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Cover photo taken by Nicole Collins '25 **Publication and cover designed by Nicole Collins '25**

From the Editor

I am excited to introduce this latest edition of Ithacation on behalf of the Cornell Chapter of the American Meteorological Society (CCAMS).

Below, you will find a variety of articles where various members of CCAMS show their passion and discuss numerous topics related to meteorology. These range from articles about past weather events to in depth forecasts and explanations of current weather phenomena.

This edition begins with an article discussing the persistent behavior of weather patterns where Joshua Pan takes an in depth look at the four nor'easters that dominated March of 2018.

We then move onto the next article, which is written by Rohan Shroff. You may have read his previous article from the Fall 2021 Ithacation edition where he provided a thorough forecast for the 2021-2022 winter. In this edition, he provides us with another winter forecast where he predicts the nature of the temperature and precipitation across the United States for this upcoming winter.

Lastly, this fall marks the 10 year anniversary of Hurricane Sandy. Therefore, Kaiden Sookdar breaks down this impactful weather event in terms of the past and the future. He includes a discussion of the predictions made for this event and how we can prepare for a storm of this nature in the future.

I hope you enjoy the wealth of information as well as the broad array of weather related topics shared in this edition. I would also like to thank you for your continued support as Ithacation provides a valuable platform for members of CCAMS to share their passion and knowledge across the many different areas of meteorology. I hope you enjoy your time reading through each of these articles as I thoroughly enjoyed compiling this edition.

Sincerely,

Nicole Collins [*Editor-in-Chief*]

In this issue:

Why are weather patterns so persistent?

Joshua Pan ‘23

It is often difficult to explain observed weather patterns with our most basic physical intuitions, not least because the Earth is a rotating sphere. However, let’s start with one intuition that does hold: atmospheric motions overall act to reduce equator-to-pole temperature gradients that arise from uneven solar heating. These motions include the mid-latitude cyclones we know and love. One might expect temperature gradients to flatten uniformly, as though hot air were spreading across a room. This is where intuition breaks down. Take March 2018—the month that produced four nor’easters (March 1-3, 6-8, 12-14, and 20-22). Fig. 1a shows the 300 mb winds averaged over the entire month. It is apparent that the jet stream sat much farther south than usual. If mid-latitude cyclones are supposed to erase the energy gradients that spawn them and that drive the jet stream, then how does a displaced jet stream stay put through four developing nor’easters and an entire month? To address this question, I present a hypothesis on how mid-latitude weather systems can reinforce existing weather patterns.

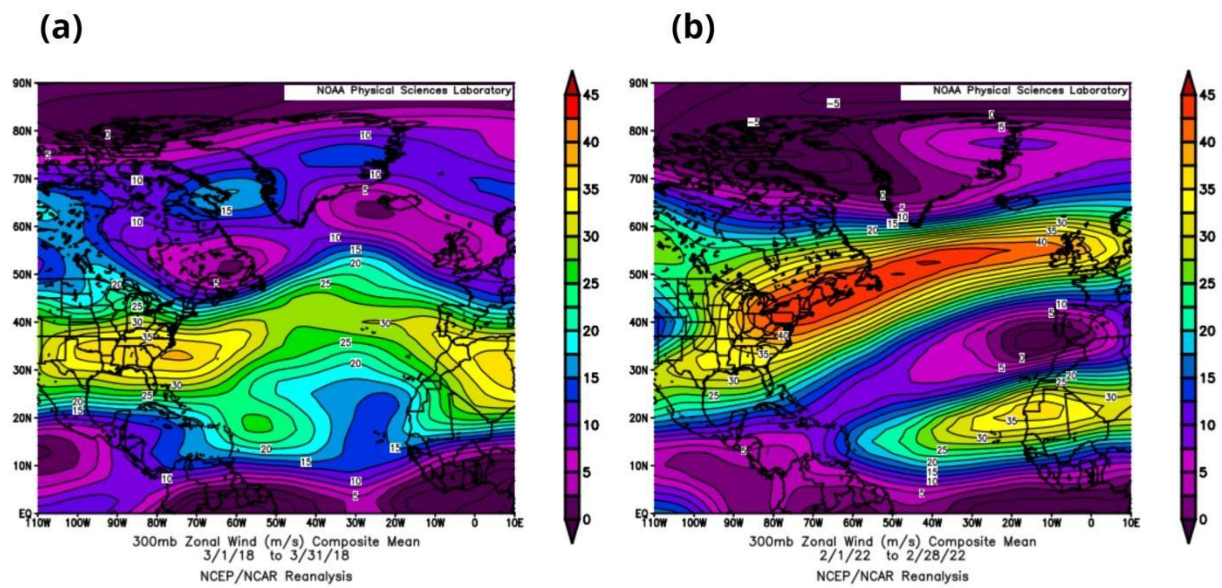

Fig. 1. Monthly mean 300 mb zonal (westerly) winds from the NCEP/NCAR Reanalysis for (a) March 2018, which featured a negative North Atlantic Oscillation (NAO). (b) February 2022, a month with a positive NAO.

To further reveal how mid-latitude circulations seemingly fly in the face of our intuitions about energy, we turn to the temperature fields and their relation to the strengthening of the

March 2018 nor'easters. Mid-latitude storms such as nor'easters grow by converting the potential energy stored in temperature gradients into the kinetic energy of winds. As such, they reduce north-south temperature gradients and the available potential energy (i.e., baroclinicity) associated with them. Fig. 2 seems to contradict this picture. Fig 2a. illustrates that the strongest low-level temperature gradients sat around 35-50°N over the Eastern US in March 2018. Fig. 2b reveals that three out of the four nor'easters that month strengthened rapidly in a narrow latitudinal band spanning 33-41°N. It is remarkable that the strongest temperature gradients remained intact in the same areas where multiple cyclones were dissipating large amounts of potential energy. This spatial overlap is neither a coincidence, nor does it violate the conservation of energy. This sharp temperature gradient would likely be even stronger, (at least in the zonal mean), if these storms had not existed (Kidston et al. 2010). In the rest of this article, I will lay out a conceptual model to explain our observations thus far.

