OZONE DURING SUDDEN STRATOSPHERIC WARMING : A THREE-DIMENSIONAL SIMULATION

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1. INTRODUCTION

Sudden warmings which are currently observed in the winter stratosphere are believed to be due to the upward propagation of planetary waves originating in the troposphere. Major warmings are characterized by local increases of the temperature in a deep layer beyond the stratopause with values of the order of 50 K at 10 mbar appearing over a short period of time (a few days) and leading to significant changes in the rate constant of several chemical reactions. During such events, the dynamical fields in the stratosphere are completely altered, so that dramatic changes in the transport of trace constituents are expected.

The purpose of this short note is to report preliminary results of a 3-D model simulation of the ozone behavior during winter in connection with the appearance of a stratospheric warming. This paper will concentrate mainly on the middle stratosphere (12 mb or approximately 32 km) where the chemical lifetime of odd oxygen is quite long and consequently transport plays a major role. Further studies will deal with the response of ozone at higher altitude (where the direct relation between ozone chemistry and temperature becomes more important) and extend into a 3 dimensional frame the previous 2-D studies of Hartmann and Garcia (1979) and Kawahira (1982).

2. BRIEF MODEL DESCRIPTION

The 3-D dynamical model which is used in the present study is described by Rose (1983). It is based on the so-called primitive equations which are solved using a finite difference technique in a space of grid-points with a longitudinal interval of 22°5, a latitudinal interval of 5° and a vertical resolution of 3 km. The model is hemispheric and extends from 10 to 80 km altitude. Diabatic processes are parameterized using a Newtonian cooling approximation. In order to simulate the propagation of planetary waves, a wavenumber 1 and 2 forcing in the geopotential height is imposed at the lower boundary.

The distribution and evolution of ozone is derived by solving for odd oxygen a continuity equation (see e.g. Brasseur and Solomon, 1984). The chemical source term takes into account the production of odd oxygen by photodissociation of O_2 and its destruction by direct recombination

of O and O_3 as well as the loss due to the presence of odd hydrogen and odd nitrogen. In the present stage of development of the model, the water vapor (H_2O) and odd nitrogen (NO_x = NO + NO_2) content is specified by a given mixing ratio (5 ppmv for H_2O and an altitude dependent value for NO_x). Photochemical equilibrium conditions are assumed for $O(^3P)$, $O(^1D)$, H, OH and HO_2. Moreover, NO_2 is assumed to be in immediate equilibrium with NO. The model does not yet consider any diurnal variation in the solar illumination and consequently in the photodissociation rates, which is a good approximation for the low levels under consideration, where the photochemical lifetime of odd oxygen is much longer than a day. Further development of the model will include longitudinal variations in the source term instead of a zonally averaged value, as in these preliminary calculations.

3. RESULTS

In order to perform an initialisation of the odd oxygen distribution, we first run the chemical model for 25 days with the initial temperature field of the dynamical model. After this initialisation, a numerical simulation of a sudden stratospheric warming is started and performed as described in detail by Rose (1983).

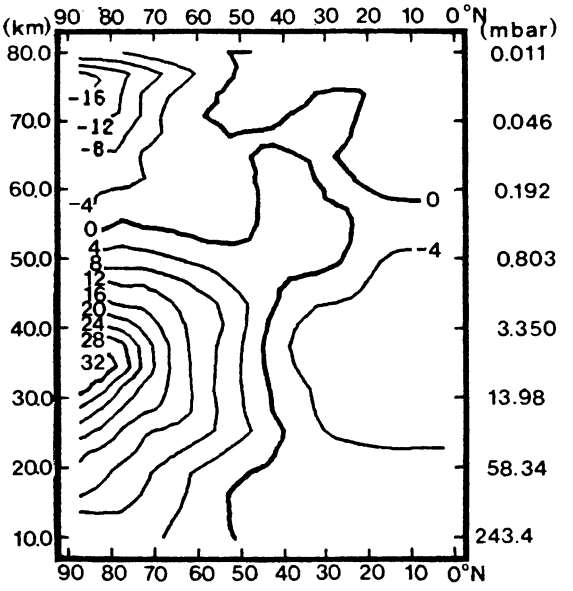

Fig. 1.- Meridional cross section of the difference in the mean zonal temperature at day 21 relative to the initial state (°K).

