QOS 2021

October 3 (Sunday) - 9 (Saturday), 2021

Online Meeting

QUADRENNIAL OZONE SYMPOSIUM

[A69] Record low ozone values observed in the Arctic in spring 2020

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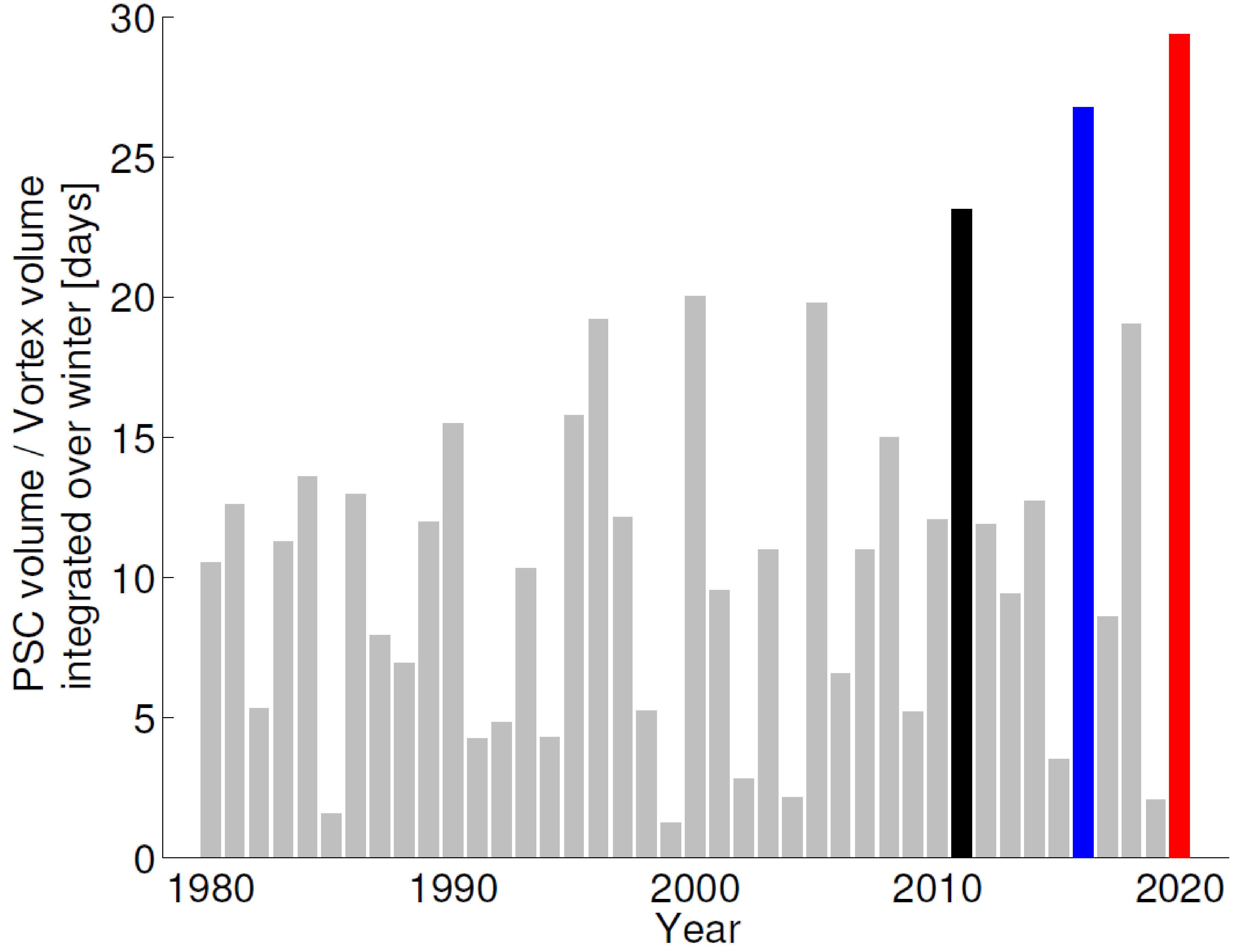
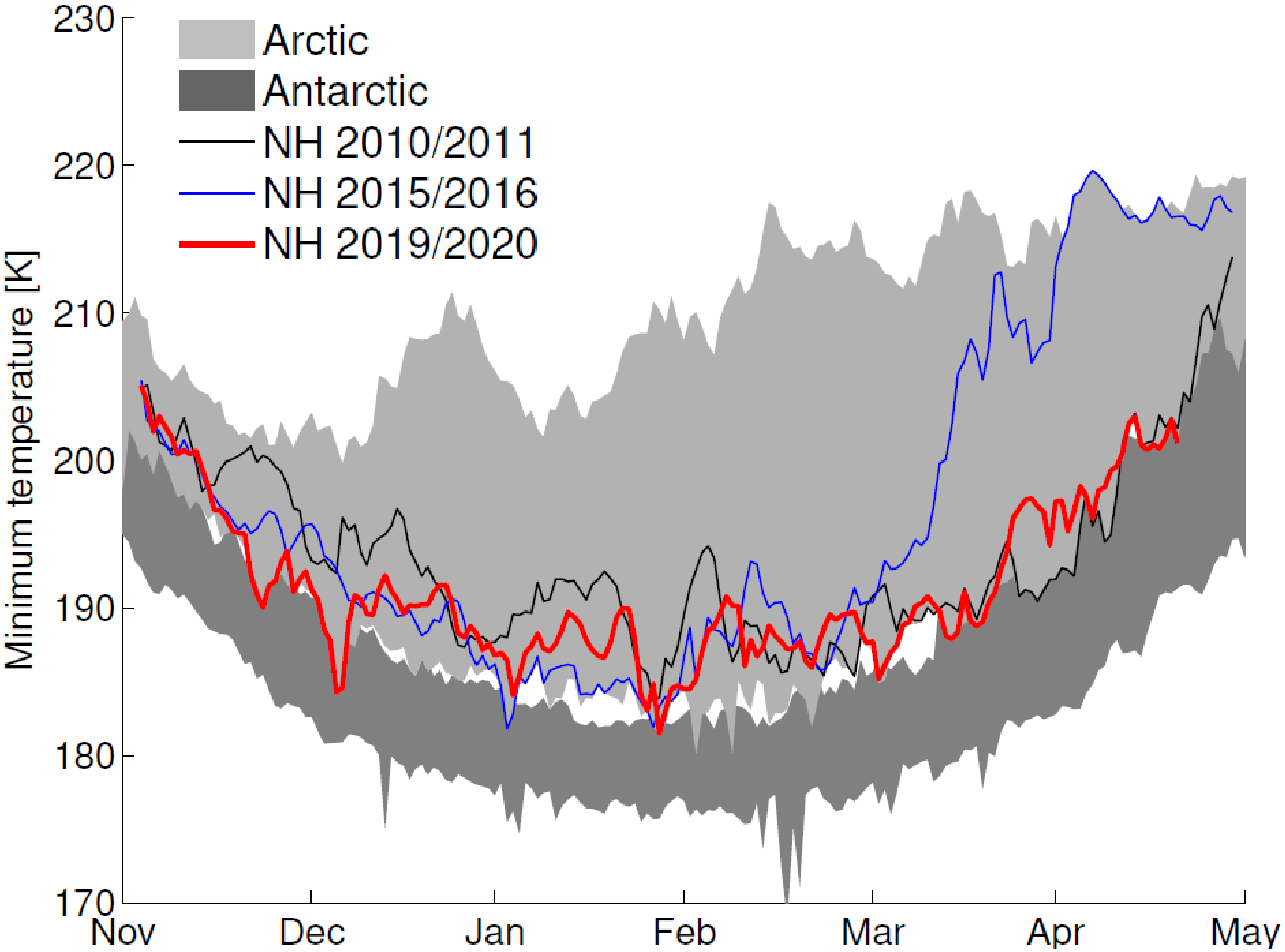


