EGU22-6083, updated on 14 Aug 2022
https://doi.org/10.5194/egusphere-egu22-6083
EGU General Assembly 2022

Investigation of the Ozone Enhancement during the 2019 Sudden Stratospheric Warming in the Southern Hemisphere

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Sudden stratospheric warmings (SSWs) are dynamic events associated with the rise in stratospheric temperature and the reversal in zonal mean zonal winds. SSWs are driven by large-scale planetary waves that propagate to the stratosphere. These large-scale waves are produced in regions of variable topography such as mountains or due to temperature differences at the warm ocean - cold landmass interfaces. The breaking of the planetary waves propagated to the stratosphere leads to the deceleration and perturbation of the polar vortex circulation, resulting in the sudden increase in polar stratospheric temperature. Due to the highly variable nature of the topography, the northern hemispheric polar vortex is more disturbed by planetary waves than the southern hemisphere. Far more stable winters are seen in the southern hemisphere, with the Antarctic polar vortex in concentric alignment with the south pole terminator.

Despite the usual stability of the southern hemisphere and the infrequency of SSW events, the dynamic event of 2019 was rare and strong, following the likes of the 2002 southern hemispheric SSW. The 2019 SSW event occurred around 29 August and spanned close to three weeks, increasing stratospheric temperature and O_3 (ozone) concentration. In this study, we investigate the impacts of the 2019 SSW on the stratosphere using the Solar Occultation for Ice Experiment (SOFIE) instrument onboard the Aeronomy of Ice in the Mesosphere (AIM) spacecraft and other measurements.

SOFIE uses solar occultation to measure solar energy passing through the limb of the earth's atmosphere at sunrise and sunset. Measurements are typically made at high latitudes (65^o-85^o N/S) with a vertical field-of-view of ~ 1.6 km covering wavelengths from 0.29 to 5.26 microns. Temperature measurements from SOFIE in 2019 indicate that the average stratospheric temperature during mid-September was higher than in the past years in the 20-30 km altitude range, attributed to the exceptional meteorology during August and September.

In the springtime, stratospheric O_3 depletion occurs when polar stratospheric clouds (PSCs) convert halogen reservoir species into O_3-destroying reactive forms. The sharp increase in stratospheric temperature during SSWs evaporates PSCs and prevents halogen activation, thus, inhibiting O_3 destruction. PSCs are composed of HNO_3 (nitric acid) and H_2O (water). HNO_3 is formed by water reacting with NO_2 (nitrogen dioxide), formed by the oxidization of NO (nitric oxide). Thus, using NO and H_2O (from SOFIE) as proxies for HNO_3, we deduce that both species were higher in 2019 after the SSW than past years' average during the same period. This indicates a lesser loss of HNO_3 to PSCs through denitrification. Consequentially, SOFIE O_3 in 2019 (August – mid-October) is significantly higher than the past years' average, indicating a smaller O_3 hole, also reported by NASA O_3 watch (for 7 September- 13 October).

This study investigates the 2019 Antarctic O_3 enhancement and analyzes the underlying chemistry and mechanism using SOFIE and other measurements.