

Meteorological Monitoring



A Supplement to the
INL Site Environmental Report for 2024

METEOROLOGICAL MONITORING

Background

The Special Operations and Research Division (formerly known as the Field Research Division) of the National Oceanic and Atmospheric Administration Air Resources Laboratory (NOAA ARLSORD) provides meteorological support to the Idaho National Laboratory (INL) Site. This includes issuing weather forecasts and hazardous weather alerts, maintaining the NOAA/INL meteorological tower network (the NOAA/INL Mesonet), and providing emergency operations center on-call support.

History of Monitoring

Meteorological monitoring at the INL started with the creation of the National Reactor Testing Station (NRTS) in 1949. At that time, the U.S. Weather Bureau, by agreement with the Reactor Development Division of the Atomic Energy Commission (AEC), established a Weather Bureau Research Station as part of the Special Projects Section at the NRTS. This station included a complete complement of meteorologists and technicians. The initial objective of the station was to describe the meteorology and climatology of the NRTS with a focus on protecting the health and safety of site workers and nearby residents. The office provided a full range of hourly and daily meteorological observations, including balloon soundings, which were transmitted to the U.S. Weather Bureau [and later the National Weather Service (NWS)] observations network.

After 15 years of operation, the first complete climatology of the area was published (Yanskey et al. 1966). It was based on an assemblage of four previous reports (DeMarrais 1958a, b; DeMarrais and Islitzer 1960; Johnson and Dickson 1962). Regular observation functions related solely to weather forecasting were then reduced to allow for more intense research on atmospheric transport and diffusion. However, basic meteorological observations at the renamed Idaho National Engineering Laboratory (INEL) were continued to satisfy U.S. Department of Energy (DOE) environmental and safety requirements.

Numerous other climatological and specialized research studies of atmospheric transport and diffusion have been conducted and reported over the years (Start 1984). However, in 1989, the second official edition of the climatology (Clawson et al. 1989) was issued to integrate new information acquired since the publication of the first edition. The period of record permitted, for the first time, the calculation of standard 30-year normalized climatological values for all important atmospheric parameters. Building upon the atmospheric dispersion climatology of the first edition, it also included summaries of wind transport trajectories for sources near the Central Facilities Area (CFA). By this second edition, the Idaho research station had been reorganized as the Field Research Division of the National Oceanic and Atmospheric Administration's Air Resources Laboratory (NOAA ARLFRD).

In 2007, a third edition of the INL climatology was published (Clawson et al. 2007) with climatological parameters updated through 2006. That edition included new insights on winds and temperatures aloft derived from remote sensing systems, channeled wind flows, statistical wind trajectory groupings, and precipitation return periods. Three distinct local microclimate regimes (INL

North, INL Southwest, INL Southeast) were also introduced during this edition, based primarily on wind flow patterns.

In 2018, a fourth edition of the INL climatology was published (Clawson et al. 2018) based on meteorological observations through 2015. In addition to updating various climatological parameters, this edition included new research focused on the outflows of the Birch Creek Valley that strongly affect the Specific Manufacturing Capability (SMC) wind regime on the north end of the INL. The fourth edition of the INL climatology is anticipated to continue to be helpful to planners and operations staff.

In 2022, the NOAA ARLFRD was renamed the Special Operations and Research Division of the National Oceanic and Atmospheric Administration's Air Resources Laboratory (NOAA ARLSORD). ARLSORD's support to the INL Site is provided through an interagency agreement between NOAA and the DOE Idaho Operations Office. This long-term partnership provides significant benefits to both agencies. ARLSORD continues to furnish weather and climate support to the INL, producing weather forecasts/alerts and contributing to INL Emergency Operations Center drills and on-call staffing.

NOAA/INL Mesonet

What is now called the NOAA/INL Mesonet (MESOscale meteorological monitoring NETwork) began with a single monitoring station at CFA in 1949. Between 1950 and 1970, six on-site and 16 off-site monitoring stations were added to form an expanded observational network. The number of meteorological monitoring stations continued to expand and change over the years in support of various projects and also to gain a better understanding of the climatology of the INL Site, in particular, and the Eastern Snake River Plain (ESRP) in general. The current configuration of the Mesonet meets the needs of INL Site planners, emergency managers, scientists, engineers, operations personnel, and the general public.

There were 34 meteorological observation stations in operation at the INL and the surrounding area as of December 31, 2024. Thirteen of these are located within the boundaries of the INL Site. The remaining stations are at key locations throughout the ESRP. The location of each tower comprising the Mesonet is depicted in Figure 1 and Figure 2 for on-site and off-site locations, respectively. Twenty-nine of the stations have 50 ft. (15 m) tall towers. Three other towers range in height from 150 to 250 ft. (46 to 76 m) and are the "primary" on-site observation stations in the three INL microclimate zones. These tall towers are at Grid 3/INTEC (GRI), MFC, and SMC. The two remaining towers, one on the summit of Big Southern Butte and another at Craters of the Moon National Monument, are restricted in height for aesthetic reasons. These towers are 20 ft. (6 m) and 30 ft. (9 m) tall, respectively. A typical Mesonet tower, representative of the configuration and instrument layout, is shown in Figure 3.

Four of the NOAA/INL Mesonet stations, called Community Monitoring Stations (CMS), are at locations frequented by the public to enhance relations with the local communities. These CMS locations were developed in partnership with the DOE Idaho Operations Office, the State of Idaho INL Oversight Program, the Shoshone-Bannock Tribes, the City of Idaho Falls, and the Idaho Transportation Department. The CMS stations include a walk-up kiosk that displays current meteorological parameters and describes each measured variable.

Standard meteorological parameters are measured at each Mesonet station. All meteorological instruments are carefully selected to meet required and generally accepted guidelines, including DOE/EH-0173T, Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE 1991); DOE Guide 151.1D, Comprehensive Emergency Management System (DOE 2016); and ANSI/ANS 3.11-2015, Determining Meteorological Information at Nuclear Facilities.

