History of NOAA in Boulder

NOAA – the National Oceanic and Atmospheric Administration – was formed by executive order in 1970 by President Richard Nixon. The order created an amalgamated agency, bundling together the National Weather Service, ocean and fisheries services, satellite operations, and environmental research. A major component of our nation's environmental research had already been operating in Boulder since the early 1950s, and by 1966 was placed under the Environmental Science Services Administration.

The earliest ancestor of NOAA in Boulder was the Central Radio Propagation Laboratory (CRPL). The CRPL was created after World War II to continue research into over-the-horizon communications that had begun with military necessity. This research of the upper atmosphere, solar disturbances and wave propagation through the atmosphere all became part of the research and data sections of NOAA.

The CRPL landed in Boulder due to a few happy circumstances:

1. When it needed a new facility, the CRPL was looking for a "radio quiet zone" in which to conduct research; Boulder was able to meet that need (and, in fact, the Department of Commerce labs still maintain a radio quite zone just north of town on Table Mountain);

2. The requirements for the lab included proximity to a research university and an airport, and both are located in or near Boulder;

3. Community leaders jumped into the competition to win the federal lab and raised nearly $100,000 to buy land that was at the time being used for livestock pasture; and,

4. President Truman, fearing the Soviets would attack Washington, D.C., when they developed an A-bomb, decreed that new government construction should be well outside the nation's capitol.

In the early 1950s, however, when scientists at the CRPL were asked to relocate to the foothills of the Rocky Mountains, many balked at leaving cutting-edge science communities in the East, near to venerable institutions like MIT, Harvard and Princeton. One scientist later said Colorado and Boulder were considered a "scientific Siberia."

Things change. Now, due to the Boulder area's heralded quality of life, including natural beauty and an attractive climate, scientists are hotly competing for jobs in atmospheric, environmental, and space sciences here – at NOAA, the University of Colorado and Colorado State University, and the National Center for Atmospheric Research (NCAR), among others. In fact, with employees at these institutions and with private companies spinning off from federal and state-sponsored research, the Rocky Mountain Front Range region, including Boulder, boasts one of the highest concentrations of scientists engaged in studying the atmosphere and solar-terrestrial physics in the entire world.

Science On a Sphere

Science On a Sphere (SOS)® is a unique and captivating visualization tool, invented by Dr. Alexander MacDonald, director of the NOAA Earth System Research Laboratory in the mid 1990s. Science On a Sphere® is a room-sized, global display system that uses computers and video projectors to display planetary data onto a six-foot diameter sphere, like a giant animated globe.

Researchers at NOAA developed Science On a Sphere® as an educational tool to help illustrate Earth System science to people of all ages. Animated images of atmospheric storms, climate change, and ocean temperature can be shown on the sphere, which is used to explain what are sometimes complex environmental processes, in a way that is both intuitive and captivating. You can find most of the datasets online and view them on your computer at home.

Space Weather Prediction Center

The [Space Weather Prediction Center](#) (SWPC), headquartered in Boulder, is part of the National Weather Service and is the nation's official source of space weather alerts, watches and warnings. SWPC's Space Weather Forecast Office (SWFO) coordinates services jointly with the U.S. Air Force space weather group located at Offutt AFB, Omaha, Neb.

Space weather begins with solar eruptions; the effects can travel across the 93 million miles between the sun and our planet and can impact Earth systems, such as communications, navigation, spacecraft operations, aviation and electric power. The SWFO provides forecasts and warnings of solar activity and the changes such activity can bring to Earth and its magnetic cloak as well as electronic interference. People in government and the private sector who are responsible for preparing and protecting affected systems use SWPC forecasts.

To provide real-time monitoring of the space environment, solar forecasters analyze information from a variety of sources, including telescopes on the ground and satellites pointed at the sun or the environment between the sun and Earth.

Like our weather on Earth, space weather can follow a pattern of events through the storming process. Space-weather forecasts evolve similarly, from announcing activity on the sun to describing what's expected to happen on Earth.

Starting with an analysis of sunspots, forecasters assess the size and magnetic complexity of sunspot groups. Like meteorologists monitoring a deep low-pressure center, forecasters monitor these sunspot groups to get an idea of the strength, complexity and potential of the storm site. Forecasters will estimate the probability of these areas producing a solar flare – a sudden eruption of energy in the solar atmosphere. When a solar flare occurs, it produces a burst of electromagnetic radiation traveling at the speed of light. This radiation can cause significant ionization in the ionosphere and upper atmosphere. This can cause interference in high frequency (HF) radio communications signals that airlines use - referred to as Radio Blackouts.

