Meteorological Monitoring

A Supplement to the
INL Site Environmental Report for 2022

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 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 the 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 climatography 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 at that time 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 in order 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 climatography (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 the time of 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 climatography 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 were

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

In 2018, a fourth edition of the INL climatography 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 wind regime of the Specific Manufacturing Capability (SMC) on the north end of the INL. It is anticipated that the fourth edition of the INL climatography will continue to be useful 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, as well as 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 in an effort 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 surrounding area as of December 31, 2022. 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 each of the three INL microclimate zones. These tall towers are at Grid 3/INTEC (GRI), MFC, and SMC. 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 of the measured variables.

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 both 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
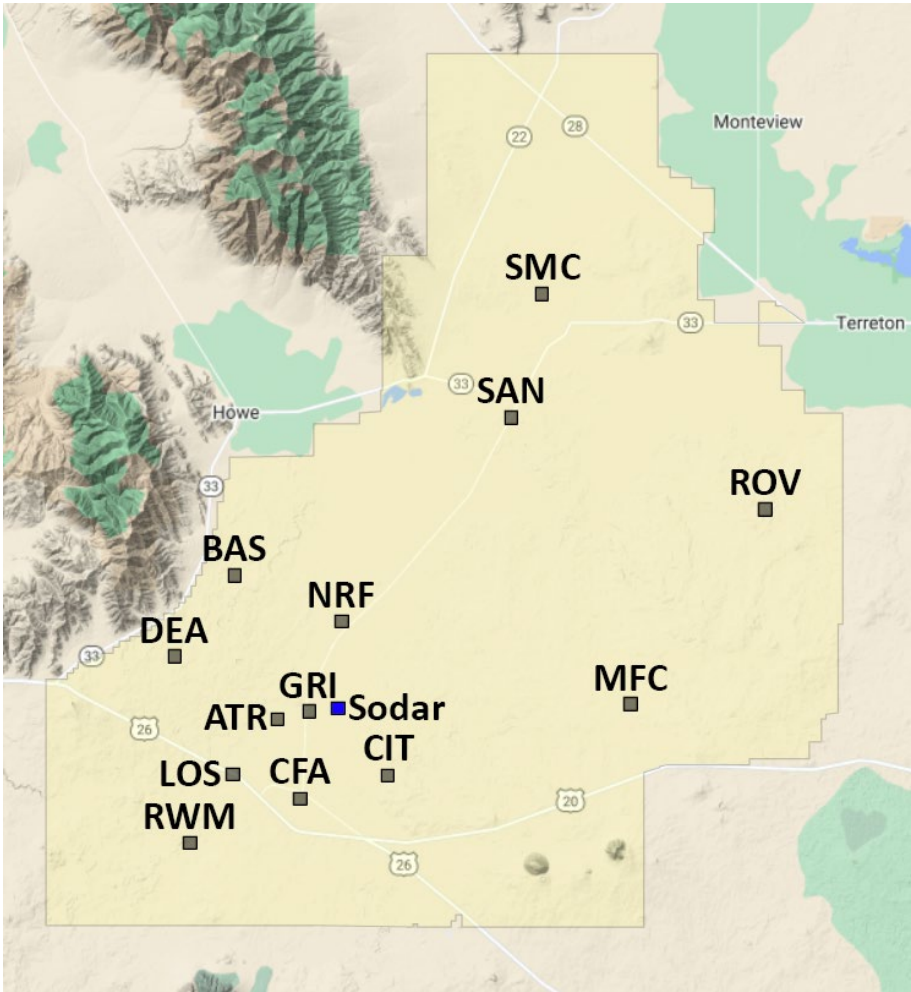