Tables 1 and 2 list the parameters and the location of each Mesonet station on and off the INL Site, respectively. The station name (location), three-letter designator, elevation, instrument height, and types of data being collected at each level on the tower are provided in the tables. Air temperature and relative humidity are measured at all Mesonet stations at the conventional

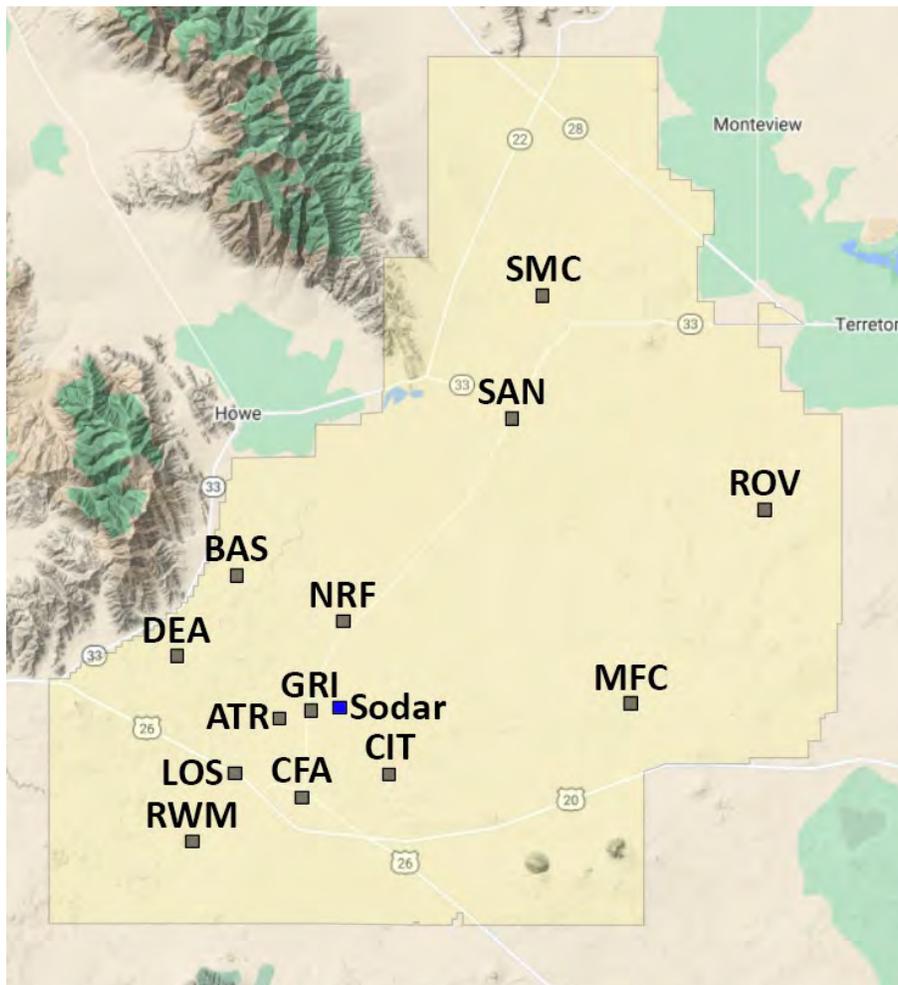


Figure 1. NOAA/INL Mesonet Stations on the INL Site as of December 31, 2024. The blue square is the location of the Sodar.

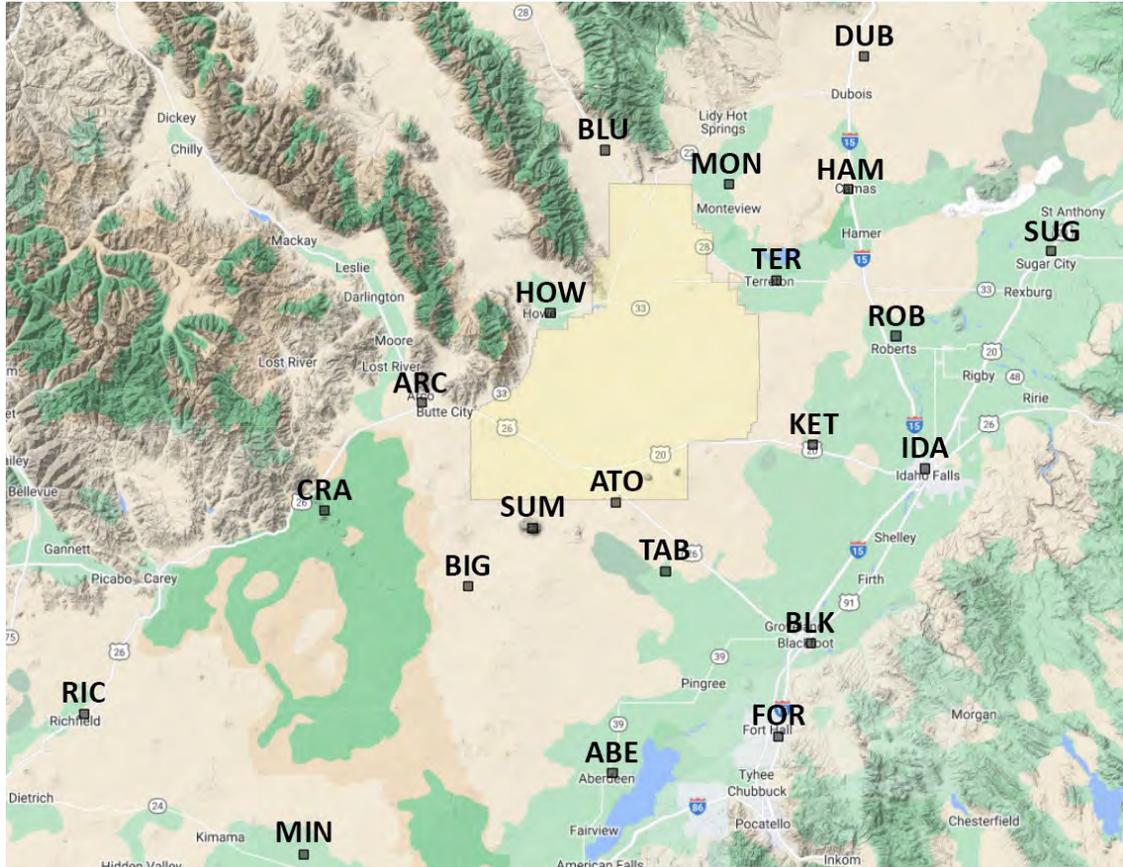


Figure 2. NOAA/INL Mesonet Stations outside the INL Site as of December 31, 2024.



Figure 3. Example NOAA/INL Mesonet Station Layout and Community Monitoring Station Kiosk (foreground) on the Idaho Falls Greenbelt at the John’s Hole Bridge and Forebay.

Table 1. NOAA/INL Mesonet Stations on the INL Site as of December 2024.

