Analysis of Ozone and Meteorological Balloon Profile Data from Summit, Greenland

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ABSTRACT

Ozone is an important atmospheric gas that has positive and negatives effects on the Earth System. Recent studies have demonstrated that the total amount of ozone in the troposphere has increased by 36% since 1750. These changes are of concern because tropospheric ozone is a toxic or dangerous gas to breathe and it has been recognized that increased tropospheric ozone causes crop losses in agriculture. In order to get a better understanding of the global tropospheric ozone budget, especially about the sources and sinks that control the quantity of this gas, we investigated processes that control the depletion of ozone at the Earth’s surface. In this research, meteorological conditions were analyzed that may affect ozone concentration. We used vertical profile data generated in 3D contour maps using IDL (Interactive Data Language) software. The data were obtained at Summit, Greenland. This site has a flat topography with year-round snow cover. It experiences periods of extreme cold temperatures and 24 hours of darkness during winter. During the period of spring sunrise, chemicals accumulated in the snow are photochemically activated and changes in surface-atmosphere trace gas fluxes are observed. The 3D contour maps developed in this project are used to decipher meteorological changes and air transport, which is an important tool to reveal diurnal and seasonal controls of ozone transport, photochemical formation and surface deposition at Summit.

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INTRODUCTION

Ozone is an important atmospheric gas that has positive and negative effects on every aspect of the human activity. Its concentration is very low, typically in the tens parts-per-billion (ppb) range in the lower troposphere. However, the total amount of ozone in the troposphere is estimated to have increased by 36% since 1750 (IPCC 2001), making it a toxic or dangerous gas to breathe and also causes problems to agriculture. Ozone concentrations are significantly higher in the stratosphere, where it works as a protecting layer, which in normal conditions is crucial for life by its action in the absorption of short wavelength radiation, specific the ultraviolet range.

There are three main reasons to study ozone. First, the recent discovery of the ozone hole in the polar stratosphere, as a result of industrial chlorofluorocarbon emissions (Crutzen and Lelieveld, 2001), has stimulated scientists. Second, ozone is the third most important greenhouse gas present in both the stratosphere and troposphere (IPCC 2001) where methane (CH₄) and carbon dioxide (CO₂) are the principal components. This order was established by the relative percent contribution of each one in the well-mixed greenhouse gases: 52.5% of CO₂, 17.3% of CH₄, and 12.5% of O₃ (IPCC 2001). The halocarbons, with a 12.2%, and nitrous oxide, with a 5.4%, (ICPP 2001) complete the group. Third, ozone presents a dangerous and harmful environment not only for vegetation, as for example forest trees on its carbon metabolism (Dizengremel, 2001), but also for humans (Kim et al., 2001).

Several studies around the world have looked for the sources and sinks that control the quantity of ozone to get a better understanding of the global tropospheric ozone budget. However, none of these studies were made in the Arctic region. Summit, Greenland presents extreme conditions for studying the ozone budget. It has flat and snow covered topography and its location within the Arctic circle, which is delimited by 68° N latitude. This means that during winter there are extended periods of darkness. During these dark periods, the deposition and accumulation of trace gases from the atmosphere into the snow is observed. Meanwhile in spring, when there are extended periods of sunlight, the accumulated chemicals are photochemically activated and changes in surface-atmosphere trace gas fluxes are observed.

METHODOLOGY

Particular ozone fluxes, temperature, wind speed, wind direction, and relative humidity were studied during June 2000 at Summit, Greenland, by vertical profiling from a tethered balloon. Only three of the parameters were analyzed in this study due to the time factor. Wind direction, wind speed, and potential temperature were analyzed because they are important in the establishment of the environmental conditions that complement the ozone behavior that will be analyzed as a next step of this research. Three weeks of 133 meteorological and 82 ozone vertical profile data sets were collected from the surface to a maximum altitude of 1400 meters above ground (Helming et al., 2002) by data storage or radio-transmission. Four meteorological parameters in addition to ozone were identified for the vertical profiling analyses. They are: potential temperature (k), wind direction (degrees), wind speed (m/s) and water vapor (mbar).

