August 3, 2000

Mr. Scott Mathias
MD-15
USEPA Mailroom
Research Triangle Park, NC 27711

Dear Mr. Mathias[1]:

On behalf of EPRI, the sponsors of the Southeastern Aerosol Research and Characterization project (SEARCH), and my co-investigators, I am pleased to provide you with this initial summary of SEARCH $PM_{2.5}$ for 1999. In May you requested a summary of the SEARCH data for use in EPA's upcoming Criteria Document (CD) and Staff Paper for Particulate Matter. After a few iterations, a series of specific data analysis summaries were identified as something we could provide by mid-July. As you know, the SEARCH data set is quite extensive and continues to grow and evolve over time. It has been quite a challenge for us to prepare the data for these summaries while continuing to deploy new instrumentation to our sites. One result is that we are a few weeks late with this submittal. Hopefully, the information is still useful for the CD and Staff Paper.

Another consequence of this effort is that we must consider these summaries as "initial" and subject to minor changes as the data undergo continuing review and validation, and as new data are received from our analytical laboratories. We do plan to submit 1999 SEARCH data to the NARSTO archive by January 31, 2001 in order to support your need for reference and "public discovery." We will send you updated summaries at the end of the year that will be consistent with the data submitted to NARSTO. In the meantime, we would appreciate any feedback on the methods and assumptions used to generate these data summaries.

Through this letter and its attachments, we provide:

- a list of the specific data analysis summaries requested,
- a brief overview of SEARCH, and
- for each of the summaries:
  - a description of how each of the summaries were derived and critical assumptions,

[1] This is a revised version of the original transmittal letter, dated August 2, 2000. This letter includes the following corrections: 1) entries in Table 2, for BHM TEOM values due to correction factors not being applied to original values, 2) entry in Table 2 for JST TEOM value in section "All Available Valid Data – CY 1999," due to erroneous inclusion of "-999" values in original average, 3) entries in Table 2 for YRK values in the section "All Available Data Where All Parms Valid – TEOM As Reference Mass – CY 1999" due to erroneous deletion of 21 valid samples from the data set used to calculate the original values, and 4) deletion of reference to large overestimate of TEOM PM2.5 mass relative to FRM mass in the "Insights" section referring to Attachment C due to elimination of this large bias when the correct correction factors were used for the TEOM data.

- a discussion of important caveats about the data base and the summaries, and
- our initial insights from the summaries.

Requested Data Summaries

In your email-dated June 6, 2000, the following data summaries were requested:

1. Annual average composition for 1999 for each SEARCH site.
2. Quarterly or seasonal average composition for 1999 for each SEARCH site.
3. Average composition for high (90^{th} percentile) and low (10^{th} percentile) mass days for each quarter or season for 1999 for each SEARCH site.
4. Diurnal total mass patterns by hour of day for entire year and for each quarter or season from TEOM data for 1999 for each SEARCH site.
5. Correlation of mass, sulfate, nitrate, ammonium, elemental carbon (EC), and organic carbon (OC) vs. distance for 1999 for all SEARCH sites.
6. Same as 5. But by quarter or season.
7. Same as 5. But for mass only on the high (90^{th} percentile) mass days.

We have provided the above with the following exceptions and/or additions.

Item	Comment
1	Summaries provided for 7 of 8 SEARCH sites (not Gulfport). Used FRM (or TEOM) mass. Such data not available for Gulfport. Additional information about FRM vs. TEOM relationships, as well as impact of sample population on mass concentrations also provided.
2	Summaries provided for 7 of 8 SEARCH sites (not Gulfport).
3	Summaries provided for 7 of 8 SEARCH sites (not Gulfport).
4	Summaries provided for North Birmingham (7/99 - 12/99, courtesy of Randy Dillard, JCHD), Jefferson Street (9/98 - 9/99), and Yorkville, Centreville, and Oak Grove (all CY99). Also provided are diurnal plots of EC and organic material (OM defined as OC multiplied by 1.4) for Jefferson Street based on the R&P 5400 continuous carbon analyzer.
5	Summaries provided for all eight SEARCH sites (except Gulfport for FRM mass). Also provided are correlation plots of crustals (as oxides).
6	Summaries not provided.
7	Summaries provided for 7 of 8 SEARCH sites (not Gulfport).

SEARCH Overview

EPRI and Southern Company initiated SEARCH in mid-1998, building upon the existence of their three sites in the Southern Oxidant Study (SOS) Southeastern Consortium Intermediate Oxidant Network (SCION). SEARCH is currently funded through 2005. The attached Fact Sheet (**Attachment A**) provides background on the motivation for SEARCH, its goals and

objectives, and a basic description of its sites and measurements. Important strengths of SEARCH are:

- Establishment of a close working relationship with the States who are considered a primary audience for SEARCH data and results.
- A focus on atmospheric "aerosol" (measuring both gases and particles).
- A focus on "climatology" (i.e., routine, year-round measurements through 2005).
- A focus on contrasts between urban and rural, inland and coastal, large city to small city.
- Deployment of continuous (i.e., hourly or better time resolution) $PM_{2.5}$ mass and speciation samplers.
- A strong focus on research.

SEARCH currently consists of the following eight sites:

- Jefferson Street, Atlanta, GA (JST)
- Yorkville, GA (YRK)
- North Birmingham, AL (BHM)
- Centreville, AL (CTR)
- Gulfport, MS (GPT)
- Oak Grove, MS (OAK)
- Downtown Pensacola, FL (PNS)
- Suburban Pensacola, FL (OLF)

Because of the evolving nature of SEARCH, as well as technological advances, changes are often made to what is measured, where it is measured, how it is measured, and how often it is measured. **Table 1** summarizes routine particle measurements for SEARCH during 1999. The period of data coverage is shown above the slash, while sample frequency (temporal resolution for TEOM) is below the slash.

Table 1. SEARCH Routine Particle Measurements, 1999.

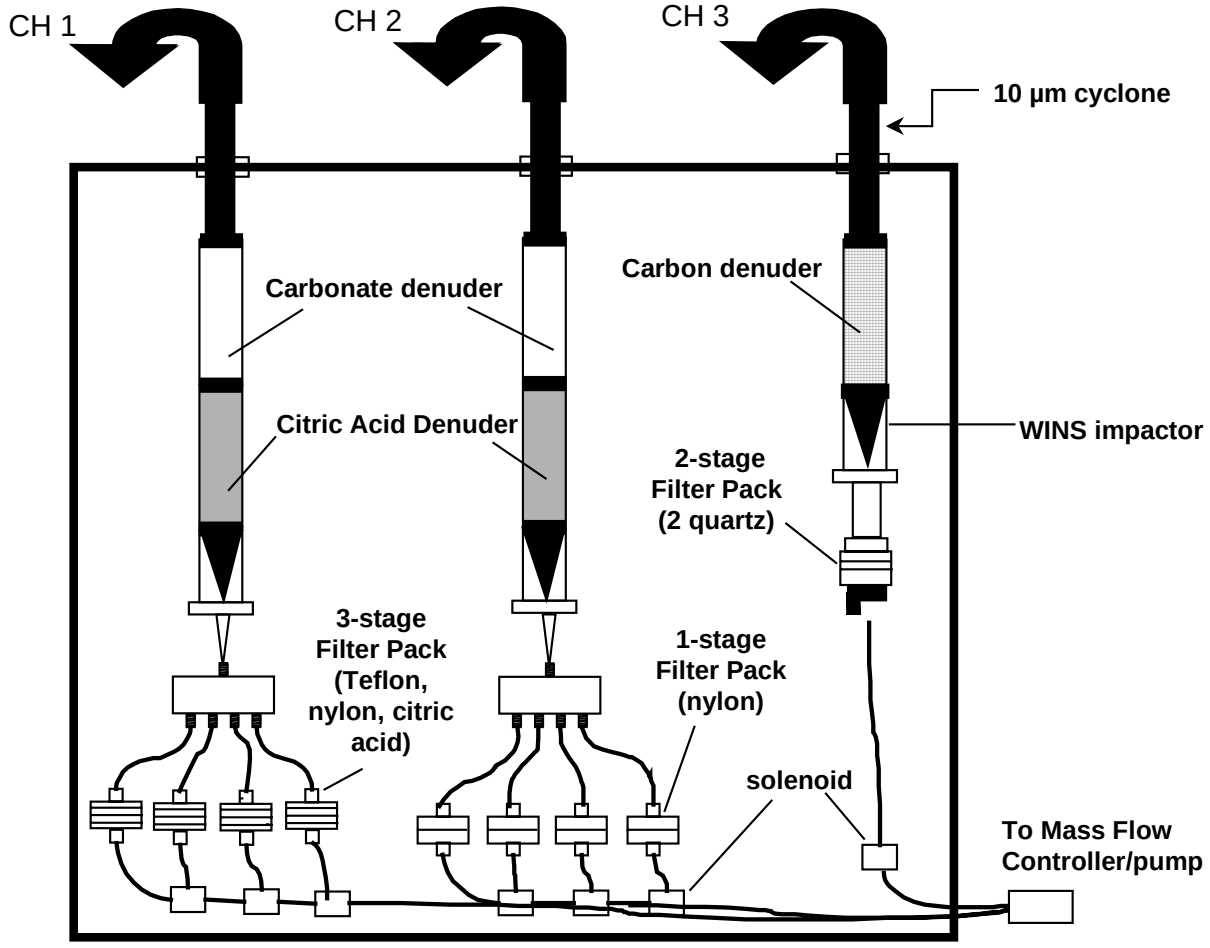
Site	FRM	PCM	Dichotic (PM_{10})	TEOM ($PM_{2.5}$)
N. Birmingham, AL	**CY99/daily**	**CY99/daily**	**CY99/3-day**	**7/99-12/99/hourly***
Centreville, AL	**CY99/3-day**	**CY99/daily**	**CY99/3-day**	**CY99/hourly**
Jefferson Street, GA	**CY99/daily**	**CY99/daily**	**CY99/daily**	**1/99-9/99/hourly#**
Yorkville, GA	**CY99/3-day**	**CY99/daily**	**CY99/3-day**	**CY99/hourly**
Oak Grove, MS	**CY99/3-day**	**CY99/daily**	**not deployed**	**CY99/hourly**
Gulfport, MS	**not deployed**	**4/99-12/99/daily**	**not deployed**	**not deployed**
Pensacola, FL	**1/99-12/99/daily**	**1/99-12/99/daily**	**1/99-12/99/3-day**	**not deployed**
OLF, FL	**2/99-12/99/daily**	**2/99-12/99/daily**	**2/99-12/99/3-day**	**not deployed**

* in collaboration with the Jefferson County Health Department
\# in collaboration with the Georgia Institute of Technology

Below are brief descriptions of the Particle Composition Monitor (PCM), the SEARCH speciation monitor, the modified TEOM, and the R&P 5400.

$PM_{2.5}$ Speciation – Particle speciation data for SEARCH are collected using a sequential, multi-channel sampler known as the Particle Composition Monitor (PCM), shown schematically in **Figure 1**. The PCM consists of three parallel sampling channels that each sample ambient air at 16.7 lpm. The inlet for each channel consists of a 10 μm cyclone, followed by one or more denuders to remove contaminant gases, followed by a 2.5 μm WINS impactor. Channel 1 (PCM1) consists of a Teflon filter preceded by sodium carbonate and citric acid denuders. The Teflon filter is analyzed gravimetrically for mass, then by X-ray fluorescence for trace elements and finally by ion chromatography (IC) for sulfate, nitrate, and ammonium. PCM1 also includes two additional filters downstream of the Teflon filter: a nylon filter and a glass fiber filter coated with citric acid to collect nitric acid and ammonia, respectively, volatilized from particulate ammonium nitrate collected on the Teflon filter. Channel 2 is identical to Channel 1 from the inlet to the WINS impactor. After that, it has a one-stage filter pack containing a nylon filter, which is extracted and analyzed by IC for sulfate, nitrate, ammonium and chloride. It provides, beyond the chloride analysis, a cross check on sampling efficiency of Channels 1 and 2 for nitrate and a redundancy check for sulfate. The third PCM channel (PCM3) is analyzed for $PM_{2.5}$ carbon. An oil free WINS impactor is preceded by an aluminum, parallel-plate denuder with carbon-impregnated filter paper coating the plates. Downstream of the denuder and impactor are two quartz filters, which are analyzed for organic and elemental carbon via Thermal Optical Reflectance (TOR). Additional channels on the PCM have been used from time to time for experimental purposes.

Figure 1. SEARCH Particle Composition Monitor (PCM) Schematic



Continuous $PM_{2.5}$ – Continuous (hourly) $PM_{2.5}$ measurements were made with a modified R&P Model 1400 a/b Tapered-Element Oscillating Micro balance (TEOM). The TEOM estimates $PM_{2.5}$ concentration by collection of sample on the end of an oscillator. As material collects, the frequency of the oscillator changes. Ambient concentration is then calculated based on sample flow rate and change in frequency of the oscillator. ARA modifications include: 1) air, cap and filter temperatures set to 30C, rather than 50C; 2) drying of air stream to minimize water effects; and 3) heavy insulation of the inlet to minimize effects of temperature transients within the shelter. Sample air (16.7 lpm) is pulled through a cyclone (Dp_{50} = 2.5 µm) and then through a flow splitter which directs 3.0 lpm of sample air to the TEOM and dumps the remaining 13.7 lpm. After the splitter, sample air passes through a nafion drier (Perma-Pure, PD-1000-12PS) and then into the TEOM. Sheath flow for the nafion drier is ambient air under mild vacuum (20-24 inches Hg). This arrangement dries sample air to 10-20 % relative humidity under most conditions. A water heater blanket is used to insulate the indoor components of the system (including nafion drier) between the ceiling and the TEOM transducer. Data are collected with

slope and intercept coefficients (1.03 and 3.0, respectively) recommended by R&P; however, these are later removed during data validation.

Continuous OC/EC – Organic and elemental carbon is measured with 1-hour time resolution with an R&P Model 5400 Particulate Carbon Analyzer. The 5400 collects sample air through an external cyclone (Dp_{50} = 2.5 μm) and then through an internal impactor (Dp_{50} = 0.12 μm). The impactor is then subjected to a heating cycle with up to four temperature plateaus and dwell times, in the presence of filtered air. During heating, particulate carbon is converted to CO2, which is then quantified via infrared absorption. In practice, SEARCH uses a 2-stage heating cycle to provide an operational split between organic and elemental carbon that mimics, to a reasonable degree, the split obtained with TOR (PCM3). The temperature for the first plateau is 275C, while that for the second (last) plateau is 750C.

Average Composition by Site

In this section we provide information related to:

- Annual average composition for 1999 for each SEARCH site.
- Quarterly average composition for 1999 for each SEARCH site.
- Average composition for the highest (90^{th} percentile) and the lowest (10^{th} percentile) mass days for each quarter for 1999 for each SEARCH site.

The data summaries are included in **Attachment B**. The summaries are presented for all sites except GPT.

For each site, there are four figures:

- annual and quarterly average composition, by mass,
- annual and quarterly average composition, in percent,
- quarterly average composition, in percent, of the highest (90^{th} percentile) mass days, and
- quarterly average composition, in percent, of the lowest (10^{th} percentile) mass days.

Methods and Assumptions

We have assumed that the primary goal of these summaries is to "explain" $PM_{2.5}$ mass as measured by the FRM (or the TEOM, as a surrogate for the FRM). As such, we have chosen to use the Teflon filter only from PCM1 to represent nitrate and ammonium, as this best approximates what the FRM sees.

Since the FRM and TEOM agree well (see **Attachment C**) and we wanted as large a number of samples as possible, the larger population of either FRM or TEOM mass was used. Therefore, the first step in the analysis was to create mass vs. composition "pairs" and to assess the total number of valid pairs for FRM and TEOM. The larger "N" was chosen unless they were similar, in which case the FRM population was used to calculate the averages. Attachment C also

contains plots of number of mass samples collected using the FRM, TEOM and PCM at each site and the influence in both an absolute and relative sense on the annual average as well as the average over all valid samples of $PM_{2.5}$ mass.

We applied the following procedure:

At each sampling station, we considered only 1999 data. Reconstructed mass was determined from the sum of $PM_{2.5}$ components measured on the PCM for all days in which the following measurements were valid:

- SO_4^{2-}, NO_3^-, and NH_4^+ from ion chromatography on the PCM1 Teflon filter;
- Crustals from the sum of oxides equation:

$$[Crustal] = 2.14[Si] + 1.89[Al] + 1.43[Fe] + 1.67[Ti] + 1.40[Ca] + 1.20[K]$$

  using elemental concentration data obtained by XRF analysis of the PCM1 Teflon filter; and

- OC and EC from thermal optical reflectance (TOR) analysis of the PCM3 front quartz filter.

Organic material was estimated by multiplying OC concentrations by 1.4 to account for non-carbon atoms (H, N, O, etc.) in organic molecules. "Other" $PM_{2.5}$ mass was determined as the difference between gravimetrically measured $PM_{2.5}$ mass from the TEOM or FRM and the sum of the chemical components measured on the PCM:

$$[Other] = [PM_{2.5}\ Mass] - \left([SO_4^{2-}] + [NO_3^-] + [NH_4^+] + [Crustal] + 1.4[OC] + [EC]\right)$$

Days for which any one of the chemical analytes did not have a valid value were excluded from the data presentation in the pie charts. For quarterly, percentile, or annual averages in which the average [Other] is ≤ 0, the pie charts presented in this analysis show the contribution of each species to the reconstructed mass. In these cases, [Other] is excluded from the pie chart. In all cases, average gravimetric mass (FRM or TEOM) is listed above the pie chart. Average values thus represent the population of sample days with complete speciation data. All other days are excluded. Descriptive statistics for the complete data set were compared with the data after removal of days with missing analytes to examine the impact of this method. In many cases, the mean of the reduced data for $PM_{2.5}$ mass or a chemical component differed from the mean of all available data by more than one standard error of either mean. However, the differences of the means never exceeded two standard errors of either mean. The fact that these means differ highlights the sensitivity of PM summary statistics to days excluded by sampling schedule, analytical problems or other factors

Caveats

- As described above, annual averages for $PM_{2.5}$ mass and composition represent only those days with complete speciation data. The pie charts thus provide a good representation of

relative composite, but may not provide the best measure of absolute concentration for individual species. This point is illustrated in Table 2, which presents average concentrations for SEARCH based on: 1) all available data for each species (upper set of figures); and 2) all days with a valid PM2.5 measurement (FRM) and complete speciation data (lower set of figures). In many cases, the mean of the reduced data for $PM_{2.5}$ mass or a chemical component differs from the mean of all available data by more than one standard error of either mean. However, the differences of the means never exceeded two standard errors of either mean. The fact that these means differ highlights the sensitivity of PM summary statistics to days excluded by sampling schedule, analytical problems or other factors, including aggregation rules.

- Some of the pie charts are based on TEOM data rather than FRM data, as an index of $PM_{2.5}$. We have calculated means and standards errors of the mean for both sample sets when both samplers operated at a site and can provide that information if desired. In general, the means of both data sets agree to within 2 standard errors of the mean of either set.

- An alternative approach to using the FRM or TEOM mass and the Teflon nitrate and ammonium would be to use PCM1 mass and both the Teflon and back-up filters (representing volatile losses of nitrate and ammonium), but that would have been addressing a goal other than attempting to approximate what the FRM samples. However, we have worked up the data this way and could supply those plots if you so desire.

- The apparent agreement between TEOM and FRM data is not sufficient to justify a comparison of **Attachment B** values to the annual $PM_{2.5}$ NAAQS. We have shown that the sampling frequency, and thus the number of samples making up the annual average, can make a significant difference in the annual average relative to the NAAQS of 15 $\mu g/m^3$. In **Attachment D** we provide the annual average $PM_{2.5}$ mass based on all valid FRM data for 7 of 8 SEARCH sites. Note how these differ from the values reported in the pie charts of **Attachment B**. Furthermore, the effect of sampling frequency (i.e., daily versus every third versus every sixth day) is also shown in **Attachment D**. Note how sensitive CTR, YRK, and PNS are to sampling frequency when comparing the averages to the annual NAAQS. This observation highlights the sensitivity of $PM_{2.5}$ summary statistics to days excluded by sampling schedule or analytical problems.

- As noted above, there are numerous ways to aggregate this data set into average composition, depending on what question is being addressed and what one believes each measurement to mean. The averages can then change, possibly significantly, depending on the aggregations assumptions made. For example:
  - we have not included chloride (which was measured) or carbonate (which was not measured) in reconstructed mass;
  - we have used conversion factors to derive crustals based solely on the stoichiometry of the most prevalent oxides of Al, Si, Ca, Fe and Ti; and
  - we have chosen not to include the back-up filter values (volatile components?) for nitrate and ammonium.

  We believe it is critical to ask each investigator to clearly articulate their aggregation assumptions if one is to understand and compare results across studies. The figures provide

the best available representation of relative contribution to $PM_{2.5}$, but may not (and probably don't) provide the best estimate of annual or quarterly concentrations of individual components.

- We have used the factor of 1.4 to convert OC to OM. We believe that the factor varies significantly with time (e.g., season) and location but have deferred to historical precedent in the current analysis. Much work is needed, and indeed ongoing, to determine if a single or variable factor, depending on circumstances, should be used.
- Quantifying and defining "other" is challenging. In general, "other" may contain species that exist on the filter but are not measured, as well as errors related to species that are measured. A list (by no means exhaustive) of possible contributors is provided below:
  - particle-bound water,
  - hydronium ions (acidity),
  - unmeasured trace metals and their chemically associated elements (e.g., N and O),
  - the uncertainty of the OC to OM and crustal scaling factors, and
  - the accumulated measurement uncertainty (bias, both positive and negative, and imprecision) of each measured component.

  The magnitude of the "other" varies from sample to sample, and with concentration. We have noticed that "other" can be a substantial fraction of the 90^{th} percentile composition while it tends to be quite small (and sometimes negative) for the 10^{th} percentile composition. Numerous explanations are possible and will be investigated in the future.
- Because we use PCM1 Teflon nitrate and ammonium measurements, it should be noted that we are certainly underestimating the real contributions of these components to $PM_{2.5}$ since particle phase ammonium nitrate is very poorly retained by Teflon filters.

Table 2. Parameter values as a function of sample population size

ALL AVAILABLE VALID DATA - CY 1999

	BHM	N	CTR	N	GFP	N	JST	N	OAK	N	OLF	N	PNS	N	YRK	N
FRM Mass	19.93	314	11.43	84		0	19.46	307	12.62	127	12.74	311	14.38	309	15.36	111
TEOM	21.18	199	14.85	335		**0**	17.16	261	12.19	331	10.40	66		0	14.96	325
PCM1 Teflon NO3	0.06	283	0.03	322	0.04	222	0.11	307	0.04	265	0.04	267	0.05	285	0.06	289
PCM1 Teflon NH4	1.86	301	1.54	299	1.45	240	2.03	316	1.21	298	1.36	306	1.39	301	1.86	322
PCM1 Sulfate	5.51	301	4.72	301	4.44	240	5.59	317	3.81	300	4.14	305	4.21	300	5.35	319
PCM1 Crustals	0.96	320	0.36	315	0.55	240	0.53	294	0.45	350	0.40	312	0.48	299	0.30	335
PCM3 EC	2.69	276	0.67	282	0.92	257	2.03	361	0.57	306	0.77	331	1.16	309	0.80	342
PCM3 OC	5.55	276	3.29	282	2.95	257	4.68	363	2.71	306	2.68	331	3.34	309	3.49	342

ALL AVAILABLE DATA WHERE ALL PARMS VALID - FRM AS REFERENCE MASS - CY 1999

	BHM	N	CTR	N	GFP	N	JST	N	OAK	N	OLF	N	PNS	N	YRK	N
FRM Mass	21.09	188	12.14	54		0	19.17	239	12.24	66	12.12	234	14.35	257	14.66	76
PCM1 Teflon NO3	0.05	188	0.02	54		0	0.10	239	0.04	66	0.04	234	0.05	257	0.06	76
PCM1 Teflon NH4	2.04	188	1.12	54		0	2.02	239	1.21	66	1.29	234	1.33	257	1.71	76
PCM1 Sulfate	6.06	188	3.31	54		0	5.53	239	3.77	66	3.90	234	4.02	257	5.00	76
PCM1 Crustals	1.08	188	0.34	54		0	0.52	239	0.54	66	0.42	234	0.51	257	0.33	76
PCM3 EC	2.73	188	0.60	54		0	2.02	239	0.52	66	0.76	234	1.19	257	0.75	76
PCM3 OC	5.53	188	3.02	54		0	4.91	239	2.47	66	2.64	234	3.40	257	3.33	76
Other	1.40		2.53				2.10		2.69		2.02		2.49		2.16	

ALL AVAILABLE DATA WHERE ALL PARMS VALID - TEOM AS REFERENCE MASS - CY 1999

	BHM	N	CTR	N	GFP	N	JST	N	OAK	N	OLF	N	PNS	N	YRK	N
TEOM	23.25	125	16.21	227		0	16.58	203	11.83	192	10.56	61		0	13.92	241
PCM1 Teflon NO3	0.04	125	0.02	227	0.04	77	0.08	203	0.03	192	0.04	61		0	0.06	241
PCM1 Teflon NH4	2.24	125	1.63	227	1.14	77	2.23	203	1.18	192	0.96	61		0	1.73	241
PCM1 Sulfate	6.62	125	5.11	227	3.26	77	6.11	203	3.71	192	2.72	61		0	4.92	241
PCM1 Crustals	1.17	125	0.34	227	0.40	77	0.53	203	0.42	192	0.27	61		0	0.27	241
PCM3 EC	2.87	125	0.68	227	1.20	77	1.84	203	0.56	192	0.93	61		0	0.79	241
PCM3 OC	5.88	125	3.36	227	3.80	77	4.49	203	2.64	192	3.03	61		0	3.42	241
Other	2.07		3.72		-11.35		-0.50		2.21		1.40				1.37	

Initial Insights

Regarding the annual plots:

- For the $PM_{2.5}$ mass annual averages presented in **Attachment B,** comparison of reported mass to the NAAQS may be problematic given the caveats above and the lack of a three-year data set (inter-annual variability is largely unknown for this region). Note that many of the same caveats apply to the officially sanctioned FRM sampling. The 1999 annual average of all valid FRM data shows that BHM, JST, and YRK are above 15 $\mu g/m^3$ and the remaining sites (except GPT, at which there was no SEARCH FRM in 1999) are below 15 $\mu g/m^3$. No site has a day above 65 $\mu g/m^3$. See **Attachment D**.
- OM is the largest contributor to $PM_{2.5}$ at all urban sites (BHM, JST, and PNS), followed by sulfate. Sulfate is generally the largest contributor at rural sites (YRK, CTR, OAK, and OLF) followed by OM.
- Carbon (EC + OM) is enhanced at all urban sites relative to their paired rural site.
- There is a north to south gradient in $PM_{2.5}$ mass, SULFATE, and OM for the rural sites. The picture, for the urban sites, is obscured by other factors such as city size, geography (inland versus coastal), etc.
- The contribution of nitrates to total mass is essentially negligible given that only nitrate from the Teflon filter is included (assumed as most representative of the nitrate fraction captured by the FRM). If we include the backup filters, we see more of a contribution, especially in urban areas in the winter, when we account for the volatile fraction.
- Crustals contribute well below 10% of $PM_{2.5}$ mass at all sites.

Regarding the quarterly plots:

- SULFATE peaks in the 3rd quarter (relative and absolute concentrations) at all sites.
- OM peaks in the 4th quarter at the urban sites. There is no consistent pattern at the rural sites.
- EC peaks in the 4th quarter for the urban sites and quarters 1 and 4 are consistently higher than quarters 2 and 3. For the rural sites, EC peaks in the 3rd quarter consistently.
- OM is the single largest contributor at all sites during the 1st and 4th quarters. However, sulfate is the largest contributor at all sites (except BHM and JST) during the 2nd and 3rd quarters.

Regarding the 10th and 90th percentile plots:

- Sulfate is a greater fraction of the mass on the 90th percentile days than on the 10th percentile days in the 3rd quarter, reversed in the 1st quarter (except CTR), and mixed for the 2nd and 4th quarters.
- OM is consistently a greater fraction of the mass on 10th percentile days than on 90th percentile days.
- On the 90th percentile days EC has its highest fraction of mass in the 4th quarter for BHM and JST but in the 1st quarter at the remainder of the sites. There is no consistent pattern for the 10th percentile days. PNS has unusually high EC fractions, relative to the other sites, on 10th percentile days.

- "Other" is largest for 90th percentile days and lowest (in some case negative) on 10th percentile days. This finding suggests that measurement uncertainty and/or contributions of unmeasured species (e.g., the composition of organic material in the aerosol phase) may differ between high $PM_{2.5}$ and low $PM_{2.5}$ days. For example, if more aged organic aerosol were present at the higher $PM_{2.5}$ concentration days, the scaling factor of 1.4 used to convert OC to OM would underestimate the actual contribution of organic compounds to $PM_{2.5}$ mass. Similarly, the 1.4 factor may overestimate OM's contribution for more recently emitted, less highly oxygenated organic compounds.

Regarding the plots in Attachment C:

- There is no clear pattern of bias between samplers. TEOM mass exceeds that of the other samplers at BHM, CTR and GFP, but the FRM gives the highest mass of the three samplers at the other sites equipped with an FRM. A thorough understanding of the basis for the differences awaits further analysis.

Average Diurnal $PM_{2.5}$ Mass (TEOM) and EC/OM (R&P 5400) by Site

In this section we provide information related to:

- Average annual and quarterly diurnal $PM_{2.5}$ mass (TEOM) patterns by hour of day for five SEARCH sites.
- Average annual and quarterly diurnal EC and OM patterns (R&P 5400) by hour of day for JST.

The data summaries are included in **Attachments E (TEOM) and F (EC/OM)**. The summaries are presented for JST, YRK, BHM, CTR, and OAK.

There are five figures, one annual and four quarterly diurnal plots, each for TEOM and EC/OM.

Methods and Assumptions

TEOM diurnal profile plots by year and quarter are created using the following steps.

Step 1: Select all valid hourly TEOM data for the time period in question.

Step 2: Correct the TEOM data by backing out the PM_{10} based slope/intercept correction built into the instruments data reduction algorithm. 3 $\mu g/m^3$ are subtracted from the raw data and the resulting quantity is divided by 1.03.

Step 3: Average all data from the same hour of day for the entire period ending up with 24 values – one for each hour.

Step 4: Create the plot.

EC/OM diurnal profile plots by year and quarter are created using the same process as the TEOM but using a different data correction step

Step 1: Select all valid hourly EC/OC data for the time period in question.

Step 2: Convert the OC data to OM – multiplying by 1.4

Step 3: Average all data from the same hour of day for the entire period ending up with 24 values – one for each hour.

Step 4: Create the plot.

Caveats

- Composite diurnal plots tend to smooth out a lot of specific behavior. While they can describe the general character of a site relative to expectations (e.g., urban vs. mountaintop), distinguishing between meteorological and source contributions to concentration changes is problematic.
- Regarding the TEOM data, fourth quarter 1999 data from JST not included due to equipment malfunction. Fourth quarter 1998 provided instead.
- The EC and OM data are experimental and have lower validation status than other components. Initial evaluations of the 5400 indicate that total carbon is well represented, relative to filter-based measurements. As indicated below, operating parameters have been adjusted several times to evaluate sensitivity of the EC/OC split to combustion conditions.
- Regarding the EC/OM data, first quarter 1999 data from JST not available. First quarter 2000 provided instead.
- The OC value was multiplied by 1.4 to obtain OM. See caveat above as to uncertainty in this assumption.
- There was an adjustment in the temperature profile program on 6/4/99 that altered the split between EC/OC. The change was made to bring the 5400 split in line with the DRI split, obtained from the TOR analysis of PCM3 quartz filters. The result in the change was to move a bit more carbon out of EC and into the OC fraction.

Initial Insights

- $PM_{2.5}$ mass is highest at all sites in the third quarter.
- Urban sites show more evidence of hour-to-hour variability than rural sites. This behavior is indicative of local sources. Trace gas measurements at JST (i.e., CO, NOx, and NOy) suggest that much of this variability is associated with rush hour emissions.
- Note that all sites except Yorkville show a 'meteorological' diurnal profile with mass concentration increasing to a local peak before sunrise under the nocturnal boundary layer and quickly drops to a lower level once the boundary layer collapses and what appears to be relatively cleaner air aloft is mixed down. The amplitude of the profile appears to be largely

determined by the local source strength for $PM_{2.5}$ - the two urban sites show the highest amplitude profile due to significant local sources.

- Yorkville does not exhibit this type of profile most likely due to its elevation - around 395 meters - and is perched on top of Vinson Mountain (not much of a mountain -- but the terrain at Yorkville is unique in the network). Yorkville is well-ventilated and subject to strong capping inversions much less frequently than our other sites.
- The EC and OM profiles for JST show pronounced diurnal variability. Like $PM_{2.5}$, peak concentrations are typically observed early and late, which is likely a consequence of both meteorology and timing of emissions. Quarterly plots show the greatest diurnal variability in the 4th quarter (when the meteorological day is shortest) and only moderate variability in the 2nd quarter.

Correlation of Composition with Distance Among Sites

In this section we provide information related to:

- Correlation of mass, sulfate, nitrate, ammonium, EC, and OC vs. distance for 1999 for all SEARCH sites.

The data summaries are included in **Attachment G**. The summaries are presented for all eight SEARCH sites. GFP is not included in the FRM mass plot since there were no SEARCH FRM measurements available in 1999 but is included in the remainder of the plots.

There are eight plots, one each for FRM mass, PCM mass, sulfate, ammonium, nitrate, crustals, EC, and OM.

Methods and Assumptions

Creation of an intersite distance correlation plot is a 4-step process.

Step 1: Select all data from a pair of sites for the time period and parameter desired where both sites have valid data.

Step 2: Calculate the Pearson's R correlation coefficient for the data set

Step 3: Create an x,y pair consisting of the Pearson's R value and the distance in km between the two sites.

Step 4: Repeat Steps 1-3 for all possible pairs in the SEARCH network – then compile all the x,y pairs and create the plot.

Caveats

- In interpreting these plots, it is important to distinguish between what they say about the character of the component's behavior (are concentrations levels locally or regionally distributed) versus what they say about the cause(s) of that behavior. Causes include both meteorological factors (which affect both movement and conversion of emissions) as well as emissions strength and location, and cannot, necessarily, be inferred from these analyses alone.

Initial Insights

- There is a roughly linear fall-off in intersite correlations with distance – although there is no *a priori* reason to expect a linear fall-off.
- Sulfate is more highly correlated among sites than other analytes, exceeding 0.5 even at the largest distance, ~600 km and shows the smoothest fall-off behavior. This indicates a more regional character (distribution) than for other analytes.
- PCM1 mass and crustals have smooth and essentially identical fall-off behavior.
- Given their non-reactive, ubiquitous source location, fine crustals may prove to be an indicator of important meteorological factors underlying $PM_{2.5}$ behavior.
- FRM mass has more scatter in its fall-off behavior than PCM1 mass, although, on average, it is the same. This may indicate larger and more variable sampling artifacts for the FRM relative to PCM1.
- Elemental carbon and nitrate show the lowest intersite correlations and the greatest scatter in fall-off behavior of the analytes. Since both these analytes have low values, this may indicate less relative precision in their measurement as well as stronger local than regional influences on airborne concentrations.

Correlation of 90th Percentile Mass with Distance Among Sites

In this section we provide information related to:

- Correlation of mass (90th Percentile) vs. distance for 1999 for all SEARCH sites.

The data summaries are included in **Attachment H.** The summaries are presented for 7 of 8 SEARCH sites. GFP is not included since there was no SEARCH FRM measurements available in 1999.

There are seven plots, one for each site.

Methods and Assumptions

Mass correlation plots by site against all other sites on 90th percentile mass days at the primary site are created as follows.

For each pair of sites, one is designated the primary site and the other the secondary site. The primary site is the site where we're looking for the 90th percentile mass data. The secondary site provides the companion data to generate the x,y pairs upon which the Pearson's R is calculated.

Step 1: Select the FRM mass data from the pair of sites where **both** sites have valid samples (i.e. if either site has invalid data that potential data pair is thrown out).

Step 2: Select the data pairs from this data set where the mass data from the primary site make up the 90th percentile of the data set generated in Step 1.

Step 3: Calculate the Pearson's R correlation coefficient for the data set generated in Step2.

Step 4: Create a data pair consisting of the Pearson's R and the name of the secondary site.

Step 5: Repeat Steps 1-4 for the remaining possible secondary sites in the network – then compile the data pairs and create the plot.

Step 6: Repeat Steps 1-5 for the remaining 'primary sites'

Caveats

- We selected the top 10 percent of valid FRM mass values for each site where a valid FRM mass sample existed for the comparison site. In some cases, the number of samples was only 8- - in the best cases it approached 30 samples.
- There is no reason for the correlation between site A and site B to be the same as the correlation between site B and site A. This is because the two populations are not necessarily and, indeed, are not likely to be the same (i.e., the highest days at one site may not correspond to the highest days at another site).
- Note that a large fraction of the correlations are not significant at the 95%, or even the 90%, level of confidence. Some of this lack of significance is likely due to low sample number, but spatial variability in high observations must also be a factor. Only long-term measurements can address the issues raised by this type of analysis.

Initial Insights

- In general, the correlations are not very strong. They are weakest when generated from JST and BHM - suggesting that the peak mass days in urban environments are local, not regional, in nature. Rural sites show generally stronger correlations with other sites, the only strong (absolute value of r >0 .5) correlations were between PNS and OLF, between OLF and PNS, between PNS and OAK, and between OAK and CTR.

Quality Assurance and Data Validation

I will not detail the QA procedures, including data validation, we follow in gathering and processing the data because I feel it is outside the scope of this letter. Suffice it to say that we have a comprehensive set of QA procedures in place to ensure that our data are credible. Should you desire a description of those procedures we would be happy to provide it.

Closing

In closing, I want to thank you for your interest in SEARCH. I trust the attached information is useful and look forward to your feedback. If you require an electronic version of this letter or the attachments, please let me know. We strongly believe that the information provided here is just the beginning of the information to be learned from the Project. We will continue to seek that information through analysis and continued data gathering. If you have any questions, please call me at 650/855-2738.

Sincerely,

D. Alan Hansen
SEARCH Project Manager

Attachments

A. SEARCH Fact Sheet
B. Annual, Quarterly, 90th, and 10th Percentile Composition Summaries
C. TEOM versus FRM scatter plots
D. Annual FRM Mass and Effect of Sampling Frequency
E. Average Diurnal $PM_{2.5}$ Mass (TEOM) by Site
F. Average Diurnal $PM_{2.5}$ EC/OM (R&P 5400) by Site
G. Correlation of Composition with Distance Among Sites
H. Correlation of 90th Percentile Mass with Distance Among Sites

cc:

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Keith Stephens

Atmospheric Research & Analysis
Eric Edgerton
Ben Hartsell

Detroit Edison
Dennis Leonard

EPRI
Tina Bahadori
Mike Van Loy
Ron Wyzga

Oglethorpe Power
Boyd Vaughan

Southern Company
John Jansen

SEARCH: Southeastern Aerosol Research and Characterization

New, as well as proven measurement technologies combine to establish a detailed aerosol climatology for the Southeast.

