Memorandum

To: George C. Murray, Jr

CC: Alan Klimek, Brock Nicholson

From: Wayne L. Cornelius

Date: 21 August 1998

Re: Detection in NC of Smoke from Central America

Contents

List of Tables

List of Figures

Introduction

Throughout the Spring of 1998, as happens every Spring, thousands of fires in Central America have been burning. However, the 1998 fires are said to be about twice as intense as the normal year. As a result, smoke has been lingering over southern Mexico, Guatemala and Honduras since late February 1998 throughout the Spring, and smaller incursions of smoke palls have reached the US Gulf Coast, particularly Florida. Unlike earlier years, the research community has followed with keen interest the 1998 Central American fires by a variety of UV, visible and infrared remote sensors from satellites[1].

Brett Schichtel, Washington University, St. Louis, MO. requested through Rich Poirot continuous PM-10 data to track the spread of smoke subsequent to a stagnation episode in Central America 10-12 May. (The smoke was transported North, reaching Western Ontario by 14 May. On 16-17 May, a moving cold front pushed the pall of smoke eastward.)

After responding to this request, I had my staff assemble a database of *daily*, not continuous, PM-10 data to see whether *we* could recognize the effect of this smoke. In particular, do PM-10 samples from 17 May in NC have substantially higher concentrations than on 11 May – not attributable to localized effects, normal seasonal variation, or other influences that can be distinguished from the phenomenon?

Methods

We retrieved all the NC daily PM-10 data samples available in AIRS for the 7 years 1992-98, between the dates 2 March through 29 June. We divided this 120-day period into 20 6-day blocks, and analyzed the samples as representing the time block in which they fell. (Because of the 1996 Leap Year, this didn't quite succeed at putting 1 sample from every day of the week in every block.)

The sites active *in* 1998 are shown on a map in Figure 1.

We examined two groupings of sites: (i) 15 sites at which monitoring data exist in *every* one of the 7 years, and (ii) about 50 sites at which monitoring data exist in *any* one or more of the 7 years.

Results

In Table 1 (and also Figure 2), average concentrations are shown for each time block and year. Marginal column and row maximums are also shown. The averages are arithmetic means over the 15 sites shown in the header of the table. Table 2 shows the number of sites that were averaged for each cell of Table 1.

In Table 3, average concentrations are shown for each time block and year. Marginal column and row maximums are also shown. The averages are arithmetic means over the sites shown in the header of the table. Table 4 shows the number of sites that were averaged for each cell of Table 3.

Because the difference between concentrations of 11 May and 17 May 1998 are of special interest, the specific samples for those dates are listed in Table 5 and shown as boxplots in Figure 3. The 11 May 1998 samples range from 4 to 23 $\mu g/m^3$ (mean 15.0, s.e. 4.6) , and the 17 May 1998 samples range from 30 to 61 $\mu g/m^3$ (mean 46.9, s.e. 7.9). The 17 May concentrations exceed all other data in Table 1 and Table 3, with the possible exception of 24-29 June in 1992 and 1993, 25-30 May 1994, and 19-24 May 1996; whereas the concentrations on 11 May 1998 are among the smallest concentrations found on any date within the range covered.

Table 6 lists the samples of 26 May 1994, and Table 7 lists the samples of 21 May 1996.

[1] <*http://capita.wustl.edu/Central-America/*> , accessed 16 June 1998.

Discussion

PM-10 concentrations appear to have more than tripled from 11 May to 17 May, and this increase appears to be uniform statewide. On 24 May the concentrations decreased to merely double those of 11 May. This finding does not prove that Central American smoke *caused* the increased PM-10 concentrations, but it is very strong correlative evidence for a relationship between the smoke episode observed by satellite data and the concentrations observed by PM-10 sampling.

Table 1 and Table 3 show that on 2 other occasions a rather high average concentration (over 40 $\mu g/m^3$) is sandwiched between immediately earlier and later averages that are only about ½ as large, for example 25-30 May 1994 and 19-24 May 1996. Figure 2 shows a very emphatic view of the pattern (although the dates are not explicitly labeled).This pattern, which we have never noticed before, because we never looked for it before, may be cautiously interpreted as evidence that some widespread PM-10 "event" probably occurred during the time that the high concentration was observed. However, closer inspection of the data seems to rule out such an event on these 2 dates.We are not certain that candidate events can be identified for these dates. Moreover, when the individual samples are examined (Table 6 and Table 7), it is clear that the high concentrations are not found uniformly at all sites. The 26 May 1994 samples range from 24 to 81 (mean 44.8, s.e. 10.3) and the 21 may 1996 samples range from 23 to 54 (mean 39.4, s.e. 7.9).

