Effects of Hunga Tonga eruption using WACCM6 simulations on stratospheric ozone

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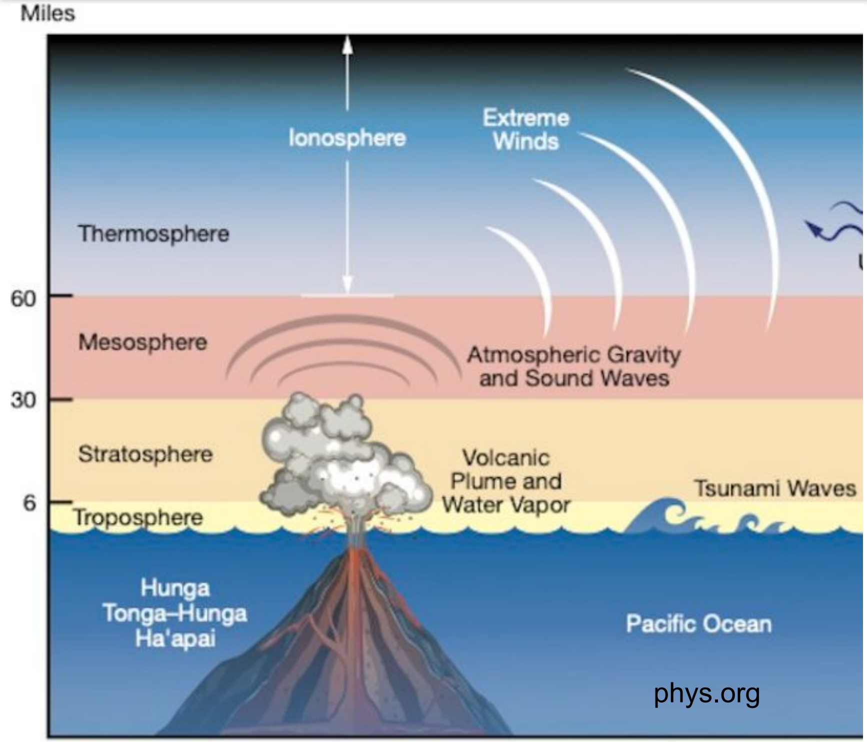
Unprecedented water-rich Hunga Tonga eruption



150 Tg water along with
0.42 Tg sulfur dioxide injection

additional source of water vapor
↓
increases hydroxy radical (OH)
↓
enhance HOx O_3 loss cycle

SO_2 injection forms sulfate aerosol
↓
enhance the aerosol surface area density
↓
facilitate heterogenous chemistry