Background

In July 1997 EPA revised the national ambient air quality standards for ground-level ozone and particulate matter. EPA's action created a new standard for fine particulate matter ($PM_{2.5}$) and set its levels at 15 micrograms per cubic meter (ug/m^3) for an annual average (averaged over 3 years) and 65 ug/m^3 for a daily average (3-year average of the 98^{th} percentile daily concentration). Analysis of the very limited existing data suggests that the new $PM_{2.5}$ standard will be more difficult to achieve than the older PM_{10} standard and will dramatically increase the number of PM nonattainment areas.

Unlike other criteria pollutants such as ozone, fine particles typically comprise mixtures of hundreds of compounds. Therefore, in order to identify sources of $PM_{2.5}$ and to attribute health effects to specific components, we must measure $PM_{2.5}$ composition as well as its mass.

Consistent with its July 1997 Presidential directive, EPA will not require control of $PM_{2.5}$ precursors until after it has conducted further scientific review of the $PM_{2.5}$ standards and it has officially designated nonattainment areas. Such designation is expected in the 2004 to 2005 time frame. State implementation plans (SIPs) must be submitted within three years of the EPA attainment designation.

Given this ambitious schedule, EPA is leading the states in a massive monitoring program to characterize the chemical and physical nature and geographical distribution of $PM_{2.5}$. A nationwide network consisting of more than 1100 $PM_{2.5}$ monitoring sites is currently in place. A small subset of these (the "speciation network") will be devoted to compositional measurements. The "speciation" network is being implemented in phases during 2000 and 2001. EPA has also initiated a series of so-called "SuperSites" across the nation dedicated to gathering detailed information and performing sophisticated aerosol measurements in support of methods development, health studies, and atmospheric process research. An Integrated SuperSite Experiment (ISSE) is planned for July 2001. EPRI has been advising EPA on the design and implementation of this program, and a dialogue has been established to coordinate public and private sector efforts.

The Inception of SEARCH

From the outset, it has been clear that public-private collaboration could greatly accelerate our understanding of the $PM_{2.5}$ issue. Therefore, Southern Company and

EPRI have taken the initiative to deploy instrumentation designed to measure $PM_{2.5}$ mass and composition over a broad geographical region of the Southeast on a rapid time track. Building on the existing SCION component of the Southern Oxidants Study, Southern Company and EPRI have established a highly instrumented eight-station network in the states of AL, FL, GA and MS. Figure 1 shows a map of the network. Several of the sites in Figure 1are operated in collaboration with State or local air monitoring networks. In addition, the Jefferson Street site is the focal point of a major epidemiological study in the City of Atlanta (see ARIES Fact Sheet) and was the site of EPA's first SuperSite experiment in August 1999.

SEARCH Objectives

1. To work interactively with the States and to assist them in:
   a) meeting their $PM_{2.5}$ monitoring obligations and
   b) gathering a data set appropriate for evaluating and applying (as in SIP development) air quality models.
2. To provide an ambient data set with minimal sample adulteration and of sufficient breadth, in terms of measured variables, geographical diversity and extent, frequency of measurement , and duration of the measurement campaign such that:
   a) a PM and oxidant climatology for the region will be established,
   b) coarse and fine PM concentrations will be distinguished,
   c) chemical constituents of PM and their physical states will be characterized and correlations among precursor and product materials in the atmosphere will be determined, allowing hypotheses regarding pollutant sources to be tested,
   d) insights into aerosol formation mechanisms can be gained,
   e) differences between airborne materials in coastal vs. inland, and rural vs. urban areas will be documented, and
   f) biases in measurement methods, such as use of a single Teflon filter in the Federal Reference Method for $PM_{2.5}$, will be characterized.
3. To deploy reliable continuous methods in order to observe and understand processes governing $PM_{2.5}$ and co-pollutant emissions, formation, transport and deposition.

Results To Date

Deployment of the SEARCH PM network began in early 1998 and continues today as new technologies are brought to bear (see Tables 1 and 2).

An unprecedented data set, consisting of daily $PM_{2.5}$ measurements (mass and composition), was collected at all SEARCH sites during calendar year 1999. A summary of these data was requested by and presented to EPA in late 2000. This summary has also been shared with collaborating state and local agencies. These data will also be submitted to the NARSTO data archive in January 2001.

Key observations to date include:

1. Carbonaceous material (elemental and organic carbon) and sulfate are the dominant components of $PM_{2.5}$ (see Figure 2).
2. There is significant season-to-season, day-to-day, and hour-to-hour variability in the concentration and composition of $PM_{2.5}$ (see Figure 3).

3. $PM_{2.5}$ concentrations are significantly higher at urban sites than at regionally representative rural sites. This phenomenon is largely explained by differences in carbonaceous material (higher concentrations in urban areas).
4. Methodological issues (e.g., sampling frequency and blank correction) and natural sources of $PM_{2.5}$ (e.g., sea-salt, African dust, fires) can have a determining affect on the attainment status of a monitoring site (see Figure 4 for the effect of sampling frequency).
5. Initial data from continuous mass and speciation monitors demonstrate the importance of real-time information for understanding sources and processes leading to $PM_{2.5}$ formation. (see Figure 3).

SEARCH at a Glance

Funding
Approximately $16,000,000 from 1998 to 2005

Monitoring Stations
8 - arranged in 4 urban-rural pairs in each of GA, AL, MS, and FL. See Tables 1 and 2 for measured variables.

Sponsors
Southern Company
EPRI
Oglethorpe Power
Detroit Edison
Alabama Electric Cooperative
Allegheny Energy

Contractors
Atmospheric Research & Analysis (ARA)
Chester LabNet
Desert Research Institute
Harding-ESE

Collaborators
Southern Oxidants Study
Southern Center for the Integrated Study of Secondary Air Pollutants
Aerosol Research Inhalation Epidemiological Study
Assessment of Spatial Aerosol Composition in Atlanta
Alabama Department of Environmental Management
Florida Department of Environmental Protection
Georgia Environmental Protection Division
Jefferson County Department of Health
Mississippi Department of Environmental Quality

Who to Contact

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Table 1. SEARCH Integrated Filter-Based Measurements (24-hour average)

	$PM_{2.5}$				PM_{coarse}			
Site	**Mass (FRM)**	**Ions[1]**	**OC & EC[2]**	**XRF[3]**	**Mass**	**Ions**	**OC & EC**	**XRF**
Yorkville, GA	**B,b,b,a**	**b,a,b,c**	**b,a,b,c**	**b,a,b,b**	**b,b,c,c**	**b,b,c,c**	**x,x,x,x**	**b,b,c,c**
Jefferson St., GA	**a,a,a,a,**	**a,a,a,a**	**a,a,a,c**	**a,a,a,a**	**a,a,a,a**	**a,a,a,a**	**z**	**a,a,a,a**
Centreville, AL	**b,b,b,a**	**b,a,b,c**	**b,a,b,c**	**b,a,b,b**	**b,b,c,c**	**b,a,b,c**	**z**	**b,b,c,c**
N. Birmingham, AL	**a,a,b,a**	**b,a,b,c**	**b,a,b,c**	**b,a,b,b**	**b,b,c,c**	**b,a,b,b**	**z**	**b,b,c,c**
OLF, FL	**x,a,b,a**	**x,a,b,c**	**x,a,b,c**	**x,a,b,b**	**x,b,c,c**	**x,a,b,b**	**x,x,x,x**	**x,b,c,c**
Pensacola, FL	**x,a,b,a**	**x,a,b,c**	**x,a,b,c**	**x,a,b,b**	**x,b,c,c**	**x,a,b,b**	**x,x,x,x**	**x,b,c,c**
Oak Grove, MS	**b,b,b,a**	**b,a,b,c**	**b,a,b,c**	**b,a,b,b**	**x,x,x,c**	**x,x,x,c**	**x,x,x,x**	**x,x,x,c**
Gulfport, MS	**x,x,b,a**	**x,a,b,c**	**x,a,b,c**	**x,a,b,b**	**x,x,x,c**	**x,x,x,c**	**x,x,x,x**	**x,x,x,c**

Sampling schedule: a-daily; b-third day; c-sixth day; x-not collected; z-episodic collection.
1st position - 1998; 2nd position - 1999; 3rd position - 2000; 4th position - 2001 through 2005.

1. Ions include sulfate, nitrate and ammonium analyzed by ion chromatography, Teflon filter.
2. OC/EC analyzed by thermal-optical reflectance, quartz filter.
3. X-ray fluorescence (XRF) analysis of trace and crustal elements, Teflon filter.

Table 2. SEARCH Continuous $PM_{2.5}$ and Gas Measurements[1] (1-min. to 60-min. averages)

	Continuous $PM_{2.5}$					Continuous Gases					
Site	**Mass[2]**	**OC & EC**	**NO3 & NH4**	**SO4**	**b_{scat} & b_{abs}**	**O_3**	**NO & NOy**	**NO_2**	**HNO_3**	**CO & SO_2**	**NH_3**
Yorkville, GA	**A**	**C**	**C**	**D**	**D**	**A**	**A**	**A**	**A**	**A**	**D**
Jefferson St., GA	**A[3]**	**B**	**D**	**D**	**D**	**A**	**A**	**A**	**A**	**A**	**D**
Centreville, AL	**A**	**C**	**D**	**D**	**A**	**A**	**A**	**A**	**A**	**A**	**D**
N. Birmingham, AL	**B**	**C**	**D**	**D**	**D**	**C[3]**	**C**	**D**	**C**	**C**	**D**
OLF, FL	**B**	**C**	**D**	**D**	**D**	**B[3]**	**B**	**B**	**B**	**B**	**D**
Pensacola, FL	**C**	**C**	**D**	**D**	**D**	**B[3]**	**D**	**D**	**D**	**D**	**D**
Oak Grove, MS	**A**	**C**	**D**	**D**	**D**	**A**	**A**	**A**	**A**	**A**	**D**
Gulfport, MS	**C**	**C**	**D**	**D**	**D**	**B[3]**	**C**	**D**	**C**	**C**	**D**

Installation Schedule: A - installed prior to 1999; B - installed in 1999; C - installed in 2000; D - installed 2001-2002

1. Surface met (WS, WD, T, RH, solar radiation, BP, precipitation) also measured at each site.
2. TEOM (30C, dried)
3. Provided through collaboration with GA Tech, Jefferson County (AL) Department of Health, FL Department of Environmental Protection, and MS Department of Environmental Quality.

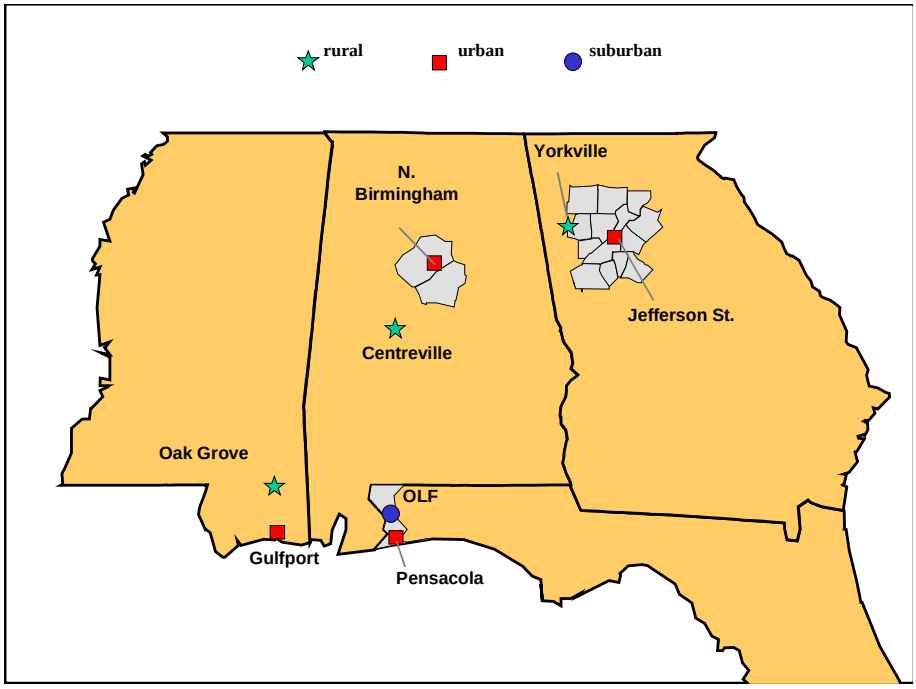


Figure 1. SEARCH Network

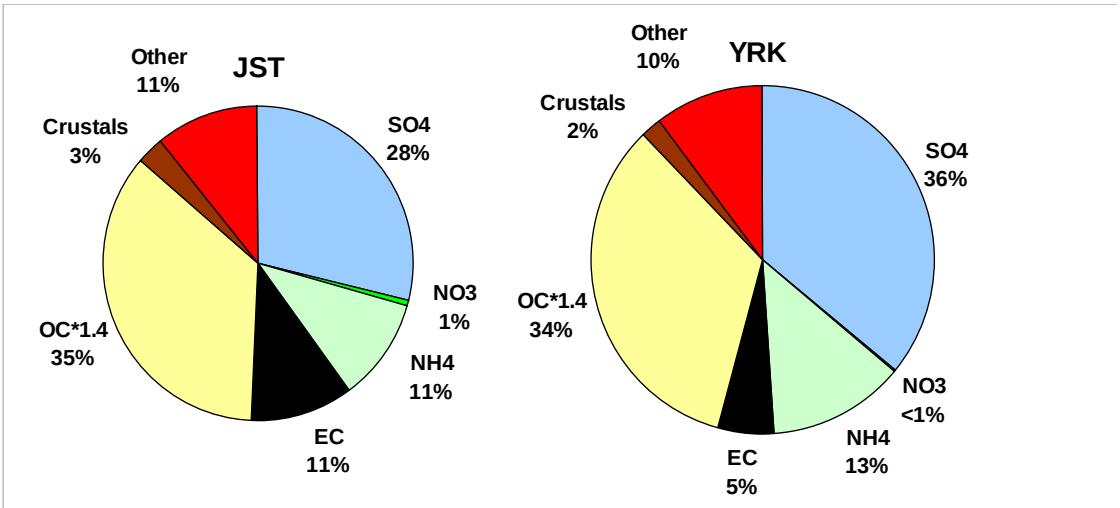


Figure 2. 1999 $PM_{2.5}$ composition for Jefferson Street, GA (left) and Yorkville, GA (right), based on annual average $PM_{2.5}$ concentrations of 19.2 ug/m^3 and 13.9 ug/m^3, respectively. Note: NO3 data is from the Teflon filter and may be an underestimate.

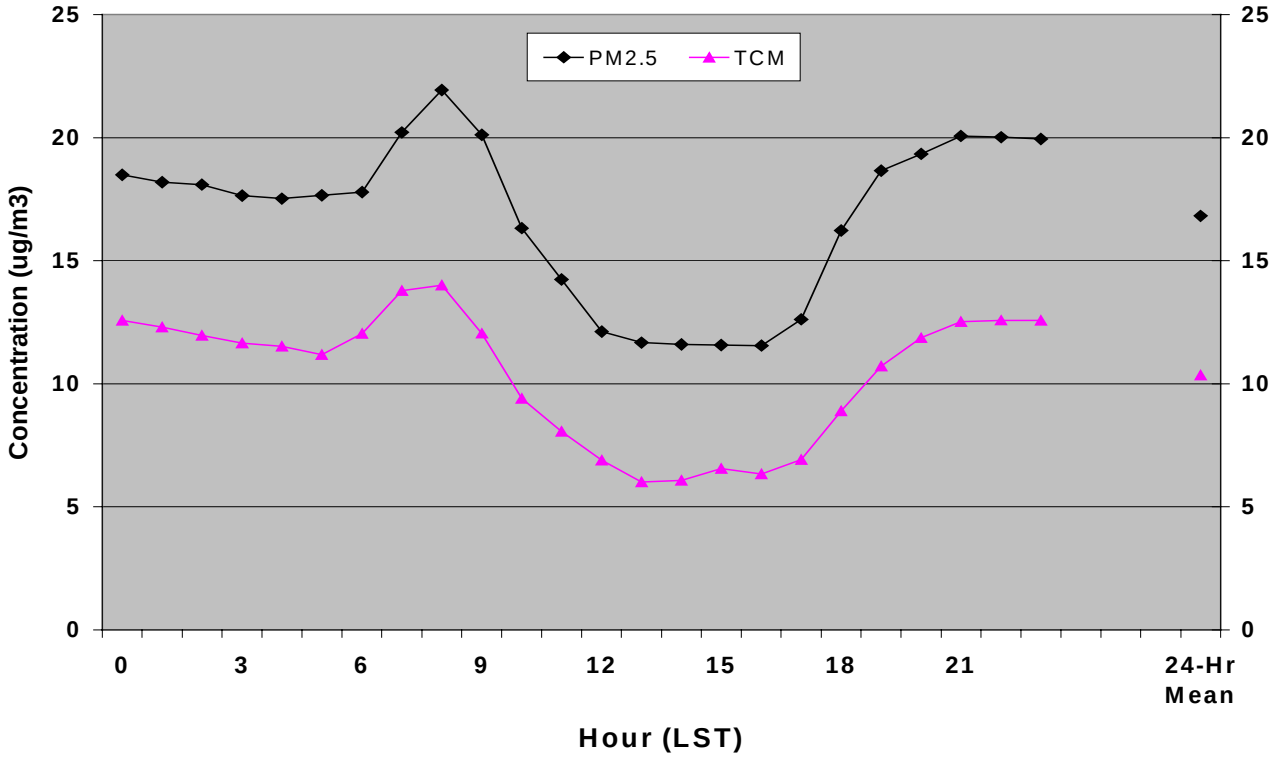
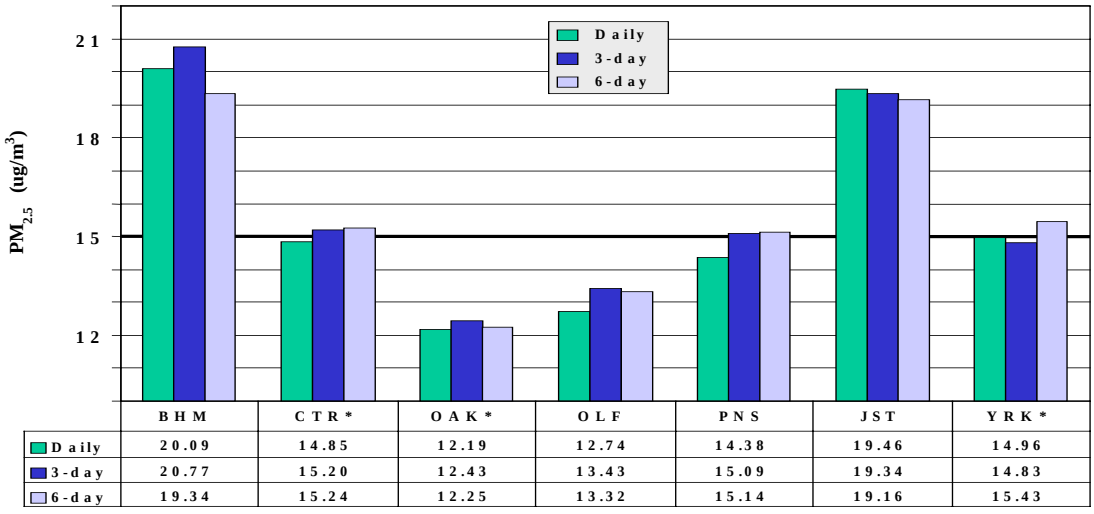


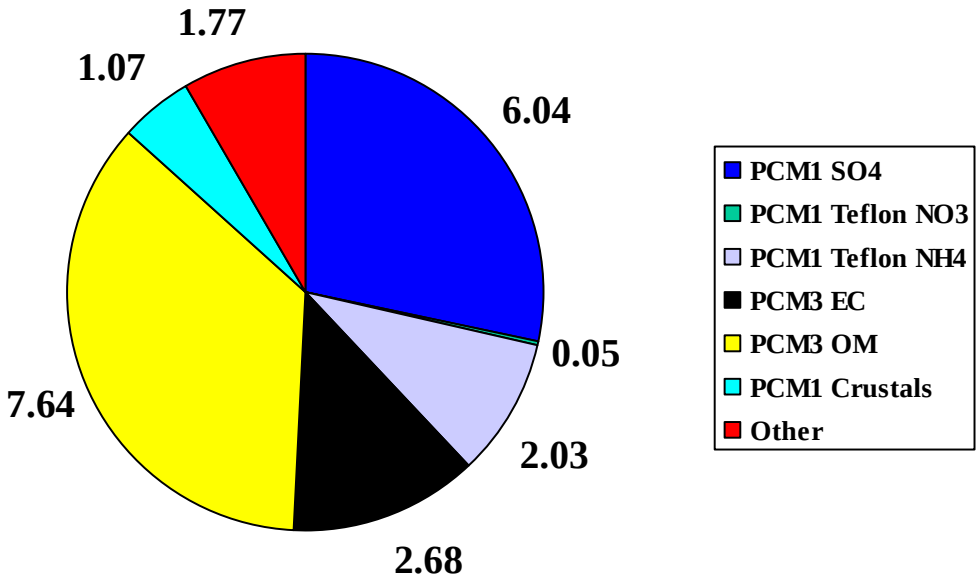
Figure 3. Diurnal plot of hourly $PM_{2.5}$ and TCM (OM + EC) for Jefferson Street. $PM_{2.5}$ data for 4th quarter 1998, TCM data for 4th quarter 1999.



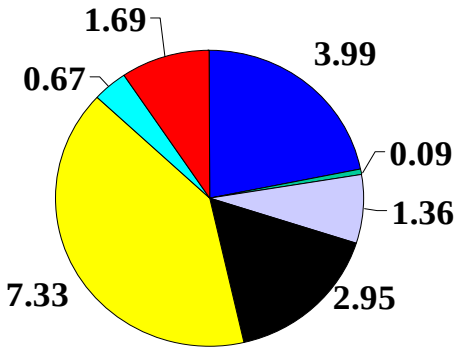
	BHM	CTR*	OAK*	OLF	PNS	JST	YRK*
Daily	20.09	14.85	12.19	12.74	14.38	19.46	14.96
3-day	20.77	15.20	12.43	13.43	15.09	19.34	14.83
6-day	19.34	15.24	12.25	13.32	15.14	19.16	15.43

Figure 4. Effect of sample collection schedule on annual $PM_{2.5}$ concentration for 1999. Asterisks indicate combined FRM and TEOM data sets.

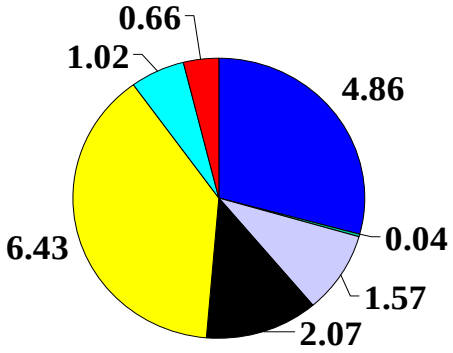
BHM 1999 Annual Average PM2.5 Composition by Mass
Average FRM mass = 21.28 ug/m3, n=191



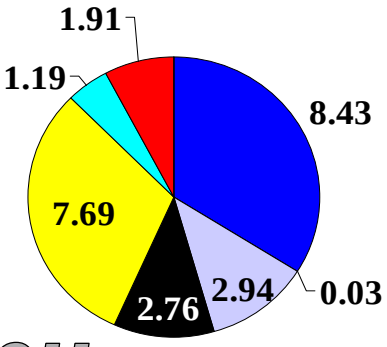
BHM 1st Qtr 1999
Avg FRM mass = 18.09 ug/m3, n=31



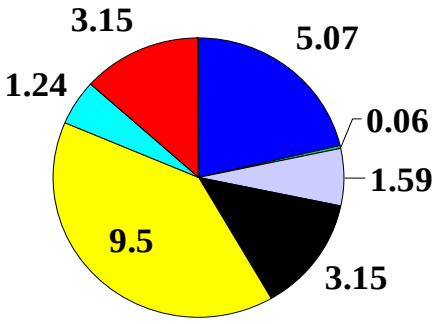
BHM 2nd Qtr 1999
Avg FRM mass = 16.66 ug/m3, n=53



BHM 3rd Qtr 1999
Avg FRM mass = 24.95 ug/m3, n=69



BHM 4th Qtr 1999
Avg FRM mass = 23.76 ug/m3, n=38

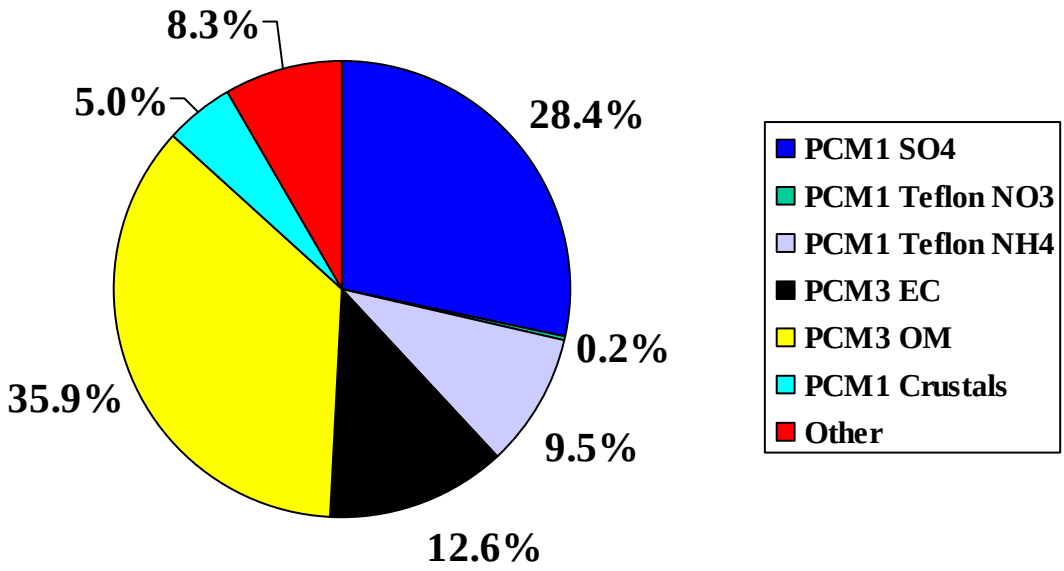


SEARCH

Principal Investigators:
Eric Edgerton and Ben Hartsell; ARA, Inc.
Alan Hansen, Tina Bahadori, Michael Van Loy, EPRI
John Jansen, Southern Company

Data Provided by EPRI to EPA on 8/2/2000
Database available through NARSTO archive by 1/31/2001
For further information contact Alan Hansen @ 650/855-2738

BHM 1999 Annual Average PM2.5 Composition by Percent
Average FRM mass = 21.28 ug/m3, n=191



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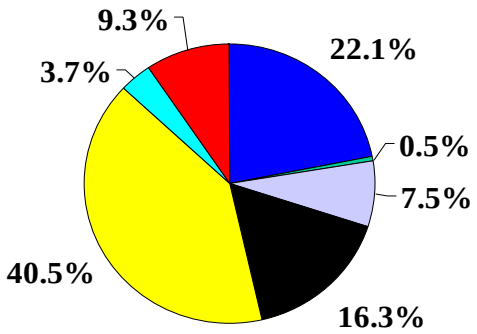
Avg FRM mass = 18.09 ug/m3, n=31



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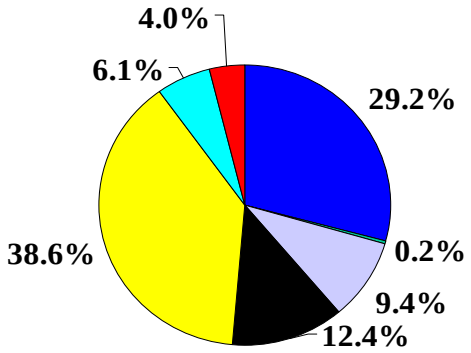

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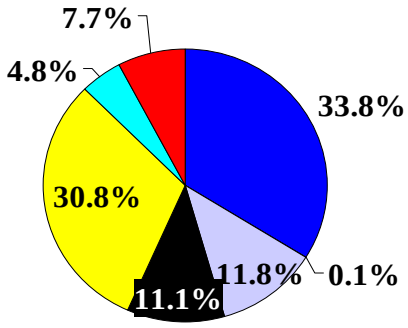
Avg FRM mass = 24.95 ug/m3, n=69



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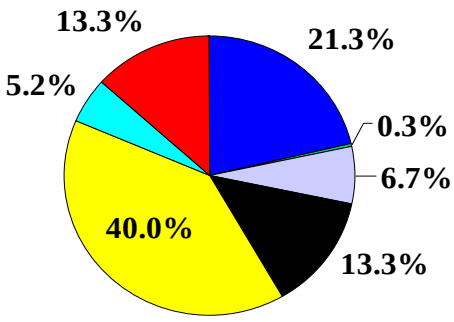

SEARCH

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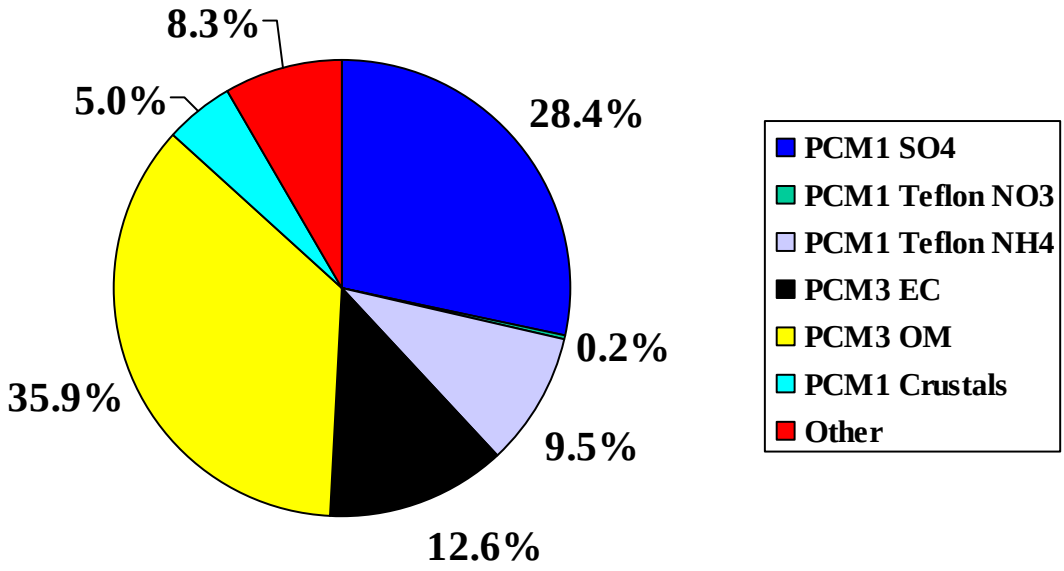
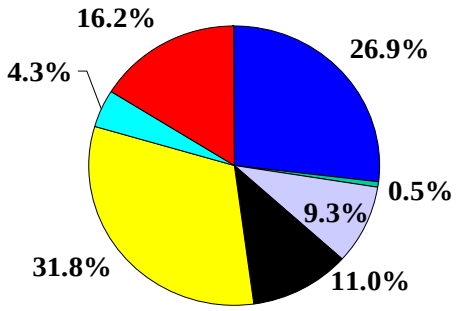
For further information contact Alan Hansen @ 650/855-2738

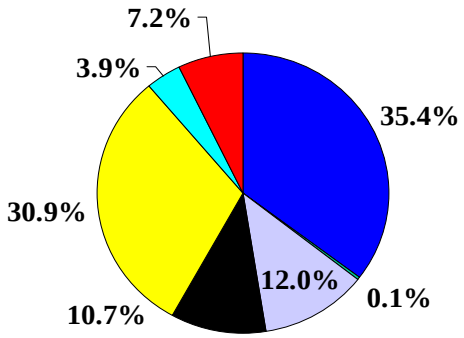
BHM Annual Average PM2.5 Composition by Percent
Average FRM mass = 21.28 ug/m3, n=191



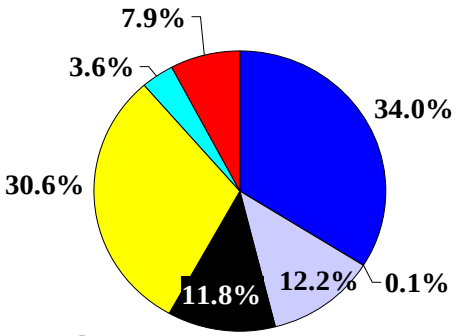
BHM 1st Qtr 1999 90th Percentile
Avg FRM mass =28.61 ug/m3, n=3



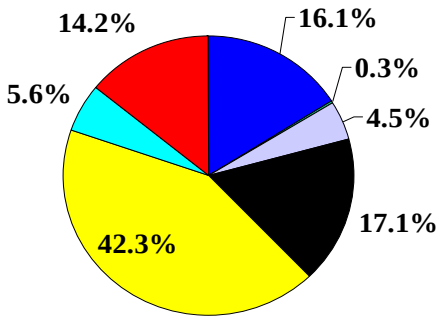
BHM 2nd Qtr 1999 90th Percentile
Avg FRM mass = 28.28 ug/m3, n=6



BHM 3rd Qtr 1999 90th Percentile
Avg FRM mass = 45.34 ug/m3, n=8



BHM 4th Qtr 1999 90th Percentile
Avg FRM mass = 44.62 ug/m3, n=5



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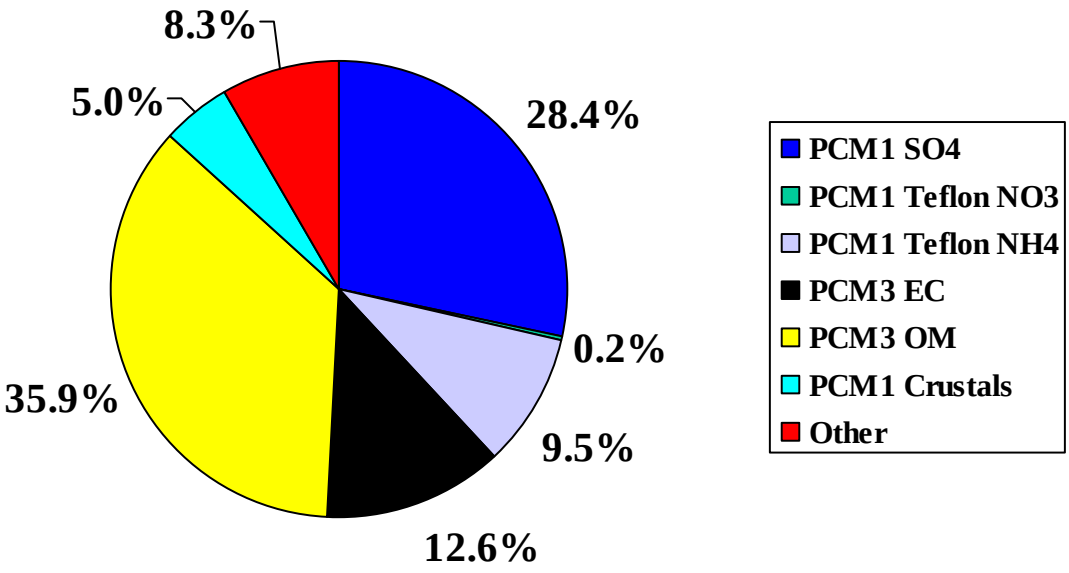
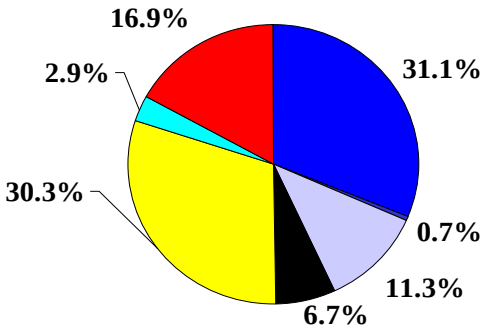
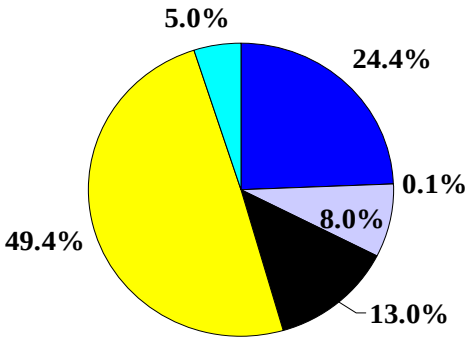


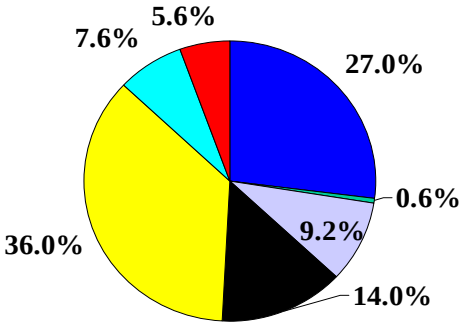
BHM 1st Qtr 1999 10th Percentile
Avg FRM mass =7.14 ug/m3, n=3



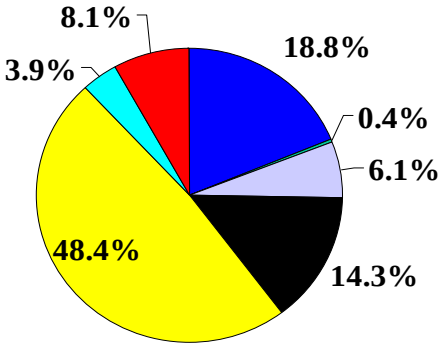
BHM 2nd Qtr 1999 10th Percentile
Avg FRM mass = 6.4 ug/m3, n=6