Recommendations

Media interest in this topic seems to have passed away already, before we could assemble the data to study it most effectively. This will be useful information for reference in the 1997 Annual Air Quality Report, if nowhere else.

Also, although the episode did not produce PM-10 exceedances, we have hereby developed a case for validity-flagging our AIRS PM-10 data for 17 May 1998 to indicate abnormal observations or a statewide "exceptional event", if we wish to do so. (Unfortunately, the only suitable AIRS code available is the one for "misc.".)

Table 1. Block Means of PM-10 Concentrations, Using Sites That Have Been Active in Every Covered Year[2].

Dates	92	93	94	95	96	97	98	MAX
02-07.Mar	14.1	30.7	14.7	18.8	22.80	22.1	27.8	30.7
08-13.Mar	19.1	18.3	20.7	22.6	17.00	21.3	15.8	22.6
14-19.Mar	15.7	15.8	26.4	32.3	24.40	21.5	14.9	32.3
20-25.Mar	25.6	21.5	29.4	21.9	19.50	16.2	20.1	29.4
26-31.Mar	21.0	22.9	17.1	26.1	9.13	21.2	29.9	29.9
01-06.Apr	25.3	17.7	26.9	34.2	23.70	33.9	15.6	34.2
07-12.Apr	16.7	17.7	22.0	22.8	20.00	22.1	16.9	22.8
13-18.Apr	23.0	29.0	21.5	19.6	24.30	32.1	22.4	32.1
19-24.Apr	31.7	23.0	35.3	26.9	17.60	23.6	13.1	35.3
25-30.Apr	32.9	24.7	31.1	29.1	21.10	12.4	22.8	32.9
01-06.May	17.0	31.9	24.1	19.1	29.50	14.9	20.4	31.9
07-12.May	35.3	36.0	17.8	34.1	31.00	15.1	15.0	36.0
13-18.May	30.4	24.4	29.0	27.3	23.10	20.3	46.9	46.9
19-24.May	35.3	24.9	18.0	22.2	41.60	21.9	33.5	41.6
25-30.May	14.9	31.0	45.8	25.6	23.60	17.3	38.2	45.8
31-05.Jun	22.4	20.9	29.8	19.8	18.10	13.5	28.0	29.8
06-11.Jun	29.1	21.6	21.1	32.9	18.30	21.4	21.0	32.9
12-17.Jun	30.6	32.4	35.0	25.3	32.30	28.9	29.1	35.0
18-23.Jun	39.1	35.3	26.2	22.1	25.50	35.3	32.7	39.1
24-29.Jun	40.1	48.5	22.4	27.4	30.10	24.6	41.2	48.5
MAX	40.1	48.5	45.8	34.2	41.60	35.3	46.9	48.5

Table 2. Number of Sites Sampled That Are Active Every Year.

Dates4	92	93	94	95	96	97	98
02-07.Mar	13	13	15	13	15	15	15
08-13.Mar	14	14	14	13	14	15	15
14-19.Mar	11	13	14	14	13	15	14
20-25.Mar	14	13	15	15	15	14	15
26-31.Mar	14	14	13	13	15	15	15
01-06.Apr	15	14	15	13	15	15	14
07-12.Apr	13	15	15	15	15	14	11
13-18.Apr	13	14	14	15	15	15	13
19-24.Apr	15	14	13	15	15	15	14
25-30.Apr	15	15	14	15	15	13	13
01-06.May	15	14	14	15	15	14	14

[2] [1] "370210003" "370510004" "370670009" "370810009" "370850001"
[6] "370870002" "371110002" "371190010" "371191001" "371191005"
[11] "371210001" "371330004" "371390001" "371830003" "371910004"

Dates4	92	93	94	95	96	97	98
07-12.May	15	12	14	15	14	15	14
13-18.May	14	14	15	15	15	15	14
19-24.May	15	14	15	15	14	15	13
25-30.May	15	15	15	15	13	15	14
31-05.Jun	14	14	15	14	14	15	14
06-11.Jun	15	15	15	14	14	15	13
12-17.Jun	14	15	14	15	14	14	14
18-23.Jun	15	14	14	15	14	15	14
24-29.Jun	14	15	13	15	13	14	13

Table 3. Block Means of PM-10 concentrations, Using all NC active sites[3].