At day 21 of this simulation, the zonal mean temperature between 30 km and 35 km near the pole has increased by 32°K as compared to the initial state (fig. 1). As in the real atmosphere, a simultaneous cooling in the stratosphere at low latitude and in the mesosphere at high latitude is observed. This change of the mean state corresponds to a southward displacement of the polar vortex (fig. 2), which had its center directly upon the pole in the zonally symmetric initial conditions. The O_3 mixing ratio, which, had also a minimum value directly upon the pole in the initial distribution at 12 mbar and which behaves as a perfect tracer in the polar night at the altitude of the 12 mbar level (fig. 3) reveals that the polar vortex might be interpreted as a material entity, since the air parcels with low O_3 mixing ratio remain in the center at the displaced vortex (cf. fig. 2). Air of relatively high O_3 mixing ratio is advected counterclockwise around the polar vortex leading to higher values in polar latitudes. In the further course of the simulation, the polar vortex is split and air from the region of highest O_3 mixing ratio is advected across the pole. At day 21, the region of small gradients in both, geopotential height and O_3

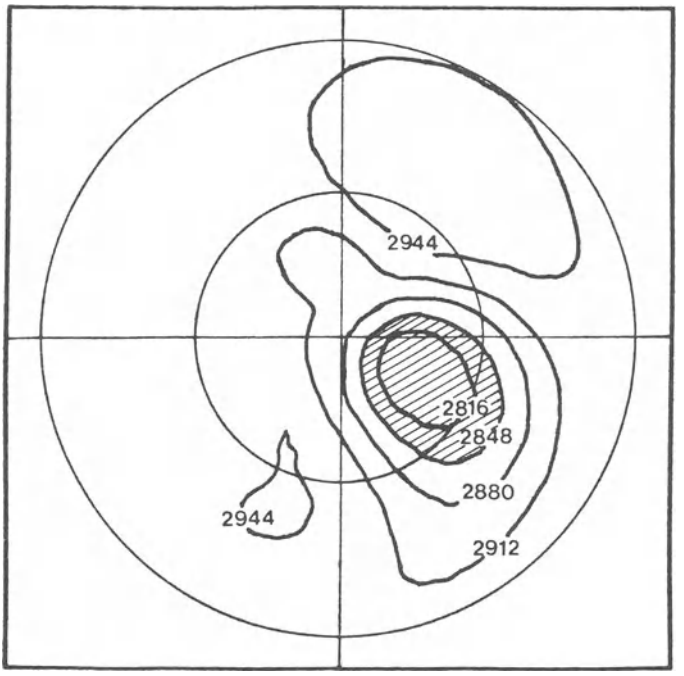

Fig. 2.- Geopotential height (gpdam) for the 12 mbar level at day 21.

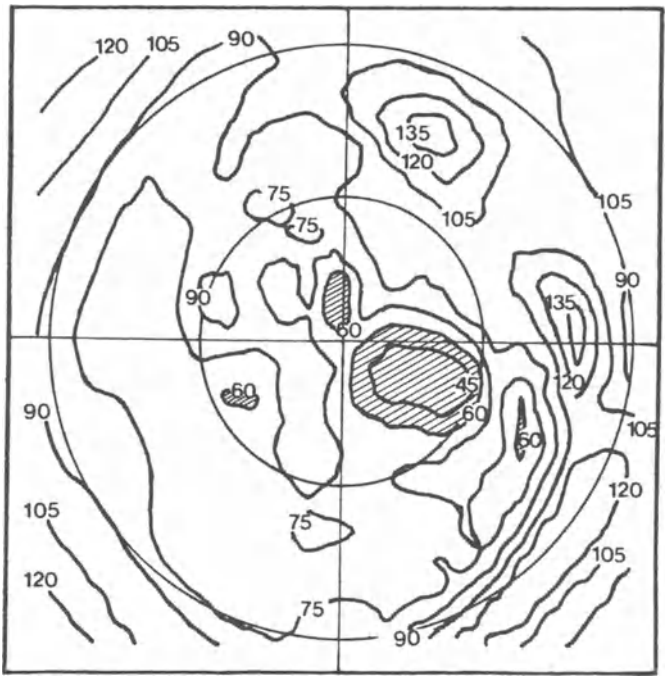

Fig. 3.- Isopleths of O_3 mixing ratio at the 12 mbar level ——— at day 21 (10 ppm).

mixing ratio, seems to be the location where mixing of polar air and air from the lower latitudes takes place. So, according to ideas of McIntyre (1982), the southward displacement of the polar vortex is not a reversible moving to and fro, but rather the result of nonconservative upward propagating waves.

