Meteorological Monitoring

A Supplement to the
INL Site Environmental Report for 2021

METEOROLOGICAL MONITORING

Background

The Field Research Division of the National Oceanic and Atmospheric Administration Air Resources Laboratory (NOAA ARLFRD) 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 running atmospheric dispersion models for emergency response applications.

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.

Today, ARLFRD'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. ARLFRD continues to furnish weather forecast, climatological, and emergency support to the INL. As part of the ongoing support, a fourth edition of the INL climatography has been published (Clawson et al. 2018) based on meteorological observations through 2015. In addition to updating various climatological parameters, this new edition includes 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.

NOAA/INL Mesonet

What is now called the NOAA/INL Mesonet (MESOscale meteorological monitoring NETwork) began with a single 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, 2021. 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

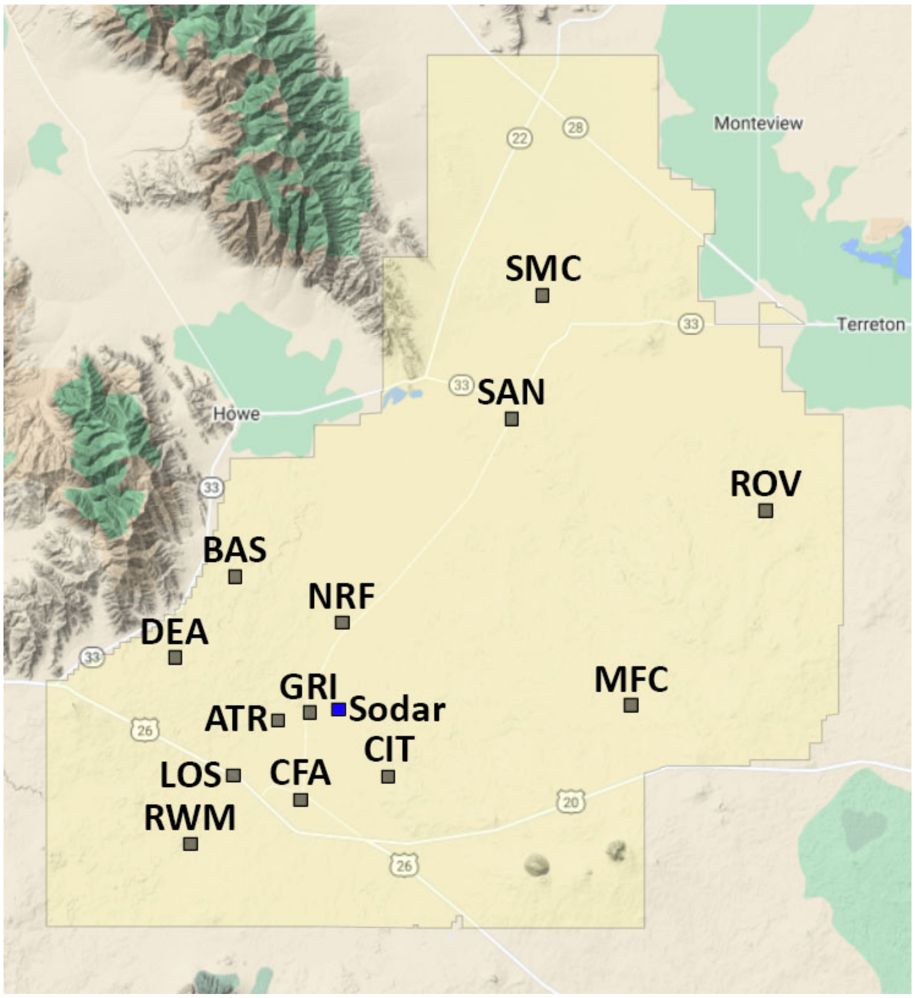

Figure 1. NOAA/INL Mesonet Stations on the INL Site as of December 31, 2021. The blue square is the location of the Sodar.

