Concentration of Airborne Uranium and other Elements in the Town of Concord

November 14, 1999

Frederick Seward, *Concord, MA*
Charles Haldeman, *Concord, MA*
William F. McDonough, *Department of Earth and Planetary Sciences, Harvard University, 20 Oxford St., Cambridge, MA*
Pamela Rockwell, *Concord, MA*

Abstract

During the 1997-1998 cleanup of the Starmet Holding Basin, airborne dust was collected at several Concord residences. Samples were collected and analyzed weekly and concentrations of U and 10 other elements were measured. Natural fluctuations in dust concentration were observed. There was no increase in U concentration due to the cleanup. In fact, the level of U and other material was low compared to data from several US cities. This report discusses the measurement technique, presents the data, and shows plots of concentrations of several elements as a function of time for each sampling location. Tests for validity of the data are discussed.

The Holding Basin

The Holding Basin at Starmet (formerly Nuclear Metals Inc. or NMI) was used from 1958 to 1985 as a repository for waste from the processing of depleted uranium. The primary constituents of this material were depleted uranium oxide, copper, and nitrates. The material was in the form of a green "sludge" with total content estimated as 200,000 kg of U and 400,000 kg of Cu (Nuclear Metals Decommissioning Plan, 1997). Approximately 8000 m^3 of sludge and underling gravel were excavated and removed (to Utah) from September 1997 to October 1998.

The April 1996 Concord town meeting appropriated $25,000 to independently monitor air quality during the cleanup. Even though a temporary structure was built over the Basin to prevent the escape of dust, Concord citizens wanted an independent measure of the material in the air. The element of concern was, of course, uranium, spread as air-borne particulate material. The Article 41 Committee was formed to review environmental specifications for the cleanup and to oversee the measurement of air-borne dust. Monitoring equipment was purchased, tested, and sampling stations were setup and operated during the period; July, 1997 to September, 1998.

Previous data, units, and hazardous levels

There is not much data concerning the amount and composition of dust in a suburban environment. Most studies have been aimed at air quality in cities (Rahn, 1976) and many measurements are only sensitive to large, perhaps-hazardous concentrations. Therefore, the "normal" uranium background is not well known. The expected concentration of dust in rural air is about 20 micrograms per cubic meter (Shapiro, 1990). Multiplying this by the average concentration of U in the earth's crust of about 3 parts per million (ppm) led the Committee to expect a "natural" background of about 0.06 nanogram of U per cubic meter of air (ng/m^3). Indeed, the concentrations measured were close to or below this level.

The NRC environmental limit (Shapiro, 1990, Federal Register, 1991) for air-borne radioactivity from U in a residential environment is .06 picoCuries/cubic meter of air (pCi/m^3). Using a conversion factor of 0.36 microCi/g gives a limit of 180 ng/m^3.

An alternate calculation using an inhalation cancer slope factor of 1.2×10^{-8} risk/pCi, risk = 10^{-6}, and ventilation rate = 15 l/min gives a one year limit of 28 ng/m^3. So, the concentrations of U that we have measured, as discussed in this report, are far below levels considered possibly hazardous to health.

Samplers, location, technique, timeline,

Eight samplers, each a simple pump and filter, were set up and operated at local homes varying from 0.3 to 7 km distant from the Starmet (NMI) plant. Each sampler consisted of a plastic filter holder, 1 m of plastic intake tubing, a Dwyer ball-type adjustable flowmeter, a Gast double-diaphram linear pump, and a 1 m length of exhaust hose, all connected in series in the above order, and encased in a weatherproof aluminum box. When power was applied to the pump it also started a resettable timer which measured the duration of each run to an accuracy of 0.1 hour. The filter holder was a cylinder with one end open and the filter and intake tube at the other. In use the filter holder was

positioned outdoors with the open end facing down, protecting the filter from rain and other precipitation. Locations and characteristics of the samplers are listed in table 1.

Table 1 - Sampler locations and characteristics

#	Location	hgt	num	Start	Stop	Dist	Dir	Comments
1	Under deck	1m	42	8/11/97	7/5/98	0.7	NNE	
2	In box at side of house	0.3	26	8/23/97	5/23/98	3.2	ESE	Sample collection erratic
3	On porch Filter outside	1	45	8/18/97	9/27/98	0.3	SE	
4	Pump in garage Filter outside window.	1	47	8/13/97	9/27/98	7.1	NNE	
5	Under deck	0.7	12	8/13/97	11/6/97	2.7	WNW	
6	Middle of yard with Tarpaulin cover	1	44	8/13/97	6/21/98	2.2	NNE	
7	Pump in garage Filter outside window	2	23	8/20/97	6/1/98	1.2	ESE	Sample collection erratic, some contaminated
8	Pump in garage Filter outside window	1	23	8/26/97	4/28/98	3.3	ENE	
8c	Pump in office Filter outside window	10	6	5/21/98	8/3/98	-	-	Forth floor office in Cambridge

Columns are:

- The unit identification number.
Location - Physical circumstances in which sampler was operated.
Hgt - Height of filter above ground in m
Num - Number of valid samples collected and analyzed.
Start - Date when first valid sample was started.
Stop - Date when last valid sample was collected.
Dist - Distance from Holding Basin in km.
Dir - Direction of sampler from holding basin.
Comments - Unusual circumstances or problems.

Filters were 47 mm diameter Millipore cellulose filters with hole size 0.22 microns. Filter holders were entirely plastic. Each filter was held in its holder by a plastic ring which pressed against an O-ring which, in turn, pressed the edge of the filter against the support grid. In operation air pressure pressed the filter against this grid and the O-ring formed an airtight seal around the edge of the filter. After insertion of a new filter, flow was adjusted to 10 liters/minute (l/min). After one week, the flow was still 10 l/min so there was little reduction of flow due to filter clogging. The runs were nominally one week in duration during which 100 cubic meters of air passed through the filter. After this time, the filter was coated with a gray-brown layer with the pattern of the support grid, which blocked the flow, forming a "shadow" where dust collection was minimal. Thus there was a visual indication that the air sample had indeed passed through the filter. A few samples were discarded because there was obvious indication of a leak through a hole in the filter or under the O-ring.

Samplers were first operated July 12, 1997, and after adding O-rings to prevent leaks around the edges of filters, good samples were routinely obtained after August 13, 1997. Most samplers were operated until June 21,1998, and the last samples were obtained September 27, 1998. Work started on the enclosure over the holding Basin August 1997 and 4000 m^3 of sludge was removed between September 1997 and January, 1998. Between January 1998 and October 1998 an additional 4000 m^3 of underlying gravel was excavated and removed. The structure was removed in May 1998. After this, some material was removed which had been inaccessible because of building supports.

Filters were collected from each unit weekly. The used filter was removed and bagged and a new filter inserted by a designated member of the household where the sampling unit was located. Some of the filters were collected on Wednesday, and some on Saturday, giving a time resolution of 3-4 days in measurements. In practice this ideal collection schedule was hard to achieve. Vacations, travel, and forgetfulness resulted in some runs of 2 or 3 weeks duration. For a while we collected some samples using the mail but found that weekly personal interaction with the individual sample collectors was important. Collected filters were cut in half with a precision of 10%. One half was sent for analysis and the other archived for future use. A few of these archived samples were used to verify doubtful or unusual results. Collected samples were sent to the analysis lab in batches every one or two weeks.

Between August 13, 1997 and September 27, 1998 268 good samples were collected and analyzed. (28 early samples were rejected because of leaks and broken filters.) During subsequent operations, 8 samples were excluded from the analysis because of leaks, contamination, or because of inability to assign a definite date to a specific filter (mislabeling). 7 samples were physically lost. The 3 obviously contaminated samples contained material from nearby welding (black filters) and spray painting (yellow filter). It was interesting that even though concentrations of Cu, Zn, and Ba in the welding-contaminated samples were 20-100 times higher than normal, the U concentration was still low. Even under these circumstances, the U-monitoring function was apparently valid.

Analysis of samples

The halved Millipore filters were placed into screw-top, teflon beakers (from Savillex Corp.), and approximately 5 ml of 2% nitric acid was added. The beakers were capped and placed on a hotplate at approximately 100 degrees C. Dissolution of the filter began immediately upon acid attack and was completed within an hour of heating. After visual inspection for complete dissolution of the filter, the covers were removed and solutions were evaporated to dryness. Samples remained as dried stains at the bottom of the beakers until needed for analyses. Prior to analyses, samples were re-dissolved in 10 ml of 2% nitric acid and pipetted into disposable low-density polyethelyne test tubes.

The apparatus used for analysis was a quadrapole-based inductively coupled plasma mass spectrometer (ICP-MS). (type PQ 2+, made by VG Elemental).

Samples for each analysis session were placed in test tubes in a Gilson autosampler along with processing blanks, standard solutions, and reference solutions. These solutions were mixed with a spike solution prior to introduction into the mass spectrometer using a peristaltic pump with a T-connector fitted down line. The spike solution contained a known concentration of Sc (atomic mass 45), In (atomic mass 115),

and Re (atomic mass = 185) and these were used to calibrate the mass response curve of the ICP-MS. If, for example, the sensitivity were to change with time, the response to spike-solution elements could be used to normalize the results.

Solutions were introduced to the ICP-MS by a Meinhard nebulizer and a Scott double-pass spray chamber. Standard gas flow rates and RF power were used when operating the ICP-MS. Manufacturer-supplied software was used to acquire the spectra and process the data. Concentrations of elements in the samples were determined by reference to standard solutions, which contained known concentrations of all elements measured from the filter samples. The system background was measured by the analysis of "blanks", samples treated in the standard manner except that no filter residue was included. The contribution of the processing blanks to each analysis was below 1% for all elements.

Data quality was monitored by the analyses of reference solutions that were interspersed throughout the analysis sequence. These, like the standard solutions, contained known amounts of various elements but, unlike the standard solutions, were identical from run to run. This quality control gave an absolute comparison of one run with another.

The precision of the analysis technique was measured using standard and reference solution data from 9 separate data sets; each containing results from 15-20 filter-paper samples. The Al, Mn, Co, Ga, and Sr concentrations were reproducible to 5% or better. The Fe, Ni, Cu, Zn, Ba, and U concentrations were reproducible to 10% or better. These numbers are applicable to samples where abundance levels are at least 5 times that of the blank contribution.

Results - validity of data

Our results, weekly measurements of 11 elements at 8 locations, are listed in Appendix 1. These data are displayed in plots, showing concentrations measured for each sampler, in Appendix 2. In Appendix 3 these plots are rearranged to illustrate variations in concentrations of individual elements.

The curves in Appendix 2 show that there is great variation in the measured concentration of any element in any sampler from week to week. Changes of a factor of 2 or 3 are the norm. To determine the reality of these fluctuations, we performed two basic tests: 1) Unused filters were analyzed to measure the background. 2) The second halves of several filters were analyzed to check on repeatability of the data.

Table 2 compares results from pairs of samples, which should be identical - two halves of the same filter. Generally differences between measured concentrations were 10%-30%. However, it was not uncommon to have a factor of two difference in one of the elements. This often showed as an abnormally high concentration, as if some elements were contained in flakes or patches which were not distributed evenly over the filter. The reason for these discrepancies is unknown. The largest differences did not involve a consistent element or group of elements. Contamination during sampling, collection, or analysis is not ruled out but there is no consistent pattern.

Table 2 - Comparison of 2 "identical" samples

Sample	b	Al	Mn	Fe	Co	Ni	Cu	Zn	Ga	Sr	Ba	U	Mn-Ba
406	5	2200	86	723	5.4	282	139	861	6.2	23	59	0.37	589
906	5	3190	90	731	6.1	153	84	959	7.1	21	64	0.48	412
Ratio		0.69	0.96	0.99	0.89	1.84	1.65	0.90	0.87	1.10	0.92	0.77	1.43

209	11	4608	129	4027	6	98	106	782	4	28	49	12.8	410
912	18	4493	111	4905	7	114	132	694	4	29	85	0.5	471
Ratio		1.03	1.16	0.82	0.86	0.86	0.80	1.13	1.0	0.97	0.58	25	0.87

115	16	2070	57	2030	5	89	49	552	3	21	68	0.14	284
916	16	1510	75	2800	6	151	97	679	4	21	80	0.3	424
Ratio		1.37	0.76	0.72	0.8	0.59	0.51	0.81	0.7	1.0	0.85	0.47	0.67

135	27	4590	185	5140	6	91	174	390	5	41	109	0.94	600
926	27	4900	187	5340	6	92	101	461	5	40	107	1.03	527
Ratio		0.94	0.99	0.96	1.0	0.99	1.72	0.85	1.0	1.02	1.02	0.91	1.14

449		3546	227	10671	6	200	180	1897	5	37	442	1.3	1086
250		3689	211	8941	5	155	133	560	4	30	365	1.1	894
Ratio		0.96	1.08	1.19	1.2	1.29	1.35	3.39	1.2	1.23	1.21	1.18	1.21

Data are sample weights in ng. Sample pairs are two halves of a particular filter except for 449/250 which were obtained using two sampling units run side by side. The collection time for 449 was longer than for 250 and the expected ratio of 449 to 250 is consequently 1.09. Sampling units, for each table, reading down, were 4, 2, 1, 1, and 4/2. The "b" column is analysis batch number. The "Mn-Ba" column is the summed weight of Mn, Cu, Ni, Sr, and Ba, a quantity used for normalization.

We note that the natural concentration of U is low and we expect relative fluctuations in the measured concentration which are somewhat larger than for the other elements. Even so, in the first half of sample 209 there was an abnormally high U concentration. Since the second half of this filter yielded a normal reading, we believe the high reading to be spurious. This was the only abnormal U concentration observed.

Table 3 gives average concentrations measured from 9 sampling locations and average background obtained from 11 unused filters. This background is 10%-20% of the measured concentration of all elements, including U.

Table 4 gives median concentrations derived from these same data. Comparing median and average values shows how a few large numbers can change the average. The element Al shows the greatest relative difference between median and average concentration especially for unit 8c .The plots in Appendix 2 indeed show one very high value for Al for this unit. Other examples are unit 3 with a few high Al points and unit 5 with a few low points for Fe. The distribution of values for any element here is not

Gaussian and the median concentrations in table 4 represent "normal" readings better than the average values in table 3.

Table 3 - Average concentration of the elements

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 8c	Bkgd
Al	85	55	62	79	28	69	60	71	146	5
Mn	3.09	1.81	1.94	2.49	1.47	2.30	2.41	2.26	2.53	0.26
Fe	99	58	70	92	44	76	77	72	134	7
Co	0.173	0.124	0.216	0.132	0.109	0.211	0.173	0.145	0.119	0.033
Ni	2.87	2.24	2.80	2.48	1.71	2.83	2.76	2.49	2.99	0.29
Cu	3.60	1.98	2.60	2.54	1.77	2.73	2.93	3.44	4.14	0.43
Zn	17.3	12.8	15.3	13.0	17.0	16.0	22.2	13.7	16.0	3.6
Ga	0.147	0.094	0.092	0.105	0.090	0.107	0.274	0.149	0.155	0.014
Sr	0.74	0.48	0.52	0.57	0.49	0.61	0.70	0.59	0.78	0.16
Ba	3.00	1.60	1.96	2.32	1.18	2.26	5.64	2.79	7.62	0.13
U	0.0189	0.0074	0.0550	0.0122	0.0081	0.0090	0.0084	0.0091	0.0066	0.0009
Mn-Ba	13.3	8.1	9.8	10.4	6.6	10.7	14.4	11.6	18.1	1.3
Unorm	0.0142	0.0091	0.056	0.0117	0.0122	0.0084	0.0058	0.0078	0.0036	0.007

Concentrations are listed in nanograms/cubic meter (ng/m^3).
The last column, background, was calculated using element weights from blank filters and assuming a flow of 10 l/min for one week.
Mn-Ba is Mn+Cu+Ni+Sr+Ba.
Unorm is proportional to the ratio of U to Mn-Ba concentration.