Dates	92	93	94	95	96	97	98
02-07.Mar	13.7	31.7	12.7	18.2	19.8	20.3	27.7
08-13.Mar	18.1	17.4	18.8	19.3	15.6	19.2	15.2
14-19.Mar	15.6	13.9	23.1	31.5	21.4	19.8	14.7
20-25.Mar	25.8	22.7	28.6	22.2	15.7	14.3	19.3
26-31.Mar	21.2	27.0	16.4	22.6	8.3	19.3	28.0
01-06.Apr	25.9	17.2	26.3	30.2	21.0	33.3	15.3
07-12.Apr	16.9	17.9	20.2	23.5	17.8	20.7	16.3
13-18.Apr	24.1	27.7	19.4	18.6	23.0	29.1	21.8
19-24.Apr	32.3	21.9	33.8	26.6	16.0	23.1	13.3
25-30.Apr	31.8	24.4	31.1	25.4	19.0	11.8	22.2
01-06.May	17.7	29.9	22.6	19.4	26.2	12.9	19.8
07-12.May	36.0	36.2	17.7	30.1	31.9	13.9	15.0
13-18.May	30.7	26.9	28.6	26.7	23.7	19.1	46.9
19-24.May	35.2	24.4	17.7	23.1	39.4	21.7	34.2
25-30.May	16.2	30.8	44.8	25.7	22.3	16.0	36.9
31-05.Jun	22.0	23.7	28.7	19.7	17.6	12.6	27.8
06-11.Jun	29.9	23.6	22.2	31.5	18.5	20.4	21.7
12-17.Jun	31.7	34.3	34.9	24.2	32.0	28.6	27.6
18-23.Jun	38.7	36.1	26.2	23.5	25.5	35.1	31.2
24-29.Jun	41.0	46.6	24.9	26.2	29.8	24.4	41.3

[3] [1] "370010002" "370030003" "370130005" "370210003" "370210032"
[6] "370210033" "370250004" "370350004" "370370004" "370510004"
[11] "370570002" "370571002" "370590099" "370630001" "370650002"
[16] "370650099" "370670009" "370670013" "370670020" "370670023"
[21] "370670024" "370671001" "370710014" "370770002" "370810009"
[26] "370811005" "370830002" "370850001" "370870002" "370891006"
[31] "371090003" "371110002" "371190001" "371190003" "371190010"
[36] "371191001" "371191005" "371210001" "371290005" "371290007"
[41] "371330004" "371390001" "371470003" "371550003" "371591006"
[46] "371730002" "371830003" "371890003" "371910004" "371950002"

Table 4. Number of Sites Sampled[4].

Dates	92	93	94	95	96	97	98
02-07.Mar	19	33	39	49	40	43	28
08-13.Mar	21	36	38	51	38	42	27
14-19.Mar	18	33	37	53	39	40	26
20-25.Mar	21	35	36	53	43	42	26
26-31.Mar	21	35	36	53	43	41	28
01-06.Apr	21	36	37	51	42	41	25
07-12.Apr	19	43	38	53	41	41	24
13-18.Apr	20	39	37	54	40	42	23
19-24.Apr	22	40	36	54	36	41	26
25-30.Apr	22	42	38	54	40	40	24
01-06.May	22	41	39	53	43	41	27
07-12.May	22	36	38	54	42	44	27
13-18.May	21	44	39	50	42	41	27
19-24.May	22	45	40	52	41	42	26
25-30.May	22	47	39	53	42	42	27
31-05.Jun	21	47	39	49	41	41	27
06-11.Jun	22	46	39	46	40	42	26
12-17.Jun	22	48	36	47	38	40	27
18-23.Jun	23	43	38	48	39	40	27
24-29.Jun	21	46	39	48	37	39	26

[4] Some date blocks in 1993 and 1995 have more samples than the number of sites, because the two continuous monitors (370210032, 370210033) provided up to 6 samples per block. I have not investigated why these monitors are represented in only these two years.