Coldest Arctic stratospheric winter since start of reliable observations in 1979

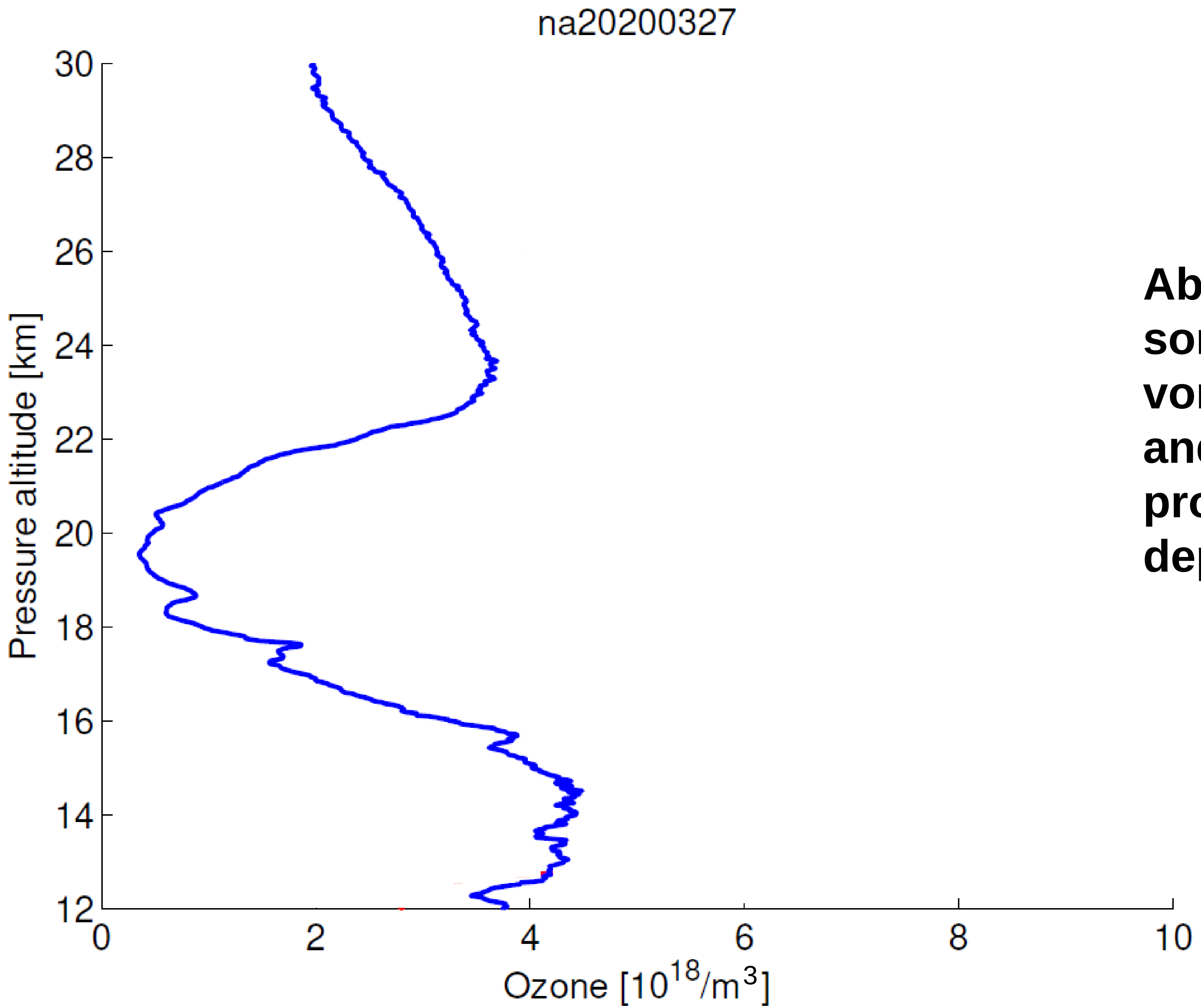
Fraction of polar vortex volume below upper temperature limit for formation of polar stratospheric clouds (NAT), integrated over winter (Nov-Apr), hence the unit of days (ECMWF ERA5)

