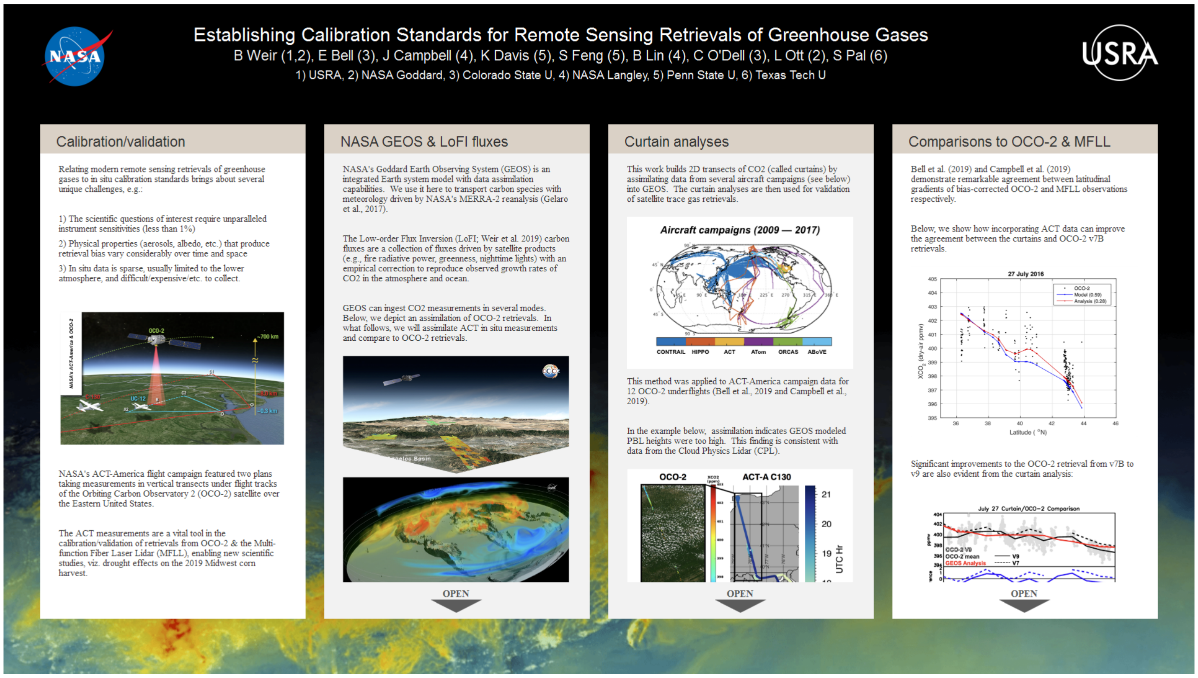
Establishing Calibration Standards for Remote Sensing Retrievals of Greenhouse Gases



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1) USRA, 2) NASA Goddard, 3) Colorado State U, 4) NASA Langley, 5) Penn State U, 6) Texas Tech U

PRESENTED AT:

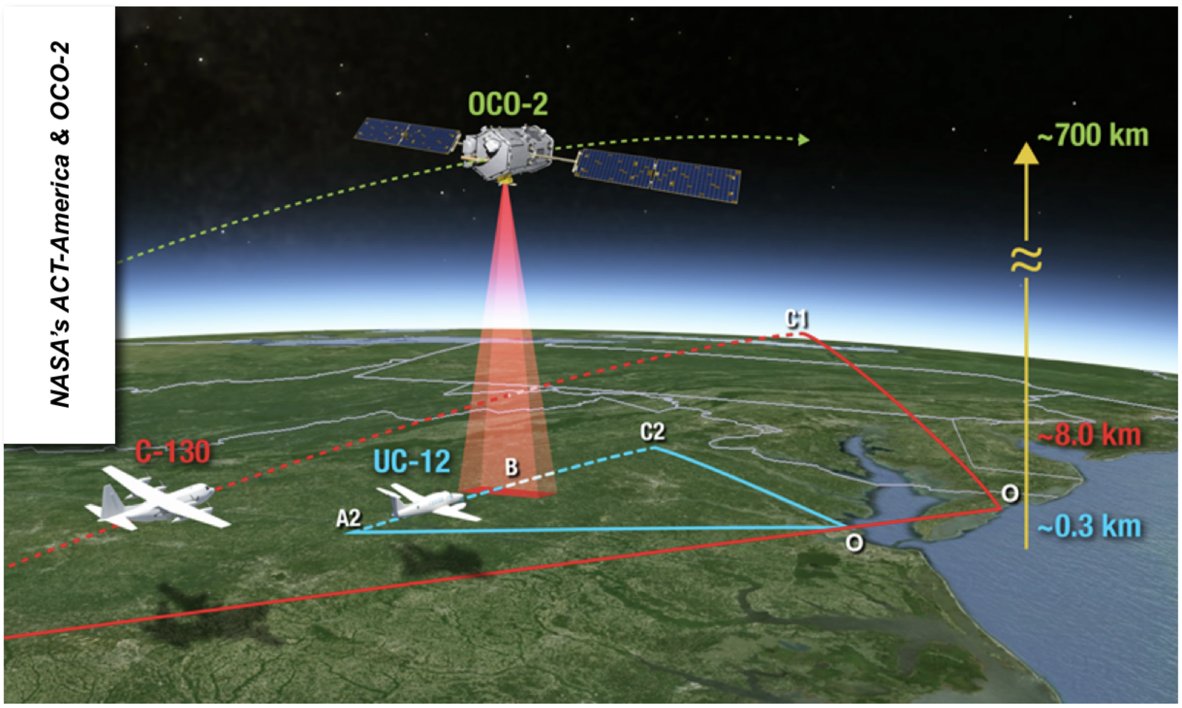
CALIBRATION/VALIDATION

Relating modern remote sensing retrievals of greenhouse gases to in situ calibration standards brings about several unique challenges, e.g.:

1) The scientific questions of interest require unparalleled instrument sensitivities (less than 1%)

2) Physical properties (aerosols, albedo, etc.) that produce retrieval bias vary considerably over time and space

3) In situ data is sparse, usually limited to the lower atmosphere, and difficult/expensive/etc. to collect.



NASA's ACT-America flight campaign featured two plans taking measurements in vertical transects under flight tracks of the Orbiting Carbon Observatory 2 (OCO-2) satellite over the Eastern United States.

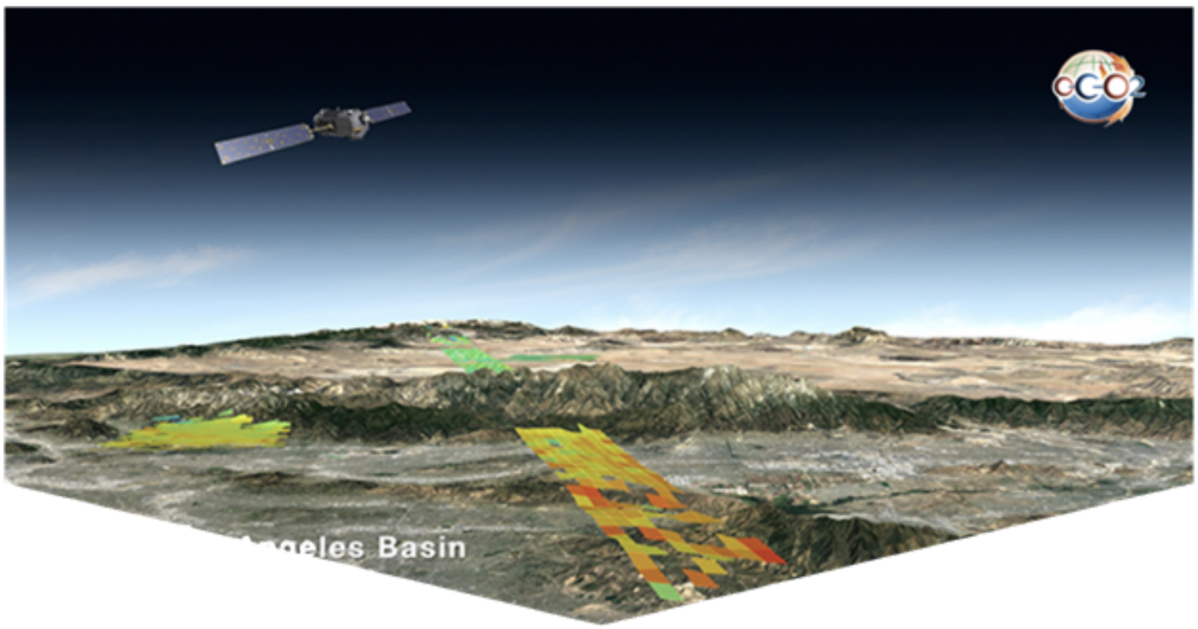
The ACT measurements are a vital tool in the calibration/validation of retrievals from OCO-2 & the Multi-function Fiber Laser Lidar (MFLL), enabling new scientific studies, viz. drought effects on the 2019 Midwest corn harvest.