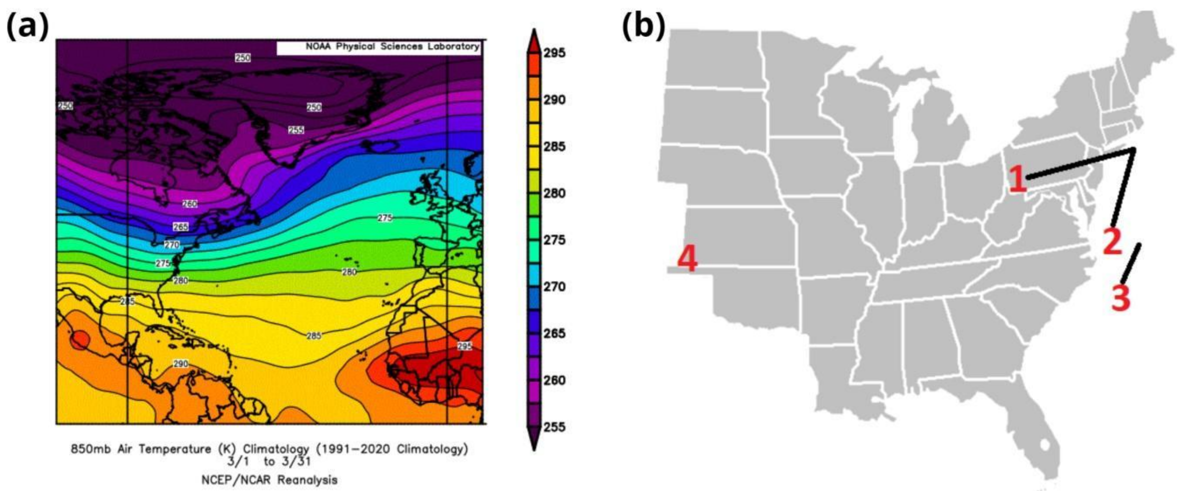

Fig. 2. A comparison of the latitudinal location of the strongest temperature gradients and regions of cyclone development. (a) NCEP/NCAR Reanalysis monthly mean 850 mb air temperatures for March 2018. (b) Based on U of Wyoming 12-hourly surface plots, the four numbers sequentially mark where each of the nor'easters achieved a sea-level pressure of 1000 mb within the mapped domain. Black lines extending from the numbers show the locations of the low-pressure centers 12 hours later, provided that they deepened to 990 mb.

Fig. 3 portrays the conceptual model. We start with the temperature gradients. Here, thermal wind balance implies that if temperatures decrease going northward, there must be positive vertical shear in the westerlies (i.e., westerly winds increase with height). Hence, the jet stream is located above the largest temperature gradients. Recall that these temperature gradients also contain potential energy. Developing mid-latitude cyclones preferentially develop where the most energy is available (Gerber and Vallis 2009). This is the intuitive part of the story: these storms draw on the potential energy, weakening the north-south thermal gradient and the jet stream.

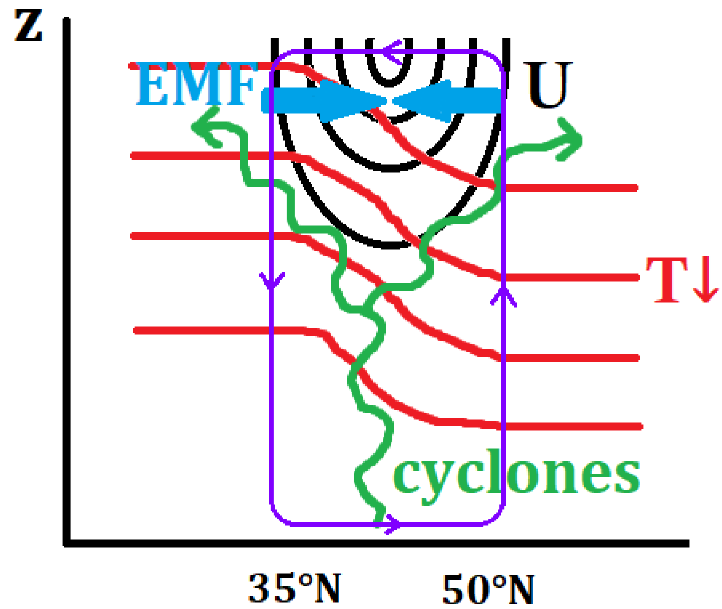

Fig. 3. A schematic representation of mid-latitude cyclones reinforcing existing temperature gradients and the jet stream. Red contours are isotherms, with the warmest air located to the south and at low altitudes. Concentric black contours depict a westerly jet stream (air moving out of the page) in thermal wind balance. Green wavy arrows represent mid-latitude cyclones developing within the strongest thermal gradients, propagating upwards and then meridionally away. The departing cyclones advect westerly momentum back into the jet core. This momentum transport is shown by the converging blue arrows (eddy momentum fluxes; EMF). The purple rectangle with arrows outlines a secondary overturning circulation that restores thermal wind balance and reinvigorates the existing temperature gradients.

