Success Stories on User Engagement

Global Science & Technology, Inc.

Success Story 8: Weather Service Providers

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i. Success Stories on User Engagement

This report examines user engagement with NOAA's National Centers for Environmental Information (NCEI) climate and weather data. It demonstrates the value that the free and publicly available provision of NCEI's information to the weather service provider industry. Interviews conducted with key sector stakeholders and supplemental desk-based research illustrate how weather service providers use climate and weather data from NCEI to create value-added products and services to serve a range of sectors. NCEI's information provides an important resource to weather service providers, a rapidly growing sub-sector that contributes $7 billion annually to the U.S. economy.

Acronyms Used

CDD: Cooling Degree Days

COOP: Cooperative Observer Network

DOC: Department of Commerce

FERC: Federal Energy Regulatory Commission

GHCN-D: Global Historical Climatology Network, Daily

HDD: Heating Degree Days

LCD: Local Climatological Data

NCDC: National Climatic Data Center (now, NCEI)

NCEI: National Centers for Environmental Information

NESDIS: National Environmental Satellite, Data, and Information Service

NASA: National Aeronautics and Space Administration

NCEP: National Centers for Environmental Prediction

NOAA: National Oceanic and Atmospheric Administration

NSSL: National Severe Storms Laboratory

NWS: National Weather Service

USDM: U.S. Drought Monitor

Terms and Definitions

Anomalies: the departure or difference from an average, or baseline, value (like temperature). Baseline climate values are typically computed by averaging 30 or more years of data

Bulk climate and weather data: electronic collection of high-volume datasets that are typically available in a raw or quality-checked format

Heating and Cooling Degree Days: measures of expected energy usage for heating and cooling, based on cumulative daily average temperature observations below (heating degree days) or above (cooling degree days) a specific threshold, typically 65°F (NCDC, 2010)

Weather service provider, (third party) weather vendor, decision-support provider: commercial weather service providers combine climate and weather data, often with industry specific data, to develop customized products, tools, and services for their clients

Weather service product: outputs produced by weather service providers for their clients. They include but are not limited to: maps, charts, graphics and reports, or software tools and dashboards that integrate weather data with users' operating systems

1. INTRODUCTION

IMPACTS OF WEATHER TO BUSINESS AND THE U.S. ECONOMY

Figure 1: Storm conditions
Source: NOAA's National Severe Storms Laboratory (NSSL)

An estimated 30 percent of the Nation's economy is impacted by weather, as disruptions to the supply chain affect businesses' ability to produce and sell products and meet customer demand. Weather influences Gross Domestic Product (GDP) fluctuations between 3 to 6 percent a year, or up to $1.3 trillion dollars in economic gain or loss (using 2011–2014 GDP estimates) (NWS, 2017).

Weather impacts the economy in a multitude of ways. Economic impacts can be influenced by slight temperature changes, extreme events like hurricanes or slow onset events like drought. Weather events do not create uniform positive or negative impacts. A snowstorm can bring transportation to a standstill but increase demand for outdoor recreation. A rainy week can reduce foot traffic foot fall at retail locations but boost online shopping. A hailstorm can damage crop production but drive demand for roof repair. A hurricane warning can create an economic payroll deficit but offer a competitive advantage to bottled water companies allocating stock in the projected hurricane track.

Actionable weather information is therefore valuable across all economic sectors. Every industry, and virtually every company, uses weather information in some capacity. This may range from a cursory glance at a forecast to see the next day's weather, to appointing the services of a weather vendor to answer an optimization query, or hiring meteorological staff to enhance in-house capabilities (C. Walter, personal communication, July 26, 2017).

VALUE-ADDED WEATHER SERVICE INDUSTRY

In response to weather's influence on commerce, a thriving value-added service industry has emerged over the past 30 years, especially the last decade. These value-added providers are often referred to as

third party weather vendors, weather service providers, or decision support providers terms that are used interchangeably throughout the industry. These companies combine climate and weather data, often with company specific information, to develop products and services that support company decision-making. The analytics offer a competitive advantage to businesses, allowing them to capitalize on weather-dependent behavior and implement risk management strategies (NWS, 2017).

