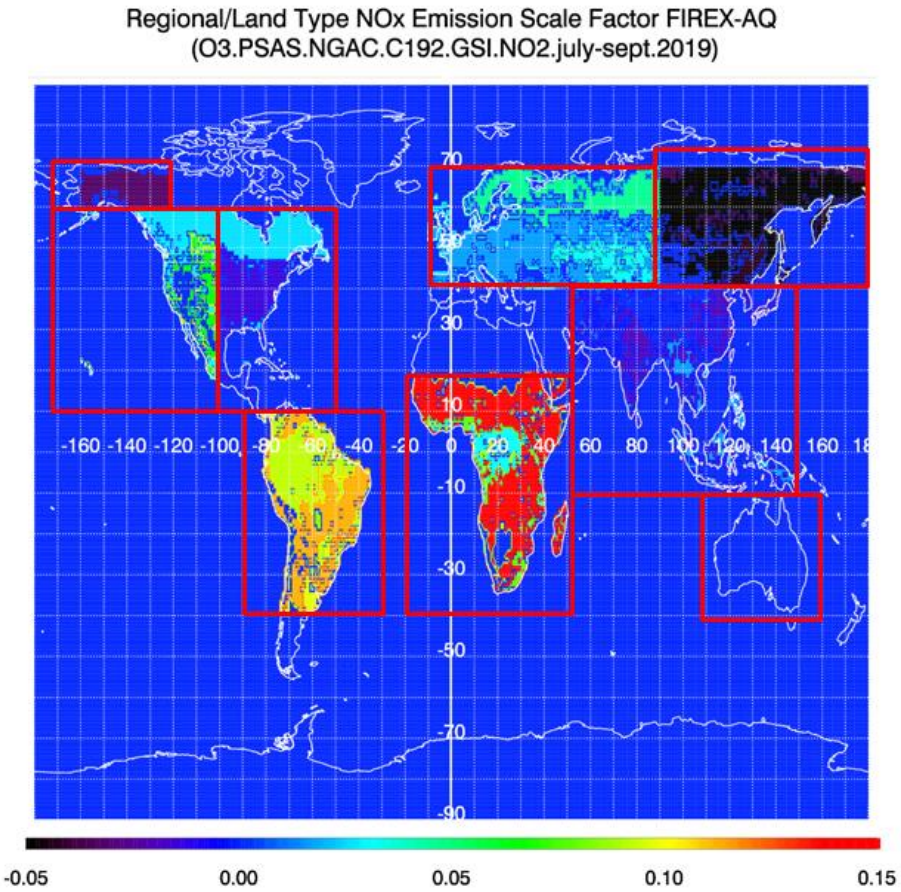


$$\text{nox\_scale\_factor} = \frac{\Delta E}{E}$$

UFS-RAQMS TROPOMI based wildfire NOx emission factor (left) for July-September, 2019 and UFS-RAQMS Land Type (right). Both quantities are unitless.

FY2019 Accomplishments:

- UFS-RAQMS TROPOMI NO2 off-line NOx emission adjustment experiments



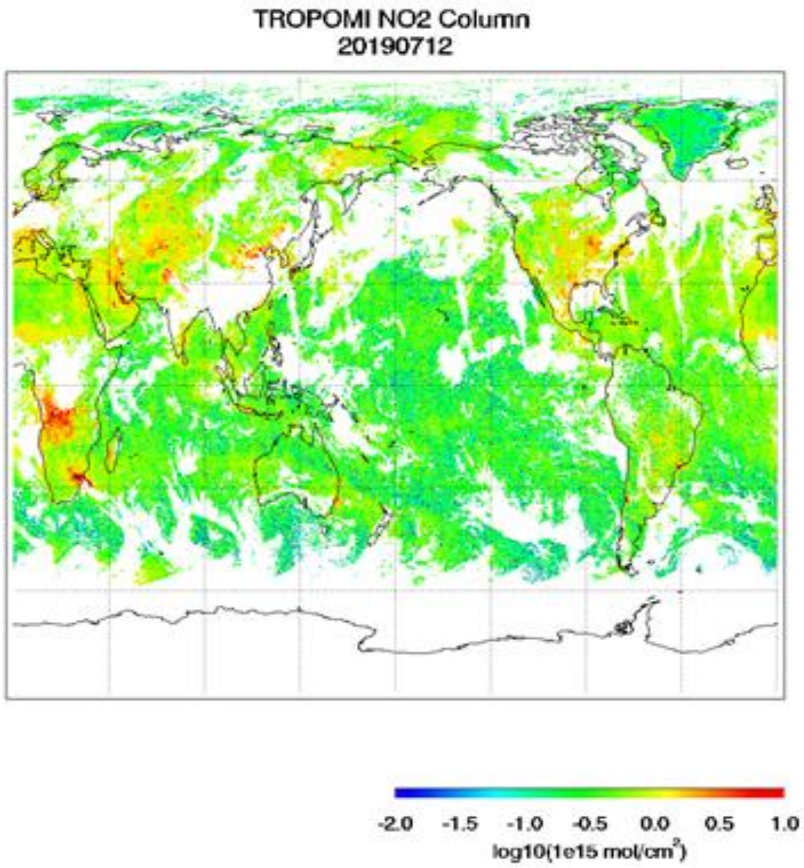
The scale factor is applied as follows:

