

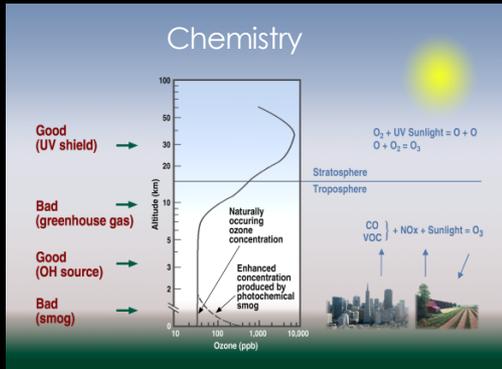
Tropospheric Ozone and its Precursors from Earth System Sounding (TROPESS) – An Element of NASA's Ozone Trend Science (OTS) Program

thomas p kurosu, Kevin W. Bowman, John Worden, and the JPL TROPESS team
NASA Jet Propulsion Laboratory/California Institute of Technology

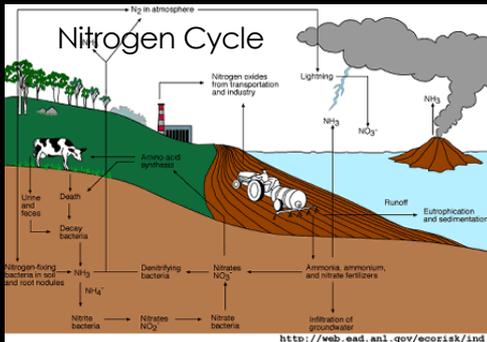
2019 GEMS Science Team Meeting
Seoul, Korea 21st November 2019



TES: From Atmospheric Discovery to Earth System Sounding

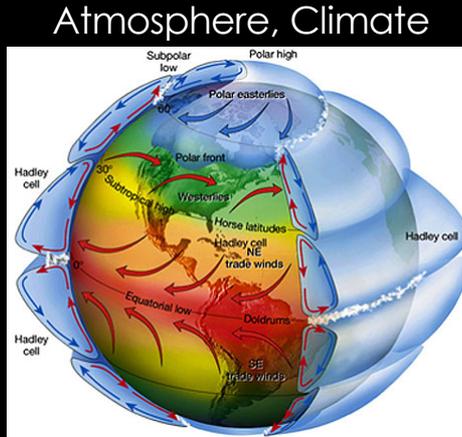


Ozone (O₃), Carbon Monoxide (CO), Methanol (CH₃OH), Formic Acid (HCOOH)

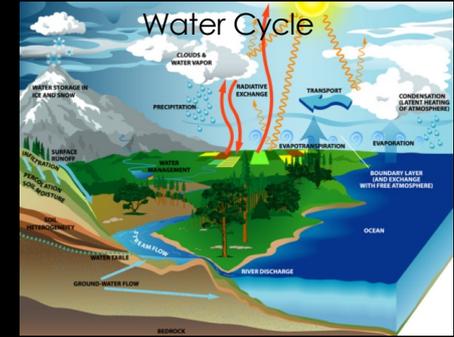


Ammonia (NH₃), PAN (CH₃COONO₂)

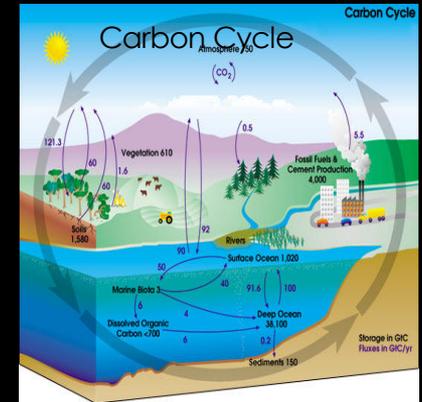
TES has pioneered well-characterized tropospheric composition retrievals that span across the Earth System



Radiative Kernels, Surface Temperature, Atmospheric Temperature, Cloud Optical Depth and Pressure, Surface Emissivity



Water Vapor and Isotopes (H₂O and HDO)



Carbon Dioxide (CO₂), Methane (CH₄), Carbonyl Sulfide (OCS)



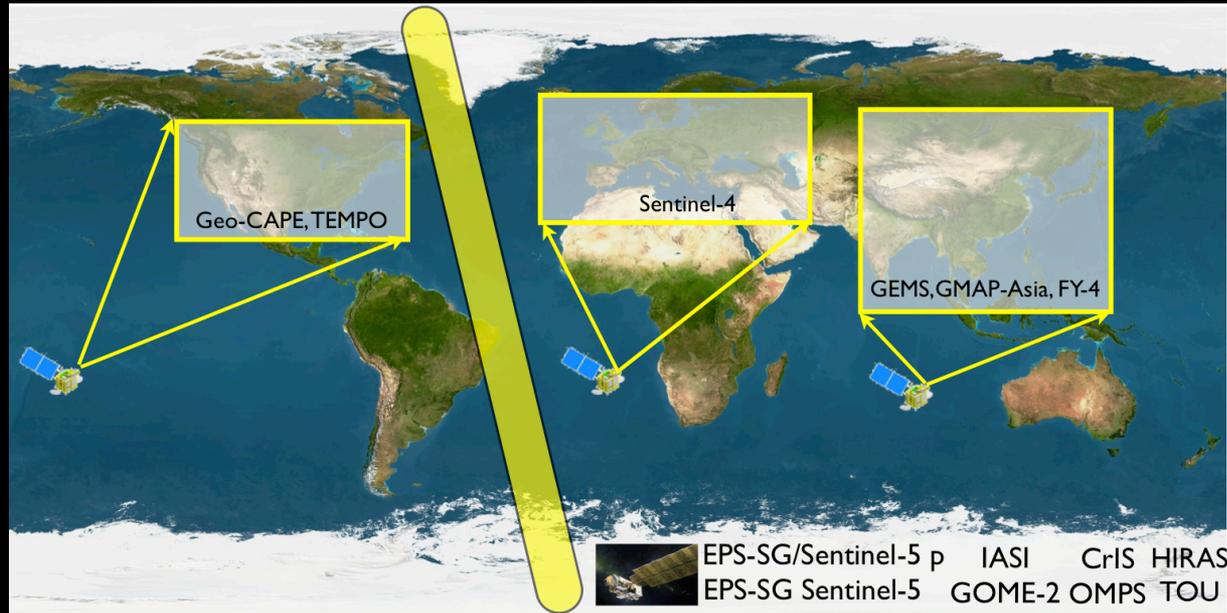
TROPES: Objectives

- TES has borne witness to a **changing trajectory of atmospheric composition** in the troposphere and revealed its complex interactions within the broader Earth System
- **Characterizing and predicting this trajectory requires a broad suite of well-characterized measurements linking emissions to concentrations** in the context of natural and anthropogenic variability.
- **TROPES** will produce long term, Earth Science Data Records (ESDRs) with uncertainties and observation operators pioneered by TES and enabled by the **MULTi-SpEctra, MULTi-SpECies, Multi-SEnsors (MUSES)** retrieval algorithm and ground data processing system.
- **Promote** the dissemination, utilization, and assimilation of these ESDRs to support scientific and application communities, e.g., IGAC, IPCC.
- **Support** the science of **Decadal Survey and CEOS Atmospheric Composition Virtual Constellation (AC-VC)** missions through a dependable forward stream of composition ESDR from existing and planned LEO instruments.
- **Support** NASA activities including **fields campaigns, mission formulation**, e.g., Observing System Simulation Experiments (OSSES)



