Abstract

Ozone is a significant trace gas in the atmosphere that is primarily found in the stratosphere. However, measurements from the ground and space spotted a great depression in ozone in the Antarctic stratosphere in late 1970s; the ozone hole. The loss continued and made a situation of saturation in loss of the ozone there by late 1980s, which resulted in the enactment of an international treaty, the Montreal Protocol. Due to the decrease in stratospheric chlorine by the implementation of the Protocol, Antarctic ozone has showed signs of recovery after 2000. On the other hand, the ozone in the troposphere is a pollutant, which has serious climate and health implications.

This study demonstrates the application of a state-of-the-art causal discovery framework based on a deep temporal convolutional network for identifying the drivers of surface ozone and tropospheric ozone variability in Antarctica. The study reveals overarching influence of the stratosphere on surface ozone variability in Antarctica, buttressed by the southern annular mode and tropospheric wave forcing in mid-latitudes. The analysis using receptor models based on backward trajectories identifies the Antarctic Plateau as the most dominant source region especially in the summer season for near-surface ozone, complemented by long-range transport from the southern South American in the lower troposphere. Transport from the stratosphere also contributes significantly to the tropospheric ozone. Furthermore, the ozonesonde measurements show an increasing trend in the lower and middle troposphere, but a decreasing trend in the upper troposphere. The increasing trend is significant even after accounting for natural variability arising from intra- and inter-annual processes; suggesting rising ozone concentrations in Antarctica and is a serious environmental problem.

A number of studies have already reported the early signs of the healing of ozone hole. However, there has not been any study reporting the healing in saturation layers. Ozone loss saturation layers are the atmospheric layers in the lower stratosphere (13–21 km) where the complete destruction of ozone occurs. The study of long-term evolution of ozone in loss saturation layers shows that the ozone is increasing and recovering at these altitudes. In addition, the chemistry transport model based analysis of ozone loss in Antarctica shows that both dynamics and chemistry play very important roles in the ozone loss process in there. The disappearance of near-zero ozone concentrations between 12 and 21 km is a key milestone in the recovery of Antarctic ozone. Since there are already significant changes in the southern hemispheric climate owing to the Antarctic ozone loss, the recovery from loss saturation is very likely to affect that. The recovery indicated in the loss saturation layer robustly suggests that the Montreal Protocol has definitely saved the ozone layer and climate of the southern hemisphere. However, the saturation of ozone loss is expected to continue to occur in very cold winters due to the still high levels of ODSs in the stratosphere, as the reduction processes of atmospheric halogens are comparatively slow.

Keywords: Antarctica, Tropospheric Ozone, Multiple Linear Regression, Causal Discovery, Loss Saturation, Chemistry Transport Model