# A study of the transport of ozone into the surface over Antarctica

**K Satheesan[1], Sheila Kirkwood[1], and Aki Virkkula[2]**

[1]Swedish Institute of Space Physics, Kiruna, Sweden

[2]Finnish Meteorological Institute, Helsinki, Finland

## 1. Introduction

OZONE plays an important role in the chemistry and radiative budget of the troposphere. The radiative effects of the tropospheric ozone is more significant in the polar regions because of the low water vapour and thus its low radiative effects. The distribution of ozone in the troposphere is determined by in-situ production and transport from the stratosphere. The in-situ photochemical production and distribution of ozone in the troposphere exceeds the downward flux of ozone from the stratosphere. Nevertheless, the ozone flux across the tropopause is an important source of tropospheric ozone. In Antarctica, the seasonal cycle of surface ozone shows a maximum in winter followed by photochemical destruction in summer(1). Recent observations suggest that the annual ozone cycle with an expected minimum during the Antarctic summer months, is disturbed by the frequent occurrence of events with largely increased surface ozone levels(2). These episodes of high ozone amounts have influenced the overall long-term pattern in change in surface ozone(3). In the present work we study an event in which the ozone at the surface levels was enhanced at a location in Antarctica.

## 2. Data

The experiment was conducted at Wasa / Aboa the Swedish/Finnish research station (73°03'S, 13°25'W) during January 2008. The station is equiped with a 54.5 MHz radar, Movable Atmospheric Radar for Antarctica (MARA). In-situ observations of ozone were made along with complementary wind and turbulence from MARA. Back trajectories of ozone from the station were calculated using a trajectory model, FLEXPART(4) which is driven by the model data from the European Centre for Medium-Range Weather Forecasts (ECMWF). The ECMWF data has a horizontal resolution of 1° and a time resolution of 3 hours by making use of the analyses at 0000, 0600, 1200, and 1800 UTC and 3 hour forecasts at 0300, 0900, 1500, and 2100 UTC. In addition as the input data to the FLEXPART, ECMWF analyses of ozone and wind profiles were also used to interpret the measurement data. The ozone profiles from ECMWF in summer compares well with observations in Antarctica

## 3. Results and Discussions

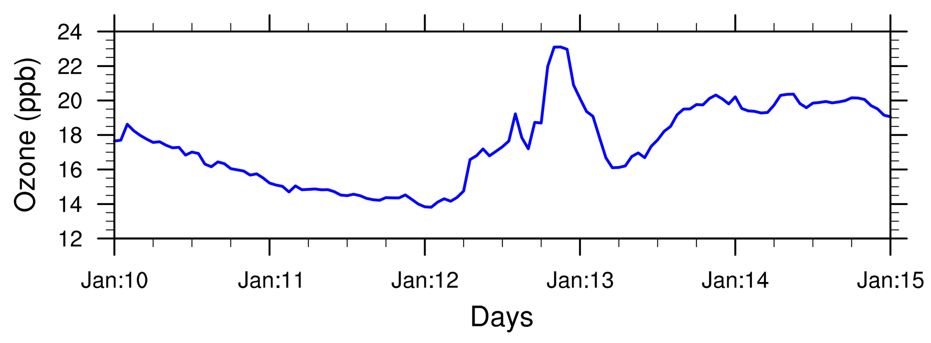
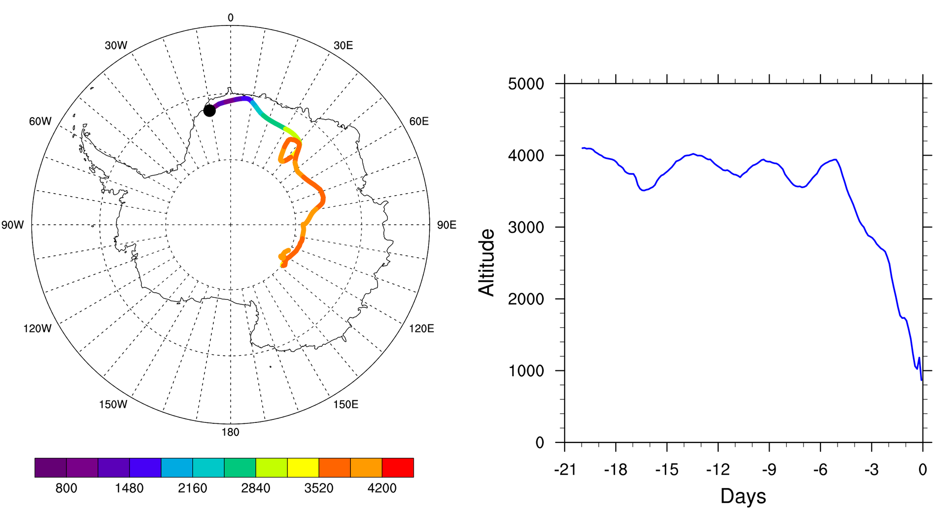


