Evaluation of National Atmospheric Deposition Program Measurements for Co-located Sites CO89 and CO98 at Rocky Mountain National Park, 2012

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SALLY JEWELL, Secretary

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Suzette M. Kimball, Acting Director

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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	0.0002471	acre (ac)
hectare (ha)	2.471	acre (ac)
	Volume	
milliliter (mL)	0.034	ounce, liquid (oz)
liter (L)	1.057	quart (qt)
	Mass	
milligram (mg)	3.527×10^{-5}	ounce, avoirdupois (oz)
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

Vertical coordinate information is referenced to the “North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the “North American Datum of 1983 (NAD 83).

Percent (%)

Abbreviations and Acronyms

Abbreviation	Full name
CAL	Central Analytical Laboratory
cm	centimeters
kg/ha	kilograms per hectare
m	meters
mg/L	milligrams per liter
mm	millimeters
mL	milliliters
μEq/L	microequivalents per liter
μS/cm	microSiemens per centimeter
N	nitrogen
NADP	National Atmospheric Deposition Program
NH_4^+	ammonium ion
NO_3^-	nitrate ion
NTN	National Trends Network
ppt	precipitation
PWMC	precipitation-weighted mean concentration
RMNP	Rocky Mountain National Park
SO_4^{2-}	sulfate ion
USGS	United States Geological Survey

Evaluation of National Atmospheric Deposition Program Measurements for Co-located Sites CO89 and CO98 at Rocky Mountain National Park, 2012

Abstract

Atmospheric wet-deposition monitoring in Rocky Mountain National Park included precipitation depth and aqueous chemical measurements at co-located National Atmospheric Deposition Program (NADP) sites CO89 and CO98 (Loch Vale) during 2012. The co-located sites are separated by approximately 6.5 meters horizontally and 0.5 meters in altitude, which meets NADP siting criteria.

Median weekly absolute percent differences for selected parameters including: sample volume, 8.0 percent; ammonium concentration, 9.1 percent; nitrate concentration, 8.5 percent; sulfate concentration, 10.2 percent. Annual precipitation-weighted mean concentrations were higher for CO98 compared to CO89 for all analytes. The chemical concentration record for CO98 contains more valid samples than the CO89 record. Therefore, the CO98 record is more representative of 2012 total annual deposition at Loch Vale. Daily precipitation-depth records for the co-located precipitation gages were 100 percent complete, and the total annual precipitation depths between the sites differed by 0.1 percent for the year (91.5 and 91.4 cm).

Introduction

National Atmospheric Deposition Program / National Trends Network (NADP/NTN) sites CO89 and CO98 are located at approximately 3,159 meters (m) altitude; 40.2878 degrees north latitude; 105.6628 degrees west longitude, in Rocky Mountain National Park, Colorado. Each site contains a rain gage to measure precipitation depth and a precipitation collector to capture samples for chemical analysis. The collectors are spaced approximately 6.2 m apart horizontally and within 0.5 meters vertically; the rain gages are spaced approximately 6.5 m apart horizontally and within 0.5 meters vertically, in compliance with NADP siting criteria (NADP, 2011). Figure 1 shows photographs of the sites. The original CO98 site was installed in 1983, and the co-located CO89 site was installed in 2009. Co-location of equipment allows variability in NADP measurements at the site to be determined. The results presented herein are for calendar year 2012, the third full calendar year of co-located site data collection at CO89.

Purpose and Scope

This report presents an evaluation of variability based on measured difference in data collected at co-located NADP sites CO89 and CO98 for calendar year 2012. Weekly precipitation chemistry data are included in the appendix. Comparisons of precipitation depths, sample volumes, and concentration differences at the two sites are presented.

Analyte concentrations and sample volumes for weekly wet-deposition samples were downloaded from the NADP web site: *http://nadp.isws.illinois.edu/NTN/ntnData.aspx.* on July 26, 2013. Precipitation records in 15-minute and daily increments were accessed from: *http://nadp.isws.illinois.edu/*precip on July 30, 2013. Weekly precipitation amounts were calculated

from the 15-minute rain gage records using sample start and end times provided by Mark Rhodes, NADP Quality Assurance Manager (written commun., Aug. 1, 2013).

