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ON THE LAMINATED STRUCTURE OF OZONE IN THE SUB-TROPICAL ATMOSPHERE

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ABSTRACT

Ozone data recorded by balloon-borne sondes released at various sites around the world revealed that frequently the vertical ozone distribution in the stratosphere is remarkably laminated. Recently, measurements of ozone profiles near the winter polar vortex have shown strong laminae close to the vortex boundary. Also, a statistical study published recently has shown that laminae are most commonly found between 12 and 18 km at high latitudes in winter and spring in both hemispheres but they are not found in the tropics and are rarely observed in the subtropics.

Ozonesonde ascents performed in Athens (37.9°N, 23.8°E) during the winter 1991-1992 in the framework of the European Arctic Stratospheric Ozone Experiment (EASOE) have shown that the lamination phenomenon was very frequently present in our region which is in contradiction with previous measurements at our latitudes. The characteristic minimum of ozone at 15 km has been also detected. Finally, the correlation of the occurence of these two phenomena in relation with the circulation of air masses showed that the laminated profiles are connected with the North-Northwest circulation in the lower stratosphere while the appearance of the ozone minimum around 15 km is connected with the influence of the subtropical jet-stream.

INTRODUCTION

The existence of a laminar structure (layers of enhanced and depleted ozone) in ozone profiles has been first reported about thirty years ago (Hering, 1964; Hering and Borden, 1964) based on ozonesoundings performed over North America and Switzerland. Dobson (1973) made a systematic analysis of the laminar structure in ozone profiles in the lower stratosphere over a wide longitudinal and latitudinal range, adopting ozone partial pressure change > 30 nb as criteria for the detection of laminae. For the statistical analysis of the laminar structure he divided the ozone profiles into three groups :

group 0 - profiles containing almost no lamina
group I - profiles exhibiting moderate lamination
group II - profiles extensively laminated

He found that the features of the laminated structure vary with latitude. Between January and April the lamination phenomenon is most frequently found. At latitudes below about 20°N in the spring and below about 30°N in the autumn, a laminated structure of the ozone is very seldom found. About 35% of all profiles were group-II at high latitudes in spring, while group-I days reached a peak frequency of 70% in June. Group-II days were rarely observed at any latitude during the summer, while group I was found in Polar regions throughout the year. Dobson (1973) could not find an explanation for the incidence of these layers at a preferred height of 15 km nor for the constancy of the preferred height with latitude. He showed though that there is a strong correlation between the existence of a characteristic ozone minimum at 15 km with the occurence of a double tropopause especially in latitudes around 40°N. He made also the assumption that the laminated structure and the ozone minima at 15 km are of the same origin since the variations in the frequency of their appearance with both season and latitude are very similar.

Another statistical study of the lamination phenomenon has been published recently (Reid and Vaughan, 1991). In this study the laminar stuctures found in the altitude range 9.5-21.5 km were only examined. Laminae were categorized according to their vertical extent (called depth) as well as the change in ozone partial pressure inside them (called magnitude). They used also same criteria to separate genuine laminar features from instrumental noise or large-scale features in the ozone profile. The acceptable depth for laminae was chosen to be beetween 200 m and 2.5 km while the minimum magnitude 20 nbars. The above study showed that laminae are most abundant bellow 18 km at high latitudes during winter and spring which is in accordance with the findings of the Dobson's study. But Reid and Vaughan (1991) disagree with Dobson (1973) as far as the origin of laminae is concerned. Based on the observation that their magnitude is greatest and their depth least during winter and spring they rule out the suggestion of Dobson (1973) that they all originate near the subtropical jet-stream, although the possibility remains that a small number of laminae may be generated by stratosphere-troposphere exchange around these features (Begum 1989). Instead of that they suggest that laminae may represent evidence for a process which can cause exchange of air in and out of the polar vortex. This suggestion is supported by recent polar ozone campaigns where laminae particularly sharp and deep near the winter polar vortex have been detected. (Mc Kenna et al., 1989). Given the ozone distruction which is known to take place within the vortex, the possibility that such exchange can spread ozone depletion to lower latitudes should be taken into consideration.