Record years highlighted



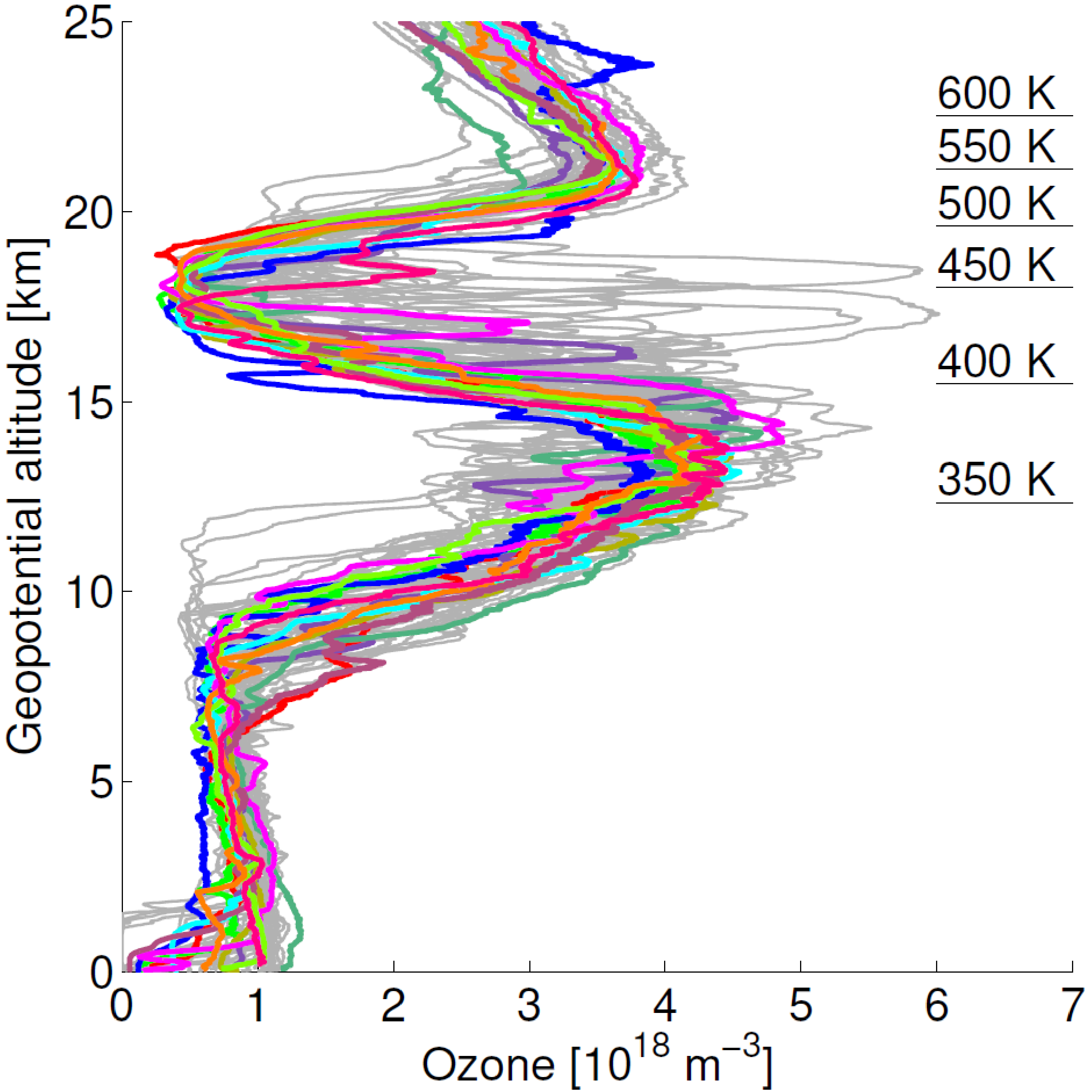
Unusually strong, long-lasting and record cold polar vortex

