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Multi-Sensor Retrievals of Air Quality Relevant Trace Gases from CrIS and TROPOMI using the Tropospheric Ozone and its Precursors from Earth System Sounding (TROPESS) Framework.

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tropess

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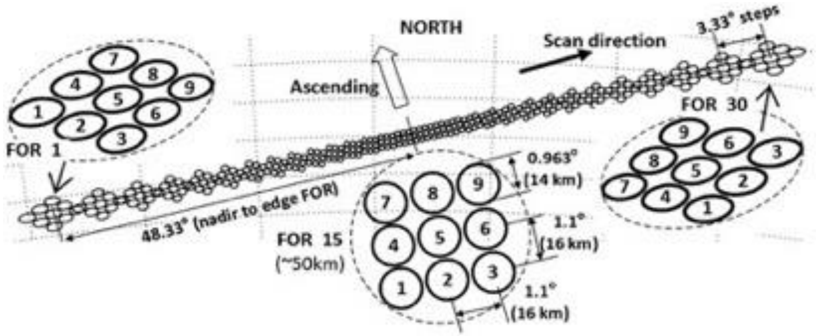
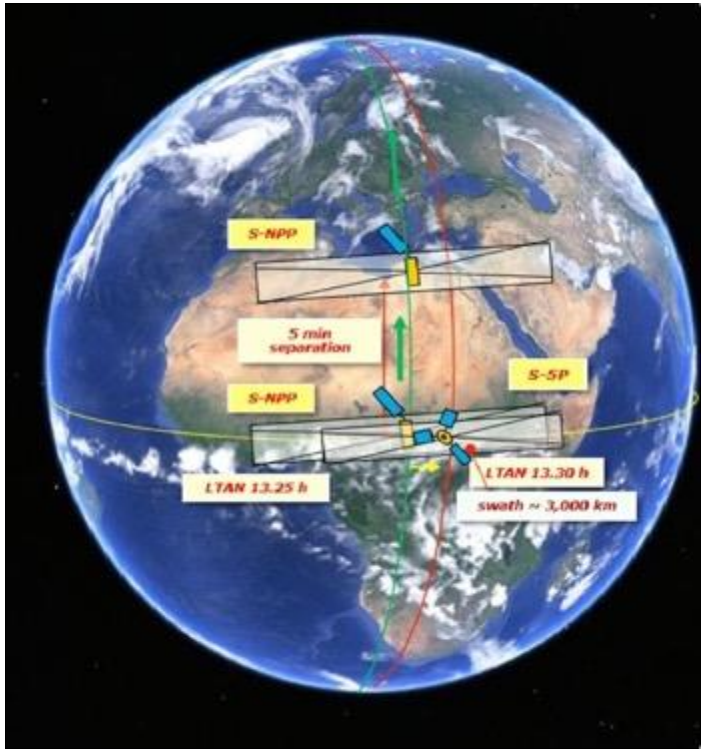
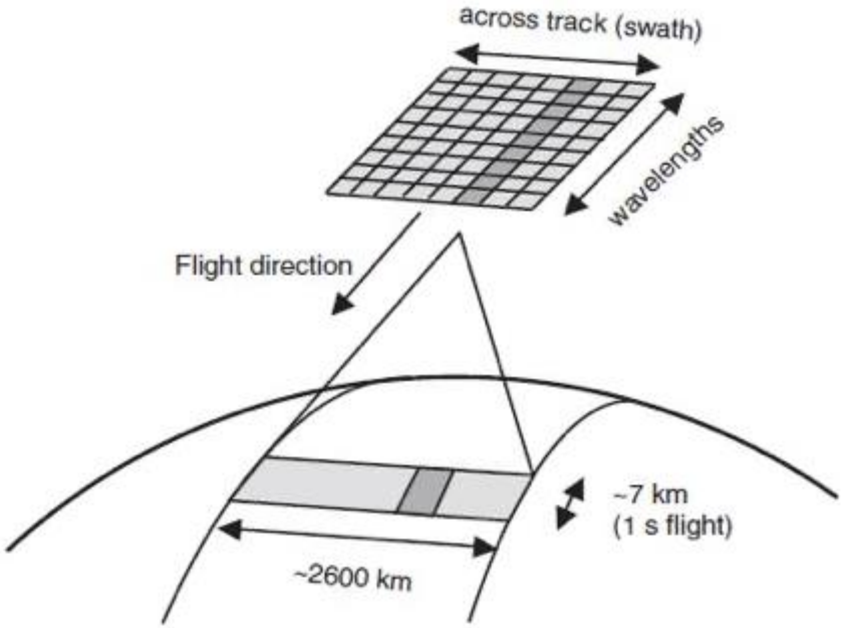
Suomi NPP CrIS and S5P/TROPOMI

CrIS is a TIR FTS instrument making daily measurements in three separate bands (650-1095 cm^{-1}, 1210-1750 cm^{-1}, 2155-2550 cm^{-1})

TROPOMI is a UV-SWIR imaging spectrometer making daily measurements in a number of spectral bands, from 270-2380 nm.







CrIS ground track illustration taken from Han et al., 2013. MUSES algorithm allows FOV thinning to reduce processing overheads.

TROPOMI ground track illustration taken from Veefkind et al., 2012.

More eyes are better than one:
The panspectral approach and the MUSES algorithm

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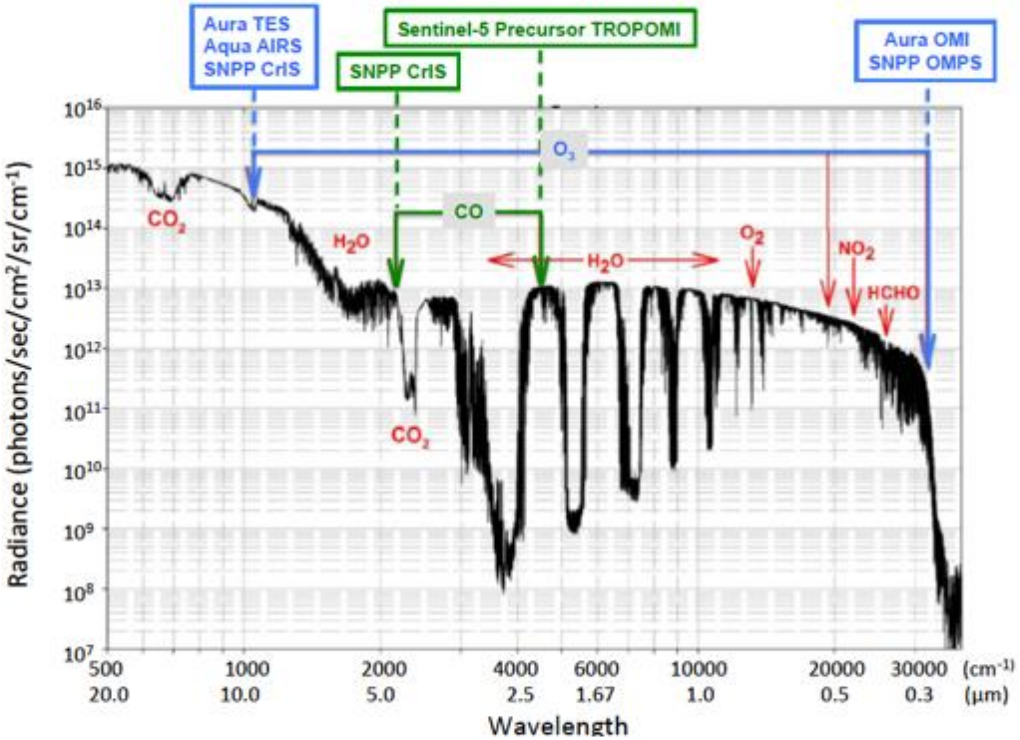
IR-NIR
- TES
- AIRS
- IASI
- CrIS
- OCO-2
- TROPOMI

