Ozone within and below the west coast temperature inversion

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ABSTRACT

The oxidant concentration in the air over the San Francisco Bay Area and the Pacific Ocean was measured up to an altitude of 2500 m and the observed distribution in the vertical and horizontal has been related to the characteristics and behavior of the west coast temperature inversion. Vertical time sections at fixed points and vertical cross sections were constructed of oxidant concentration, temperature, humidity and winds measured from aircraft and radar.

The oxidant concentration in polluted air is strongly dependent on the destruction rate. The mean destruction rate within the surface layer depends directly on the intensity of eddy mixing and inversely on the square of the depth of the vertical mixing. Thus, the existence of a temperature inversion does not necessarily lead to a high concentration of oxidants, since the destruction rate may be high in a shallow mixing layer. The highest oxidant concentration was observed almost invariably at the edges of the west coast marine inversion, where pollutants are available for ozone production and the mixing layer is deep. Explanations are offered for the maxima of ozone that often occur above the inversion base. Distribution patterns of oxidants clearly depict the waving of the inversion layer.

1. Introduction

Ozone in the atmosphere has been recognized as a rather effective tracer in the lower stratosphere and upper troposphere (see, e.g., Hering, 1966; Junge, 1963; Kulkarni, 1966), where it is relatively well conserved, but not in the lower troposphere. The natural level of ozone in the lower troposphere is typically very small—only 2 to 4 pphm—and the surface is a strong sink. In addition, the polluted air of urban areas can be a significant source, as well as a sink, involving a complex series of chemical reactions (see, e.g., Haagen-Smit & Wayne, 1968).

Despite these complications, we decided to add ozone concentration as one of the parameters that we measure from aircraft over the San Francisco Bay Area. It was hoped that the ozone measurements might aid in determining the possible exchange process across the temperature inversion that is so persistent in this area during the summer. We had observed that radioactive material tends to concentrate within the sub-tropical inversion over Hawaii (Kruger & Miller, 1966) and that there is often a peak of ozone within the inversion layer over the San Francisco Bay Area (Lovill & Miller, 1968) and over Southern California (Lea, 1968). In the vicinity of San Francisco, this peak ozone concentration often coincides with the location of a jet frequently found in the inversion layer (Miller, 1968).

We set out to determine, as well as we could, both the temporal and spatial variations of ozone in relation to the west coast temperature inversion. In the process, we believe that we have uncovered some information that may be significant in predicting the oxidant levels in so-called photochemical smog.

2. Procedure

The observational program of ozone was designed to sample a volume of air that completely blankets significant source regions up to an altitude where the effects of the surface on production and destruction become negligible. In order to measure the distribution of ozone, temperature, and moisture in the horizontal and vertical, we equipped a small, twin-engined, Apache aircraft with the portable electrochemical (KI)

