Observation of Cold Air Outbreak using CrIS on S-NPP and its Comparison with MERRA-2 and ERA-5 (*Poster #617*)

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Abstract

A cold air outbreak (CAO) is an extreme weather phenomenon that has significant social and economic impacts over a large region of the midlatitudes. However, the dynamical mechanism of the occurrence and evolution of CAO events, particularly the role of stratosphere, is not well understood due to limited observation.

One extreme CAO episode occurred on 27-31 January 2019 across much of the US Midwest was studied using a single-field-view (SFOV) Sounder Atmospheric Products (SiFSAP) with a spatial resolution of ~14 km at nadir) from the Cross-track Infrared Sounder (CrIS) onboard Suomi National Polar-Orbiting Partnership (SNPP) in conjunction with the NASA's Modern-Era Retrospective Analysis for Research and Applications Version-2 (MERRA-2) and the fifth-generation ECMWF reanalysis (ERA5) data. Through analysis of the changes of temperature (T), water vapor, ozone (O_3), wind fields, geopotential height (GPH) and potential velocity (PV), we tried to better understand the thermodynamic structure of this CAO and the difference between SiFSAP and reanalysis products.

The transport path of cold air from polar to lower latitude can be well mapped from the enhanced O_3, low relative humidity (RH), and wind fields. The link of cold air transport with the stratospheric intrusion that brought O_3-riched and dry stratospheric air to lower altitudes in the atmosphere is proven from the high correlation of the change of surface with O_3 (R>0.8). To get more insights about the impact of stratosphere on CAO, we analyzed the longitude-pressure cross-sections of temperature, potential temperature (Θ), RH, and its relationship with thermal and dynamic tropopause (based on PV). Further comparison of the mean profiles of T and RH between ERA5, MERRA-2 with SiFSAP is given.

Introduction

- Extreme cold air outbreak (CAO) is a severe weather system that usually leads to the transport of cold and dry air masses from polar to mid-latitude regions, causing snow storms across Europe and North America, and affecting a large region of the midlatitudes during the winter months.
- CAO is usually linked with breakup of the northern polar vortex, a large-scale low-pressure system, which spins counterclockwise in the stratospheres over the north and south poles and is unusually persistent during winter and spring. The strength of the northern hemisphere polar vortex is generally recognized as an important element for coupling between the stratosphere and troposphere during winter and spring (e.g., Kidston et al., 2015).
- The frozen Arctic winds brought record-low temperatures across much of the US Midwest. Temperatures in Chicago dropped to a low of around -30°C on Jan 30, 2019, and brought up to 13 inches (33 cm) of snow in some regions from 27–29 January 2019.

- Satellite Data used:
  - SiFSAP from CrIS on SNPP with a resolution of ~ 14 km at nadir;
  - *Ozone* Mapping and Profiler Suite (*OMPS*) on SNPP;

