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OZONE MAXIMA OVER SOUTHERN AFRICA : A MID-LATITUDE LINK

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ABSTRACT

The relationship between patterns of total ozone and day-to-day weather was explored over South Africa for the period 1987 to 1988. Generally, there was a fairly poor relationship (variance less than 20%) between total ozone and the heights of the 100, 300 and 500 hPa geopotential heights at 5 South African stations. However, over a shorter period, October to December 1988, fluctuations in the height of the 300 hPa surface accounted for 53% of the variance in total ozone at Cape Town. High ozone amounts are associated with the lowering of the 300 Hpa surface in the presence of an upper-air trough. The role of the mid-latitude westerly waves in this respect is discussed.

1. INTRODUCTION

Dobson *et al* (1929) were the first to notice the relationship between day-to-day variations in total ozone and surface weather. They found that maximum positive deviations of daily ozone values from monthly means (high ozone values) generally occur to the rear of surface low-pressure systems (west of cyclonic centres), while maximum negative deviations (low ozone values) are found to the rear of surface highs or within anticyclones. Later, Reed (1950) was responsible for describing the relationship between total ozone and weather in more detail. He put forward a model for the Northern Hemisphere in which he attributed the relationship to the effects of horizontal advection and/or vertical motion. More recently, Danielsen (1968), Danielsen and Mohnen (1977), Reiter (1975), Shapiro (1980), Singh *et al* (1980) and Wakamatsu *et al* (1989) have studied the dynamics of the tropopause and the injection of stratospheric air into the troposphere in association with upper level-troughs.

Stemming from these findings, it is expected that similar relationships will be found for Southern African data and that the observed variations in total ozone may be explained by the passage of mid-latitude weather systems.

2. DATA

The following data have been utilised in this study:

2.1 TOMS data

Version 6 TOMS data for the period January 1987 to December 1988 for 5 South African stations, namely Cape Town (33° 56'S 18° 28'E), Port Elizabeth (33° 58'S 25° 36'E), Durban (29° 53'S 31°E), Bloemfontein (29° 7'S 26° 14°E) and Pretoria (25° 45'S 28° 12'E); and gridded TOMS data, for the same period for an area bounded by longitudes 10°W and 50°E and latitudes 0°S and 50°S. The grid spacing used was 5°.

2.2 Meteorological data

Geopotential heights (gpm) of the 500, 300, and 100 hPa surfaces were obtained from radiosonde data for 1987 and 1988 for the 5 stations mentioned above. Gridded ECMWF upper-air data were obtained for 1987 and 1988 for an area bounded by longitudes 10°W and 50°E and latitudes 0°S and 50°S. The grid spacing selected was 5°.

3. RESULTS AND DISCUSSION

The relationship between TOMS total ozone and mid-to upper-tropospheric weather was investigated at 5 South African stations for a two year period, 1987 to 1988. Statistical analysis using simple linear least squares regression and making no allowance for serial autocorrelation in the time series revealed that a negative relationship exists between total ozone and the heights of the 100, 300 and 500 Hpa geopotential heights at 5 South African stations. The results are summarised in Table 1.

The relationships are generally poor, with a maximum of 20% of the variance in total ozone explained by the variations in the height of the 300 hPa surface at Cape Town. However, a far better relationship was observed between total ozone and the 300 and 500 hPa geopotential heights for all 5 stations investigated over a shorter period between October to December 1988 (Table 2). The fluctuations in the height of the 300 hPa surface were found to account for between 53% at Cape Town, and 35% at Pretoria, of the variance in total ozone with correlation coefficients ranging between -0.73 to -0.59 respectively.

