

To: Proposed Permit for IBRWF Expansion

Docket: #2022-P-W-0008

1. Introduction:

I am Dr. Gerry Bell. I have a doctorate degree in meteorology. I have two additional degrees in meteorology, and one in mathematics. I recently retired from a 30-year career with the Climate Prediction Center of the National Weather Service. I am an internationally recognized expert in many aspects of meteorology, including analysis, prediction and understanding both large- and small scale weather patterns across the globe. I am also an internationally recognized expert in climate research and climate assessment, and in seasonal hurricane analysis, monitoring and forecasting. In these efforts, I have authored or co-authored 98 scientific publications and done more than 100 scientific presentations.

In this submission, I address several issues related to the proposed permit for the Inland Bays Regional Wastewater Facility (IBRWF) expansion (sections 2, 3.1-3.5). These are damning. I have also performed a detailed meteorological analysis of precipitation, snowfall, snow depth, and temperature (section 3.6). The purposes of this analysis are to quantify and provide guidance for understanding the frequency of significant meteorological events which, based on permit specifications, can render the IBRWF effluent wastewater spray fields non-sprayable.

2. Issues related to the proposed permit for IBRWF expansion

Since 2003, I have lived downstream of the Inland Bays Regional Wastewater Facility (IBRWF). I have seen and lived the horrors of what that facility has done to locals and to my own family.

As with the current facility, I expect the failure to protect public health and the environment to continue due to mismanagement, corruption, not operating according to permits, and not fixing known problems as they arise. Because of those actions, and because of the ongoing disingenuousness of Sussex County regarding the IBRWF and its expansion, I feel that DNREC and Sussex County have lost much credibility. I don't believe them.

We must get rid of those now in charge. Get rid of corruption at both the County Administrator and County Engineer levels, and at DNREC. Then, hire credible people who can build a reliable wastewater facility that is not guaranteed to fail, that will not continue harming my family and community, and that will actually act according to permit specifications.

I have the following related issues regarding the proposed permit for the IBRWF expansion. I then will go into a more detailed discussion for each in section 3.

Issue 1. History has shown that both DNREC and Sussex County suffer from a lack of integrity and credibility regarding IBRWF. Yet, these entities are responsible for the creation, approval, and enforcement of this permit. In no way does this instill public trust.

Issue 2. The proposed language in the permit is designed to ensure accountability of both Sussex County (the Permittee) and the operator of IBRWF. This language is similar to the old permit.

History has proven this language is meaningless. Some of the stated consequences to Sussex County for not following the permit are unenforceable, and have historically been backed by zero enforcement.

Issue 3. Some aspects of the permit are designed to instill public trust. There is a pretense in the permit, also stated at the public hearing, that Sussex County strives to have the IBRWF be 100% permit compliant. Yet, there is no history them being compliant with Phase 1, and their own words and actions repeatedly reinforce they have no intention of being compliant in the future.

Issue 4. There are no backup mechanisms for when multiple spray fields become compromised, as has been the case for all existing spray fields throughout this past winter and spring. There is no alternative to spraying when the fields are saturated, flooded, frozen, or barren.

Spraying wastewater effluent on barren fields for months at a time, as IBRWF has done all winter and spring, is strictly prohibited, and doing so represents an abject failure to protect public health and the environment.

Photos show they also did not grow crops in the winter/ spring of 2020-21, yet they sprayed throughout the entire period. In fact, I routinely drive along Cannon Road and do not recall that they ever planted the permit-required winter grain crop. Sounds like corruption to me! Where is the money going?

Issue 5. The proposed expansion of the IBRWF incorporates the creation of an additional three effluent spray fields in largely wooded areas. This spraying will occur in areas that are not easily visible to the public. Therefore, the public cannot see if they are continuing their long history of operating against the permits. Given, the IBRWF's repeated permit failures regarding its current spray fields, one can only see this as yet another public trust crime just waiting to happen.

Issue 6. I have performed an analysis of meteorological conditions related to how the facility can and will fail to spray effluent according to permit specifications. These conditions include excessive precipitation amounts that can occur in any week or month, long periods when the ground remains saturated or flooded (as we saw during winter 2010), and cold periods with excessive snowfall and/ or frozen ground.

3. Discussion

3.1. History has shown that both DNREC and Sussex County suffer from a lack of integrity and credibility regarding the IBRWF. Yet, these entities are responsible for the creation, approval, and enforcement of this permit. In no way does this instill public trust.

3.1a. Both DNREC and Sussex County were likely involved in highly questionable, perhaps illegal, activities related to purported Mountaire Farms' illegal sludge deposits on the southern portion of the IBRWF.

A civil lawsuit (C.A. No.: S18C-06-009 CAK) against Mountaire Farms was recently settled in court on April 12, 2022. Page 2 of the settlement agreement¹ states that Mountaire Farms must pay \$65 million to affected people in Sussex County for damages caused by Mountaire's disposal of "contaminated wastewater and liquefied sludge on lands near Plaintiffs' residences. Plaintiffs allege that this wastewater and sludge have seeped into the groundwater throughout the area, causing nitrates and other contaminants to enter Plaintiffs' drinking water wells, resulting in health effects and property diminution for a class of individuals living...".

Page 119 of the settlement document states "The area of groundwater concern was updated in the October 2018 letter to Chase Brockstedt based upon additional information, including records that indicated Mountaire had disposed of sludge on the southern portion of the Hettie Lingo field, on the south edge of the Inland Bays water treatment facility". Chase Brockstedt, (lead attorney in the civil suit) stated in a personal e-mail that he had told DNREC of Mountaire's illegal activities on IBRWF property.

The proposed permit indicates that DNREC will inform citizens if their water gets contaminated. Yet, at no time did DNREC or Sussex County alert the public to Mountaire's illegal activity, nor did they publically recognize those activities even took place. At no time was the public in the areas downstream of the IBRWF alerted that their wells could have been contaminated, which they were. Ongoing public trust crimes such as these are wholly unacceptable, and they are one reason why I feel both Sussex County and DNREC have so little (if any) credibility.

The proposed permit for the Inland Bays expansion (p. 1)² states "The Department's purpose in issuing this Operations Permit Renewal and Modification and in imposing the conditions and requirements specified herein, is to ensure that all systems and discharges at the Inland Bays Regional Wastewater Treatment Facility (IBRWTF) are operated and maintained so as not to create a public health hazard or cause water pollution." Clearly, this was not the case regarding Mountaire's dumping on the IBRWF. Those activities contaminated people's wells, made them very sick, and killed others. The IBRWF continues to spray on that contaminated area to this day, often when it is crop-barren.

Moreover, instead of alerting people and going after Mountaire for their illegal activities, DNREC tried to get them off the hook. Perhaps we the taxpayers are not DNREC's only source of income.

3.1b. Infractions addressed in the 2018 Notice of Non-Compliance

- i. Unpermitted storage of sludge from another facility
"Concern: Permittee is storing sludge from another facility, South Coastal, (sludge drier installation planned in 2019 to make class A biosolids) without a permit."

- ii. Ongoing excessive nitrates in many monitoring wells

¹ <https://www.mountairesettlement.com/pdf/Cuppels-v-Mountaire-Mtn-for-Final-with-ex.pdf>

² <https://documents.dnrec.delaware.gov/Admin/Hearings/2022-P-W-0008/exhibits/2022-05-06-IBWTF-Draft-Operations-Permit.pdf>

A FOIA request was made for the IBRWF monitoring well data. Those data show that for 2015, 38 of 89 (57.7%) monitoring well reports had nitrate levels exceeding the permitted 10 mg/L. In 2016, 40 of 92 (43.5%) monitoring well reports had excessive nitrate levels. In 2017, 33 of 87 (37.9%) monitoring well reports had excessive nitrate levels.

For the period 2018-2020, page 20 of the updated Design Engineering Report for the IBRWF Phase II Expansion³ indicates the following. In 2018, 55% of the monitoring well reports had excessive nitrate levels. In 2019, 24% of the monitoring well reports had had excessive nitrate levels. For the first half of 2020, 27% of monitoring well reports had excessive nitrate levels.

The 2018 Notice of Non-Compliance indicates concern over ongoing excessive nitrate levels. It points out that in 2017, nine monitoring wells “exceeded the annual Federal and State primary drinking water nitrate standard of 10 mg/L. As noted in previous compliance inspections, nitrate in MWs off-site have continued to exceed the drinking water standard. During the same period, Lysimeter 237807 (#1), Lysimeter 237808 (#2) and Lysimeter 252842 (#5) were also above the annual primary drinking water nitrate standard of 10 mg/L.”

iii. Failure to plant crops on the spray fields

Failure to plant crop on the effluent wastewater spray fields is an ongoing, extremely serious problem. This concern was expressed in the Notice of Non-Compliance, which states “The South field did not have crop (soybeans) on a good portion of the field”.

The obvious solution to this problem is to actually plant the required winter grain crop. Yet this solution has proven unattainable. Throughout this past winter and spring, there were no crops on the effluent spray fields. The incessant spraying that occurred during this period is strictly prohibited by the permit, and doing so represents an abject failure to protect public health and the environment.

Photos (see submission from Donald Burdick) show they also did not grow crops in the winter/ spring of 2020-21, yet they sprayed throughout the entire period. In fact, I routinely drive along Cannon Road and do not recall that they ever planted the permit-required winter grain crop. Sounds like corruption to me! Where is the money going? I know our money has been going to purchasing well water treatment systems for ourselves and our neighbors this spring so that we don't suffer and die! Why have the county and state done nothing? Why do they continue doing nothing year after year after year?

iv. Failure to put up perimeter signs

The Notice of Non-Compliance reported “Signs indicating the facility is spraying wastewater were not located along the perimeter of the spray fields.” Perimeter signs

³ <https://documents.dnrec.delaware.gov/Admin/Hearings/2022-P-W-0008/exhibits/2020-10-IBRWF-Phase-2-DER-Update.pdf>

were missing along Mount Joy Road until late 2021, when we complained to County Engineer Hans Medlarz about this, yet another, permit violation. The permit requires signs for a reason, which is presumably to protect public health. Again, the IBRWF was less than interested for many, many years until someone finally said something.

3.2. The proposed language in the permit is designed to ensure accountability of both Sussex County (the Permittee) and the operator of IBRWF. This language is similar to the old permit. History has proven this language to often be meaningless. The stated consequences to Sussex County for not following the permit are unenforceable, and have been backed by zero enforcement. This permit needs effective oversight and an effective way to fix transgressions in real time.

3.2a. Holding the permittee (i.e. Sussex County) accountable

The proposed permit purports to hold the permittee (i.e. Sussex County) accountable. For example, Page 41 states “The Department may revoke a permit if, among other things, the Permittee violates any permit condition” or “these regulations”. This same wording was included in the previous permit. History has proven there is no way DNREC will revoke the IBRWF permit from Sussex County, no matter how badly they bastardize the permit. Therefore, this has not been a meaningful mechanism or incentive to force corrective actions at the IBRWF for blatant permit violations, mismanagement, and other violations identified in Notice of Non-Compliance.

In effect, there is no penalty for non-compliance, and therefore no accountability. Both DNREC and Sussex County know full well of the disasters that would occur if the IBRWF permit were revoked. This is why Sussex County can engage in non-permitted activity and get away with it. Indeed, DNREC did little to force change following the damning Notice of Non-Compliance sent in 2018. That Notice of Non-Compliance was obtained by FOIA request and can be found here⁴.

This failure to develop a set of enforceable consequences has allowed the IBRWF to operate with impunity. In fact, Sussex County routinely engages in non-permitted activity at the IBRWF, and DNREC routinely allows it. This proposed permit effectively allows the public trust crimes and mismanagement to continue unabated. To reiterate, history has shown that both DNREC and Sussex County suffer from a lack of integrity and credibility regarding IBRWF. The non-permitted activity, lies, cover-ups, disingenuousness, and lack of transparency continue to this day. Yet, DNREC allows it.

Some of the permit violations we have seen over the years include:

- Spraying wastewater when the ground is saturated occurs regularly. The permit (p. 34, item 6) specifically states “Spray irrigation is **Prohibited** when saturated or frozen soil conditions exist”.
- Spraying wastewater when there are no crops also occurs regularly, typically throughout the entire winter and spring. This is a huge problem because specific crops are required to

⁴ <https://brokenbambi.com/20181227InlandBaysInspRprtNOC.pdf>

ensure nitrogen uptake from the effluent spray fields. The permit (p. 34, item 5a) emphatically states “Spray irrigation of wastewater **shall only occur** on fields being prepared for planting or already planted with a crop and **shall not occur** on fields with crops not actively growing or on voluntary vegetation.”

- Failure to plant crops or to maintain the crops in optimal condition. The permit (p. 34, item 5e) states "The spray irrigation field's crops **MUST** be maintained in optimal condition, including any necessary weed management, **RESEEDING**, or other vegetative management".
- Failure to fix wrongs indicated in the Notice of Non-Compliance, such as relentless high nitrate levels and overly-acidic PH in the monitoring well readings
- Mountaire was likely given an OK to dump on the Inland Bays Regional Wastewater Facility.
- The wastewater spray fields have routinely had large areas of standing water for many years. The permit (p. 34, item 5b) states “Should pooled areas become evident, spraying on those areas **SHALL BE PROHIBITED** until saturated conditions no longer exist. Only in the last year are they finally doing something about it. Hmm!

