Some Applications of SiFSAP for Wildfires, Weather and Atmospheric Dynamics Studies

Xiaozhen(Shawn) Xiong, Xu Liu, Wan Wu,
Liqiao Lei, Qiguang Yang, Daniel K. Zhou,Allen M. Larar
NASA Langley Research Center, Hampton, VA, USA

K.Emma Knowland
NASA Goddard Space Flight Center, GMAO

Fanglin Yang
NOAA/NEC/EMC

Lihang Zhou
NOAA/NESDIS

Xiaozhen.Xiong@nasa.gov

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Outline

- **Introduction**
  - **CrIS Single Field-of-View (FOV) Sounder Atmospheric Products (SiFSAP): retrievals algorithms and products;**
  - **Two reanalysis data are matched up with SiFSAP (using closest point and making time interpolation)**
    1. NASA's Modern-Era Retrospective Analysis for Research and Applications Version-2 (MERRA-2);
    2. The fifth generation of European Centre for ECMWF atmospheric reanalysis of the global climate (ERA5);

- **Application 1: Monitoring of Wildfires and CO transport**
  - Australia Fires (Dec 2019 – Jan 2020);

- **Application 2: Observation of O_3 transport associated with Stratospheric Intrusion (SI)**
  - Xiong et al., 2022, *Atmos. Environ*.

- **Application 3: Moinitoring of Cold air outbreak (CAO) and impact of stratosphere**
  - Xiong et al, 2022, *Atmosphere*

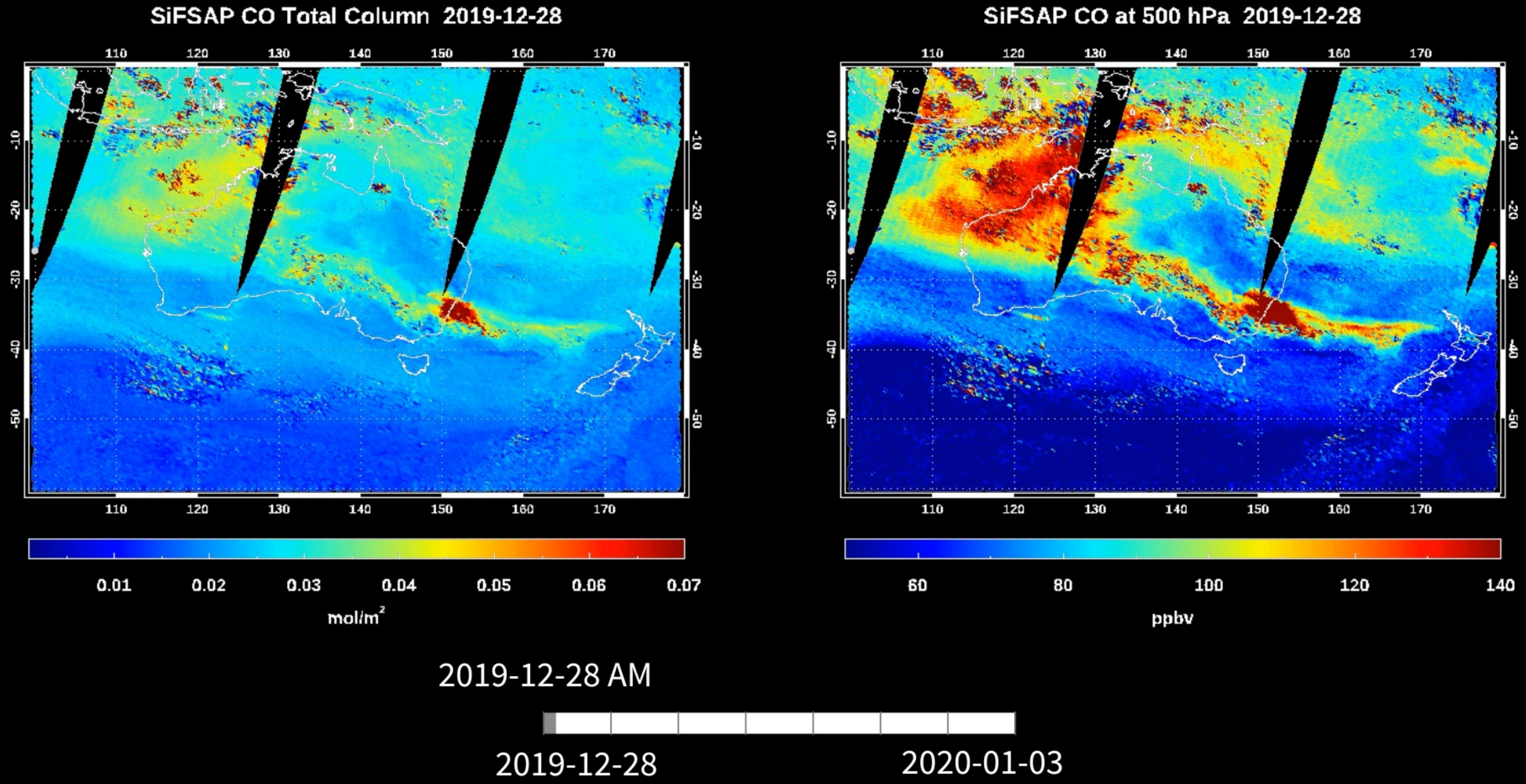
- **Summary**

SiFSAP Products and Other Data Used

- SiFSAP (Single Field-of-View Sounder Atmospheric Products) and Retrieval Algorithm
  1. **Based on Principal Component (PC) Radiative Transfer Model (PCRTM)**
     - *Enable calculations of whole Cross-track Infrared Sounder (CrIS) spectrum with fast speed;*
     - *Able to compute cloud multiple scattering accurately;*
     - *Provides Jacobian needed for a physical retrieval algorithm;*
  2. **Using Optimal Estimation (OE) method to do simultaneous retrieval in PC domain**
     - *Uses 120-200 PCs- equivalent to use all spectral channels;*
     - *Uses all available spectral information to separate contributions from atmospheric trace gases, cloud and surfaces;*
     - *Uses PCA to reduce random measurement noises;*
     - *No need to account for errors due to non-retrieved parameters (such as those in a sequential inversion algorithm);*
  3. **SiFSAP products (with a resolution of ~ 14 km at nadir) include**
     - *Atmospheric Temperature, Water, CO_2, CO, CH_4, O_3, and N_2O profiles;*
     - *Cloud phase, height, temperature, size, optical depth;*
     - *Surface emissivity spectrum and skin temperature;*

