Record low ozone values observed in the Arctic in spring 2020

Based on the paper „Near complete local reduction of Arctic stratospheric ozone by severe chemical loss in spring 2020“, doi:10.1029/2020GL089547

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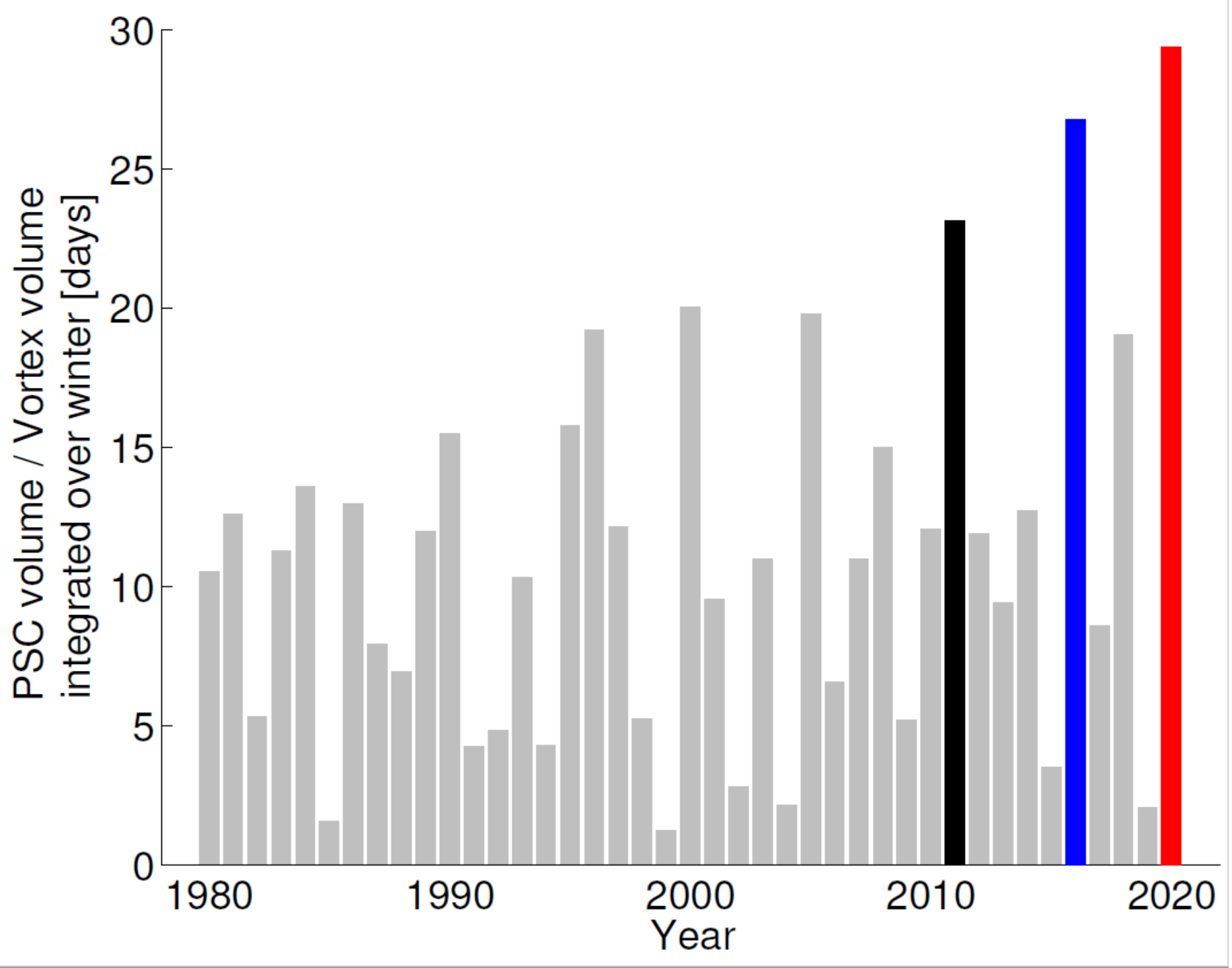
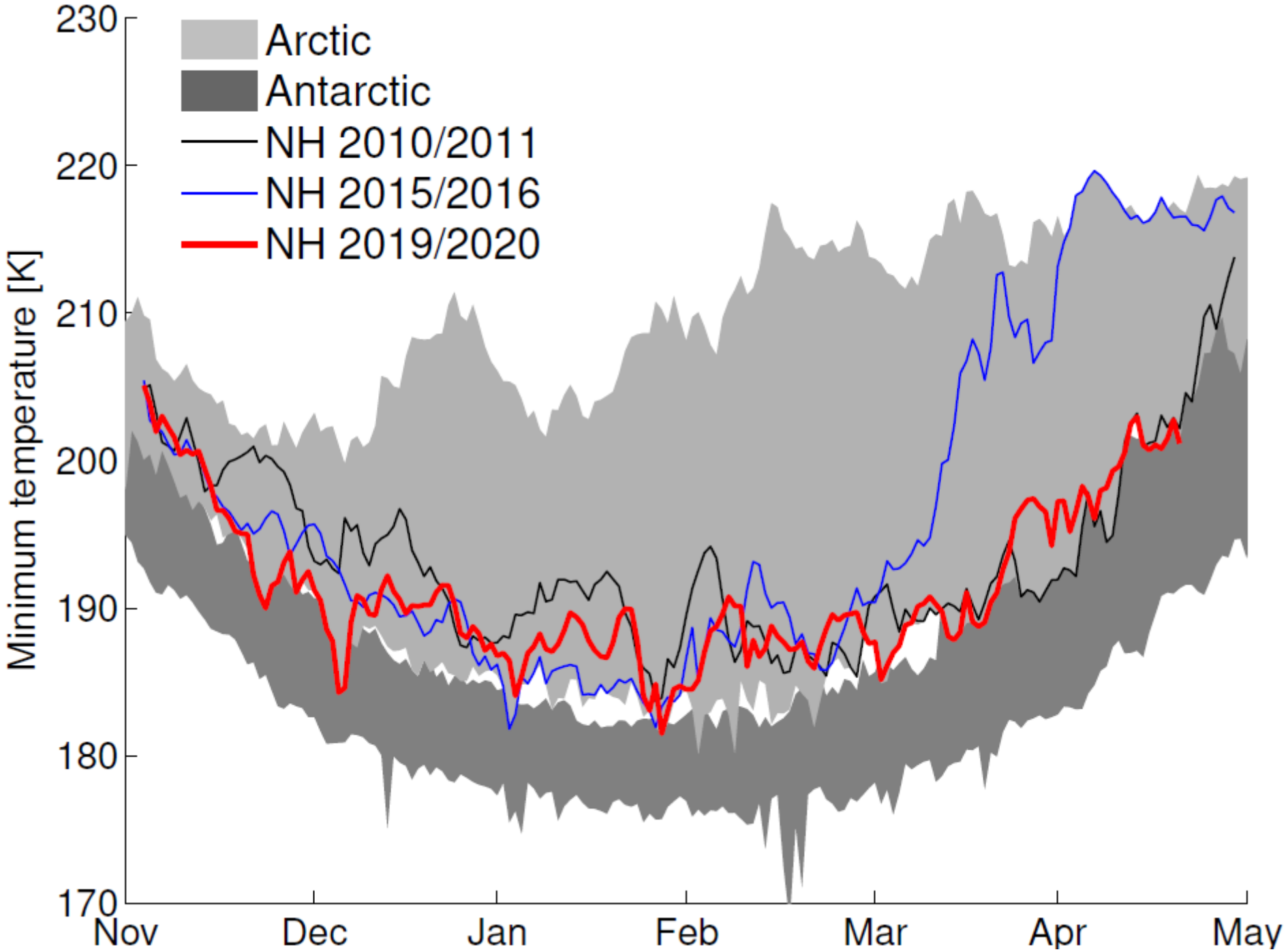