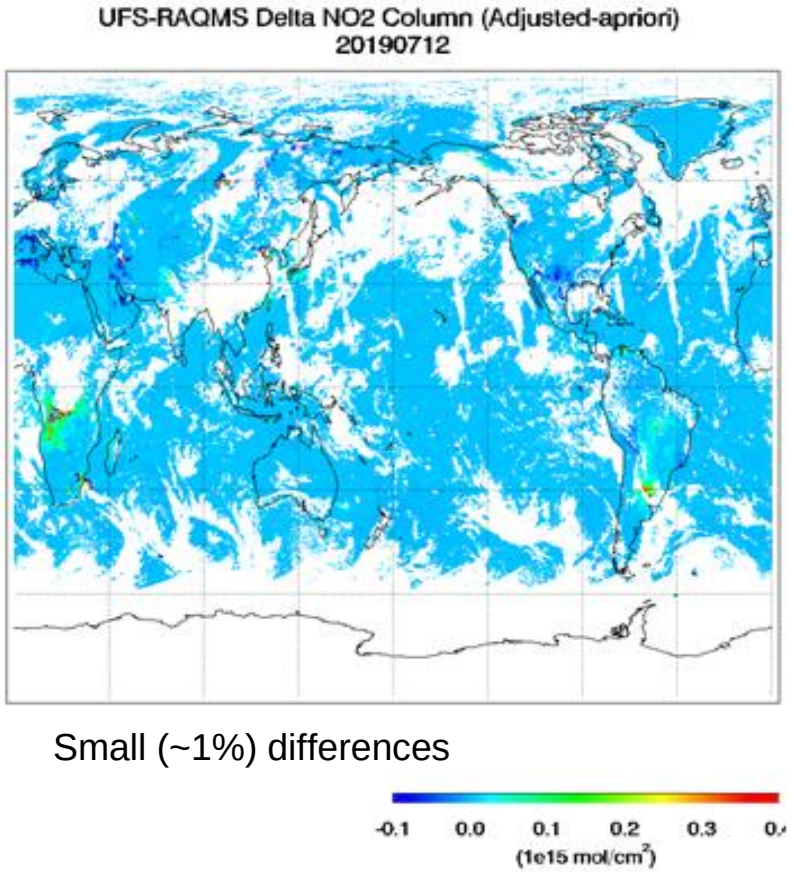
bb_nox_adjusted=bb_nox+nox_scale_factor*bb_nox

UFS-RAQMS TROPOMI based Regional/Land Type wildfire NOx emission factor for July-Sept, 2019 (unitless).

FY2019 Accomplishments:

- UFS-RAQMS TROPOMI NO2 off-line NOx emission adjustment experiments





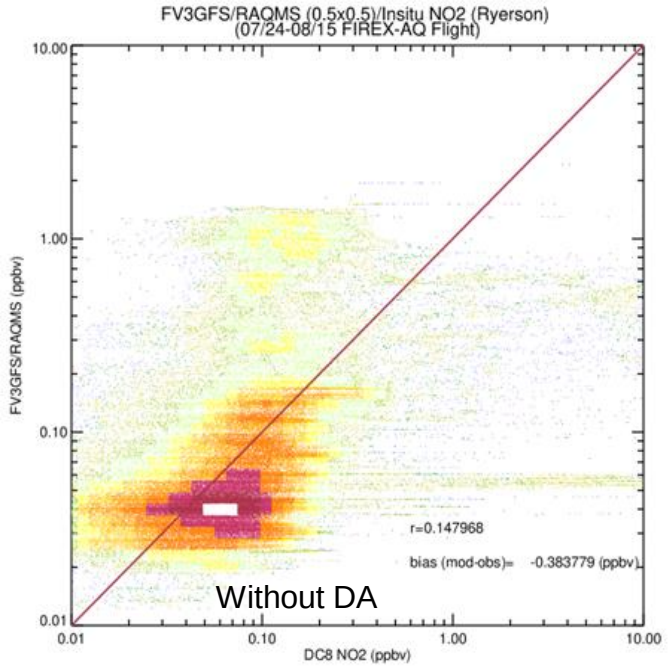
Small (~1%) differences

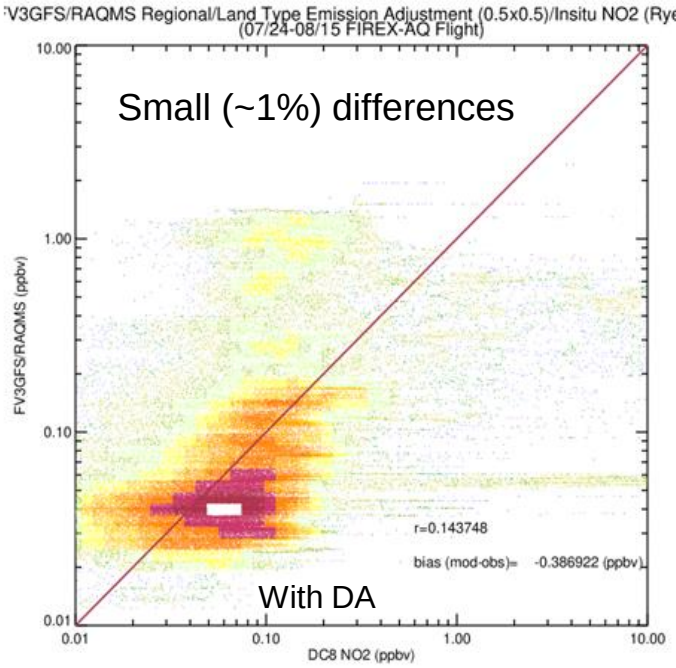
TROPOMI (left) and UFS-RAQMS difference (with minus without emission adjustment, right) on July 12, 2019. Log10 of the TROPOMI tropospheric NO2 column is contoured so that the full dynamic range can be shown except for the difference (lower right). Units are $1e^{15}$ mol/cm^2

FY2019 Accomplishments:

- UFS-RAQMS TROPOMI NO2 off-line NOx emission adjustment experiments

Verification during 2019 NASA/NOAA FIREX-AQ field campaign

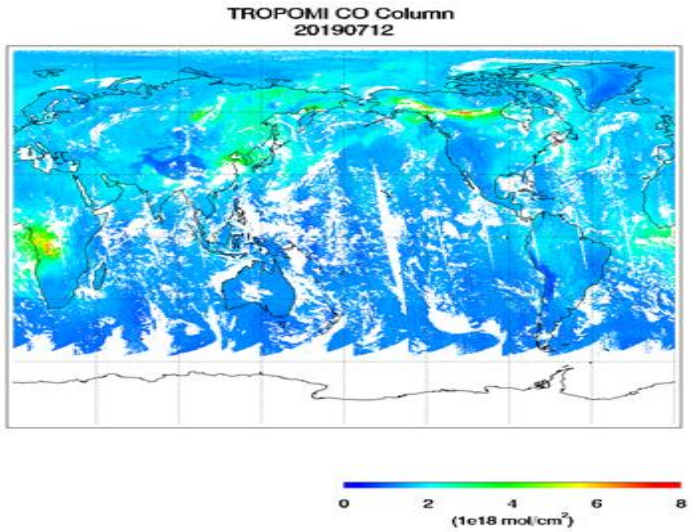


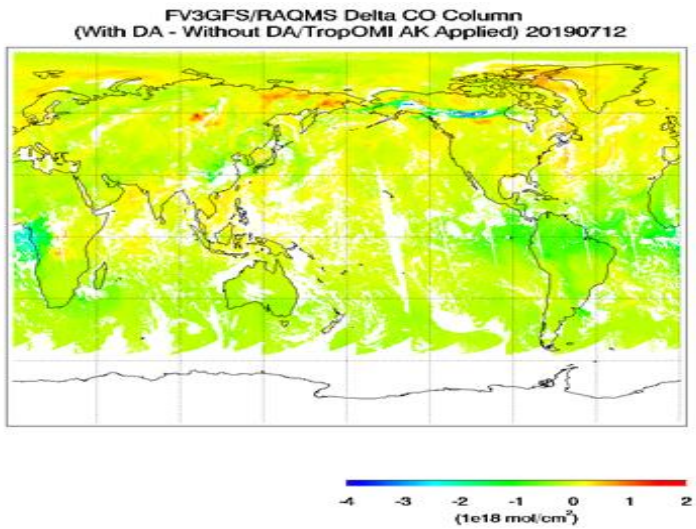


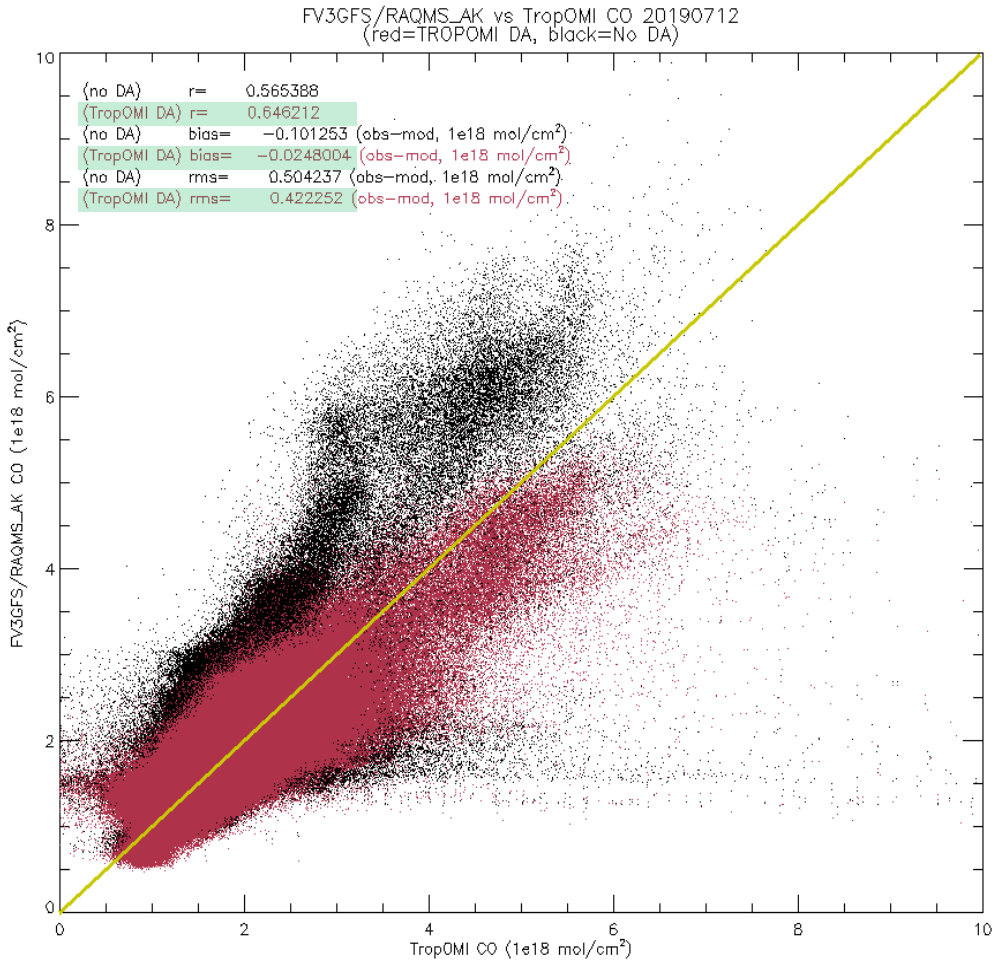
These wildfire NOx emission adjustment experiments during the NASA NOAA FIREX-AQ field campaign demonstrate the difficulties in using TROPOMI tropospheric NO2 columns to provide off-line constraints on global wildfire emissions.