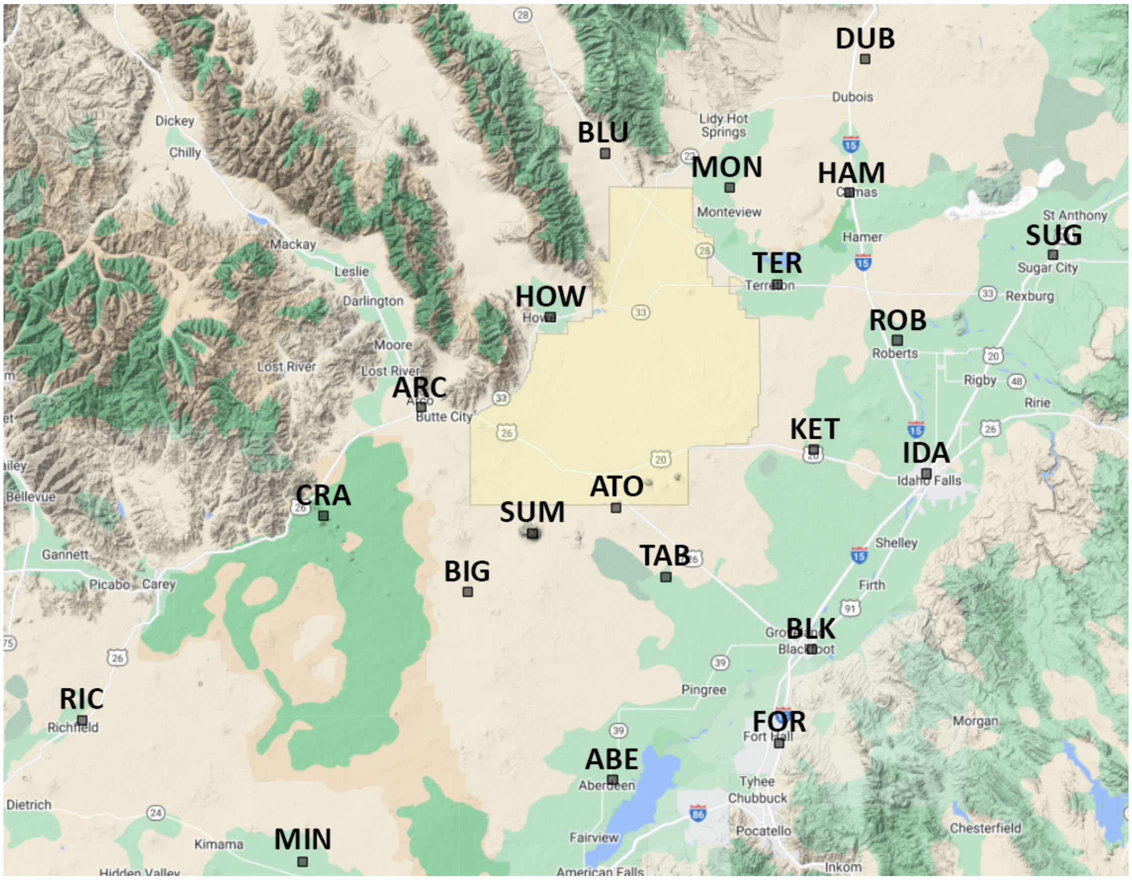

Figure 2. NOAA/INL Mesonet Stations outside the INL Site as of December 31, 2021.

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 2021.

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	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 2021.

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. ARLFRD 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 ARLFRD. 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 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 (<u>So</u>und <u>D</u>etection <u>a</u>nd <u>R</u>anging) 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 FRD 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. ARLFRD 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

(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, ARLFRD 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 ARLFRD-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 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