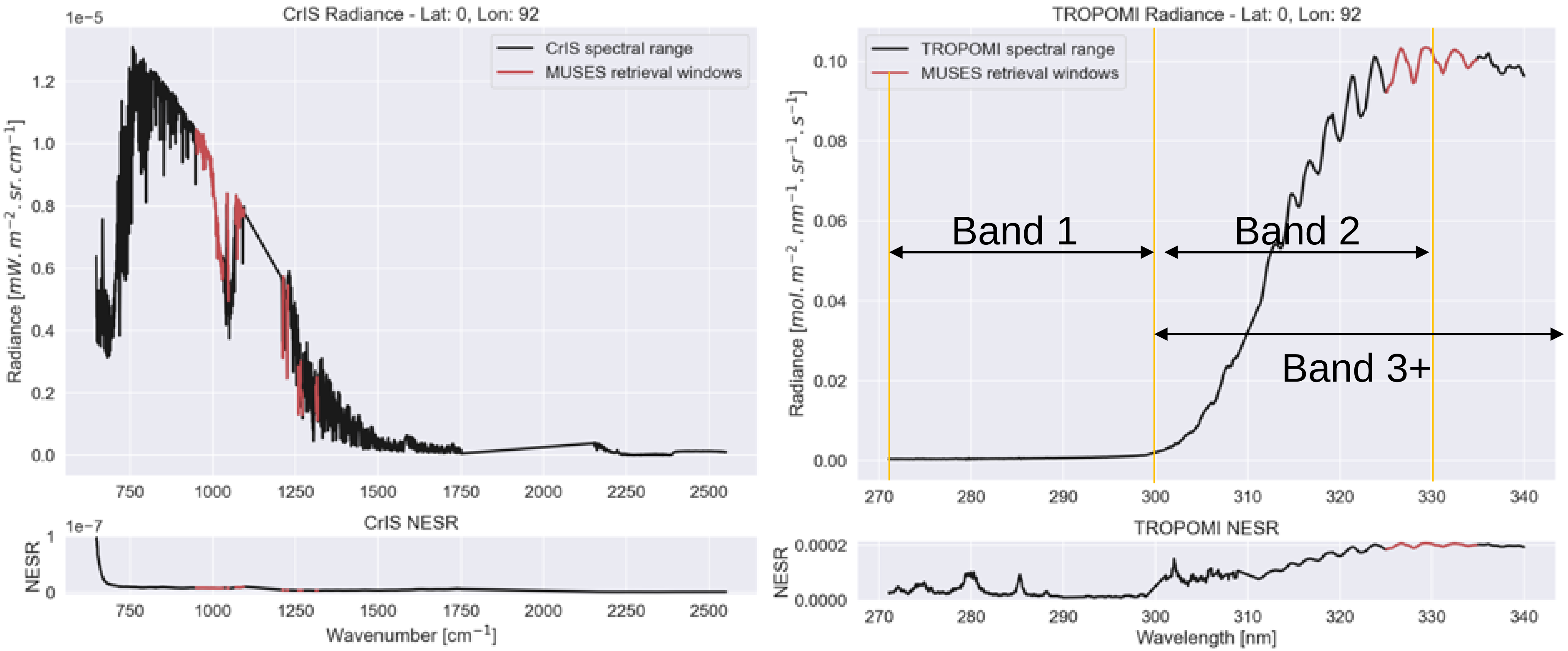


UV-Vis
- SCIAMACHY
- OMI
- GOME
- GOME-2
- OMPS
- TROPOMI

- Panspectral techniques provide better vertical sensitivities than individual bands → critical for relating concentrations to emissions
- Systematic errors between instruments and spectroscopy must be assessed

TROPESS has considerable heritage in **multi-spectral, multi-instrument retrieval algorithms** for UV, IR,NIR, microwave (Worden et al., 2007; Natraj et al., 2011; Luo et al., 2013; Fu et al., 2013; Kuai et al., 2013; Worden et al., 2015; Fu et al., 2016) for ozone, CO, CO_2, and CH_4.

MUSES CrIS-TROPOMI Spectral Windows for Ozone



CrIS MUSES O3 uses a series of short micro-windows.

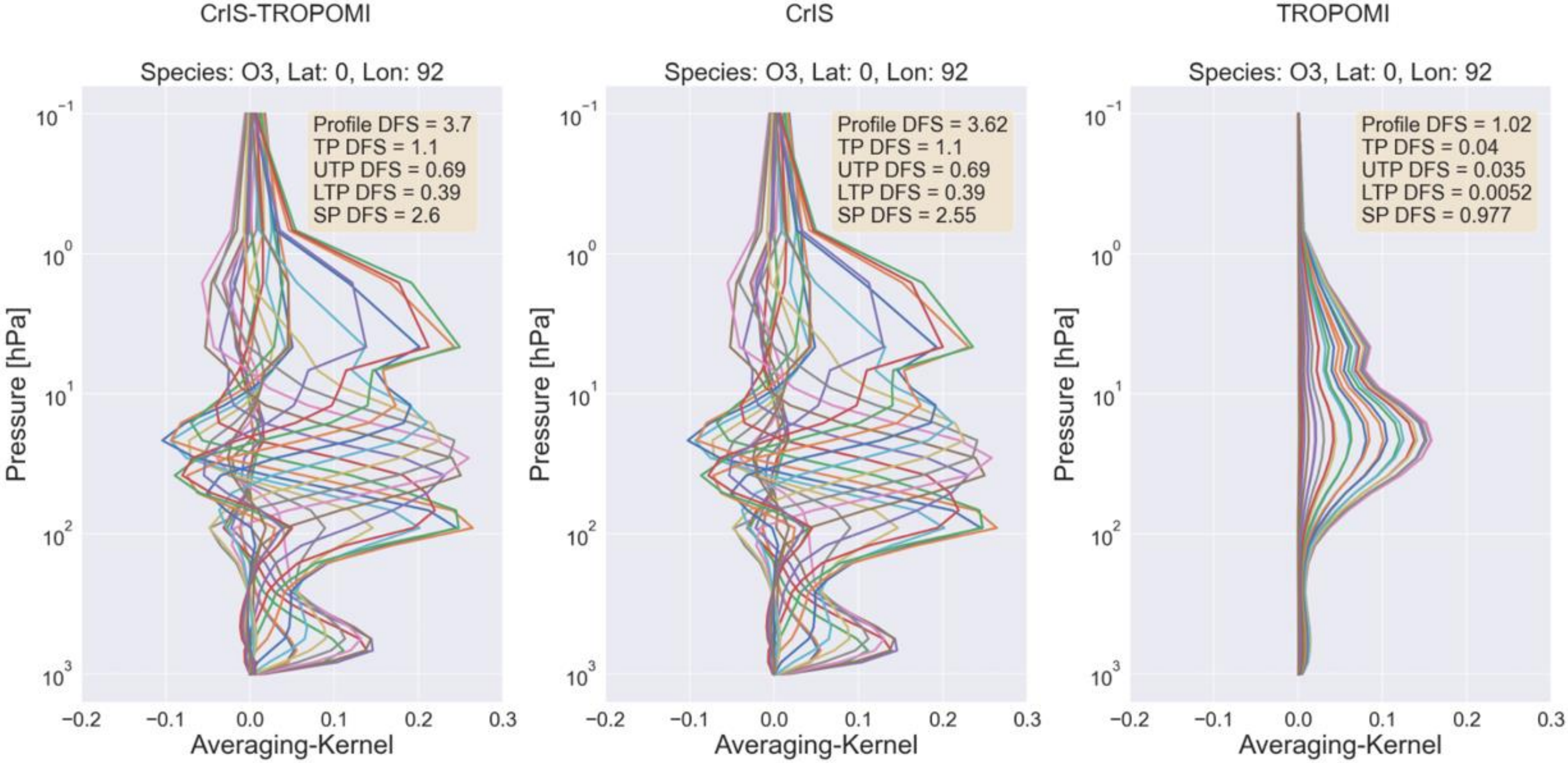
TROPOMI MUSES O3 uses a short micro-window, the 'Huggins band', 325-335 nm.

Spectral combination performed by MUSES algorithm.

TROPOMI MUSES window chosen to minimise current calibration challenges with Bands 1, 2 & 3.

TROPOMI V2.01 L1B data shows considerable improvement in Bands 2 and 3, assessments ongoing.

CrIS-TROPOMI Ozone Characterisation (Averaging Kernels)



Ozone Cross Comparison and Validation datasets

- **Satellites:**
  - **Microwave Limb Sounder (MLS) – Microwave instrument based on the Aura satellite.**
    - **Stratosphere comparisons only, scientific interpretation not recommend below 200 hPa.**
  - MUSES AIRS-OMI
  - TROPOMI OFFL Total Column Product

MLS and Ozonesondes shown in this presentation.

- **Chemical Reanalysis**
  - Copernicus Atmospheric Monitoring Service – Reanalysis.
    - CAMS pressure grid interpolated to MUSES pressure grid, and CrIS-TROPOMI AK applied.
  - JPL Multi-mOdel Multi-cOnstituent Chemical Reanalysis (MOMO-Chem)
    - MOMO-Chem pressure grid interpolated to MUSES pressure grid, and CrIS-TROPOMI AK applied.

- **Ozonesondes**
  - **In-situ sensors based on a network of balloons operated worldwide.**