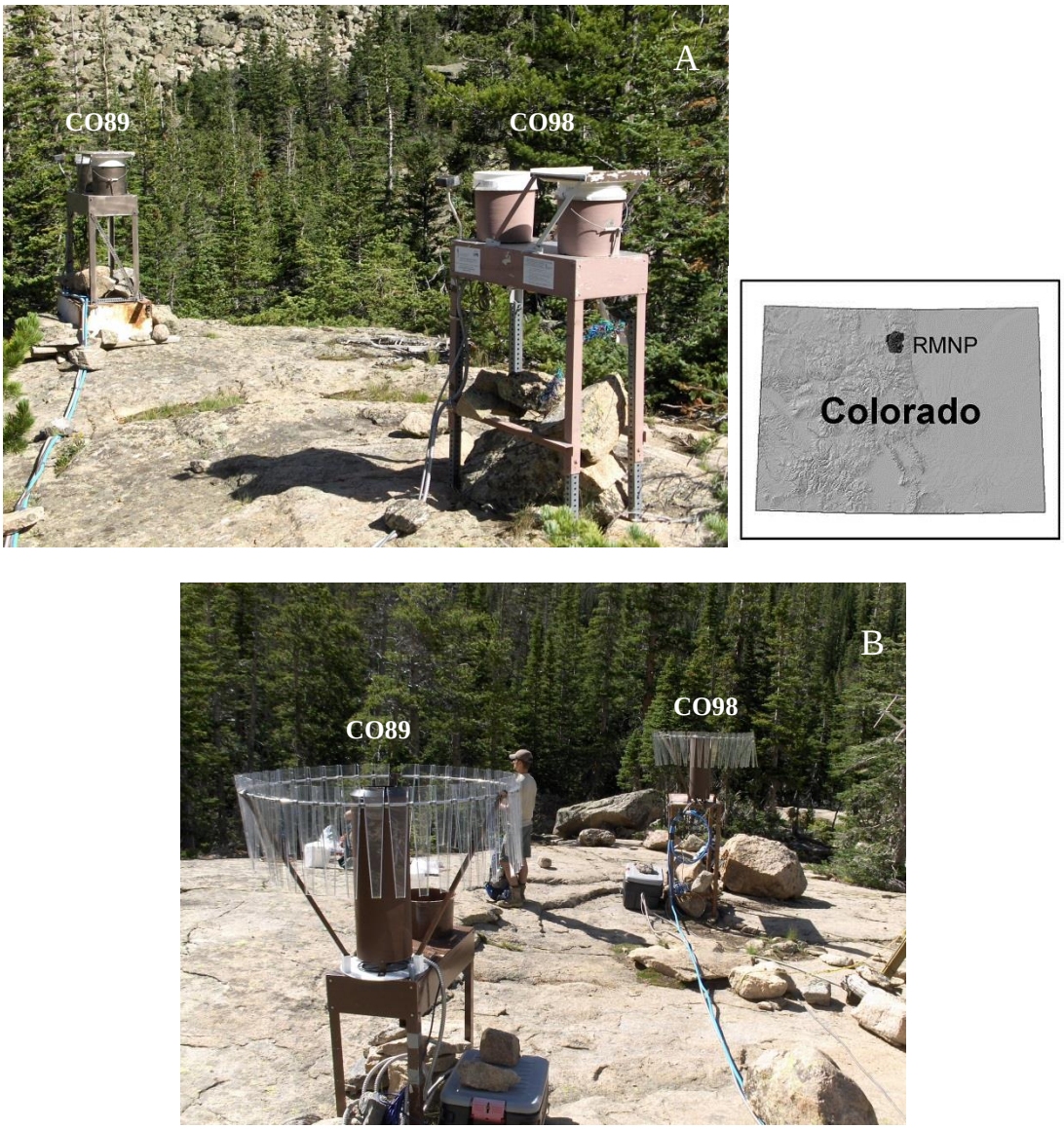

Figure 1. Co-located National Atmospheric Deposition Program/ National Trends Network collectors (A) and rain gages (B) at sites CO89 and CO98 at Rocky Mountain National Park (RMNP), Colorado. Inset map obtained from Richer and Baron, 2011.

Methods

CO89 and CO98 are official NADP/NTN sites. Field and laboratory procedures are identical for the two sites. All samples are analyzed by the Central Analytical Laboratory (CAL) in Champaign, Illinois. Sample-collection and quality-assurance methods are described by Dossett and Bowersox (1999). Sample analysis methods are accessible via the CAL web site at: *http://nadp.sws.uiuc.edu/cal/*.

Variability in solute concentration, specific conductance, and sample volume was determined using weekly paired samples with: a) sufficient volume for analysis without dilution, and b) not flagged by NADP as contaminated or otherwise invalid. Hydrogen-ion concentrations in microequivalents per liter (μEq/L) were calculated from laboratory pH measurements. Total nitrogen concentrations (in mg/L as N) were calculated by summing weekly ammonium (NH_4^+) and nitrate (NO_3^-) concentrations multiplied by the mole fraction of nitrogen (N) for each constituent. Thirteen concentration values less than the analytical detection limits were set to their associated detection limit values. Substitutions for magnesium (4 values), potassium (5 values), nitrate (1 value), and chloride (3 values) can cause subsequently calculated quantities to be biased positive (Helsel, 2012).

Paired relative differences were obtained by subtracting the CO89 site values from the CO98 site values. Paired differences (original site-minus-co-located site) in concentration, specific conductance, and sample volume were compared statistically using the paired Wilcoxon signed rank test (Hollander and Wolfe, 1999) at the α=0.1 significance level (90-percent confidence). The R software, version 2.14.0, was used for all statistical determinations.

Summary statistics for the co-located data were calculated as:

Median relative difference = $M_{i-j}(C_{oi} - C_{coi})$, and (1)

Median absolute difference (in percent) = $M_{i-j}\{abs[(C_{oi} - C_{coi})/(C_{oi} + C_{coi})/2]\} \bullet 100$, (2)

where:

M_{i-j} = median of all paired differences for weekly sample pairs i through j, where j is the total number of weekly samples for the year;

C_{coi} = weekly sample concentration, in milligrams per liter (mg/L); specific conductance in microSiemens per centimeter (μS/cm); or weekly sample volume, in milliliters (mL), from the co-located wet-deposition sampler (CO89); or daily precipitation depth from the CO89 gage.

C_{oi} = weekly sample concentration, in mg/L; specific conductance, in μS/cm; or weekly sample volume, in mL, from the original wet-deposition sampler (CO98); or daily precipitation depth from the CO98 gage.

