Comment on “Effects of Cosmic Rays on Atmospheric Chlorofluorocarbon Dissociation and Ozone Depletion”

In a recent letter [1], the authors propose a new pathway contributing to the atmospheric ozone ($O_3$) depletion. In this comment, we point out that this study has ignored some of the current understanding of the $O_3$ budget. We argue that the proposed pathway is not a major contributor to $O_3$ loss.

The work in [1] presents results based on the correlations observed between cosmic ray intensity and $O_3$ loss in various space-time regions. The peak $O_3$ loss at both the altitude and latitude regions as well as total column $O_3$ trends are fairly well understood based on the variations in solar irradiance due to 11 year solar cycle, abundance of halocarbons (e.g. CFCs), greenhouse gases and the polar stratospheric clouds (PSCs) [2]. Some studies also show that $O_3$, at around 18 km height over 75°N, would increase during sudden cosmic ray bursts called solar proton events [3].

In this study [1] the authors have not considered the $O_3$ loss and cosmic ray intensity change beyond one 11-year solar cycle when the correlation starts to disappear. In Fig 1, we plot the $O_3$ loss against the sunspot numbers (anti-correlated with cosmic ray intensity). It does not reveal the correlation reported by the authors. A plot like Fig. 3 of [1] for an extended period beyond a solar cycle would look different. The ‘suggested correlation’ between cosmic ray intensity and $O_3$ loss rate during 1981-1991 tends to alter in the adjacent solar cycles, namely 1970-1981 and 1991-present. Further, the El Chichon volcanic eruption in 1982 injected several megatons of sulphur gases into the stratosphere that led to manifold increase of PSC formation a couple of years later. The role of PSCs is to trigger ClOx formation from their non-rective reservoir species [2], resulting in an enhanced $O_3$ depletion. This suggests that the covariation of cosmic rays and $O_3$ loss with time is only a case of statistical correlation. Infact, the decrease in cosmic ray intensity near the ground is shown to be tightly correlated to the global cloud cloud cover below 3 km (ref.3 of of [1]).

The authors suggest that the differences in the CFC-12 distribution between the early spring Antarctic stratosphere (i.e. September) and the fall (i.e. March) could be related...
to cosmic radiation and PSCs in the winter polar stratosphere. However, such seasonal
differences in the CFC-12 distribution is known to be primarily caused by the changes in the
stratospheric mean circulation [4]. The stratosphere experiences downward transport in the
winter hemisphere bringing the CFC depleted air from higher altitudes, whereas the rapid
cross-isentropic mixing in the summer hemisphere supplies more CFCs to the higher altitude
and latitude. One could visualise this effect as a gradual decrease in CFC-12 concentration
from equator to the poles, like a bell shape. This bell shape projects upward in the summer
hemisphere.

Finally, the lifetime of CFC-12 and CFC-11, physisorbed on the PSCs, estimated to be about 6.5 and
FIGURES

FIG. 1. Trends in total column O$_3$, from two longest serving stations in northern (Arosa; 46.8°N, 9.6°E; circle) and southern (Halley Bay; 75.5°S, 26.5°W; triangle) hemisphere, are plotted along with sunspot number (dashed line). The trends are calculated with respect to 1979 O$_3$ value. Loss rates for Halley Bay are multiplied by $\frac{1}{2}$ to fit in the plot.

0.8 hrs respectively, provides a clue to the relative importance of the suggested pathway for O$_3$ loss in the overall O$_3$ depletion budget. The estimated lifetimes would leave no trace of CFCs on PSCs in the winter lower stratosphere. The winter vortex isolates the pole from source of CFCs (i.e. low latitude) and within the vortex downward transport brings in CFC depleted air [5]. In the source region, i.e. tropical stratosphere, CFC-12 and CFC-11, with the estimated lifetime of the order of 10 days at around 40 km altitude, show vanishing concentration of these gases ($\sim$ a few parts per trillon) [6]. As the authors point out, the Cl yield depends on CFCs and H$_2$O concentration. Thus, we believe that the cosmic ray induced CFC dissociation on the PSCs cannot play a significant role in O$_3$ depletion.

The O$_3$ data from Arosa [5] (www.umnw.ethz.ch) and Halley Bay [7] (www.nerc-bas.ac.uk), and the sunspot numbers (www.ngdc.noaa.gov) can be obtained from the worldwide web.

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REFERENCES


Fig. 1 (reply): Diagram showing trends of O3 over Halley Bay and Arosa. Though the data appear noisy in the Fig. 1 of comment, the salient features of Fig. 3 in Lu and Sanche is captured. The O3 level over a particular location depends on trace gas concentration, stratospheric temperature, and strength of polar vortex. The observed trends at Halley Bay (75 S) are much larger compared to TOMS observed, because the Halley Bay is situated deep inside the polar vortex.