To finish explaining the persistent storminess of March 2018, we must answer how the cyclones in our model reinforce the jet stream and temperature gradients at their original latitude. We shall consider the cyclones to be separate from the mean jet stream. The maturing cyclones (idealized Rossby wave packets) propagate upward and away to the north and south (Ait-Chaalal and Schneider 2015; Shepherd 1987). As the storms leave their source latitude, they advect momentum back towards the jet stream (Robinson 2000). This momentum transport is a result of the structure of Rossby waves and accelerates the jet at its current latitude. This jet strengthening enhances positive vertical shear in the westerlies for two reasons. First, because the momentum advection is greatest at high altitudes (Ait-Chaalal and Schneider 2015), it primarily strengthens westerlies aloft. Second, surface friction dissipates much of the momentum that is advected at low altitudes (Robinson 2000). To complete the feedback loop, we must show how the atmosphere increases the temperature gradient to balance out this increase in westerly shear.

The main way for the atmosphere to restore thermal wind balance after its disruption is through secondary overturning circulations. In our cartoon model, this overturning produces rising winds and adiabatic cooling on the poleward flank of the jet. Simultaneously, it generates subsidence and adiabatic warming on the equatorward flank. (This overturning seems akin to the U-shaped dip in the transformed Eulerian mean streamlines, which Robinson [2006] referred to.) Thus, in the process of returning to thermal wind balance, the atmosphere ultimately fortifies the existing north-south temperature gradients. Incredibly, mid-latitude cyclones bolster the very energy gradients they spawn from! This positive feedback does not violate the conservation of energy because temperature gradients are ultimately weaker than uneven solar heating (or more precisely, radiative-convective equilibrium) would suggest (Kidston et al. 2010). Rather, our result is remarkable because the temperature gradient is strongest in the exact region where we would expect cyclones to destroy it.

Returning to March 2018, it is now less surprising that the jet stream was so persistently displaced. Our conceptual model states that each storm initially weakened the sharp temperature contrasts but subsequently reinvigorated them. Taking a broader view, this process of reinforcement can also explain why the mid-latitude (eddy-driven) jet streams and polar fronts are so narrow in the climatological mean. There are, of course, limitations to our highly simplified model. First, we have neglected zonal variations in the jet and storm life cycles. Second, our model does not apply to any individual storm system because real-world cyclones generate large wind anomalies compared to the background jet stream. The timeframe of our model must be sufficiently long (perhaps at least a couple of weeks) to separate the mean jet stream from cyclones (eddies). Finally, in contrast to Robinson (2000), my model neglects the dissipation of eddies. For me, this thought experiment raises a question: how strong would mid-latitude temperature gradients be in the presence of eddies but in the absence of this positive feedback? As for our intuitions, we were right about the poleward redistribution of energy. It's just that this energy courses through a winding river full of eddies.

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2022-2023 Winter Forecast

Rohan Shroff '24

The time has once again come to speculate on what the upcoming winter season has in store for the United States. Every year, the months right before winter present an opportunity for weather enthusiasts and meteorologists to roll up their sleeves and try to predict what the upcoming winter season is going to be like. Fortunately, the Earth generously provides us with multiple indicators that help to give us some potential clues. One of the most important is the ENSO or the El Nino Southern Oscillation, which is a measure of water temperatures in the tropical Pacific. The 2022-2023 winter is uniquely challenging, with La Niña conditions being anticipated for a third consecutive winter, something that has only happened 2 other times in recorded history. There is strong agreement for the La Niña this winter to be on the border between the weak and moderate classification (-0.7 C to -1.2 C) in the Nino 3.4 region, with La Niña conditions weakening as the winter season progresses. Furthermore, when making seasonal forecasts, determining the placement of the coldest/warmest waters during a La Niña or El Niño is also crucial. This year, the coldest pool of waters should be centered in the eastern Pacific but may also drift slightly further west (hybrid La Niña). Attached below is the geopotential height anomaly composite of all weak and moderate La Niña events that were eastern or hybrid for the December – February time frame.

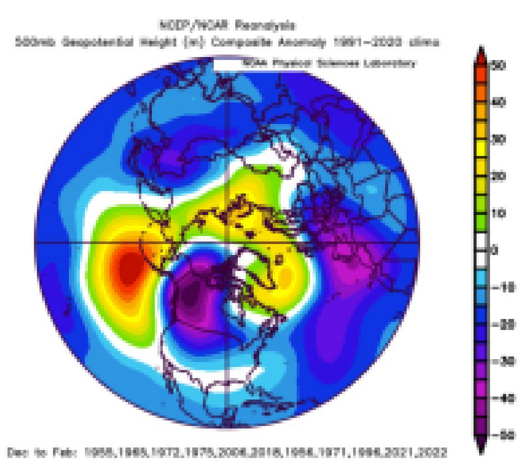


Figure 1 – Geopotential Height Anomalies (NOAA)

The first thing that sticks out is a large area of below average heights in the Pacific northwest and western Canada that stretches into the Midwest. A – NAO signal is also evident with above average heights over Greenland, which promotes a wavier Jetstream. This set up leads to a warm eastern and southern US, with colder than average conditions in the northwest and Midwest. What's unique here is that a consistently warm southeast US signal shows up even with the negative North Atlantic Oscillation (-NAO).

Analogs:

Another factor that plays an important role is the QBO or Quasi-Biennial Oscillation. The QBO is currently in the westerly phase and is ascending. Research has shown that the westerly phase of the QBO tends to decrease the likelihood of high latitude blocking, which makes it harder in the mid-latitudes to experience colder than normal conditions. The westerly QBO phase also makes it more difficult to allow warming events to occur in the stratosphere, which disrupts and weakens the polar vortex, and when that happens, cold air often spills down into the mid latitudes (where we are).

