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Carbon Monoxide Episodes

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Background

Carbon Monoxide is commonly thought of as a local pollutant affecting relatively small geographic areas. Since most CO emissions result from the operation of motor vehicles, high CO concentrations are associated with the congested areas of large urban central business districts. In the presence of moderate winds and in the absence of a continuing source of emissions, ambient CO concentrations diminish fairly quickly. High concentrations measured during evening rush hour traffic, for example, often diminish to background concentration levels between three and six a.m.

Against this background, Kreiss and Lansinser[1] postulated that because of CO's relatively long residence life (about 30 days), certain meteorological conditions could cause CO to accumulate over a large area. If such meteorological conditions persisted long enough, background levels might eventually become great enough to become a significant proportion of the total CO budget. For the purposes of this paper, episodes are defined generally as a sequence of days during which the minimum daily CO concentration increases from one day to the next. The existence of such episodes would imply that CO is not only a "hot spot" (localized) problem, but is sometimes an area wide problem as well. It would also imply that vehicle traffic on one day might contribute to high ambient CO concentrations on the next day.

Data Base

The data used in this analysis were derived from the Storage and Retrival of Aerometric Data (SAROAD) system[2], and consists of hourly concentrations for various U.S. cities during the January 1, 1975 to December 31, 1977 period. All data were screened for possible errors prior to analysis. Of the few errors discovered, most were transcription errors. These were corrected.

Analytical Procedures

For each SAROAD site studied, the hourly data were converted to eight hour moving averages. Values for one or two missing hours within an eight hour period were interpolated before the averaging process was applied. Finally, the minimum and maximum eight hour averages for each day were calculated and subjected to the episode criteria.

The purpose of the episode criteria was to isolate only the major CO episodes. Episodes which lasted fewer than five days or during which at least one daily maximum did not exceed the CO standard were ignored. To this end, the following criteria were established:

1) The second daily minimum value must be greater than the first daily minimum value, and any daily minimum after the third day must be greater than the minimum value three days previous. Otherwise, the episode terminates.

2) At least once during the episode period the daily maximum value must exceed 9 ppm.

3) Only one missing day can exist during the entire episode period, and that cannot be the first, second or fourth days.

4) The episode lasts at least five days.

Site Selection

The following seven cities were analyzed for CO episodes: Portland, OR; Seattle, WA; Chicago, IL; Pittsburg, PA; Salt Lake City, UT; Denver, CO; and New York City, NY. These cities represent a wide range of geographical areas and provide a good test of the areal CO hypothesis. Of the seven, only Chicago and New York City failed to report any episodes. Both Chicago and New York are characterized by moderately high wind speed which is conducive to high dispersion rates.

Associated Meteorology

The analysis of 10 major CO episodes from among the cities studied showed that meteorological conditions accompanying each episode were nearly identical[3]. Immediately before an episode began, an area generally experienced the passage of a low pressure system and a moderate to strong cold front. Associated with the low pressure systems were strong winds and precipitation. These conditions have a cleansing effect and generally cause ambient CO concentrations to fall to background levels.

After the low pressure system passed, a large strong high pressure system would gradually move toward the city. As a result, light surface winds and relatively little atmospheric mixing would prevail over the area for approximately one week. As the high pressure system moved across the area, both the maximum and minimum CO levels increased steadily. CO accumulation was taking place in the high's stable air. The peak CO values for both the maximum and minimum 8 hour levels occurred when the high pressure system was directly over the city. This would be expected, since the strength of a high's inversion is generally greatest at its center. In fact, fog almost always accompanied the maximum CO level during an episode. (The inversion prevents the dispersion of both water vapor and CO and thus causes both to accumulate near the surface.)

The termination of an episode was also generally the same for each site. After about seven days, another storm and cold front would pass by and again cleanse the atmosphere. However, on some occasions, the CO level fell without a storm passage. In these instances one can often attribute the decrease in CO to the reduced mobile source weekend activity.