ARLFRD 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

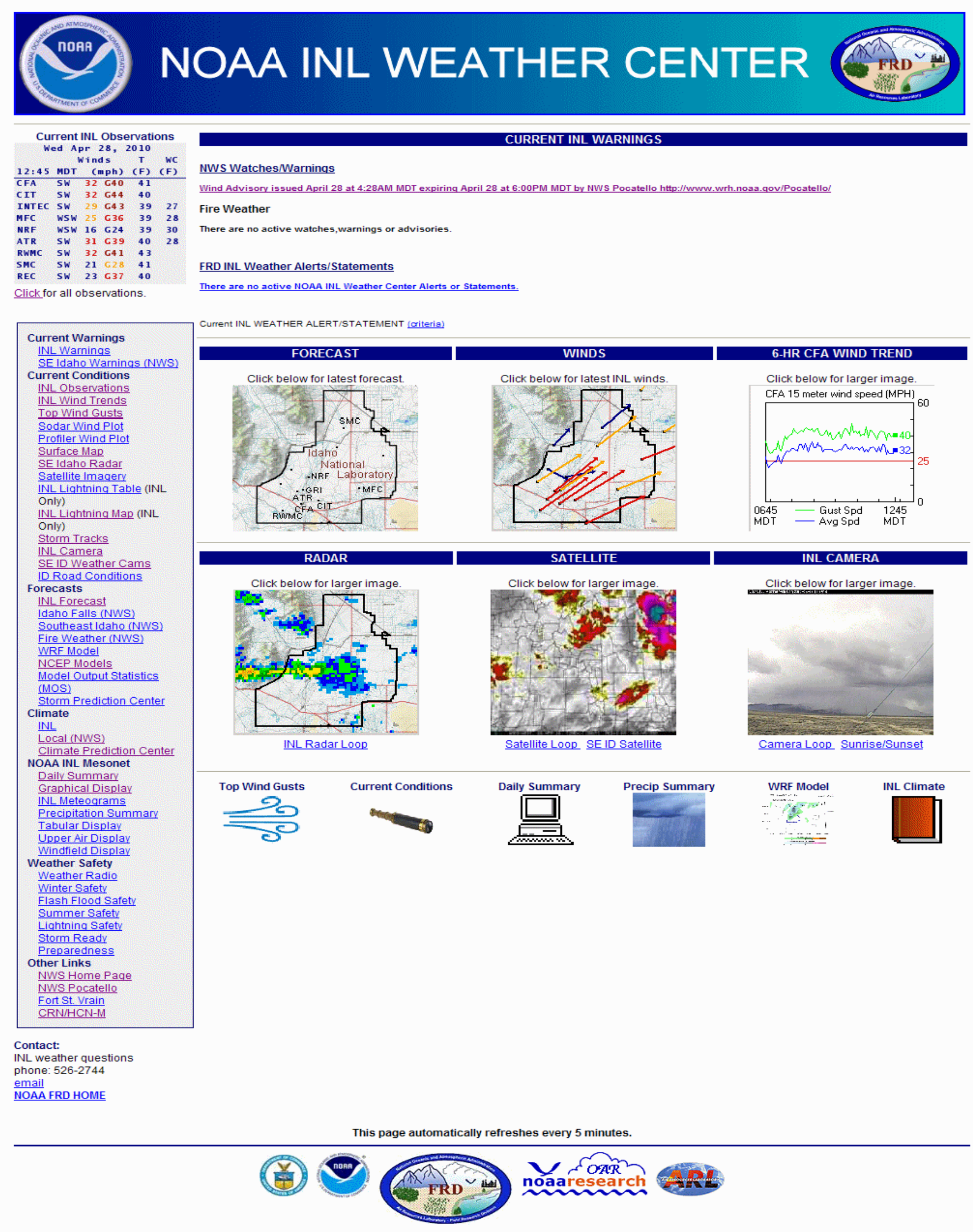

Figure 5. NOAA/INL Weather Center web page.

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.

ARLFRD has 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.

Adoption of HYSPLIT is beneficial to both the INL Site and NOAA, because the limited NOAA staff in Idaho Falls is supported by a much broader group of HYSPLIT users and developers. Also, any model improvements made for INL Site applications can be shared more widely within NOAA. Some of the benefits of adopting HYSPLIT for use at the INL Site are:

- Use of more realistic wind fields that account for the local topography and changes in the wind with height
- Improvement of the dispersion model output so it is more useful to decision makers in the INL Emergency Operations Center
- Capability to forecast future plume movements using gridded atmospheric models
- A simpler mechanism for developing release scenarios for INL facilities.