Figure 1. NOAA/INL Mesonet Stations on the INL Site as of December 31, 2022. The blue square is the location of the Sodar.
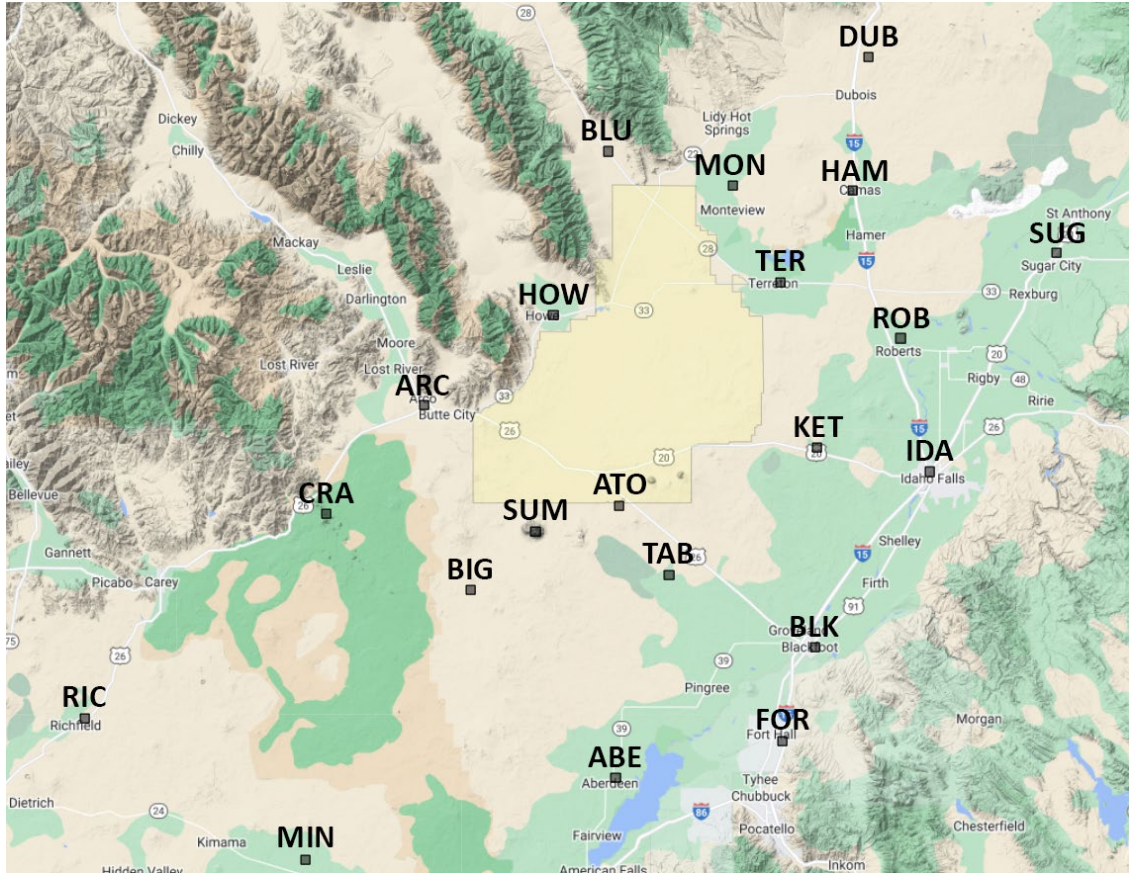
Figure 2. NOAA/INL Mesonet Stations outside the INL Site as of December 31, 2022.

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 2022.

Station Name	Station ID	Latitude (deg N)	Longitude (deg W)	Elevation MSL (ft)	Bottom Level Data	Bottom Level Height	Middle Level(s) Data	Middle Level(s) Height	Top Level Data	Top Level Height	Other Data
ATR Complex	ATR	43.584633	112.968667	4,937	t,r	6 ft (2 m)	w,T	50 ft (15 m)			p,s,b
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 w,T 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 w,T 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 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 Climatography 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 Climatography of the INEL.

Table 2. NOAA/INL Mesonet Stations off the INL Site as of December 2022.