It appears then, that the lowering of the pressure surfaces is associated with high ozone amounts and that this relationship is strongest for more southerly located stations. This observation may be a function of the time of year for which the analysis has been performed. For instance, the patterns observed may be a reflection of the southward migration of the westerlies between August and December over South Africa. The more northerly located stations of Pretoria (26°S) and Bloemfontein (29°S) will experience the influence of the mid-latitude westerly waves to a lesser degree than the more southerly stations, which exhibit relatively larger r^2 values, and consequently undergo correspondingly smaller day-to-day fluctuations. At the onset of spring, the Inter Tropical Convergence Zone (ITCZ) begins to move southwards and as a result South Africa comes under the influence of air of tropical origin. During this warm season, total ozone values are relatively

STATION	Correlation between TOMS & 100hPa	r^2 100hPa	Correlation between TOMS & 300hPa	r^2 300hPa	Correlation between TOMS & 500hPa	r^2 500hPa
CAPE TOWN	-0.26	6.93	-0.45	20.34	-0.37	14.44
PORT ELIZABETH	-0.21	4.54	-0.37	13.91	-0.31	9.37
DURBAN	-0.15	2.46	-0.25	6.21	-0.20	4.13
BLOEMFONTEIN	-0.16	2.45	-0.28	7.82	-0.21	4.54
PRETORIA	-0.12	1.33	-0.15	2.36	-0.10	1.00

significant at 95% confidence level

r^2 = percent variance

Relationship between daily TOMS total ozone and the 100, 300 and 500 hPa geopotential heights for 5 South African stations, 1987-1988.

STATION	Correlation between TOMS & 300hPa	r^2 300hPa	Correlation between TOMS & 500hPa	r^2 500hPa
CAPE TOWN	- 0.73	52.97	-0.63	39.45
PORT ELIZABETH	-0.64	41.20	-0.57	32.17
DURBAN	-0.63	39.32	-0.51	26.07
BLOEMFONTEIN	-0.63	39.14	-0.51	25.60
PRETORIA	-0.59	34.59	-0.46	23.11

significant at 95% confidence level

r^2 = percent variance

Table 2 Relationship between daily TOMS total ozone and the 300 and 500 hPa geopotential heights for 5 South African stations, October to December 1988.

lower throughout the country, and less variability is observed due to the reduced frequency of the transient waves of the mid-latitudes.

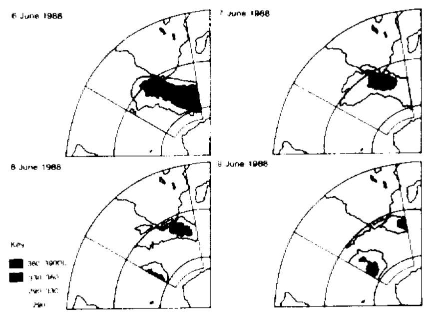

Fig. 1 The distribution of TOMS total ozone (DU) over South Africa, 6-9 June 1988. Illustration compiled by Space Physics Research Institute, University of Natal, Durban, from TOMS data supplied by the NSSDC, U.S.A.

The variability in total ozone associated with the passage of the mid-latitude westerly waves is illustrated in Figure 1, which shows ozone concentrations for four days commencing on 6 June 1988. The west to east movement of an ozone front across South Africa is clearly visible.

The occurrence of ozone maxima was explored in greater detail using gridded data over the entire country for 1987 and 1988. For each day, statistical analysis of the relationship between total ozone and the heights of the 100, 300 and 500 hPa surfaces using simple linear least squares regression and making no allowance for spatial autocorrelation in the time series was undertaken. A strong significant (at the 95% confidence level) negative correlation was evident (Fig. 2).

This analysis revealed that on the majority of the days (approximately 600 days) out of the two year period, between 50% and 95% of the spatial variance in total ozone is explained by the variation in the height of the 100, 300 and 500 hPa surfaces. Again, the relationship was strongest for the 300 hPa surface.