The HYSPLIT system employed for emergency response uses an Internet browser interface to set up and display the plume model runs. This allows one copy of the client software to be maintained centrally rather than having a separate program copy on every computer that needs to run the model. The plume contours are displayed on a map background based on the Leaflet mapping api. This provides a map that can be panned and zoomed in addition to displaying roads, place names, and topography. Other map layers can be added as needed.

ARLFRD has worked with the INL Site to ensure that the HYSPLIT system contains release scenarios that have been identified from risk studies at the site. Because HYSPLIT has a more sophisticated treatment of radiological doses, the information required to develop HYSPLIT scenarios for the INL Site differs from that required in the older MDIFF model. In 2018, an updated version of the HYSPLIT system was deployed.

INL Site Climate During 2021

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 2021, the average daily mean temperature measured at CFA was warmer than the 1991-2020 30-year normal (Table 3). The 2021 average was 44.9°F, 2.2°F above the 30-year normal. July was the warmest month, with an average daily mean temperature of 74.7°F, 5.3°F above normal. June was the month with the largest departure from normal during the year which was 8.0°F above normal. January was the coldest month, with an average of 19.4°F, 2.3°F above normal. The highest air temperature in 2021 was 102°F recorded on July 7^{th}. The lowest temperature at CFA during 2021 was -7°F recorded on December 18^{th} and 28^{th}.

Thirteen highest daily maximum temperatures were set in 2021. April 30^{th} recorded a maximum temperature of 84°F that broke the previous highest daily maximum of 78 °F from 1977. June 2nd recorded a maximum temperature of 91°F that broke the previous highest daily maximum temperature of 89 °F from 1986. June 3^{rd} recorded a maximum of temperature of 95 °F that broke the previous highest daily maximum temperature of 89 °F from 1988. June 4^{th} recorded a maximum temperature of 95°F that broke the previous highest daily maximum temperature of 92 °F from 1988. June 13^{th} recorded a maximum temperature of 97 °F that broke the previous highest daily maximum temperature of 93 °F from 1974. July 7^{th} recorded a maximum temperature of 102 °F that broke the previous highest daily maximum temperature of 99 °F set in 1989. July 26^{th} recorded a maximum temperature of 98 °F that broke the previous highest daily maximum temperature of 97 °F set in 2016. September 8^{th} recorded a maximum temperature of 94 °F that broke the previous highest daily maximum temperature of 90 °F set in 1979, 1990, 1994, and 2005. September 9^{th} recorded a maximum temperature of 95 °F that broke the previous highest daily maximum temperature of 90 °F set in 1988 and 1990. September 10^{th} recorded a maximum temperature of 91 °F that broke the previous highest daily maximum temperature of 90 °F set in 1959. November 29^{th} recorded a maximum temperature of 54 °F that broke the previous highest daily maximum temperature of 51 °F set in 1995. December 2^{nd} recorded a maximum temperature of 50 °F that broke the previous highest daily maximum temperature of 48 °F set in 2013. December 5^{th} recorded a maximum temperature of 52 °F that broke the previous highest daily maximum temperature of 51 °F set in 1987.

Six highest daily minimum temperatures were set in 2021. June 5^{th} recorded a minimum temperature of 60 °F that broke the previous highest daily minimum temperature of 56 °F from 1957 and 1985. June 26^{th} recorded a minimum temperature of 61 °F that broke the previous highest daily minimum temperature of 60 °F from 1988. June 30^{th} recorded a minimum temperature of 60 °F that broke the previous highest daily minimum temperature of 59 °F from 2015. July 28^{th} recorded a minimum temperature of 68 °F that broke the previous highest daily minimum temperature of 64 °F set in 1956. October 7^{th} recorded a minimum temperature of 48 °F that broke the previous highest daily minimum temperature of 47 °F set in 1989. November 14^{th} recorded a minimum temperature of 38 °F that broke the previous highest daily minimum temperature of 37 °F set in 1981.

May 29^{th} recorded a minimum record of 27 °F that broke the previous lowest daily minimum temperature record of 28 °F from 1977.

