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ARL Support and Analysis to the Army Public Health Command Kabul Air Quality Data Collection (Spring 2014)

by Alan Wetmore and Thomas DeFelice

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**ARL Support and Analysis to the
Army Public Health Command
Kabul Air Quality Data Collection
(Spring 2014)**

by Alan Wetmore and Thomas DeFelice
Computational and Information Sciences Directorate, ARL

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1. Introduction

These data are part of the US US Army Research Laboratory's (ARL) report to the Army Public Health Command (APHC) in support of their Air Quality Surveillance Program. APHC conducted a data collection exercise at Camp Phoenix, Afghanistan, in February and March 2014. ARL supported this effort by supplying a Magee "Next Generation" Aethalometer, Model AE-33, to measure "black carbon" aerosol concentrations. ARL also supplied portable meteorological (MET) stations to record the surface weather parameters and prepared 2 Davis Rotating-Unit for Monitoring (DRUM) aerosol samplers and arranged for measurements of the collected aerosol after their return.

2. Location and Times

The data collection took place approximately 1 km southeast of the Kabul International Airport at Camp Phoenix. Figure 1 shows a map of the area near the airport and Fig. 2 shows an aerial photograph of Camp Phoenix, both retrieved from Google Maps.¹

3. Data Quality Assurance

The data were collected during February and March 2014 by APHC personnel at Camp Phoenix, Kabul, Afghanistan. This report details the data from the Model AE-33 7-channel aethalometer, MET data from Meteorological Aerodrome Report (METAR) records from the Kabul Airport, and data from the DRUM samplers.

All times were originally recorded in coordinated universal time (UTC).

3.1 What Data Are Recorded

The aethalometers record a great deal of information in their data files. Most of the information is for internal monitoring and controlling the operation of the aethalometer. This information is recorded sequentially into daily data files internal to the aethalometer. After the collection period, the instrument is returned, these files are copied from the instrument onto a universal serial bus (USB) drive and then analyzed and plotted. The aethalometer was configured to run continuously with a 1-min sampling period. The aethalometer does not have an uninterruptible power supply and shuts down when power becomes unavailable. It is configured to auto-

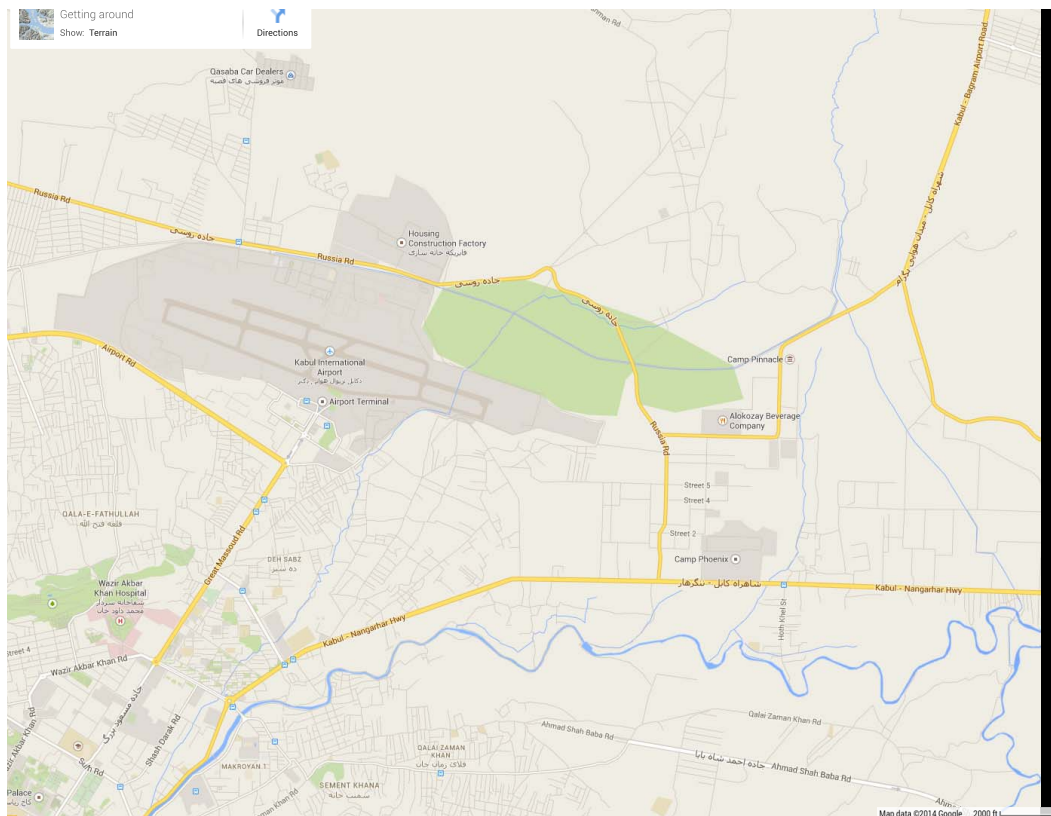


Fig. 1 Overview map for Kabul showing Camp Phoenix in relation to the airport



Fig. 2 Aerial photo of Camp Phoenix

restart and resume collecting data when the power is restored. Each data file consists of header information including the following:

AETHALOMETER

Serial number = AE33-S01-00089

Application version = 1.0.5.1

Number of channels = 7

The header information is followed by 62 columnar fields of data:

Date (yyyy/MM/dd); Time (hh:mm:ss); Timebase;
 RefCh1; Sen1Ch1; Sen2Ch1; RefCh2; Sen1Ch2; Sen2Ch2;
 RefCh3; Sen1Ch3; Sen2Ch3; RefCh4; Sen1Ch4; Sen2Ch4;
 RefCh5; Sen1Ch5; Sen2Ch5; RefCh6; Sen1Ch6; Sen2Ch6;
 RefCh7; Sen1Ch7; Sen2Ch7; Flow1; Flow2; FlowC;
 Pressure(Pa); Temperature(°C); RH(%); ContTemp;
 SupplyTemp; Status; ContStatus; DetectStatus;
 LedStatus; ValveStatus; LedTemp;
 BC11; BC12; BC1; BC21; BC22; BC2; BC31; BC32; BC3;
 BC41; BC42; BC4; BC51; BC52; BC5; BC61; BC62; BC6;
 BC71; BC72; BC7;
 K1; K2; K3; K4; K5; K6; K7; TapeAdvCount;

The most significant data fields are shown in Table 1.

Table 1 Primary aethalometer data

DATE	Date(yyyy/mm/dd)
TIME	Time(hh:mm:ss)
BC1	Black Carbon ultraviolet (UV) Channel
BC2	Black Carbon Blue Channel
BC3	Black Carbon Green Channel
BC4	Black Carbon Yellow Channel
BC5	Black Carbon Red Channel
BC6	Black Carbon infrared (IR) 1 Channel
BC7	Black Carbon IR 2 Channel
TapeAdvCount	Incrementing tape advance counter

3.2 Portable MET Station Data

Due to logistics problems and a software glitch in the data collection computer, neither of the MET stations collected data during this test. We have used the World Meteorological Organization (WMO) surface observation data routinely collected hourly at Kabul International Airport to characterize the local environment. The data were retrieved from the National Climate Data Center (NCDC) in Ashville, North Carolina.² The Kabul airport is approximately 1 km west-northwest of Camp Phoenix. We also used the WeatherSpark website to plot archived weather data from the Kabul Airport.

3.3 The METAR Data

The full METAR surface observations (hourly and special observations) from Kabul Airport were collected. The descriptions of the data and keys to the coding of the individual columns are tabulated in Appendix B.

3.3.1 Wind Roses

One important quantity derived from the NCDC data is the probability of wind speed and direction near the data collection site. Figure 3 is a wind rose summarizing the wind speeds and directions during the data collection.

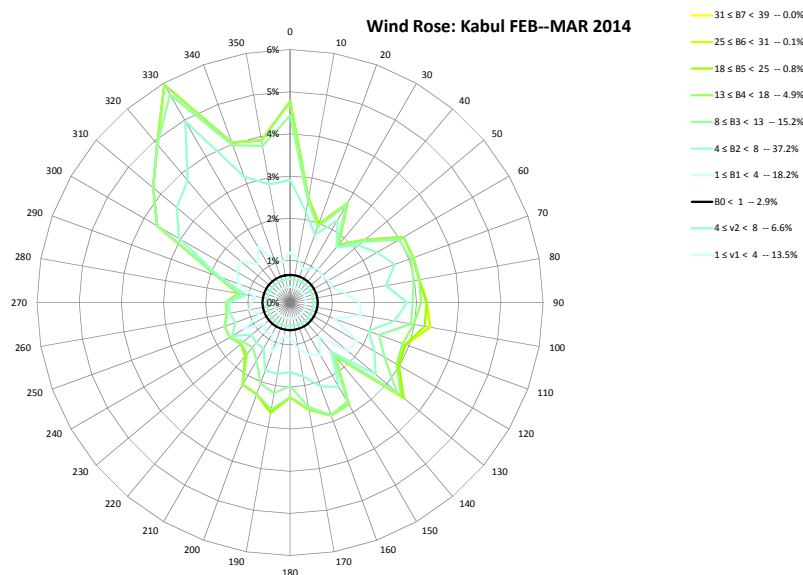


Fig. 3 Wind rose for Kabul. The scale shows wind speeds (mph) in ranges corresponding to the Beaufort scale and includes 2 speed ranges (v1 and v2) of variable direction winds.

3.3.2 HYSPLIT Trajectories

We also used the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory's Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT)³ model to plot (Fig. 4) back trajectories for the air mass arriving at Kabul each day during the data collection period. The HYSPLIT trajectories show both the horizontal and vertical "path" that the air parcel traveled to arrive at a particular time. The plot of the parcel's altitude is shown with time running from the arrival time on the left "backwards" to earlier times to the right. This is useful for estimating what influences the surrounding terrain had on the arriving air and possible distant sources of aerosol. In this example, the arriving air spent the last 30 h traveling close to the ground over the terrain south and west of the airport.

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 01 Mar 14
 GDAS Meteorological Data

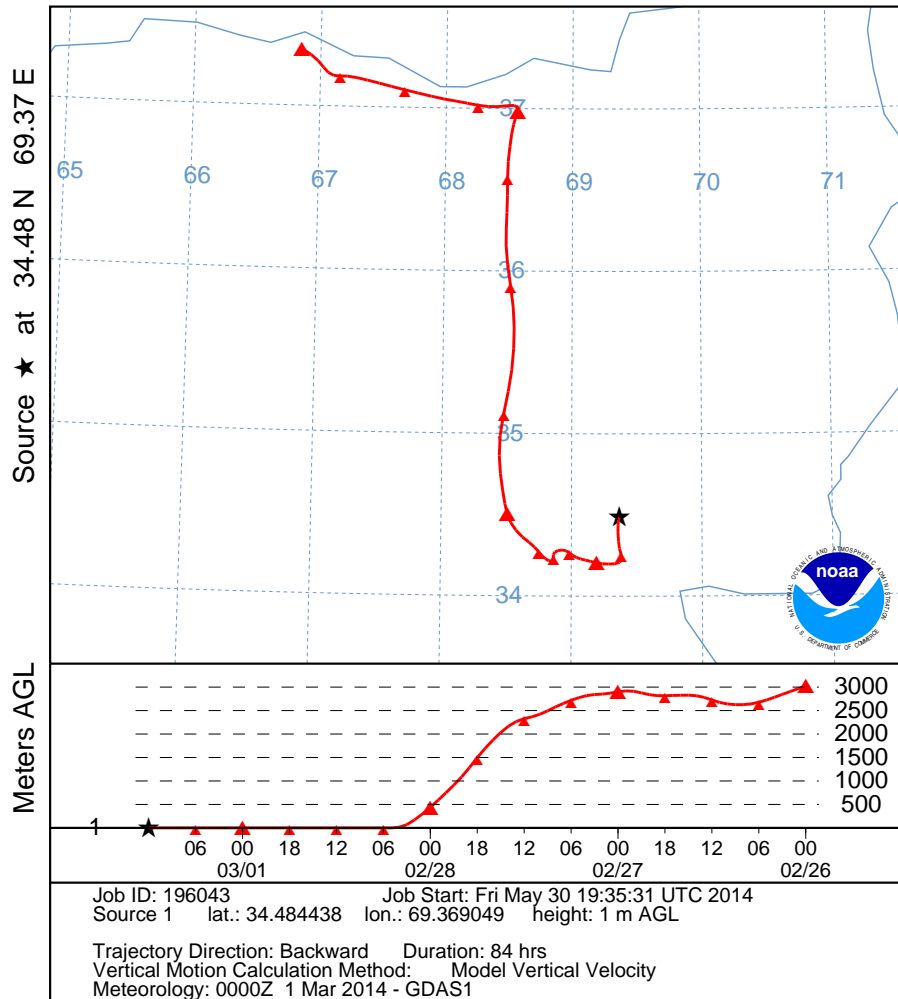


Fig. 4 HYSPLIT back trajectory 01 Mar 2014

3.3.3 Graphical Weather Summary

We also used the WeatherSpark⁴ website to prepare a summary (Fig. 5) of NOAA archived weather data from Kabul during the data collection period.

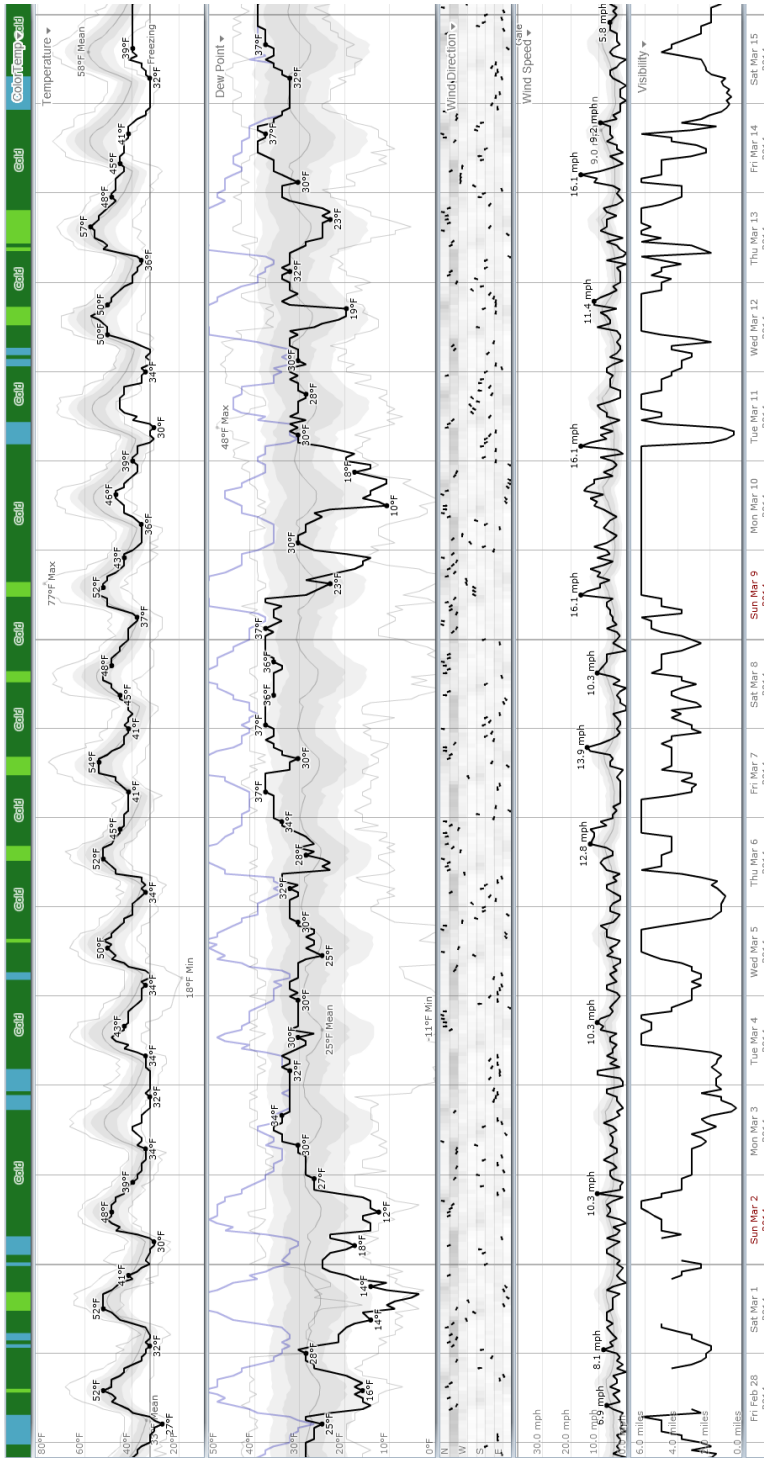


Fig. 5 Temperature (ColorTemp top row); temperature and dew point temperature (°F — second and third rows); wind direction (fourth row); wind speed (mph — fifth row); and visibility (miles — sixth row)⁴

Approved for public release; distribution is unlimited.

3.4 University of California (UC) Davis DRUM Data

Two UC Davis DRUM samplers were operated during the data collection. The data from these are referenced as CaPh32 and CaPh34. The CaPh32 strips suffered from an improper rotational orientation of the drums in the sampler leading to a large data gap in the middle of the data collection where the sampling stream crossed the region of the drum where the ends of the strips are mounted to the drum. The CaPh34 drums had a smaller orientation error and their data were continuous.

The DRUM samplers collect particulate matter onto Mylar[®] strips mounted on 8 synchronized, slowly rotating drums. The air being sampled is pulled through a series of calibrated nozzles and is focused onto the strips. At each stage, as the airflow bends around the strip, the particles with a sufficiently large aerodynamic diameter hit and stick to the strip. The smaller particles flow around the strip mounted on the drum and proceed to the next stage, repeating the process through a smaller nozzle. Each stage of the sampler accelerates the air to higher speeds collecting progressively smaller particles. Table 2 lists the size ranges of the particles collected onto each of the 8 strips. For more detailed description and analysis of the DRUM collection process, see Raabe.⁵

Table 2 Particle size ranges for each DRUM stage

Stage	Diameter (μm)
1	5.0–10.0
2	2.5–5.0
3	1.15–2.5
4	0.75–1.15
5	0.56–0.75
6	0.34–0.56
7	0.26–0.34
8	0.09–0.26

The aerosols are characterized by examining a small area of the Mylar[®] strip and measuring how much mass is at that point. This value is expressed in nanograms per square centimeter. The length of time a particular portion of the strip is exposed to the jet of air containing the aerosol's particles, determines how many particles collect at that spot. The longer an area of the strip is exposed, the more cubic meters of air impact that part of the strip.

The rotational speed of the drums can be set to several values, changing both the col-

lecting time and time resolution of the samples. For this data collection, the DRUMS were set to the 4-week rotation setting yielding a 2-h sampling time resolution.⁶

The data from the DRUM samples are the result of performing 2 analyses on the strips after their return and removal from the sampler. The first analysis is β -gauge for total mass. The second is x-ray fluorescence (XRF), which detects the characteristic elemental spectral fluorescence from the material as it is bombarded with high-energy x-rays. Not all elements are detected using the XRF method. Table 3 shows which elements are measured using the XRF system, as well as elements that are not measured but can have significant mass contributions: elemental (black) carbon, organic molecules (hydrocarbons, carbonyls, ketones, amines, and imines) as well as carbonates and nitrates.

Table 3 Periodic table of the elements showing (green highlight) those elements measured using XRF and (red highlight) unmeasured elements having significant mass contributions

Periodic Table of the Elements

1 H 1.00794																	2 He 4.002602						
3 Li 6.941	4 Be 9.012182																	5 B 10.811	6 C 12.011	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989768	12 Mg 24.3050																	13 Al 26.981539	14 Si 28.0855	15 P 30.973762	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.93805	26 Fe 55.845	27 Co 58.93320	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92159	34 Se 78.96	35 Br 79.904	36 Kr 83.80						
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29						
55 Cs 132.90543	56 Ba 137.327	La Lu	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.08	79 Au 196.96654	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98037	84 Po (209)	85 At (210)	86 Rn (222)						
87 Fr (223)	88 Ra (226)	Ac Lr	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)															
57 La 138.9055	58 Ce 140.115	59 Pr 140.90765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.965	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04	71 Lu 174.967									
89 Ac (227)	90 Th (232.0381)	91 Pa (231.03588)	92 U (238.0289)	93 Np (237)	94 Pu (239)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)									

Both the β -gauge and XRF measurements' raw data are significantly post-processed to arrive at the equivalent airborne mass concentrations in nanograms per cubic meter (delivered as Excel spreadsheets). For both instruments, a conversions from a mass per square centimeter measurement must be accomplished by using the flow rate through the DRUM sampler and the rotation rate of the collecting drums to produce the volume of air in cubic meters to which the Mylar[®] strips were exposed. That, combined with a sticking efficiency, can be used to determine the average mass per cubic meter of air. For the XRF measurements, the processing chain is longer. The fluorescence spectra is curvefit to extract the height data of the peaks for

each element, which are calibrated by elemental standards measurements to obtain the individual elemental areal densities. These areal densities then are converted to an equivalent mass per cubic meter of air in the same way as the β -gauge mass measurements.

Because the β -gauge measures total mass, we can estimate PM_{10} , $PM_{2.5}$, and PM_1 by combining the β -gauge mass measurements from the appropriate strips.

4. General Notes on the Equipment Operation

The equipment was set up on 28 February 2014 and operated until 14 March.

4.1 Aethalometer

4.1.1 Aethalometer Operations Summary

Figure 6 is a graphical depiction of the operating status of the various aethalometer subsystems during the test. For each reading in the data files, the status of the various subsystems are plotted as points. The density of points make most of these data appear as lines. The green points indicate normal functioning of the systems; yellow points are routine calibration and tape advance functions. The blue points indicate “valid data” and the red points indicate system error status. The lowest (rightmost) green “line” indicates the aethalometer is operating, the adjacent blue “line” indicates nominally valid data, and the adjacent yellow points are the tape advance indicators. The gaps in the data are generally believed to be caused by power outages during the collection or shorter gaps by either momentary power faults or perhaps manually restarting the aethalometer.

Table 4 is a summary the aethalometer operation. The aethalometer operated almost continuously throughout the data collection except for 3 tape error events that resolved themselves during the first couple of days and 2 power failures, one on 3 March 3 and another on 6 March.

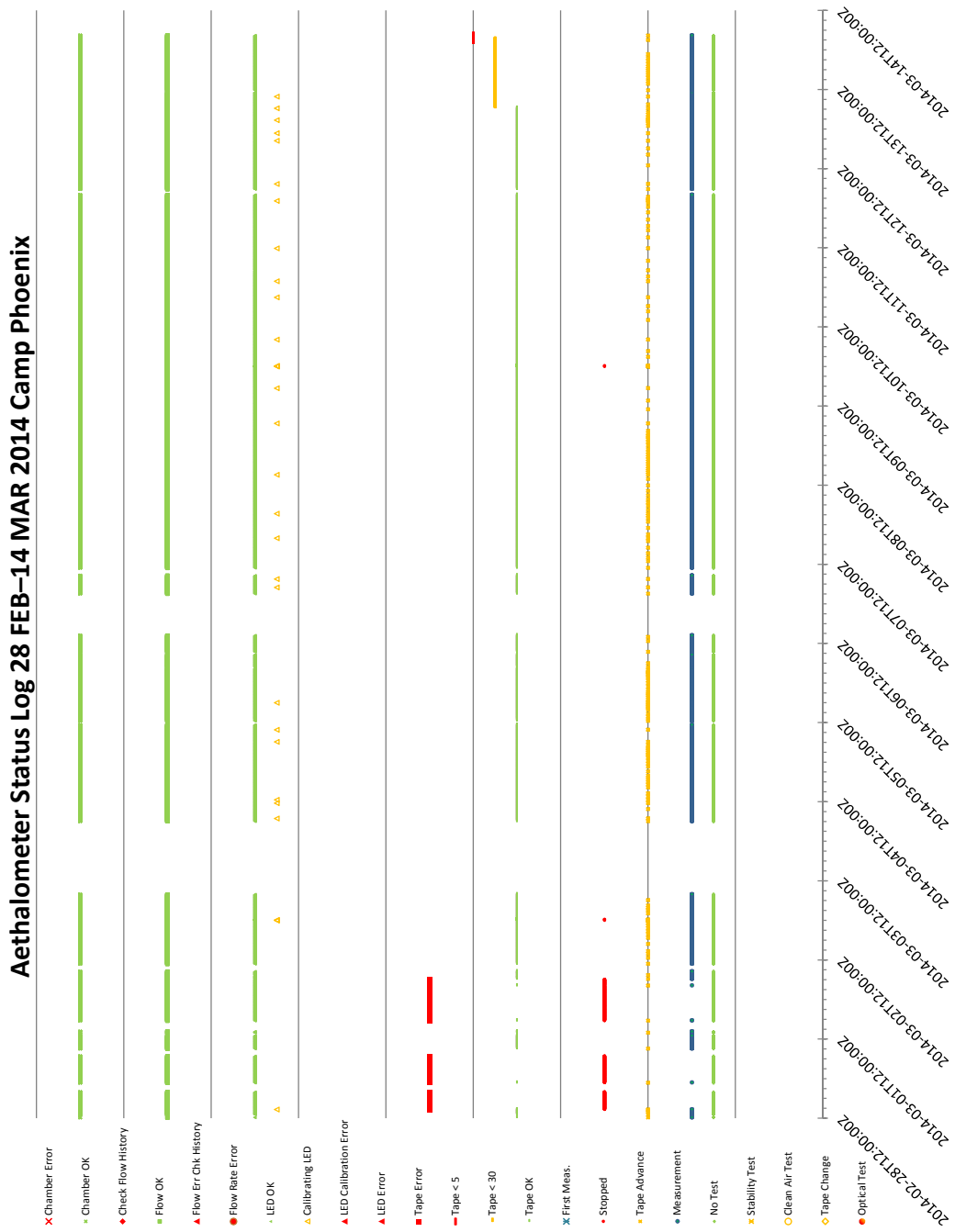


Fig. 6 The Aethalometer Status Log. See the text for a description.

Table 4 Aethalometer timeline

Date	Time	Event	
2014-02-28	12:11:00	Aethalometer turned on	
2014-02-28	16:00	Start of first tape error	
2014-02-28	19:56		power off
2014-02-28	22:43		power on
2014-03-01	06:48		power off
2014-03-01	09:04		power on
2014-03-01	10:39	End of first tape error	
2014-03-01	12:58	Start of second tape error	
2014-03-01	13:02		power off
2014-03-01	13:53		power on
2014-03-01	14:17		power off
2014-03-01	17:33		power on
2014-03-02	06:03		power off
2014-03-02	06:12		power on
2014-03-02	07:10		power off
2014-03-02	07:22		power on
2014-03-02	06:24	End of second tape error	
2014-03-02	08:29		power off
2014-03-02	10:47		power on
2014-03-03	07:52		power off
2014-03-04	06:01		power on
2014-03-05	07:52		power off
2014-03-05	11:18		power on
2014-03-05	12:47		power off
2014-03-05	12:56		power on
2014-03-06	04:26		power off
2014-03-06	04:56		power on
2014-03-06	08:35		power off
2014-03-06	09:24		power on
2014-03-06	12:28		power off
2014-03-07	03:06		power on
2014-03-07	08:33		power off
2014-03-07	10:52		power on
2014-03-11	05:00		power off
2014-03-11	05:07		power on
2014-03-12	04:02		power off
2014-03-12	05:45		power on
2014-03-13	11:10		power off
2014-03-13	11:44		power on
2014-03-14	04:23	Final Power Off	

4.1.2 Aethalometer Example Data

Figure 7 is a sample of the aethalometer data showing the black carbon concentrations at Camp Phoenix and the visibility as measured at the Kabul airport. As expected, the highest peaks in the black carbon concentrations correspond to very low visibilities.

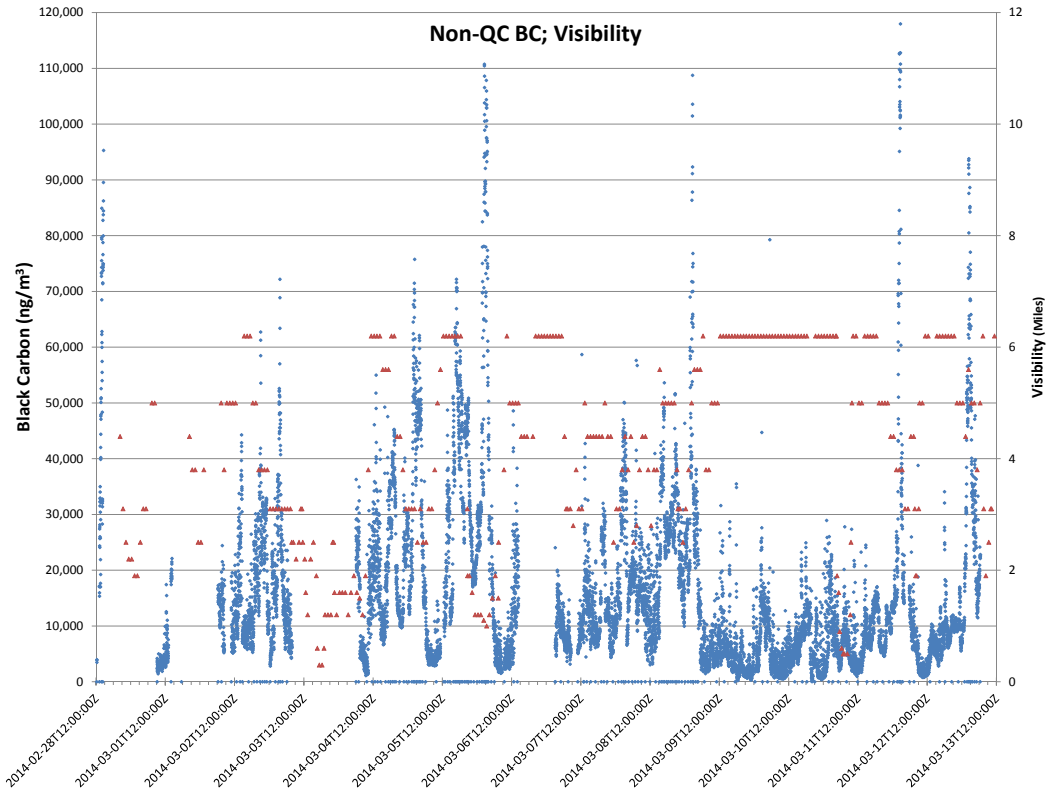


Fig. 7 Aethalometer measured black carbon and visibility for the entire measurement period. The black carbon data are plotted in blue (using the left axis) and the visibility data are plotted in red (using the right axis).

4.2 DRUMs

4.2.1 DRUM Operations Summary

Table 5 is a summary of the DRUM operation. The DRUM samplers appear to have operated continuously throughout the data collection.

Table 5 DRUM timeline

Date	Time	Event
2014-02-28	10:28	DRUMs Turned on
2014-03-14	13:00	Final Power Off

The 2 DRUM samplers and all data files are identified in this report as CaPh32 and CaPh34. While both samplers operated continuously; the drums in CaPh32 were not registered correctly and part of the data was not collected. These missing data are different from the “gap” that the controller inserts by quickly rotating the drums several degrees in the middle of the data collection period to provide a way to align the data across the 8 strips. The missing data include the samples from 2014-03-03T1628Z to 2014-03-08T0028Z.

4.2.2 Sample DRUM Data

Figure 8 is a plot showing the total XRF and β -gauge mass, (i.e., PM_{10}) from the CaPh34 DRUM and the ratio of mass measured by XRF, M_{XRF} , to mass measured by β -gauge, M_{β} shown on a log scale. When the ratio of $\frac{M_{XRF}}{M_{\beta}}$ decreases, we can infer that more of the mass is from lighter elements such as, hydrogen (H), carbon (C), nitrogen (N), and oxygen (O), not measured by the XRF method.

Figure 9 is a plot of the CaPh34 data showing the total β -gauge mass, (i.e., PM_{10}), showing the contributions from each of the size ranges.

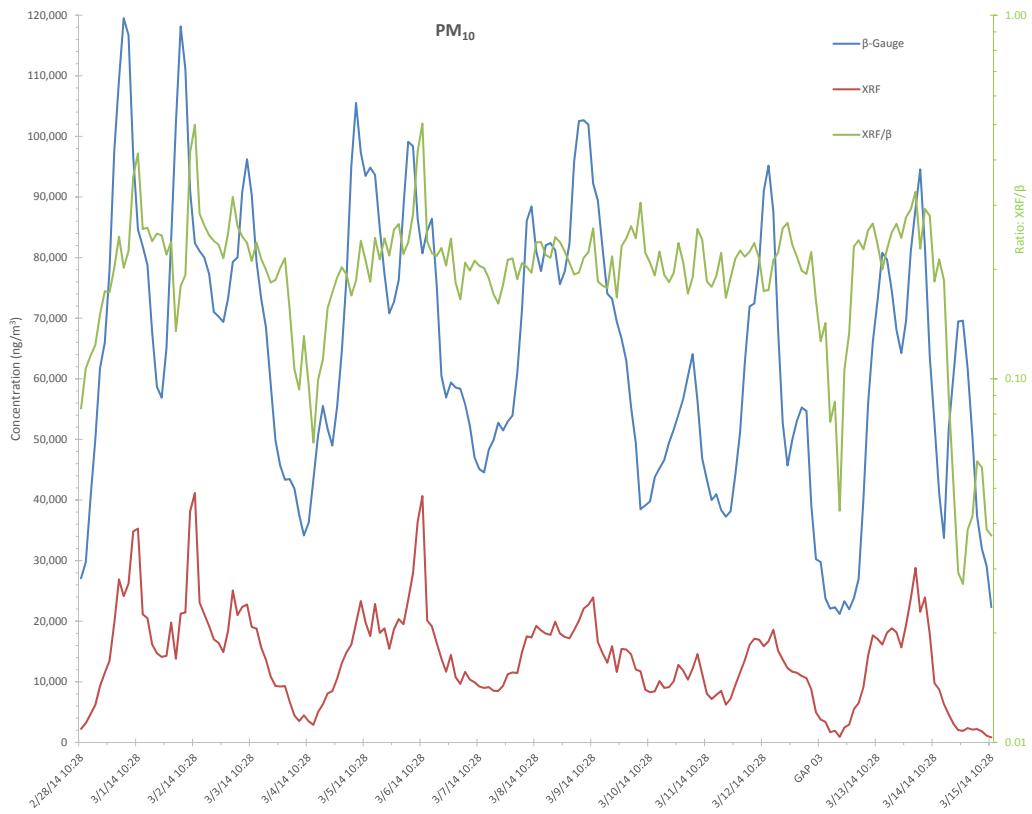


Fig. 8 The CaPh34 XRF and β -gauge masses

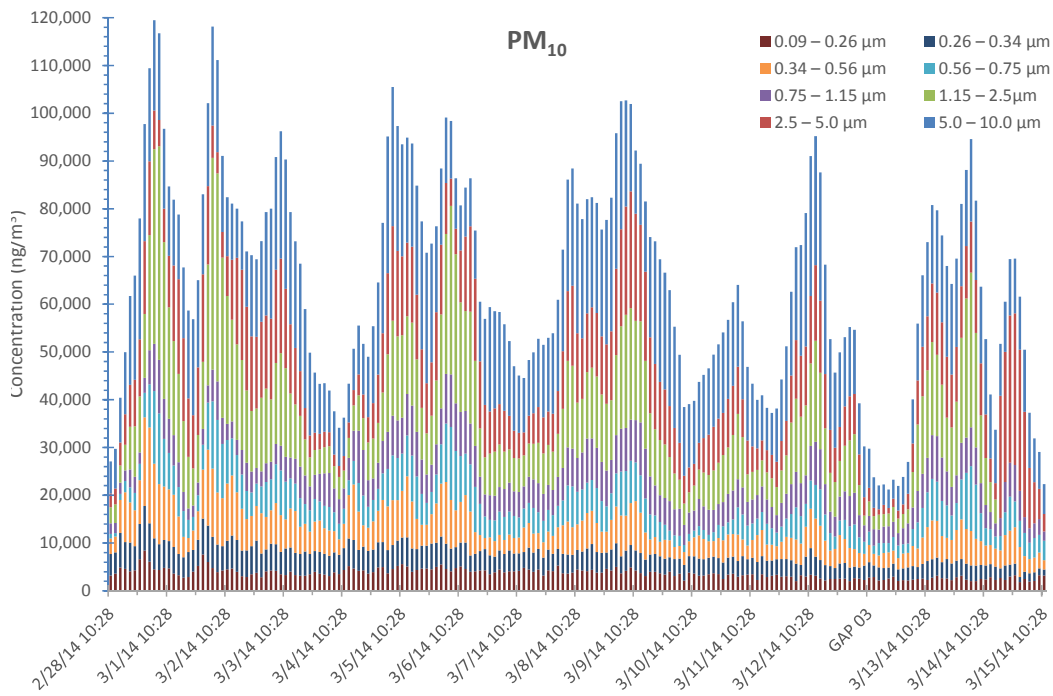


Fig. 9 The caPh34 β -gauge masses showing the 8 size bins

5. Conclusion

An aethalometer to measure black carbon and 2 DRUM samplers to collect size-resolved aerosol samples were deployed to Camp Phoenix, Kabul, Afghanistan from 28 February to 14 March 2014 as part of the APHC's Air Quality Surveillance Program. The exposed strips from the DRUM samplers were analyzed using XRF for elemental mass concentrations and β -gauge for total mass estimates. Contemporaneous MET data from nearby Kabul International Airport were retrieved from the NCDC allowing comparison with observations such as visibility. Plots of black carbon, total mass, size-resolved mass, and size-resolved elemental composition are presented. The data files used for the report are embedded in the electronic version and may be extracted using the links in Appendix E.

6. References

1. Google and Maps. Google; 2014 [accessed 2014 Jul 17]. <https://www.google.com/maps>.
2. NOAA. National Climate Data Center; Kabul data. 2014 Sep 10 [accessed 2014 Jun 10]. http://www7.ncdc.noaa.gov/CDO/cdodateoutmod.cmd?p_ndatasetid=11&datasetabbv=DS3505&p_cqueryby=ENTIRE&p_ncntryid=&p_nrgnid=&p_nstprovid=&p_cfileform=&p_csubqueryby=STATION&resolution=40&poeoption=SIMPLE&p_asubqueryitems=40948099999.
3. HYSPLIT Model. NOAA; 2014 [accessed 2014 May 30]. http://www.arl.noaa.gov/HYSPLIT_info.php.
4. Beautiful Weather Graphs and Maps — WeatherSpark. WeatherSpark; 1998 [accessed 2015 Sep 02]. <https://weatherspark.com/#!dashboard;a=Afghanistan/Kabul>.
5. Raabe OG, Braaten DA, Axelbaum RL, Teague SV, Cahill TP. Calibration studies of the DRUM impactor. *J Aerosol Sci.* 1988;19(2):183–195.
6. Barnes DE. Kabul AQ: Elemental Composition and Mass Analysis. Davis, CA 95616: University of California, Davis; 2015 Jun 15. Contract Report No.: ARL W911QX-14-P-0467.

Appendix A. Images

Figures A-1 through A-4 show photographic images of the DRUM strips.

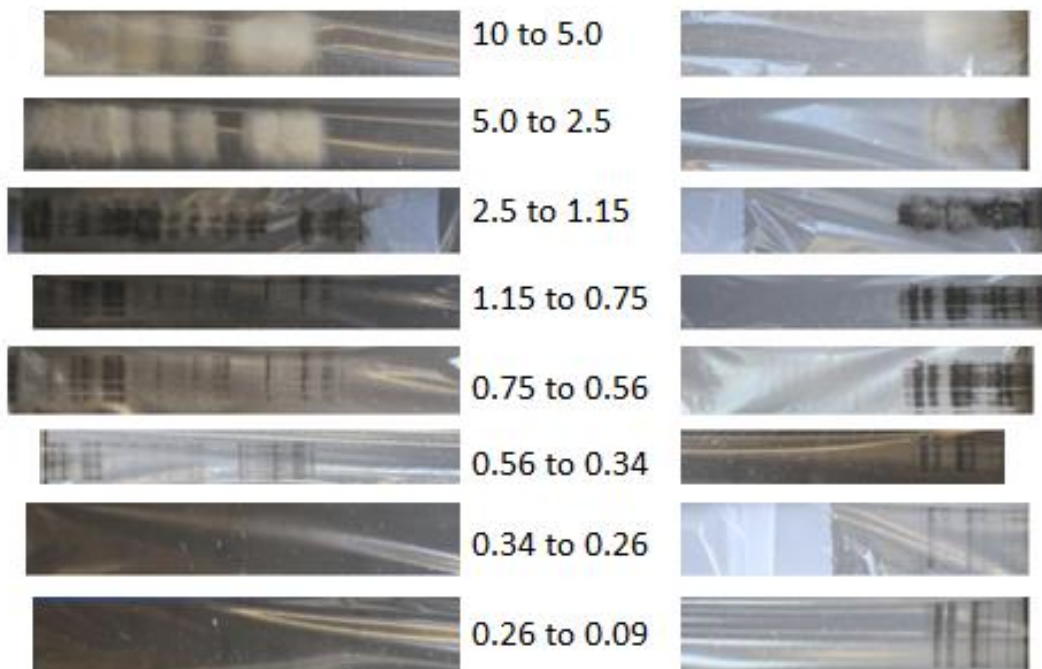


Fig. A-1 Photos of the CaPh 32 DRUM strips on a black background showing the gap in the middle of the collection period. The black background emphasizes scattering aerosols.

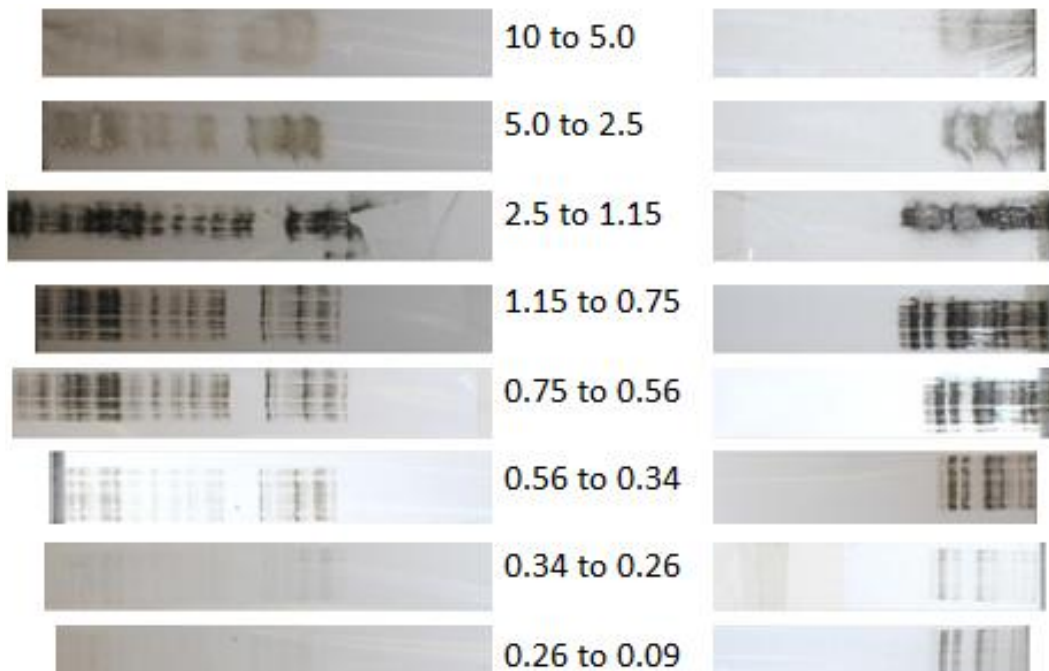


Fig. A-2 Photos of the CaPh 32 DRUM strips on a white background showing the gap in the middle of the collection period. The white background emphasizes absorbing aerosols.

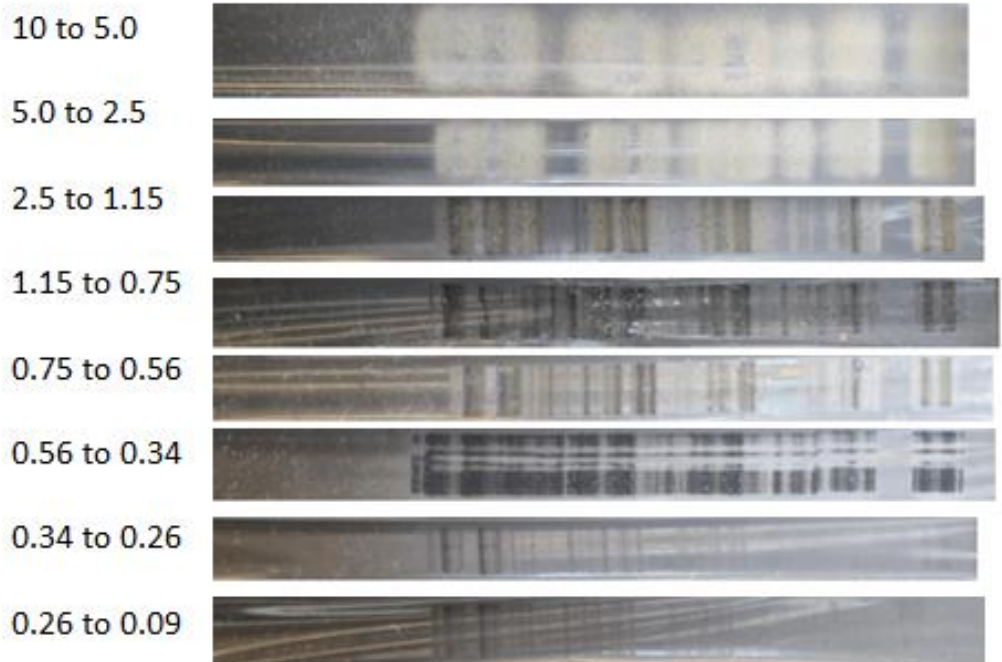


Fig. A-3 Photos of the CaPh 34 DRUM strips on a black background. The black background emphasizes scattering aerosols.

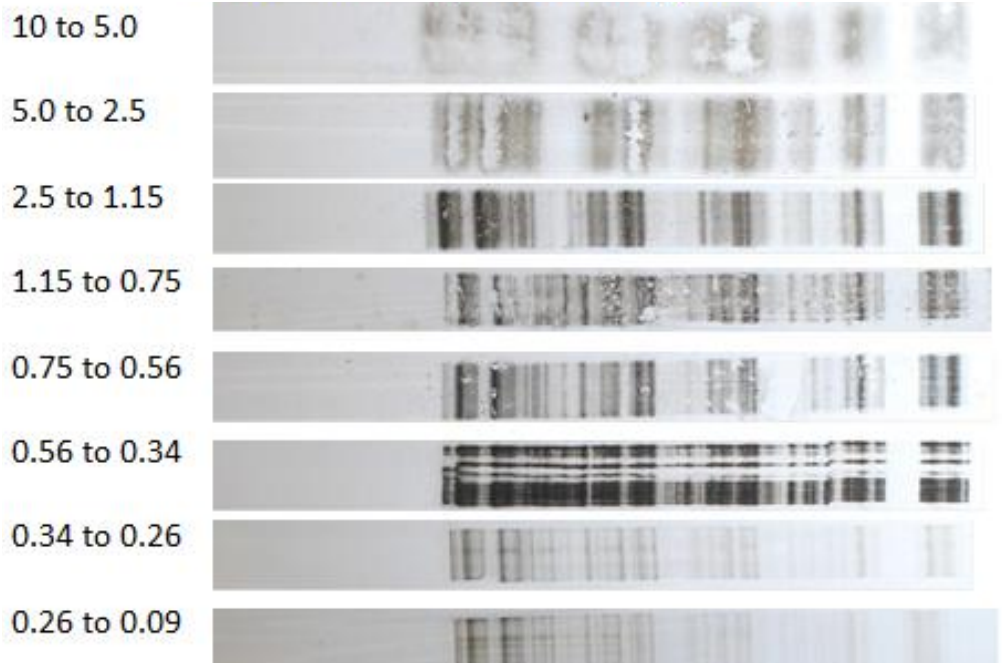


Fig. A-4 Photos of the CaPh 34 DRUM strips on a white background. The white background emphasizes absorbing aerosols.

Appendix B. METAR Key

METAR data files contain fixed length, space delimited records of the observed MET data. The following tables describe the format and coding used in METAR files attached in Appendix E. Table B-1 lists the data fields reported in the hourly METAR records. Tables B-2, B-3, and B-4 give the codes for the low, middle, and high clouds in columns 47–51 of the METAR records. Table B-5 gives an overview of the types of “present weather codes” in the METAR records. Table B-6 is a comprehensive list of the “present weather codes” found in columns 58–80 of the METAR records. Table B-7 lists the past weather codes found in column 82 of the METAR records.

Table B-1 Key to METAR data

Columns	Data description
01–06	␣USAF␣= Air Force catalog station number
08–12	␣WBAN = NCDC Weather-Bureau-Army-Navy (WBAN) number
14–25	YEARMODAHRMN = year-month-day-hour-minute in Greenwich Mean Time (GMT)
27–29	DIR = wind direction in compass degrees, 990 = variable, reported as '****' when air is calm (spd will then be 000)
31–37	SPD␣GUS = wind speed and gust in miles per hour
39–41	CLG = cloud ceiling—lowest opaque layer with 5/8 or greater coverage, in hundreds of feet, 722 = unlimited
43–45	SKC = sky cover — CLR-clear, SCT-scattered-1/8 to 4/8, BKN-broken-5/8 to 7/8, OVC-overcast, OBS-obscured, POB-partial obscuration
47–47	L = low cloud type, see Table B-2
49–49	M = middle cloud type, see Table B-3
51–51	H = high cloud type, see Table B-4
53–56	␣VSB = visibility in statute miles to nearest tenth note: for some stations, visibility is reported only up to a maximum of 7 or 10 miles in METAR observations, but to higher values in synoptic observations, which causes the values to fluctuate from one data record to the next. Also, values originally reported as '10' may appear as '10.1' due to data being archived in metric units and converted back to English.
58–68	MW␣MW␣MW␣MW = manually observed present weather—listed in Table B-6
70–80	AW␣AW␣AW␣AW = auto-observed present weather—listed in Table B-6
82–82	W = Past weather indicator, see Table B-7
84–92	TEMP␣DEWP = temperature and dew point in Fahrenheit
94–99	␣␣␣SLP = sea level pressure in millibars to nearest tenth
101–105	␣␣ALT = altimeter setting in inches to nearest hundredth
107–112	␣␣STP = station pressure in millibars to nearest tenth
114–116	MAX = maximum temperature in Fahrenheit (time period varies) (continued ...)

Table B-1 Key to METAR data (continued)

Columns	Data description
118–120	MIN = minimum temperature in Fahrenheit (time period varies)
122–126	PCP01 = 1-h liquid precip report in inches and hundredths – that is, the precip for the preceding 1-h period
128–132	PCP06 = 6-h liquid precip report in inches and hundredths – that is, the precip for the preceding 6-h period
134–138	PCP24 = 24-h liquid precip report in inches and hundredths that is, the precip for the preceding 24-h period
140–144	PCPXX = liquid precip report in inches and hundredths, for a period other than 1, 6, or 24 h (usually for 12-h period for stations outside the United States, and for 3-h period for the United States) T = trace for any precip field
146–147	SD = snow depth in inches

Table B-2 METAR Low Cloud Type Codes

Code	Cloud type observed
0	No low clouds
1	Cumulus humilis or Cumulus fractus other than of bad weather or both
2	Cumulus mediocris or congestus, with or without Cumulus of species fractus or humilis or Stratocumulus, all having bases at the same level
3	Cumulonimbus calvus, with or without Cumulus, Stratocumulus, or Stratus
4	Stratocumulus cumulogenitus
5	Stratocumulus other than Stratocumulus cumulogenitus
6	Stratus nebulosus or Stratus fractus other than of bad weather, or both
7	Stratus fractus or Cumulus fractus of bad weather, or both (pannus) usually below Altostratus or Nimbostratus
8	Cumulus and Stratocumulus other than Stratocumulus cumulogenitus, with bases at different levels
9	Cumulonimbus capillatus (often with an anvil), with or without Cumulonimbus calvus, Cumulus, Stratocumulus, Stratus, or pannus

Table B-3 METAR Middle Cloud Type Codes

Code	Cloud type observed
0	No middle clouds
1	Altostratus translucidus
2	Altostratus opacus or Nimbostratus
3	Altostratus translucidus at a single level
4	Patches (often lenticular) of Altostratus translucidus, continually changing and occurring at one or more levels
5	Altostratus translucidus in bands, or one or more layers of Altostratus translucidus or opacus, progressively invading the sky; these Altostratus clouds generally thicken as a whole
6	Altostratus cumulogenitus (or cumulonimbogenitus)
7	Altostratus translucidus or opacus in 2 or more layers, or Altostratus opacus in a single layer, not progressively invading the sky, or Altostratus with Altostratus or Nimbostratus
8	Altostratus castellanus or floccus
9	Altostratus of a chaotic sky; generally at several levels

Table B-4 METAR High Cloud Type Codes

Code	Cloud type observed
0	No High Clouds
1	Cirrus fibratus, sometimes uncinus, not progressively invading the sky
2	Cirrus spissatus, in patches or entangled sheaves, which usually do not increase and sometimes seem to be the remains of the upper part of a Cumulonimbus; or Cirrus castellanus or floccus
3	Cirrus spissatus cumulonimbogenitus
4	Cirrus uncinus or fibratus, or both, progressively invading the sky; they generally thicken as a whole
5	Cirrus (often in bands) and Cirrostratus, or Cirrostratus alone, progressively invading the sky; they generally thicken as a whole, but the continuous veil does not reach 45° above the horizon
6	Cirrus (often in bands) and Cirrostratus, or Cirrostratus alone, progressively invading the sky; they generally thicken as a whole; the continuous veil extends more than 45° above the horizon, without the sky being totally covered
7	Cirrostratus covering the whole sky
8	Cirrostratus not progressively invading the sky and not entirely covering it
9	Cirrocumulus alone, or Cirrocumulus predominant among the High clouds

Table B-5 Present Weather METAR Codes: Overview

Code	Weather description
00-49	No precipitation at the station at the time of observation
00-19	No precipitation: fog, ice fog (except for 11 and 12), duststorm, sandstorm, drifting or blowing snow at the station at the time of observation or, except for 09 and 17, during the preceding hour
20-29	Precipitation, fog, ice fog, or thunderstorm at the station during the preceding hour, but not at the time of observation
30-39	Duststorm, sandstorm, or blowing snow
40-49	Fog or ice fog at the time of observation
50-99	Precipitation at the station at the time of observation
50-59	Drizzle
60-69	Rain
70-79	Solid precipitation not in showers
80-99	Showery precipitation, or precipitation with current or recent thunderstorm

Table B-6 Present Weather METAR Codes

Codes	Weather description
00-49	No precipitation at the station at the time of observation
00-19	No precipitation: fog, ice fog (except for 11 and 12), duststorm, sandstorm, drifting or blowing snow at the station at the time of observation or, except for 09 and 17, during the preceding hour
00	Cloud development not observed or not observable
01	Clouds generally dissolving or becoming less developed
02	State of sky on the whole unchanged
03	Clouds generally forming or developing
04	Visibility reduced by smoke, e.g., veldt or forest fires, industrial smoke or volcanic ashes.
05	Haze
06	Widespread dust in suspension in the air, not raised by wind at or near the station at the time of observation
07	Dust or sand raised by wind at or near the station at the time of observation, but no well-developed dust whirl(s) or sand whirl(s), and no duststorm or sandstorm seen or, in the case of ships, blowing spray at the station
08	Well developed dust whirl(s) or sand whirl(s) seen at or near the station during the preceding hour or at the time of observation, but no duststorm or sandstorm
09	Duststorm or sandstorm within sight at the time of observation, or at the station during the preceding hour
10	Mist
11	Patches of shallow fog or ice fog at the station, whether on land or sea, not deeper than about 2 m on land or 10 m at sea
12	More or less continuous shallow fog or ice fog at the station, whether on land or sea, not deeper than about 2 m on land or 10 m at sea (continued ...)

Table B-6 Present Weather METAR Codes (continued)

Code(s)	Weather description
13	Lightning visible, no thunder heard
14	Precipitation within sight, not reaching the ground or the surface of the sea
15	Precipitation within sight, reaching the ground or the surface of the sea, but distant, i.e., estimated to be more than 5 km from the station
16	Precipitation within sight, reaching the ground or the surface of the sea, near to, but not at the station.
17	Thunderstorm, but no precipitation at the time of observation.
18	Squalls at or within sight of the station during the preceding hour or at the time of observation.
19	Funnel cloud(s) (Tornado cloud or waterspout) at or within sight of the station during the preceding hour or at the time of observation.
20–29	Precipitation, fog, ice fog, or thunderstorm at the station during the preceding hour, but not at the time of observation
20	Drizzle (not freezing) or snow grains not falling as shower(s)
21	Rain (not freezing) not falling as shower(s)
22	Snow not falling as shower(s)
23	Rain and snow or ice pellets not falling as shower(s)
24	Freezing drizzle or freezing rain not falling as shower(s)
25	Shower(s) of rain
26	Shower(s) of snow or of rain and snow
27	Shower(s) of hail (hail, small hail, snow pellets), or rain and hail
28	Fog or ice fog
29	Thunderstorm (with or without precipitation)
30–39	Duststorm, sandstorm, or blowing snow
30	Slight or moderate duststorm or sandstorm has decreased during the preceding hour
31	Slight or moderate duststorm or sandstorm no appreciable change during the preceding hour
32	Slight or moderate duststorm or sandstorm has begun or has increased during the preceding hour
33	Severe duststorm or sandstorm has decreased during the preceding hour
34	Severe duststorm or sandstorm no appreciable change during the preceding hour
35	Severe duststorm or sandstorm has begun or has increased during the preceding hour
36	Slight or moderate drifting snow generally low (below eye level)
37	Heavy drifting snow generally low (below eye level)
38	Slight or moderate blowing snow generally high (above eye level)
39	Heavy blowing snow generally high (above eye level)
40–49	Fog or ice fog at the time of observation
40	Fog or ice fog at a distance at the time of observation, but not at the station during the preceding hour, the fog or ice fog extending to a level above that of the observer (continued ...)

Table B-6 Present Weather METAR Codes (continued)

Code(s)	Weather description
41	Fog or ice fog in patches
42	Fog or ice fog, sky visible, has become thinner during the preceding hour
43	Fog or ice fog, sky invisible, has become thinner during the preceding hour
44	Fog or ice fog, sky visible, no appreciable change during the preceding hour
45	Fog or ice fog, sky invisible, no appreciable change during the preceding hour
46	Fog or ice fog, sky invisible, has begun or has become thicker during the preceding hour
47	Fog or ice fog, sky invisible, has begun or has become thicker during the preceding hour
48	Fog, depositing rime, sky visible
49	Fog, depositing rime, sky invisible
50-99	Precipitation at the station at the time of observation
50-59	Drizzle
50	Drizzle, not freezing, intermittent, slight at time of observation
51	Drizzle, not freezing, continuous, slight at time of observation
52	Drizzle, not freezing, intermittent, moderate at time of observation
53	Drizzle, not freezing, continuous, moderate at time of observation
54	Drizzle, not freezing, intermittent, heavy (dense) at time of observation
55	Drizzle, not freezing, continuous, heavy (dense) at time of observation
56	Drizzle, freezing, slight
57	Drizzle, freezing, moderate or heavy (dense)
58	Drizzle and rain, slight
59	Drizzle and rain, moderate or heavy
60-69	Rain
60	Rain, not freezing, intermittent, slight at time of observation
61	Rain, not freezing, continuous, slight at time of observation
62	Rain, not freezing, intermittent, moderate at time of observation
63	Rain, not freezing, continuous, moderate at time of observation
64	Rain, not freezing, intermittent, heavy at time of observation
65	Rain, not freezing, continuous, heavy at time of observation
66	Rain, freezing, slight
67	Rain, freezing, moderate or heavy
68	Rain or drizzle and snow, slight
69	Rain or drizzle and snow, moderate or heavy
70-79	Solid precipitation not in showers
70	Intermittent fall of snowflakes, slight at time of observation
71	Continuous fall of snowflakes, slight at time of observation
72	Intermittent fall of snowflakes, moderate at time of observation
73	Continuous fall of snowflakes, moderate at time of observation

(continued ...)

Table B-6 Present Weather METAR Codes (continued)

Code(s)	Weather description
74	Intermittent fall of snowflakes, heavy at time of observation
75	Continuous fall of snowflakes, heavy at time of observation
76	Diamond dust (with or without fog)
77	Snow grains (with or without fog)
78	Isolated star-like snow crystals (with or without fog)
79	Ice pellets
80–99	Showery precipitation, or precipitation with current or recent thunderstorm
80	Rain shower(s), slight
81	Rain shower(s), moderate or heavy
82	Rain shower(s), violent
83	Shower(s) of rain and snow mixed, slight
84	Shower(s) of rain and snow mixed, moderate or heavy
85	Show shower(s), slight
86	Snow shower(s), moderate or heavy
87	Shower(s) of snow pellets or small hail, with or without rain or rain and snow mixed, slight
88	7 Shower(s) of snow pellets or small hail, with or without rain or rain and snow mixed, moderate or heavy
89	Shower(s) of hail (hail, small hail, snow pellets), with or without rain or rain and snow mixed, not associated with thunder, slight
90	Shower(s) of hail (hail, small hail, snow pellets), with or without rain or rain and snow mixed, not associated with thunder, moderate or heavy
91	Slight rain at time of observation, thunderstorm during the preceding hour but not at time of observation
92	Moderate or heavy rain at time of observation, thunderstorm during the preceding hour but not at time of observation
93	Slight snow, or rain and snow mixed or hail (hail, small hail, snow pellets), at time of observation, thunderstorm during the preceding hour but not at time of observation
94	Moderate or heavy snow, or rain and snow mixed or hail (hail, small hail, snow pellets) at time of observation, thunderstorm during the preceding hour but not at time of observation
95	Thunderstorm, slight or moderate, without hail (hail, small hail, snow pellets), but with rain and/or snow at time of observation, thunderstorm at time of observation
96	Thunderstorm, slight or moderate, with hail (hail, small hail, snow pellets) at time of observation, thunderstorm at time of observation
97	Thunderstorm, heavy, without hail (hail, small hail, snow pellets), but with rain and/or snow at time of observation, thunderstorm at time of observation
98	Thunderstorm combined with duststorm or sandstorm at time of observation, thunderstorm at time of observation
	(continued ...)

Table B-6 Present Weather METAR Codes (continued)

Code(s)	Weather description
99	Thunderstorm, heavy, with hail (hail, small hail, snow pellets) at time of observation, thunderstorm at time of observation

Table B-7 Past Weather METAR Weather Codes

Code	Specific type of past weather observed
0	Cloud covering 1/2 or less of the sky throughout the appropriate period
1	Cloud covering more than 1/2 of the sky during part of the appropriate period and covering 1/2 or less during part of the period
2	Cloud covering more than 1/2 of the sky throughout the appropriate period
3	Sandstorm, duststorm or blowing snow
4	Fog or ice fog or thick haze
5	Drizzle
6	Rain
7	Snow, or rain and snow mixed
8	Shower(s)
9	Thunderstorm(s) with or without precipitation

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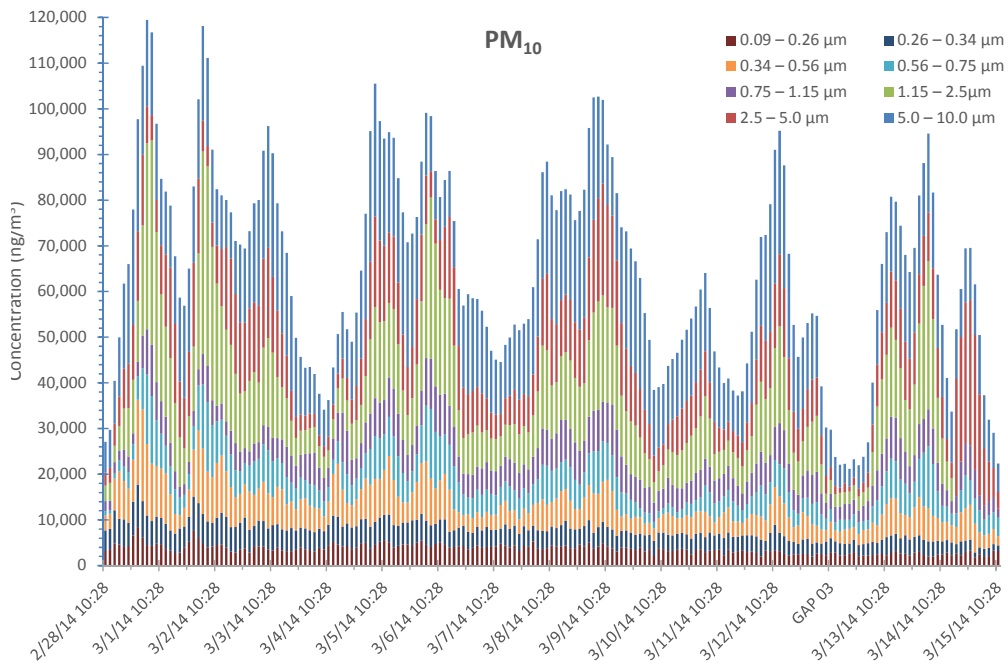
Appendix C. DRUM Data Plots

C-1 Mass Concentration Plots

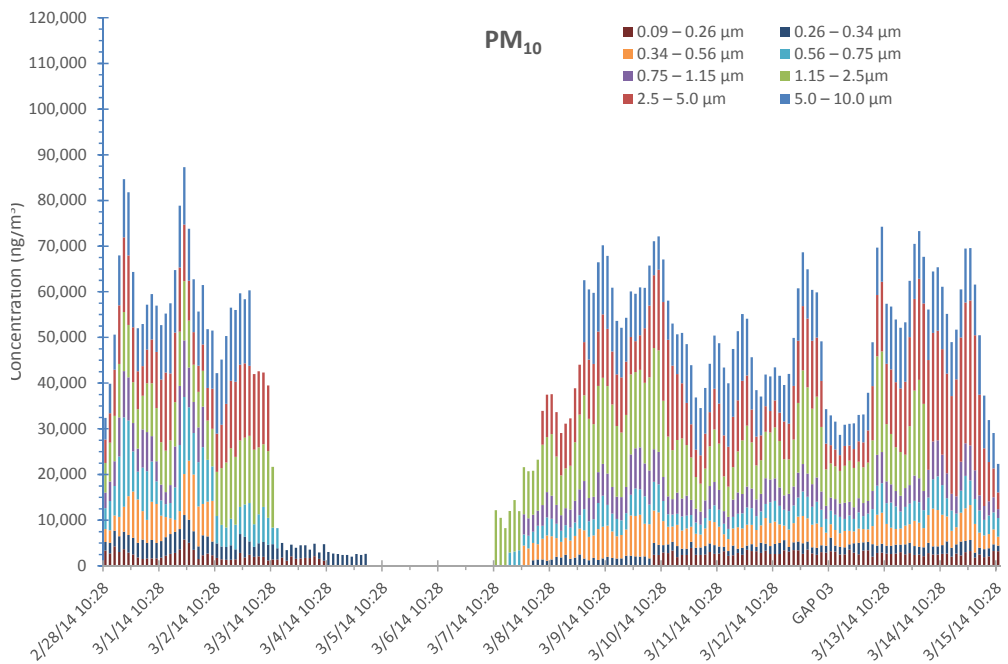
C-1.1 β -Gauge Estimates of PM_x

We can use the β -gauge data to estimate different PM_x since the β -gauge measurement is sensitive to total mass. Based on the particle sizes that the 8 strips collect, PM_{10} is simply the sum of masses on all 8 strips. Similarly, $PM_{2.5}$ is the sum of the masses on strips 2 through 8. Estimating PM_1 is slightly more complicated; strip 4 collects particles from 0.75–1.15 μm in diameter, so only a portion of this should be included in estimating PM_1 . The simplest choice is to include a fraction ($5/8 = \frac{1.0-0.75}{1.15-0.75}$) of the mass on strip 4 plus the masses on strips 5 through 8.

To begin, we show the PM_{10} β -gauge results for both the CaPh32 and CaPh34 DRUMs in Fig. C-1 and follow with $PM_{2.5}$ in Fig. C-2 and PM_1 in Fig. C-3.

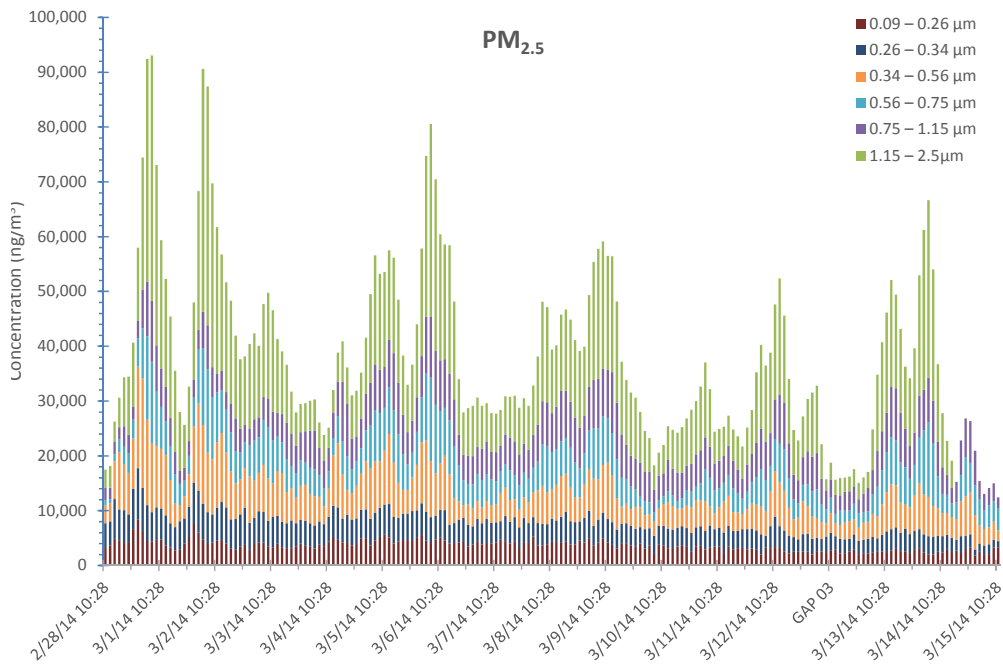


a) CaPh 34 DRUM: β -gauge estimate of PM₁₀

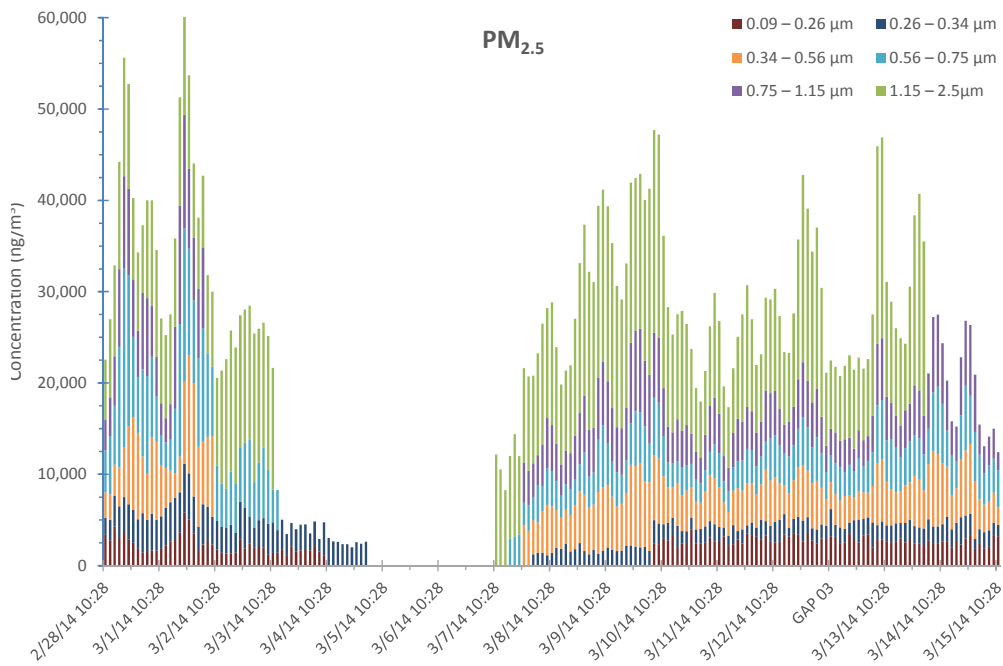


b) CaPh 32 DRUM: β -gauge estimate of PM₁₀

Fig. C-1 DRUM: (a) CaPh 34 and b) CaPh 32 β -gauge estimates of PM₁₀

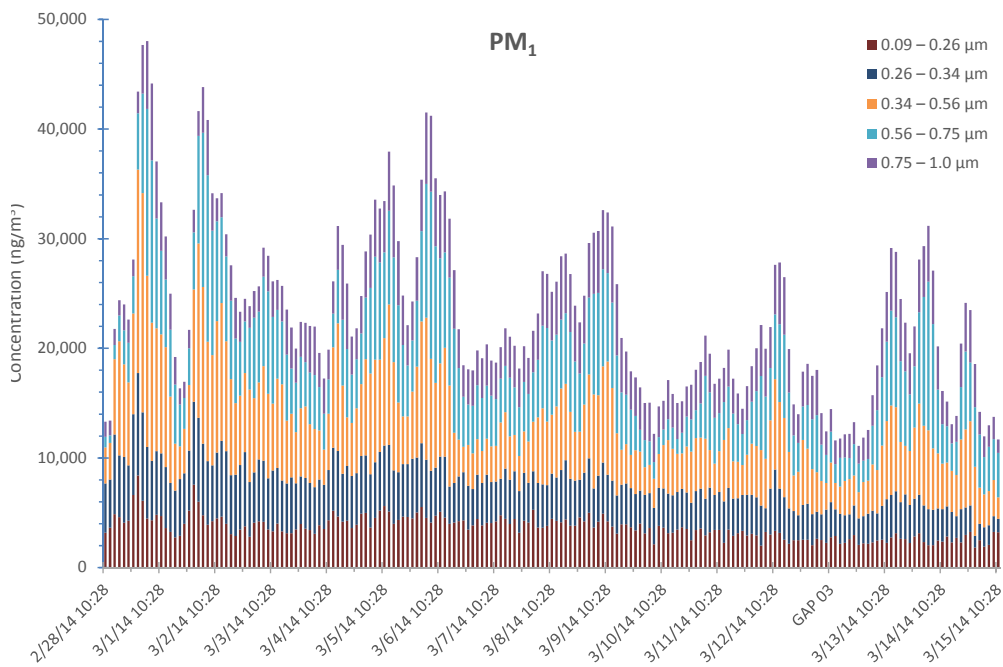


a) CaPh 34 DRUM: β -gauge estimate of $PM_{2.5}$

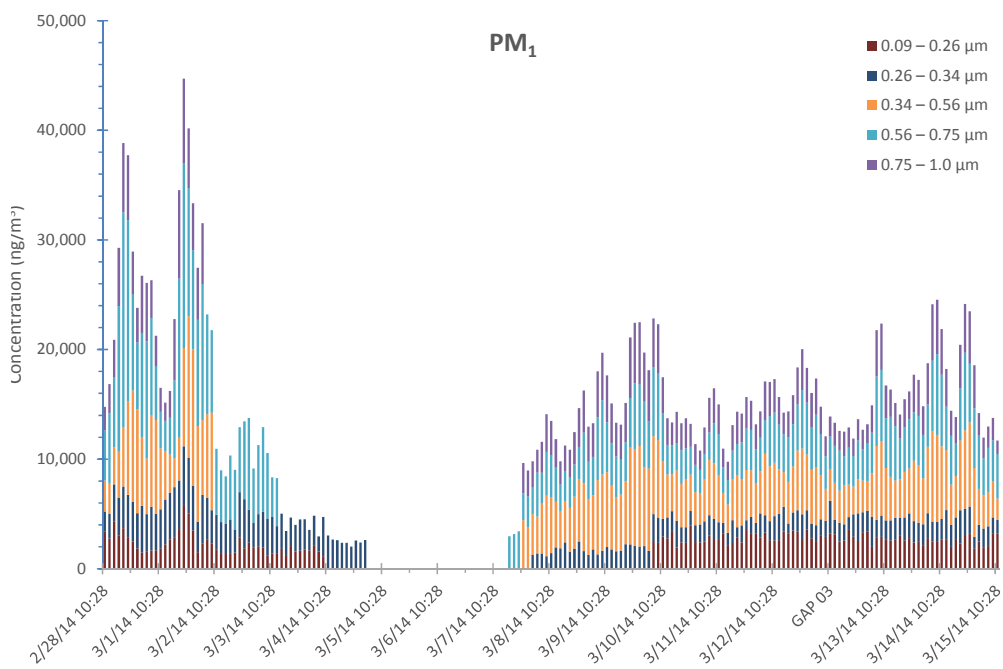


b) CaPh 32 DRUM: β -gauge estimate of $PM_{2.5}$

Fig. C-2 DRUM: a) CaPh 34 and b) CaPh 32 β -gauge estimates of $PM_{2.5}$



a) CaPh 34 DRUM: β -gauge estimate of PM_{10}



b) CaPh 32 DRUM: β -gauge estimate of PM_{10}

Fig. C-3 DRUM: β -gauge estimates of a) CaPh 34 PM_{10} and b) CaPh32 PM_{10}

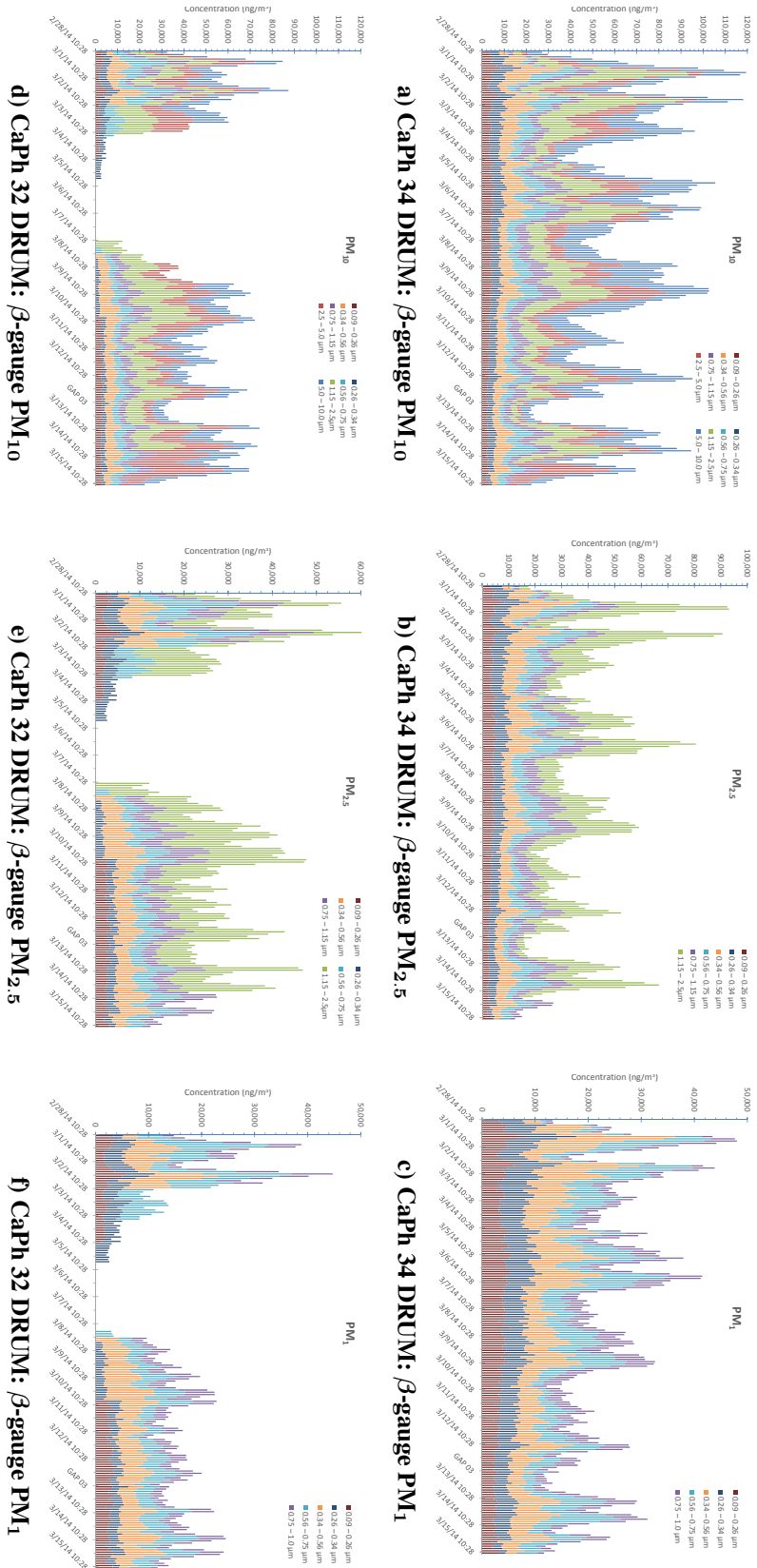
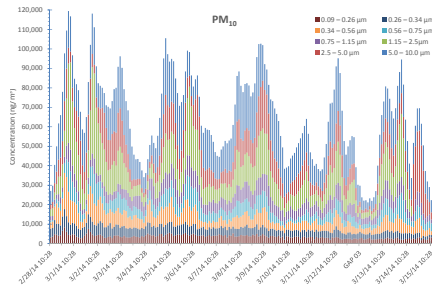
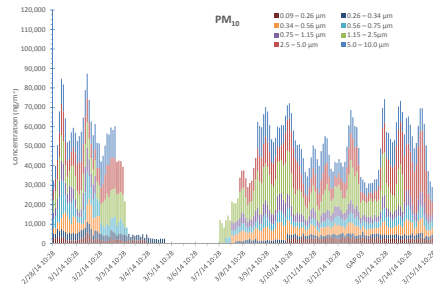


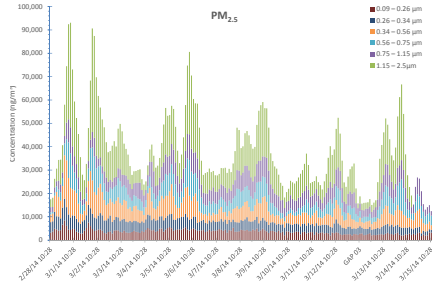
Fig. C-4 DRUM: β -gauge estimates of a) Caph 34 PM₁₀, b) Caph34 PM_{2.5}, c) Caph34 PM₁, d) Caph32 PM₁₀, e) Caph32 PM_{2.5}, and f) Caph 32 PM₁



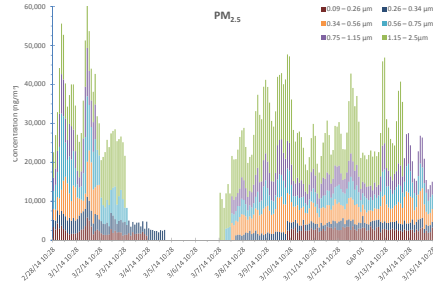
a) CaPh 34 DRUM: β -gauge estimate of PM_{10}



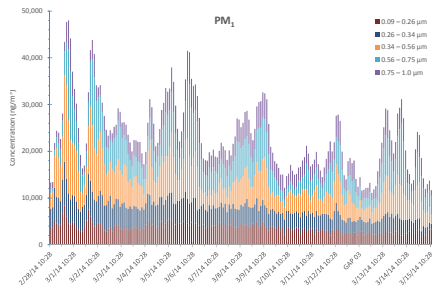
b) CaPh 32 DRUM: β -gauge estimate of PM_{10}



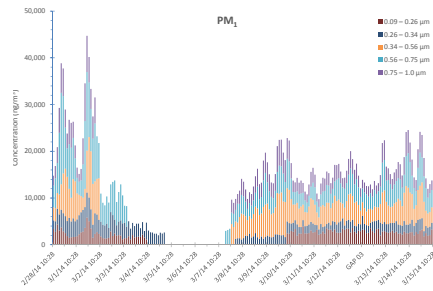
c) CaPh 34 DRUM: β -gauge estimate of $PM_{2.5}$



d) CaPh 32 DRUM: β -gauge estimate of $PM_{2.5}$



e) CaPh 34 DRUM: β -gauge estimate of PM_1

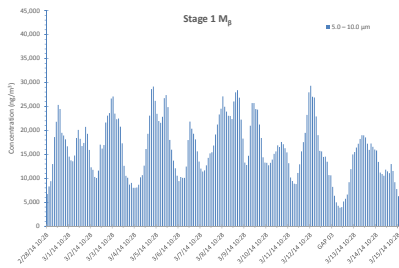


f) CaPh 32 DRUM: β -gauge estimate of PM_1

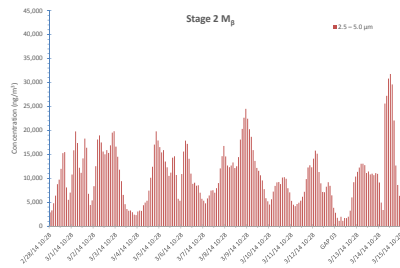
Fig. C-5 DRUM: β -gauge estimates of: PM_{10} , a) CaPh 34, b) CaPh 32; $PM_{2.5}$ c) CaPh 34, d) CaPh 32; PM_1 e) CaPh 34, and f) CaPh 32

C-1.2 β -Gauge Estimates of Mass by Stage

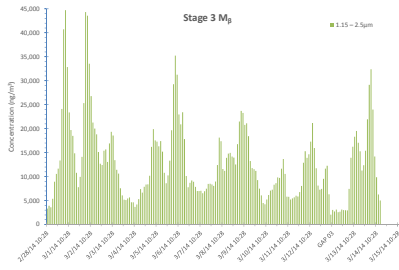
Figure C-6 shows the β -gauge measurements of mass on each of the stages of the CaPh 34 DRUM and Figs. C-7–C-14 are the individual CaPh 34 DRUM plots. Similarly, Fig. C-15 shows the β -gauge measurements of mass on each of the stages of the CaPh 32 DRUM, and Figs. C-16–C-23 are the individual CaPh 32 DRUM plots.



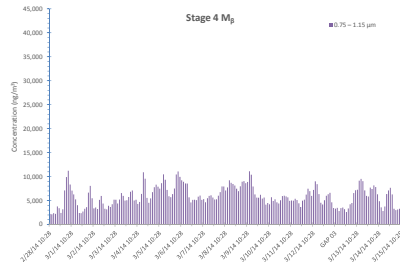
a) β -gauge stage 1 mass



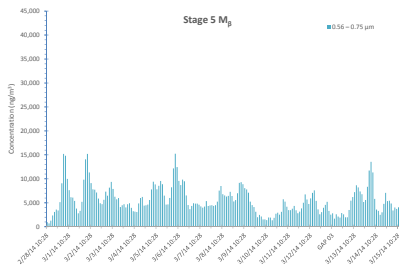
b) β -gauge stage 2 mass



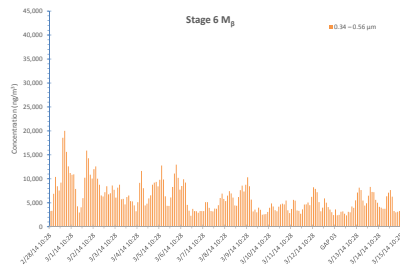
c) β -gauge stage 3 mass



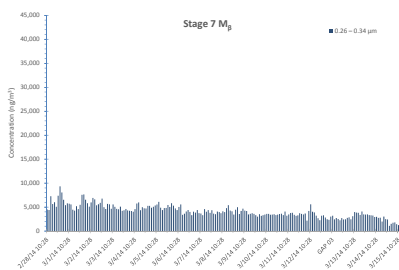
d) β -gauge stage 4 mass



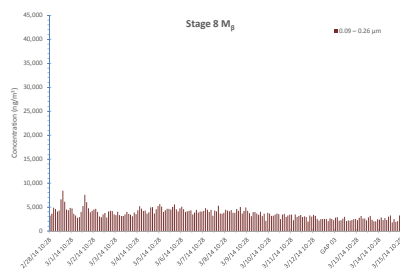
e) β -gauge stage 5 mass



f) β -gauge stage 6 mass



g) β -gauge stage 7 mass



h) β -gauge stage 8 mass

Fig. C-6 CaPh 34 DRUM: β -gauge estimates of mass; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

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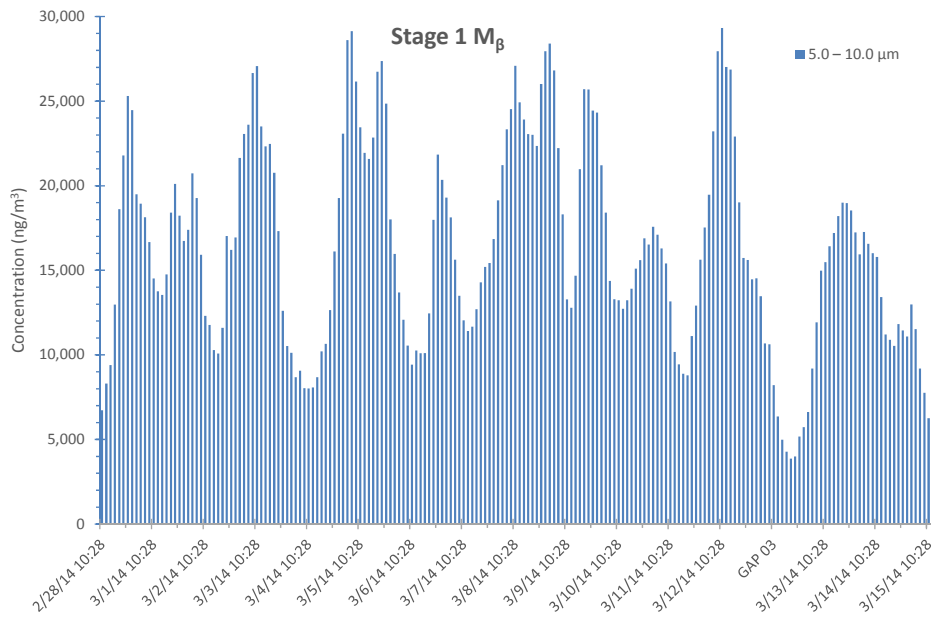


Fig. C-7 CaPh 34 DRUM: β -gauge estimate of stage 1 mass

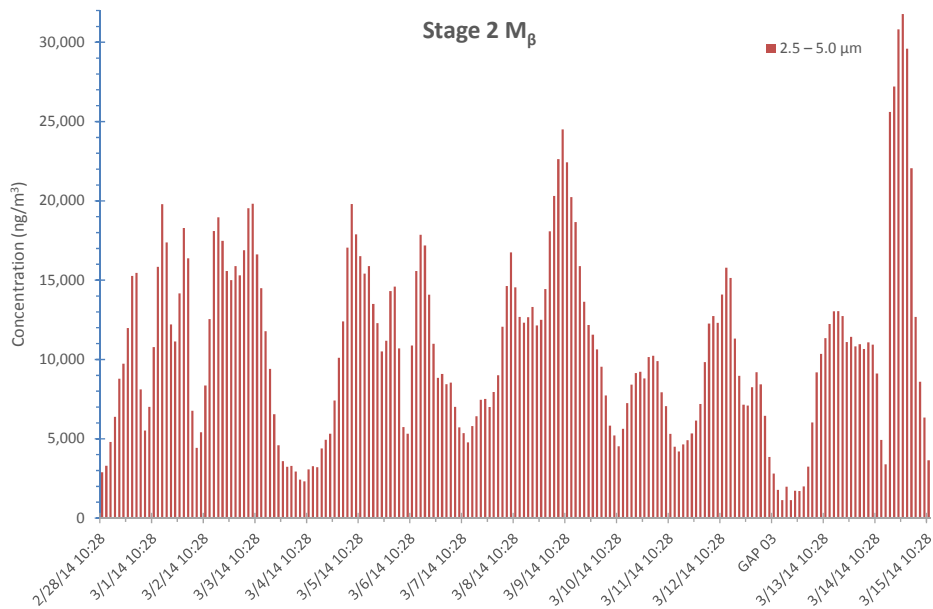


Fig. C-8 CaPh 34 DRUM: β -gauge estimate of stage 2 mass

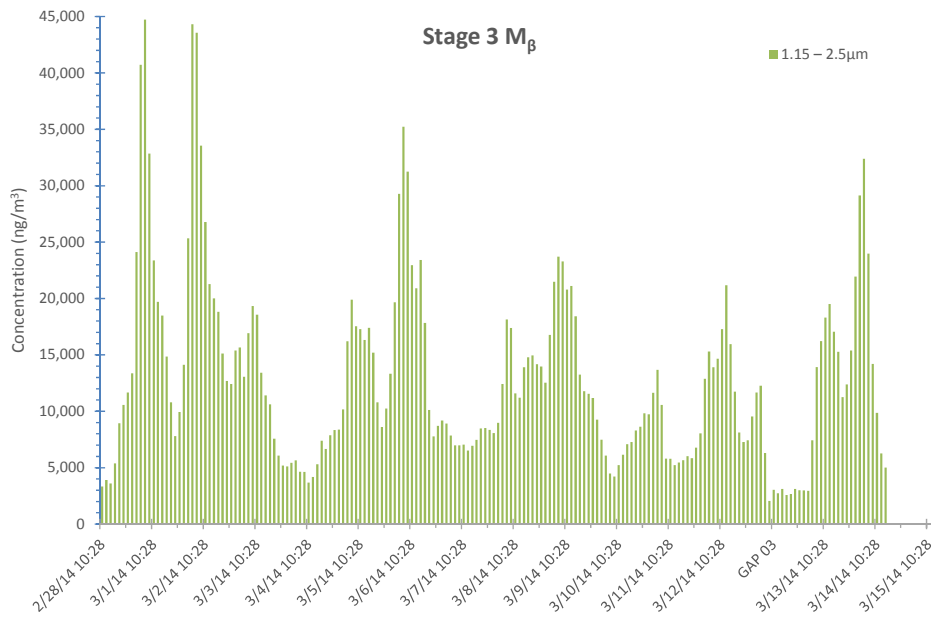


Fig. C-9 CaPh 34 DRUM: β -gauge estimate of stage 3 mass

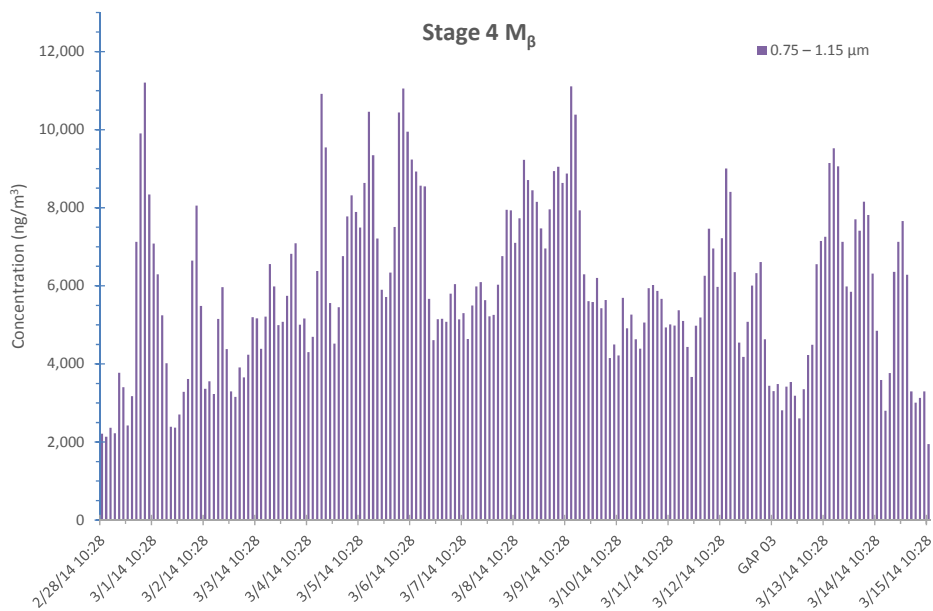


Fig. C-10 CaPh 34 DRUM: β -gauge estimate of stage 4 mass

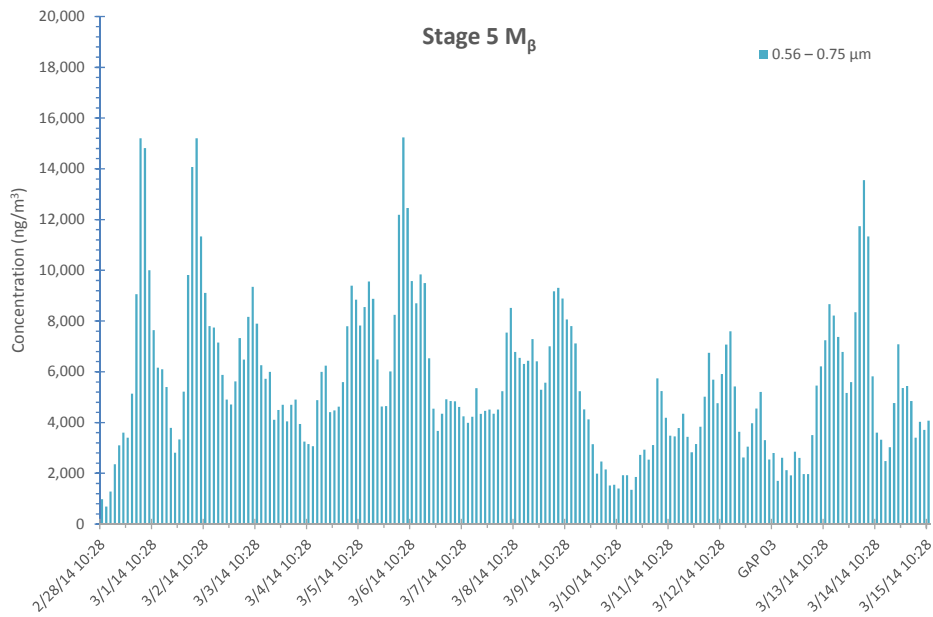


Fig. C-11 CaPh 34 DRUM: β -gauge estimate of stage 5 mass

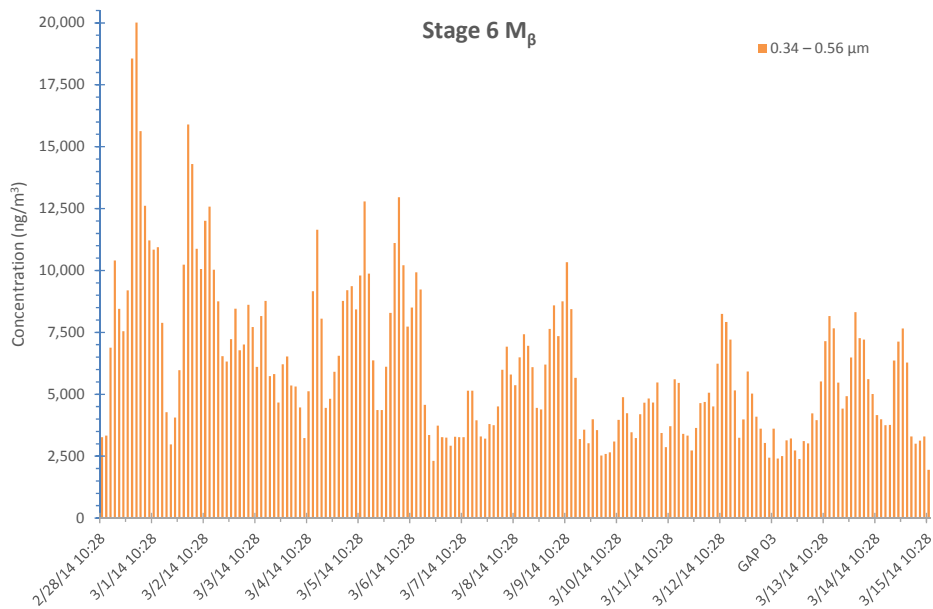


Fig. C-12 CaPh 34 DRUM: β -gauge estimate of stage 6 mass

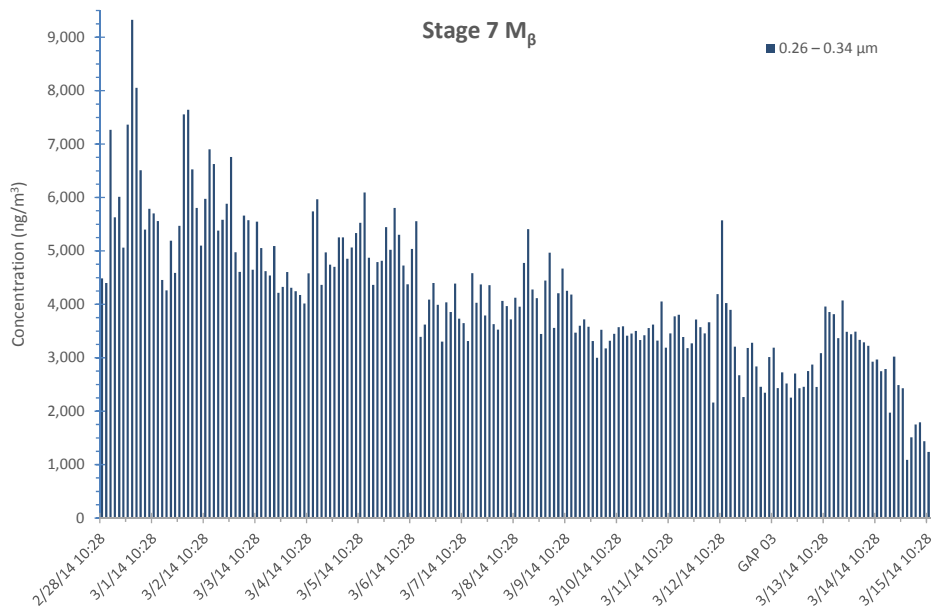


Fig. C-13 CaPh 34 DRUM: β -gauge estimate of stage 7 mass

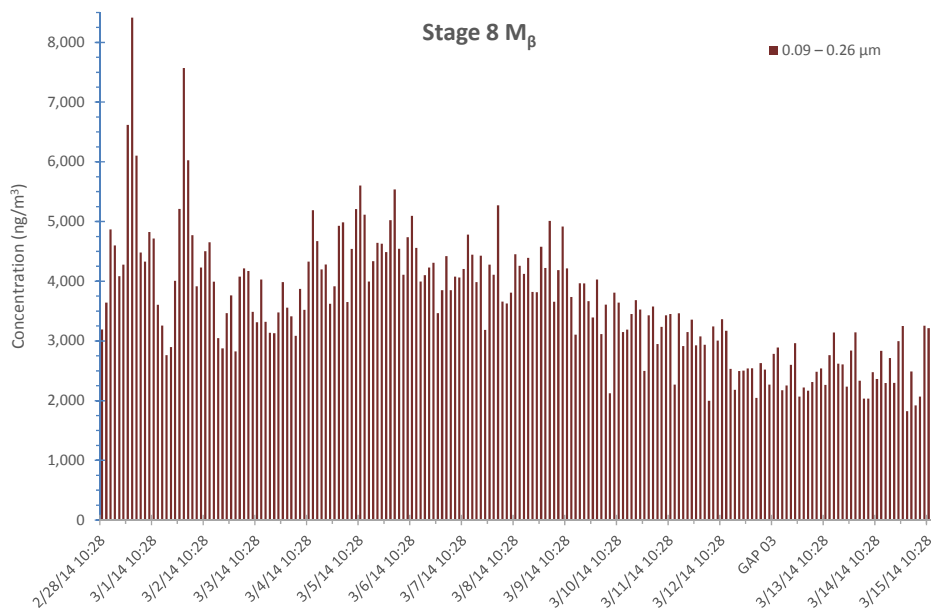
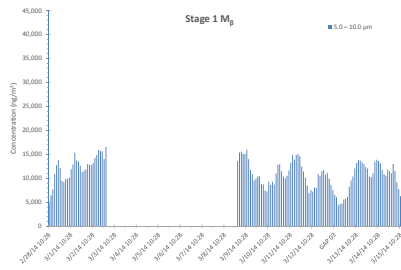
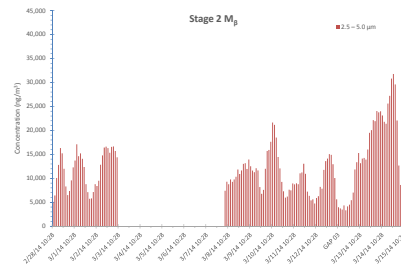


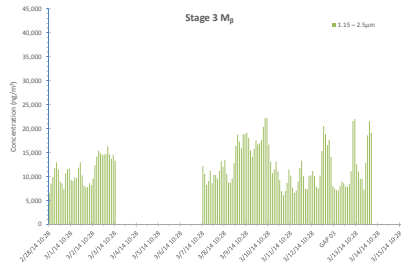
Fig. C-14 CaPh 34 DRUM: β -gauge estimate of stage 8 mass



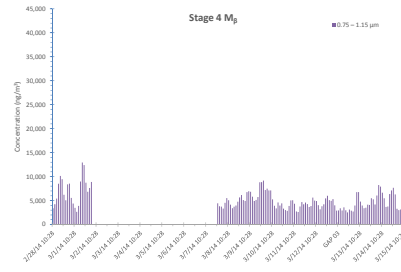
a) β -gauge stage 1 mass



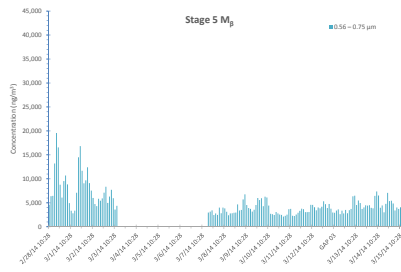
b) β -gauge stage 2 mass



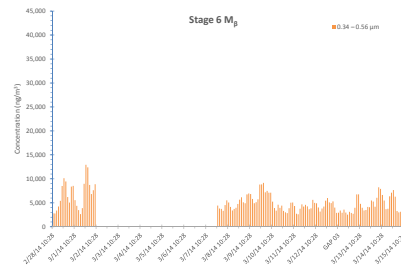
c) β -gauge stage 3 mass



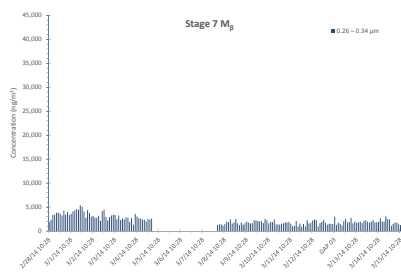
d) β -gauge stage 4 mass



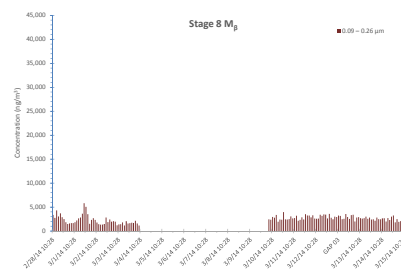
e) β -gauge stage 5 mass



f) β -gauge stage 6 mass



g) β -gauge stage 7 mass



h) β -gauge stage 8 mass

Fig. C-15 CaPh 32 DRUM: β -gauge estimates of mass; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

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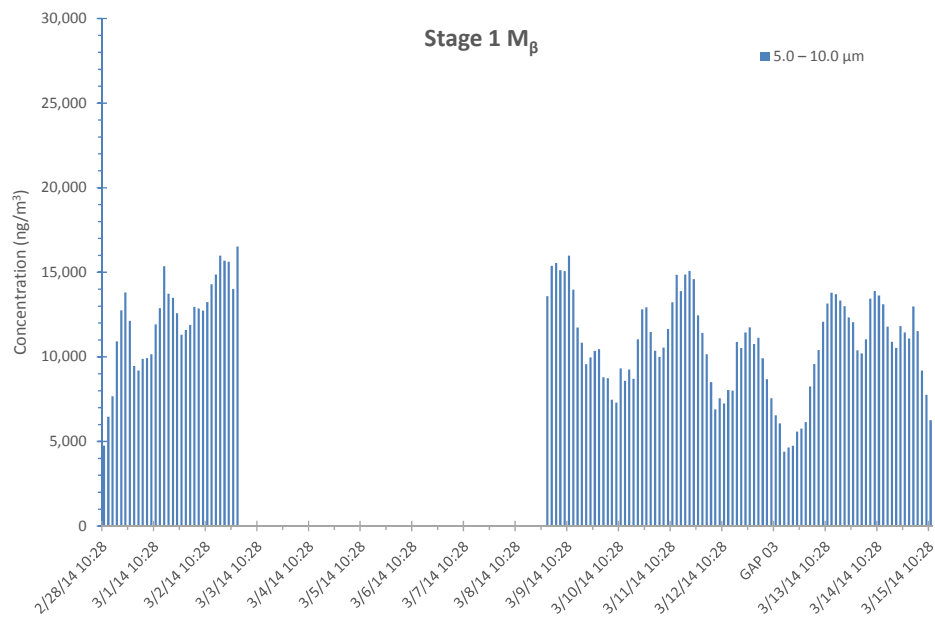


Fig. C-16 CaPh 32 DRUM: β -gauge estimate of stage 1 mass

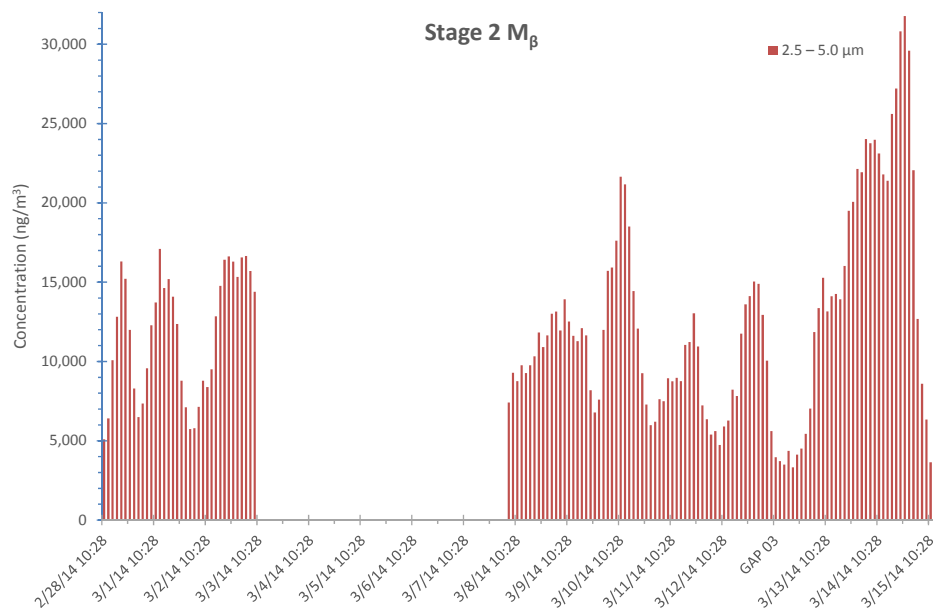


Fig. C-17 CaPh 32 DRUM: β -gauge estimate of stage 2 mass

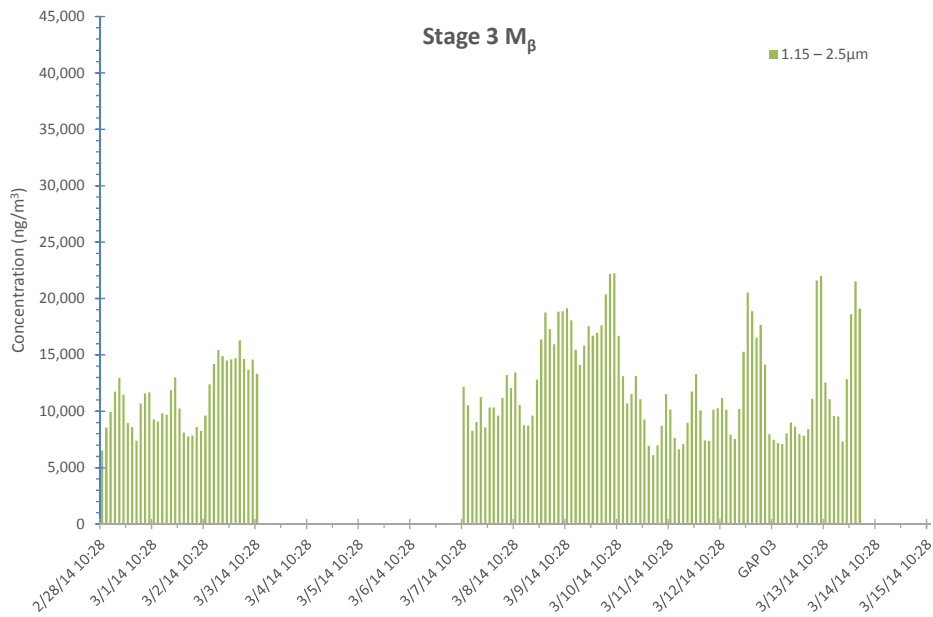


Fig. C-18 CaPh 32 DRUM: β -gauge estimate of stage 3 mass

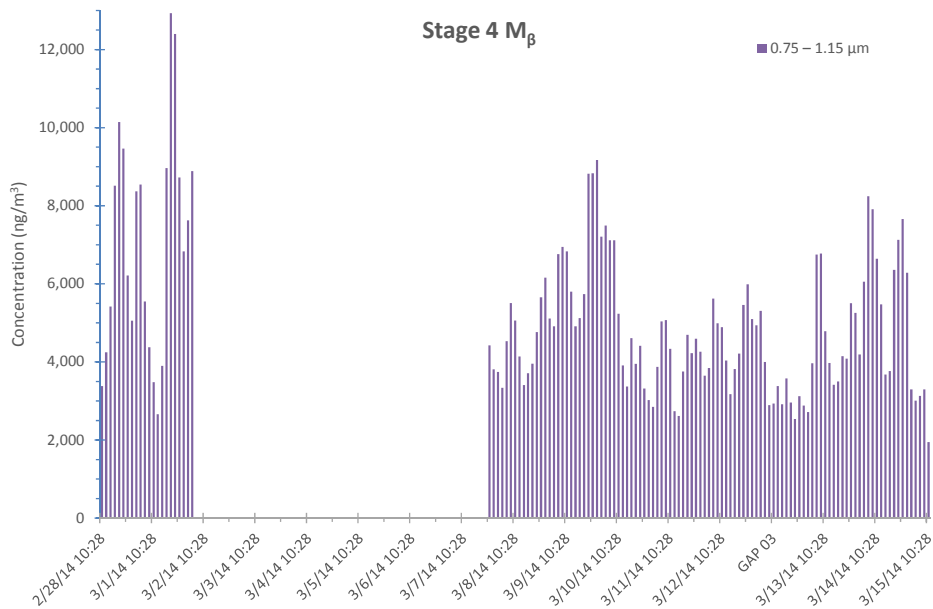


Fig. C-19 CaPh 32 DRUM: β -gauge estimate of stage 4 mass

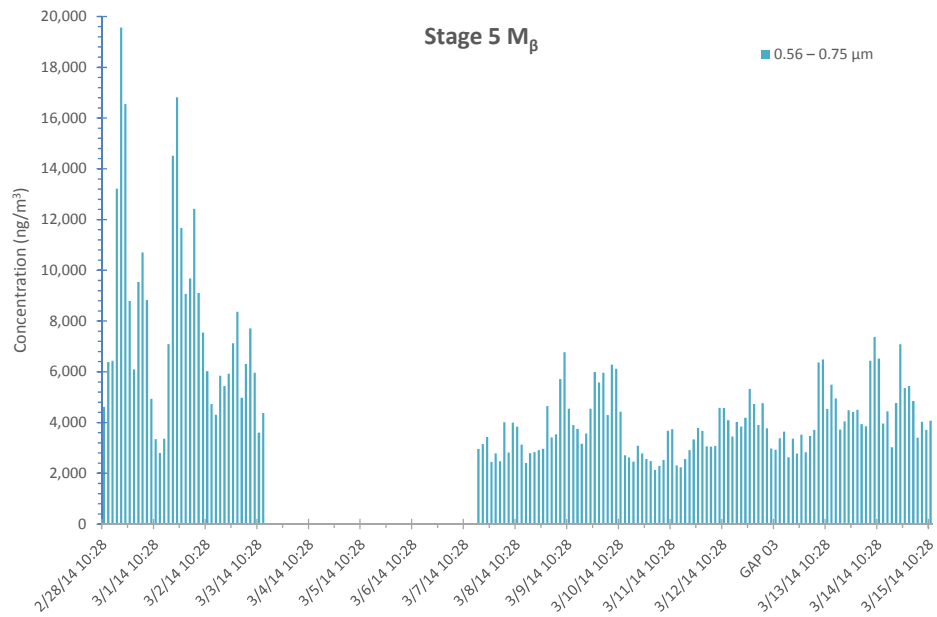


Fig. C-20 CaPh 32 DRUM: β -gauge estimate of stage 5 mass

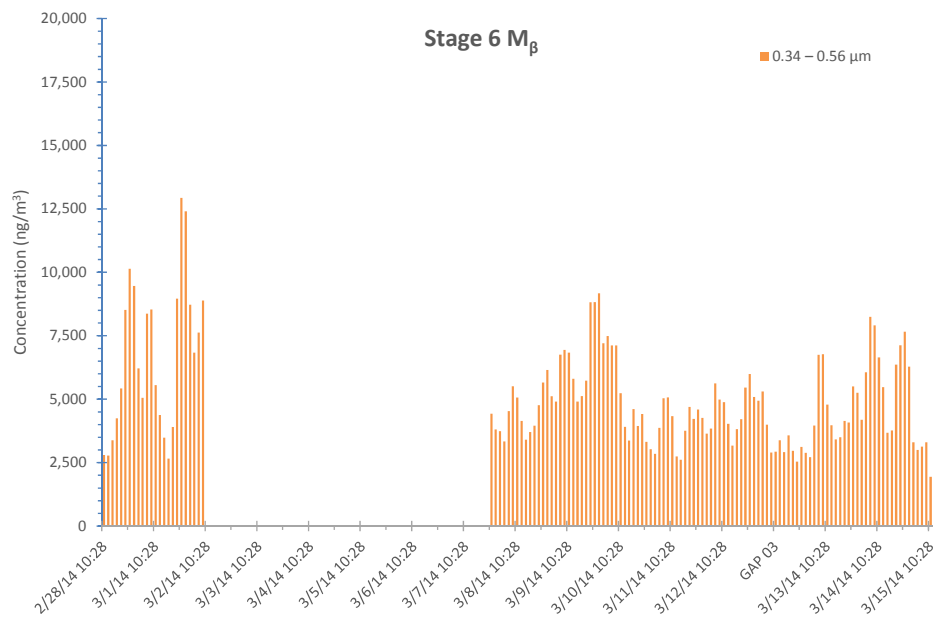


Fig. C-21 CaPh 32 DRUM: β -gauge estimate of stage 6 mass

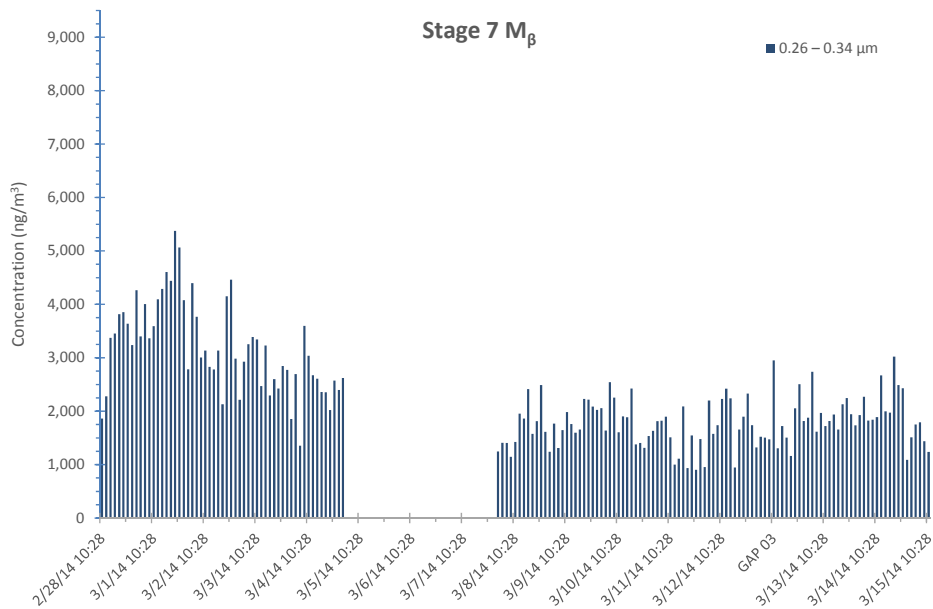


Fig. C-22 CaPh 32 DRUM: β -gauge estimate of stage 7 mass

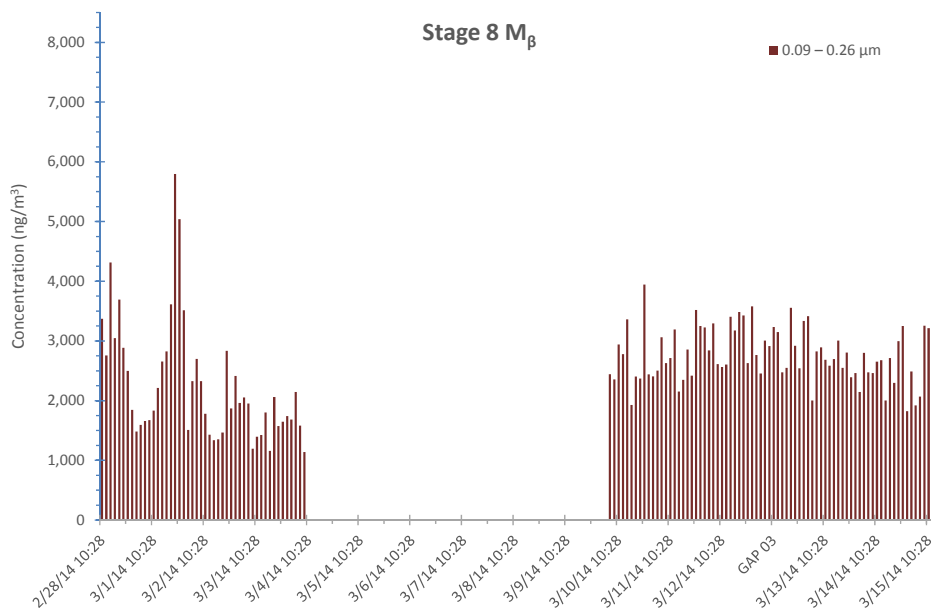
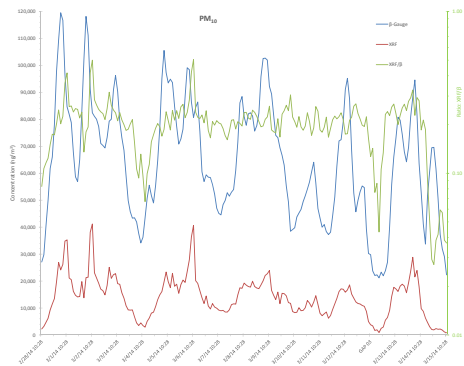


Fig. C-23 CaPh 32 DRUM: β -gauge estimate of stage 8 mass

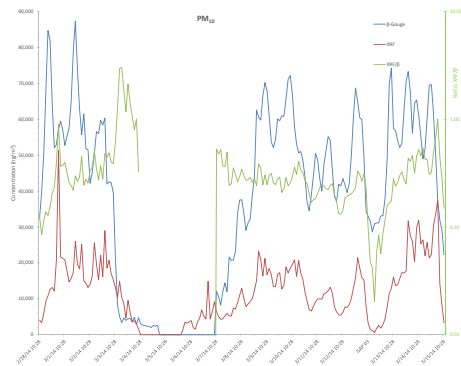
C-2 XRF and β -Gauge Mass

Figure C-24 shows plots of the PM_x estimates for both the CaPh 43 (left column) and CaPh32 (right column) DRUMS. These show both the β -gauge and XRF results as well as the ratio of M_{XRF}/M_{β} .

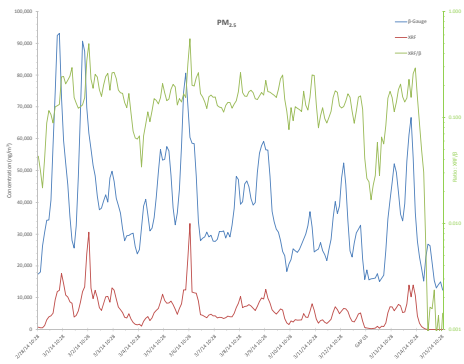
In general, we expect that M_{XRF} will be less than M_{β} , since the XRF measurement is not sensitive to elements lighter than sodium (Na), omitting the mass contributed by H, C, N, and O as mentioned in Section 3.3.3 and shown in Table 3.



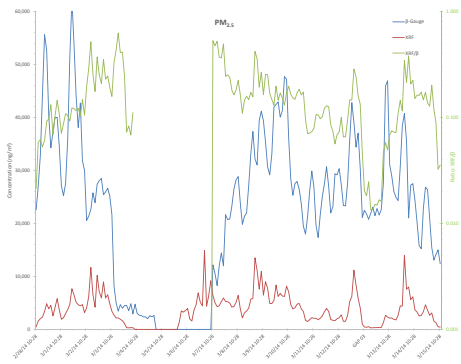
a) CaPh 34 DRUM PM₁₀



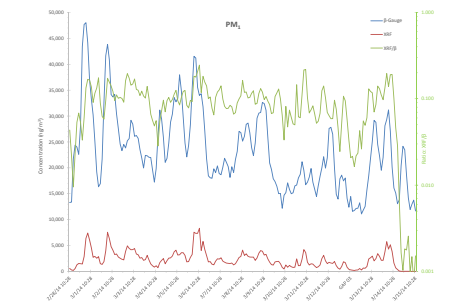
b) CaPh 32 DRUM PM₁₀



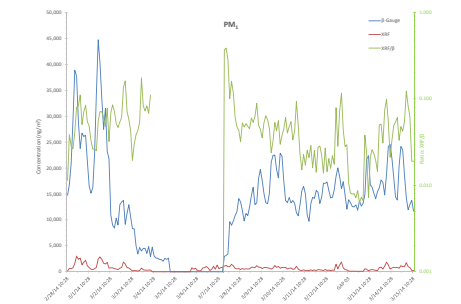
c) CaPh 34 DRUM PM_{2.5}



d) CaPh 32 DRUM PM_{2.5}



e) CaPh 34 DRUM PM₁

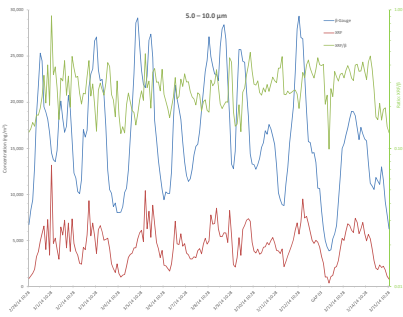


f) CaPh 32 DRUM PM₁

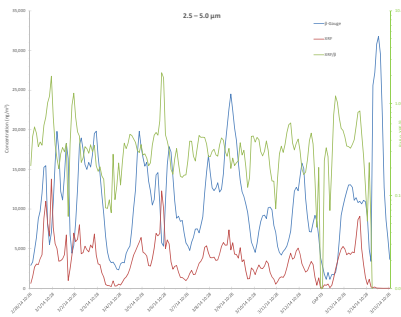
Fig. C-24 XRF and β -gauge estimates of mass: PM₁₀, a) CaPh 34, b) CaPh 32; PM_{2.5} c) CaPh 34, d) CaPh 32; PM₁₀, e) CaPh 34, f) CaPh 32

Figure C-25 shows plots of the mass measurements for the 8 CaPh 34 DRUM strips. Figure C-26 shows similar plots of the mass measurements for the 8 CaPh 32 DRUM strips. These show both the β -gauge and XRF results as well as the ratio of M_{XRF}/M_{β} .

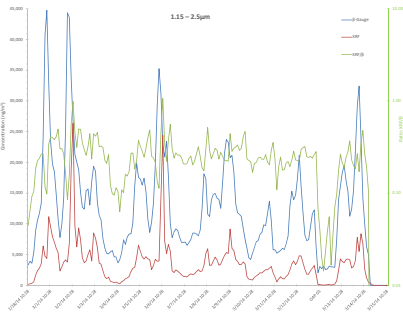
Examining the plots, the trend is a decrease in the ratio of M_{XRF}/M_{β} as the size of the sampled particles decreases from stage 1 to stage 8. This indicates that an increasing fraction of the mass in the smaller particles is from elements such as H, C, N, and O that are not able to be measured with the XRF method. Also, the data from stage 7 and 8 of the CaPh 34 DRUM show a marked decrease in total mass during the sampling period as measured by the β -gauge. This is less evident in the data from the CaPh 32 DRUM.



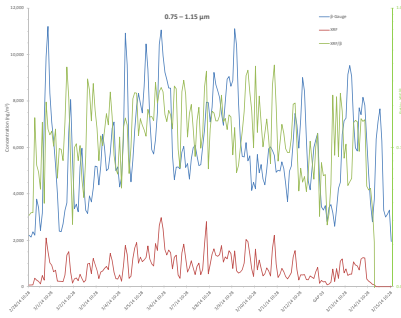
a) CaPh 34 DRUM stage 1 mass



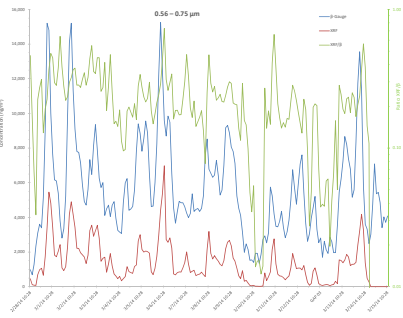
b) CaPh 34 DRUM stage 2 mass



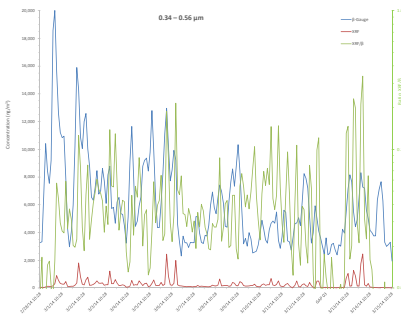
c) CaPh 34 DRUM stage 3 mass



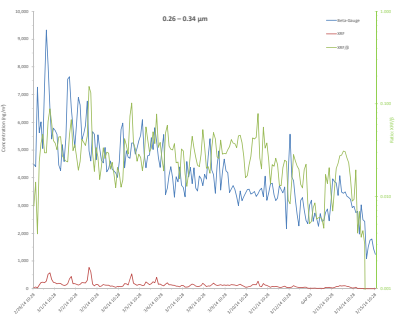
d) CaPh 34 DRUM stage 4 mass



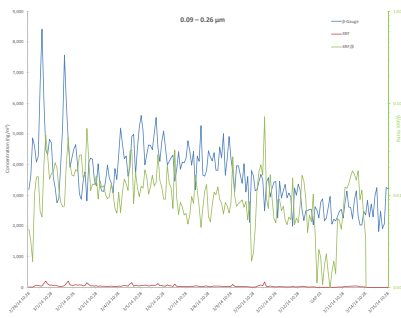
e) CaPh 34 DRUM stage 5 mass



f) CaPh 34 DRUM stage 6 mass

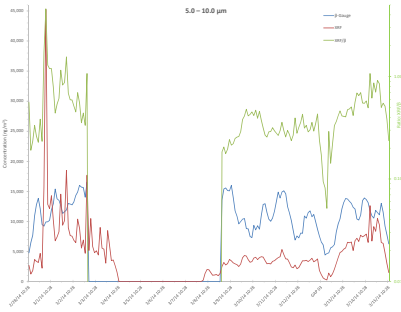


g) CaPh 34 DRUM stage 7 mass



h) CaPh 34 DRUM stage 8 mass

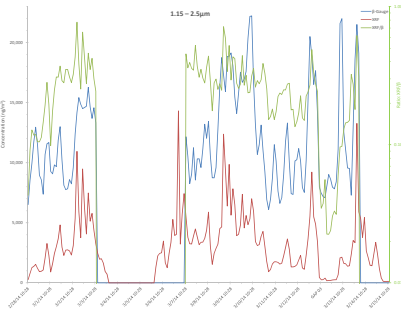
Fig. C-25 CaPh 34 DRUM: total mass; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



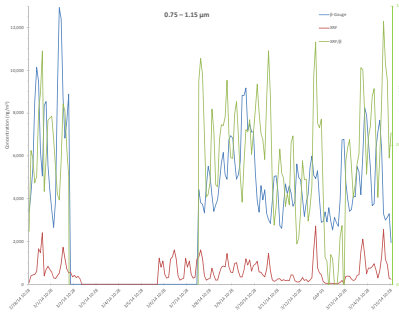
a) CaPh 32 DRUM stage 1 mass



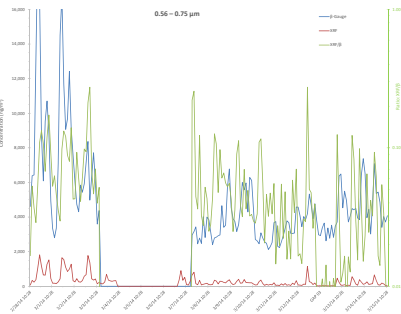
b) CaPh 32 DRUM stage 2 mass



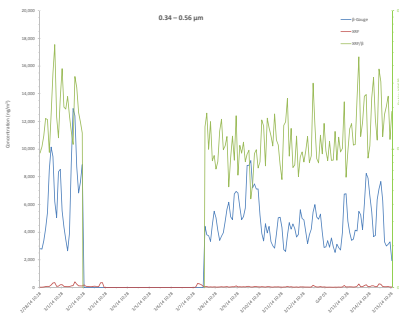
c) CaPh 32 DRUM stage 3 mass



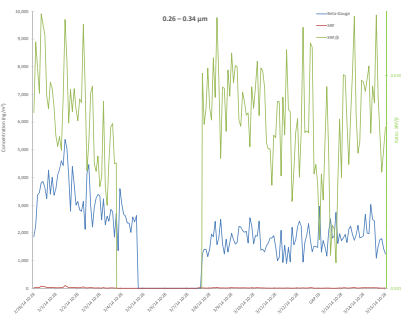
d) CaPh 32 DRUM stage 4 mass



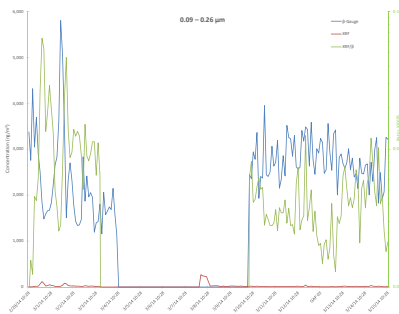
e) CaPh 32 DRUM stage 5 mass



f) CaPh 32 DRUM stage 6 mass



g) CaPh 32 DRUM stage 7 mass



h) CaPh 32 DRUM stage 8 mass

Fig. C-26 CaPh 32 DRUM: total mass; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

C-3 Total Elemental Mass Concentration Plots

The elemental concentrations are only available using the XRF data. This section plots the elemental composition for each of the 8 DRUM stages showing the abundance of each element versus time. The diurnal cycle is evident, especially in the plots of the larger sized particles. Figures C-27 through C-34 are for the CaPh 34 DRUM and Figs. C-35 through C-42 are for the CaPh 32 DRUM.

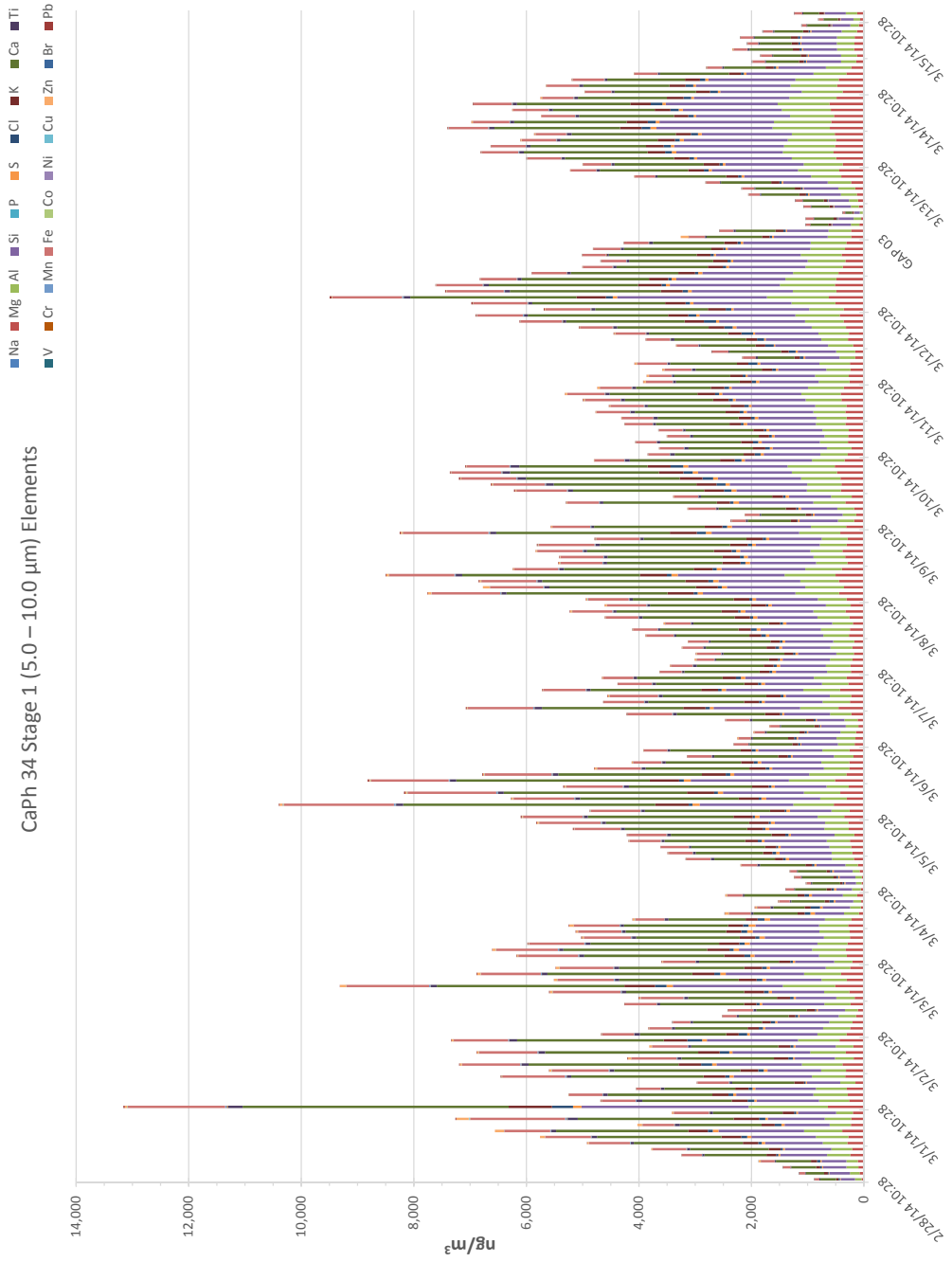


Fig. C-27 CaPh 34 DRUM: mass by element stage 1

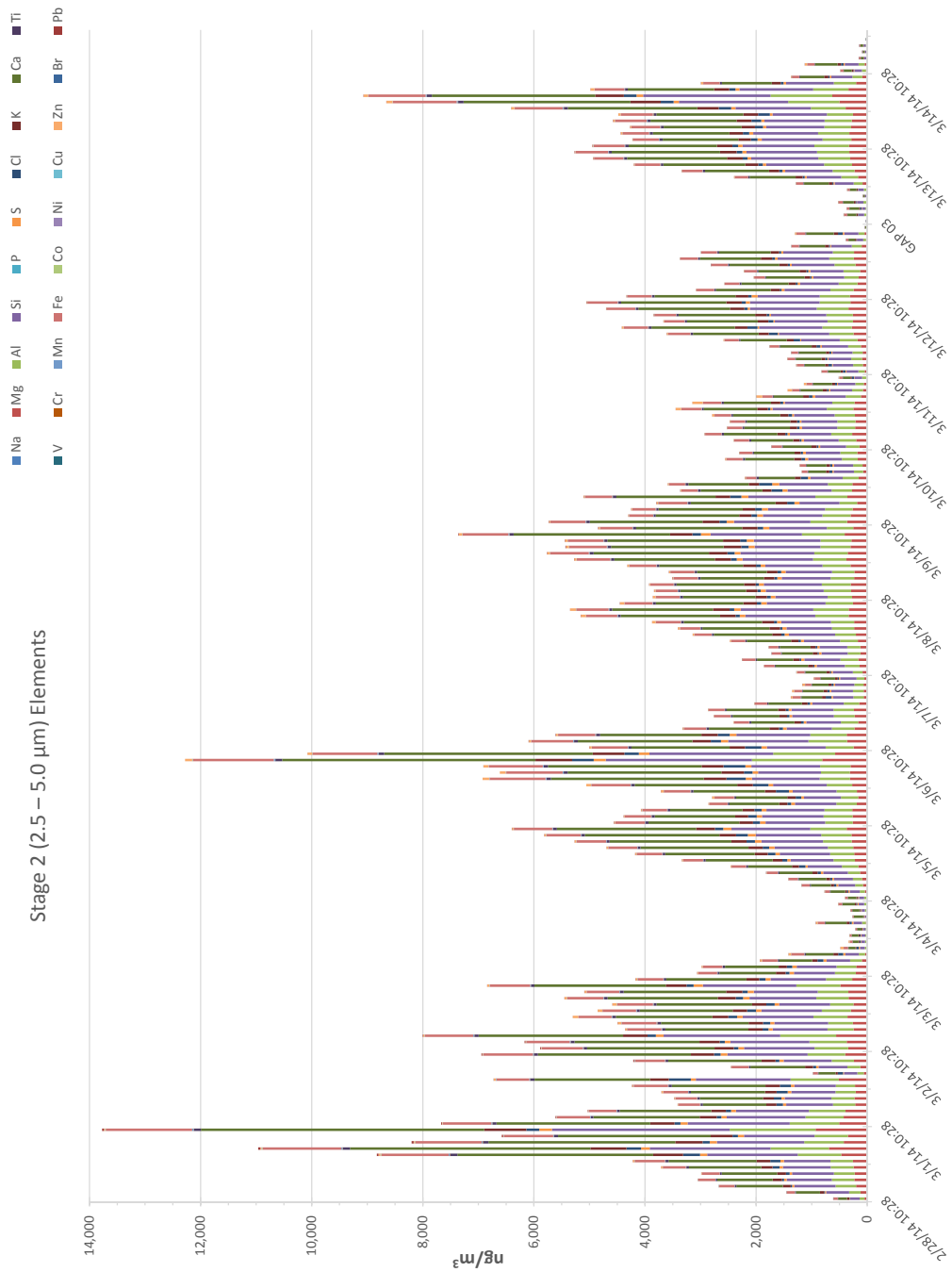


Fig. C-28 CaPh 34 DRUM: mass by element stage 2

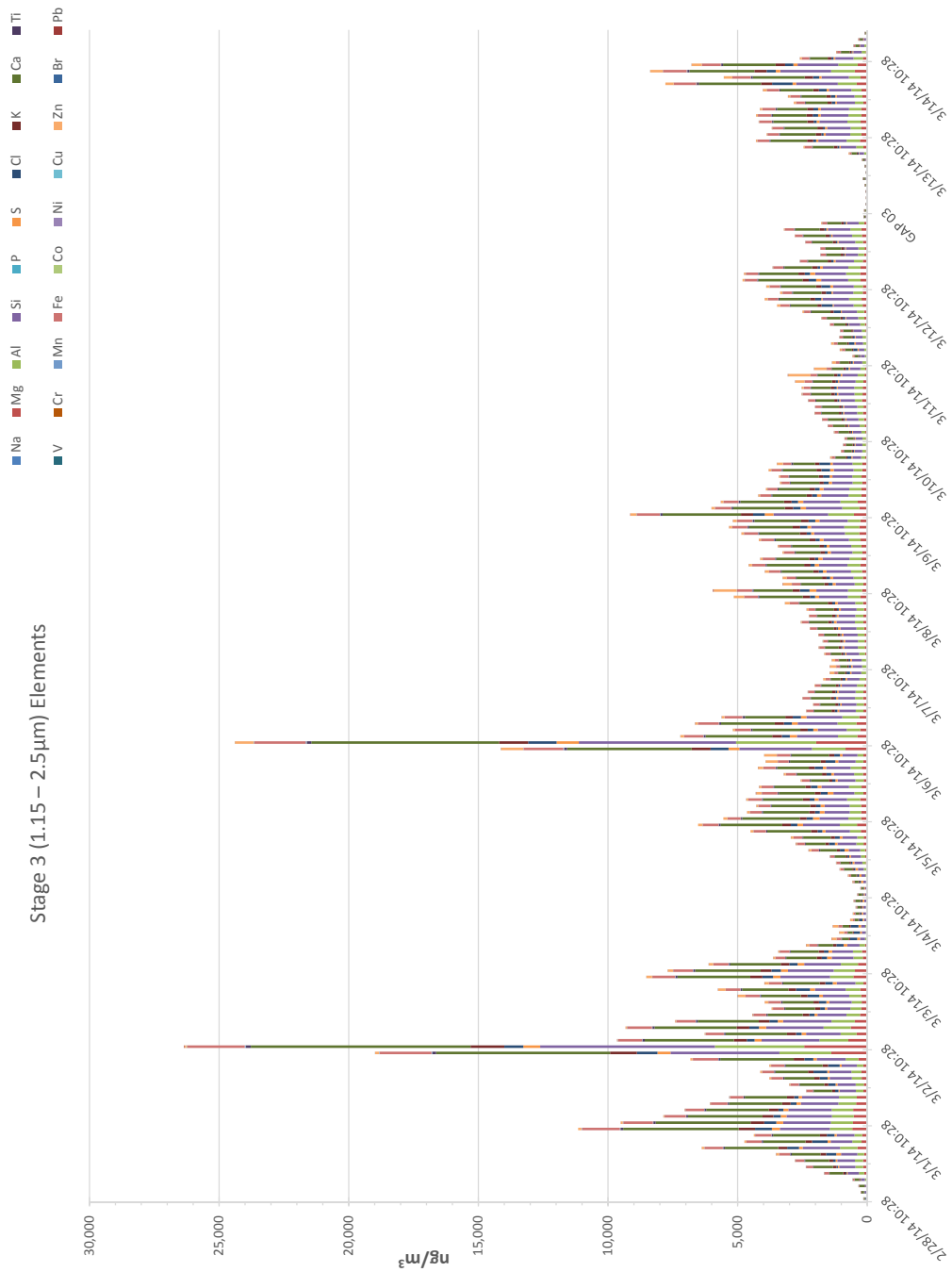


Fig. C-29 CaPh 34 DRUM: mass by element stage 3

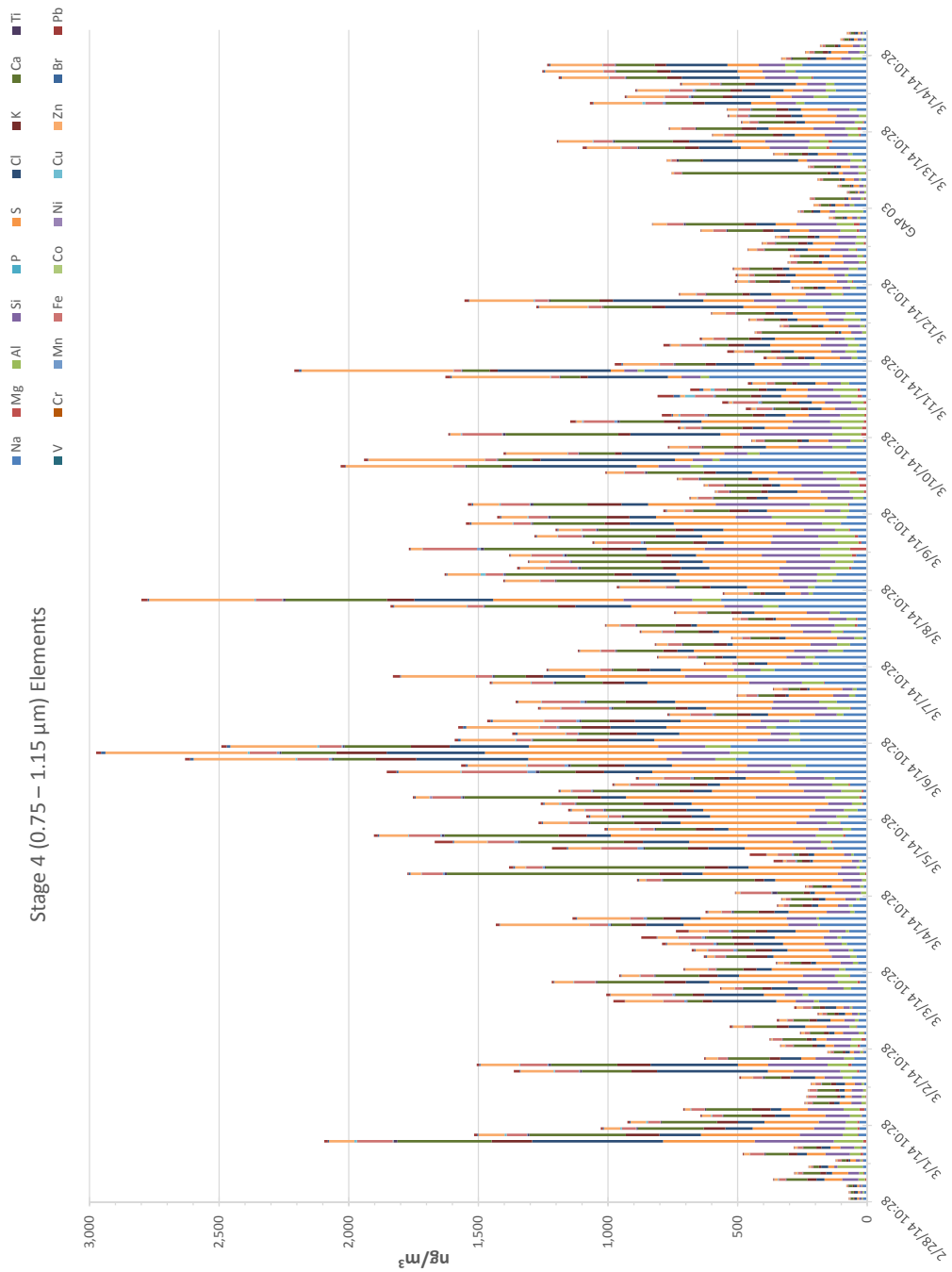


Fig. C-30 CaPh 34 DRUM: mass by element stage 4

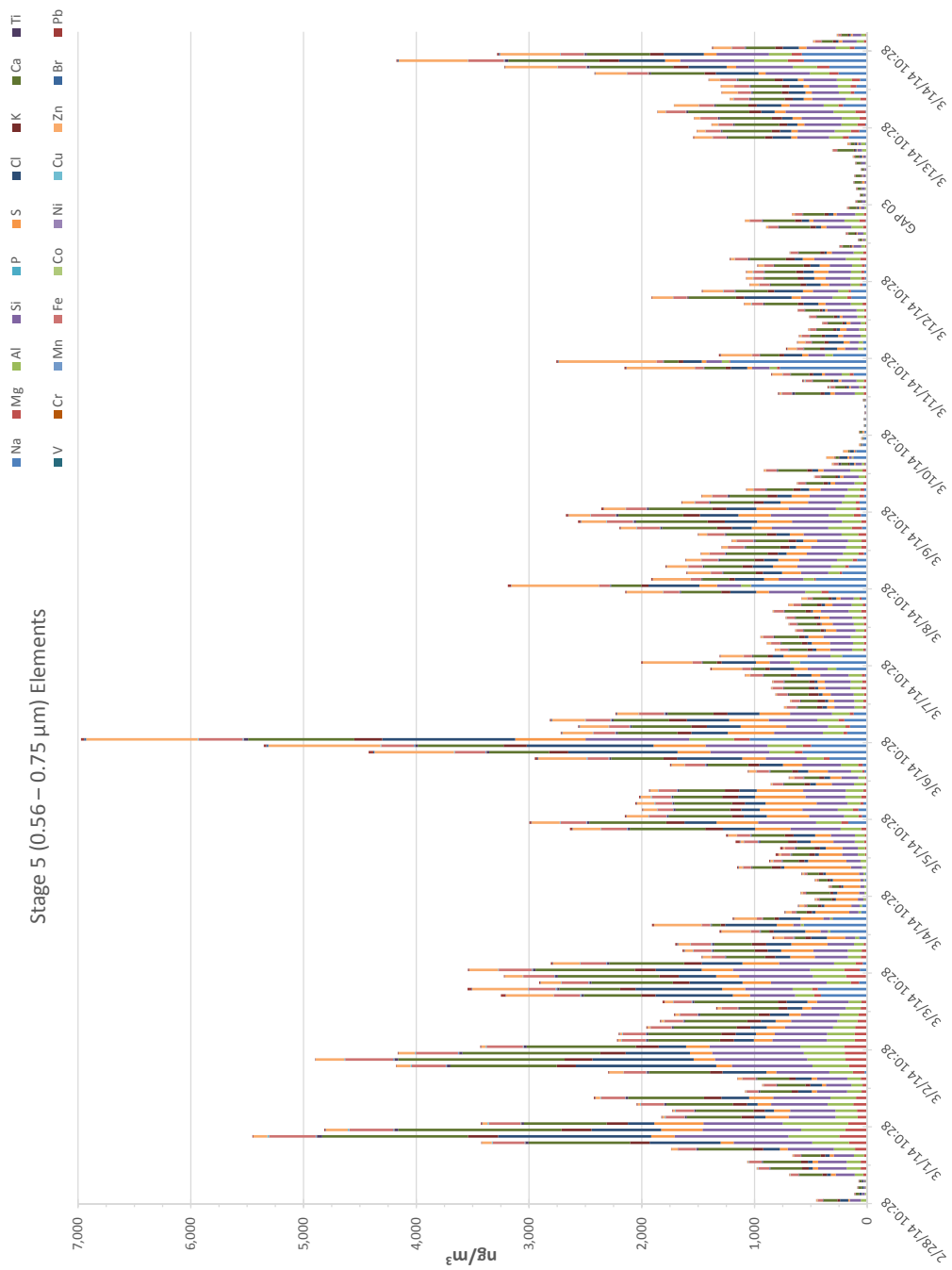


Fig. C-31 CaPh 34 DRUM: mass by element stage 5

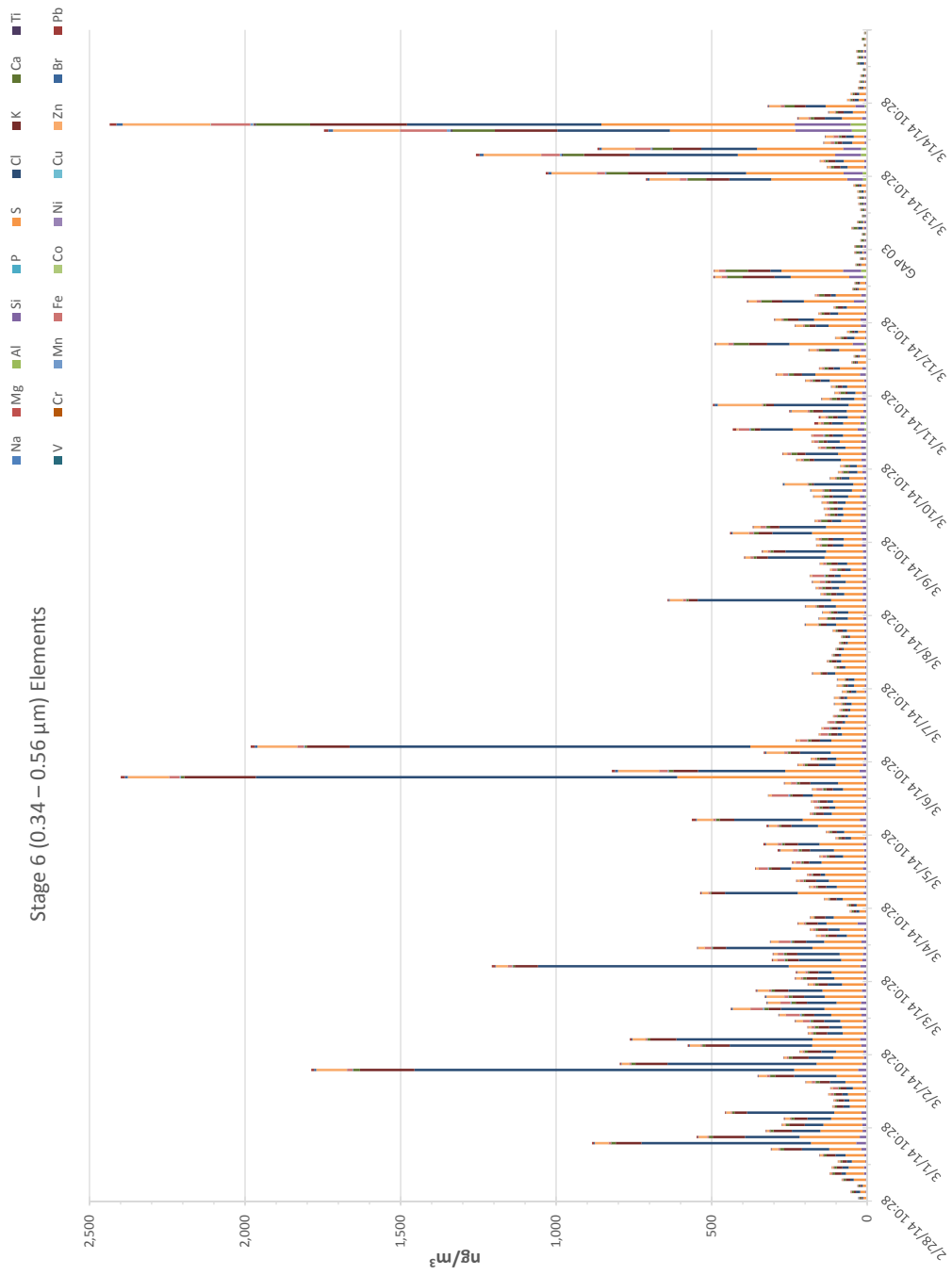


Fig. C-32 CaPh 34 DRUM: mass by element stage 6

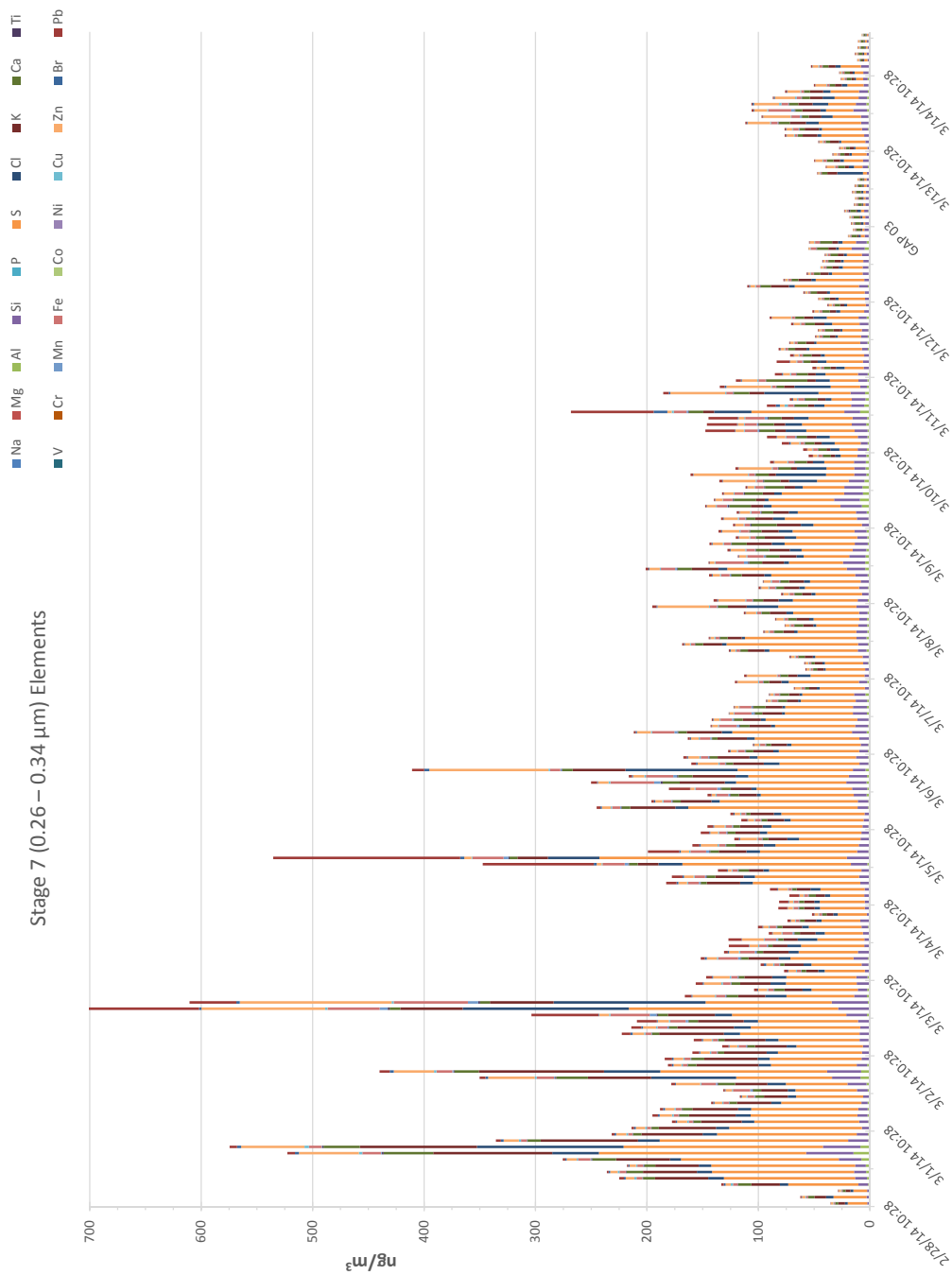


Fig. C-33 CaPh 34 DRUM: mass by element stage 7

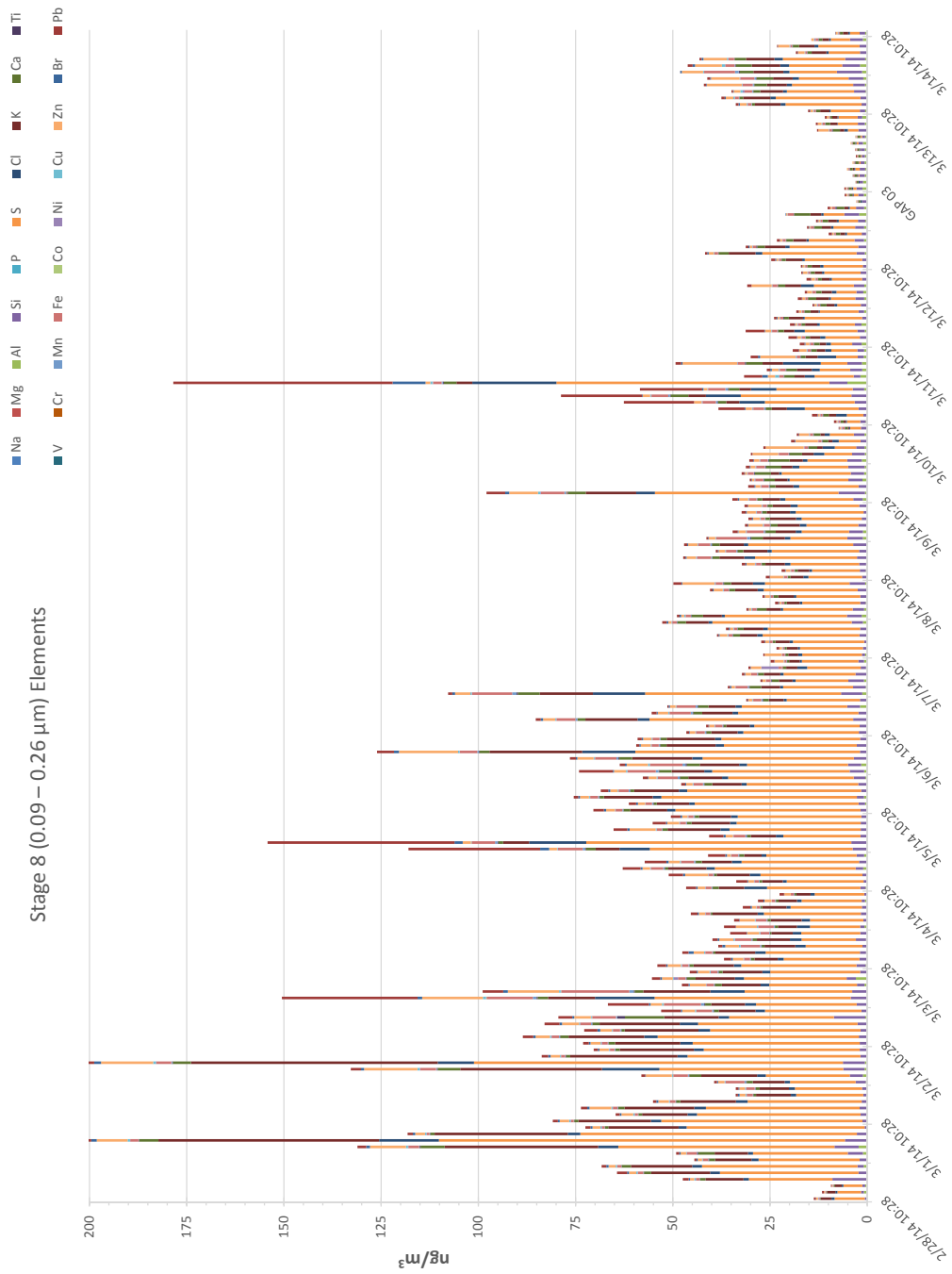


Fig. C-34 CaPh 34 DRUM: mass by element stage 8

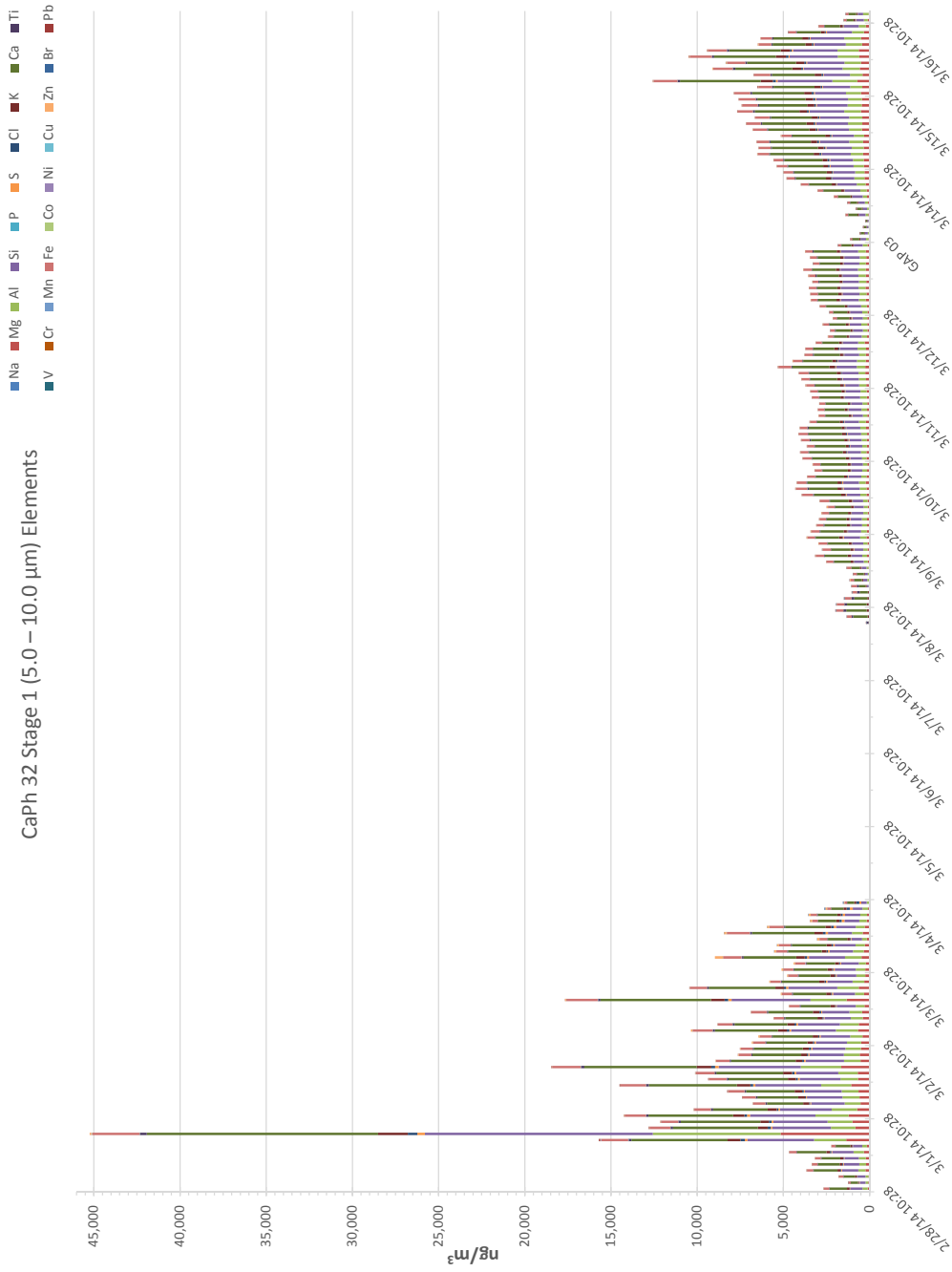


Fig. C-35 CaPh 32 DRUM: mass by element stage 1

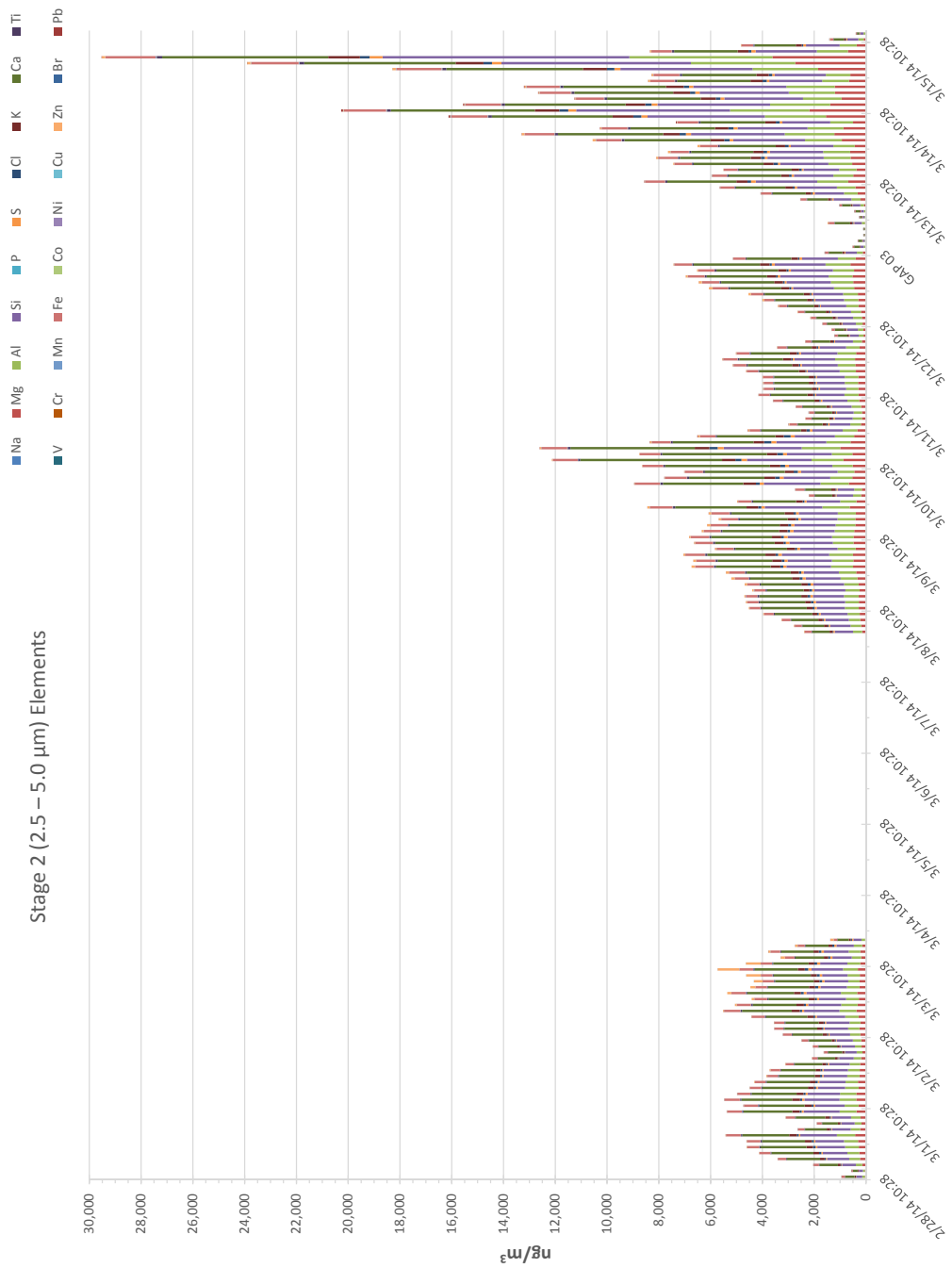


Fig. C-36 CaPh 32 DRUM: mass by element stage 2

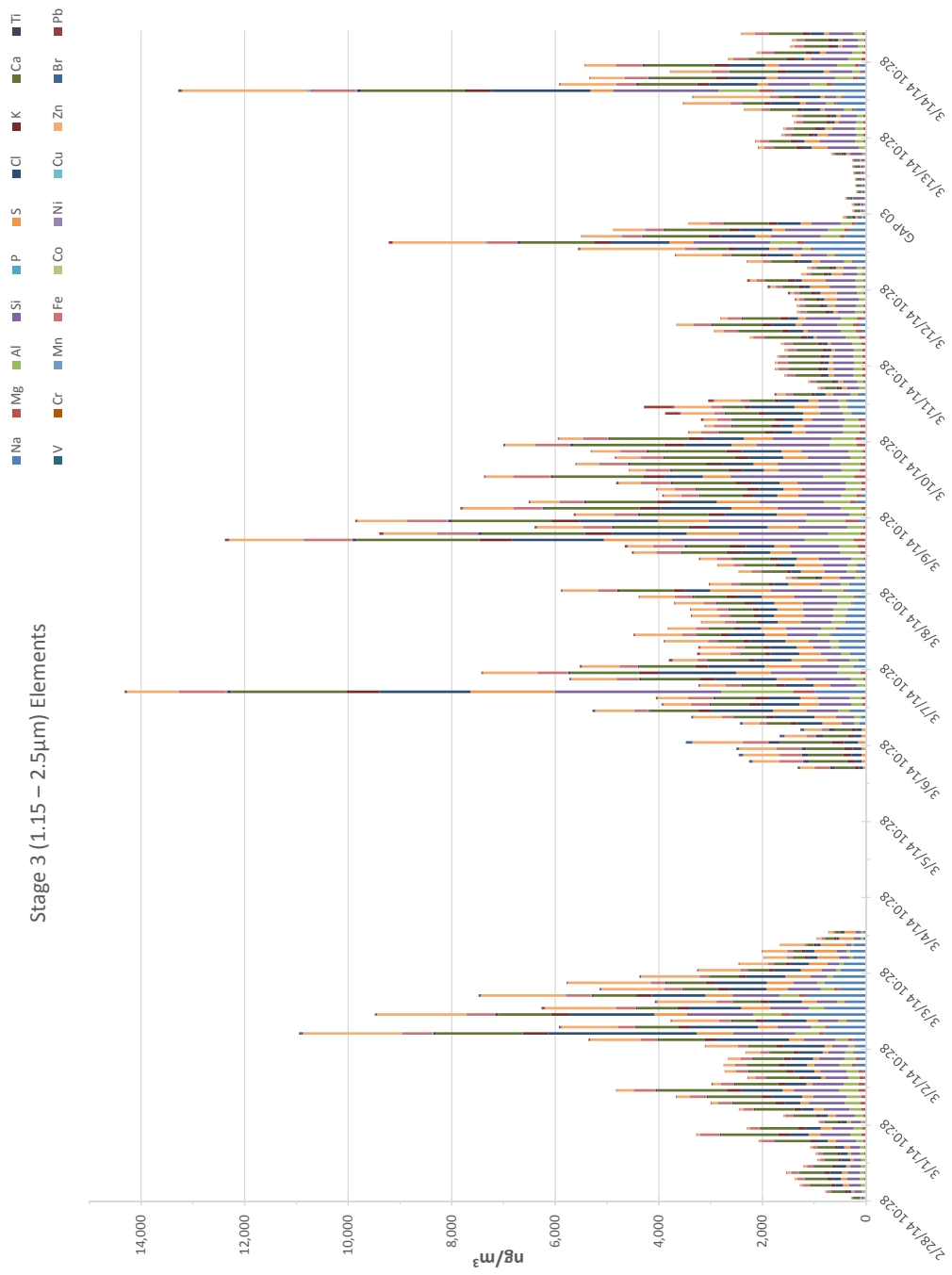


Fig. C-37 CaPh 32 DRUM: mass by element stage 3

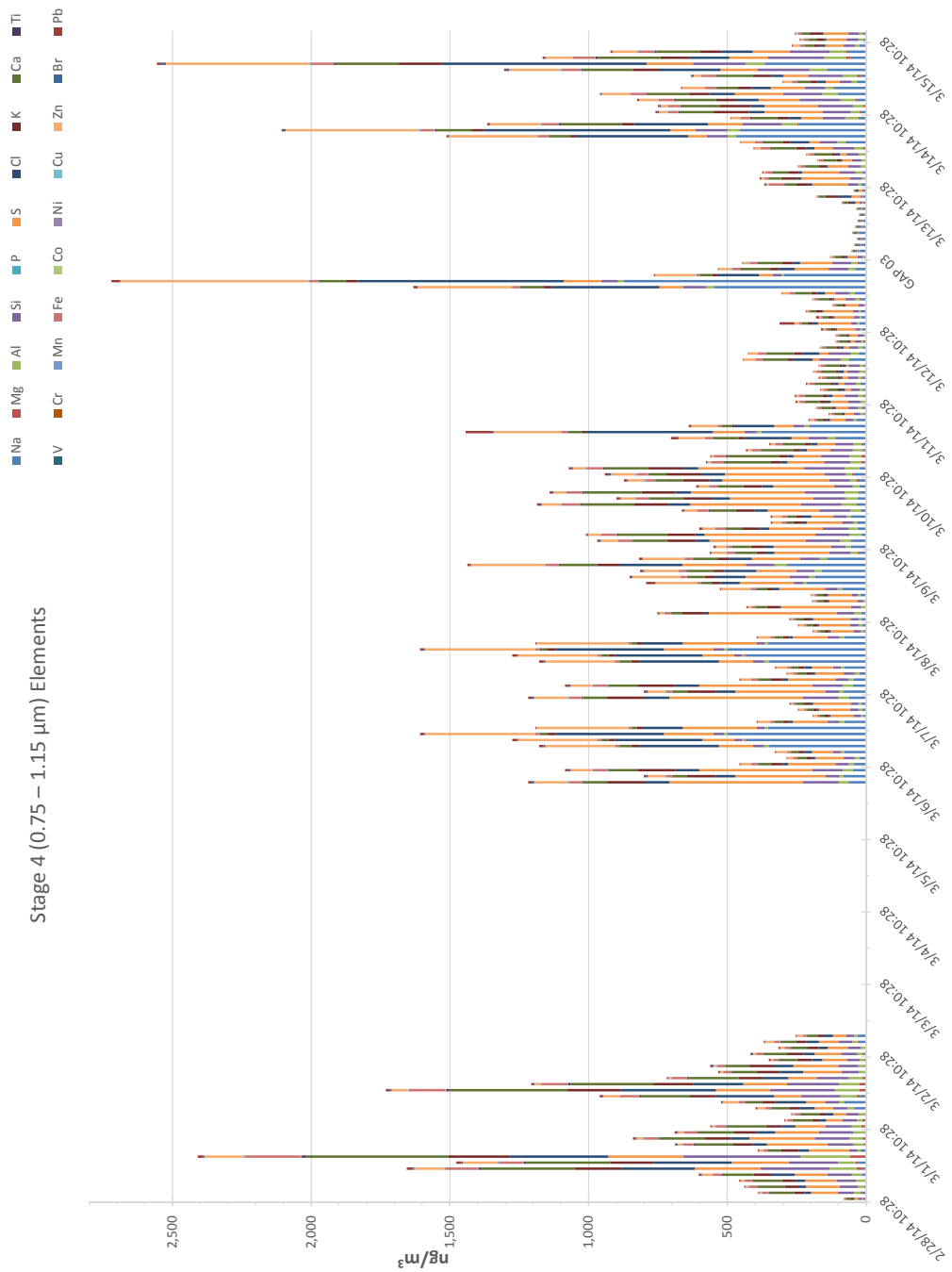


Fig. C-38 CaPh 32 DRUM: mass by element stage 4

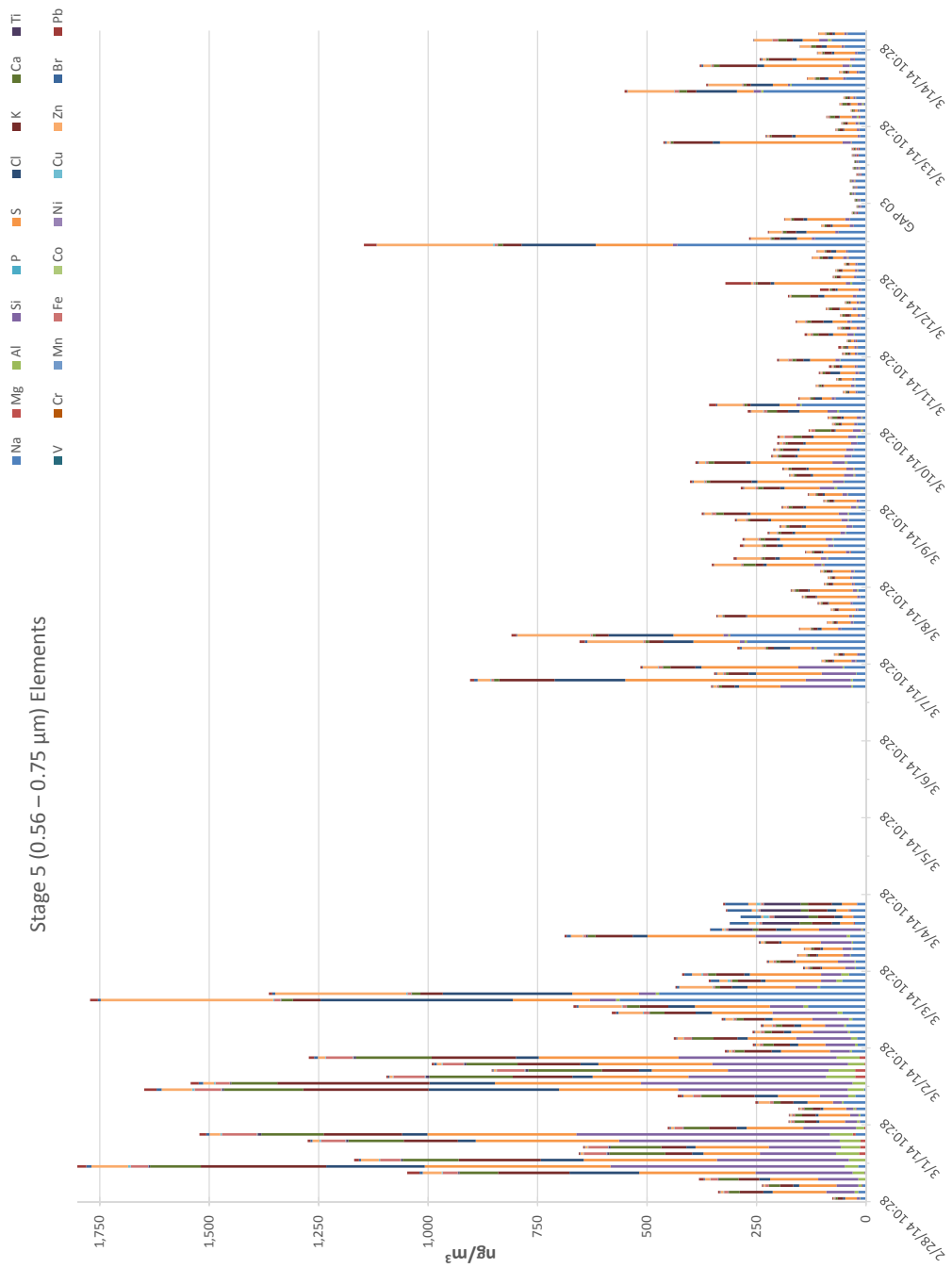


Fig. C-39 CaPh 32 DRUM: mass by element stage 5

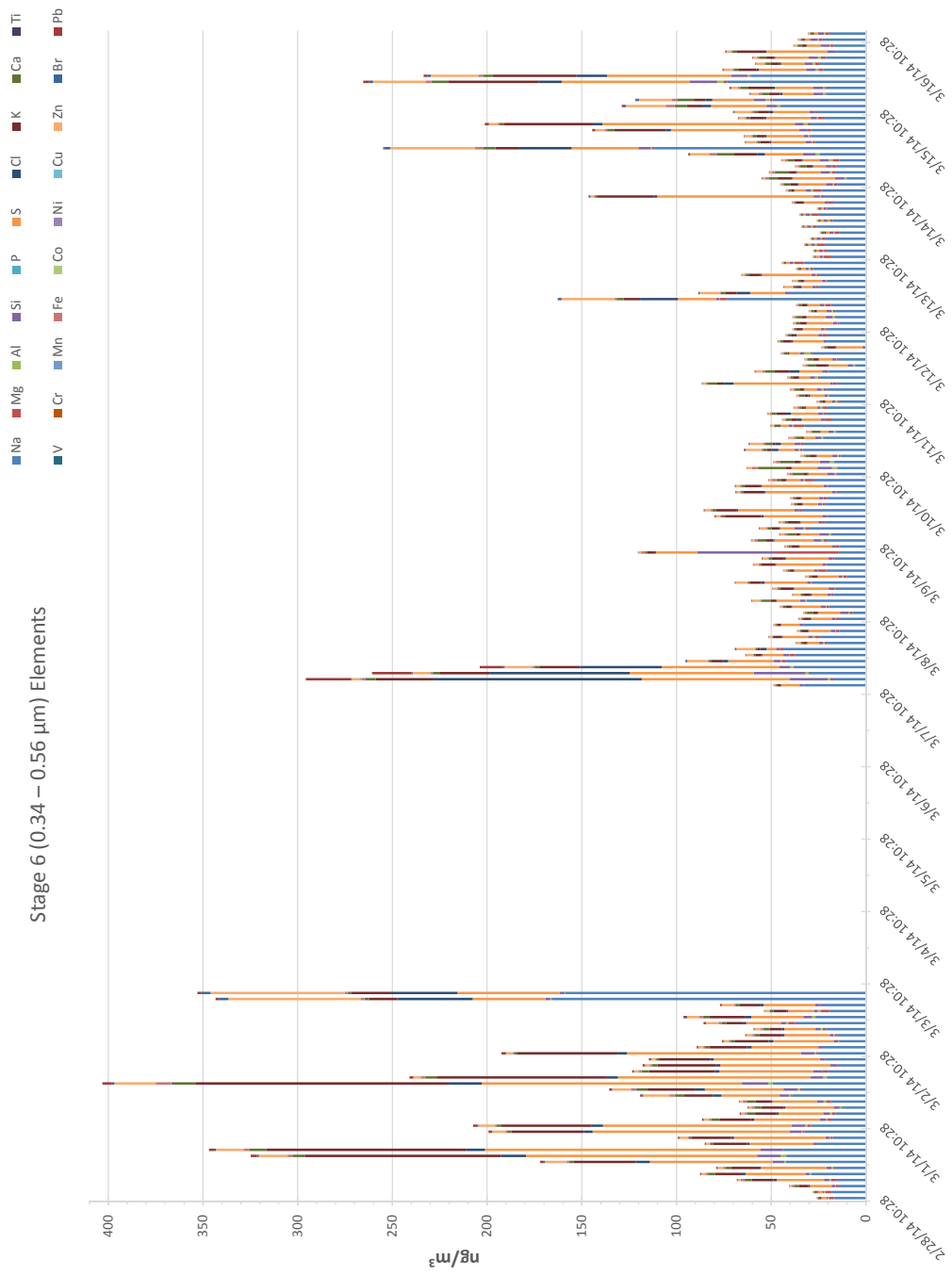


Fig. C-40 CaPh 32 DRUM: mass by element stage 6

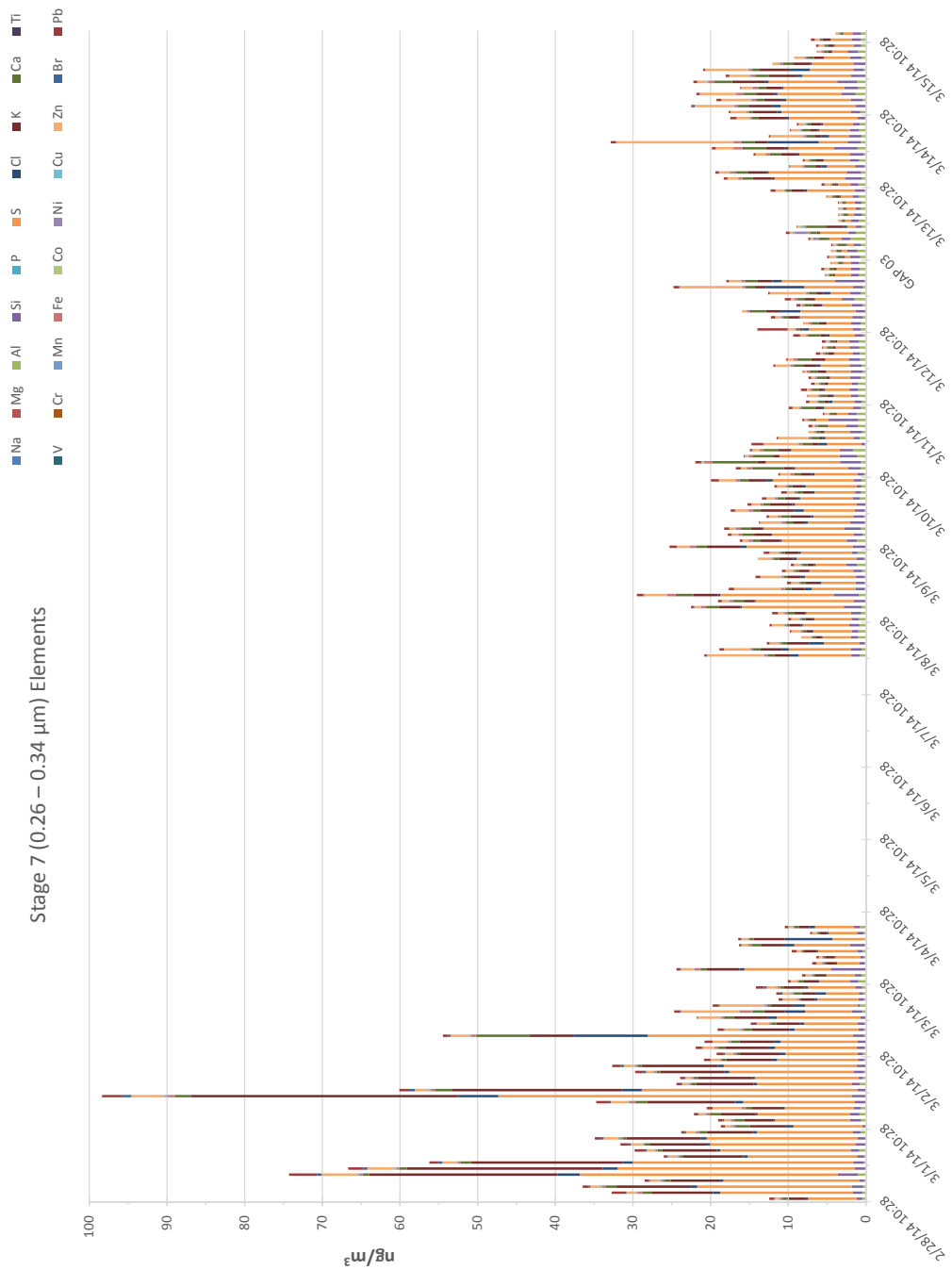


Fig. C-41 CaPh 32 DRUM: mass by element stage 7

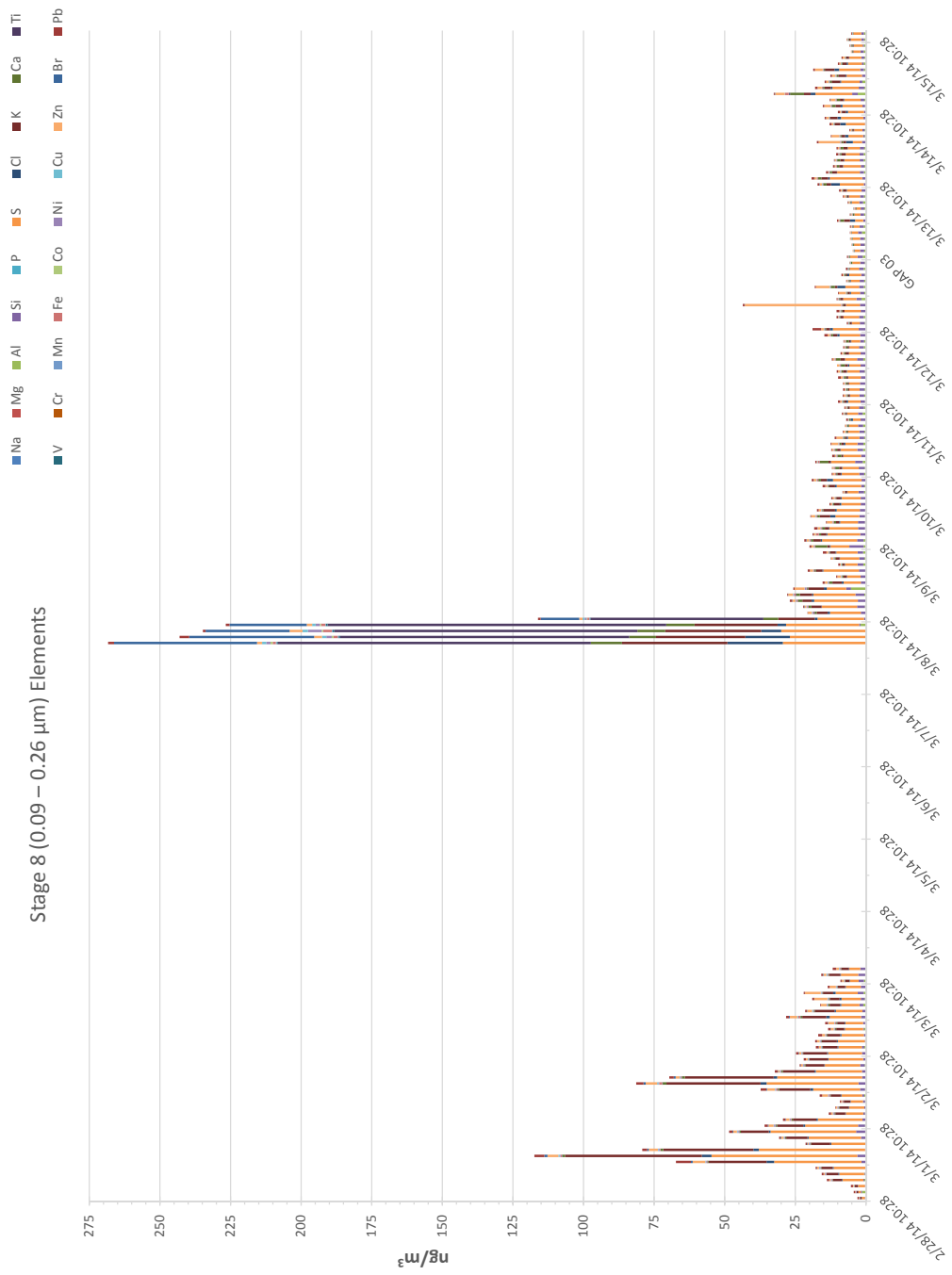


Fig. C-42 CaPh 32 DRUM: mass by element stage 8

C-4 Elemental Mass Concentration Plots

The elemental concentrations are only available using the XRF data. Sections C-4.1 through C-4.20 show the data from each element.