BHM 3rd Qtr 1999 10th Percentile
Avg FRM mass = 8.44 ug/m3, n=8



BHM 4th Qtr 1999 10th Percentile
Avg FRM mass = 8.22 ug/m3, n=5



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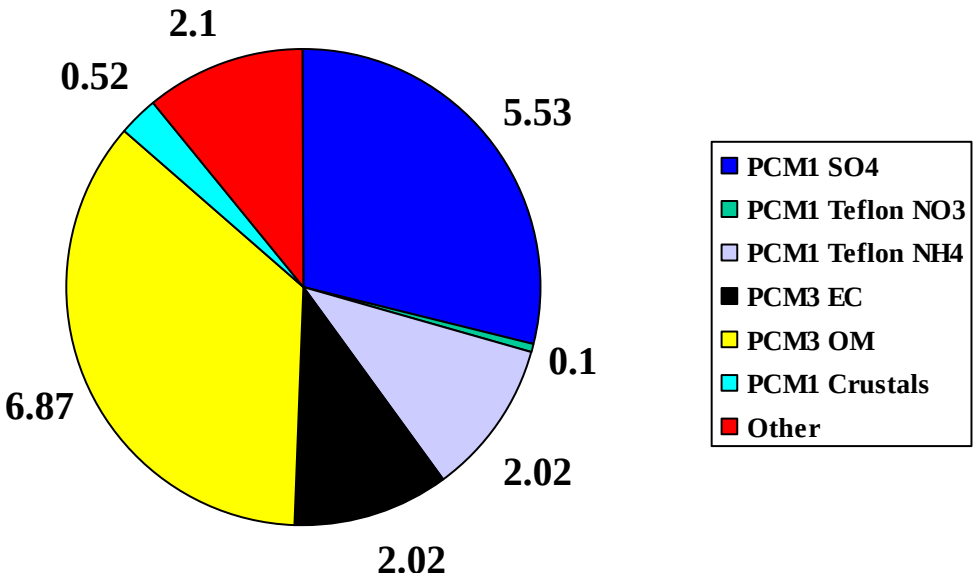
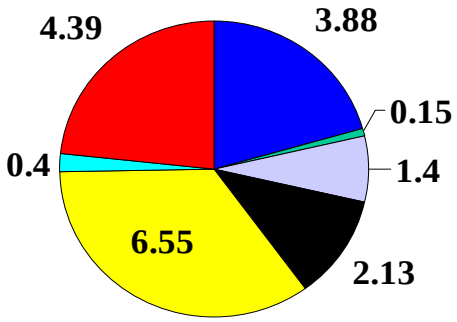
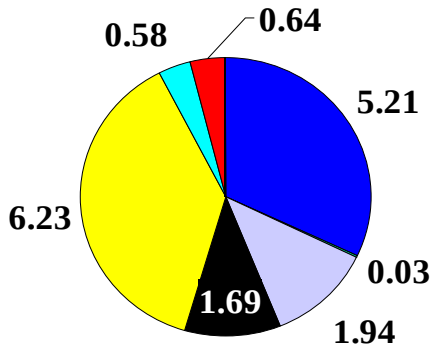
JST 1999 Annual Average PM2.5 Composition by Mass
Average FRM mass = 19.17 ug/m3, n=239



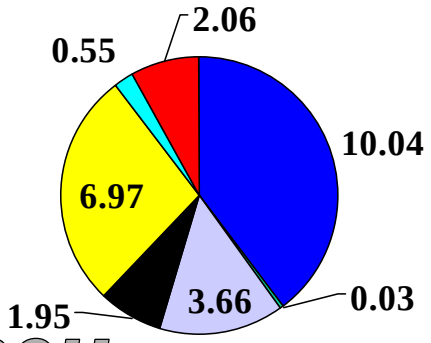
JST 1st Qtr 1999
Average FRM mass = 18.89 ug/m3,n=52



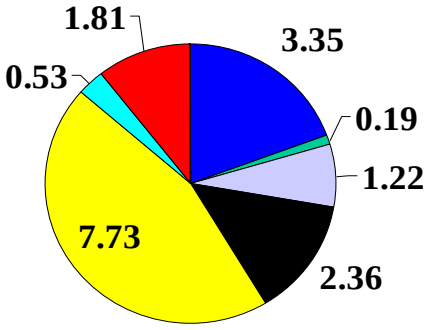
JST 2nd Qtr 1999
Average FRM mass = 16.32 ug/m3,n=68



JST 3rd Qtr 1999
Average FRM mass = 25.26 ug/m3, n=55



JST 4th Qtr 1999
Average FRM mass = 17.18ug/m3,n=64



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JST 1999 Annual Average PM2.5 Composition by Percent
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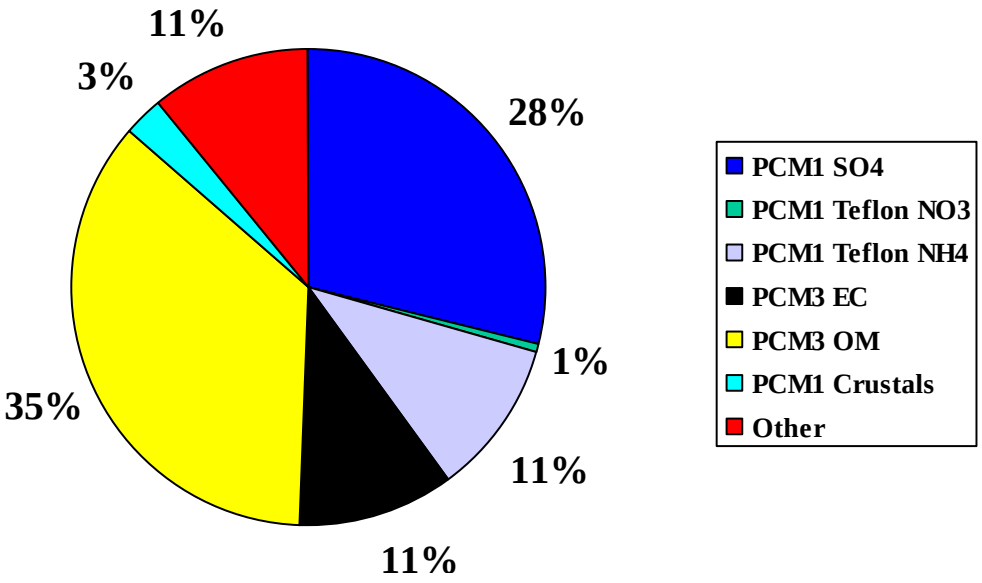
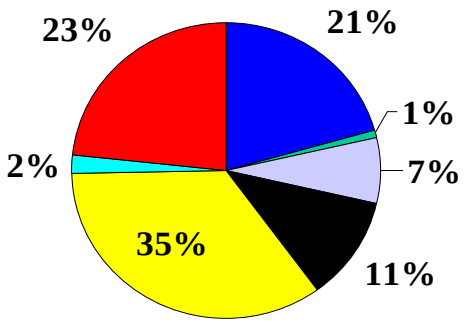
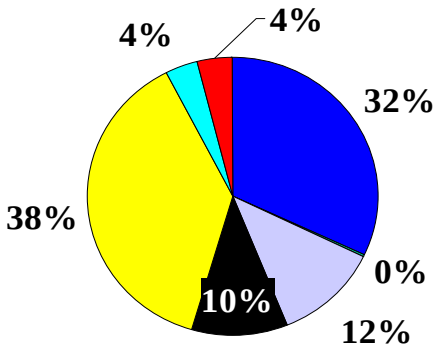


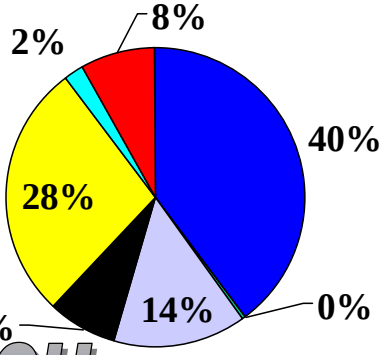
JST 1st Qtr 1999
Average FRM mass = 18.89 ug/m3,n=52



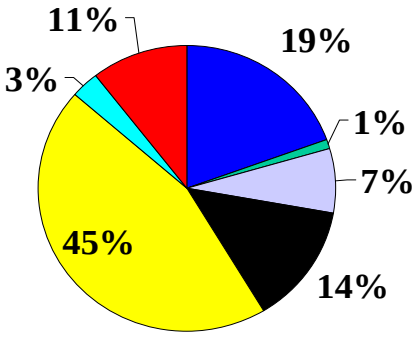
JST 2nd Qtr 1999
Average FRM mass = 16.32 ug/m3,n=68



JST 3rd Qtr 1999
Average FRM mass = 25.26 ug/m3, n=55



JST 4th Qtr 1999
Average FRM mass = 17.18ug/m3,n=64



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JST Annual Average PM2.5 Composition by Percent
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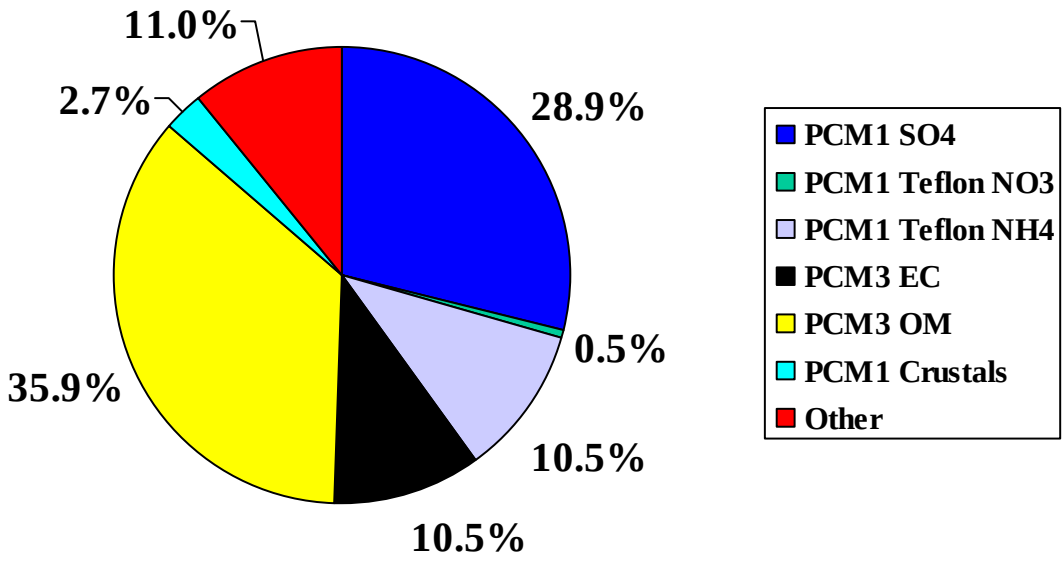
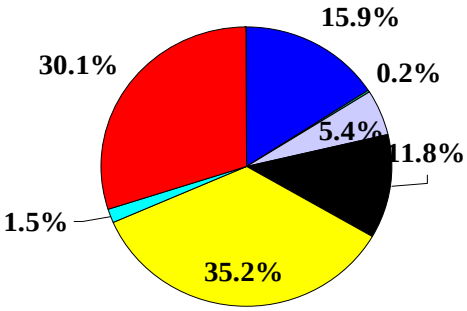
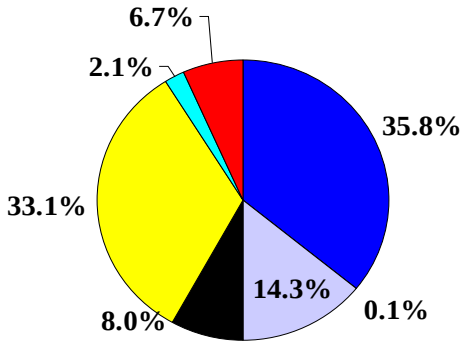


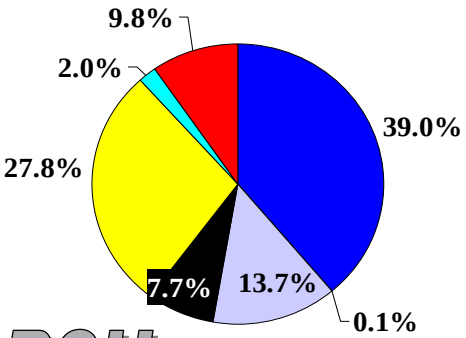
JST 1st Qtr 1999 90th Percentile
Avg FRM mass =34.72 ug/m3, n=6



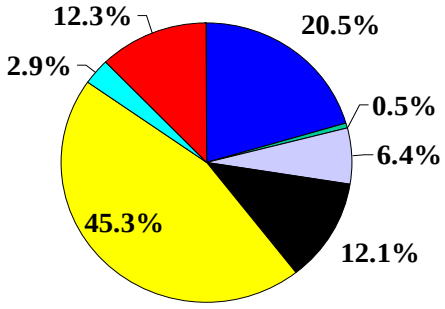
JST 2nd Qtr 1999 90th Percentile
Avg FRM mass = 28.06 ug/m3, n=8



JST 3rd Qtr 1999 90th Percentile
Avg FRM mass = 38.98 ug/m3, n=6



JST 4th Qtr 1999 90th Percentile
Avg FRM mass = 34.16 ug/m3, n=7



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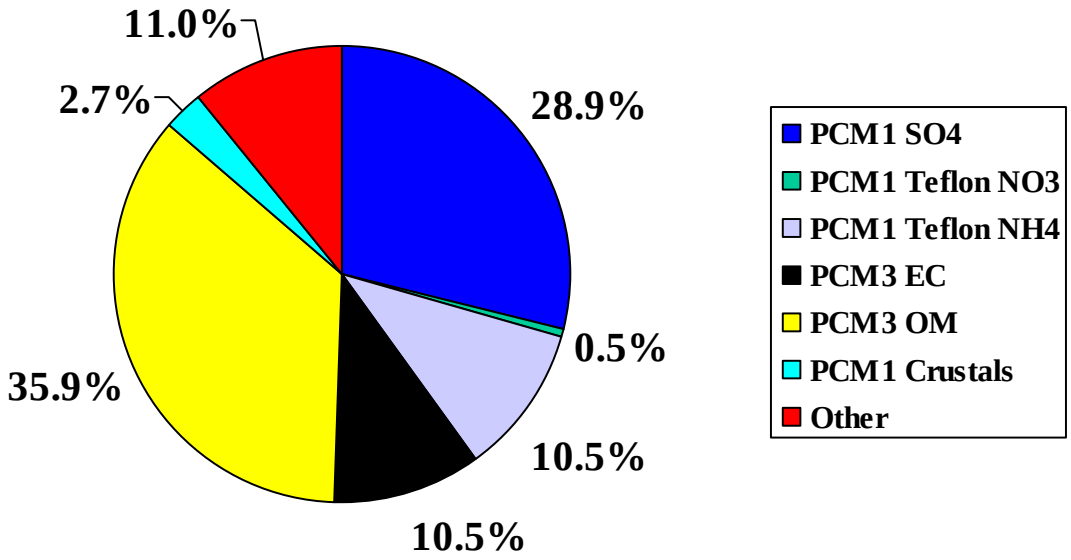
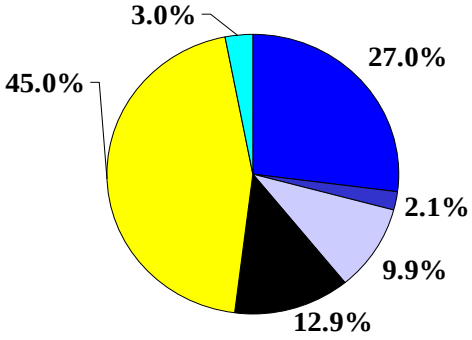
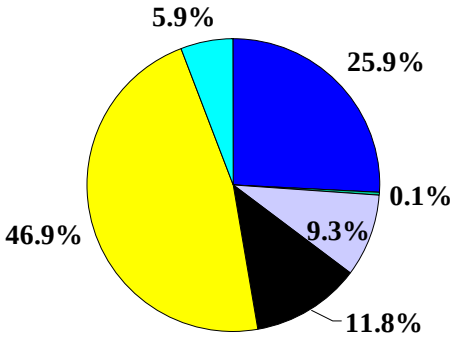
JST Annual Average PM2.5 Composition by Percent
Average FRM mass = 19.17 ug/m3, n=239



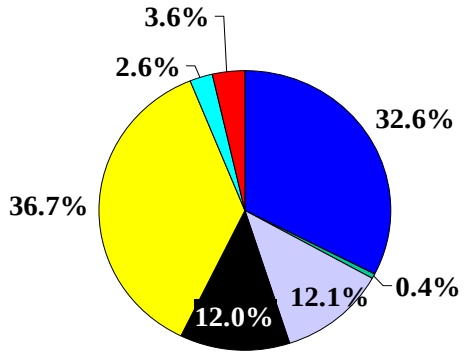
JST 1st Qtr 1999 10th Percentile
Avg FRM mass =6.05 ug/m3, n=6



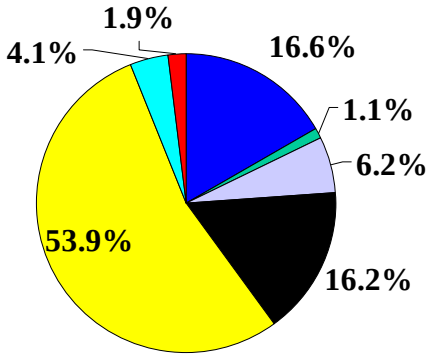
JST 2nd Qtr 1999 10th Percentile
Avg FRM mass = 6.57 ug/m3, n=8



JST 3rd Qtr 1999 10th Percentile
Avg FRM mass = 10.65 ug/m3, n=6



JST 4th Qtr 1999 10th Percentile
Avg FRM mass = 6.33 ug/m3, n=7



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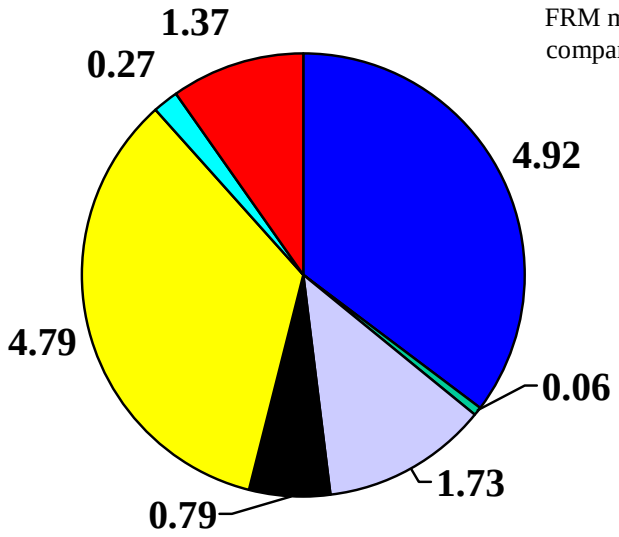
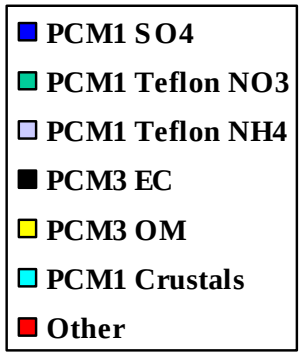
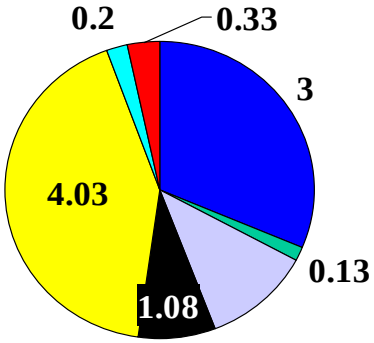
YRK 1999 Annual Average PM2.5 Composition by Mass
Average TEOM* mass = 13.92 ug/m3, n=241

*TEOM run @ 30C and dehumidified. Substituted for FRM mass to increase number of samples. See comparison of FRM & TEOM data for this site

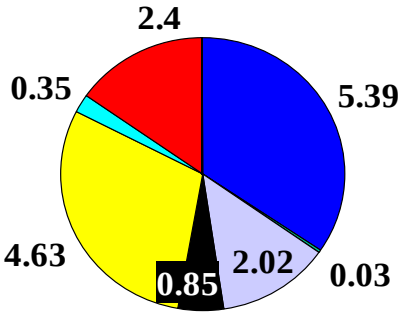




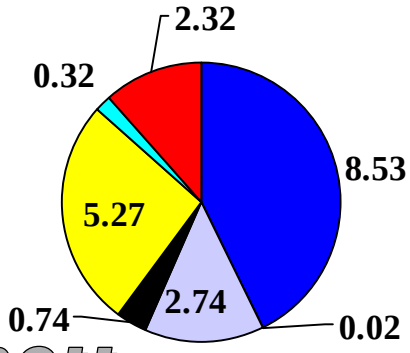
YRK 1st Qtr 1999
Average TEOM* mass =9.51ug/m3, n=48



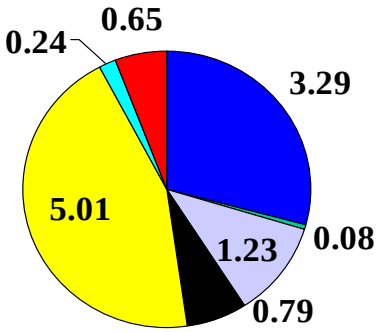
YRK 2nd Qtr 1999
Average TEOM* mass = 15.67 ug/m3,n=54



YRK 3rd Qtr 1999
Average TEOM* mass = 19.94 ug/m3, n=56



YRK 4th Qtr 1999
Average TEOM* mass = 11.28 ug/m3,n=83



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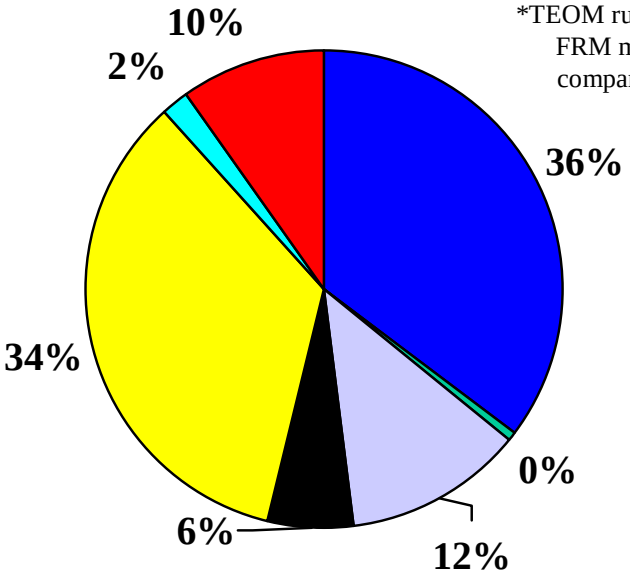
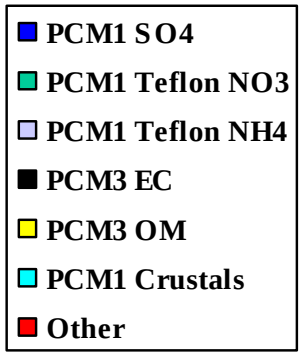


*TEOM run @ 30C and dehumidified. Substituted for FRM mass to increase number of samples. See comparison of FRM & TEOM data for this site



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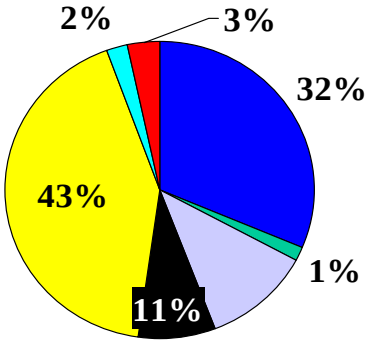

YRK 2nd Qtr 1999
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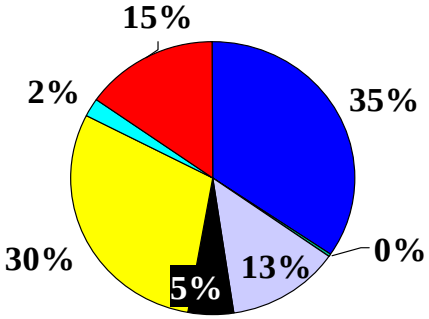

YRK 3rd Qtr 1999
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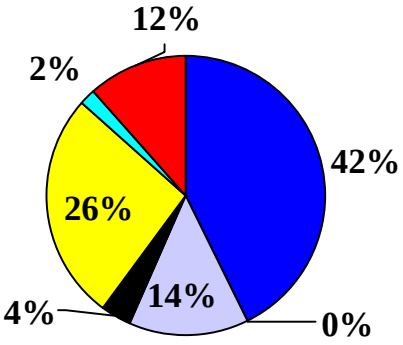

YRK 4th Qtr 1999
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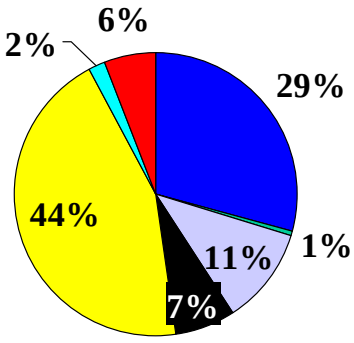

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YRK 1999 Annual Average PM2.5 Composition by Percent
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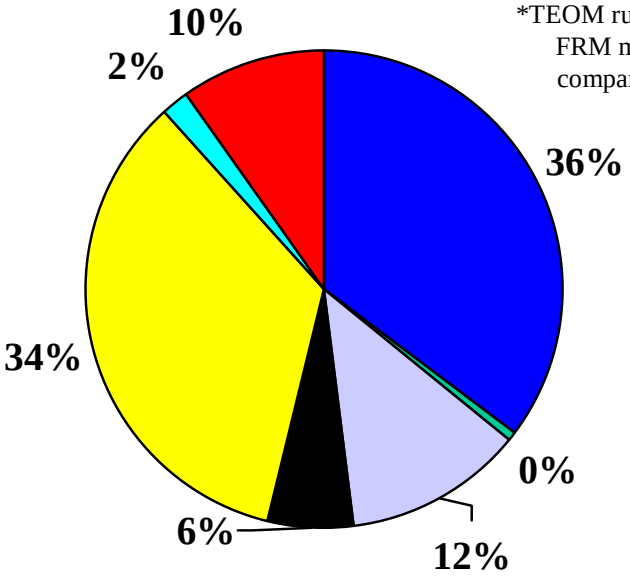
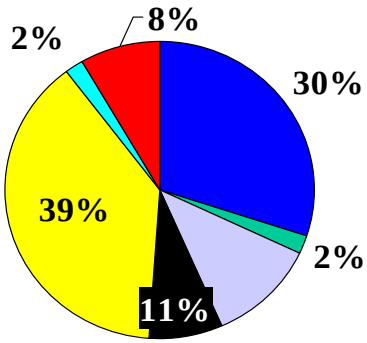
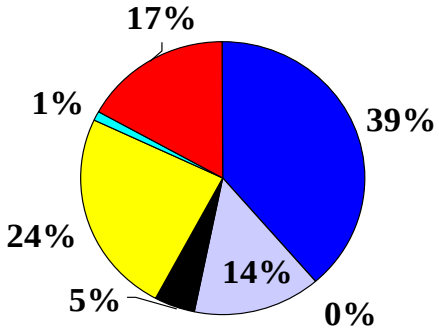


- PCM1 SO4
- PCM1 Teflon NO3
- PCM1 Teflon NH4
- PCM3 EC
- PCM3 OM
- PCM1 Crustals
- Other

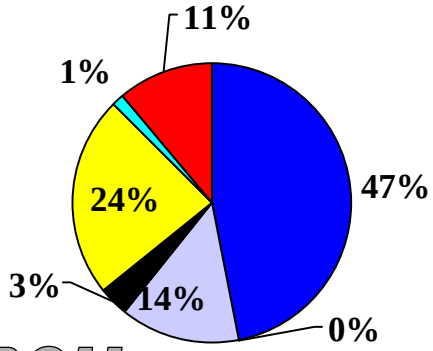
YRK 1st Qtr 1999 90th Percentile
Average TEOM* mass =18.0 ug/m3, n=6



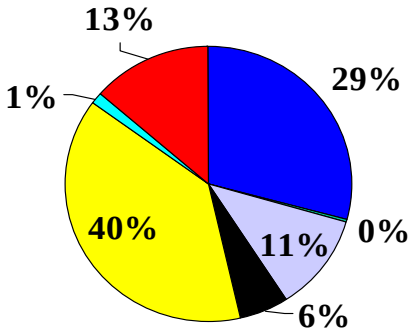
YRK 2nd Qtr 1999 90th Percentile
Average TEOM* mass = 29.00 ug/m3,n=6



YRK 3rd Qtr 1999 90th Percentile
Average TEOM* mass = 32.36 ug/m3, n=6



YRK 4th Qtr 1999 90th Percentile
Average TEOM* mass = 27.37 ug/m3,n=9



SEARCH

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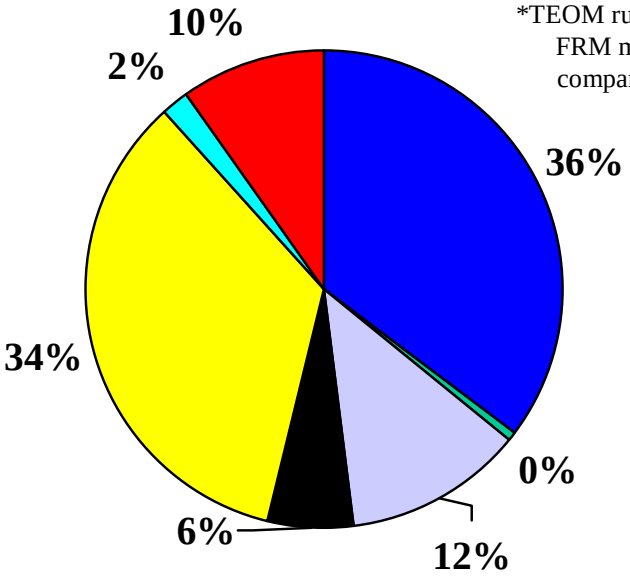
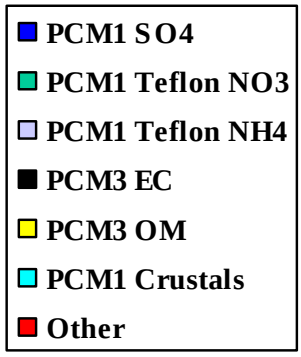
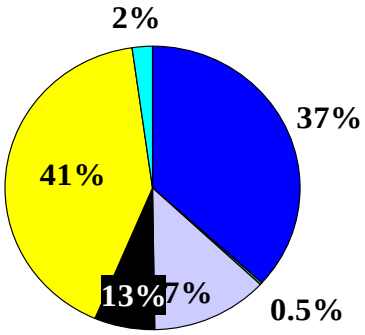
YRK 1999 Annual Average PM2.5 Composition by Percent
Average TEOM* mass = 13.92 ug/m3, n=241

*TEOM run @ 30C and dehumidified. Substituted for FRM mass to increase number of samples. See comparison of FRM & TEOM data for this site

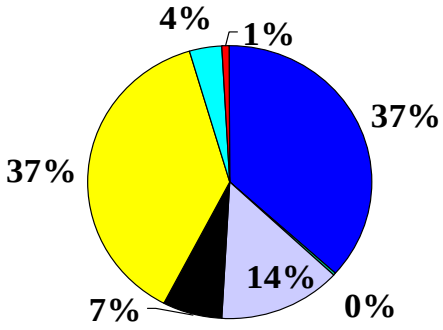




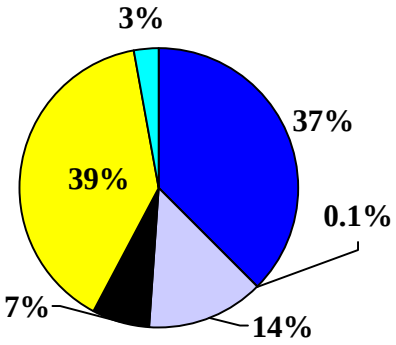
YRK 1st Qtr 1999 10th Percentile
Average TEOM* mass =3.18 ug/m3, n=6



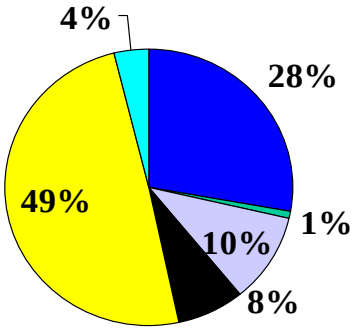
YRK 2nd Qtr 1999 10th Percentile
Average TEOM* mass = 6.25 ug/m3,n=6



YRK 3rd Qtr 1999 10th Percentile
Average TEOM* mass =6.33ug/m3, n=7



YRK 4th Qtr 1999 10th Percentile
Average TEOM* mass =2.93 ug/m3,n=9



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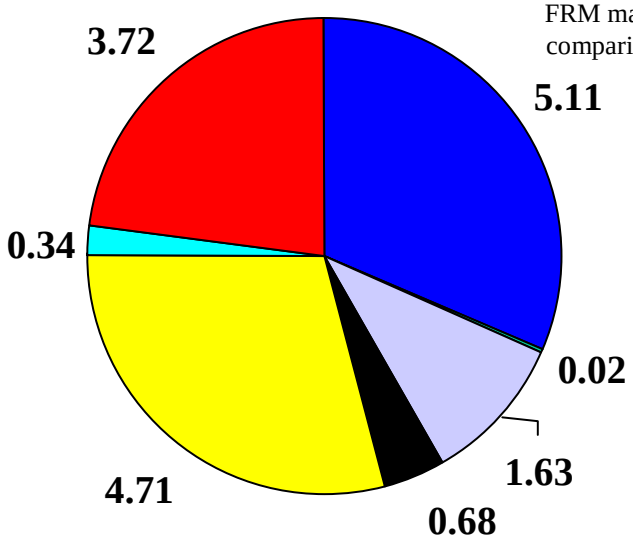
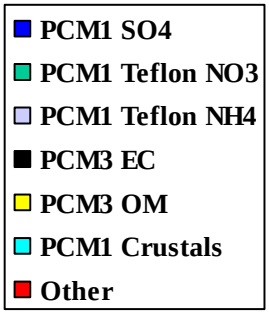
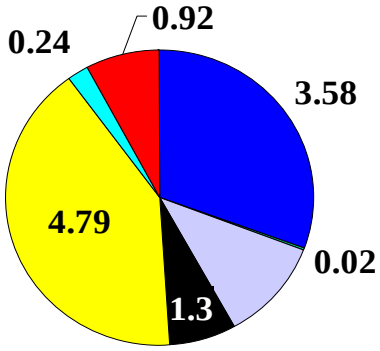
CTR 1999 Annual Average PM2.5 Composition by Mass
Average TEOM* mass = 16.21 ug/m3, n=227

*TEOM run @ 30C and dehumidified. Substituted for FRM mass to increase number of samples. See comparison of FRM & TEOM data for this site

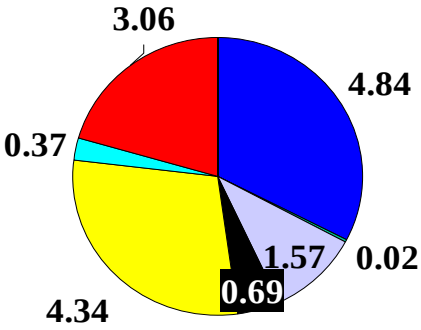




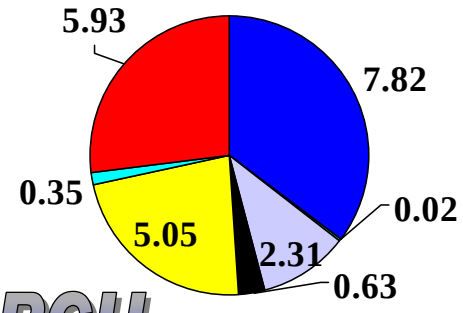
CTR 1st Qtr 1999
Average TEOM* mass =11.66 ug/m3, n=24



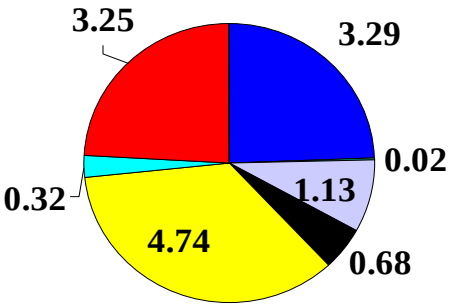
CTR 2nd Qtr 1999
Average TEOM* mass = 14.90 ug/m3,n=70



CTR 3rd Qtr 1999
Average TEOM* mass = 22.10 ug/m3, n=66



CTR 4th Qtr 1999
Average TEOM* mass = 13.45 ug/m3,n=67



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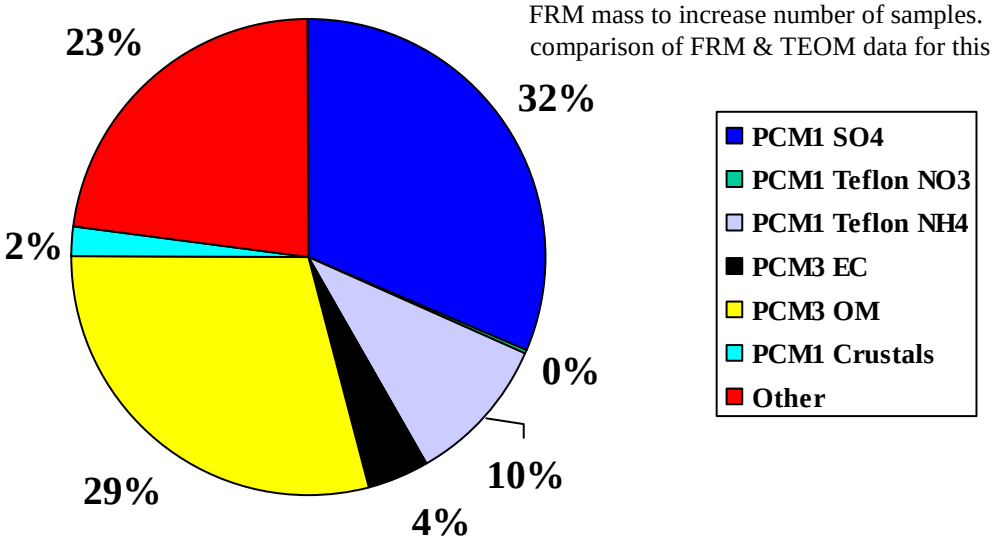
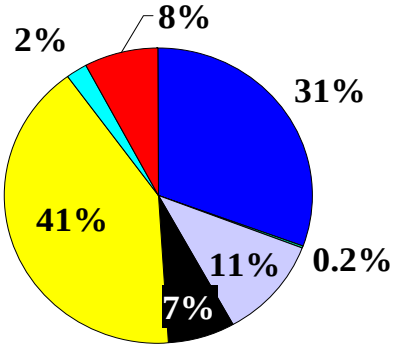
CTR 1999 Annual Average PM2.5 Composition by Percent
Average TEOM* mass = 16.21 ug/m3, n=227

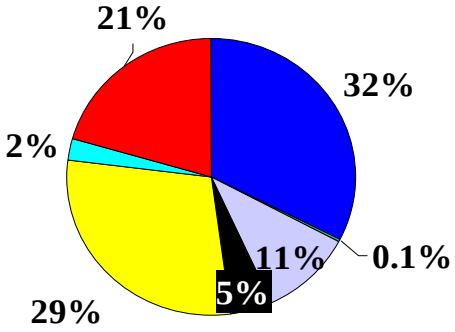
*TEOM run @ 30C and dehumidified. Substituted for FRM mass to increase number of samples. See comparison of FRM & TEOM data for this site