No lowest daily maximum temperature records were set last year.

Table 3. Average Daily Maximum, Minimum and Mean Air Temperatures by Month for CFA Normals from 1991 through 2020 and for 2021, including Departure from the Average, and Annual Average and Departures from the 30-year Normals.

	Average Daily Maximum Temperature			Average Daily Minimum Temperature			Average Daily Mean Temperature		
Month	1991-2020 (°F)	2021 (°F)	Departure (°F)	1991-2020 (°F)	2021 (°F)	Departure (°F)	1991-2020 (°F)	2021 (°F)	Departure (°F)
January	28.3	29.7	+1.4	5.9	9.1	+3.2	17.1	19.4	+2.3
February	33.3	32.5	-0.8	10.2	10.4	+0.2	21.8	21.5	-0.3
March	46.4	48.1	+1.7	21.3	19.1	-2.2	33.9	33.6	-0.3
April	57.4	58.4	+1.0	28.4	26.6	-1.8	42.9	42.5	-0.4
May	67.3	68.3	+1.0	36.8	37.1	+0.3	52.1	52.7	+0.7
June	77.5	88.0	+10.5	43.6	48.9	+5.3	60.6	68.5	+8.0
July	88.9	94.5	+5.6	49.9	54.8	+4.9	69.4	74.7	+5.3
August	86.8	83.8	-3.0	47.7	48.6	+0.9	67.3	66.2	-1.1
September	76.0	78.3	+2.3	38.4	35.3	-3.1	57.2	56.8	-0.4
October	59.7	59.2	-0.5	27.2	32.1	+4.9	43.5	45.7	+2.3
November	42.5	45.8	+3.3	16.2	21.1	+4.9	29.4	33.5	+4.2
December	29.1	32.4	+3.3	6.6	12.9	+6.3	17.9	22.6	+4.8
Annual	57.8	60.1	+2.3	27.7	29.8	+2.1	42.7	44.9	+2.2

The year 2021 was drier than normal at CFA. Table 4 shows the monthly and annual precipitation summary. The annual total was 6.51” (1.92” below normal) or 77% of normal. The wettest month was October (1.98” of precipitation) which was 1.26” above normal. The driest month of the year was in July (with 0.02” of precipitation) which was 0.35” below normal. October was the month with largest departure from normal precipitation.

Three daily precipitation records were set in 2021. March 20th recorded 0.28” which broke the previous record of 0.27” from 1995. August 2nd recorded 0.63” of precipitation that broke the previous daily record of 0.23” from 2004. October 8th recorded 1.04” of precipitation that broke the previous daily record of 0.58” from 1973.

Monthly and annual total snowfall and monthly average snow depth statistics for 2021 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 2021 was 18.0” or 73% of normal. December was the snowiest month with 7.5”, which was 0.1” above normal (or 101% of average). The highest average monthly snow depth during 2021 occurred in January with 2.7” (3.0” below normal). No daily snowfall records were set in 2021.

Table 4. Monthly and Annual Average Precipitation, Snowfall and Snow Depth for CFA Normals from 1991 through 2020 and 2021 and Total Precipitation Departure from the 30-year Normals.

Month	Total Precipitation			Total Snowfall		Mean Snow Depth	
	1991-2020 (in.)	2021 (in.)	Departure (in.)	1991-2020 (in.)	2021 (in.)	1991-2020 (in.)	2021 (in.)
January	0.67	0.39	-0.28	6.7	5.5	5.7	2.7
February	0.50	0.27	-0.23	4.5	3.5	6.1	1.9
March	0.64	0.71	+0.07	1.9	1.5	2.0	1.0
April	0.91	0.24	-0.67	1.0	0.0	0.0	0.0
May	1.31	0.47	-0.84	0.0	0.0	0.0	0.0
June	0.96	0.27	-0.69	0.0	0.0	0.0	0.0
July	0.37	0.02	-0.35	0.0	0.0	0.0	0.0
August	0.47	1.36	+0.89	0.0	0.0	0.0	0.0
September	0.67	0.12	-0.55	0.0	0.0	0.0	0.0
October	0.72	1.98	+1.26	0.4	0.0	0.0	0.0
November	0.49	0.18	-0.31	2.6	0.0	0.3	0.0
December	0.72	0.50	-0.22	7.4	7.5	2.8	2.4
Annual	8.43	6.51	-1.92	24.5	18.0	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 1950-2021. 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 summer (June-August) and winter (December-February) seasons. For the winter season, the computed temperature trends are actually slightly negative for the daily maximum, average, but slightly positive for minimum temperatures (Figure 8). 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 9). 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 0.35°F per decade.