> Commercial **weather service providers** combine climate and weather data, often times with industry specific data, to develop customized products, tools, and services for their clients.

The value-added industry serves its clients by developing customized products such as maps, charts, graphics, and reports, or software tools and dashboards that integrate weather data with users' operating systems. This information, often accompanied with consulting support, serves to enhance business performance or manage risk (NWS, 2017). Examples may include a software tool that helps trucking companies to route vehicles around high winds, a warning system that alerts railways to tornado risk, a two-week outlook that allows energy companies to forecast heating and cooling demand, or a temperature map that allows retailers to optimize product placement. Service providers also support clients in collecting and analyzing historical weather information for legal or insurance claims. For example, a service provider may access historical radar data to recreate weather at a particular location, in support of an insurance claim for hail damage.

While estimates vary, roughly 250 commercial weather service providers offer industry-specific or cross-sectoral weather analytics (Brin, 2011). The Weather Company and AccuWeather own 50% of the market share of weather services, while the remainder are offered by smaller companies with fewer than 150 employees. The market value of the climate and weather industry is an estimated $7 billion and projected to grow 10-15% per year as it continues to serve customers domestically and internationally (Dutton, 2002). The continued growth of the value-added industry is predicated on access to NOAA, NCEI, and other federal data (NWS, 2017).

The potential growth prospects of combining weather analytics with industry-specific data are demonstrated by several recent high-profile acquisitions. In 2013 Monsanto acquired Climate Corp, and Panasonic acquired AirDat, while in 2016 IBM acquired The Weather Company (NWS, 2017). Estimates show that if fully monetized, the value of weather data that could be realized across all U.S. industries is on the order of $13 billion (NWS, 2011).

Weather service providers not only serve industry-specific clients, they also serve one another. For example, Weather Source relies on NCEI's information to develop a high-resolution gridded *OnPoint climatology* product which is then used by other value-added providers such as Earth Networks to develop products and services for their client base. Earth Networks believes it's more efficient to license a ready-to-use climatology product from Weather Source, rather than "re-inventing the wheel" devoting staff resources to reproducing the process in-house (M. Hozekma, personal communication, Jan 16, 2018).

The general public also consumes value-added information. Baron and The Weather Company own the majority market share of weather forecast licenses, which are then broadcast on news programs by meteorologists (S. Bray, personal communication, Jan 9 2018). Baron's technology reaches two-thirds of the U.S. population through its television, internet, and radio broadcasting clients (Baron, 2016). Weather Underground, a subsidiary of The Weather Company, employs weather bloggers who produce online weather content, reaching millions of readers per year. Individuals also use this information for day-to-day decision-making that influences economic activity. The Weather Company's native weather apps available on Android or iPhone, tailor advertisements based on localized weather conditions (Paul Walsh, Personal Communication, March 19, 2018). Consumer behavior and tailored advertisements may drive a consumer to purchase barbeque food over umbrellas on a sunny day.

Value-added industry is predicated on access to NOAA's information

The U.S. model for free and publicly open data access has enabled a robust weather services market both in the U.S. and worldwide. Data agencies like NOAA's National Centers for Environmental Information (NCEI), NOAA's data archive, provide basic services (as opposed to specialized, value-added services) which are characterized as non-rival, non-excludable, public goods (Gunasekera, 2004). Once produced, NCEI data are available at no cost, generating boundless market potential. Weather service providers rely on NCEI along with other public agency data (e.g. NOAA, NASA), to serve as foundational components in their products and services (Weiher, 2008).

Value-added service providers depend on public data for a number of reasons. Generating weather and climate information requires extensive capital investment, infrastructure development (e.g. building and launching satellites, installing ground-based networks, etc), and management and coordination over long time periods, that can only be effectively executed on a large scale by a government agency.

Further, raw data collection may not offer an immediate return on investment or may have a primary public-safety benefit versus commercial benefit and may be unprofitable for the private sector to produce (NWS, 2017). While NOAA and NCEI do produce user-friendly tools and products,[1] much of the information is available in bulk format that is accessed primarily by expert users. This presents skilled entrepreneurs with a market opportunity to source bulk data, develop value-added processes, and produce commercially viable products (Weiher, 2008).

