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LARGE- SCALE CIRCULATION PATTERNS ASSOCIATED WITH HIGH CONCENTRATIONS OF TROPOSPHERIC OZONE IN THE TROPICAL SOUTH ATLANTIC OCEAN

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ABSTRACT

Several years of satellite observations indicate the presence of enhanced amounts of tropospheric ozone over the tropical South Atlantic during the austral springs. Widespread biomass burning is prevalent over Africa and South America during the same time of the year. Another recent satellite technique has identified the locations of fires over the continents. In this study, we present an analysis of the prevailing meteorological conditions when the highest amounts of tropospheric ozone are present.

1. INTRODUCTION

Recently, a methodology has been developed at the NASA Langley Research Center for the indirect measurement of the tropospheric ozone (known as tropospheric residual) using observations of two satellite instruments (Total Ozone Measurement Spectrometer [TOMS] and Stratospheric Aerosol and Gas Experiment [SAGE], Fishman et al., 1990). The tropospheric residual ozone was obtained by subtracting stratospheric ozone measured by SAGE instruments from the total column of atmospheric ozone measured by TOMS. The analysis of several years of satellite observations indicates that large amounts of tropospheric ozone are often present over the tropical South Atlantic Ocean (Fishman et al., 1991). The highest amounts of ozone are generally observed during austral spring (September-November). Based on these analyses, the figure below shows the annual average of the global distribution of tropospheric ozone (Fig. 1).

INTEGRATED TROPOSPHERIC OZONE (1979-1990)

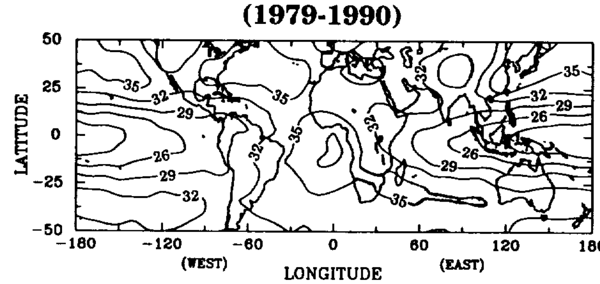

Figure. 1

In this study, we present a case study analysis of the prevailing meteorological conditions when high tropospheric amounts are present. Another technique has been developed to identify hotspots and thus anthropogenic origin of greenhouse gases by using Advanced Very High Resolution Radiometer (AVHRR) satellite imagery. Using these techniques, we have located the regions of highest ozone concentration and their relationship to the source regions using isentropic trajectory analyses. A case study of a fire in the Okavango River delta in northern Botswana is shown below.

Though isobaric surfaces are a conventional way of most meteorological analyses, the quasi-conservative three-dimensional

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airflow takes place quite closely on the surfaces of equal potential temperature (Danelsen, 1961). Therefore, we have chosen isentropic surfaces for prevailing meteorological analysis (Haagenson and Shapiro, 1979). The use of an isentropic trajectory model unveils a complex three-dimensional flow regime over the tropical South Atlantic Ocean of continental origin which is typical during the burning season.

Utilizing all these analyses, we will determine the relative contributions from tropospheric sources in both Africa and South America, as well as attempt to quantify how much ozone in the troposphere had been recently transported from the lower stratosphere and upper troposphere. Our analyses also have utilized observations from ozonesonde launches (Cros et al., 1992; Fishman et al., 1992) made simultaneously at Ascension Island (8° S, 15° W) and Brazzaville, Congo (4° S, 15° E).

2. OZONESONDE OBSERVATIONS AND TRAJECTORIES

The ozonesonde measurements at two stations reveal high ozone during the burning season of equatorial southern sub-tropical Africa. Typically ozone maxima in Ascension Island are lower in concentration and at a higher altitude than at Brazzaville, Congo (Fig. 2).

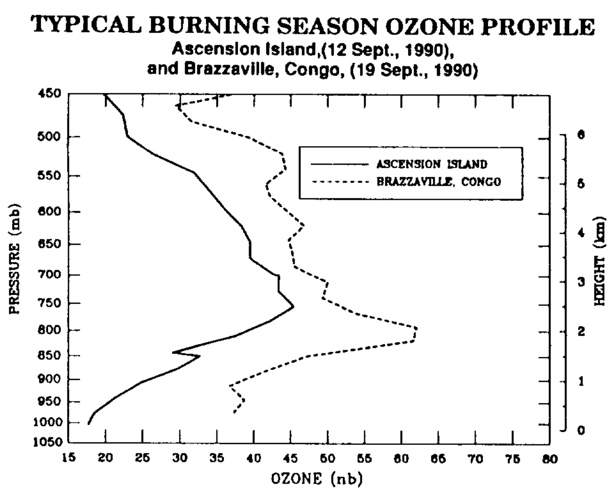

Figure 2

The isentropic trajectories of air parcels from equatorial Africa confirmed that ozone-rich air ascends slowly during westward transit across the Atlantic by the prevailing trade-winds (Fig. 3). The Montgomery stream functions generated by the isentropic analyses indicate the flow pattern of the region on the given potential temperature surfaces.