Annual total deposition of chemical constituents in units of kilograms per hectare (kg/ha) is calculated from the weekly NADP data by first calculating the annual precipitation-weighted mean concentration (PWMC, Equation 3) and then multiplying the PWMC by the annual total precipitation depth measured by the precipitation gage (Equation 4).

$$\text{Annual PWMC (mg/L)} = \left(\frac{\sum_{1}^{w} \left[\left(ppt_w \times C_w \right) \right]}{\sum_{1}^{w} ppt_w} \right), \quad (3)$$

where: ppt_w = weekly precipitation depth associated with weekly composite samples,

C_w = chemical constituent concentrations, in mg/L, for weekly composite samples, and

w = number of weeks with samples and associated precipitation depths.

$$\text{Annual total constituent deposition (kg/ha)} = \text{PWMC} \times \text{ppt}_{annual\ total} \times 0.1. \quad (4)$$

where: PWMC = precipitation-weighted mean concentration, in mg/L,

$\text{ppt}_{annual\ total}$= total precipitation depth measured by precipitation gage for year, in centimeters (cm), and

0.1=factor for conversion of mg to kg and square meters to ha. This factor was omitted from Equation 4 in the 2011 report as a typographical error. Calculated deposition values in the 2011 report are correct.

Absolute percent differences in total annual deposition values were calculated relative to the CO98 values (Equation 5):

$$\text{Total Annual Deposition Percent Difference} = \left(\frac{TDep_{CO98} - TDep_{CO89}}{TDep_{CO98}} \right) \times 100 \ , \quad (5)$$

where: $TDep_{CO98}$ = total deposition estimated from site CO98 record, in kg/ha, and

$TDep_{CO89}$ = total deposition estimated from site CO89 record, in kg/ha.

NADP data completeness criteria 1 through 3 were evaluated for each site. Site records must meet Criteria 1, 2, and 3 for inclusion in NADP's national map products as follows:

- **Criterion 1:** Valid samples are available for greater than 75% of summary period.
- **Criterion 2:** Precipitation amounts are available for greater than 90% of summary period.
- **Criterion 3:** Valid samples are available for greater than 75% of the total precipitation amount for summary period.

Results

Wet-deposition data for CO98 meet NADP Data Completeness Criterion 1 for valid samples; at least 75 percent of summary period must be represented by samples (table 1). Data for CO89 did not meet Data Completeness Criterion 1. An inventory of wet-deposition samples collected at CO89 and CO98 during 2012 is shown in tables 1 and 2.

Various 15-minute increment precipitation-depth data are missing; summing to 5.5 hours for CO89 and 14.5 hours for CO98 over various days of the year, but missing records did not preclude calculation of daily precipitation depths. Therefore, daily precipitation-depth records for CO89 and CO98 are 100 percent complete for calendar year 2012. This meets NADP Data Completeness Criterion 2. Cumulative precipitation-depth data for CO89 and CO98 are plotted in figure 2. The total annual precipitation depth was 91.5 centimeters (cm) for CO89 and 91.4 cm for CO98 (table 3). The median daily difference between the two gages was zero.

Table 1. Wet-deposition valid and invalid sample inventory for National Atmospheric Deposition Program / National Trends Network sites CO89 and CO98 during calendar year 2012.

Sample descriptions	Number of samples by site	
	CO89	CO98
Valid samples with sufficient volume for chemical analysis	28	36
Valid samples with insufficient volume for chemical analysis	3	3
Valid dry collection period	3	3
Dry week quality assurance samples	1	1
Invalid Samples		
Contaminated	12	6
Undefined sample (collector open – unintentionally)	1	1
Extended sampling period (2 weeks)	1	1
Insufficient volume for analysis, non-bulk sample	2	0
Total:	**51**	**51**
Percentage of valid samples for Data Completeness Criterion 1:	**67**	**82**

Table 2. Wet-deposition sample types collected at National Atmospheric Deposition Program / National Trends Network sites CO89 and CO98 during calendar year 2012. [mL, milliliters]

Sample type descriptions	Number of samples by site	
	CO89	CO98
Sample of approximately 35 mL or more	40	41
Trace sample of less than 10 mL with incomplete analyses	5	3
Sample volume less than 35 mL, dilution required	2	3
Totals:	47	47

