2015

Clean Air Status and Trends Network Five Year Network Assessment

Clean Air Markets Division

Office of Atmospheric Programs

US Environmental Protection Agency

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Five Year Network Assessment

1. Introduction

A. Purpose

Monitoring agencies that submit data to the U.S. Environmental Protection Agency (EPA) for regulatory purposes are required to conduct an assessment of their air quality surveillance system once every five years (40 CFR Part 58.10). The EPA has adapted these requirements to conduct this assessment for the Clean Air Status and Trends Network (CASTNET). The purpose of the assessment is to determine, at a minimum, if the network meets the monitoring agencies' objectives. The focus of this assessment is on the CASTNET ozone (O_3) monitoring program from 2012 to 2014, reflecting the 2011 network enhancements in accordance with federal regulatory requirements. The assessment includes a review of the network's effectiveness in reporting trends and regional concentrations of O_3 and recommendations to improve network performance as CASTNET adapts to meet agency objectives.

B. CASTNET Objectives

CASTNET is a long-term monitoring network designed to measure regionally representative concentrations of acidic pollutants, base cations, chloride (Cl^-), and ambient O_3. The Environmental Protection Agency – Clean Air Markets Division (EPA), the National Park Service – Air Resources Division (NPS), and the Bureau of Land Management – Wyoming State Office (BLM-WSO) collaboratively manage and operate CASTNET. In addition to EPA, NPS, and BLM-WSO, numerous other participants including Tribes, other federal agencies, States, private land owners, and universities provide network support. CASTNET monitors provide critically important, regionally representative data used to provide air quality trends, estimate background O_3 concentrations, and evaluate air quality models in the absence of local emissions (Cooper et al., 2012; Fiore et al., 2002; Lin et al., 2012; Rieder et al., 2013; Zhang et al., 2011; Zoogman et al., 2014). Additionally, CASTNET data are used to evaluate the effectiveness of national and regional emission reduction control programs, gauge compliance with National Ambient Air Quality Standards (NAAQS), and provide input into regional air quality and total deposition models.

CASTNET currently operates 93 monitoring stations throughout the contiguous United States, Alaska, and Canada. EPA operates 63 CASTNET monitoring stations, NPS operates 25 CASTNET stations, and BLM-WSO operates five CASTNET stations. More than 25 years of consistent, long-term measurements reported by CASTNET demonstrate reductions in O_3, nitrogen, and sulfur concentrations throughout the United States. Additionally, continuous trace-level gas monitoring for sulfur dioxide (SO_2), nitrogen oxide/total reactive oxides of nitrogen (NO/NO_Y), and carbon monoxide (CO) is ongoing at four, eight, and three CASTNET sites, respectively.

CASTNET's three operating agencies, EPA, NPS, and BLM-WSO coordinate their resources to fulfill the following goals:

- monitor the status and trends in regional air quality and atmospheric deposition;
- provide information on the contribution of atmospheric pollution to ecosystem conditions; and
- provide measurements for validating and improving atmospheric models

Each operating agency also utilizes CASTNET to fulfill their own monitoring objectives. Specific examples are described below.

EPA utilizes CASTNET measurements to provide air pollutant concentration data to evaluate the effectiveness of national and regional emission reduction programs and to determine compliance with O_3 NAAQS. EPA uses these data to provide consistent, long-term measurements for determining relationships between changes in emissions and subsequent changes in air quality, atmospheric deposition, and ecological effects. Under Title IV of the Clean Air Act Amendments (CAAA), the Acid Rain Program (ARP) was promulgated to reduce emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from electric generating units (EGUs). A critical component of the CAAA required CASTNET to assess and track real-world environmental results as the ARP was implemented and emissions were reduced.

The NPS uses CASTNET monitoring data to assess environmental conditions and trends in O_3, sulfur and nitrogen deposition. Coupled with special studies data, this information allows the NPS to understand how air pollutants are currently impacting park air quality and air quality related values (AQRVs). These data help the NPS and the public understand which parks are at highest risk for impacts, and where conditions of park air quality and AQRVs are declining or improving. Specifically, ambient measurements of O_3, NO_x and SO_2 concentrations, deposition, and effects on visibility, soils, waters, and plants are critical components of periodic assessments. For example, O_3 and vegetation data from Sequoia and Yosemite NPs have been used to document the concentrations at which O_3 pollution causes damage to Ponderosa pine trees.

The BLM-WSO uses CASTNET data to identify air quality concerns and evaluate air strategy effectiveness. These data also fulfill air monitoring commitments in Resource Management Plans (RMPs) and Records of Decisions (RODs). Lastly, CASTNET data provide necessary information to assess existing conditions, impacts of federal actions, and long-term trends in air quality and deposition on BLM land.

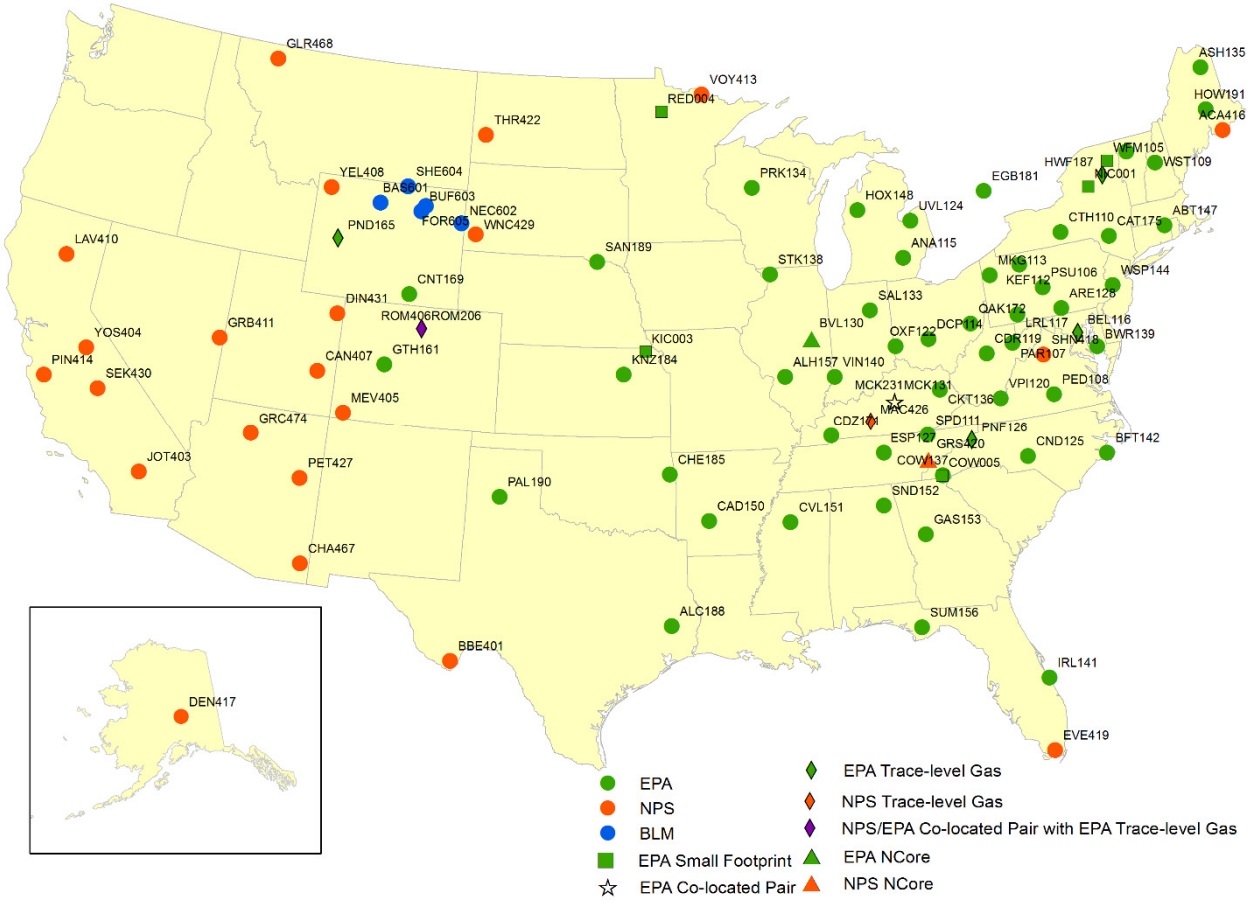
While these CASTNET monitoring objectives go beyond the scope of this assessment, they are provided here in brief to illustrate the utility and breadth of the data generated by CASTNET. In this assessment we provide an overview of the CASTNET monitoring program, the sponsoring agencies' objectives for the regulatory O_3 monitoring program, O_3 trends and annual results, quality assurance metrics, and the future outlook for the program.