Toward an Composition-Climate Constellation

Bowman, Atm. Env. 2013



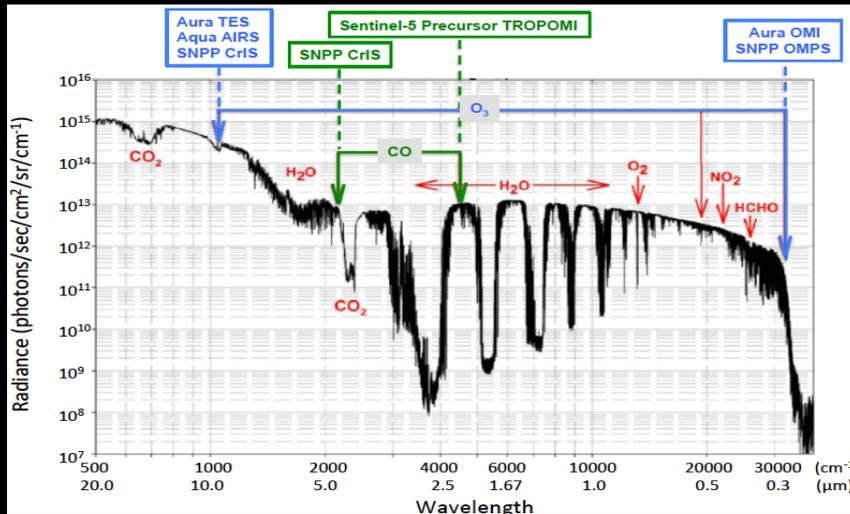
TROPESSE will support the exploitation of a Earth System Convoy initiated by Suomi-NPP and Sentinel 5p that will be the pillar of a composition constellation and the backbone of Decadal Survey composition missions.

- Sustained observations for the next decade.
- Continuity with the EOS program
- LEO observations to integrate GEO platforms

More eyes are better than one: The pan-spectral approach

IR-NIR

TES
AIRS
IASI
CrIS
OCO-2
TROPOMI



UV-Vis

SCIAMACHY
OMI
GOME
GOME-2
OMPS
TROPOMI

- Pan-spectral techniques provide better accuracies and vertical sensitivities than individual bands → critical for relating concentrations to emissions
- Considerable progress has been made in generating long-term ESDRs from multiple measurements leveraging the TES D&A/SIP infrastructure.

JPL has led the development of multi-spectral, multi-instrument retrieval algorithms for UV, IR, NIR, microwave (Worden *et al*, GRL, 2007, Luo *et al*, 2013, Fu *et al*, ACP, 2013, Kuai *et al*, 2013, Worden *et al*, 2015, Fu *et al*, 2016) for ozone, CO, CO₂, and CH₄.

Past and Current Activities

- ❖ Production and utilization of multi-spectral measurements, e.g., joint AIRS/OMI retrievals
- ❖ AIRS/OMI retrievals in support for KORUS-AQ, ORACLES, POSIDON (2016)
- ❖ Suomi/NPP CrIS retrievals of O₃ and CO in support of FIREX-AQ
- ❖ Working toward CrIS/OMPS multi-spectral/multi-sensor retrievals
- ❖ Initiating satellite radiance and composition products inter-comparisons



Toolbox Development for Cross-Sensor Comparison and Validation

What We Want to Do

- ❖ Compare CO from CrIS and TropOMI and O₃ from CrIS, TropOMI, OMI, and SNPP/OMPS to assess CrIS retrieval products for FIREX-AQ
- ❖ Compare radiances between TropOMI and OMPS to assess consistency in radiometric and spectral calibration

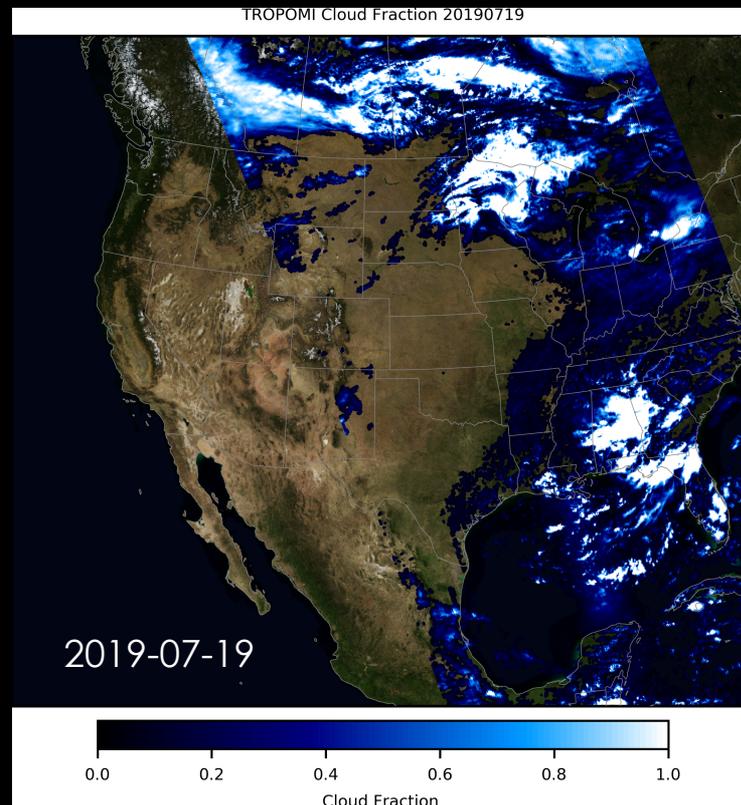
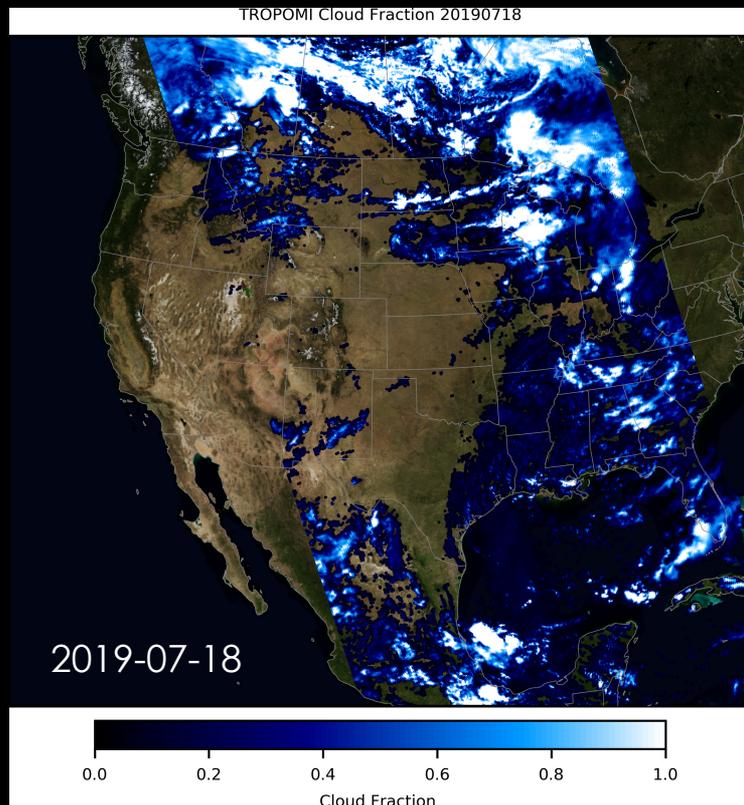
How We Are Starting on the Development of That

- ❖ Select days during FIREX-AQ – 18&19 July 2019
- ❖ Map the different satellite ground footprints onto each other ...
- ❖ ... but let's start out easy and cheat: treat TropOMI footprints as point measurements