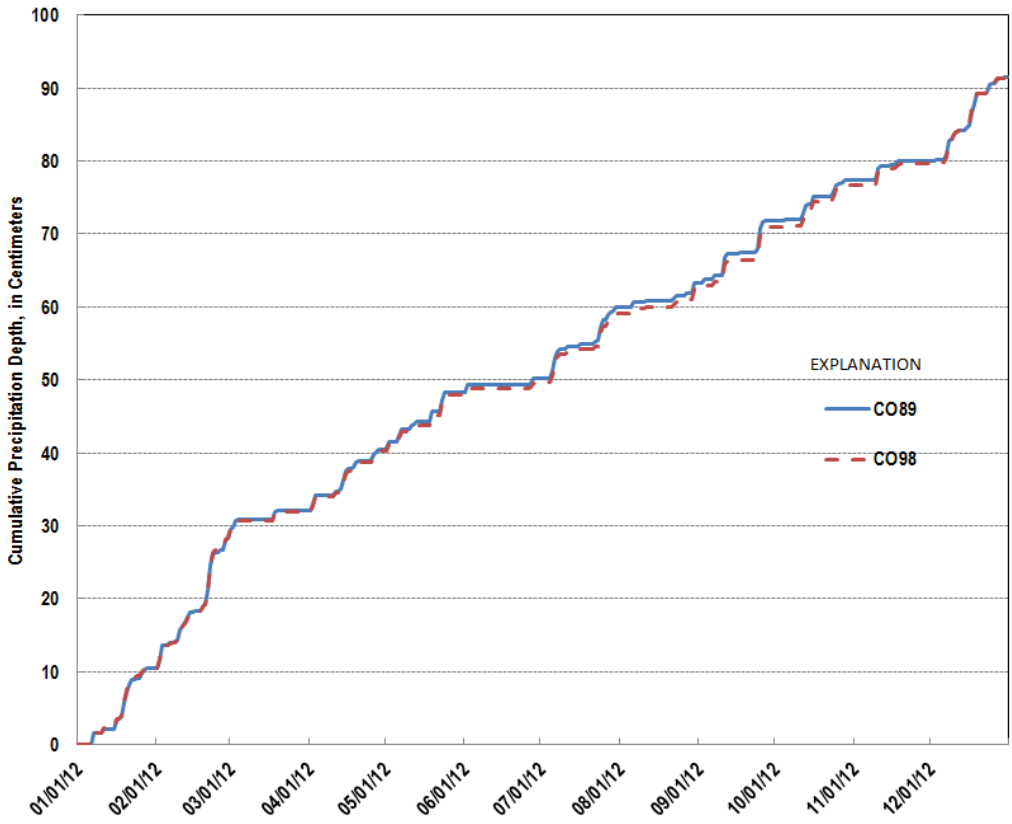

Figure 2. Cumulative daily precipitation depth measured at National Atmospheric Deposition Program / National Trends Network sites CO89 and CO98 during calendar year 2012.

Data Completeness Critierion 3 specifies that there must be valid samples for at least 75 percent of the total precipitation amount reported for the summary period. Table 3 shows the precipitation depths represented by weekly composite wet-deposition samples.

Table 3. Precipitation-depth represented by wet-deposition samples for co-located sites CO89 and CO98 for calendar year 2012.

[NADP/NTN, National Atmospheric Deposition Program / National Trends Network; cm, centimeters]

NADP/NTN site	Precipitation depth represented by weekly wet-deposition samples (cm)	Total measured precipitation depth (cm)	Percentage of total annual precipitation depth represented by weekly wet-deposition samples
CO89	58.3	91.5	64
CO98	77.3	91.4	85

All 2012 data for CO98 meet NADP completeness criteria for inclusion in national wet-deposition maps, whereas CO89 data do not. Approximately 85 percent of the total annual precipitation depth is represented by valid samples for CO98, compared to 64 percent for CO89.

NADP assigns “lab-type” codes to identify weeks with insufficient volumes of wet deposition for chemical analysis. NADP also assigns qualifier codes with the analytical results called “invalcodes”, which provide reasons for flagging samples as invalid. A variety of conditions can cause NADP to invalidate samples, including sample contamination, equipment malfunction and undefined samples. Twelve samples were collected at CO89 and six samples were collected at CO98 that were censored due to field contamination. Undefined samples are collected when equipment malfunctions, resulting in extended periods of “dry exposure”. Table 4 summarizes precipitation depth not represented by NADP samples relative to Data Completeness Criterion 3.

Table 4. Precipitation depths for excluded wet-deposition samples at National Atmospheric Deposition Program / National Trends Network sites CO89 and CO98 during calendar year 2012.

Conditions for sample exclusion	Precipitation depth (centimeters)	
	CO89	CO98
Precipitation depth with insufficient volume for analysis	1.07	0.01
Precipitation depth for extended (14-day) sampling period	3.99	4.39
Precipitation depth sampled but contaminated	24.6	8.64
Precipitation depth sampled with collector in undefined mode[1]	3.56	1.12

[1]Undefined samples are obtained during extended periods of "dry exposure" due to equipment malfunction.

Median absolute percent differences in the co-located measurements describe the overall measurement variability for the CO89/CO98 data (Equation 2). Table 5 lists the ranges of relative differences and the median absolute percent differences for the weekly co-located samples. CO98 concentrations were higher than CO89 for most analytes measured (appendix). The median differences in weekly concentration values were not significantly different from zero based on Wilcoxon signed rank test (α=0.10) results for all analytes except hydrogen-ion. For comparison purposes, results from previous NADP co-located equipment studies (1989-2001) are included in table 5 (Wetherbee and others, 2005).

Table 5. Weekly co-located sampler concentration differences for valid paired samples collected at National Atmospheric Deposition Program / National Trends Network sites CO89 and CO98 during calendar year 2012, results of Wilcoxon signed rank test for significance (shaded values significant at α=0.10), and comparison to results from previous studies at other NADP sites.

[NADP/NTN, National Atmospheric Deposition Program / National Trends Network; mg/L, milligrams per liter; µEq/L, microequivalents per liter; µS/cm, microSiemens per centimeter; mL, milliliters; *p*-value, probability of incorrectly concluding that the median CO98-CO89 difference is not zero.; -- no data]

Analyte (units)	Range of weekly CO98-minus-CO89 relative differences (units)	Median of weekly absolute differences (Percent)	Wilcoxon signed rank test for weekly pairs (*p*-value)	Median absolute differences for 41 co-located sampler sites 1989-2001 (percent)[1]
Calcium (mg/L)	-0.164 to 0.034	14.6	0.1004	13.3
Magnesium (mg/L)	-0.018 to 0.009	16.0	0.2371	11.8
Sodium (mg/L)	-0.076 to 0.010	18.2	0.1933	14.7
Potassium (mg/L)	-0.046 to 0.029	16.7	0.1939	24.4
Ammonium (mg/L)	-0.149 to 0.146	9.1	0.4385	11.3
Chloride (mg/L)	-0.070 to 0.010	8.9	0.6472	5.0
Nitrate (mg/L)	-0.360 to 0.115	8.5	0.5642	10.4
Sulfate (mg/L)	-0.213 to 0.058	10.2	0.4492	4.3
Inorganic Nitrogen (mg/L)	-0.163 to 0.137	6.8	0.3816	--
Hydrogen Ion (from pH, µEq/L)	-2.757 to 2.372	11.0	0.0653	9.2
Specific Conductance (µS/cm)	-2.2 to 0.9	7.7	0.6577	5.9
Sample Volume (mL)	-260 to 281	8.0	<0.0001	3.2

[1]Data obtained from Wetherbee and others, 2005

Annual PWMCs, total deposition values, PWMC differences, and total deposition percent differences with respect to CO98 values (Equation 5) are listed in table 6. PWMCs and total annual deposition amounts were higher for CO98 than for CO89 for most analytes likely due to more complete record at CO98, but not for ammonium, nitrate, total nitrogen and chloride.