> *"NCEI's data is used broadly as a foundational component along, with NOAA and other government data, and all the data and capabilities generated using Accuweather, in order to develop value-added products and services."* – Jonathan Porter, *Vice President of Business Services and General Manager of Enterprise Solutions*, Accuweather

From an economic model perspective, centers like NCEI exist to fulfill the supply side, and weather service providers fulfill the demand side. It is not NCEI's mission, nor does NCEI have the capacity, to develop company-specific value-added products. NOAA's public-private partnership policy, which NCEI follows, recognizes the benefit in working together, and not in competition, with the private sector and academia for the provision of weather information (M. Brewer, personal communication, Mar 28, 2018). Bulk climate and weather data are considered a competitive advantage as they require the expertise of a value-added service provider to make these data useable. If agencies like NCEI provided user-friendly, ready-to-use products, this would limit the commercial viability of weather service providers (J. Porter, personal communication, Jan 17, 2018).

NCEI, NOAA's data archive, collects and archives weather and climate observations from around the U.S. and globally and is recognized as the largest repository of authoritative climate and weather data in the world. Weather service providers depend on NCEI's information, along with other data, to develop a range of products and services. NCEI's information contributes too many applications, including energy demand forecasting and trading, forensic analysis, probability and planning, and providing context to historical weather events. With over 250 weather service provider businesses supporting a range of industry stakeholders, this study is limited in its ability to capture all present and emerging applications of NCEI's information. Rather, this study demonstrates conventional applications of NCEI's information to develop products and services for sector-specific groups.

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[1] Examples include; Coral Reef Watch, U.S. Drought Monitor

2. APPLICATIONS

2.1. CLIMATOLOGY: ENERGY

Figure 2: Frozen power lines
Source: NOAA NSSL

A long-term weather record, or climatology, can demonstrate how the weather tomorrow or next week deviates from normal conditions. A climatology provides the foundation for a variety of analyses that businesses seek to understand how their weather-related performance deviates from normal. Many weather service providers cater to energy companies and financial services trading energy on markets, supporting volatile demand management. This section explains climatology application development in relation to energy supply and energy trading.

Table 1: NCEI products used for energy demand forecasting

Product Name	Description
Global Forecast System (GFS) Reanalysis	The GFS is a weather forecast model that provides atmospheric and land/soil variables, including temperature, wind, precipitation, soil moisture, and atmospheric ozone concentration. GFS provides global coverage with base horizontal resolution of 18 miles (28 kilometers) between grid points that drops to 44 miles (70 kilometers) between grid points for forecasts greater than one week. The GFS is a coupled model, composed of four separate models (an atmosphere model, an ocean model, a land/soil model, and a sea ice model), which work together to provide an accurate picture of weather conditions. GFS is produced by National Centers for Environmental Prediction (NCEP) and archived by NCEI (NCEI, 2018a).
Coupled Forecast System (CFS) Reanalysis & CFS Hindcast Reforecast	The CFS model represents global interaction between Earth's land, atmosphere, and oceans. This model offers hourly data with a horizontal resolution of one-half of a degree (approximately 35 miles) for many variables. CFS is produced by the NCEP and archived by NCEI (NCEI, 2018b).

Energy supply disruptions have significant economic and operational impacts to energy companies, and industries that rely on their services, including hospitals, food production, water supply, and more. As energy cannot be stored in large quantities, energy supply must match demand in order to avoid economic losses (more supply than demand) and brownouts (more demand than supply). To support optimal energy production, weather service providers develop proprietary forecasts and long-range outlooks (sub-seasonal, seasonal) to serve energy and utility clients. Weather is a primary influencer of energy demand. Subscription-based services help natural gas, hydroelectric power suppliers, and electricity distributors estimate short- and long- term demand, and optimize generation on daily, monthly, and yearly time scales. These forecasts can help companies increase personnel during potentially hazardous weather conditions that may pose a threat to infrastructure or installations.