Figures 1-10 show the maximum and minimum daily CO concentrations and the meteorology associated with each of the ten CO major episodes analyzed.

Discussion

Other similarties among episodes exist on a broader scale. Episodes occurred most frequently during the winter months and occurred least frequently during summer months. This can be attributed to the usually large increase in CO emissions from motor vehicles at cold temperatures. Table 1 shows the seasonal distribution of episodes. (In addition to the ten major episodes displayed in Figures 1-10, 40 less prominent episodes are included in the tables that follow.)

Table 1

Average Number of Episodes by Season

	Winter (Dec, Jan, Feb)	Spring (Mar, Apr, May)	Summer (Jun, Jul, Aug)	Autumn (Sept, Oct, Nov)	Annual
Seattle	4 (40.3)*	1 (49.2)	1 (66.0)	4 (52.1)	11
Portland	5 (40.5)	1 (51.0)	1 (65.2)	4 (53.8)	10
Denver	5 (31.8)	3 (47.2)	3 (70.2)	3 (51.4)	13
Pittsburg	3 (32.0)	3 (51.7)	1 (73.0)	3 (55.5)	10
Salt Lake City	4 (30.6)	0 (49.0)	0 (72.5)	3 (52.1)	7

Interestingly, no statistical differences could be detected between winter and summer episodal durations. (See Table 2.) Since the passages of cleansing weather systems occur much more frequently in the winter than in the summer, one would expect winter episodes to be shorter. However, in this instance the five day restriction on the duration of episodes may have resulted in the lack of seasonal differences.

Table 2

Average Duration of Episodes by Season
(Number of Days)

	Winter	Spring	Summer	Autumn
Seattle	7	9	6	7
Portland	7	7	7	7
Denver	7	7	7	6
Pittsburg	7	7	7	8
Salt Lake City	7	0	0	7

No episodes occurred in Salt Lake City during the spring and summer months.

Table 3 shows the average increase in background CO levels over the course of an episode. After the air has been cleansed by the passage of a low pressure system, daily minimum CO concentrations average 1.1 ppm. These increase over the life of an episode to 4.5 ppm, roughly three times the original level.

*Average 30 year temperature in degrees Fahrenheit.

Table 3

Average Increase in Daily Minimum CO Concentrations (ppm)

	Starting Daily Minimum	Highest Daily Minimum	Difference
Seattle	1.2	4.5	3.3
Portland	.6	3.7	3.1
Denver	1.7	5.3	3.6
Pittsburgh	1.0	4.3	3.3
Salt Lake City	1.0	4.6	3.6
Average	1.1	4.5	3.4

Table 4

Average Increase in Daily Maximum CO Concentrations (ppm)

	Starting Daily Maximum	Highest Daily Maximum	Difference
Seattle	5.2	11.9	6.7
Portland	5.7	12.9	7.2
Denver	6.5	12.3	5.8
Pittsburgh	4.2	12.8	8.6
Salt Lake City	5.7	12.8	7.1
Average	5.5	12.5	7.0

In the same fashion, daily maximum concentrations begin an episode at 5.5 ppm and increase to 12.5 ppm. (See Table 4.) If man-made CO dispersed completely from day to day, then it is likely that the highest daily maximum concentration measured at these sites would be substantially below 12.5 ppm. Also, the fact that high CO concentrations do not appear to disperse completely during episode periods indicates that during these episodes relatively high CO concentrations permeate the entire urban area. More than the immediate vicinity of a few congested intersections is affected. As Table 5 shows, there was at least one episode in each of the five cities during which the daily minimum reached 7.2 ppm. During one episode in Pittsburgh, the <u>minimum</u> concentration recorded during one day was 11.1 ppm, well above the CO NAAQS.