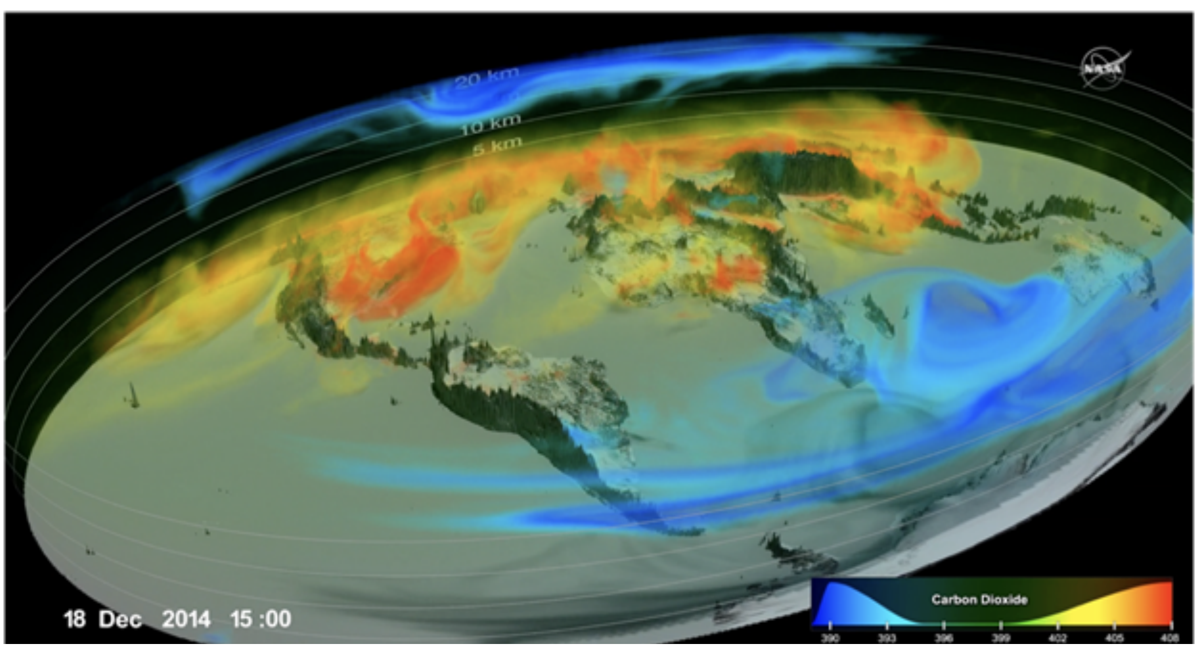
NASA GEOS & LOFI FLUXES

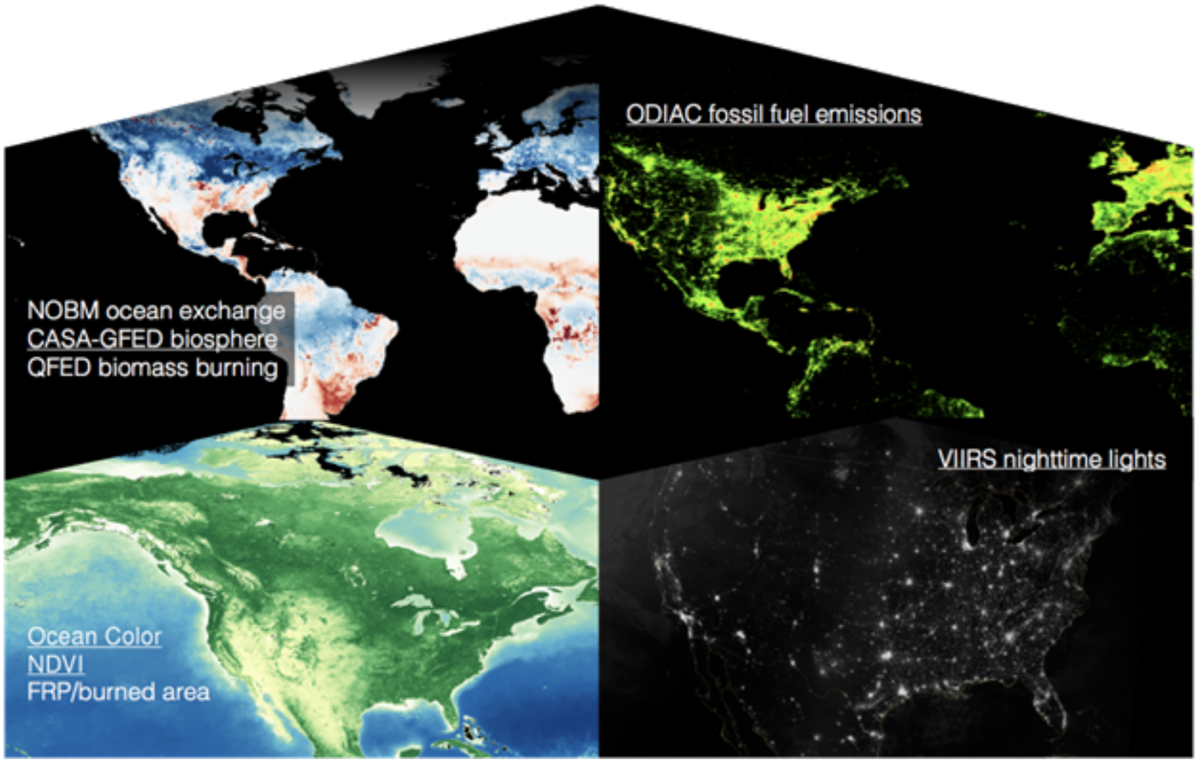
NASA's Goddard Earth Observing System (GEOS) is an integrated Earth system model with data assimilation capabilities. We use it here to transport carbon species with meteorology driven by NASA's MERRA-2 reanalysis (Gelaro et al., 2017).