- Other Data used: **matched up with SiFSAP using closest data point and making linear temporal interpolation**
  1. TROPOspheric Monitoring Instrument (TROPOMI): (5.5 × 7 km); OMPS (50 x 50 km);
  2. Measurement of Pollution in the Troposphere (MOPITT) on EOS Terra: Surface CO and CO total Column (22 x 22 km);
  3. NASA's Modern-Era Retrospective Analysis for Research and Applications Version-2 (MERRA-2), 3 hours;
  4. The fifth generation of European Centre for ECMWF atmospheric reanalysis of the global climate (ERA-5), 1 hour;

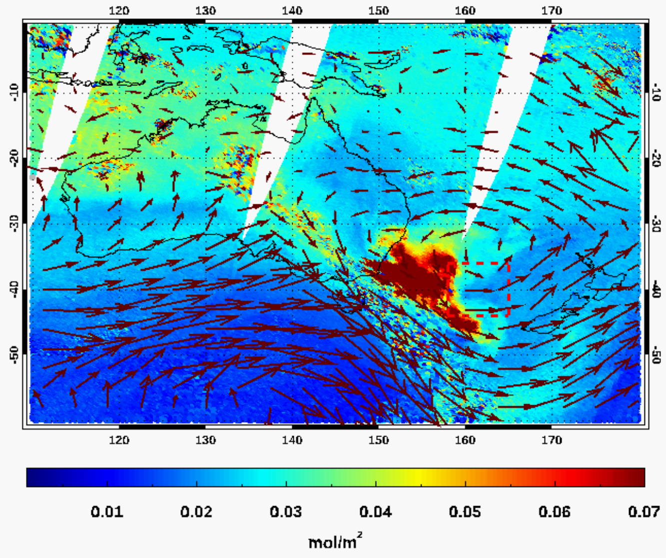
Observing CO from Australia Fires using S-NPP CrIS SiFSAP



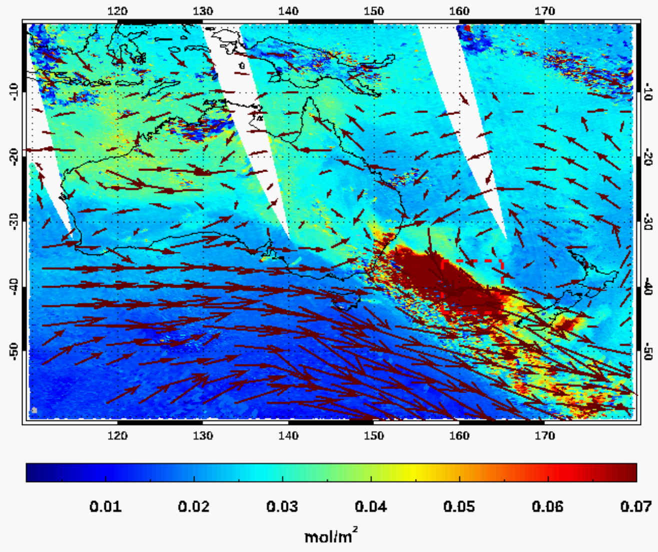
Application `: *Transport of CO Plume from Australia Fires*

(SiFSAP total column CO overlaid with MERRA-2 wind fields at 850 hpa)