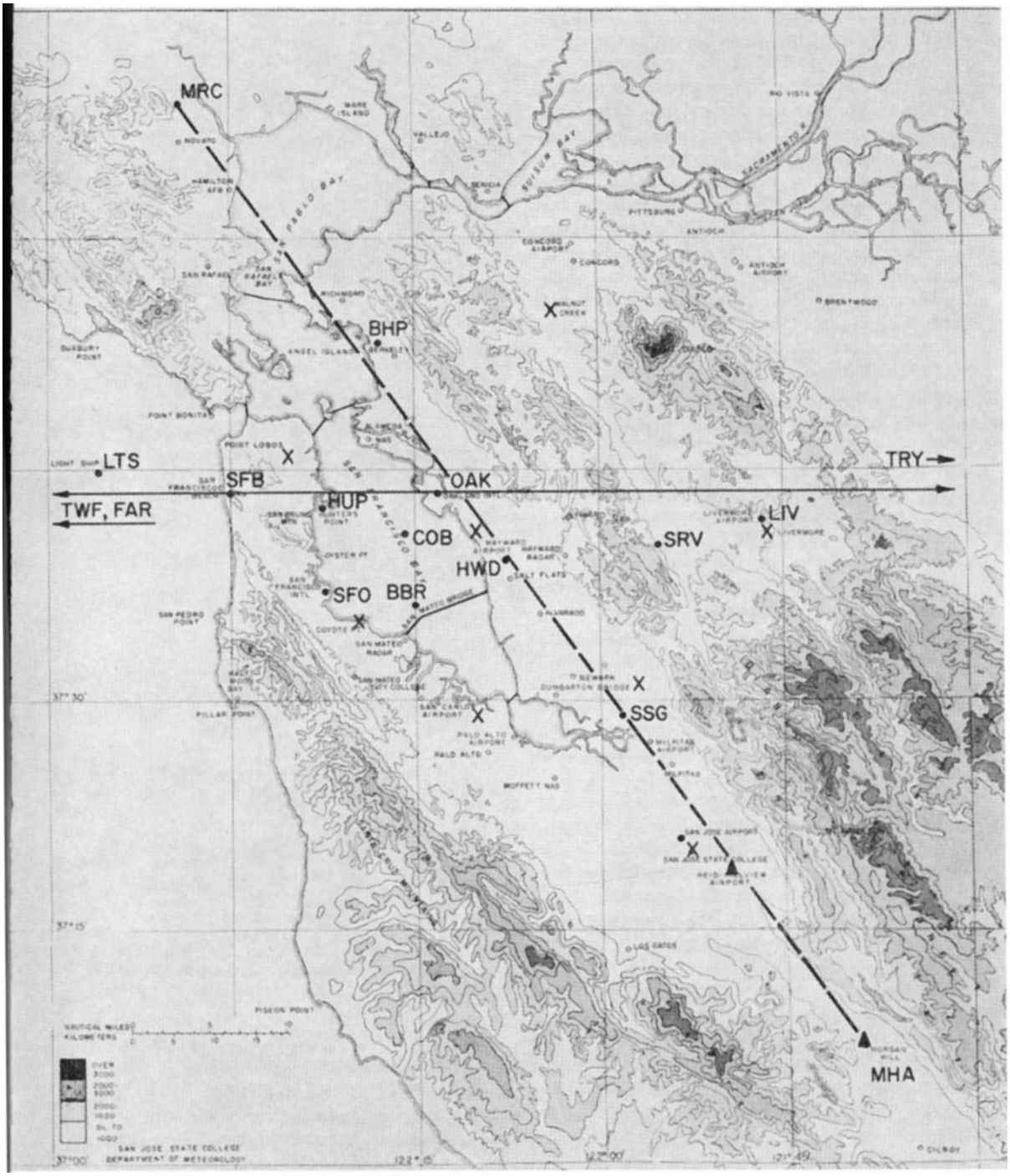

Fig. 1. The San Francisco Bay Area. Solid line: transverse sections of valley; dashed line: longitudinal sections; dots: vertical soundings; triangles: serial vertical soundings; crosses: ground-level sampling stations.

ozone meter[1] designed by Komhyr (1968), wet and dry bead thermistors, and a Bourns pressure transducer; all of these were connected to strip chart recorders. Exposures of sensors and of the intake tube for the oxidant meter were such that significant influences on the temperature readings by the fuselage or contamination of the ozone samples by the aircraft's engines were very unlikely. The dry and wet bulbs were shielded against radiation and the temperatures corrected for air speed. The uncertainty of the ozone meter is about 5 % of the indicated value; its response time for a 90 % stepwise change in ozone is less than 60 sec. The probable error and time constant of the temperatures are about 0.2°C and 0.1 sec, respectively; for the pressure device, about 0.4 mb and 0.5 sec. The aircraft's cruising speed in level flight was about 60 ms^{-1} and the typical ascent/descent rate was 3 ms^{-1}.

Two types of flights were made: (1) periodic, slow ascents and descents over one or two points throughout a day and (2) straight-line paths that traversed the San Francisco Bay Area in west-to-east and northwest-to-southeast directions, with frequent vertical descents enroute. (See map of Fig. 1) The serial ascents were made at the south end of Santa Clara Valley—over Reid-Hillview (RHV) and Morgan Hill (MHA) Airports. The west-east flights generally followed a path from Tracy (TRY) to a point (TWF) about 25 n mi west of the Farallon Islands (FAR), a total distance of about 190 km, with vertical soundings at such places as Livermore (LIV), San Ramon Village (SRV), Hayward (HWD), etc. The northwest-southeast flights generally extended from the north shore of San Pablo Bay to Morgan Hill Airport, a total distance of about 160 km, with descents over Berkeley (BHP), Hayward, Sky Sailing Airport (SSG), etc.

The airplane measurements were supplemented by winds aloft obtained by means of automatic radar tracking of balloon-borne reflectors at San Francisco (SFB) and at Hayward; occasionally optically tracked pilot balloon observations were made at San Jose and Livermore.

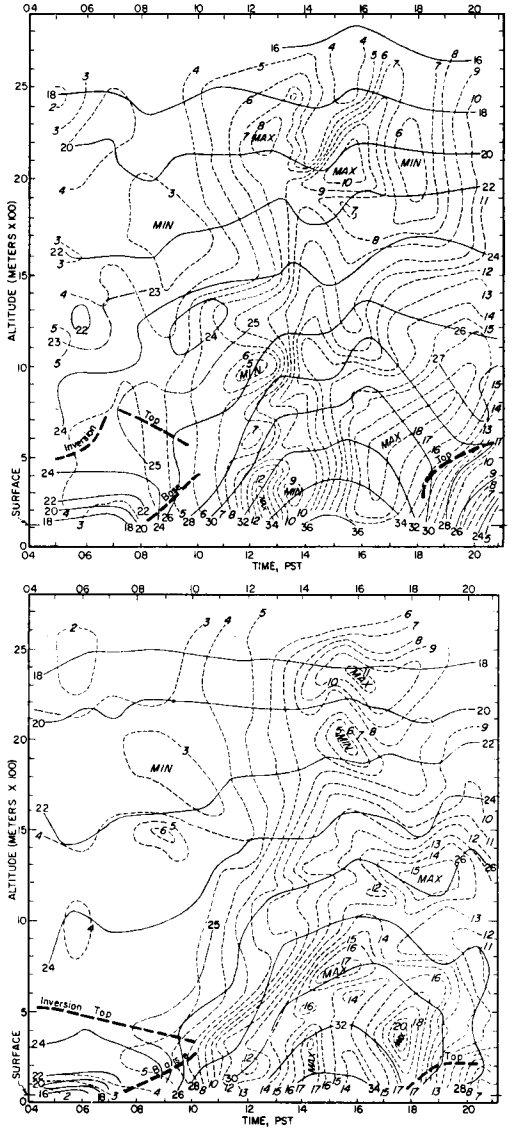

Fig. 2. Vertical time sections of temperature (C) and oxidant concentration (pphm) on 29 Aug. 1968. (*a*) Morgan Hill Airport, (*b*) Reid-Hillview Airport.

3. Discussion of results

a. *Vertical distribution of oxidants as a function of time*

Fig. 2 shows vertical time sections of ozone and temperature constructed for two sites in the southern end of the valley that are about 27 km apart. Soundings were made at 1–2 hour intervals between 0400 and 2100 PST on 29 August 1968. Note that: (1) the ozone concentration in the lowest few hundred meters increases sharply

[1] The ozone meter responds to *total oxidants in* the air. However, most of the oxidants, even those produced photochemically in polluted air, is ozone.