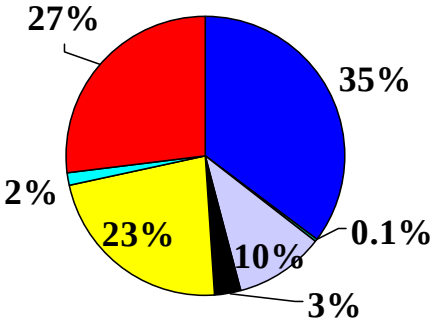
CTR 1st Qtr 1999
Average TEOM* mass =11.66 ug/m3, n=24



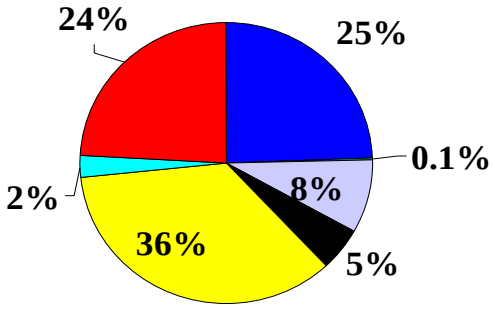
CTR 2nd Qtr 1999
Average TEOM* mass = 14.90 ug/m3,n=70



CTR 3rd Qtr 1999
Average TEOM* mass = 22.10 ug/m3, n=66



CTR 4th Qtr 1999
Average TEOM* mass = 13.45 ug/m3,n=67



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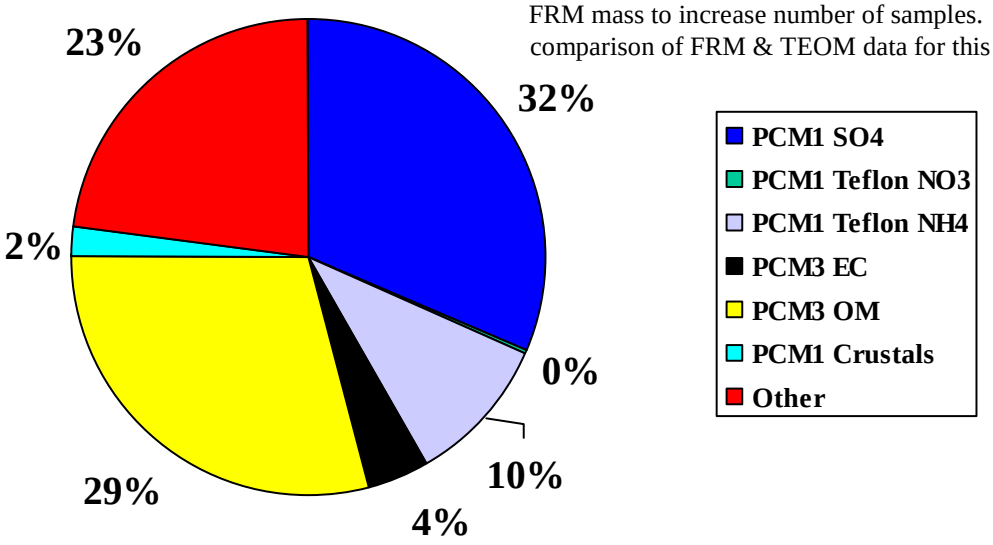
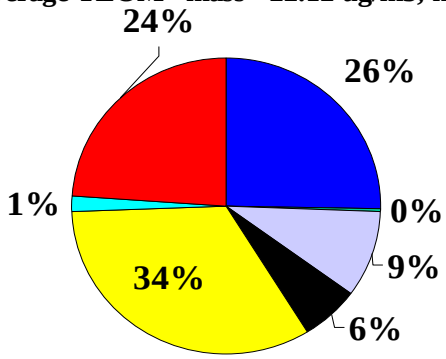
CTR 1999 Annual Average PM2.5 Composition by Percent
Average TEOM* mass = 16.21 ug/m3, n=227

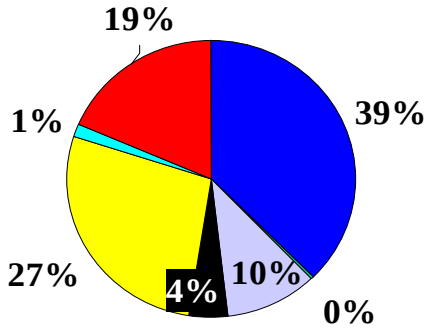
*TEOM run @ 30C and dehumidified. Substituted for FRM mass to increase number of samples. See comparison of FRM & TEOM data for this site



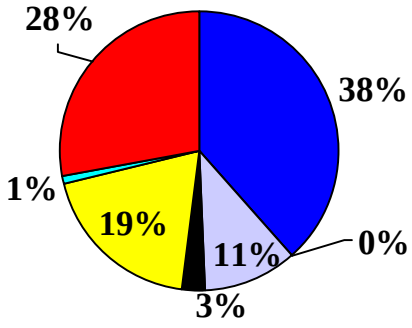
CTR 1st Qtr 1999 90th Percentile
Average TEOM* mass =22.12 ug/m3, n=3



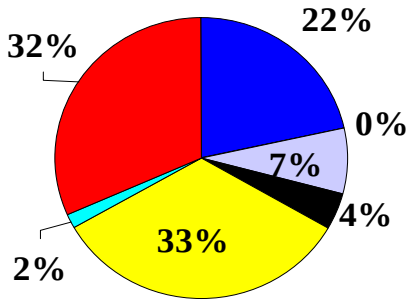
CTR 2nd Qtr 1999 90th Percentile
Average TEOM* mass = 26.11 ug/m3,n=8



CTR 3rd Qtr 1999 90th Percentile
Average TEOM* mass = 38.98 ug/m3, n=7



CTR 4th Qtr 1999 90th Percentile
Average TEOM* mass = 30.22 ug/m3,n=8



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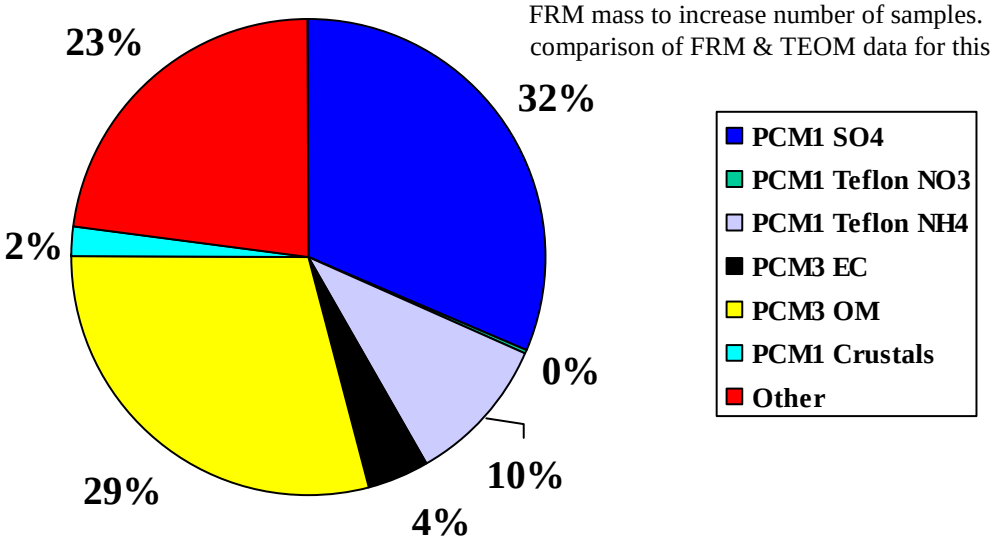
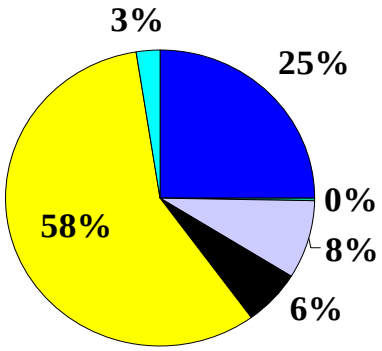
CTR 1999 Annual Average PM2.5 Composition by Percent
Average TEOM* mass = 16.21 ug/m3, n=227

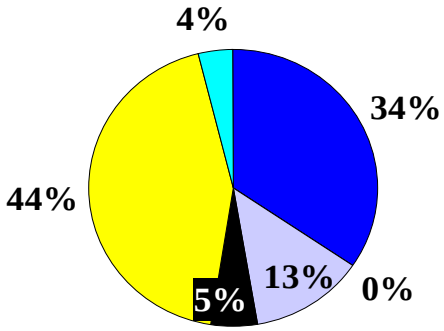
*TEOM run @ 30C and dehumidified. Substituted for FRM mass to increase number of samples. See comparison of FRM & TEOM data for this site



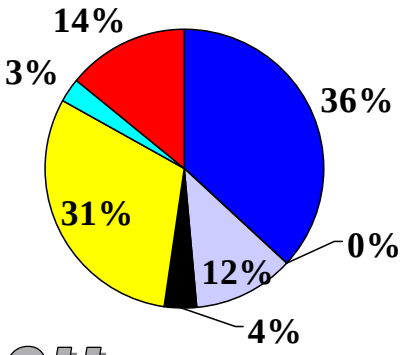
CTR 1st Qtr 1999 10th Percentile
Average TEOM* mass =5.63 ug/m3, n=3



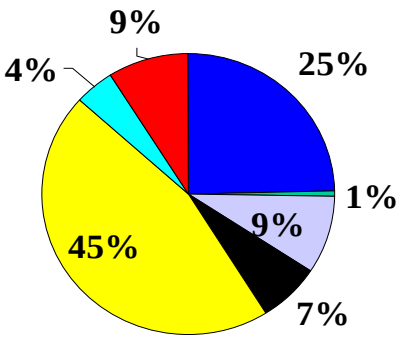
CTR 2nd Qtr 1999 90th Percentile
Average TEOM* mass =5.46 ug/m3,n=8



CTR 3rd Qtr 1999 90th Percentile
Average TEOM* mass = 9.29 ug/m3, n=8



CTR 4th Qtr 1999 90th Percentile
Average TEOM* mass = 4.34 ug/m3,n=8



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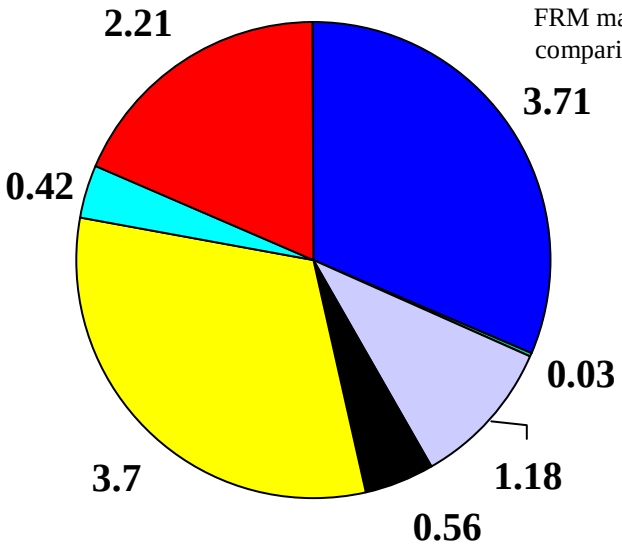
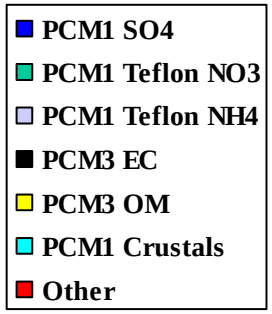
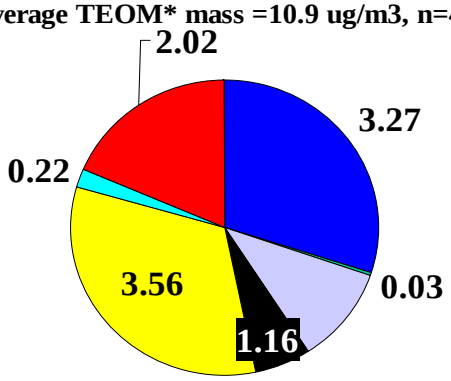
OAK 1999 Annual Average PM2.5 Composition by Mass
Average TEOM* mass = 11.83 ug/m3, n=192

*TEOM run @ 30C and dehumidified. Substituted for FRM mass to increase number of samples. See comparison of FRM & TEOM data for this site

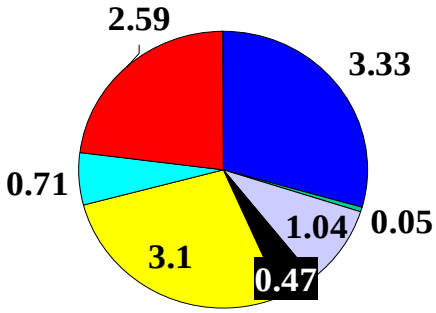




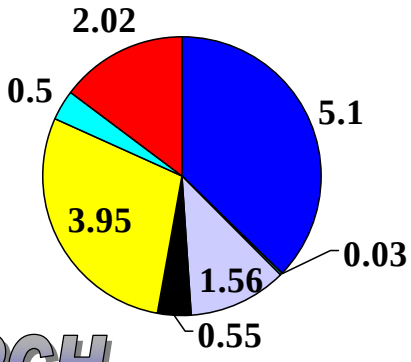
OAK 1st Qtr 1999
Average TEOM* mass =10.9 ug/m3, n=44



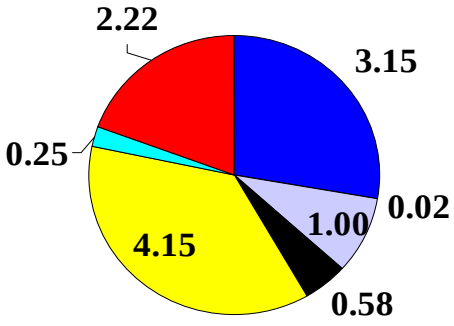
OAK 2nd Qtr 1999
Average TEOM* mass = 11.28 ug/m3,n=48



OAK 3rd Qtr 1999
Average TEOM* mass = 13.70 ug/m3, n=48



OAK 4th Qtr 1999
Average TEOM* mass = 11.38 ug/m3,n=52



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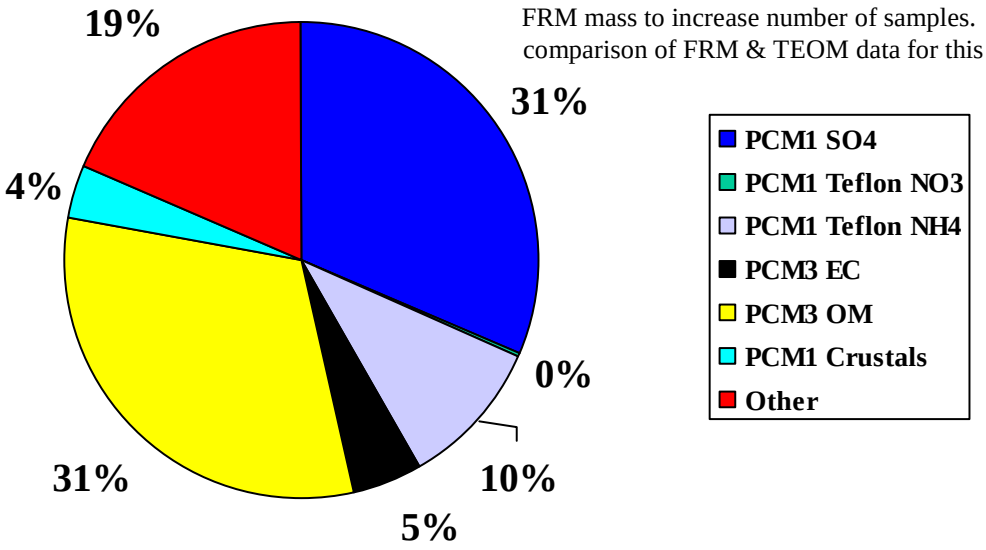
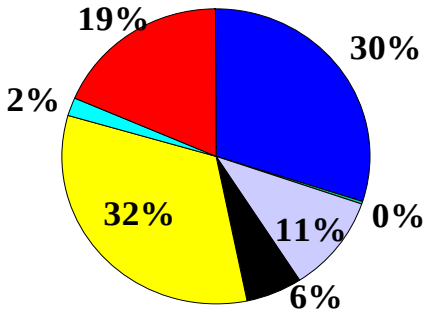
OAK 1999 Annual Average PM2.5 Composition by Percent
Average TEOM* mass = 11.83 ug/m3, n=192

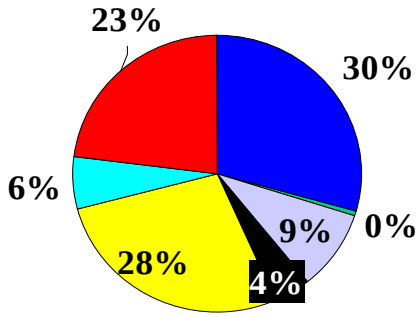
*TEOM run @ 30C and dehumidified. Substituted for FRM mass to increase number of samples. See comparison of FRM & TEOM data for this site



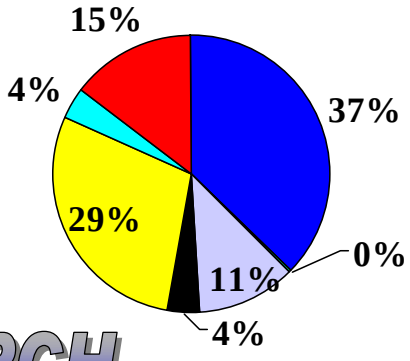
OAK 1st Qtr 1999
Average TEOM* mass =10.9 ug/m3, n=44



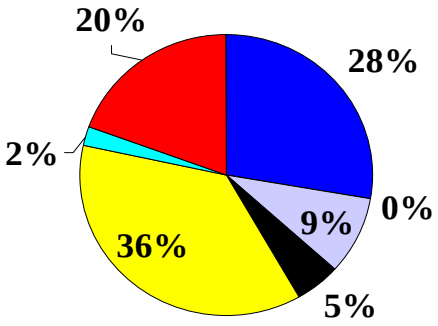
OAK 2nd Qtr 1999
Average TEOM* mass = 11.28 ug/m3,n=48



OAK 3rd Qtr 1999
Average TEOM* mass = 13.70 ug/m3, n=48



OAK 4th Qtr 1999
Average TEOM* mass = 11.38 ug/m3,n=52



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OAK 1999 Annual Average PM2.5 Composition by Percent
Average TEOM* mass = 11.83 ug/m3, n=192

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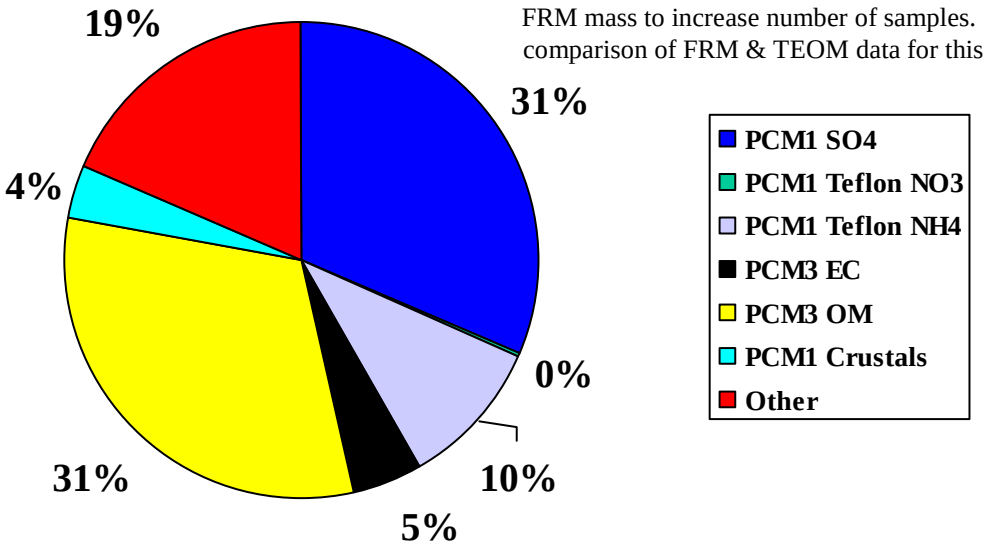
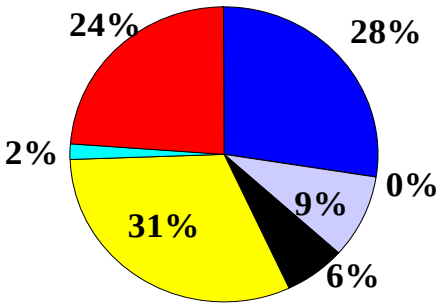
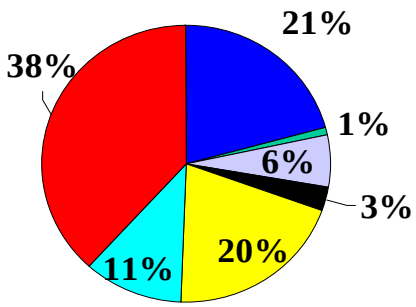


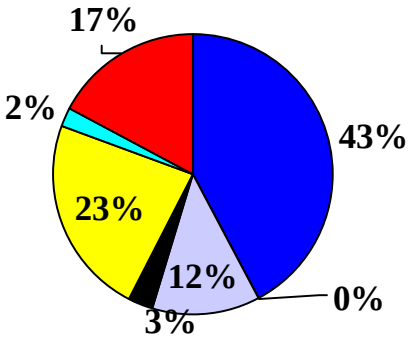
OAK 1st Qtr 1999 90th Percentile
Average TEOM* mass =21.67 ug/m3, n=4



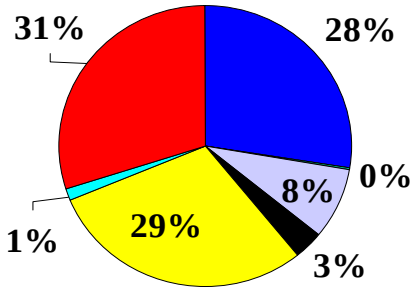
OAK 2nd Qtr 1999 90th Percentile
Average TEOM* mass =18.51 ug/m3,n=5



OAK 3rd Qtr 1999 90th Percentile
Average TEOM* mass = 24.99 ug/m3, n=6



OAK 4th Qtr 1999 90th Percentile
Average TEOM* mass = 27.64 ug/m3,n=6



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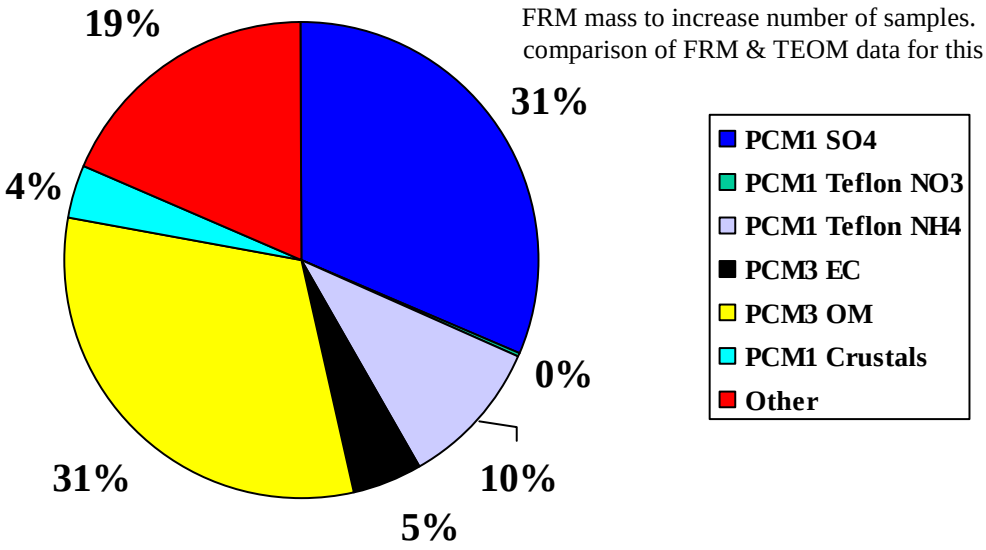
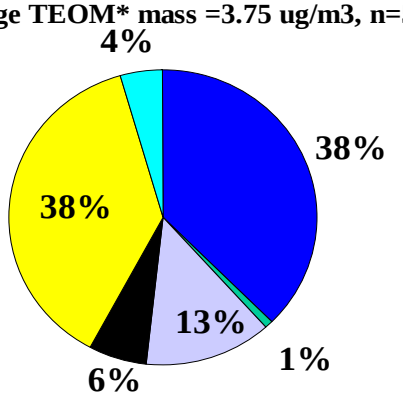
OAK 1999 Annual Average PM2.5 Composition by Percent
Average TEOM* mass = 11.83 ug/m3, n=192

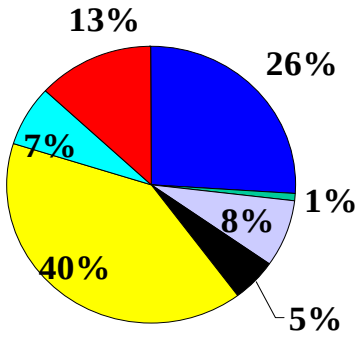
*TEOM run @ 30C and dehumidified. Substituted for FRM mass to increase number of samples. See comparison of FRM & TEOM data for this site



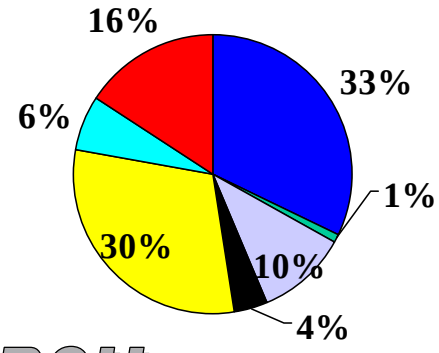
OAK 1st Qtr 1999 10th Percentile
Average TEOM* mass =3.75 ug/m3, n=5



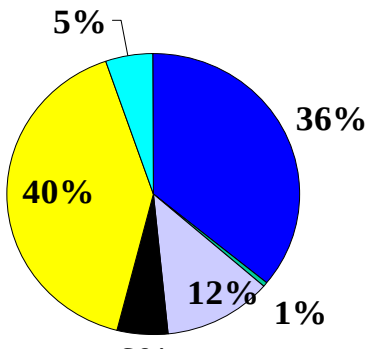
OAK 2nd Qtr 1999 10th Percentile
Average TEOM* mass =6.09 ug/m3,n=6



OAK 3rd Qtr 1999 90th Percentile
Average TEOM* mass = 4.64 ug/m3, n=6



OAK 4th Qtr 1999 90th Percentile
Average TEOM* mass = 3.02 ug/m3,n=6



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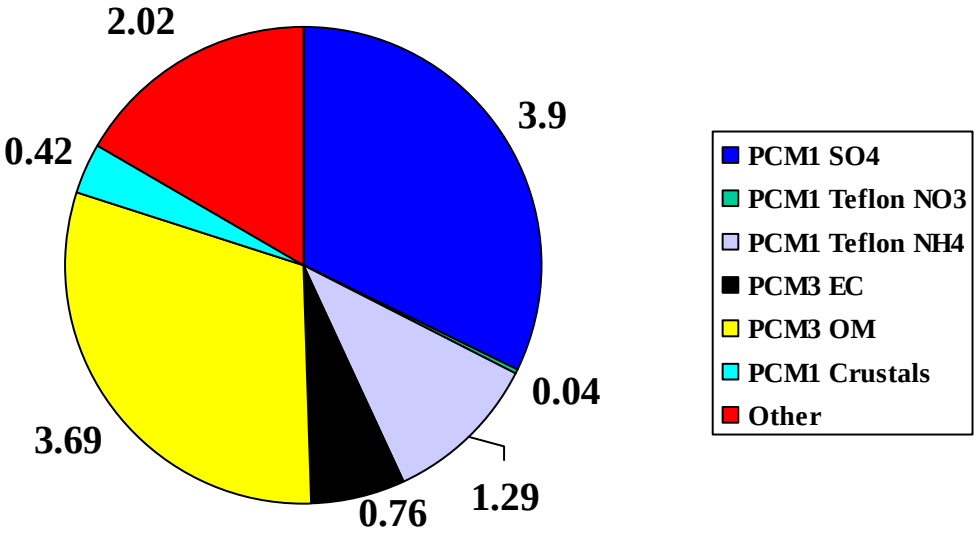
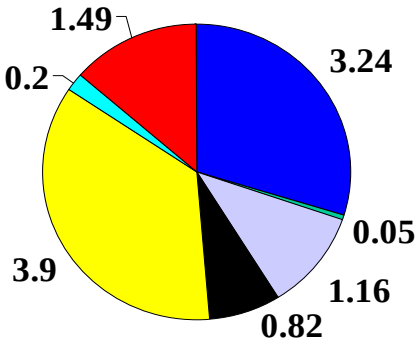
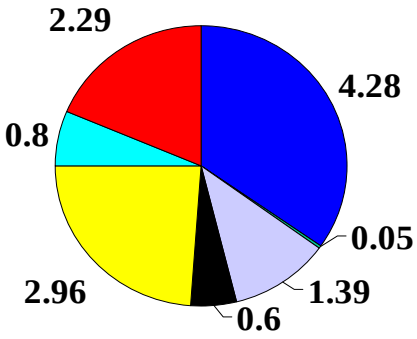
OLF 1999 Annual Average PM2.5 Composition by Mass
Average FRM mass = 12.12 ug/m3, n=234



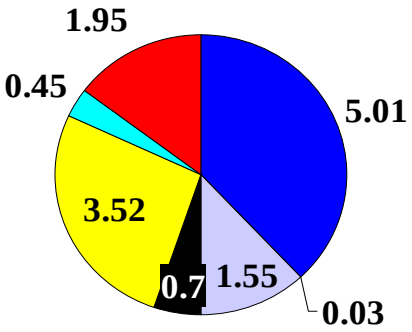
OLF 1st Qtr 1999
Avg FRM mass = 10.86 ug/m3, n=50



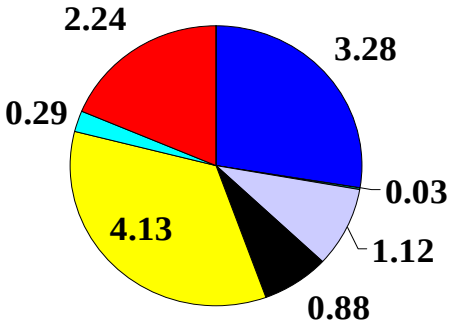
OLF 2nd Qtr 1999
Avg FRM mass = 12.38 ug/m3, n=49



OLF 3rd Qtr 1999
Avg FRM mass = 13.21 ug/m3, n=56



OLF 4th Qtr 1999
Avg FRM mass = 11.98 ug/m3, n=79



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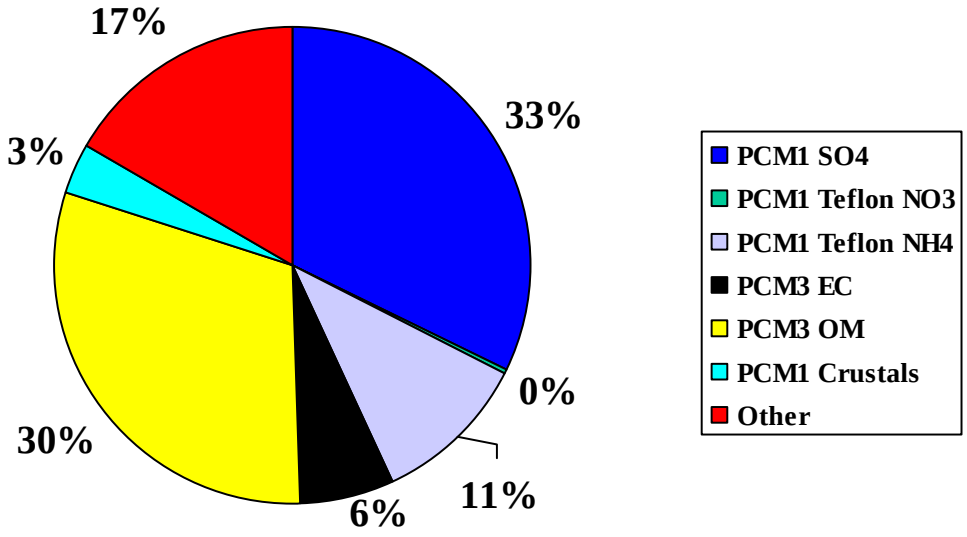
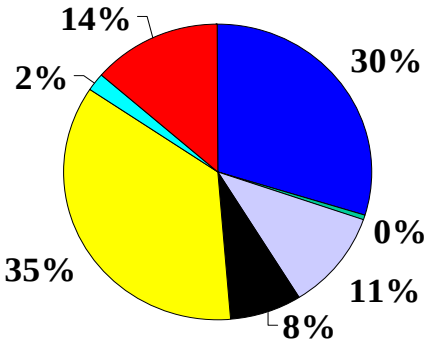
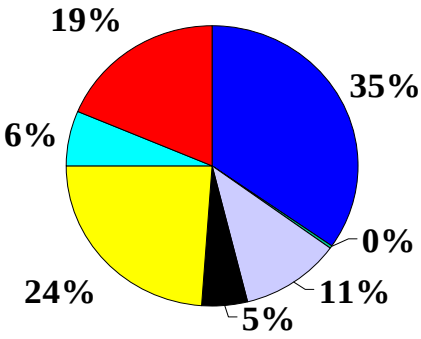
OLF 1999 Annual Average PM2.5 Composition by Percent
Average FRM mass = 12.12 ug/m3, n=234



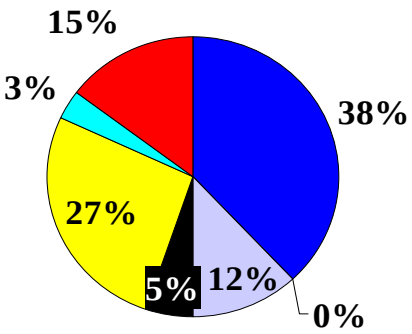
OLF 1st Qtr 1999
Avg FRM mass = 10.86 ug/m3, n=50



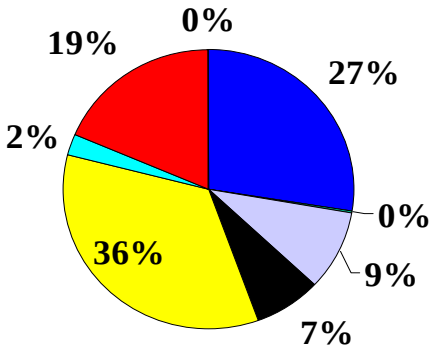
OLF 2nd Qtr 1999
Avg FRM mass = 12.38 ug/m3, n=49



OLF 3rd Qtr 1999
Avg FRM mass = 13.21 ug/m3, n=56



OLF 4th Qtr 1999
Avg FRM mass = 11.98 ug/m3, n=79



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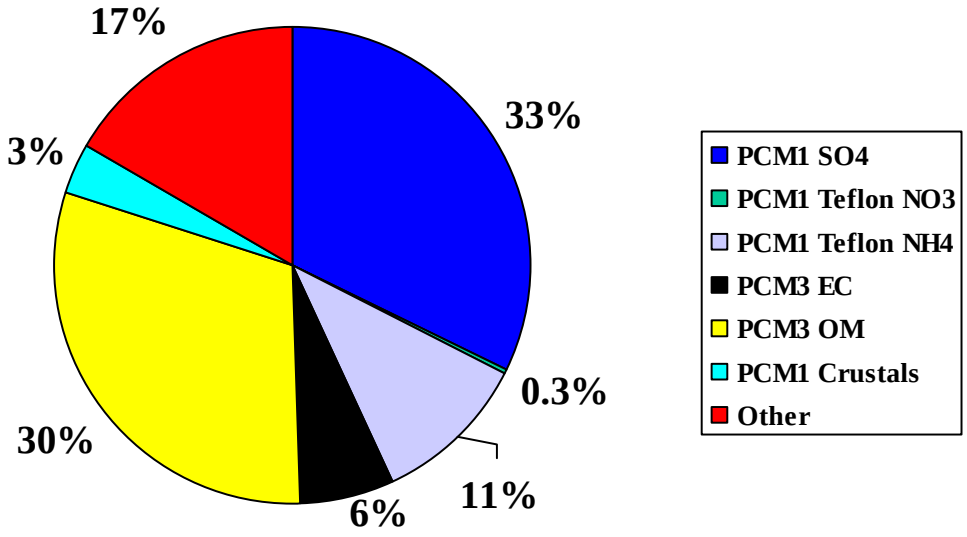
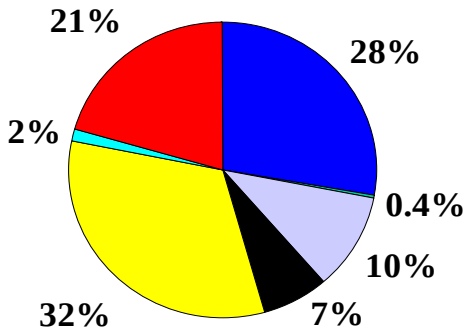
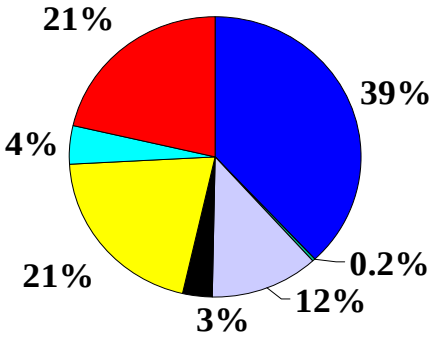
OLF 1999 Annual Average PM2.5 Composition by Percent
Average FRM mass = 12.12 ug/m3, n=234



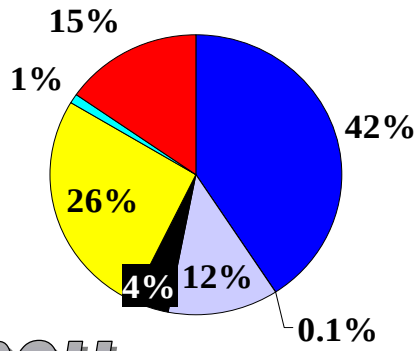
OLF 1st Qtr 1999 90th Percentile
Avg FRM mass = 20.74 ug/m3, n=6