Minimum temperature at 475 K in polar vortex

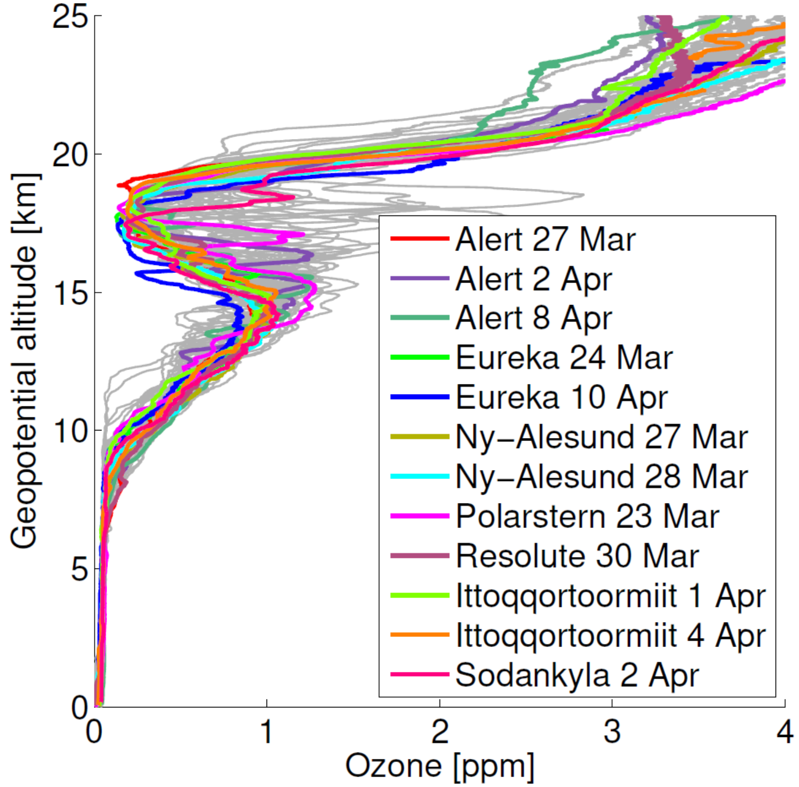


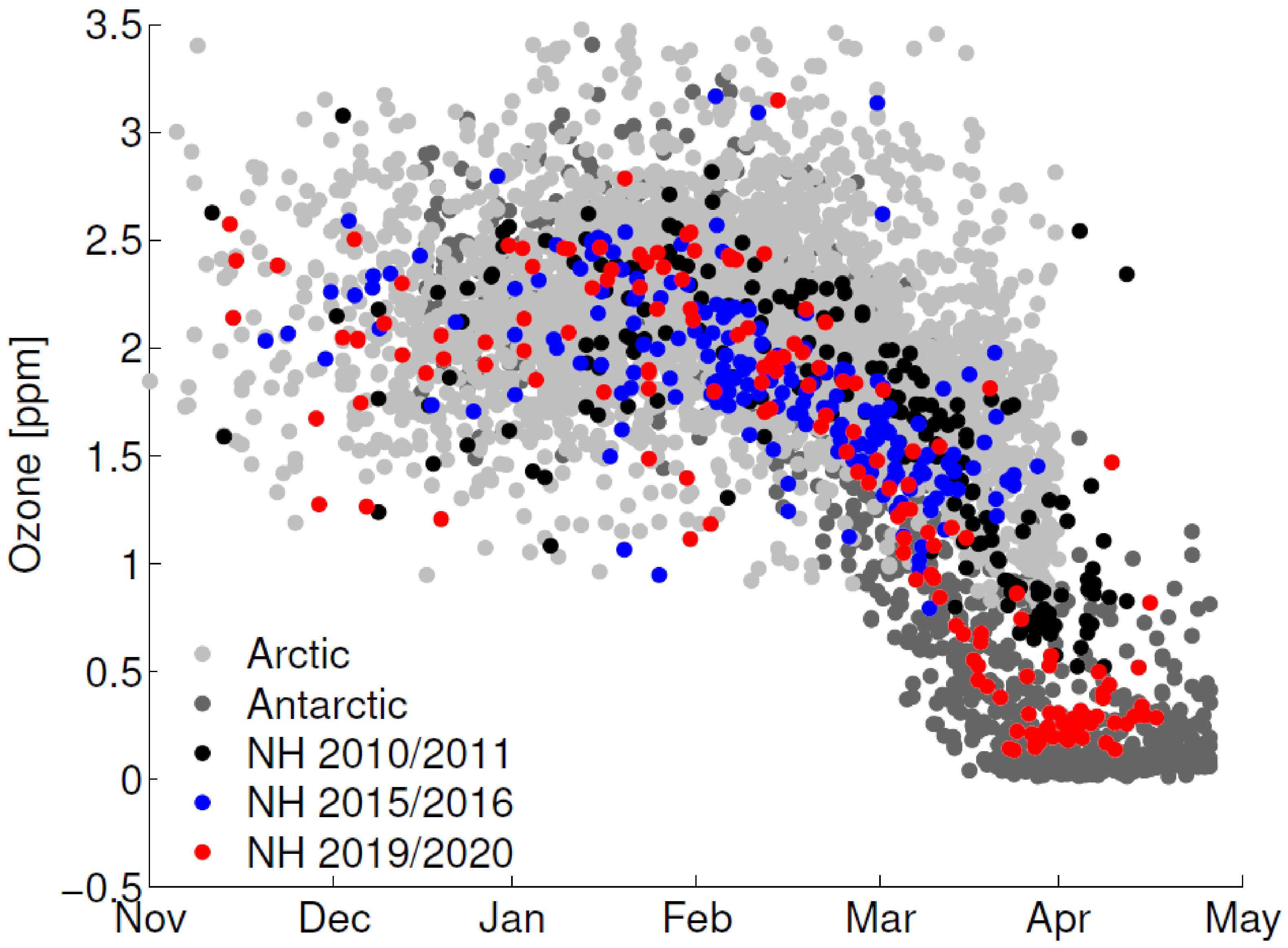
About 20% of the ozone sondes launched in vortex between 17 March and 17 April show pronounced layer highly depleted in ozone

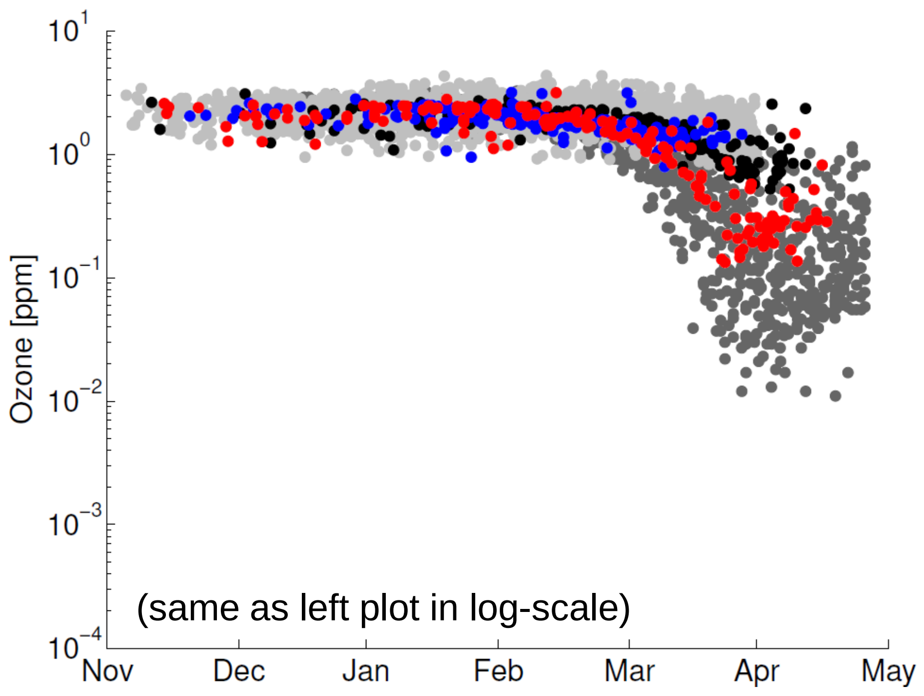
Example:
Ozone concentrations
Ozone sonde Ny-Alesund
27 March