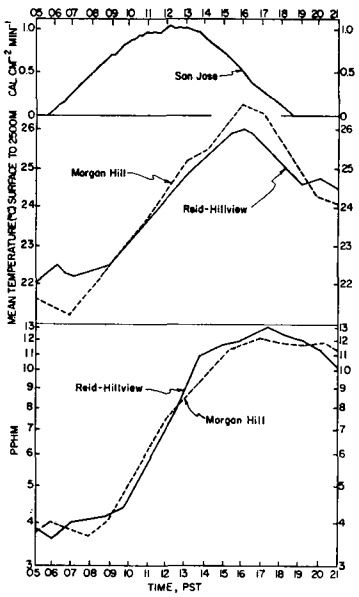

Fig. 3. Mean O_3 concentration (pphm) and temperature (C) from surface to 2500 m, 29 Aug. 1968, at Morgan Hill (114 m) and Reid-Hillview (43 m) Airports; total (hemispheric) radiation at San Jose on the same day.

when the temperature inversion breaks down between 0900 and 1000 PST and decreases rapidly after about 1800 PST, as the inversion forms again. (2) Between about 1000 PST and 1500–1600 PST the ozone concentration increases at all levels up to 2700 m. These observations seem to indicate that ozone concentration is closely linked to the degree of vertical mixing, but in a sense *contrary* to the idea of pollutant trapping.

Most studies of oxidants associated with air pollution have concentrated on the meteorological and photochemical processes that affect the *production* of ozone. Laboratory studies have attempted to establish the complex series of reactions that occur when polluted air containing oxides of nitrogen and hydrocarbons are irradiated by ultraviolet light (Haagen-Smith & Wayne, 1968); meteorological studies (e.g., Neiburger, 1959) have examined the air circulation patterns that cause an increase of pollutant concentration. The notion that weak winds and stable stratification lead to a trapping of pollutants, a large production rate and therefore high oxidant concentration, is now generally accepted. The few measurements of oxidant distribution in the vertical (Renzetti, 1955; Neiburger *et al.*, 1955) seem to confirm that it is the trapping of pollutants below the temperature inversion that leads to a high concentration.

Very little attention has been given to what may be a more significant factor than production in determining the observed concentration of oxidants in polluted air: destruction rate. The observations that follow demonstrate, we believe, that the concentration of oxidants is far more sensitive to the destruction rate of the oxidant than it is to the amount of pollutants present (production rate).

Ozone is destroyed by combination with gaseous and particulate trace substances, but primarily through contact with the earth's surface (Junge, 1963). Some idea of the typical destruction rate within the boundary layer of air and at the surface can be obtained from the studies of several investigators. For example, Junge & Czeplak (1968) estimate that natural ozone from the stratosphere is injected into the troposphere at the rate of 4.7×10^{14} g/yr in the northern hemisphere, so that the average destruction rate must be about 6×10^{-12} g/cm²/sec, most of which occurs close to the earth's surface. Kroening & Ney (1962), from their measurements over Minneapolis during the summer, estimated the surface sink strength at about 5×10^{-12} g/cm²/sec. Regener (1957), from his ozone profiles over O'Neill, Nebraska, found the sink strength to average about 8×10^{-12} g/cm²/sec.

The average concentration for the entire layer of air up to 2500 m elevation for the two sites, as a function of time, is presented in Fig. 3. The maximum mean concentration occurred at

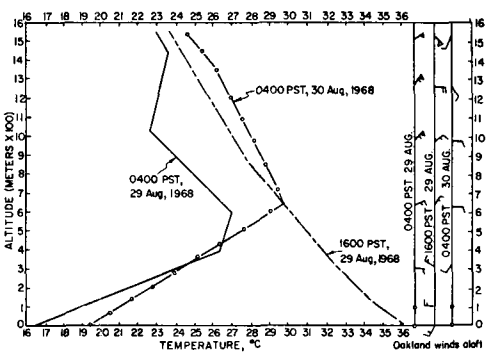

Fig. 4. Oakland rawinsonde observations, 29–30 Aug. 1968. (Wind barbs: triangle, 5 ms^{-1}; full barb, 2 ms^{-1}.)

about 1715 PST, an hour before sunset, about 5 hours after the time of maximum solar and sky radiation recorded at San Jose and about an hour after the maximum mean temperature of the 2500 m layer. If the entire layer is broken into 200 m increments and the time variation of O_3 and hydrostatic stability are examined, there is an almost perfect inverse relationship between stability and O_3: strong lapse corresponds to *high* O_3 in each layer and stability to *low* O_3 concentration.

The horizontal transport of ozone or reagents on 29 August 1968 was weak, so that the time variation of the mean concentration in the 2500-m layer depended principally on the production and destruction rates. Note, first of all, that the average oxidant concentration for the layer is almost equal at the two stations (25 km apart) throughout the day, with a maximum difference between the two at any time of only 0.9 pphm. The winds were generally light throughout the day: the average for the layer was NE, 3 ms^{-1} (Fig. 4); near the surface, the maximum wind was 6 ms^{-1} from the northwest between 1400 and 1530 PST, but during most of the observation period it was 3 ms^{-1} or less. Relatively-high oxidant readings were recorded near the surface everywhere in the valley (Fig. 5), with no advection pattern discernible. At San Francisco, e.g., the highest oxidant value of the summer—17 pphm—and possibly the highest temperature—97°F—were recorded on this day (an indication of the weakness of the seabreeze). The peaks at Redwood City, Fremont, and San Jose, which lie on an approximate NW-SE line, occurred at about the same hour.