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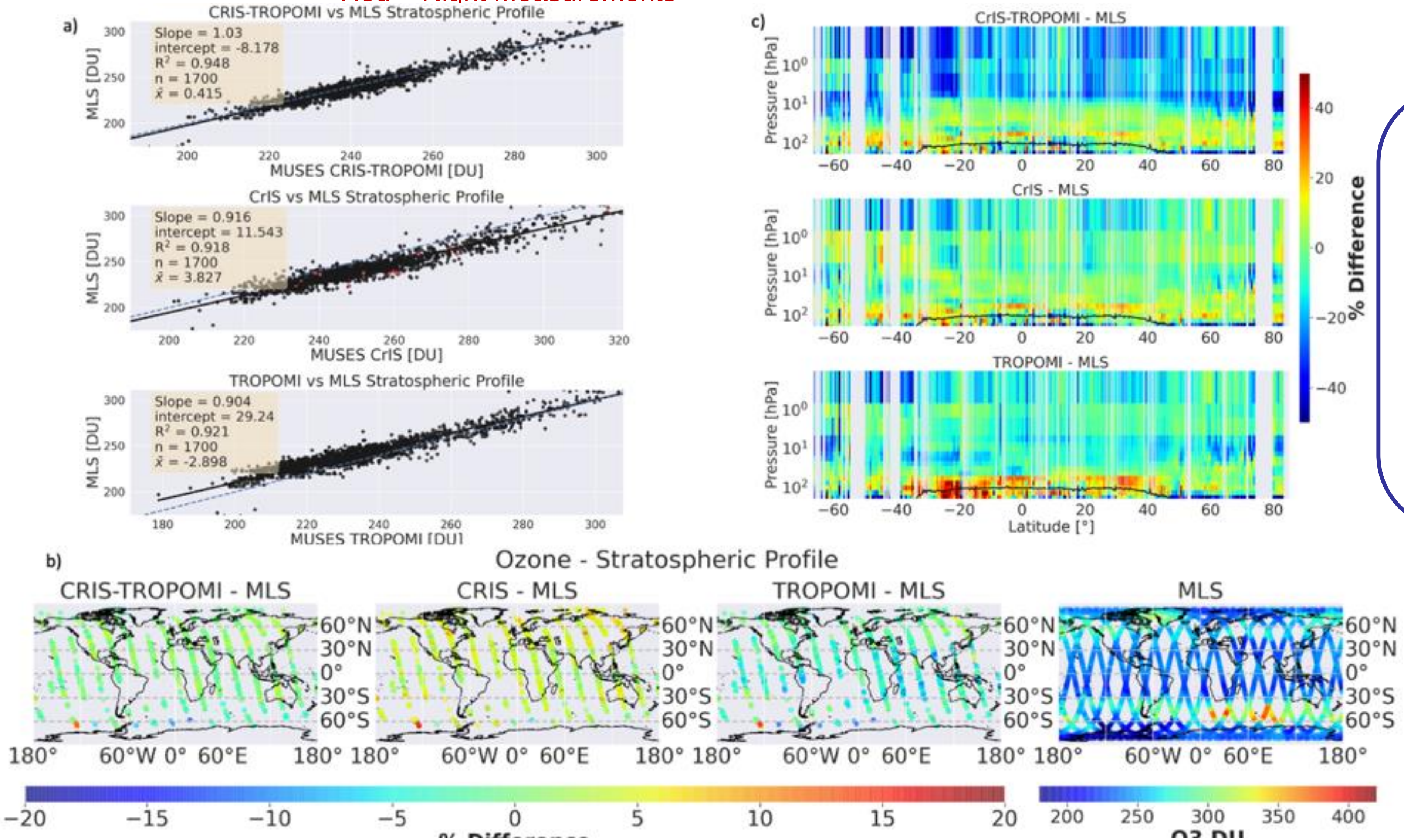
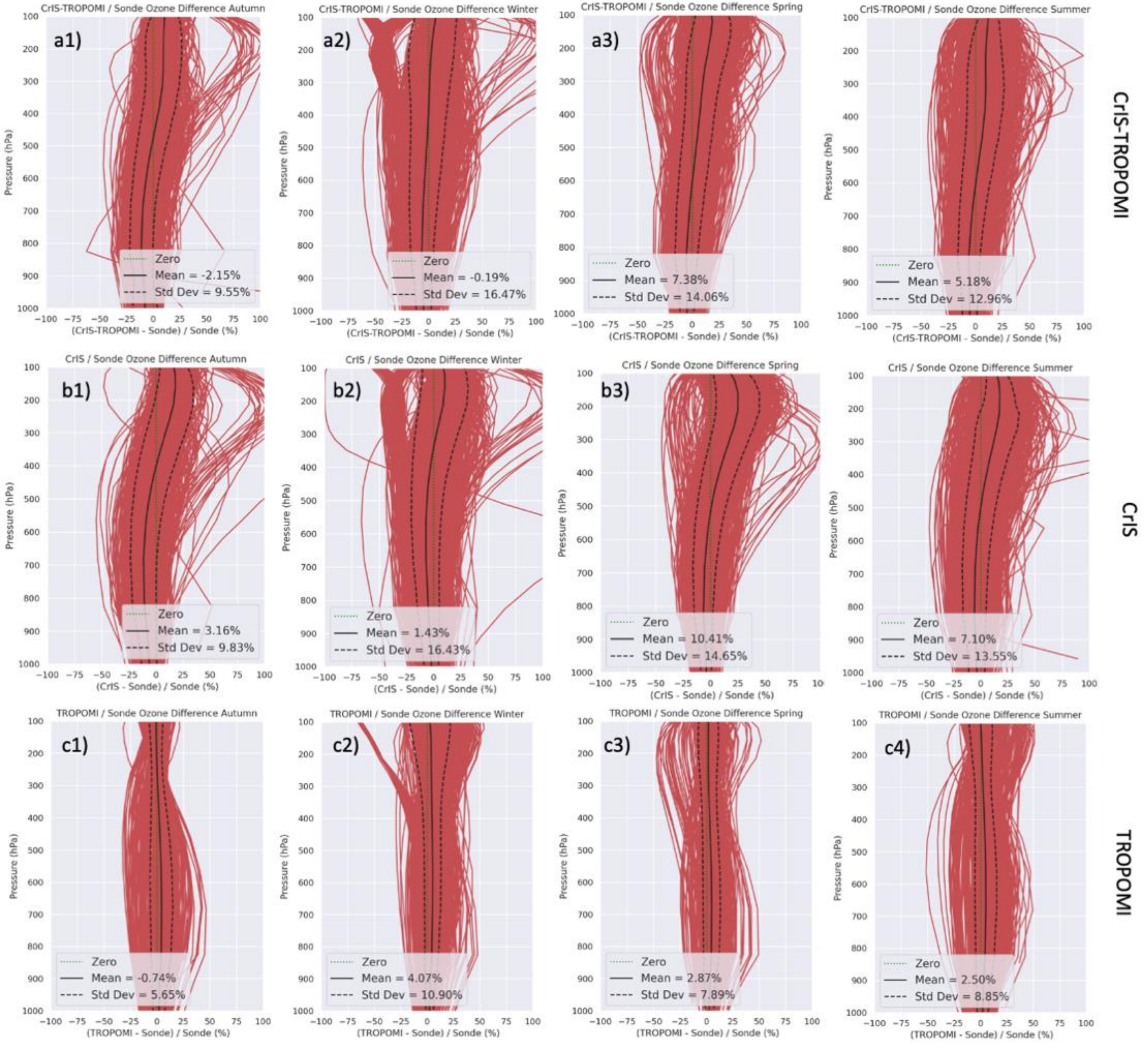
Cross Comparisons - MLS (August 2020)

Black = Day Measurements
Red = Night Measurements



1. High quality comparisons in the stratosphere.
2. CrIS-TROPOMI adds clear value, above CrIS-only and TROPOMI-only.
3. CrIS-only and TROPOMI-only offer valuable comparisons individually.

Validation with Ozonesondes



1. ~100 ozonesonde comparisons over the course of 1 year, at colocation distance of ~100 km.
2. CrIS-TROPOMI in general shows closer comparisons than either CrIS or TROPOMI alone.
3. Results are consistent with joint AIRS-OMI retrievals.

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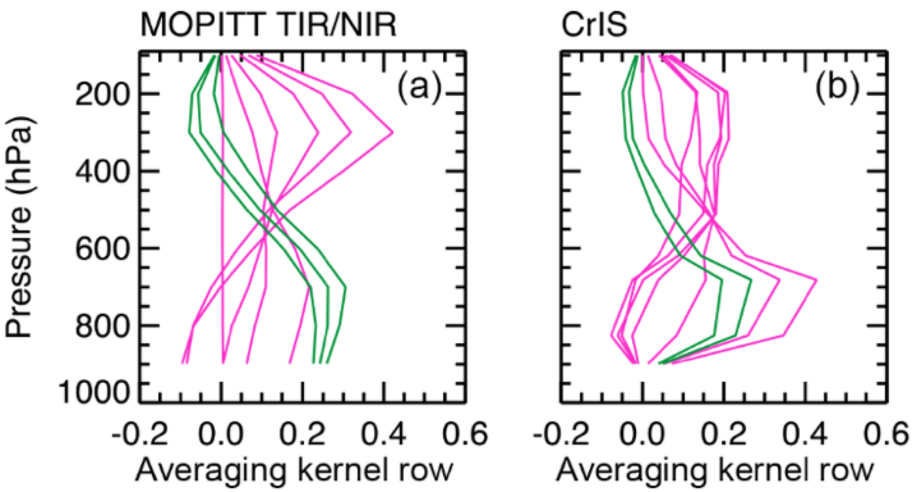
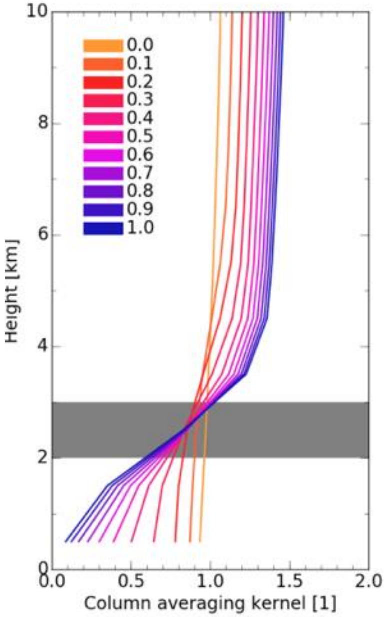
Characterisation of CrIS CO