Table 4 - Median concentration of the elements

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 8c	Bgnd
Al	61	36	42	55	26	39	39	50	67	5.6
Mn	2.88	1.63	1.90	2.41	1.66	1.92	2.01	2.08	2.53	0.18
Fe	91	57	65	82	71	64	80	72	136	6.5
Co	0.176	0.122	0.157	0.139	0.119	0.138	0.137	0.156	0.144	0.024
Ni	2.94	2.18	2.56	2.17	1.71	2.48	2.48	2.39	2.33	0.23
Cu	2.99	2.11	2.28	2.11	1.74	2.58	2.61	3.27	4.08	0.40
Zn	14.6	9.9	12.4	11.1	13.9	12.9	21.2	14.4	17.4	3.1
Ga	0.121	0.079	0.092	0.105	0.099	0.103	0.256	0.151	0.153	0.020
Sr	0.66	0.45	0.47	0.56	0.52	0.60	0.64	0.57	0.76	0.18

Ba	2.57	1.24	1.71	1.97	0.99	1.90	5.56	2.12	7.08	0.16
U	0.0159	0.0070	0.0380	0.0099	0.0061	0.0073	0.0087	0.0072	0.0061	0.0008

Concentrations are listed in nanograms/cubic meter (ng/m^3).

We conclude that repeatability of data is generally good, less than the observed weekly fluctuation of concentration in any particular sampler. However, there may be some high-concentration data points which are unreliable. The background from elements in the filters and in the analysis apparatus is generally small compared to material in the dust samples and does not appear to be a problem.

Results - natural phenomena

The curves of appendices 2 and 3 show fluctuations of about a factor of two in the concentration of all elements from week to week. Generally, concentrations of most elements increased or decreased together, indicating that sometimes there was more material in the air than at others. The relative composition of the dust did not change much. Concentrations of Al and Fe were 40 times higher than the concentrations of Cu and Ba, which were, in turn, 200 times higher than the concentration of U.

There were global effects that can be seen in the concentration plots. On day 375 (Jan 3-10, 1998) the concentrations of Al, Fe, and U were low. On days 410 (Feb 7-14) and 510-520 (May 8-25), the Al concentration was high. On days 420-430 (Feb 17-Mar 6), the concentration of Zn was low and this also shows in the concentrations of Fe and Ga. On days 490-500 (Apr 27-May 14), there was a large drop in the concentration of U. Periods when the ground was covered with snow and of unusually heavy rain are indicated on the plots of Appendix 2. No changes in concentration were connected with the snow cover but there was rain at the time of the unusual drop in U concentration. In fact, There were 11 straight days of measurable rain between May 1 and May 11 (days 486-497) giving the 4^{th} wettest May in 128 years (Boston Globe, June 1998). Remember that the measuring interval is the week before the time indicated in the plots, which is the time of sample collection.

Concentrations measured by sampler unit 5 were generally low.

Results - uranium

Because the concentration of U is low, fluctuations in the measured concentration are large. Weekly concentrations of U varied from a maximum of 0.3 ng/m^3 to a minimum, which was below the threshold of detection of approximately 0.01 ng/m^3. The average concentration from the 8 samplers ranged from.008 ng/ m^3 to 0.045 ng/m^3. Highest concentrations were measured from the unit closest to Starmet and might be explained as emissions from the plant during normal U processing. Even this highest concentration is below our expected background and far below the NRC level of concern. No changes of U concentration were observed which could be associated with excavation of the Starmet Holding Basin.

Concord air is clean. The typical U concentration measured was a factor of 10 less than the median of measurements in a sample of large US cities.. Indeed, concentrations of

all elements in Concord were considerably less than the concentrations measured in cities. (Israel & Israel, 1974; Rahn, 1976). Our own small sample shows slightly higher concentrations of Al, Fe, and Ba at one location in Cambridge, but the U concentration was comparable to that in Concord.

We searched for variations in the relative concentration of U to that of other elements. We compared U values to Mn, Cu, Ni, Sr, and Ba, elements which did not exhibit extreme fluctuations in concentration. These results are listed in table 3 and plotted in the last figure of appendix 3. The observed fluctuations in relative U concentration appear about the same as the absolute concentration in the previous figure.

Acknowledgements

We thank the Concord citizens who tolerated noisy samplers in their yards and garages, The Scouts of Troop 32 who assisted with sample collection, David Peters and other members of the Article 41 Committee, and Eric Anderson of Starmet, who attended all our meetings and kept us up-to-date on the status of the holding-basin cleanup.

References

Federal Register, Vol. 56, No. 98, "Standards for Protection against Radiation", May 21, 1991

H. Israel and G. Israel, "Trace Elements in the Atmosphere," *Ann Arbor Science Publishers,* 1974

Nuclear Metals Inc., "Decommissioning Plan for the Holding Basin", Rev. 1, Jan. 1997

K. A. Rahn, "The Chemical Composition of the Atmospheric Aerosol", *Graduate School of Oceanography, University of Rhode Island,* 1976 (NCAR Library #28039)

J. Shapiro, "Radiation Protection", *Harvard University Press*, 1990

Appendix A - data tables

These tables list all data, from good samples and bad. Each line represents one sample. A semicolon (;) in front of the line indicates that these data are from a leaky or contaminated filter and are excluded from the analysis, or that this was a background sample. Filters for which no concentrations are listed were not analyzed; either because there was an obvious leak or because they were lost (these are not included in the digital tables).

Column 1 - the number of the unit. The number 9 was used to identify background samples or the second half of divided samples. There was no mechanical unit 9.

2 - the number of the sample.

3 - the day on which the sample was collected. Units are Day of Year 1997; so Jan.1, 1997 is day 1; Jul. 1, 1997 is day 182; Jan. 1, 1998 is day 366, etc.

4 - the number of hours the pump was on for each sample.

5 - the average flow rate in liters/ minute.

6 - indicates whether the filter was cut in half. If = 1, the entire sample was analyzed. If = 2, only 1/2 the sample was used.

7 - a spare column included for data processing but never used.

8 - 19 - the mass of individual elements found in that part of the filter analyzed . Units are nanograms (ng). Some false numbers have been entered to keep the plotting program from failing. These are: 1) .001 means not recorded - there is no data for this element. The plotting program leaves a gap in the record when this value occurs. 2) When the U concentration was below the threshold for detection, we have entered a value of 0.018. 3) When this occurred for Co or Ga, we have entered values of 0.500. These are conservative lower limits and allow the points to be plotted to show unusually low concentrations.

Data Unit 1

1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19
u	sam	doy	hrs	flw	hf	Al	Mn	Fe	Co	Ni	Cu	Zn	Ga	Sr	Ba	Pb	U
;1	1	200	165	10	1	282	.001	.001	.001	.001	31	367	.001	42	50	6	.056
;1	2	207	173	10	1	1416	.001	.001	.001	.001	68	623	.001	32	50	11	.017
;1	3	215	169	10	1	1764	.001	.001	.001	.001	104	900	.001	37	47	11	.063
;1	4	222	171	10	1	1534	198	526	75	73	106	748	3.4	19	18	0.08	0.40
;1	5	229	140	10	1	820	103	398	3.6	47	33	1020	3.6	19	34	0.18	0.22
1	6	236	171	10	1	6260	264	1920	16	240	213	2470	21	212	163	.001	1.31
1	7	243	165	10	1	2440	153	1330	12	187	1770	3950	8.5	47	138	.001	1.06
1	8	250	172	10	2	1999	177	5989	10	157	224	755	9	31	68	.001	1.1
1	9	257	165	10	2	1586	110	2813	7	156	123	989	6	32	57	.001	0.5
1	10	264	170	10	2	4357	239	2056	9	128	162	600	12	32	80	.001	1.6
1	11	271	160	10	2	966	120	.001	10	84	99	609	8	25	73	.001	1.44
1	12	278	177	10	2	3419	163	10991	14	162	159	709	6	35	82	.001	0.9
1	13	285	166	10	2	3459	219	3006	7	119	161	670	6	37	113	.001	2.4
1	13/2	292	169	10	2	6302	218	7988	10	181	209	886	8	37	100	.001	1.1
1	14	299	167	10	2	3564	226	9445	14	65	101	881	16	43	84	.001	0.7
1	15	306	169	10	2	2070	57	2030	5	89	49	552	3	21	68	.001	0.14
1	916	313	169	10	2	1860	100	4480	8	101	176	831	7	36	160	.001	0.8
1	16	320	167	11	2	1690	82.4	3170	7	78	128	694	5	22	90	.001	0.2
1	17	327	168	12	2	7428	244	12549	13	188	319	1048	20	50	435	.001	1.4
1	18	334	168	10	2	3982	147	6527	16	150	159	779	8	34	154	.001	0.8
1	19	342	191	10	2	2358	131	3949	11	139	160	755	9	25	159	.001	0.5
1	20	349	168	10	2	6345	243	8725	13	167	227	1400	18	44	315	.001	1.3
1	21	355	141	10	2	8351	311	10275	17	245	329	1502	25	52	421	.001	2.1
1	22	362	170	10	2	2028	107	4181	7	170	184	919	10	26	172	.001	0.54
1	23	369	168	10	2	3548	145	5601	12	120	164	894	11	51	203	.001	1.7
1	24	376	168	10	2	363	42	1544	8	122	120	490	5	22	115	.001	0.1
1	25	390	337	10	2	6175	226	9087	13	290	212	1076	13	50	224	.001	3.0
1	26	397	166	10	2	1624	87	3607	14	163	146	800	8	38	148	.001	1.0
1	27	404	169	10	2	5004	204	7998	11	192	247	1337	12	50	229	.001	2.8
1	28	411	167	10	2	13396	205	4399	10	179	249	741	13	47	203	.001	1.2
1	29	418	166	10	2	2605	122	2273	.500	95	147	223	0.37	23	128	.001	0.51
1	30	425	170	10	2	2818	111	2350	.500	92	158	206	0.50	25	134	.001	0.41
1	31	435	238	10	2	3838	148	8076	11	212	180	808	8.0	29	153	.001	1.0
1	32	439	94	10	2	740	56	6267	6	132	81	565	2.5	18	30	.001	0.4
1	33	446	169	10	2	1613	93	6958	10	194	126	573	5.8	25	99	.001	1.6
1	34	453	160	10	2	6800	237	9783	16	219	199	693	10.7	51	213	.001	3.0
1	35	460	168	10	2	4590	185	5140	6	91	174	390	5	41	109	.001	0.94
1	36	467	168	10	2	2630	150	4120	5	148	131	448	5	44	123	.001	0.21
1	37	474	168	10	2	8080	327	9070	12	218	161	556	9	88	228	.001	1.34
1	38	481	166	10	2	2686	89	4291	6	124	152	3326	4	32	118	.001	0.9
1	39	488	171	10	2	6600	361	6850	11	138	107	491	6	48	188	.001	1.03
1	40	495	167	10	2	3350	119	3020	22	441	247	490	4	32	190	.001	.018
1	41	504	212	10	2	12456	309	6705	7.5	200	158	1599	7	62	188	.001	0.09
1	42	509	125	10	2	10208	165	4510	4.6	83	65	1698	3	26	80	.001	0.56
1	43	523	326	10	2	29193	413	13007	10.2	106	122	1046	6	44	251	.001	1.28
1	44	537	214	10	2	2391	130	5840	6	285	160	962	4	33	424	.001	0.9
1	45	551	333	10	2	2281	152	1 5910	6	211	143	856	4	43	462	.001	1.4

Data Unit 2

1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19
u	sam	doy	hrs	flw	hf	Al	Mn	Fe	Co	Ni	Cu	Zn	Ga	Sr	Ba	Pb	U
;2	1	199	216	7	1	377	36.2	271	2.5	75.9	8.4	940	1.7	32.1	36.5	15.1	0.13
;2	2	210	265	10	1	446	30	139	2.4	36	27	316	1.6	14	12	0.1	0.07
;2	3	221	253	7	1	1291	114	288	6.8	70	58	574	3.1	22	19	0.11	0.24
;2	4	228	169	12	1	956	61	310	3.3	12.6	10.5	244	1.2	12	8.0	0.11	0.09
2	5	235	168	10	1	5690	123	1260	7.6	90	147	4610	6.8	24	57	.001	0.93
2	6	245	246	10	2	2383	155	7847	9	195	173	2558	13	33	100	.001	0.9
2	7	253	188	10	2	7294	204	6658	8	109	106	1925	9	32	69	.001	1.1
2	8	267	272	10	2	1606	152	.001	8	89	118	810	8	32	68	.001	0.75
;2	9	274	167	12	2	4608	129	4027	6	98	106	782	4	28	49	.001	12.8
2	912	274	167	12	2	4493	111	4905	7	114	132	694	4	29	85	.001	0.5
2	10	281	151	10	2	5256	147	4385	10	185	162	849	6	33	74	,001	0.5
2	11	292	265	10	2	790	54	2181	3	42	57	465	1	22	16	.001	0.1
;2	12	298	138	10	2	479	25	752	1	28	82	419	1	16	8	.001	0.06
2	13	305	163	10	2	1510	75	2800	6	151	97	679	4	21	80	.001	0.3
2	14	311	150	10	2	714	61.4	2350	7	98	98	540	4	28	100	.001	0.2
2	15	318	188	10	2	657	42.6	1770	5	73	74	397	3	22	61	.001	0.2
2	16	341	529	10	2	10804	326	10028	28	361	391	1573	22	64	349	.001	1.4
2	17	347	143	10	2	2592	77	2802	5	86	110	571	5	24	87	.001	0.30
2	18	369	530	8.5	2	9836	366	12578	27	416	384	1636	28	97	503	.001	1.8
2	19	377	192	10	2	840	52	1698	7	148	123	459	4	22	71	.001	0.5
2	20	403	380	10	2	11102	177	3983	11	328	246	714	15	58	218	.001	1.3
2	21	410	167	10	2	7113	109	2203	8	132	103	438	7	35	95	.001	0.13
2	22	418	192	10	2	2095	79	1924	.500	86	64	136	.500	19	62	.001	0.34
2	23	431	311	10	2	3041	139	8055	10	247	160	667	6.2	24	116	.001	0.5
2	24	438	174	10	2	1302	69	6414	6	157	110	443	2.9	21	35	.001	0.4
2	25	445	165	10	2	1200	57	1440	7	94	70	315	2	18	46	.001	0.15
2	26	452	166	10	2	1670	81	2000	9	107	91	381	2	26	53	.001	0.18
2	28	466	168	10	2	2100	87	3630	8	93	109	229	2	25	58	.001	0.03
2	29	481	360	10	2	3120	107	2500	5	89	87	390	2	29	72	.001	0.13
2	30	488	167	10	2	8020	278	7240	11	221	166	616	8	86	252	.001	0.73
2	31	497	169	10	2	3307	114	3935	10.3	308	129	676	4	25	167	.001	.018

note: No data from samples 27, 32, 33. Samples 2 and 12 are background.

