Final Report

to

Air Resources Board, State of California

"Isotopic Analysis of Smog Component Phases"

(ARB Contract No. A2-127-32)

by

Rainer Berger

Institute of Geophysics and Planetary Physics

University of California

Los Angeles, CA 90024

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EXECUTIVE SUMMARY


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Summary


Over the years smog concentrations in certain parts of the State of
California have decreased visibility so much that serious concern arose
over the origin of visual pollution. Inasmuch as visibility reduction
and odor pollution go hand in hand, the average citizen can see smog
and qualitatively judge its intensity. Thus apart from the esthetic
problems affecting the people of this state and the tourist industry,
there are serious visibility concerns involving aircraft safety, certain
types of aerospace testing and observation, and last not least adverse
health effects on man, animals and crops.

With respect to the visibility problems, a small fraction of the total
smog components can be blamed: suspended particles. These arise from the
incomplete combustion of fuels, especially fuel oils and gasoline, but a
significant portion was also thought to be the result of trees emitting
terpenes and other resinous substances in small droplet form. In fact,
there was voiced concern that the harvesting of agricultural crops might
also have a contributing effect on smog. A simple test is to walk over a
freshly mowed alfalfa or hay field, or through a sun-lit forest and smell
all the organic compounds many of which enter the atmosphere in droplet
form. As a result it became necessary to distinguish between particles (TSP)
produced by living plant sources and those left from combustion of fossil
fuels.

This differentiation can be made by isotopically analyzing particulate
samples for their radiocarbon content. Carbon from fossil fuel sources con-
tains no longer any measureable traces of radiocarbon. All has decayed by a
nuclear process over millions of years of geologic time when the fossil fuels
were first produced. However, carbon in all presently living things contains
radiocarbon introduced during photosynthesis when plants fix carbon dioxide
and water to produce carbohydrates: starch, tissue, wood, etc. Originally
radiocarbon is produced in the stratosphere when cosmic ray particles break
atoms of the atmosphere into their nuclear components: electrons, protons and
neutrons. The neutrons react with nitrogen to produce radiocarbon which is
oxidized to carbon dioxide, mixed virtually uniformly by the earth's wind

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systems and then made available to all plants world-wide. As a result modern carbon particles are mildly radioactive and of known radiocarbon concentration.

In order to measure the radioactivity of carbon particles it was necessary to design,construct and test a special small volume counting device so that relatively small quantities of particles collected on air filters could be successfully analyzed. This was accomplished and the results are listed in the body of the full report.

As a result we now know that in all areas tested fossil fuel sources and their contaminating effects play a predominant role in TSP-pollution. This applies to the Los Angeles air basin as well to Lake Tahoe,Bakersfield or El Cajon east of San Diego. An exception to this rule are particles produced by field burning ( Chico ) or forest fires.

In southern California the concentration of carbon particles is controlled by the seasons. During the spring or summer and into the fall when onshore winds control the climate the highest particulate concentrations are found inland. In contrast, during Santa Ana episodes, particle concentrations rise markedly along the coast and reduce the quality of air to conditions similar to inland pollution during the summer.

It must be emphasized that the sampling record is not as continuous as one would like to see. This is due to inadequate collection amounts having been obtained earlier in this study. During the later stages of this work, provisions had been made to collect larger samples, and the problem of inadequate sample size was overcome.

As part of this measurement program, a high volume air sampler was successfully tested.Also contamination effects of the motors driving the sample collectors were investigated. Throughout the collection program such self-contamination was avoided and the results must be representative of the pollution levels encountered.

Finally it is proposed to continue the monitoring program to obtain a continuous record throughout the year. Many samples have already been collected and need to be assayed. Thereafter a monitoring program at a reduced level would keep a check on compliance with stricter emission laws notably aimed at Diesel engines known to be primary producers of particulates. Without such checks there could be no effective law enforcement aimed at improving the air quality and public health in this state.

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Abstract

Over the years smog concentrations in certain parts of the
State of California have decreased visibility so much that the
phrase visual pollution was coined.  In fact, the total suspended
particle load of the atmosphere is there for every citizen to see
and most noticeable as an indicator of smog.  Apart from the est-
hetic effect there are serious concerns about visibility affect-
ing aircraft safety, certain types of aerospace testing and ob-
servation, and potential direct impacts on the welfare of man,
animals and plants.

In this study the origin of the carbonaceous fraction of the
total suspended particle load was analyzed using the principle
that carbon from fossil fuel sources contains no measurable quanti-
ties of the radioactive isotope carbon-14, whereas all recent car-
bon derived from the biosphere does.  Thus carbon from diesel or
other fossil combustion sources can be differentiated from carbon
which is part of pollen, tree emissions or organic dust.

Samples were collected by ARB personnel in a number of locations
in the state, principally in the Los Angeles Metropolitan air basin
while the radiometric analyses were carried out at UCLA.  The results
of this study can be briefly summarized as follows:

In all areas analyzed, except for Chico, fossil fuel sources
are the predominant polluters.  In the air basins of Southern
California the concentration of carbon particles is controlled by
the seasons ranging from below the detection limit ($0.1$ $\mu g/m^3$) to
$21$ $\mu g/m^3$.  While in the summer from west to east, the average
concentrations at Pacific Palisades, downton Los Angeles and
Upland are $0.6$, $10.3$ and $118$ $\mu g/m^3$ respectively, the winter data
for the same locations are $4.2$, $10.0$ and $7.8$.  Thus during Santa
Ana conditions, the air quality directly on the coast at Pacific
Palisades is greatly reduced.

In addition, an Electric Power Research Institute massive high-
volume air sampler was tested for obtaining size-segregated samples.
As a result it was found that the smallest and most dangerous

particles are principally composed of fossil carbon (77%).
Therefore it is recommended to carry out further analyses
using size-segregated samples in the state to monitor
the most dangerous fraction of particles impacting public health
and visibility.

## Acknowledgements

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## Disclaimer

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## Summary and Conclusions

In this study the origin of the carbon fraction in total aerosol particles was investigated. There is no question that in all the areas analyzed, except for Chico, fossil fuel sources play the predominant role. The concentration of carbon particles is often controlled by the seasons in the air basins of Southern California as apparent from the comparison below.

| | Start | End | No. of Days | Pacific Palisades | Fossil Carbon µg/m³ Downtown LosAngeles | Upland |
|---|---|---|---|---|---|---|
| Summer 1982 | 6/8 | 6/21 | 10 | | 9.4 | 9.0 |
| | 7/19 | 7/30 | 10 | 1.6 | 15.0 | 8.9 |
| | 8/9 | 8/20 | 10 | 0.2 | 6.5 | 17.6 |
| | | Average | | 0.6 | 10.3 | 11.8 |
| Winter 82-83 | 11/30 | 12/13 | 10 | 7.6 | 15.9 | 14.2 |
| | 1/25 | 2/7 | 9 | 3.7 | 4.3 | 1.9 |
| | 2/7 | 2/21 | 11 | 1.5 | 10.5 | 7.3 |
| | | Average | | 4.2 | 10.0 | 7.8 |
| % Carbon in TSP | | Summer 82 | | 3.0 | 15.3 | 12.8 |
| | | Winter 82-83 | | 6.7 | 17.0 | 14.0 |
| % Fossil Carbon in Total Carbon | | Summer 82 | | 25 | 95 | 87 |
| | | Winter 82-83 | | 64 | 75 | 67 |

Inspection of these data shows that not only the east-of-the-coast lying communities such as downtown Los Angeles and Upland are affected but also those on the coast itself (Pacific Palisades) when Santa Ana conditions prevail. In other words, the air quality at times during the winter months at Pacific Palisades located directly on the ocean can be almost as bad as that in downtown Los Angeles or Upland during the summer.

When the state-wide data are inspected they show average carbon concentrations ranging from the about 1-21 µg/m³. In one case involving straw burning near Chico, the percentage of carbon in particulates reached 34% based on 42.9 µg/m³ of total particulates containing 14.7 µg/m³C.

However, due to the non-continuous data points presented so far as a result of sometimes inadequate sample amounts received from the air collection units, more sampling is necessary to present ultimately a complete seasonal record of carbon particulates in the air basins of California.

In addition, a massive high-volume air sampler on loan from the Electric Power Research Institute (EPRI) was tested whose impaction plates are coated with teflon. Since this plastic contains fluorine which was thought to interfere with radiometric assay, a test sample was run and found to be measureable in the UCLA system. Therefore, this type of sampler can be utilized in future monitoring providing either necessary quantities in less time or large enough samples when the ambient particle concentration is low.

Furthermore this air sampler allows size-segregated analyses with the following preliminary results:

|  | Size ($\mu$) | Weight (g) | (%) | Biol.C (g) | (%) | Fossil C (g) | (%) |
|---|---|---|---|---|---|---|---|
| Large impactor | 20-3.5 | 0.7408 | 30.6 | 0.4297 | 58 | 0.3111 | 42 |
| Small impactor | 3.5-1.7 | 0.6540 | 27.0 | 0.3401 | 52 | 0.3139 | 48 |
| Precipitator | up to 1.7 | 1.030 | 42.4 | 0.2369 | 23 | 0.7931 | 77 |
|  |  | 2.4248 | 100 | 1.0067 |  | 1.4181 |  |

This table shows that much more information is obtainable by size-segregated samples than by ordinary air sampling techniques which combine all fractions into one single sample. Taking these data as indicative of the isotopic carbon content of particulates, then the smallest fraction is composed mainly of fossil carbon. This suggests that it is due mainly to motor vehicles and in particular to diesels. The smallest-sized particles are known to be the most harmful from a public health point of view since they readily enter the smallest lung capillaries. Thus the EPRI massive high-volume sampler permits us to follow and monitor the most dangerous fraction of carbon particles which is not possible with the conventional units used so far.

Recommendations

First, the body of data obtained so far is not continuous
due to lack of adequate samples in certain time periods. These
seasonal holes should be closed by further collections and analy-
sis.

Second, the UCLA laboratory still has a large number of
filter samples that have not yet been analyzed due to the fact
that funding ended at the beginning of 1984 even though we have
continued to work on this project until now in the interest of
providing the best continuous set of data obtainable. It must
be realized that the University is not in session during 3½
summer months. Moreover, we are still receiving samples now
from the El Monte Haagen-Smit Laboratory. It is suggested
that we receive funding to complete the entire set of samples
so that a truly comprehensive data set is available.

Third, inasmuch as the EPRI massive high volume air units
provide size-segregated samples, it would be desirable to conduct
a study for a full year in o ne of the smoggiest locations, either
downtown Los Angeles or Upland, to understand better size distribu-
tion and origin of carbon particles. UCLA could purchase an EPRI-
type unit for such a study within the framework of an ARB contract.

Four, since the ARB is charged with a monitoring function of
air quality, a continued study of carbon particles at a meaningful
level is recommended to assess the success of air quality control
legislation over the next several years.