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 Climatography of the INEL was published (ATO started in April 1995, BLK started in August 2001, COX and CRA started in April 1993, FOR started in March 1997, SUG started in April 1993, SUM started 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 6 ft (2 m), 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 Monteview 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 the 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 individual 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. All of 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 located 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 tower. Precipitation is collected in a rain gauge located about 50 feet (15.2 m) southwest of the tower and is manually measured weekly. Daily total precipitation is interpolated from this weekly total using the five-minute data from a separate electronic rain gauge located about 15 feet (4.6 m) east of the CFA tower. Snow depth is measured manually at the same time as precipitation and interpolated to a daily depth. Total daily snowfall is estimated using a snow depth sensor installed at CFA but also takes into account the precipitation amount, temperatures at time of precipitation, and the INL weather camera. This dataset is what compromises the National Weather Service cooperative observer station known as Idaho Falls 46W (or IDA 46W). The data from IDA 46W are also included in NOAA's National Centers for Environmental Information (NCEI) database, which is 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 operates by emitting a sound pulse at 4.5 KHz, listening to the atmospheric echo from that pulse, and then calculating the winds based on Doppler shifts. Five-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 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.

Figure 4. Sodar near Grid 3.

A camera for monitoring weather phenomena during daylight hours was installed at Grid 3 in 1998. The data are available in real-time at the ARLSORD office through a dedicated line. 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 degrade 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 of the problems in the database and, if needed, notify a technician to quickly fix the problem.

Data Dissemination

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

NOAA INL WEATHER CENTER

Current INL Observations
Wed Apr 28, 2010

12:45 MDT	Winds (mph)	T (F)	WC (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 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
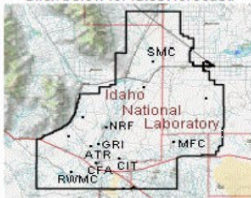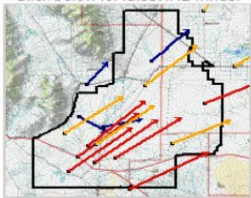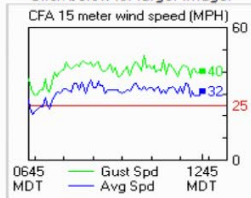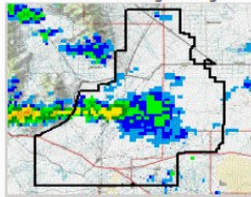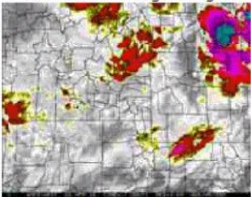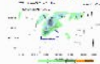
Contact:
INL weather questions
phone: 526-2744
email
NOAA FRD HOME

CURRENT INL 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 INL WEATHER ALERT/STATEMENT (criteria)

FORECAST	WINDS	6-HR CFA WIND TREND
Click below for latest forecast.	Click below for latest INL winds.	Click below for larger image.

RADAR	SATELLITE	INL CAMERA
Click below for larger image.	Click below for larger image.	Click below for larger image.
INL Radar Loop	Satellite Loop SE ID Satellite	Camera Loop Sunrise/Sunset

Top Wind Gusts   Current Conditions   Daily Summary   Precip Summary   WRF Model   INL Climate

This page automatically refreshes every 5 minutes.

Figure 5. NOAA/INL Weather Center web page.

(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 issued watches and warnings are issued 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 of 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 bottom of the NIWC page. Some of these products are current observations that include a lightning map and table (only available to INL Internet users), links to NWS zone 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 that is 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.

Back 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 be used to provide HYSPLIT with forecast winds many hours into the future. This model has been a valuable tool in the INL Emergency Operations Center for many years.

Finally, in more recent years the NARAC (National Atmospheric Release Advisory Center) suite of model products plays an important role in current emergency management operations. NARAC took the idea of assimilating 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 on a 24/7 basis 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.