Data Unit 3

1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19
u	sam	doy	hrs	flw	hf	Al	Mn	Fe	Co	Ni	Cu	Zn	Ga	Sr	Ba	Pb	U
;3	1	200	164	10	1	4920	352	3140	9.4	210	226	1610	15.5	134	297	748	3.2
;3	2	208	203	10	1	156	.001	.001	.001	.001	170	196	.001	20	11	3	.025
;3	3	215	164	10	1	5892	.001	.001	.001	.001	196	1190	.001	24	40	12	0.48
;3	4	222	169	10	1	6064	181	1066	7.8	77	328	1228	8.6	38	54	0.93	4.7
;3	5	230	190	10	1	15970	435	3590	40	1760	1470	12420	18	97	141	.001	5.81
3	6	236	112	10	1	2760	106	876	14	152	153	2240	7.7	40	73	.001	2.71
3	7	244	191	10	1	3750	159	1680	11	183	102	3880	6.0	46	94	.001	2.76
3	8	250	142	10	2	1091	104	3246	44	95	95	616	6	23	44	.001	4.2
3	9	257	165	10	2	1612	102	2199	8	398	512	3095	5	34	43	.001	0.4
3	10	264	146	10	2	5139	192	2168	10	180	325	1337	14	39	89	.001	8.4
3	11	271	182	10	2	385	95	.001	10	98	116	676	6	25	58	,001	4.11
3	12	278	167	12	2	848	59	1975	3	42	58	533	1	23	11	.001	0.04
3	13	287	209	10	2	3443	152	6416	10	176	142	793	7	35	106	.001	1.8
3	14	292	132	10	2	1050	46	1880	5	101	73	303	2	18	55	.001	0.1
;3	15	299	167	10	2	219	16	816	1	15	34	136	14	44	30	.001	0.04
9	13	299	167	10	2	1789	93	3133	12	99	83	490	4	21	96	.001	3.5
3	16	306	168	10	2	2440	117	4380	8	138	301	1290	6	34	138	.001	0.3
3	17	311	332	10	2	2270	103	4800	11	234	197	1040	8	33	170	.001	4.1
3	18	327	170	10	2	2070	107	4637	15	206	172	622	7	31	157	.001	1.7
3	19	334	170	10	2	2182	98	3687	119	291	120	560	5	28	105	.001	2.5
3	20	341	169	10	2	1241	79	2236	11	179	123	524	5	21	83	.001	2.8
3	21	348	169	10	2	3684	150	5268	13	189	163	852	11	32	183	.001	2.5
3	22	355	170	10	2	2134	137	3753	78	272	187	868	9	39	165	.001	6.2
3	23	362	166	10	2	1940	80	2865	9	194	149	616	7	24	116	.001	1.3
3	24	369	166	10	2	2909	130	4338	11	259	192	1059	8	45	134	.001	2.0
3	25	376	170	10	2	443	32	881	7	112	104	374	3	17	46	.001	0.1
3	26	383	167	10	2	1920	81	2714	6	162	115	507	4	25	85	.001	0.8
3	27	390	168	10	2	2484	89	3393	6	117	125	578	5	29	80	.001	1.1
;3	28	397	166	10	2	46	6	133	1	6	20	148	.500	9	5	.001	0.1
3	29	404	167	10	2	4220	164	7145	10	200	147	678	8	40	143	.001	2.1
3	30	412	193	10	2	10029	141	2904	12	276	211	534	9	38	139	.001	2.0
3	31	418	143	10	2	1493	101	1651	.500	139	413	503	.500	33	63	.001	0.73
3	32	427	216	10	2	2214	93	1967	.500	122	134	183	.500	23	107	.001	1.67
3	33	432	120	10	2	1026	46	1182	13	92	43	142	.500	16	47	.001	1.30
3	34	439	168	10	2	1417	76	6755	9	226	129	445	3.2	22	42	.001	1.9
3	35	446	170	10	2	1411	90	7422	8	179	120	487	4.0	22	65	.001	0.5
3	36	453	179	10	2	2950	109	7219	11	182	133	488	4.9	34	80	.001	4.9
3	37	460	168	10	2	3095	78	3302	4	77	92	1132	2	32	64	.001	7.6
3	39	481	146	10	2	662	43	1570	4	91	74	827	2	20	74	.001	0.9
3	40	488	168	10	2	13719	214	7398	7.2	119	66	540	3	29	146	.001	1.50
3	41	495	169	10	2	7774	102	2963	11.3	505	123	766	5	22	98	.001	.018
3	42	502	168	10	2	2418	71	2681	4.0	152	134	632	5	47	75	.001	0.06
3	43	509	163	10	2	8475	128	4459	5.5	164	110	945	3	23	64	.001	4.62
3	44	523	312	10	2	22170	264	9571	6.2	114	129	1390	4	37	192	.001	17.5
3	45	537	339	10	2	1662	116	5255	6	287	180	1721	4	36	389	.001	1.3
3	46	551	290	10	2	1381	119	3138	4	141	125	515	3	39	357	.001	3.8
3	47	565	311	10	2	10236	240	12324	12	208	242	1717	13	56	261	.001	13.1
3	48	580	306	9	2	5650	162	7372	7	95	154	1539	7	39	152	.001	12.2
3	49	593	291	10	2	6046	167	9002	9	95	181	1134	8	38	186	.001	2.7
3	50	607	316	10	2	6212	180	8544	10	139	184	1001	9	39	180	.001	5.8
3	51	619	248	10	2	3821	162	5584	12	104	150	840	6	34	144	.001	7.4
3	52	635	368	10	2	6094	193	9045	10	155	319	1428	12	48	225	.001	5.1

note: No data from sample 38

Data Unit 4

1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19
u	sam	doy	hrs	flw	hf	Al	Mn	Fe	Co	Ni	Cu	Zn	Ga	Sr	Ba	Pb	U
;4	2	204	83	10	1	479	37.5	477	2.7	64.3	52.6	547	3.2	25.2	56.6	58.8	0.45
;4	3	211	168	9	1	380	36	245	2.5	42	34	279	1.5	14	14	.092	0.10
;4	4	218	166	8.5	1	579	55	322	1.7	28	22	368	2.0	16	15	0.11	0.09
4	6/1	232	167	9.5	2	2200	86	723	5.4	282	139	861	6.2	23	59	.001	0.37
4	7	239	167	9	1	537	76	422	3.0	74	113	1590	2.2	35	35	.001	0.38
4	8	246	169	9	2	1596	110	5011	7	163	111	2737	8	26	55	.001	0.4
4	9	253	168	9.5	2	2348	139	3732	7	75	91	694	6	28	46	.001	0.4
4	10	260	169	10	2	3566	146	1776	9	239	132	650	11	33	68	.001	0.5
4	11	267	156	10	2	1100	154	.001	7	80	101	764	8	27	78	.001	0.71
4	12	274	166	10	2	4574	142	5583	8	94	98	700	6	28	57	.001	1.0
4	13	281	167	10	2	2070	130	7024	7	131	140	621	5	31	83	.001	1.5
4	14	288	169	10	2	10020	267	10605	12	366	307	950	9	43	100	.001	1.7
4	15	295	167	10	2	2296	107	3854	5	97	116	601	3	26	53	.001	1.0
4	16	303	178	10	2	665	81	3849	3	35	52	412	5	27	89	.001	1.4
4	17	309	160	10	2	2440	117	4380	8	138	301	1290	6	34	138	.001	0.3
4	18	316	142	10	2	2070	56.6	2030	5	89	49	552	3	21	68	.001	0.1
4	19	323	168	10	2	2817	112	4154	9	111	149	567	6	29	110	.001	0.3
4	20	331	179	10	2	4167	165	7512	10	164	236	760	9	40	190	.001	0.8
4	21	337	153	10	2	3089	84	4059	7	103	97	373	4	23	84	.001	0.3
4	22	347	239	10	2	8115	238	7556	13	208	219	1054	17	45	258	.001	1.0
4	23	353	134	10	2	5748	174	5773	10	181	194	776	12	39	195	.001	0.8
4	24	363	242	10	2	4032	174	5441	10	183	160	806	10	40	191	.001	1.0
4	25	369	149	10	2	3448	92	3451	6	97	293	474	6	38	111	.001	0.6
4	26	376	161	10	2	402	37	1166	4	97	82	402	3	18	58	.001	0.2
4	27	383	158	10	2	2320	92	3471	6	141	99	464	5	25	94	.001	1.0
4	28	389	150	10	2	2396	91	3454	4	82	89	486	4	27	73	.001	1.6
4	29	397	186	10	2	2878	111	4088	6	127	102	474	6	34	97	.001	1.8
4	30	403	150	10	2	4515	170	6452	11	165	135	606	9	40	156	.001	2.5
4	31	411	181	10	2	13261	197	3773	8	190	163	534	13	45	160	.001	1.0
4	32	418	171	10	2	2098	114	2004	.500	72	73	184	0.10	23	99	.001	0.47
4	33	424	142	10	2	2364	84	1922	.500	84	37	146	.500	23	73	.001	0.30
4	34	432	190	10	2	3065	144	2242	.500	99	94	185	0.91	24	113	.001	0.58
4	35	439	170	10	2	1630	82	6746	6	136	96	404	3.0	22	47	.001	0.3
4	36	445	139	10	2	1602	92	7187	10	224	113	515	4.3	23	69	.001	0.5
4	37	453	188	10	2	3660	178	4470	11	110	134	495	5	42	122	.001	0.57
4	38	459	152	10	2	4130	153	4400	11	85	94	334	4	37	90	.001	0.38
4	39	466	161	10	2	2570	101	2480	7	93	72	319	3	31	79	.001	0.04
4	40	473	178	10	2	8710	284	7770	13	282	141	566	8	96	253	.001	0.82
4	41	482	215	10	2	3340	115	2940	4	193	97	452	3	36	115	.001	0.14
4	42	488	141	10	2	5740	199	4760	8	86	686	610	5	42	141	.001	0.31
4	44	502	154	10	2	7016	114	4778	9.3	468	134	3130	5	55	131	.001	.018
4	46	523	326	10	2	24130	308	11776	6.9	77	126	788	6	35	203	.001	0.75
4	47	538	360	10	2	1739	101	4116	5	219	136	637	3	26	355	.001	0.3
4	48	553	348	9.5	2	2524	161	6091	4	180	165	1514	4	37	511	.001	0.6
4	49	565	298	10	2	3546	227	10671	6	200	180	1897	5	37	442	.001	1.3
4	50	580	359	10	2	11951	303	16917	15	96	158	798	12	49	222	.001	1.1
4	51	593	301	10	2	7383	200	10901	31	135	192	807	9	35	182	.001	0.7
4	52	608	347	10	2	8838	236	11373	13	113	187	935	10	40	206	.001	0.8
4	53	623	360	10	2	10824	292	14994	14	252	185	890	12	48	205	.001	1.0
4	54	635	294	10	2	15558	241	13922	10	137	357	1188	13	46	215	.001	1.0

note: No data from samples 1, 5, 43, 45. Samples 3 and 4 are background.

Data Unit 5

1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19
u	sam	doy	hrs	flw	hf	Al	Mn	Fe	Co	Ni	Cu	Zn	Ga	Sr	Ba	Pb	U
;5	3	218	166	10	1	289	12	99	1.7	23	9.8	193	0.8	8.4	4.6	0.08	0.10
;5	4	225	170	10	1	43	2.9	12.9	0.2	1.3	1.3	15.7	0.07	0.54	0.54	.007	0.01
5	5	232	168	10	1	5320	138	1160	6.1	100	119	2260	11	44	100	.001	0.63
5	6	239	169	10	1	1540	95	898	9.1	138	110	1410	6.1	44	100	.001	0.62
5	7	246	169	10	1	1050	83	743	8.3	124	122	3510	5.4	40	92	.001	0.33
5	8	253	167	10	2	1194	91	3573	4	67	83	694	6	24	47	.001	0.3
5	9	260	168	10	2	1323	55	1548	7	86	56	453	4	20	42	.001	0.3
5	10	267	169	10	2	399	80	.001	6	73	88	594	5	21	52	.001	0.25
;5	11	271	94	10	2	.001	34	.001	6	38	72	392	3	17	32	.001	0.1
5	12	278	168	10	2	1752	94	5553	6	108	122	516	4	27	50	.001	0.5
5	13	286	192	10	2	3144	145	4139	8	211	150	569	5	31	90	.001	1.6
5	14	292	111	10	2	1553	89	5816	7	96	102	634	4	26	43	.001	0.7
5	15	299	168	10	2	850	68	3134	3	37	82	514	6	26	44	.001	0.2
5	16	306	157	10	2	956	78	3490	9	87	169	758	6	32	134	.001	0.3
5	17	310	88	10	2	1050	45.6	1880	5	101	73	303	2	18	55	.001	0.1

note: No data from samples 1, 2. Sample 3 is background.

Background Data Units 2, 4, 5, 9

1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19
u	sam	doy	hrs	flw	hf	Al	Mn	Fe	Co	Ni	Cu	Zn	Ga	Sr	Ba	Pb	U
2	2	210	265	10	1	446	30	139	2.4	36	27	316	1.6	14	12	0.1	0.07
4	3	211	168	9	1	380	36	245	2.5	42	34	279	1.5	14	14	.092	0.10
4	4	218	166	8.5	1	579	55	322	1.7	28	22	368	2.0	16	15	0.11	0.09
5	3	220	166	10	1	289	12	99	1.7	23	9.8	193	0.8	8.4	4.6	0.08	0.10
9	7	254	168	10	2	484	6	1056	2	20	24	289	1	10	5	.001	0.2
9	8	285	168	10	2	621	4	1054	4.5	10	24	406	1	9	8	.001	0.02
2	12	298	138	10	2	479	25	752	1	28	82	419	1	16	8	.001	0.06
9	11	339	168	10	2	32	6	36	3	5	11	108	.500	11	8	.001	0.001
;9	19	350	168	10	2	395	15	603	8	625	37	311	1	16	15	.001	0.04
9	20	366	168	10	2	414	14	1358	1	23	72	262	1	9	12	.001	0.04
9	22	400	168	10	2	59	9	250	1	10	20	129	1	10	9	.001	.01
9	27	460	168	10	2	282	9	450	.500	7	24	118	0.03	9	7	.001	.018
9	29	485	168	10	2	103	8	330	6	11	9	113	.500	8	6	.001	.018

