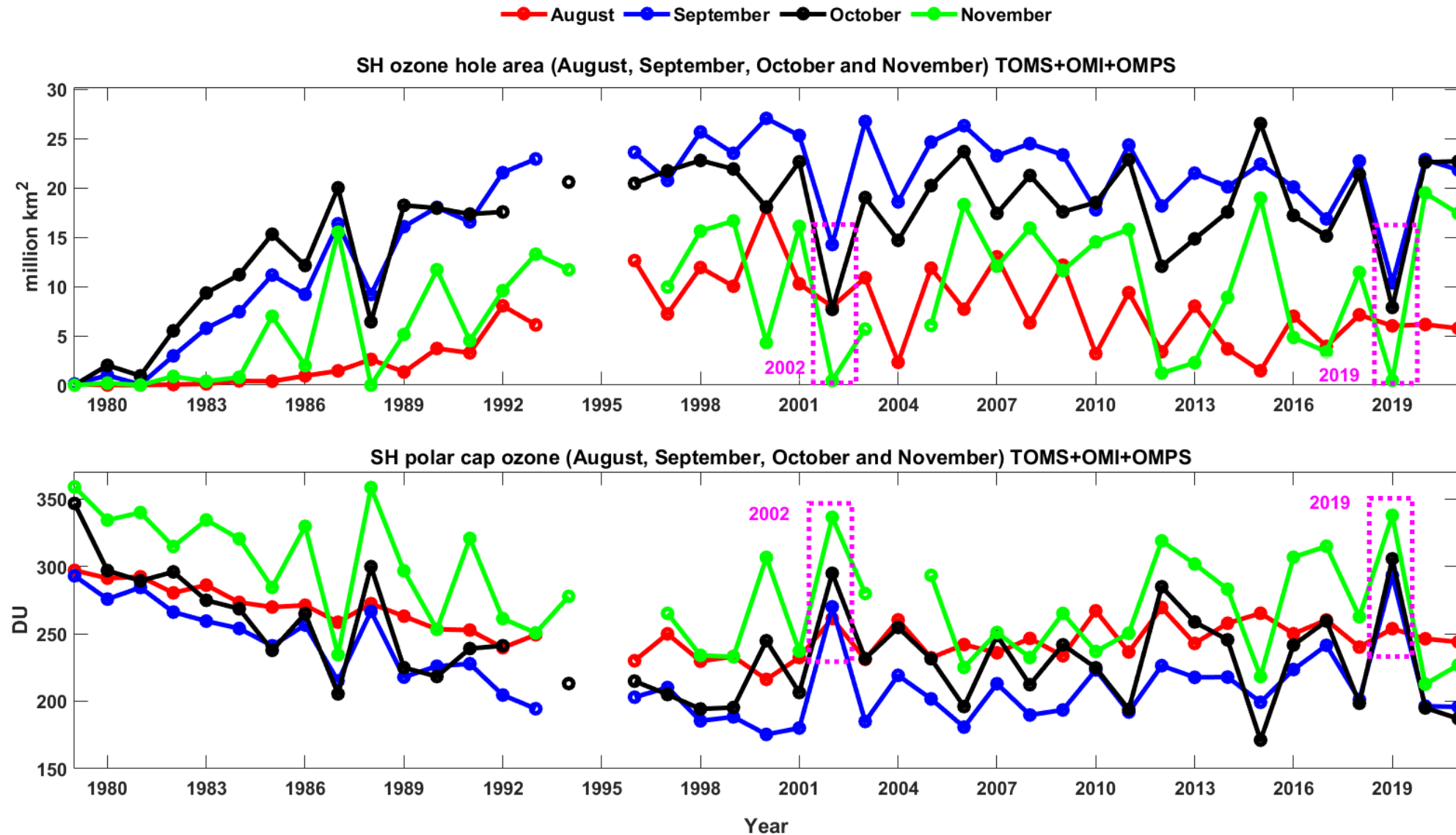


Investigation of the Ozone Enhancement during the 2019 Sudden Stratospheric Warming in the Southern Hemisphere