- *Model Data used: MERRA-2, ERA-5;*

Temperature, GPH and Warmer Air over Cold Center

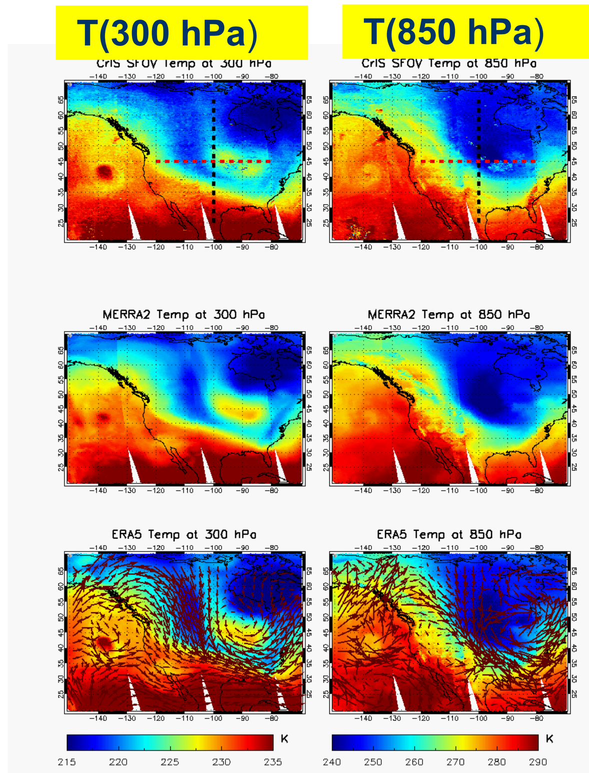

Figure 1 Temperature from SiFSAP and its comparison with MERRA-2 and ERA-5 at 300 hPa and 850 hPa, overlaid with winds from ERA-5

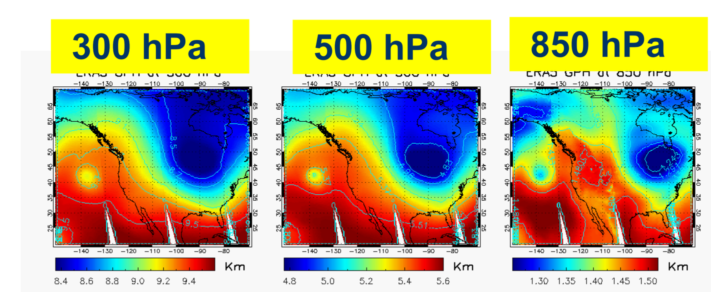

Figure 2 Geopotential heights (GPH) from ERA5 reanalysis data at 300, 500 and 850 hPa.

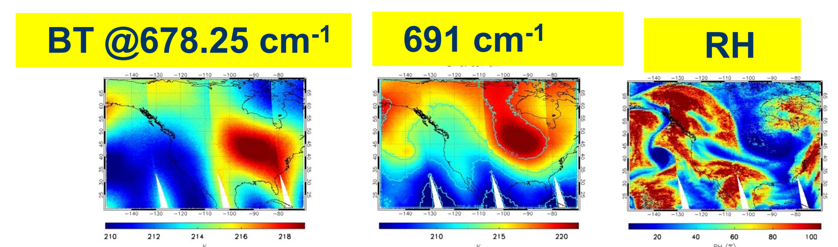

Figure 3 Left two panels are the BTs from CrIS measurement at channel 678.25 cm^{-1} and channel 691 cm^{-1} (sensitive to lower altitude). Right panel is the RH at 300 hPa from CrIS SFOV retrieval