Table 5

Highest Daily Minimum and Maximum CO Concentrations

	Number of Episodes	Highest Daily Minimum	Highest Daily Maximum
Seattle	34	8.1	16.1
Portland	31	7.5	16.7
Denver	42	9.1	20.7
Pittsburgh	31	11.1	21.4
Salt Lake City	24	7.2	16.7

While any exceedance of the NAAQS is important, State Implementation Plans for CO are generally targeted to reduce the second highest eight hour average CO concentration to a level at or below 9 ppm. The current standard specifies that the NAAQS is not to be exceeded more than once per year; one excursion above the standard level is allowed. Since the second excursion constitutes a violation, states seek to reduce the second highest eight hour standard.

For each of the cities studied in this report, the twenty highest measured CO concentrations were obtained for each of the three years, 1975-1977. These values were then classified as to whether or not they were associated with a CO episode. Table 6 displays the results of 300 possible values, over half were associated with an episode. More than one-half of the second highest measured CO concentrations were associated with CO episodes.

Table 6

Incidence of CO Episodes Among Highest Twenty CO Concentrations

	1975	1976	1977	Total
Seattle	12*	1	9	22
Portland	0	12	7	19
Denver	5	**	13	**
Pittsburgh	20	15	8	43
Salt Lake City	12	16	20	48

*Number of highest CO concentrations associated with episodes.

**Missing data.

Conclusions

Clearly, CO episodes contribute in an important way to violations of the National Ambient Air Quality Standard. During episodes, the average daily maximum increases from 1.1 ppm to 4.5 ppm; the average daily maximum increases from 5.5 ppm to 12.5 ppm. In the cities examined for this report, more than one-half the worst NAAQS violations are associated with episode periods.