A similar regression analysis was undertaken for precipitation. Daily precipitation totals were averaged for each year of record at CFA (1951-2021). A linear regression and an analysis of variance were performed on the averaged data (Figure 10). The linear regression indicates that CFA precipitation has a negative trend of 0.005 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 29-year period of 1993-2021. 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 0.007 mph per decade. However, this trend is not significantly different from zero at a 95% confidence level.

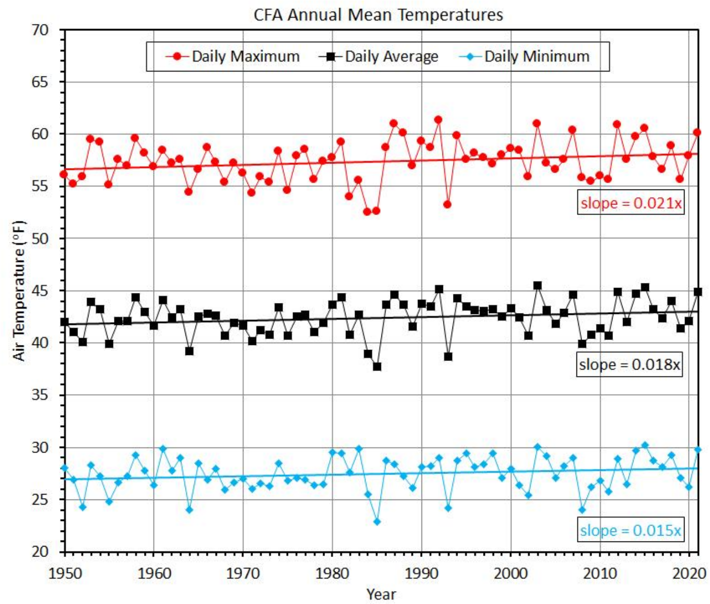

Figure 6. Mean air temperature for INL Site using daily maximum (dot), daily average (square), or daily minimum (diamond) temperatures from 1950 through 2021. Linear trend lines and the linear regression slopes are also shown.

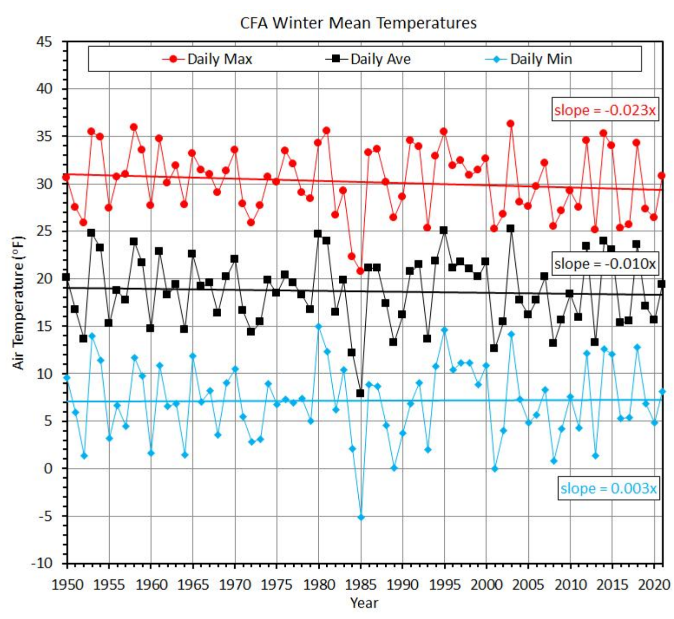

Figure 7. Winter season mean air temperature for CFA using daily maximum (dot), daily average (square), or daily minimum (diamond) temperatures from 1950 through 2021. Linear trend lines and the regression slopes are also shown. The year on the plot represents the year the Winter season started.