- 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

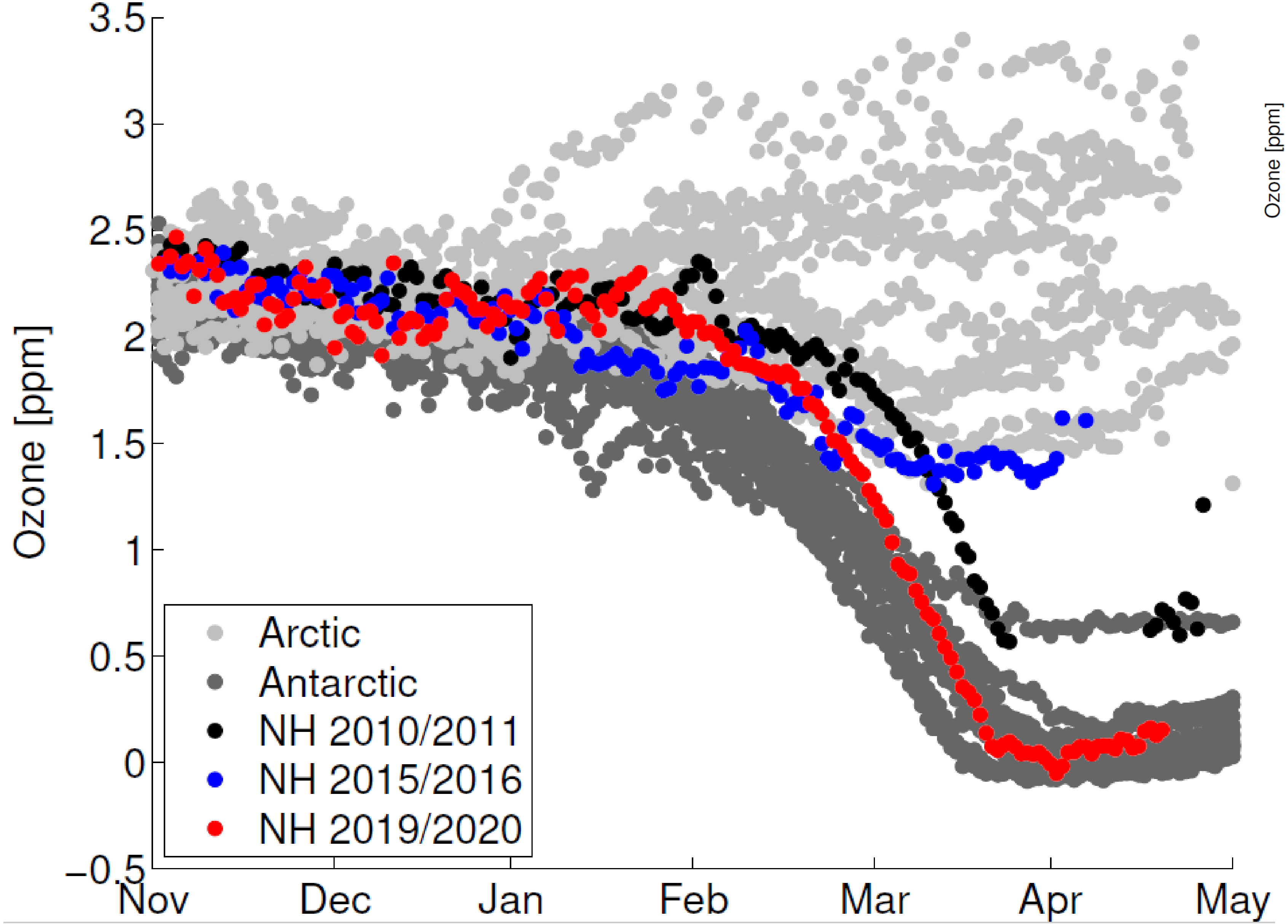


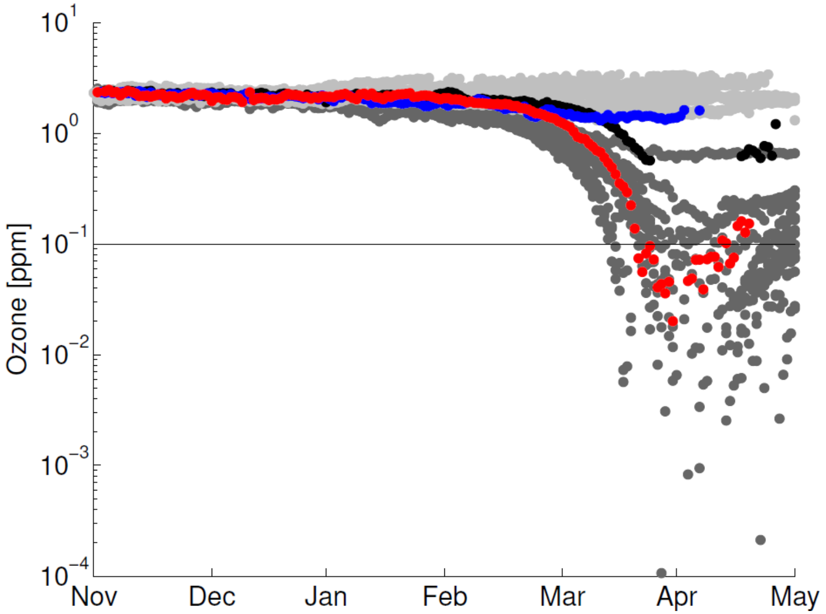




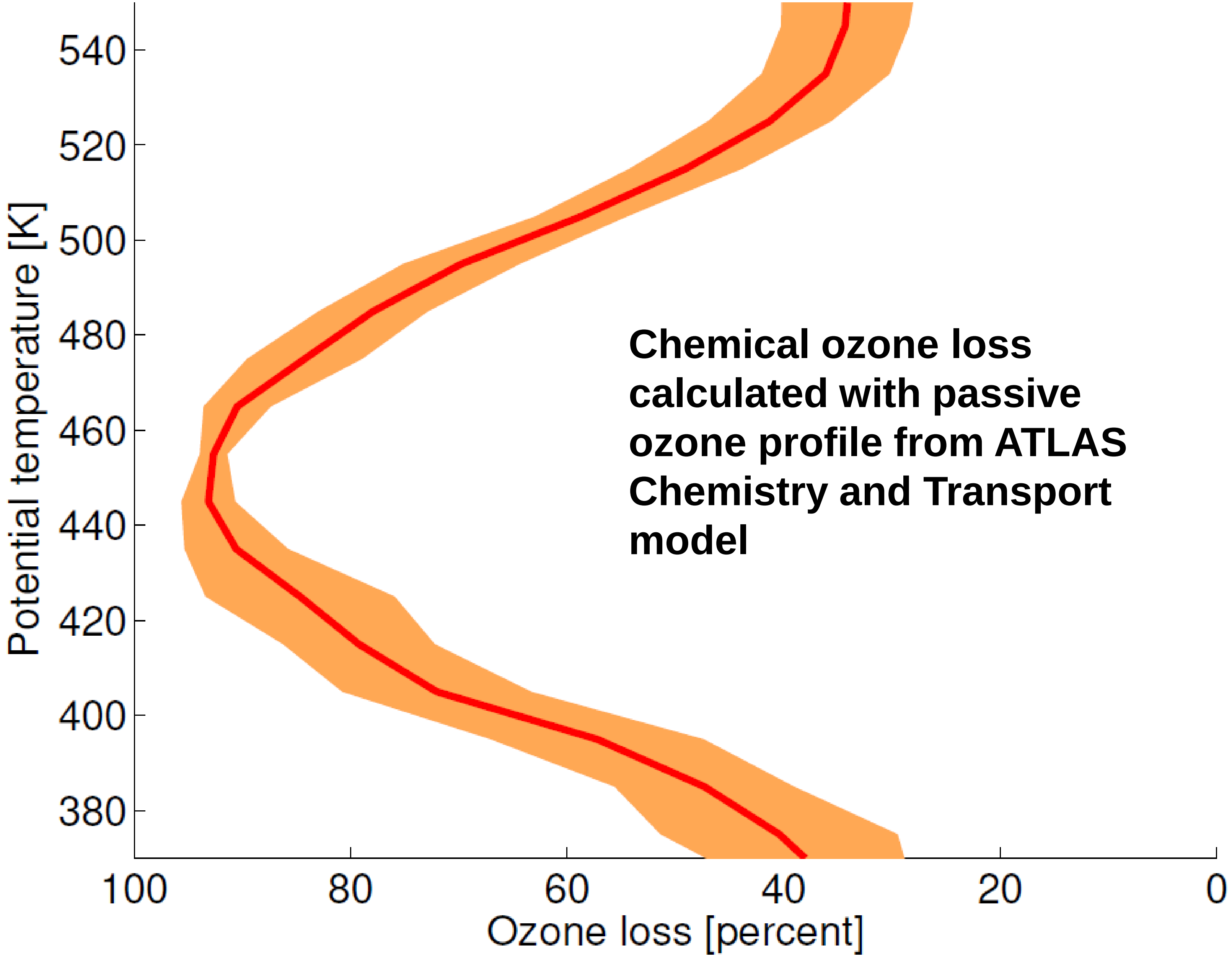
Minimum values from sondes (370-550 K) as function of season