note: Background data from several units at different times

Data Unit 6

1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19
u	sam	doy	hrs	flw	hf	Al	Mn	Fe	Co	Ni	Cu	Zn	Ga	Sr	Ba	Pb	U
;6	1	202	168	10	1	1380	53	513	2.6	37.1	43.5	510	3.4	24.7	55.3	54.6	0.31
;6	2	211	167	10	1	1452	.001	.001	.001	.001	80	641	.001	30	37	8	.026
6	7	232	145	10	1	4890	167	1350	9.4	204	178	2730	13	49	125	.001	0.59
6	8	239	165	10	1	1510	109	1090	11.2	228	198	2710	7.9	52	148	.001	0.81
6	9	246	168	10	1	1250	106	968	8.8	211	138	3300	7.7	47	133	.001	0.71
6	10	253	168	10	2	1843	141	5509	5	75	107	811	8	30	57	.001	0.4
6	11	260	168	10	2	2111	98	2739	7	111	90	527	6	27	65	.001	0.5
6	20	267	169	10	2	358	121	.001	7	124	124	821	6	29	59	.001	0.78
6	21	271	93	10	2	.001	66	.001	7	83	99	557	4	22	45	.001	0.59
6	22	278	157	10	2	1349	99	17893	35	122	130	602	4	28	67	.001	0.4
6	23	287	212	10	2	4141	173	8974	10	163	206	822	7	39	121	.001	1.6
6	24	292	124	10	2	2223	103	1949	5	115	159	890	4	27	57	.001	0.4
6	25	299	170	10	2	1860	100	4480	8	101	176	831	7	36	160	.001	0.8
6	26	303	92	10	2	443	46	1520	2	66	97	516	2.7	19	59	.001	0.14
6	27	306	75	10	2	657	43	1770	5	73	74	397	3	22	61	.001	0.2
6	28	313	166	10	2	956	77.6	3490	9	87	169	758	6	32	134	.001	0.3
6	29	320	172	10	2	443	46.4	1520	2	66	97	516	3	19	59	.001	0.1
6	30	327	170	10	2	2607	122	5816	7	130	196	776	9	34	223	.001	0.6
6	31	334	168	10	2	1299	71	2723	4	90	220	643	4	25	81	.001	0.3
6	32	341	164	10	2	497	48	1421	6	73	82	428	4	17	54	.001	0.13
6	33	349	187	10	2	3782	173	6228	9	153	213	1060	15	35	254	.001	0.7
6	34	355	183	10	2	2975	191	6142	18	185	232	1177	17	42	305	.001	0.8
6	35	362	162	10	2	1214	77	2671	7	150	151	762	7	23	135	.001	0.30
6	36	369	166	10	2	1445	87	3155	9	97	106	656	7	34	128	.001	0.30
6	37	376	171	10	2	490	37	1229	5	109	96	452	3	20	61	.001	0.1
6	38	384	187	10	2	2384	94	3241	6	136	99	610	6	30	105	.001	0.9
6	39	390	146	10	2	1727	67	2414	6	103	90	448	4	20	74	.001	0.7
6	40	397	172	10	2	1314	71	2690	5	132	123	595	6	32	125	.001	0.7
6	41	404	168	10	2	3901	169	6427	13	183	169	790	10	44	204	.001	1.8
6	42	411	160	10	2	9934	124	2835	8	140	121	541	10	35	140	.001	0.51
6	43	418	174	10	2	18997	89	1436	.500	72	91	182	1.17	21	80	.001	0.30
6	44	425	168	10	2	1420	71	1395	.500	63	78	151	.500	20	79	.001	0.26
6	45	432	164	10	2	1773	84	1727	.500	68	93	186	0.48	19	101	.001	0.36
6	46	440	191	10	2	1970	128	7377	10	716	315	2594	3.6	36	62	.001	0.34
6	47	446	149	10	2	1270	86	7286	13	206	106	498	3.7	21	70	.001	0.4
6	48	453	167	10	2	4099	181	8820	13	191	147	600	6.7	46	133	.001	0.89
6	49	460	167	10	2	3550	159	6470	12	103	165	465	4	36	87	.001	0.21
6	50	467	171	10	2	2900	144	4800	5	145	153	441	4	42	116	.001	0.13
6	51	474	160	10	2	5300	212	6080	9	174	124	408	7	67	174	.001	0.59
6	52	481	168	10	2	3468	80	4397	5	125	117	1152	3	28	77	.001	0.3
6	53	488	175	10	2	5670	227	4430	8	109	92	433	5	41	149	.001	0.33
6	54	495	167	10	2	2190	91	2430	159	478	104	430	3	27	149	.001	.018
6	55	501	134	10	2	4048	72	3243	6.1	152	231	1859	4	54	98	.001	.018
6	56	508	162	10	2	24071	551	4095	5.8	174	228	764	5	29	75	.001	.018
6	57	523	332	10	2	22684	286	10450	7.3	77	186	782	5	41	236	.001	0.50
6	58	537	246	10	2	1704	110	4749	6	279	231	851	4	37	387	.001	0.3

notes: The first sample labelled 649 (there were 2) was used as 646. Batch records indicate this is correct.
No data from samples 3-6, 12-19

Data Unit 7

1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19
u	sam	doy	hrs	flw	hf	Al	Mn	Fe	Co	Ni	Cu	Zn	Ga	Sr	Ba	Pb	U
;7	1	201	161	10	1	35	5.7	107	0.3	23	5.3	415	20	6.8	208	.027	0.01
;7	2	220	447	5	1	435	29	173	2.3	17	12	482	13	18	105	0.10	0.09
;7	3	225	116	10	1	530	121	490	5.8	69	126	1993	10	26	85	0.56	0.21
7	4	232	172	10	1	571	24	279	1.3	27	26	1280	10	26	121	.001	0.12
7	5/1	236	104	10	2	263	32	414	4.0	57	34	818	4.8	20	101	.001	0.29
7	6/1	242	133	10	2	497	38	436	3.6	62	58	989	4.8	21	106	.001	0.37
;7	7	250	148	10	2	455	133	.001	19	64	179	2768	24	33	231	.001	0.4
;7	8	257	158	10	2	.001	13	.001	3	29	18	514	10	13	115	.001	0.0
7	11	271	167	10	2	993	60	7257	10	102	99	1449	19	29	440	.001	0.5
;7	12	277	142	10	2	11602	46	152900	709	31	105	4233	64	57	1001	.001	0.04
7	13	284	175	10	2	6838	191	13507	22	193	205	1771	35	58	423	.001	0.9
7	15	292	167	10	2	14198	327	7753	26	277	288	1758	20	58	241	.001	1.6
7	17	317	171	10	2	491	26.9	1610	4	38	86	892	17	23	405	.001	0.1
7	18	327	172	10	2	4680	242	6584	30	367	328	1907	31	58	550	.001	1.2
;7	19	334	164	10	2	498	34	1564	2	30	105	1421	46	28	957	.001	0.07
7	21	348	168	10	2	1906	107	2472	10	159	240	1006	17	32	320	.001	0.44
7	23	369	336	10	2	3579	199	8063	19	306	402	2911	37	63	798	.001	0.8
:7	24	376	168	10	2	12049	3508	37123	12	224	248	2485	48	1131	13034	.001	1.0
7	25	390	169	10	2	.001	59	838	3	72	55	575	13	23	282	.001	0.08
7	26	404	335	10	2	18577	384	6814	20	438	448	1142	27	107	444	.001	1.8
;7	27	412	187	10	2	13695	594	12117	17	78	12568	165123	104	98	1902	.001	0.94
7	28	426	340	10	2	1406	100	1066	2	14	193	1757	2.2	9	94	.001	0.14
7	28c	447	170	10	2	2120	127	2500	7	163	165	1080	5	31	133	.001	0.20
7	29d	454	168	10	2	2850	142	4260	11	125	258	996	5	40	144	.001	0.27
7	30e	461	168	10	2	1960	99	4580	5	90	116	493	2	31	73	.001	0.04
7	29	468	143	10	2	6600	244	6340	14	295	163	678	7	84	203	.001	0.81
7	31	475	165	10	2	1560	57	2520	6	41	129	351	2	23	84	.001	.018
7	32	482	164	10	2	6160	305	6860	11	172	180	938	8	54	298	.001	0.49
7	33	496	334	10	2	2937	150	6991	15.5	470	170	3200	69	76	1429	.001	.018
7	34	503	169	10	2	8880	102	5227	4.7	174	112	1716	9	32	387	.001	.018
7	35	510	165	10	2	11666	151	4950	5.5	76	92	1264	15	33	334	.001	0.94
7	36	517	165	10	2	13117	159	5419	4.2	91	185	1606	17	38	360	.001	0.48

note: no data from samples 9, 10, 14, 16, 20, 22,

Data Unit 8

1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19
u	sam	doy	hrs	flw	hf	Al	Mn	Fe	Co	Ni	Cu	Zn	Ga	Sr	Ba	Pb	U
8	1	246	191	10	2	1410	106	5538	9	168	157	2037	11	29	92	.001	0.4
8	2	253	169	10	2	2279	123	3711	6	91	109	1428	7	32	63	.001	0.4
8	3	260	168	10	2	921	105	.001	8	178	136	689	8	32	81	.001	0.60
8	4	268	178	10	2	3008	125	4937	6	94	125	791	4	27	57	.001	0.5
8	5	275	180	10	2	864	66	3710	5	77	94	667	3	21	47	.001	0.1
8	6	284	211	10	2	1450	131	6466	11	151	193	914	5	31	101	.001	0.7
8	7	295	171	10	2	2989	122	3268	8	107	201	990	7	29	76	.001	0.6
8	8	302	170	10	2	2550	112	5180	9	72	189	679	8	29	154	.001	0.3
8	9	310	188	10	2	2190	164	8160	10	151	339	1360	14	44	302	.001	0.4
8	10	316	147	10	2	12460	53	3920	4	95	109	649	5	24	83	.001	0.1
8	11	323	72	10	2	704	33	1162	2	25	74	328	3	17	41	.001	0.12
8	12	333	233	10	2	4361	159	5028	15	171	230	1023	14	39	217	.001	0.6
8	13	337	104	10	2	1710	44	2077	6	83	109	504	4	19	66	.001	0.17
8	14	353	378	10	2	6141	346	12790	30	327	513	2649	32	66	676	.001	2.4
8	15	358	124	10	2	1769	90	2973	7	97	172	667	7	25	136	.001	0.40
8	16	376	424	10	2	7288	184	4559	15	288	497	740	20	49	295	.001	0.70
8	17	386	247	10	2	6107	132	2731	9	204	177	592	12	38	197	.001	0.62
8	18	393	168	10	2	6672	105	2584	6	142	165	612	10	38	169	.001	0.12
8	19	400	170	10	2	1295	72	1703	5	116	401	538	7	31	129	.001	0.04
8	20	407	166	10	2	12219	204	4846	8	504	360	668	15	54	203	.001	1.0
8	21	432	594	10	2	7291	302	5088	9	107	396	381	7	46	324	.001	1.28
8	30	450	129	10	2	1450	57.6	2510	4.1	56.7	65.9	301	1.7	21.5	56.1	.001	0.23
;8	31	463	411	9	2	1270	52	1770	11	47	59	369	1	19	35	.001	.001
8	32	483	376	10	2	17970	525	14850	23	398	298	1100	17	131	580	.001	1.75

note: No data from samples 22-29

Data Unit 8c

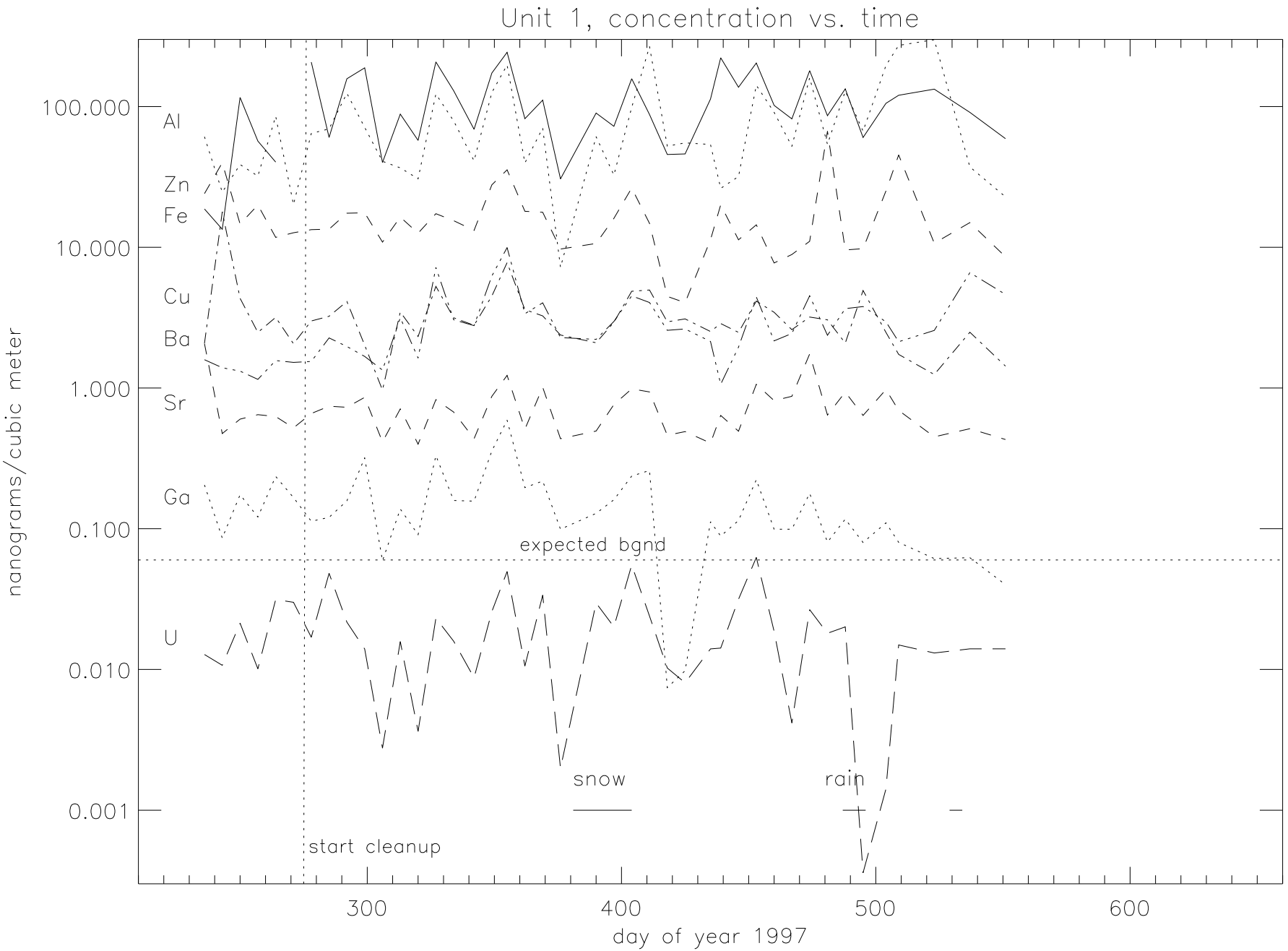
1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19
u	sam	doy	hrs	flw	hf	Al	Mn	Fe	Co	Ni	Cu	Zn	Ga	Sr	Ba	Pb	U
8	50	514	174	10	2	41412	182	8153	7.2	89	191	900	8	36	261	.001	0.02
8	51	524	220	10	2	2377	167	6289	4	140	187	1322	4	44	467	.001	0.4
8	52	538	278	10	2	2643	169	11240	12	589	454	1607	9	63	1004	.001	0.4
8	53	553	291	10	2	2202	155	7958	5	203	356	734	7	75	962	.001	0.4
8	54	566	265	10	2	12416	269	15700	13	207	363	1386	23	85	415	.001	1.1
8	55	580	296	10	2	5968	216	12120	13	138	342	1360	20	56	376	.001	0.7