A solar flare may also signal an acceleration of solar energetic particles, mostly protons and electrons, contained in the eruption as both the flare and coronal mass ejection (CME). A CME can also occur independently from a flare. These energetic protons typically arrive 1-12 hours after the eruption is detected on the sun. These storms are referred to as Solar Radiation Storms. Satellite operations can experience memory device problems, noise on imaging systems, star-tracker orientation problems and damage to solar panels. NASA monitors radiation hazards for the biological effects on astronauts in space. Airlines also respond to solar radiation storms by rerouting flights away from the poles, or in some cases, lowering altitude.

One to four days after the solar eruption, a cloud of solar material and magnetic field associated with the CME reaches Earth. This creates a Geomagnetic Storm. During a geomagnetic storm, changes to the solar plasma in solar wind interact with (and can add energy to) Earth's magnetic field. The resulting disturbance (magnetic storm) affects (heats) the upper atmosphere and enhances currents already present in Earth's magnetic field. A visual affect from these storms is the beautiful aurora (the interaction of high-energy particles striking Earth's upper atmosphere). Geomagnetic storms may result in electric power grids experiencing problems with voltage control; transformers may experience damage, and some grid systems may experience complete collapse or blackouts. Upper atmospheric changes affect satellite operations and navigation, and can cause GPS signal errors.

The NOAA Space Weather Scales were introduced as a way to communicate to the general public the current and future space weather conditions and their possible effects on people and systems. The scales describe the environmental disturbances for three event types: Geomagnetic Storms, Solar Radiation Storms, and solar flare Radio Blackouts. The scales have numbered levels, analogous to hurricanes, tornadoes, and earthquakes that convey severity. The Fujita scale (F0-F5) is used to measure the severity of a tornado, for example.

National Weather Service

The NWS Weather Forecast Office (WFO) in the Denver/Boulder region provides weather forecasts and warning to 2.5 million citizens in 22 counties in northeast and north central Colorado. Because the WFO is an operational office, it is open 24 hours a day, seven days a week. The WFO provides zone forecasts and short-term forecasts to the general public, fire weather forecasts to land management agencies, and aviation forecasts to the aviation community.

The National Weather Service Forecast Office in Boulder is one of 122 local offices across the country. Wherever you go in the United States, there is a local NWS office providing forecasts and warnings for you. The National Weather Service also has several national centers including the Space Weather Prediction Center located on the first floor of the NOAA Boulder DSRC. You might be familiar with other national centers such as the National Hurricane Center in Miami and the Storm Prediction Center in Norman, Oklahoma.

The workstations you see in this office are AWIPS systems (Advanced Weather Interactive Processing Systems) AWIPS was developed by the Forecast Systems Lab (now Global Systems Division). They are located next door in the Skaggs building. Each workstation consists of three graphics screens for analyzing data, and one text screen for viewing other forecast text, or editing forecast products.

On the workstation monitors, a forecaster can download information from the many sources bringing in data from across the globe – from satellites flying in geostationary orbit 22,500 miles above the equator and local radars tracking nearby storms to ground-based weather stations delivering temperature, humidity, pressure and other atmospheric attributes. In addition, the forecaster looks at numerical weather models, from NOAA and other science agencies, that begin with information on the current state of the atmosphere and apply it to a simulation of the Earth system and how it behaves, and can give us an idea of what's going to happen next.

Each local office is responsible for issuing forecasts for the next seven days, including all warnings and advisories. The forecasts are produced in several formats, including public forecasts, aviation forecasts, fire weather forecasts and marine forecasts.

This office serves not only rural areas on the plains to the east toward Kansas, but several of the state's larger cities, including Denver, Fort Collins and Boulder as well as the mountains and foothills to the west. The varied terrain can make for interesting forecasting challenges. This office never closes its doors, so operational staff work rotating shifts. Said one, "We get to see a lot of sunrises and sunsets. We also work a number of weekends and holidays."