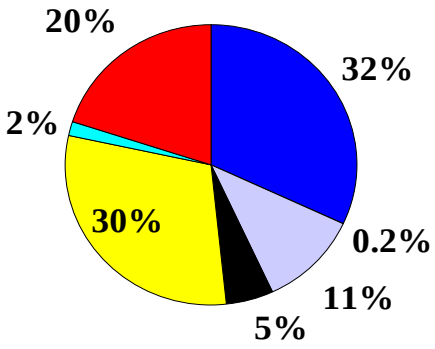
OLF 2nd Qtr 1999 90th Percentile
Avg FRM mass = 20.71 ug/m3, n=6



OLF 3rd Qtr 1999 90th Percentile
Avg FRM mass = 27.69 ug/m3, n=6



OLF 4th Qtr 1999 90th Percentile
Avg FRM mass = 25.08 ug/m3, n=9



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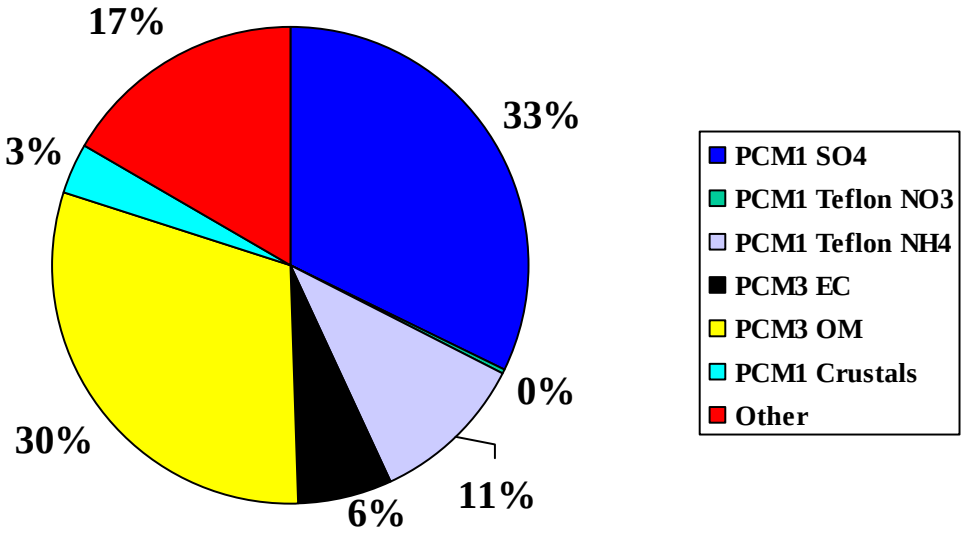
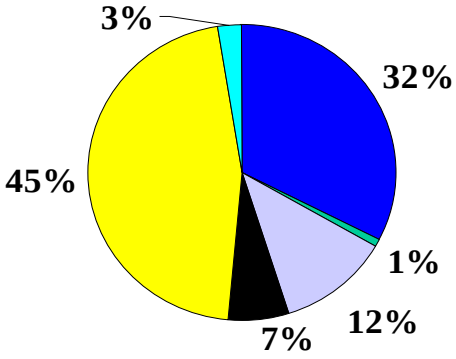
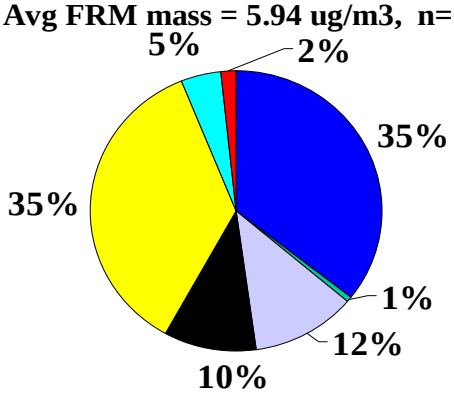
OLF 1999 Annual Average PM2.5 Composition by Percent
Average FRM mass = 12.12 ug/m3, n=234



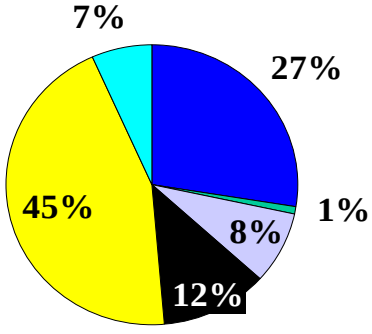
OLF 1st Qtr 1999 10th Percentile
Avg FRM mass = 3.53 ug/m3, n=6



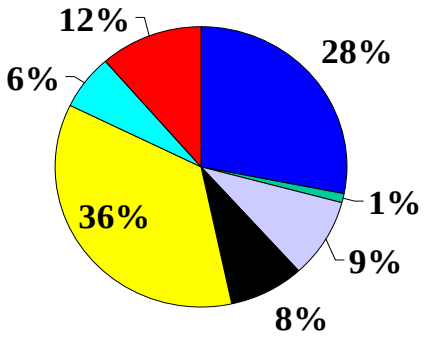
OLF 2nd Qtr 1999 10th Percentile
Avg FRM mass = 5.94 ug/m3, n=6



OLF 3rd Qtr 1999 10th Percentile
Avg FRM mass = 3.96 ug/m3, n=7



OLF 4th Qtr 1999 90th Percentile
Avg FRM mass = 4.78 ug/m3, n=9



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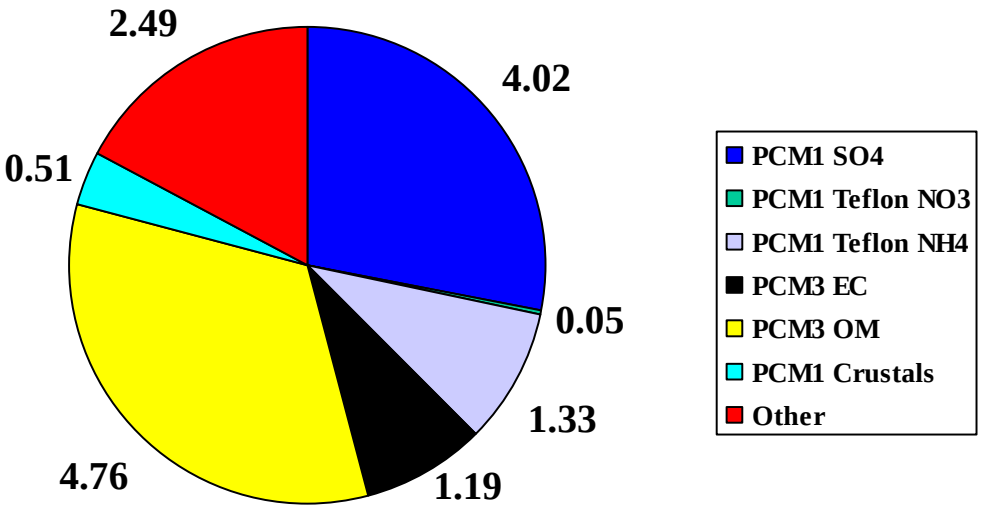
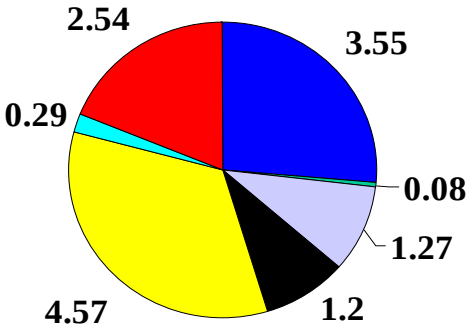
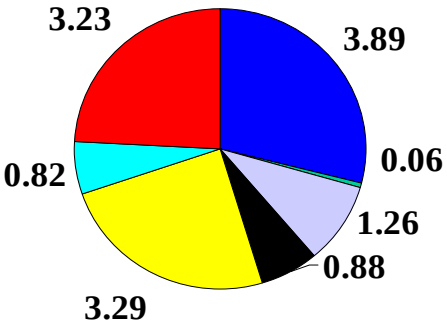
PNS 1999 Annual Average PM2.5 Composition by Mass
Average FRM mass = 14.35 ug/m3, n=237



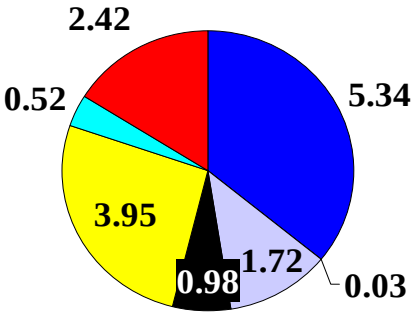
PNS 1st Qtr 1999
Avg FRM mass = 13.50 ug/m3, n=45



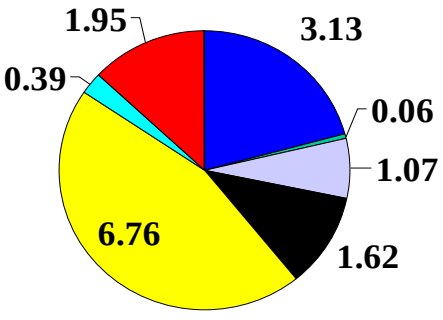
PNS 2nd Qtr 1999
Avg FRM mass = 13.43 ug/m3, n=60



PNS 3rd Qtr 1999
Avg FRM mass = 14.96 ug/m3, n=74



PNS 4th Qtr 1999
Avg FRM mass = 14.98 ug/m3, n=78



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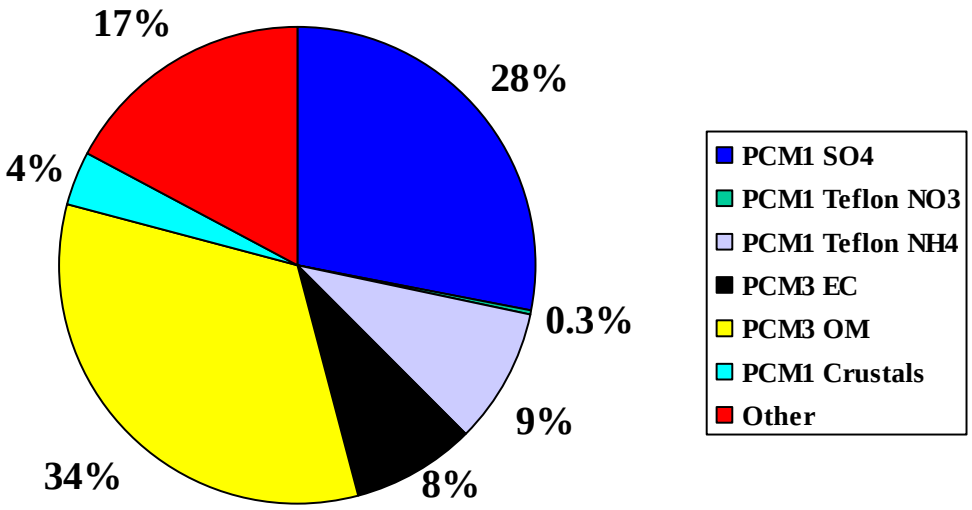
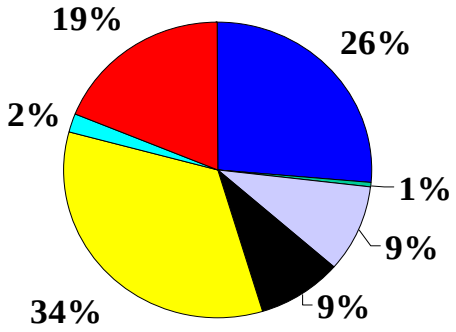
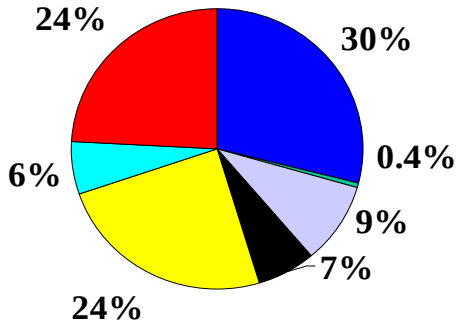
PNS 1999 Annual Average PM2.5 Composition by Percent
Average FRM mass = 14.35 ug/m3, n=237



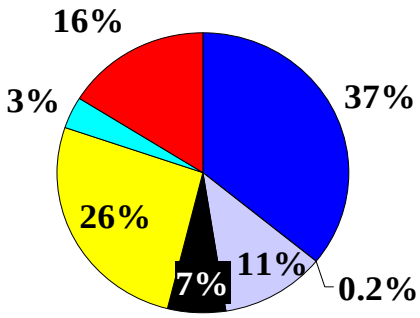
PNS 1st Qtr 1999
Avg FRM mass = 13.50 ug/m3, n=45



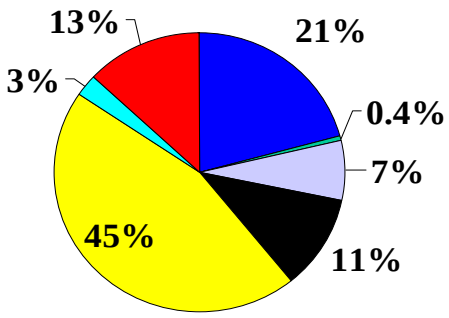
PNS 2nd Qtr 1999
Avg FRM mass = 13.43 ug/m3, n=60



PNS 3rd Qtr 1999
Avg FRM mass = 14.96 ug/m3, n=74



PNS 4th Qtr 1999
Avg FRM mass = 14.98 ug/m3, n=78



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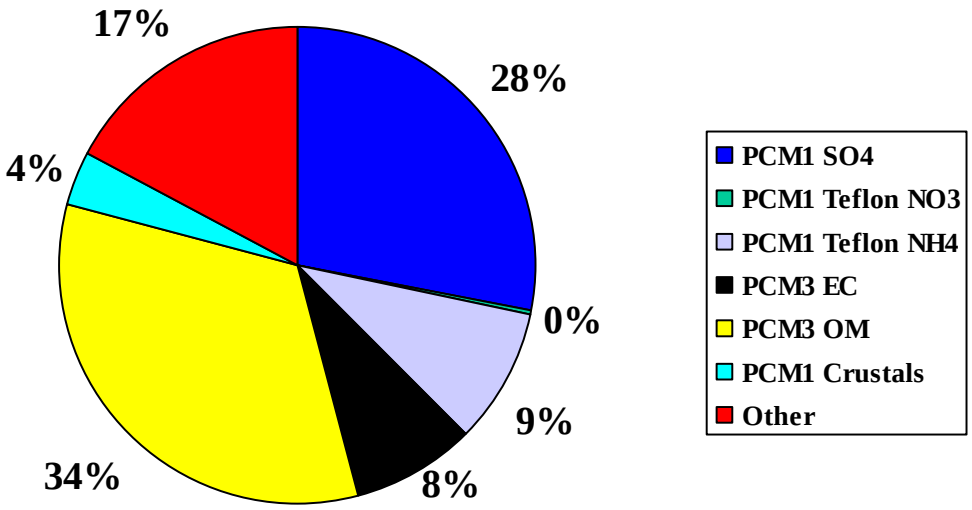
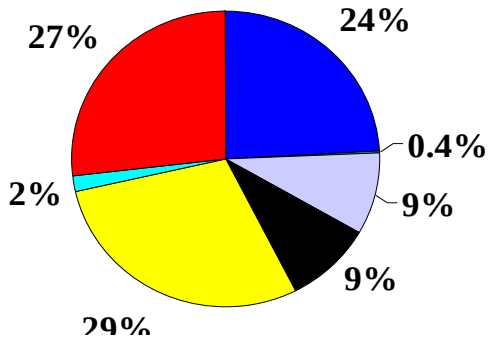
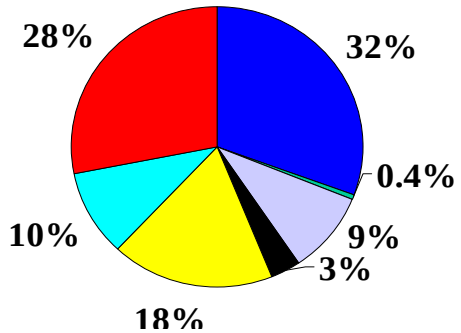
PNS 1999 Annual Average PM2.5 Composition by Percent
Average FRM mass = 14.35 ug/m3, n=237



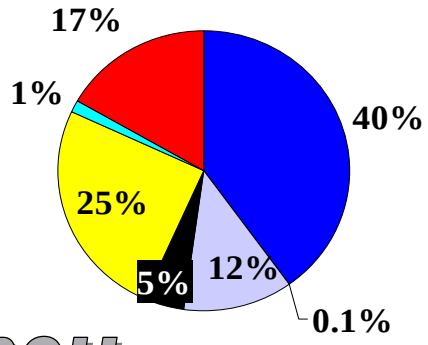
PNS 1st Qtr 1999 90th Percentile
Avg FRM mass =24.62 ug/m3, n=5



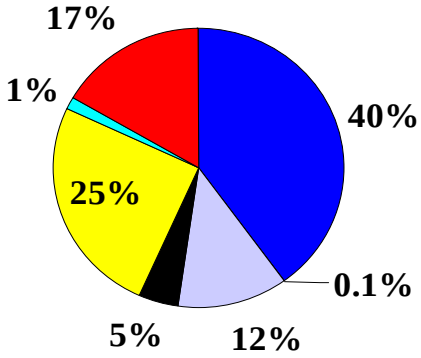
PNS 2nd Qtr 1999 90th Percentile
Avg FRM mass = 24.06 ug/m3, n=7



PNS 3rd Qtr 1999 90th Percentile
Avg FRM mass = 29.94 ug/m3, n=8



PNS 4th Qtr 1999 90th Percentile
Avg FRM mass = 29.16 ug/m3, n=9



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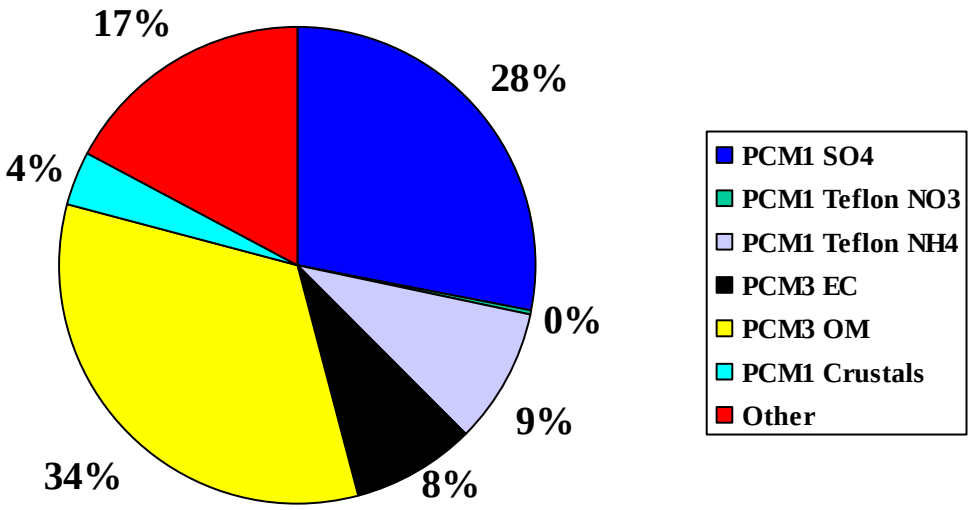
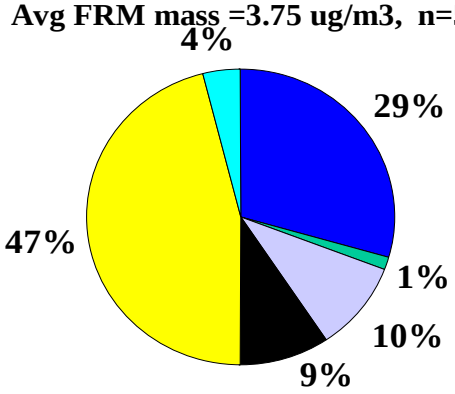
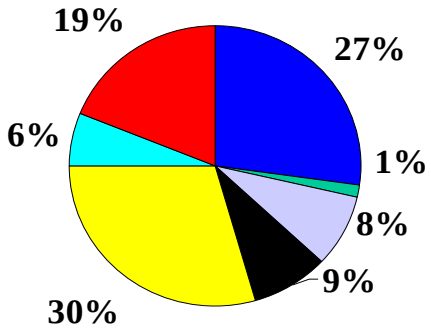
PNS 1999 Annual Average PM2.5 Composition by Percent
Average FRM mass = 14.35 ug/m3, n=237



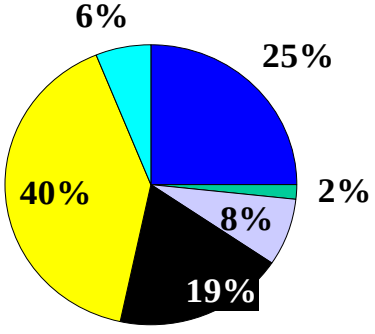
PNS 1st Qtr 1999 10th Percentile
Avg FRM mass =3.75 ug/m3, n=5



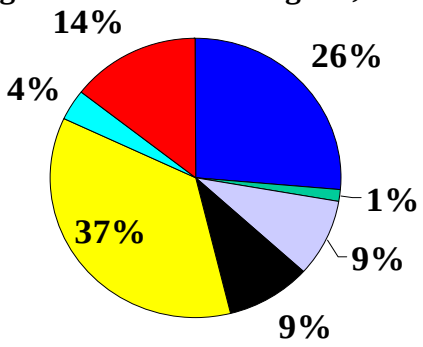
PNS 2nd Qtr 1999 10th Percentile
Avg FRM mass = 6.38 ug/m3, n=7



PNS 3rd Qtr 1999 10th Percentile
Avg FRM mass = 4.40 ug/m3, n=8



PNS 4th Qtr 1999 10th Percentile
Avg FRM mass = 6.19 ug/m3, n=9



SEARCH

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John Jansen, Southern Company

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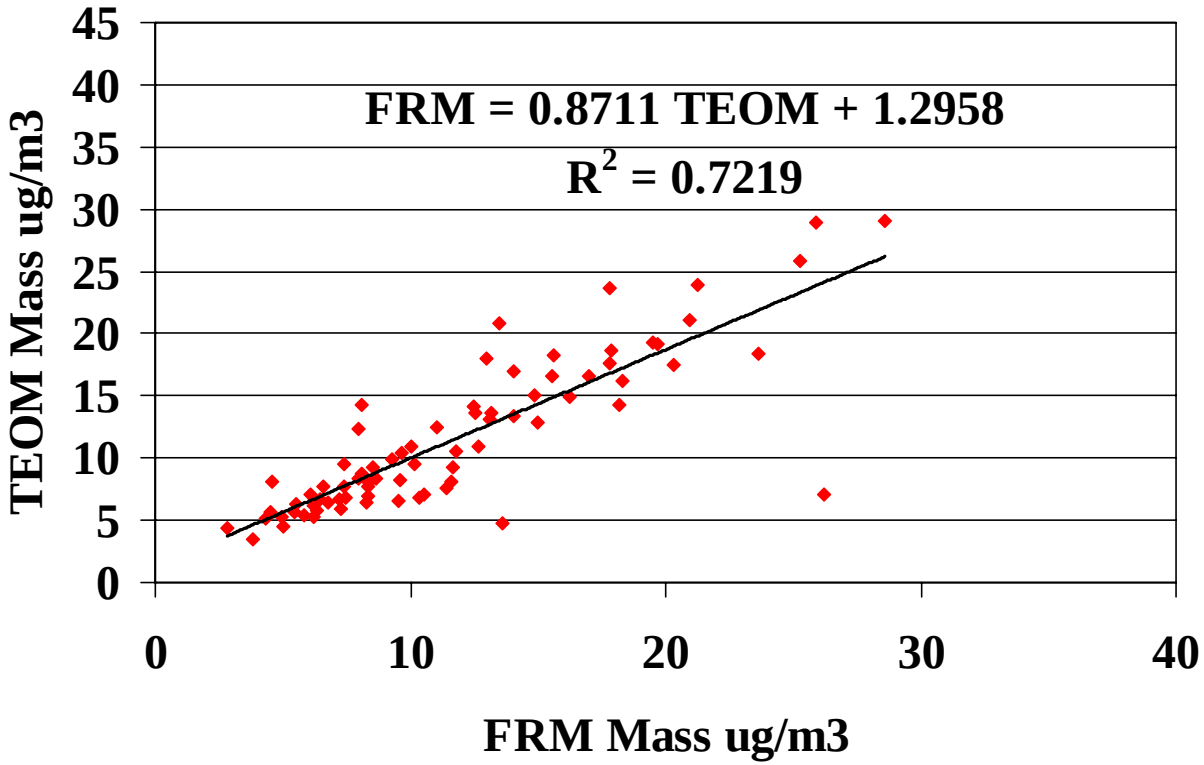
# CTR TEOM Mass vs FRM Mass
n=78



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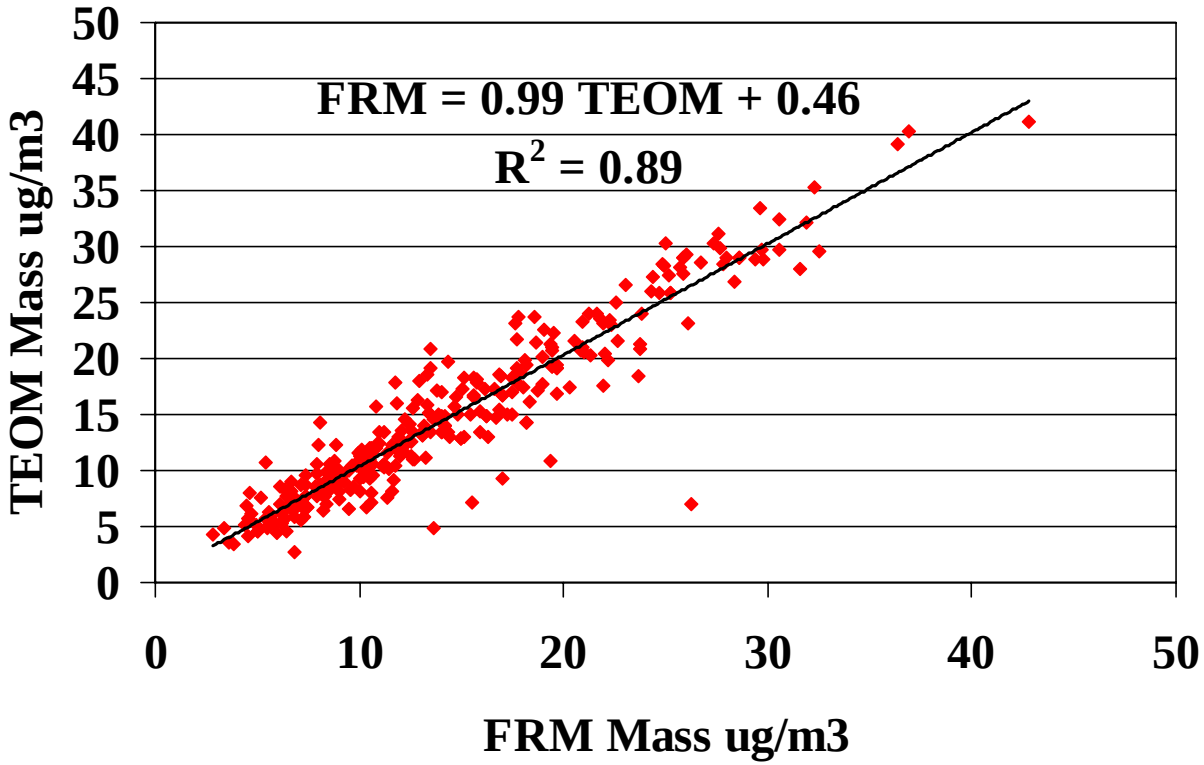
# Project To Date CTR TEOM Mass vs FRM Mass
n=286



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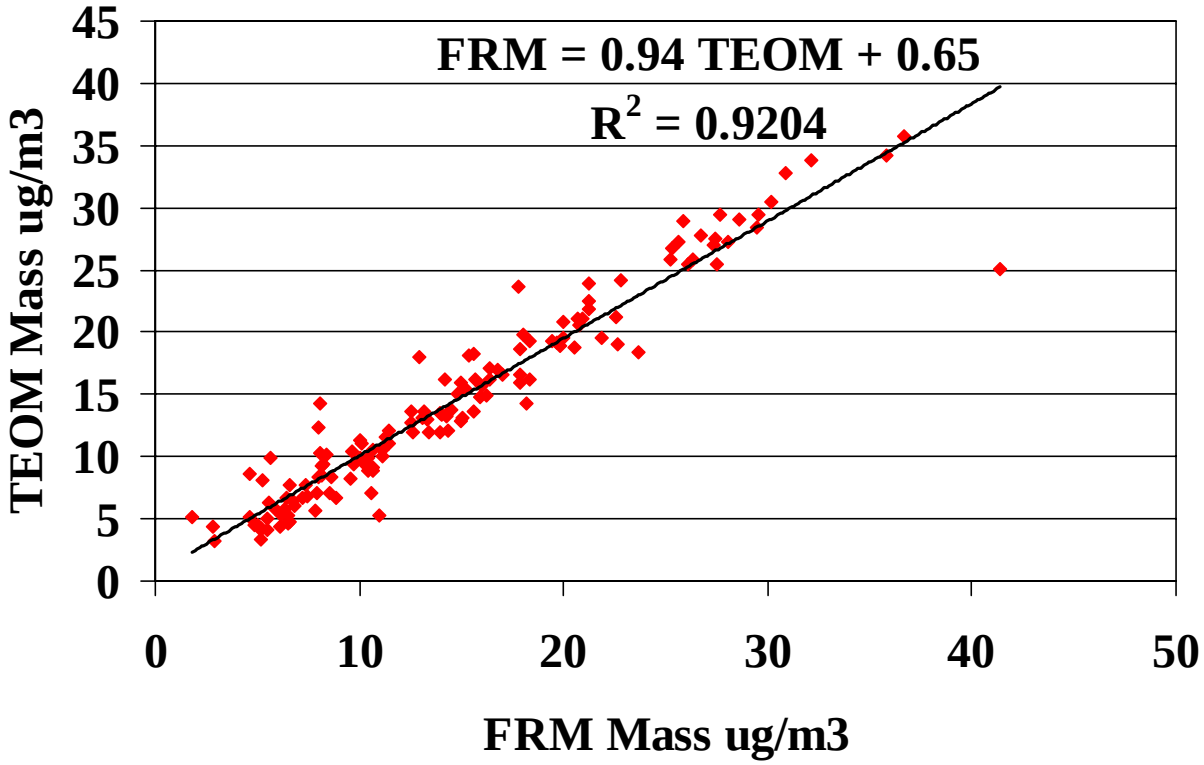
# YRK TEOM Mass vs FRM Mass
n=100



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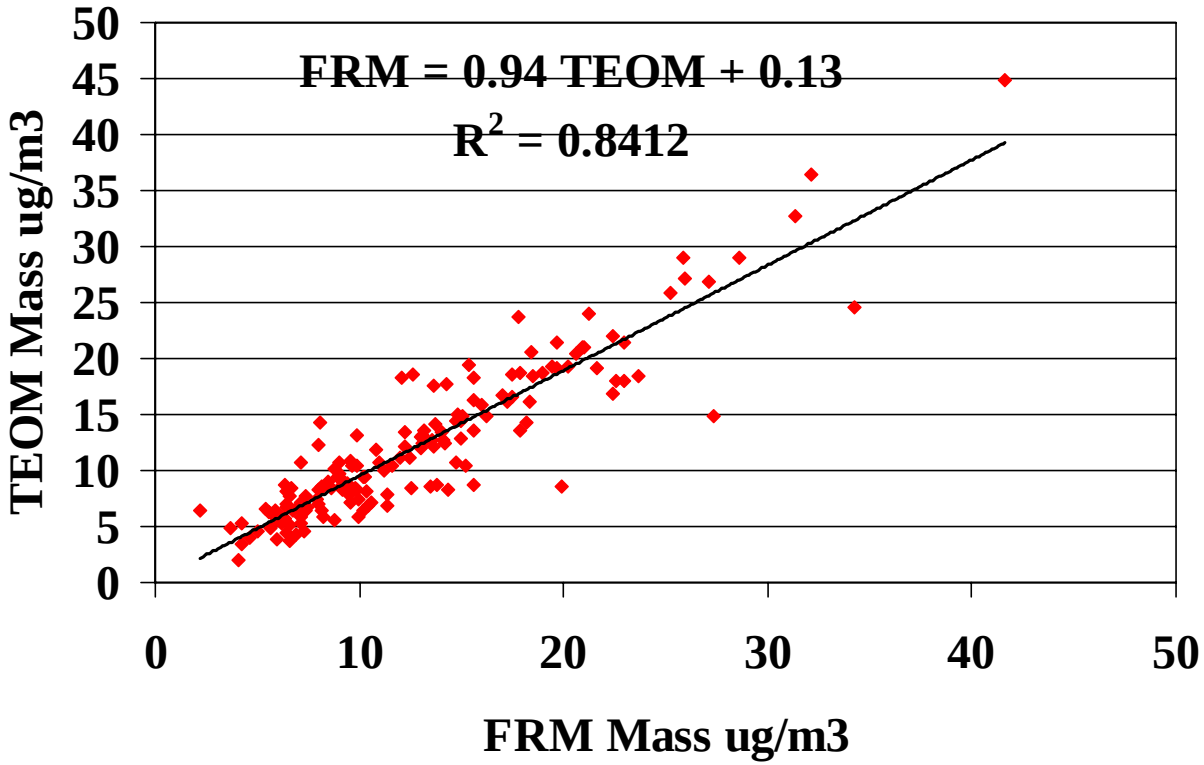
# OAK TEOM Mass vs FRM Mass
n=119



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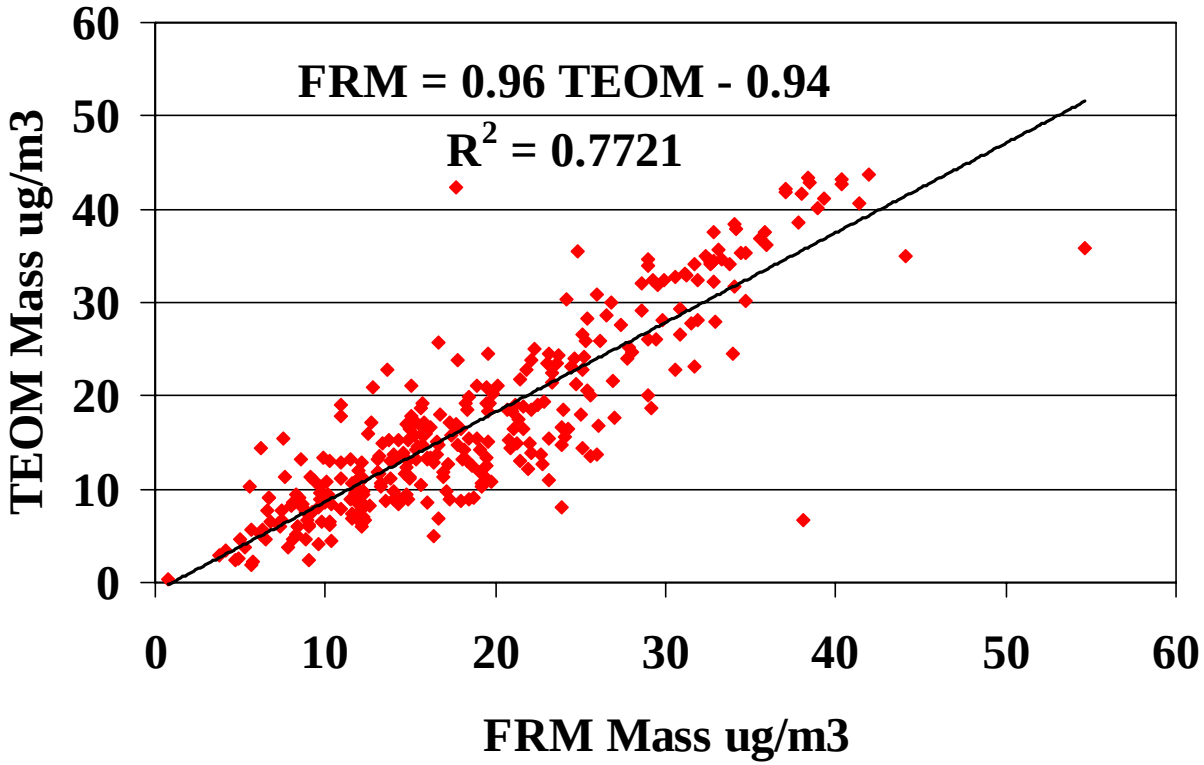
# JST TEOM Mass vs FRM Mass
n=307



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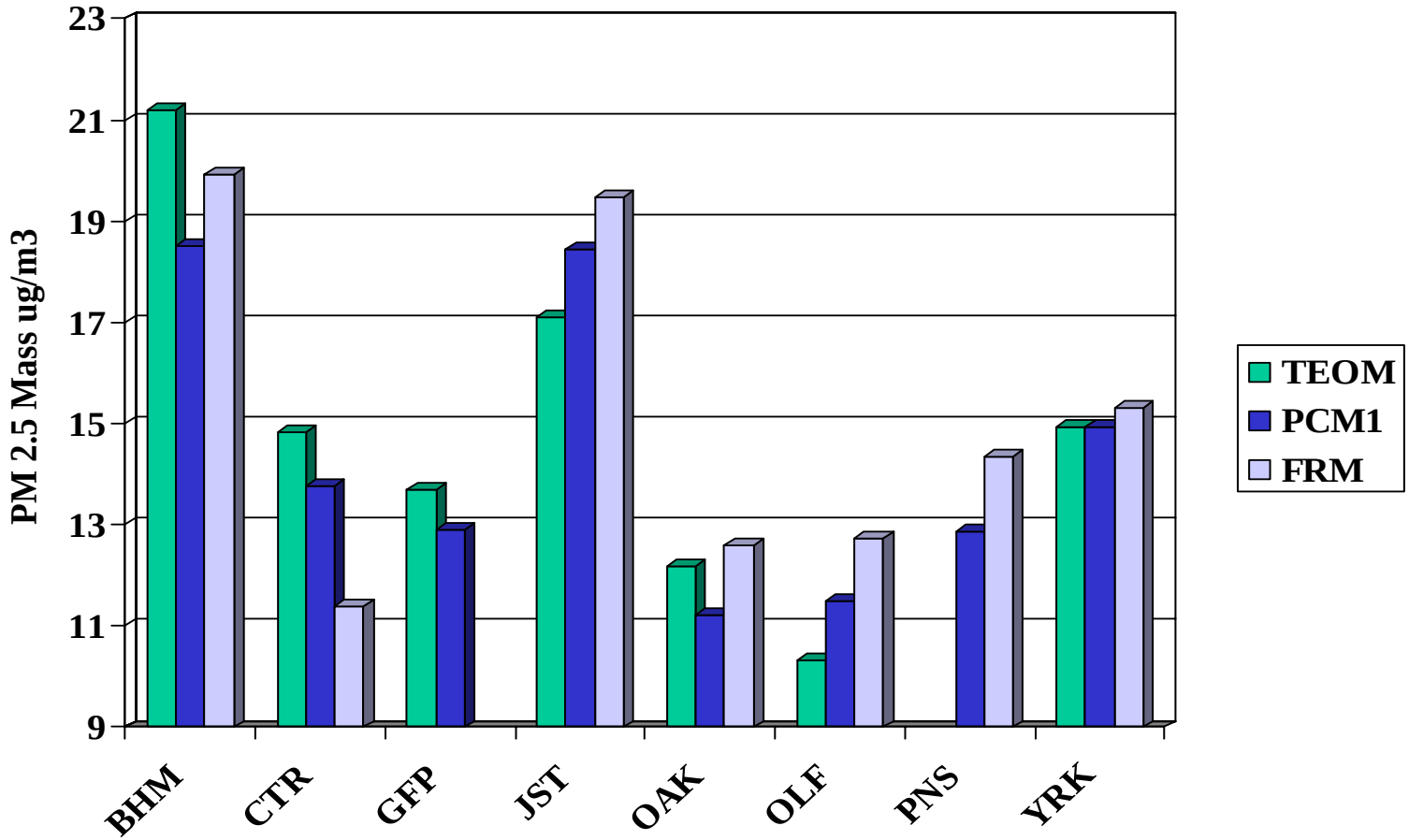
Comparison of 1999 Annual Average PM 2.5 Mass from Three different Mass Samplers operated on Different Sample Collection Schedules