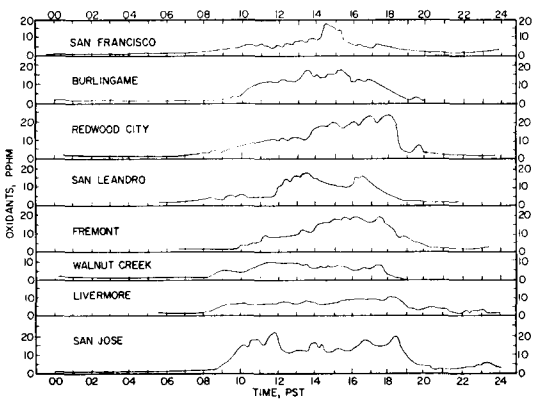

Fig. 5. Oxidant concentration near ground level, 29 Aug. 1968.

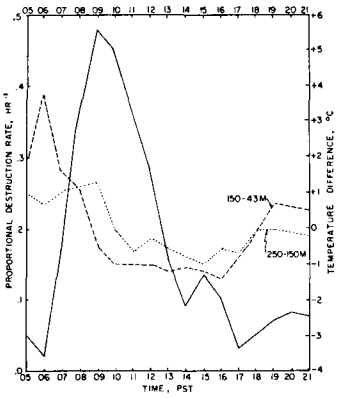

Fig. 6. Computed relative destruction rate at Reid-Hillview Airport on 29 Aug. 1968. Dashed curves: temperature difference 150 m-surface and 250 m–150 m.

Assuming the production of ozone was only a function of total radiation intensity (a measurement of just the UV component was not available), that the production rate equaled the desctruction rate at about 1715 PST (time of maximum O_3) and that this destruction rate was approximately equal to that ($\sim$0.8 pphm/hr) during the post-sunset hours of 1830–2000 PST (see Fig. 3), the production rate throughout the day can be computed. The destruction rate as a function of time can then be obtained from the differences between the observed rates of change of mean oxidant concentration and the computed production rates throughout the period. Fig. 6 presents the relative destruction rate,

$$\frac{1}{c}\left(\frac{\Delta c}{\Delta t} - P\right),$$

as a function of time, where c is the concentration (pphm) and P is the production rate; it shows more clearly perhaps what might also be inferred from the vertical time sections of Fig. 2. The mean destruction rate in the layer was at a minimum just after sunrise, when the stability was greatest and, presumably, the vertical eddy diffusion weakest. (Note the temperature difference curves for the layers between the surface and 150 m and between 150 and 250 m.) As heating began and the stability in the lowest layer of air decreased, presumably the intensity of vertical mixing

increased and the destruction rate increased abruptly. This increase continued until the inversion was completely destroyed and the mixing layer greatly deepened shortly after 0900 PST; the mean destruction rate then decreased sharply. In the early evening, stability was reestablished from the surface upward so that the intensity of eddy mixing was progressively reduced from the surface upward, and the mean destruction rate remained low. In fact, a peak of ozone formed above the inversion, in the air that had been cut off from surface contact. During the three hours after sunset, the average concentration decreased by 8 pphm in the relatively stable air below 650 m while there was little change in the layer above 1250 m, where lapse conditions persisted.

The average relative destruction rate in a layer of polluted air above the surface should depend directly on the intensity of eddy mixing and inversely on the square of the depth of vertical mixing, if we assume that the relative destruction rate in the layer is governed by the heat conduction equation. Thus, the depth of vertical mixing affects the concentration of oxidants generated near the surface in a sense that is opposite to the behavior of more inert contaminants. The inverse of the relative destruction rate presented in Fig. 6 is a measure of the typical residence time. The maximum residence time for the 2500 m layer, which occurs at the time of maximum stability, is about 40 hours and the minimum is about 2 hours; the average for the 16-hour observation period is 6 hours and interpolation throughout the night-time hours yields an estimate for the average over 24 hours of about 7 hours. For purposes of comparison, Junge & Czeplak (1968) estimate the "most likely" residence time for the entire troposphere to be approximately 3 months; note that the ratio of the residence times, 7 hours 3 months, is approximately proportional to the squares of the mean mixing depths, $(0.5\ \text{km})^2$: $(9\ \text{km})^2$.

That the observed concentration of oxidants in polluted air depends strongly on the average destruction rate, which is related to the intensity and depth of eddy mixing in the vertical, tends to be confirmed by the typical time variation of surface oxidants. The peaks of NO, NO_2, and hydrocarbons near the surface normally occur prior to 0900 local time each day, which is when the air is most stable; oxidants, however, usually reach their peak near 1500 (U.S. Dept. Commerce, 1967), which is typically the time of minimum stability and greatest depth of vertical mixing.[1] Haagen-Smit & Wayne (1968) indicate that the maximum concentration of ozone in polluted air over the Los Angeles Basin is perhaps a seventh or less of the total destroyed during the day. If this is so, a small percentage change in the destruction rate could strongly affect the observed concentration.

Finally, the time sections of Fig. 2 illustrate how maxima of the ozone that has been generated in the surface layer can appear above an inversion. As the inversion reformed, the ozone above it, cut off from the surface and new pollutants generated at the surface, evidently was destroyed at a much slower rate than that below the inversion layer; vertical convergence within the descending air above the inversion (Miller, 1968) may have helped to confine the O_3 to this layer.

b. *Spatial variations of* O_3

The vertical cross sections shown in the next few figures illustrate very dramatically the role played by air motion in determining the amount of oxidants in polluted air, through cntrol of the destruction rate. The first west-east cross section (Fig. 7*a*), constructed from observations taken within 2 hours of sunrise, is the first of a series of five obtained throughout a 26-hour period. Between a point 90 km west of the shoreline and the east side of the San Francisco Bay, the base of the temperature inversion was at an altitude of about 400 m; from there, the base sloped gradually downward over a distance of some 70 km, reaching an altitude of about 100 m over Tracy. The O_3 concentration was only 1–2 pphm everywhere within the marine air beneath the inversion. But above the inversion base the concentration increased and there were maxima of 7 pphm about 1200 m above the base. Evidently destruction was strong within the marine layer and weak above the inversion layer, with a sharp transition zone within the inversion. Note the waving of the inversion over the San Francisco Bay—a phenomenon that we have often observed. As we shall show more clearly later on,

[1] This applies to areas *not* subject to a seabreeze circulation; in areas that do experience such a circulation, advection of cool marine air can reestablish an inversion in midday.