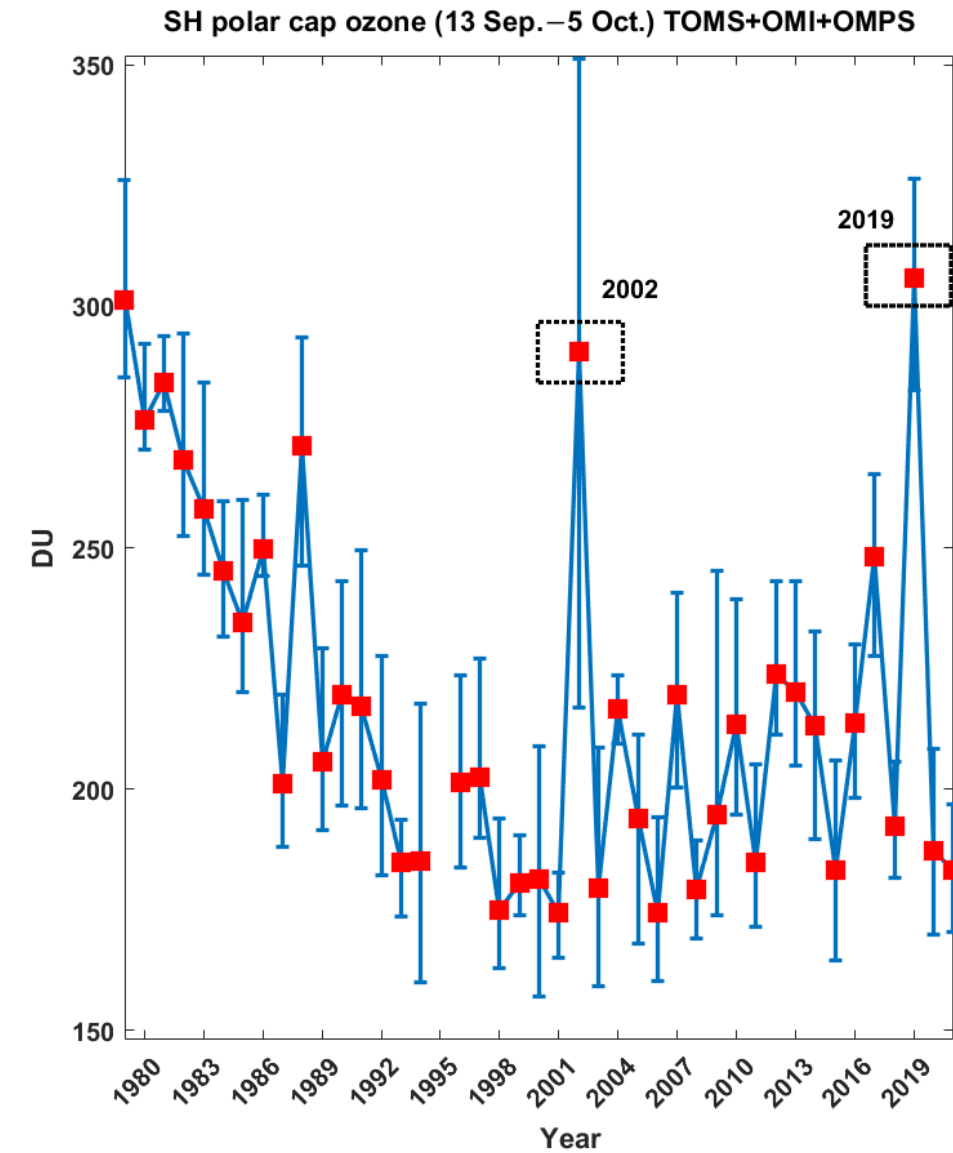
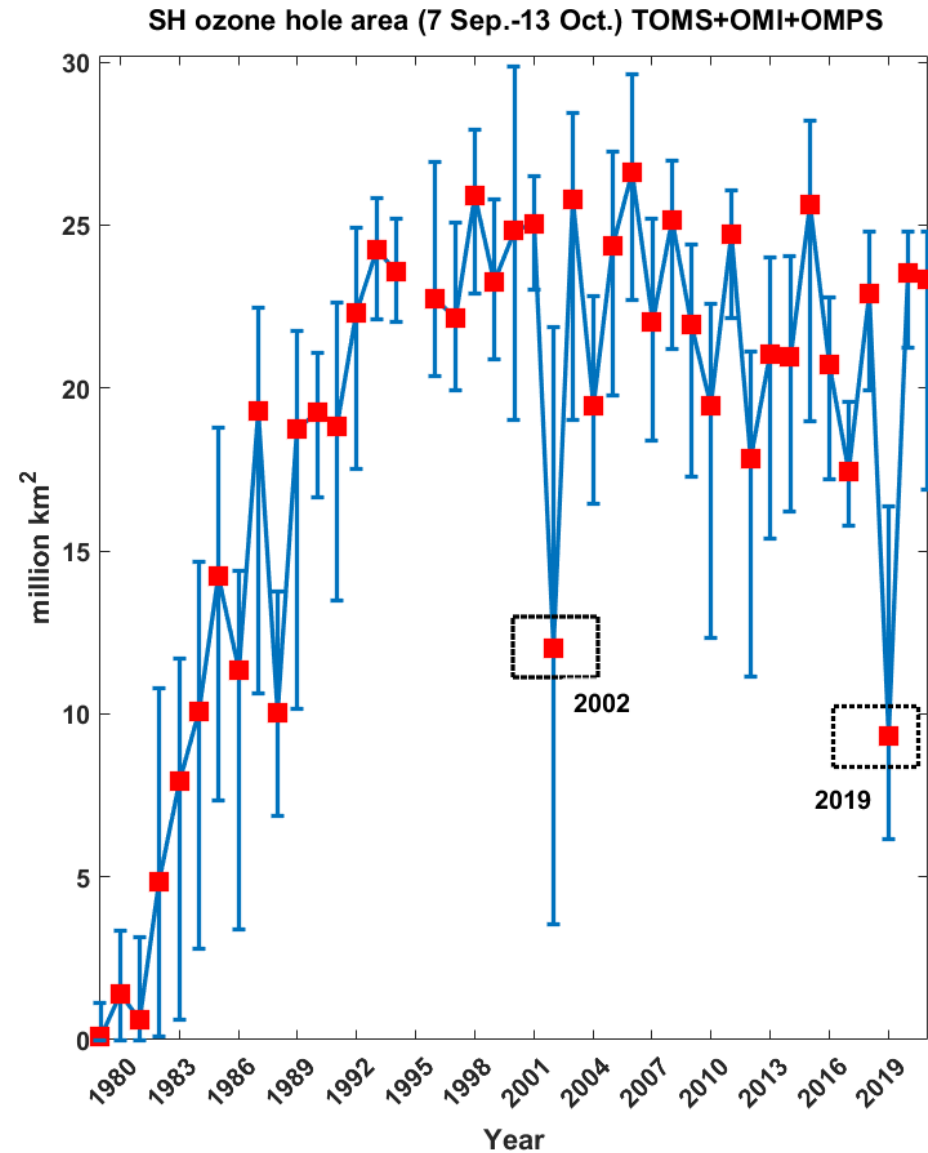
Saswati Das¹, Brentha Thurairajah¹, Scott M Bailey¹

