CESM Atmosphere & Whole Atmosphere
& Chemistry-Climate Working Groups Meeting
08 - 12 February 2021

MIT ATMOSPHERIC CHEMISTRY

Updating SD-WACCM's De-NOY Parameterization Improves Simulation of Arctic Ozone Loss Under Extreme Conditions

Catherine Wilka (MIT)

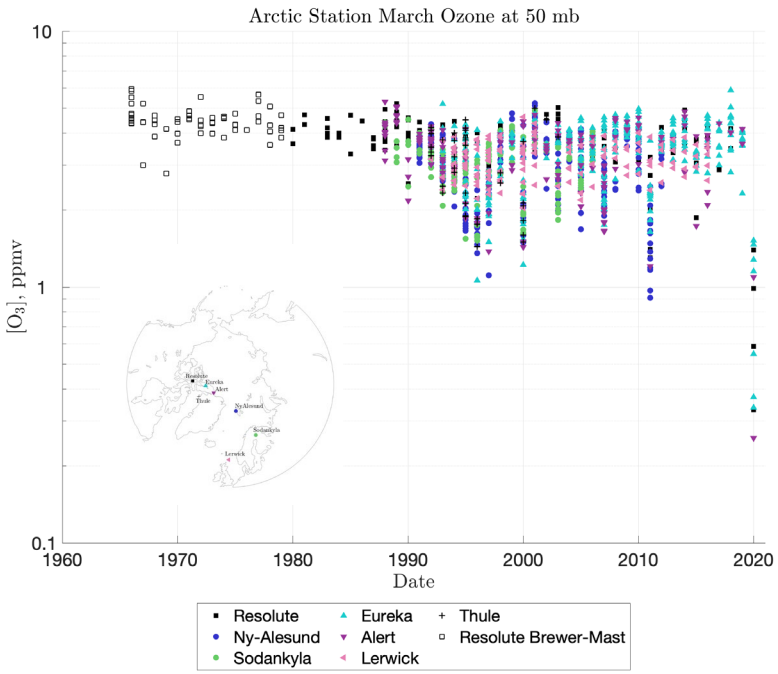
With Thanks to Collaborators:
S. Solomon (MIT), D. Kinnison (NCAR),
and D. Tarasick (ECCC)

Massachusetts Institute of Technology

Motivation: The Extreme Arctic Spring of 2020

- Observations from balloons and satellites of the Arctic 2020 spring saw lowest mixing ratios ever in the heart of the depletion accompanied by extensive denitrification (Manney et al., 2020; Wohltmann et al., 2020; Inness et al., 2020; others)

- Mainly due to a cold, stable polar vortex which allowed the formation of more PSCs than usual and persisted into the spring