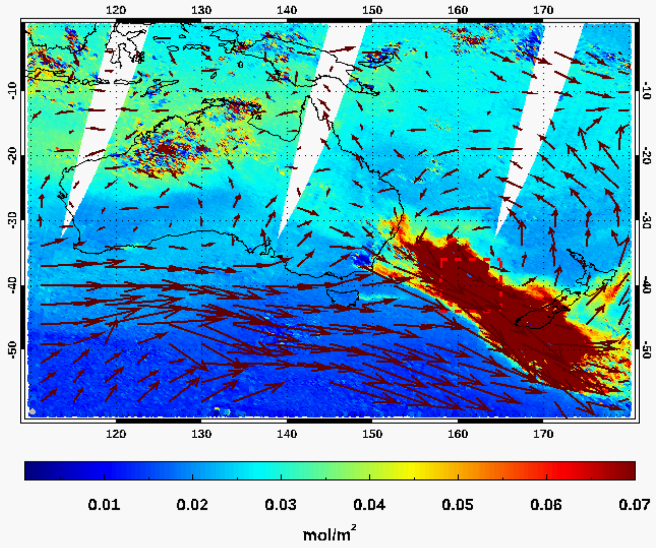
SiFSAP CO Total Column 2019-12-30



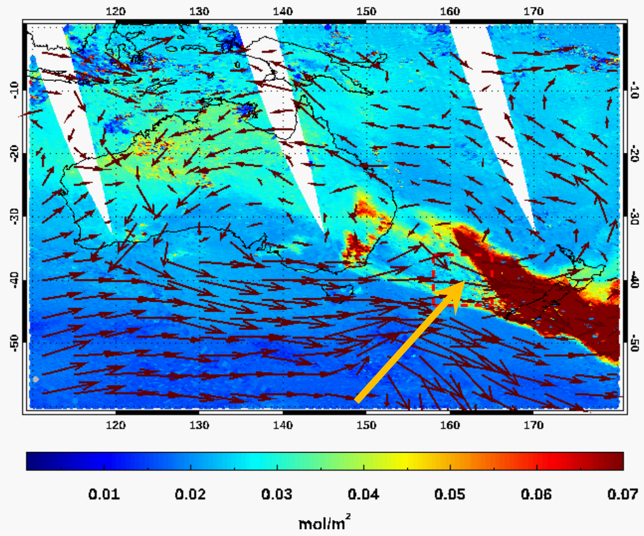
SiFSAP CO Total Column 2019-12-31



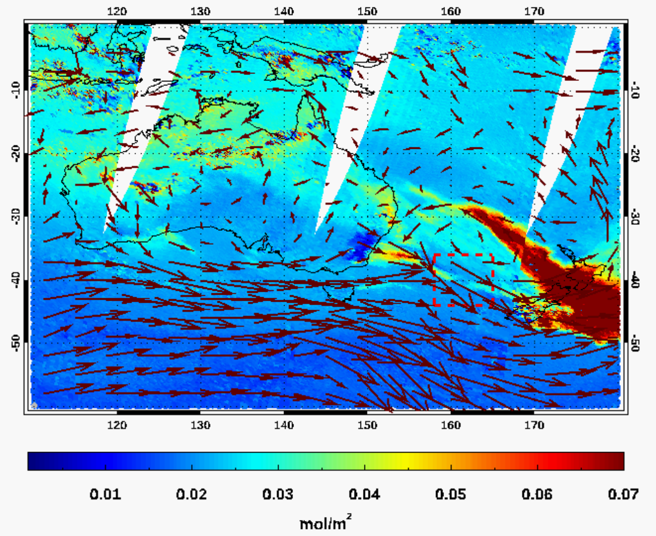
SiFSAP CO Total Column 2019-12-31



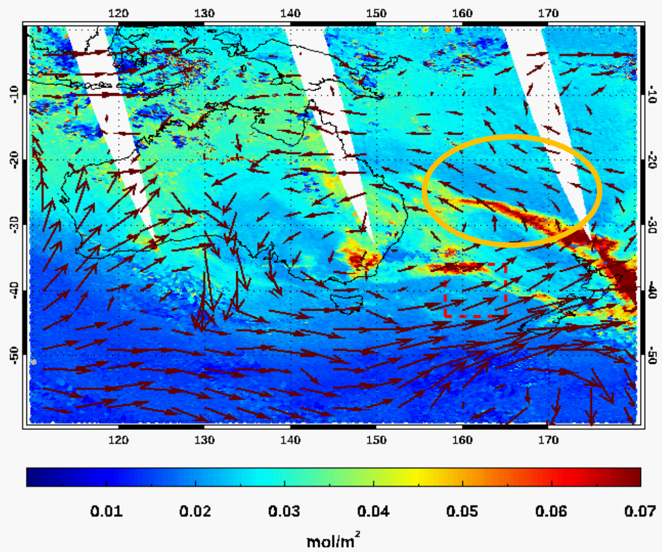
SiFSAP CO Total Column 2020-01-01



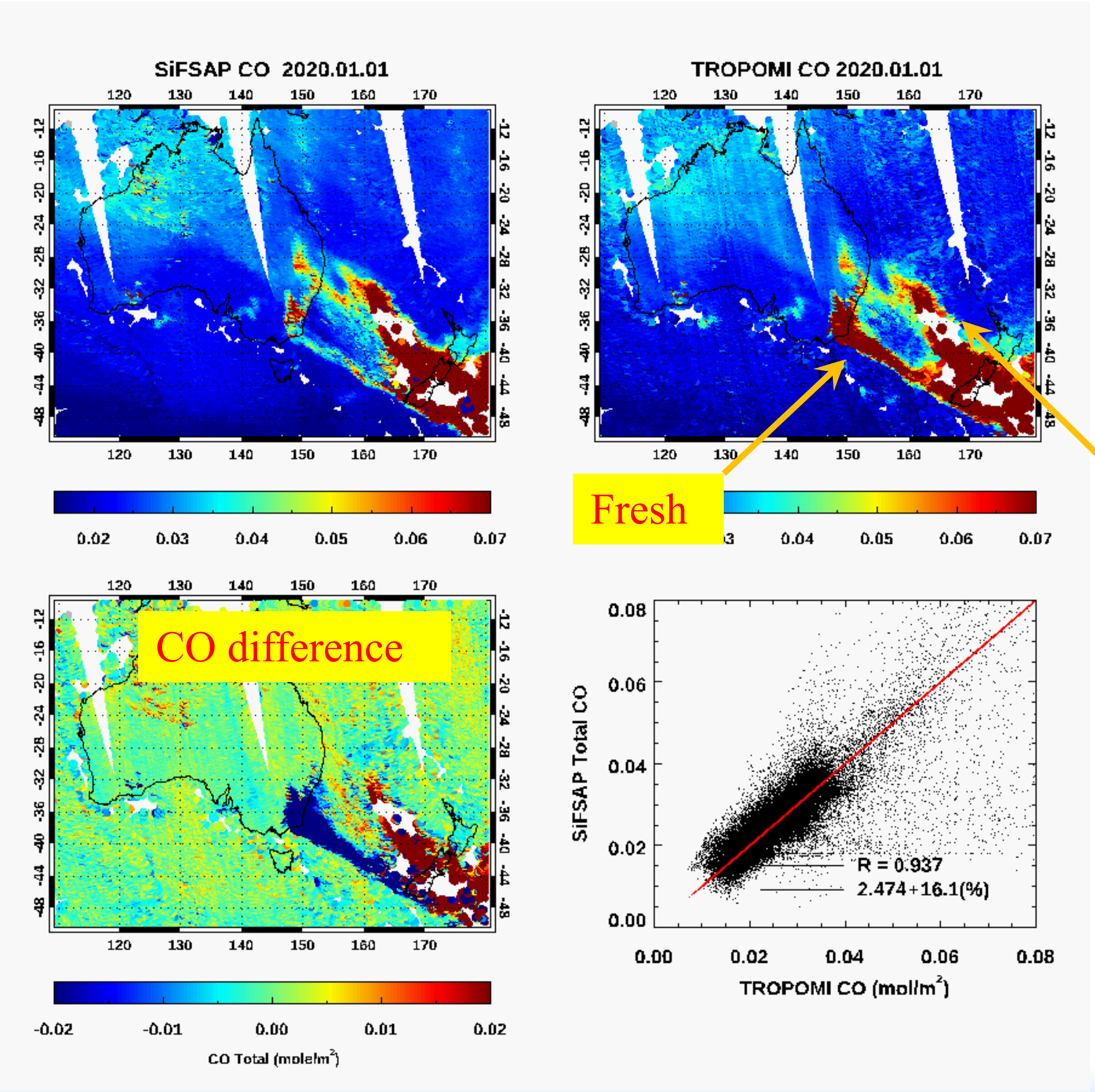
SiFSAP CO Total Column 2020-01-01

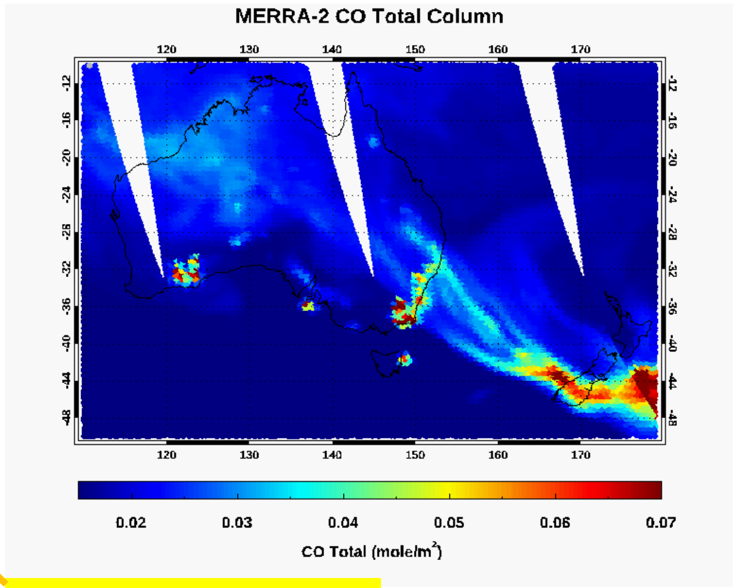


SiFSAP CO Total Column 2020-01-02



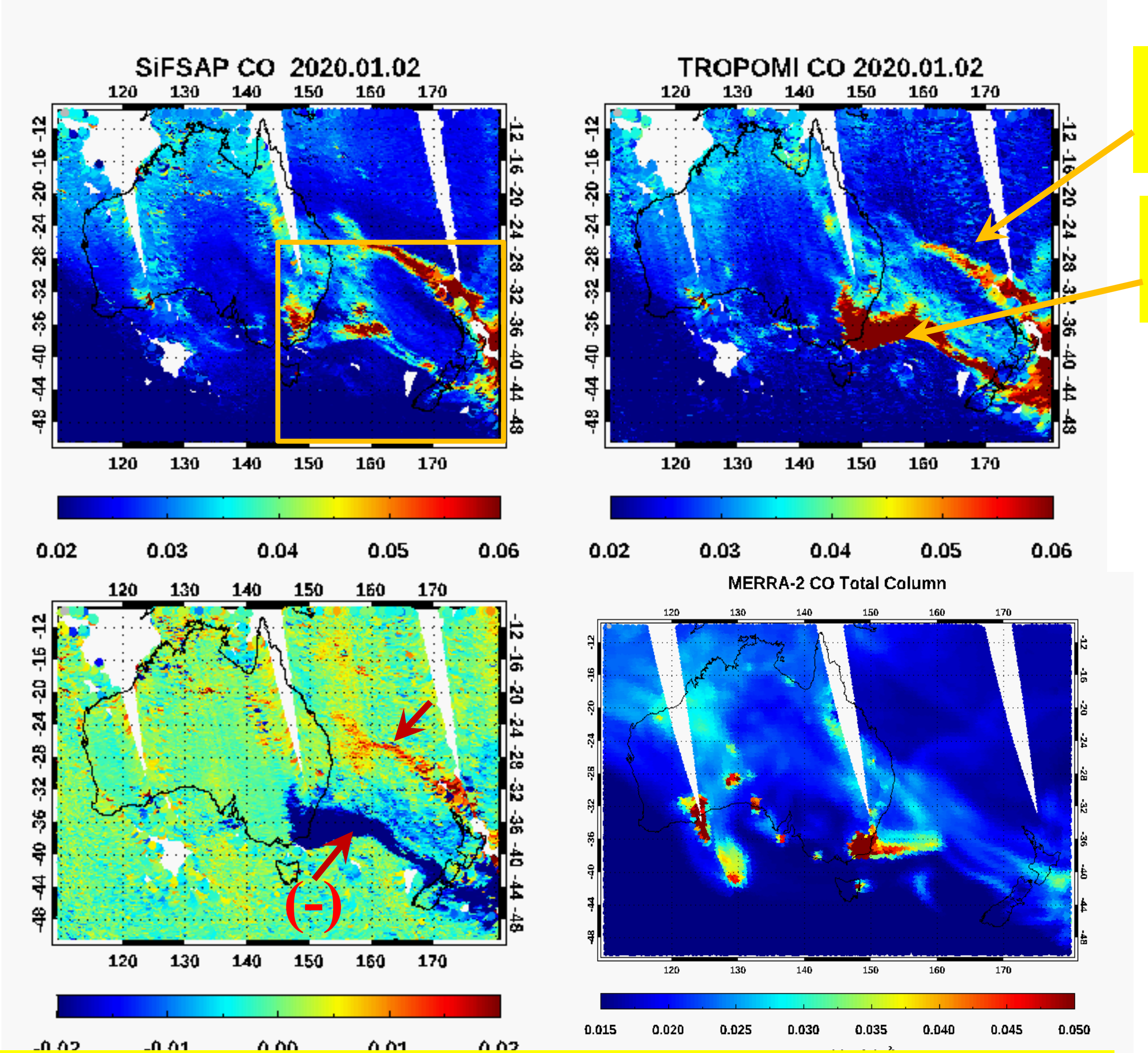