Carbon Cycle Greenhouse Gases Group

The Carbon Cycle Greenhouse Gases group of the Global Monitoring Division takes consistent measurements at clean air sites every day and supplements these with a network of weekly air samples collected all over the world, consisting of the largest network and most accurate measurements of this kind. The clean-air baseline observatories are located in very remote places, to limit the amount of urban pollution being collected. NOAA's observatories are located at the South Pole; Barrow, Alaska; American Samoa; Mauna Loa, Hawaii; Summit Station in Greenland, and Trinidad Head, California. NOAA began managing operations at the first four sites when NOAA was formed in 1970; however, the atmospheric observations at the South Pole and Mauna Loa began in 1957-1958 during the International Geophysical Year.

Dots on the map indicate locations where volunteers collect air samples at designated sampling sites. The volunteers are trained and provided with a calibrated suitcase-like device (like the one shown on the tour) called a Portable Sampling Unit, along with two glass flasks per week. Glass is used to collect and transport the air samples as it does not react with the six trace gases measured: carbon dioxide (CO2), carbon monoxide (CO), Sulfur Hexafluoride (SH6), methane (CH4), molecular hydrogen (H2), and Nitrous Oxide (N2O).

Two flasks are sampled each time (on-the-fly quality control) once a week at each site and mailed back to NOAA Boulder via courier services and U.S. embassies. About 16,000 flasks are processed in the flask lab per year, using gas chromatographs and other instruments for measuring concentrations as small as parts per trillion. When daily calibration standards are counted, over 20,000 samples are measured each year.

Vertical representations of the atmosphere are also collected using aircraft, which take samples in increments as they leave ground and ascend to lower pressures (altitude: 20,000 ft); these airplane samples are represented by the yellow dots with planes in them.

Global Monitoring Division also monitors samples from a network of tall towers, denoted by the green dots, which collect daily air samples similar to the baseline observatories at altitudes of 100, 300, 500 and 1000 feet high. A map showing the entire sampling network is available online. Clicking a colored dot enables the user to see the measurement values at each site.

The dynamic graph presented here tells the story of carbon dioxide concentrations in the atmosphere. The pump handle graph shows the seasonal variability measured against surface latitude since 1979. You can see a much larger seasonal variation in the Northern Hemisphere. The majority of the world's forests and cities are located in the Northern Hemisphere, whereas the Southern Hemisphere consists of mostly oceans and ice. Therefore, the majority of the sampling takes place in the Northern Hemisphere. If you notice the graph of CO2 concentrations from the baseline observatories you'll notice that the Earth has a natural breathing cycle; the terrestrial biosphere takes up CO2 for making woody plant material in the spring and summer months during photosynthesis then releases the CO2 back into the atmosphere as the leaves and green material decays in the colder fall and winter months during respiration.

The graph also shows the Keeling Curve (carbon dioxide measurements at Mauna Loa, Hawaii, since 1956) and a number of ice core records spanning 800,000 years of carbon dioxide cycles indirectly measured in fossil air pockets found in ice on Greenland and Antarctica.

Wind Profiler

The wind profiler has helped to revolutionize our ability to improve severe weather forecasts including tornadoes. If you want to understand where tornadoes may form, you need to have a good forecast for the upper level winds – upstream from the forecast area. This takes a good computer model of the atmosphere, but it also takes actual accurate real-time measurements of the winds to help constrain the forecast model. The wind profiler was an invention of labs within the Earth System Research Laboratory in order to improve our knowledge of the upper-level winds. The bulk of the wind profilers are located now throughout the mid-section of the U.S. where most of the Nation's tornadic weather occurs and are operational through the NOAA Profiler Network for the National Weather Service, aiding in weather forecasting.

The discovery that radar could determine wind speed and directions patterns in the upper atmosphere was by accident, as many good scientific inventions are. Scientists were using this radar to study the ionosphere by bouncing a radio wave off the ionosphere and each time they would get a noise in the signal. They finally decided to figure out what was causing the noise. We now operate these radars because the noise they discovered was a piece of very valuable information, the actual reflection of the turbulence of the wind patterns above.

The profiler technology works by bouncing radio waves off of turbulence in the atmosphere. It is possible to see the result of atmospheric turbulence with the naked eye. For example, when you see a heat wave shimmering over a road surface; that is turbulence caused by warm air rising up from the hot pavement surface interacting with cooler air not in contact with the pavement. Another example is the appearance of twinkling stars, which results from the turbulent atmosphere that exists between you and the star above your head.