Coldest Arctic stratospheric winter since start of reliable observations in 1979

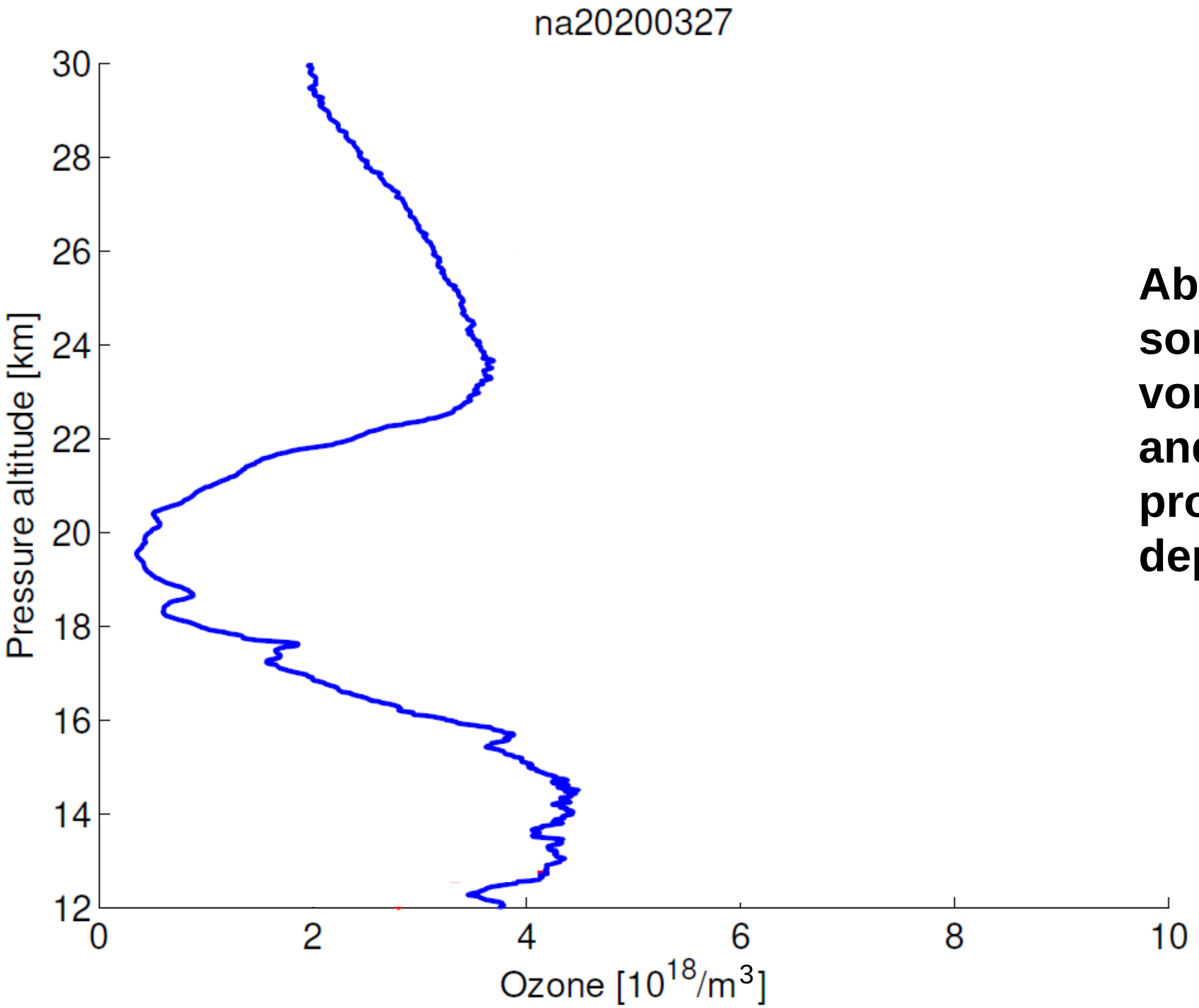
Fraction of polar vortex volume below threshold temperature for formation of polar stratospheric clouds (NAT), integrated over winter (Nov-Apr), hence the unit of days (ECMWF ERA5)