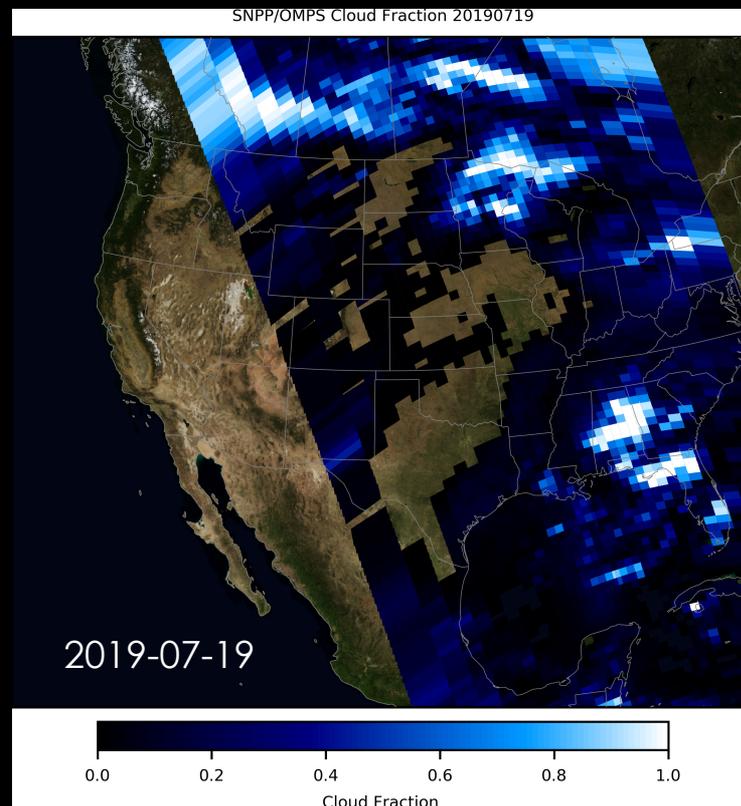
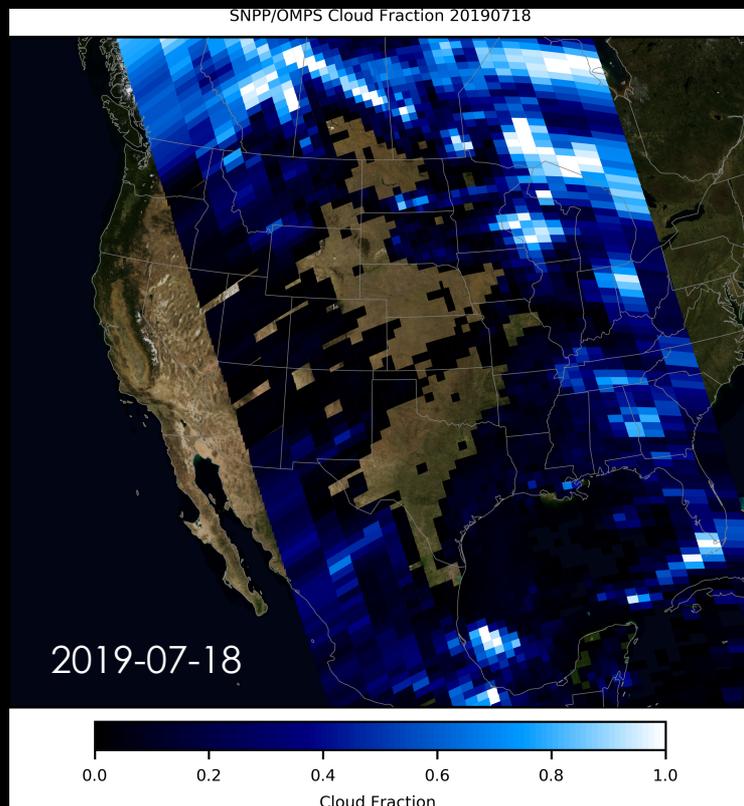
two days during FIREX-AQ: 18&19 July 2019

S5P/TropOMI Cloud Fraction ($C_f = 0$ not plotted)



two days during FIREX-AQ: 18&19 July 2019

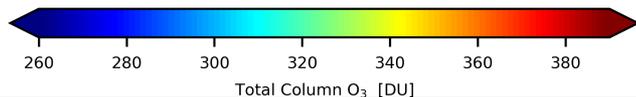
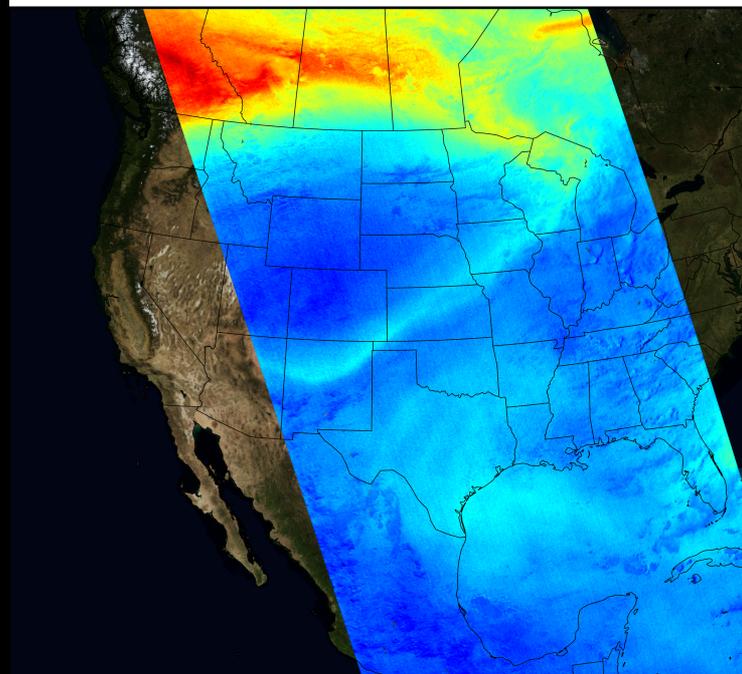
this is how SNPP/OMPS sees it ($C_f = 0$ not plotted)



Total Column O₃ – 19 July 2019

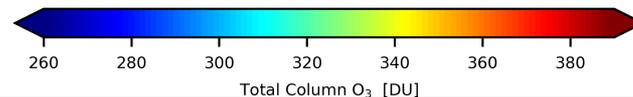
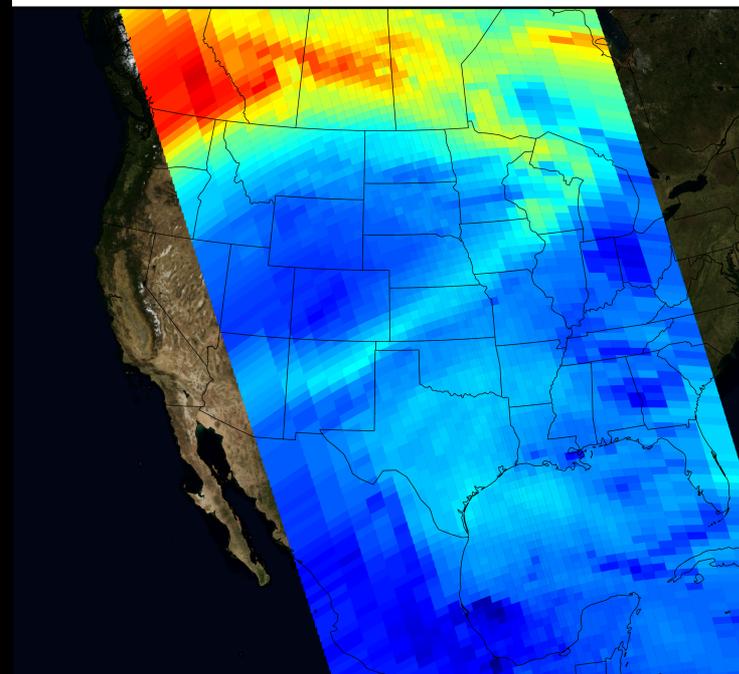
TropOMI O₃ 2019-07-19