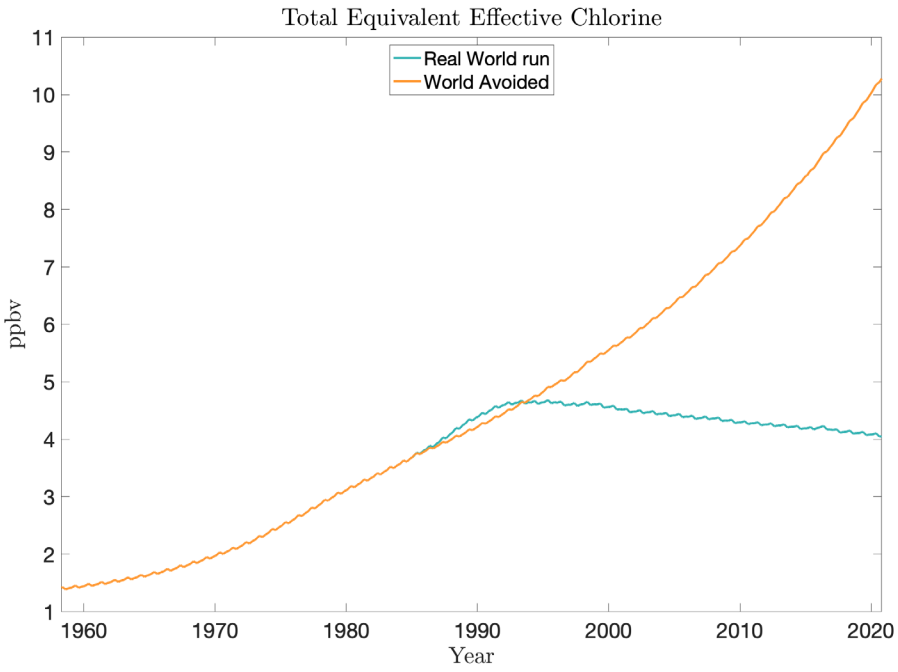
Wilka et al., *in review*

Massachusetts Institute of Technology

Our "World Avoided" Scenario

- We simulate both the real world (RW) using SD-WACCM4 nudged to MERRA2's meteorological fields and an even more extreme "World Avoided" (WA) without the Montreal Protocol

- Increase anthropogenic ODS's at uniform 3.5% per year from 1985 onward in the model except CH_3Br which is assumed to be half natural half anthropogenic

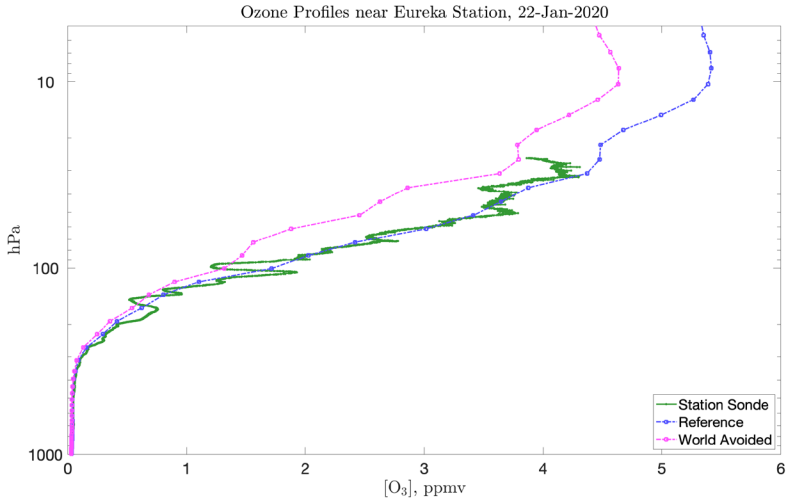


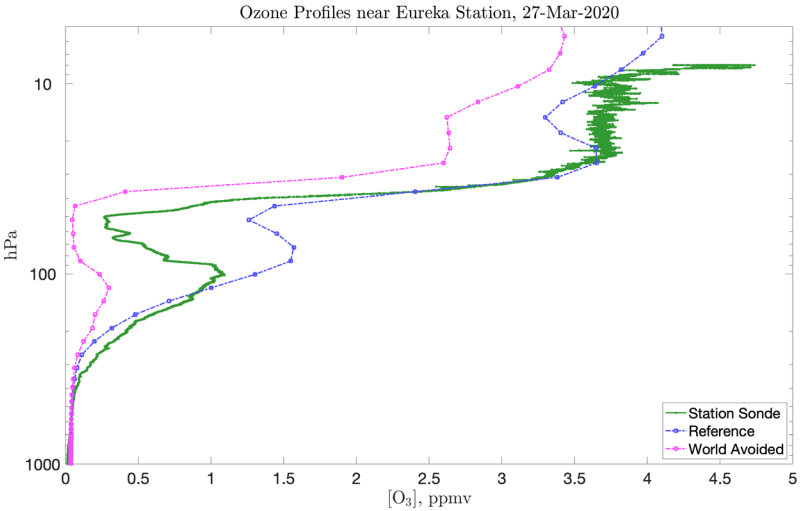
Wilka et al., *in review*

Massachusetts Institute of Technology

Accurate Denitrification is Important

- Initially, the TCO depletion and ozone profiles in the RW run weren't depleting as much as observations
- Reactive nitrogen will bond with chlorine and convert active chlorine back to reservoir form, thus short-circuiting the catalytic ozone depletion cycles
- SD-WACCM wasn't denitrifying enough early on compared to MLS, and HNO_3 recovered faster in the model than in observations