Record years highlighted



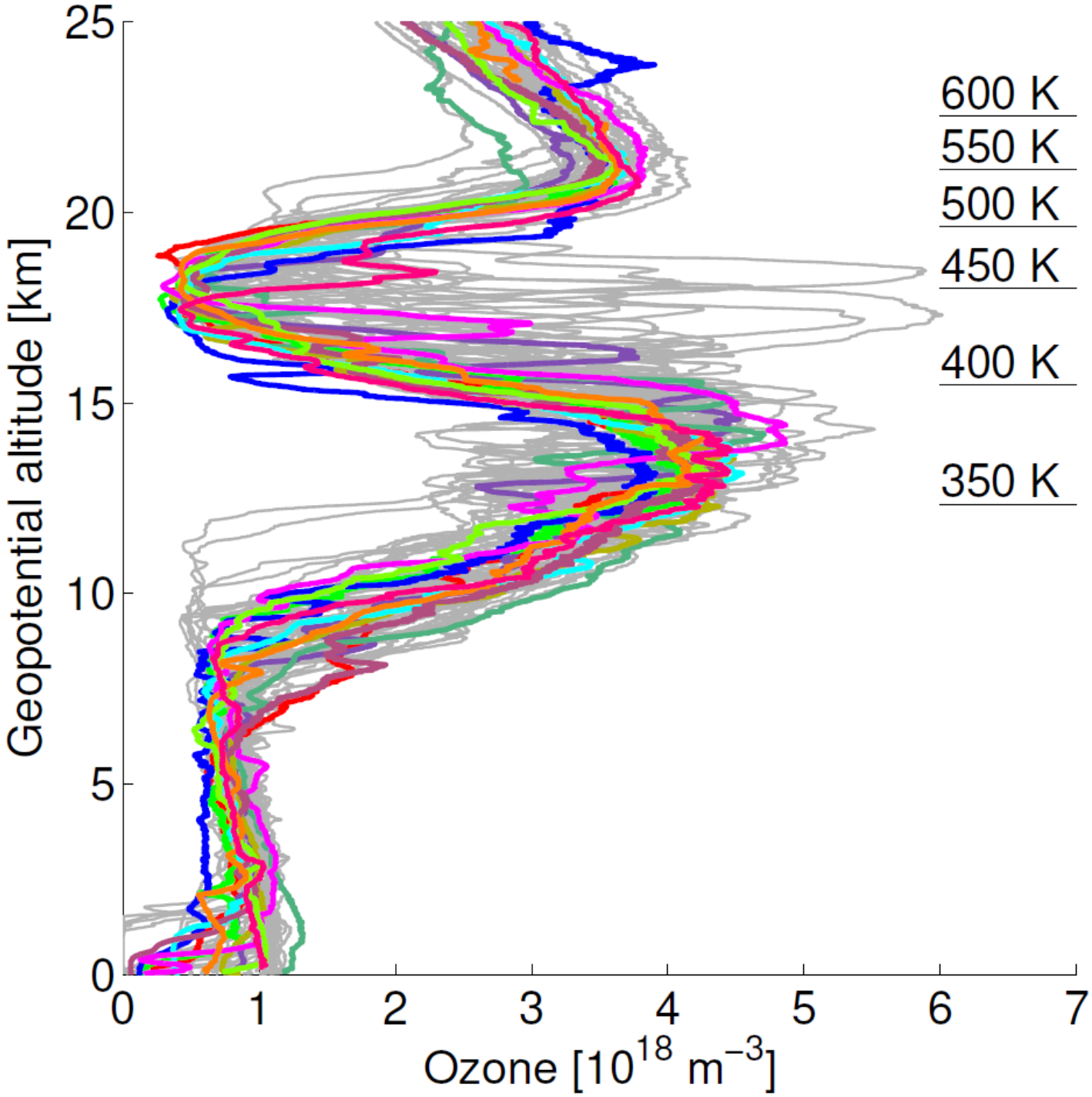
Unusually strong, long-lasting and record cold polar vortex