C. Network Overview

CASTNET was established under the 1990 CAAA, expanding the National Dry Deposition Network (NDDN), which began in 1987. NPS began its participation with CASTNET in 1994 under an agreement with EPA. With the involvement of NPS, the network became a national, rather than a primarily eastern, network. BLM-WSO began participation in CASTNET in late 2012, with additional coverage provided in Wyoming. CASTNET was designed to provide measurements for determining relationships between changes in emissions and subsequent changes in air quality, atmospheric deposition, and ecological effects. To meet those goals, CASTNET site locations were selected in rural areas to provide regionally representative concentrations and estimates of dry deposition fluxes. CASTNET has historically used the Multi-Layer Model (MLM) to estimate dry deposition fluxes using measured concentrations, on-site meteorology and site characteristics, including land use and vegetation, as input. The CASTNET filterpack

measurements provide weekly concentrations of gaseous sulfur dioxide (SO_2) and nitric acid (HNO_3), and particulate sulfate (SO_4^{2-}), nitrate (NO_3^-), ammonium (NH_4^+), base cations (Ca^{2+}, K^+, Mg^{2+}, Na^+), and chloride (Cl^-). A single laboratory, operated under contract to the EPA, analyzes the filterpack samples for all CASTNET sites. Figure 1 shows the locations of all CASTNET monitoring sites. Circles represent sites operating a filterpack and a continuous O_3 monitor. Continuous O_3 concentrations are measured at 79 sites. Diamonds represent sites with trace gas monitors operated by EPA or NPS. Sites at Bondville, IL (BVL130) and Great Smoky Mountains National Park – Look Rock, TN (GRS420) are NCore sites with trace gas NO/NOy, SO_2, and CO. Additionally, there are five EPA sites that operate filterpack only sites, represented by a square on the map in Figure 1 (EPA Small Footprint Sites). These are sites without a temperature-controlled monitoring shelter. Thirty six CASTNET sites measure hourly meteorological parameters including all NPS sites, all BLM-WSO sites, and six EPA sites. Additional information and data from the CASTNET monitoring program can be found on the CASTNET website at http://www.epa.gov/castnet.

Figure 1. Map of CASTNET sites (May 2015). EPA-sponsored sites are green, NPS-sponsored sites are orange and BLM-sponsored sites are blue. CASTNET sites with filter pack and ozone monitoring are circles. CASTNET small footprint, filterpack-only sites are squares. Sites that also report trace gas data are represented by triangles (NCore) and diamonds.



D. CASTNET Partners

In addition to EPA, NPS, and BLM, numerous other participants including Tribes, other federal agencies, States, private land owners, and universities provide network support (Table 1). CASTNET partners may provide local operational support, space for shelters and equipment, or scientific expertise. The EPA contractor, AMEC Foster Wheeler (AMEC), manages the day-to-day operations for the EPA-sponsored sites while the NPS and BLM contractor, Air Resource Specialists, Inc. (ARS), manages the operations for the remaining sites.

Table 1. CASTNET Program Partners

Program Partners		
Federal	**State/Local/Tribal**	**University**
Allegheny National Forest (NF) Apalachicola NF Environment Canada Gunnison NF Holly Springs NF Hubbard Brook Experimental Forest Medicine Bow-Routt NF Monongahela NF Nantahala NF National Park Service (NPS) United States Army Engineering District/Louisville US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) USDA Agricultural Research Center (ARS) USDA Southern Research Station Coweeta Hydrological Lab US Fish & Wildlife Service USDA- Forest Service (FS) Timber & Watershed Lab USDA-FS Forestry Sciences Laboratory USDA-FS Rocky Mountain Research Station USDA-FS Toecane District US Department of Interior (DOI)-Bureau of Land Management White Mountain NF	Alabama-Coushatta Tribe of Texas Cedar Creek State Park WV Division of Natural Resources Cherokee Nation Cumberland St. Forest VA Department of Forestry Deer Creek State Park OH Dept. of Natural Resources (DNR) Edgar Evans State Park TN Dept. of Environmental Conservation (DEC) Laurel Hill State Park PA Dept. of Conservation & Natural Resources (DCNR) ME Dept. of Environmental Protection (ME DEP) Maurice K. Goddard State Park (PA DCNR) New York DEC ND Department of Health NYS Energy Research & Development Authority Rocky Mountain Biological Laboratory Santee Sioux Tribe of Nebraska St. Johns River Water Management District SD Dept. of Environmental & Natural Resources (SD DENR) Vermont DEC Washington Crossing State Park (NJ DEP)	Auburn University Alabama Agricultural Experiment Station Cornell University, Ecology & Evolutionary Biology KS State University (KSU) Division of Biology/Konza Prairie Long-term ecological research (LTER) Miami University Institute for the Environment & Sustainability Ouachita Baptist University School of Natural Sciences Pennsylvania State University (PSU) Fruit Research & Extension Center PSU Department of Meteorology Proctor Maple Research Center (UVM) Purdue University Department of Agronomy State University of NY (SUNY) ESF Adirondack Ecology Center Texas A&M Agrilife Research & Extension Center University of GA, College of Agriculture & Environmental Science University of IL, Illinois State Water Survey University of Maine Plant, Soil & Environmental Science University of MD Department of Atmospheric & Oceanic Science University of Michigan School of Natural Resources University of NC Institute of Marine Sciences VA Tech Department of Plant Pathology, Physiology & Weed Science

E. CASTNET Ozone Monitoring Program

CASTNET operates 93 monitoring sites throughout the US and Canada and 79 of those sites measure ground-level, continuous O_3 following the regulations in the 40 Code of Federal Regulations (CFR) Part 58 and EPA's "Quality Assurance Handbook for Air Pollution Measurement Systems: Volume II: Ambient Air Quality Monitoring Program" (US EPA, 2013a). CASTNET O_3 monitors are located in 37 States with at least one CASTNET O_3 monitor in each of the ten EPA Regions. Three CASTNET O_3 sites are located on Tribal Lands including Santee Sioux, NE (SAN189), Cherokee Nation, OK (CHE185), and Alabama-Coushatta, TX (ALC188).

Figure 2 shows the location of CASTNET monitoring sites reporting regulatory O_3 data to EPA's Air Quality System (AQS) database. These sites meet the siting criteria described in 40 CFR Part 58 Appendix E. Most CASTNET ozone monitoring sites are used for regulatory purposes; however, the EPA-sponsored Rocky Mountain National Park, CO (ROM206) and Mackville Collocated, KY (MCK231) sites are operated for the purpose of network quality assurance (QA) and are designated as '*NAAQS Excluded*' within AQS. The Howland, ME (HOW191) site does not meet the siting criteria requirements in 40 CFR Part 58 Appendix E and is operated as a special study site (see Figure 1). Ozone data from HOW191 are not reported to AQS. Additional information about CASTNET siting criteria can be found in the Quality Assurance Project Plan version 8.2 at http://java.epa.gov/castnet/documents.do (AMEC, 2014b).

Figure 2. CASTNET Regulatory Ozone Monitors (May 2015)