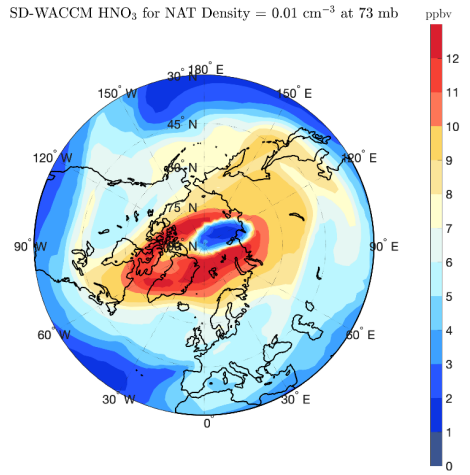


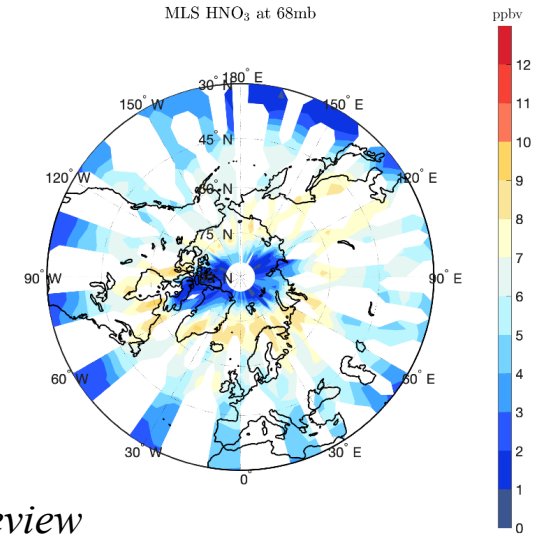
Massachusetts Institute of Technology

Accurate Denitrification is Important

Feb 20th

- Initially, the TCO depletion and ozone profiles in the RW run weren't depleting as much as observations
- Reactive nitrogen will bond with chlorine and convert active chlorine back to reservoir form, thus short-circuiting the catalytic ozone depletion cycles
- SD-WACCM wasn't denitrifying enough early on compared to MLS, and HNO_3 recovered faster in the model than in observations





Massachusetts Institute of Technology

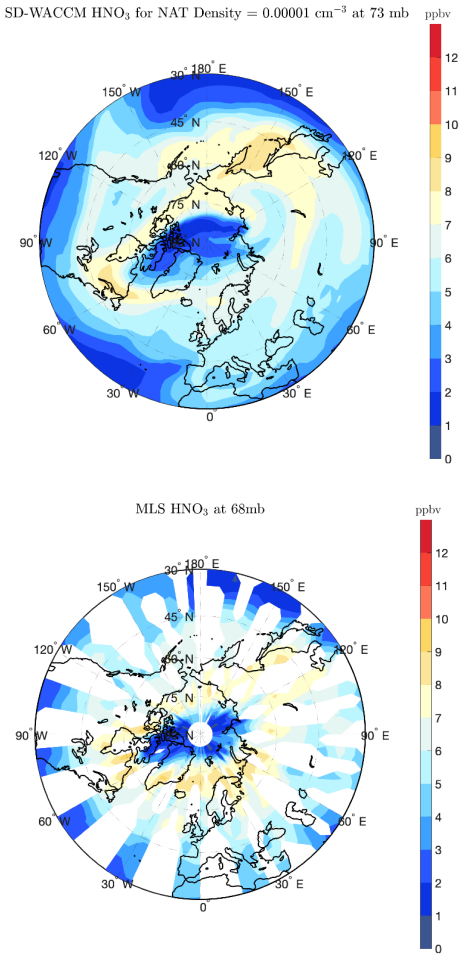
Wilka et al., *in review*

Accurate Denitrification is Important

Feb 20th

- We ran multiple versions of the reference runs with different NAT particle densities to drive denitrification harder and our HNO_3 and ozone levels now match better