3.2b. Notifying DNREC regarding Non-Compliance

The permit (pg. 38) states “The Permittee shall report to the Groundwater Discharges Section orally within 24 hours from the time the Permittee became aware of any noncompliance that may endanger the public health or the environment by contacting the Groundwater Discharges Section.”

The permit (pg. 24) also states “If for any reason the Permittee does not comply with, or will be unable to comply with, any effluent limitations or other conditions specified in this Permit, the Permittee shall provide the Department with the following information in writing within five days of becoming aware of any actual or potential noncompliance:

- A description and cause of the non-compliance with any limitation or condition;
- The period of non-compliance including exact dates and times; or, if not yet corrected, the anticipated time the non-compliance is expected to continue; and
- The steps being taken or planned to reduce, eliminate and/or prevent recurrence of the non-compliant condition.”

These notifications do not mean anything if DNREC itself is involved in the incidence of non-compliance (as with the case of Mountaire Farms’ sludge dumping).

These notifications also do not mean anything if the permittee chooses not to alert DNREC since, as stated previously, the lack of accountability in this proposed permit effectively allows the public trust crimes and mismanagement to continue unabated. Again, DNREC has shown they will not revoke the permit.

These notifications again do not mean anything if DNREC fails to act. The notifications have certainly proven to mean nothing during the last five months of this year (or during the 2020-21

winter and spring) when, instead of doing anything related to permit compliance, the IBRWF simply sprayed and sprayed and sprayed on barren spray fields. All the while, the suffering public was never told. Spraying wastewater effluent on barren fields for months at a time represents a willful intent of permit non-compliance, and an abject failure to protect public health and the environment. In reference to the ongoing non-permitted spraying at IBRWF, John Rebar (head of DNREC's Ground Water Discharges Section who will be assessing the proposed permit and reading these comments), stated on the phone (5/25/2022) "I am well aware of the situation down there." Yet DNREC has done nothing. To my further consternation, Mr. Rebar said we should write up our complaint and include it in these comments. His statement reinforces the obvious-- DNREC has no intention of insuring permit compliance in this regard.

To make matters worse, Mr. Medlarz was told by citizens on March 18th (see Donald Burdick comments, his p. 15) that the non-permitted spraying was a public emergency because our wells were being contaminated, and because we were bleeding, burning, itching, had bumps and sores, had intestinal issues requiring surgery, and had huge numbers of kidney stones. Did Sussex County alert DNREC of this extreme permit violation? If not, Why? Presuming they did alert DNREC, it was meaningless since DNREC did absolutely nothing. Why? Yet again, both DNREC and Sussex County suffer from a lack of integrity and credibility regarding the operation, health and safety of the IBRWF.

All of the above are blatant examples of the public trust crimes that routinely permeate the IBRWF, Sussex County, and DNREC. Moreover, they highlight the obvious fact that there is no practical or meaningful oversight and no guarantee to right the wrongs. In these regards, the existing expired permit and the proposed permit are both a joke!

3.3. Some aspects of the permit are designed to instill public trust

Additional focus on the lack of public trust is very telling. Trying to instill trust becomes problematic when one's own words and actions repeatedly prove one is not trustworthy. It also becomes problematic when the public routinely sees public trust crimes and lies paraded proudly in front of them by the IBRWF, Sussex County, and DNREC.

There is a palpable pretense in this proposed permit, and at the May 10th public hearing for the IBRWF permit⁵, that Sussex County strives for 100% permit compliance. Yet, there is no history of their actions doing so with Phase 1 of the IBRWF, and their own words and actions repeatedly reinforce they have no intention of doing so now or in the future.

The lies, cover-ups, disingenuousness, and lack of transparency continue to this day. At the public hearing for the IBRWF permit, Sussex County Administrator Todd Lawson stated "And Finally, goal number four: Assure the public of Sussex County's continued, continued commitment to 100 percent DNREC permit compliance and full transparency." Let us recall that the 2018 Notice of Non-Compliance was sent directly to Mr. Lawson, who appears to have

⁵ <https://documents.dnrec.delaware.gov/Admin/Hearings/2022-P-W-0008/Public-Hearing-Transcript-IBWTF-20220510.pdf>

promptly dis-regarded it since most of the issues were never addressed. Mr. Lawson did not mention this. His statement about 100% transparency is not credible.

The next speaker at the hearing was County Engineer Mr. Medlarz, who reiterated “our goal is 100 percent compliance all the time.” These statements regarding 100% compliance are not credible. They are disingenuous, and they also have a complete lack of transparency. Neither speaker stated that IBRWF had been spraying effluent on barren fields since winter, and nor that said spraying was literally taking place at that moment. Neither speaker said they planted a triple dose of rye that miraculously got entirely eaten by snow geese, which was why Mr. Medlarz claimed to my husband that the spray fields were barren (What is the excuse for the lack of crops last winter/ spring, and the winters before that?)

In the vain of 100% permit compliance and 100% transparency, questions we were forced to ask this year should never be necessary such as:

- What is your justification for the non-permitted spraying of effluent wastewater throughout the crop-barren and weed-laden spray fields at the IBRWF for at least the last five months?
- What is your justification for not warning citizens downstream that you fully intended to spray effluent wastewater throughout the crop-barren and weed-laden spray fields at the IBRWF for at least the last five months?
- When do you intend to stop spraying effluent wastewater on the crop-barren, weed-laden spray fields at the IBRWF?
- Also in the light of full transparency, when do you plan on alerting the public and the media of your non-permitted spraying of effluent wastewater throughout the crop-barren and weed-laden spray fields at the IBRWF for at least the last five months?
- When do you plan on alerting the public and the media of the 2018 Notice of Non-Compliance issued to Sussex County regarding failures at the IBRWF?

The disingenuousness and lack of transparency were on further display at the hearing when Mr. Medlarz presented “And if you...multiply out what each well has to be analyzed for per year, you can roughly calculate over 7000 groundwater quality data points will be collected to be consistent for permit compliance.” Mr. Medlarz failed to report that a significant fraction of the current monitoring wells have for years shown acidity levels and nitrate levels far higher than the permit allows. Numerous wells also suffer from ongoing, extremely high specific conductivity.

The disingenuousness and lack of transparency continued to build at the public hearing when Mr. Lawson presented his slide 14, which states The Operations Permit ... will include ... contingency plans designed to protect public health and the environment “. Let us recall that it was Sussex County and DNREC that allowed the IBRWF to spray effluent wastewater on barren spray fields since last winter. All the while, the suffering public was never told or aided in any way, shape, or form.

3.4. There are no backup mechanisms for when multiple spray fields become compromised, as is currently the case for all existing spray fields.

Let us also recall the old IBRWF permit (p. 23, item 1a), which states “Spray irrigation of wastewater **SHALL NOT** occur on barren fields.” The proposed new permit (p. 34, item 5a) states “Spray irrigation of wastewater **SHALL ONLY OCCUR** on fields being prepared for planting or already planted with a crop, and **SHALL NOT** occur on fields with crops not actively growing or on voluntary vegetation”. These permits make it abundantly clear that spraying on barren fields in a no-no.

I reiterate---Spraying wastewater effluent on barren fields for months at a time, as IBRWF has done all winter and spring, is prohibited, and doing so represents an abject failure to protect public health and the environment.

Having barren spray fields throughout the entire IBRWF, as existed this winter and spring, was not an unforeseen situation. As I noted above, the spray fields were barren the previous winter/ spring, and they have been barren during winter/ spring for as long as I can remember.

Those situations were brought on by the permittee itself. There is no contingency plan to deal with spraying effluent when there are no crops for an extended period. There is also no effective contingency plan to deal with situations when the effluent spray fields are flooded or frozen for any length of time.

The plan enacted this winter and spring (as in previous years) was nothing more than to just keep spraying, which they did day after day, month after month. When asked if they could stop spraying until crops were planted, Mr. Medlarz stated he would “as soon as people stop flushing their toilets”. Ugh! Did they warn us residents who live immediately downstream? No. Instead, when Mr. Medlarz was told it wasn’t fair that my community should suffer because our well water was being poisoned, he told my husband he could not stop spraying because it would cause a major public emergency. I believe the widespread poisoning of well water is a public emergency!

3.5. The proposed expansion of the IBRWF incorporates the creation of three additional effluent spray fields, all in in largely wooded areas. This spraying will occur in areas that are not visible to the public.

Since this proposed spraying is not visible to the public, we cannot see if they are continuing their long history of permit non-compliance. Given, the IBRWF’s repeated permit failures regarding its current spray fields, one can only see this as yet another public trust crime just waiting to happen.

3.6. Analysis of meteorological conditions related to how the facility can and will fail to spray effluent according to permit specifications.

3.6a. Motivation for the analysis

The documents reference how the IBRWF itself is designed to handle a 100-yr flood event. However, this does not address more frequently occurring situations that routinely affect the spray fields themselves.

The proposed permit (pg. 34, item 6) states “Spray irrigation is prohibited when saturated or frozen soil conditions exist”. A host of conditions can produce saturated or frozen soil conditions, including freezing temperatures, snow cover, a single storm, several storms occurring in a short period, and long periods of heavy precipitation.

Excessive precipitation amounts can and do occur in any month. The area can be subjected to long periods when the ground remains completely saturated or flooded (as we saw during winter 2010), to cold periods with excessive snowfall, and to the cold air outbreaks when the ground remains frozen for an extended period.

The purpose of this analysis is provide guidance to help better understand the frequency of these types of conditions, especially as they relate to the IBRWF effluent wastewater spray fields. This entire analysis will have been in vain if effluent wastewater continues to be sprayed at will, regardless of weather, crop, or soil conditions.

Data used in the analysis is in section 3.6b. Freezing temperatures are discussed in section 3.6c. Precipitation is discussed in section 3.6d. Snowfall and snow depth are discussed in section 3.6e and 3.6f, respectively. Climate patterns and implications are discussed in section 3.6g. A brief summary is presented in section 3.6h.

3.6b. Data used in the analysis

The data (Appendix A) analyzed for this analysis are based on daily data for Dover, DE, which is contained in the Global Historical Climate Network (GHCN). The data were obtained from the NOAA National Centers for Environmental Information (NCEI)⁶. According to the NCEI, the GHCN dataset “was developed to meet the needs of climate analysis and monitoring studies that require data at a sub-monthly time resolution (e.g., assessments of the frequency of heavy rainfall, heat wave duration, etc.). The dataset includes observations from World Meteorological Organization, Cooperative, and CoCoRaHS networks.”

The records examined in this analysis include daily precipitation, snowfall, snow depth, and both minimum and maximum temperature. Sporadic data errors in snowfall and snow depth included non-zero values in the warm months when daily minimum and maximum temperatures were well above freezing (e.g. 65°F). Those values were manually set to zero. Seven-day and monthly averages were then derived from the daily data. Only months with at least 25 reporting days are included in the monthly averages.

The data spans the period 1893- Feb. 2022. However, there were several years in which precipitation and temperatures were not reported. These data gaps include 1897, 1899-1905,

⁶ <https://www.ncei.noaa.gov/cdo-web/datasets#GHCND>

1917-1919, portions of 2020 and 2021, and eight other months spread randomly throughout the record. Snow depths were not reported until 1919.

The Dover, DE location was chosen for analysis because of its relative proximity to the IBRWF, and because of its long and mostly continuous data record. By contrast, the daily records for Georgetown, DE, which is closer to the IBRWF, span only 22 years beginning in 1998. The daily records for Millsboro exist from 1893 to January 1954 and from 2014-present, but are absent during the 60-year period of February 1954-2013. Both stations were rejected because of their limited data.

3.6c. Freezing Temperatures

The proposed permit (pg. 34, item 6) states “Spray irrigation is prohibited when ... frozen soil conditions exist”. Frozen soil is directly related to the presence and duration of freezing temperatures. Air temperature analyses for Dover, DE are shown in pp. A3-A24.

Analyses based on monthly averages for daily minimum, maximum, and mean temperatures are shown in pp. A3-A8. The 1893-Feb. 2022 average monthly minimum temperature (pp. A3, A6) is below freezing in December, January, and February (30.1°F in December, 26.6°F in January, and 27.5°F in February), and somewhat above freezing in March (34.5°F). In February, the monthly minimum temperatures are below freezing most often (87.1% of years, p. A7), followed closely by January (86.1% of years) and then December (67.2% of years) and March (18.4% of years). The coldest values for each month (p. A6) are 19.2°F in December (1989), 14.4°F in January (1944), 12.9°F in February (1934), and 25.9°F in March (1960).

The 1893-Feb. 2022 average monthly maximum temperature (pp. A4, A6) is above freezing throughout December-March. In fact, no month in the record has had an average maximum temperature below freezing. However, monthly maximum temperatures were near-freezing (p. A6) during the coldest December (33.4°F in 1989), January (32.1°F in 1940) and February (32.3°F in 1960) on record.