Station Name	Station ID	Latitude (deg N)	Longitude (deg W)	Elevation MSL (ft)	Bottom Level		Middle Level(s)		Top Level		Other Data
					Data	Height	Data	Height	Data	Height	
					ATR Complex	ATR	43.584633	112.968667	4,937	t,r	
Base of Howe Peak	BAS ^b	43.677533	113.006033	4,900	t,r	6 ft (2 m)	w,T	50 ft (15 m)		s,b	
Central Facilities Area Building 690	CFA ^{b,c}	43.532617	112.947733	4,950	t,r	6 ft (2 m)	w,T	50 ft (15 m)		p,s,b	
Critical Infrastructure Test Range Complex	CIT	43.547483	112.869683	4,910	t,r	6 ft (2 m)	w,T	50 ft (15 m)		p,s,b	
Dead Man Canyon	DEA ^b	43.625067	113.059783	5,108	t,r	6 ft (2 m)	w,T	50 ft (15 m)		s,b	
Grid 3/INTEC	GRI	43.589700	112.939933	4,897	t,r	6 ft (2 m)	w,T	33 ft (10 m) 50 ft (15 m) 150 ft (46 m)	w,T	200 ft (61 m)	p,s,b, l
Lost River Rest Area	LOS ^b	43.548683	113.009900	4,983	t,r	6 ft (2 m)	w,T	50 ft (15 m)		p,s,b	
Materials and Fuels Complex	MFC	43.594133	112.651733	5,143	t,r	6 ft (2 m)	w,T	33 ft (10 m) 50 ft (15 m) 150 ft (46 m)	w,T	250 ft (76 m)	p,s,b, l
Naval Reactor Facility	NRF	43.647867	112.911233	4,847	t,r	6 ft (2 m)	w,T	50 ft (15 m)		p,s,b	
Radioactive Waste Management Complex	RWM	43.503433	113.046033	5,025	t,r	6 ft (2 m)	w,T	50 ft (15 m)		p,s,b	
Rover	ROV	43.720600	112.529567	5,008	t,r	6 ft (2 m)	w,T	50 ft (15 m)		s,b	
Sand Dunes	SAN	43.779667	112.758183	4,820	t,r	6 ft (2 m)	w,T	50 ft (15 m)		p,s,b	
Specific Manufacturing Capability	SMC	43.859767	112.730267	4,790	t,r	6 ft (2 m)	w,T	33 ft (10 m) 50 ft (15 m)	w,T	150 ft (46 m)	p,s,b, l

- a. Abbreviations: b = Barometric pressure (mean pressure); l = Soil temperature and moisture (mean temperature and volumetric water content); p = Precipitation (total precipitation); r = Relative humidity (mean relative humidity); s = Solar radiation (mean solar radiation); T = Temperature (mean temperature); t = Temperature (mean temperature, maximum temperature, minimum temperature); w = Wind (mean speed, peak 3-second wind gust, mean direction, direction standard deviation)
- b. New stations since 2nd edition of Climatology of the INEL was published (BAS, CFA and DEA started in April 1993, LOS started in April 1995).
- c. CFA Building 690's public Station ID has remained CFA even though it is a different station than the CFA tower in the 2nd edition of Climatology of the INEL.

Table 2. NOAA/INL Mesonet Stations off the INL Site as of December 2024.

Station Name	Station ID	Latitude (deg N)	Longitude (deg W)	Elevation MSL (ft)	Bottom Level		Middle Level		Other Data
					Data ^a	Height	Data	Height	
Aberdeen	ABE	42.954933	112.824533	4,392	w,t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s,b,l
Arco	ARC	43.624550	113.297100	5,290	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s
Atomic City	ATO ^b	43.443733	112.815650	5,058	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s,b
Blackfoot	BLK	43.189850	112.333200	4,520	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s,b
Blue Dome	BLU	44.075000	112.842033	5,680	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s
Cox's Well	COX ^b	43.294167	113.181283	5,200	t,r	6 ft (2 m)	w,T	50 ft (15 m)	s
Craters of the Moon	CRA ^b	43.429183	113.538300	5,996	t,r	6 ft (2 m)	w,T	30 ft (9 m)	p,s,b
Dubois	DUB	44.242383	112.201833	5,465	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s,b
Fort Hall	FOR ^b	43.022000	112.411983	4,452	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s,b
Hamer	HAM	44.007417	112.238833	4,843	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s
Howe	HOW	43.784117	112.977317	4,815	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s
Idaho Falls	IDA	43.504133	112.050133	4,709	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s,b
Kettle Butte	KET	43.547567	112.326250	5,190	w,t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s,b
Minidoka	MIN	42.804417	113.589650	4,285	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s,b
Monteview	MON	44.015367	112.535917	4,797	w,t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s,b
Richfield	RIC	43.060600	114.134583	4,315	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s,b
Roberts	ROB	43.743517	112.121117	4,760	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s
Sugar City	SUG ^b	43.896583	111.737617	4,895	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s,b
Big Southern Butte Summit	SUM ^b	43.396333	113.021850	7,576	t,r	6 ft (2 m)	w	20 ft (6 m)	s,b
Taber	TAB	43.318683	112.691800	4,730	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s
Terreton	TER	43.841683	112.418250	4,792	t,r	6 ft (2 m)	w,T	50 ft (15 m)	p,s,b

- a. Abbreviations: b = Barometric pressure (mean pressure); l = Soil temperature (mean temperature); p = Precipitation (total precipitation); r = Relative humidity (mean relative humidity); s = Solar radiation (mean solar radiation); T = Temperature (mean temperature); t= Temperature (mean temperature, maximum temperature, minimum temperature); w = Wind (mean speed, peak 3-second wind gust, mean direction, direction standard deviation)
- b. New station since 2nd edition of Climatology of the INEL was published (ATO began in April 1995, BLK began in August 2001, COX and CRA began in April 1993, FOR began in March 1997, SUG began in April 1993, SUM began in November 2000).

6 ft. (2 m) level. Wind measurements (speed and direction, gusts, and standard deviation of the wind direction) are collected at the top of all Mesonet stations, normally at 50 ft. (15 m) above ground level. For the three tall towers, additional wind and air temperature measurements are recorded at the 33 ft (10 m), 50 ft (15 m), and 150 ft (46 m) levels. Other reported parameters include precipitation, atmospheric pressure, and solar radiation at most stations. Still more wind measurements are made at the 6 ft. (2 m) level at the Aberdeen, Kettle Butte, and Montevue stations in support of the U.S. Bureau of Reclamation's Agrimet Program. ARLSORD provides these additional meteorological measurements through a partnership agreement with Agrimet for regional crop water use modeling.

Mesonet data are recorded as averages, totals, or extremes over a 5-minute period. Wind speed, wind direction, air temperature, relative humidity, and solar radiation are measured every 1 second and averaged over a 5-minute period. Precipitation is totaled over the 5-minute interval. Maximum and minimum air temperatures for each 5-minute period are based on the one-minute averages collected during the period. A 3-second average wind gust is computed as the maximum of a 3-second running average of wind speed. Data are collected at each station by a datalogger and transmitted every 5 minutes through a radio link back to ARLSORD. Data are also stored for a short time at each station and can be retrieved manually if the radio link fails for an extended period of time. Each datalogger is also supplied with power by a deep-cycle marine battery for extended operation and data storage in the absence of line power. These data are continuously added to the INL climatological database and are available for customized analyses.