Reference Run	NAT Particle density (particles/cm^3)
REF 003	0.01
REF 004	0.005
REF 005	0.001
REF 006	0.0001
REF 007	0.00005
REF 008	0.00001



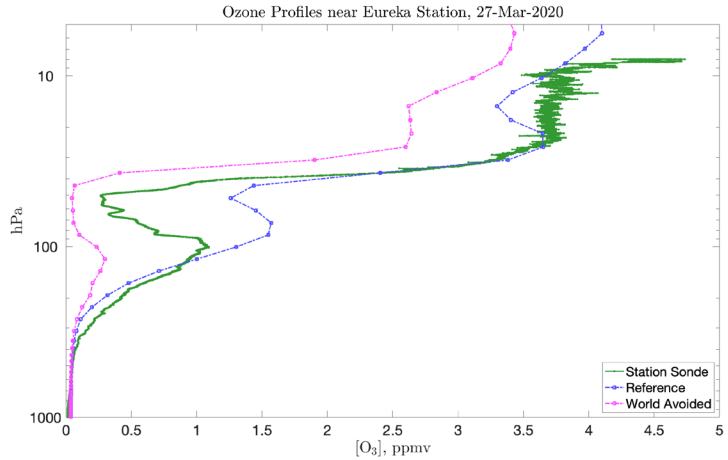
Wilka et al., *in review*

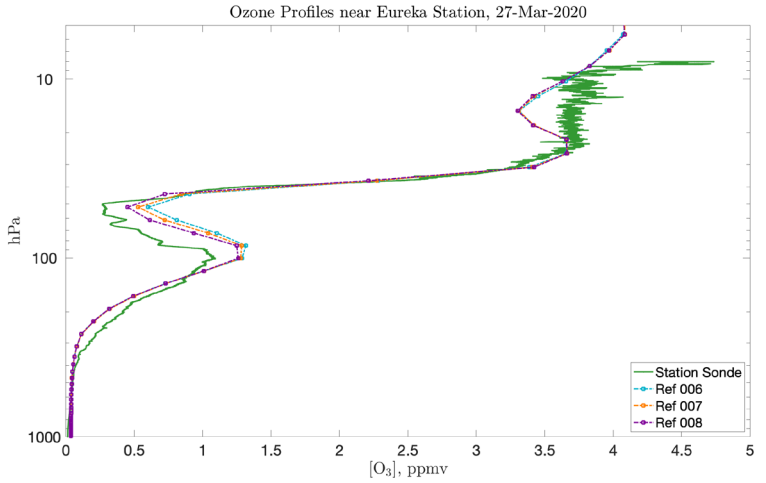
Massachusetts Institute of Technology

Accurate Denitrification is Important

- We ran multiple versions of the reference runs with different NAT particle densities to drive denitrification harder and our HNO_3 and ozone levels now match better

Reference Run	NAT Particle density (particles/cm^3)
REF 003	0.01
REF 004	0.005
REF 005	0.001
REF 006	0.0001
REF 007	0.00005
REF 008	0.00001