Next up is the NAO or North Atlantic Oscillation. The NAO looks to be neutral to negative this year. Dynamical models have been very consistent in showing increased chances for a negative NAO this winter, especially in the first half. That combined with the standardized JFM NAO index reaching its peak recently, neutral to negative NAO conditions should be favored this winter.

Finally, the PDO, or Pacific Decadal Oscillation, should remain firmly negative into the winter with a large pool of very warm waters in the far western Pacific tanking the index negative. Negative PDO values are common during La Niña winters.

So to summarize, a hybrid to eastern-based weak to maybe moderate La Niña looks to be the best bet. The QBO is ascending and is westerly, the NAO looks to be neutral to negative, and the PDO will be strongly negative. What years most closely match this? More weight was placed on analogs that met all conditions, and years with less than 3 matches were thrown out.

The closest years are: 1954-55, 1955-1956, 1964-65, 1970-71, 1971-72, 1995-96, 2020-21 What were the outcomes for those winters averaged together?

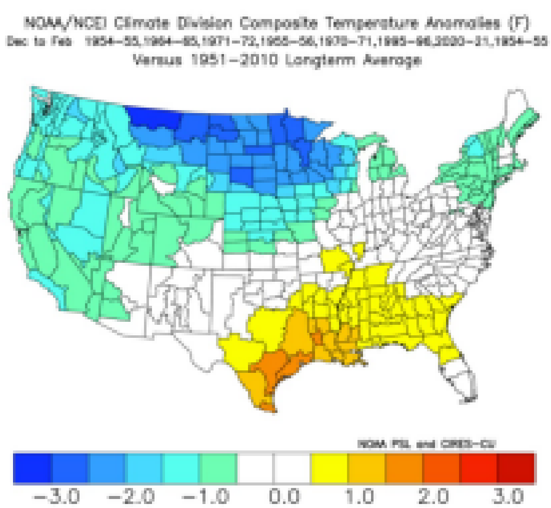


Figure 2 – Geopotential Height Anomalies (NOAA)

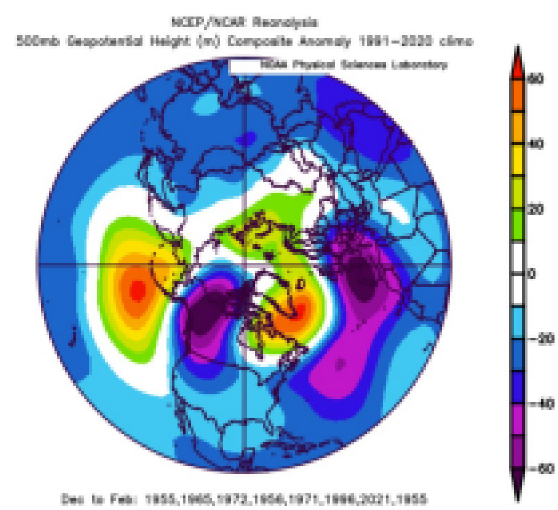


Figure 3 – Surface Temperature Anomalies (NOAA)

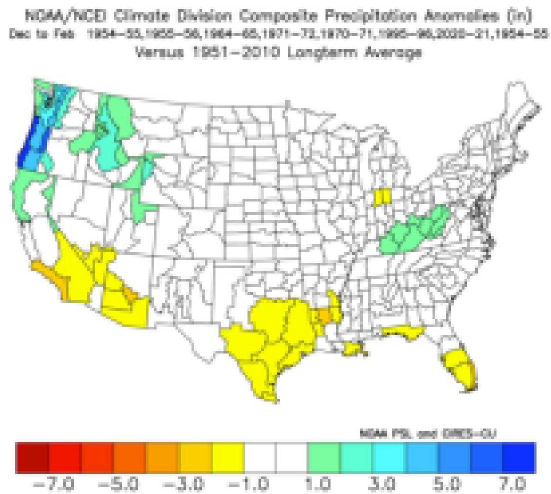


Figure 4 – Precipitation Anomalies (NOAA)

This composite is still remarkably similar to the earlier composite that only looked at eastern pacific and hybrid La Niña winters that were weak to moderate in strength. However, the warm signal is a bit reduced in the southern US, while below average temperatures show up over the northwestern US and Midwest. A rather strong – NAO signal as expected is present (selected for it) and a deep trough signal shows up in the northwestern US and into northern Canada. It's important to note that even when the – NAO signal is not selected for, the same warm south and east and cold north and west pattern shows up. An equally strong ridge southwest of Alaska suggests a roaring polar jet into the northern US coastline. While the precip signal is rather weak for the nation as a whole, above average precipitation looks to be a good bet for the Pacific Northwest. A weak dry signal for the southern third of the US and a hint of a wet signal shows up for the Ohio valley region.

The wildcard every winter is predicting the strength of the polar vortex and whether a Sudden Stratospheric Warming event will or will not occur. While it's too early to have any confidence regarding the polar vortex's behavior this winter, the upper air analog composite suggests that any major cold air outbreak would be focused in the western and central United States with cold air then bleeding east. Once the month of October concludes, indicators about the polar vortex such as Siberian snowfall cover and the amount of forecasted high latitude blocking will be ready to be analyzed.

The upcoming winter should once again prove to be an active and interesting one, especially for winter weather lovers in the Pacific Northwest and Midwest. But what about more specifically for the Ithaca, NY region?