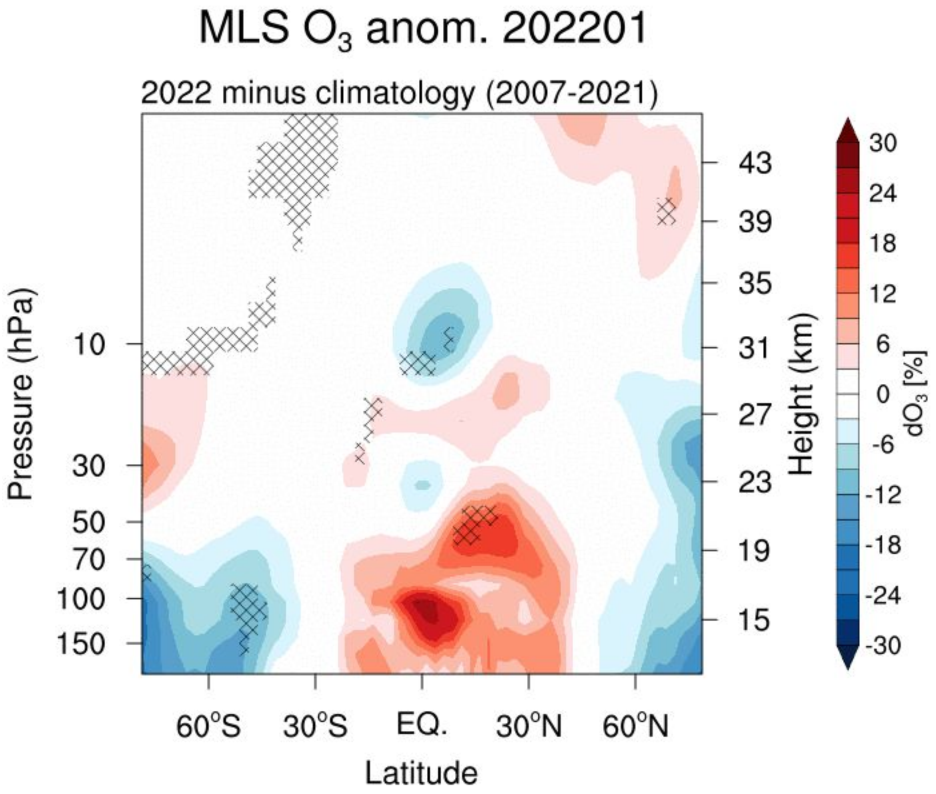
↓

adversely deplete stratospheric ozone

Zhu et al., Earth & Environment, 2022

2022 Ozone anomaly relative to climatology

Aura MLS - Microwave Limb Sounder



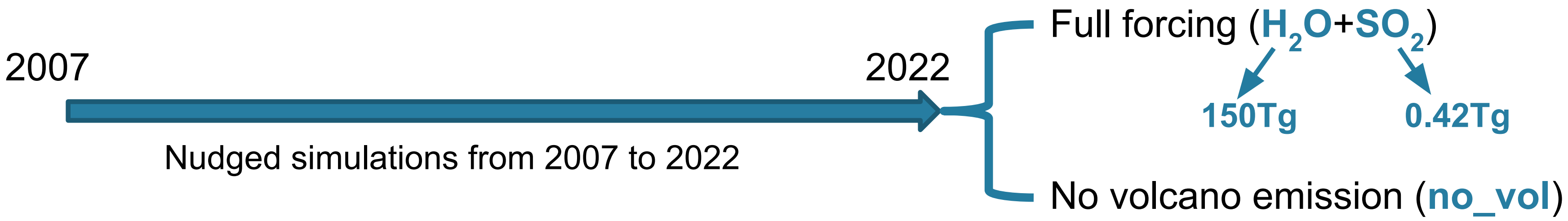
- 2007 to 2021 15 years climatology
- Hatched regions indicate where the 2022 anomalies are outside the range of all variability during 2007-2021
- Large anomaly over the **SH mid-latitudes** and **Antarctic polar region** (ozone hole)

CESM Whole Atmosphere Community Climate Model

- **WACCM6, 110L**, horizontal resolution of ~**1.0°** and a vertical resolution of ~**500m** in the Upper Troposphere and Lower Stratosphere.