Natural gas and electricity are traded on the markets like any other commodity, such as copper, coal, or corn. The market for natural gas and electricity has surged in recent decades as markets have matured and investors recognize the commodities as investments. The global revenue for energy trading and risk management is estimated at $1.22 billion and is growing at a rate of 2.32% per year (NBC, 2018). Energy traders speculate on how a range of factors that influence supply and demand (including weather) will drive the market price of electricity and natural gas. In response to these factors, traders then buy, sell, or trade commodities to profit from the change in price (FERC, 2015).

> *"A few years ago, when natural gas was at an all-time high there was this energy trader, a meteorologist from Boston, who went to work as a trader in NYC. On his first day of work he made one trade and retired. The trade was worth $30 million dollars." – Dr. Michael Ventrice, Meteorological Scientist, IBM*

IBM's The Weather Company develops energy demand forecasts to help traders understand how weather will influence demand. The Weather Company relies on NCEI's Coupled Forecast System (CFS) archived model data and CFS hindcast, reforecast reanalysis data to compute deviations from average climatic conditions on a global grid. This deviation is a value of the departure from average conditions of a parameter (e.g. +1°C or -1°C for temperature) at a given

Figure 3: Coupled Forecast System
Source: NOAA NCEI

point location (e.g. 49°N 100°W) over the course of a base 30-year period, for each day of the year. The deviations are compared against real-time model outputs to understand how demand will be influenced
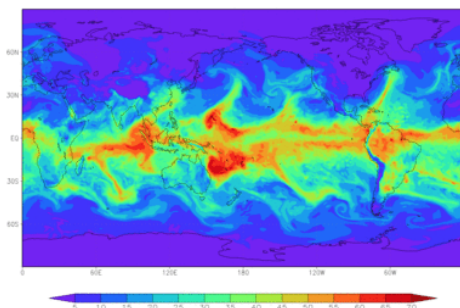
in the short-term and medium range (1 - 15 day) and sub-seasonal range (5 - 6 weeks). Energy traders use this population-weighted information to speculate on how weather may impact demand for energy and drive decision-making to buy, sell, or trade energy on the market (M. Ventrice, personal communication, Jan 9, 2018).

> *"I find the data from NCEI to be extremely valuable, specifically the CFSV2 sub-seasonal model, if mean (sic) if we didn't have this it would hurt our forecast skill." – Dr. Michael Ventrice, Meteorological Scientist, IBM's The Weather Company*

The Weather Company also uses Global Forecast System (GFS) reanalysis data to develop sub-seasonal and seasonal weather forecast anomalies (5 to 6 weeks). While The Weather Company archives GFS data internally, they rely on NCEI when the internal system malfunctions. In this regard, NCEI serves as an important backup to ensure the information is always available. NCEI's information is also used to validate the

Figure 4: Energy traders at work
Source: Energy Management Services

accuracy of in-house forecasts and guide improvements (M. Ventrice, personal communication, Jan 9, 2018). In 2016 Forecast Watch, the Nation's authority on meteorological accuracy validation, awarded The Weather Company "the most accurate third-party forecasting company" (Floehr, 2016).

2.2. FORENSIC ANALYSIS: LEGAL AND INSURANCE

Figure 5: Hailstones
Source: NOAA NSSL

Table 2: NCEI Certified Products used for forensic analysis

Product Name	Description
Global Historical Climatology Network Daily (GHCN-D)	GHCN-D is a global, land-based (*in situ*) database that collects observations from a number of different observing networks. It contains records from over 80,000 stations in over 180 countries and territories and is the most comprehensive daily global dataset available. Variables include maximum and minimum temperature, total daily precipitation, snowfall, and snow-depth. Data for the U.S. is reported once daily (usually in the mornings) from stations across the country (Menne, et al., 2012).
Local Climatological Data (Quality Checked)	LCD consists of local climate data summaries (hourly, daily, monthly) for about 1,600 land-based stations across the U.S. (NCEI, 2018d).
Cooperative Observer Network (COOP)	Volunteer *in situ* observations collected in rural, urban, and suburban locations across the U.S. COOP data generally consist of daily maximum and minimum temperature, snowfall, and 24-hour precipitation totals (NCEI, 2018e).