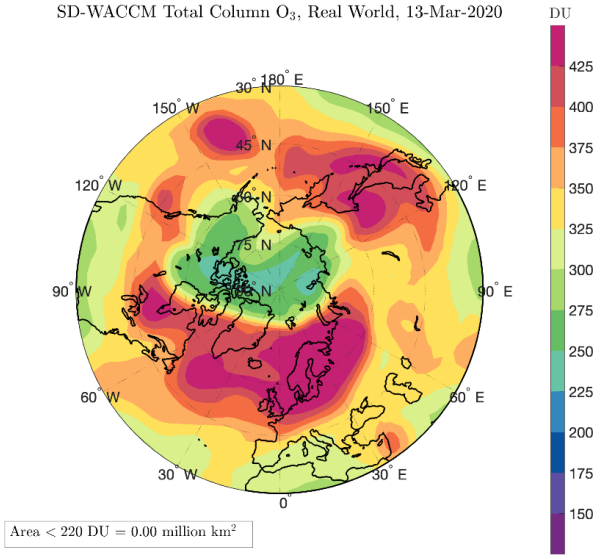


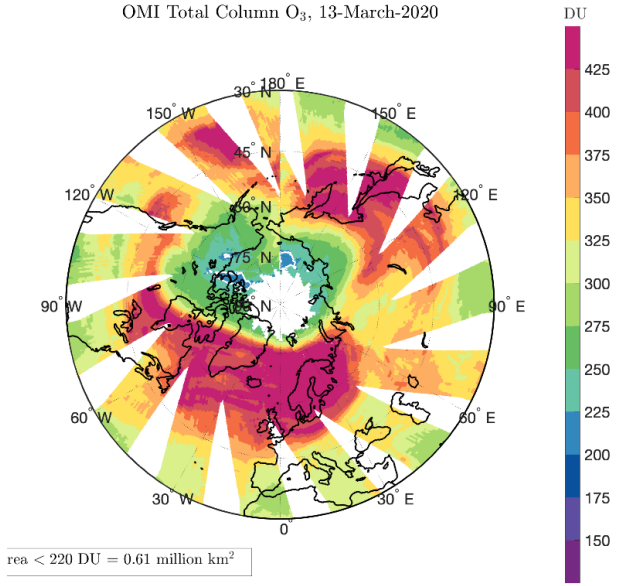


Massachusetts Institute of Technology

No Arctic Ozone Hole in the Real World

- Our RW run compares well with OMI for Total Column measurements
- We don't find any contiguous area below 220 DU in WACCM, although the higher-resolution satellite finds a few small spots