The radar is able to measure the winds because the turbulence that the radar detects is carried by the wind. The radar beam consists of a series of pulses. The time it takes for a pulse to bounce off of turbulence in the atmosphere and return to the radar determines how far the pulse traveled. The returns from thousands of pulses are averaged together. This is necessary because the return power is only a very small fraction of the power that was sent out in the pulse.

Because the frequency of the return signals is Doppler shifted by the speed at which the turbulence is carried by the wind along the direction of the radar beam, the radar can detect whether the air was moving toward or away from the radar antenna. The same type of Doppler shift is heard when you hear a train passing and the sound goes from higher to lower frequency. This apparent shift in tone of the train whistle isn't because the whistle has changed its transmitted frequency, but because in one case the sound waves are being transmitted from a platform moving toward your ear and in the other case the sound waves are being transmitted from a platform moving away from your ear, thus imparting the Doppler shift.

In order to get a 3-dimensional measurement of the wind, the wind profiler sends a beam out in three directions and collects up/down, north/south, and east/west components of the wind. A computer collects these measurements, rotates them with geometric equations, and produces profiles of both wind speed and direction. These profiles are displayed on the Internet for end users and are often color-coded by wind speed.

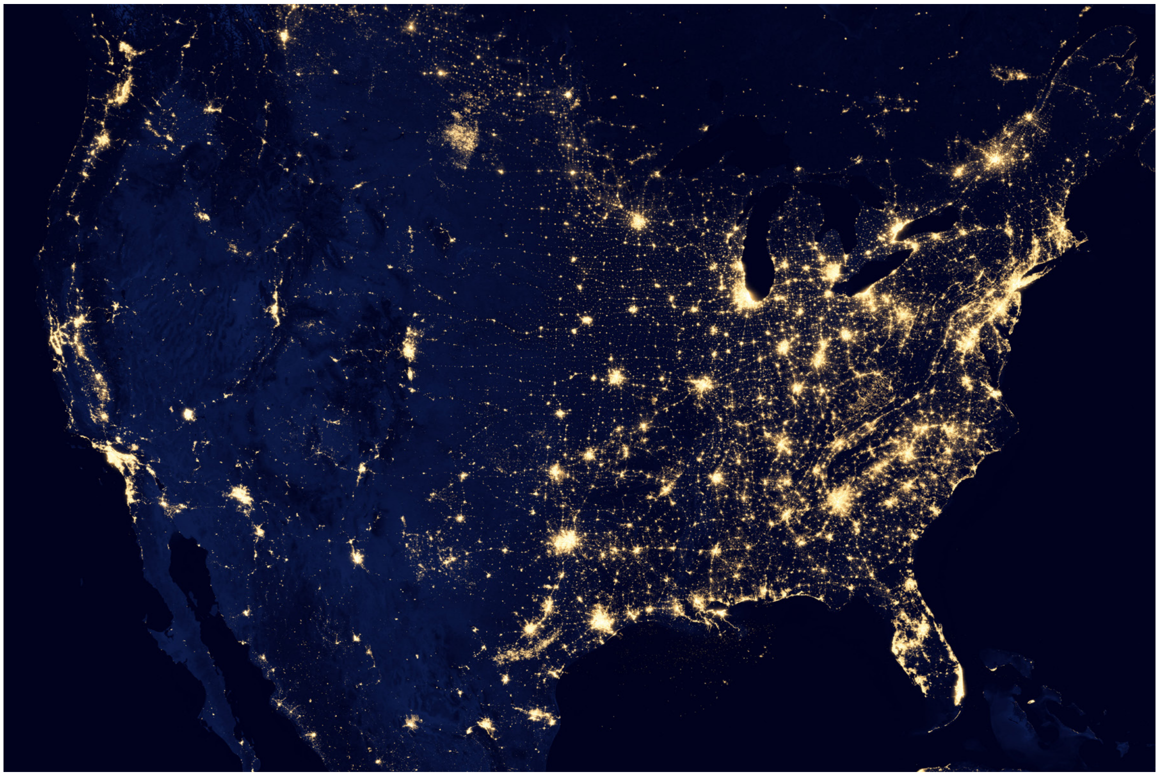
A wind measurement at a particular altitude is often displayed as a flag, with the pole of the flag pointing in the direction that the wind is coming from. The number of barbs or triangles displayed on the flag determines the wind speed.

