Observation of stratospheric intrusions and ozone transport using CrIS SiFSAP Products

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Abstract

The Single Field of View (SFOV) ozone (O_3) profiles derived from the Cross-track Infrared Sounder (CrIS) onboard Suomi National Polar-Orbiting Partnership (SNPP), with a high horizontal resolution of approximately 14 km at nadir and good sensitivity to O_3 in the upper troposphere and lower stratosphere (UTLS), provide a prominent opportunity to examine stratosphere to troposphere (STT) transport. A process-oriented analysis was performed to examine the fine-scale features of a stratospheric intrusion (SI) event on June 11–13, 2017 in the southwestern US using the CrIS SFOV products together with wind and potential velocity (PV) from models. It was found that the location and strength of O_3 enhancement correlate well with the PV contours, and the intrusion depth can be characterized using the vertical cross-sections of O_3 and relative humidity (RH). In addition, the capability to use total column ozone (TCO) to identify SI events was confirmed through analysis of TCO from CrIS SFOV and other satellite and reanalysis products. The ozone/PV ratio was derived using SFOV O_3 and model PV, and the values, ranging from 23.2 to 35.8 ppbv PVU^{-1} (1 PV unit (PVU) = 10^{-6} km^2 kg^{-1} s^{-1}), are in the lower end of previous estimations. These results demonstrate the advantages of the SFOV products in monitoring the fine-scale ozone transport and thermodynamic structure of SI events, as well as their potential value for weather and climate study.

Introduction

- As an important source to the tropospheric O_3 budget, SIs may contribute 37% to the tropospheric O_3 budget in the mid-latitudes of the Northern Hemisphere. The air from SIs is usually characterized with relatively high O_3, low CO and low water vapor (H_2O), as compared to their concentrations in the troposphere, and is associated with relatively high levels of potential vorticity (PV) .
- AIRS and IASI products have been used to map SI events in a couple of studies using TCO, RH or O_3/CO ratios.
- It was found that AIRS and IASI have some skills in identifying SI events, but the individual retrieved O_3 profiles in the UTLS show too much noise, and cannot resolve the horizontal fine structure seen in the aircraft measurements as well as the vertical fine structure seen in the aircraft and lidar measurements.
- Recently, Robinson et al. (2020) used the Pandora ground-based TCO measurements to study the STT episodes in March 2018, and found that the mean bias of AIRS TCO relative to Pandora is +4.41% (ranging from +2.43% to +7.52%).

- Data used in this study:
  - SiFSAP from CrIS on SNPP with a resolution of ~ 15 km;
  - *Ozone* Mapping and Profiler Suite (*OMPS*) on SNPP;
  - *Reanalysis Products from MERRA-2 and ERA-5;*

Mapping the SI Processes using CrIS SFOV Ozone at 300 hPa

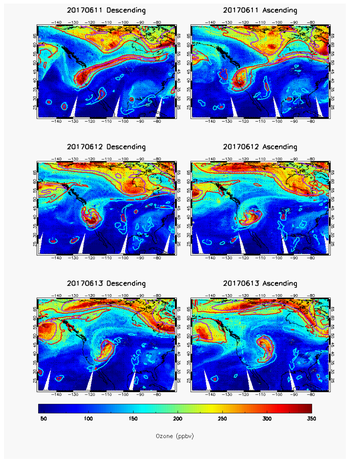

Figure 1 Distribution of CrIS SFOV O_3 mixing ratio at 300 hPa overlaid with MERRA-2 PV (Cyan line is for contour of 1 PVU, red line is 2 PVU and purple line is 5 PVU). Movement of the "hook-shaped" streamer counter-clockwise is evident on 12-13 June 2017.

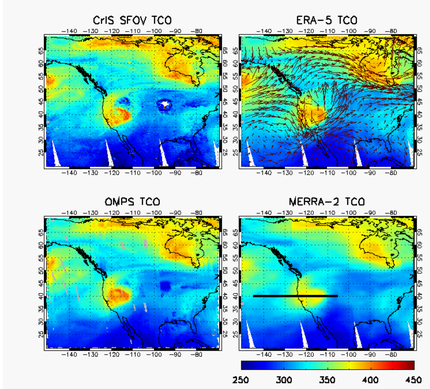

Figure 2 Distribution of total column ozone (TCO) from CrIS SFOV, OMPS, ERA-5 and MERRA-2 on 12 June 2017 (1:30 pm). Upper right panel shows TCO overlaid with wind at 300 hPa (from ERA-5). Dark solid line in lower right panel marks the pressure-longitude cross-section to be plotted in Fig.3.