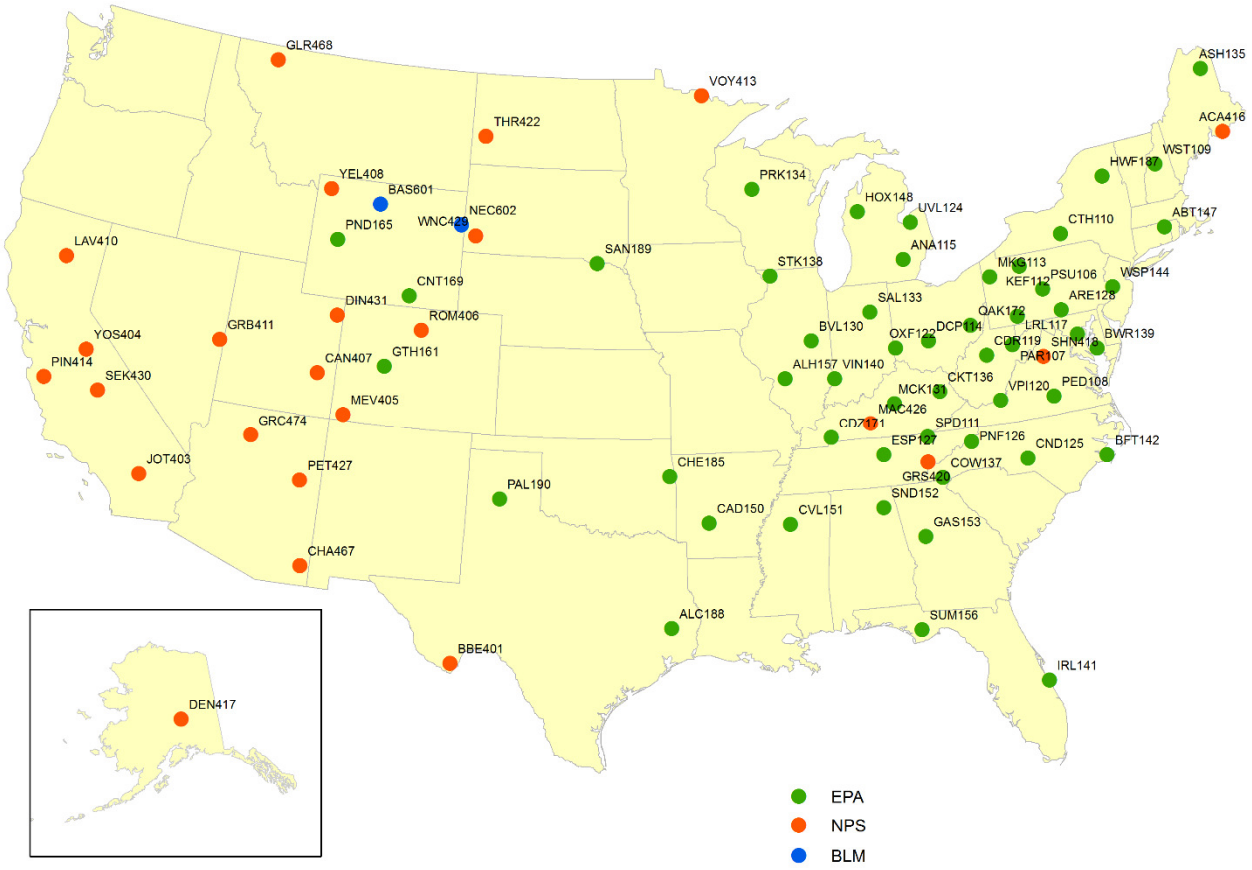


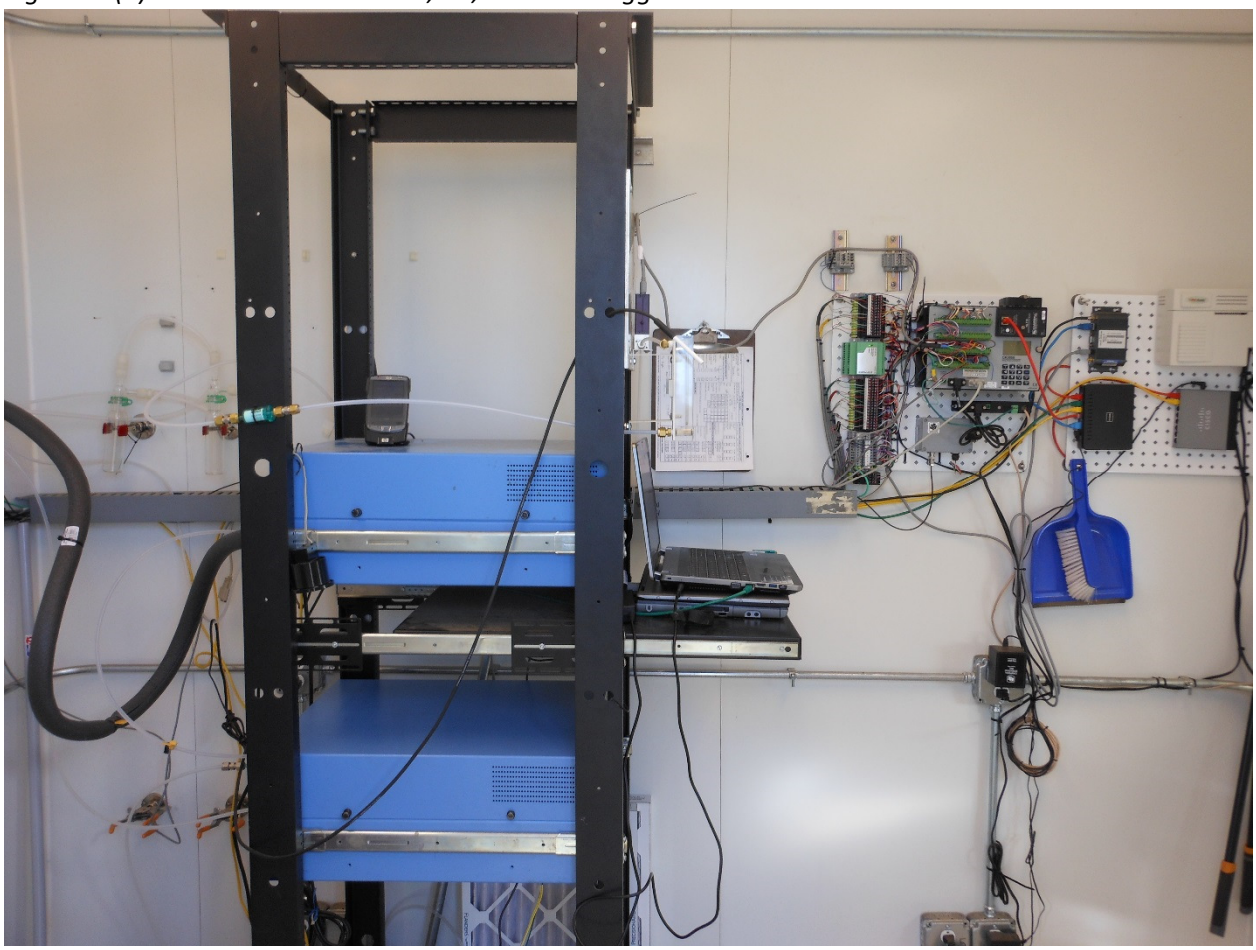
Figure 3 shows photographs of the typical configuration of a CASTNET site with the full suite of monitoring equipment including the temperature controlled shelter, and 10-m tipping tower. The O_3 inlet is located within the rain shield at the top of the 10-m tipping tower which also houses the CASTNET filter pack. Two NPS-sponsored CASTNET sites, Wind Cave National Park, SD (WNC429) and Theodore Roosevelt National Monument, ND (THR422), have O_3 inlet heights at 3.35 m and 12.2 meters, respectively. Ambient temperature is measured at every CASTNET site.

CASTNET O_3 analyzers, site transfer standards, data loggers, and computers are located within a temperature controlled shelter. The data logger can be operated remotely to run manual quality assurance (QC) checks, review status flags, or recover missing data. Each on-site transfer standard has been verified against a National Institute of Standards and Technology (NIST) -traceable Level II transfer standard.

Figure 3. (a) CASTNET monitoring site

Pinedale, WY (PND165)

Figure 3. (b) Ozone instrumentation, PC, and data logger inside a CASTNET shelter



Palo Duro, TX (PAL190)

F. Network Modifications for Regulatory Ozone Monitoring

The National Park Service established their regulatory O_3 monitoring program prior to 1990. The transition to regulatory status for EPA-sponsored CASTNET sites was completed in 2011, when all O_3 analyzers were replaced with Thermo Scientific™ Model 49i's, Thermo Scientific™ Model 49i's with onboard O_3 generators were installed as on-site transfer standards, and the QA/QC procedures were implemented to comply with the requirements in 40 CFR Part 58. CASTNET uses the monitoring quality objectives from the Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Appendix D (US EPA, 2013a) to ensure that the highest quality data are being submitted to EPA's Air Quality System (AQS) database. The upgrades to the CASTNET O_3 program have improved the overall quality of data, reliability of the analyzers, and comparability of the data with other regulatory monitoring networks (e.g., State and Local Air Monitoring Sites (SLAMS)). On-going improvements to site equipment and infrastructure are posted to the individual CASTNET site information pages (http://java.epa.gov/castnet/epa_jsp/sites.jsp).

Prior to being used for regulatory monitoring, zero, span, and precision (ZSP) checks of the O_3 analyzer at EPA-sponsored sites were performed every week; now all sites perform ZSP checks daily. In addition to the daily ZSP QC checks, technicians perform semi-annual system checks at each CASTNET site. During these semi-annual visits, technicians audit the on-site analyzer, reverify the on-site transfer standard, calibrate the on-site analyzer to the traveling transfer standard (Level 2) as needed, and verify the responses of the data logger and shelter temperature probe with NIST-traceable standards. All on-site O_3 transfer standards at CASTNET sites are NIST-traceable at Level 3. Audit results are used to perform the final validation on the hourly O_3 data and validated data are submitted to the sponsoring agency.