First, we can take a look at everyone's favorite category, snowfall! Below are the seasonal snowfall totals for DJF for each analog year chosen above. The 30-year average is 45.7 inches.

1954-55: 49.3 1955-56: 26.7 1964-65: 36.5 1970-71: 58.1 1971-72: 58.5 1995-96: 59.1

2020-21: 69.5

5/7 analog years have above average snowfall, but the 2 that are below average are well below average. Interestingly enough, the two years with below average snowfall were both in the easterly and descending QBO phase, while all other analogs were either westerly or ascending. This leads me to believe that there are increased chances this winter of average to slightly above average snowfall.

Average of Analogs = 51.1 / Ithaca 30 Year Average Total Snowfall (Dec 1 – Feb 28) = 45.7

Ithaca, NY Winter Forecast:

December:

Temperature: Slightly Below Average
Precipitation: Above Average
Snowfall: Above Average

January:

Temperature: Near Average
Precipitation: Below Average
Snowfall: Below Average

February:

Temperature: Slightly Above Average
Precipitation: Above Average
Snowfall: Slightly Below Average

Overall:

Temperature: Near Average
Precipitation: Slightly Above Average
Snowfall: Near Average

To recap for Ithaca, NY, winter should once again arrive quickly this year with below average temperatures in December and above average snowfall. The lake effect machine should also be in full effect with a persistent northwest flow regime setting up over the area. Things should quiet down for January with drier and less snowy conditions, although temperatures will be close to average if not slightly below average. Finally, for the month of February, things look to become unsettled and wet, but snowfall should be around average to slightly below average. Temperatures will also be favored to be a bit warmer than normal. When all is said and done, the one word that should best describe this winter is average, with persistent major arctic outbreaks or sustained record warmth looking unlikely.

This concludes my 2022-2023 winter forecast. I hope you enjoyed it! Below are temperature and precipitation forecasts maps for the lower 48.

Feel free to follow me on Twitter @firstinweather so you don't miss my final winter forecast that will be released in November!