Matchup of SiFSAP, TROPOMI and MERRA-2 CO on 01 Jan 2020





1) TROPOMI and CrIS SiFSAP agree well (~2%, R=0.94) in the observed CO transport from Australia to New Zealand, but CO plume from MERRA-2 reanalysis data is much less;
2) TROPOMI has higher resolution but more missing pixels due to impact by fire emitted particles and cloud;
3) For aged/uplifted plume, SiFSAP CO > TROPOMI but for fresh emitted plume SiFSAP < TROPOMI.

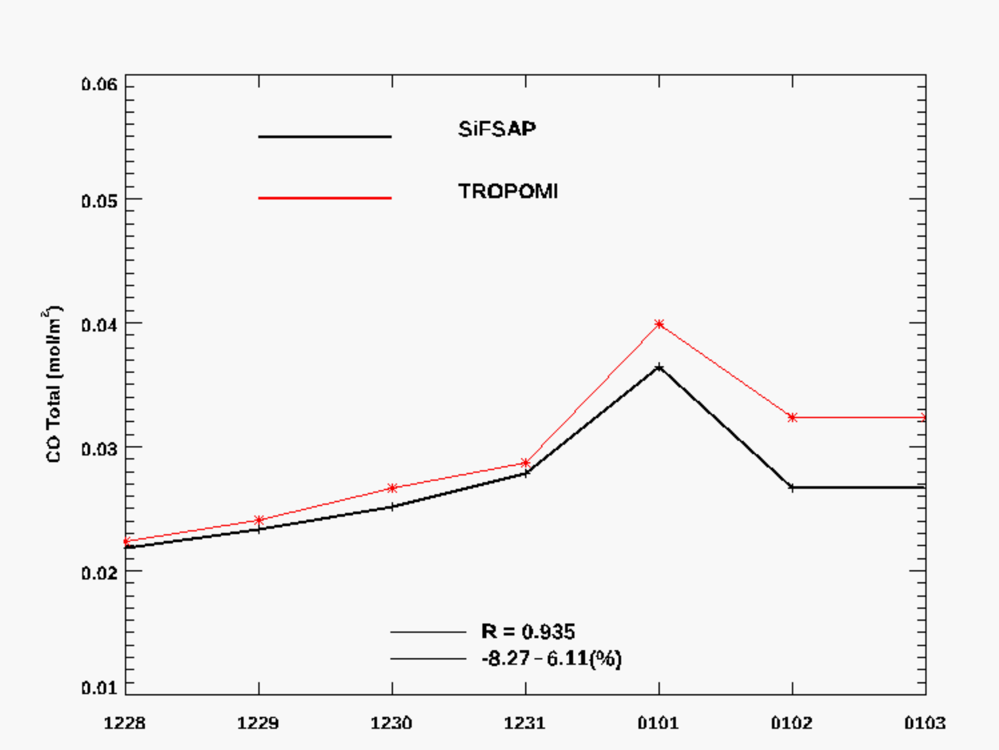
Matchup of SiFSAP, TROPOMI and MERRA-2 CO on 02 Jan 2020