Analyzing meteorological parameters from this vertical profile data and the generation of 3D contour maps shows the behavior of these factors under extreme conditions. We made 3D contour maps to observe the patterns that control the ozone budget. We used the data collected at Summit, Greenland in the summer of 2000 over time and at different altitudes. The 3D maps
show us if the meteorological fluxes depend on seasonal conditions and snow photochemical processes. The raw data came from instruments that were launched with the tethered balloon. The ozone measurements came from ECC (electrochemical concentration cell) sondes. Meanwhile the meteorological measurements were taken by two other instruments. One of them was the RS-80 Vaisala radiosondes which measured the relative humidity, pressure and temperature and transmitted data every 8 seconds. The other one was the TSP-5A-SP Vaisala tethersonde which measured the relative humidity, pressure, temperature, wind speed and wind direction with transmission every 1.25 seconds (See Figure 1). This data was cleaned as an Excel file by eliminating some readings that were errors over the instrument’s reading range. These errors were identified by their higher values in comparison with the real values for the parameters (ex. 9999) or sudden changes in the altitude’s values. Then the data set was transferred into a text file for processing and analyses.

Figure 1 – Instruments for Tethered Balloon Vertical Profiling

The generation of 3D maps required a specialized computer language program, like Interactive Data Language (IDL). Such 3D maps can show patterns among three components that might explain ozone transport, photochemical processes and the ozone budget. These components are time, altitude, and one of the parameters mentioned previously, such as temperature or wind speed. This software presents several advantages in comparison with a 2D plot. For example, it gives the opportunity to observe more clearly and define the patterns that we want to capture with the vertical profiles. We had to create an IDL program to generate the contour maps taking into account our data files and the manner that they were organized (See Figure 2). This program had to be adapted for each parameter.
RESULTS AND DISCUSSION

The 3D contour maps were generated for potential temperature (k), wind speed (m/s), and wind direction (degrees) using measurements from the highest altitude IDL identified on the data files. To observe with more detail the conditions near the surface, second generations of the contour maps were made using measurements up to 300m in the y-range.

In the potential temperature graph, using the highest altitude (See Figure 3), we found several patterns. First, there are no diurnal trends visible above 200m, such as coldest temperatures during night hours and an increasing temperatures during the daytime. Second, potential temperature increases with altitude, and then remains nearly constant at high altitudes. Third, during June 14 to June 16 there was a slight decrease in temperature which may be due to weather events during those days. Meanwhile in the 300m graph (See Figure 4), evidence of diurnal trends was observed and the coldest temperatures were found closest to the surface.

In the wind speed graph (See Figure 5) we observed decreasing wind speed at high altitude that we can not yet explain. A very high wind speed event was registered during the first three days of measurements June 4 to June 7. Viewing the first 300 m above the surface (See Figure 6) shows that near the surface occurs the lowest wind speed. There are abrupt changes from high wind speed to low wind speed in a very short period of time, but we have no explanation for this pattern.

With the wind direction analysis we had some problems trying to identify the coordinates’ values in the contour maps because 360 and 0 represent the same direction: north. IDL read the data files as different factors and assigned the blue colors for 0 values and red colors for the 360 value, even though both values are equivalent directions. Keeping this in mind, we can observe that at high altitudes (See Figure 7) and near the surface (See Figure 8) the wind direction is constant coming from the north – northeast.
Figure 3 – Potential Temperature

Figure 4 – Pot. Temp. to 300m
Figure 5 – Wind Speed

Figure 6 – Wind Speed to 300m
Figure 7 – Wind Direction

Figure 8 – Wind Direction to 300m
CONCLUSIONS

Our 3D data analyses provide a tool to decipher meteorological changes and air transport of ozone. These data also reveal diurnal and seasonal controls of ozone transport, photochemical formation, and surface deposition at Summit. These data will also improve our understanding of the role of polar regions in the global ozone budget. There are several more steps needed for the accomplishment of our research. First, we have to analyze measurements of ozone and water vapor to compare with our parameters established since the beginning of the research. Second, the IDL program has to be improved to obtain better 3D contour maps, that is to smooth the curves and eliminated some noise in the display. And third, we need to use surface data as a complement to the vertical profile data for better resolution of surface conditions.

REFERENCES

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