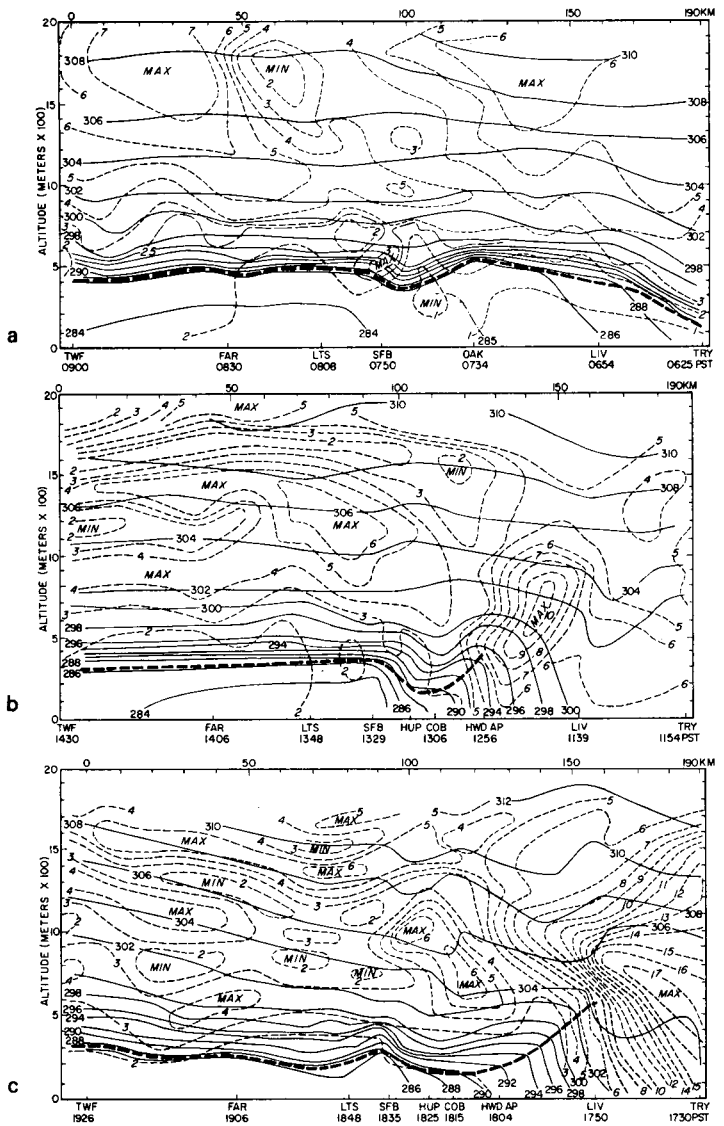

Fig 7 a, b, c

there is often significant mass exchange across the boundary in the vicinity of these waves.

The cross section along the same line about 5 hours later (Fig. 7*b*) shows that the interior portion of the inversion had broken down east of Hayward (east side of the San Francisco Bay). West of Hayward, within the marine air, the ozone concentration was not more than 2 or 3 pphm; above the inversion, the ozone was highly stratified, the laminae evidently associated with zones of vertical flux divergence. However, at the very edge of the inversion, between Hayward and Livermore, a strong maximum (> 10 pphm) of O_3 had developed.

About 5 or 6 hours later (~ 1830 PST, Fig. 7*c*) the seabreeze had penetrated inland, with the inversion extending eastward to Livermore. Note that the peak O_3 concentration was just west of Tracy, having been displaced inland along with the leading edge of the inversion. The oxidant values at Livermore actually decreased since the time of the earlier cross sec-

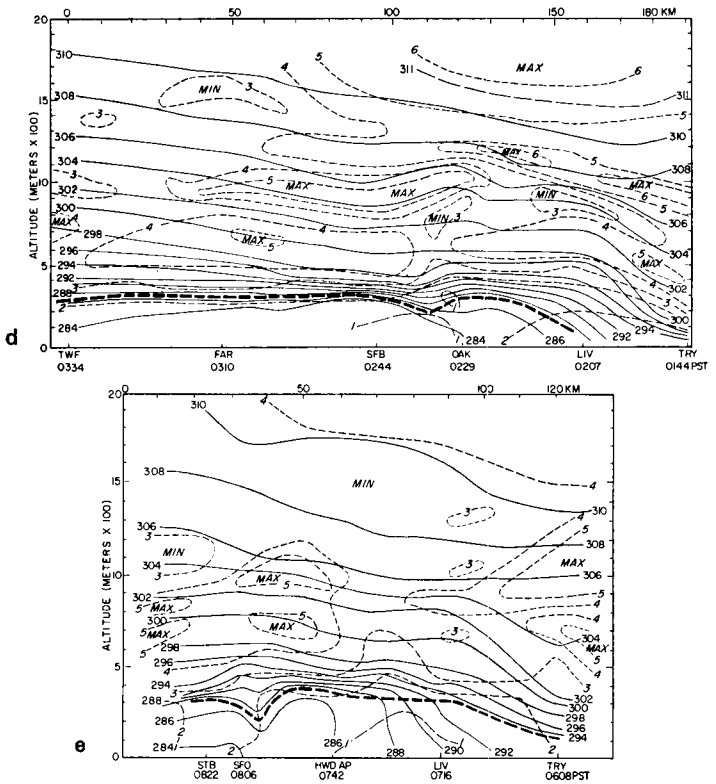

Fig. 7. Vertical west-east cross sections. (Solid lines: potential temperature, K; dashed lines: O_3 concentration, pphm; heavy dashed line: inversion base. Sites and times of vertical soundings are indicated along lower border; distance scale along upper border. Data were also available along at least two horizontal legs for each cross section.) (*a*) 10 July 1968, 0625–0900 PST; (*b*) 10 July 1968, 1139–1430 PST; (*c*) 10 July 1968, 1730–1926 PST; (*d*) 11 July 1968, 0144–0344 PST; (*e*) 11 July 1968, 0608–0832 PST.