TROPOMI Total O₃ 20190718



OMPS O₃ 2019-07-19

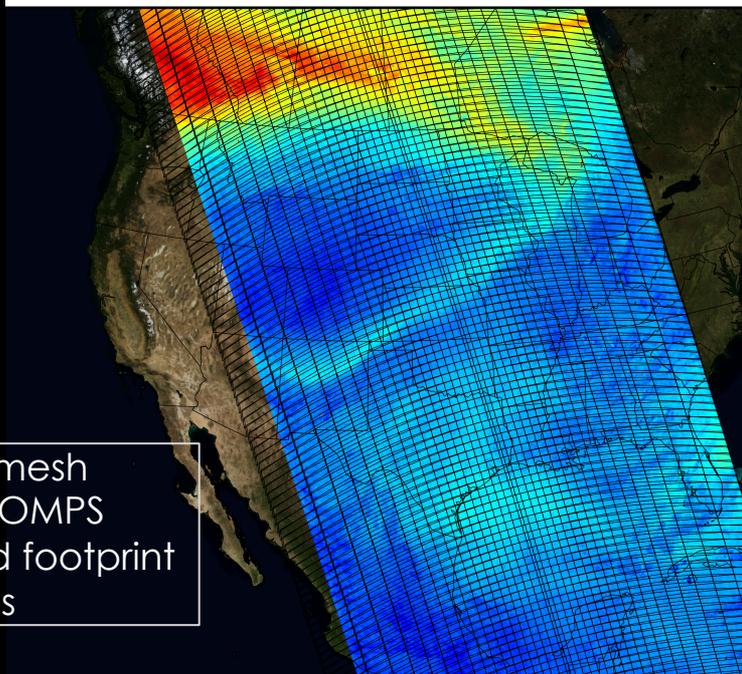
SNPP/OMPS Total O₃ 20190718



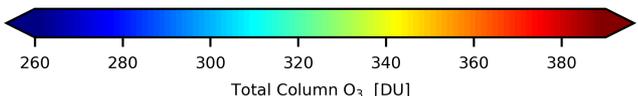
Total Column O₃ – 19 July 2019

TropOMI O₃ 2019-07-19

TROPOMI Total O₃ 20190718, with OMPS Grid

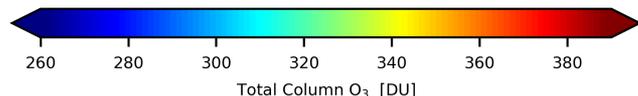
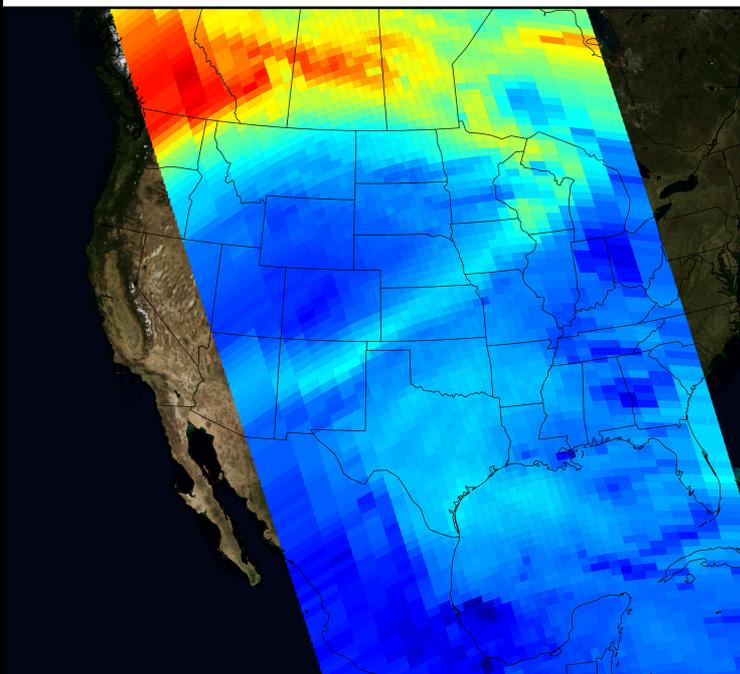


black mesh shows OMPS ground footprint outlines



OMPS O₃ 2019-07-19

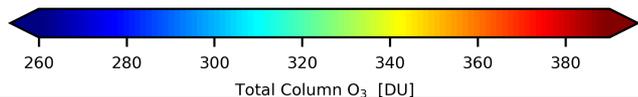
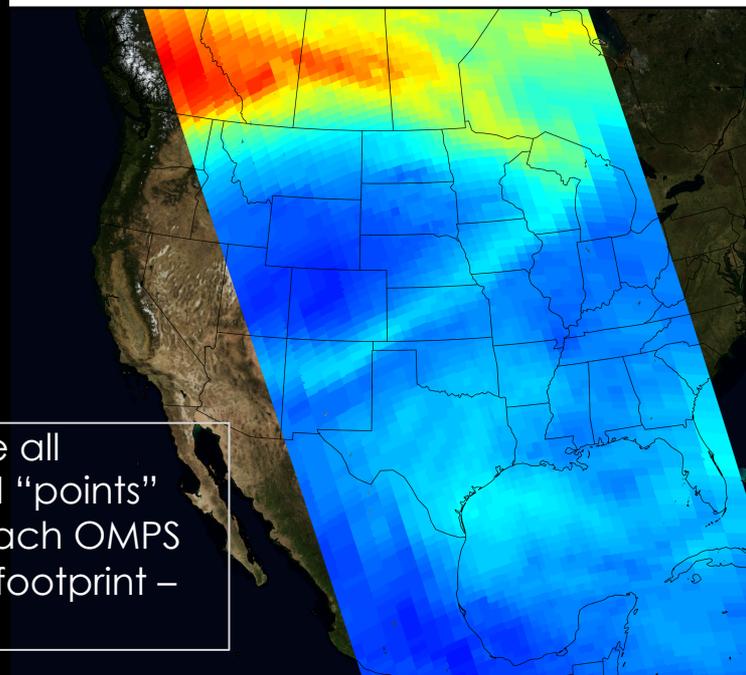
SNPP/OMPS Total O₃ 20190718



Total Column O₃ – 19 July 2019

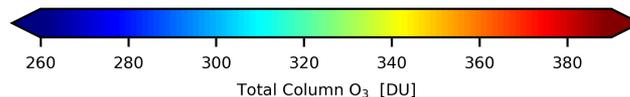
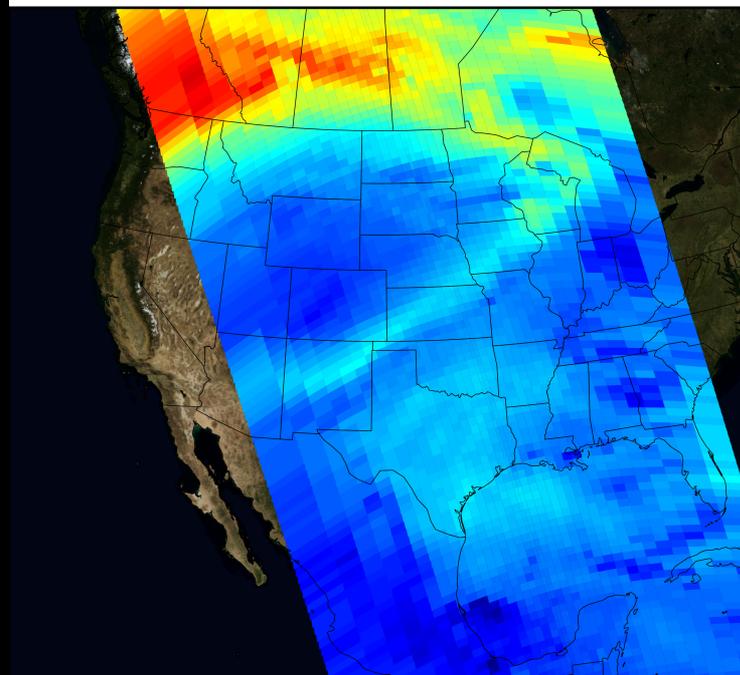
TropOMI "OMPS-like" O₃ 2019-07-19