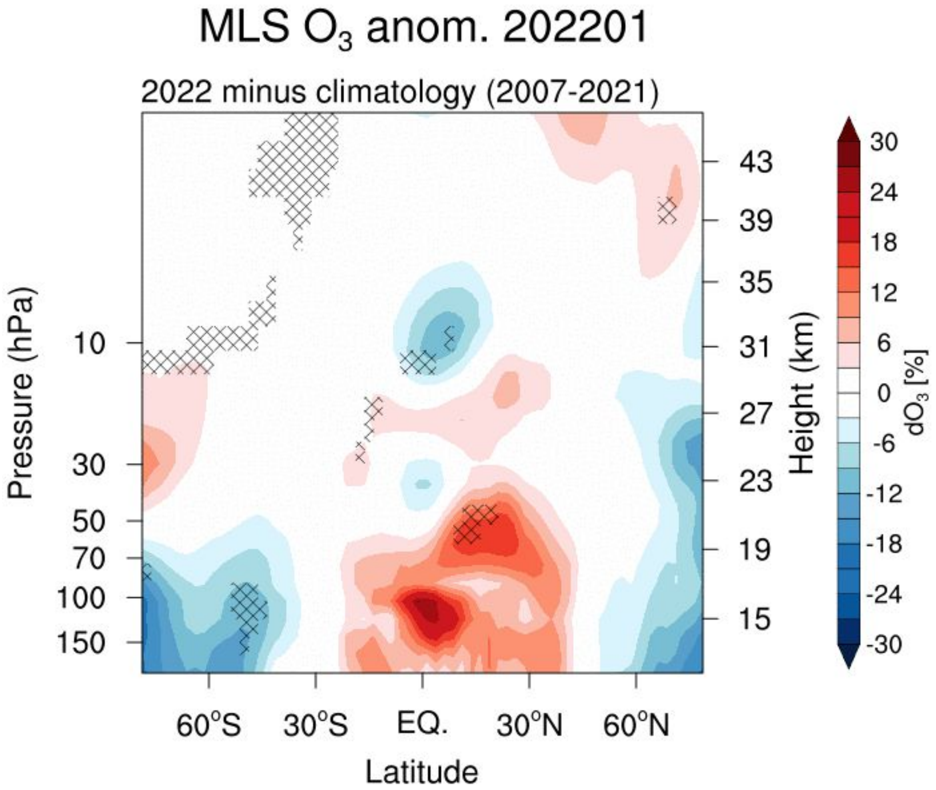
- Full interactive tropospheric and stratospheric chemistry.

- **Specified dynamics** – nudged towards MERRA-2 reanalysis fields (T, U, V).