Aged/uplifted plume

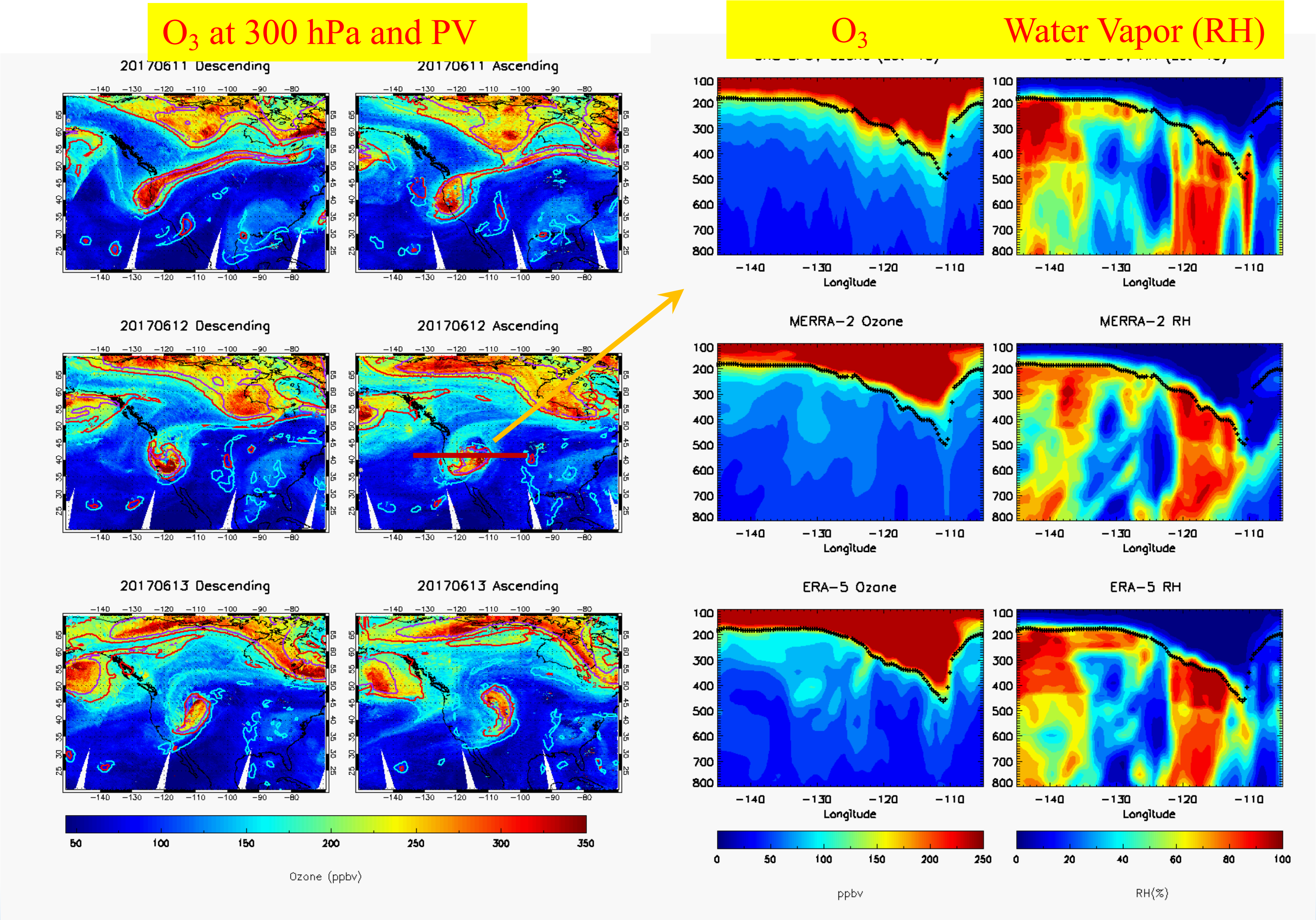
Fresh emitted plume

Large difference between satellite observation and MERRA-2



CO in Seven Days [145º~180º,-50 ~25º]

Application 2: Stratospheric Intrusion (11-13 June 2017)