Prior to 2011, all CASTNET sites were visited once every other year by an independent auditor (Audit Agency) to verify equipment was working properly and data were consistent across the network. As required by 40 CFR Part 58 Appendix A, an annual Performance Evaluation (PE) is now conducted at each CASTNET O_3 site by an independent Audit Agency. For most CASTNET sites the Audit Agency is Environmental Engineering & Measurement Services (EE&MS); however, some States act as an Audit Agency and perform PEs at CASTNET sites.

The validated hourly O_3 concentrations are submitted monthly to AQS by the sponsoring agency's contractor. Additionally, the daily 1-point precision checks are submitted quarterly to AQS for each site. PE results are submitted to AQS routinely by the designated Audit Agency. A subset of the CASTNET partners act as the principal quality assurance organizations (PQAOs) – a unique role where States and Tribes collect and own O_3 data at CASTNET sites. This subset includes Acadia National Park, ME (ACA416) submitted by Maine Department of Environmental Protection, Wind Cave National Park, SD (WNC429) submitted by South Dakota Department of Environment and Natural Resources, Cherokee Nation, OK (CHE185) submitted by Cherokee Nation Clean Air Program, and Theodore Roosevelt National Monument, ND (THR422) submitted by North Dakota Department of Health.

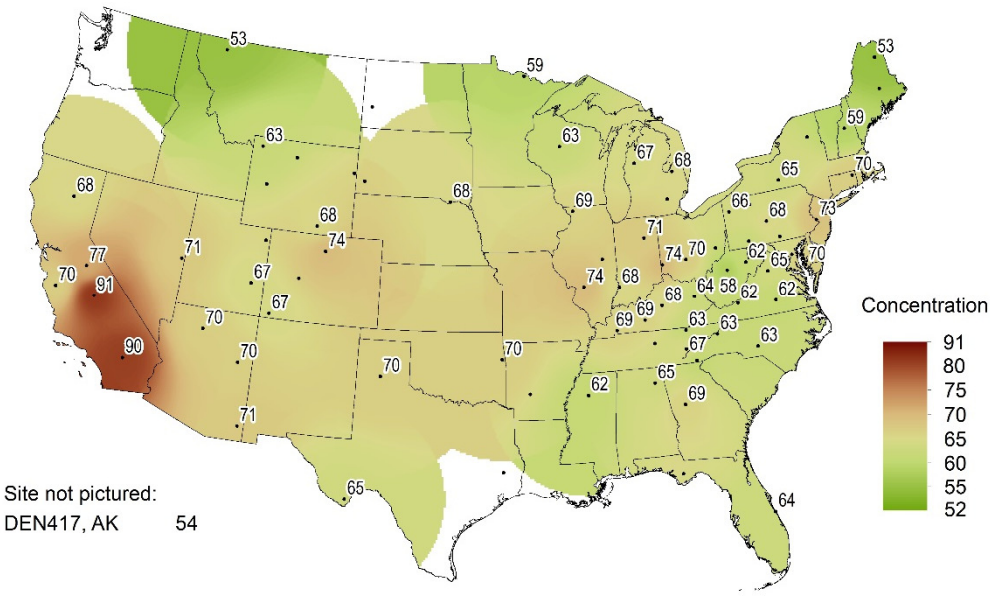
2. Monitoring Results

A. Ambient Ozone Concentrations

CASTNET data provides an assessment tool for quantifying the improvements in air quality due to regional and national emission reduction programs (e.g., the NOx Budget Trading Program, Clean Air Interstate Rule, and Cross State Air Pollution Rule).

Ozone concentrations from CASTNET are used to gauge compliance with the primary NAAQS. Design values are used to designate and classify nonattainment areas, as well as to assess progress towards meeting the NAAQS. The design values are based on the 3-year average of the fourth highest daily maximum 8-hour average. Figure 4 depicts the 2012-2014 fourth highest daily maximum 8-hour O_3 average for all sites that met the completeness criteria (40 CFR Part 50, Appendix I). Ozone concentrations are not included (shown as dots with no value) if the 3-year average was not available because of incomplete data. In this map, exceptional events are not excluded because AQS data flags for exceptional events that occurred in 2014 are not required to be submitted until July 1, 2015 (40 CFR Part 50.14). In 2012-2014, three sites exceeded the primary O_3 standard of 75 ppb.

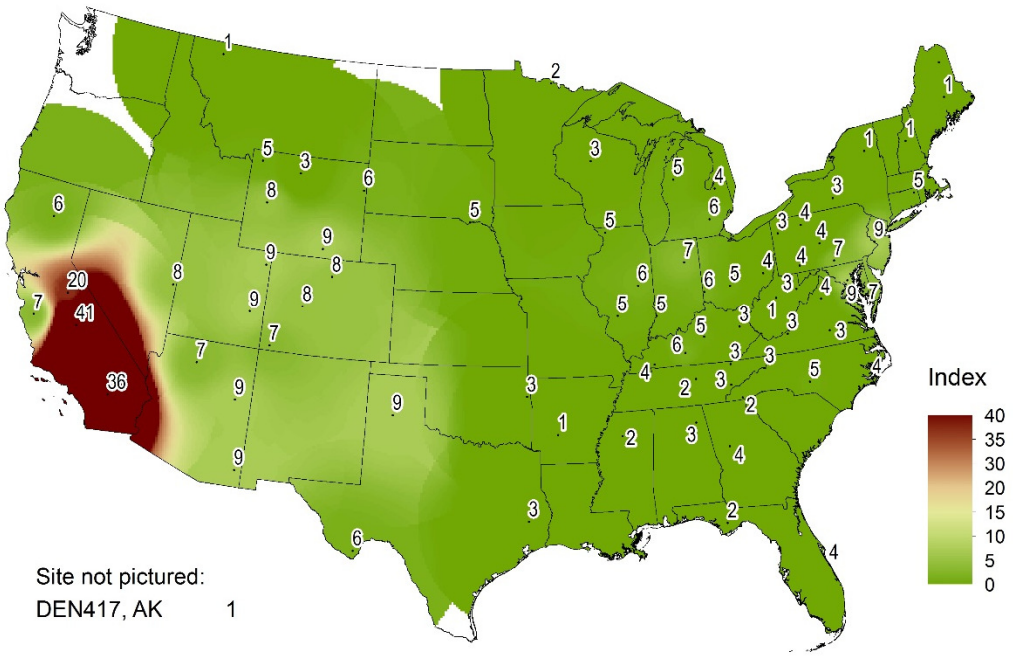
Figure 4. Map of 2012-2014 fourth highest daily maximum 8-hour ozone average



B. W126

CASTNET also provides a unique dataset for evaluating the secondary NAAQS, which protect against vegetation-related effects and other deleterious impacts to public welfare. The secondary O_3 NAAQS is currently set equal to the primary NAAQS. While the secondary NAAQS is currently set equal to the primary NAAQS, the W126 index is often used to relate vegetation loses, such as reduced crop yield, foliar injury, and decreased biomass accumulation, with O_3 exposure. The W126 index is a cumulative metric that sums weighted hourly O_3 concentrations during the O_3 season. The W126 is reported as the maximum weighted monthly average during three consecutive months in the growing season when daytime O_3 concentrations are the highest and plant growth is most likely to be affected. CASTNET sites are located in rural areas and often in sensitive ecosystems where vegetation related effects are significant. Figure 5 shows the W126 values from CASTNET sites in 2014.

Figure 5. Maximum W126 value for 2014



C. Ozone Trends

For the purpose of reporting long-term regional trends, CASTNET sites are labeled as “western” or “eastern” depending on whether they are west or east of 100 degrees west longitude (Figure 6). Eastern long-term sites have been operating since at least 1990, while Western long-term sites have been operating since at least 1996.