TROPOMI Total O₃ 20190718, OMPS-like

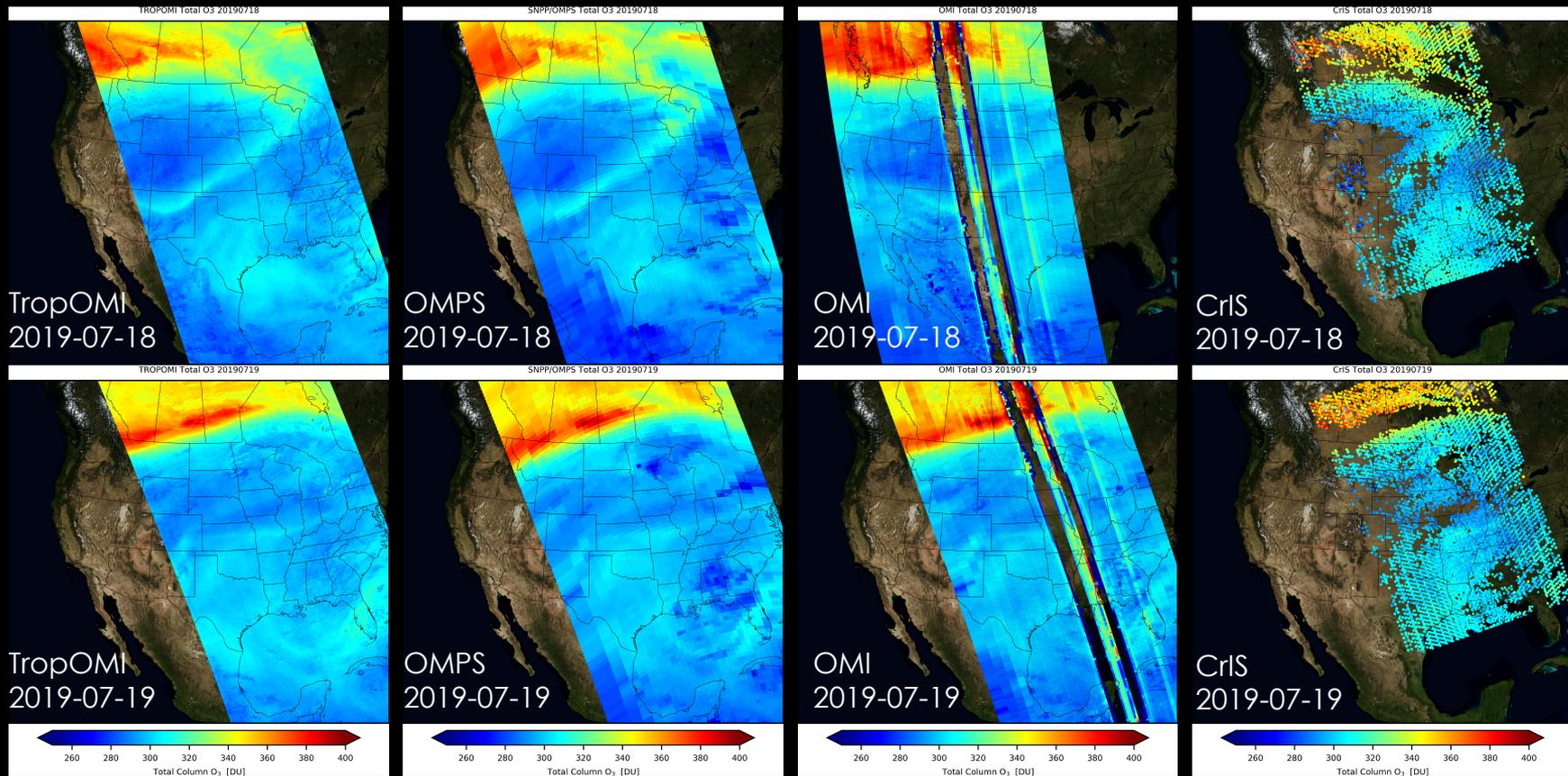


OMPS O₃ 2019-07-19

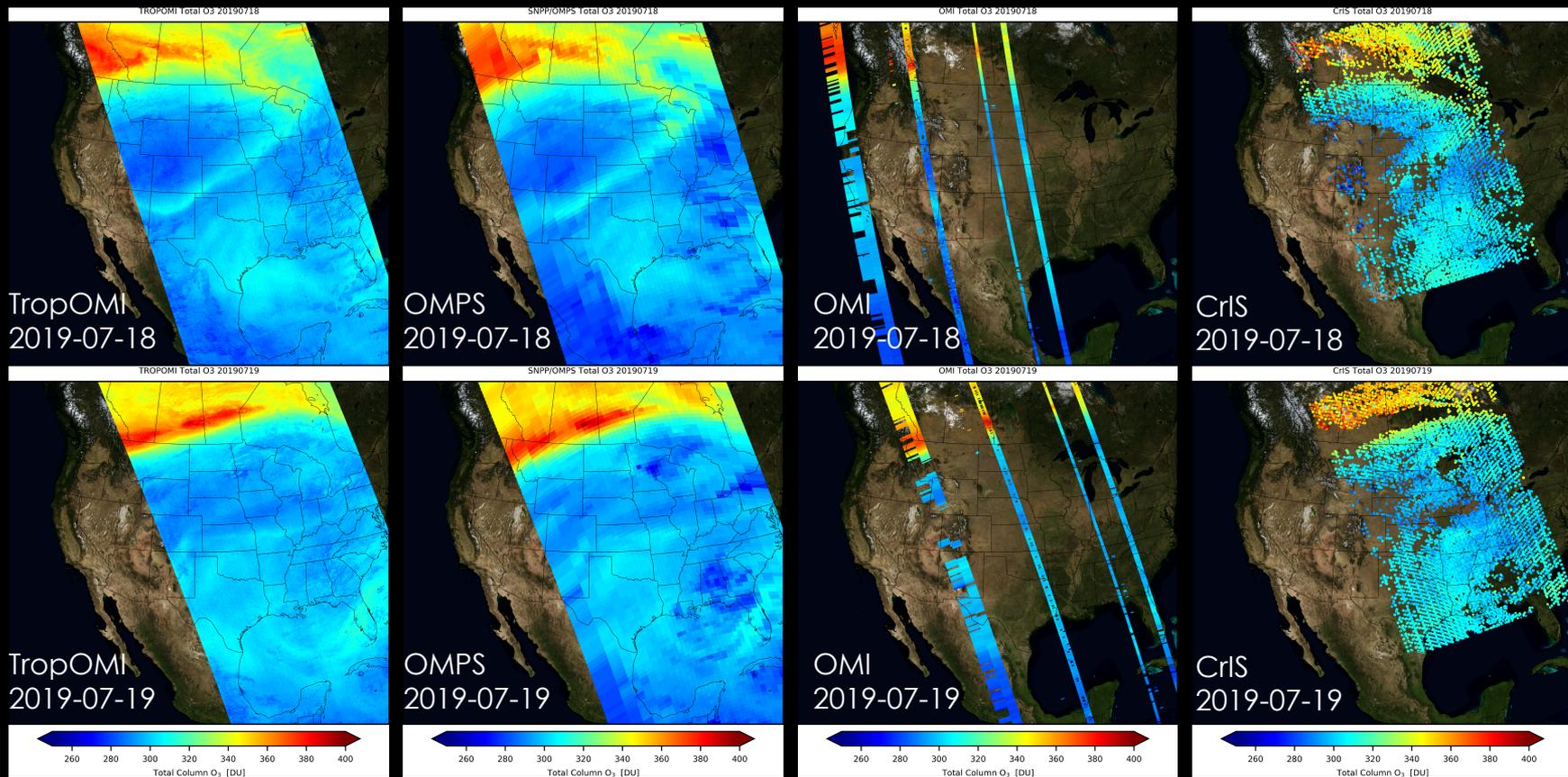
SNPP/OMPS Total O₃ 20190718



TropOMI, OMPS, OMI, CrIS O₃ – FIREX-AQ 18&19 July 2019



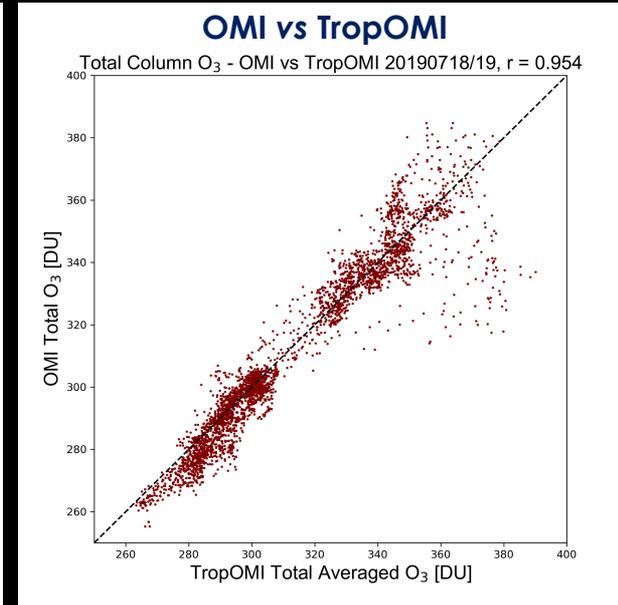
