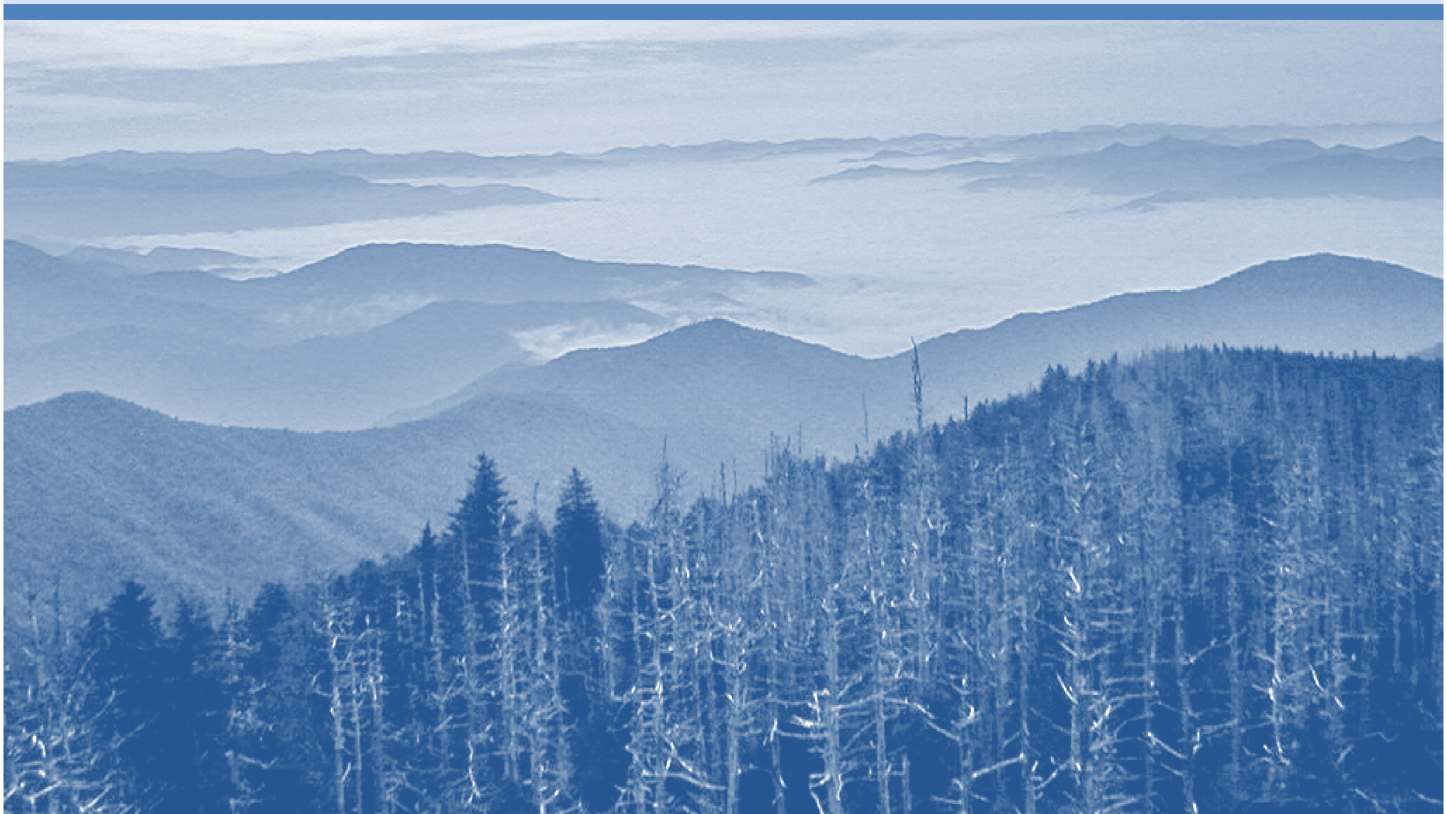
Cloud Deposition Monitoring
Clingmans Dome, Tennessee
Great Smoky Mountains National Park
2010



U.S. Environmental Protection Agency
Clean Air Markets Division
Office of Air and Radiation
Washington, DC

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Prepared for:

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List of Acronyms and Abbreviations

°C	degrees Celsius
Ca^{2+}	calcium ion
CAAA	Clean Air Act Amendments
CAIR	Clean Air Interstate Rule
Campbell	Campbell Scientific, Inc.
CASTNET	Clean Air Status and Trends Network
CLOUD	cloud water deposition computer model
Cl^-	chloride ion
CLD303	Clingmans Dome, TN sampling site
cm	centimeter
cm/s	centimeters per second
CCV	continuing calibration verification spikes
DAS	data acquisition system
EGU	electric generating unit
Element	Element DataSystem for laboratory information management
EPA	U.S. Environmental Protection Agency
$g/cm^2/min$	grams per square centimeter per minute
g/m^3	grams per cubic meter
GRS420	Great Smoky Mountains National Park, TN dry deposition sampling site
H^+	hydrogen ion
HNO_3	nitric acid
IC	ion chromatography
ICP-AES	inductively coupled argon plasma - atomic emission spectrometer
IP	Internet protocol
K^+	potassium ion
kg/ha	kilograms per hectare
Lpm	liters per minute
LWC	liquid water content
m	meters
m/sec	meters per second
MACTEC	MACTEC Engineering and Consulting, Inc.
MADPro	Mountain Acid Deposition Program
MCCP	Mountain Cloud Chemistry Program
Mg^{2+}	magnesium ion
mL	milliliter
MLM	Multi-Layer Model dry deposition computer model
mm	millimeter

List of Acronyms and Abbreviations (continued)

N	nitrogen
Na^+	sodium ion
NADP/NTN	National Atmospheric Deposition Program/National Trends Network
NAPAP	National Acid Precipitation Assessment Program
NBP	NO_x Budget Trading Program
NH_4^+	ammonium ion
NIST	National Institute for Standards and Technology
NO_3^-	nitrate ion
NO_x	oxides of nitrogen
NPS	National Park Service
OTC	Ozone Transport Commission
pH	p(otential of) H(ydrogen)
PVM	particle volume monitor
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RPD	relative percent difference
S	sulfur
SIP	State Implementation Plan
SO_4^{2-}	sulfate ion
SO_2	sulfur dioxide
SSRF	Site Status Report Form
TN11	Elkmont, TN NADP/NTN wet deposition sampling site
TVA	Tennessee Valley Authority
µeq/L	microequivalents per liter
µg/filter	micrograms per filter
$\mu g/m^3$	micrograms per cubic meter

Acknowledgements

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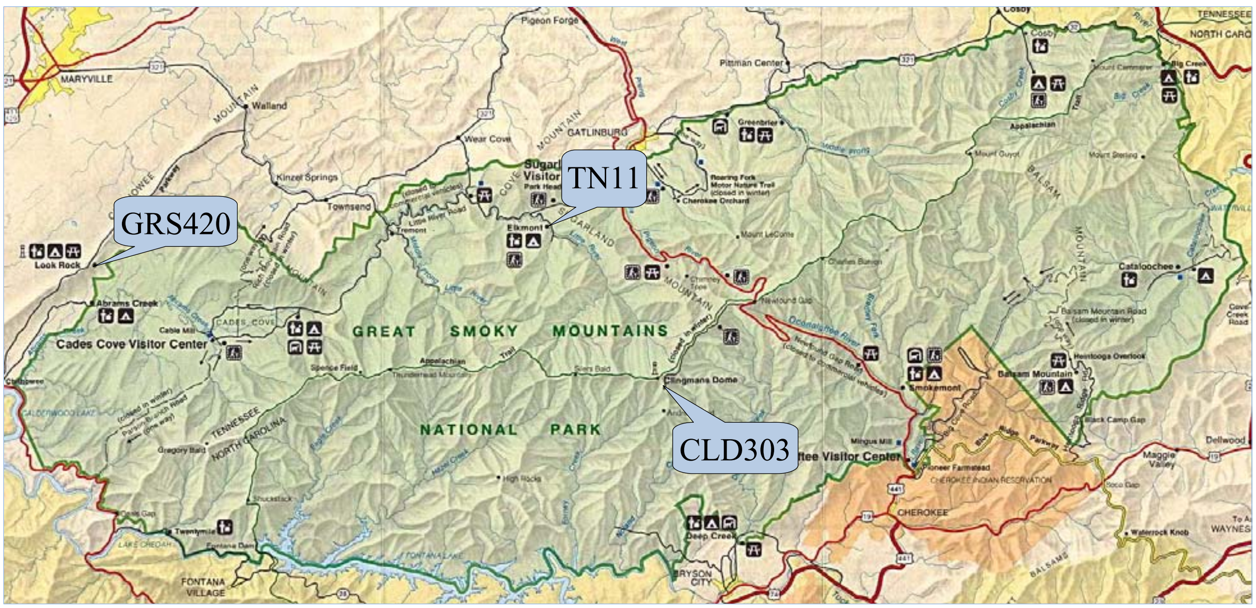
1.0 Introduction

The 1990 Clean Air Act Amendments (CAAA) established the Acid Rain Program, which mandated significant reductions in sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions from electric generating units (EGUs). The SO_2 emission reductions were implemented in two phases. The first phase began in 1995 when large electric generating facilities reduced emissions. The second phase began in 2000 and targeted other power plants. More recent NO_x emission control programs also produced substantive declines in NO_x emissions in the eastern United States. These programs include the Ozone Transport Commission (OTC) NO_x Budget (1999–2002) and the NO_x State Implementation Plan (SIP) Call/NO_x Budget Trading Program (NBP), which operated from 2003 through 2008. The NBP placed a cap on total NO_x emissions from EGUs in the eastern United States during the ozone season (May 1 through September 30) when the potential for ozone formation is high. The Clean Air Interstate Rule (CAIR), which was issued in March 2005, aimed to permanently lower SO_2 and NO_x emissions in the eastern United States. CAIR, as promulgated, established three compliance programs: an annual NO_x program, an ozone season NO_x program, and an annual SO_2 program. Although CAIR was remanded back to the U.S. Environmental Protection Agency (EPA) in 2008, these programs remain in effect while EPA works to develop a replacement rule. The first phase of the annual and ozone season NO_x requirements began in 2009. The SO_2 requirements began in 2010. On July 6, 2010, EPA proposed the Transport Rule, which, if finalized as proposed, will replace the CAIR. The Transport Rule, as proposed, would require 31 states and the District of Columbia to achieve additional reductions in power plant SO_2 and NO_x emissions. EPA further expects that by 2014, the Transport Rule and other state and EPA actions would reduce power plant SO_2 emissions by 71 percent and NO_x emissions by 52 percent from 2005 levels.

Titles IV and IX of the CAAA require that the environmental effectiveness of the Acid Rain Program be assessed through environmental monitoring. This monitoring is required to gauge the impact of emission reductions on air pollution, atmospheric deposition, and the health of affected human populations and ecosystems. The Clean Air Status and Trends Network (CASTNET) was established by EPA in 1991 to provide an effective monitoring and assessment network for determining the status and trends in air quality and pollutant deposition, as well as relationships among emissions, air quality, deposition, and ecological effects. CASTNET measurements collected over the period 1990 through 2009 (MACTEC, 2011a) have shown significant declines in atmospheric sulfur pollutants [SO_2 and particulate sulfate (SO_4^{2-})] and more recently, declines in nitrogen pollutants [nitric acid (HNO_3) and particulate nitrate (NO_3^-)]. The Mountain Acid Deposition Program (MADPro) was initiated in 1993 as part of the research necessary to support CASTNET's objectives. MACTEC Engineering and Consulting, Inc. (MACTEC) operates both CASTNET and MADPro on behalf of EPA and other agencies.

MADPro's main objective is to update the cloud water concentration and deposition data collected in the Appalachian Mountains during the National Acid Precipitation Assessment Program (NAPAP) in the 1980s. MADPro measurements were conducted from 1994 through

1999 during the warm season (May through October) at three mountaintop sampling stations. These sampling stations were located at Whiteface Mountain, NY; Clingmans Dome, TN; and Whitetop Mountain, VA. A mobile manual sampling station also was operated at two locations in the Catskill Mountains in New York during 1995, 1997, and 1998. Measurements during the 2000 and 2001 sampling seasons were collected from two sites: Whiteface Mountain, NY and Clingmans Dome, TN. From the 2002 sampling season forward, cloud water measurements have been collected solely from the site at Clingmans Dome, TN (CLD303). The project was not funded in 2008; therefore, the CLD303 site did not operate. For the 2009 and 2010 sampling seasons, CLD303 was operated under the direction and funding of EPA and the Tennessee Valley Authority (TVA) with infrastructure support provided by the National Park Service (NPS). This report is specifically for the activities and results from the CLD303 site during the 2010 field sampling season.



For 2010, cloud water and meteorological data were measured at the CLD303 site. Atmospheric pollutant concentrations for estimating dry deposition were obtained from the nearest CASTNET site (GRS420, TN). Wet deposition data were obtained from Elkmont, TN (TN11), which is operated by NPS for the National Atmospheric Deposition Program / National Trends Network (NADP/NTN).

2.0 Site Description and Methods

2.1 Site Description

Clingmans Dome (35'33'47"N, 83'29'55"W) is the highest mountain [summit 2,025 meters (m)] in the Great Smoky Mountains National Park. The solar-powered MADPro site is situated at an elevation of 2,014 m approximately 100 m southeast of the summit tourist observation tower. Electronic instrumentation is housed in a small NPS building, and the cloud water collector, particle volume monitor (PVM), and meteorological sensors are positioned on top of a 50-foot scaffold tower.

Collection at the site is initiated each spring as soon as local weather conditions allow. In 2010, the site was installed in late April and sample collection began in early May.

2.2 Field Operations

The site collects cloud water samples and measures those meteorological parameters necessary for operation of the automated cloud collection system and PVM. The cloud collection system consists of an automated cloud water collector for bulk cloud water sampling, a PVM for continuous determination of cloud liquid water content (LWC), and a data acquisition system (DAS) for collection and storage of electronic information from the various monitors and sensors. The DAS was upgraded in 2009 with a Campbell Scientific, Inc. (Campbell) data logger fitted with a relay bank to control mechanical functions and monitor the status of all components of the cloud water collector. Continuous measurements of wind speed, wind direction, temperature, solar radiation, relative humidity, wetness, and precipitation were collected through 2004. Beginning in 2005, only those sensors essential for the operation of the cloud collector (namely, temperature and precipitation sensors and a rain gauge) were deployed. The scalar wind speed data required for calculation of cloud deposition estimates were obtained from the NPS instrument situated on a tower located next to the cloud collection tower. Prior to 2005, the site deployed the same 3-stage filter pack system for dry deposition estimation that is used at all CASTNET sites. Starting in 2005, these data were obtained from the Great Smoky Mountains National Park, TN, CASTNET site (GRS420), which is located 26 miles west, northwest of the Clingmans Dome cloud water sampling site.

The core of the automated cloud collection system is a passive string collector previously used in the Mountain Cloud Chemistry Program (MCCP) study. Collection occurs when ambient winds transport cloud water droplets onto 0.4-millimeter (mm) diameter Teflon fibers strung between two circular disks (Falconer and Falconer, 1980; Mohnen and Kadlecek, 1989). Once impacted, the droplets slide down the strings, are collected into a funnel, and flow through Teflon tubing into a tipping bucket for sample volume determination and then into sample collection bottles housed in an enclosure. The development and design of the original system is described in detail in Baumgardner *et al.* (1997).

The PVM-100 by Gerber Scientific (Gerber, 1984) measures LWC and effective droplet radius of ambient clouds by directing a diode-emitted 780-nanometer wavelength laser beam along a 40-centimeter (cm) path. The forward scatter of the cloud droplets in the open air along the path is measured, translated, and expressed as water in grams per cubic meter (g/m^3) of air. The data logger is programmed so that the collector will be activated and projected out of the protective housing when threshold levels for LWC (0.05 g/m^3) and ambient air temperature [≥ 2 degrees Celsius (°C)] are reached. In addition, the system is activated only when no precipitation is measured. Within the context of MADPro, a cloud is defined by a LWC of 0.05 g/m^3 or higher, as measured by the PVM. This threshold was established to maintain comparability with the MCCP measurements, which were made for the most part with Mallant Optical Cloud Detectors set at a threshold of approximately 0.04 g/m^3 (Mohnen *et al.*, 1990). In previous years, a wind speed threshold of 2.5 meters per second (m/sec) was also used because hourly cloud water collection is erratic and inefficient at lower wind speeds. Higher wind speeds were necessary to yield the minimum 30 milliliters (mL) of cloud water required for sample analysis. Since the commencement of 24-hour bulk sampling in 2000, however, the collection of at least 30 mL of sample has not been an issue. Therefore, the wind speed threshold criterion was eliminated starting in 2004. The temperature limit serves to protect against damage from rime ice formation. The absence of rainfall is required because within the objectives of this study, as well as MCCP, only samples from non-precipitating clouds are collected. If a rain detector is activated, the string collector will retract into the protective case and collection will be suspended.

Particle Volume Monitor

Beginning with the 1999 field season, a modified automated cloud collector has been used. The collector was modified by switching from an electrical to a pneumatic system to send the collector up and down. This collector measures and accumulates the cloud sample using a funnel positioned under a tipping bucket that is hooked up to the cloud collector with Teflon tubing. In 2004, the tipping bucket was removed from the cloud collection system, as it was no longer necessary to track hourly collection volumes. In 2009, the tipping bucket was reintegrated into the system for determination of total sample volume. The tipping bucket provides another method for determining sample volume and complements the manual determination of this important parameter. Modifications made to the cloud collection system during 2009 included:

- upgrading the communication system to conform with the Federal Communications Commission's mandated transition from analog to digital communication

- installing a Campbell data logger
- incorporating a tipping bucket into the sampling stream for determination of sample volume
- installing a pressure transducer for monitoring the air tank pressure
- installing a new optical rain detector
- reconfiguring and installing new control boxes to house the DAS and communications system, as well as the valve system for directing the flow of cloud water
- installing additional collection bottles
- upgrading the electrical and plumbing systems
- automating the cloud water rinse mechanism

For the 2010 season the upgraded valve/plumbing system was further modified/redesigned in order to eliminate air leakage problems through the valves, which was experienced during the 2009 season.

The PVM is operated continuously. Consequently, collection of cloud samples only when the threshold criteria are met does not result in the loss of cloud frequency and cloud duration information. All LWC values of 0.05 g/m^3 or greater, independent of the type of cloud (i.e., precipitating or non-precipitating), are used to calculate cloud frequency and cloud duration information. It is possible that the cloud deposition estimates presented later in Section 4.0 may underestimate actual cloud deposition because clouds are not sampled when precipitating. However, the bias due to this lack of sampling during a precipitation event is offset by the fact that cloud deposition totals are estimated by multiplying the duration-weighted mean chemical fluxes by the cloud hours for the month. The cloud hours are calculated as the cloud frequency times the total hours in the month. The PVM is calibrated at start-up and again at the end of the season (weather permitting). Calibration checks of the PVM were also scheduled to be performed biweekly (weather permitting) throughout the field season. The results were used to adjust the instrument immediately after the calibration check.

The site operator gathers cloud water samples from the collector at least twice a week, whether or not collection has occurred. The time, date, and volume of each 24-hour bulk sample are recorded on the Cloud Water Sample Report Form. Each sample is then carefully decanted into one pre-cleaned 250-mL sample bottle. Excess sample volume is discarded. The sample date and time are recorded on the 250-mL sample bottle label. The site operator analyzes each sample for pH and conductivity and records the results on the Cloud Water Sample Report Form. The samples are then packed into coolers with the corresponding form and shipped to the CASTNET laboratory in Gainesville, FL. Periodically, selected rinse samples are included in shipments. Starting in 2005, some of the 24-hour samples shipped from the field were bulked together in the MACTEC laboratory in order to keep the number of samples analyzed by the laboratory within the number of samples allotted for analysis in the budget. In 2010, 20 of the 24-hour samples collected between July 2 and October 26 were combined into 8 bulk samples.

Filter packs for collection of dry deposition samples at the nearby GRS420 site are prepared and shipped to the field on a weekly basis and exchanged at the site every Tuesday. For a description of the filter pack set-up, types of filters used, and the fraction collected on each filter, refer to the CASTNET Quality Assurance Project Plan (QAPP) (MACTEC, 2010). A discussion of filter pack sampling artifacts can be found in Anlauf *et al.* (1986) and Lavery *et al.* (2007). Filter pack flow is maintained at 3.0 liters per minute (Lpm) with a mass flow controller.

3-Stage Filter Pack

2.3 Laboratory Operations

Cloud water samples and filter extracts were stored at 4 °C until analysis. All analyses were performed within 30 days of sample receipt at the laboratory. The effects of storage on wet deposition samples have been addressed in NAPAP Report #6 (Sisterson *et al.*, 1991). This discussion applies, for the most part, to cloud water samples as well. Results of all valid filter pack and cloud water analyses are stored in the laboratory information management system, Element DataSystem (Element).

Cloud water samples for the 2010 sampling season were analyzed for sodium (Na^+), potassium (K^+), ammonium (NH_4^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), NO_3^-, and SO_4^{2-} ions in the CASTNET laboratory. pH and conductivity were analyzed in the field through June 3, 2010. No additional pH analyses were conducted in the field after this date due to problems with the pH probe. All samples were analyzed for pH and conductivity in the MACTEC Gainesville laboratory for comparison with the field values.

Concentrations of the three anions (SO_4^{2-}, NO_3^-, Cl^-) were determined by micromembrane-suppressed ion chromatography (IC). Analysis of samples for Na^+, Mg^{2+}, Ca^{2+}, and K^+ was performed with a Perkin-Elmer Optima 7300 Dual View inductively coupled argon plasma-atomic emission spectrometer (ICP-AES). The automated indophenol method using a Bran+Luebbe Autoanalyzer 3 was used to determine NH_4^+ concentrations. The 2010 hydrogen (H^+) ion concentrations for each sample were determined based on laboratory pH measurements.

Filter pack samples were loaded, shipped, received, extracted, and analyzed at the CASTNET laboratory. For specific extraction procedures refer to Anlauf *et al.* (1986) and the CASTNET QAPP (MACTEC, 2010). Filter packs contain three filter types in sequence: a Teflon filter for collection of aerosols, a nylon filter for collection of HNO_3 and SO_2, and dual potassium carbonate-impregnated cellulose filters for collection of SO_2. Following receipt from the field, exposed filters and unexposed blanks were extracted and analyzed for SO_4^{2-}, NO_3^-, Cl^-, and the cations, NH_4^+, Na^+, Mg^{2+}, Ca^{2+}, and K^+, as described previously for cloud water samples. Refer to the CASTNET QAPP (MACTEC, 2010) for detailed descriptions of laboratory receipt, breakdown, storage, extraction, and analytical procedures.

Atmospheric concentrations derived from filter extracts are calculated based on the volume of air sampled following validation of the hourly flow data. Atmospheric concentrations of particulate SO_4^{2-}, NO_3^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, and Cl^- are calculated based on analysis of Teflon filter extracts; HNO_3 is calculated based on the NO_3^- found in the nylon filter extracts; some SO_2 is trapped by the nylon filter, so SO_2 is calculated based on the sum of SO_4^{2-} found in nylon and cellulose filter extracts.

2.4 Data Management

Continuous data (temperature, precipitation, LWC, and cloud collector status information) are collected in hourly and 5-minute averages. Hourly data are collected daily via Internet Protocol (IP)-based polling. The polling software also recovers status files and power failure logs from the previous seven days. The hourly data and associated status flags are ingested into Microsoft Excel spreadsheets. The PVM data are validated based on the end-of-season calibration results, periodic calibration check results, and information provided by status flags and logbook entries.

Discrete data for cloud water sample results and filter pack sample results are managed by Element. In Element, the analytical batches are processed through an automated quality control (QC) check routine. For each analytical batch, an alarm flag is generated if any of the following occur:

- Insufficient QC data were run for the batch;
- Sample response exceeded the maximum standard response in the standard curve (i.e., sample required dilution);
- Continuing calibration verification (CCV) spikes exceeded recovery limits; or
- Reference samples exceeded accuracy acceptance limits.

A batch with one or more flags is accepted only if written justification is provided by the Laboratory Operations Manager or his designee.

For cloud water samples, an additional check involves calculating the percent difference of cations versus anions (ion balance), which provides another diagnostic for determining whether the analysis should be repeated or verified.

Atmospheric concentrations for filter pack samples are calculated by merging validated continuous flow data with the laboratory data [micrograms per filter (µg/filter)].

2.5 Quality Assurance

The quality assurance (QA) program consists of the same routine audits performed for CASTNET, if applicable, and testing/comparison of instruments unique to cloud water sampling. QA procedures are documented in greater detail in the MADPro Quality Assurance Plan, which is an appendix to the CASTNET QAPP (MACTEC, 2010). The sections below provide a brief description of those procedures.

2.5.1 Field Data Audits

The following audits are conducted for field data:

- Review of reported problems with sensors and equipment at the site and of the actions taken to solve such problems.
- Comparison of final validated data tables to the raw data tables for identification and verification of all changes made to the data. Summary statistics and results of diagnostic tests for assessment of data accuracy are also reviewed.

2.5.2 Laboratory Data Audits

Laboratory data audits consist of:

- Review of all media acceptance test results,
- Review of chain-of-custody documentation, and
- Review of all QC sample results associated with analytical batches.

2.5.3 Precision and Accuracy

With the exception of the automated cloud collector and PVM, accuracy of field measurements (i.e., meteorological instruments used in conjunction with the cloud collection system and PVM) is determined by challenging instruments with standards that are traceable to National Institute for Standards and Technology (NIST). Continuing accuracy is verified by end-of-season calibrations by MACTEC personnel. No certified standards are currently available for determination of cloud collector and the PVM accuracy on a routine basis. Overall precision of field measurements is best determined by collocating instruments and assessing the difference between simultaneous measurements. Even though collocated dry deposition and meteorological sampling is not conducted at the CLD303 site, it is conducted at two other CASTNET sites. Since the meteorological instrumentation on the CLD303 tower is identical to that used at CASTNET sites, precision of these instruments can be inferred from the precision and accuracy results presented in the CASTNET Quarterly QA Reports (e.g., MACTEC, 2011b) and the CASTNET annual reports for 1998 through 2009, the most recent of which can be found on EPA’s Web site: http://java.epa.gov/castnet/documents.do.

Accuracy of laboratory measurements is determined by analyzing an independently prepared reference sample in each batch and calculating the percent recovery relative to the target value. The percent recovery is expected to meet or exceed the acceptance criteria listed in the CASTNET QAPP (MACTEC, 2010). When possible, the references are traceable to NIST or obtained directly from NIST. On occasion, references are ordered from other laboratories.

Analytical precision within sample batches is assessed by calculating the relative percent difference (RPD) and percent recovery of CCV run within that batch. CCV are independently produced standards that approximate the midpoint of the analytical range for an analyte and are run after every tenth environmental sample. Precision within a batch is also assessed by replicating 5 percent of the samples within a run. Replicated samples are selected randomly.

Cloud Water Collector

Collector in Up Position

Cloud Collection Tower

3.0 Liquid Water Content and Cloud Water Chemistry

3.1 Cloud Frequency and Mean Liquid Water Content

Monthly mean cloud frequencies by year from 1994 through 2007 and 2009 through 2010 are summarized in Table 3-1. Monthly mean, minimum, and maximum cloud frequency statistics are also depicted as a bar chart in Figure 3-1. Monthly mean cloud frequency values for 2010 versus the historical monthly means (1994–2007, 2009) are shown in Figure 3-2. Monthly cloud frequencies were determined by calculating the relative percent of all hourly LWC values equal to or greater than 0.05 g/m^3, or:

$$CF = \frac{100 * (\#\ of\ valid\ hourly\ LWC\ values \geq 0.05\ g/m^3)}{n}$$

where: n is the number of valid hourly LWC values per month and
CF is cloud frequency

Any month with less than 70 percent valid LWC data is usually not considered representative of the monthly weather conditions for that month. Cloud frequencies vary from month to month, year to year, and from location to location. As can be seen from Figure 3-2, the monthly cloud frequencies for 2010 were lower than the historical means. The June 2010 cloud frequency value is the project minimum value for this month, and the 2010 annual mean cloud frequency value is the project minimum annual mean (Table 3-1, Figure 3-1).

Monthly mean, minimum, and maximum LWC values for the months of June through September for 1994 through 2007 and 2009 through 2010 are shown in Figure 3-3. Mean LWC was calculated by taking the average of all hourly LWC values equal to or greater than 0.05 g/m^3 during the month. Monthly mean LWC values for 2010 versus the historical monthly means (1994–2007, 2009) are shown in Figure 3-4. Only valid values passing the 70 percent completeness criterion are plotted. The 2010 annual mean LWC value of 0.238 g/m^3 is the third lowest for the project with only the years 2000 (0.210 g/m^3) and 2007 (0.235 g/m^3; Figure 3-3) registering lower LWC annual means.

3.2 Cloud Water Chemistry

During the 2010 sampling season, the CASTNET laboratory received 67 cloud water samples from CLD303. Samples sent to the CASTNET laboratory for analysis were packed in Styrofoam coolers with frozen ice packs to keep the samples cool during shipping. Upon receipt of the samples, the sample receiving technician verified the condition of the samples and the contents of the shipment against the enclosed Cloud Water Sample Report Form. All samples were received in good condition.

Annual summary statistics for cloud water chemistry and LWC for all analyzed samples are presented in Table 3-2. Table 3-3 lists the total number of samples or "records" that were collected each season of operation at CLD303. Samples were accepted and used for estimation of cloud water deposition if they met acceptance criteria based on the cation-to-anion ratio. Samples were usually eliminated if:

- Both the anion sum and cation sum were ≤ 100 microequivalents per liter (μeq/L), and the absolute value of the RPD was > 100 percent; or
- Either the anion sum or the cation sum was > 100 μeq/L, and the absolute value of the RPD was > 25 percent.

The RPD was calculated from the following formula:

$$RPD = 200 * |cations - anions|/(cations + anions)$$

On occasion, samples exceeding these criteria will be accepted and used for analyses if there is valid justification to do so. In most of these cases, a low field pH value (high hydrogen concentration) causes the cation sum to be larger, which in turn causes exceedance of the acceptance criteria.

3.2.1 Samples Accepted for Analysis

Twenty of the 67 cloud water samples were bulked into 8 analytical samples, which resulted in a total of 55 cloud water samples analyzed for the 2010 season. Cloud water analytical and QC data for the 2010 sampling season are presented in Appendix B. Five samples collected from May through mid-July were invalidated resulting in a final count of 50 samples used for data analysis.

The May samples, collected on May 8 (sample #2) and May 12 (sample #3), were invalidated because sample #2 failed the cation-anion ratio acceptance criteria, and sample #3 had a sample duration time of only 18 seconds.

The June samples, collected on June 5 (sample #17) and June 7 (sample #18) were invalidated because the actual collection dates for these samples could not be determined. There were no cloud events from June 5 through June 7, and adjacent dates were already assigned cloud samples. Without an actual date and duration time, it is impossible to determine the sample LWC and wind speed, and the validity of each sample is also called into question.

The July 15 sample (#32) was invalidated because the actual collection date could not be determined.