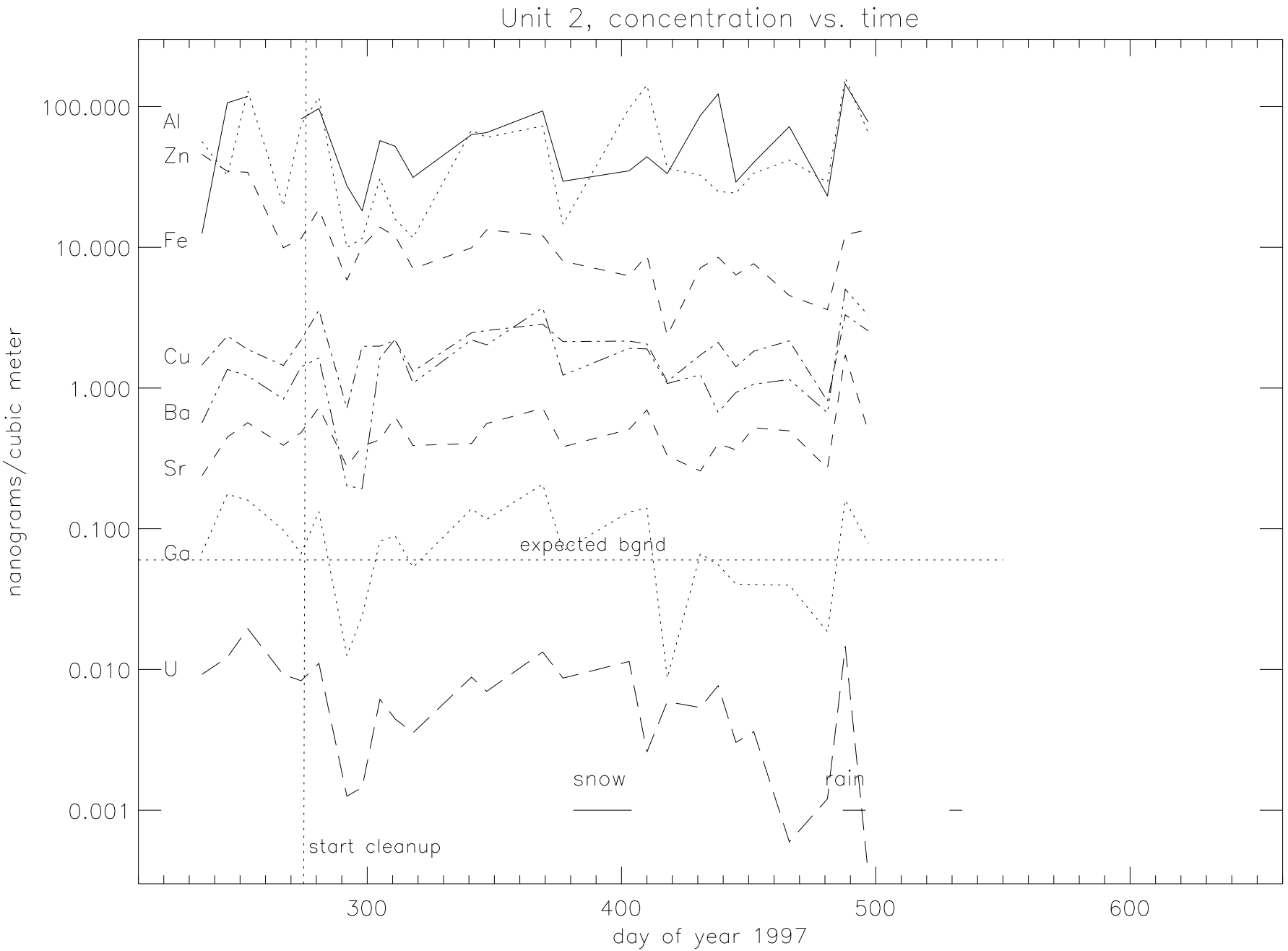
Appendix B - element concentration vs. time for each sampler

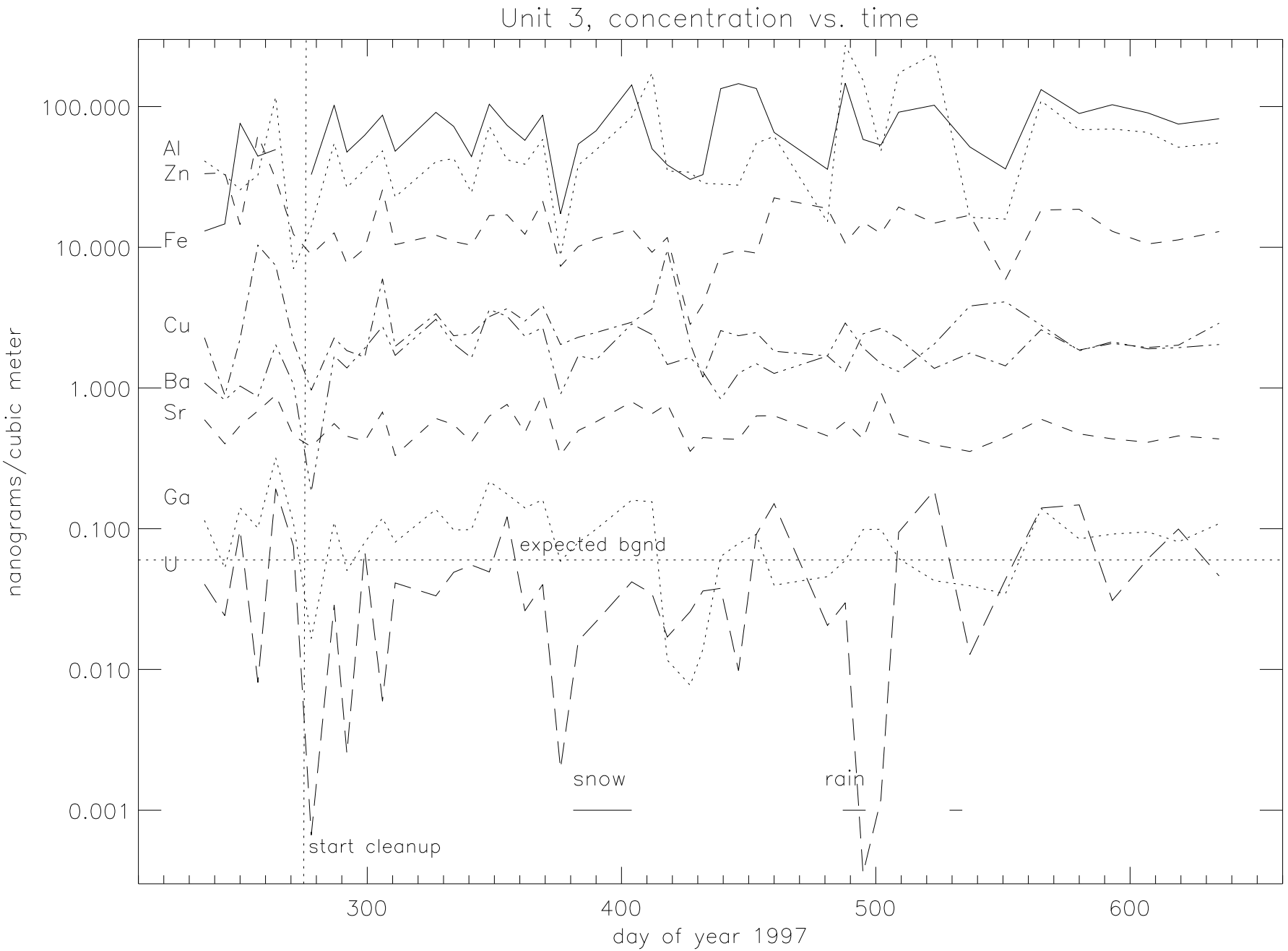
Here, concentrations have been derived for each sampler by dividing the elemental masses by the volume of air passing through the filter. Data taken before mid-August 1997, before filter leaks were fixed, have not been included. Data from contaminated or leaky filters have not been included.

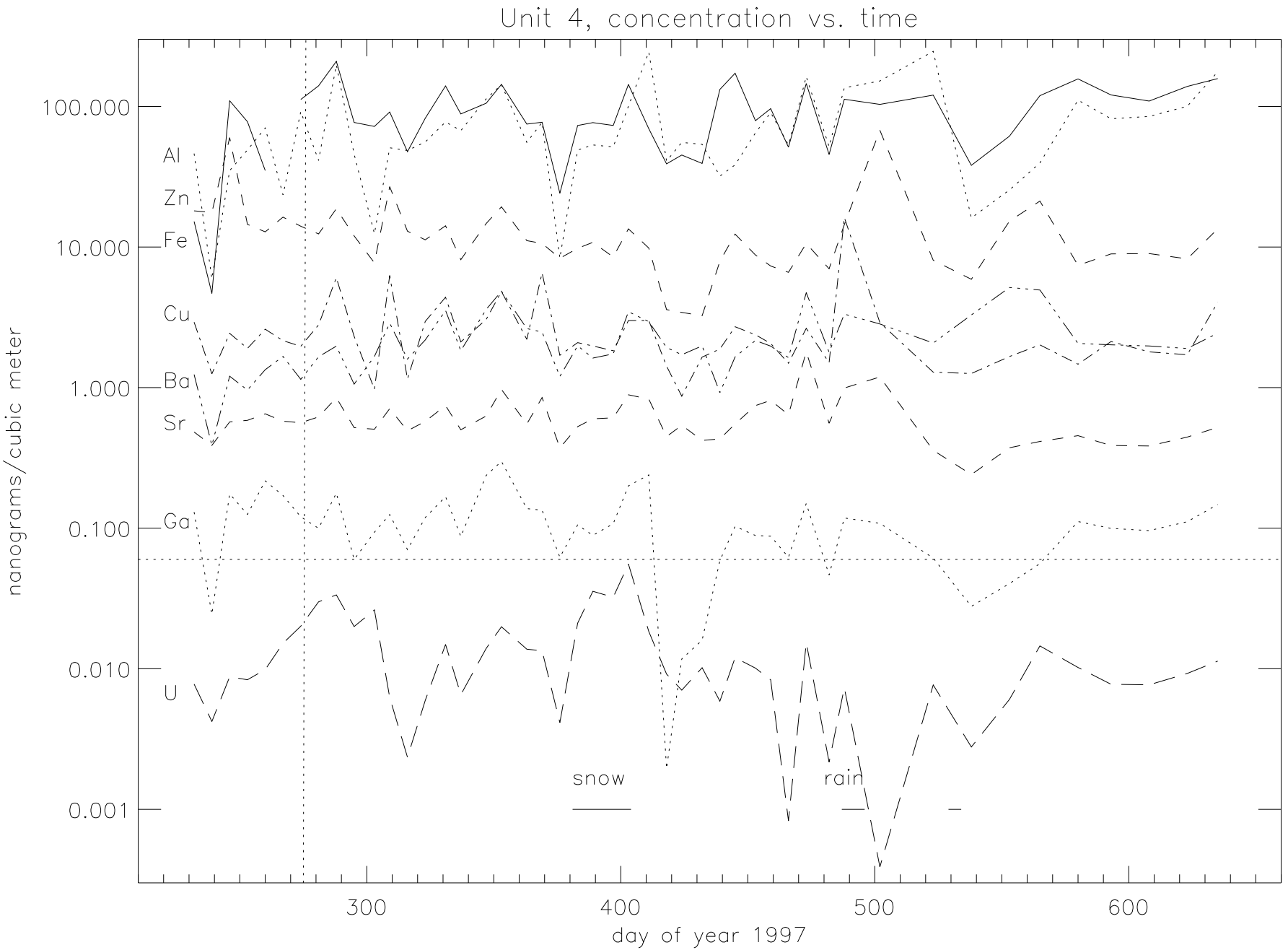
The vertical scale is logarithmic. The vertical dotted line at day 275 (Oct. 2, 1997) shows the time when excavation of the Holding Basin started. The horizontal dotted line is the expected background U concentration. Solid horizontal bars show periods when snow covered the ground and periods of heavy rain.

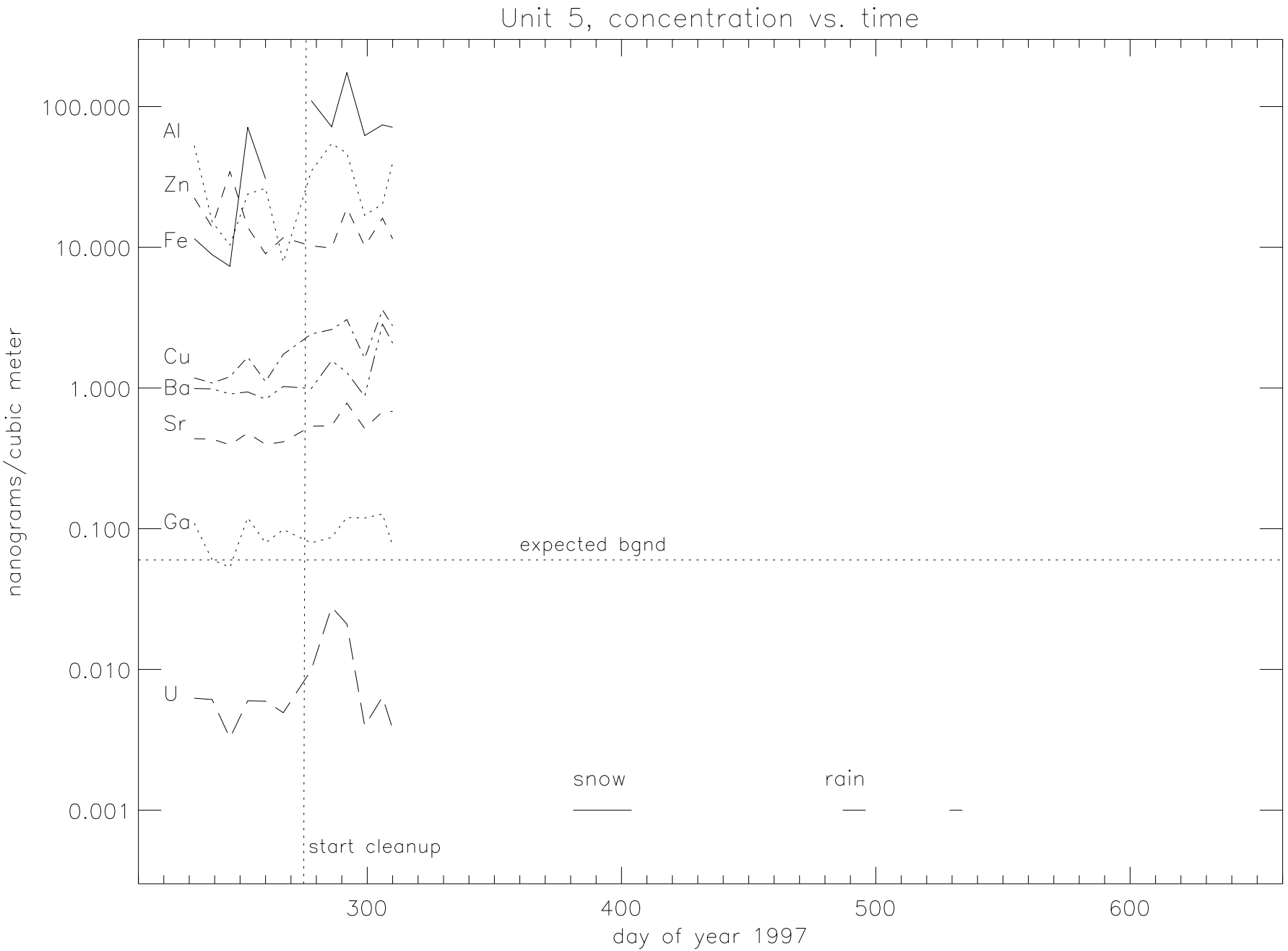
The last set of curves, labeled unit 8, from day 520 to day 580, are from samples collected in Cambridge.