INL Site Climate During 2022

This section describes the basic climate observations at the INL Site using data from CFA. The database includes information on daily air temperature maximums and minimums, precipitation, snowfall, and snow depth.

For 2022, the average daily mean temperature measured at CFA was cooler than the 1991-2020 30-year normal (Table 3). The 2022 average temperature was 40.9°F, 1.8°F below the 30-year normal. July was the warmest month, with an average daily mean temperature of 73.5°F, 4.1°F above normal. February was the month with the largest departure from normal during the year which was 10.5°F below normal. January was the coldest month, with an average of 11.0°F, 6.1°F below normal. The highest air temperature in 2022 was 99°F and was recorded on July 14th, September 3rd, and September 7th. The lowest temperature at CFA during 2022 was -23°F and was recorded on December 22nd.

Eight highest daily maximum temperatures were set or tied in 2022. March 25th recorded a maximum temperature of 69 °F that tied the previous highest daily maximum temperature set in 2012. March 26th recorded a maximum temperature of 68 °F that broke the previous highest daily maximum temperature of 66 °F set in 1966. August 31st recorded a maximum temperature of 96 °F that broke the previous highest daily maximum of 95 °F from 1955. September 1st recorded a maximum temperature of 96 °F that tied the previous highest daily maximum temperature from 1950. September 3rd recorded a maximum temperature of 99 °F that broke the previous highest daily maximum temperature of 96 °F set in 1950. September 4th recorded a maximum temperature of 96 °F that tied the previous highest daily maximum temperature set in 1950. September 6th recorded a maximum temperature of 98 °F that broke the previous highest daily maximum temperature of 96 °F set in 1955. September 7th recorded a maximum temperature of 99 °F that broke the previous highest daily maximum temperature of 93 °F set in 1955, 1977, and 1979.

Three highest daily minimum temperatures were set in 2022. May 27th recorded a minimum temperature of 57 °F that broke the previous highest daily minimum temperature of 53 °F set in 1974. September 4th recorded a minimum temperature of 59 °F that broke the previous highest daily minimum temperature of 58 °F set in 1982 and 1990. September 8th recorded a minimum temperature of 60 °F that broke the previous highest daily minimum temperature of 58 °F set in 1950.

Six lowest daily minimum temperatures were set or tied in 2022. March 10th recorded a minimum temperature of -11 °F that broke the previous lowest daily minimum temperature of -7 °F set in 1969. May 11th recorded a minimum temperature of 17 °F that broke the previous lowest daily minimum temperature of 18 °F set in 1999. November 18th recorded a minimum temperature of -10 °F that tied the previous lowest daily minimum temperature from 2014. November 19th recorded a minimum temperature of -9 °F that broke the previous lowest daily minimum temperature of -5 °F set in 1953 and 1977. November 20th recorded a minimum temperature of -9 °F that broke the previous lowest daily minimum temperature of -6 °F set in 2000. December 19th recorded a minimum temperature of -21 °F that tied the previous lowest daily minimum temperature set in 1984 and 2016.

Seven lowest daily maximum temperature records were set last year. April 11th recorded a maximum temperature of 36 °F that broke the previous lowest daily maximum of 37 °F from 1970. April 12th recorded a maximum temperature of 32 °F that broke the previous lowest daily maximum temperature of 39 °F set in 1974 and 2020. April 13th recorded a maximum temperature of 36 °F that broke the previous lowest daily maximum temperature of 40 °F set in 1970 and 2020. May 22nd recorded a maximum temperature of 48 °F that tied the previous lowest daily maximum temperature set in 2010. November 11th recorded a maximum temperature of 22 °F that broke the previous lowest daily maximum of 23 °F from 2014. December 16th recorded a maximum temperature of 9 °F that broke the previous lowest daily maximum temperature of 12 °F set in 1967 and 1992. December 19th recorded a maximum temperature of 5 °F that broke the previous lowest daily maximum temperature of 6 °F set in 1998.