- 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

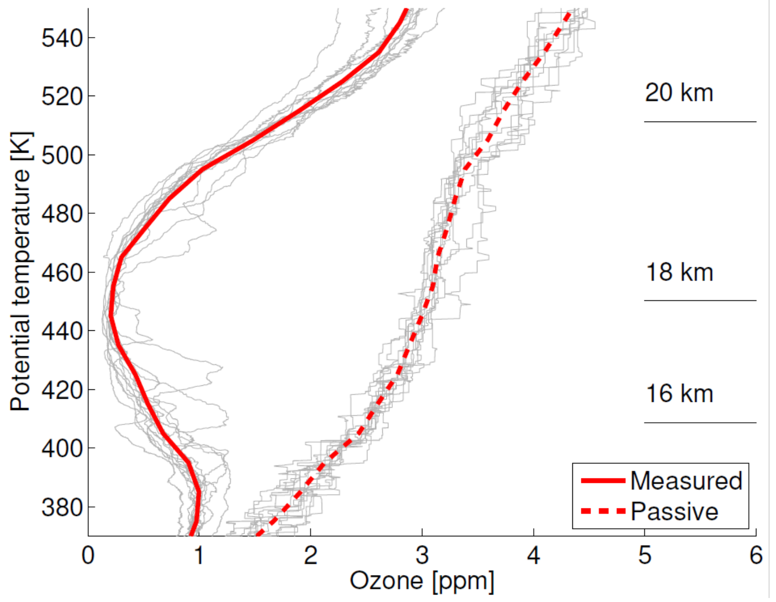




Same as last slide but with MLS satellite data



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

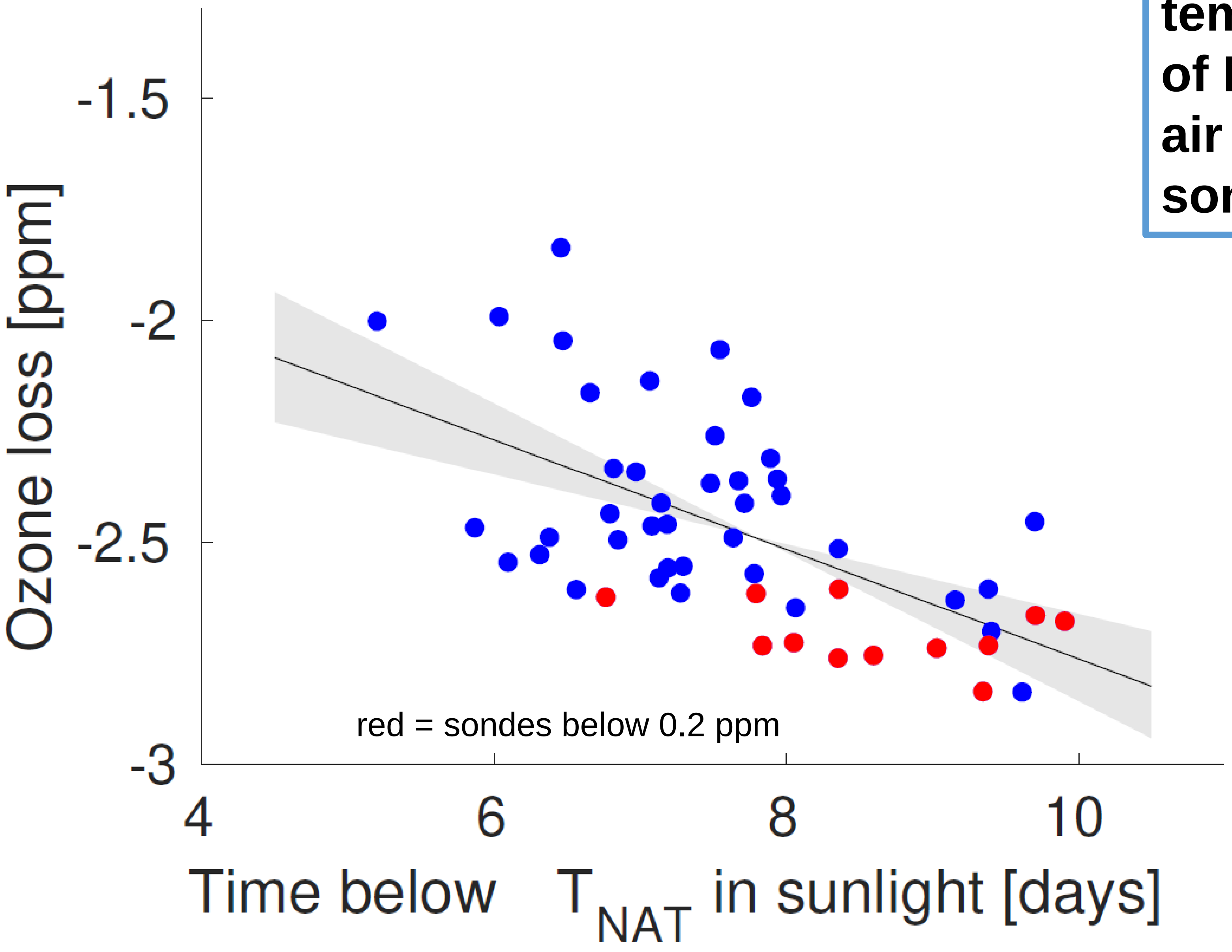


Percentage loss

- 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



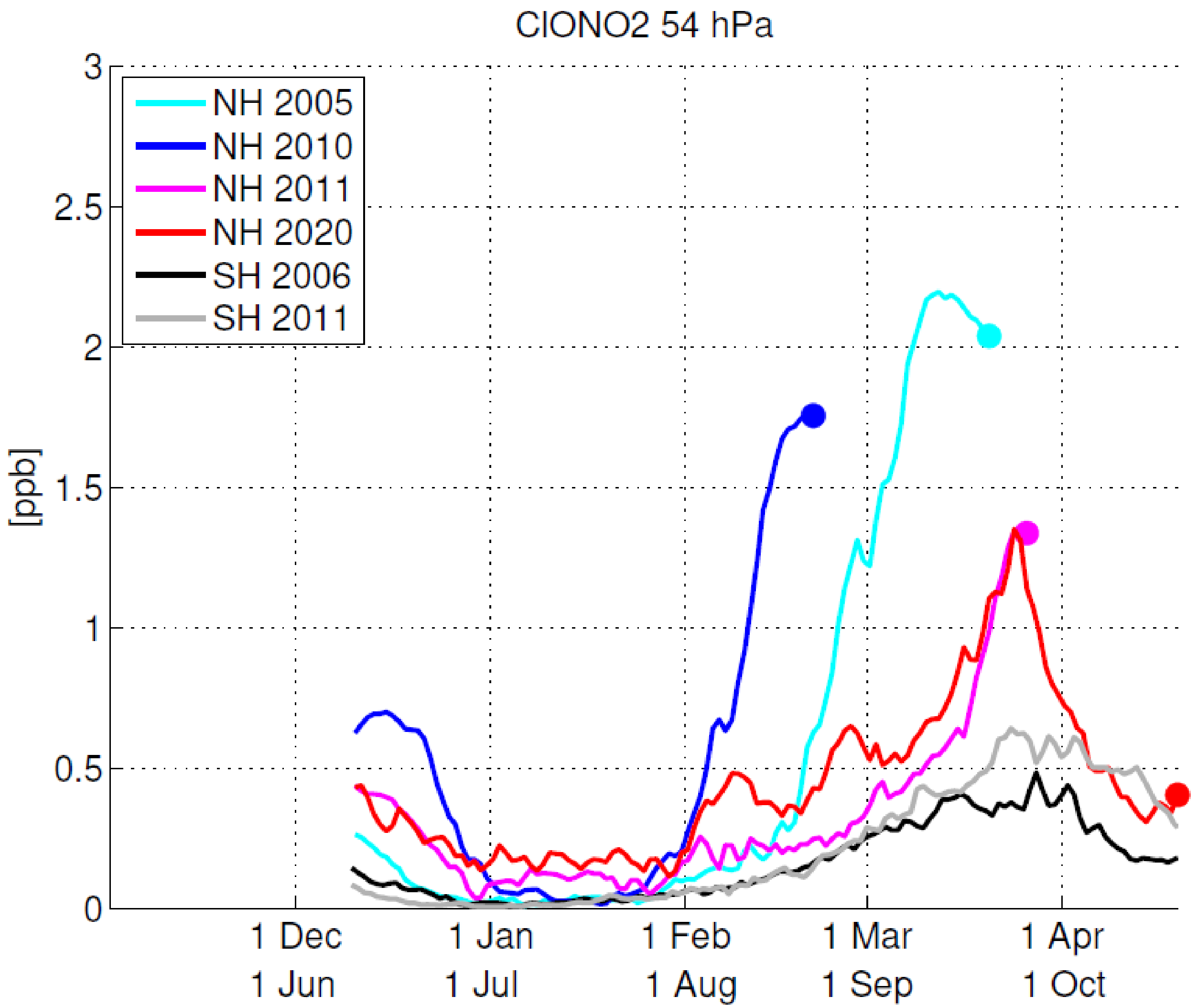
Time spent below upper temperature limit for formation of NAT clouds and in sunlight for air masses measured by sondes…

Obtained from 4-month backward trajectories started from the measurement locations (mean 430-470 K, 1 K steps) for each sonde (accumulated time periods below 90º SZA and below T_{NAT})