Five, no studies have been conducted of air quality in large
buildings with self-contained climate control. Because a sizeable
population is affected in office structures, large department stores
and living complexes, the ARB should begin monitoring air pollution
inside which is not now carried out by any agency at all.

Six, the emissions of jet aircraft at major airports such as
Los Angeles International Airport are clearly visible to everybody.
However no data exist at airport locations in terms of air quality
or lack of it.

Seven, the same problems exist at locations downwind from oil refineries in the state as well as oil fields onshore or off-shore. Given the southern California climate, especially oil facilities near or in urban centers need to be assessed for carbon particle emissions.

Introduction

Recently, Appel et al. (1983) found that 20% of the total
suspended particle load in air is carbonaceous and the major single
class constituating TSP-loads at three California locations. Inas-
much as smog occurs in both the urban and rural areas of the state,
the question was raised to what extent plant emissions from, for
example, pine trees contribute to the overall smog problem. In
fact a scenario was presented a few years ago where terpene-
emitting conifers would produce more smog-causing chemicals in
wet growth years, whereas during dry periods less plant emissions
and therefore less smog-production could be expected (Sandberg,
Basso and Okin 1978; Bufalini 1979; Miller, Pitts and Winer 1979;
Sandberg, Basso and Okin 1979). On the other hand state agencies
like the ARB have long been concerned with smog-producing emissions
from fossil fuel combustion by automotive and industrial sources.
Thus it became necessary to determine to what extent aerosols are
composed of recent biospheric (contemporary) and fossil fuel emis-
sion products.

This distinction can be made by analyzing total suspended
particles (TSP) for their radiocarbon content. Fossil fuels
contain carbon without a measureable trace of the radioactive
isotope carbon-14 or radiocarbon, since its half-life is only
5730±30 years. Due to the great age of petroleum or coal re-
sources all carbon-14 has decayed and is no longer detectable.
In contrast, all recent biospheric carbon contains radiocarbon.
This isotope is constantly produced in the upper atmosphere,
oxidized to $^{14}CO_2$ and fixed via photosynthesis in all plant
matter. From there it finds its may also into animals and men
resulting in a near uniform distribution of the isotope in the
worldwide biosphere. By assaying TSP samples for radiocarbon
it is possible to calculate the fossil and contemporary carbon
contributions to the aerosol particles and thus determine their
origin (Lodge, Bien and Suess 1960; Berger, Johnson, and Holmes,
1983).

Sample Collection

The TSP-samples were collected by ARB-personnel using chemically and isotopically clean quartz fiber filter papers at several locations in California, predominantly in the Los Angeles Metropolitan Region. The filters were placed in front of fans which drew air at a measurable rate through the quartz fiber paper.

All sampling was performed with size selective inlet (PM15) hi-volume samplers unless otherwise indicated by TSP (Total Suspended Particulates). These TSP samplers were used in El Monte as part of a re-entrainment test to insure that carbon from the sampler motor brushes was not contaminating the samples. TSP samplers were also used at Lake Tahoe early in the project since SSI samplers were not available.

The sampling period at Pacific Palisades, Los Angeles, El Monte and Upland generally ran from 1000-1800 Monday through Friday. During this time of day the wind is generally onshore. El Cajon operated during the same hours but seven days a week due to timer limitations.

Sampling periods at Tahoe, Bakersfield, and Chico were generally 24 hours a day for the entire period indicated due to equipment limitations. The Upland sampler was temporarily moved to Tahoe between July and September of 1983 allowing for 18-hour sampling intervals. More than 8 hours a day sampling was needed in Tahoe due to a low loading rate.

To test the purity of the filters, blanks were run at UCLA and found to contain no detectable carbon content either chemically or radiochemically. Moreover, the sampling methodology used was tested in the field by checking the effect of the cooling air of the electric motors driving the collection fans.

At one point it was feared that the abrading carbon brushes of the motors might introduce carbon particles into the filters producing erroneous results. However, it was determined that such concern was groundless.

In an experiment motor exhaust was ducted away from the

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air sampling unit and compared to a non-ducted experiment. The carbon assay for both filters was identical within experimental error. If however, the motor exhaust was directly ducted onto the filter surface an effect was noticed lowering the biospheric carbon level as expected. This is due to the fossil carbon origin of the electric motor brushes. The results of this test are summarized below in Table I.

### Table I
### Control Test at El Monte, CA.

| Lab No. | Conditions | Radioactivity |
|---|---|---|
| UCLA-2451-D | Exhaust not ducted | 0.61 cpm |
| -2451-A | Exhaust ducted into filter | 0.36 cpm |
| -2451-B | Exhaust ducted away | 0.52 cpm |
| -2451-C | Exhaust not ducted | 0.54 cpm |
| -2449 | Electric motor brush carbon | no activity |

UCLA-2451 A and D were collected from 10/18/83 to 10/28/83 and UCLA-2451 B and C from 9/27/83 to 10/14/83.

In some cases the amount of TSP collected on the quartz filters was insufficient for radiocarbon analysis due to variations in TSP-loading of the air samples. This explains why the sampling record is not always continuous.

### Radiometric Analysis

Since TSP concentrations are typically low in the $100\pm50$ $\mu g/m^3$ range a special small volume proportional counter was designed, constructed and tested. For a complete fill or optimum detection conditions only 100 mg of carbon are needed. The counting chamber is located inside an anticoincidence guard assembly which in turn is protected from ambient environmental radiation by a 7.5-ton radioactively clean steel shield. The anticoincidence guard allows the subtraction of cosmic ray flux which still penetrates the steel shield due to its high energy particles from space.

The electronics which permit the actual radiocarbon assay

consist of an all-solid-state unit with three anti-coincidence and three coincidence channels. The entire counting system is powered by ultra-stable high voltage power supplies. Its counting characteristics are summarized briefly in Table 2. For the purpose of standardization three standards are used: (1) By international convention 95% of the count rate of National Bureau of Standards oxalic acid for radiocarbon laboratories (equivalent to the biosphere of 1890 prior to the $CO_2$ contamination of the atmosphere by industrialization), (2) $CO_2$ derived from marble (measures the intrinsic radioactivity in the counter wall and electronic noise effects), and (3) a $CO_2$-gas sample derived from a deck plank of the funerary boat of Sesostris III which has an historically known age of 1800 B.C. The latter standard is used to assure that the dating equipment performs accurately. For practical purposes the age of the Sesostris sample is calculated using its count rate and that of the oxalic acid and marble background. As can be seen from Table 2, the equipment performs very well because the age of the Sesostris $CO_2$-gas can be calculated to date close to its historical age of 1800 B.C. This type of standardization procedure is carried out repeatedly to insure continued accurate radiocarbon assays.

The sample measurement protocol in its entirety is as follows: Depending on the filter loading which varies from about 0.5 to 1.5 g 1-2 quartz filters are placed into an isotopically clean Vycor-quartz tube and burnt in a stream of analytically pure oxygen. The resulting $CO_2$ is purified by passing through silver nitrate and chromic acid solutions and is then dried. Any CO is converted to $CO_2$ by hot copper oxide. Finally, all electronegative impurities that interfere with proportional counting, such as $O_2$, $NO_2$ or halogens are removed by repeated passage of the gas over hot, clean elementary copper. Subsequently the clean $CO_2$ sample gas is stored in high pressure steel cylinders.

Inasmuch as all biospheric and fossil carbon samples contain ppm-quantities of uranium which is present worldwide, a certain amount of radon gas is continuously produced in the smog particulates. As soon as they have been burnt to $CO_2$ no more radon is

Table 2


Performance of 200 ml-Proportional Counter


Background, consisting of radioactive contamination
    in counter materials and electronic noise,
    determined by measuring pure carbon dioxide
    from Missouri marble (radioactively dead)

                                    0.870 ± 0.005 cpm*

Recent biosphere, equivalent to the count rate
    of 95% of the activity of National Bureau of
    Standards oxalic acid for radiocarbon labor-
    atories

                                    1.010 ± 0.015 cpm*

Historical sample, a deck plank from the funerary
    boat of Sesostris III who did near 1800 B.C.

                                    0.645 ± 0.015 cpm*

                          equivalent to 1800 B.C. after
                          tree ring calibration



*Net counting rates in counts per minute (cpm)

See R. Berger, 1983, for counter construction details.

Table 3

Smog Particulate Carbon Isotope Analysis

| UCLA No. | Origin | Collection Date | Loading Rate (g/min) | Biospheric Contribution (%) | Fossil Fuel Contribution (%) | $\delta^{13}C$ (‰) |
|----------|--------|-----------------|----------------------|------------------------------|-------------------------------|--------------------|
| 2211A | Riverside | 9/29/78 | 0.00019 | 42 ± 2% | 58 ± 2% | -26.33 |
| 2211B | " | 10/03/78 | 0.00031 | 41 ± 2% | 59 ± 2% | -29.72 |
| 2211C | " | 10/06/78 | 0.00022 | 34 ± 2% | 66 ± 2% | -27.42 |
| 2211D | " | 10/10/78 | 0.00019 | * | * | -26.30 |
| 2211E | " | 10/13/78 | 0.00025 | 45 ± 2% | 55 ± 2% | -26.90 |

The calculations of biospheric and fossil fuel contributions are based on the radiocarbon concentration of $CO_2$ in the troposphere of 1978 which was +35% above the reference level of 95% NBS Oxalic Acid for radiocarbon laboratories (Berger, in press; Levin, Münnich and Wiess, 1980).

added by the inorganic or ash portion found in most natural
samples. This uranium daughter then decays with a half-life of
3.8 days. In order to eliminate any counting errors due to radon,
samples are stored for a period of one month to permit complete
radon decay. In practice this means that each sample takes about
4-5 weeks to analyze. However, analyses are run in a staggered
mode so that roughly every few days a new sample is processed.
Total counting time per sample varies from 2 to 4 days. Standard-
ization of the counter requires on the average 6 days if no adjust-
ments are necessary.

### Stable Isotope Analyses

It might be argued that beside the aerosol particles the
glass filters also may have adsorbed inorganic dust which in the
Los Angeles area might contain inorganic carbonates. In order to
check such a possibility a number of samples were analyzed for
their $^{13}C/^{12}C$ ratio (Table 3). This is a good indicator of the
origin of carbon. In inorganic soil-derived carbon the $^{13}C/^{12}C$
ratio is close to 1, whereas land plants metabolizing by the bio-
logical C-3 pathway or petroleum have a ratio of about -25‰ with
respect to the internationally accepted PDB standard. All samples
measured had values much closer to 25 than 1. Consequently, car-
bonate contamination of the aerosol samples can be ruled out.

### Results and Discussion

For purposes of overview the data obtained in this study are
listed numerically at the end of the report in Tables 4-11 and
graphically presented in Figures 1-12. The composition of TSP
ranges from 0 to 100% biological or fossil carbon content depend-
ing on sample location and season. Seasonal variations in the
predominant surface wind flow patterns in California are shown in
Figures 17-20.

