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Ozone loss driven by nitrogen oxides and triggered by stratospheric warmings can outweigh the effect of halogens

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Ozone loss in the lower and middle stratosphere in spring and summer, in particular over polar regions, is driven by halogens and nitrogen oxides (NOx). Whereas the stratospheric chlorine levels are expected to decrease in the future, the role of NOx for the ozone budget in a changing climate is not well quantified. Here, we combine satellite measurements and model simulations to diagnose the accumulated ozone loss during the winter and spring 2002-2003 in the Arctic polar stratosphere. The signature of the polar ozone loss shows two separate characteristic branches, one driven by halogens and one by NOx. Whereas, until beginning of March, the polar column ozone loss is mainly caused by the halogen chemistry within the vortex, the column ozone loss in March and April is dominated by the NOx chemistry in ozone-rich air masses transported from the sub-tropics and mixed with the vortex air. This NOx-related branch of ozone loss starts around mid of December 2002 in sub-tropical air masses above 30 km, moves poleward after the major warming in January, descends down to 22 km with an increasing magnitude and, finally, results in surprisingly high values of up to 50% local ozone loss around the end of April. To some extent, this loss is enhanced by mesospheric air trapped in the vortex at the begin of the winter as a layer of few km in the vertical and transported downwards within the vortex. The relative influence of NOx on the ozone budget significantly increases by extending the considered region from high to mid-latitudes. The comparison with other winters

shows that ozone loss driven by NOx may be significantly accelerated by major warmings dominated by wave-2 when ozone- and NOx-rich air masses from the sub-tropics are transported poleward and mixed with the vortex air.