¹Center for Space Science and Engineering Research, Virginia Tech

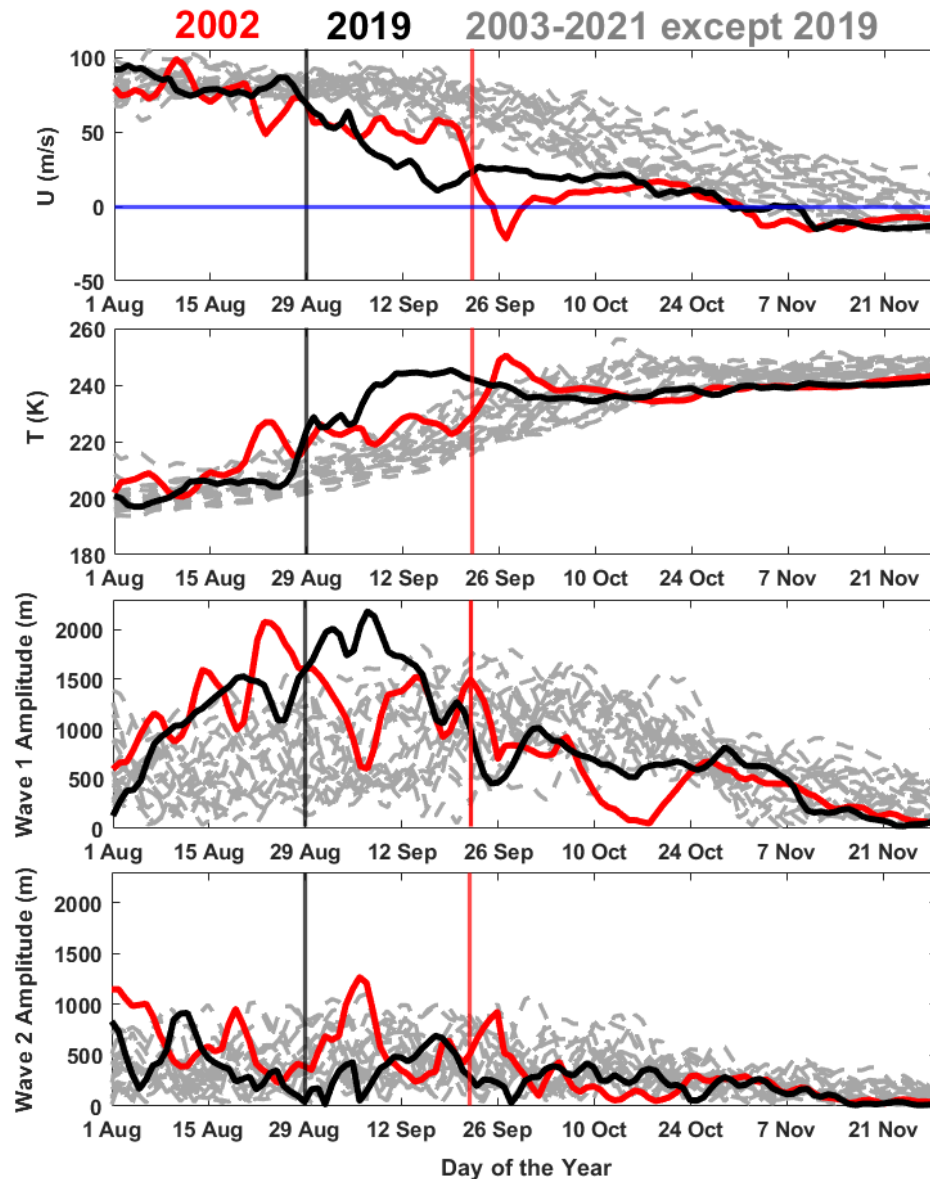
Reduction in Ozone Hole area and Ozone Enhancement in 2019



Reduction in Ozone Hole area and Ozone Enhancement in 2019



2019 Sudden Stratospheric Warming Event from MERRA-2



- $U_{60S, 10 \text{ hPa}}$**
- Wind weakening with **no reversal** was observed in 2019, unlike in 2002.



- Temperature_{60S-90S}**
- Sudden rise in 2019 temperature that attained peak value in mid-September.
 - Higher temperature increment in 2019 than 2019 during the warming period.



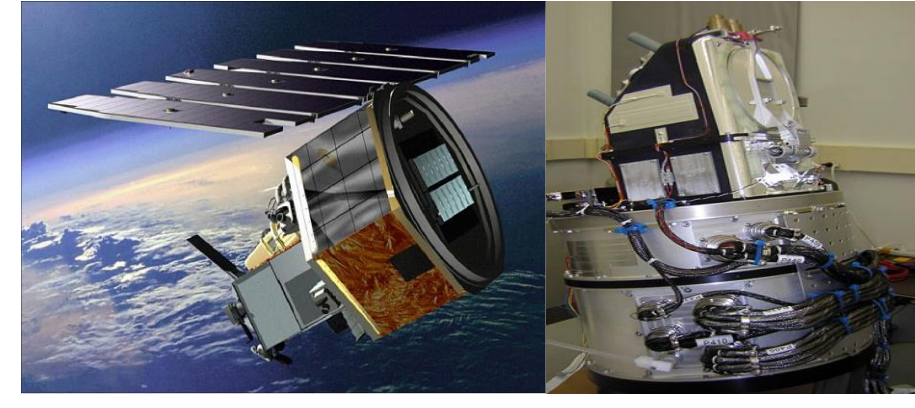
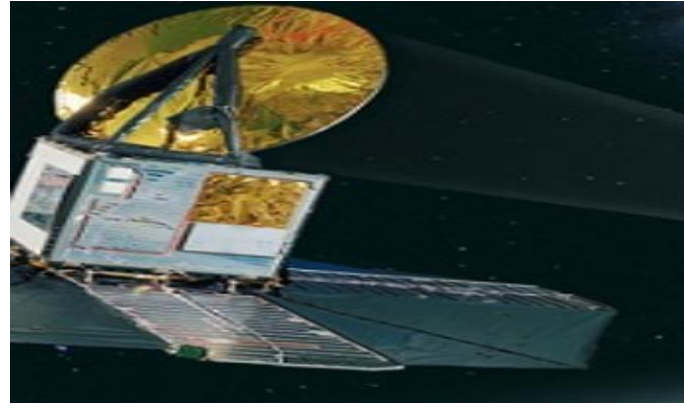
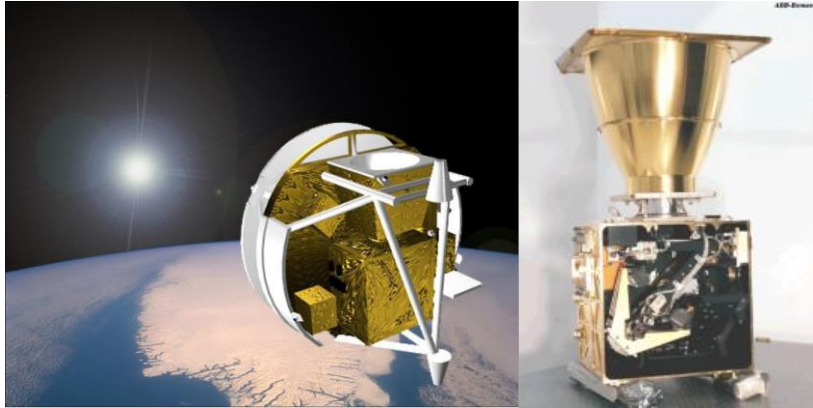
- $Z1_{60S, 10 \text{ hPa}}$ and $Z2_{60S, 10 \text{ hPa}}$**
- Anomalous PW1 amplification in 2019 > 2002 during 1-7 September.
 - During this time, PW2 amplification in 2019 < 2002.



- The state of the 2019 Antarctic stratosphere was unusual.

Satellite Instruments

- Different satellite instruments are used to complement each other.



ACE- Atmospheric Chemistry Experiment

- Solar Occultation method
- Measures at Sunrise/Sunset
- Latitude = 80°N-80°S
- Vertical field-of-view = ~ 3-4 km.
- Data – Temperature, ClONO₂, HCl, ClO, HNO₃, and O₃.