FY2019 Accomplishments:

- UFS-RAQMS TROPOMI CO assimilation experiments





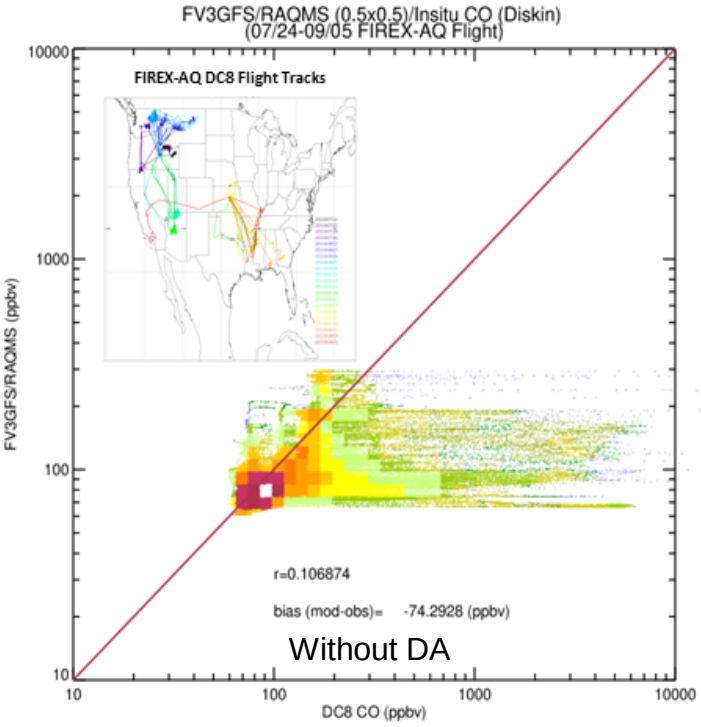


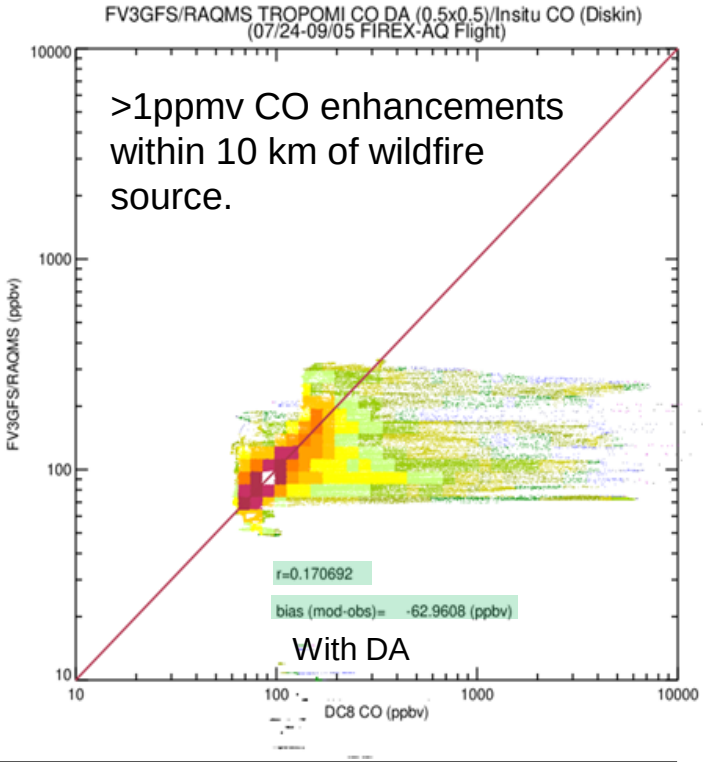
TROPOMI O-A July 12, 2019

FY2019 Accomplishments:

- UFS-RAQMS TROPOMI CO assimilation experiments

Verification during 2019 NASA/NOAA FIREX-AQ field campaign





These TROPOM CO column assimilation experiments during the NASA NOAA FIREX-AQ field campaign demonstrate the benefits of assimilating column retrievals based on CO absorption of reflected solar radiation (2.3microns) which is able to provide a true estimate of the CO column.

What was baselined that did not get accomplished?

- The only milestones that did not get accomplished were the assimilation of the NUCAPS CO retrievals and joint assimilation of the NUCAPS and TROPOMI CO retrievals.