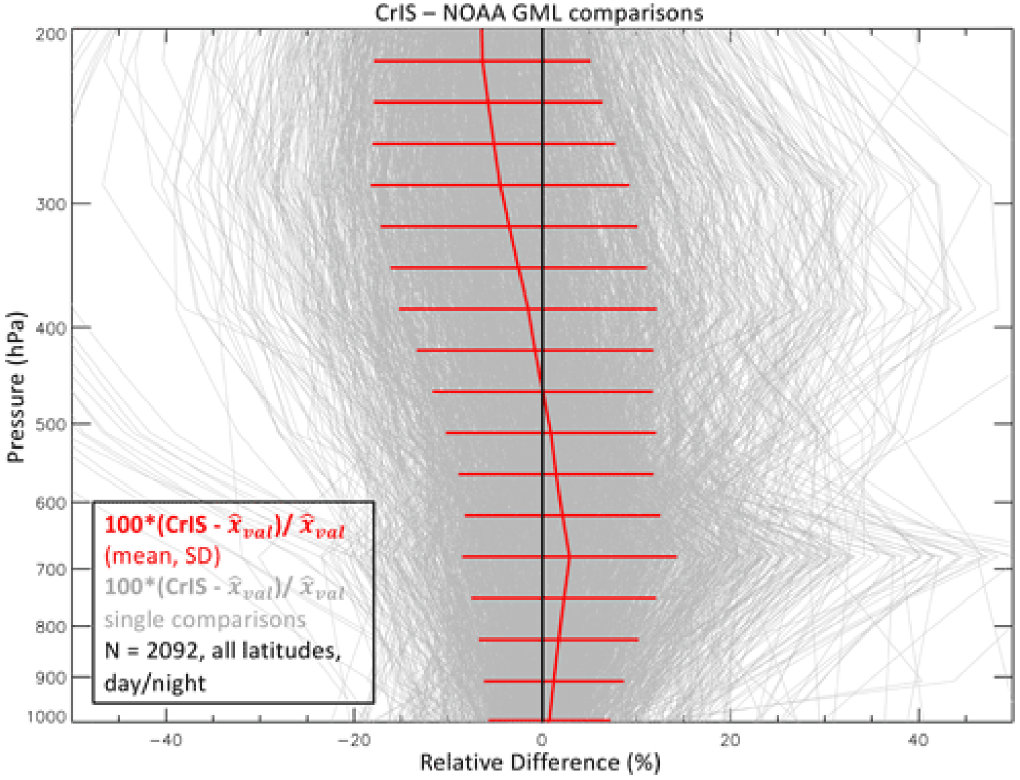


Example MOPITT and CrIS CO AK from Fu et al 2018.



Example TROPOMI CO AK from Landgraf et al 2016.

CrIS CO and TROPOMI CO retrievals peak in the troposphere at similar pressure levels



CrIS CO comparisons against NOAA aircraft from Worden et al 2022.

TROPESS provides multi-year high quality CO retrievals datasets from CrIS.

TROPESS MUSES CrIS-TROPOMI/TROPOMI-only CO product development underway.

2019-2020 Wildfires in Australia, ozone and CO perspective

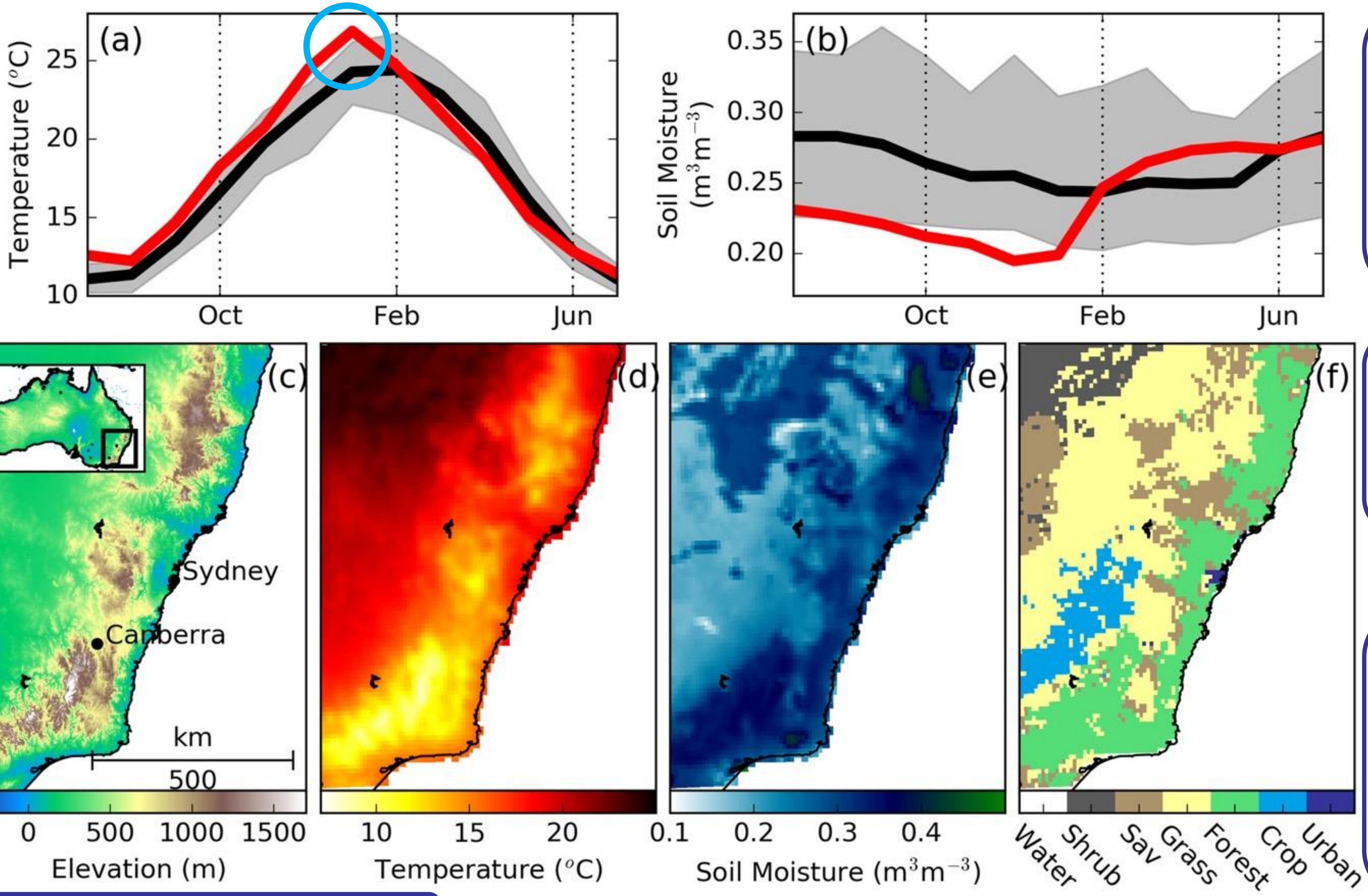


Figure from Byrne et al 2021.

2019 was the hottest and driest year on record for southeast Australia leading to bushfires of unprecedented extent.

Peaking in January.

Byrne et al. 2021 found that 113–236 TgC of CO2 were released during these wildfire events.

Ozone is complicated in the presence of fires. Fires do not form ozone directly, but generate the necessary precursors to form ozone down stream of the fires.

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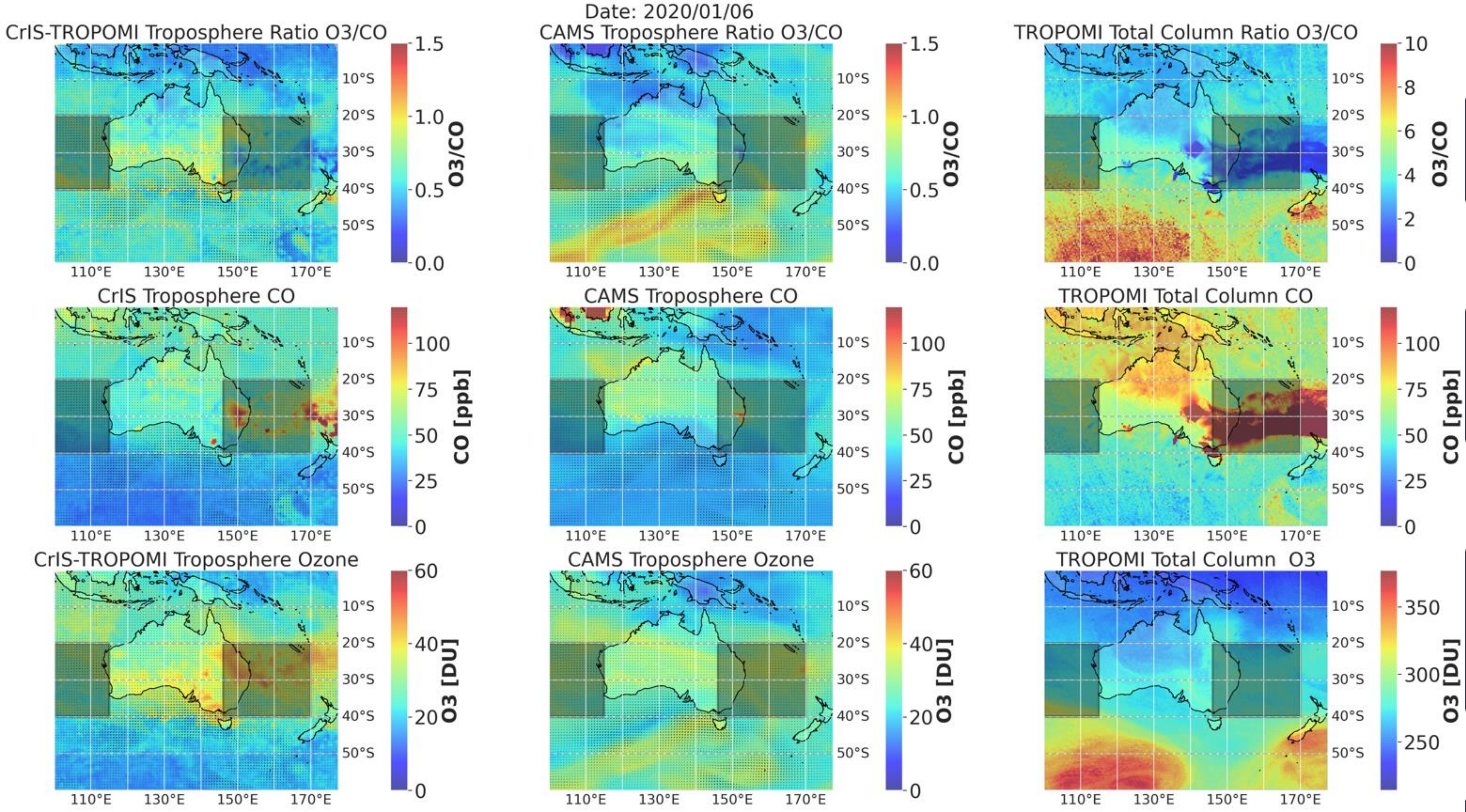
Australian Ozone and CO January



Example results from Jan 6th 2020.