Enhancement of Ozone (O_3) over CAO

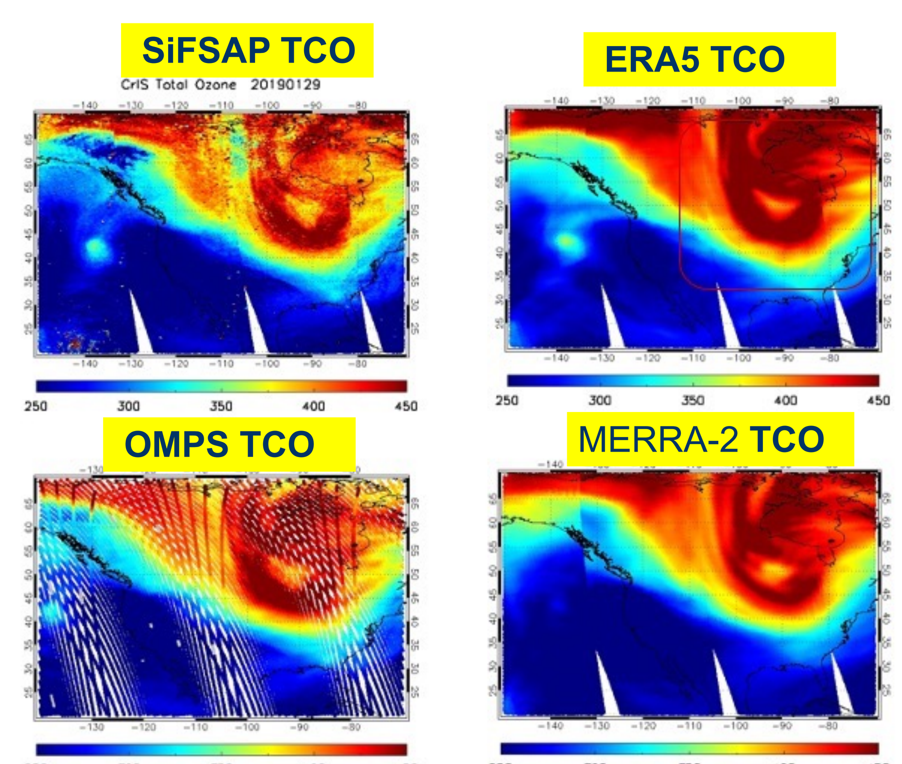

Fig 4 Total ozone from CrIS agrees well with OMPS measurement and model simulated data from ERA-5 and MERRA-2. It is also evident that CrIS SFOV product has a better spatial resolution than OMPS.

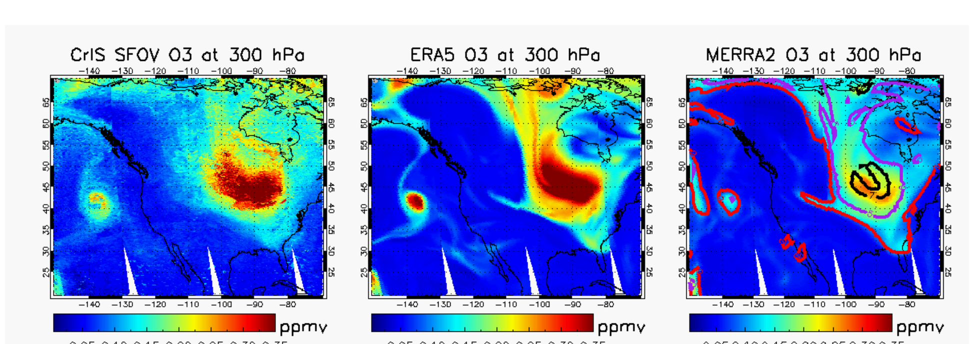

Figure 5 Distribution of O_3 at 300 hPa from SiFSAP, ERA5 and MERRA-2, with contours (red line for 2 PVU, purple line for 5 PVU, and black line for 7 PVU).