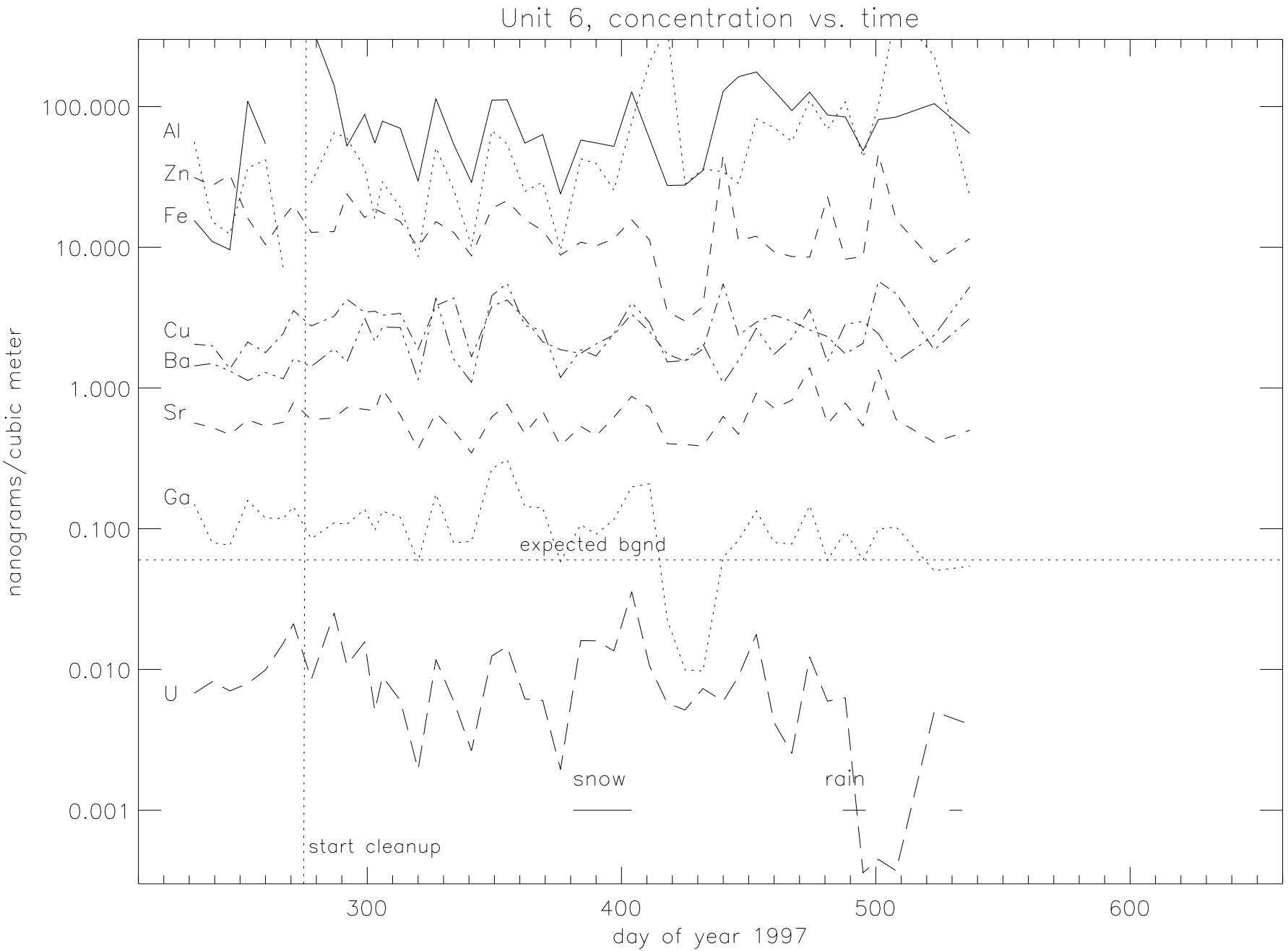

Unit 1, concentration vs. time
nanograms/cubic meter
100.000
10.000
1.000
0.100
0.010
0.001
Al
Zn
Fe
Cu
Ba
Sr
Ga
U
expected bgnd
snow
rain
start cleanup
300
400
500
600
day of year 1997

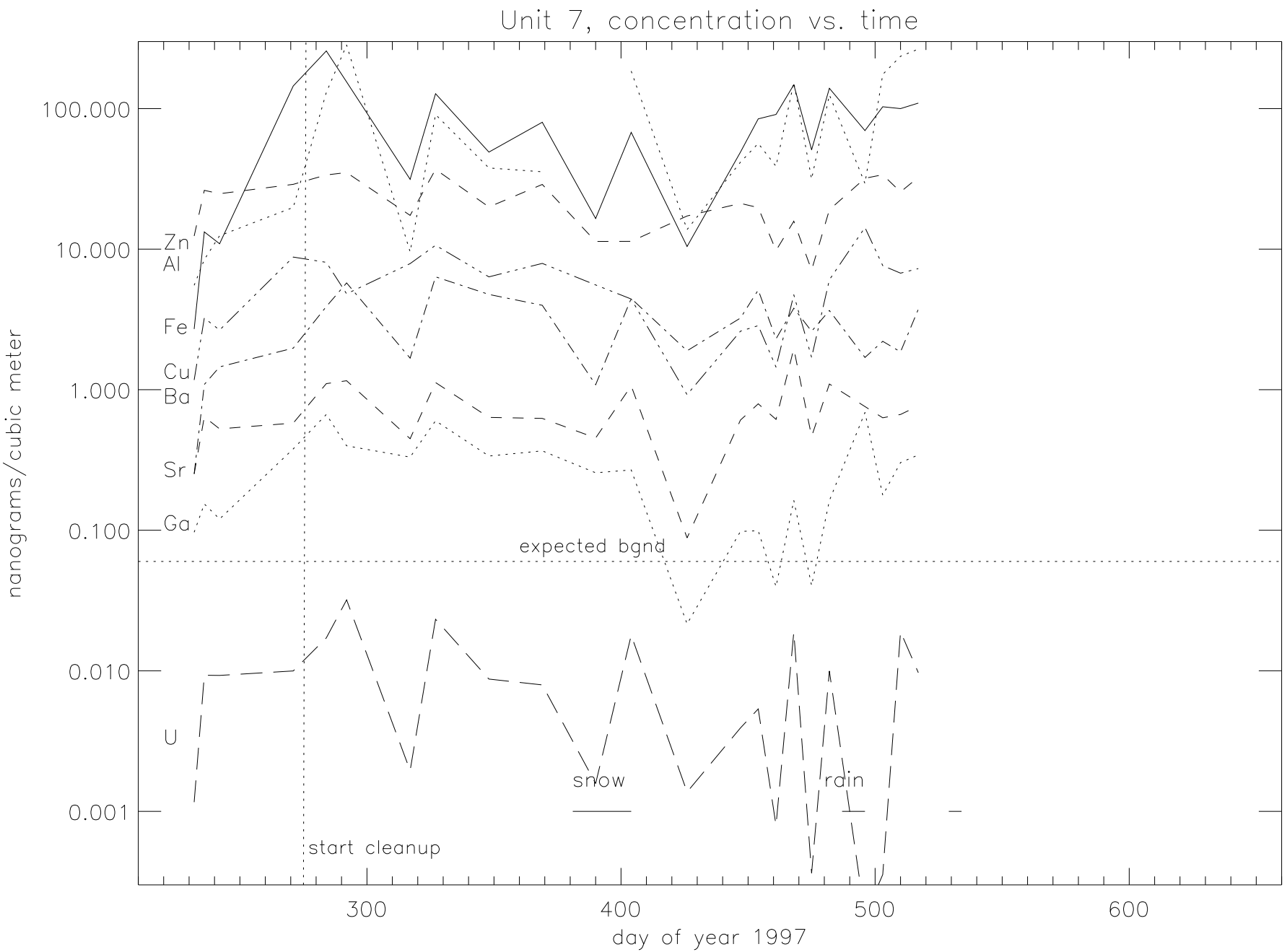

Unit 2, concentration vs. time
100.000
10.000
1.000
0.100
0.010
0.001
nanograms/cubic meter
Al
Zn
Fe
Cu
Ba
Sr
Ga
U
expected bgnd
snow
rain
start cleanup
300
400
500
600
day of year 1997

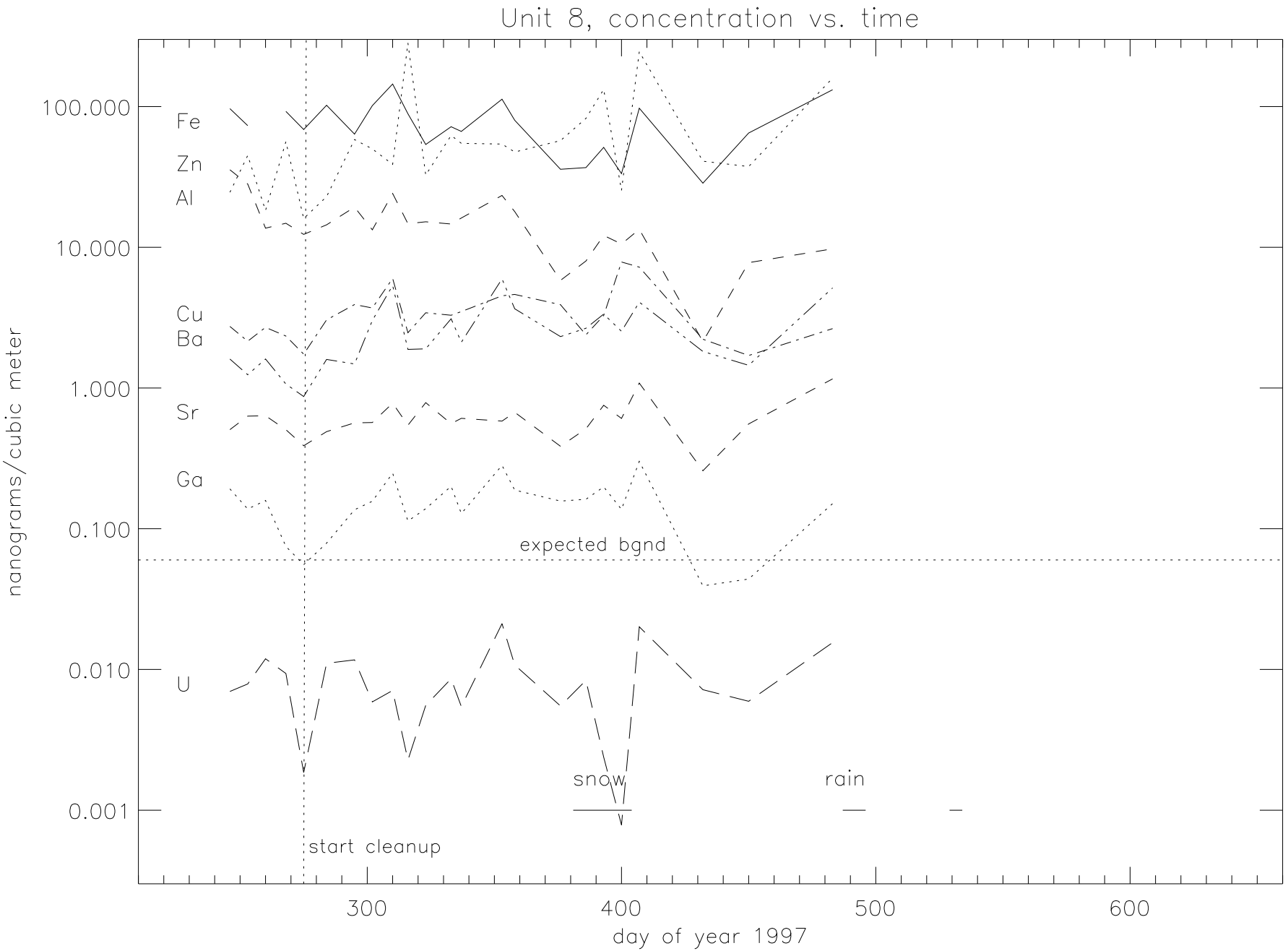

Unit 3, concentration vs. time
100.000
10.000
1.000
0.100
0.010
0.001
nanograms/cubic meter
Al
Zn
Fe
Cu
Ba
Sr
Ga
U
expected bgnd
snow
rain
start cleanup
300
400
500
600
day of year 1997

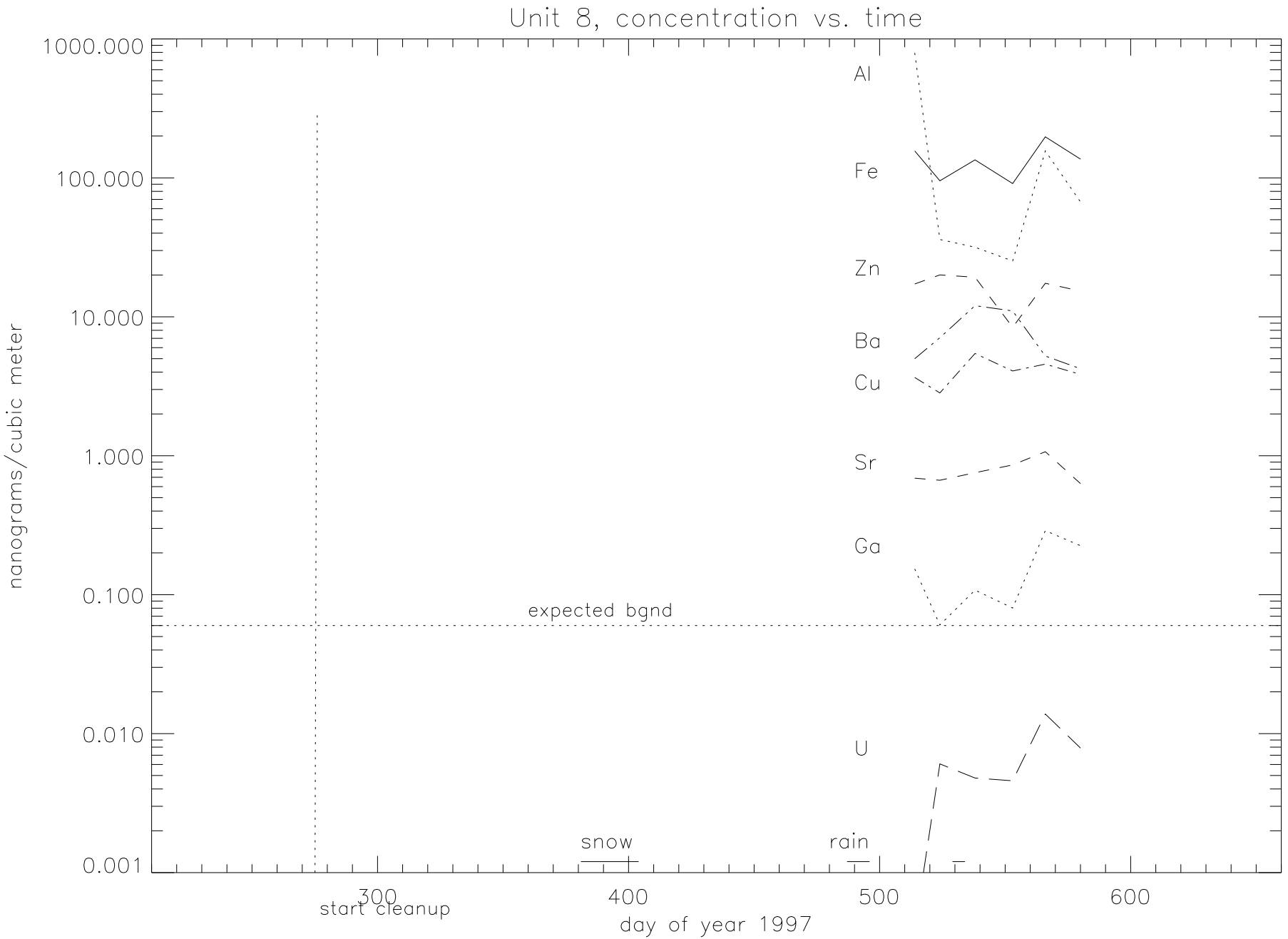

Unit 4, concentration vs. time
100.000
10.000
1.000
0.100
0.010
0.001
nanograms/cubic meter
Al
Zn
Fe
Cu
Ba
Sr
Ga
U
snow
rain
300
400
500
600
day of year 1997