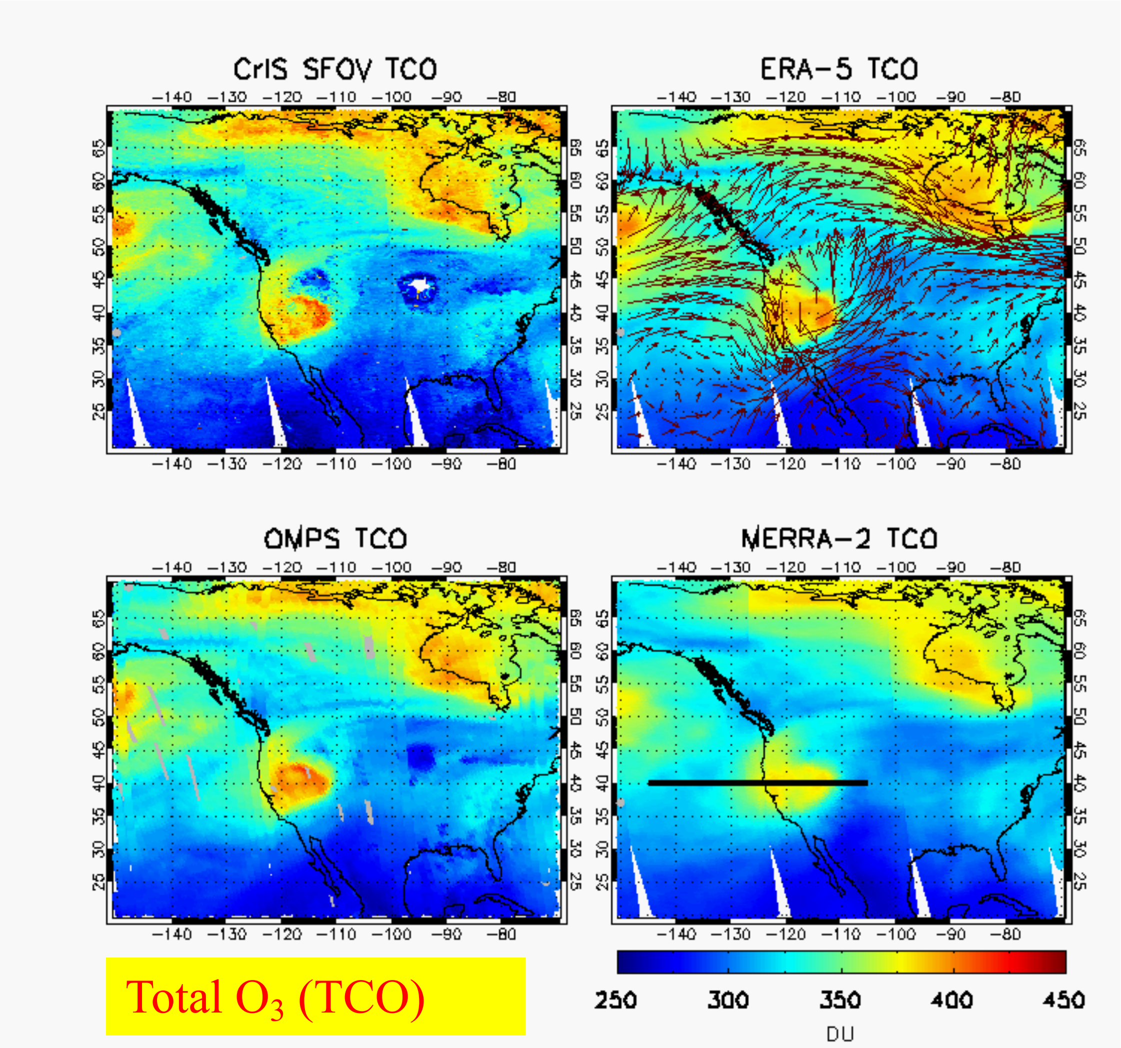


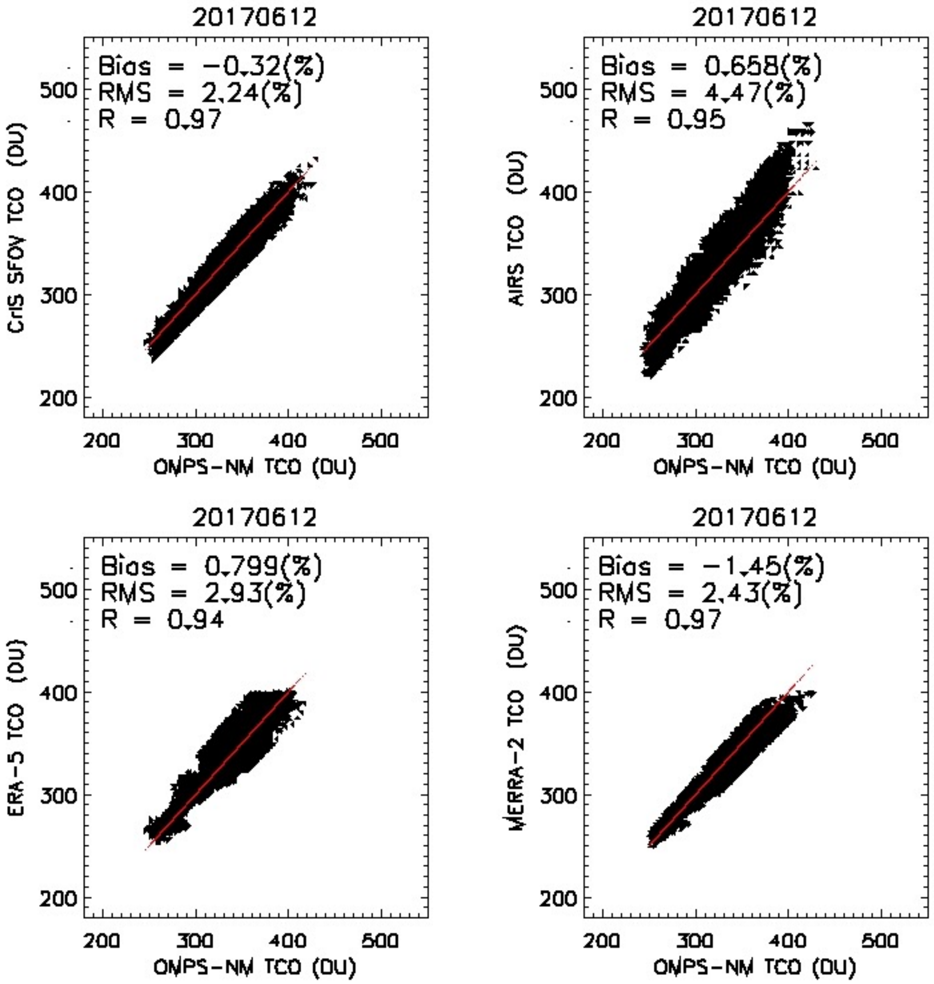
1. For this stratospheric intrusion (SI) event, the location and strength of O_3 (at 300 hpa) enhancement correlate well with the PV contours (left panels);

2. The intrusion depth can be characterized using the vertical cross-sections of O_3 and relative humidity (RH), and agree well with dynamic tropopause (PV = 2 PVU).

Xiong et al., 2022: Satellite observation of stratospheric intrusions and ozone transport using CrIS on SNPP. ***Atmos. Environ.*** **2022,** ***273*****, 118956.**

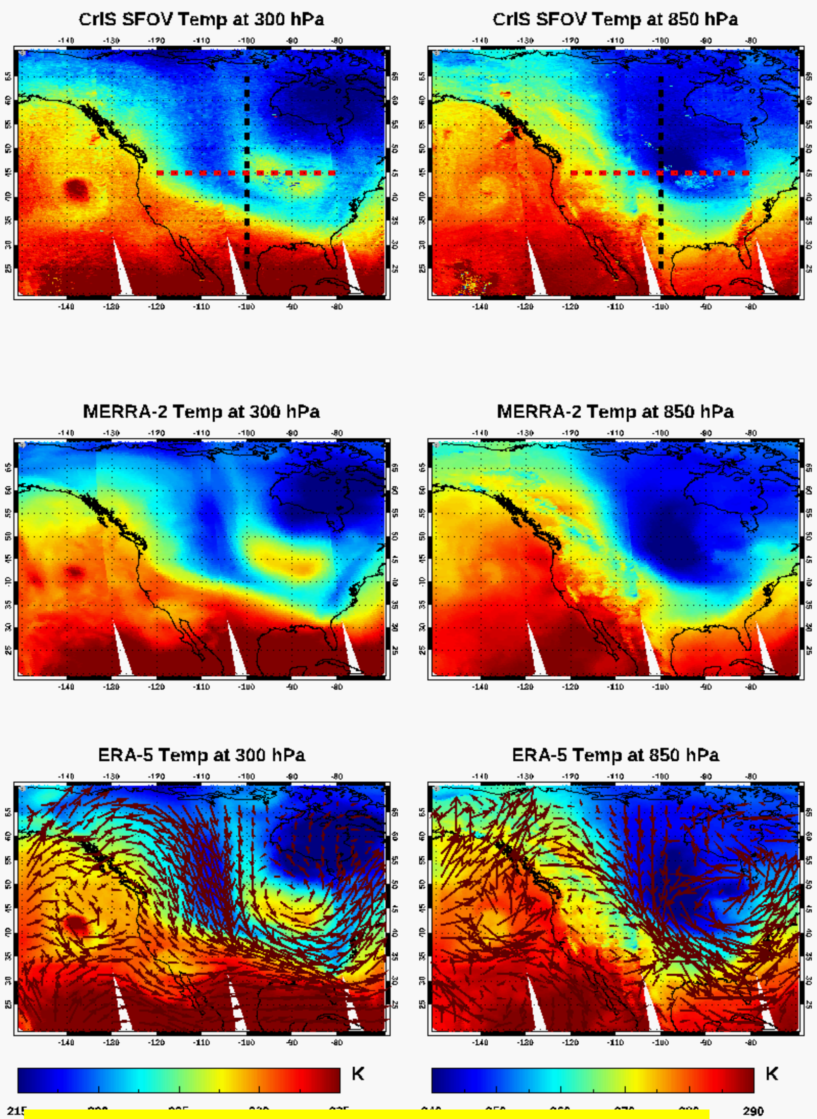
Total O_3 from SiFSAP, AIRS, ERA-5, MERRA-2 and OMPS (12 June 2017)