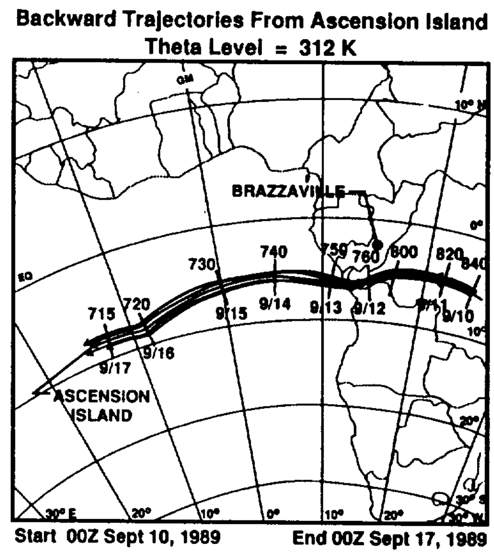

Figure 3

3. CASE STUDY: OKAVANGO DELTA FIRE

Our analyses of AVHRR imagery can be used to identify active fires, smoke, and the burn scars during the case study (Matson and Dozier, 1981; Thomas and Tag, 1990). For our case of study, we have analyzed ozone, meteorological and AVHRR data in conjunction with widespread burning taking place in near the Okavango River delta.

The progress of the fire fronts, the development of the burn scars, and the plumes of smoke indicated at least three different directions of air flow in this region during the time of the fire (Fig. 4). The forward trajectories from the delta region confirmed the three different directions of transport of trace gases (Fig. 5). Allowing the time and suitable condition of photochemical production of ozone, a significant increase in the tropospheric ozone was found along the trajectories as shown in figure 6.

Okavango River Delta Fire, September 3, 1989 **Progression of Biomass Burning, Okavango River Delta**