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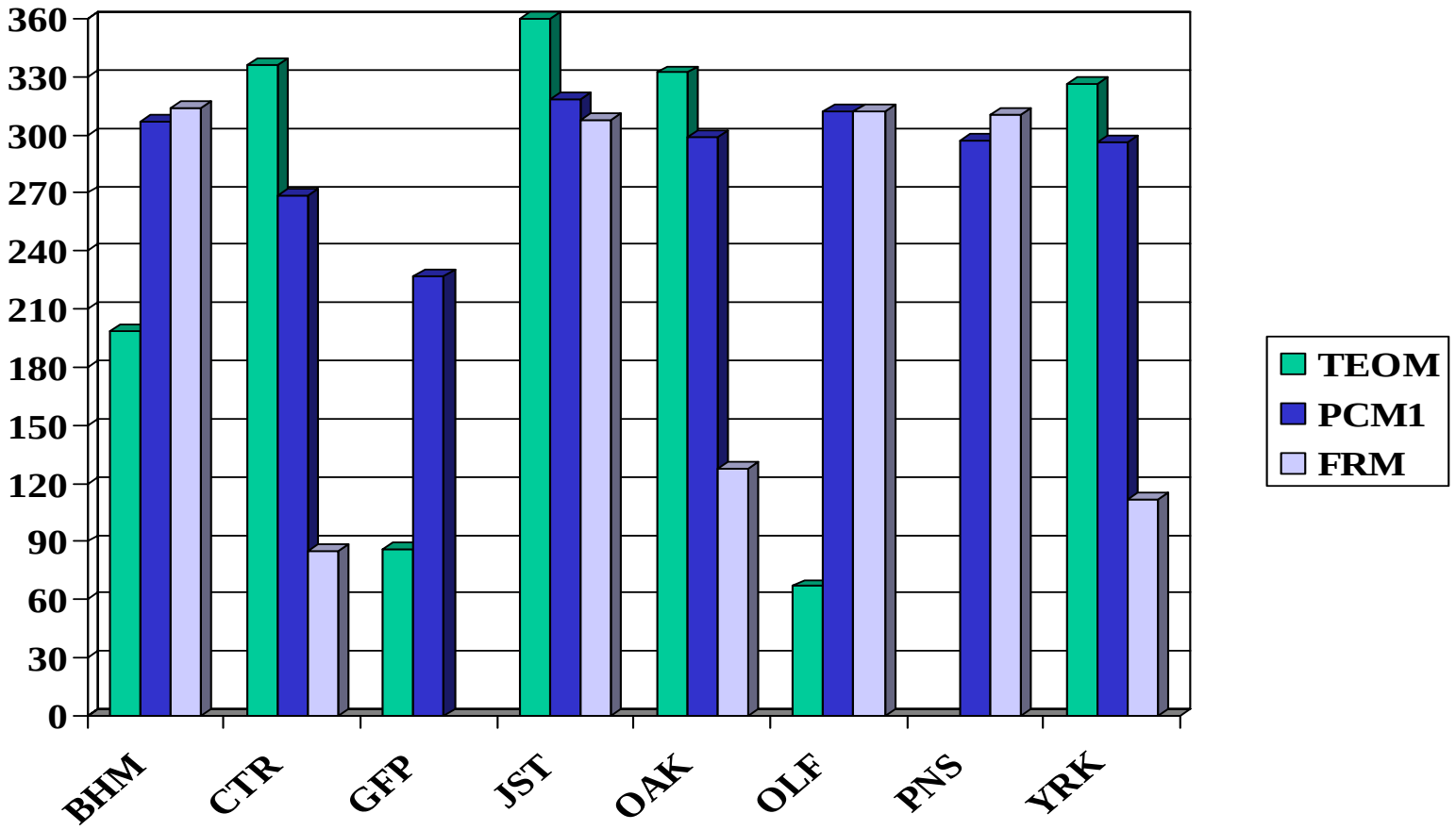
Number of Samples Included in 1999 Annual Mass Average



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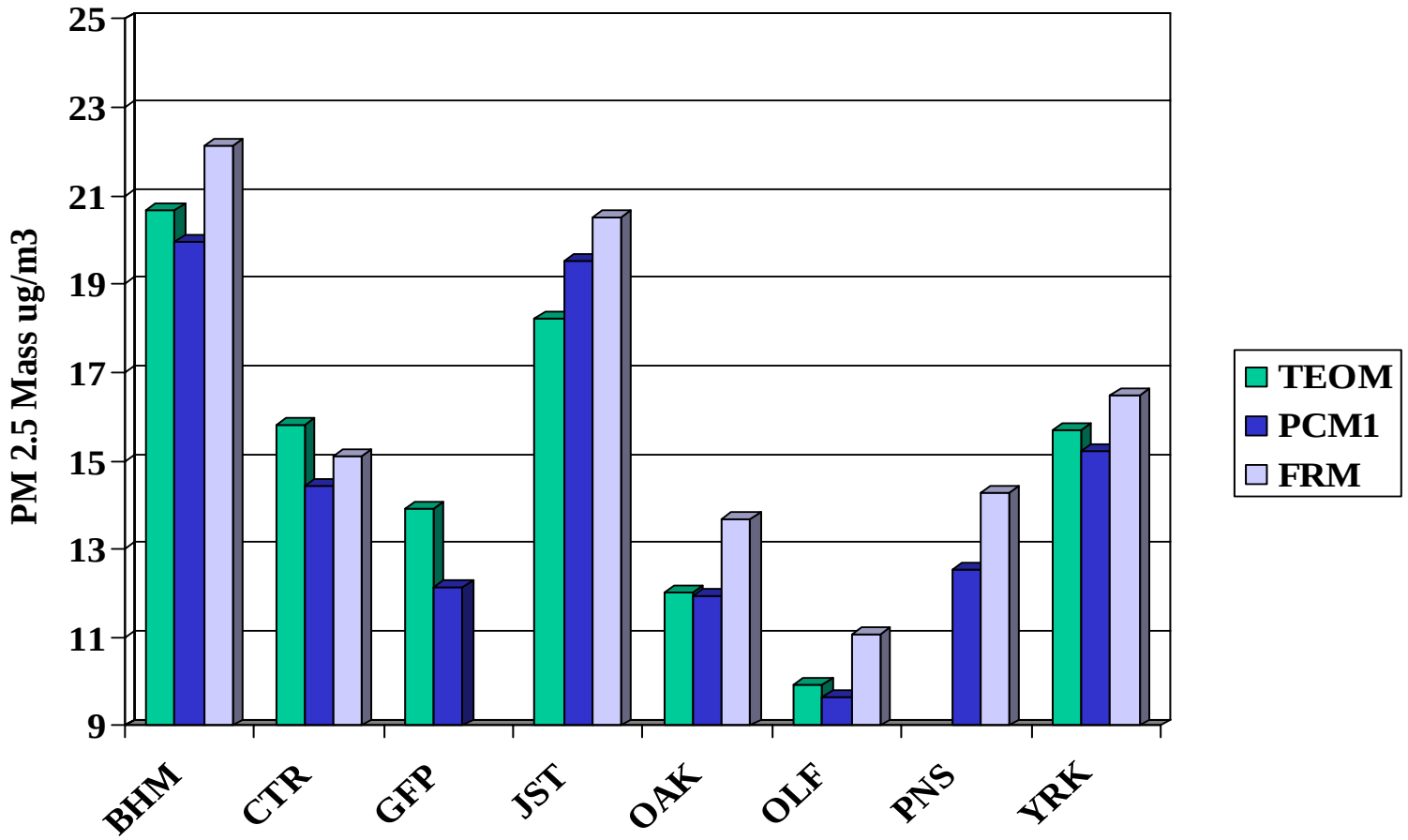
Comparison of Project To Date Average PM 2.5 Mass from Three different Mass Samplers operated on Different Sample Collection Schedules



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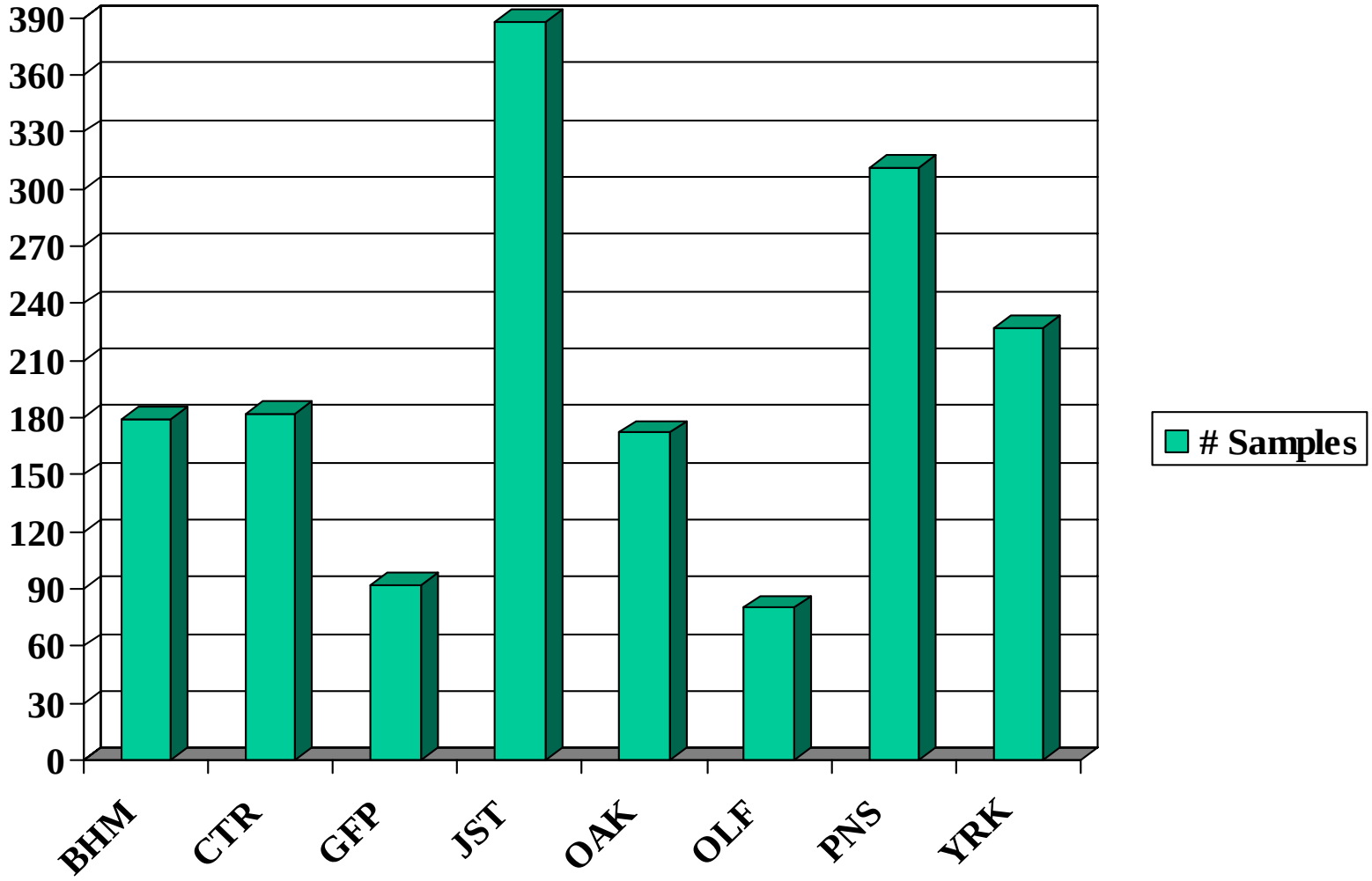

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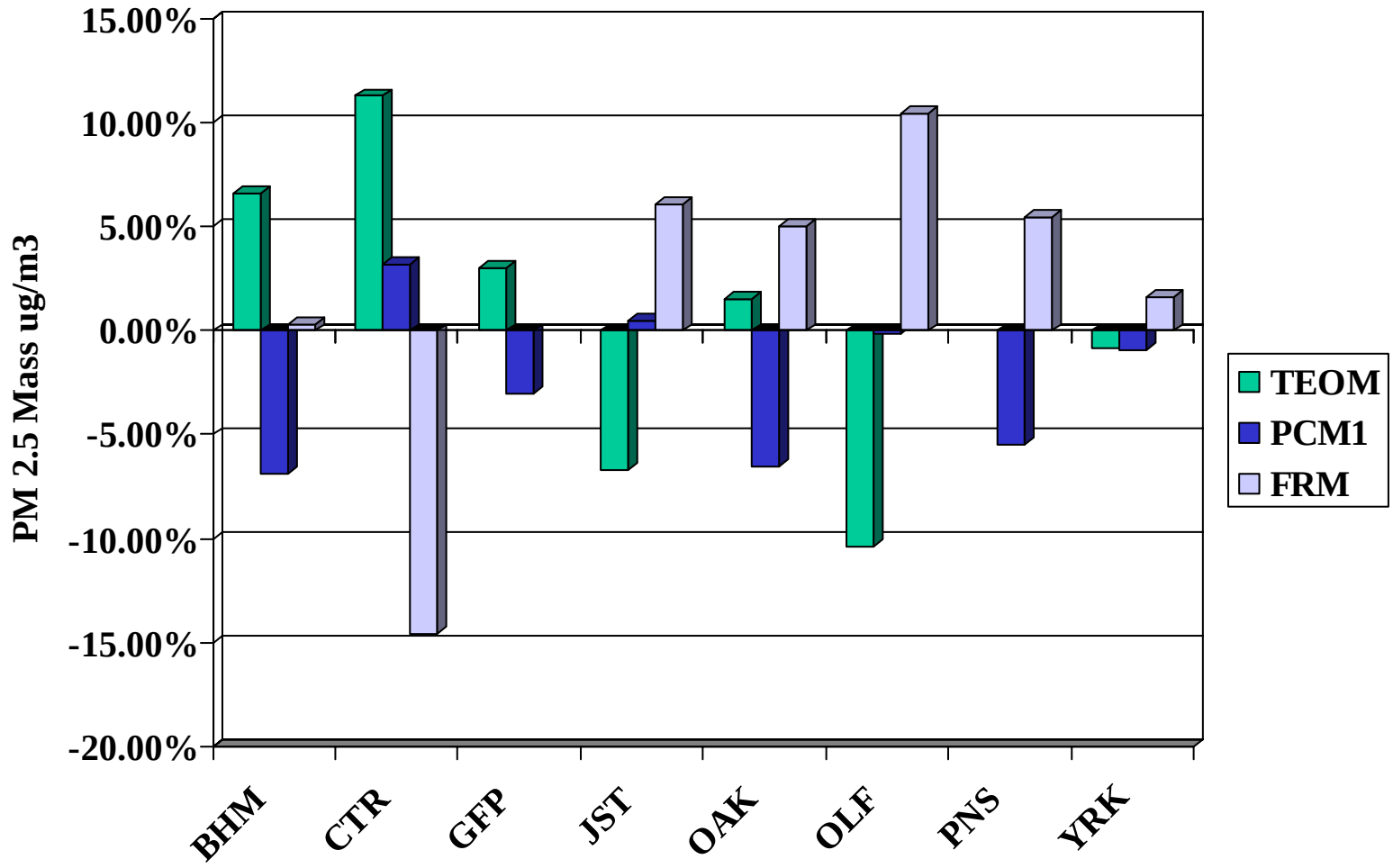
Deviation of 1999 Annual Average PM 2.5 Mass from Three different Mass Samplers from Mean of All Mass Measures



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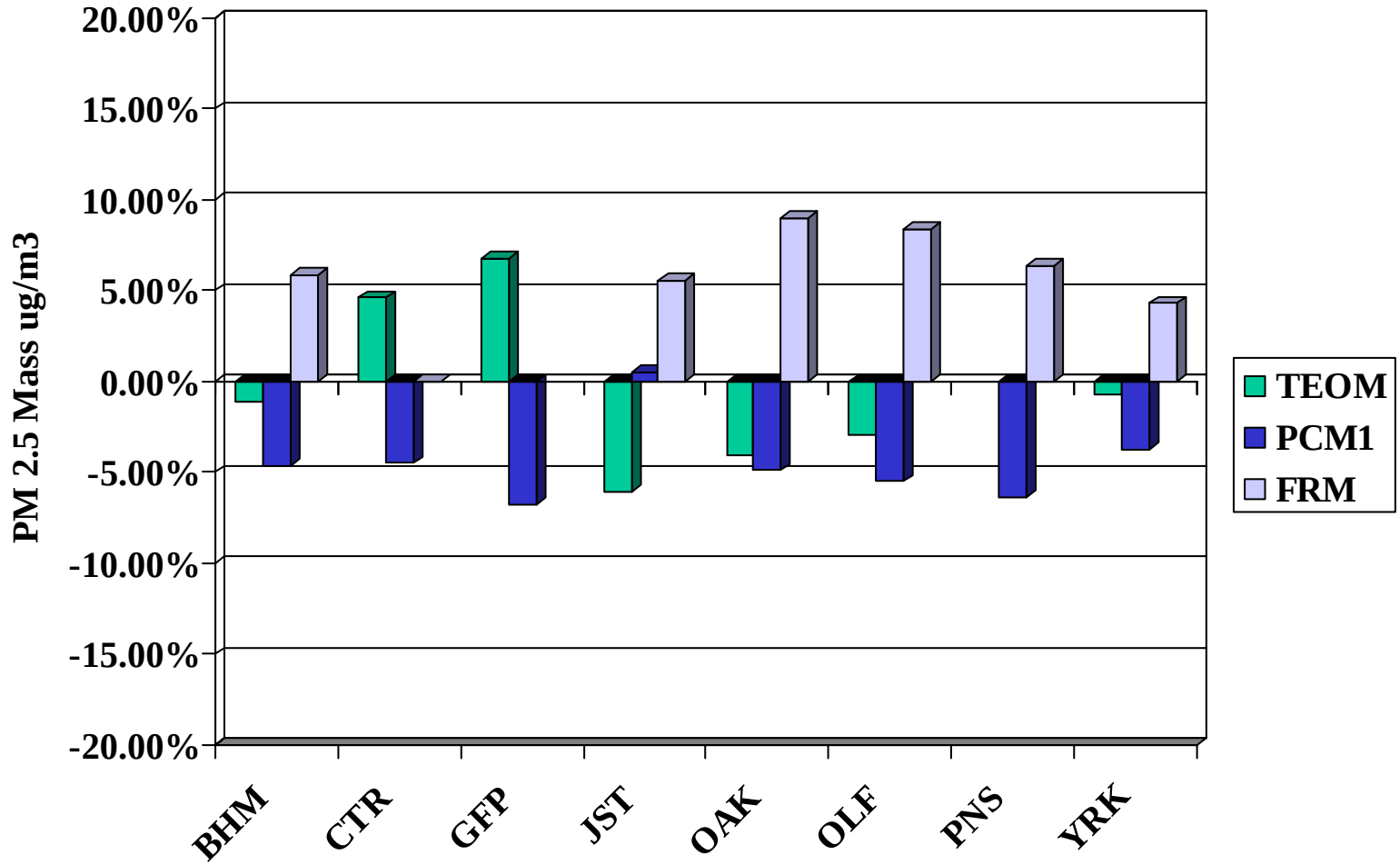

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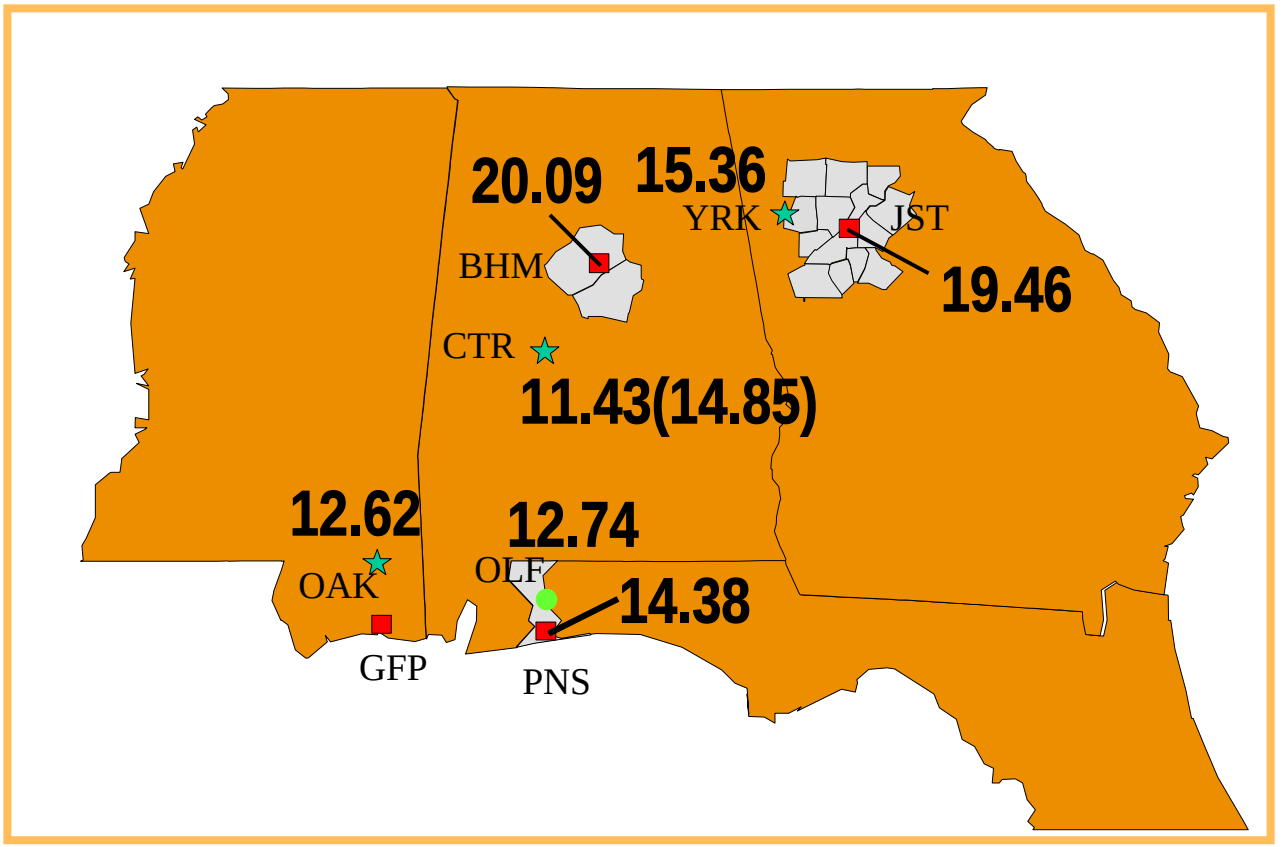
SEARCH 1999 Mean $PM_{2.5}$ Federal Reference Method (FRM) (ug/m^3)

Note: TEOM annual average also shown for CTR. FRM value suspect due to low sample recovery



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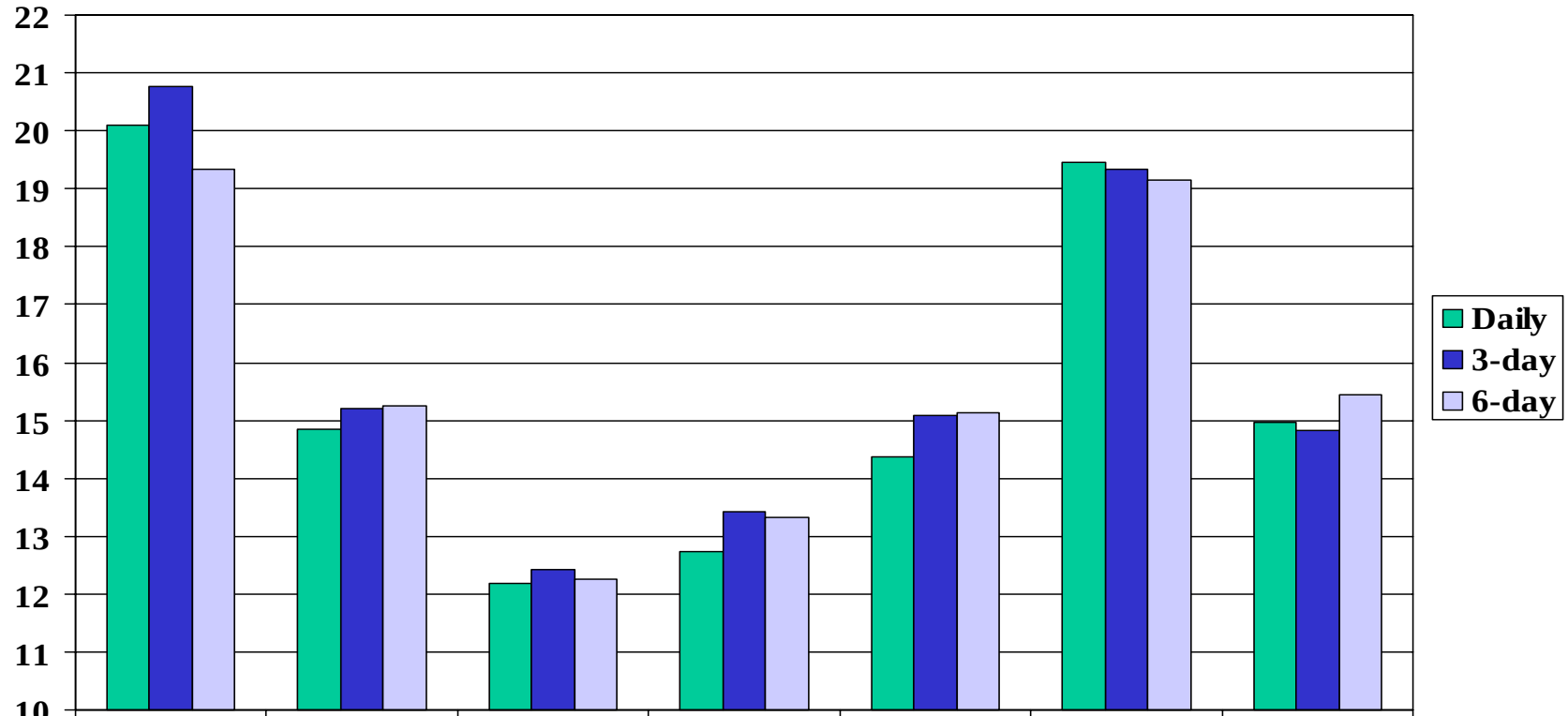
Effect of Sampling Frequency on Estimate of Annual PM 2.5 Mass Concentration

* Denotes TEOM mass data substituted for FRM mass data where FRM sampling was not daily



	BHM	CTR*	OAK*	OLF	PNS	JST	YRK*
Daily	20.09	14.85	12.19	12.74	14.38	19.46	14.96
3-day	20.77	15.20	12.43	13.43	15.09	19.34	14.83
6-day	19.34	15.24	12.25	13.32	15.14	19.16	15.43

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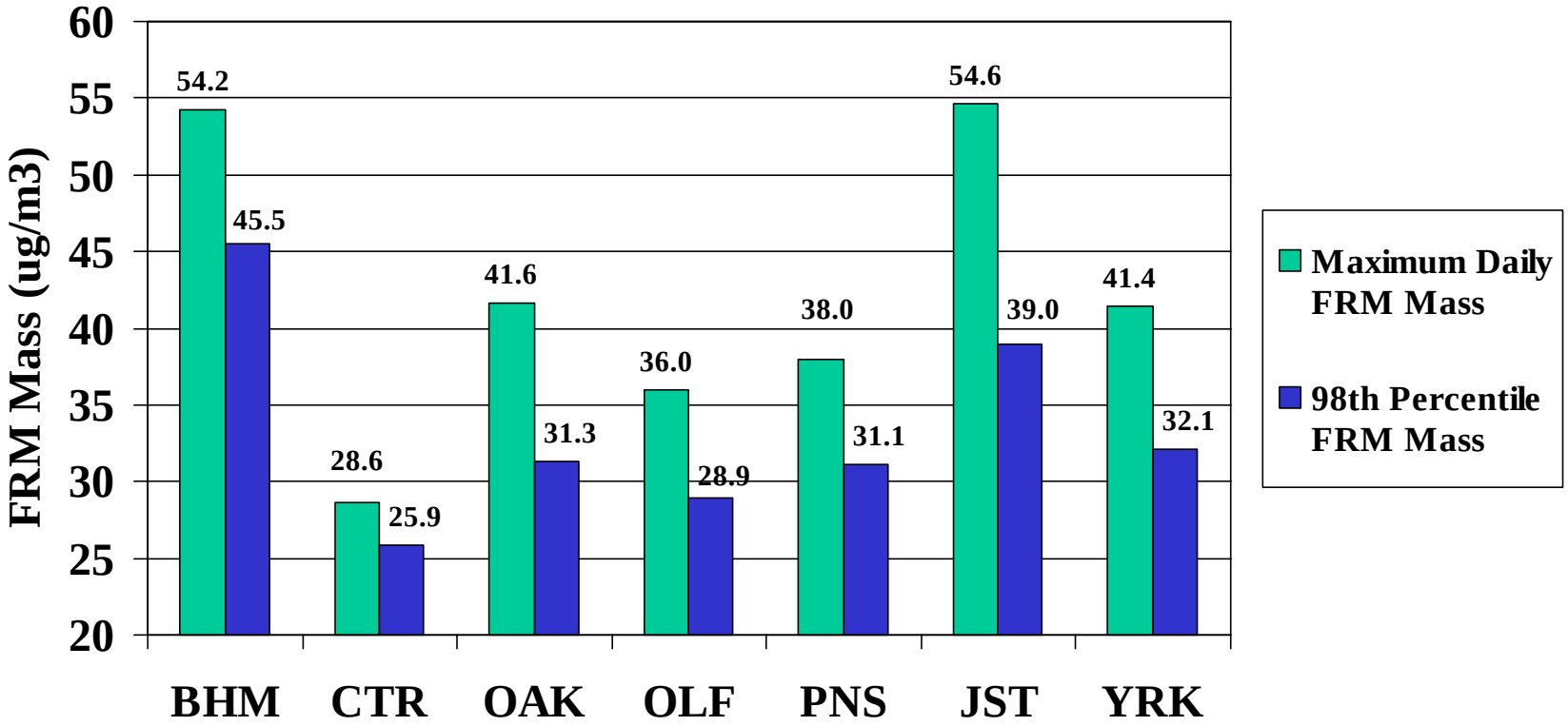
Annual Max and 98th Percentile FRM Mass

CY 1999



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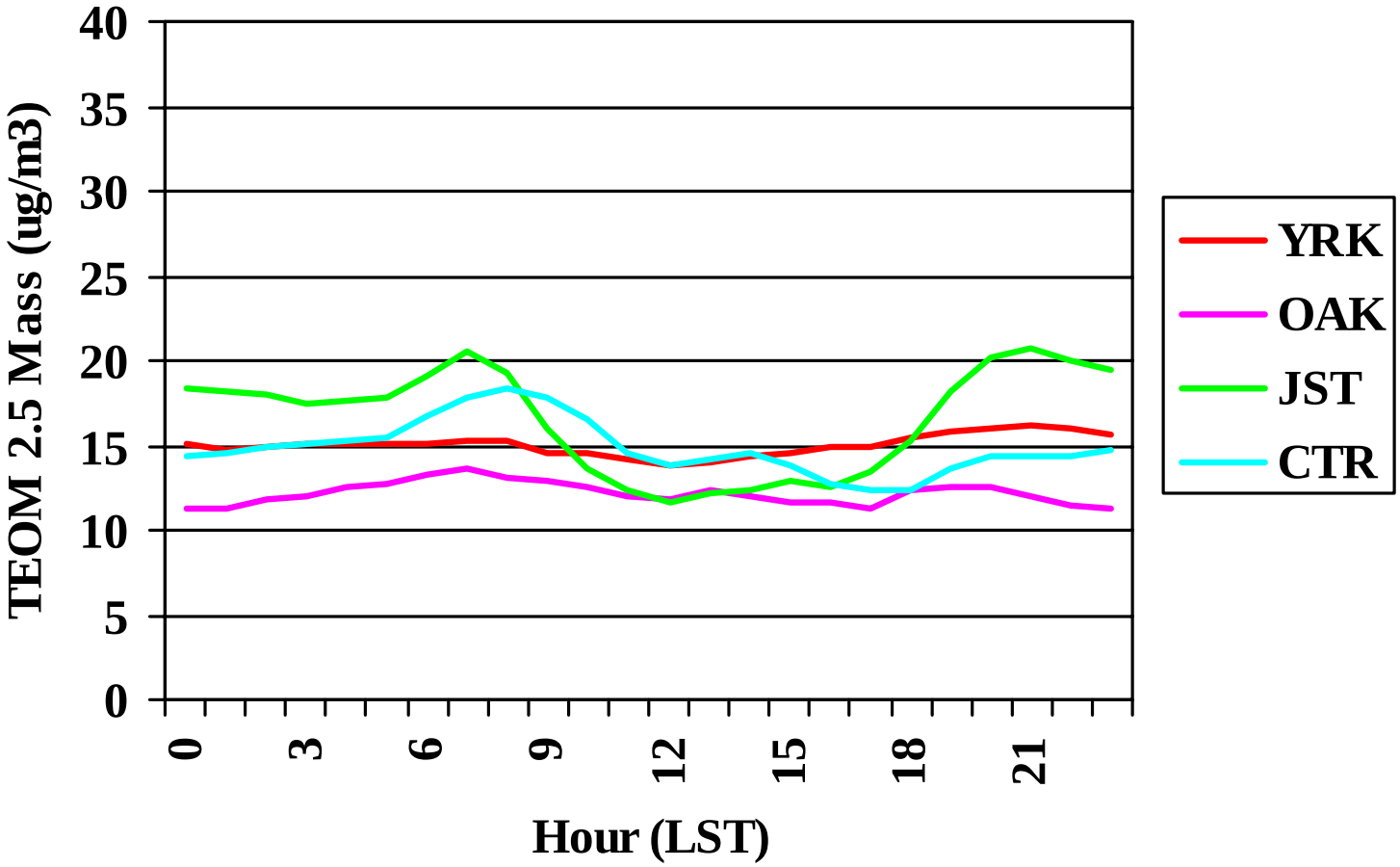
TEOM PM 2.5 Diurnal Profile
CY 1999*

4th Quarter '98 Data substituted for JST due to instrument malfunction in 4th Quarter '99



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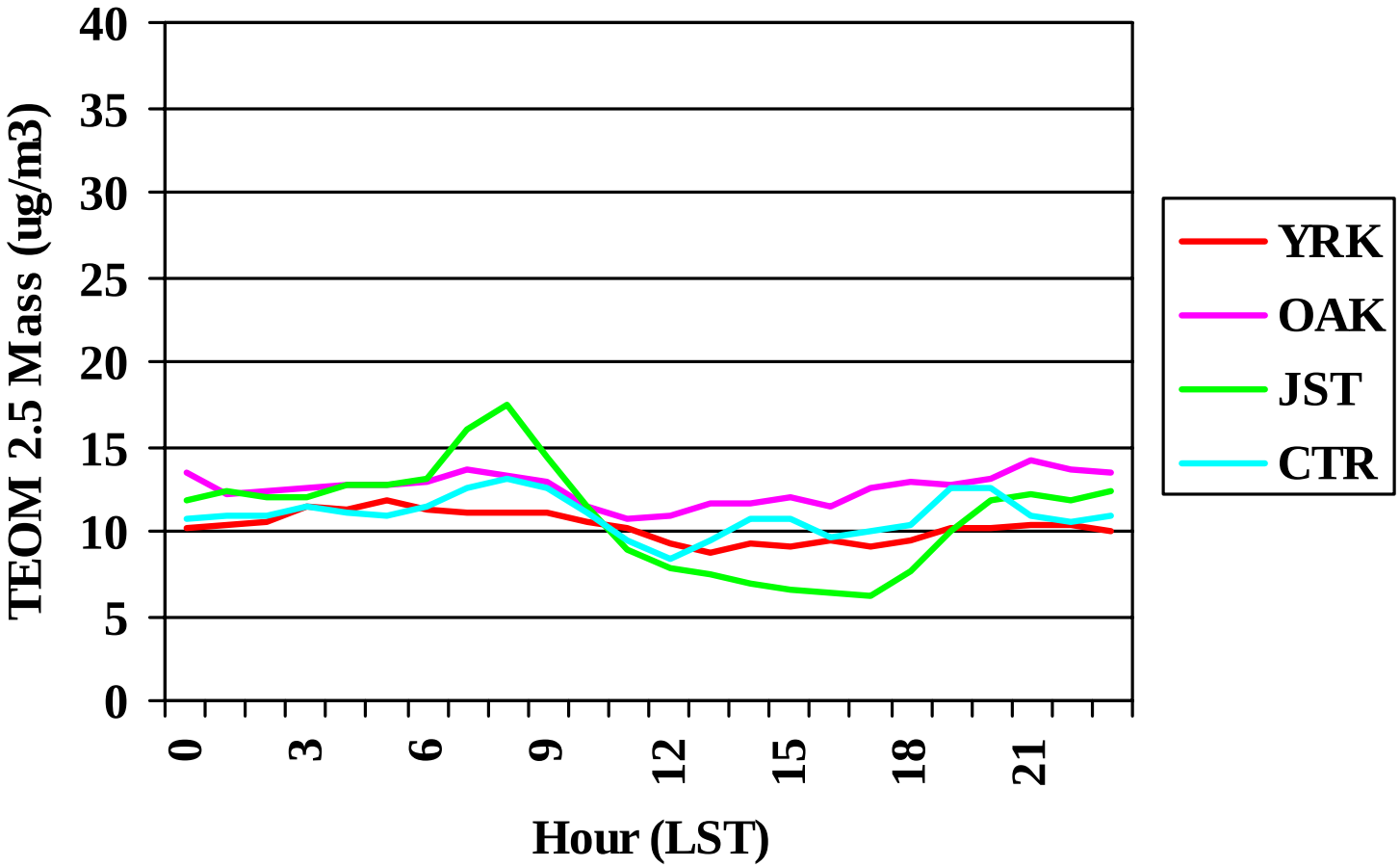
TEOM PM 2.5 Diurnal Profile
1st Quarter '99