tion, evidently because of the reestablishment of the temperature inversion. Note how the isopleths of concentration bend westward above the advancing inversion between Livermore and Hayward; this may be because the destruction rate in the air above the inversion was less than that within the marine air. The inversion to the west was wavy and 100 to 200 m lower, on the average, than during the early morning; the lowering can be attributed to horizontal divergence of the eastward-flowing marine air. (The surge of the marine air at Livermore at about 1600 PST could be clearly detected from hourly winds aloft observations.) Above the inversion, the laminae of ozone-rich air remained as before.

That night (~0230 PST, Fig. 7*d*), the inversion reestablished itself over the interior, reaching down to the surface east of Livermore. At the surface, the ozone concentration was again only 1–2 pphm everywhere. The strong peak that was located between Livermore and Tracy was either dissipated and/or it was advected still further inland. The last cross section of the day (Fig. 7*e*, ~0730 PST) only extended westward as far as the coastline. Below the inversion, the concentration of O_3 was only 1–2 pphm everywhere; above, the concentration was somewhat more uniform than it was earlier, but nevertheless, stratification was evident.

The buildup of ozone concentration along the inversion's edge can be explained in terms of destruction rate. The inversion edge marks the approximate limit of penetration of polluted marine air in which there is production of oxidants. The vertical mixing depth increases brusquely and, therefore, the mean destruction rate decreases rapidly along a line normal to this boundary, as one moves out of the marine

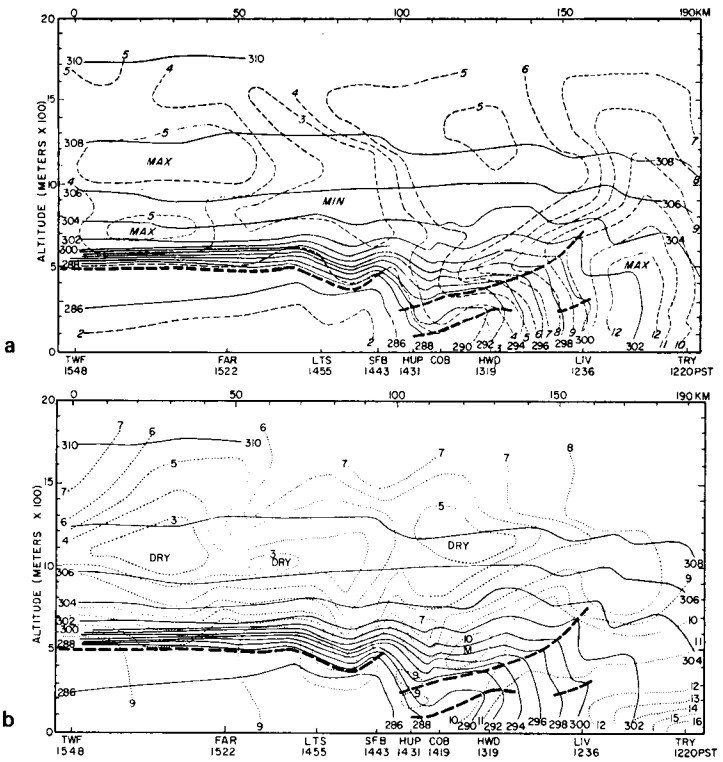

Fig. 8. Vertical west-east cross sections, 30 July 1968, 1220–1548 PST. (*a*) O_3 and potential temperature (see legend of Fig. 7). (*b*) Mixing ratio (g kg^{-1}) and potential temperature (K).

air. Thus, the seabreeze circulation determines where the maximum concentration occurs, since it largely determines where the edge of the inversion will be located. North-south cross sections that have been constructed along the east side of the valley (not shown) confirm the existence of belts of high concentration along the inversion's border.

The origin of the ozone maxima above the inversion over areas where the inversion never breaks could be any of the following: (1) thin laminae that are extruded from the stratosphere and descend around the Pacific Anticyclone (see, e.g., Kroening & Ney, 1962); (2) vertical flux convergence of tropospheric ozone in the descending air of the inversion layer; (3) upward transport of oxidants through the inversion, especially in the vicinity of strong waving; (4) ozone carried westward above the marine inversion from the interior where the inversion has been broken by heating. This last possibility must be rare in this area because the wind is normally from the west throughout the day at all levels. For example, in the last case shown, winds aloft taken throughout the 26-hour period at San Francisco, Hayward, Livermore, and San Jose always had a westerly component at all levels; during the three days preceding this observational period, there was never an easterly component reported at any level below 5 km at Oakland.

In the west-east cross section of 30 July (~1400 PST, Fig. 8), the moisture pattern gives some indication of the origin of the various ozone peaks. The low-level peak at the interior edge of the inversion was evidently created in polluted air, as indicated by the high moisture content over Livermore and Tracy. Above the inversion, the weak maximum near 1200 m coincided with dry air, thus indicating a high-level source.