Figure 6. CASTNET Western and Eastern Reference Sites

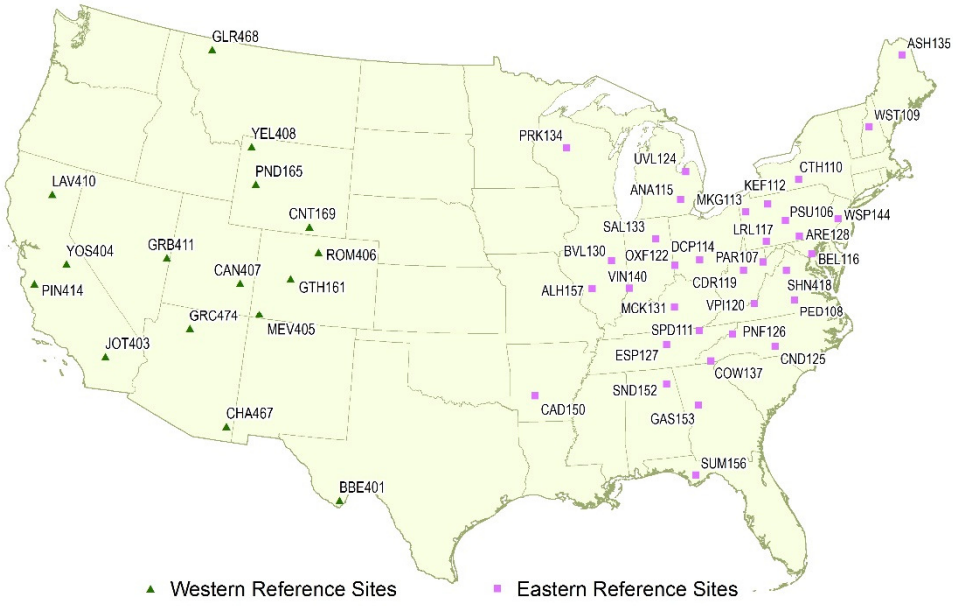
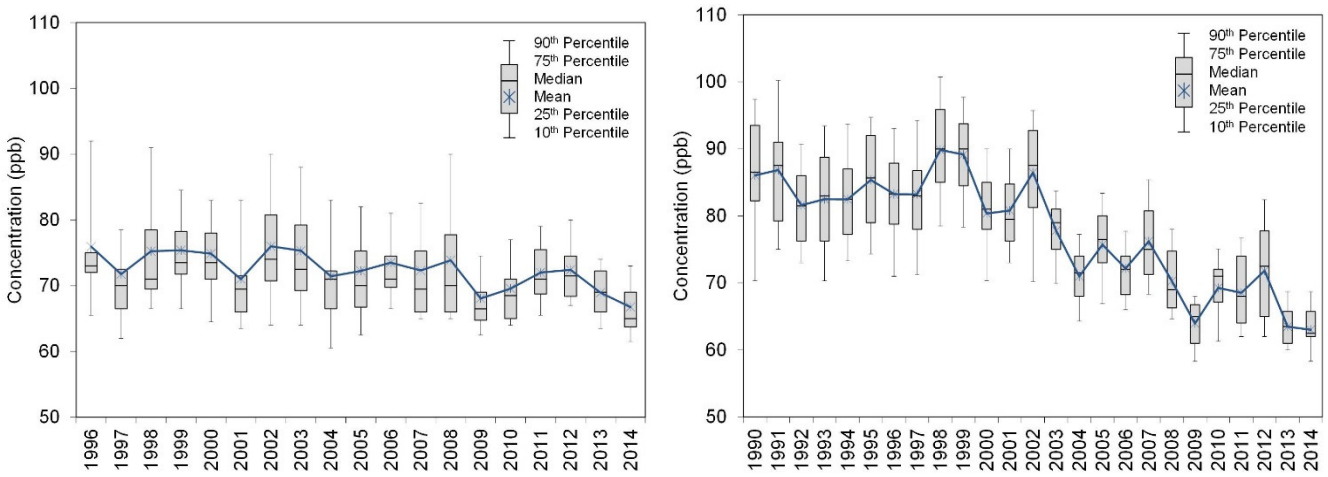


Figure 7 shows the hourly trends in ambient O_3 concentrations from 1990-2014 (eastern sites) and 1996-2014 (western sites). Hourly O_3 data from the 34 Eastern reference sites show an overall reduction in concentrations since 2002. The Eastern reference sites realized a 22% reduction between 2000-2002 and 2012-2014. In 2014, the median fourth highest daily maximum 8-hour average for the Eastern reference sites was 62.5 ppb, the lowest level in the history of the network. The western reference sites do not show the same dramatic reductions in O_3 concentrations. There was a 5% reduction in O_3 concentrations as measured by the Western reference sites between 2000-2002 and 2012-2014. In 2014, the median fourth highest daily maximum 8-hour average was 65 ppb at the 16 western reference sites.

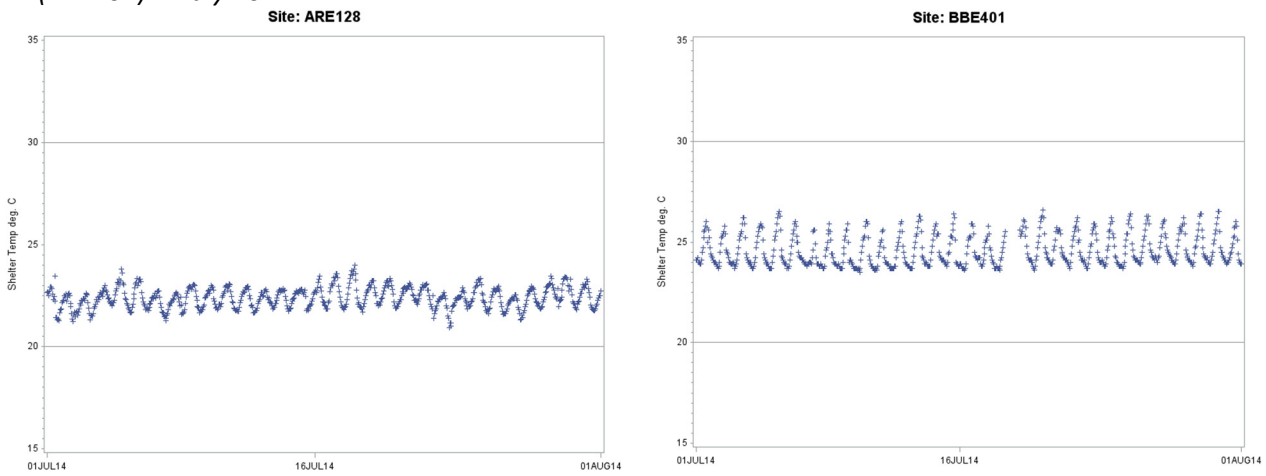
Figure 7. Annual trends in hourly ozone concentrations from the eastern (right) and western (left) CASTNET sites.



D. Shelter Temperature

Continuous gas analyzers are designed to operate within a specific temperature range. EPA guidance recommends that shelter temperatures should be maintained at 20°C to 30°C with a standard deviation of ± 2°C over a 24 hour period; however, a larger temperature range may be acceptable depending on the model of the analyzer (US EPA, 2013a). Shelter temperature is measured continuously at all CASTNET sites submitting O_3 data to AQS and are polled hourly using the on-site data logger. Examples of hourly shelter temperature measurements from July 2014 are shown in Figure 8. Daily review of the O_3 concentration data includes verifying that the shelter temperature is within the recommended range and additional review of O_3 data is required when it is not. During the ozone seasons of 2012-2014, the network met the shelter temperature criteria approximately 88 percent of the time. Field notes from the independent site auditor's Technical System Audit (TSA) reports indicated that most of the failures observed were due to the site's shelter temperature sensors having slow response times as the shelter heating and cooling systems cycled on and off (EE&MS, 2013).

Figure 8. Hourly shelter temperature measured at Arendtsville, PA (ARE128) and Big Bend National Park, TX (BBE401) in July 2014.



In an effort to provide more stable shelter temperatures and improve data capture efficiency, EPA plans to upgrade the heating and cooling systems at approximately 40 sites in 2015. The upgrade will include re-wiring and replacement of the site shelter thermostat with solid state relays controlled by the data logger at the site, which will allow remote monitoring and control of the heating and cooling systems.

3. Quality assurance

A. Overview

The purpose of the CASTNET quality assurance (QA) program is to ensure that all reported data are of known and documented quality in order to meet the CASTNET objectives and to be reproducible and comparable with data from other monitoring networks. The CASTNET QA program is managed by an independent QA Manager and Project QA Supervisor. The QA manager routinely performs internal systems audits, reviews concentration and audit data, and prepares QA reports to management.

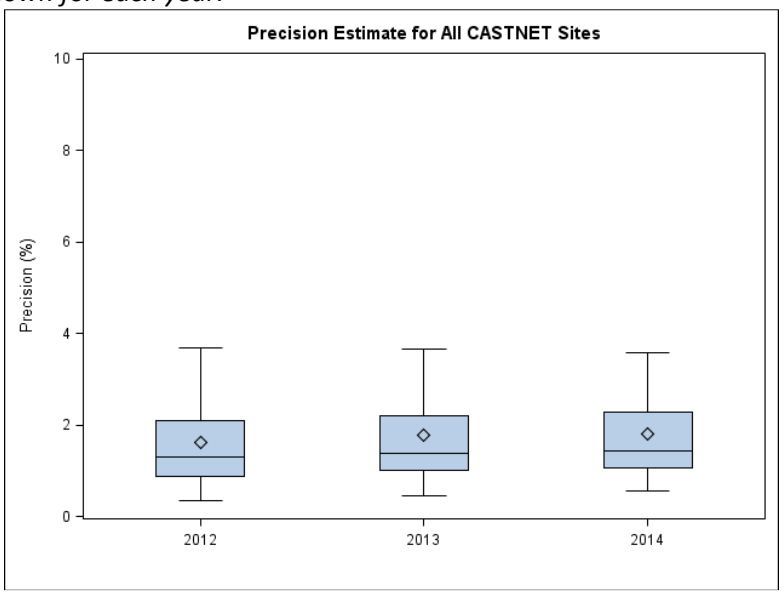
The CASTNET QAPP revision 8.2 (AMEC, 2014b) is comprehensive and covers all aspects of the monitoring program. The QAPP is reviewed and updated by the contractor annually. Details on field, data, and laboratory operations, training, SOPs, system audits, and reporting are examples of information that can be found in the QAPP (http://java.epa.gov/castnet/documents.do).