Additional Equipment

The weather station at CFA, installed in 1949, was the first meteorological observation station established at the INL Site. It is the longest continually operating station at the site. For many years, the temperature at CFA was recorded on a mechanical thermograph inside a thermoscreen shelter. This thermograph has now been removed, and the daily temperatures are obtained from the standard temperature sensor located at 2 m on the CFA Mesonet tower. Precipitation was collected in a rain gauge about 50 feet (15.2 m) southwest of the tower. Precipitation was manually measured weekly and interpolated into a daily value with the help of the CFA Mesonet electronic rain gauge located about 15 feet (4.6 m) east of the CFA Mesonet tower. Now, the official precipitation record is the same as the CFA Mesonet electronic rain gauge. Snow depth was also measured manually simultaneously with precipitation and interpolated to a daily depth. The daily snow depth also considers information including the CFA Mesonet snow depth sensor, the precipitation amount, temperatures at the time of precipitation, and the INL weather camera. Beginning in the fall of 2024, the official snow depth will be the snow depth measurement recorded with a new snow depth sensor associated with the CFA Mesonet station. This dataset comprises the National Weather Service cooperative observer station, Idaho Falls 46W (or IDA 46W). The data from IDA 46W are also included in NOAA's National Centers for Environmental Information (NCEI) database, the nation's primary climatological database.

The NOAA/INL Mesonet dataset also includes near-surface vertical wind profiles obtained from a sodar (Sound Detection and Ranging) located near Grid 3 (Figure 4). In operation since 2008, the sodar is an acoustic instrument that emits a sound pulse at 4.5 KHz, listens to the atmospheric echo from that pulse, and then calculates the winds based on Doppler shifts. Ten-minute averages of wind speed and direction in 16-foot (5-m) increments from 66 to 656 feet (20 m to 200 m) AGL are calculated using this approach. It also provides turbulence statistics such as the standard deviations



Figure 4. Sodar near Grid 3.

of the vertical and horizontal wind components and a visualization of the height of the boundary layer when the top of the boundary layer is below the maximum sensing level. In 2024, the sodar became end of life and was turned off. ARLSORD is hoping that funding will allow us to purchase another one in the near future.

A camera for monitoring weather phenomena during daylight hours was installed at Grid 3 in 1998. The data are available in real time through a dedicated line at the ARLSORD office. The camera can be remotely controlled and can zoom and pan to areas of interest, such as wildfires or severe storms. It has proven to be a valuable tool for monitoring site weather from the office in Idaho Falls. Routine archiving of the images began in May 2007.

Data Quality Control

The NOAA/INL Mesonet uses a detailed and comprehensive data quality assurance program. ARLSORD has adopted the standards listed in ANSI/ANS 3.11-2015, *Determining Meteorological Information at Nuclear Facilities*, and ANSI/ANS 3.2-2012, *Managerial, Administrative, and Quality Assurance Controls for the Operational Phase of Nuclear Power Plants*, for data quality control guidance. To help follow these guidelines, the quality assurance program uses an excellent set of software tools to display trended meteorological data. This enhances the data quality evaluations and makes them more efficient. The quality control program consists of both manual and automated processes. Every 5-minute data period for every station is plotted for missing or spiked data. Data are also screened for electronic noise, malfunctioning aspirators that affect air temperature and relative humidity values, orientation errors in the wind direction, stalled wind sensors, rime icing in the winter that degrades wind speeds, and other erroneous values caused by maintenance, sprinklers, bird droppings, small animals, etc. Plotting the data allows the meteorologist to identify and flag any problems in the database and, if needed, notify a technician to fix the problem quickly.

Data Dissemination

The primary method of dissemination of NOAA/INL Mesonet data is through the NOAA/INL Weather Center (NIWC) web page (Figure 5) at <https://niwc.noaa.inl.gov/>. This centralized weather



NOAA INL WEATHER CENTER



Current INL Observations

Wed Apr 28, 2010		Winds		T		WC	
12:45 MDT		(mph)	(CF)	(F)	(F)		
CFA	SW	32	G40	41			
CIT	SW	32	G44	40			
INTEC	SW	29	G43	39	27		
MFC	WSW	25	G36	39	28		
NRF	WSW	16	G24	39	30		
ATR	SW	31	G39	40	28		
RWMC	SW	32	G41	43			
SMC	SW	21	G28	41			
REC	SW	23	G37	40			

[Click](#) for all observations.

CURRENT INL WARNINGS

NWS Watches/Warnings

Wind Advisory issued April 28 at 4:28AM MDT expiring April 28 at 6:00PM MDT by NWS Pocatello <http://www.wrh.noaa.gov/Pocatello/>

Fire Weather

There are no active watches, warnings or advisories.

FRD INL Weather Alerts/Statements

There are no active NOAA INL Weather Center Alerts or Statements.

Current Warnings

- [INL Warnings](#)
- [SE Idaho Warnings \(NWS\)](#)

Current Conditions

- [INL Observations](#)
- [INL Wind Trends](#)
- [Top Wind Gusts](#)
- [Sodar Wind Plot](#)
- [Profiler Wind Plot](#)
- [Surface Map](#)
- [SE Idaho Radar](#)
- [Satellite Imagery](#)
- [INL Lightning Table \(INL Only\)](#)
- [INL Lightning Map \(INL Only\)](#)
- [Storm Tracks](#)
- [INL Camera](#)
- [SE ID Weather Cams](#)
- [ID Road Conditions](#)

Forecasts

- [INL Forecast](#)
- [Idaho Falls \(NWS\)](#)
- [Southeast Idaho \(NWS\)](#)
- [Fire Weather \(NWS\)](#)
- [WRF Model](#)
- [NCEP Models](#)
- [Model Output Statistics \(MOS\)](#)
- [Storm Prediction Center](#)

Climate

- [INL](#)
- [Local \(NWS\)](#)
- [Climate Prediction Center](#)

NOAA INL Mesonet

- [Daily Summary](#)
- [Graphical Display](#)
- [INL Meteograms](#)
- [Precipitation Summary](#)
- [Tabular Display](#)
- [Upper Air Display](#)
- [Windfield Display](#)

Weather Safety

- [Weather Radio](#)
- [Winter Safety](#)
- [Flash Flood Safety](#)
- [Summer Safety](#)
- [Lightning Safety](#)
- [Storm Ready](#)
- [Preparedness](#)

Other Links

- [NWS Home Page](#)
- [NWS Pocatello](#)
- [Fort St. Vrain](#)
- [CRN/HCN-M](#)

Contact:
 INL weather questions
 phone: 526-2744
[email](#)
[NOAA FRD HOME](#)

Current INL WEATHER ALERT/STATEMENT [\(criteria\)](#)

FORECAST	WINDS	6-HR CFA WIND TREND
<p>Click below for latest forecast.</p>	<p>Click below for latest INL winds.</p>	<p>Click below for larger image.</p> <p>CFA 15 meter wind speed (MPH)</p> <p>0645 MDT 1245 MDT</p> <p>Gust Spd Avg Spd</p>
RADAR	SATELLITE	INL CAMERA
<p>Click below for larger image.</p> <p>INL Radar Loop</p>	<p>Click below for larger image.</p> <p>Satellite Loop SE ID Satellite</p>	<p>Click below for larger image.</p> <p>Camera Loop Sunrise/Sunset</p>

Top Wind Gusts 	Current Conditions 	Daily Summary 	Precip Summary 	WRF Model 	INL Climate
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This page automatically refreshes every 5 minutes.