Figure 1
Seattle

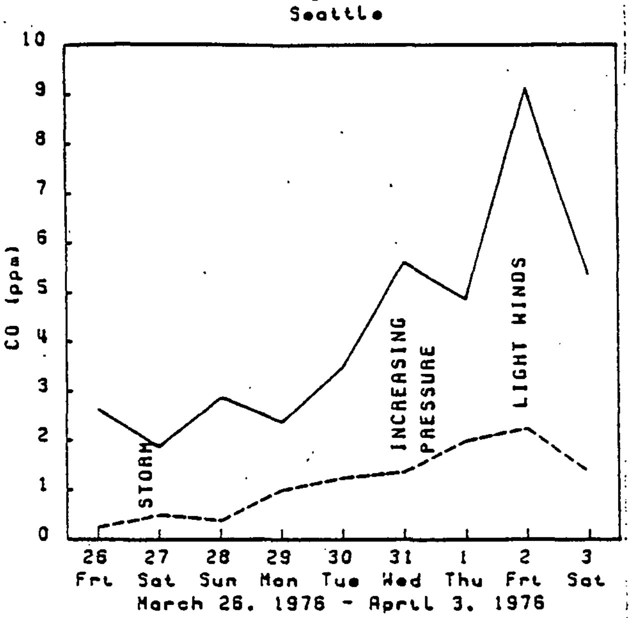


Figure 2
Seattle

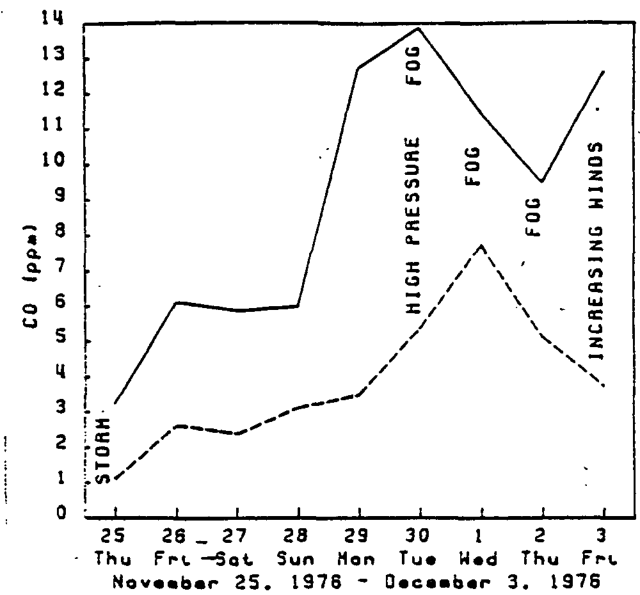


Figure 3
Portland

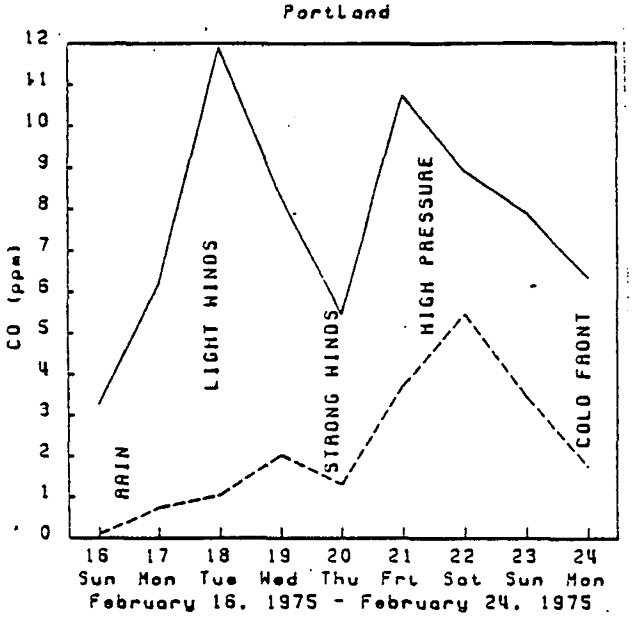
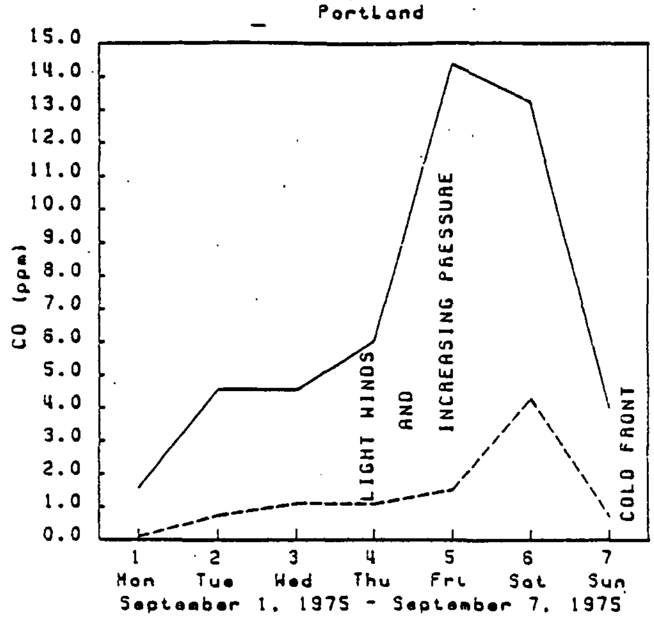