CASTNET data quality indicators include precision, accuracy, bias, completeness, representativeness, and comparability. CASTNET data are evaluated against the data quality indicators (DQI) and the QA results are reported quarterly and annually to assess overall measurement uncertainty (AMEC, 2013; 2014a; 2015). The CASTNET contractor reports the O_3 precision, as calculated by results from the 1-point QC checks, by site in the quarterly QA report. The accuracy and bias of each O_3 monitor is reported by the independent auditor and summarized in the Audit Program Annual Report (EE&MS, 2015). A summary of the DQIs presented in the quarterly reports is included below.

B. Precision

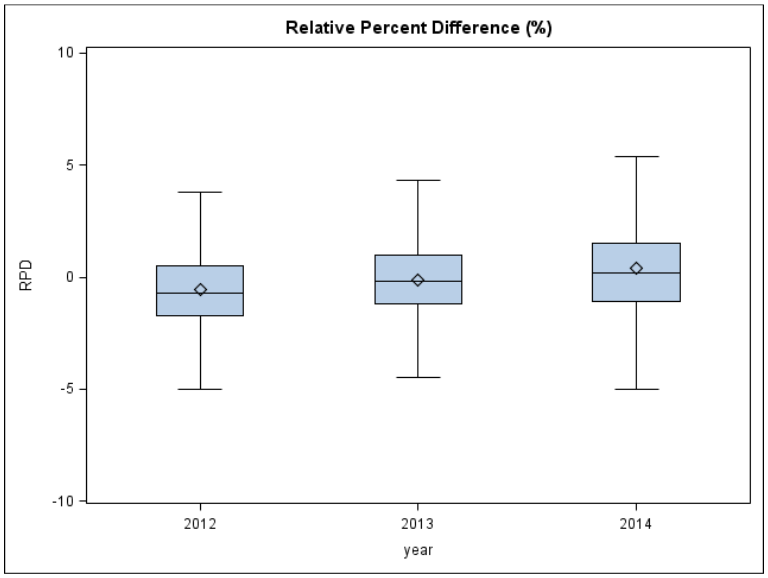
Ozone precision is reported as the 90 percent confidence limit (CL) of the coefficient of variation (CV) as measured by the 1-point QC checks (40 CFR Part 58, Appendix A 4.1.2). The 1-pt QC check is the difference between a known O_3 concentration and the response of the O_3 analyzer. For a site to meet the acceptance criterion, the 90% CL of the CV must be ≤ 7%. The analyzer is challenged with 60 ppb of O_3 during the daily 1-point QC check, which is considered representative of the ambient concentrations measured within the network. Prior to 2014, the analyzers were challenged at 90 ppb of O_3.
The overall network precision is shown in Figure 9 for 2012-2014. Results from the 1-point QC checks are loaded into AQS quarterly. Additional data review is required for sites that do not meet the 7% criterion. In 2012 and 2013 all sites met the 7% acceptance criterion. In 2014, all sites except Cadiz (CDZ171, KY, 8.9%) met the acceptance criteria.

Figure 9. Box Plot showing all CASTNET precision estimates for 2012-2014. The mean (diamond) and median (line) are shown for each year.



Precision may also be estimated as the relative percent difference (RPD) between the expected concentration and the analyzer response. Figure 10 shows the annual RPD for all CASTNET sites using the 1-point QC checks. The median RPD for 2012, 2013 and 2014 was -0.38, -0.010, and 0.21 ppb, respectively.

Figure 10. Relative percent difference between expected response and analyzer response for the 1-point QC checks at all CASTNET sites. The mean (diamond) and median (line) are shown for each year.



C. Bias

The bias estimate is also calculated using results from the 1-point QC checks. A site is required to meet a 95 percent CL of the absolute bias estimate (40 CFR Part 58 App A sec 4.1.3). A site meets the acceptance criterion if the absolute bias is ≤ 7%.

A positive or negative direction is assigned to the bias estimate when the signs of both the 25th and 75th percentiles of the percent differences for each site are in the same direction. No direction is assigned if the percentiles are of different signs. Signed bias results, by site, for 2014 are shown in Table 2. Sites are shaded green if the bias estimate was positive, orange if the bias estimate was negative, and not shaded if the bias estimate had no sign. Each site met the 7% acceptance criterion for 2014.

Table 2. The bias estimate calculated from one-point QC checks for 2014.

Site	State	Bias (%)	Site	State	Bias (%)	Site	State	Bias (%)
DEN417	AK	1.8	MCK131	KY	1.2	CHE185	OK	3.1
SND152	AL	2	MCK231	KY	1.4	ARE128	PA	1.2
CAD150	AR	1.7	BEL116	MD	4.5	KEF112	PA	1.8
CHA467	AZ	2.8	BWR139	MD	1.9	LRL117	PA	0.8
GRC474	AZ	3.1	ACA416	ME	0.7	MKG113	PA	1.3
PET427	AZ	0.9	ASH135	ME	0.8	PSU106	PA	3.5
JOT403	CA	1.9	ANA115	MI	1.7	WNC429	SD	0.4
LAV410	CA	1.4	HOX148	MI	1.2	ESP127	TN	1.4
PIN414	CA	1.9	UVL124	MI	1.5	GRS420	TN	0.9
SEK430	CA	1.2	VOY413	MN	1.2	SPD111	TN	1.9
YOS404	CA	0.7	CVL151	MS	2.6	ALC188	TX	2.9
GTH161	CO	1.8	GLR468	MT	3.3	BBE401	TX	1.5
MEV405	CO	2.3	BFT142	NC	1.8	PAL190	TX	2
ROM206	CO	2.3	CND125	NC	2.3	CAN407	UT	2.7
ROM406	CO	2.1	COW137	NC	1.3	DIN431	UT	0.9
ABT147	CT	1.8	PNF126	NC	2.8	PED108	VA	2.6
IRL141	FL	1.3	THR422	ND	3.1	SHN418	VA	2.6
SUM156	FL	2	SAN189	NE	1.2	VPI120	VA	1.2
GAS153	GA	0.9	WST109	NH	1.8	PRK134	WI	1.8
ALH157	IL	1.9	WSP144	NJ	1.4	CDR119	WV	1.3
BVL130	IL	3.6	GRB411	NV	2.4	PAR107	WV	2.6
STK138	IL	0.6	CTH110	NY	1.7	BAS601	WY	2.6
SAL133	IN	1	HWF187	NY	4.9	CNT169	WY	1.5
VIN140	IN	1.2	DCP114	OH	1.9	NEC602	WY	1
CDZ171	KY	3.3	OXF122	OH	1.6	PND165	WY	2.7
CKT136	KY	3.1	QAK172	OH	2.2	YEL408	WY	1.4
MAC426	KY	1.8						