Next follows a discussion of the data from the different
sampling locations beginning with Metropolitan Los Angeles which
includes Pacific Palisades, Downtown Los Angeles, El Monte and
Upland stations.

## Pacific Palisades

The air samples were collected in Will Rogers State Park. Carbon concentrations ranged from about $1-8\mu g/m^3$ of air sampled. The total solids adsorbed on the filters varied from 57.2 to 149.6 $\mu g/m^3$. Figure 1 shows a seasonal effect resulting in highest carbon and total solids loading during the fall and winter months when Santa Ana conditions prevail with offshore winds. Table 4 indicates a range of biologic to fossil carbon ratios from one extreme to the other. During the spring and summer months (Figures 9 and 10) onshore winds during the day result in the lowest carbon concentrations of the year. Thus the air quality in Pacific Palisades is seasonally controlled with an optimum during the spring and summer.

## Downtown Los Angeles

The sampling location is the Department of Water and Power Building in the downtown center of the City of Los Angeles. The data analyzed so far show carbon concentrations up to about twice as high as in Pacific Palisades near the ocean. There does not seem to exist a pronounced seasonal effect as in Palisades. Total solids collected on the air filters range from about 57 to 102 $\mu g/m^3$ of air. Yet there is a preponderance of fossil carbon suspended in downtown air as evident from Table 15.

## El Monte

Samples were collected at the Haagen-Smit ARB facility in El Monte east of downtown Los Angeles. Concentration levels of carbon and total solids in air are very similar to the downtown environment. There appears to be an indication of a seasonal effect (Table 16) with high TSP concentrations in October 1983. However the data base is too incomplete to establish a clear-cut relationship. Again more often than not fossil carbon predominates in the air over El Monte.

Upland

At Upland TSP concentrations appear to fall into two distinct categories, either predominently biologic or mainly fossil carbon (Table 19). Moreover the carbon and total solids concentration in ambient air are similar to El Monte or Downtown samples, perhaps slightly higher. There is some seasonal effect discernible in the data obtained so far: carbon concentrations appear to be highest during the summer (Figure 7). Carbon concentrations at Upland on the average are similar to those at the Palisades during the strongest Santa Ana conditions.

For the Los Angeles Metropolitan Region then the following pattern emerges: During the spring and summer as air predominantly flows from west to east filter loading increases in the same direction. During the winter carbon concentrations inland are of an average level around $10 \mu g/m^3$ where as on the coast they have reached their maximum. Thus the TSP loads follow in overall pattern the smog distribution observed.

Chico

In northern California 2 sets of measurements were made in 1982 to assess the impact of air pollution in Chico during the fall of 1982.

The filter analysis of the Chico samples reveal predominantly biologic carbon concentrations. Total carbon levels are about $10 \pm 5 \ \mu g/m^3$ of air and total solids range from c. 28 to 43 $\mu g/cm^3$ of air analyzed. If field burning was the principal reason for obtaining these samples, it is surprising to find that about one quarter of the carbon collected is of fossil origin.

Lake Tahoe

This environmentally sensitive area was sampled repeatedly during 1982 and 1983. During the spring and fall high carbon concentrations were measured from 15.3 to 21.2 $\mu g/m^3$. This carbon was predominantly of fossil origin. In contrast, during the summer

carbon concentrations were lower at 4.6 to 6.7 $\mu g/m^3$, but most
of the carbon was also of fossil sources except for one period
in late July 1983 when biologic carbon predominated at 80% bio-
logic over 20% fossil sources. Inspection of Table 23 suggests
spread-out distributions of biologic and fossil carbon from 80%
biologic to 53% fossil sources. On balance, fossil-fuel-derived
carbon plays at Lake Tahoe an equal if not greater role than carbon
derived from recent biologic sources such as trees and shrubs. This
very fact is surprising in view of the forests surrounding this
mountain resort area.

Bakersfield

In south central California Bakersfield is a center of oil
production and refining. Therefore, series of samples were collect-
ed to assess the impact of this industry on the southern San Joaquin
Valley.

Carbon levels range from 5 to 19 $\mu g/m^3$ of air with total
solids loading from 47 to 147 $\mu g/m^3$. During the winter season,
Bakersfield appears to be subject to a seasonal increase in carbon
and total particles concentration. So far there are not yet avail-
able data for an entire calendar year to fully confirm this observa-
tion. It is not certain whether the prevailing winds during the
summer dilute TSP concentrations or if stagnant air during the
winter allows an increase. Bakersfield air samples are the most
difficult to measure in the laboratory, because they require an
unusual amount of chemical cleaning to reduce electro-negative
impurity levels. While winter samples may be sometimes mainly
of recent biologic origin (64 to 94% bio) they can also contain
as much as 60 to 80% fossil carbon. The main emphasis in Bakers-
field TSP-carbon tends to lie on the fossil origin side as apparent
from Table 25.

El Cajon

In southern California, the second largest city in the state,
San Diego, experiences air pollution particularly in its eastern

environs such as El Cajon.

In El Cajon typically carbon concentrations are under 10 μg/m$^3$ of air and total suspended solids range from 27 to 40.5 μg/m$^3$. All samples contain mostly fossil fuel carbon (Table 27). There appears to be operating also a seasonal effect as seen in Tables 26 and 28. However the data base is not yet sufficiently developed to clearly state the case for definite seasonal control. However, as more data becomes available this question can also be solved.


From a general point of view, it is difficult with the present incomplete data set to make clear-cut seasonal comparisons with other pollutants such as carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide or lead, sulfates and nitrates. Such a comparative evaluation must wait until a complete seasonal set of measurements has been obtained for TSP concentrations and their carbon component.

Notes for Tables 4-11

Dates collected:  May not be inclusive

$\mu g/m^3$:  Particulates per cubic meter at air sampled; both total particulates and carbon particulates are expressed in micrograms ($g \times 10^{-6}$)

NC:  Not counted, insufficient sample

% Bio:     Contribution from contemporary biosphere, remainder is from fossil fuel

% Fossil:  Contribution from fossil fuel sources

Errors of the %Bio or %Fossil column are $\pm$ 2 % for a full fill of counter

# Table 4

## Palisades

| UCLA No. | Date Collected | μg/m$^3$ Total | C | %C | Carbon %Bio | %Fossil |
|---|---|---|---|---|---|---|
| 2428A | 4/28 - 4/30  82 | 80.9 | 4.3 | 5.3 | 100 | 0 |
| 2428 B&C | 5/4 - 5/13  82 | 86.5 | 2.8 | 3.2 | 99 | 1 |
| 2428E | 5/18 - 5/31  82 | 66.2 | <1.2 | <2.0 | NC | - |
| 2428F | 6/8 - 6/21  82 | 57.2 | 1.2 | 2.1 | 100 | 0 |
| 2430A | 6/28 - 7/9  82 | 62.0 | <1.3 | <2.0 | NC | - |
| 2431A | 7/19 - 7/30  82 | 82.6 | 2.3 | 2.8 | 32 | 68 |
| 2433B | 8/9 - 8/20  82 | 89.6 | 3.6 | 4.0 | 94 | 6 |
| 2433I | 9/20 - 10/18 82 | 142.1 | 4.9 | 3.4 | 72 | 28 |
| 2433E | 10/11 -10/25 82 | 149.6 | 5.6 | 3.7 | 65 | 35 |
| 2439D | 11/1 - 11/12 82 | 97.3 | 6.6 | 6.8 | 28 | 72 |
| 2439B | 11/30- 12/13 82 | 70.8 | 7.9 | 11.1 | 4 | 96 |
| 2440F | 1/25 - 2/7  83 | 121.8 | 5.4 | 4.4 | 32 | 68 |
| 2444C | 2/7 - 2/21  83 | 123.1 | 5.5 | 4.5 | 72 | 28 |
| 2445E | 4/4 - 4/15  83 | 85.1 | 3.6 | 4.1 | 70 | 30 |
| 2448A | 4/25 - 5/6  83 | 99.3 | 2.2 | 2.2 | 100 | - |
| 2448J | 5/16 - 5/27  83 | 72.0 | 4.3 | 6.0 | 41 | 59 |
| 2450F | 6/8 - 6/22  83 | 65 | 2.0 | 3.1 | 28 | 72 |
| 2453E | 6/27 - 7/8  83 | 73 | 2.7 | 3.7 | 0 | 100 |
| 2456A | 7/18 - 7/29  83 | 81.2 | 1.9 | 2.4 | 63 | 37 |
| 2458D | 8/29 - 9/9  83 | 100.8 | 2.7 | 2.7 | 62 | 38 |
| 2459F | 9/19 - 9/30  83 | 76.7 | 1.9 | 2.5 | 66 | 34 |
| 2452A | 10/11 - 25  83 | 118.3 | 3.0 | 3.1 | 39 | 41 |
| 2459C | 11/7 - 18  83 | 117.8 | 8.7 | 7.4 | 76 | 24 |

Table 5

Downtown Los Angeles

|  |  | $\mu g/m^3$ |  |  | Carbon | |
| --- | --- | --- | --- | --- | --- | --- |
| UCLA No. | Date Collected | Total | C | %C | %Bio | %Fossil |
| 2428D | 4/27 - 4/29 82 | no data | | 10.1 | 57 | 43 |
| 2428G | 5/18 - 5/31 82 | 68.1 | 11.8 | 17.3 | 88 | 12 |
| 2428H | 6/7 - 6/18 82 | 74.5 | 9.4 | 12.6 | 0 | 100 |
| 2430B | 6/28 - 7/9 82 | 61.9 | 15.0 | 24.2 | 0 | 100 |
| 2431B | 7/19- 7/30 82 | 82.0 | 7.5 | 9.1 | 14 | 86 |
| 2433J | 9/20 - 10/1 82 | 66.5 | 7.4 | 11.2 | 87 | 13 |
| 2440E | 11/29 - 12/10 82 | 94.1 | 20.1 | 21.4 | 21 | 79 |
| 2438E | 1/10 - 1/24 83 | 57.1 | 6.1 | 10.7 | 30 | 70 |
| 2444D | 2/7 - 2/21 83 | 74.7 | 14.0 | 18.8 | 25 | 75 |
| 2448K | 5/16 - 5/27 83 | 102.4 | 16.5 | 16.9 | 22 | 78 |
| 2450E | 6/8 - 6/22 83 | 94 | 10.0 | 10.6 | 24 | 76 |
| 2453F | 6/27 - 7/8 83 | 69 | 10 | 14.4 | 26 | 74 |
| 2456C | 7/18 - 7/29 83 | 78.5 | 12.5 | 15.9 | 25 | 75 |
| 2457C | 8/8 - 8/19 83 | 75.1 | 9.6 | 12.8 | 43 | 57 |
| 2458E | 8/29 - 9/9 83 | 75.7 | 15.5 | 20.5 | 29 | 71 |
| 2459E | 9/19 - 10/1 83 | 83.7 | 13.2 | 15.8 | 38 | 62 |
| 2452B | 10/11 - 10/25 83 | 97 | 15.6 | 16.2 | 24 | 76 |
| 2459B | 11/7 - 11/19 83 | 71.1 | 13.2 | 18.6 | 32 | 68 |