Table 3. Average Daily Maximum, Minimum and Mean Air Temperatures by Month for CFA Normals from 1991 through 2020 and for 2022, including Departure from the Average, and Annual Average and Departures from the 30-year Normals.

Month	Average Daily Maximum Temperature			Average Daily Minimum Temperature			Average Daily Mean Temperature		
	1991-2020 (°F)	2022 (°F)	Departure (°F)	1991-2020 (°F)	2022 (°F)	Departure (°F)	1991-2020 (°F)	2022 (°F)	Departure (°F)
January	28.3	21.4	-6.9	5.9	0.6	-5.3	17.1	11.0	-6.1
February	33.3	23.2	-10.1	10.2	-0.6	-10.8	21.8	11.3	-10.5
March	46.4	46.2	-0.2	21.3	19.5	-1.8	33.9	32.9	-1.0
April	57.4	52.3	-5.1	28.4	23.7	-4.7	42.9	38.0	-4.9
May	67.3	62.1	-5.2	36.8	34.9	-1.9	52.1	48.5	-3.6
June	77.5	77.4	-0.1	43.6	43.1	-0.5	60.6	60.3	-0.3
July	88.9	93.8	+4.9	49.9	53.1	+3.2	69.4	73.5	+4.1
August	86.8	89.6	+2.8	47.7	53.9	+6.2	67.3	71.7	+4.5
September	76.0	80.4	+4.4	38.4	42.7	+4.3	57.2	61.6	+4.4
October	59.7	64.0	+4.3	27.2	26.7	-0.5	43.5	45.4	+2.0
November	42.5	32.6	-9.9	16.2	9.1	-7.1	29.4	20.9	-8.5
December	29.1	23.5	-5.6	6.6	3.0	-3.6	17.9	13.3	-4.6
Annual	57.8	55.8	-2.0	27.7	26.0	-1.7	42.7	40.9	-1.8

The year 2022 was drier than normal at CFA. Table 4 shows the monthly and annual precipitation summary. The annual total was 8.11" (0.32" below normal) or 96% of normal. The wettest month was August (1.80" of precipitation) which was 1.26" above normal. The driest month of the year was in February (with 0.02" of precipitation) which was 0.48" below normal. August was the month with largest departure from normal precipitation.

Six daily precipitation records were set in 2022. May 30th recorded 0.56" of precipitation that broke the previous daily record of 0.47" from 1999. June 12th recorded 0.42" of precipitation that broke the previous daily record of 0.21" from 1955. July 2nd recorded 0.32" of precipitation that broke the previous daily record of 0.10" from 2004. August 13th recorded 0.95" of precipitation that broke the previous daily record of 0.59" from 1968. December 11th recorded 0.27" of precipitation that broke the previous daily record of 0.16" from 1996. December 27th recorded 0.39" of precipitation that broke the previous daily record of 0.27" from 1964.

Monthly and annual total snowfall and monthly average snow depth statistics for 2022 are given in Table 4 together with the 30-year normal. Normal annual snow depth statistics are not included

because they are not very meaningful. Total snowfall for 2022 was 28.0" or 114% of normal. December was the snowiest month with 13.5", which was 6.1" above normal (or 182% of average). The highest average monthly snow depth during 2022 occurred in December with 7.0" (4.2" above normal).

Three daily snowfall records were set in 2022. March 8th recorded 1.0" of snowfall which broke the previous daily record of 0.5" from 1951. November 8th recorded 3.0" of snowfall which broke the previous daily record 1.5" from 1986. December 11th recorded 3.0" of snowfall which broke the previous daily record of 2" from 1996 and 2020.

Table 4. Monthly and Annual Average Precipitation, Snowfall and Snow Depth for CFA Normals from 1991 through 2020 and 2022 and Total Precipitation Departure from the 30-year Normals.