A number of weather service providers are wholly dedicated to the practice of forensic meteorology, including Forensic Weather Consultants and Veritas Weather, while other service providers including WeatherBELL Analytics and Accuweather offer forensic analysis as a part of a broader service provision. Forensic meteorology, the practice of reconstructing a past weather event for a specific time and location, informs legal proceedings and insurance claims, where weather contributed to the accident or damage. For example, if a plaintiff brings forward a case for a slip and fall incident, the verdict may depend on timing of the incident. If the plaintiff slipped and fell *during* the snowstorm and the defendant did not have sufficient time to clear the snow, they may be absolved of legal liability. If the person fell two days *after* the snowstorm, when the snow had already turned to ice, the defendant could be liable as a result of negligence to clear the walkway. A weather service provider may be asked to recreate weather at the time of the incident on behalf of the plaintiff or the defendant to serve as evidence in the court of law. Weather service providers support legal and insurance firms in recreating

historical weather events on a case-by-case basis. Recreating these analyses often depends on aggregating data from multiple sources to develop time and location specific analysis, a task that is too time consuming and technical for non-experts to perform. Table 4 lists NCEI products that are commonly used for forensic analysis and can be certified by the Department of Commerce (DOC). Another common forensic analysis example are time and location specific hail swath maps. Insurance companies, or policyholders interested in proving (or disproving) hail damage to a crop field, vehicle, or property can use the maps as proof in a court of law. Forensic analyses are common for slip and fall incidents and transportation accidents, particularly involving snow, ice, and high winds, and property damage from hail, high winds, tornadoes, and hurricanes (T. Riggi, personal communication, Jan 16, 2018).

Normally, a court of law will only accept meteorological data certified by DOC, as evidence. Designated within the DOC, NCEI-certified products are therefore invaluable to forensic analysis and the legal sector. This data has the potential to validate or vindicate a client of legal liability, thereby potentially savings millions of dollars in legal liability on a per case basis. Further, clients of weather service providers feel reassured knowing that the data supporting their case is from a trusted and reliable government source (T. Downs, personal communication, Jan 16, 2018).

2.3.   PROBABILITY AND PLANNING: RETAIL AND MAINTENANCE

Figure 6: Winter weather
Source: NOAA NSSL

Table 3: Sample NCEI products used for probability and planning

Product Name	Description
GHCN-D	(See Table 2)
Regional Snowfall Index (RSI)	A regional snowfall index produced for each of the six NCEI climate regions in the eastern two-thirds of the nation. RSI is a ranking of snowstorm impacts on a scale from 1 to 5 based on storm spatial extent, snowfall accumulation, and population density obtained from the U.S. Census (Squires, et al., 2014).
U.S Drought Monitor (USDM)	An online drought-monitoring map and accompanying narrative summary that tracks the magnitude, spatial extent, and probability of occurrence of drought across the U.S. The USDM is developed through a cooperative effort between NOAA, including the Regional Climate Centers, the U.S. Department of Agriculture (USDA), and the National Drought Mitigation Center (NDMC). Under NOAA, NCEI is a key partner in the USDM, producing many climatological inputs that are ingested into the USDM and providing three of about a dozen rotating authors (Fuchs, 2017).

Weather service providers support their clients in a many ways, to answer planning and optimization queries. They analyze historical weather data to determine the likelihood of certain event(s), e.g. snowstorm, windy day, or sunny day. While these analyses are applicable to a range of sectors, they are common among weather-sensitive industries such as retail, transportation, construction, and seasonal maintenance. For example, WeatherBELL Analytics uses NCEI's information to help winter maintenance companies budget for crew time and resources including salt, plows, and snow and ice removal equipment, to prepare for the winter season. When bad weather hits, maintenance companies usually contracted by a municipality or company must be prepared and available on short notice. WeatherBELL Analytics uses NCEI's snowfall indices and station data to understand the average frequency and severity of snow events in a given region during the winter season. Maintenance companies then use these

analyses to budget and prepare resources and personnel in advance of the season (T. Downs & T. Riggi, personal communication, Jan 16, 2018).