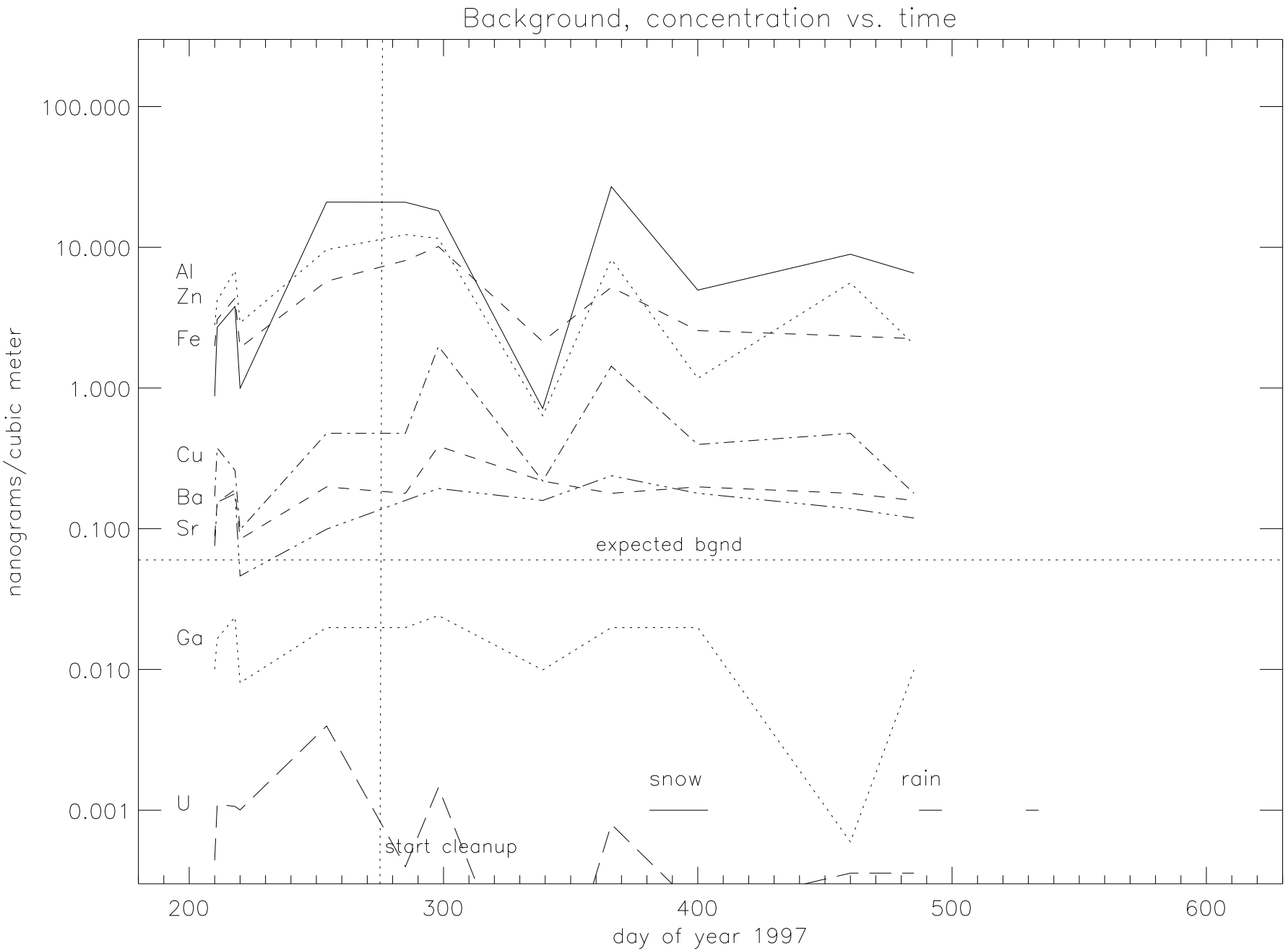

Unit 5, concentration vs. time
100.000
10.000
1.000
0.100
0.010
0.001
nanograms/cubic meter
Al
Zn
Fe
Cu
Ba
Sr
Ga
U
expected bgnd
snow
rain
start cleanup
300
400
500
600
day of year 1997


Unit 6, concentration vs. time
100.000
10.000
1.000
0.100
0.010
0.001
nanograms/cubic meter
Al
Zn
Fe
Cu
Ba
Sr
Ga
U
expected bgnd
snow
rain
start cleanup
300
400
500
600
day of year 1997


Unit 7, concentration vs. time
100.000
10.000
1.000
0.100
0.010
0.001
nanograms/cubic meter
Zn
Al
Fe
Cu
Ba
Sr
Ga
U
expected bgnd
snow
rain
start cleanup
300
400
500
600
day of year 1997


Unit 8, concentration vs. time
100.000
10.000
1.000
0.100
0.010
0.001
nanograms/cubic meter
Fe
Zn
Al
Cu
Ba
Sr
Ga
U
expected bgnd
snow
rain
start cleanup
300
400
500
600
day of year 1997


Unit 8, concentration vs. time
1000.000
100.000
10.000
1.000
0.100
0.010
0.001
nanograms/cubic meter
Al
Fe
Zn
Ba
Cu
Sr
Ga
U
expected bgnd
snow
rain
start cleanup
300
400
500
600
day of year 1997


Background, concentration vs. time
100.000
10.000
1.000
0.100
0.010
0.001
nanograms/cubic meter
Al
Zn
Fe
Cu
Ba
Sr
Ga
U
expected bgnd
snow
rain
start cleanup
200
300
400
500
600
day of year 1997

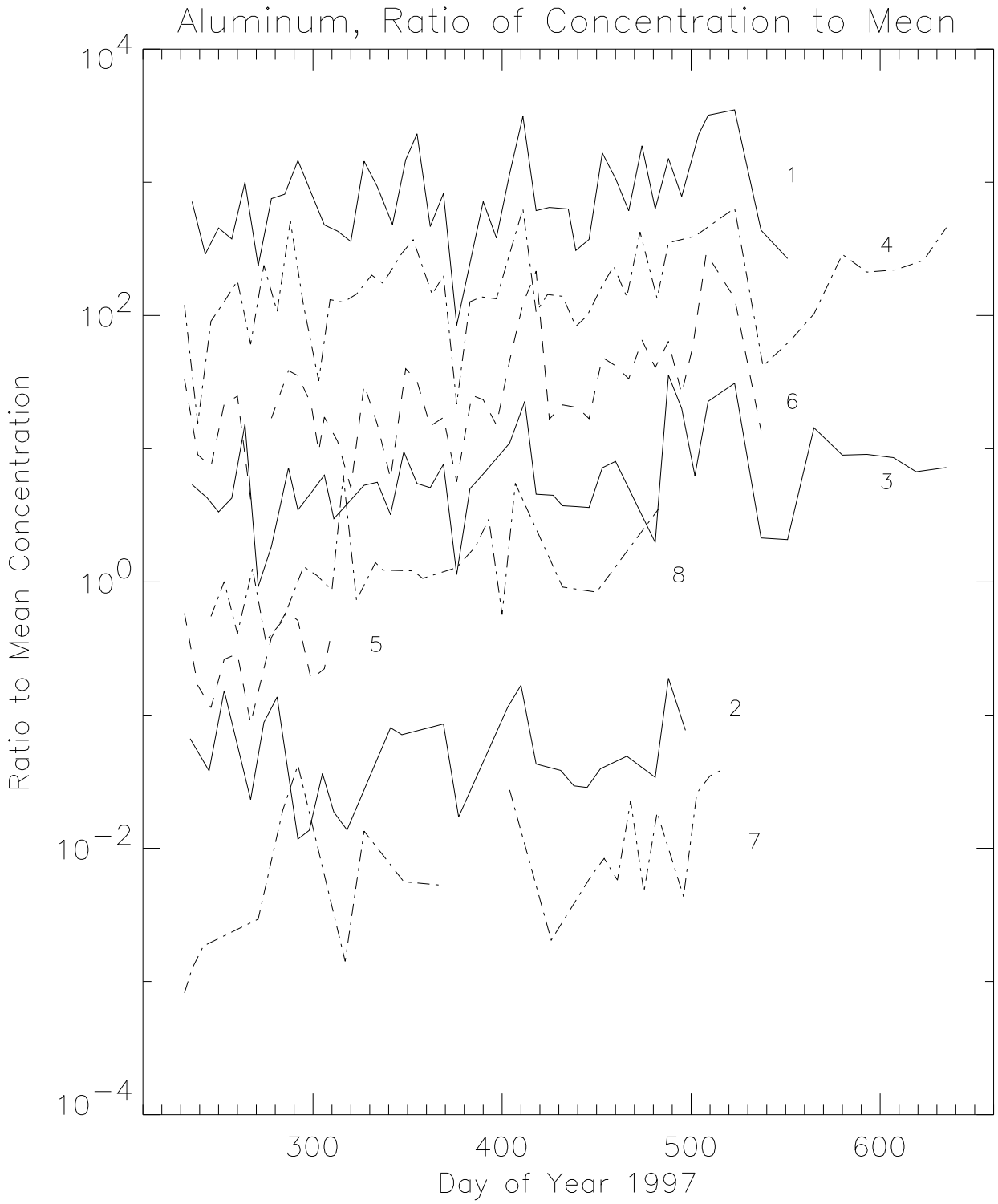
Appendix C - concentration vs. time for several elements

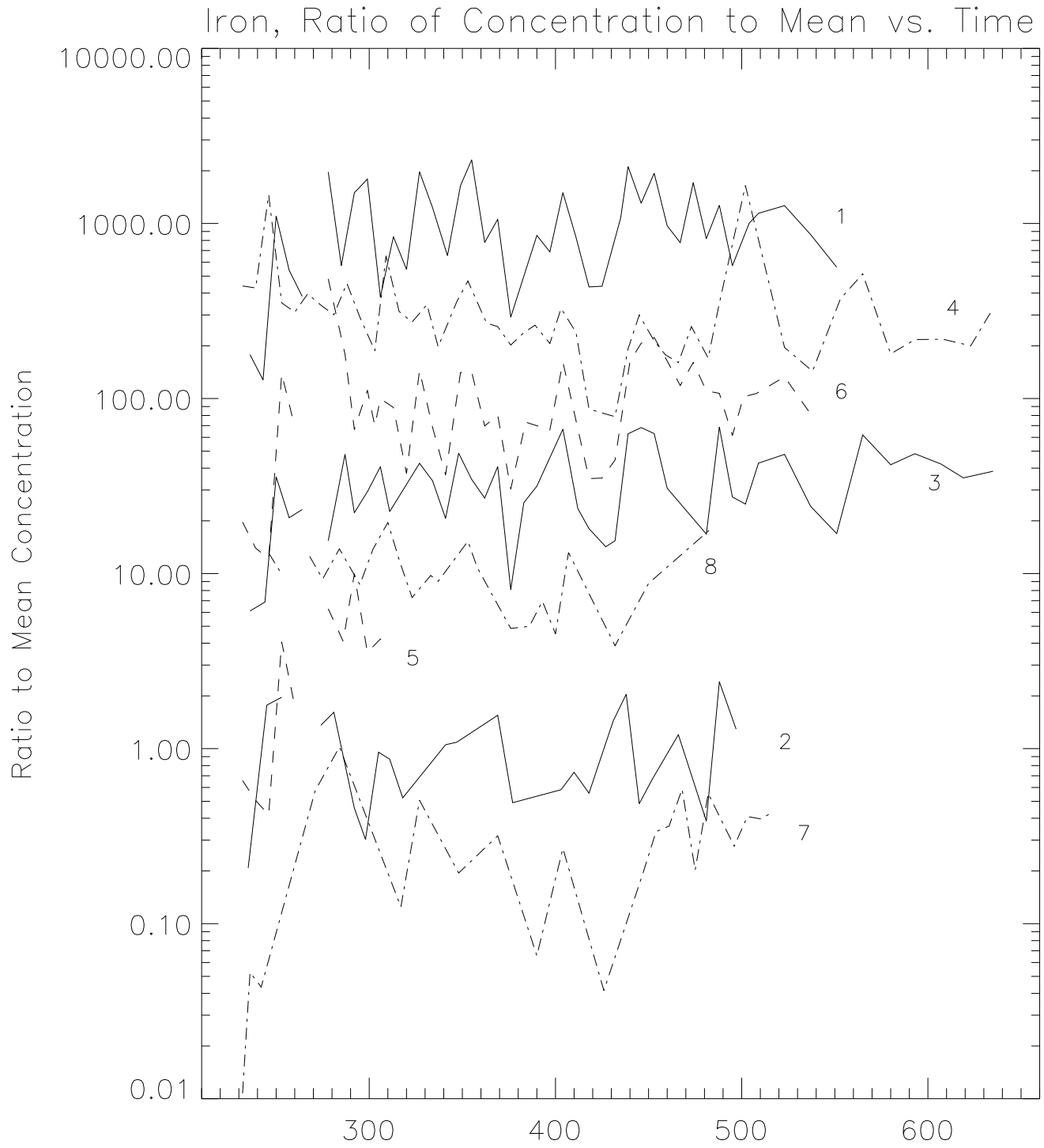
Here the concentration vs. time for the different samplers is shown on the same page for a given element. The sampler number is shown to the right of each curve.

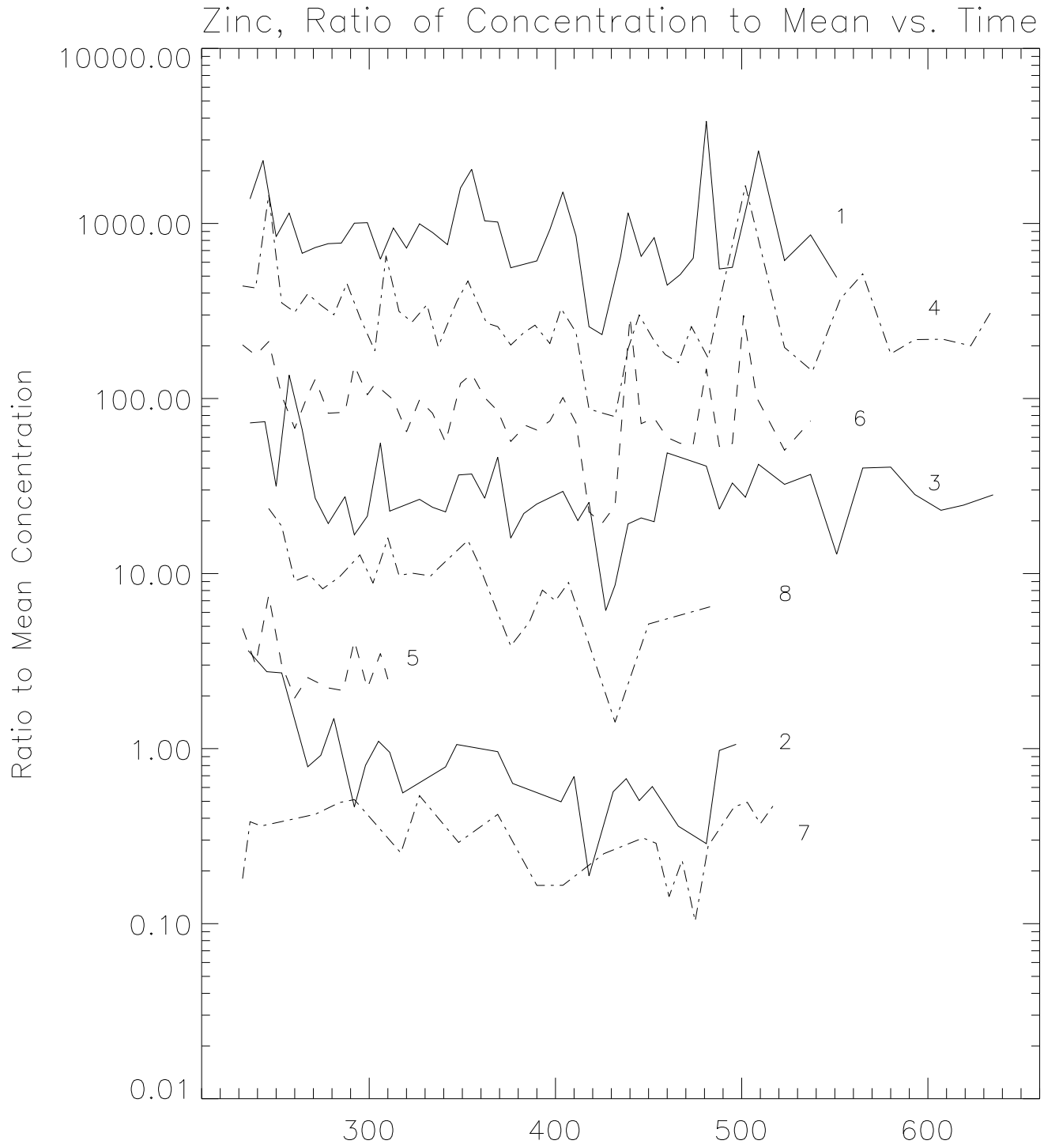
The purpose of these plots is to aid the search for times when all samplers show the same fluctuation, which might indicate a real global increase or decrease in concentration of a particular element.