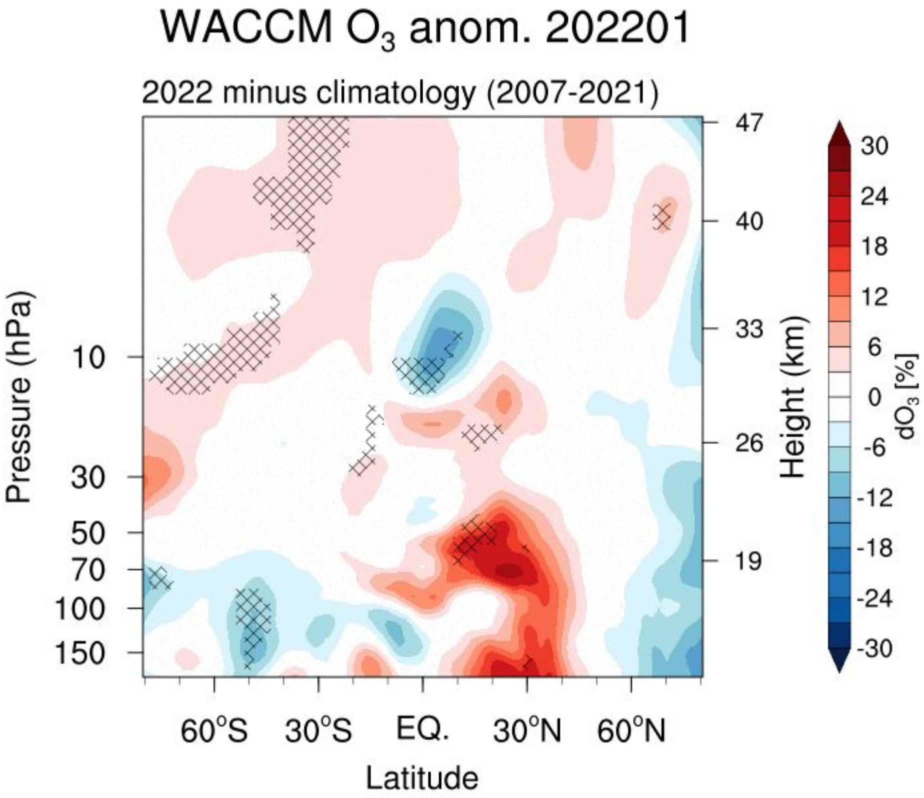


2022 Ozone anomaly MLS and WACCM comparison

MLS



WACCM

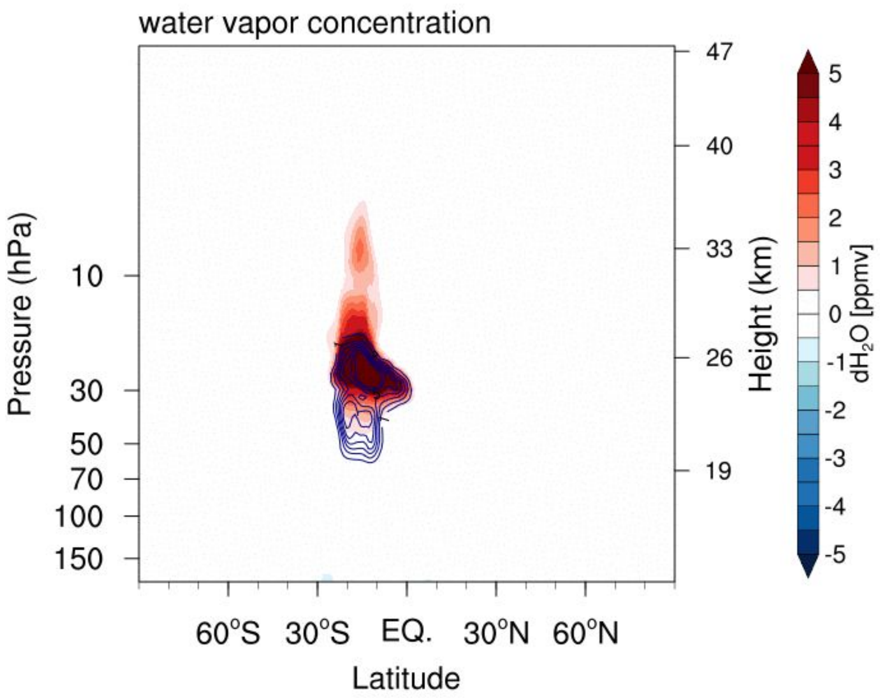


HT Water plume and aerosol SAD evolution

Full forcing (H_2O+SO_2) – control (no_vol)

- Water plume propagates from SH subtropics to high-latitude in 2022.
- Aerosol surface area density is more than doubled relative to background level.