C-4.1 Sodium (Na)

The data from the DRUM strips from CaPh 34 only had Na detected on strips 4 (0.75–1.15 μm) and 5 (0.56–0.75 μm). The data from the DRUM strips from CaPh 32 had Na detected on strips 3, 4, 5, and 6.

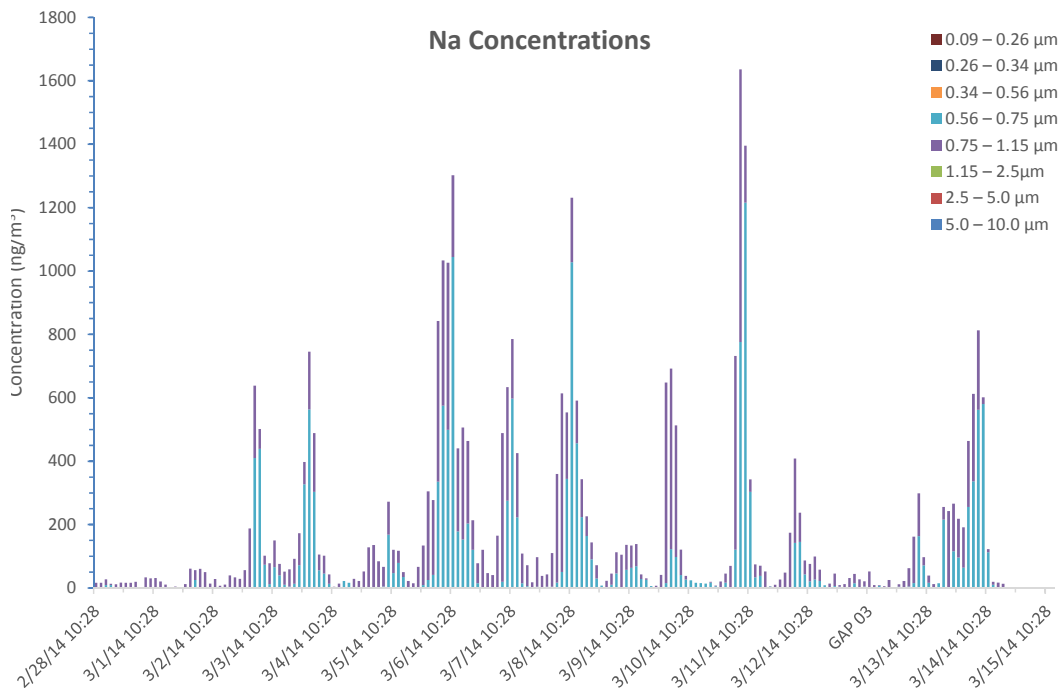


Fig. C-43 CaPh 34 DRUM: Na mass all stages

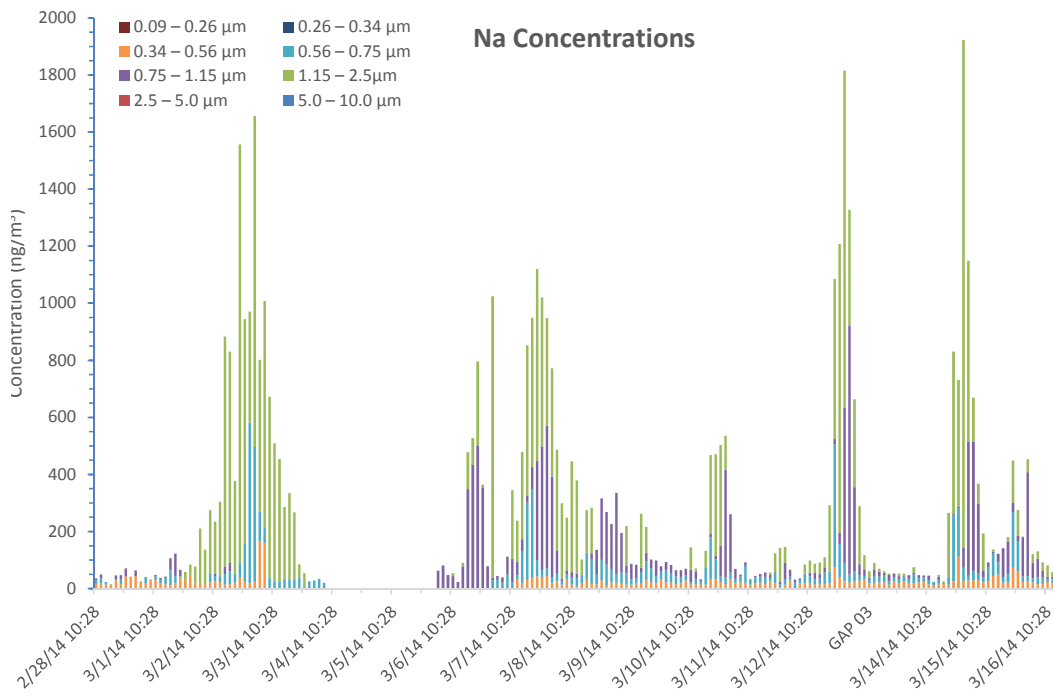


Fig. C-44 CaPh 32 DRUM: Na mass all stages

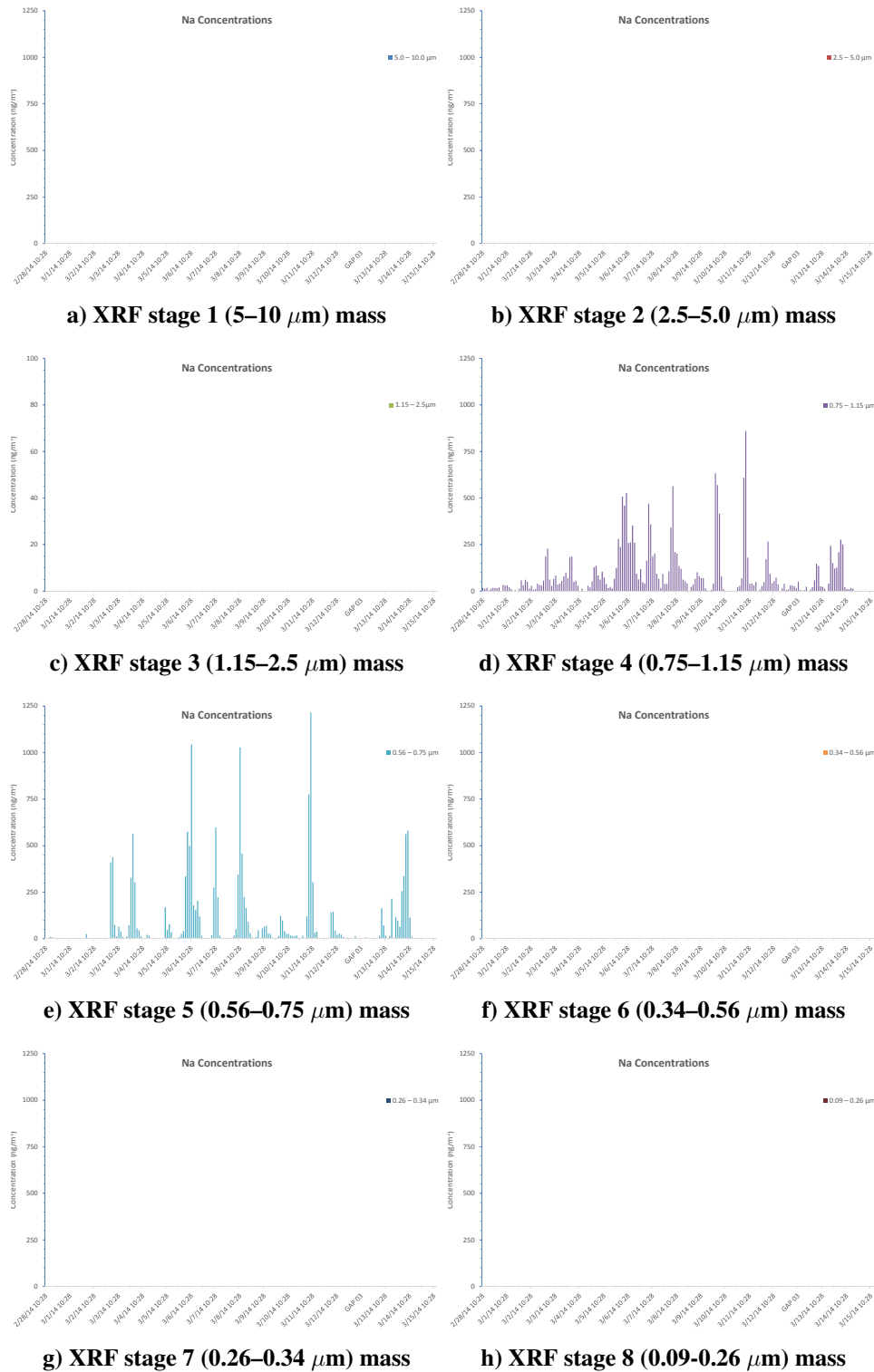


Fig. C-45 CaPh 34 DRUM: XRF mass Na; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

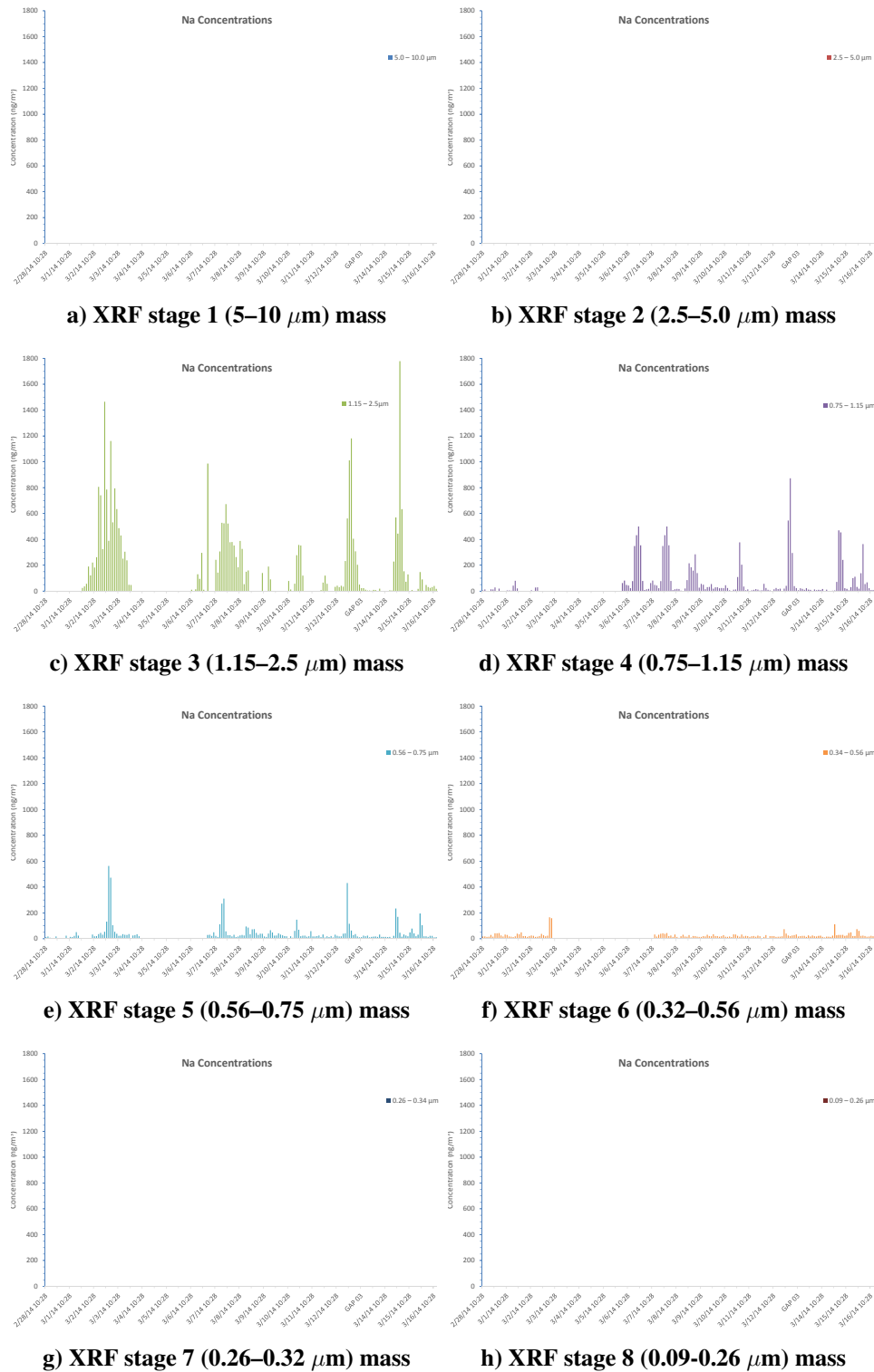


Fig. C-46 CaPh 32 DRUM: XRF mass Na; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

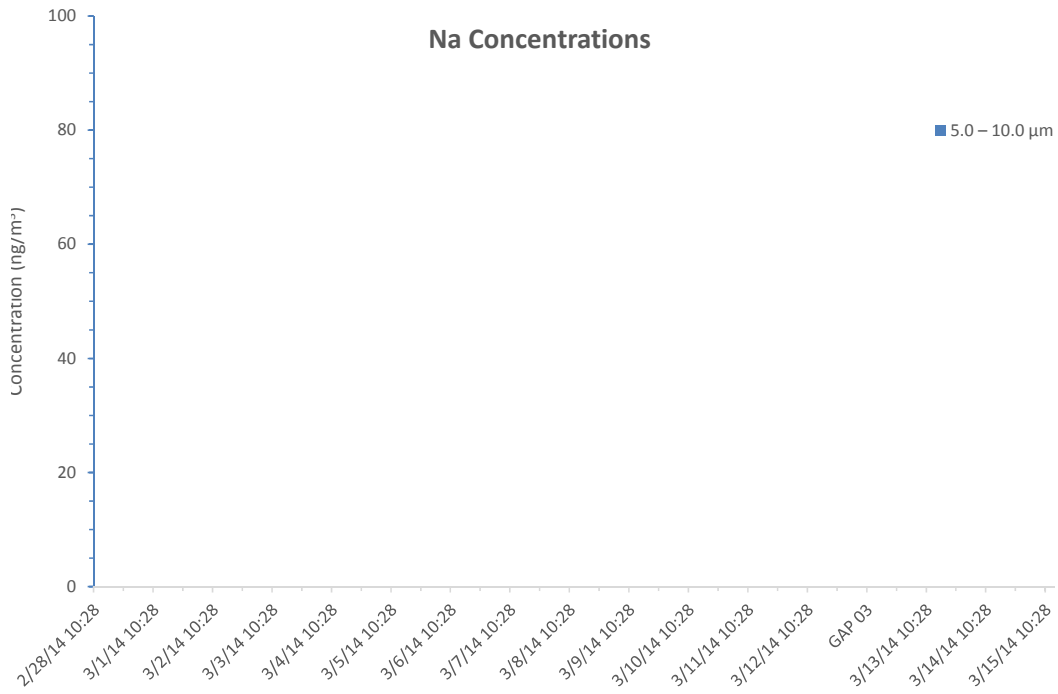


Fig. C-47 CaPh 34 DRUM: Na mass stage 1

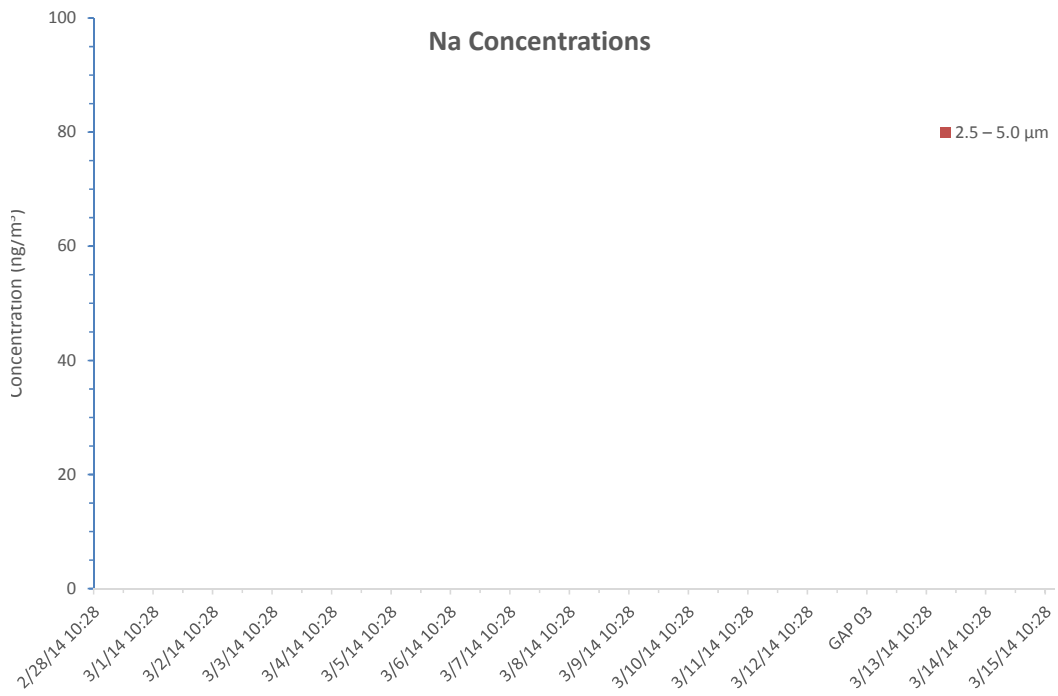


Fig. C-48 CaPh 34 DRUM: Na mass stage 2

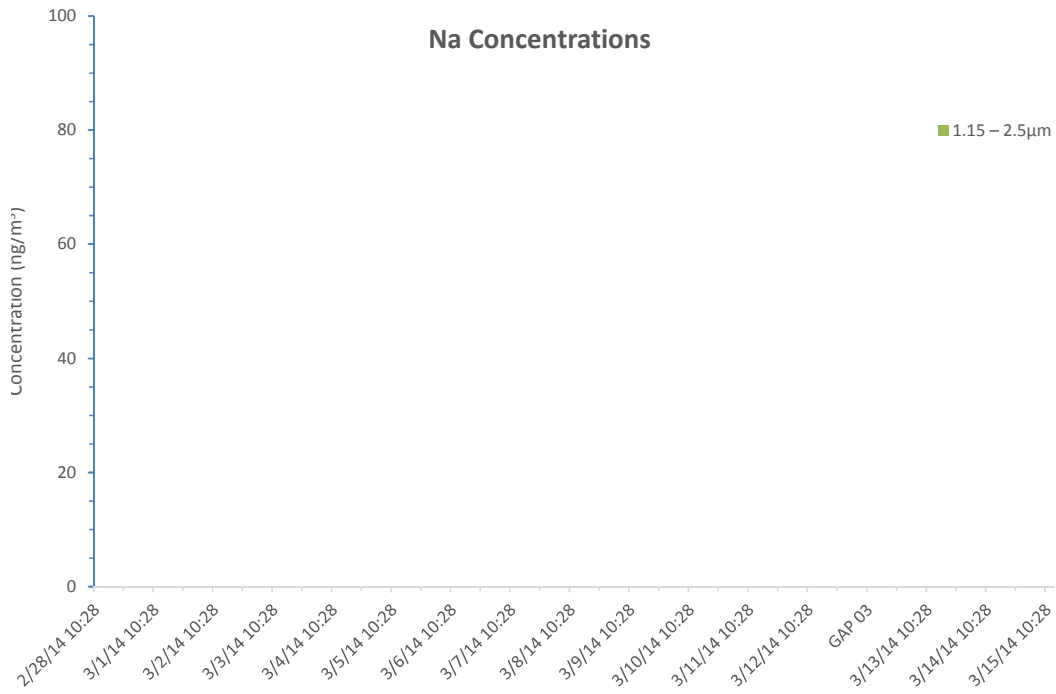


Fig. C-49 CaPh 34 DRUM: Na mass stage 3

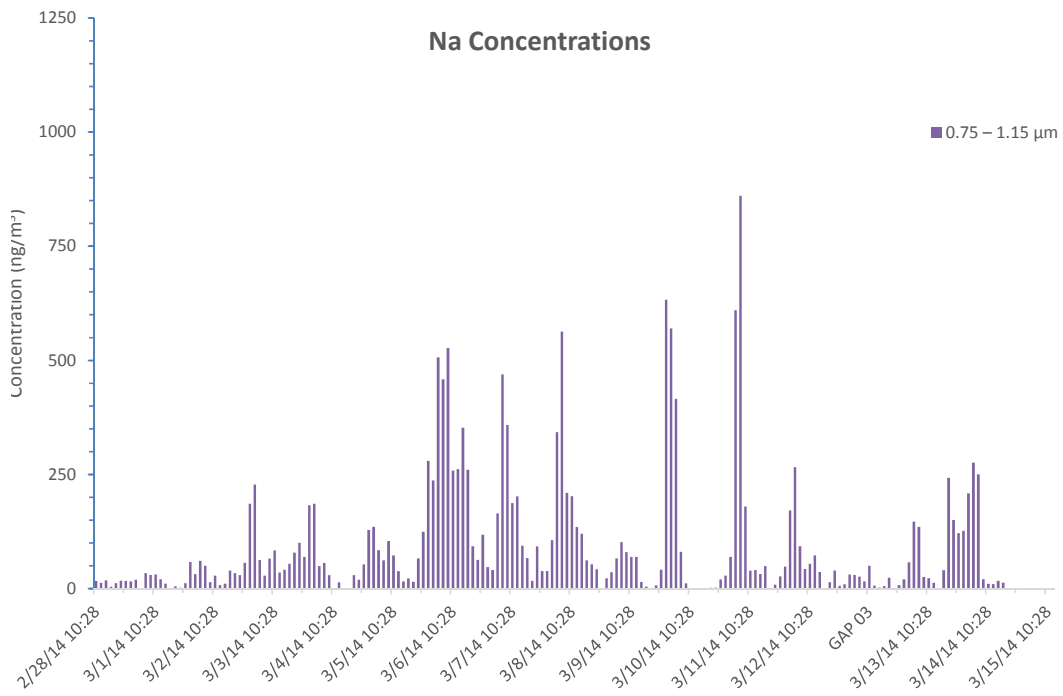


Fig. C-50 CaPh 34 DRUM: Na mass stage 4

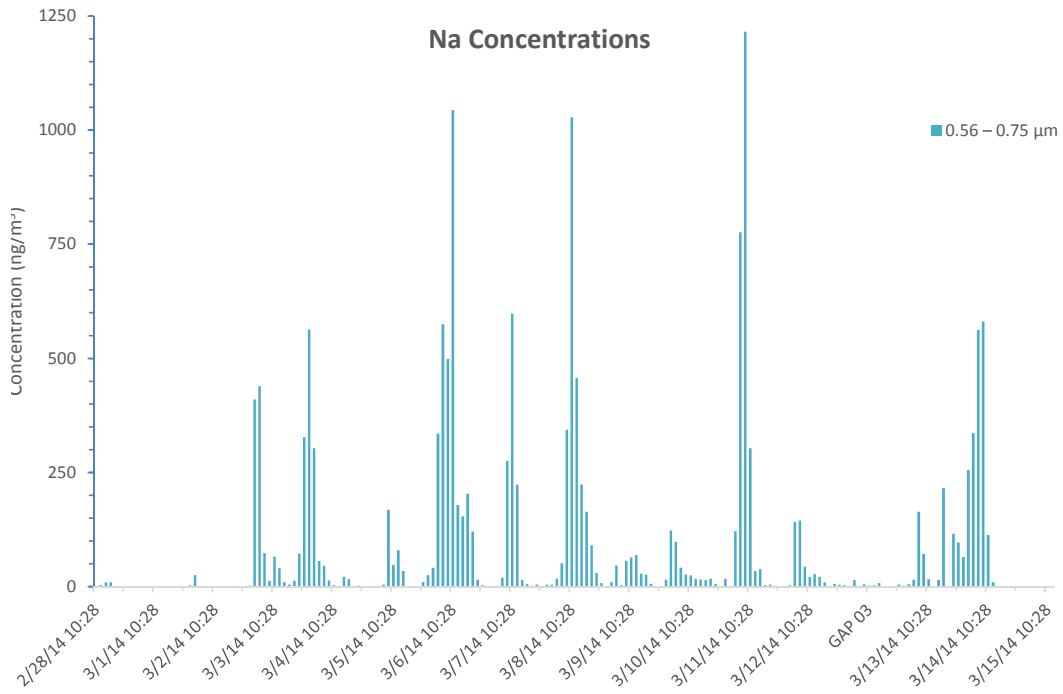


Fig. C-51 CaPh 34 DRUM: Na mass stage 5

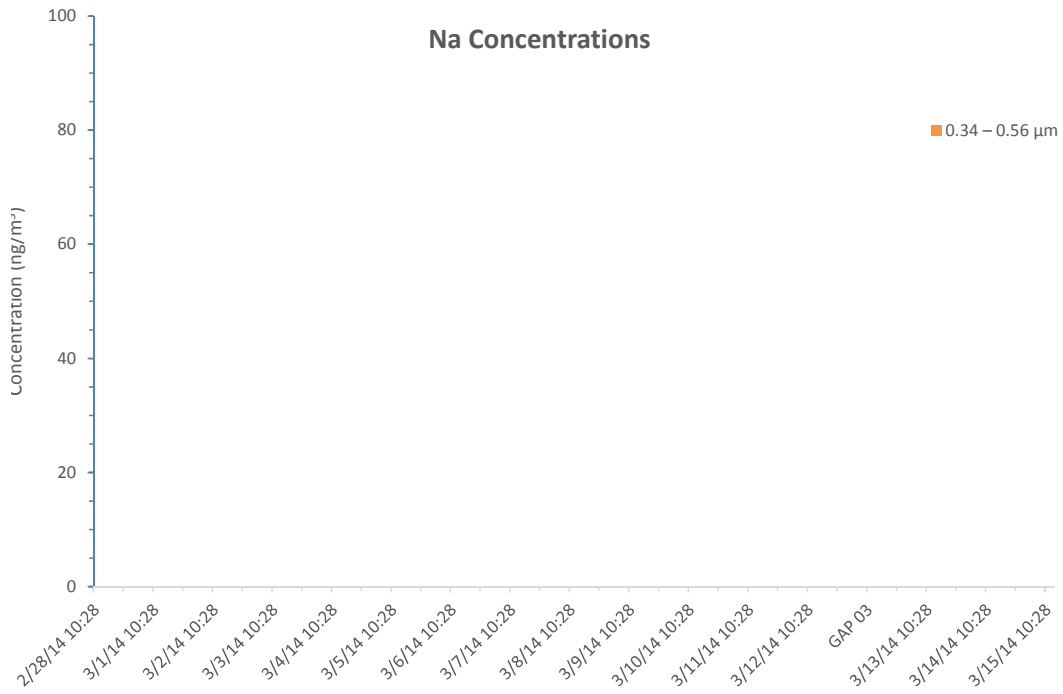


Fig. C-52 CaPh 34 DRUM: Na mass stage 6

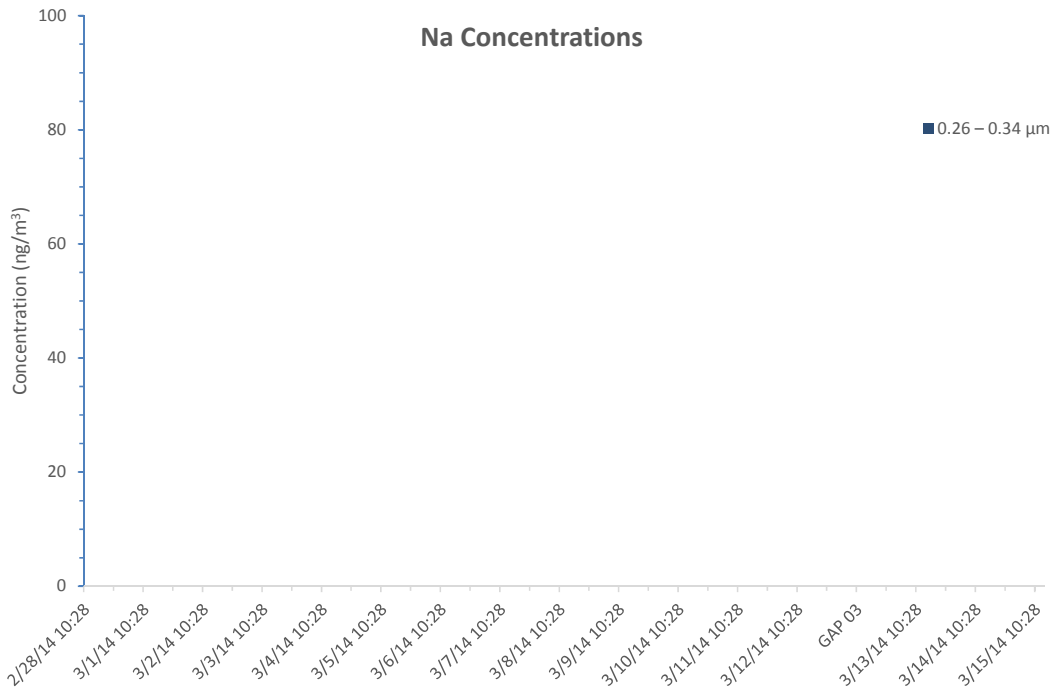


Fig. C-53 CaPh 34 DRUM: Na mass stage 7

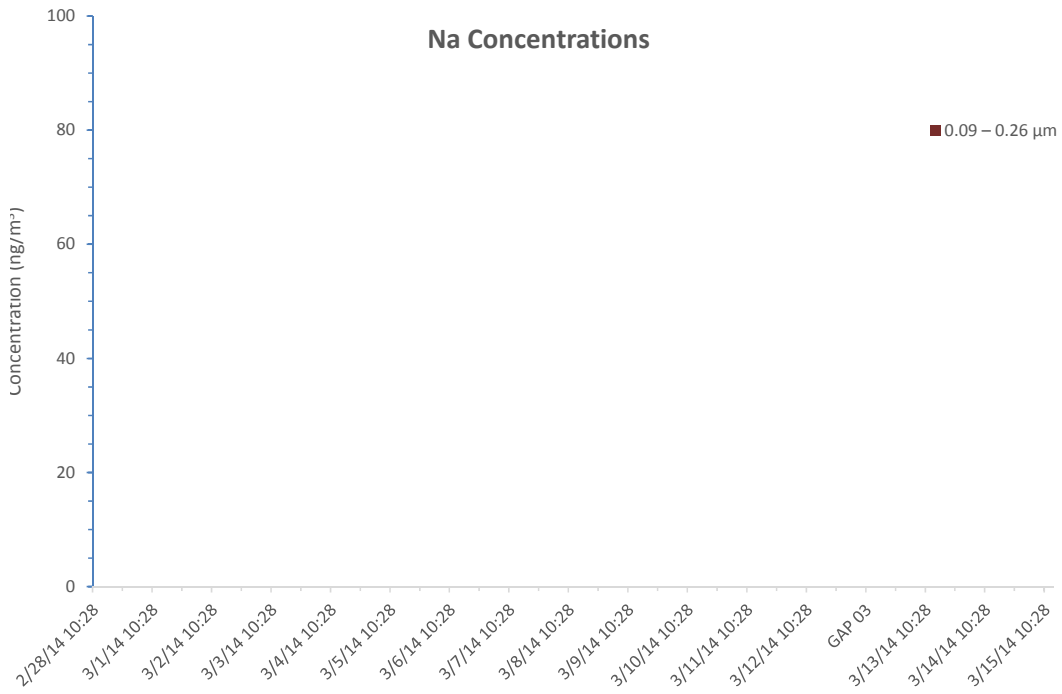


Fig. C-54 CaPh 34 DRUM: Na mass stage 8

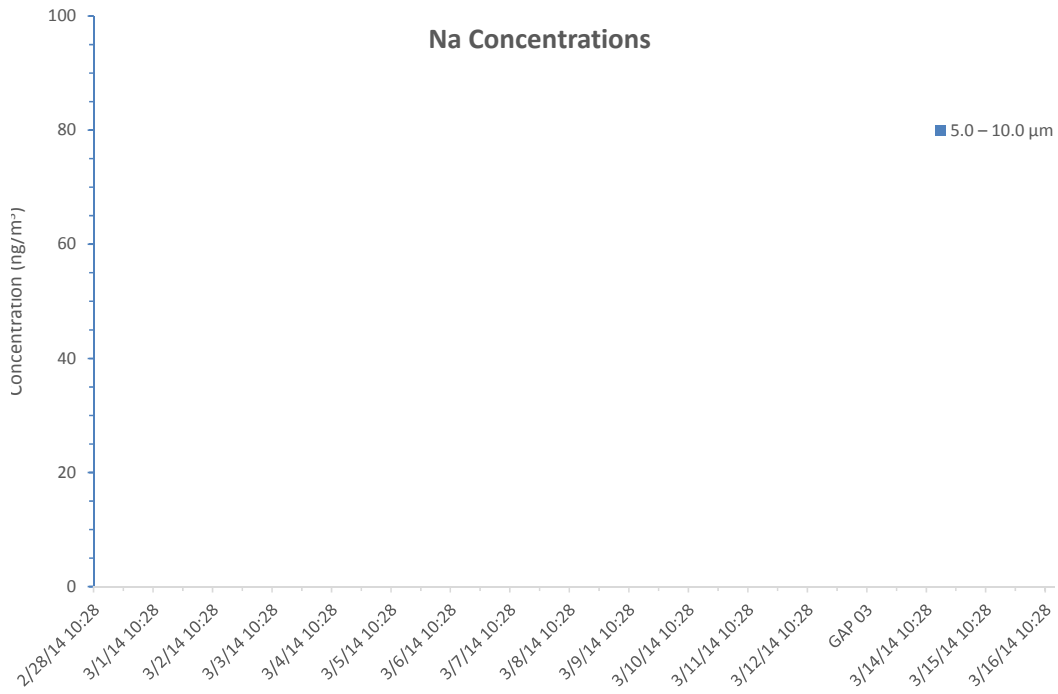


Fig. C-55 CaPh 32 DRUM: Na mass stage 1

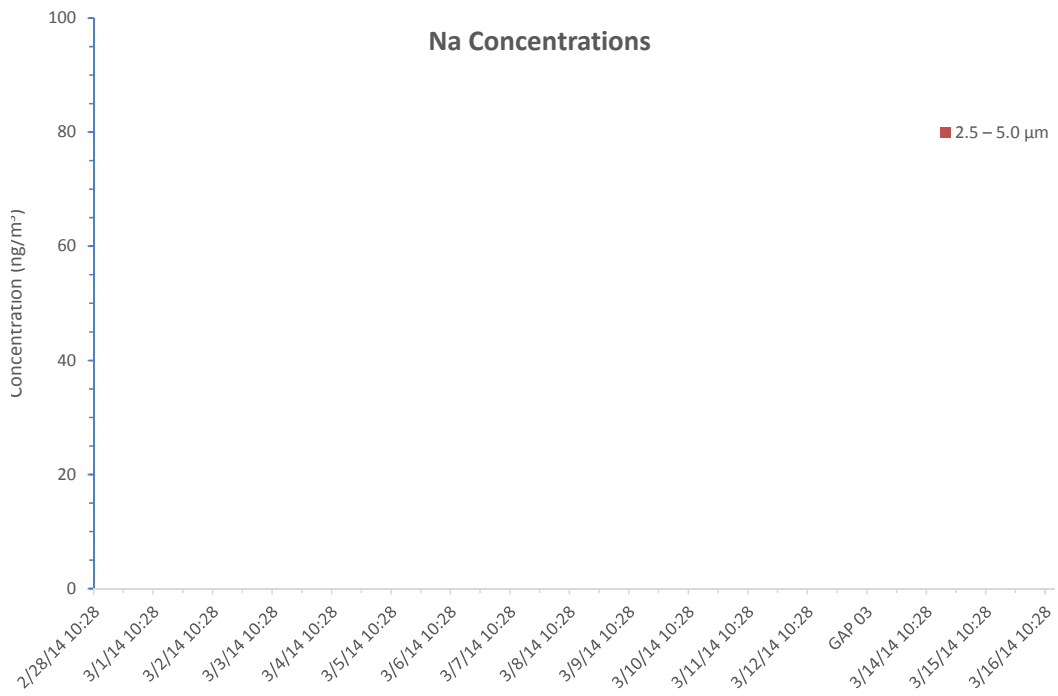


Fig. C-56 CaPh 32 DRUM: Na mass stage 2

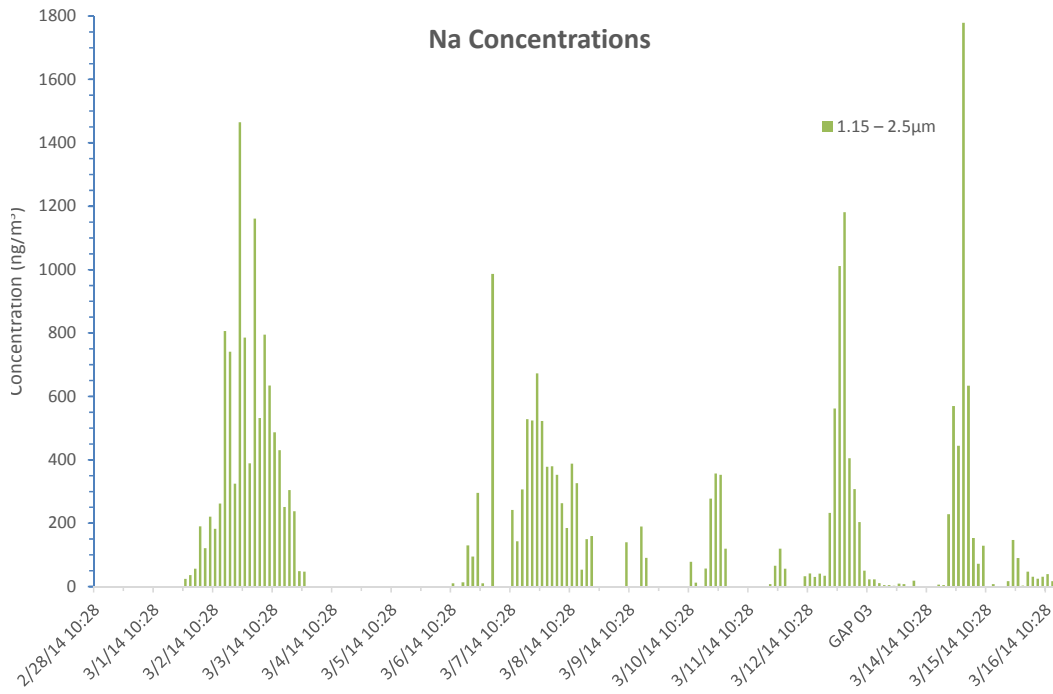


Fig. C-57 CaPh 32 DRUM: Na mass stage 3

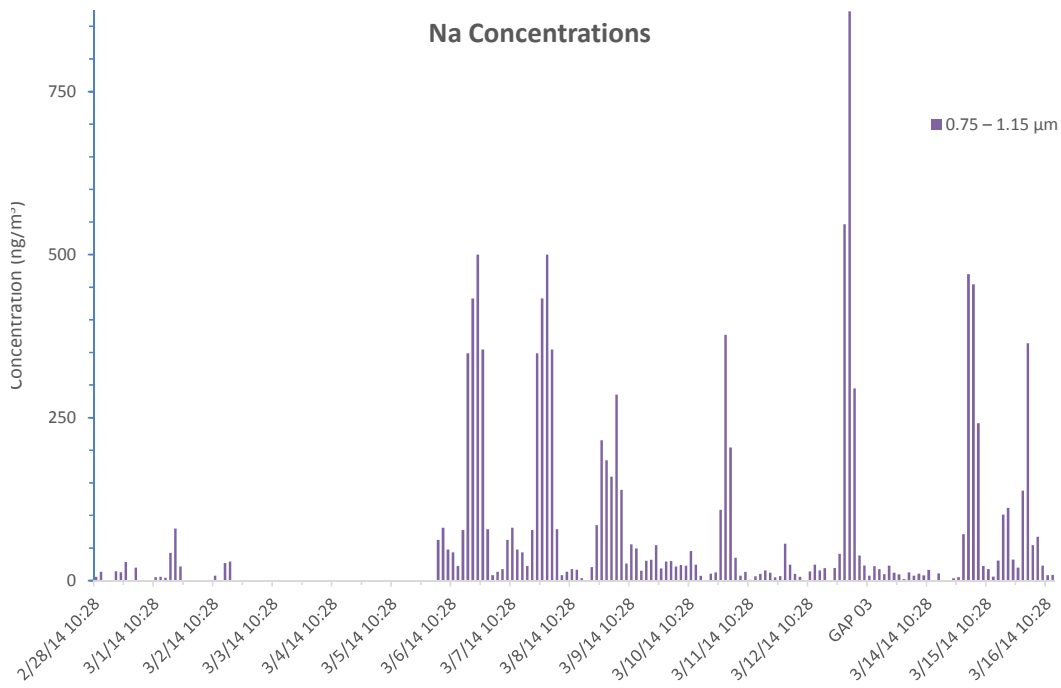


Fig. C-58 CaPh 32 DRUM: Na mass stage 4

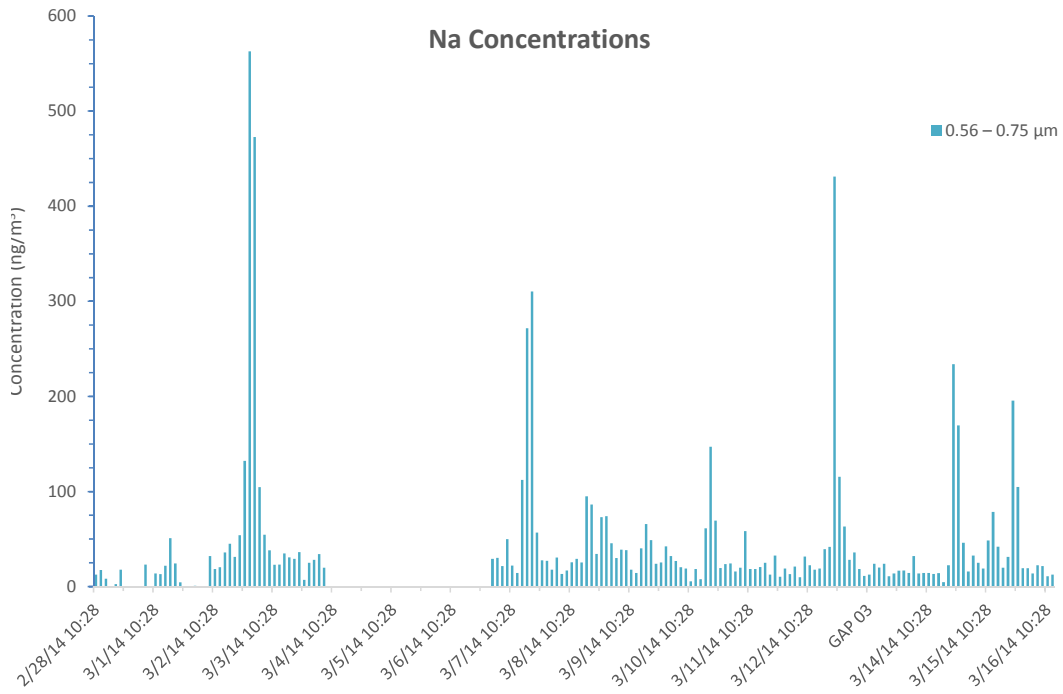


Fig. C-59 CaPh 32 DRUM: Na mass stage 5

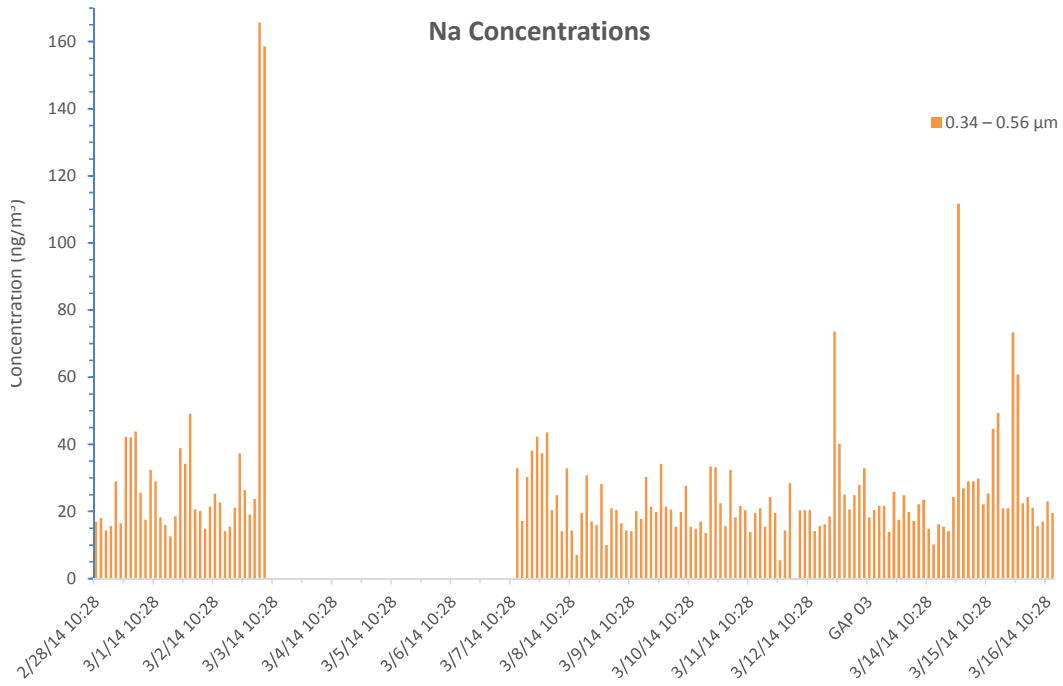


Fig. C-60 CaPh 32 DRUM: Na mass stage 6

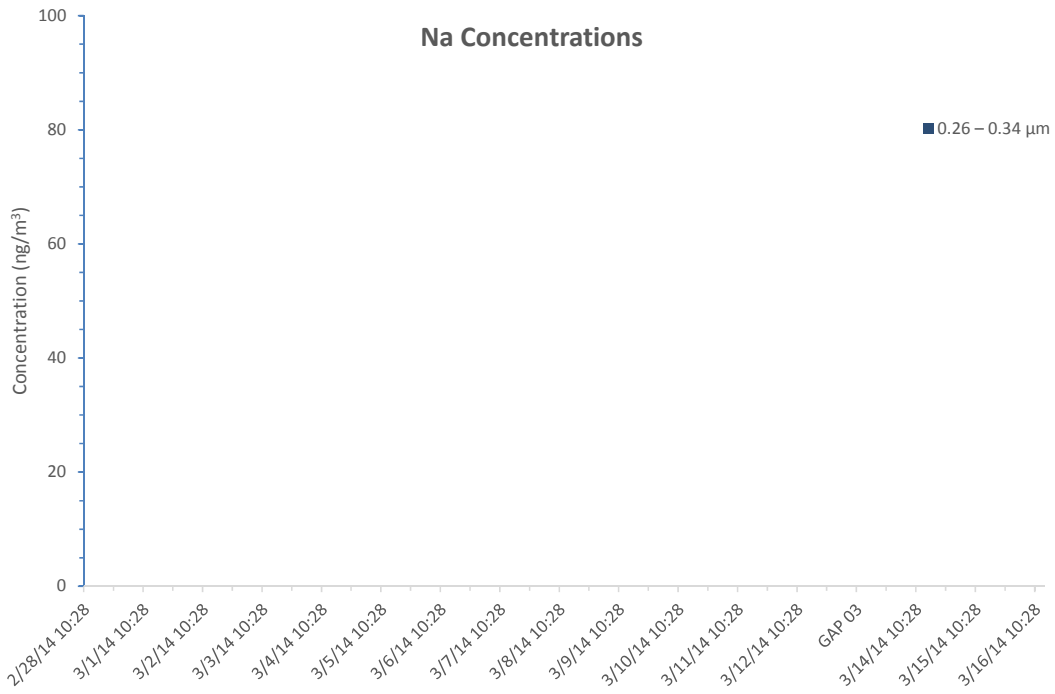


Fig. C-61 CaPh 32 DRUM: Na mass stage 7

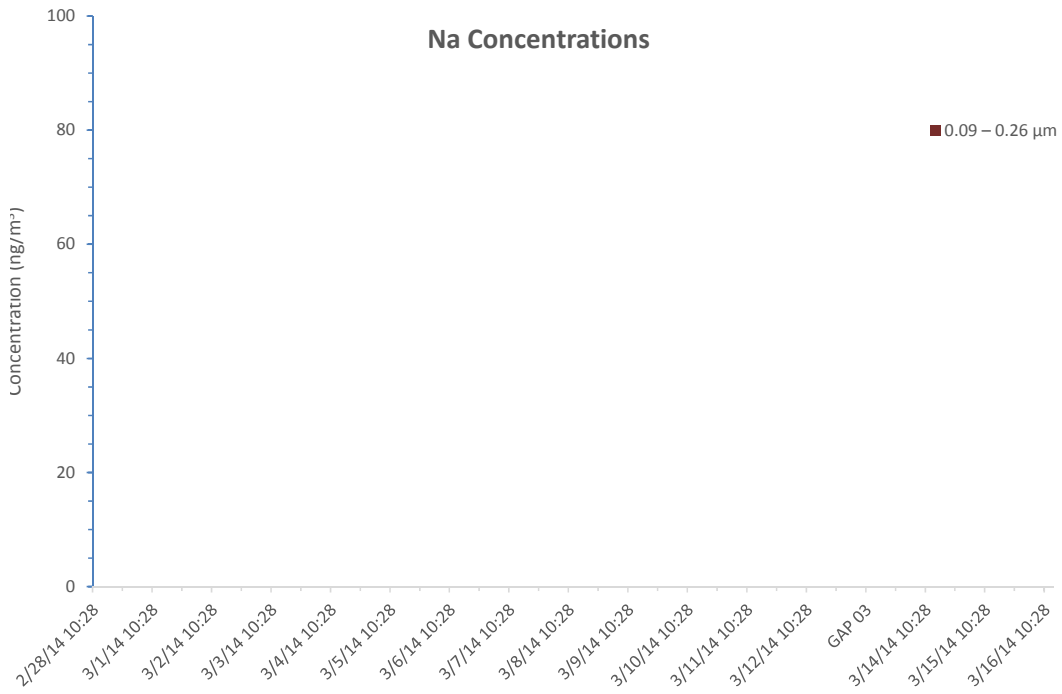


Fig. C-62 CaPh 32 DRUM: Na mass stage 8

C-4.2 Magnesium (Mg)

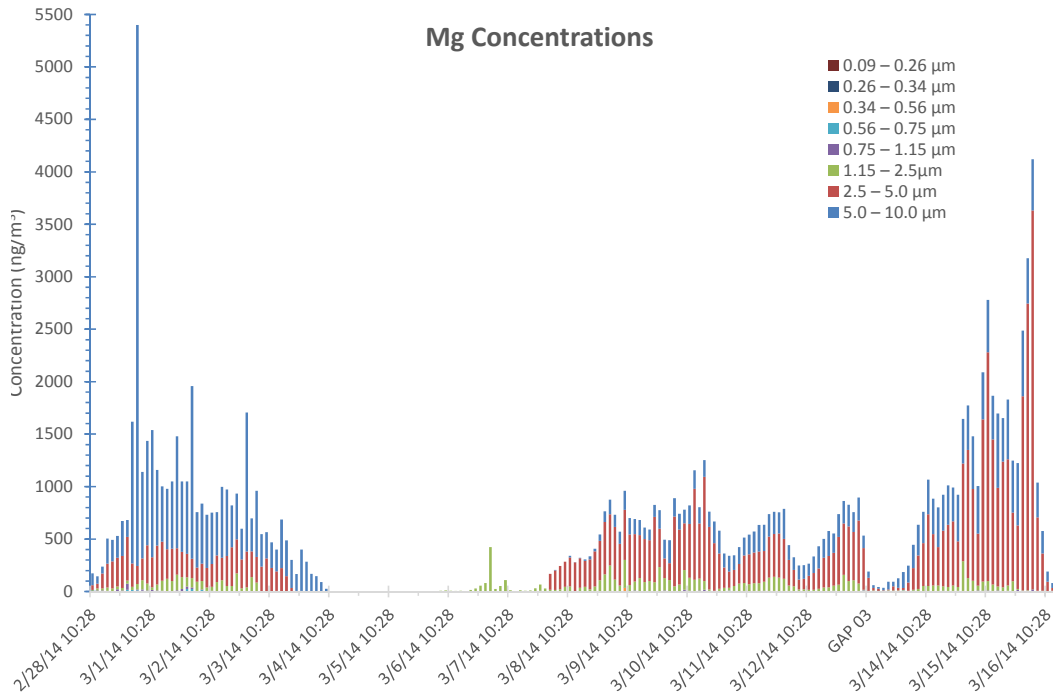


Fig. C-63 CaPh 32 DRUM: Mg mass all stages

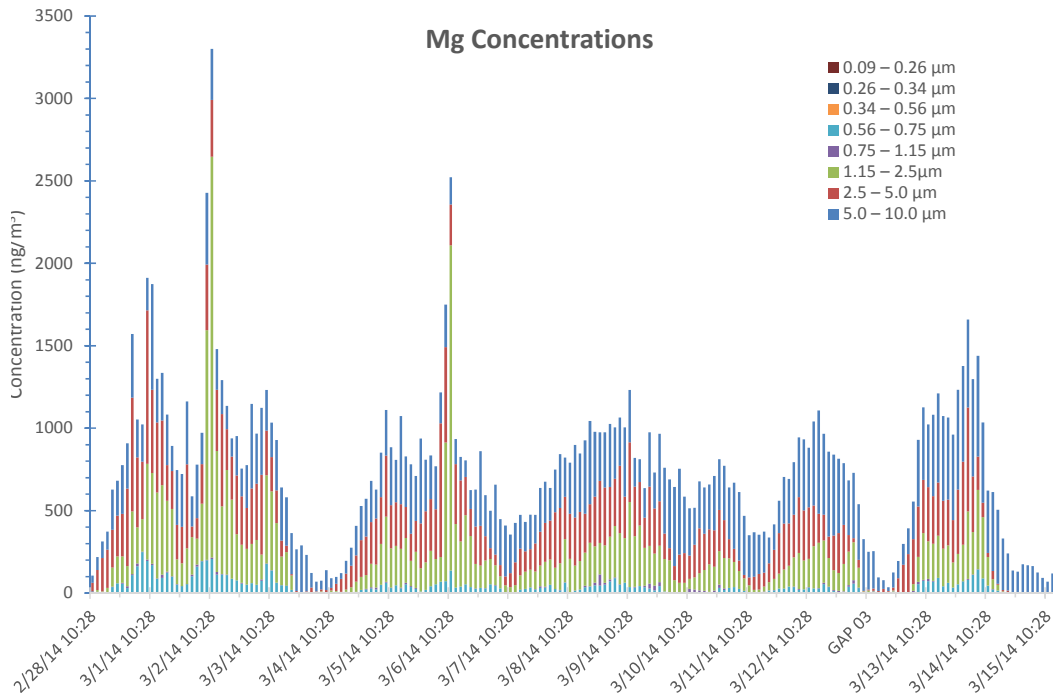


Fig. C-64 CaPh 34 DRUM: Mg mass all stages

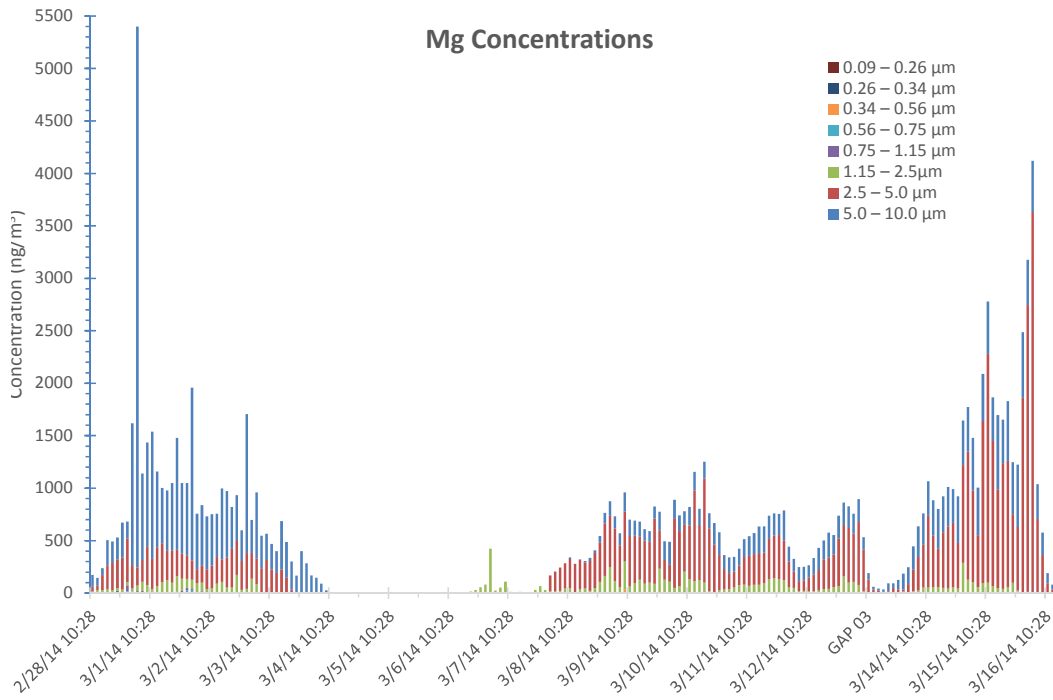
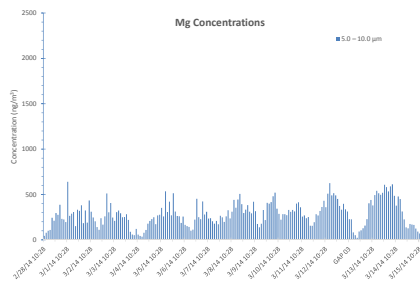
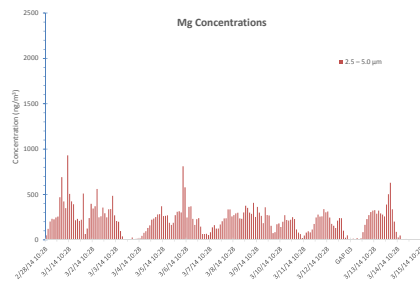


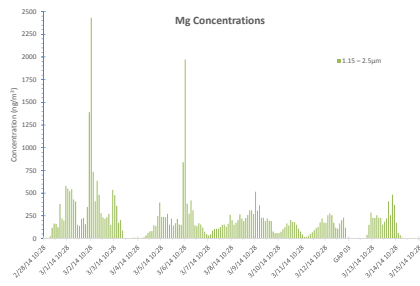
Fig. C-65 CaPh 32 DRUM: Mg mass all stages



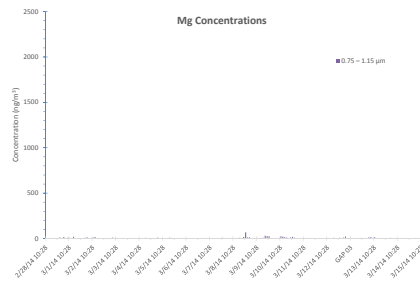
a) XRF stage 1 (5–10 µm) mass



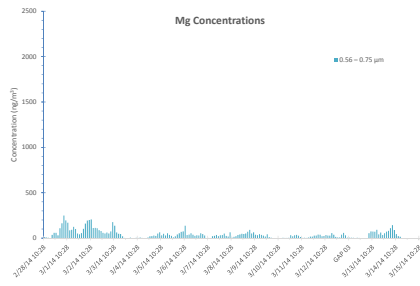
b) XRF stage 2 (2.5–5.0 µm) mass



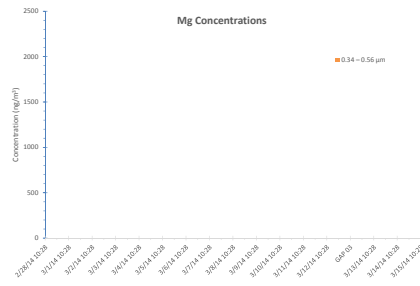
c) XRF stage 3 (1.15–2.5 µm) mass



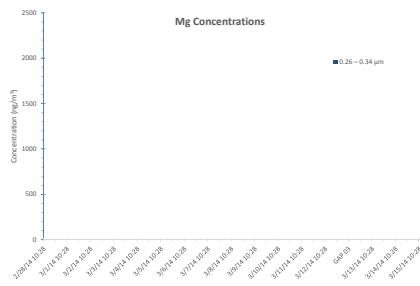
d) XRF stage 4 (0.75–1.15 µm) mass



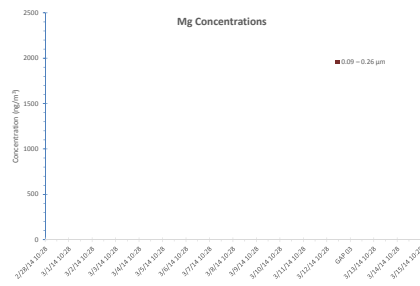
e) XRF stage 5 (0.56–0.75 µm) mass



f) XRF stage 6 (0.34–0.56 µm) mass

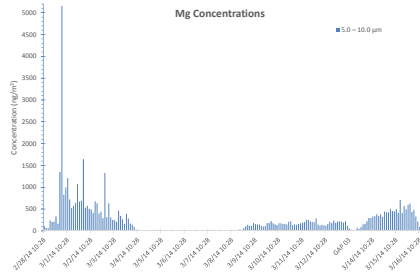


g) XRF stage 7 (0.26–0.34 µm) mass

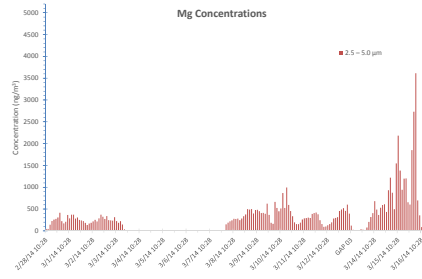


h) XRF stage 8 (0.09–0.26 µm) mass

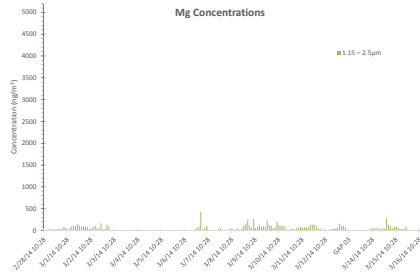
Fig. C-66 CaPh 34 DRUM: XRF mass Mg; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



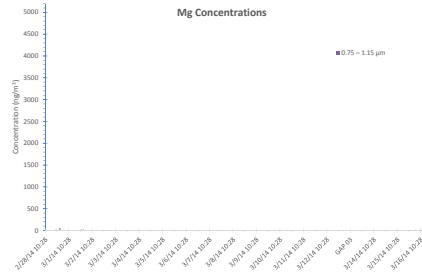
a) XRF stage 1 (5–10 µm) mass



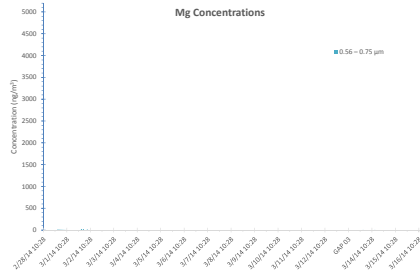
b) XRF stage 2 (2.5–5.0 µm) mass



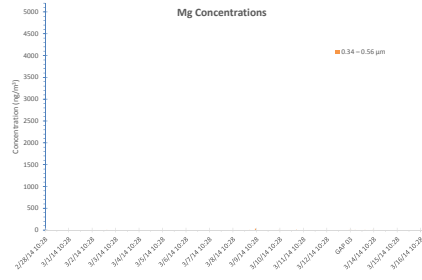
c) XRF stage 3 (1.15–2.5 µm) mass



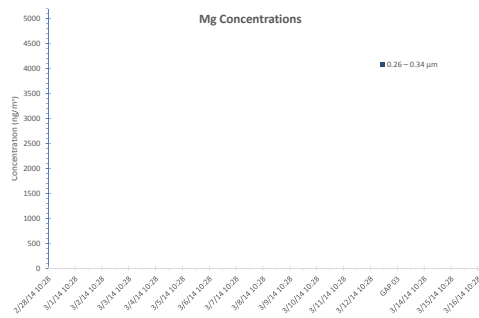
d) XRF stage 4 (0.75–1.15 µm) mass



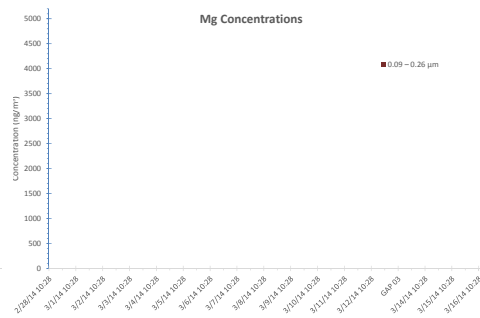
e) XRF stage 5 (0.56–0.75 µm) mass



f) XRF stage 6 (0.32–0.56 µm) mass



g) XRF stage 7 (0.26–0.32 µm) mass



h) XRF stage 8 (0.09–0.26 µm) mass

Fig. C-67 CaPh 32 DRUM: XRF mass Mg; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

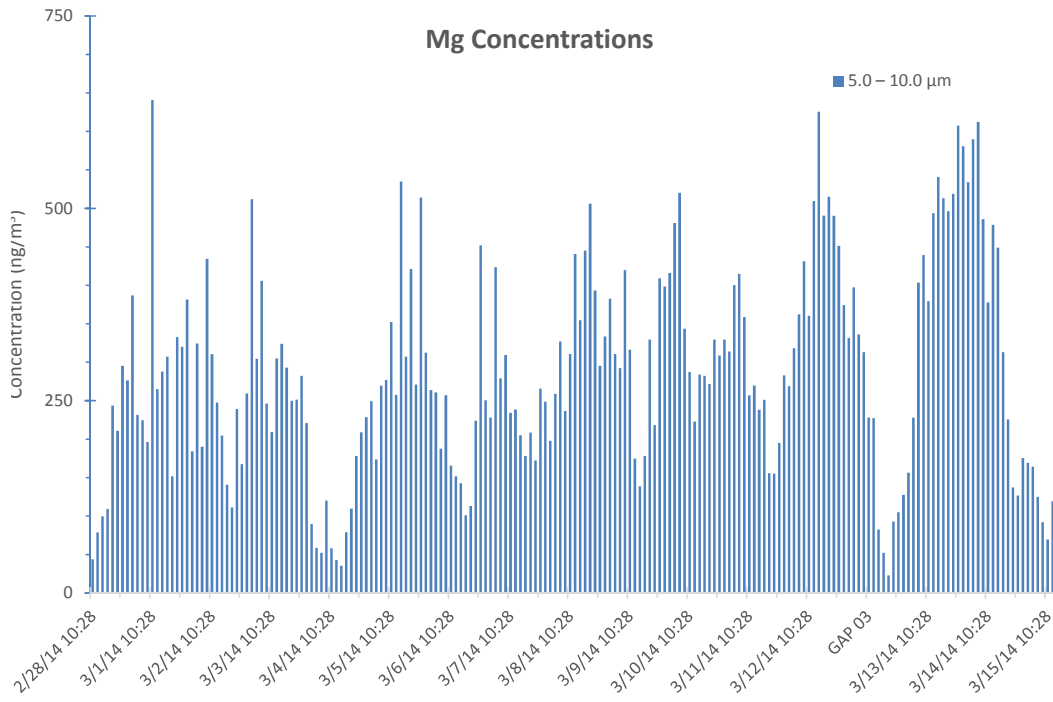


Fig. C-68 CaPh 34 DRUM: Mg mass stage 1

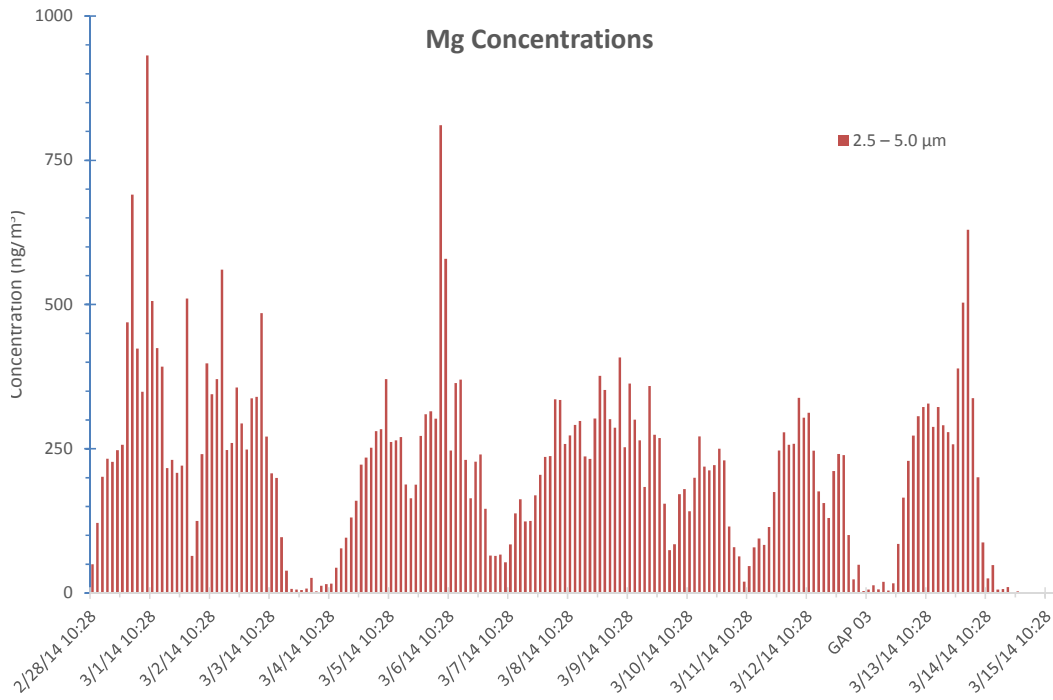


Fig. C-69 CaPh 34 DRUM: Mg mass stage 2

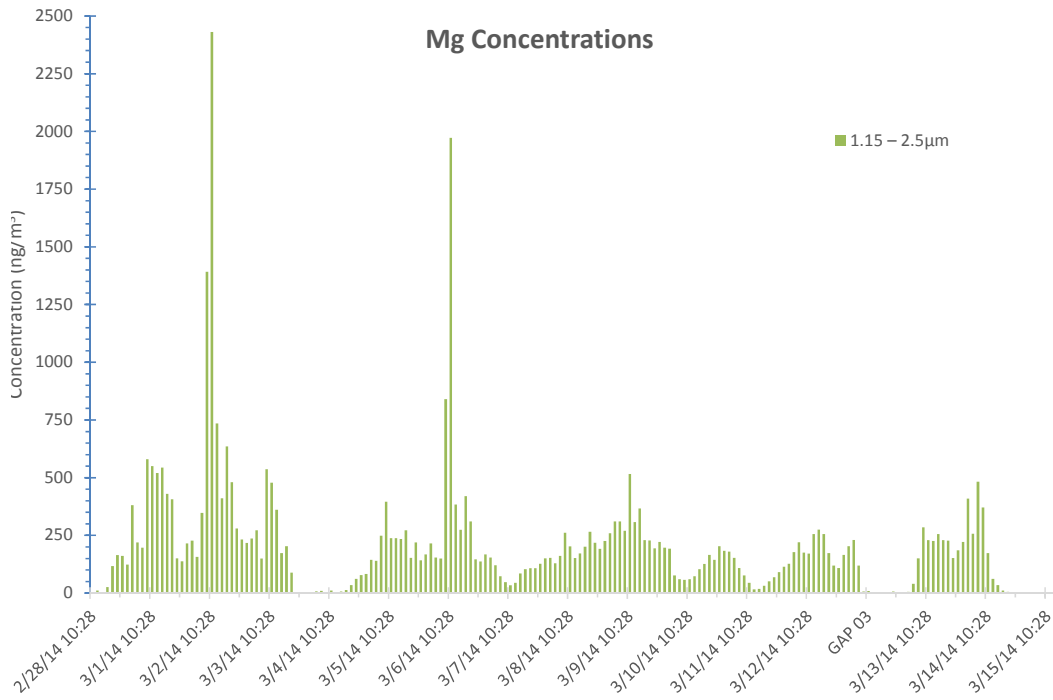


Fig. C-70 CaPh 34 DRUM: Mg mass stage 3

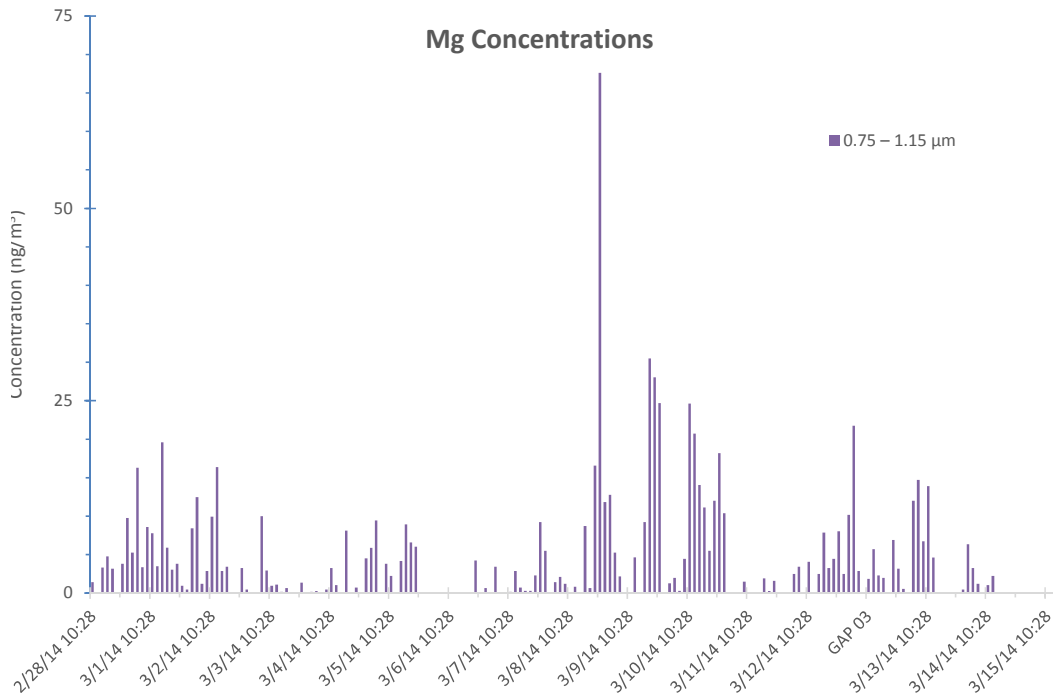


Fig. C-71 CaPh 34 DRUM: Mg mass stage 4

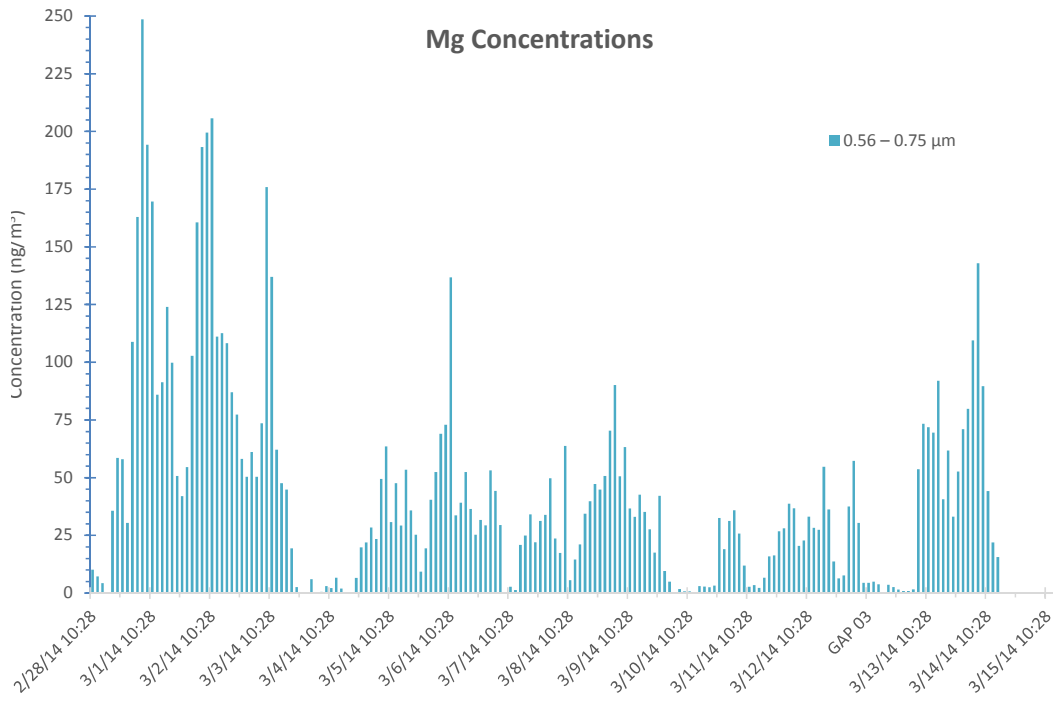


Fig. C-72 CaPh 34 DRUM: Mg mass stage 5

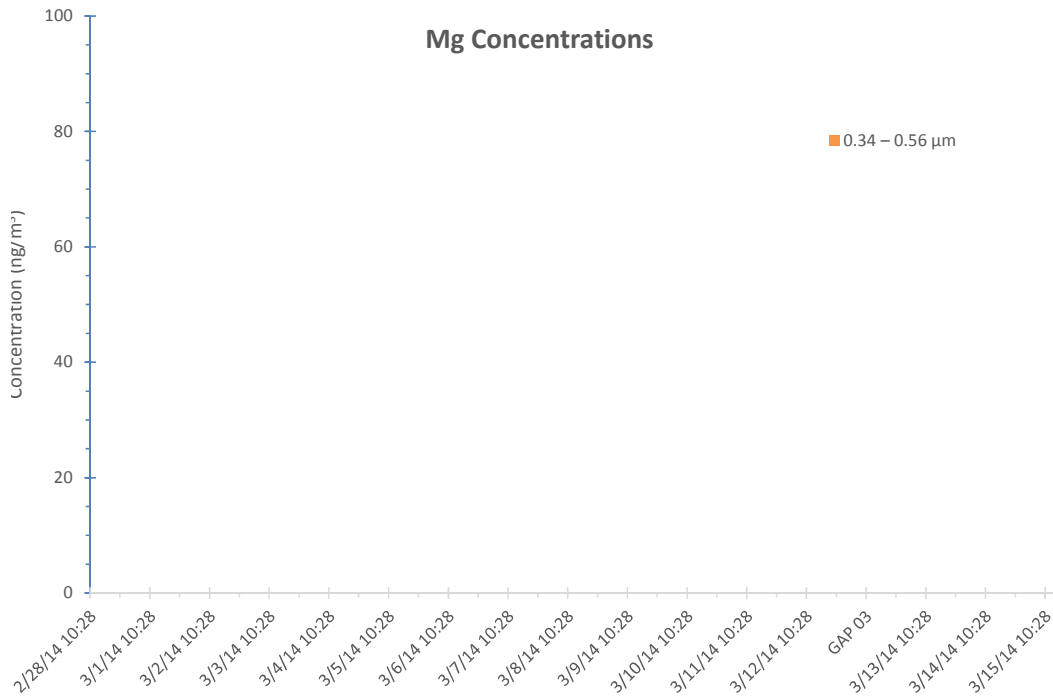


Fig. C-73 CaPh 34 DRUM: Mg mass stage 6

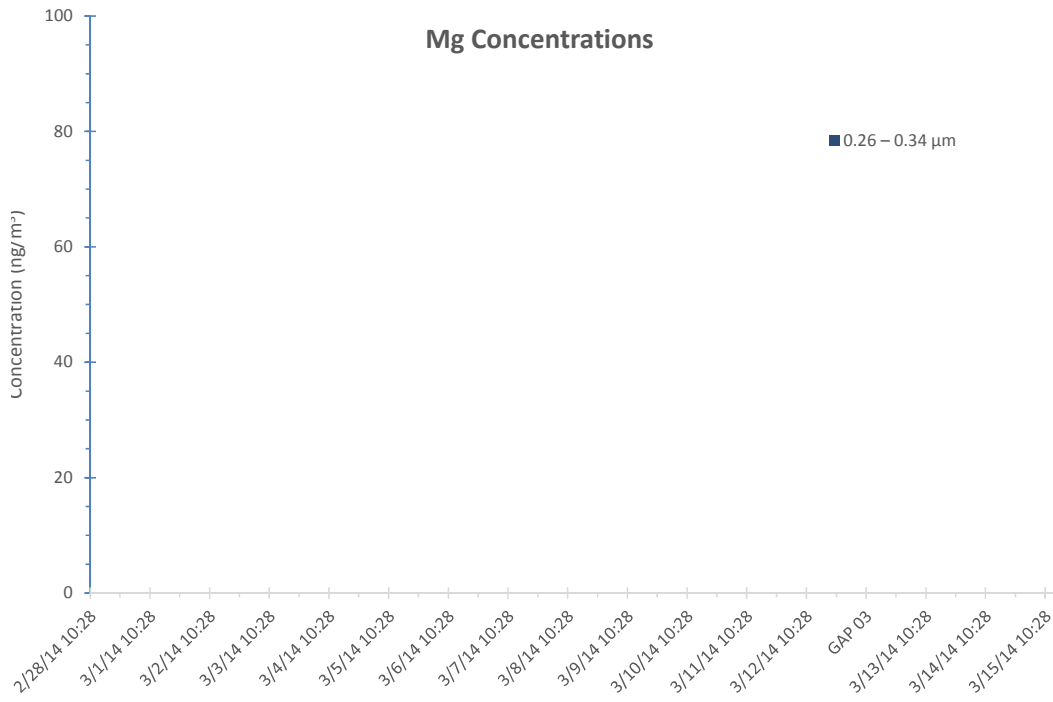


Fig. C-74 CaPh 34 DRUM: Mg mass stage 7

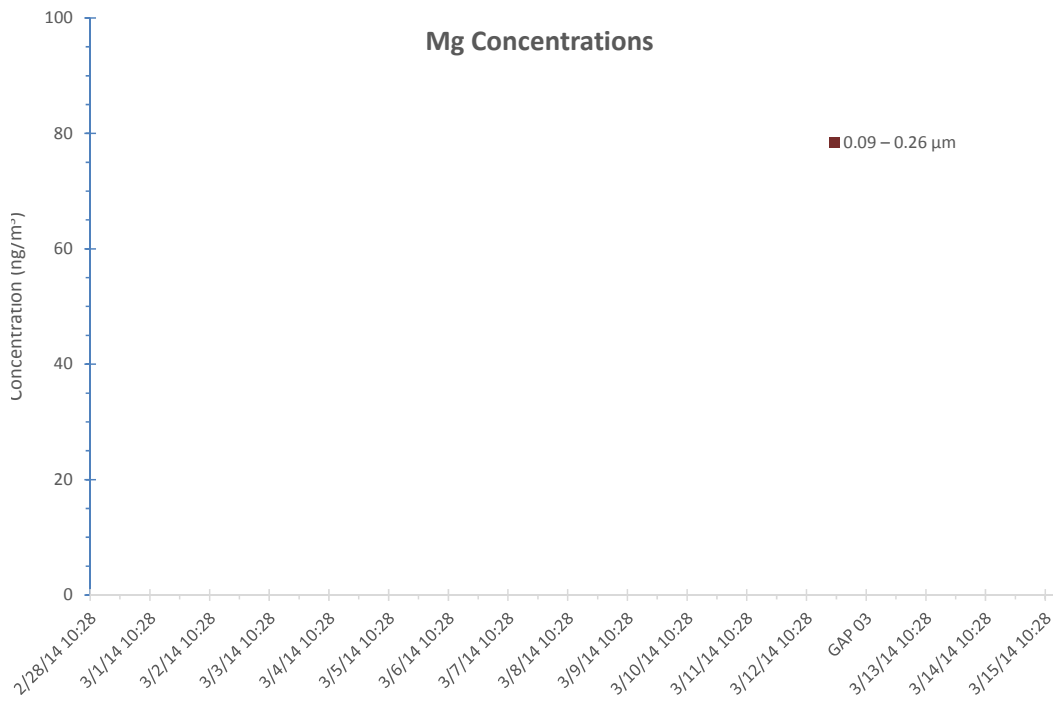


Fig. C-75 CaPh 34 DRUM: Mg mass stage 8

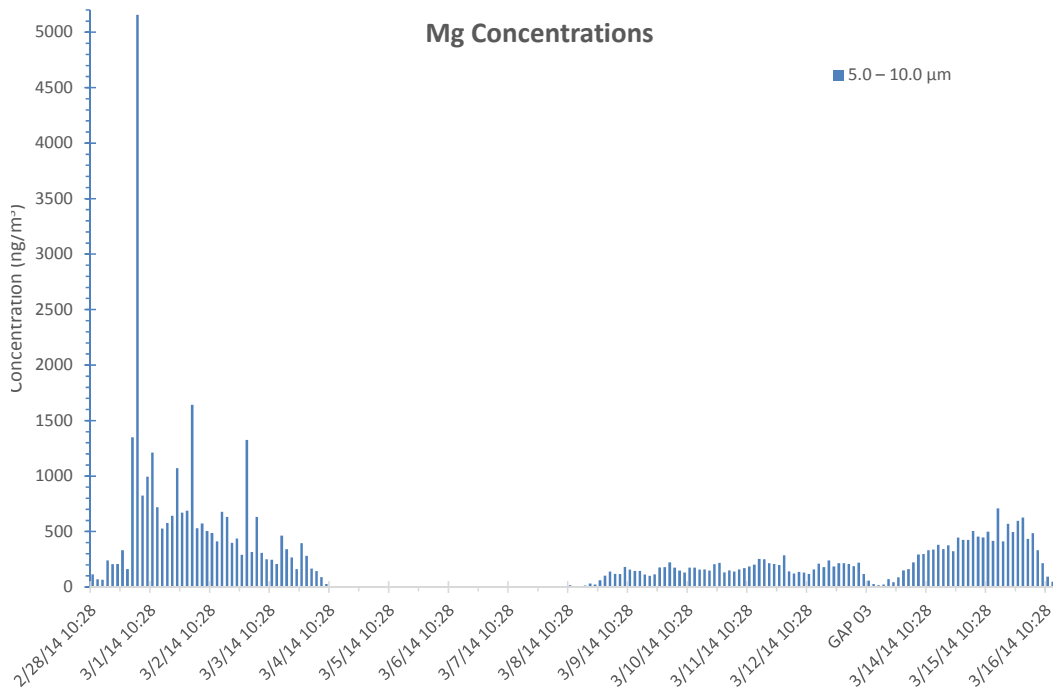


Fig. C-76 CaPh 32 DRUM: Mg mass stage 1

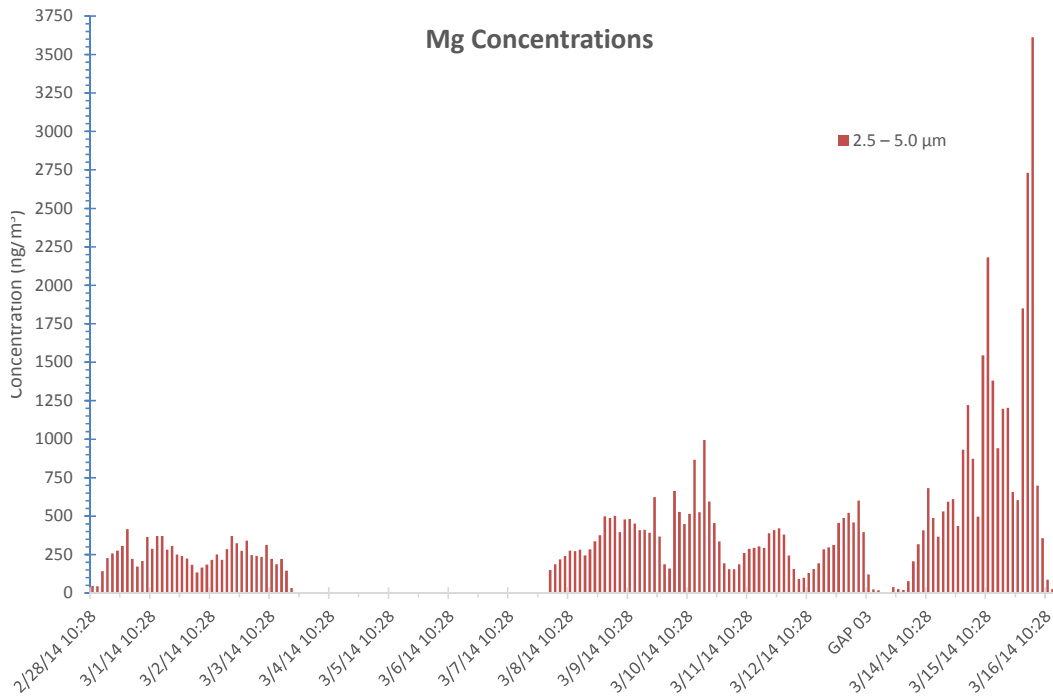


Fig. C-77 CaPh 32 DRUM: Mg mass stage 2

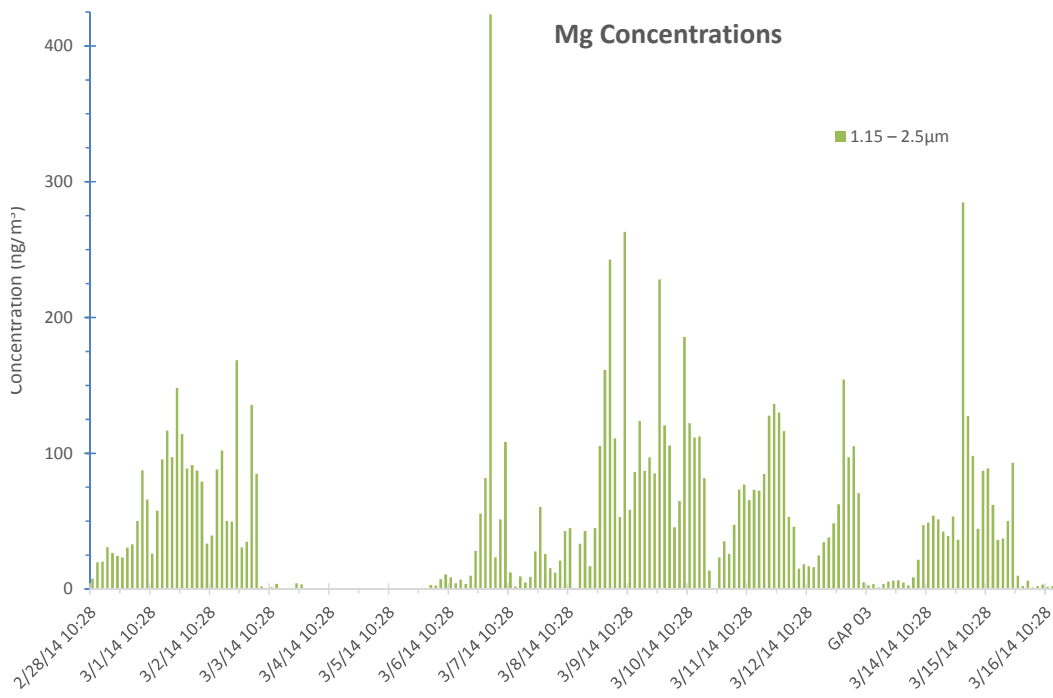


Fig. C-78 CaPh 32 DRUM: Mg mass stage 3

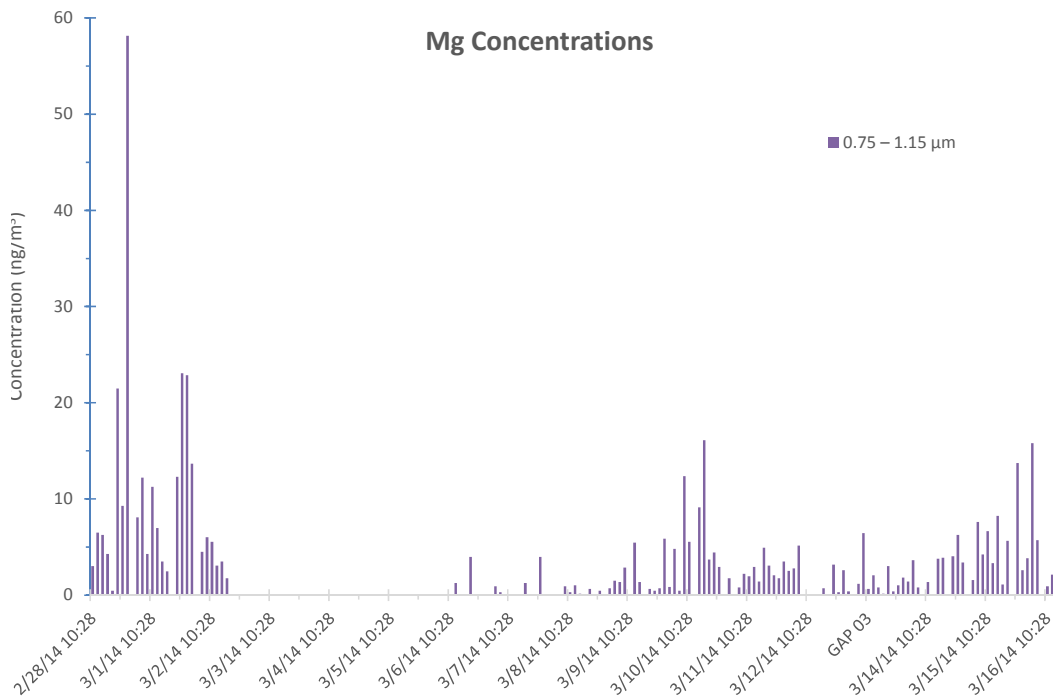


Fig. C-79 CaPh 32 DRUM: Mg mass stage 4

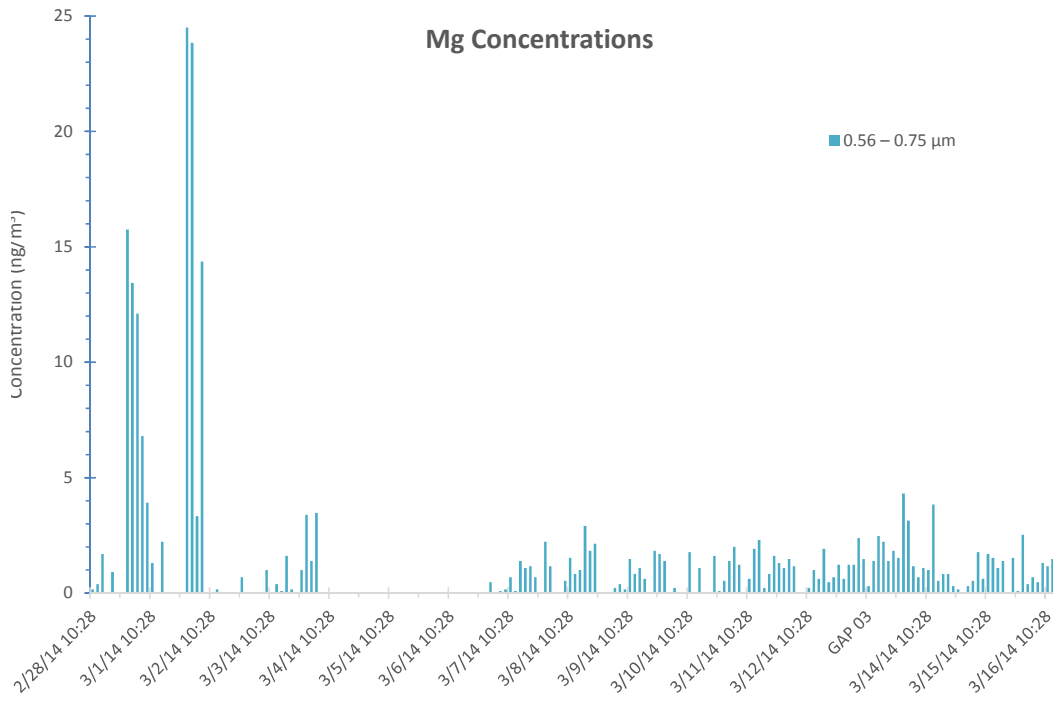


Fig. C-80 CaPh 32 DRUM: Mg mass stage 5

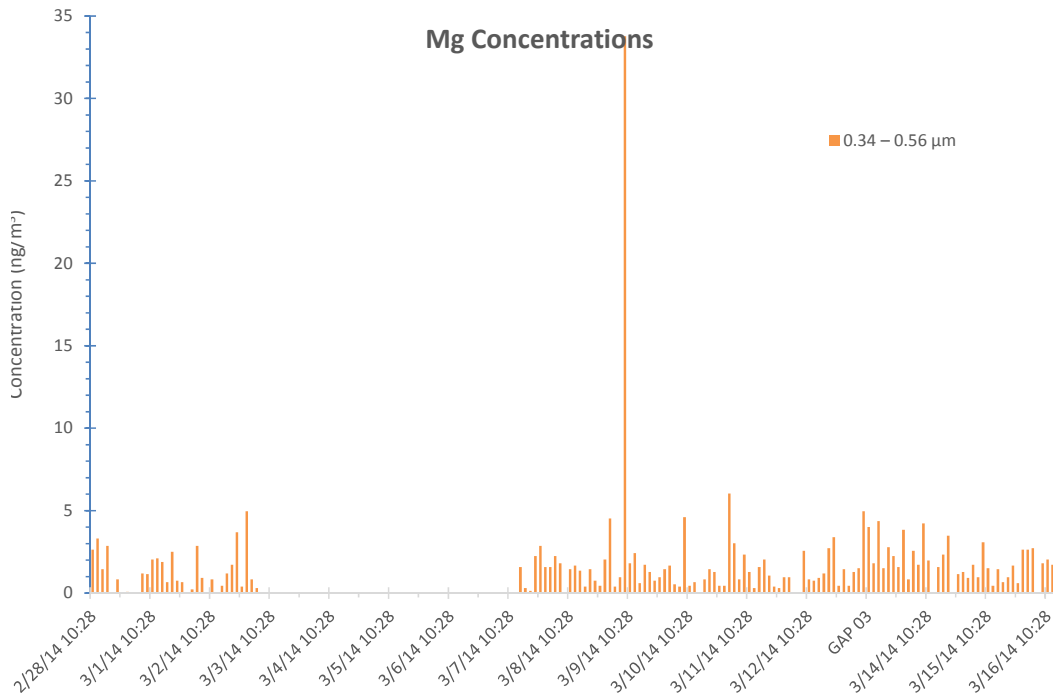


Fig. C-81 CaPh 32 DRUM: Mg mass stage 6

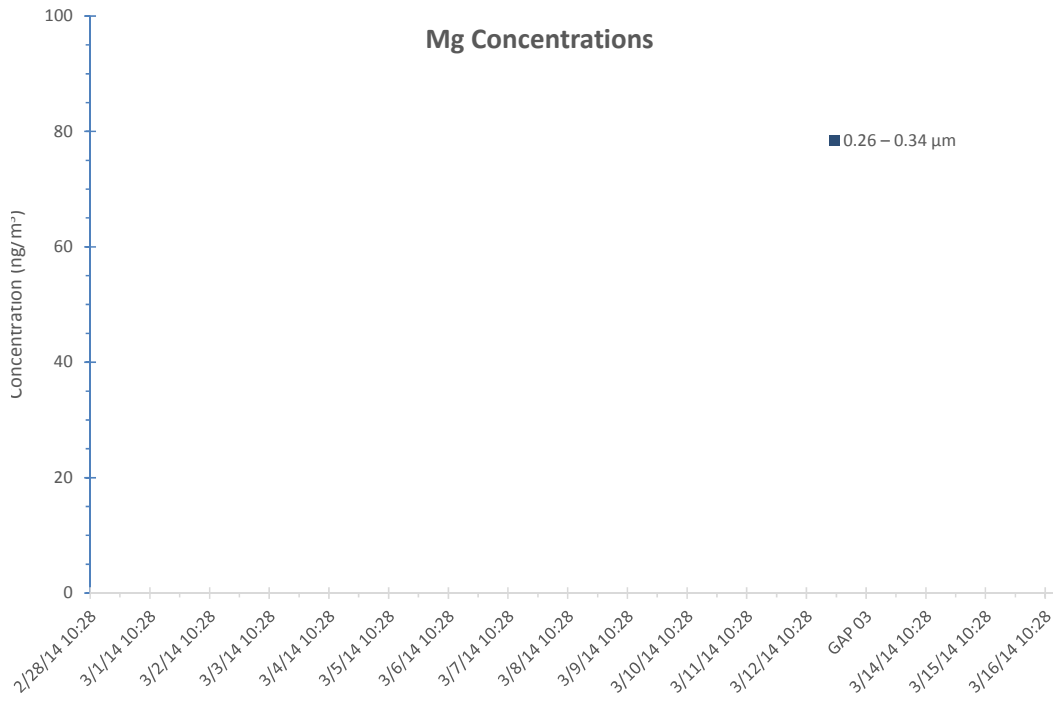


Fig. C-82 CaPh 32 DRUM: Mg mass stage 7

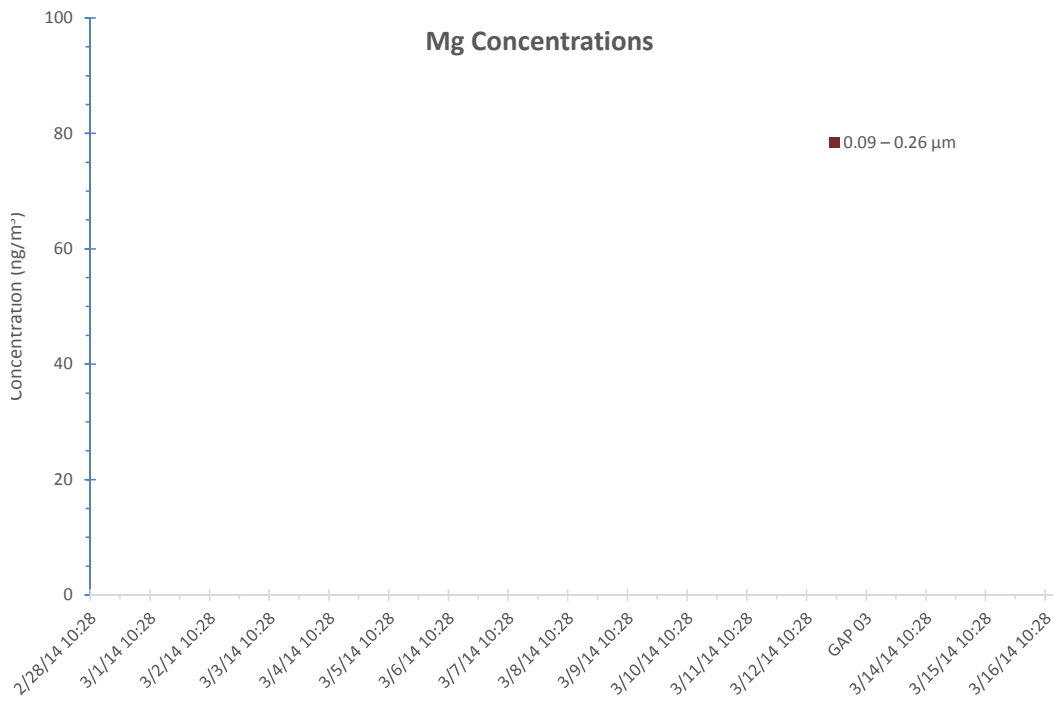


Fig. C-83 CaPh 32 DRUM: Mg mass stage 8

Approved for public release; distribution is unlimited.

C-4.3 Aluminum (Al)

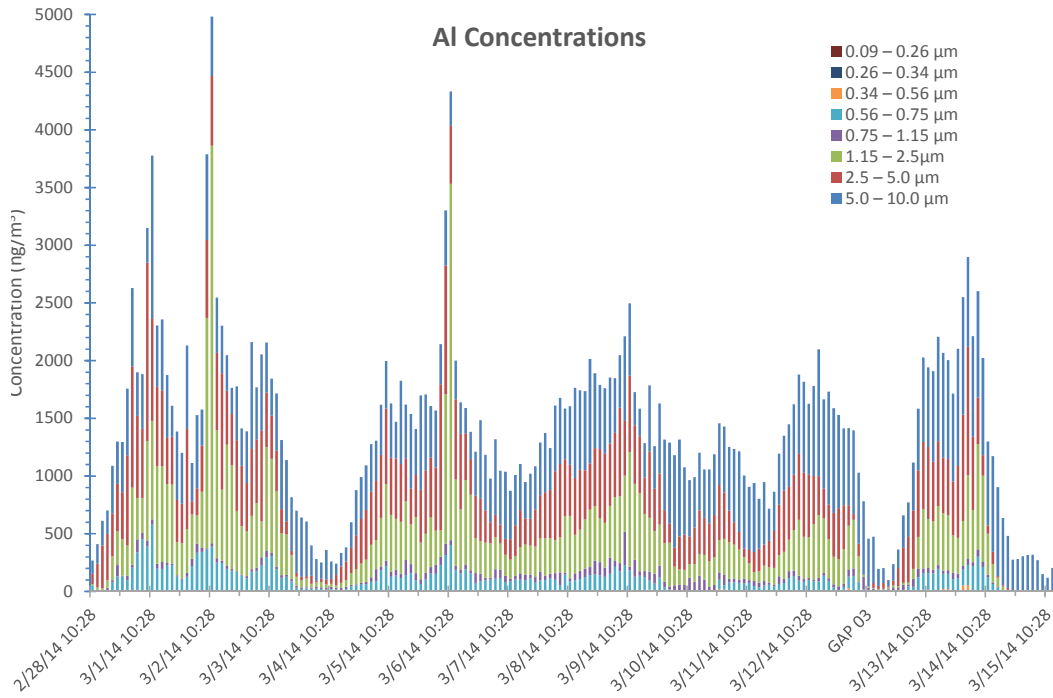


Fig. C-84 CaPh 34 DRUM: Al mass all stages

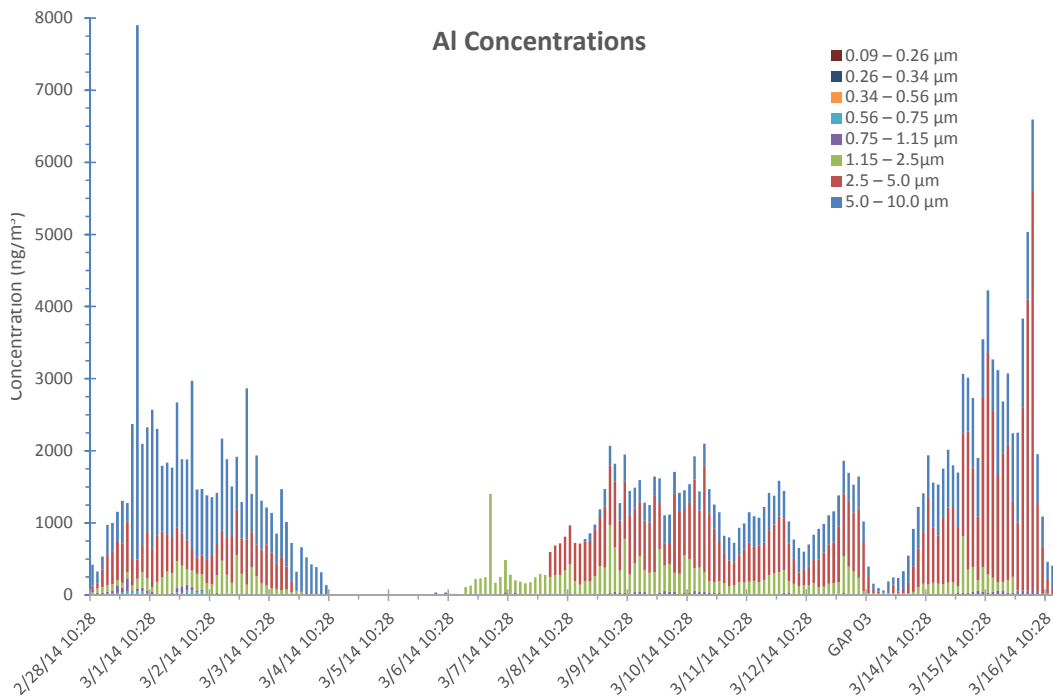


Fig. C-85 CaPh 32 DRUM: Al mass all stages

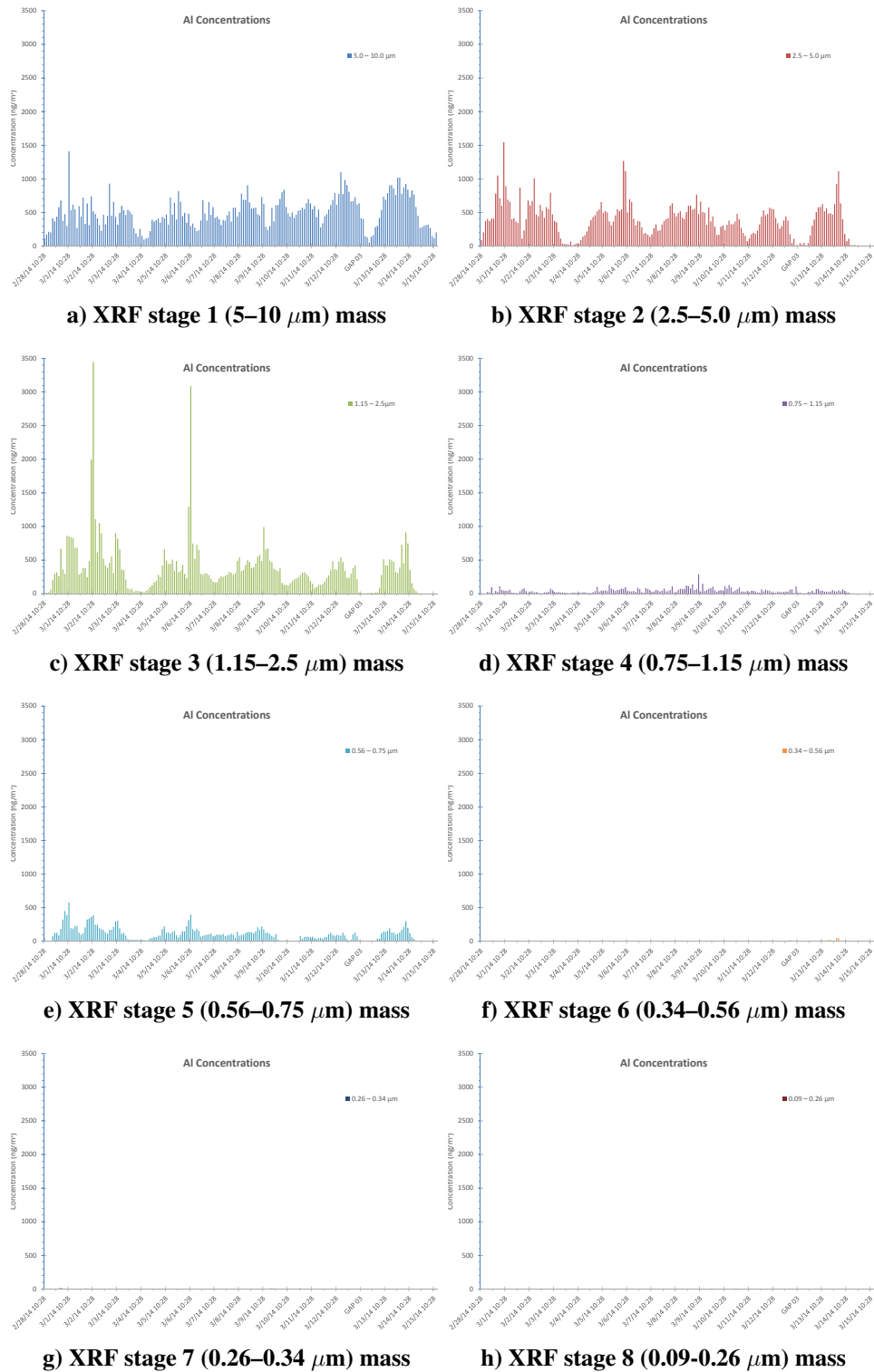
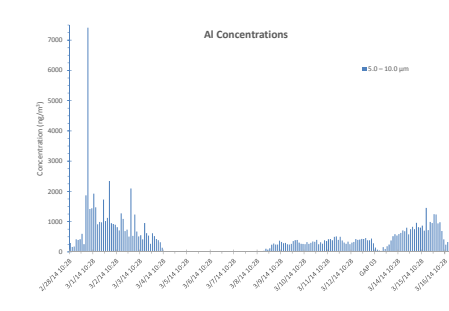
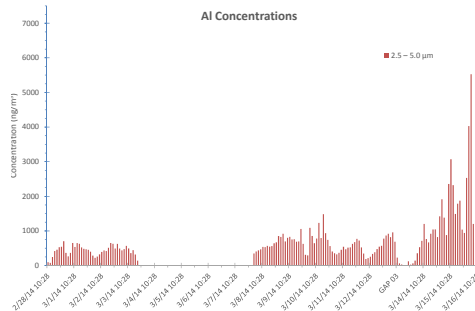


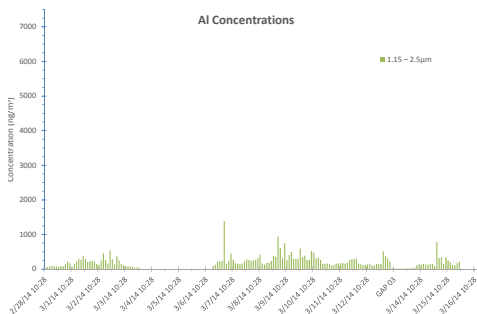
Fig. C-86 CaPh 34 DRUM: XRF mass Al; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



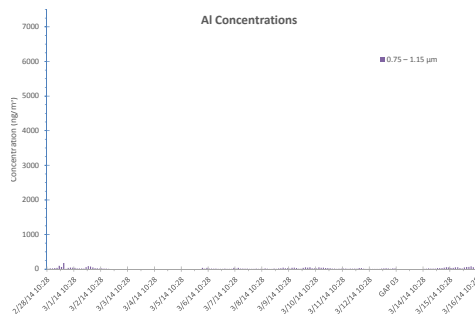
a) XRF stage 1 (5–10 μm) mass



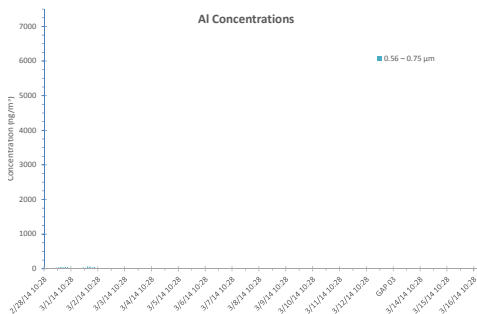
b) XRF stage 2 (2.5–5.0 μm) mass



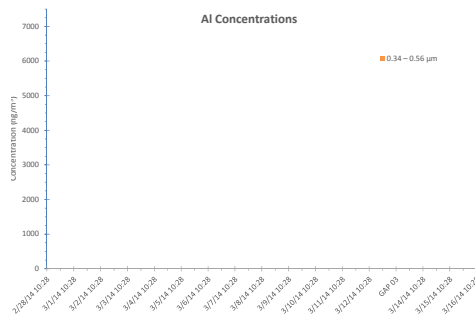
c) XRF stage 3 (1.15–2.5 μm) mass



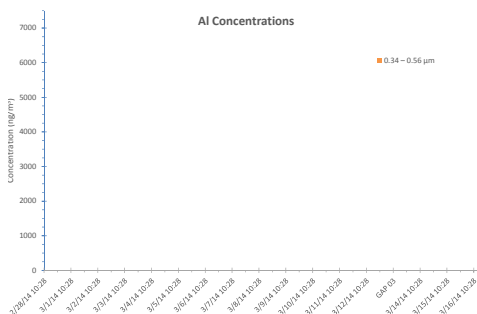
d) XRF stage 4 (0.75–1.15 μm) mass



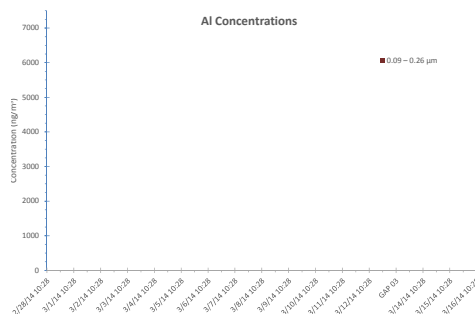
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-87 CaPh 32 DRUM: XRF mass Al; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

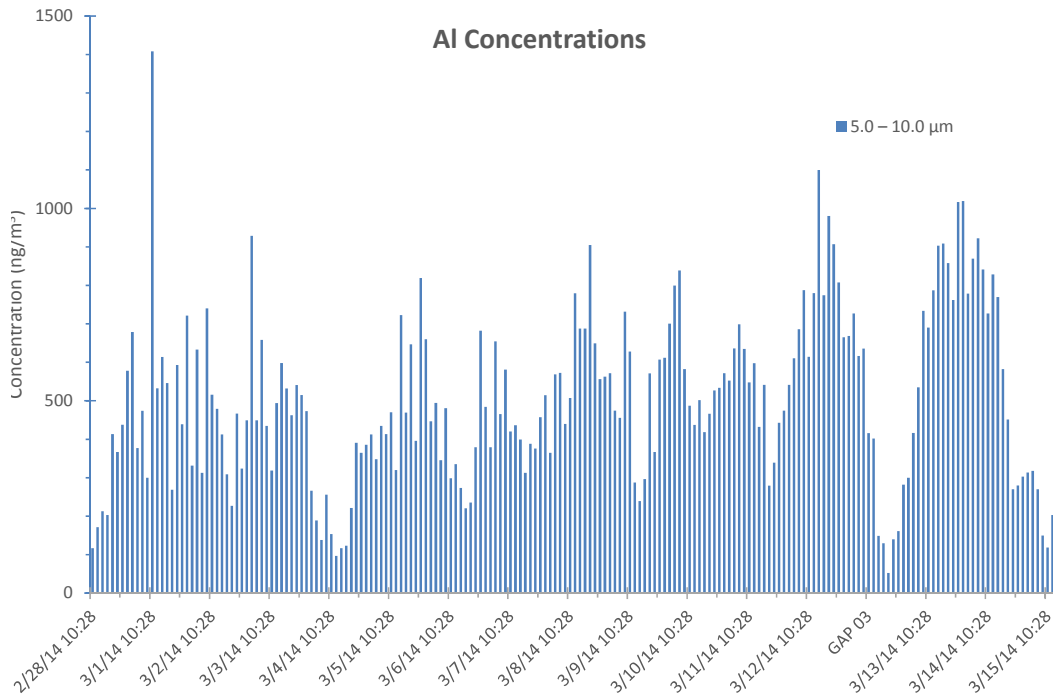


Fig. C-88 CaPh 34 DRUM: Al mass stage 1

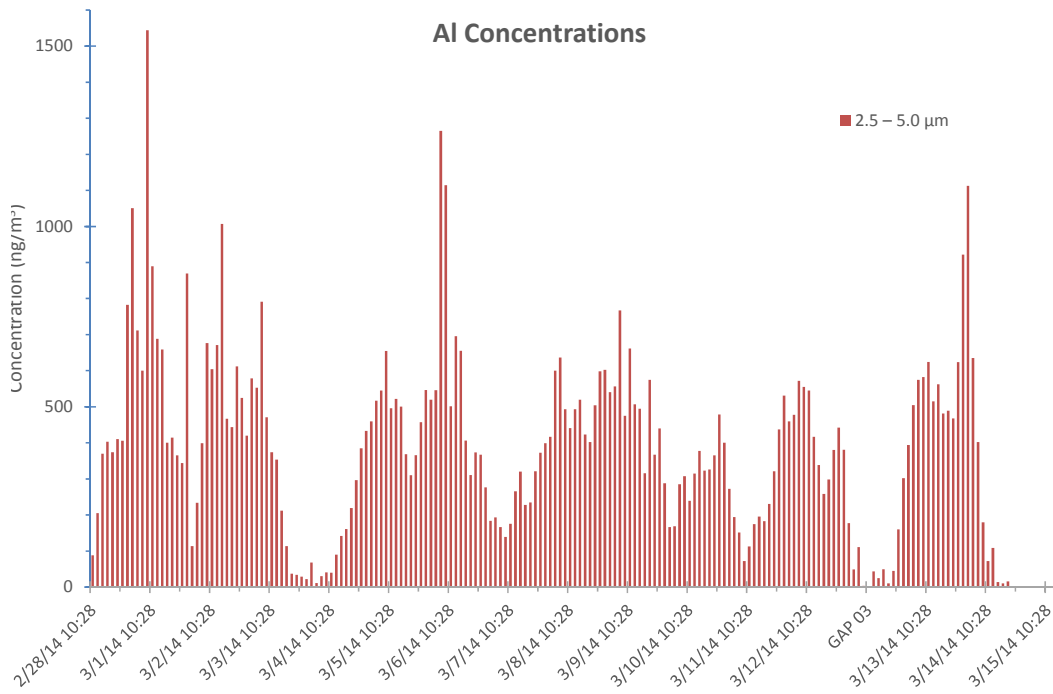


Fig. C-89 CaPh 34 DRUM: Al mass stage 2

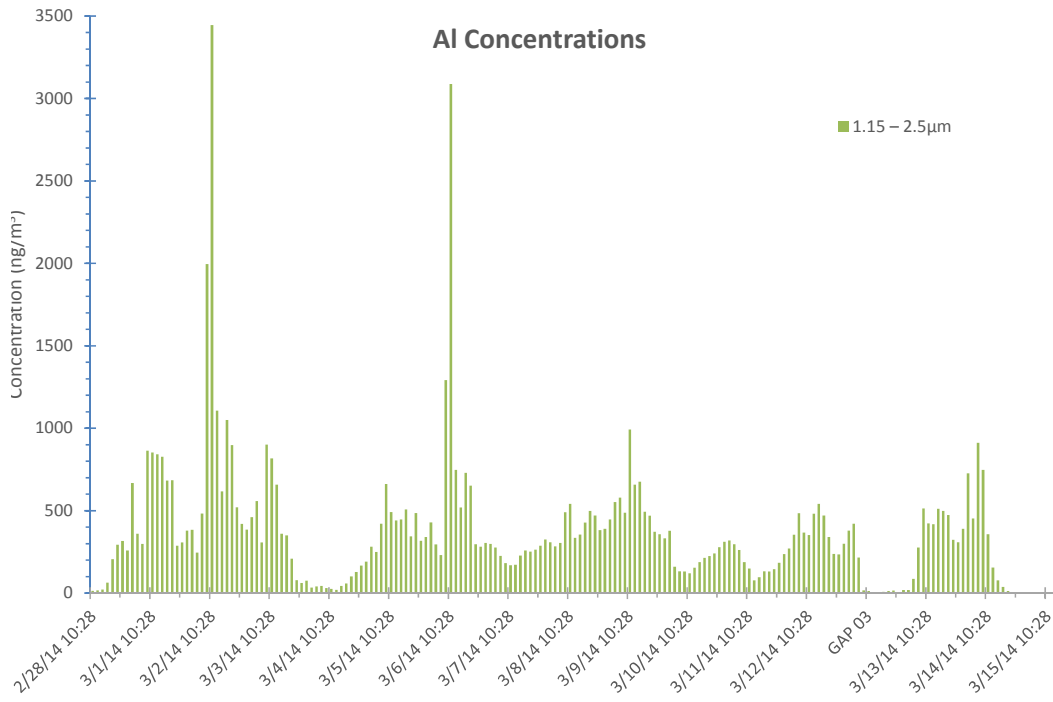


Fig. C-90 CaPh 34 DRUM: Al mass stage 3

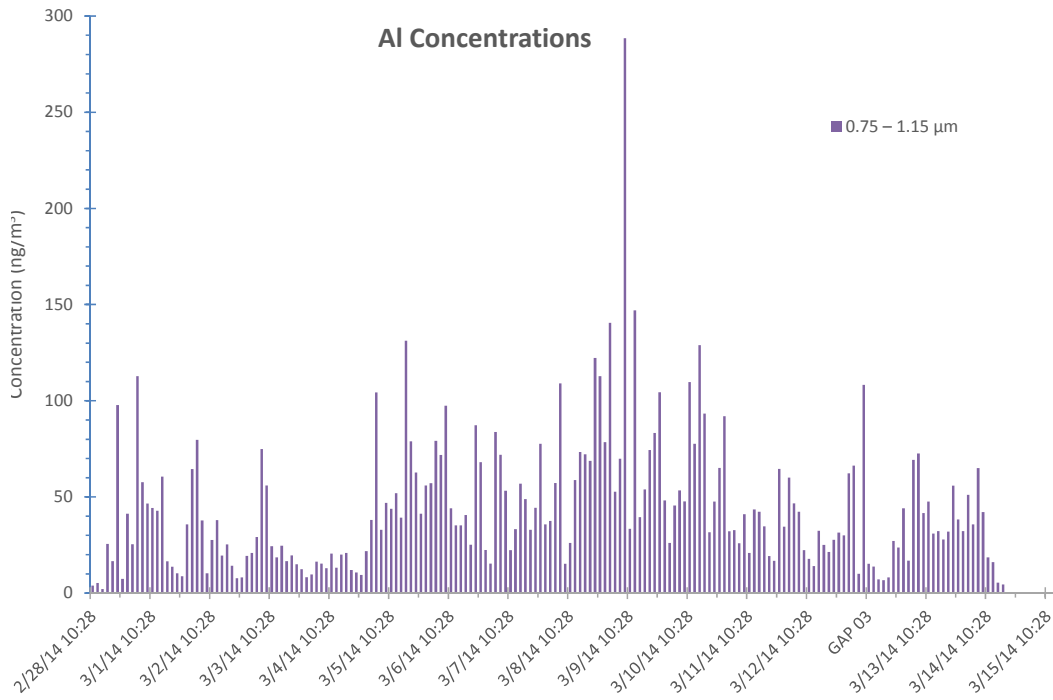


Fig. C-91 CaPh 34 DRUM: Al mass stage 4

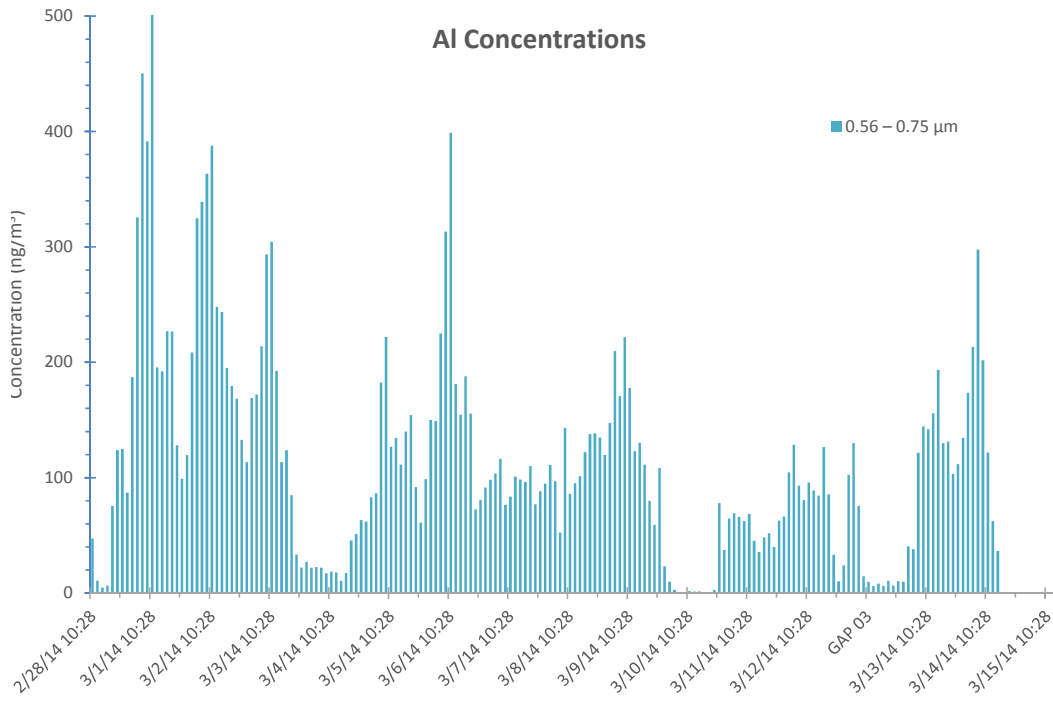


Fig. C-92 CaPh 34 DRUM: Al mass stage 5

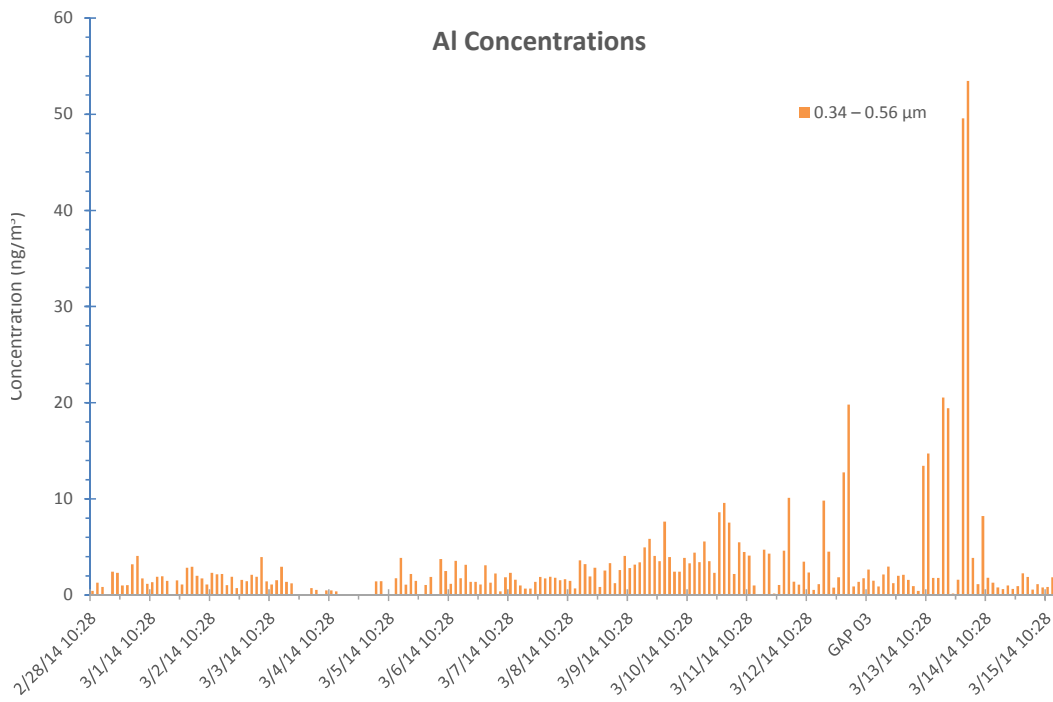


Fig. C-93 CaPh 34 DRUM: Al mass stage 6

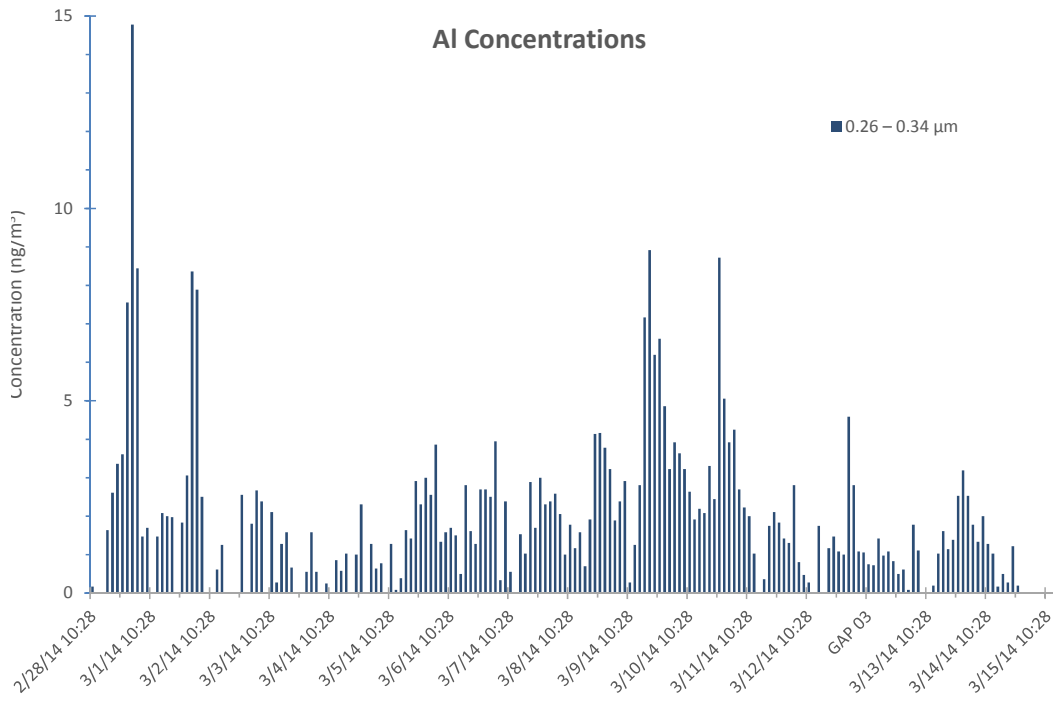


Fig. C-94 CaPh 34 DRUM: Al mass stage 7

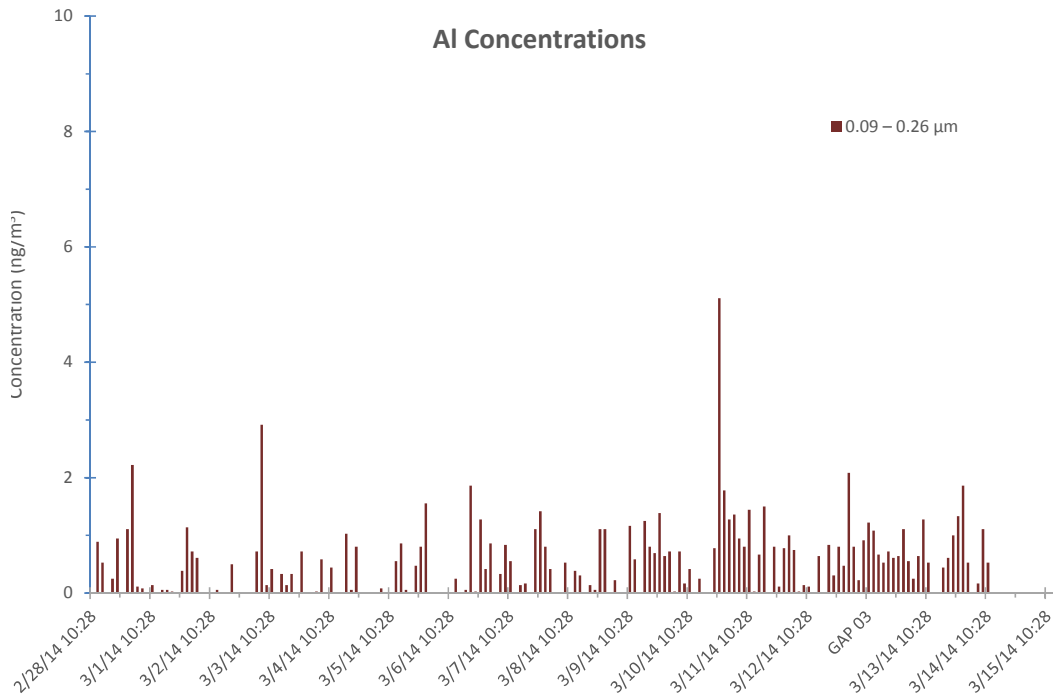


Fig. C-95 CaPh 34 DRUM: Al mass stage 8

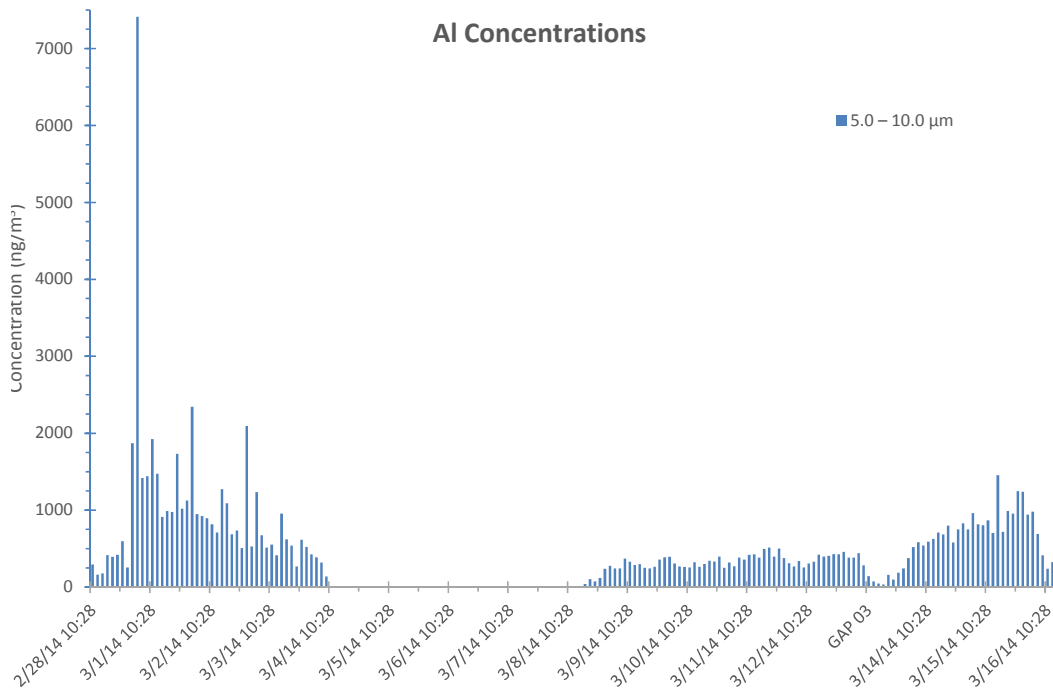


Fig. C-96 CaPh 32 DRUM: Al mass stage 1

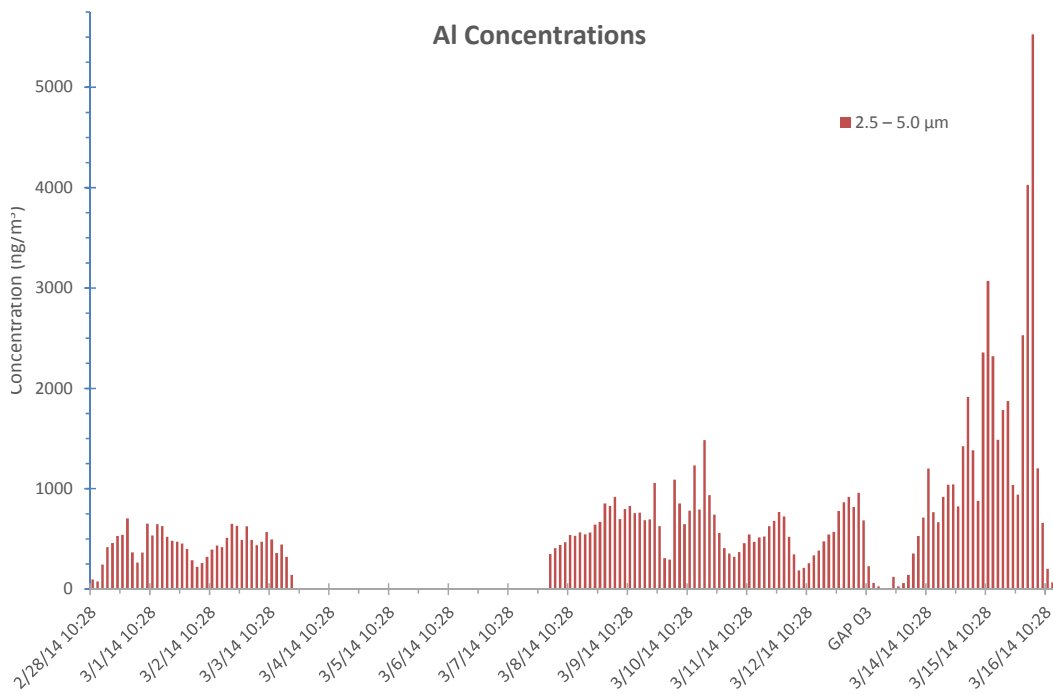


Fig. C-97 CaPh 32 DRUM: Al mass stage 2

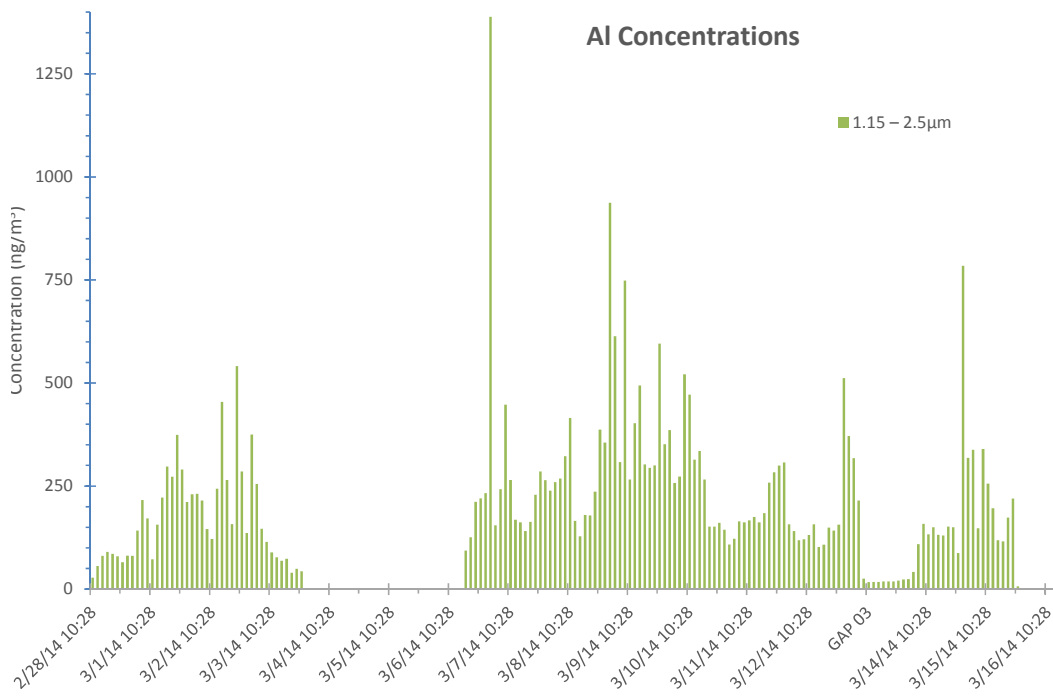


Fig. C-98 CaPh 32 DRUM: Al mass stage 3

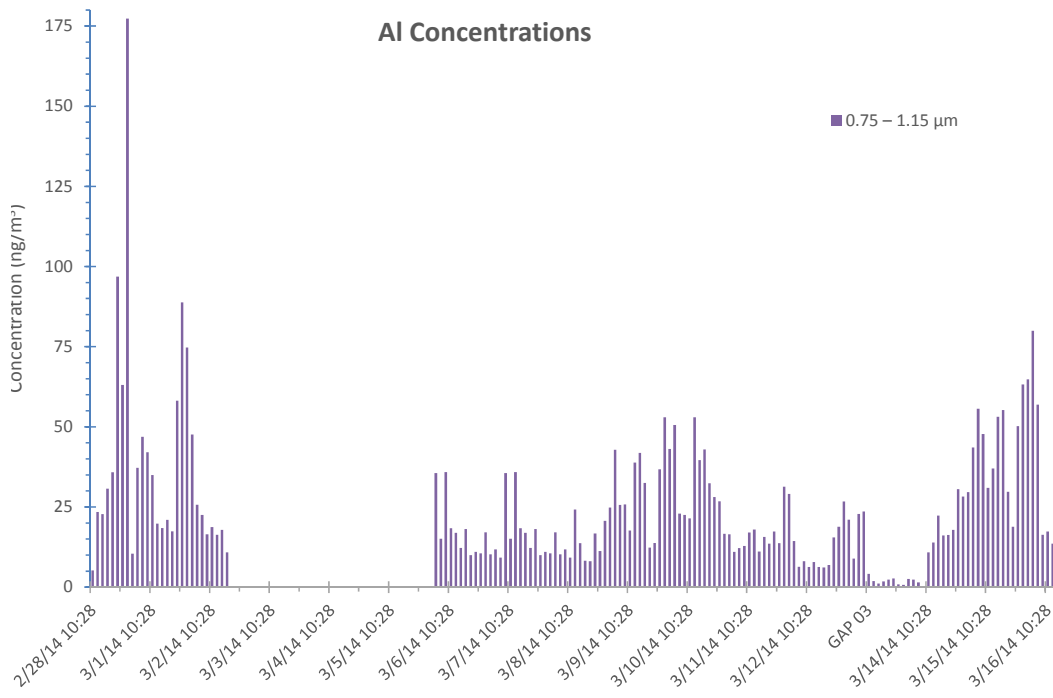


Fig. C-99 CaPh 32 DRUM: Al mass stage 4

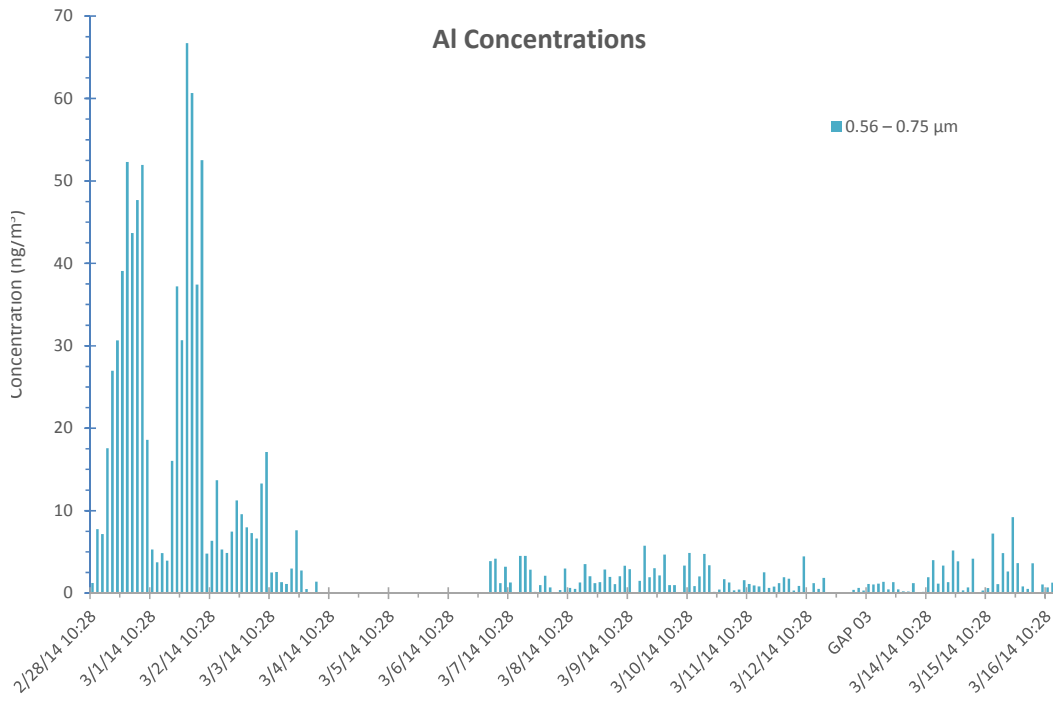


Fig. C-100 CaPh 32 DRUM: Al mass stage 5

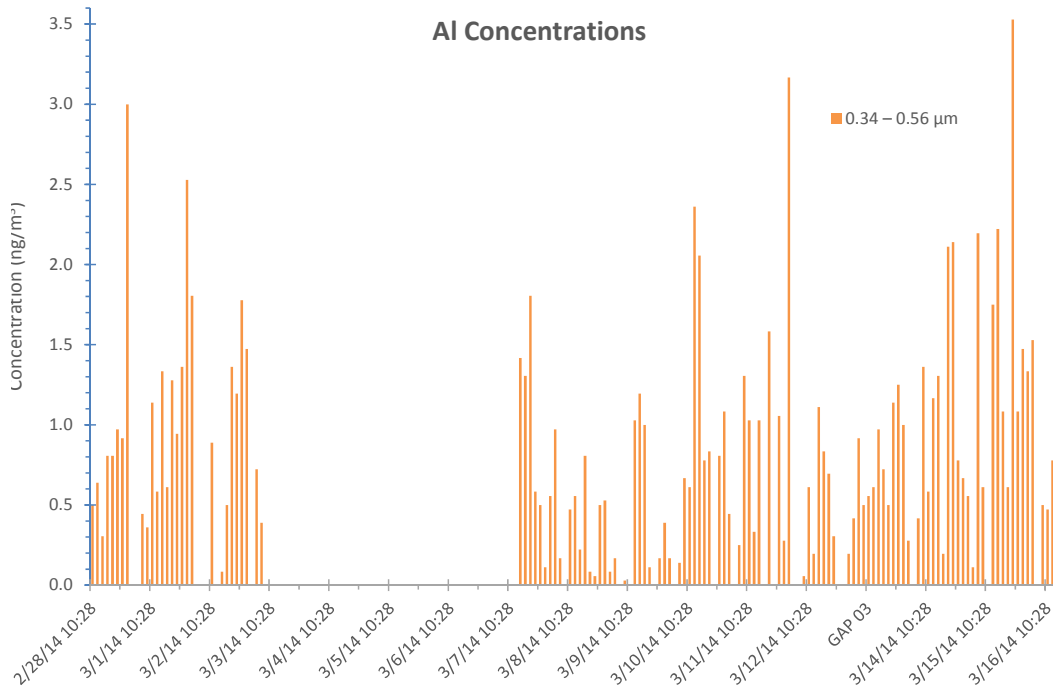


Fig. C-101 CaPh 32 DRUM: Al mass stage 6

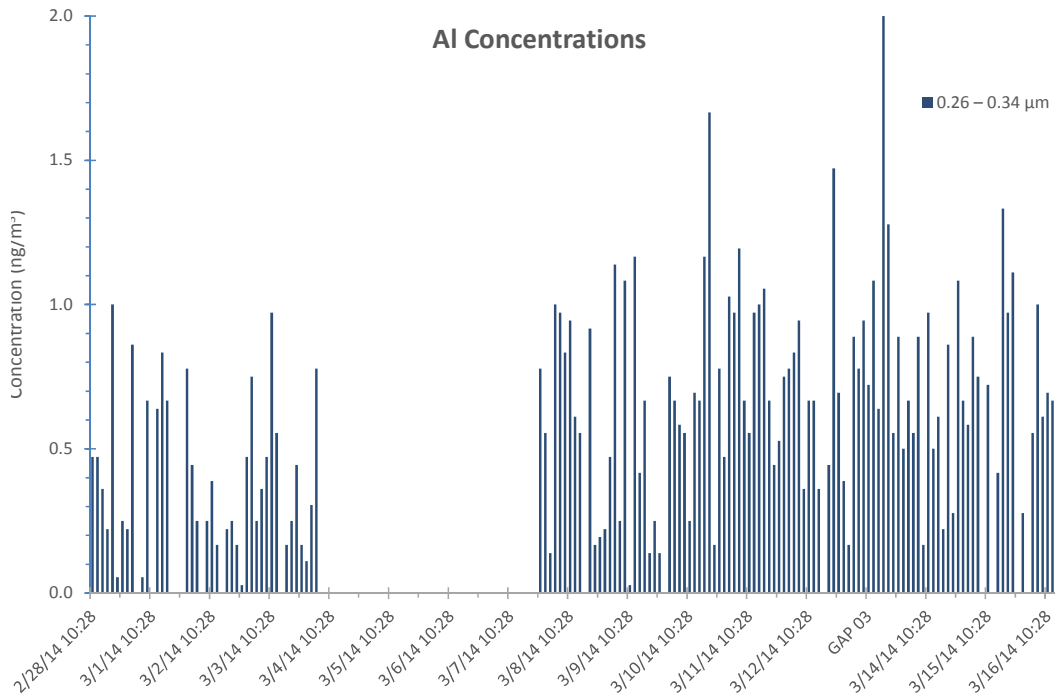


Fig. C-102 CaPh 32 DRUM: Al mass stage 7

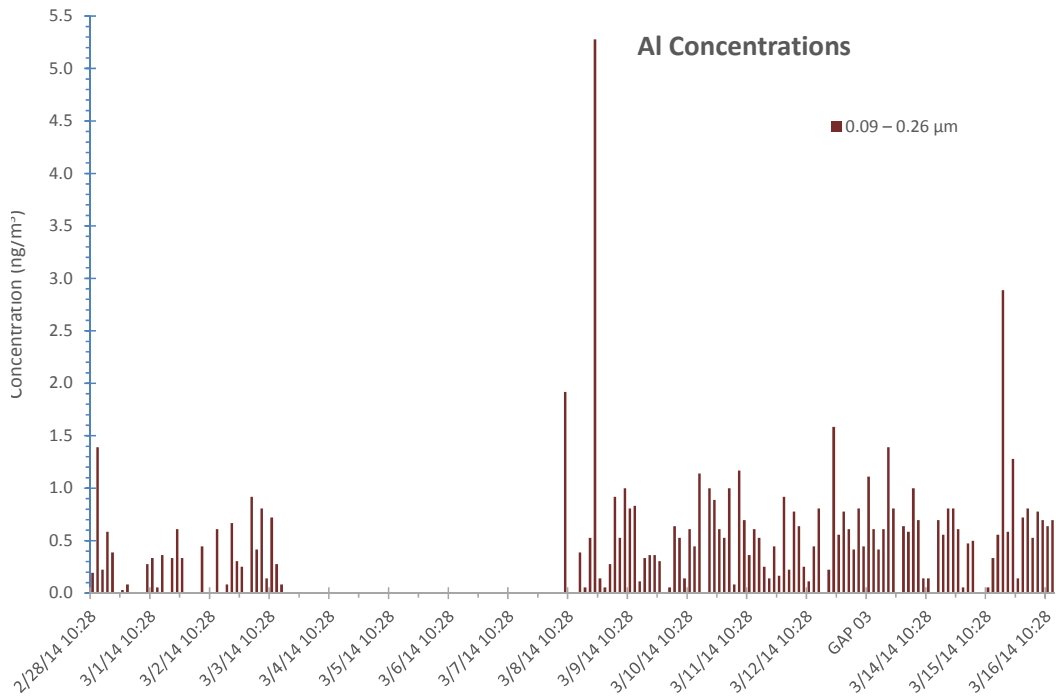


Fig. C-103 CaPh 32 DRUM: Al mass stage 8

C-4.4 Silicon (Si)

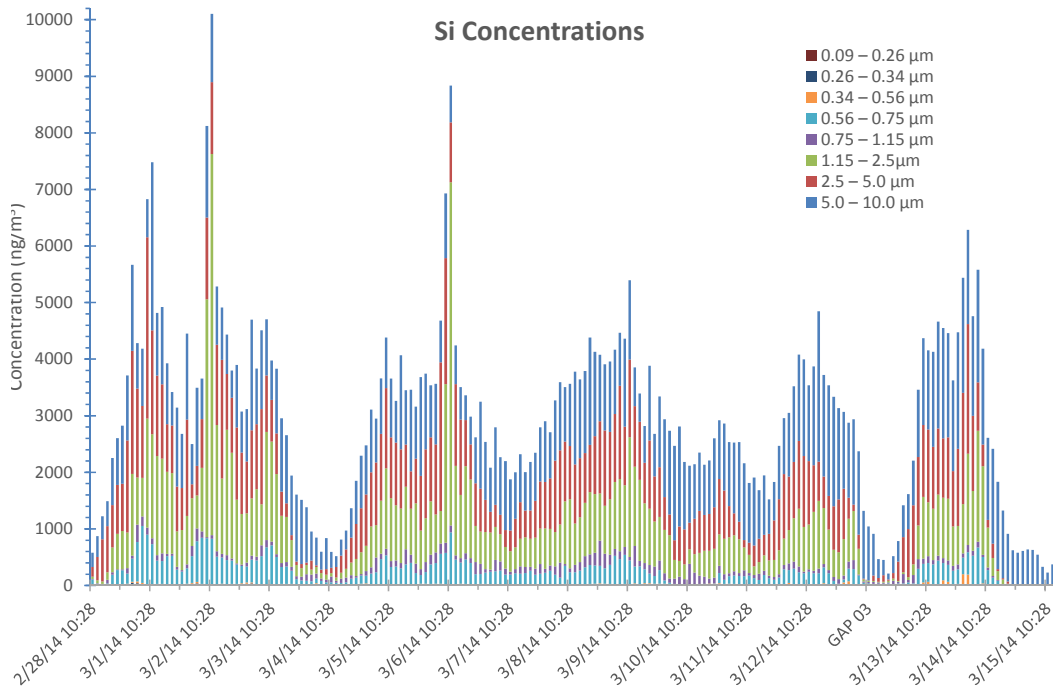


Fig. C-104 CaPh 34 DRUM: Si mass all stages

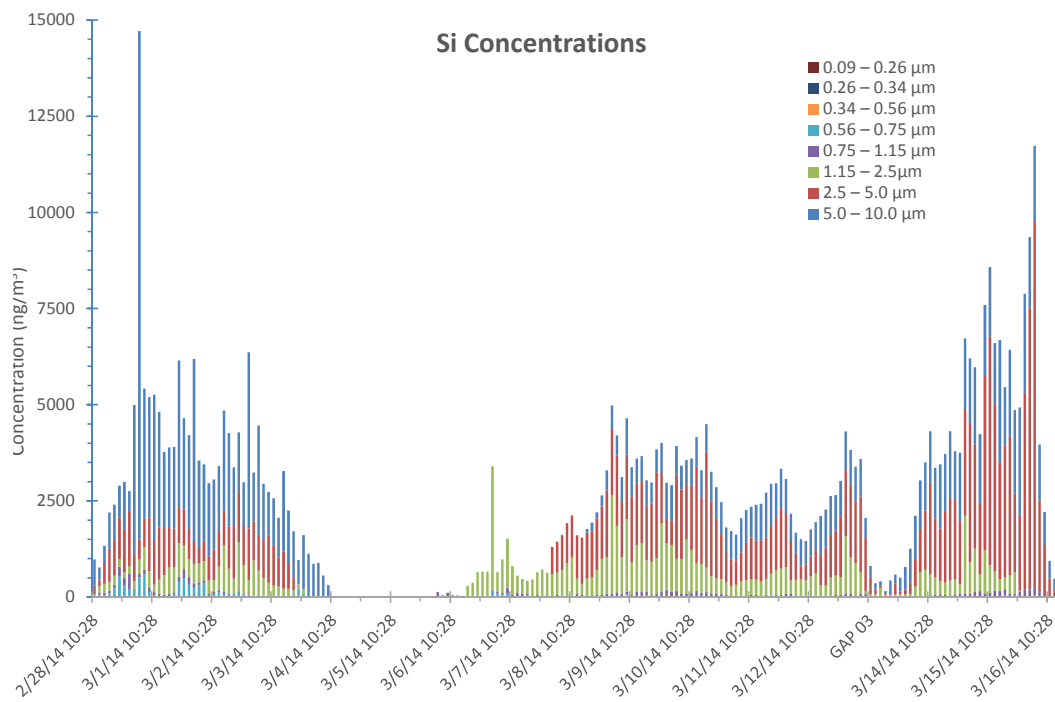


Fig. C-105 CaPh 32 DRUM: Si mass all stages

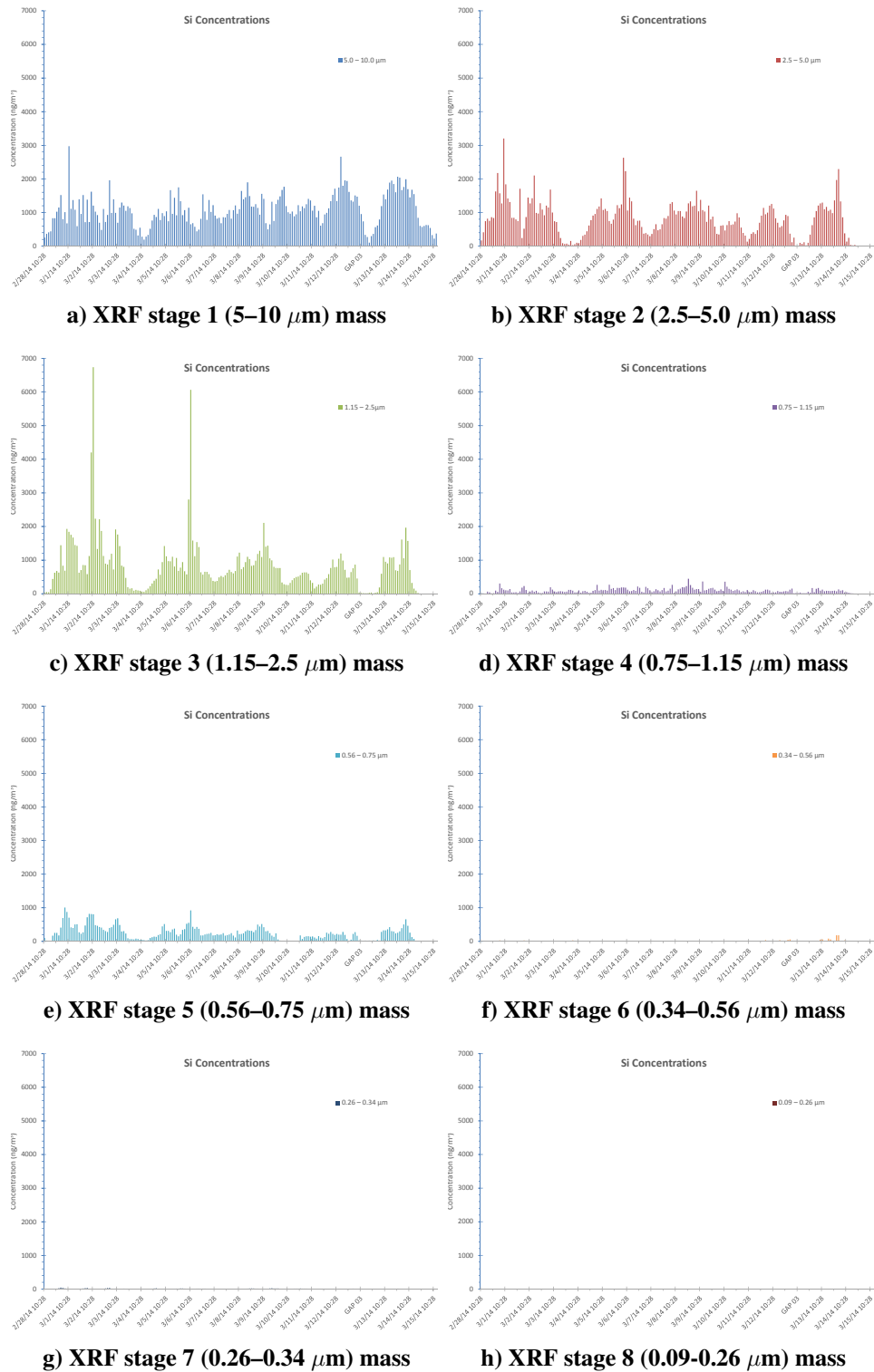
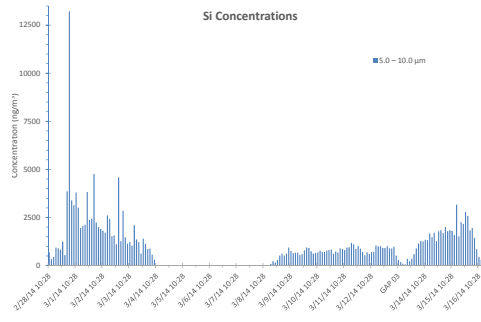
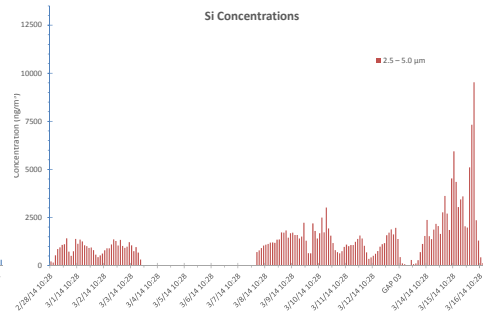


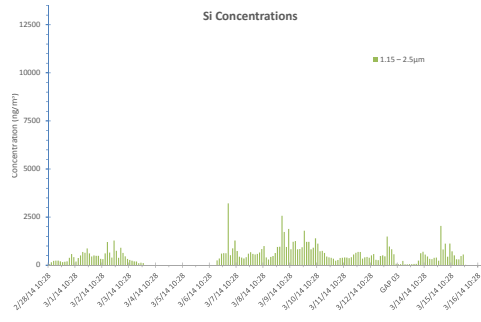
Fig. C-106 CaPh 34 DRUM: XRF mass Si; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



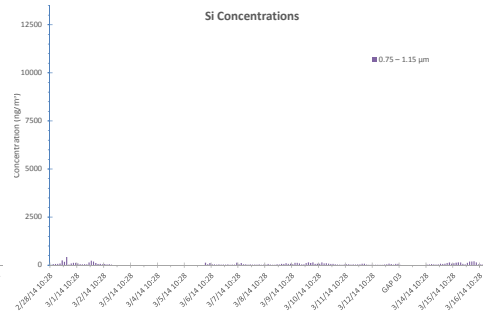
a) XRF stage 1 (5–10 μm) mass



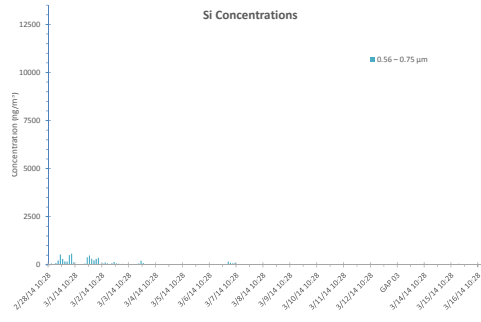
b) XRF stage 2 (2.5–5.0 μm) mass



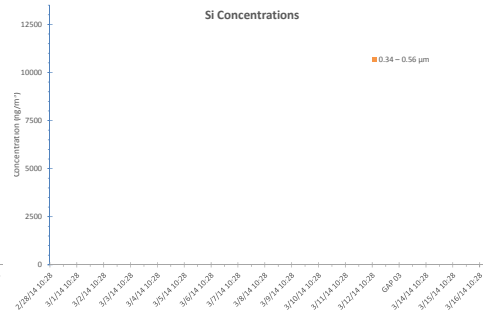
c) XRF stage 3 (1.15–2.5 μm) mass



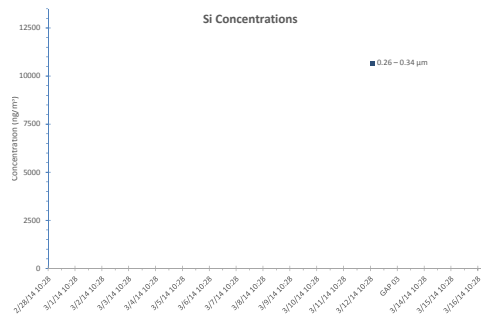
d) XRF stage 4 (0.75–1.15 μm) mass



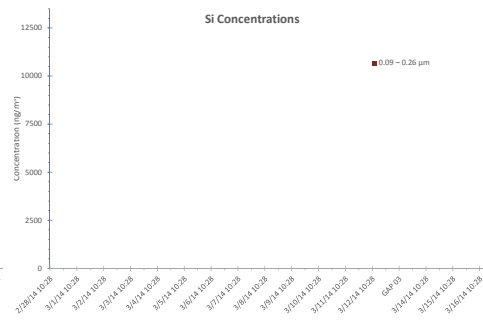
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-107 CaPh 32 DRUM: XRF mass Si; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

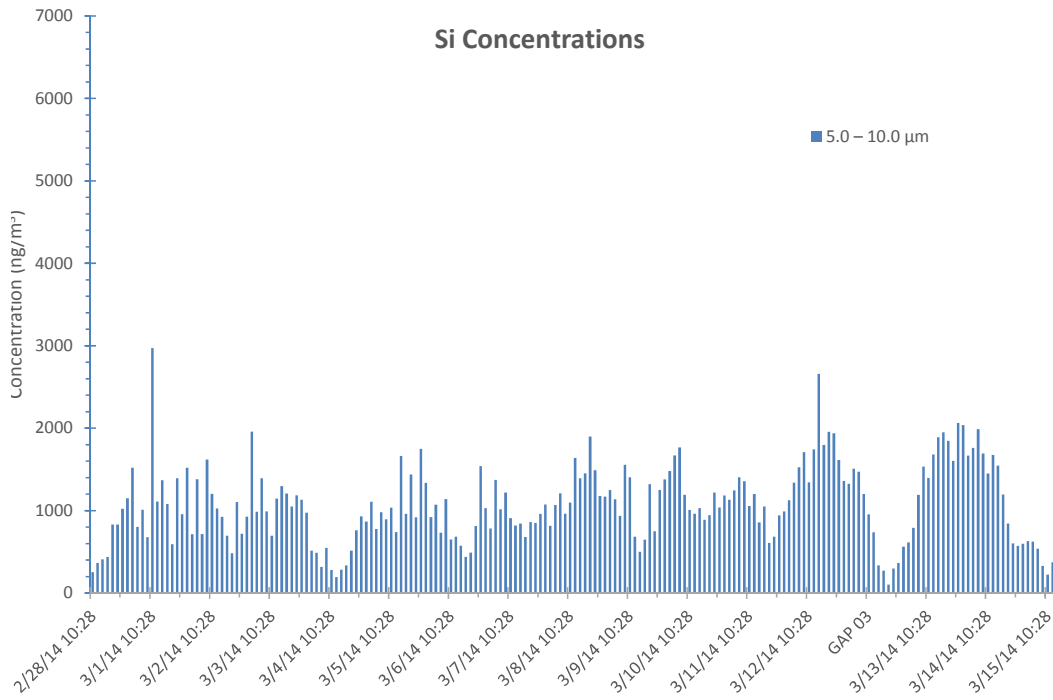


Fig. C-108 CaPh 34 DRUM: Si mass stage 1

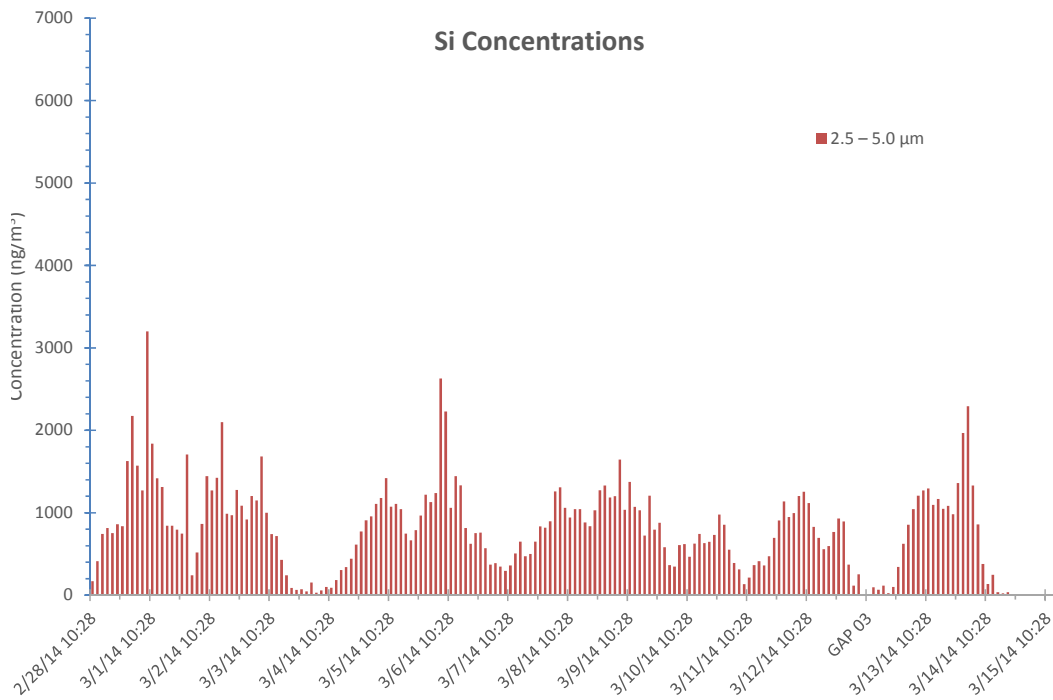


Fig. C-109 CaPh 34 DRUM: Si mass stage 2

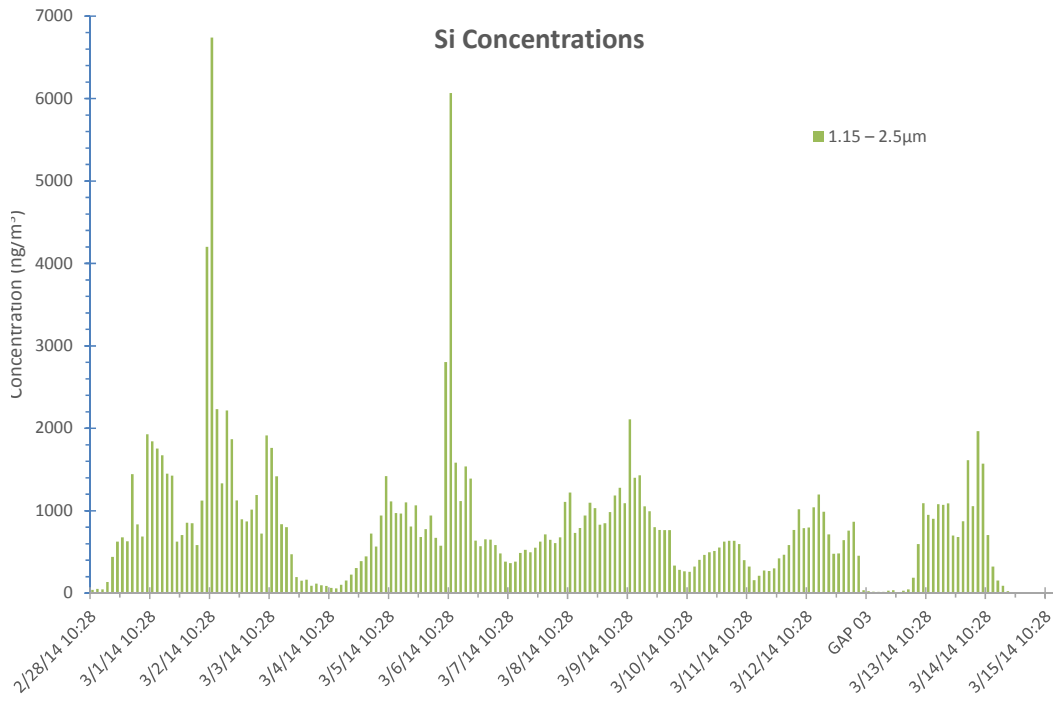


Fig. C-110 CaPh 34 DRUM: Si mass stage 3

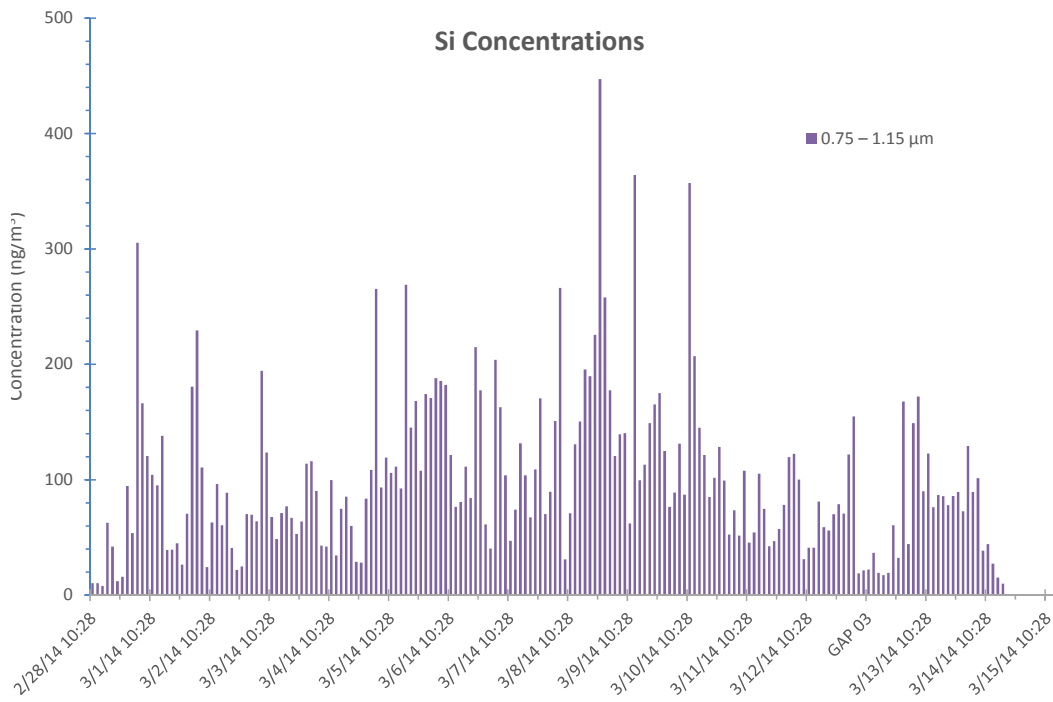


Fig. C-111 CaPh 34 DRUM: Si mass stage 4

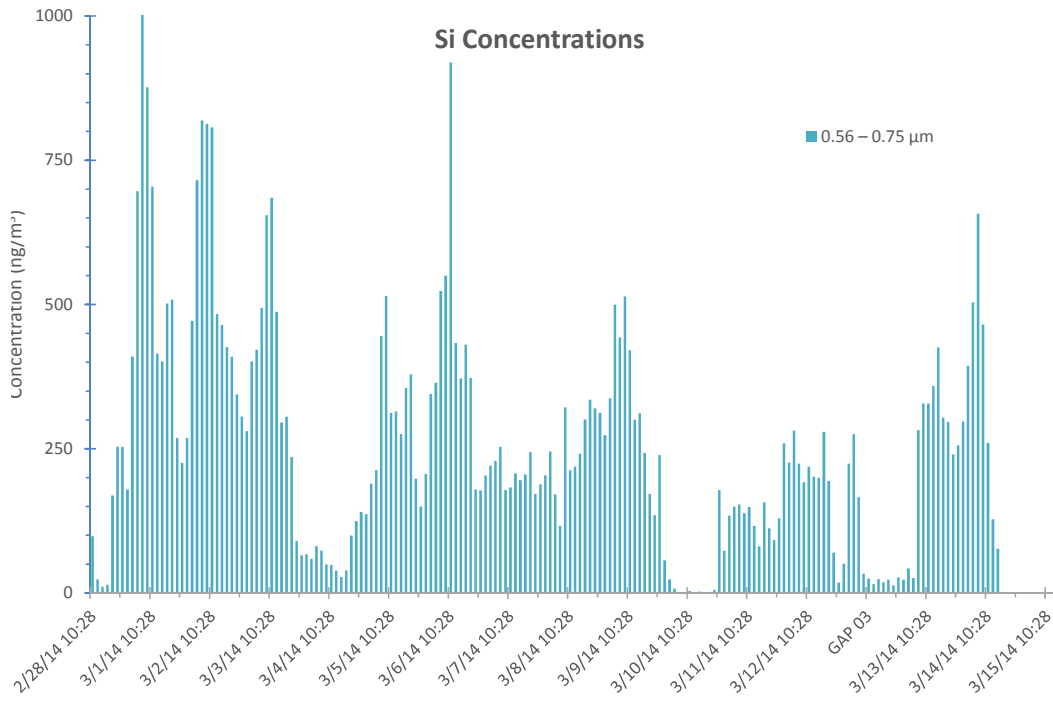


Fig. C-112 CaPh 34 DRUM: Si mass stage 5

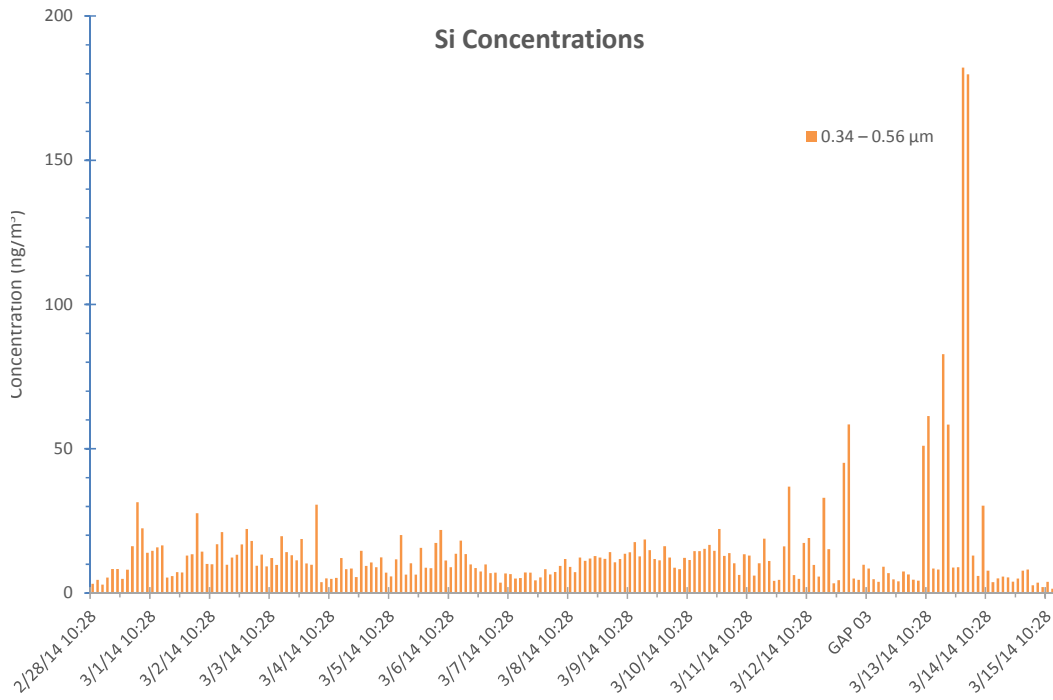


Fig. C-113 CaPh 34 DRUM: Si mass stage 6

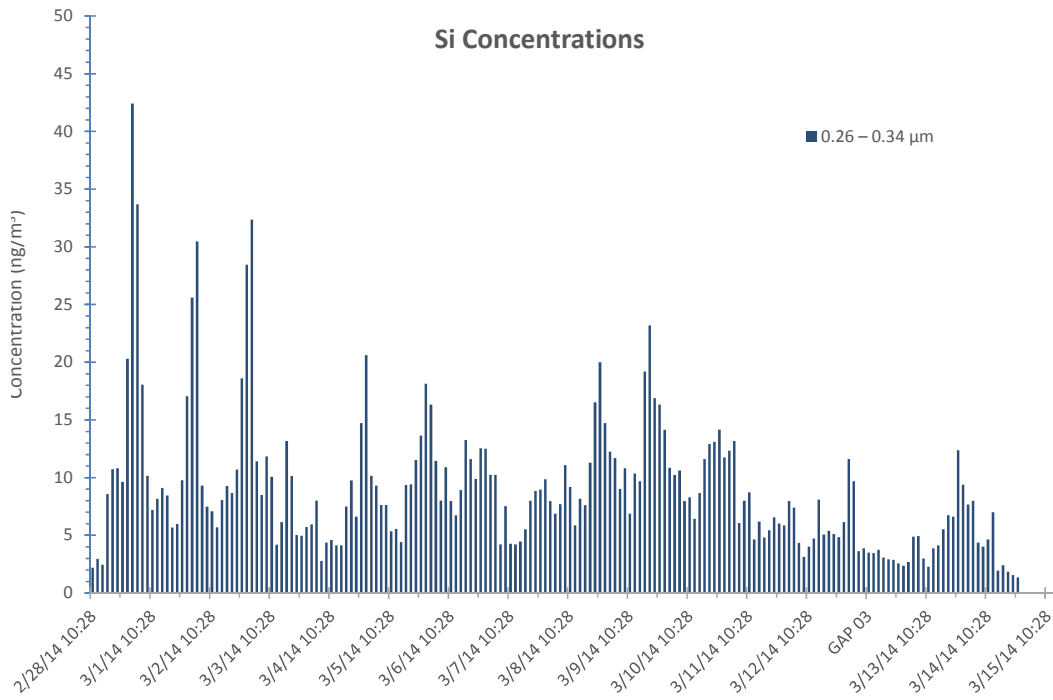


Fig. C-114 CaPh 34 DRUM: Si mass stage 7

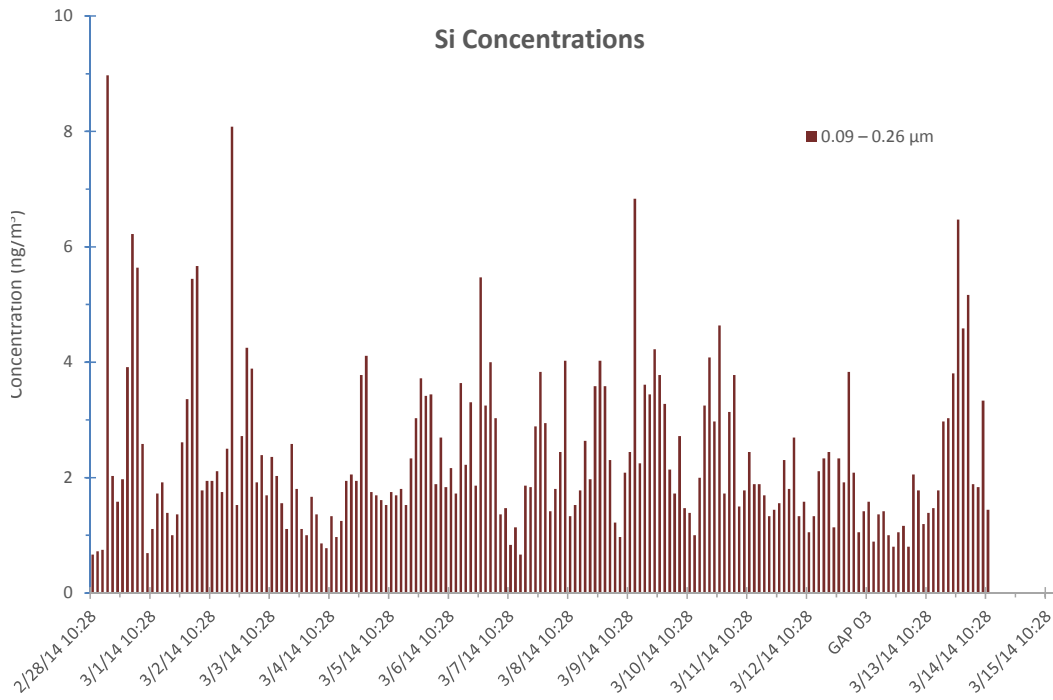


Fig. C-115 CaPh 34 DRUM: Si mass stage 8

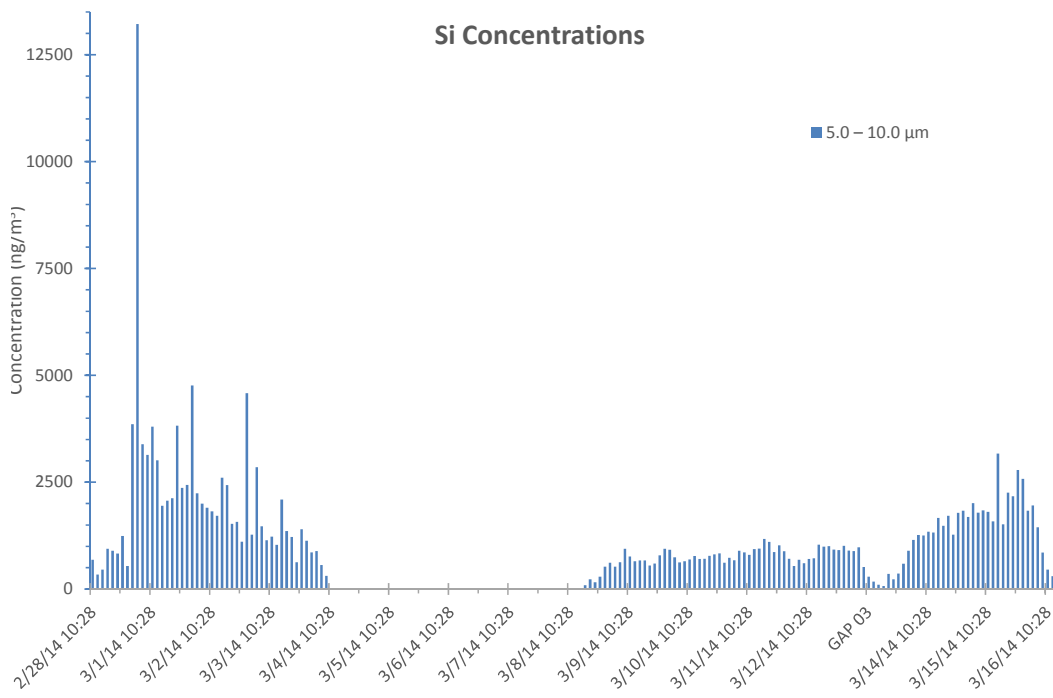


Fig. C-116 CaPh 32 DRUM: Si mass stage 1

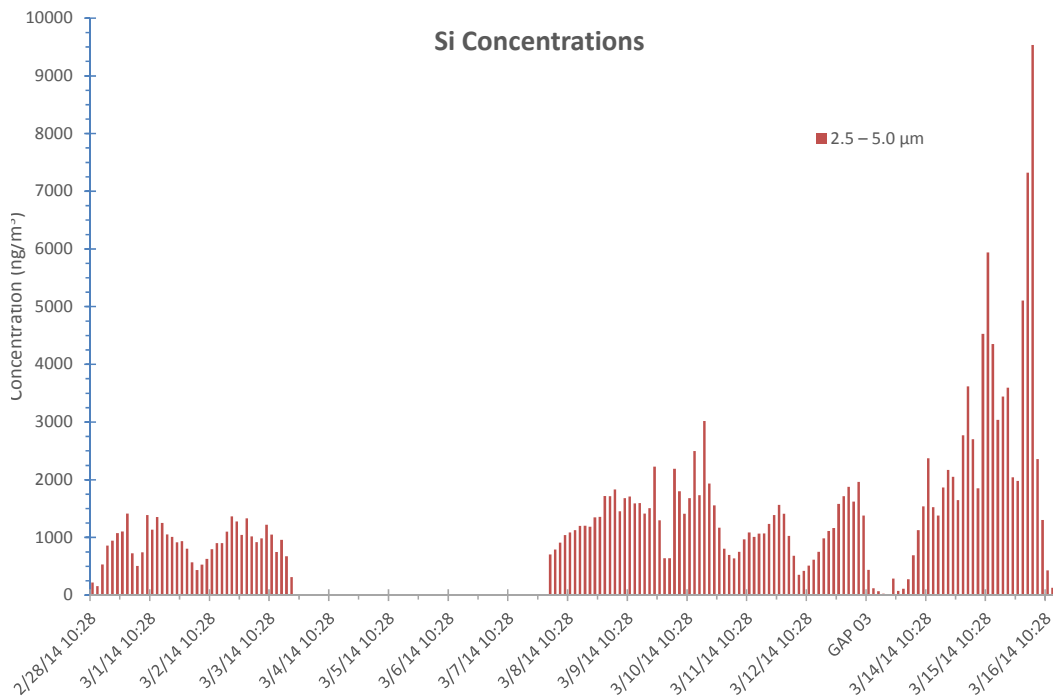


Fig. C-117 CaPh 32 DRUM: Si mass stage 2

Approved for public release; distribution is unlimited.