- This was not accomplished within the allotted timeframe due to issues that arose associated with the generation of the NUCAPS science retrievals with averaging kernels and apriori information needed to assimilate the NUCAPS CO.

What work remains (if any) to get to a final report?:

- Final Report Submitted on 10/12/2020

Summarize how 2019 work transitions and/or relates to FY2020 funded projects:

- No FY2020 OPPA/TMP funding, however:

- Proposal for *evaluation and transition of L3 TROPOMI-NUCAPS boundary layer CO product* submitted to Fire and Smoke Initiative of FY21 JPSS PGRR call for proposals

- Proposal for *transition of UFS-RAQMS chemical data assimilation capabilities to NOAA/ESRL* submitted to Fire and Smoke Initiative of FY21 JPSS PGRR call for proposals.

Technology Readiness Level (TRL) Discussions:

- Based on previous work, the entry Technology Readiness Level (TRL) of the TROPOMI data assimilation within UFS-RAQMS is TRL 4 (Component/subsystem validation).

- The exit TRL is 6 (Demonstration in a relevant end-to-end environment) with completion of UFS-RAQMS TROPOMI data assimilation experiments.

- The TRL of the NUCAPS data assimilation within UFS-RAQMS remains at TRL 4 (Component/subsystem validation).

2019 Project Cost Assessment and Status:

- The following table summarizes the project cost assessment and status. Less than 1% of the original project budget has been costed.

Expense	TMP FY2019 Budget	Spent to Date
Labor & Travel	$124,720	$124,417
Overhead	66,101	65,462
Total	$190,821	$189,879

Exploit TROPOMI Sensor (TMP 18/19-09)

PI:Tim Schmit Organization: NESDIS/STAR

Objective

- Combine NUCAPS and TROPOMI CO retrievals to constrain boundary layer CO concentrations within UFS.
- Utilize TROPOMI tropospheric NO2 retrievals to constrain UFS global nitrogen oxide (NOx) emission inventories.
- Develop a multi-sensor level 3 (L3) boundary layer CO product by combining NUCAPS and TROPOMI CO retrievals.

Key Milestones

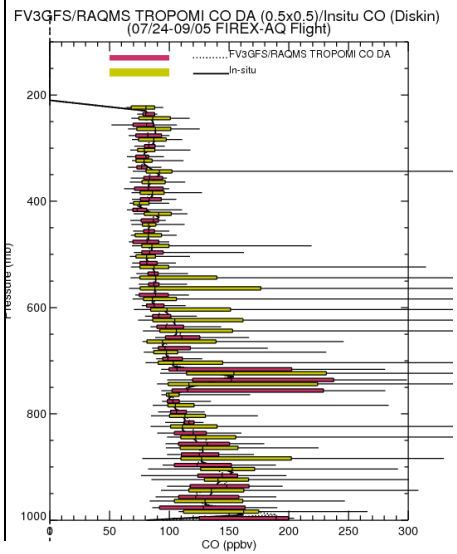
Project Start		09/19
Complete UFS-RAQMS Port		12/19
Complete L3 NUCAPS/TROPOMI		03/20
Complete CO assimilation	04/20	
Completed NO2 assimilation	06/20	
UFS-RAQMS impact study		09/20
EOY Reporting		10/20

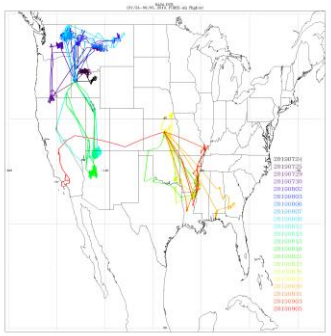
TRL_{IN} : 4 TRL_{OUT} : 6

Approach

TROPOMI carbon monoxide (CO) and nitrogen dioxide (NO2) retrievals used for chemical data assimilation within UFS-RAQMS and evaluated using measurements from FIREX-AQ field campaign. supports situational awareness for NWS Incident Meteorologists (IMET) through better estimates of the vertical distribution of pollution from wildfires.

Col's: Allen Lenzen, Tommy Jasmin, Collaborator Brad Pierce





TROPOM CO column assimilation experiments during the NASA NOAA FIREX-AQ field campaign demonstrate the benefits of assimilating column retrievals based on CO absorption of reflected solar radiation (2.3microns) which is able to provide a true estimate of the CO column.