WACCM H_2O & SAD perturb. 202201

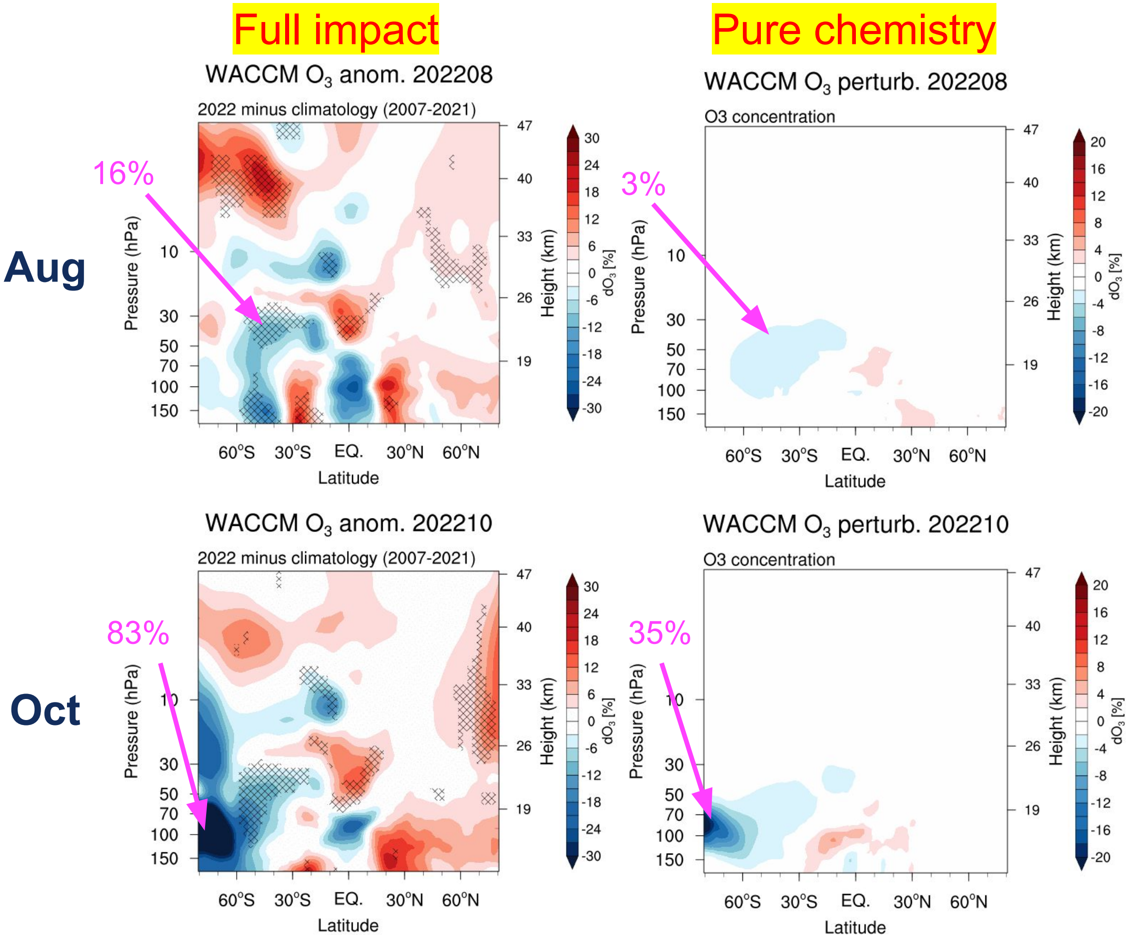


Aerosol SAD (um^2/cm^3)