The strong maxima above the inversion in the W-E cross section of 1 August (~1300 PST, Fig. 9*a*) appear to be generally of low-level origin, at least those up to 1500 m. The winds on this and the preceding day were in-

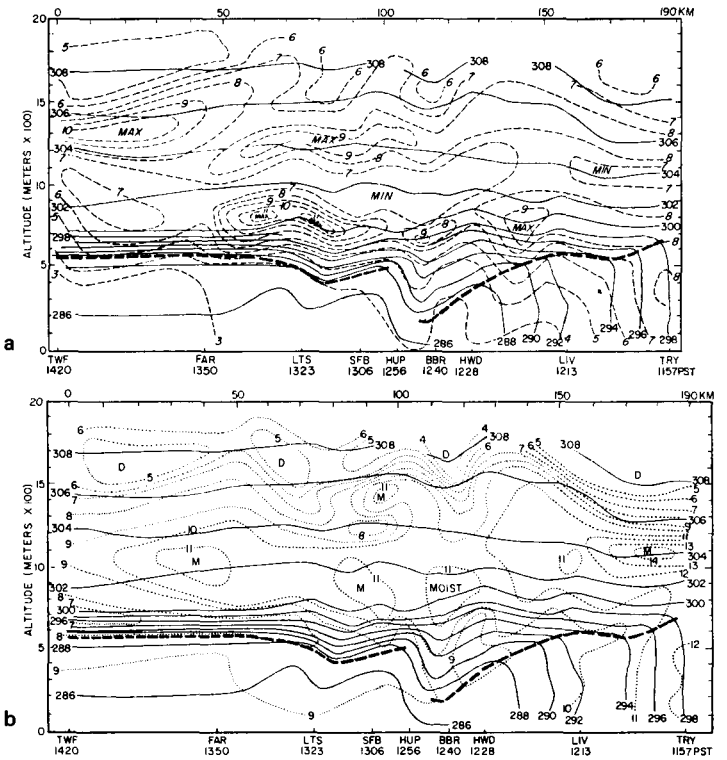

Fig. 9. Vertical west-east cross sections, 1 Aug. 1968, 1157–1420 PST. (*a*) O3 and potential temperature (see legend of Fig. 7). (*b*) Mixing ratio (g kg^{-1}) and potential temperature (K).

variably between NW and SW at all levels up to 3 km. It appears that these maxima were due to transport across the inversion, perhaps through waving action. Later cross sections of the same day (~1700 PST) show these maxima at about the same positions.

The maxima just above the base of the inversion, west of the coastline, could have been injected westward within internal waves that break toward the upstream direction, somewhat in the manner shown by the laboratory experiments of Thorpe (1968) and others. The same may be true of the following case of 8 August 1968. Our observations are much too coarse to show whether these waves actually do break upstream.

The ozone distribution can elucidate the broad features of waves. On 8 August 1968, the temperature inversion was relatively weak and

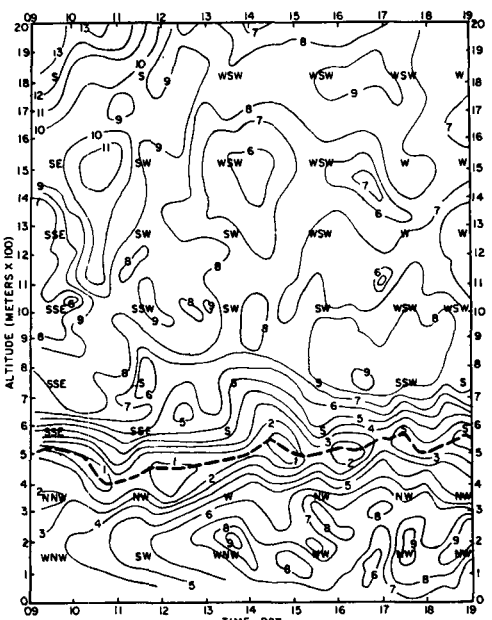

Fig. 10. Vertical time section of radar winds aloft at Hayward on 8 Aug. 1968. (Isotachs at intervals of 1 ms^{-1}; heavy dashed line: inversion base. Observations taken at 30-minute intervals.)

showed strong waving, even in the morning. Strong wind shear existed across the inversion base, as is illustrated by the time section of half-hourly radar winds aloft at Hayward (Fig. 10). The west-east cross sections at ~0830 PST (Figs. 11*a* and 11*b*) show the general downward slope of the inversion east of the San Francisco Bay that is normal in the early morning. However, waving was intense, with a possible break over the San Francisco peninsula. There was a maximum of ozone concentration above the break in the inversion and an unusually high surface value over San Francisco, where there was evidently a "folding" of the inversion. Note also the moist, low-oxidant area above 1500 m between Tracy and Livermore.

Later on the same day (~1530 PST, Figs. 12*a* and 12*b*), the waves were unstable over the entire San Francisco Bay Area, with the inversion completely disappearing near Tracy. Note the extreme variations of ozone within the waving inversion layer, especially east of Hayward; in the crests (breaks) the ozone reached 11–13 pphm while in the troughs the ozone concentration diminished to only 3 pphm, thus producing horizontal gradients of 7–10 pphm in less than 10 km. The vertical amplitudes of these waves were between 120 and 150 m. (Such a wave amplitude has been measured on several other occasions in the San Francisco Bay Area and over the Pacific Ocean.) The intense waving and ozone variations occurred almost precisely in the layer of strong wind shear (Fig. 10). The correlation of ozone and moisture indicate that the origin of the ozone was within the marine air. Note however that the slight maximum at 1500 m over Livermore was in dry air; evidently this air was descending. Where the inversion