The profiler network in the central U.S. has been in operation for about 15 years and has had successes in saving lives, especially on May 3rd, 1999, when Oklahoma City had a tremendous outbreak of tornadoes. It was possible to forecast the atmospheric conditions conducive to tornado formation in advance because earlier that day, the wind profiler at Tucumcari, New Mexico, had detected an unusual anomaly in the jet stream.

The National Weather Service forecast models predicted an extremely convective region in Texas that would be pointing right at Oklahoma City. The local forecasters then advised everyone during the morning commute to pay very close to their radios that afternoon. The convective cell that eventually produced a tornado moved into the southern suburbs of Oklahoma City that afternoon and the local forecast office put out a 30-minute lead time for a tornado warning, which was enough time for the TV stations to get their helicopters in place to actually see the funnel cloud touch down.

Entire subdivisions of southern Oklahoma City were evacuated. What they could not forecast was how strong the tornado would be, and it turned out to be an F-5 tornado, one of the worst kinds, capable of producing a devastating loss of life and property. There were 40 or 50 tornadoes as part of that outbreak, and because of the profiler network, we estimate that NOAA saved about 400 lives that day.

Nighttime Lights



The Nighttime Lights products of the Earth Observation Group (EOG) within the Solar-Terrestrial Physics (STP) Division of the [National Geophysical Data Center (NGDC)] represent the epitome of data reuse. The original data come from the Air Force's Defense Meteorological Satellite Program (DMSP), a series of polar-orbiting satellites intended to collect weather data for the Department of Defense. The EOG has used that data, sent to them by the Air Force Weather Agency (AFWA) for archiving, to build an ongoing data base of stable and ephemeral light sources, from which they continue to derive an amazing array of products – from the nighttime lights posters to a study for the World Bank, quantifying for the first time the amount of global gas flaring.

The DMSP has been collecting data since 1972, data which was initially collected on film and upon being declassified after 72 hours, ended up being archived at the Federal Records Center. NGDC began to speculate on the potential usefulness of the data for purposes beyond its original targeted role, and when the Air Force transitioned to digital data, which would be destined for the bit bucket upon declassification, NGDC stepped in and requested that they provide an archive for the data.

That archiving began in 1992 and continues to the present, with a current flux of data of the order of 8.5 Gigabytes (GB) per day. These data are analyzed for patterns of light that both match and contrast with previous establish patterns. This provides a continual pattern of changing lights, analyzed for stability and classification.

The original intent was to generate a mask of stable light that was present consistently from night to night in order to detect the ephemeral lights, lights that appeared and disappeared, which might be fires. However, when the mask was generated, the pattern of stable nighttime lights was stunning and made for a delightful graphic presentation, which has now graced a number of media and posters.

However, among the stable lights were some peculiar anomalies to what was expected: lights at sea, in the midst of the Sahara desert, or off in Siberia. These were eventually sorted out to be fishermen, using intensely bright lights to attract fish or squid into nets and gas flaring from petroleum production areas, both onshore and offshore. Additionally the analysts were able to detect fires as anticipated in the original intent of the project.

Additionally, with the appropriate calibrations, the nighttime lights proved to be an effective proxy for population, energy consumption, carbon production, economic vigor, etc. By building a time-series database of lighting patterns, change analysis can be applied to look at socio-economic and environmental change, trends and disruptions. To expand on this latter aspect of change analysis, the EOG is now going back and digitizing the old film archives of DMSP data to extend the digital record back in time to establish a longer baseline for change analysis.

With this data we have been able to quantify, for the first time, the total, global amount of gas flaring at over 150 billion cubic meters per year, worth US $60 billion in today's prices, and sending 400 million tons of carbon dioxide directly into the atmosphere. In another interesting twist on using the data, if we know where the lights are normally on, we can detect where the lights have gone out. Now we can detect widespread power outages, as seen on the left with analysis products for the passage of Hurricane Katrina across the Gulf Coast.

These data have been enhanced by the Air Force, allowing us to vary the gain on the instruments to permit the capture of calibrated radiance, not just the presence or absence of light. There was, however, one city in the entire world that still saturated the instrument, despite the gain being at its lowest setting. It was not Paris, The City of Lights, nor London or New York. Viva Las Vegas!

So what was originally data for weather analysis and prediction, good for three days, has become a source of information about socioeconomic trends, fishing, fires, gas flaring and power outages as an aid to emergency response. All this information coming from what was once regarded as digital discards. But one man's garbage is another man's gold.