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Innovations Beyond the Sunrise: How Weather Has Transformed Our Society

Remember the time when you were that one poor soul who forgot their umbrella? You walked solemnly around campus, drenched from head to toe, kicking yourself for not checking the weather forecast that morning to see if it would rain. Sometimes we're thankful that weather forecasts are readily available and fairly accurate, so that we can plan what to wear each day and if we need to bring an umbrella along with us. But, I'm positive that you've also experienced times when you never want to look at a weather forecast again. The moments when your local television meteorologist insisted that it would snow tomorrow, but all you got was rain and tragically school was not cancelled. You really want to send that mean tweet or email to the meteorologist expressing your displeasure and clearly stating that you will never listen to their forecasts ever again. But the fact of the matter is that predicting the future is hard, and even downright impossible at times. Fortunately, meteorologists now have more tools at their disposal than ever before, such as advanced computer models, radar and satellite images, mathematical equations, and a plethora of data accessible via the internet, to help them make their best attempt at predicting the weather in the future. These superior weather forecasting capabilities that have been developed since the 1940s caused the accuracy of weather predictions to skyrocket, directly leading to a shift in the way that people view weather forecasts, from not being talked about and not being trusted between the 1840s and the 1940s to now having our entire society rely on these

forecasts every day, saving lives in the times of natural disasters, and sparking our culture to become consumed and captivated by all of this exciting weather data.

Scientists have been curious about Earth's atmosphere for thousands of years, and in the years before 1840 many influential discoveries laid the foundation for modern weather forecasting. Over two thousand years ago, scientists, such as the famous Greek philosopher Aristotle, became interested in learning more about the weather and attempting to understand why weather formed. Around 340 B.C., Aristotle wrote *Meteorologica*, which included theories about the formation of rain, clouds, hail, wind, thunder, lightning, and hurricanes (Graham). Even though many of Aristotle's claims were erroneous, his four-volume text was considered by many to be the authority on weather theories until about the 17th century (Graham). People accepted Aristotle's claims to be true and they tried to produce weather predictions from these theories. However, by the end of the Renaissance, it became increasingly obvious that greater knowledge needed to be obtained in order to further scientists' understanding of the atmosphere and create better predictions for the future. In order to do this, weather instruments such as the hygrometer, thermometer, and barometer were all invented between 1450 and 1650 so that scientists could measure properties of the atmosphere and obtain greater knowledge about how the atmosphere behaves (Graham). As these instruments improved their accuracy through multiple refinements, individuals at various locations around the world began to make and record atmospheric measurements, such as temperature, humidity, and pressure readings (Graham). Unfortunately, nothing much could be done with this raw data since it could not be aggregated from the individual locations to see what was happening in a broader sense across a much larger area.

A great deal of progress was made from the 1840s to 1900, since weather data could now be comminuted easier and the government established a service for the weather, but forecasting

techniques were still rather primitive. The invention of the telegraph in the 1840s not only revolutionized the way people communicate over long distances, but it also had a massive positive impact on the way people could now transmit weather information (History.com Staff). Telegraph networks were formed, such as in 1849, when the Smithsonian Institution supplied weather instruments to telegraph companies and established an extensive observation network of over 150 volunteers regularly reporting weather observations back to the Smithsonian (NWS). With these observations coming from all over the United States, crude weather maps could now be drawn, surface wind patterns were able to be identified, and storm systems could be studied (Graham). This ability to observe and display simultaneously observed weather data quickly led to people attempting to predict the weather, using synoptic weather forecasting for the first time, even though many of their forecasts were inaccurate since almost everything had to be done by hand. Collecting all of the weather observations over much of the country required substantial structure and organization, leading to the formation of the United States Weather Bureau in 1870 under President Ulysses S. Grant (NWS). The United States Weather Bureau was vital in the expansion of communicating weather information to the public, as they became the ones who issued weather forecasts and warning for years to come. However, in 1870 atmospheric prediction was just getting off of the ground and forecasts were vaguely worded, typically covering a large area of the country and only for a 24-hour period (Robbins). For instance, a forecast typically sounded something like, “through tomorrow, probably fair with a fresh breeze,” which is much different than the specific 7-day forecasts that we commonly see today (Robbins). Over 140 years ago, it took tremendous faith in this emerging science and the ability to see its true potential in the years to come for people to support the new United States Weather Bureau. However, it should be noted that in 1872, just two years after the Weather Bureau was established, the New York Herald published this text: “No department of the government has