Figure 5. NOAA/INL Weather Center web page.

web page was designed to provide INL site-specific meteorological information to both emergency and daily operations managers. The highlight of the NIWC page is the presentation of severe weather hazard information. Weather watches, warnings, and advisories issued by the National Weather Service (NWS) in Pocatello specific to the INL Site are displayed at the top of the page under the “Current INL Warnings” section. The INL Site has additional forecast requirements. Therefore, ARLSORD issues its own weather alerts and statements to give additional hazardous weather information specific to the site. These INL weather alerts and statements are also displayed under the “Current INL Warnings” section. The NWS issues watches and warnings 24 hours a day, 7 days a week, while ARLSORD-issued weather statements or alerts are issued only during normal working hours.

Six large thumbnail images located beneath the “Current INL Warnings” section display popular INL-related weather products. These thumbnails include a link to the current 7-day INL Site weather forecast, a plot of the current NOAA/INL Mesonet wind vectors, a graph of the current CFA wind speed trend for the last 6 hours, a current INL site-specific weather radar image, the current Idaho satellite image, and the current image from the INL weather camera. These thumbnail images give emergency and daily operations managers a quick glance at the overall weather across the site. Each of the images can be enlarged for more detail and easier viewing. The web page automatically refreshes every five minutes to keep weather watches, warnings, statements, alerts, and images up to date.

Other INL site-related and general weather information is available in the menus on the left-hand side and at the bottom of the NIWC page. Some of these products are current observations that include a lightning map, links to NWS zones and weather forecast models, INL climate information, other NOAA/INL Mesonet data, and weather safety information.

Atmospheric Dispersion Modeling

ARLSORD for many years used the MDIFF and MDIFFH computer models (Sagendorf et al. 2001) for estimating concentration patterns of airborne materials released from a single location. They were designed to use wind data derived from the NOAA/INL Mesonet and were well suited for calculating the transport and dispersion of airborne material on and near the INL Site. The models were based on the MESODIF computer program (Start and Wendell 1974), one of the first diffusion models developed for use on modern computers. MDIFF and MDIFFH are both classified as puff models because they simulate an atmospheric release using a series of puffs that move and grow independently.

MDIFF was used to model short-term releases based on the 5-minute averages from the Mesonet, but has been superseded by the HYSPLIT model described below. MDIFFH was used for annual or other long-term simulations but has now also been replaced by a special configuration of the HYSPLIT model. MDIFF and MDIFFH both used the same basic code, but MDIFFH included modifications to allow an annual simulation to be completed in a reasonable amount of time on available computing resources.

The HYSPLIT dispersion model (Draxler and Hess 1997) is maintained and used by NOAA and is also used by many other organizations. Within NOAA, it is used for many applications, including plume forecasting for toxic releases, predicting smoke from wildfires, and forecasting the movement of

ash plumes from volcanic eruptions. Instead of using puffs like MDIFF and MDIFFH, HYSPLIT uses a Lagrangian particle approach to model dispersion. A release is represented by a cloud of individual particles transported by the wind and scattered apart by atmospheric turbulence. Mathematically, the effect of the turbulence is computed using a random number generator that imparts a random displacement to each particle. The primary advantage of this approach is that it provides a more realistic representation of plume dispersion in complicated situations such as mountainous terrain or when the wind speed and direction change significantly with height.

In 2009, ARLSORD developed software to generate a three-dimensional HYSPLIT wind field based directly on the NOAA/INL Mesonet data. This capability is crucial to ensure that the projected plume movement is derived from the most up-to-date information available from the tower network. When plume forecasts are desired, either NOAA forecast models or local modeling can provide HYSPLIT with forecast winds many hours into the future. This model was a valuable tool in the INL Emergency Operations Center for many years.

Finally, in recent years, the NARAC (National Atmospheric Release Advisory Center) suite of model products has played an important role in current emergency management operations. NARAC assimilated observations into a plume model and increased it substantially to produce results for not just our region, but globally. NARAC's operations center and staff are available 24/7 to respond to emergencies anywhere in the world. NARAC has become the go-to product for DOE facilities across the nation, and indeed, its usage is mandated by DOE Guide 151.1D (DOE, 2016).

INL Site Climate During 2024

The climate of the high desert environment of the INL Site is characterized by sparse precipitation (about 20.7 cm/yr [8.18 in./yr]), warm summers (with a normal daily temperature of 18.9°C [66.1°F]), and cold winters (with a normal daily temperature of -7.4°C [18.6°F]), based on observations at Central Facilities Area (CFA) from 1994 through 2024.

For 2024, the average daily mean temperature measured at CFA was warmer than the years between 1994-2023 (Table 3). The 2024 average temperature was 45.1°F, 2.5°F above the mean. July was the warmest month, with an average daily mean temperature of 71.7°F, 1.8°F above normal. February was the month with the largest departure from normal during the year, which was 8.6°F above normal. January was the coldest month, with an average of 20.9°F, 4.2°F above normal. The highest air temperature in 2024 was 101°F and was recorded on July 11th and 13th. The lowest temperature at CFA during 2024 was -32°F and was recorded on January 13th.

Five highest daily maximum temperatures were set or tied in 2024. April 13th recorded a maximum temperature of 74°F, which tied the previous highest daily maximum from 1951 and 1988. July 24th recorded a maximum temperature of 99°F, which tied the previous highest daily maximum from 1978 and 1988. August 3rd recorded a maximum temperature of 100°F, which broke the previous highest daily maximum temperature of 97°F from 1961. October 4th recorded a maximum temperature of 83°F, which broke the previous highest daily maximum temperature of 82°F from 1980, 1988, and 1993. October 9th recorded a maximum temperature of 81°F, which tied the previous highest daily maximum temperature from 1996.