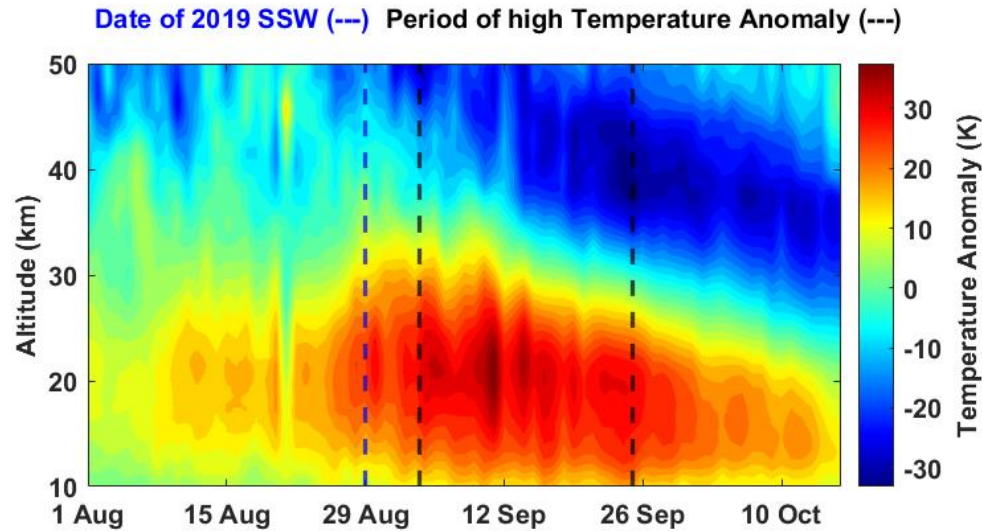
Odin/Sub Millimeter Radiometer

- Latitude = 82°N-82°S
- Vertical resolution = ~ 2 km, typically and ~ 7 km during upward-downward scanning.
- Data – ClO, HNO₃, and O₃.

SOFIE- Solar Occultation for Ice Experiment

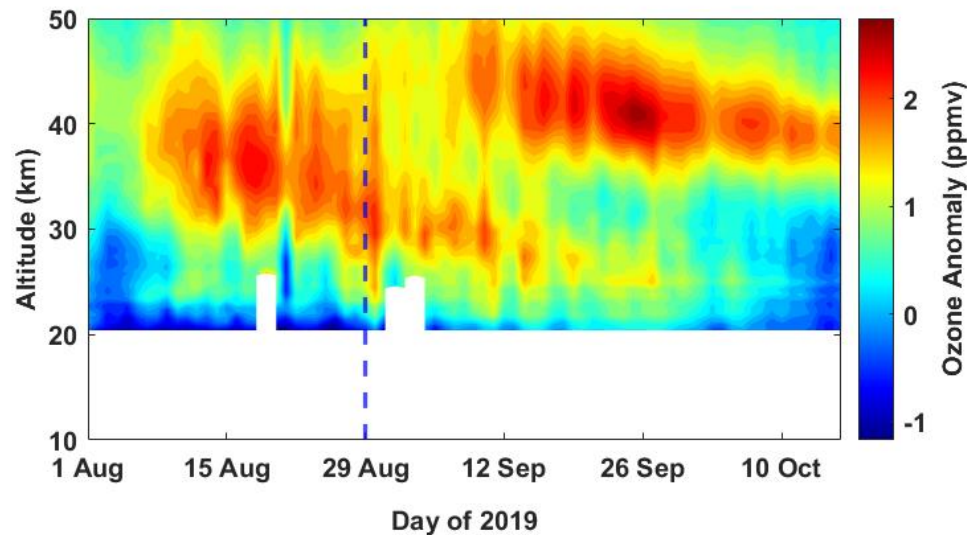
- Solar Occultation method
- Measures at Sunrise/Sunset
- Latitude = 65° – 85° N/S (typically)
- Vertical resolution = ~ 1.8 km.
- Data – Temperature, NO, H₂O, and O₃.
- *SOFIE viewed lower latitudes than usual during 2019 due to the change in SR/SS hemispheres.

Temperature and Ozone Anomalies from SOFIE



Temperature Anomaly (2019-Average (2008-2014))

- Average increase in stratospheric temperature was ~ 34 ° in mid-September.
- Large temperature anomaly observed between 6 Sep - 25 Sep.

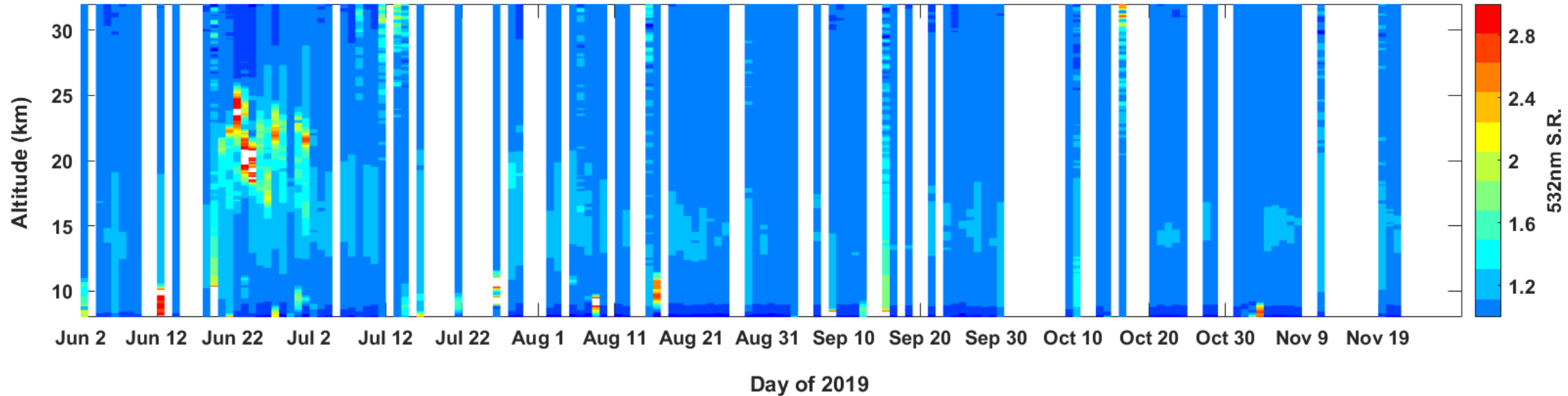


Ozone Anomaly (2019-Average (2008-2014))

- Positive Ozone anomaly recorded during high-temperature anomaly.