3.2.2 Cloud Water pH

The pH values for CLD303 are shown in Figures 3-5 and 3-6. The frequency distribution in both figures shows that a minority of the 2010 samples (approximately 6 percent for laboratory pH and 0 percent for field pH) had values of pH 3.9 or lower. The minimum pH values in 2010 for laboratory and field pH were 3.82 and 4.27, respectively as listed in Table 3-2. The 2010 mean pH value of 4.32 for laboratory pH was higher than the 2009 mean laboratory pH value of 4.17. The 2010 mean pH value is the highest mean annual pH value in the history of the project. Historically (1994–2007, 2009), the majority of the pH values measured at CLD303 fell within the range of pH 3.2 to 3.8, which is the range identified in the 1992 NAPAP report to Congress

(1993) as "acidic cloud water." Annual pH values for 2009 and 2010 are the only years in which the majority of the pH values were above 3.9.

As can be seen from these figures and the summary statistics for pH and H^+ ion concentrations in Table 3-2, the 2010 field pH values averaged higher than the laboratory pH values. However, field pH was measured only for the first 13 samples collected, after which the pH meter could not be calibrated. The problem was eventually determined to be a malfunctioning probe, and the situation was not resolved for the remainder of the season. Due to the scarcity and short duration of time for which field pH data were measured, the laboratory pH data were used this year (rather than field data) for calculation of the cloud hydrogen deposition values for purposes of maintaining consistency in results throughout the season.

3.2.3 Major Ions in Cloud Water

The major ions are identified as SO_4^{2-}, H^+, NH_4^+, and NO_3^-. Figure 3-7 presents the seasonal mean major ion concentrations in cloud water samples for 1995 through 2007 and 2009 through 2010. All 2010 mean major ion concentrations, except for H^+, show an increase with respect to 2009 mean concentrations. The 2010 mean NO_3^- concentration (112.58 µeq/L) shows a 35.6 percent increase from the 2009 mean, and the 2010 mean SO_4^{2-} concentration (228.55 µeq/L) is 25.6 percent higher than the 2009 mean. All 2010 seasonal concentrations, except NO_3^-, peaked in August (Figure 3-8). NO_3^- concentrations peaked in July. SO_4^{2-} and H^+ concentrations were lowest in September, and NO_3^- and NH_4^+ concentrations were lowest in June. Summary statistics of all major ion concentrations, as well as Ca^{2+} concentrations, averaged across all years (1994–2007, 2009–2010) are presented in Table 3-4.

The increases in seasonal concentrations between 2009 and 2010 may be partially explained by the lower LWC values during the 2010 season. Lower LWC is often associated with higher concentrations as a result of the concentration of the ions in the lesser amount of water within the cloud.

3.2.4 Minor Ions in Cloud Water

Seasonal mean concentrations of the minor ions (Ca^{2+}, Mg^{2+}, Na^+, K^+, and Cl^-) for 1995 through 2007 and 2009 through 2010 are presented in Figure 3-9. Concentrations of all minor ions increased with respect to 2009 concentrations. Seasonal concentrations for the minor ions, except for K^+, peaked in July (Figure 3-10). Ca^{2+} and Mg^{2+} exhibited their lowest concentrations in June, and Na^+ and Cl^- in August. K^+ concentrations were equivalent in June and July (5.82 and 5.81 µeq/L, respectively), and lower, but also equivalent, in August and September with values of 3.77 ueq/L for both months.

3.3 Comparison of Cloud Water versus Precipitation Concentrations

Precipitation concentration data were obtained from the NADP/NTN site at Elkmont, TN (TN11) to assess whether mean seasonal (June through September) SO_4^{2-} and NO_3^- concentrations exhibited the same pattern as mean seasonal cloud water SO_4^{2-} and NO_3^- concentrations. Figures 3-11 and 3-12 show mean seasonal cloud water and precipitation concentrations for SO_4^{2-} and NO_3^-, respectively, from 2000 through 2010. The cloud water concentrations are plotted on the left y-axis and the precipitation concentrations are plotted on the right y-axis. Both figures show that the increase in the 2010 cloud water SO_4^{2-} and NO_3^- concentrations was mirrored by precipitation SO_4^{2-} and NO_3^- concentrations. The 25.2 percent increase in 2010 cloud water SO_4^{2-} concentrations from 2009 concentrations is paralleled by a 29.1 percent increase in precipitation SO_4^{2-} concentrations. The 34.2 percent increase in 2010 cloud water NO_3^- concentrations is matched by a 35.2 percent increase in 2010 precipitation NO_3^- concentrations with respect to 2009 concentrations. On average, both the seasonal precipitation SO_4^{2-} and NO_3^- concentrations are within 6 to 17 percent of the seasonal cloud water concentrations from 2000 through 2010.

View from Tower

4.0 Cloud Deposition

This section presents the modeled cloud water deposition estimates for Clingmans Dome from 1994 through 2007 and 2009 through 2010. Deposition was estimated by applying the CLOUD model (Lovett, 1984), parameterized with site-specific cloud water chemistry and meteorological data from CLD303 as screened and provided by MACTEC. The complete report discussing 2010 cloud deposition modeling results by Gary M. Lovett, PhD (2011) is presented in Appendix A. The following subsections present a summary of Dr. Lovett's results.

4.1 Cloud Water Deposition Model

Briefly, the CLOUD model uses an electrical resistance network analogy to model the deposition of cloud water to forest canopies. The model is one-dimensional, assuming vertical mixing of droplet-laden air into the canopy from the top. Turbulence mixes the droplets into the canopy space where they cross the boundary layers of canopy tissues by impaction and sedimentation. Sedimentation rates are strictly a function of droplet size. Impaction efficiencies are a function of the Stokes number, which integrates droplet size, obstacle size, and wind speed (Lovett, 1984). The impaction efficiency as a function of the Stokes number is based on wind tunnel measurements by Thorne *et al.* (1982).

The forest canopy is modeled as stacked 1-m layers containing specified amounts of various canopy tissues such as leaves, twigs, and trunks. Wind speed at any height within the canopy space is determined based on the above-canopy wind speed and an exponential decline of wind speed as a function of downward-cumulated canopy surface area. The wind speed determines the efficiency of mixing of air and droplets into the canopy and also the efficiency with which droplets impact onto canopy surfaces. The model is deterministic and assumes a steady state, so that for one set of above-canopy conditions it calculates one deposition rate. The model requires as input data:

- The surface area index of canopy tissues in each height layer in the canopy,
- The zero-plane displacement height and roughness length of the canopy,
- The wind speed at the canopy top,
- The LWC of the cloud above the canopy, and
- The mode of the droplet diameter distribution in the cloud.

From these input parameters, the model calculates the deposition of cloud water expressed both as a water flux rate in grams per square centimeter per minute ($g/cm^2/min$) and as a deposition velocity [flux rate/LWC, in units of centimeters per second (cm/s)]. Deposition rates of ions are calculated by multiplying the water deposition velocity by the ion concentration in cloud water above the canopy. In the original version of the model, a calculation of the evaporation rate from the canopy was also included in order to estimate net deposition of cloud water. For this project, the calculation of the evaporation rate from the canopy was not invoked, resulting in estimation of only the gross deposition rate.

The structure of the CLOUD model and its application to these data followed exactly the procedures used to calculate fluxes for the MADPro cloud sites reported by Lovett (2000). After the model was run for all time periods, seasonal and monthly means and totals were calculated in a SAS program. Approaches in data analysis that were different between this effort and the analysis reported by Lovett (2000) are:

- The data provided to Lovett for this report were pre-screened by MACTEC.
- Because there were no missing months, summed deposition fluxes were calculated for the season by simply summing all the monthly deposition amounts.

The 2010 data set contained 50 samples (or time periods), and the model was run for only 37 of these samples/time periods due to missing wind speed data for 12 samples in May. Wind speed data were invalidated from May 12 at 1600 through June 4 at 0700 due to data logger/wiring problems. The one remaining sample in May with wind speed data was not included in the model since it was the only sample for the month. All calculations presented in Appendix A for 2010 followed the same procedures as calculations for 2000–2002, 2004–2005, 2007, and 2009. Seasonal depositions for 2010, presented in Appendix A, were calculated by summing the monthly depositions for June through October. Slightly different procedures were employed for the 2003 and 2006 seasons because of either a shorter sampling season or lack of data completeness for some of the months due to equipment malfunction. Please refer to the 2003 and 2006 MADPro Reports, Appendix A (MACTEC, 2004 and 2007) for details of the 2003 and 2006 procedures.

4.2 Results

4.2.1 Monthly Means

For the 2010 season, wind speed and cloud water deposition velocity values were relatively constant from month to month with the exception of a decline in both values in July (Appendix A). Duration-weighted mean monthly concentrations for SO_4^{2-}, H^+, and NH_4^+ were highest in August, whereas NO_3^- peaked in October. Except for NO_3^-, the lowest concentrations for the major ions were seen in October, and NO_3^- concentrations were lowest in September. The minor cations and Cl^- had the lowest duration-weighted concentrations in August. The volume-weighted mean LWC in 2010 (0.23 g/m^3) was significantly lower than in 2009 (0.36 g/m^3) and lower than the project mean of 0.31 g/m^3.

Monthly deposition estimates [kilograms per hectare (kg/ha)] for major ions, Ca^{2+}, and water for all months sampled during 1994, 1995, 1997 through 2007, 2009, and 2010 are presented in Table 4-1. Despite the fact that all concentrations, except H^+, increased in 2010 (Figures 3-7 and 3-9), total cloud deposition decreased in 2010 for all ions (Appendix A Tables I-1, I-2, I-3, and Figure 6).

The seasonal (June through September) monthly CLOUD model deposition estimates for the major ions and Ca^{2+} for years 1999 through 2007, 2009, and 2010 are presented in Figures 4-1 through 4-5. There is no readily apparent trend for the seasonal monthly deposition estimates other than estimates of three of the major ions (SO_4^{2-}, NH_4^+, and H^+) peaked in August and were lowest in September. NO_3^- depositions peaked in July, and like the other major ions, were lowest in September. The September 2010 depositions for H^+, SO_4^{2-}, and NH_4^+ are the lowest seasonal monthly deposition rates thus far in project history. The lowest seasonal deposition rate for NO_3^- occurred in June 2006.

Table 4-2 presents the mean monthly deposition rates estimated for 1995 through 2007, and 2009 through 2010. These estimates are based on available data shown in Table 4-1. It is difficult to compare the estimates from year to year since the mean monthly deposition rates were calculated for different combinations of months for different years depending on data completeness.

4.2.2 Seasonal Deposition Estimates

The seasonal deposition values for major ions are presented in Table 4-3. Data sets from 1997, 1999 through 2007, and 2009 through 2010 were sufficiently complete to estimate a seasonal value. A season is defined as June through September, and three of the four months were required to calculate the seasonal deposition. The 2010 data show that deposition estimates for all ions decreased with respect to 2009 estimates. This decrease in deposition estimates is opposite to the increase in seasonal concentrations (except for hydrogen) and could reflect the lower water deposition in 2010. The water deposition in 2009 was 9.1 cm/month versus 2.9 cm/month in 2010. The lowest water deposition before 2010 occurred during 2007 (3.5 cm/month), which was a drought year.

The information in Table 4-3 can also be compared by averaging the data in 3-year increments from 1999 through 2001 and from 2007 through 2010. When analyzed this way, the decreases in average SO_4^{2-}, NO_3^-, and NH_4^+ deposition estimates between 1999–2001 and 2007–2010 are 75 percent (84.2 kg/ha versus 21.2 kg/ha), 77 percent (48.8 kg/ha versus 11.5 kg/ha), and 60 percent (13.7 kg/ha versus 5.5 kg/ha), respectively. Figure 4-6 depicts in graphical form the same data as in Table 4-3 for SO_4^{2-}, NO_3^-, NH_4^+, and H^+. In this figure, the overall decrease in the seasonal deposition estimates is readily apparent. Because the H^+ deposition estimates are much lower with respect to the other three ions, only H^+ deposition estimates are plotted in Figure 4-7 to better illustrate the decrease in these values over the years.

4.3 Comparison of Cloud Water versus Wet Deposition Estimates

Wet deposition data from 2000 through 2010 were obtained from NADP/NTN site TN11 for comparison to cloud water deposition estimates for 2000 through 2007 and 2009 through 2010. Figures 4-8 and 4-9 show the seasonal SO_4^{2-} and NO_3^- deposition estimates, respectively, for both cloud water and precipitation data. The cloud water deposition estimates are plotted against the left y-axis and the wet deposition values are plotted against the right y-axis. Starting in 2003 both species follow a similar pattern for cloud water and wet deposition estimates with some exceptions. The main exceptions are: 1) the wet SO_4^{2-} deposition value for 2009 decreased with respect to the 2007 value, while the cloud SO_4^{2-} deposition value increased with respect to the 2007 value; 2) the wet NO_3^- deposition value shows a minor increase (0.63 percent) in 2010 with respect to the 2009 value, while the cloud NO_3^- deposition value shows a 48.9 percent decrease; and 3) both the wet deposition SO_4^{2-} and NO_3^- estimates show a greater variability from year to year, since 2003, than the cloud water deposition SO_4^{2-} and NO_3^- estimates. In 2010 both SO_4^{2-} deposition estimates decreased with respect to 2009 values, but the cloud SO_4^{2-} deposition showed a greater decrease (56 percent) than the wet SO_4^{2-} deposition, which decreased by only 3.9 percent.

The June through September deposition values for cloud water and precipitation show a larger range of percentages with respect to each other from year to year than the concentration values. Wet deposition SO_4^{2-} values are from 7 to 39 percent of cloud water SO_4^{2-} depositions, and wet deposition NO_3^- values are from 8 to 51 percent of cloud water NO_3^- depositions from 2000 through 2010. Both the SO_4^{2-} and NO_3^- seasonal precipitation concentrations were 6 to 17 percent of cloud water concentrations from 2000 through 2010.

View from Clingmans Dome Parking Area

5.0 Filter Pack Concentrations, Dry Deposition, and Total Deposition

Atmospheric sampling for sulfur and nitrogen species was integrated over weekly collection periods (Tuesday to Tuesday) using a 3-stage filter pack. In this approach, particles and selected gases were collected by passing air at a controlled flow rate through a sequence of Teflon, nylon, and dual impregnated cellulose filters. Weekly air pollutant concentrations measured during the 2010 field season, together with the weekly dry deposition values estimated from the concentrations and modeled deposition velocities, are presented in this section. The data presented here are from the CASTNET site at Great Smoky Mountains National Park, TN (GRS420) since filter pack sampling at CLD303 was discontinued after the 2004 sampling season.

5.1 Filter Pack Concentrations

Over the course of the 2010 sampling season (June through September), the CASTNET laboratory analyzed 18 filter pack samples. The filter packs were installed on the sampling tower each Tuesday and then removed the following Tuesday. At the site, the site operator sealed each exposed filter pack with end caps and placed it in a resealable plastic bag. Subsequently, each filter pack was securely packed into a polyvinyl chloride shipping tube with its corresponding Site Status Report Form (SSRF) and returned to MACTEC weekly. Any discrepancies or problems with the shipment were recorded on the SSRF by the receiving laboratory technician. All of the filter pack samples were received in good condition.

Upon receipt, all of the samples were logged in and unpacked. Each filter type was extracted and analyzed by the CASTNET laboratory for SO_4^{2-} and/or NO_3^-. The Teflon filter received additional analyses for Cl^-, NH_4^+, Ca^{2+}, Mg^{2+}, Na^+, and K^+. Sample handling and analyses followed the procedures described in the CASTNET Laboratory Standard Operating Procedures (MACTEC, 2010). The filter pack analytical and QC data for the sampling season are presented in Appendix C.

Table 5-1 presents the atmospheric concentrations in micrograms per cubic meter (µg/m^3) resulting from analysis of each weekly filter pack exposed for sampling during the 2010 sampling season. Upon receipt of each weekly filter pack, the receiving technician assigned a sample number composed of various identifiers for sample type, year, week, and site. The on/off dates and times presented in Table 5-1 correspond with the entries recorded on the SSRF.

Starting in 1996 and continuing through the 2003 sampling season, the flow to the filter pack at the CLD303 site was programmed to shut off during a cloud or rain event to allow for determination of dry deposition only. In 2004, the filter pack sampled during rain events as well, and the flow was shut off only during a cloud event. This procedural change was implemented to better match CASTNET protocols. CASTNET sites sample continuously and due to their lower elevations, most of the CASTNET sites do not experience cloud events. Therefore, sampling during cloud events is rarely experienced at CASTNET sites.

Filter pack sampling at CLD303 was discontinued altogether after 2004 due to funding limitations. From 2005 on, filter pack data have been obtained from the GRS420 CASTNET site. Besides continuous filter pack sampling, there is an elevation difference of 1,221 meters between the CLD303 site (elevation 2,014 m) and the GRS420 site (elevation 793 m). The differences in sampling protocols and elevation should be taken into consideration by the data user when comparing filter pack concentrations before 2005 and after 2005. Preliminary analysis indicates that use of GRS420 data may result in an overestimate in dry deposition of sulfur and nitrogen species at CLD303. However, dry deposition is a small component of the total deposition at CLD303 (see section 5.3) and the uncertainty due to use of GRS420 data should not be considered significant when evaluating total deposition at CLD303.

The average flow is presented in units of Lpm and represents the average filter pack flow during dry deposition sampling events. The volume for each sample was determined by using the hours sampled and average flow in the following equation:

$$\text{Volume in cubic meters} = \frac{\text{hours sampled (hr)} \times \text{average flow} \times 60}{1{,}000}$$

The atmospheric concentrations for the filter pack samples were calculated by using the laboratory data (µg/filter) in the following equation.

$$\text{Atmospheric concentrations } (\mu g/m^3) = \frac{\mu g \text{ of analyte/filter} \times \text{analyte dependent constant}}{\text{volume}}$$

The following constants were used for converting the chemistry data:

Teflon		Nylon		Cellulose	
Parameter	**Constant**	**Parameter**	**Constant**	**Parameter**	**Constant**
SO_4^{2-}	1.0	SO_4^{2-}	1.0	SO_2	0.667
NO_3^-	4.429	HNO_3	4.5	NA	NA
NH_4^+	1.286	NA	NA	NA	NA

Note: NA = not applicable

Table 5-1 presents the ambient concentrations for each sample and filter type for the captured particles and gases. Total ambient SO_2 was determined by this equation:

$$\text{Total } SO_2 = \text{cellulose } SO_2 + (\text{nylon } SO_4^{2-} * 0.667)$$

5.2 Dry Deposition

The Multi-Layer Model (MLM) was used to calculate dry deposition velocities (Meyers *et al*., 1998; Finkelstein *et al*., 2000), which were combined with the measured concentrations to estimate dry deposition for Clingmans Dome. The MLM calculations were considered reasonable and representative for Clingmans Dome, at least through 2004, because on-site meteorological measurements were used directly in the model as well as filter pack measurements obtained from a filter pack system collocated with the automated cloud sampler. Starting in 2005, both the filter pack and meteorological measurements used for estimating dry deposition were obtained from the GRS420 site. The representativeness of these measurements to Clingmans Dome is questionable due to the difference in elevation, distance, and sampling protocol with respect to the CLD303 site. However, the data are presented here since the results may still be useful in a very general way.

Even though the MLM was developed and evaluated using measurements from flat terrain settings, the model evaluation results are considered roughly applicable to this site. The data from Meyers *et al.* (1998) show little overall bias and up to 100 percent differences for individual 1/2-hour simulations. Other data (Finkelstein *et al*., 2000) suggest that the MLM underestimates deposition velocities for SO_2 for complex, forested sites. The differences are expected to be lower for longer averaging times (i.e., monthly and seasonal periods). Consequently, the uncertainty in the dry deposition estimates is approximately 100 percent or lower, and the MLM calculations probably underestimate the dry fluxes.

The weekly dry deposition estimates, the seasonal (June through September) fluxes, and the seasonal mean deposition velocities for 2010 are presented in Table 5-2. The seasonal fluxes were calculated by summing the weekly fluxes and then multiplying this sum by the number of weeks in the season and dividing by the number of weeks with valid flux estimates. The formula used for the 2010 field season is:

Total seasonal flux = 18/18 (sum of all valid weekly deposition estimates)

All 18 filter packs analyzed were used to calculate dry deposition estimates.

Since 1999 total dry sulfur deposition estimates have decreased 66.9 percent and total dry nitrogen deposition estimates have decreased 73.9 percent (Figure 5-1).

5.3 Total Deposition

Total sulfur and nitrogen deposition estimates for the 1999 through 2007 and 2009 through 2010 sampling seasons are presented in Table 5-3. The deposition season is defined as the period from June through September. For cloud water, the total sulfur deposition was determined by converting the SO_4^{2-} deposition estimated from the CLOUD model to sulfur (S). Total sulfur for the dry component was determined by using the SO_2 and SO_4^{2-} total seasonal fluxes presented in Table 5-2. These values were converted to S and then summed to determine the total dry sulfur deposition.

Total cloud water nitrogen deposition was determined by converting the NO_3^- and NH_4^+ deposition estimated from the CLOUD model to nitrogen (N). Total dry nitrogen deposition was determined by converting the HNO_3, NO_3^-, and NH_4^+ total seasonal fluxes presented in Table 5-2 to N. All of the nitrogen species were summed to provide the total nitrogen deposition.

Figure 5-1 presents total sulfur and nitrogen deposition estimates for both the cloud water and dry components during the 1999 through 2007 and 2009 through 2010 sampling seasons. This figure shows that cloud water sulfur deposition for 2010 decreased approximately 56 percent from 2009 measurements, and dry sulfur deposition decreased by about 17.7 percent. Total nitrogen deposition decreased 50 percent for cloud water and increased 35.3 percent for dry deposition. The decreases in cloud sulfur and nitrogen deposition were influenced by the lower seasonal mean LWC value for 2010 (0.23 g/m^3 for 2010 versus 0.32 g/m^3 for 2009), as well as the lower seasonal mean wind speed values (3.8 m/s for 2010 versus 4.6 m/s for the project mean). Despite the fact that the filter pack data for 2010 are from a different site with a substantially lower elevation, it is still evident that dry deposition was and continues to be a small contributor to the deposition of pollutants to high elevations, while cloud deposition was and still is a significant source. This figure does not present the contribution from deposition produced by precipitation.

CASTNET Dry Deposition Site at Great Smoky Mountains National Park, TN (GRS420)

6.0 Conclusions and Recommendations

The Clingmans Dome cloud water deposition estimates show an overall decline in sulfur and nitrogen deposition estimates over the history of the project despite interannual increases observed for both species in 2001, 2004, 2006, and 2009. The small increase in the 2009 cloud water deposition estimates (Figure 4-6) was attributed to the higher amount of water deposition in 2009 and offsets the substantial decreases in ion concentrations (Figure 3-7). Despite some annual variability, estimates of total deposition, i.e. deposition produced by cloud + dry components, show a general, overall decline since 1999 (Figure 6-1). Since 1999, total sulfur deposition decreased 85.6 percent and total nitrogen deposition decreased 77.5 percent. Total cloud water sulfur deposition has decreased 86.2 percent since 1999 with a 73.9 percent decrease in total cloud water nitrogen deposition. The 2010 seasonal estimates show that dry deposition is a small contributor to the deposition of pollutants at high elevations (Table 5-1). Cloud deposition is the significant pathway for deposition at these elevations.

The principal recommendation for the 2011 season is to improve the efficiency of the power supply system to ensure proper operation of the cloud collection system, specifically control of the valve opening and closing functions. Random valve openings and/or simultaneous valve openings occurred throughout the second half of the 2010 season resulting in uncertainty in collection dates as well as sample volumes. Power fluctuations were suspected of causing these erroneous valve openings, but the actual cause was not specifically determined during the 2010 field season. This problem will be thoroughly investigated at MACTEC’s Gainesville, FL test location and at the CLD303 site before commencement of the 2011 season.

A new field pH probe will be purchased to replace the field pH probe that failed early in the 2010 season. In addition to continuing laboratory pH and conductivity measurements in order to verify proper operation of the field pH meter and probe and to provide backup measurements for this important parameter, an audit of the field laboratory is recommended. Although an audit was conducted in 2010, problems with the field pH and conductivity measurement protocols during the 2006, 2007, 2009, and 2010 field seasons, necessitate the audit for the 2011 season. The audit should also include the PVM calibration procedures and documentation, as well as cloud water sample collection, handling, and documentation procedures. New site operators should be provided with continual on-the-job training during the first year of performance. Returning site operators should continue to be trained and monitored carefully since the cloud water collection system is complex with many different components and requires several years of operational experience before proficiency can be achieved. There will be additional modifications to the cloud collection system for the 2011 season in order to resolve the random valve opening problem and to improve the efficiency of the power supply system.

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Tables

Table 3-1. Monthly Mean Cloud Frequency Summary

Clingmans Dome (CLD303)		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2009	2010	Mean[4]
May	Cloud Frequency[1]				81.78%			31.07%	47.17%	34.50%	91.67%					99.29%	44.52%	39.32%
	Cloud Hours[2]				67			174	350	256	330					279	329	
	Completeness				11%			75%	100%	100%	48%					38%	99%	
June	Cloud Frequency[1]				61.63%	48.58%	41.38%	49.72%	43.33%	43.47%	54.61%	67.89%	54.93%	23.62%	36.64%	48.80%	22.97%	44.31%
	Cloud Hours[2]				106	205	276	270	312	313	361	387	390	163	255	326	164	
	Completeness				24%	59%	93%	75%	100%	100%	92%	79%	99%	96%	97%	93%	99%	
July	Cloud Frequency[1]		29.47%	46.64%	34.34%	55.42%	44.75%	41.67%	57.08%	49.06%	42.78%	56.66%	40.50%	15.50%	48.38%	55.00%	28.67%	44.04%
	Cloud Hours[2]		84	139	227	399	328	140	391	340	314	370	290	97	314	412	213	
	Completeness		38%	40%	89%	97%	99%	45%	92%	93%	99%	88%	96%	84%	87%	100%	100%	
August	Cloud Frequency[1]		49.44%		41.49%	71.43%	24.93%	43.45%	67.84%	28.02%	42.58%	46.64%	30.63%	50.87%	23.39%	56.41%	27.36%	39.96%
	Cloud Hours[2]		351		256	5	185	305	367	202	152	347	223	264	174	418	203	
	Completeness		95%		83%	1%	100%	94%	73%	97%	48%	100%	98%	65%	100%	100%	100%	
September	Cloud Frequency[1]	32.41%	30.37%		33.18%	43.93%	27.65%	50.65%	37.78%	51.60%	39.74%	47.18%	12.92%	50.42%	62.54%	51.07%	28.15%	41.37%
	Cloud Hours[2]	128	106		212	170	172	349	136	322	242	334	89	363	394	359	201	
	Completeness	55%	48%		93%	54%	86%	96%	50%	87%	85%	98%	96%	100%	88%	98%	99%	
October	Cloud Frequency[1]	40.27%		23.64%	35.52%	30.32%		5.98%	41.72%			48.56%	46.91%	32.65%		37.56%	44.49%	36.20%
	Cloud Hours[2]	267		78	200	211		34	141			287	296	159		246	331	
	Completeness	89%		44%	76%	94%		76%	46%[3]			79%	85%	66%		88%	100%	
November	Cloud Frequency[1]				59.70%													
	Cloud Hours[2]				40													
	Completeness				9%													

Note: [1] Cloud frequency is not used in subsequent analyses if the completeness criterion of 70 percent is not met. Monthly deposition estimates for 2003 and August 2006 were exceptions.

[2] Number of records where LWC ≥ 0.05 g/m^3

[3] Site shutdown on 10/16. Completeness at time of shutdown was 91.85 percent.

[4] The average cloud frequency values are calculated only from those annual values that meet the completeness criterion.

Table 3-2. Summary Statistics for Cloud Water Samples 2010

2010 Total Records Accepted = 50					
	n	**mean**	**std dev**	**min**	**max**
LWC	50	0.251	0.108	0.08	0.637
pH - Field	13	4.50	0.33	4.27	5.36
pH - Lab	50	4.32	0.69	3.82	6.58
Cond - Field	20	60.34	29.81	8.00	134.40
Cond - Lab	50	69.86	31.47	8.94	151.50
H^+ - Field	13	31.82	16.44	4.37	53.70
H^+ - Lab	50	48.85	38.31	0.26	151.36
NH_4^+	50	172.08	107.97	1.43	522.75
SO_4^{2-}	50	217.70	110.34	25.88	549.22
NO_3^-	50	115.39	70.00	0.57	333.70
Ca^{2+}	50	70.81	60.70	9.98	286.34
Mg^{2+}	50	23.57	18.82	4.22	86.15
Na^+	50	46.28	58.65	6.18	287.82
K^+	50	7.40	7.39	0.13	36.50
Cl^-	50	27.81	31.15	2.99	151.02
Cations - Field	13	381.34	288.73	47.55	1133.71
Cations - Lab	50	368.59	197.31	46.32	1111.94
Anions	50	360.90	189.52	44.50	1019.85

Note: All units are μeq/L except for LWC (g/m^3), pH (standard units), and conductivity (micro ohms/cm)

The following acceptance criteria were used based on the cation and anion concentrations:

1) If both cation and anion sums were less than or equal to 100 μeq/L, then the RPD criterion (defined below) was ≤ 100 percent for a record to be accepted.
2) If either or both of the cation or anion sums were greater than 100 μeq/L, then the RPD criterion was ≤ 25 percent for a record to be accepted.

max = maximum
min = minimum
n = sample size used in calculations
RPD = The absolute value of difference in cation and anion concentrations divided by the average of the cation and anion concentrations multiplied by 200
std dev = sample standard deviation

Table 3-3. Number of Cloud Water Samples Accepted for Analyses

Year	Total Number of Samples	Number of Samples Accepted	Percent Accepted
1994[a]	14	9	64
1995[a]	142	136	96
1996[a]	122	105	86
1997[a]	334	324	97
1998[a]	341	269	79
1999[a]	174	174	100
2000[b]	104	102	98
2001[c]	73	70	96
2002[c]	75	65	87
2003[c]	78	78	100
2004[c]	73	73	100
2005[c]	64	63	98
2006[c]	45	45	100
2007[c]	54	54	100
2009[c]	85	58	68
2010[c]	55	50	91
Total	**1833**	**1675**	**91%**

Note: [a] Hourly samples — sample collection bottle changed every hour.
[b] Hourly + daily samples (62 hourly and 42 24-hour samples in year 2000)
[c] Daily samples — sample collection bottle changed every 24 hours.

Table 3-4. Summary Statistics of Major Ion and Calcium Concentrations (µeq/L) of Cloud Water Samples (1994–2007, 2009–2010)

	H^{+} *	NH_4^+	SO_4^{2-}	NO_3^-	Ca^{2+}
Mean	310.86	220.69	403.30	166.67	49.10
Minimum	0.26	0.71	3.54	0.29	0.15
Maximum	2137.96	1650.01	3686.91	1342.88	1051.89
Median	218.78	173.57	306.20	130.80	27.13

Note: * Laboratory pH data instead of field pH data were used for calculating the 2001, 2002, 2006, 2007, 2009, and 2010 hydrogen values.