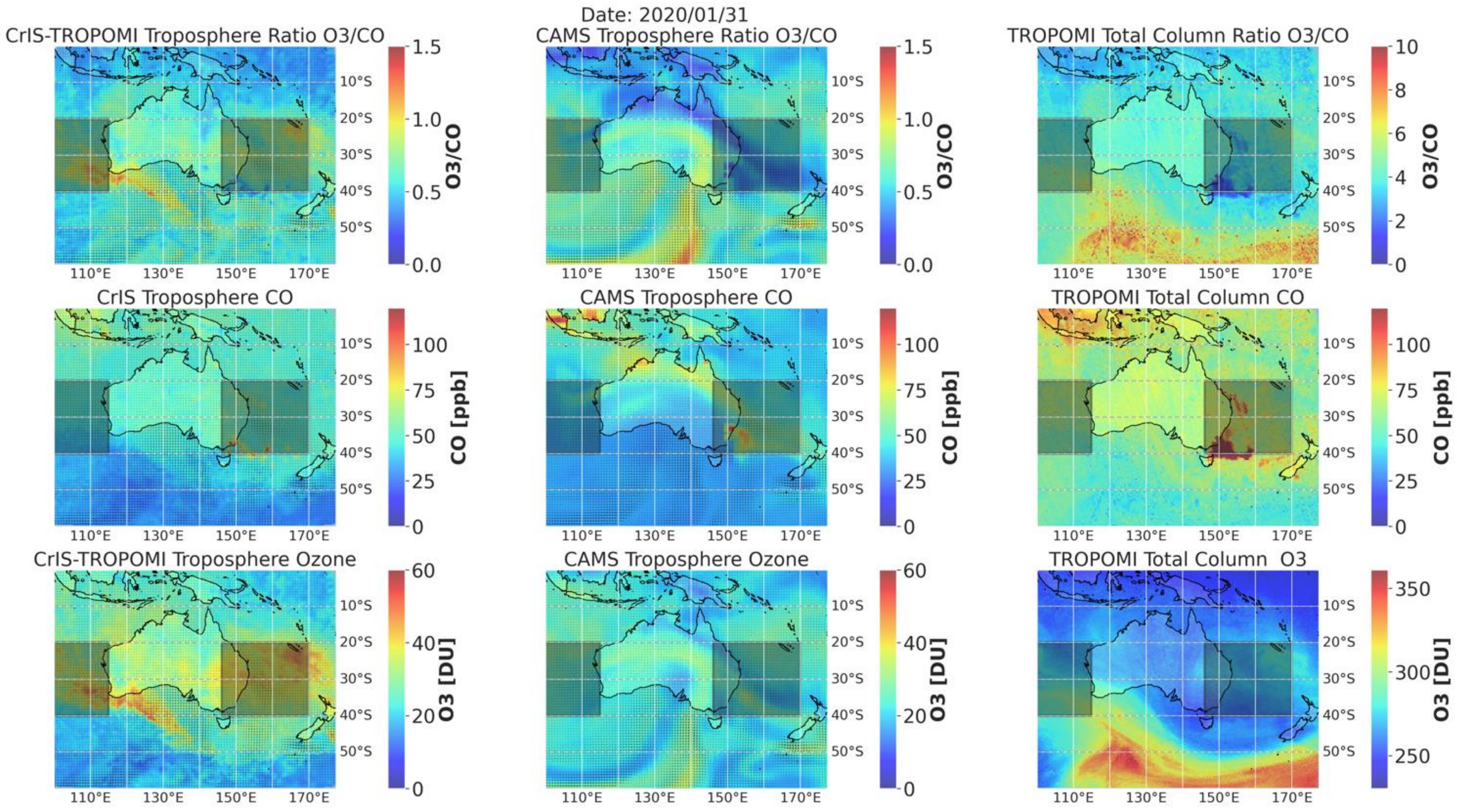
Clear evidence of CO plumes from fires in Eastern Australia.

O3/CO ratio should be low near fires due to NO titration, and high downwind of fires.

Obvious similarities between operational TROPOMI and TROPESS CrIS-TROPOMI.

CAMS shows significant differences.

Australian Ozone and CO January (end of)

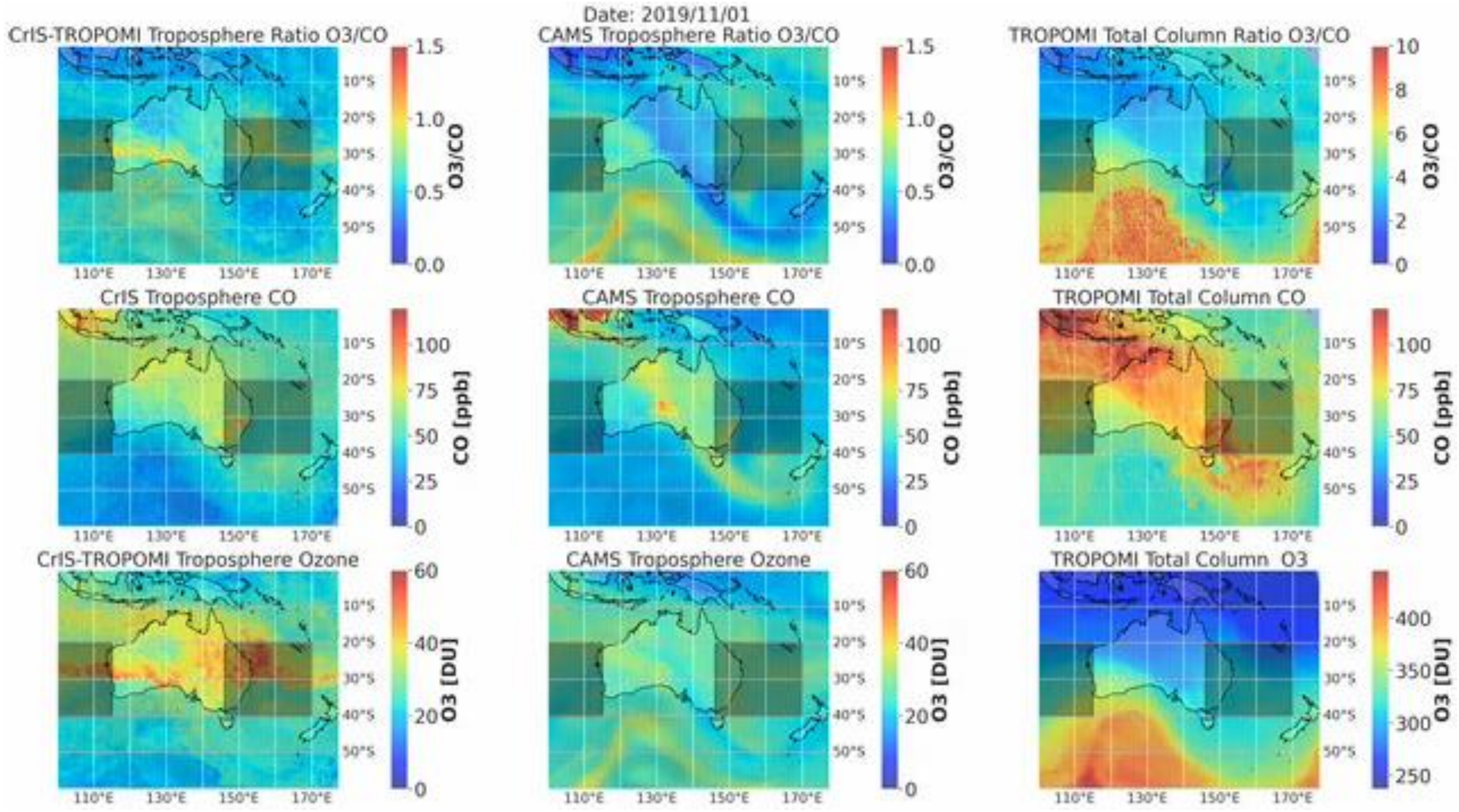


Obvious similarities between operational TROPOMI and TROPESS CrIS-TROPOMI.

CAMS results continues to show significant differences, most notably in tropospheric ozone.

Remains challenging to differentiate transported ozone from ozone generated as a part of wildfires.

Time-lapse of fires



Focusing on O3/CO ratio, we see peaks and troughs. Potentially indicating an initial high concentration of CO from fires, then a reduction in CO as O3 increases.

Substantial differences between CrIS-TROPOMI and CAMS.