Month	Total Precipitation			Total Snowfall		Mean Snow Depth	
	1991-2020 (in.)	2022 (in.)	Departure (in.)	1991-2020 (in.)	2022 (in.)	1991-2020 (in.)	2022 (in.)
January	0.67	0.08	-0.59	6.7	2.5	5.7	5.5
February	0.50	0.02	-0.48	4.5	1.0	6.1	5.4
March	0.64	0.20	-0.44	1.9	1.5	2.0	1.0
April	0.91	0.53	-0.38	1.0	2.0	0.0	0.1
May	1.31	1.07	-0.24	0.0	0.0	0.0	0.0
June	0.96	0.50	-0.46	0.0	0.0	0.0	0.0
July	0.37	0.36	-0.01	0.0	0.0	0.0	0.0
August	0.47	1.80	+1.33	0.0	0.0	0.0	0.0
September	0.67	1.25	+0.58	0.0	0.0	0.0	0.0
October	0.72	0.08	-0.64	0.4	0.0	0.0	0.0
November	0.49	0.83	+0.34	2.6	7.5	0.3	1.2
December	0.72	1.39	+0.67	7.4	13.5	2.8	7.0
Annual	8.43	8.11	-0.32	24.5	28.0	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 analysis was conducted for the period 1950-2022. 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 air temperature as measured at the CFA Thermoscreen. The trend is most visible in the average daily maximum temperature and least visible in the average daily minimum temperature. Climate change research actually indicates that minimum temperatures are in general rising faster than maximum temperatures, though there are many exceptions (IPCC, 2018). The computed trend for the average daily maximum temperature is 0.18°F for each decade. But this 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, followed by the daily average temperature. 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 maximum air temperature followed by the daily mean and minimum temperatures (Figure 8). The slopes for the summer daily maximum and daily mean temperatures are both 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 average trend being 0.37°F per decade.

A similar regression analysis was undertaken for precipitation. Daily precipitation totals were averaged for each year of record at CFA (1951-2022). A linear regression and an analysis of variance were performed on the averaged data (Figure 9). The linear regression indicates that CFA precipitation has a negative trend of 0.05 inches per decade. However, this trend is not significantly different from zero at a 95% confidence level. A separate analysis of seasonal precipitation did not show any difference between the winter and summer seasons.