Table 4-1. Cloud Water Monthly Deposition Estimates Produced by the CLOUD Model (kg/ha)[a]

Year	Month	H^+	SO_4^{2-}	NO_3^-	NH_4^+	Ca^{2+}	H_2O (cm)
1994	October	0.04	3.90	2.30	1.05	0.24	6.42
1995	August	0.13	9.33	4.96	1.67	0.35	9.83
1997	July	0.23	14.13	6.87	3.03	0.54	5.54
	August	0.24	14.16	8.37	3.04	0.69	8.74
	September	0.18	11.10	4.52	2.03	0.28	10.43
	October	0.31	19.71	12.22	4.71	0.67	7.02
1998	July	0.45	23.58	13.33	7.61	0.75	10.76
	October	0.22	11.79	9.83	3.02	0.78	9.10
1999	June	0.61	30.31	15.90	6.36	0.76	20.27
	July	0.88	39.79	18.75	4.67	1.57	7.80
	August	0.23	13.25	6.94	2.29	0.92	7.37
	September	0.16	7.58	4.25	1.23	0.47	8.56
2000	May	0.05	6.88	4.46	2.00	0.56	4.74
	June	0.18	13.00	9.40	2.89	0.93	9.68
	August	0.41	25.54	12.52	3.78	1.31	10.22
	September	0.30	14.36	5.85	1.84	0.11	12.82
	October	0.09	4.63	2.86	1.14	0.15	1.11
2001	May	0.09	8.19	6.72	2.83	0.64	5.01
	June	0.28	18.84	18.92	3.87	3.53	9.34
	July	0.30	16.85	9.22	2.63	0.64	9.16
	August	0.44	26.77	18.88	4.35	1.20	10.50
2002	May	0.14	9.51	4.08	1.97	0.50	9.50
	June	0.15	8.84	5.34	1.95	0.53	5.98
	July	0.17	9.33	5.40	1.64	0.36	10.80
	August	0.17	10.18	5.12	1.84	0.33	4.90
	September	0.29	21.41	10.61	3.92	1.10	14.86
2003	May [b]	0.09	7.32	4.23	1.60	0.60	14.52
	June	0.11	7.35	3.18	1.32	0.42	8.53
	July	0.11	6.72	3.69	1.25	0.37	7.63
	August [c]	0.19	10.93	5.01	1.83	0.42	5.89
	September	0.17	10.68	5.43	2.20	0.50	7.20
2004	June	0.17	9.43	3.77	1.67	0.34	9.69
	July	0.27	11.12	4.82	1.83	0.46	11.81
	August	0.25	11.88	4.57	2.08	0.30	6.44
	September	0.28	13.12	3.97	2.05	0.25	16.96
	October	0.35	12.10	6.71	2.69	0.46	8.06
2005	June	0.17	12.77	4.89	2.66	0.63	14.85
	July	0.13	7.65	2.93	1.18	0.41	9.85
	August	0.12	7.59	3.16	1.42	0.24	6.83
	September	0.06	5.25	2.49	1.24	0.39	1.75
	October	0.15	5.68	3.97	0.92	0.20	10.35
2006	June	0.04	2.92	1.37	0.71	0.17	3.72
	July	0.04	4.05	1.47	1.07	0.16	1.57
	August [d]	0.47	30.62	8.16	4.81	0.65	10.32
2007	June	0.03	3.54	1.75	1.00	0.19	2.66
	July	0.05	5.17	2.23	1.22	0.23	4.88
	August	0.04	4.06	1.65	0.91	0.20	1.02
	September	0.14	9.76	4.38	1.94	0.34	5.53
2009	June	0.06	9.52	5.22	2.83	1.04	9.02
	July	0.05	7.83	4.69	2.29	1.05	8.90
	August	0.07	7.05	4.14	1.60	0.56	11.54
	September	0.05	4.13	2.08	1.02	0.22	6.95
2010	June	0.02	2.95	2.13	0.99	0.31	3.19
	July	0.02	3.20	2.34	0.80	0.43	2.72
	August	0.02	4.09	2.21	1.28	0.32	3.05
	September	0.01	2.31	1.57	0.68	0.32	2.71
	October	0.00	1.63	2.33	0.57	0.62	2.89

Note: [a] Deposition estimates for 1996 were not calculated.
[b] May 2003 data represent May 17-31, 2003, only.
[c] August 2003 had only 48 percent completeness.
[d] August 2006 deposition estimate includes one invalid sample LWC value.

Table 4-2. Cloud Water Monthly Mean Deposition Rates for Several Ions (kg/ha/month) and Water (cm/month)

Year	Water (cm/month)	H^+	NH_4^+	SO_4^{2-}	NO_3^-	Ca^{2+}
1995-98[a]	8.1	0.23	3.0	14.3	7.7	0.54
1999[b]	11.0	0.47	3.6	22.7	11.5	0.93
2000[a]	9.7	0.29	3.0	16.9	8.8	0.68
2001[a]	8.6	0.31	3.3	18.4	12.5	1.28
2002[a]	9.2	0.18	2.3	11.9	6.1	0.56
2003[a]	10.5	0.14	1.8	9.3	4.7	0.53
2004[c]	10.6	0.27	2.1	11.5	4.8	0.36
2005[c]	8.7	0.12	1.5	7.8	3.5	0.37
2006[d]	5.2	0.18	2.2	12.6	3.7	0.33
2007[b]	3.5	0.07	1.3	5.6	2.5	0.24
2009[b]	9.1	0.06	1.9	7.1	4.0	0.72
2010[c]	2.9	0.02	0.9	2.8	2.1	0.40

Note: [a] May through September
[b] June through September
[c] June through October
[d] June through August

Table 4-3. Cloud Water Seasonal* Deposition Estimates Produced by the CLOUD Model (kg/ha)

Year	H^+	NH_4^+	SO_4^{2-}	NO_3^-	Ca^{2+}
1997	0.86	10.20	52.53	26.35	2.01
1999	1.88	14.55	90.93	45.84	3.72
2000	1.19	11.35	70.53	37.03	3.13
2001	1.36	14.47	83.28	62.69	7.16
2002	0.78	9.35	49.76	26.47	2.32
2003	0.58	6.60	35.68	17.31	1.71
2004	0.97	7.63	45.55	17.13	1.35
2005	0.48	6.50	33.26	13.47	1.67
2006	0.73	8.80	50.40	14.80	1.32
2007	0.27	5.07	22.54	10.01	0.95
2009	0.24	7.74	28.53	16.13	2.87
2010	0.07	3.76	12.56	8.24	1.37

Note: * Season is defined from June through September
Three of the four months were required to calculate seasonal deposition. The 3-month deposition was multiplied by 4/3.

Table 5-1. Great Smoky Mountains National Park, TN (GRS420) Ambient Concentrations ($\mu g/m^3$) – June through September 2010

			Teflon								Nylon		Cellulose					
Sample Number	On Date/Time	Off Date/Time	SO_4^{2-}	NO_3^-	NH_4^+	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	HNO_3	SO_2	Total SO_2	Total NO_3^-	Comment Codes	Valid Hours	Actual Volume (m^3)
1023001-36	6/1/10 12:00	6/8/10 11:02	3.818	0.080	1.316	0.129	0.032	0.081	0.073	0.017U	0.305	1.294	0.526	0.729	1.354		168	30.223
1024001-36	6/8/10 11:06	6/15/10 11:37	3.301	0.202	0.909	0.176	0.052	0.219	0.092	0.017U	0.402	1.313	0.447	0.715	1.494		167	30.222
1025001-36	6/15/10 11:45	6/22/10 10:58	3.385	0.037	1.112	0.199	0.039	0.076	0.112	0.017U	0.300	1.448	0.501	0.701	1.462	T01	167	30.046
1026001-36	6/22/10 10:58	6/29/10 10:29	3.556	0.116	1.072	0.203	0.048	0.152	0.059	0.017U	0.530	1.400	1.301	1.655	1.494		168	30.230
1027001-36	6/29/10 10:35	7/6/10 11:30	5.410	0.119	1.745	0.266	0.057	0.080	0.095	0.016U	0.385	1.650	1.165	1.422	1.742		169	30.409
1028001-36	7/6/10 11:34	7/13/10 10:18	5.062	0.051	1.469	0.283	0.054	0.077	0.082	0.031	0.441	1.574	0.807	1.101	1.600		167	30.046
1029001-36	7/13/10 10:24	7/20/10 10:58	3.301	0.029U	0.898	0.114	0.035	0.108	0.066	0.017U	0.327	1.104	0.379	0.597	1.116		165	30.222
1030001-36	7/20/10 11:05	7/27/10 11:40	3.878	0.337	0.691	0.448	0.126	0.421	0.131	0.017U	0.459	1.540	0.770	1.076	1.853		168	30.220
1031001-36	7/27/10 11:46	8/3/10 11:46	4.342	0.100	1.218	0.205	0.044	0.107	0.075	0.017U	0.526	1.389	0.492	0.843	1.467		168	30.216
1032001-36	8/3/10 11:53	8/10/10 10:37	5.528	0.052	1.768	0.216	0.043	0.077	0.112	0.017U	0.459	1.779	0.672	0.978	1.803		167	30.047
1033001-36	8/10/10 10:44	8/17/10 10:40	5.263	0.029U	1.594	0.129	0.030	0.078	0.069	0.017U	0.419	1.469	0.857	1.136	1.474		168	30.230
1034001-36	8/17/10 10:43	8/24/10 10:40	3.091	0.057	0.877	0.095	0.022	0.051	0.060	0.017U	0.354	1.005	0.361	0.597	1.047		168	30.214
1035001-36	8/24/10 10:50	8/31/10 10:36	5.741	0.198	1.698	0.198	0.039	0.098	0.062	0.017U	0.419	1.378	0.872	1.151	1.554		167	30.224
1036001-36	8/31/10 10:40	9/7/10 12:53	1.806	0.089	0.601	0.297	0.043	0.046	0.073	0.016U	0.360	1.270	1.334	1.574	1.340		170	30.587
1037001-36	9/7/10 12:57	9/14/10 10:35	2.646	0.070	0.743	0.287	0.040	0.043	0.067	0.017U	0.457	1.707	1.199	1.504	1.750		166	29.865
1038001-36	9/14/10 10:40	9/21/10 10:50	3.325	0.214	1.167	0.246	0.034	0.065	0.483I	0.017U	0.335	1.550	1.272	1.495	1.740		168	30.224
1039001-36	9/21/10 10:55	9/28/10 11:22	1.892	0.264	0.657	0.080	0.024	0.099	0.101	0.020	0.364	0.878	0.655	0.898	1.128	T01 W03	169	30.409
1040001-36	9/28/10 11:38	10/5/10 11:15	2.405	0.293	0.732	0.181	0.028	0.010	0.044	0.017U	0.347	1.095	1.080	1.311	1.371		167	30.226
		Mean	3.764	0.130	1.126	0.208	0.044	0.105	0.103	0.018	0.399	1.380	0.816	1.082	1.488			
		Standard Deviation	1.230	0.097	0.395	0.089	0.023	0.091	0.097	0.003	0.070	0.245	0.337	0.349	0.238			

Data Status Flags: **U** = Value is less than detection limit.
I = Invalid

Comment Codes:
01 = unidentified debris/particles on filter
03 = excessively wet filter
T = Teflon
W = cellulose

Table 5-2. Great Smoky Mountains National Park, TN (GRS420) Dry Deposition Fluxes (kg/ha) Report for the 2010 Deposition Season (June through September)

Sample Number*	On Date	Off Date	Fluxes (kg/ha)					Deposition Velocities (cm/sec)		
			SO_2	HNO_3	SO_4^{2-}	NO_3^-	NH_4^+	SO_2	HNO_3	Particle
1023001-36	6/1/10 9:00	6/8/10 8:00	0.011	0.116	0.023	0.000	0.008	0.278	1.605	0.110
1024001-36	6/8/10 9:00	6/15/10 8:00	0.013	0.124	0.022	0.001	0.006	0.324	1.711	0.121
1025001-36	6/15/10 9:00	6/22/10 8:00	0.011	0.131	0.026	0.000	0.009	0.294	1.646	0.141
1026001-36	6/22/10 9:00	6/29/10 8:00	0.021	0.126	0.028	0.001	0.008	0.235	1.634	0.143
1027001-36	6/29/10 9:00	7/6/10 8:00	0.019	0.172	0.047	0.001	0.015	0.237	1.880	0.155
1028001-36	7/6/10 9:00	7/13/10 8:00	0.014	0.149	0.038	0.000	0.011	0.226	1.715	0.135
1029001-36	7/13/10 9:00	7/20/10 8:00	0.011	0.098	0.022	0.000	0.006	0.339	1.602	0.120
1030001-36	7/20/10 9:00	7/27/10 8:00	0.017	0.117	0.024	0.002	0.004	0.294	1.394	0.112
1031001-36	7/27/10 9:00	8/3/10 8:00	0.015	0.115	0.026	0.001	0.007	0.329	1.490	0.108
1032001-36	8/3/10 9:00	8/10/10 8:00	0.017	0.132	0.031	0.000	0.010	0.318	1.359	0.104
1033001-36	8/10/10 9:00	8/17/10 8:00	0.016	0.120	0.034	0.000	0.010	0.260	1.483	0.116
1034001-36	8/17/10 9:00	8/24/10 8:00	0.011	0.096	0.021	0.000	0.006	0.329	1.711	0.120
1035001-36	8/24/10 9:00	8/31/10 8:00	0.018	0.149	0.044	0.002	0.013	0.280	1.960	0.141
1036001-36	8/31/10 9:00	9/7/10 8:00	0.019	0.130	0.015	0.001	0.005	0.219	1.829	0.147
1037001-36	9/7/10 9:00	9/14/10 8:00	0.020	0.141	0.015	0.000	0.004	0.241	1.486	0.105
1038001-36	9/14/10 9:00	9/21/10 8:00	0.024	0.144	0.023	0.001	0.008	0.284	1.670	0.123
1039001-36	9/21/10 9:00	9/28/10 8:00	0.011	0.071	0.010	0.001	0.004	0.214	1.452	0.096
1040001-36	9/28/10 9:00	10/5/10 8:00	0.017	0.147	0.020	0.002	0.006	0.224	2.345	0.145
		Total Seasonal Flux	0.286	2.275	0.470	0.016	0.141			
		Mean Seasonal Deposition						0.274	1.665	0.124

Note: MLM simulations were performed for each 168-hour period from 0800 on the On Date to 0800 on the Off Date.
* Original sample numbers within the MACTEC laboratory information management system contain the suffix "-36" to indicate that the sample was collected from the GRS420, TN site

Table 5-3. Cloud Water and Dry Sulfur and Nitrogen Deposition for Clingmans Dome (June through September 1999–2007, 2009–2010)

	Year	Total Sulfur[1] (kg/ha)	Total NO_3^--N (kg/ha)	Total NH_4^+-N (kg/ha)	Total Nitrogen[2] (kg/ha)
Cloud Water	1999	30.362	10.360	11.298	21.658
	2000	28.288	10.003	11.460	21.463
	2001	30.670	14.127	12.882	27.009
	2002	16.610	5.982	7.260	13.242
	2003	11.917	3.912	5.129	9.041
	2004	15.210	3.871	5.925	9.796
	2005	11.100	3.043	5.047	8.090
	2006	16.828	3.345	6.833	10.178
	2007	7.526	2.262	3.937	6.199
	2009	9.526	3.645	6.01	9.655
	2010	4.194	1.862	2.920	4.782
Dry	1999	0.907	2.184	0.194	2.378
	2000	0.572	1.453	0.124	1.577
	2001	0.843	2.043	0.214	2.257
	2002	0.675	1.904	0.183	2.087
	2003	0.439	1.027	0.107	1.134
	2004	0.434	1.212	0.107	1.319
	2005*	0.829	0.657	0.165	0.822
	2006*	0.738	0.624	0.165	0.789
	2007*	0.888	0.783	0.222	1.005
	2009*	0.247	0.325	0.076	0.401
	2010*	0.300	0.510	0.110	0.620

Note: Season is defined as June through September.

[1] Total sulfur deposition includes SO_4^{2-} in cloud water plus ambient SO_2 and SO_4^{2-}.

[2] Total nitrogen deposition includes NO_3^- and NH_4^+ in cloud water plus ambient NO_3^-, NH_4^+, and HNO_3.

*Dry deposition values for 2005 through 2007, 2009, and 2010 were obtained from the Great Smoky Mountains National Park (GSR420) site at Look Rock, TN.

Figures

Figure 3-1. Monthly Cloud Frequency Statistics (1994–2007, 2009–2010)

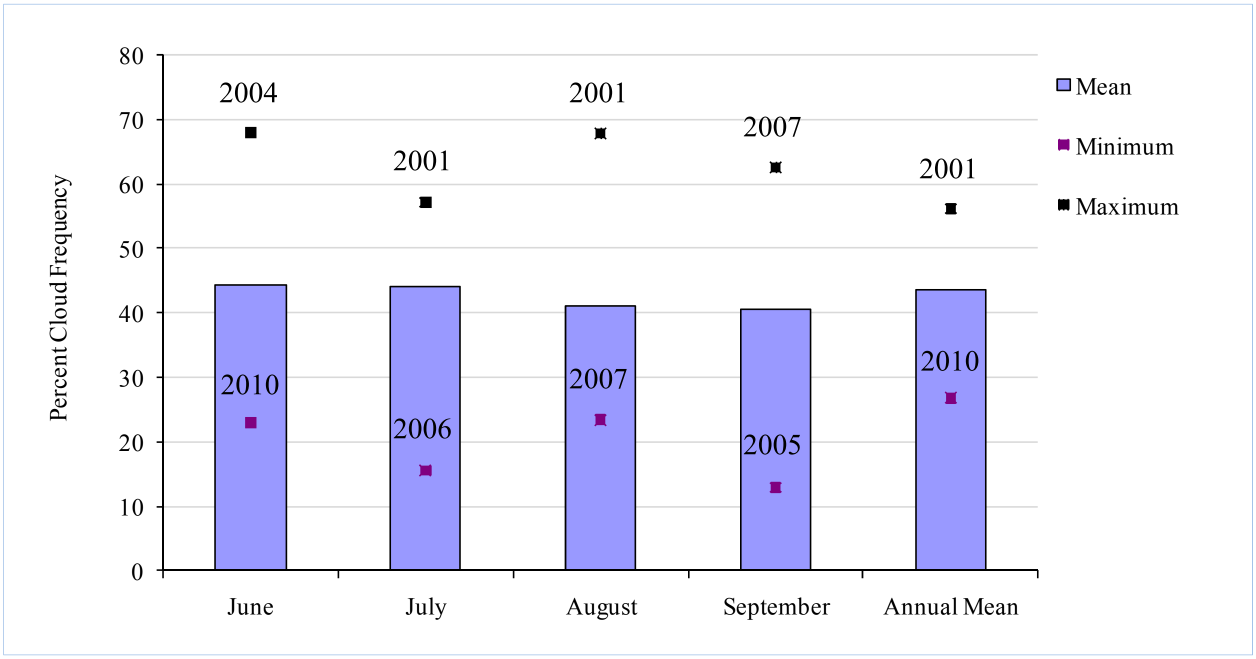


Figure 3-2. Monthly Mean Cloud Frequency – 2010 versus Historical Mean Values (1994–2007, 2009)

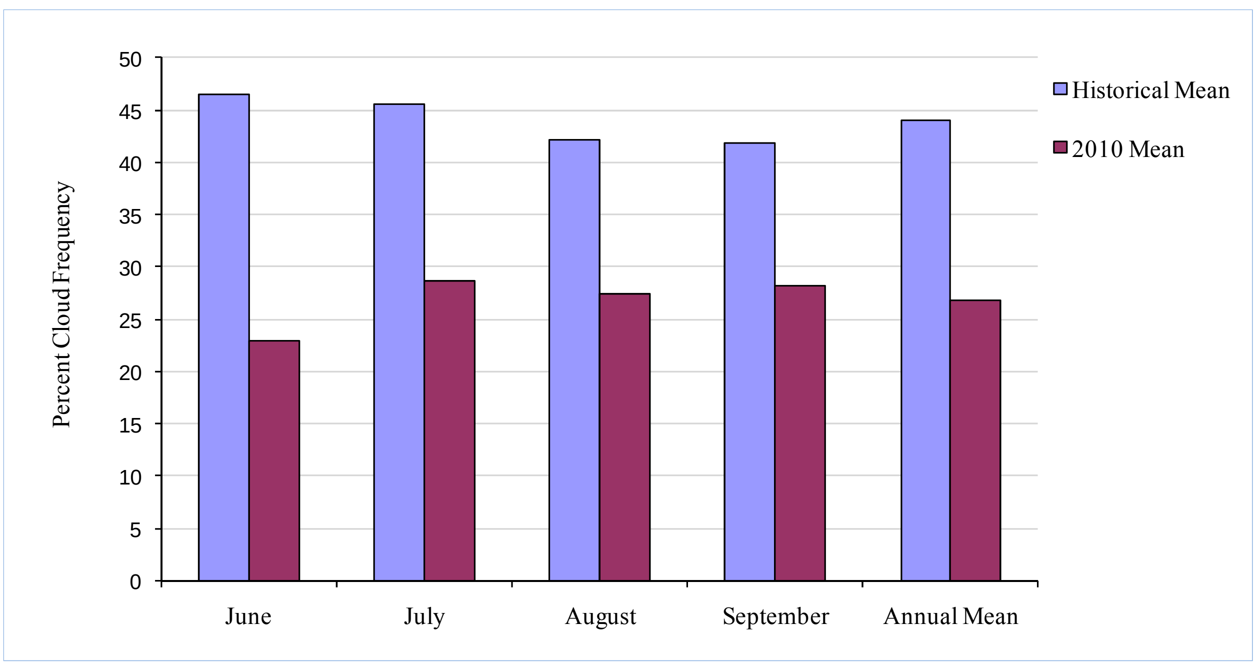


Figure 3-3. Monthly Mean Liquid Water Content Statistics (1994–2007, 2009–2010)

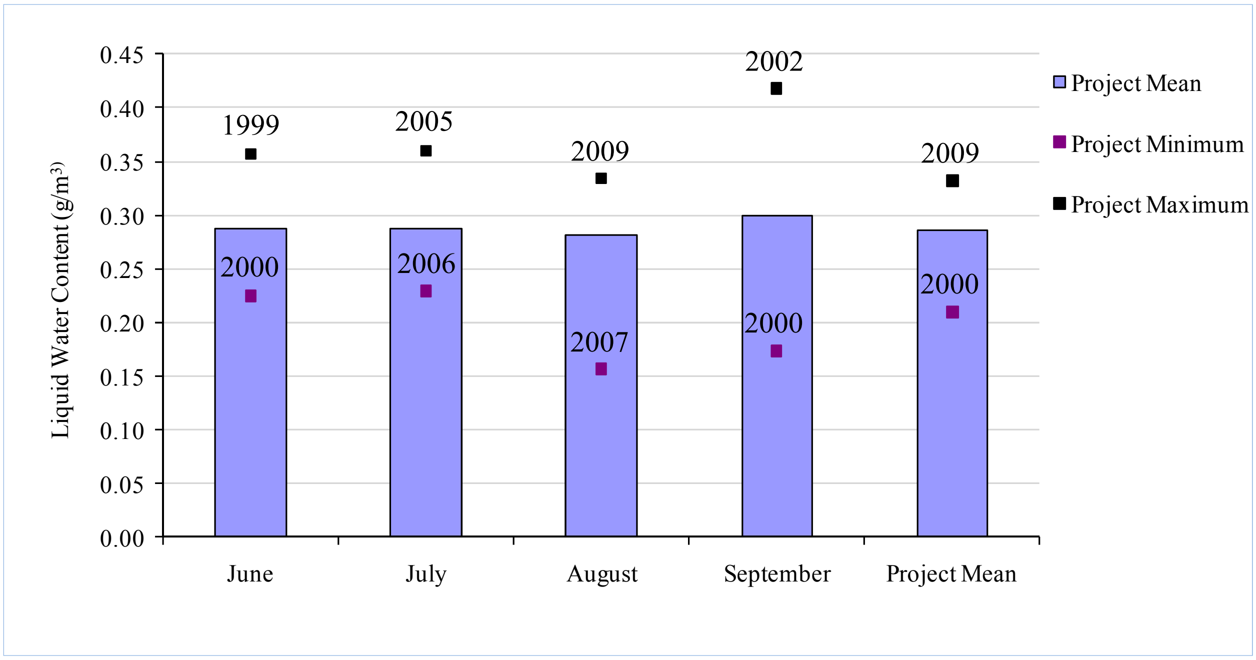


Figure 3-4. Monthly Mean Liquid Water Content – 2010 versus Historical Mean Values (1994–2007, 2009)

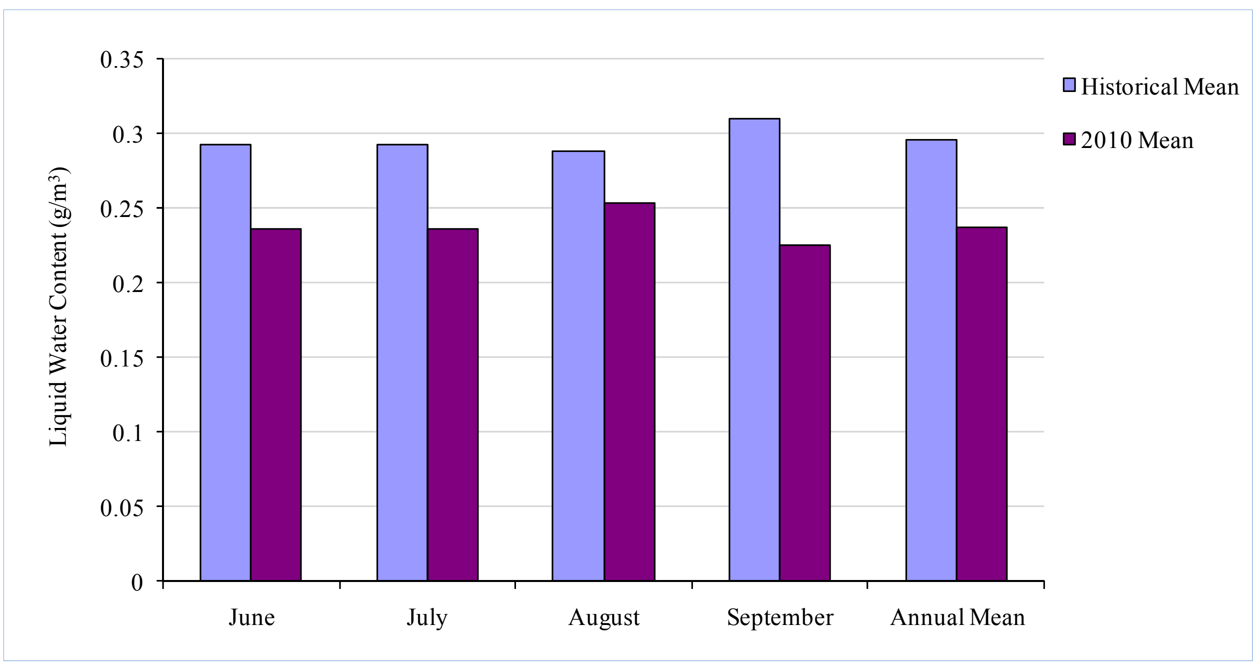


Figure 3-5. Frequency Distribution for Cloud Water pH (laboratory) at Clingmans Dome, TN (2010)

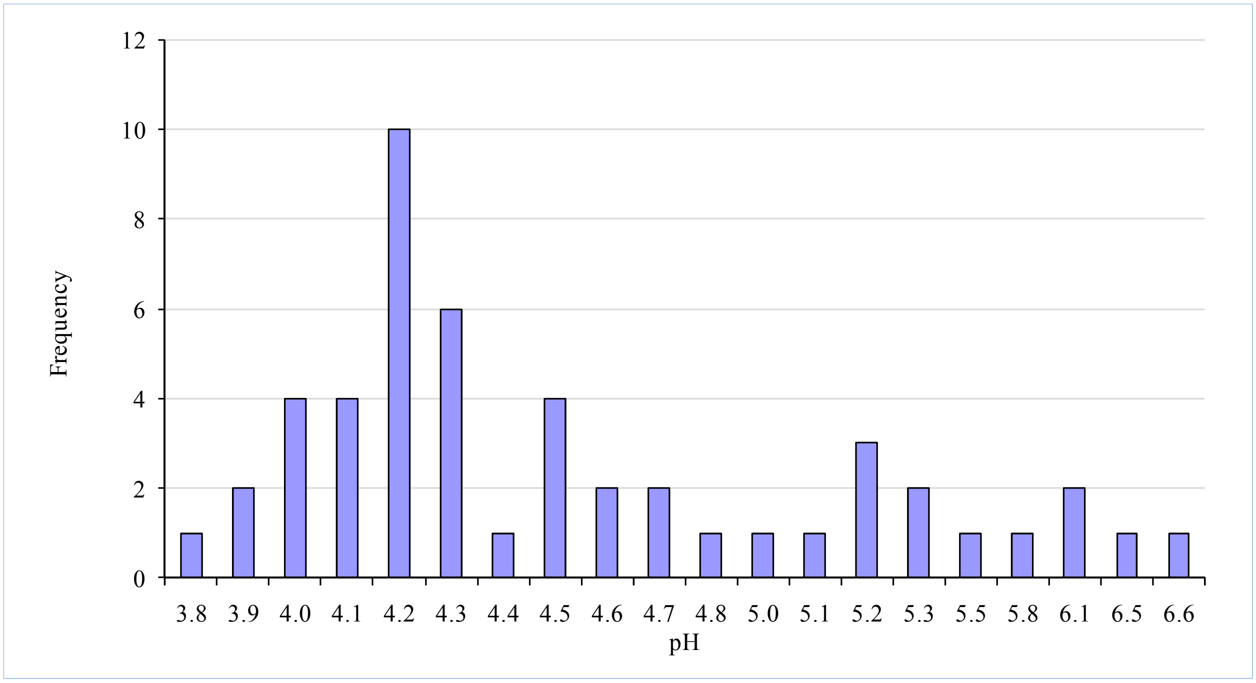


Figure 3-6. Frequency Distribution for Cloud Water pH (field) at Clingmans Dome, TN (2010)

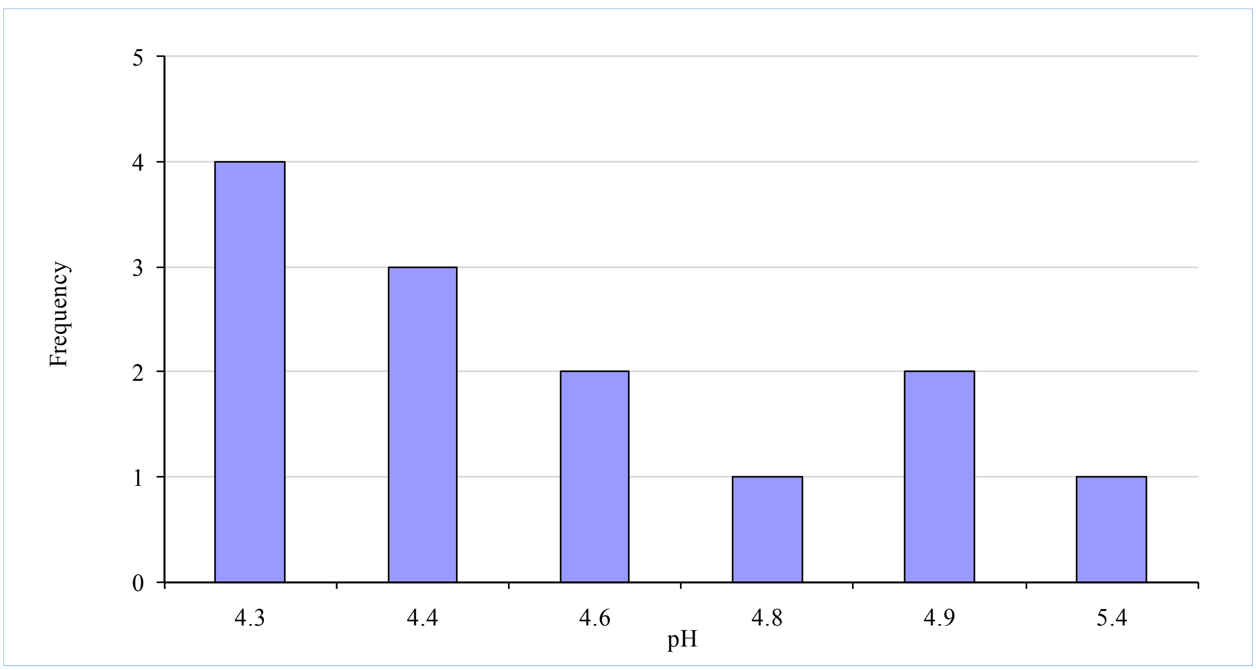
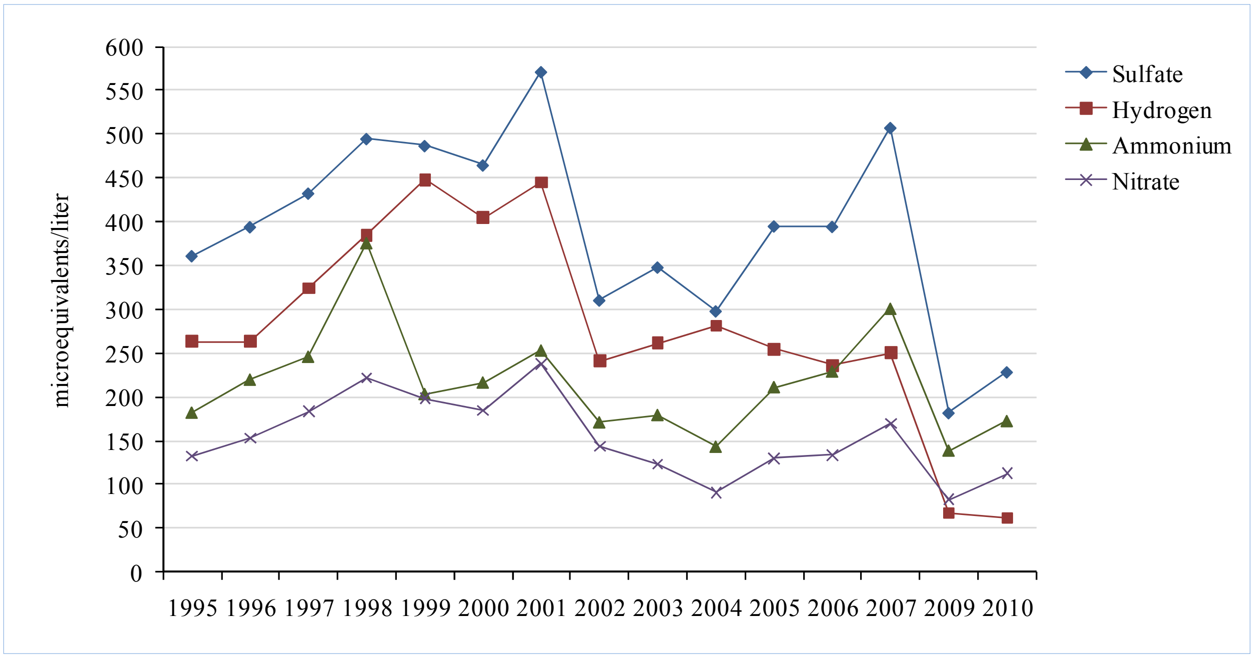


Figure 3-7. Mean Major Ion Concentrations of Cloud Water Samples (1995–2007, 2009–2010)



Note: * Laboratory pH data instead of field pH data were used for calculating the 2001, 2006, 2007, 2009, and 2010 hydrogen concentration values.