Table 6. Annual precipitation-weighted mean concentrations and total deposition values for National Atmospheric Deposition Program / National Trends Network sites CO89 and CO98 during calendar year 2012.

[NADP/NTN, National Atmospheric Deposition Program / National Trends Network; mg/L, milligrams per liter; kg/ha, killograms per hectare; NH_4^+, ammonium ion; NO_3^-, nitrate ion; N, nitrogen; SO_4^{2-}, sulfate ion; μEq/L, microequivalents per liter]

Analyte (units)	Annual precipitation-weighted mean concentration (units)		Annual precipitation-weighted mean concentration differences[1] (percent)	Annual total deposition (kg/ha)		Annual total deposition differences[1] (percent)
	CO89	CO98		CO89	CO98	
Calcium (mg/L)	0.138	0.242	43.0	1.26	2.22	43.2
Magnesium (mg/L)	0.017	0.022	22.7	0.15	0.20	25.0
Potassium (mg/L)	0.017	0.020	15.0	0.16	0.18	11.1
Sodium (mg/L)	0.029	0.035	17.1	0.26	0.32	18.8
Ammonium (mg/L as NH_4^+)	0.185	0.179	-3.4	1.69	1.64	-3.0
Nitrate (mg/L as NO_3^-)	0.597	0.570	-4.7	5.46	5.21	-4.8
Total Nitrogen (mg/L as N)	0.278	0.268	-2.6	2.54	2.45	-5.7
Chloride (mg/L)	0.040	0.039	-7.0	0.37	0.35	-7.1
Sulfate (mg/L as SO_4^{2-})	0.330	0.355	3.7	3.02	3.25	3.7
Hydrogen Ion (μEq/L from pH)	3.986	4.263	6.5	0.04	0.04	0.0

[1]Percent differences calculated as CO98-minus-CO89 divided by CO98 times 100. (Note: this calculation is different from the 2011 NADP report to the National Park Service (U.S. Geological Survey, 2012), where the calculation is relative to CO89. This change was made to show differences relative to the site with the most complete record).

Summary and Conclusions

Measurements of precipitation depths and wet-deposition sample volumes and concentrations were conducted at co-located NADP/NTN monitoring sites CO89 and CO98 at Rocky Mountain National Park, Colorado during 2012. Valid chemical analyses were available for 36 weekly samples for CO98 compared to 28 valid samples for CO89. Daily precipitation-depth records were 100-percent complete for both precipitation gages.

Paired data for daily precipitation depth and weekly sample concentrations were used to evaluate differences in the data collected by the co-located sites. Precipitation-depth differences between the two sites in 2012 were negligible. The median daily precipitation-depth difference was zero centimeters for days with precipitation, and total annual precipitation depths differed by 0.1 percent. Median absolute percent differences in weekly ammonium, nitrate, and sulfate concentrations were 9.1, 8.5, and 10.2 percent, respectively. Median absolute percent difference in weekly hydrogen-ion concentration was 11.0 percent. Median weekly concentration differences for all analytes were not significantly (α=0.1) different from zero except hydrogen ion. The difference in valid wet-deposition sample volume for CO98 compared to CO89 was statistically significant (α=0.1), with CO98 having 8 percent (median) greater volume for calendar year 2012.

Annual precipitation-weighted mean concentration values and total annual deposition values were higher for CO98 compared to CO89 for most analytes. NADP Data Completeness Criteria 1, 2, and 3 were met for CO98, but not for CO89. CO89 data are useful for estimating measurement variability, but not exclusively for estimating total annual wet deposition at Rocky Mountain National Park's Loch Vale site.

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Appendix

Wet-deposition sample analysis data for co-located sites CO89 and CO98 for 2012 obtained from NADP, July 26, 2013; concentrations in milligrams per liter.

[Date On, start of weekly sample collection; Date Off, end of weekly sample collection; Ca, calcium; Mg, magnesium; K, potassium; Na, sodium; NH4, ammonium; NO3, nitrate; Cl, chloride; SO4, sulfate; <, less than method detection limit; pH, negative log of hydrogen-ion molarity; Cond, specific conductance in microSeimens per centimeter; Svol, sample volume in milliliters; RG Precip, rain gage precipitation depth in millimeters; Sub Ppt, sample volume converted to depth substituted for missing weekly RG Precip; --, no data; Lab Types: w=sufficient volume for analysis; wd=dilution necessary to obtain volume for analysis; d=valid dry week; t=valid trace sample with insufficient volume for analysis; Invalcodes: c, contaminated; e, extended sampling period; u, undefined; v, inadequate volume for analysis; wd, diluted sample; Notes: ns, no chemistry data reported due to compromised sample; v, inadequate volume for analysis.