The meridional cross section of the percentage change of O_3 mixing ratio relative to the start of the simulation (fig. 4) displays a nearly overall increase of O_3 in the model atmosphere below 60 km. While the large changes north of 60° N are due to transport the slight increase south of 30°N is probably connected with the temperature decrease, which leads to a somewhat lower O_3 destruction rate. Thus, a sudden stratospheric warming, as simulated in the present model, leads to an hemispheric increase of O_3 in the middle atmosphere up to 60 km.

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We would like to thank E. Falise for his very efficient help in preparing computer programs.

The edited files still contain some spurious readings which escape the initial editing routines. The data files are filtered in an attempt to remove any remaining erroneous data records which appear as spikes in the record (7).

Differences, Δ, are taken between sucessive one minute ozone records. If sucessive Δ's exceed 10 ppb and the simultaneous inter-instrument difference also exceeds 10 ppb then the appropriate ozone record is deleted. Other rules cover special cases.

The effect of this filtering is shown in Figure 4 where the number distribution of values of Δ per logarithmic size interval vs absolute value of Δ is presented. The filter has removed all data where Δ is greater than 10 ppb. Examination of the original records shows that the 0.2% of the records with values of Δ in the range 10 to 5000 ppb are associated with instrument malfunction and electrical noise. Therefore the filter technique appears very satisfactory.

5. Verification of Ambient Data

The verification of measured ozone concentrations monitored at Cape Grim is achieved by comparison of the values obtained from two or three of the ozone monitors. We see from Figure 5 and 6 that on 99% of occasions the hourly lmean concentrations differ by less than 4.5 ppb, on 99% of occasions daily mean concentrations differ by less than 2.5 ppb and all 21 monthly mean concentrations differ by less than 2 ppb.

An international comparison, of a similar nature involving five types of ozone monitors used for measurements in clean air was carried out at the Hohenpeissenberg Observatory between 1 October, 1978 and 30th April, 1979, (8). The deviations of the hourly mean values of each monitor from the collective mean were within the range ±9 ppb with about 60% of the deviations lying in the range ±2 to ±3 ppb depending on the monitor.

More international comparisons of this type are desirable to provide a firm basis for relating measurements made at different stations or in different networks.

6. The Representativeness of These Ambient Measurements

One particular concern with this program is whether the ozone concentration measured is representative of that present in baseline (unpolluted lower tropospheric) air.

When ozone was sampled at 3 m and 10 m height above the roof deck at Cape Grim using the two indistinguishable teflon inlets a systematic difference in ozone concentration was found with lower values occuring at the 3 m level, as illustrated in Figure 8. The extreme cases observed were:

(1) when winds were from 180° through 270° to 360°, that is from over the ocean (see figure 7) the ozone difference was 2-3% {(10m - 3m)x100/10m} for the wind speed range 20 to 75 km/hr; whereas

(2) with winds from 0° through 90° to 180°, that is from over land, the ozone loss varied from around 8% at 20 km hr^{-1} to around 2% at 55 km hr^{-1}.

This difference in ozone loss for the land and oceanic sectors probably reflects both the different ozone destruction rates of the underlying surfaces and the greater stability (weaker atmospheric mixing) which occurs over land compared with ocean surfaces (9,10).

Hence data selection based on wind speed and direction is necessary if the ozone data from Cape Grim is to be representative of the lower atmosphere.

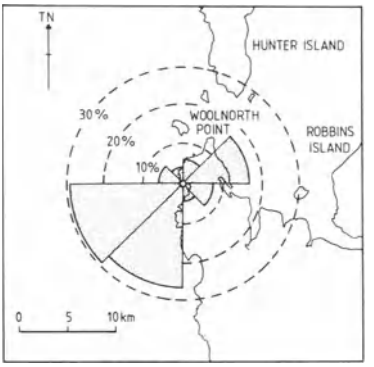

FIGURE 7

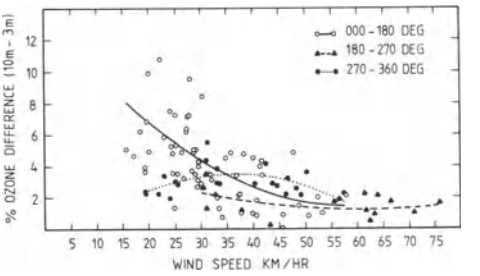

FIGURE 8

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L'OZONE SERAIT-IL L'OXYDANT PRINCIPAL DU SULFURE DE DIMETHYLE EN MILIEU OCEANIQUE ?