Minimum temperature at 475 K in polar vortex

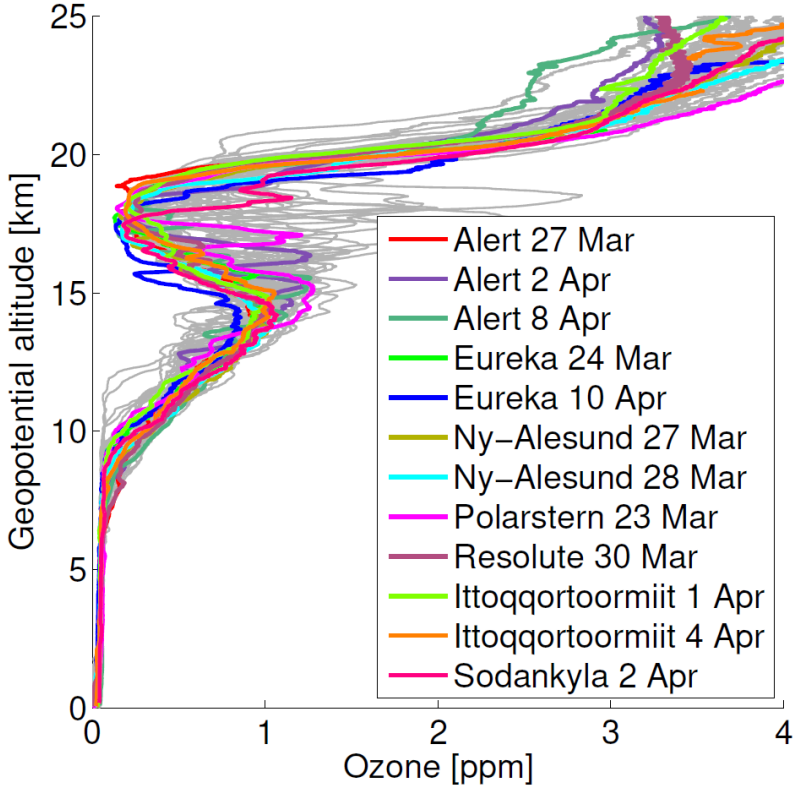


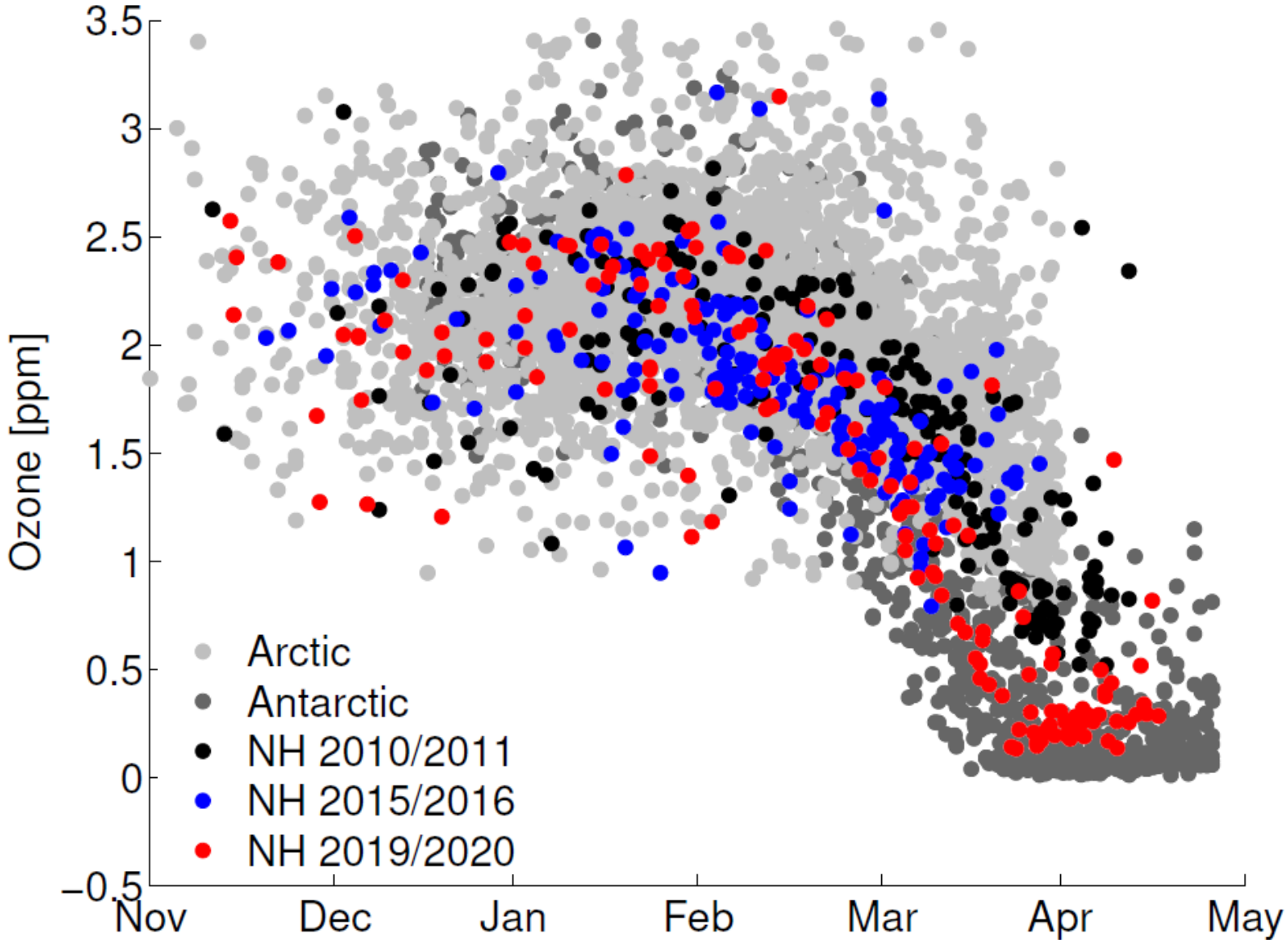
About 20% of the ozone sondes launched in vortex between 17 March and 17 April show pronounced layer highly depleted in ozone

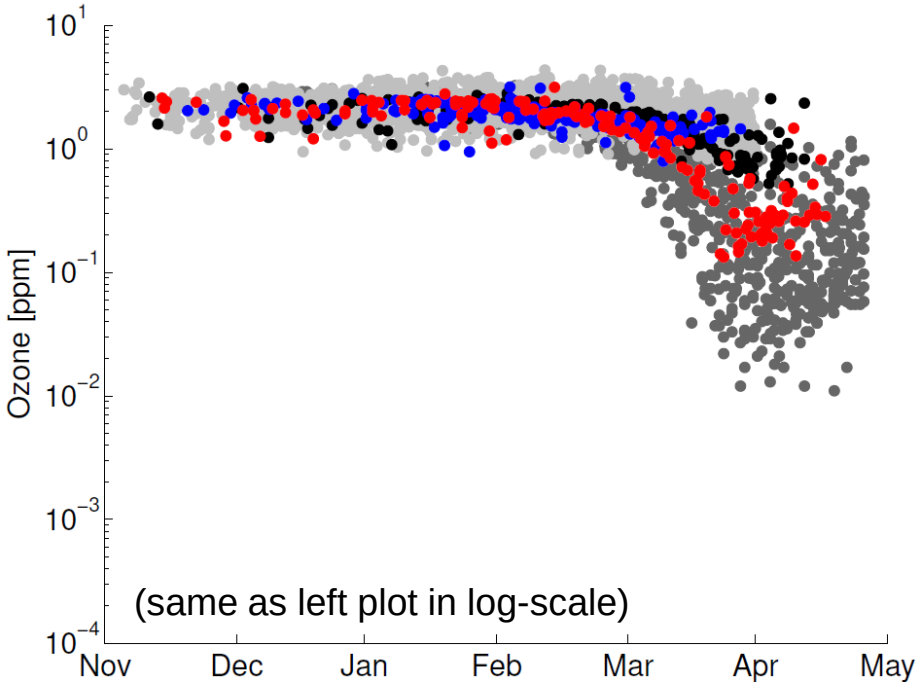
Example:
Ozone concentrations
Ozone sonde Ny-Alesund
27 March