The Low-order Flux Inversion (LoFI; Weir et al. 2019) carbon fluxes are a collection of fluxes driven by satellite products (e.g., fire radiative power, greenness, nighttime lights) with an empirical correction to reproduce observed growth rates of CO2 in the atmosphere and ocean.

GEOS can ingest CO2 measurements in several modes. Below, we depict an assimilation of OCO-2 retrievals. In what follows, we will assimilate ACT in situ measurements and compare to OCO-2 retrievals.



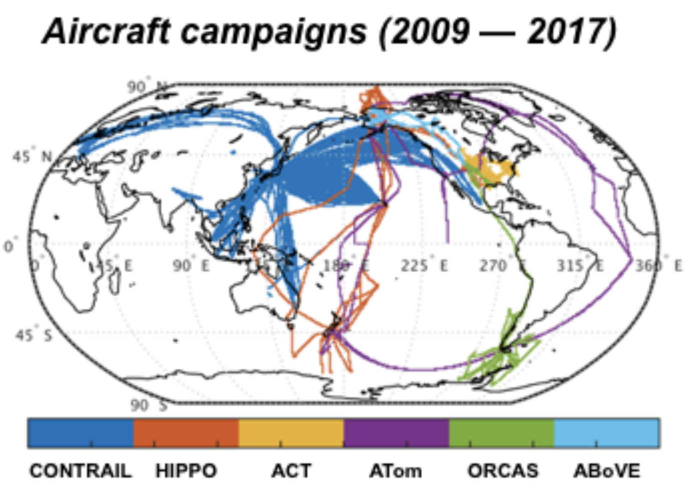




The following movie, which cannot embed here, depicts assimilated OCO-2 observations transported in space and time: https://science.sciencemag.org/highwire/filestream/700579/field_highwire_adjunct_files/1/aam5745s1.mp4 (https://science.sciencemag.org/highwire/filestream/700579/field_highwire_adjunct_files/1/aam5745s1.mp4)