Table 6

El Monte

|  |  | | µg/m$^3$ | | | Carbon | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| UCLA No. | Date Collected | | Total | C | %C | %Bio | %Fossil |
| 2427 A&B | 3/25 - 4/9 | 82 | 82.4 | 10.9 | 13.4 | 84 | 16 |
| 2427 C,D&E | 4/12 - 4/19 | 82 | 60.4 | 3.9 | 6.5 | 100 | 0 |
| 2427F | 4/19 - 4/22 | 82 | 84.3 | 13.5 | 19.7 | 45 | 55 |
| 2428I | 5/18 - 5/26 | 82 | 90.9 | 10.2 | 11.2 | 98 | 2 |
| 2428J | 6/7 - 6/18 | 82 | 83.6 | 9.7 | 11.6 | 0 | 100 |
| 2430C | 6/28 - 7/9 | 82 | 63.8 | 1.5 | 2.2 | 0 | 100 |
| 2431C | 7/19 - 7/30 | 82 | 85.8 | 11.5 | 13.5 | 0 | 100 |
| 2433C | 8/9 - 8/20 | 82 | 112.3 | 14.9 | 13.3 | 0 | 100 |
| 2464E | 3/28 - 4/26 | 84 | 56.9 | 8.5 | 15.0 | 38 | 62 |
| 2445A | 4/14 - 4/19 | 83 | 66.8 | 12.9 | 19.4 | 28 | 72 |
| 2445B | 4/14 - 4/19 | 83 | 64.3 | 6.5 | 14.5 | 20 | 70 |
| 2464A | 4/23 - 5/14 | 84 | 79.1 | 10.6 | 13.4 | 38 | 63 |
| 2451B | 9/27 - 10/14 | 83 | 70.2 | 10.7 | 15.2 | 40 | 60 |
| 2451C | 9/27 - 10/14 | 83 | 73.8 | 9.9 | 13.4 | 40 | 60 |
| 2451A | 10/18 - 10/28 | 83 | 84.1 | 14.8 | 17.6 | 27 | 73 |
| 2451D | 10/18 - 10/28 | 83 | 139.6 | 19.0 | 13.6 | 45 | 55 |
| 2449A | Brush | | - | - | 100 | 0 | 100 |
| 2449B | Large impactor | | - | - | 5.1 | 58 | 42 |
| 2449C | Small impactor | | - | - | 6.9 | 52 | 48 |
| 2449D | Precipitator | | - | - | 13.3 | 23 | 77 |

Table 7

Upland

| UCLA No. | Date Collected | | Total | C | %C | Carbon %Bio | %Fossil |
|---|---|---|---|---|---|---|---|
| | | | μg/m³ | | | | |
| 2428K | 5/18 - 5/31 | 82 | 90.7 | 11.9 | 13.1 | 17 | 83 |
| 2428L | 6/7 - 6/18 | 82 | 94.3 | 11.6 | 12.3 | 22 | 78 |
| 2430D | 6/28 - 7/9 | 82 | 60.9 | 3.4 | 5.6 | 0 | 100 |
| 2431D | 7/19 - 7/30 | 82 | 95.2 | 9.6 | 10.1 | 7 | 93 |
| 2433A | 8/9 - 8/20 | 82 | 120.5 | 19.3 | 16.0 | 9 | 91 |
| 2433H | 9/20 - 10/1 | 82 | 74.8 | 9.0 | 12.1 | 65 | 35 |
| 2433G | 10/11 - 10/22 | 82 | 101.7 | 9.2 | 9.0 | 95 | 5 |
| 2439A | 12/6 - 12/17 | 82 | 82.4 | 14.2 | 17.3 | 0 | 100 |
| 2438F | 1/10 - 1/21 | 83 | 61.2 | 6.9 | 11.2 | 72 | 28 |
| 2444A | 2/8 - 2/21 | 83 | 72.3 | 9.8 | 13.5 | 26 | 74 |
| 2448H | 5/16 - 5/27 | 83 | 106.5 | 16.9 | 15.9 | 17 | 83 |
| 2450G | 6/8 - 6/21 | 83 | 110 | 15.0 | 13.6 | 16 | 84 |
| 2459A | 11/7 - 11/18 | 83 | 73.7 | 12.0 | 16.3 | 45 | 55 |

Table 8

Chico

| UCLA No. | Date Collected | μg/m³ | | | Carbon | |
|---|---|---|---|---|---|---|
| | | Total | C | %C | %Bio | %Fossil |
| 2433F | 9/21 – 10/7  82 | 28.0 | 5.0 | 17.7 | 79 | 21 |
| 2439G | 10/28 – 11/10 82 | 42.9 | 14.7 | 34.1 | 75 | 25 |

## Table 9

## Lake Tahoe - various sites

| UCLA No. | Date Collected | | μg/m$^3$ Total | C | %C | %Bio | %Fossil |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 2426 A&B | 2/11 - 2/14 | 82 | 134.6 | 15.3 | 11.4 | 47 | 53 |
| 2426 C&D | 2/29 - 3/4 | 82 | 81.9 | 6.2 | 7.6 | 47 | 53 |
| 2426 E | 3/4 - 3/10 | 82 | 158.8 | 21.2 | 13.4 | 47 | 53 |
| 2426 F | 3/10 - 3/16 | 82 | 43.3 | 8.0 | 20.7 | 47 | 53 |
| 2433 D | 9/2 - 9/20 | 82 | 81.9 | 6.2 | 7.4 | 14 | 86 |
| 2456D | 7/11 - 7/24 | 83 | 33.2 | 4.0 | 12.0 | 29 | 71 |
| 2450 B | 7/25 - 8/2 | 83 | 26.6 | 4.6 | 17.4 | 80 | 20 |
| 2450 A | 8/2 - 8/8 | 83 | 39.0 | 6.7 | 17.2 | 25 | 75 |
| 2457 A | 8/8 - 8/22 | 83 | 15.1 | 2.8 | 18.3 | 57 | 43 |
| 2457 F | 8/15 - 8/22 | 83 | 22.1 | 4.9 | 22.3 | 36 | 64 |
| 2458 F | 8/22 - 9/6 | 83 | 29.3 | 4.9 | 16.7 | 50 | 50 |
| 2459 H | 9/5 - 9/11 | 83 | 16.4 | 6.8 | 41.3 | 64 | 36 |
| 2459 I | 9/13 - 9/19 | 83 | 25.5 | 5.0 | 19.5 | 42 | 58 |
| 2452 E | 9/19 - 10/3 | 83 | 9.6 | 1.7 | 17.8 | 55 | 45 |
| 2452C | 9/19 - 10/3 | 83 | 76.0 | 20.0 | 26.4 | 55 | 45 |

Table 10

Bakersfield

$\mu g/m^3$

| UCLA No. | Date Collected | | Total | C | %C | %Bio | Carbon %Fossil |
|---|---|---|---|---|---|---|---|
| 2438B | 12/7 - 12/10 | 82 | 108.3 | 14.0 | 12.9 | 64 | 36 |
| 2438C | 12/20 - 12/23 | 82 | 89.2 | 19.0 | 21.4 | no data | |
| 2438A | 1/17 - 1/21 | 83 | 94.1 | 17.0 | 18.2 | 94 | 6 |
| 2438D | 1/24 - 1/28 | 83 | 147.0 | 10.1 | 6.9 | 30 | 70 |
| 2444F | 2/7 - 2/10 | 83 | 73.8 | 6.1 | 8.3 | 40 | 60 |
| 2444E | 2/10 - 2/14 | 83 | 66.9 | 13.9 | 21.6 | 19 | 81 |
| 2448E | 4/5 - 4/11 | 83 | 46.9 | 5.2 | 11.1 | 32 | 78 |
| 2453A | 5/12 - 5/20 | 83 | 60 | 5.0 | 8.3 | 38 | 62 |
| 2453B | 6/2 - 6/7 | 83 | 66 | 6.6 | 10.0 | 40 | 60 |
| 2453C | 6/27 - 7/1 | 83 | 75 | 7.5 | 10.1 | 42 | 58 |
| 2453D | 7/6 - 7/11 | 83 | 87 | 7.3 | 8.4 | 36 | 63 |
| 2458B | 8/24 - 9/2 | 83 | 75.7 | >6.3 | > 8.3 | 52 | 48 |
| 2458A | 9/20 - 9/26 | 83 | 83.2 | 2.2 | 2.6 | 73 | 27 |

Table 11


El Cajon


| UCLA No. | Date Collected | μg/m³ | | Carbon | | |
|---|---|---|---|---|---|---|
| | | Total | C | %C | %Bio | %Fossil |
| 2439C | 11/30 - 12/13 82 | 38.3 | 8.2 | 21.2 | 36 | 64 |
| 2438H | 12/29/82-1/12/83 | 40.5 | 7.8 | 19.2 | 39 | 61 |
| 2438G | 1/12 - 1/26   83 | 32.4 | 9.8 | 30.1 | 24 | 76 |
| 2445D | 3/30 - 4/26   83 | 27.0 | 2.8 | 10.6 | 23 | 77 |
| 2448I | 4/27 - 5/17   83 | 34.7 | 3.5 | 10.1 | 42 | 58 |
| 2448G | 5/18 - 6/8    83 | 37.1 | 4.9 | 13.4 | 28 | 72 |
| 2450D | 6/9 - 6/28    83 | 47 | 2.5 | 5.3 | 28 | 72 |
| 2456B | 6/29 - 7/19   83 | 44 | 3.8 | 8.7 | 27 | 73 |
| 2450C | 7/20 - 8/9    83 | 47 | 5.4 | 11.5 | 46 | 54 |
| 2457D | 8/10 - 8/30   83 | 32.5 | 3.2 | 9.7 | 50 | 50 |
| 2459G | 8/31 - 9/20   83 | 43.3 | 3.6 | 8.2 | 31 | 69 |
| 2452D | 9/21 - 10/18  83 | 27.3 | 3.5 | 13.0 | 38 | 62 |

FIG. 1.