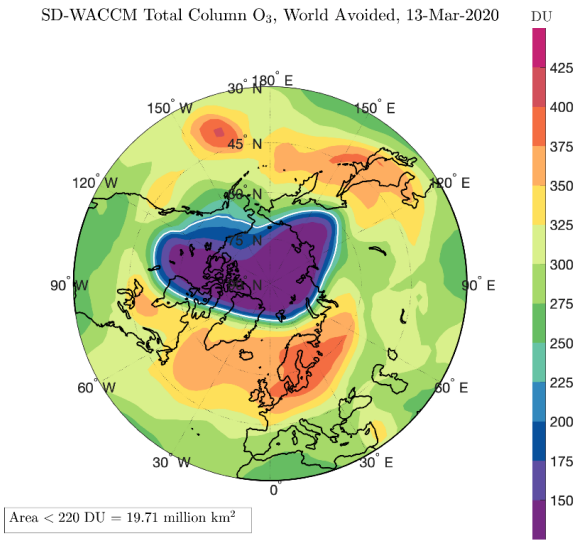


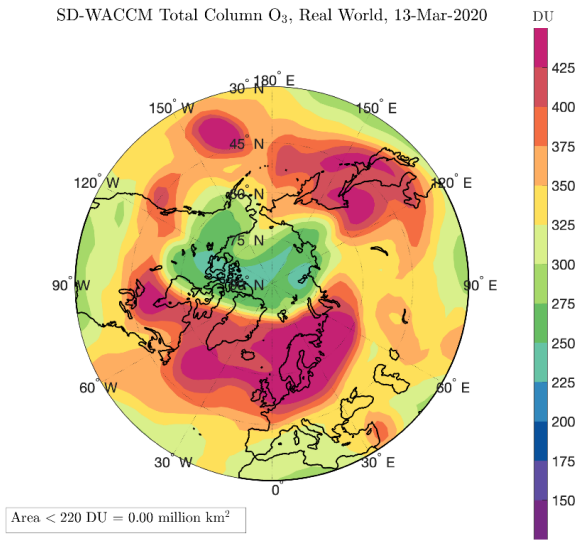
Wilka et al., *in review*

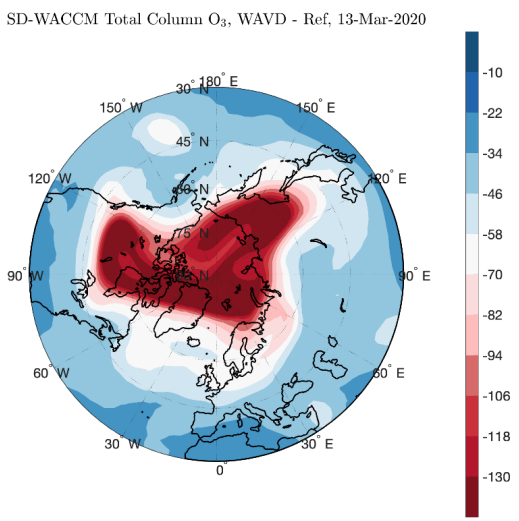
Massachusetts Institute of Technology

A 2020 Arctic Ozone Hole in the World Avoided

- Area of the ozone hole (defined as < 220 DU) in the World Avoided is now 19.71 million km^2 in 2020
- The Arctic ozone hole would have stretched across the pole and over much of Canada, Greenland, and Russia