done more for the honor of science and the good of the people, according to its means, than the Weather Bureau; and the whole nation will be disappointed if Congress does not provide for it most liberally and put it upon the best possible footing” (Robbins). Even in its earliest years with unreliable forecasts, the Weather Bureau and the emerging profession of meteorology were highly regarded by members of our society and our government as a service that would be helpful for all of humanity far into the future.

Between 1900 and 1940, new and intriguing advancements in the field continued, however weather forecasting techniques were still very undeveloped and terribly inaccurate causing them to be trusted by very few people. In 1901, founder of the Weather Bureau, Cleveland Abbe, proposed that the motion of the atmosphere is defined by the principles and exceptionally complex equations that apply to liquids and gases, known as fluid dynamics (Robbins). By solving these mathematical equations, numerical weather forecasting was born in 1904 by Vilhelm Bjerknes and Lewis Fry Richardson, but many refinements would need to be made to it before it could be deemed as accurate (Graham). For instance, it took Richardson at least six weeks, working by hand, with these new equations to produce a widely inaccurate forecast for a single location over a six-hour time period (Robbins). Obviously, a six-hour forecast is not useful in any way to the general public if it takes six weeks to produce. Richardson concluded that in order to produce weather forecasts while also keep up with the weather, it would require about 64,000 human computers continuously solving the complex equations of fluid motion and thermodynamics by hand (Robbins). Clearly there had to be a better way to solve these complicated equations in a timelier fashion. Richardson expressed his hope that “perhaps someday in the dim future it will be possible to advance the computations faster than the weather advances and at a cost less than the saving to mankind due to the information gained. But that is a dream” (Robbins).

Fortunately, Richardson's dream came true in the 1940s and 1950s, when a technological breakthrough occurred and the first electronic computer was released, revolutionizing the way that meteorologists predicted the weather for good. In 1950, a group of meteorologists at the Institute for Advanced Study in Princeton, New Jersey successfully produced the first weather forecast using the Electronic Numerical Integrator and Computer, or ENIAC (Robbins). Using a revised set of equations and the power of the computers, the computer calculations produced a series of successful 24-hour forecasts and marked the beginning of numerical weather prediction as we know it (Graham). In 1955, numerical weather prediction models became operational by the United States Weather Bureau and they continued to evolve and drastically improve in the decades to follow (Robbins). By the mid-1950s, numerical weather forecasts were being made on a regular basis, finally demonstrating to the general public for the first time that they could trust the weather forecasts produced by meteorologists.

Advancements in weather prediction techniques continued to evolve from the 1960s until today, making forecasts more reliable year after year and creating a shift in the way that people think about and trust weather predictions. For instance, twenty-five surplus radars were gifted to the Weather Bureau from the military after World War II, helping them to launch a network of weather surveillance radars (commerce.gov). These radars helped meteorologists see what was happening in terms of precipitation near the ground, assisting forecasters to make forecast models even more accurate. Additionally, in 1960 the first polar-orbiting satellite, TRIOS 1, was launched, giving forecasters access to observations and data from remote areas of the globe that are only able to be seen from space (Graham). Over the past 50 years, both satellite and radar sensor technologies have advanced immensely, providing meteorologists with images and data that helps their forecasts to be even more accurate. Additionally, the equations that govern the weather and the properties of the atmosphere are so complex that supercomputers are now