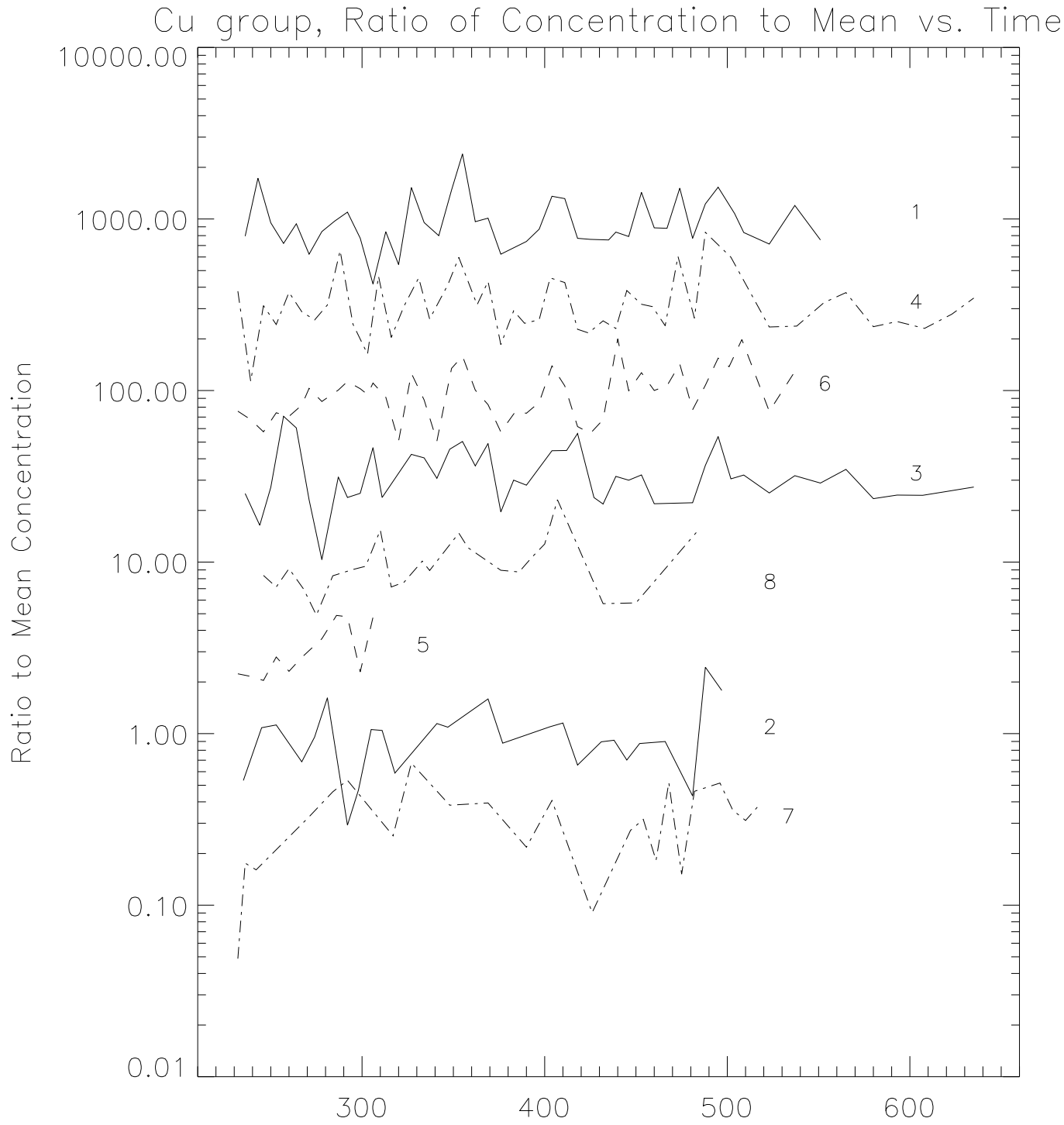
The vertical scale is logarithmic but curves have been displaced so they do not run together. Thus the absolute concentration indicated is not correct in this presentation. There are plots for Al, Fe, Zn, the Cu group (Mn+Cu+Ni+Sr+Ba), and U. The last plot is "normalized" U concentration; the U concentration has been divided by the Cu-group concentration. This was an attempt to show the concentration of U relative to that of other elements. The weekly fluctuations are somewhat lessened but there is not a dramatic difference.

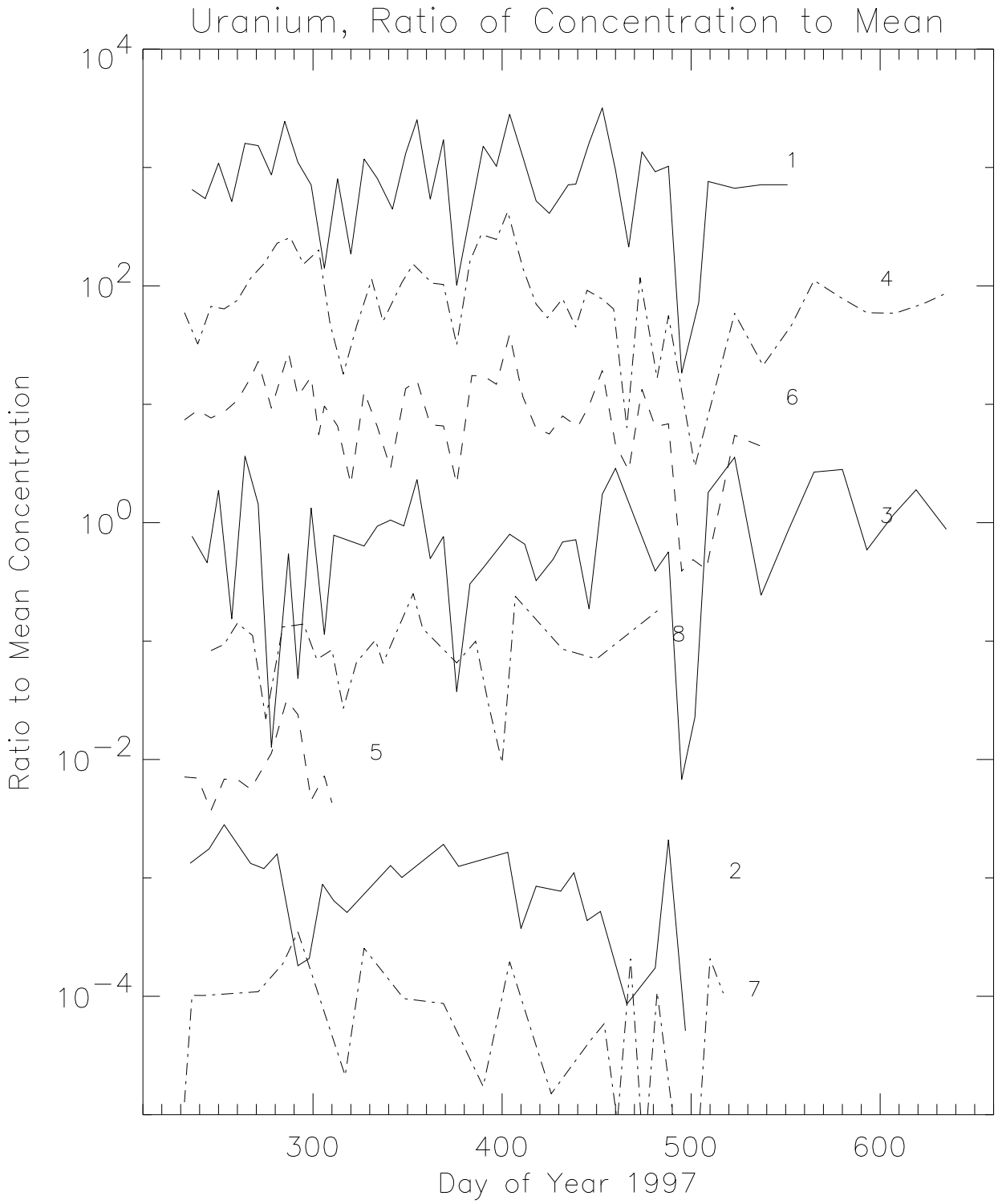
Changes, which are probably real, can be seen in the concentrations of Fe and Zn during day 420-430 and in the concentration of U during day 490-500.

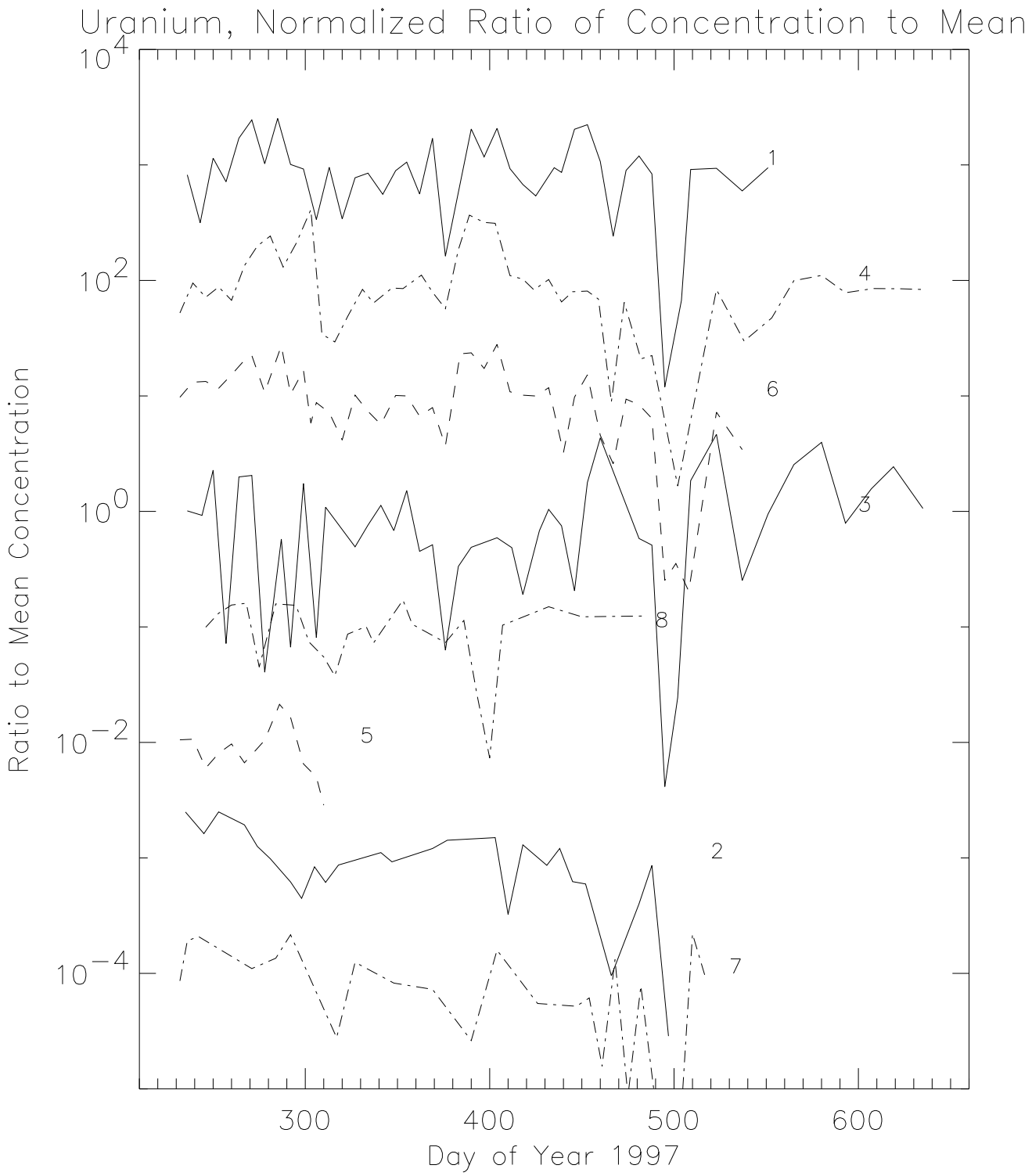

Aluminum, Ratio of Concentration to Mean
Ratio to Mean Concentration
10^4
10^2
10^0
10^{-2}
10^{-4}
300
400
500
600
Day of Year 1997
1
2
3
4
5
6
7
8


Iron, Ratio of Concentration to Mean vs. Time
Ratio to Mean Concentration
10000.00
1000.00
100.00
10.00
1.00
0.10
0.01
300
400
500
600
1
2
3
4
5
6
7
8


Zinc, Ratio of Concentration to Mean vs. Time
Ratio to Mean Concentration
10000.00
1000.00
100.00
10.00
1.00
0.10
0.01
300
400
500
600
1
2
3
4
5
6
7
8


Cu group, Ratio of Concentration to Mean vs. Time
Ratio to Mean Concentration
10000.00
1000.00
100.00
10.00
1.00
0.10
0.01
300
400
500
600
1
4
6
3
8
5
2
7


Uranium, Ratio of Concentration to Mean
Ratio to Mean Concentration
10^4
10^2
10^0
10^{-2}
10^{-4}
300
400
500
600
Day of Year 1997
1
2
3
4
5
6
7
8


Uranium, Normalized Ratio of Concentration to Mean
Ratio to Mean Concentration
10^4
10^2
10^0
10^{-2}
10^{-4}
300
400
500
600
Day of Year 1997
1
2
3
4
5
6
7
8

Appendix D – data sheet used for sample collection
(Original on file at Concord Board of Health)

Town of Concord – Airborne Dust Sample Report

Location:

Air sampler number: Filter number: Height above ground:

New filter inserted by:

Start time: Flow rate: liters/minute
Start date: Timer: hours

Collected by:

Stop time: Flow rate: liters/minute
Stop date: Timer: hours

Weather:

Comments:

Elapsed time: days, hours

Elapsed meter hours:

Average flow rate:

Sample disposition

If problem call: Fred Seward 369 8805 or Pam Rockwell 369 8512 or Chuck Haldeman 369 8562