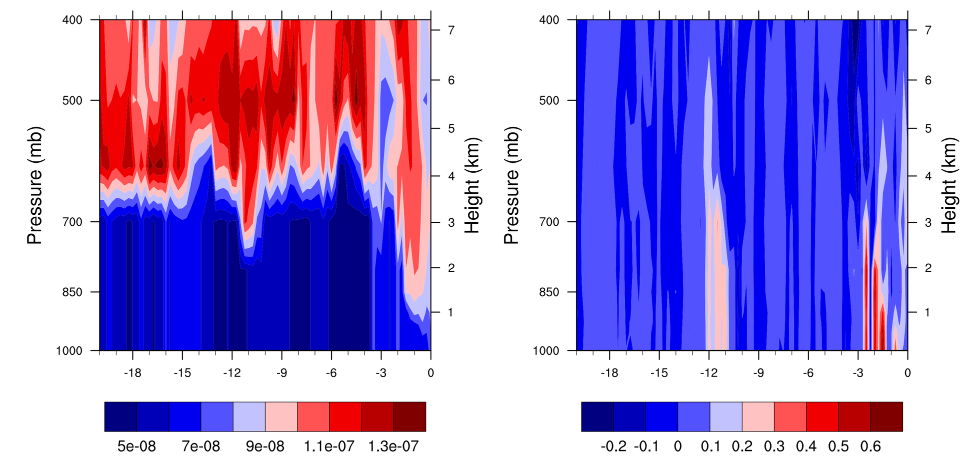

**Figure 1:** *Ozone time series.*

The time series of surface ozone for the period January 10–15 measured at the Wasa/Aboa is shown in Figure 1. The striking feature of the observations is the sudden enhancement of surface ozone on January 12 when it is enhanced by about 50 % from 15 ppbv. After peaking with a value of 24 ppbv, it is decreased sharply to 16 ppbv and then increased and remained constant around 20 ppbv. The sharp reduction in the ozone suggest that the process is mainly driven by a change of air mass since a reduction of ozone by chemical reaction needs more time. In order to find the sources of this enhanced ozone at the site, backward trajectories were computed using FLEXPART from the site. The model run was started from 2000 Hrs UTC on January 12, 2008. Back trajectories were calculated for 20 days. The back trajectories are shown in Figure 2(a) and (b). The back trajectory shows that the air masses were transported from an altitude of 4 km over the Antarctic plateau from the eastern sector. A striking feature of the trajectory is that the air mass was at this altitude for a number of days and it was transported to the lower levels within the last 4 days. This shows that the ozone increase at the surface was due to the transport of ozone enriched air mass from the middle troposphere.




(a) (b)

**Figure 2:** *(a)Ozone trajectory (b) its vertical profile with time and (c) the transect along the trajectory from ECMWF analysis.*




(a) (b)

**Figure 3:** *Transect of (a) ozone and (b) vertical wind (Pa/s) along the trajectory from ECMWF analysis.*

In order to find the vertical distribution of ozone along the trajectory, transect of ozone from the ECMWF analysis was extracted. Similar transect of vertical velocity was extracted along the trajectory. The ozone transect along the trajectory is shown in Figure 3a. The ECMWF data is coarser but a similar behaviour of the increase of ozone reported at some of the nearby stations also. The transect of ozone shows a layer of enhanced ozone in the mid troposphere above roughly 4 km from the surface. This layer was around this height for most of the time, but started extending downwards during the last 4 days. This is consistant with the trajectory also. Figure 3b shows the transect of vertical velocity from the ECMWF analysis. Upward motion was observed along the trajectory during the initial period, but strong downward motion was observed during the last 4 days.