Quantify pure chemistry induced ozone change

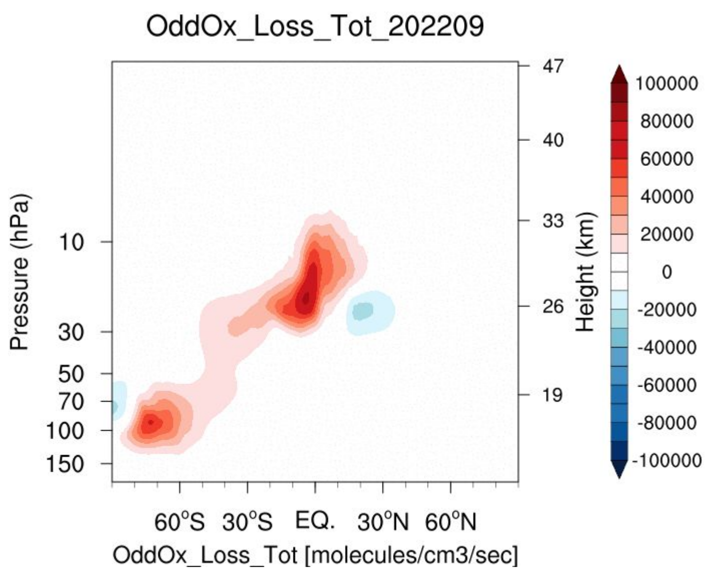
$(H_2O+SO_2) – (no\_vol)$

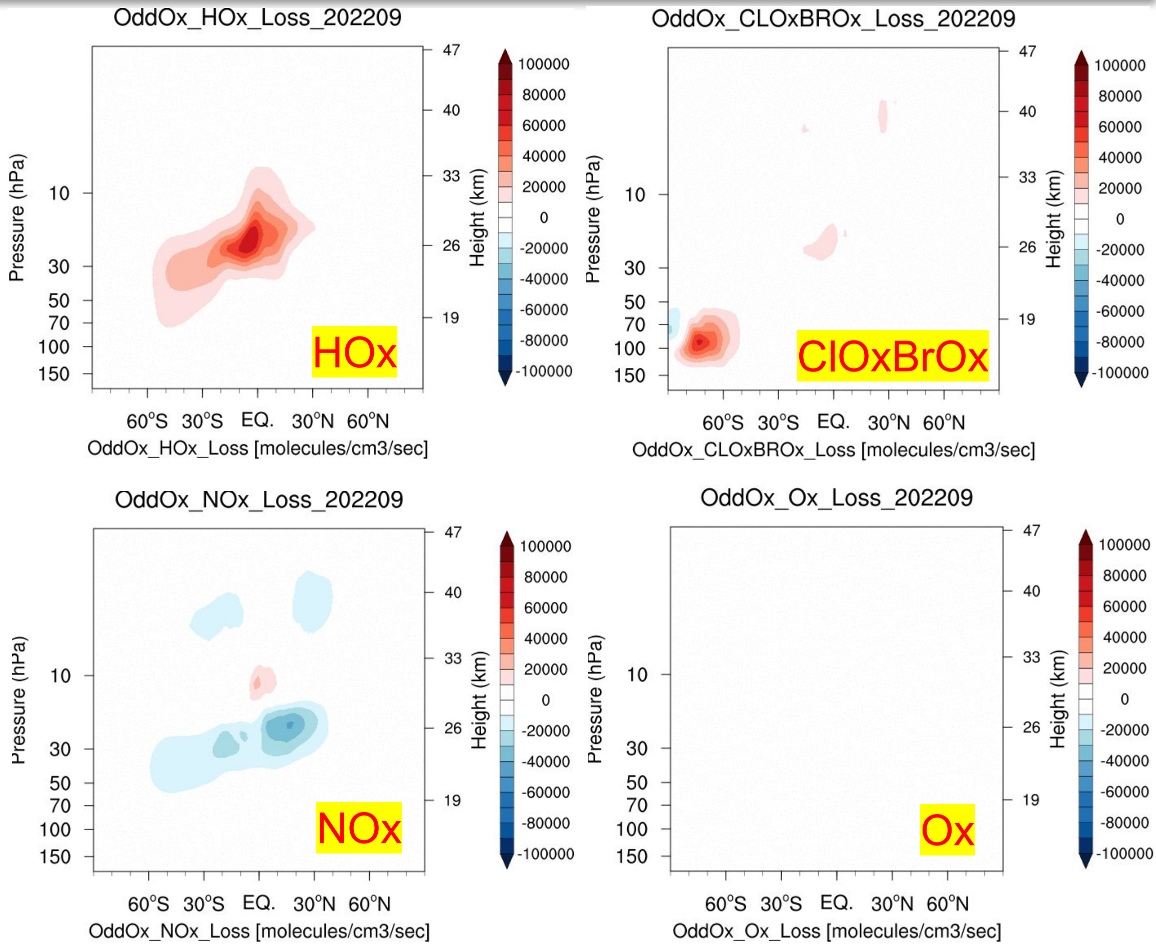
- Chemistry contribution to ozone depletion occurs at both **mid-latitudes** and **polar region**.
- In the mid-latitudes, pure chemistry contributes to ~ 20% of ozone depletion.
- In the Antarctica region, the contribution from pure chemistry is around 42%.