- 12 of 52 sondes from 17 March to 17 April show less than 0.2 ppm (colored)
- Values as low as 0.13 ppm reached
- For comparison: Typical mixing ratios in Antarctic ozone hole: 0.01 ppm to 0.1 ppm

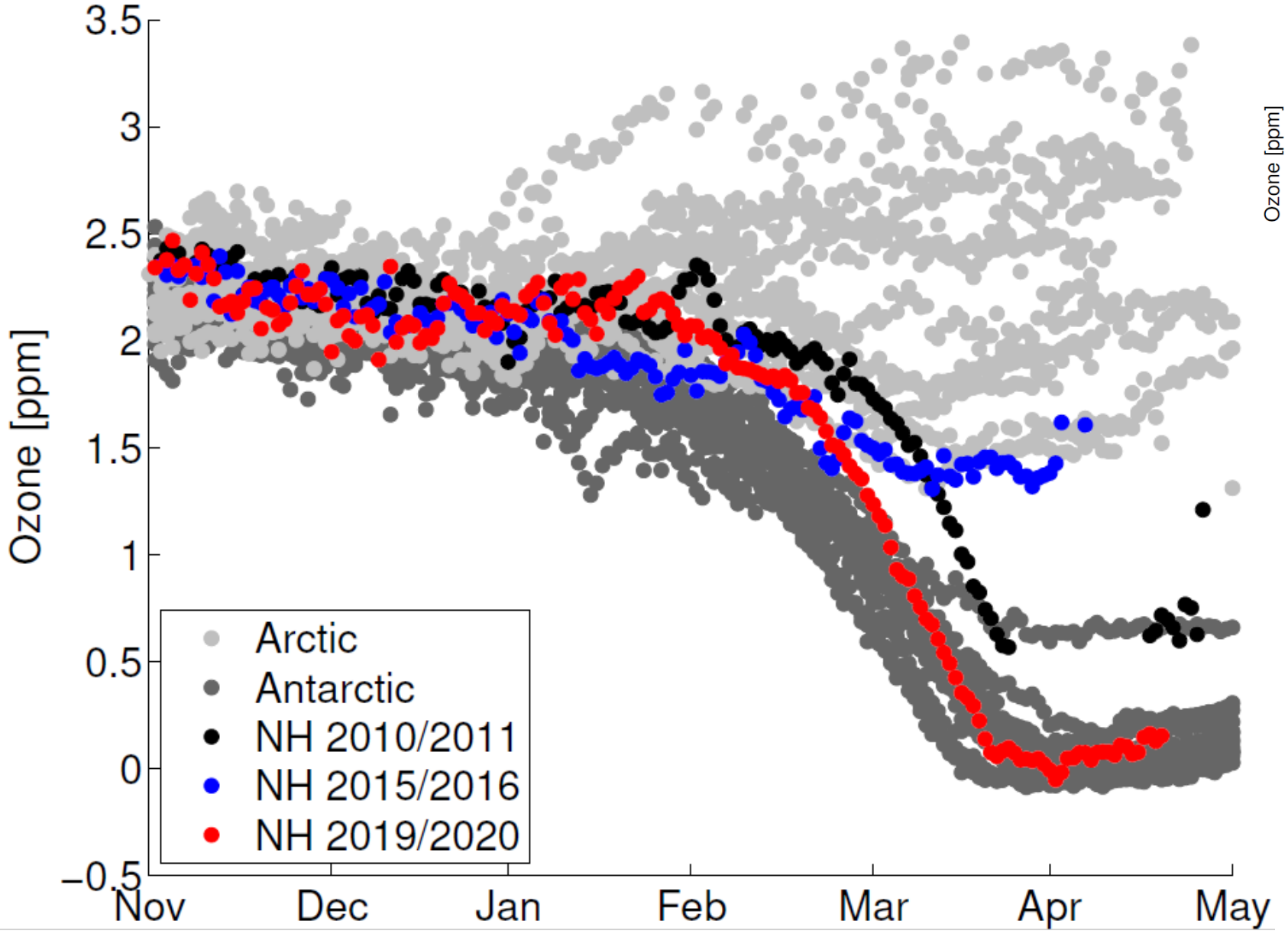


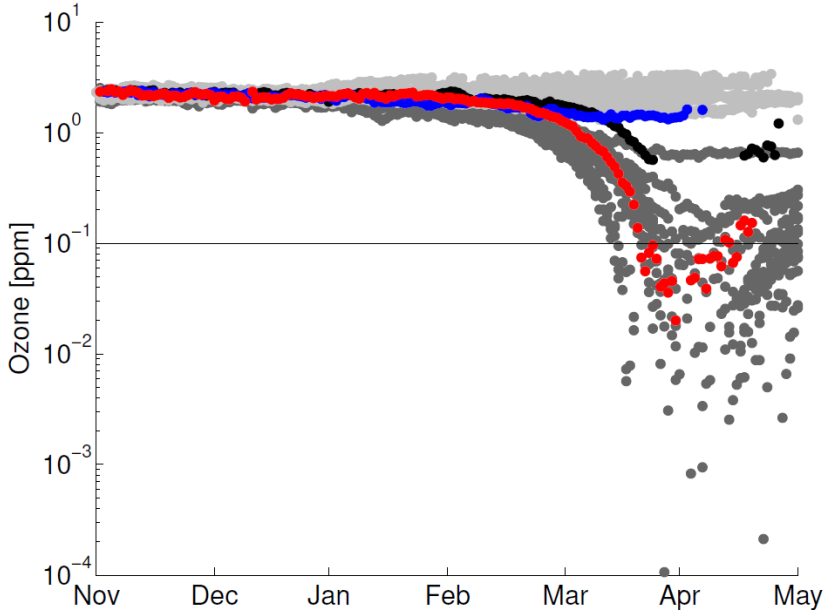




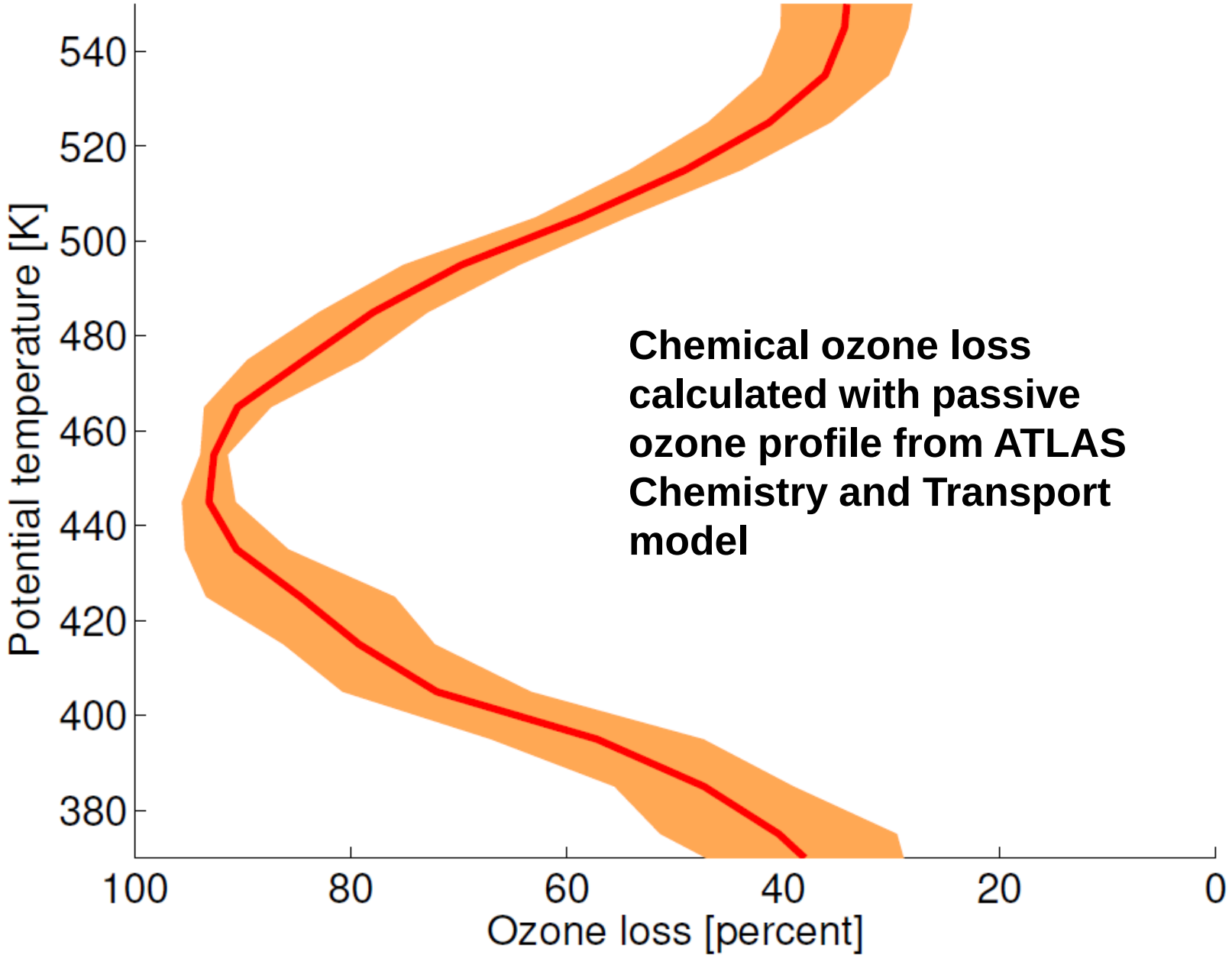
Minimum values from sondes (370-550 K) as function of season