Table 5. Central America Smoke Episode Samples. Boldface rows are used in Table 1. All rows are used in Table 3.

AIRS Number	PM-10 Concentration		
	11 May	17 May	23 May
370250004	17	53	31
370350004	17	46	35
370571002	14	55	32
370630001	11	42	30
370650002	13	43	32
370710014	17	46	38
370811005	15	61	35
370891006	17	43	42
371190001	19	58	45
371190003	18	56	45
371290007	10	34	29
371470003	11	35	27
371730002	15	37	33
370210003	**17**	**47**	**36**
370510004	**11**	**50**	**28**
370810009	**12**	**57**	**34**
370850001	**10**	**47**	**28**
370870002	**23**	**51**	**40**
371110002	**22**	**48**	**34**
371190010	**18**	**54**	**42**
371191001	**16**	**51**	**38**
371191005	**22**	**54**	**52**

AIRS Number	PM-10 Concentration		
	11 May	17 May	23 May
371210001	**22**	**45**	**NA**
371330004	**10**	**37**	**24**
371390001	**04**	**30**	**18**
371830003	**13**	**45**	**34**
371910004	**10**	**41**	**28**
Mean	15.0	46.9	34.2
Std. Dev.	4.6	7.9	7.3

Table 6. Samples From 26 May 1994.

	AIRS	year	month	day	PM10
15	370010002	94	5	26	43
112	370030003	94	5	26	46
306	370210003	94	5	26	26
753	370250004	94	5	26	60
864	370350004	94	5	26	41
944	370370004	94	5	26	45
1044	370510004	94	5	26	58
1155	370570002	94	5	26	48
1356	370590099	94	5	26	37
1416	370630001	94	5	26	47
1499	370650002	94	5	26	53
1608	370650099	94	5	26	47
1726	370670009	94	5	26	40
1844	370670013	94	5	26	42
2003	370670023	94	5	26	45
2099	370670024	94	5	26	36
2196	370671001	94	5	26	41
2279	370770002	94	5	26	45
2400	370810009	94	5	26	41
2510	370811005	94	5	26	43
2619	370830002	94	5	26	47
2728	370850001	94	5	26	52
2856	370870002	94	5	26	30
2939	370891006	94	5	26	34
3043	371090003	94	5	26	43
3159	371110002	94	5	26	40
3332	371190003	94	5	26	56
3457	371190010	94	5	26	56
3571	371191001	94	5	26	47
3690	371191005	94	5	26	54
3807	371210001	94	5	26	27
4050	371330004	94	5	26	37
4178	371390001	94	5	26	81
4276	371470003	94	5	26	43
4437	371591006	94	5	26	44
4611	371830003	94	5	26	48
4690	371890003	94	5	26	24
4807	371910004	94	5	26	50
4916	371950002	94	5	26	49
mean					44.77
std.err.					10.27

Table 7. Samples from 21 May 1996.

	AIRS	year	month	day	PM10
51	370010002	96	5	21	50
150	370030003	96	5	21	32
227	370130005	96	5	21	33
343	370210003	96	5	21	29
791	370250004	96	5	21	31
900	370350004	96	5	21	38
1081	370510004	96	5	21	43
1192	370570002	96	5	21	50
1285	370571002	96	5	21	47
1537	370650002	96	5	21	38
1647	370650099	96	5	21	43
1764	370670009	96	5	21	44
1880	370670013	96	5	21	46
2037	370670023	96	5	21	46
2115	370670024	96	5	21	41
2233	370710014	96	5	21	35
2318	370770002	96	5	21	40
2438	370810009	96	5	21	49
2548	370811005	96	5	21	54
2650	370830002	96	5	21	34
2764	370850001	96	5	21	39
2893	370870002	96	5	21	41
2976	370891006	96	5	21	33
3081	371090003	96	5	21	36
3198	371110002	96	5	21	45
3266	371190001	96	5	21	40
3371	371190003	96	5	21	45
3610	371191001	96	5	21	42
3729	371191005	96	5	21	53
3845	371210001	96	5	21	42
3960	371290007	96	5	21	23
4088	371330004	96	5	21	26
4211	371390001	96	5	21	38
4315	371470003	96	5	21	29
4377	371550003	96	5	21	42
4476	371591006	96	5	21	42
4517	371730002	96	5	21	24
4650	371830003	96	5	21	49
4727	371890003	96	5	21	27
4846	371910004	96	5	21	43
4952	371950002	96	5	21	34
mean					39.41
std.err.					7.85