required to solve them. Modern-day numerical weather models are run on National Weather Service supercomputers in Maryland, where they solve over 2.8 quadrillion mathematical calculations every second (NOAA). With each successive upgrade in the computing power of these supercomputers, the accuracy of the weather forecasts has also improved. In 1955, when numerical weather prediction models were first used by the National Weather Service, these computers predicted the weather for the next 36 hours with about a 25% accuracy (Robbins). However, in 2015, after the countless upgrades to these computers, drastically increasing their computing power, these computers were able to be correct about 83% of the time when predicting the weather for the next 36 hours (Robbins). Weather forecasts have drastically been enhanced by upgrades to computing power, but also due to the fact that they have access to an increasing amount of data from around the world. The National Weather Service supercomputers collect observations from weather balloons, satellites, buoys, radar, sensors on aircrafts and ships, coastal and river gages, and a nationwide network of ground-based observing sites, and plug all of this data into the complex equations that they use (NOAA). Being able to obtain data from a variety of different sources is vital in ensuring that the weather forecasts that are produced are accurate. It should also be noted that many of these sources of data were unavailable to forecasters before the 1940s and 1950s, which contributed to their forecast being horribly inaccurate. However, now that all of this data is available to meteorologists at their disposal, they can use it to create more sophisticated forecasts that the general public will approve of. Coupled with the increase in the reliability and accuracy of weather forecasts is the increase in trust that the general public has in weather forecasts. When a meteorologist says that it will rain tomorrow, more people will believe that statement today than they did before the 1940s and 1950s, demonstrating that our faith in meteorologists has increased proportionally to the accuracy of their forecasts.

Granted, there are still the naysayers out there who will stand firm to their argument that meteorologists have never been able to accurately and reliably predict the weather. For example, New England Patriots head coach Bill Belichick recently said, “based on the forecasts we’ve gotten so far this year, none of them have been close to what game conditions were. There was a 100% chance of rain last week, and the only water I saw was on the Gatorade table. They’re almost always wrong” (Samenow). Belichick’s comments are similar to the typical criticisms that some people complain about when talking about weather forecasts’ accuracy. However, the majority of the general public has agreed that believing weather predications to be correct is now easier than ever before. A one-day temperature forecast is now typically accurate to within two to two and a half degrees of the predicted value, demonstrating that weather predictions have come a long way since the early 1900s (Samenow). Since meteorologists are now able to make more accurate forecasts, they are able to help to save more lives from weather related phenomena and help make our daily lives easier to plan around the weather.

One major impact of this paradigm shift in weather forecasting on our society is the fact that with improved and more accurate forecasts, natural disasters, such as hurricanes and tornadoes, are easier to predict and warn people about these disasters to ultimately help save more lives. It may seem hard to believe, but without the advanced forecasting techniques and tools that I described earlier, Americans didn’t even have tornado forecasts up until the 1950s. No tornado warnings were able to be sent out to specific areas of the country and no radar data was available before the 1950s to notify people that a deadly tornado was approaching (Morris). Therefore, Americans have had to endure decades of harrowing blows from Mother Nature, many victims dying in these storms simply because they were unaware that they were happening. Tornadoes were actually being researched as early as 1882, but the word “tornado” was banned from official forecasts until 1950 since forecasters were concerned that the word would cause