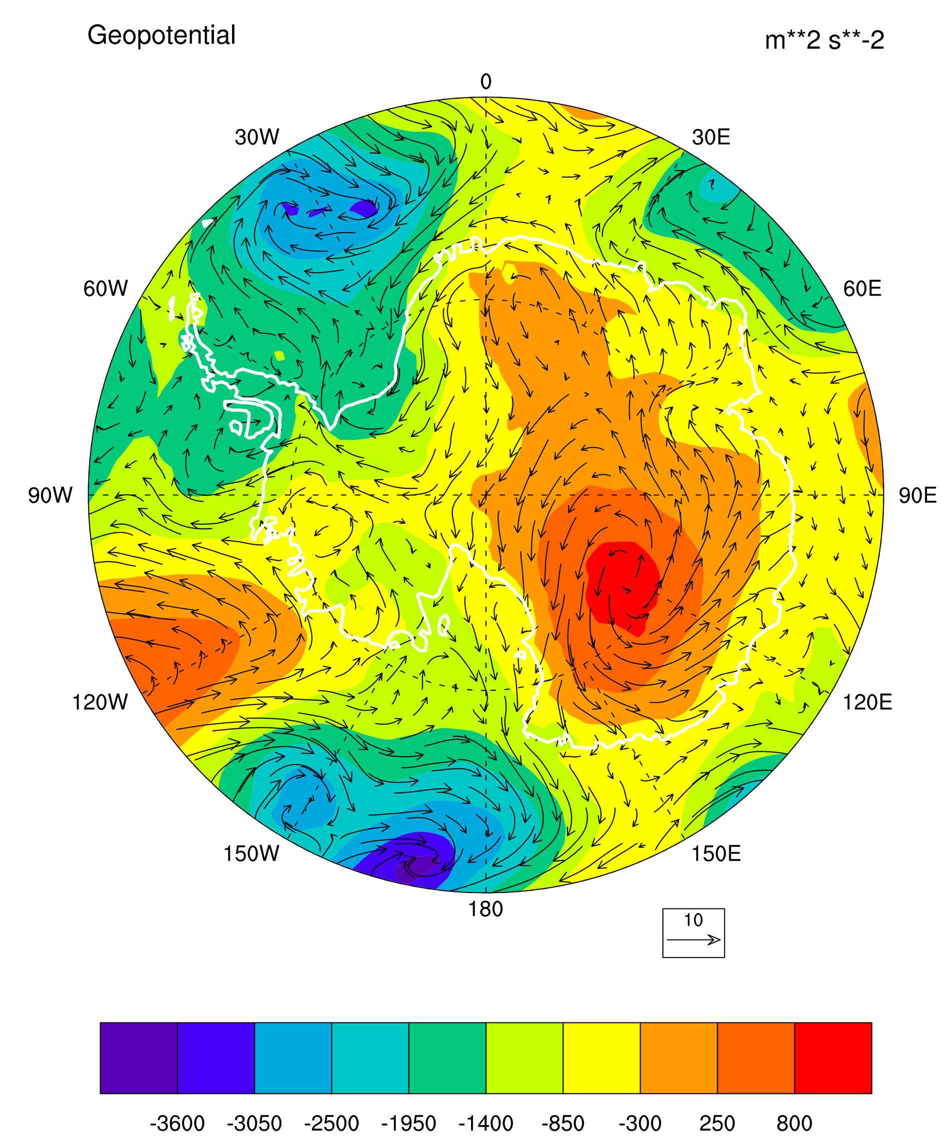



**Figure 4:** *Geopotential and horizontal wind vectors at 1000 hPa on January 12, 1800 Hrs.*

The contour map of geopotential and the wind vectors at 1000 hPa over Antarctica at 1800 Hrs UTC on January 12 is shown in Figure 4. There is a low pressure system centered roughly at $(65°S, 30°W)$ surrounded by a high pressure centered roughly at $(80°S, 120°W)$. The trajectory shows that the ozone enriched air mass from the middle troposphere was transported to the lower levels along the narrow edge between the high pressure and the low pressure systems. The vertical velocity at this region from the ECMWF analyses also shows downward transport. During this period, we have radar observations of wind and turbulence as shown in Figure 5.