Site	Date On	Date Off	Ca	Mg	K	Na	NH4	NO3	Cl	SO4	pH	Cond	Svol	RG Precip	Sub Ppt	Lab Type	Inval code	Notes
CO89	1/3/2012	1/10/2012	0.008	<0.002	<0.003	0.004	0.026	0.213	<0.009	0.045	5.24	2.3	715.5	15.75	15.748	w		
CO89	1/10/2012	1/17/2012	0.120	0.015	0.013	0.028	0.124	0.598	0.027	0.271	5.28	4.5	194.2	18.54	18.542	w		
CO89	1/17/2012	1/24/2012	0.291	0.040	0.033	0.117	0.112	0.567	0.128	0.350	5.90	4.4	121.8	56.9	56.896	w		
CO89	1/24/2012	1/31/2012	0.223	0.023	0.025	0.051	0.185	0.675	0.061	0.519	5.35	5.5	108.6	13.21	13.208	w		
CO89	1/31/2012	2/7/2012	--	--	--	--	--	--	--	--	--	--	1,167.2	35.56	35.56	w	u	ns
CO89	2/7/2012	2/14/2012	0.045	0.006	0.006	0.014	0.075	0.273	0.016	0.233	5.28	3.7	697.9	37.08	37.084	w		
CO89	2/14/2012	2/21/2012	0.109	0.011	0.008	0.024	0.104	0.622	0.033	0.240	5.21	4.8	282.8	19.81	19.812	w		
CO89	2/21/2012	2/28/2012	--	--	--	--	--	--	--	--	--	--	361.1	74.93	74.93	w	c	ns
CO89	2/28/2012	3/6/2012	--	--	--	--	--	--	--	--	--	--	255.5	37.85	37.846	w	c	ns
CO89	3/6/2012	3/13/2012	--	--	--	--	--	--	--	--	--	--	0	0	0	d		
CO89	3/13/2012	3/20/2012	--	--	--	--	--	--	--	--	--	--	135.4	11.43	11.43	w	c	ns
CO89	3/20/2012	3/27/2012	--	--	--	--	--	--	--	--	--	--	0	0	0	d		
CO89	3/27/2012	4/3/2012	0.319	0.037	0.025	0.066	0.591	0.686	0.056	0.481	6.55	7.1	981.3	20.32	20.32	w		
CO89	4/3/2012	4/10/2012	0.258	0.026	0.011	0.043	0.237	0.462	0.067	0.221	5.88	4.5	28.7	0.51	0.508	wd		
CO89	4/10/2012	4/17/2012	0.148	0.016	0.015	0.021	0.361	0.818	0.043	0.611	5.65	5.4	1,475.9	36.07	36.068	w		
CO89	4/17/2012	4/24/2012	0.087	0.013	0.005	0.009	0.078	0.278	0.023	0.236	5.54	3.1	249.6	11.43	11.43	w		
CO89	4/24/2012	5/1/2012	--	--	--	--	--	--	--	--	--	--	472.1	15.49	15.494	w	c	ns

Site	Date On	Date Off	Ca	Mg	K	Na	NH4	NO3	Cl	SO4	pH	Cond	Svol	RG Precip	Sub Ppt	Lab Type	Inval code	Notes
CO89	5/1/2012	5/8/2012	--	--	--	--	--	--	--	--	--	--	1,103.9	27.94	27.94	w	c	ns
CO89	5/8/2012	5/15/2012	--	--	--	--	--	--	--	--	--	--	511.2	9.65	9.652	w	c	ns
CO89	5/15/2012	5/22/2012	--	--	--	--	--	--	--	--	--	--	765	13.97	13.97	w	c	ns
CO89	5/22/2012	5/29/2012	--	--	--	--	--	--	--	--	--	--	990.6	27.43	27.432	w	c	ns
CO89	5/29/2012	6/5/2012	0.508	0.062	0.120	0.031	0.043	0.657	0.079	0.411	5.80	5.2	596.7	8.89	8.89	w		
CO89	6/5/2012	6/12/2012	--	--	--	--	--	--	--	--	--	--	19.1	0.25	0.254	t	v	
CO89	6/12/2012	6/19/2012	--	--	--	--	--	--	--	--	--	--	0.1	0.51	0.508	t	v	
CO89	6/26/2012	7/3/2012	--	--	--	--	--	--	--	--	--	--	549.3	9.4	9.398	w	c	ns
CO89	7/3/2012	7/10/2012	0.123	0.013	0.025	0.012	0.353	0.993	0.029	0.389	5.42	5.9	2538	39.12	39.116	w		
CO89	7/10/2012	7/17/2012	--	--	--	--	--	--	--	--	--	--	470.3	7.11	7.112	w	c	ns
CO89	7/17/2012	7/24/2012	--	--	--	--	--	--	--	--	--	--	323.9	5.33	5.334	w	c	ns
CO89	7/24/2012	7/31/2012	0.095	0.010	0.012	0.015	0.253	0.855	0.031	0.432	5.22	5.9	2,909.7	44.96	44.958	w		
CO89	7/31/2012	8/7/2012	0.267	0.032	0.025	0.026	0.269	1.310	0.069	0.513	5.18	7.5	557.6	7.62	7.62	w		
CO89	8/7/2012	8/14/2012	0.401	0.038	0.106	0.041	0.661	1.742	0.107	0.848	5.68	9.6	68.9	1.27	1.27	w		
CO89	8/14/2012	8/21/2012	--	--	--	--	--	--	--	--	--	--	4.7	0	0	t		
CO89	8/21/2012	8/28/2012	0.148	0.017	0.034	0.016	0.392	1.141	0.057	0.396	5.15	7	709.6	10.92	10.922	w		
CO89	8/28/2012	9/4/2012	0.220	0.026	0.017	0.027	0.402	1.432	0.057	0.634	5.16	8.5	1,241.6	18.8	18.796	w		
CO89	9/4/2012	9/11/2012	--	--	--	--	--	--	--	--	--	--	385.2	5.59	5.588	w	c	ns
CO89	9/11/2012	9/18/2012	0.100	0.012	0.011	0.010	0.116	0.416	0.023	0.169	5.56	3.1	1,979.2	30.99	30.988	w		
CO89	9/18/2012	9/25/2012	0.198	0.024	0.015	0.039	0.469	1.301	0.095	0.948	4.96	9.7	348.8	6.1	6.096	w		
CO89	9/25/2012	10/2/2012	0.027	0.003	0.003	0.003	0.141	0.330	0.011	0.188	5.39	3.2	2,564.3	37.59	37.592	w		
CO89	10/2/2012	10/9/2012	0.853	0.091	0.070	0.189	0.283	1.590	0.141	0.896	6.50	9.9	60.4	1.52	1.524	w		
CO89	10/9/2012	10/16/2012	0.073	0.009	0.011	0.012	0.110	0.367	0.027	0.261	5.23	3.7	416	20.83	20.828	w		
CO89	10/16/2012	10/23/2012	0.306	0.047	0.036	0.028	0.152	0.562	0.034	0.446	5.76	4.4	395.5	10.67	10.668	w		
CO89	10/23/2012	10/30/2012	0.161	0.018	0.013	0.035	0.103	0.577	0.024	0.457	5.40	4.5	629.1	21.84	21.844	w		
CO89	10/30/2012	11/6/2012	--	--	--	--	--	--	--	--	--	--	0.2	0	0	t		
CO89	11/6/2012	11/13/2012	0.141	0.014	0.013	0.016	0.048	0.255	0.017	0.154	5.70	2.4	288.1	20.83	20.828	w		
CO89	11/13/2012	11/20/2012	0.124	0.011	<0.010	0.014	0.182	0.616	0.041	0.403	5.07	6	21	6.35	6.35	wd		
CO89	11/20/2012	11/27/2012	--	--	--	--	--	--	--	--	--	--	0	0	0	d		
CO89	11/27/2012	12/11/2012	--	--	--	--	--	--	--	--	--	--	149.1	39.88	39.878	w	e	