Four lowest daily minimum temperatures were set or tied in 2024. January 13th recorded a minimum temperature of -32°F, which broke the previous lowest daily minimum of -29°F from 2013. May 2nd recorded a minimum temperature of 14°F, which broke the previous lowest daily minimum temperature of 15°F set in 2011. May 19th recorded a minimum temperature of 23°F, which broke the previous lowest daily minimum temperature of 29°F set in 1954 and 1973. September 4th recorded a minimum temperature of 68 °F, which broke the previous highest daily minimum temperature of 60 °F from 1951.

Five highest daily minimum temperatures were set or tied in 2024. January 24th recorded a minimum temperature of 31 °F, which tied the previous highest daily minimum from 1959. February 2nd recorded a minimum temperature of 33°F, which broke the previous highest daily minimum of 31°F from 1987. February 6th recorded a minimum temperature of 32°F, which broke the previous highest daily minimum of 31°F from 1978. May 4th recorded a minimum temperature of 61°F, which broke the previous highest daily minimum temperature of 58°F set in 1959. May 26th recorded a minimum temperature of 61°F, which tied the previous highest daily minimum temperature set in 2021.

Table 3. Average Daily Maximum, Minimum, and Mean Air Temperatures by Month for CFA from 1994 through 2023 compared with 2024, including Departure from the Average, and Annual Average and Departures.

Month	Average Daily Maximum Temperature			Average Daily Minimum Temperature			Average Daily Mean Temperature		
	1994-2023 (°F)	2024 (°F)	Departure (°F)	1994-2023 (°F)	2024 (°F)	Departure (°F)	1994-2023 (°F)	2024 (°F)	Departure (°F)
January	27.6	31.9	+4.4	5.7	9.8	+4.1	16.7	20.9	+4.2
February	31.7	37.6	+5.9	9.0	20.3	+11.3	20.3	28.9	+8.6
March	45.6	44.9	-0.8	20.2	21.0	+0.9	32.9	33.0	+0.0
April	56.8	59.0	+2.2	27.5	28.0	+0.4	42.2	43.5	+1.3
May	67.1	64.6	-2.5	36.2	32.8	-3.4	51.7	48.7	-3.0
June	77.9	82.9	+5.0	43.3	45.8	+2.5	60.6	64.3	+3.7
July	89.9	91.6	+1.7	50.1	51.9	+1.8	70.0	71.7	+1.8
August	86.9	86.8	-0.1	47.8	48.9	+1.2	67.3	67.9	+0.6
September	75.9	79.0	+3.1	38.1	41.7	+3.7	57.0	60.4	+3.4
October	59.6	66.9	+7.3	27.1	28.8	+1.7	43.4	47.8	+4.5
November	42.8	40.7	-2.1	16.2	17.4	+1.2	29.5	29.1	-0.4
December	29.3	35.8	+6.5	7.3	14.5	+7.2	18.3	25.1	+6.8
Annual	57.7	60.2	+2.5	27.5	30.1	+2.6	42.6	45.1	+2.5

The year 2024 was drier than normal at CFA. Table 4 shows the monthly and annual precipitation summary. The annual total was 7.60" (0.58" below the mean) or 93% of the mean. The wettest month was February (1.68" of precipitation), which was 1.23" above the mean or 373% of the mean. February was also the month with the largest departure from the mean. The driest month of the year was in July (with 0.02" of the mean), which was 0.33" below the mean.

Six daily precipitation records were set last year. January 25th recorded 0.18" of precipitation that broke the previous daily record of 0.15" from 2009. February 5th recorded 0.47" of precipitation that broke the previous daily record of 0.13" from 1978. February 6th recorded 0.38" of precipitation that broke the previous daily record of 0.28" from 1998. March 25th recorded 0.38" of precipitation that broke the previous daily record of 0.30" from 1993. September 17th recorded 0.51" of precipitation that broke the previous daily record of 0.45" from 1961. December 14th recorded 0.33" of precipitation that broke the previous daily record of 0.30" from 1977.

Monthly and annual total snowfall and monthly average snow depth statistics for 2024 are given in Table 4, together with the 31-year mean. Average annual snow depth statistics are not included because they are not meaningful. Total snowfall for 2024 was 24.5" or 1.5" below the mean (or 6% below the mean). December was the snowiest month with 6.6", 0.7" below the mean (or 90% of the mean). The highest average monthly snow depth during 2024 occurred in January and December with 1.8", 3.8" or 0.9" below normal, respectively (or 32% and 67% of normal, respectively).

Five daily snowfall records were set or tied in 2024. February 5th recorded 5.0" of snowfall, which broke the previous daily record of 3.5" from 1975. March 5th recorded 3.0" of snowfall, which broke the previous daily record of 2.3" from 1960. March 25th recorded 3.0" of snowfall, which tied the previous daily record from 1975. May 3rd recorded 3.5" of snowfall, which had never had any measurable snowfall on that date previously. December 14th recorded 3.5" of snowfall, which broke the previous daily record of 2" from 2001.

Table 4. Monthly and Annual Average Precipitation, Snowfall and Snow Depth for CFA from 1994 through 2023 and 2024 and Total Precipitation Departures.

Month	Total Precipitation			Total Snowfall		Mean Snow Depth	
	1994-2023 (in.)	2024 (in.)	Departure (in.)	1994-2023 (in.)	2024 (in.)	1994-2023 (in.)	2024 (in.)
January	0.64	0.55	-0.09	6.8	6.3	5.7	10.5
February	0.45	1.68	+1.23	4.2	4.6	6.1	10.9
March	0.64	1.20	+0.56	2.5	2.9	2.0	14.6
April	0.86	0.53	-0.33	0.9	1.6	0.0	1.9
May	1.22	1.10	-0.12	0.0	0.4	0.0	0.0
June	0.81	0.06	-0.75	0.0	0.0	0.0	0.0
July	0.35	0.02	-0.33	0.0	0.0	0.0	0.0
August	0.55	1.49	-0.06	0.0	0.0	0.0	0.0
September	0.69	0.79	+0.10	0.0	0.0	0.0	0.0
October	0.76	0.28	-0.48	0.4	0.5	0.0	0.0
November	0.49	0.32	-0.17	2.4	3.0	0.3	0.3
December	0.73	0.58	-0.15	7.3	6.6	2.8	0.0
Annual	8.18	7.60	-0.58	24.5	26.0	NA ^a	NA ^a

a. NA = Not applicable.