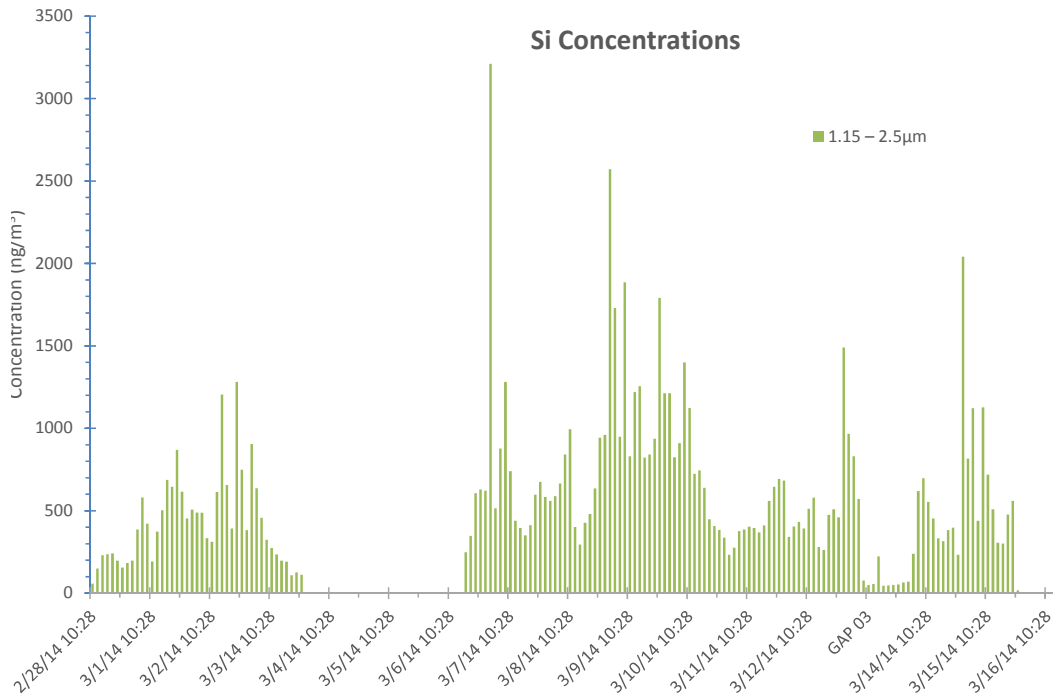


Fig. C-118 CaPh 32 DRUM: Si mass stage 3

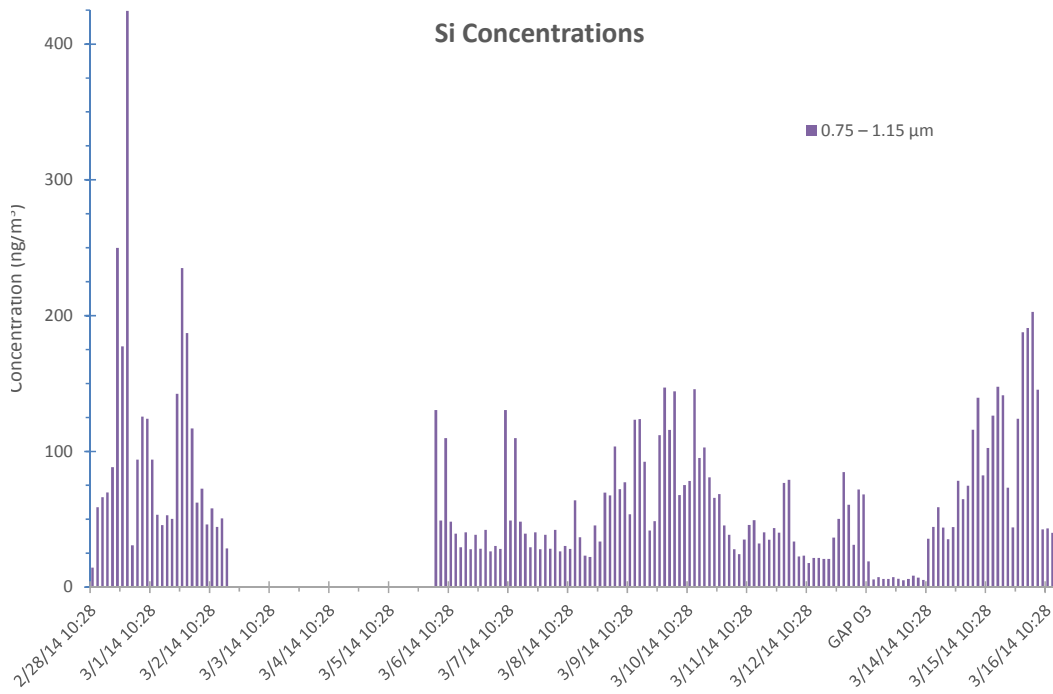


Fig. C-119 CaPh 32 DRUM: Si mass stage 4

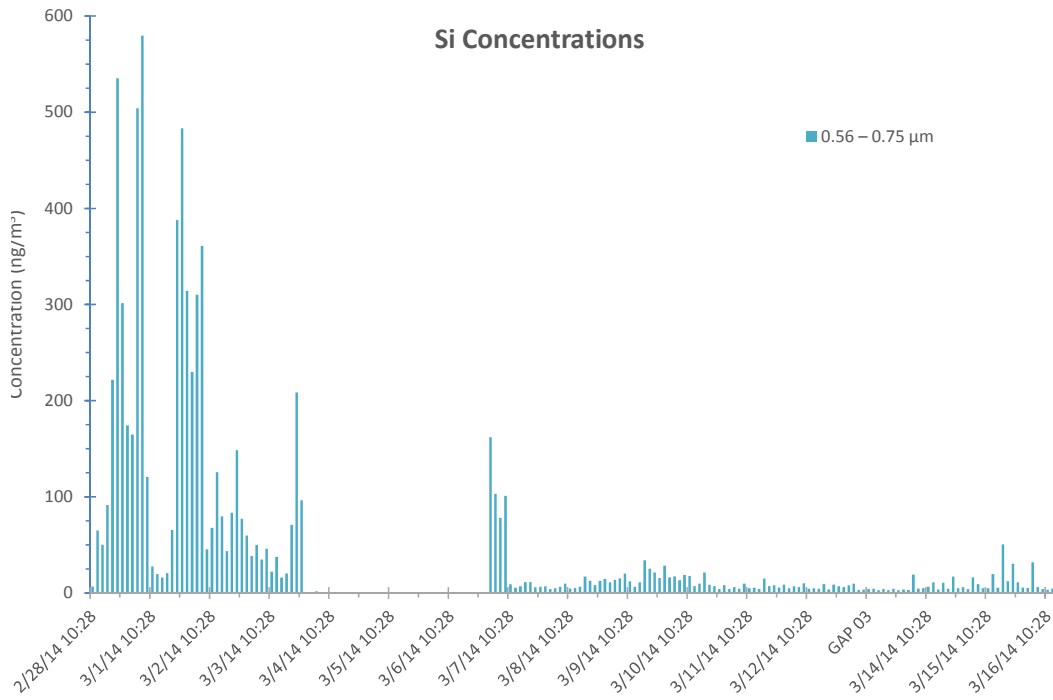


Fig. C-120 CaPh 32 DRUM: Si mass stage 5

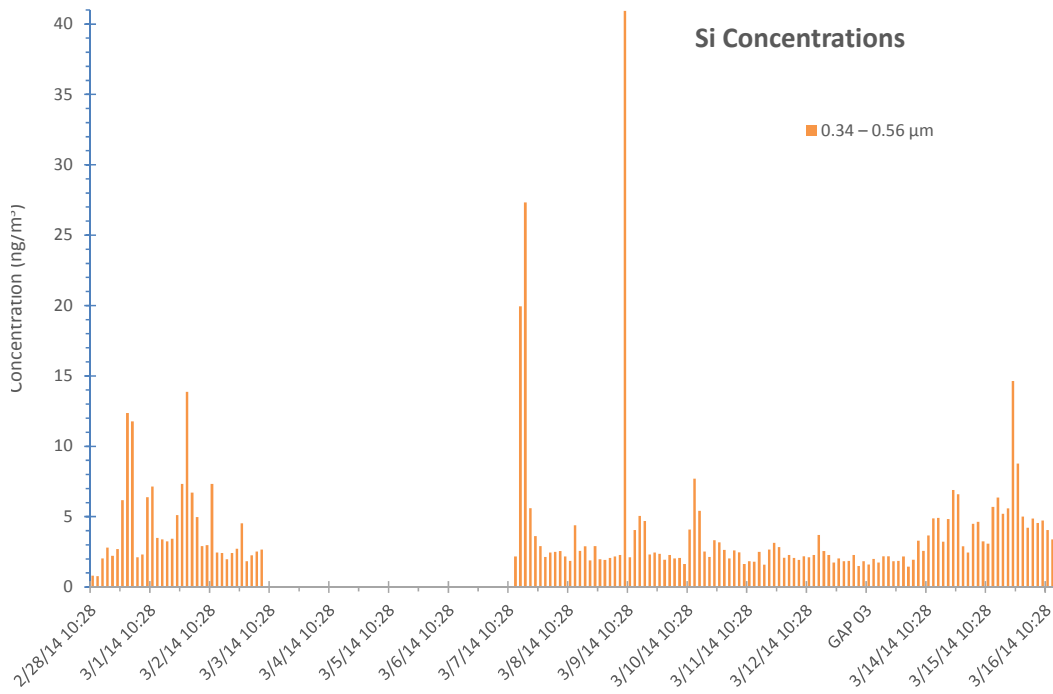


Fig. C-121 CaPh 32 DRUM: Si mass stage 6

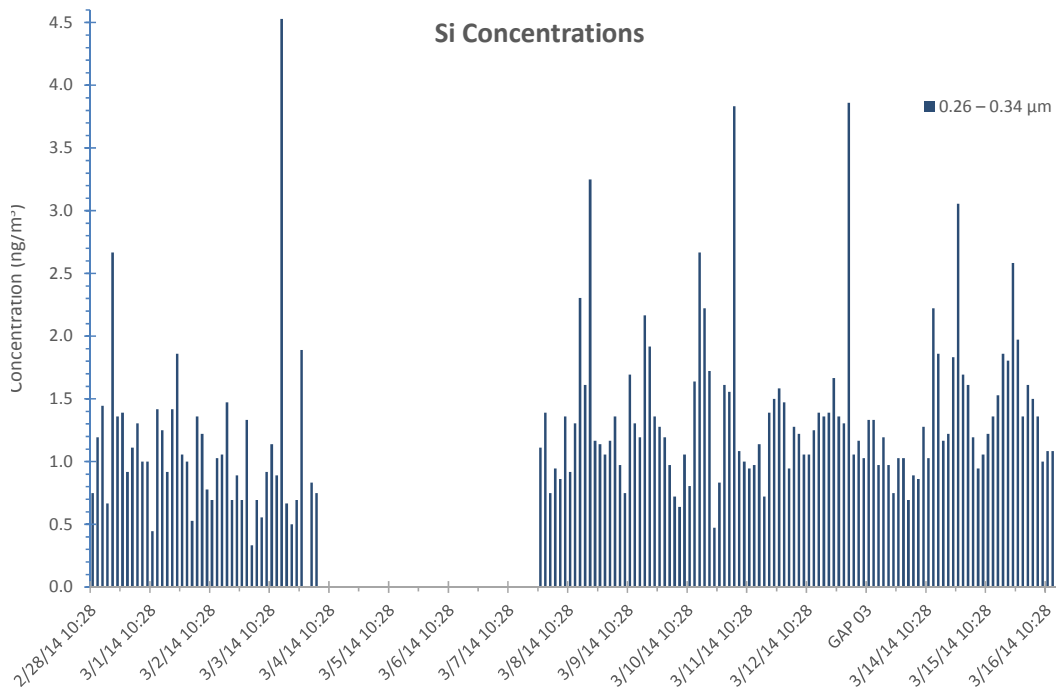


Fig. C-122 CaPh 32 DRUM: Si mass stage 7

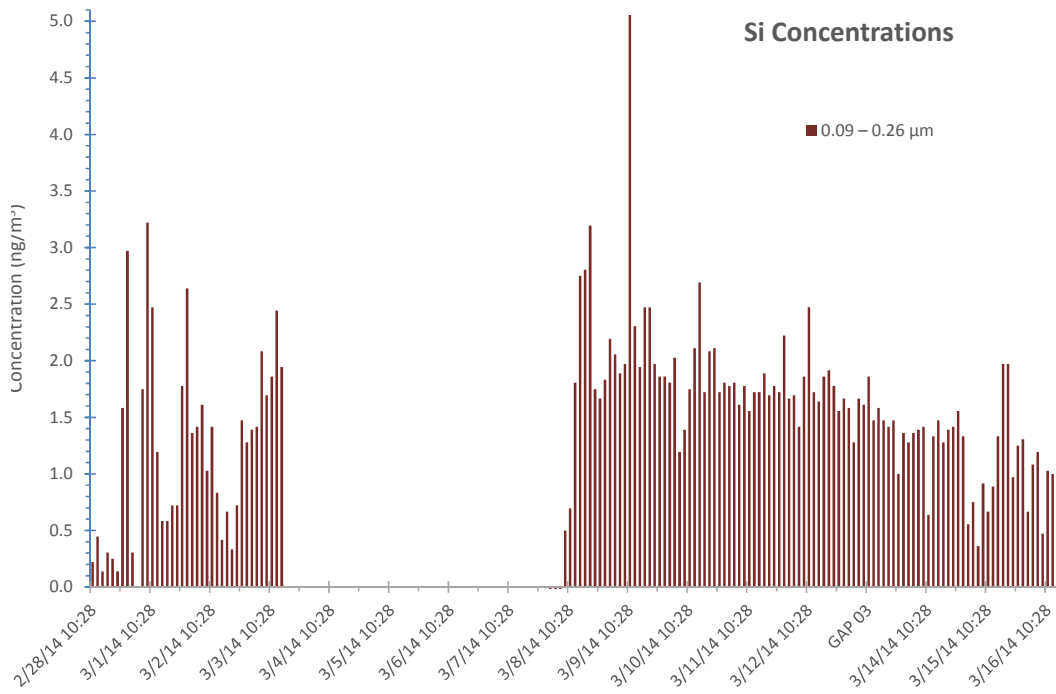


Fig. C-123 CaPh 32 DRUM: Si mass stage 8

C-4.5 Phosphorous (P)

There was no P detected on the DRUM strips. This was true for both the CaPh32 and CaPh34 strips.

C-4.6 Sulfur (S)

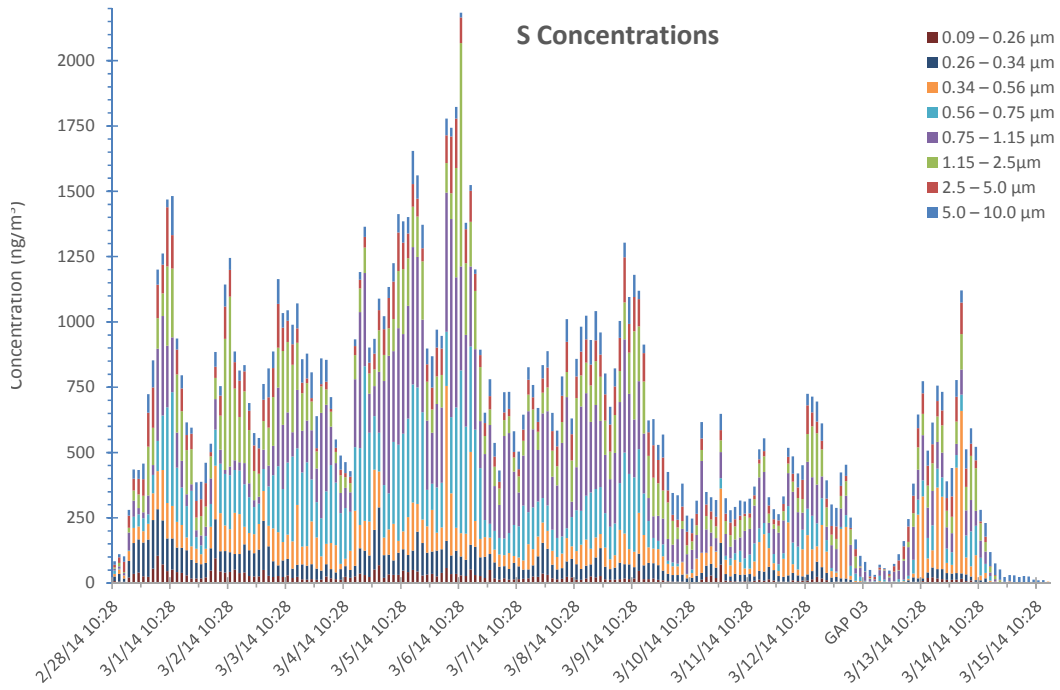


Fig. C-124 CaPh 34 DRUM: S mass all stages

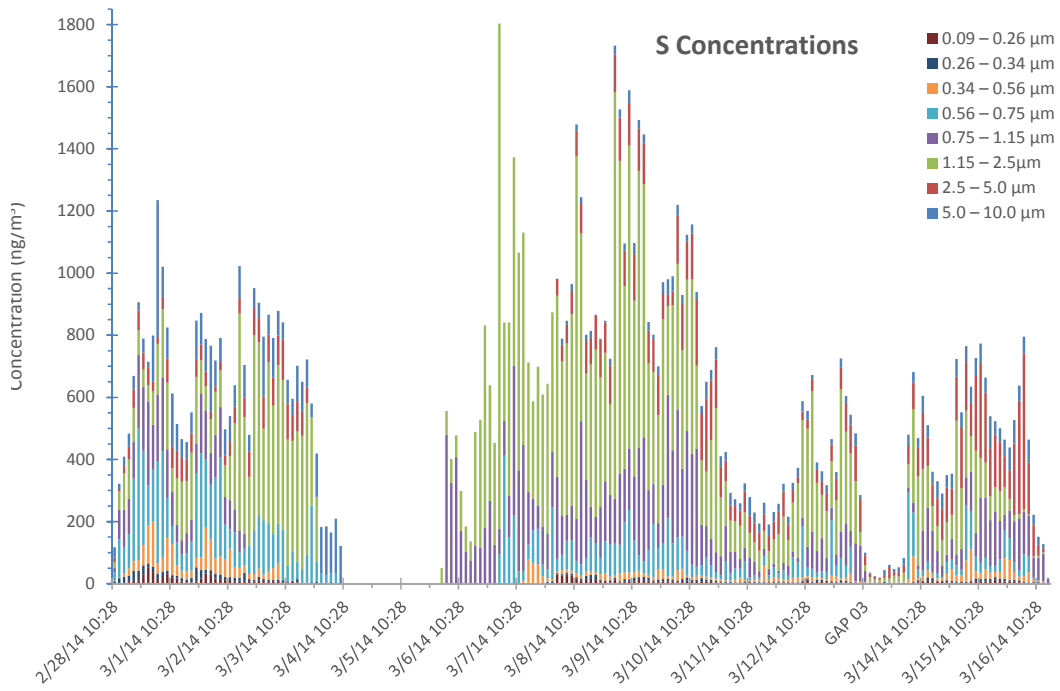
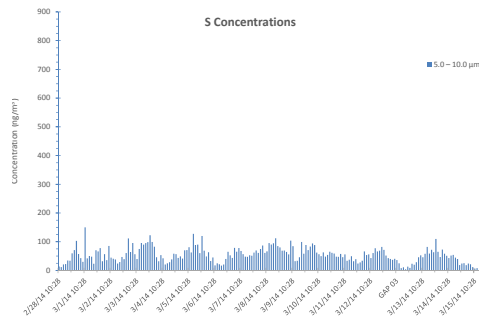
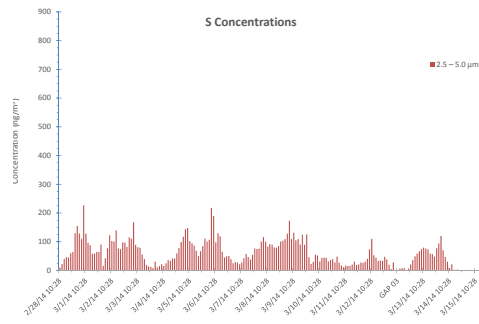


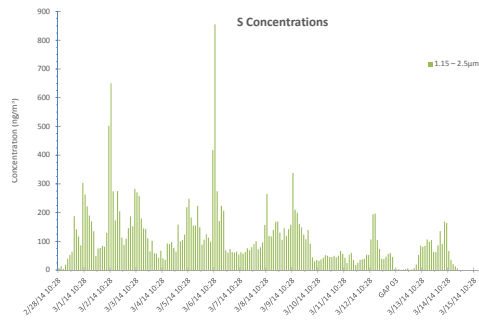
Fig. C-125 CaPh 32 DRUM: S mass all stages



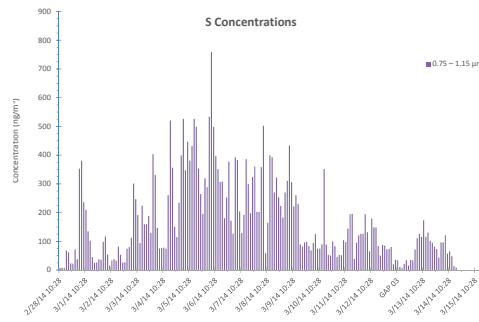
a) XRF stage 1 (5–10 μm) mass



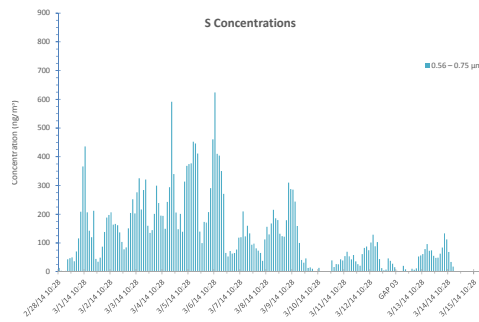
b) XRF stage 2 (2.5–5.0 μm) mass



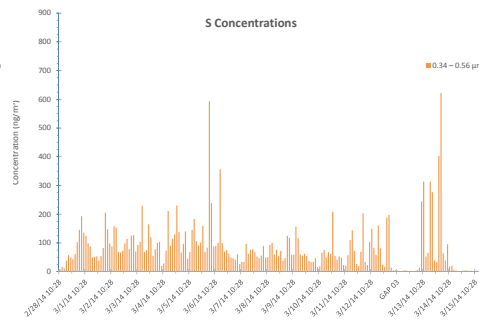
c) XRF stage 3 (1.15–2.5 μm) mass



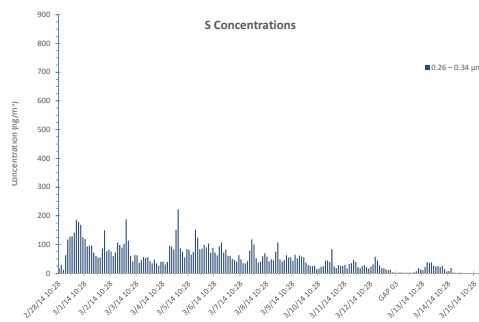
d) XRF stage 4 (0.75–1.15 μm) mass



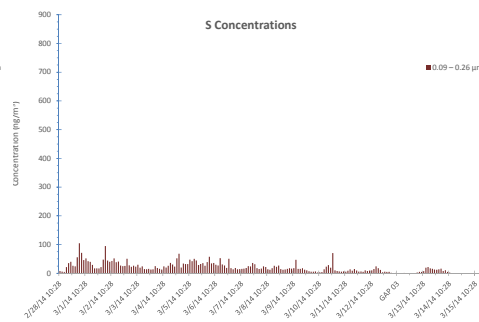
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.34–0.56 μm) mass

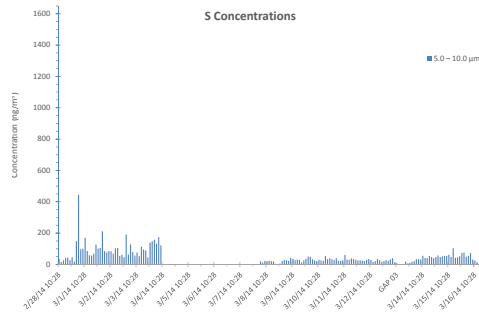


g) XRF stage 7 (0.26–0.34 μm) mass

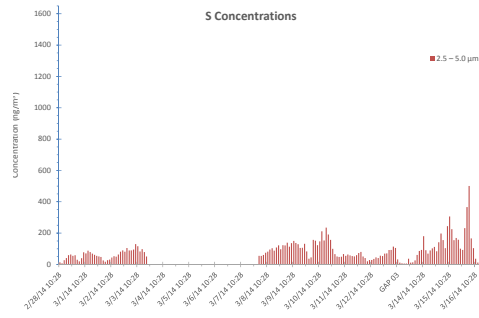


h) XRF stage 8 (0.09–0.26 μm) mass

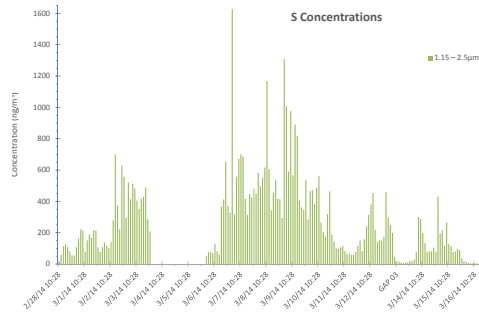
Fig. C-126 CaPh 34 DRUM: XRF mass S; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



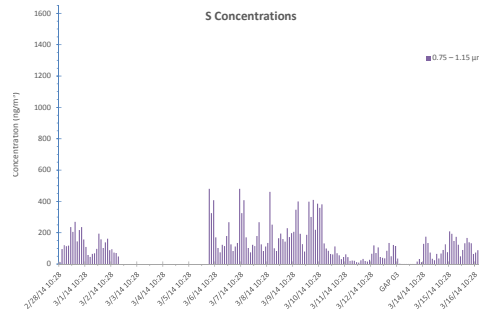
a) XRF stage 1 (5–10 μm) mass



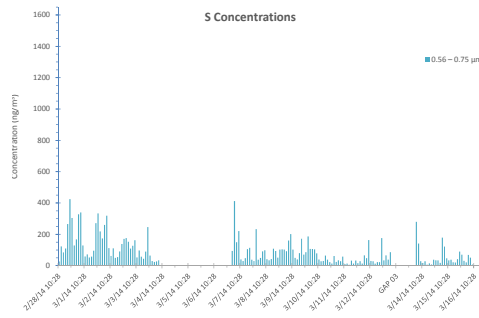
b) XRF stage 2 (2.5–5.0 μm) mass



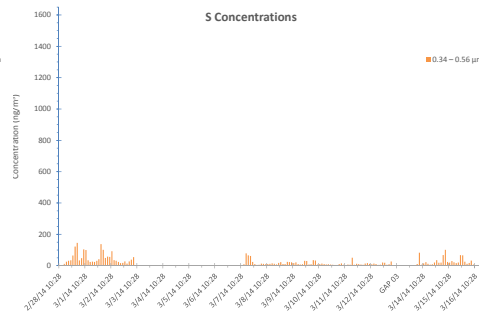
c) XRF stage 3 (1.15–2.5 μm) mass



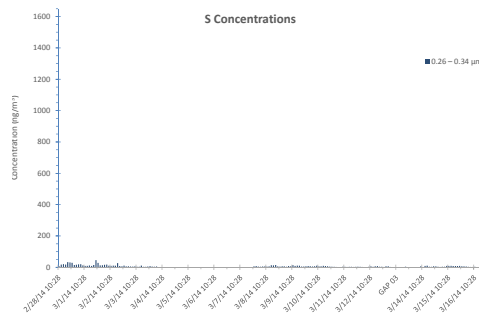
d) XRF stage 4 (0.75–1.15 μm) mass



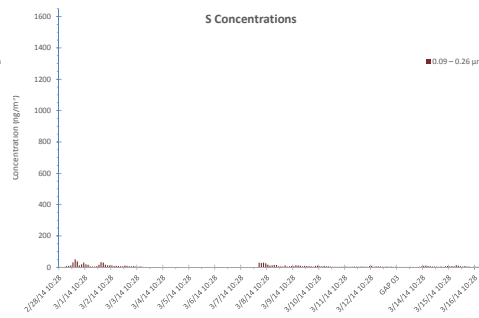
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-127 CaPh 32 DRUM: XRF mass S; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

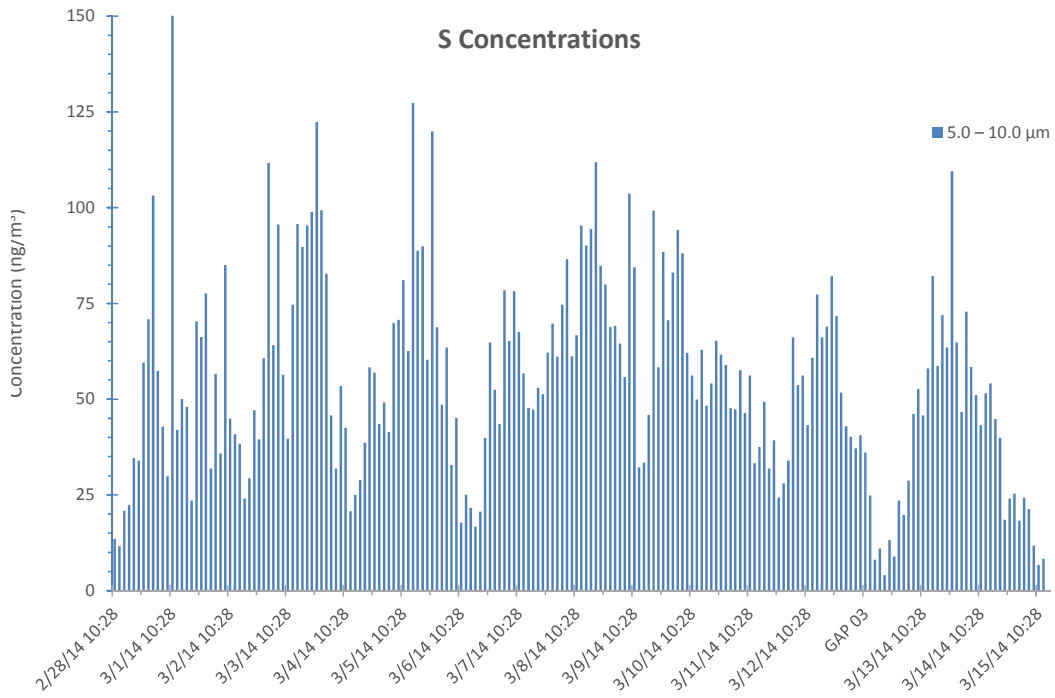


Fig. C-128 CaPh 34 DRUM: S mass stage 1

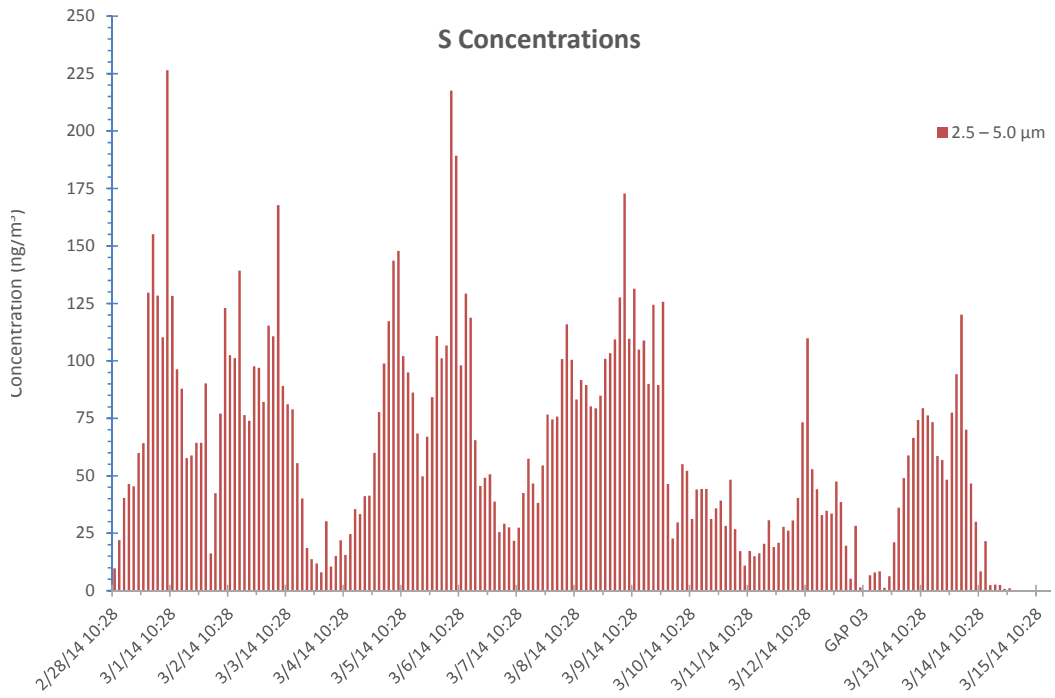


Fig. C-129 CaPh 34 DRUM: S mass stage 2

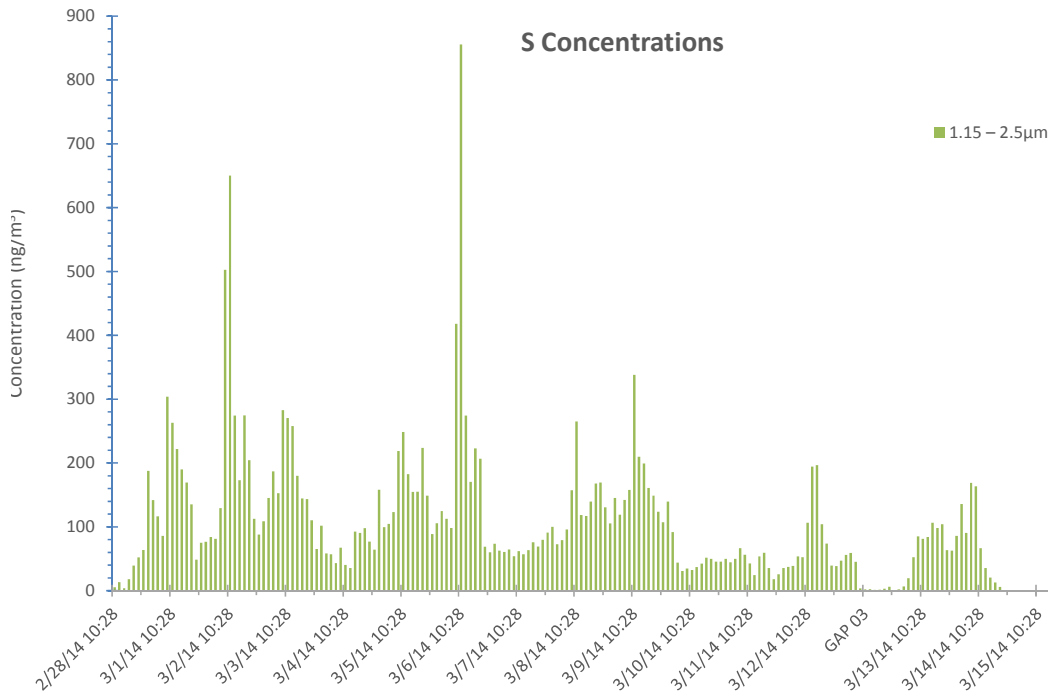


Fig. C-130 CaPh 34 DRUM: S mass stage 3

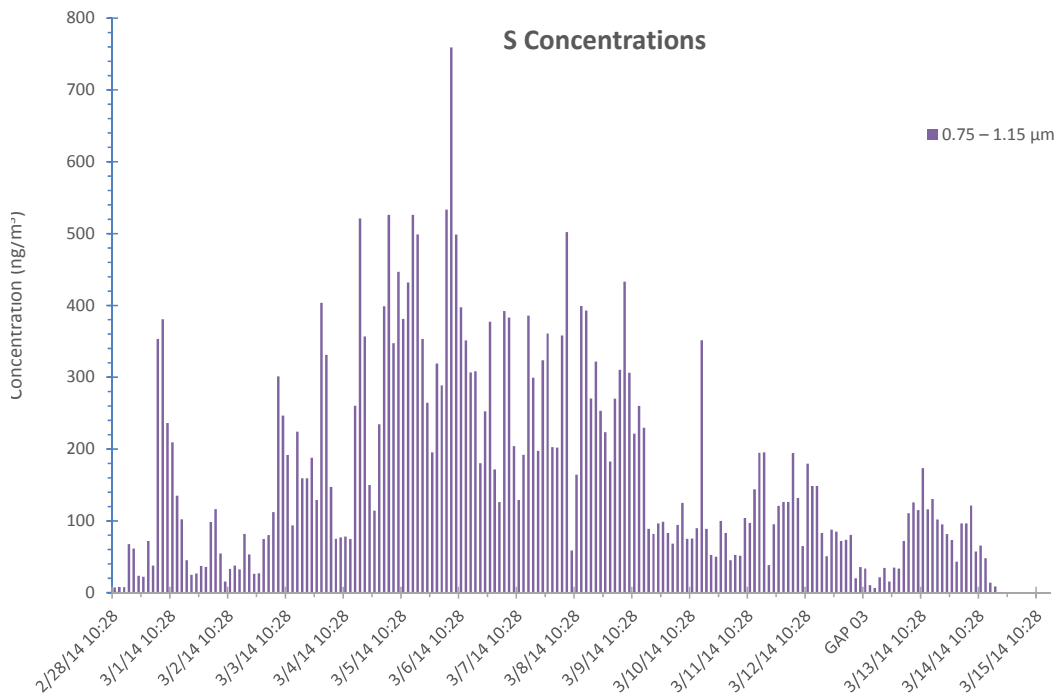


Fig. C-131 CaPh 34 DRUM: S mass stage 4

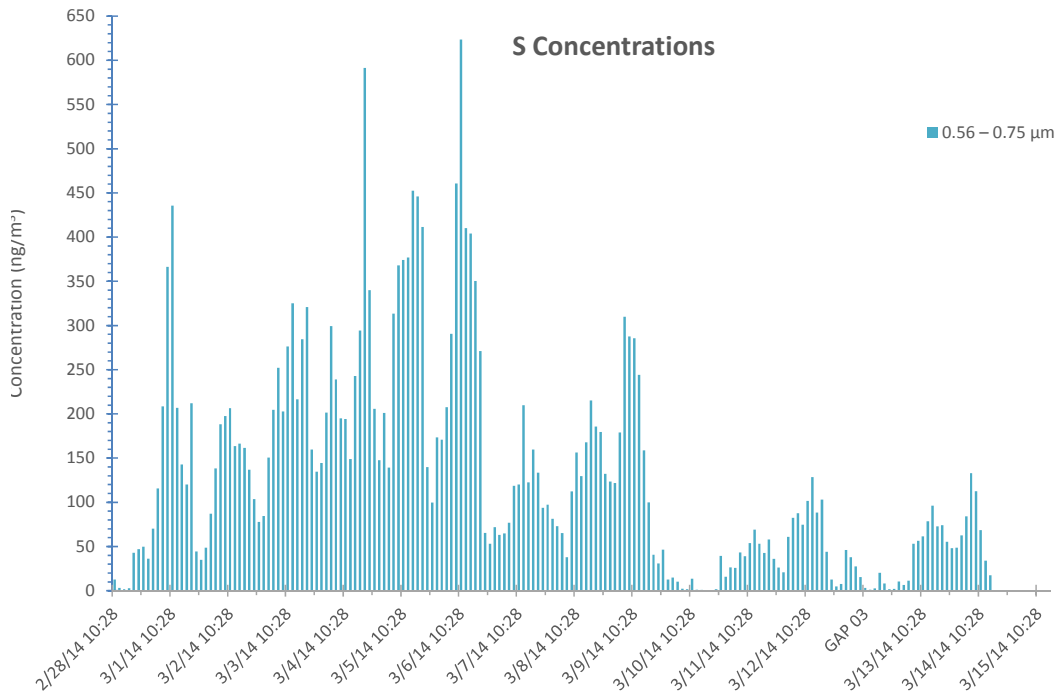


Fig. C-132 CaPh 34 DRUM: S mass stage 5

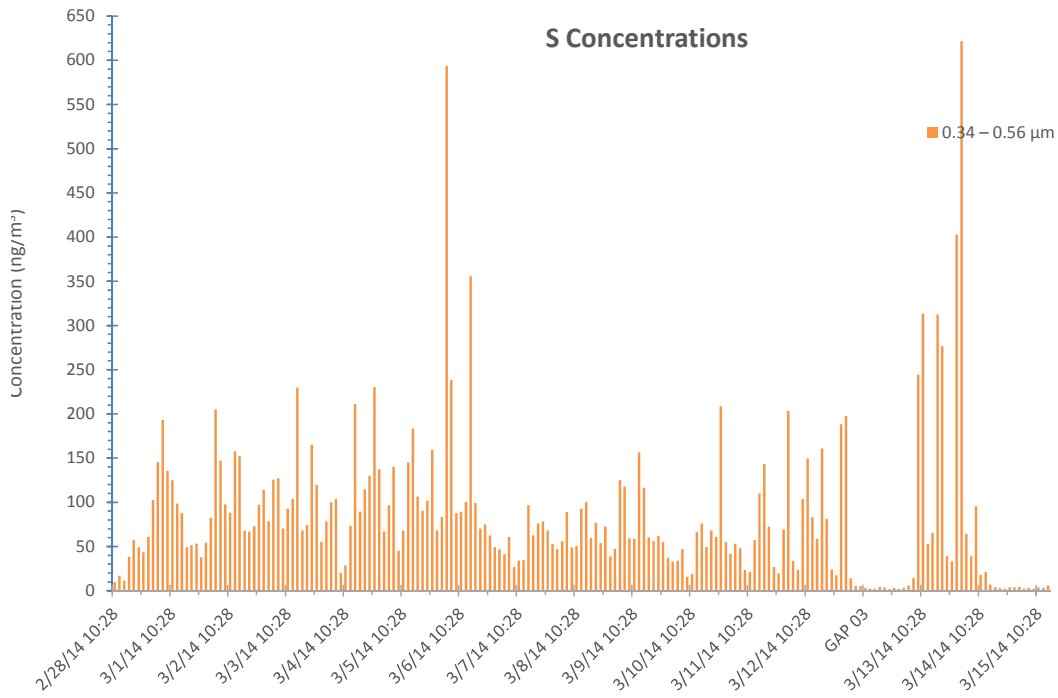


Fig. C-133 CaPh 34 DRUM: S mass stage 6

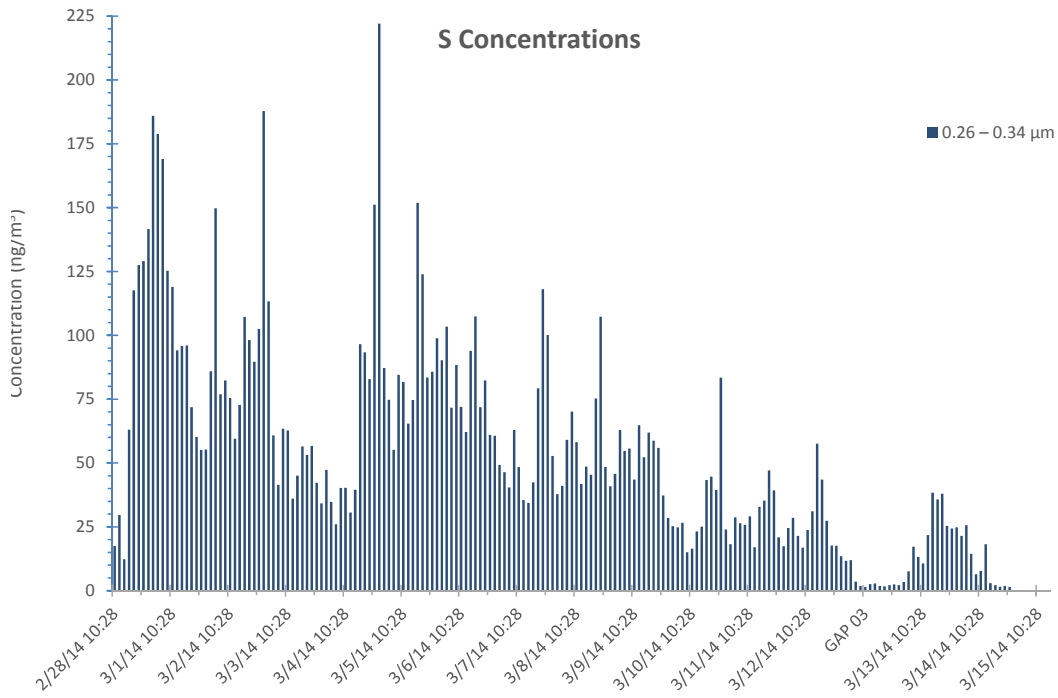


Fig. C-134 CaPh 34 DRUM: S mass stage 7

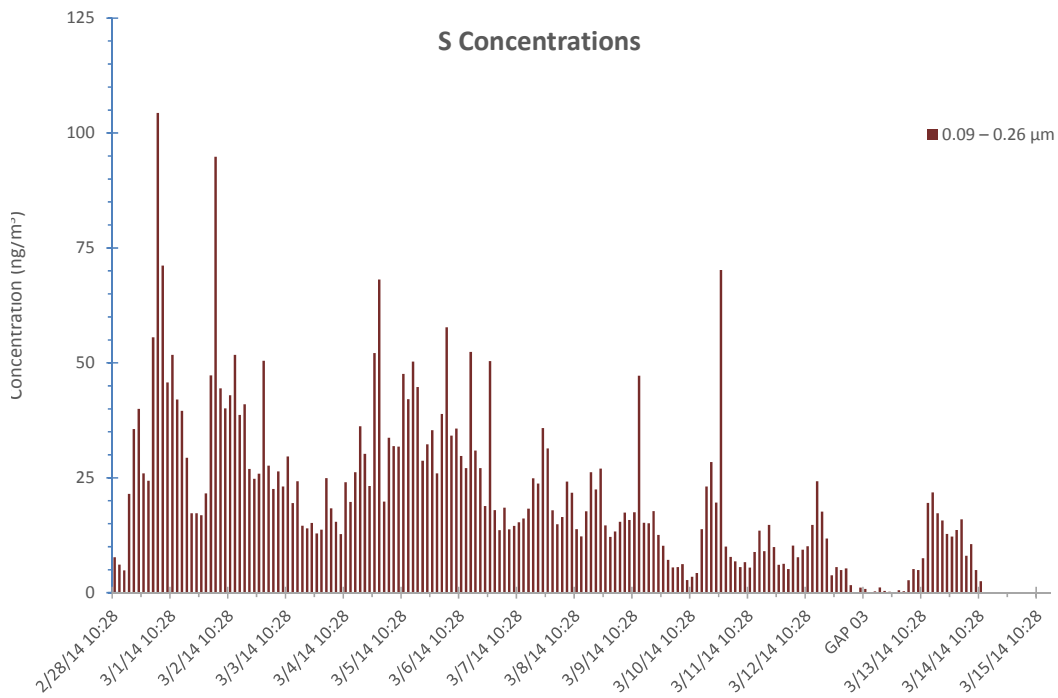


Fig. C-135 CaPh 34 DRUM: S mass stage 8

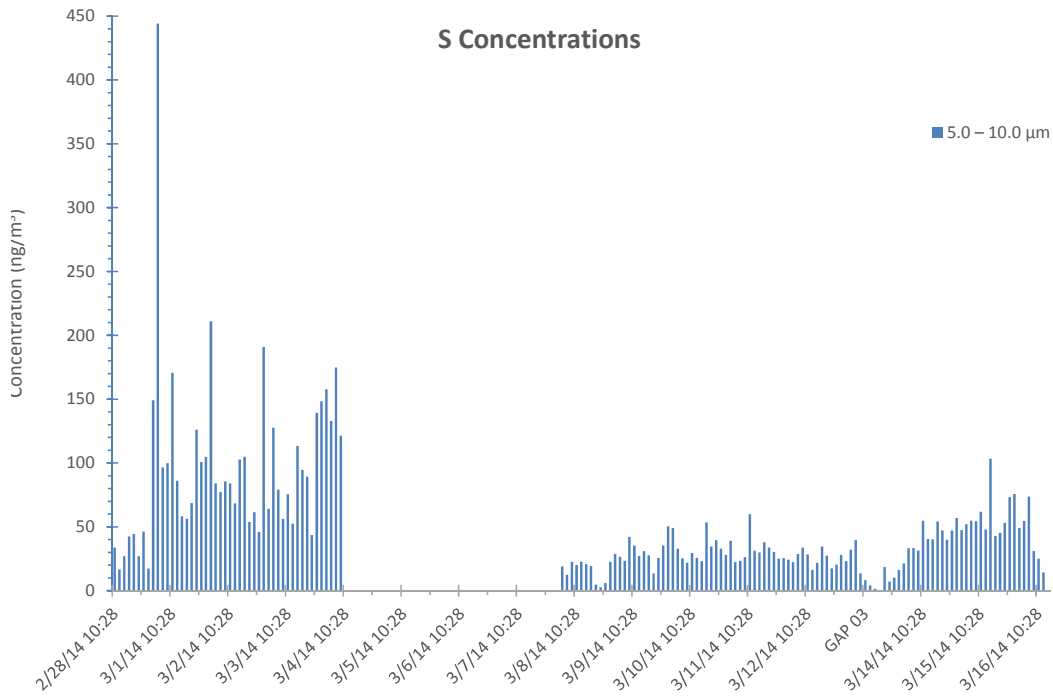


Fig. C-136 CaPh 32 DRUM: S mass stage 1

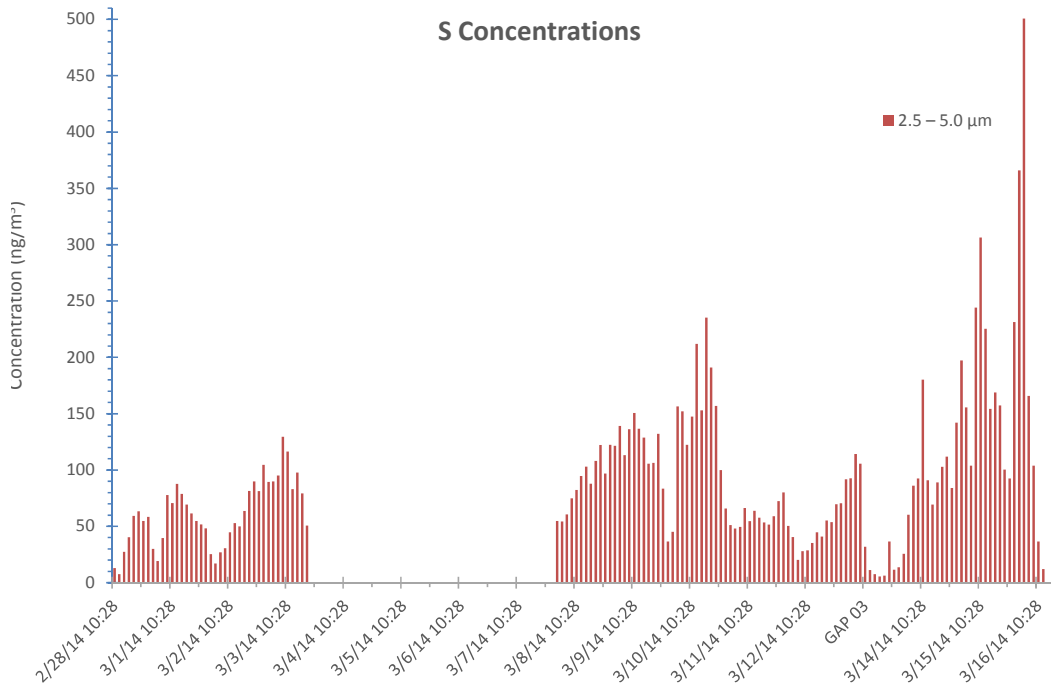


Fig. C-137 CaPh 32 DRUM: S mass stage 2

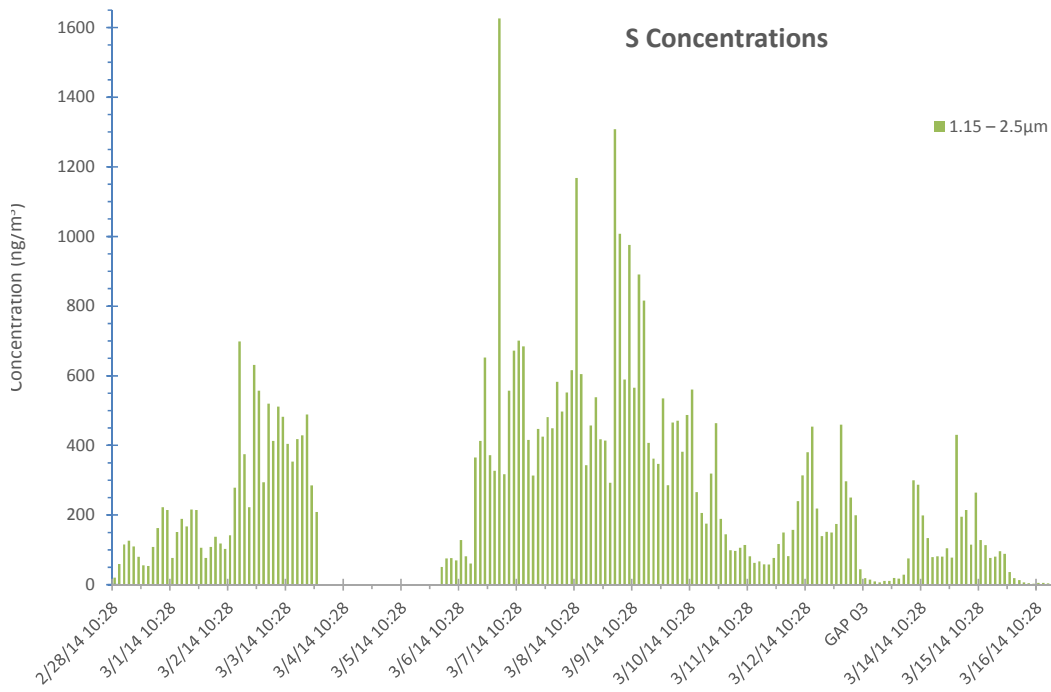


Fig. C-138 CaPh 32 DRUM: S mass stage 3

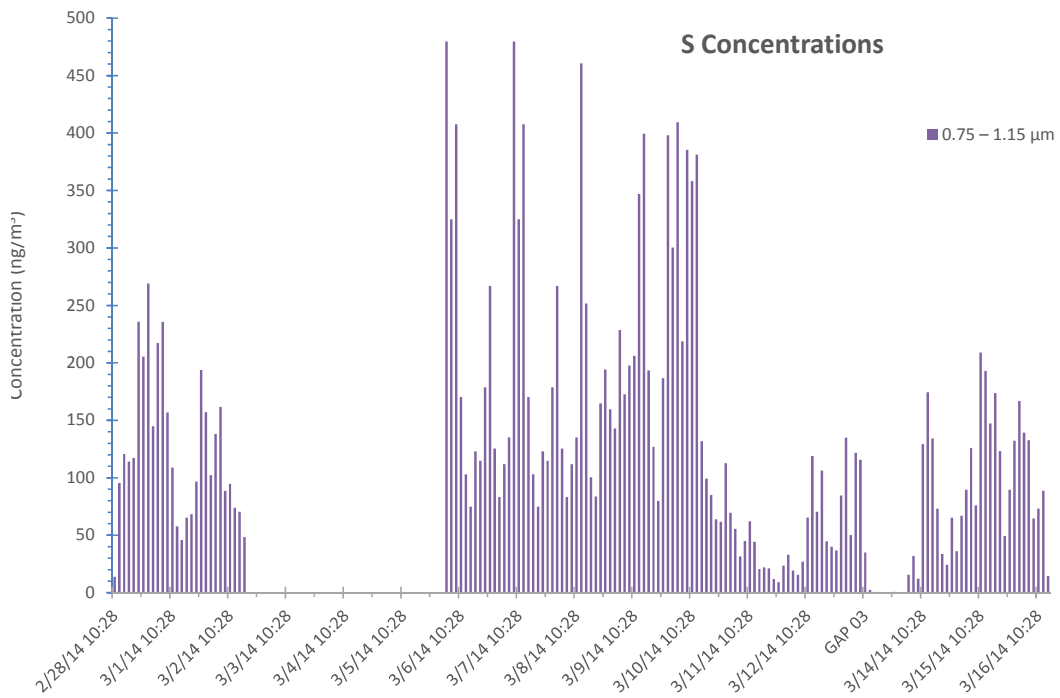


Fig. C-139 CaPh 32 DRUM: S mass stage 4

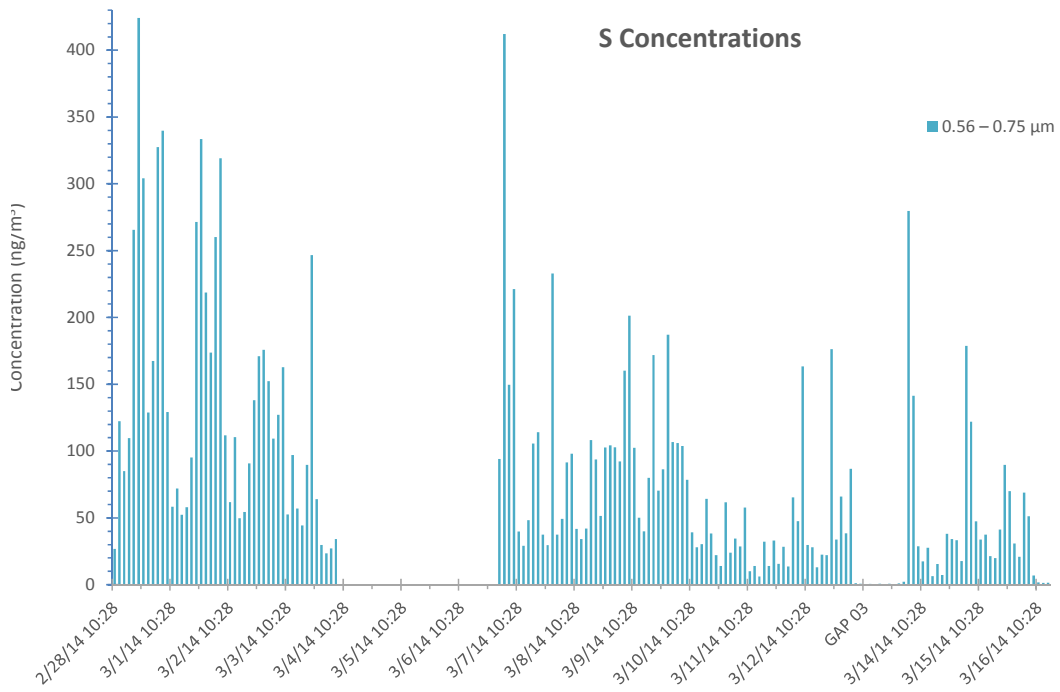


Fig. C-140 CaPh 32 DRUM: S mass stage 5

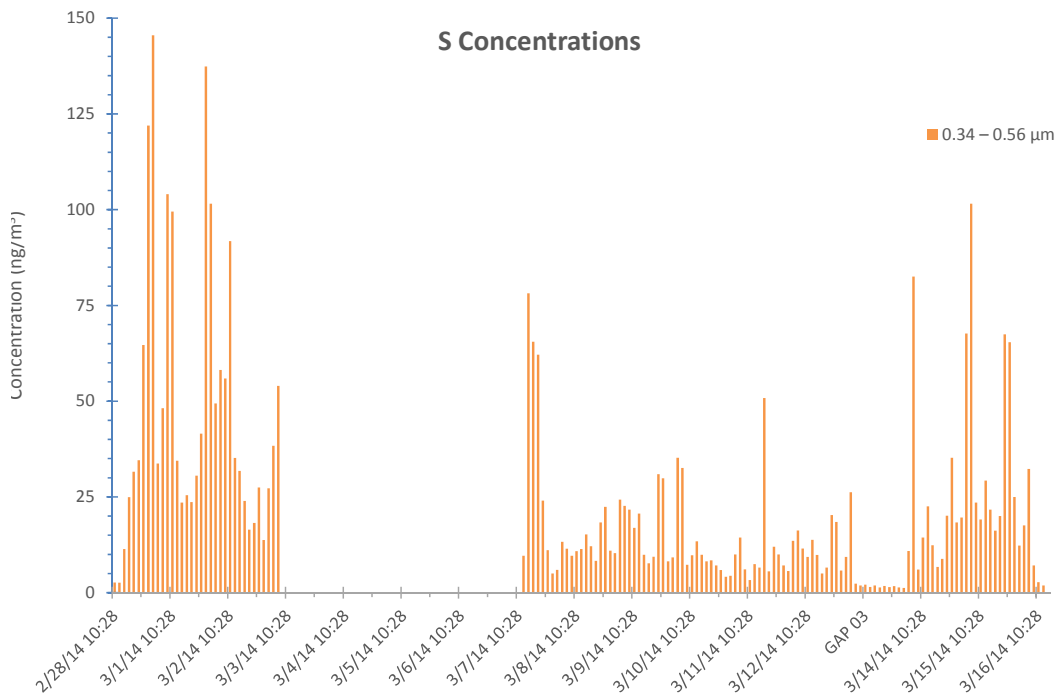


Fig. C-141 CaPh 32 DRUM: S mass stage 6

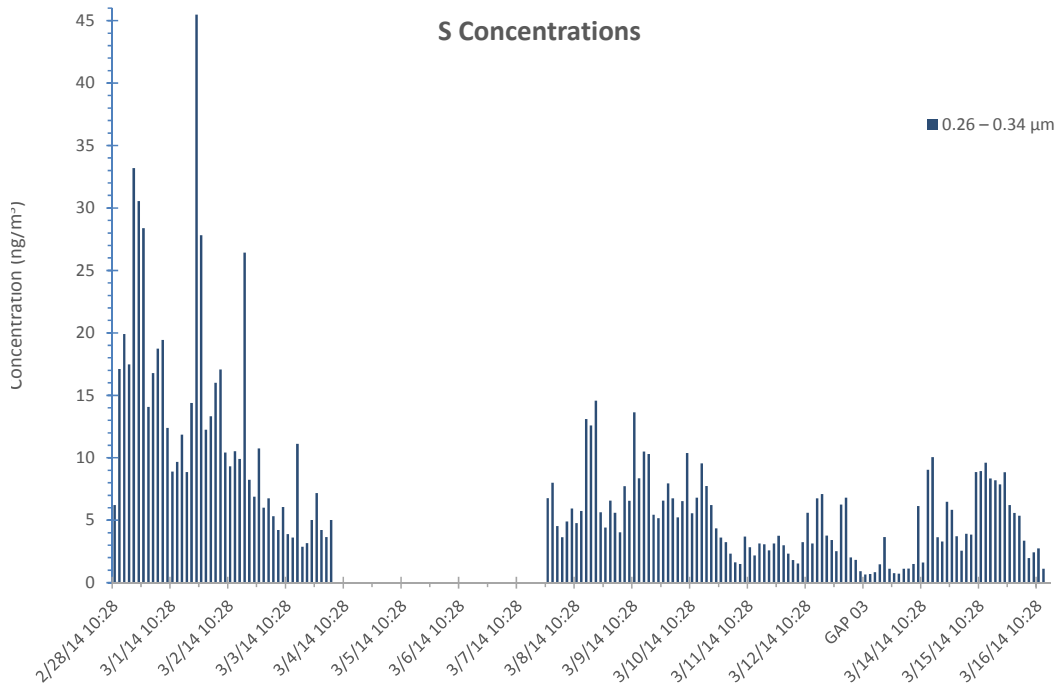


Fig. C-142 CaPh 32 DRUM: S mass stage 7

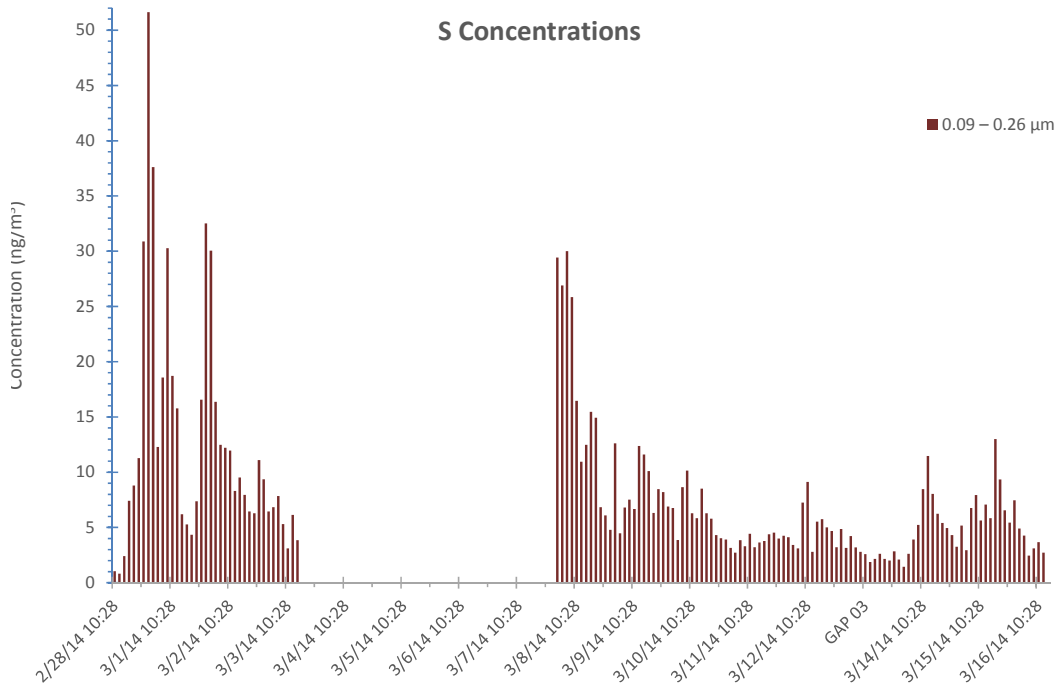


Fig. C-143 CaPh 32 DRUM: S mass stage 8

C-4.7 Chlorine (Cl)

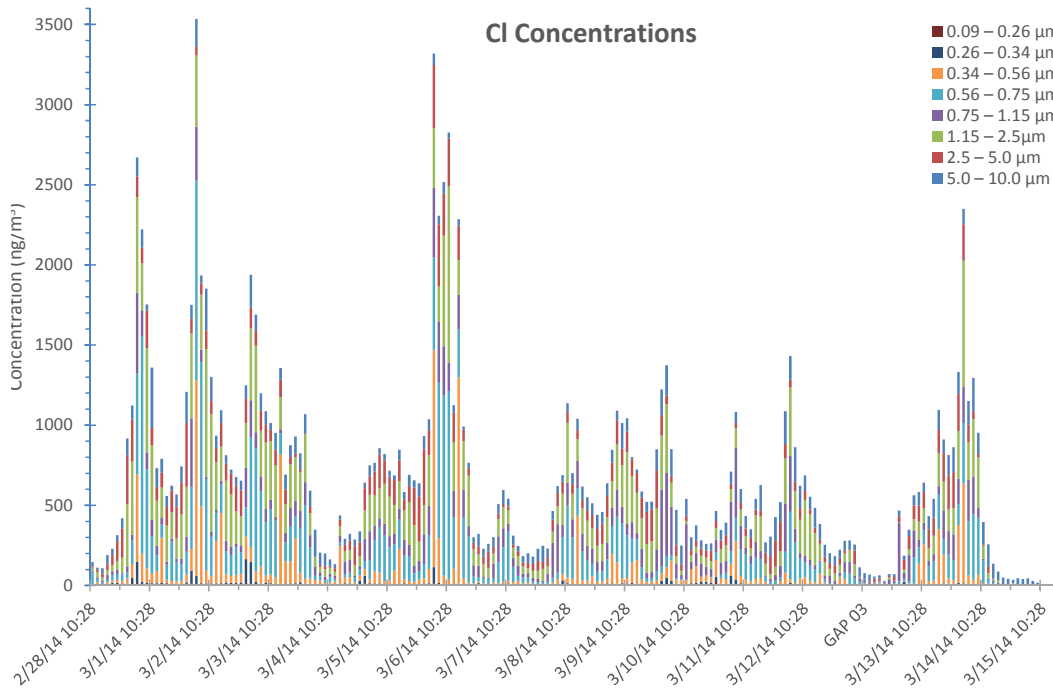


Fig. C-144 CaPh 34 DRUM: Cl mass all stages

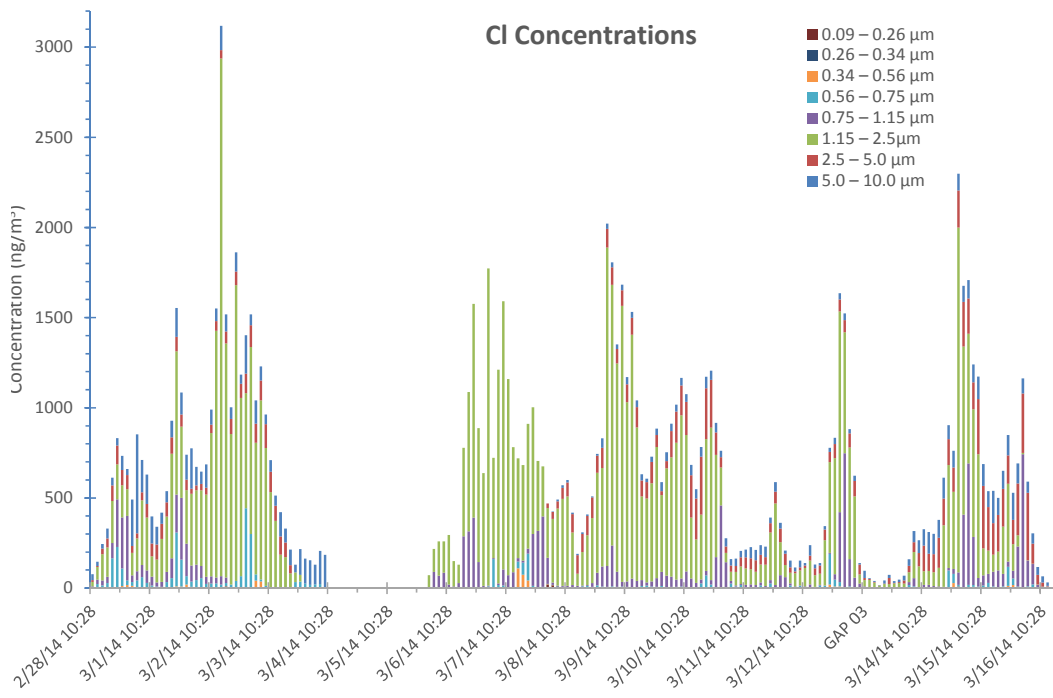


Fig. C-145 CaPh 32 DRUM: Cl mass all stages

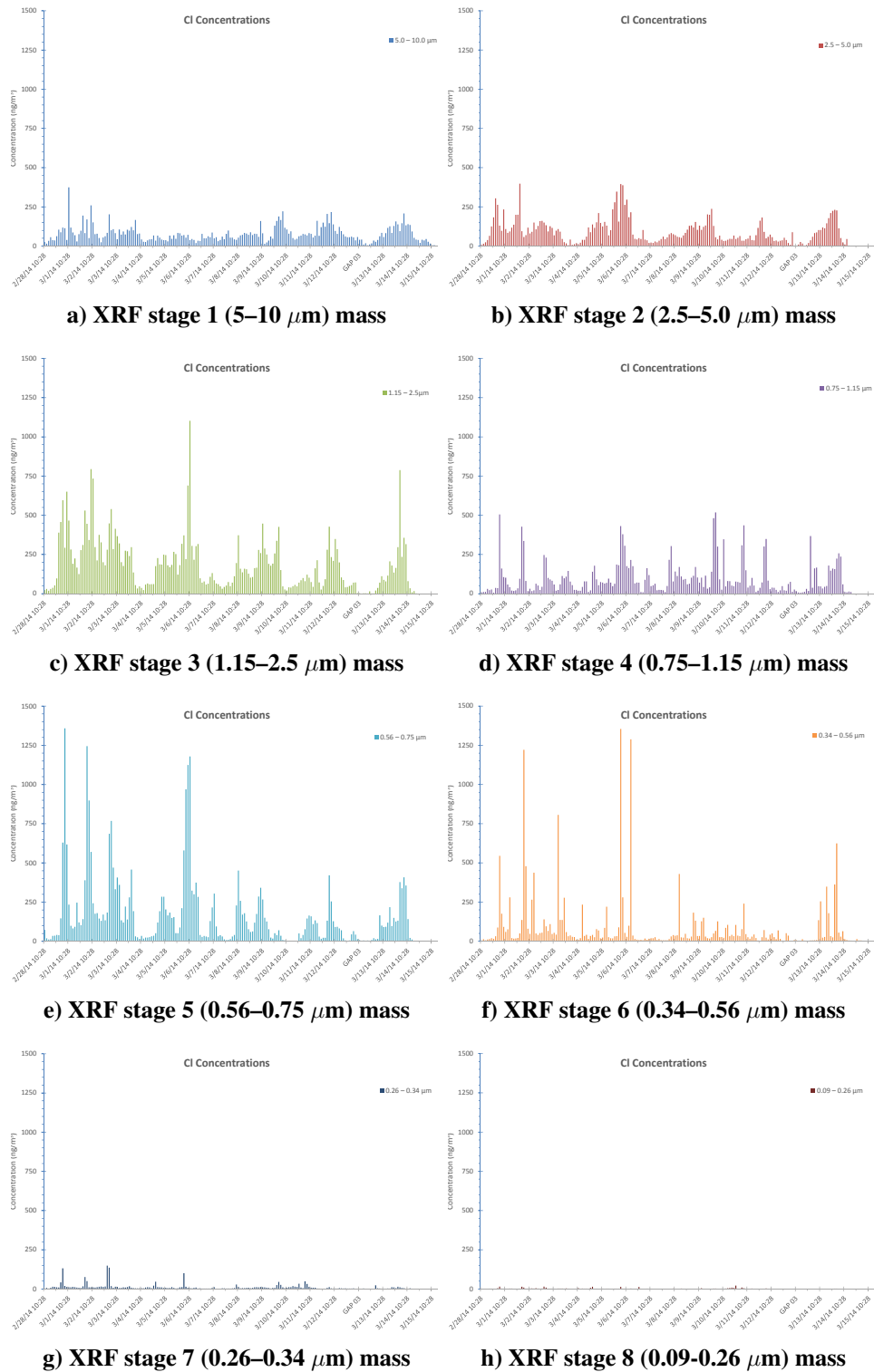
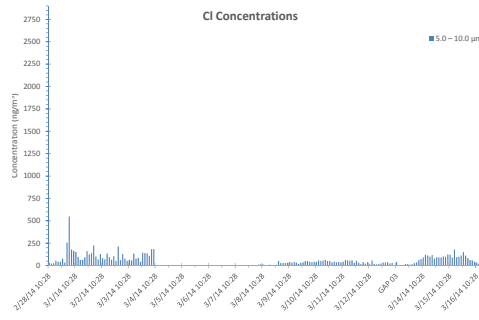
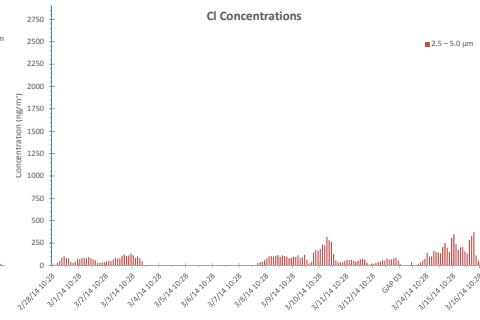


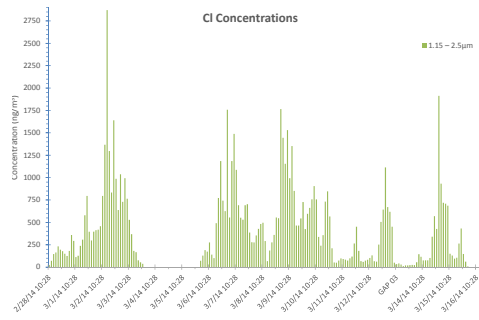
Fig. C-146 CaPh 34 DRUM: XRF mass Cl; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



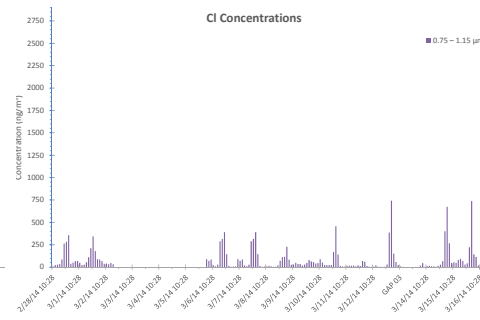
a) XRF stage 1 (5–10 μm) mass



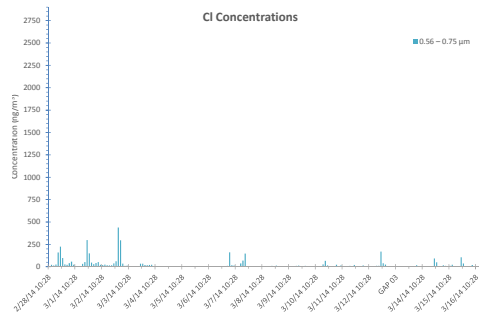
b) XRF stage 2 (2.5–5.0 μm) mass



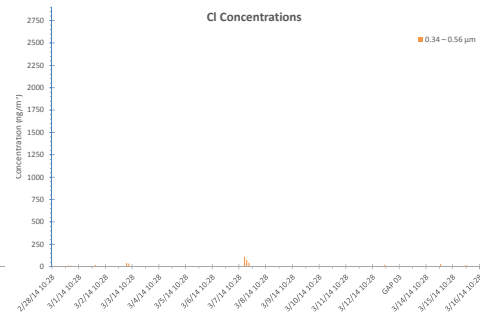
c) XRF stage 3 (1.15–2.5 μm) mass



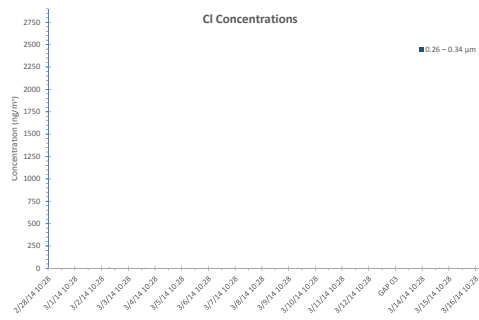
d) XRF stage 4 (0.75–1.15 μm) mass



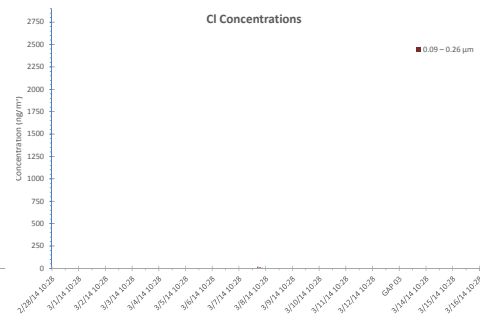
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-147 CaPh 32 DRUM: XRF mass Cl; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

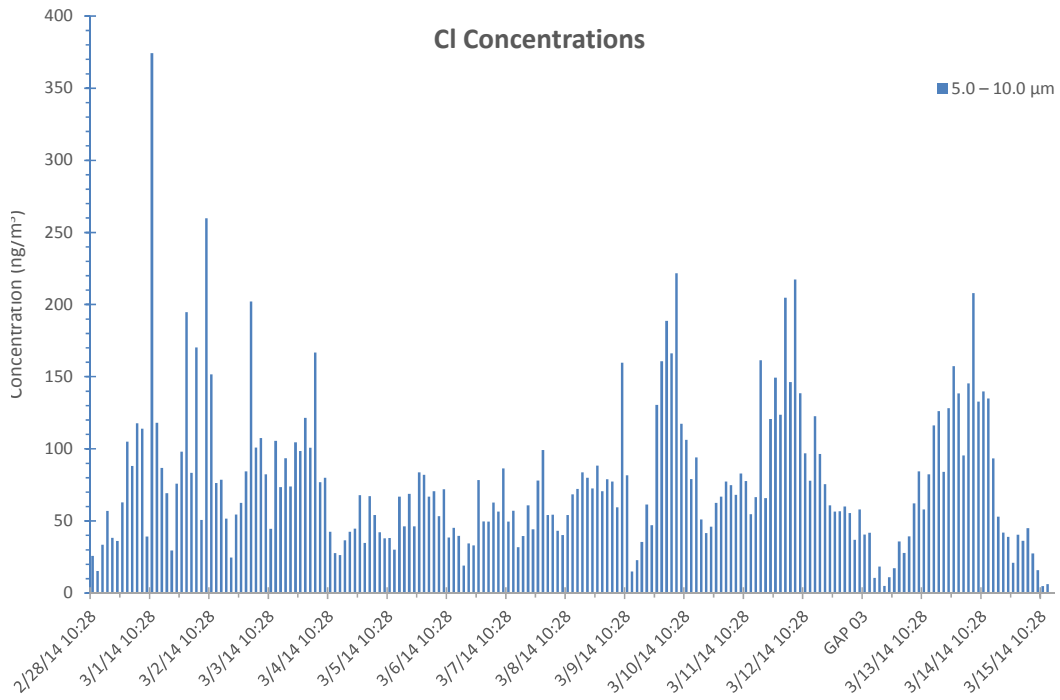


Fig. C-148 CaPh 34 DRUM: Cl mass stage 1

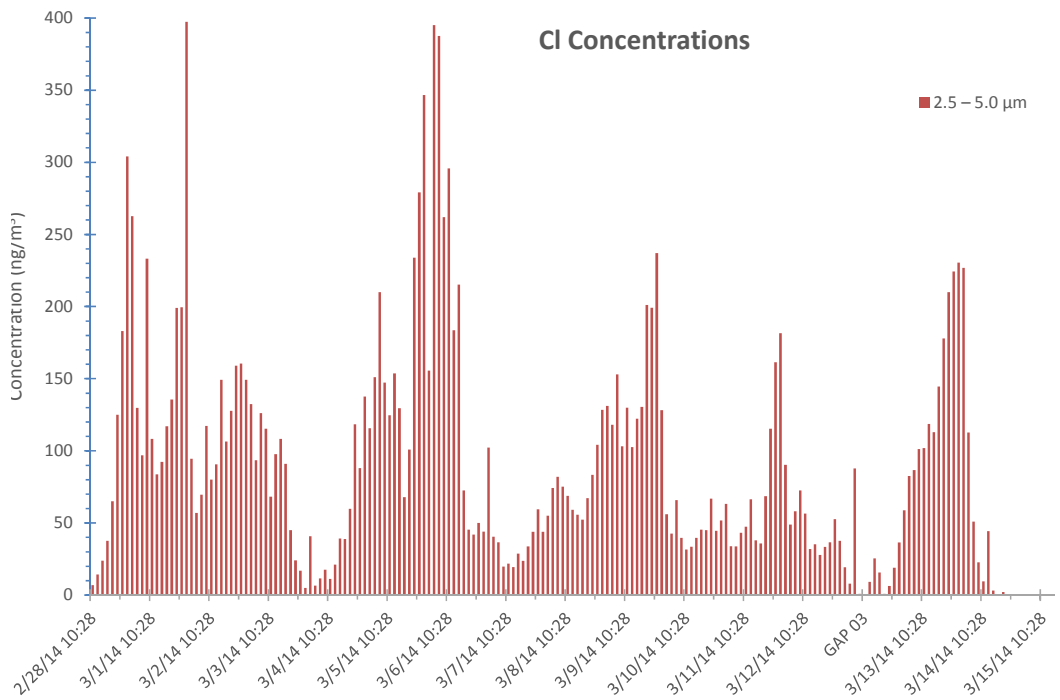


Fig. C-149 CaPh 34 DRUM: Cl mass stage 2

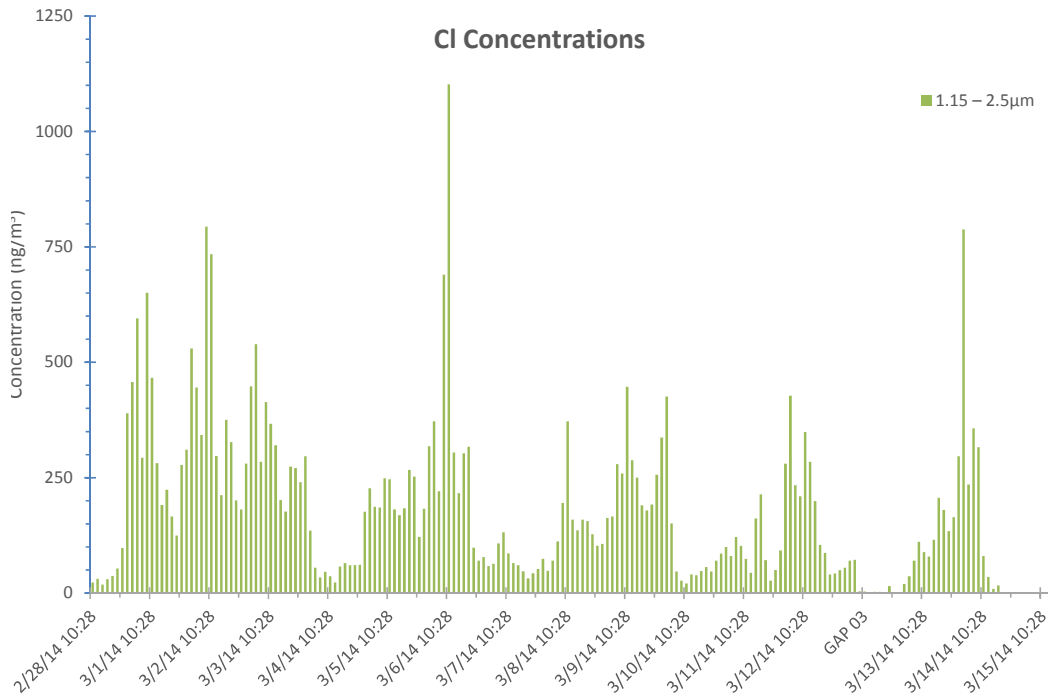


Fig. C-150 CaPh 34 DRUM: CI mass stage 3

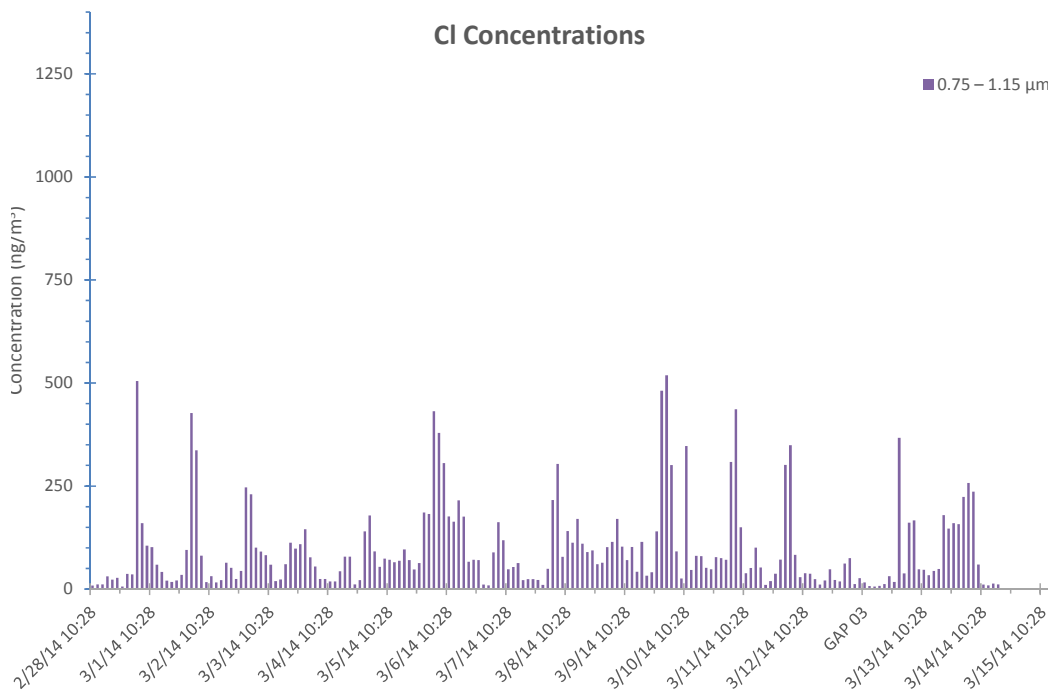


Fig. C-151 CaPh 34 DRUM: CI mass stage 4

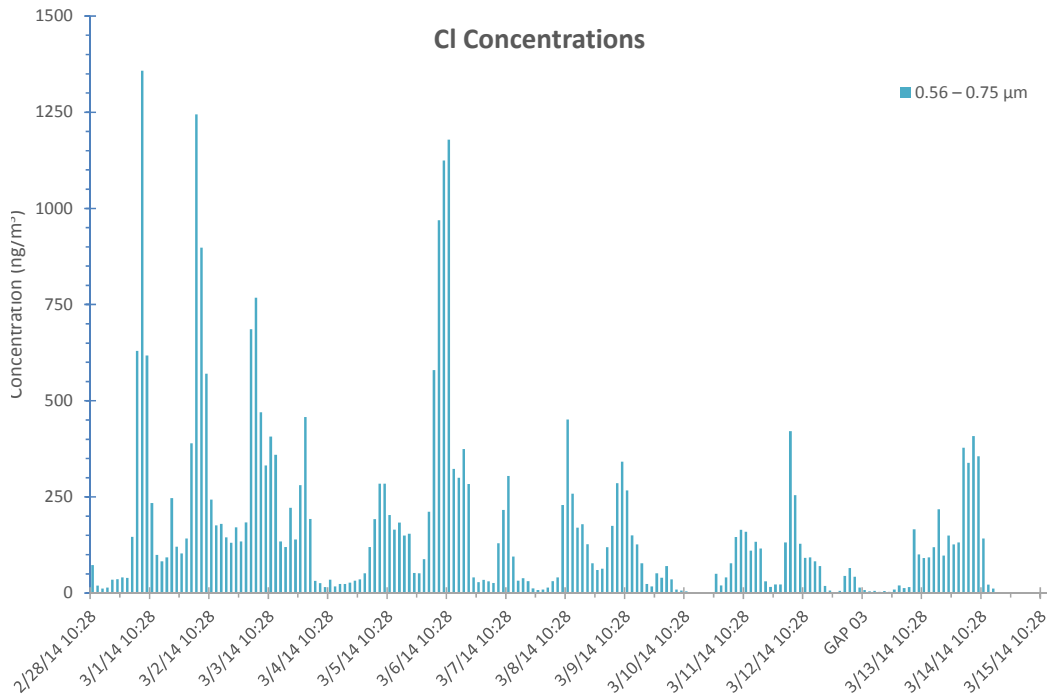


Fig. C-152 CaPh 34 DRUM: CI mass stage 5

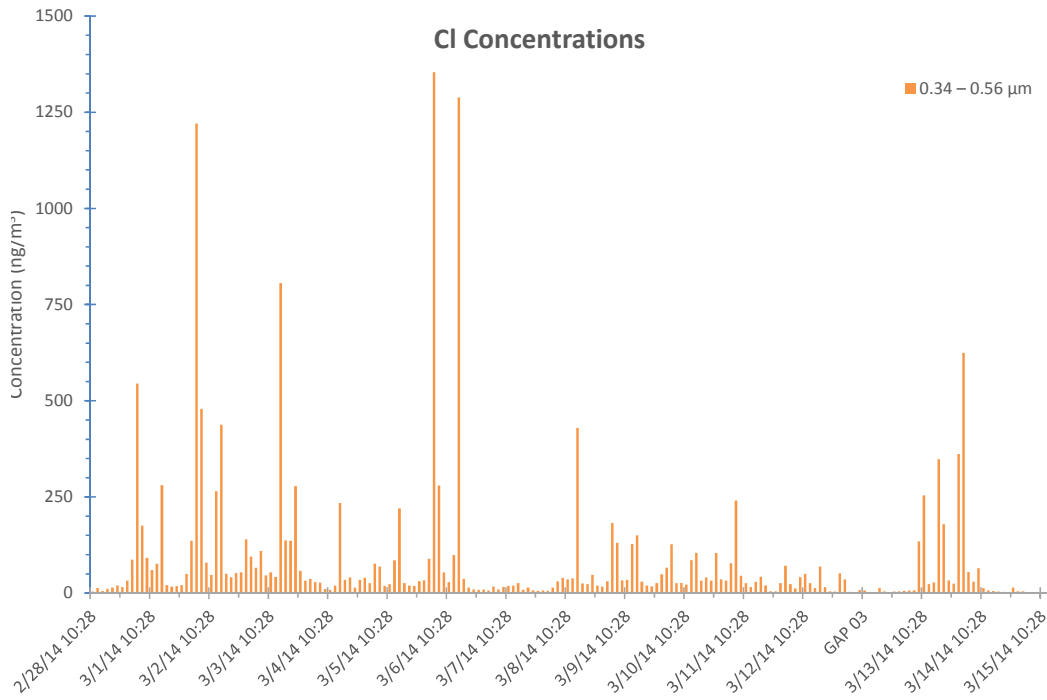


Fig. C-153 CaPh 34 DRUM: CI mass stage 6

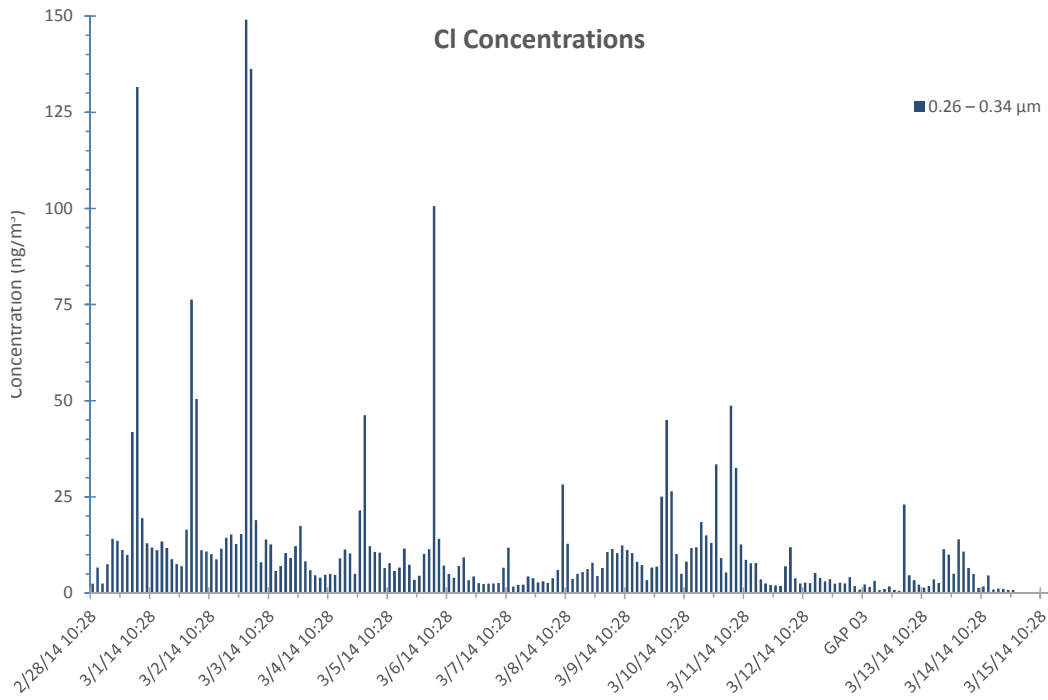


Fig. C-154 CaPh 34 DRUM: Cl mass stage 7

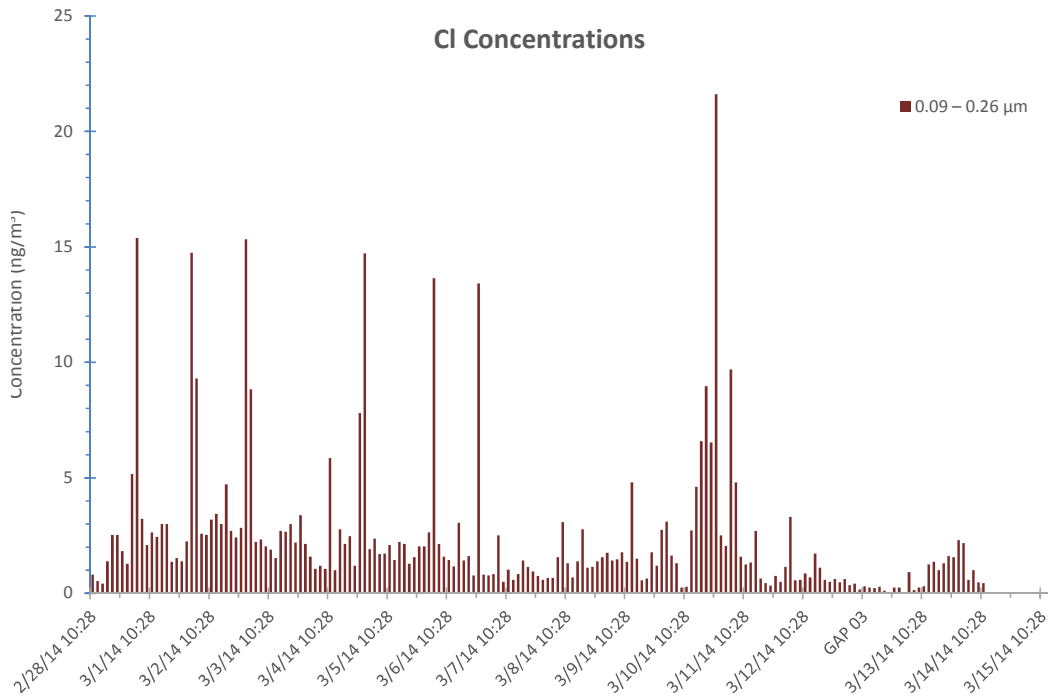


Fig. C-155 CaPh 34 DRUM: Cl mass stage 8

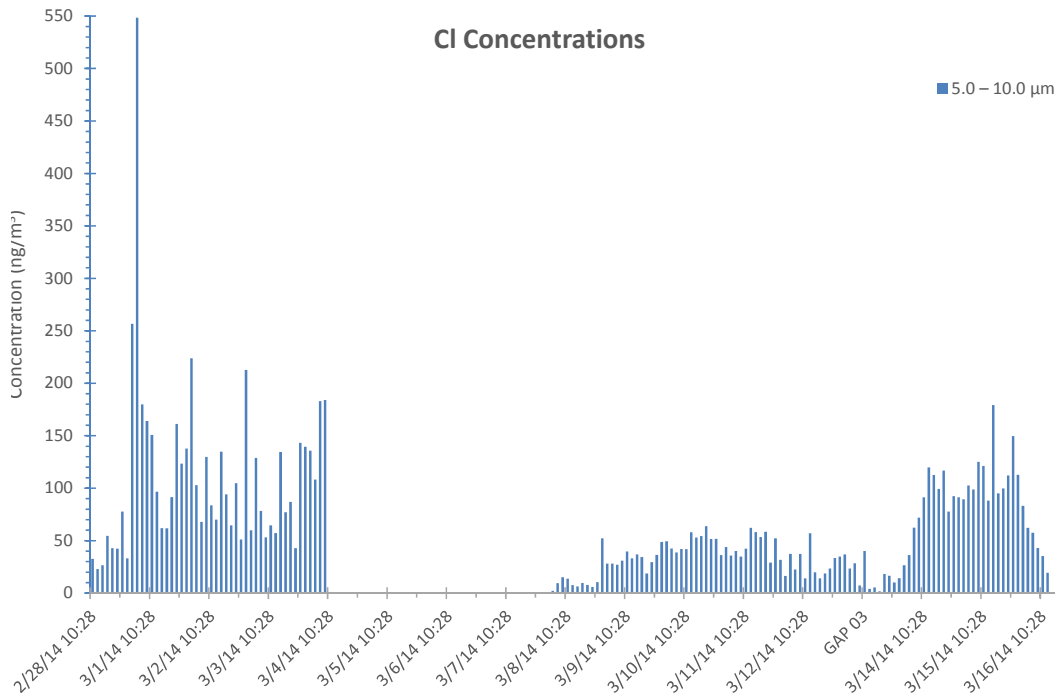


Fig. C-156 CaPh 32 DRUM: Cl mass stage 1

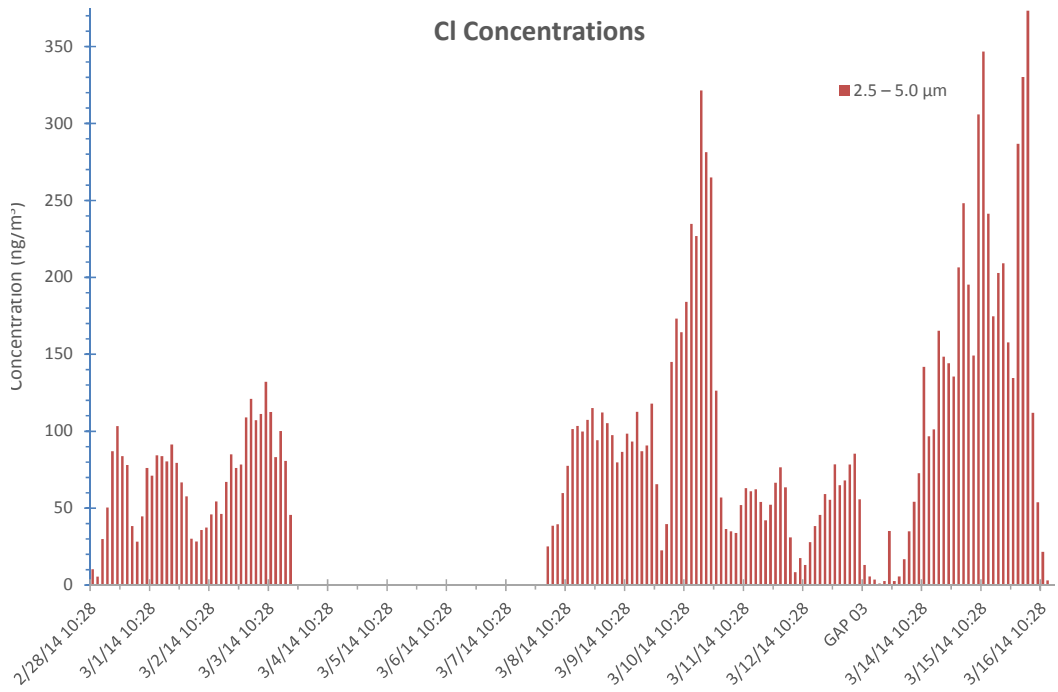


Fig. C-157 CaPh 32 DRUM: Cl mass stage 2

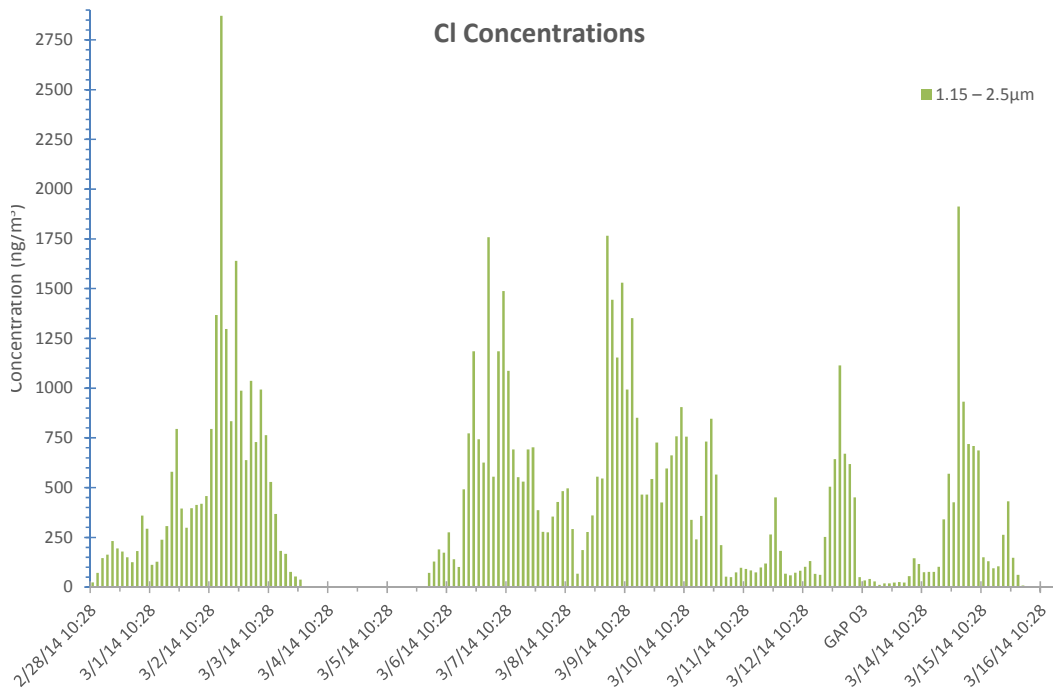


Fig. C-158 CaPh 32 DRUM: CI mass stage 3

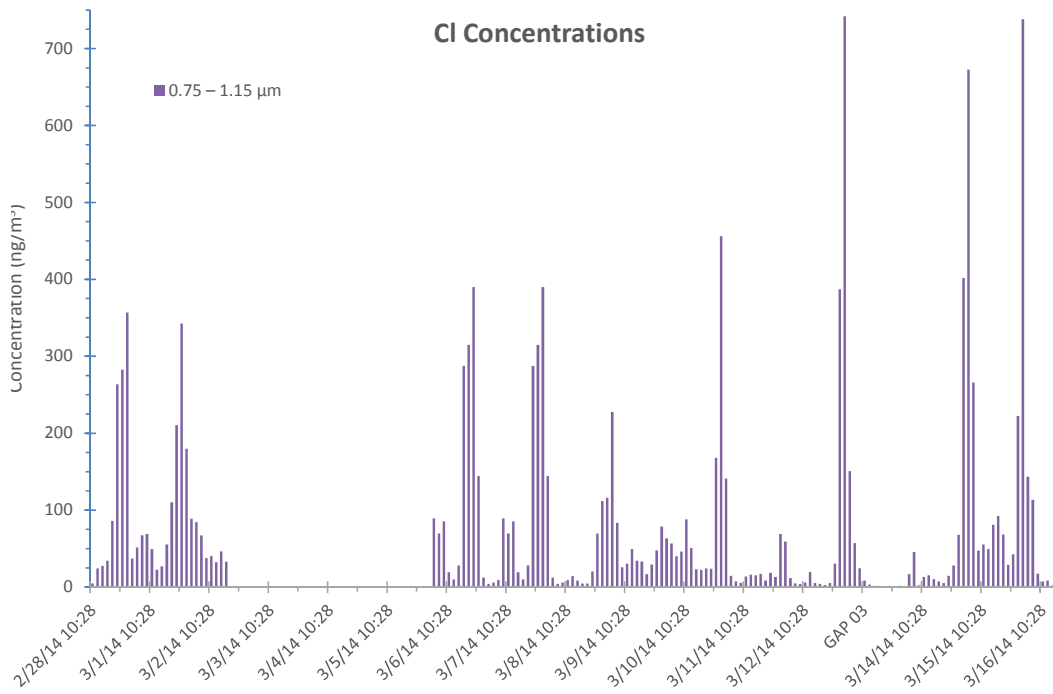


Fig. C-159 CaPh 32 DRUM: CI mass stage 4

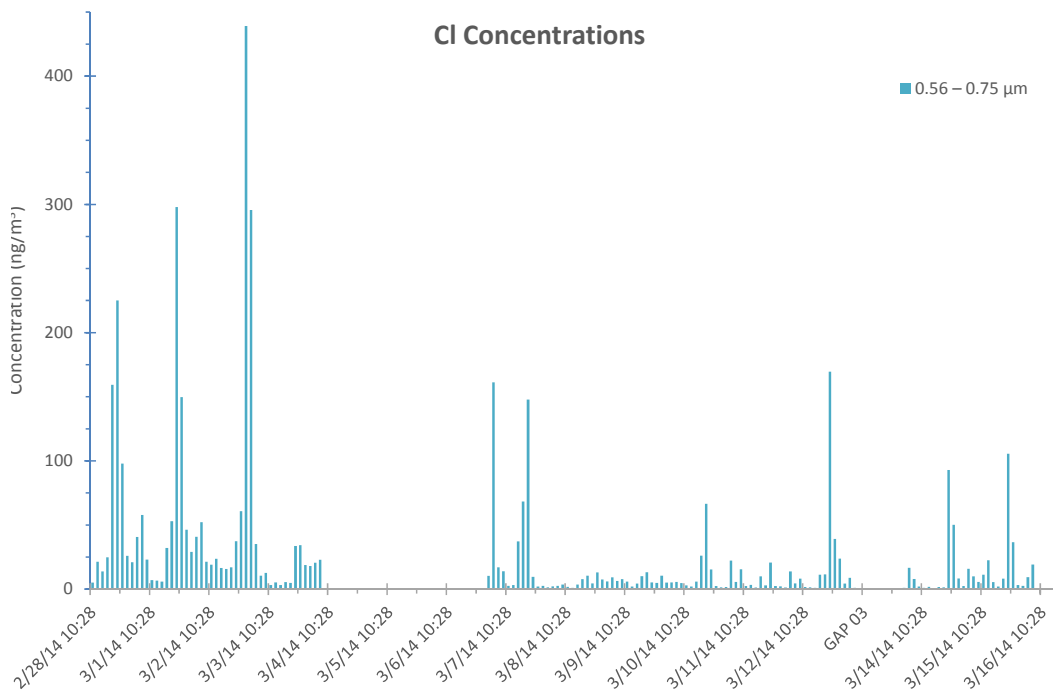


Fig. C-160 CaPh 32 DRUM: Cl mass stage 5

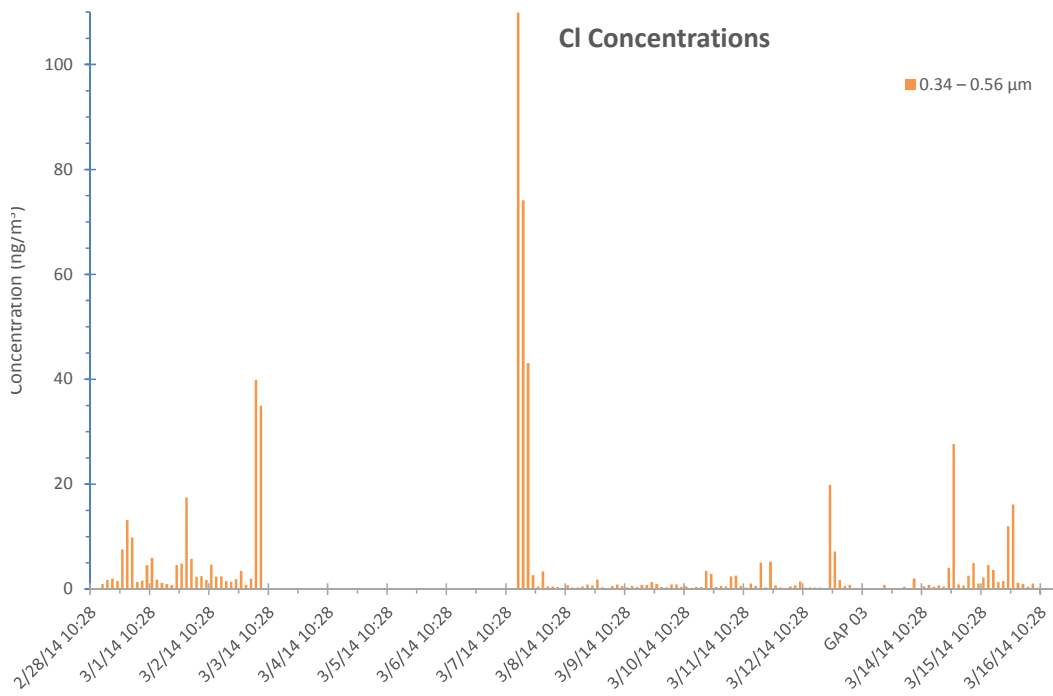


Fig. C-161 CaPh 32 DRUM: Cl mass stage 6

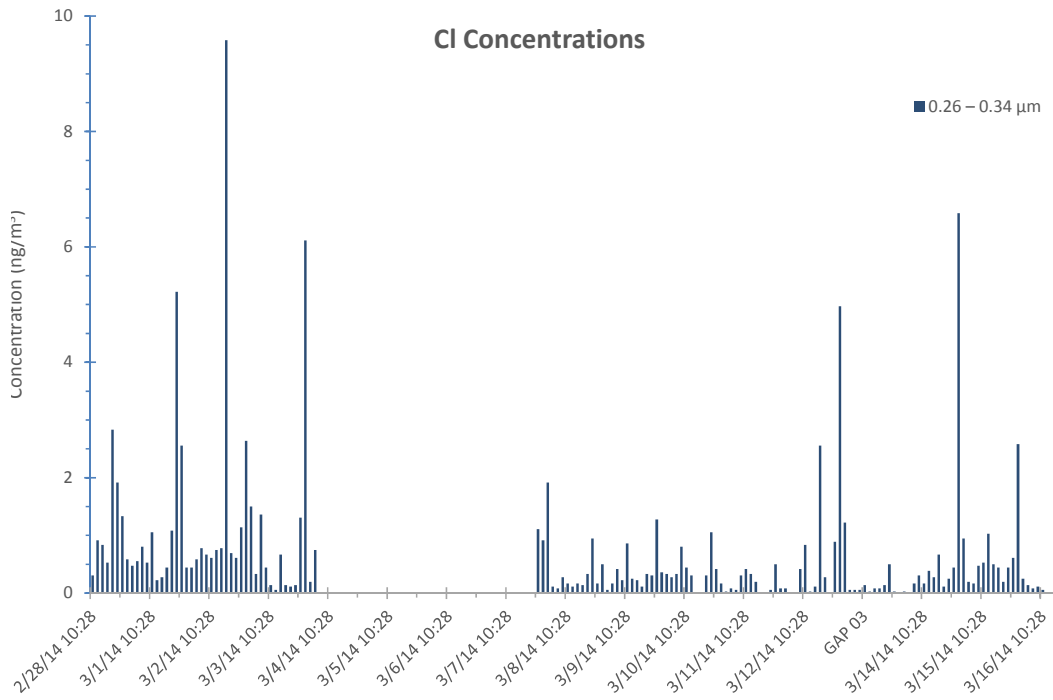


Fig. C-162 CaPh 32 DRUM: Cl mass stage 7

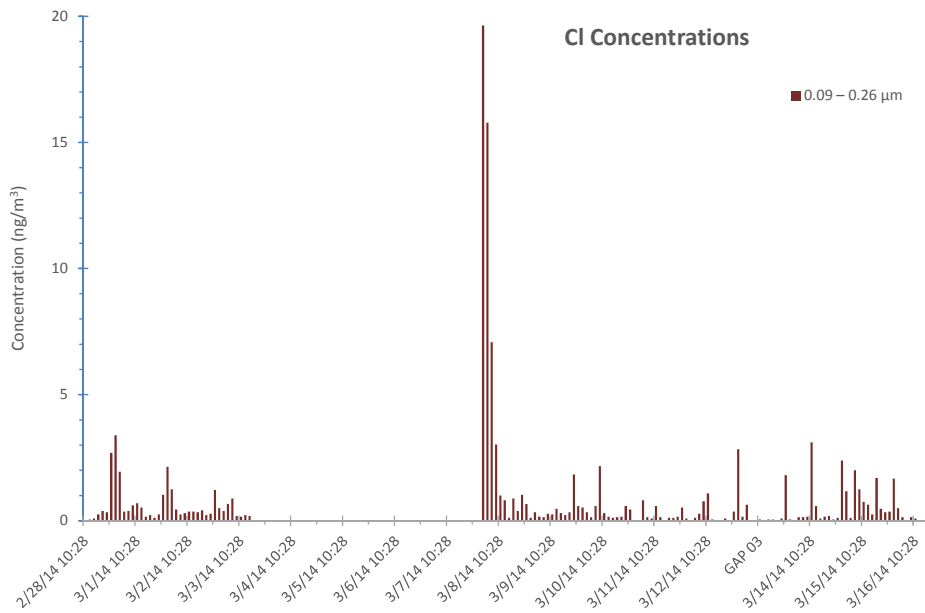


Fig. C-163 CaPh 32 DRUM: Cl mass stage 8

C-4.8 Potassium (K)

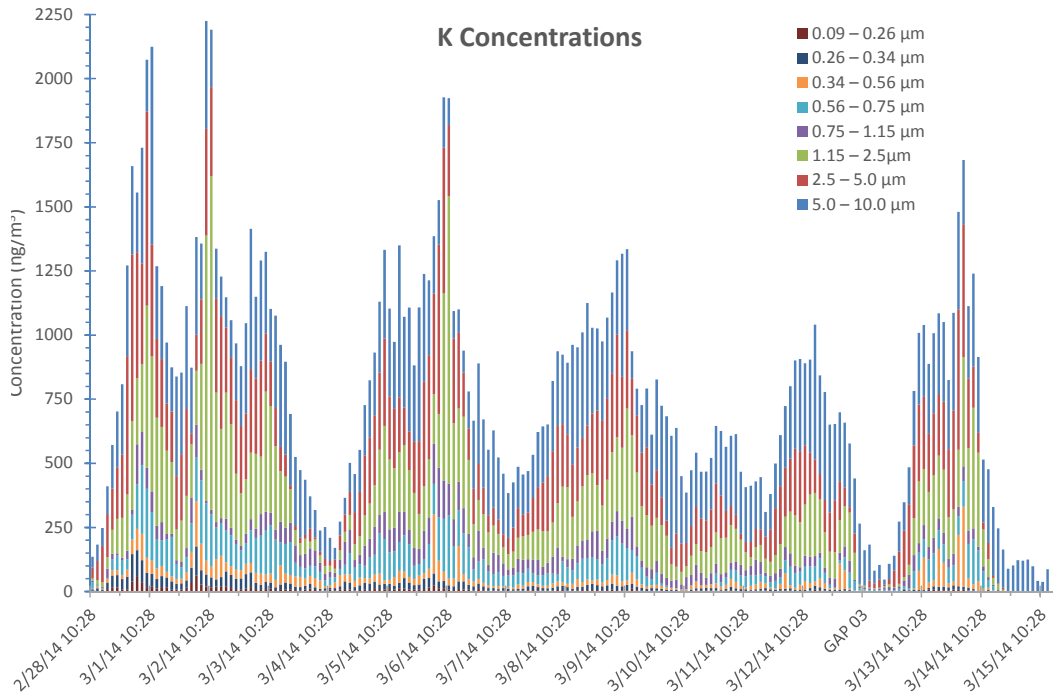


Fig. C-164 CaPh 34 DRUM: K mass all stages

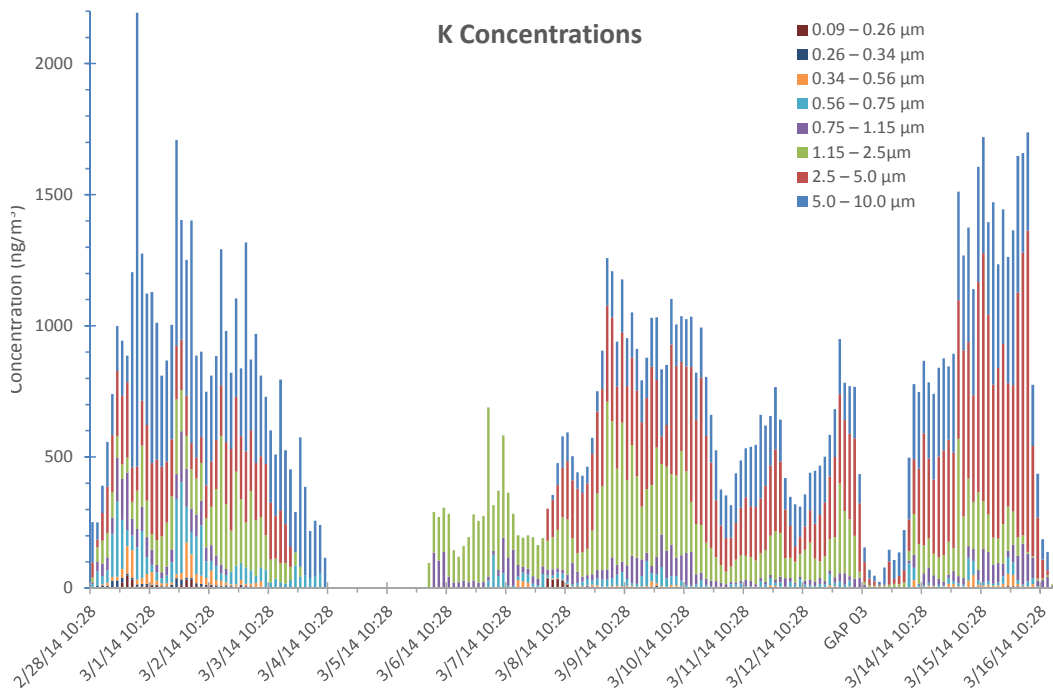
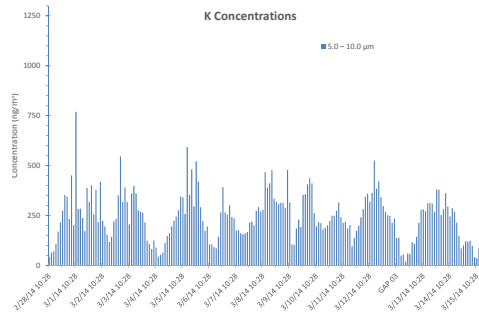
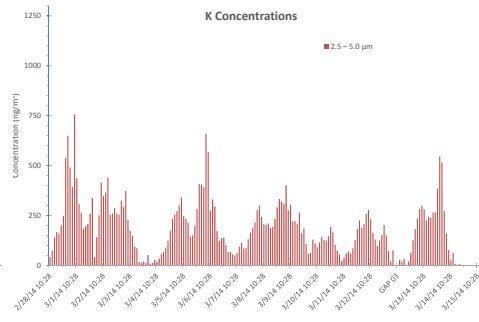


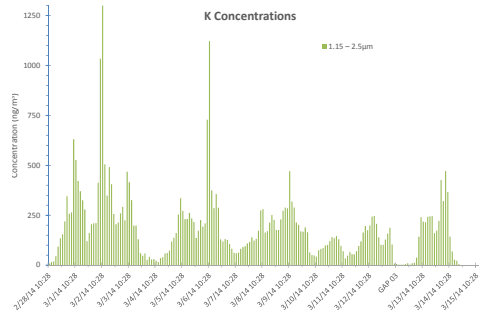
Fig. C-165 CaPh 32 DRUM: K mass all stages



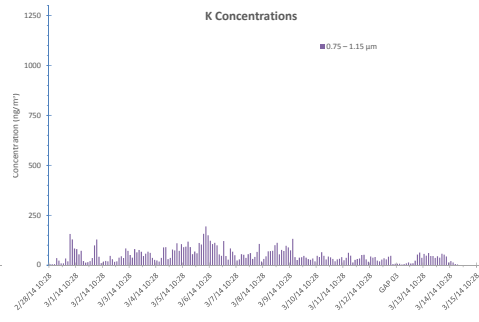
a) XRF stage 1 (5–10 μm) mass



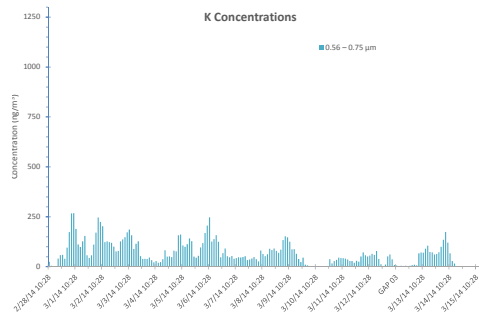
b) XRF stage 2 (2.5–5.0 μm) mass



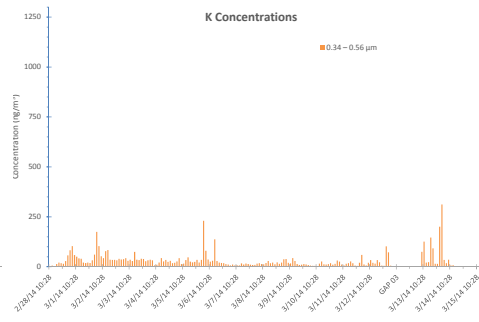
c) XRF stage 3 (1.15–2.5 μm) mass



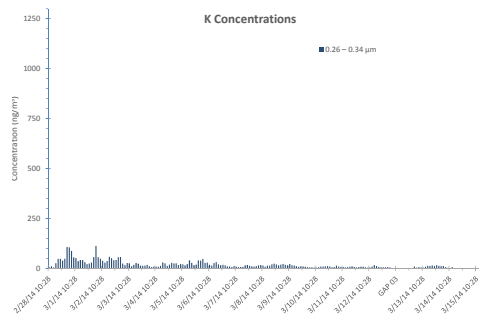
d) XRF stage 4 (0.75–1.15 μm) mass



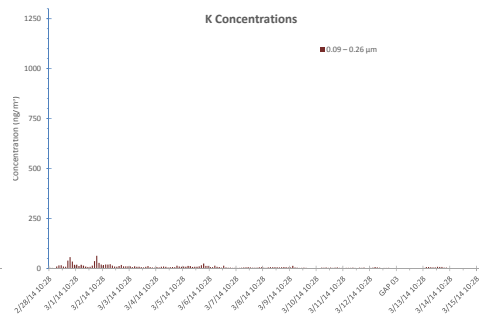
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.34–0.56 μm) mass



g) XRF stage 7 (0.26–0.34 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-166 CaPh 34 DRUM: XRF mass K; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

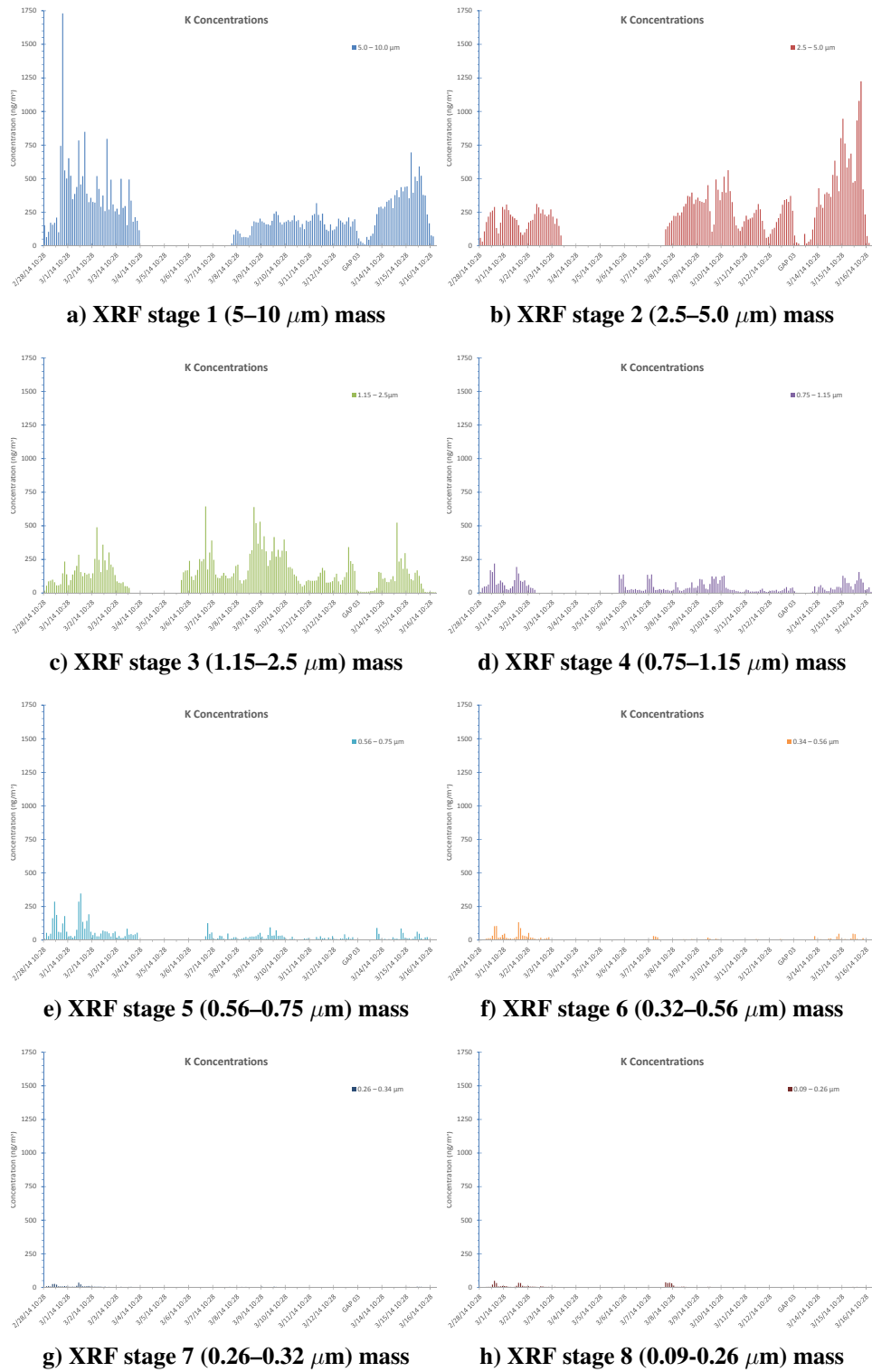


Fig. C-167 CaPh 32 DRUM: XRF mass K; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

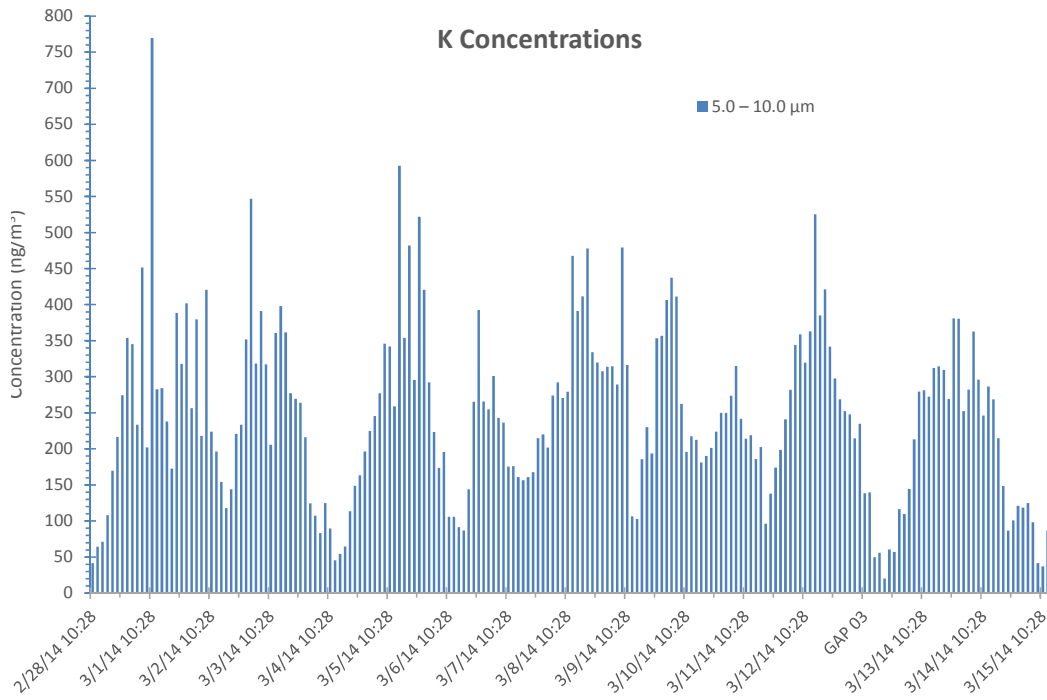


Fig. C-168 CaPh 34 DRUM: K mass stage 1

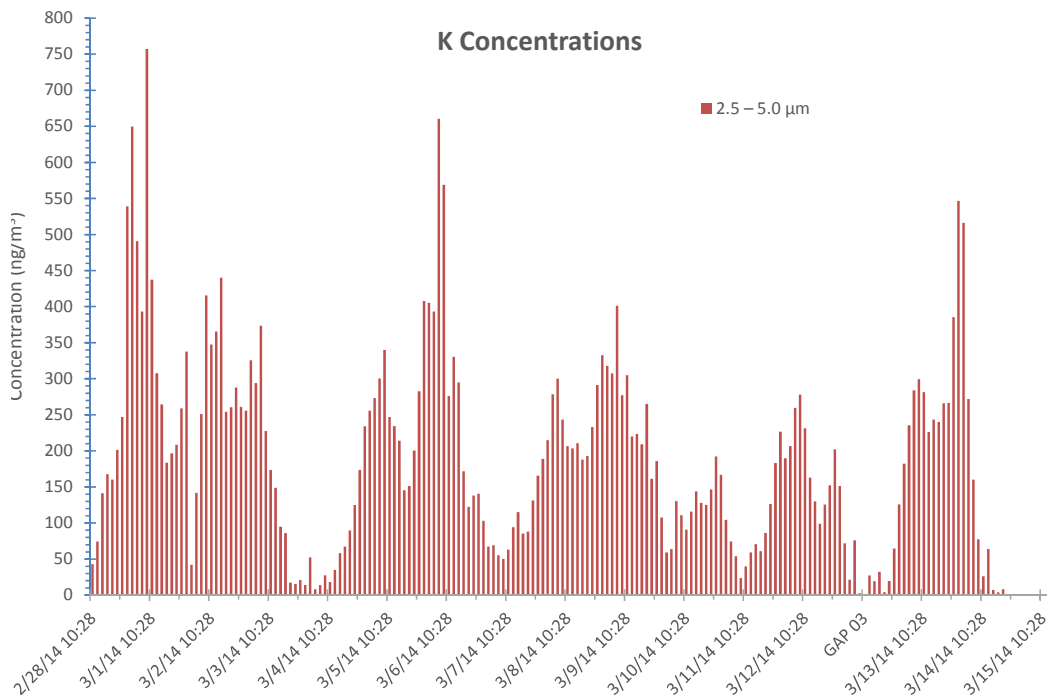


Fig. C-169 CaPh 34 DRUM: K mass stage 2

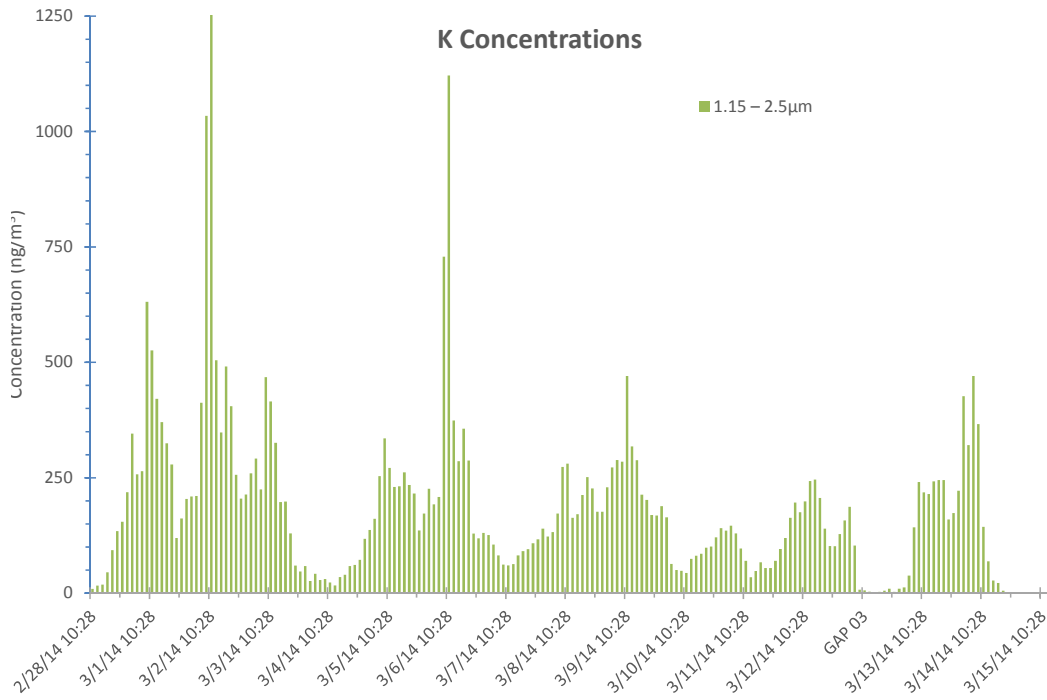


Fig. C-170 CaPh 34 DRUM: K mass stage 3

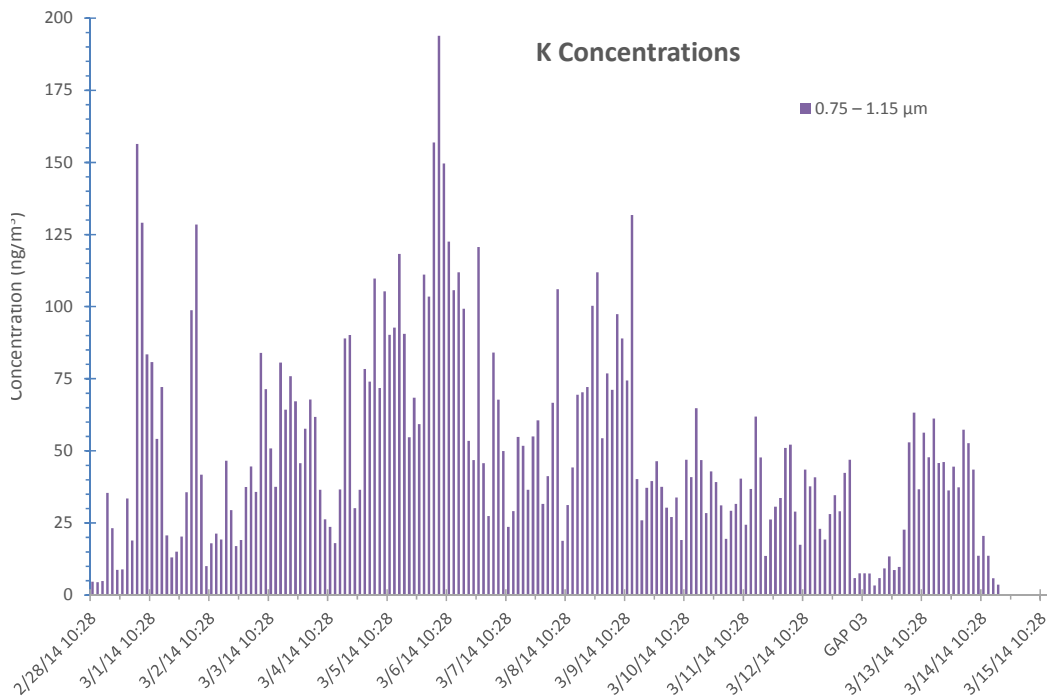


Fig. C-171 CaPh 34 DRUM: K mass stage 4

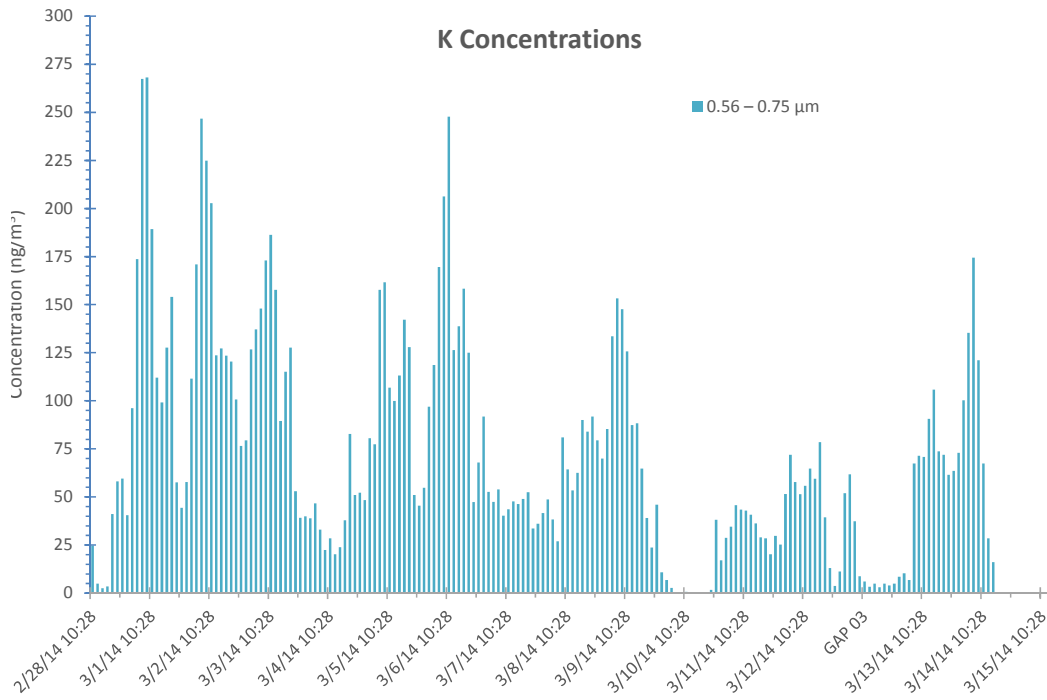


Fig. C-172 CaPh 34 DRUM: K mass stage 5

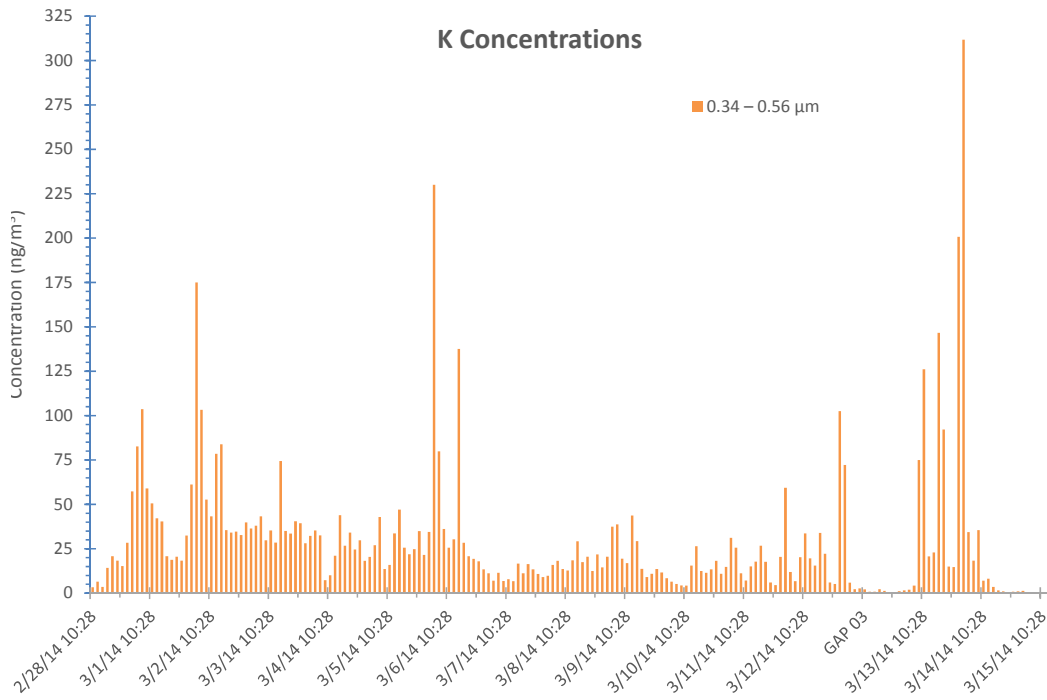


Fig. C-173 CaPh 34 DRUM: K mass stage 6

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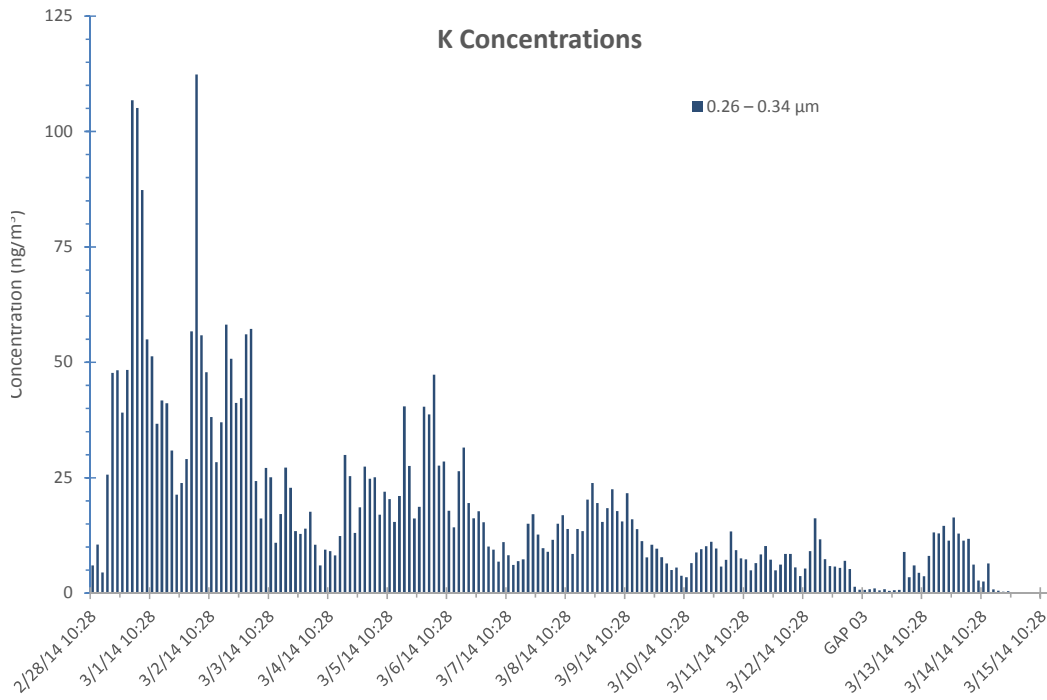


Fig. C-174 CaPh 34 DRUM: K mass stage 7

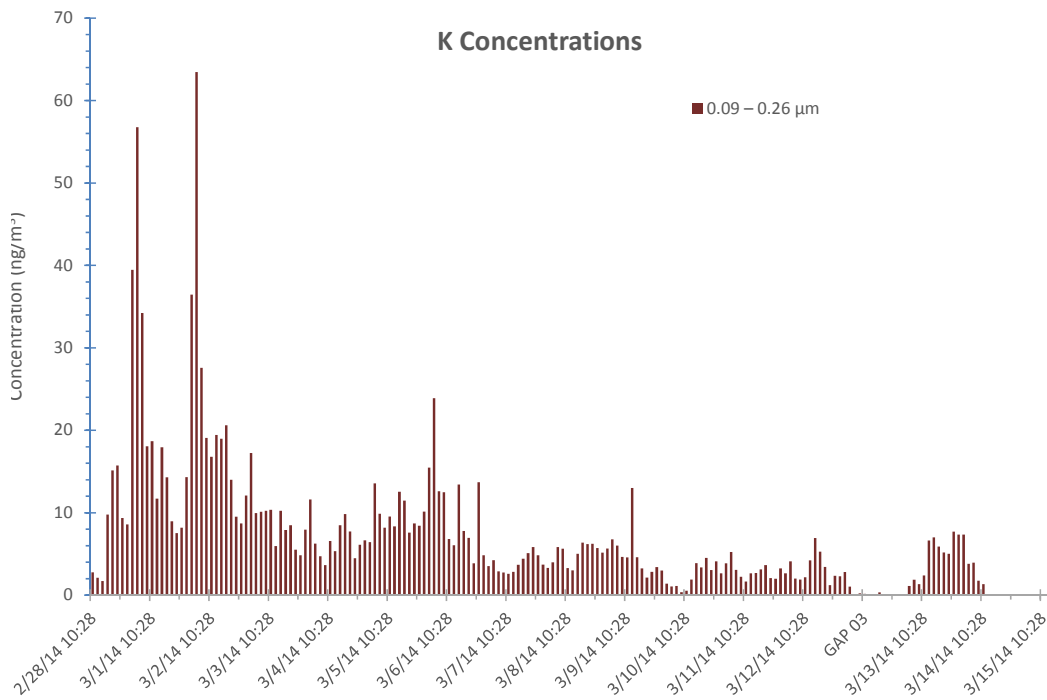


Fig. C-175 CaPh 34 DRUM: K mass stage 8

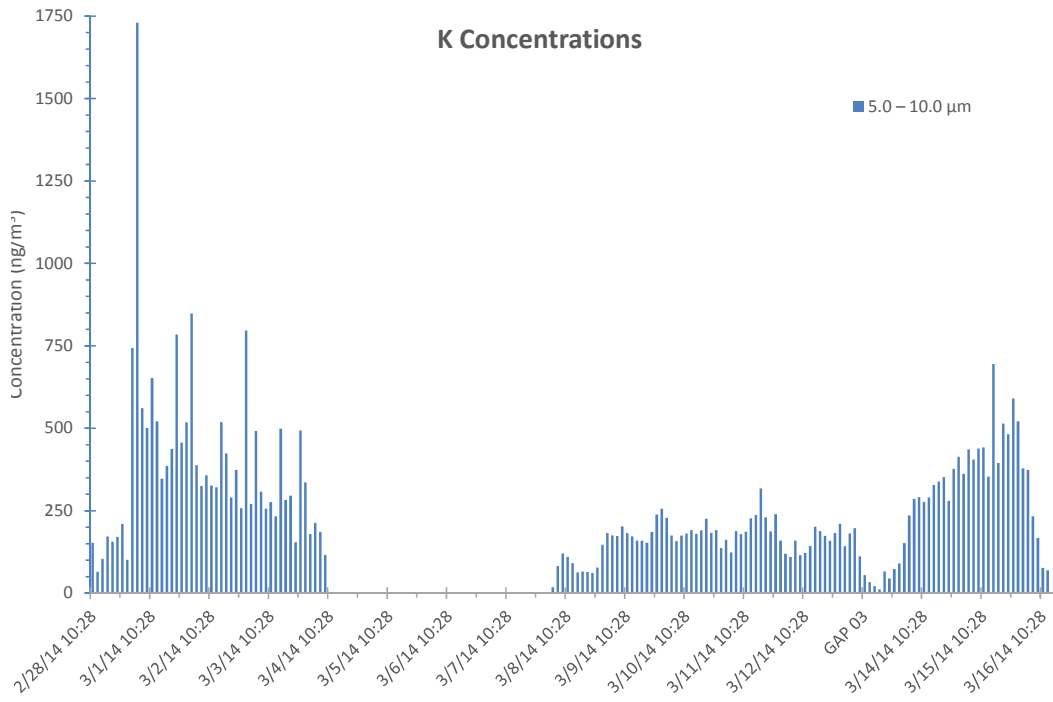


Fig. C-176 CaPh 32 DRUM: K mass stage 1

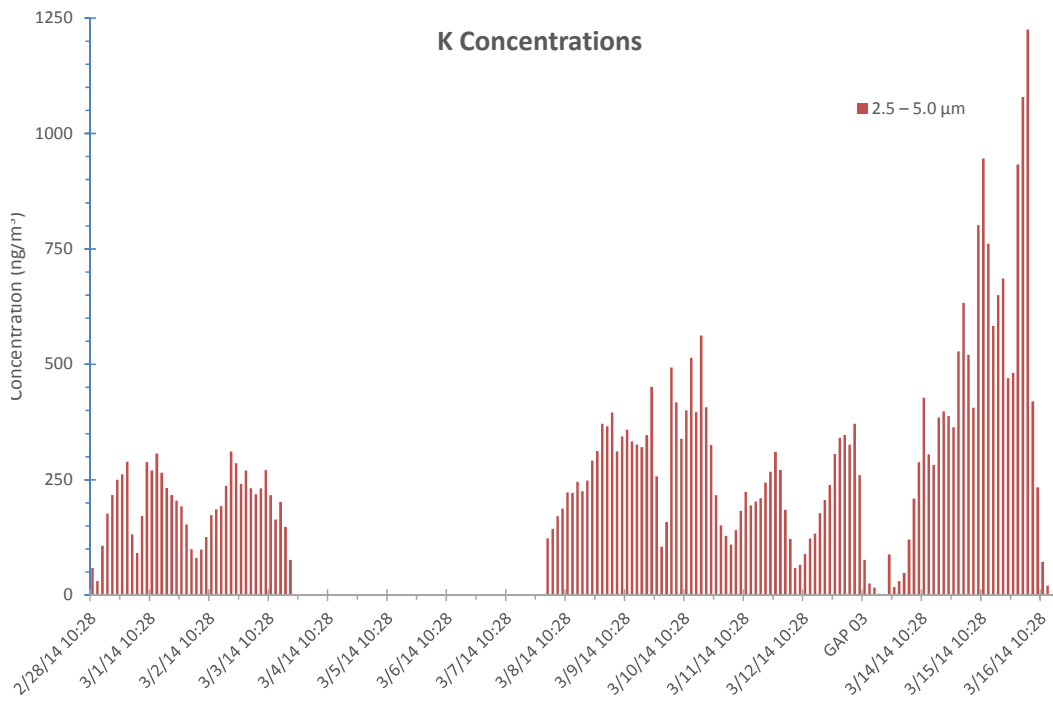


Fig. C-177 CaPh 32 DRUM: K mass stage 2

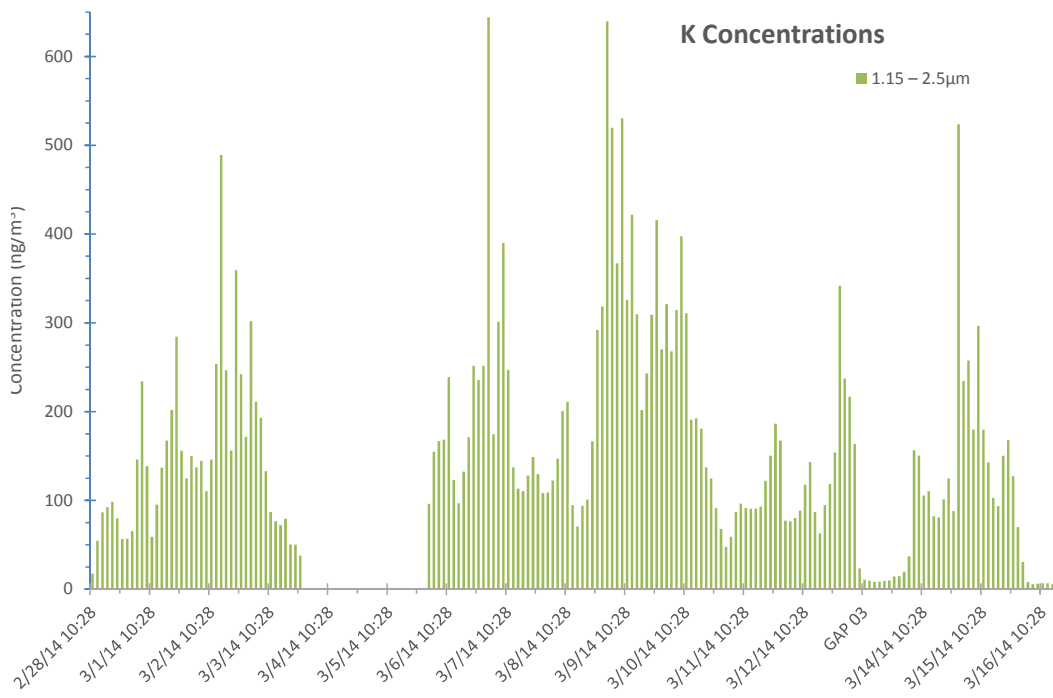


Fig. C-178 CaPh 32 DRUM: K mass stage 3

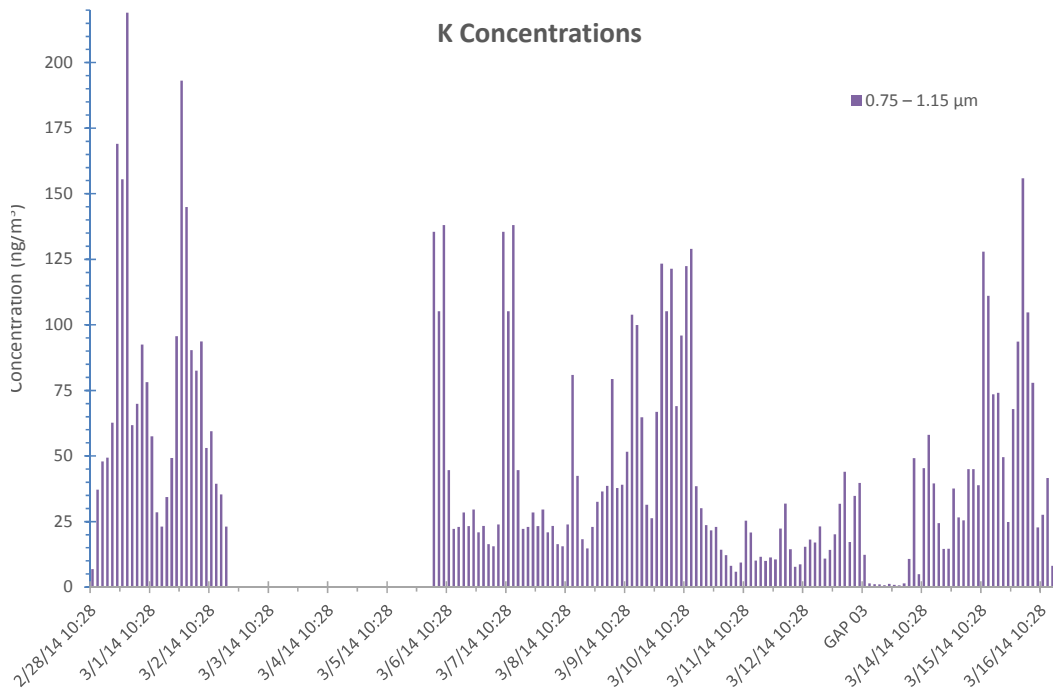


Fig. C-179 CaPh 32 DRUM: K mass stage 4

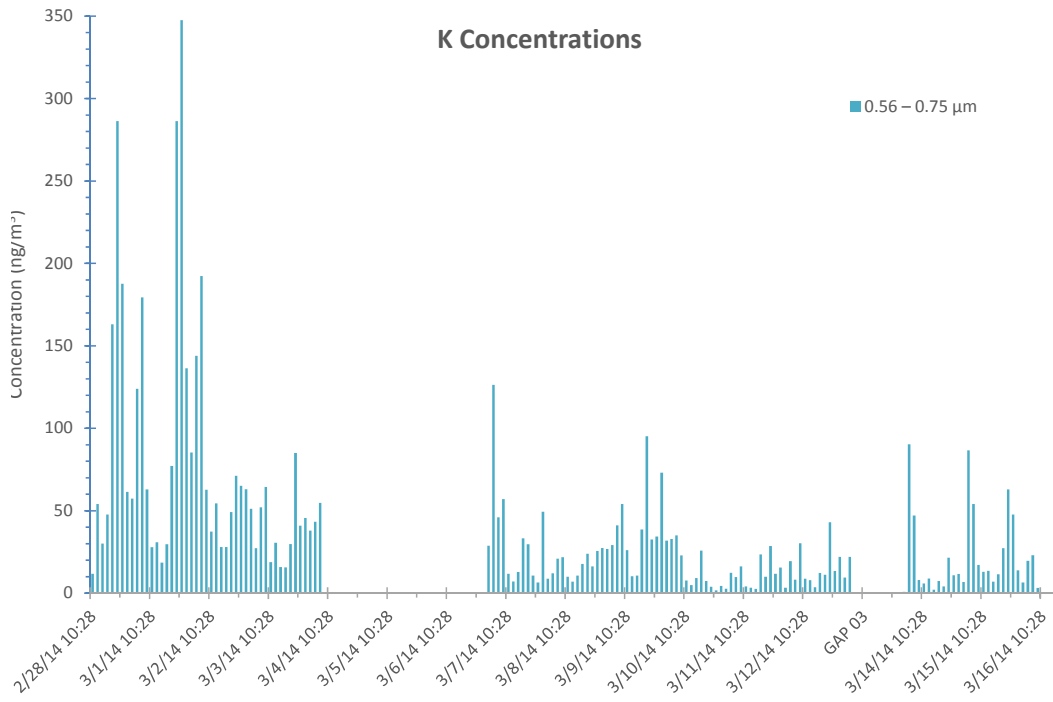


Fig. C-180 CaPh 32 DRUM: K mass stage 5

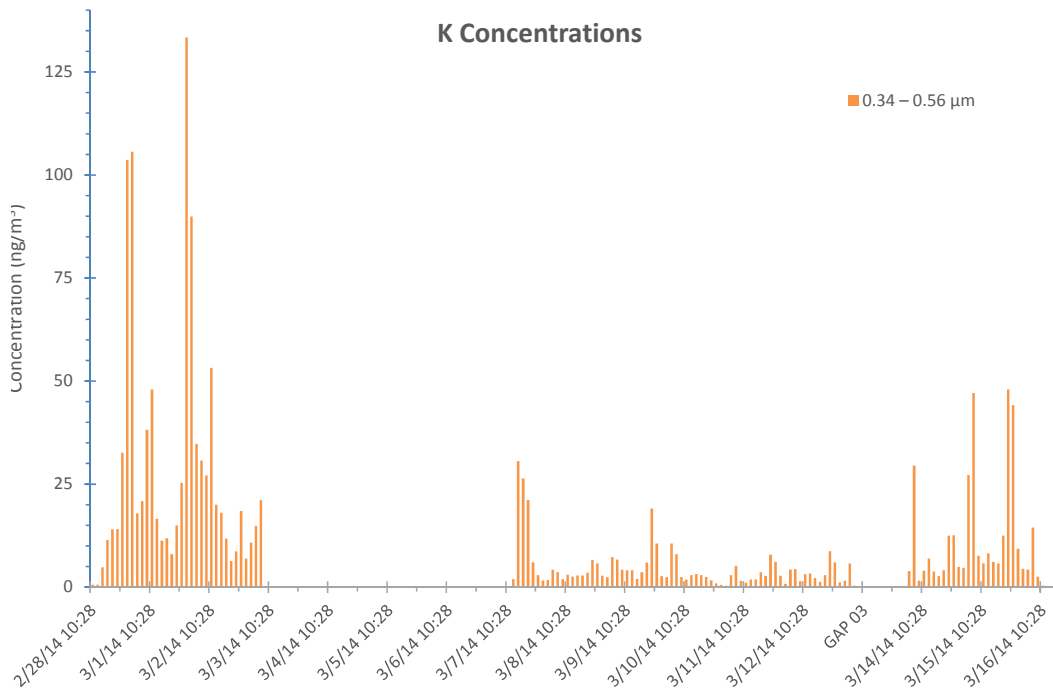


Fig. C-181 CaPh 32 DRUM: K mass stage 6

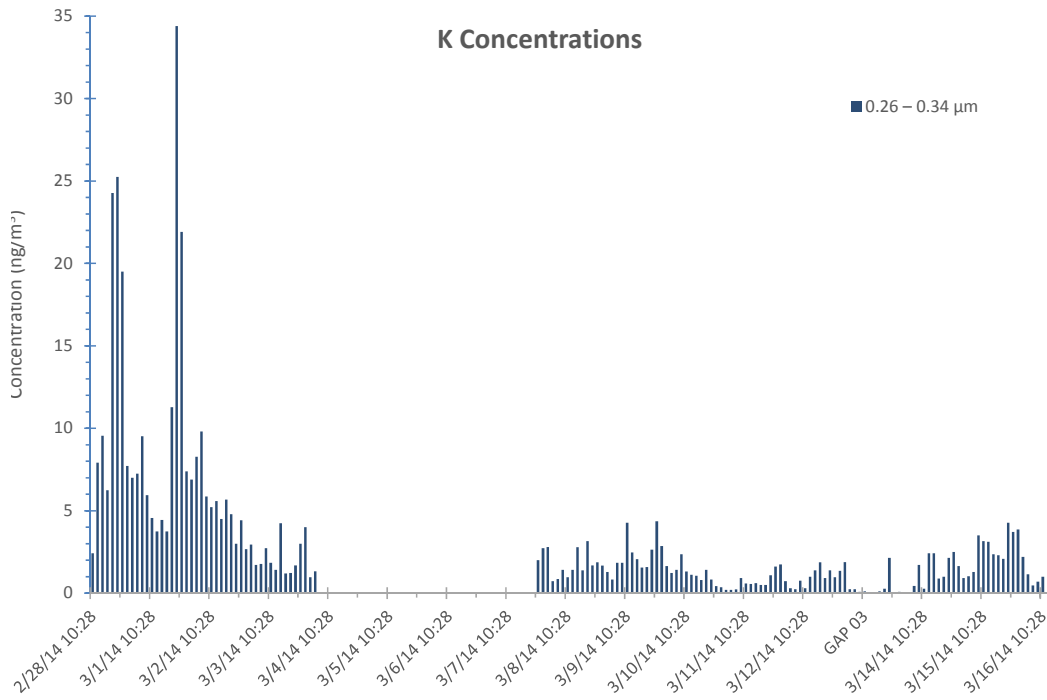


Fig. C-182 CaPh 32 DRUM: K mass stage 7

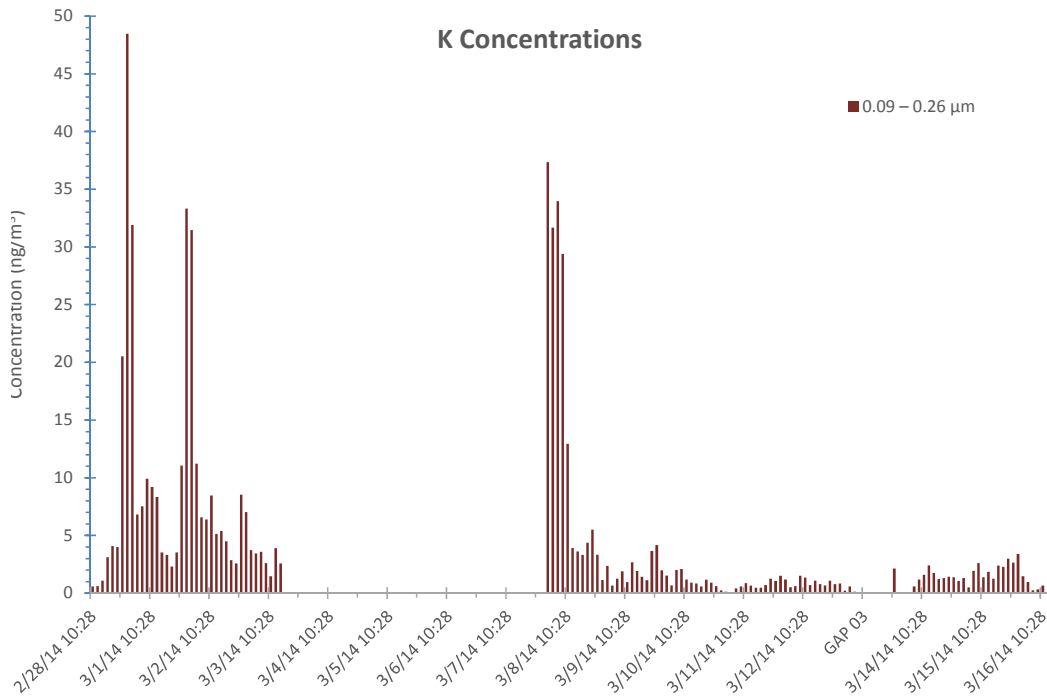


Fig. C-183 CaPh 32 DRUM: K mass stage 8

C-4.9 Calcium (Ca)