Identification of SI Events using CrIS SFOV TCO and its Comparison with OMPS, AIRS, MERRA-2 and ERA-5 Reanalysis

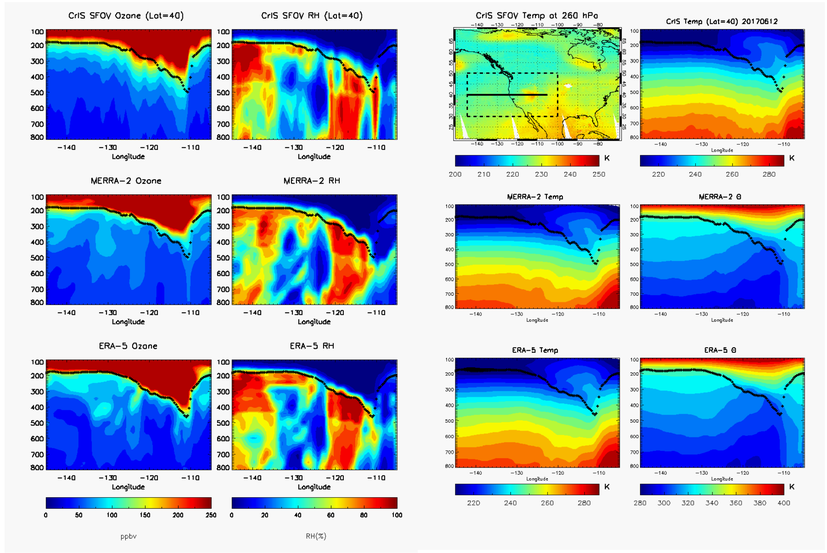

Figure 3 Pressure-longitude cross-sections along 40°N for O_3 (left columns) and RH (right columns) using data from CrIS SFOV retrievals (top), MERRA-2 (middle) and ERA-5 (bottom) on 12 June 2017 (ascending, 1:30 pm). The dark crosses are the dynamic tropopause (2 PVU) from MERRA-2 in the top four panels and ERA-5 in the bottom two panels.

Figure 4 The distribution of CrIS SFOV temperature at 260 hPa (top left) and the cross-sections of temperature (Temp) and potential temperature (Θ). The pressure-longitude cross-sections of Θ for MERRA-2 and ERA-5 are in the middle and lower right, respectively. Dashed box marks the area where the data are used for calculating O_3/PV ratio as shown in Figure 7.

Total O_3 and Correlations

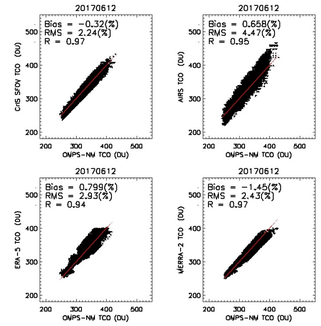

Figure 5 Scatter plot of CrIS SFOV, AIRS, ERA-5 and MERRA-2 relative to OMPS-NM TCO using data on 12 June 2017 (ascending). Red lines are the 1:1 lines.

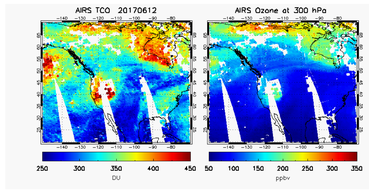

Figure 6 Distribution of AIRS TCO and the AIRS O_3 mixing ratio at 300 hPa on 12 June 2017

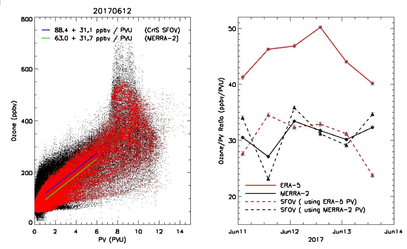

Figure 7 Left: scatter plot of PV versus O_3 using the data between 515 to 200 hPa on 12 June 2017 (area marked in Fig.4). Red dots and the fitted green line represent the data from MERRA-2, and black dots and the fitted blue line represent the SFOV O_3 and the MERR-2 PV. Only the data with PV from 1 to 6 PVU is used for fitting. Right: variation of the O_3/PV ratio from 11-13 June 2017 (two observations per day). Solid red and black lines represent the O_3/PV ratios from ERA-5 and MERRA-2 data, and two dash lines represent the ratios derived using the CrIS SFOV O_3 but different PV from ERA-5 (red dash) and MERRA-2 (black dash) respectively.

Summary and Conclusions

1. The enhancement of O_3 correlates well with the PV contours and dynamic tropopause;
2. The counterclockwise movement of the SI center in the three days can be captured from the enhanced O_3 at 300 hPa and TCO;
3. The depth of intrusion is well captured from O_3 and RH cross-sections;
4. The potential temperature field during this SI process can indicate the frontal structure of the cyclone and the transport pathways for the stratospheric O_3 within the SI folding.
5. The difference between SFOV and OMPS TCO is -0.32% (2.22 %), which is smaller than AIRS V6: 0.64% (4.54 %).
6. The derived O_3/PV ratio is in a range from 23.2 to 35.8 ppbv PVU^{-1}, which is in the lower end of previous estimates.

This study confirmed that TCO from AIRS and CrIS can be used to identify the SI events, and demonstrated the advantages of the SFOV sounder products for a process-oriented analysis of the fine-scale features of SIs.

References

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