D. Accuracy

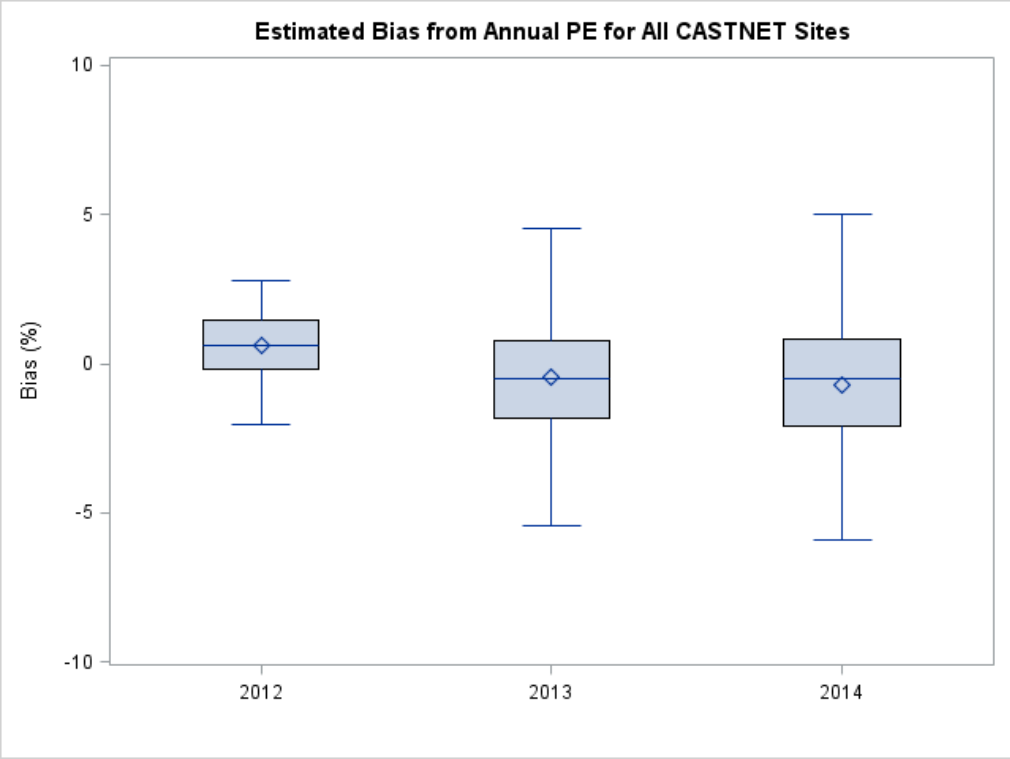
1. Semi-Annual Site Visits

Approximately every six months, technicians managed by the Field Operations Manager perform semi-annual performance checks to the on-site analyzer and reverify the on-site transfer standard, calibrate the on-site analyzer to the traveling transfer standard (Level 2) as needed, and verify the data logger and the shelter temperature probe using NIST traceable standards. These results are used to perform final validation on the hourly O_3 data.

2. Independent PE Results

The Audit Agency performs annual PEs in accordance with 40 CFR Part 58 Appendix A Section 3.2.2 and EPA's Quality Assurance Handbook for Air Pollution Measurement Systems: Volume II and submits these results to AQS on a quarterly basis (US EPA, 2013a). In 2010, EPA issued a memorandum expanding the allowable audit levels required in the CFR Appendix A from 5 to 10 (US EPA, 2010). The auditor is required to select audit levels that bracket 80 percent of the ambient data; however, the audit levels do not need to be consecutive. In 2011, EPA issued a second memorandum revising the acceptance criteria for the expanded audit levels (US EPA, 2011). For levels 1 and 2 (which includes the range of 4 to 19 ppb), the acceptance criteria is ±1.5 ppb difference or ± 15 percent difference, whichever is greater. The acceptance criteria for levels 3 – 10 remains ±15 percent difference.

Figure 11. Estimated Bias in O_3 concentrations from PE Audit Results for All CASTNET Sites



The bias is estimated from the PE values for the years 2012, 2013, and 2014 and displayed in Figure 11. The median and mean for all sites have been within ±1% for all years. Ninety percent of all sites have realized a bias within ±6% for the 3 years shown.

E. Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct, normal conditions. For comparison with the NAAQS for a given 3-year period, a site must meet two completeness criteria: having at least 75 percent valid data for each of the three ozone seasons comprising the period, and having at least 90 percent valid data for all three ozone seasons combined. For the 2012-2014 time period, 64 out of 81

(78 percent) CASTNET O_3 sites met both of these completeness criteria. Three sites did not meet the completeness criteria because they were decommissioned during the 3-year time period. These sites were Howland, ME (HOW132), Konza Prairie, KS (KNZ184), and Mount Rainier, WA (MOR409). Additionally, three sites did not meet completeness criteria because they began collecting ozone measurements after the beginning of the 2012 ozone season, including Basin, WY (BAS601), New Castle, WY (NEC602), and Dinosaur National Monument, UT (DIN431).

4. Precursor Measurements and Meteorology

A. NO_y Monitoring

Reactive nitrogen compounds are precursors for both O_3 and $PM_{2.5}$ formation. Total reactive oxidized nitrogen (NO_y) is defined as NO_x (NO + NO_2) plus NO_z (PAN, HNO_3, HNO_2, PPN, other organic nitrates, and NO_2^-). EPA and NPS operate eight trace-level continuous NO_y analyzers at CASTNET sites (Figure 1). Great Smokies National Park, TN (GRS420) operated by NPS and Bondville, IL (BVL130) operated by EPA are also NCore stations. GRS420, TN and BVL130, IL also measure trace SO_2 and CO as part of the NCore suite of measurements. The Beltsville, MD (BEL116) NO_y analyzer has been converted to an "enhanced" NO_y analyzer which includes a heated stainless steel converter (TN_x), Light Emitting Diode (LED) converter (NO_x) and molybdenum converter (NO_x). The sample stream switches between each converter (or no converter for NO) to measure or calculate speciated reactive nitrogen, including NO_y, NO_2, NO_x, TN_x, NH_x, NO, and NO_z. BEL116 also measures continuous trace SO_2 concentrations.

Total reactive oxidized nitrogen (NO_y) is measured using a thermal molybdenum converter at the inlet to convert reactive nitrogen species to NO followed by the detection of NO by chemiluminescence. The EPA-sponsored CASTNET sites with trace NO_y each have a Teledyne (API) T200U chemiluminescence analyzer, 701H zero air system, and a T700U multi-gas calibrator in addition to the typical suite of CASTNET equipment (e.g., data logger, ozone analyzer, etc.).

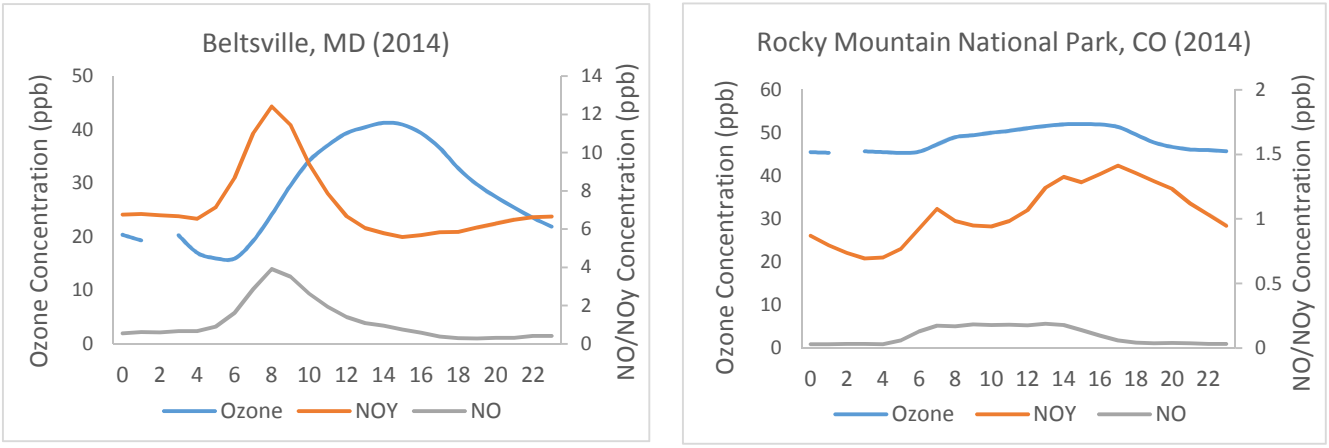
Trace NO_y is audited twice per year by the CASTNET contractor and audited once every other year by an independent 3rd party. The ambient data are submitted to AQS monthly and the QC results are submitted quarterly. Trace-level precision is verified against the acceptance criteria in 40 CFR Part 58 Appendix A. The acceptance criterion is an upper 90 CL for the CV of 10%. The NO_y analyzer is challenged with 15 ppb NO every other day. The precision estimates for 2013 and 2014 for the trace gas NO/NOy analyzers are shown in Table 3. Efforts to better understand the trace gas methods and quality control procedures are on-going between CAMD, EPA's Office of Air Quality Planning and Standards (OAQPS), the EPA Regions, the manufacturer, and contractors.

Table 3. Precision estimates (CV %) from EPA NO_y sites calculated from Equation 3 in 40 CFR Part 58 Appendix A Section 4.1.3.