…and ozone loss of these sondes correlate well

Only 21-46 additional hours below T_{NAT} 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 of loss rates)

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



Chlorine deactivation into both $ClONO_2$ and HCl in 2019/2020

Typically:
Into $ClONO_2$ in Arctic
Into HCl in Antarctic

ATLAS model results:

- $ClONO_2$ mixing ratios averaged over vortex core at 54 hPa for six winters.
- Antarctic values shifted by half a year.
- Dots: Vortex breakup

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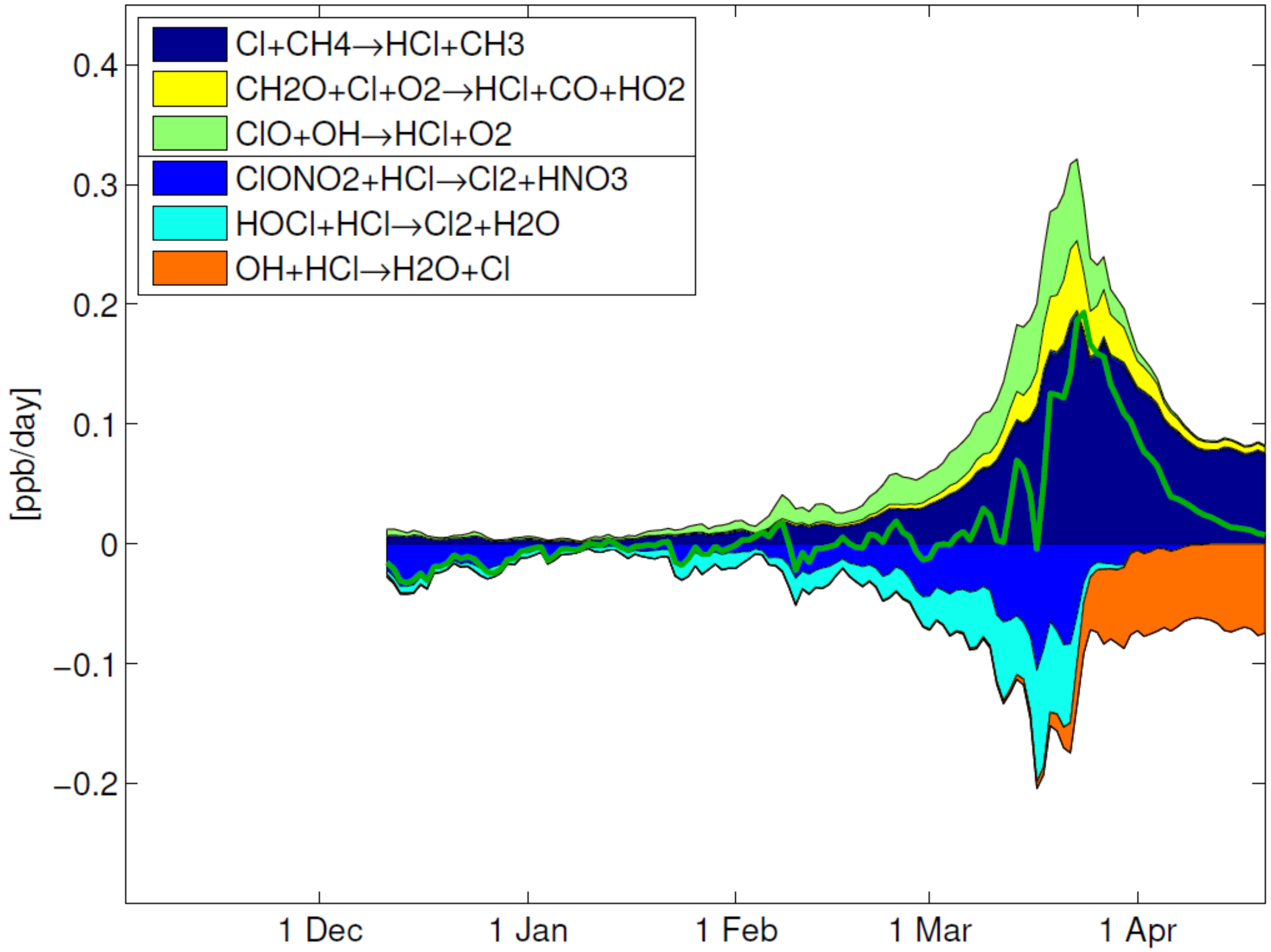