The Feb. 2022 average monthly mean temperature (pp. A4, A6), calculated as the average of the monthly minimum and maximum temperatures, is somewhat above freezing during January (35.2°F) and February (36.6°F), and increases to 38.6°F in December and 44.5°F in March. Nonetheless, the individual monthly mean temperatures are often at or below freezing. This occurs most frequently in January (23.5% of years, p. A7) and February (18.4% of years), followed by December (6.9% of years). Based on mean temperatures, the coldest year for each month (p. A6) was again December 1989 (26.3°F), January 1940 (23.2°F) and February 1944 (22.6°F). For March, the coldest monthly mean temperature (35.1°F in 1960) is above freezing.

To help assess the frequency of occurrence of various temperature ranges associated with each calendar month, temperature percentiles were calculated for monthly minimum, maximum, and mean temperature (p. A8). In this context, the percentile indicates the percentage of years in which monthly temperatures were colder than the temperature corresponding to that percentile. For example, looking at the percentiles for monthly mean temperature (bottom panel) during January, the temperature along the vertical axis corresponding to the 10th percentile bar (orange

bar at left) is 29.8°F. Therefore, monthly mean temperatures during January were colder than 29.8°F in 10% of years.

During January, the monthly mean temperatures corresponding to the 5th and 30th percentiles are 28.1°F and 32.8°F, respectively. This means the January monthly mean temperature was below 27.5°F in 5% of years, and below 32.8°F in 30% of years. Similarly, the February monthly mean temperature was below 28.1°F in 5% of years, and below 33.3°F in 20% of years. For December, the monthly mean temperature was below 31.5°F in 5% of years, and below 32.4°F in 10% of years.

Understanding and quantifying shorter term (daily and weekly) temperature variability is also relevant to IBRWF planning, since it too relates to flooding, cold-air outbreaks and surface freezing, snow storms and snow depth. Two types of analyses are shown for daily (pp. A9-A16) and weekly (pp. A17-A24) temperature variability during the months of November-April. These include percentiles (pp. A9, A17), frequency of occurrence of specified temperature thresholds (pp. A10-A15 and A18-A23). The results are summarized in pp. A16 and A24.

Looking at the daily data, more than 30% of days during January and February, and more than 22% of days during December, have mean temperatures at or below freezing (p. 16, bottom). Even in March, almost 8% of daily mean temperatures are below freezing. Since most cold snaps last more than a few days, the results for the weekly temperature variability (p. A24) are qualitatively similar to the daily variability.

During January, the 25th percentile of daily mean temperatures is 26.8°F and the 10th percentile is 22.2°F (p. A9). The corresponding 25th and 10th percentiles of 7-day mean daily temperature are 29.9°F and 25.6°F, respectively (p. A17). A large number of these days and weeks have well below-freezing minimum temperatures (pp. A16, A24).

To summarize, the 1893-2021 average of monthly mean temperatures exceeds 32°F for all calendar months. However, this statistic is of little use when gauging the potential for frozen ground over an extended period. The analysis shows that below-freezing mean temperatures often occur on monthly time scales during December-February, due to a combination of well below-freezing minimum temperatures and near-freezing maximum temperatures. Therefore, below-freezing temperatures on a monthly time scale should be a very real concern for IBRWF planning.

Similarly, a significant number of daily and weekly mean temperatures are at or below freezing during December-February, with values often well below 32°F. These temperatures are typically associated either with individual cold-air outbreaks or with a persistent jet stream pattern that drives the cold air southward from Canada for weeks or months at a time. Because of the intensity of these cold snaps, the ground surface is more likely to freeze and remain frozen. Therefore, shorter-term cold snaps, because of their intensity, should also be a very real concern for IBRWF planning.

Yet, there is no actionable plan for the IBRWF to deal with prolonged freezing (or flooding) conditions.

3.6d. Precipitation

Precipitation (rain and snow) controls factors that can affect the IBRWF spray fields, such as saturated ground, runoff, flooding, snowfall, snow cover and snow depth. The wastewater spray cannot go into the ground if the ground is saturated, flooded or frozen. As such, precipitation is an important factor that helps determine whether or not the spray fields are suitable for receiving effluent wastewater spray.

We get saturated ground all the time around here, and this occurs for a variety of reasons, none of which have to do with a so-called 100-year storm. The reasons include a powerful thunderstorm or snow storm, a slow-moving tropical storm, and several heavy precipitation events over a short period. Even an extra-wet month makes the ground susceptible to saturation or significant snow cover. Remember back in 2010? That winter, a series of storms followed an exceptionally wet period in the fall and resulted in standing water here for 2-months or more.

Because of the varying impacts of precipitation on the spray fields, it is important to understand and quantify precipitation variability in all months of the year.

Time series of monthly precipitation totals are shown in pp. A25-A27. All calendar months show considerable variability from one year to the next. For each calendar month the largest monthly totals (p. A28) exceed 7 inches. For July-September the largest monthly totals exceed 12 inches, with peaks of 16.1 inches and 15.5 inches recorded in August 1939 and 1967, respectively.

Monthly precipitation percentiles (p. A29) further quantify the year-to-year variability. The top 15% of monthly totals exceed 5 inches during January, March-June, and November, and exceed 6 inches during July-September. The heaviest rainfall typically occurs in July and August, when top 15% of monthly totals exceed 6.9 inches and 7.8 inches, respectively.

Probability of exceedance thresholds (p. A30) are shown for specified monthly precipitation totals. For all calendar months except February, at least 14% of monthly totals exceed 5 inches. For March and May-September, at least 25% of monthly totals exceed 5 inches. Extreme monthly precipitation totals of ~8+ inches have been seen in all calendar months except February (p. A28), but are most frequent during June-September with the highest frequency occurring in July (8.8 % of years) and August (13% of years). Looking at even wetter periods, precipitation totals have exceeded 10 inches during August in 13% of years, during September in 5.2% of years, and during July in 3.6% of years.

Daily and weekly precipitation totals were also calculated, and the statistics shown are based on days or periods when precipitation was occurring. Daily percentiles (pp. A31), probability of exceedance thresholds (pp. A32-A35), and record high totals (p. A36) are shown, along with weekly percentiles (pp. A37), probability of exceedance thresholds (pp. A38-A41), and record high totals (p. A42)

Extreme daily or weekly precipitation amounts can cause saturated ground, flooding, and snow cover to persist not only during the precipitation event but sometimes even well after. Daily

totals of 1-2 inches or more are seen in all calendar months of the year (pp. A31-A35). Weekly totals above that range are obviously far more common (pp. A37-A41). The calendar months with at least 10% of precipitation days exceeding 1 inch are March and July-November. During August and September, roughly 5% of precipitation days produce at least 2 inches.

Looking at higher amounts, daily precipitation totals have exceeded 3+ inches in most calendar months, although those events are far less common. July-September have the highest percentages (1.5% to 2.2%) of precipitation days with 3+ inches (1.5% to 2.2%), 4+ inches (0.56 to 1.15%), 5+ inches (0.28% to 0.48%), 6+ inches (0.09% to 0.23%).

The record high daily precipitation totals for each calendar month (p. A36) are staggering, especially during July-September when the daily records reach 8.5 inches in July, 7.3 inches in August and 6.3 inches in September. Record high precipitation totals are much lower in winter (2.7 to 3.4 inches), but can produce a massive snow storm if temperatures are cold enough.

Looking further at weekly precipitation totals, one can anticipate that during the warm season 3+ inches spread out over a week will produce some level of ground saturation. However, lesser totals can also be problematic if the ground is already at or near saturation. Lesser totals can also be problematic in winter because 1-2 inches of precipitation can translate into 20-24 inches of snow or perhaps lesser amounts of very heavy and wet snow.

During May-September (pp. A38, A39, weeks that did have precipitation saw totals of 3+ inches at least 10% of the time. Those percentages were highest in July (16%) and August (19.4%). The record high weekly totals exceeded 11 inches in July-September (p. A42).

For winter, weeks that did have precipitation saw totals of 1+ inch at least 30% of the time (pp. A38, A41). Weeks with 2+ inches of precipitation occurred around 7% to 10% of the time. The record high weekly precipitation totals during winter (p. A42) were 4.2 inches (January), 4.4 inches (February), 6.1 inch (March), and 5.0 inches (December).

3.6e. Snowfall

Monthly snowfall totals are shown (p. A43), along with the corresponding ranges (p. A28), percentiles (p. A29) and probabilities for specified thresholds (p. A30). Monthly snowfall totals (p. A43) are highly variable from one winter to the next. Each month from December-March features numerous years with monthly totals exceeding 10 inches (p. A30), and at least a few years with monthly totals exceeding 20 inches. The highest monthly total snowfall (p. A28) reached 38 inches in February, 25 inches in December, 23 inches in March, 20.5 inches in January, and 10 inches in November.

The percentile analysis (p. A29) indicate that during January, 20% (80th percentile) of monthly snowfall totals exceed 9 inches, 15% exceed 11 inches, 10% exceed 15 inches, and 5% exceed 17.1 inches. The totals for these percentiles increase during February, with 20% of years recording at least 10 inches during the month, 15% of years recording at least 12 inches, 10% of years recording at least 13.8 inches, and 5% of years recording at least 22 inches.

These extreme totals are less frequent during December and March, but are by no means less impactful.

Looking at daily snowfall, percentiles (p. A31) are shown, along with probabilities for specified thresholds (pp. A44-A45) and record high amounts (p. A36). About 20% of daily snowfall totals (pp. A31 and A32) are near or above 4 inches in the calendar months of January-March and November-December. About 10% of daily snowfall totals in those months exceed 6 inches, and at least 5% exceed 8 inches. The record high amounts (p. A36) for each month are considerable, reaching 24 and 25 inches in December and February, respectively, and reaching 14 inches and 8.5 inches in January and March, respectively.

The corresponding weekly total snowfall percentiles (p. A37) are shown, along with probabilities for specified thresholds (pp. A46-A47) and record high amounts (p. A42). As with the daily totals, significant weekly snowfall totals are relatively common. About 10% of weekly snowfall totals exceed 8 inches during January-February and November-December, and at least 5% exceed 10 inches (p. A46). The record weekly snowfall amounts (p. A42) for each month are considerable, reaching 23.5 32.5 and 25 inches in January, February, and December, respectively, and 18.6 inches in March.

3.6f. Snow depth

Monthly average snow depths are shown (p. A48), along with the corresponding ranges (p. A28), percentiles (p. A29), and probabilities for specified thresholds (p. A30). Various combinations of conditions can yield the same monthly average snow depth, and thus this parameter is more difficult to interpret. Hypothetically, an average depth of 1 inch can be associated with a very cold month in which there is little snow melt so that snow persists each day of the month. It can also be associated with a more active snowfall pattern in which there are multiple larger snowfall events followed by significant melting between each event.

The larger monthly average snow depths tend to be associated with multiple snowfall events followed by comparatively little melting during the month. Examples are February 2003 and 2010 (p. A48), which had all-time records of 6.8 inches and 6.4 inches of snow depth averaged over the course of the month (p. A28). For the other months, the highest monthly average snow depth (p. A28) reached 3.6 inches in January, 3.1 inches in December, 1.5 inches in March, and 0.4 inches in November.

Although monthly snow depths (p. A48) are highly variable from one winter to the next, there are many instances when values exceed 0.5 inches. The highest frequency of snow depths above this value (at least 30% of years) occur during January and February (pp. A29, A30), when 10% of years have an average snow depth of at least 1.5 inches and 5% of years have an average depth of at least 2 inches. (p. A30). Significant snow depths for the months of December and March are less common. Roughly 14% of years during December having an average snow depth of at least 0.5 inches and 5% of years having an average depth of at least 1 inch. During March, only about 5% of years have an average snow depth of at least 0.5 inches.

Now looking only at daily data for days when there is snow cover, percentiles are shown (p. A31), along with probabilities for specified thresholds (pp. A49-50) and record high amounts (p. A36).

During January-March and November-December, 25% of days with snow cover have a snow depth of at least 4 inches (p. A31). 20% of days have a snow depth of at least 6 inches during January-March and December. 10% of days have a snow depth of at least 9 inches during January-February and at least 7 inches during November-December. 5% of days during January and February have more than a foot of snow.

The record daily snow depths (p. A36) for each calendar month are considerable, reaching 25 inches in February, 18 inches in December, 16 inches in January, 12 inches in March, and 9 inches in November.

The corresponding weekly average snow depth percentiles (p. A37) are shown, along with probabilities for specified thresholds (pp. A51-A52) and record high amounts (p. A42). As with the individual days, significant weekly snow depths occur frequently. In January, February, and December, 25% of weeks with snow cover have an average snow depth of approximately 4 inches (p. A37). Also in January-February, 15% of weeks have an average snow depth of near 6 inches, 10% of weeks have an average depth of at least 7 inches, and 5% of weeks have an average depth of 9+ inches. In December, 15% of weeks have an average snow depth of 4.5 inches, 10% of weeks have an average depth of near 5.4 inches, and 5% of weeks have an average depth of 6.5 inches.

3.6g. Climate patterns and implications

Interannual and multi-decadal variability is seen in the precipitation, temperature and snow depth records for Dover, DE, which is consistent with much of the rest of the country. I will discuss two known causes of that variability, both of which I am a recognized international expert in diagnosing, predicting and analyzing.

A significant source of interannual variability is the El Niño/ Southern Oscillation (aka ENSO, the El Niño/ La Niña cycle, and Pacific warm and cold episodes). An ENSO tutorial, which I wrote many years ago, can be found on NOAA's Climate Prediction Center website⁷.