The occurrence of high ozone amounts in association with the lowering of the 300 hPa surface due to the presence of an upper-air trough is clearly depicted in the contour maps for 3 October 1987 (Fig. 3). On 3 October 1987, the synoptic chart (Fig. 3a) depicts a surface cold front moving eastward towards Madagascar and a surface high pressure system ridging in behind the cold front. A further surface cold front is evident to the south-west of

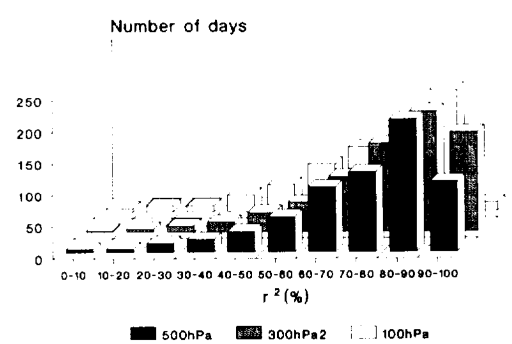

Fig. 2 Relationship between gridded total ozone (TOMS) and the 100, 300 and 500 hPa geopotential heights (ECMWF) over South Africa expressed as r^2 values, January 1987 - December 1988.

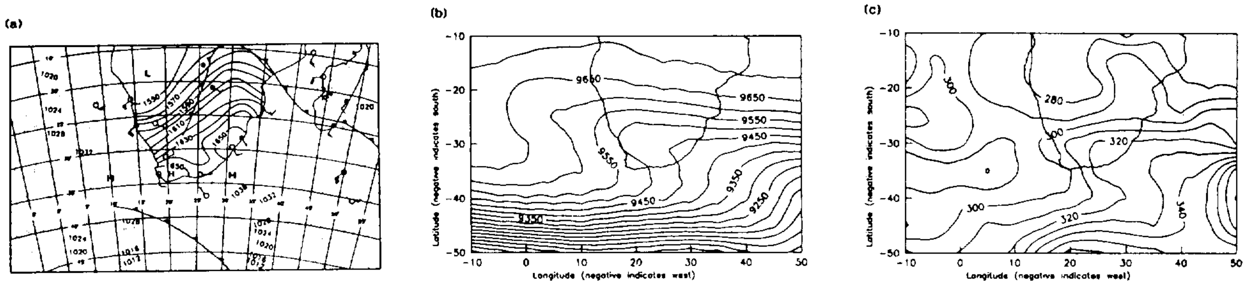

Fig. 3 3 October 1987
a) Surface synoptic chart. Surface pressure expressed as isobars (hPa) over the sea and heights of the 850 hPa (gpm) over the land. Source: SAWB. b) Heights of the 300 hPa surface (gpm). Prepared from the ECMWF data. Source: SAWB. c) Distribution of TOMS total ozone (DU) gridded data. Source: DC, U.S.A.

Cape Town. The upper-air trough at 300 hPa, associated with the first cold front, appears to the rear of the surface front and is aligned west-northwest/east-southeast across the country (Fig. 3b). Total ozone values (Fig. 3c) show a maximum in the vicinity of the well developed 300 hPa trough extending over South Africa with values increasing in a south-easterly direction in association with the lowering of the 300 hPa surface in this region.

5. SUMMARY

Ozone maxima have been related to mid- to upper-tropospheric daily weather patterns over South Africa. It has been shown that an inverse relationship exists between TOMS total ozone and the heights of the 100, 300 and 500 hPa geopotential heights. Although the relationship is poor at individual stations for the two year period between 1987 and 1988, it improves significantly for the three month period between October to December 1988. The relationship appears to be strongest for more southerly located stations such as Cape Town and Port Elizabeth. This may be explained by the extent of the area influenced by the mid-latitude westerly waves.

A strong negative correlation between gridded total ozone data and the heights of the 100, 300 and 500 hPa surfaces was found to exist for an area covering the entire country. Strong evidence was found to support the idea that daily weather patterns play a significant role in influencing total ozone levels in the southern hemisphere mid-latitudes. The fluctuations in the heights of the 100, 300 and 500 hPa surfaces were found to account for between 50% and 95% of the variance in total ozone, for the majority of days investigated in the two year period.

It is suggested, that the origin of ozone maxima over Southern Africa is largely due to dynamics of the atmosphere and that on days showing a weak relationship between total ozone and daily weather, ozone maxima may be explained by mechanisms other than forcing by mid-latitude westerly waves.

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