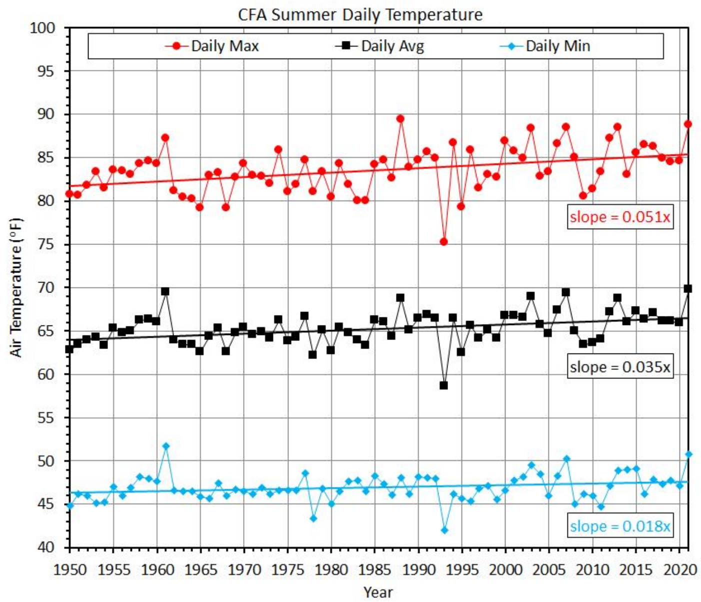

Figure 8. Summer season mean air temperature for CFA using daily maximum (dot), daily average (square), or daily minimum (diamond) temperatures from 1950 through 2021. Linear trend lines and the regression slopes are also shown.

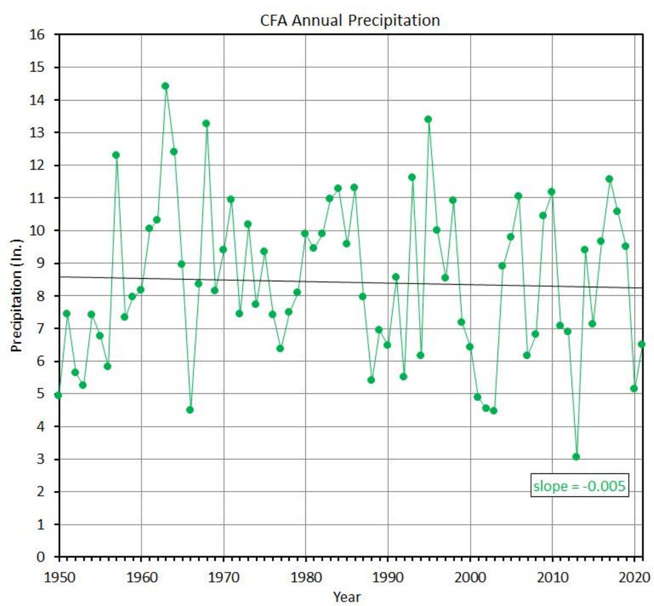

Figure 9. Mean annual precipitation for CFA using daily precipitation totals averaged for each year of record at CFA from 1950 through 2021. The linear trend line and regression slope are also shown.