Site	Date On	Date Off	Ca	Mg	K	Na	NH4	NO3	Cl	SO4	pH	Cond	Svol	RG Precip	Sub Ppt	Lab Type	Inval code	Notes
CO89	12/11/2012	12/18/2012	0.029	0.004	0.011	0.010	0.058	0.167	0.015	0.160	5.44	2.6	469.5	32.77	32.766	w		
CO89	12/18/2012	12/25/2012	0.014	<0.002	<0.003	0.005	0.075	0.367	0.014	0.048	5.41	2.8	1,223.8	32.26	32.258	w		
CO89	12/25/2012	1/1/2013	--	--	--	--	--	--	--	--	--	--	17.9	9.906	9.906	t		v
CO98	1/3/2012	1/10/2012	0.012	<0.002	<0.003	0.003	0.036	0.229	<0.009	0.055	5.27	2.9	731.5	16.51	16.510	w		
CO98	1/10/2012	1/17/2012	0.076	0.009	0.006	0.021	0.101	0.489	0.023	0.201	5.21	3.8	307.8	19.05	19.050	w		
CO98	1/17/2012	1/24/2012	0.127	0.022	0.038	0.041	0.087	0.293	0.058	0.236	5.44	3.9	161.2	57.91	57.912	w		
CO98	1/24/2012	1/31/2012	0.080	0.008	0.008	0.020	0.118	0.376	0.023	0.323	5.18	4.6	174.6	12.19	12.192	w		
CO98	1/31/2012	2/7/2012	0.039	0.004	0.003	0.006	0.199	0.216	0.010	0.075	5.64	2.7	1,084.7	33.53	33.528	w		
CO98	2/7/2012	2/14/2012	0.042	0.005	0.005	0.014	0.074	0.286	0.017	0.244	5.21	3.7	752.3	36.58	36.576	w		
CO98	2/14/2012	2/21/2012	0.106	0.011	0.008	0.022	0.109	0.649	0.032	0.254	5.11	4.9	274.8	18.29	18.288	w		
CO98	2/21/2012	2/28/2012	0.154	0.017	0.014	0.034	0.148	0.329	0.040	0.207	5.75	3.3	306.7	79.5	79.502	w		
CO98	2/28/2012	3/6/2012	0.284	0.031	0.011	0.086	0.048	0.375	0.069	0.242	6.06	3.3	248.4	34.04	34.036	w		
CO98	3/6/2012	3/13/2012	--	--	--	--	--	--	--	--	--	--	0	0	0	d		
CO98	3/13/2012	3/20/2012	6.853	0.364	0.261	0.635	<0.009	0.476	0.096	3.422	7.42	41.7	80	11.43	11.430	w		
CO98	3/20/2012	3/27/2012	--	--	--	--	--	--	--	--	--	--	0	0	0	d		
CO98	3/27/2012	4/3/2012	0.335	0.037	0.025	0.075	0.585	0.688	0.062	0.485	6.56	7.1	993.1	20.07	20.066	w		
CO98	4/3/2012	4/10/2012	0.123	0.027	0.007	0.024	0.088	0.254	0.061	0.079	5.63	3.3	51	0.51	0.508	w		
CO98	4/10/2012	4/17/2012	0.137	0.017	0.014	0.019	0.352	0.787	0.039	0.605	5.34	6.3	1,600.4	36.07	36.068	w		
CO98	4/17/2012	4/24/2012	0.065	0.011	0.004	0.007	0.054	0.224	0.017	0.189	5.54	2.7	283.2	11.94	11.938	w		
CO98	4/24/2012	5/1/2012	--	--	--	--	--	--	--	--	--	--	664.8	15.24	15.240	w	c	ns
CO98	5/1/2012	5/8/2012	--	--	--	--	--	--	--	--	--	--	1,384.6	25.91	25.908	w	c	ns
CO98	5/8/2012	5/15/2012	--	--	--	--	--	--	--	--	--	--	491.2	8.89	8.890	w	c	ns
CO98	5/15/2012	5/22/2012	0.952	0.090	0.059	0.110	0.195	1.207	0.120	0.696	6.38	9	787.1	13.97	13.970	w		
CO98	5/22/2012	5/29/2012	--	--	--	--	--	--	--	--	--	--	1,248.1	27.43	27.432	w	c	ns
CO98	5/29/2012	6/5/2012	0.532	0.060	0.074	0.041	0.189	0.764	0.085	0.469	6.06	6.1	648.3	8.89	8.890	w		
CO98	6/5/2012	6/12/2012	--	--	--	--	--	--	--	--	--	--	0	0	0	d		
CO98	6/12/2012	6/19/2012	--	--	--	--	--	--	--	--	--	--	40.8	0.51	0.508	wd	c	ns
CO98	6/26/2012	7/3/2012	--	--	--	--	--	--	--	--	--	--	552.9	8.38	8.382	w	c	ns
CO98	7/3/2012	7/10/2012	0.129	0.013	0.026	0.012	0.369	1.016	0.030	0.397	5.48	5.9	2,658.8	38.1	38.1	w		