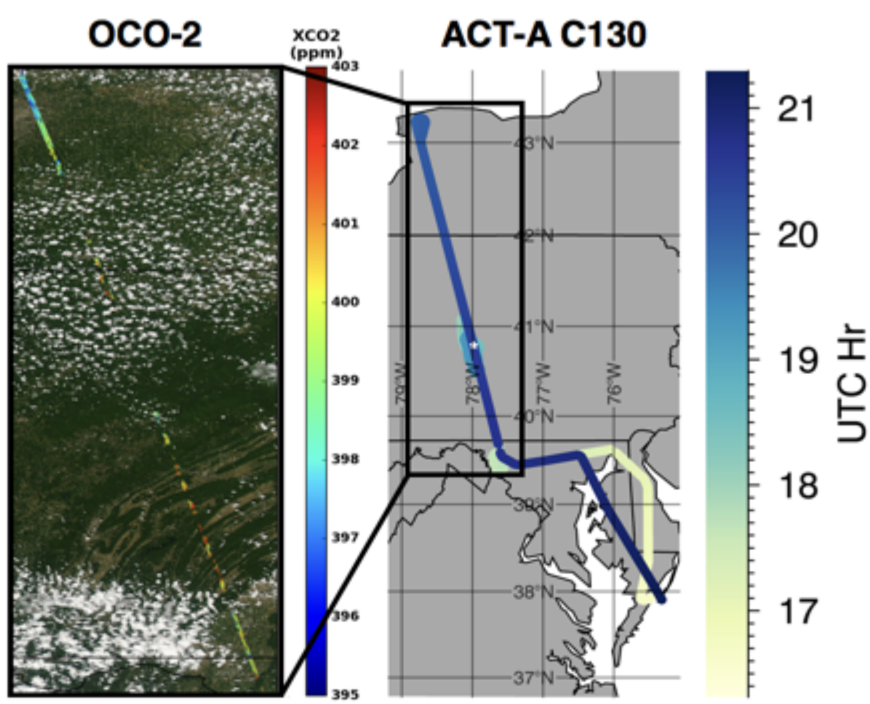
CURTAIN ANALYSES

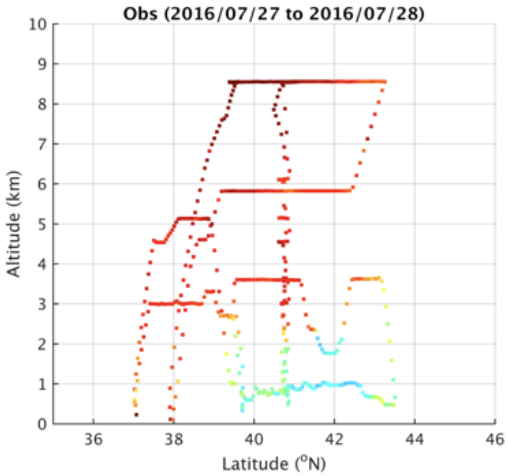
This work builds 2D transects of CO_2 (called curtains) by assimilating data from several aircraft campaigns (see below) into GEOS. The curtain analyses are then used for validation of satellite trace gas retrievals.

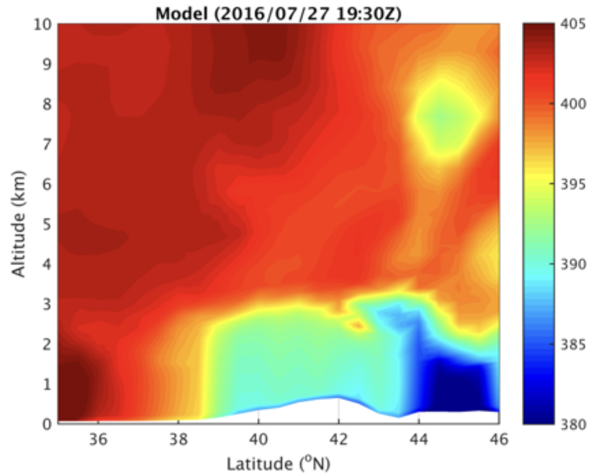


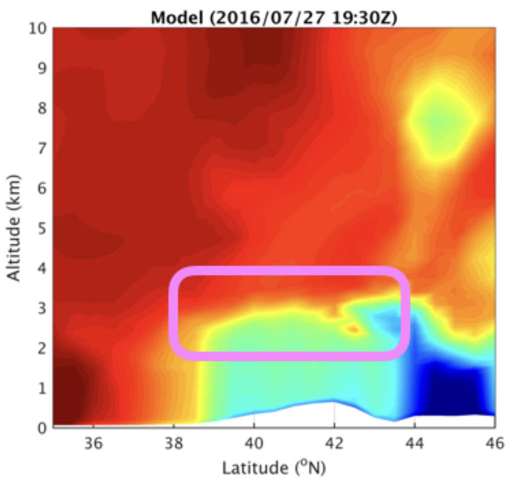
This method was applied to ACT-America campaign data for 12 OCO-2 underflights (Bell et al., 2019 and Campbell et al., 2019).

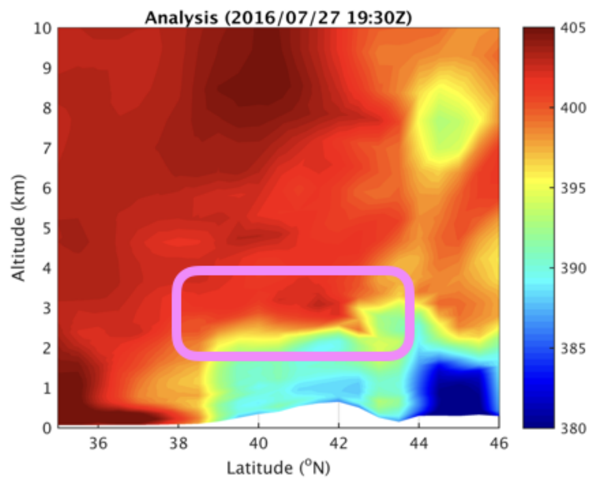
In the example below, assimilation indicates GEOS modeled PBL heights were too high. This finding is consistent with data from the Cloud Physics Lidar (CPL).