Figure 4
Portland



——— Maximum

- - - - - Minimum

Figure 5
Denver

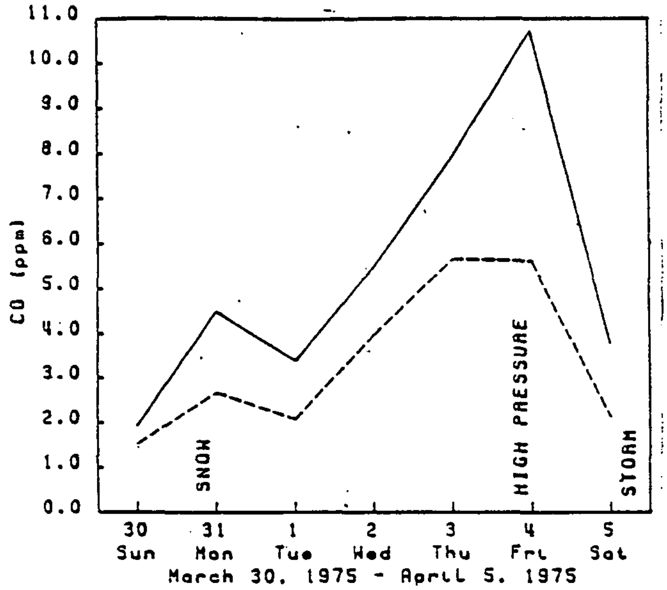


Figure 6
Pittsburg

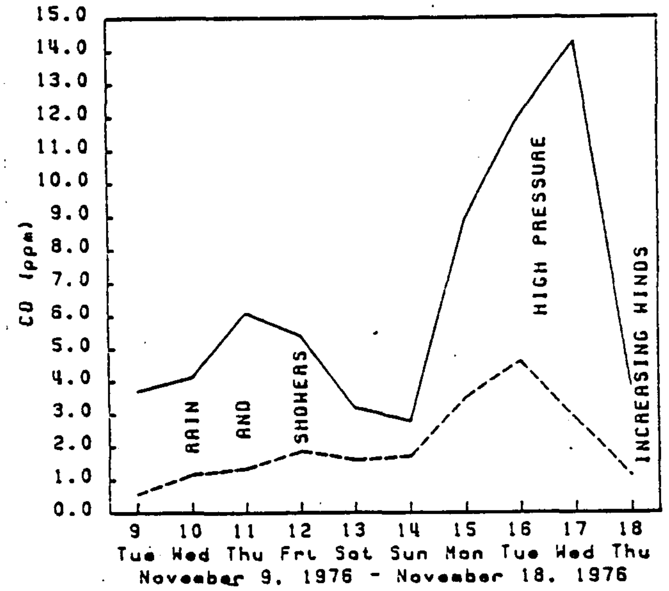


Figure 7
Salt Lake City

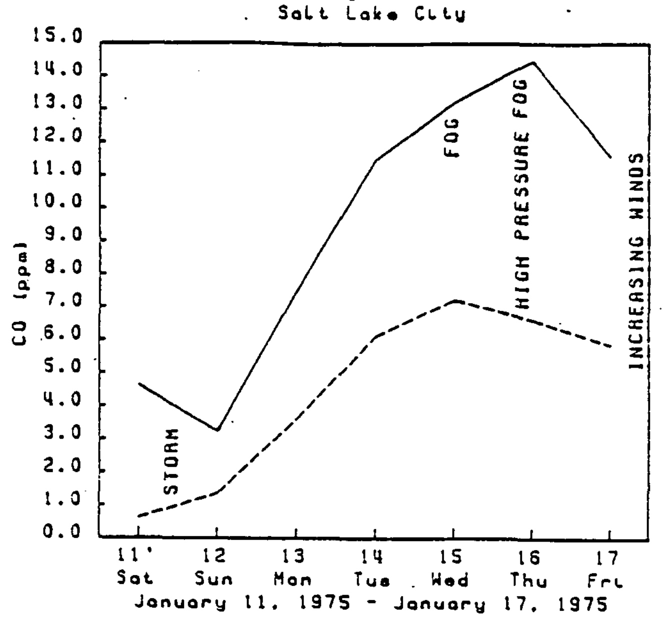
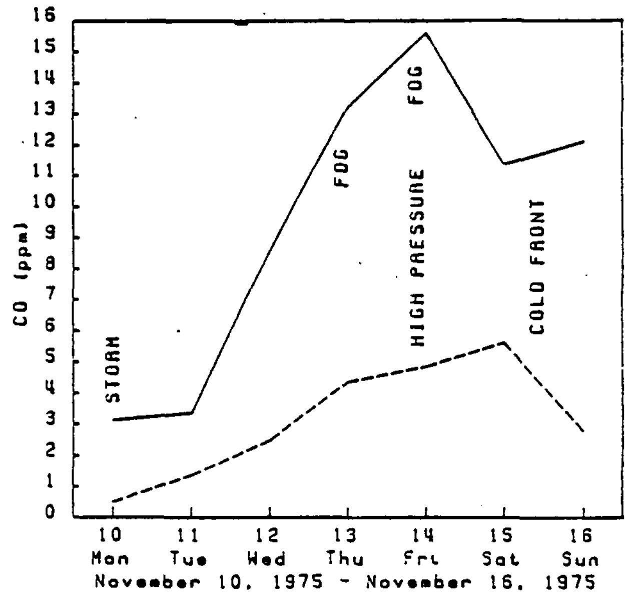