RESULTS AND DISCUSSION

We have performed 29 ozonesoundings in the period between December 1991 and April 1992 (6 in December, 7 in February, 8 in March, 8 in April). The ozonesondes which has been used for the vertical soundings were the electrochemical concentration cells (ECC, Scientific Pump) after Komhyr (1969). For the measurement of temperature and humidity as well as the data transmission we used RS-80 radiosondes (Vaisala). The interface card for the digitization of signals and the receiving system were also from Vaisala. The data were taken during the ascent of the balloon (TOTEX, 1200g). The ascent velocity was about 5m/s. The ozonesoundings were performed at 10 h G.M.T.

For the identification of laminar structures the same criteria were used as in the work of Reid and Vaughan (laminar depths less than 2.5 km and magnitudes higher than 20 nb). Features having depths higher than 2.5 km are regarded as ozone maxima and minima.

The first important finding of our study is that the lamination phenomenon has been very frequently observed over our region. These laminar events were significantly more frequent observed than those in previous measurements at our latitudes. This difference becomes much more pronounced in February and March where the lamination frequency over Athens is about twice as that observed over Cagliari, Italy (39.1°N) (fig. 1). We should mention here that the data of Cagliari were taken in the period between 1972-1975. This fact in combination with the observation that the laminar events are much more pronounced at the edge of the polar vortex leads to a possible explanation that the polar vortex has been moved more southwards during the last 20 years. The on going discussions about ozone depletion in the middle latitudes over the last 15 years mention this possibility (Stolarski et. al., 1991). It is worth noting that the nearest ozonesounding station to Athens (in Hohenpeissenberg Germany 47,5°N) is quite far in order to more information about the situation over our region.

If we examine the weather maps provided by the German Weather Service we observe that there is a significant correlation between the appearance of laminar events and the establishment of a North-Northwest circulation in the lower stratosphere over our site. In this case we could also say that the site is under the influence of the polar vortex. The above observation is in agreement with the findings mentioned above about the enhancement of laminar phenomena at the vortex boundary. One characteristic example we observe in fig. 2. Eight days with the above characteristic have been observed in our data set.

We found also at least 4 days where a distinct minimum at 15 km was observed. By examining the weather maps we find out that during these days our site was influenced by the subtropical jet-stream. One characteristic example is observed in fig. 4. This is in agreement with the observations made by Dobson that the 15 km minimum is associated with air coming from the subtropical region. Finally in fig. 6 we observe a case where our site was influenced by both types of circulation of air masses in the lower stratosphere. The distinct minimum around 15 km as well as laminar structures are clearly shown.

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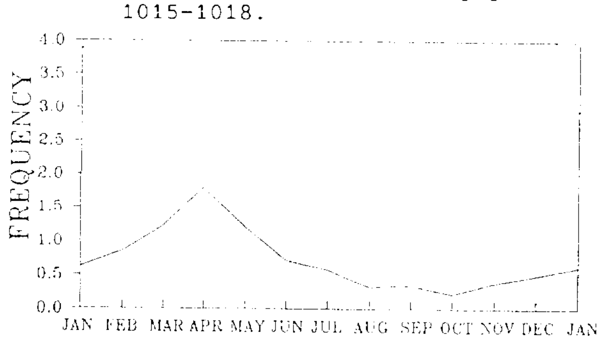

Figure 1. Monthly variation of the average lamina frequency per profile for Cagliari (dashed line) and Athens (asterisks).