Time series (Troposphere Enhancement)

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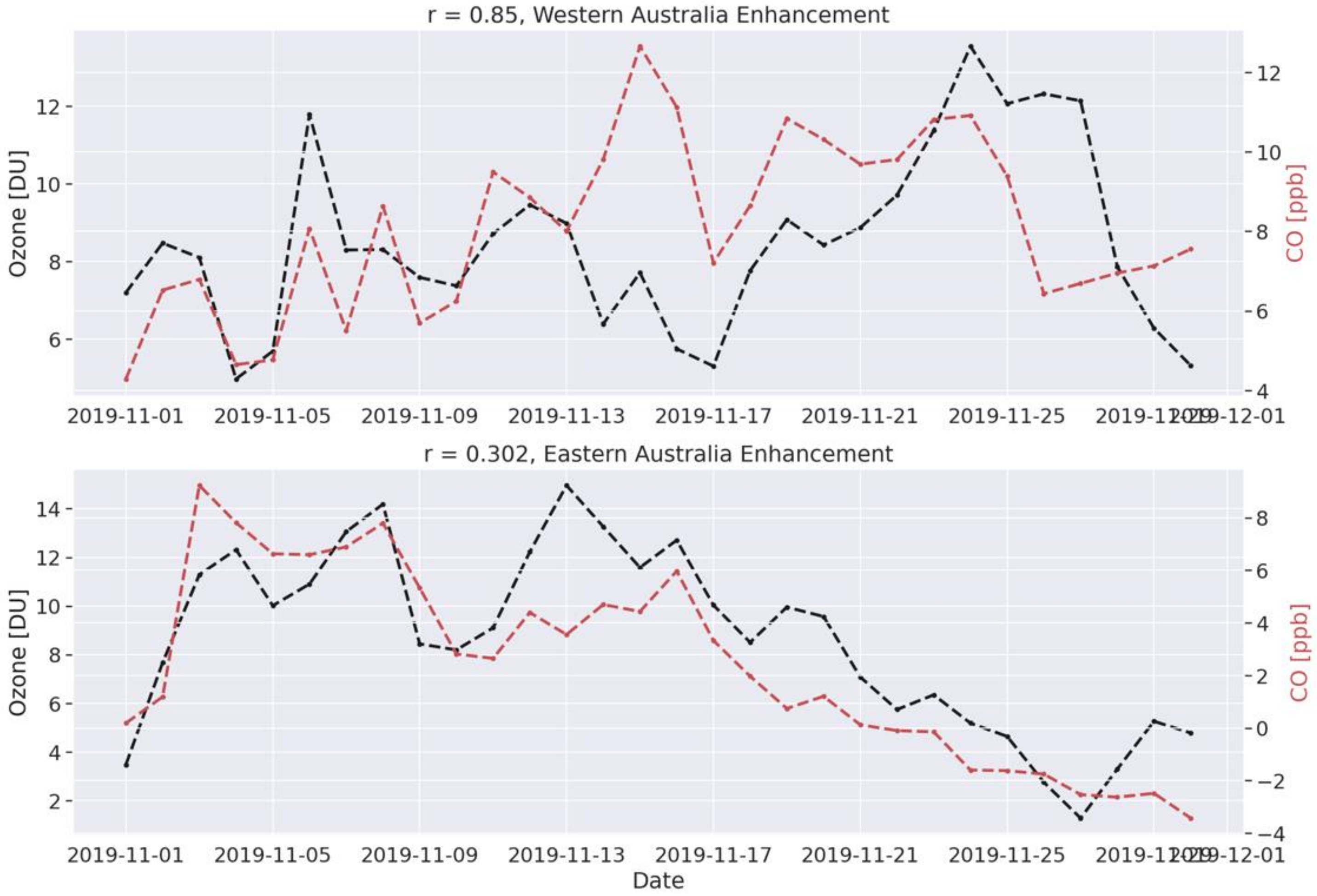
Time series show enhancements of highlighted boxes from previous plots, relative to the whole plotted area.

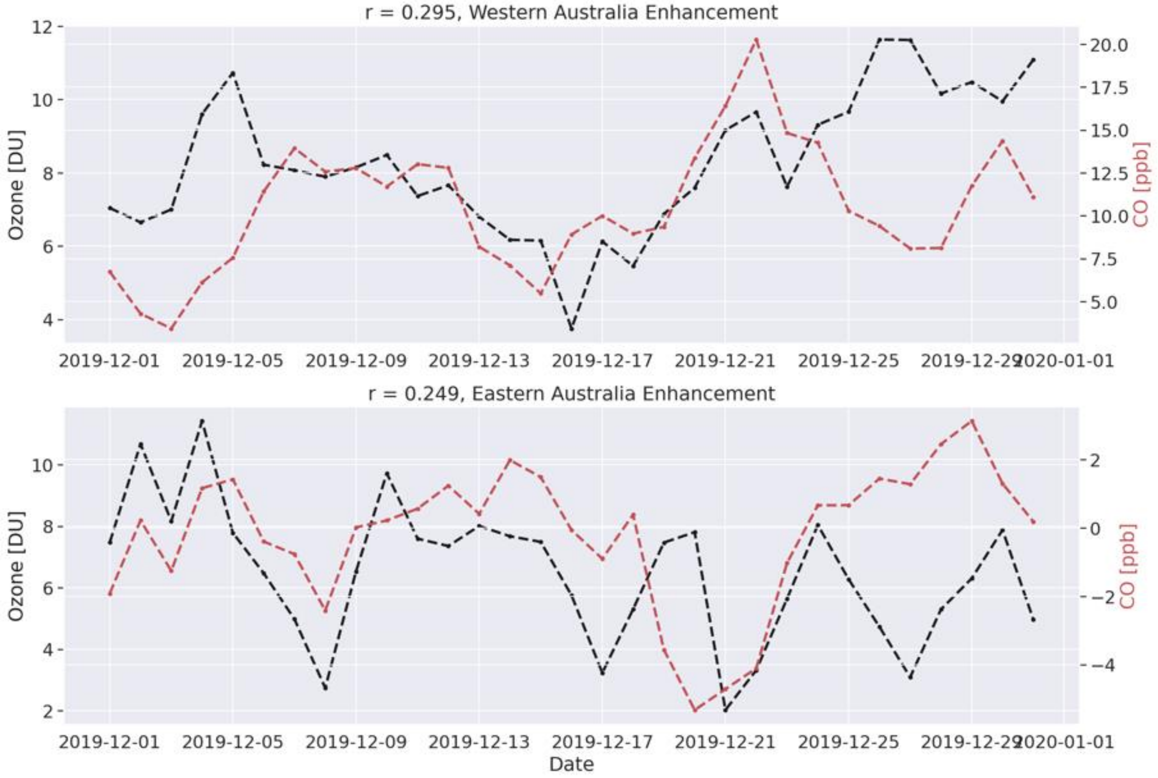


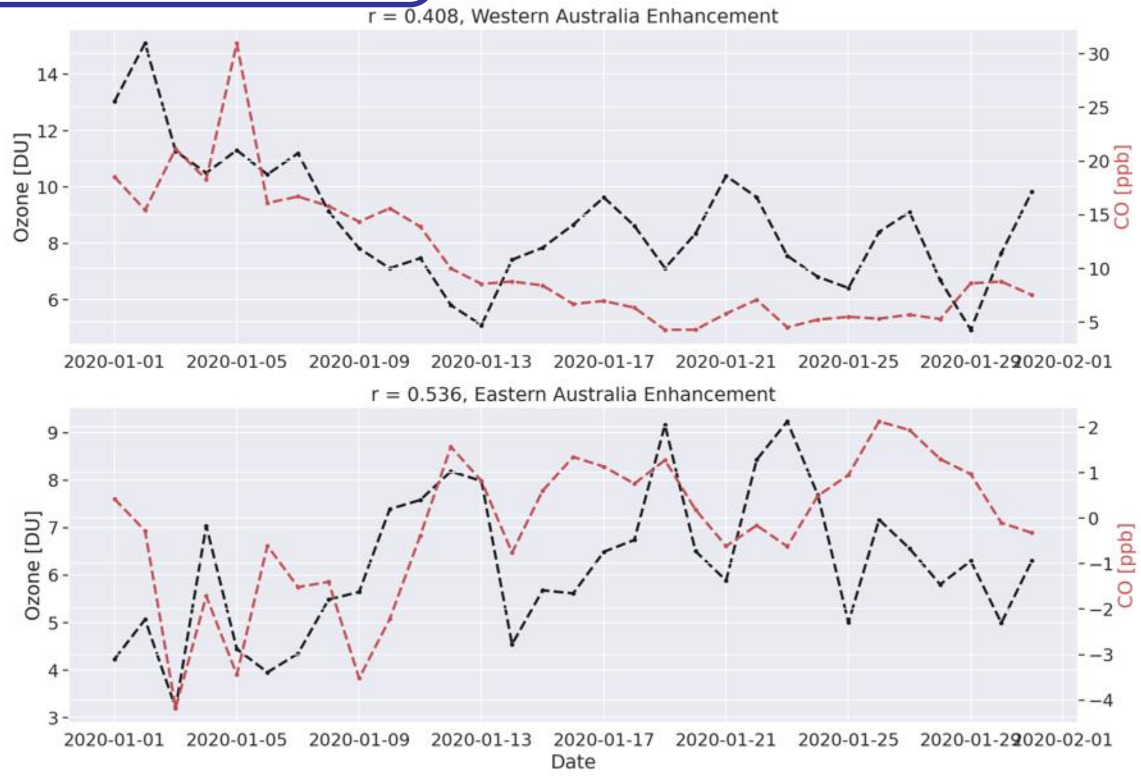
November 2019
Clear correlation between Ozone and CO enhancements in both the highlighted regions, potentially

Data from MUSES CrIS/TROPOMI retrievals shown only.

Time series (Enhancement)

Time series show enhancements of highlighted boxes from previous plots, relative to the whole plotted area.