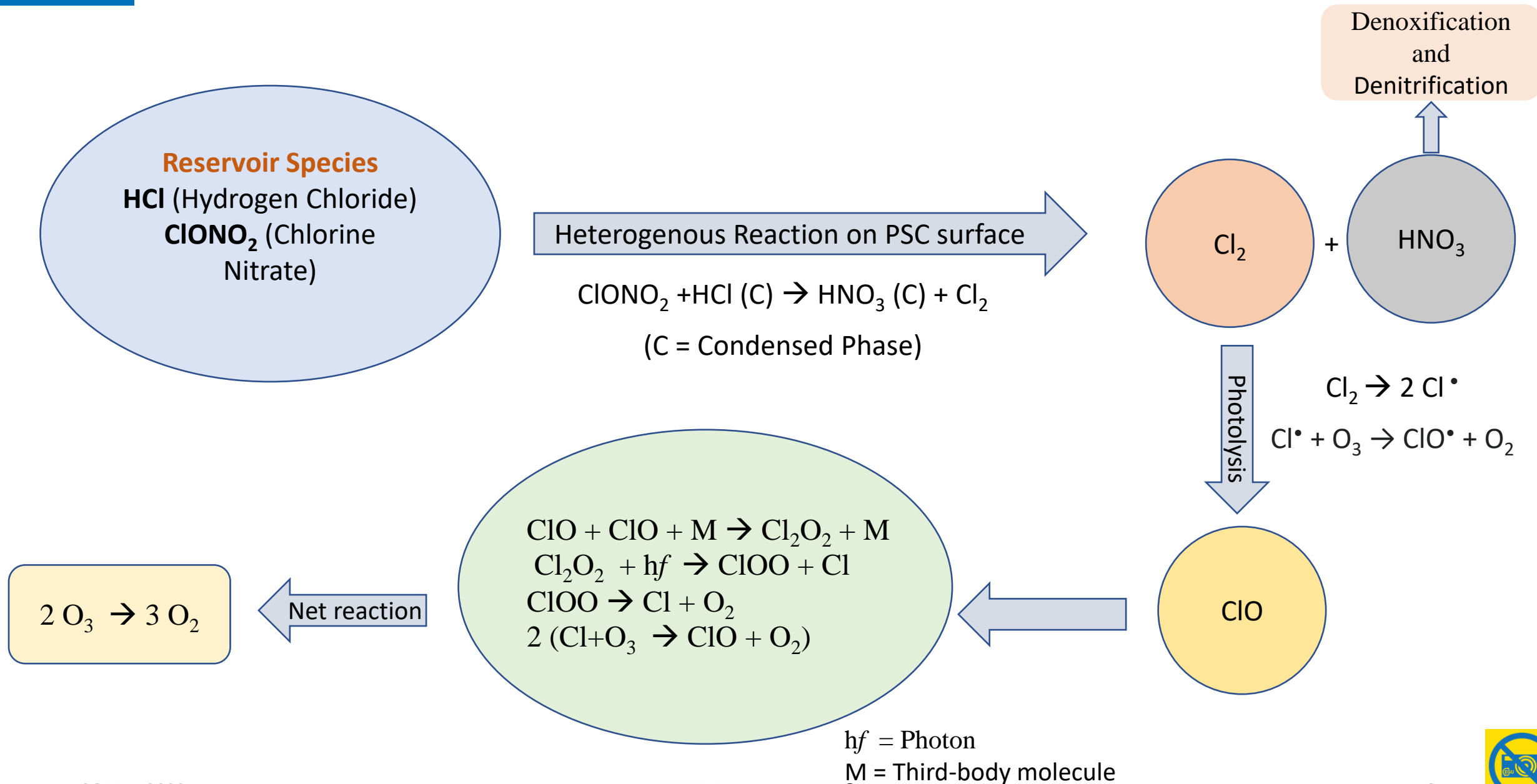
Polar Stratospheric Cloud Detection

532-nm attenuated backscatter, Dumont d'Urville (DDU) station (66°S to 140°E)



- The 532-nm backscatter ratio is used as a measure of the PSC occurrence at DDU from June to November.
- The backscatter ratio when higher than 1 PSC presence during stratospheric winters.
- PSC season is a key indicator of ozone depletion with an unusual PSC season recorded in 2019.
- High PSC was reported in mid-June with the PSC episodes extending to July and August.

Ozone Loss Mechanism



Variation in Chemistry after the SSW event

After SSW Date

$$T_{2019} > T_{\text{Average}(2004-2018)}$$

Lower conversion of ClONO_2 to Cl_2 in 2019. Large uncertainties reported for HCl.

2004 - 2018 Time Series of Each Species (Average)