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 30-year period of 1993-2022. Annual averages were obtained from the five-minute record. A linear regression and an analysis of variance were performed on the averaged data (Figure 10). The linear regression indicates that CFA winds has a slight negative trend of 0.09 mph per decade. However, this trend is not significantly different from zero at a 95% confidence level.
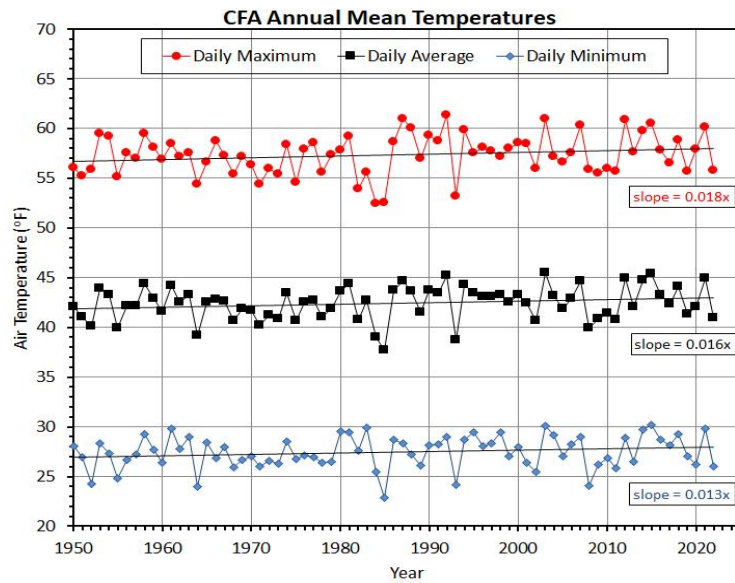
Figure 6. Mean air temperature for INL Site using daily maximum (dot), daily average (square), or daily minimum (diamond) temperatures from 1950 through 2022. Linear trend lines and the linear regression slopes are also shown.
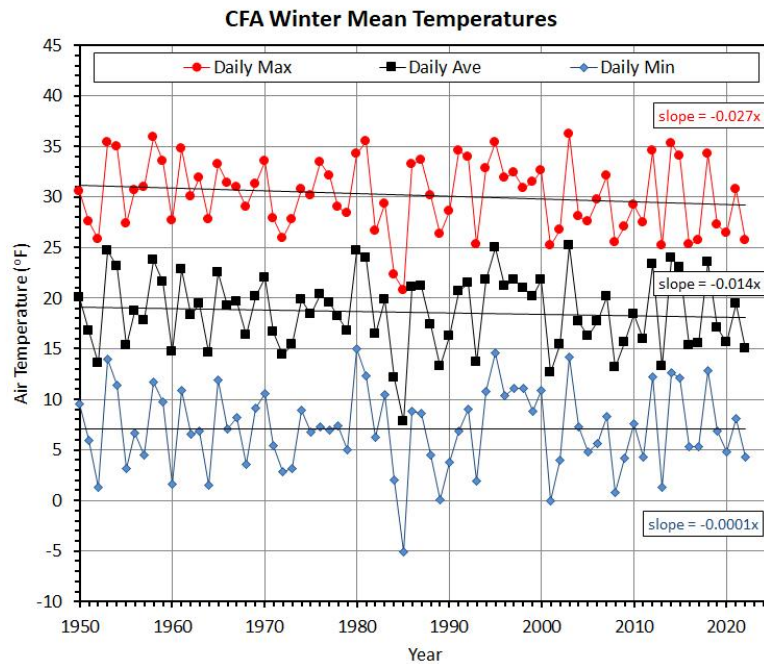

Figure 7. Winter season mean air temperature for CFA using daily maximum (dot), daily average (square), or daily minimum (diamond) temperatures from 1950 through 2022. Linear trend lines and the regression slopes are also shown. The year on the plot represents the year the Winter season started.
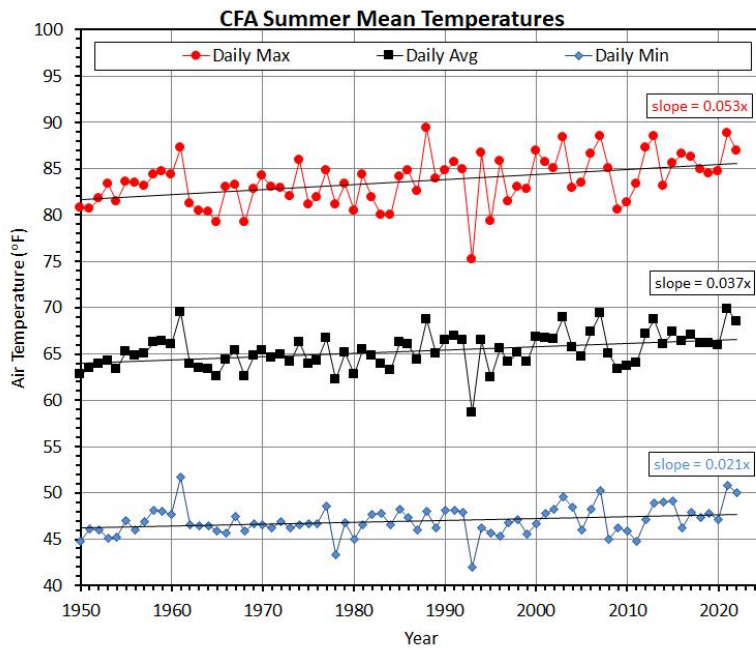
Figure 8. Summer season mean air temperature for CFA using daily maximum (dot), daily average (square), or daily minimum (diamond) temperatures from 1950 through 2022. Linear trend lines and the regression slopes are also shown.
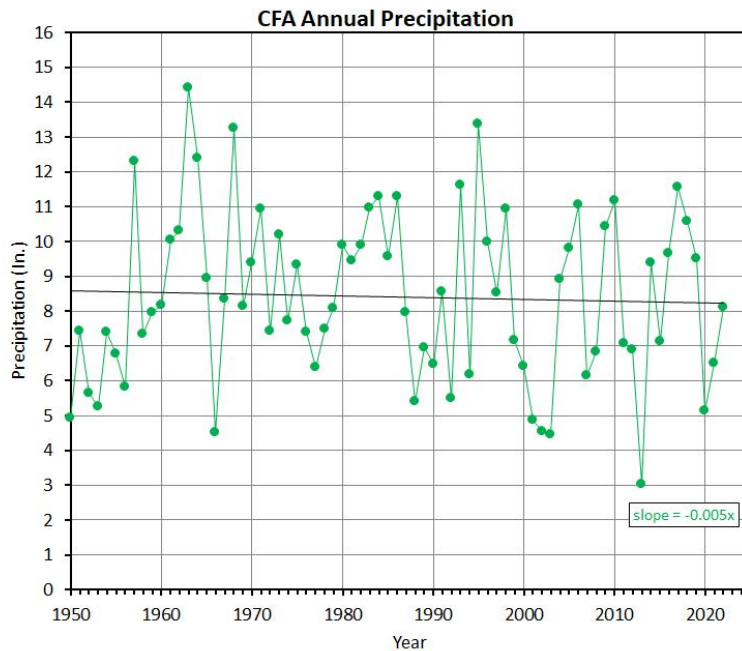