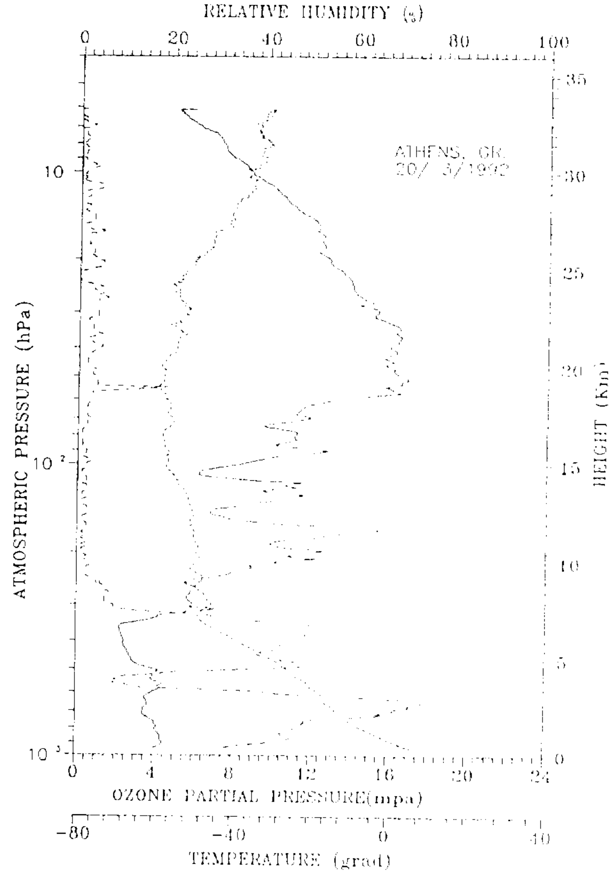

Figure 2. An example of an ozone profile with laminar structure, over Athens.

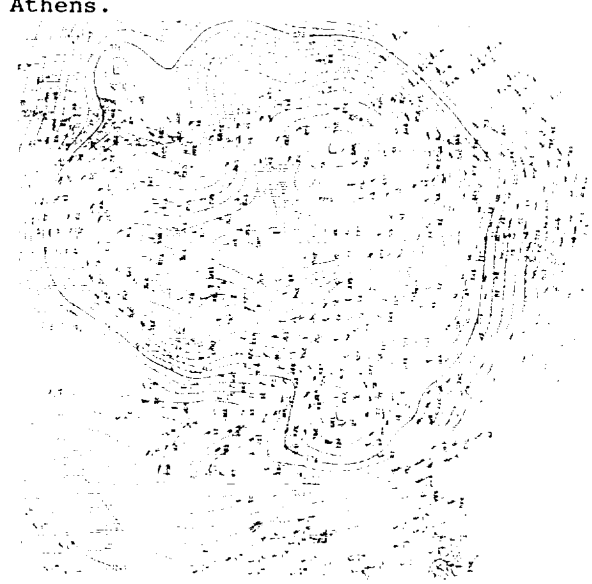

Figure 3. Weather map at 200 hPa of the day when the profile of the figure 2 was taken.

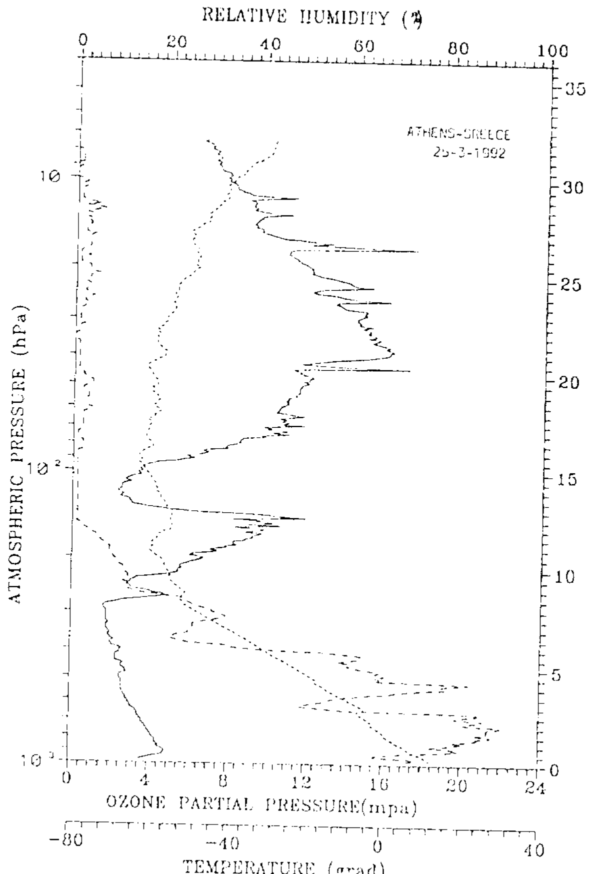

Figure 4. An example of an ozone profile with a distinct minimum at 15 km, over Athens.