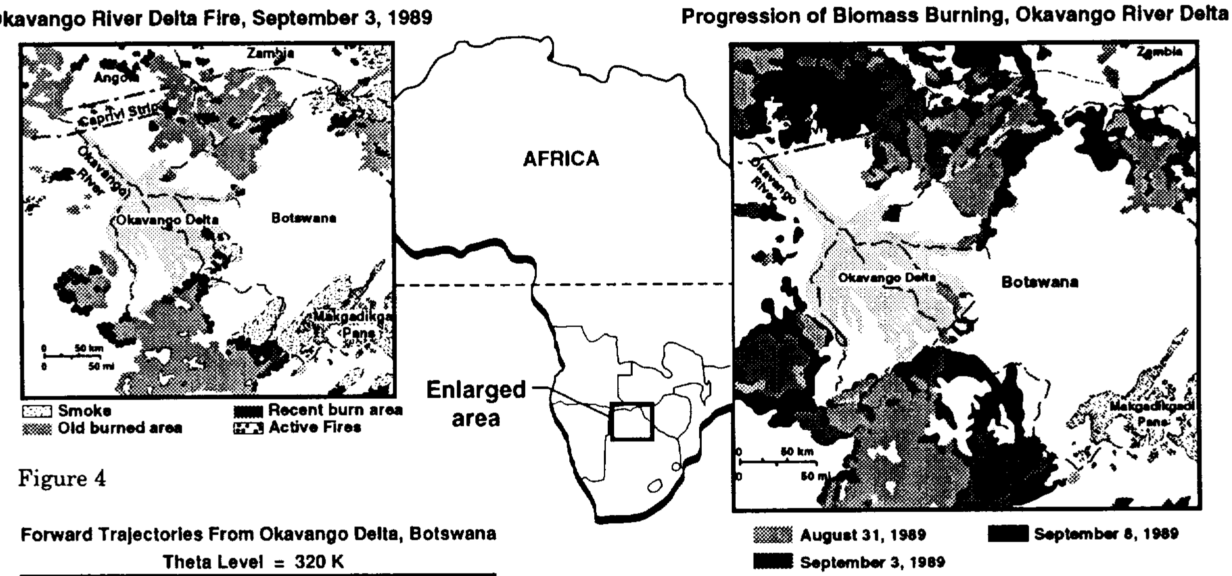

Figure 4

Forward Trajectories From Okavango Delta, Botswana
Theta Level = 320 K

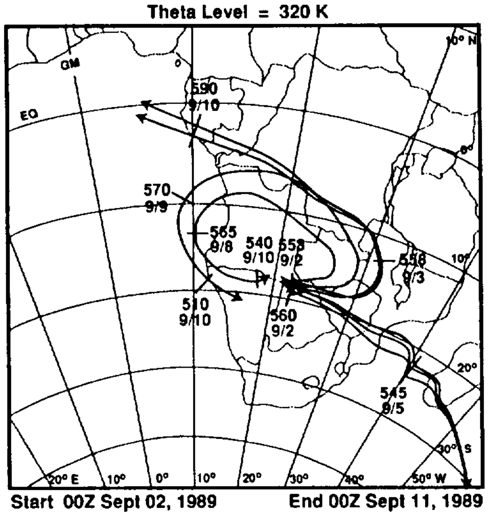

Figure 5

4. THREE-DIMENSIONAL FLOW REGIME

We have constructed a generalized three-dimensional flow regime of atmospheric circulation over the tropical South Atlantic Ocean for the month of September, 1989 by calculating bulk isentropic trajectories of continental air parcels that originated over the regions of biomass burning (Fig. 7). This analysis suggests that the source of ozone-rich air off the coast of Angola is result of a fairly complex flow regime that consists of air originating from South America as well as from southern Africa.

Residual Ozone Difference
September 3 – August 31, 1989

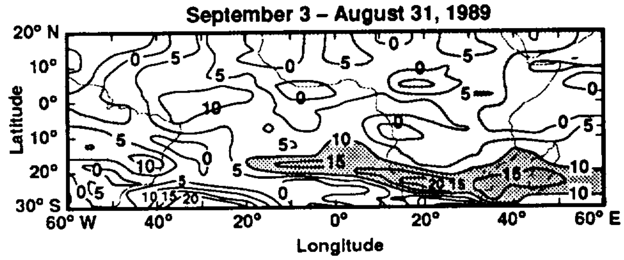

Figure 6

5. CONCLUSION

Recent scientific interest on global warming and pollution highlights the need to understand atmospheric chemistry and biomass burning in the tropics. The subsequent transport of trace gases is also an important issue, along with the photochemistry. At the present time very little is known about the tropical meteorology of this region of the world.

This study of the three dimensional flow regime in the southern tropics is among the first of its kind (Fig. 7). These analyses show that the circulation pattern is more

Middle and Lower Tropospheric Flow Regime (September, 1989)

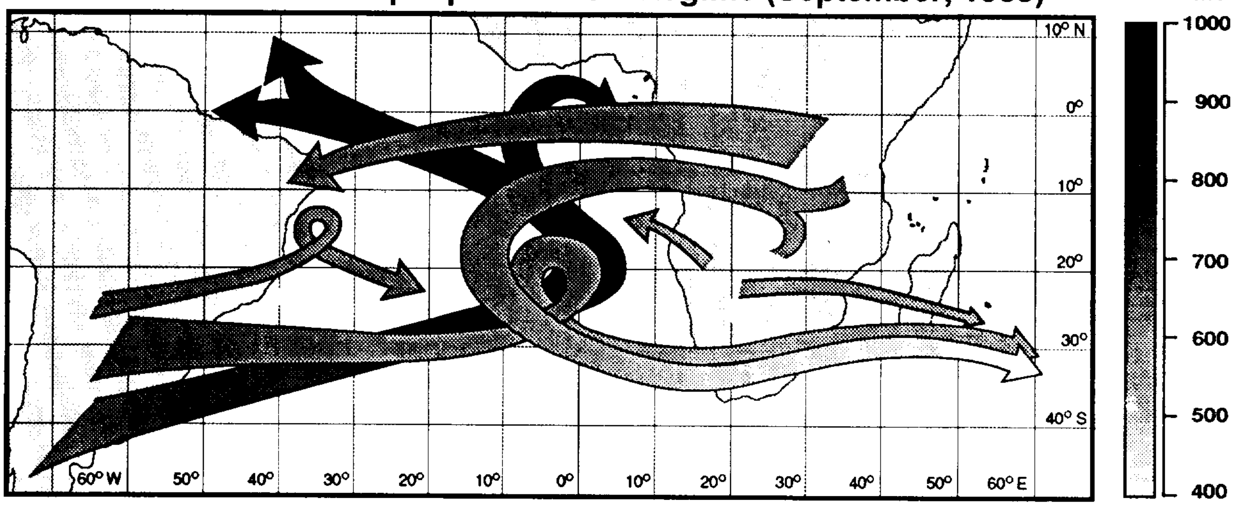

Figure 7

complex than previously thought. The elevation of the African landmass and the presence of a semi-permanent high pressure system, in addition to the migration of the Inter-Tropical Convergence Zone (ITCZ) and subtropical jet stream greatly complicate the observed circulation pattern. Further studies are needed to understand fully the dynamics of this region.

Tropical meteorologists, atmospheric chemists and environmentalists are now enthusiastic about the study of this region. It is expected that considerable insight will come forth as a result of the upcoming Transport and Atmospheric Chemistry near the Equator -- Atlantic (TRACE-A) mission which is scheduled in August-October, 1992..

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