Service providers support retailers in optimizing product placement in favor of weather conditions. For example, persistent drought conditions during springtime may impact the sale of lawn care items such as pesticides and lawnmowers. Service providers analyze drought indices such as the U.S. Drought Monitor and temperature and precipitation data, along with store-specific data, to understand how weather conditions influence the sale of these items. Further, they may combine this analysis with forecasts to recommend reorganization of stock and inventory to align better with consumer trends, helping retailers maximize in-store sales.

In addition to merchandise allocation, retail applications may guide staffing decisions. High winds are a concern that grocery and department stores must manage. With large, open parking lots, shopping carts may blow into parked cars, causing vehicle damage. This can lead to economic loss through direct liability, customer dissatisfaction, and poor brand reputation. Weather service providers analyze NCEI's historical wind data to understand how often, on average, winds exceed a certain threshold and pose store liability. The retailer uses this analysis to inform staffing decisions, for example, scheduling cart collection and budgeting for additional staff (T. Downs & J. Riggi, personal communication, Jan 16, 2018).

Applications also include selecting optimal site locations for businesses. For example, StormGeo supports its clients in weather-related site assessments. A tech client planning a new data center was interested in evaluating severe weather risk to potential candidate sites. Using NCEI's data, StormGeo conducted an analysis of historical severe weather risk to the potential sites to identify the location least prone to extreme weather events (M. Chambers, personal communication, Jan 10, 2018).

2.4.   CONTEXTUALIZING WEATHER: MEDIA AND EDITORIALS

Figure 7: Hurricanes Carl, Igor, and Julia
Source: NOAA

Table 4: NCEI information that supports content creation

Product Name	Description
U.S. Drought Monitor (USDM)	(See Table 3)
State of the Climate Reports	The State of the Climate reports are monthly and annual summaries that recap climate-related conditions on a national and global scale. These reports place the month (or year) within the historical context of all prior months (or years). For example, January 2018 ranks as the 36th warmest January on record, as compared to all other Januaries in the period of record (1895 to present) (NCEI, 2017a).
Climate Extremes Index (CEI)	A framework for quantifying observed climatic changes within the contiguous U.S. The CEI is based on a set of indicators including heavy one-day precipitation events, drought severity, extremes in monthly mean maximum and minimum temperatures, number of days with and without precipitation, and wind intensity of landfalling tropical cyclones (NCEI, 2018f).
Billion Dollar Disasters	NCEI's **U.S. Billion Dollar Disasters** report, a quarterly publication that began in 1980, highlights aggregate losses for major weather and climate events that have occurred in the U.S. The report quantifies losses for numerous weather and climate events that meet or exceed $1 billion each in economic losses. These events include tropical cyclones, severe convective storms (tornadoes, hail, and straight-line wind damage), floods, droughts, heatwaves, wildfires, crop freeze events, and winter storms. The loss estimates reflect the direct impacts of the weather and climate events, and the total insured and uninsured losses including: physical damage to buildings, material assets within a building, business down time, vehicles, public and private infrastructure, and agricultural assets (e.g. livestock, forestry, and crops) (Smith & Katz, 2013).

"NCEI's data is valuable to understand what has occurred. What's the context of a particular event? How rare is an event? When have similar types of weather situations occurred in the past?" – Jonathan Porter, Vice President of Business Services and General Manager of Enterprise Solutions, Accuweather

Weather service providers use NCEI's information to provide context to weather events that impact a client's operations. It can contextualize weather events within prior weather events and address questions pertaining to event frequency and likelihood. For example, a railway company may want to understand whether a tornado that toppled a train car was an 'act of God' or an increasingly common severe weather event that railways should plan for. An insurance company may seek to understand whether a hurricane of a given magnitude has occurred in the past, and if so, how much damage it caused (J. Porter, personal communication, Jan 17, 2018).

Weather service providers often have a department or subsidiary that produces content for a broader audience, either through online or TV broadcast or editorial articles and blogs. For example, IBM's The Weather Company owns Weather Underground, Accuweather writes a weather blog, and EarthNetworks, until recently, owned WeatherBug.