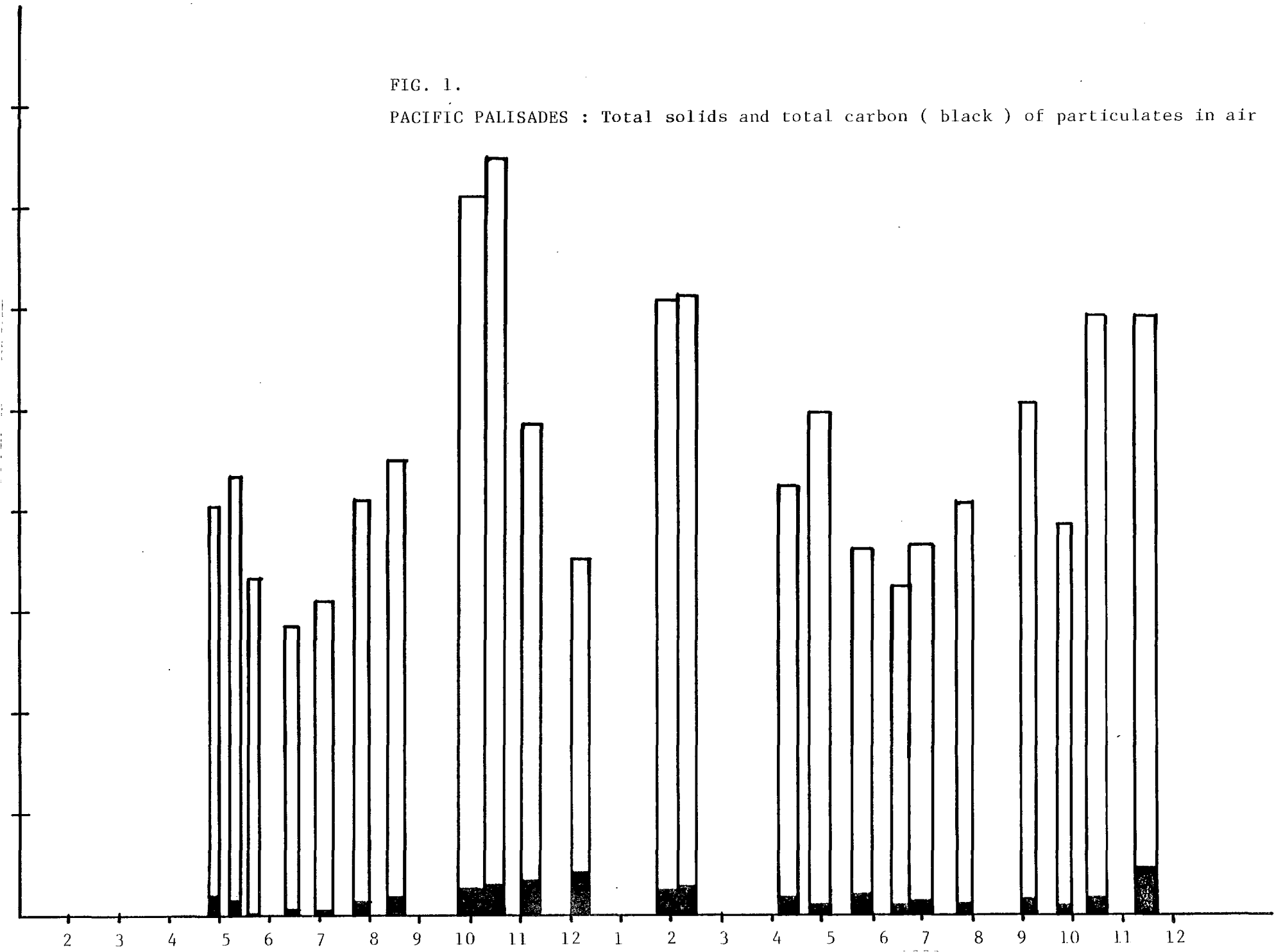PACIFIC PALISADES : Total solids and total carbon ( black ) of particulates in air

FIG.2.

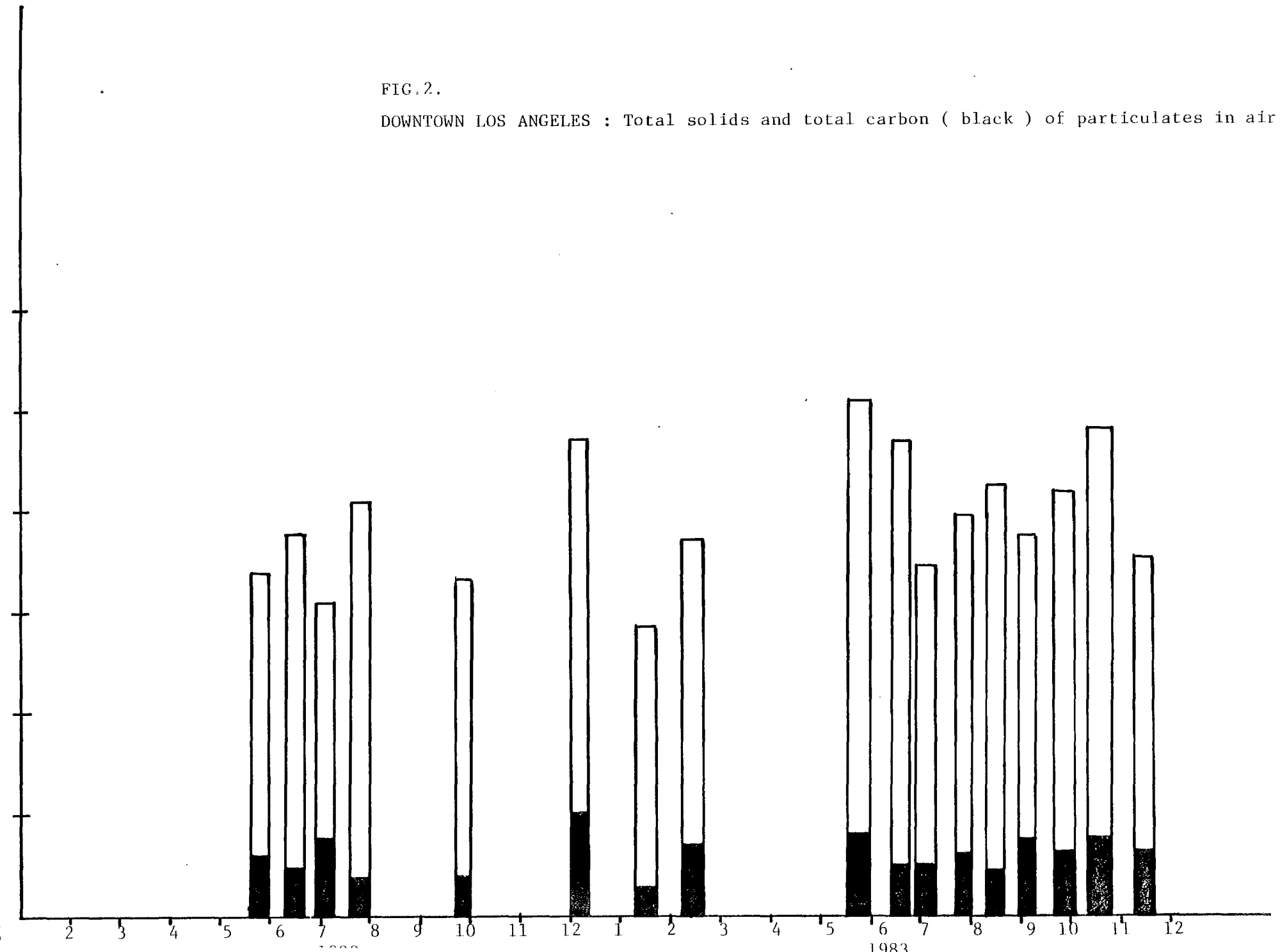DOWNTOWN LOS ANGELES : Total solids and total carbon ( black ) of particulates in air

FIG.3.
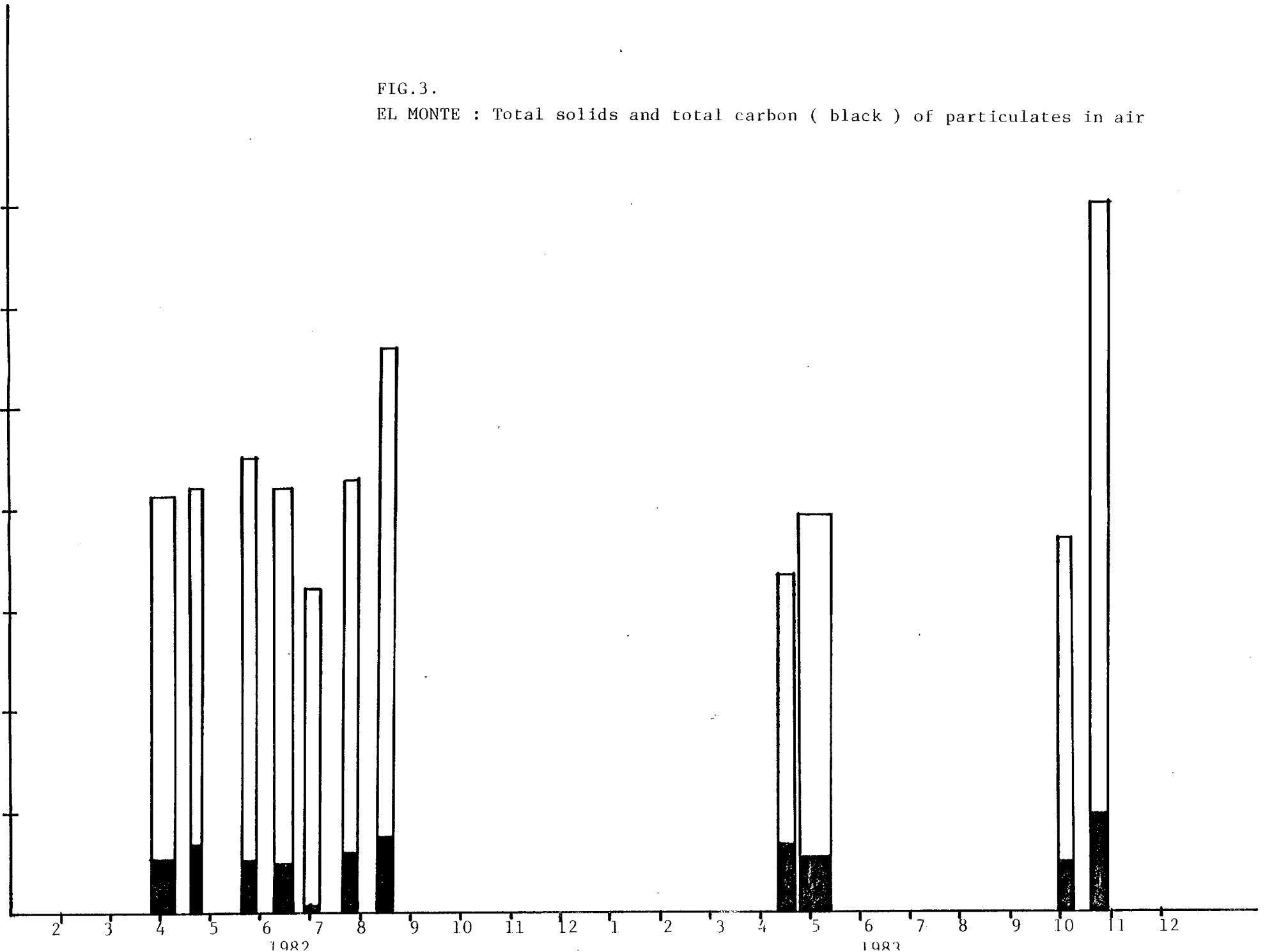EL MONTE : Total solids and total carbon ( black ) of particulates in air

FIG.4.