- 2020 minima of 0.13-0.2 ppm by far lower than any minimum values observed in previous years
- Decline remarkably similar to typical evolution in Antarctic
- Former record 0.5 ppm in 2011

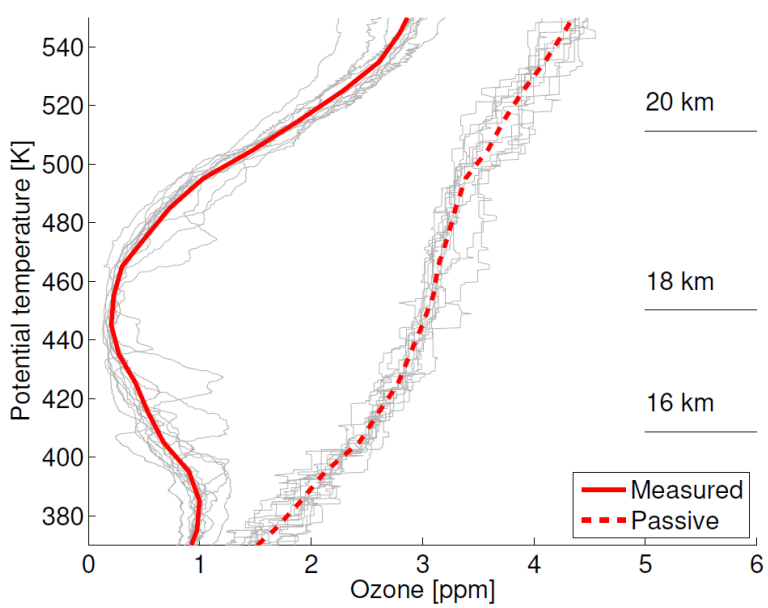




Same as last slide but with MLS satellite data



Chemical ozone loss calculated with passive ozone profile from ATLAS Chemistry and Transport model