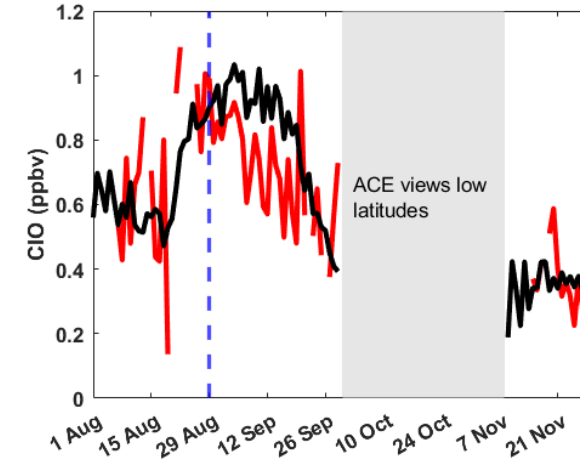
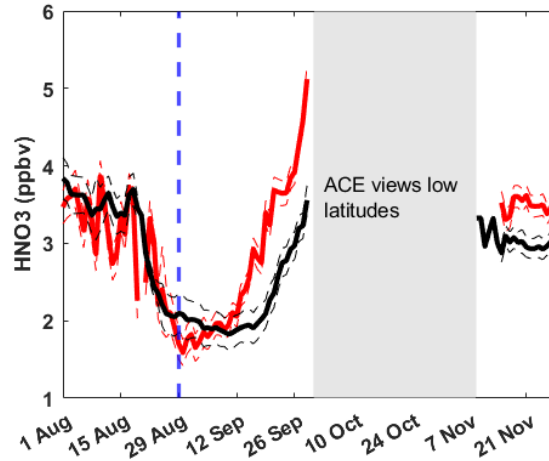
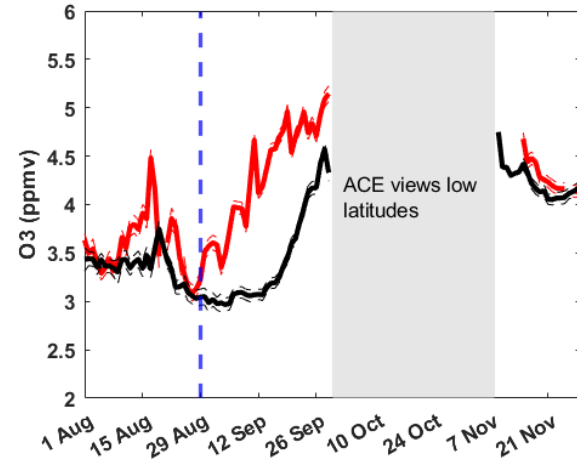
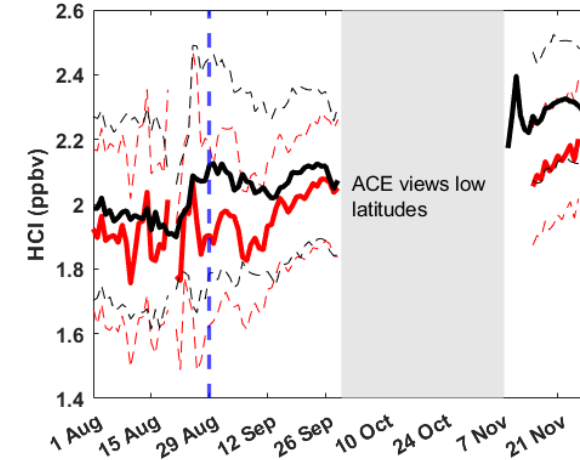
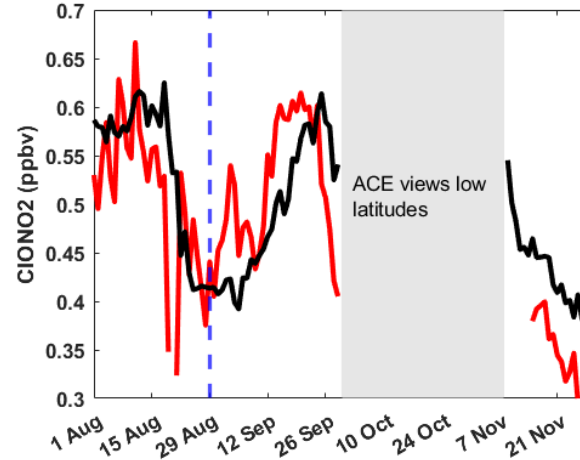
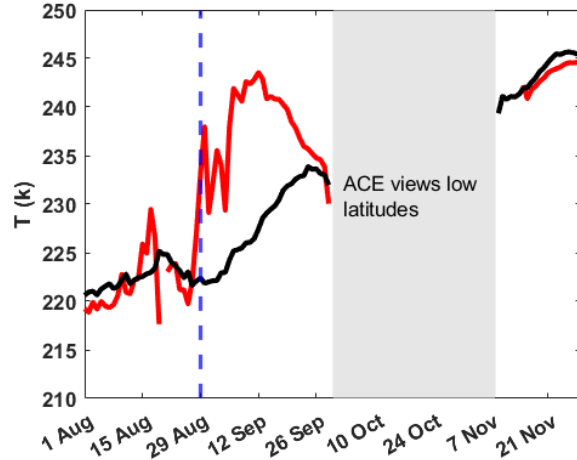
2019 Time Series of Each Species

2004 - 2018 Error Average (---)

2019 Error (---)

2019 SSW Date (---)

Unavailable Data



Day of the Year

$$\text{O}_3 \text{ 2019} > \text{O}_3 \text{ (Average(2004-2018))}$$

$$\text{HNO}_3 \text{ 2019} > \text{HNO}_3 \text{ (Average(2004-2018))}$$

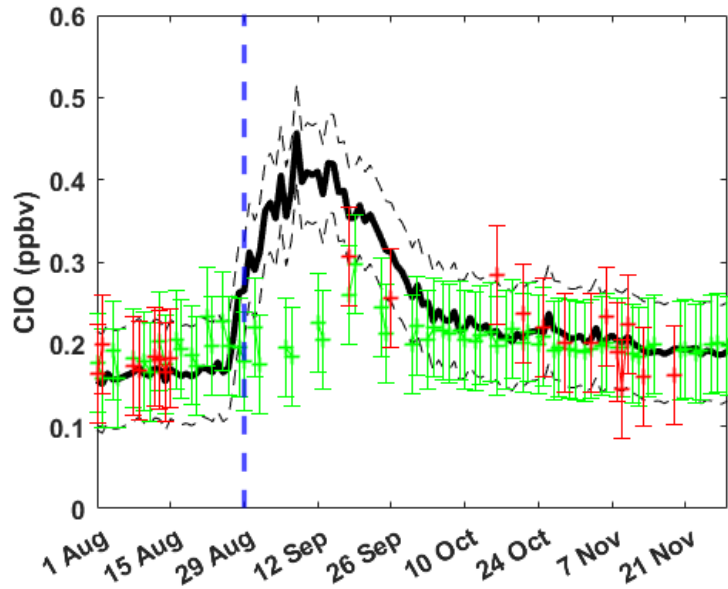
$$\text{ClO}_{2019} < \text{ClO}_{\text{Average}(2004-2018)}$$

26 May 2022

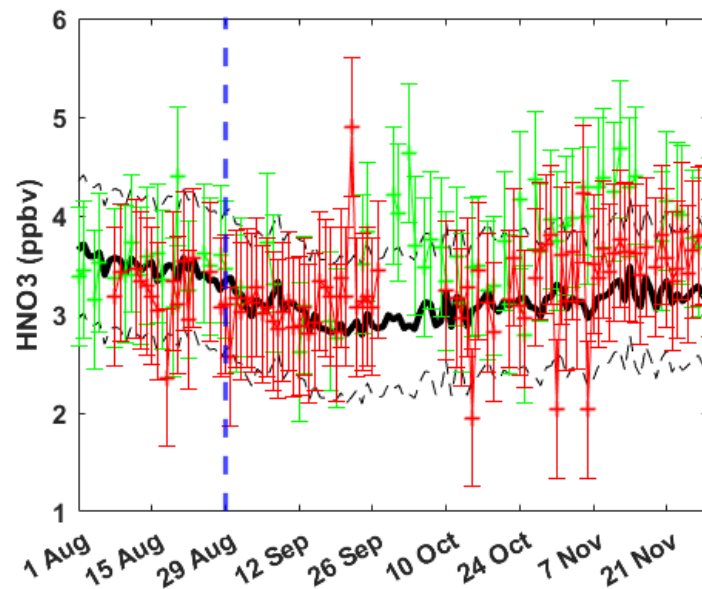
Results from SMR

- Fewer datapoints in 2019 than other years.