Figure 3-8. Mean Monthly Major Ion Concentrations for 2010

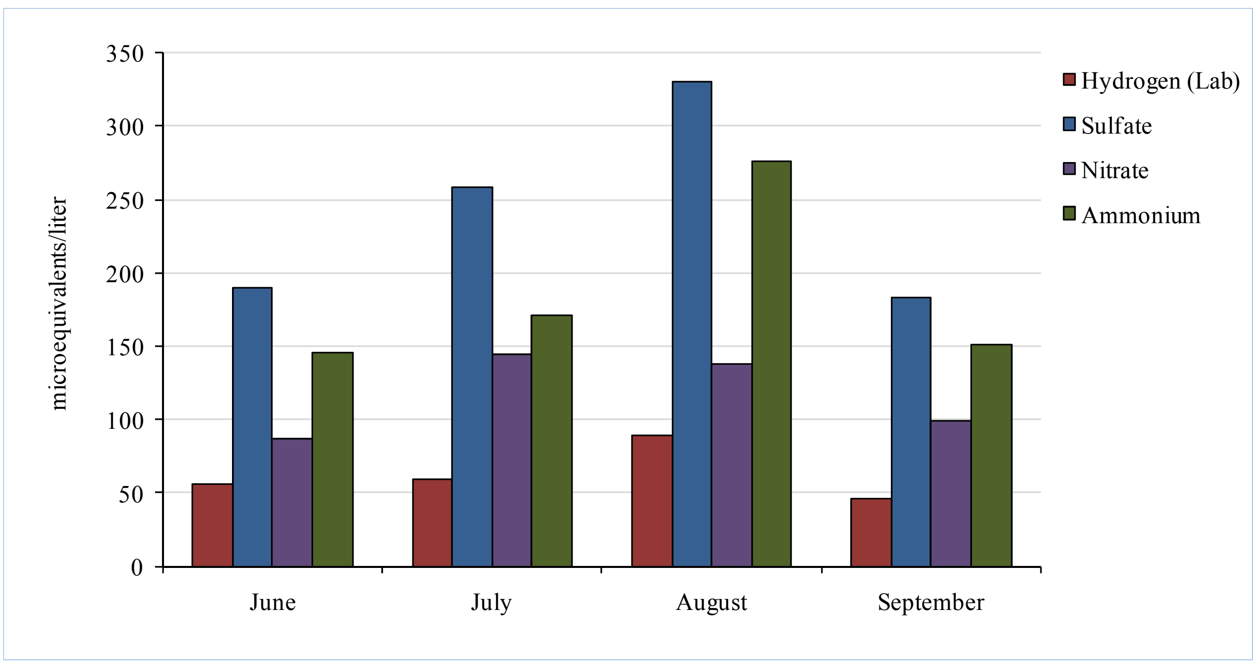


Figure 3-9. Mean Minor Ion Concentrations of Cloud Water Samples (Cations and Chloride) 1995–2007, 2009–2010

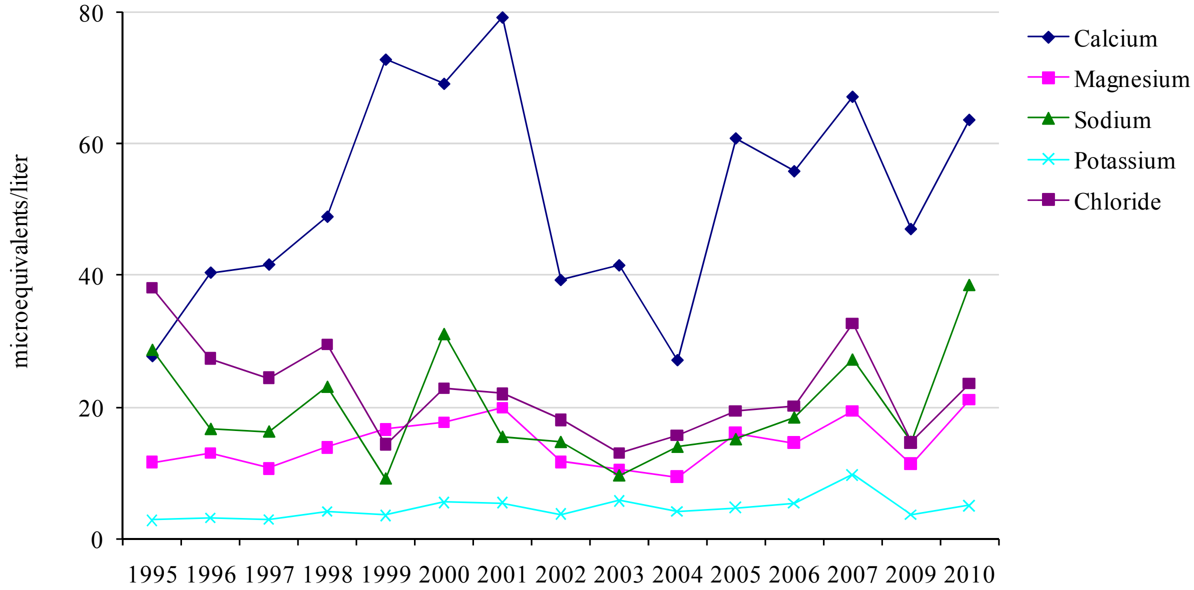


Figure 3-10. Mean Monthly Minor Ion Concentrations for 2010

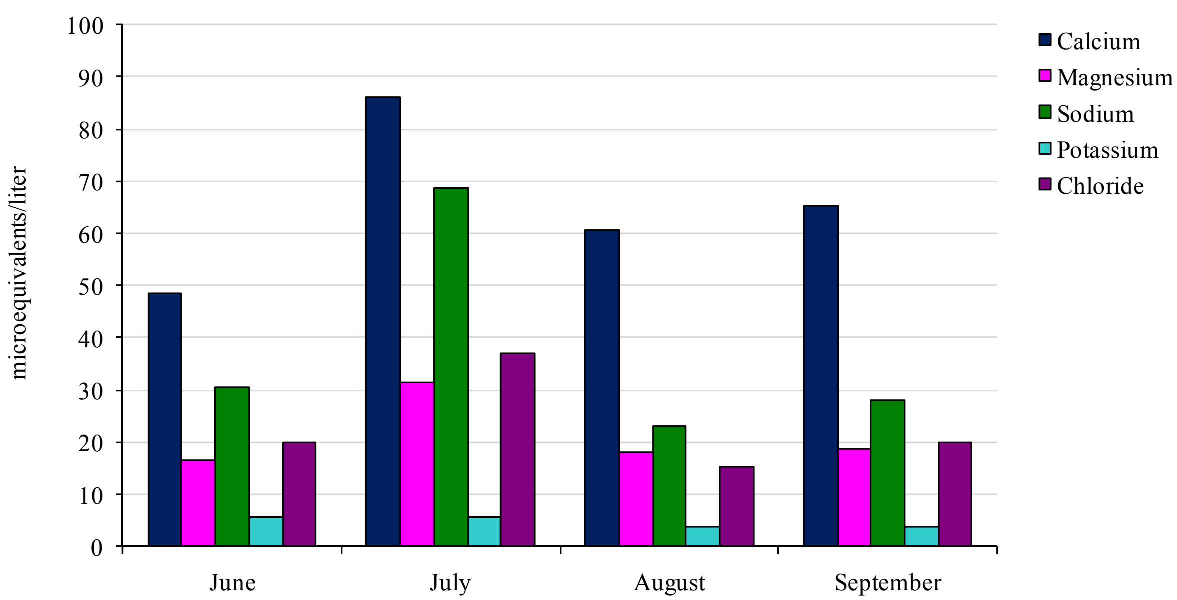


Figure 3-11. Mean Seasonal Cloud Water versus Mean Seasonal Precipitation Sulfate Concentrations, 2000–2010

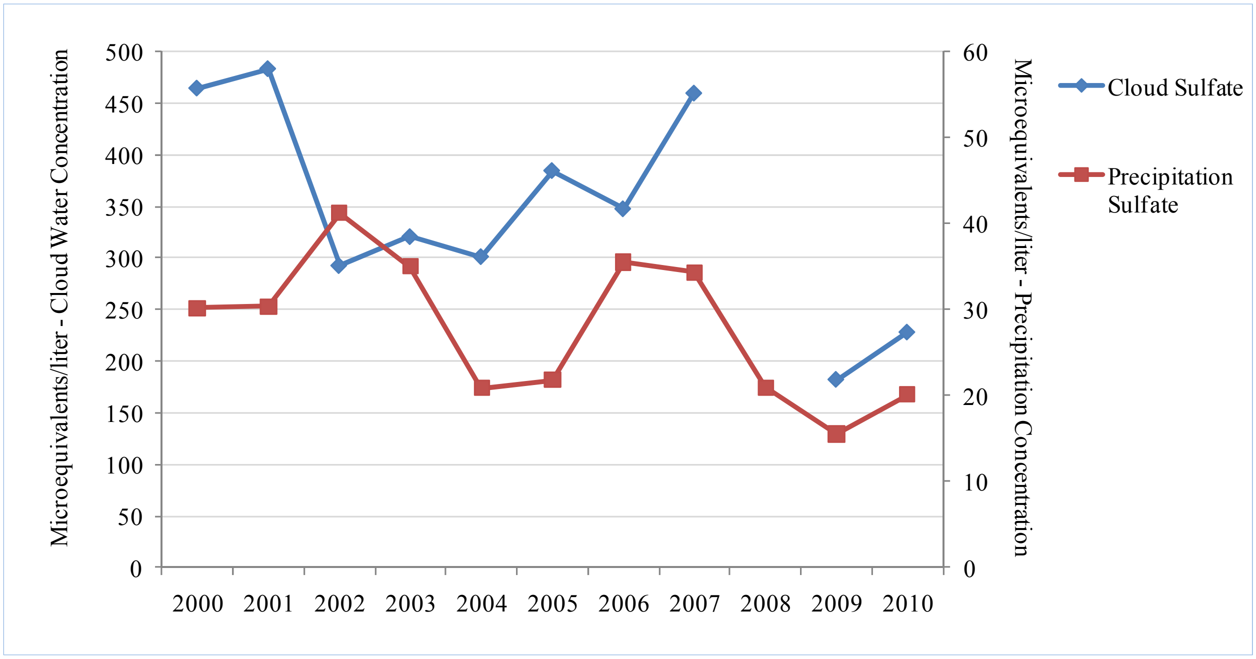


Figure 3-12. Mean Seasonal Cloud Water versus Mean Seasonal Precipitation Nitrate Concentrations, 2000–2010

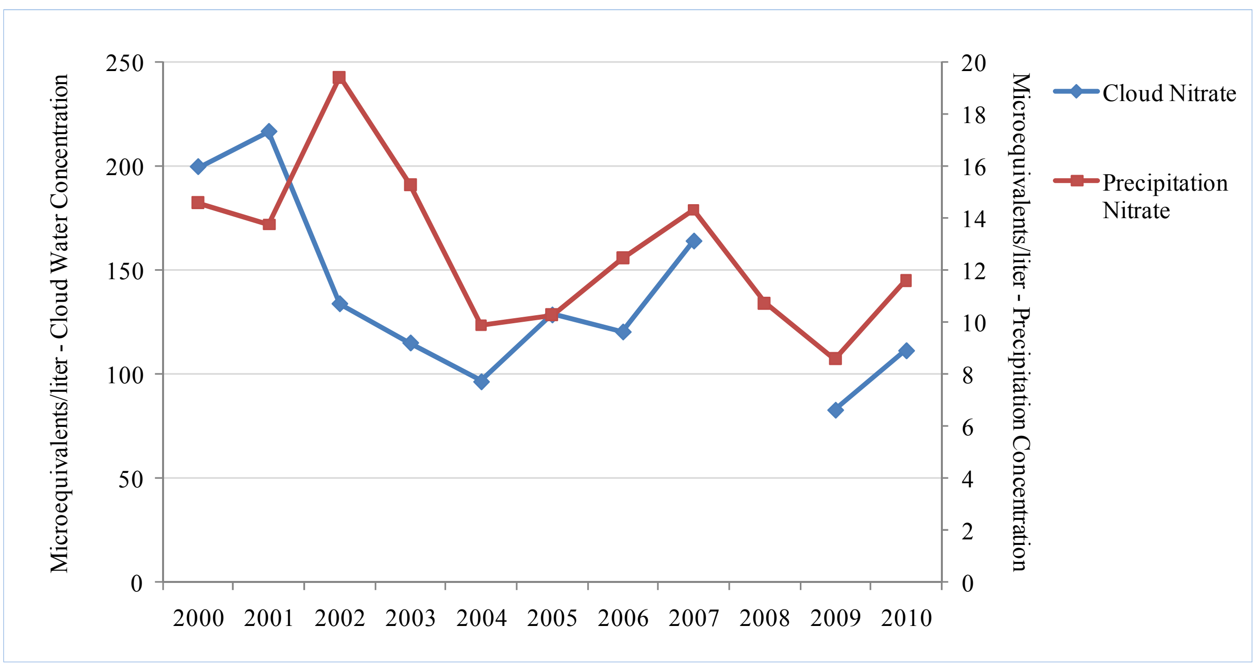


Figure 4-1. Monthly Deposition Estimates – CLOUD Model (SO_4^{2-})

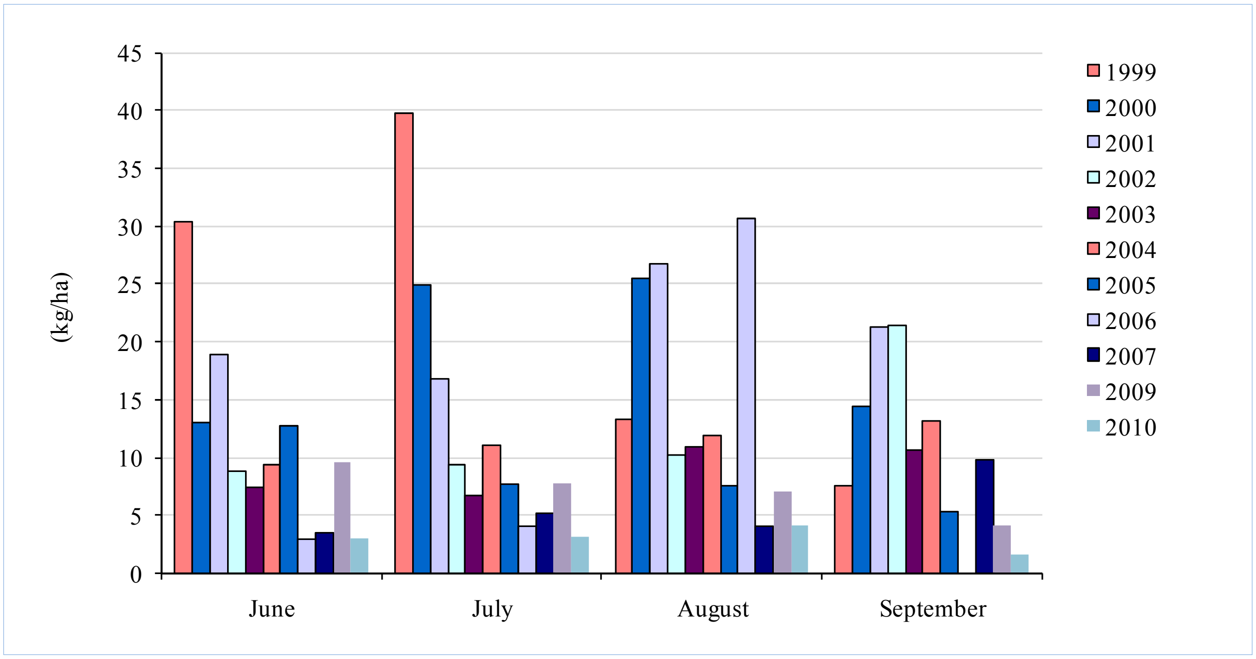


Figure 4-2. Monthly Deposition Estimates – CLOUD Model (NO_3^-)

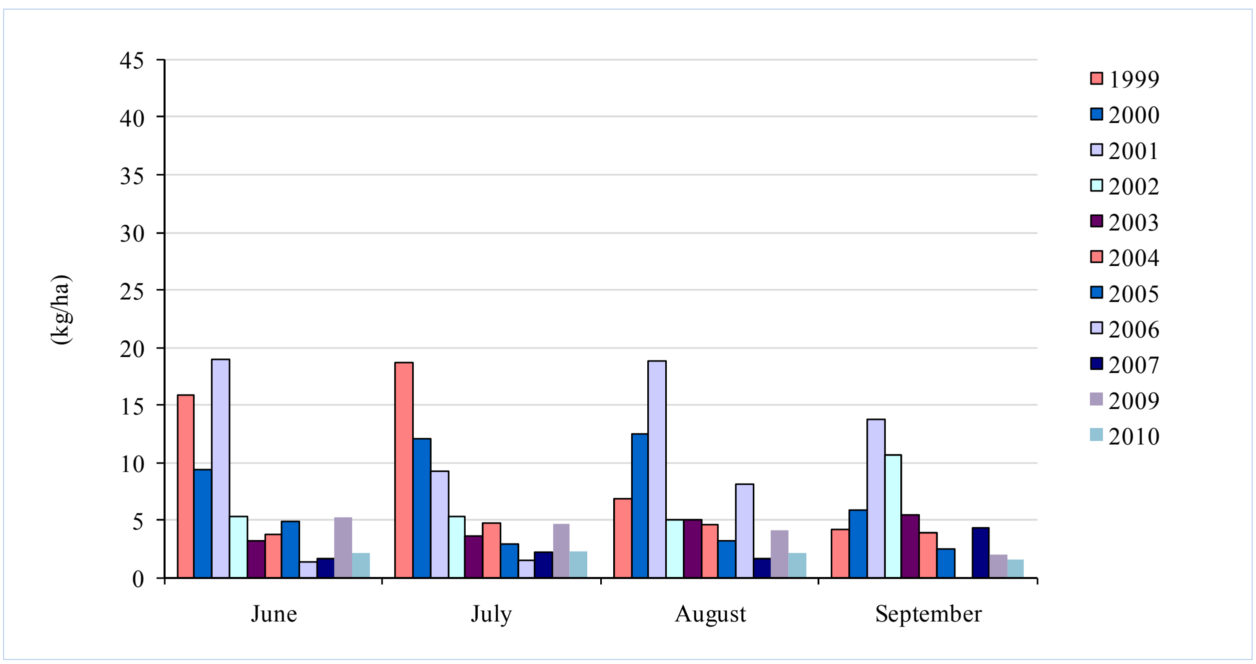


Figure 4-3. Monthly Deposition Estimates – CLOUD Model (NH_4^+)

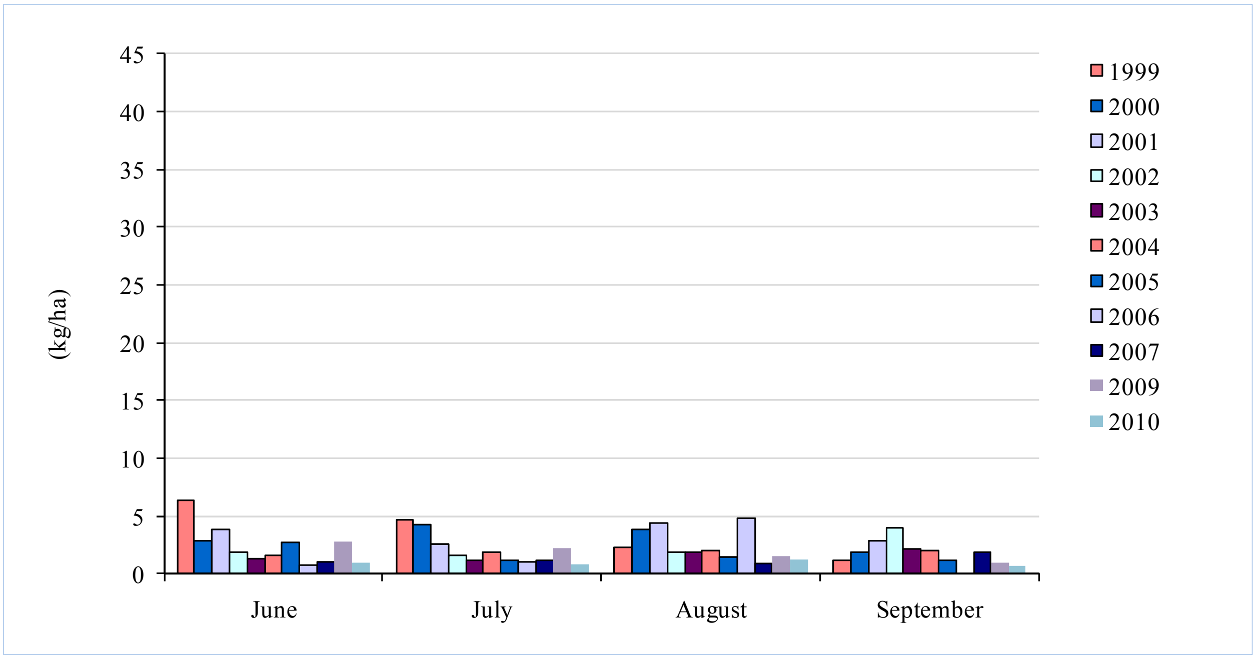


Figure 4-4. Monthly Deposition Estimates – CLOUD Model (H^+)

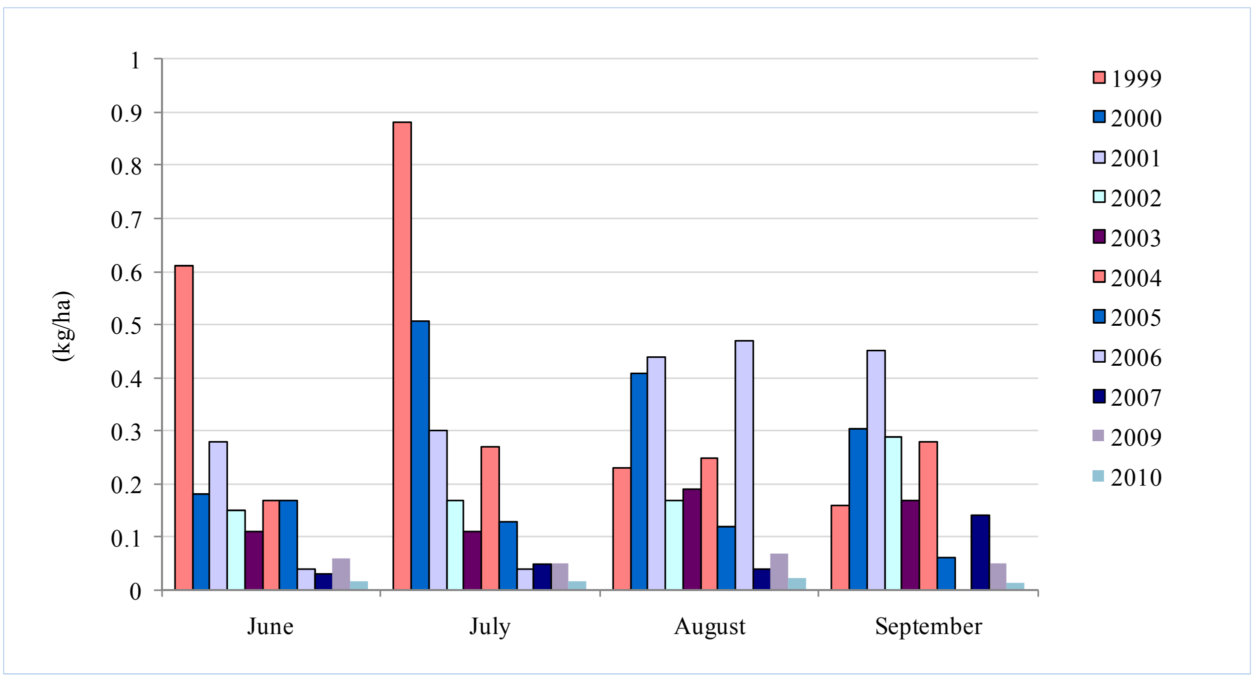


Figure 4-5. Monthly Deposition Estimates – CLOUD Model (Ca^{2+})

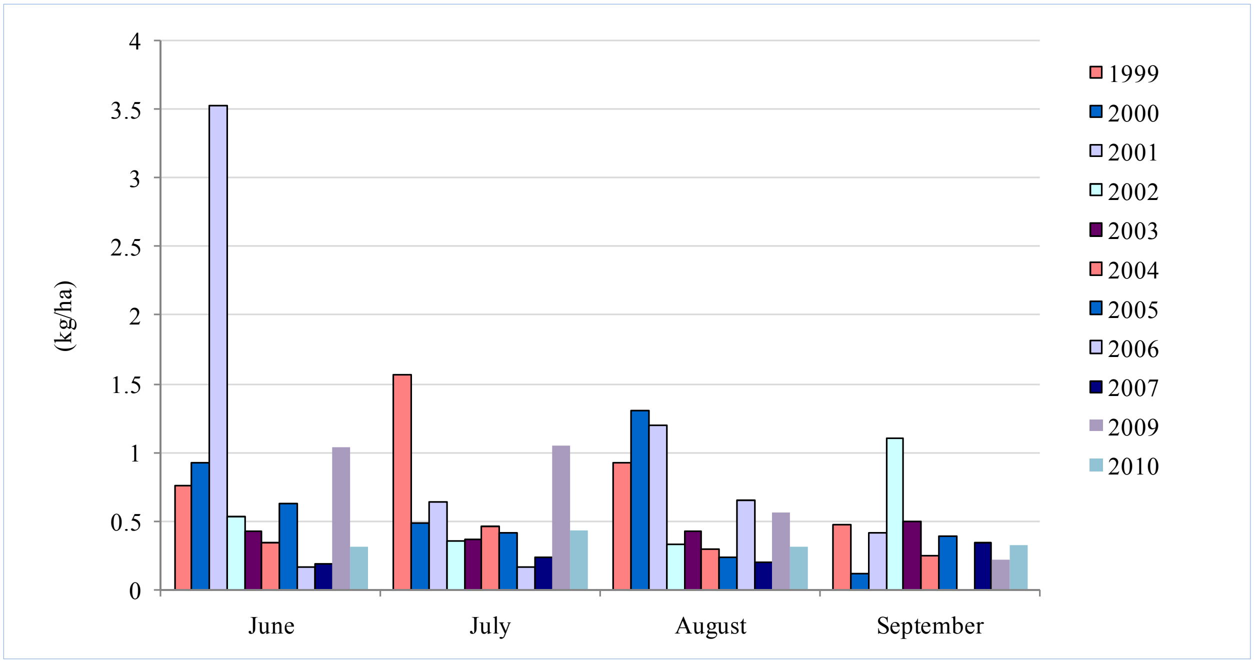


Figure 4-6. Seasonal Deposition Estimates for Major Ions (1999–2007, 2009–2010)