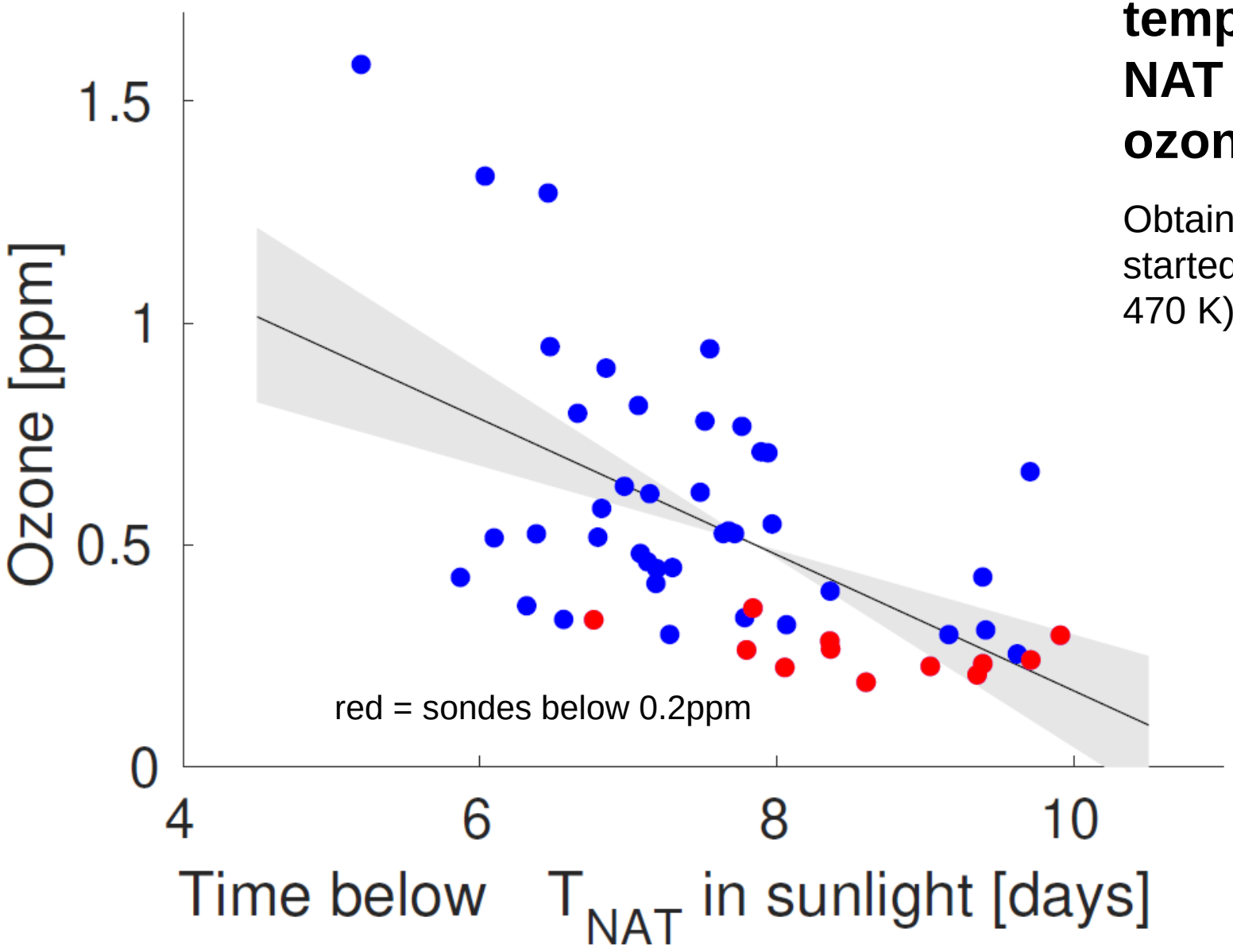


Percentage loss

- 93% average local loss over ozone sondes <0.2 ppm (2.8 ppm loss) (450 K)
- 96% maximum local loss in individual profile
- Vortex average: 73% peak loss

For comparison:

- Antarctic: 95%-99% local loss
- Arctic: <80% local loss so far



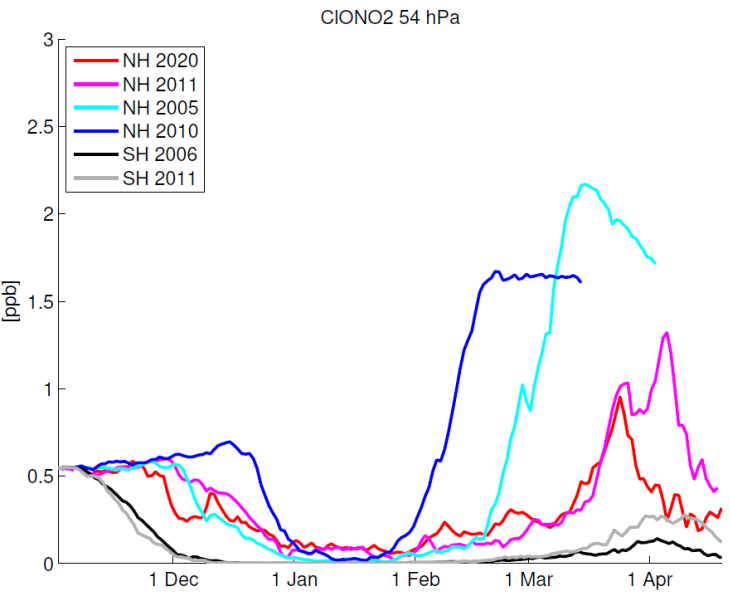
Time below the threshold temperature for formation of NAT clouds and in sunlight vs. ozone

Obtained from 4-month backward trajectories started from the measurement locations (430-470 K) for each sonde