ENSO is a naturally occurring climate phenomenon centered over the central and eastern Pacific Ocean. El Niño refers to periods (typically 9-12 months) when sea surface temperatures (SSTs) are warmer than average in the equatorial Pacific Ocean, and La Niña refers to 9-12 month periods when SSTs are colder than average. These areas of SST departures are extensive, typically spanning ¼ of the way around the globe.

El Niño and La Niña events recur about every 3-5 years⁸. They typically develop in the late summer or fall, reach peak strength in winter, and then last well into the following spring.

⁷ https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/enso_cycle.shtml

⁸ https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

El Niño and La Niña impact the weather and climate patterns globally. These vast impacts occur because the tropical rainfall/ convection patterns across the equatorial Pacific Ocean are strongly linked to the underlying SSTs. El Niño's warmer SSTs shift/ extend deep tropical convection from the western Pacific/ southeastern Asia to the central and eastern Pacific, while La Niña's cooler SSTs help to confine the deep tropical convection to the western Pacific/ southeastern Asia. Thus, the tropical convection patterns directly linked to El Niño and La Niña span a truly mammoth distance of nearly 1/2 of the way around the globe. In turn, these anomalous tropical convection patterns affect global wind and storm patterns over much of the globe, including the monsoons, hurricane frequency and intensity, and the jet stream.

For our area, one main ENSO impact is rainfall related to anomalous Atlantic hurricane activity. El Niño suppresses Atlantic hurricane activity during the peak months (August-October) of the season, and La Niña enhances it. While our area has never had a direct hurricane hit, it has been impacted by hurricanes that have remained offshore. These systems are less likely during El Niño. We have also had close hurricane calls, such as Hurricane Sandy which missed us but devastated the eastern coastline northward of Cape May. Our area has also been struck by a number of tropical storms that have recently lost their hurricane intensity. A slow-moving tropical storm can cause tremendous damage and flooding.

Another main ENSO impact to our area occurs in winter, when it affects the jet stream, winter storms, temperature, and precipitation across the Pacific basin and North America (pg. A53).

Composite wintertime temperature, precipitation and snowfall over the continental U.S. during El Niño and La Niña are shown on p. A54)⁹. For the mid-Atlantic region of the U.S, El Niño typically brings cooler and wetter conditions during winter, along with more snow. Conversely, La Niña typically brings drier conditions and less snow.

Another important naturally-occurring climate pattern that affects our area during winter is called the North Atlantic Oscillation (NAO). The NAO reflects recurring jet stream patterns, and extends from the central U.S. to Europe (p. A55). The two phases of the NAO are called the positive phase and the negative phase. The phases and amplitude of the NAO pattern are measured by the NAO index (p. A56¹⁰). The amplitude and phase of the NAO can vary daily, weekly, monthly, and yearly, as well as on both decadal, and multi-decadal time scales. Especially prominent is the prevalence of the negative NAO phase during 1950-1980 and the positive phase during 1990-2021. Implications of this multi-decadal variability on wintertime conditions recorded at Dover, DE are discussed further down (pp. 61-66).

The wintertime NAO affects temperatures¹¹ on continental scales, as seen during an extreme positive and negative phase (p. A57¹²), along with winds, and precipitation¹³. My own calculations show a more regional, composite view of the temperature and wind patterns

⁹ <https://www.cpc.ncep.noaa.gov/products/precip/CWlink/ENSO/composites/>

¹⁰ I developed the NAO index nearly 30 years ago and it is still in use at the NOAA Climate Prediction Center

¹¹ <https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.loading.shtml>

¹² <https://www.climate.gov/news-features/understanding-climate/climate-variability-north-atlantic-oscillation>

¹³ https://www.cpc.ncep.noaa.gov/data/teledoc/nao_pmap.shtml

associated with opposing phases of the wintertime NAO (p. A58). To highlight the stronger events, the amplitude of the NAO must have reached at least \pm standard deviation to be included in these calculations.

For the positive phase of the wintertime NAO, the southeastern U.S. is warmer than average and the Midwest and northeast are cooler than average. The mid-Atlantic region is right on the border between and above- and below- average. However, for the negative phase of the wintertime NAO, the entire central and eastern U.S. is cooler than average due to an anomalous northerly flow from Canada.

In some years, we see a strong NAO pattern while an El Niño or La Niña is also taking place. The result (pp. A59-60) is a significant modulation of the composite patterns shown above.

The combination of El Niño and the negative NAO reinforce each other, while the combination of La Niña and the negative NAO tend to offset each other (p. A59). As such, the temperature anomalies seen with the combination of El Niño and the negative NAO are much colder across the U.S., including the mid-Atlantic region, compared to the combination of El Niño and the positive NAO.

The combination of La Niña and the positive NAO produces above-average temperatures in large portions of the U.S., with slightly above temperatures in the mid-Atlantic region (p. A60). In contrast, much of the country including the mid-Atlantic region is anomalously cold when La Niña and the negative NAO are present.

The differences in wintertime conditions recorded at Dover, DE due to the multi-decadal variability of the NAO are shown in pp. 61-66. Here, we are comparing the 1950-1980 period mean (corresponding to the negative NAO) with the 1990-2021 period mean (corresponding to the positive NAO).

Looking at the difference in monthly averaged temperatures between the two periods (p. 61, bottom), it is seen that the wintertime minimum, maximum and mean temperatures at Dover were all warmer during 1990-2021. During December-February, monthly minimum temperatures averaged 2.5°F+ warmer than during the period, maximum temperatures averaged 1°F -2°F warmer, and mean temperatures averaged 1.7°F to 2.6°F warmer. These warmer temperatures during 1990-2021 were associated with a decreased number of days (pp. A62-63) and weeks (pp. A64-A65) with mean temperatures below freezing.

Compared to 1950-1980, December 1990-2021 saw an almost 10% decrease in the number of days and weeks with mean temperatures below freezing. It also saw a 10% increase in the number of days with mean temperatures above 40°F and a 13% increase in the number of weeks with mean temperatures above 40°F. Similarly, January and February saw a 6-8% decrease in the number of days with mean temperatures below freezing, and also had a corresponding increase in the number of days with mean temperatures above 40°F. Hence there was less ground freeze compared to the 1950-1980 period.

The increase in minimum and mean temperatures during 1990-2021 was accompanied by increased precipitation (especially during March) (p. A66) and decreased in snowfall. On average, March recorded 2 inches less snowfall during 1990-2021, January and February recorded about 1 inch less snowfall, November and December recorded about ½ inch less snowfall. Therefore, over a 31-year period, March 1981-2021 had about 65 inches (5 ½ feet) less snow than March 1950-1980. February saw a total decrease in snowfall of about 3 feet and January saw a decrease of about 2 feet.

Given this multi-decadal variability, it is reasonable to expect that the atmosphere will at some point shift back into another decades-long negative NAO pattern. The increased number of freezing days and snowfall during winter and early spring would likely result in an increased number of days when the IBRWF spray fields are frozen and when they are frozen farther into the ground.

February 2010 provides a recent and extreme example of what to expect with a strong negative NAO pattern. The winter of 2009-2010 had one of the strongest negative NAO patterns in the record (pp. A56-A57), and it also had a strong El Niño. These reinforcing factors produced month-after-month of very heavy precipitation and snow in Dover, DE. During November 2009-March 2010, Dover recorded a liquid precipitation total of 23 inches (50% above average), and 5 ½ feet of snowfall (4 times higher than average). February 2010 had an average daily snow depth of 6 ½ inches, which was over 11 times the average. We saw similar conditions in Millsboro. Clearly the IBRWF spray fields were impacted. To compound matters, this period was immediately preceded by 22 inches of rain during August-October 2009. The result was months of widespread flooding during winter and spring 2010, and an even longer period of saturated soils. I still vividly recall that period.

Unfortunately, the proposed IBRWF permit provides no realistic guidance for spraying effluent wastewater in these types of conditions which last months, just as it provided no realistic guidance for when there are no crops planted for months at a time. There is no alternative to non-permitted spraying. That is an unacceptable failure.

3.6h. Summary

I have provided a very detailed set of analyses designed to promote understanding of the types of weather conditions that would force non-permitted spraying at the IBRWF. The data suggests that the effluent wastewater spray fields at the IBRWF can be regularly compromised by excessive rainfall, excessive snowfall, and/or freezing temperatures.

History has shown that these conditions occur on many different time scales. They can be especially problematic at longer time scales (such as weeks or months), as we recently saw in 2010. Given the multiple ways and multiple time scales that the spray fields can be impacted, any suggestion that the spray fields can handle a 10-year storm or event appears to have limited merit.

Appendix A

Dover, DE Meteorological Analysis

Dr. Gerry Bell, Meteorologist

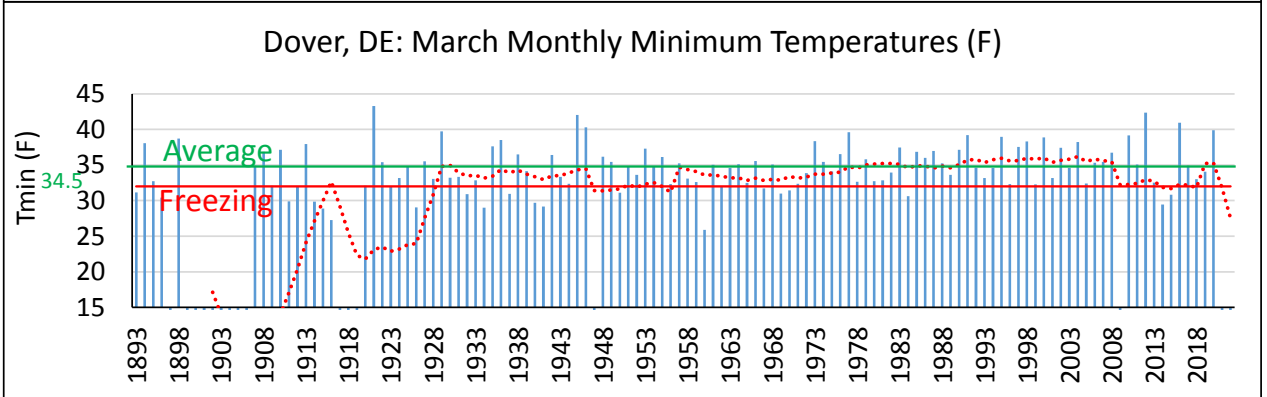
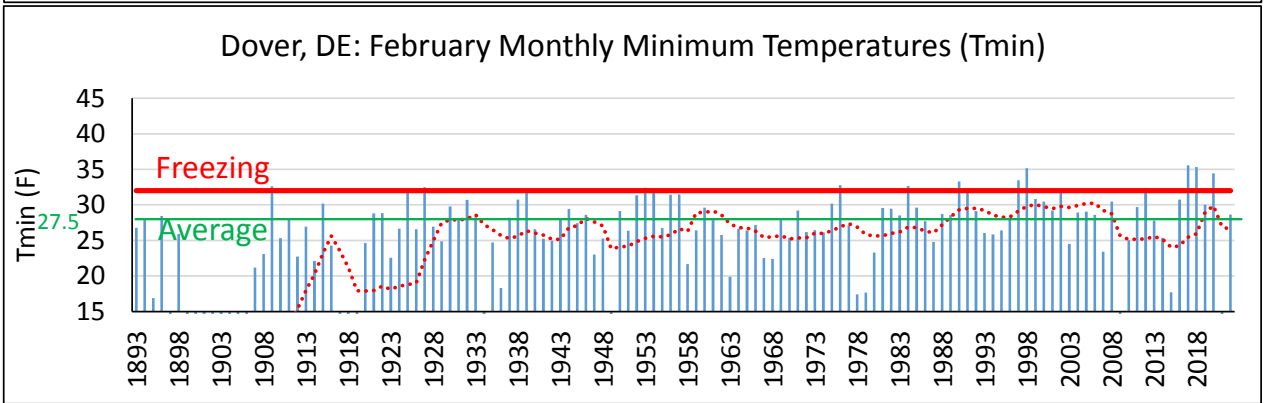
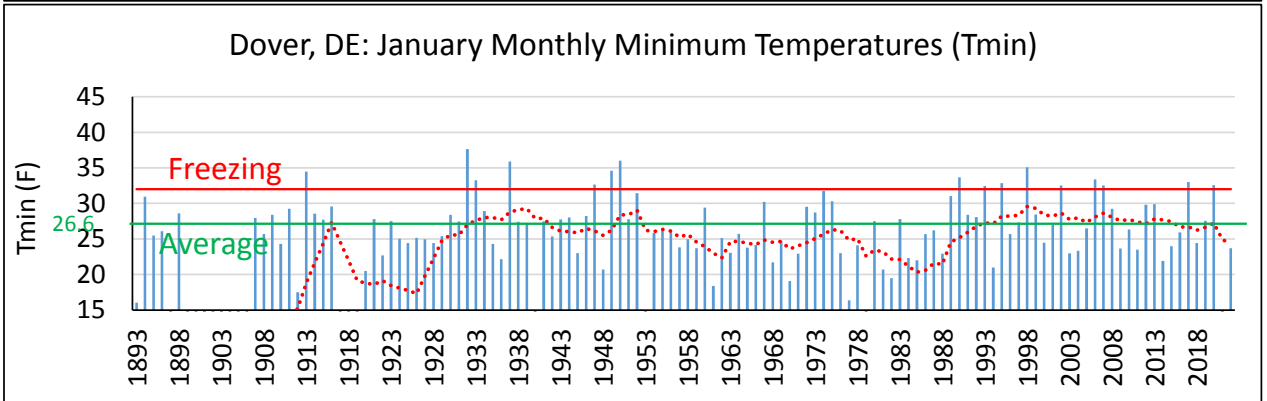
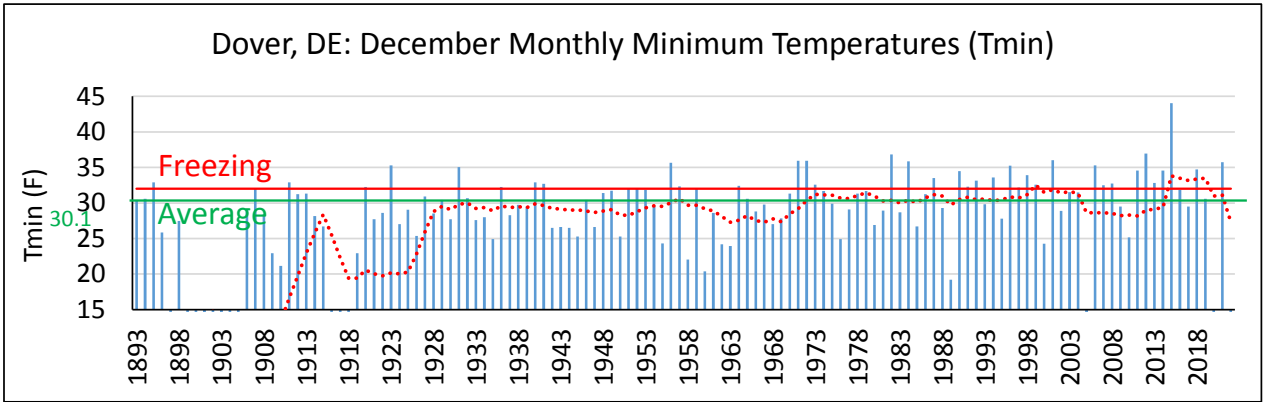
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Monthly Mean Temperatures		A5
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Thresholds for 7-Day Mean Temperatures		
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Appendix A (Cont.)