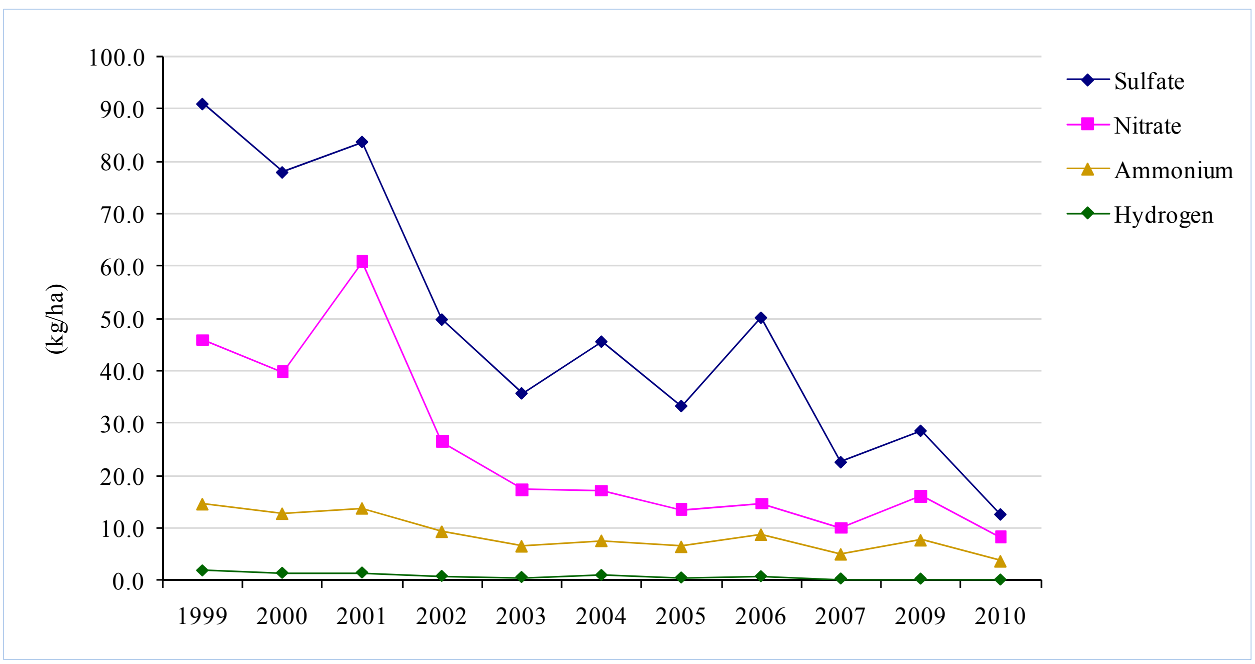


Figure 4-7. Seasonal Deposition Estimates for Hydrogen from 1999–2007, 2009–2010

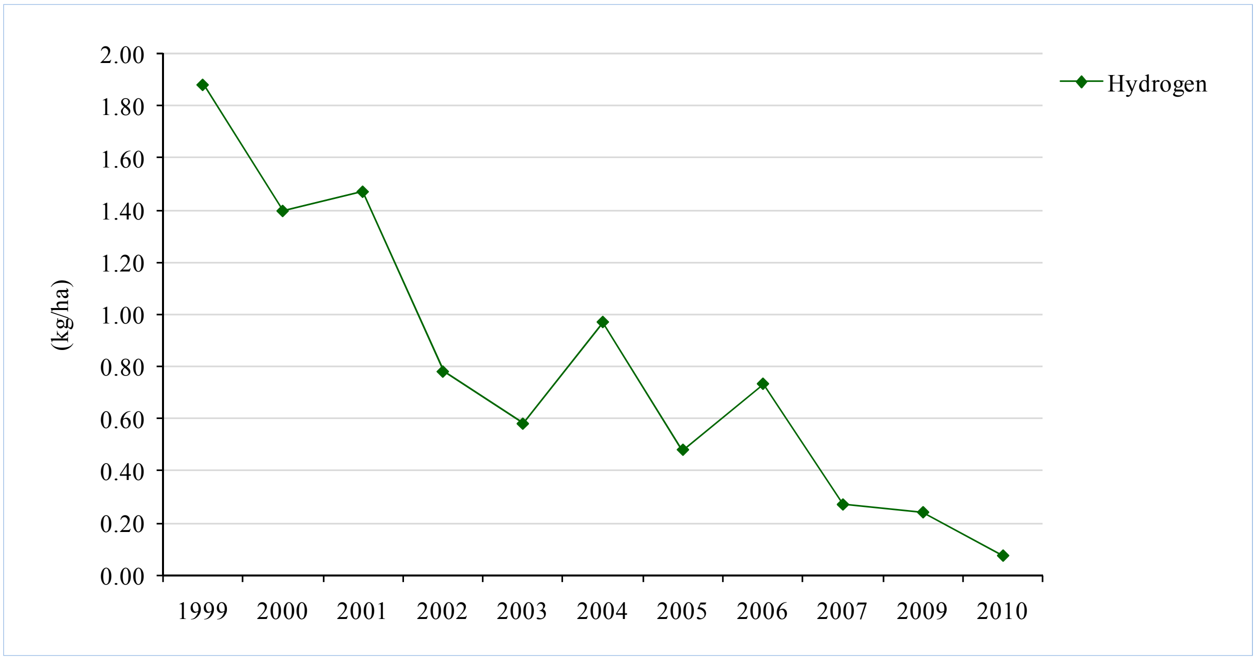


Figure 4-8. Cloud Water and Wet Sulfate Deposition Estimates (June through September), 2000–2010

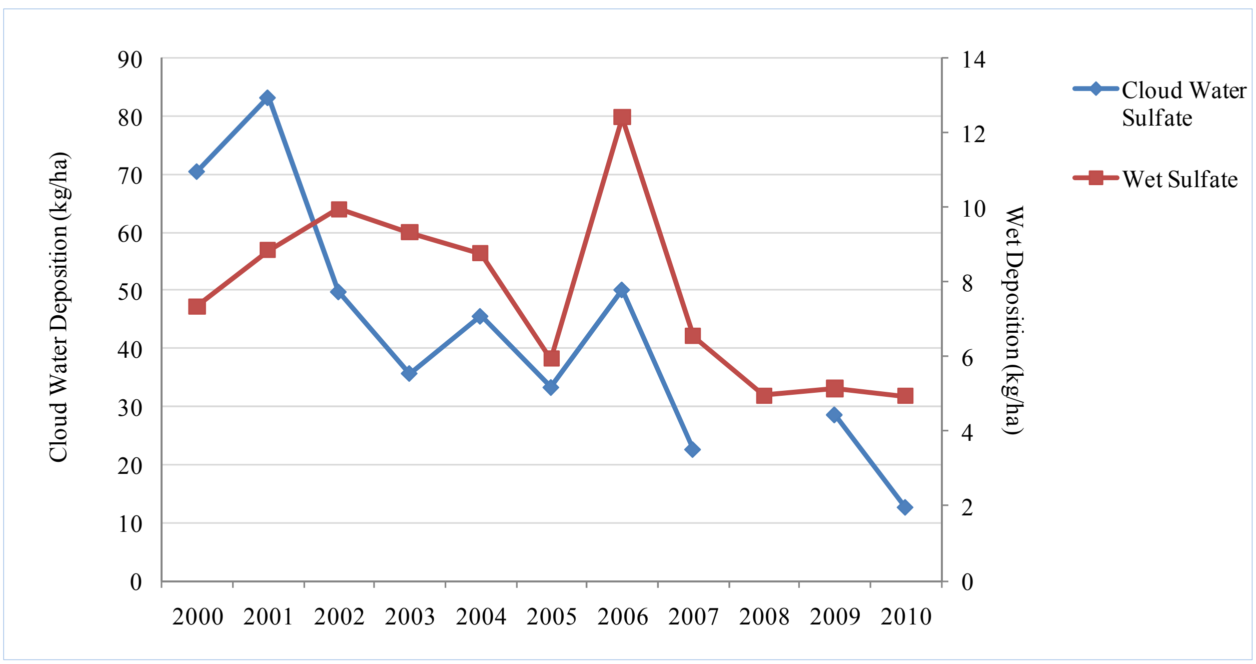


Figure 4-9. Cloud Water and Wet Nitrate Deposition Estimates (June through September), 2000–2010

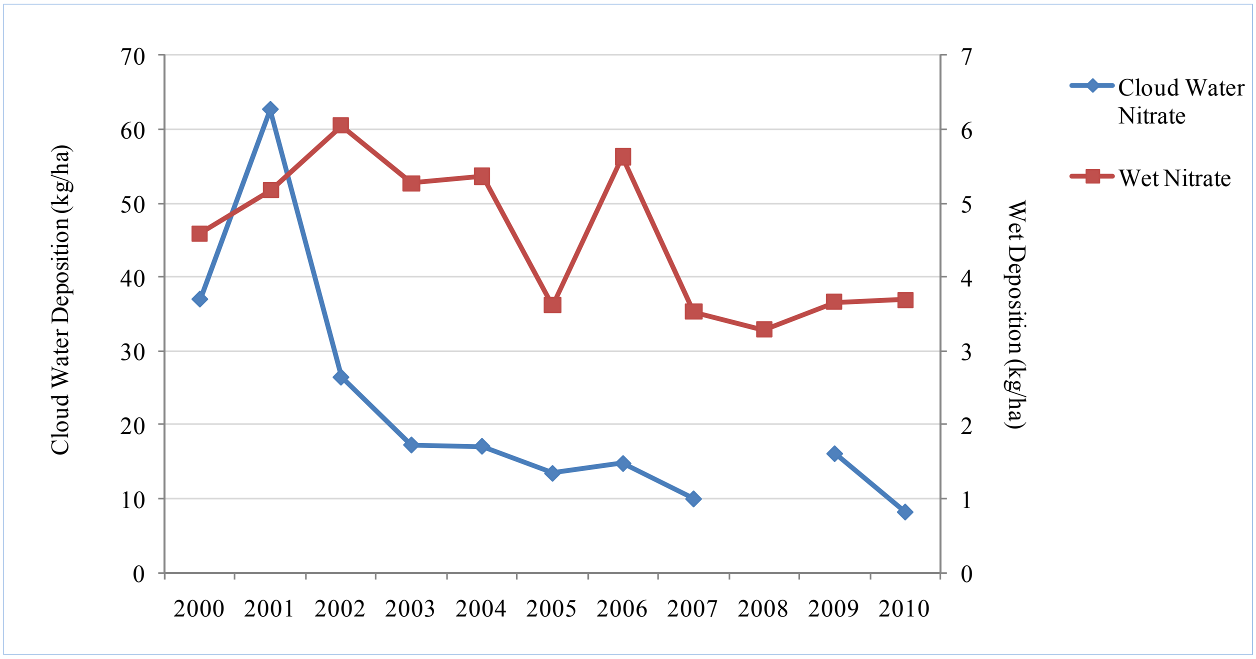


Figure 5-1. Total Sulfur and Nitrogen Cloud Water and Dry Deposition Estimates (June through September) 1999–2007, 2009–2010

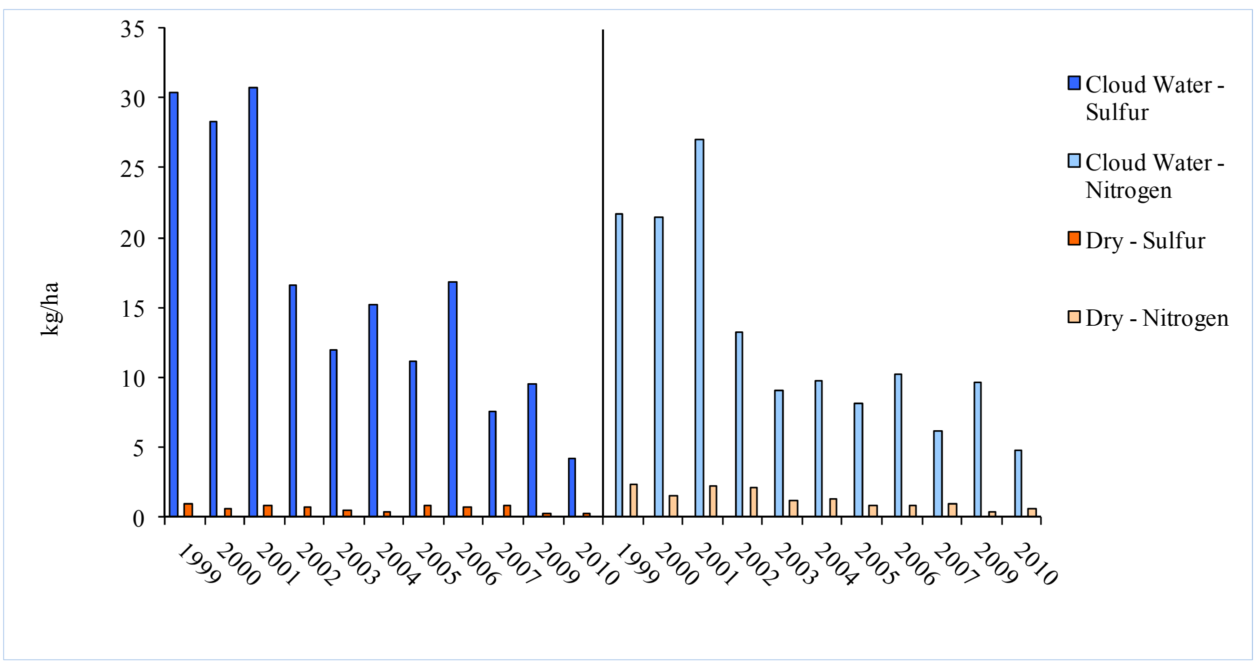
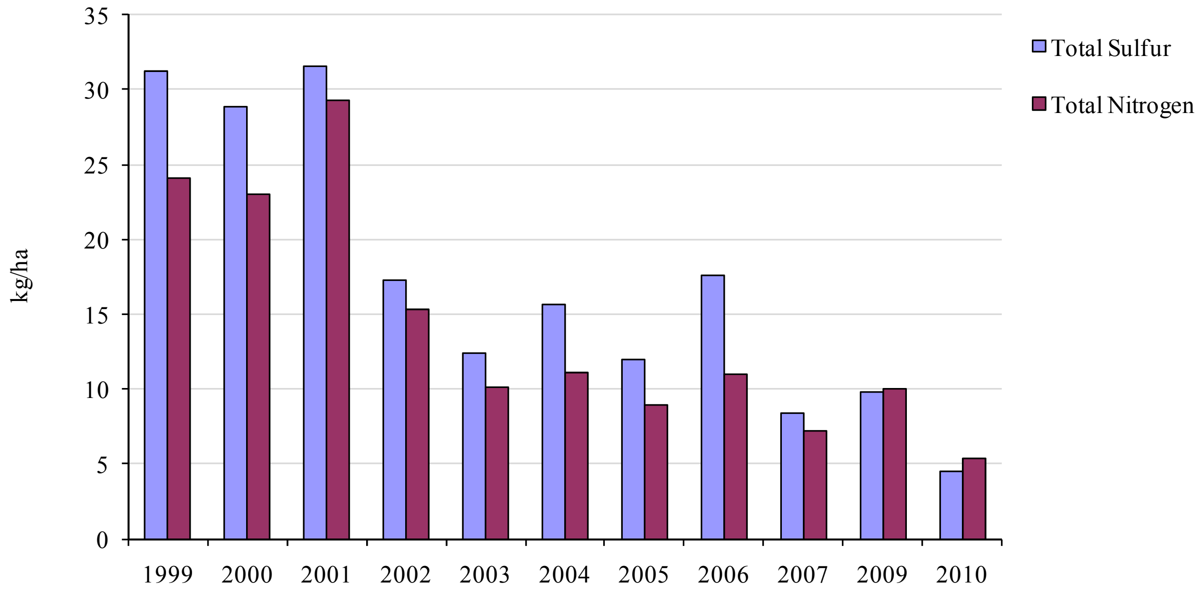


Figure 6-1. Total Sulfur and Nitrogen Deposition Estimates (Dry + Cloud Components) for 1999−2007, 2009–2010



Appendix A

Cloud Water Deposition to Clingmans Dome in 2010

Cloud Water Deposition to Clingmans Dome in 2010

Report to MACTEC by

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CASTNET/MADPRO
MACTEC Project Job # 6064100017 0006

Report Date: March 11, 2011

Introduction

This brief report accompanies the Excel spreadsheet CLD 2010.xls, which gives the results of the cloud water deposition modeling for the Clingmans Dome (CLD303) site for the field season of 2010. Raw chemical concentration, meteorological, and cloud frequency data were provided to me by MACTEC (Selma Isil). I ran the CLOUD model (Lovett 1984) on these data to estimate cloud water deposition to this site, and calculated seasonal and monthly mean values of key parameters.

Briefly, the CLOUD model uses an electrical resistance network analogy to model the deposition of cloud water to forest canopies. The model is one-dimensional, assuming vertical mixing of droplet-laden air in to the canopy from the top. Turbulence mixes the droplets into the canopy space, where they cross the boundary layers of canopy tissues by impaction and sedimentation. Sedimentation rates are strictly a function of droplet size. Impaction efficiencies are a function of the Stokes number, which integrates droplet size, obstacle size, and wind speed (Lovett 1984). The impaction efficiency is calculated as a function of the Stokes number based on wind tunnel measurements by Thorne et al (1982).

The forest canopy is modeled as stacked 1-m layers containing specified amounts of various canopy tissues such as leaves, twigs, and trunks. Wind speed at any height within the canopy space is determined based on the above-canopy wind speed and an exponential decline of wind speed as function of downward-cumulated canopy surface area. The wind speed determines the efficiency of mixing of air and droplets into the canopy and also the efficiency with which droplets impact onto canopy surfaces. The model is deterministic and assumes a steady-state, so that for one set of above-canopy conditions it calculates one deposition rate. The model requires as input data:

1) the surface area index of canopy tissues in each height layer in the canopy,
2) the zero-plane displacement height and roughness length of the canopy
3) the wind speed at the canopy top
4) the liquid water content (LWC) of the cloud above the canopy
5) the mode of the droplet diameter distribution in the cloud

From these input parameters, the model calculates the deposition of cloud water, expressed both as a water flux rate (g cm^{-2} min^{-1}), and as a deposition velocity (flux rate/LWC, in units of cm/s). Deposition rates of ions are calculated by multiplying the water deposition rate by the ion concentration in cloud water above the canopy. In the original version of the model, a calculation of the evaporation rate from the canopy was also included in order to estimate net deposition of cloud water. For this project, only gross deposition rate was required so the evaporation routine was not invoked.

The 2010 data set covered the period June-October 2010. Only cloud events in this 5-month period, and having valid wind speed, cloud LWC and event duration data were used for this modeling. Events meeting these criteria included 12 events in June, 8 in July, 7 in August, 6 in September, and 4 in October, for a total of 37 events for the season. All months had sampling completeness values greater than 99% for cloud frequency.

The calculations done here for 2010 followed closely those done previously for the Clingmans Dome site (e.g., Lovett 2010). As in previous reports, these model runs were made assuming a 10-m tall, intact, homogeneous conifer canopy. The actual canopy structure at Clingmans Dome has not been quantified, and may differ substantially from the modeled canopy structure. Consequently, this deposition estimate is best viewed as an index of cloud deposition that can be used to compare the effects of changing meteorological and cloud chemical conditions across different sites and different times, assuming that the same "standard" canopy was present at each site and time.

Because the measurement periods vary in length, all the means presented here are weighted by the duration of the sampling event. Duration-weighting the seasonal and monthly means in this way avoids giving a 10-minute event the same weight as a 10-hour event. This is analogous to the standard practice of volume-weighting the means of precipitation chemistry. After the model was run for all sample periods, seasonal and monthly means and totals were calculated in a SAS program. Monthly deposition totals were calculated as the product of the duration-weighted mean concentration and the total measured cloud duration for the month. Total seasonal deposition was calculated by summing the five monthly totals.

Results

The model was run on 37 time periods as discussed above, and the results are presented as deposition velocities and deposition fluxes in the CLD 2010.xls spreadsheet and in Appendix I.

Monthly mean concentrations of ions in cloud water and in meteorological and deposition variables are given in Appendix I. During the measurement period, duration-weighted mean concentrations of SO_4^{2-}, H^+ and NH_4^+ were highest in August, but NO_3^- concentrations were highest in October (Fig. 1).

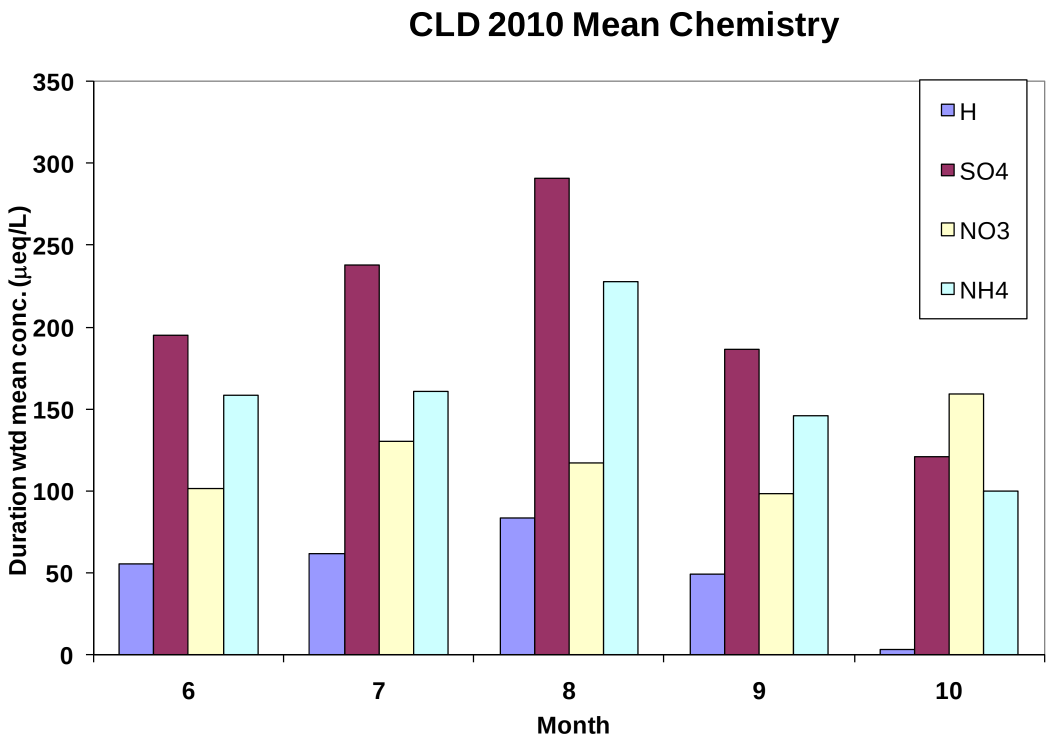

Figure 1. *Duration-weighted mean concentration of four ions in cloud water, calculated by month.*

Seasonal mean concentrations (duration-weighted) of these ions in 2010 were similar to 2009 (Fig. 2). Since the late 1990s, the concentrations of hydrogen ion and sulfate have been in general declining. Nitrate and ammonium concentrations have been relatively flat since about 2003.

Some of the variation from year to year in ion concentrations can be explained by dilution, as higher LWC is often associated with lower concentrations. In essence, if the same amount of sulfate (or any soluble pollutant) is dissolved in a larger amount of water, the result will be a lower concentration. We can correct the sulfate trend for changes in LWC by calculating the amount of dissolved sulfate per cubic meter of air (by multiplying the sulfate concentration in cloud water by the LWC), which removes some of the noise in the sulfate trend . In these data, the 2010 values continue the general downward trend in sulfate since the 1990s (Fig. 3).

The trends shown in Figures 2 and 3 are based on duration-weighted mean concentrations and represent only those data used for modeling cloud water deposition (i.e. those events for which liquid water content and wind speed were also measured). These trends may not match other calculations of trends if more complete chemistry datasets or non-duration-weighted means are used. Also, the trends in hydrogen ion shown in Fig. 2 must be interpreted with caution because of the variation from year to year in whether lab pH or field pH was used. In general, lab pH values are higher (i.e. lower H^+ concentration, less acidic) than field pH values because H^+ is very reactive and

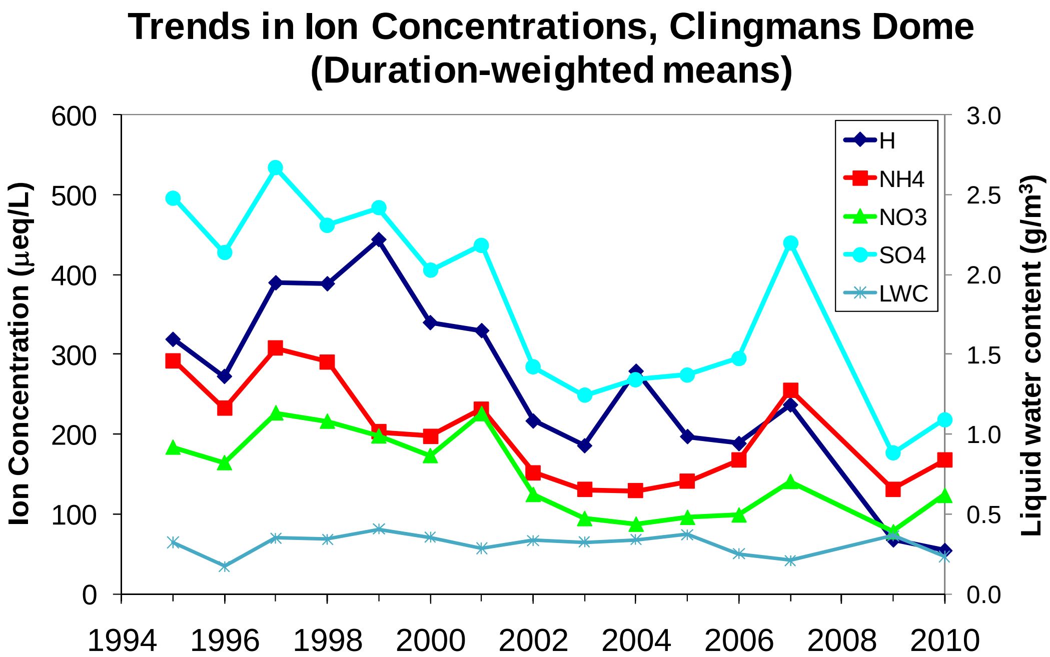

Figure 2. *Trends in ion concentrations and LWC at Clingmans Dome, 1995-2010. Data are duration-weighted means for the warm season and include only the samples for which deposition was modeled (i.e. LWC and meteorological data were also present).*

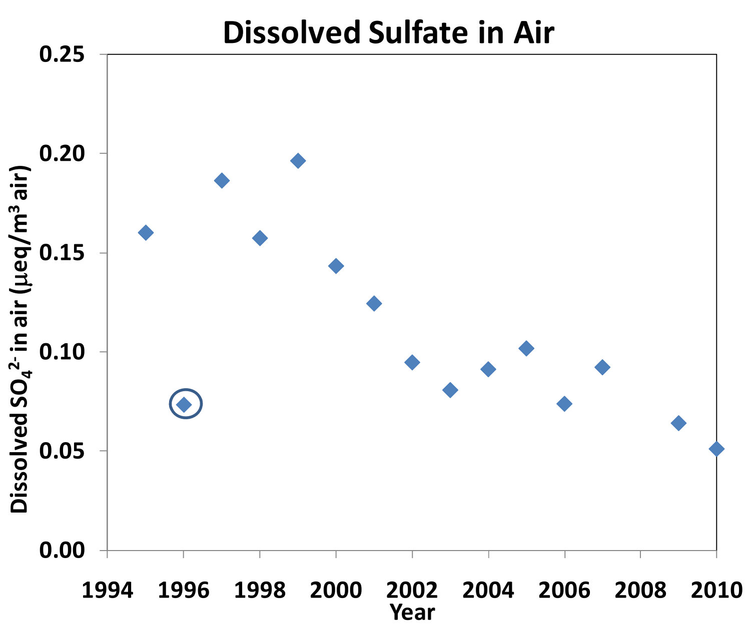

Figure 3. *Mean values of dissolved sulfate per cubic meter of air (= cloud water sulfate concentration x LWC/1000) for Clingmans Dome. Circled year (1996) has anomalously low LWC data, perhaps because of instrument error.*

is consumed during the sample holding period prior to laboratory analysis. Since 2006 data we used exclusively lab pH values because of an incomplete record of field pH.

Wind speed and cloud water deposition velocity were relatively constant from month to month during the sampling period, with the lowest values of both parameters in July (Fig. 4). Mean duration-weighted deposition velocity for the 2010 season was 15.5 cm/s, well below the 1995-2009 mean of 20.7 cm/s (see accompanying Excel workbook). The deposition velocity probably was lower than the average because the mean wind speed (3.8 m/s) was also lower than the average (4.6 m/s), and wind drives cloud water deposition.

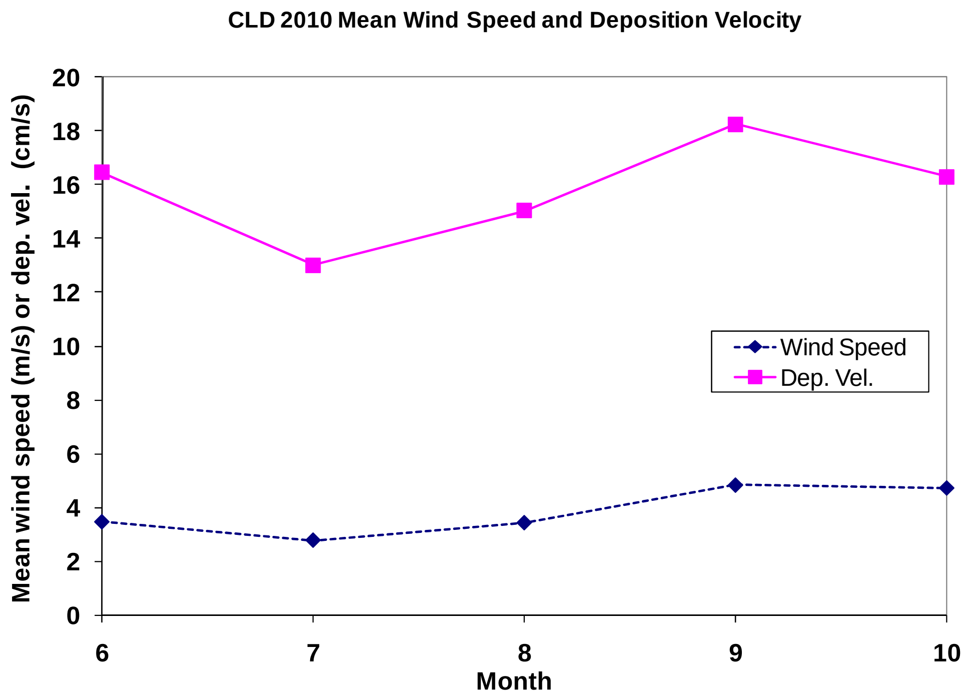

Figure 4. *Mean wind speed and deposition velocity for each month.*

Monthly mean cloud LWC declined through the season, from over 0.3 g/m^3 in June to less than 0.15 g/m^3 in October (Fig. 5), with a seasonal mean of 0.23 g/m^3, well below the long-term mean of 0.31.

Seasonal deposition totals were calculated by summing across all 5 months. For comparison with the results of previous reports, these means are expressed in Fig. 6 as the mean monthly deposition rate, calculated by dividing the seasonal total by 5. The rates for water and ion deposition for 2010 are the lowest in the period of record (Fig. 6), because 2010 had a combination of low LWC, low wind speed, and relatively low ion concentrations.