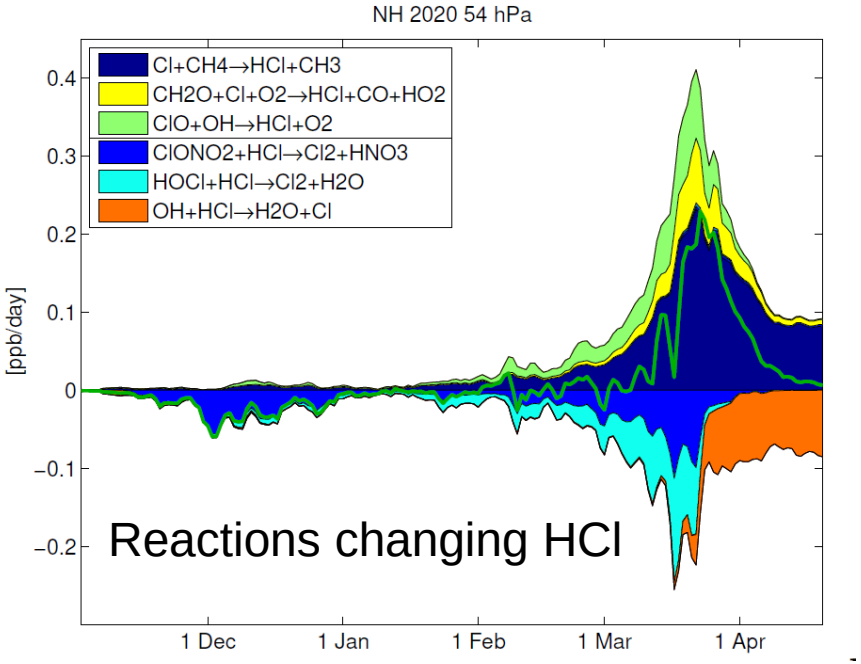
- Correlates well with ozone in spring (and ozone loss, not shown)
- **Only 28-50 additional hours below PSC threshold temperatures and in sunlight would have been necessary to reduce ozone to near zero (~0.05 ppm) locally (in the 20% of the vortex where ozone <0.2 ppm)** (by a simple extrapolation)

Some insights from ATLAS model

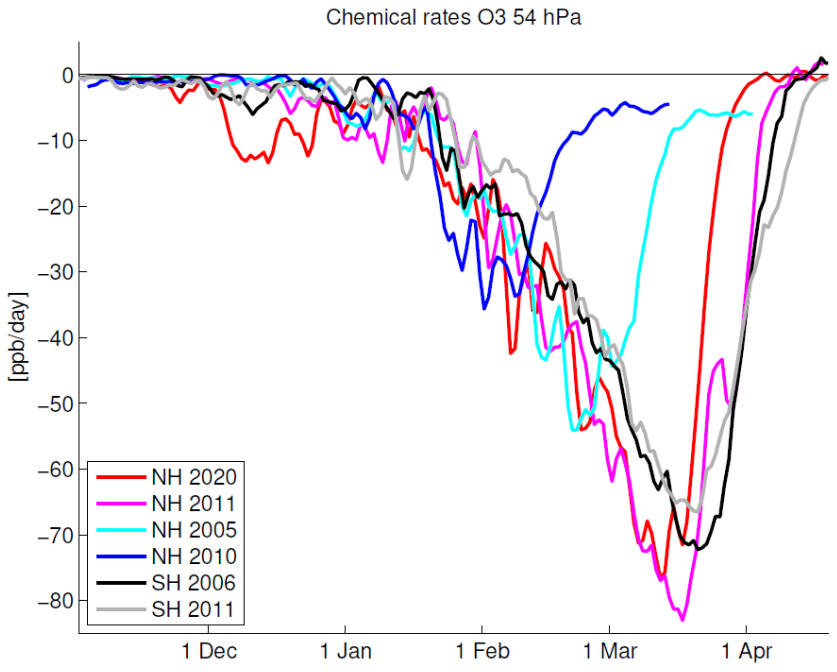
Arctic winter 2019/2020 was in the middle between typical Arctic and Antarctic conditions



Chlorine deactivation into both $ClONO_2$ and HCl (typically, into $ClONO_2$ in Arctic and into HCl in Antarctic)



Significant activation via HOCl+HCl (usually only observed in Antarctic)



Ozone depletion rates comparable to Antarctic (at 54 hPa)

Summary

Ozone

- Minimum ozone mixing ratios of 0.13-0.2 ppm observed by sondes locally in Arctic polar vortex significantly lower than in any previous year (>0.5 ppm)
- Maximum local ozone loss (96%) and minimum mixing ratios (0.13 ppm) comparable to values in Antarctic ozone hole (95%-99%, 0.01-0.1 ppm)
- Only 28-50 additional hours below PSC threshold temperatures and in sunlight would have been necessary to reduce ozone to near zero (~0.05 ppm) locally (in the 20% of the vortex where ozone <0.2 ppm)
- Vortex mean loss among largest observed, comparable to 2010/2011

Temperature

- 2019/2020 is the coldest Arctic stratospheric winter on record
- Coldest Arctic winters have been suggested to become colder in recent decades, counteracting the slow decline of ozone depleting substances in individual winters (see talk of von der Gathen et al. in this session)

A note of caution

We avoid calling the ozone depletion in 2019/2020 an Arctic ozone hole

There are still large differences compared to the Antarctic ozone hole

- Area below 220 DU in 2019/2020 is at maximum less than 5% of the typical area of the Antarctic ozone hole
- Vertical extent of minimum ozone values is much larger in Antarctic (425–485 K versus approximately 350–510 K)
- Much longer time period of low ozone values in Antarctic (several months versus at most 5 weeks in Arctic)

References

Presentation is based on:

- Wohltmann et al. (2020), Near-Complete Local Reduction of Arctic Stratospheric Ozone by Severe Chemical Loss in Spring 2020, Geophys. Res. Lett., 47, 20, doi:10.1029/2020GL089547
- Wohltmann et al. (2021), Chemical evolution of the exceptional Arctic stratospheric winter 2019/2020 compared to previous Arctic and Antarctic winters, J. Geophys. Res., in review

See also:

- von der Gathen et al. (2021) , The influence of climate change on chemical loss of ozone in the Arctic stratosphere, Nature Comm., in review
- Manney et al. (2020), Record-Low Arctic Stratospheric Ozone in 2020: MLS Observations of Chemical Processes and Comparisons With Previous Extreme Winters, doi:10.1029/2020GL089063
- … and all papers in the joint GRL/JGR special issue: “The Exceptional Arctic Polar Vortex in 2019/2020: Causes and Consequences”