NCEI's information supports the development of editorial content. Accuweather uses the USDM maps in its blogs to provide a visual overview of the state of drought in the U.S. WeatherBug recreates the USDM map in its weekly drought updates. The maps and editorial summaries are curated to meet a target audience's interests (M. Hoekzema, personal communication, Jan 16, 2018). Weather Underground, owned by The Weather Company, produces a monthly U.S. and Global Round Up which compares the prior month's weather within the historical context of that month's weather on record (e.g. January 2018, compared against all Januaries on record). To create the Round Ups, Weather Underground summarizes the content and maps from NCEI's monthly State of the Climate Reports. The Round Ups also use NCEI's Billion Dollar Disasters data[2] to show the number of U.S. disasters that exceed $1 billion in damages for that month. Weather Underground also produces Category 6, a popular blog that contextualizes extreme events such as hurricanes, tornadoes, floods, and heatwaves within a climate context. The content is paid for through advertisements, or members can pay an annual subscription fee to access the articles ad-free. Millions of readers access Weather Underground publications daily, thereby indirectly accessing NCEI content (B. Henson, personal communication, Jan 10, 2018).

> *"Without these climate summaries, our editorial content would not exist. Please protect NOAA's ability to write about climate change." – Bob Henson, Meteorologist and Author of Category 6, Weather Underground*

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[2] Obtained indirectly through editorial content produced by Aon Benfield

Companies such as The Weather Company and Baron are two leading vendors of weather forecasts that are licensed to web and TV stations. Although Baron doesn't use NCEI data to produce forecasts, it does recommend NCEI climate information to provide context to its forecasts. For example, if the forecast is showing an anomalously warm winter day, Baron may recommend including Climate Normals, to show viewers how the day's weather deviates from the average. Or, if a region is experiencing drought conditions, it may recommend using the USDM to show drought conditions across the country. In this way, NCEI's information can add a broader narrative to a forecast and help inform audiences about climate change (S. Bray, personal communication, Jan 9, 2018). Countless reporting and media outlets, including Bloomberg and Climate Central, not characterized as weather service providers, also use NCEI information in their programming and editorials.

3. ROOM FOR IMPROVEMENT

Weather service providers offer three primary recommendations to improve to NCEI products and services:

- **Data availability in more conventional formats** (e.g. CSV, shapefile). NCEI's data are often available in unconventional file formats. Users have to first convert the file into a conventional format, before they can use the data, which is considered to be an extra and unnecessary step.
- **Easier navigation of the NCEI website**. Users often express difficultly locating information on NCEI's website. A more user-friendly interface would make website navigation and data retrieval easier.
- **In situ products available in gridded format** (e.g. GHCN-D). Gridded products are often required for the types of client-specific analysis that weather service providers undertake. Gridded data would streamline analysis and the value-added processes.

These enhancements would make NCEI's information easier to use among the service provider community.
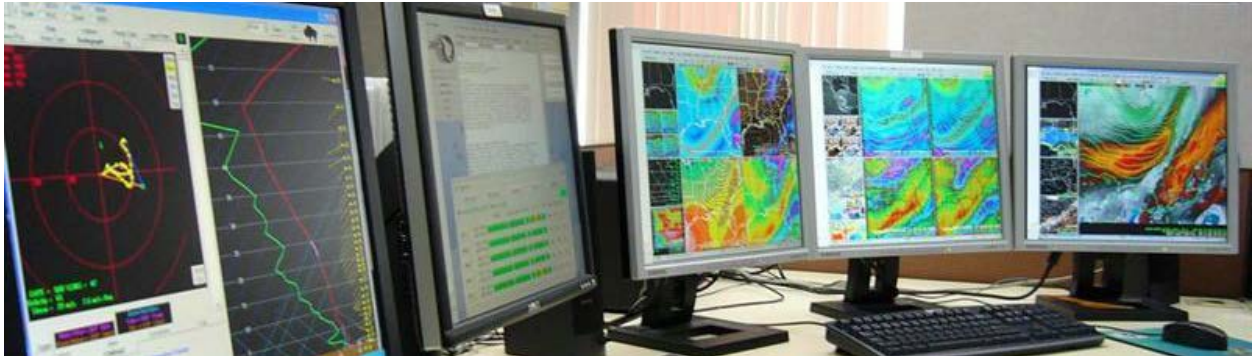
4. CONCLUSIONS