Dover, DE Meteorological Analysis

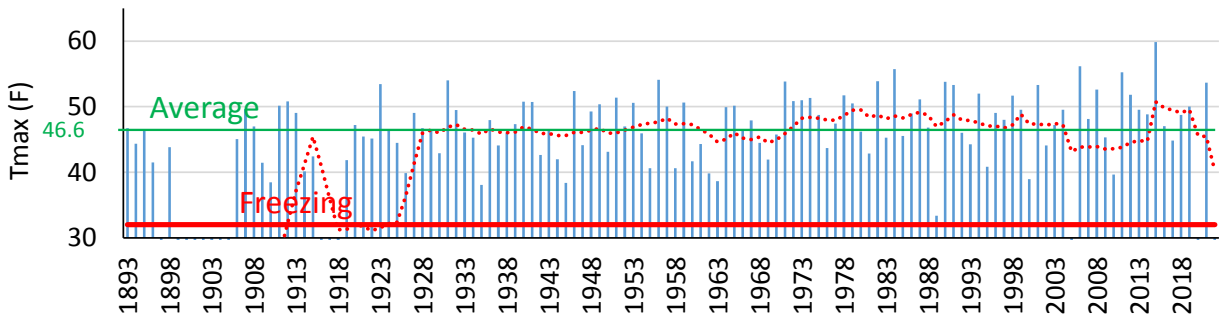
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Thresholds of Weekly Freezing/Non-Freezing Temperatures	A65
Monthly Precipitation, Snowfall, Average Snow Depth	A66

Time Series of Monthly Minimum Temperatures During December-March

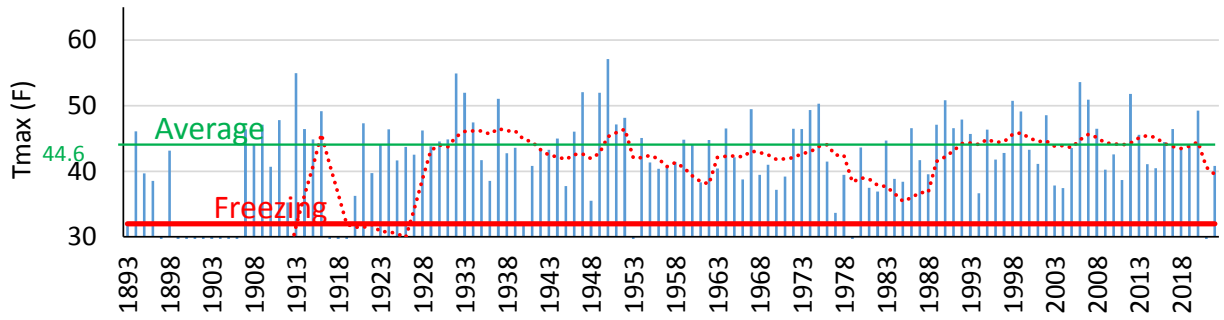


Time Series of Monthly Maximum Temperatures During December-March

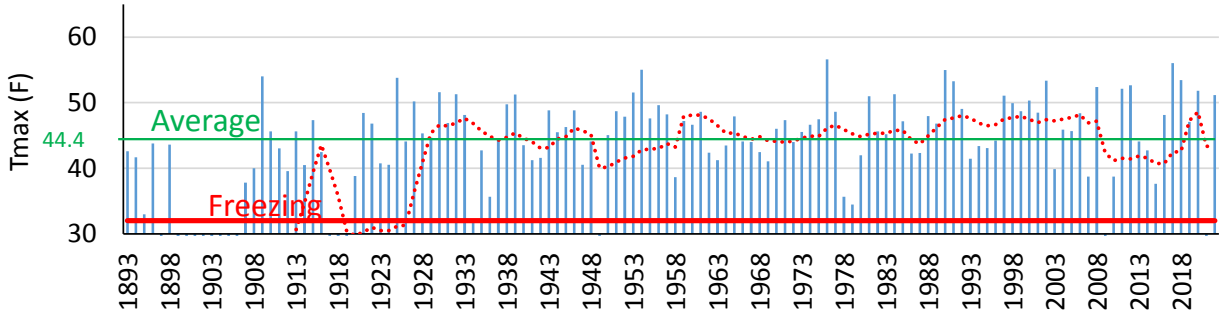
Dover, DE: December Monthly Maximum Temperatures (Tmax)



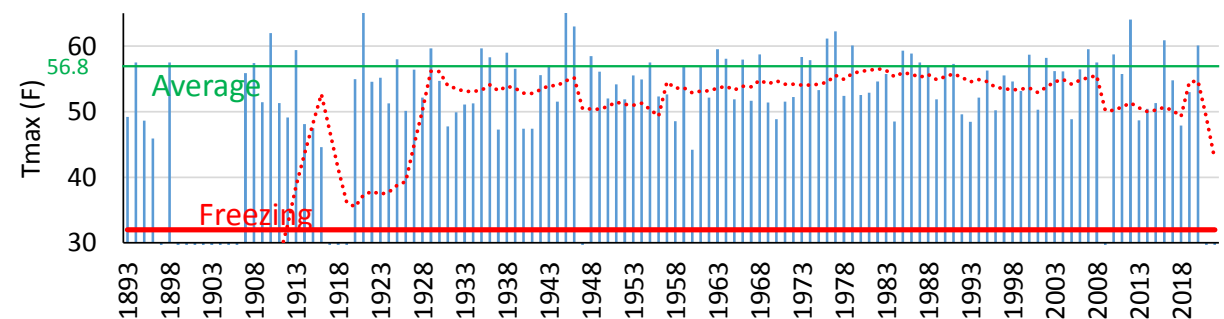
Dover, DE: January Monthly Maximum Temperatures (Tmax)



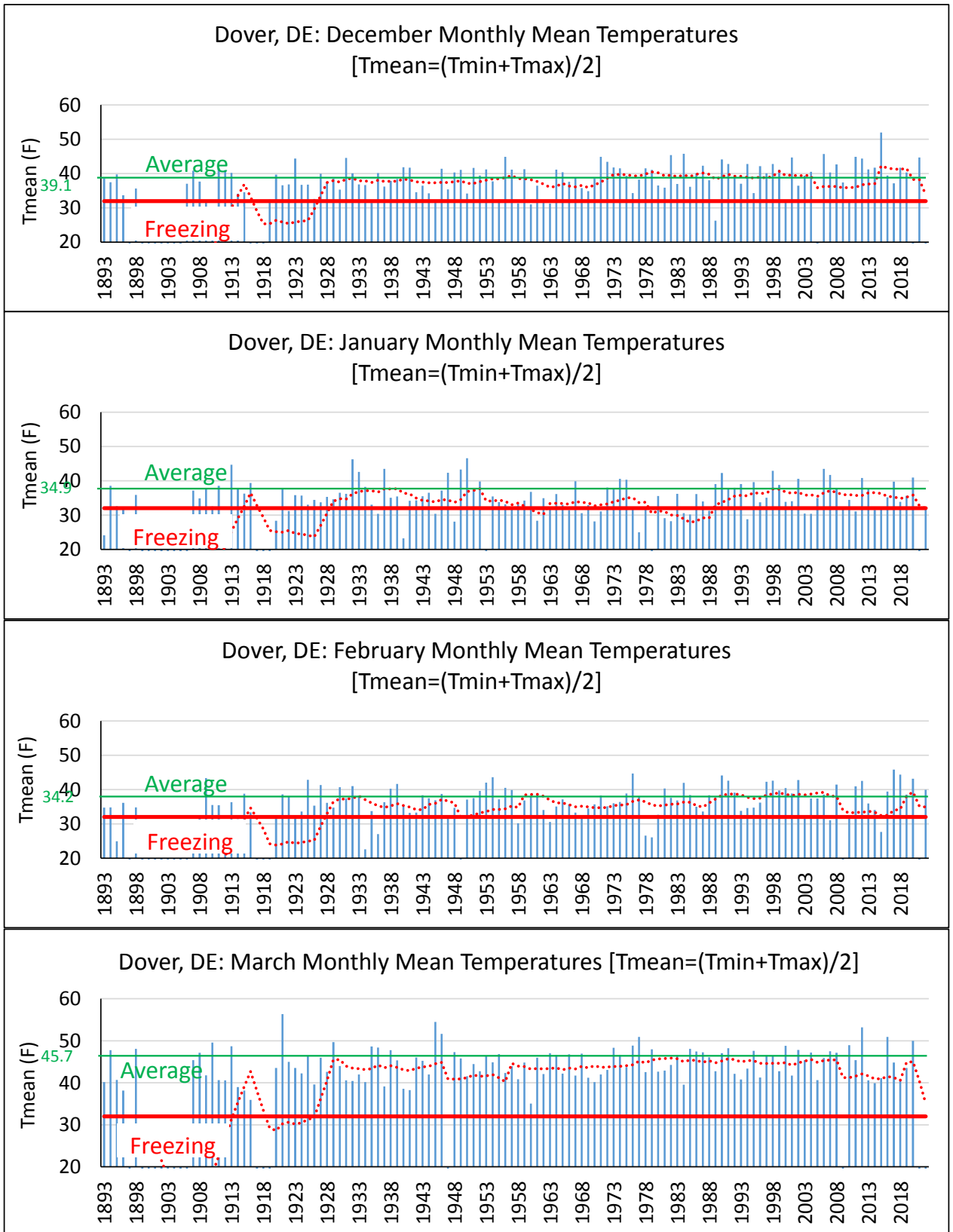
Dover, DE: February Monthly Maximum Temperatures (Tmax)