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Résumé

Les composés organo-soufrés sont la principale source de dioxyde de soufre en milieu océanique non pollué. Le problème du mécanisme de leur photooxydation n'est pas encore complètement élucidé. Pour mettre en accord certains résultats récemment publiés, nous avons été amené à formuler l'hypothèse de l'existence d'un cycle catalytique d'oxydation du DMS par l'ozone impliquant les espèces $I^{\bullet}$ et $IO^{\bullet}$.

Introduction

En milieu océanique non pollué, les composés organo-soufrés d'origine biogénique et particulièrement le sulfure de diméthyle sont les précurseurs principaux du dioxyde de soufre, et par conséquent de la fraction du sulfate de l'aérosol qui ne provient pas directement de la mer par pétillement.

Les mécanismes de l'oxydation du sulfure de diméthyle (DMS) dans la troposphère ont fait l'objet de nombreuses études, plus particulièrement ces cinq dernières années, mais comme le montrera notre discussion, tous les résultats ne concordent pas et aucun mécanisme pleinement satisfaisant n'a encore été démontré. Grâce à des résultats nouveaux, obtenus à la Pointe de Penmarc'h en Bretagne, où un très grand champ d'algues émet localement des quantités extrêmement importantes de composés organo-soufrés dans une atmosphère très peu polluée, il nous est possible d'émettre certaines hypothèses qu'il faudra vérifier minutieusement, mais qui permettent aujourd'hui de concilier certains résultats apparamment contradictoires.

Données Géochimiques

Dès 1972, LOVELOCK et al. (*1*) avançait l'hypothèse que l'océan émettait d'importantes quantités de soufre réduit sous forme de DMS. Depuis, plusieurs équipes de géochimistes ont précisé le flux d'émission global et la répartition géographique de ces émissions (*2-20*). On peut aujourd'hui estimer que le flux total de DMS de l'océan vers l'atmosphère est compris entre 28 et 360 Mt(S)/an. La répartition des émissions à la surface des mers est très inégale, et en première approximation varie comme la production biogénique primaire. Grâce à une étude du profil vertical de la concentration de DMS et de SO_2, NGUYEN et coll. (*15,20*) ont pu déterminer une première estimation de l'ordre de grandeur de la durée de vie du DMS dans la basse troposphère

qui serait d'environ un quart d'heure.

Données Cinétiques

On peut trouver dans la littérature des mesures de la vitesse de réaction du DMS avec quatre réactifs classiques de la troposphère : $O^{\cdot}(3P)$, $OH^{\cdot}$, O_3 et $NO_3^{\cdot}$.

- DMS + $O^{\cdot}(3P)$ (21-25)

Malgré la forte réactivité de $O^{\cdot}(3P)$ ($k \simeq 5 \times 10^{-11}$), cette réaction n'intervient sûrement pas car $O^{\cdot}(3P)$ est beaucoup trop peu abondant.

- DMS + $OH^{\cdot}$ (26-35)

Si l'on excepte la valeur de WINE et al., on dispose de 4 mesures presque cohérentes de la constante de vitesse ($k \simeq 9 \times 10^{-12}$). Très récemment BARNES et al. (33) ont trouvé que cette constante variait très légèrement avec la pression d'oxygène. Cependant la valeur de $k = 9 \times 10^{-12}$ et une concentration diurne typique de 2.10^6 radicaux/cm3 (36-37) pour $OH^{\cdot}$ conduisent à une durée de demi-vie de l'ordre de 20 h. pour le DMS.

- DMS + O_3 (38)

La réaction directe est beaucoup trop lente et sa constante de vitesse n'a pu être mesurée.

- DMS + $NO_3^{\cdot}$ (35)

$NO_3^{\cdot}$ est probablement le responsable principal des transformations chimiques nocturnes dans la troposphère (37,39-42). La constante de vitesse de la réaction DMS + $NO_3^{\cdot}$ a été, tout récemment, mesurée par ATKINSON et al. (35) : $k = 5{,}4 \times 10^{-13}$. Comme la concentration nocturne de $NO_3^{\cdot}$ peut être élevée $\simeq 2\ 10^{8}$ radicaux/cm3, on obtient alors une durée de demi-vie du DMS de l'ordre de 3 h.