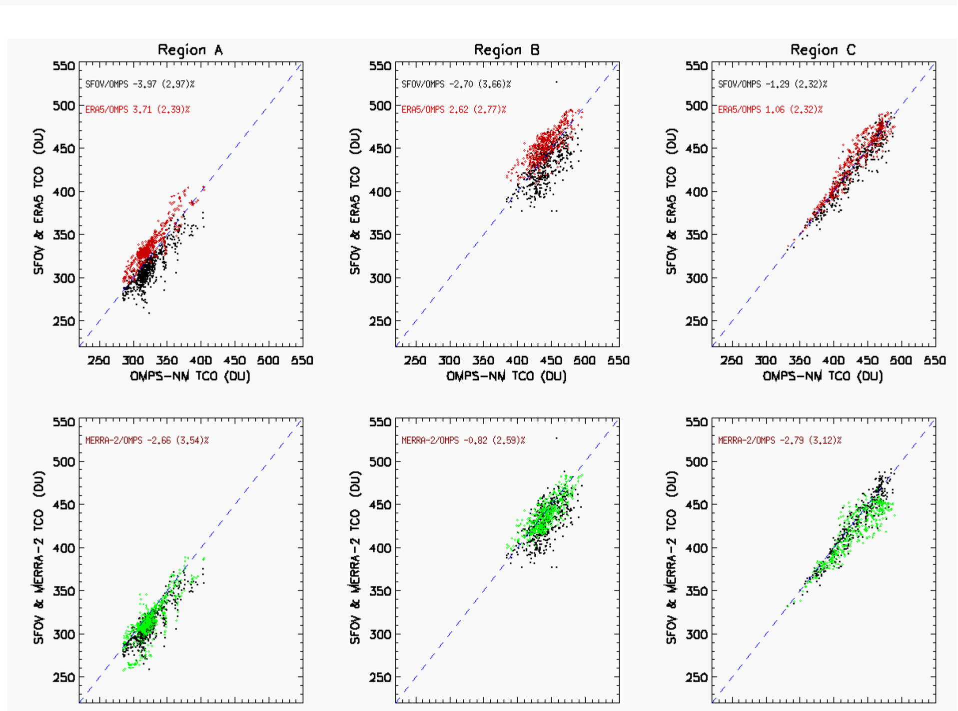

Figure 6 Upper panels are the scatter plots of CrIS SFOV (black dots) and ERA5 (red dots) TCO vs OMPS TCO in three regions. Lower panels are CrIS SFOV (black dots) and MERRA-2 TCO (green dots) vs OMPS TCO.

Stratospheric Air Downward Transport Based on the Cross-sections of T, RH and O_3