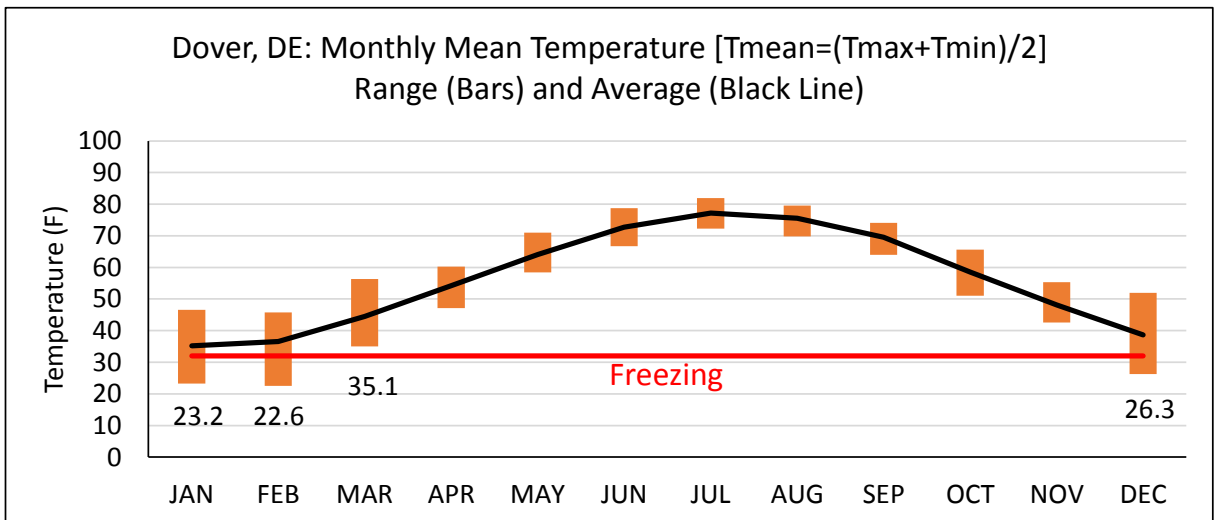
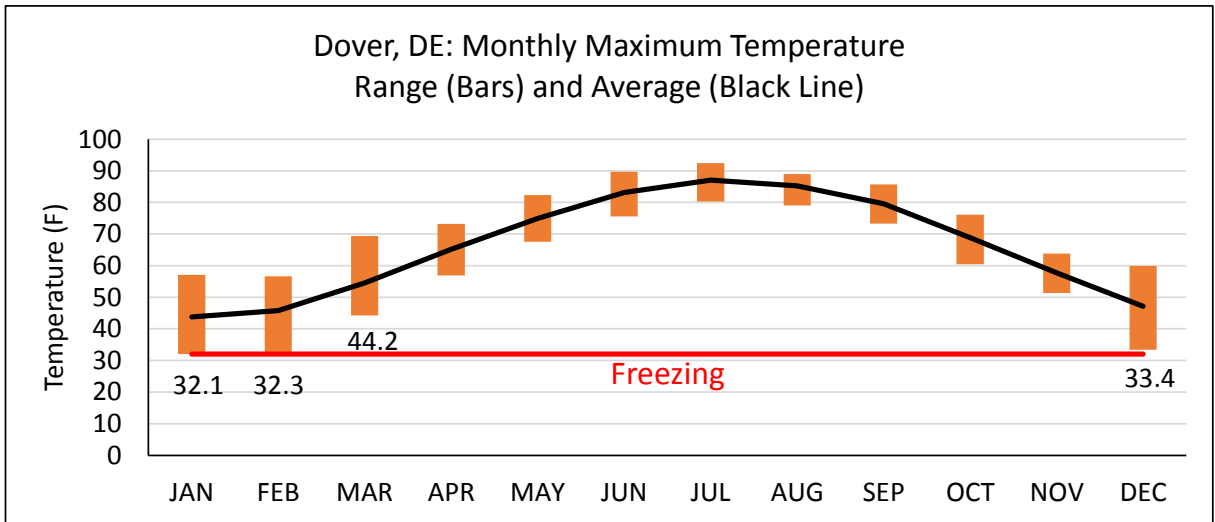
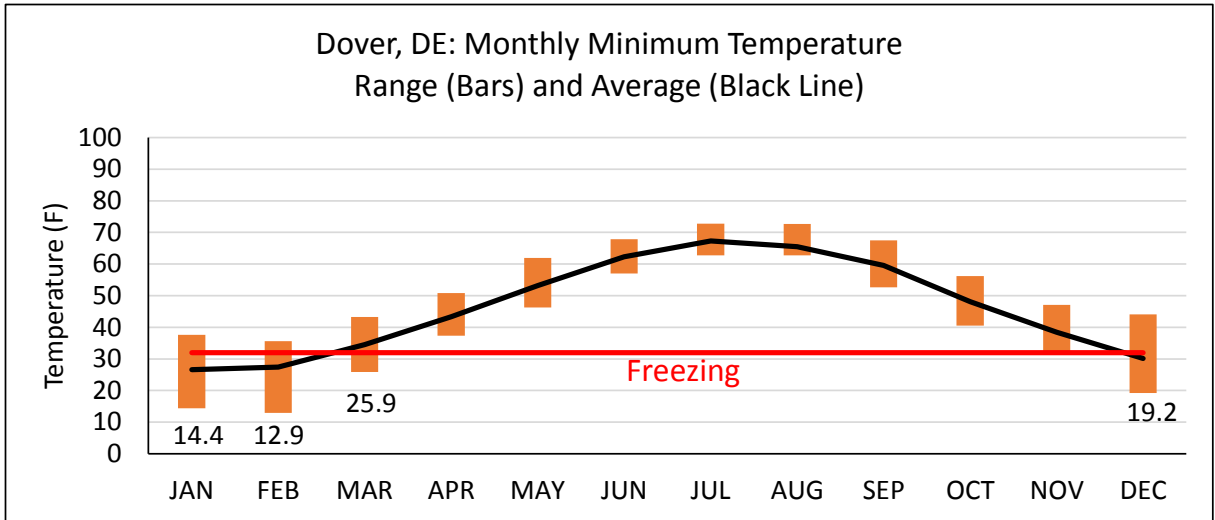
Dover, DE: March Monthly Maximum Temperatures (Tmax)



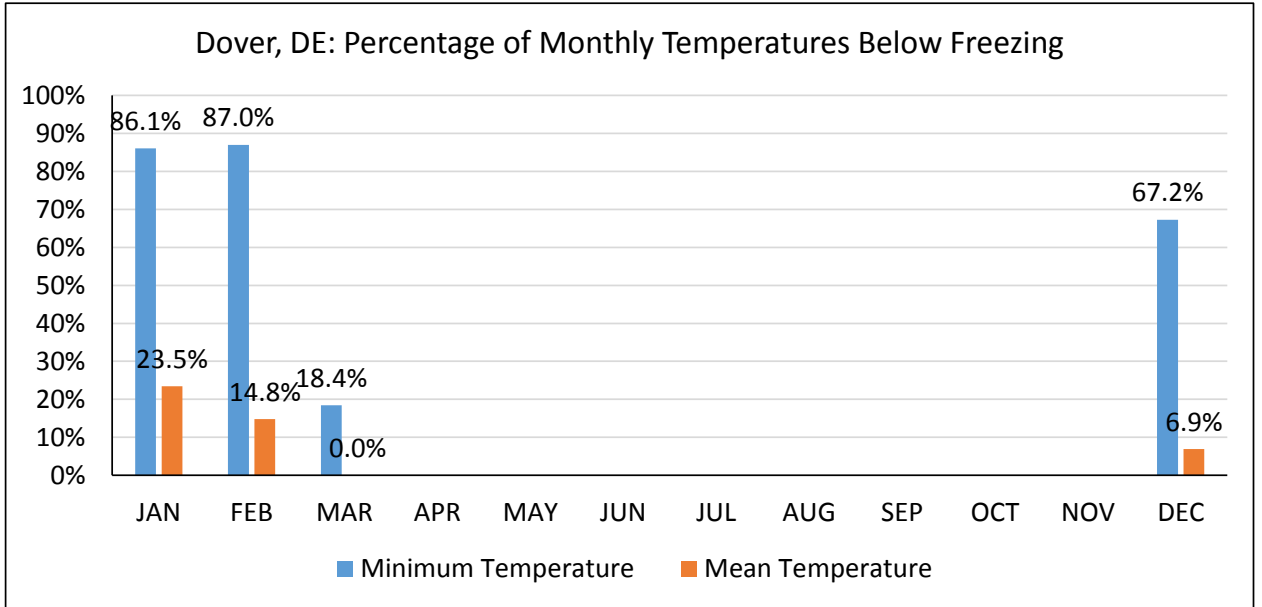
Time Series of Monthly Mean Temperatures During December-March



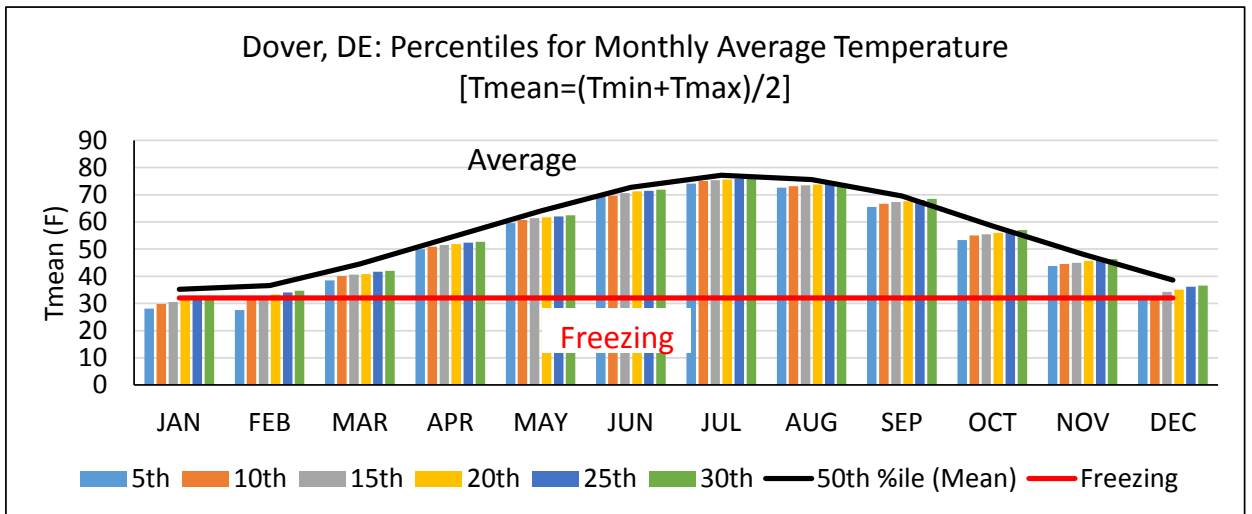
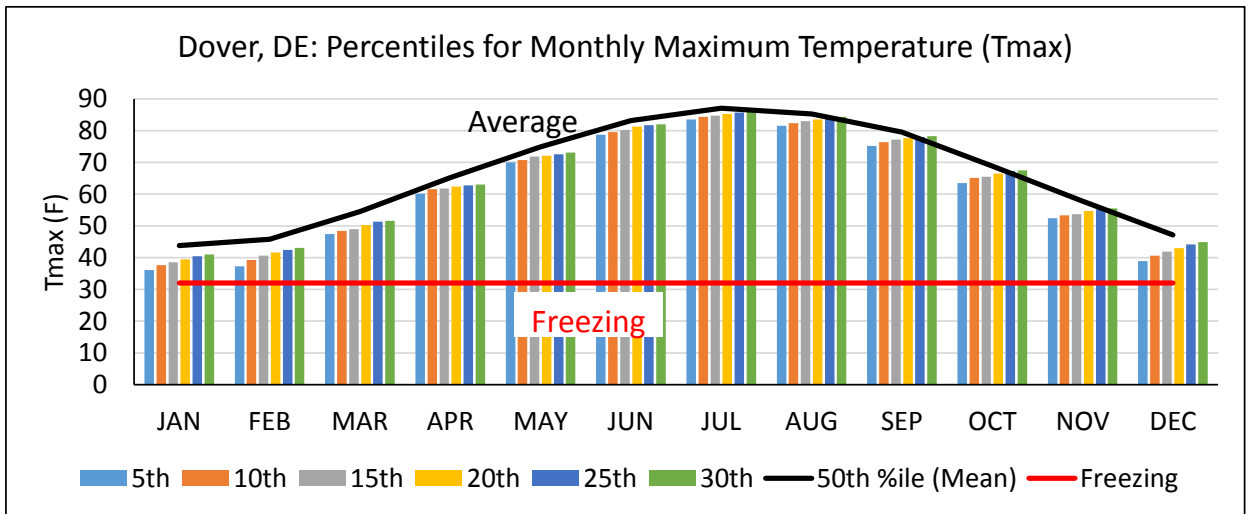
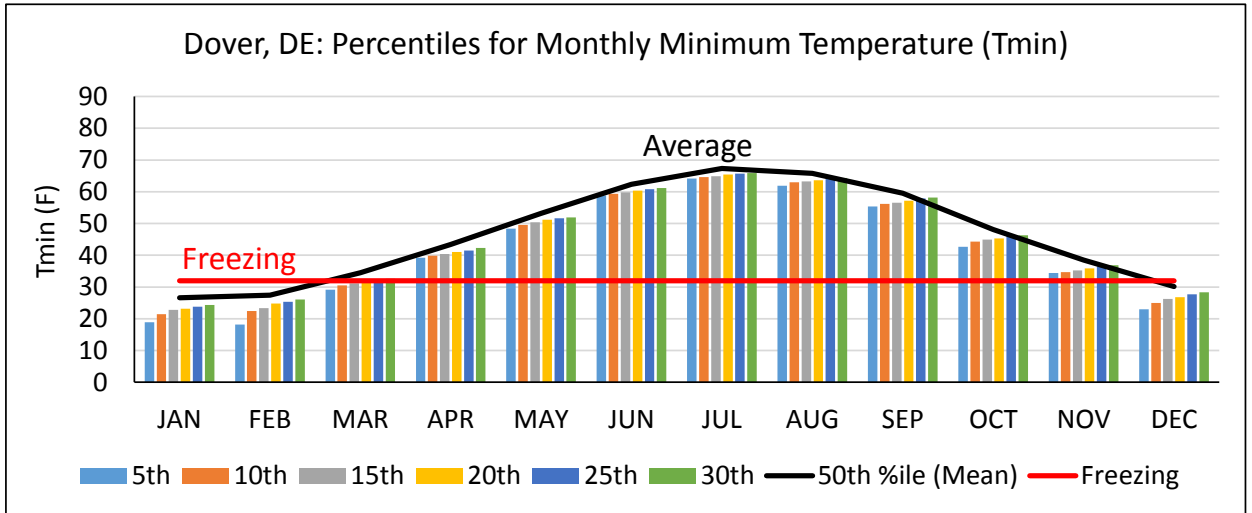
Monthly Temperature Ranges