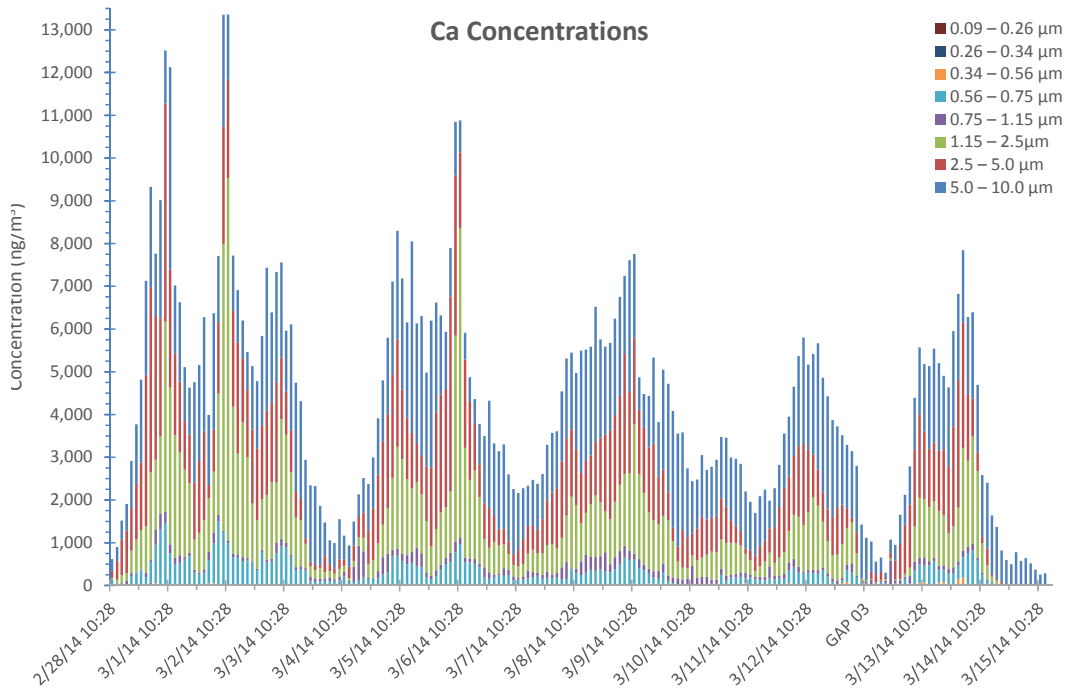


Fig. C-184 CaPh 34 DRUM: Ca mass all stages

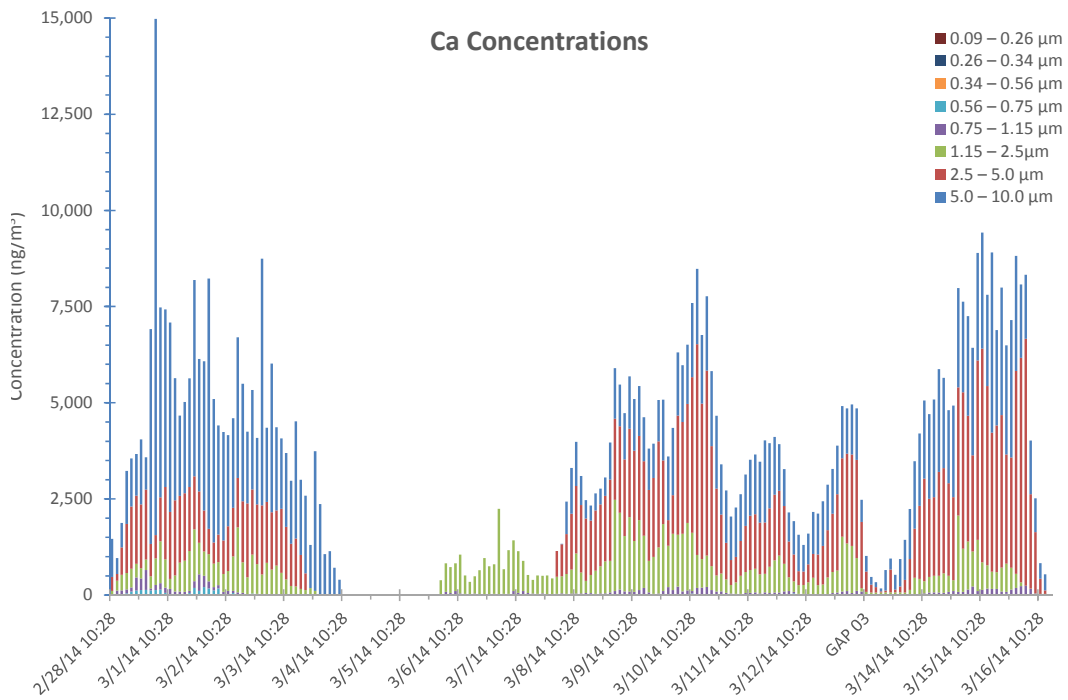
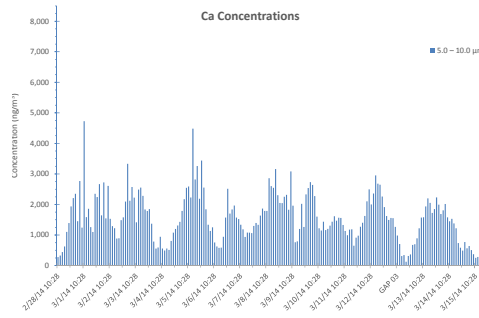
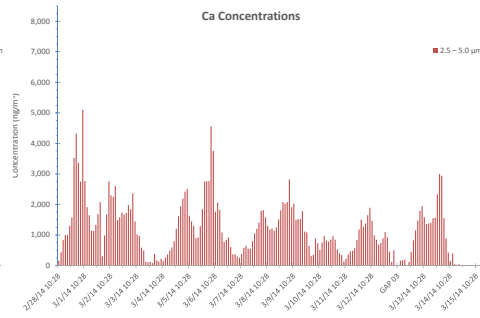


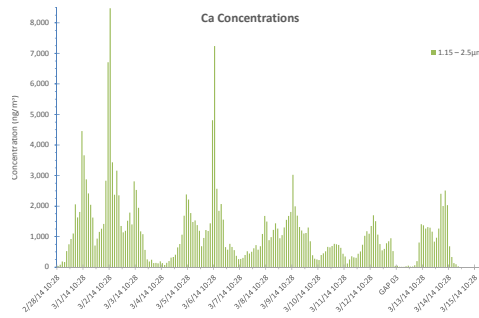
Fig. C-185 CaPh 32 DRUM: Ca mass all stages



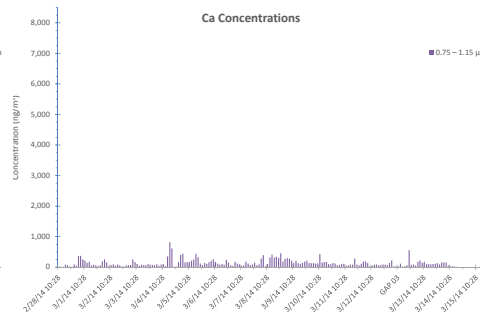
a) XRF stage 1 (5–10 μm) mass



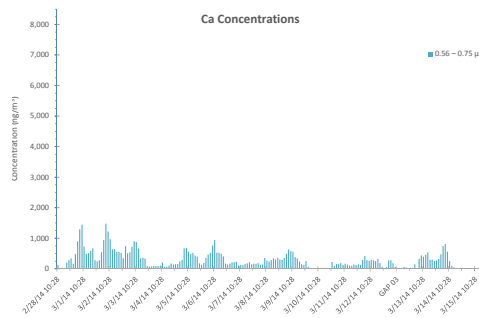
b) XRF stage 2 (2.5–5.0 μm) mass



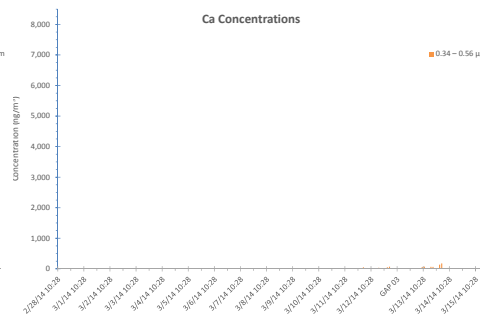
c) XRF stage 3 (1.15–2.5 μm) mass



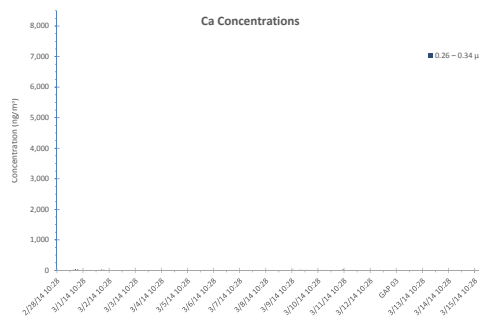
d) XRF stage 4 (0.75–1.15 μm) mass



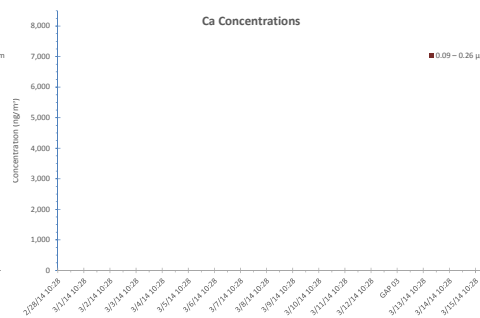
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.34–0.56 μm) mass



g) XRF stage 7 (0.26–0.34 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-186 CaPh 34 DRUM: XRF mass Ca; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

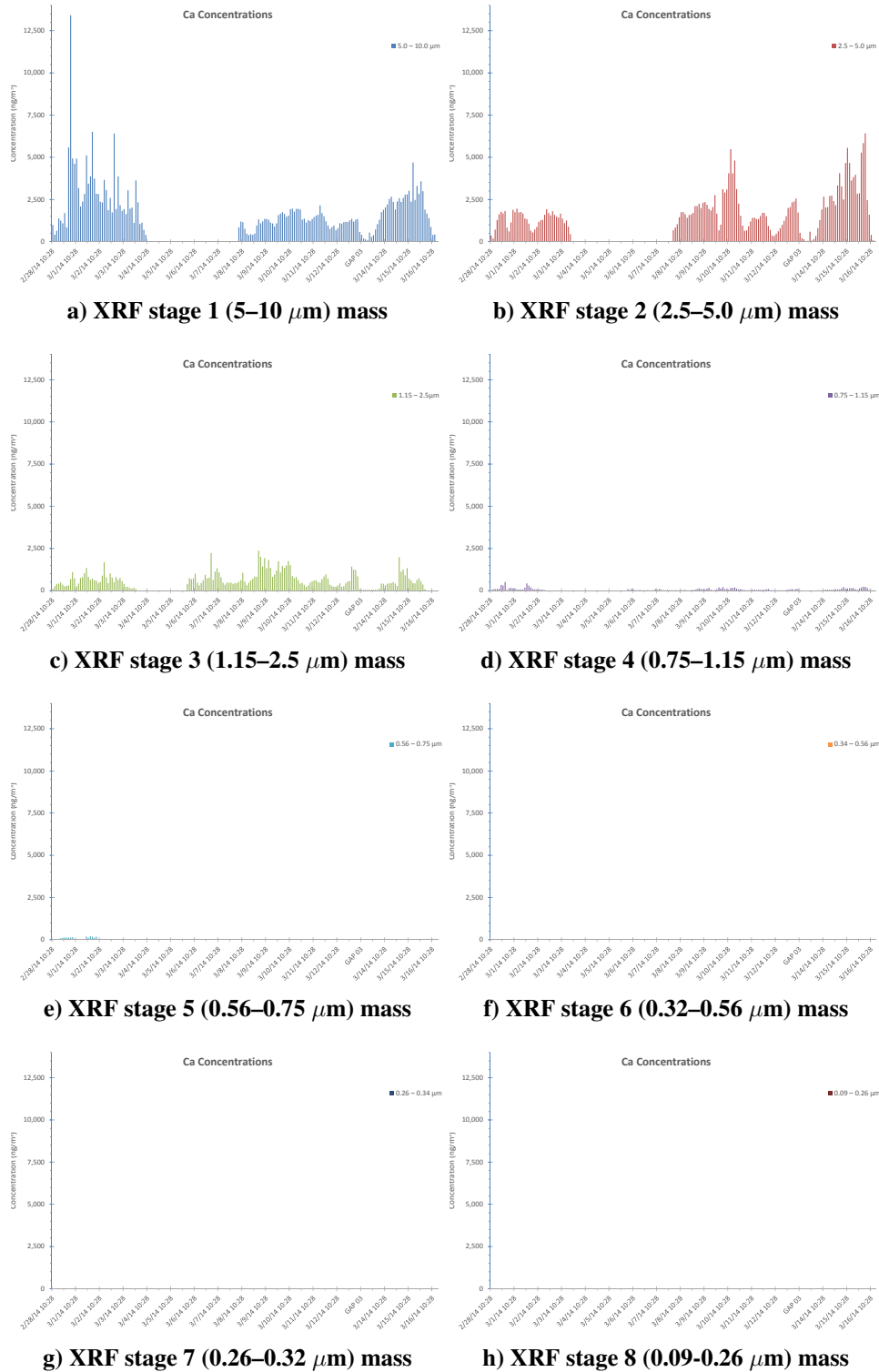


Fig. C-187 CaPh 32 DRUM: XRF mass Ca; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

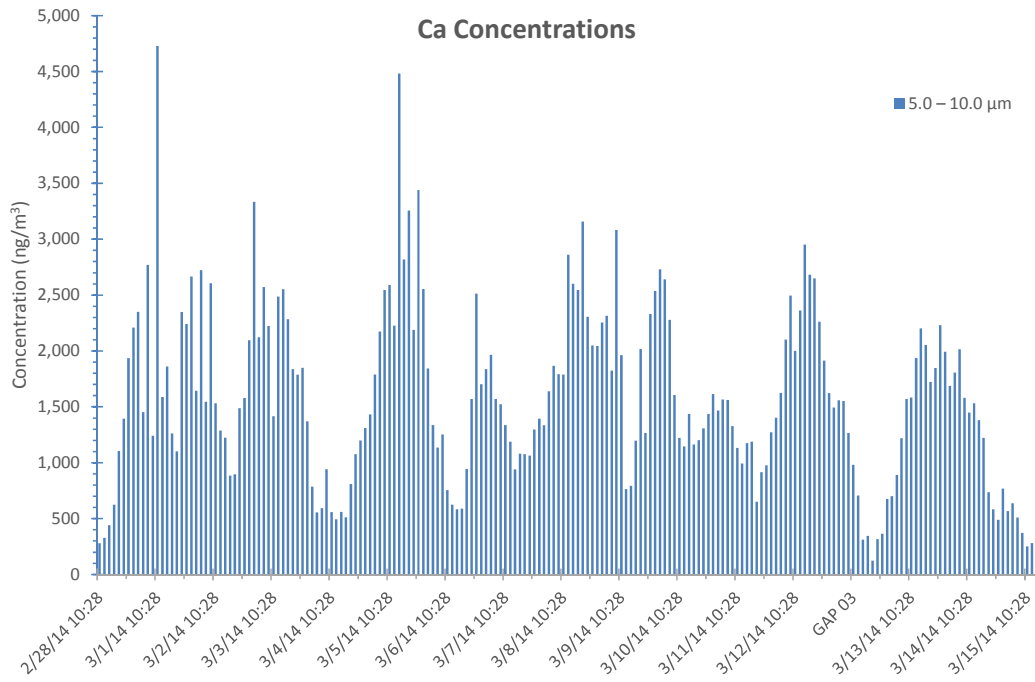


Fig. C-188 CaPh 34 DRUM: Ca mass stage 1

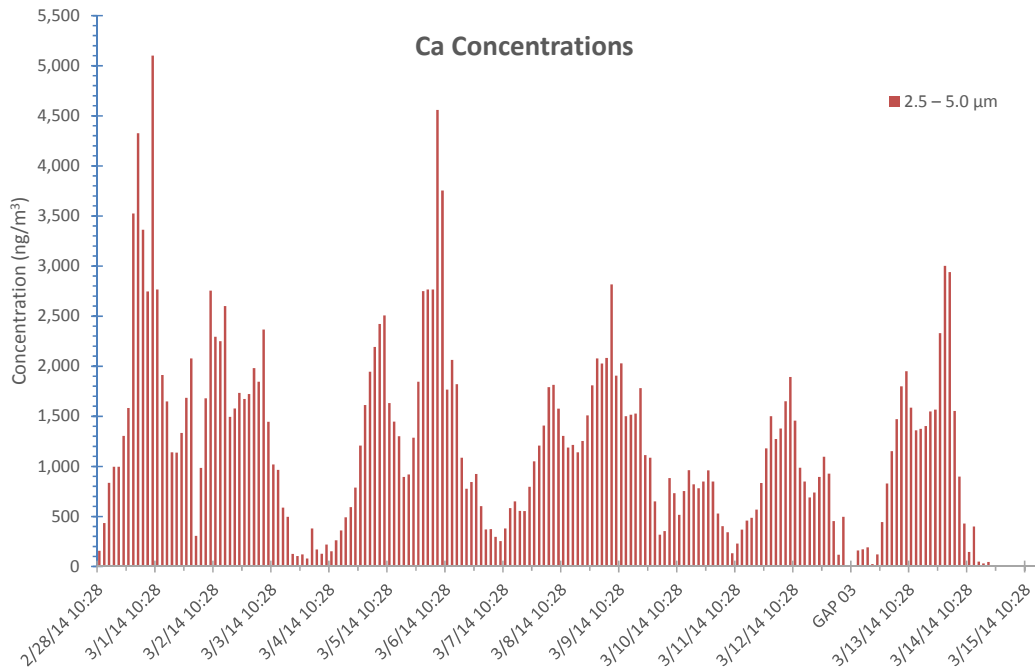


Fig. C-189 CaPh 34 DRUM: Ca mass stage 2

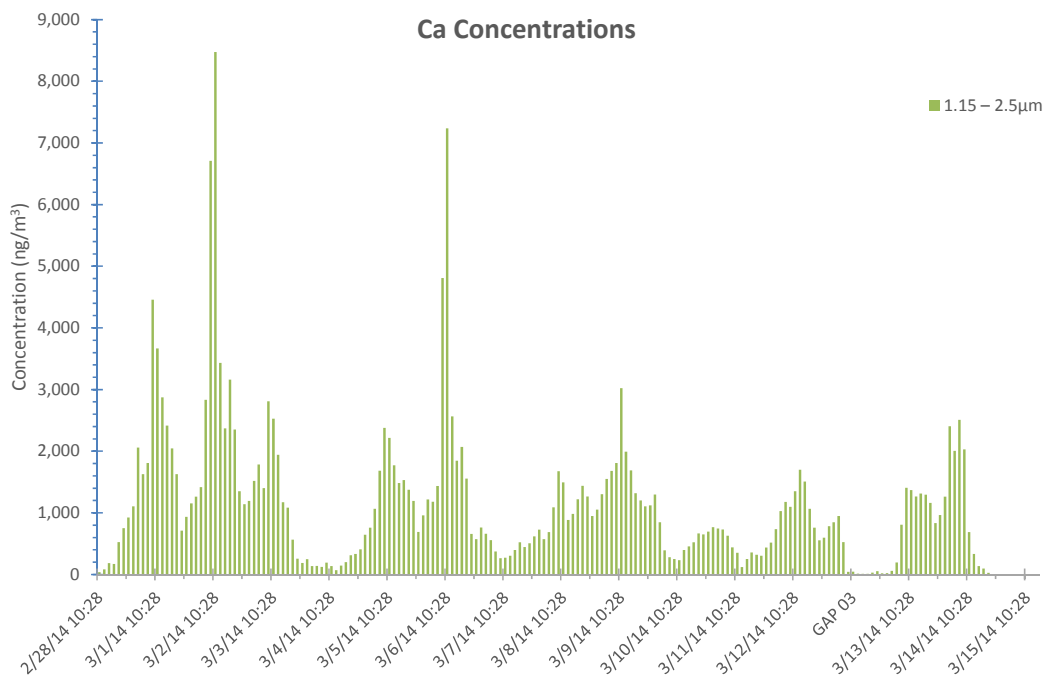


Fig. C-190 CaPh 34 DRUM: Ca mass stage 3

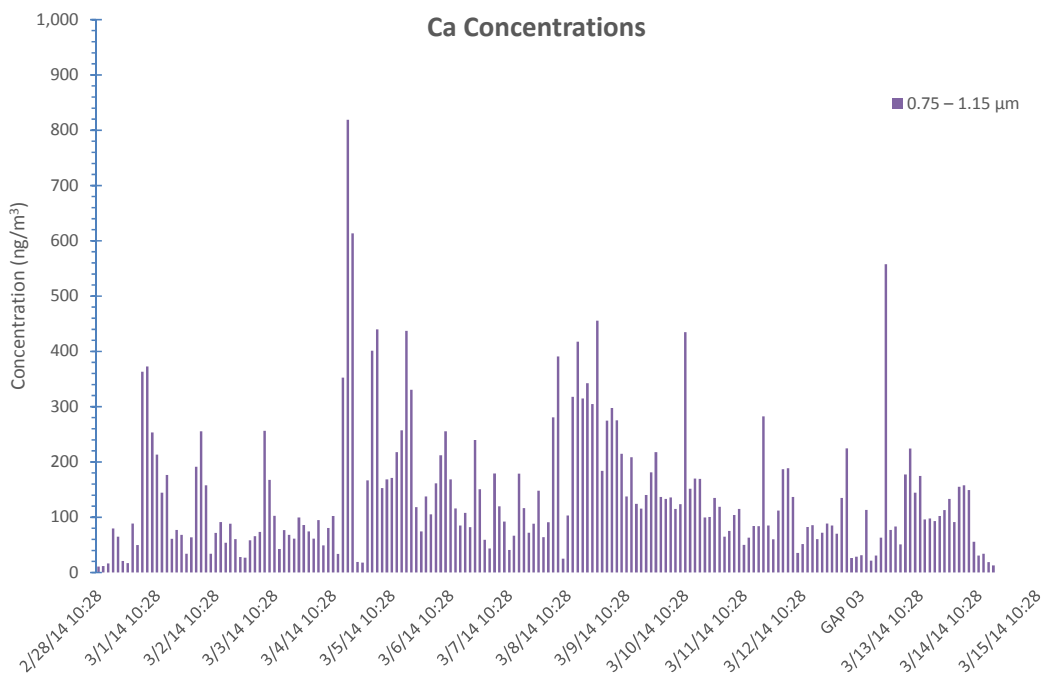


Fig. C-191 CaPh 34 DRUM: Ca mass stage 4

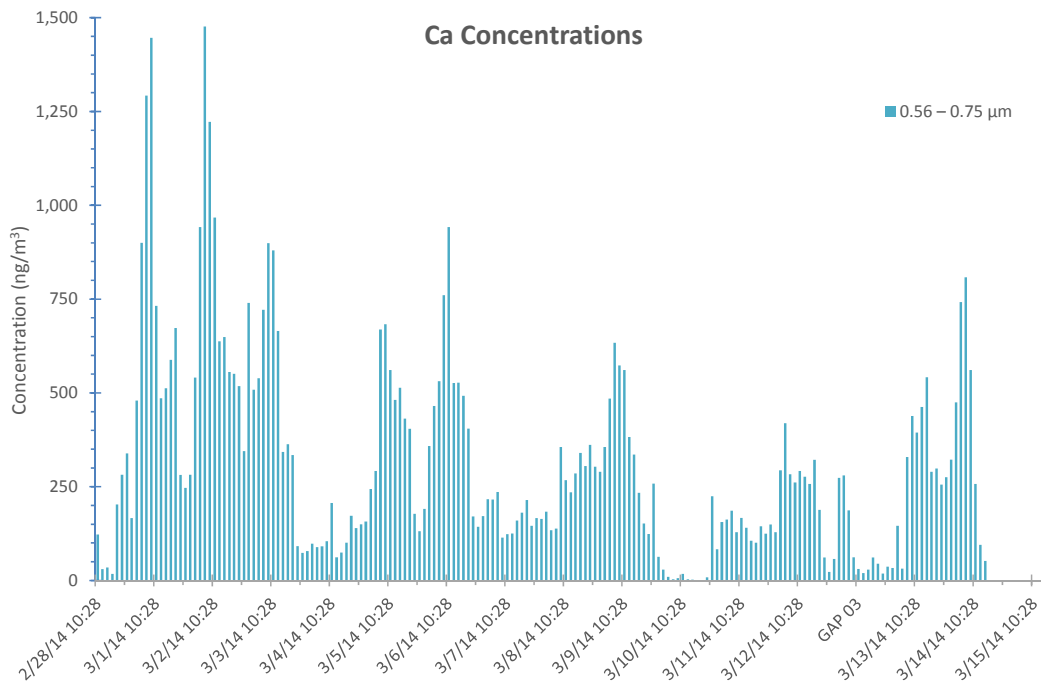


Fig. C-192 CaPh 34 DRUM: Ca mass stage 5

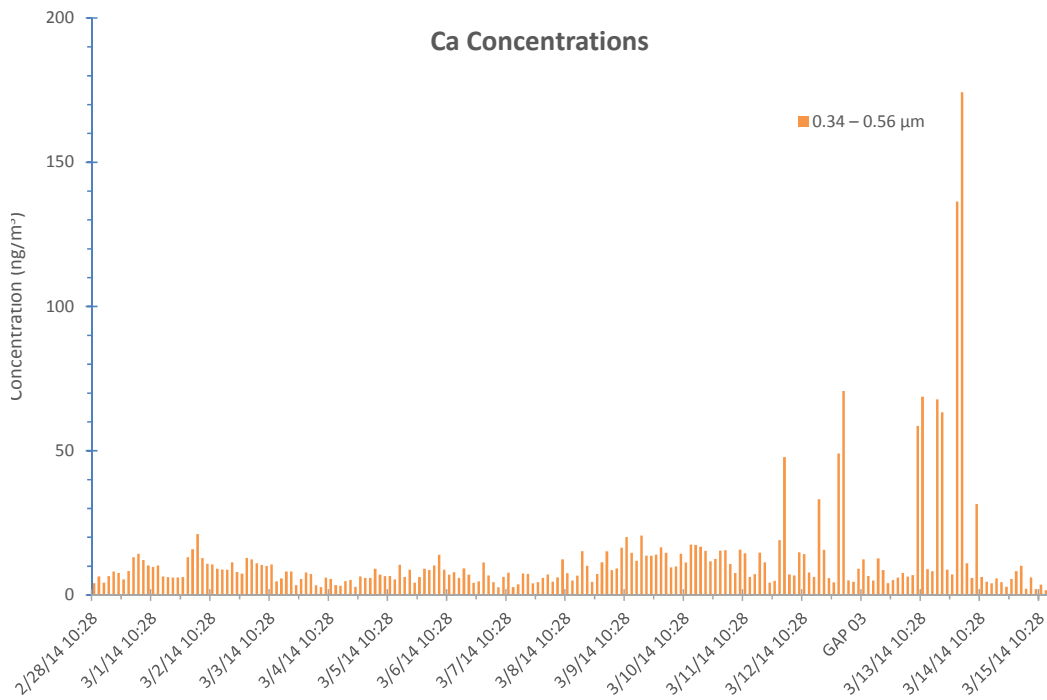


Fig. C-193 CaPh 34 DRUM: Ca mass stage 6

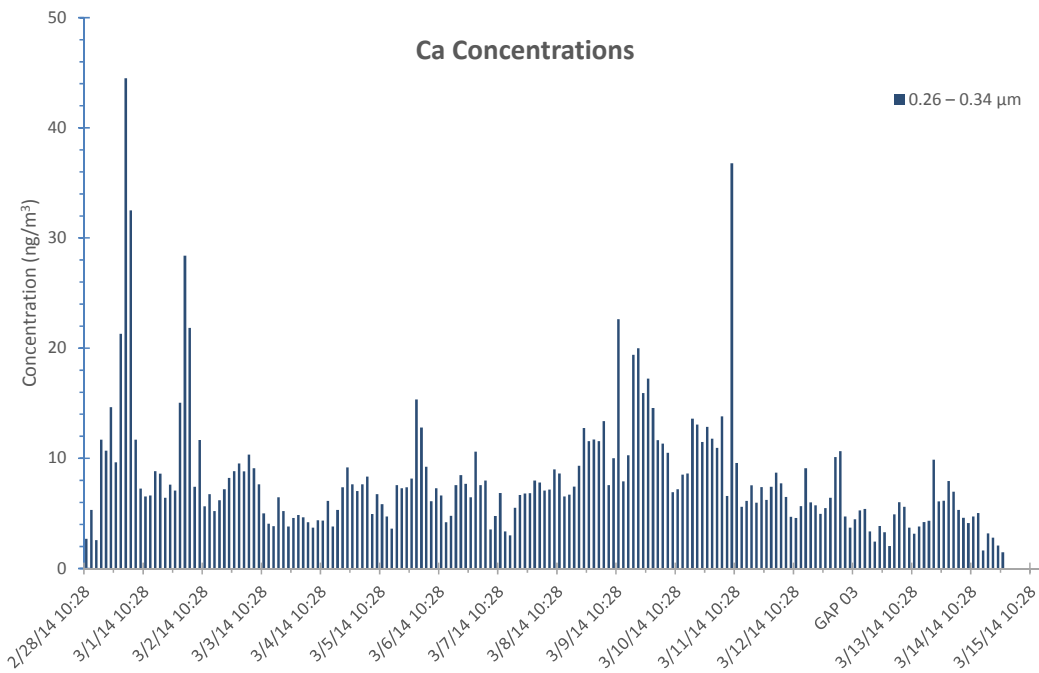


Fig. C-194 CaPh 34 DRUM: Ca mass stage 7

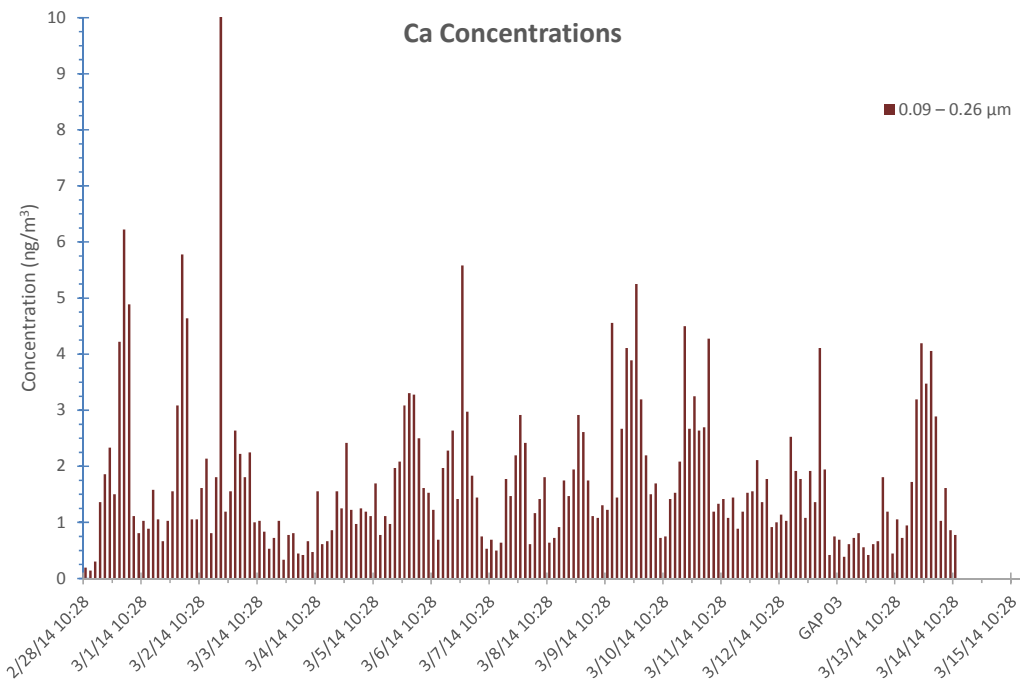


Fig. C-195 CaPh 34 DRUM: Ca mass stage 8

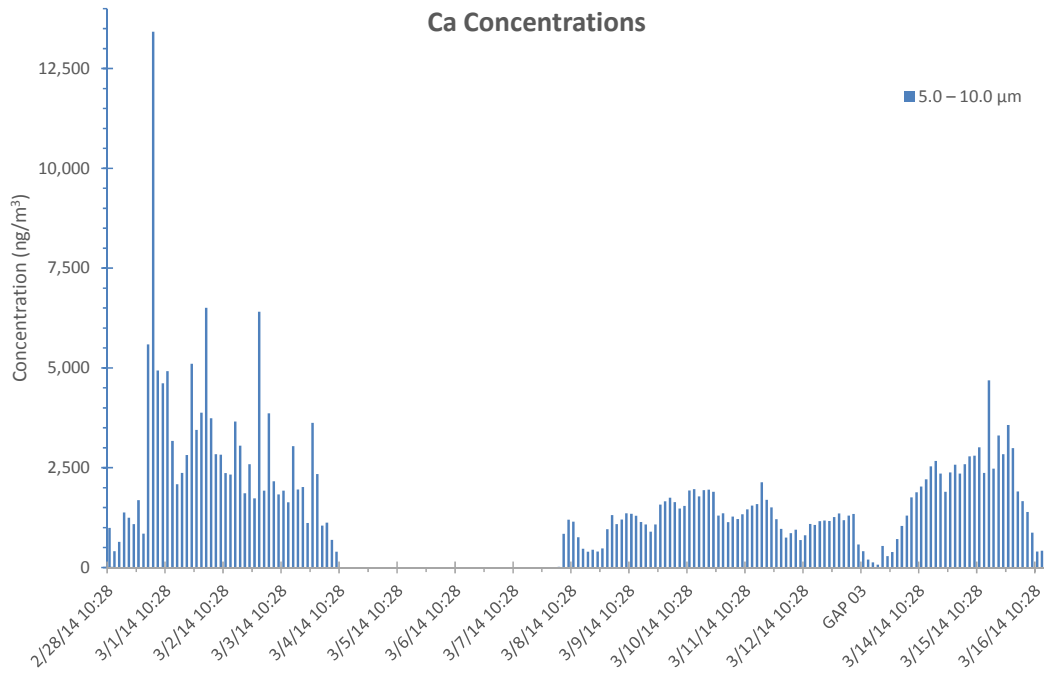


Fig. C-196 CaPh 32 DRUM: Ca mass stage 1

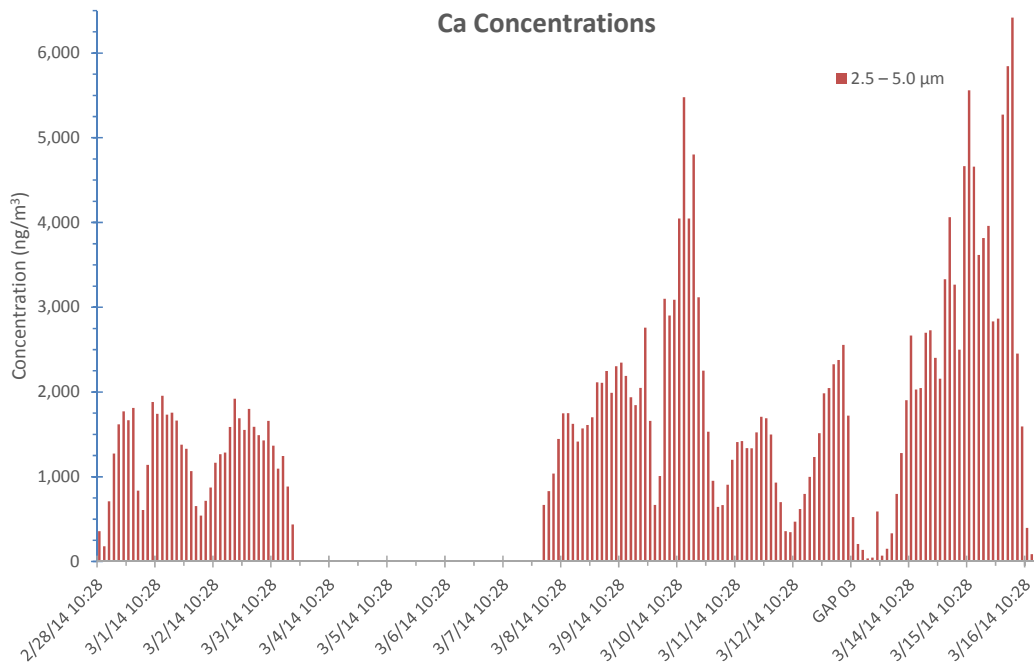


Fig. C-197 CaPh 32 DRUM: Ca mass stage 2

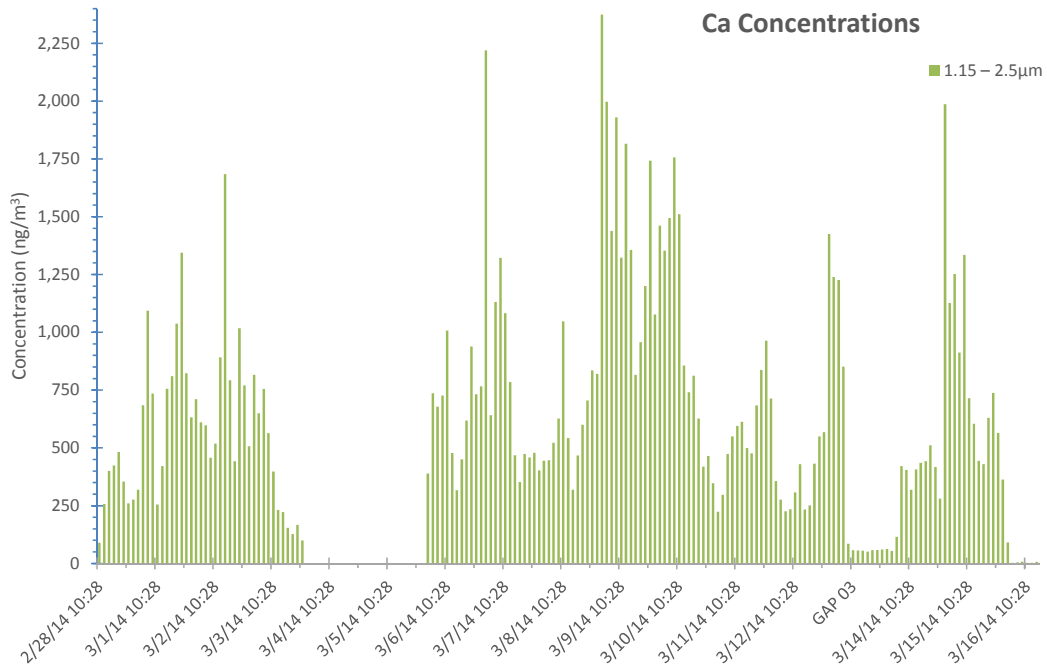


Fig. C-198 CaPh 32 DRUM: Ca mass stage 3

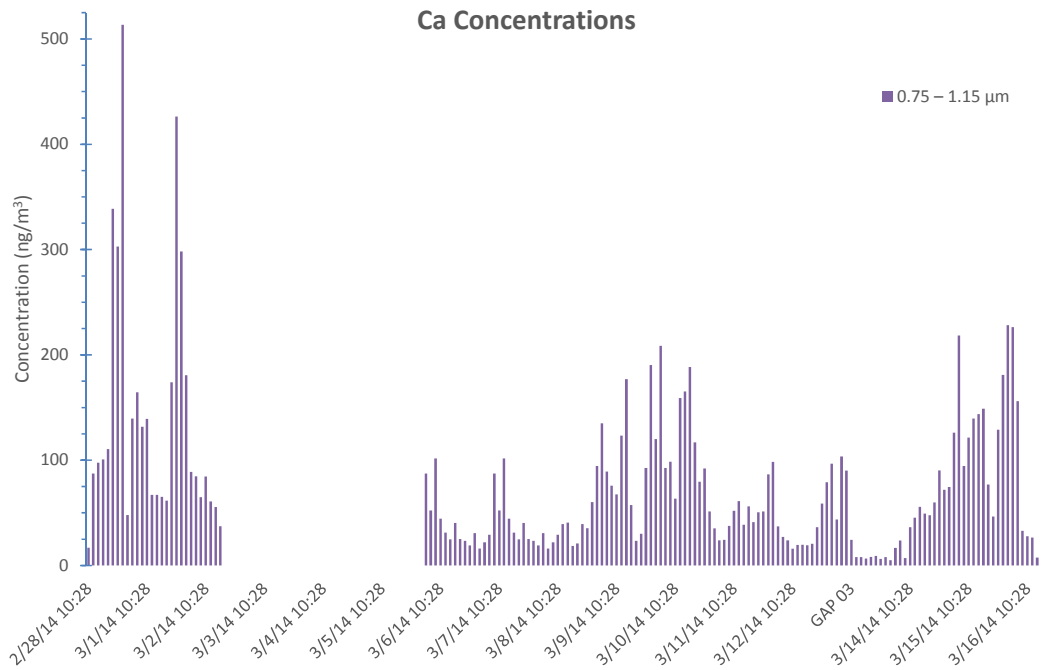


Fig. C-199 CaPh 32 DRUM: Ca mass stage 4

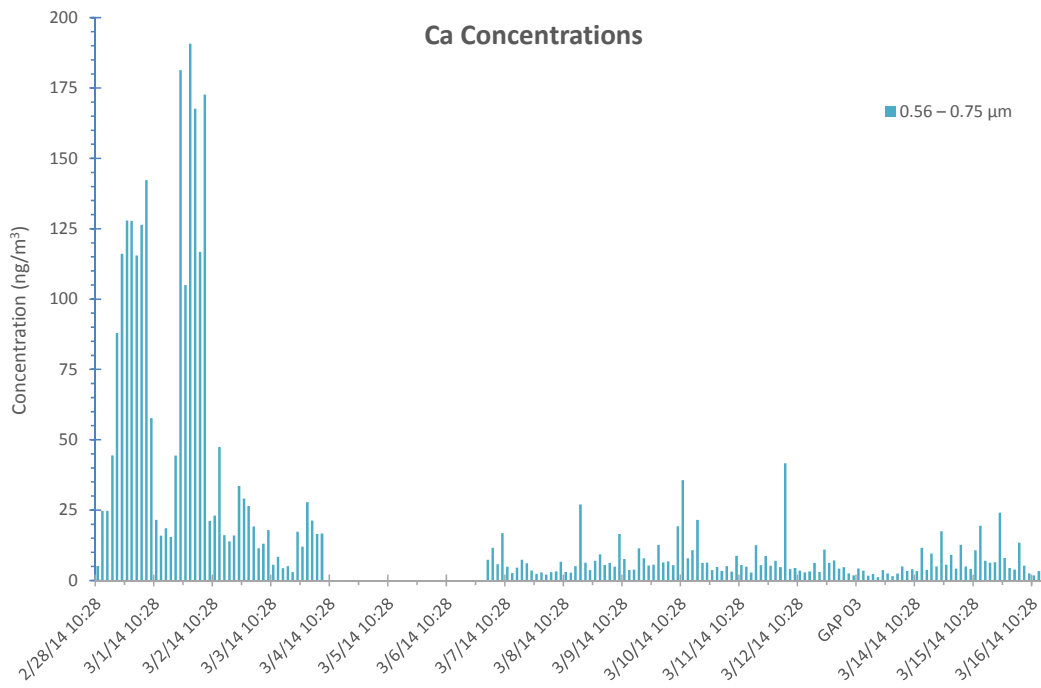


Fig. C-200 CaPh 32 DRUM: Ca mass stage 5

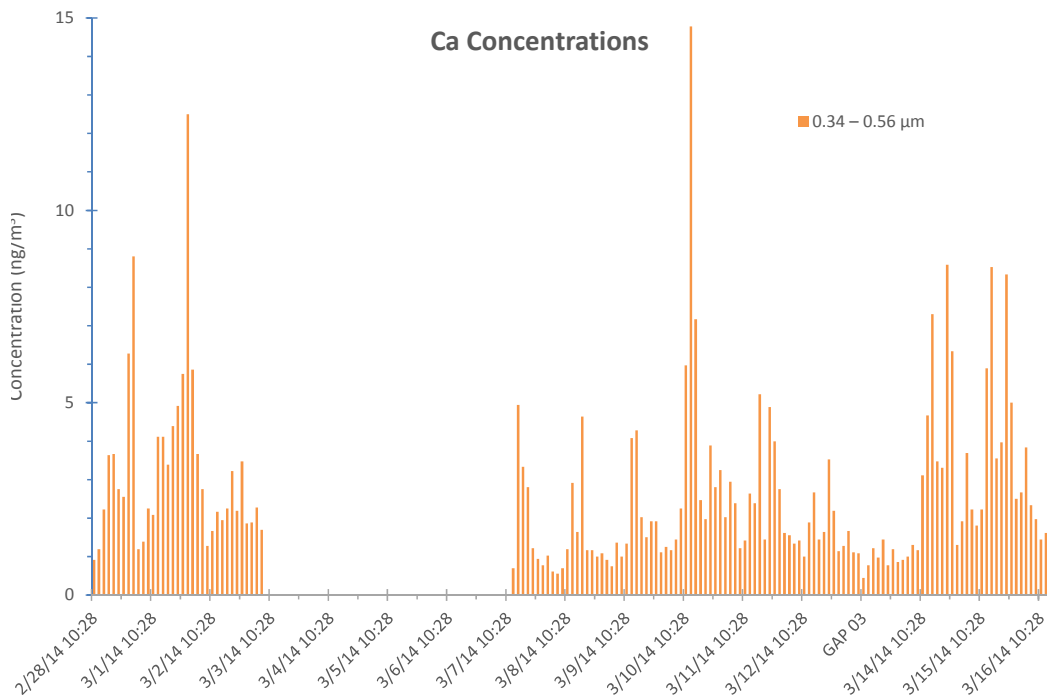


Fig. C-201 CaPh 32 DRUM: Ca mass stage 6

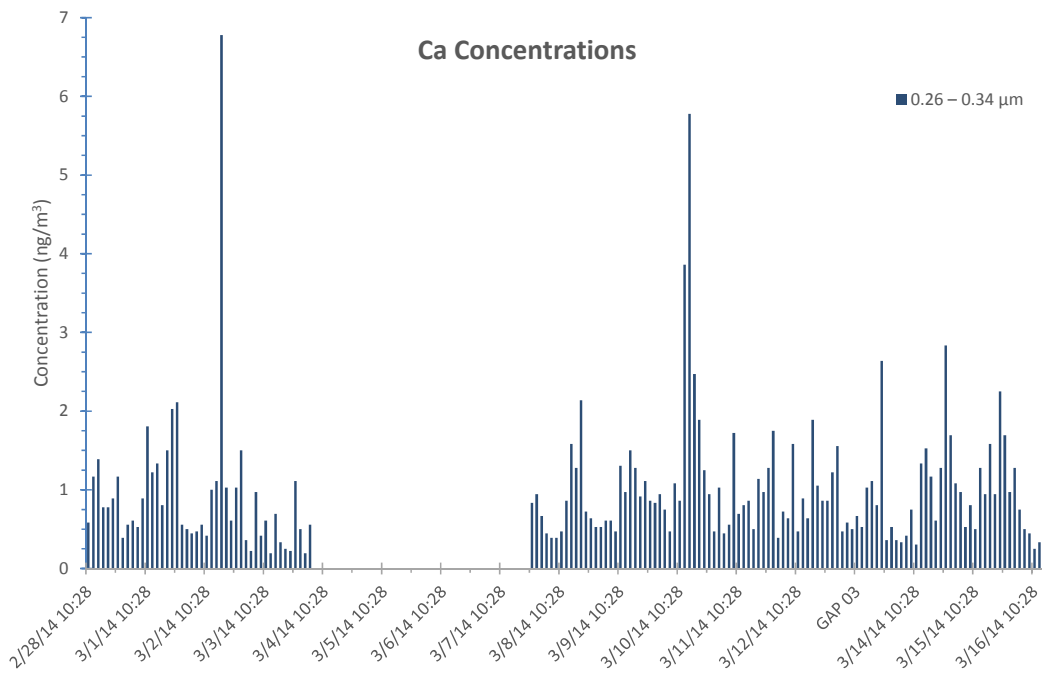


Fig. C-202 CaPh 32 DRUM: Ca mass stage 7

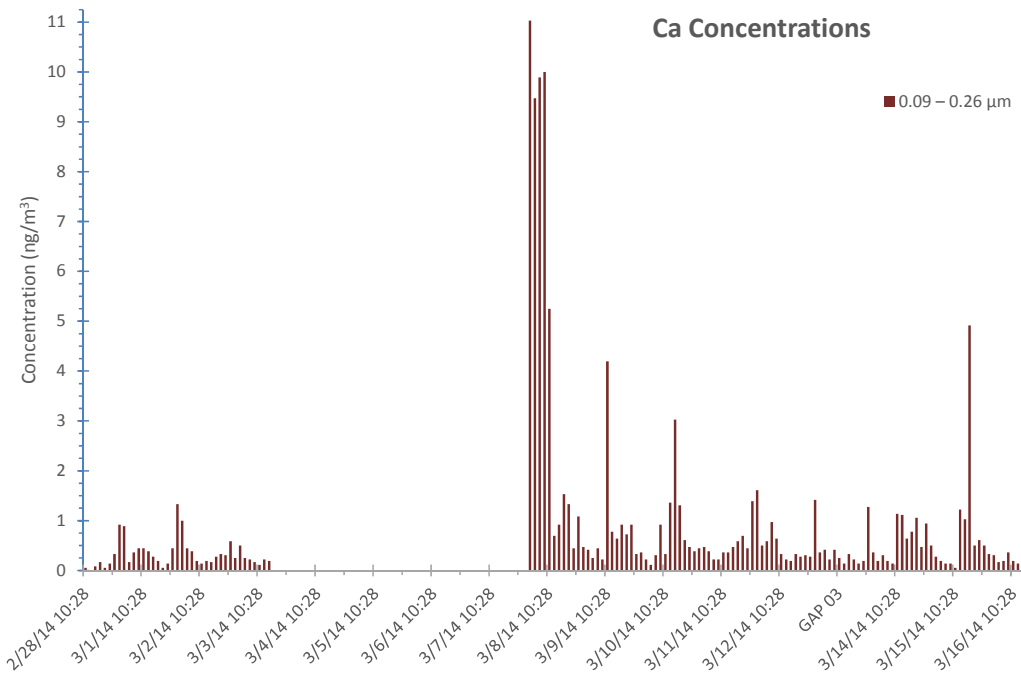


Fig. C-203 CaPh 32 DRUM: Ca mass stage 8

C-4.10 Titanium (Ti)

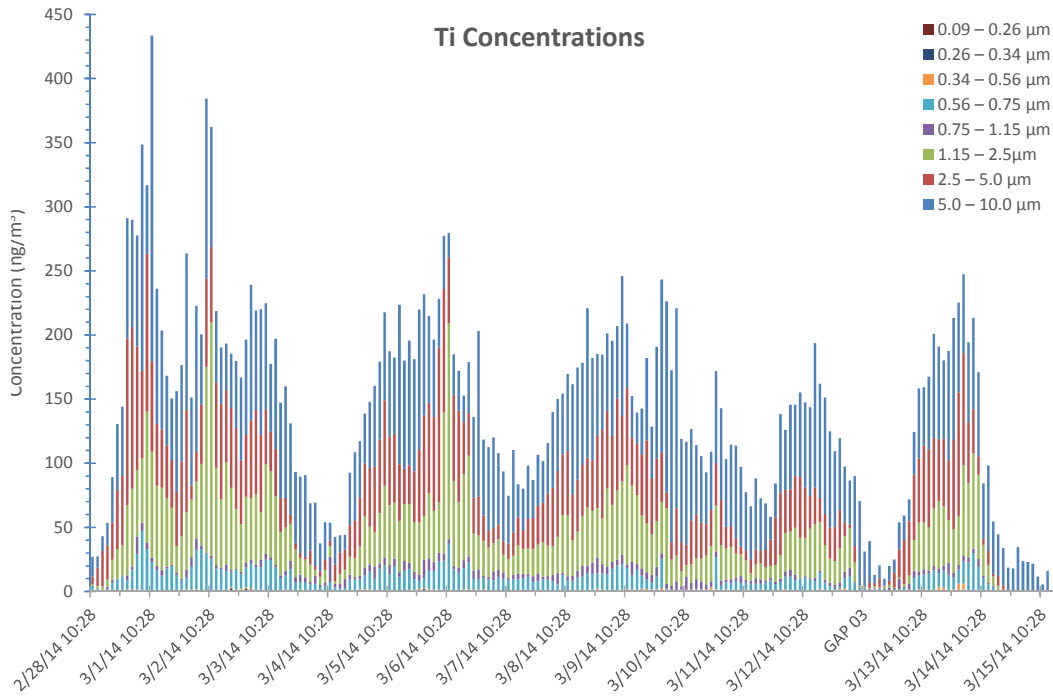


Fig. C-204 CaPh 34 DRUM: Ti mass all stages

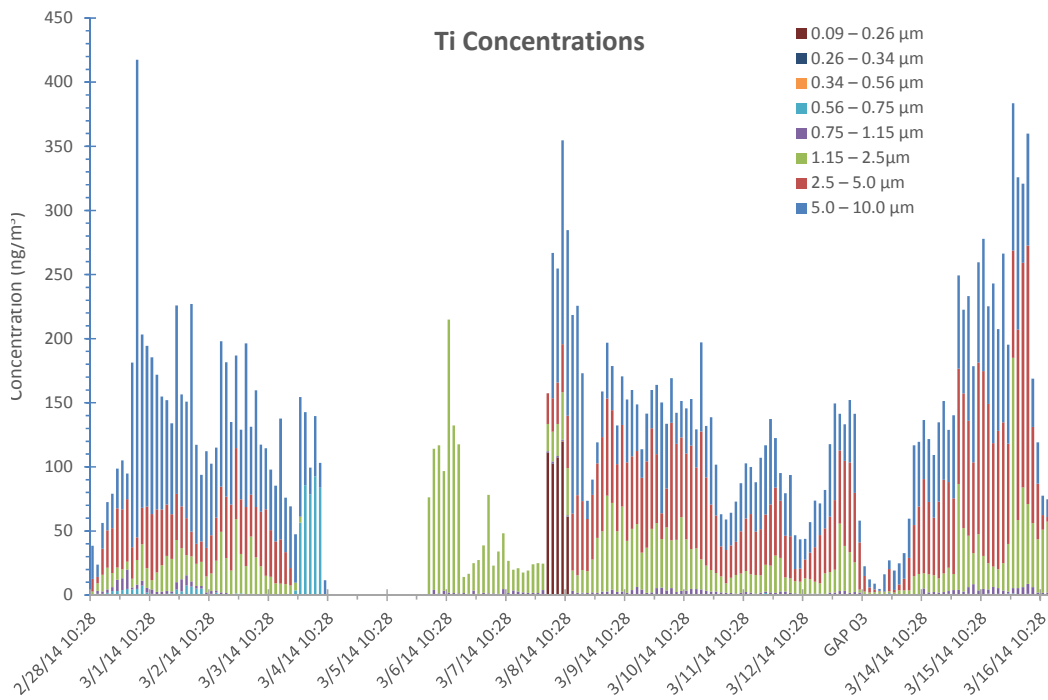
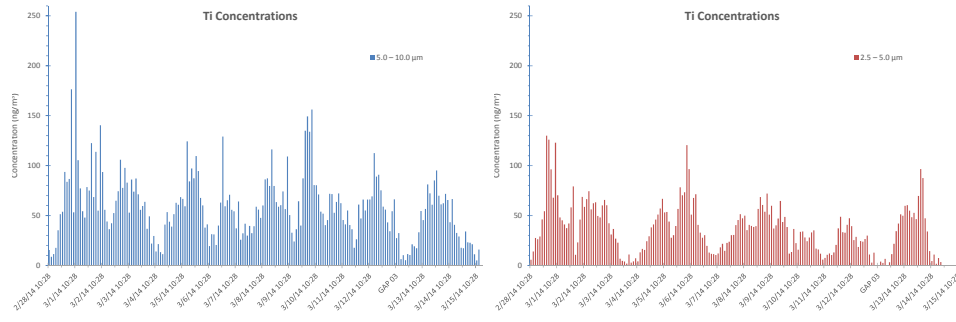
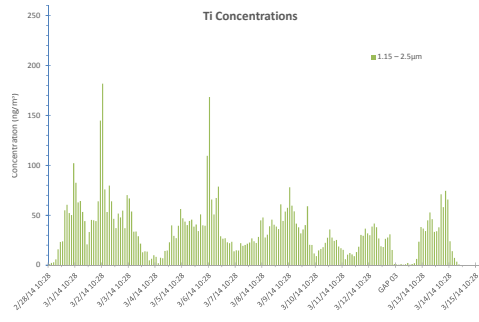


Fig. C-205 CaPh 32 DRUM: Ti mass all stages

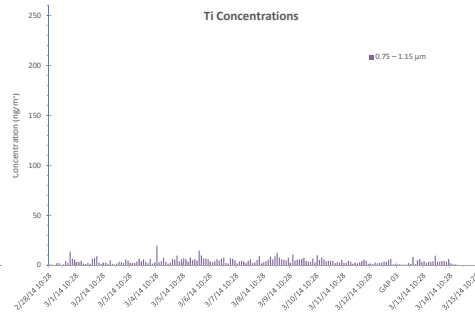


a) XRF stage 1 (5–10 μm) mass

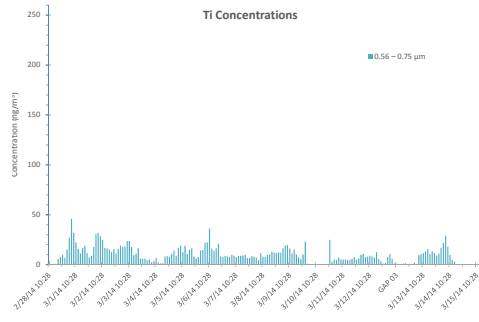
b) XRF stage 2 (2.5–5.0 μm) mass



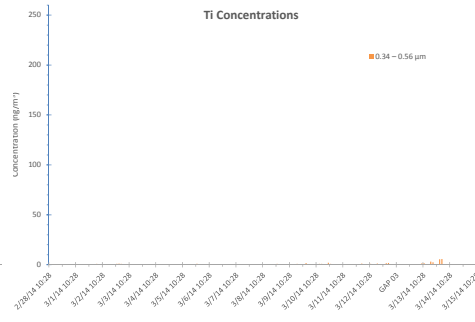
c) XRF stage 3 (1.15–2.5 μm) mass



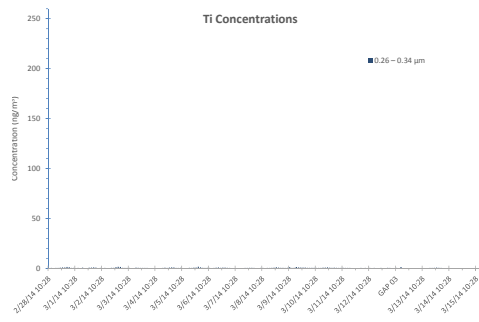
d) XRF stage 4 (0.75–1.15 μm) mass



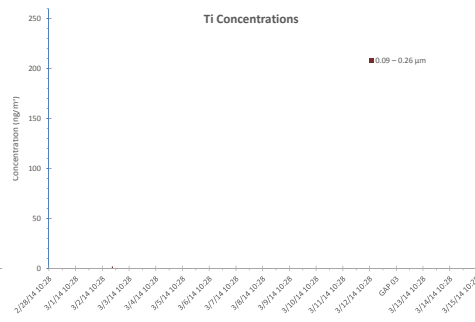
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.34–0.56 μm) mass

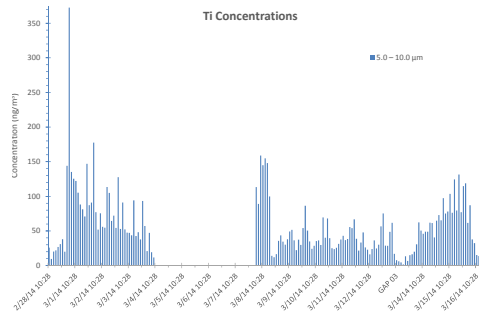


g) XRF stage 7 (0.26–0.34 μm) mass

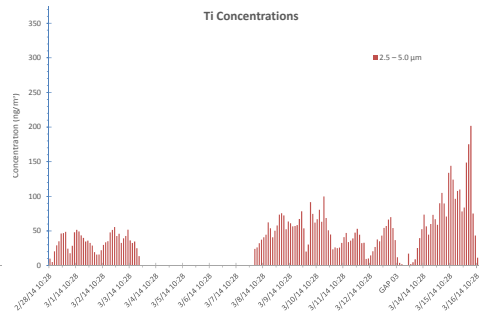


h) XRF stage 8 (0.09–0.26 μm) mass

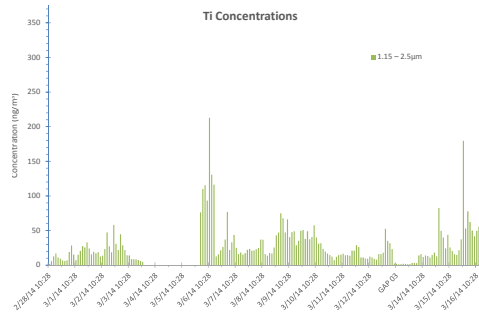
Fig. C-206 CaPh 34 DRUM: XRF mass Ti; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



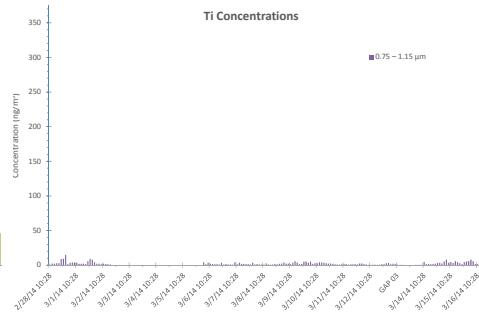
a) XRF stage 1 (5–10 μm) mass



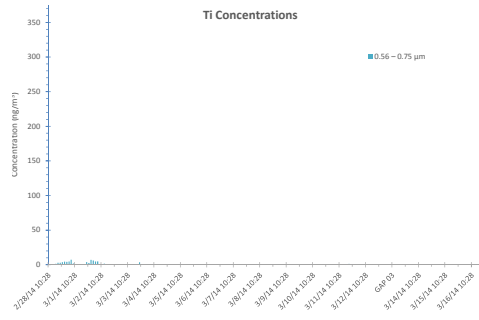
b) XRF stage 2 (2.5–5.0 μm) mass



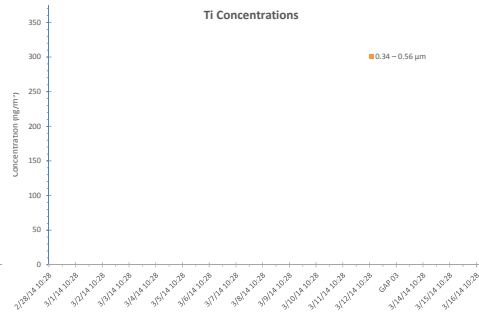
c) XRF stage 3 (1.15–2.5 μm) mass



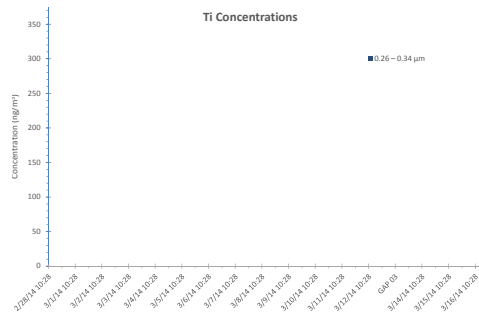
d) XRF stage 4 (0.75–1.15 μm) mass



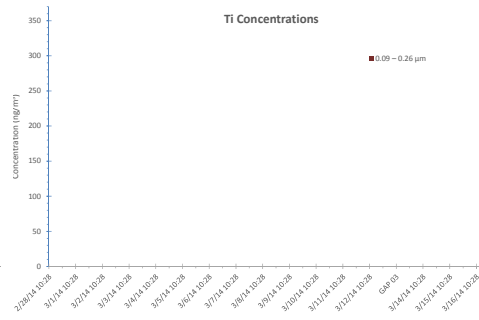
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-207 CaPh 32 DRUM: XRF mass Ti; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

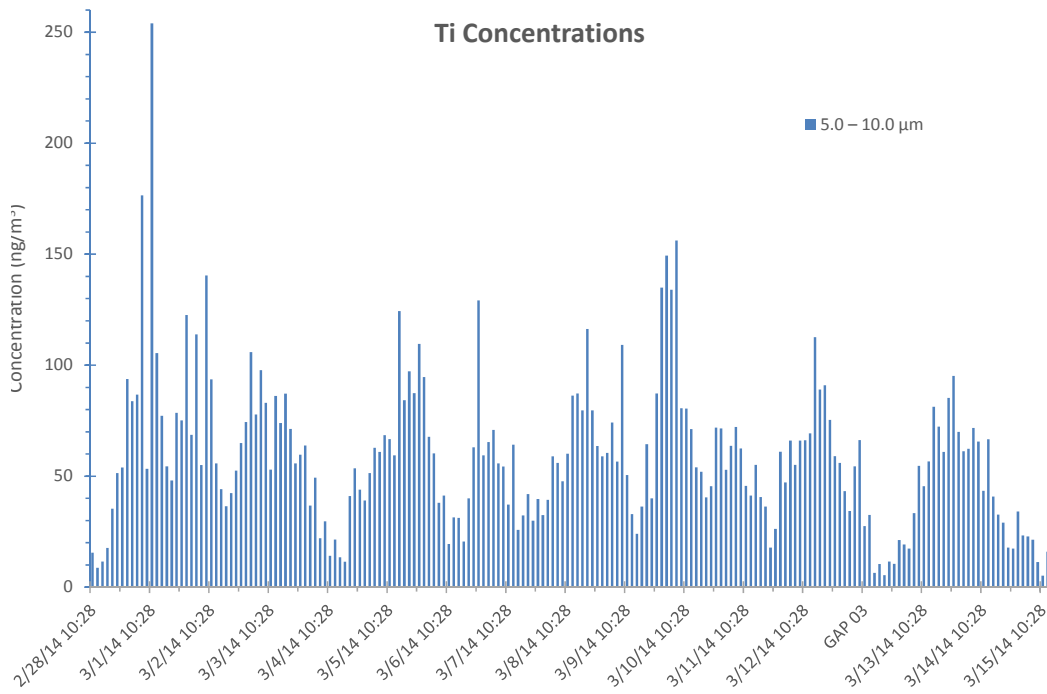


Fig. C-208 CaPh 34 DRUM: Ti mass stage 1

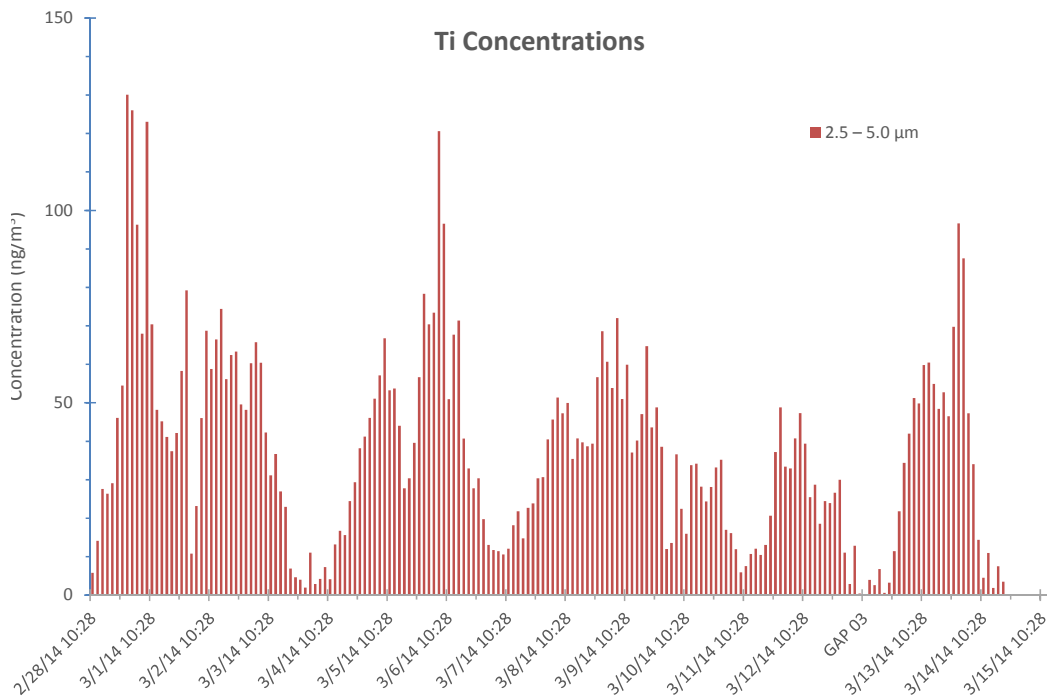


Fig. C-209 CaPh 34 DRUM: Ti mass stage 2

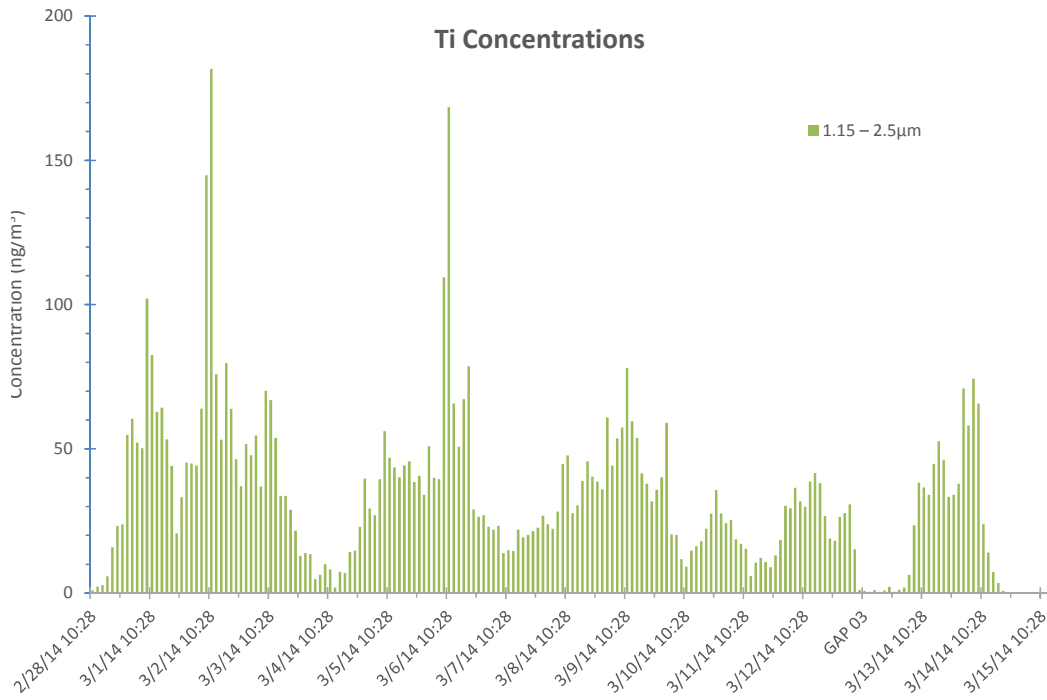


Fig. C-210 CaPh 34 DRUM: Ti mass stage 3

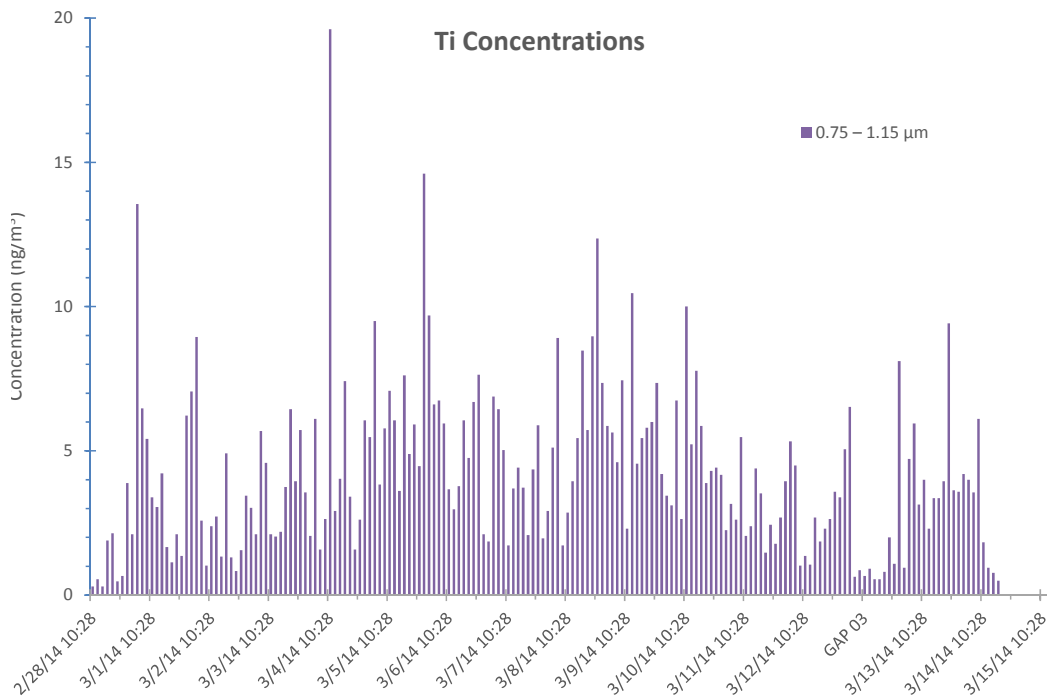


Fig. C-211 CaPh 34 DRUM: Ti mass stage 4

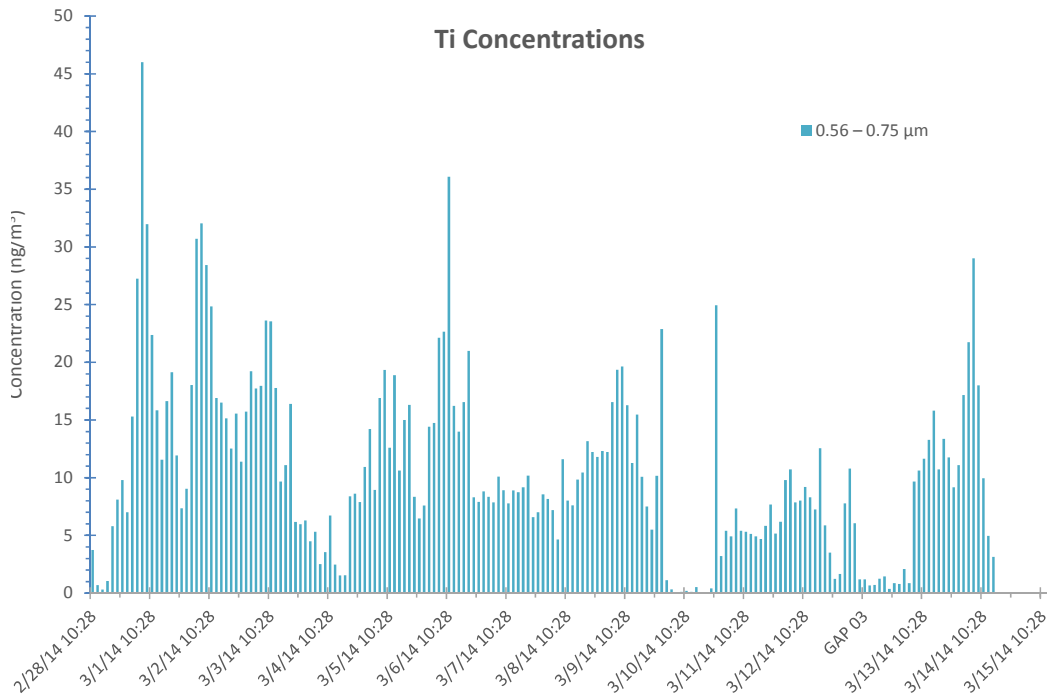


Fig. C-212 CaPh 34 DRUM: Ti mass stage 5

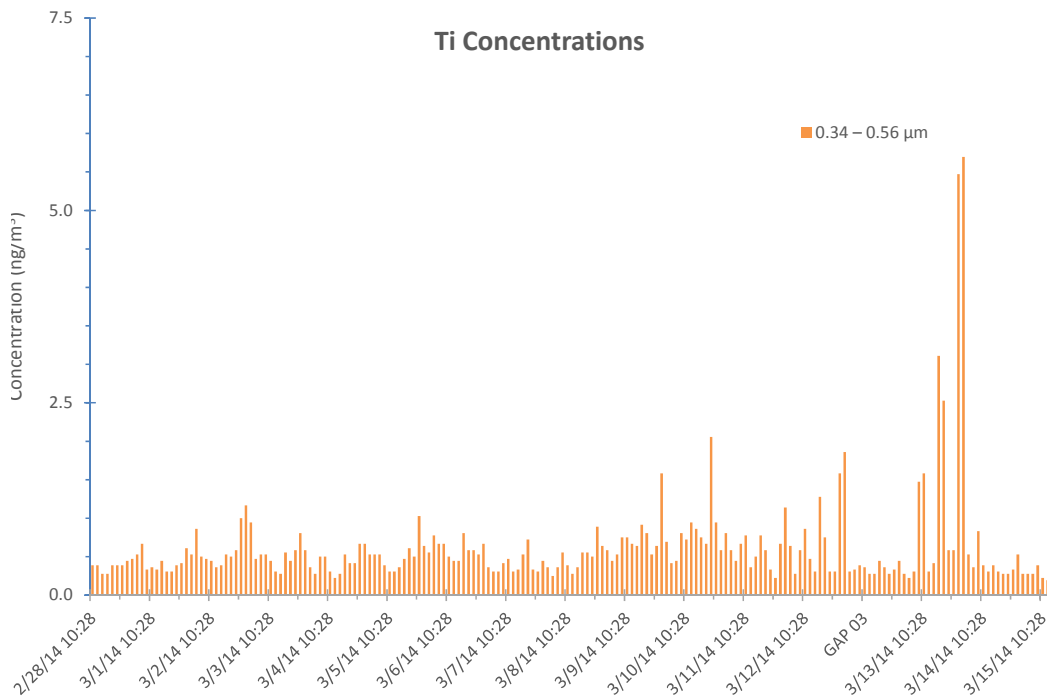


Fig. C-213 CaPh 34 DRUM: Ti mass stage 6

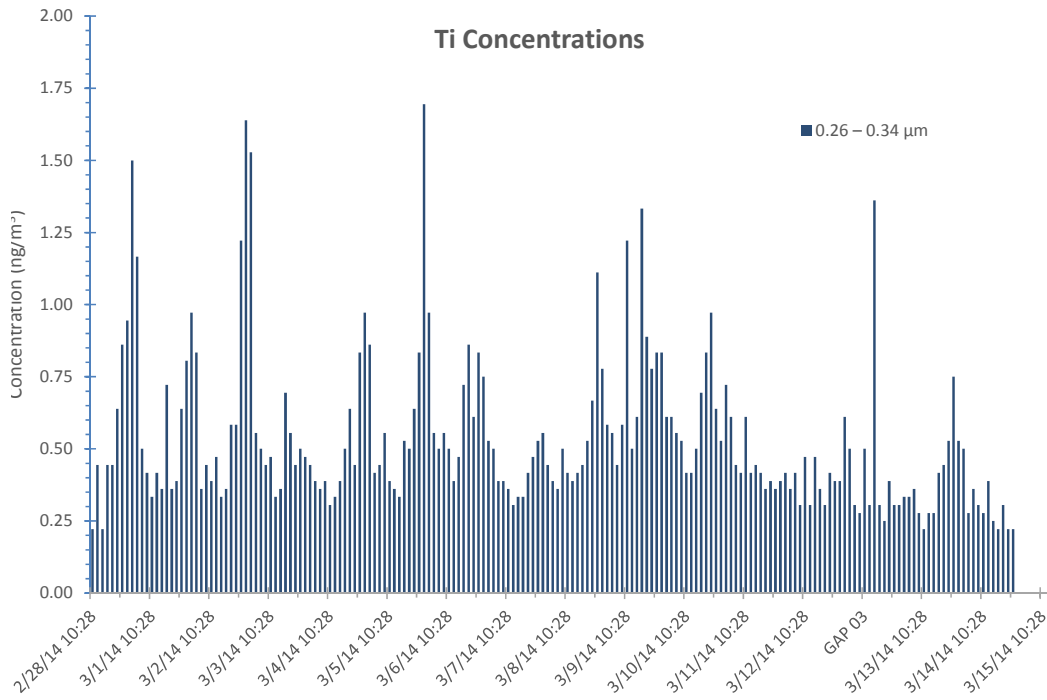


Fig. C-214 CaPh 34 DRUM: Ti mass stage 7

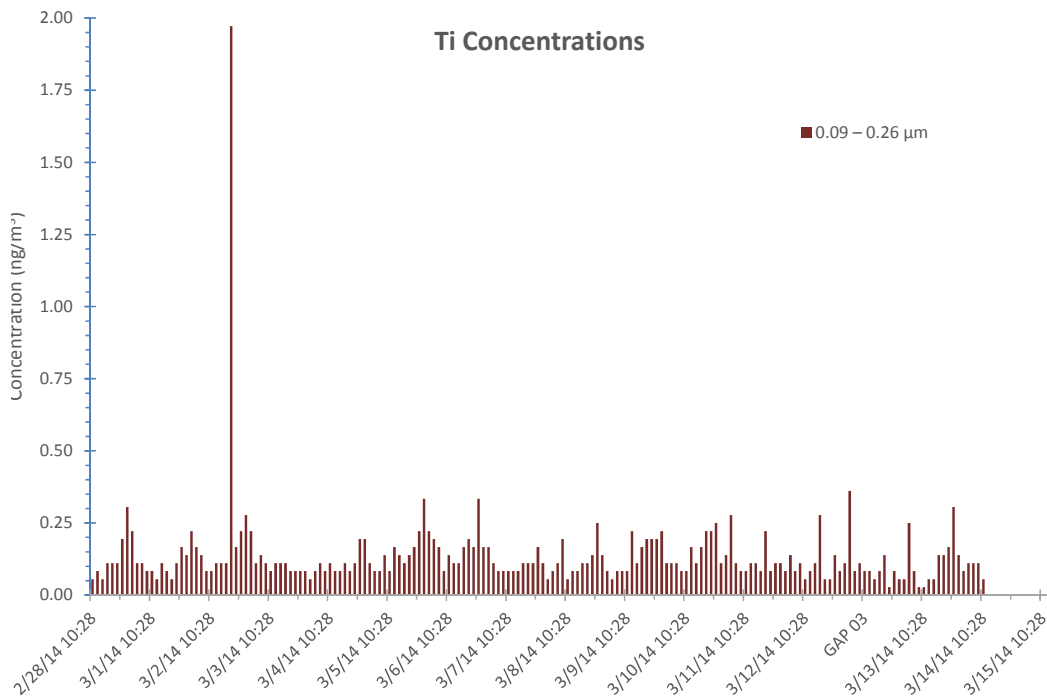


Fig. C-215 CaPh 34 DRUM: Ti mass stage 8

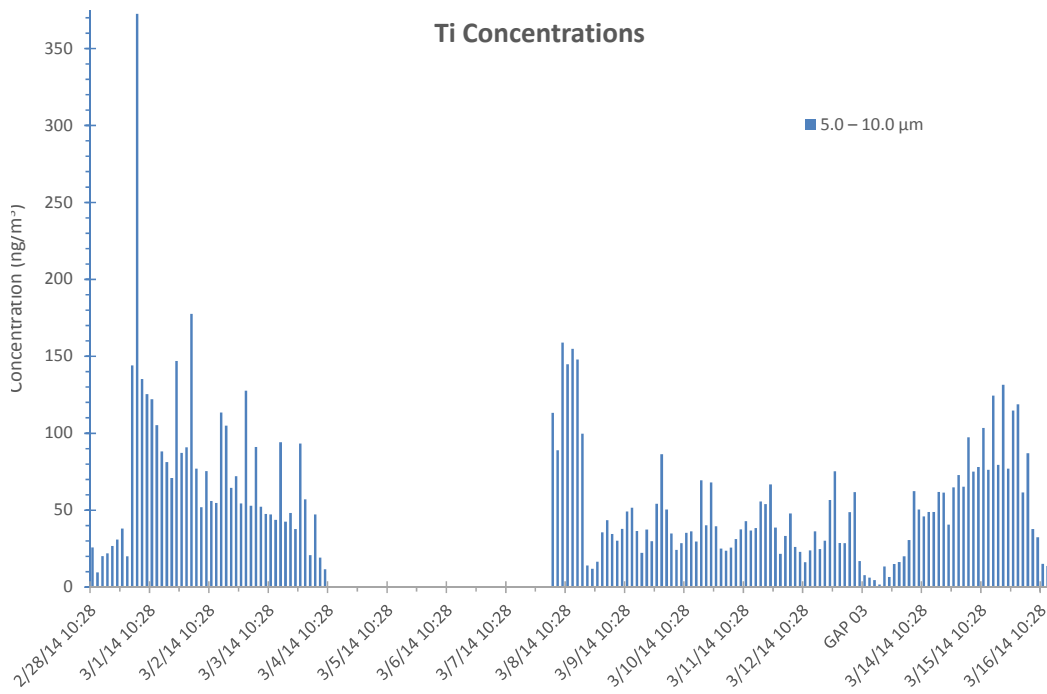


Fig. C-216 CaPh 32 DRUM: Ti mass stage 1

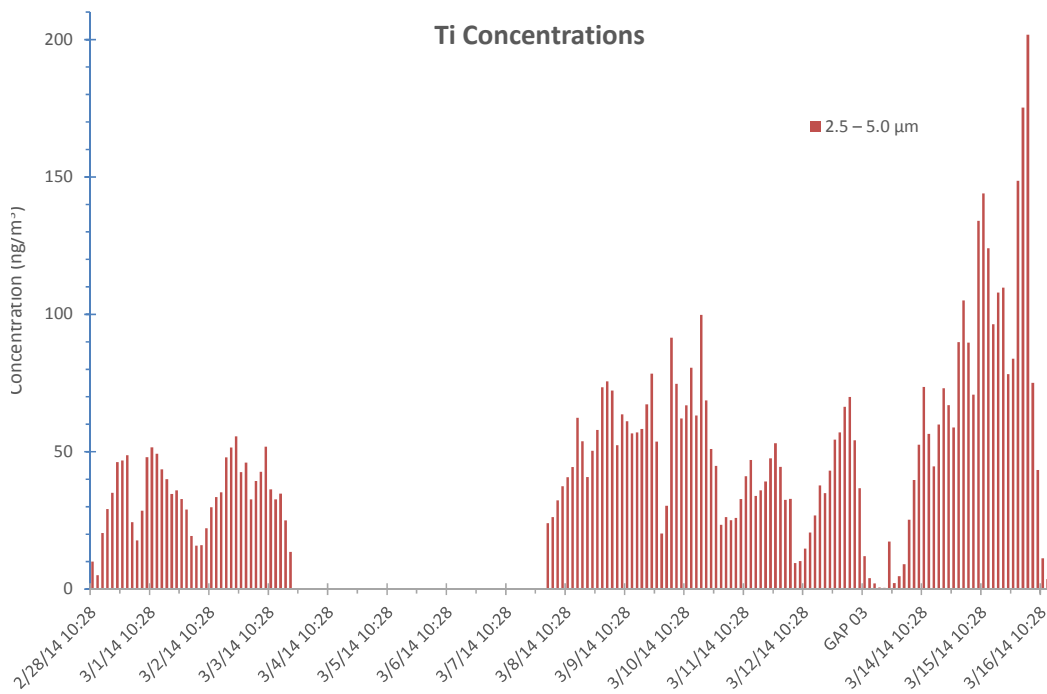


Fig. C-217 CaPh 32 DRUM: Ti mass stage 2

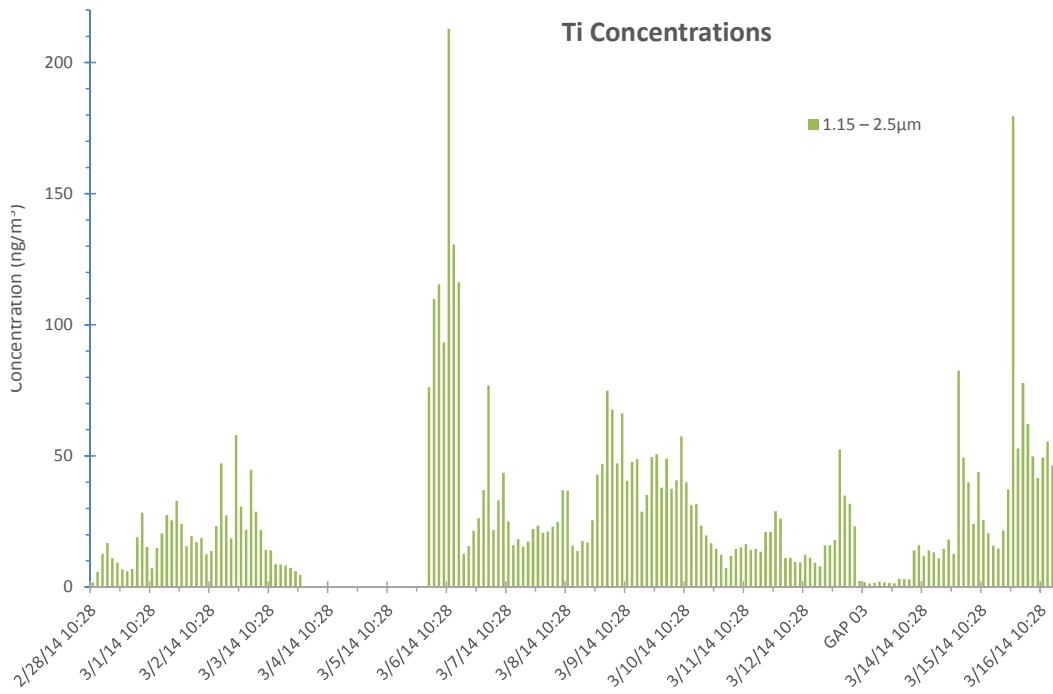


Fig. C-218 CaPh 32 DRUM: Ti mass stage 3

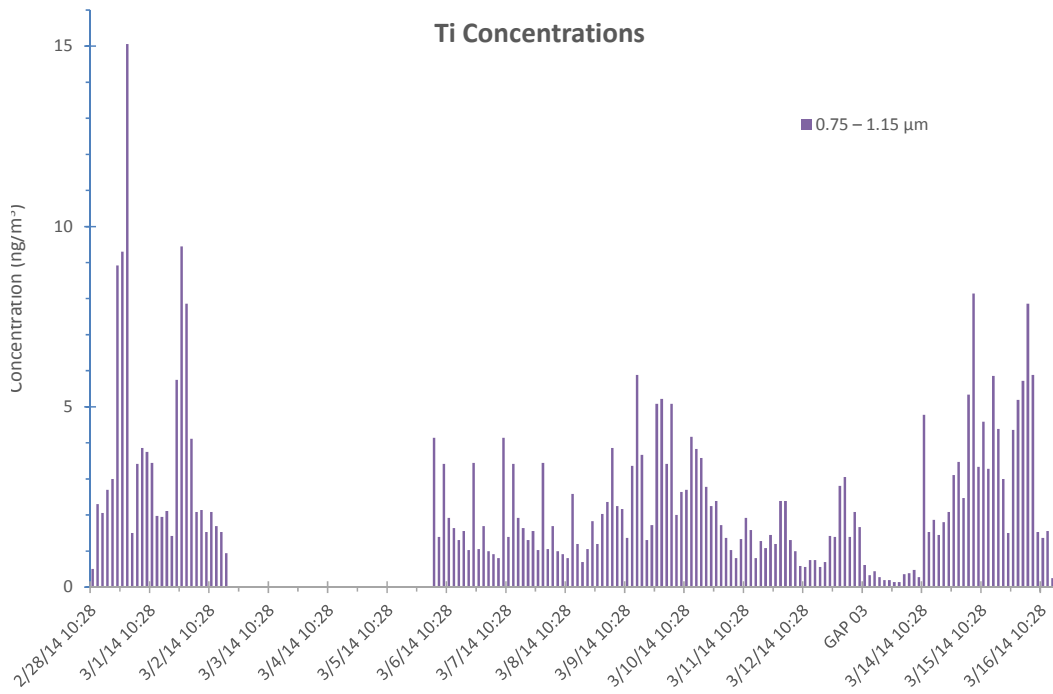


Fig. C-219 CaPh 32 DRUM: Ti mass stage 4

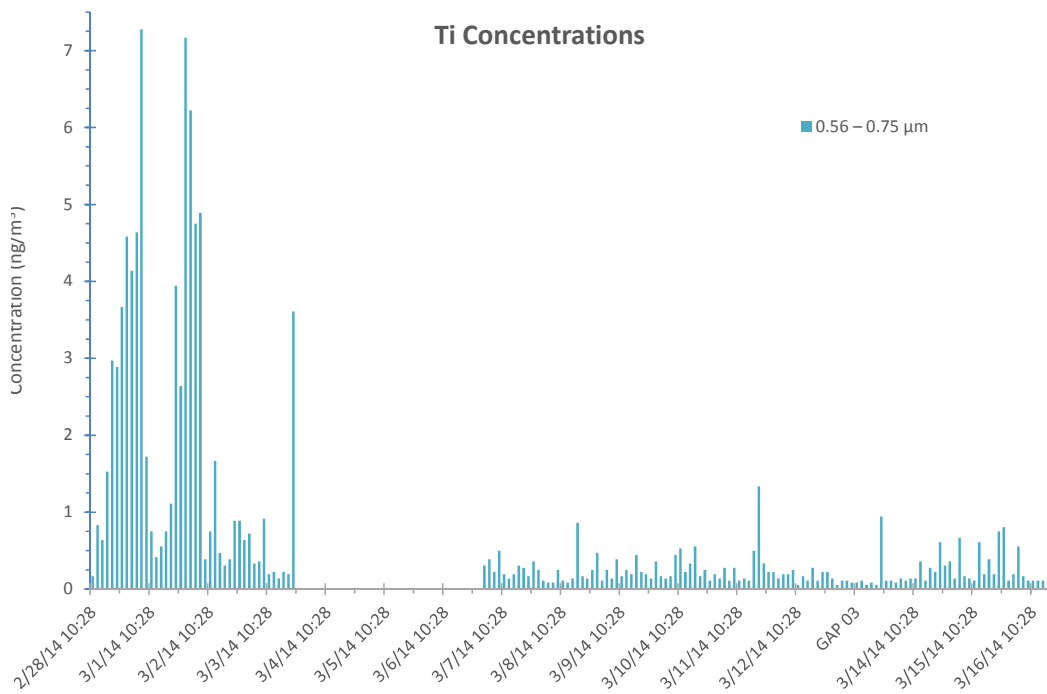


Fig. C-220 CaPh 32 DRUM: Ti mass stage 5

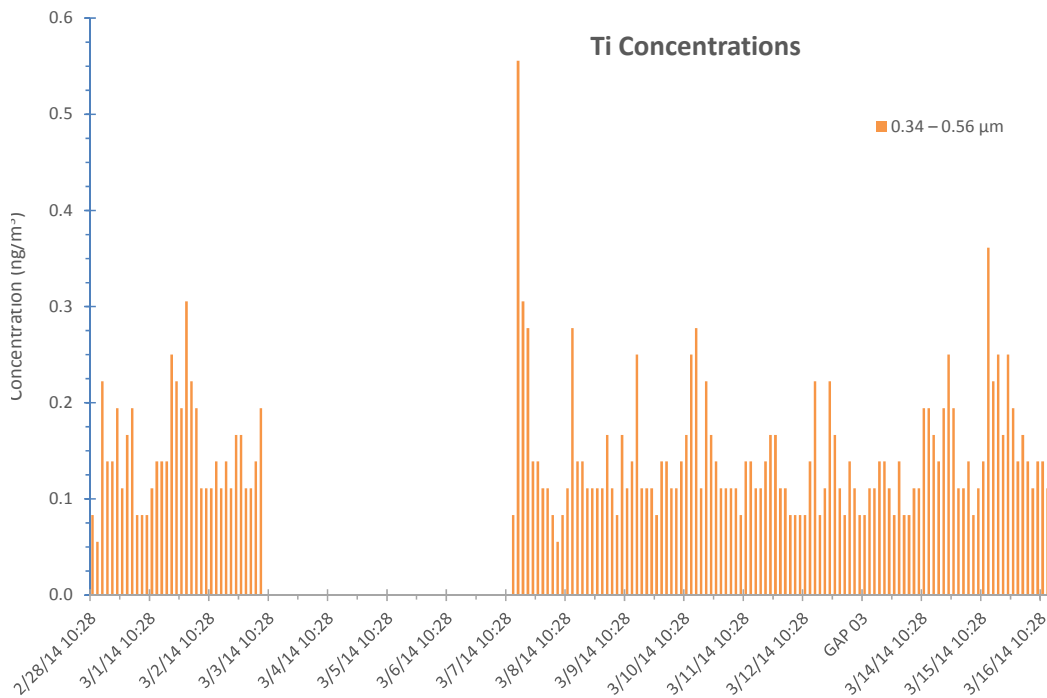


Fig. C-221 CaPh 32 DRUM: Ti mass stage 6

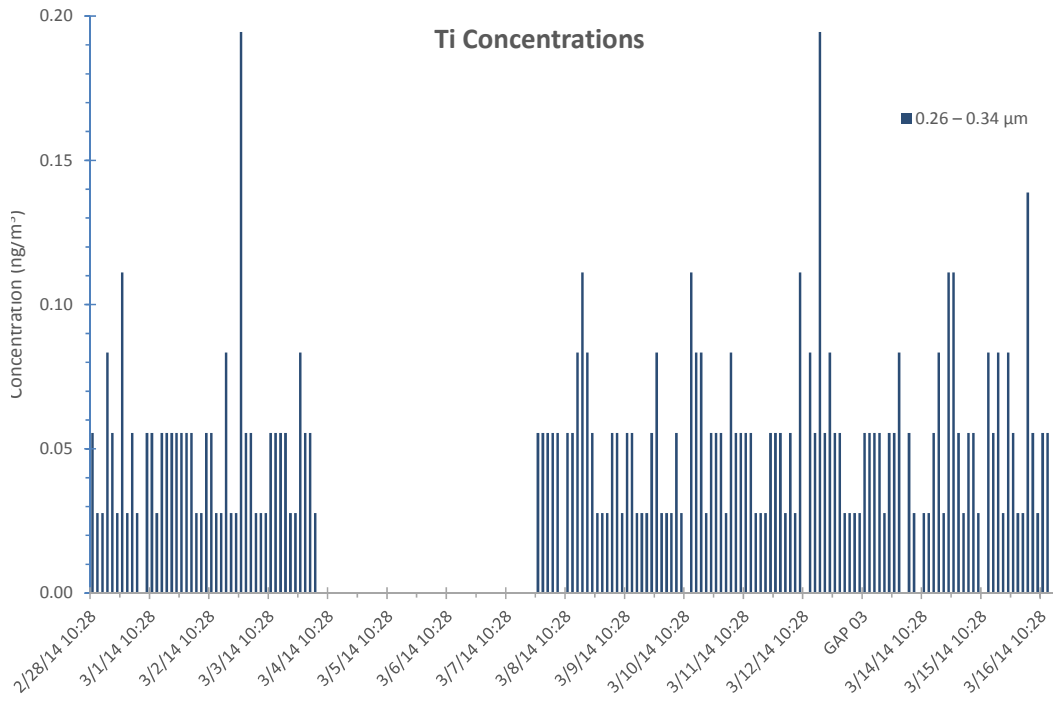


Fig. C-222 CaPh 32 DRUM: Ti mass stage 7

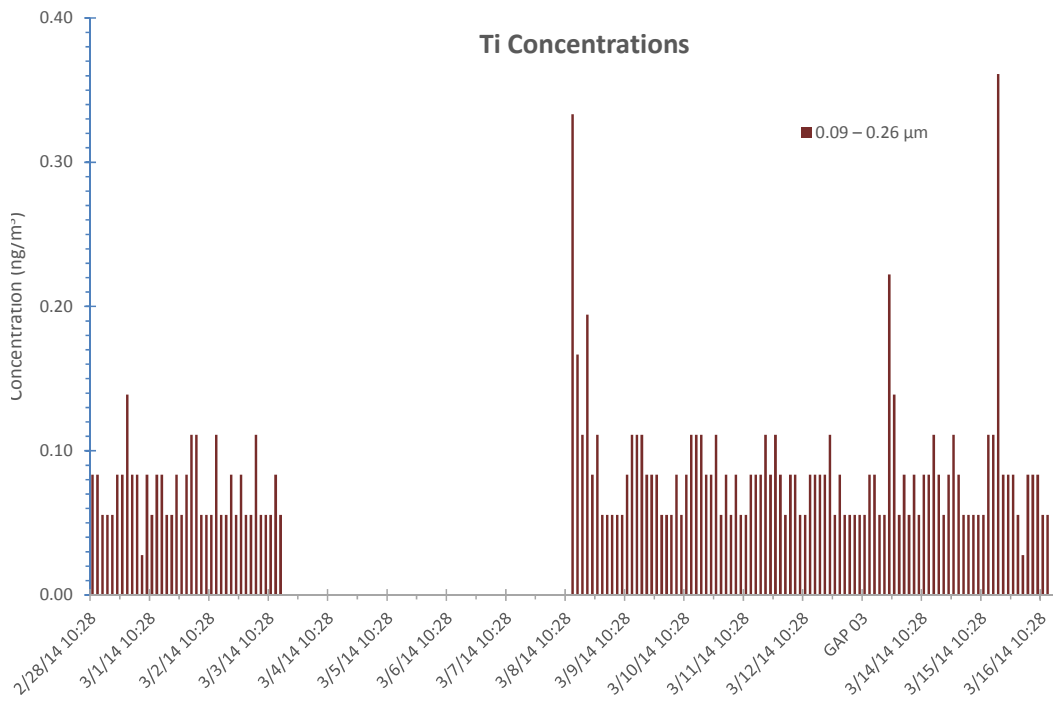


Fig. C-223 CaPh 32 DRUM: Ti mass stage 8

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C-4.11 Vanadium (V)

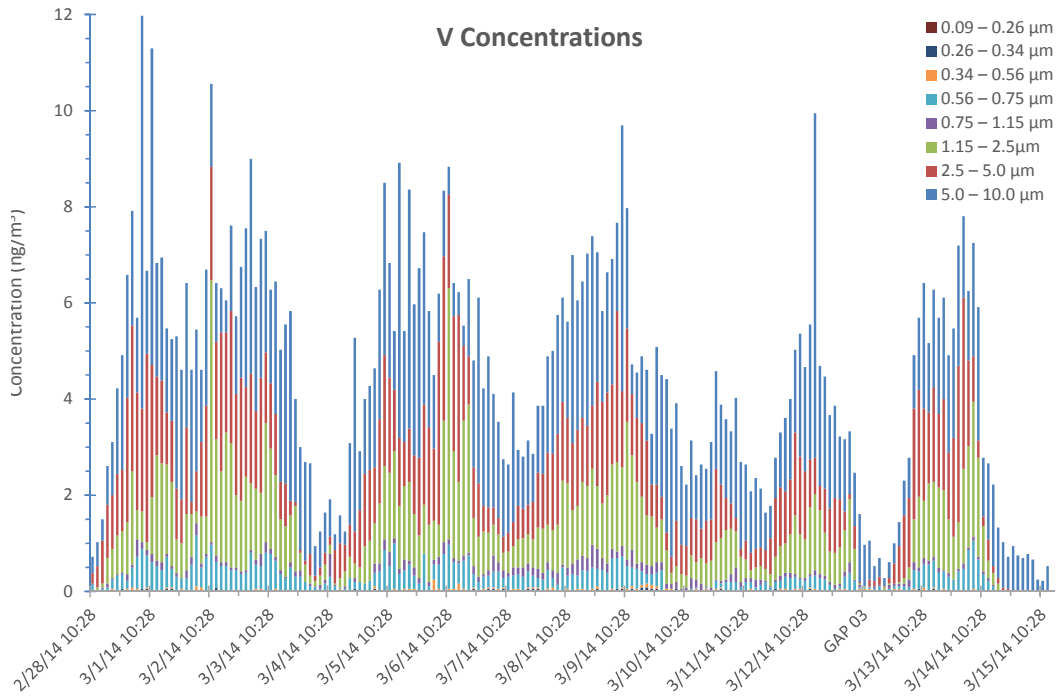


Fig. C-224 CaPh 34 DRUM: V mass all stages

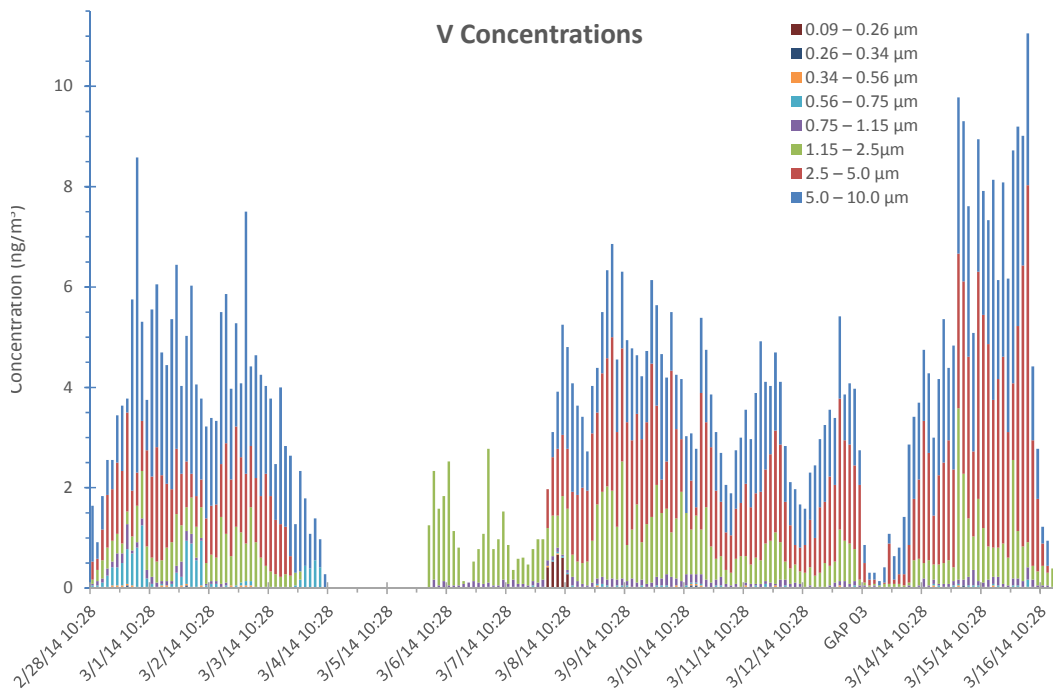
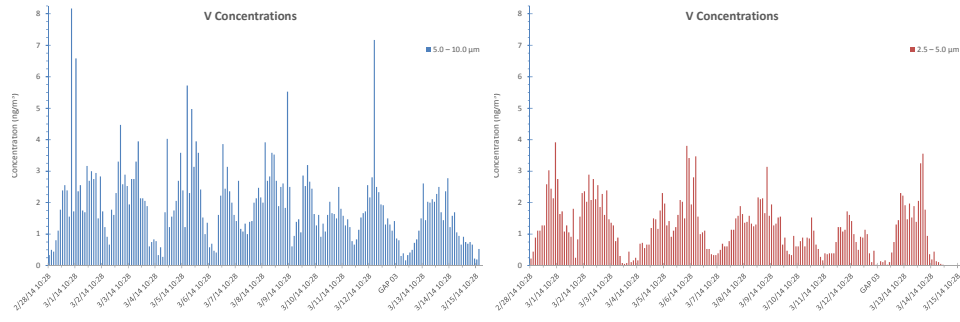
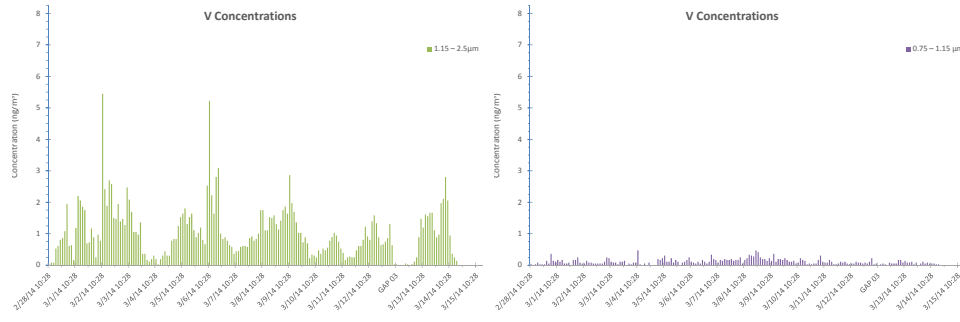


Fig. C-225 CaPh 32 DRUM: V mass all stages



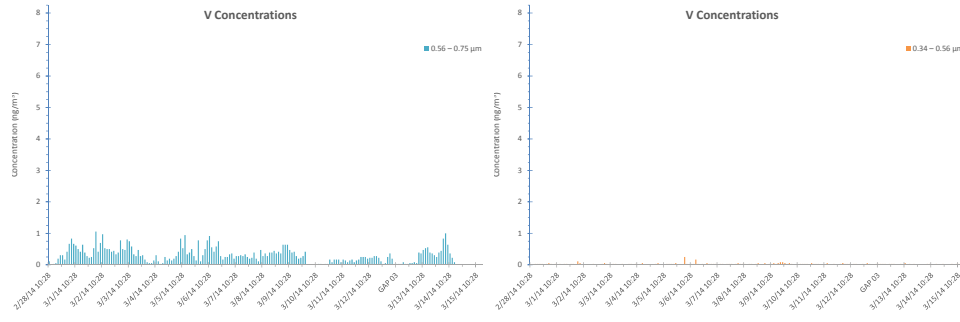
a) XRF stage 1 (5–10 μm) mass

b) XRF stage 2 (2.5–5.0 μm) mass



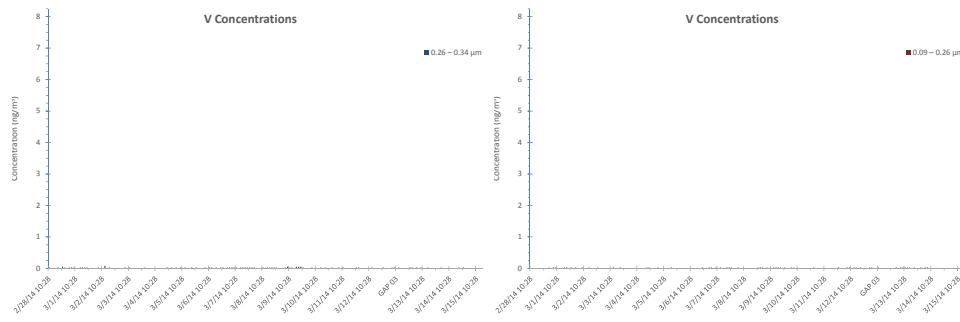
c) XRF stage 3 (1.15–2.5 μm) mass

d) XRF stage 4 (0.75–1.15 μm) mass



e) XRF stage 5 (0.56–0.75 μm) mass

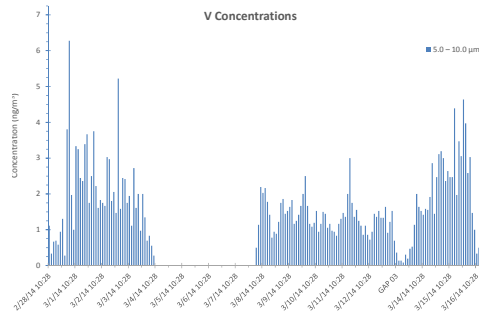
f) XRF stage 6 (0.34–0.56 μm) mass



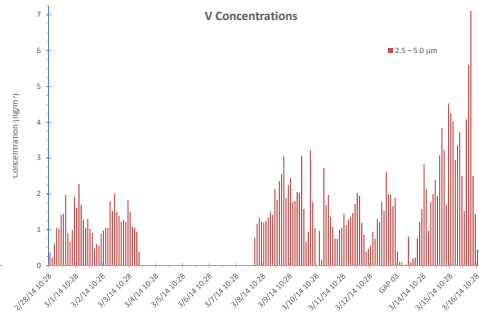
g) XRF stage 7 (0.26–0.34 μm) mass

h) XRF stage 8 (0.09–0.26 μm) mass

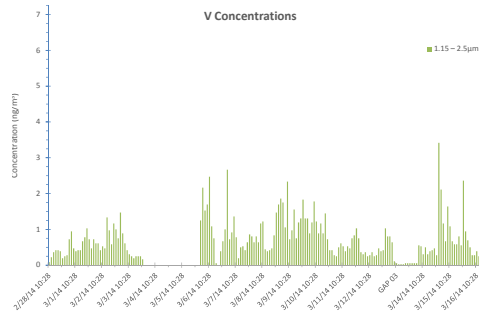
Fig. C-226 CaPh 34 DRUM: XRF mass V; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



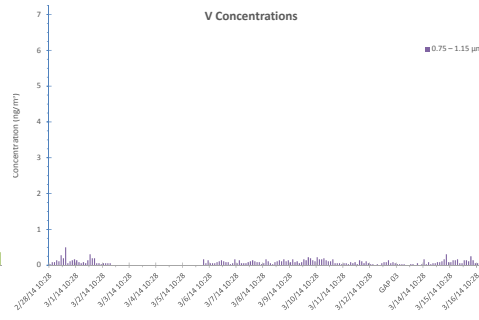
a) XRF stage 1 (5–10 μm) mass



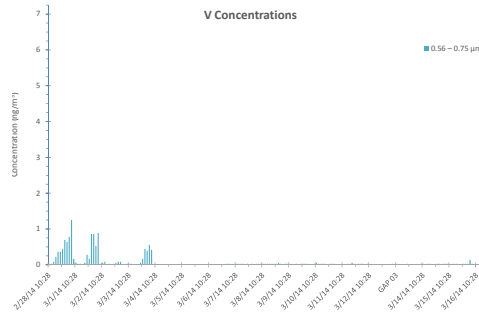
b) XRF stage 2 (2.5–5.0 μm) mass



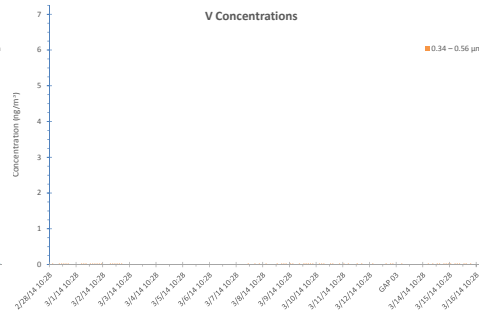
c) XRF stage 3 (1.15–2.5 μm) mass



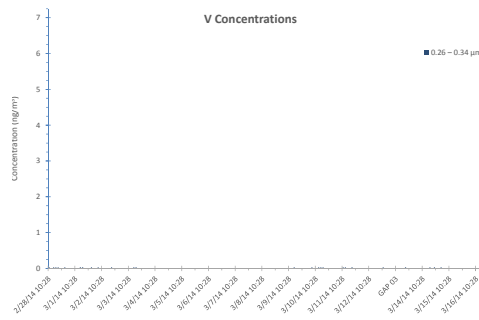
d) XRF stage 4 (0.75–1.15 μm) mass



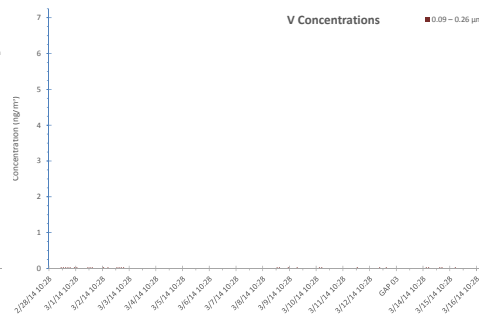
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-227 CaPh 32 DRUM: XRF mass V; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

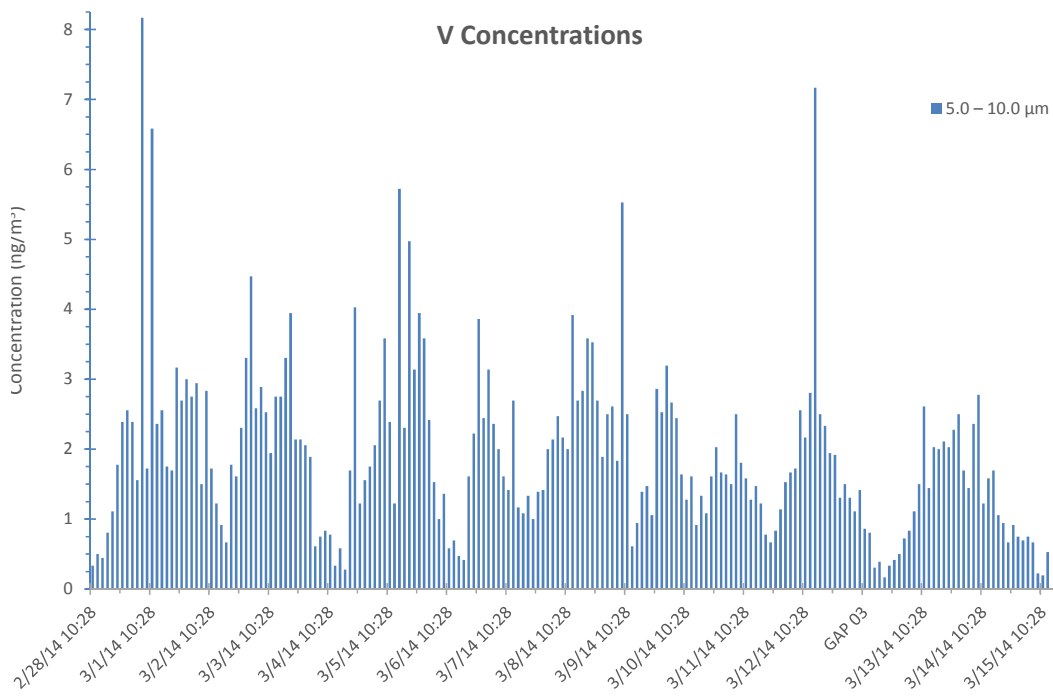


Fig. C-228 CaPh 34 DRUM: V mass stage 1

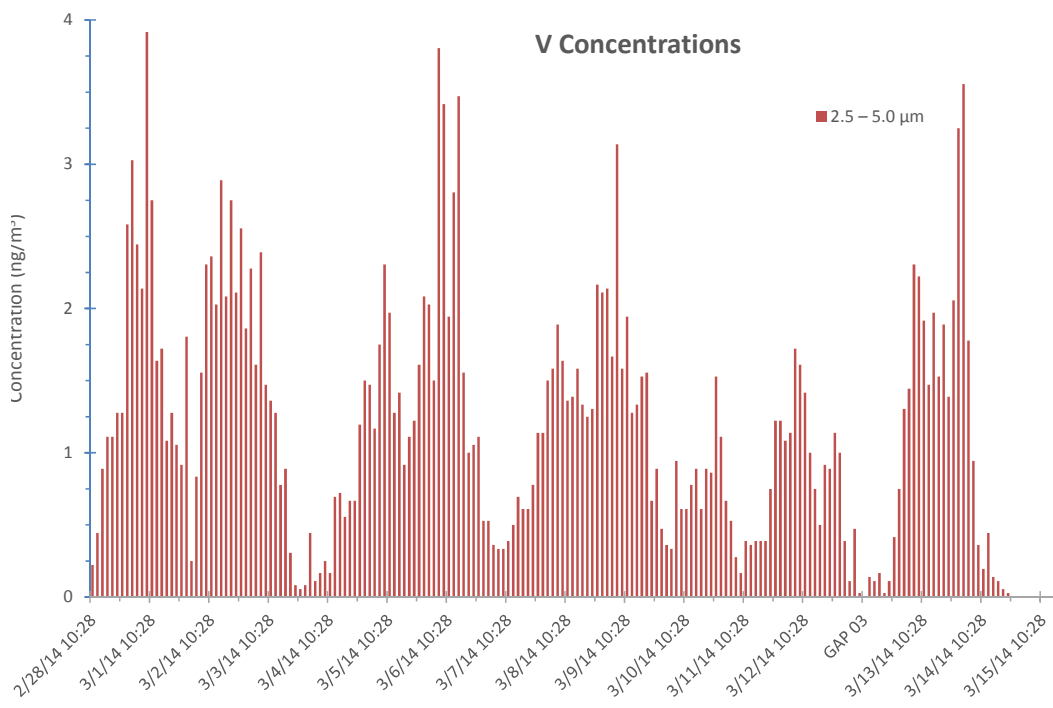


Fig. C-229 CaPh 34 DRUM: V mass stage 2

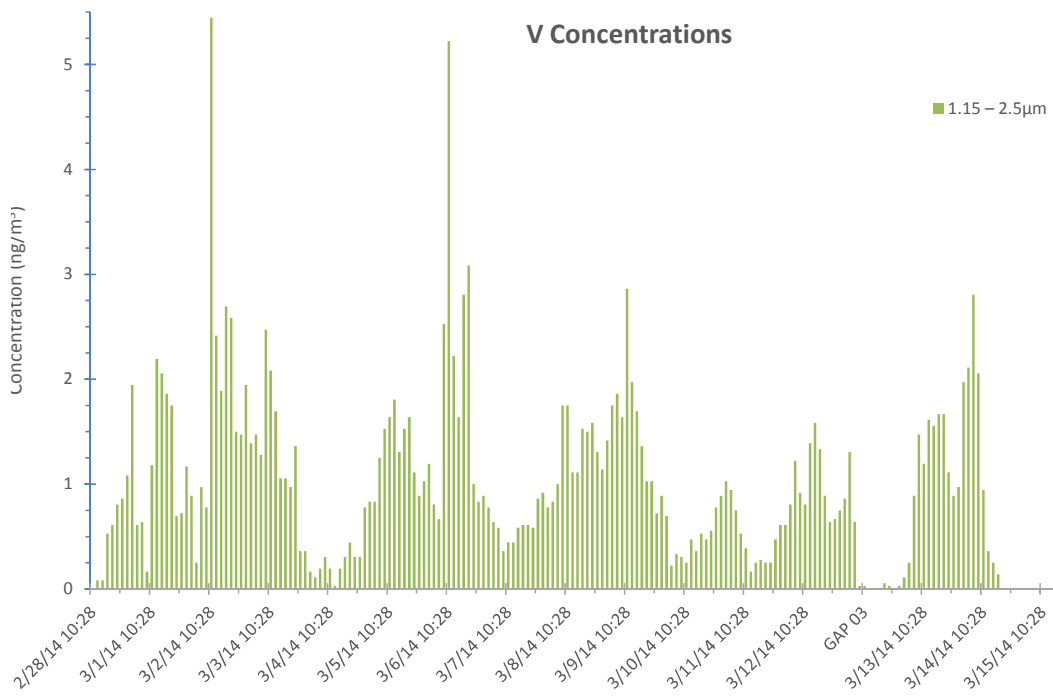


Fig. C-230 CaPh 34 DRUM: V mass stage 3

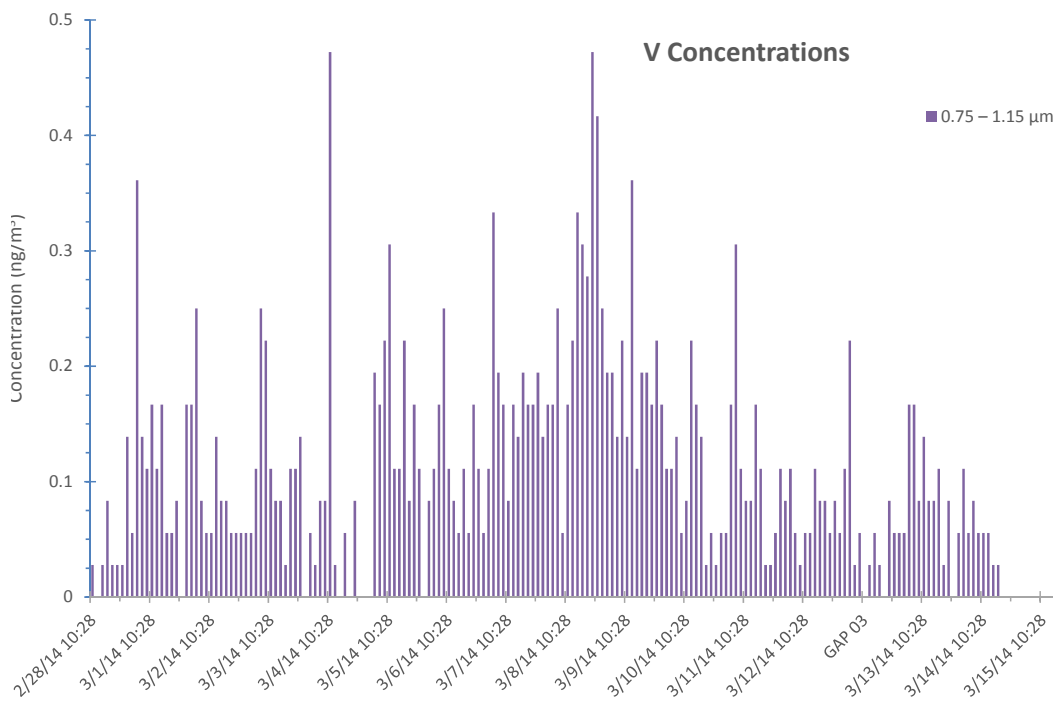


Fig. C-231 CaPh 34 DRUM: V mass stage 4

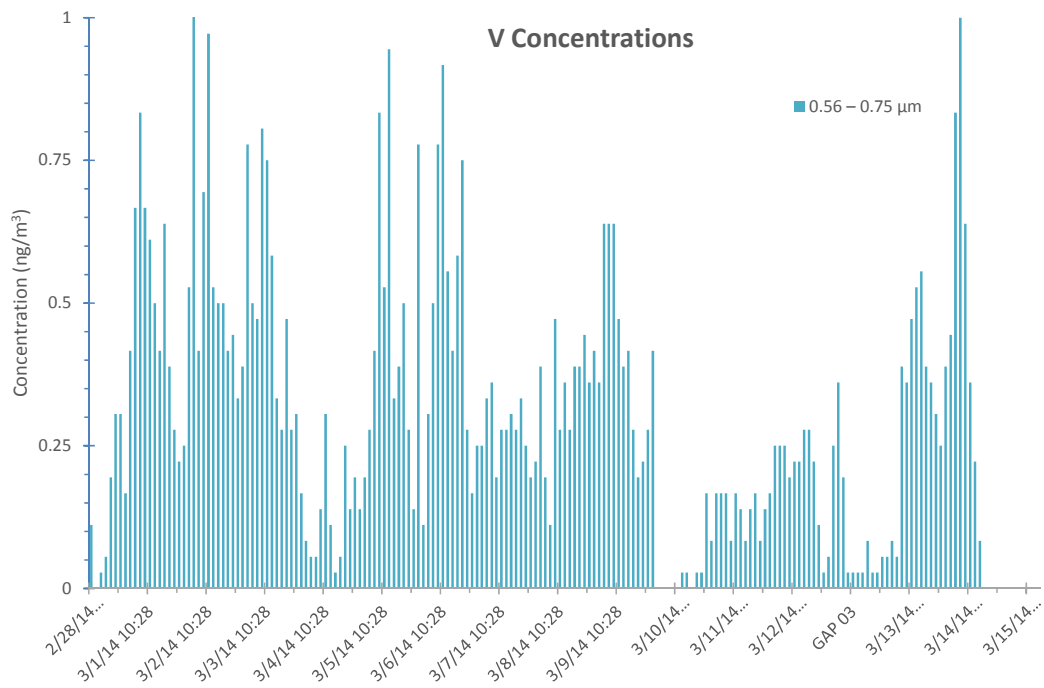


Fig. C-232 CaPh 34 DRUM: V mass stage 5

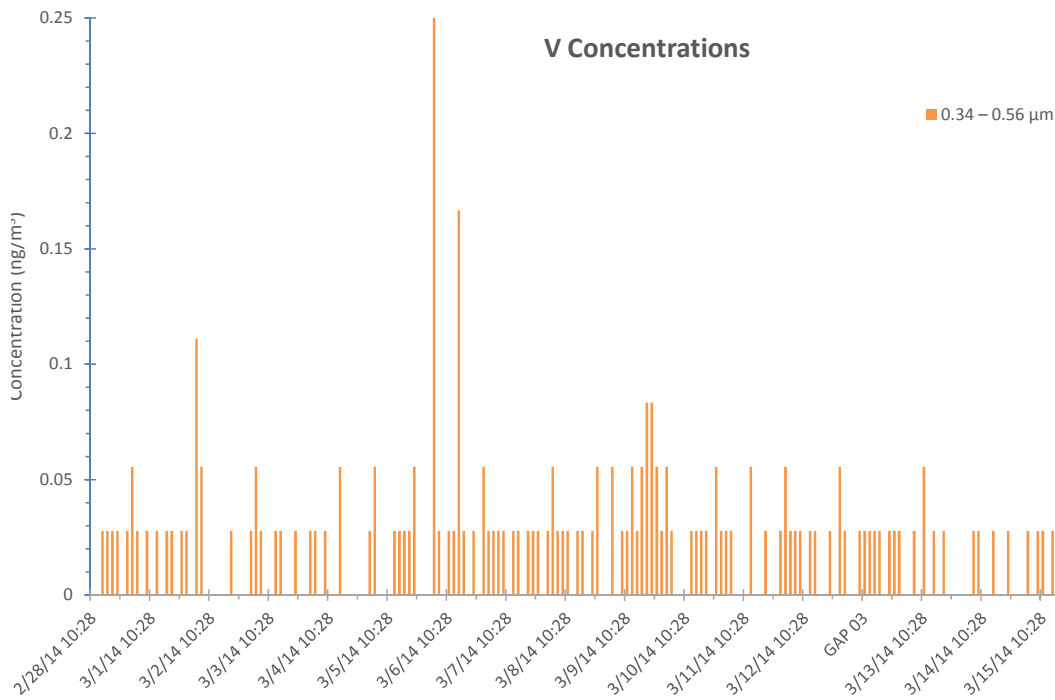


Fig. C-233 CaPh 34 DRUM: V mass stage 6

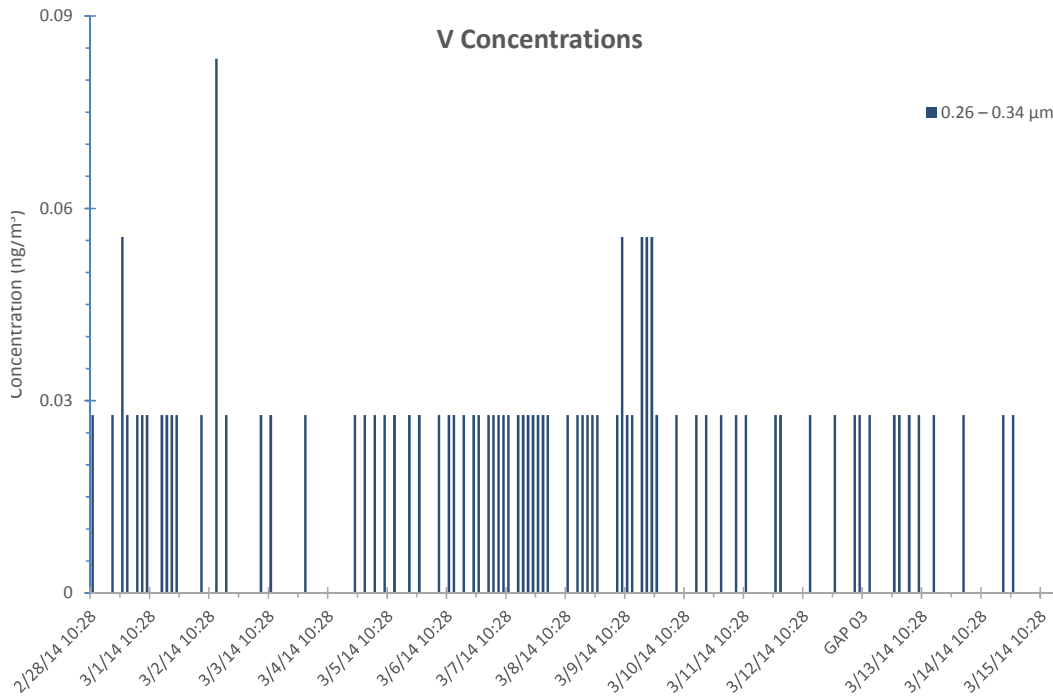


Fig. C-234 CaPh 34 DRUM: V mass stage 7

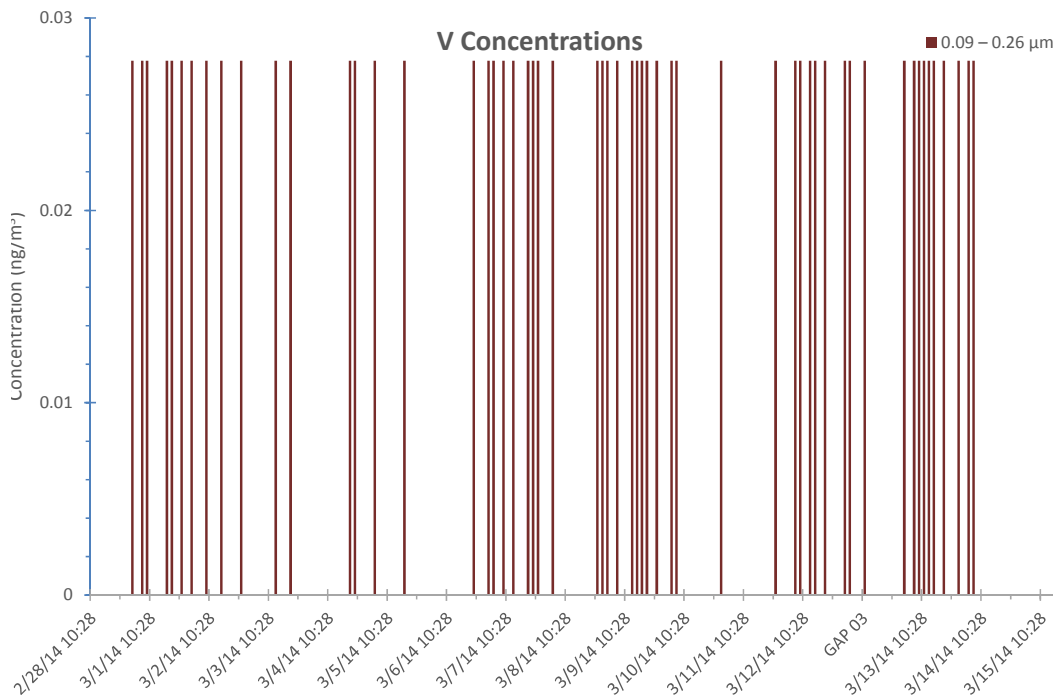


Fig. C-235 CaPh 34 DRUM: V mass stage 8

Approved for public release; distribution is unlimited.

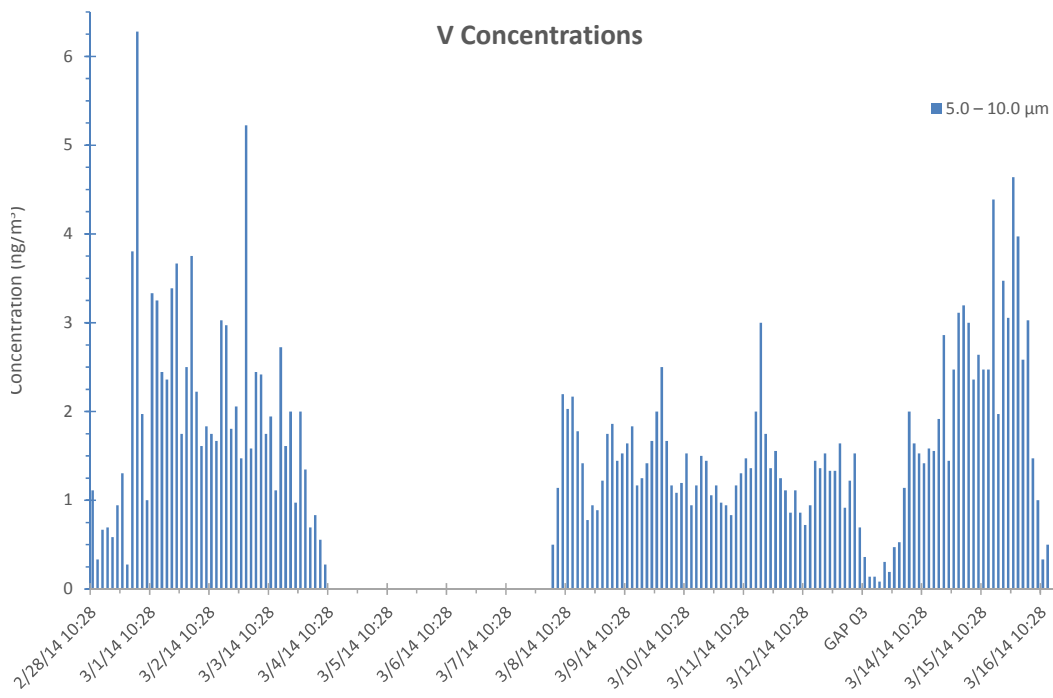


Fig. C-236 CaPh 32 DRUM: V mass stage 1

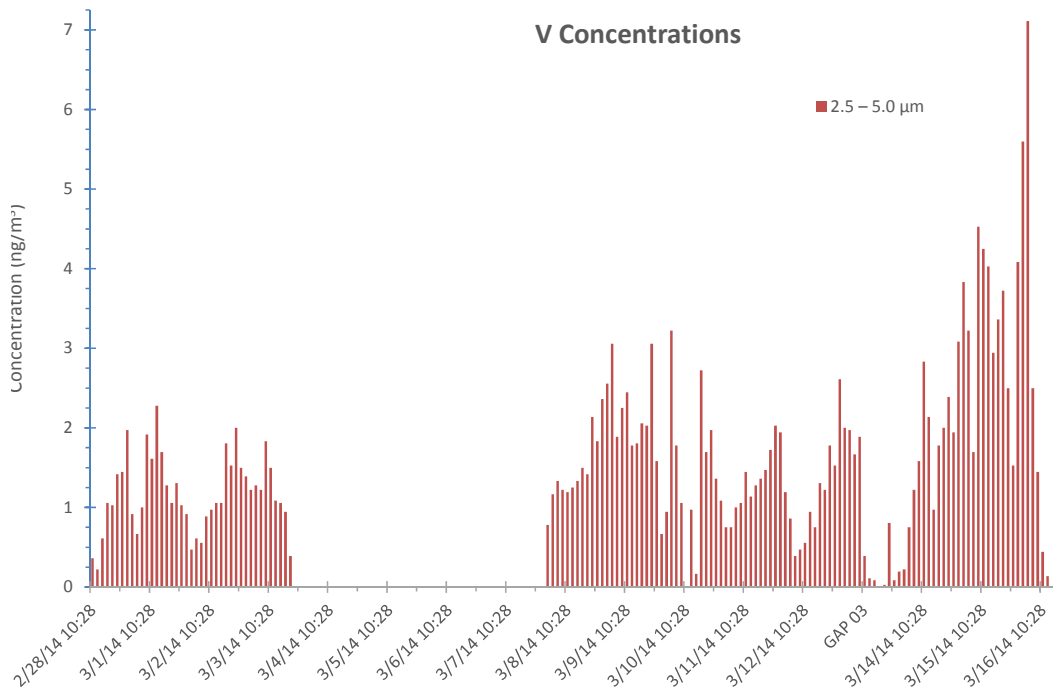


Fig. C-237 CaPh 32 DRUM: V mass stage 2

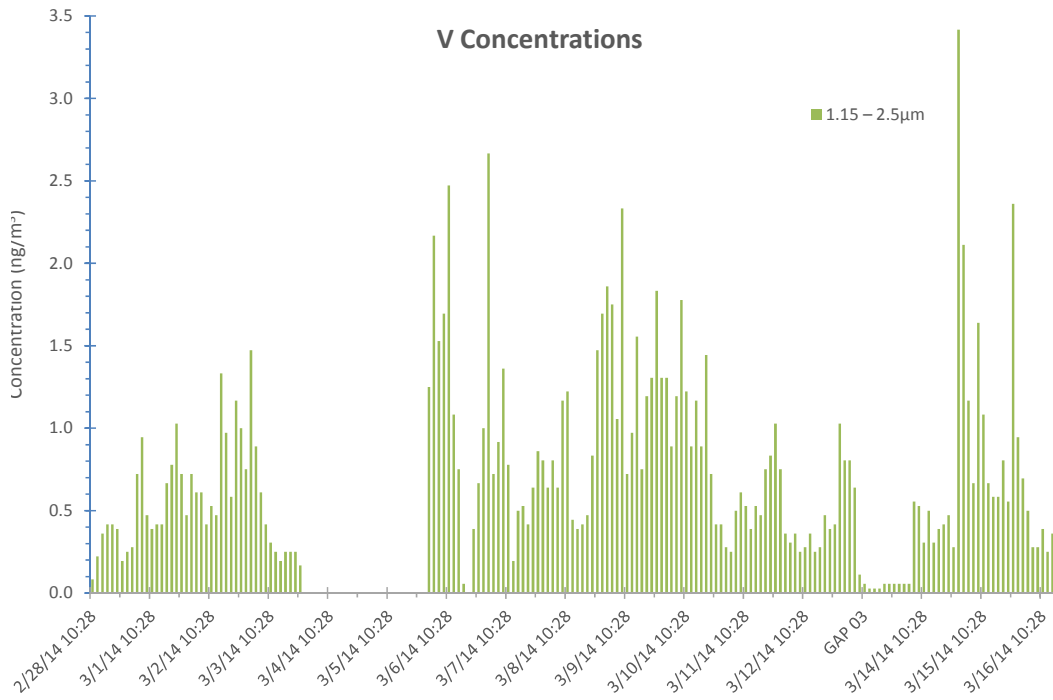


Fig. C-238 CaPh 32 DRUM: V mass stage 3

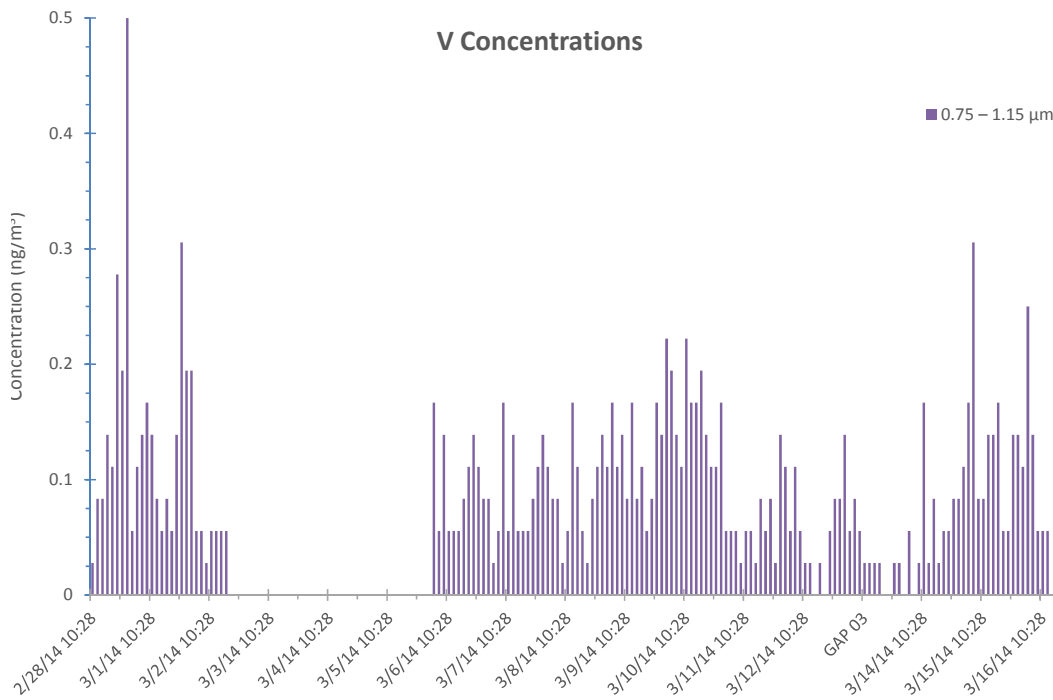


Fig. C-239 CaPh 32 DRUM: V mass stage 4

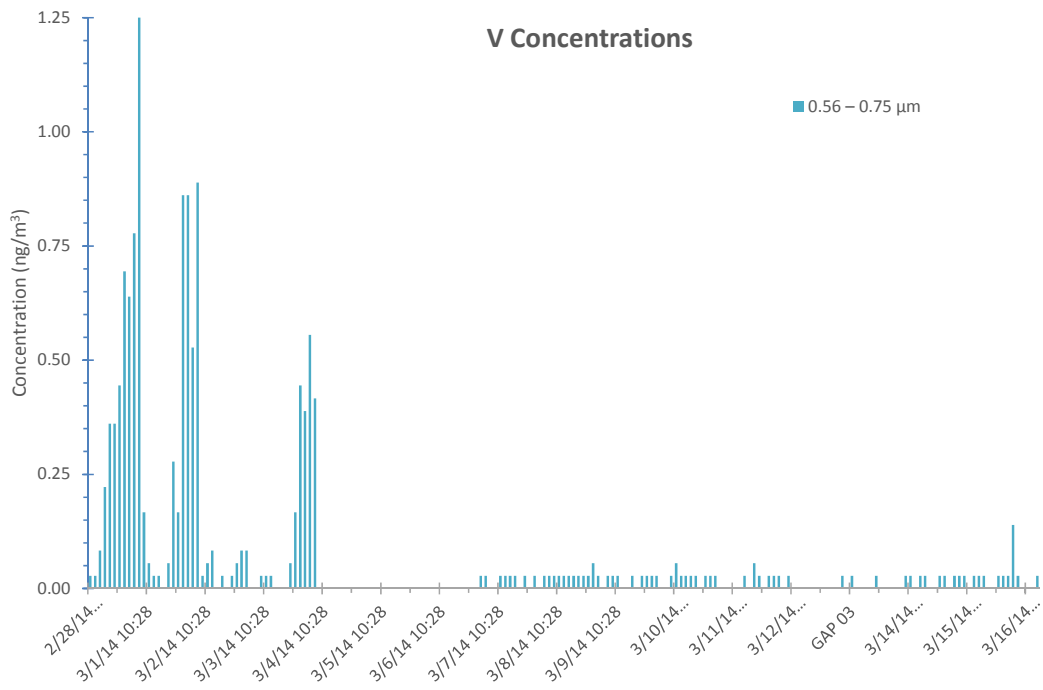


Fig. C-240 CaPh 32 DRUM: V mass stage 5

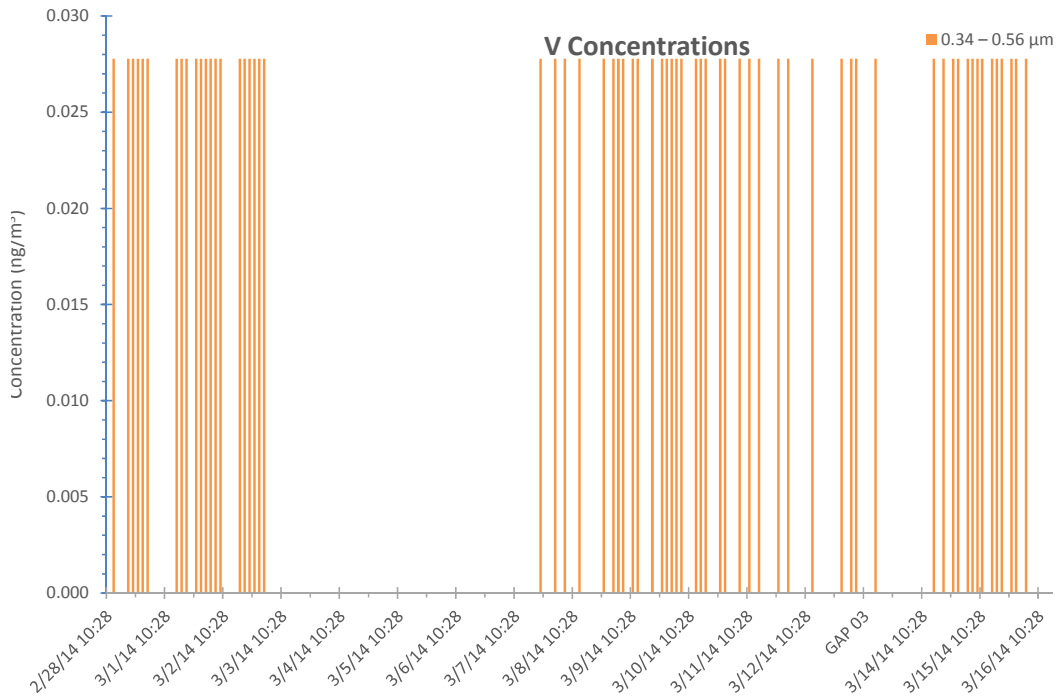


Fig. C-241 CaPh 32 DRUM: V mass stage 6

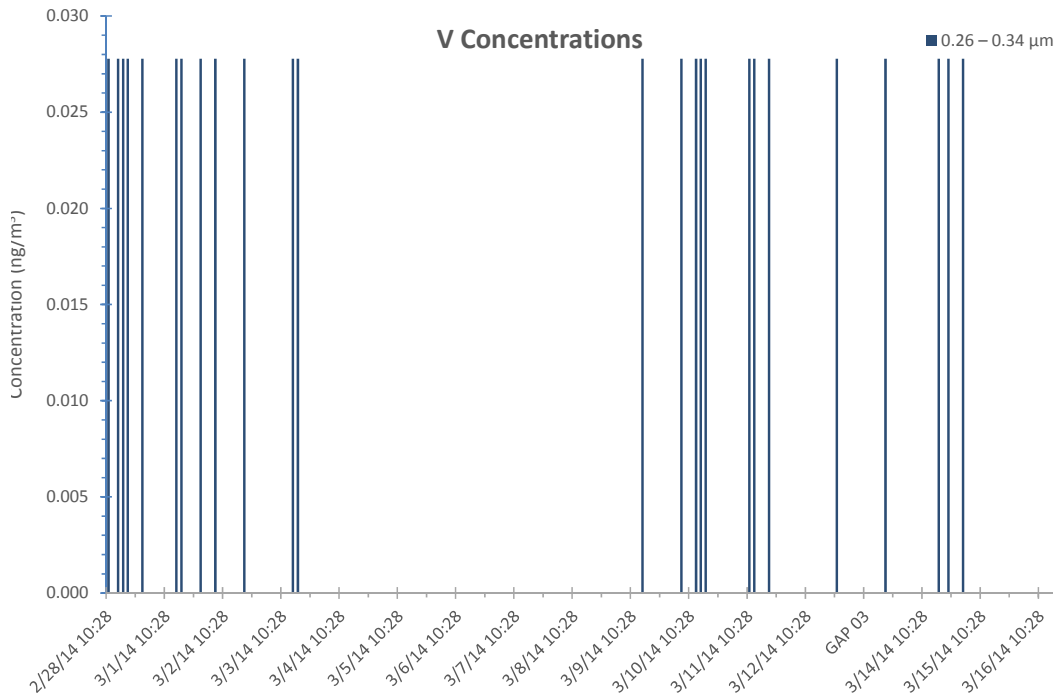


Fig. C-242 CaPh 32 DRUM: V mass stage 7

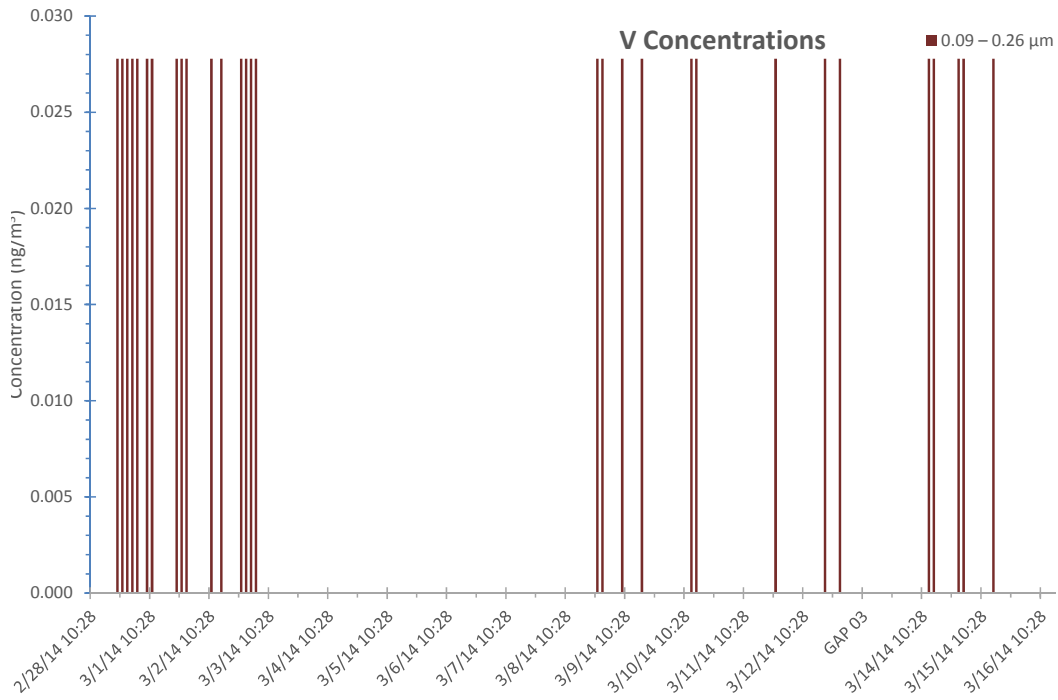


Fig. C-243 CaPh 32 DRUM: V mass stage 8

C-4.12 Chromium (Cr)

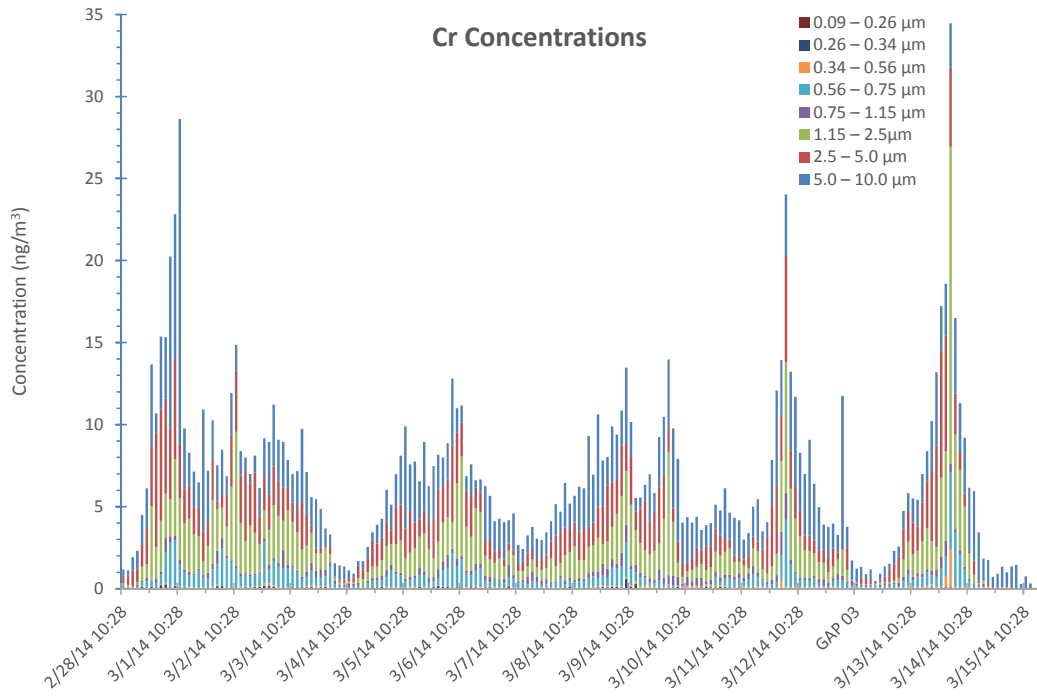


Fig. C-244 CaPh 34 DRUM: Cr mass all stages

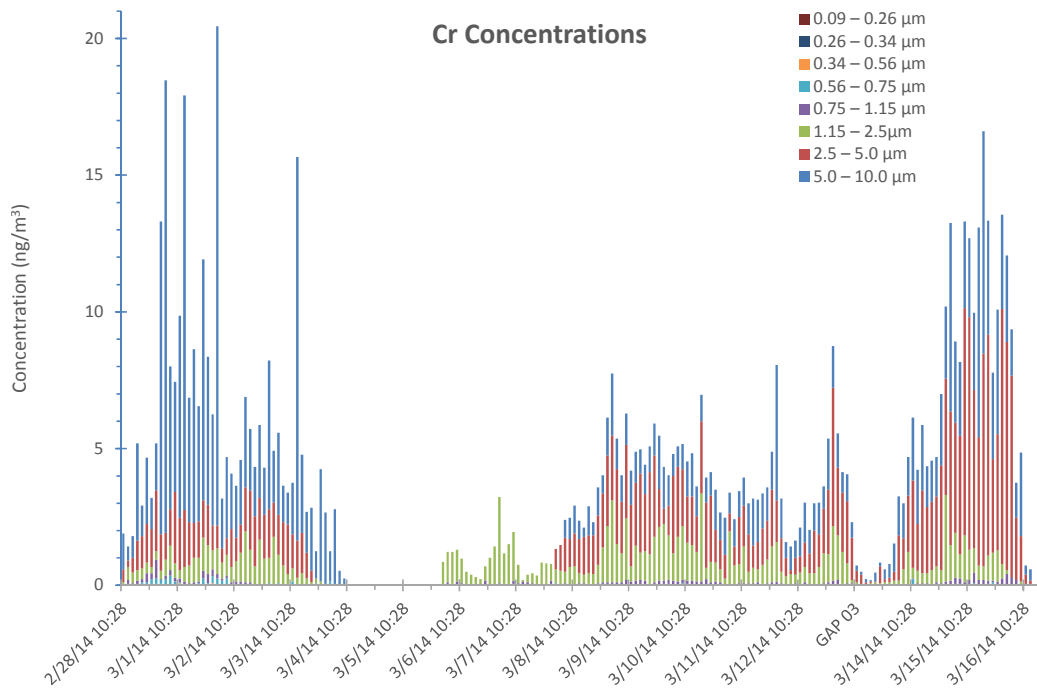


Fig. C-245 CaPh 32 DRUM: Cr mass all stages

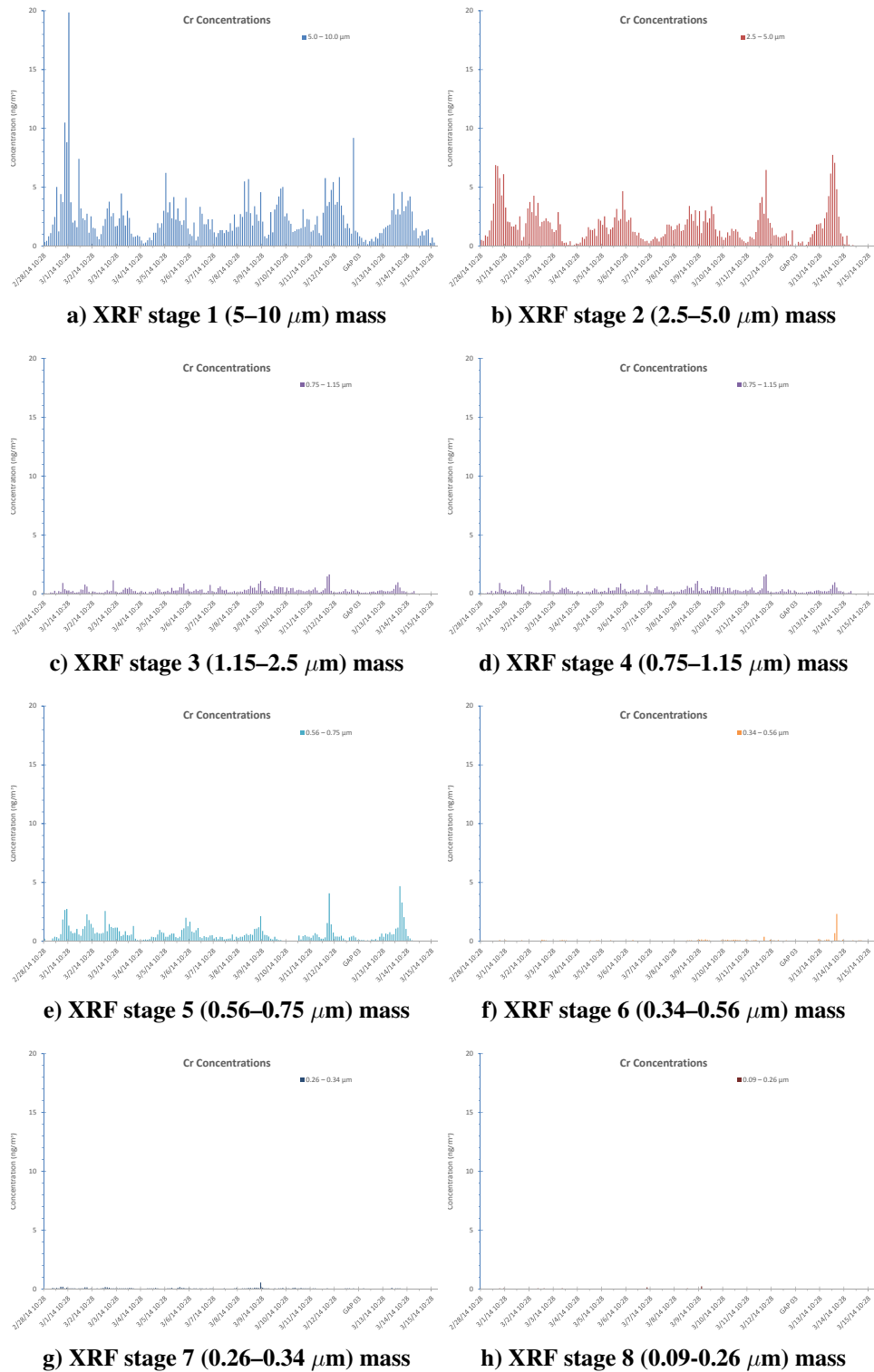
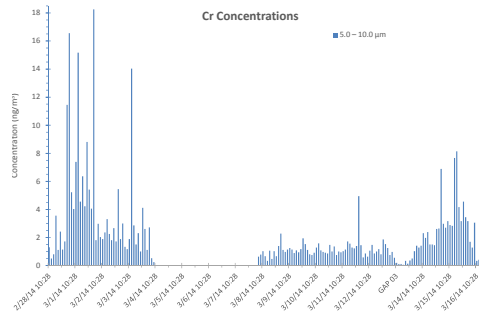
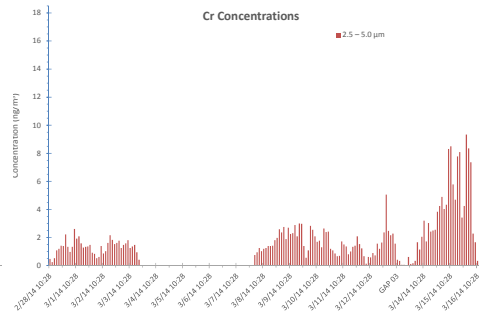


Fig. C-246 CaPh 34 DRUM: XRF mass Cr; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

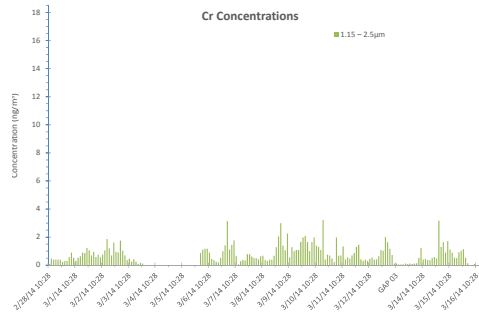
Approved for public release; distribution is unlimited.



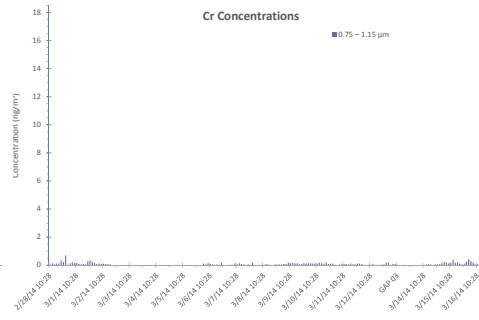
a) XRF stage 1 (5–10 μm) mass



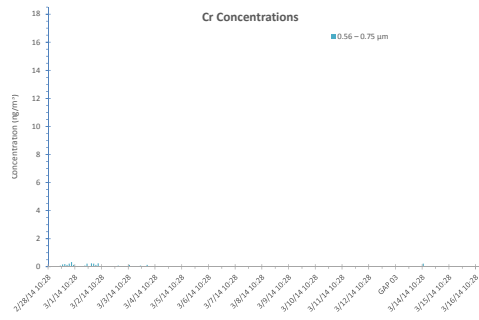
b) XRF stage 2 (2.5–5.0 μm) mass



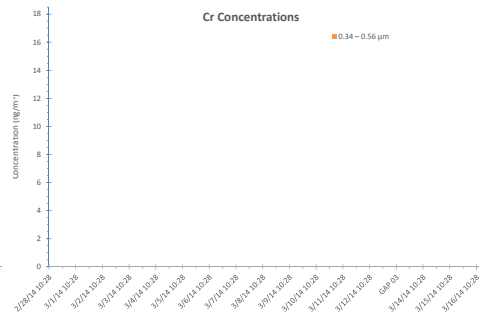
c) XRF stage 3 (1.15–2.5 μm) mass



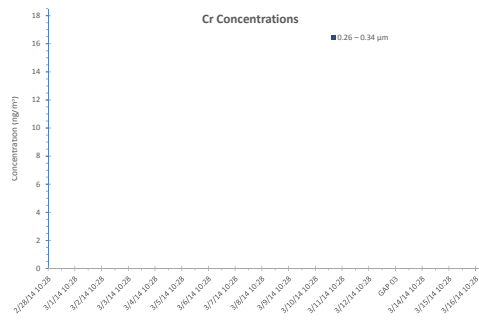
d) XRF stage 4 (0.75–1.15 μm) mass



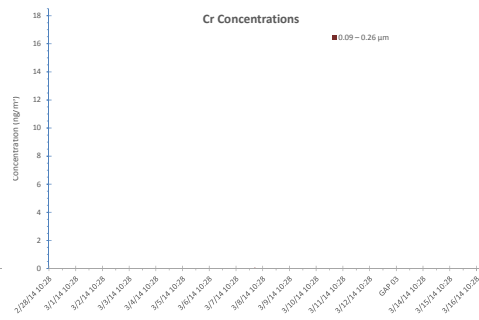
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-247 CaPh 32 DRUM: XRF mass Cr; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

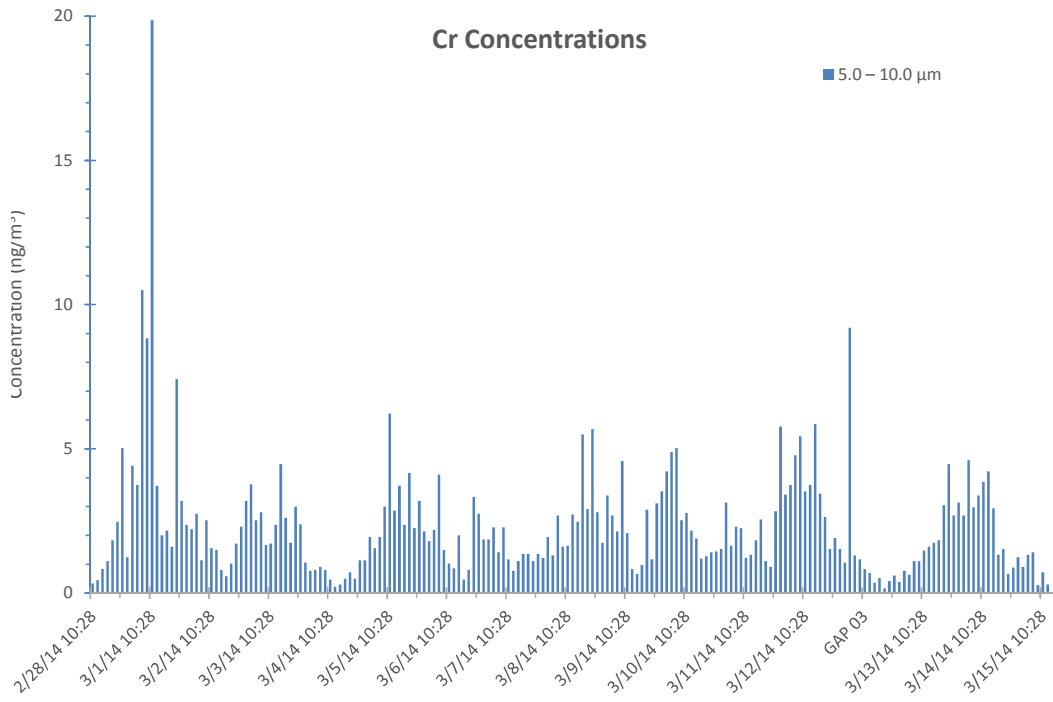


Fig. C-248 CaPh 34 DRUM: Cr mass stage 1

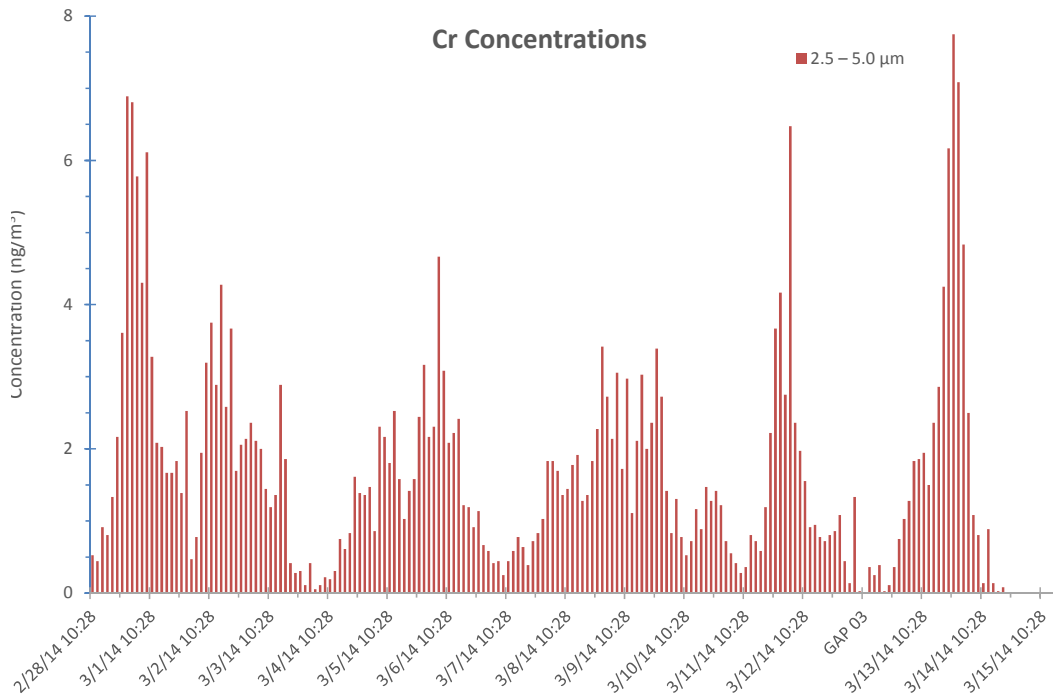


Fig. C-249 CaPh 34 DRUM: Cr mass stage 2

Approved for public release; distribution is unlimited.

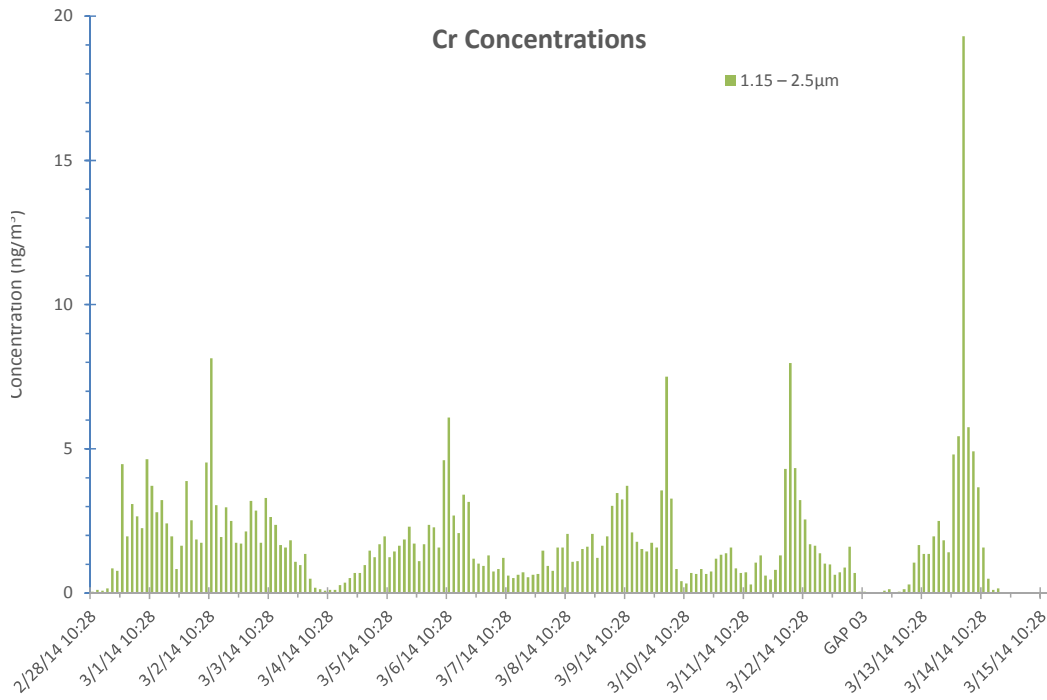


Fig. C-250 CaPh 34 DRUM: Cr mass stage 3

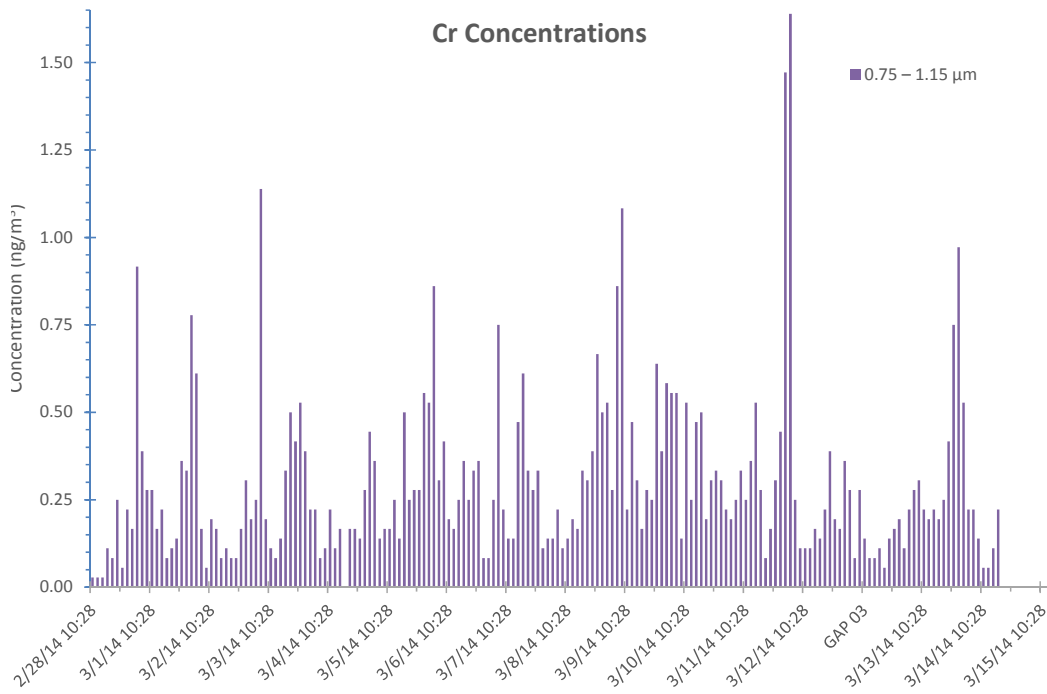


Fig. C-251 CaPh 34 DRUM: Cr mass stage 4

Approved for public release; distribution is unlimited.

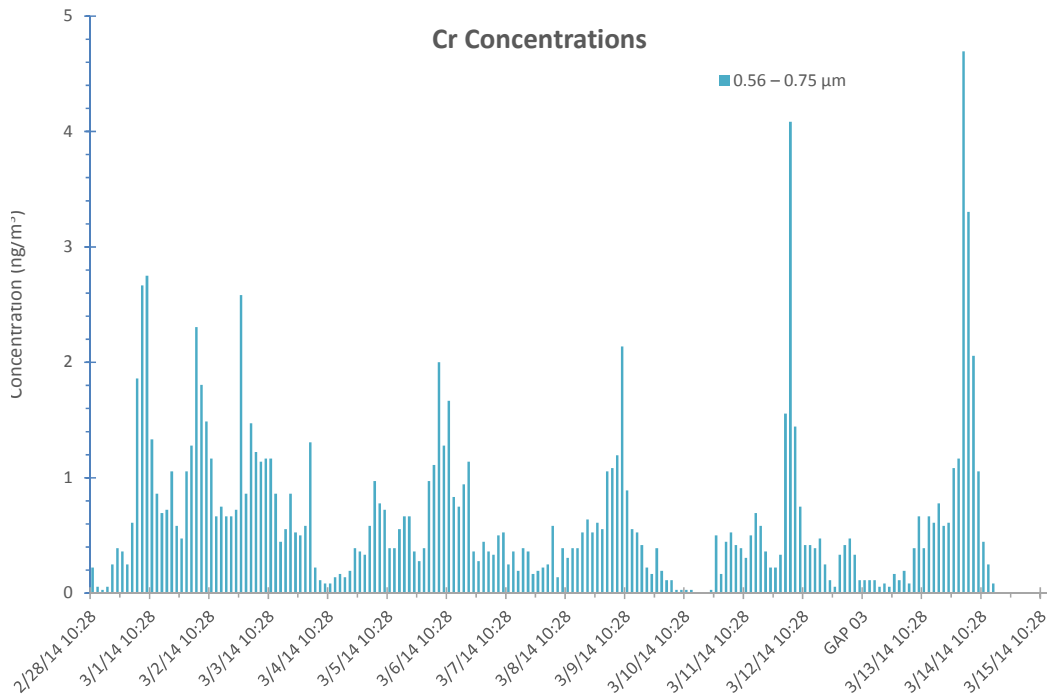


Fig. C-252 CaPh 34 DRUM: Cr mass stage 5

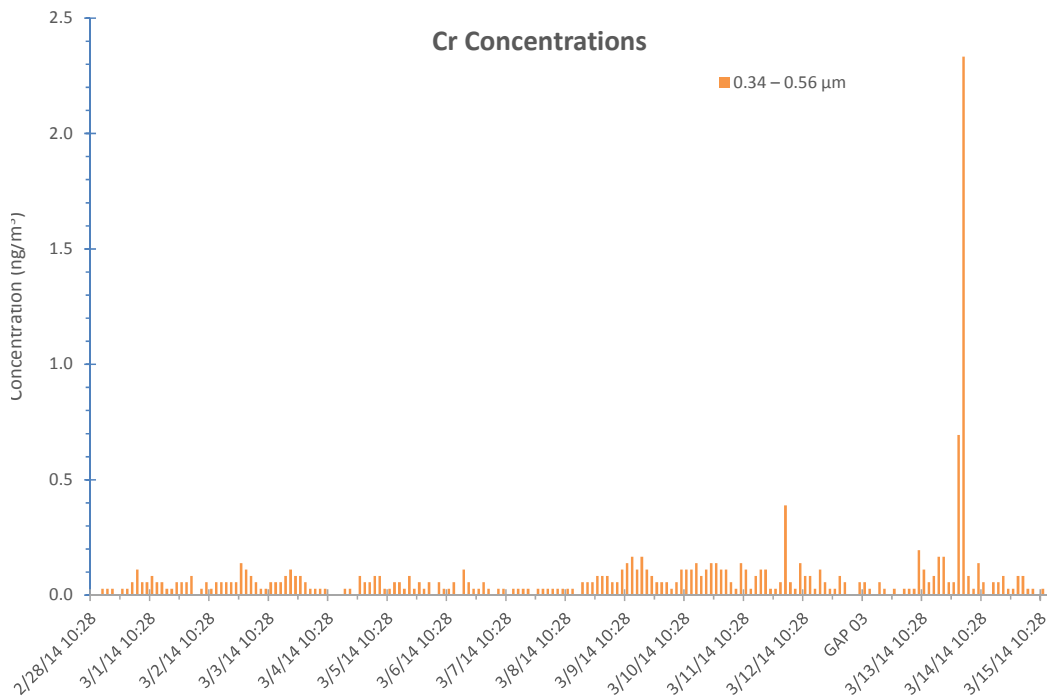


Fig. C-253 CaPh 34 DRUM: Cr mass stage 6

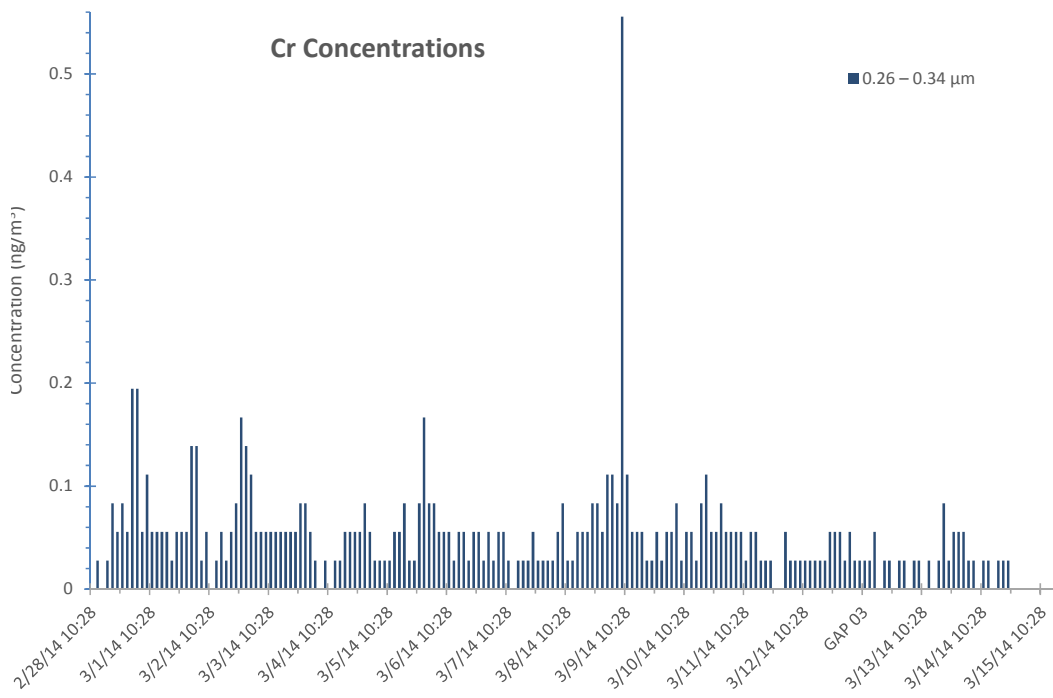


Fig. C-254 CaPh 34 DRUM: Cr mass stage 7

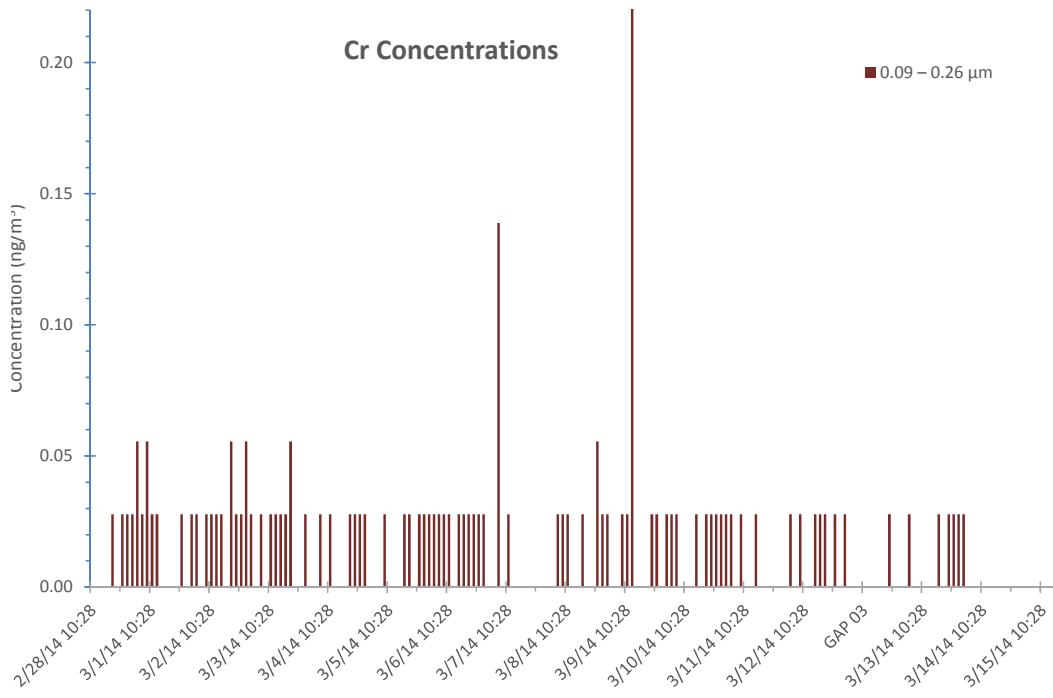


Fig. C-255 CaPh 34 DRUM: Cr mass stage 8

Approved for public release; distribution is unlimited.