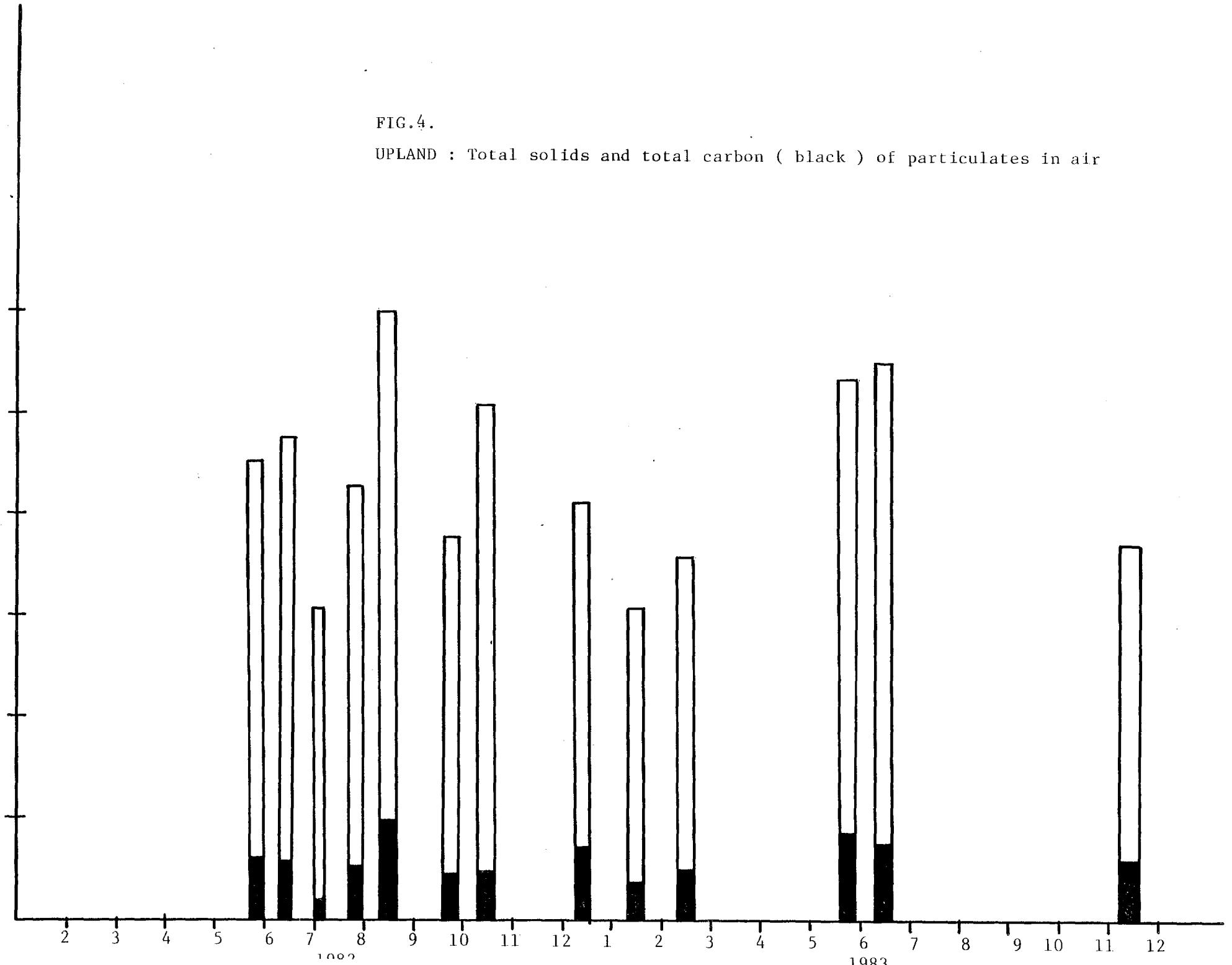UPLAND : Total solids and total carbon ( black ) of particulates in air

FIG.5.

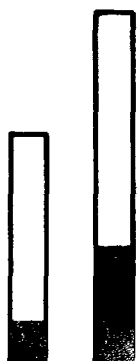CHICO:    Total solids and total carbon ( black ) of particulates in air

FIG.6.
LAKE TAHOE : Total solids and total carbon ( black ) of particulates in air

FIG.7.

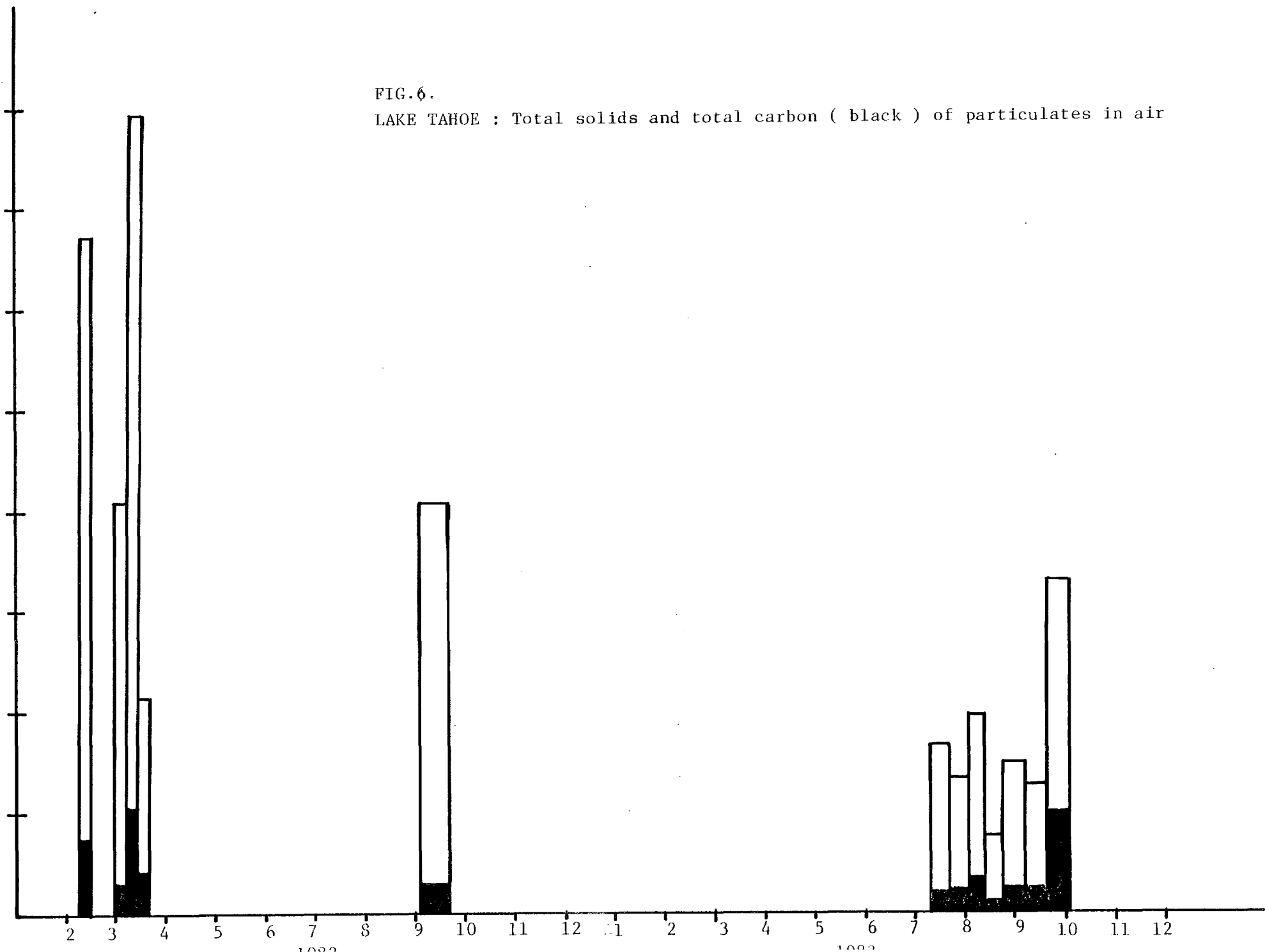BAKERSFIELD : Total solids and total carbon ( black ) of particulates in air
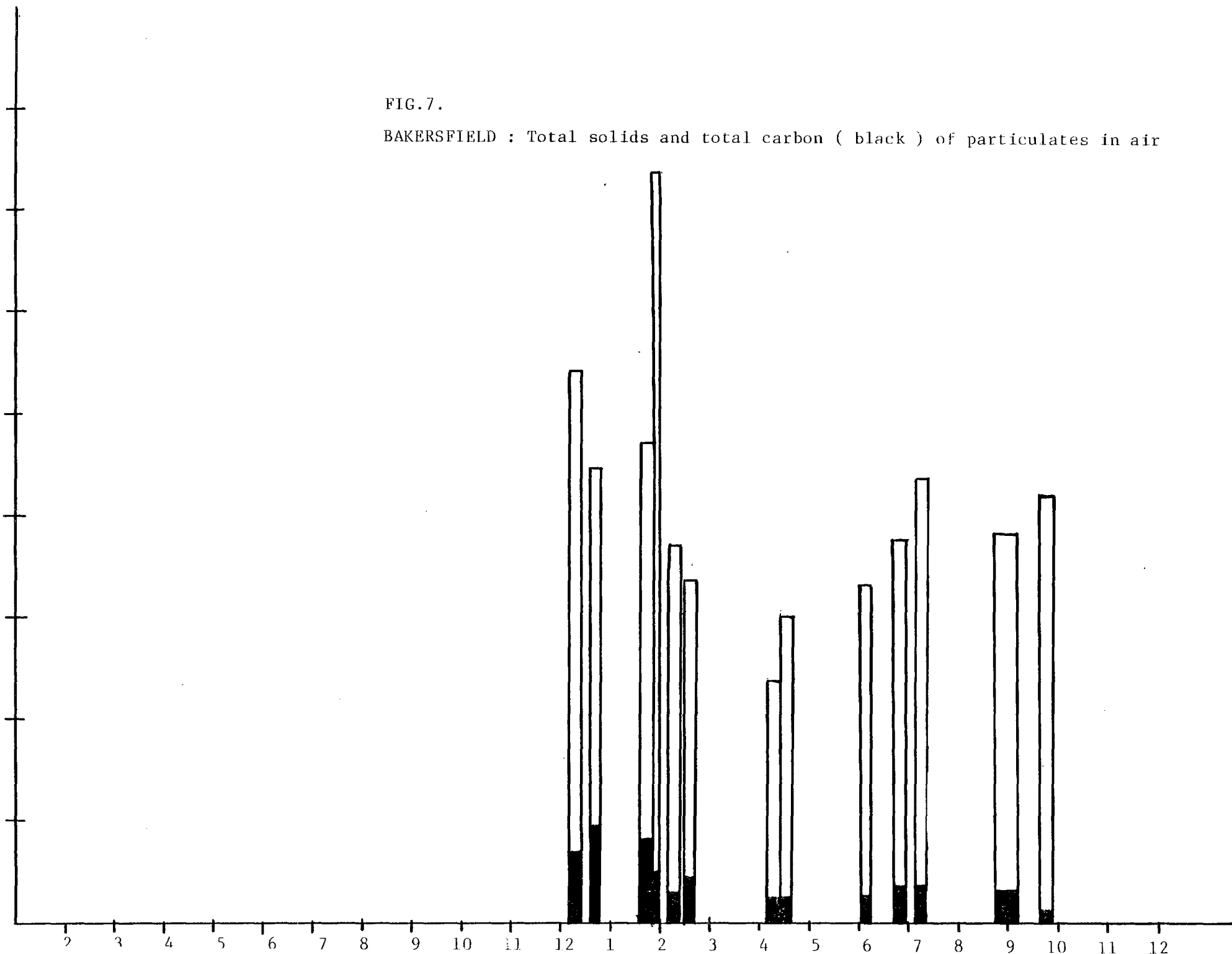
FIG.8.