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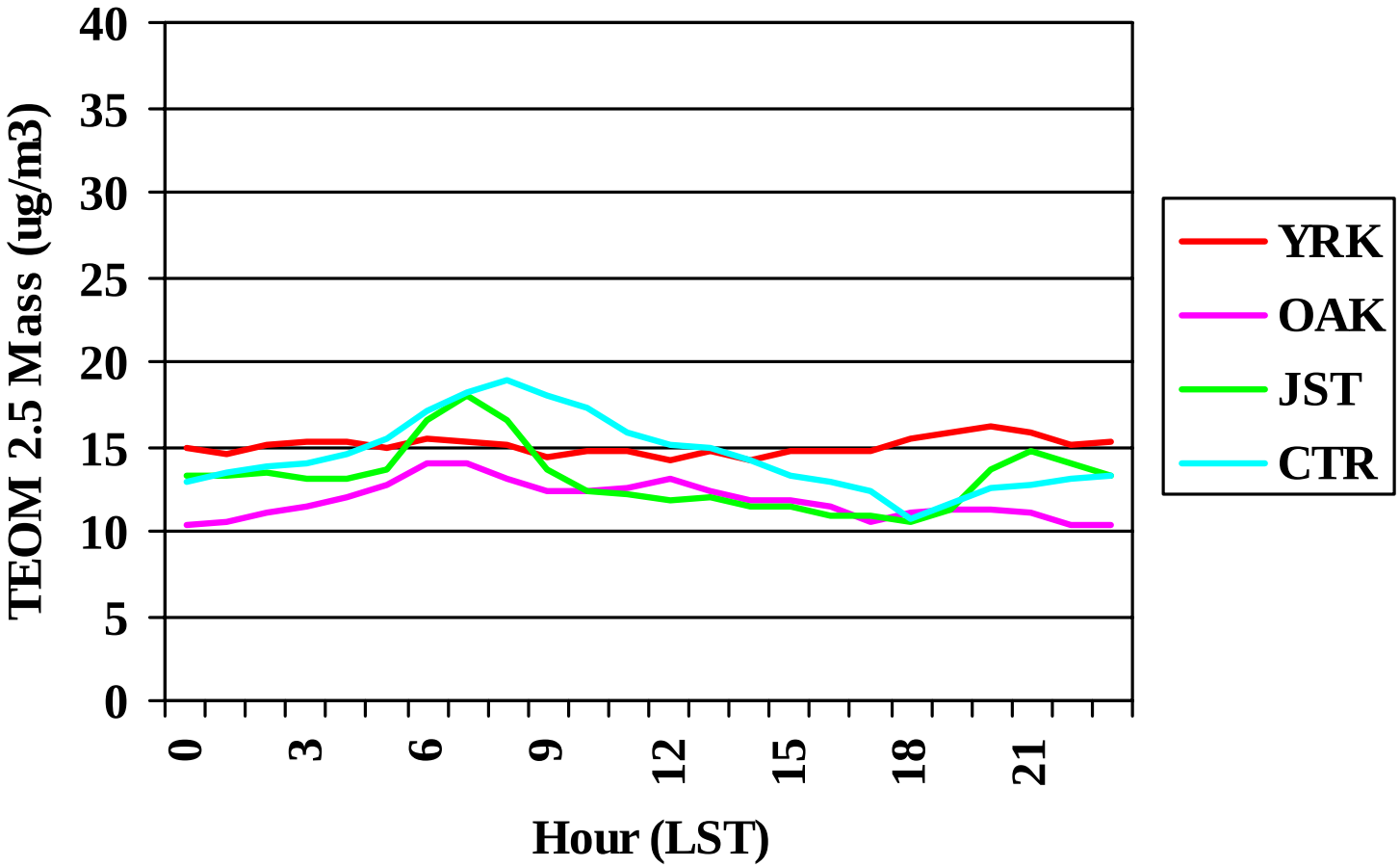
TEOM PM 2.5 Diurnal Profile
2nd Quarter '99



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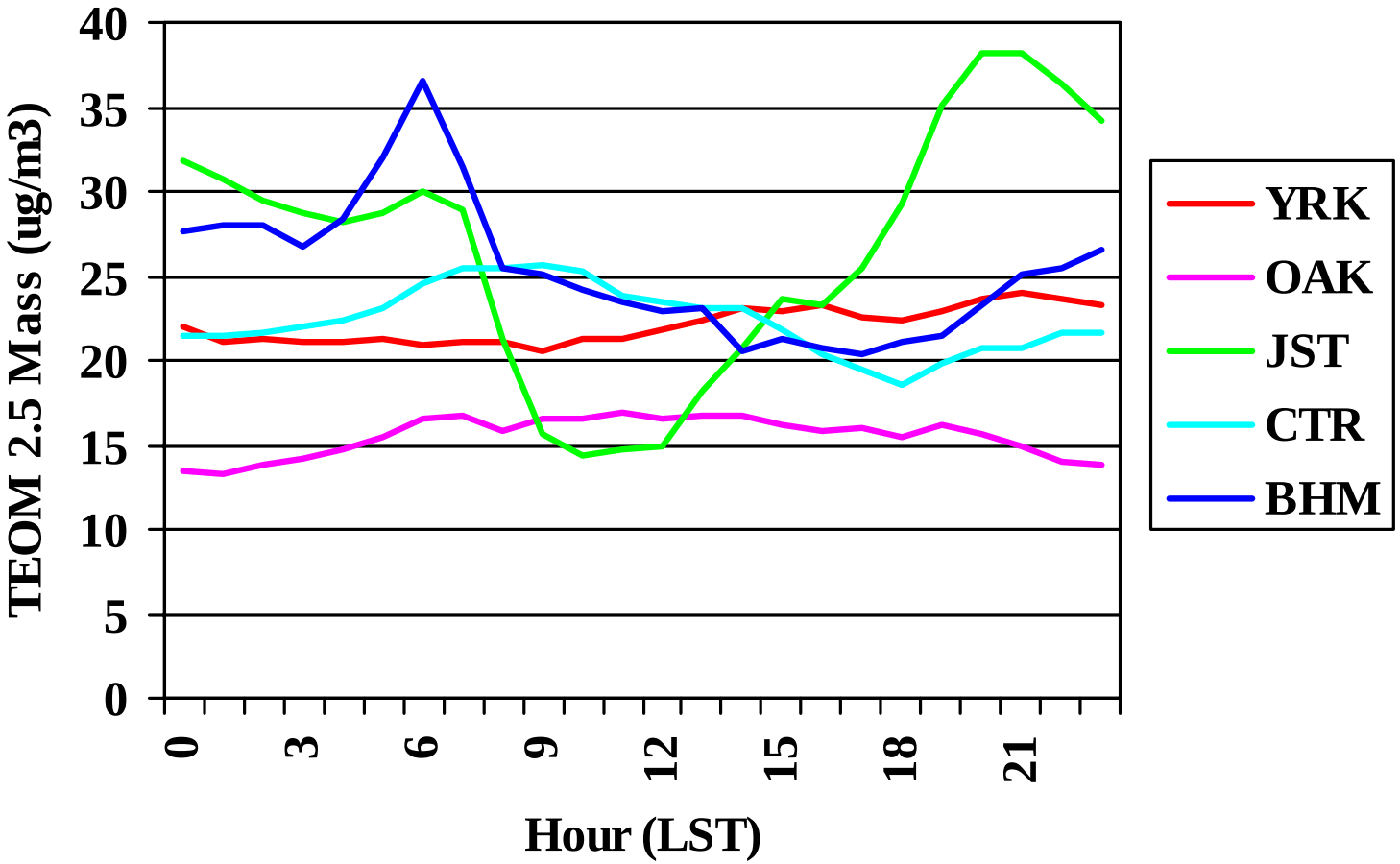
TEOM PM 2.5 Diurnal Profile
3rd Quarter '99



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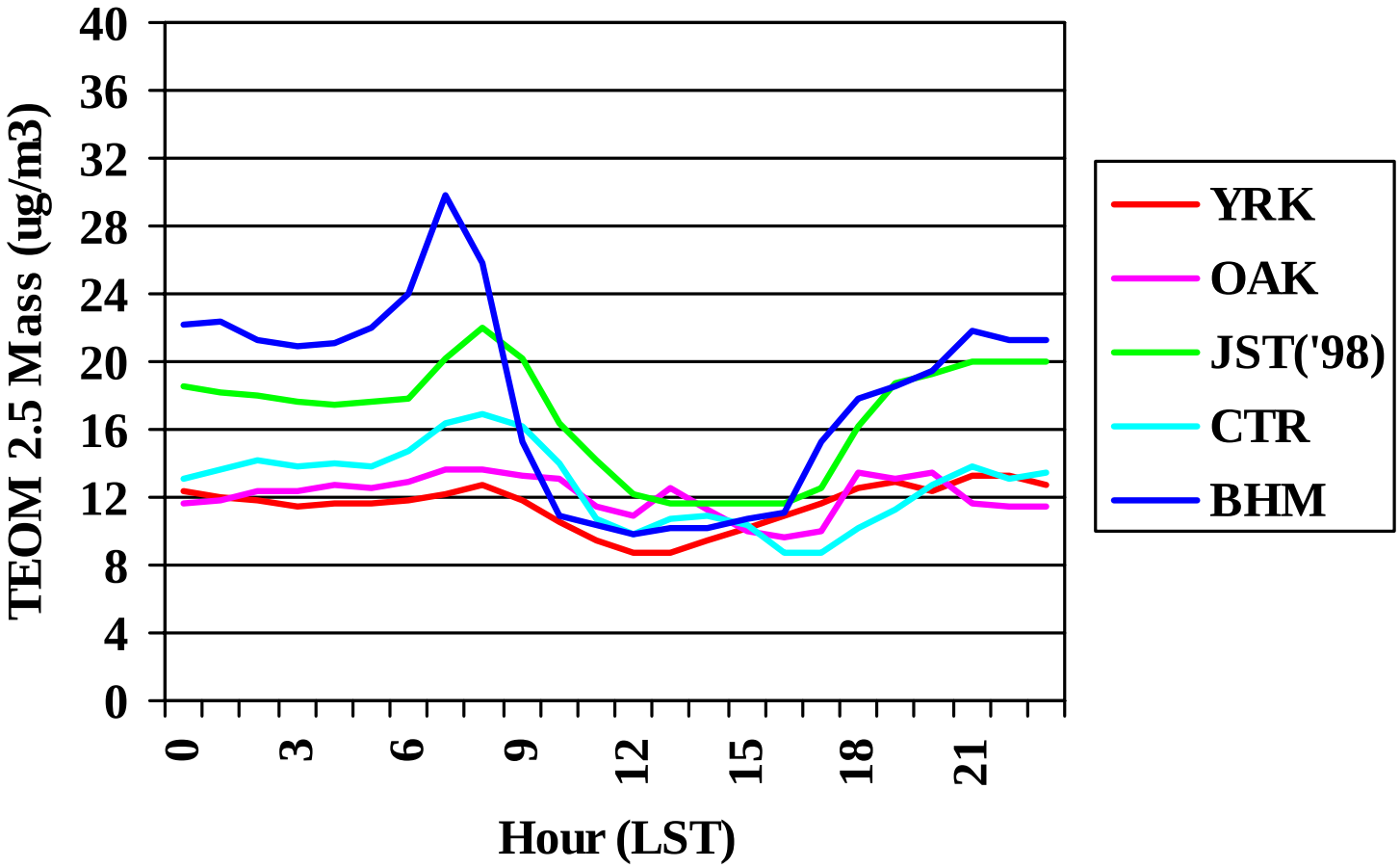
TEOM PM 2.5 ‘99 Diurnal Profile
4th Quarter ’99*

4th Quarter ’98 Data substituted for JST due to instrument malfunction in 4th Quarter ‘99



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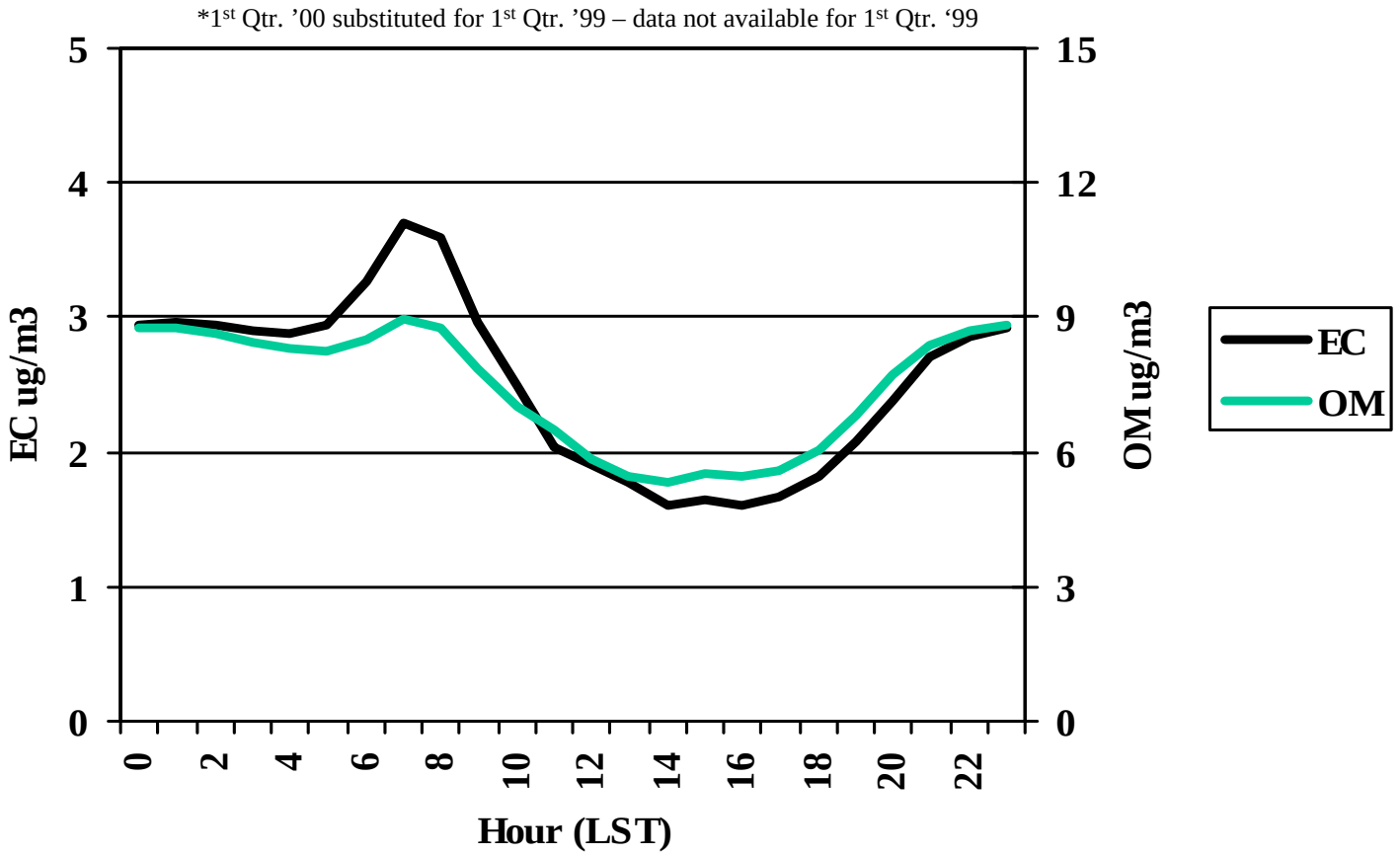
JST EC/OM Diurnal Profile
CY 1999*

Semi-Continuous Data from R&P 5400



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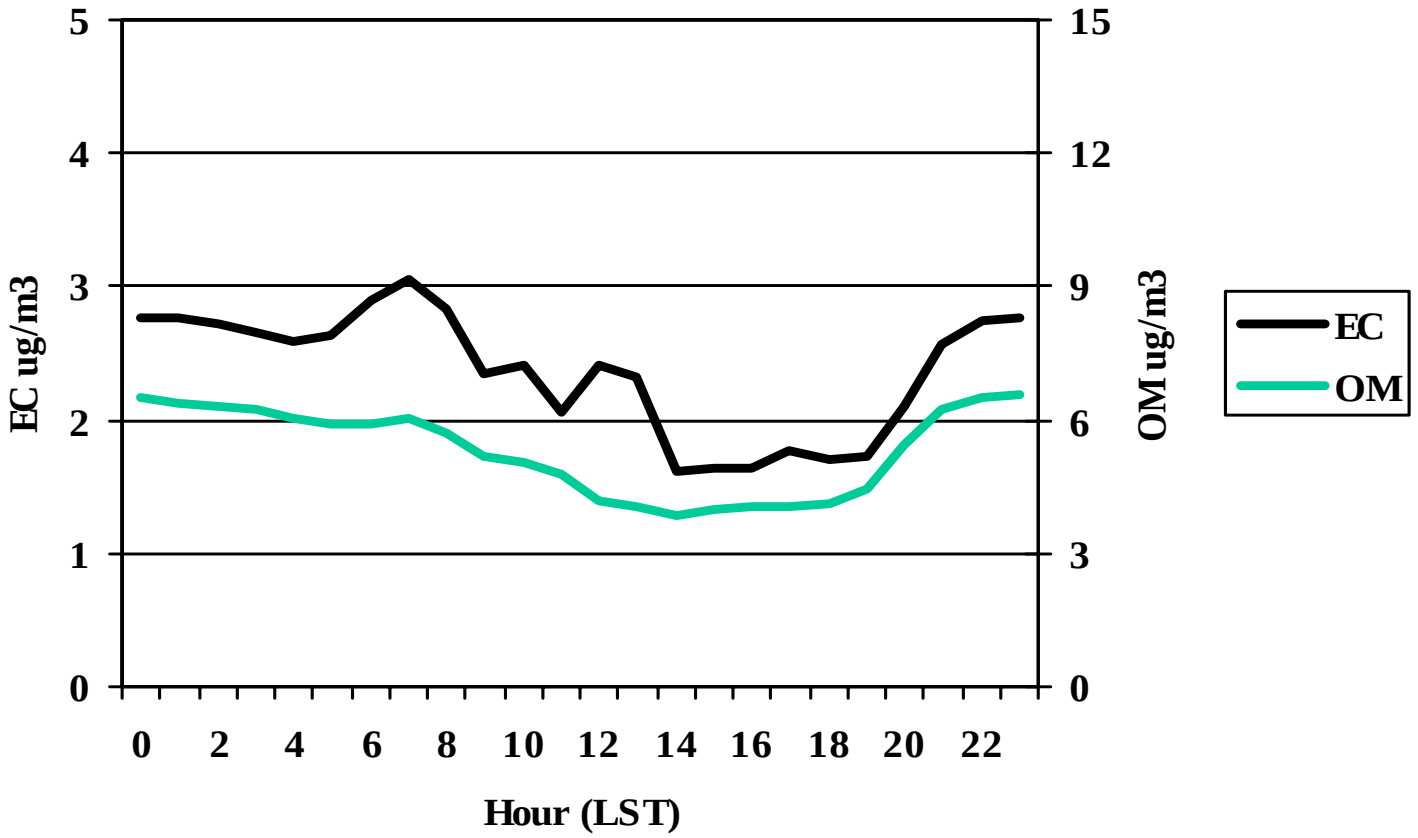
JST EC/OM Diurnal Profile
2nd Qtr. ’99
Semi-Continuous Data from R&P 5400



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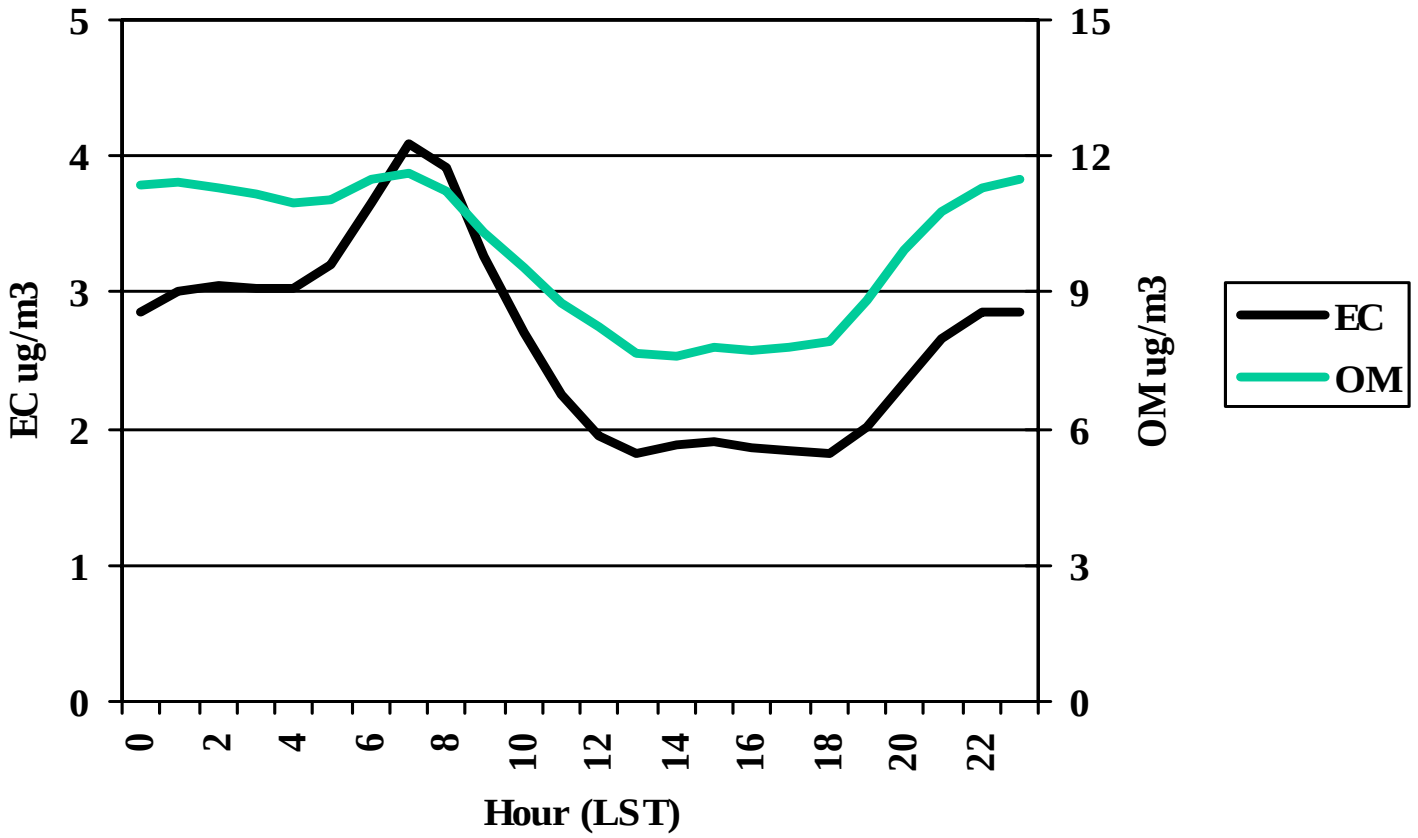

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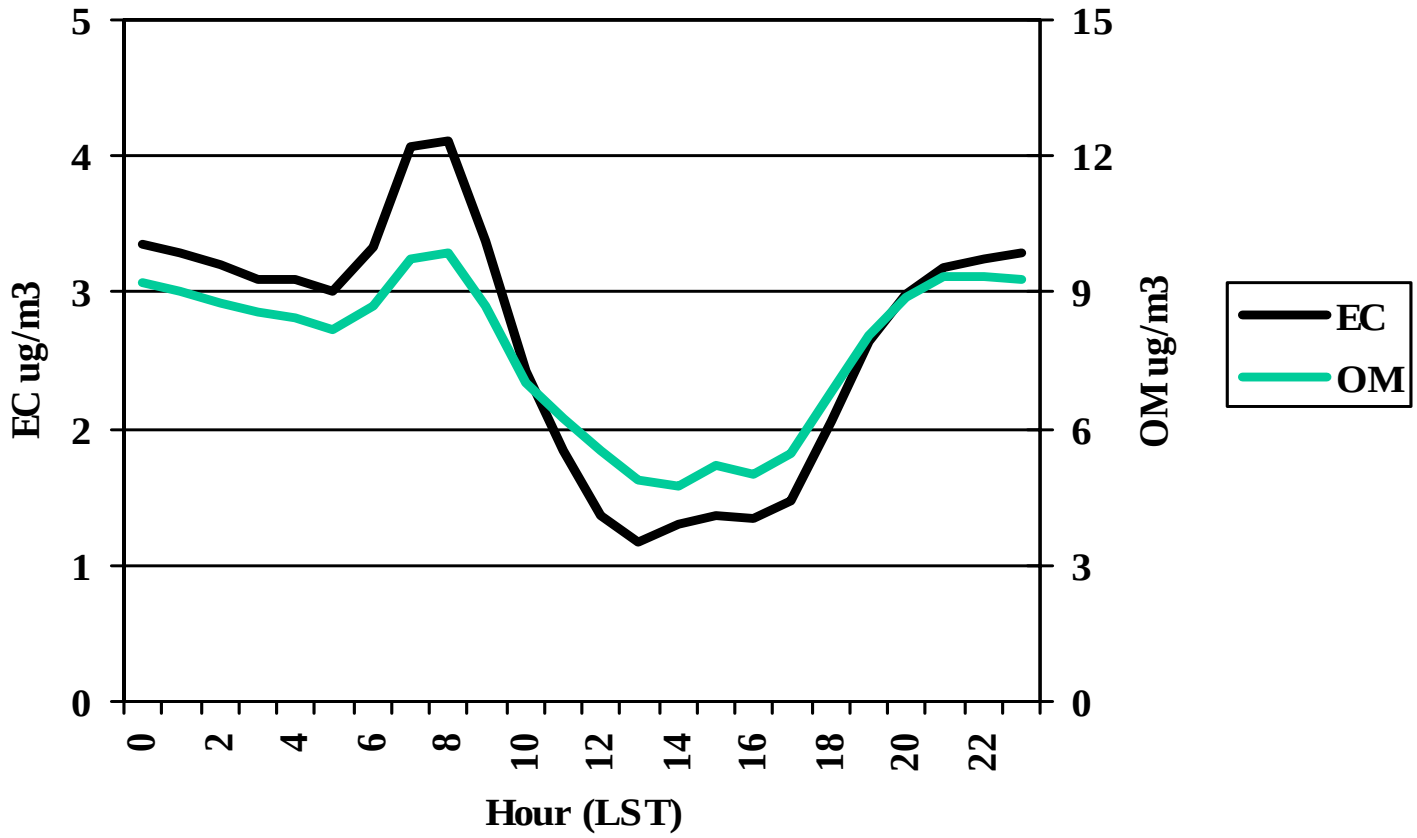
JST EC/OM Diurnal Profile
4th Qtr. ’99
Semi-Continuous Data from R&P 5400



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1st Qtr. ’00

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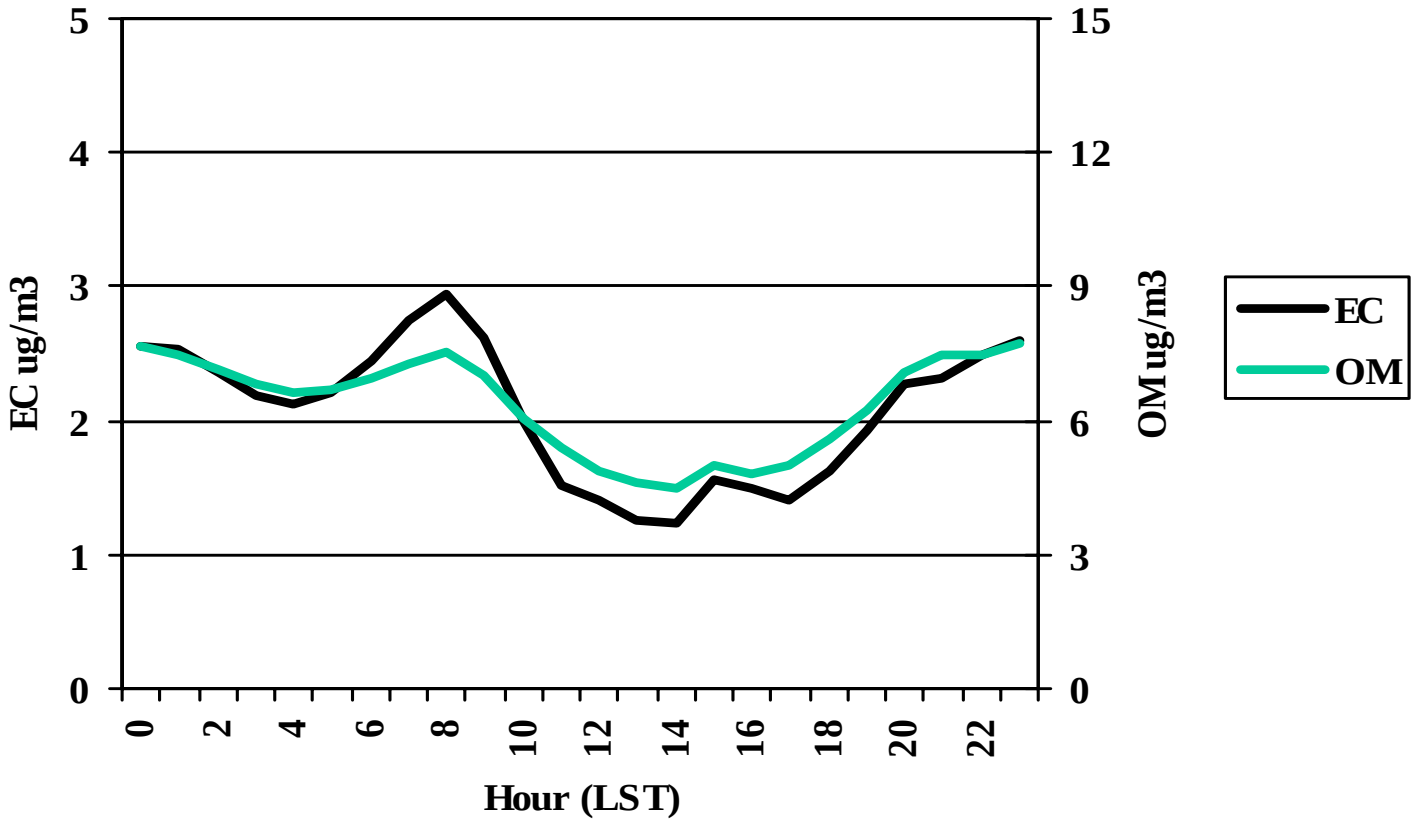

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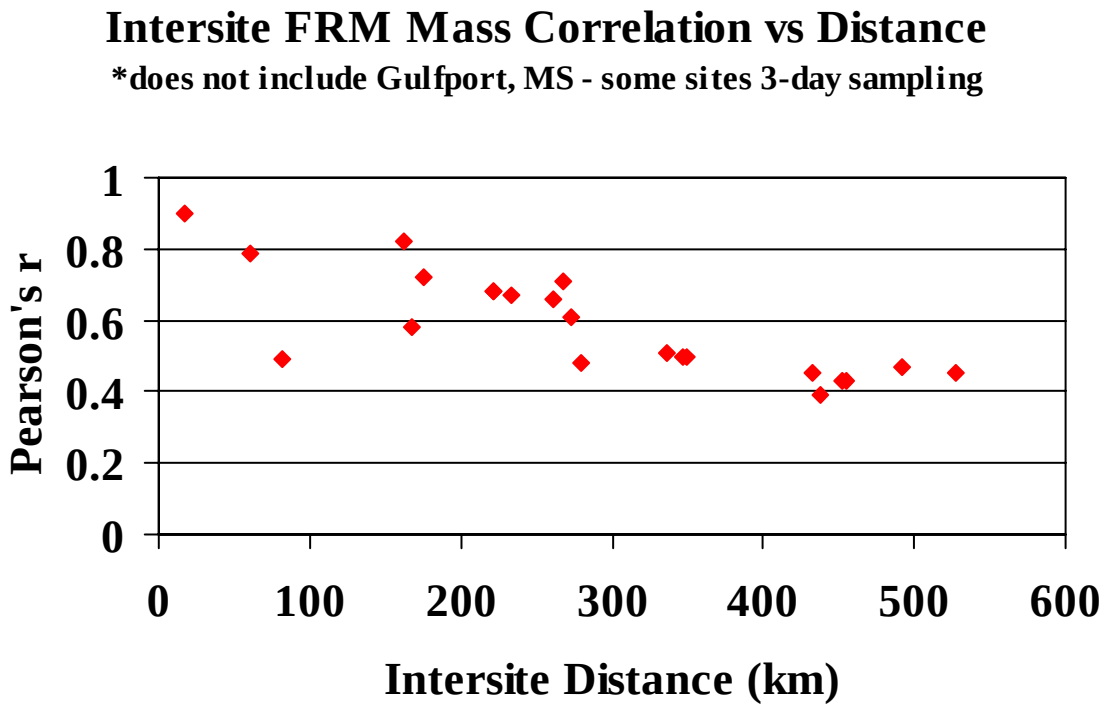
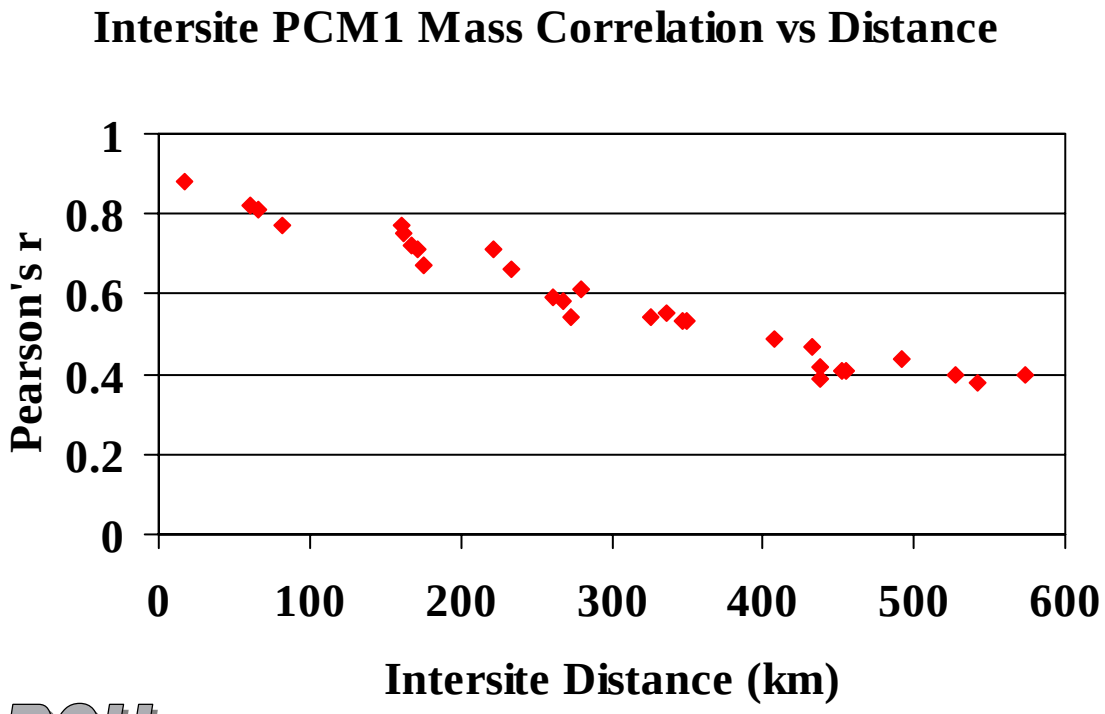
Mass Correlation vs. Intersite Distance
All SEARCH Sites 1999 Daily Sampling





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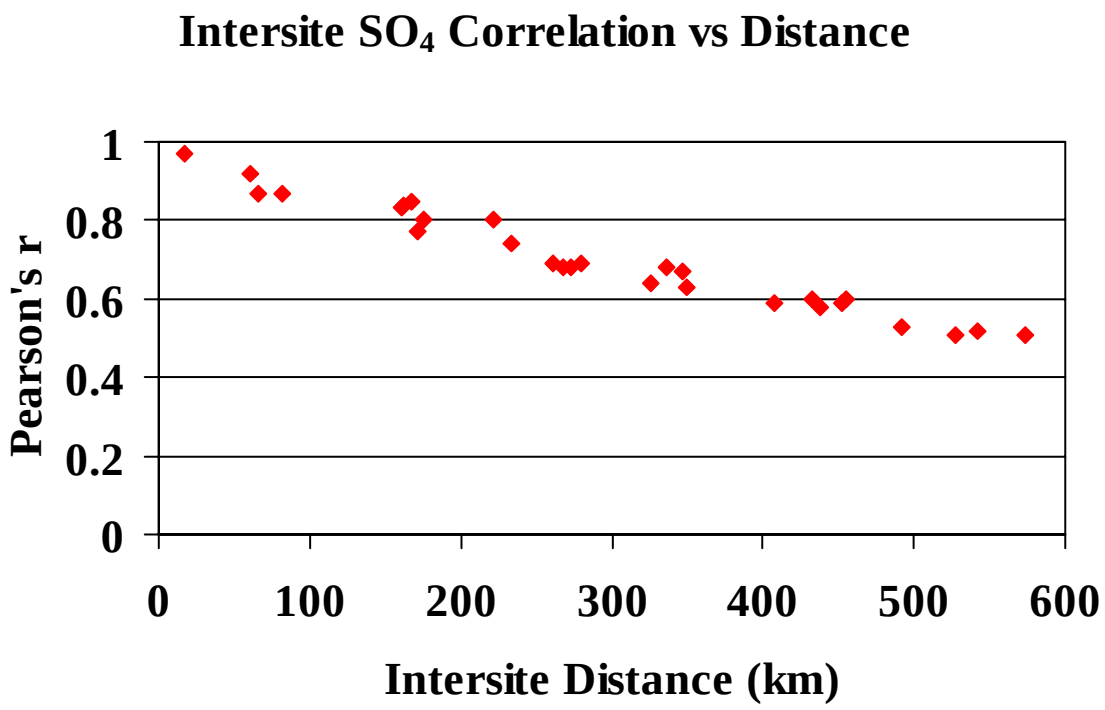
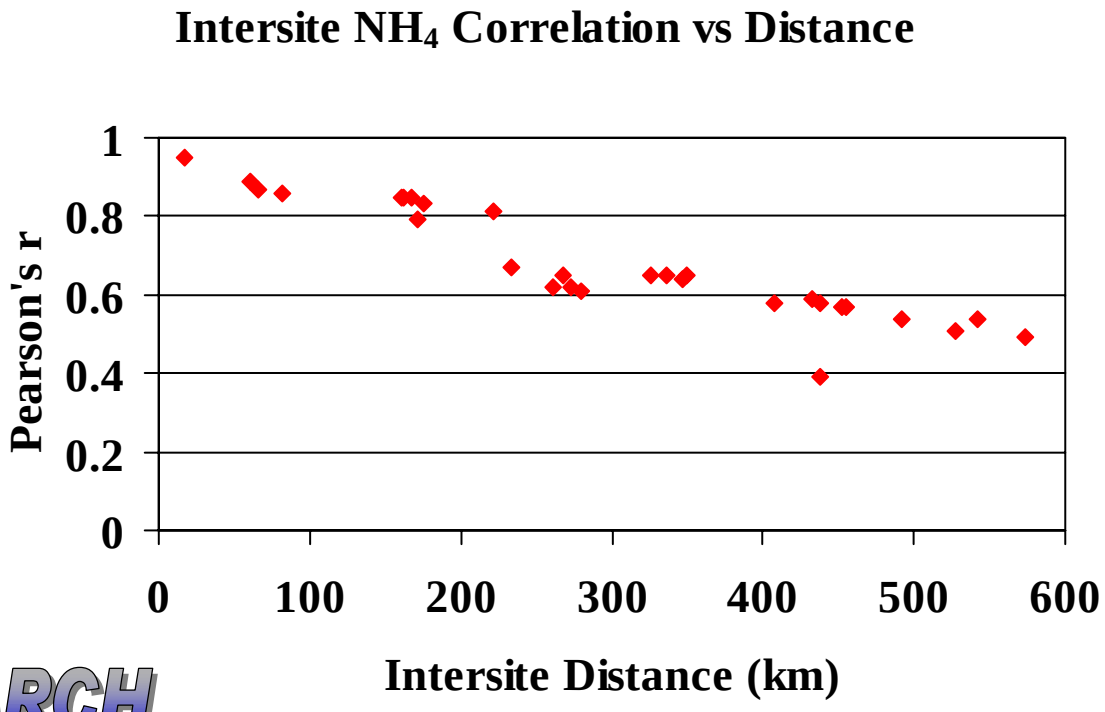
SO_4 & NH_4 Correlation vs. Intersite Distance
All SEARCH Sites 1999 Daily Sampling