Percent of Monthly Temperatures Below Freezing

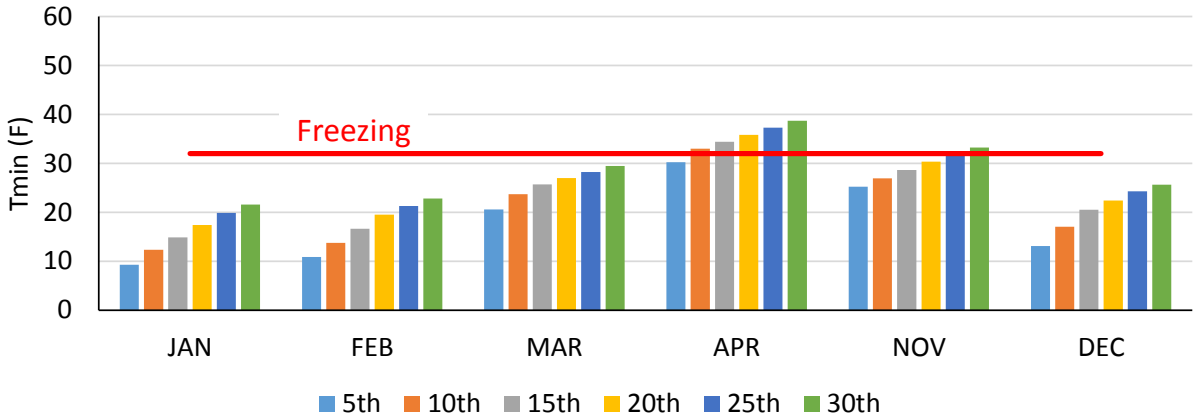


Percentiles of Monthly Temperatures

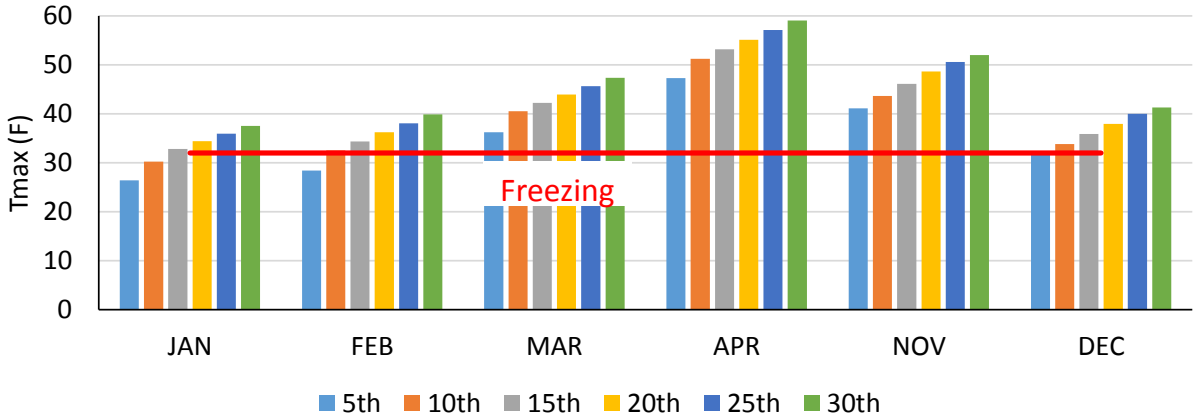


Percentiles of Daily Temperatures

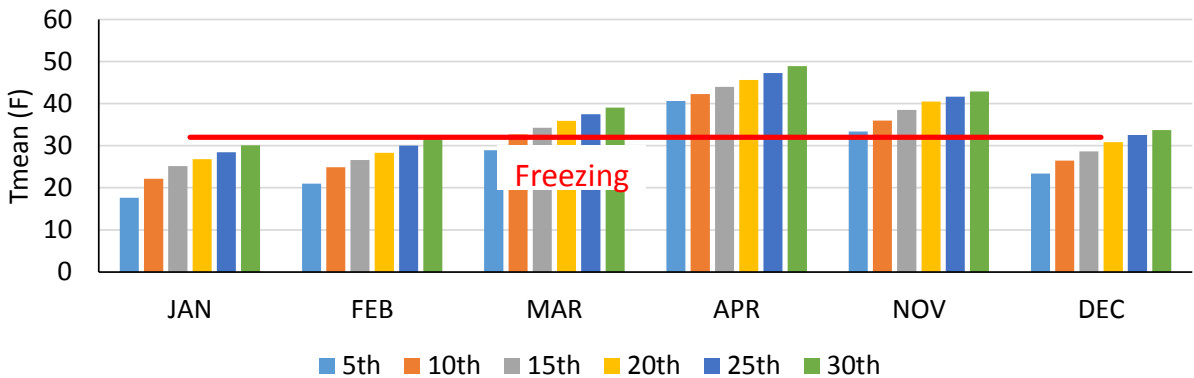
Dover, DE: Daily Minimum Temperature (Tmin) Percentiles



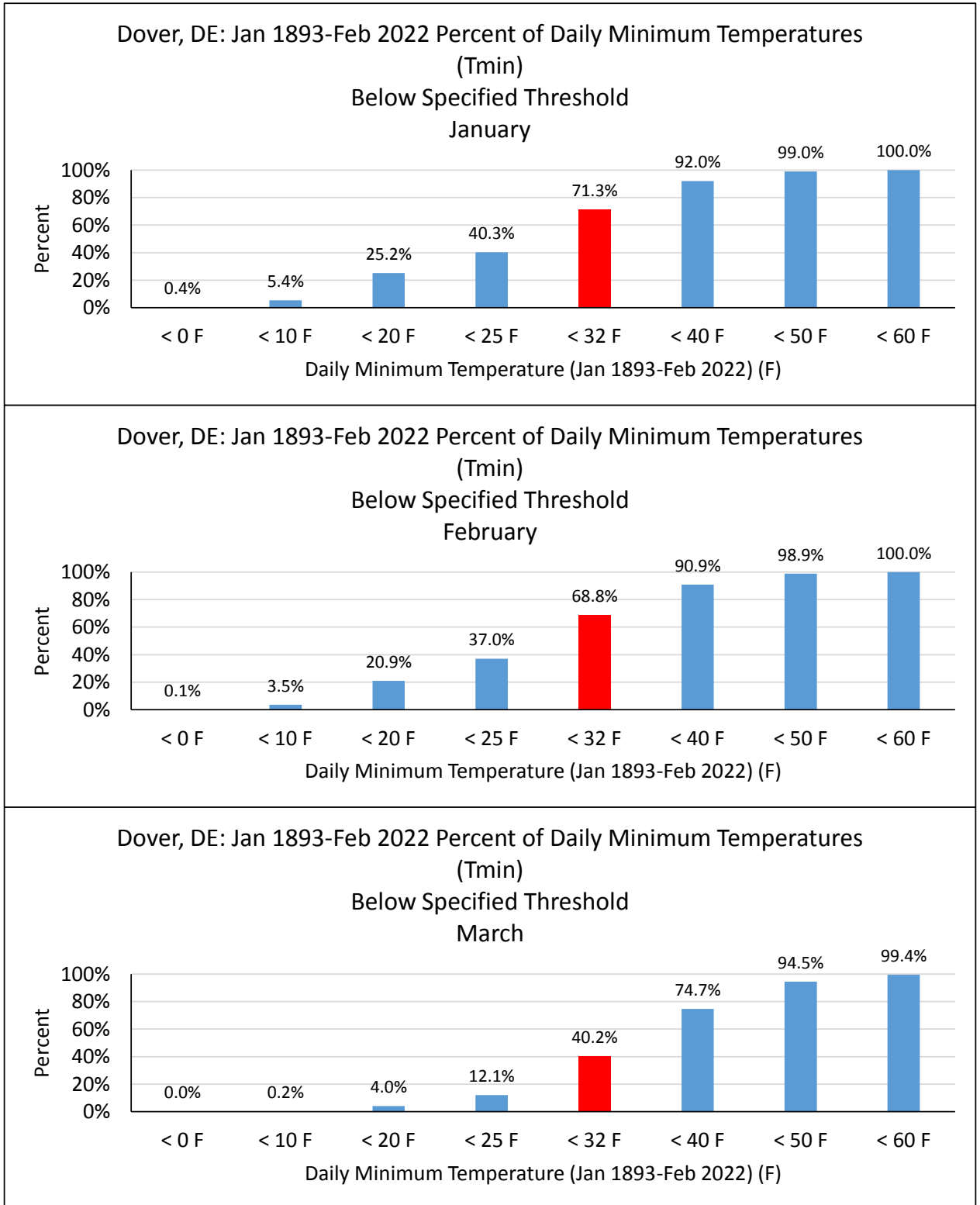
Dover, DE: Daily Maximum Temperature (Tmax) Percentiles



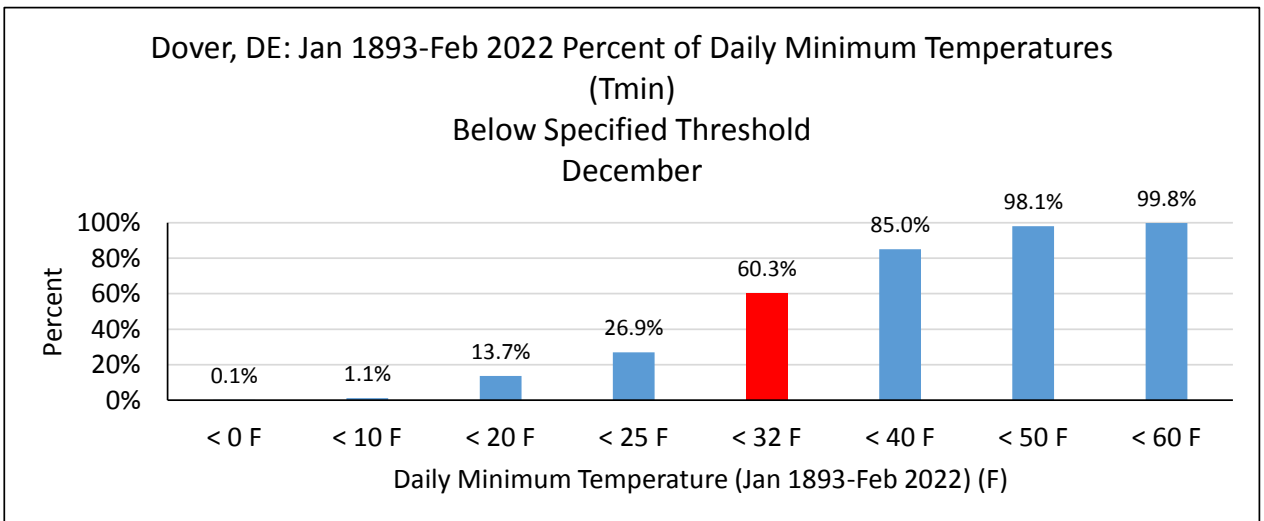
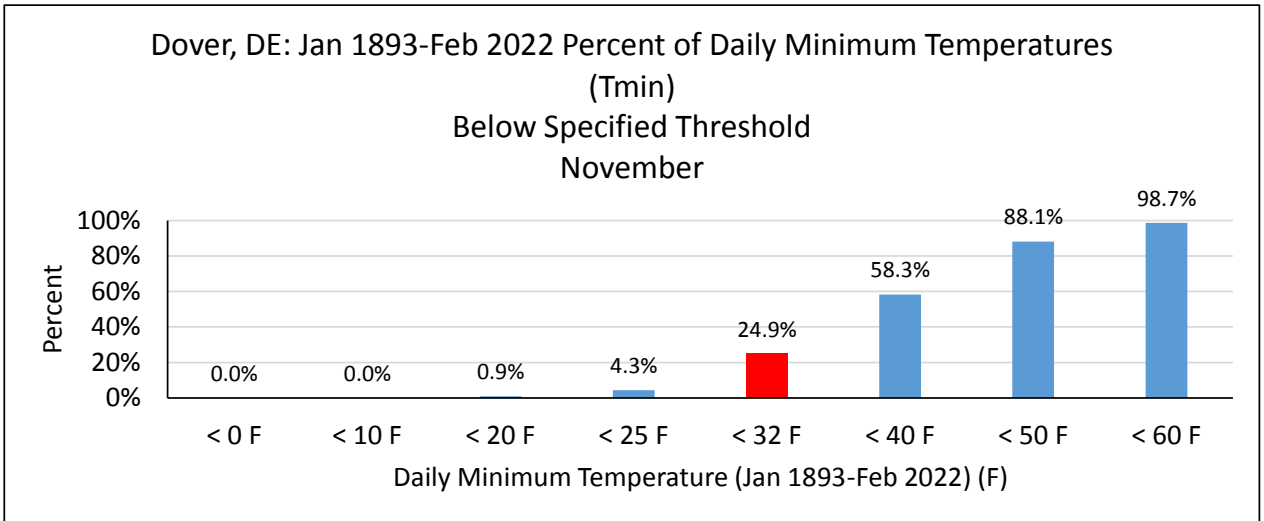
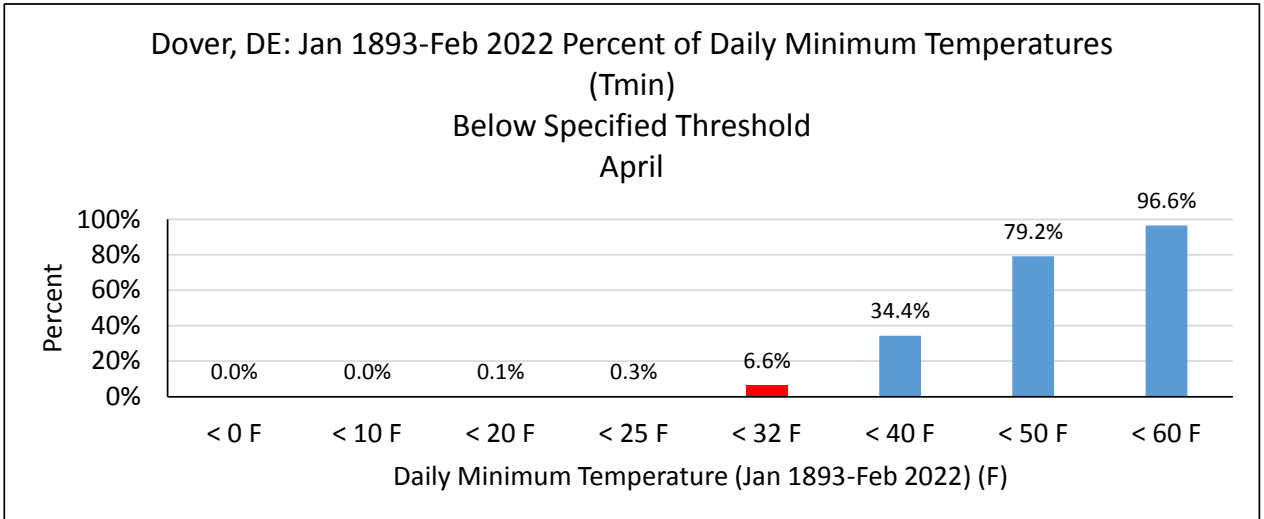
Dover, DE: Daily Mean Temperature (Tmean) Percentiles: [Tmean=(Tmax+Tmin)/2]