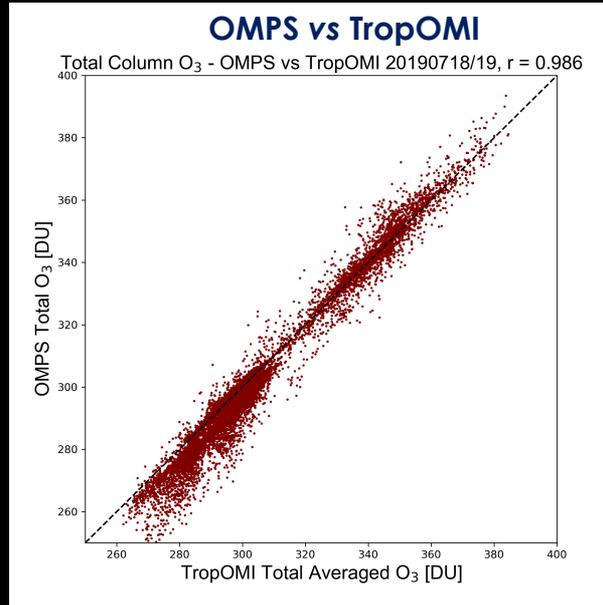
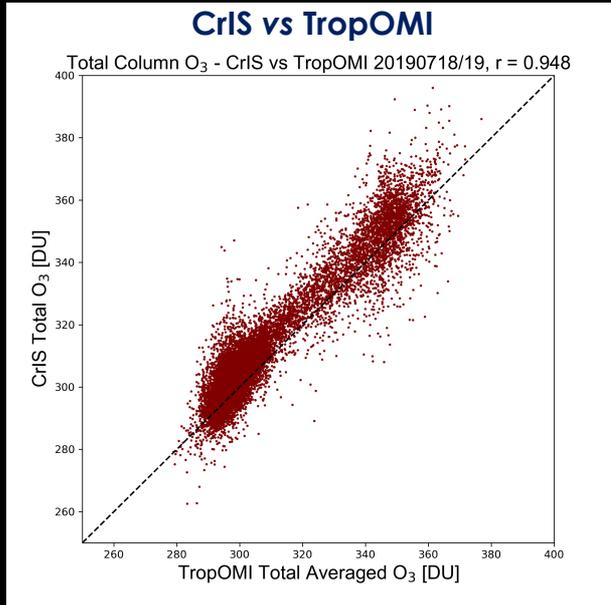
TropOMI, OMPS, OMI, CrIS O₃ – FIREX-AQ 18&19 July 2019



OMTO3 QA flags applied
product developers, mind thy quality flags!

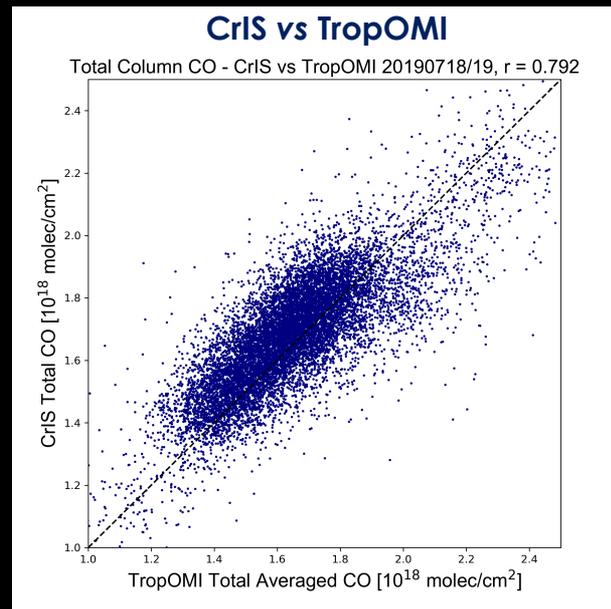
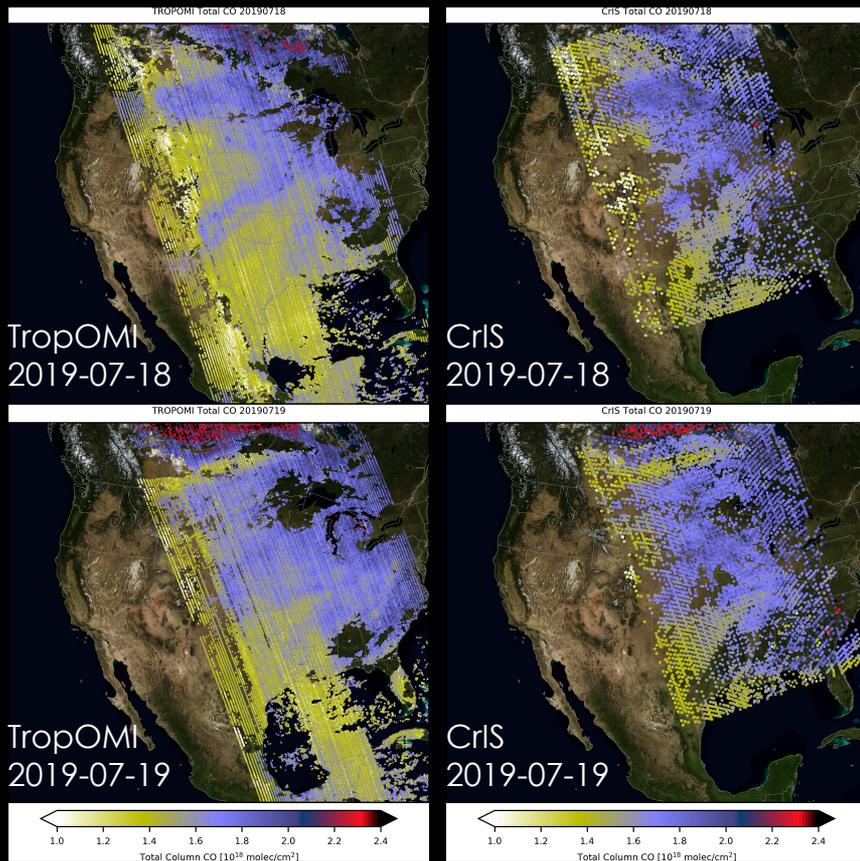