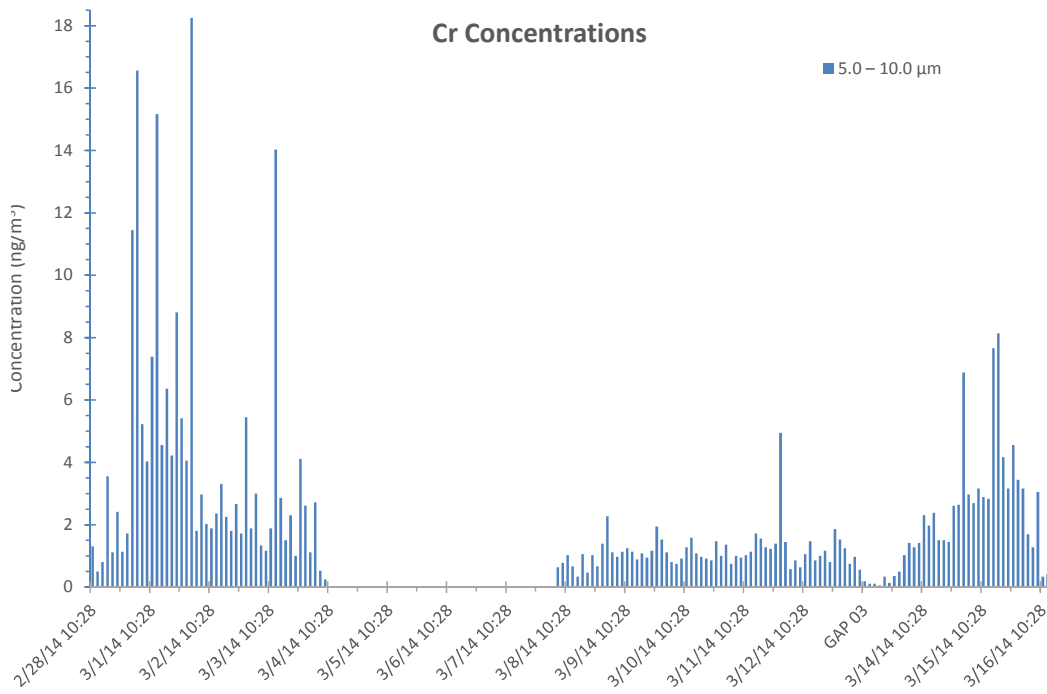


Fig. C-256 CaPh 32 DRUM: Cr mass stage 1

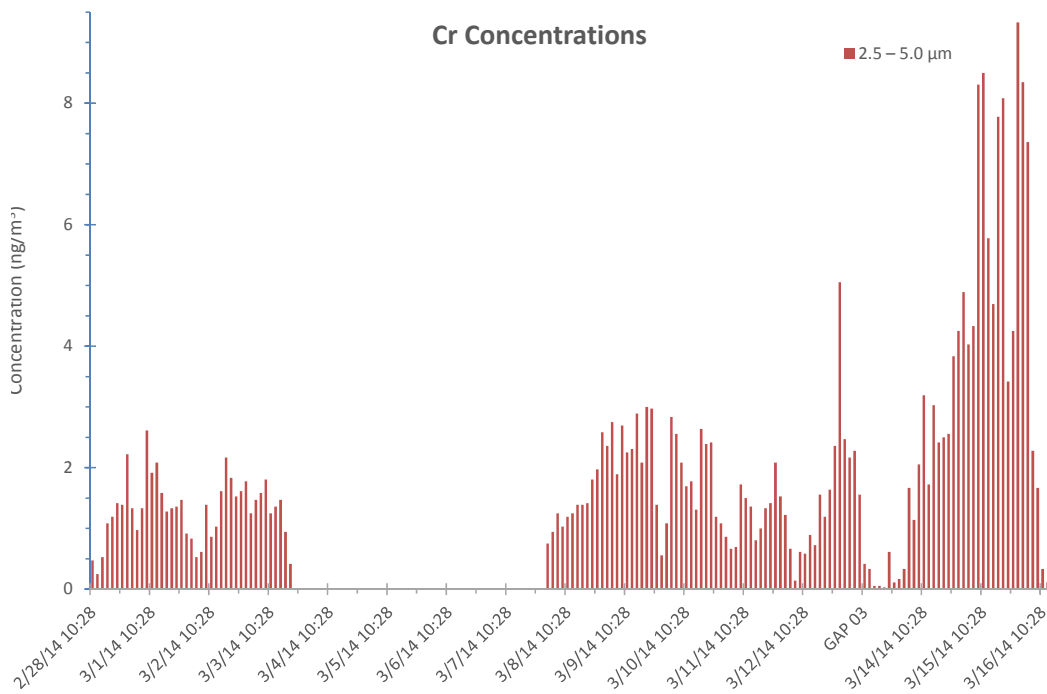


Fig. C-257 CaPh 32 DRUM: Cr mass stage 2

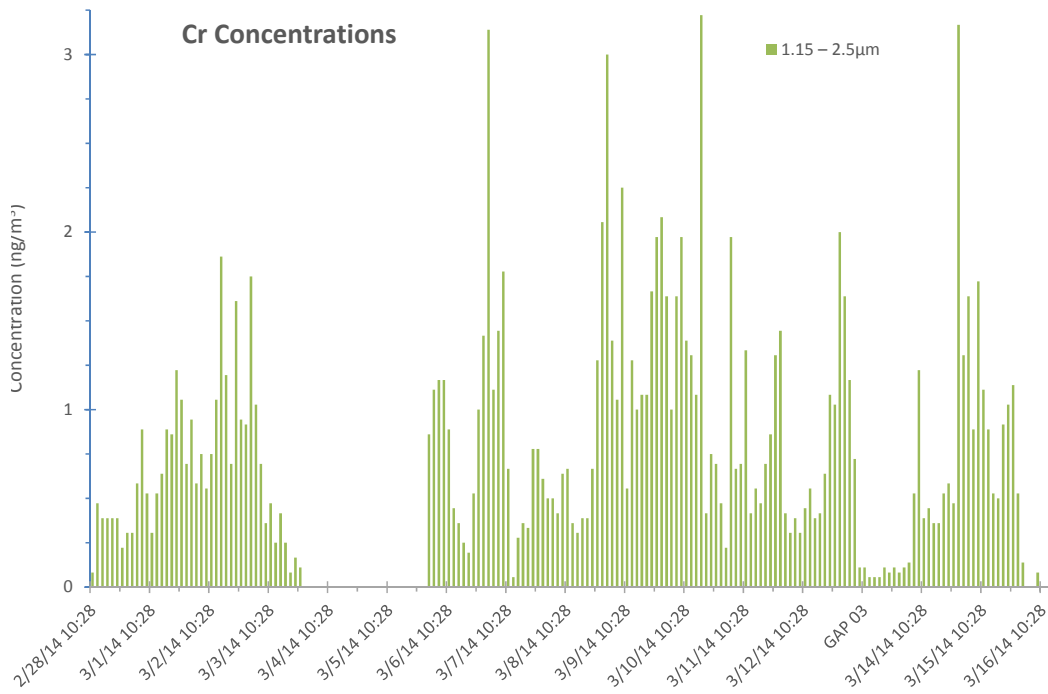


Fig. C-258 CaPh 32 DRUM: Cr mass stage 3

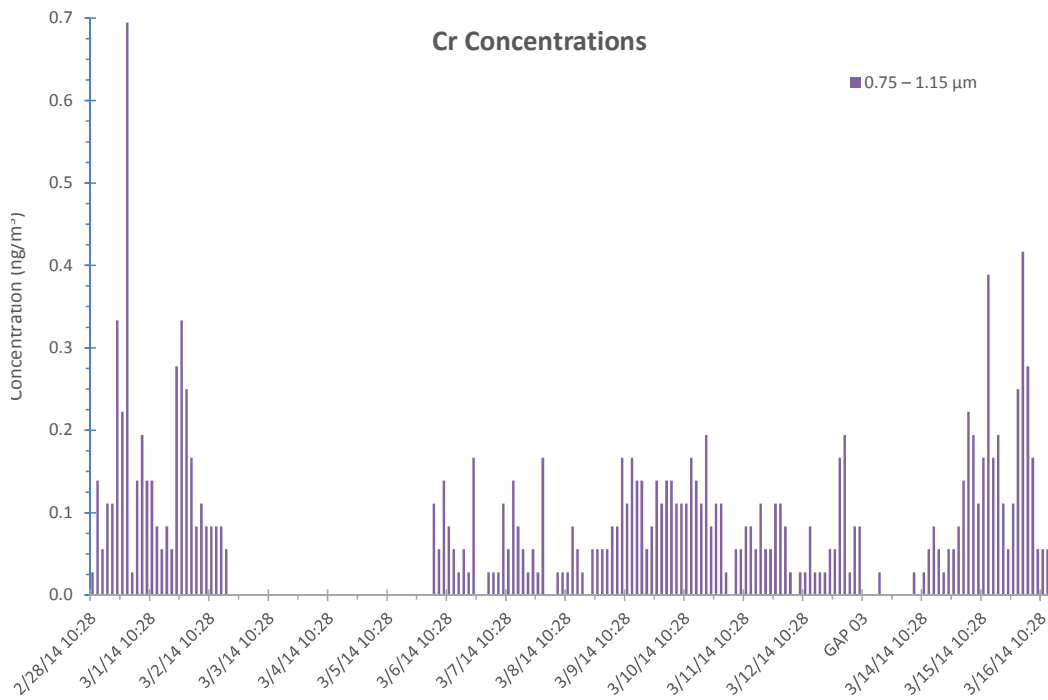


Fig. C-259 CaPh 32 DRUM: Cr mass stage 4

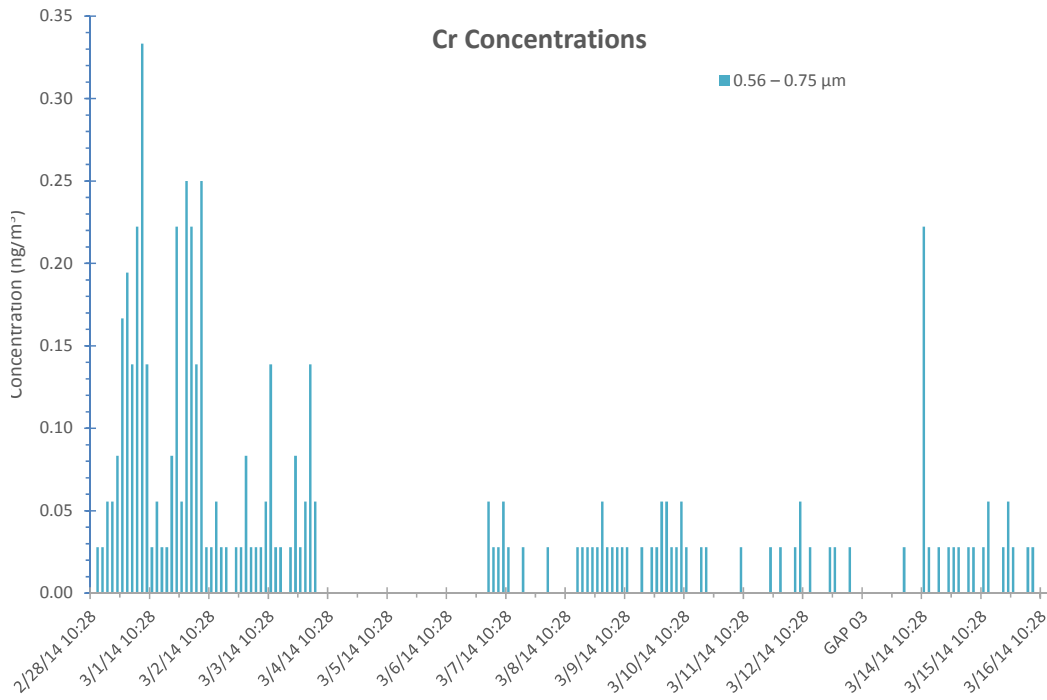


Fig. C-260 CaPh 32 DRUM: Cr mass stage 5

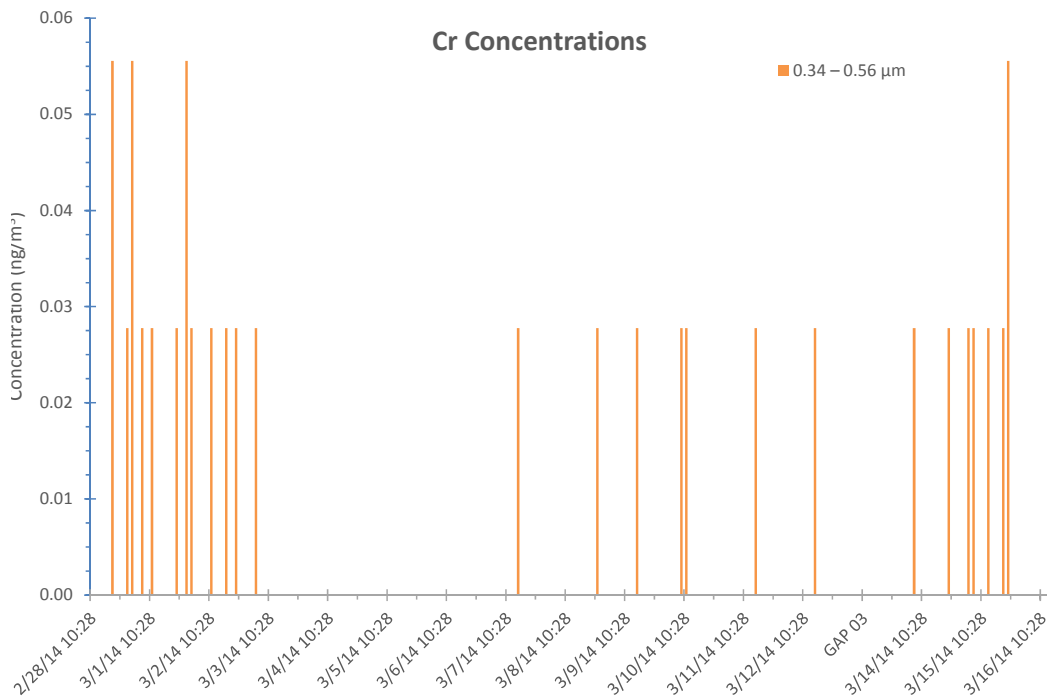


Fig. C-261 CaPh 32 DRUM: Cr mass stage 6

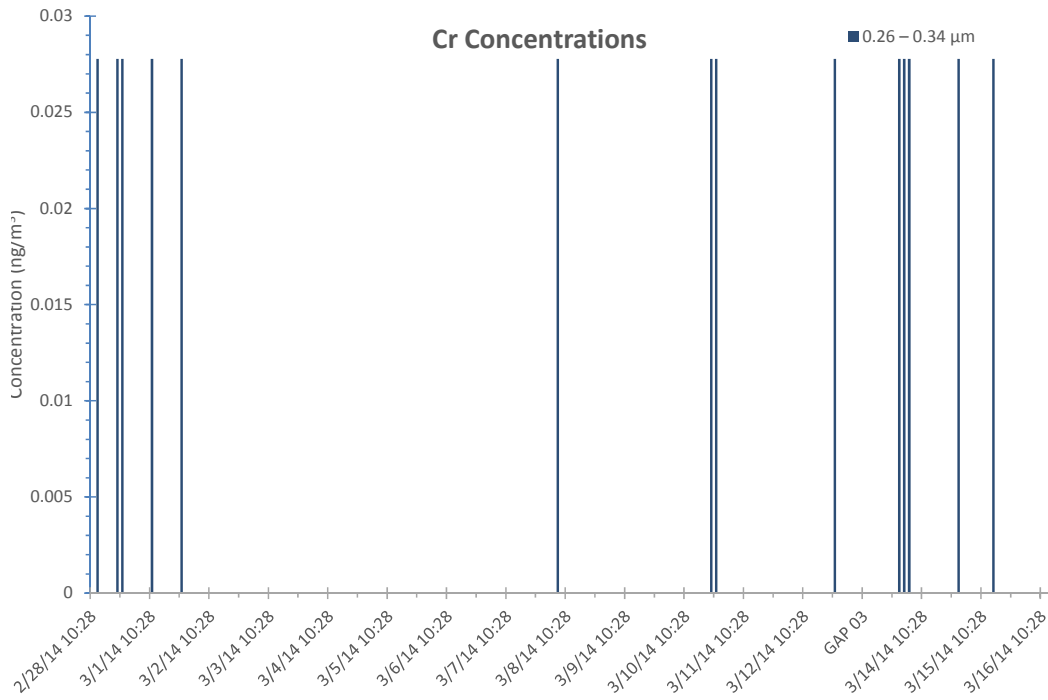


Fig. C-262 CaPh 32 DRUM: Cr mass stage 7

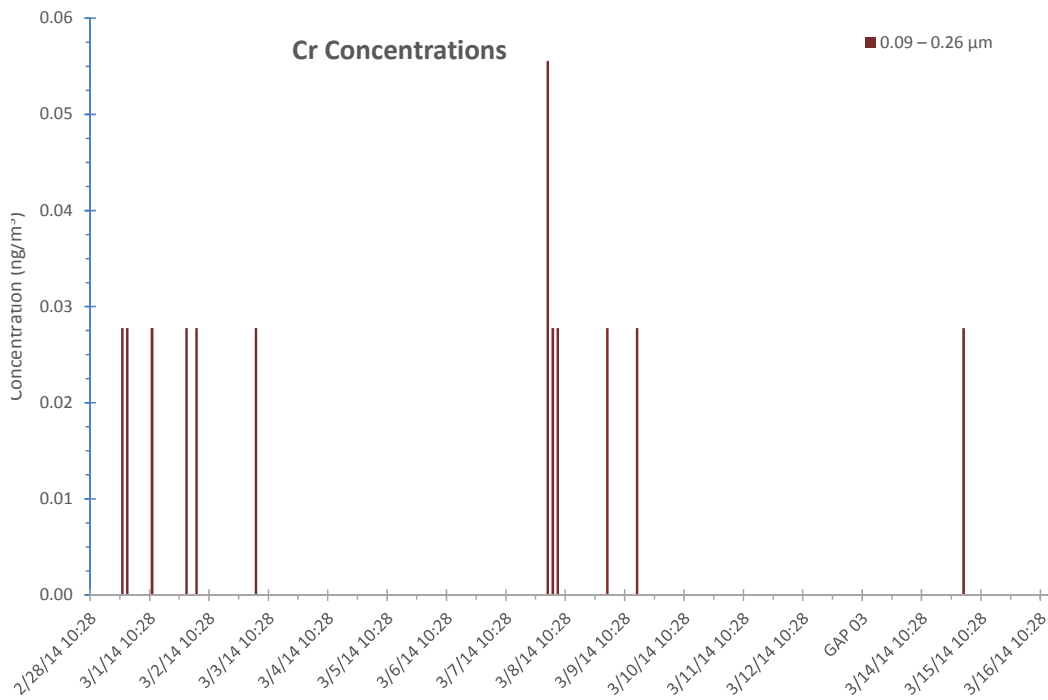


Fig. C-263 CaPh 32 DRUM: Cr mass stage 8

Approved for public release; distribution is unlimited.

C-4.13 Manganese (Mn)

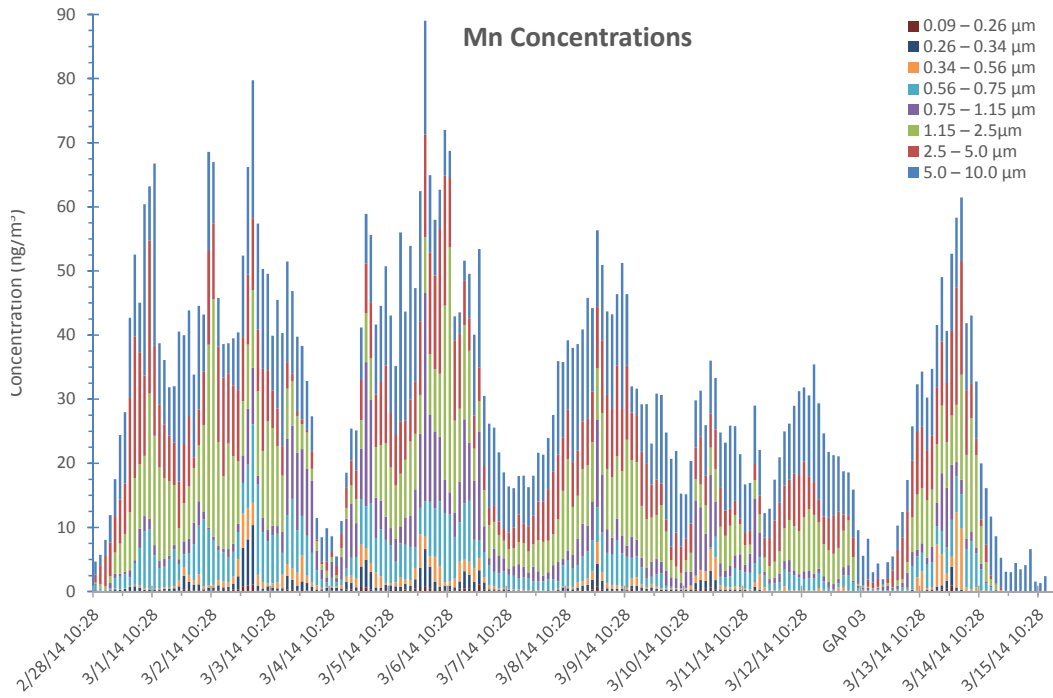


Fig. C-264 CaPh 34 DRUM: Mn mass all stages

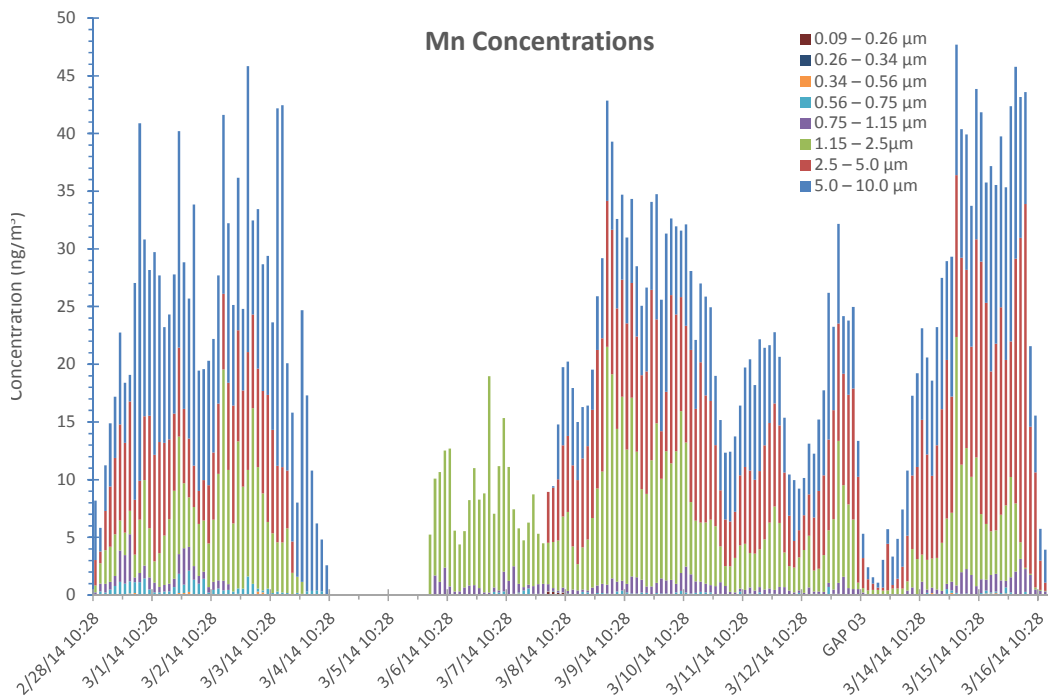


Fig. C-265 CaPh 32 DRUM: Mn mass all stages

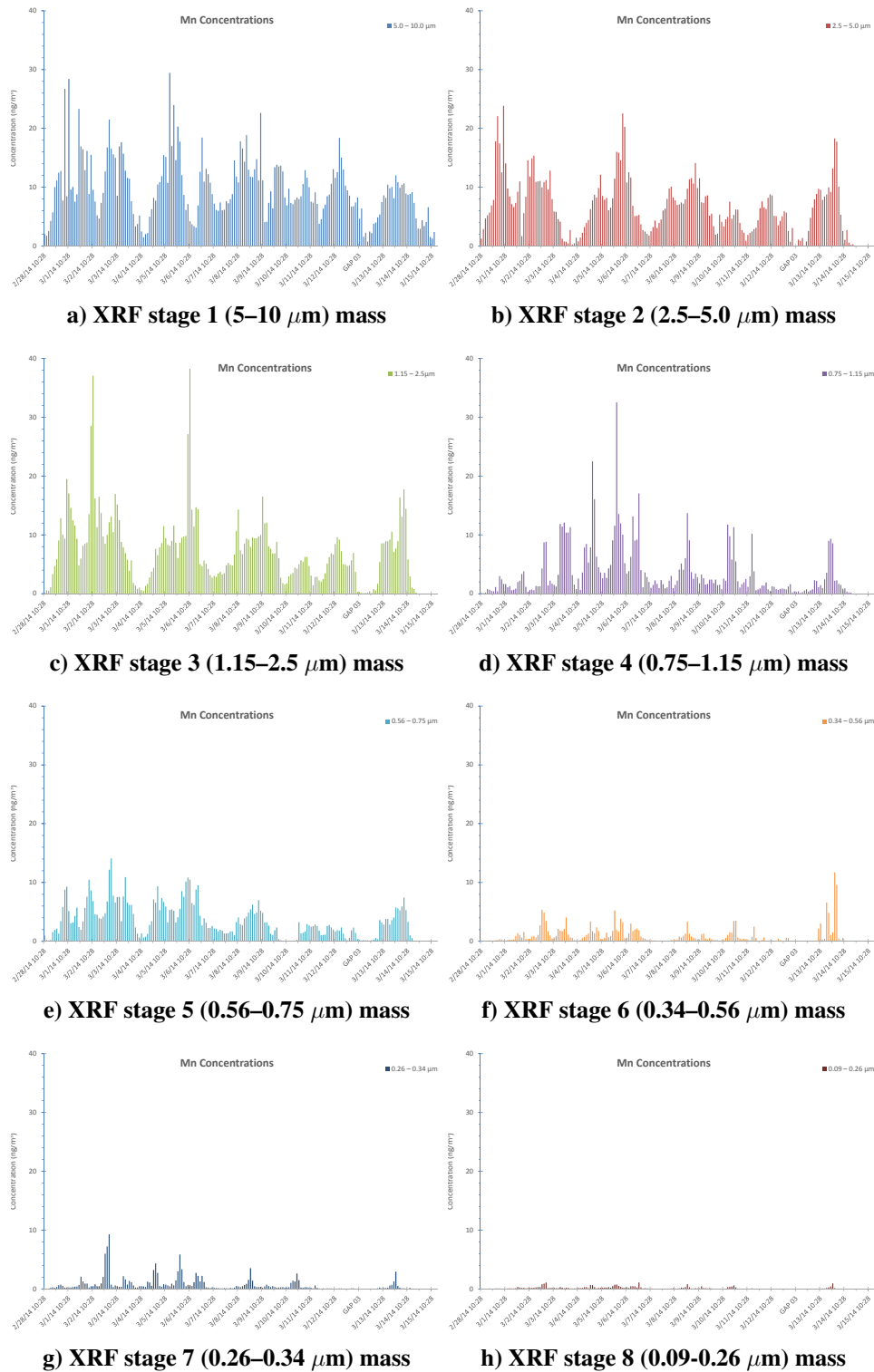
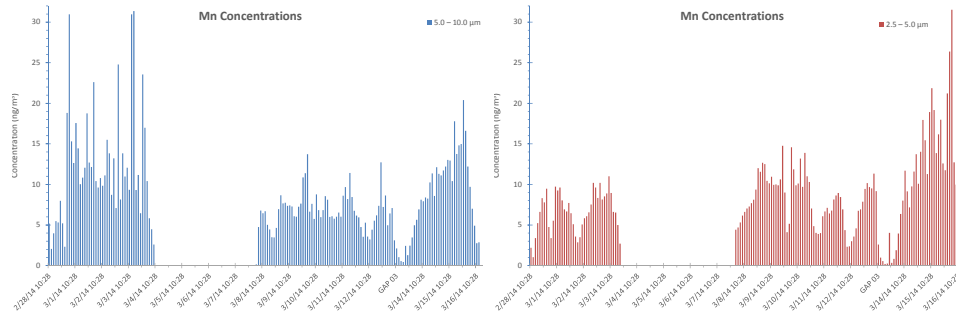
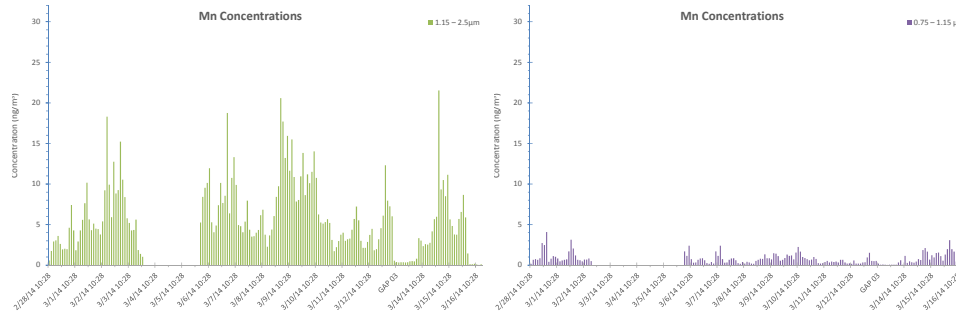


Fig. C-266 CaPh 34 DRUM: XRF mass Mn; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



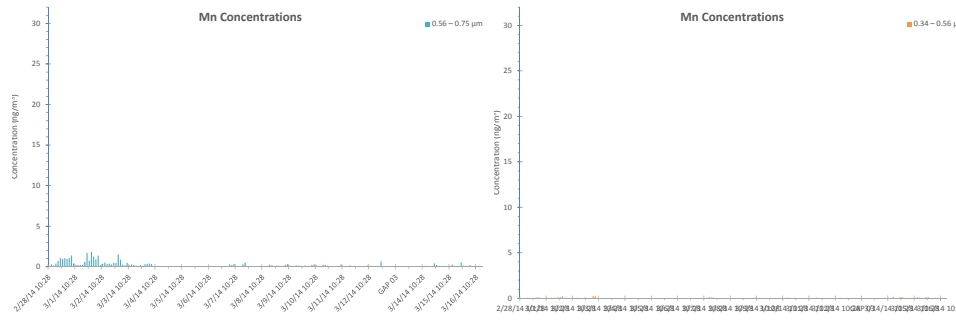
a) XRF stage 1 (5–10 μm) mass

b) XRF stage 2 (2.5–5.0 μm) mass



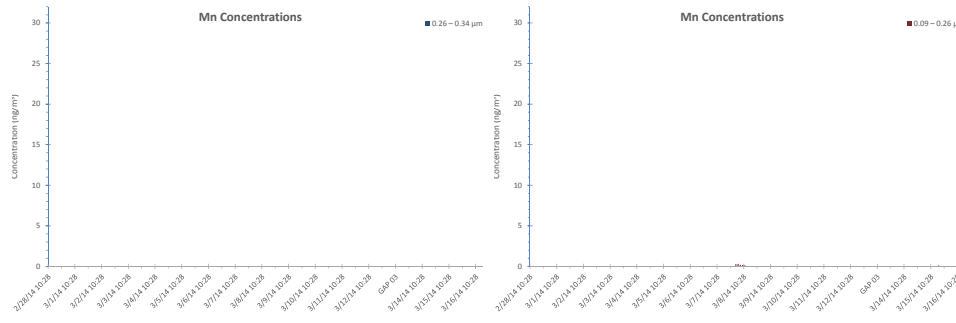
c) XRF stage 3 (1.15–2.5 μm) mass

d) XRF stage 4 (0.75–1.15 μm) mass



e) XRF stage 5 (0.56–0.75 μm) mass

f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass

h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-267 CaPh 32 DRUM: XRF mass Mn; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

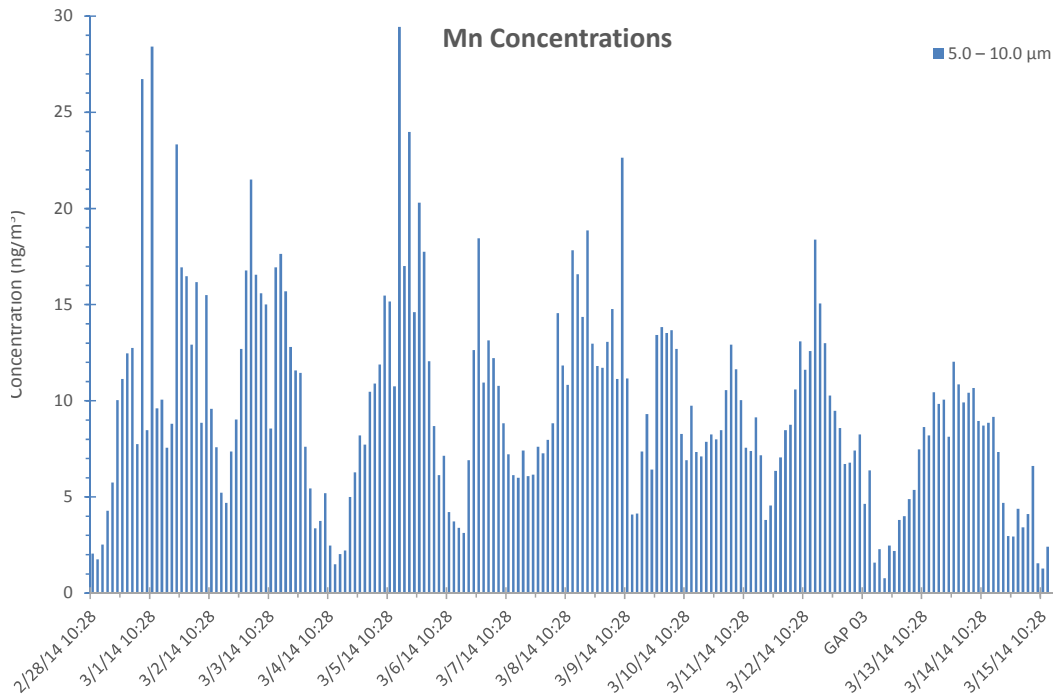


Fig. C-268 CaPh 34 DRUM: Mn mass stage 1

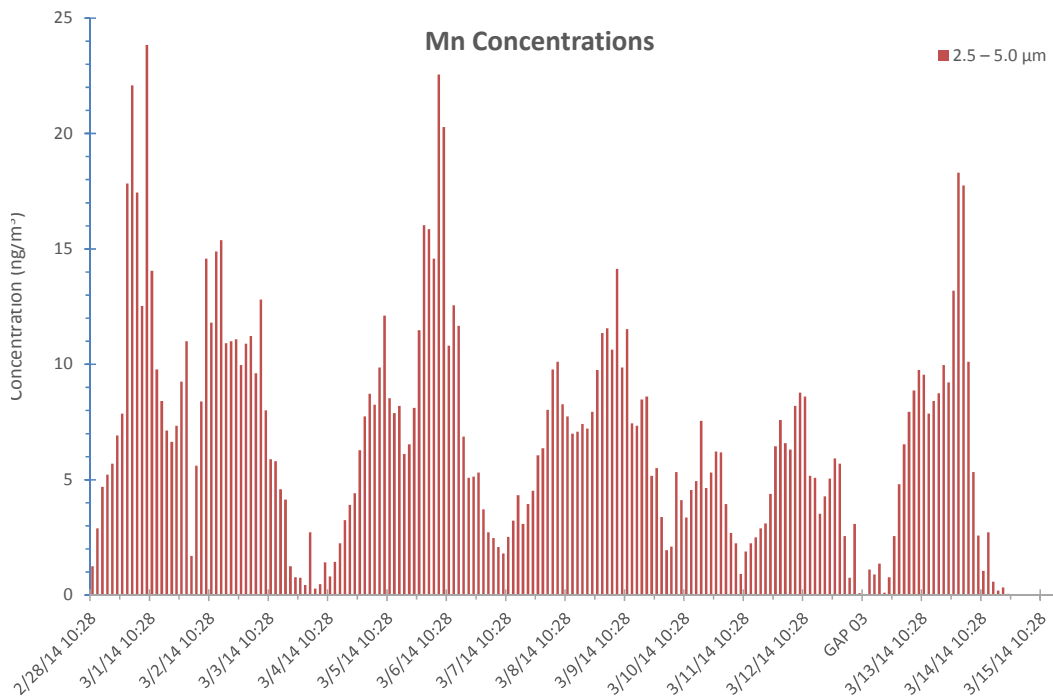


Fig. C-269 CaPh 34 DRUM: Mn mass stage 2

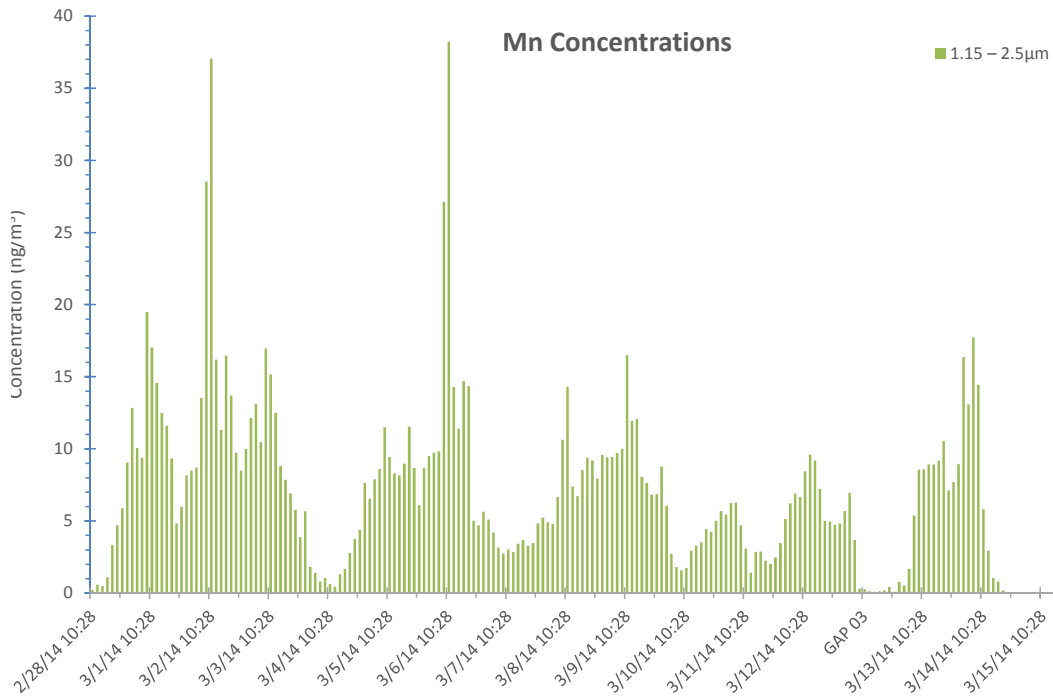


Fig. C-270 CaPh 34 DRUM: Mn mass stage 3

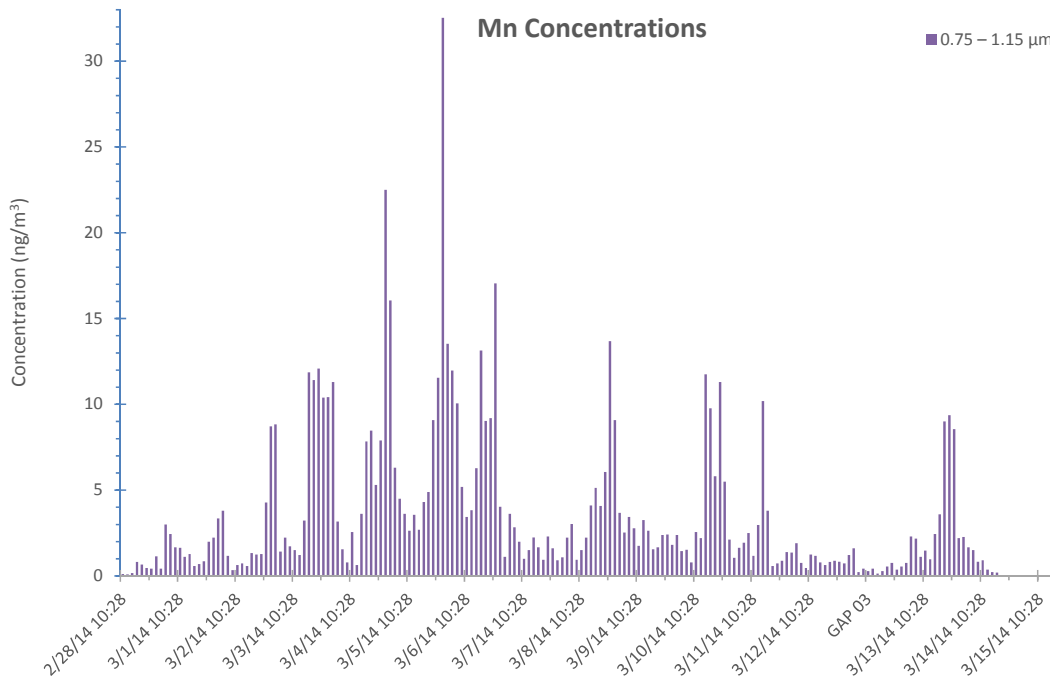


Fig. C-271 CaPh 34 DRUM: Mn mass stage 4

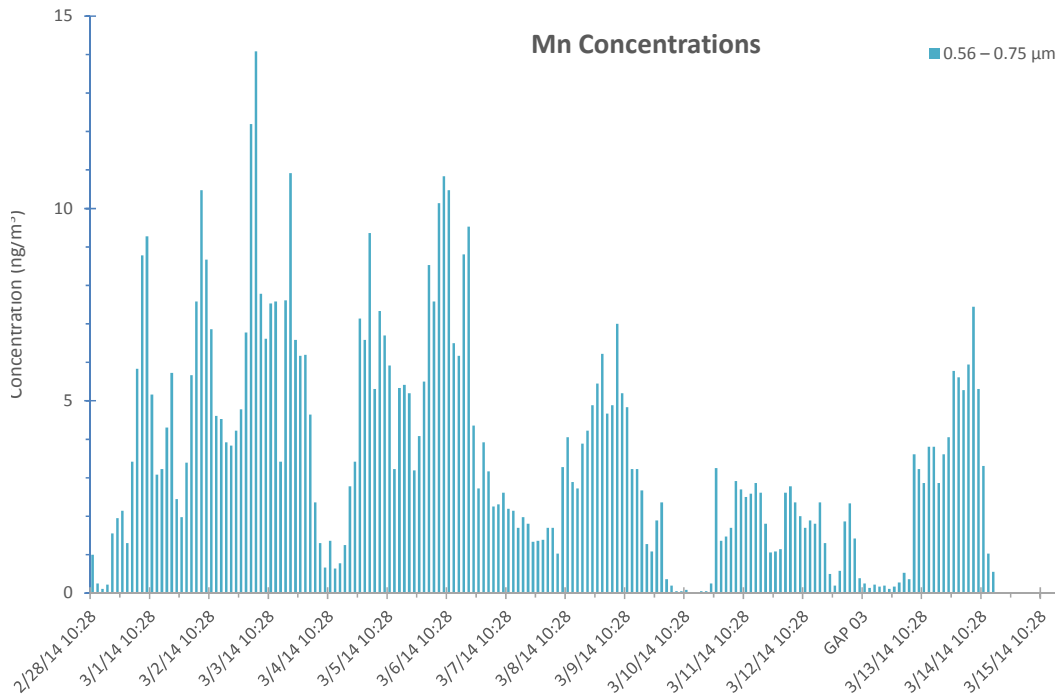


Fig. C-272 CaPh 34 DRUM: Mn mass stage 5

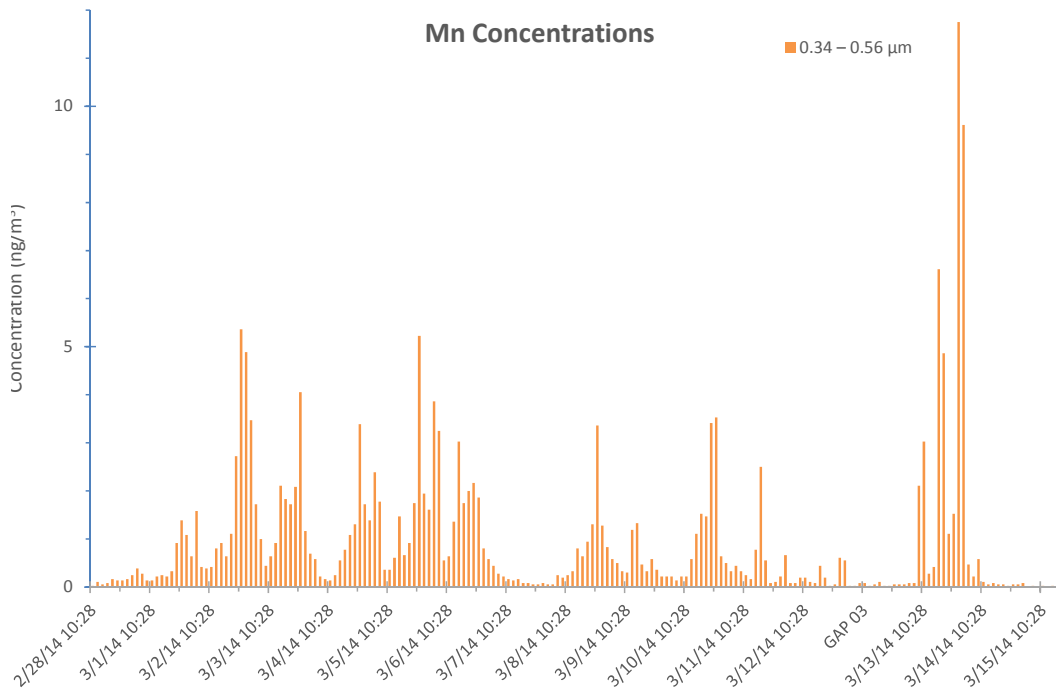


Fig. C-273 CaPh 34 DRUM: Mn mass stage 6

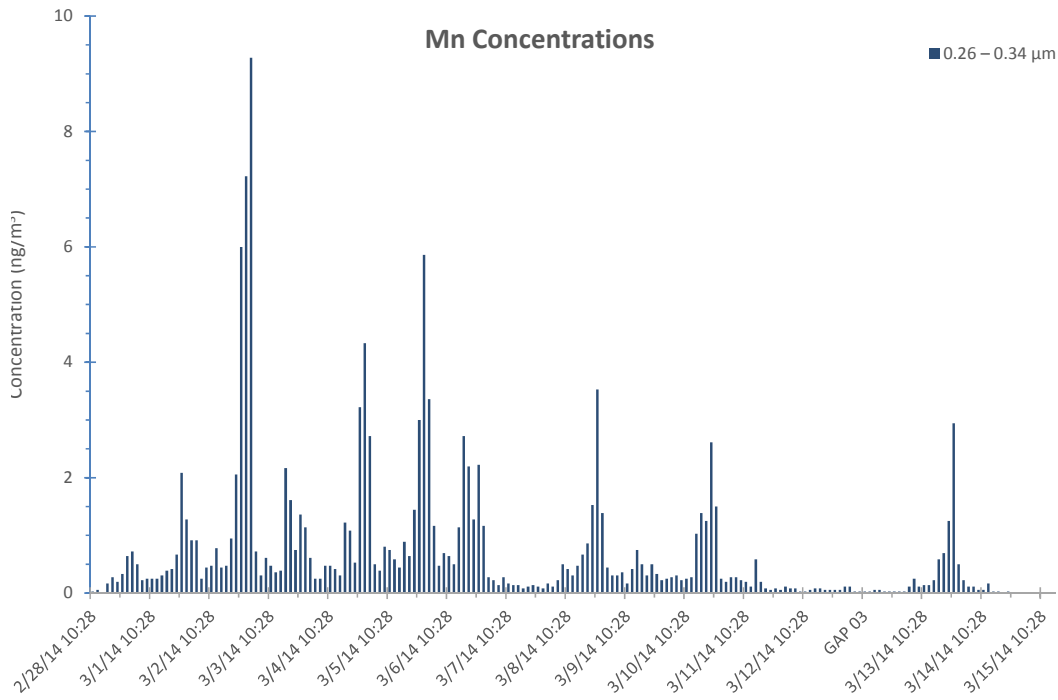


Fig. C-274 CaPh 34 DRUM: Mn mass stage 7

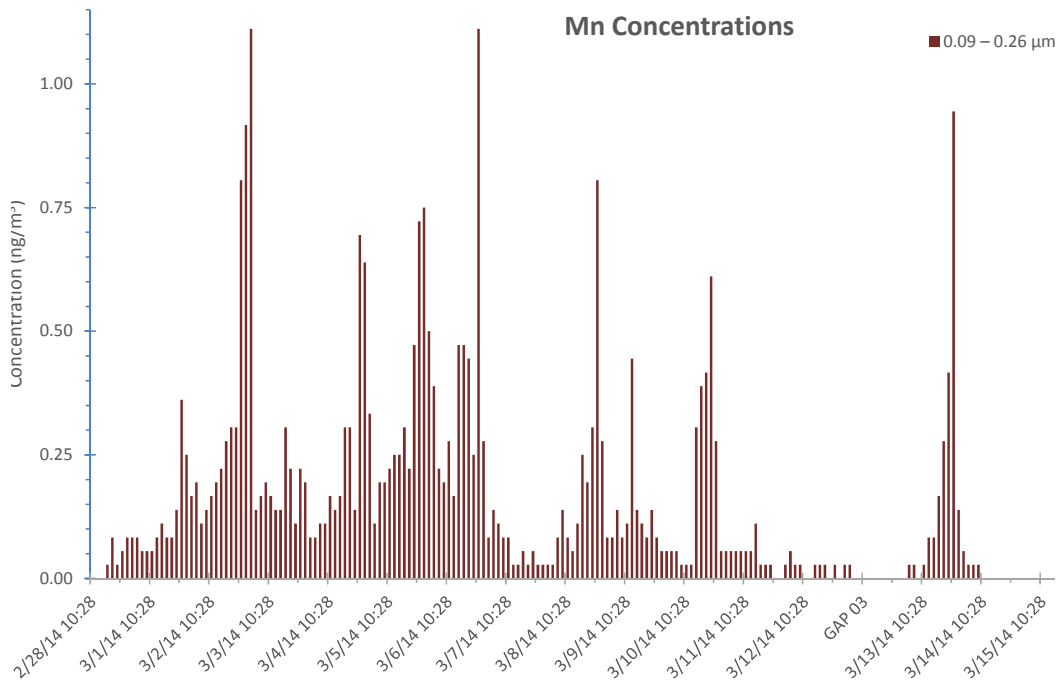


Fig. C-275 CaPh 34 DRUM: Mn mass stage 8

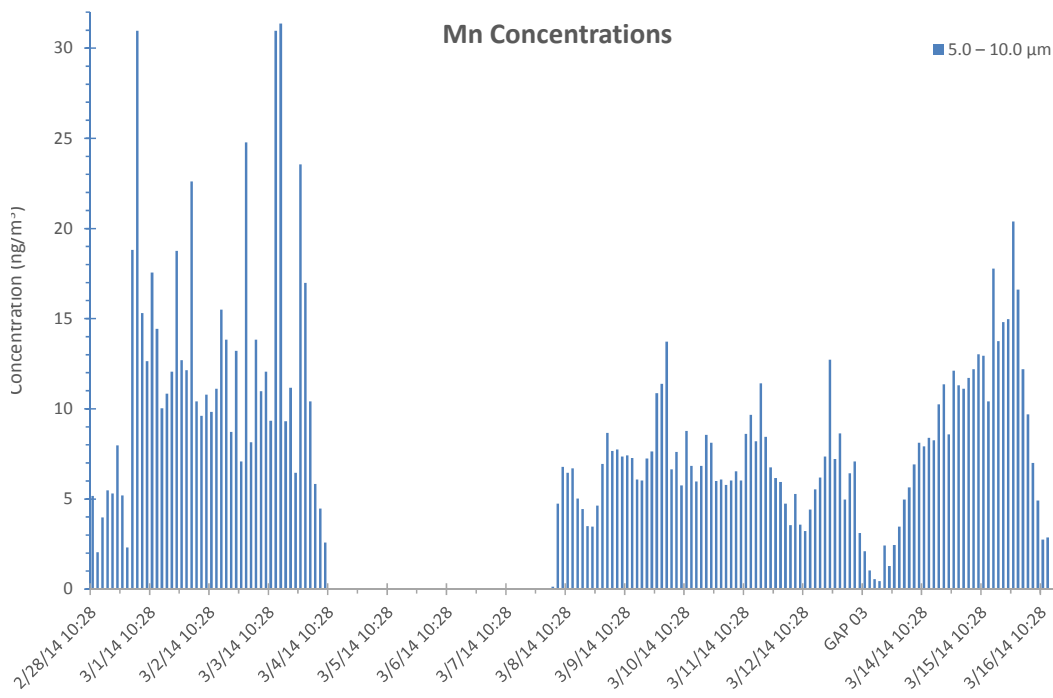


Fig. C-276 CaPh 32 DRUM: Mn mass stage 1

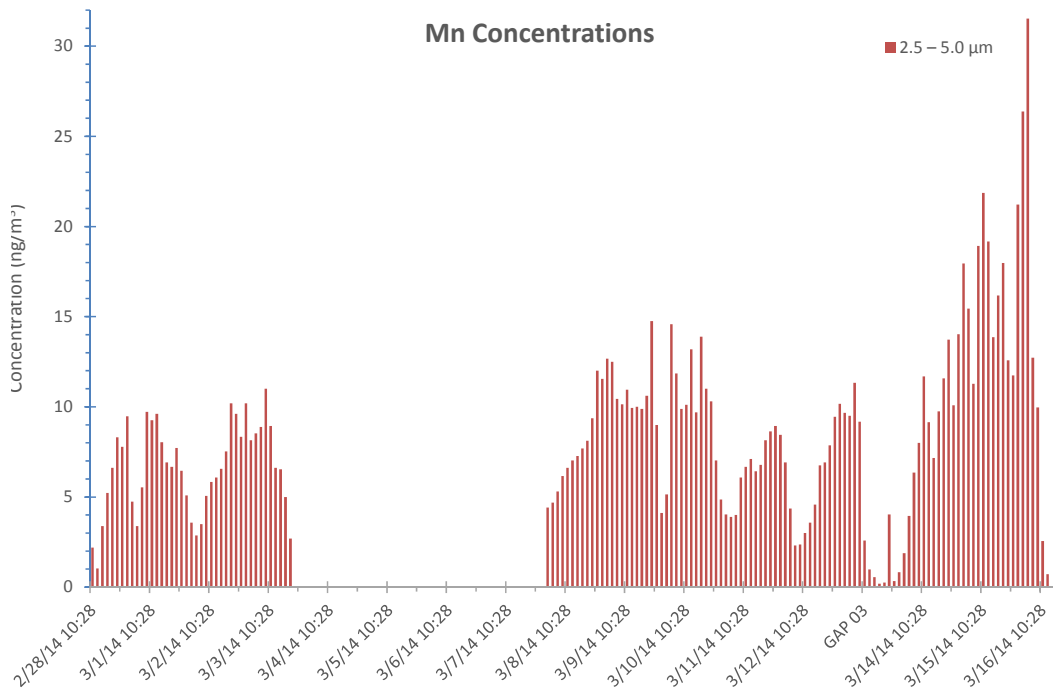


Fig. C-277 CaPh 32 DRUM: Mn mass stage 2

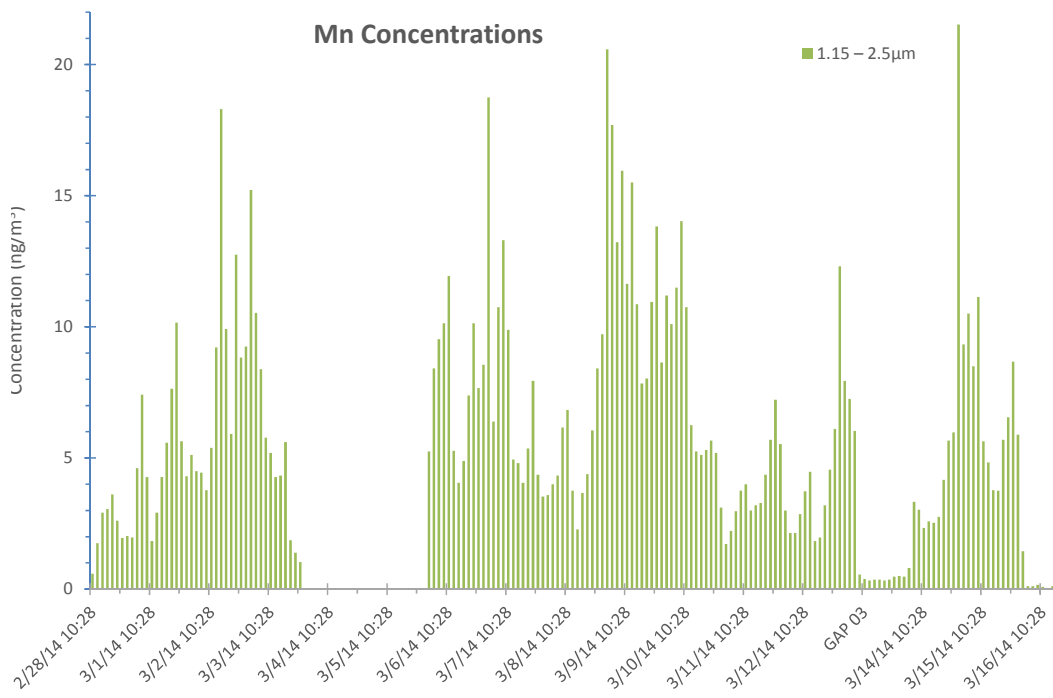


Fig. C-278 CaPh 32 DRUM: Mn mass stage 3

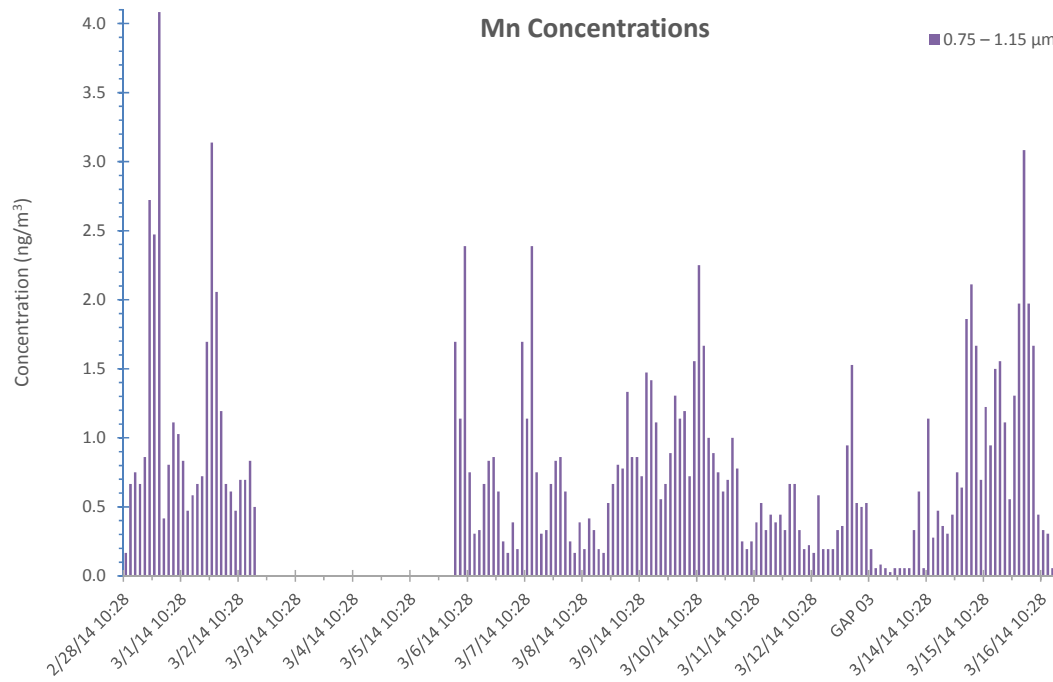


Fig. C-279 CaPh 32 DRUM: Mn mass stage 4

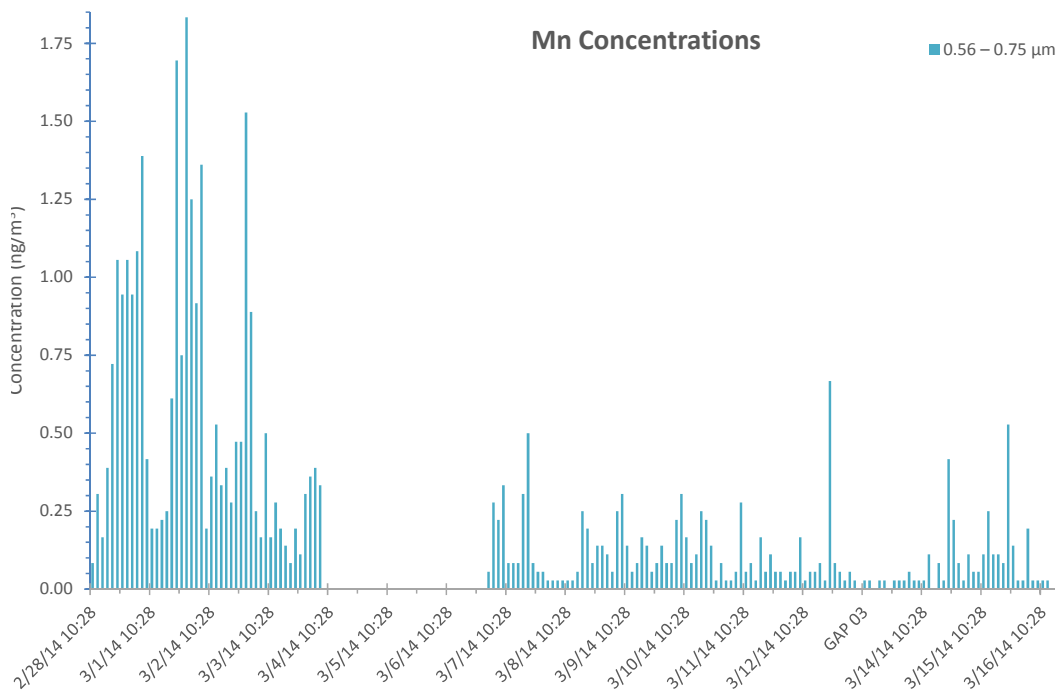


Fig. C-280 CaPh 32 DRUM: Mn mass stage 5

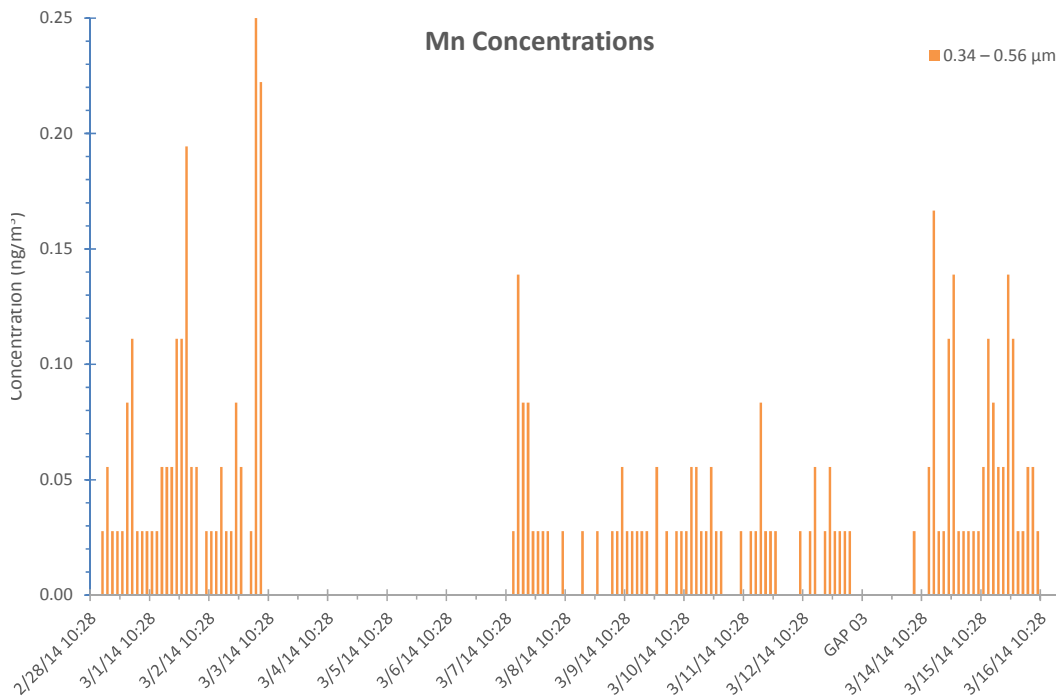


Fig. C-281 CaPh 32 DRUM: Mn mass stage 6

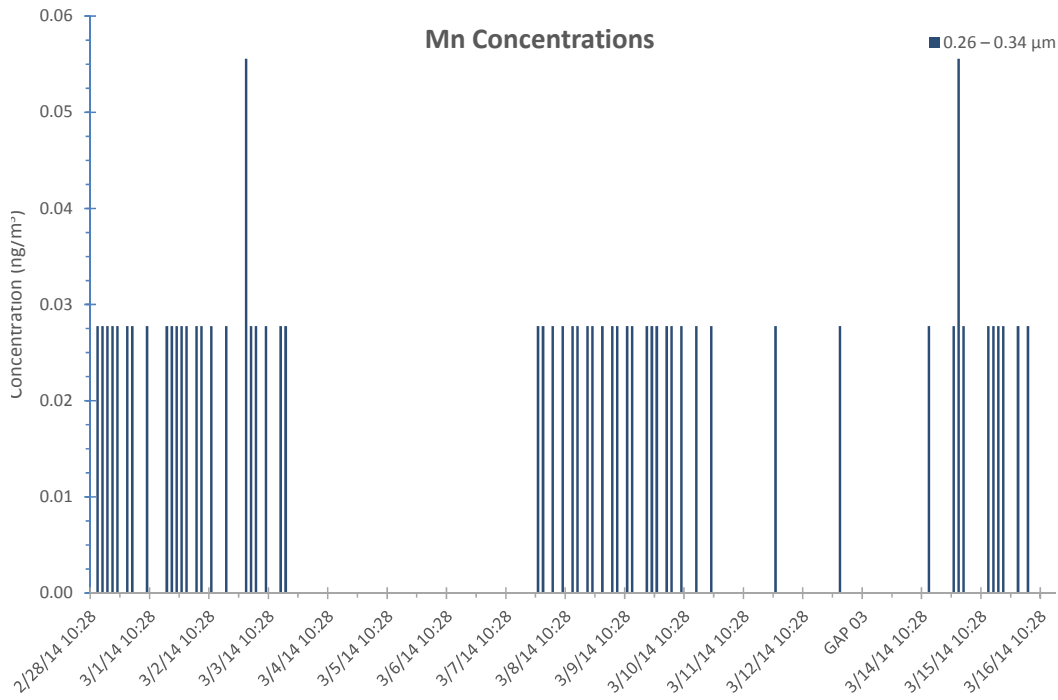


Fig. C-282 CaPh 32 DRUM: Mn mass stage 7

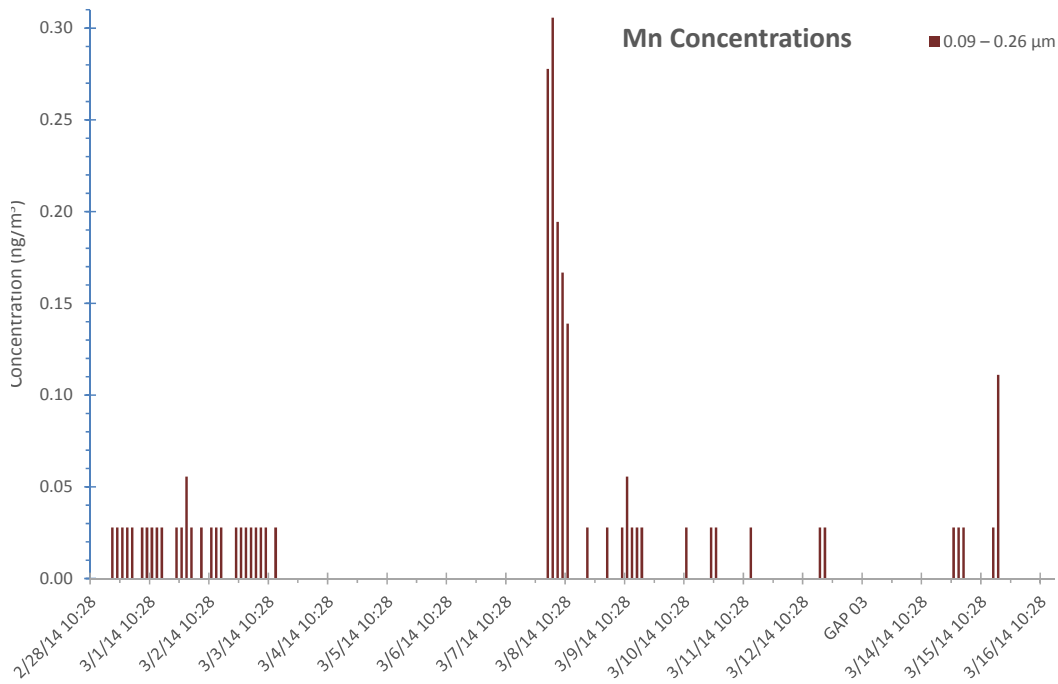


Fig. C-283 CaPh 32 DRUM: Mn mass stage 8

C-4.14 Iron (Fe)

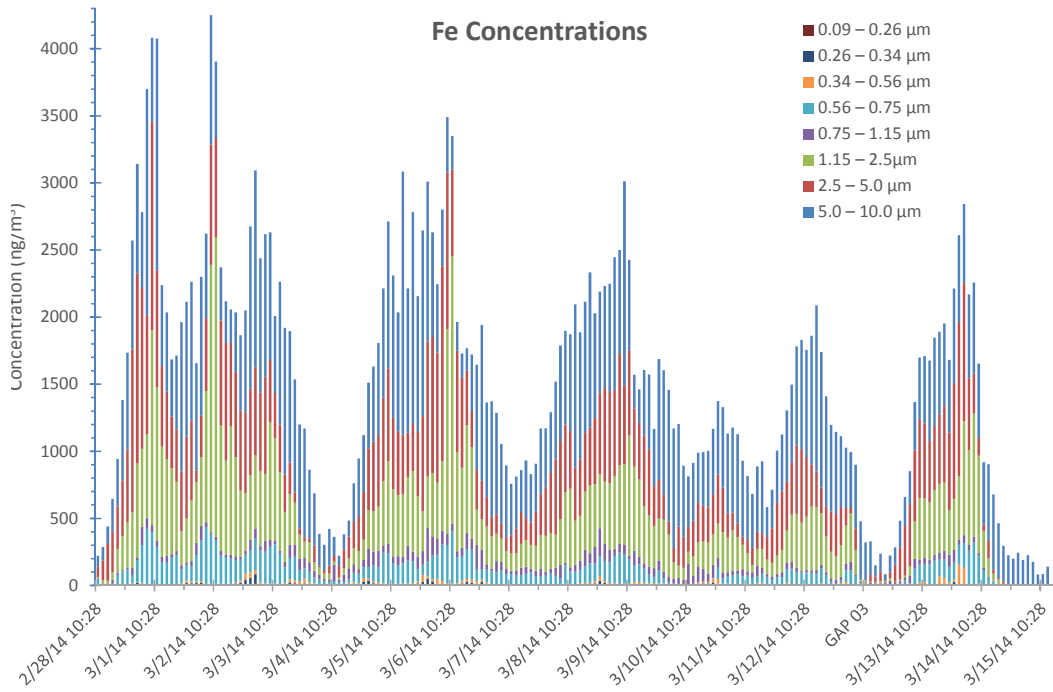


Fig. C-284 CaPh 34 DRUM: Fe mass all stages

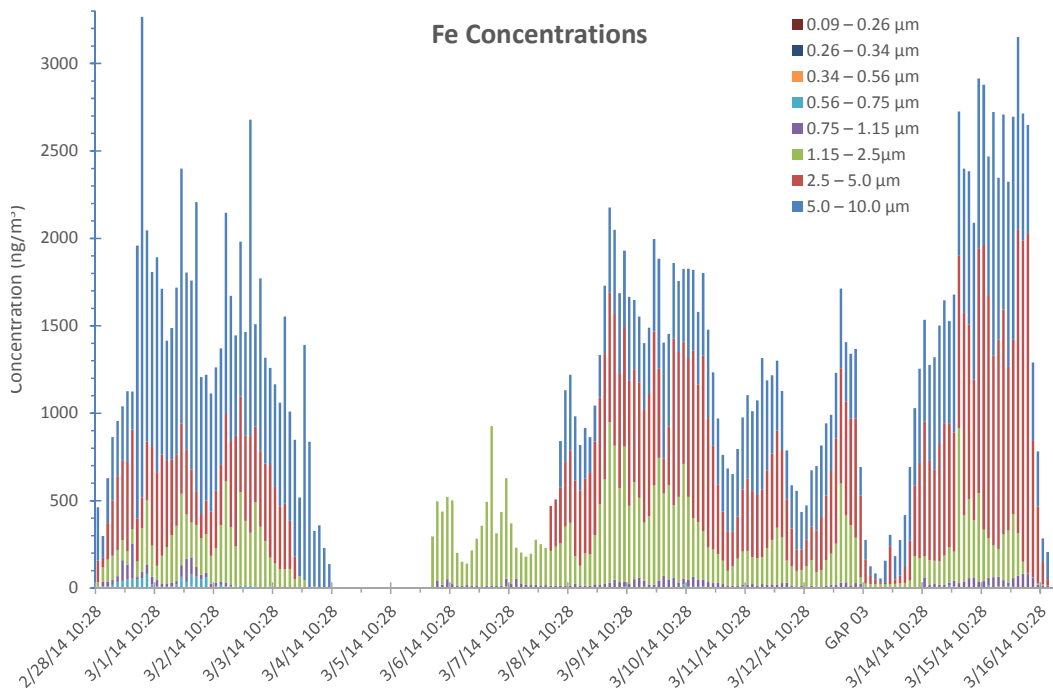


Fig. C-285 CaPh 32 DRUM: Fe mass all stages

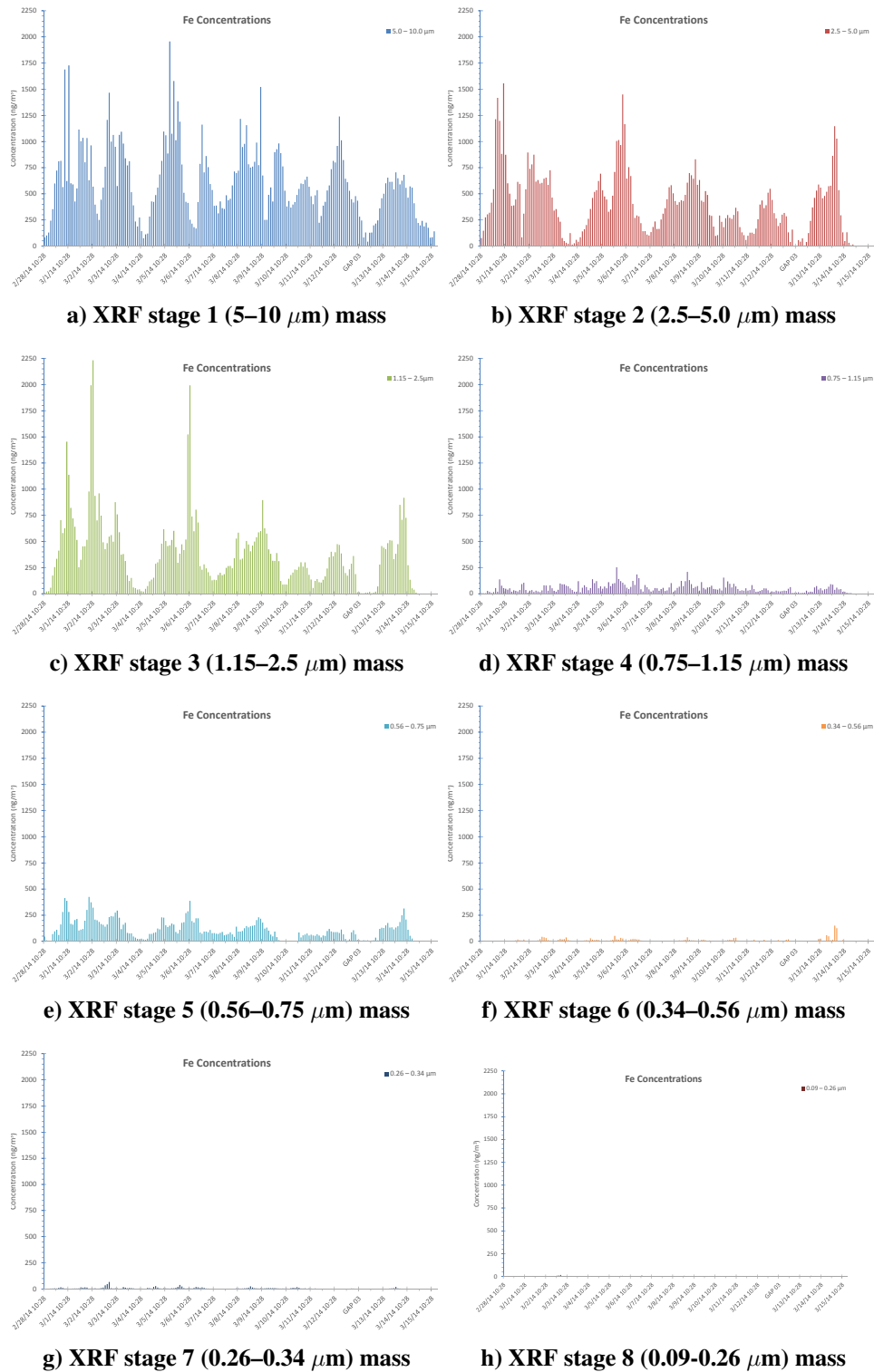
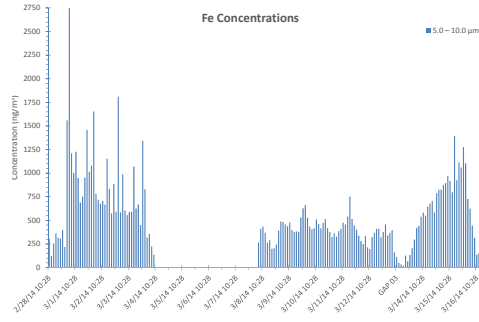
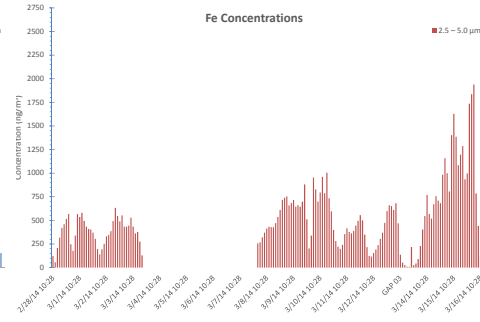


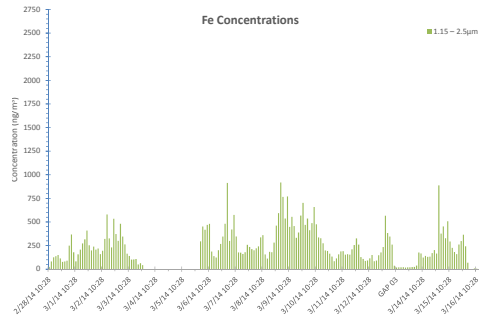
Fig. C-286 CaPh 34 DRUM: XRF mass Fe; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



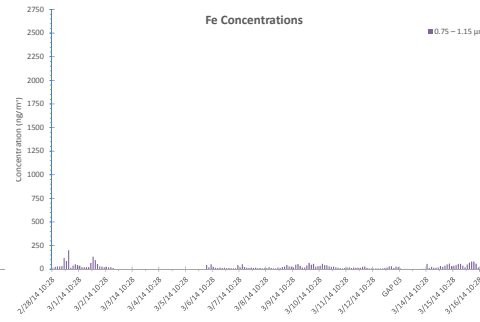
a) XRF stage 1 (5–10 μm) mass



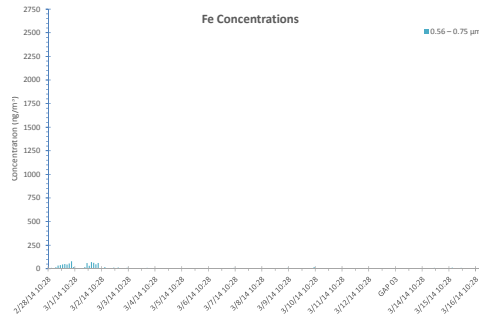
b) XRF stage 2 (2.5–5.0 μm) mass



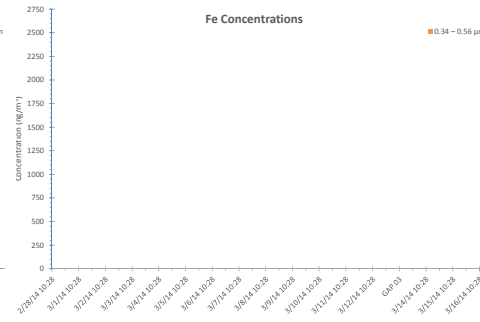
c) XRF stage 3 (1.15–2.5 μm) mass



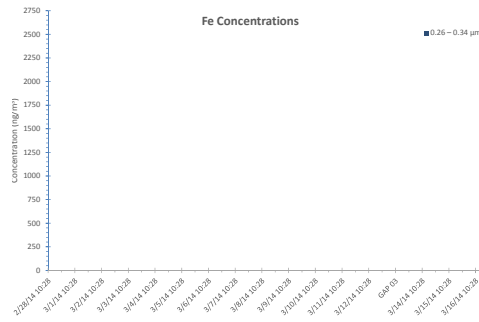
d) XRF stage 4 (0.75–1.15 μm) mass



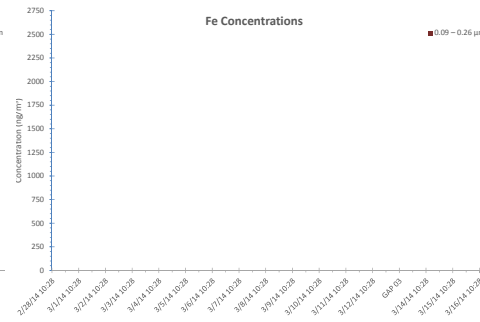
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-287 CaPh 32 DRUM: XRF mass Fe; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

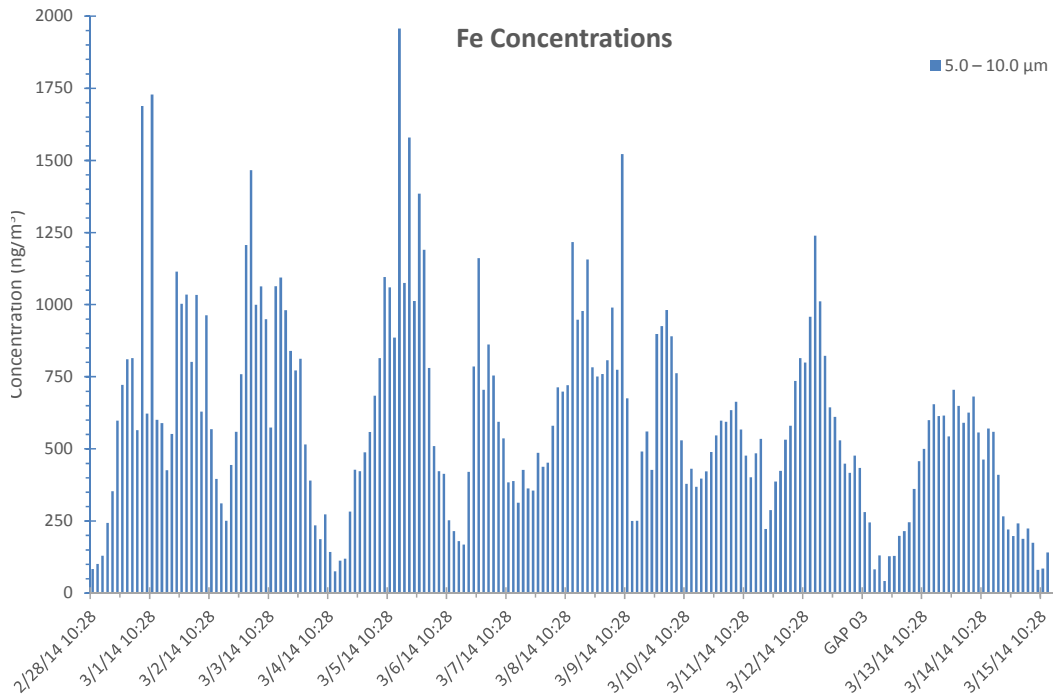


Fig. C-288 CaPh 34 DRUM: Fe mass stage 1

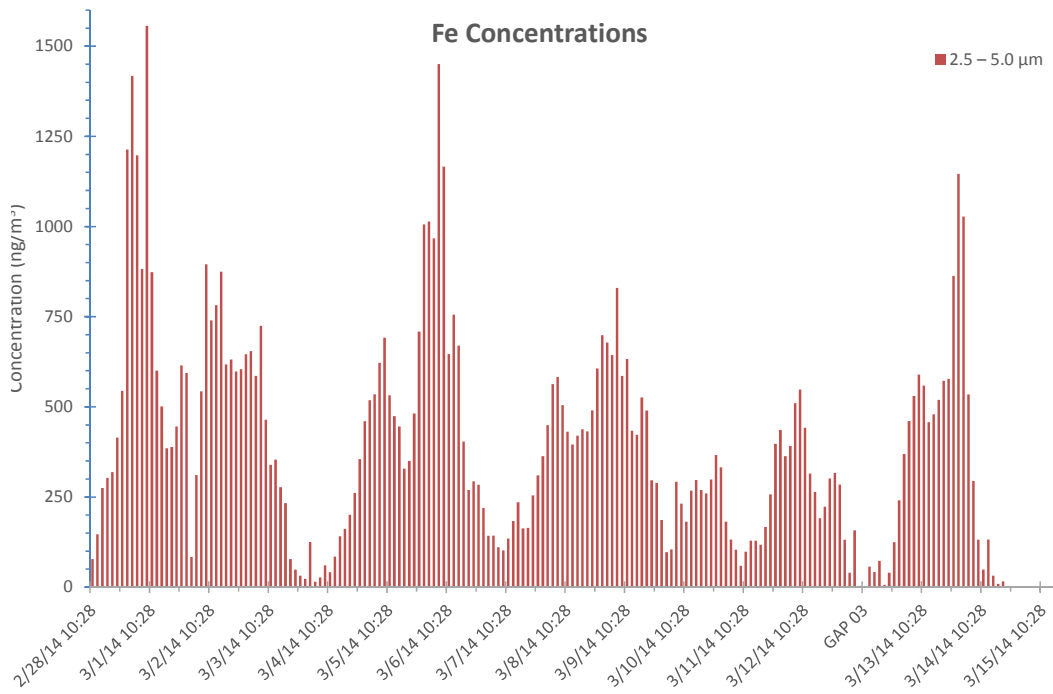


Fig. C-289 CaPh 34 DRUM: Fe mass stage 2

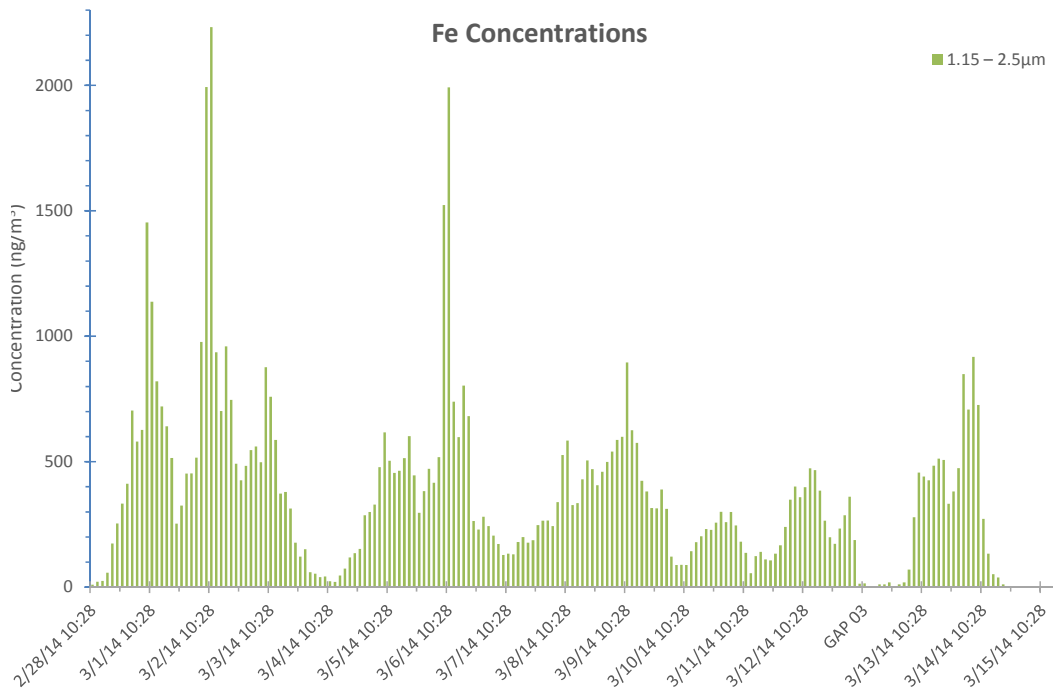


Fig. C-290 CaPh 34 DRUM: Fe mass stage 3

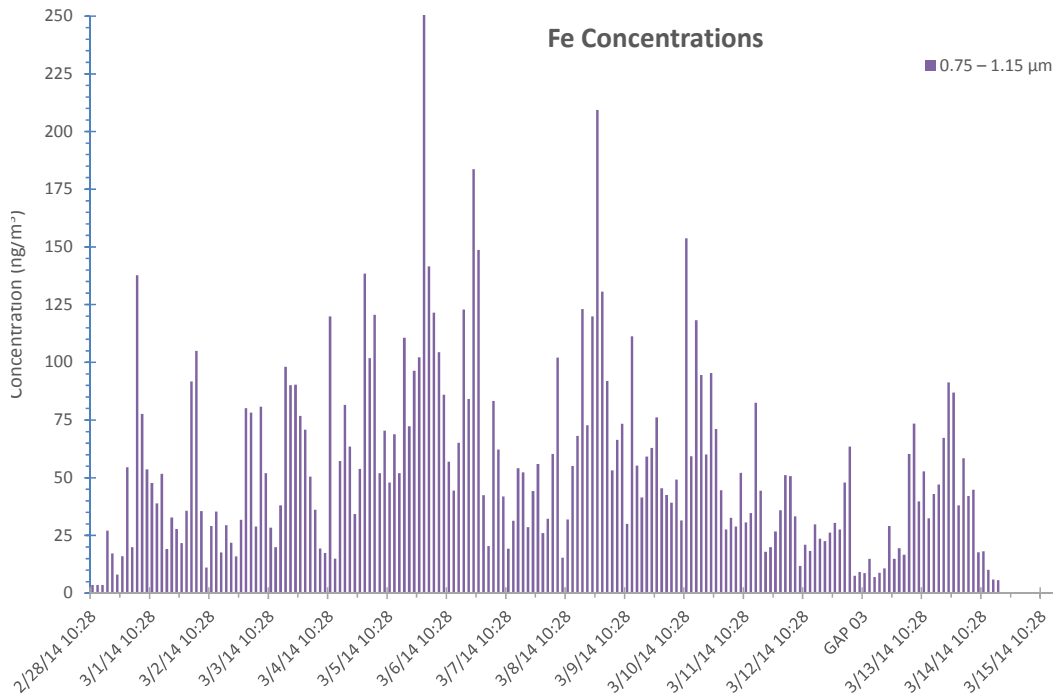


Fig. C-291 CaPh 34 DRUM: Fe mass stage 4

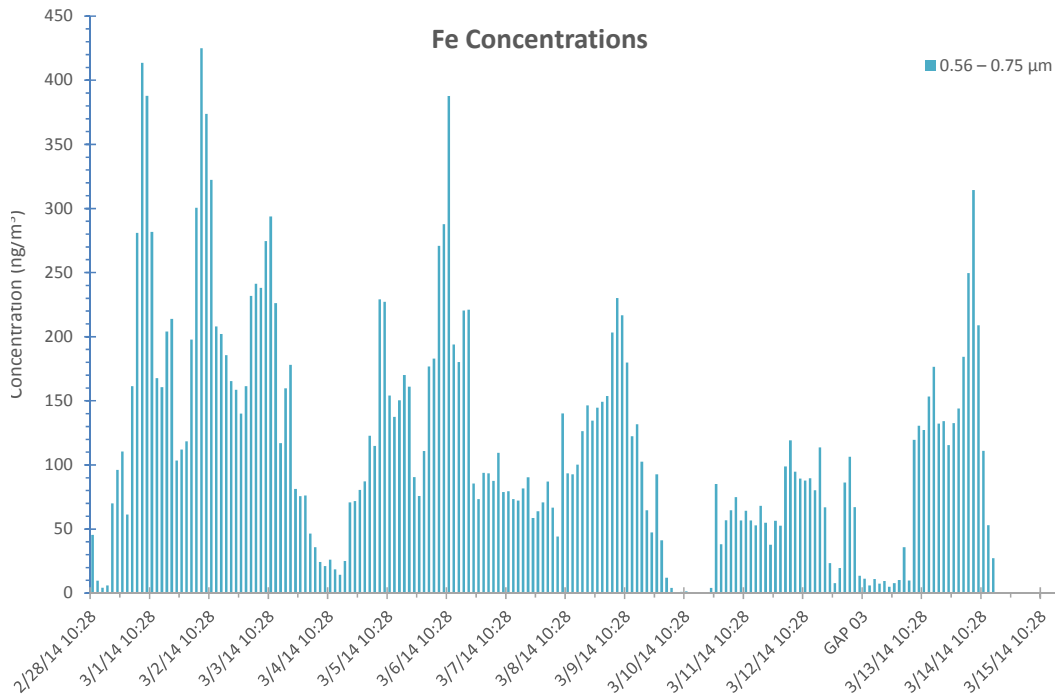


Fig. C-292 CaPh 34 DRUM: Fe mass stage 5

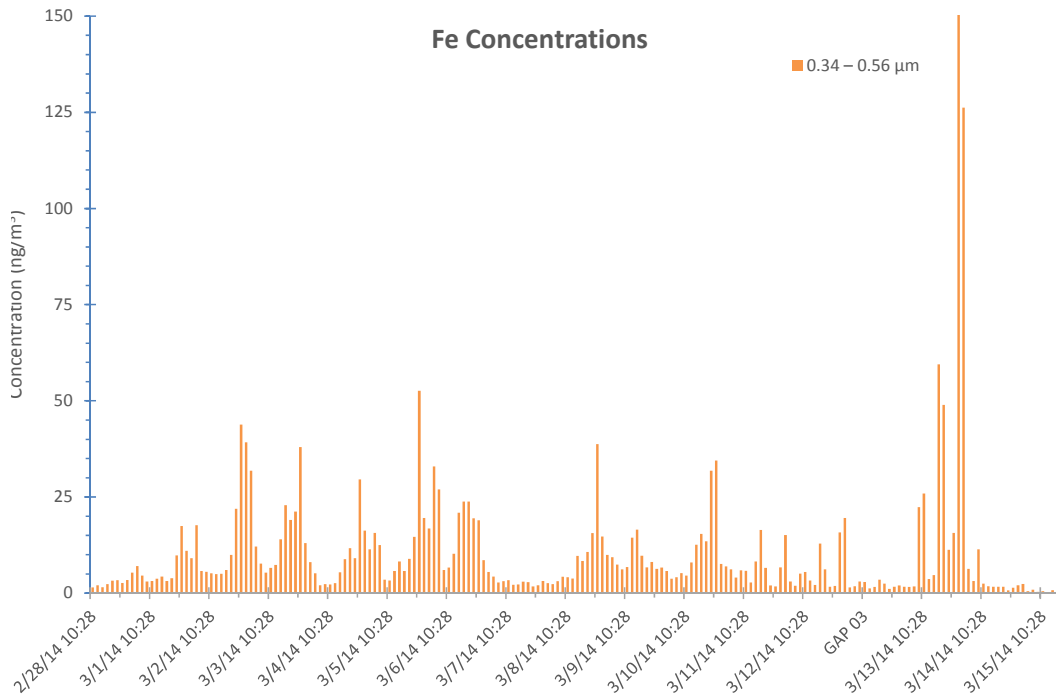


Fig. C-293 CaPh 34 DRUM: Fe mass stage 6

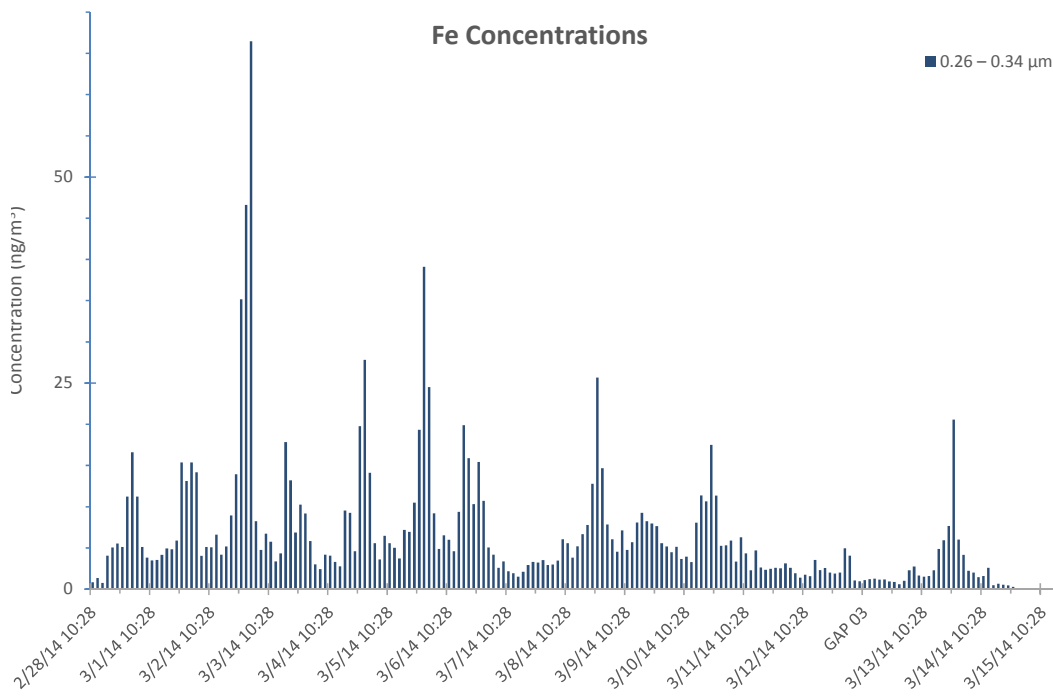


Fig. C-294 CaPh 34 DRUM: Fe mass stage 7

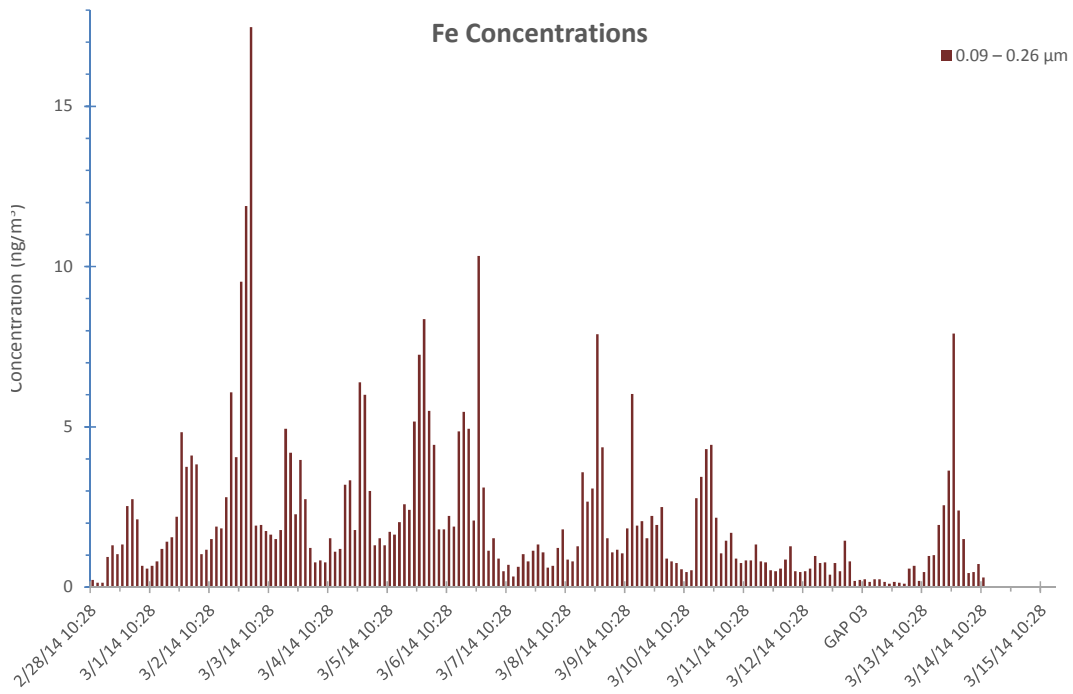


Fig. C-295 CaPh 34 DRUM: Fe mass stage 8

Approved for public release; distribution is unlimited.

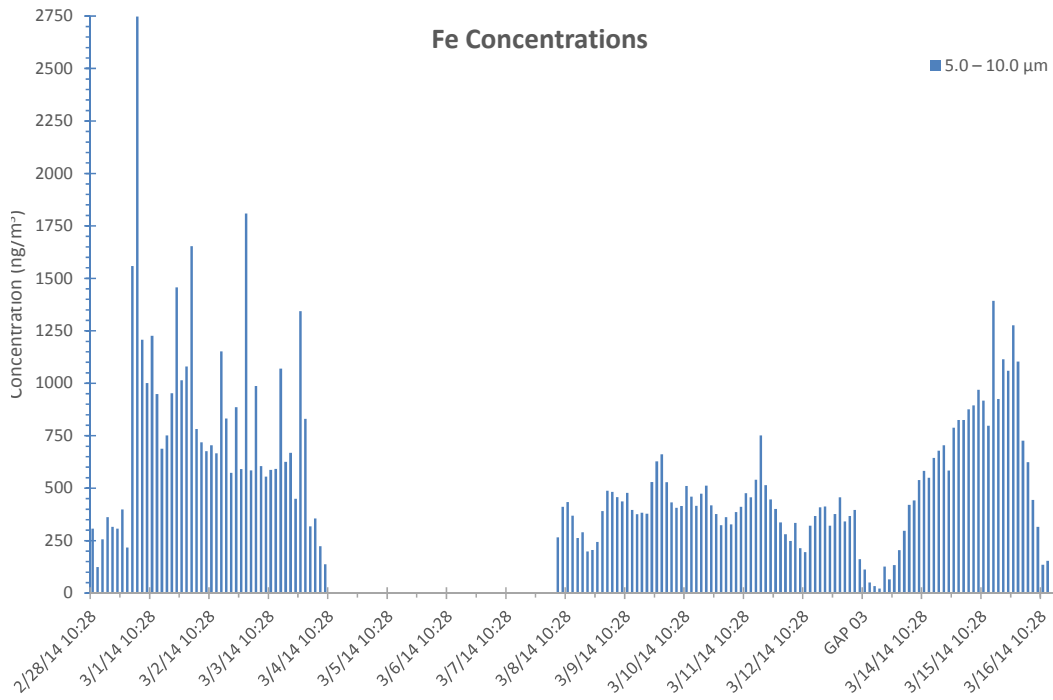


Fig. C-296 CaPh 32 DRUM: Fe mass stage 1

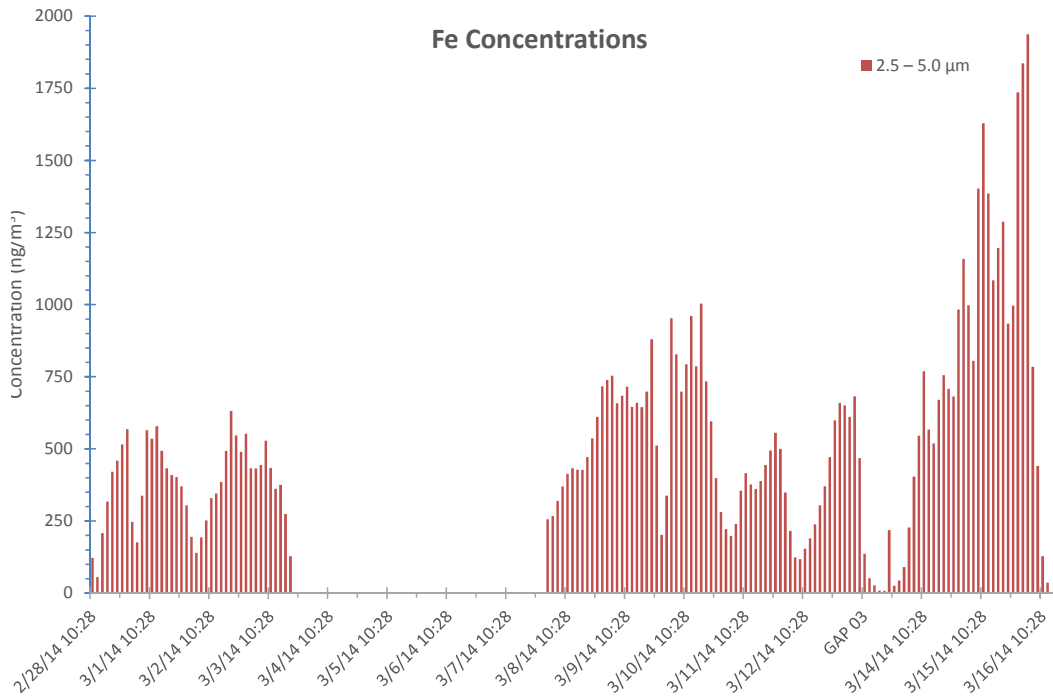


Fig. C-297 CaPh 32 DRUM: Fe mass stage 2

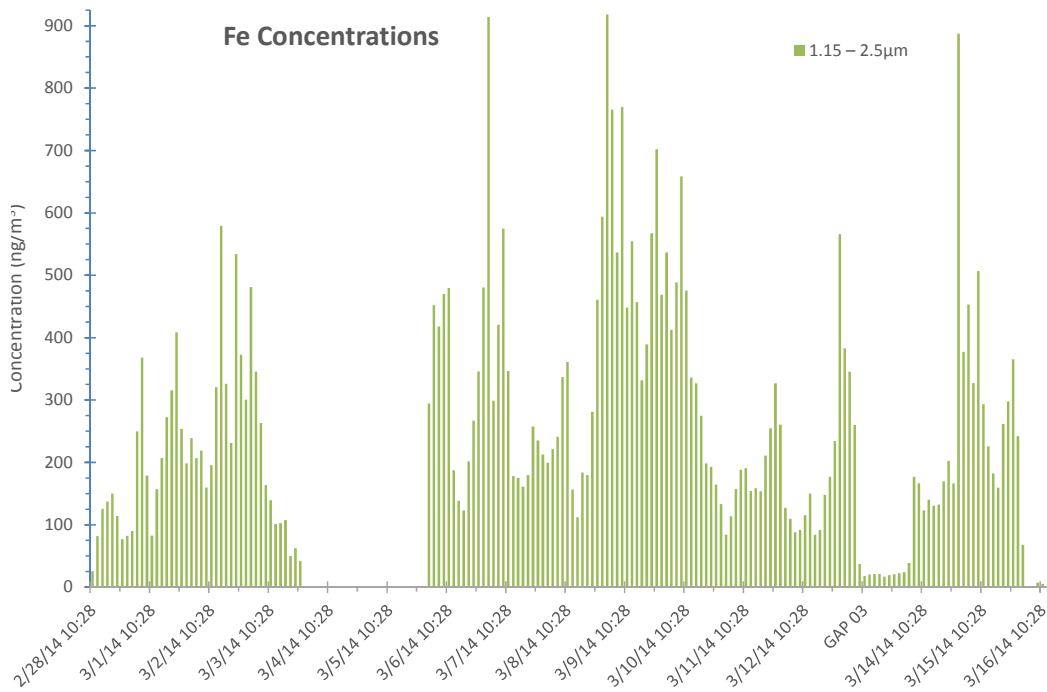


Fig. C-298 CaPh 32 DRUM: Fe mass stage 3

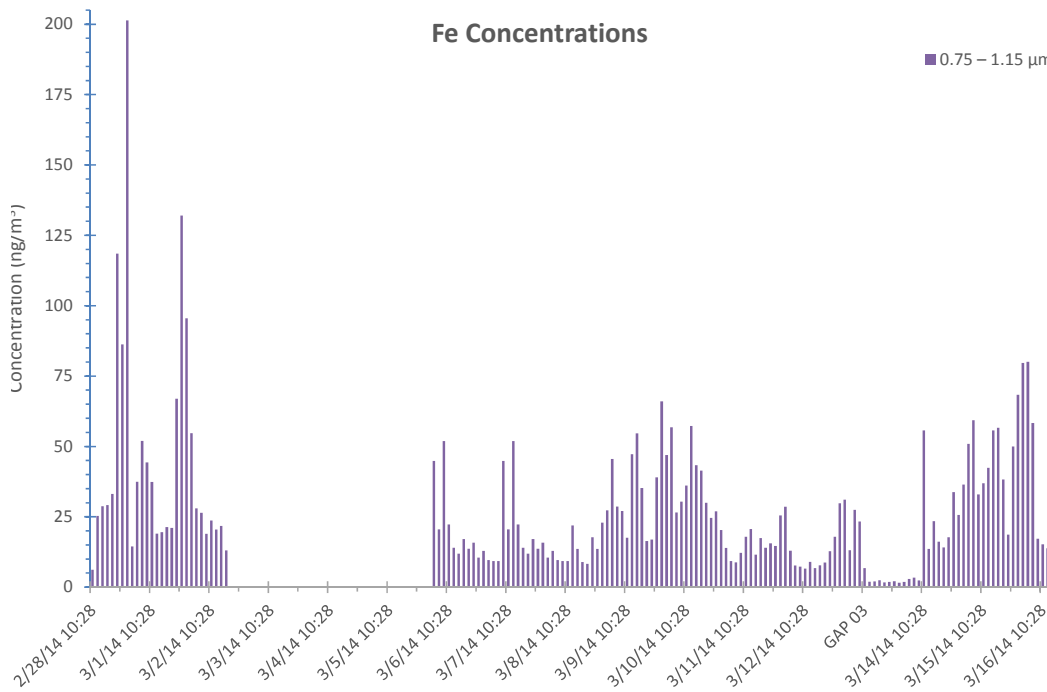


Fig. C-299 CaPh 32 DRUM: Fe mass stage 4

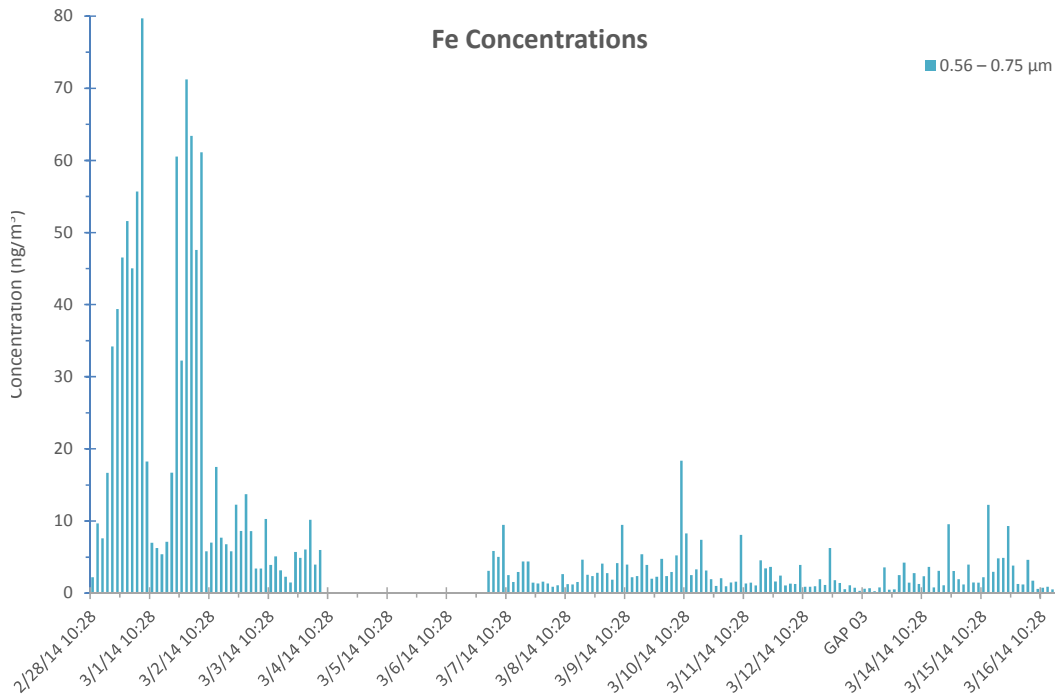


Fig. C-300 CaPh 32 DRUM: Fe mass stage 5

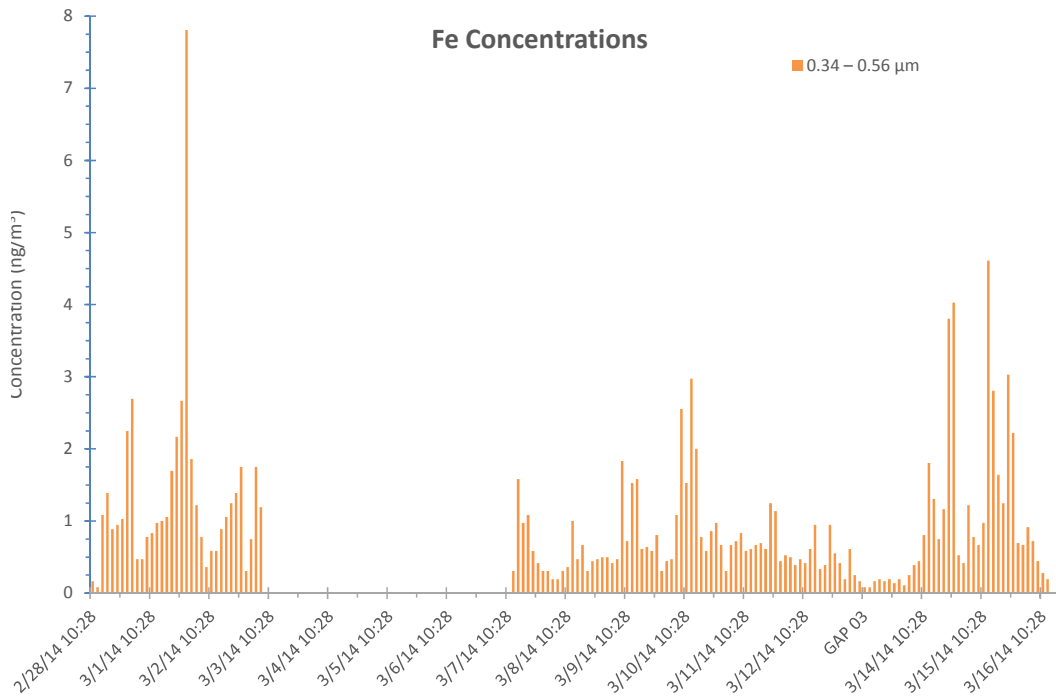


Fig. C-301 CaPh 32 DRUM: Fe mass stage 6

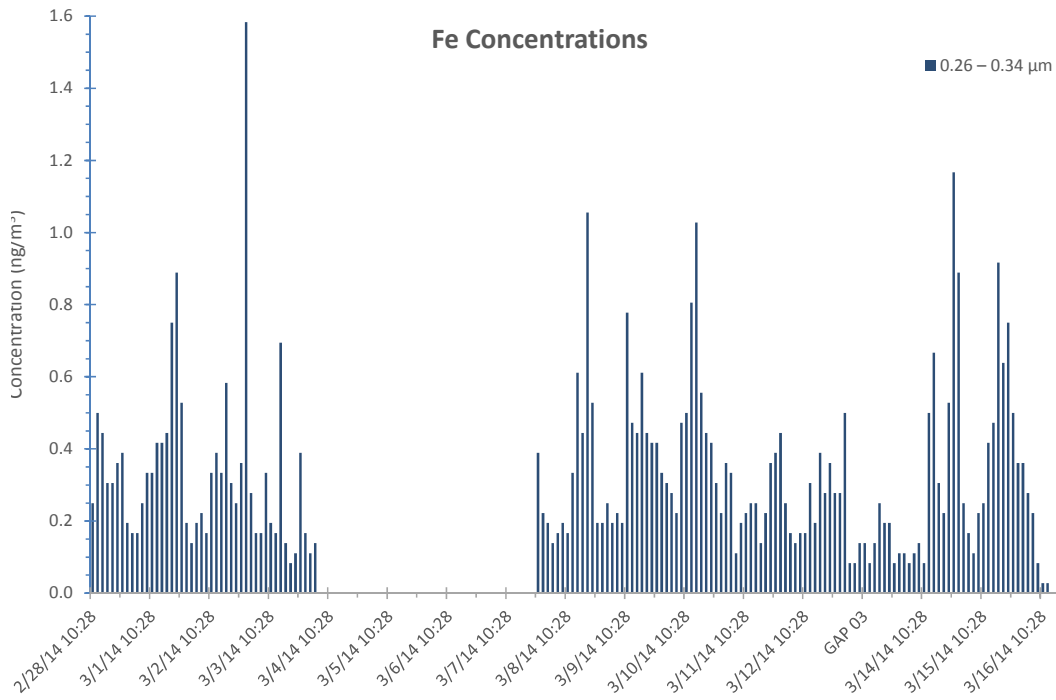


Fig. C-302 CaPh 32 DRUM: Fe mass stage 7

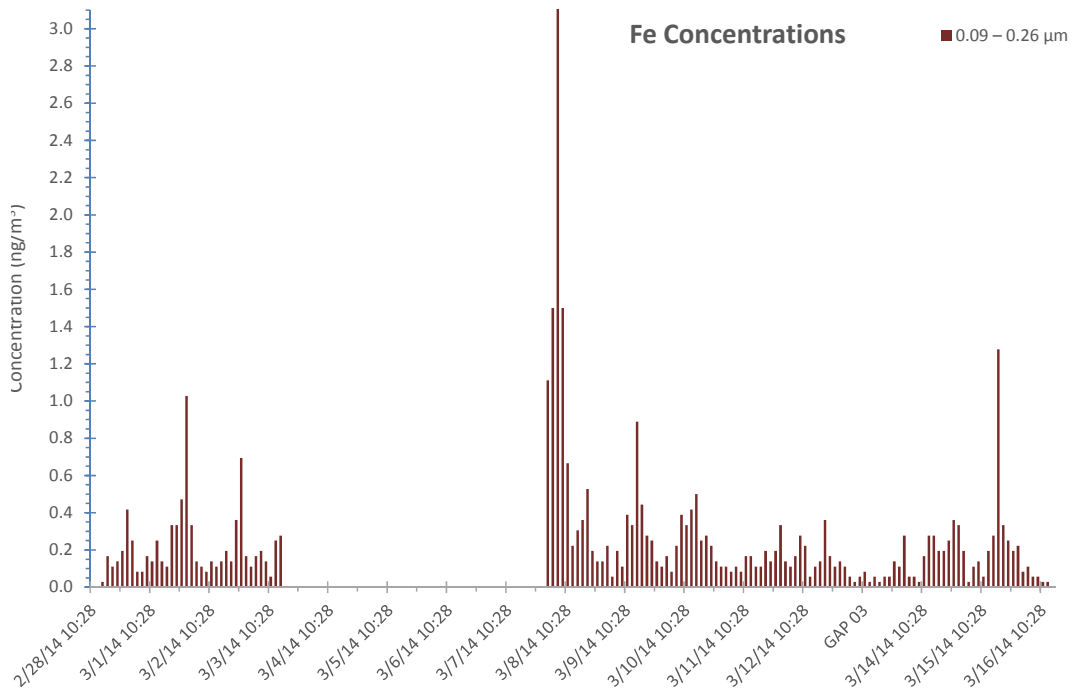


Fig. C-303 CaPh 32 DRUM: Fe mass stage 8

C-4.15 Cobalt (Co)

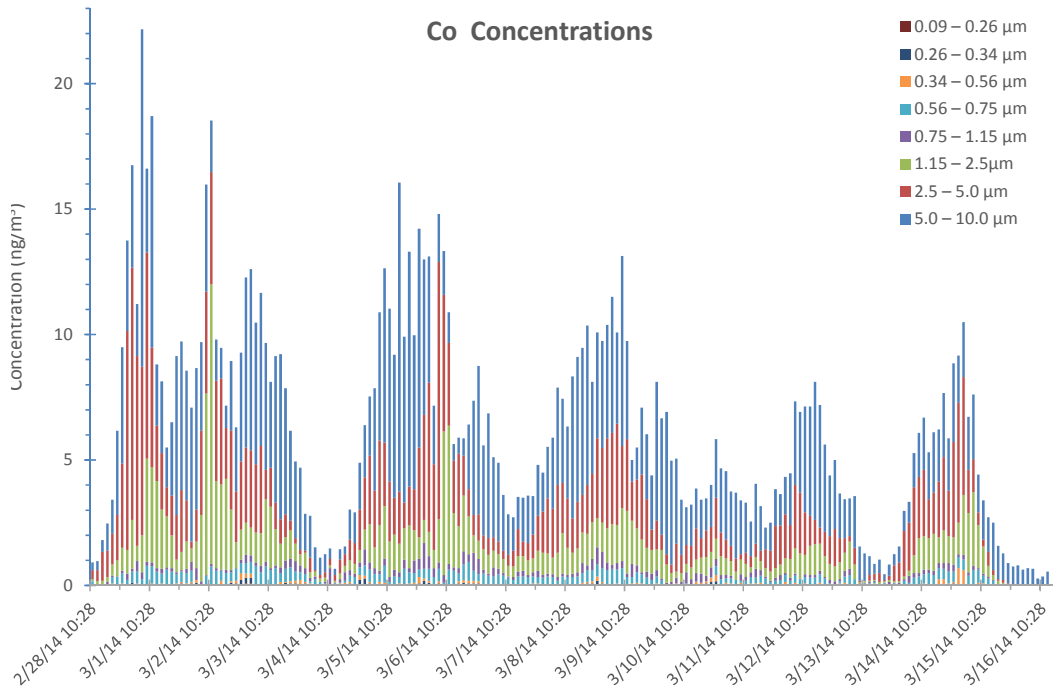


Fig. C-304 CaPh 34 DRUM: Co mass all stages

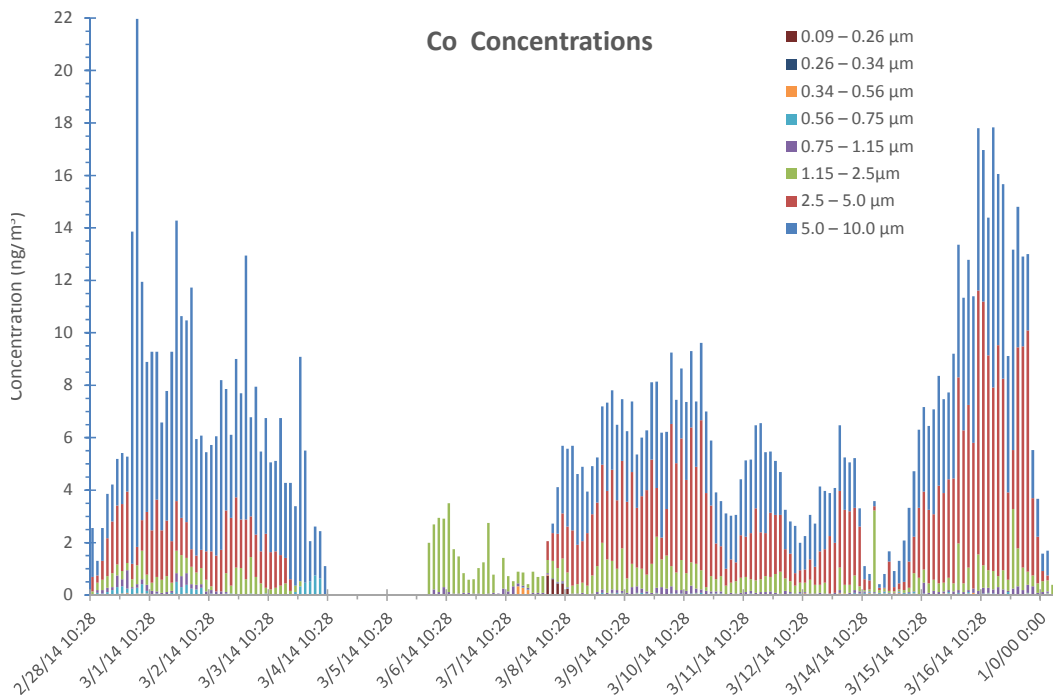
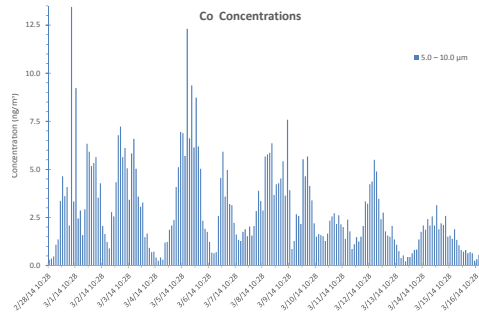
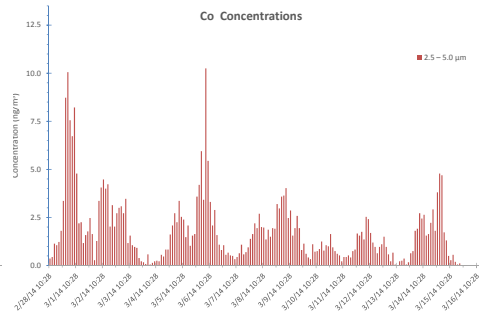


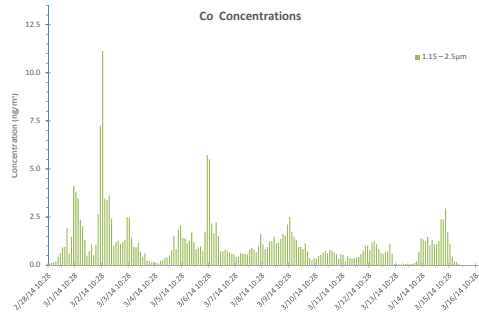
Fig. C-305 CaPh 32 DRUM: Co mass all stages



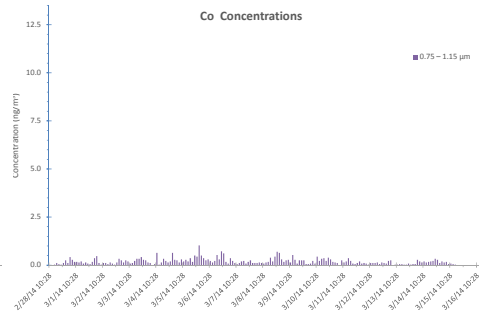
a) XRF stage 1 (5–10 μm) mass



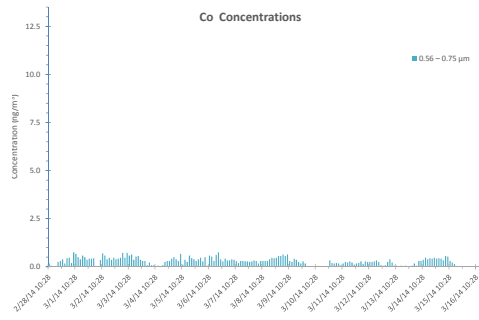
b) XRF stage 2 (2.5–5.0 μm) mass



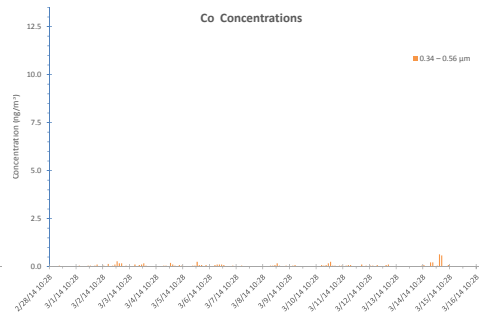
c) XRF stage 3 (1.15–2.5 μm) mass



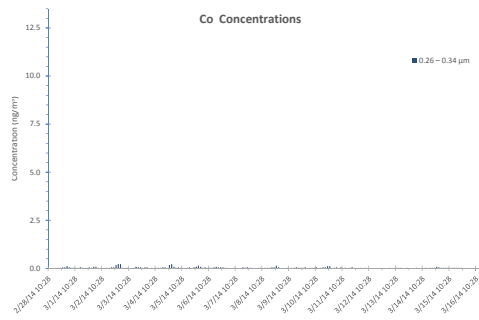
d) XRF stage 4 (0.75–1.15 μm) mass



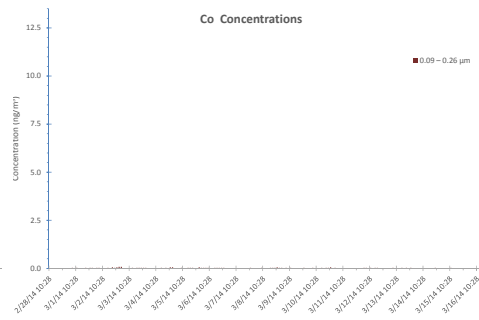
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.34–0.56 μm) mass

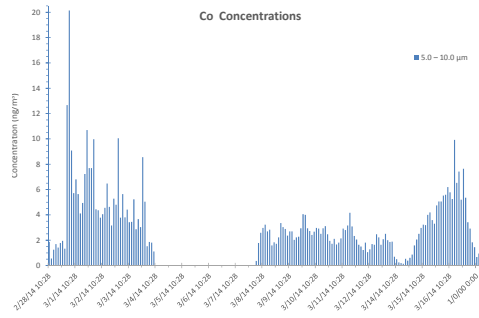


g) XRF stage 7 (0.26–0.34 μm) mass

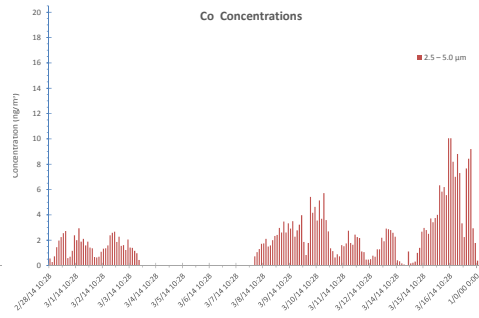


h) XRF stage 8 (0.09–0.26 μm) mass

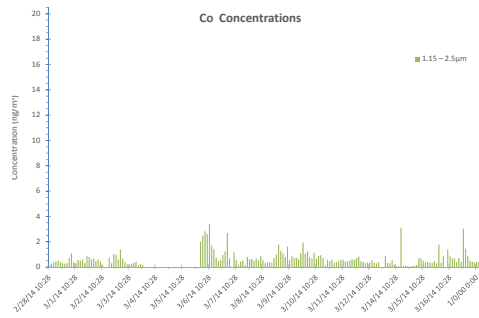
Fig. C-306 CaPh 34 DRUM: XRF mass Fe; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



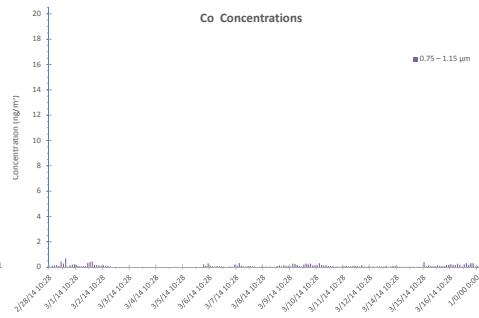
a) XRF stage 1 (5–10 μm) mass



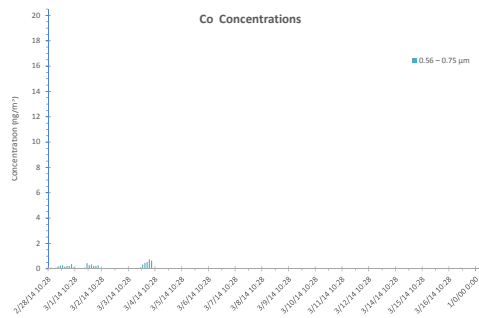
b) XRF stage 2 (2.5–5.0 μm) mass



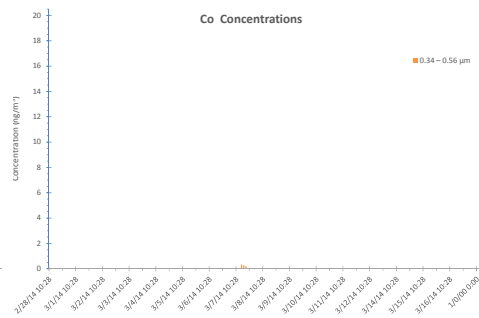
c) XRF stage 3 (1.15–2.5 μm) mass



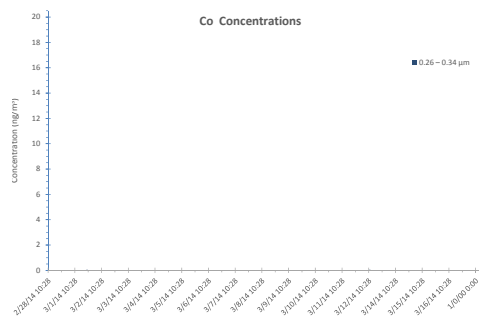
d) XRF stage 4 (0.75–1.15 μm) mass



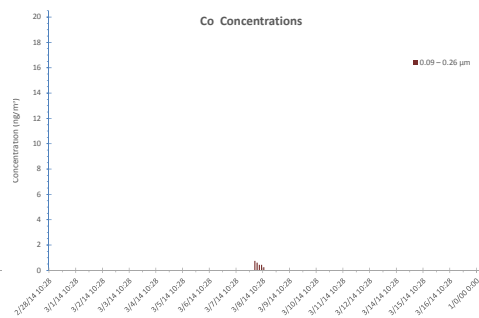
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-307 CaPh 32 DRUM: XRF mass Fe; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

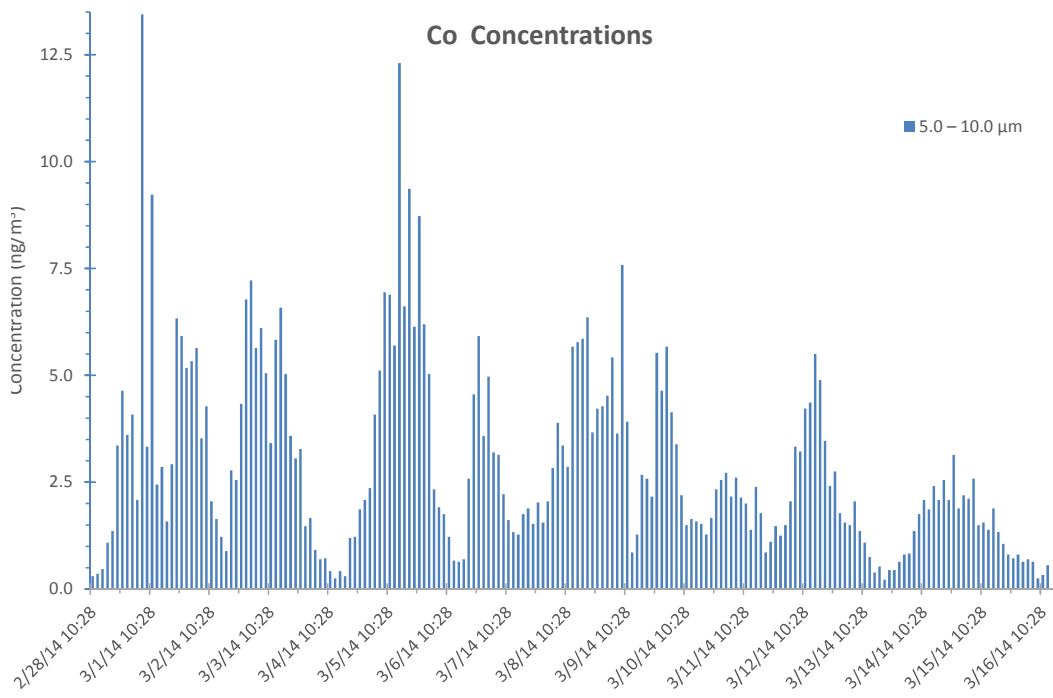


Fig. C-308 CaPh 34 DRUM: Co mass stage 1

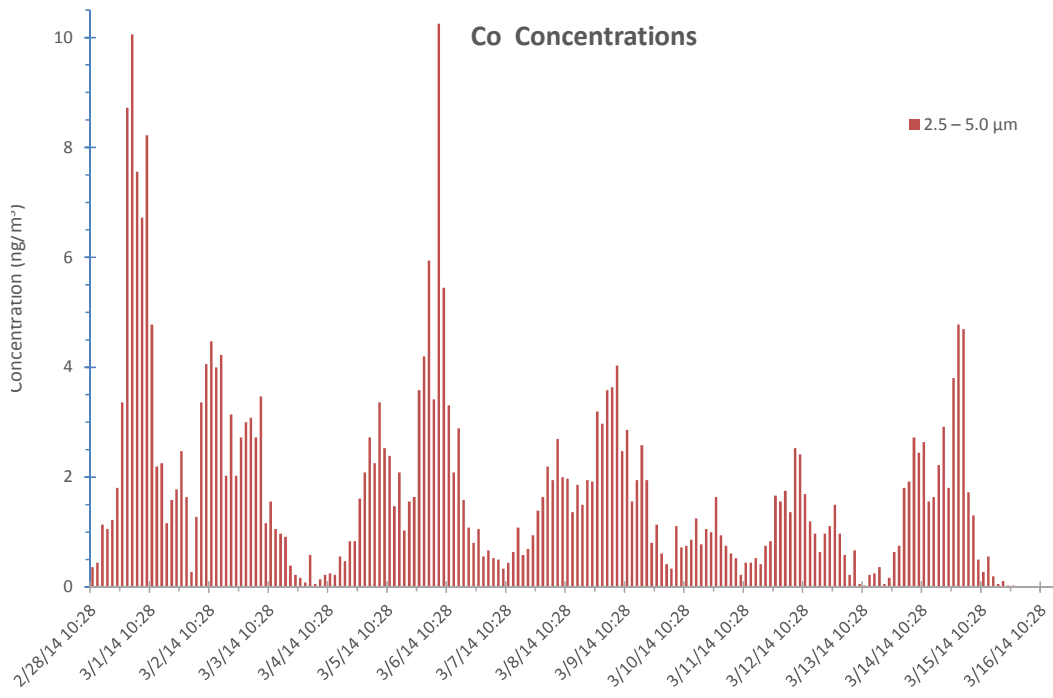


Fig. C-309 CaPh 34 DRUM: Co mass stage 2

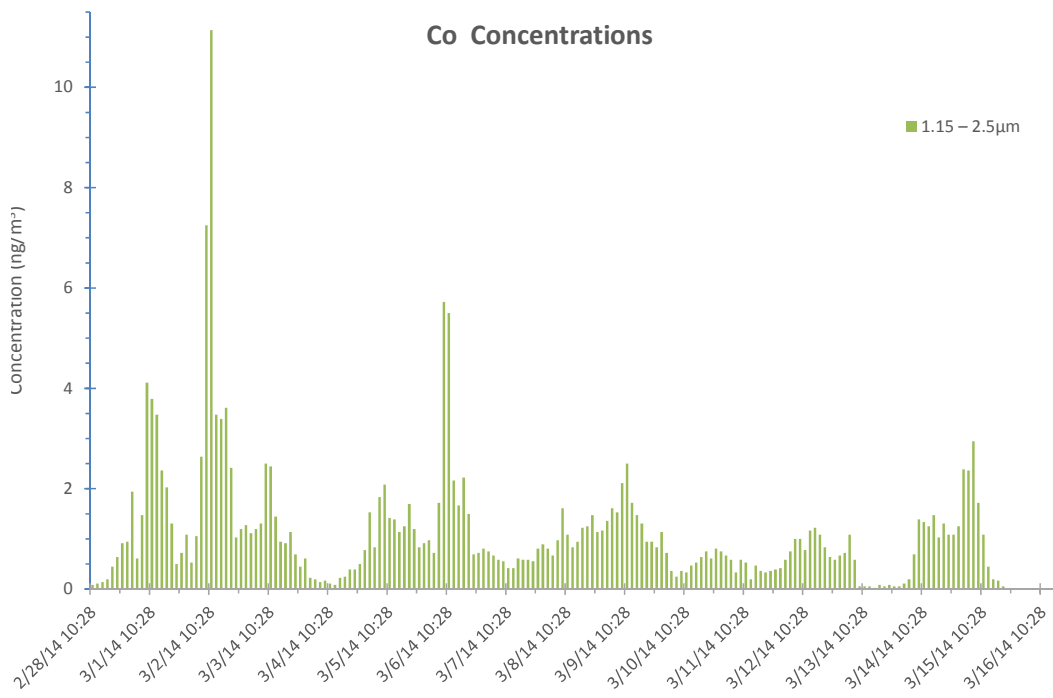


Fig. C-310 CaPh 34 DRUM: Co mass stage 3

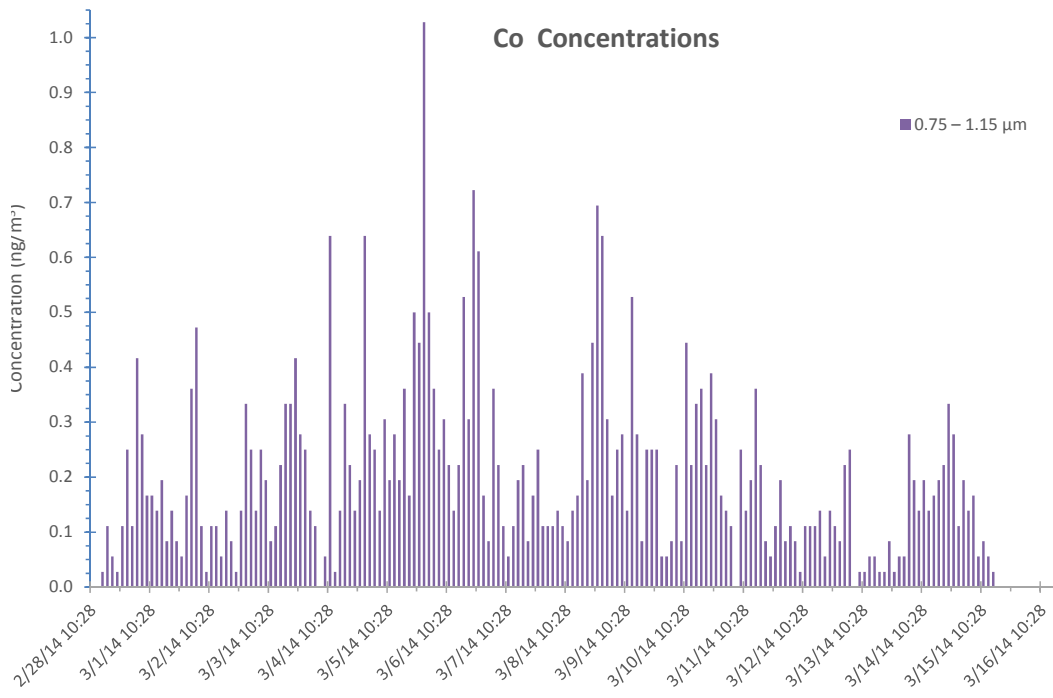


Fig. C-311 CaPh 34 DRUM: Co mass stage 4

Approved for public release; distribution is unlimited.

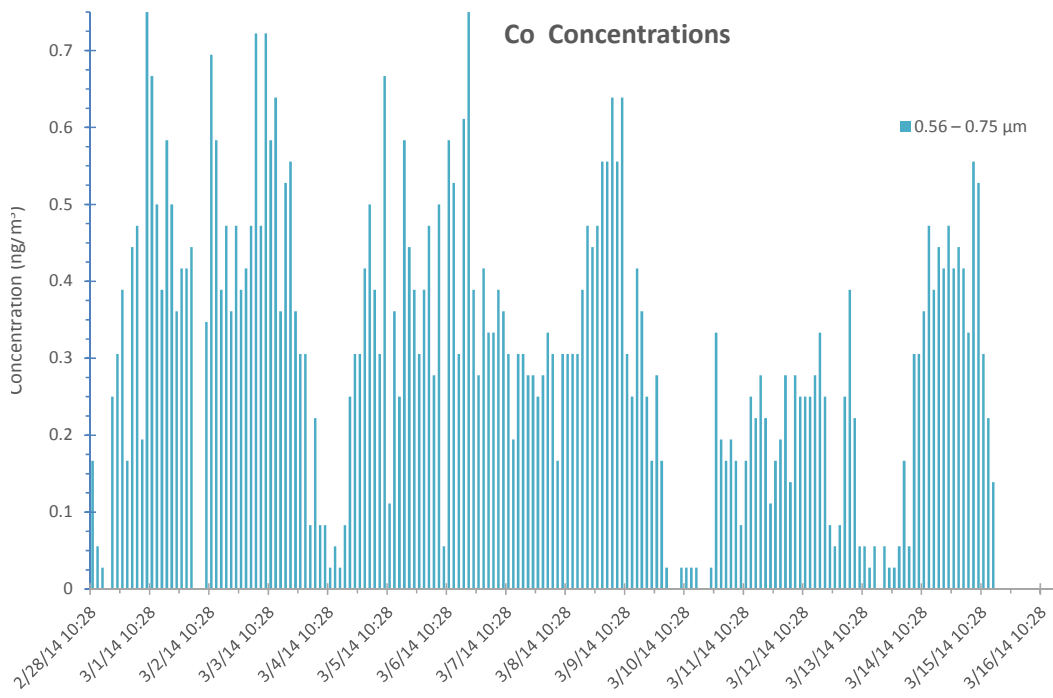


Fig. C-312 CaPh 34 DRUM: Co mass stage 5

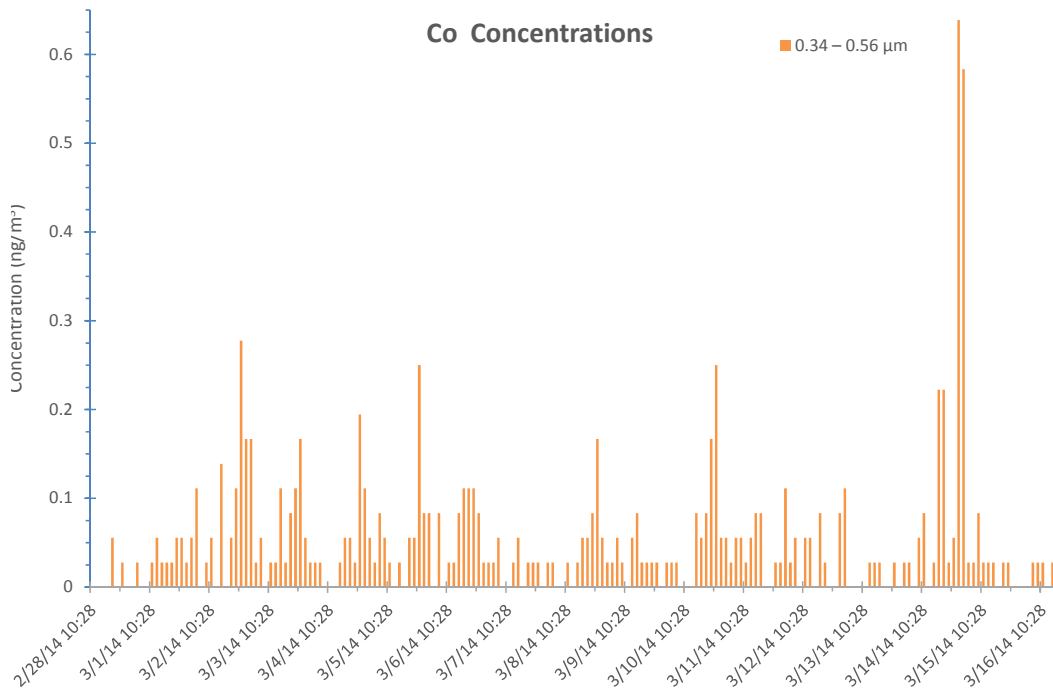


Fig. C-313 CaPh 34 DRUM: Co mass stage 6

Approved for public release; distribution is unlimited.

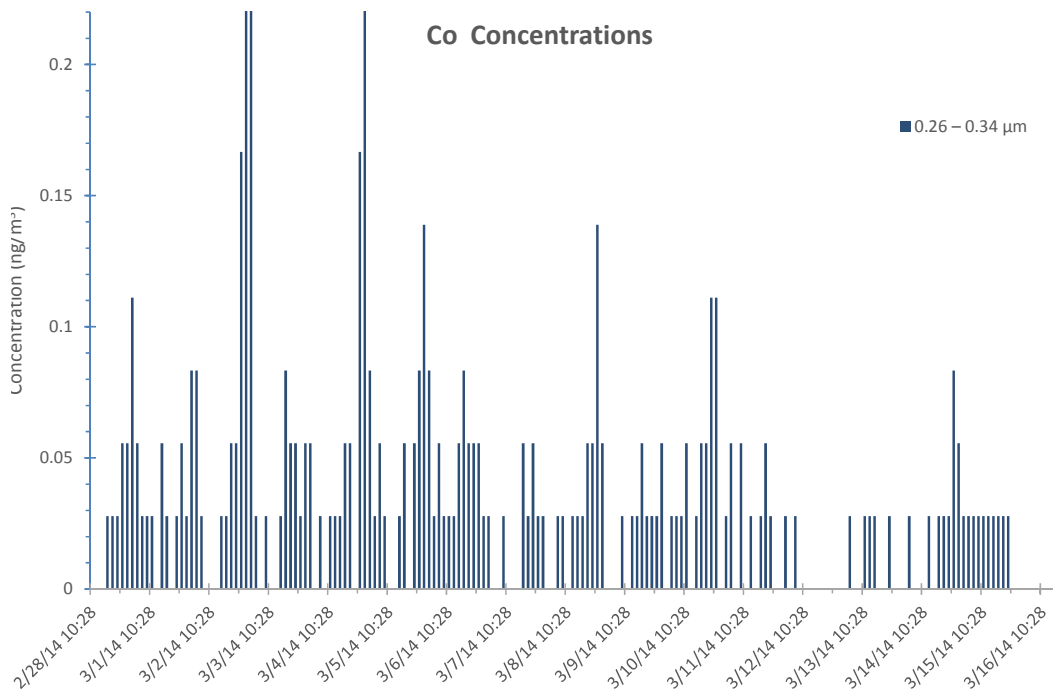


Fig. C-314 CaPh 34 DRUM: Co mass stage 7

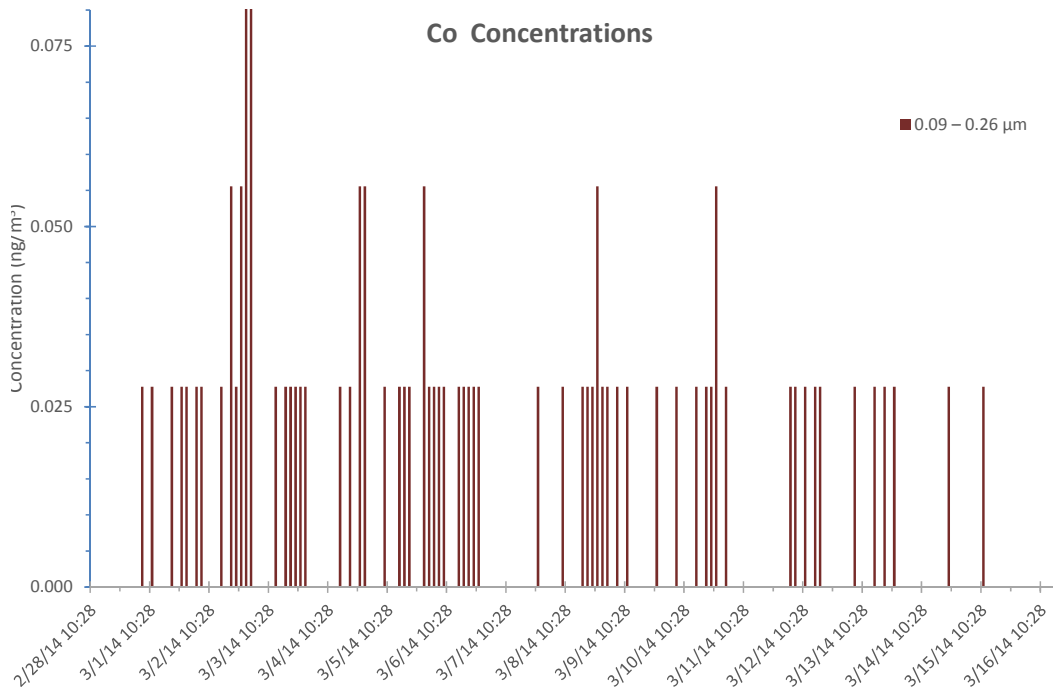


Fig. C-315 CaPh 34 DRUM: Co mass stage 8

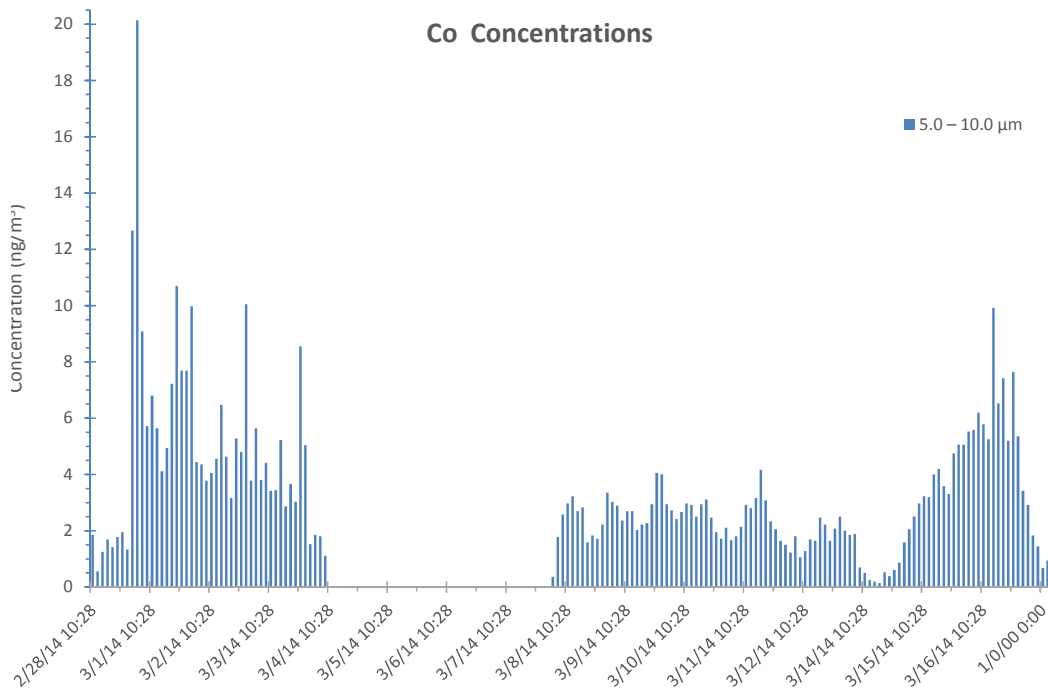


Fig. C-316 CaPh 32 DRUM: Co mass stage 1

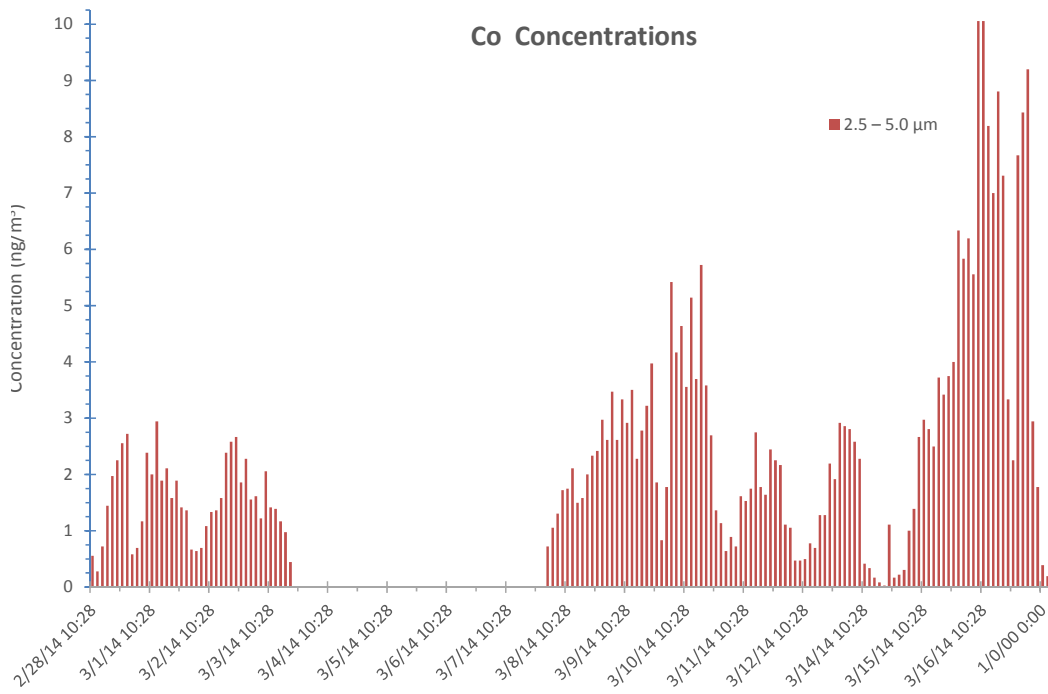


Fig. C-317 CaPh 32 DRUM: Co mass stage 2

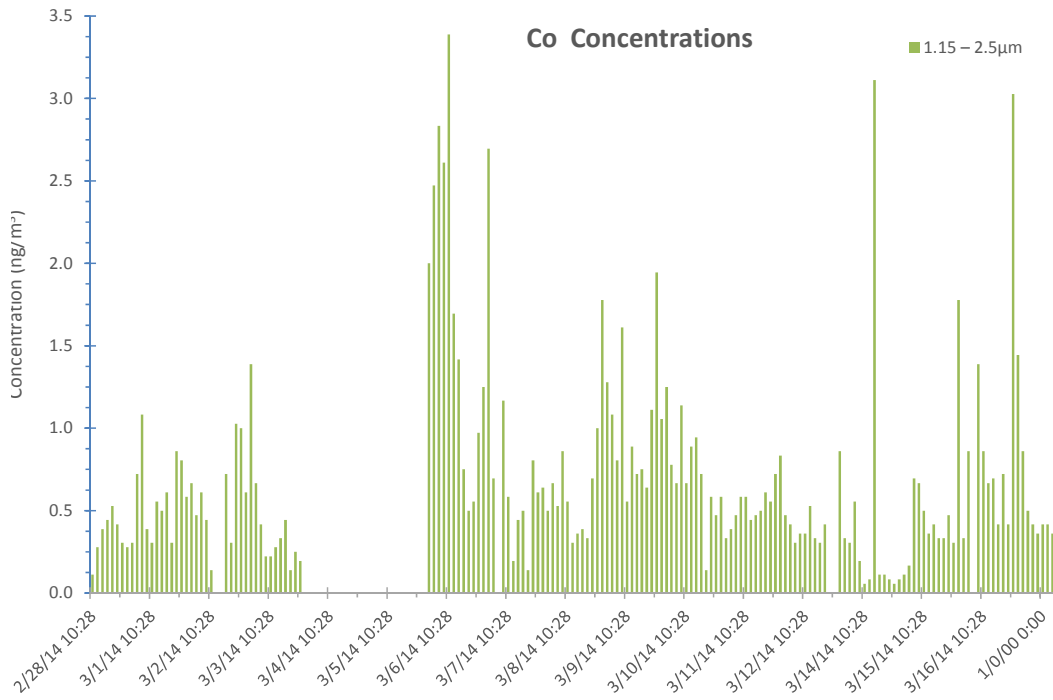


Fig. C-318 CaPh 32 DRUM: Co mass stage 3

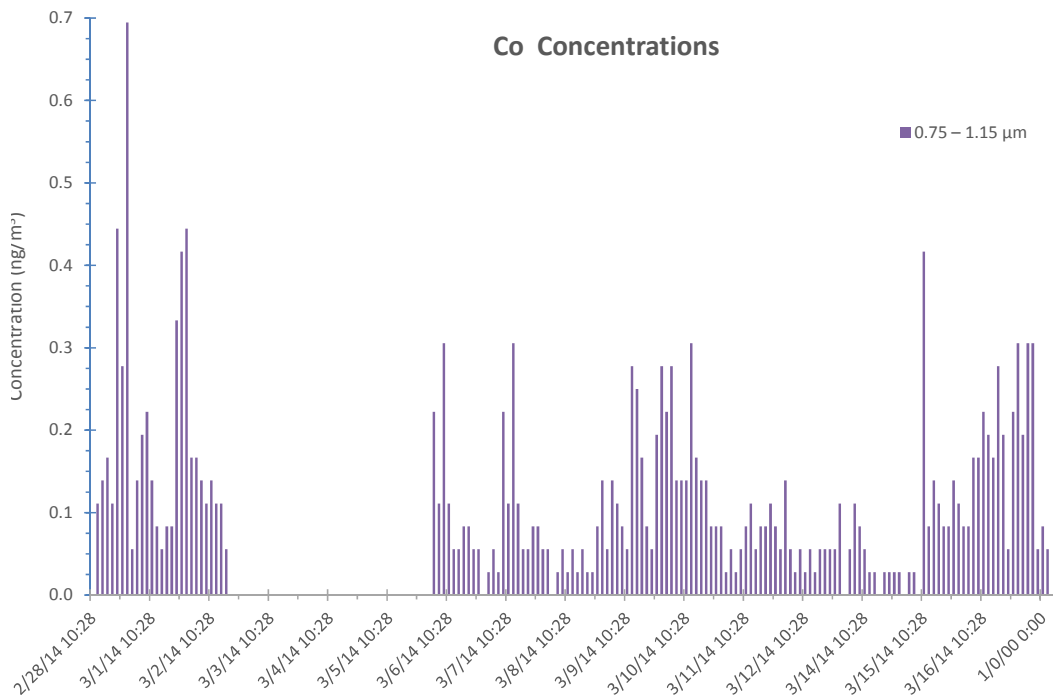


Fig. C-319 CaPh 32 DRUM: Co mass stage 4

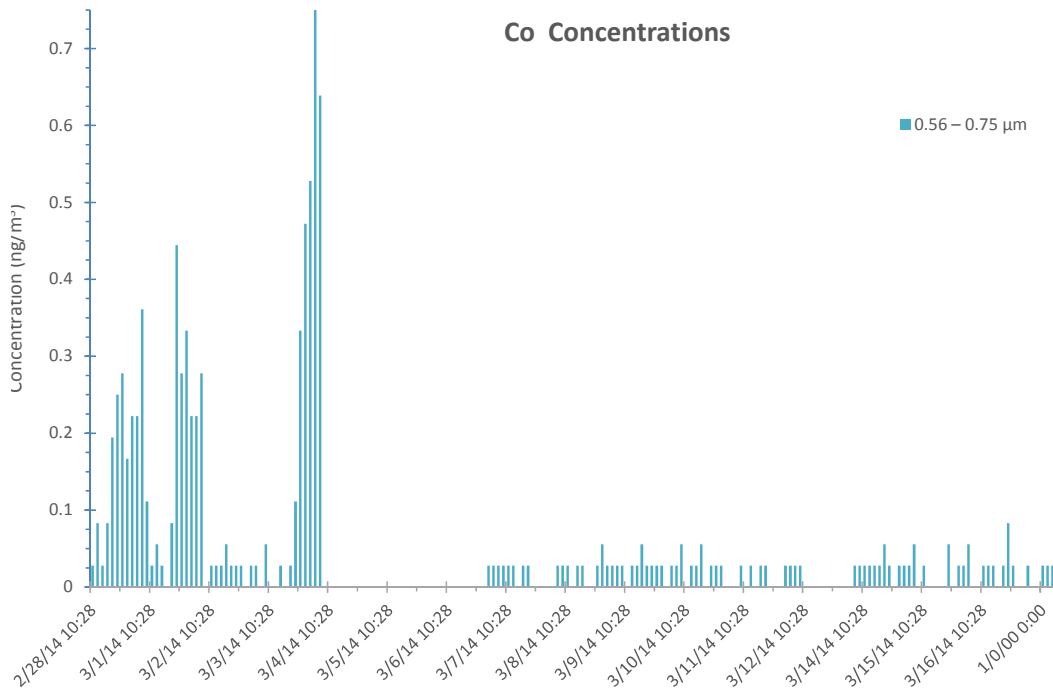


Fig. C-320 CaPh 32 DRUM: Co mass stage 5

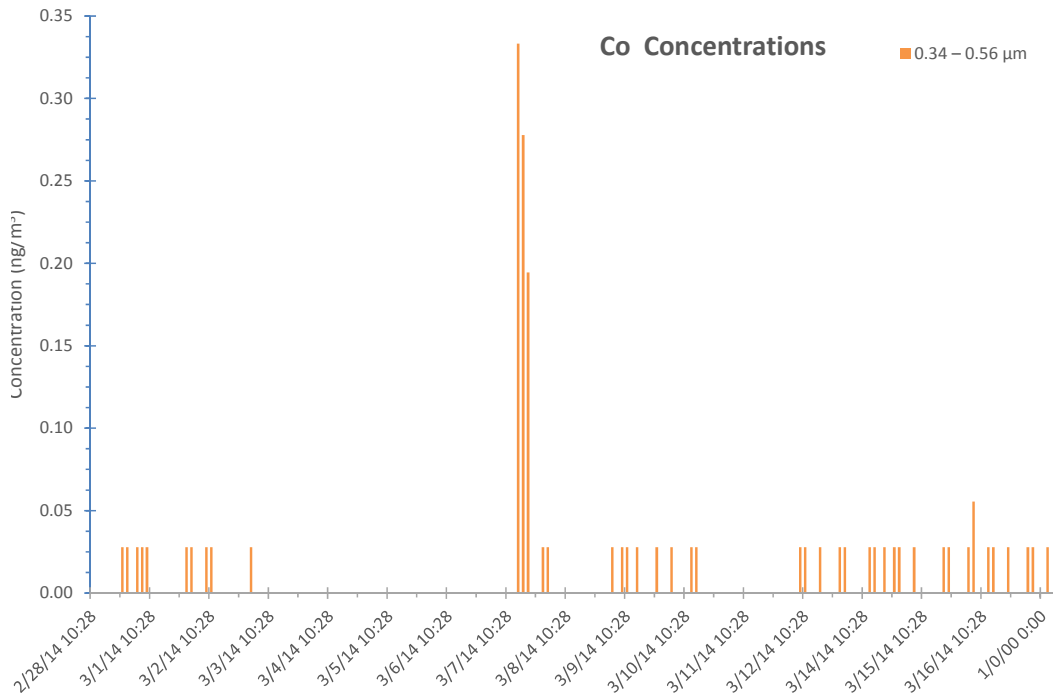


Fig. C-321 CaPh 32 DRUM: Co mass stage 6

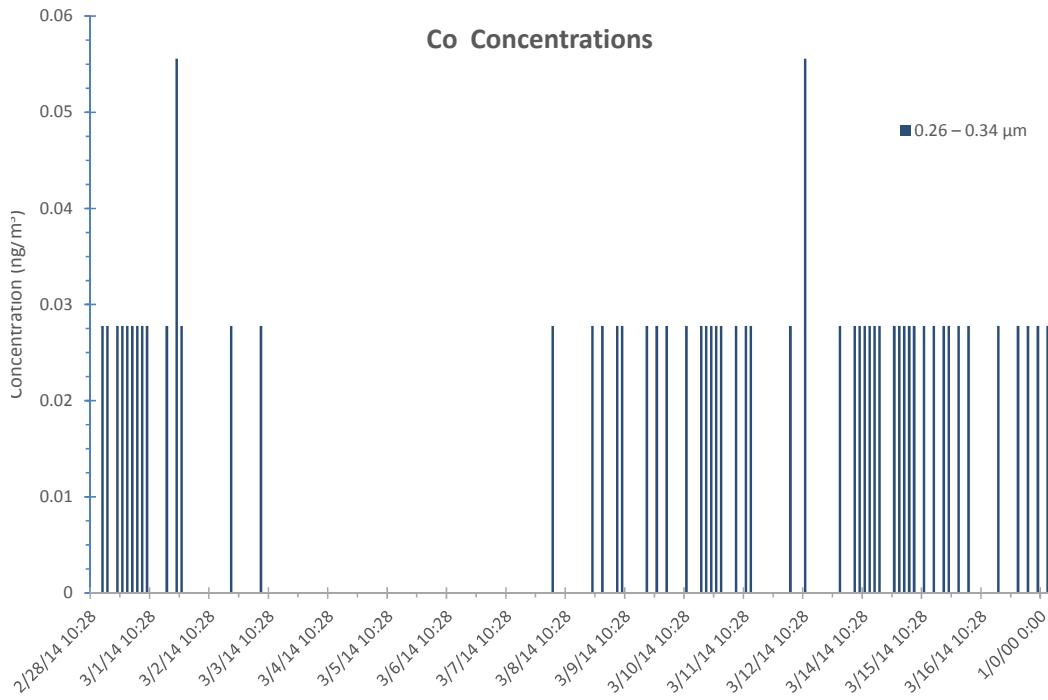


Fig. C-322 CaPh 32 DRUM: Co mass stage 7

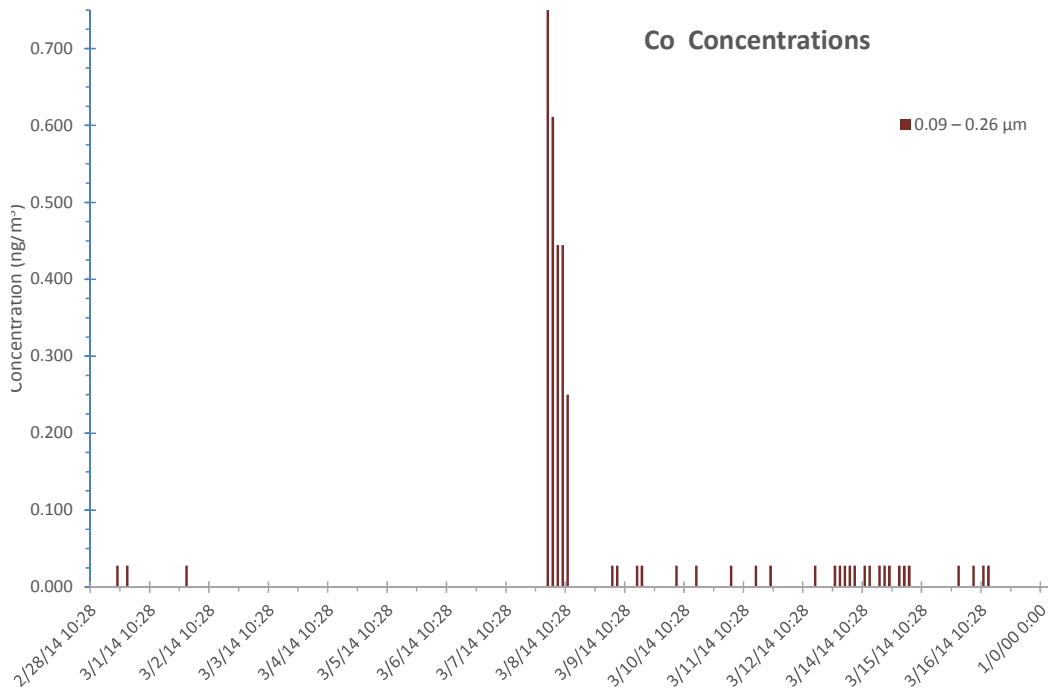


Fig. C-323 CaPh 32 DRUM: Co mass stage 8

Approved for public release; distribution is unlimited.