Données de la campagne à Penmarc'h (43-44)

Cette campagne a eu lieu du 12 au 30 Septembre 1983. Sa conception et les premiers résultats ont été présentés au 3ème Symposium Européen sur le Comportement Physico-Chimique des Polluants. L'ensemble des résultats sera publié par ailleurs. Outre l'analyse des composés organo-soufrés en trois points de mesure, nous avons mesuré également le SO_2, l'ozone, les oxydes d'azote et fait quelques tentatives de mesures des composés carbonylés. Par ailleurs, nous disposons de données météorologiques classiques, température, pression, humidité, direction et vitesse de vent, puissance de l'irradiation solaire.

Les conclusions principales sont les suivantes :

- Les concentrations de DMS observées sont, à l'abord du champ d'algues, souvent de plusieurs ordres de grandeurs supérieures au fond océanique, tel qu'il a été caractérisé par d'autres équipes et tel que nous l'avons mesuré à la Pointe du Raz, situé à 60 km dans une zone dépourvue d'algues.

- Outre le DMS, trois autres composés organo-soufrés ont été identifiés sans ambiguité : le sulfure de diéthyle, le disulfure de diméthyle et l'éthanedithiol.

- Le disulfure de diméthyle est sûrement un composé secondaire issu du DMS.

- Les teneurs en aldéhydes mesurés près du champ d'algues sont très

élevées pour le milieu naturel (par ex : 30 ppb CH_2O, 20 ppb CH_3CHO) et sont comparables à celles d'un milieu urbain moyennement pollué. Ces fortes teneurs ne s'expliquent que par la conversion des émissions du champ d'algues.

- La durée de demi-vie du DMS, estimée à partir des variations de concentration relative du DMS et du DMDS entre les divers points de mesure, est très courte (5 - 20 min.) et est en excellent accord avec les résultats de NGUYEN et al., compte-tenu des très fortes incertitudes entâchant nécessairement ce type d'estimation. De ce fait, on n'observe pas de différence significative entre les valeurs diurnes et nocturnes.

Discussion

Il est donc manifeste que ces résultats sont en désaccord avec l'hypothèse que l'étape déterminante de la disparition du DMS soit l'attaque des radicaux $OH^\bullet$ à la concentration de 2.10^6 radicaux/cm3. Il faut donc envisager l'intervention d'autres phénomènes.

- La concentration de 2.10^6 $OH^\bullet$/cm3, issue des modèles de LOGAN et al. (37) ou de WEINSTOCK et al. (36) est généralement considérée comme un maximum possible (atmosphère parfaitement calme, irradiation maximum) en l'absence de pollution hydrocarbonée. Comme justement, les teneurs en aldéhydes mesurées sont assez élevées, on peut soupçonner une plus forte concentration en radicaux $OH^\bullet$. Cependant, atteindre une concentration de 10^8 $OH^\bullet$/cm3 paraît bien improbable.

- La réaction avec $NO_3^\bullet$ semble effectivement expliquer une bonne partie des transformations chimiques de nuit, mais ne peut en aucun cas être évoquée pour les transformations de jour.

- Une explication plausible peut être trouvée, en tenant compte du rôle possible d'un autre composé très facilement photolysable, présent dans les atmosphères marines : l'iodure de méthyle (45-46).

Par photolyse CH_3I donne deux radicaux $CH_3^\bullet$ et $I^\bullet$. $CH_3^\bullet$ va essentiellement contribuer à enrichir l'atmosphère en formaldéhyde. Le rôle possible de l'atome d'iode dans la troposphère a été discuté par CHAMEIDES & DAVIS (47). Le phénomène qui nous importe le plus pour l'oxydation du sulfure de diméthyle est la formation d'espèce $IO^\bullet$ par la réaction :

$$I^\bullet + O_3 \rightarrow IO^\bullet + O_2$$

$IO^\bullet$ est un oxydant énergique de CO et NO

$$IO^\bullet + NO \rightarrow I^\bullet + NO_2 \qquad (k = 1{,}7\ 10^{-11})$$
$$IO^\bullet + CO \rightarrow I^\bullet + CO_2 \qquad (k = 10^{-17})$$

comparable à $NO_3^\bullet$

$$NO_3^\bullet + NO \rightarrow 2\ NO_2 \qquad (k = 2 \times 10^{-11})$$
$$NO_3^\bullet + CO \rightarrow NO_2 + CO_2 \qquad (k = 10^{-17})$$

On peut alors émettre l'hypothèse que la réaction

$CH_3\text{-}S\text{-}CH_3 + IO^\bullet \rightarrow CH_3\text{-}SO\text{-}CH_3 + I^\bullet$ a une constante de vitesse du même ordre de grandeur que