Odd Ox (O_3 + O) loss chemistry cycles

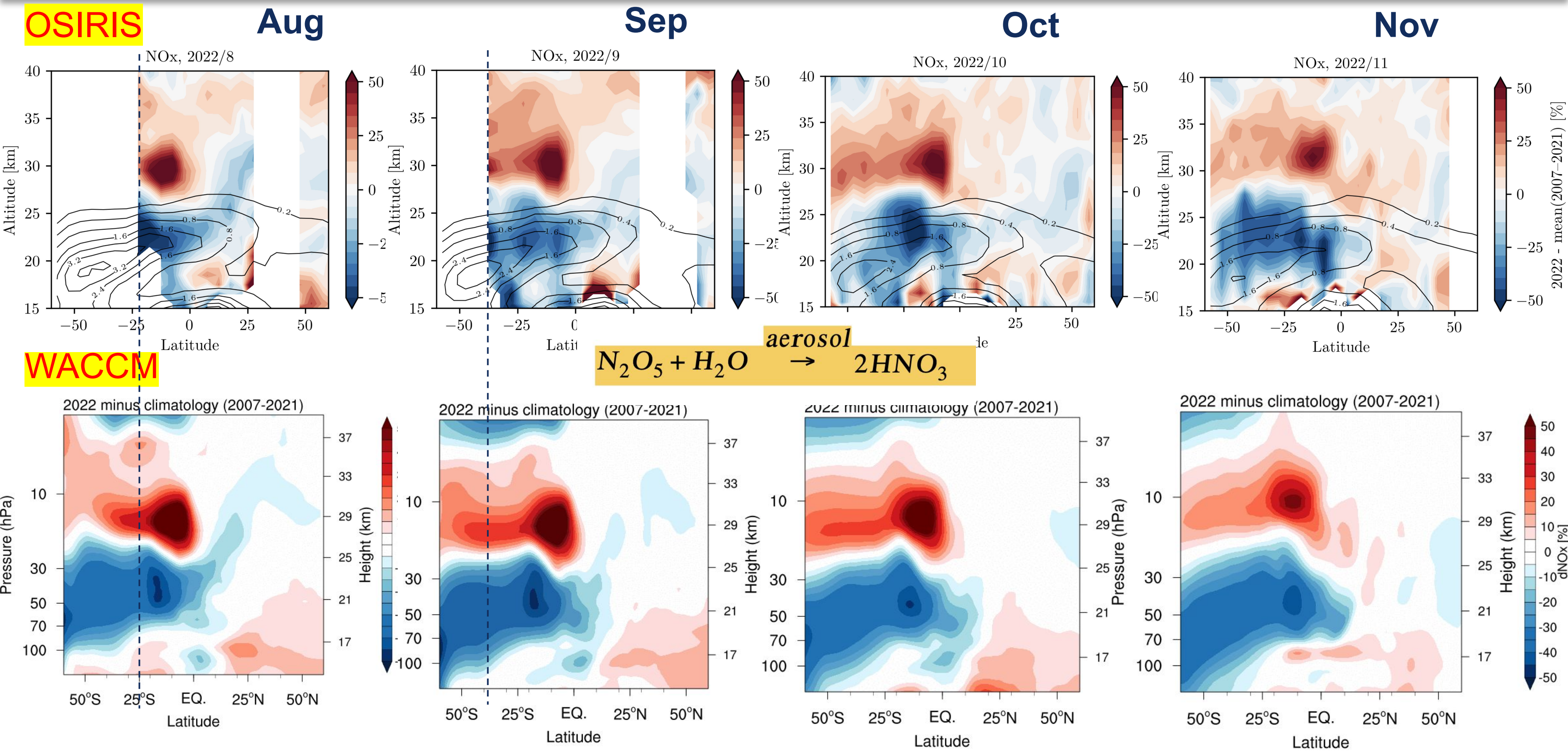
Total





- HOx and ClOxBrOx Ox loss cycles are playing major roles in ozone depletion.
- NOx Ox loss cycle is suppressed.

NOx anomaly from OSIRIS and WACCM



$$N_2O_5 + H_2O \xrightarrow{aerosol} 2HNO_3$$

Summary

- WACCM6 110L nudged simulation shows a very good agreement with MLS ozone anomaly and also reproduce NOx anomaly in 2022 very well compared to OSIRIS.

- Nudged simulations can be used to quantify the chemistry contribution to the ozone anomaly.

- Chemistry contribution to ozone depletion occurs at both mid-latitudes and polar region, accounting for 20% and 42% respectively to the total negative anomaly.

Free running ensemble simulations from 2022 to 2025. Wang et al., 2023 (preprint)

Thank you for your attention ☺
Contact me for any comments and questions! **jzhan166@ucar.edu**