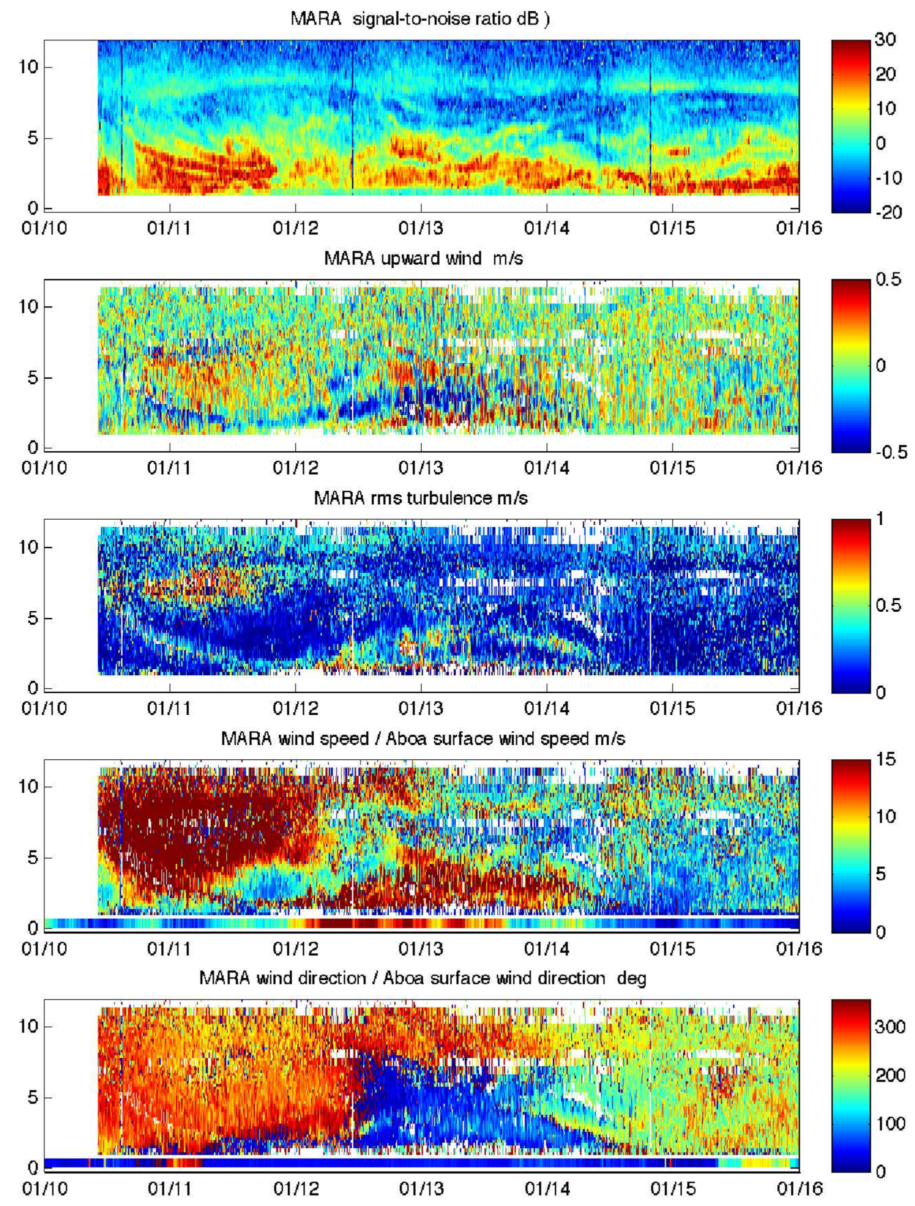
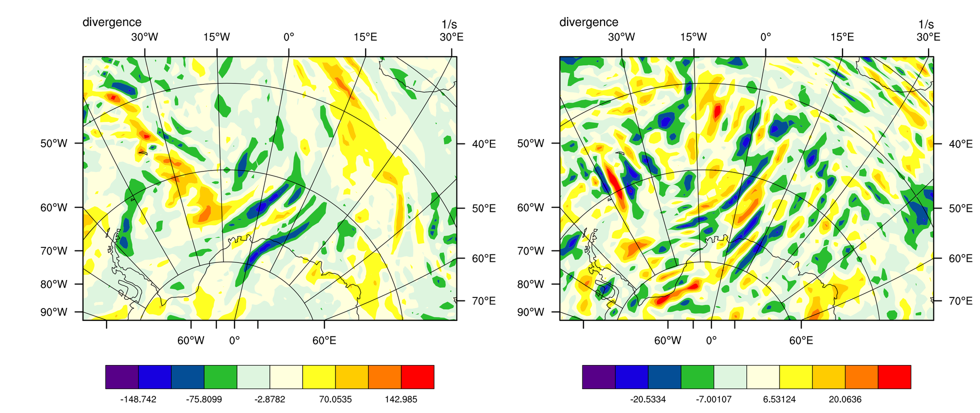



**Figure 5:** *The radar observations of wind, turbulence and signal to noise ratio.*

The terrain in the Antarctic plateau on the east and south east of the site consists of many small mountains. Under favourable conditions, they can be a source of mountain waves. The wind data from MARA shows signatures of mountain wave whenever the wind speed exceeded 10 m/s. This can be observed from the vertical velocity from MARA. High levels of turbulence were also observed upto 7 km associated with the mountain waves. The downward transport of ozone as shown by the trajectory occured during the periods of high turbulence. Figure 6 shows the horizontal divergence at 5 and 30 kms above the surface, which shows wave activity over this region. The surface wind speed was perpendicular to observed wave fronts. This may be a signature of mountain wave, but needs to be studied further.



(a) (b)

**Figure 6:** *Horizontal divergence at (a) 5 km and (b) 30 km at 12 Hrs on January 12, 2008*

## 4. Conclusions

An increase of ozone at the surface was observed at the Wasa/Aboa station in Antarctica. The enhanceemnt of ozone was associated with a low pressure system formed north west of the station. The enhanced ozone was transported from the middle troposphere over the Antarctic plateau east and south east of the station along the edge of the low pressure system. The wind speed was high during this period. Signatures of mountain waves were observed in the radar observations. High levels of turbulence were observed upto 7 km associated with the mountain waves. Vertical mixing by the turbulence associated with the mountain waves could lead to the ozone remaining at surface levels.

## References

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