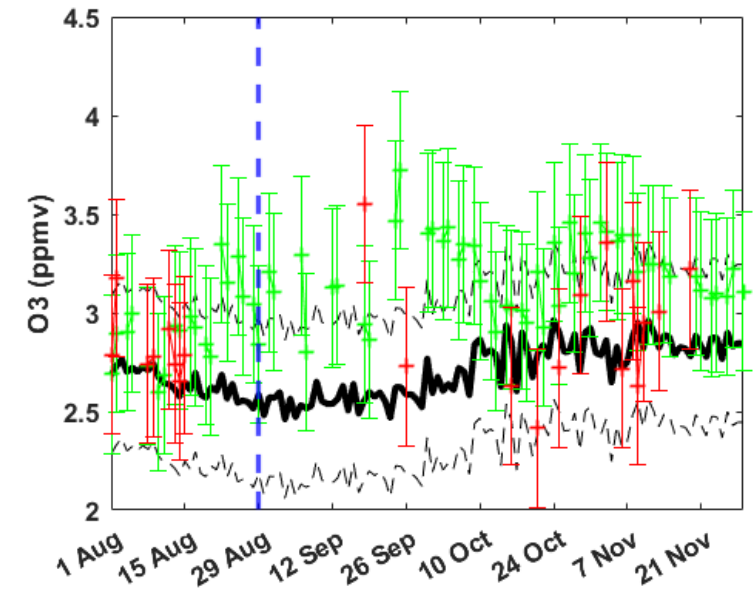
— 2003 - 2018 Time Series of Each Species (Average) - - - 2003 - 2018 Error (Average)
 - - - 2019 SSW Date + 2002 Each Species
 + 2002 Error + 2019 Each Species
 - - - 2019 Error



- $\text{CIO}_{2019} < \text{CIO}_{(\text{Average}(2003-2018))}$, typically after the SSW date.
- Similar CIO decrease observed in 2002.

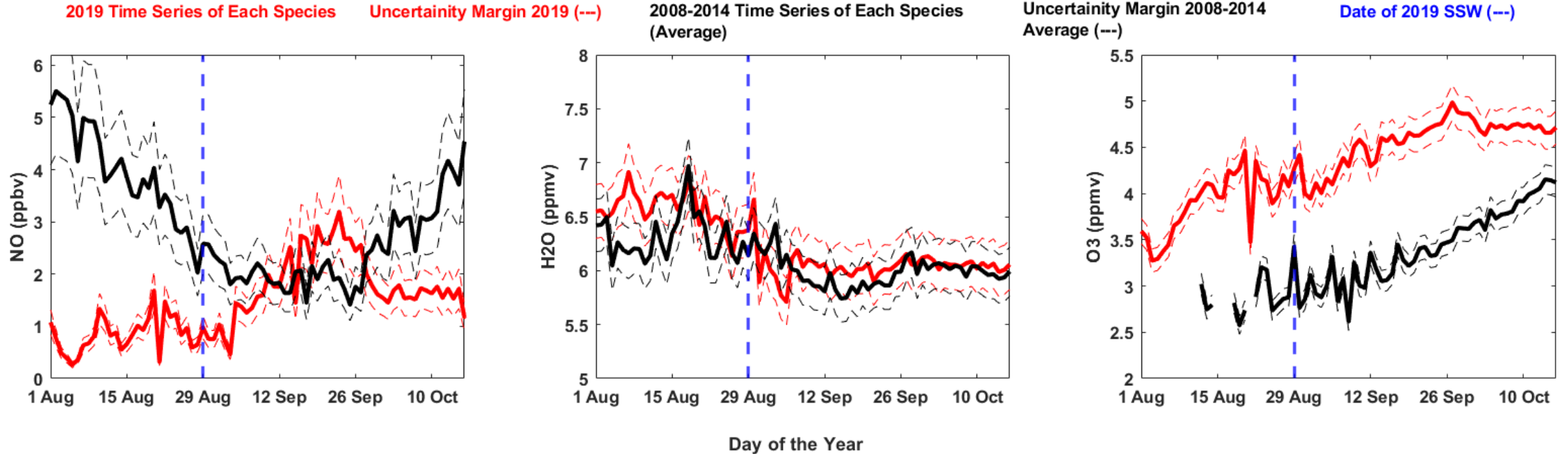


- $\text{HNO}_3_{2019} > \text{HNO}_3_{(\text{Average}(2003-2018))}$, typically after the SSW date.
- Low denitrification observed.
- Similar HNO_3 enhancement observed in 2002.

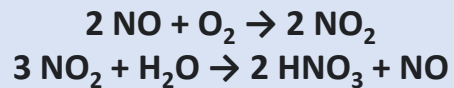


- $\text{O}_3_{2019} > \text{O}_3_{(\text{Average}(2003-2018))}$, typically after the SSW date.
- Similar O_3 enhancement observed in 2002.

Results from SOFIE



Nitric Acid Formation

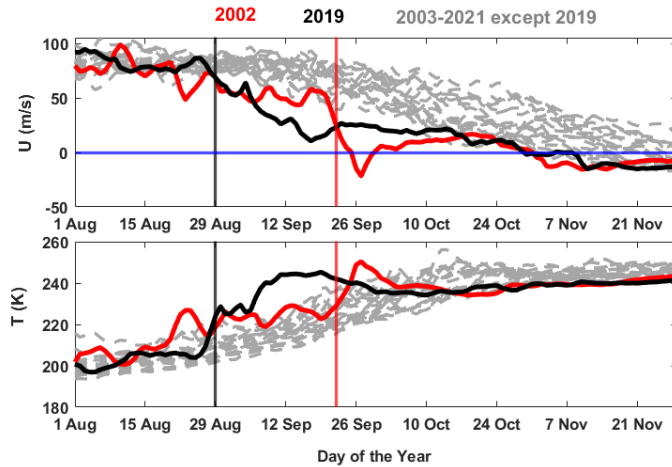


- We use NO and H₂O as proxies for HNO₃.
- Increase in NO and H₂O in 2019 after the SSW indicates an enhancement in HNO₃ (i.e., low HNO₃ uptake by PSCs).
- Enhancement in O₃ is observed in 2019 with a strong increase just after the SSW date.