Figure 8: Weather forecast models
Source: NOAA NWS

Recent trends show that businesses that traditionally did not use weather data are increasingly turning to weather information to inform decision-making (NWS, 2017). However, weather information in and of itself, for example a weather forecast, may be of limited value to businesses if it's not related to company performance. Weather service providers offer just this – they combine climate and weather data often with industry-specific data to develop customized products and services that support business decision-making. They also create content that supports public understanding of climate and weather.

Weather service providers cater to a range of sectors, most commonly those with weather-sensitive operations or outputs including energy, insurance, retail, seasonal maintenance, transport, legal, media, and agriculture. Value-added products and services offer businesses a range of benefits that ultimately protect against economic loss, boost profits, and avoid risk. For example, they can help provide guidance to an energy trader that leads to a lucrative trade on the market, a retailer capitalize on weather-dependent behavior to maximize sales, a transportation provider avoid risk or liability, a maintenance company prepare for the winter season ahead, and a media outlet contextualize a weather phenomenon for millions of viewers. These services directly benefit businesses and their clients. The value of weather information has far-reaching benefits to commerce and individual citizens.

Weather service providers depend on access to NOAA's free and publicly available information to develop value-added products and services. Within NOAA, NCEI's archived information is a foundational component of the maps, tools, graphics, charts, dashboards, reports, and other products that weather service providers produce for their audiences and clients. While there are numerous applications of

NCEI's information, they commonly include climatology development, verifying and testing models, recreating past weather events for forensic analysis, probability analysis to inform planning, and adding context to weather forecasts or editorial publications.

For many value-added providers, NCEI's information is integral to the products and services they create, and to others it's indispensable. Some service providers stated that their entire business model is predicated on NOAA and NCEI data, and without this information they would "not be in business" (M. Roffer, personal communication, Feb 8, 2018). For applications like forensic analysis, NCEI's information is the standard with its DOC certification. Even for service providers that archive their own information, NCEI's information serves as an important backup in case internal processes fail.

With more volatile and costly billion-dollar disasters, demand for weather services continues to grow as does demand for NCEI information. With NCEI's free and publicly available information, the potential for continued market expansion in the weather service provider community is considerable. In the words of John Firth, CEO of Acclimatise, 'The changes we are now seeing in climate and weather, and the impact they are having on our daily lives – our need for data and information is self-evident. NCEI is the world's greatest repository of climate and weather data and we need its information to manage our new reality".

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ANNEX A: INTERVIEWEES

Weather Service Providers

Steven Bray, Director of Broadcast Meteorology, Baron, Jan 9, 2018

Mark Chambers, Vice President Oil and Gas, StormGeo, Jan 10, 2018

Thomas Downs, Forensic Meteorologist, WeatherBELL Analytics, Jan 16, 2018

Mark Gibbas, CEO, Weather Source, Jan 10, 2018

Mark Hoezkema, Chief Meteorologist and Director of Meteorological Operations, Earth Networks, Jan 16 2018

Jonathan Porter, Vice President of Business Services and General Manager of Enterprise Solutions, Accuweather, Jan 18 2018

Toni Riggi, Meteorological Developer, WeatherBELL Analytics, Jan 16, 2018

Mitch Roffer, Founder, Roffer's Ocean Fishing Forecasting Service, Feb 6, 2018

Michael Ventrice, Meteorological Scientist, IBM's The Weather Company, Mar 3, 2018

Paul Walsh, Vice President, Weather Analytics, IBM's The Weather Company, March 19, 2018

Management Consultant

Christof Walter, Founder, Christof Walter Associates, July 26, 2017

NOAA Employees

Mike Brewer, Chief of Customer Engagement, NOAA's National Centers for Environmental Information, Mar 28, 2018

Mike Tanner, Director of the Center for Weather and Climate, NOAA's National Centers for Environmental Information, Mar 16, 2018