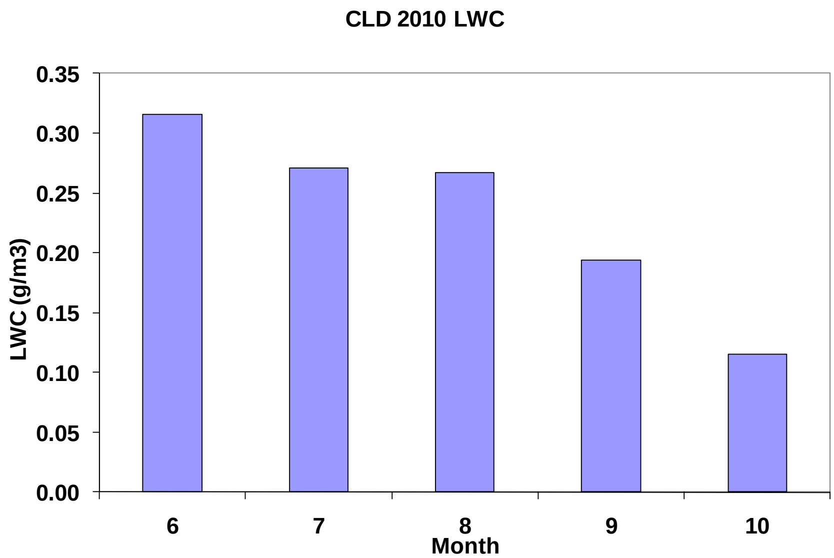

Figure 5. *Mean liquid water content for each month of the study.*

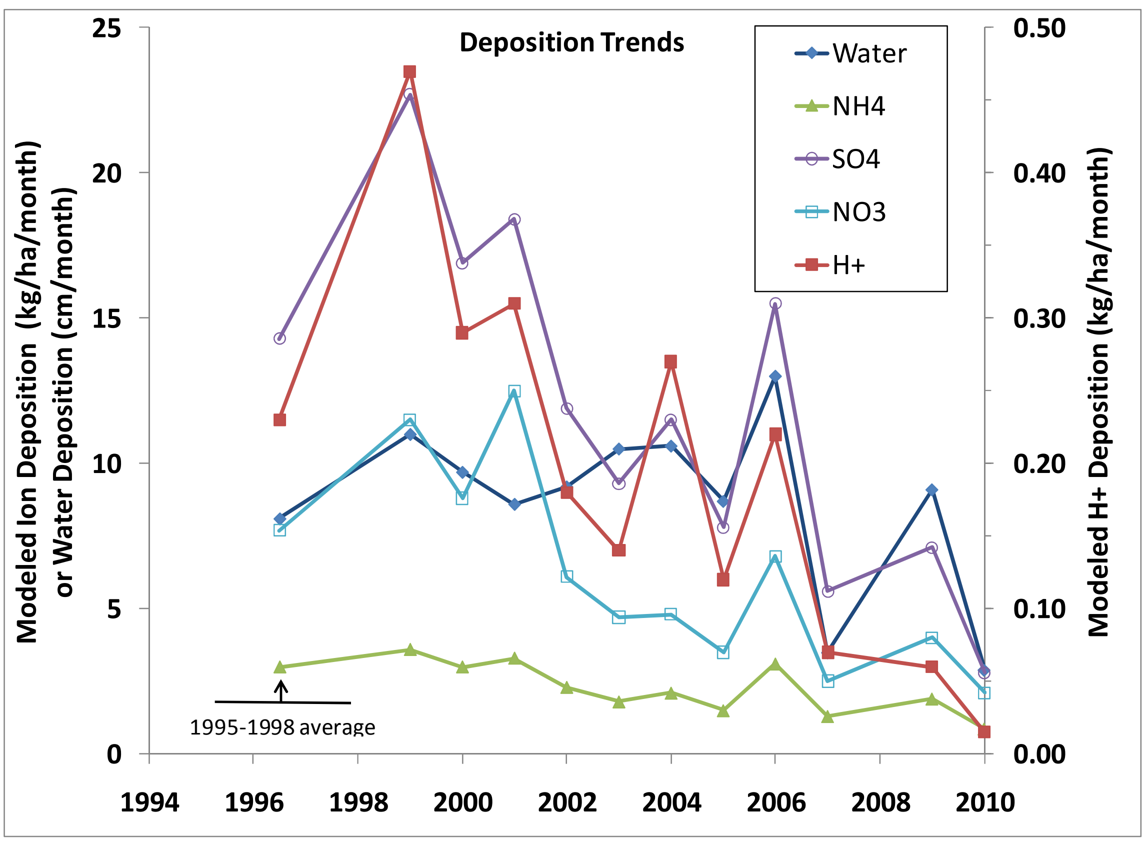

Figure 6. *Mean monthly deposition rates for several ions (in kg/ha/month) and water (cm/month) for the Clingmans Dome site for the 1995-2010 period. The seasonal averages include the months of June-September for 2007 and 2009, June-October for 2004-2006 and 2010 and May-September for years prior to 2004.*

8.0 Literature Cited

Lovett, G. M. 1984. Rates and mechanisms of cloud water deposition to a subalpine balsam fir forest. Atmospheric Environment **18**:361-371.

Lovett, G.M. 2010. Cloud water deposition to Clingmans Dome in 2009. Report to MACTEC, March 2008. 8 pp.

MACTEC. 2007. Cloud Deposition Monitoring,Clingmans Dome, TN,Great Smoky Mountains National Park,2006. Report for EPA Contract 68-D-03-052. MACTEC Engineering and Consulting, Inc. Gainesville, FL.

Thorne, P. G., G. M. Lovett, and W. A. Reiners. 1982. Experimental determination of droplet deposition on canopy components of balsam fir. J..Appl. Meteorol. **21**:1413-1416.

Appendix I. Mean monthly values of meteorological, chemical and deposition variables for 2010.

Table I-1. Monthly mean meteorological and deposition variables. All means are duration-weighted. TUBFLUX , SEDFLUX and TOTFLUX are turbulent, sedimentation and total water fluxes ($g/cm^2/min$) for the time period, and TURBVD, SEDVD and TOTVD are the corresponding deposition velocities (cm/s). WS is wind speed (m/s) and LWC is cloud liquid water content in g/m^3.

MONTH	OBS	DURATION	VOLUME	WS	LWC	TURBFLUX	SEDFLUX	TOTFLUX	TURB VD	SED VD	TOT VD
6	12	4.97	288.50	3.46	0.32	1.91E-04	1.31E-04	3.22E-04	9.70	6.76	16.46
7	8	11.93	741.00	2.78	0.27	1.05E-04	1.08E-04	2.12E-04	6.53	6.49	13.01
8	7	15.22	1212.77	3.43	0.27	1.43E-04	1.07E-04	2.49E-04	8.84	6.19	15.04
9	6	9.40	893.88	4.83	0.19	1.56E-04	6.71E-05	2.23E-04	13.25	5.00	18.25
10	4	18.81	1542.08	4.72	0.12	1.15E-04	3.02E-05	1.45E-04	12.16	4.13	16.29

Table I- 2. Monthly mean ion concentrations (μeq/L). All means are duration-weighted.

Month	H (lab)	Ca	Mg	K	Na	NH4	SO4	NO3	Cl
6	55.53	54.24	18.98	5.54	31.94	158.70	195.05	101.27	22.95
7	62.05	75.62	26.11	4.70	49.56	160.96	237.88	130.41	26.48
8	83.91	53.84	15.52	3.24	17.96	227.57	290.84	117.41	12.47
9	49.15	65.33	19.48	3.66	36.60	145.89	186.70	98.42	26.36
10	3.27	163.08	32.88	3.77	34.17	100.02	121.20	159.41	30.91

Table I-3. Monthly deposition in µeq/m^2/month. Water deposition in cm/month.

Month	HDEP	KDEP	NADEP	CADEP	MGDEP	NH4DEP	SO4DEP	NO3DEP	CLDEP	H2ODEP
6	1764.14	173.58	1035.75	1531.35	550.76	5520.28	6147.15	3429.24	761.04	3.19
7	1781.40	132.17	1411.74	2146.24	742.32	4450.37	6657.63	3774.84	738.70	2.72
8	2400.53	93.58	625.29	1571.86	440.70	7098.78	8521.87	3555.37	396.95	3.05
9	1362.90	94.90	851.75	1598.00	472.80	3793.65	4816.43	2525.35	608.42	2.71
10	218.73	112.78	619.62	3093.51	716.53	3188.24	3382.82	3758.60	579.83	2.89

Appendix B

Cloud Water Data and QC Summary

Cloud Water Data and QC Summary

Analytical data for the 50 cloud deposition samples are presented in Table B-1 including measured field pH, field conductivity, sample volume, average LWC, valid hours, average scalar wind speed, and calculated cations and anions. A cumulative volume-weighted mean is shown for the various indicated analytes and ions.

Tables B-2, B-3, and B-4 provide summaries of the QC results associated with the samples. The QC results for all parameters are within the measured criteria of the CASTNET QC program (MACTEC, 2010). Table B-2 summarizes the QC data for the reference samples for each parameter in each analytical batch. The reference sample is traceable to NIST and is supplied in a matrix similar to the cloud samples. An independent laboratory supplies these reference samples with a certificate of analysis stating the target values. A reference sample is analyzed at the beginning and end of each analytical batch to verify the accuracy and stability of the calibration curve. The QC limits require the measured value to be within ± 5 percent of the known value for anions, and within ± 10 percent of the known value for cations. The data from all required reference samples analyzed with the Clingmans Dome samples are within the CASTNET QC criteria.

The results of the analyses of the CCV for each parameter in each analytical batch are provided in Table B-3. A CCV is a NIST-traceable solution supplied in a matrix similar to that of the sample being analyzed with a target value at approximately the midpoint of the calibration curve. This QC solution is supplied to MACTEC by a laboratory independent of the laboratory supplying the reference sample solution. A CCV is analyzed after every 10 environmental samples to verify that the instrument calibration has not drifted more than ± 5 percent for anions and base cations, ± 10 percent for NH_4^+, and ± 0.05 pH units for pH. The results of all CCV analyses were within acceptance criteria.

Table B-4 summarizes the percent difference between samples reanalyzed within the same analytical batch. Five percent of the samples in each analytical batch were randomly selected for replicate analysis. This table presents only the samples that were replicated. The replicate percent difference criterion is ± 20 percent for anions and cations. For pH, the difference between the two values cannot be more than ± 0.05 pH units. The data from all required replicate samples are within the CASTNET QC criteria.

Table B-1. Cloud Water Analytical Data for 2010 Sampling Season (1 of 2)

Number	Sample Date	Valid Hours	Volume mL	LWC g/m^3	Scalar Wind m/sec	pH Field	pH Lab	Cond. Field	Cond. Lab	Ca^{2+} mg/L	Mg^{2+} mg/L	Na^+ mg/L	K^+ mg/L	NH_4^+ mg/L	SO_4^{2-} mg/L	NO_3^- mg/L	Cl^- mg/L	Field Cation µeq/L	Lab Cation µeq/L	Anion µeq/L	Field Cation/ Anion	Lab Cation/ Anion
1	5/7/2010	5.91	207	0.135	4.18	4.92	5.20	12.2	13.46	11.028	8.656	41.074	14.918	1.428	35.081	14.850	28.827	89.128	83.415	78.758	12.35	5.74
2	5/14/2010	0.28	87	0.246	NA	4.33	4.51	91.1	101.70	130.446	72.780	242.845	17.404	180.984	308.336	203.759	151.020	691.232	675.361	663.115	4.15	1.83
3	5/15/2010	2.96	144	0.203	NA	4.36	4.66	134.4	151.50	156.844	86.152	287.821	36.496	522.747	549.217	333.696	136.939	1133.711	1111.937	1019.852	10.57	8.64
4	5/16/2010	4.34	458	0.345	NA	4.31	4.27	68.9	77.10	60.382	31.745	95.128	12.097	200.189	227.765	132.722	61.292	448.520	453.245	421.779	6.15	7.19
5	5/18/2010	2.29	53	0.174	NA	4.91	6.52	34.3	43.20	27.980	14.712	36.181	12.537	219.108	140.552	75.963	16.557	322.822	310.821	233.073	32.29	28.59
6	5/19/2010	3.70	180	0.259	NA	4.78	5.78	56.3	68.50	69.914	25.944	17.790	13.836	352.329	279.189	154.426	14.949	496.410	481.473	448.564	10.13	7.08
7	5/20/2010	1.25	171	0.319	NA	4.41	5.14	61.0	64.80	58.735	25.138	16.346	21.402	299.069	287.933	97.667	10.408	459.595	427.935	396.008	14.86	7.75
8	5/21/2010	1.70	110	0.252	NA	4.57	4.53	35.6	38.90	30.865	15.033	31.905	16.670	49.026	126.270	35.768	10.606	170.415	173.012	172.644	-1.30	0.21
9	5/22/2010	4.17	745	0.323	NA	5.36	5.28	8.0	8.94	9.981	4.222	6.181	2.793	20.005	25.879	15.635	2.990	47.546	48.429	44.504	6.61	8.45
10	5/23/2010	3.93	57	0.234	NA	4.44	4.60	35.3	36.10	31.733	15.091	36.420	19.962	38.360	126.353	34.555	8.180	177.874	166.685	169.088	5.06	-1.43
11	6/1/2010	5.26	344	0.310	NA	4.58	4.84	55.6	49.40	30.386	12.869	22.579	5.729	228.960	202.886	70.252	12.524	326.826	314.978	285.661	13.44	9.76
12	6/2/2010	1.57	48	0.157	NA	4.27	3.94	65.3	75.00	37.582	10.360	35.420	0.468	84.959	204.010	50.618	12.975	222.491	283.604	267.603	-18.41	5.81
13	6/3/2010	3.76	238	0.217	NA	4.33	4.24	75.4	72.50	29.487	10.072	11.279	4.839	268.441	245.253	81.389	7.052	370.892	381.662	333.694	10.56	13.41
14	6/4/2010	0.77	21	0.192	2.40	NA	5.22	NA	27.19	34.762	17.378	25.163	27.852	64.155	100.433	26.844	6.826	NA	175.336	134.103	NA	26.65
15	6/8/2010	0.41	124	0.084	4.30	NA	4.59	43.5	44.70	28.285	11.454	42.636	3.419	120.870	140.594	68.039	29.306	NA	232.368	237.939	NA	-2.37
16	6/9/2010	7.22	721	0.335	5.99	NA	4.05	84.2	90.00	41.908	14.449	26.855	4.458	187.623	220.894	148.928	24.286	NA	364.419	394.108	NA	-7.83
17	6/12/2010	7.19	157	0.389	3.10	NA	6.09	NA	38.60	22.930	11.372	45.498	7.033	191.836	118.837	58.400	29.278	NA	279.482	206.516	NA	30.03
18	6/13/2010	3.93	146	0.310	3.42	NA	4.67	NA	50.60	35.131	14.754	44.889	5.535	171.488	164.495	98.524	31.394	NA	293.177	294.412	NA	-0.42
19	6/14/2010	0.81	164	0.320	3.95	NA	4.30	NA	59.30	32.402	13.470	42.445	4.281	132.150	175.799	94.169	30.350	NA	274.867	300.318	NA	-8.85
20	6/15/2010	2.21	118	0.269	2.28	NA	4.33	NA	65.00	40.232	16.407	51.501	4.836	177.128	219.853	114.302	31.732	NA	336.878	365.888	NA	-8.26
21	6/23/2010	3.68	588	0.414	2.93	NA	4.25	73.9	62.10	41.394	13.116	17.629	2.637	186.338	148.505	101.808	10.267	NA	317.349	260.580	NA	19.65
22	6/24/2010	4.66	324	0.315	3.25	NA	4.09	66.0	70.60	46.943	15.601	37.190	7.315	107.876	210.068	81.675	25.724	NA	296.209	317.467	NA	-6.93
23	6/25/2010	3.52	127	0.220	2.48	NA	4.19	35.9	39.30	22.381	5.395	10.944	0.128	1.428	99.475	0.571	6.036	NA	104.842	106.083	NA	-1.18
24	6/26/2010	1.44	30	0.126	2.85	NA	3.82	NA	100.80	131.194	30.922	22.775	1.203	16.678	228.181	129.795	17.939	NA	354.128	375.915	NA	-5.97
25	6/29/2010	5.52	73	0.300	2.47	NA	4.17	95.8	102.50	153.201	52.777	23.371	7.570	242.954	363.091	178.343	22.339	NA	547.482	563.773	NA	-2.93
26	7/2/2010	15.29	1009	0.297	2.18	NA	3.95	NA	100.80	57.737	16.177	9.748	2.803	221.250	301.674	124.226	9.731	NA	419.917	435.631	NA	-3.67
27	7/9/2010	7.87	477	0.176	3.41	NA	4.18	74.0	79.10	74.804	22.719	24.485	3.637	195.976	267.946	106.948	17.319	NA	387.690	392.214	NA	-1.16
28	7/15/2010	17.46	1037	0.260	2.58	NA	5.31	NA	11.09	12.071	4.452	10.174	1.074	13.651	34.186	17.563	5.726	NA	46.320	57.474	NA	-21.49
29	7/19/2010	1.76	73	0.202	2.15	NA	4.17	NA	94.60	84.485	35.283	97.129	4.064	150.498	308.128	126.296	59.290	NA	439.069	493.714	NA	-11.72
30	7/20/2010	2.53	123	0.201	3.13	NA	4.21	NA	107.50	120.715	53.131	135.320	11.708	180.555	348.934	210.256	87.750	NA	563.088	646.940	NA	-13.86
31	7/24/2010	4.72	256	0.221	3.94	NA	5.22	NA	121.20	223.464	81.428	210.700	17.332	375.604	378.081	316.919	85.437	NA	914.555	780.437	NA	15.83

Table B-1. Cloud Water Analytical Data for 2010 Sampling Season (2 of 2)

Number	Sample Date	Valid Hours	Volume mL	LWC g/m^3	Scalar Wind m/sec	pH Field	pH Lab	Cond. Field	Cond. Lab	Ca^{2+} mg/L	Mg^{2+} mg/L	Na^+ mg/L	K^+ mg/L	NH_4^+ mg/L	SO_4^{2-} mg/L	NO_3^- mg/L	Cl^- mg/L	Field Cation µeq/L	Lab Cation µeq/L	Anion µeq/L	Field Cation/ Anion	Lab Cation/ Anion
32	7/25/2010	11.55	618	0.338	2.63	NA	4.03	NA	126.80	144.319	50.424	103.741	7.821	224.962	384.744	243.026	52.097	NA	624.592	679.866	NA	-8.47
33	7/27/2010	6.04	618	0.318	3.47	NA	4.11	NA	68.40	37.277	14.556	17.547	2.734	93.312	168.617	109.519	10.549	NA	243.051	288.685	NA	-17.16
34	7/29/2010	18.80	2009	0.342	2.87	NA	4.36	NA	44.30	20.290	5.202	8.891	1.153	87.672	129.788	44.479	6.234	NA	166.859	180.501	NA	-7.85
35	8/3/2010	13.39	1677	0.335	4.02	NA	4.20	NA	97.20	82.988	20.324	33.140	4.465	292.572	332.903	141.146	14.893	NA	496.587	488.942	NA	1.55
36	8/8/2010	8.99	1193	0.434	3.06	NA	4.00	NA	98.10	51.699	11.347	11.114	2.246	261.016	274.817	142.074	11.029	NA	437.422	427.920	NA	2.20
37	8/13/2010	19.16	1206	0.263	2.44	NA	3.90	NA	113.70	40.077	13.618	19.287	3.629	264.872	346.228	130.080	15.175	NA	467.375	491.483	NA	-5.03
38	8/20/2010	10.62	365	0.172	3.43	NA	4.33	NA	78.60	37.766	13.881	13.336	5.072	304.995	304.589	101.308	9.844	NA	421.824	415.741	NA	1.45
39	8/25/2010	17.53	699	0.110	4.05	NA	3.96	NA	104.50	91.721	25.352	10.335	3.294	183.268	341.855	144.787	11.424	NA	423.618	498.066	NA	-16.15
40	8/28/2010	5.66	706	0.272	5.89	NA	4.05	NA	115.10	59.085	24.183	50.892	3.916	350.973	380.371	166.848	28.827	NA	578.173	576.046	NA	0.37
41	9/3/2010	4.98	1250	0.411	4.83	NA	4.31	NA	48.90	24.397	9.101	19.330	2.598	86.244	111.821	67.682	14.498	NA	190.648	194.001	NA	-1.74
42	9/7/2010	6.65	425	0.220	3.70	NA	4.50	NA	90.10	192.774	40.978	29.874	6.535	270.726	368.088	138.719	18.644	NA	572.509	525.451	NA	8.57
43	9/11/2010	11.89	1202	0.139	4.96	NA	4.19	NA	61.80	47.562	13.453	20.000	3.427	114.016	148.963	106.520	17.516	NA	263.024	272.999	NA	-3.72
44	9/13/2010	7.24	135	0.076	7.19	NA	4.20	NA	67.10	49.084	14.893	25.411	3.949	173.345	197.618	101.380	15.344	NA	329.778	314.342	NA	4.79
45	9/17/2010	1.17	540	0.637	5.54	NA	4.17	NA	69.00	45.222	13.783	23.388	3.483	174.772	196.910	99.381	14.385	NA	328.257	310.676	NA	5.50
46	9/25/2010	12.33	1185	0.171	3.86	NA	4.47	NA	50.70	41.699	21.139	71.031	2.614	114.516	148.110	79.462	51.448	NA	284.883	279.020	NA	2.08
47	9/29/2010	9.51	1844	0.254	8.75	NA	4.95	NA	37.40	55.991	17.058	6.594	3.813	121.584	114.091	100.880	7.249	NA	216.260	222.220	NA	-2.72
48	10/12/2010	21.34	1140	0.081	3.19	NA	6.08	NA	45.60	182.444	30.478	7.769	2.767	109.233	121.565	151.498	7.982	NA	333.523	281.046	NA	17.08
49	10/21/2010	5.45	821	0.092	5.51	NA	6.58	NA	57.00	286.342	34.551	7.216	6.527	86.387	96.727	219.180	12.270	NA	421.286	328.177	NA	24.85
50	10/23/2010	23.40	1954	0.096	4.30	NA	5.53	NA	52.60	160.238	41.109	75.729	4.031	86.030	129.455	176.486	65.777	NA	370.087	371.719	NA	-0.44
						Volume Weighted Mean				70.808	23.570	46.281	7.402	172.083	217.703	115.387	27.805	381.343	368.590	360.895	8.190	2.074

Table B-2. Cloud Deposition 2010 Sampling Season – QC Batch Summary for Cloud Samples – Reference Samples (1 of 3)

Lab pH					NH_4^+-N					SO_4^{2-}				
Batch Number	Lab Key	Target STD Units	Found STD Units	Percent Recovery	Batch Number	Lab Key	Target mg/L	Found mg/L	Percent Recovery	Batch Number	Lab Key	Target mg/L	Found mg/L	Percent Recovery
L006007	L006007-SRM1	3.80	3.81	100.3	L006010	L006010-SRM1	0.736	0.7360	100.0	L006015	L006015-SRM1	10.0	9.94	99.4
L006007	L006007-SRM2	3.80	3.82	100.5	L006010	L006010-SRM2	0.747	0.7466	100.0	L006015	L006015-SRM2	10.0	9.97	99.7
L006027	L006027-SRM1	7.65	7.63	99.7	L007002	L007002-SRM1	0.735	0.7351	100.0	L006015	L006015-SRM3	10.0	10.03	100.3
L006027	L006027-SRM2	7.65	7.66	100.1	L007002	L007002-SRM2	0.738	0.7381	100.0	L007004	L007004-SRM1	10.0	9.82	98.2
L006027	L006027-SRM3	7.65	7.61	99.5	L007047	L007047-SRM1	0.767	0.7666	100.0	L007004	L007004-SRM2	10.0	9.85	98.5
L007019	L007019-SRM1	7.65	7.61	99.5	L007047	L007047-SRM2	0.767	0.7668	100.0	L007046	L007046-SRM1	10.0	9.79	97.9
L007019	L007019-SRM2	7.65	7.63	99.7	L007047	L007047-SRM3	0.766	0.7664	100.0	L007046	L007046-SRM2	10.0	9.79	97.9
L008005	L008005-SRM1	7.65	7.63	99.7	L008017	L008017-SRM1	0.759	0.7588	100.0	L007046	L007046-SRM3	10.0	9.54	95.4
L008005	L008005-SRM2	7.65	7.60	99.3	L008017	L008017-SRM2	0.756	0.7558	100.0	L007046	L007046-SRM4	10.0	9.68	96.8
L008047	L008047-SRM1	7.65	7.69	100.5	L008017	L008017-SRM3	0.759	0.7585	100.0	L008066	L008066-SRM1	10.0	9.96	99.6
L008047	L008047-SRM2	7.65	7.70	100.7	L009024	L009024-SRM1	0.764	0.7636	100.0	L008066	L008066-SRM2	10.0	9.80	98.0
L009038	L009038-SRM1	7.65	7.61	99.5	L009024	L009024-SRM2	0.771	0.7708	100.0	L009029	L009029-SRM1	10.0	9.78	97.8
L009038	L009038-SRM2	7.65	7.63	99.7	L010015	L010015-SRM1	0.721	0.7207	100.0	L009029	L009029-SRM2	10.0	9.73	97.3
L010017	L010017-SRM1	7.65	7.61	99.5	L010015	L010015-SRM2	0.750	0.7503	100.0	L009029	L009029-SRM3	10.0	9.83	98.3
L010017	L010017-SRM2	7.65	7.60	99.3	L011017	L011017-SRM1	0.755	0.7549	100.0	L010019	L010019-SRM1	10.0	9.80	98.0
L011036	L011036-SRM1	7.65	7.60	99.3	L011017	L011017-SRM2	0.759	0.7591	100.0	L010019	L010019-SRM2	10.0	9.73	97.3
L011036	L011036-SRM2	7.65	7.61	99.5	L011033	L011033-SRM1	0.747	0.7471	100.0	L011038	L011038-SRM1	9.0	8.82	98.0
					L011033	L011033-SRM2	0.734	0.7336	100.0	L011038	L011038-SRM2	9.0	8.93	99.2
Mean				**99.8**	**Mean**				**100.0**	**Mean**				**98.2**
Standard Deviation				**0.45**	**Standard Deviation**				**0.00**	**Standard Deviation**				**1.16**
Count				**17**	**Count**				**18**	**Count**				**18**

Table B-2. Cloud Deposition 2010 Sampling Season – QC Batch Summary for Cloud Samples – Reference Samples (2 of 3)

NO_3^- -N					Cl^-					Ca^{2+}				
Batch Number	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch Number**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch Number**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
L006015	L006015-SRM1	1.6	1.58	98.4	L006015	L006015-SRM1	0.96	0.988	102.9	L006009	L006009-SRM1	0.053	0.0546	103.0
L006015	L006015-SRM2	1.6	1.57	98.4	L006015	L006015-SRM2	0.96	0.986	102.7	L006009	L006009-SRM2	0.053	0.0554	104.6
L006015	L006015-SRM3	1.6	1.58	98.6	L006015	L006015-SRM3	0.96	0.982	102.3	L007001	L007001-SRM1	0.053	0.0529	99.9
L007004	L007004-SRM1	1.6	1.58	98.8	L007004	L007004-SRM1	0.96	0.973	101.4	L007001	L007001-SRM2	0.053	0.0539	101.7
L007004	L007004-SRM2	1.6	1.59	99.1	L007004	L007004-SRM2	0.96	0.981	102.2	L008002	L008002-SRM1	0.053	0.0497	93.7
L007046	L007046-SRM1	1.6	1.60	99.7	L007046	L007046-SRM1	0.96	0.977	101.8	L008002	L008002-SRM2	0.053	0.0525	99.0
L007046	L007046-SRM2	1.6	1.59	99.5	L007046	L007046-SRM2	0.96	0.975	101.6	L008065	L008065-SRM1	0.053	0.0533	100.6
L007046	L007046-SRM3	1.6	1.58	98.9	L007046	L007046-SRM3	0.96	0.978	101.9	L008065	L008065-SRM2	0.053	0.0537	101.3
L007046	L007046-SRM4	1.6	1.60	100.1	L007046	L007046-SRM4	0.96	0.986	102.7	L009025	L009025-SRM1	0.053	0.0525	99.1
L008066	L008066-SRM1	1.6	1.62	101.3	L008066	L008066-SRM1	0.96	0.982	102.3	L009025	L009025-SRM2	0.053	0.0521	98.3
L008066	L008066-SRM2	1.6	1.60	100.0	L008066	L008066-SRM2	0.96	0.976	101.7	L010041	L010041-SRM1	0.054	0.0548	101.5
L009029	L009029-SRM1	1.6	1.60	99.8	L009029	L009029-SRM1	0.96	0.992	103.3	L010041	L010041-SRM2	0.054	0.0555	102.9
L009029	L009029-SRM2	1.6	1.58	98.9	L009029	L009029-SRM2	0.96	0.983	102.4	L011037	L011037-SRM1	0.054	0.0533	98.8
L009029	L009029-SRM3	1.6	1.60	99.7	L009029	L009029-SRM3	0.96	0.996	103.8	L011037	L011037-SRM2	0.054	0.0539	99.7
L010019	L010019-SRM1	1.6	1.61	100.9	L010019	L010019-SRM1	0.96	0.980	102.1					
L010019	L010019-SRM2	1.6	1.61	100.8	L010019	L010019-SRM2	0.96	0.992	103.3					
L011038	L011038-SRM1	1.6	1.63	102.1	L011038	L011038-SRM1	0.93	0.942	101.3					
L011038	L011038-SRM2	1.6	1.68	104.9	L011038	L011038-SRM2	0.93	0.967	104.0					
Mean				**100.0**	**Mean**				**102.4**	**Mean**				**100.3**
Standard Deviation				**1.60**	**Standard Deviation**				**0.80**	**Standard Deviation**				**2.63**
Count				**18**	**Count**				**18**	**Count**				**14**

Table B-2. Cloud Deposition 2010 Sampling Season – QC Batch Summary for Cloud Samples – Reference Samples (3 of 3)

Mg^{2+}					Na^{+}					K^{+}				
Batch Number	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch Number**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch Number**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
L006009	L006009-SRM1	0.052	0.0533	102.5	L006009	L006009-SRM1	0.39	0.400	102.5	L006009	L006009-SRM1	0.098	0.0980	100.0
L006009	L006009-SRM2	0.052	0.0530	101.9	L006009	L006009-SRM2	0.39	0.402	103.0	L006009	L006009-SRM2	0.098	0.0976	99.6
L007001	L007001-SRM1	0.052	0.0536	103.1	L007001	L007001-SRM1	0.39	0.400	102.6	L007001	L007001-SRM1	0.098	0.0969	98.9
L007001	L007001-SRM2	0.052	0.0529	101.7	L007001	L007001-SRM2	0.39	0.404	103.7	L007001	L007001-SRM2	0.098	0.0955	97.5
L008002	L008002-SRM1	0.052	0.0524	100.8	L008002	L008002-SRM1	0.39	0.381	97.7	L008002	L008002-SRM1	0.098	0.0936	95.5
L008002	L008002-SRM2	0.052	0.0526	101.1	L008002	L008002-SRM2	0.39	0.386	98.9	L008002	L008002-SRM2	0.098	0.0925	94.4
L008065	L008065-SRM1	0.052	0.0537	103.3	L008065	L008065-SRM1	0.39	0.398	102.0	L008065	L008065-SRM1	0.098	0.0982	100.2
L008065	L008065-SRM2	0.052	0.0542	104.2	L008065	L008065-SRM2	0.39	0.398	101.9	L008065	L008065-SRM2	0.098	0.0948	96.8
L009025	L009025-SRM1	0.052	0.0543	104.4	L009025	L009025-SRM1	0.39	0.399	102.3	L009025	L009025-SRM1	0.098	0.0992	101.3
L009025	L009025-SRM2	0.052	0.0540	103.8	L009025	L009025-SRM2	0.39	0.393	100.8	L009025	L009025-SRM2	0.098	0.0968	98.8
L010041	L010041-SRM1	0.052	0.0547	105.2	L010041	L010041-SRM1	0.40	0.404	101.1	L010041	L010041-SRM1	0.100	0.1003	100.3
L010041	L010041-SRM2	0.052	0.0540	103.8	L010041	L010041-SRM2	0.40	0.407	101.7	L010041	L010041-SRM2	0.100	0.0998	99.8
L011037	L011037-SRM1	0.052	0.0534	102.8	L011037	L011037-SRM1	0.40	0.391	97.7	L011037	L011037-SRM1	0.100	0.0941	94.1
L011037	L011037-SRM2	0.052	0.0536	103.0	L011037	L011037-SRM2	0.40	0.397	99.3	L011037	L011037-SRM2	0.100	0.0940	94.0
Mean				**103.0**	**Mean**				**101.1**	**Mean**				**97.9**
Standard Deviation				**1.27**	**Standard Deviation**				**1.96**	**Standard Deviation**				**2.55**
Count				**14**	**Count**				**14**	**Count**				**14**