	2013 Precision (%)	2014 Precision (%)
BEL116, MD	25.01	5.62
BVL130, IL	3.87	6.23
HWF187, NY	2.49	13.64
PND165, WY	4.27	3.17
PNF126, NC	N/A	4.26

Daily trends in total reactive nitrogen vary between urban sites or sites influenced by mobile sources and high elevation or remote sites. As shown in Figure 12, trace NO_y data from BEL116 (a suburban site NE of Washington DC) peaks in the morning and is associated with NO_x emissions (e.g. vehicular traffic), with a slow decline in total reactive nitrogen in the afternoon as O_3 is produced through photochemical reactions. There is a loss of O_3 in the evening, which is more pronounced at BEL116 than ROM206. At CASTNET high elevation sites, such as ROM206 (elevation 2,742 m), the peak NO_y concentrations are generally lower than BEL116, MD including a less pronounced morning peak. The diurnal O_3 concentrations are usually less variable at ROM206, which is typical at high elevation sites. For example, at high elevation sites, the absence of a shallow boundary layer can facilitate stratospheric ozone intrusions at night (prevalent during the winter) along with reduced scavenging of O_3 by NO_2 (Ambrose et. al., 2011, Brodin et. al., 2010). CASTNET NO_y data are useful for model evaluation and validation, as high elevation sites provide a unique data set to the modeling community.

Figure 12. Diurnal pattern of O_3, NO and NO_y from Beltsville, MD (left) and Rocky Mountain National Park, CO (right) for 2014. Note, scales are different.

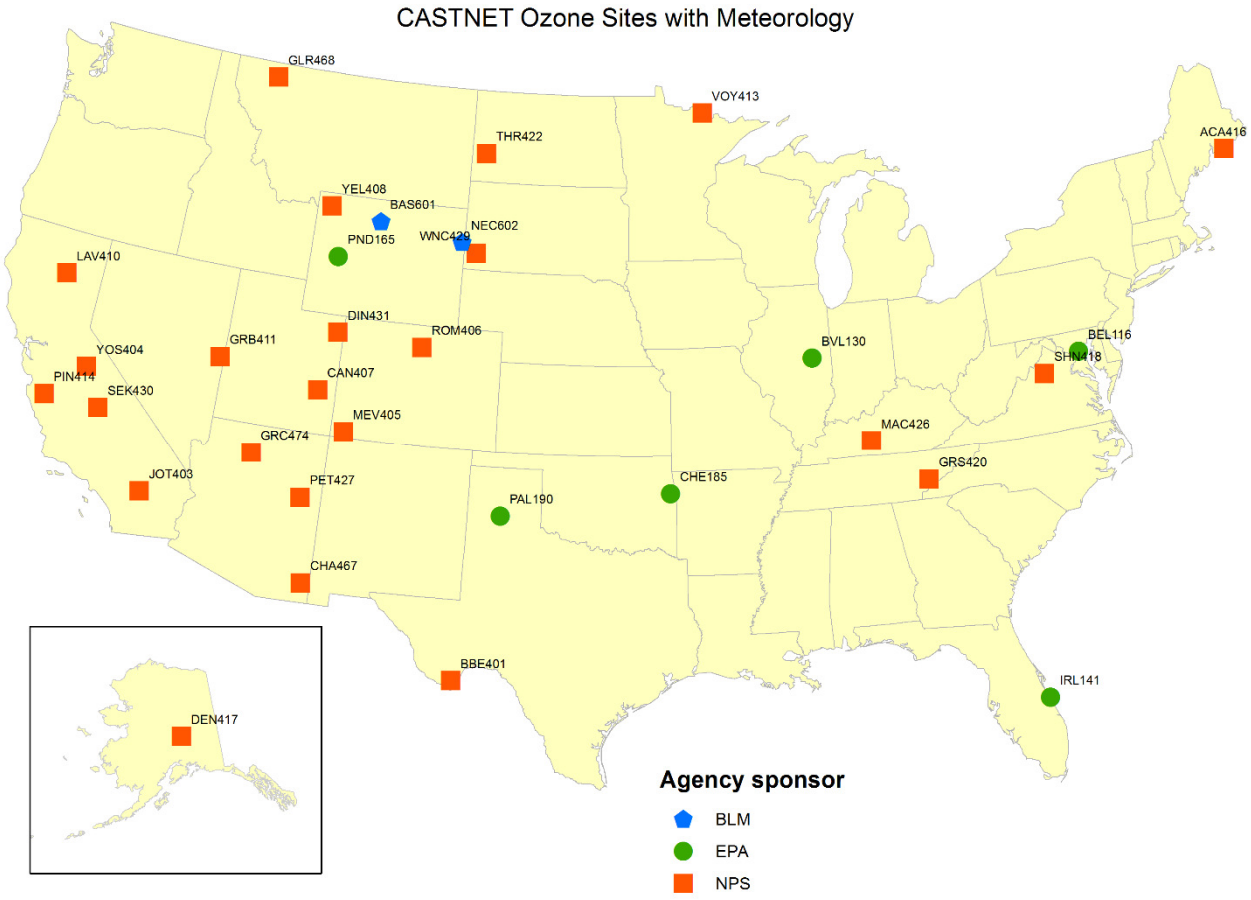


B. CASTNET meteorology

All NPS-sponsored and all BLM-WSO-sponsored CASTNET sites include meteorological measurements. Six EPA-sponsored CASTNET sites: Beltsville, MD (BEL116); Bondville, IL (BVL130); Cherokee Nation Stilwell, OK (CHE185); Indian River Lagoon, FL (IRL141); Palo Duro, TX (PAL190); and Pinedale, WY (PND165) also collect meteorological data. The locations of the 32 CASTNET sites reporting meteorological measurements with regulatory O_3 are displayed in Figure 13. Historically, CASTNET on-site meteorology has been used for calculating deposition velocities using the MLM (Meyers et al., 1998). At sites without meteorological measurements, missing deposition velocity (V_d) values resulting from missing meteorological data are replaced based on the results in Bowker et al. (2011), which substitutes hour-specific historical averages of V_d for missing V_d values at specific sites. The substitution procedure was shown to result in long-term, unbiased estimates of the annual mean V_d. In addition to calculating deposition velocity values, on-site meteorology is particularly important for identifying environmental conditions with high potential for ozone formation, pollutant transport (back trajectories), and model validation (Zhang et al., 2011; Zoogman et al., 2014).

On-site meteorology at a CASTNET site includes measurements of temperature (9m at EPA-sponsored sites, 2m at most NPS-sponsored sites, and at select locations 9m and 2m), relative humidity, solar radiation, precipitation, wind speed, wind direction, sigma theta (standard deviation of the wind direction), and wetness reported as hourly averages.

Figure 13. Sites with on-site meteorology and regulatory O_3 measured by CASTNET (May 2015)



5. Summary

The CASTNET ozone monitoring program provides critical information to stakeholders and has met its primary monitoring objectives through consistent, long-term measurements since 1989. The rural ozone monitors detect regional air quality signals, provide a unique data set for evaluating the effects of O_3 on vegetation and ecosystems, and are used to evaluate the primary and secondary O_3 NAAQS. Federal land managers use CASTNET data to assess environmental conditions and risk of air quality impacts on nationally-recognized sensitive areas and other federal lands. Other stakeholders and

participants include Tribes, States, other federal agencies, and universities who use CASTNET data to evaluate air quality models and determine human health and environmental risks in their areas.

With over 25 years of data from many of its sites, CASTNET has measured a significant reduction in regional O_3 concentrations in the Eastern US in response to emission control programs, allowing policy makers to assess the effectiveness of these programs for improving air quality and reducing negative impacts of air pollution. Moving forward, CASTNET data in the coming years will allow stakeholders to evaluate the effectiveness of current policies and ongoing emission reduction programs such as the Cross-State Air Pollution Rule.

The enhanced quality assurance program implemented in 2011 has improved the quality of CASTNET O_3 monitoring data. Data quality indicators indicate that most CASTNET sites are meeting the network quality assurance criteria for accuracy, bias, and precision for 2012-2014, the most recent 3-year period available. While 78 percent of CASTNET sites met the completeness criteria for inclusion in NAAQS nonattainment decisions for 2012-2014, many of the sites that did not meet the criteria were due to the difficulty in operating technical equipment in remote and unattended locations. Efforts to improve the data capture efficiency throughout the network are ongoing.

CASTNET remains committed to improving our understanding of reactive nitrogen and other O_3 and $PM_{2.5}$ precursors in the ambient environment. Eight monitoring sites already provide continuous NO_y data, and several of these sites also measure continuous SO_2 and CO. In addition, a speciated NO_y monitor is being developed and tested for broader deployment within the network. Expanded use of these and other continuous monitors will enhance the utility of CASTNET data in model evaluation and development.

CASTNET has been a stable platform for regional air monitoring for over 25 years and the program continues to evolve within the constraints of budgets, regulatory demands, and agency priorities. Developing long-term solutions to improve the cost-effectiveness of routine measurements and leveraging existing and new partnerships has been crucial for the continuity of CASTNET, and these attributes will continue to be important over the next five years as CASTNET strives to improve data capture, enhance the types of measurements collected, and expand into areas with limited air quality monitoring.

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