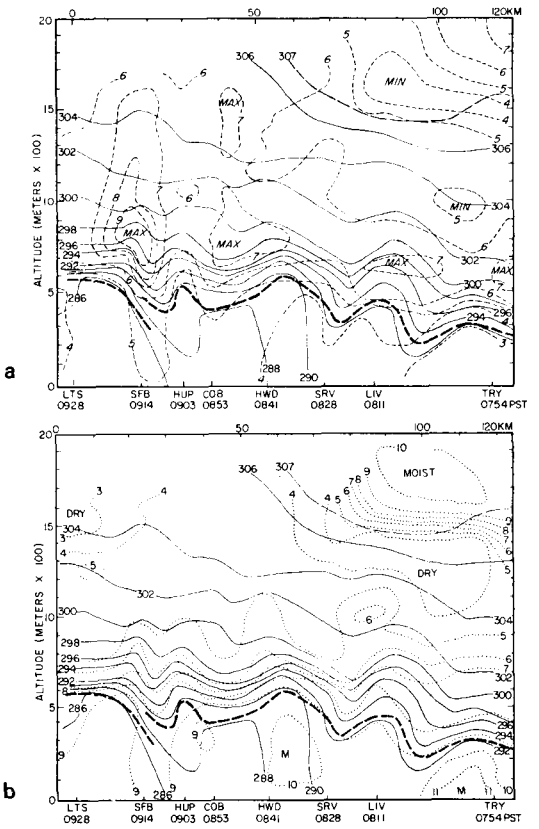

Fig. 11. Vertical west-east cross sections, 8 Aug. 1968, 0754–0928 PST. (*a*) O_3 and potential temperature. (See legend of Fig. 7.) (*b*) Mixing ratio (g kg^{-1}) and potential temperature (K).

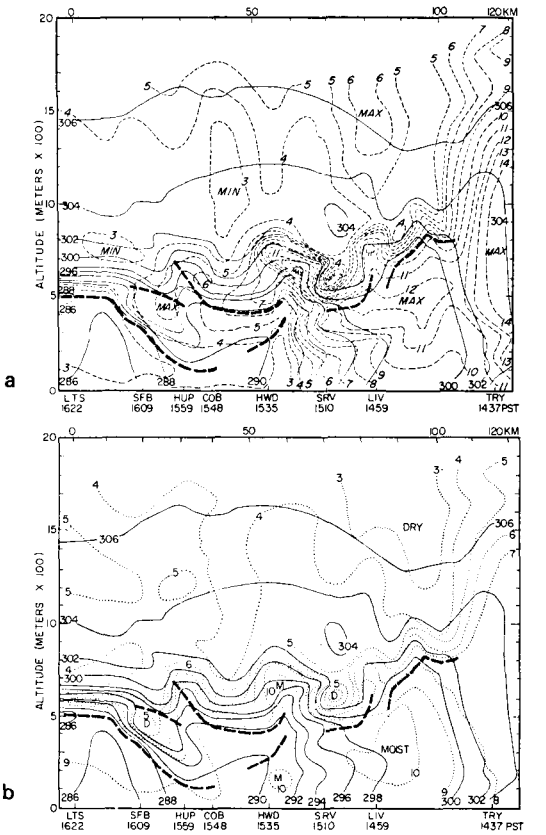

Fig. 12. Vertical west-east cross sections, 8 Aug. 1968, 1437–1622 PST. (*a*) O_3 and potential temperature. (See legend of Fig. 7.) (*b*) Mixing ratio (g kg^{-1}) and potential temperature (K).

completely disappeared, just west of Tracy, the "edge effect" caused the ozone concentration to be high from the surface up to 2000 m.

4. Conclusions

(1) The maximum daily oxidant level produced photochemically in polluted air is largely dependent on the destruction rate. The relative destruction rate appears to be directly related to the intensity of vertical mixing and inversely to the square of the depth of the "mixing layer". The highest oxidant concentrations are found where production is possible *and* the destruction rate is low, such as along the inland periphery of the west coast inversion.

Thus, the maximum oxidant level is probably a poor measure of the degree of air pollution. The increasing levels of daily maximum oxidant concentration over the years may reflect decreasing destruction rates, as well as increased pollution, as urbanization, which tends to decrease the air's stability and increase the depth of vertical mixing, progresses. When a high concentration of ozone results from the imbalance of production and destruction rates, perhaps the latter could be slightly enhanced artificially under some circumstances.

(2) Oxidants, and perhaps other pollutants, may be used as tracers in the study of eddy flux of mass in the vertical, mass exchange across thermal barriers, and the structure of gravity-shear waves.

(3) The relatively high ozone concentration often observed within the west coast temperature inversion layer appears to have two principal origins: (*a*) ozone that is produced in polluted air and transported upward into the inversion in the vicinity of waves on the interface; (*b*) polluted-air ozone that is transported aloft in areas where the inversion breaks down and, after the inversion reforms, is then separated from the surface destruction capability. In any event, the ozone aloft, insulated from the surface by the inversion layer, has a relatively long life time compared to that of the air close to the surface.

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ОЗОН ВНУТРИ И НИЖЕ ТЕМПЕРАТУР- НОЙ ИНВЕРСИИ НАД ЗАПАДНЫМ ПОБЕРЕЖЬЕМ США

Измерялась концентрация окислов в воздухе над заливом Сан-Франциско до высоты 2500 *м*. Наблюденное распределение концентраций по вертикали и горизонтали было связано с характеристиками и поведением температурной инверсии над западным побережьем. Для концентрации окислов, температуры, влажности и скорости ветров, измеренных с помощью самолета и радиолокатора, были построены временные хода в фиксированных точках и вертикальные разрезы.

Концентрации окислов в загрязненном воздухе сильно зависят от скорости их разрушения. Средняя скорость разрушения внутри поверхностного слоя прямо пропорциональна интенсивности турбулентного перемешивания и обратно пропорциональна квадрату глубины вертикального перемешивания. Таким образом, существование температурной инверсии не обязательно ведет к высоким концентрациям окислов, поскольку скорость их разрушения может быть велика и в тонких слоях перемешивания. Наибольшие концентрации окислов почти неизменно наблюдались на краях инверсии над морем, где имеются примеси для образования озона и где слой перемешивания глубокий. Предлагаются объяснения для максимумов содержания озона, которые часто встречаются над основанием инверсии. Характер распределения концентрации окислов четко отражает внутренние волны в инверсионном слое.