Climate Trends at the INL Site

An analysis of long-term observations at CFA was undertaken to determine if climate trends are detectable in the available data. However, it should be pointed out that computing climate trends from a single station has significant limitations due to instrument uncertainty, land-use changes, and the natural variability in the observations. The temperature and wind data are taken from the more reliable CFA Mesonet station between 1994 through 2024, whereas the precipitation data (including snowfall) is taken from the Thermoscreen dataset measured between 1950 through 2024. Daily mean, maximum, and minimum air temperatures were averaged for each year of the record. A linear regression and analysis of variance was conducted on the resulting annual-average data set (Figure 6). The regression indicates a slight upward trend in annual daily average mean air temperatures with 0.008°F per year (or 0.08°F per decade). The trend is negative for the daily maximum temperatures with -0.013°F per year (or -0.13°F per decade) but a positive trend for the average daily minimum temperature with 0.028°F per year (or 0.28°F per decade). Climate change research indicates that minimum temperatures are in general rising faster than maximum temperatures, though there are many exceptions (IPCC, 2018) which agrees with our dataset. The annual daily average air temperature trend is not statistically significant at a 95% level as indicated by an analysis of variance, so the CFA observations by themselves do not provide strong evidence for a trend in annual temperatures.

The analysis of air temperature was further examined in light of the winter (December-February) and summer (June-August) seasons. For the winter season, the computed temperature trends are actually slightly negative for the daily maximum, average, and minimum temperatures (Figure 7). The steepest slope is observed in the daily maximum temperature with -0.113°F per year (or -1.13°F per decade). None of the winter slopes, however, are significantly different from zero at a 95% level as determined by the analysis of variance. Analysis of the summer temperature trends provided the strongest signals in the CFA data. As is the case with the annual data, the largest summer trend is observed in daily minimum air temperature (Figure 8) with 0.113°F per year (or 1.13°F per decade). The slope for the summer daily maximum is not significantly different from zero at a 95% confidence level. Hence, the summer CFA data show the strongest evidence of a long-term trend, with the daily minimum and daily average temperatures.

A similar regression analysis was undertaken for precipitation and snowfall. A linear regression and an analysis of variance were performed on the average precipitation data (Figure 9) and snowfall data (Figure 10). The linear regression indicates that CFA precipitation has a negative trend of 0.003 inches per year (or $0.03''$ per decade). An analysis of variance shows this trend is not significantly different from zero at a 95% confidence level. The linear regression indicates that CFA snowfall has a negative trend of 0.043 inches per year (or $-0.43''$ per decade). An analysis of variance also shows this trend is not significantly different from zero at a 95% confidence level.

Wind speeds were similarly analyzed to determine if there was any longer-term trend in the signal. For this variable the CFA data are limited to the 31-year period of 1994-2024. Annual averages were obtained from the five-minute record. A linear regression and an analysis of variance were performed on the averaged data (Figure 11). The linear regression indicates that CFA winds has a slight negative trend of 0.017 mph per year or $(0.17$ mph) per decade. However, this trend is not significantly different from zero at a 95% confidence level.

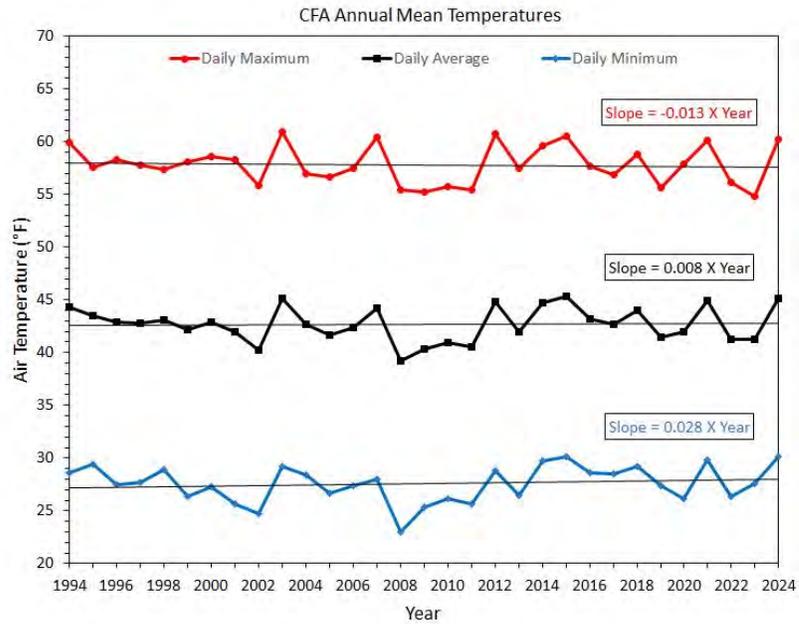


Figure 6. Mean air temperature for INL Site using daily maximum (dot), daily average (square), or daily minimum (diamond) temperatures from 1994 through 2024. Linear trend lines and the linear regression slopes are also shown.

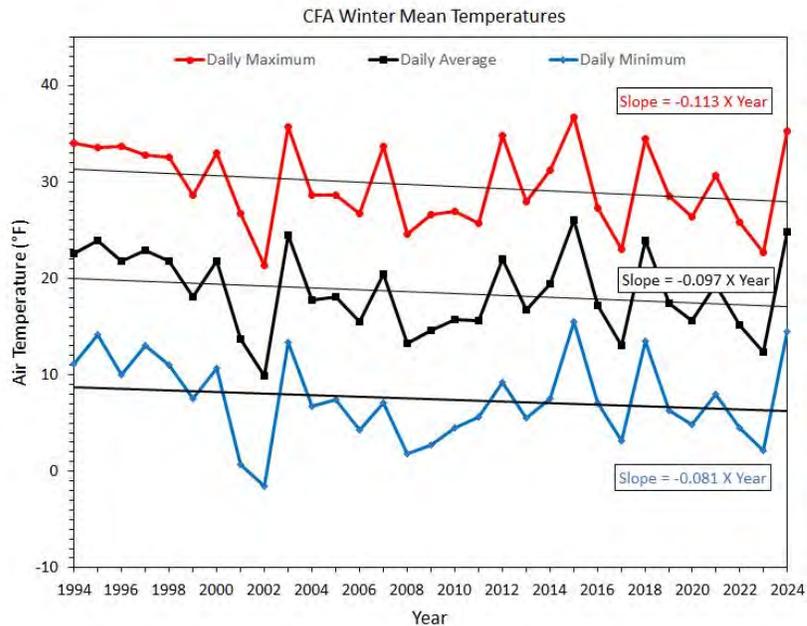


Figure 7. Winter season mean air temperature for CFA using daily maximum (dot), daily average (square), or daily minimum (diamond) temperatures from 1994 through 2024. Linear trend lines and the regression slopes are also shown. The year on the plot represents the year the winter season started.