Temperature Forecast

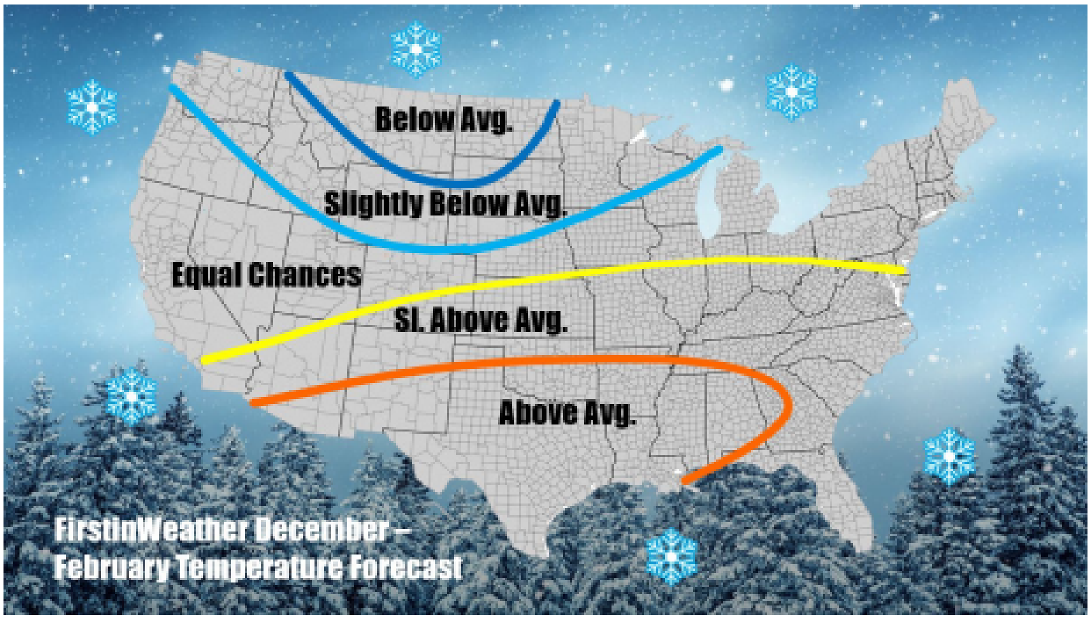


Figure 5 – DJF Temperature Anomaly Forecast

Precipitation Forecast

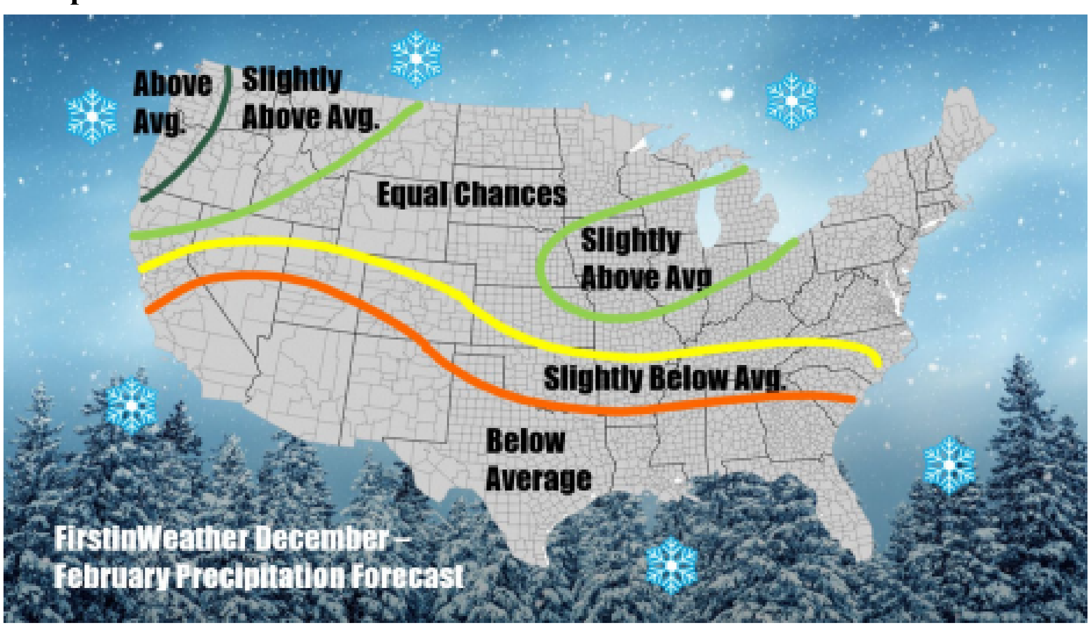


Figure 6 – DJF Precipitation Anomaly Forecast

10 Years After Sandy: Remembering, Reflecting, and Looking Towards the Future

Kaiden Sookdar '24

This month (October 2022) marks the 10th anniversary of Hurricane Sandy. Despite the passed time, the memory of Sandy's impact remains strong, especially in the NY/NJ coastal regions. In some extreme cases, the recovery from Sandy has only recently concluded or is still ongoing 10 years later. This article will take a quick revisit to the formation and impacts of Sandy, go over some of the changes made in the years following Sandy with regards to advisories, forecast model accuracy, and official NHC forecast accuracy. Finally, I will take a look at the factors that go into an effective hurricane response, and how we can continue to improve on that front.

A Brief Meteorological Synopsis

What would become Hurricane Sandy was initially a tropical disturbance in the Caribbean Sea that became Tropical Depression Eighteen south of Jamaica on October 22nd. Sandy then would move north, steadily intensifying. On the 24th, Sandy made landfall as a Category 1 Hurricane near Kingston, Jamaica. After moving offshore again, Sandy underwent a period of rapid intensification prior to its second landfall in Eastern Cuba. By the early 25th, Hurricane Sandy made landfall as a 115mph Category 3 Hurricane just west of Santiago de Cuba.

After emerging off the Cuban Coast, Sandy turned northwest towards the Bahamas. By this point it was losing some of its tropical characteristics, beginning to transition into an extratropical cyclone. It was also in a high shear environment as it moved parallel to the US East Coast, and briefly weakened to a tropical storm. However, while the magnitude of maximum winds decreased, the wind field of the storm expanded greatly as a direct result of this wind shear. Tropical Storm force (greater than or equal to 39mph) winds from Sandy expanded to an unprecedented radius of 500+ miles. On the 28th, there was a period of re-intensification where Sandy briefly became a Category 2 Hurricane again. This was also the same day that Sandy made its now-infamous westward turn, due to the orientation of an upper level low over the US East Coast and a ridge located over Atlantic Canada.

Approaching the coast on the 29th, Sandy would complete its extratropical transition. Sandy ultimately made landfall as an extratropical cyclone with maximum winds of 75mph. The direct impact along coastal regions in New York and New Jersey due to wind and storm surge was the worst seen in over a generation. At the time, Sandy was the 2nd costliest Atlantic hurricane to ever impact the basin, with normalized damage of $73.5 billion dollars.

Figure 1: A map depicting the track of Hurricane Sandy over its lifetime as first a tropical cyclone and then an extratropical cyclone.

The Forecast Product Changes Introduced After Sandy

Based on the response and impact of Sandy, the National Hurricane Center (NHC) made several necessary changes to the way they issue advisories for tropical cyclones:

1. The NHC did not issue Tropical Storm Warnings and Hurricane Warnings in the Northeast because Sandy had transitioned to an extratropical cyclone. The lack of official warnings likely impeded the response greatly. After Sandy, the NHC began to issue tropical products for storms that recently underwent an extratropical transition (for example, Isaias in 2020) for the sake of better communicating impacts.
2. Water, particularly storm surge, is the most deadly impact related to tropical cyclones. The storm surge in the Northeast US associated with Sandy was particularly bad, and shattered records in the region (most infamously in New York City's Battery Park). But at the time, there was no tropical weather product that addressed storm surge. In the years following Sandy, a storm surge watch/warning product was developed and was in its experimental testing phase by 2015 and became fully operational by 2017.
3. Efforts were introduced to improve public and partner understanding of the various warning products issued by the NHC.

The "Model Wars": Is the Euro Still King?

One of the factors that hampered forecast lead times was the disparity between forecast model projections between the American GFS model and the European ECMWF model. From approximately 6 days in advance (23 October), the Euro was correctly depicting that Sandy would make a left turn into the Northeast US, but the GFS was taking it out to sea. It took until the 27th for the GFS to come into agreement with the Euro. There was widespread criticism from inside and outside the meteorological community about the GFS's performance. Legislation was even passed in 2013 by Congress to improve funding, and ultimately the performance of the model. Despite the influx of funding in recent years, statistics show that the ECMWF has retained its accuracy advantage, *generally* speaking.