C-4.16 Nickel (Ni)

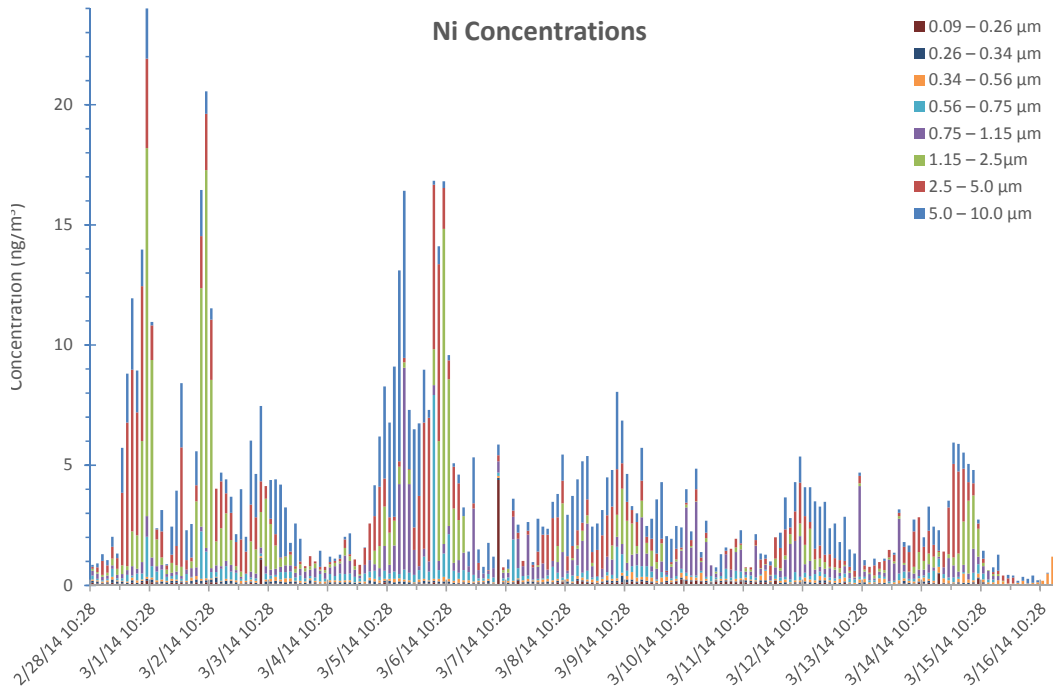


Fig. C-324 CaPh 34 DRUM: Ni mass all stages

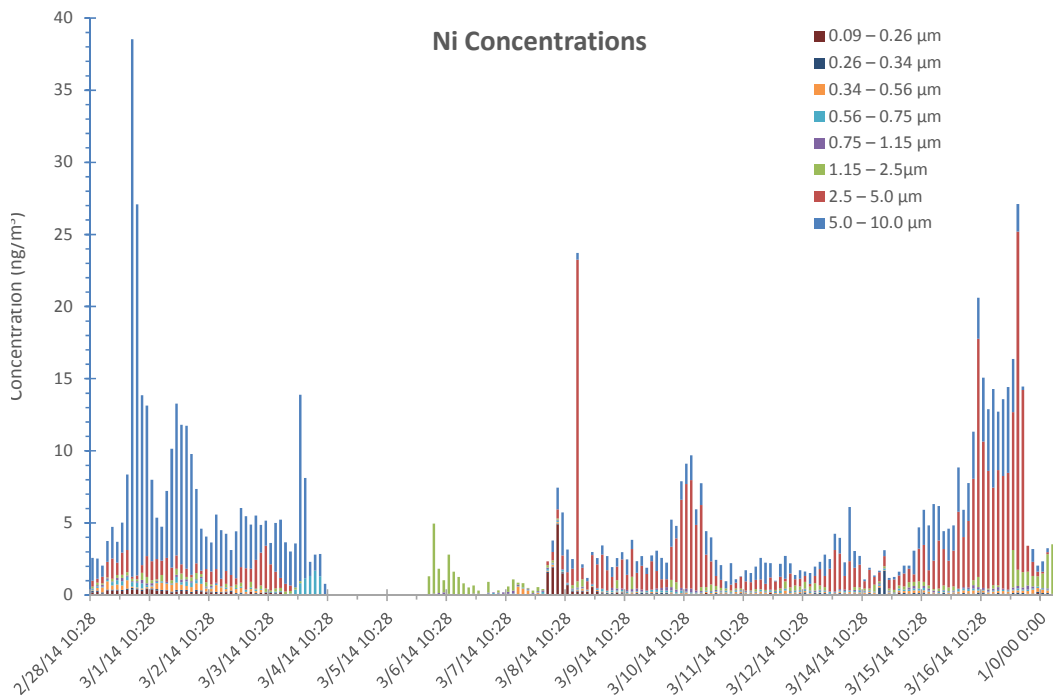
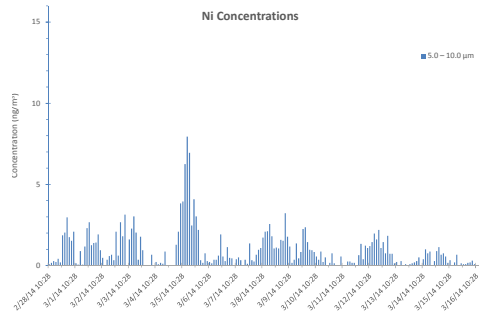
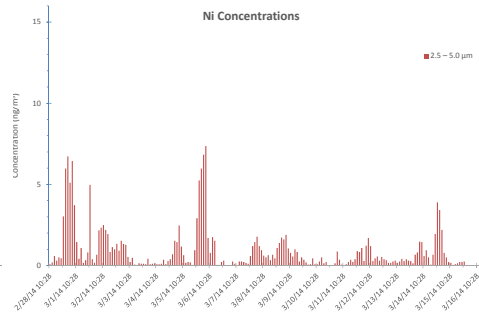


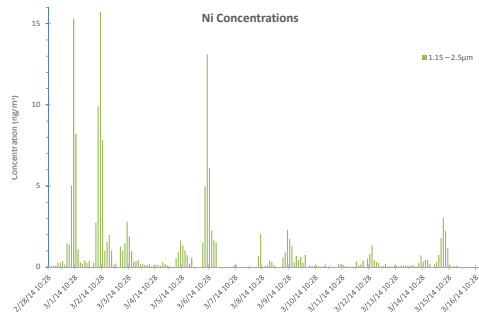
Fig. C-325 CaPh 32 DRUM: Ni mass all stages



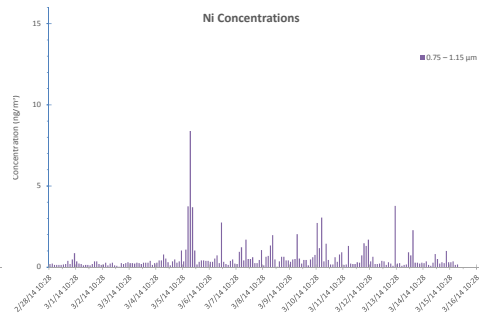
a) XRF stage 1 (5–10 μm) mass



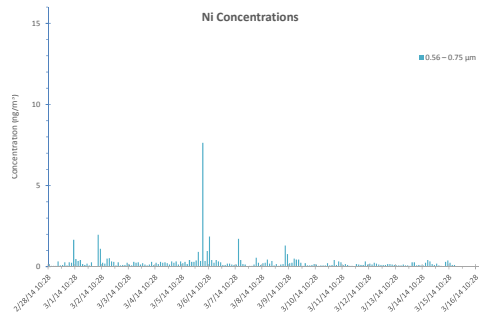
b) XRF stage 2 (2.5–5.0 μm) mass



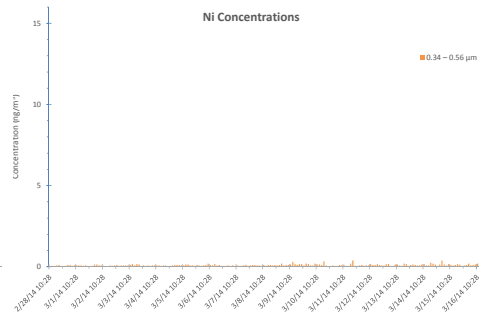
c) XRF stage 3 (1.15–2.5 μm) mass



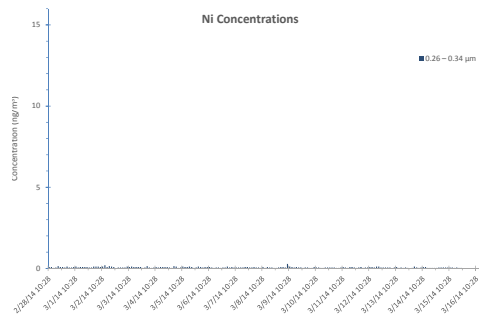
d) XRF stage 4 (0.75–1.15 μm) mass



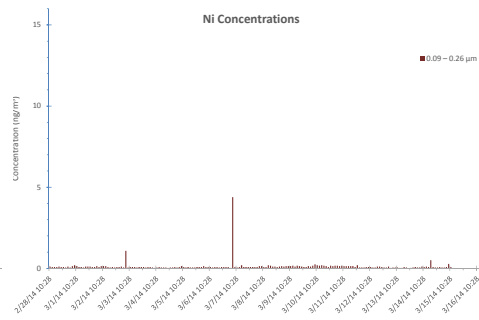
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.34–0.56 μm) mass

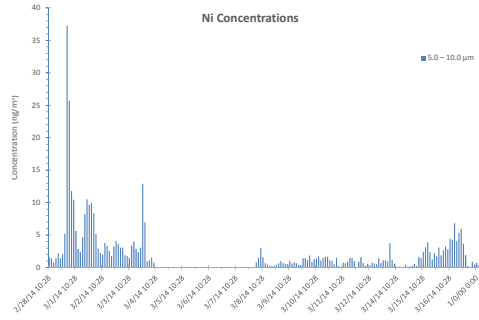


g) XRF stage 7 (0.26–0.34 μm) mass

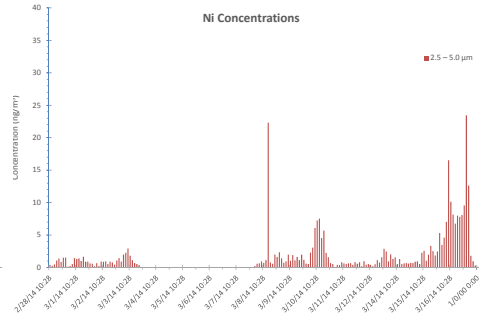


h) XRF stage 8 (0.09–0.26 μm) mass

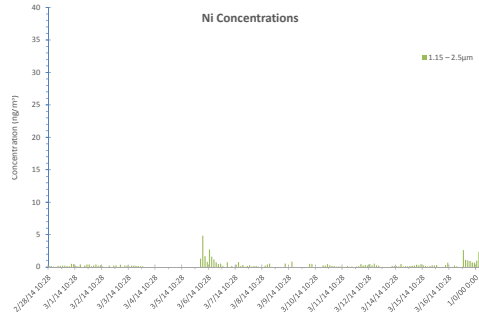
Fig. C-326 CaPh 34 DRUM: XRF mass Ni; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



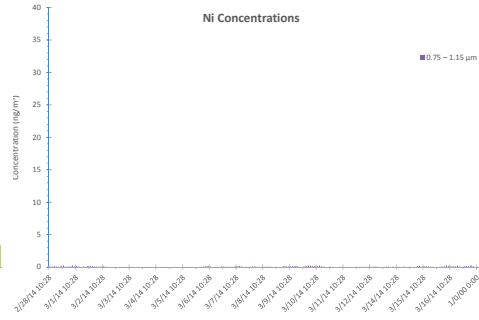
a) XRF stage 1 (5–10 μm) mass



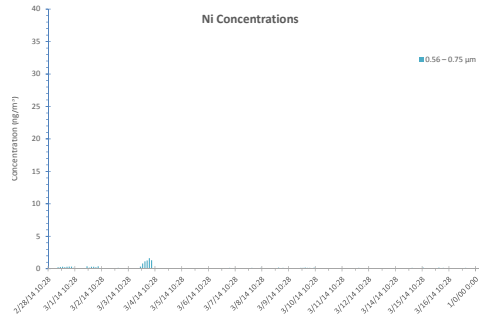
b) XRF stage 2 (2.5–5.0 μm) mass



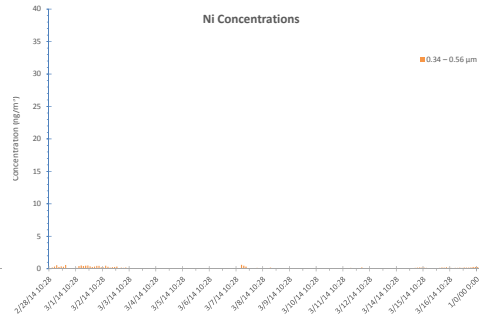
c) XRF stage 3 (1.15–2.5 μm) mass



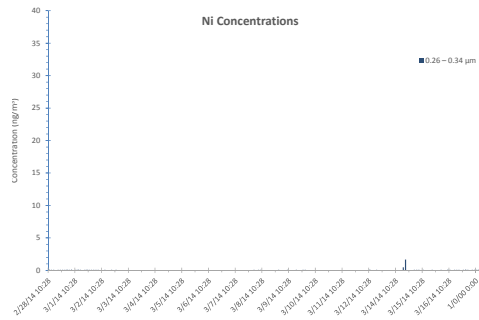
d) XRF stage 4 (0.75–1.15 μm) mass



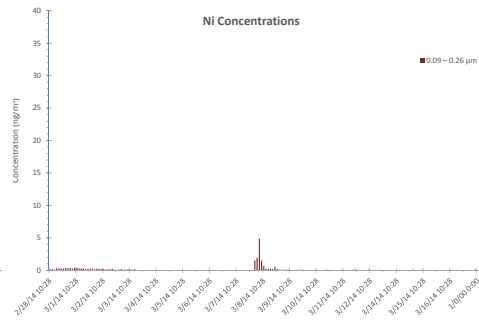
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-327 CaPh 32 DRUM: XRF mass Ni; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

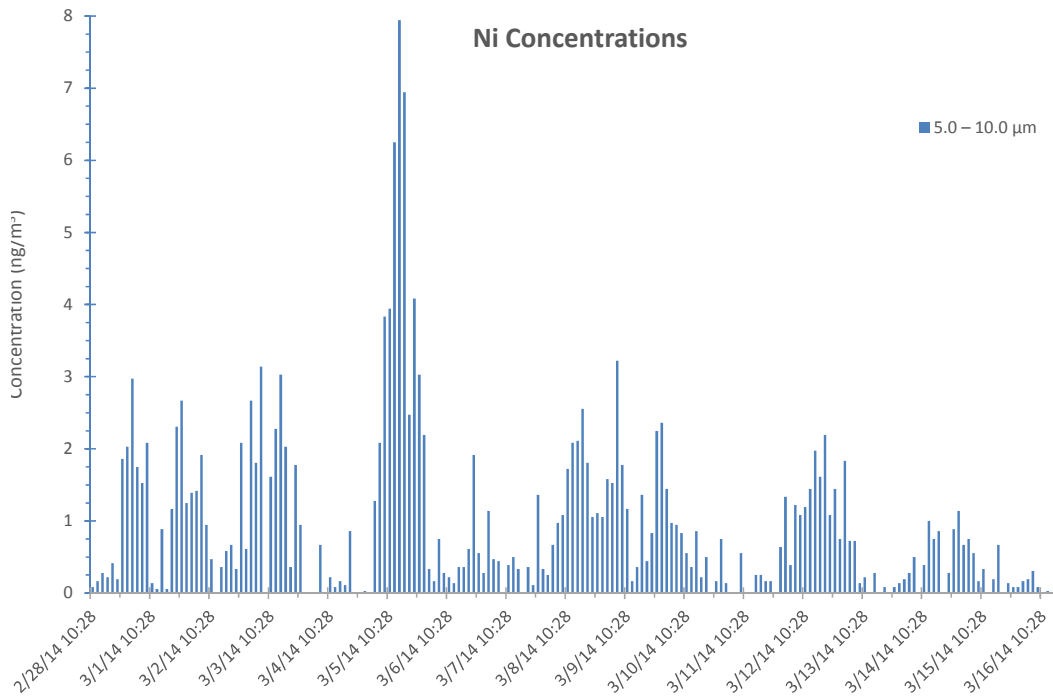


Fig. C-328 CaPh 34 DRUM: Ni mass stage 1

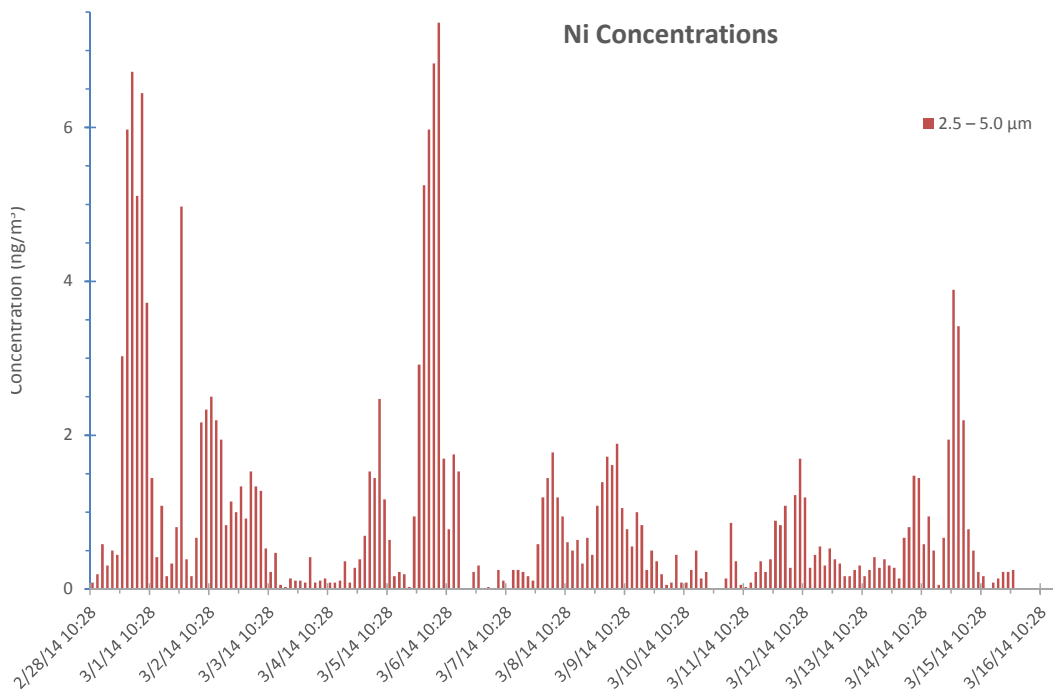


Fig. C-329 CaPh 34 DRUM: Ni mass stage 2

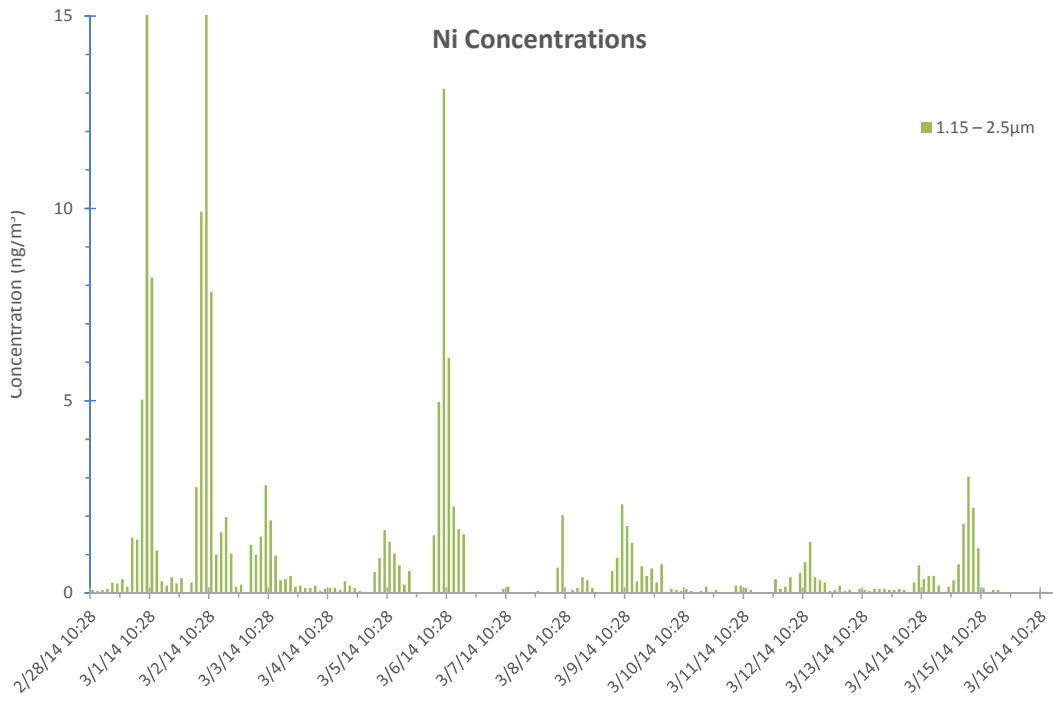


Fig. C-330 CaPh 34 DRUM: Ni mass stage 3

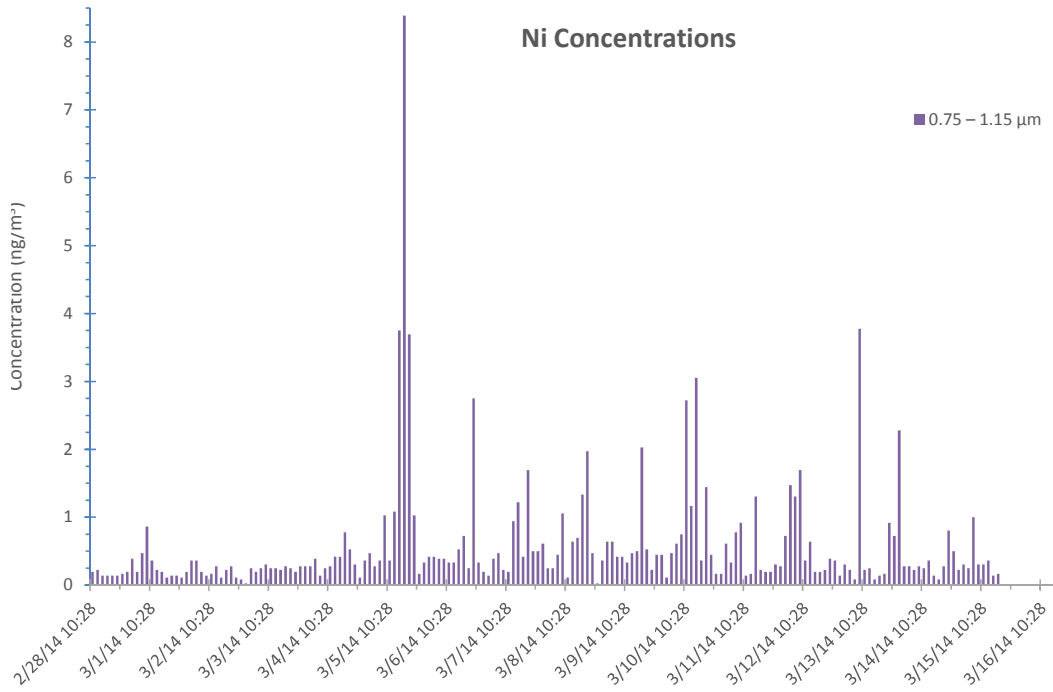


Fig. C-331 CaPh 34 DRUM: Ni mass stage 4

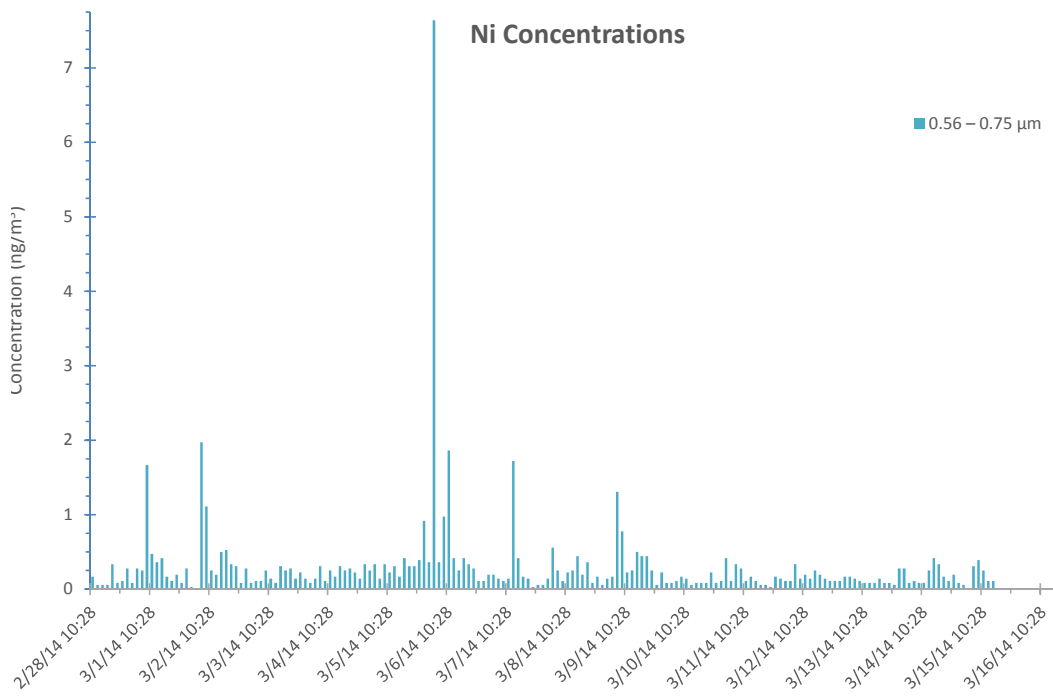


Fig. C-332 CaPh 34 DRUM: Ni mass stage 5

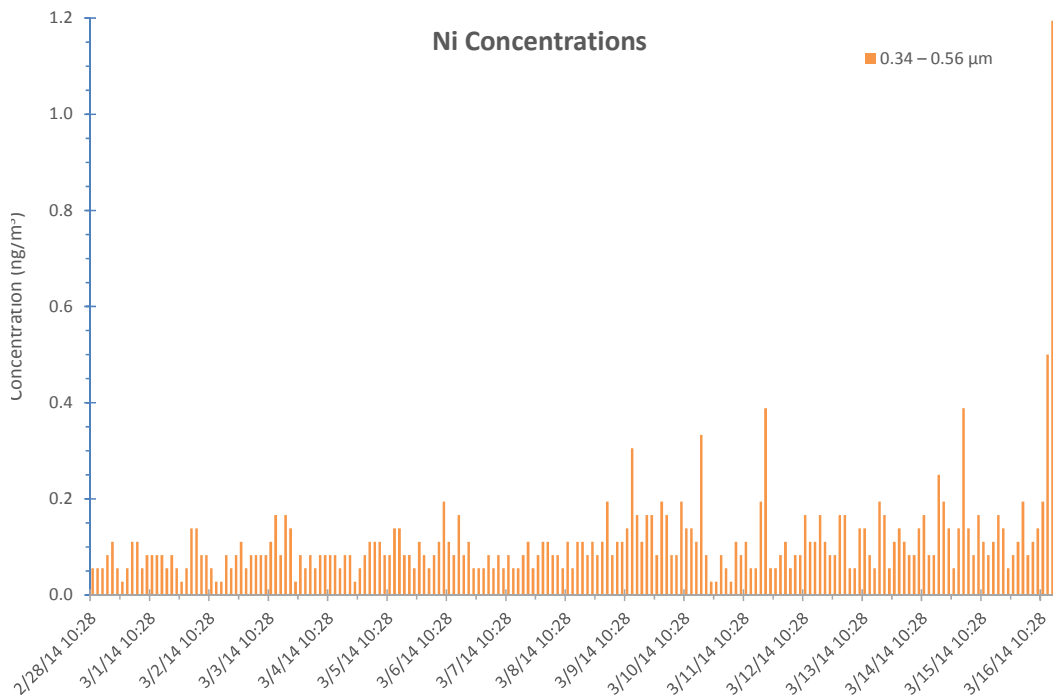


Fig. C-333 CaPh 34 DRUM: Ni mass stage 6

Approved for public release; distribution is unlimited.

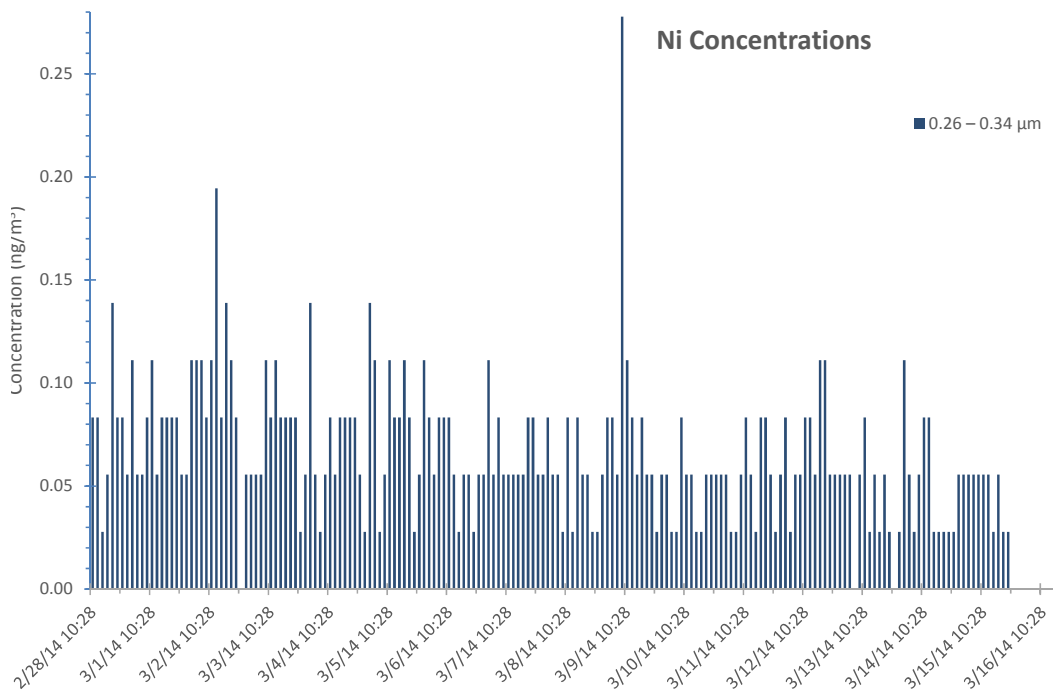


Fig. C-334 CaPh 34 DRUM: Ni mass stage 7

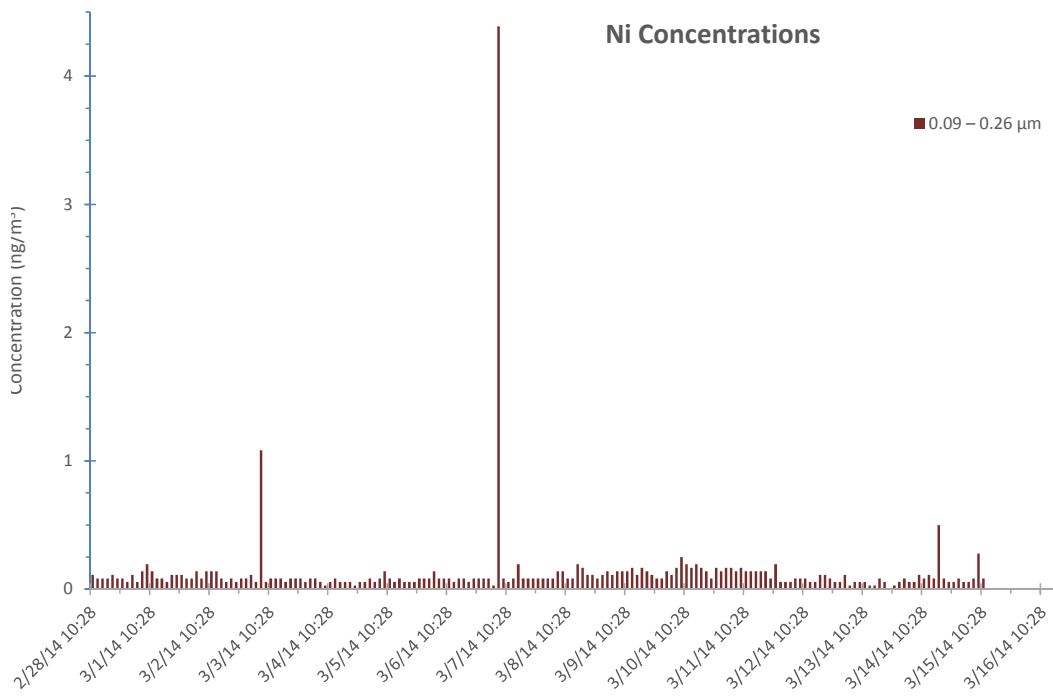


Fig. C-335 CaPh 34 DRUM: Ni mass stage 8

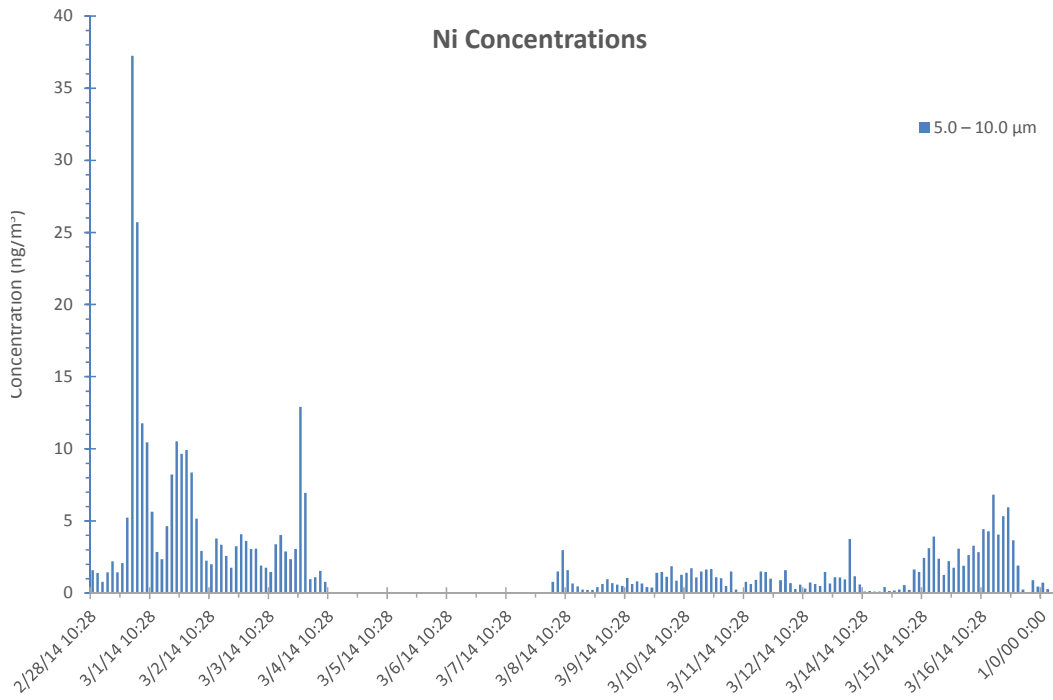


Fig. C-336 CaPh 32 DRUM: Ni mass stage 1

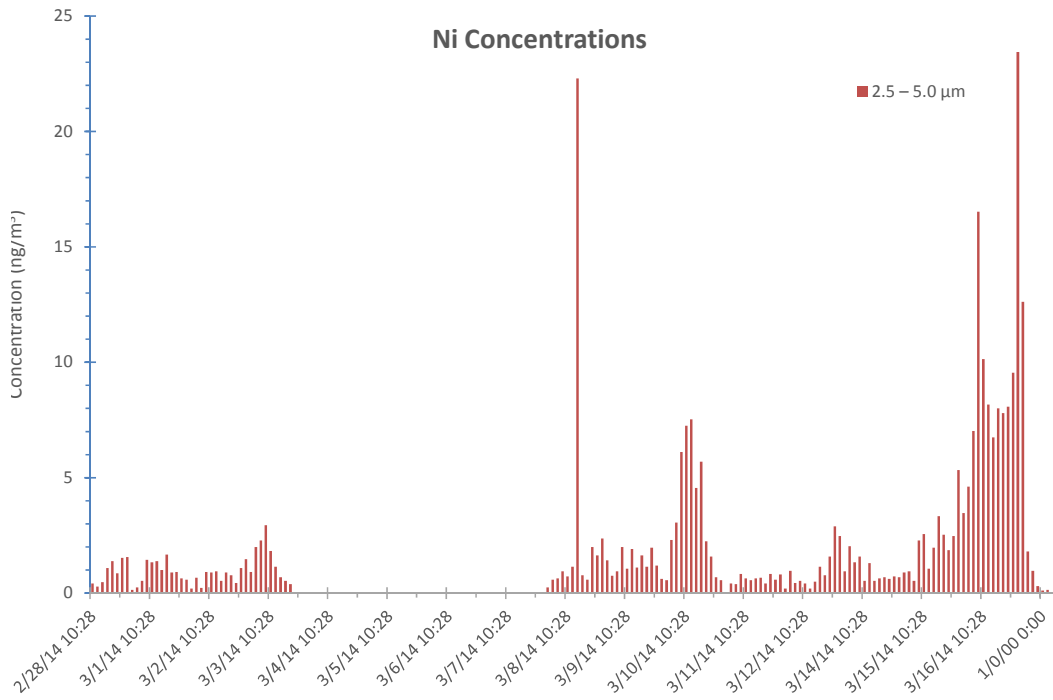


Fig. C-337 CaPh 32 DRUM: Ni mass stage 2

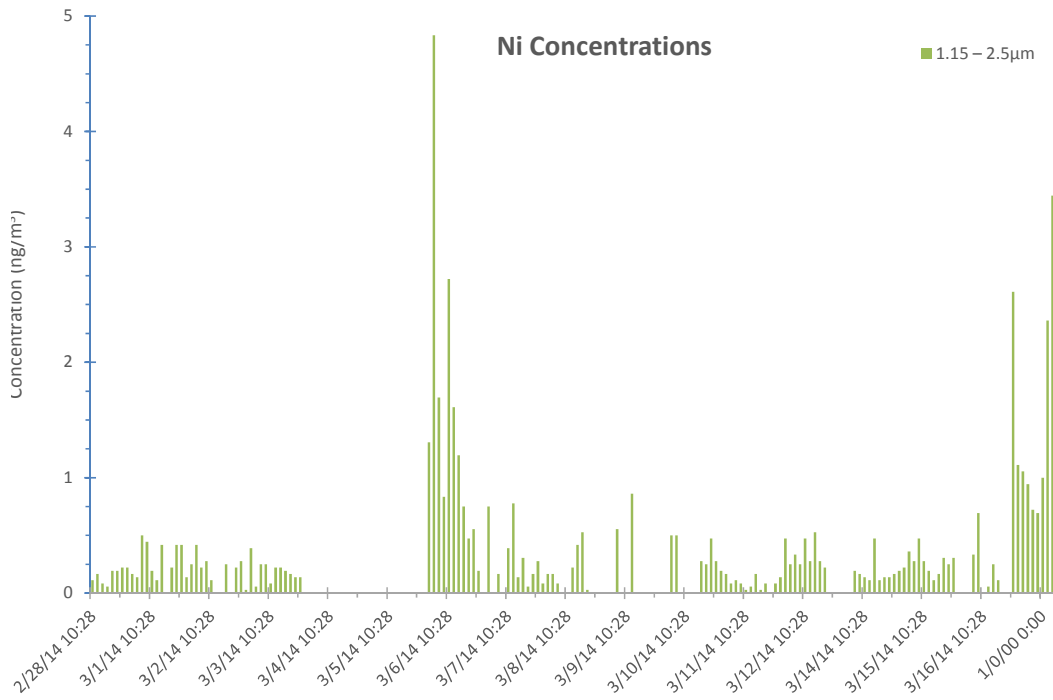


Fig. C-338 CaPh 32 DRUM: Ni mass stage 3

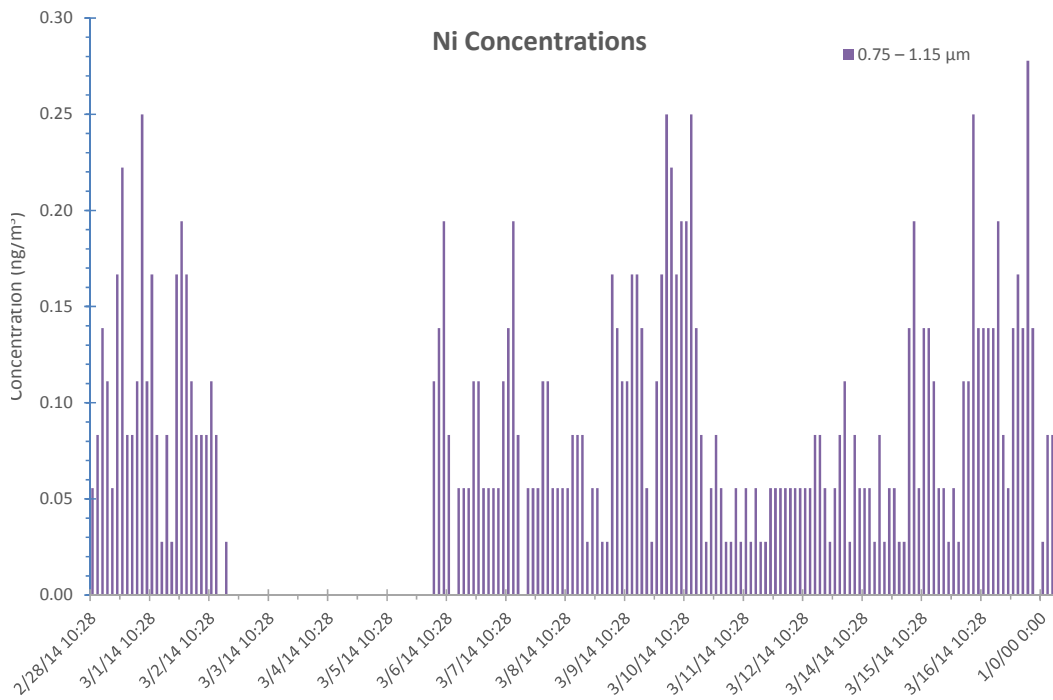


Fig. C-339 CaPh 32 DRUM: Ni mass stage 4

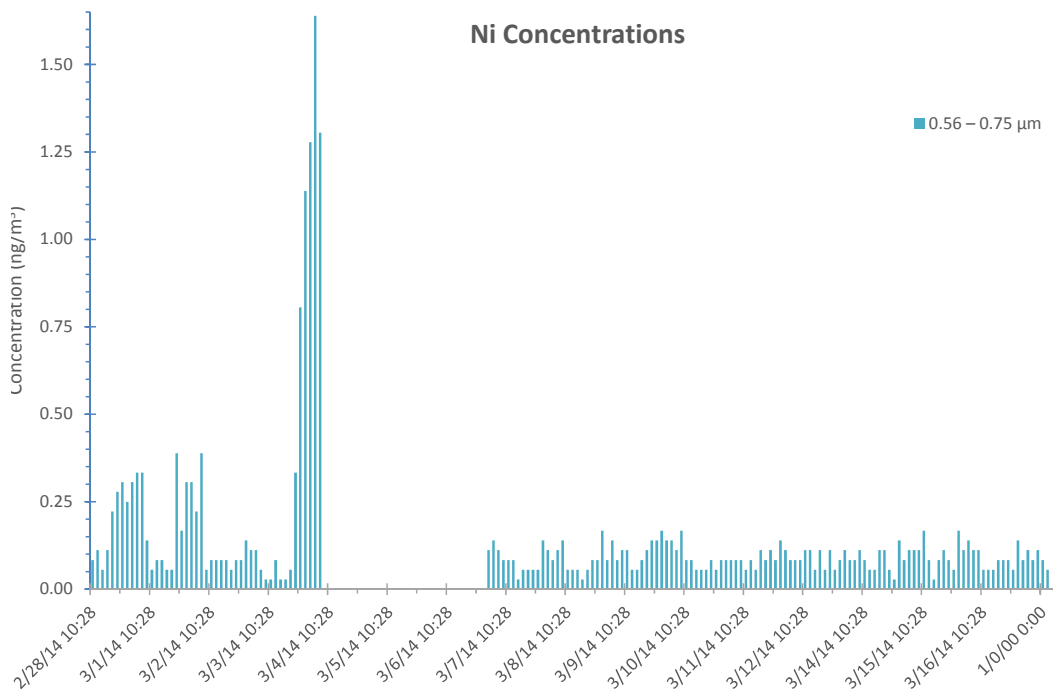


Fig. C-340 CaPh 32 DRUM: Ni mass stage 5

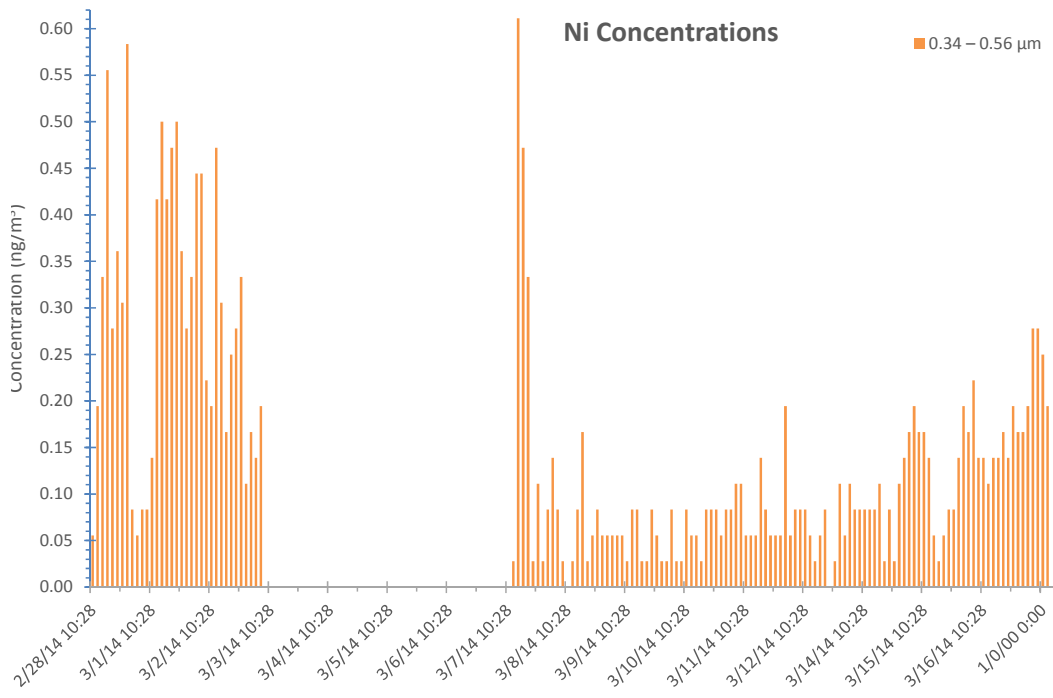


Fig. C-341 CaPh 32 DRUM: Ni mass stage 6

Approved for public release; distribution is unlimited.

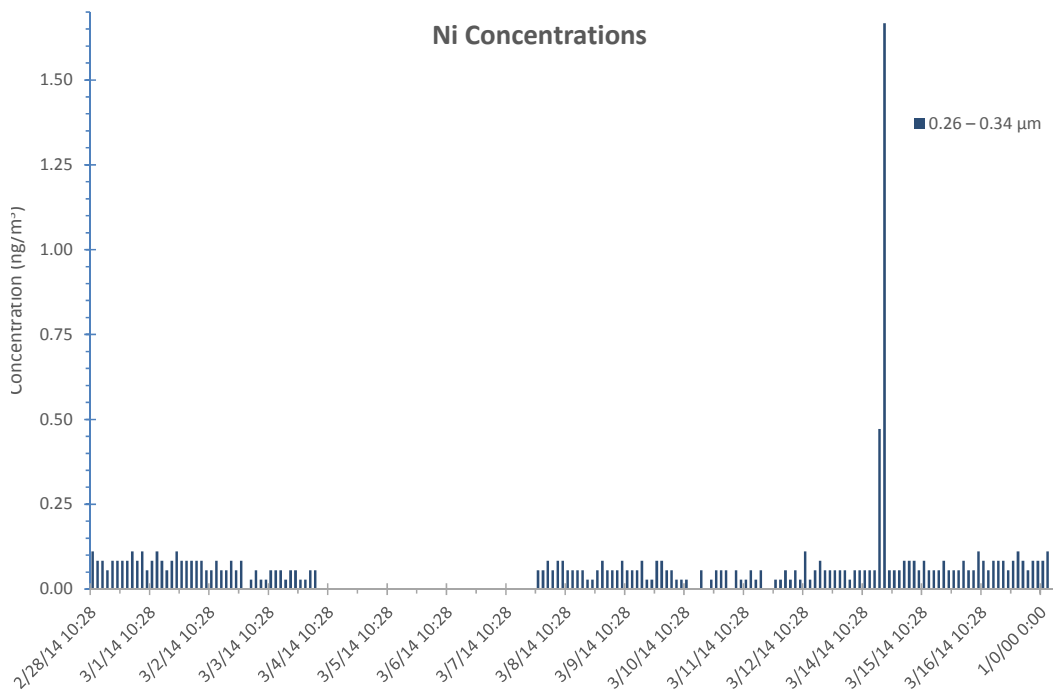


Fig. C-342 CaPh 32 DRUM: Ni mass stage 7

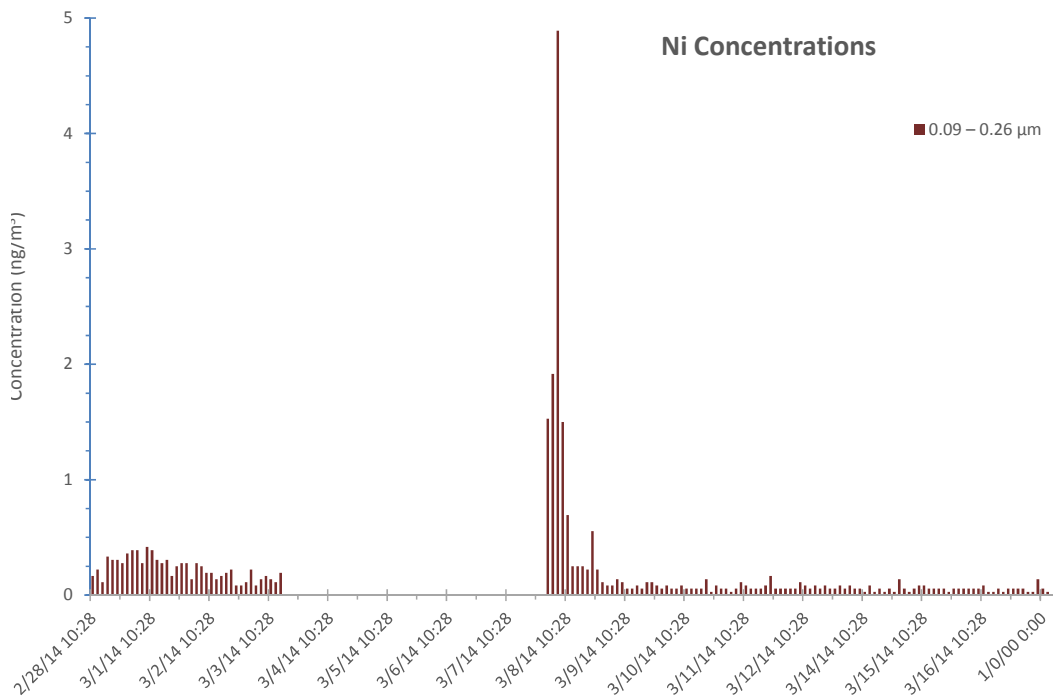


Fig. C-343 CaPh 32 DRUM: Ni mass stage 8

Approved for public release; distribution is unlimited.

C-4.17 Copper (Cu)

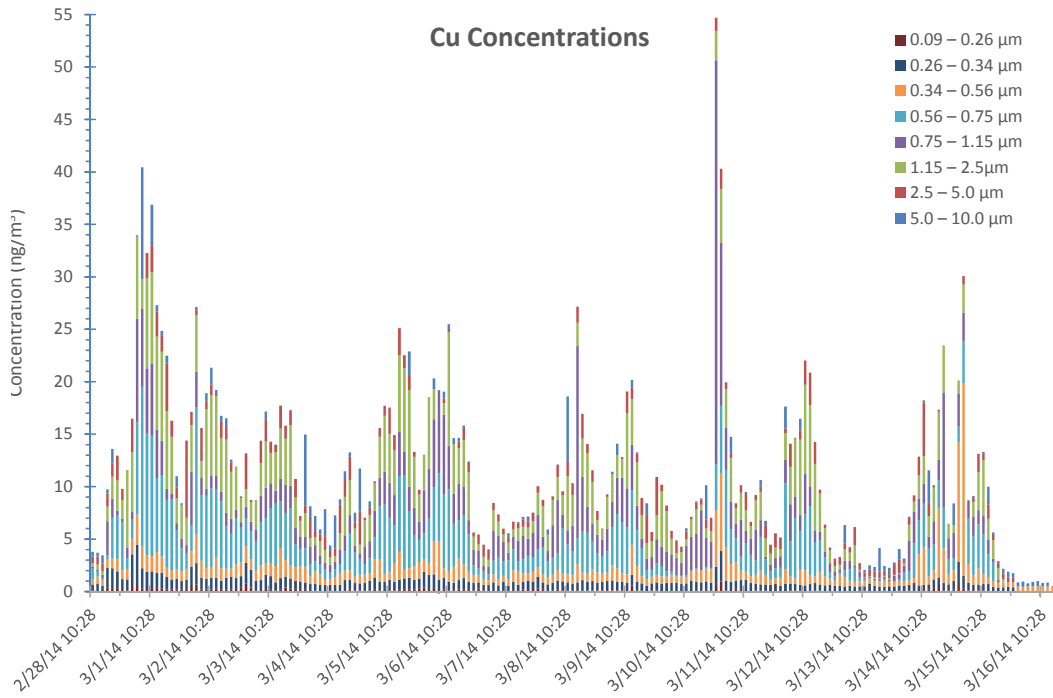


Fig. C-344 CaPh 34 DRUM: Cu mass all stages

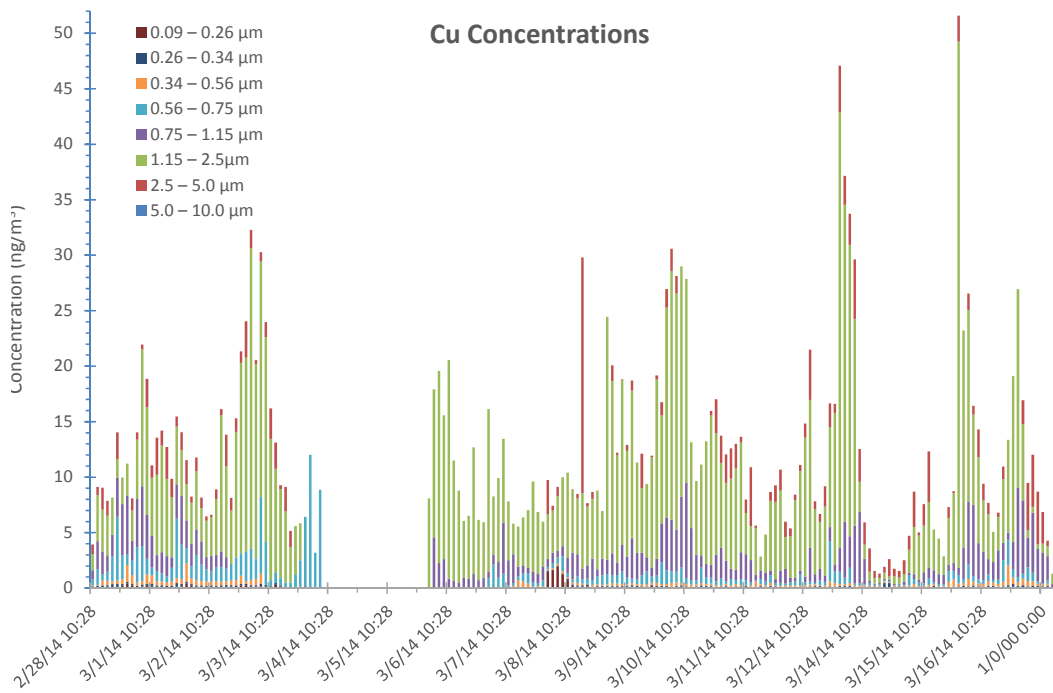
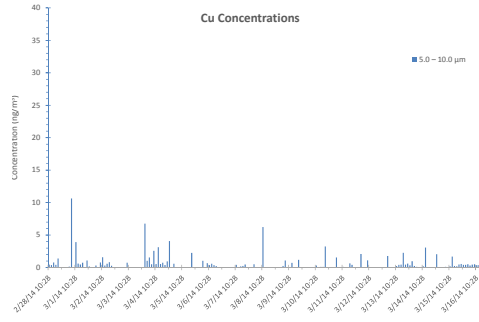
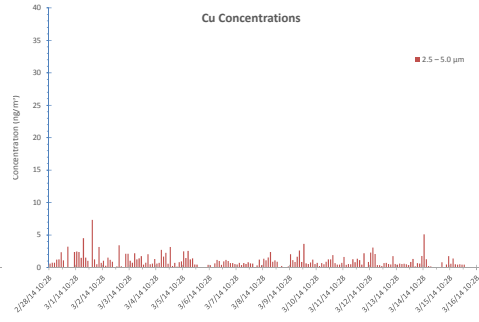


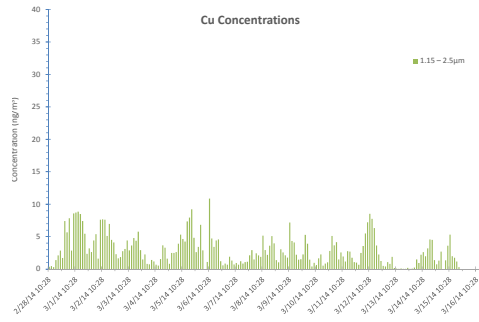
Fig. C-345 CaPh 32 DRUM: Cu mass all stages



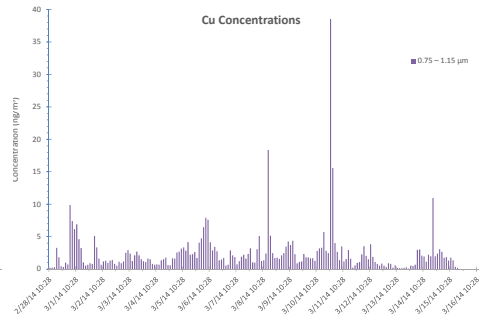
a) XRF stage 1 (5–10 μm) mass



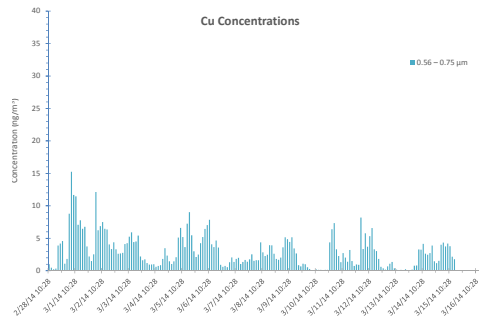
b) XRF stage 2 (2.5–5.0 μm) mass



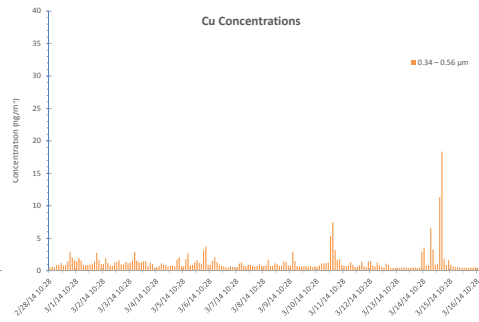
c) XRF stage 3 (1.15–2.5 μm) mass



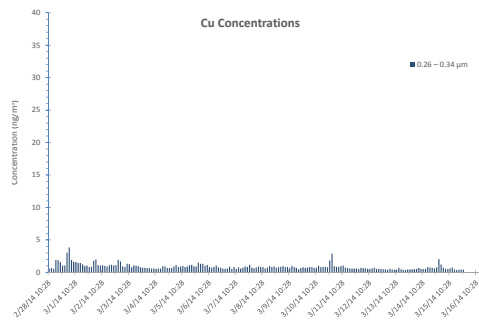
d) XRF stage 4 (0.75–1.15 μm) mass



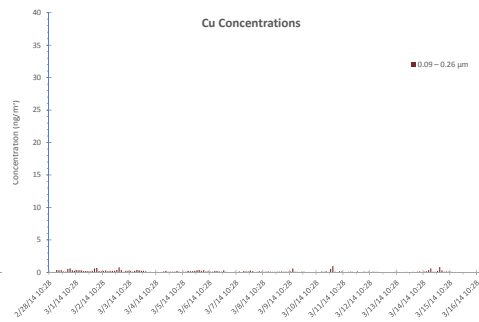
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.34–0.56 μm) mass

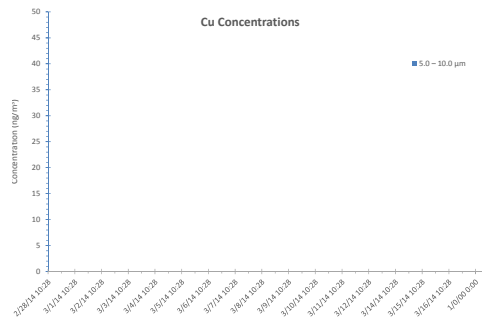


g) XRF stage 7 (0.26–0.34 μm) mass

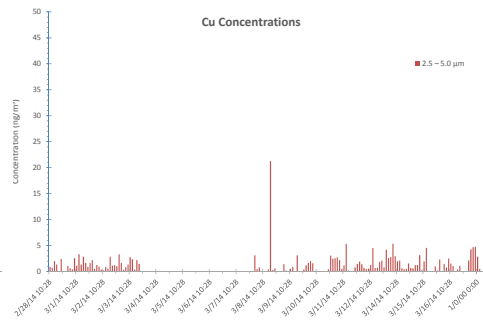


h) XRF stage 8 (0.09–0.26 μm) mass

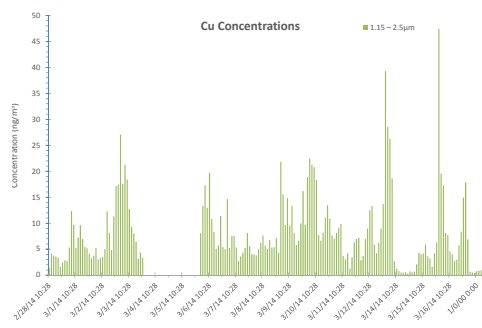
Fig. C-346 CaPh 34 DRUM: XRF mass Cu; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



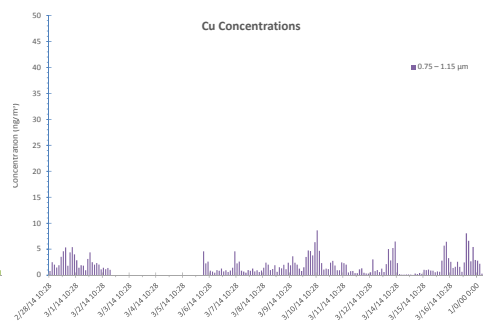
a) XRF stage 1 (5–10 μm) mass



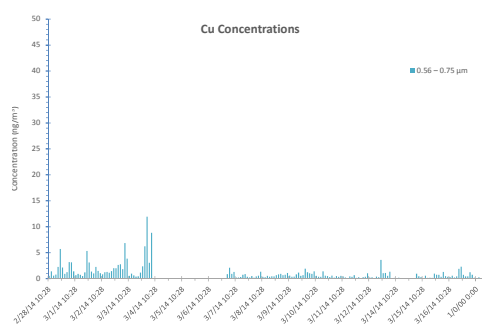
b) XRF stage 2 (2.5–5.0 μm) mass



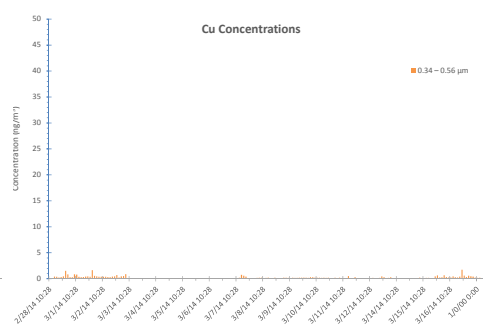
c) XRF stage 3 (1.15–2.5 μm) mass



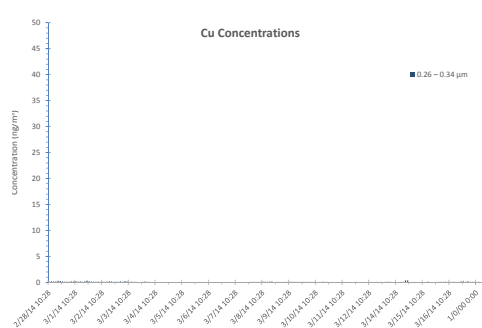
d) XRF stage 4 (0.75–1.15 μm) mass



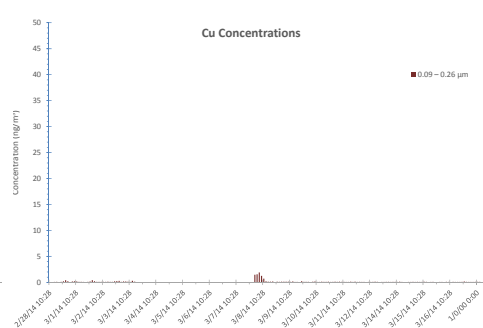
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-347 CaPh 32 DRUM: XRF mass Cu; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

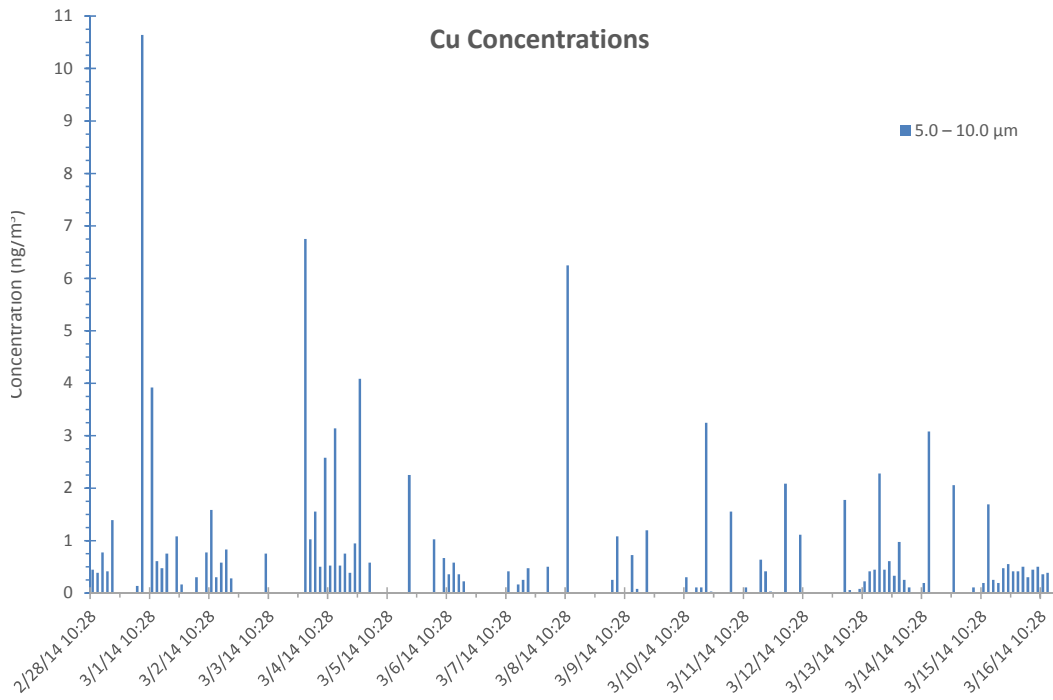


Fig. C-348 CaPh 34 DRUM: Cu mass stage 1

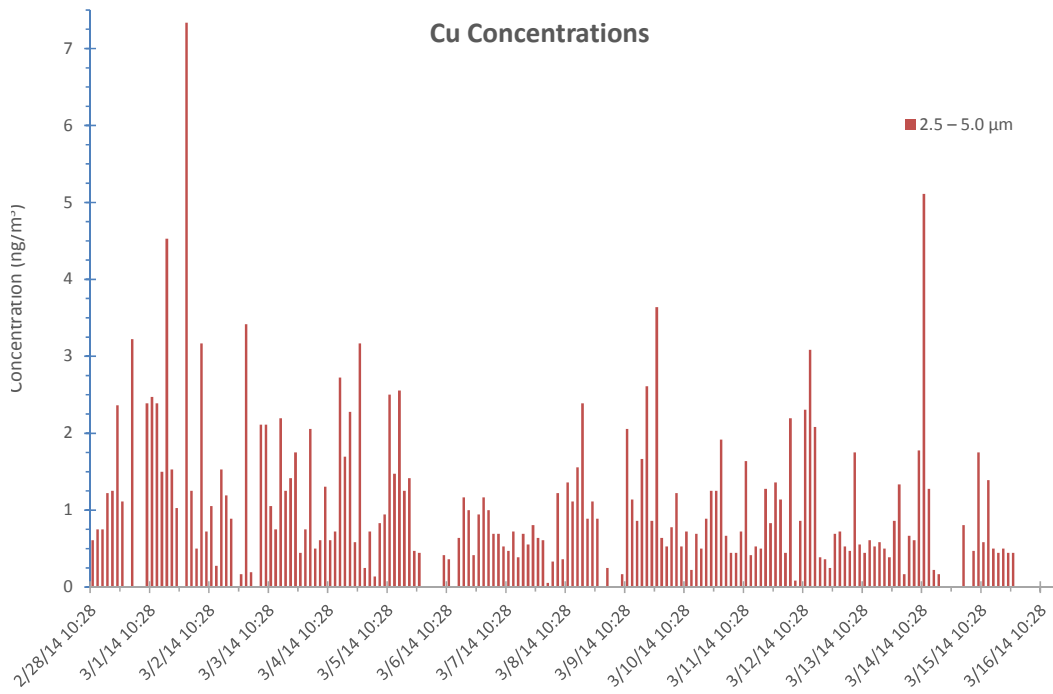


Fig. C-349 CaPh 34 DRUM: Cu mass stage 2

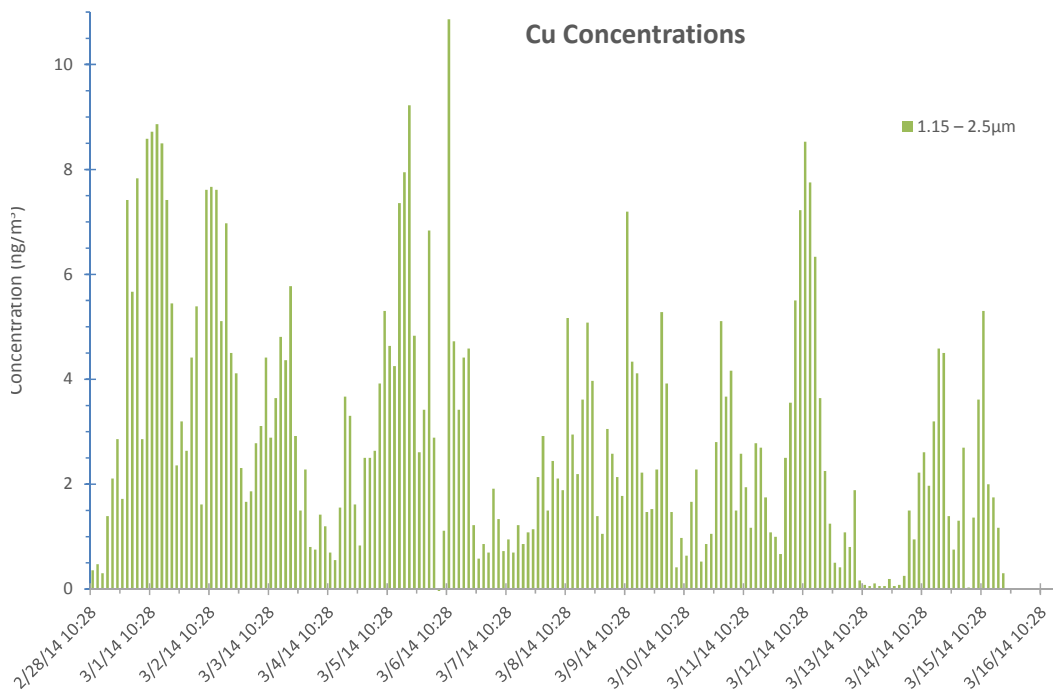


Fig. C-350 CaPh 34 DRUM: Cu mass stage 3

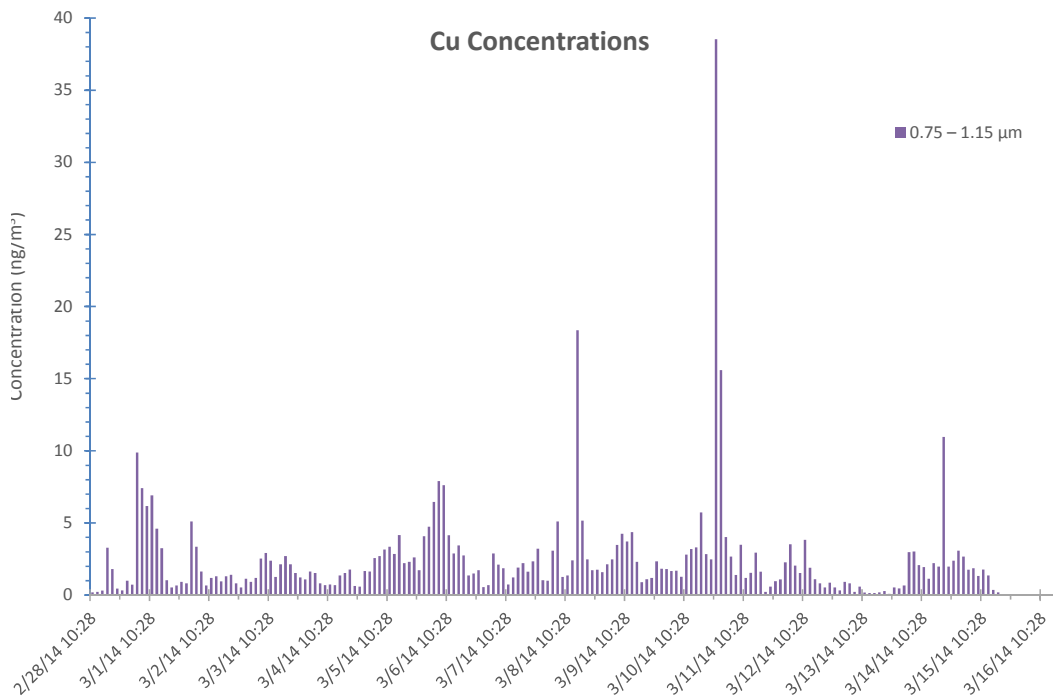


Fig. C-351 CaPh 34 DRUM: Cu mass stage 4

Approved for public release; distribution is unlimited.

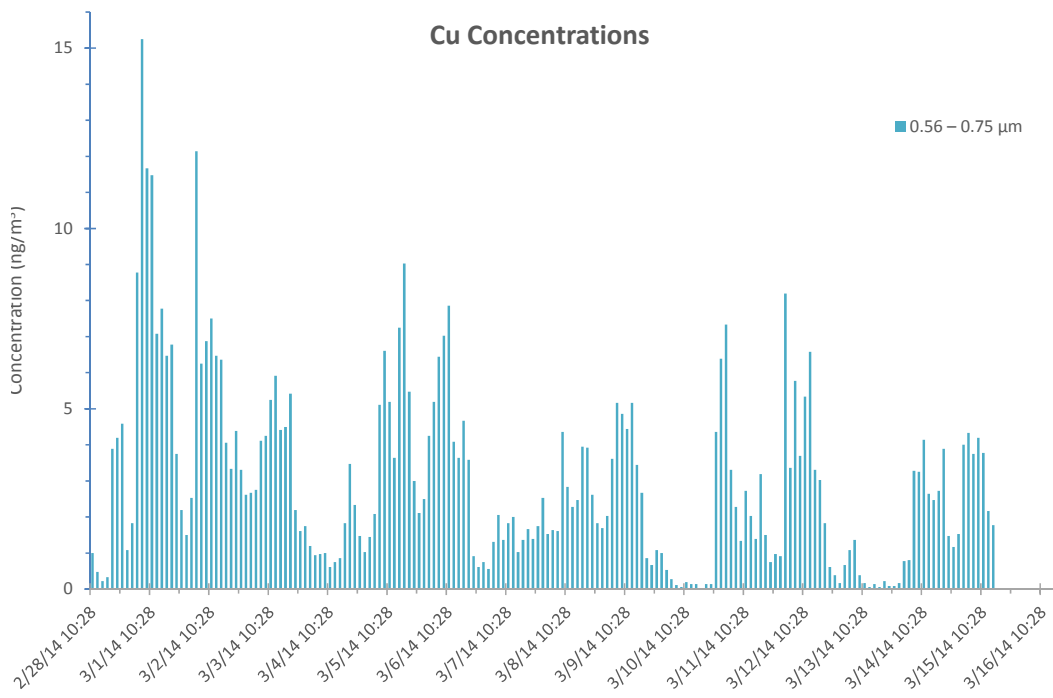


Fig. C-352 CaPh 34 DRUM: Cu mass stage 5

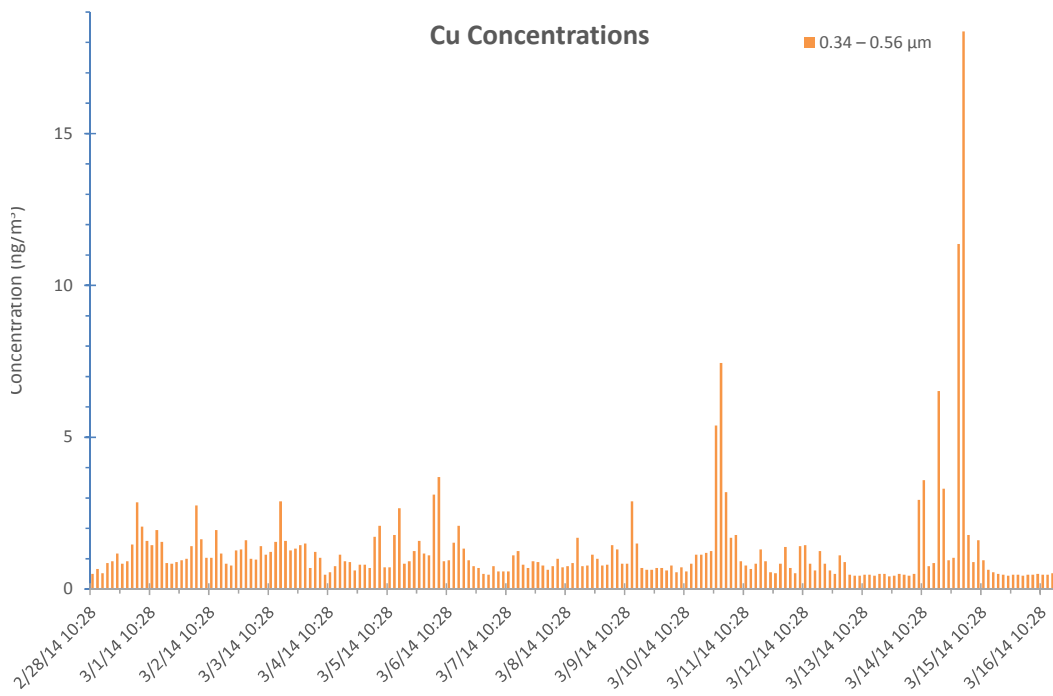


Fig. C-353 CaPh 34 DRUM: Cu mass stage 6

Approved for public release; distribution is unlimited.

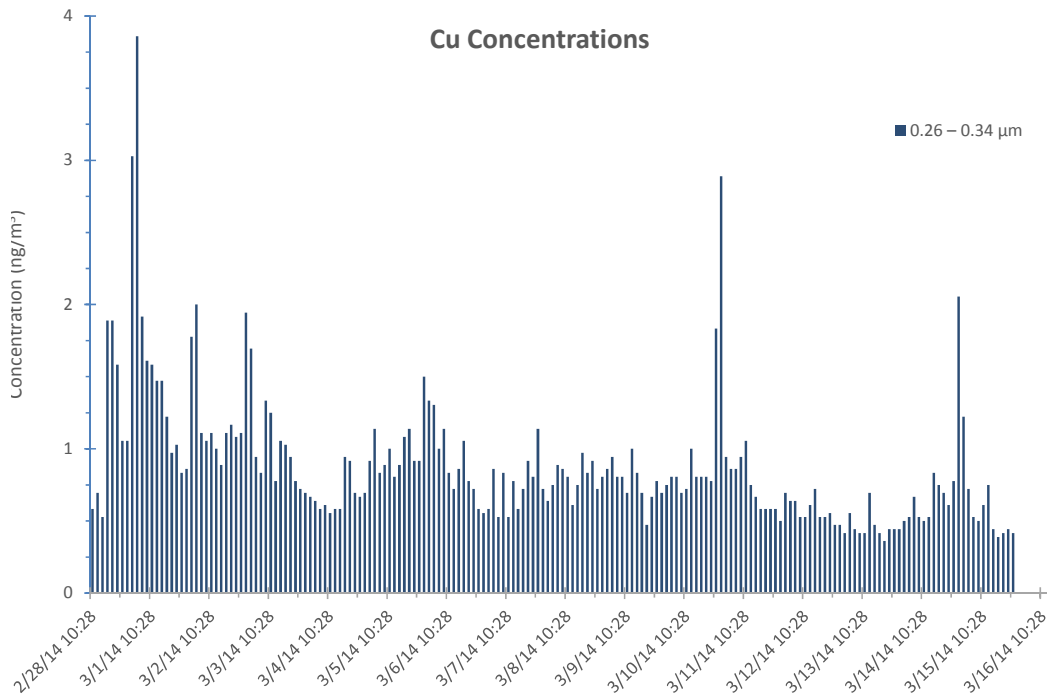


Fig. C-354 CaPh 34 DRUM: Cu mass stage 7

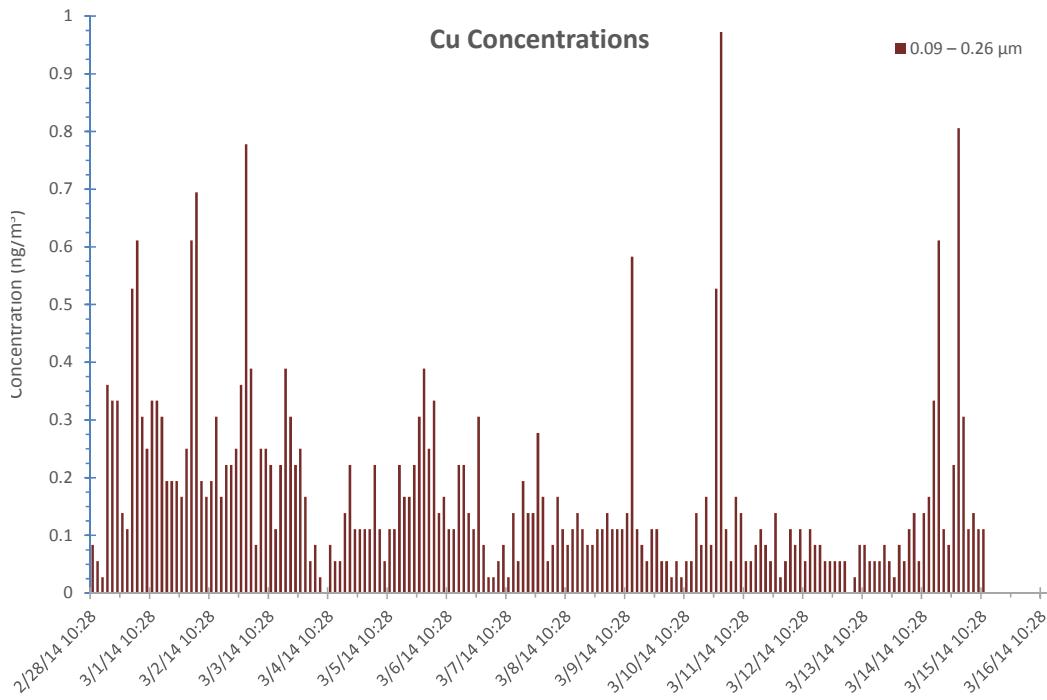


Fig. C-355 CaPh 34 DRUM: Cu mass stage 8

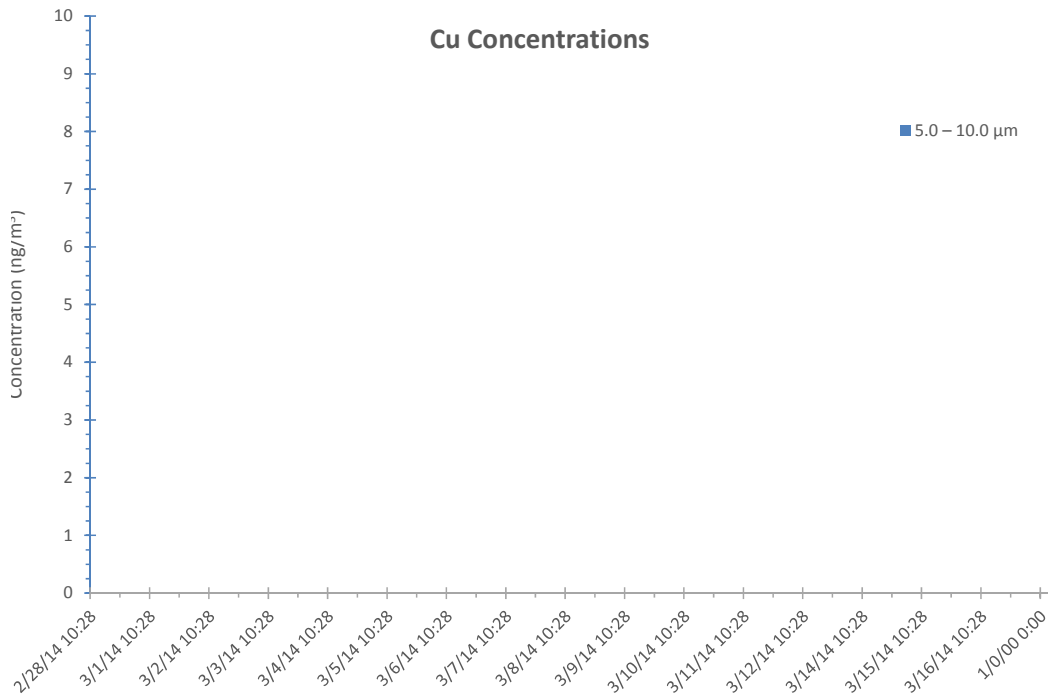


Fig. C-356 CaPh 32 DRUM: Cu mass stage 1

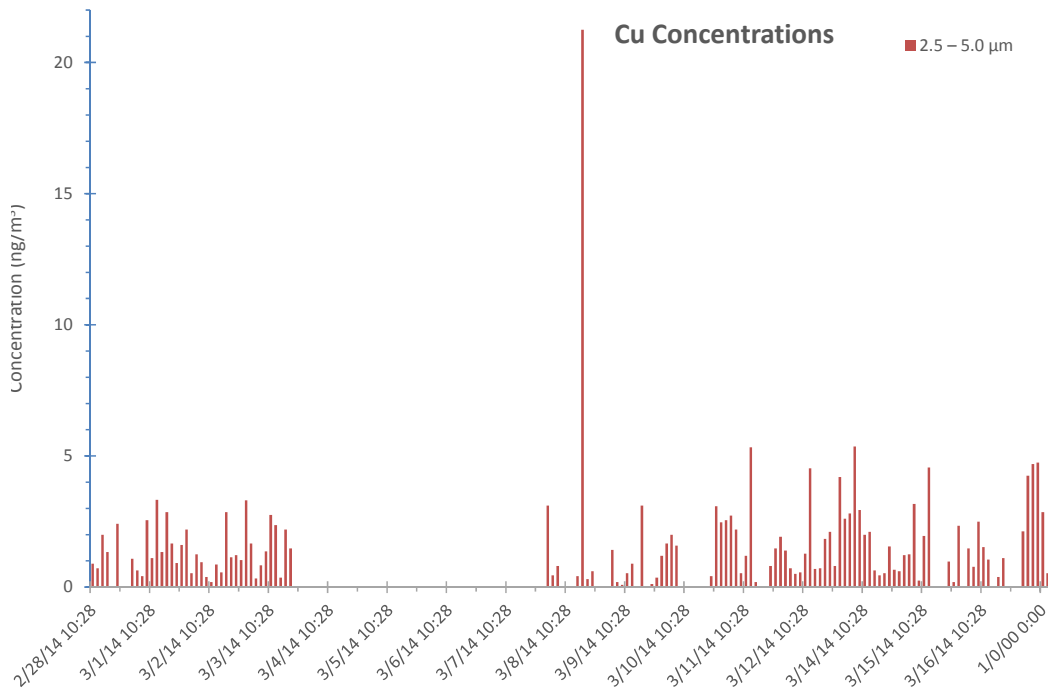


Fig. C-357 CaPh 32 DRUM: Cu mass stage 2

Approved for public release; distribution is unlimited.

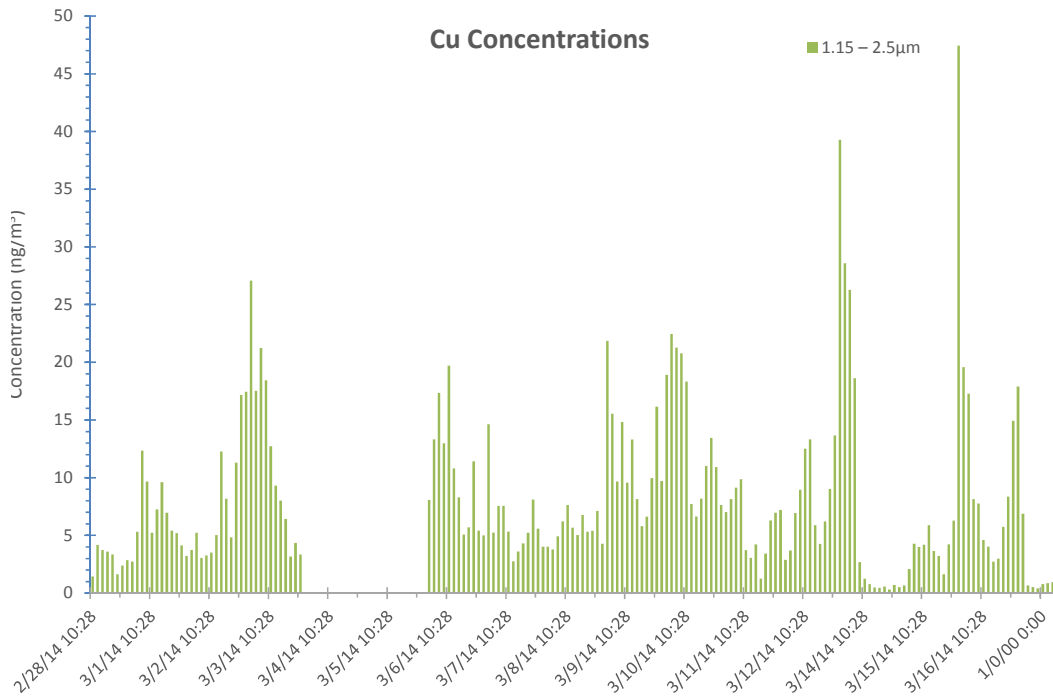


Fig. C-358 CaPh 32 DRUM: Cu mass stage 3

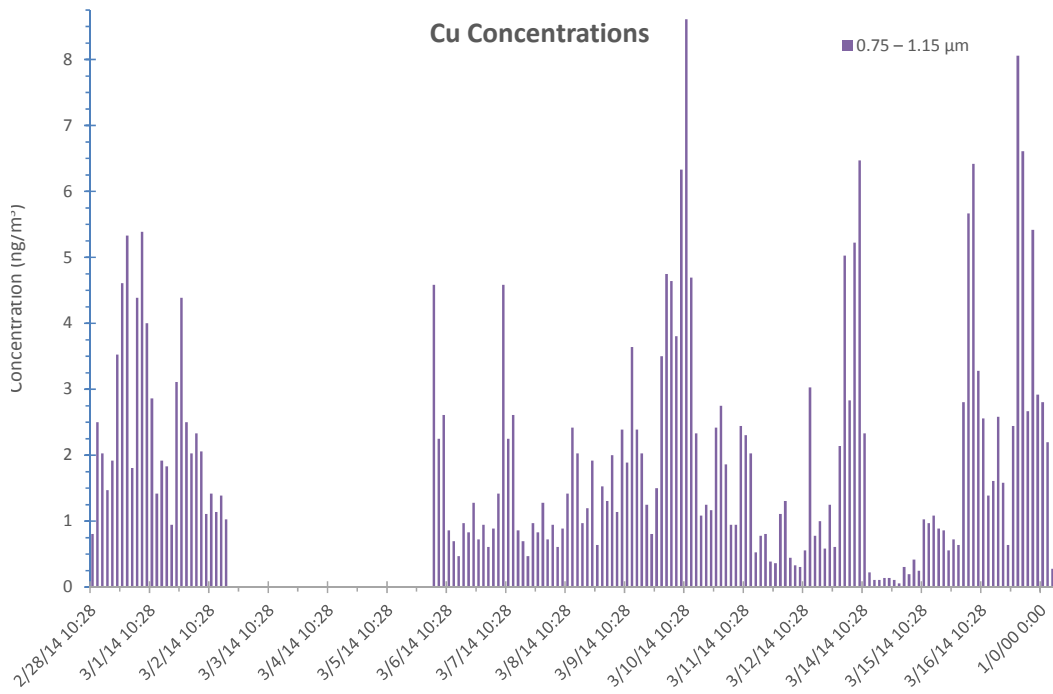


Fig. C-359 CaPh 32 DRUM: Cu mass stage 4

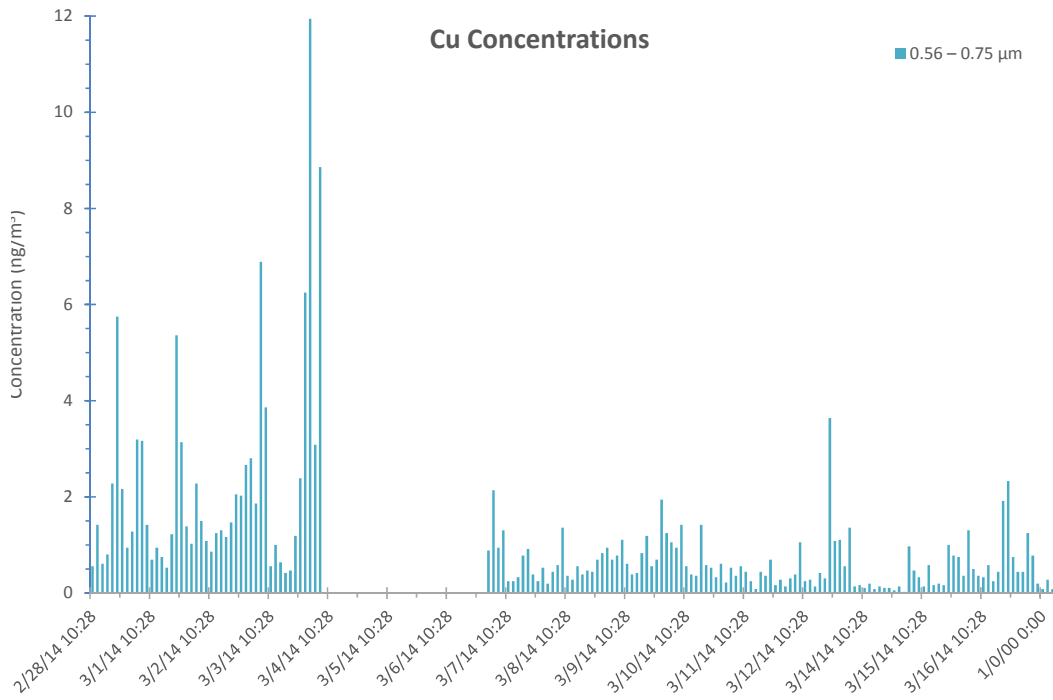


Fig. C-360 CaPh 32 DRUM: Cu mass stage 5

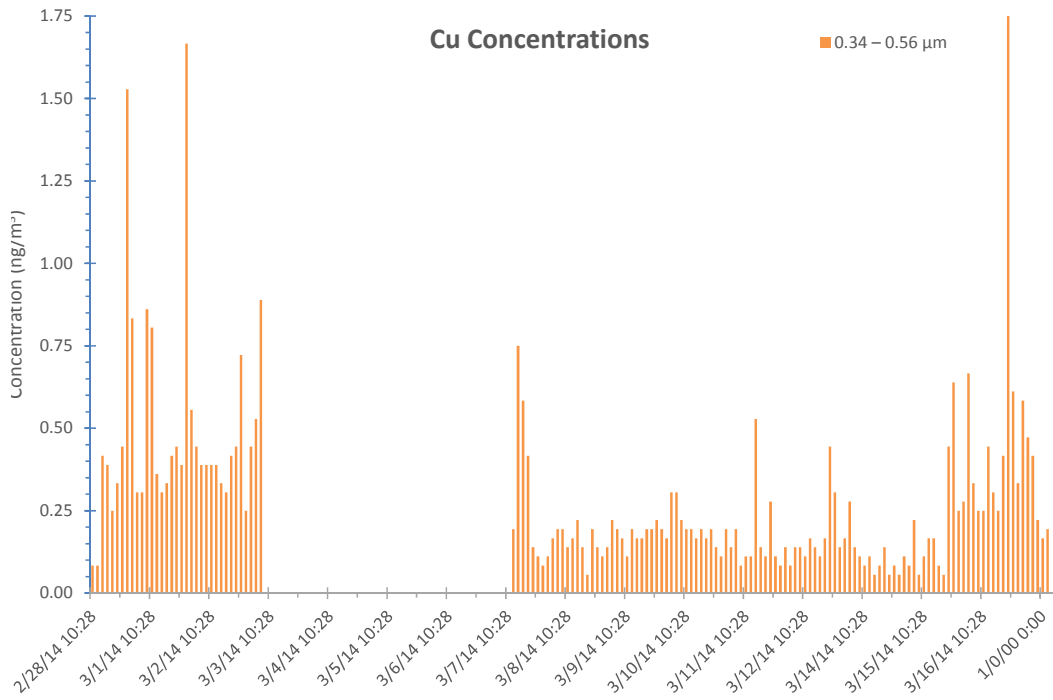


Fig. C-361 CaPh 32 DRUM: Cu mass stage 6

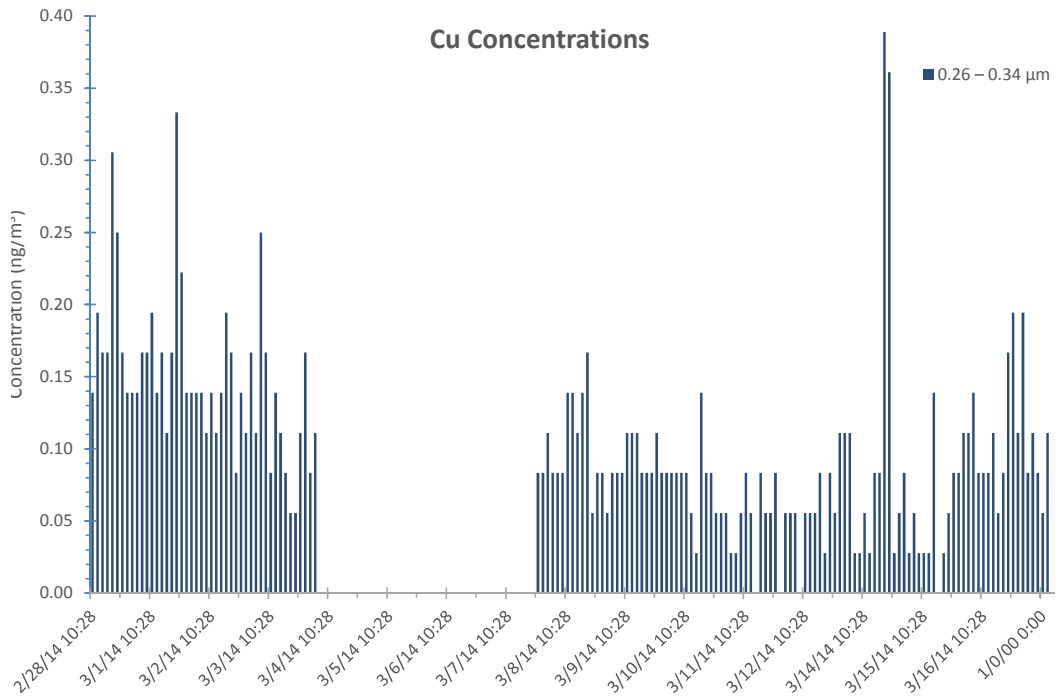


Fig. C-362 CaPh 32 DRUM: Cu mass stage 7

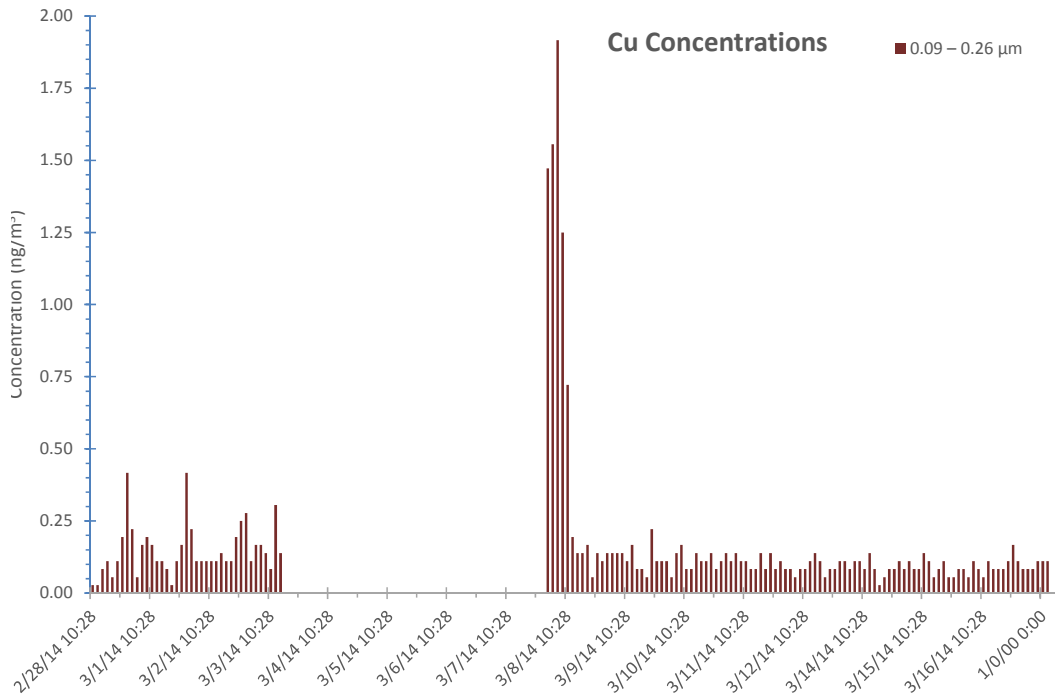


Fig. C-363 CaPh 32 DRUM: Cu mass stage 8

Approved for public release; distribution is unlimited.

C-4.18 Zinc (Zn)

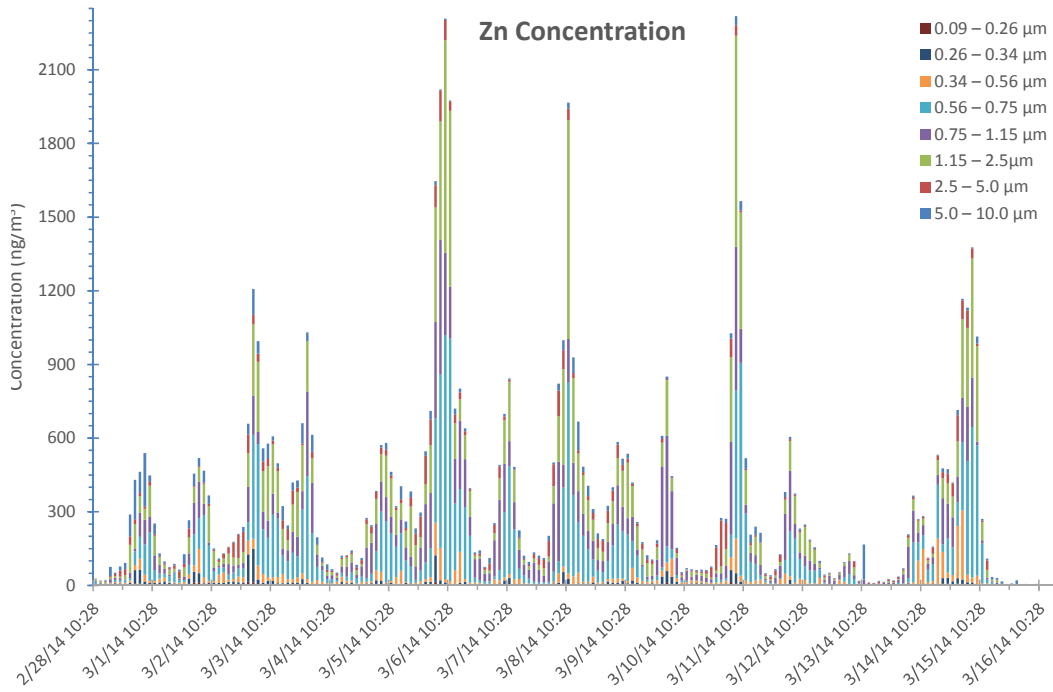


Fig. C-364 CaPh 34 DRUM: Zn mass all stages

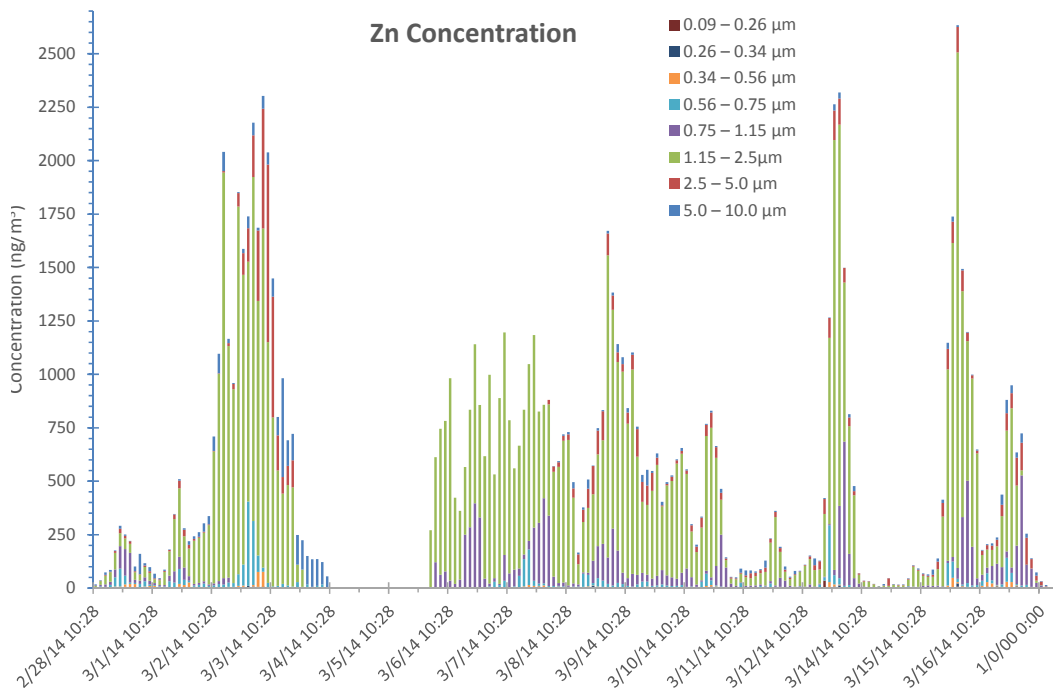
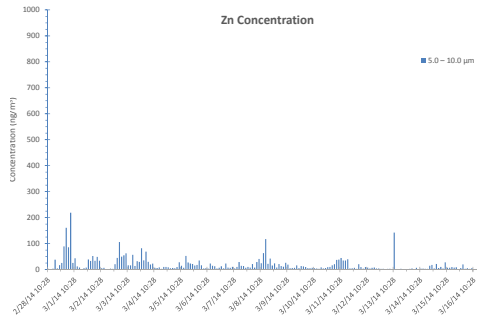
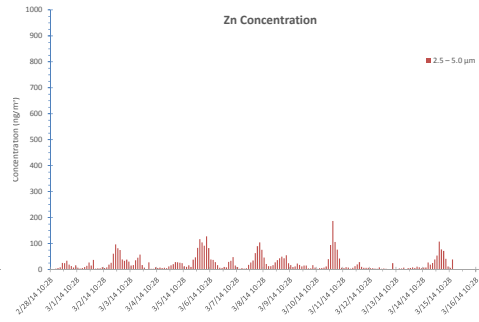


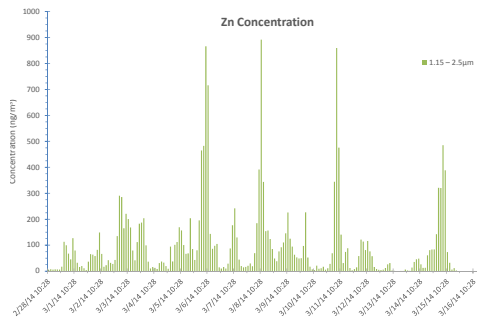
Fig. C-365 CaPh 32 DRUM: Zn mass all stages



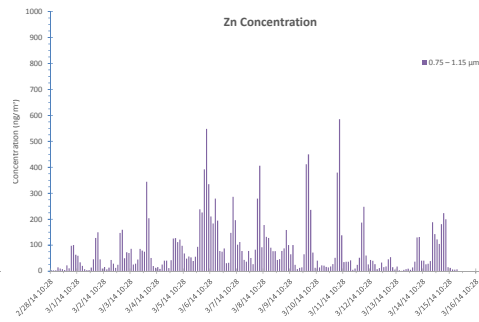
a) XRF stage 1 (5–10 μm) mass



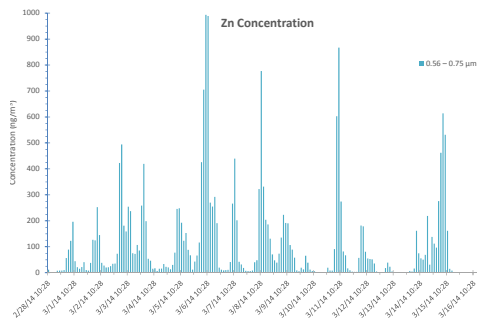
b) XRF stage 2 (2.5–5.0 μm) mass



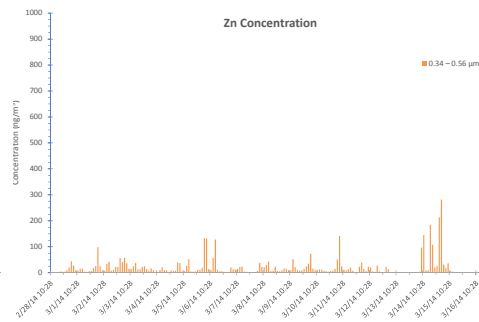
c) XRF stage 3 (1.15–2.5 μm) mass



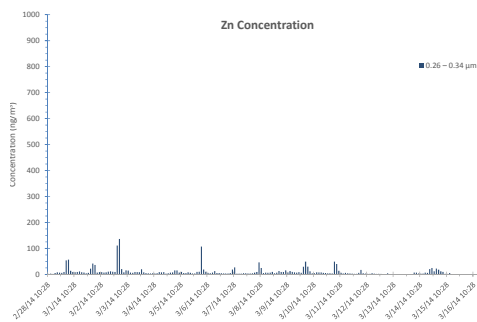
d) XRF stage 4 (0.75–1.15 μm) mass



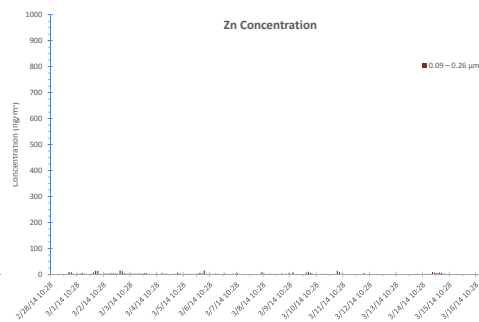
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.34–0.56 μm) mass

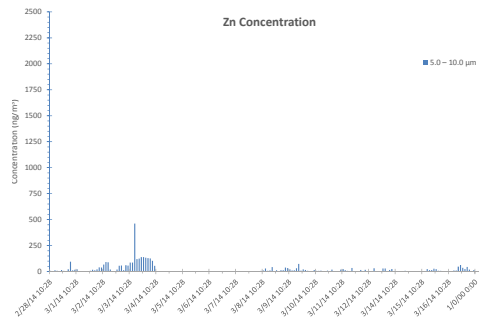


g) XRF stage 7 (0.26–0.34 μm) mass

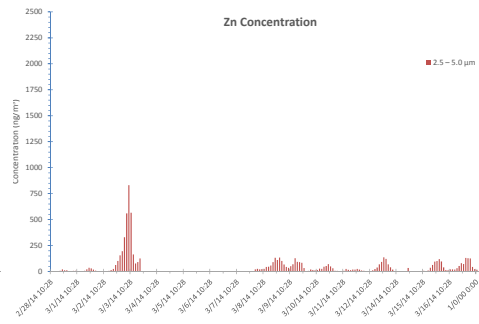


h) XRF stage 8 (0.09–0.26 μm) mass

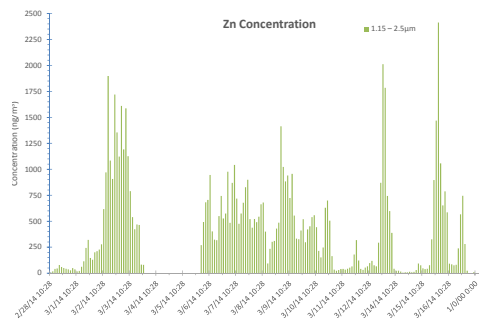
Fig. C-366 CaPh 34 DRUM: XRF mass Zn; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



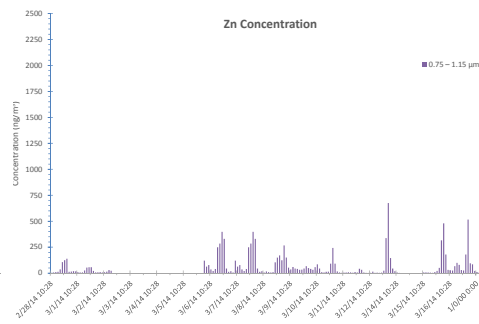
a) XRF stage 1 (5–10 μm) mass



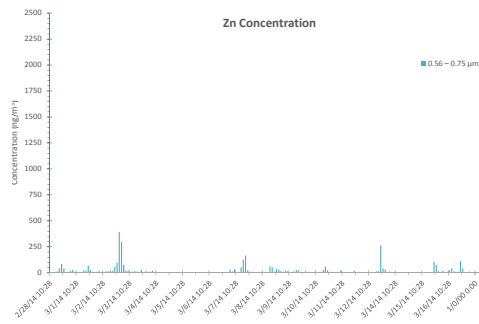
b) XRF stage 2 (2.5–5.0 μm) mass



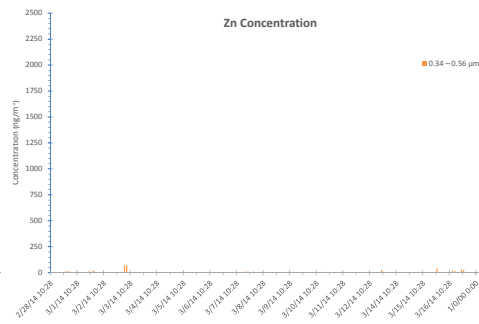
c) XRF stage 3 (1.15–2.5 μm) mass



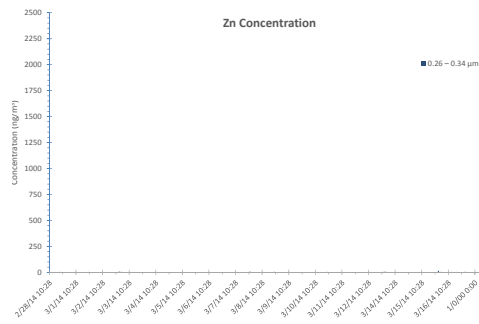
d) XRF stage 4 (0.75–1.15 μm) mass



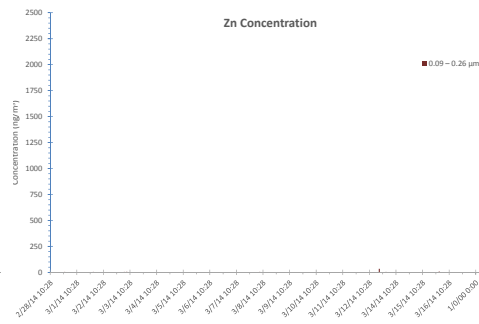
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-367 CaPh 32 DRUM: XRF mass Zn; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

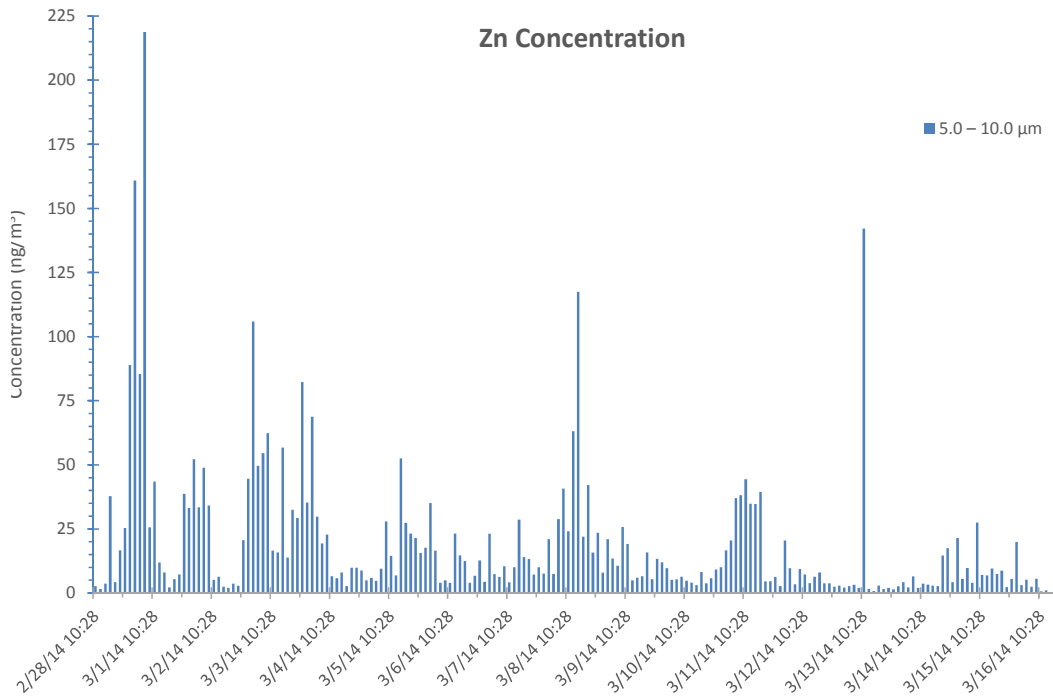


Fig. C-368 CaPh 34 DRUM: Zn mass stage 1

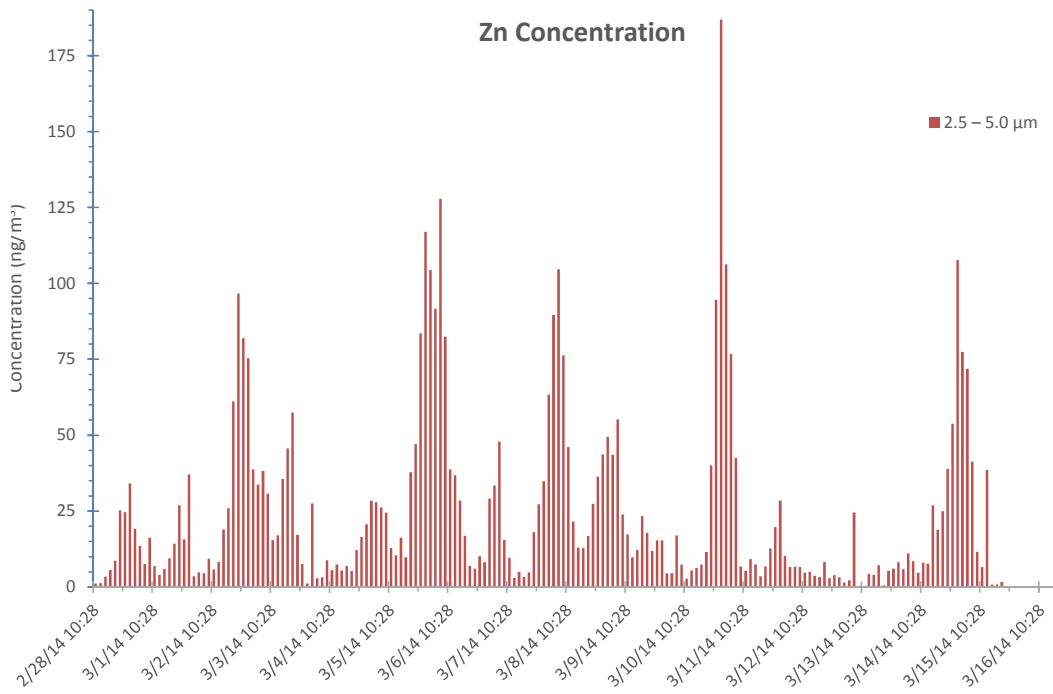


Fig. C-369 CaPh 34 DRUM: Zn mass stage 2

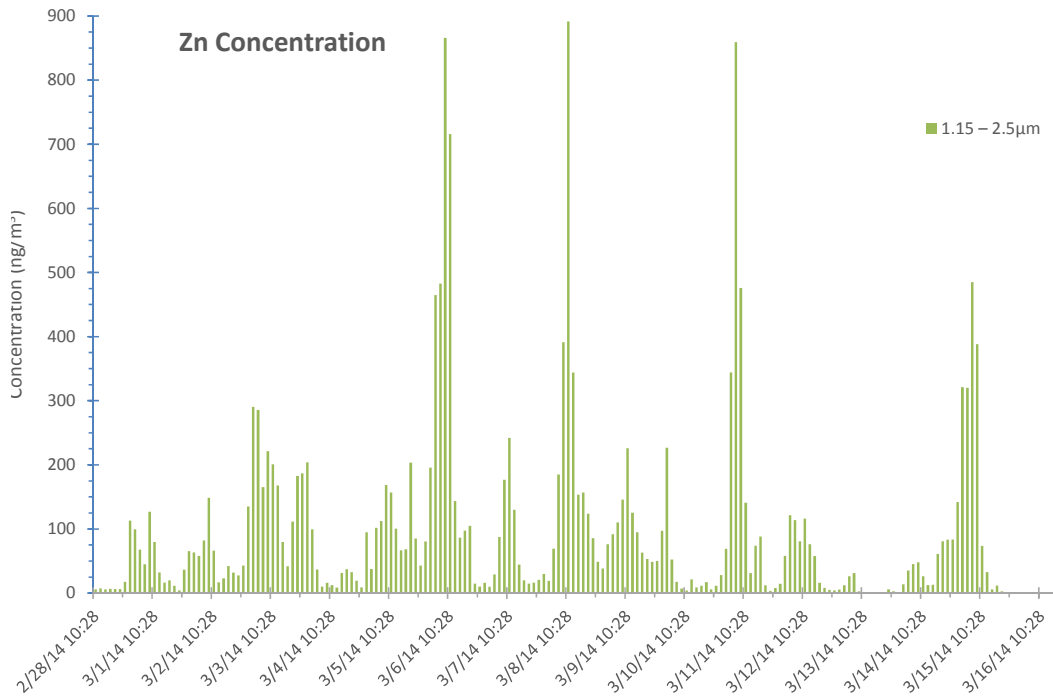


Fig. C-370 CaPh 34 DRUM: Zn mass stage 3

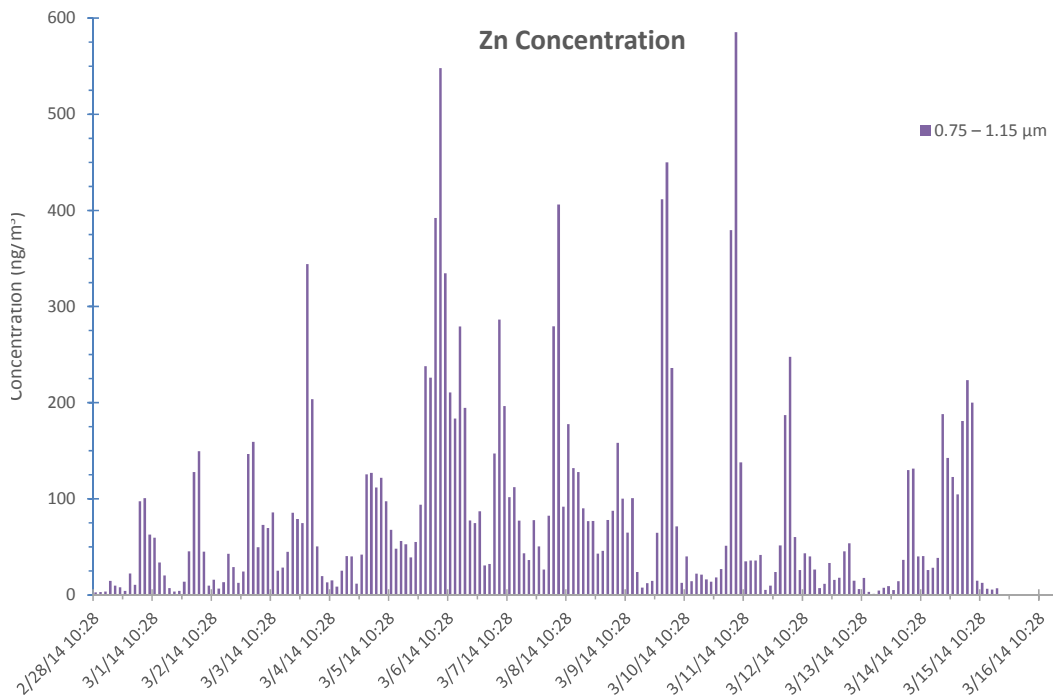


Fig. C-371 CaPh 34 DRUM: Zn mass stage 4

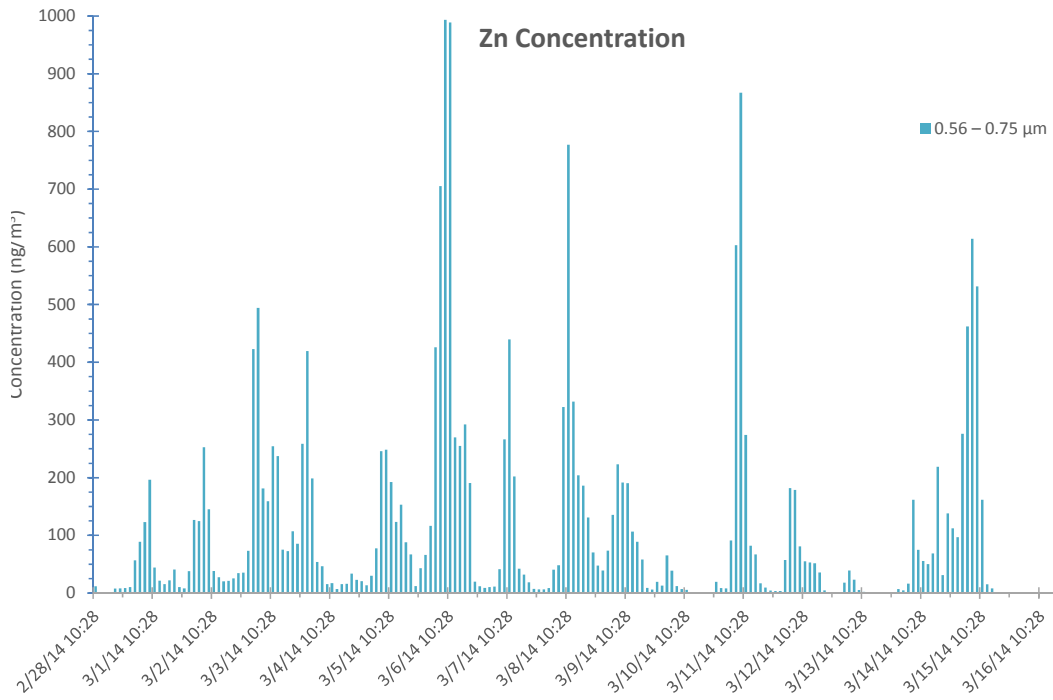


Fig. C-372 CaPh 34 DRUM: Zn mass stage 5

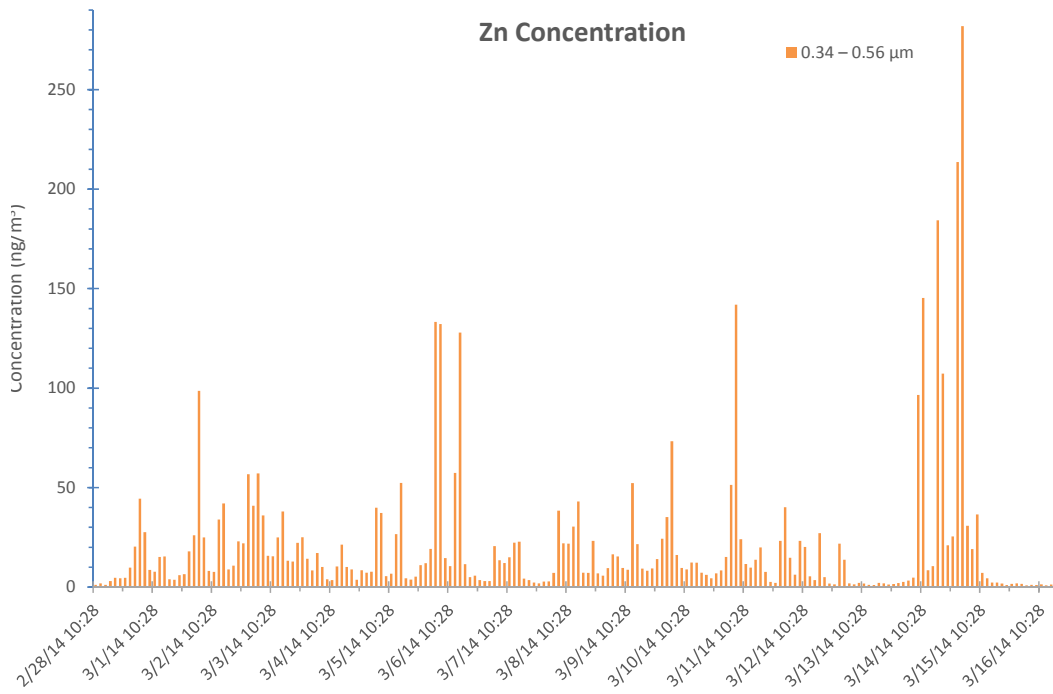


Fig. C-373 CaPh 34 DRUM: Zn mass stage 6

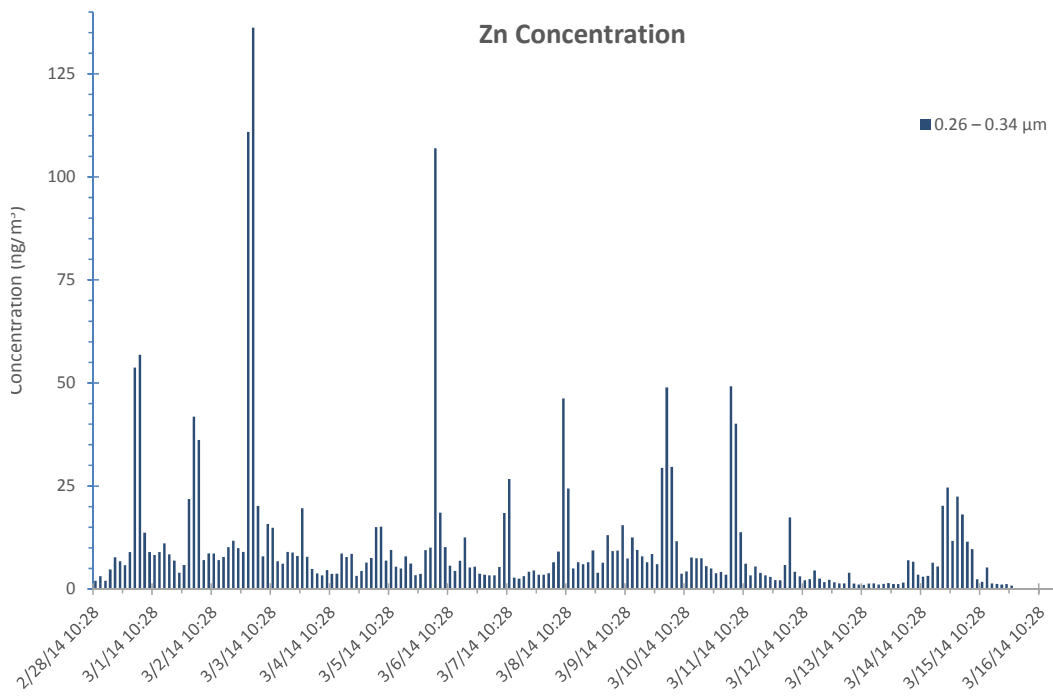


Fig. C-374 CaPh 34 DRUM: Zn mass stage 7

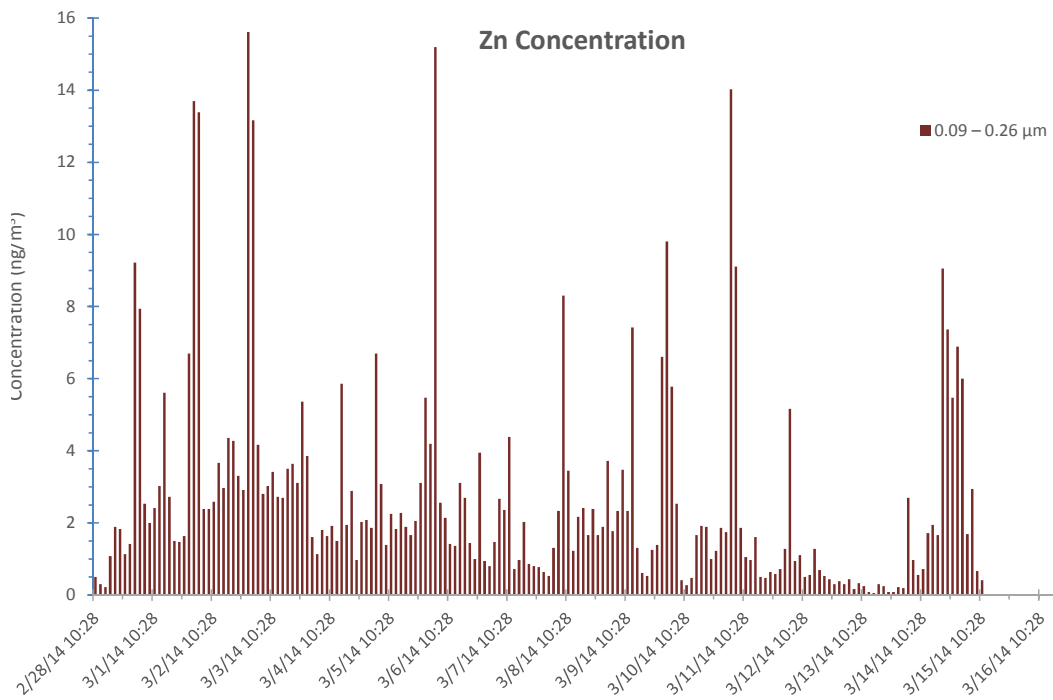


Fig. C-375 CaPh 34 DRUM: Zn mass stage 8

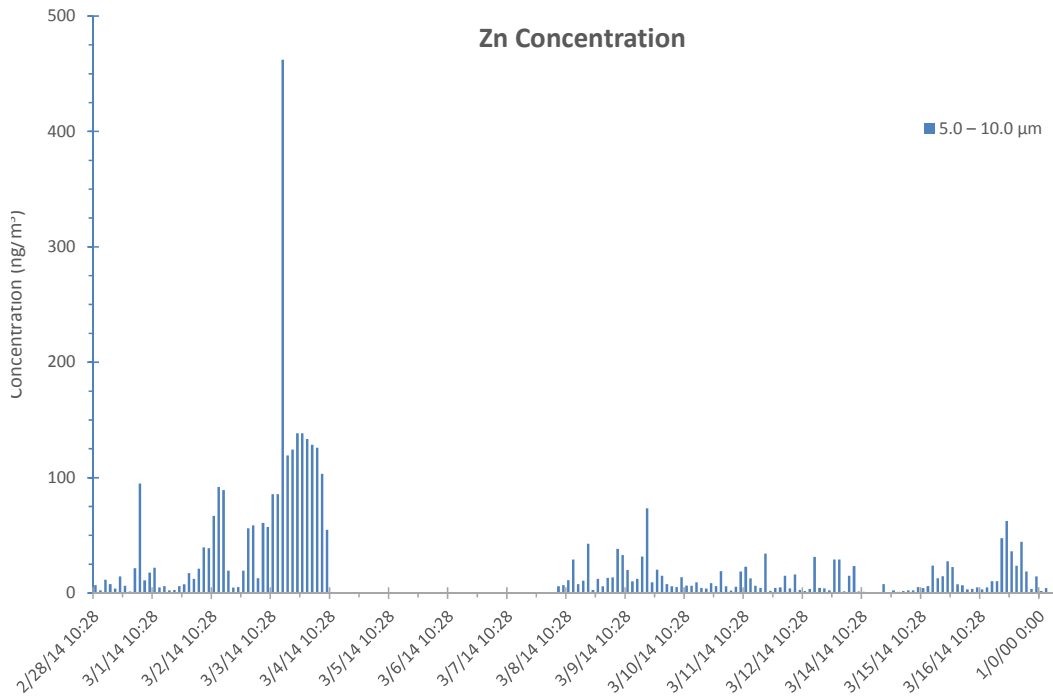


Fig. C-376 CaPh 32 DRUM: Zn mass stage 1

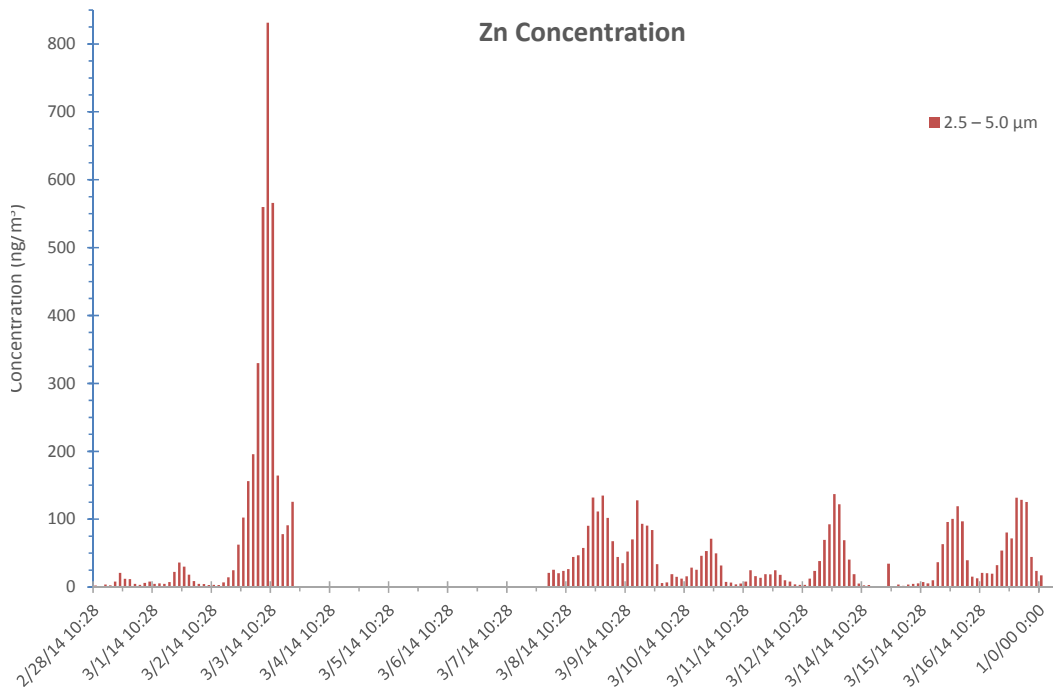


Fig. C-377 CaPh 32 DRUM: Zn mass stage 2

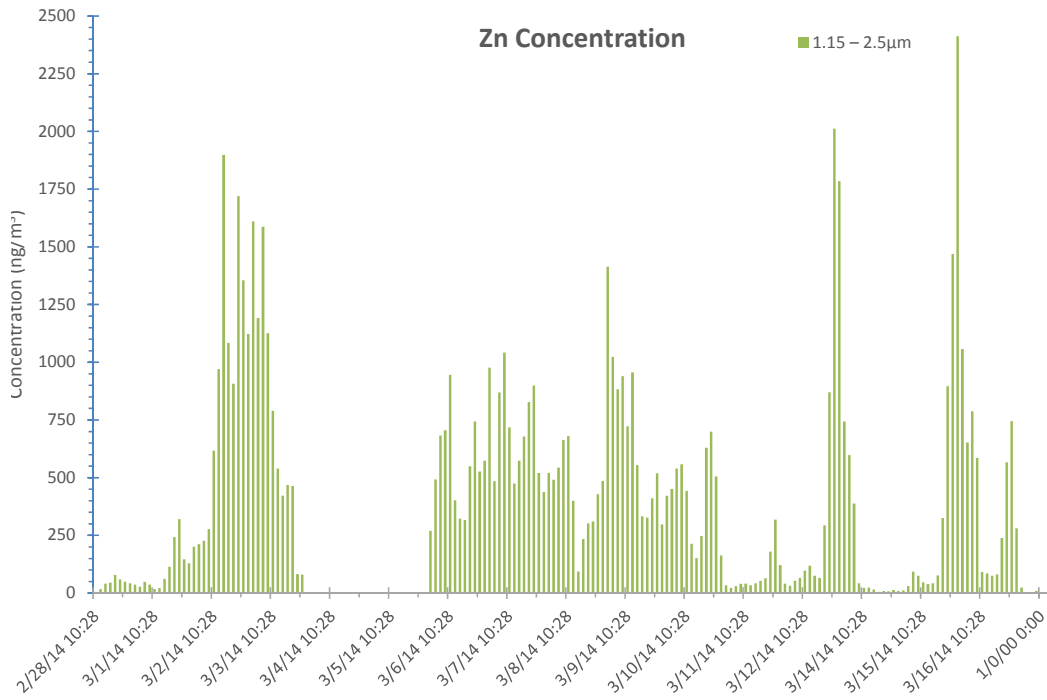


Fig. C-378 CaPh 32 DRUM: Zn mass stage 3

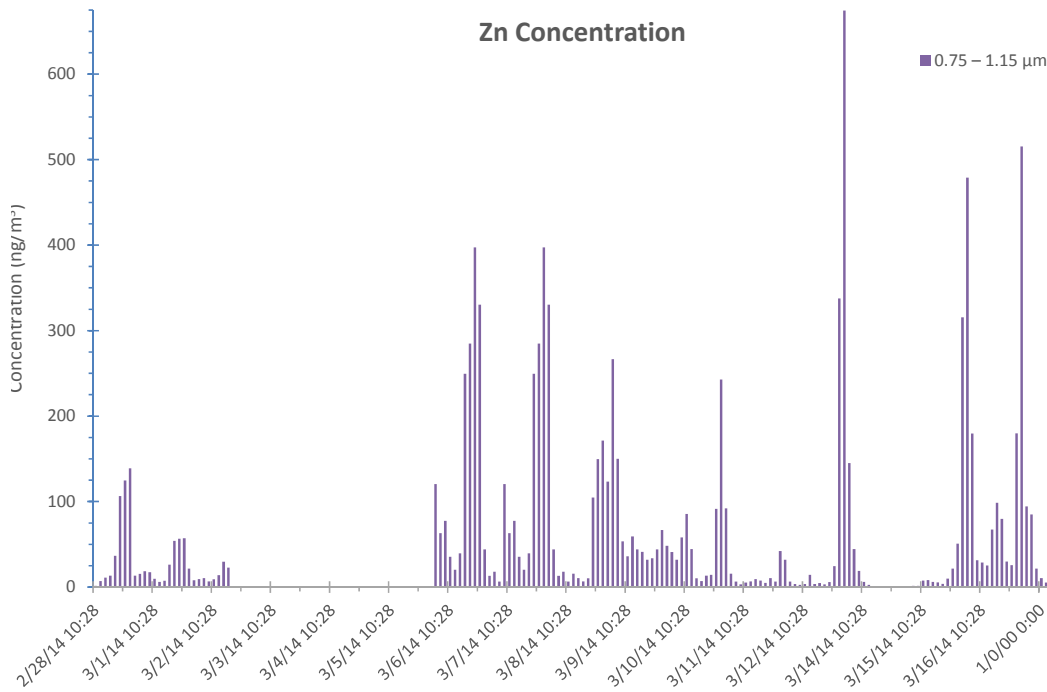


Fig. C-379 CaPh 32 DRUM: Zn mass stage 4

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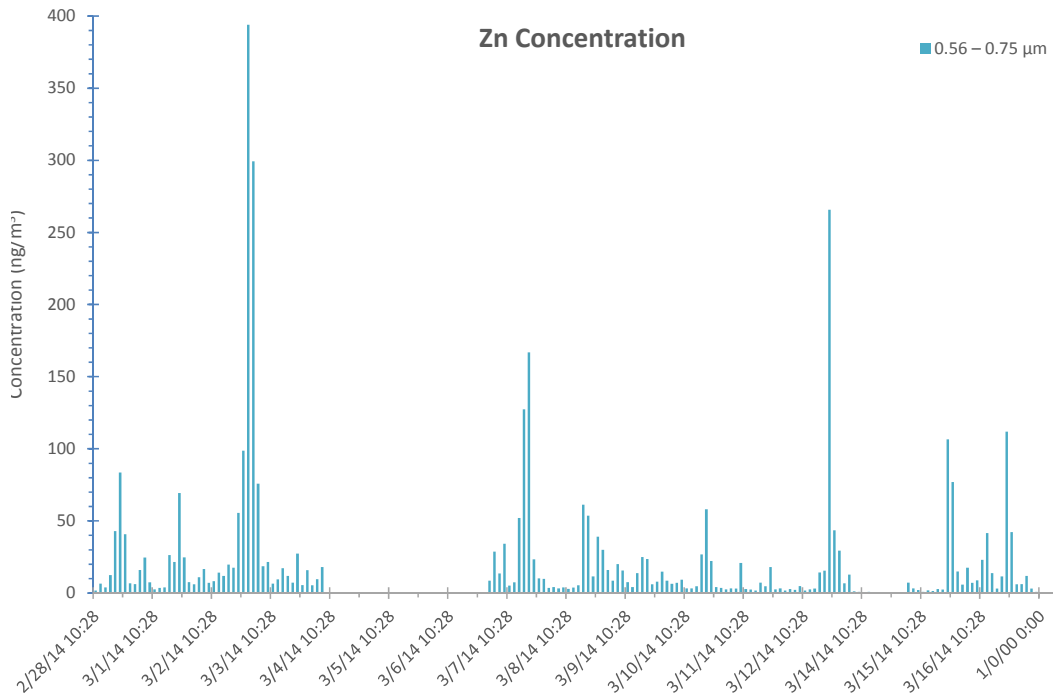


Fig. C-380 CaPh 32 DRUM: Zn mass stage 5

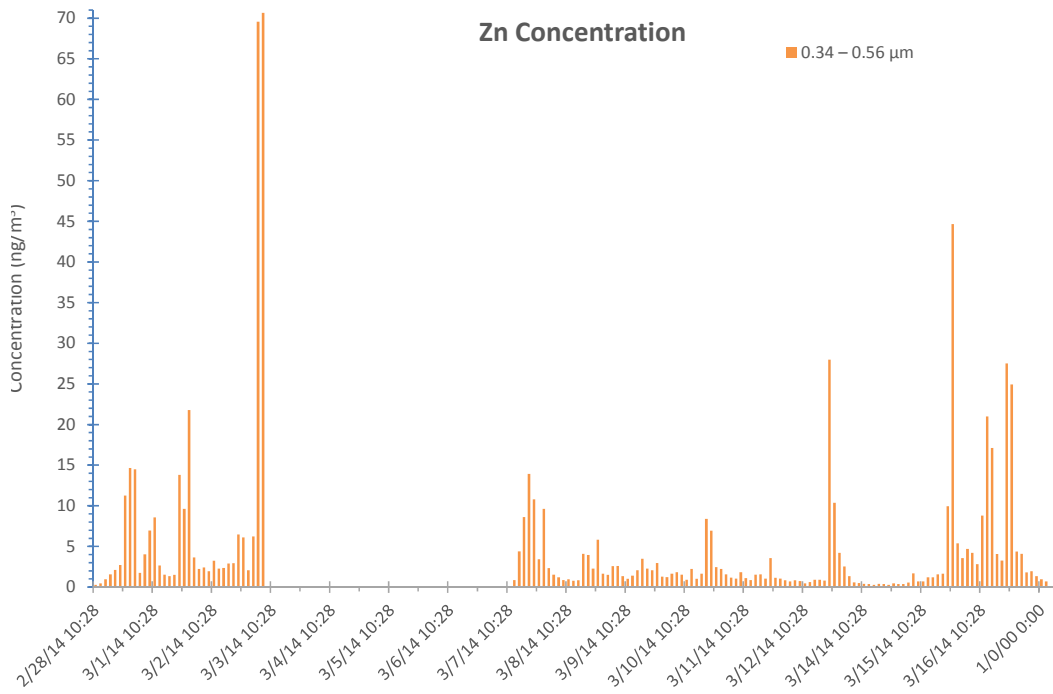


Fig. C-381 CaPh 32 DRUM: Zn mass stage 6

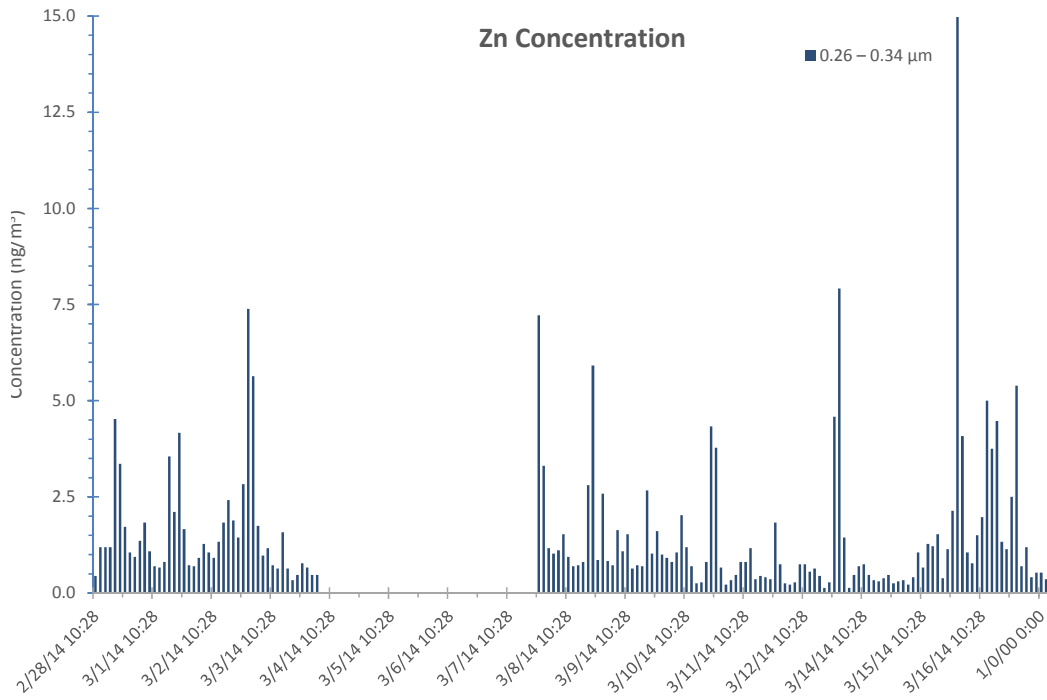


Fig. C-382 CaPh 32 DRUM: Zn mass stage 7

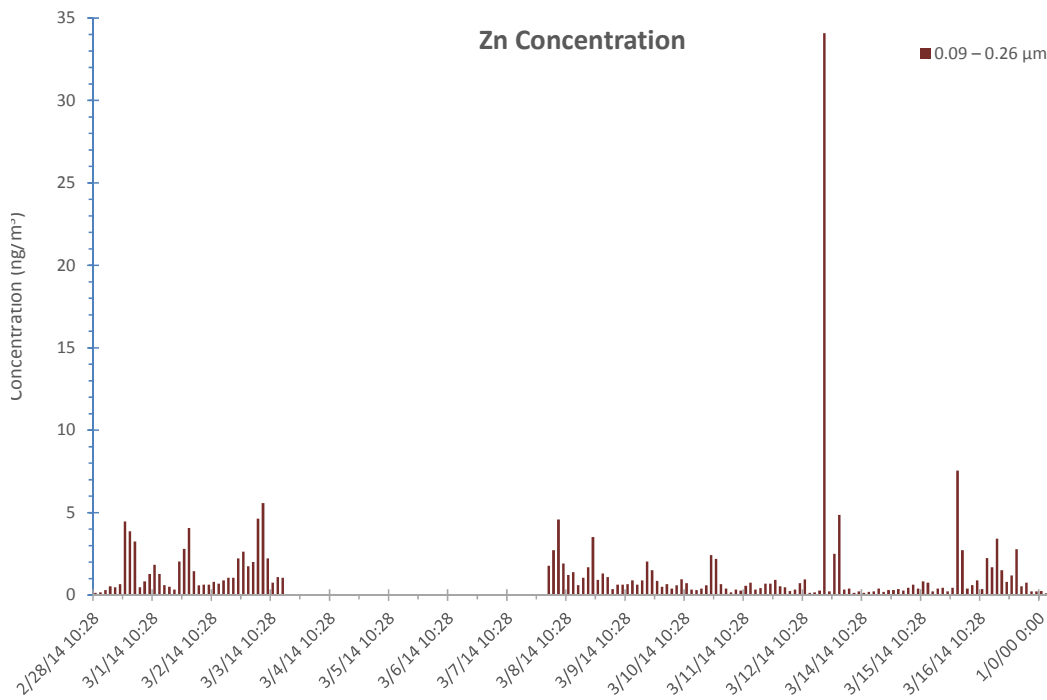


Fig. C-383 CaPh 32 DRUM: Zn mass stage 8

C-4.19 Bromine (Br)

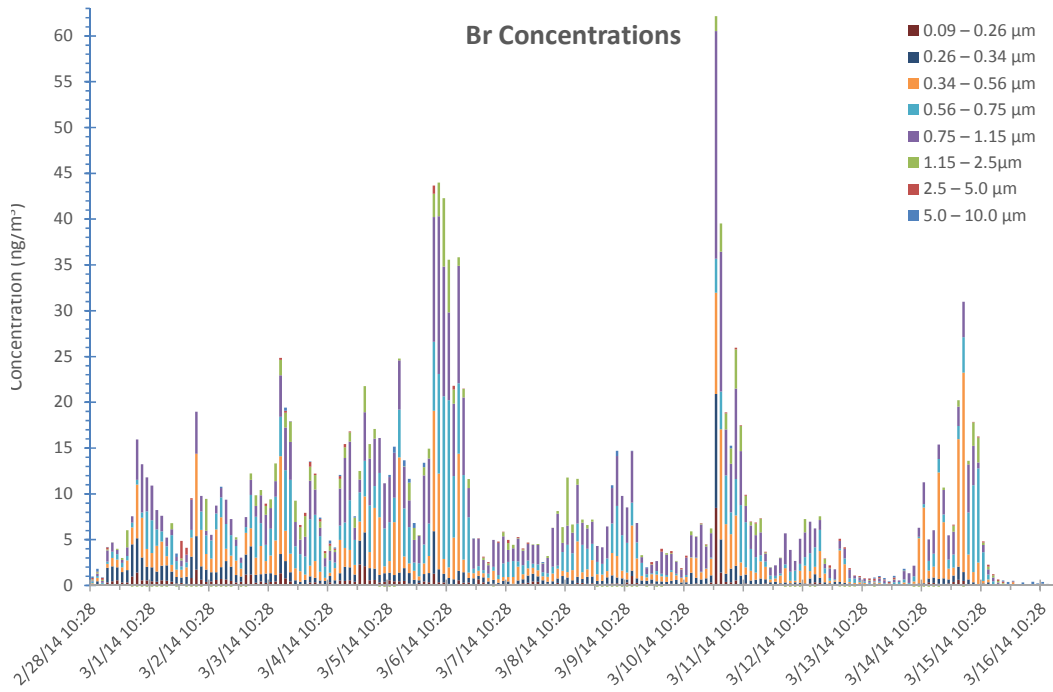


Fig. C-384 CaPh 34 DRUM: Br mass all stages

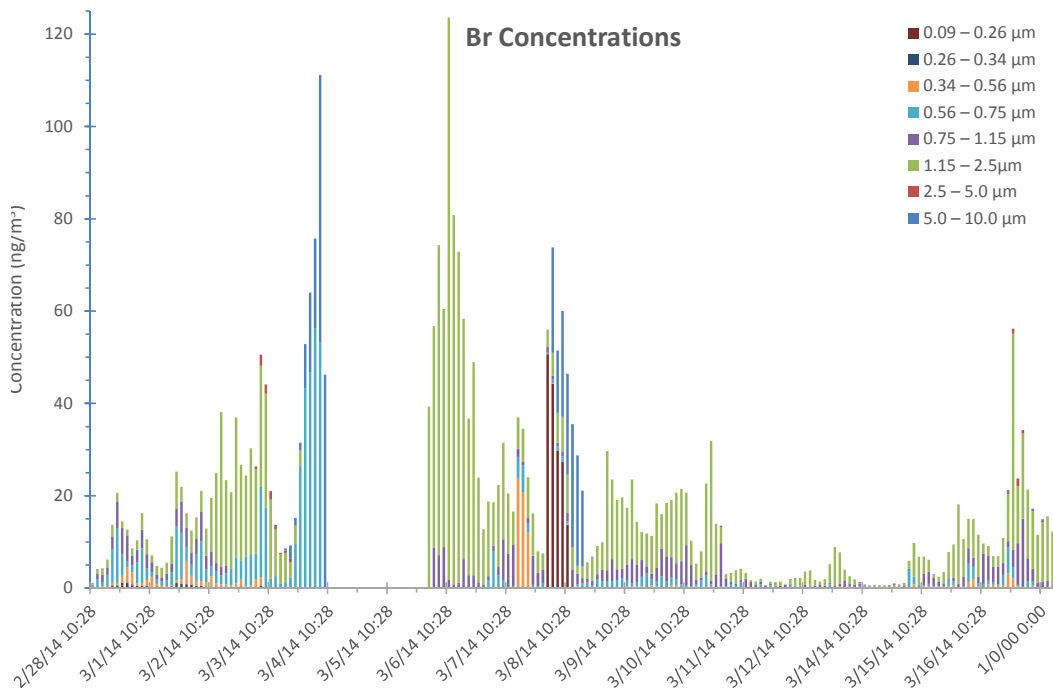
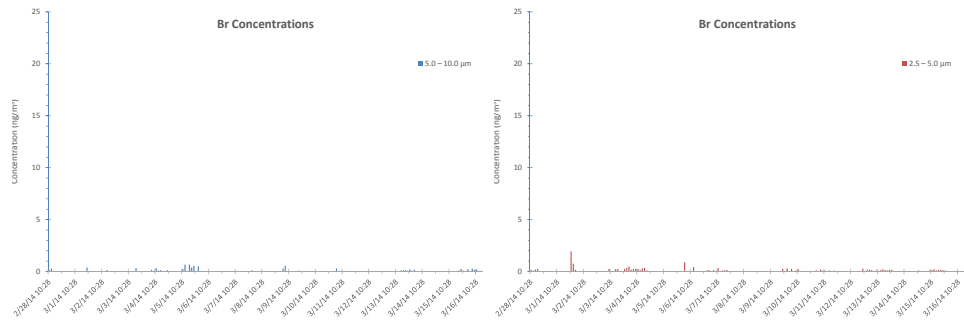
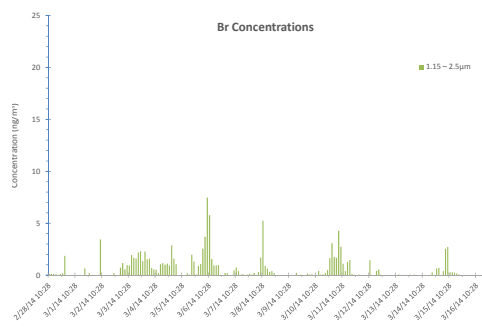


Fig. C-385 CaPh 32 DRUM: Br mass all stages

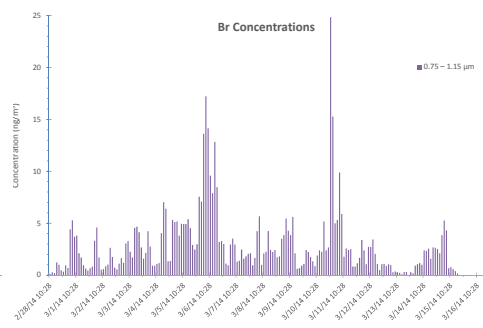


a) XRF stage 1 (5–10 μm) mass

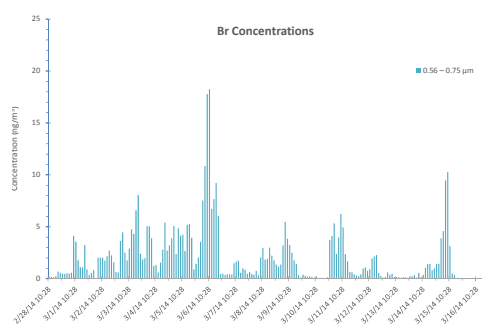
b) XRF stage 2 (2.5–5.0 μm) mass



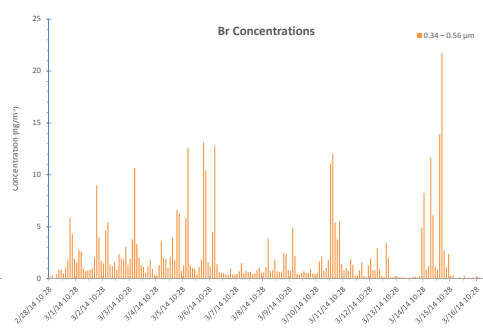
c) XRF stage 3 (1.15–2.5 μm) mass



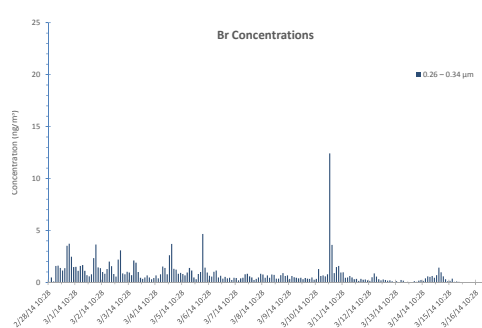
d) XRF stage 4 (0.75–1.15 μm) mass



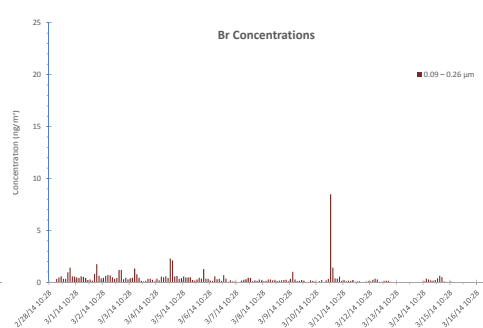
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.34–0.56 μm) mass



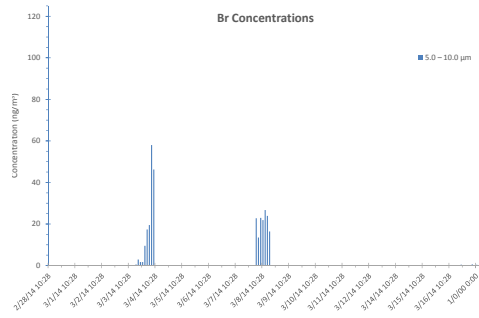
g) XRF stage 7 (0.26–0.34 μm) mass



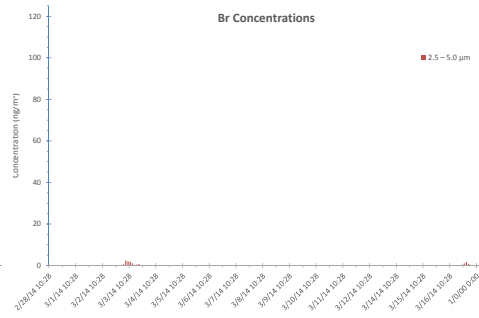
h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-386 CaPh 34 DRUM: XRF mass Br; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

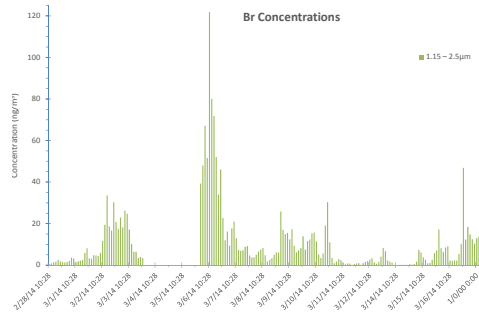
Approved for public release; distribution is unlimited.



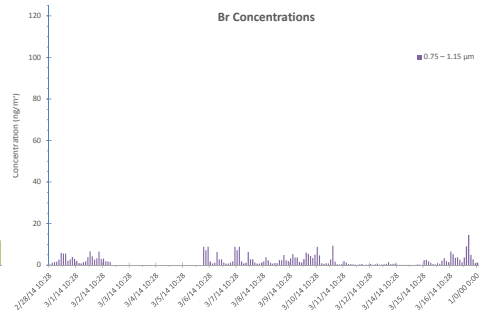
a) XRF stage 1 (5–10 μm) mass



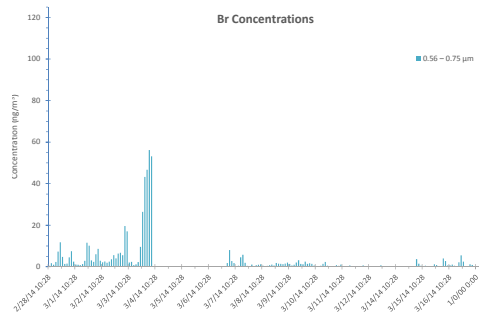
b) XRF stage 2 (2.5–5.0 μm) mass



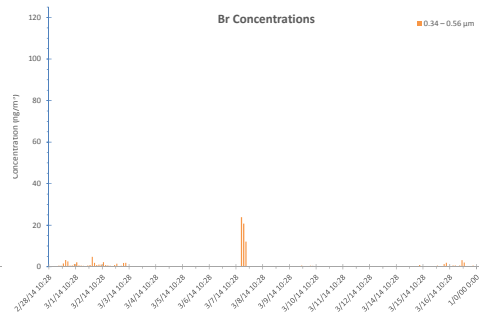
c) XRF stage 3 (1.15–2.5 μm) mass



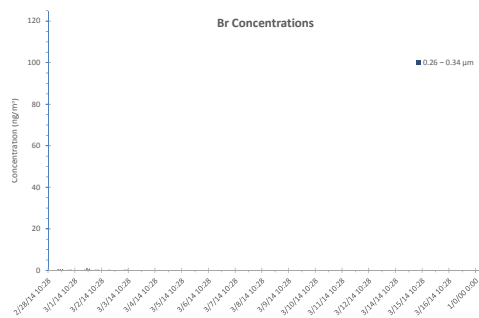
d) XRF stage 4 (0.75–1.15 μm) mass



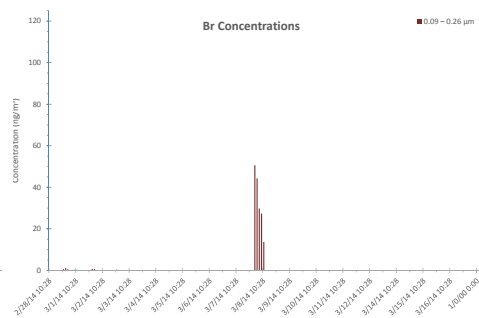
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-387 CaPh 32 DRUM: XRF mass Br; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8

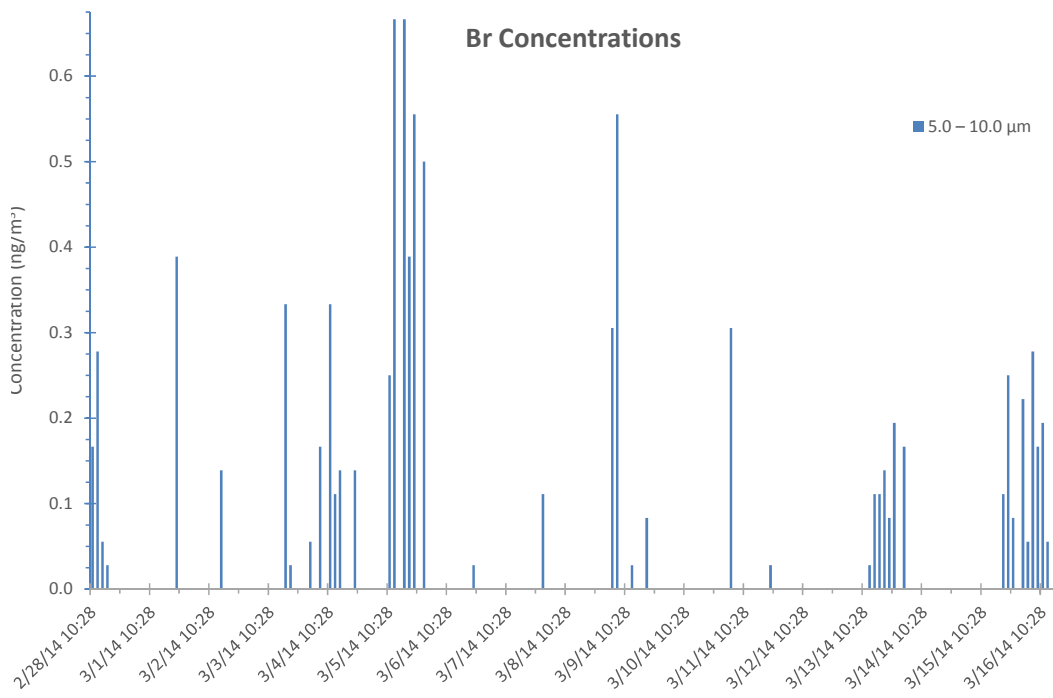


Fig. C-388 CaPh 34 DRUM: Br mass stage 1

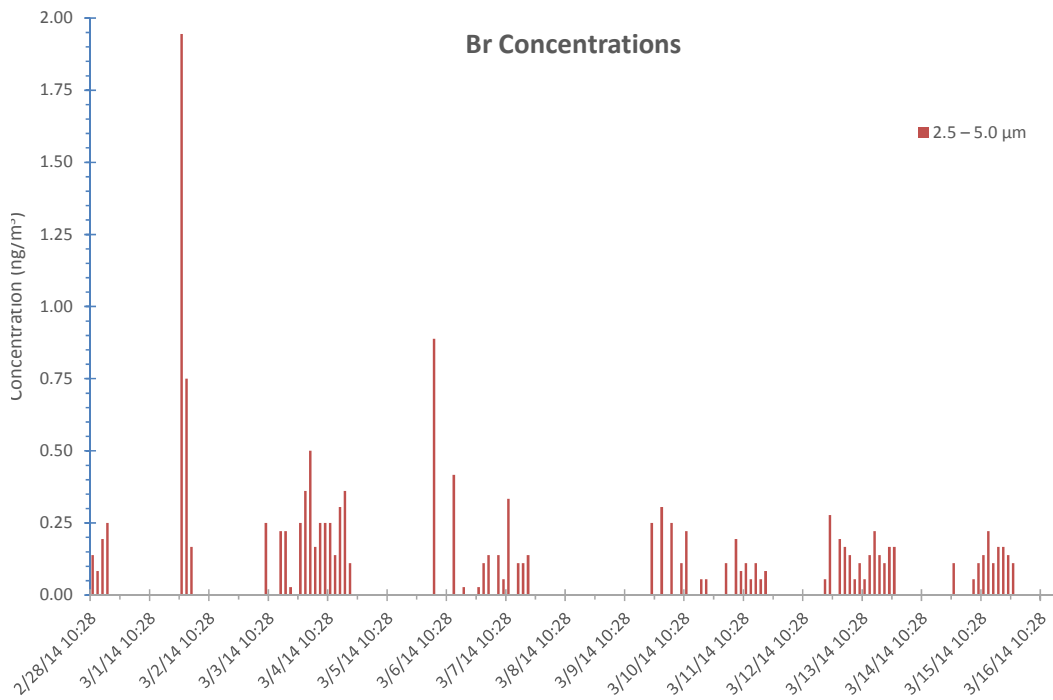


Fig. C-389 CaPh 34 DRUM: Br mass stage 2

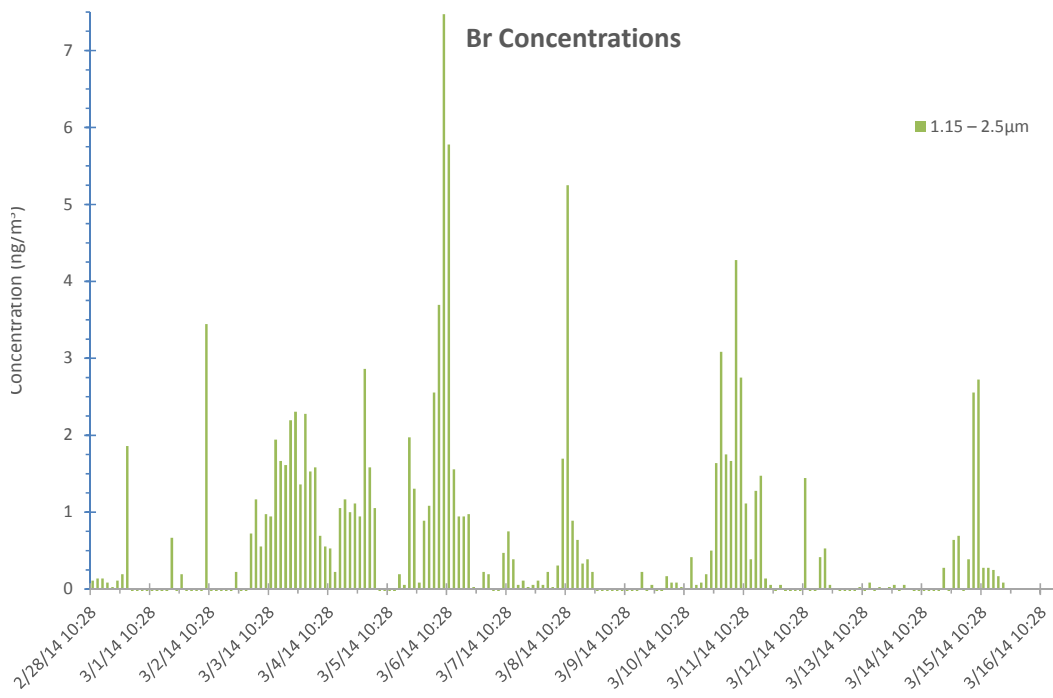


Fig. C-390 CaPh 34 DRUM: Br mass stage 3

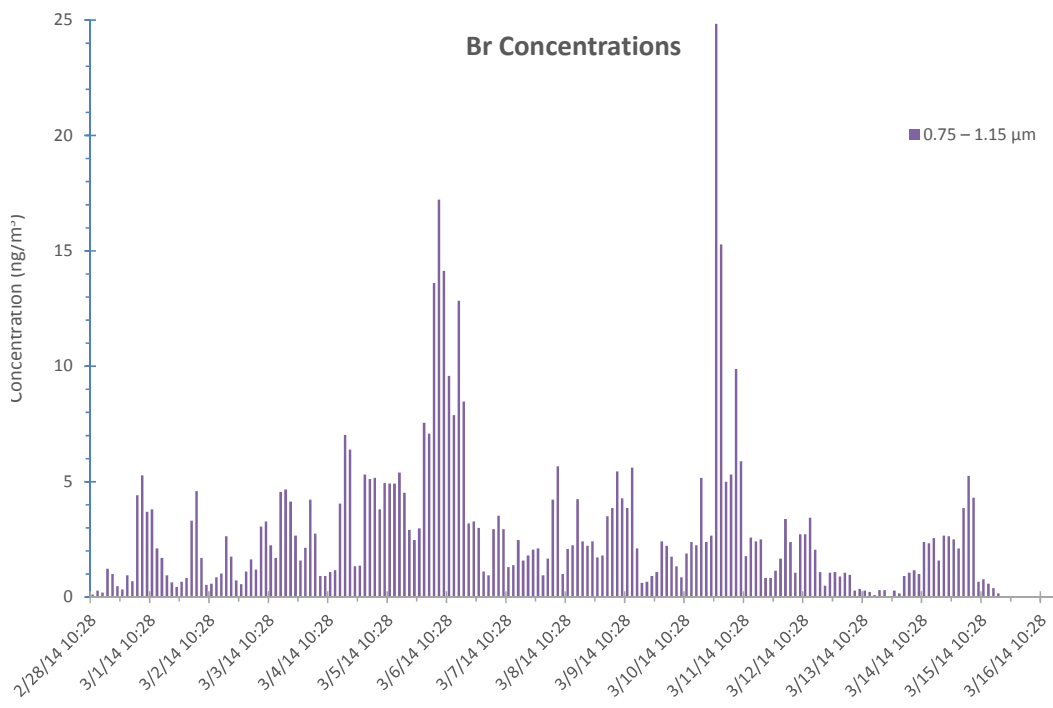


Fig. C-391 CaPh 34 DRUM: Br mass stage 4

Approved for public release; distribution is unlimited.

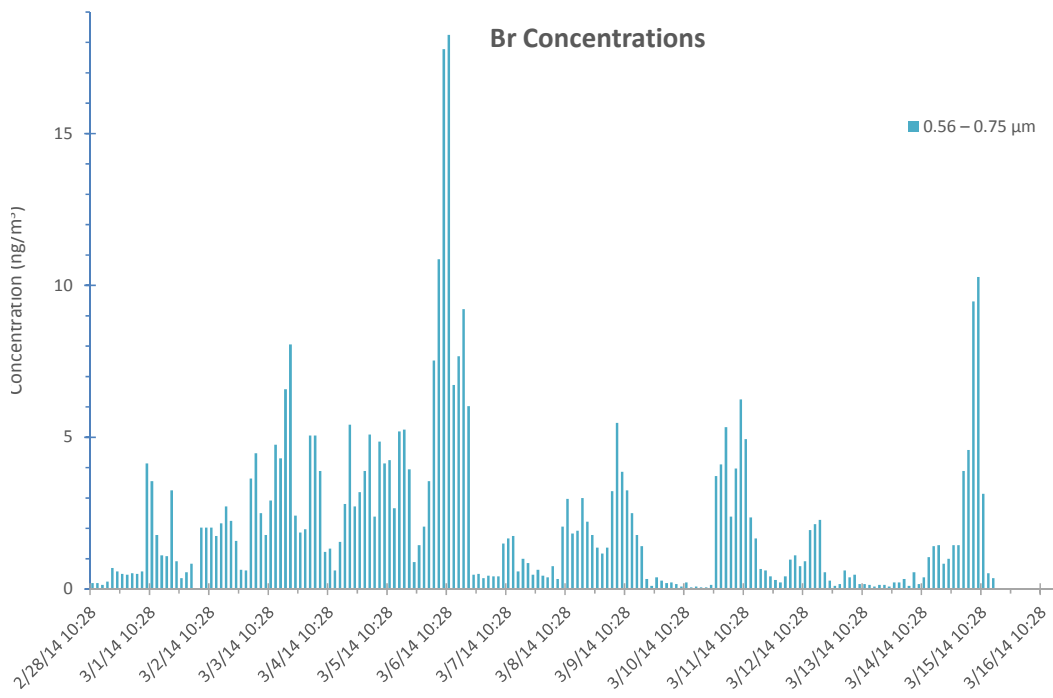


Fig. C-392 CaPh 34 DRUM: Br mass stage 5

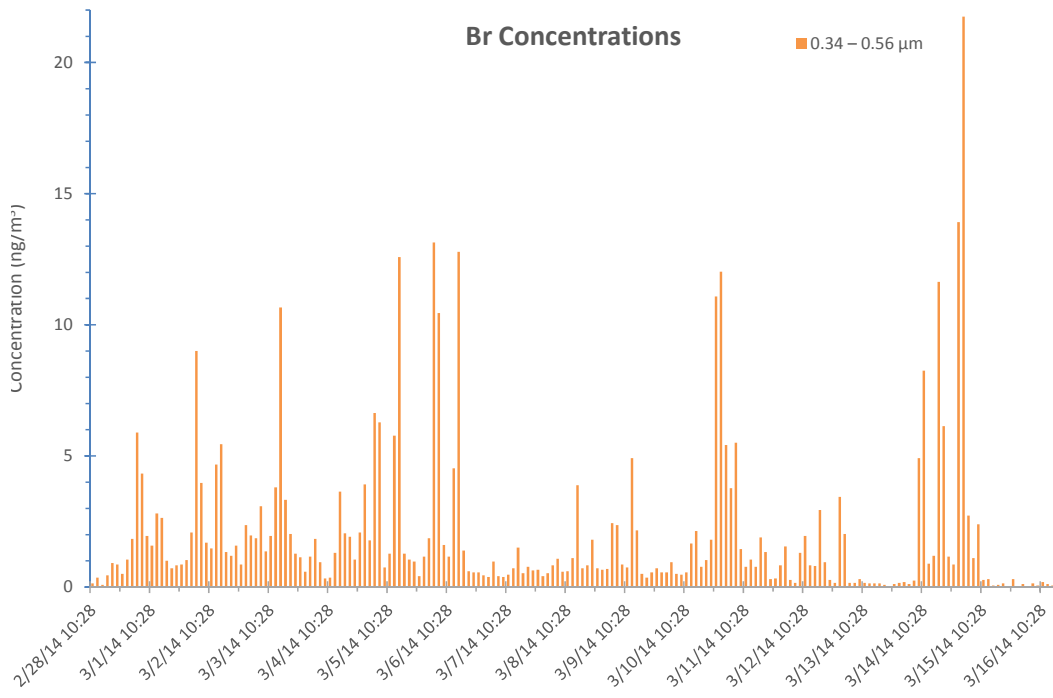


Fig. C-393 CaPh 34 DRUM: Br mass stage 6

Approved for public release; distribution is unlimited.

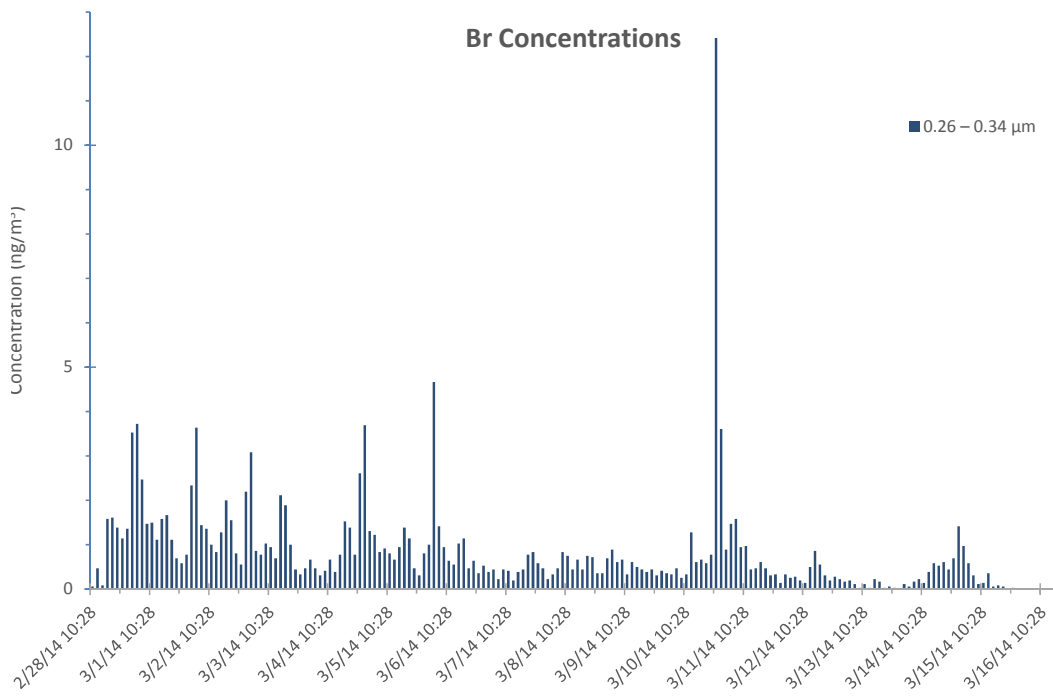


Fig. C-394 CaPh 34 DRUM: Br mass stage 7

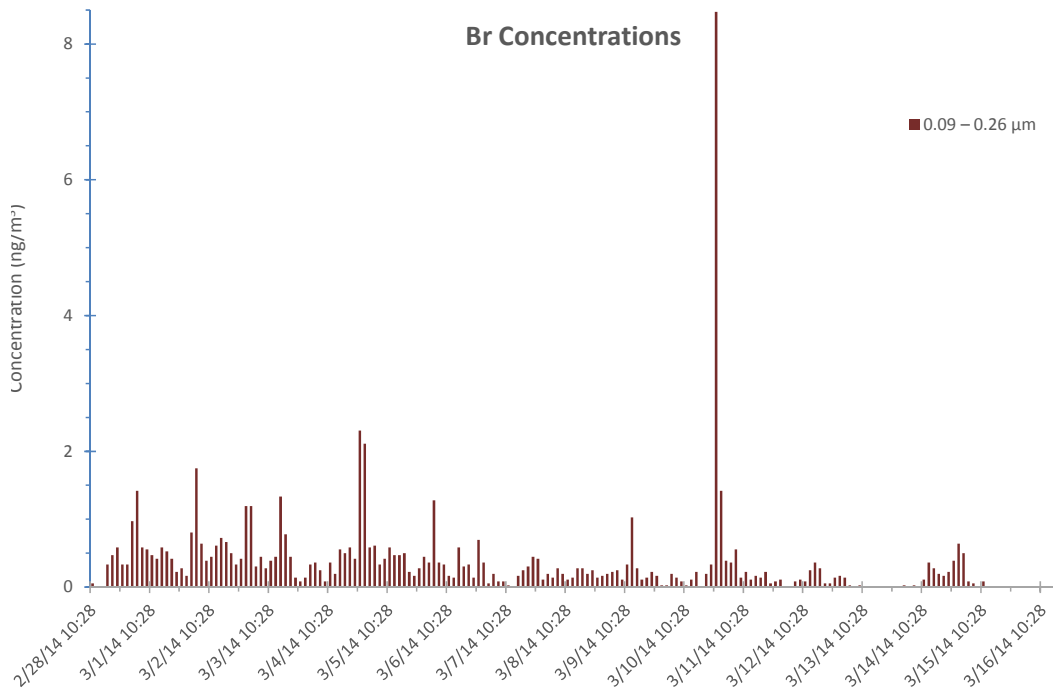


Fig. C-395 CaPh 34 DRUM: Br mass stage 8

Approved for public release; distribution is unlimited.