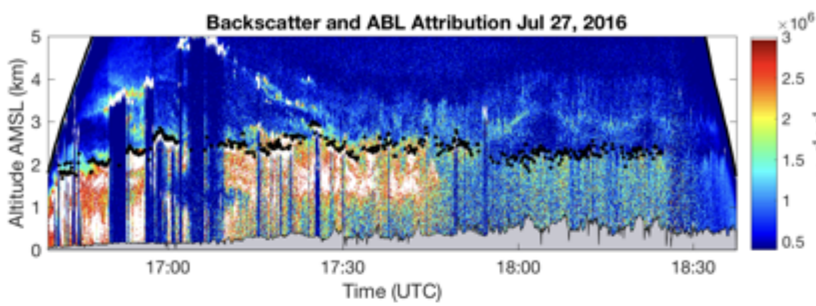


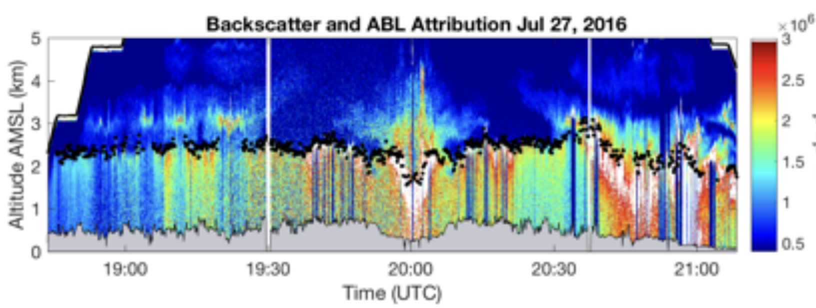

Obs (2016/07/27 to 2016/07/28)
Altitude (km)
Latitude (°N)


Model (2016/07/27 19:30Z)
Altitude (km)
Latitude (°N)
405
400
395
390
385
380


Model (2016/07/27 19:30Z)
Altitude (km)
Latitude (°N)


Analysis (2016/07/27 19:30Z)
Altitude (km)
Latitude (°N)
405
400
395
390
385
380

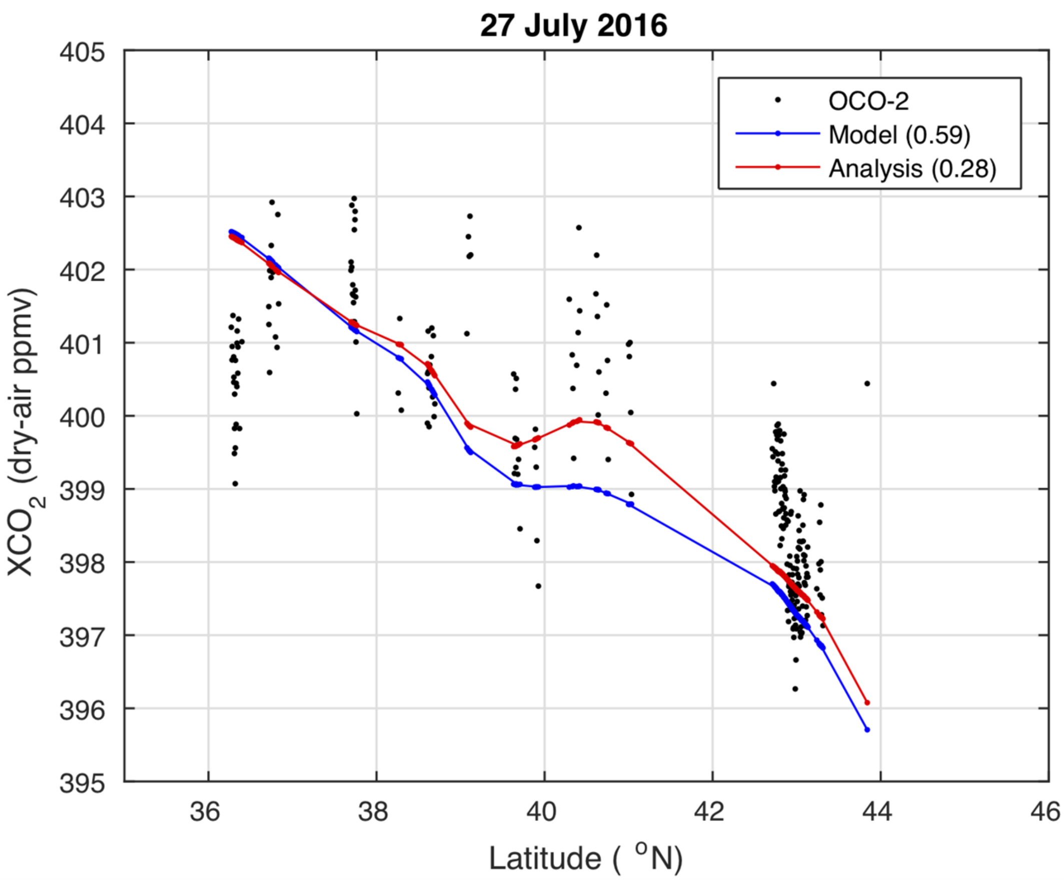

Backscatter and ABL Attribution Jul 27, 2016
Altitude AMSL (km)
Time (UTC)
17:00
17:30
18:00
18:30
×10^6
Km^-1Sr^-1