$CH_3\text{-}S\text{-}CH_3 + NO_3^\bullet \rightarrow CH_3\text{-}SO\text{-}CH_3 + NO_2$ c'est-à-dire $10^{-13} \sim 10^{-12}$

Ainsi, on voit la possibilité de l'existence d'un cycle catalytique d'oxydation du DMS par l'ozone

$$I^\bullet + O_3 \rightarrow IO^\bullet + O_2 \qquad (1)$$
$$IO^\bullet + DMS \rightarrow DMSO + I^\bullet \qquad (2)$$

Pour confirmer ou infirmer cette hypothèse de travail, il convient maintenant de mesurer la constante de vitesse de la réaction (2) et d'estimer la valeur de la concentration de $IO^{\cdot}$ dans la troposphère.

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OZONE PRODUCTION AND TRANSFER IN THE FOS-BERRE BASIN AREA

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Summary : During the 1983 European Campaign of Fos-Berre, the local ozone pollution survey network (5 analysers) have been completed by measurements on 3 sites distant of about 30-50 km far from the industrial area. A regional analysis of the set of data is performed with respect to meteorological parameters. The Fos-Berre area appears to be one of the major source of photooxidant pollution in the region (Ozone concentration of 230 ppb have been measured). Medium range transport of ozone have been evidenced and local peak concentrations have been tentatively interpreted.

1. INTRODUCTION During the 6th. European Campain of Atmospheric Pollution held in the Fos-Berre harbor agglomeration in June 83, we proposed to evaluate the behaviour of ozone at a regional scale. Our purpose was to understand the process of photooxidant pollution in the Fos -Berre area. We wanted also verify in what extend the industrial zones of the basin act as a source of ozone, formed within the plume and transported to downwind areas, as it has been studied in the case of north-eastern U.S (6-7) , or as a scavenger for preexisting ozone, as it has been shown in certain cases in north-eastern Europe (3-4). A description of the area can be found elsewhere (1-2).

2. SELECTION OF STUDIED AREAS Important meteorological and physico-chemical means were installed within a radius of 10 km around Berre basin during the campaign. In addition, two well equipped air pollution monitoring networks operate continuously in the area. We chose to complete the whole network by carrying out ozone measurements in three rural sites, supposed to be influenced by the emission of pollutants from the industrial areas. This allowed us to follow the evolution of the ozone composition of the plume in two downwind transfert cases : 1). S to SE wind system (Baux de Provence) and 2). SW wind system (St. Cannat and Sommet du Luberon). The exact localisation of the sites is shown in fig. 2.

3. MEASUREMENTS AND METEOROLOGY Ozone was measured by a U.V absorption method using Environnement SA apparatus. The meteorological and other (SO_2, NOX, HC, Aerosols...) data used in this study were provided by the permanent monitoring network and by other teams participating in the campaign. The meteorological caracterisation of the area and the description of the situations encountered during the campaign were provided by AUGUSTIN et al (2).

4. RESULTS AND INTERPRETATION An initial analysis of the results is presented in this paper. The high diurnal ozone profiles during the campaign are shown in fig.1. Sharp and intense morning peaks of ozone in the eastern area of the basin (Vitrolles, Rognac and St. Cannat), as well as in the rural areas of Baux and Luberon can be noticed. These profiles can be interpreted in terms of four major parameters :

-Background level. The rural areas clearly presented a background level of 50 ppb. This level is usually encountered, there, at an altitude between 300

and 1200 m, whatever the meteorological conditions are. The situation observed on June 6 th. at 6.00 am (fig 2) is significant of a nocturnal situation: background levels in the three rural areas and low levels in the industrial area. In rural area no diurnal cycle was observed with a few exceptions which will be discussed later on.

- Local sources of ozone scavengers. The analyser installed at Marseille was located in the center of the city. The discharge of NO emitted by traffic appears to be permanently higher than photochemical ozone production. The ozone level remains low, as it has been previously observed in other great urban centers (4-8-9). Rognac is located at sea level in the vicinity of Berre industrial area. The strong nocturnal stability of the atmosphere in this part of the basin confines the industrial emissions in the lower air layer, leading to total consumption of existing ozone during the night : nocturnal concentrations of ozone, in order of 5 ppb only, are therefore often registred in Rognac. On the contrary, the analyser at Port de Bouc, installed at a height of 60 m above sea level, was placed in an atmospheric section less supplied, during the night, of ozone scavengers. For this reason the nocturnal ozone concentration in Port de Bouc is usually higher than in other industrial areas. The residential area of Vitrolles, situated at a height of 40 m, although at the immediate proximity of Rognac, presented an intermediate nocturnal situation. All these results show that the intensity of the observed minima throughout the ozone profiles can mainly be attributed to the intensity of local sources of reducing agents that lead to ozone scavenging.