Table B-3. Cloud Deposition 2010 Sampling Season – QC Batch Summary for Cloud Samples – CCV (1 of 3)

Lab pH				
Batch Number	**Lab Key**	**Target STD Units**	**Found STD Units**	**Percent Recovery**
L006007	L006007-CCV1	5.00	5.02	100.4
L006007	L006007-CCV2	5.00	5.04	100.8
L006027	L006027-CCV1	5.00	4.99	99.8
L006027	L006027-CCV2	5.00	5.04	100.8
L006027	L006027-CCV3	5.00	5.03	100.6
L006027	L006027-CCV4	5.00	5.04	100.8
L007019	L007019-CCV1	5.00	5.02	100.4
L007019	L007019-CCV2	5.00	5.03	100.6
L007019	L007019-CCV3	5.00	5.02	100.4
L008005	L008005-CCV1	5.00	4.98	99.6
L008005	L008005-CCV2	5.00	5.02	100.4
L008047	L008047-CCV1	5.00	5.04	100.8
L008047	L008047-CCV2	5.00	5.05	101.0
L009038	L009038-CCV1	5.00	5.02	100.4
L009038	L009038-CCV2	5.00	5.02	100.4
L009038	L009038-CCV3	5.00	5.01	100.2
L009038	L009038-CCV4	5.00	5.01	100.2
L009038	L009038-CCV5	5.00	5.01	100.2
L010017	L010017-CCV1	5.00	5.02	100.4
L010017	L010017-CCV2	5.00	4.98	99.6
L011036	L011036-CCV1	5.00	5.00	100.0
L011036	L011036-CCV2	5.00	4.99	99.8
Mean				**100.3**
Standard Deviation				**0.40**
Count				**22**

NH_4^+ -N				
Batch Number	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
L006010	L006010-CCV1	1	0.9743	97.4
L006010	L006010-CCV2	1	1.0074	100.7
L006010	L006010-CCV3	1	0.9973	99.7
L006010	L006010-CCV4	1	0.9797	98.0
L007002	L007002-CCV1	1	0.9946	99.5
L007002	L007002-CCV2	1	0.9858	98.6
L007002	L007002-CCV3	1	0.9930	99.3
L007002	L007002-CCV4	1	0.9829	98.3
L007002	L007002-CCV5	1	0.9879	98.8
L007047	L007047-CCV1	1	0.9914	99.1
L007047	L007047-CCV2	1	0.9871	98.7
L007047	L007047-CCV3	1	0.9784	97.8
L007047	L007047-CCV4	1	0.9777	97.8
L007047	L007047-CCV5	1	0.9951	99.5
L007047	L007047-CCV6	1	0.9915	99.2
L008017	L008017-CCV1	1	0.9840	98.4
L008017	L008017-CCV2	1	0.9776	97.8
L008017	L008017-CCV3	1	0.9810	98.1
L008017	L008017-CCV4	1	0.9738	97.4
L008017	L008017-CCV5	1	0.9716	97.2
L008017	L008017-CCV6	1	0.9926	99.3
L008017	L008017-CCV7	1	0.9916	99.2
L009024	L009024-CCV1	1	0.9967	99.7
L009024	L009024-CCV2	1	0.9905	99.1
L009024	L009024-CCV3	1	0.9833	98.3
L009024	L009024-CCV4	1	0.9905	99.1
L009024	L009024-CCV5	1	0.9849	98.5
L010015	L010015-CCV1	1	0.9506	95.1
L010015	L010015-CCV2	1	0.9700	97.0
L010015	L010015-CCV3	1	0.9835	98.4
L011017	L011017-CCV1	1	0.9767	97.7
L011017	L011017-CCV2	1	0.9580	95.8
L011017	L011017-CCV3	1	0.9763	97.6
L011017	L011017-CCV4	1	0.9874	98.7
L011033	L011033-CCV1	1	0.9776	97.8
L011033	L011033-CCV2	1	0.9581	95.8
Mean				**98.3**
Standard Deviation				**1.17**
Count				**36**

SO_4^{2-}				
Batch Number	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
L006015	L006015-CCV1	2.5	2.49	99.6
L006015	L006015-CCV2	2.5	2.53	101.0
L006015	L006015-CCV3	2.5	2.53	101.0
L006015	L006015-CCV4	2.5	2.53	101.4
L006015	L006015-CCV5	2.5	2.53	101.3
L007004	L007004-CCV1	2.5	2.48	99.2
L007004	L007004-CCV2	2.5	2.50	99.9
L007004	L007004-CCV3	2.5	2.50	99.9
L007046	L007046-CCV1	2.5	2.48	99.3
L007046	L007046-CCV2	2.5	2.47	99.0
L007046	L007046-CCV3	2.5	2.47	98.7
L007046	L007046-CCV4	2.5	2.40	95.9
L007046	L007046-CCV5	2.5	2.44	97.4
L008066	L008066-CCV1	2.5	2.50	100.2
L008066	L008066-CCV2	2.5	2.51	100.4
L008066	L008066-CCV3	2.5	2.46	98.3
L009029	L009029-CCV1	2.5	2.45	98.0
L009029	L009029-CCV2	2.5	2.49	99.4
L009029	L009029-CCV3	2.5	2.46	98.4
L009029	L009029-CCV4	2.5	2.48	99.0
L009029	L009029-CCV5	2.5	2.50	100.1
L010019	L010019-CCV1	2.5	2.45	97.8
L010019	L010019-CCV2	2.5	2.47	98.8
L010019	L010019-CCV3	2.5	2.50	99.8
L011038	L011038-CCV1	2.5	2.52	100.6
L011038	L011038-CCV2	2.5	2.48	99.4
L011038	L011038-CCV3	2.5	2.50	99.8
Mean				**99.4**
Standard Deviation				**1.26**
Count				**27**

Table B-3. Cloud Deposition 2010 Sampling Season – QC Batch Summary for Cloud Samples – CCV (2 of 3)

NO_3^--N					Cl^-					Ca^{2+}				
Batch Number	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch Number**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch Number**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
L006015	L006015-CCV1	0.5	0.502	100.4	L006015	L006015-CCV1	0.5	0.498	99.6	L006009	L006009-CCV1	0.5	0.4980	99.6
L006015	L006015-CCV2	0.5	0.504	100.8	L006015	L006015-CCV2	0.5	0.501	100.2	L006009	L006009-CCV2	0.5	0.4997	99.9
L006015	L006015-CCV3	0.5	0.502	100.4	L006015	L006015-CCV3	0.5	0.497	99.4	L006009	L006009-CCV3	0.5	0.4890	97.8
L006015	L006015-CCV4	0.5	0.501	100.2	L006015	L006015-CCV4	0.5	0.500	100.0	L006009	L006009-CCV4	0.5	0.5033	100.7
L006015	L006015-CCV5	0.5	0.502	100.4	L006015	L006015-CCV5	0.5	0.499	99.8	L007001	L007001-CCV1	0.5	0.4951	99.0
L007004	L007004-CCV1	0.5	0.502	100.4	L007004	L007004-CCV1	0.5	0.510	102.0	L007001	L007001-CCV2	0.5	0.5002	100.0
L007004	L007004-CCV2	0.5	0.506	101.2	L007004	L007004-CCV2	0.5	0.504	100.8	L007001	L007001-CCV3	0.5	0.4996	99.9
L007004	L007004-CCV3	0.5	0.505	101.0	L007004	L007004-CCV3	0.5	0.505	101.0	L008002	L008002-CCV1	0.5	0.5002	100.0
L007046	L007046-CCV1	0.5	0.503	100.6	L007046	L007046-CCV1	0.5	0.503	100.6	L008002	L008002-CCV2	0.5	0.5065	101.3
L007046	L007046-CCV2	0.5	0.503	100.6	L007046	L007046-CCV2	0.5	0.499	99.8	L008002	L008002-CCV3	0.5	0.4982	99.6
L007046	L007046-CCV3	0.5	0.501	100.2	L007046	L007046-CCV3	0.5	0.498	99.6	L008065	L008065-CCV1	0.5	0.4968	99.4
L007046	L007046-CCV4	0.5	0.501	100.2	L007046	L007046-CCV4	0.5	0.499	99.8	L008065	L008065-CCV2	0.5	0.4984	99.7
L007046	L007046-CCV5	0.5	0.504	100.8	L007046	L007046-CCV5	0.5	0.502	100.4	L008065	L008065-CCV3	0.5	0.4934	98.7
L008066	L008066-CCV1	0.5	0.512	102.4	L008066	L008066-CCV1	0.5	0.499	99.8	L009025	L009025-CCV1	0.5	0.4884	97.7
L008066	L008066-CCV2	0.5	0.503	100.6	L008066	L008066-CCV2	0.5	0.491	98.2	L009025	L009025-CCV2	0.5	0.5030	100.6
L008066	L008066-CCV3	0.5	0.503	100.6	L008066	L008066-CCV3	0.5	0.497	99.4	L009025	L009025-CCV3	0.5	0.4915	98.3
L009029	L009029-CCV1	0.5	0.501	100.2	L009029	L009029-CCV1	0.5	0.497	99.4	L009025	L009025-CCV4	0.5	0.4874	97.5
L009029	L009029-CCV2	0.5	0.507	101.4	L009029	L009029-CCV2	0.5	0.495	99.0	L010041	L010041-CCV1	0.5	0.4955	99.1
L009029	L009029-CCV3	0.5	0.504	100.8	L009029	L009029-CCV3	0.5	0.503	100.6	L010041	L010041-CCV2	0.5	0.5026	100.5
L009029	L009029-CCV4	0.5	0.509	101.8	L009029	L009029-CCV4	0.5	0.511	102.2	L011037	L011037-CCV1	0.5	0.4887	97.7
L009029	L009029-CCV5	0.5	0.508	101.6	L009029	L009029-CCV5	0.5	0.508	101.6	L011037	L011037-CCV2	0.5	0.5058	101.2
L010019	L010019-CCV1	0.5	0.502	100.4	L010019	L010019-CCV1	0.5	0.504	100.8	L011037	L011037-CCV3	0.5	0.4904	98.1
L010019	L010019-CCV2	0.5	0.504	100.8	L010019	L010019-CCV2	0.5	0.506	101.2					
L010019	L010019-CCV3	0.5	0.518	103.6	L010019	L010019-CCV3	0.5	0.518	103.6					
L011038	L011038-CCV1	0.5	0.519	103.8	L011038	L011038-CCV1	0.5	0.506	101.2					
L011038	L011038-CCV2	0.5	0.510	102.0	L011038	L011038-CCV2	0.5	0.502	100.4					
L011038	L011038-CCV3	0.5	0.513	102.6	L011038	L011038-CCV3	0.5	0.502	100.4					
Mean				**101.1**	**Mean**				**100.4**	**Mean**				**99.4**
Standard Deviation				**1.00**	**Standard Deviation**				**1.11**	**Standard Deviation**				**1.16**
Count				**27**	**Count**				**27**	**Count**				**22**

Table B-3. Cloud Deposition 2010 Sampling Season – QC Batch Summary for Cloud Samples – CCV (3 of 3)

Mg^{2+}					Na^{+}					K^{+}				
Batch Number	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch Number**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch Number**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
L006009	L006009-CCV1	0.5	0.4992	99.8	L006009	L006009-CCV1	0.5	0.4993	99.9	L006009	L006009-CCV1	0.5	0.4975	99.5
L006009	L006009-CCV2	0.5	0.4954	99.1	L006009	L006009-CCV2	0.5	0.4996	99.9	L006009	L006009-CCV2	0.5	0.4976	99.5
L006009	L006009-CCV3	0.5	0.4886	97.7	L006009	L006009-CCV3	0.5	0.4890	97.8	L006009	L006009-CCV3	0.5	0.4896	97.9
L006009	L006009-CCV4	0.5	0.4961	99.2	L006009	L006009-CCV4	0.5	0.5028	100.6	L006009	L006009-CCV4	0.5	0.5028	100.6
L007001	L007001-CCV1	0.5	0.4995	99.9	L007001	L007001-CCV1	0.5	0.4939	98.8	L007001	L007001-CCV1	0.5	0.4944	98.9
L007001	L007001-CCV2	0.5	0.5056	101.1	L007001	L007001-CCV2	0.5	0.4992	99.8	L007001	L007001-CCV2	0.5	0.4988	99.8
L007001	L007001-CCV3	0.5	0.4908	98.2	L007001	L007001-CCV3	0.5	0.5005	100.1	L007001	L007001-CCV3	0.5	0.5020	100.4
L008002	L008002-CCV1	0.5	0.4984	99.7	L008002	L008002-CCV1	0.5	0.5007	100.1	L008002	L008002-CCV1	0.5	0.4978	99.6
L008002	L008002-CCV2	0.5	0.4976	99.5	L008002	L008002-CCV2	0.5	0.5065	101.3	L008002	L008002-CCV2	0.5	0.5060	101.2
L008002	L008002-CCV3	0.5	0.4968	99.4	L008002	L008002-CCV3	0.5	0.4987	99.7	L008002	L008002-CCV3	0.5	0.4994	99.9
L008065	L008065-CCV1	0.5	0.4954	99.1	L008065	L008065-CCV1	0.5	0.4955	99.1	L008065	L008065-CCV1	0.5	0.4986	99.7
L008065	L008065-CCV2	0.5	0.4960	99.2	L008065	L008065-CCV2	0.5	0.4976	99.5	L008065	L008065-CCV2	0.5	0.5026	100.5
L008065	L008065-CCV3	0.5	0.4969	99.4	L008065	L008065-CCV3	0.5	0.4945	98.9	L008065	L008065-CCV3	0.5	0.4942	98.8
L009025	L009025-CCV1	0.5	0.5000	100.0	L009025	L009025-CCV1	0.5	0.4875	97.5	L009025	L009025-CCV1	0.5	0.4886	97.7
L009025	L009025-CCV2	0.5	0.5022	100.4	L009025	L009025-CCV2	0.5	0.5041	100.8	L009025	L009025-CCV2	0.5	0.5043	100.9
L009025	L009025-CCV3	0.5	0.4926	98.5	L009025	L009025-CCV3	0.5	0.4927	98.5	L009025	L009025-CCV3	0.5	0.4910	98.2
L009025	L009025-CCV4	0.5	0.4917	98.3	L009025	L009025-CCV4	0.5	0.4877	97.5	L009025	L009025-CCV4	0.5	0.4890	97.8
L010041	L010041-CCV1	0.5	0.4973	99.5	L010041	L010041-CCV1	0.5	0.4945	98.9	L010041	L010041-CCV1	0.5	0.4956	99.1
L010041	L010041-CCV2	0.5	0.4967	99.3	L010041	L010041-CCV2	0.5	0.5031	100.6	L010041	L010041-CCV2	0.5	0.4986	99.7
L011037	L011037-CCV1	0.5	0.4938	98.8	L011037	L011037-CCV1	0.5	0.4875	97.5	L011037	L011037-CCV1	0.5	0.4920	98.4
L011037	L011037-CCV2	0.5	0.4985	99.7	L011037	L011037-CCV2	0.5	0.5007	100.1	L011037	L011037-CCV2	0.5	0.5040	100.8
L011037	L011037-CCV3	0.5	0.4950	99.0	L011037	L011037-CCV3	0.5	0.4896	97.9	L011037	L011037-CCV3	0.5	0.4904	98.1
Mean				**99.3**	**Mean**				**99.3**	**Mean**				**99.4**
Standard Deviation				**0.76**	**Standard Deviation**				**1.15**	**Standard Deviation**				**1.07**
Count				**22**	**Count**				**22**	**Count**				**22**

Table B-4. Cloud Deposition 2010 Sampling Season – Replicate Summary for Cloud Samples (1 of 3)

SO_4^{2-}						
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**Absolute RPD**
1021016-01	L006015-DUP1	CLD303	6/8/2010	13.830	13.440	2.82%
1024016-01	L007004-DUP1	CLD303	7/1/2010	10.610	10.600	0.09%
1025020-01	L007046-DUP1	CLD303	7/29/2010	4.778	4.780	0.04%
1029015-01	L008066-DUP1	CLD303	8/30/2010	1.642	1.645	0.18%
1032015-01	L009029-DUP3	CLD303	9/15/2010	15.990	15.900	0.56%
1039018-01	L010019-DUP1	CLD303	10/7/2010	7.114	7.305	2.68%
1043013-01	L011038-DUP1	CLD303	11/22/2010	6.218	6.222	0.06%
					Mean Percent Difference	0.92%
					Standard Deviation	0.013

NO_3^- - N						
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**Absolute RPD**
1021016-01	L006015-DUP1	CLD303	6/8/2010	2.163	2.165	0.09%
1024016-01	L007004-DUP1	CLD303	7/1/2010	2.086	2.084	0.10%
1025020-01	L007046-DUP1	CLD303	7/29/2010	<0.008	<0.008	NA
1029015-01	L008066-DUP1	CLD303	8/30/2010	0.246	0.250	1.63%
1032015-01	L009029-DUP3	CLD303	9/15/2010	1.977	1.967	0.51%
1039018-01	L010019-DUP1	CLD303	10/7/2010	1.113	1.128	1.35%
1043013-01	L011038-DUP1	CLD303	11/22/2010	2.472	2.504	1.29%
					Mean Percent Difference	0.83%
					Standard Deviation	0.007

Cl^-						
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**Absolute RPD**
1021016-01	L006015-DUP1	CLD303	6/8/2010	0.530	0.530	0.00%
1024016-01	L007004-DUP1	CLD303	7/1/2010	0.861	0.860	0.12%
1025020-01	L007046-DUP1	CLD303	7/29/2010	0.214	0.213	0.47%
1029015-01	L008066-DUP1	CLD303	8/30/2010	0.203	0.206	1.48%
1032015-01	L009029-DUP3	CLD303	9/15/2010	0.528	0.529	0.19%
1039018-01	L010019-DUP1	CLD303	10/7/2010	1.824	1.835	0.60%
1043013-01	L011038-DUP1	CLD303	11/22/2010	2.332	2.386	2.32%
					Mean Percent Difference	0.74%
					Standard Deviation	0.009

Table B-4. Cloud Deposition 2010 Sampling Season – Replicate Summary for Cloud Samples (2 of 3)

NH_4^+-N						
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**Absolute RPD**
1021017-01	L006010-DUP1	CLD303	6/7/2010	4.1890	4.193	0.10%
1024017-01	L007002-DUP1	CLD303	7/1/2010	2.6280	2.6830	2.09%
1025020-01	L007047-DUP2	CLD303	7/30/2010	<0.0200	<0.0200	NA
1031016-01	L008017-DUP3	CLD303	8/12/2010	3.1510	3.1570	0.19%
1035015-01	L009024-DUP3	CLD303	9/14/2010	2.5670	2.5530	0.55%
1039018-01	L010015-DUP1	CLD303	10/7/2010	1.6044	1.6066	0.14%
1040019-01	L011017-DUP3	CLD303	11/9/2010	1.7030	1.7141	0.65%
1043013-01	L011033-DUP1	CLD303	11/19/2010	1.2050	1.2002	0.40%
					Mean Percent Difference	0.59%
					Standard Deviation	0.007

Ca^{2+}						
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**Absolute RPD**
1021016-01	L006009-DUP1	CLD303	6/7/2010	1.4010	1.4070	0.43%
1025020-01	L008002-DUP1	CLD303	8/3/2010	0.4490	0.4448	0.94%
1029015-01	L008065-DUP1	CLD303	8/27/2010	0.2420	0.2402	0.74%
1035016-01	L009025-DUP2	CLD303	9/14/2010	1.1840	1.1740	0.84%
1036015-01	L010041-DUP1	CLD303	10/19/2010	0.4889	0.4902	0.27%
1040018-01	L011037-DUP1	CLD303	11/19/2010	0.8515	0.8522	0.08%
					Mean Percent Difference	0.55%
					Standard Deviation	0.003

Mg^{2+}						
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**Absolute RPD**
1021016-01	L006009-DUP1	CLD303	6/7/2010	0.3153	0.3154	0.03%
1024016-01	L007001-DUP1	CLD303	7/1/2010	0.1756	0.1756	0.00%
1025020-01	L008002-DUP1	CLD303	8/3/2010	0.0660	0.0654	0.92%
1029015-01	L008065-DUP1	CLD303	8/27/2010	0.0540	0.0539	0.11%
1035016-01	L009025-DUP2	CLD303	9/14/2010	0.2940	0.2934	0.20%
1036015-01	L010041-DUP1	CLD303	10/19/2010	0.1106	0.1108	0.19%
1040018-01	L011037-DUP1	CLD303	11/19/2010	0.2160	0.2166	0.29%
					Mean Percent Difference	0.25%
					Standard Deviation	0.003

Table B-4. Cloud Deposition 2010 Sampling Season – Replicate Summary for Cloud Samples (3 of 3)

Na^+						
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**Absolute RPD**
1021016-01	L006009-DUP1	CLD303	6/7/2010	0.4090	0.4113	0.56%
1024016-01	L007001-DUP1	CLD303	7/1/2010	0.6174	0.6253	1.28%
1025020-01	L008002-DUP1	CLD303	8/3/2010	0.2520	0.2555	1.39%
1029015-01	L008065-DUP1	CLD303	8/27/2010	0.2340	0.2326	0.60%
1035016-01	L009025-DUP2	CLD303	9/14/2010	1.1700	1.1580	1.03%
1036015-01	L010041-DUP1	CLD303	10/19/2010	0.4444	0.4464	0.44%
1040018-01	L011037-DUP1	CLD303	11/19/2010	0.1952	0.1967	0.78%
				Mean Percent Difference		0.87%
				Standard Deviation		0.004

K^+						
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**Absolute RPD**
1021016-01	L006009-DUP1	CLD303	6/7/2010	0.5410	0.5437	0.50%
1024016-01	L007001-DUP1	CLD303	7/1/2010	0.1743	0.1764	1.20%
1025020-01	L008002-DUP1	CLD303	8/3/2010	<0.0050	<0.0050	NA
1029015-01	L008065-DUP1	CLD303	8/27/2010	0.0420	0.0420	0.12%
1035016-01	L009025-DUP2	CLD303	9/14/2010	0.1530	0.1551	1.37%
1036015-01	L010041-DUP1	CLD303	10/19/2010	0.1016	0.1013	0.32%
1040018-01	L011037-DUP1	CLD303	11/19/2010	0.1762	0.1773	0.62%
				Mean Percent Difference		0.69%
				Standard Deviation		0.005

pH						
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**Absolute RPD**
1021014-01	L006007-DUP1	CLD303	5/27/2010	4.270	4.270	0.00%
1021019-01	L006027-DUP1	CLD303	6/16/2010	5.280	5.300	0.38%
1024016-01	L007019-DUP1	CLD303	7/13/2010	4.050	4.040	0.25%
1027013-01	L008005-DUP1	CLD303	8/4/2010	3.950	3.970	0.51%
1031018-01	L008047-DUP1	CLD303	8/20/2010	4.360	4.350	0.23%
1035016-01	L009038-DUP1	CLD303	9/20/2010	4.050	4.050	0.00%
1039018-01	L010017-DUP1	CLD303	10/7/2010	4.470	4.480	0.22%
1043013-01	L011036-DUP1	CLD303	11/19/2010	5.530	5.560	0.54%
				Mean Percent Difference		0.27%
				Standard Deviation		0.002

Appendix C

Filter Pack Data and QC Summary

Filter Pack Data and QC Summary

Table C-1 presents the total microgram data for each filter type from each sample.

Table C-2 presents the results of the analyses of the laboratory filter blank samples. Laboratory filter blanks are prepared weekly while the filter packs are being prepared for the field. Each laboratory blank is prepared using filters from the same lot of filters used to prepare the field filter packs. The analytical results of the laboratory blanks demonstrate no significant contamination. There is one laboratory blank for the nylon filters with a minor "hit" for sulfate. The field and laboratory blank results indicate that logistical and analytical processes did not contribute to the measured analytes.

The QC results for all parameters are within the measurement criteria of the CASTNET program (MACTEC, 2010). Tables C-3 through C-5 summarize the reference sample QC data for each filter type and parameter in each analytical batch. Each reference sample is a NIST-traceable solution in a matrix similar to the filter sample extracts. An independent laboratory supplies these reference samples with a certificate of analysis stating the known or target value. A reference sample is analyzed at the beginning and end of each analytical batch to verify the accuracy and stability of the instrument response. The QC limits require the measured value be within ± 5 percent of the known value for anions and within ± 10 percent of the known value for cations. The data from all reference samples analyzed with the Great Smoky Mountains National Park, TN (GSR420) samples are within the CASTNET QC criteria.

Summary statistics from the analysis of CCV for each parameter and filter type are presented in Table C-6. A CCV is a NIST-traceable solution supplied in a matrix similar to that of the sample being analyzed with a target value at approximately the midpoint of the calibration curve. This QC solution is supplied to MACTEC by a second independent laboratory. A CCV is analyzed after every 10 environmental samples to verify that the instrument calibration has not drifted more than ± 5 percent for anions and base cations, and ± 10 percent for NH_4^+. All CCV analyzed with the GSR420 samples are within the CASTNET QC criteria.

Table C-7 summarizes the percent difference of replicate samples reanalyzed within the same analytical batch. Samples are randomly selected from each analytical batch for replicate analysis. This table presents only the GRS420 samples that were replicated. The replicate percent difference criterion is ± 20 percent for all analytes.

Table C-1. Dry Deposition Filter Concentrations for 2010 Sampling Season – GRS420, TN

			Teflon		Nylon		Cellulose	Teflon					
Sample No.	Station ID	Filter Date	SO_4^{2-} T.µg	NO_3^--N T.µg	SO_4^{2-} T.µg	NO_3^--N T.µg	SO_4^{2-} T.µg	NH_4^+-N T.µg	Ca^{2+} T.µg	Mg^{2+} T.µg	Na^+ T.µg	K^+ T.µg	Cl^- T.µg
1023001-36	GRS420	6/1/10	115.40	0.55	9.20	8.69	23.82	30.92	3.88	0.98	2.45	2.22	0.50U
1024001-36	GRS420	6/8/10	99.76	1.38	12.14	8.81	20.27	21.36	5.31	1.58	6.62	2.78	0.50U
1025001-36	GRS420	6/15/10	101.70	0.25	9.01	9.67	22.56	25.98	5.99	1.18	2.27	3.36	0.50U
1026001-36	GRS420	6/22/10	107.50	0.79	16.02	9.40	58.97	25.19	6.13	1.45	4.58	1.79	0.50U
1027001-36	GRS420	6/29/10	164.50	0.81	11.72	11.15	53.12	41.26	8.10	1.75	2.44	2.88	0.50U
1028001-36	GRS420	7/6/10	152.10	0.34	13.26	10.51	36.35	34.32	8.50	1.63	2.32	2.45	0.92
1029001-36	GRS420	7/13/10	99.76	0.20U	9.88	7.41	17.17	21.10	3.45	1.07	3.26	1.98	0.50U
1030001-36	GRS420	7/20/10	117.20	2.30	13.88	10.34	34.88	16.24	13.54	3.82	12.73	3.96	0.50U
1031001-36	GRS420	7/27/10	131.20	0.68	15.90	9.33	22.29	28.62	6.21	1.34	3.22	2.27	0.50U
1032001-36	GRS420	8/3/10	166.10	0.35	13.80	11.88	30.26	41.30	6.49	1.28	2.32	3.37	0.50U
1033001-36	GRS420	8/10/10	159.10	0.20U	12.66	9.86	38.82	37.47	3.89	0.91	2.37	2.07	0.50U
1034001-36	GRS420	8/17/10	93.40	0.39	10.70	6.75	16.36	20.61	2.88	0.67	1.53	1.81	0.50U
1035001-36	GRS420	8/24/10	173.50	1.35	12.66	9.26	39.50	39.91	5.99	1.19	2.96	1.86	0.50U
1036001-36	GRS420	8/31/10	55.23	0.62	11.00	8.64	61.16	14.30	9.08	1.30	1.42	2.24	0.50U
1037001-36	GRS420	9/7/10	79.03	0.47	13.66	11.33	53.68	17.25	8.57	1.19	1.28	2.01	0.50U
1038001-36	GRS420	9/14/10	100.50	1.46	10.13	10.41	57.63	27.42	7.43	1.03	1.98	14.59I	0.50
1039001-36	GRS420	9/21/10	57.54	1.81	11.08	5.93	29.88	15.53	2.42	0.74	3.00	3.07	0.60
1040001-36	GRS420	9/28/10	72.70	2.00	10.49	7.36	48.92	17.20	5.47	0.86	0.31	1.33	0.50U

Note: U = Value is less than detection limit
I = Invalid

Table C-2. Dry Deposition 2010 Sampling Season – Laboratory Filter Pack Blanks – GRS420, TN (1 of 2)

		Teflon		Nylon		Cellulose	Teflon					
Lab Key	Analysis Date	SO_4^{2-} T.µg	NO_3^--N T.µg	SO_4^{2-} T.µg	NO_3^--N T.µg	SO_4^{2-} T.µg	NH_4^+-N T.µg	Ca^{2+} T.µg	Mg^{2+} T.µg	Na^+ T.µg	K^+ T.µg	Cl^- T.µg
1023002-01	16-Jun-10			<1.000	<0.200							
1023002-02	16-Jun-10			<1.000	<0.200							
1024002-01	22-Jun-10	<1.000	<0.200			<2.000	<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1024002-02	22-Jun-10	<1.000	<0.200			<2.000	<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1025002-01	24-Jun-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1025002-02	24-Jun-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1025002-01	01-Jul-10			<1.000	<0.200							
1025002-02	01-Jul-10			<1.000	<0.200							
1026002-01	07-Jul-10					<2.000	<0.500	<0.15	<0.075	<0.125	<0.15	
1026002-02	07-Jul-10					<2.000	<0.500	<0.15	<0.075	<0.125	<0.15	
1026002-01	08-Jul-10	<1.000	<0.200	<1.000	<0.200							<0.500
1026002-02	08-Jul-10	<1.000	<0.200	<1.000	<0.200							<0.500
1027002-01	13-Jul-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1027002-02	13-Jul-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1027002-01	14-Jul-10			<1.000	<0.200	<2.000						
1027002-02	14-Jul-10			<1.000	<0.200	<2.000						
1028002-01	21-Jul-10	<1.000	<0.200	1.392	<0.200		<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1028002-02	21-Jul-10	<1.000	<0.200	<1.000	<0.200		<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1029002-01	27-Jul-10			<1.000	<0.200	<2.000						
1029002-02	27-Jul-10			<1.000	<0.200	<2.000						
1029002-01	28-Jul-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1029002-02	28-Jul-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1030002-01	04-Aug-10	<1.000	<0.200			<2.000	<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1030002-02	04-Aug-10	<1.000	<0.200			<2.000	<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1031002-01	10-Aug-10			<1.000	<0.200							
1031002-02	10-Aug-10			<1.000	<0.200							
1031002-01	11-Aug-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1031002-02	11-Aug-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1032002-01	19-Aug-10			<1.000	<0.200							
1032002-02	18-Aug-10			<1.000	<0.200							
1032002-01	24-Aug-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1032002-02	24-Aug-10						<0.500	<0.15	<0.075	<0.125	<0.15	
1032002-02	25-Aug-10	<1.000	<0.200									<0.500
1033002-01	25-Aug-10			<1.000	<0.200	<2.000						
1033002-02	25-Aug-10			<1.000	<0.200	<2.000						