EL CAJON : Total solids and total carbon ( black ) of particulates in air

Figure 9

CALIFORNIA
PREDOMINANT SURFACE
WIND FLOW PATTERNS

SPRING (MAR. - APR. - MAY)

Legend

COASTAL WATERS

MOUNTAINOUS
ZONES

HEAVY LINES DELINEATE THE
14 CALIFORNIA AIR BASINS

CALIFORNIA AIR RESOURCES BOARD
TECHNICAL SERVICES DIVISION 7/63

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Figure 10



CALIFORNIA
PREDOMINANT SURFACE
WIND FLOW PATTERNS

SUMMER (JUN. - JUL. - AUG.)

Legend

COASTAL WATERS

MOUNTAINOUS
ZONES

NORTHEAST
PLATEAU

SACRAMENTO
VALLEY

MOUNTAIN
COUNTIES

LAKE TAHOE

NORTH COAST

LAKE COUNTY

SAN FRANCISCO
BAY AREA

SAN JOAQUIN VALLEY

GREAT BASIN VALLEYS

NORTH CENTRAL COAST

SOUTHEAST
DESERT

SOUTH CENTRAL COAST

SOUTH COAST

SAN DIEGO

W — E
S
0  20  40  60  80  100
Scale in miles
HEAVY LINES DELINEATE THE
14 CALIFORNIA AIR BASINS
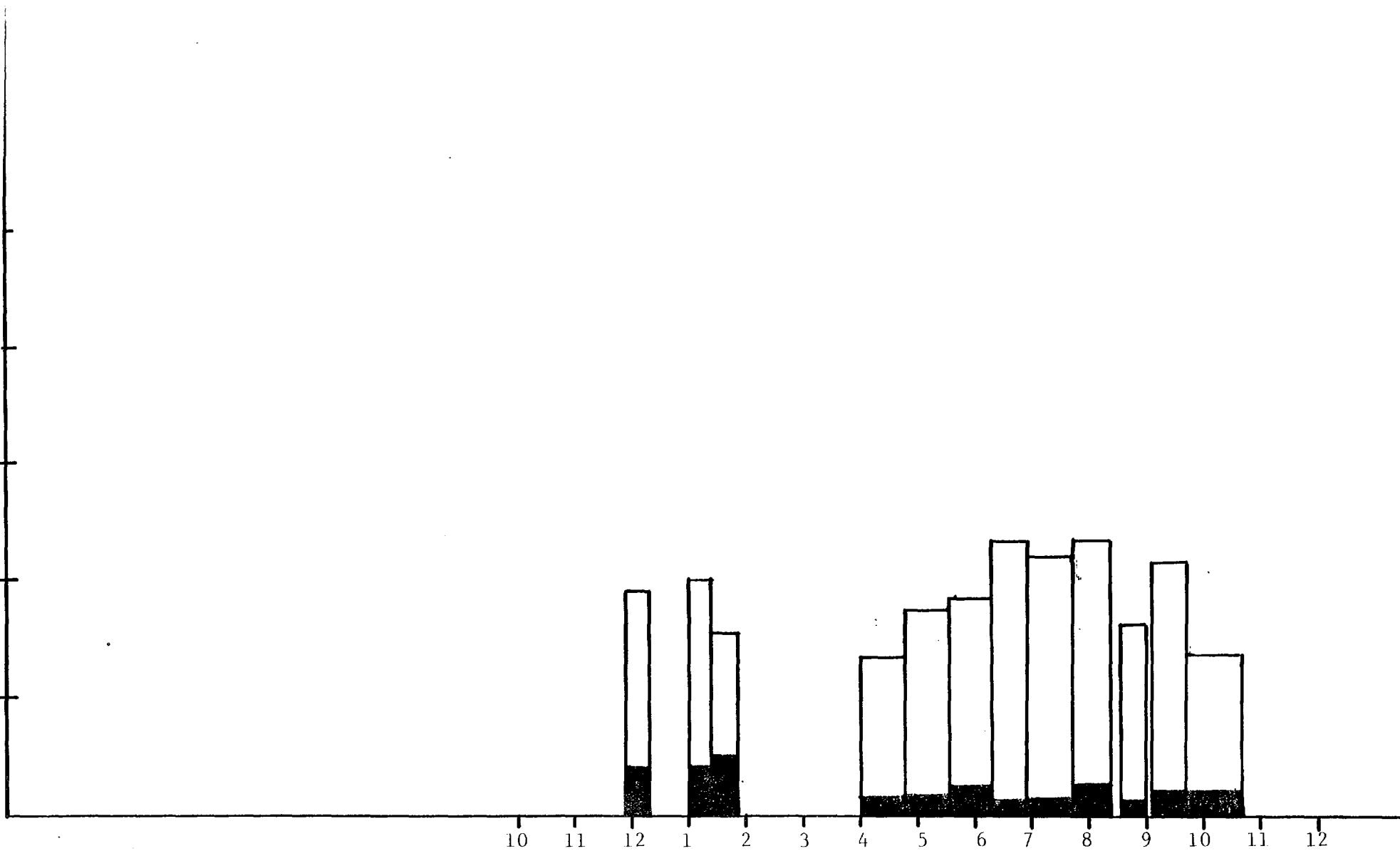
CALIFORNIA AIR RESOURCES BOARD
TECHNICAL SERVICES DIVISION 7/83

Figure 11



CALIFORNIA
PREDOMINANT SURFACE
WIND FLOW PATTERNS

FALL (SEP. - OCT. - NOV.)