Backscatter and ABL Attribution Jul 27, 2016
Altitude AMSL (km)
Time (UTC)
19:00
19:30
20:00
20:30
21:00
×10^6
Km^-1Sr^-1

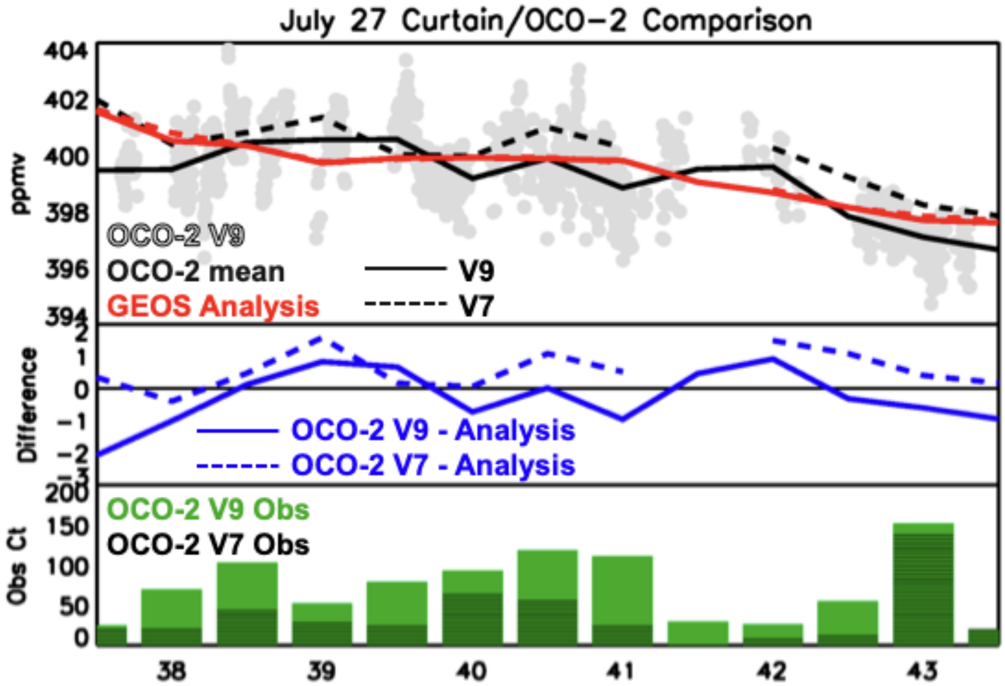
COMPARISONS TO OCO-2 & MFLL

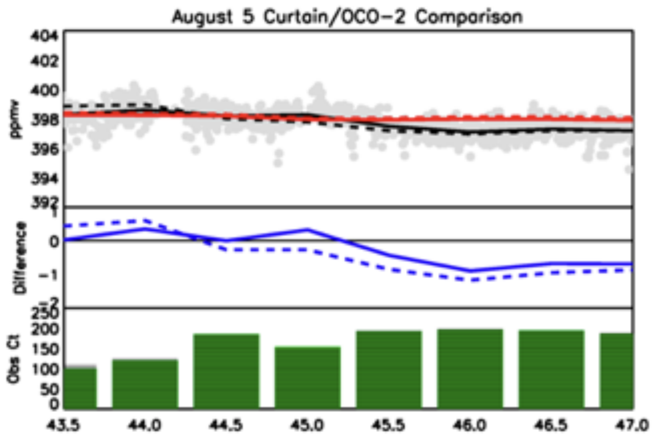
Bell et al. (2019) and Campbell et al. (2019) demonstrate remarkable agreement between latitudinal gradients of bias-corrected OCO-2 and MFLL observations respectively.

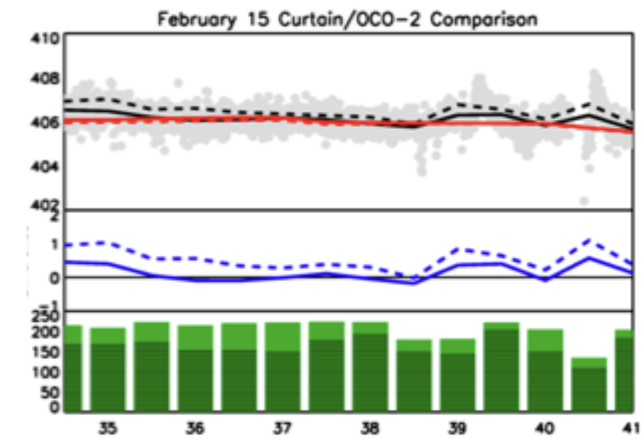
Below, we show how incorporating ACT data can improve the agreement between the curtains and OCO-2 v7B retrievals.