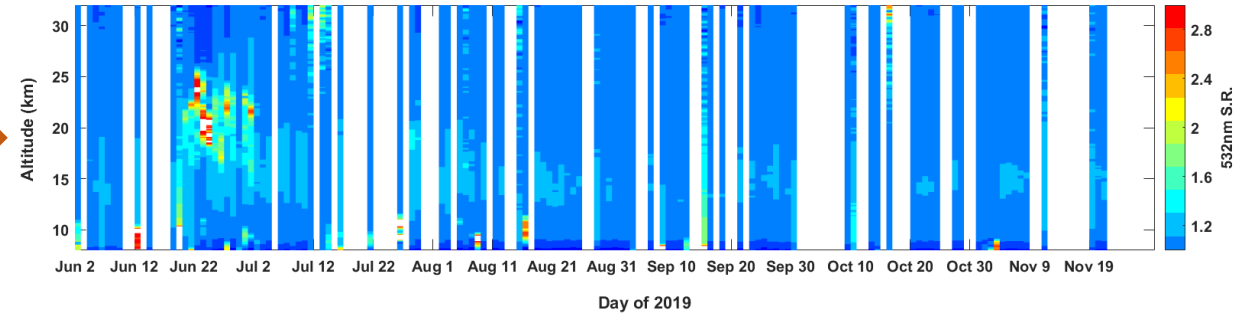
- Fewer data points poleward of 60°S in 2019 than other years. Thus, data poleward of 50°S is used (assuming less variation between 50°S – 60°S). (Limited data during 2015-2018 due to SOFIE's SR/SS hemisphere switch are not included)
- This is a work in progress.

26 May 2022

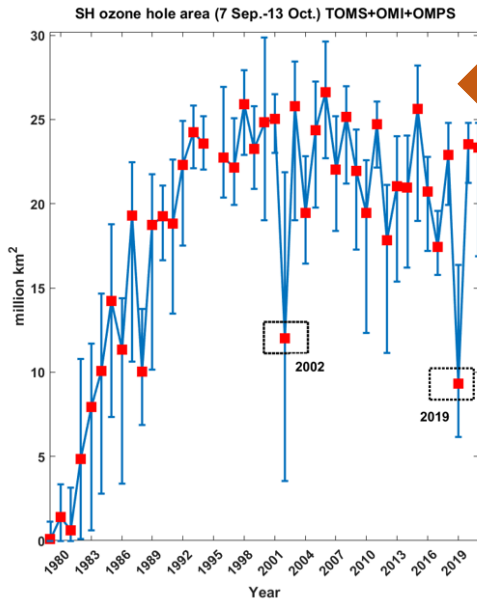
Summary



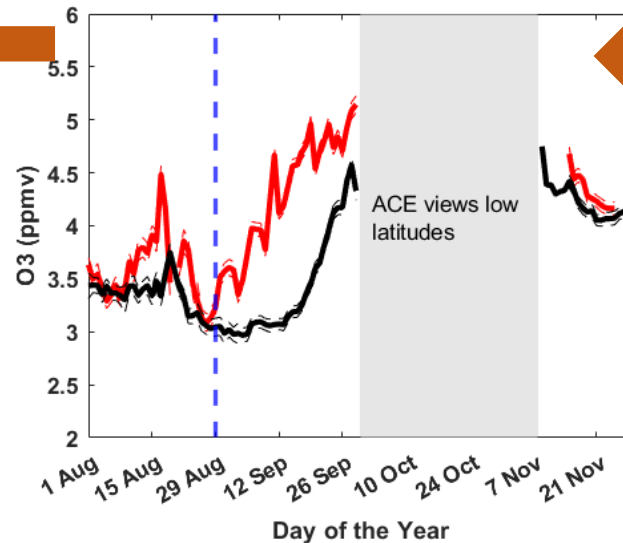
2019 SSW in the SH is indicated by zonal mean zonal wind reversal and temperature increase at 60°S, 10 hPa



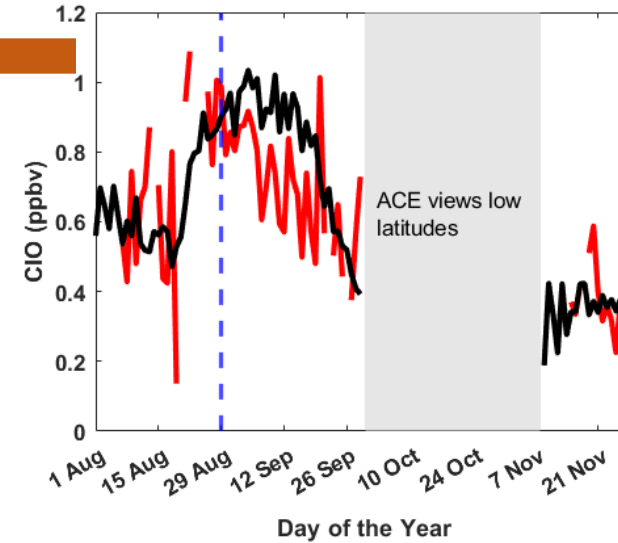
Gradual reduction in PSC concentration after mid-August



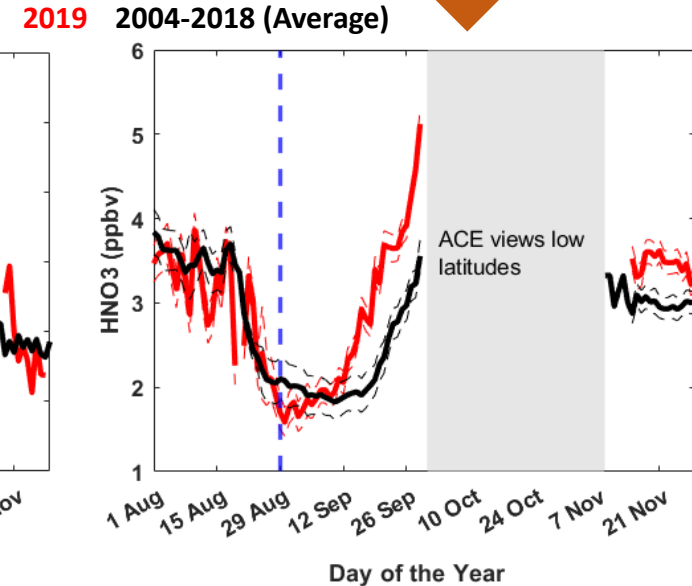
Smaller O₃ hole area



O₃ (2019) > O₃ (2004-2018Average)
Ozone Enhancement



ClO₂₀₁₉ < ClO_{2004-2018Average}
Low Chlorine Activation



HNO₃ (2019) > HNO₃ (2004-2018Average)
Lower Denitrification

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Acknowledgment

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