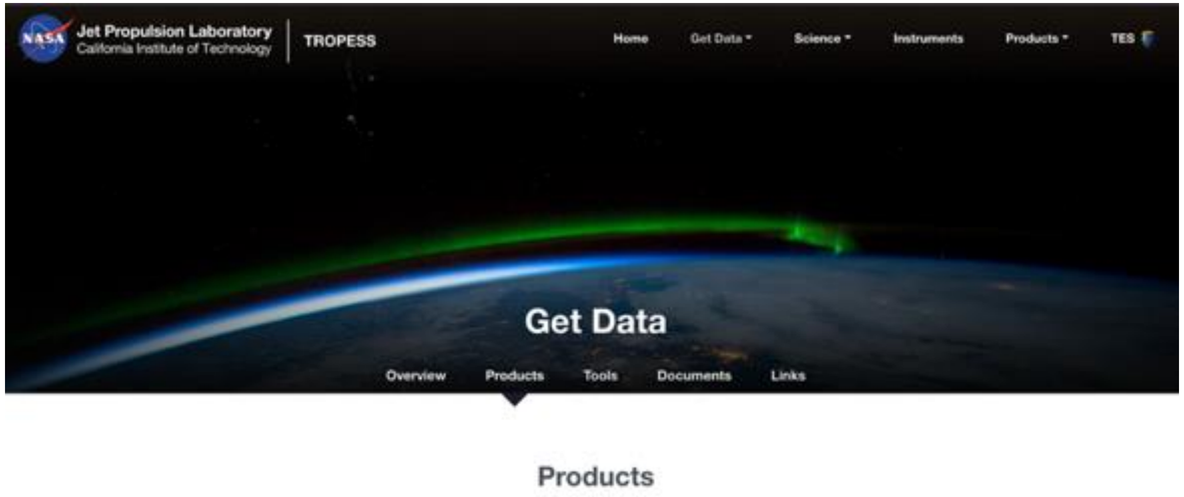


December 2019
Enhancements from ozone and CO higher than November, but no evidence of a correlation. Potentially ozone generation occurs further afield.

January 2020
Enhancements from Western Australia show a gradual decrease in CO, with variable O3. From Eastern Australia, some correlation between CO and O3 activity evident.

Conclusions

- **TROPESS has measurement-focused (rather than mission-focused) approach to atmospheric composition retrievals.**
- **CrIS-TROPOMI and CrIS O3 and CO products show good cross-comparison and validation comparison metrics.**
- **Impact of wildfires in Australia clearly identifiable with CrIS-TROPOMI retrievals. Potentially useful for lifting lid on complex O3/CO relationships with wildfires. However, further work is necessary.**
- **Further improvements to CrIS-TROPOMI O3 product ongoing, utilising V2.01 of L1b data. CrIS-TROPOMI CO product development ongoing.**



https://tes.jpl.nasa.gov/tropess/get-data

TROPESS MUSES retrievals also available for:
- AIRS
- OMI
- AIRS/OMI
- CrIS
- TROPOMI
- CrIS/TROPOMI

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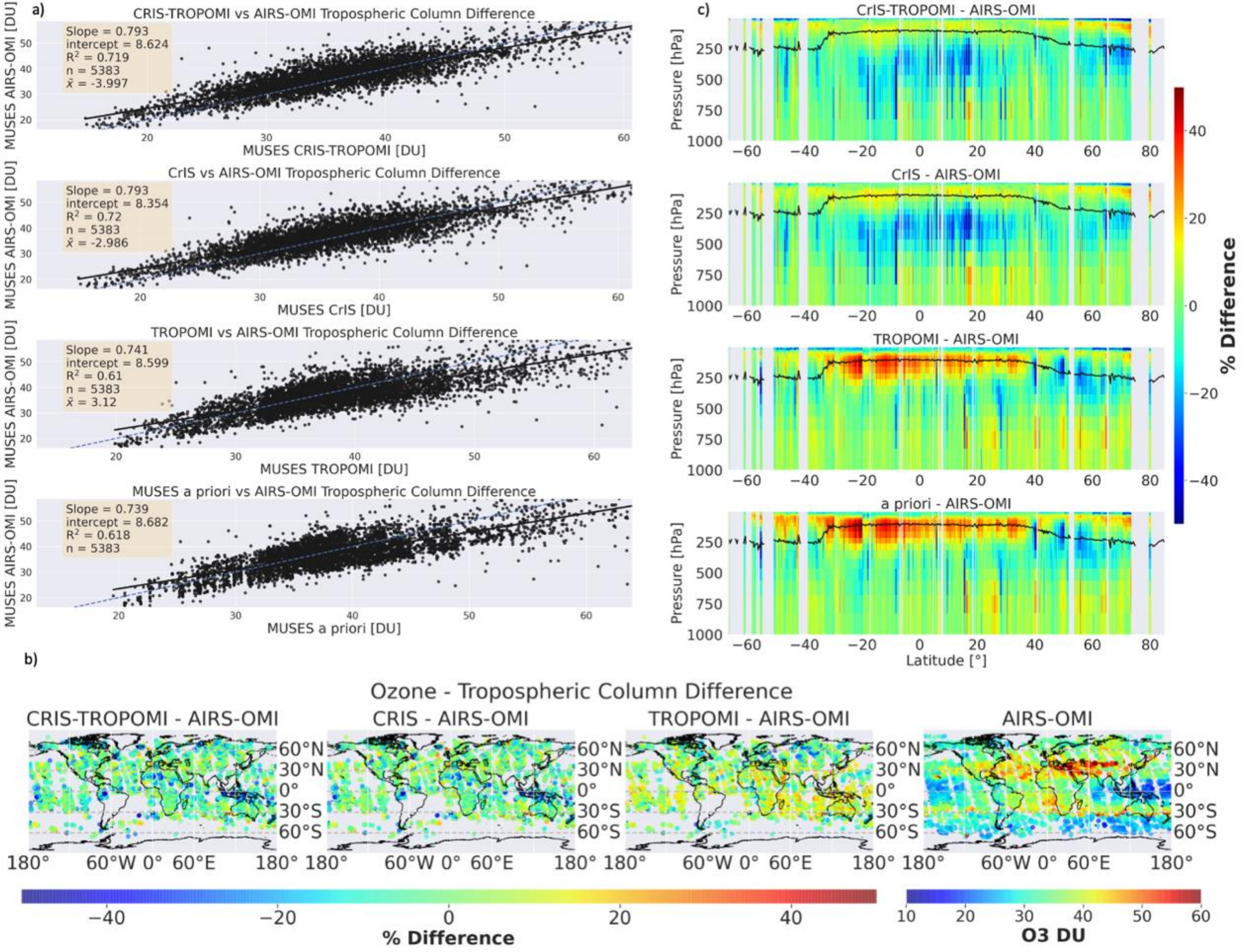
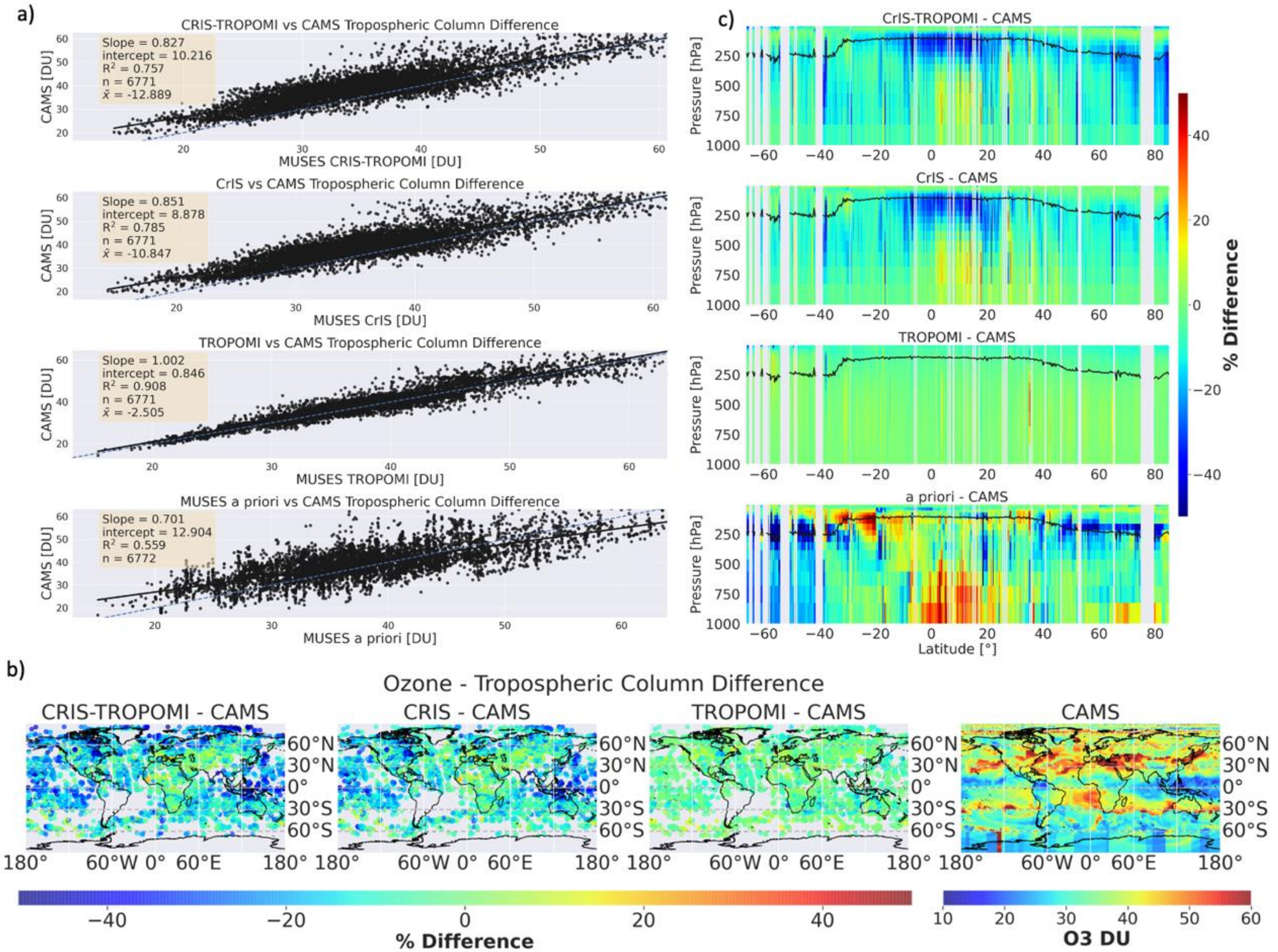
Cross Comparisons – AIRS-OMI (August 2020)