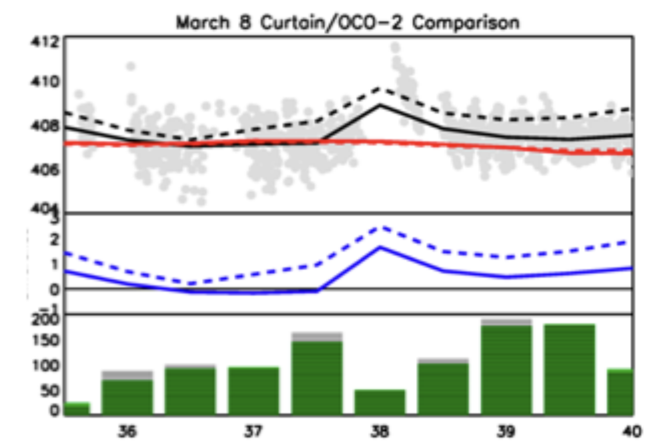


Significant improvements to the OCO-2 retrieval from v7B to v9 are also evident from the curtain analysis:


July 27 Curtain/OCO−2 Comparison
404
402
400
398
396
394
ppmv
OCO-2 V9
OCO-2 mean
GEOS Analysis
V9
V7
2
1
0
−1
−2
−3
Difference
OCO-2 V9 - Analysis
OCO-2 V7 - Analysis
200
150
100
50
0
Obs Ct
OCO-2 V9 Obs
OCO-2 V7 Obs
38
39
40
41
42
43


August 5 Curtain/OCO-2 Comparison
ppmv
Difference
Obs Ct
43.5
44.0
44.5
45.0
45.5
46.0
46.5
47.0


February 15 Curtain/OCO-2 Comparison
35
36
37
38
39
40
41


March 8 Curtain/OCO-2 Comparison
36
37
38
39
40

Flight Day	V9 Difference	V9 Obs Ct.	V7 Difference	V7 Obs Ct.
20160727	-0.3	929	0.6	475
20160805	-0.3	1329	-0.4	1346
20170215	0.1	2865	0.6	2300
20170308	0.4	1022	1.2	1080

Sorry but time is up!

ABSTRACT

While in situ greenhouse gas measurements have a concrete calibration standard, establishing a similar standard for remote sensing retrievals remains challenging. As the constellation of greenhouse gas observing satellites grows, such a standard is essential to ensure data are of the quality necessary to support scientific and policy applications. A primary goal of NASA's Atmospheric Carbon and Transport (ACT) - America aircraft campaign is to evaluate column CO2 retrievals from the Orbiting Carbon Observatory 2 (OCO-2) through coordinated underflights. The campaign also includes airborne lidar instruments that measure the amount of CO2 and CH4 below the aircraft. This presentation introduces a system that establishes calibration standards for OCO-2 and lidar retrievals based on in situ data from the ACT-America campaign. The system assimilates the in situ data into NASA's Goddard Earth Observing System (GEOS) to produce high-resolution, two-dimensional transects of CO2 along the flight path which we refer to as curtains. Excluding the ability to sample the entire atmosphere at once, any such analysis must make assumptions about the connection of measurements at different places and times to a given retrieval. We chose to use the GEOS general circulation model forced by meteorology from its data assimilation system because their scientific merits are extensively documented. Furthermore, in areas rich in data, the assimilated curtains approach a field constrained by data alone. Where data are lacking, e.g., the stratosphere, age of air and other transport diagnostics can be used to quantify the uncertainty introduced by the model. Given these uncertainties, we can determine the uncertainties of the curtains and thus our ability to evaluate remote sensing instruments. Here, we demonstrate this for several flights over North America and discuss possible applications to upcoming missions, e.g., GeoCarb.

REFERENCES

Bell et al. (2019), "Evaluation of OCO-2 XCO2 Variability at Local and Synoptic Scales using Lidar and In Situ Observations from the ACT-America Campaigns", submitted to JGR-Atmos.

Campbell et al. (2019), "Field Evaluation of Column CO2 Retrievals from Intensity-Modulated Continuous-Wave Differential Absorption Lidar Measurements during ACT-America", submitted to Earth & Space Science.

SWITCH TEMPLATE