Figure 8
Salt Lake City



——— Maximum

- - - - Minimum

Figure 9
Salt Lake City

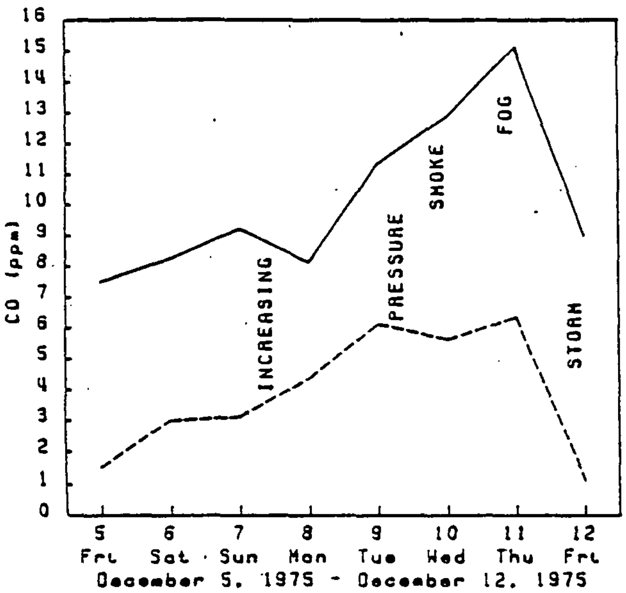
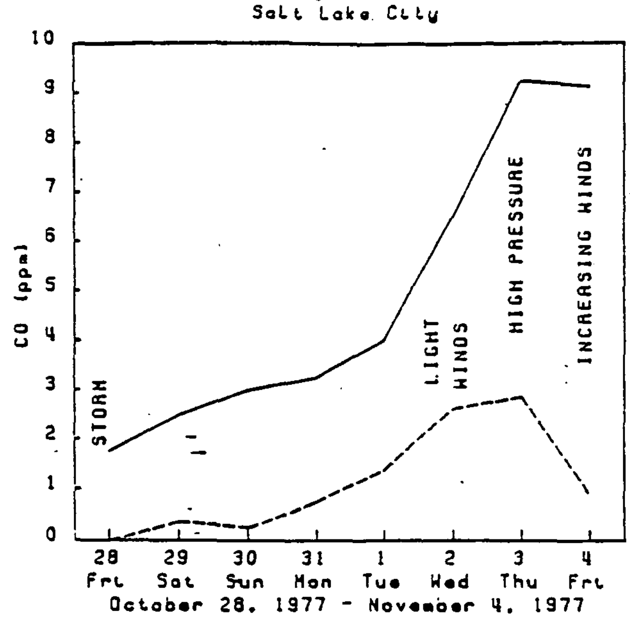


Figure 10
Salt Lake City



——— Maximum

- - - - Minimum

References

1. Kreiss, W. T. and J. M. Lansinger, "Carbon Monoxide Background Concentrations and Worst Case Analysis", Physical Dynamics, Inc., Bellevue, Washington, 98009.

2. Storage and Retrieval of Aerometric Data, U.S. Environmental Protection Agency, Office of Air Programs, Research Triangle Park, North Carolina.

3. Daily Weather Maps, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service.