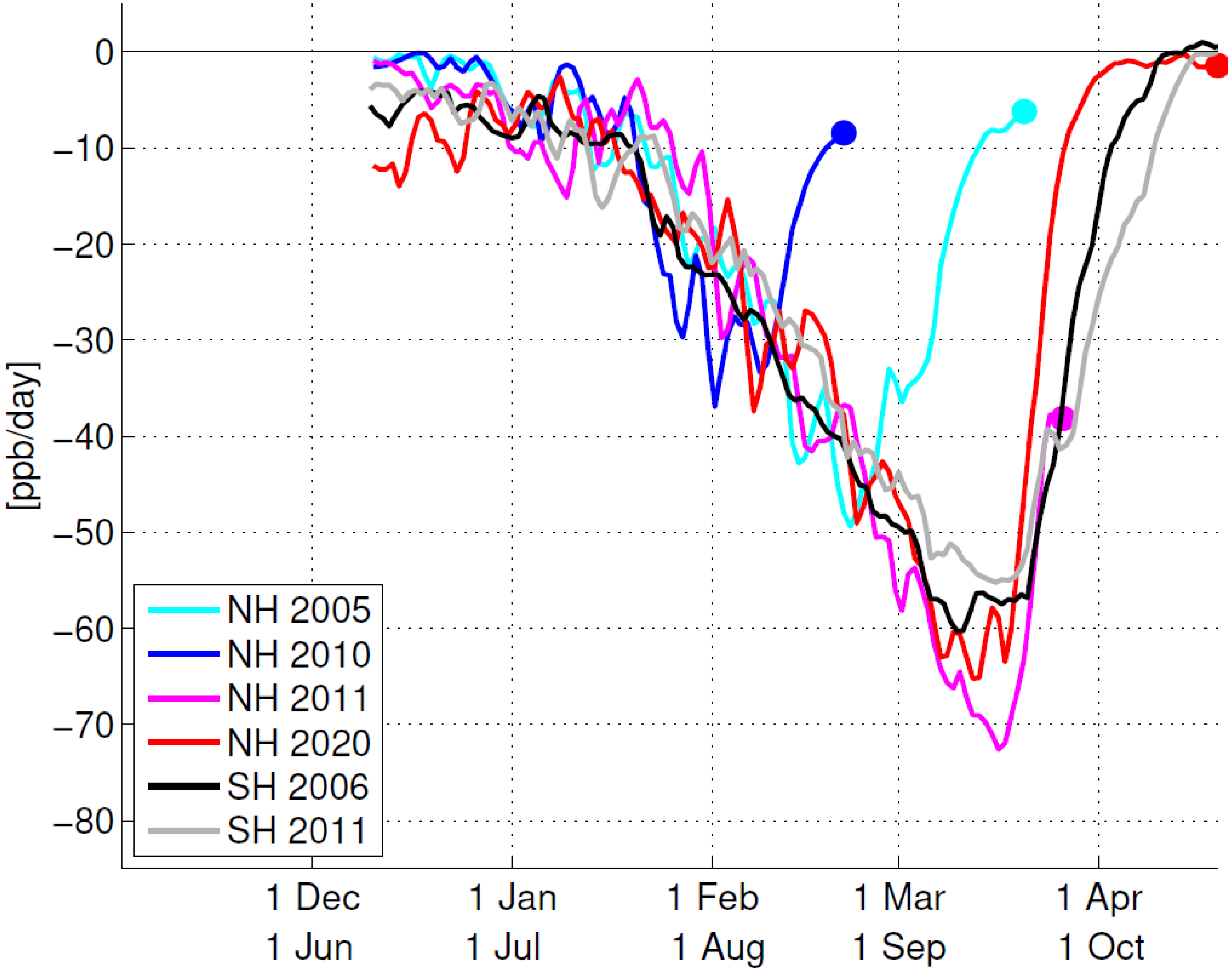
2019/2020 showed chlorine activation by HOCl+HCl in second activation phase

Normally, HOCl+HCl only significant in Antarctic

ATLAS model results:

- Reaction rates in polar vortex core at 54 hPa
- NH 2019/2020
- Reactions changing HCl
- Green line: Net HCl change

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



Ozone loss rates in 2019/2020 comparable to Antarctic loss rates at 54 hPa

ATLAS model results:

- Ozone loss rates averaged over vortex core at 54 hPa for six winters.
- Antarctic values shifted by half a year.
- Dots: Vortex breakup

Summary

- 2019/2020 is the coldest Arctic stratospheric winter on record
- 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 21-46 additional hours below upper temperature limit for PSCs 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
- Chemical evolution of the Arctic winter 2019/2020 was a hybrid between typical Arctic and typical Antarctic conditions

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., accepted

See also:

- von der Gathen et al. (2021), Climate change favours large seasonal loss of Arctic ozone, Nature Comm., 12, 3886, doi:10.1038/s41467-021-24089-6
- 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”