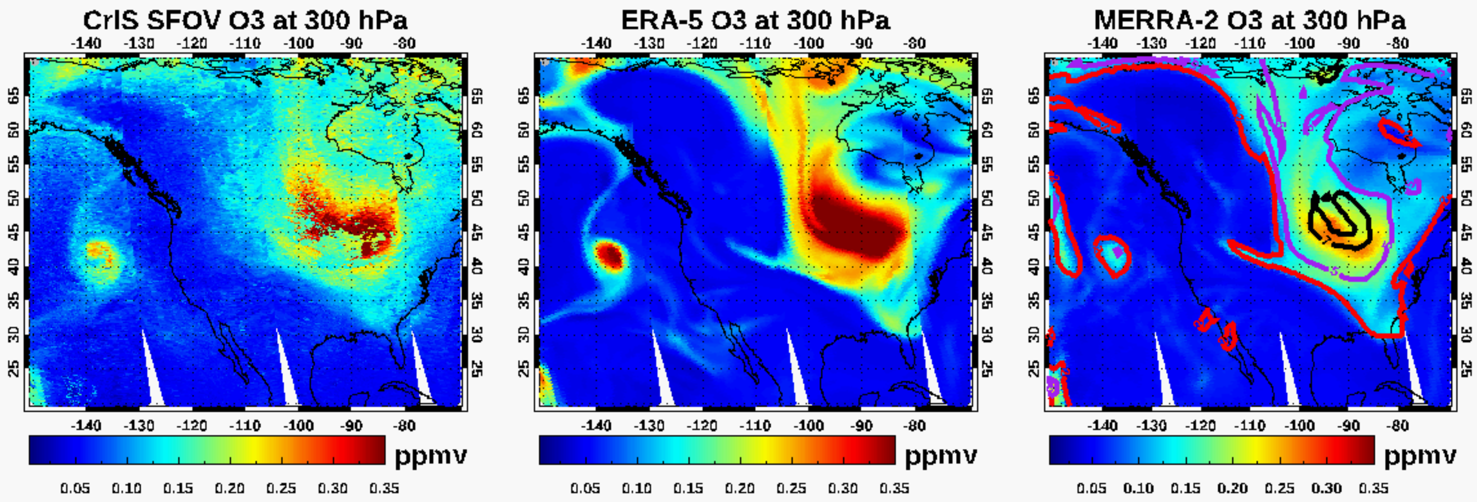


1. Enhancement of total O3 is well captured by CrIS and OMPS, and MERRA-2 agree better with them than ERA-5;
2. Total O_3 from ERA-5 is overall larger than MERRA-2 by ~2%.

Application 3: Cold Air Outbreak (CAO, 29 Jan 2019)



Temperature at 300 and 850 hPa

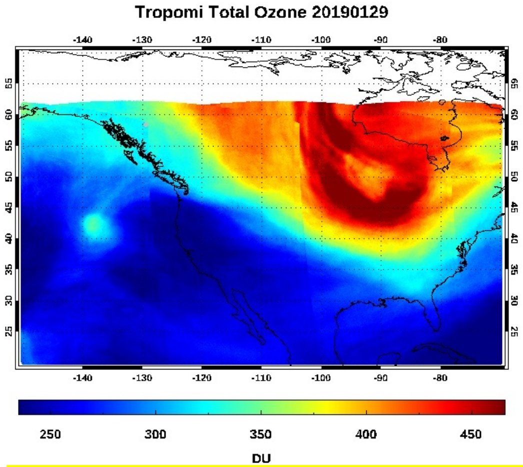


O_3 at 300 hPa and PV

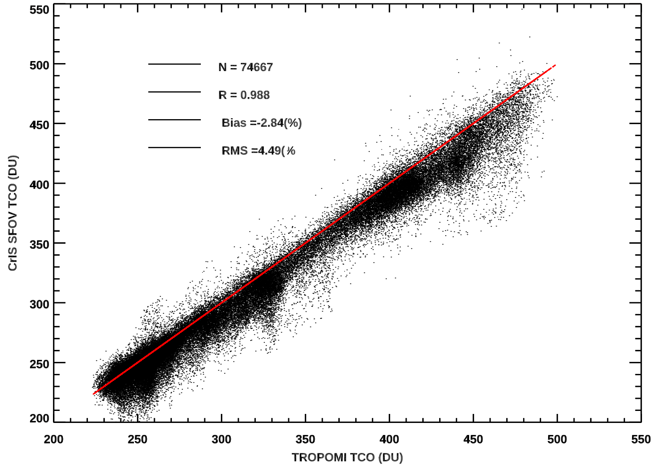
1. One extreme CAO episode that occurred on 27–31 January 2019 across much of the US Midwest;
2. A large enhancement of O_3, deep tropopause folding, significant downward transport of stratospheric dry air, and a warm center above the tropopause are observed from CrIS;
3. A good agreement of O_3 at 300 hPa from SiFSAP and ERA-5 and MERRA-2;