widespread panic (Morris). Additionally, tornado predictions weren't very accurate at the time, so meteorologists didn't want to keep forecasting false alarms, when a tornado was predicted to happen but never did. However, once radar was introduced to the weather world, meteorologists could see precipitation and likely areas where tornadoes would form. The word "tornado" was now reinserted back into a forecaster's vocabulary and the first tornado forecasts were issued in 1950 (Morris). From that point forward, fatalities from tornadoes were limited thanks to the tornado evacuation and safety measures taken by the general public after the tornado watches and warnings were issued. In the early 1990s, Doppler Weather Radar was introduced nationwide allowing forecasters to see more than just precipitation (Morris). After the Doppler Radar was deployed, lead times for tornadoes were nearly doubled, from less than five minutes to around ten to thirteen minutes, proving to be valuable time for people to get to a safe spot and limit fatalities from tornadoes even further (Morris). Similarly to how tornado forecasting has improved, so has hurricane forecasting, giving people a better idea as to where and when the hurricane will hit land and how strong it will be. Hurricane forecasting has improved partly due to the fact that the computers used for climate modeling are getting more and more powerful (Plumer). Each hurricane is different, but now hurricanes are usually following their forecasted paths, allowing meteorologists to be able to pinpoint certain location where the storm will strike land instead of having to cover a broad range of possible landfall locations. This enhanced forecasting accuracy and reliability for hurricanes, tornadoes, and other extreme weather events has allowed forecasts to be released sooner and alert people of the possible threat for severe weather in the area. More people have been able to be safely evacuate from the area or find a safe location to be at when a natural disaster is predicted to come their way in order to limit the number of fatalities related to the event.

The second major impact of this paradigm shift in weather forecasting on our society is the fact that people rely on weather forecasts every day and that Americans have become consumed and captivated by the weather in the recent past. In a recent survey, adult United States residents were found to view, on average, 3.8 weather forecasts every day, demonstrating the importance of weather forecasts in American's lives (Life Science Staff). These results tell us that people generally have a high level of interest in weather forecasts, especially when they need to plan an event that is contingent on the weather. Many people also rely on daily weather predications to determine what they will wear each day to best correspond with the temperature and precipitation predications. Additionally, with weather forecasts now available with the touch of a button on our smartphones, people are able to quickly view the weather forecast in less than thirty seconds and move along with their day. A different survey revealed that the most common source for weather forecasts that Americans view was from your phone's default weather app, closely followed by your local television news station and a specific website or app that you use (Hickey). Television has a long history of communicating weather information before the rise of the internet or the mobile phone. Meteorology made its television debut in the 1950s, providing a new way to "show" the weather to a larger audience (Zidle). These weathercasts started out with a few basic graphics, such as a paper or a chalk board weather map that meteorologists drew on by hand, but transitioned to computer displays for weather information in the 1980s (Zidle). With the ability to watch weather forecasts on television, or even gain access to uninterrupted weather information on The Weather Channel starting in 1982, people were increasingly interested in learning more about the weather. And now with forecasts and weather data available at our fingertips, I think it's fair to say that our society has become obsessed and entertained by all of the weather information that is available to us.

Our society has come a long way since the years prior to the 1940s when we hardly ever believed a forecast to be true due to the fact that weather forecasting was just getting its feet off of the ground. However, in our modern culture, Americans now access a plethora of weather information on a daily basis and forecasts can be more heavily relied on to be accurate, helping us plan our daily lives better and preventing casualties in the event of a natural disasters.

If the accuracy of forecasts continues to follow the trend of becoming increasingly valid, who knows what the future will hold for weather forecasting. What we do realize is that our forecasts can never be 100% correct over a long range of time due to the natural uncertainties of the atmosphere and predicting the future. Hopefully our forecasts do improve in the future so that people won't have to continue to pamper meteorologists with angry remarks that their forecast was wrong, and so that we can predict natural disasters better and farther in advance to give more people the opportunity to make it to safety. Nevertheless, a major component of weather forecasting is how the general public interprets and perceives meteorologists' forecasts. People need to start taking weather forecasts more seriously, since they are something that we take for granted and could not imagine living without. Numerical weather forecasts have only been around for 67 years, but the impacts that predicating the weather has had on our society are innumerable. Weather impacts almost all areas of our society including sports, our economy, education, and climate change, so by increasing our accuracy for weather predictions, these areas of our society will also see beneficial impacts. The future of weather forecasting is in our hands in our ever-changing society, and it's our job to choose what path we decide to go down as we continue to seek improvements in the ways that we predict the weather.

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