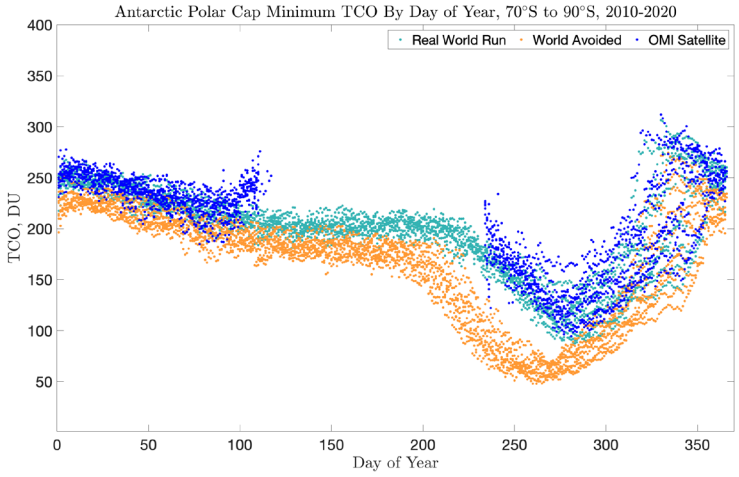


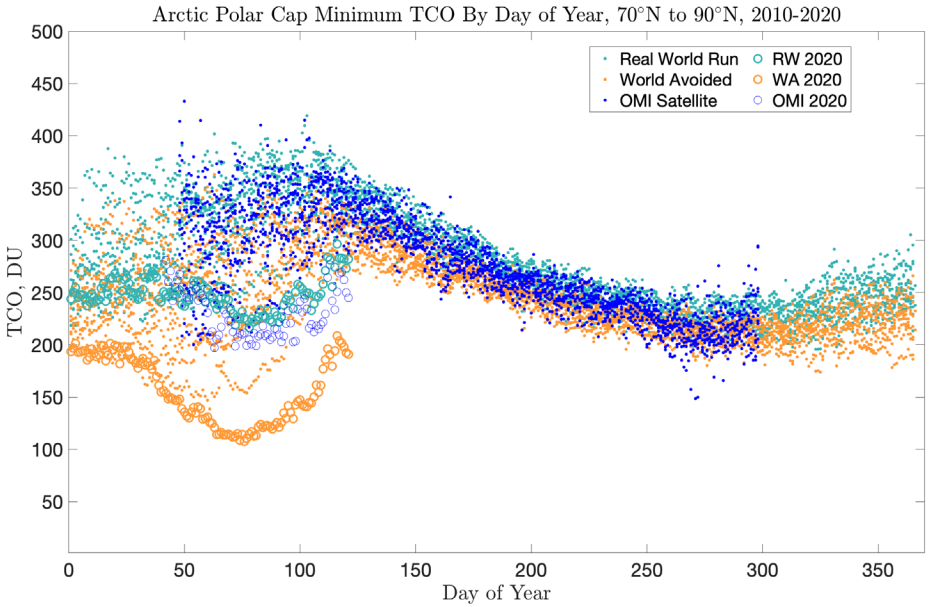
Wilka et al., *in review*

Massachusetts Institute of Technology

Total Column Ozone in 2020

- The WA minimum Arctic ozone also follows a more Antarctic-like progression throughout the season
- We see a good match with OMI observations over the entire time period





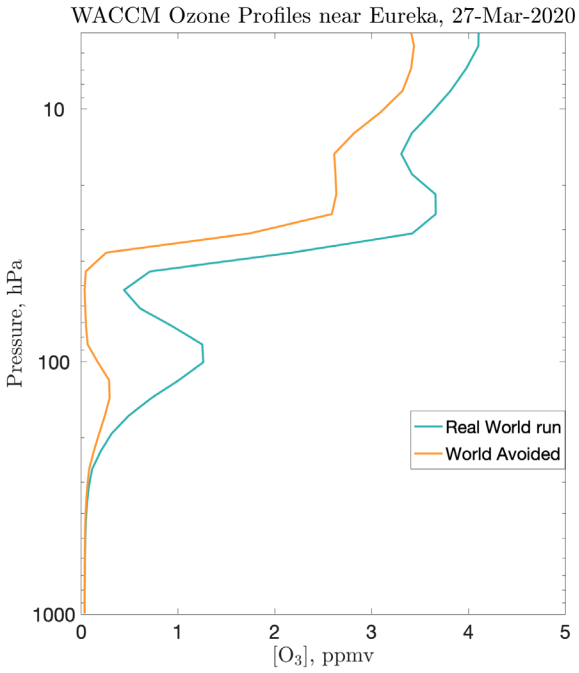
Wilka et al., *in review*

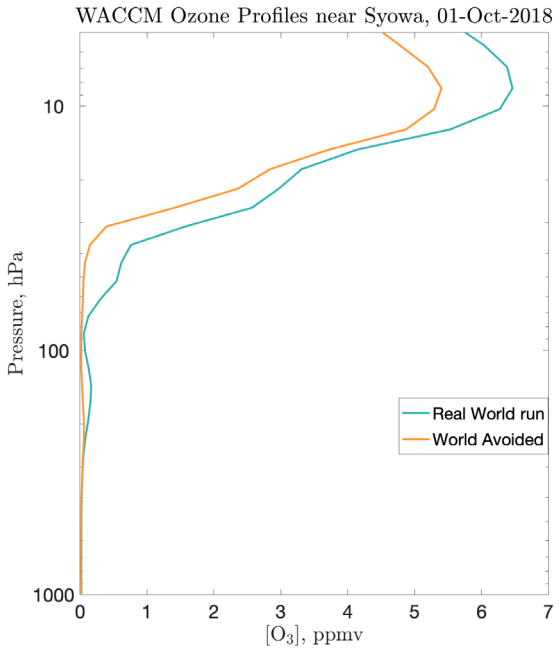
Massachusetts Institute of Technology

Ozone Vertical Profiles in 2020

- Looking at vertical profiles again, we also see a shift toward near-total depletion in a broad regions of the lower stratosphere (WA) rather than at a few levels (RW)