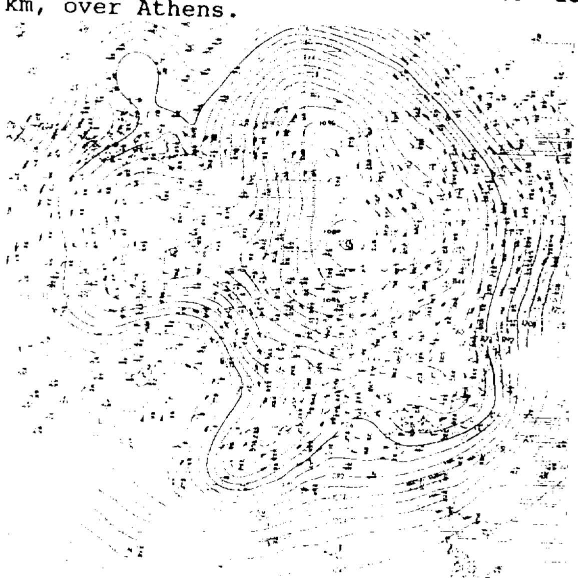

Figure 5. Weather map at 200 hPa of the day when the profile of the figure 3 was taken.

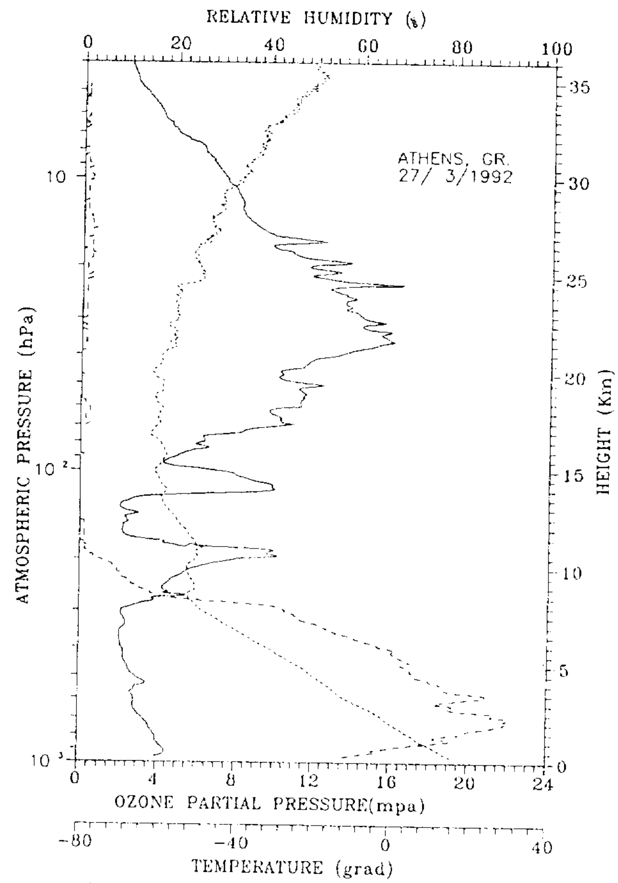

Figure 6. A day with both laminated ozone profile and the 15 km ozone minimum.

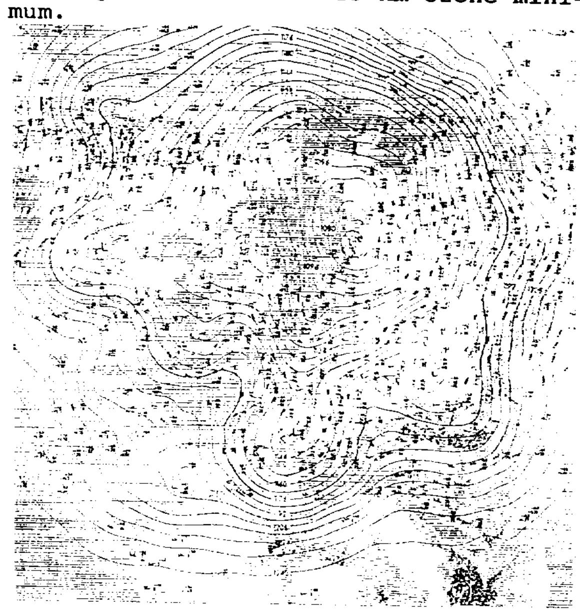

Figure 7. Weather map at 200 hPa of the day when the profile of the figure 6 was taken.