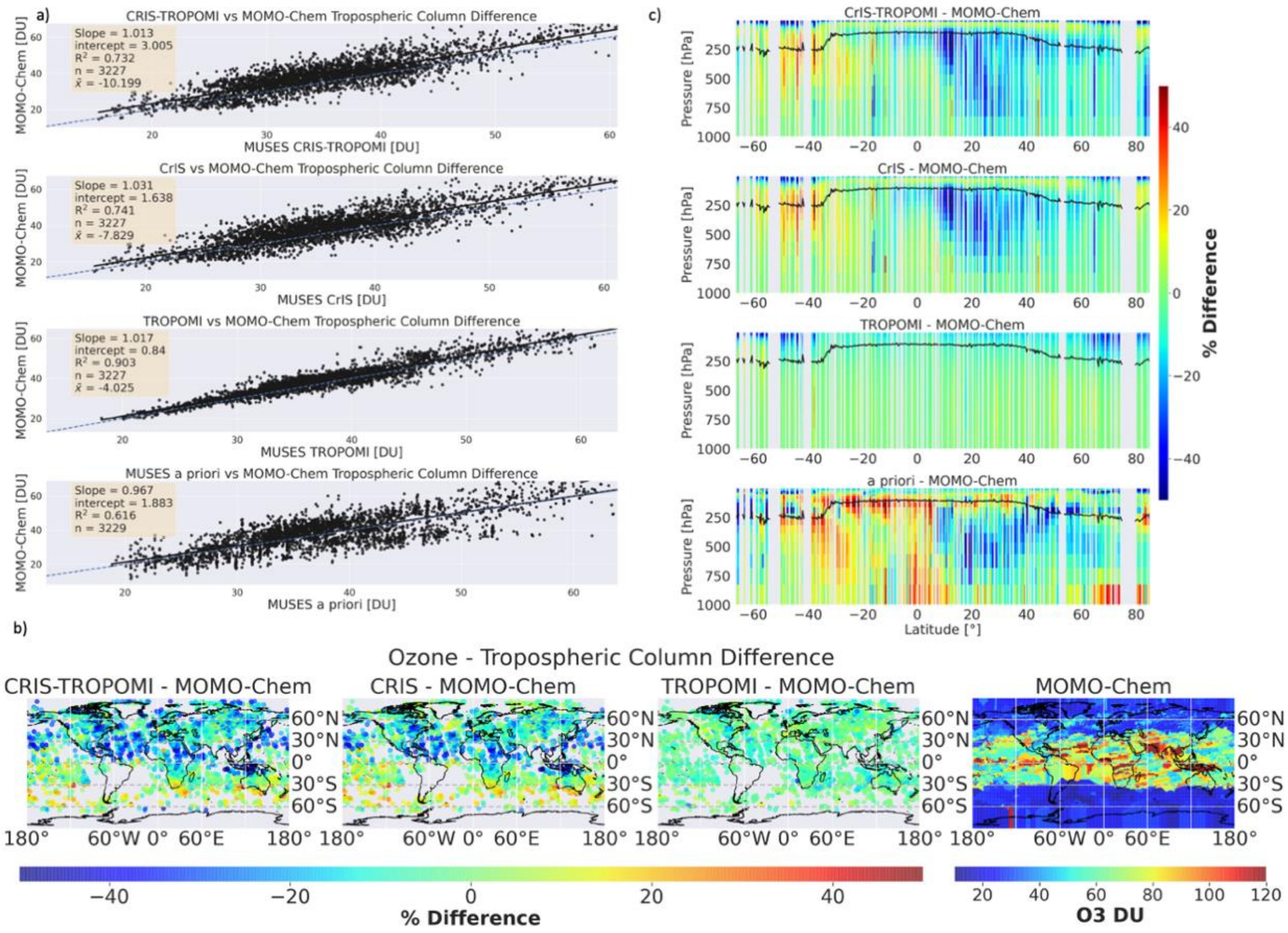
1. High quality comparisons at the example pressure level.
2. Comparable performance between CrIS-TROPOMI and CrIS-only.
3. Largest disagreements appear in the tropics.

Cross Comparisons – CAMS Global Reanalysis (August 2020)



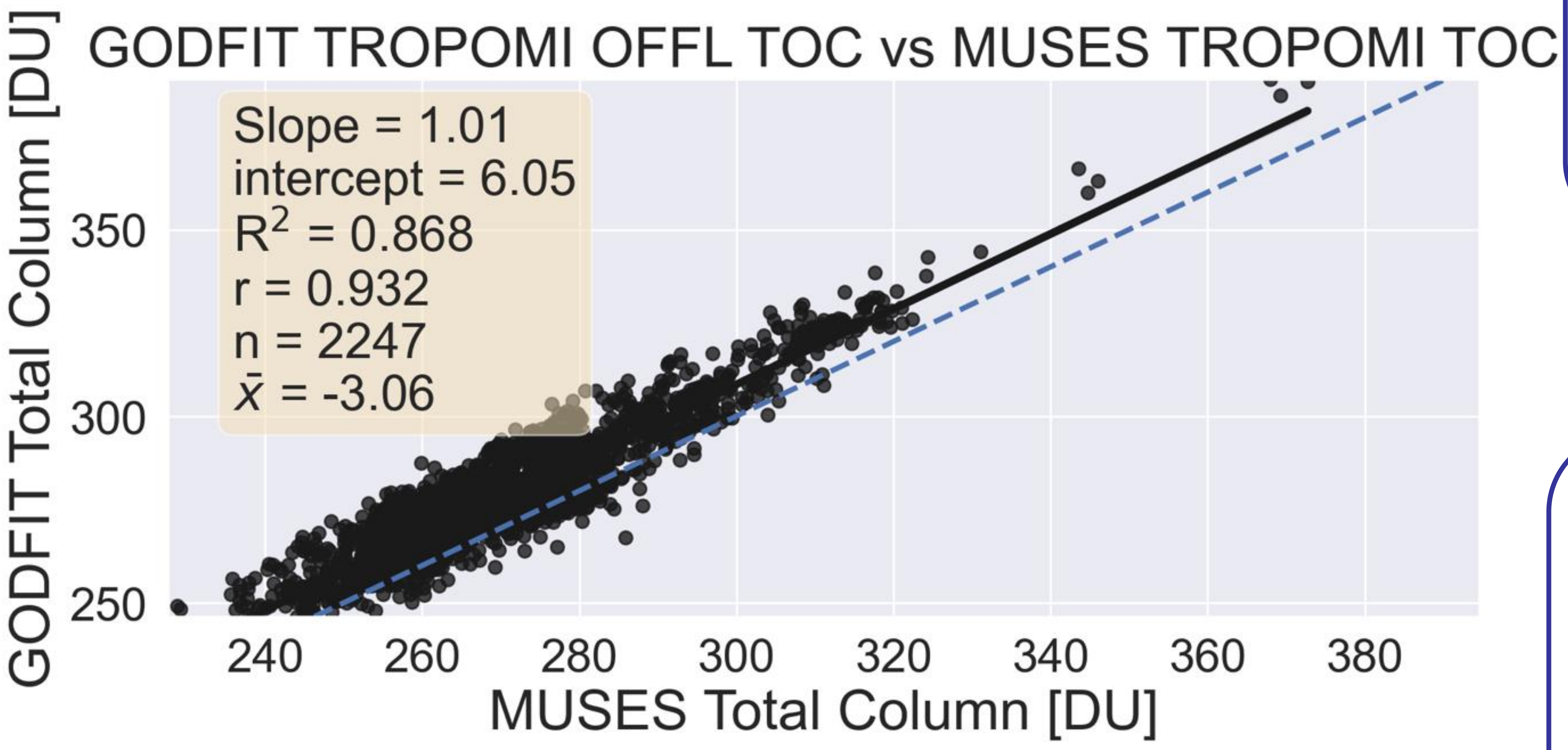
1. High quality comparisons at the example pressure level.
2. Comparable performance between CrIS-TROPOMI and CrIS-only.
3. Largest disagreements appear in the tropics.

Cross Comparisons – JPL MOMO-Chem (August 2020)



1. High quality comparisons at the example pressure level.
2. Improved comparisons when compared to CAMS.
3. Largest disagreements appear in the northern mid-latitudes.

Cross Comparisons – TROPOMI TCL



Good agreement found between MUSES TROPOMI only, and the TROPOMI OFFL TOC product.

Algorithms are significantly different, profile retrieval (MUSES) vs column shift (GODFIT). Therefore differences are expected.