TropOMI vs. OMPS, OMI, CrIS, O₃ – FIREX-AQ 18&19 July 2019



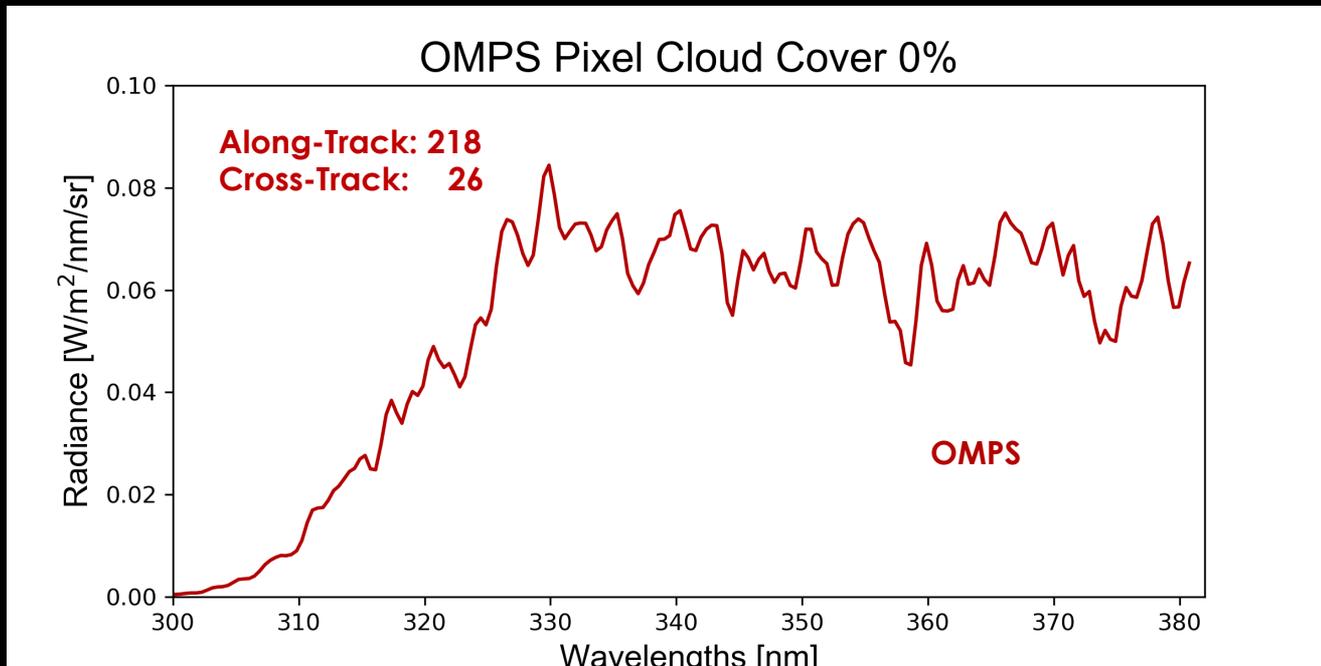
- total column O₃ from all sensors compares well ($r \gtrsim 0.95$), even OMI despite the sparse statistics
- CrIS O₃ is slightly higher than TropOMI, which goes against expectations of vertical sensitivity of IR sensors compared to UV/Vis instruments

TropOMI vs CrIS CO – FIREX-AQ 18&19 July 2019



- total column shows a respectable correlation of $r \approx 0.8$
- CrIS CO is again slightly higher than TropOMI

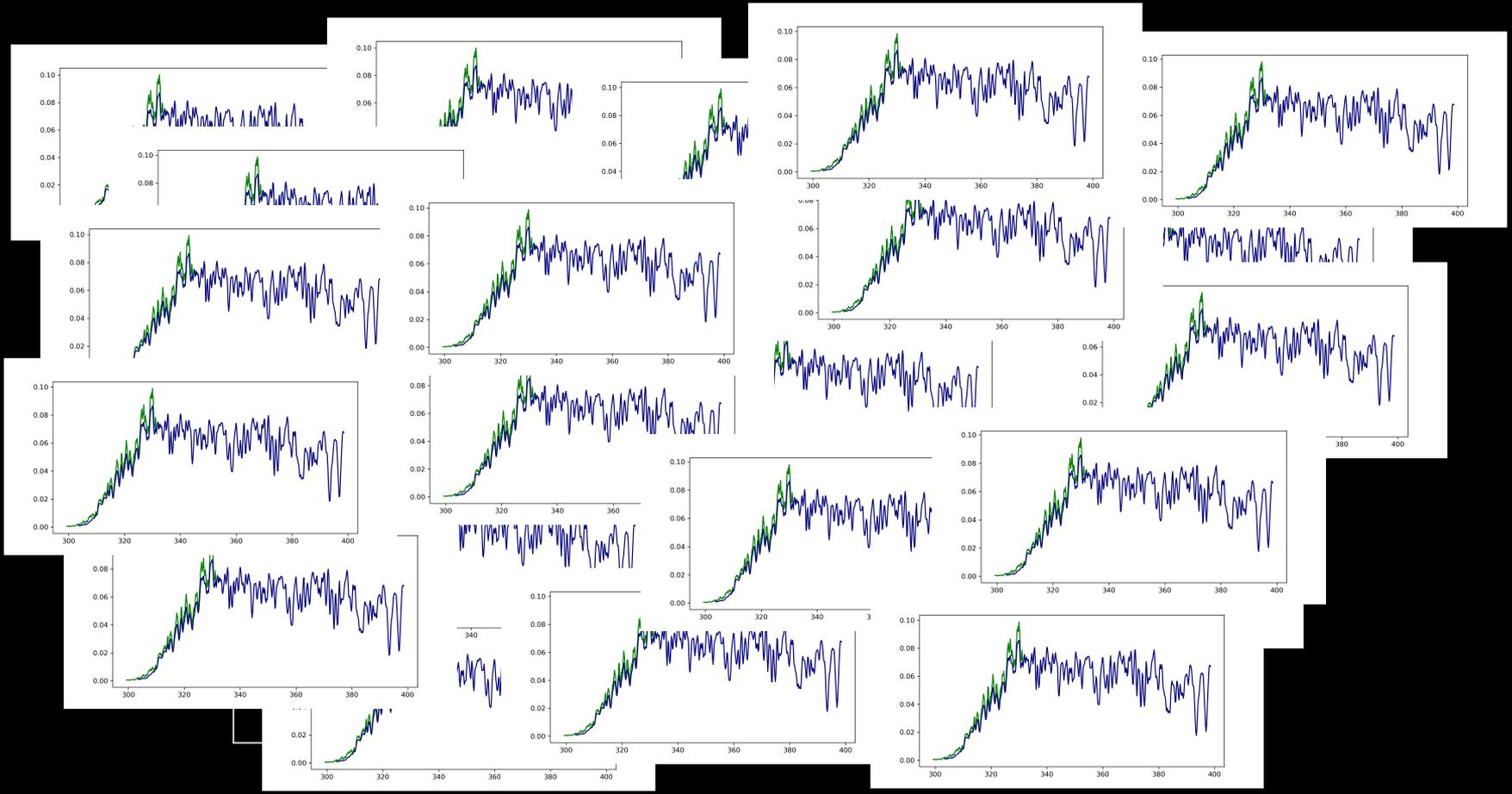
TropOMI vs OMPS Radiances – Cloud Free/Cloudy/Partially Cloudy