Legend

COASTAL WATERS

MOUNTAINOUS
ZONES

NORTHEAST
PLATEAU

SACRAMENTO
VALLEY

MOUNTAIN
COUNTIES

LAKE TAHOE

NORTH COAST

LAKE COUNTY

SAN JOAQUIN VALLEY

GREAT BASIN VALLEYS

SAN FRANCISCO
BAY AREA

NORTH CENTRAL COAST

SOUTHEAST
DESERT

SOUTH CENTRAL COAST

SOUTH COAST

SAN DIEGO

HEAVY LINES DELINEATE THE
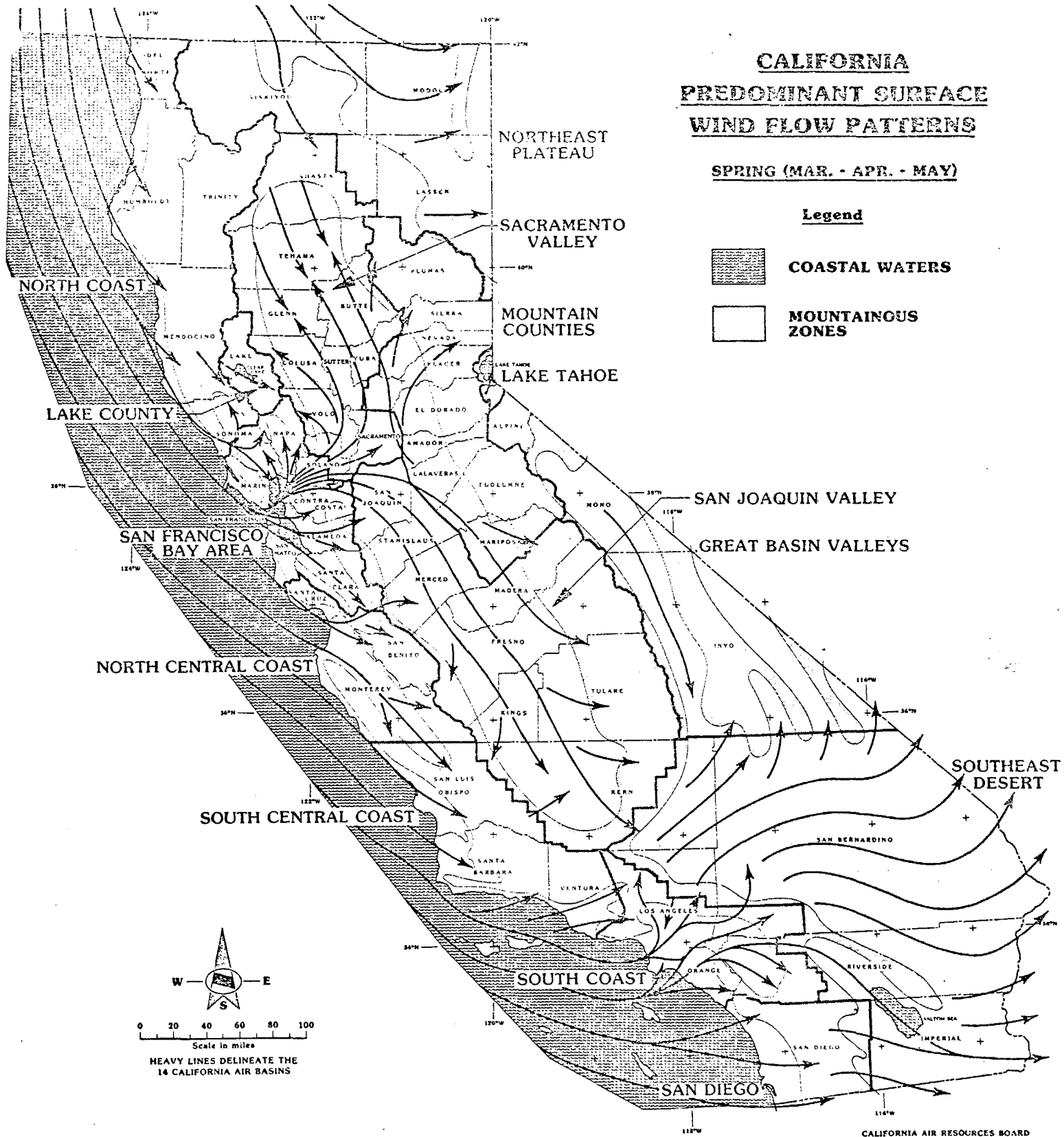14 CALIFORNIA AIR BASINS

Scale in miles
0  20  40  60  80  100

CALIFORNIA AIR RESOURCES BOARD
TECHNICAL SERVICES DIVISION 7/83

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Figure 12

# CALIFORNIA PREDOMINANT SURFACE WIND FLOW PATTERNS

## WINTER (DEC. - JAN. - FEB.)

### Legend

COASTAL WATERS

MOUNTAINOUS ZONES

NORTHEAST PLATEAU

SACRAMENTO VALLEY

MOUNTAIN COUNTIES

NORTH COAST

LAKE TAHOE

LAKE COUNTY

SAN JOAQUIN VALLEY

GREAT BASIN VALLEYS

SAN FRANCISCO BAY AREA

NORTH CENTRAL COAST

SOUTHEAST DESERT

SOUTH CENTRAL COAST

SOUTH COAST

SAN DIEGO

Scale in miles
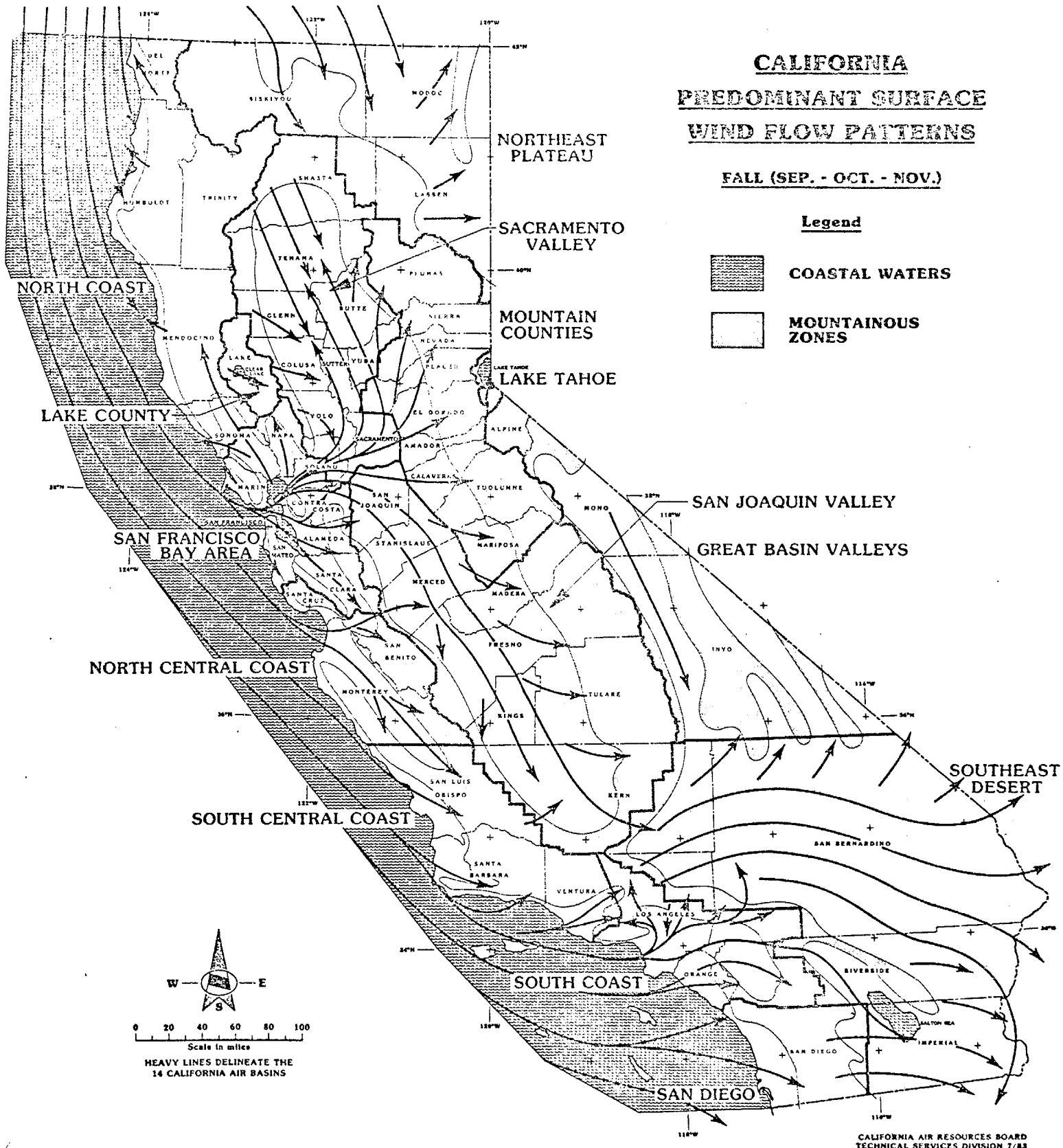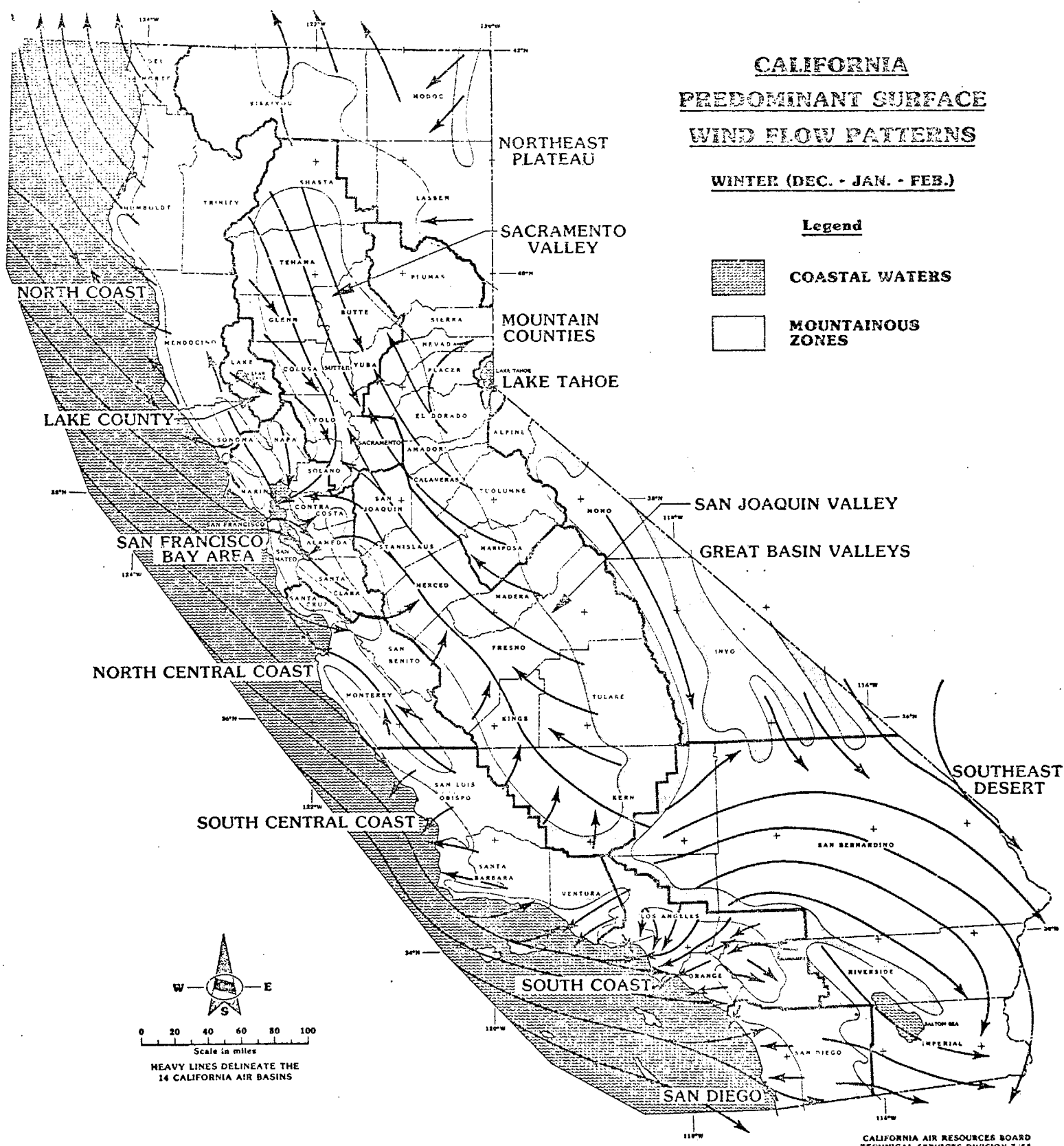0  20  40  60  80  100

HEAVY LINES DELINEATE THE
14 CALIFORNIA AIR BASINS

CALIFORNIA AIR RESOURCES BOARD
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the San Francisco air basin,Science 203,82(1979).

Publication

The following preliminary publication has appeared
in print :

"Radiocarbon measurements of particulates in smog"
Rainer Berger,R.M.Johnson and J.R.Holmes in
RADIOCARBON 25, No.2, p. 615-620 ( 1983).

## Glossary of Terms

| Term | Definition |
|------|-----------|
| Biospheric carbon | Carbon derived from modern living things |
| Carbon-13 or $^{13}C$ | Stable isotope of carbon |
| Carbon-14 or $^{14}C$ | Unstable or radioactive isotope of carbon |
| C-3 pathway | A particular biochemical metabolic pathway used by leafy plants |
| Fossil carbon | Carbon of fossil fuels such as coal or natural gas of geologic age |
| PDB Standard | An international reference standard used to compare carbon-13 concentrations |
| $^o/oo$ or per mil | Parts per thousand |
| Proportional counter | A radiation detector which registers the magnitude of radioactive disintigrations depending on the voltage applied to the counter |
| Radiocarbon | Radioactive carbon, carbon-14 or $^{14}C$ |
| Radon | A radioactive daughter product generated during uranium-series decay |
| Troposphere | The air compartment between the surface of the earth and the tropopause located at approximately 40,000 feet of altitude |
| TSP | Total suspended particles in air |