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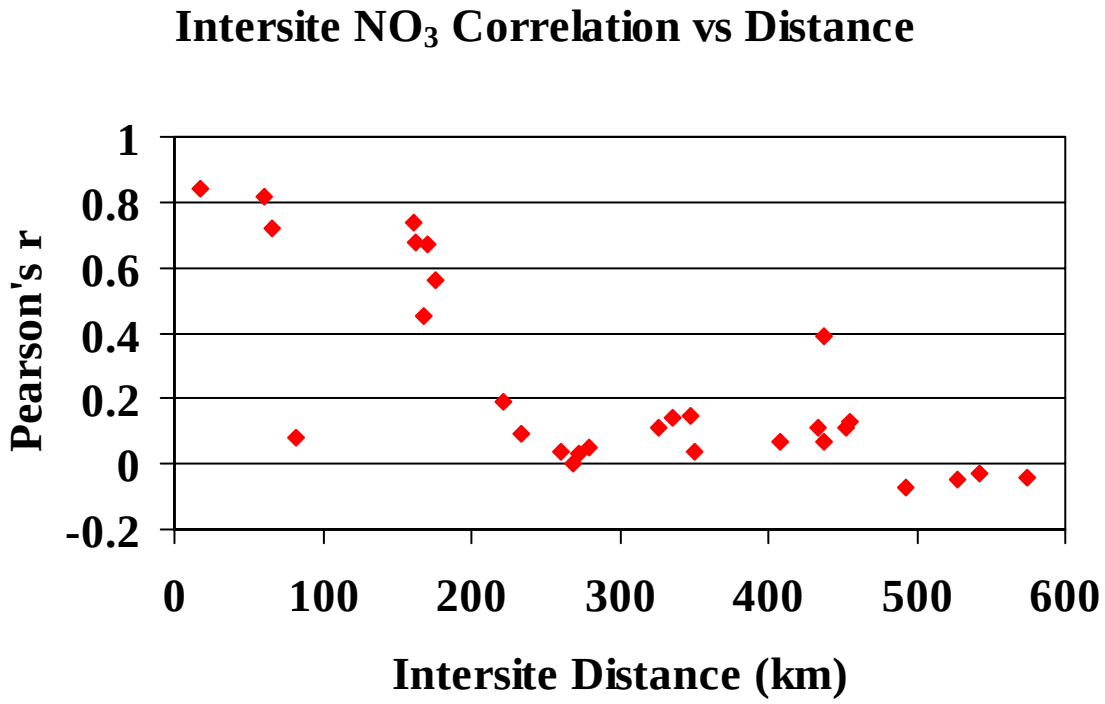
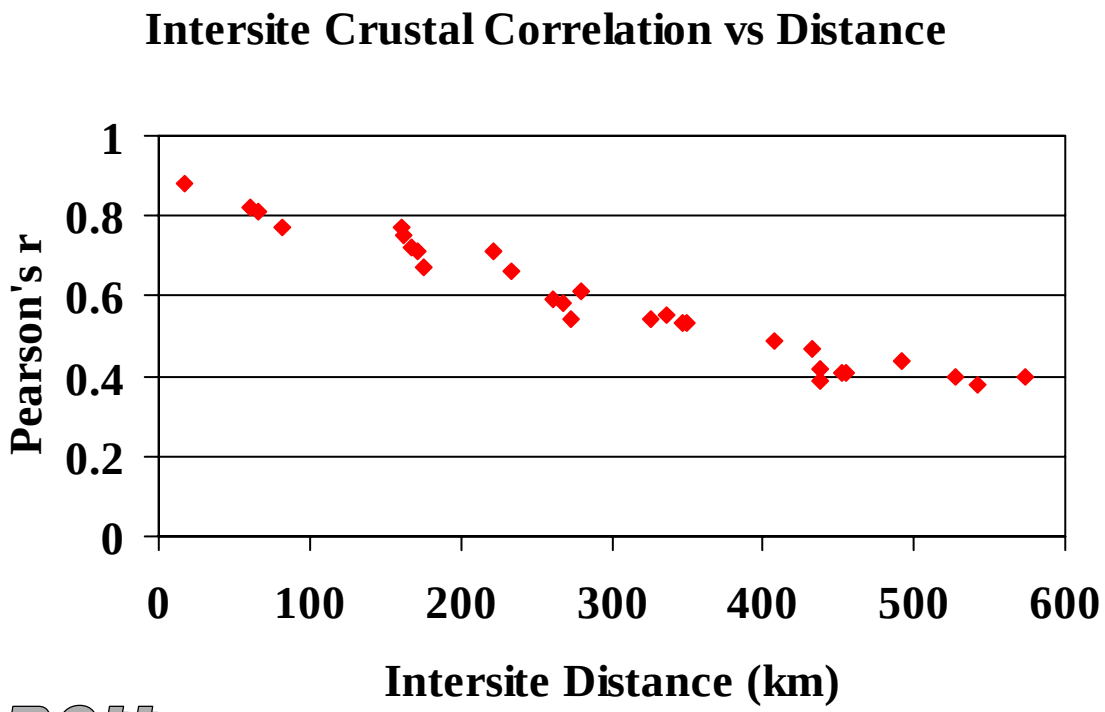
NO_3 & Crustal Correlation vs. Intersite Distance
All SEARCH Sites 1999 Daily Sampling





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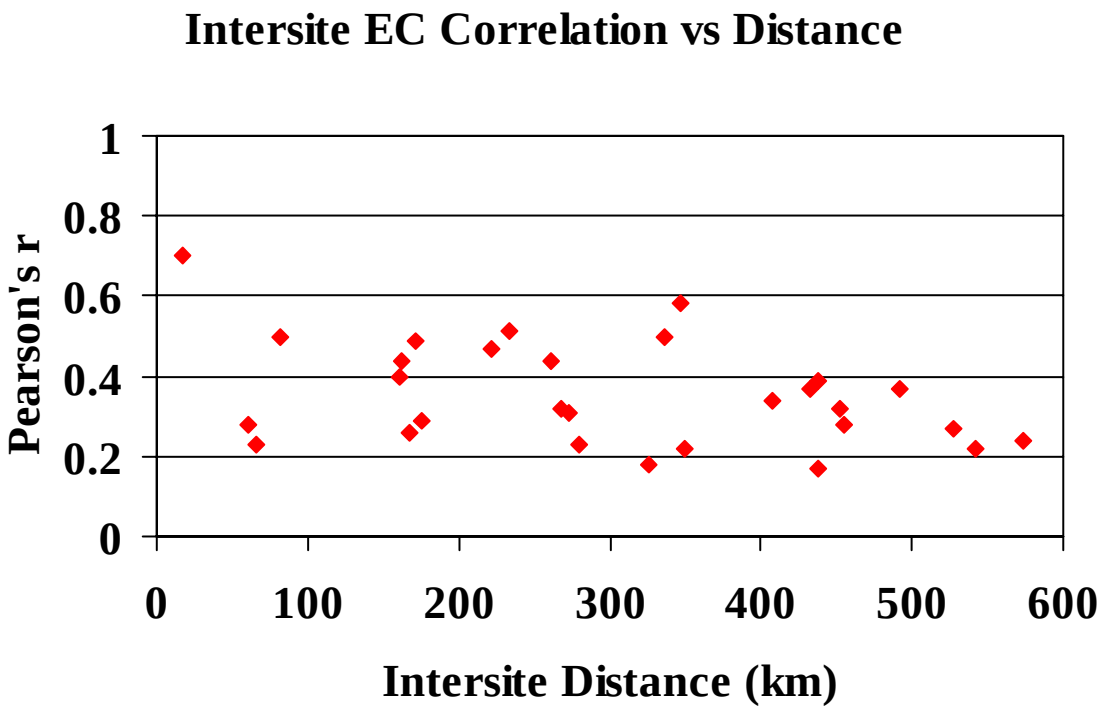
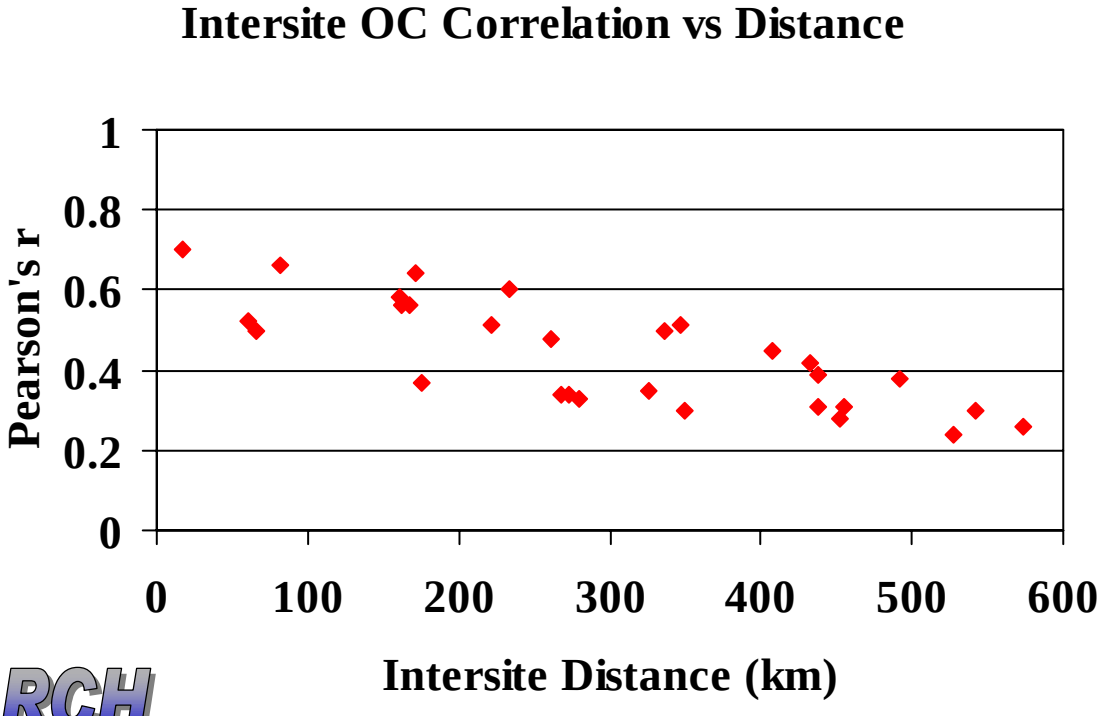
EC & OC Correlation vs. Intersite Distance
All SEARCH Sites 1999 Daily Sampling





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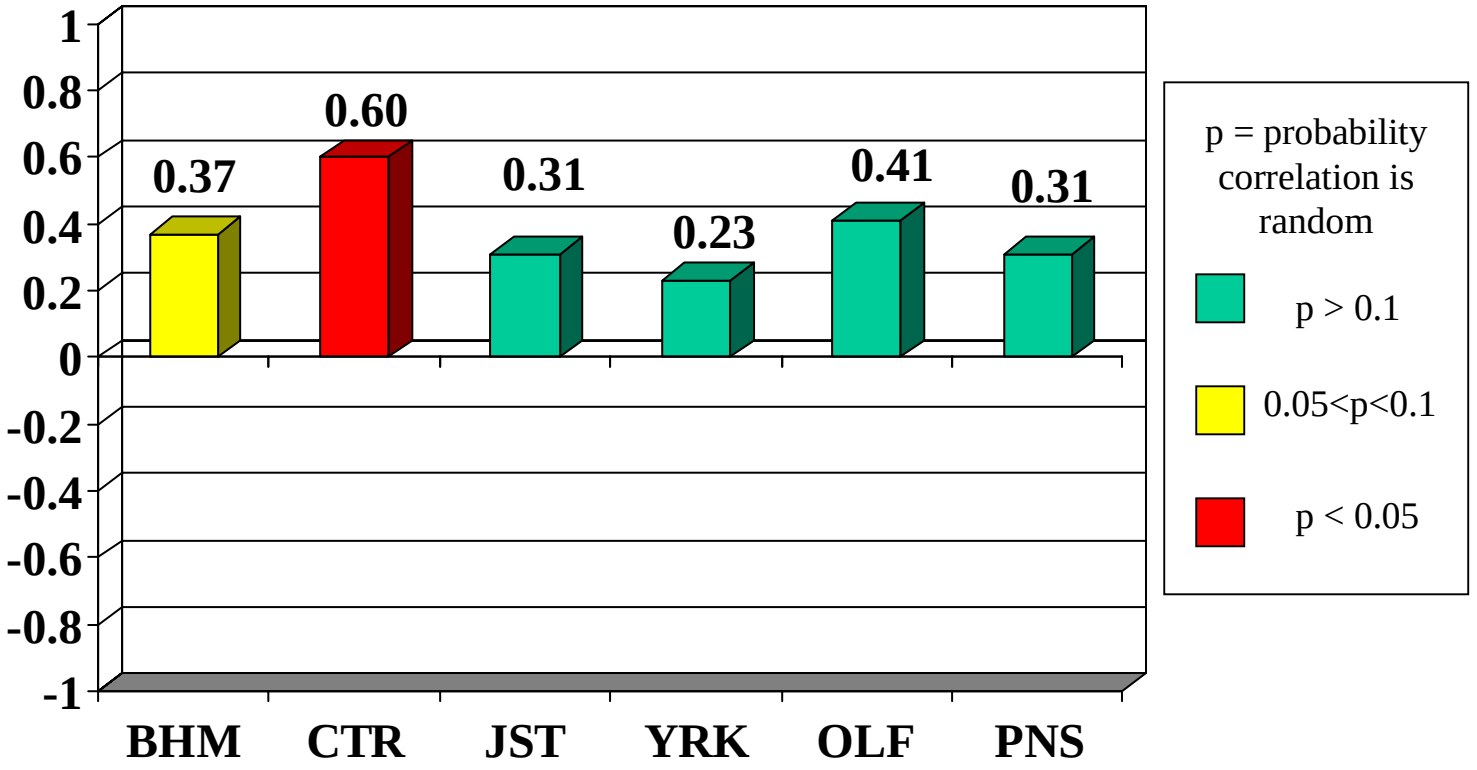
Intersite Correlations for FRM Mass
OAK, 90th Percentile Data



SEARCH

Principal Investigators:
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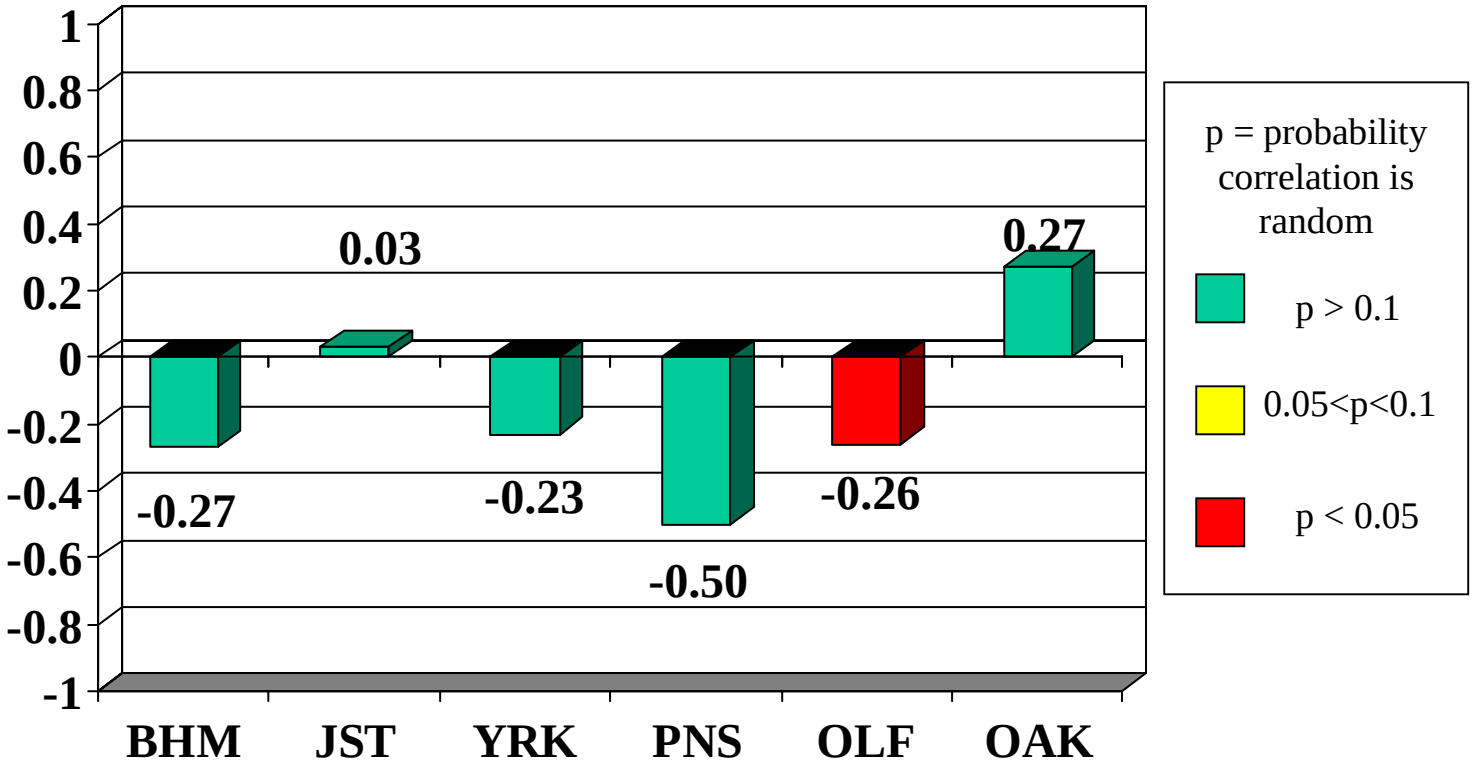
Alan Hansen, Tina Bahadori, Michael Van Loy, EPRI
John Jansen, Southern Company

Data Provided by EPRI to EPA on 8/2/2000
Database available through NARSTO archive by 1/1/2001
For further information contact Alan Hansen @ 650/855-2738

Intersite Correlations for FRM Mass
CTR, 90th Percentile Data



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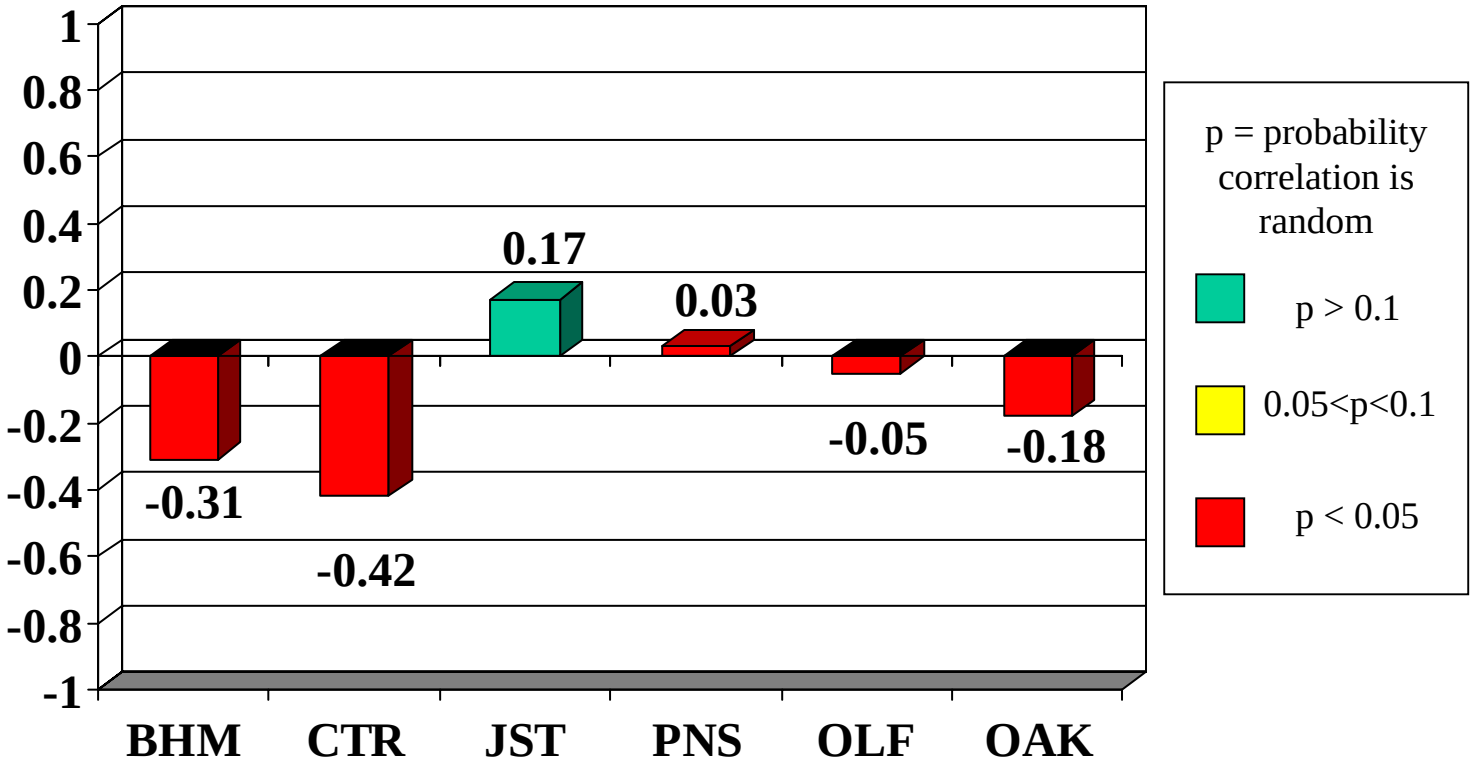
Intersite Correlations for FRM Mass
YRK, 90th Percentile Data



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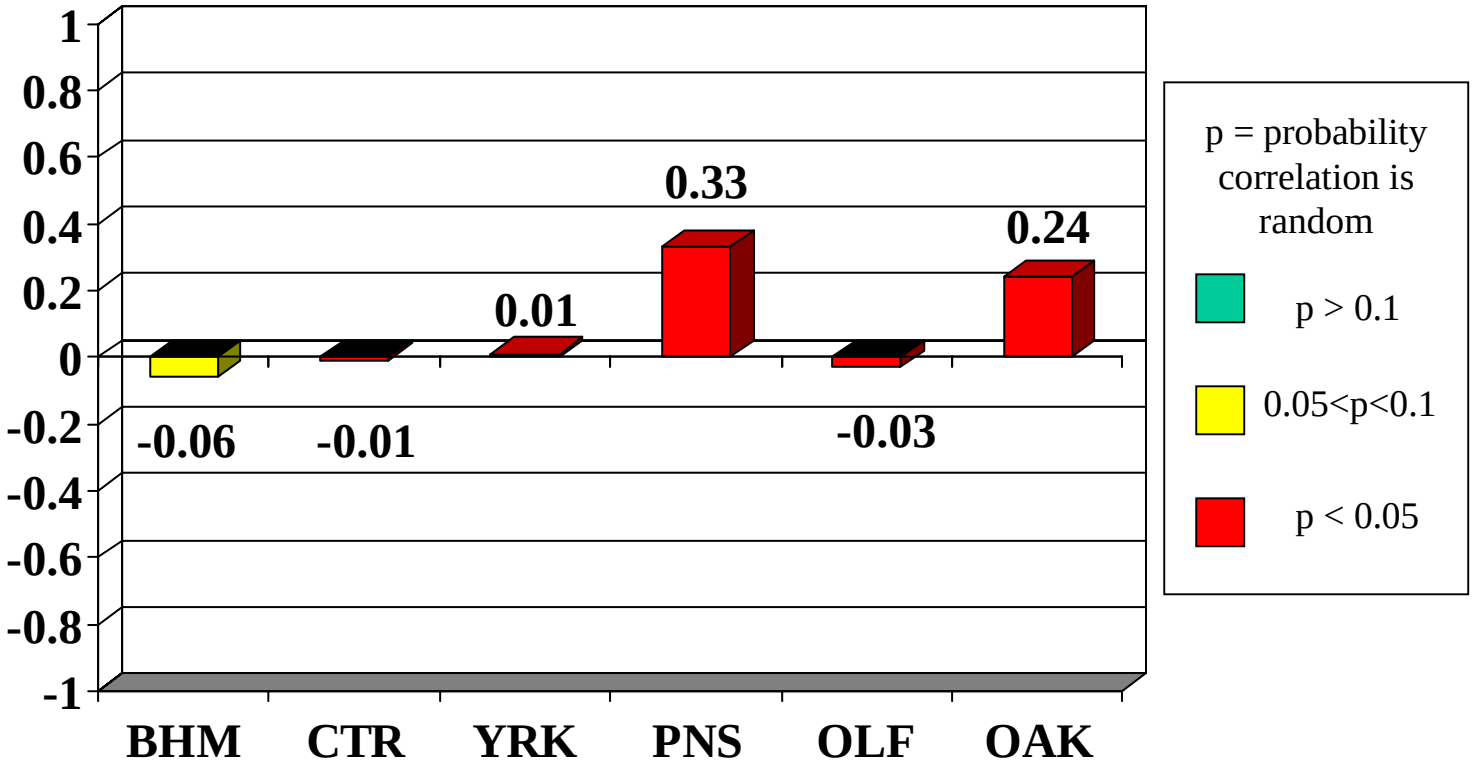
Intersite Correlations for FRM Mass
JST, 90th Percentile Data



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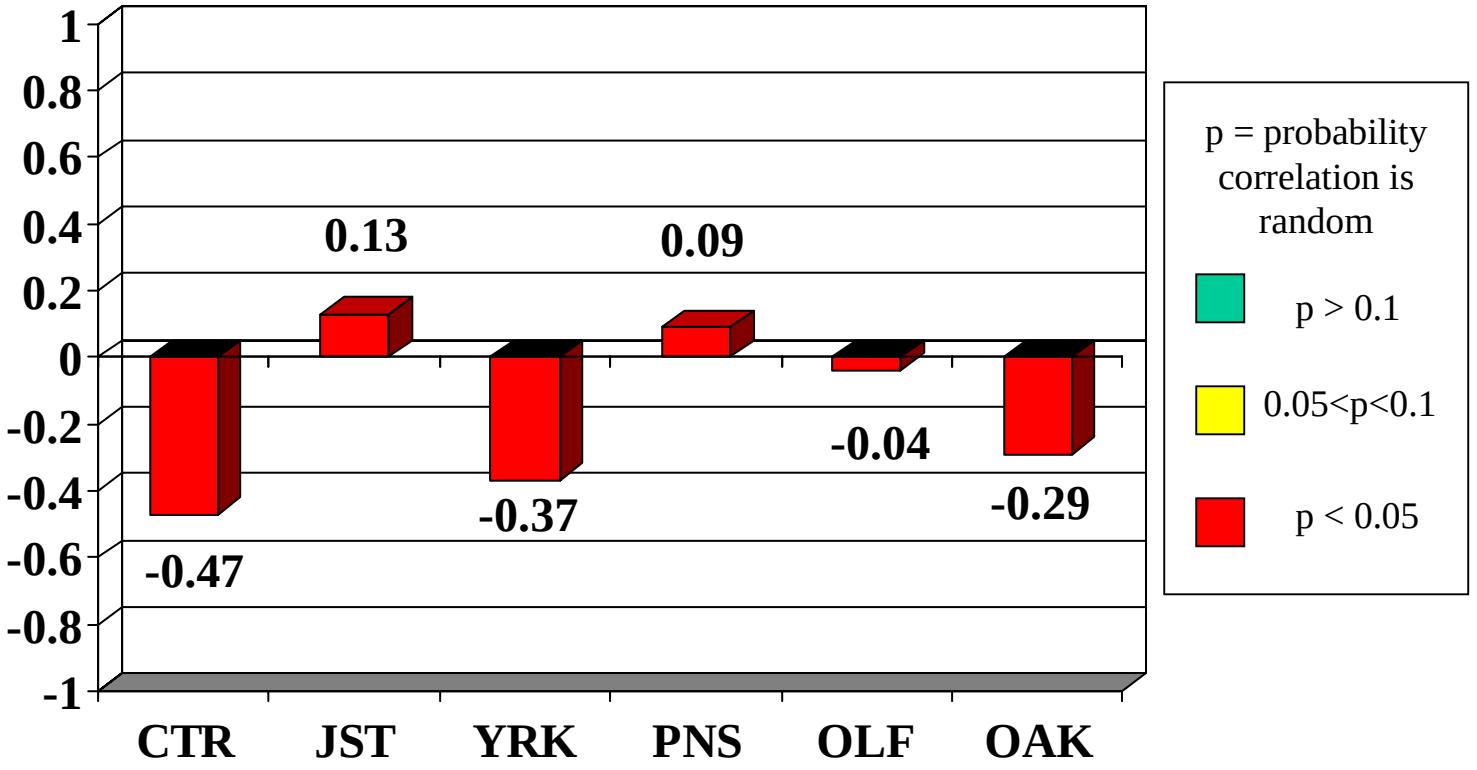
Intersite Correlations for FRM Mass
BHM, 90th Percentile Data



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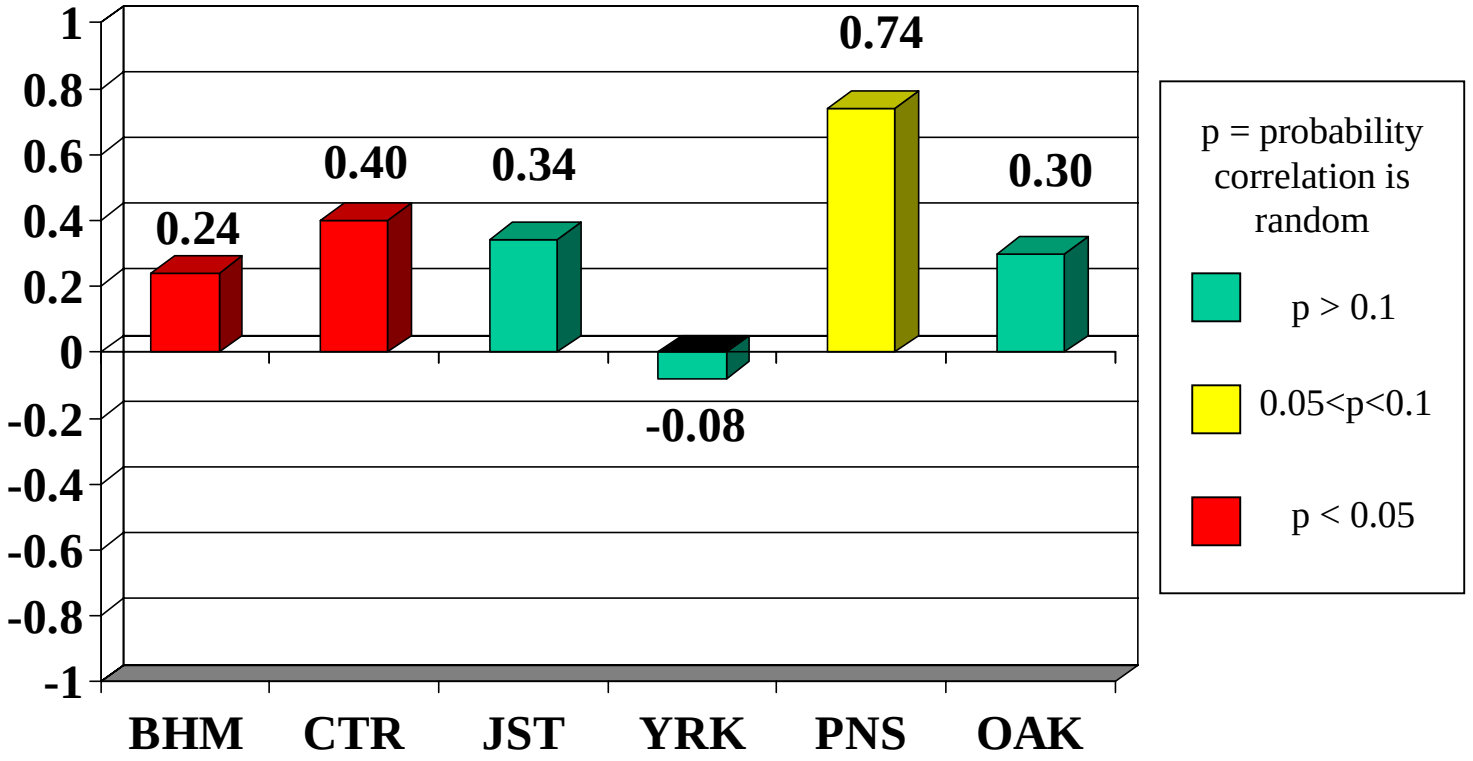
Intersite Correlations for FRM Mass
OLF, 90th Percentile Data



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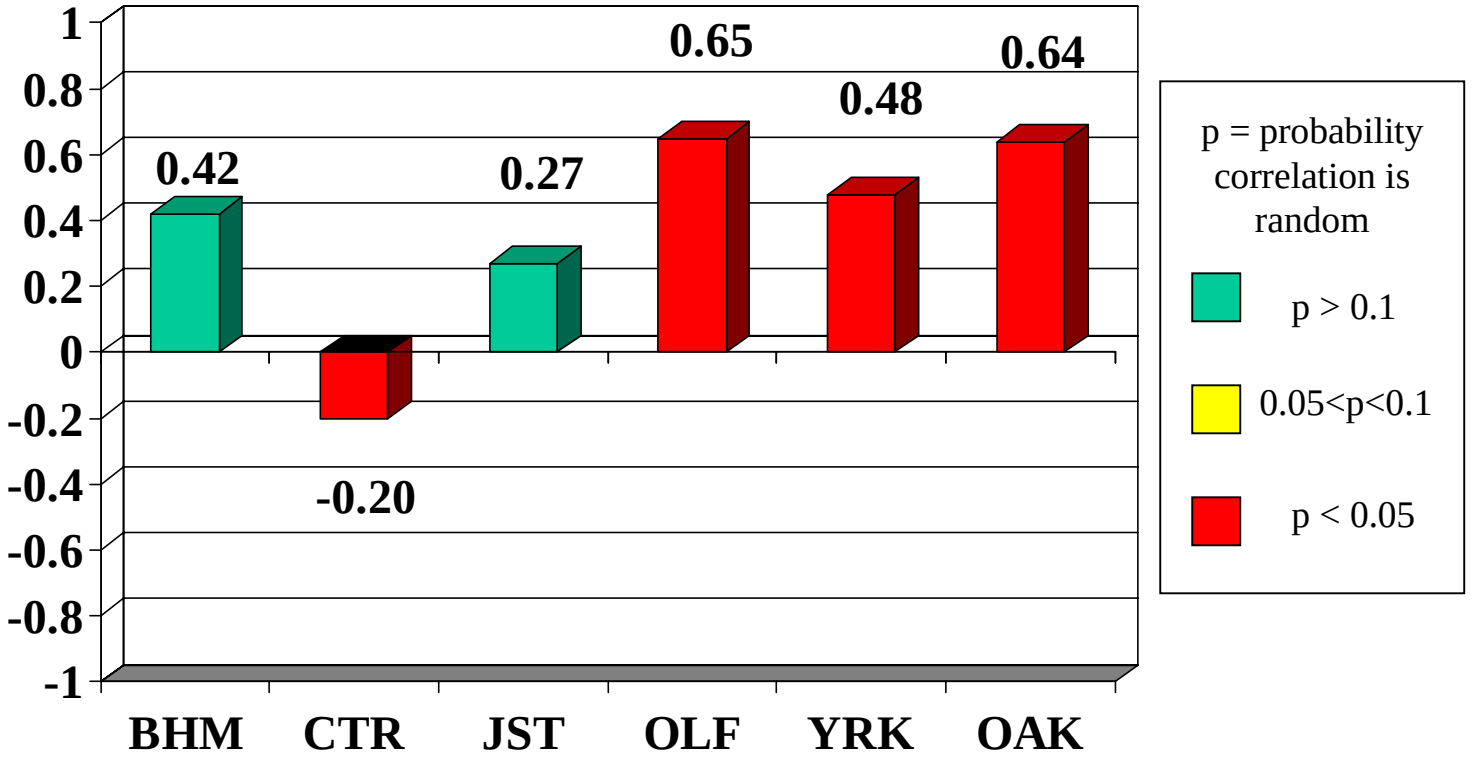
Intersite Correlations for FRM Mass
PNS, 90th Percentile Data



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