Table C-2. Dry Deposition 2010 Sampling Season – Laboratory Filter Pack Blanks – GRS420, TN (2 of 2)

		Teflon		Nylon		Cellulose	Teflon					
Lab Key	**Analysis Date**	**SO_4^{2-} T.µg**	**NO_3^--N T.µg**	**SO_4^{2-} T.µg**	**NO_3^--N T.µg**	**SO_4^{2-} T.µg**	**NH_4^+-N T.µg**	**Ca^{2+} T.µg**	**Mg^{2+} T.µg**	**Na^+ T.µg**	**K^+ T.µg**	**Cl^- T.µg**
1033002-01	31-Aug-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1033002-02	31-Aug-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1034002-01	01-Sep-10					<2.000						
1034002-02	01-Sep-10					<2.000						
1034002-01	02-Sep-10						<0.500	<0.15	<0.075	<0.125	<0.15	
1034002-02	02-Sep-10						<0.500	<0.15	<0.075	<0.125	<0.15	
1035002-01	14-Sep-10			<1.000	<0.200							
1035002-02	14-Sep-10			<1.000	<0.200							
1036002-01	15-Sep-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1036002-02	15-Sep-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1036002-01	16-Sep-10			<1.000	<0.200	<2.000						
1036002-02	16-Sep-10			<1.000	<0.200	<2.000						
1037002-01	23-Sep-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1037002-02	23-Sep-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1038002-01	29-Sep-10					<2.000						
1038002-02	29-Sep-10					<2.000						
1038002-01	30-Sep-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1038002-02	30-Sep-10	<1.000	<0.200				<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1039002-01	06-Oct-10			<1.000	<0.200							
1039002-02	06-Oct-10			<1.000	<0.200							
1040002-01	12-Oct-10	<1.000	<0.200			<2.000	<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1040002-02	12-Oct-10	<1.000	<0.200			<2.000	<0.500	<0.15	<0.075	<0.125	<0.15	<0.500
1040002-01	19-Oct-10			<1.000	<0.200							
1040002-02	19-Oct-10			<1.000	<0.200							

Table C-3. Dry Deposition 2010 Sampling Season – QC Batch Summary for Teflon Filters – Reference Samples – GRS420, TN (1 of 3)

		SO_4^{2-}					NO_3^- - N					NH_4^+ - N		
Batch	QC Key	Target mg/L	Found mg/L	Percent Recovery	Batch	QC Key	Target mg/L	Found mg/L	Percent Recovery	Batch	QC Key	Target mg/L	Found mg/L	Percent Recovery
L006039	L006039-SRM1	10	9.70	97.03	L006039	L006039-SRM1	1.6	1.59	99.38	L006031	L006031-SRM1	0.760	0.7419	97.62
L006039	L006039-SRM2	10	9.79	97.92	L006039	L006039-SRM2	1.6	1.60	100.23	L006031	L006031-SRM2	0.760	0.7439	97.88
L006044	L006044-SRM1	10	9.68	96.81	L006044	L006044-SRM1	1.6	1.58	98.91	L006041	L006041-SRM1	0.760	0.7439	97.88
L006044	L006044-SRM2	10	9.84	98.41	L006044	L006044-SRM2	1.6	1.61	100.75	L006041	L006041-SRM2	0.760	0.7479	98.41
L007015	L007015-SRM1	10	9.69	96.86	L007015	L007015-SRM1	1.6	1.58	98.96	L007011	L007011-SRM1	0.760	0.7456	98.11
L007015	L007015-SRM2	10	9.84	98.36	L007015	L007015-SRM2	1.6	1.61	100.55	L007011	L007011-SRM2	0.760	0.7462	98.19
L007021	L007021-SRM1	10	9.68	96.78	L007021	L007021-SRM1	1.6	1.58	99.06	L007016	L007016-SRM1	0.760	0.7653	100.70
L007021	L007021-SRM2	10	9.86	98.59	L007021	L007021-SRM2	1.6	1.62	101.00	L007016	L007016-SRM2	0.760	0.7613	100.17
L007028	L007028-SRM1	10	9.64	96.38	L007028	L007028-SRM1	1.6	1.58	98.73	L007023	L007023-SRM1	0.760	0.7617	100.22
L007028	L007028-SRM2	10	9.73	97.33	L007028	L007028-SRM2	1.6	1.60	99.99	L007023	L007023-SRM2	0.760	0.7515	98.88
L007035	L007035-SRM1	10	9.61	96.14	L007035	L007035-SRM1	1.6	1.58	98.99	L007027	L007027-SRM1	0.760	0.7608	100.11
L007035	L007035-SRM2	10	9.75	97.48	L007035	L007035-SRM2	1.6	1.61	100.39	L007027	L007027-SRM2	0.760	0.7674	100.98
L007044	L007044-SRM1	10	9.64	96.40	L007044	L007044-SRM1	1.6	1.58	98.69	L007039	L007039-SRM1	0.760	0.7678	101.03
L007044	L007044-SRM2	10	9.74	97.37	L007044	L007044-SRM2	1.6	1.60	99.79	L007039	L007039-SRM2	0.760	0.7702	101.34
L007044	L007044-SRM3	10	9.74	97.41	L007044	L007044-SRM3	1.6	1.59	99.66	L008003	L008003-SRM1	0.760	0.7576	99.69
L008009	L008009-SRM1	10	9.61	96.13	L008009	L008009-SRM1	1.6	1.58	98.69	L008003	L008003-SRM2	0.760	0.7710	101.45
L008009	L008009-SRM2	10	9.66	96.64	L008009	L008009-SRM2	1.6	1.59	99.47	L008015	L008015-SRM1	0.760	0.7638	100.50
L008025	L008025-SRM1	10	9.75	97.54	L008025	L008025-SRM1	1.6	1.56	97.80	L008015	L008015-SRM2	0.760	0.7714	101.50
L008025	L008025-SRM2	10	9.85	98.46	L008025	L008025-SRM2	1.6	1.58	98.69	L008049	L008049-SRM1	0.760	0.7654	100.71
L008059	L008059-SRM1	10	9.78	97.81	L008059	L008059-SRM1	1.6	1.57	98.18	L008049	L008049-SRM2	0.760	0.7602	100.03
L008059	L008059-SRM2	10	9.74	97.36	L008059	L008059-SRM2	1.6	1.57	97.96	L008067	L008067-SRM1	0.760	0.7616	100.21
L009006	L009006-SRM1	10	9.80	98.03	L009006	L009006-SRM1	1.6	1.57	98.34	L008067	L008067-SRM2	0.760	0.7674	100.98
L009006	L009006-SRM2	10	9.84	98.37	L009006	L009006-SRM2	1.6	1.58	98.81	L009005	L009005-SRM1	0.760	0.7561	99.49
L009006	L009006-SRM3	10	9.71	97.15	L009006	L009006-SRM3	1.6	1.56	97.49	L009005	L009005-SRM2	0.760	0.7620	100.26
L009014	L009014-SRM1	10	9.70	96.98	L009014	L009014-SRM1	1.6	1.59	99.49	L009026	L009026-SRM1	0.760	0.7526	99.03
L009014	L009014-SRM2	10	9.71	97.13	L009014	L009014-SRM2	1.6	1.59	99.49	L009026	L009026-SRM2	0.760	0.7721	101.59
L009035	L009035-SRM1	10	9.73	97.34	L009035	L009035-SRM1	1.6	1.60	99.95	L009052	L009052-SRM1	0.760	0.7564	99.53
L009035	L009035-SRM2	10	9.81	98.13	L009035	L009035-SRM2	1.6	1.60	100.29	L009052	L009052-SRM2	0.760	0.7650	100.66
L009063	L009063-SRM1	9	8.89	98.73	L009063	L009063-SRM1	1.6	1.62	101.28	L009079	L009079-SRM1	0.760	0.7758	102.08
L009063	L009063-SRM2	9	8.77	97.43	L009063	L009063-SRM2	1.6	1.60	99.99	L009079	L009079-SRM2	0.760	0.7741	101.86
L010004	L010004-SRM1	9	8.82	98.02	L010004	L010004-SRM1	1.6	1.61	100.54	L010027	L010027-SRM1	0.760	0.7617	100.22
L010004	L010004-SRM2	9	8.91	98.97	L010004	L010004-SRM2	1.6	1.62	101.45	L010027	L010027-SRM2	0.760	0.7687	101.15
L010032	L010032-SRM1	9	8.94	99.35	L010032	L010032-SRM1	1.6	1.63	101.96	L010034	L010034-SRM1	0.760	0.7562	99.50
L010032	L010032-SRM2	9	8.68	96.46	L010032	L010032-SRM2	1.6	1.57	98.24	L010034	L010034-SRM2	0.760	0.7787	102.46
L010032	L010032-SRM3	9	8.85	98.35	L010032	L010032-SRM3	1.6	1.61	100.36					
L010037	L010037-SRM1	9	8.87	98.59	L010037	L010037-SRM1	1.6	1.61	100.56					
L010037	L010037-SRM3	9	9.17	101.86	L010037	L010037-SRM3	1.6	1.66	103.66					
Mean				97.68	**Mean**				99.67	**Mean**				100.13
Standard Deviation				1.09	**Standard Deviation**				1.27	**Standard Deviation**				1.29
Count				37	**Count**				37	**Count**				34

Table C-3. Dry Deposition 2010 Sampling Season – QC Batch Summary for Teflon Filters – Reference Samples – GRS420, TN (2 of 3)

Ca^{2+}					Mg^{2+}					Na^{+}				
Batch	**QC Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch**	**QC Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch**	**QC Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
L006032	L006032-SRM1	0.053	0.0530	99.92	L006032	L006032-SRM1	0.052	0.0540	103.85	L006032	L006032-SRM1	0.390	0.4046	103.74
L006032	L006032-SRM2	0.053	0.0541	102.15	L006032	L006032-SRM2	0.052	0.0537	103.31	L006032	L006032-SRM2	0.390	0.4056	104.01
L006040	L006040-SRM1	0.053	0.0531	100.15	L006040	L006040-SRM1	0.052	0.0542	104.29	L006040	L006040-SRM1	0.390	0.4086	104.76
L006040	L006040-SRM2	0.053	0.0535	101.04	L006040	L006040-SRM2	0.052	0.0540	103.90	L006040	L006040-SRM2	0.390	0.4071	104.38
L007013	L007013-SRM1	0.053	0.0551	103.91	L007013	L007013-SRM1	0.052	0.0537	103.23	L007013	L007013-SRM1	0.390	0.4004	102.66
L007013	L007013-SRM2	0.053	0.0525	99.08	L007013	L007013-SRM2	0.052	0.0530	101.94	L007013	L007013-SRM2	0.390	0.3946	101.17
L007013	L007013-SRM3	0.053	0.0526	99.21	L007013	L007013-SRM3	0.052	0.0534	102.69	L007013	L007013-SRM3	0.390	0.4007	102.76
L007018	L007018-SRM1	0.053	0.0510	96.19	L007018	L007018-SRM1	0.052	0.0522	100.33	L007018	L007018-SRM1	0.390	0.3810	97.69
L007018	L007018-SRM2	0.053	0.0516	97.30	L007018	L007018-SRM2	0.052	0.0532	102.23	L007018	L007018-SRM2	0.390	0.3801	97.47
L007024	L007024-SRM1	0.053	0.0534	100.83	L007024	L007024-SRM1	0.052	0.0522	100.35	L007024	L007024-SRM1	0.390	0.3968	101.74
L007024	L007024-SRM2	0.053	0.0524	98.83	L007024	L007024-SRM2	0.052	0.0528	101.52	L007024	L007024-SRM2	0.390	0.3861	99.01
L007029	L007029-SRM1	0.053	0.0537	101.30	L007029	L007029-SRM1	0.052	0.0524	100.85	L007029	L007029-SRM1	0.390	0.3934	100.87
L007029	L007029-SRM2	0.053	0.0532	100.32	L007029	L007029-SRM2	0.052	0.0532	102.21	L007029	L007029-SRM2	0.390	0.3940	101.03
L007041	L007041-SRM1	0.053	0.0514	97.04	L007041	L007041-SRM1	0.052	0.0517	99.38	L007041	L007041-SRM1	0.390	0.3869	99.20
L007041	L007041-SRM2	0.053	0.0524	98.81	L007041	L007041-SRM2	0.052	0.0546	105.06	L007041	L007041-SRM2	0.390	0.3824	98.04
L008004	L008004-SRM1	0.053	0.0512	96.70	L008004	L008004-SRM1	0.052	0.0518	99.65	L008004	L008004-SRM1	0.390	0.3827	98.14
L008004	L008004-SRM2	0.053	0.0519	97.92	L008004	L008004-SRM2	0.052	0.0520	100.06	L008004	L008004-SRM2	0.390	0.3838	98.41
L008016	L008016-SRM1	0.053	0.0542	102.32	L008016	L008016-SRM1	0.052	0.0536	103.04	L008016	L008016-SRM1	0.390	0.4089	104.85
L008016	L008016-SRM2	0.053	0.0575	108.49	L008016	L008016-SRM2	0.052	0.0549	105.48	L008016	L008016-SRM2	0.390	0.4054	103.95
L008050	L008050-SRM1	0.053	0.0525	99.02	L008050	L008050-SRM1	0.052	0.0531	102.13	L008050	L008050-SRM1	0.390	0.4033	103.40
L008050	L008050-SRM2	0.053	0.0527	99.53	L008050	L008050-SRM2	0.052	0.0533	102.48	L008050	L008050-SRM2	0.390	0.4005	102.68
L008068	L008068-SRM1	0.053	0.0532	100.30	L008068	L008068-SRM1	0.052	0.0547	105.27	L008068	L008068-SRM1	0.390	0.4059	104.07
L008068	L008068-SRM2	0.053	0.0531	100.11	L008068	L008068-SRM2	0.052	0.0537	103.33	L008068	L008068-SRM2	0.390	0.3978	102.01
L009007	L009007-SRM1	0.053	0.0525	99.06	L009007	L009007-SRM1	0.052	0.0536	103.10	L009007	L009007-SRM1	0.390	0.3967	101.71
L009007	L009007-SRM2	0.053	0.0535	101.00	L009007	L009007-SRM2	0.052	0.0547	105.15	L009007	L009007-SRM2	0.390	0.4041	103.63
L009028	L009028-SRM1	0.053	0.0525	99.08	L009028	L009028-SRM1	0.052	0.0539	103.69	L009028	L009028-SRM1	0.390	0.4001	102.59
L009028	L009028-SRM2	0.053	0.0526	99.28	L009028	L009028-SRM2	0.052	0.0534	102.69	L009028	L009028-SRM2	0.390	0.4001	102.58
L009053	L009053-SRM1	0.053	0.0530	100.00	L009053	L009053-SRM1	0.052	0.0545	104.81	L009053	L009053-SRM1	0.390	0.3840	98.46
L009053	L009053-SRM2	0.053	0.0535	100.89	L009053	L009053-SRM2	0.052	0.0550	105.77	L009053	L009053-SRM2	0.390	0.3850	98.72
L010001	L010001-SRM1	0.053	0.0542	102.28	L010001	L010001-SRM1	0.052	0.0533	102.52	L010001	L010001-SRM1	0.390	0.3956	101.44
L010001	L010001-SRM2	0.053	0.0535	101.00	L010001	L010001-SRM2	0.052	0.0535	102.81	L010001	L010001-SRM2	0.390	0.3891	99.77
L010028	L010028-SRM1	0.053	0.0546	103.04	L010028	L010028-SRM1	0.052	0.0545	104.75	L010028	L010028-SRM1	0.390	0.3900	100.01
L010028	L010028-SRM2	0.053	0.0538	101.47	L010028	L010028-SRM2	0.052	0.0540	103.87	L010028	L010028-SRM2	0.390	0.3851	98.73
L010039	L010039-SRM1	0.054	0.0522	96.74	L010039	L010039-SRM1	0.052	0.0515	99.06	L010039	L010039-SRM1	0.400	0.3742	93.55
L010039	L010039-SRM2	0.054	0.0542	100.30	L010039	L010039-SRM2	0.052	0.0533	102.42	L010039	L010039-SRM2	0.400	0.3843	96.07
L010039	L010039-SRM3	0.054	0.0552	102.19	L010039	L010039-SRM3	0.052	0.0539	103.63	L010039	L010039-SRM3	0.400	0.3791	94.78
L010039	L010039-SRM4	0.054	0.0555	102.85	L010039	L010039-SRM4	0.052	0.0529	101.71	L010039	L010039-SRM4	0.400	0.3934	98.34
Mean				100.26	**Mean**				102.77	**Mean**				100.71
Standard Deviation				2.33	**Standard Deviation**				1.77	**Standard Deviation**				2.89
Count				37	**Count**				37	**Count**				37

Table C-3. Dry Deposition 2010 Sampling Season – QC Batch Summary for Teflon Filters – Reference Samples – GRS420, TN (3 of 3)

		K^+					Cl^-		
Batch	**QC Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch**	**QC Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
L006032	L006032-SRM1	0.098	0.0988	100.83	L006039	L006039-SRM1	0.960	0.9726	101.31
L006032	L006032-SRM2	0.098	0.0932	95.08	L006039	L006039-SRM2	0.960	0.9839	102.49
L006040	L006040-SRM1	0.098	0.1005	102.55	L006044	L006044-SRM1	0.960	0.9781	101.89
L006040	L006040-SRM2	0.098	0.0964	98.40	L006044	L006044-SRM2	0.960	0.9953	103.68
L007013	L007013-SRM1	0.098	0.0952	97.19	L007015	L007015-SRM1	0.960	0.9780	101.88
L007013	L007013-SRM2	0.098	0.0949	96.87	L007015	L007015-SRM2	0.960	0.9905	103.18
L007013	L007013-SRM3	0.098	0.0960	98.01	L007021	L007021-SRM1	0.960	0.9839	102.49
L007018	L007018-SRM1	0.098	0.0936	95.52	L007021	L007021-SRM2	0.960	1.0025	104.43
L007018	L007018-SRM2	0.098	0.0922	94.11	L007028	L007028-SRM1	0.960	0.9914	103.27
L007024	L007024-SRM1	0.098	0.0991	101.17	L007028	L007028-SRM2	0.960	1.0050	104.69
L007024	L007024-SRM2	0.098	0.0908	92.64	L007035	L007035-SRM1	0.960	1.0013	104.30
L007029	L007029-SRM1	0.098	0.0951	97.00	L007035	L007035-SRM2	0.960	0.9997	104.14
L007029	L007029-SRM2	0.098	0.0975	99.50	L007044	L007044-SRM1	0.960	0.9910	103.23
L007041	L007041-SRM1	0.098	0.0961	98.03	L007044	L007044-SRM2	0.960	0.9978	103.94
L007041	L007041-SRM2	0.098	0.0931	95.05	L007044	L007044-SRM3	0.960	1.0004	104.21
L008004	L008004-SRM1	0.098	0.0959	97.88	L008009	L008009-SRM1	0.960	0.9969	103.84
L008004	L008004-SRM2	0.098	0.0931	95.04	L008009	L008009-SRM2	0.960	1.0026	104.44
L008016	L008016-SRM1	0.098	0.0997	101.73	L008025	L008025-SRM1	0.960	0.9942	103.56
L008016	L008016-SRM2	0.098	0.0971	99.04	L008025	L008025-SRM2	0.960	0.9991	104.07
L008050	L008050-SRM1	0.098	0.1010	103.07	L008059	L008059-SRM1	0.960	0.9924	103.38
L008050	L008050-SRM2	0.098	0.0971	99.06	L008059	L008059-SRM2	0.960	0.9944	103.58
L008068	L008068-SRM1	0.098	0.1010	103.02	L009006	L009006-SRM1	0.960	0.9905	103.18
L008068	L008068-SRM2	0.098	0.0958	97.77	L009006	L009006-SRM2	0.960	1.0032	104.50
L009007	L009007-SRM1	0.098	0.0994	101.44	L009006	L009006-SRM3	0.960	0.9954	103.69
L009007	L009007-SRM2	0.098	0.0988	100.78	L009014	L009014-SRM1	0.960	1.0005	104.22
L009028	L009028-SRM1	0.098	0.0970	98.96	L009014	L009014-SRM2	0.960	0.9955	103.70
L009028	L009028-SRM2	0.098	0.0970	98.99	L009035	L009035-SRM1	0.960	1.0031	104.49
L009053	L009053-SRM1	0.098	0.0965	98.48	L009035	L009035-SRM2	0.960	1.0064	104.83
L009053	L009053-SRM2	0.098	0.0955	97.44	L009063	L009063-SRM1	0.930	0.9719	104.50
L010001	L010001-SRM1	0.098	0.1003	102.35	L009063	L009063-SRM2	0.930	0.9716	104.47
L010001	L010001-SRM2	0.098	0.0959	97.83	L010004	L010004-SRM1	0.930	0.9548	102.67
L010028	L010028-SRM1	0.098	0.0993	101.31	L010004	L010004-SRM2	0.930	0.9533	102.50
L010028	L010028-SRM2	0.098	0.0975	99.52	L010032	L010032-SRM1	0.930	0.9515	102.31
L010039	L010039-SRM1	0.100	0.0981	98.12	L010032	L010032-SRM2	0.930	0.9260	99.57
L010039	L010039-SRM2	0.100	0.1009	100.88	L010032	L010032-SRM3	0.930	0.9348	100.52
L010039	L010039-SRM3	0.100	0.1014	101.43	L010037	L010037-SRM1	0.930	0.9386	100.92
L010039	L010039-SRM4	0.100	0.1010	101.04	L010037	L010037-SRM3	0.930	0.9627	103.52
Mean				98.84	**Mean**				103.29
Standard Deviation				2.61	**Standard Deviation**				1.25
Count				37	**Count**				37

Table C-4. Dry Deposition 2010 Sampling Season – QC Batch Summary for Nylon Filters – Reference Samples – GRS420, TN

Batch	QC Key	SO_4^{2-} Target mg/L	SO_4^{2-} Found mg/L	SO_4^{2-} Percent Recovery	Batch	QC Key	NO_3^- Target mg/L	NO_3^- Found mg/L	NO_3^- Percent Recovery
L006029	L006029-SRM1	10	9.83	98.31	L006029	L006029-SRM1	1.6	1.583	98.91
L006029	L006029-SRM2	10	9.85	98.47	L006029	L006029-SRM2	1.6	1.588	99.24
L007005	L007005-SRM1	10	9.65	96.53	L007005	L007005-SRM1	1.6	1.581	98.79
L007005	L007005-SRM2	10	9.84	98.37	L007005	L007005-SRM2	1.6	1.609	100.56
L007009	L007009-SRM1	10	9.83	98.34	L007009	L007009-SRM1	1.6	1.611	100.67
L007009	L007009-SRM2	10	9.77	97.68	L007009	L007009-SRM2	1.6	1.604	100.24
L007017	L007017-SRM1	10	9.79	97.93	L007017	L007017-SRM1	1.6	1.595	99.70
L007017	L007017-SRM2	10	9.80	98.04	L007017	L007017-SRM2	1.6	1.600	99.98
L007025	L007025-SRM1	10	9.75	97.51	L007025	L007025-SRM1	1.6	1.602	100.10
L007025	L007025-SRM2	10	9.81	98.12	L007025	L007025-SRM2	1.6	1.613	100.84
L007032	L007032-SRM1	10	9.80	98.04	L007032	L007032-SRM1	1.6	1.593	99.55
L007032	L007032-SRM2	10	9.99	99.86	L007032	L007032-SRM2	1.6	1.625	101.55
L007040	L007040-SRM1	10	9.72	97.15	L007040	L007040-SRM1	1.6	1.584	99.01
L007040	L007040-SRM2	10	9.75	97.48	L007040	L007040-SRM2	1.6	1.593	99.56
L008018	L008018-SRM1	10	9.65	96.47	L008018	L008018-SRM1	1.6	1.588	99.22
L008018	L008018-SRM2	10	9.79	97.89	L008018	L008018-SRM2	1.6	1.611	100.71
L008027	L008027-SRM1	10	9.77	97.68	L008027	L008027-SRM1	1.6	1.610	100.60
L008027	L008027-SRM2	10	9.89	98.93	L008027	L008027-SRM2	1.6	1.634	102.13
L008027	L008027-SRM3	10	9.58	95.83	L008027	L008027-SRM3	1.6	1.561	97.59
L008042	L008042-SRM1	10	9.61	96.10	L008042	L008042-SRM1	1.6	1.589	99.32
L008042	L008042-SRM2	10	9.76	97.65	L008042	L008042-SRM2	1.6	1.619	101.16
L008042	L008042-SRM3	10	9.81	98.14	L008042	L008042-SRM3	1.6	1.626	101.62
L008042	L008042-SRM4	10	9.84	98.44	L008042	L008042-SRM4	1.6	1.629	101.79
L008060	L008060-SRM1	10	9.62	96.22	L008060	L008060-SRM1	1.6	1.582	98.89
L008060	L008060-SRM2	10	9.72	97.24	L008060	L008060-SRM2	1.6	1.601	100.09
L009015	L009015-SRM1	10	9.68	96.77	L009015	L009015-SRM1	1.6	1.566	97.85
L009015	L009015-SRM2	10	9.76	97.59	L009015	L009015-SRM2	1.6	1.614	100.87
L009033	L009033-SRM1	10	9.68	96.76	L009033	L009033-SRM1	1.6	1.589	99.28
L009033	L009033-SRM2	10	9.90	98.97	L009033	L009033-SRM2	1.6	1.631	101.91
L009033	L009033-SRM3	10	9.88	98.77	L009033	L009033-SRM3	1.6	1.628	101.74
L009044	L009044-SRM1	10	9.51	95.15	L009044	L009044-SRM1	1.6	1.566	97.86
L009044	L009044-SRM2	10	9.66	96.56	L009044	L009044-SRM2	1.6	1.591	99.46
L009078	L009078-SRM1	9	8.78	97.56	L009078	L009078-SRM1	1.6	1.603	100.21
L009078	L009078-SRM2	9	8.85	98.33	L009078	L009078-SRM2	1.6	1.623	101.43
L010010	L010010-SRM1	9	8.72	96.87	L010010	L010010-SRM1	1.6	1.593	99.56
L010010	L010010-SRM2	9	8.82	97.96	L010010	L010010-SRM2	1.6	1.617	101.08
L010018	L010018-SRM1	9	8.76	97.31	L010018	L010018-SRM1	1.6	1.602	100.12
L010018	L010018-SRM2	9	8.73	96.98	L010018	L010018-SRM2	1.6	1.599	99.96
L010043	L010043-SRM1	9	8.74	97.14	L010043	L010043-SRM1	1.6	1.598	99.88
L010043	L010043-SRM2	9	8.83	98.16	L010043	L010043-SRM2	1.6	1.613	100.82
Mean				97.58	**Mean**				100.10
Standard Deviation				0.95	**Standard Deviation**				1.14
Count				40	**Count**				40

Table C-5. Dry Deposition 2010 Sampling Season – QC Batch Summary for Cellulose Filters – Reference Samples – GRS420, TN

Batch	QC Key	SO_4^{2-} Target mg/L	Found mg/L	Percent Recovery
L006033	L006033-SRM1	10	9.84	98.40
L006033	L006033-SRM2	10	10.05	100.45
L006053	L006053-SRM1	10	9.82	98.17
L006053	L006053-SRM2	10	9.90	99.02
L007012	L007012-SRM1	10	9.79	97.90
L007012	L007012-SRM2	10	10.05	100.51
L007014	L007014-SRM1	10	9.87	98.73
L007014	L007014-SRM2	10	9.84	98.44
L007022	L007022-SRM1	10	9.75	97.46
L007022	L007022-SRM2	10	9.88	98.80
L007030	L007030-SRM1	10	9.80	98.04
L007030	L007030-SRM2	10	9.78	97.76
L007038	L007038-SRM1	10	10.03	100.34
L007038	L007038-SRM2	10	9.77	97.71
L008007	L008007-SRM1	10	9.78	97.84
L008007	L008007-SRM2	10	9.93	99.28
L008020	L008020-SRM1	10	9.76	97.61
L008020	L008020-SRM2	10	9.84	98.37
L008040	L008040-SRM1	10	9.77	97.72
L008040	L008040-SRM2	10	9.85	98.46
L008051	L008051-SRM1	10	9.70	96.97
L008051	L008051-SRM2	10	9.91	99.13
L009003	L009003-SRM1	10	9.74	97.45
L009003	L009003-SRM2	10	9.81	98.13
L009027	L009027-SRM1	10	9.85	98.47
L009027	L009027-SRM2	10	9.88	98.83
L009032	L009032-SRM1	10	9.72	97.20
L009032	L009032-SRM2	10	9.85	98.46
L009067	L009067-SRM1	10	9.87	98.69
L009067	L009067-SRM2	10	9.92	99.21
L009076	L009076-SRM1	10	9.79	97.85
L009076	L009076-SRM2	10	9.85	98.46
L010029	L010029-SRM1	9	8.84	98.22
L010029	L010029-SRM2	9	8.95	99.46
L010040	L010040-SRM1	9	8.87	98.53
L010040	L010040-SRM2	9	8.95	99.43
L010040	L010040-SRM3	9	9.44	104.86
Mean				98.66
Standard Deviation				1.35
Count				37

Table C-6. Dry Deposition 2010 Sampling Season - CCV (%R) – GRS420, TN

Filter Type	Parameter	Mean	Standard Deviation	Count
Teflon	SO_4^{2-}	100.08	1.27	184
	NO_3^- - N	100.95	1.25	184
	Cl^-	100.82	1.53	184
	NH_4^+ - N	98.46	1.17	188
	Ca^{2+}	99.93	0.99	193
	Mg^{2+}	99.75	0.85	193
	Na^+	99.88	0.98	193
	K^+	99.88	0.88	193
Nylon	SO_4^{2-}	99.83	1.19	193
	NO_3^- - N	100.72	0.90	193
Cellulose	SO_4^{2-}	100.13	1.15	146

Note: %R = percent recovery

Table C-7. Dry Deposition 2010 Sampling Season – Replicate Summary – GRS420, TN

Sample No.	Replicate No.	Date	Parameter	Filter Type	Sample Result	Replicate Result	Percent Difference	Mean Percent Difference	Standard Deviation	Count
1037001-36	L009052-DUP3	23-Sep-10	NH_4^+	Teflon	17.2500	17.1400	0.64	NA	NA	1
1036001-36	L009044-DUP3	16-Sep-10	NO_3^- - N	Nylon	8.6350	8.6400	-0.06	NA	NA	1
1032001-36	L008059-DUP4	25-Aug-10	NO_3^- - N	Teflon	0.3525	0.3600	-2.13			
1037001-36	L009063-DUP3	23-Sep-10	NO_3^- - N	Teflon	0.4700	0.4675	0.53	NA	NA	2
1036001-36	L009044-DUP3	16-Sep-10	SO_4^{2-}	Nylon	11.0000	11.2400	-2.18	NA	NA	1
1032001-36	L008059-DUP4	25-Aug-10	SO_4^{2-}	Teflon	166.1000	167.0000	-0.54			
1037001-36	L009063-DUP3	23-Sep-10	SO_4^{2-}	Teflon	79.0300	78.8100	0.28	NA	NA	2