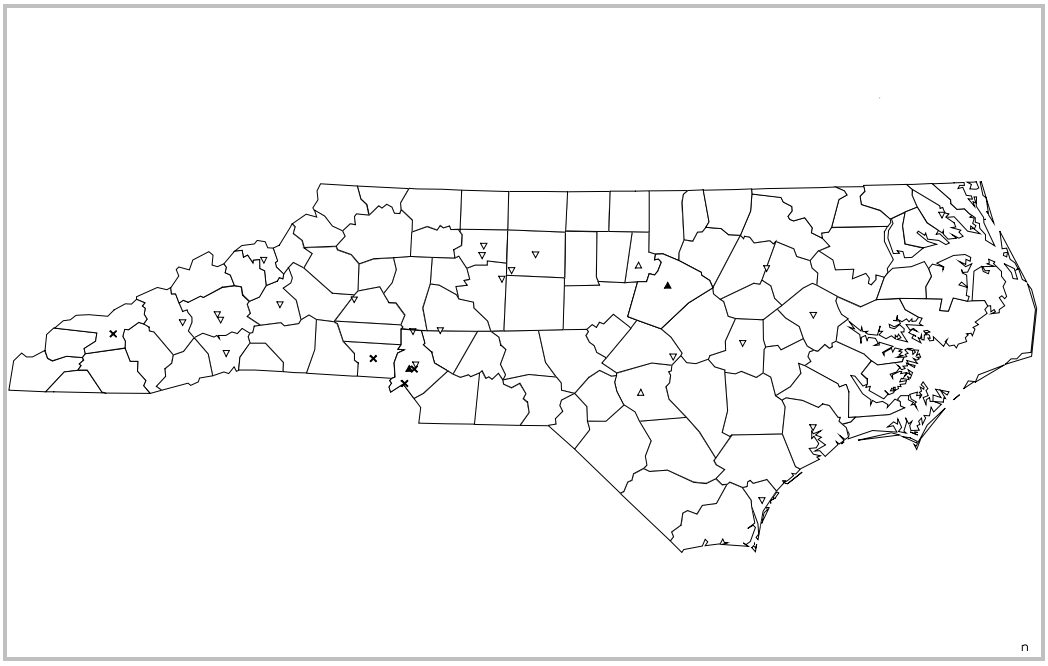

Figure 1. Locations of PM-10 Monitors Active in 1998.