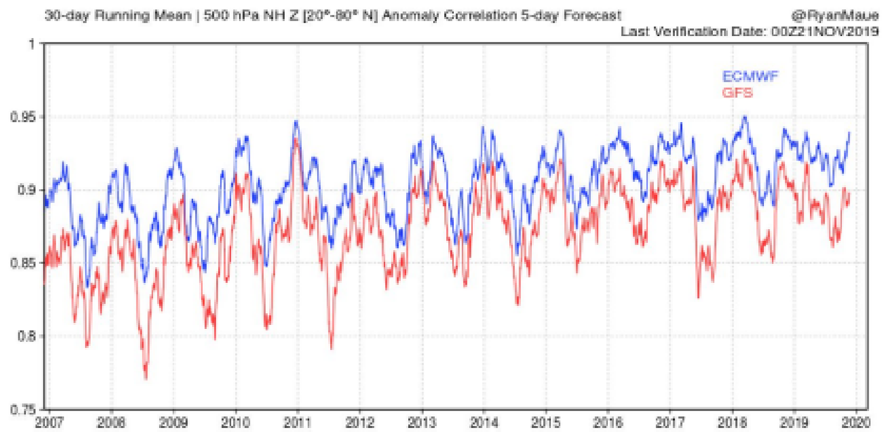


Figure 2: A graph of the skill scores of the ECMWF and GFS, overlaid, from 2007 to 2020 for 5-day forecasts in the Northern Hemisphere. As depicted by the graph, the Euro has overall been more skillful. The GFS did narrow the gap in the years right after Sandy (2013 and 2014 most notably), but the ECMWF widened the gap again in following years.

Despite this clear statistical advantage to the Euro, there have been several specific storm instances where the GFS has outperformed the Euro. One such instance was a January 2015 Nor'easter where the Euro initially projected NYC getting 2ft+ of snow while the GFS was much more bearish, projecting below a foot. Central Park received 9.8 inches of snow in that storm. The GFS was also much quicker to develop what would become Category 5 hurricane Dorian. So while the answer to the question is yes, it is not black and white.

Have NHC Hurricane Forecasts Improved in the Last 10 Years?

The most important source when it comes to hurricane forecast information is the National Hurricane Center. They are the ones who issue the advisories and the forecast cone. The information that they provide is disseminated to emergency managers, the media, and the public. Thus, it's of extreme importance that the NHC produces forecasts that are as accurate as possible.

There are two main factors that are considered when considering the accuracy of a hurricane forecast: track and intensity. Each has their own set of challenges associated with hurricane forecasting but forecasting hurricane intensity can be particularly difficult especially in a situation of rapid intensification. Since the 1990s, the NHC has consistently reduced its error in hurricane tracks, and that trend has continued in the years following Hurricane Sandy.

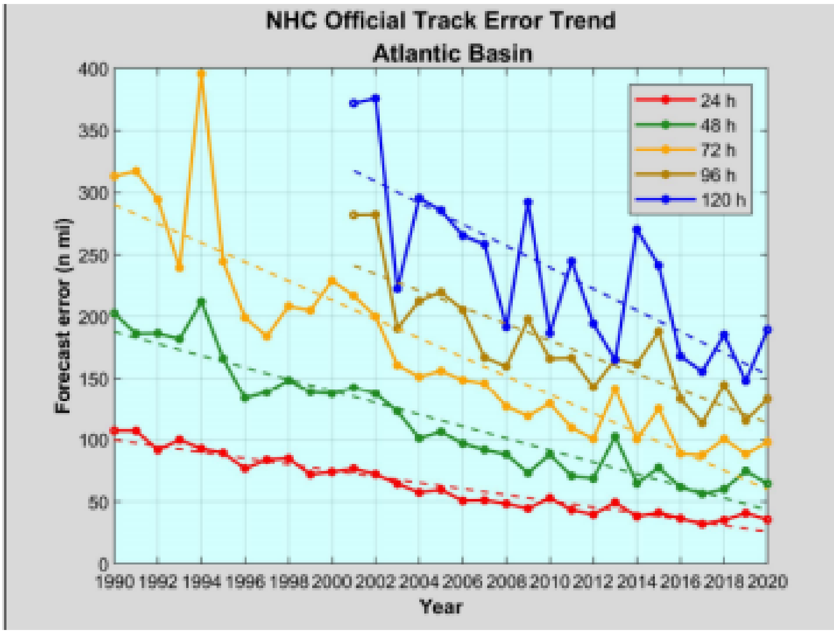


Figure 3: The NHC official track error trend, by forecast hour. Depicted by the trendlines, forecast error has continued to decrease into the 2010s at all forecast hours, with the greatest improvement seen at the 120 and 96hr segments.

A similar pattern can be seen in the forecast intensity error trend:

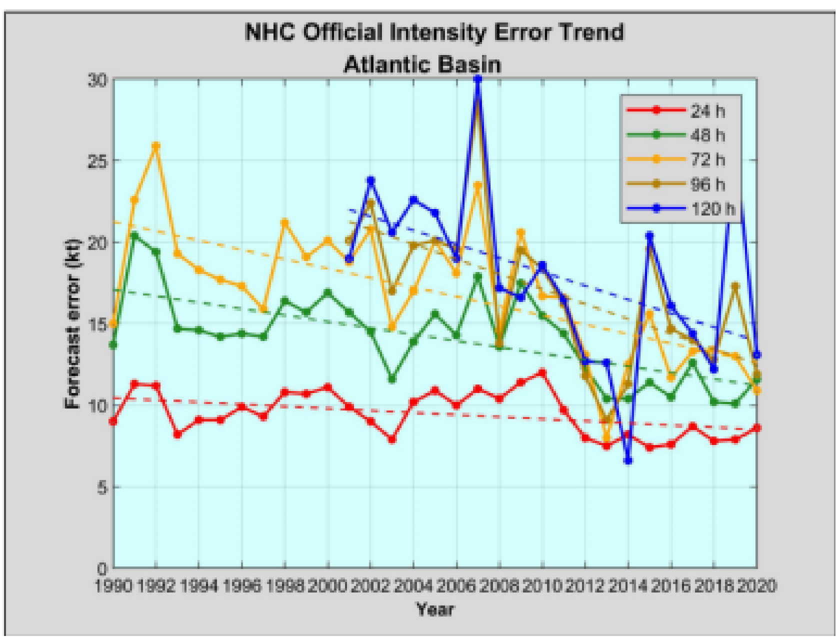


Figure 4: The NHC official forecast intensity error trend by forecast hour. As with the forecast track error trend, there is a noticeable improvement since 2012, especially in longer-range forecasts. It is notable, however, that the trendline for 24hr forecast error is relatively flat from 2012- 2020.