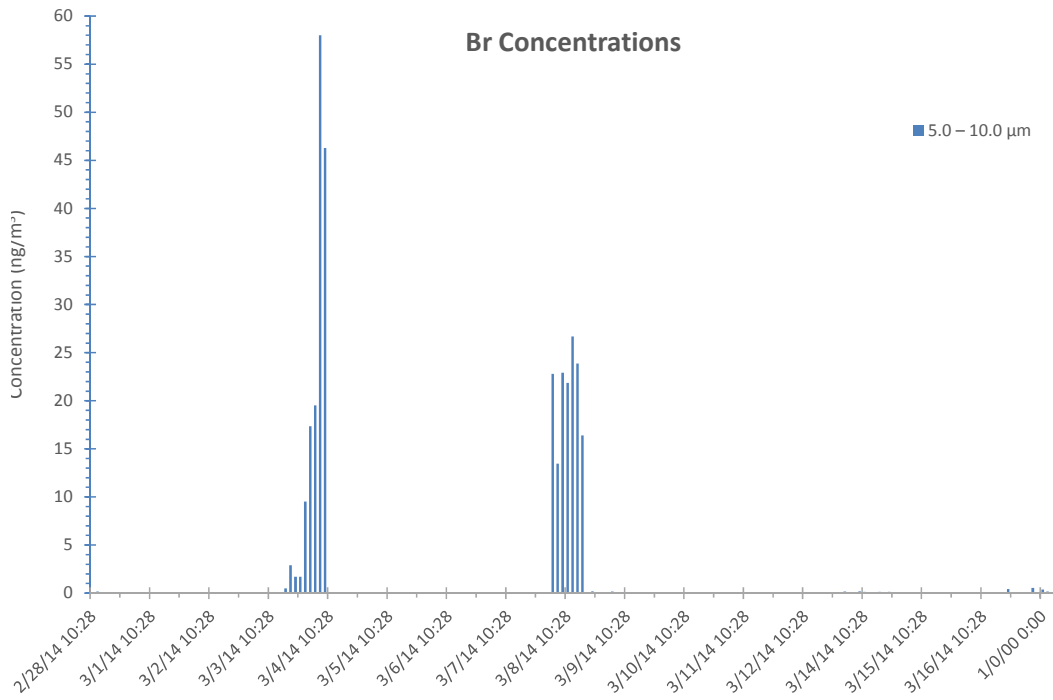


Fig. C-396 CaPh 32 DRUM: Br mass stage 1

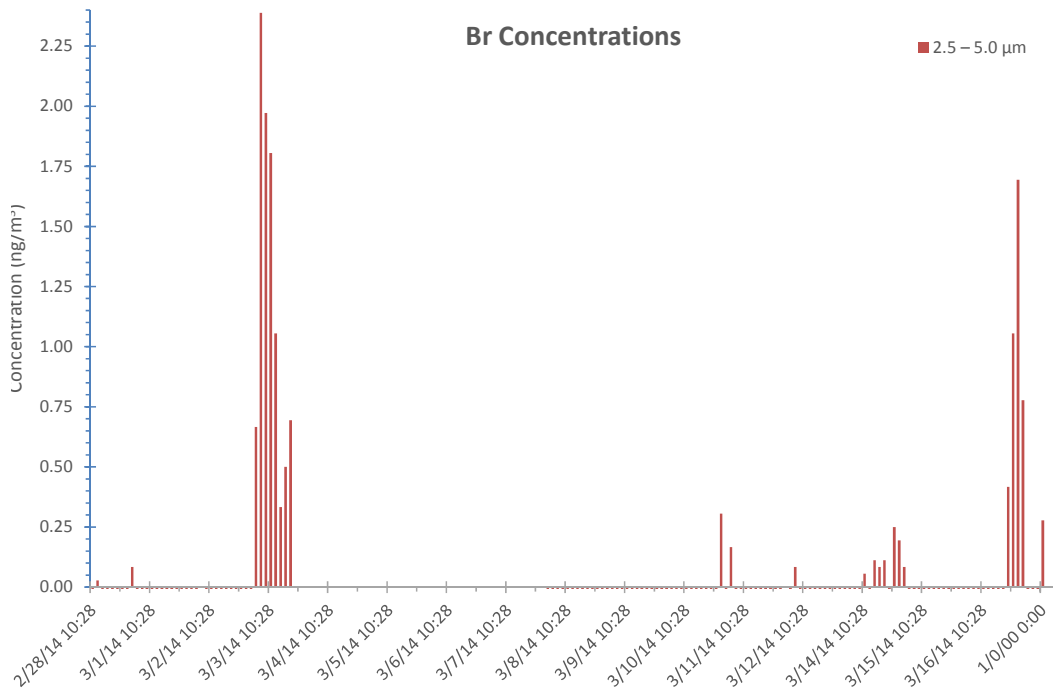


Fig. C-397 CaPh 32 DRUM: Br mass stage 2

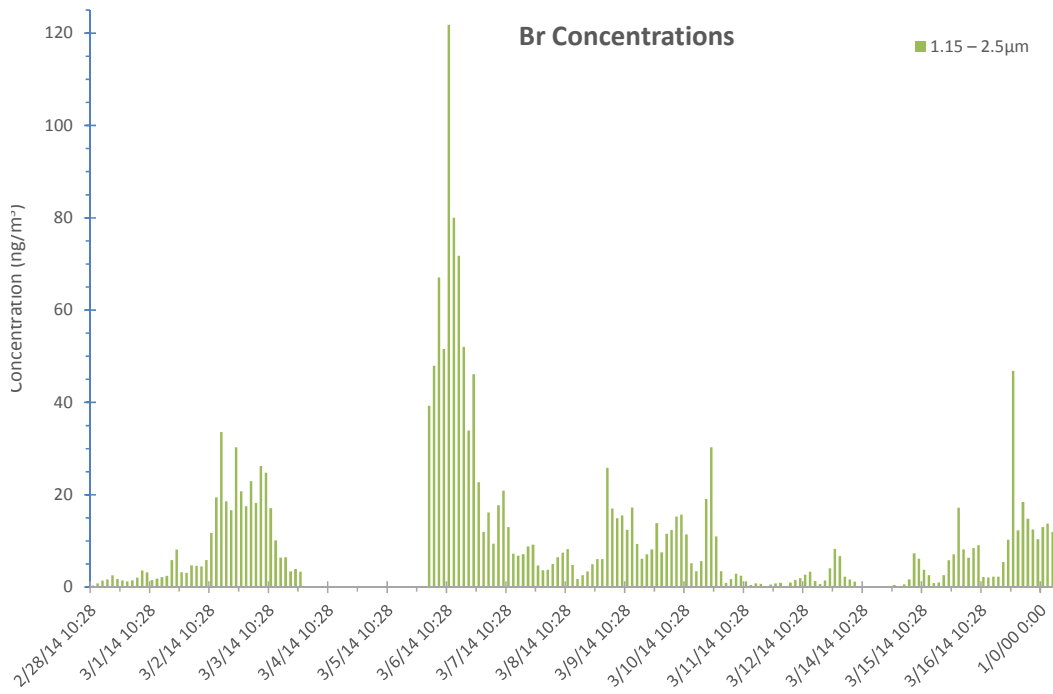


Fig. C-398 CaPh 32 DRUM: Br mass stage 3

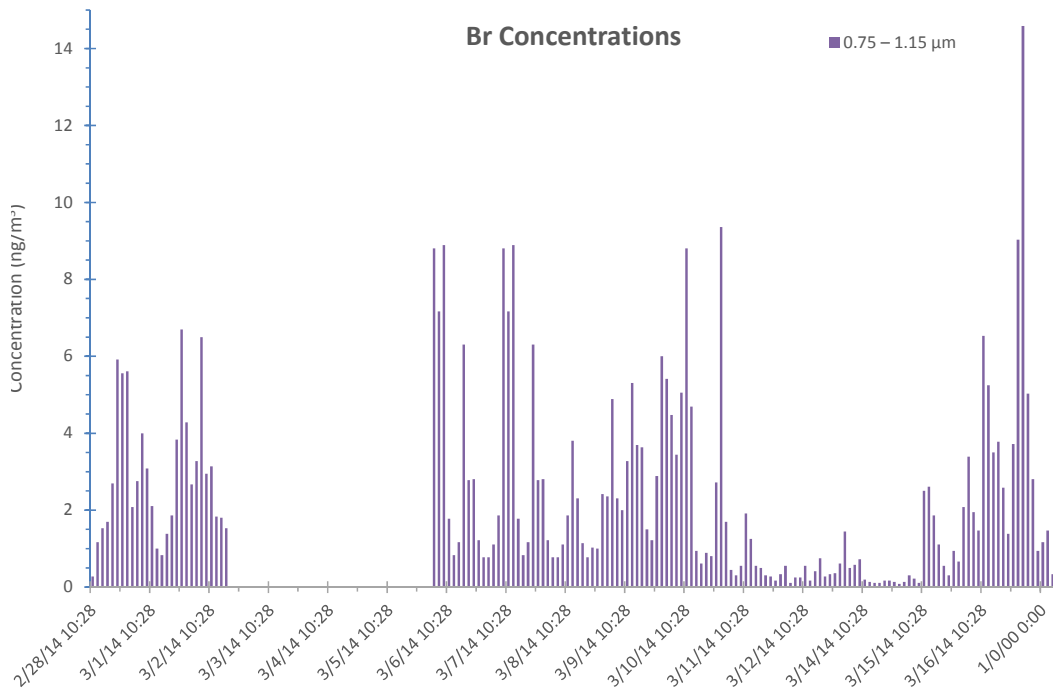


Fig. C-399 CaPh 32 DRUM: Br mass stage 4

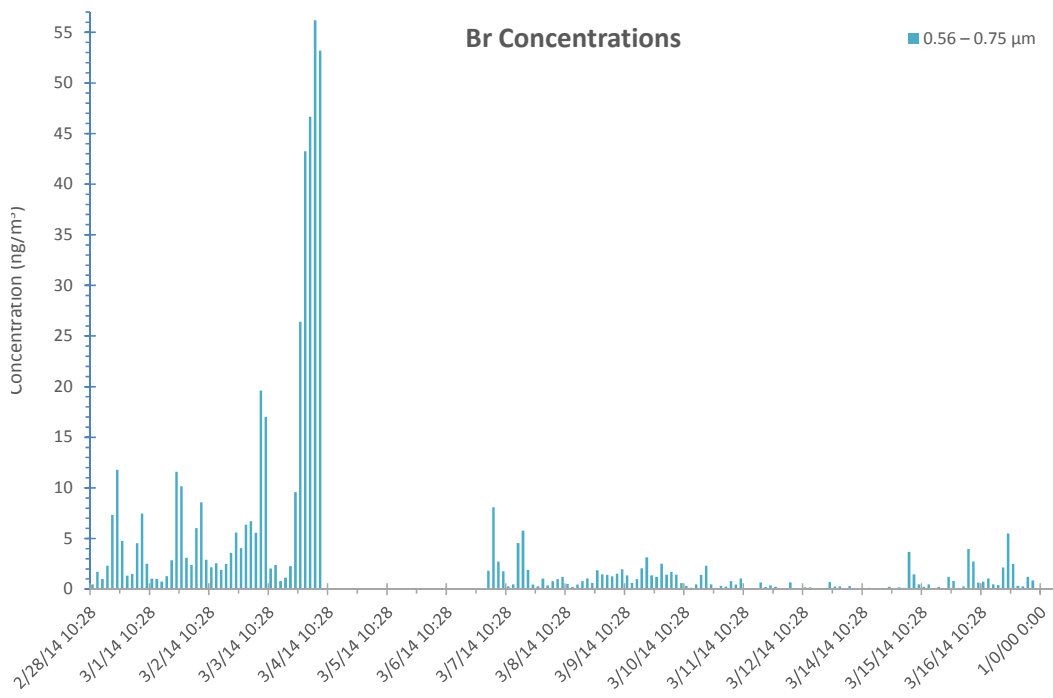


Fig. C-400 CaPh 32 DRUM: Br mass stage 5

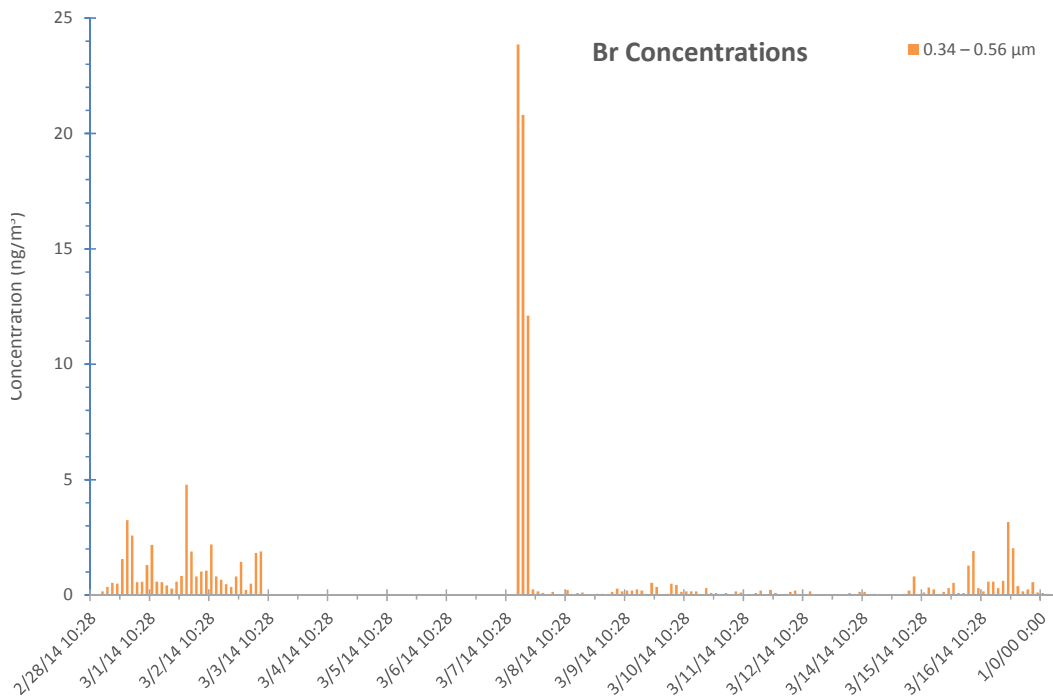


Fig. C-401 CaPh 32 DRUM: Br mass stage 6

Approved for public release; distribution is unlimited.

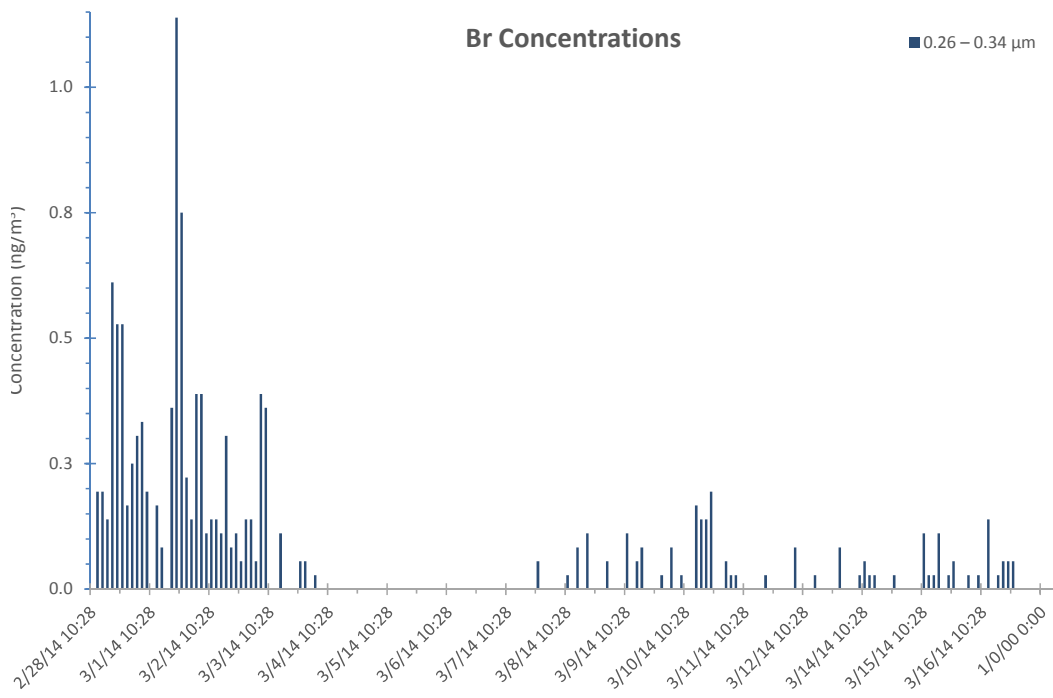


Fig. C-402 CaPh 32 DRUM: Br mass stage 7

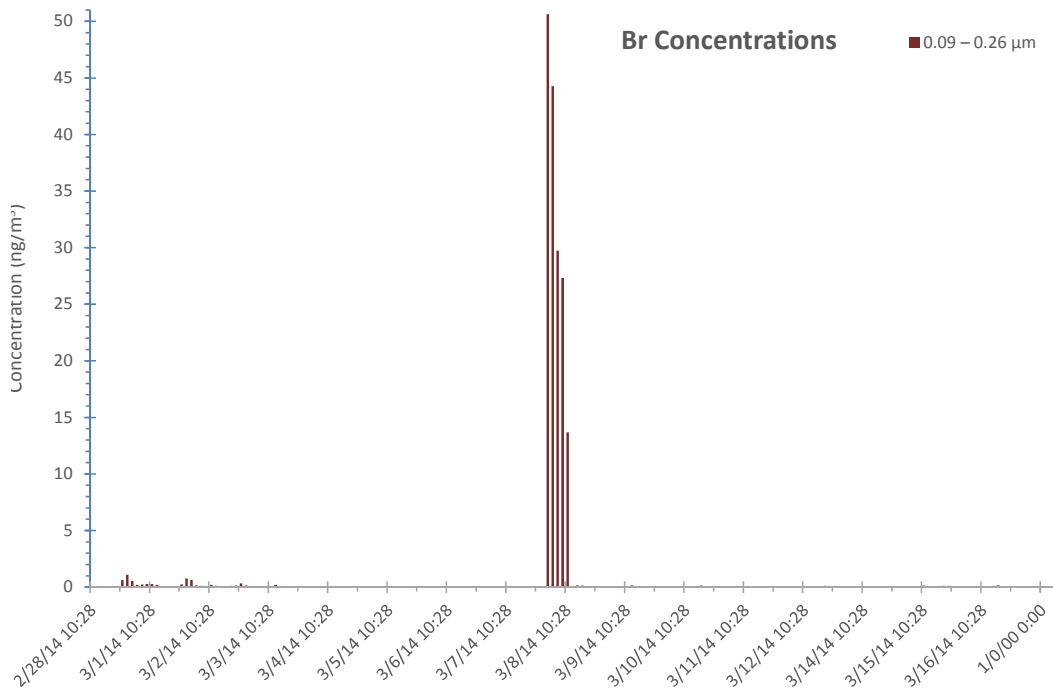


Fig. C-403 CaPh 32 DRUM: Br mass stage 8

Approved for public release; distribution is unlimited.

C-4.20 Lead (Pb)

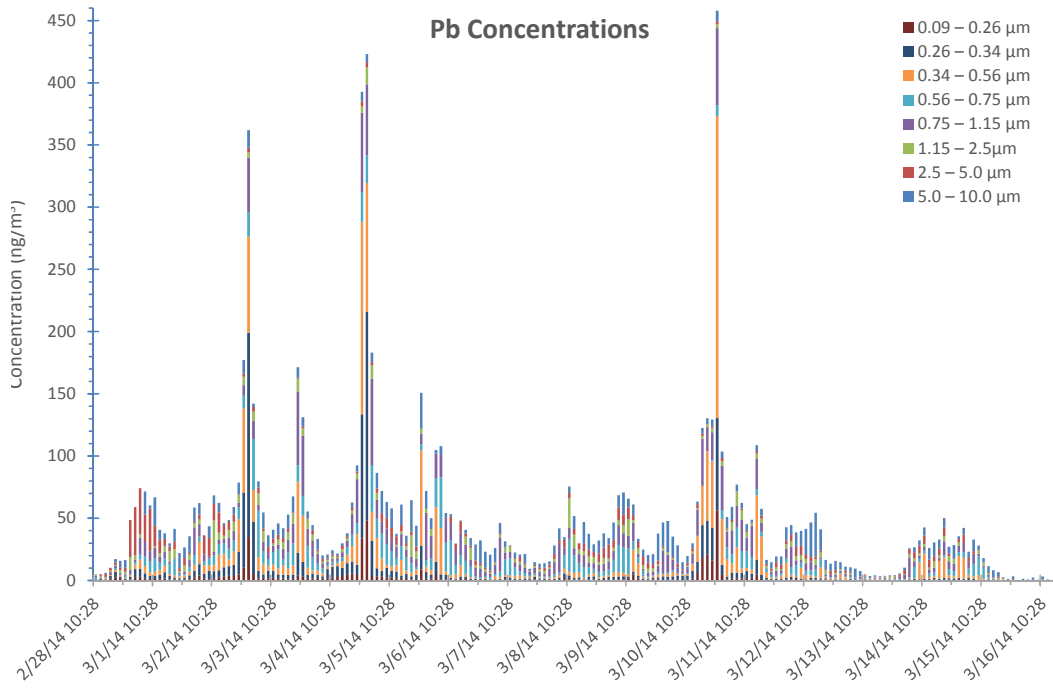


Fig. C-404 CaPh 34 DRUM: Pb mass all stages

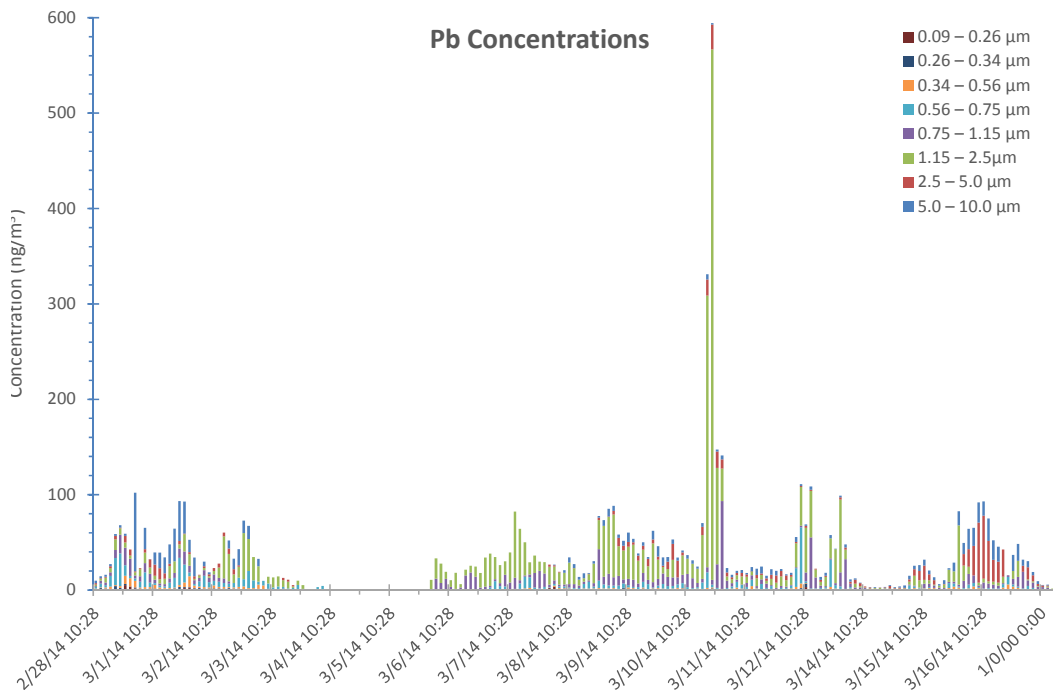
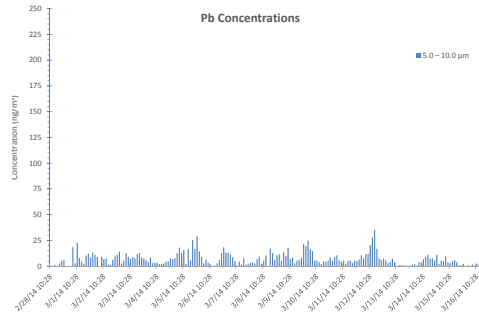
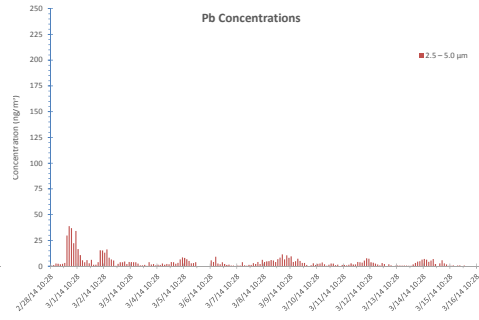


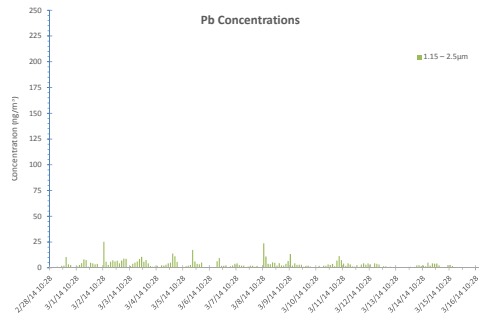
Fig. C-405 CaPh 32 DRUM: Pb mass all stages



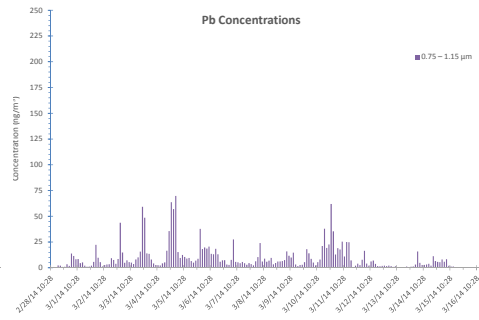
a) XRF stage 1 (5–10 μm) mass



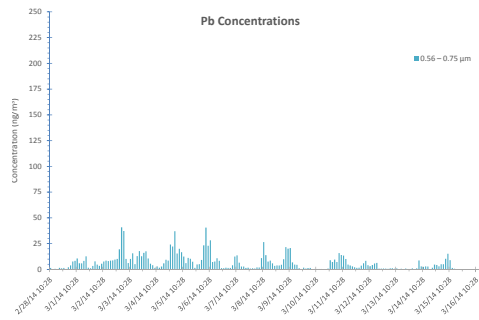
b) XRF stage 2 (2.5–5.0 μm) mass



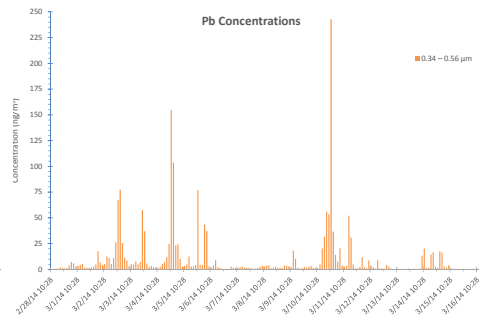
c) XRF stage 3 (1.15–2.5 μm) mass



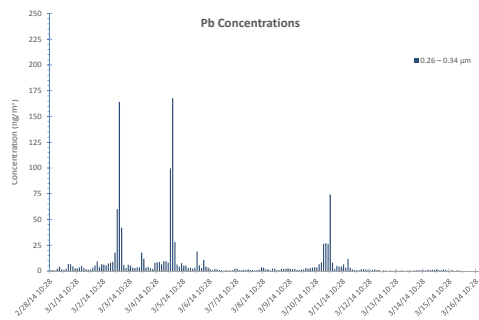
d) XRF stage 4 (0.75–1.15 μm) mass



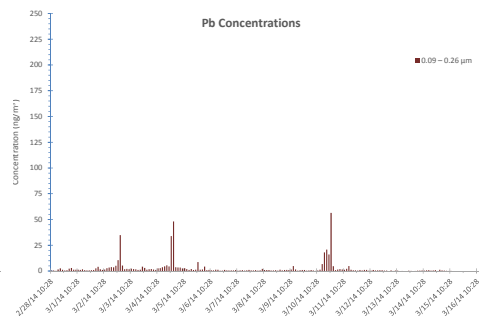
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.34–0.56 μm) mass

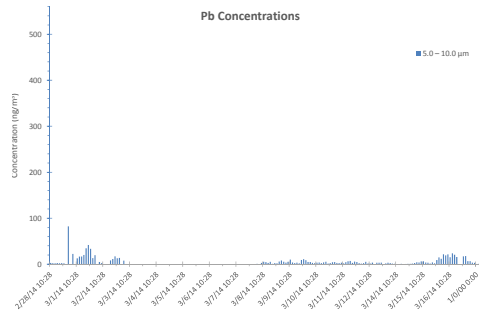


g) XRF stage 7 (0.26–0.34 μm) mass

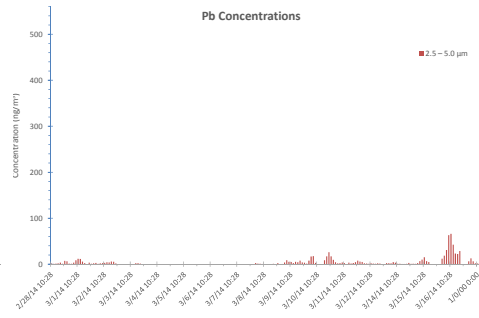


h) XRF stage 8 (0.09–0.26 μm) mass

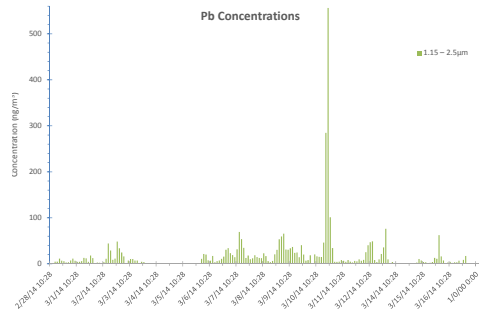
Fig. C-406 CaPh 34 DRUM: XRF mass Pb; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, (h) stage 8



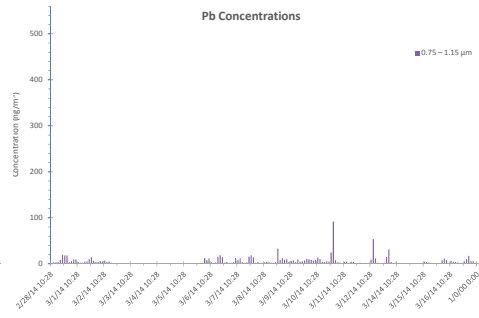
a) XRF stage 1 (5–10 μm) mass



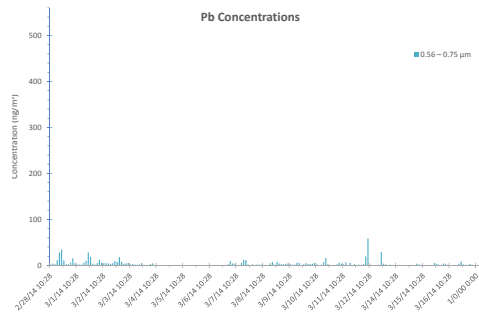
b) XRF stage 2 (2.5–5.0 μm) mass



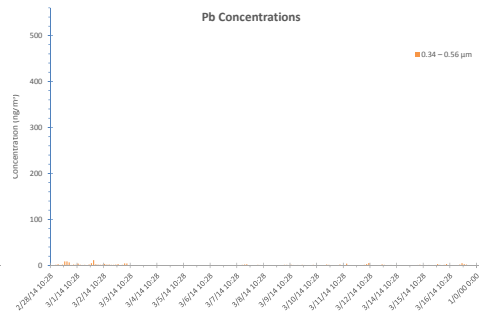
c) XRF stage 3 (1.15–2.5 μm) mass



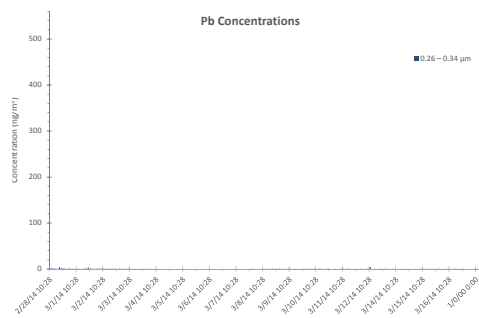
d) XRF stage 4 (0.75–1.15 μm) mass



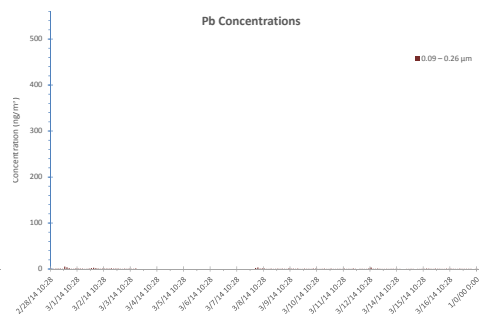
e) XRF stage 5 (0.56–0.75 μm) mass



f) XRF stage 6 (0.32–0.56 μm) mass



g) XRF stage 7 (0.26–0.32 μm) mass



h) XRF stage 8 (0.09–0.26 μm) mass

Fig. C-407 CaPh 32 DRUM: XRF mass Pb; a) stage 1, b) stage 2, c) stage 3, d) stage 4, e) stage 5, f) stage 6, g) stage 7, h) stage 8

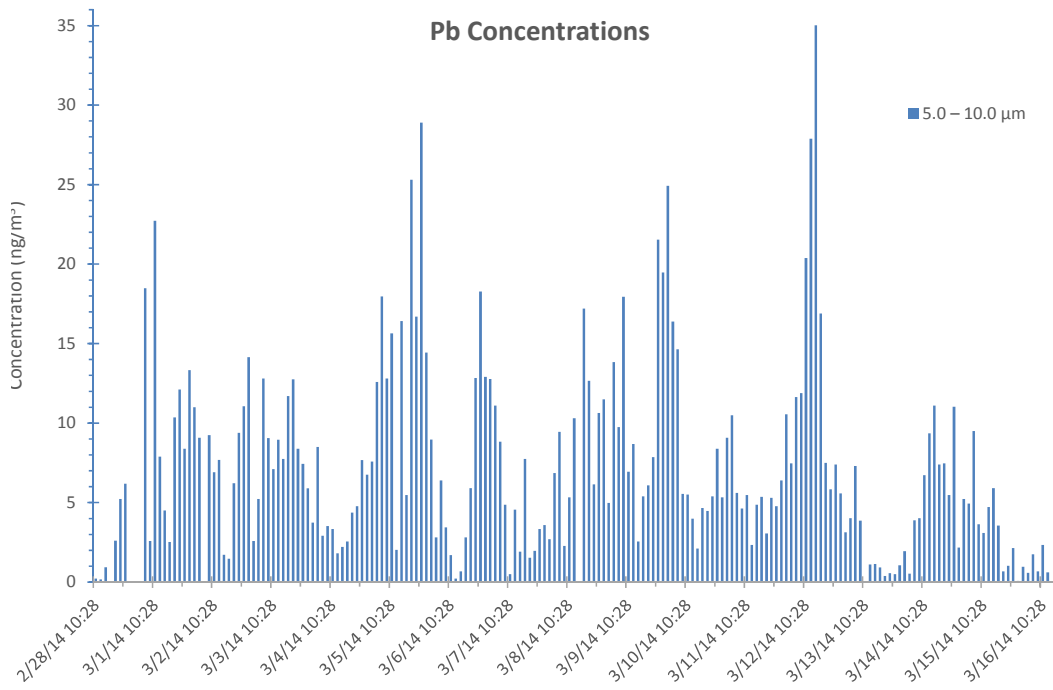


Fig. C-408 CaPh 34 DRUM: Pb mass stage 1

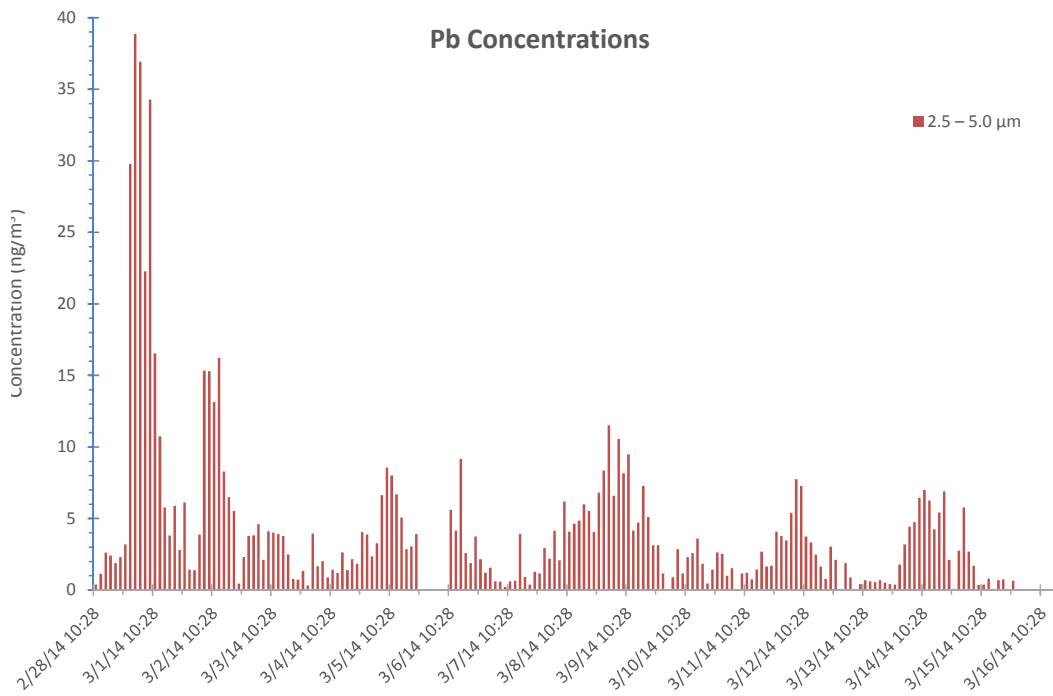


Fig. C-409 CaPh 34 DRUM: Pb mass stage 2

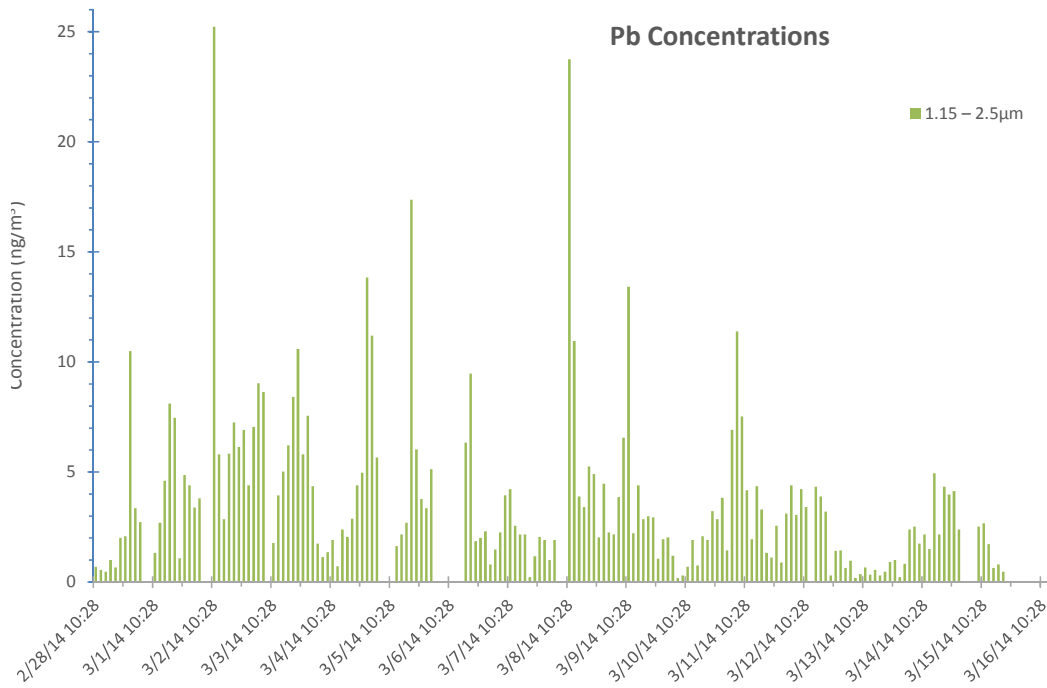


Fig. C-410 CaPh 34 DRUM: Pb mass stage 3

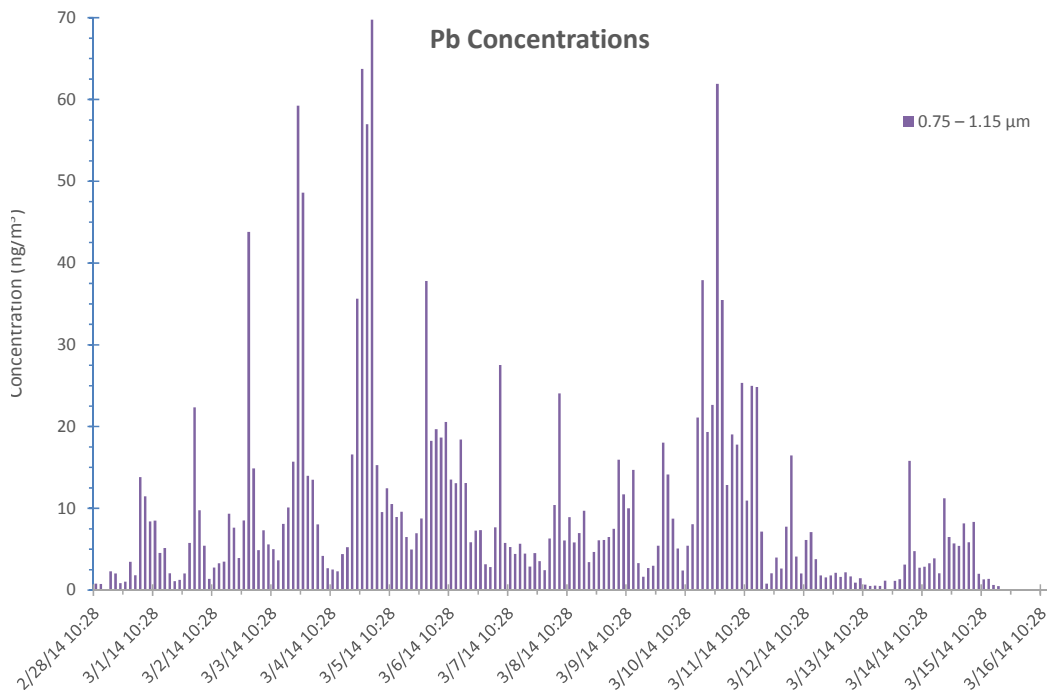


Fig. C-411 CaPh 34 DRUM: Pb mass stage 4

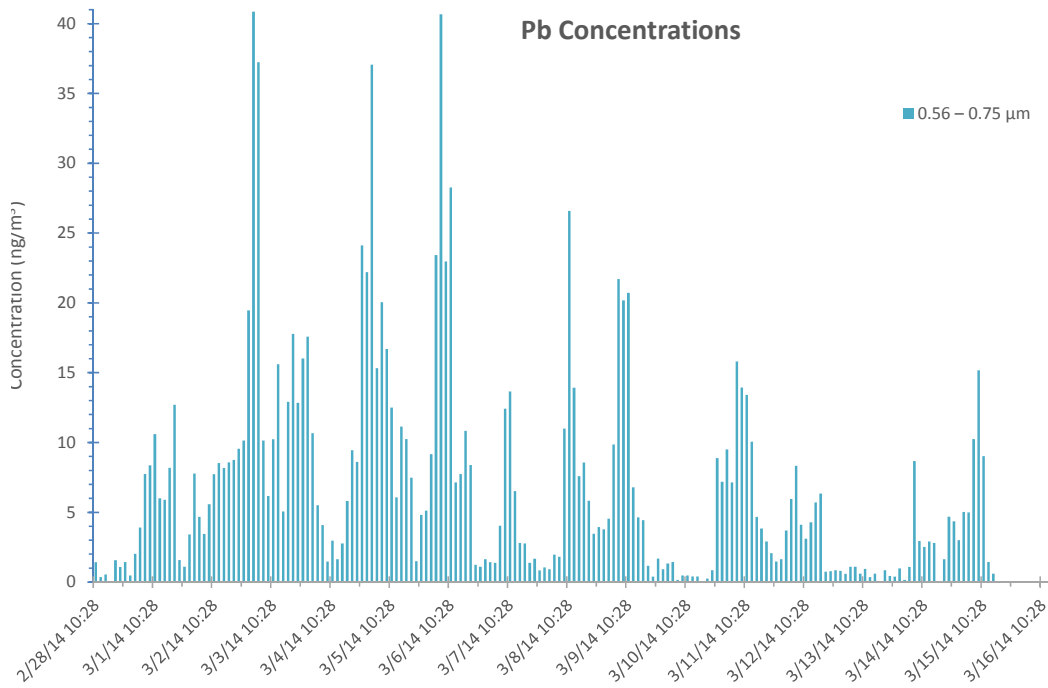


Fig. C-412 CaPh 34 DRUM: Pb mass stage 5

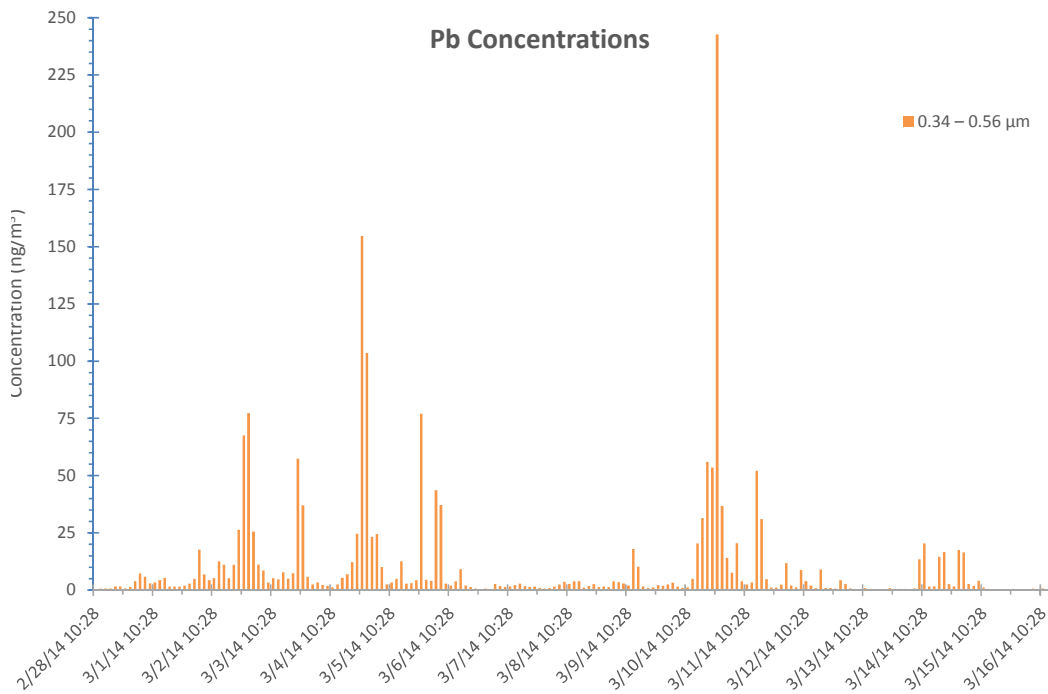


Fig. C-413 CaPh 34 DRUM: Pb mass stage 6

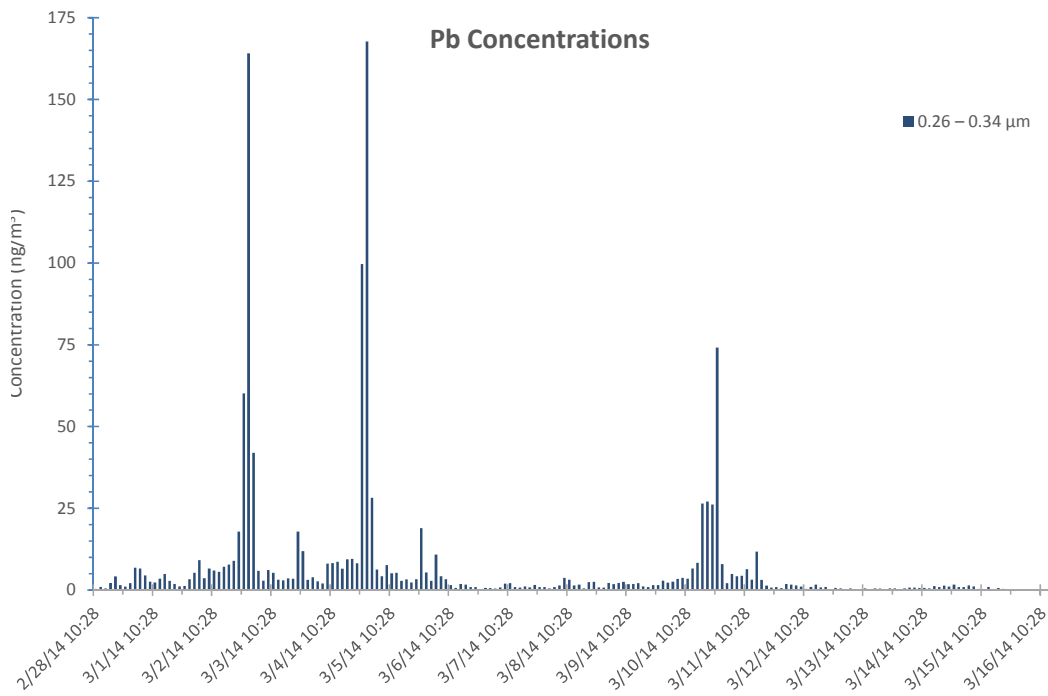


Fig. C-414 CaPh 34 DRUM: Pb mass stage 7

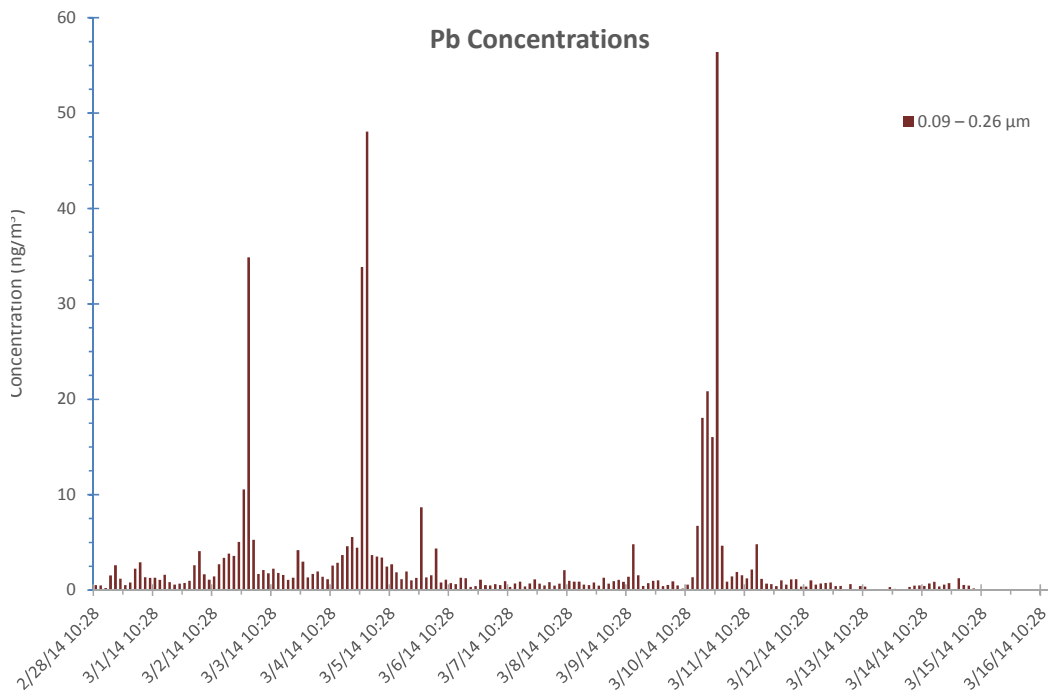


Fig. C-415 CaPh 34 DRUM: Pb mass stage 8

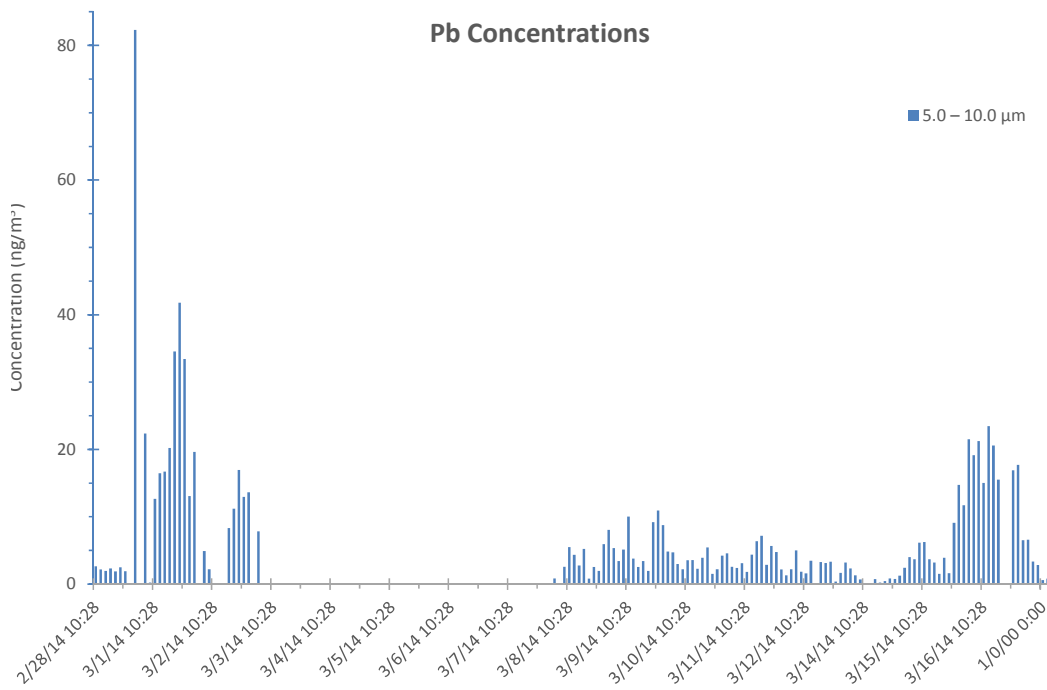


Fig. C-416 CaPh 32 DRUM: Pb mass stage 1

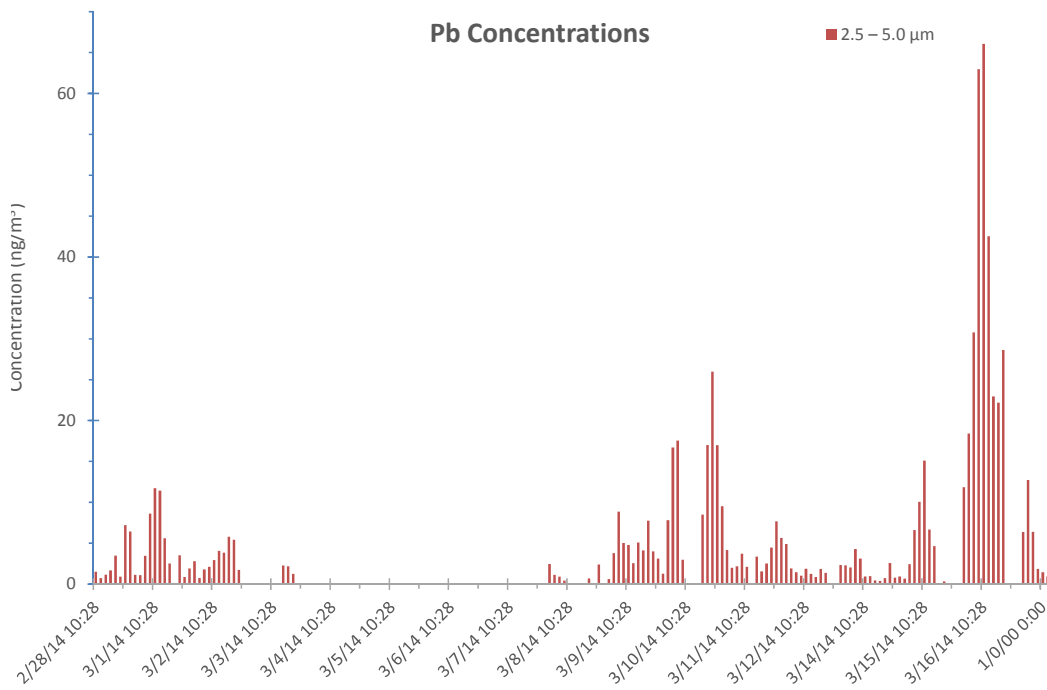


Fig. C-417 CaPh 32 DRUM: Pb mass stage 2

Approved for public release; distribution is unlimited.

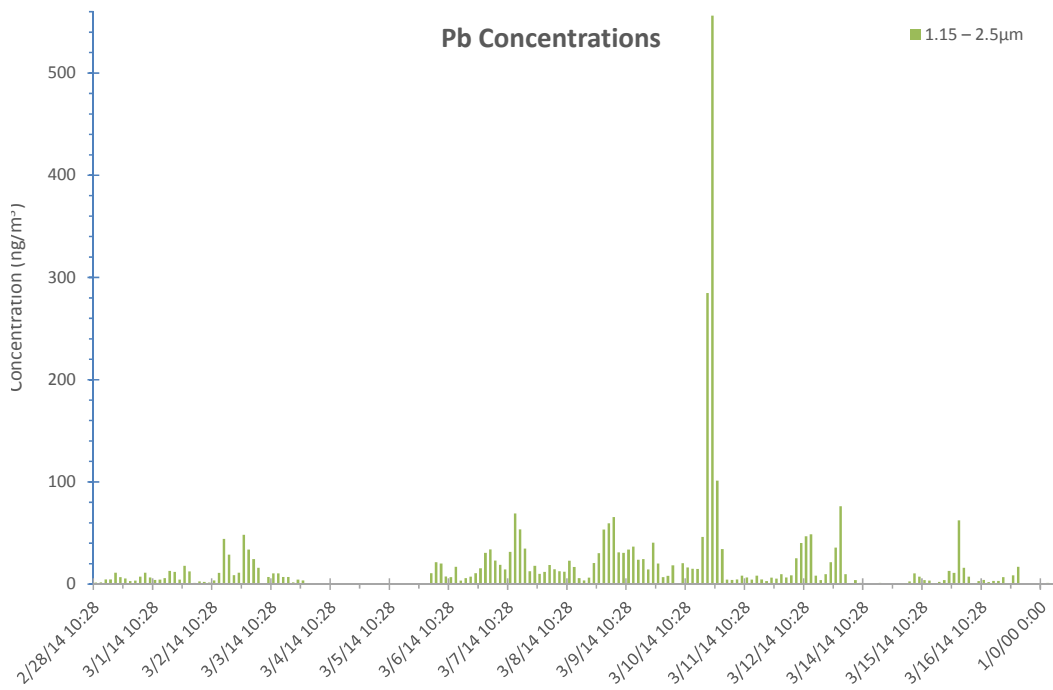


Fig. C-418 CaPh 32 DRUM: Pb mass stage 3

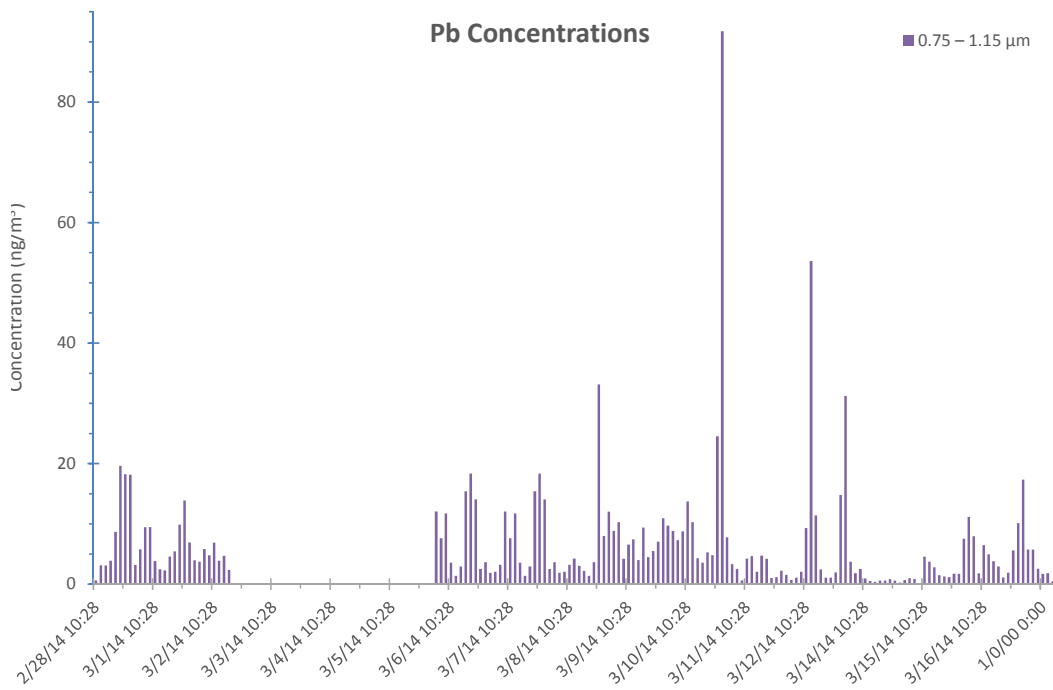


Fig. C-419 CaPh 32 DRUM: Pb mass stage 4

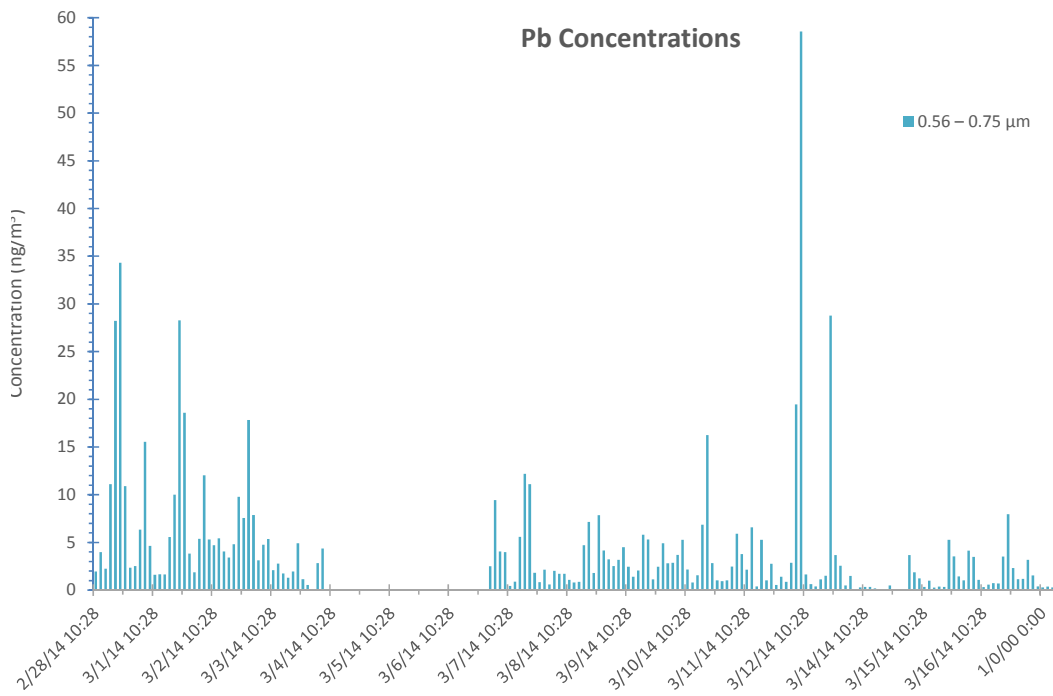


Fig. C-420 CaPh 32 DRUM: Pb mass stage 5

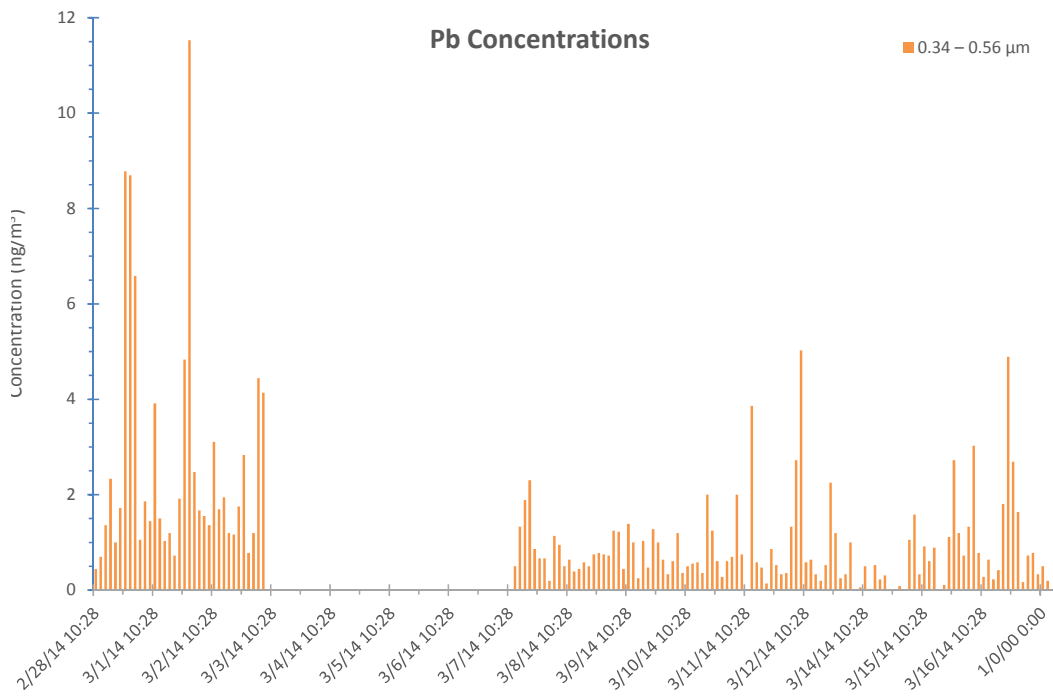


Fig. C-421 CaPh 32 DRUM: Pb mass stage 6

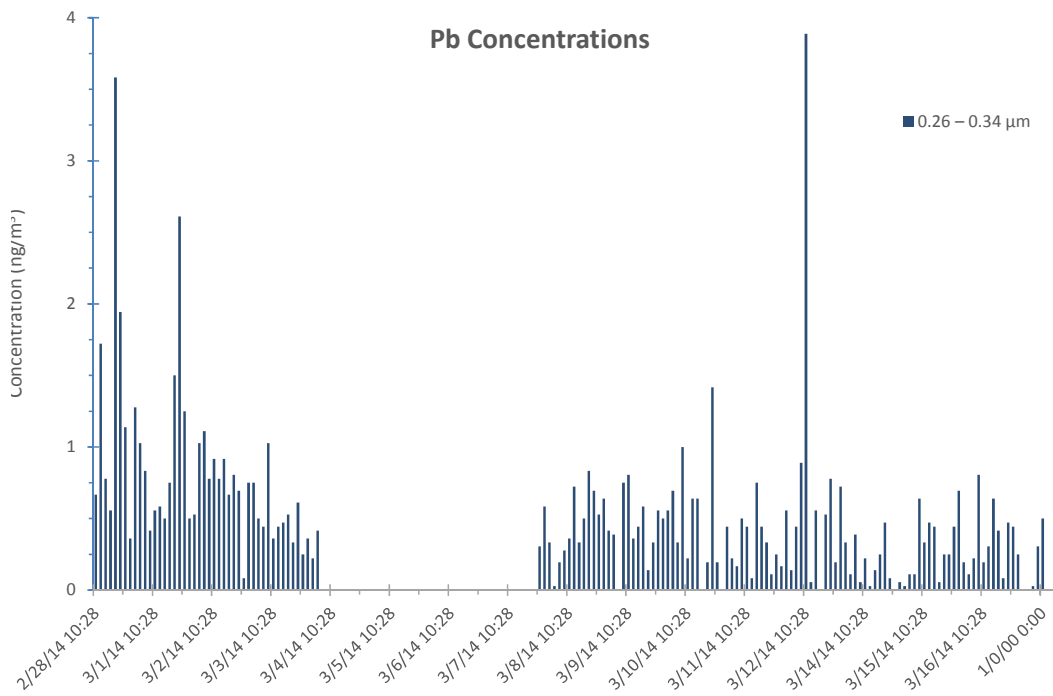


Fig. C-422 CaPh 32 DRUM: Pb mass stage 7

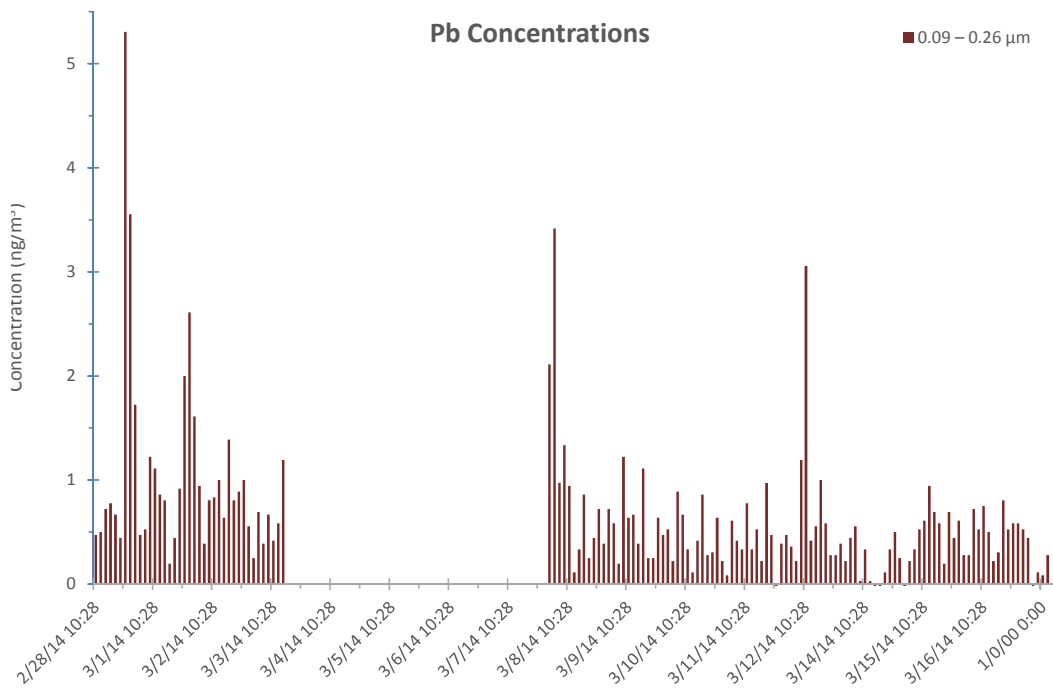


Fig. C-423 CaPh 32 DRUM: Pb mass stage 8

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Appendix D. Daily Plots

All times were originally recorded in UTC. Each day's plots includes a weather summary, HYSPLIT back trajectory, aethalometer, and DRUM β -gauge PM plots.

Each daily weather plot expands on the summary plot of Fig. 5 in Section 3.3.3 with a plot for each individual day. These plots indicate local time in Kabul and include, for context, 12 h of the preceding and the following local day.

The HYSPLIT plot for each day of the data collection shows the previous 84 h backward trajectory of the air arriving in Kabul at 1630 local time (1200 UTC) each day. Both the horizontal and vertical motion of the air is shown.

The DRUM plots show the β -gauge measured size-resolved contributions to PM_{10} , $PM_{2.5}$, and PM_1 .

D-1 28 February 2014

The air arriving spent the previous 8 h near the surface and immediately southwest of the airport after arriving from a higher altitude of 3,500 m above ground level (AGL) in the Archi district of Kunduz province in the north arriving from the west near Sheberghan in Jowzana province. There is only about an hour of aethalometer data from the evening.

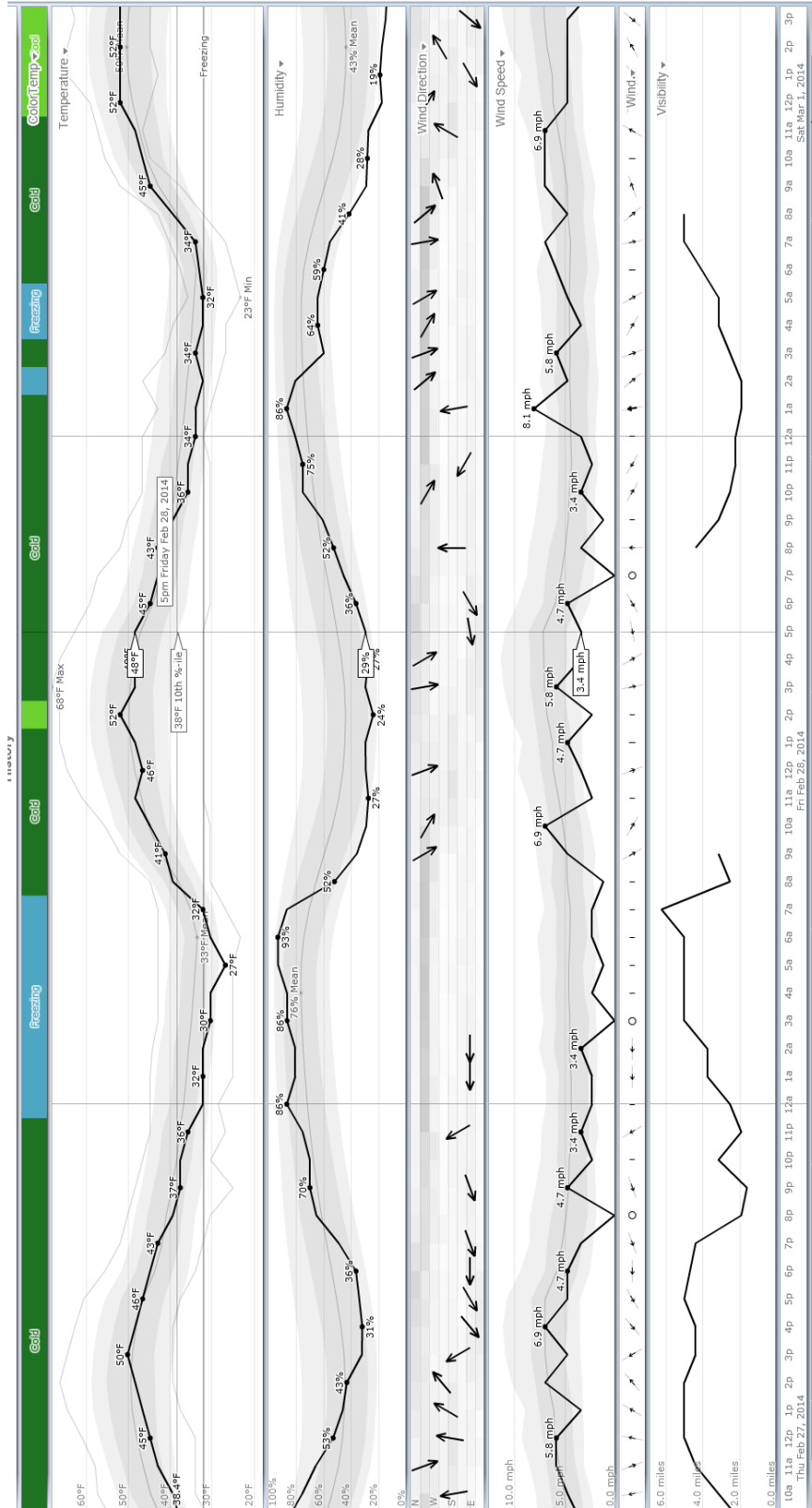


Fig. D-1 Kabul weather summary: 28 Feb 2014

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 28 Feb 14
 GDAS Meteorological Data

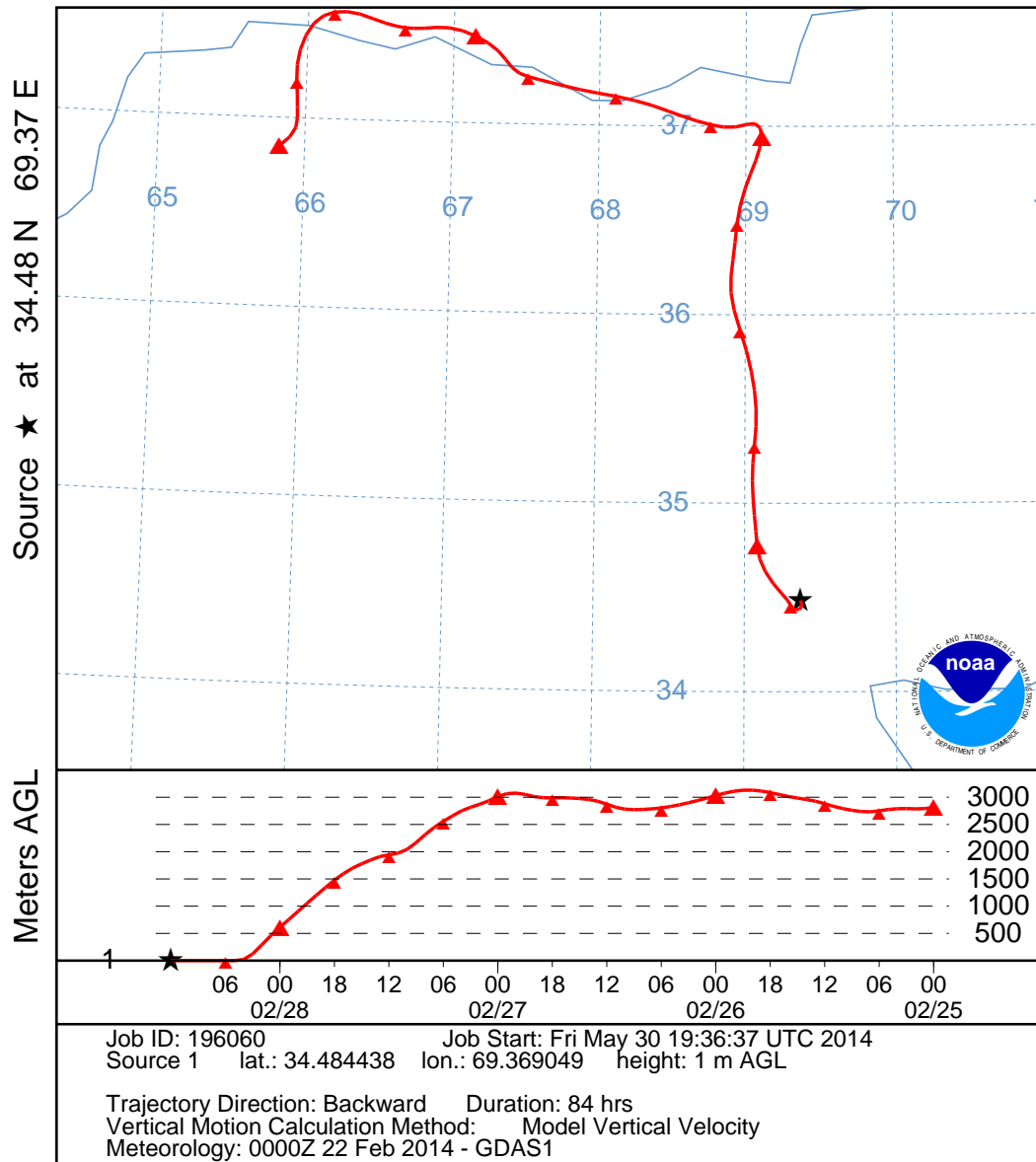


Fig. D-2 HYSPLIT back trajectory 28 Feb 2014

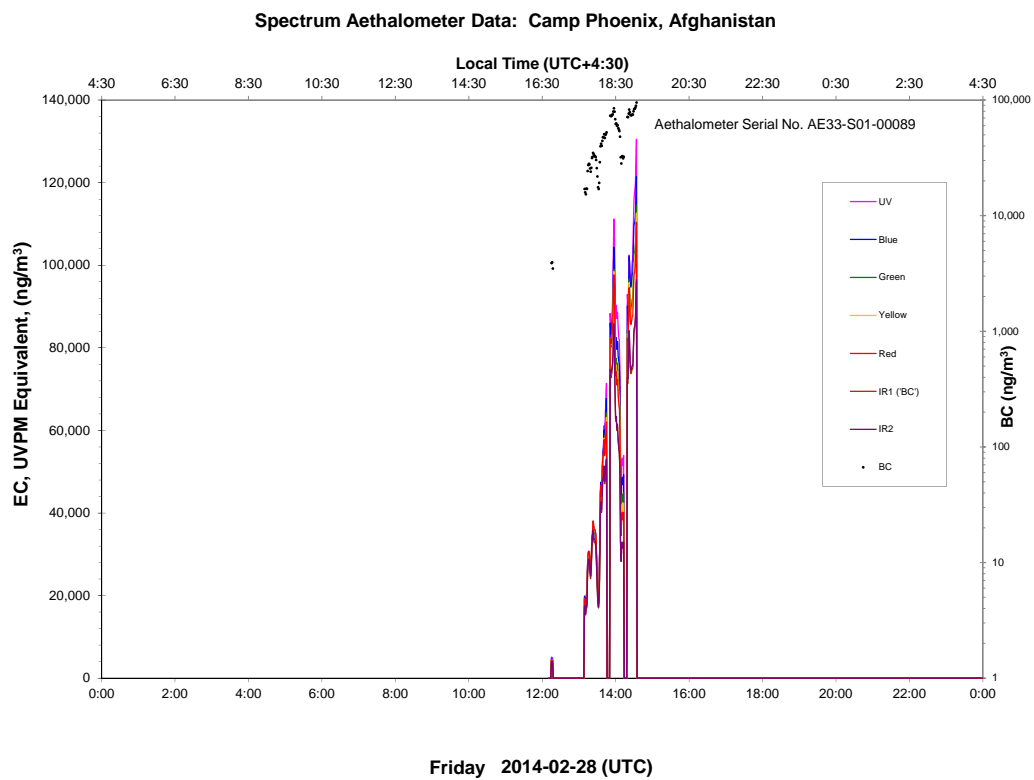


Fig. D-3 Aethalometer measured black carbon: 28 Feb 2014

D-2 01 March 2014

The air arriving spent the previous 30 h near the surface arriving from the south after traveling eastward from central Maidan Wardak province after descending from near 2,500 m AGL altitudes in the north of Kunduz province and the Shortepa district of Balkh province.

There are about 4 h of aethalometer data from 1330–1530 local time and an additional 20 min from 1800–1820 local time.

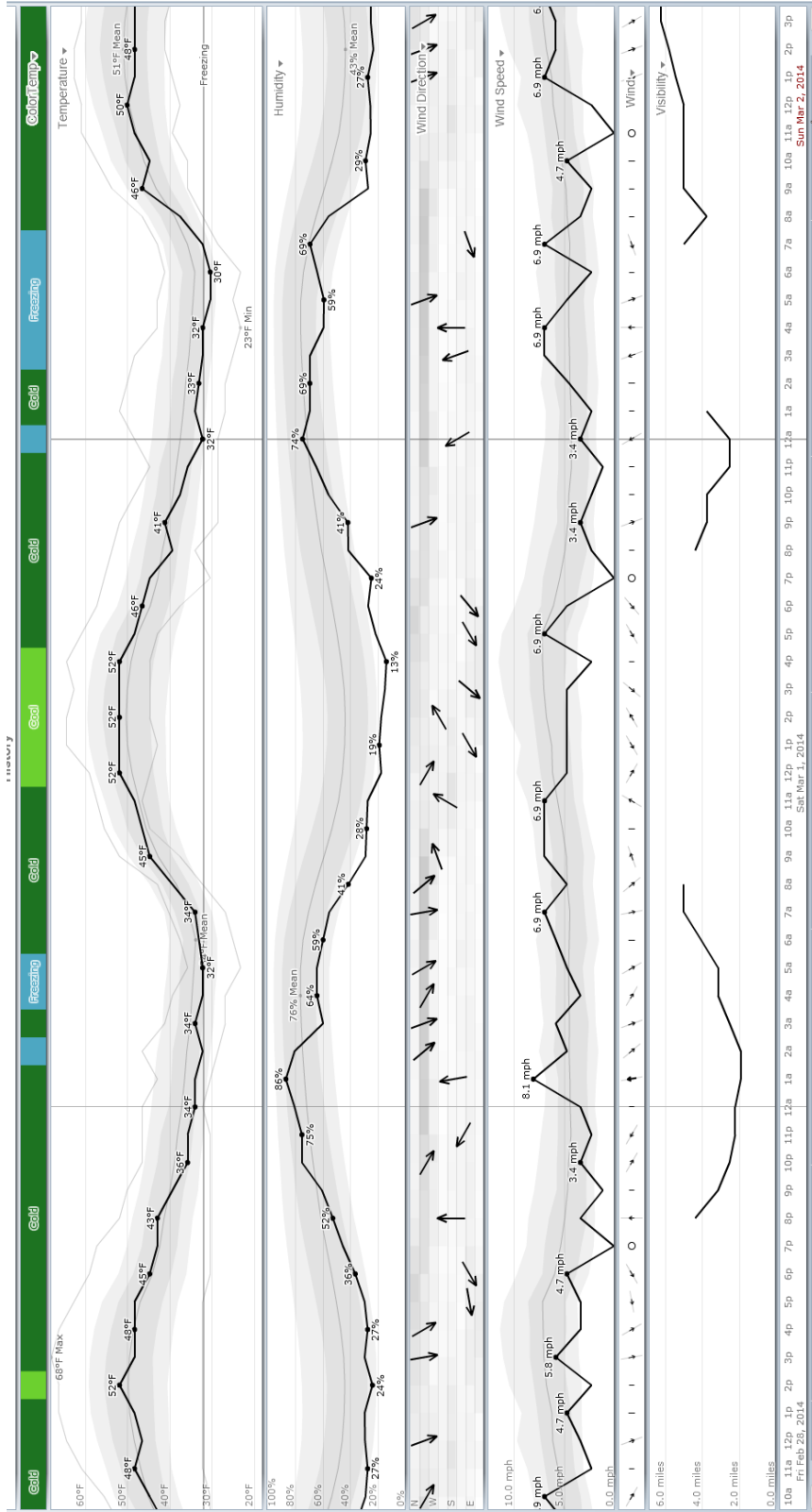


Fig. D-4 Kabul weather summary: 01 Mar 2014

Approved for public release; distribution is unlimited.

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 01 Mar 14
 GDAS Meteorological Data

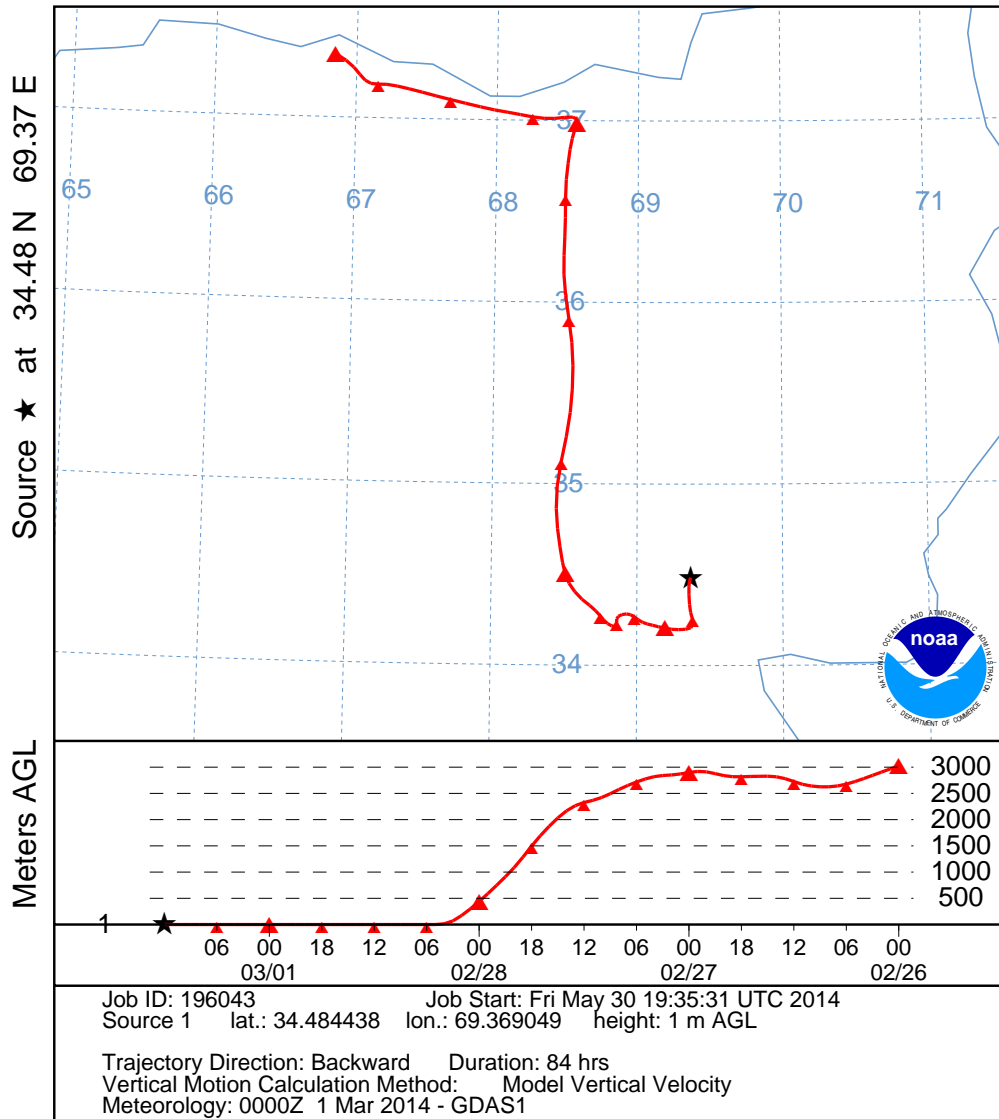


Fig. D-5 HYSPLIT back trajectory 01 Mar 2014

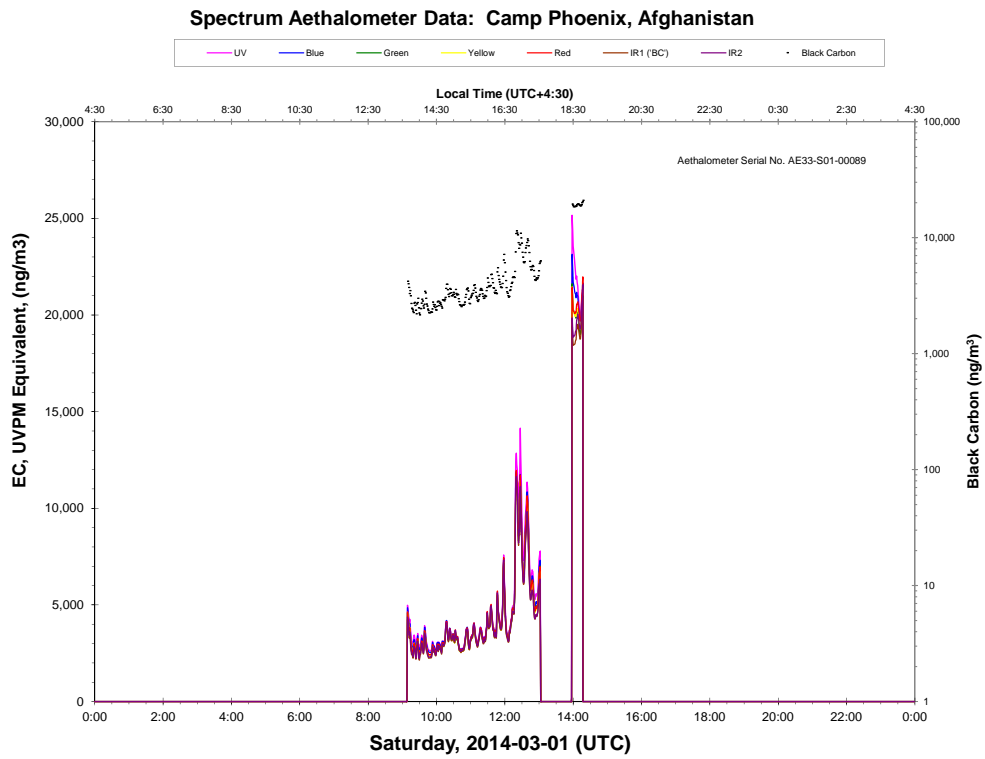
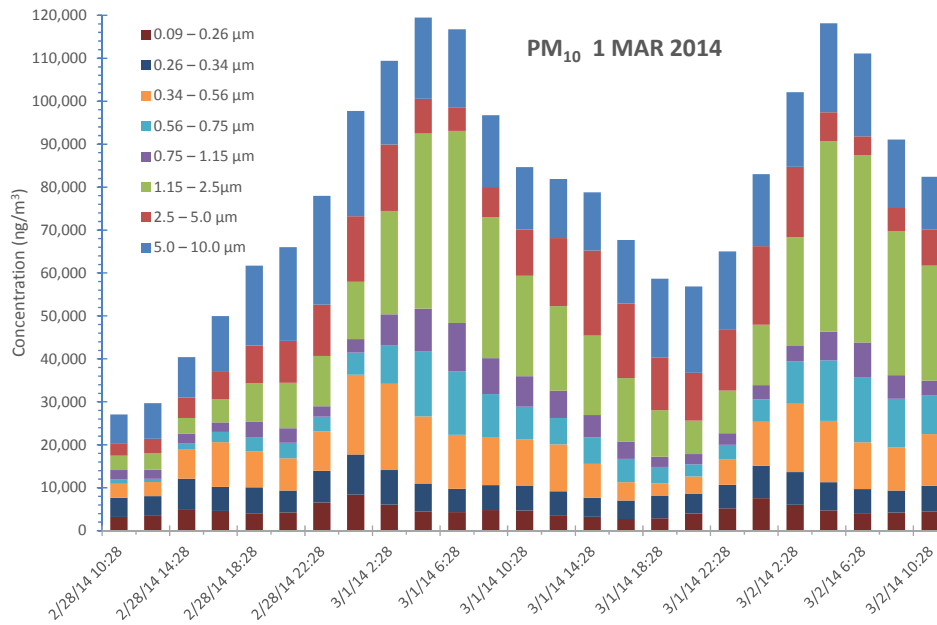
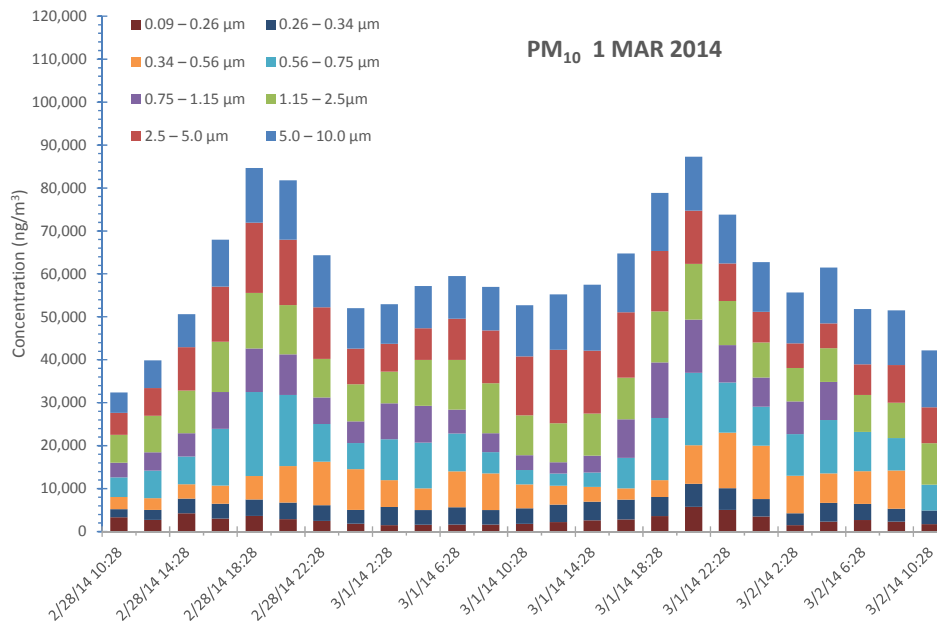


Fig. D-6 Aethalometer measured black carbon: 01 Mar 2014

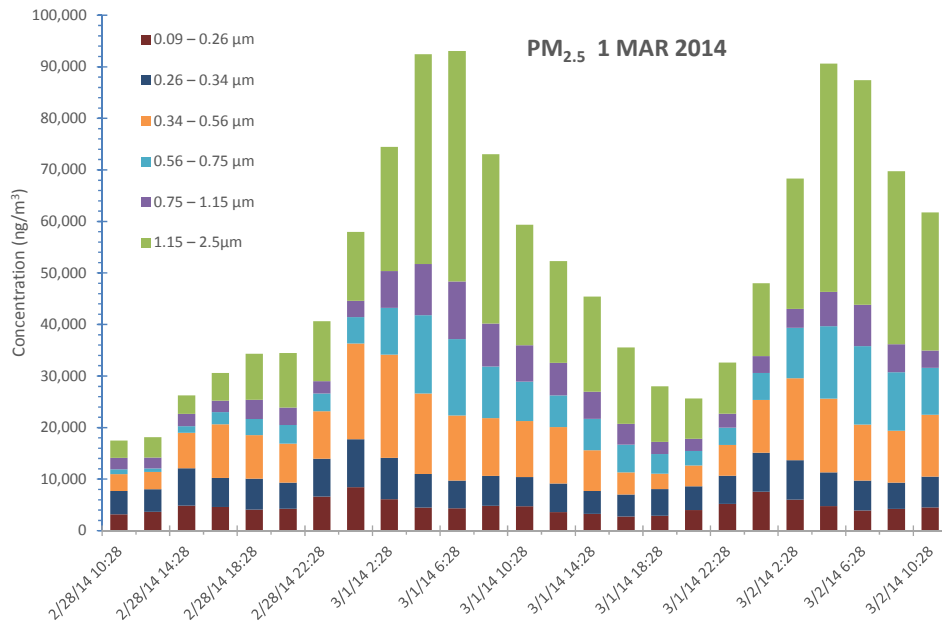


a) DRUM CaPh 34: PM₁₀ size resolved

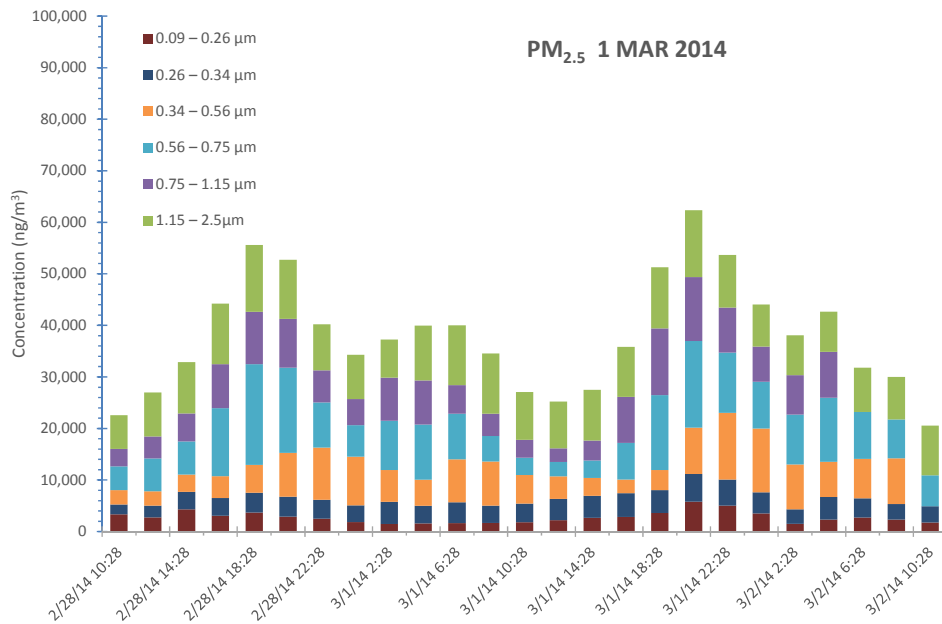


b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-7 DRUM β -gauge measured PM₁₀ size resolved: 01 Mar 2014; (a) CaPh 34, (b) CaPh 32

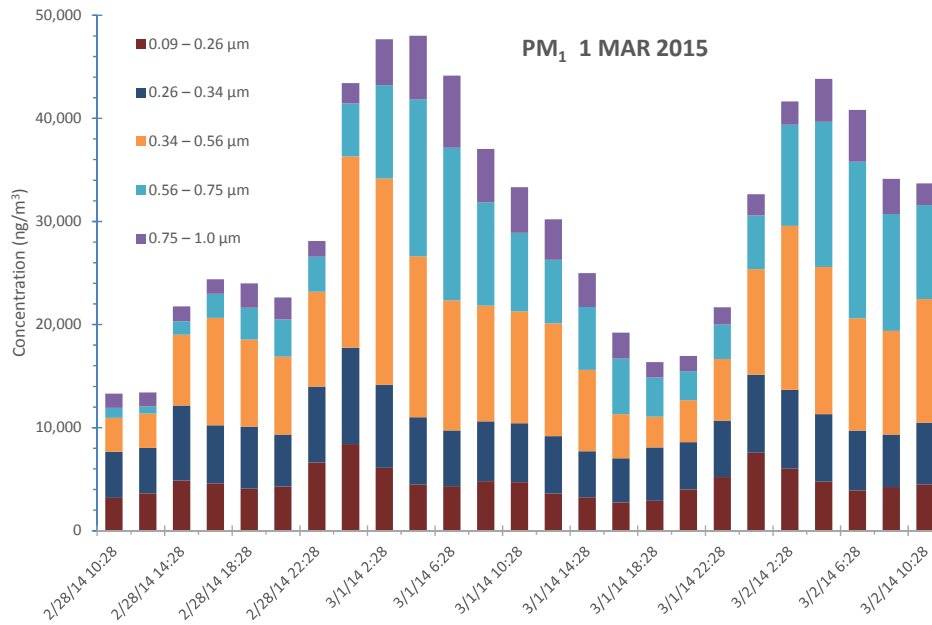


a) DRUM PM_{2.5} size resolved

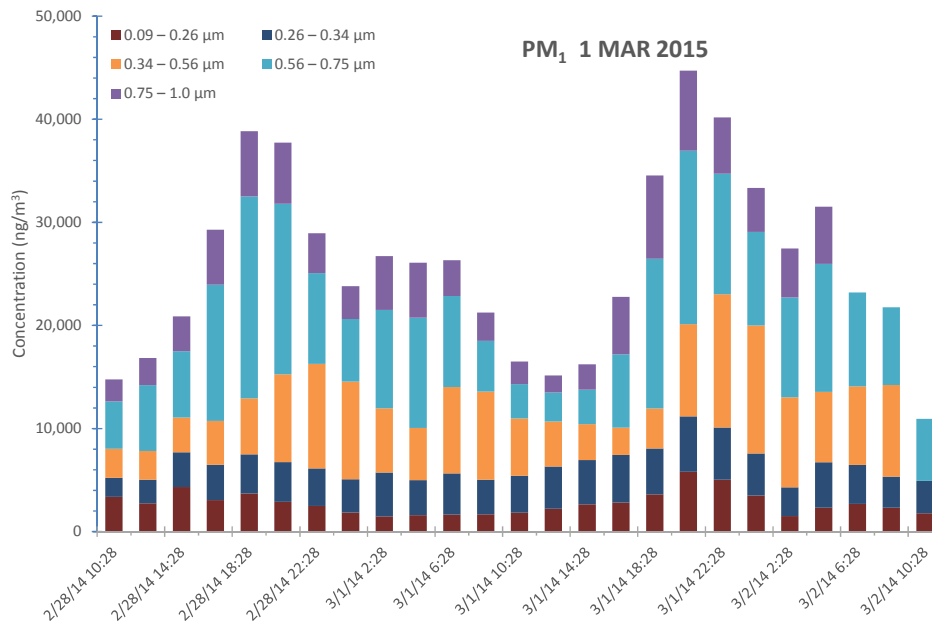


b) DRUM PM_{2.5} size resolved

Fig. D-8 DRUM β -gauge measured PM_{2.5} size resolved: 01 Mar 2014; (a) CaPh 34, (b) CaPh 32



a) DRUM PM₁ size resolved



b) DRUM PM₁ size resolved

Fig. D-9 DRUM β -gauge measured PM₁ size resolved: 01 Mar 2014; (a) CaPh 34, (b) CaPh 32

D-3 02 March 2014

The air arriving spent the previous 60 h near the surface arriving from the south near Pul-i-Alam in Logar province after traveling from the west in the Nawur district in northern Ghazni province. Prior to that the air mass had traveled from the north, descending from 2,500 m AGL.

There are aethalometer data from 1030–1330 and from 1515–0430 on 3 March (local times).

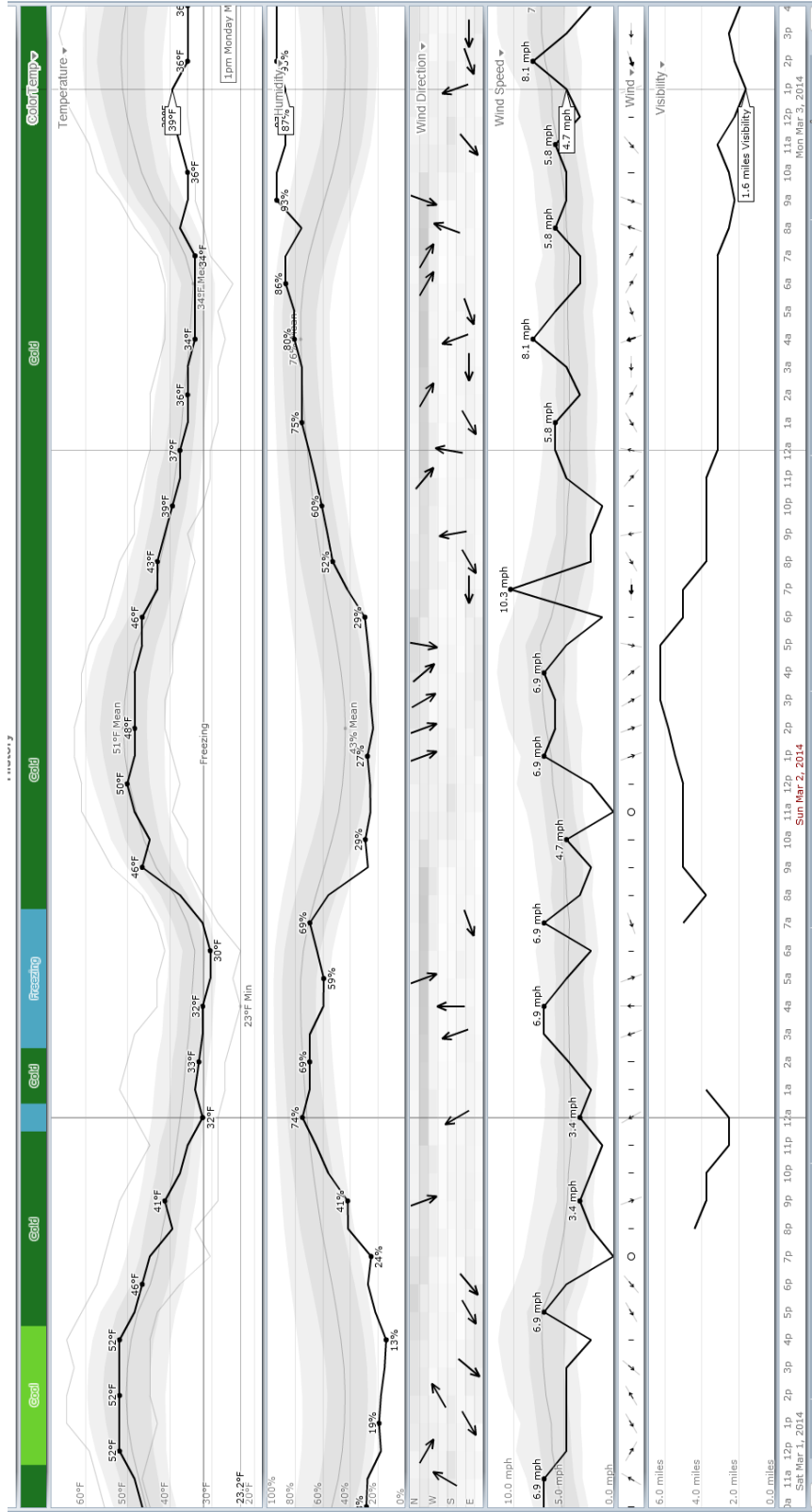


Fig. D-10 Kabul weather summary: 02 Mar 2014

Approved for public release; distribution is unlimited.

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 02 Mar 14
 GDAS Meteorological Data

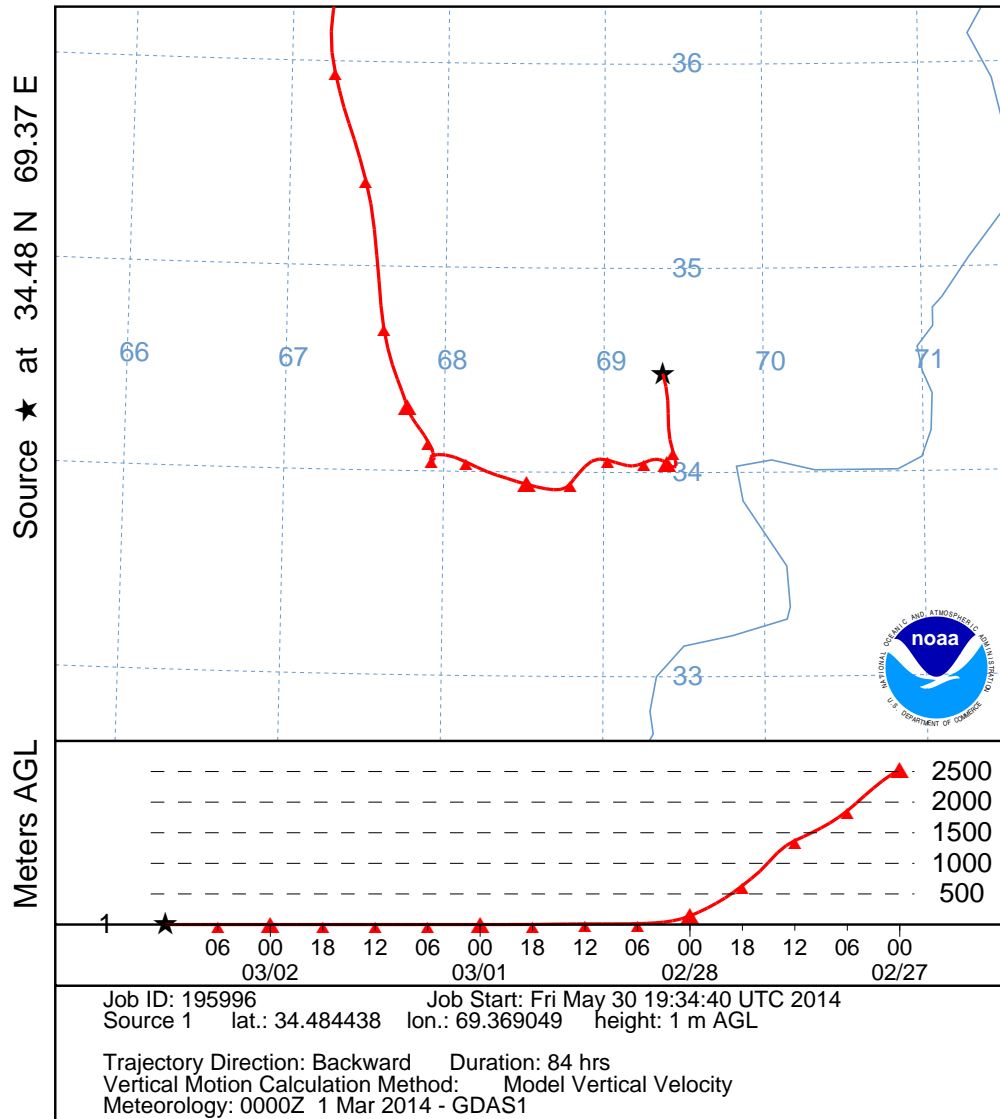


Fig. D-11 HYSPLIT back trajectory 02 Mar 2014

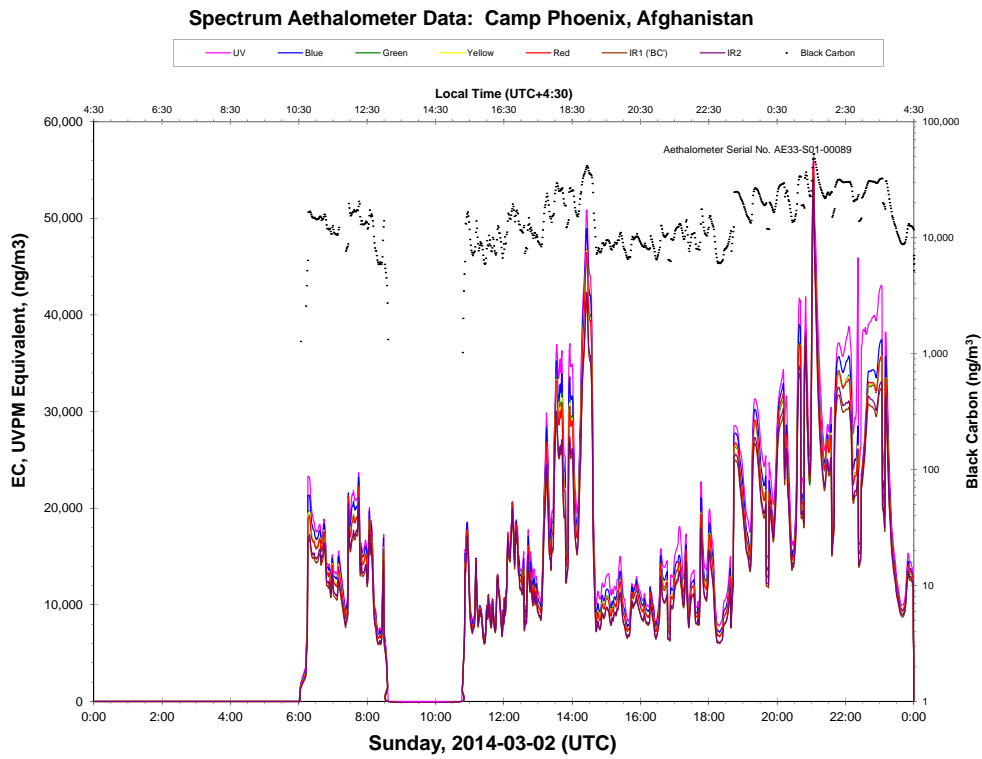
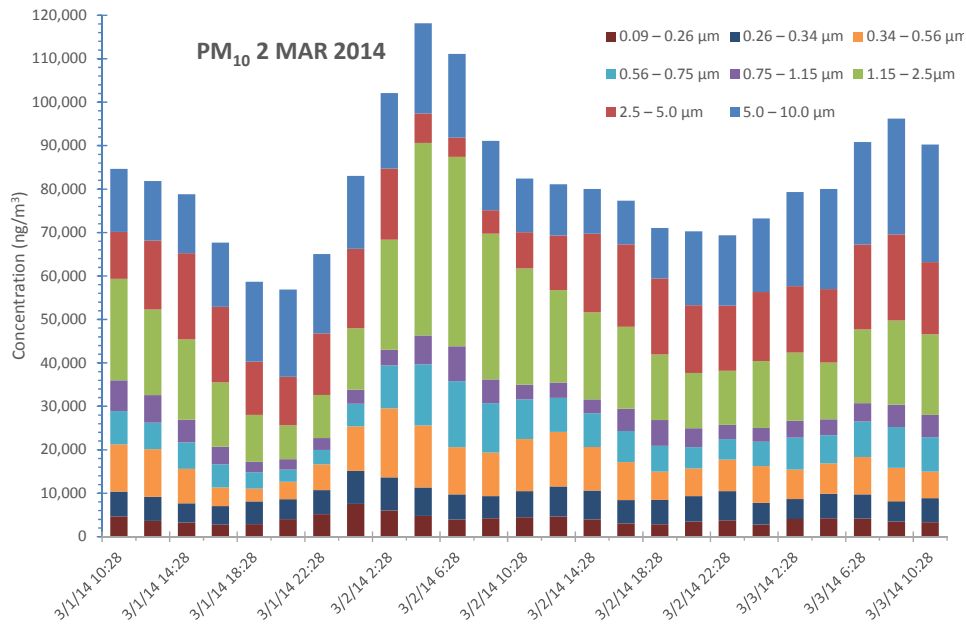
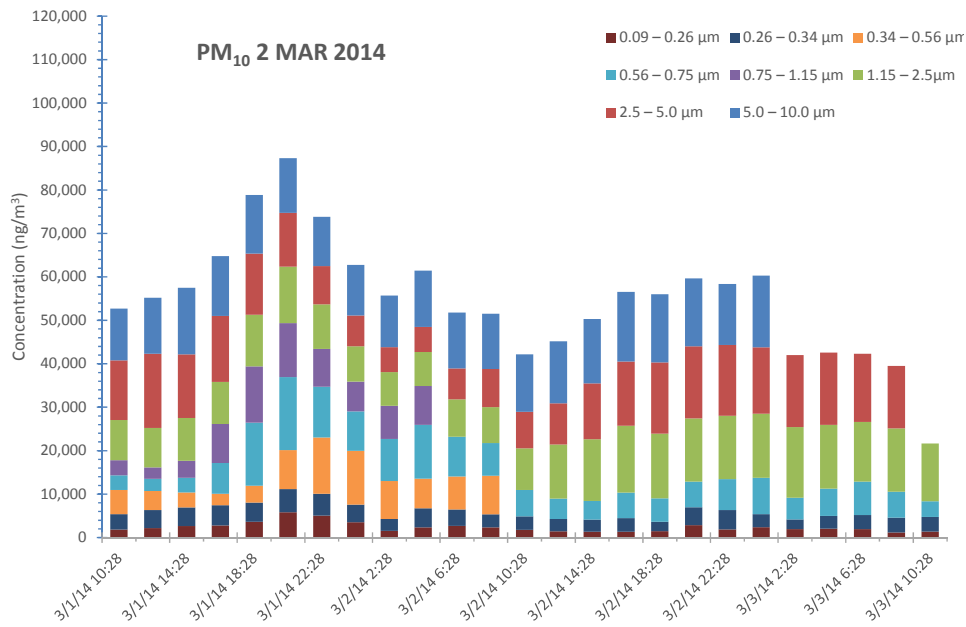


Fig. D-12 Aethalometer measured black carbon: 02 Mar 2014



a) DRUM CaPh 34: PM₁₀ size resolved



b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-13 DRUM β -gauge measured PM₁₀ size resolved: 02 Mar 2014; (a) CaPh 34, (b) CaPh 32

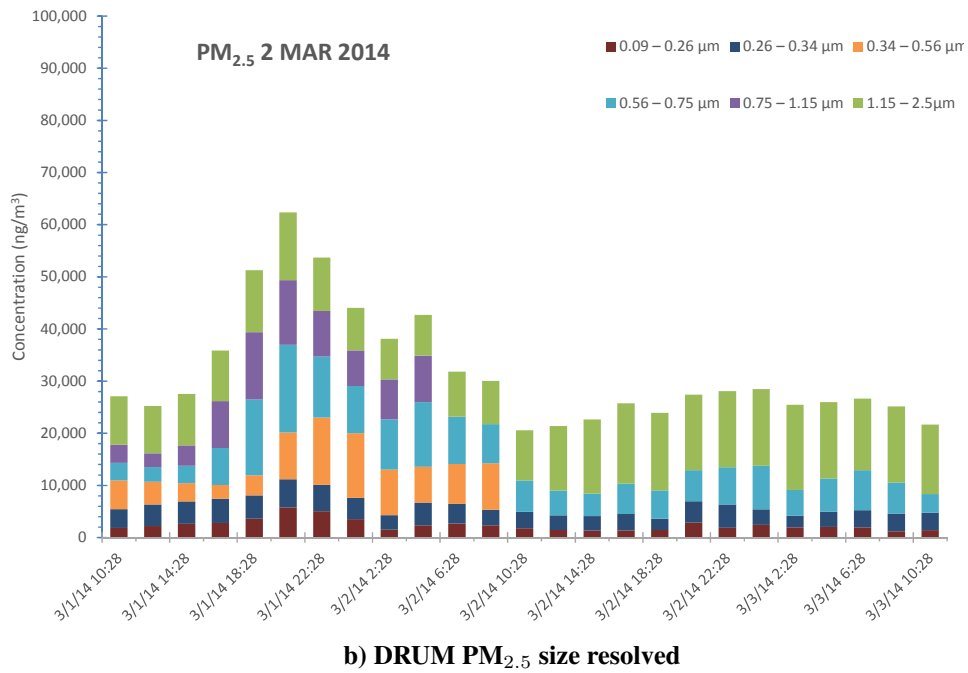
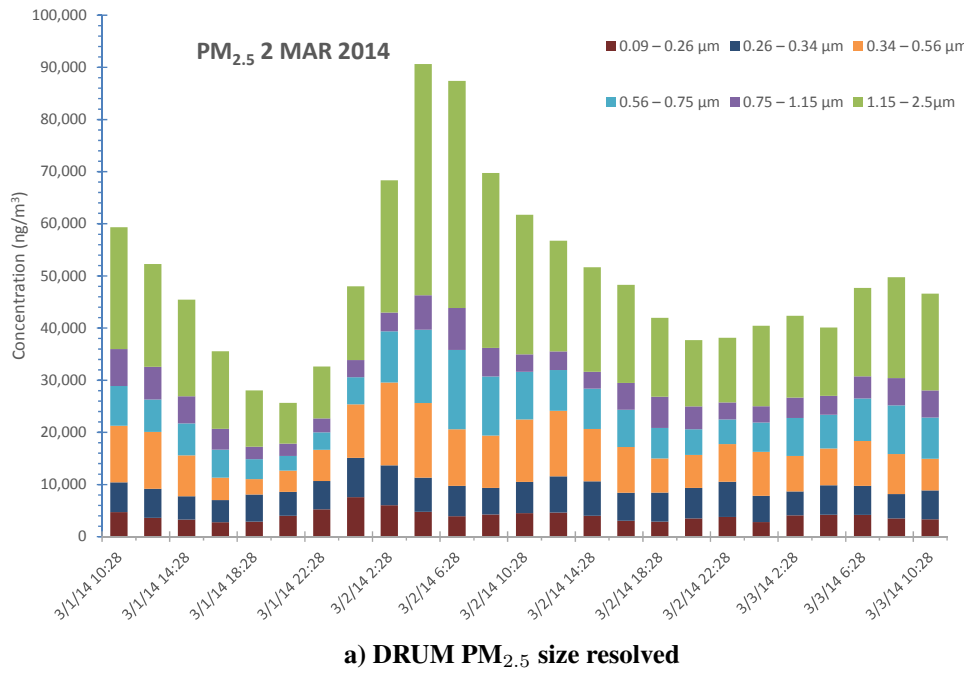
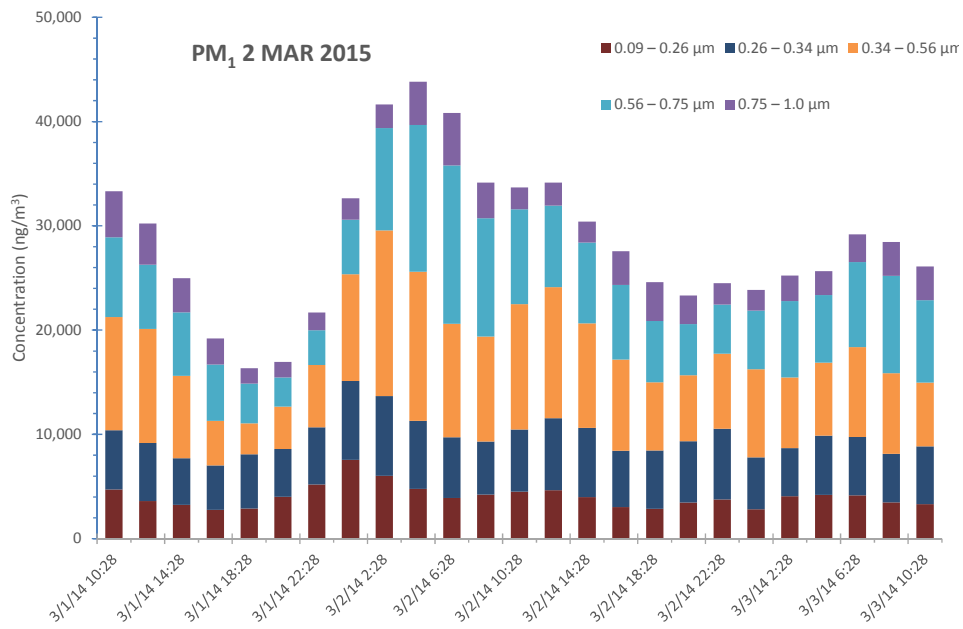
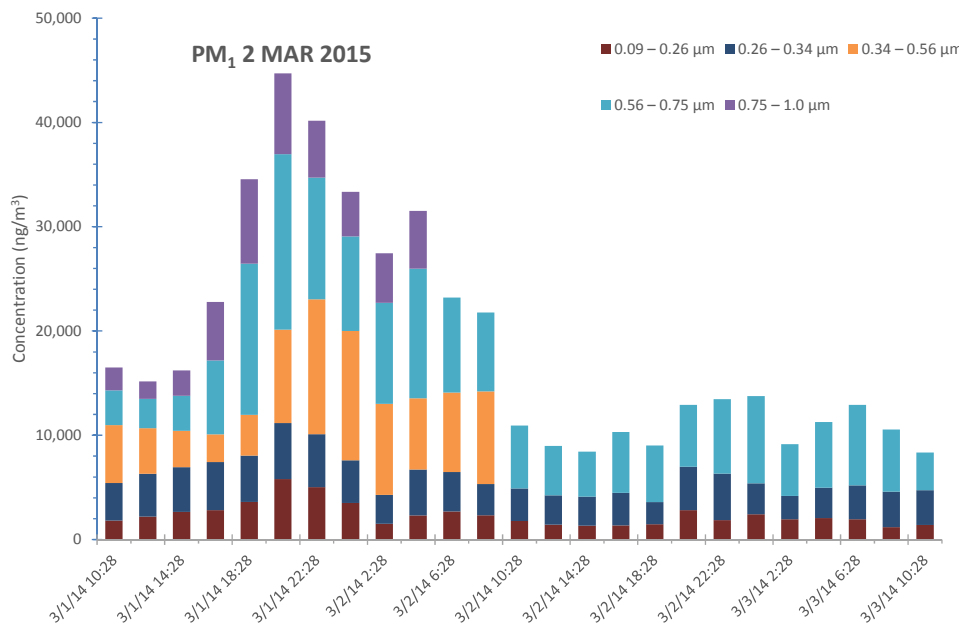


Fig. D-14 DRUM β -gauge measured PM_{2.5} size resolved: 02 Mar 2014; (a) CaPh 34, (b) CaPh 32



a) DRUM PM₁ size resolved



b) DRUM PM₁ size resolved

Fig. D-15 DRUM β -gauge measured PM₁ size resolved: 02 Mar 2014; (a) CaPh 34, (b) CaPh 32

D-4 03 March 2014

The air arriving spent the previous 80 h near the surface backtracking from the southeast along the slopes of the mountains in southern Nangarhar province.

There are aethalometer data from 0430–1230 local time.

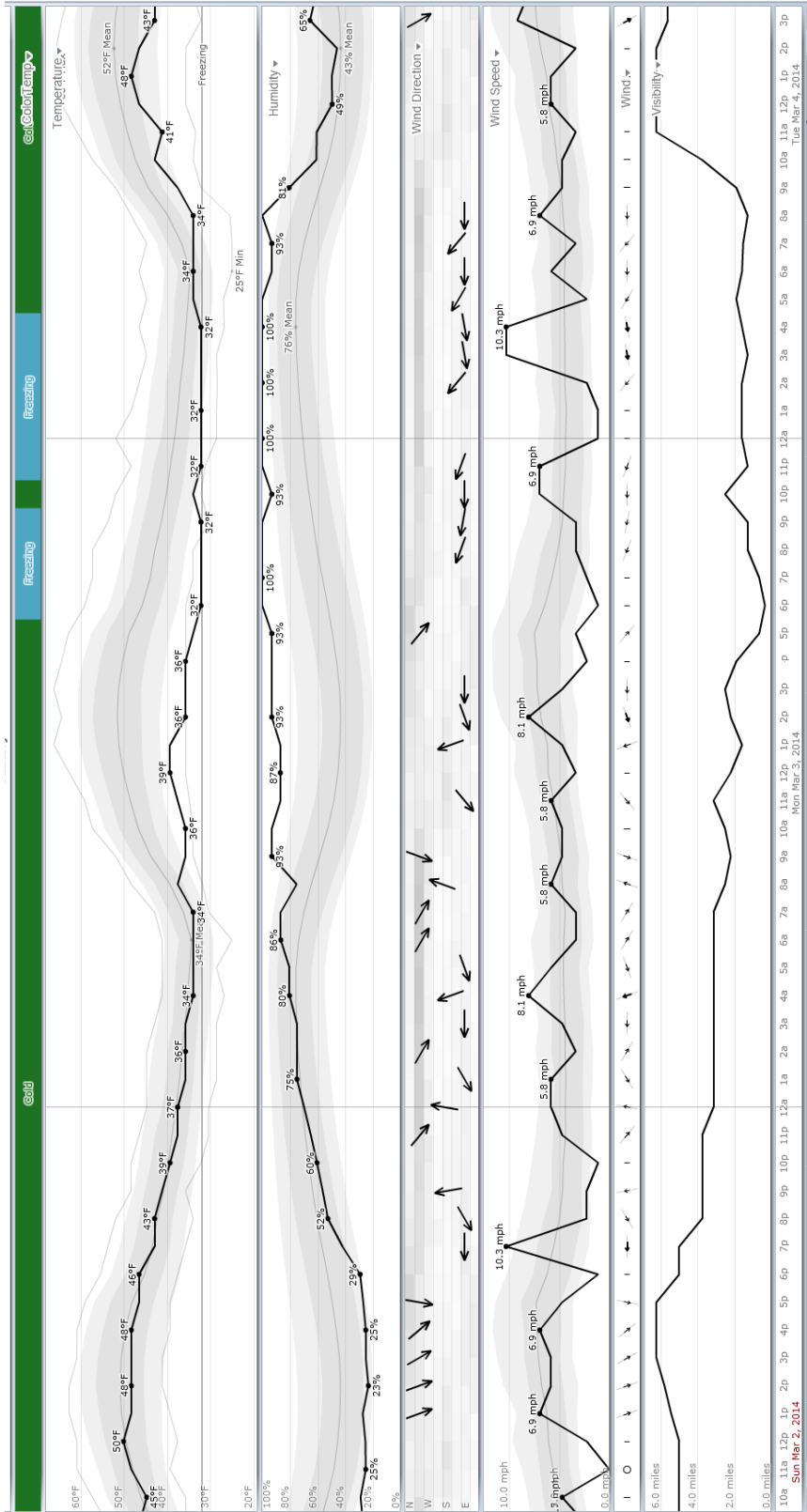


Fig. D-16 Kabul weather summary: 03 Mar 2014

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 03 Mar 14
 GDAS Meteorological Data

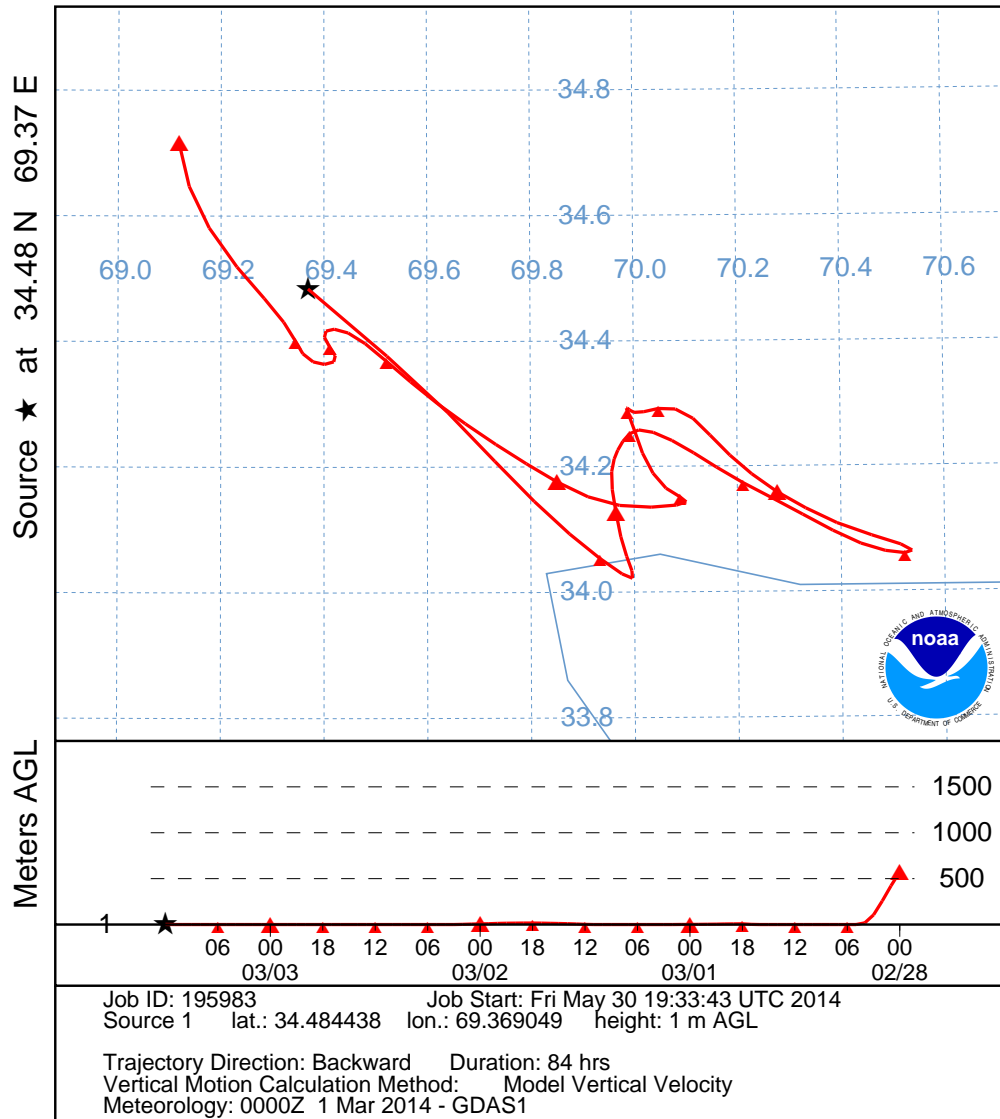


Fig. D-17 HYSPLIT back trajectory 03 Mar 2014

Spectrum Aethalometer Data: Camp Phoenix, Afghanistan

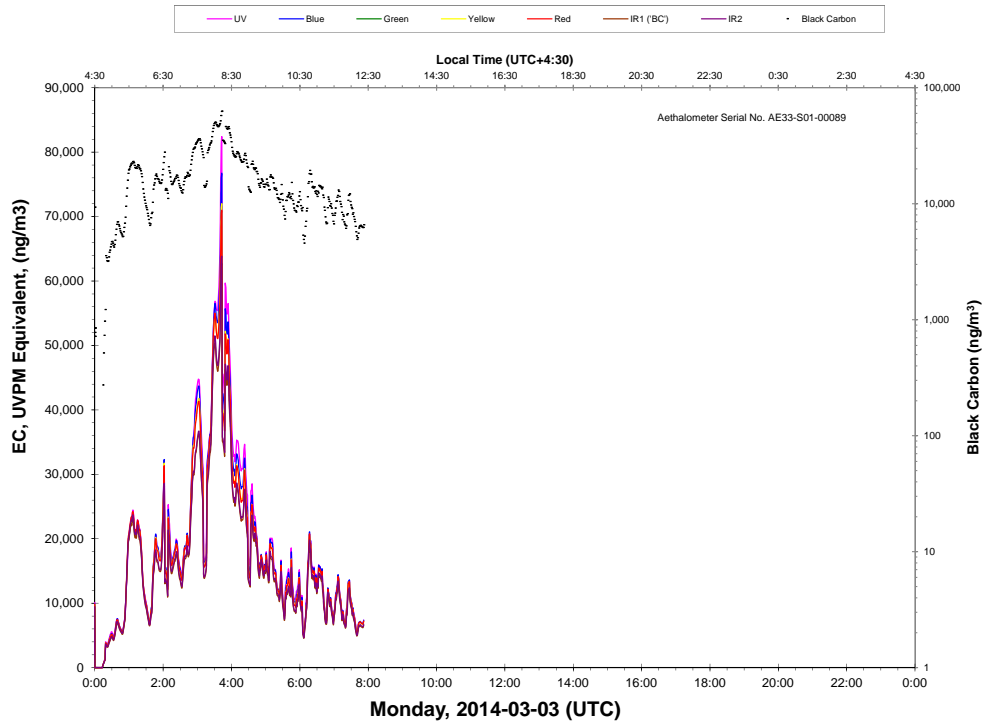
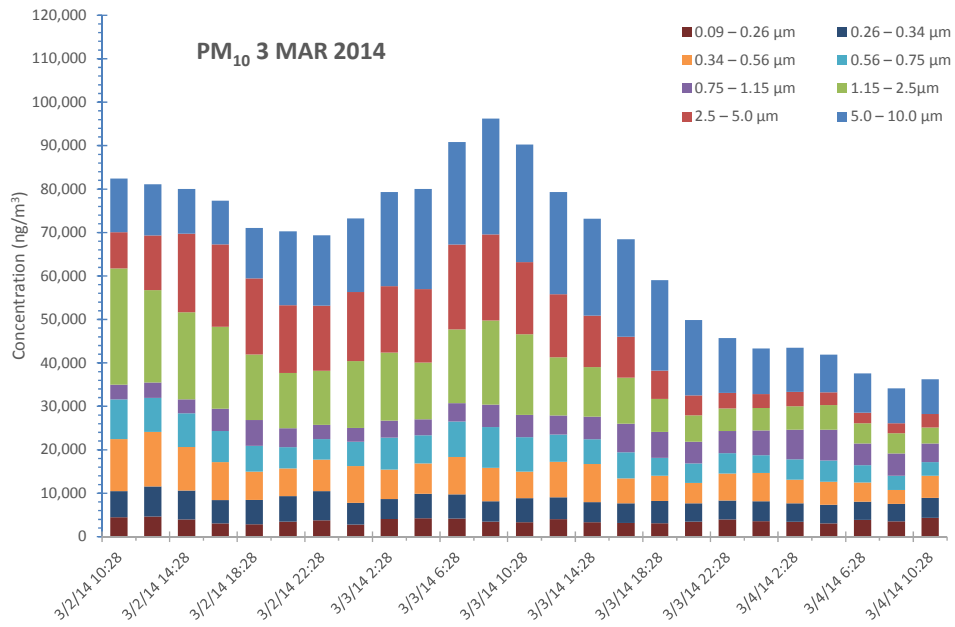
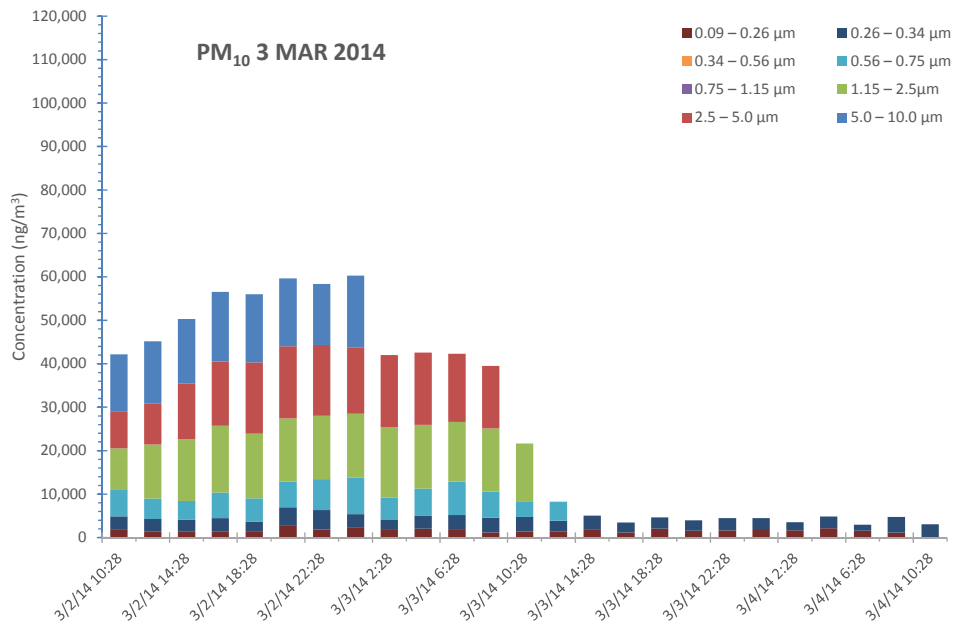


Fig. D-18 Aethalometer measured black carbon: 3 Mar 2014



a) DRUM CaPh 34: PM₁₀ size resolved



b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-19 DRUM β -gauge measured PM₁₀ size resolved: 03 Mar 2014; (a) CaPh 34, (b) CaPh 32

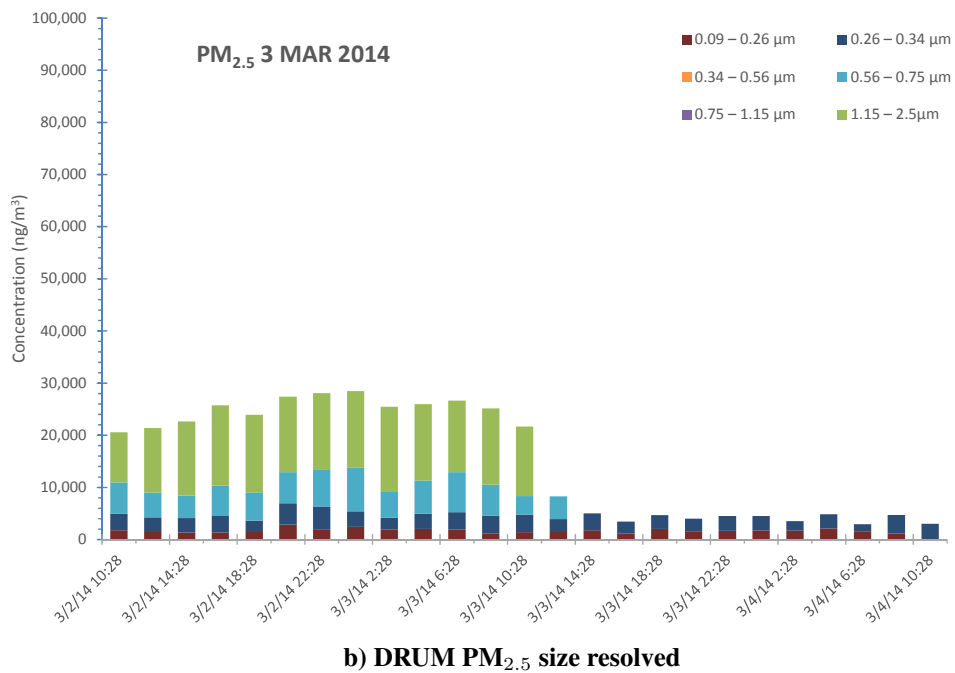
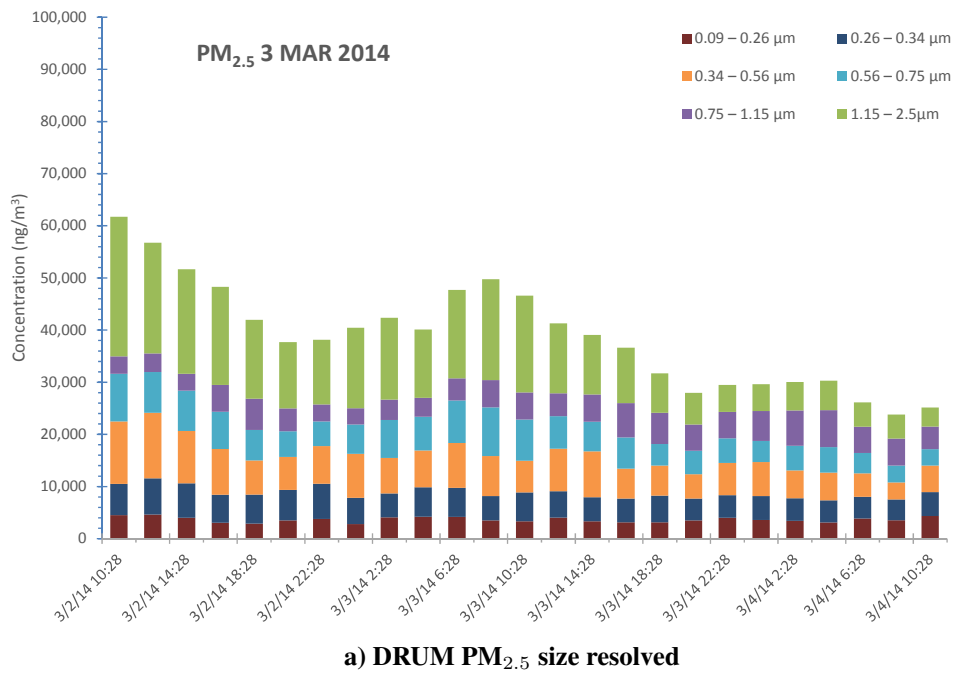
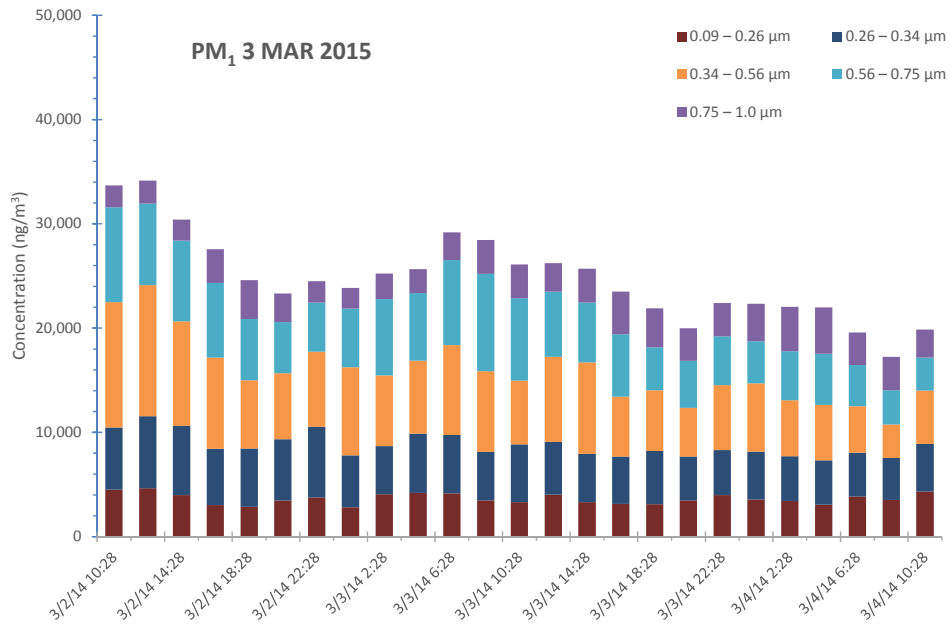
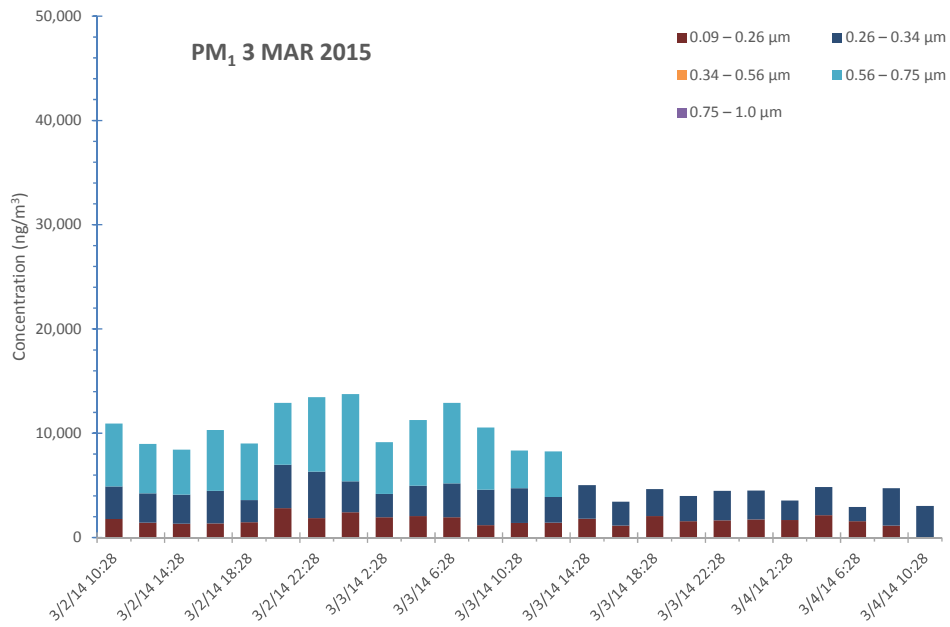


Fig. D-20 DRUM β -gauge measured PM_{2.5} size resolved: 03 Mar 2014; (a) CaPh 34, (b) CaPh 32



a) DRUM PM₁ size resolved



b) DRUM PM₁ size resolved

Fig. D-21 DRUM β -gauge measured PM₁ size resolved: 03 Mar 2014; (a) CaPh 34, (b) CaPh 32

D-5 04 March 2014

The air arriving spent the previous 84 h near the surface arriving from the south of the airport having traversed mountains arriving from the valley south of Jalalabad.

There are aethalometer data from 1030 until 0430 on 5 March (local times).

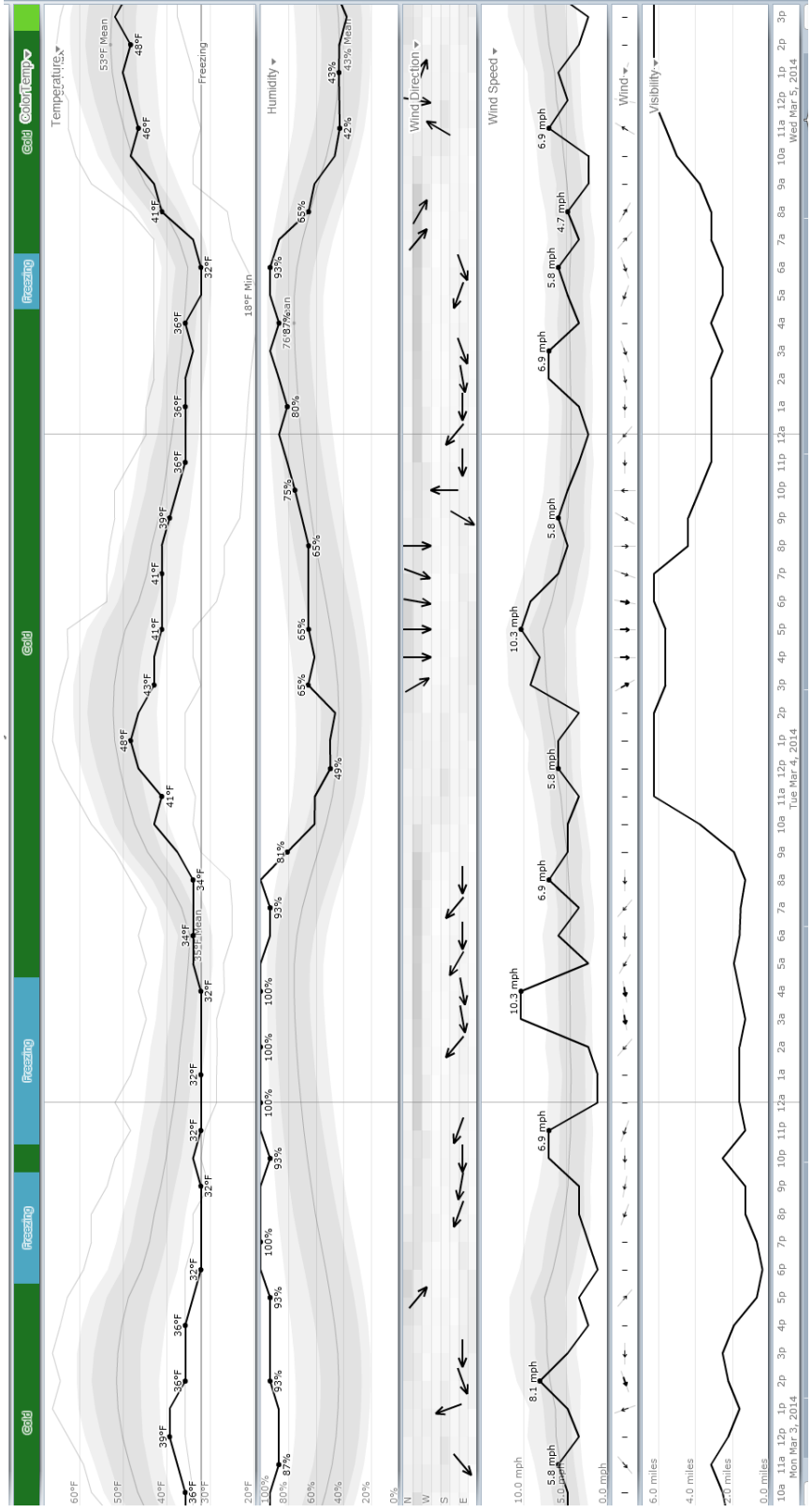


Fig. D-22 Kabul weather summary: 04 Mar 2014

Approved for public release; distribution is unlimited.

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 04 Mar 14
 GDAS Meteorological Data

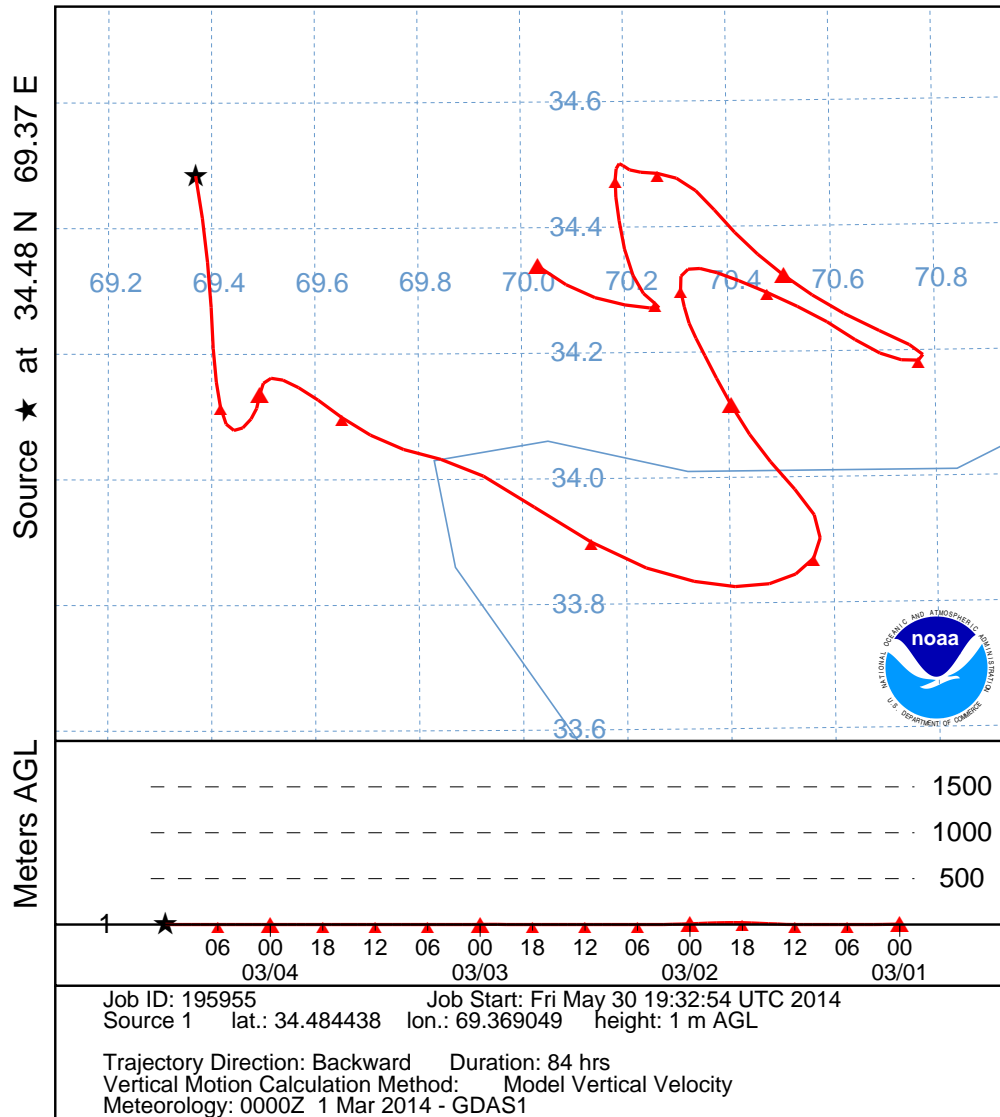


Fig. D-23 HYSPLIT back trajectory 04 Mar 2014

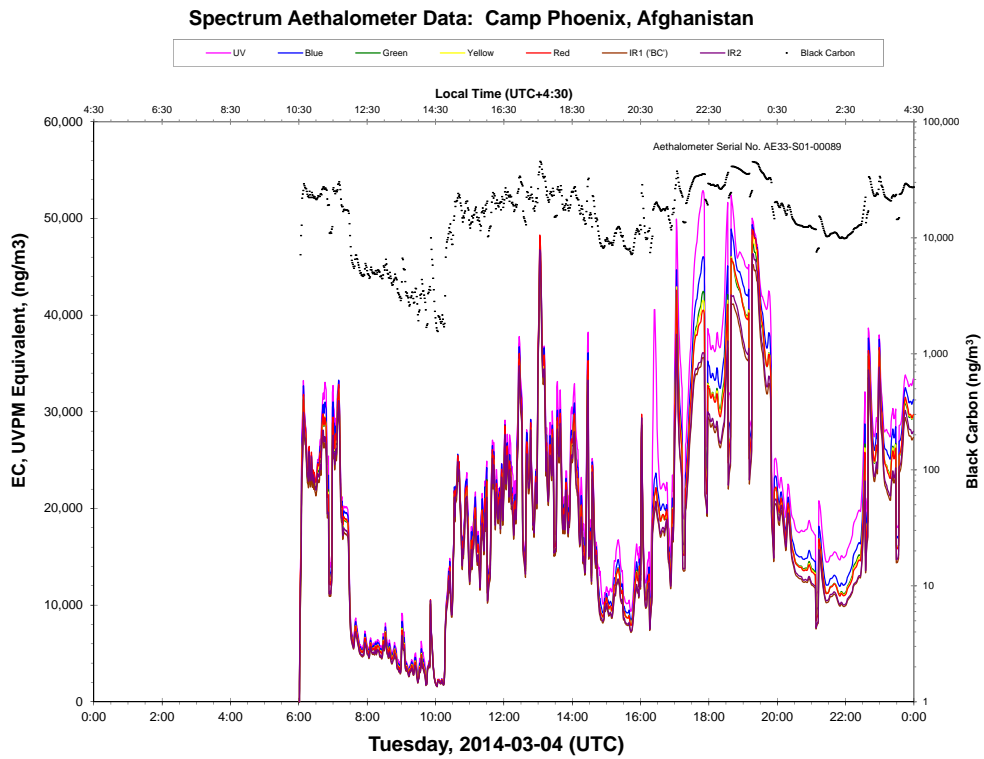
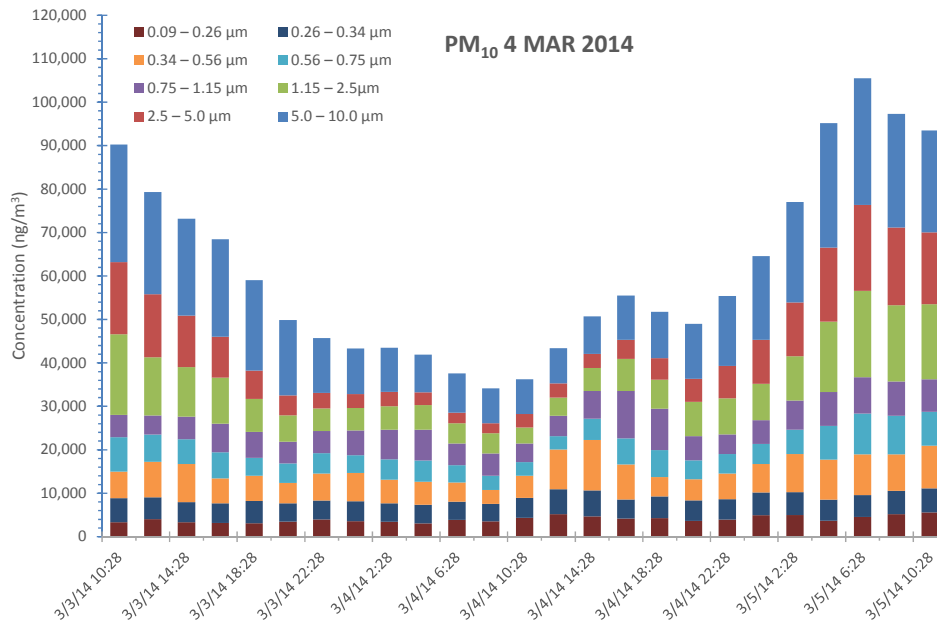
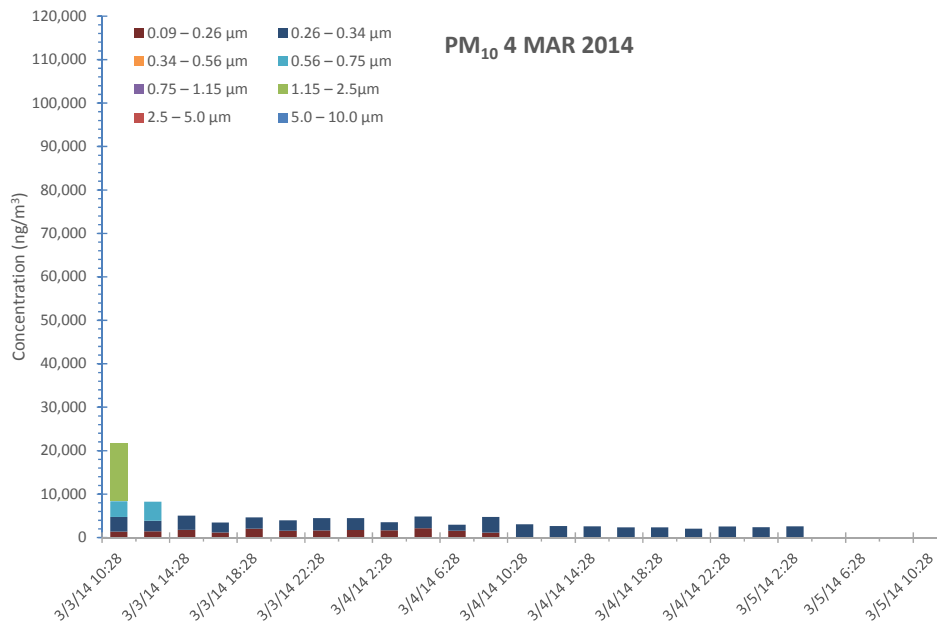


Fig. D-24 Aethalometer measured black carbon: 04 Mar 2014

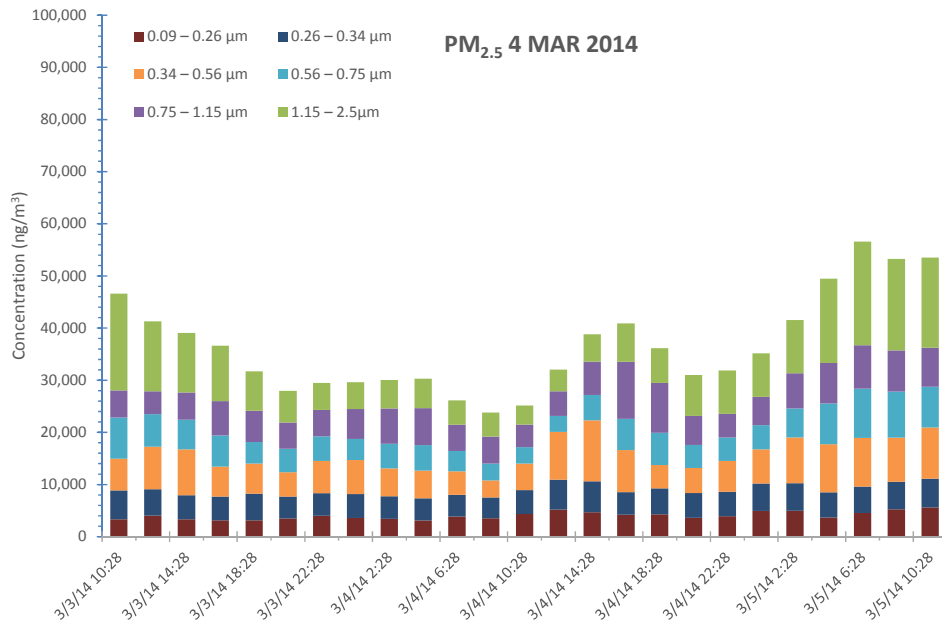


a) DRUM CaPh 34: PM₁₀ size resolved

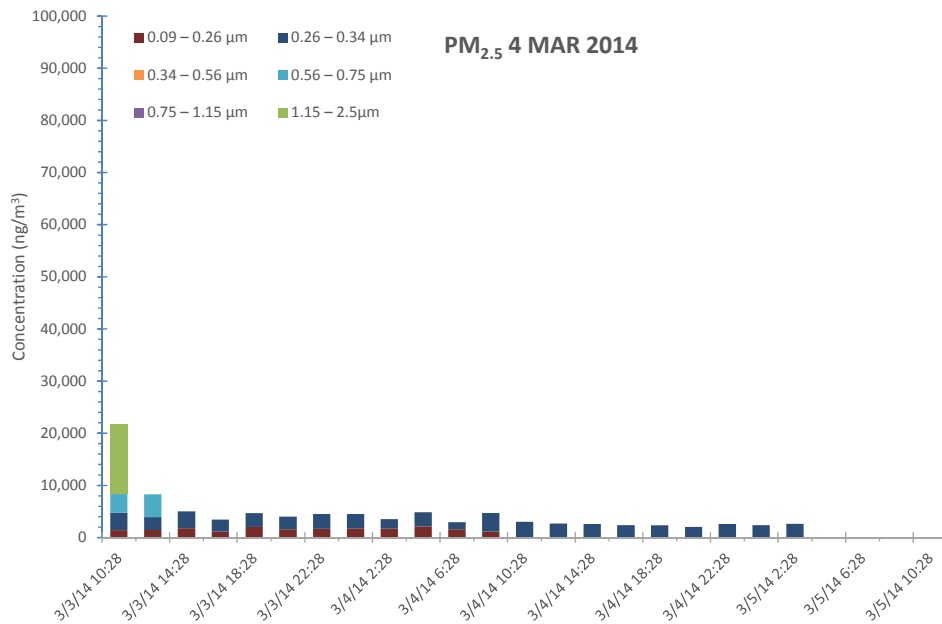


b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-25 DRUM β -gauge measured PM₁₀ size resolved: 04 Mar 2014; (a) CaPh 34, (b) CaPh 32

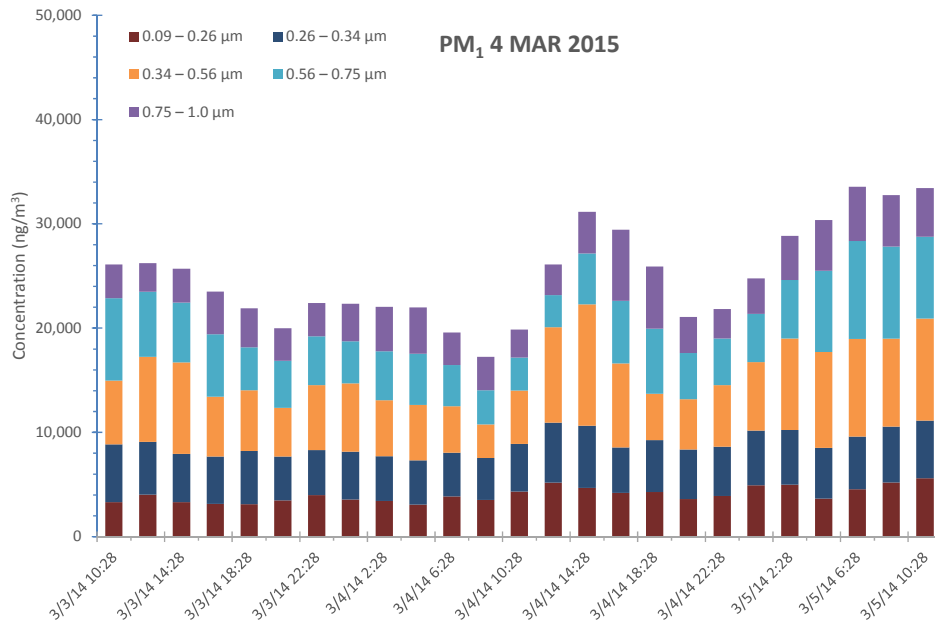


a) DRUM PM_{2.5} size resolved

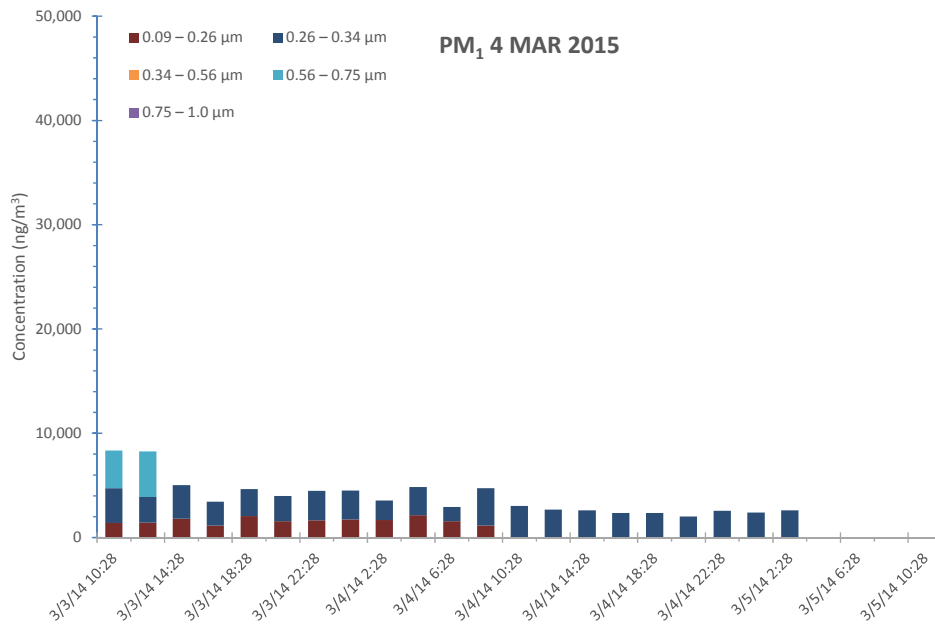


b) DRUM PM_{2.5} size resolved

Fig. D-26 DRUM β -gauge measured PM_{2.5} size resolved: 04 Mar 2014; (a) CaPh 34, (b) CaPh 32



a) DRUM PM₁ size resolved



b) DRUM PM₁ size resolved

Fig. D-27 DRUM β -gauge measured PM₁ size resolved: 04 Mar 2014; (a) CaPh 34, (b) CaPh 32

D-6 05 March 2014

Similar to the 4 March data, air arriving spent the previous 84 h near the surface arriving from the south of the airport having traversed mountains arriving from the valley south of Jalalabad. The previous 24 h before arrival the air was looping south and southwest of the airport.

There are continuous aethalometer data except for a gap from 1600–1700 local time.

There are no DRUM data from CaPh32 for this day.

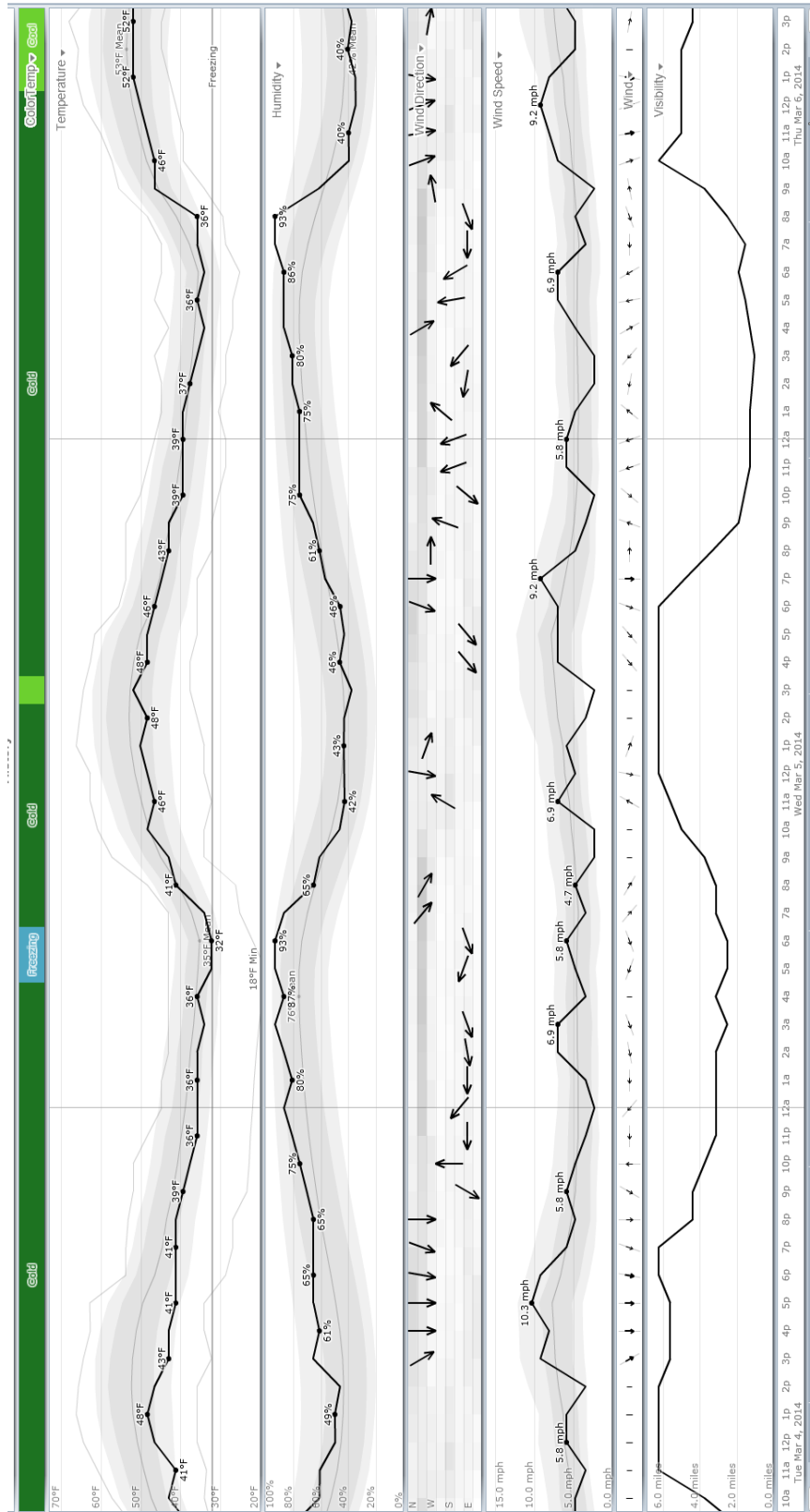


Fig. D-28 Kabul weather summary: 05 Mar 2014

Approved for public release; distribution is unlimited.

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 05 Mar 14
 GDAS Meteorological Data

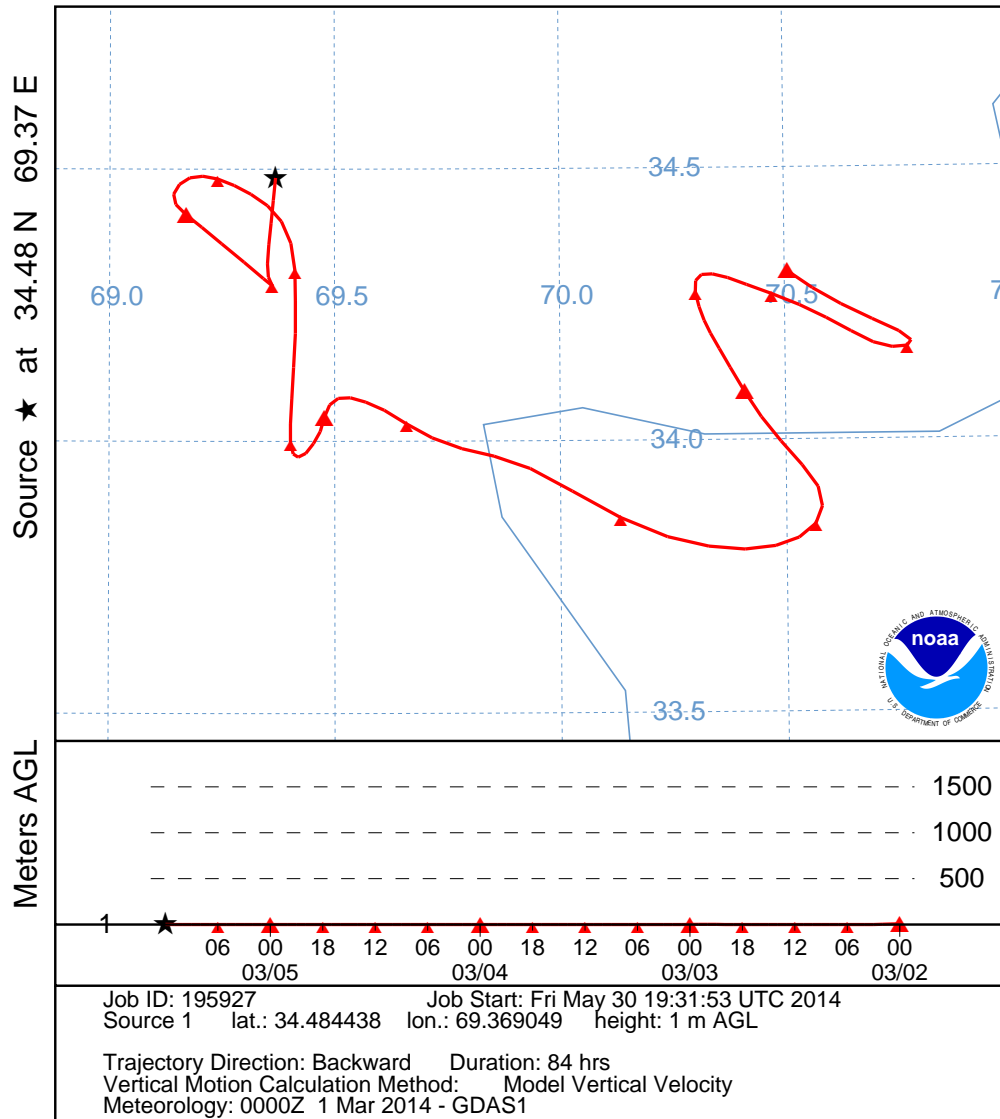


Fig. D-29 HYSPLIT back trajectory 05 Mar 2014

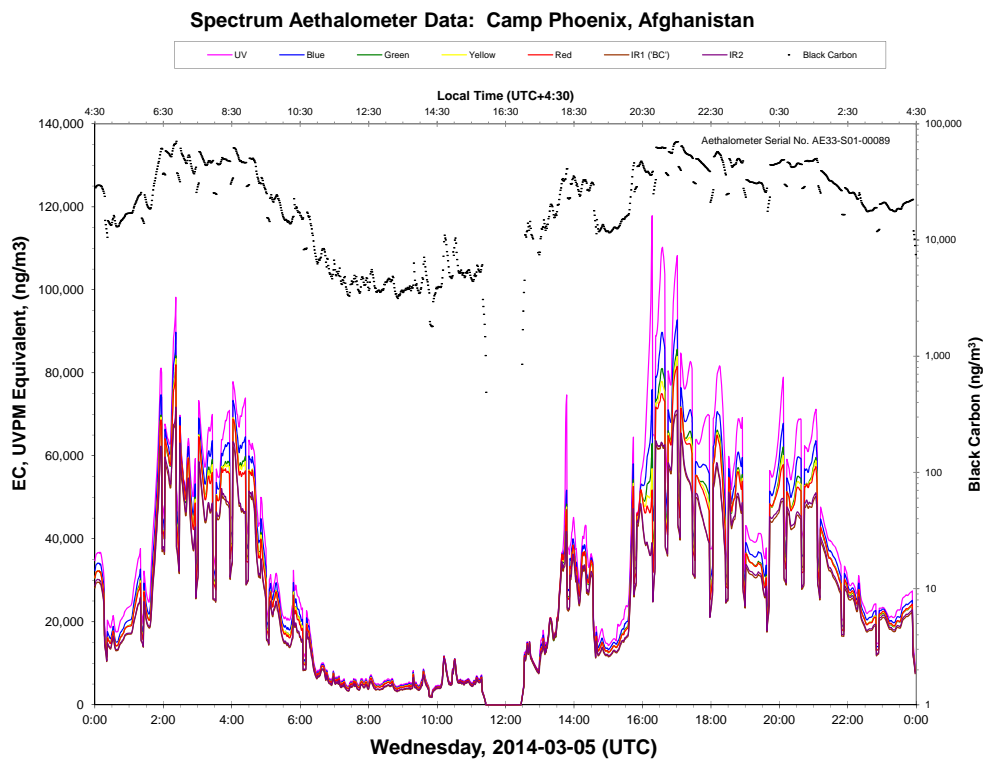
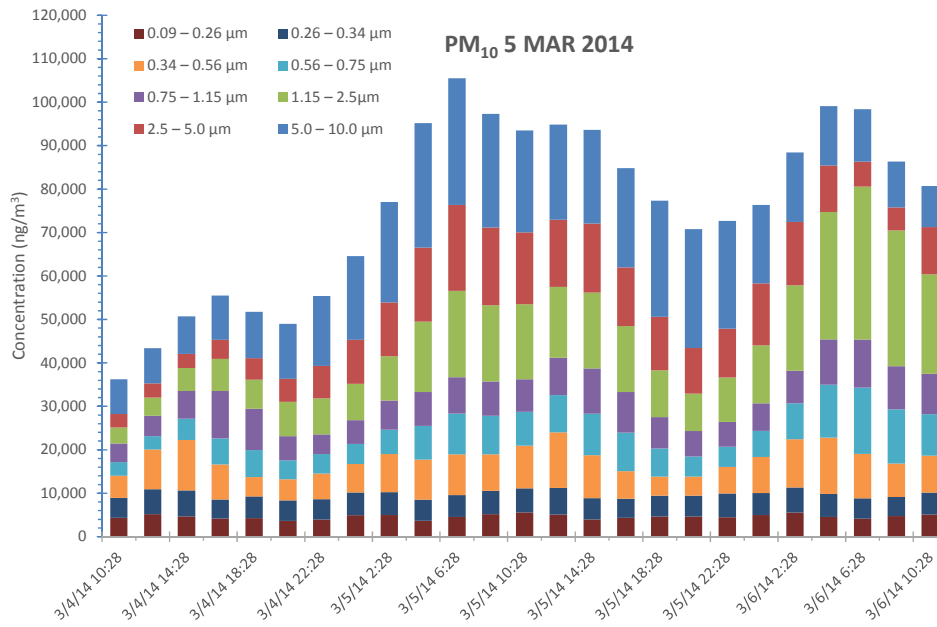
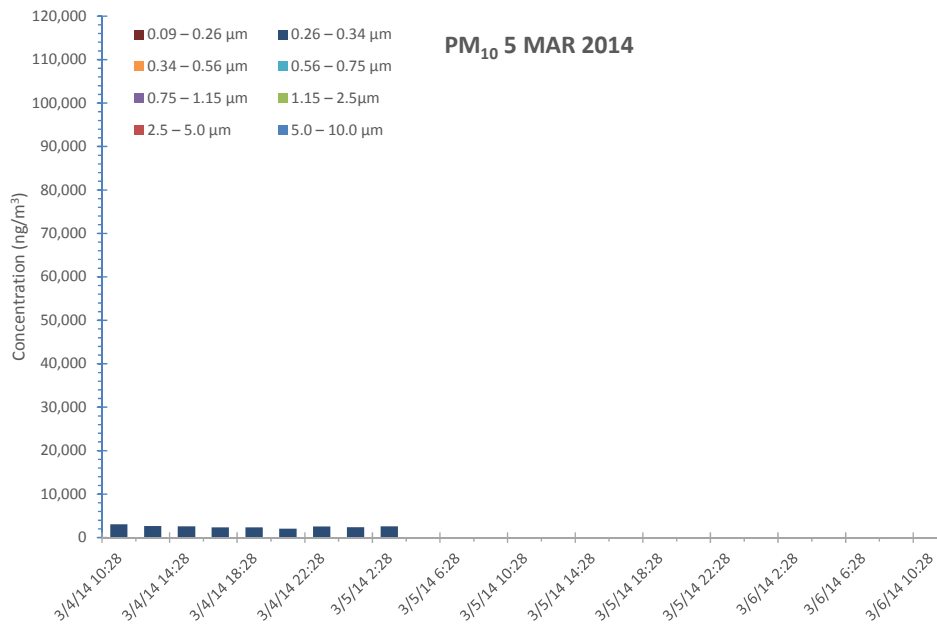


Fig. D-30 Aethalometer measured black carbon: 05 Mar 2014

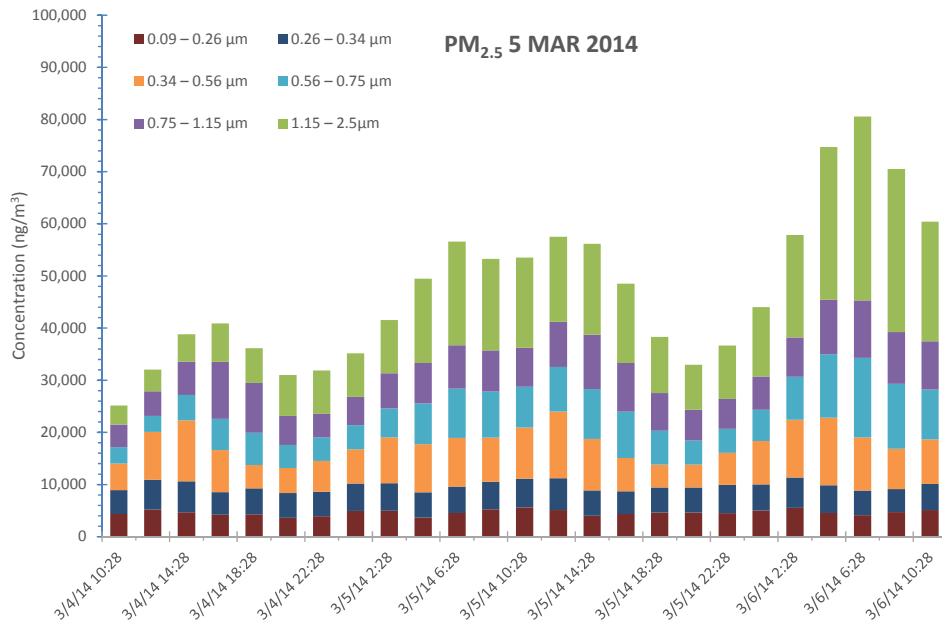


a) DRUM CaPh 34: PM₁₀ size resolved

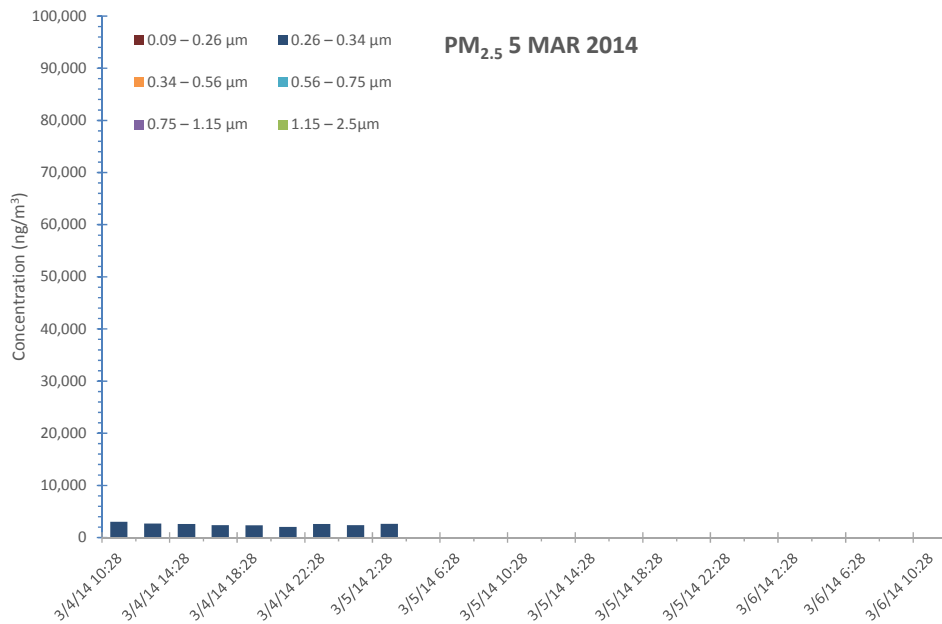


b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-31 DRUM β -gauge measured PM₁₀ size resolved: 05 Mar 2014; (a) CaPh 34, (b) CaPh 32

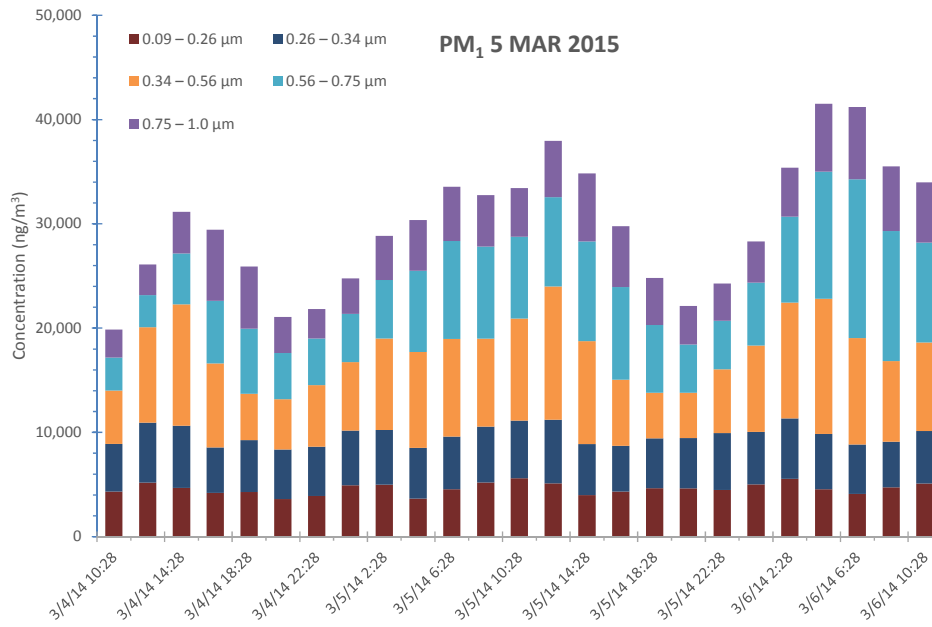


a) DRUM PM_{2.5} size resolved

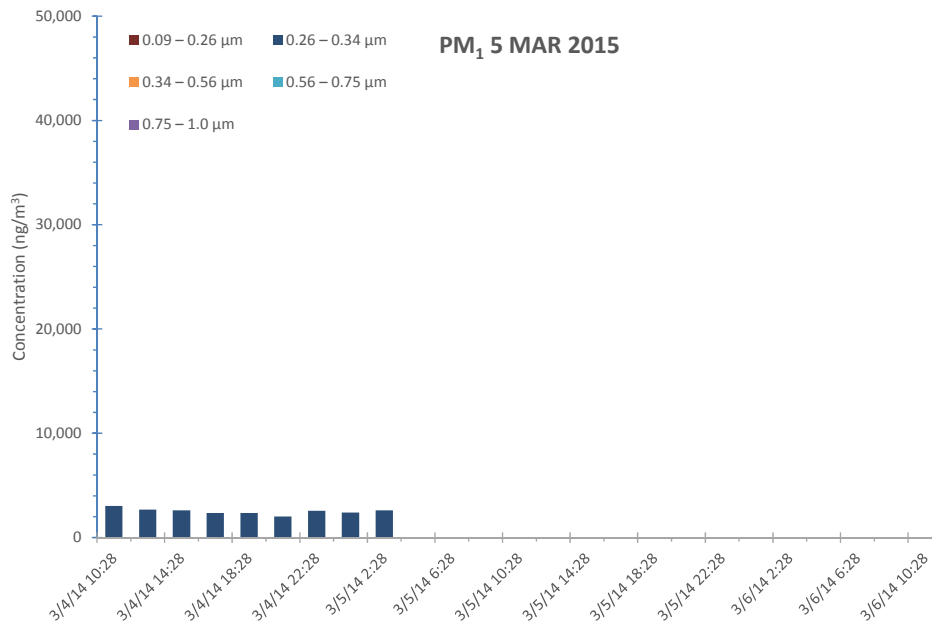


b) DRUM PM_{2.5} size resolved

Fig. D-32 DRUM β -gauge measured PM_{2.5} size resolved: 05 Mar 2014; (a) CaPh 34, (b) CaPh 32



a) DRUM PM₁ size resolved



b) DRUM PM₁ size resolved

Fig. D-33 DRUM β -gauge measured PM₁ size resolved: 05 Mar 2014; (a) CaPh 34, (b) CaPh 32

D-7 06 March 2014

The air arriving spent the previous 84 h near the surface arriving from the south and southwest around the Khakrez district of Kandahar province. Then, 36 h before arriving, the air made a small rise above the terrain near Kamar, Ghanzi province.