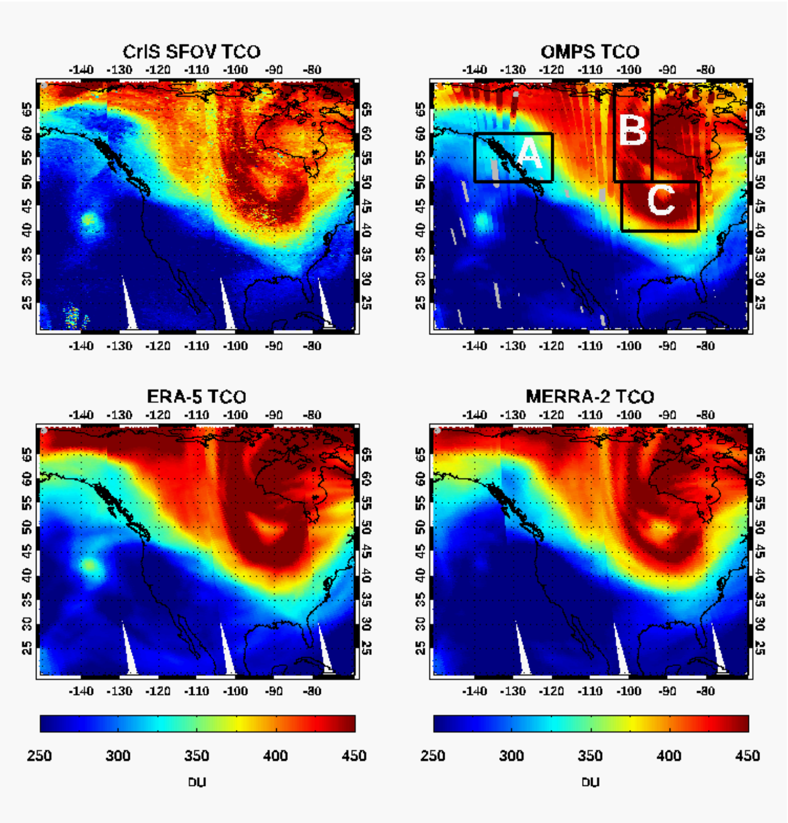
Xiong et al, 2022: Impact of Stratosphere on Cold Air Outbreak: Observed Evidence by CrIS on SNPP and Its Comparison with Models, *Atmosphere* 2022, *13*(6), 876.

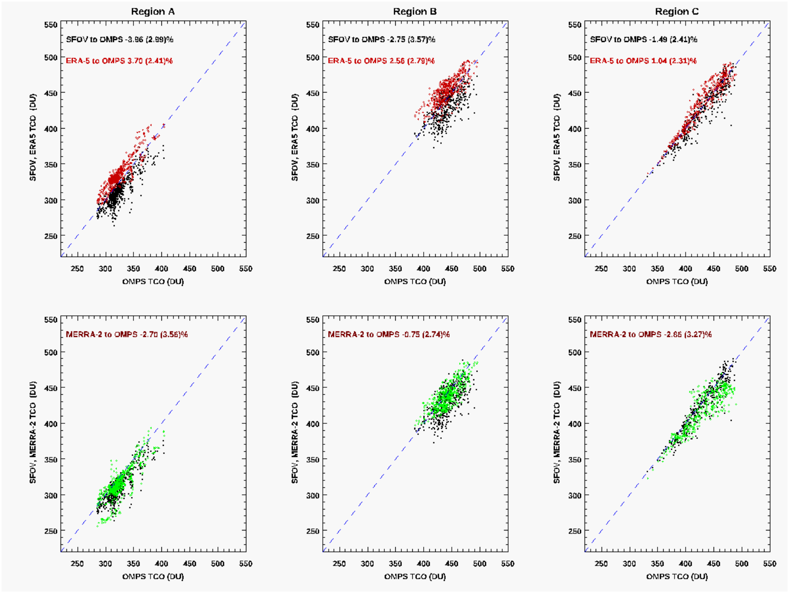
CAO: Total O_3 from CrIS, OMPS, TROPOMI, ERA-5 and MERRA-2)



Total O_3 (TCO) from TROPOMI vs SiFSAP







1. Large enhancement of total O_3 during this CAO;
2. The total O_3 from SiFSAP, TROPOMI and OMPS agree quite well with ERA-5 and MEAAR-2;
3. The difference of SIFSAP with TROPOMI is -2.8% (R = 0.99);
4. ERA-5 has a relatively larger positive bias of 2.8 ± 2.8% than OMPS;

Summary

- The Single FOV Sounder Atmospheric Products (SiFSAP) can be used *for* **process-oriented analysis of CO and O_3 dynamic transport** ***associated with wildfires and has a great prential for atmospheric dynamics study;***

- **CO – Fires**
  - Similar large emitted CO from the 2019-2020 Australia wildfires were observed using CrIS as using TROPOMI;
  - SiFSAP shows some advantage to better capture the CO transport during day and night;
  - The mean difference between SiFSAP with TROPOMI total CO is ~8.27+/-6.11%, however, for aged/uplifted plume, SiFSAP CO > TROPOMI CO, and for fresh emitted plume SiFSAP CO < TROPOMI;
  - Difference between MERRA-2 CO and satellite observations is significant (in plume path and magnitude).

- **O_3 – SI**
  - Large O_3 enhancement during SI can be observed by UV sensors like OMPS and TROPOMI, but SiFAPS provides additional information of O_3 near tropopause that can characterize the downward transport of stratospheric O_3 during day and night;

- **CAO**
  - SiFSAP provides direct observational evidence of the impact of stratosphere on tropospheric weather CAO;
  - A relatively larger positive bias of the total O3 from ERA-5 vs MERRA-2 and OMPS is found.

Xiaozhen.Xiong@nasa.gov

References

- Xiong, X., Liu, X. Wu, W., Knowland, K.E., Yang, Q., Welsh, J., Zhou, D.K., 2022: Satellite observation of stratospheric intrusions and ozone transport using CrIS on SNPP. *Atmos. Environ.* 2022, *273*, 118956. https://doi.org/10.1016/j.atmosenv.2022.118956.

- Xiong, X., Liu, X. Wu, W., Knowland, K.E., Yang, Q., Yang, F., Zhou, D.K., 2022: Impact of Stratosphere on Cold Air Outbreak: Observed Evidence by CrIS on SNPP and Its Comparison with Models, *Atmosphere* 2022, *13*(6), 876; https://doi.org/10.3390/atmos13060876.

- X. Xiong, X. Liu, W. Wu, Q. Yang and D. K. Zhou, "Observtion of Carbon Monoxide and Ozone From 2019–2020 Australia Fires Using Thermal Infrared and Near-Infrared Satellite Sensors," *IGARSS 2022 - 2022 IEEE International Geoscience and Remote Sensing Symposium*, Kuala Lumpur, Malaysia, 2022, pp. 6502-6505, doi: 10.1109/IGARSS46834.2022.9884471.

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