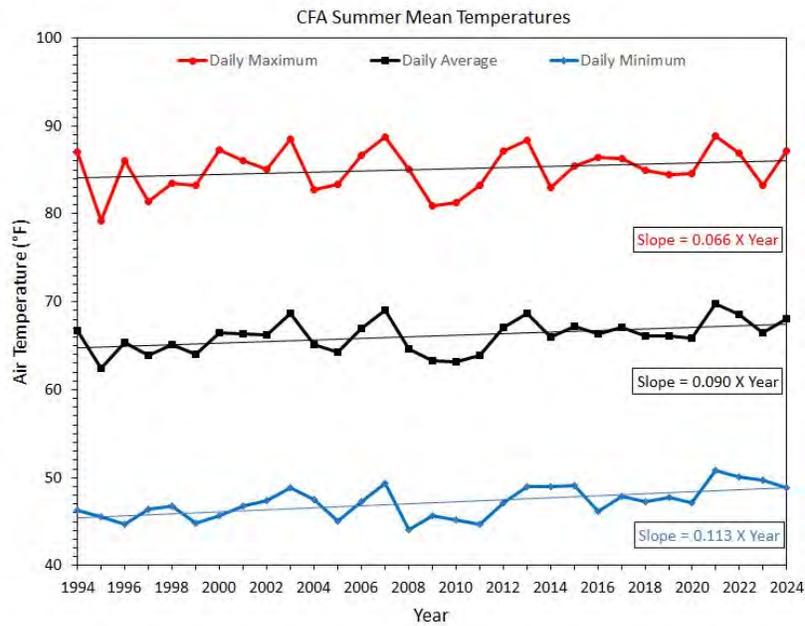


Figure 8. Summer season mean air temperature for CFA using daily maximum (dot), daily average (square), or daily minimum (diamond) temperatures from 1994 through 2024. Linear trend lines and the regression slopes are also shown.

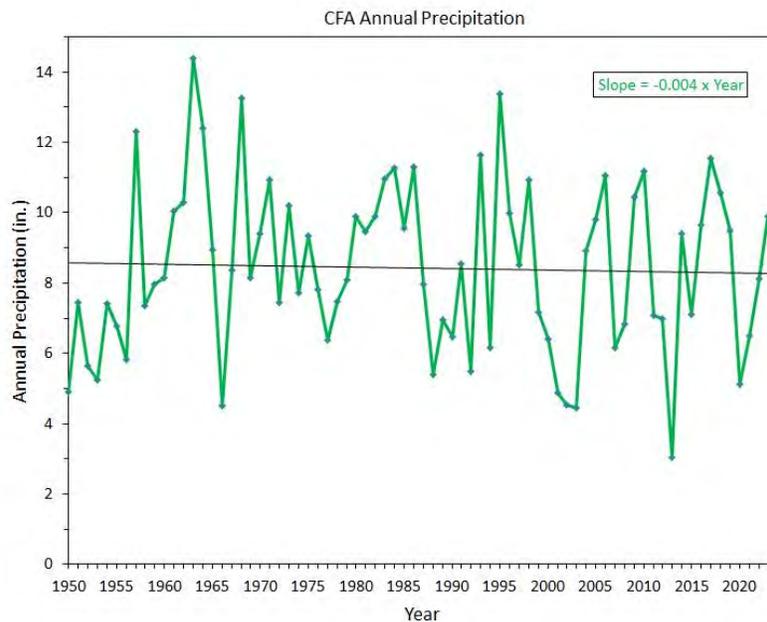


Figure 9. Mean annual precipitation for CFA using daily precipitation totals averaged for each year of record at CFA from 1950 through 2024. The linear trend line and regression slope are also shown.

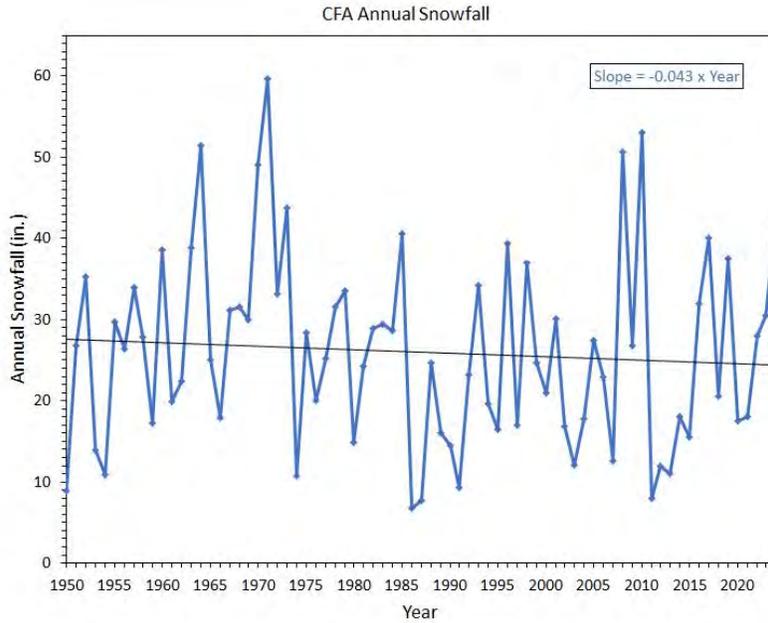


Figure 10. Mean annual snowfall data for CFA using daily snowfall totals averaged for each year of record at CFA from 1950 through 2024. The linear trend line and regression slope are also shown.

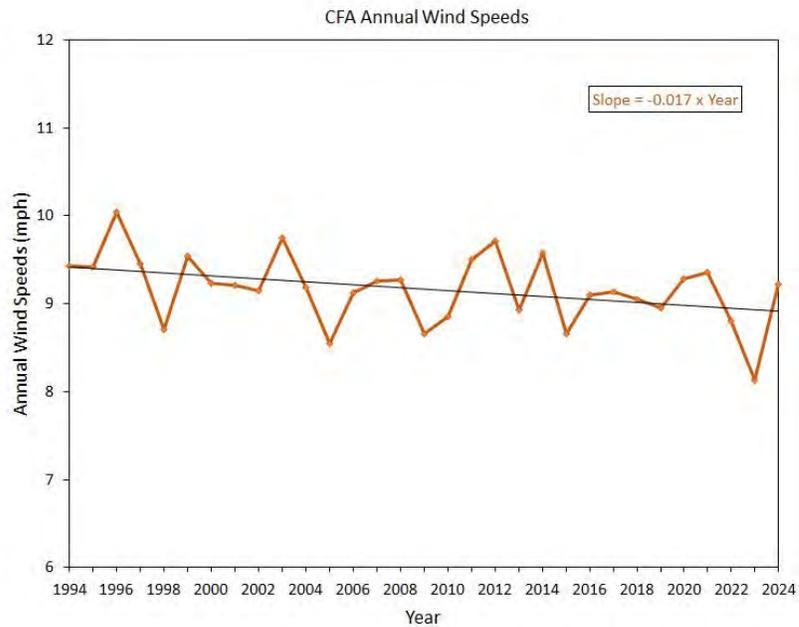


Figure 11. Mean annual wind speed data for CFA using five-minute wind speed data totals averaged for each year of record at CFA from 1994 through 2024. The linear trend line and regression slope are also shown.

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