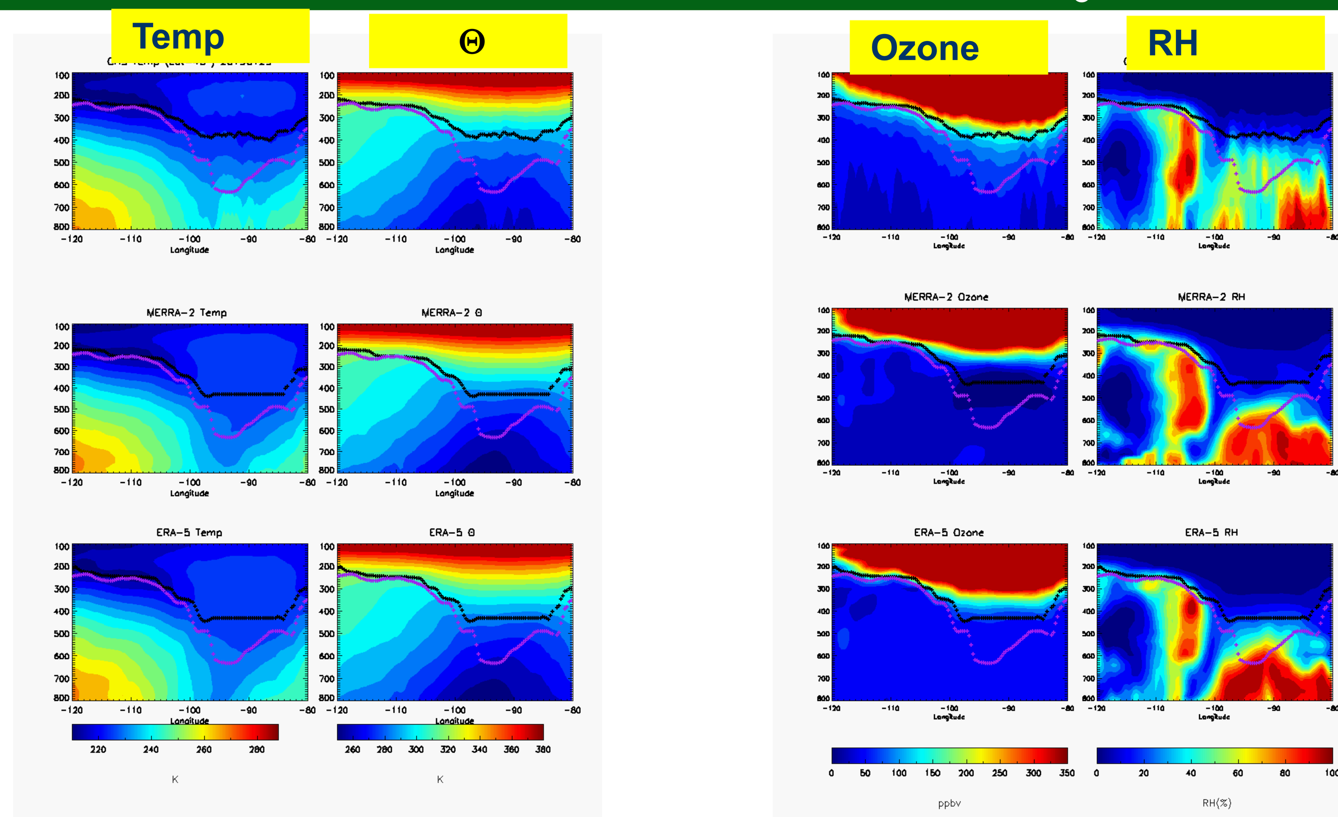

Figure 7 Longitude-pressure cross-sections of temperature, potential temperature (Θ), O_3 and RH from 120°W-80°W and along 45°N from SiFSAP (top), MERRA-2 (middle) and ERA5 (bottom). Black crosses mark the thermal tropopause, and purple symbols mark the dynamic tropopause defined by PV = 2 PVU but using MERRA-2 PV data.

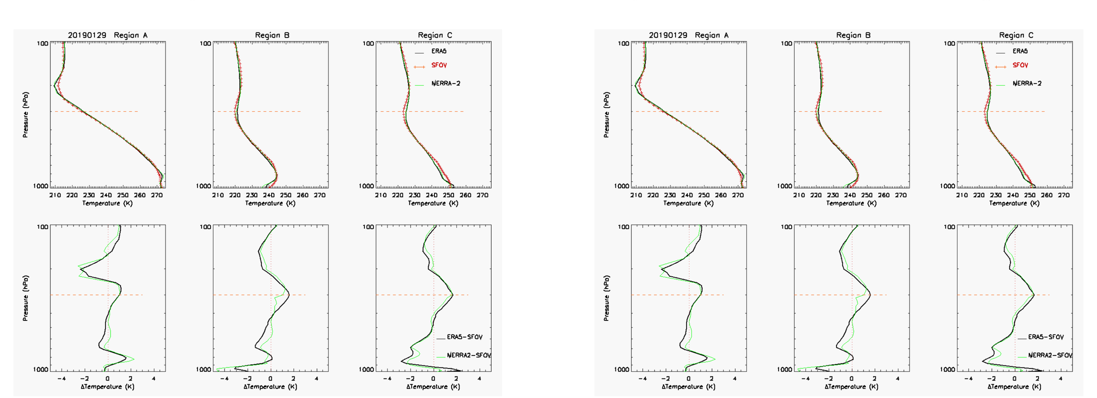

Figure 8 Comparison of the mean temperature and water vapor profiles (upper panels) and their difference (lower panels) in the regions A, B and C.

Summary and Conclusions

1. **The path of CAO was well captured from the wind fields, GPH at 300 and 850 hPa, O_3 and RH at 300 hPa and the map of TCO O_3. The correlation between the total ozone and air temperature at 850 hPa or GPH is more than 0.8-0.9.**
2. **Along the path of CAO, particularly near the coldest surface center, there exists a large enhancement of O_3, deep tropopause folding, significant downward transport of stratospheric dry air, and a warm center above the tropopause. This upper warm center is observed directly using the BT of CrIS stratospheric sounding channel.**
3. **The downward transport of stratospheric air can be seen clearly from the cross-sections of T, RH and O_3. More fine features of the transport depth can be captured using RH.**
4. **MERRA-2 shows a thicker dry layer below the tropopause than that from ERA5 and CrIS SFOV products. Comparison of TCO show that the ERA5 TCO has a larger positive bias of 2.8±2.8%.**

This study provides an observational evidence to link the CAO with the stratospheric intrusion, highlighting the potential to use O_3 at 300 hPa and TCO to monitor the stratospheric intrusion and CAO.

References

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