Figure 9. Mean annual precipitation for CFA using daily precipitation totals averaged for each year of record at CFA from 1950 through 2022. The linear trend line and regression slope are also shown.
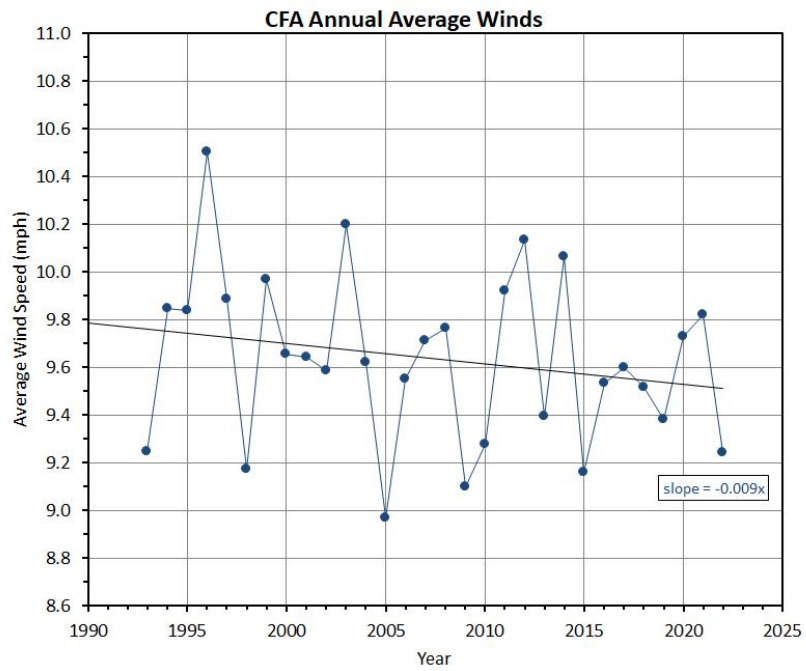
Figure 10. Mean annual wind speed data for CFA using five-minute wind speed data totals averaged for each year of record at CFA from 1993 through 2022. The linear trend line and regression slope are also shown.

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