- Convection. Ground level ozone concentrations are strongly governed by convection (3-4-5-9). Low ozone levels, observed during the night in some areas, are due to negligible nocturnal convection associated with local sources of scavengers. During the day, the convection has two opposite effects. The first is that it leads air masses, rich in ozone, to the ground level. The second effect is the dilution of primary pollutants emitted by industrial sources in a mixing layer whose height increases during the day, therefore influencing the rate of photochemical ozone production. This process will not be discussed in detail here ; we will recall it, however, in order to interprete some episodes in Vitrolles and Rognac.

- Transport. The observations carried out in the three rural sites clearly evidence ozone transports. Fig.2 shows the evolution of the concentration in the area during the daytime at June 6. The wind system is established as SW from 10 h on. The plume, rich in ozone, that was observed in Vitrolles at 10 am is carried down to St Cannat during the day where it is observed at 11 h-12 h , and it reaches Luberon at about 15 h. A this moment, the highest ozone concentration of all sites is observed at the top of Luberon. This situation lasted until about 6 pm. It should be noted that transport observation at the top of Luberon supposes a development of the mixing layer up to 1000 m. In all cases, this phenomenon may delay the hour of maximum observation at the summit with respect to the normal transfer duration. In certain cases it is possible that the plume is blocked in lower altitude.

A sharp ozone peak at Baux at noon was simultaneously observed (fig.1). The sharpness of the peak and the fact that Baux was downwind of the Berre basin since 9-10 am led us to reconstitute the air masses trajectory, using all the available data concerning the velocity and direction of the wind at ground level. Fig.3 shows the trajectories of the air masses reaching Baux respectively at 10 h, 12 h, 14 h. It can be noted that the air mass that was slowly transported above the industrial sites during the night reached Baux at noon. The observed ozone was produced in large part by photochemical

process within the plume during the morning. This situation, however, was short-lived, due to the rapid rotation of the winds, after the sea-breeze system has been established : earlier, Baux was supplied with air coming from the east ; later, it is the non polluted sea air that reaches the site.

The situation in Baux at the 7 th was very different (fig. 1). The average wind direction (2) is fixed to SE. the site is downwind of the Fos-Berre basin and concentrations clearly higher than background level are observed all day long : the profile is broad and concentrations in the order of 100 ppb or more are observed for many hours. In the same time, no particular accident was detected in Luberon.St Cannat was not downwind of the Fos-Berre basin ; the concentrations observed that day are clearly lower than the other days.

During the study, the only day when the wind blowed from the west was June 9 th. A very high ozone concentration in Vitrolles and Rognac was then observed. It was also the only day when a hight ozone concentration was detected in St Baume. The trajectory of the air mass reaching St Baume at 2 am. appears in fig 4. Despite the difficulties in making such a reconstitution (very instable breeze at night,insufficient meteorological data for the zone of nocturnal transit), it appears that the air mass passed for a first time over the Berre basin in daytime of June 8 th., then over the industrial centre of Gardanne during the night, to pass a second time over the Berre basin in the morning of the 9 th. A subsidence in the centre of the basin can probably be associated with a pond breeze observed at 9 am.(10). It can be assumed that the air mass passing around 8 am. over the basin is reintroduced at ground level by this subsidence. The particularly high ozone level observed in Vitrolles-Rognac could have been produced photochemically at high altitude during the first morning hours within the air layer rich in ozone precursors, for a first time on June 8 th. over the basin and for a second time over Gardanne during the night. The briefness of the episode can be connected on the one hand to the briefness of the pond breeze phenomenon, and on the other hand to the dilution within the mixing layer, due to an increasing convection during the morning.