Site	Date On	Date Off	Ca	Mg	K	Na	NH4	NO3	Cl	SO4	pH	Cond	Svol	RG Precip	Sub Ppt	Lab Type	Inval code	Notes
CO98	7/10/2012	7/17/2012	0.262	0.028	0.060	0.022	0.760	2.333	0.090	1.021	5.02	13	574.1	7.11	7.112	w		
CO98	7/17/2012	7/24/2012	0.365	0.034	0.025	0.044	0.501	2.198	0.083	1.017	4.90	13	347.5	4.57	4.572	w		
CO98	7/24/2012	7/31/2012	0.110	0.013	0.018	0.016	0.260	0.876	0.033	0.435	5.18	6	3,008.2	44.2	44.196	w		
CO98	7/31/2012	8/7/2012	0.301	0.035	0.018	0.028	0.283	1.419	0.075	0.568	5.14	8.1	593.2	7.62	7.62	w		
CO98	8/7/2012	8/14/2012	0.369	0.041	0.118	0.043	0.683	1.835	0.117	0.887	5.65	9.9	108.1	1.52	1.524	w		
CO98	8/14/2012	8/21/2012	--	--	--	--	--	--	--	--	--	--	5.8	0	0	t		
CO98	8/21/2012	8/28/2012	0.157	0.017	0.030	0.012	0.408	1.207	0.053	0.412	5.14	7.1	718.1	10.41	10.414	w		
CO98	8/28/2012	9/4/2012	0.231	0.035	0.046	0.029	0.358	1.483	0.064	0.652	5.08	8.8	1,262.1	18.8	18.796	w		
CO98	9/4/2012	9/11/2012	0.498	0.06	0.035	0.052	0.485	1.648	0.101	1.142	5.66	9.4	414.6	5.59	5.588	w		
CO98	9/11/2012	9/18/2012	0.128	0.014	0.013	0.013	0.127	0.526	0.031	0.214	5.56	3.5	2,025.5	30.23	30.226	w		
CO98	9/18/2012	9/25/2012	0.227	0.029	0.016	0.038	0.482	1.416	0.100	0.958	5.08	9.8	377.4	6.1	6.096	w		
CO98	9/25/2012	10/2/2012	0.026	0.003	0.004	0.003	0.145	0.336	0.011	0.191	5.32	3.3	2,586.2	38.1	38.1	w		
CO98	10/2/2012	10/9/2012	0.818	0.085	0.064	0.198	0.267	1.489	0.129	0.826	6.5	9.2	87.6	1.78	1.778	w		
CO98	10/9/2012	10/16/2012	0.043	0.005	0.006	0.010	0.123	0.302	0.023	0.226	5.27	3.4	502.6	22.61	22.606	w		
CO98	10/16/2012	10/23/2012	--	--	--	--	--	--	--	--	--	--	526.9	11.18	11.176	w	u	ns
CO98	10/23/2012	10/30/2012	0.125	0.013	0.012	0.031	0.086	0.472	0.025	0.353	5.28	3.9	678.3	22.35	22.352	w		
CO98	10/30/2012	11/6/2012	--	--	--	--	--	--	--	--	--	--	0.6	0	0	t		
CO98	11/6/2012	11/13/2012	0.076	0.008	0.005	0.010	0.037	0.190	0.015	0.115	5.66	2.1	303.2	22.1	22.098	w		
CO98	11/13/2012	11/20/2012	0.076	<0.006	<0.010	0.009	0.104	0.256	0.042	0.19	5.24	3.8	30.5	6.86	6.858	wd		
CO98	11/20/2012	11/27/2012	--	--	--	--	--	--	--	--	--	--	0.4	0	0	t		
CO98	11/27/2012	12/11/2012	--	--	--	--	--	--	--	--	--	--	190.7	43.94	43.942	w	e	
CO98	12/11/2012	12/18/2012	0.021	0.002	0.006	0.006	0.058	0.136	<0.009	0.159	5.29	2.8	556.9	37.34	37.338	w		
CO98	12/18/2012	12/25/2012	0.020	0.002	<0.003	0.007	0.090	0.410	0.016	0.063	5.43	2.9	963.5	28.45	28.448	w		
CO98	12/25/2012	1/1/2013	0.226	0.023	0.020	0.071	0.098	1.836	0.088	0.438	4.70	14	22.4	8.64	8.636	wd	wd	