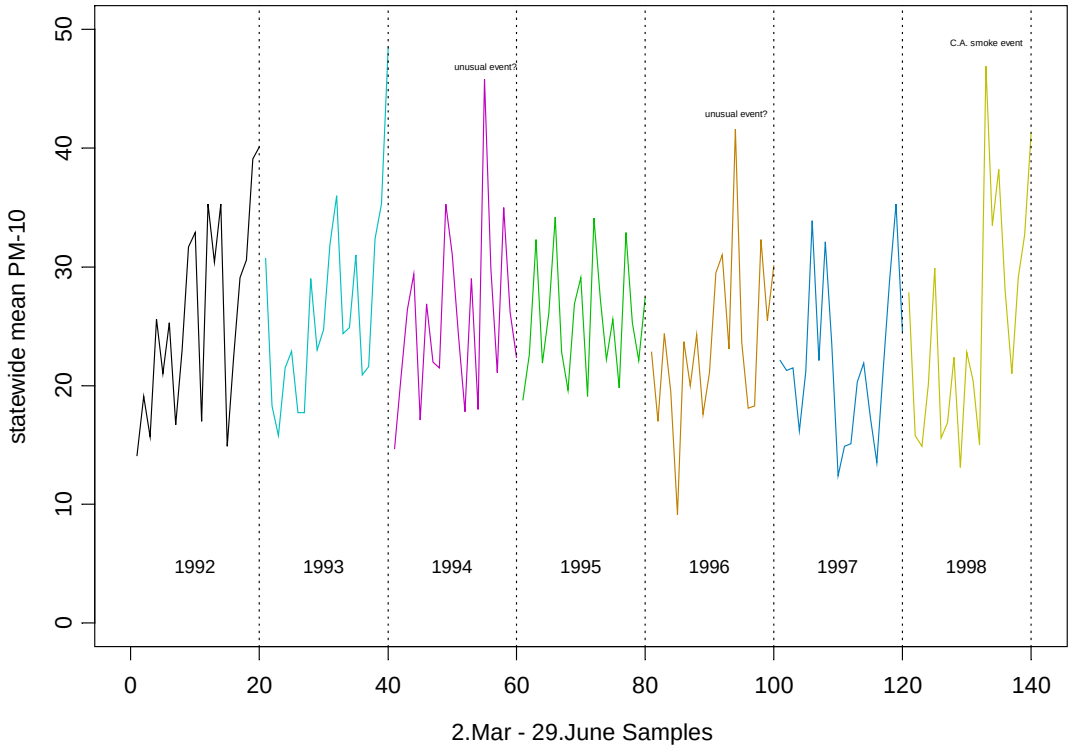

Figure 2. PM-10 Averages Shown as a Continuous Time Series. From Table 1.

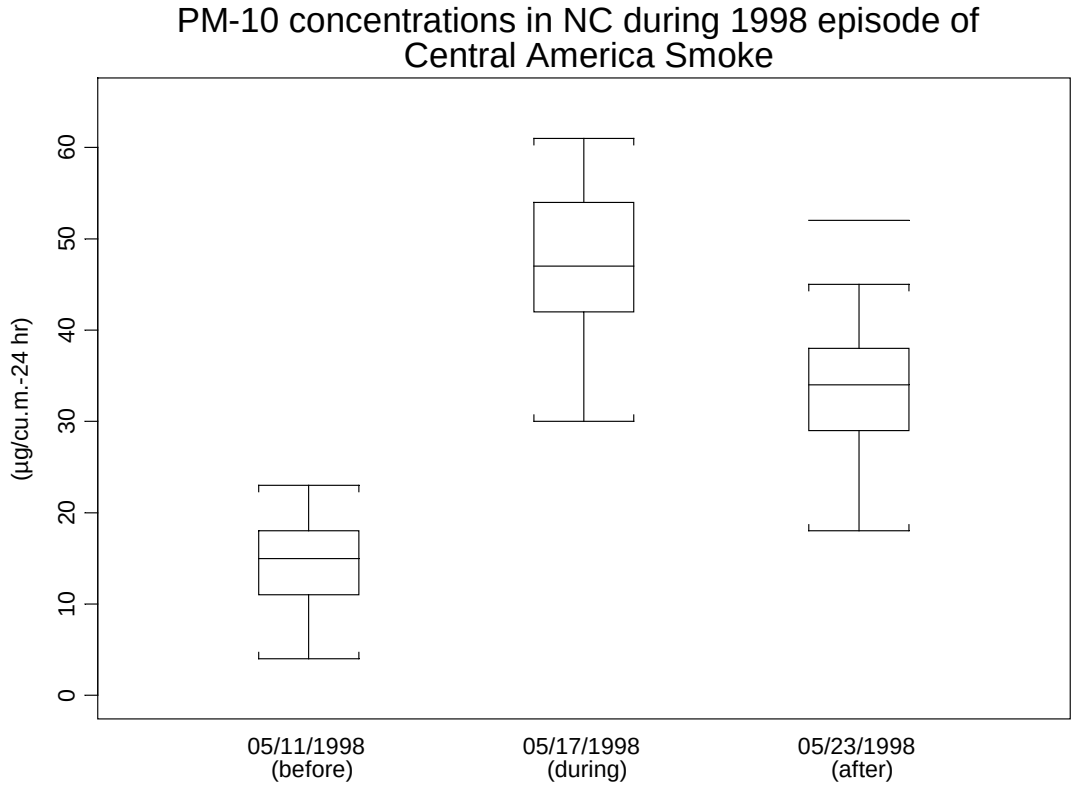

Figure 3. PM-10 Concentrations Surrounding the Central America Smoke Episode. From Table 5.