Based on this data, it is clear that NHC forecasts have continued to improve.

How can we Prepare for the "Next Sandy"?

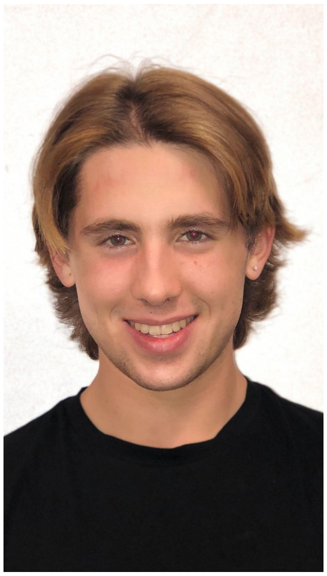
While we cannot pinpoint the exact season and day where we might see another event that was so destructive in nature as Hurricane Sandy in the Tri-State area, the region's government and residents can take proactive steps to increase overall preparedness to improve the response when such an event comes. This section will provide 3 potential ideas, their limitations, and a solution to their limitations:

1. **Improve the communication regarding uncertainties in hurricane forecasts.** A perfect but poorly communicated forecast is essentially useless. Helping people understand what the forecast uncertainty means for them can do wonders to help improve the hurricane preparation process.
   Limitation: Disinformation and lack of trust in weather forecasters.
   Solution: Meteorologists having an even more robust presence on social media, and forecasters holding themselves accountable when a forecast gets significantly off track.
2. **Address critical infrastructure issues in New York City.** The nearly-century old Subway system flooded out during Sandy and took years to recover. Billions of dollars worth of economic productivity lie only a few feet above sea level, and the city's infrastructure is the first line of defense.
   Limitation: Lack of funding and the fact that sea level rise is making these issues worse. Solution: Increase public awareness to push for funding. The US Army Corps of Engineers is proposing 6 mile long seawall along the immediate coast of New York City to mitigate storm surge inundation

3. **Continue work to improve hurricane forecasts.** A hurricane response is as efficient as the forecast for it. Being able to narrow down the "Cone of Uncertainty" can mean lives and billions of dollars of economic productivity saved.
   Limitation: There may be a point, decades from now, where forecast improvements become statistically insignificant.
   Solution: Continue to increase investment in other areas of hurricane preparedness, such as in communicating uncertainty.

CCAMS Fall 2022

Executive Board



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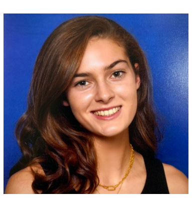
My name is **Juneau McGee** and I'm a freshman in Atmospheric Sciences here at Cornell. I am mainly interested in severe weather events and how climate change has influenced them. I greatly look forward to my next 4 years here!

Hi! My name is **Max Masleyev** and I am from Marlborough, Massachusetts. My interest in weather sparked at a young age and I've been exploring ways to get involved in weather ever since. In summer 2020, I participated in a week long meteorology workshop at Blue Hill Observatory in Milton, MA. The following summer, before my senior year, I came back to the university to intern. I'm not sure what my future career focus will be, but I am excited to continue learning and developing specific interests.

Hello, my name is **Dylan Wright** and I am from Woodbury, New York. I am interested in studying tropical weather and possibly hurricanes, but I am open to learning all different aspects of our atmosphere as well. An event that I would say brought up my interest in weather was in October 2012 when Hurricane Sandy impacted my hometown.

I am **Jaden Lau**, from Torrance, California. Since a very young age, I have been very fascinated with the weather, how it changes, and especially the development of severe storms. I knew I wanted to study weather at Cornell ever since learning about this club, the offered programs, and the large variety of weather there is. I plan to continue developing this fascination to wherever my interest leads me.



My name is **Helena Tsigos** and I am a sophomore transfer student from the University of Texas at Austin. I am from Houston, TX and am majoring in Atmospheric science with an interest in tropical meteorology and forecasting for energy companies.

Hey! My name is **Packie Young** and I am from Northport, New York. I am of Irish and German heritage, and in fact, my name is Gaelic for Patrick. Funny enough, as a child, the variable weather actually frightened me. Whenever a thunderstorm rolled overhead, I often hid in a corner or near my mother for protection. However, as I entered high school, I decided to take action on this fear and began to look into the field of meteorology. What I found shocked me: the odds of being struck by lightning are less than 1 in 15000, and those few who are struck average a 90% chance of survival. What was I so frightened of? All this research further intrigued me about other aspects of meteorology, and soon I found myself passionate about the subject. In my Junior and Senior years of High School, I decided to take a different approach to learning meteorology than my self-teaching and ended up collaborating remotely with a meteorology professor at a nearby university on a research project regarding snowflake formation. While I am no longer participating in that project, I look forward to more opportunities of this kind. I cannot wait for what the future holds!

CCAMS at Oswego GLASS 2022


LIDAR 1

Thanks for stopping in!