- Again, a common feature of the Antarctic, which is itself quite saturated and shows more change higher up



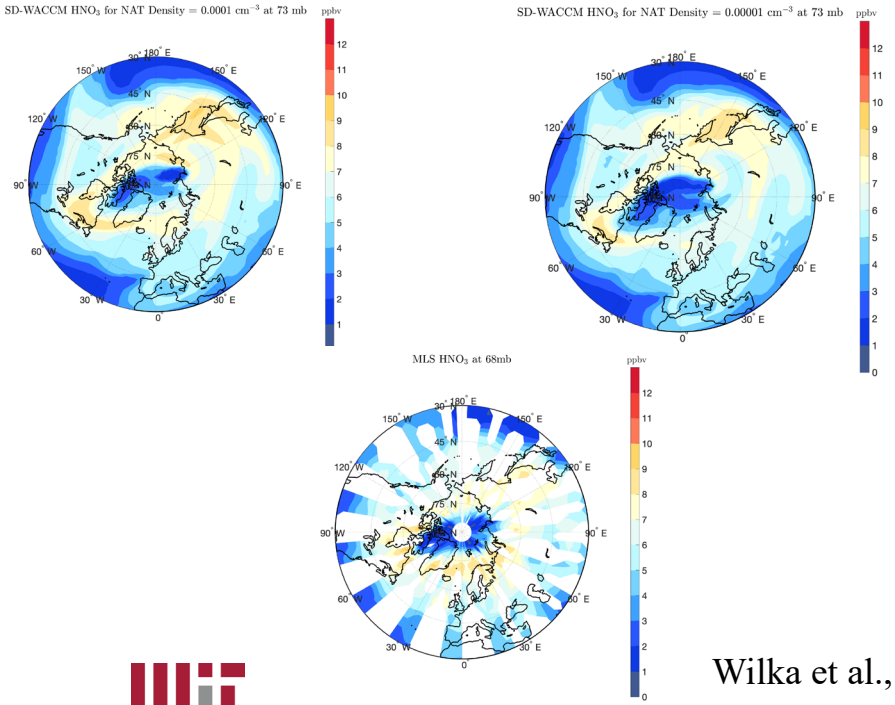


Wilka et al., *in review*

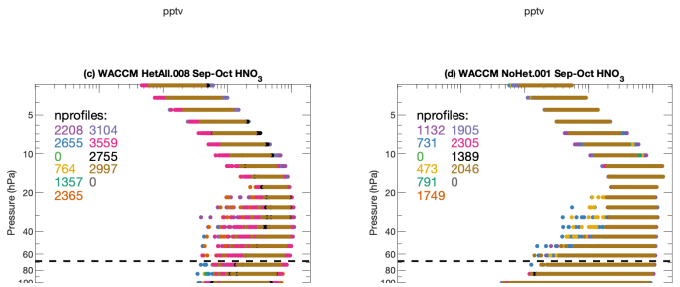
Massachusetts Institute of Technology

Next Steps: Impacts Elsewhere and WACCM6

- Looking at the Antarctic, we don't seem to be denitrifying too much
- Preliminary comparisons with MIPAS HNO3 distributions indicates our new reference state is better in the SH subpolar latitudes, but more work is needed
- More careful comparisons with obs needed to decided on final NAT param value



Wilka et al., *in review*



Zambri et al., *in prep*

Massachusetts Institute of Technology

Conclusions

- Increasing the denitrification in SD-WACCM4 allows the model to more accurately simulate the conditions of the meteorologically extreme Arctic spring of 2020
- Given this, we have more confidence in the model's ability to simulate a "World Avoided" which the real world averted through the Montreal Protocol
- This does not appear to degrade the representation of HNO_3 in the Antarctic, but quantification of this and impacts on other regions is ongoing