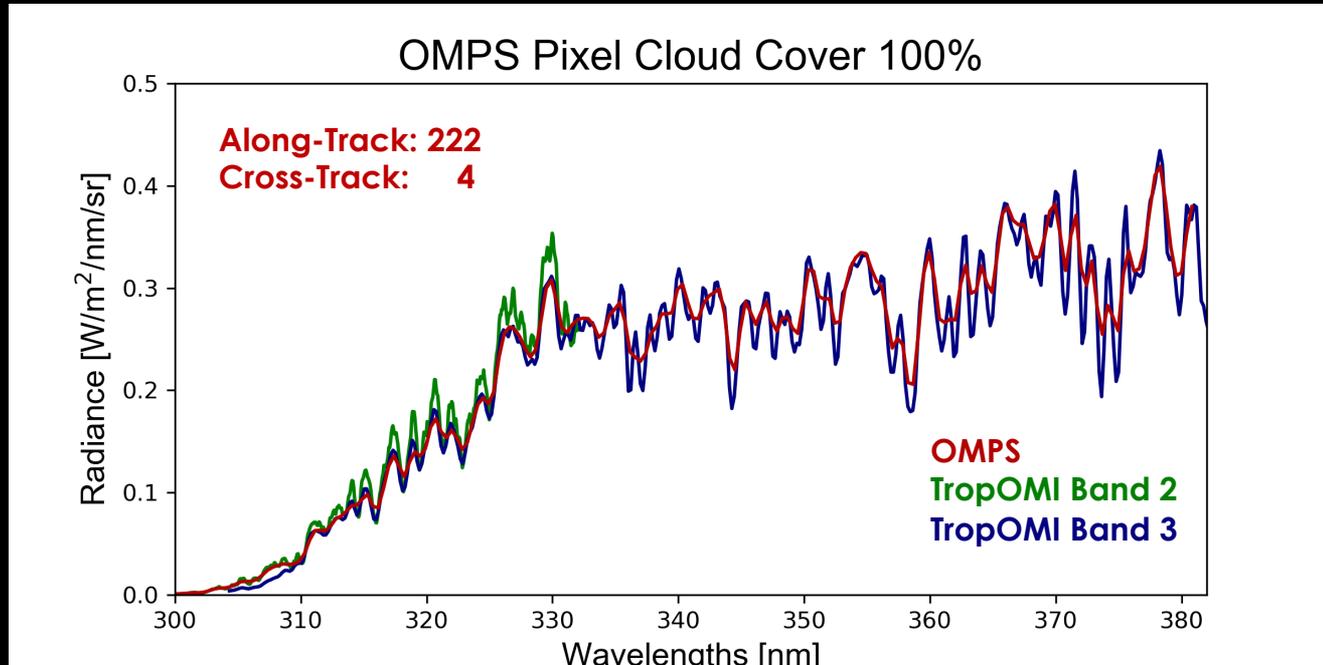
now average all TropOMI radiances within the OMPS footprint; use **Band 2** and **Band 3**



TropOMI vs OMPS Radiances – Cloud Free/Cloudy/Partially Cloudy

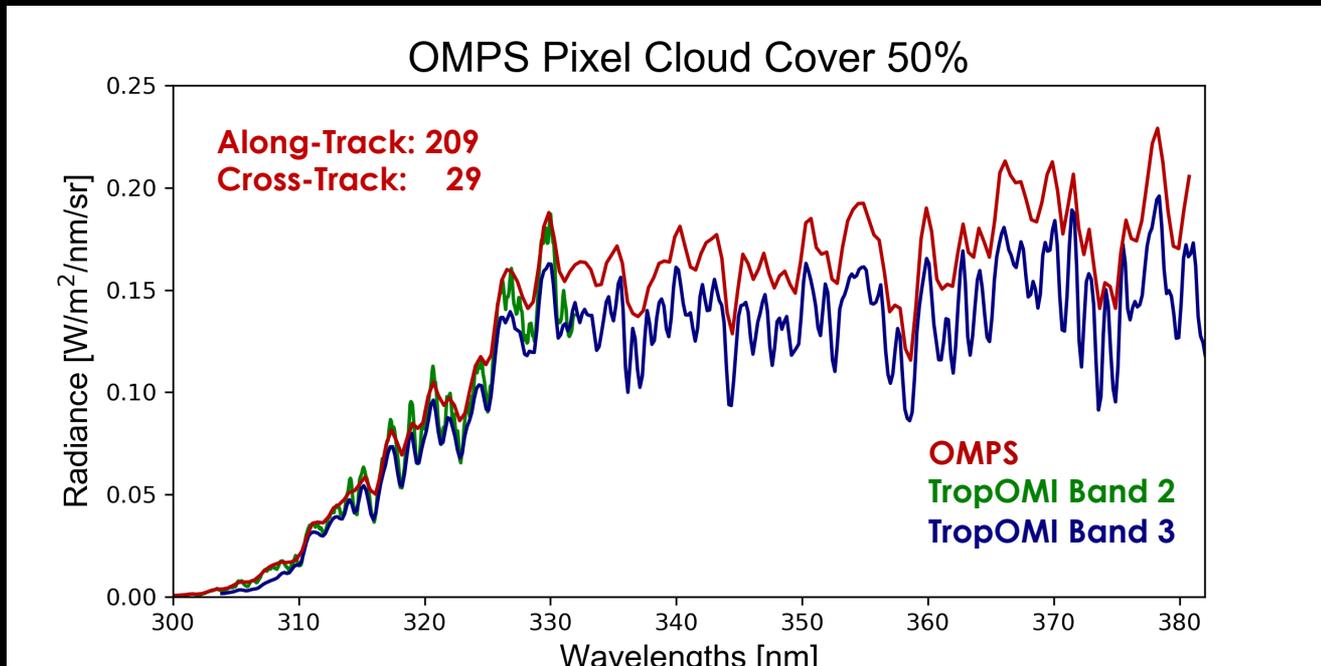


TropOMI vs OMPS Radiances – Cloud Free/Cloudy/Partially Cloudy



cloudy ... yes

TropOMI vs OMPS Radiances – Cloud Free/Cloudy/Partially Cloudy



partially cloudy ... possibly not

Summary

- ❖ the Tropospheric Ozone and its Precursors from Earth System Soundings (TROPESS) project takes a Multi-Spectral, Multi-Species, Multi-Sensors (MUSES) approach to produce Earth Science Data Records in support of Science and Application Communities
- ❖ AIRS/OMI retrievals in regional mapping and global survey mode are being performed and are available for various field campaigns, including KORUS-AQ, ORACLES, and POSIDON (all 2016)
- ❖ Suomi/NPP CrIS O₃ and CO retrievals have been performed for FIREX-AQ 2019
- ❖ MUSES retrievals of Suomi/NPP CrIS-OMPS are in preparation
- ❖ Validation tools for satellite product inter-comparisons are being developed