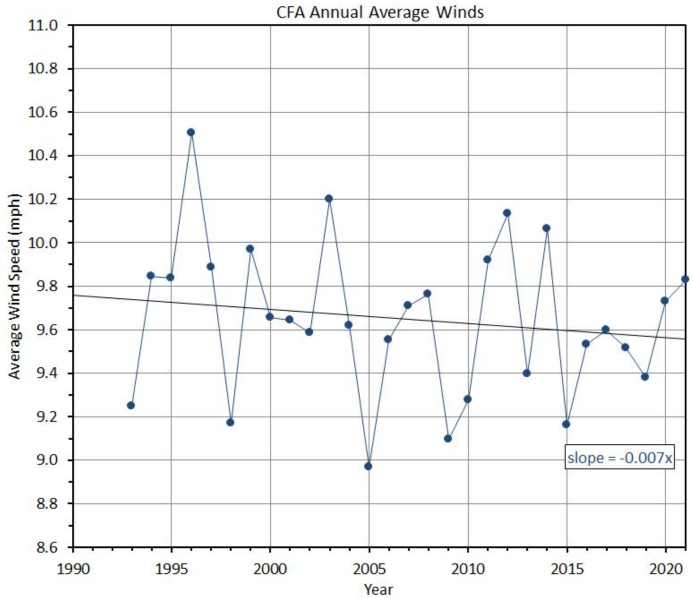

Figure 10. Mean annual wind speed data for CFA using five-minute wind speed data totals averaged for each year of record at CFA from 1993 through 2021. The linear trend line and regression slope are also shown.

REFERENCES

ANSI/ANS 3.11-2015, 2015, “Determining Meteorological Information at Nuclear Facilities,” American National Standards Institute.

ANSI/ANS 3.2-2012, 2012, “Managerial, Administrative and Quality Assurance Controls for the Operational Phase of Nuclear Power Plants,” American National Standards Institute.

Clawson, K. L., G. E. Start, and N. R. Ricks, 1989, *Climatography of the Idaho National Engineering Laboratory*, 2nd ed., DOE/ID-12118, U.S. Department of Energy Idaho Operations Office.

Clawson, K. L., R. M. Eckman, N. F. Hukari, J. D. Rich, and N. R. Ricks, 2007, *Climatography of the Idaho National Laboratory*, 3rd ed., NOAA Technical Memorandum OAR ARL-259, NOAA Air Resources Laboratory.

Clawson, K.L., J.D. Rich, R.M. Eckman, N.F. Hukari, D. Finn, B. Reese, 2018, *Climatography of the Idaho National Laboratory,* 4th ed., NOAA Technical Memorandum OAR ARL- 278 , NOAA Air Resources Laboratory.

DeMarrais, G. A., 1958a, *The Climatology of the National Reactor Testing Station*, IDO-12003, Atomic Energy Commission.

DeMarrais, G. A., 1958b, *The Engineering Climatology of the National Reactor Testing Station*, IDO-12004, Atomic Energy Commission.

DeMarrais, G. A. and N. F. Islitzer, 1960, *The Diffusion Climatology of the National Reactor Testing Station*, IDO-12015, Atomic Energy Commission.

DOE, 1991, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, DOE/EH-0173T, U.S. Department of Energy.

DOE, 2016, *Comprehensive Emergency Management System*, DOE Guide 151.1D, U.S. Department of Energy.

Draxler, R. R. and G. D. Hess, 1997, *Description of the HYSPLIT 4 Modeling System*, NOAA Tech. Memo ERL ARL-224, National Oceanic and Atmospheric Administration.

IPCC, 2018: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. In Press.

Johnson, O. J. and C. R. Dickson, 1962, *An Eight Year Summary of the Temperature Gradient below 250 feet at the National Reactor Testing Station*, IDO-12025, Atomic Energy Commission

Sagendorf, J. F., R. G. Carter, and K. L. Clawson, 2001, *MDIFF Transport and Diffusion Models*, NOAA Tech. Memo OAR ARL-238, National Oceanic and Atmospheric Administration.

Start, G.E., 1984, *Climatography of the Idaho National Engineering Laboratory*, , IDO-12048A Vol 1 and 2, U.S. Department of Energy

Start, G. E. and L. L. Wendell, 1974, *Regional Effluent Dispersion Calculation Considering Spatial and Temporal Meteorological Variation*, NOAA Tech. Memo, ERL ARL-44, National Oceanic and Atmospheric Administration.

Yanskey, G. R., E. H. Markee, Jr., A. P. Richter, 1966, *Climatography of the National Reactor Testing Station*, IDO-12048, Idaho National Engineering Laboratory.