5. CONCLUSIONS The observed ozone profiles over the area during the study result from the competition of many factors : background level, sources of ozone scavengers, precursors sources, photochemistry, convection and transport. In the early morning, an intense photochemistry with high production of oxidants occurs within the high layers rich in O3 precursors, which are typically situated at an altitude of 100 to 300 m. At ground level, the accumulation, during the night, of an important stock of reducing agents slows down the ozone production. Ozone peaks occur when ozone produced in high altitude is injected in the mixing layer because of the increase in the mixing layer height. The disappearance of the peak is due to both homogenisation by convection and displacement of the air masses. These effects can be accentuated according to the history of air masses and to specific phenomena, such as the pond breeze. Long distance transports have been observed, indicating that high ozone levels can be observed far away from any sources of precursors of photochemical pollutants.

We intend to analyse further the fransfer process as soon as the whole wind data concerning the study zone will be available.

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Figure 1 : Diurnal ozone profiles during the campaign.

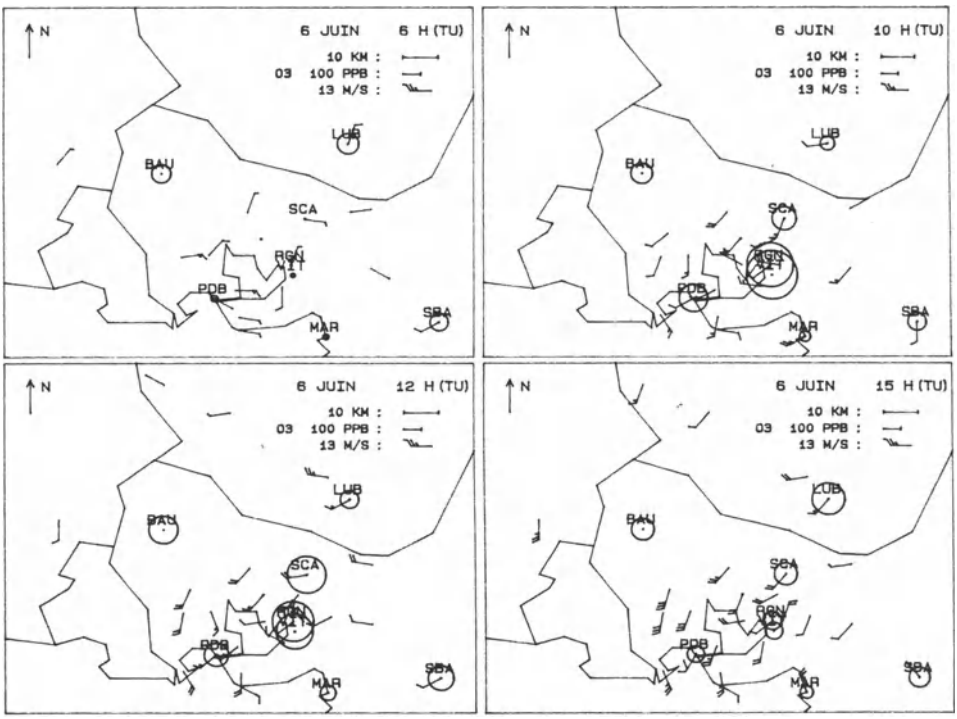

Figure 2 : Ozone distribution over the studied area on June 6.

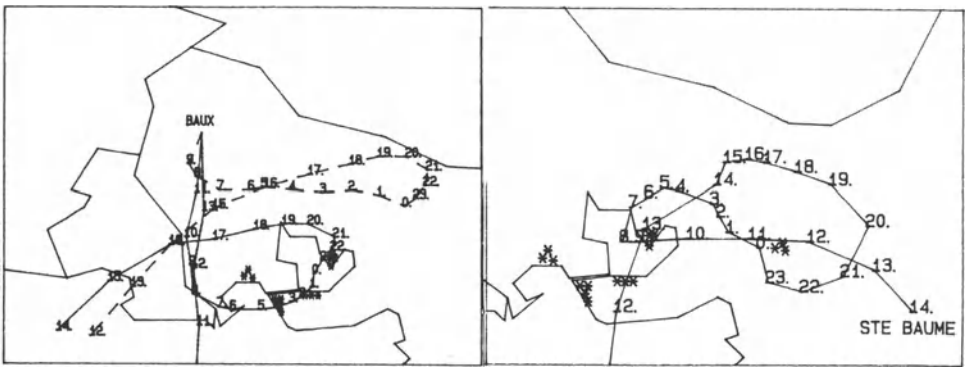

Figure 3 : Air mass trajectories reaching Baux at 10 am(– –),12 am(——) and 14 am(---) on June 6.

Figure 4 : Air mass trajectory reaching Vitrolles at 10 am and St Baume at 14 am on June 9.

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