There are aethalometer data until 1900 except for a gap from 1300–1400 local time.

There are no DRUM data from CaPh32 for this day.

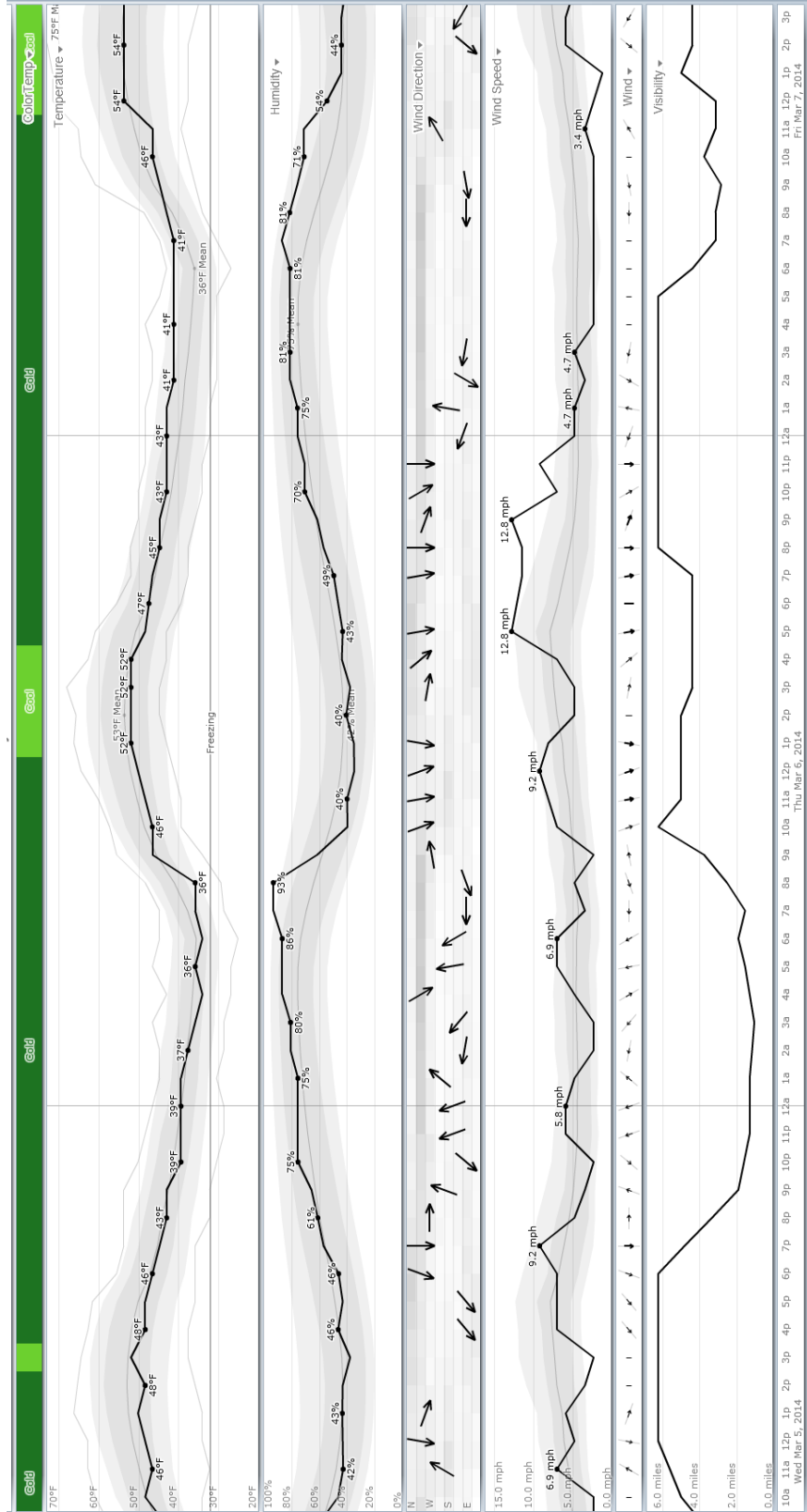


Fig. D-34 Kabul weather summary: 06 Mar 2014

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 06 Mar 14
 GDAS Meteorological Data

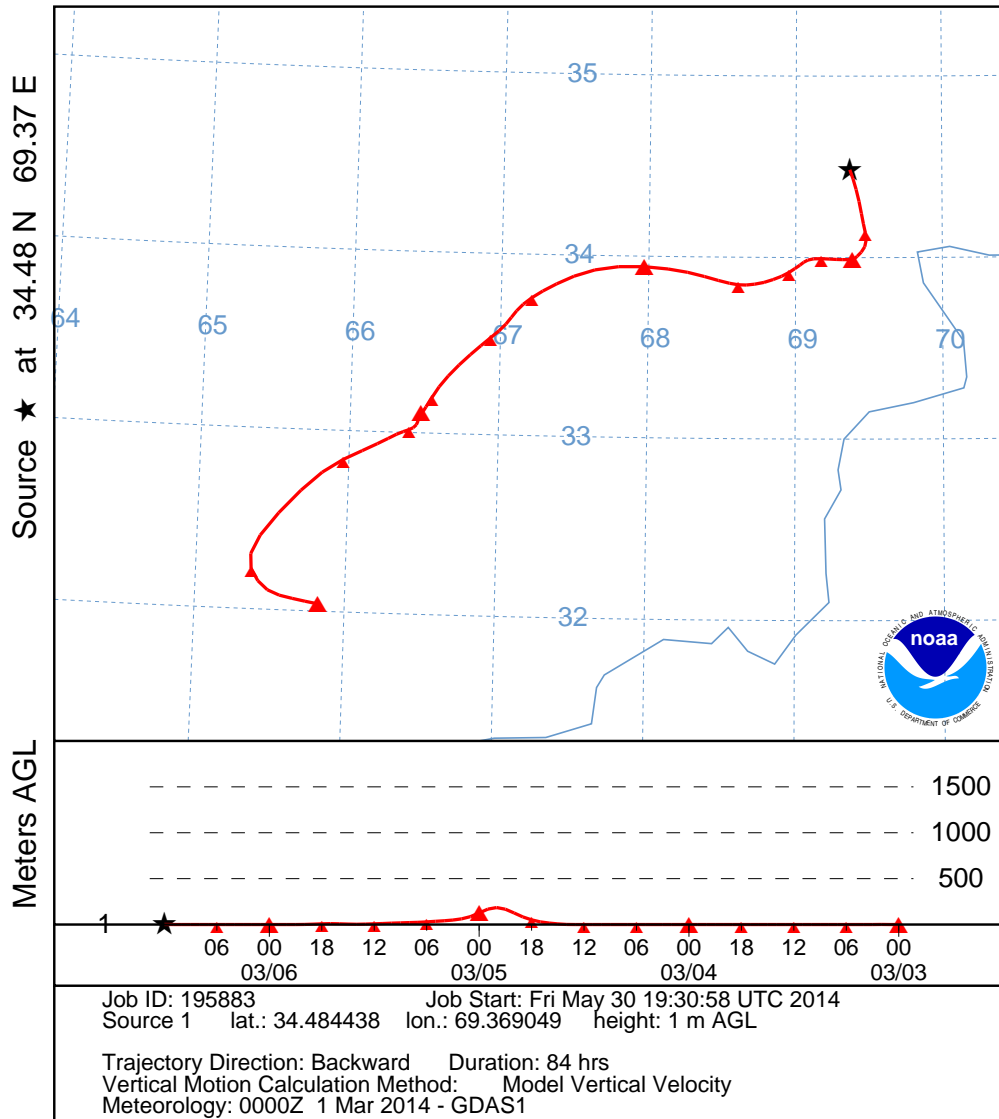


Fig. D-35 HYSPLIT back trajectory 06 Mar 2014

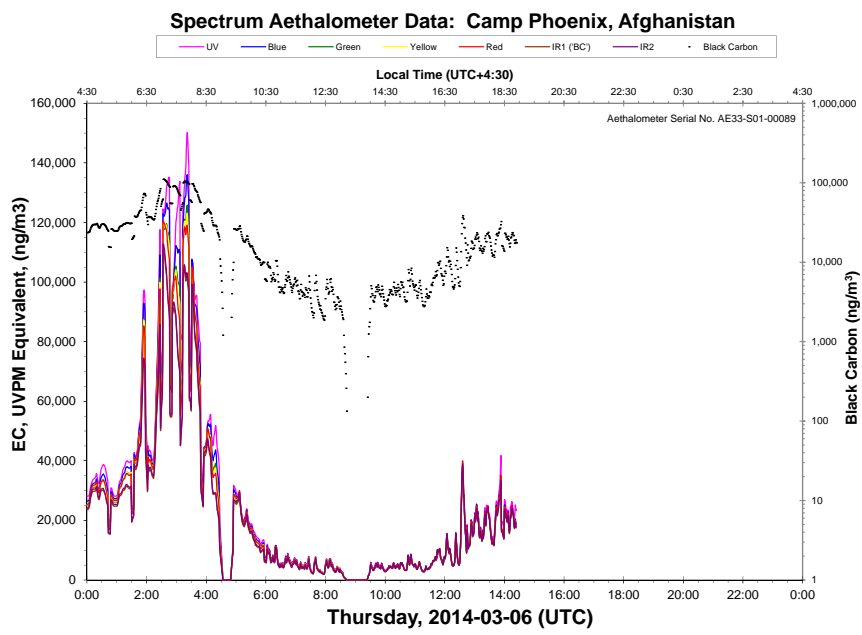
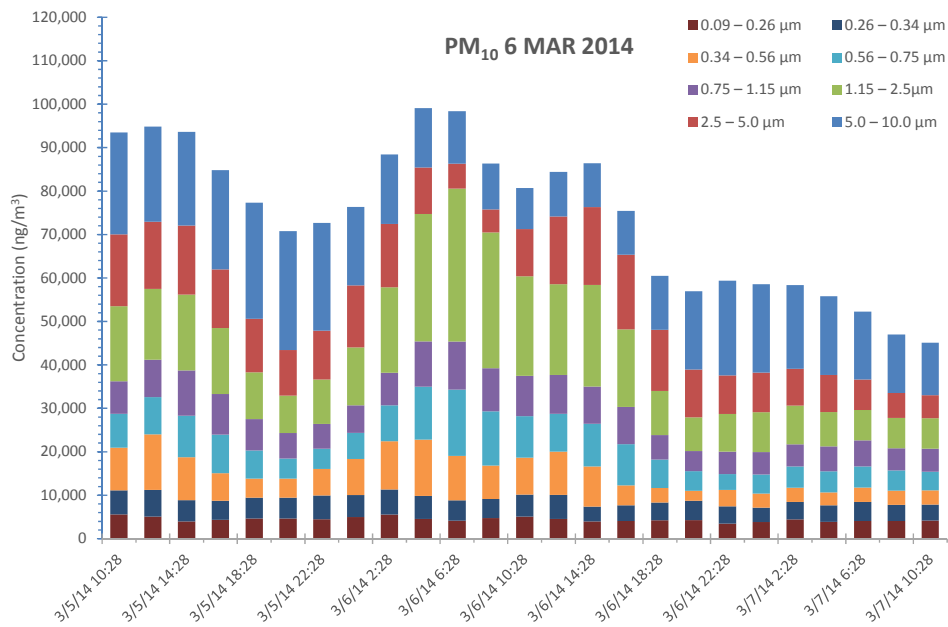
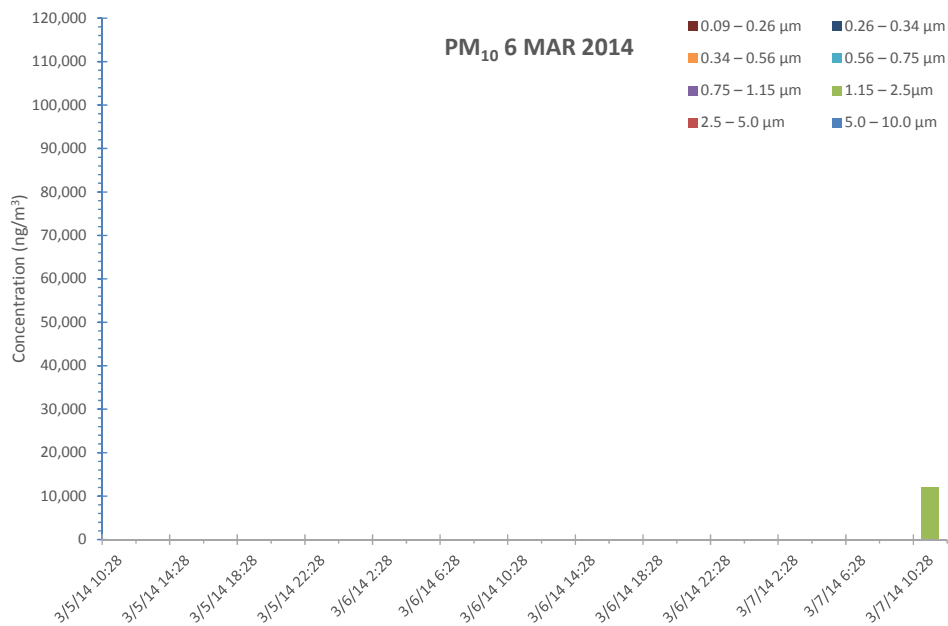


Fig. D-36 Aethalometer measured black carbon: 06 Mar 2014

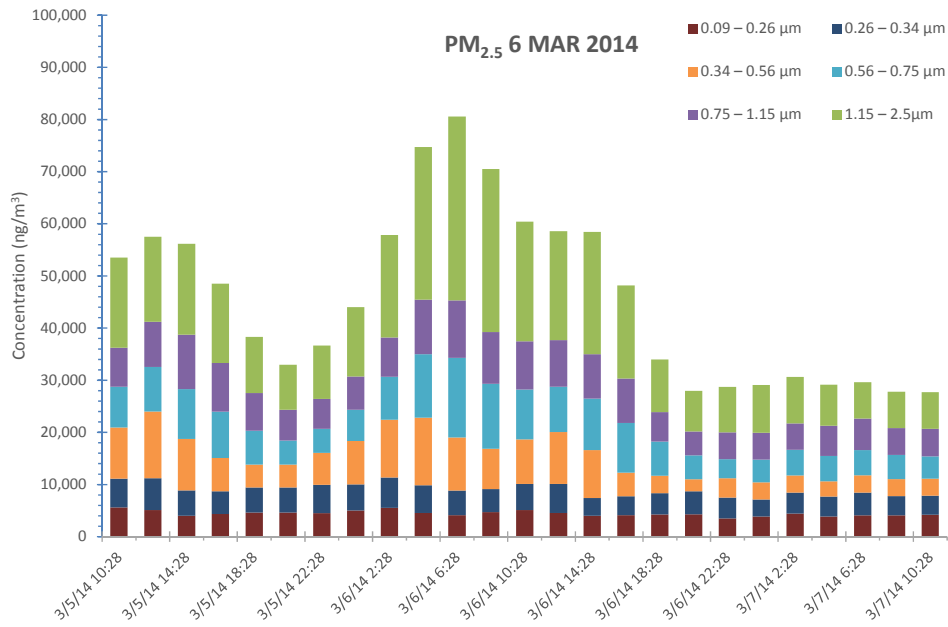


a) DRUM CaPh 34: PM₁₀ size resolved

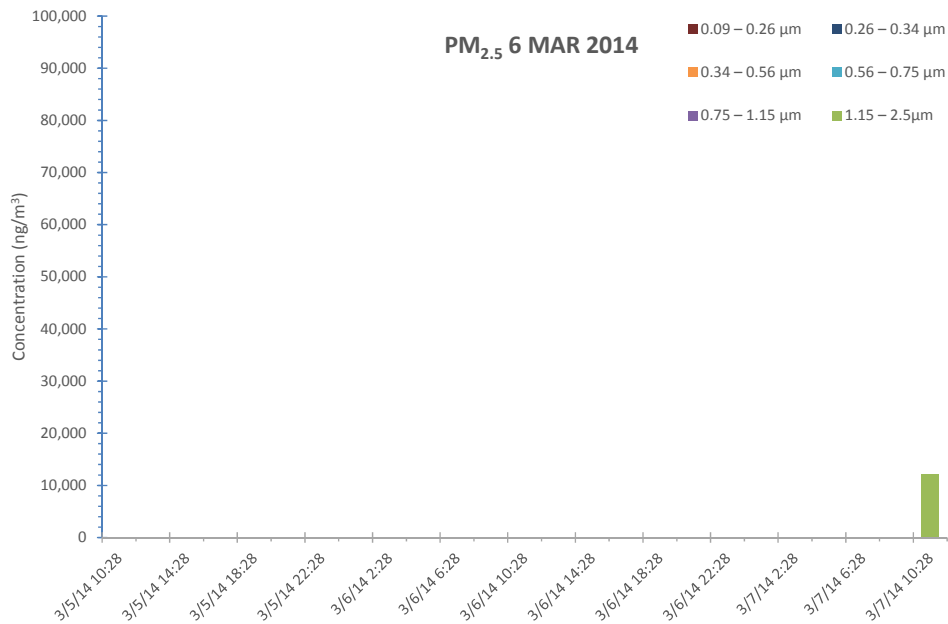


b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-37 DRUM β-gauge measured PM₁₀ size resolved: 06 Mar 2014; (a) CaPh 34, (b) CaPh 32

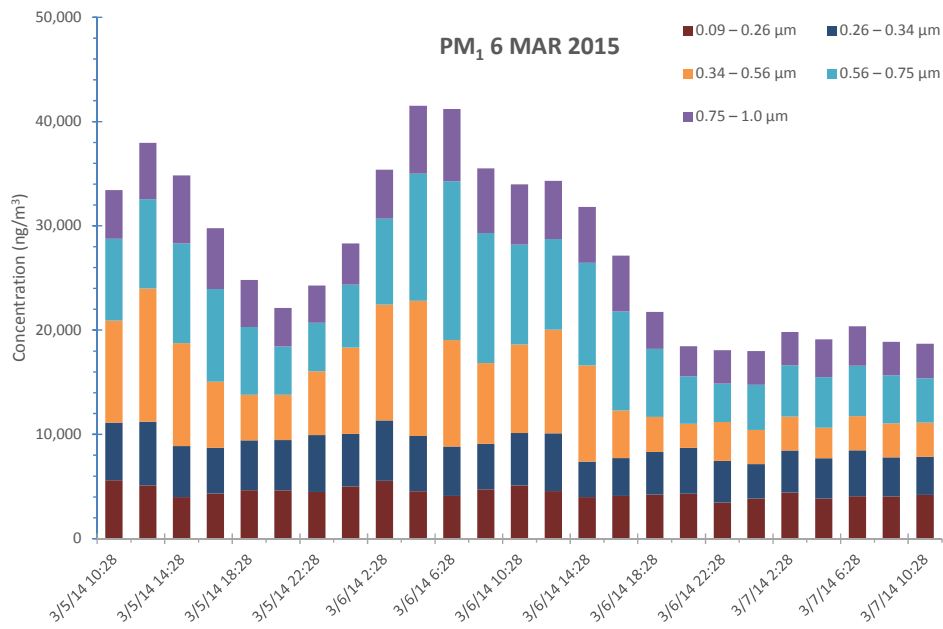


a) DRUM PM_{2.5} size resolved

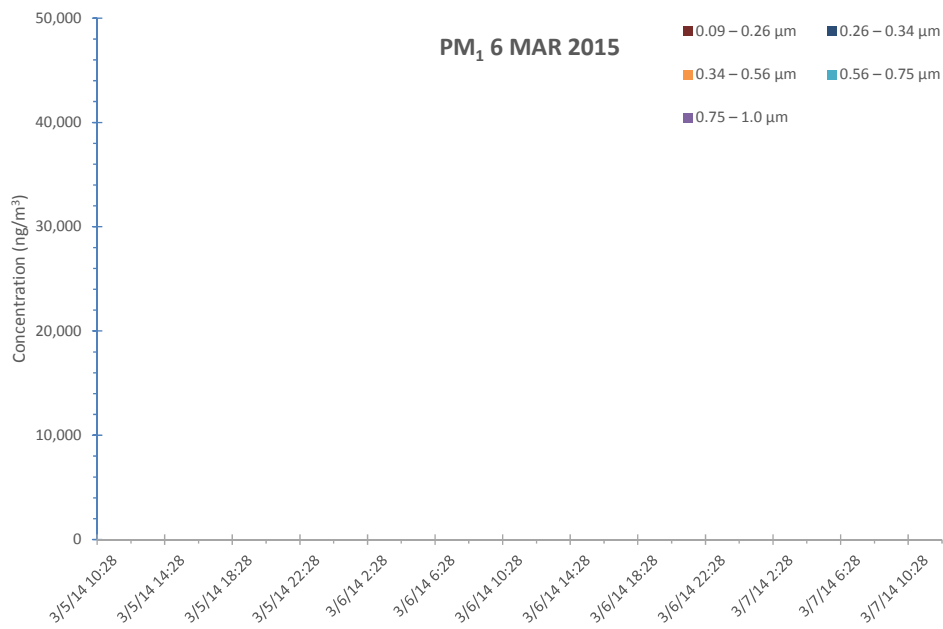


b) DRUM PM_{2.5} size resolved

Fig. D-38 DRUM β-gauge measured PM_{2.5} size resolved: 06 Mar 2014; (a) CaPh 34, (b) CaPh 32



a) DRUM PM₁ size resolved



b) DRUM PM₁ size resolved

Fig. D-39 DRUM β -gauge measured PM₁ size resolved: 06 Mar 2014; (a) CaPh 34, (b) CaPh 32

D-8 07 March 2014

The air arriving spent the previous 84 h near the surface arriving from the south after following a very meandering and backtracking path.

There are aethalometer data from 0730–1300, a gap from 1300–1500, then continuous data until 0430 on 8 March (local times).

There are no DRUM data from CaPh32 for this day.



Fig. D-40 Kabul weather summary: 07 Mar 2014

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 07 Mar 14
 GDAS Meteorological Data

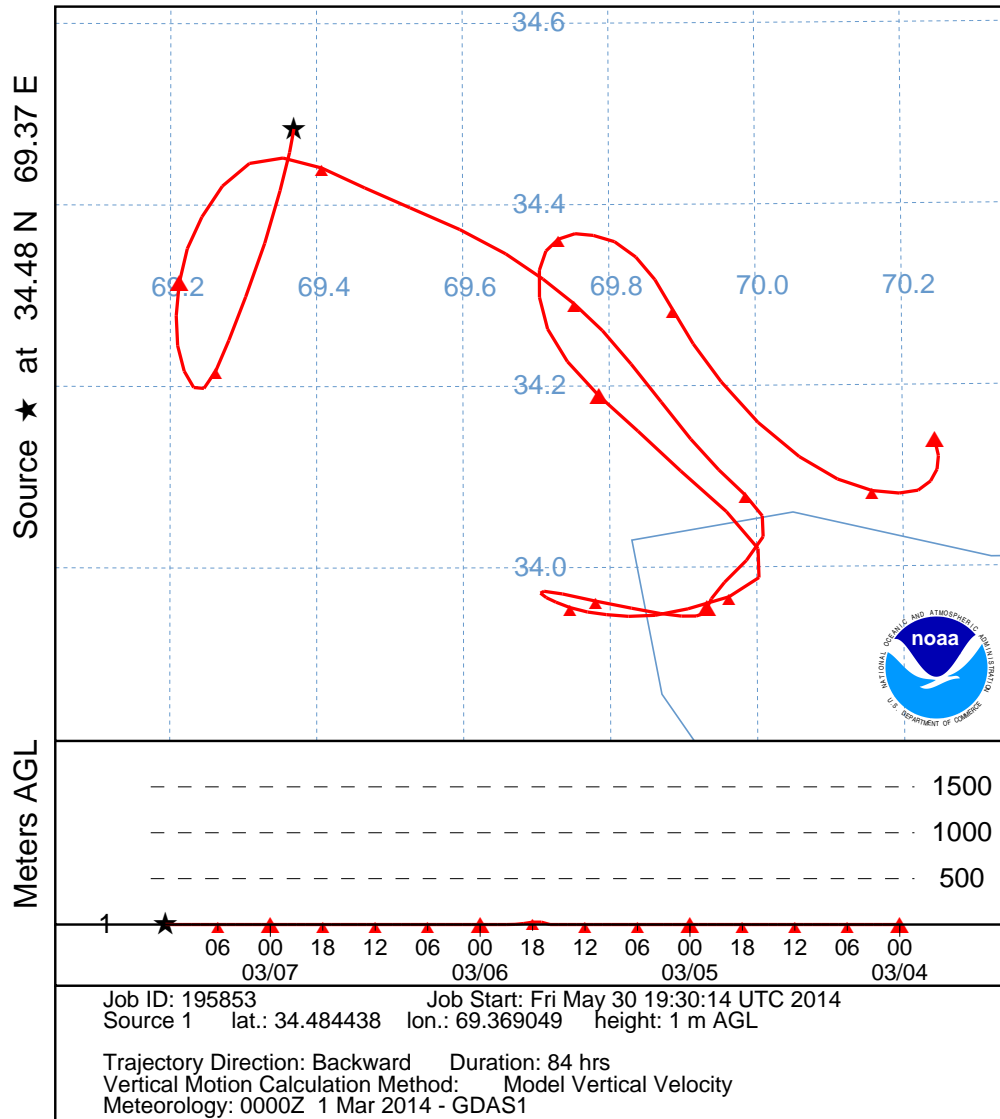


Fig. D-41 HYSPLIT back trajectory 07 Mar 2014

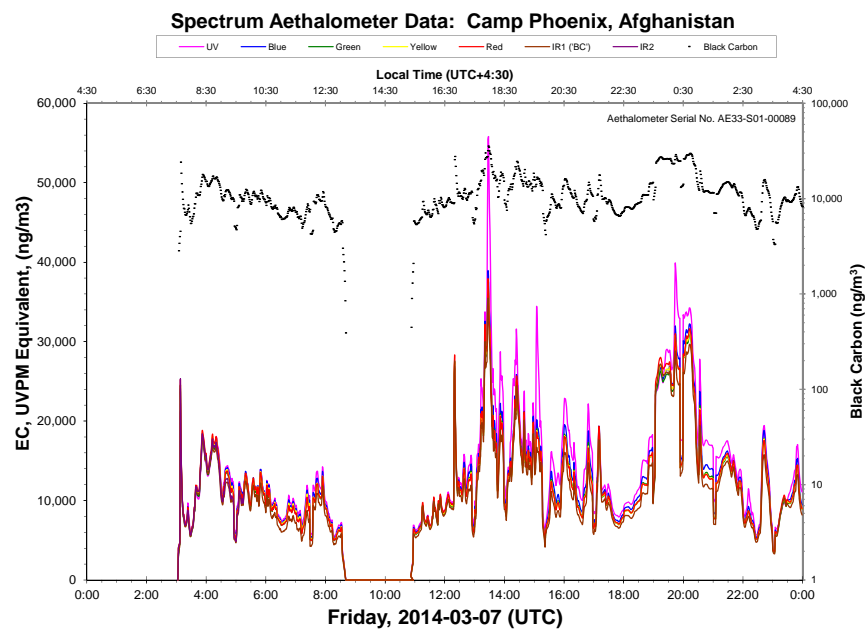
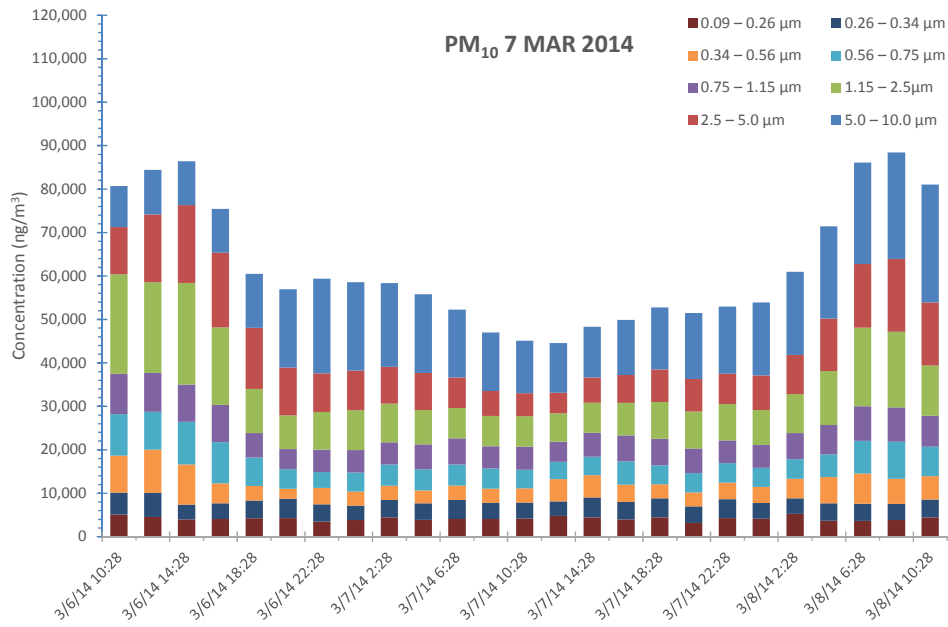
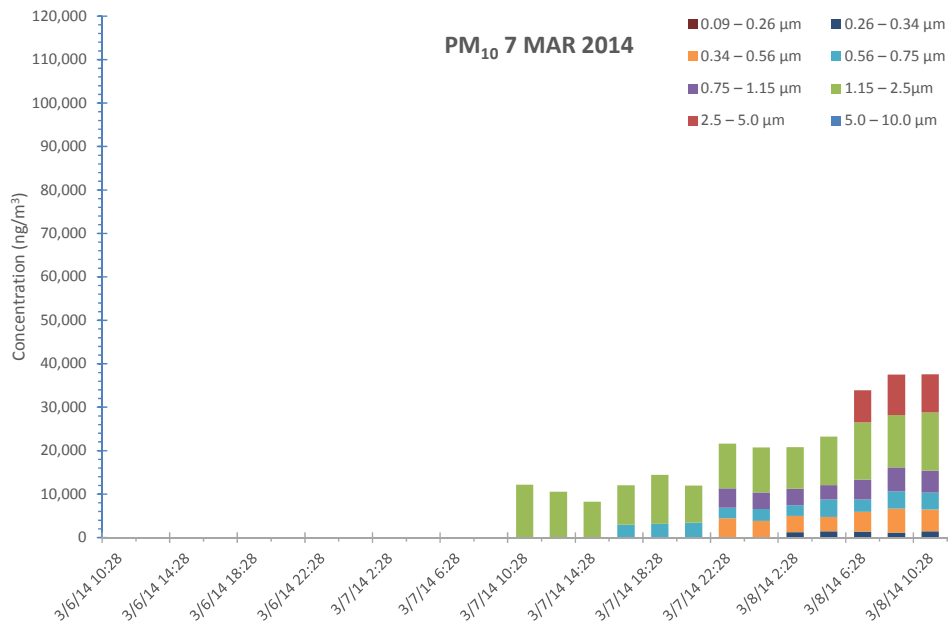


Fig. D-42 Aethalometer measured black carbon: 07 Mar 2014

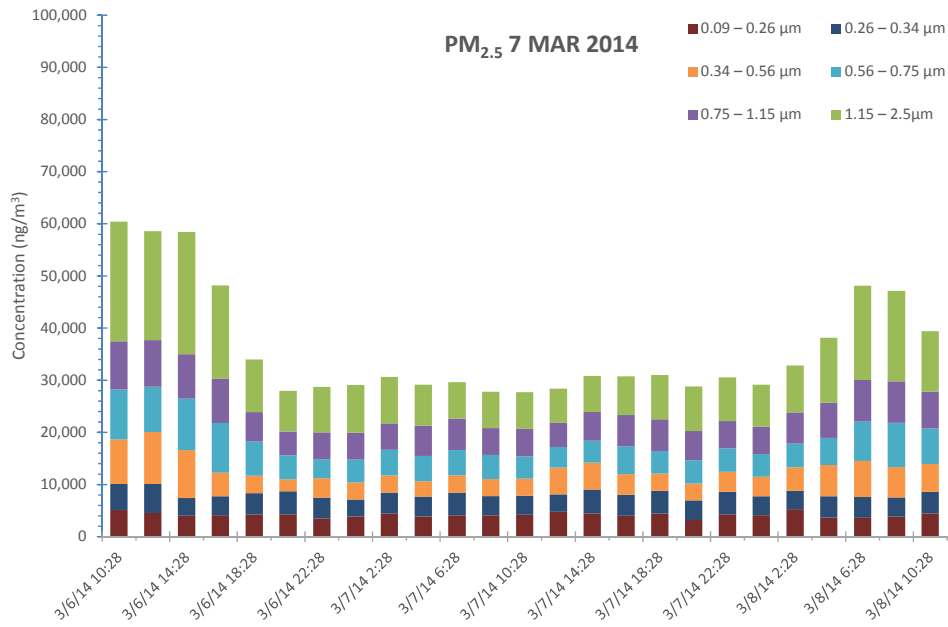


a) DRUM CaPh 34: PM₁₀ size resolved

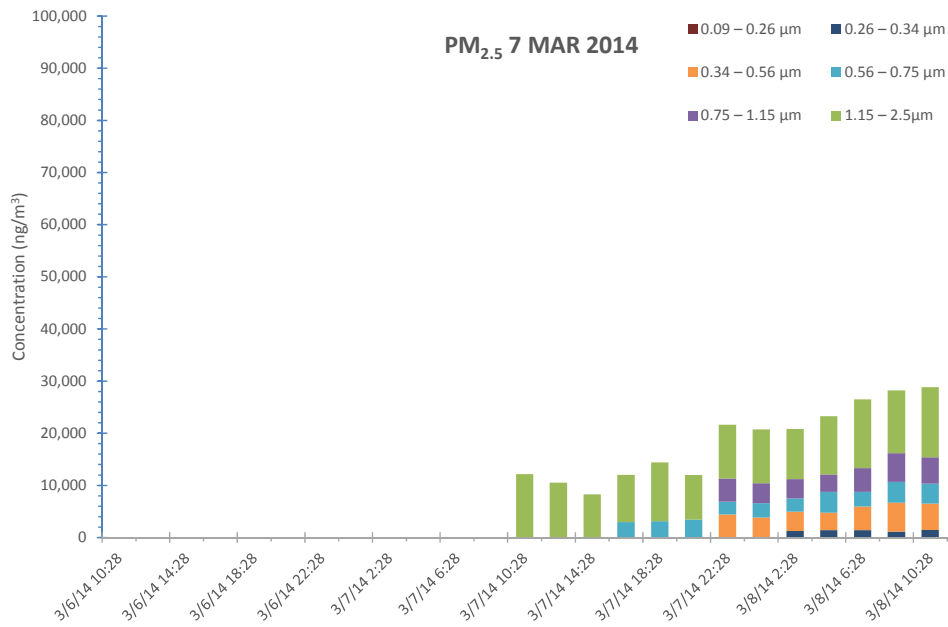


b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-43 DRUM β -gauge measured PM₁₀ size resolved: 07 Mar 2014; (a) CaPh 34, (b) CaPh 32

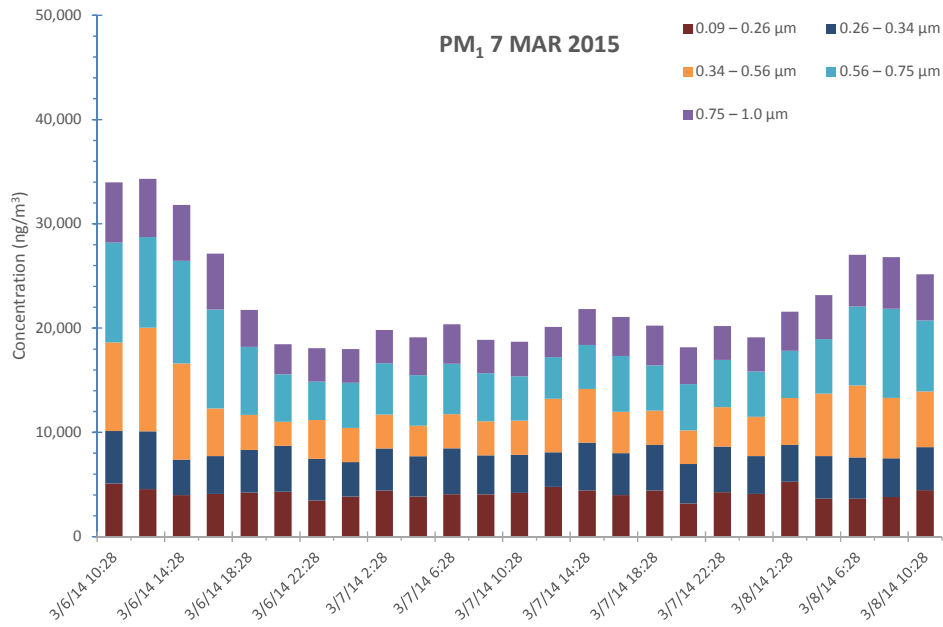


a) DRUM PM_{2.5} size resolved

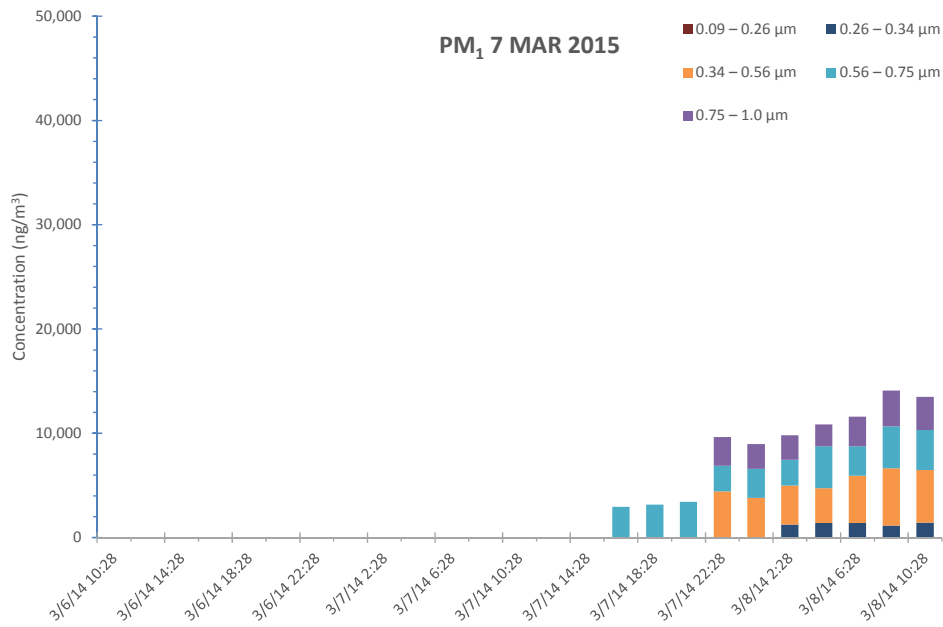


b) DRUM PM_{2.5} size resolved

Fig. D-44 DRUM β -gauge measured PM_{2.5} size resolved: 07 Mar 2014; (a) CaPh 34, (b) CaPh 32



a) DRUM PM₁ size resolved



b) DRUM PM₁ size resolved

Fig. D-45 DRUM β -gauge measured PM₁ size resolved: 07 Mar 2014; (a) CaPh 34, (b) CaPh 32

D-9 08 March 2014

The air arriving spent the previous 84 h near the surface arriving from the south and west-southwest, Gizab district of Daykundi province after a period of stagnation 6 to 18 h before arrival.

There are continuous aethalometer data.

There are some DRUM data from CaPh32 beginning in the afternoon.

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 08 Mar 14
 GDAS Meteorological Data

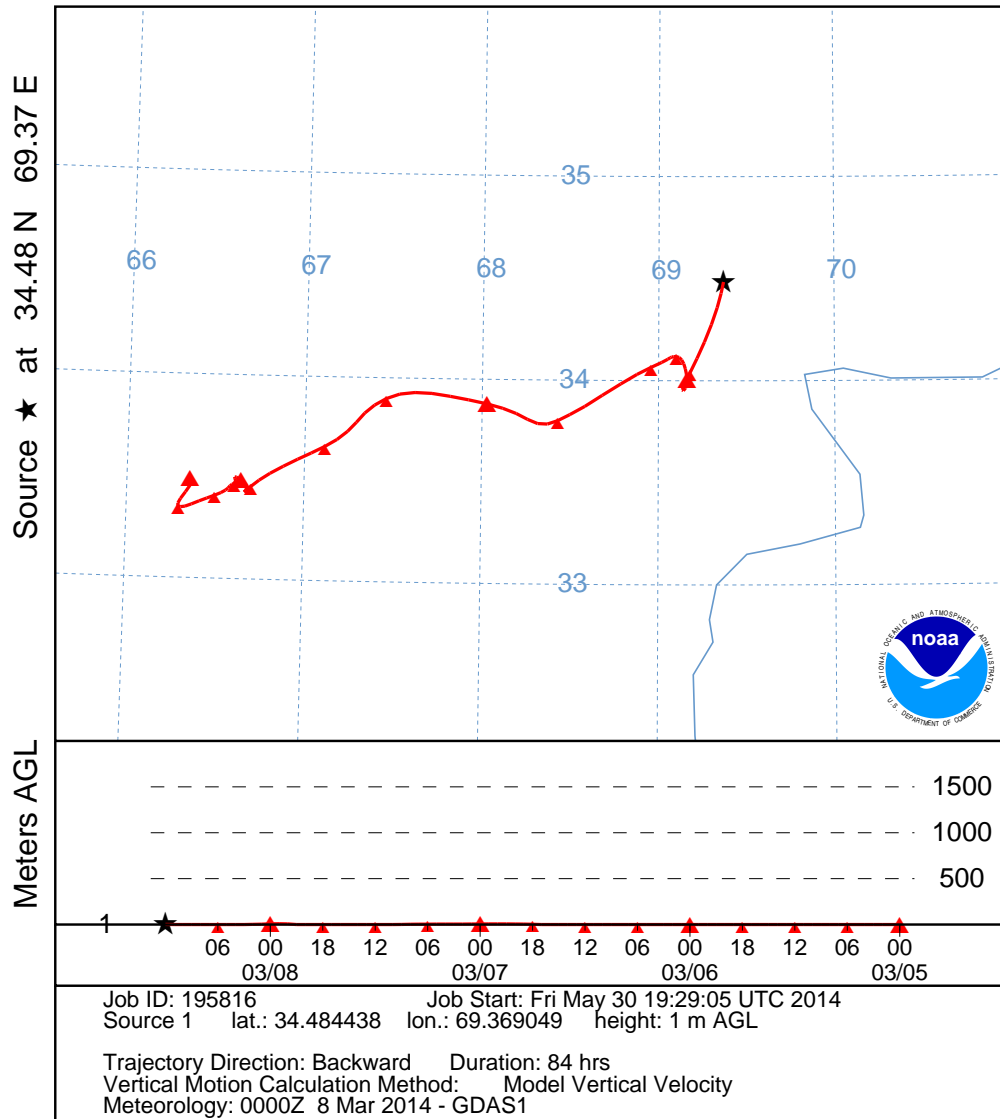


Fig. D-47 HYSPLIT back trajectory 08 Mar 2014

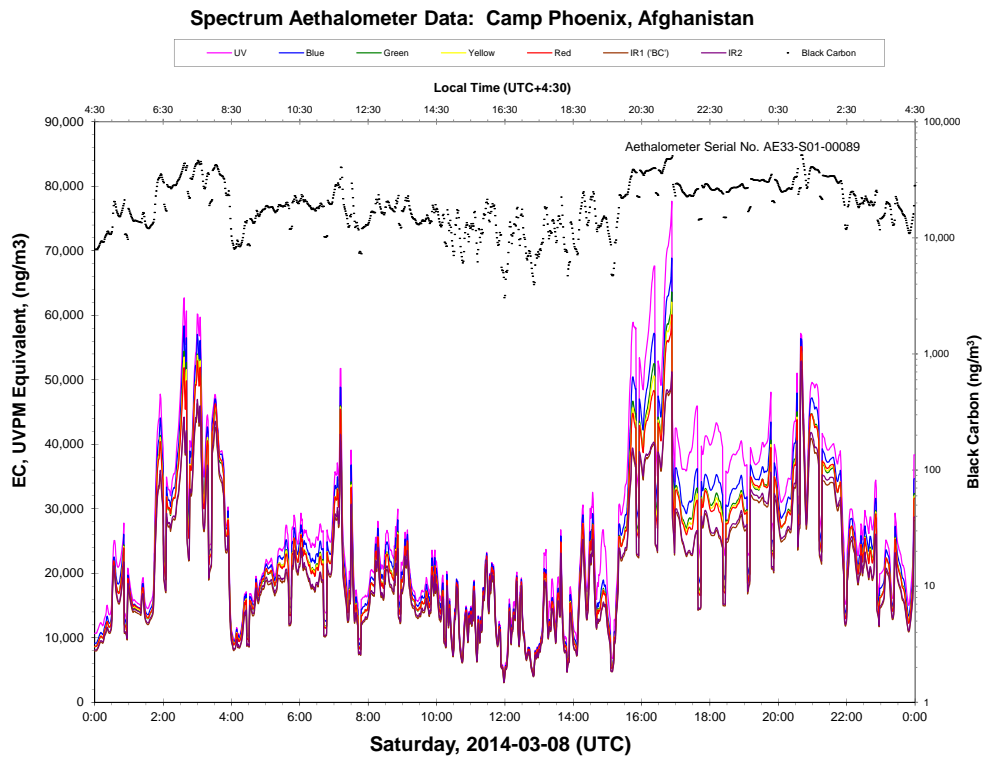
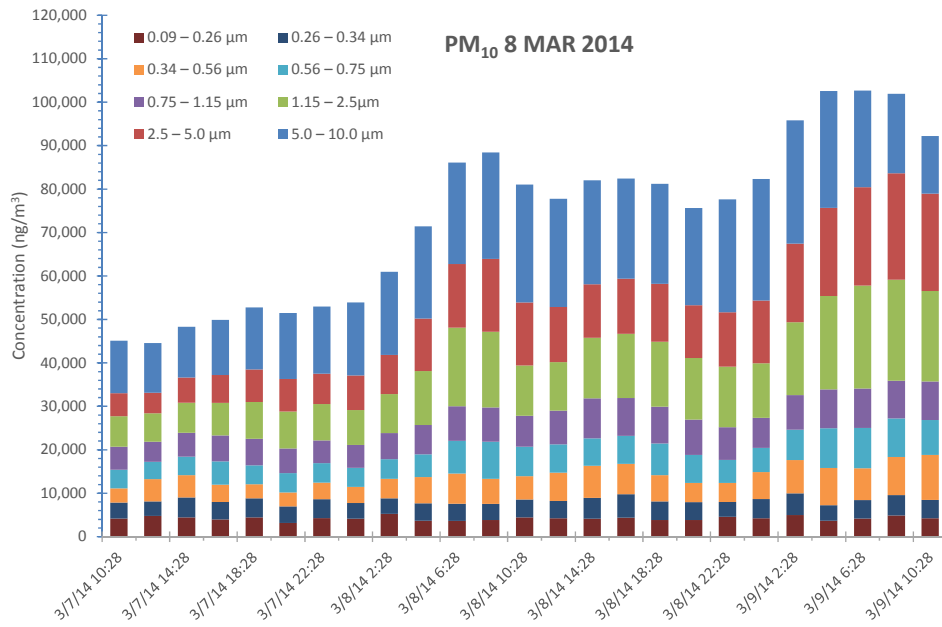
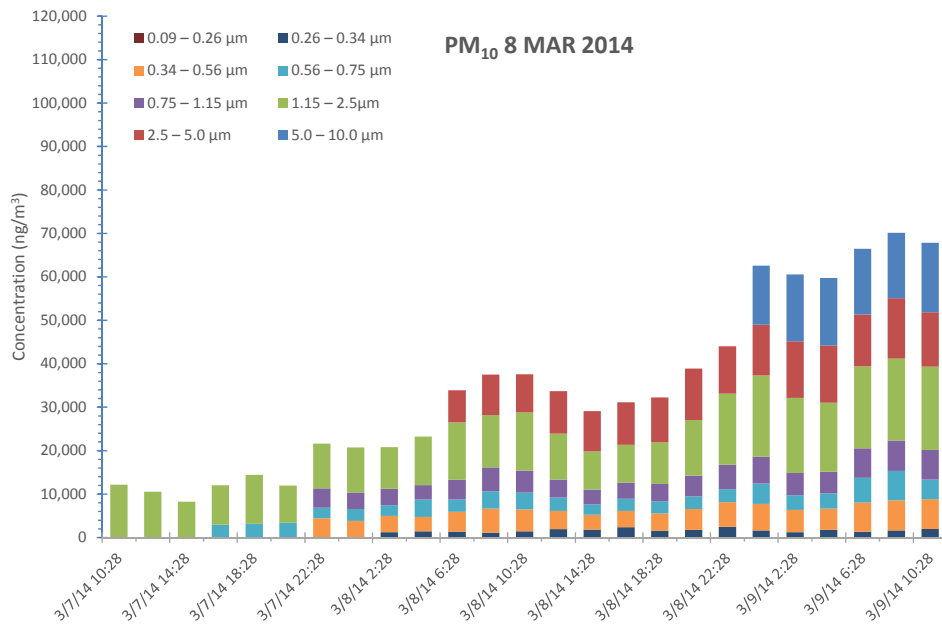


Fig. D-48 Aethalometer measured black carbon: 08 Mar 2014

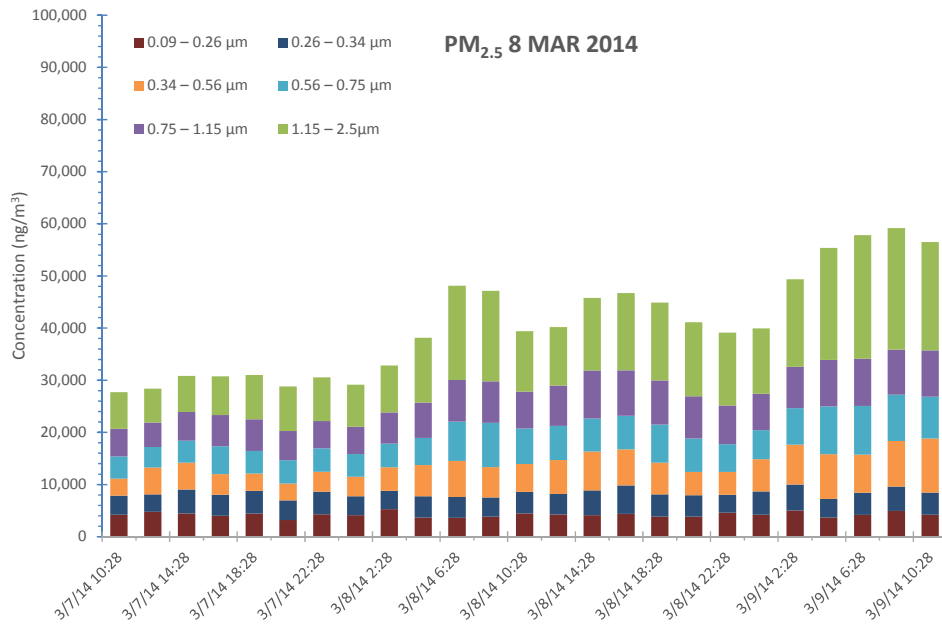


a) DRUM CaPh 34: PM₁₀ size resolved

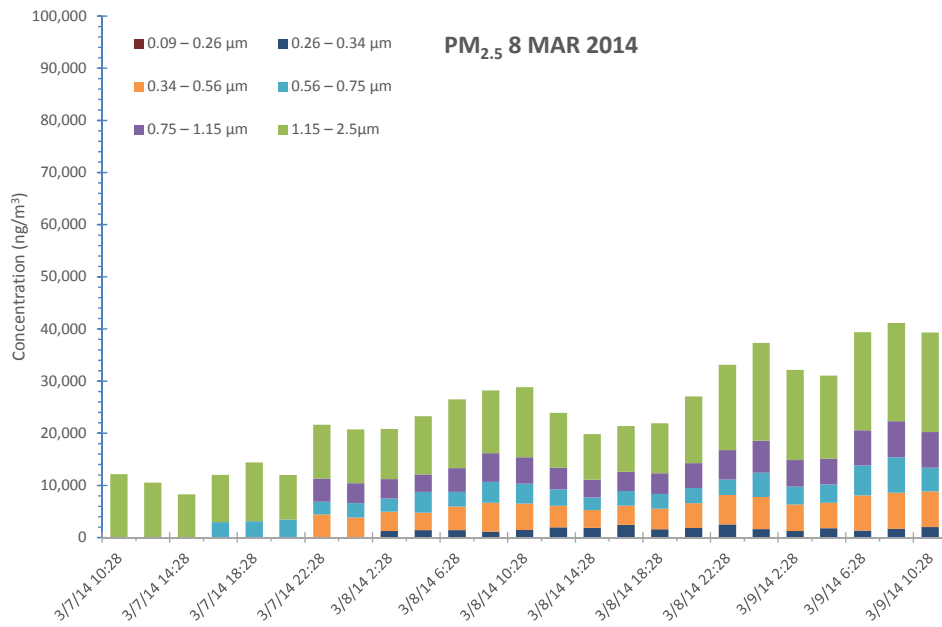


b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-49 DRUM β -gauge measured PM₁₀ size resolved: 08 Mar 2014; (a) CaPh 34, (b) CaPh 32

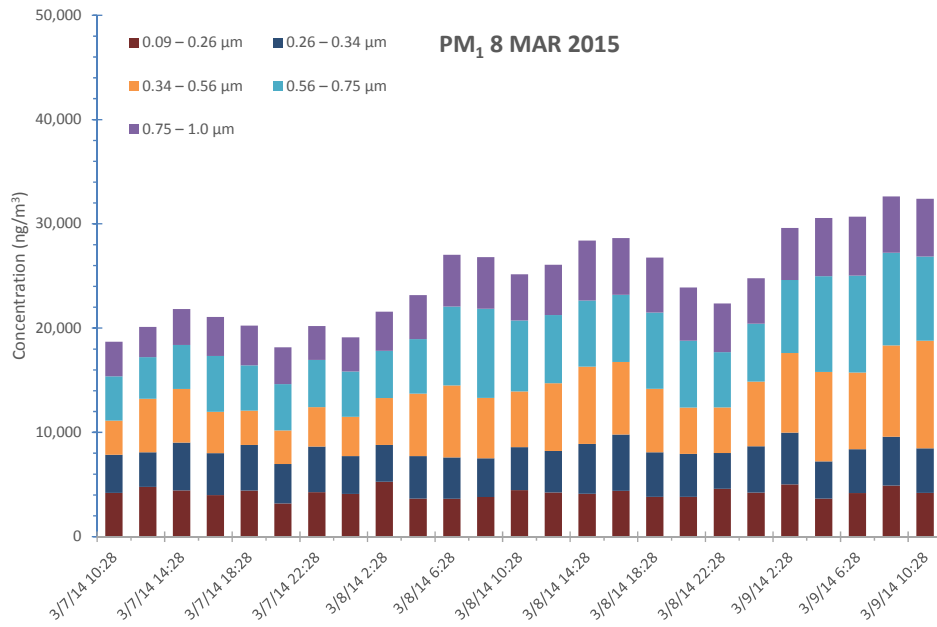


a) DRUM PM_{2.5} size resolved

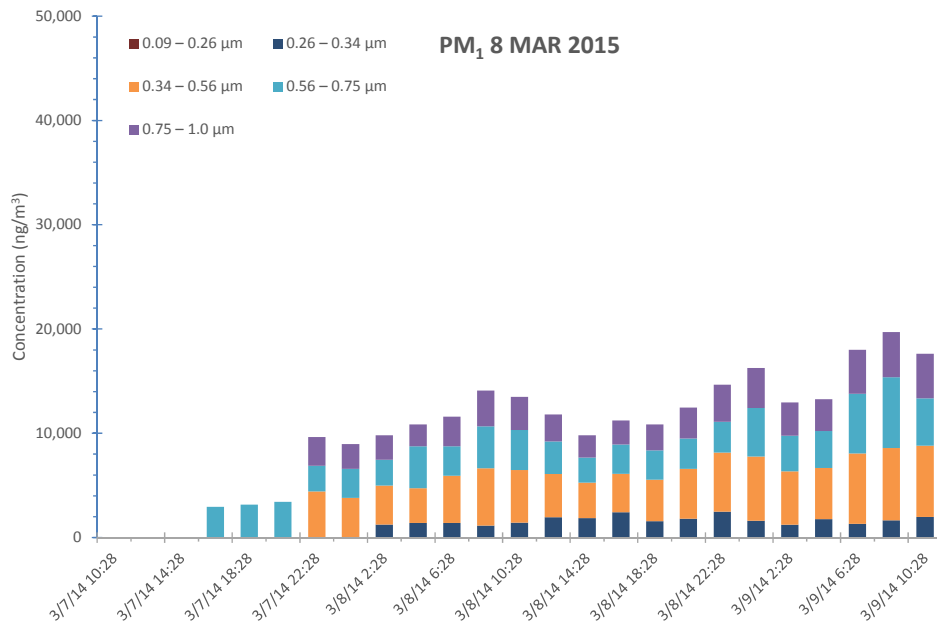


b) DRUM PM_{2.5} size resolved

Fig. D-50 DRUM β -gauge measured PM_{2.5} size resolved: 08 Mar 2014; (a) CaPh 34, (b) CaPh 32



a) DRUM PM₁ size resolved



b) DRUM PM₁ size resolved

Fig. D-51 DRUM β -gauge measured PM₁ size resolved: 08 Mar 2014; (a) CaPh 34, (b) CaPh 32

D-10 09 March 2014

The air arriving spent the previous 12 h very slightly elevated above the surface arriving from the north preceded by 60 h at the surface tracing a large loop near Mazar-i-Sharif, Kholm, and Kunduz in northern Afghanistan.

There are continuous aethalometer data.

There are DRUM data from both CaPh32 and CaPh34.

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 09 Mar 14
 GDAS Meteorological Data

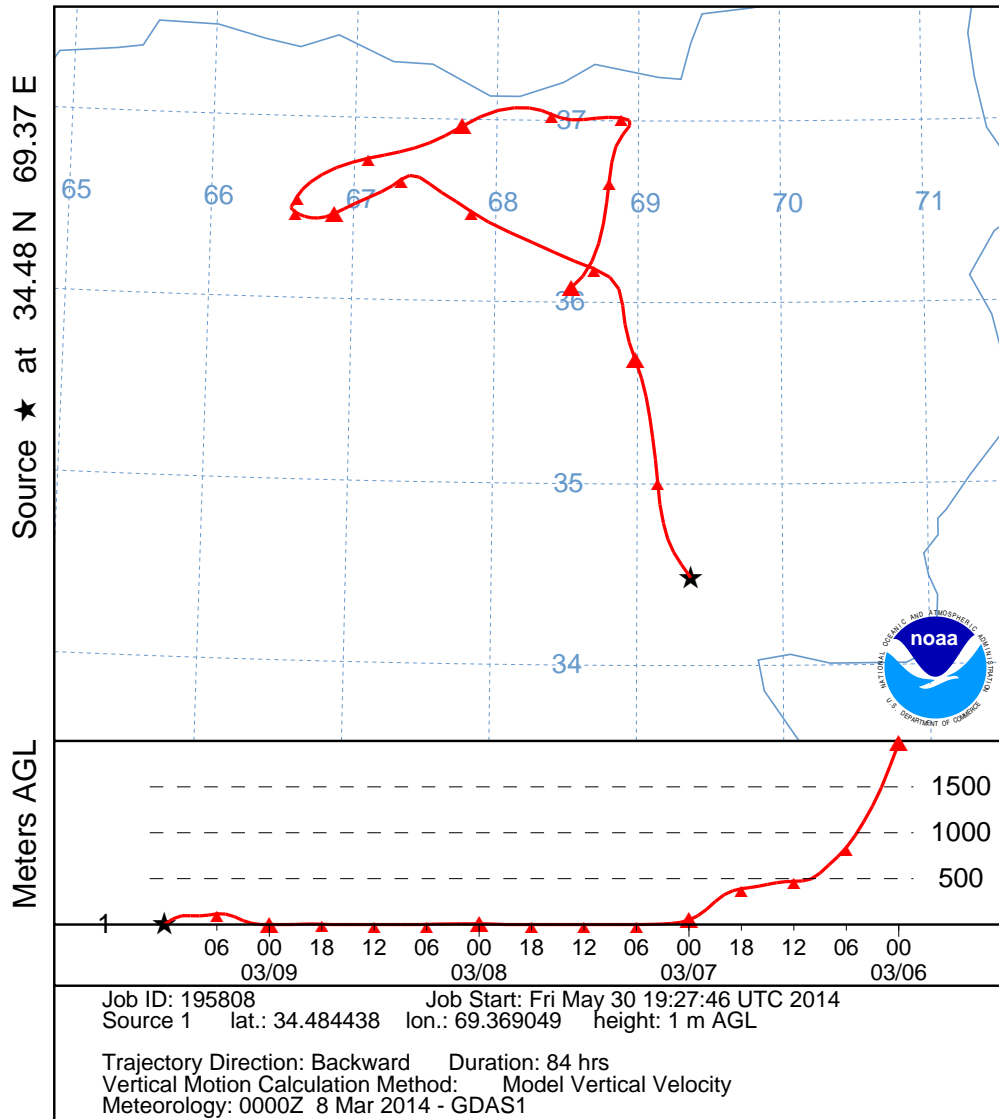


Fig. D-53 HYSPLIT back trajectory 09 Mar 2014

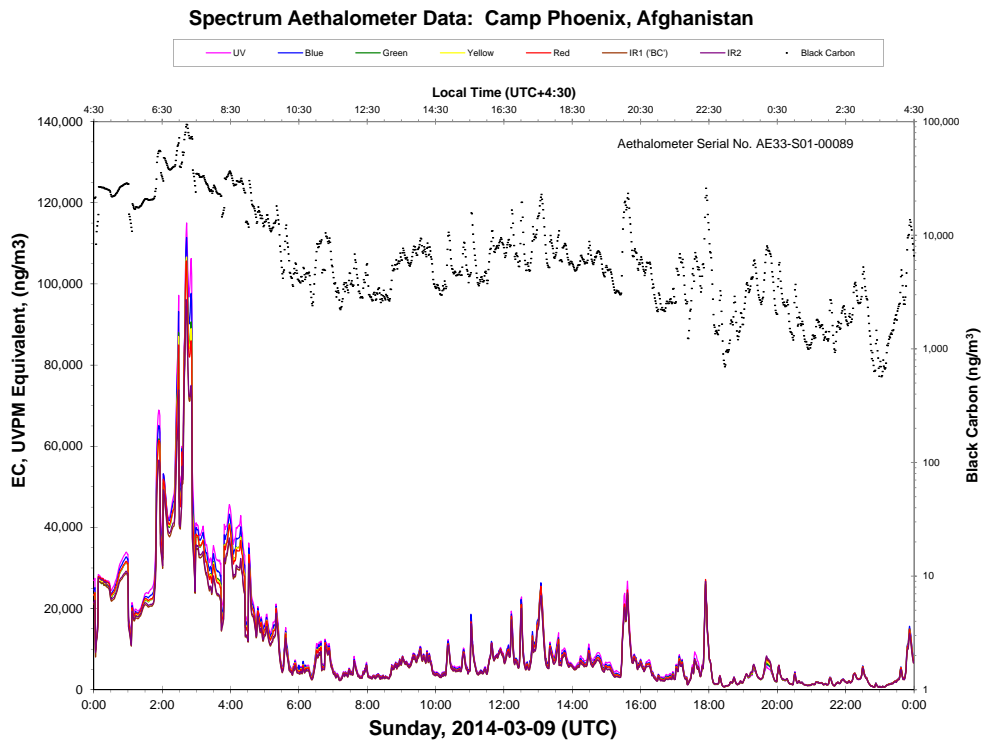
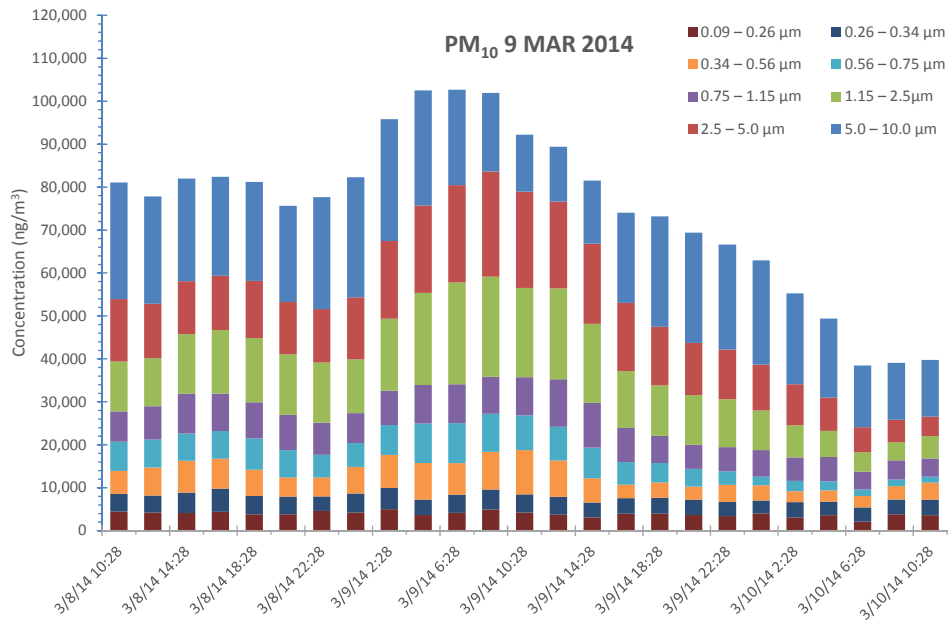
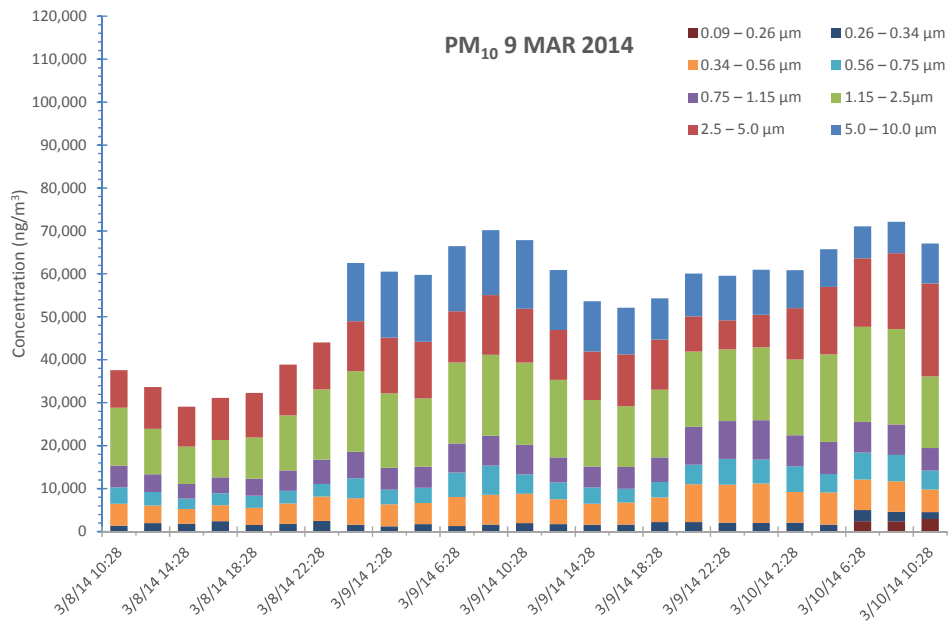


Fig. D-54 Aethalometer measured black carbon: 09 Mar 2014

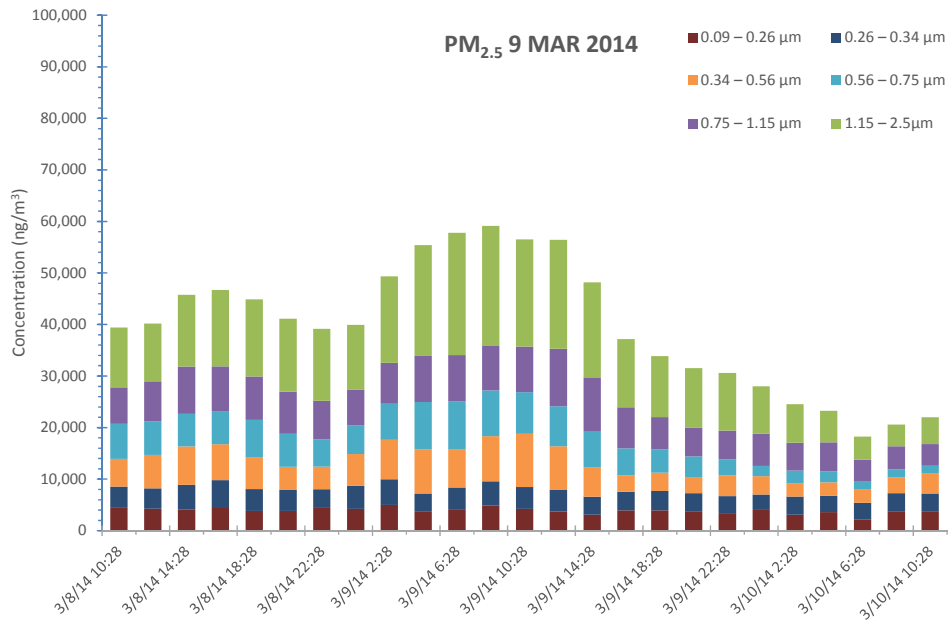


a) DRUM CaPh 34: PM₁₀ size resolved

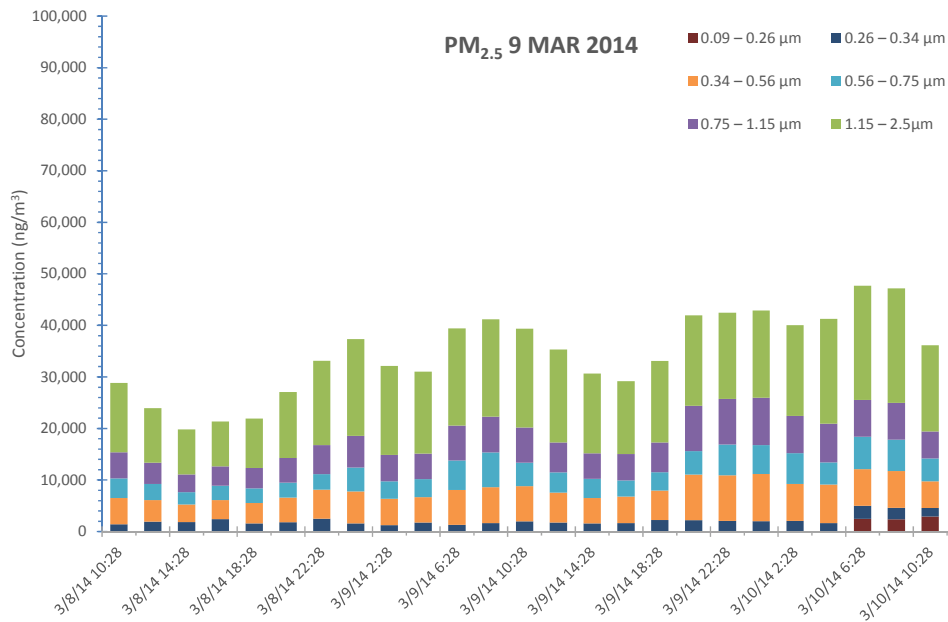


b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-55 DRUM β -gauge measured PM₁₀ size resolved: 09 Mar 2014; (a) CaPh 34, (b) CaPh 32

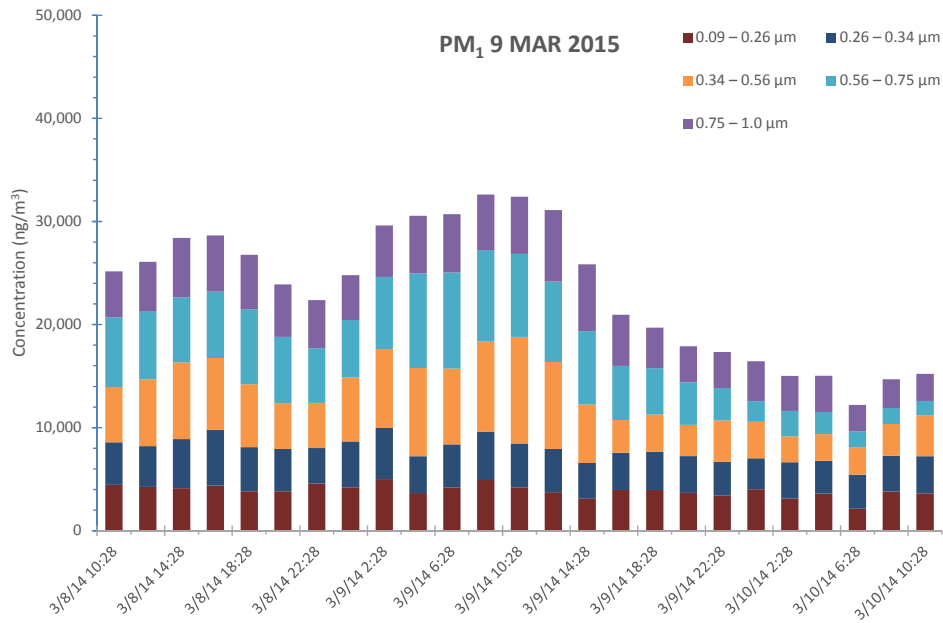


a) DRUM PM_{2.5} size resolved

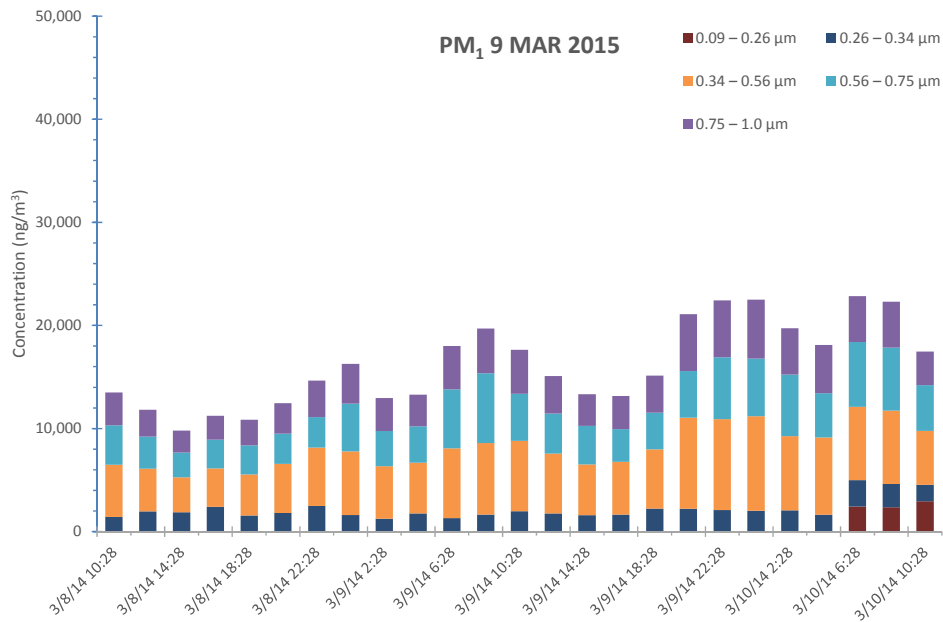


b) DRUM PM_{2.5} size resolved

Fig. D-56 DRUM β -gauge measured PM_{2.5} size resolved: 09 Mar 2014; (a) CaPh 34, (b) CaPh 32



a) DRUM PM₁ size resolved



b) DRUM PM₁ size resolved

Fig. D-57 DRUM β -gauge measured PM₁ size resolved: 09 Mar 2014; (a) CaPh 34, (b) CaPh 32

D-11 10 March 2014

The air arriving spent the previous 84 h elevated well above the surface arriving from the west and north near the Russian Republic of Bashkortostan.

There are almost completely continuous aethalometer data.

There are DRUM data from both CaPh32 and CaPh34.

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 10 Mar 14
 GDAS Meteorological Data

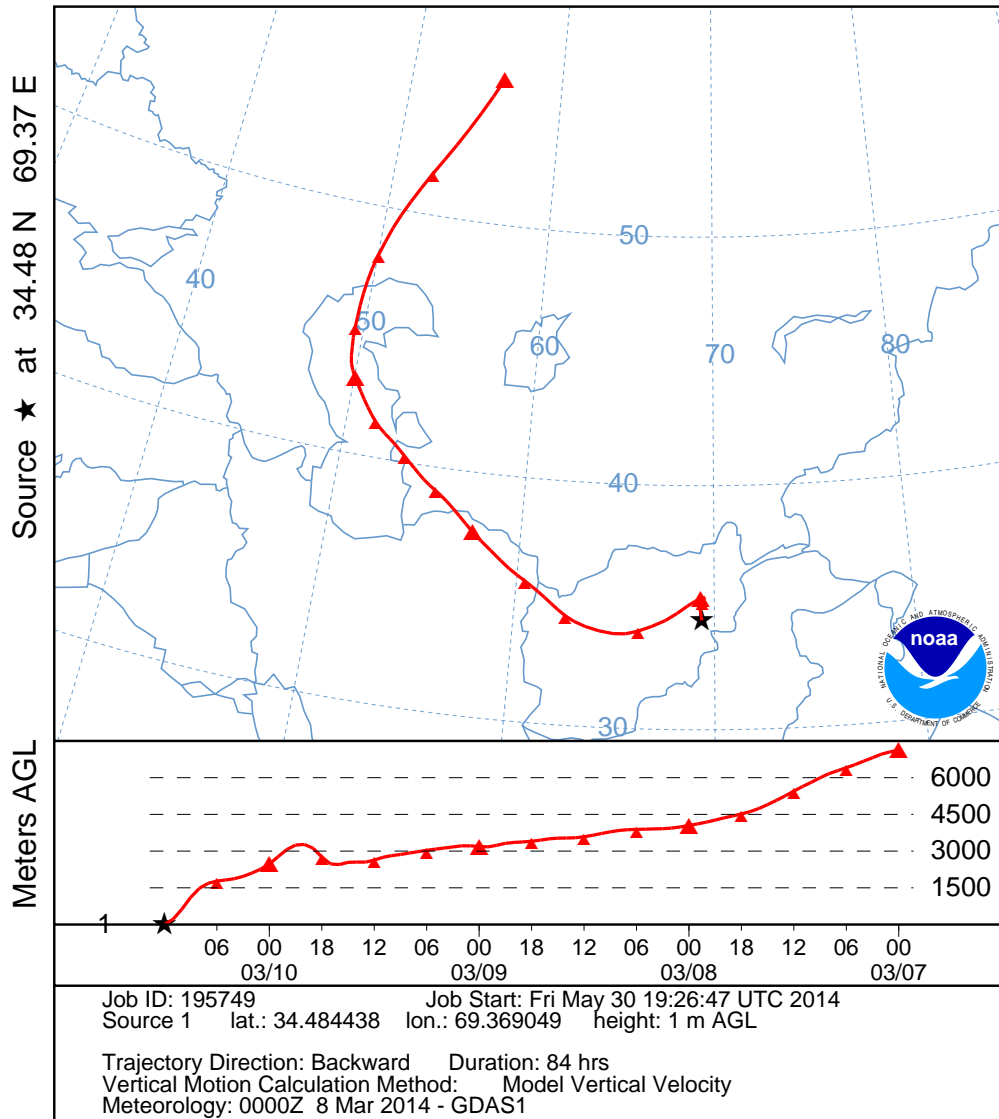


Fig. D-59 HYSPLIT back trajectory 10 Mar 2014

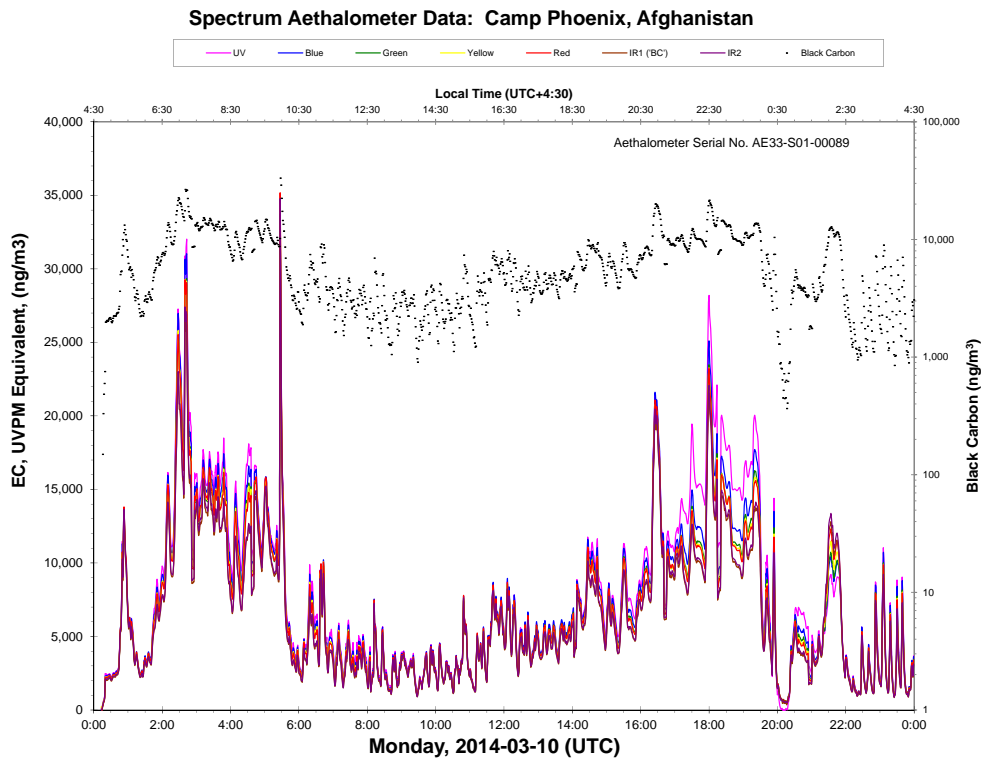
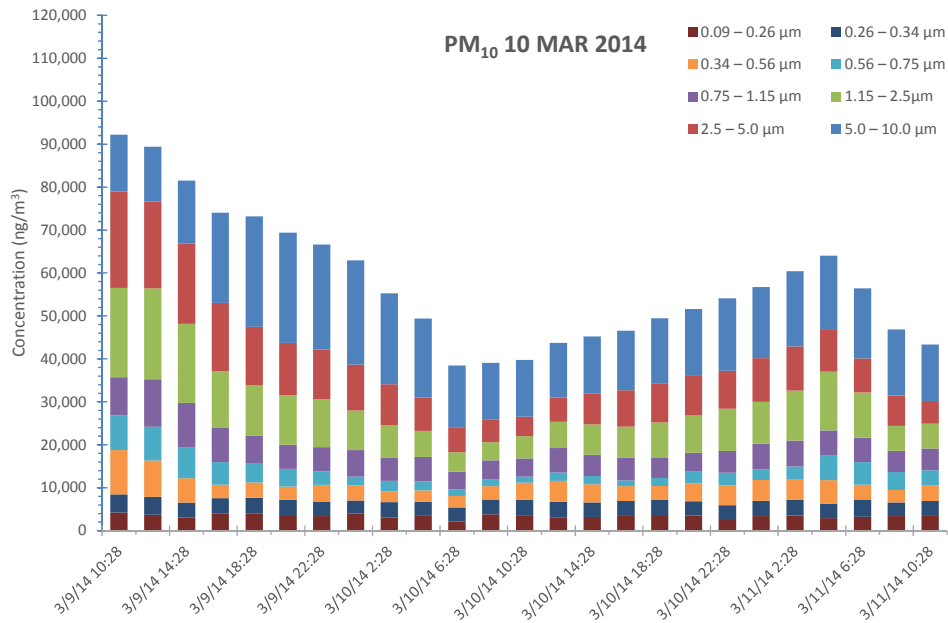
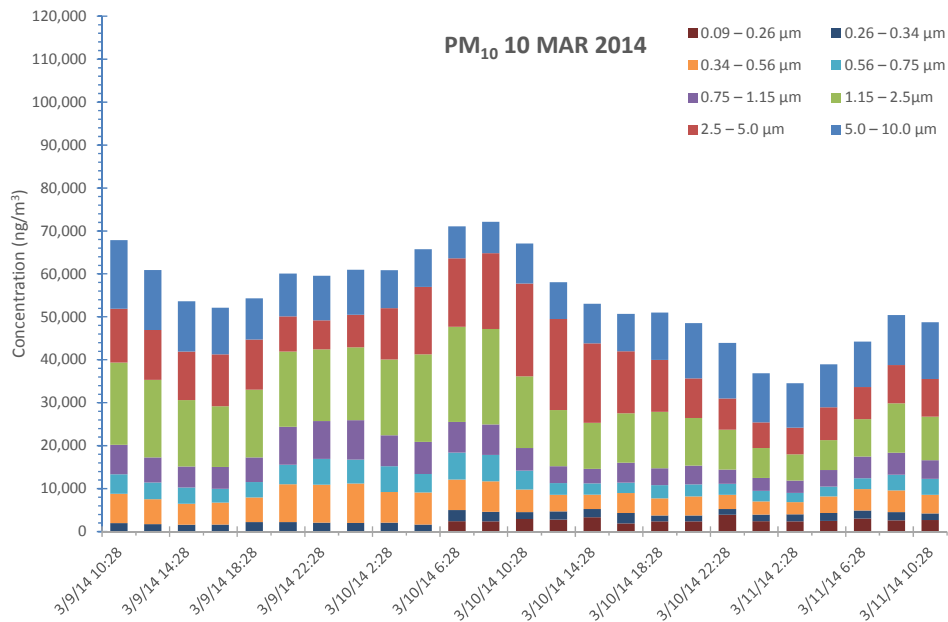


Fig. D-60 Aethalometer measured black carbon: 10 Mar 2014

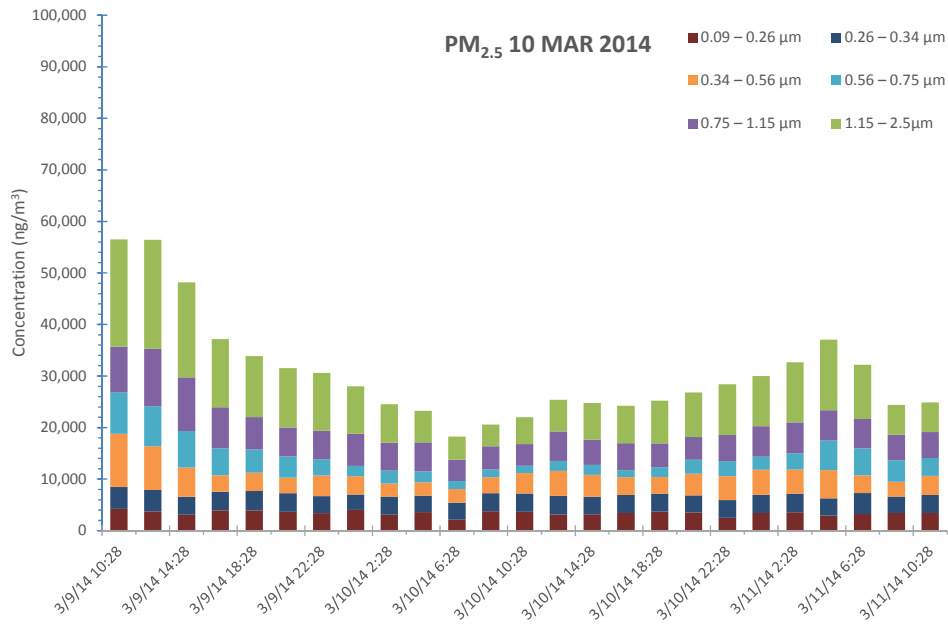


a) DRUM CaPh 34: PM₁₀ size resolved

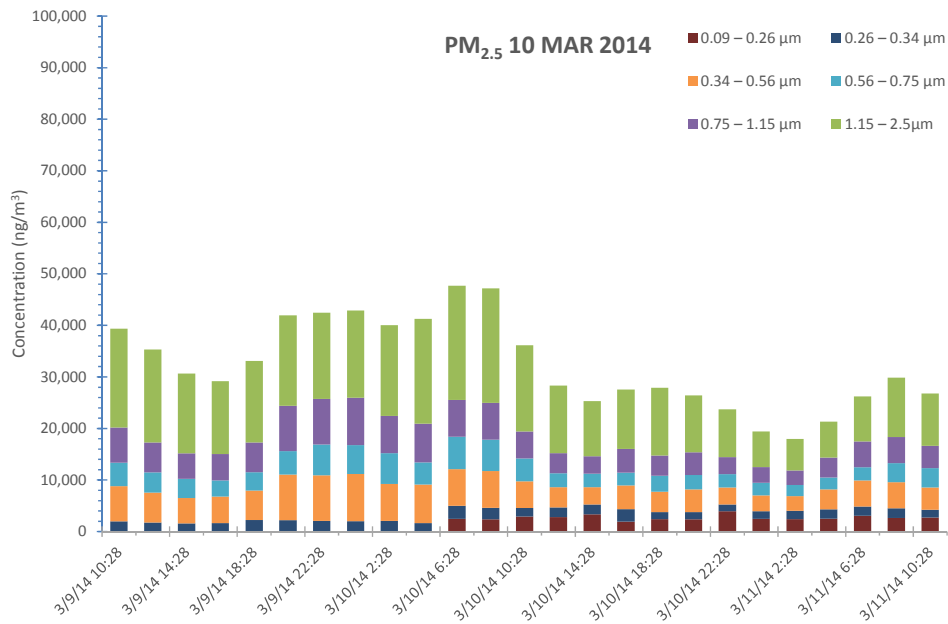


b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-61 DRUM β -gauge measured PM₁₀ size resolved: 10 Mar 2014; (a) CaPh 34, (b) CaPh 32

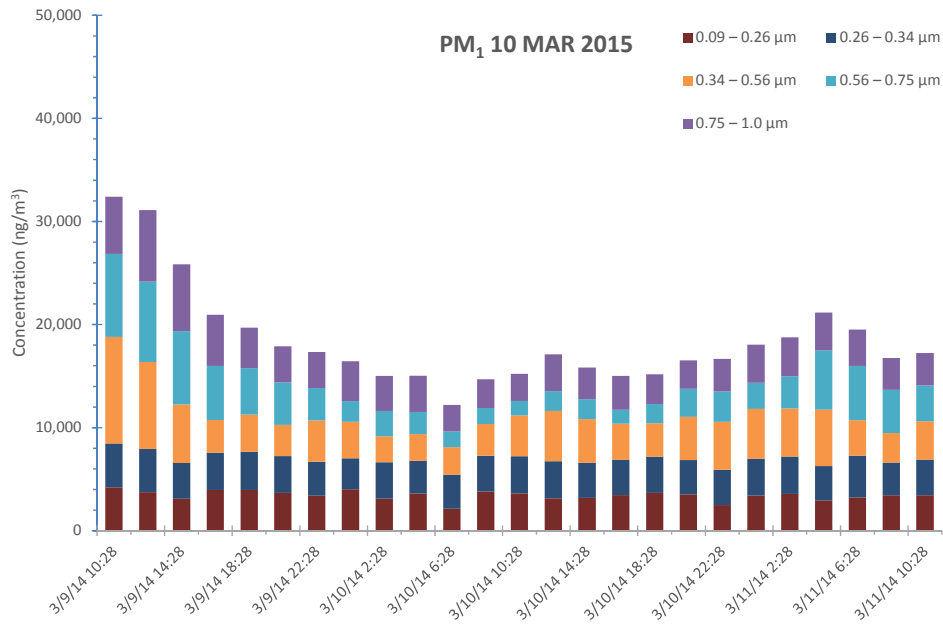


a) DRUM PM_{2.5} size resolved

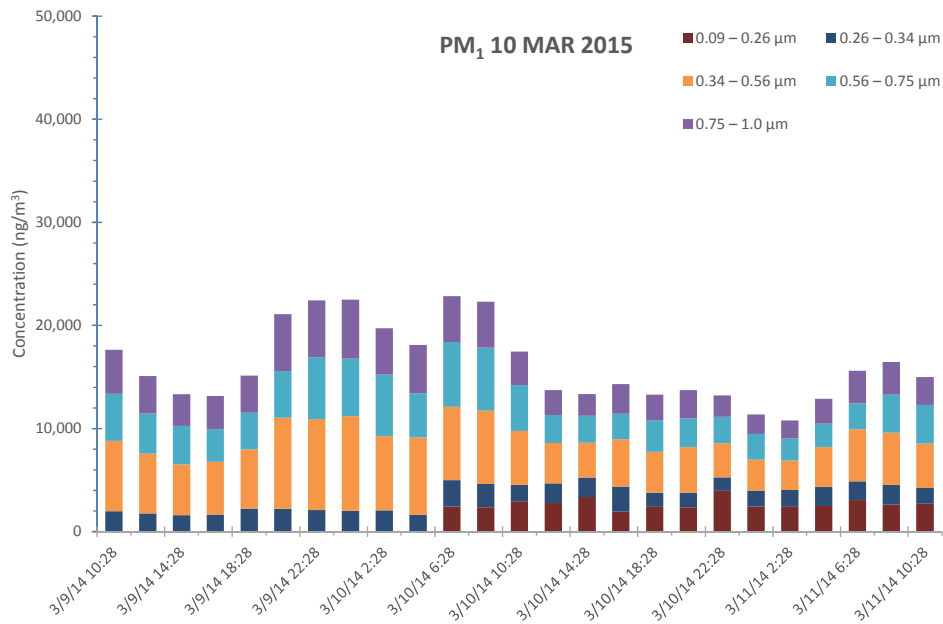


b) DRUM PM_{2.5} size resolved

Fig. D-62 DRUM β -gauge measured PM_{2.5} size resolved: 10 Mar 2014; (a) CaPh 34, (b) CaPh 32



a) DRUM PM₁ size resolved



b) DRUM PM₁ size resolved

Fig. D-63 DRUM β -gauge measured PM₁ size resolved: 10 Mar 2014; (a) CaPh 34, (b) CaPh 32

D-12 11 March 2014

The air arriving spent the previous 10 h near the surface preceded by 47 h elevated well above the surface arriving from the north and northwest near the Aral Sea in Kazakhstan.

There are continuous aethalometer data.

There are DRUM data from both CaPh32 and CaPh34.

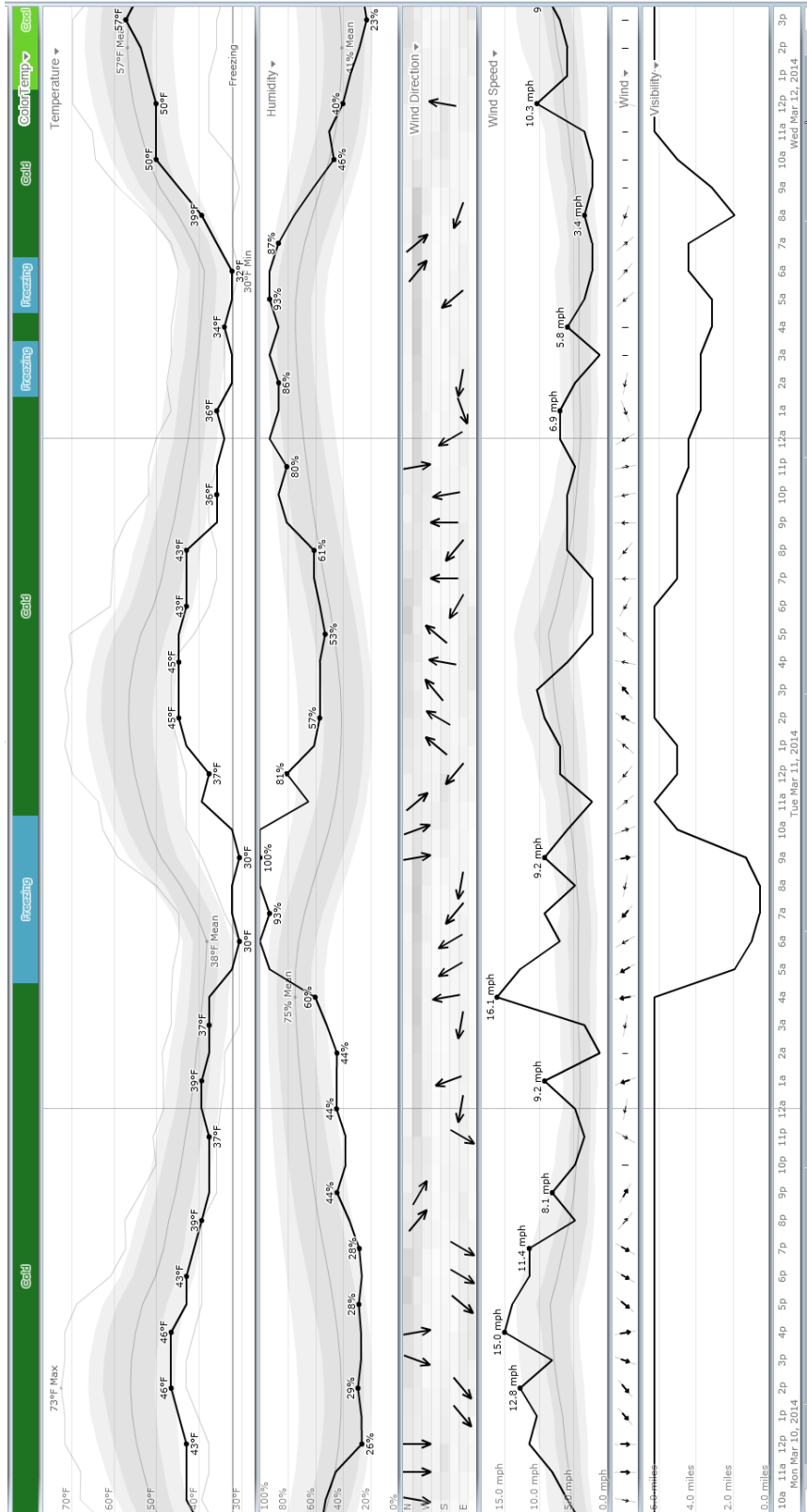


Fig. D-64 Kabul weather summary: 11 Mar 2014

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NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 11 Mar 14
 GDAS Meteorological Data

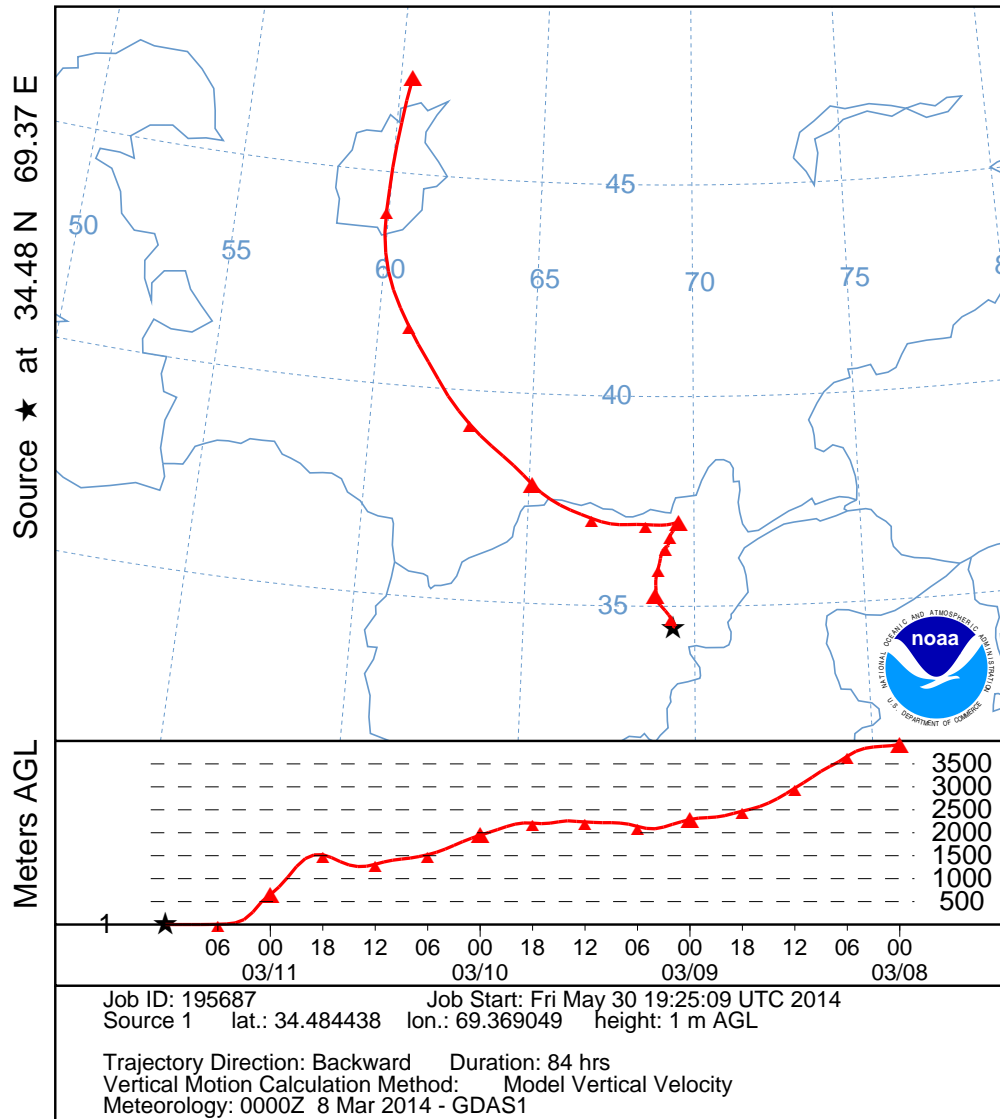


Fig. D-65 HYSPLIT back trajectory 11 Mar 2014

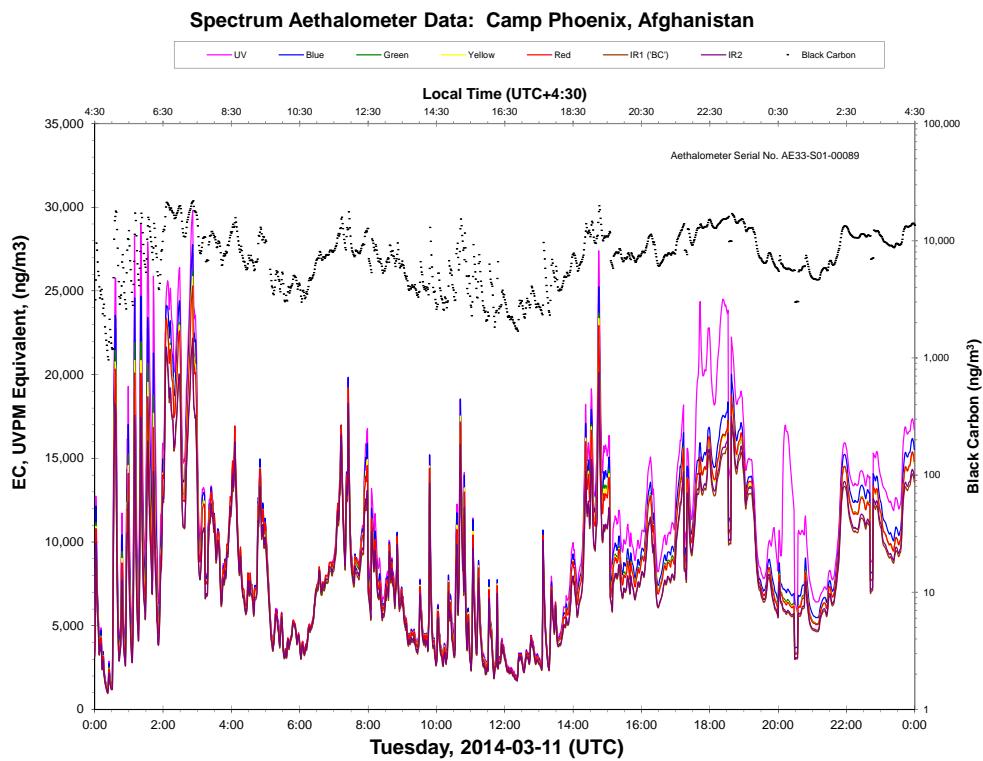
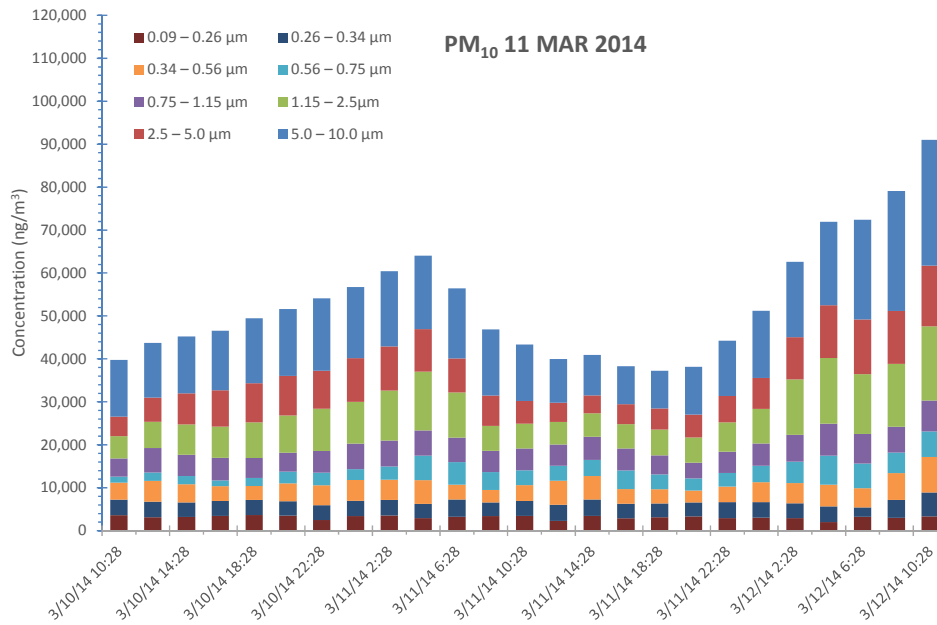
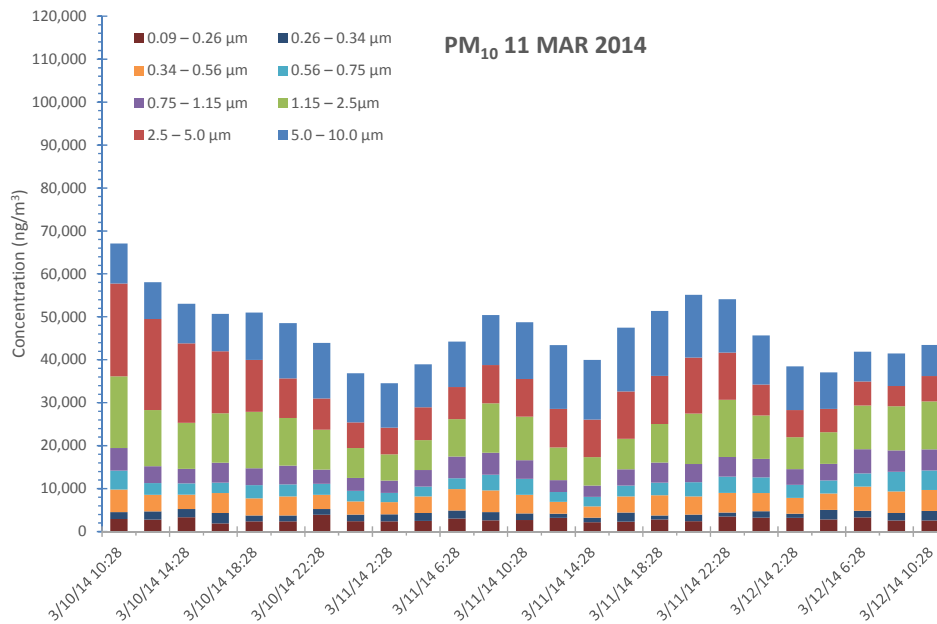


Fig. D-66 Aethalometer measured black carbon: 11 Mar 2014

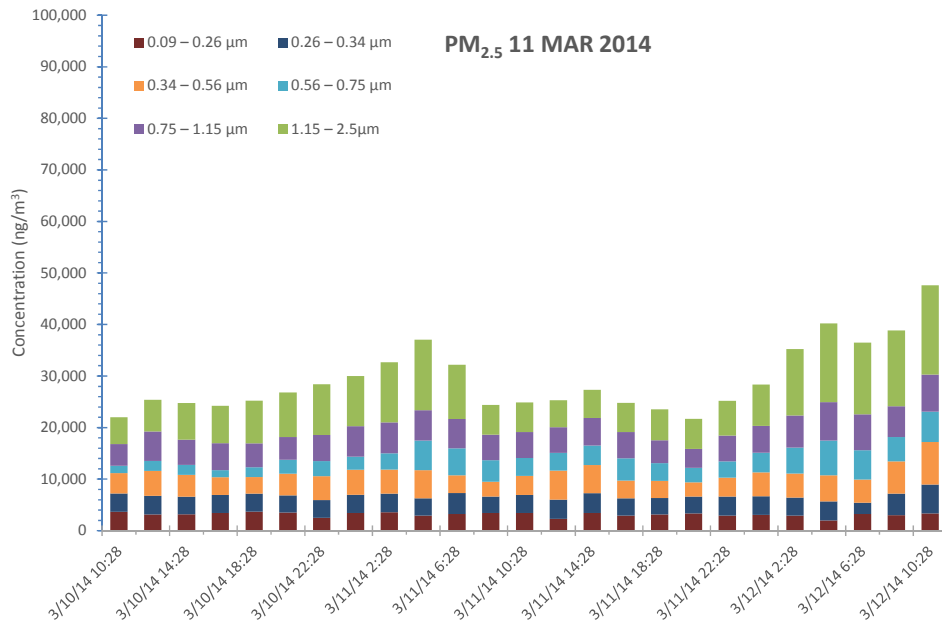


a) DRUM CaPh 34: PM₁₀ size resolved

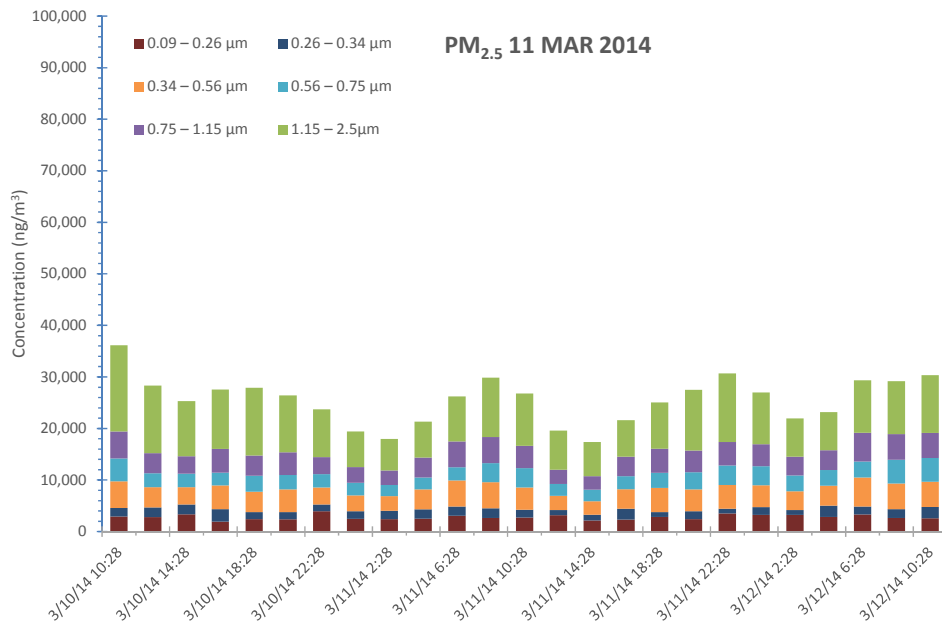


b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-67 DRUM β -gauge measured PM₁₀ size resolved: 11 Mar 2014; (a) CaPh 34, (b) CaPh 32

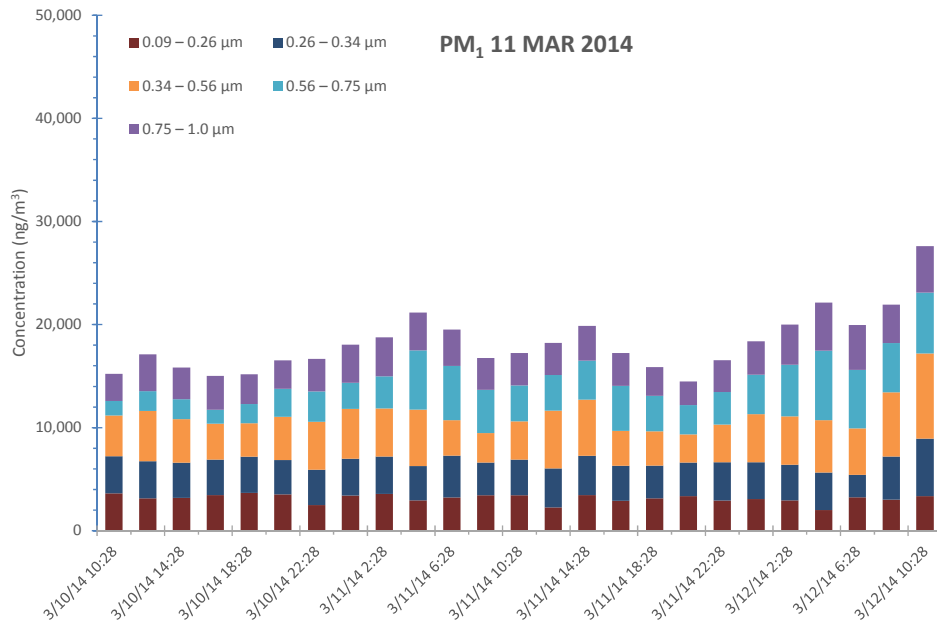


a) DRUM PM_{2.5} size resolved

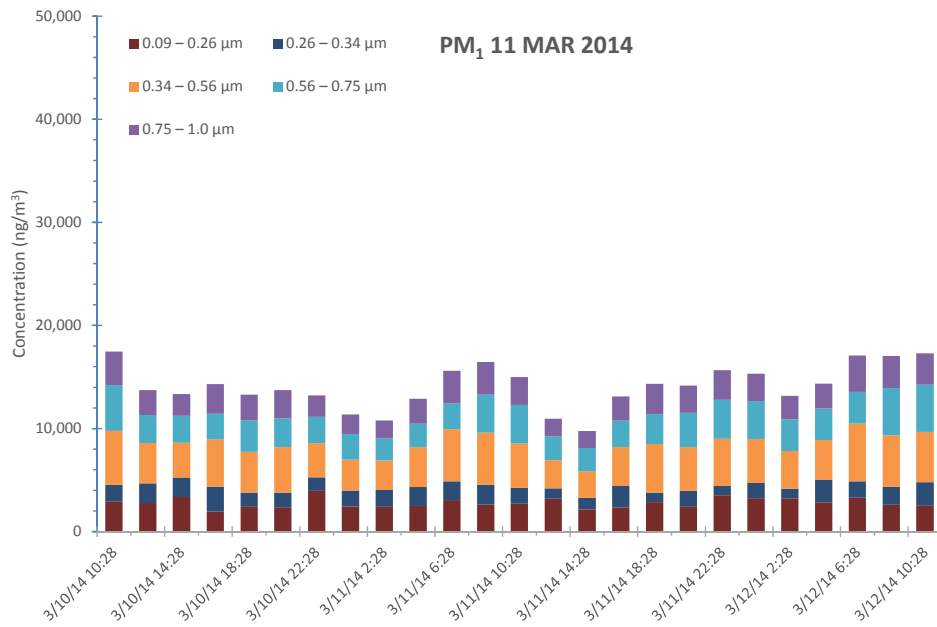


b) DRUM PM_{2.5} size resolved

Fig. D-68 DRUM β -gauge measured PM_{2.5} size resolved: 11 Mar 2014; (a) CaPh 34, (b) CaPh 32



a) DRUM PM₁ size resolved



b) DRUM PM₁ size resolved

Fig. D-69 DRUM β -gauge measured PM₁ size resolved: 11 Mar 2014; (a) CaPh 34, (b) CaPh 32

D-13 12 March 2014

The air arriving spent the previous 30 h near the surface arriving from the south after following a backtracking path from the north over Kabul. From 72 to 30 h prior to arrival, the air was significantly elevated after being near the surface for hours 84 to 72.

There are continuous aethalometer data except for a gap from 0830 until 1015 on 12 March (local time).

There are DRUM data from both CaPh32 and CaPh34.

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 12 Mar 14
 GDAS Meteorological Data

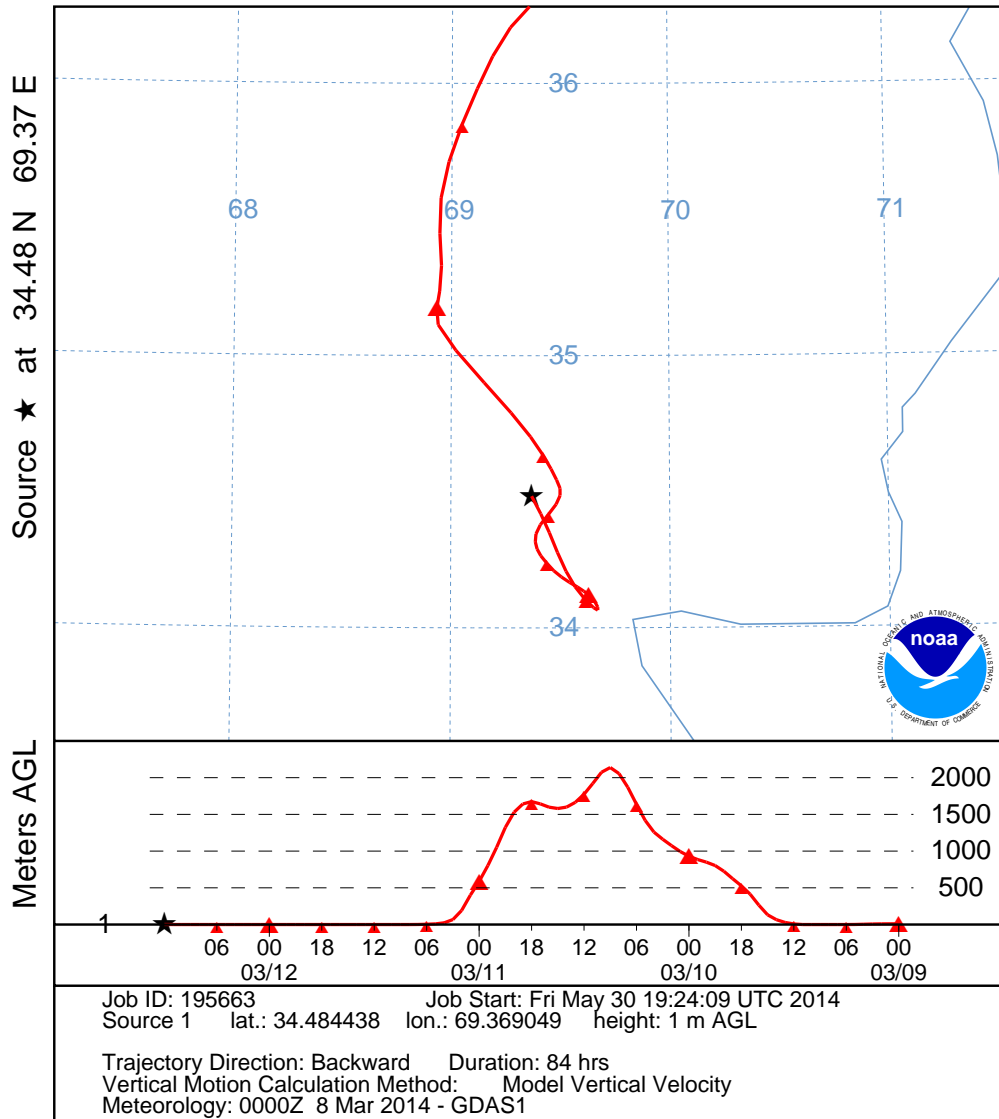


Fig. D-71 HYSPLIT back trajectory 12 Mar 2014

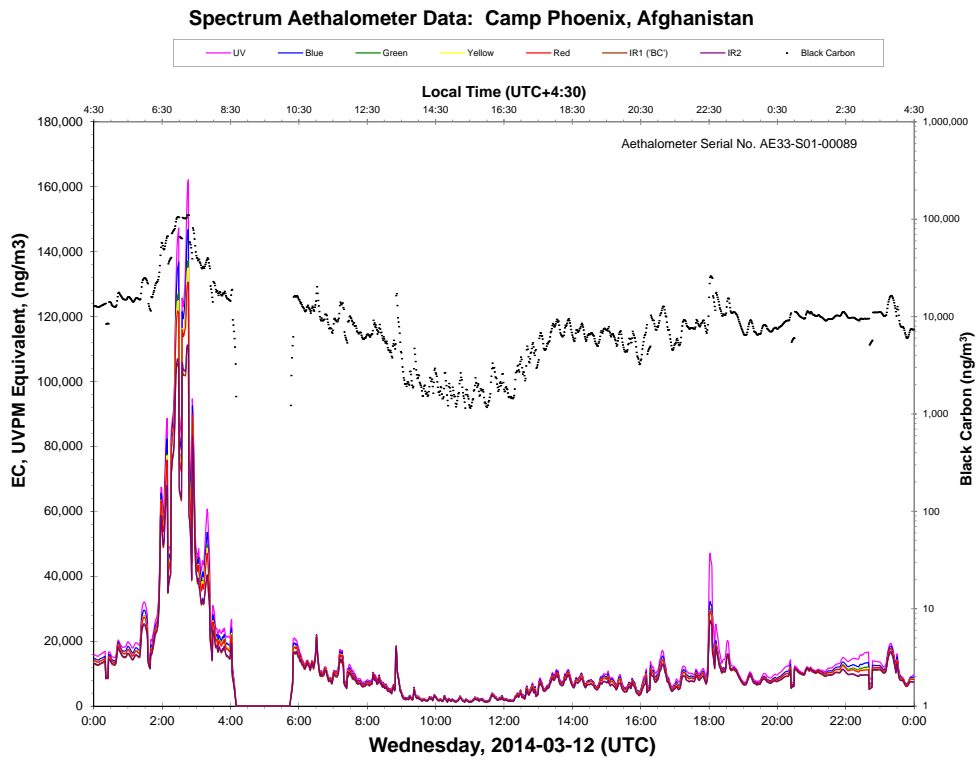
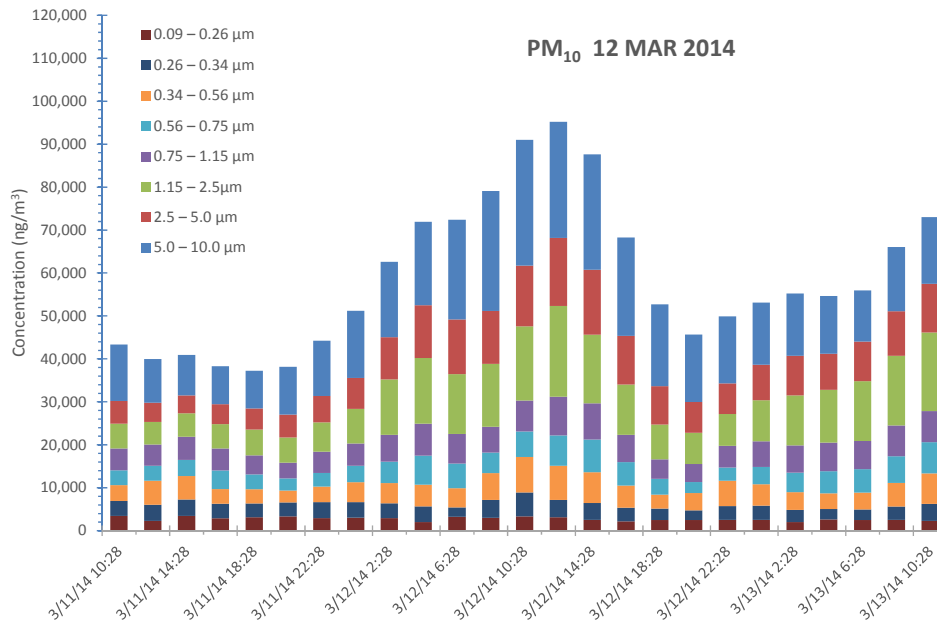
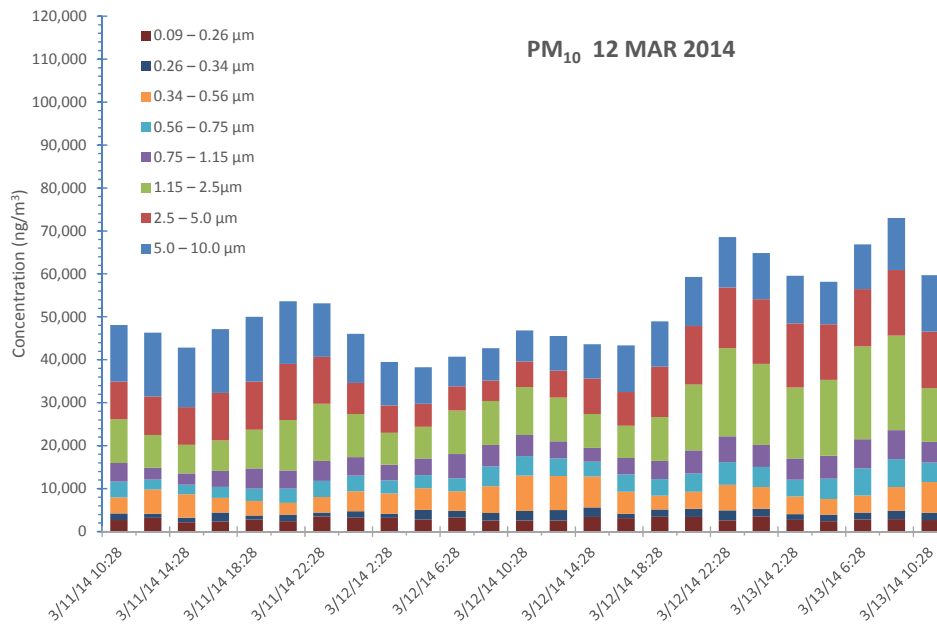


Fig. D-72 Aethalometer measured black carbon: 12 Mar 2014



a) DRUM CaPh 34: PM₁₀ size resolved



b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-73 DRUM β -gauge measured PM₁₀ size resolved: 12 Mar 2014; (a) CaPh 34, (b) CaPh 32

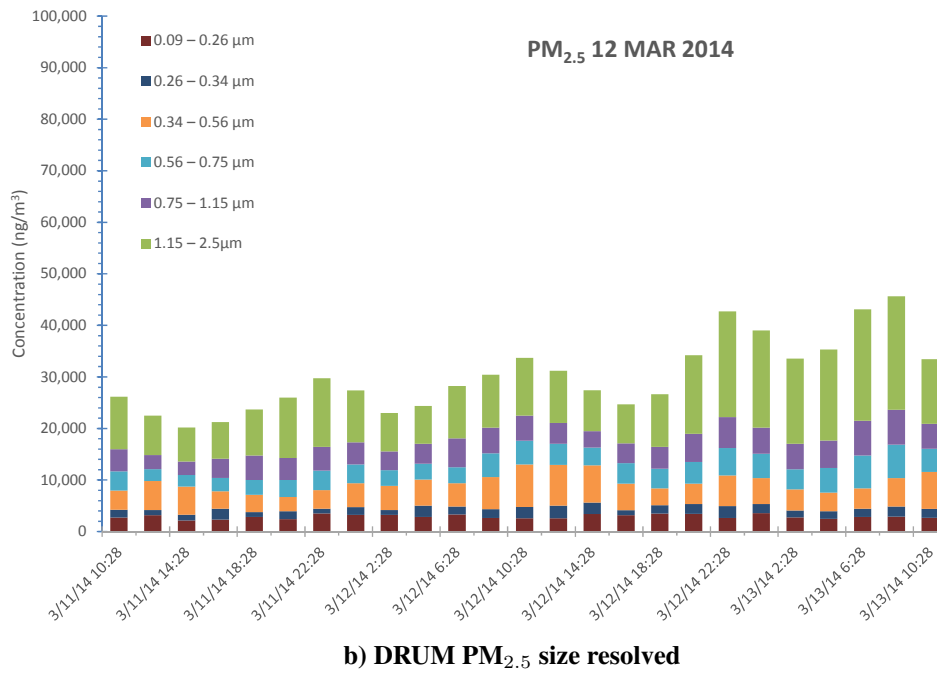
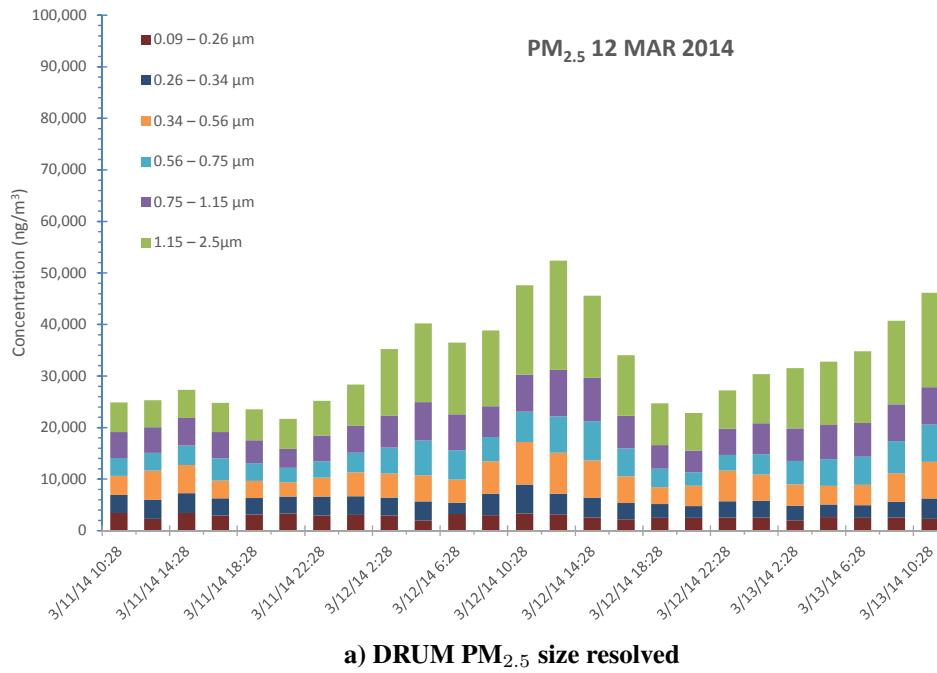
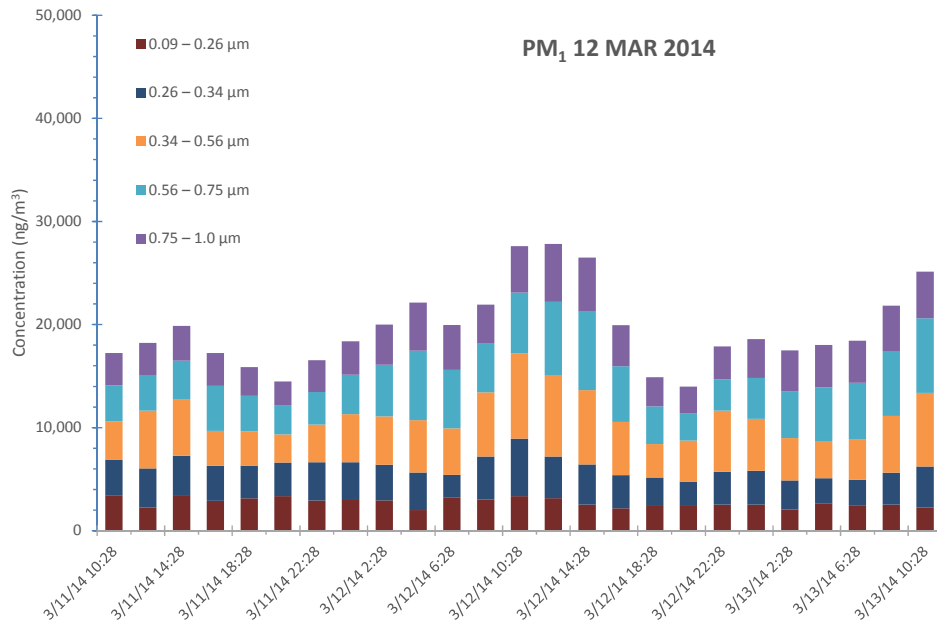
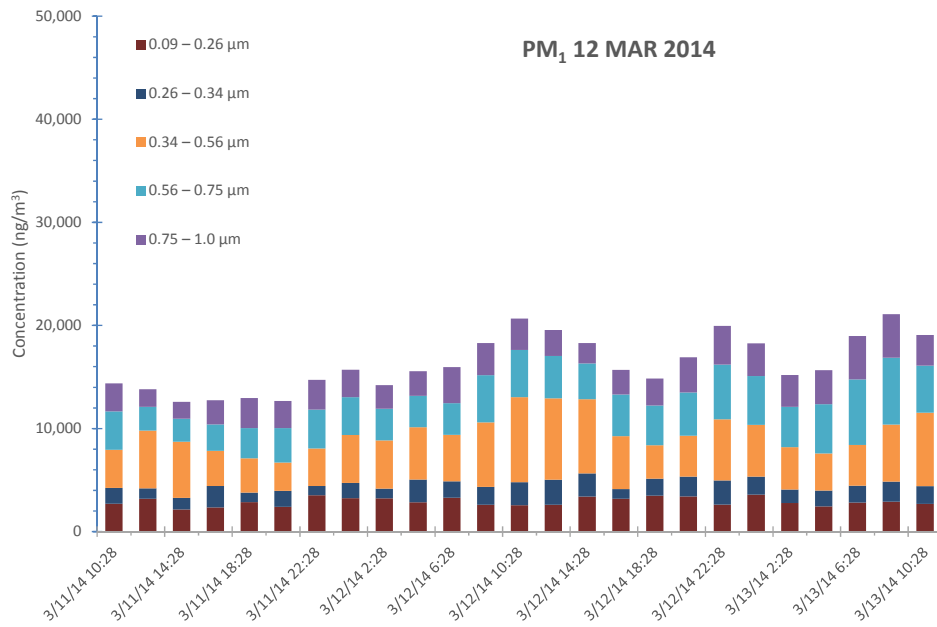


Fig. D-74 DRUM β -gauge measured PM_{2.5} size resolved: 12 Mar 2014; (a) CaPh 34, (b) CaPh 32



a) DRUM PM₁ size resolved



b) DRUM PM₁ size resolved

Fig. D-75 DRUM β -gauge measured PM₁ size resolved: 12 Mar 2014; (a) CaPh 34, (b) CaPh 32

D-14 13 March 2014

This case is very similar to 12 March the air arriving spent the previous 52 h near the surface arriving from the south after following a backtracking path from the north over Kabul. From 52 to 84 h prior to arrival, the air was significantly elevated.

There are continuous aethalometer data except for a short gap from 1545 until 1615 on 13 March (local time).

There are DRUM data from both CaPh32 and CaPh34.

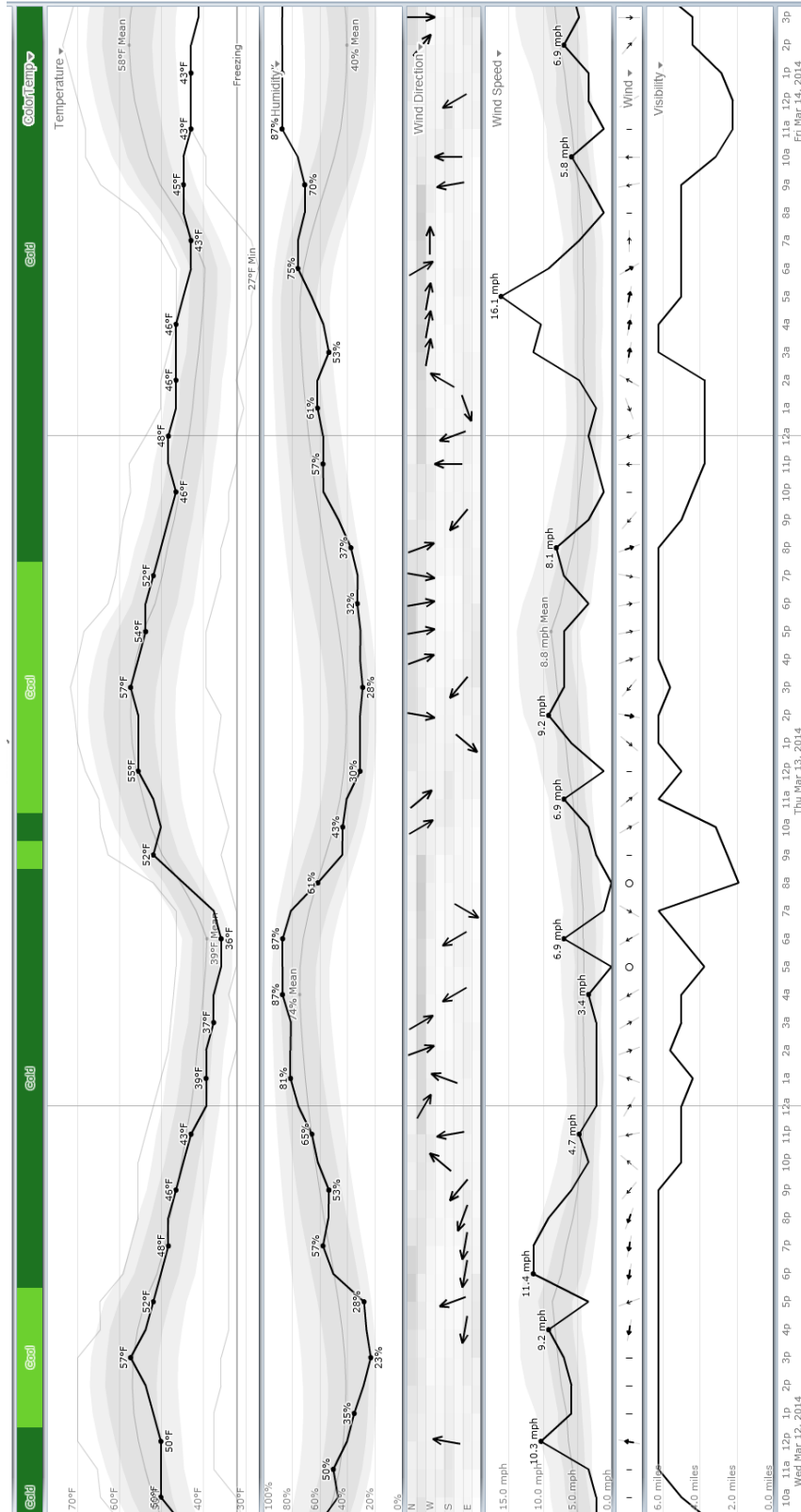


Fig. D-76 Kabul weather summary: 13 Mar 2014

NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 13 Mar 14
 GDAS Meteorological Data

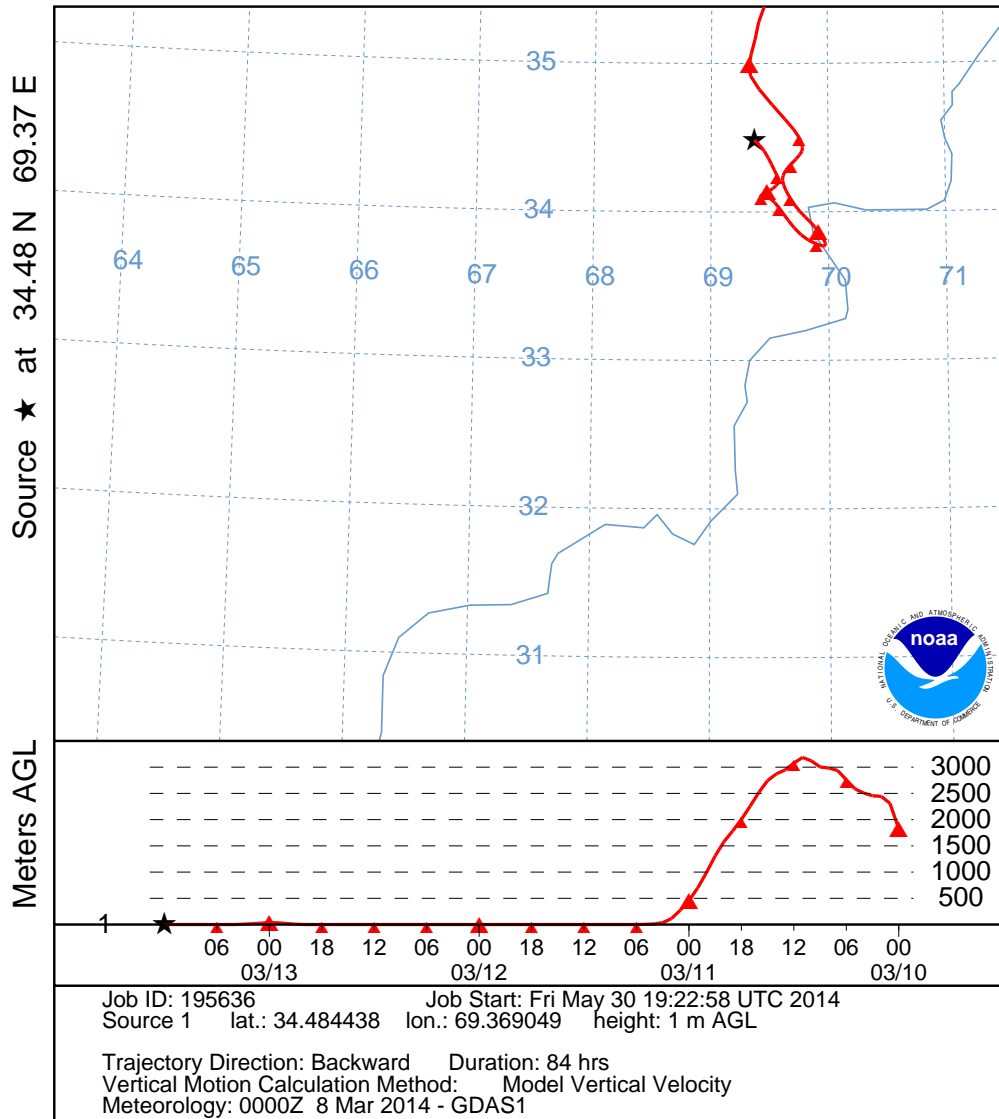


Fig. D-77 HYSPLIT back trajectory 13 Mar 2014

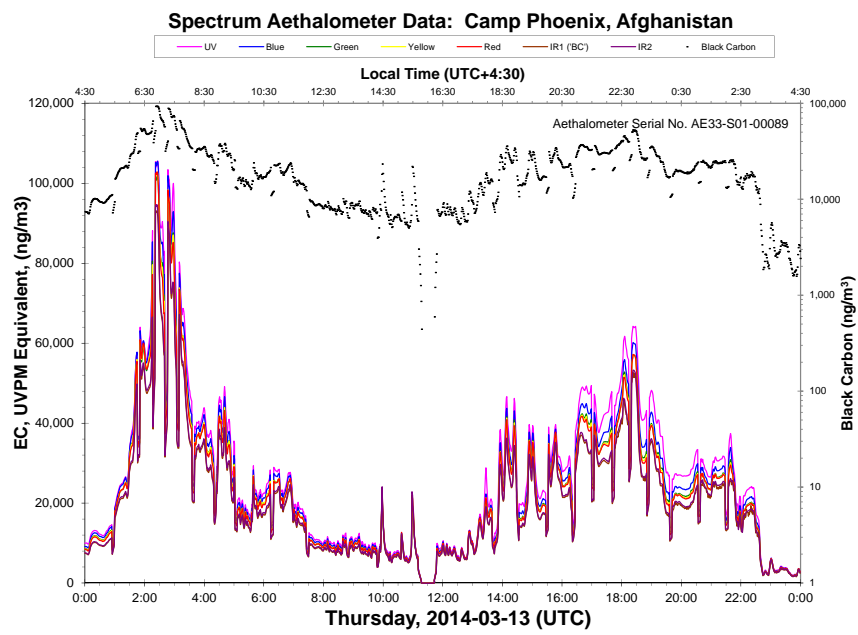
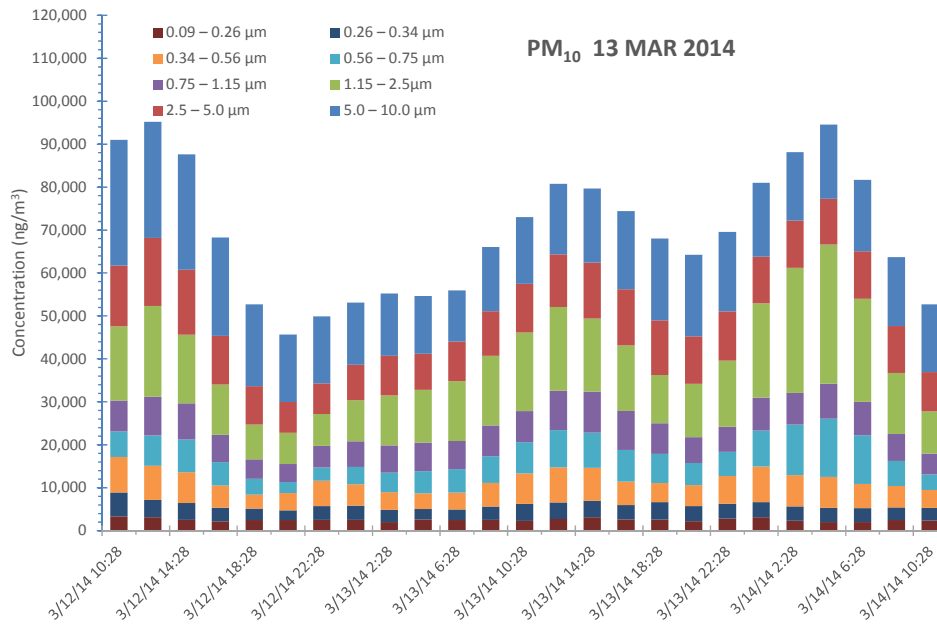
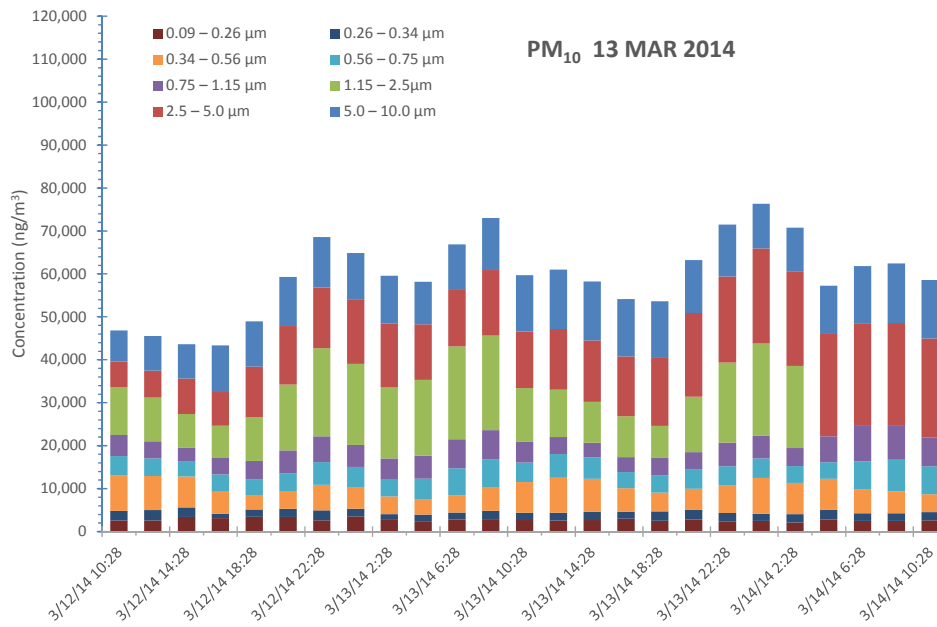


Fig. D-78 Aethalometer measured black carbon: 13 Mar 2014



a) DRUM CaPh 34: PM₁₀ size resolved



b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-79 DRUM β -gauge measured PM₁₀ size resolved: 13 Mar 2014; (a) CaPh 34, (b) CaPh 32

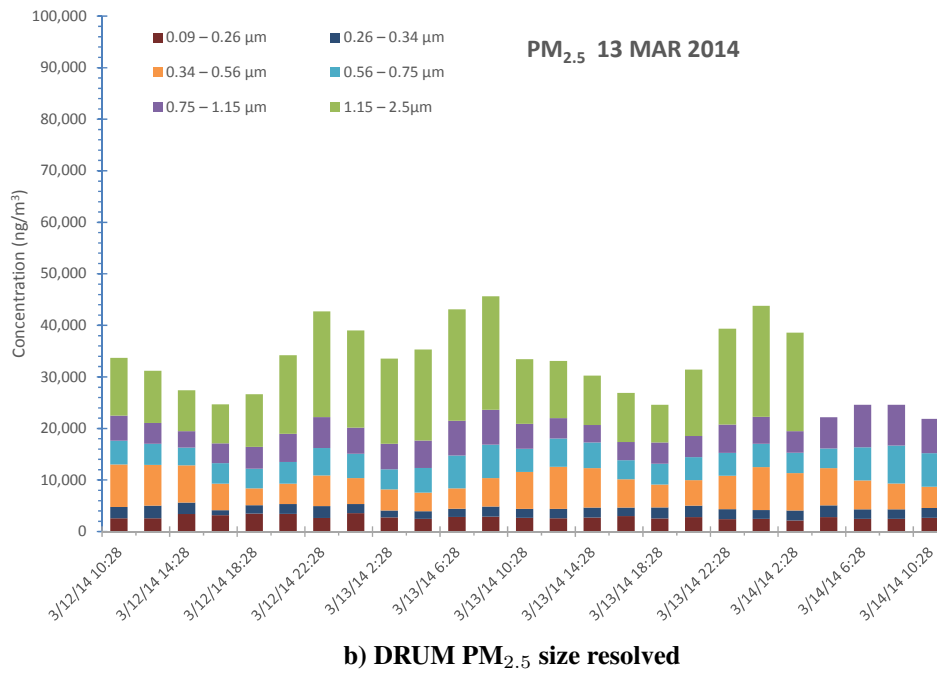
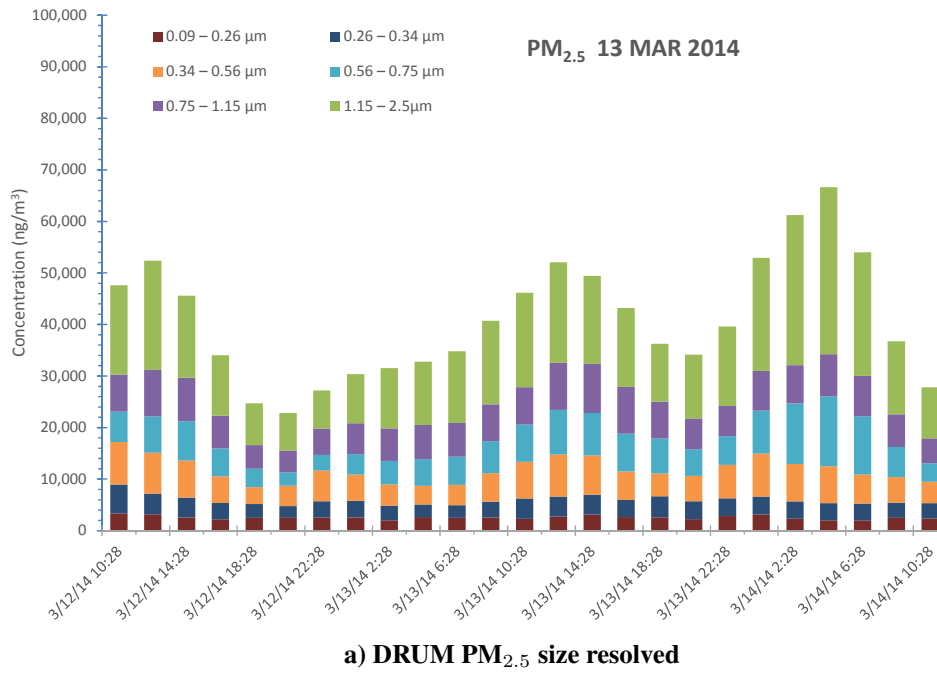
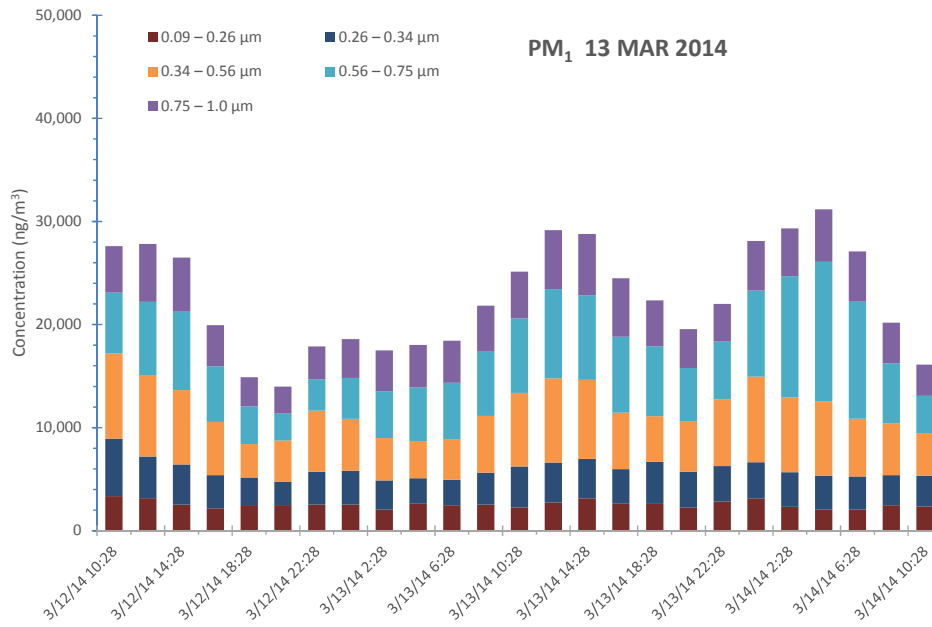
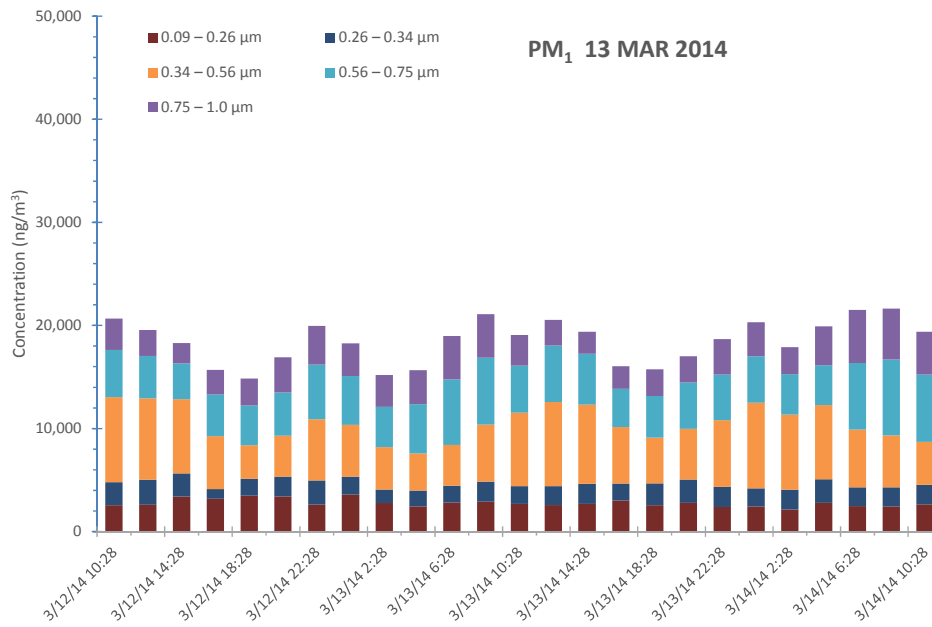


Fig. D-80 DRUM β -gauge measured PM_{2.5} size resolved: 13 Mar 2014; (a) CaPh 34, (b) CaPh 32



a) DRUM PM₁ size resolved



b) DRUM PM₁ size resolved

Fig. D-81 DRUM β -gauge measured PM₁ size resolved: 13 Mar 2014; (a) CaPh 34, (b) CaPh 32

D-15 14 March 2014

The air arriving spent the previous 8 h near the surface arriving from the southeast after following an elevated looping path from 8 to 54 h prior, extending to near Parachinar, Pakistan. From 54 to 84 h prior to arrival, the air was again close to the surface flowing east from the northeastern part (Miya Nishan district) of Kandahar province, and then northeast.

The aethalometer data were continuous until 0900 when the data collection ended (local time).

There are DRUM data from both CaPh32 and CaPh34.

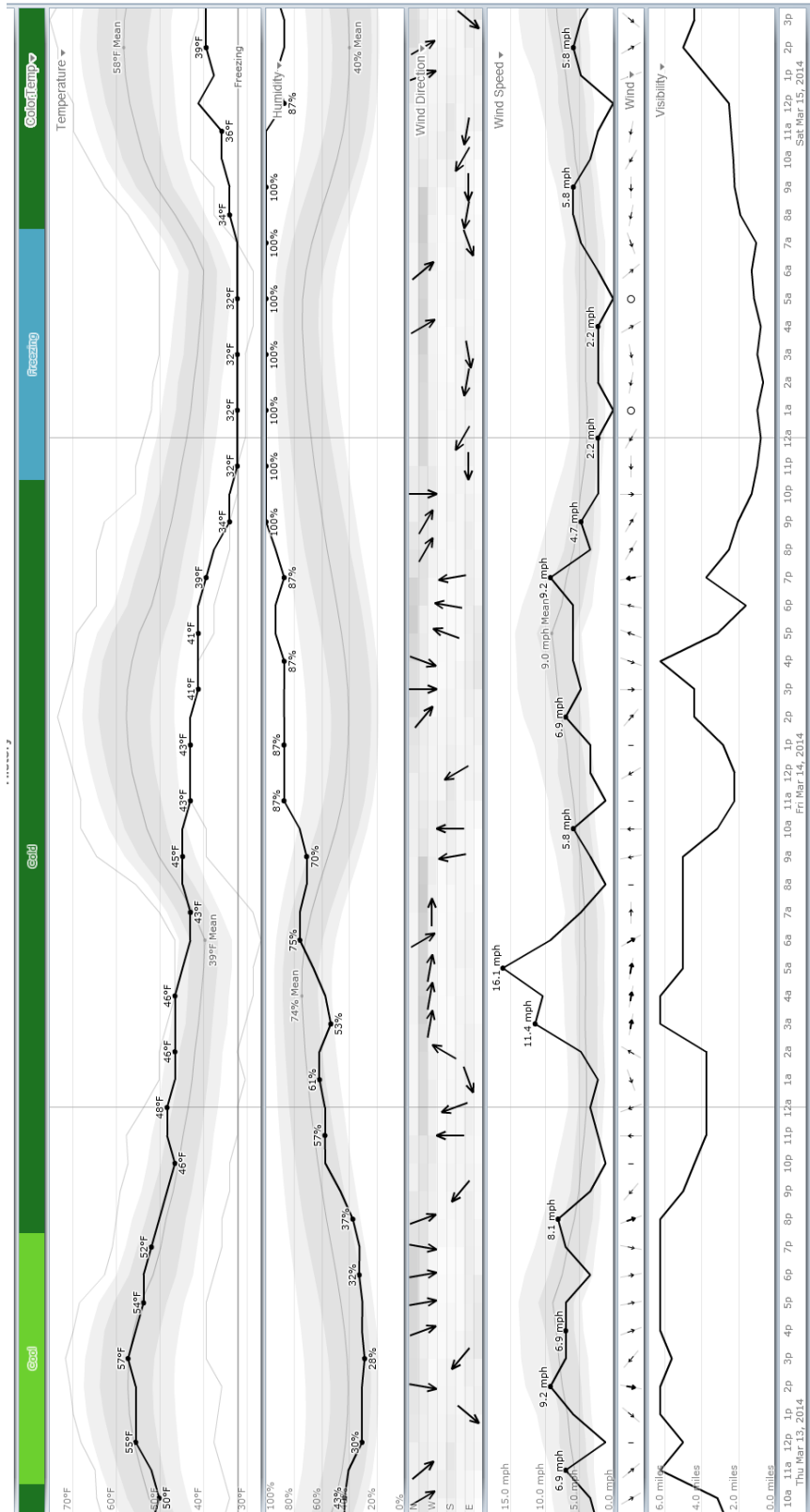


Fig. D-82 Kabul weather summary: 14 Mar 2014

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NOAA HYSPLIT MODEL
 Backward trajectory ending at 1200 UTC 14 Mar 14
 GDAS Meteorological Data

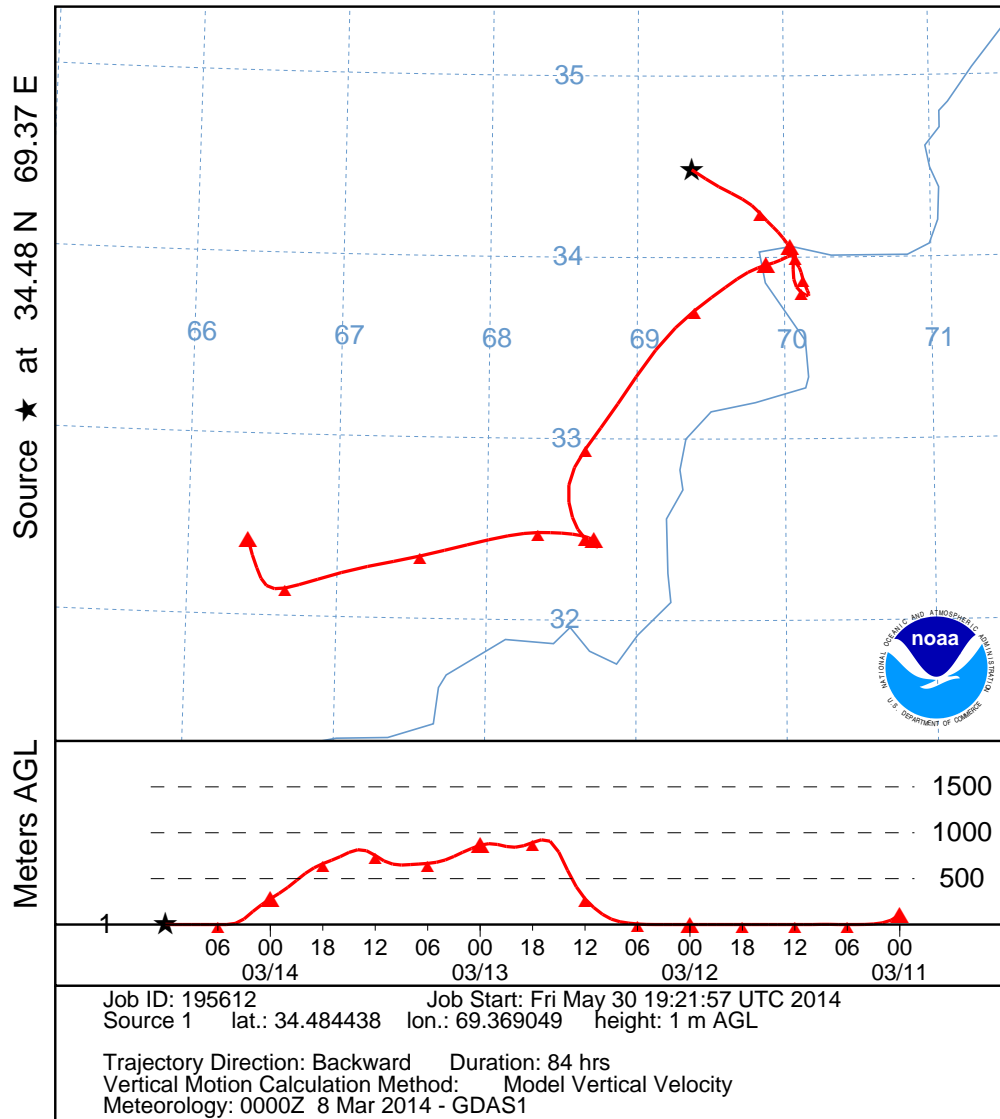


Fig. D-83 HYSPLIT back trajectory 14 Mar 2014

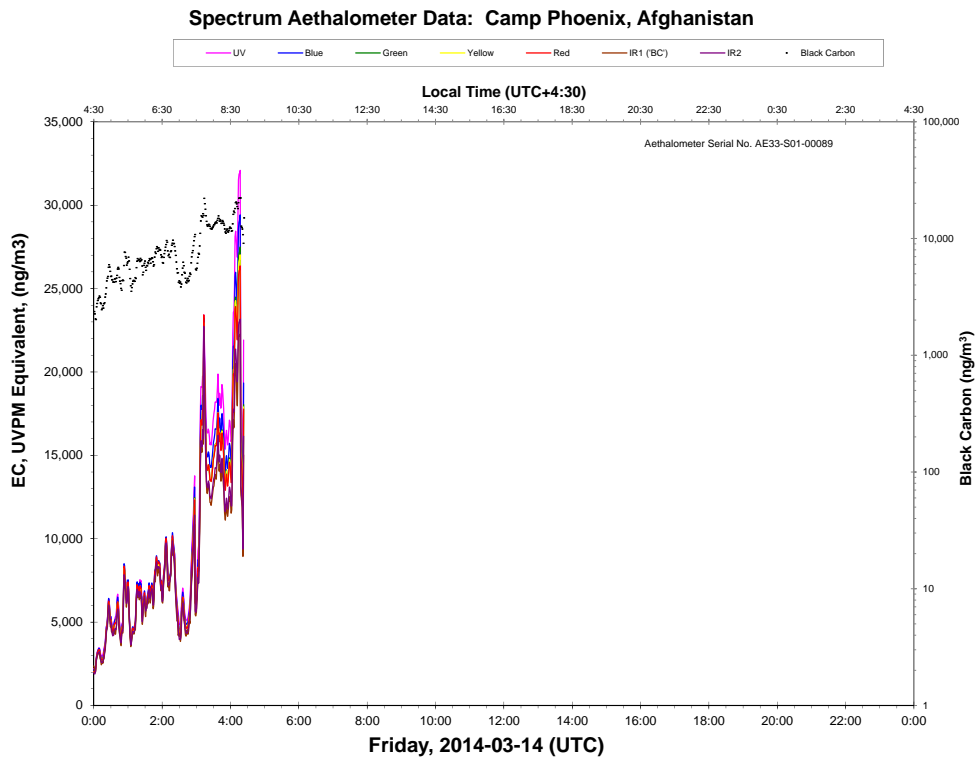
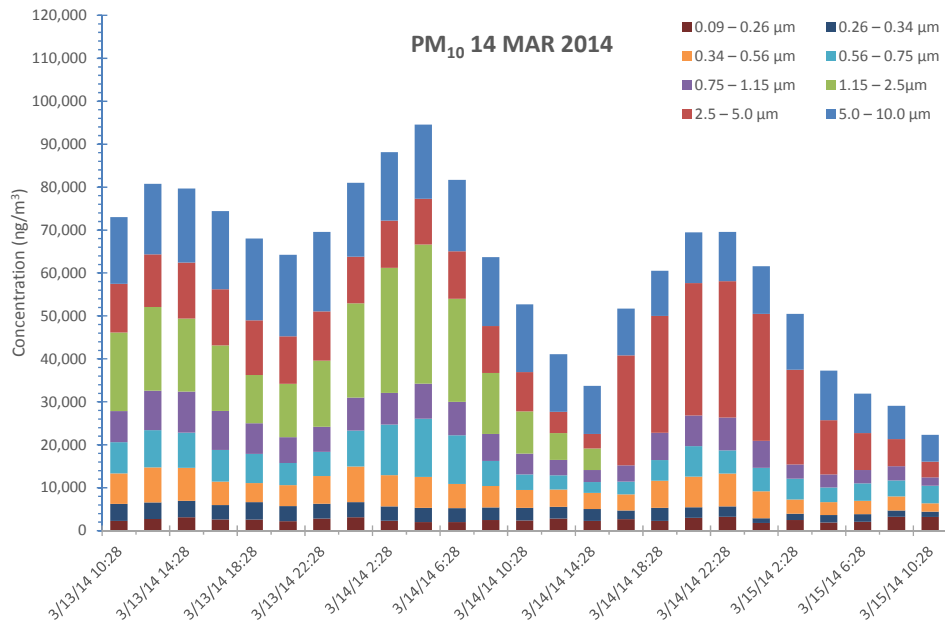
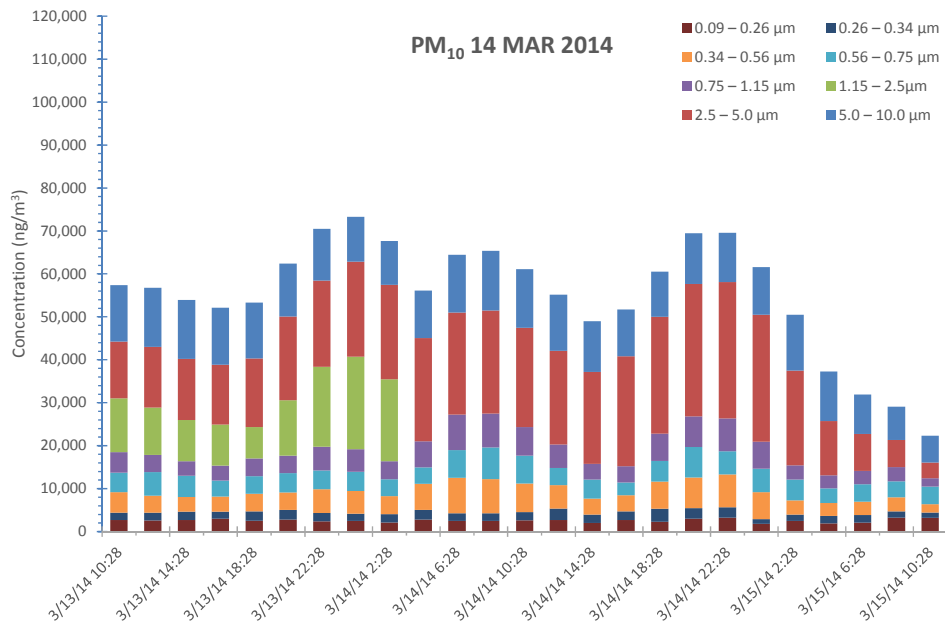


Fig. D-84 Aethalometer measured black carbon: 14 Mar 2014



a) DRUM CaPh 34: PM₁₀ size resolved



b) DRUM CaPh 32 PM₁₀ size resolved

Fig. D-85 DRUM β -gauge measured PM₁₀ size resolved: 14 Mar 2014; (a) CaPh 34, (b) CaPh 32

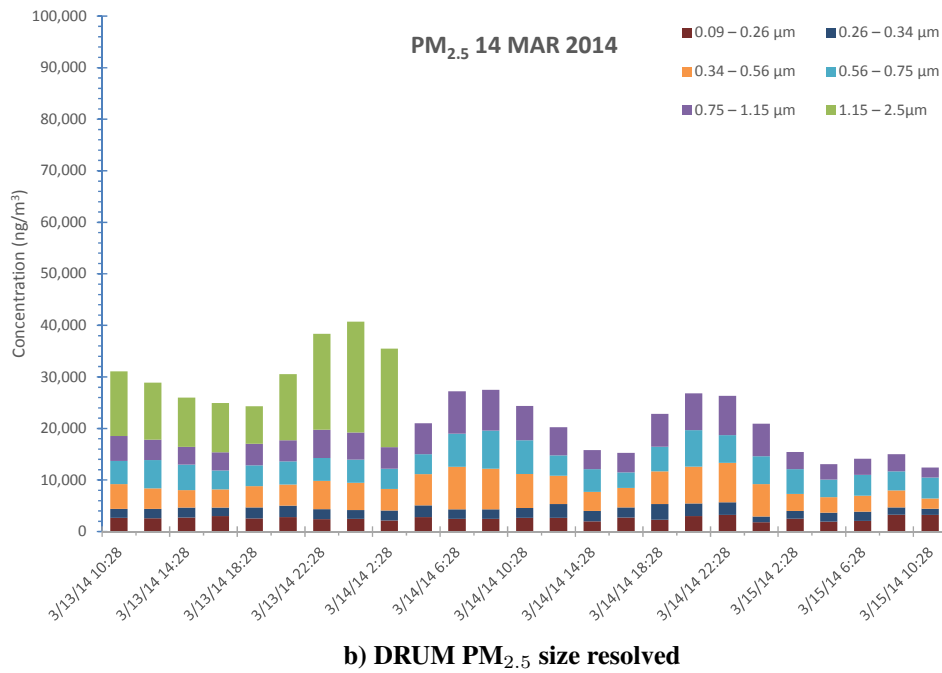
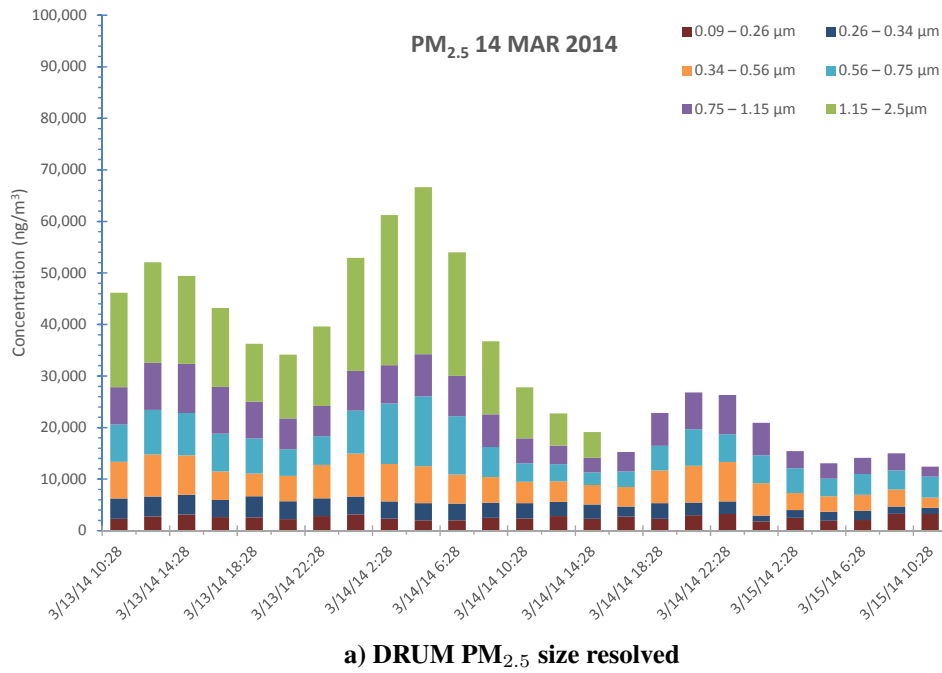


Fig. D-86 DRUM β -gauge measured PM_{2.5} size resolved: 14 Mar 2014; (a) CaPh 34, (b) CaPh 32

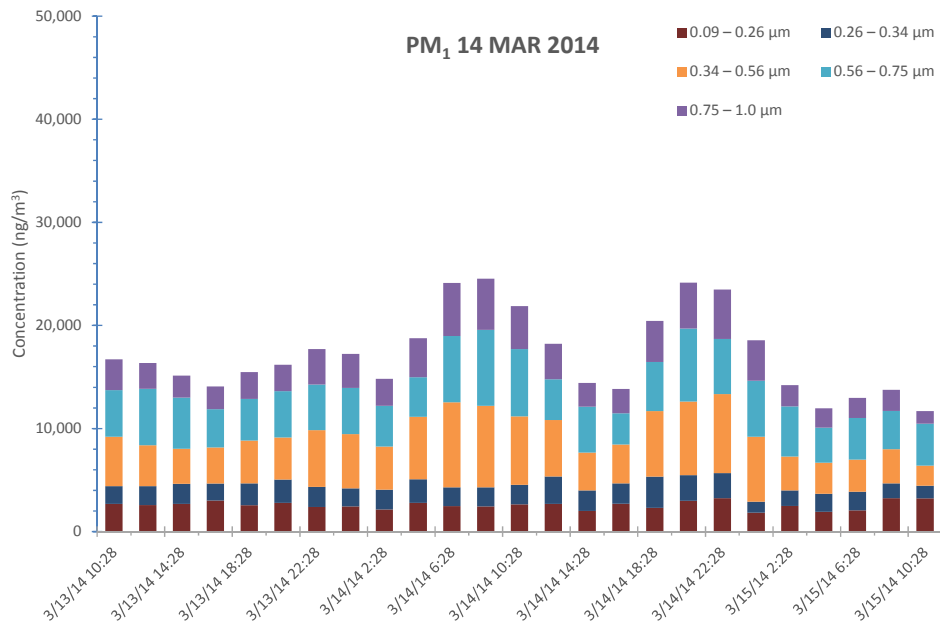
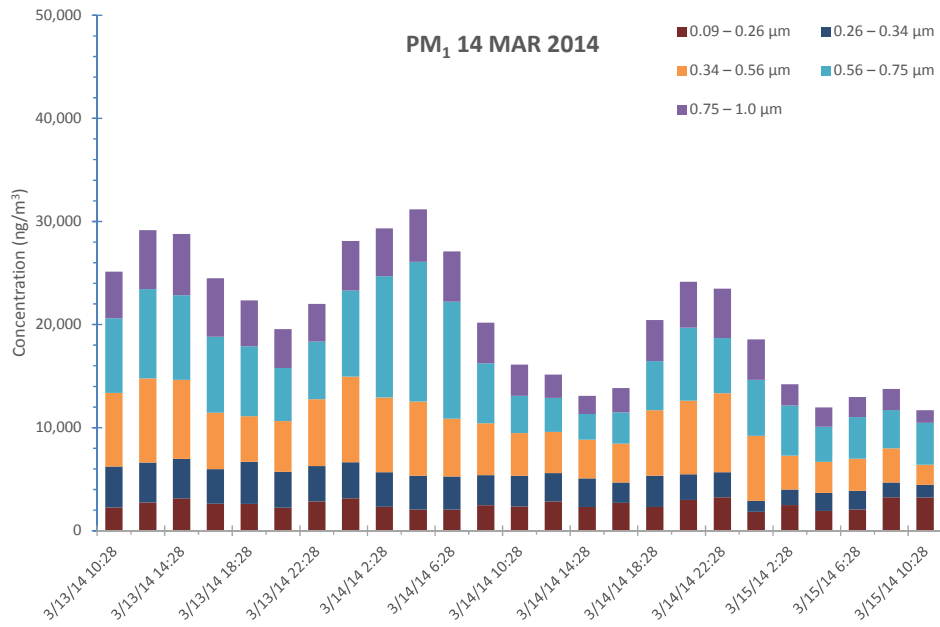



Fig. D-87 DRUM β -gauge measured PM₁ size resolved: 14 Mar 2014; (a) CaPh 34, (b) CaPh 32

Appendix E. Data Files

This appendix contains links to the embedded, or “attached”, copies of the data files used in preparation of this report. The data files can each be extracted when viewing the electronic version of this document by “right clicking” on one of the  icons and selecting the “Save Embedded File to Disk...” menu option.












Meteorological Data Files

These are the file attachments for the MET data. “Station Data” contains information about the reporting station including the Air Force ID, station name, country, latitude, longitude, and elevation. “Meteorological Data” contains the actual METAR records as described in Appendix B

Station Data:  Meteorological Data: 


Aethalometer Data Files

These are the file attachments for the aethalometer data, one file for each day:

2015-02-28:  2015-03-01:  2015-03-02: 
2015-03-03:  2015-03-04:  2015-03-05: 
2015-03-06:  2015-03-07:  2015-03-08: 
2015-03-09:  2015-03-10:  2015-03-11: 
2015-03-12:  2015-03-13:  2015-03-14: 

DRUM Data Files

β -Gauge Data Files

This is the file attachment for the DRUM β -gauge file with data for both the CaPh 32 and CaPh 34 DRUMS. 

XRF Data Files

These are the file attachments for the DRUM XRF data files, one for each DRUM.


CaPh 32:  CaPh 34: 

List of Symbols, Abbreviations, and Acronyms

Symbols

M_{β} Particulate mass measured using the β -gauge

M_{XRF} Particulate mass measured using XRF

 Identifies a link to an embedded datafile

PM₁ Particulate Matter 1, particles with a diameter of 1 μm or less

PM₁₀ Particulate Matter 10, particles with a diameter of 10 μm or less

PM_{2.5} Particulate Matter 2.5, particles with a diameter of 2.5 μm or less

Acronyms

AGL above ground level

APHC Army Public Health Command

ARL US Army Research Laboratory

DRUM Davis Rotating-Unit for Monitoring

HYSPLIT Hybrid Single-Particle Lagrangian Integrated Trajectory

IR infrared

MET meteorological

METAR Meteorological Aerodrome Report

NCDC National Climate Data Center

NOAA National Oceanic and Atmospheric Administration

UC University of California

USB universal serial bus

UTC coordinated universal time

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UV ultraviolet

WBAN Weather-Bureau-Army-Navy

WMO World Meteorological Organization

XRF x-ray fluorescence

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(PDF) INFORMATION CTR
DTIC OCA
- 2 DIRECTOR
(PDF) US ARMY RESEARCH LAB
RDRL CIO LL
IMAL HRA MAIL & RECORDS MGMT
- 1 GOVT PRINTG OFC
(PDF) A MALHOTRA
- 2 ARMY PUBLIC HEALTH CENTER
(PDF) (PROVISIONAL)
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J KIRKPATRICK
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