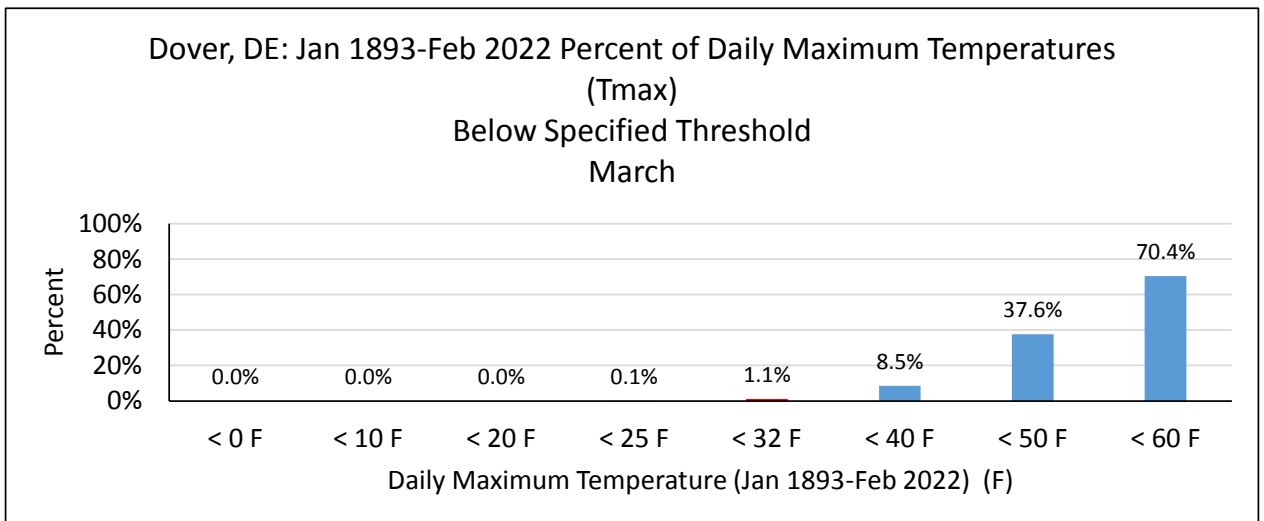
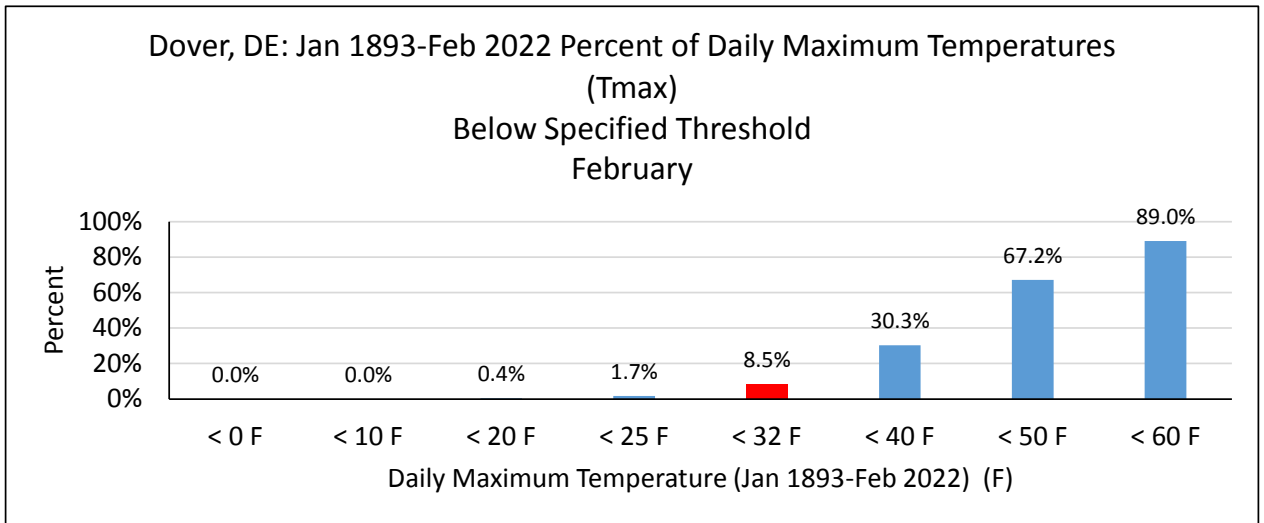
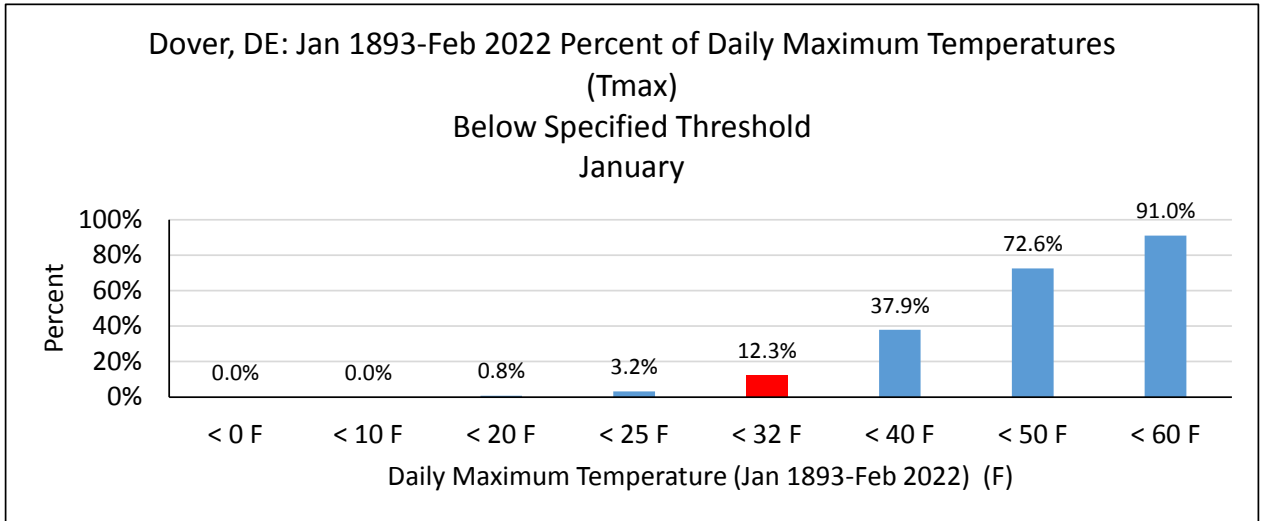
Thresholds for Daily Minimum Temperatures: January-March



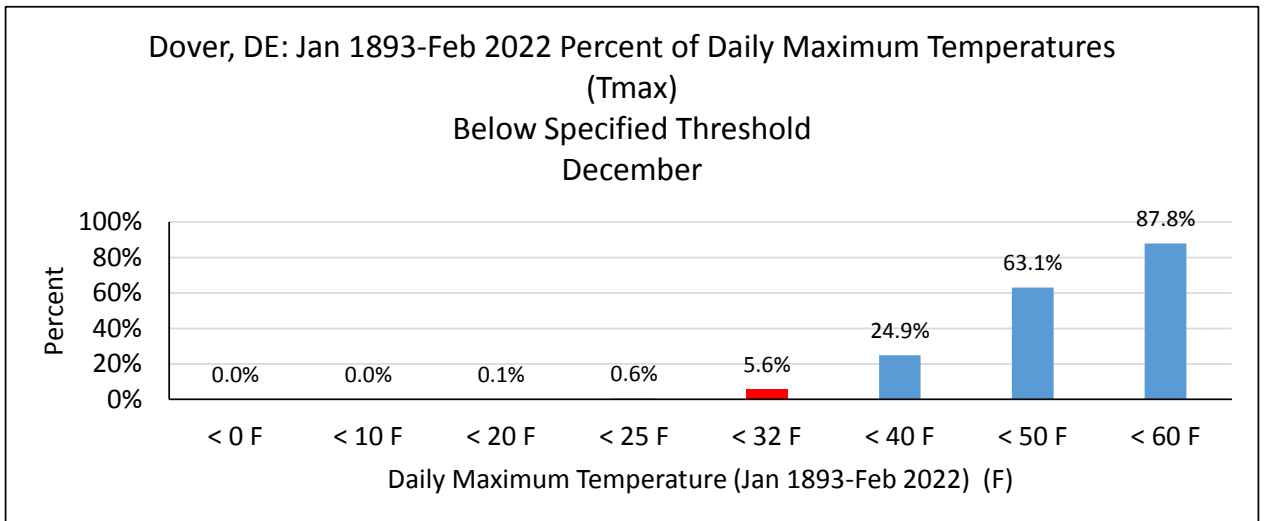
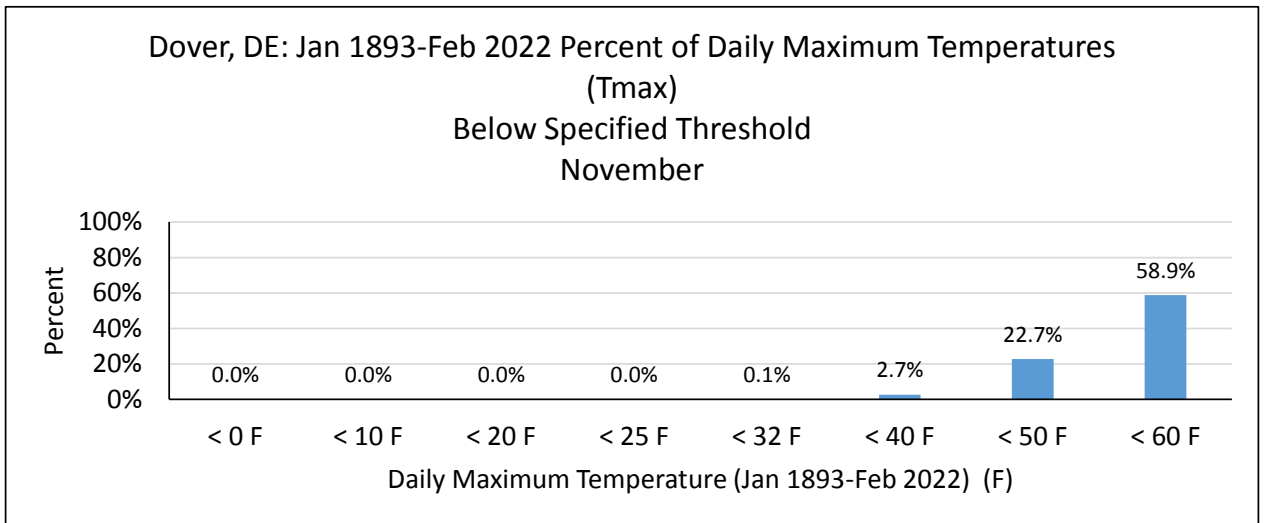
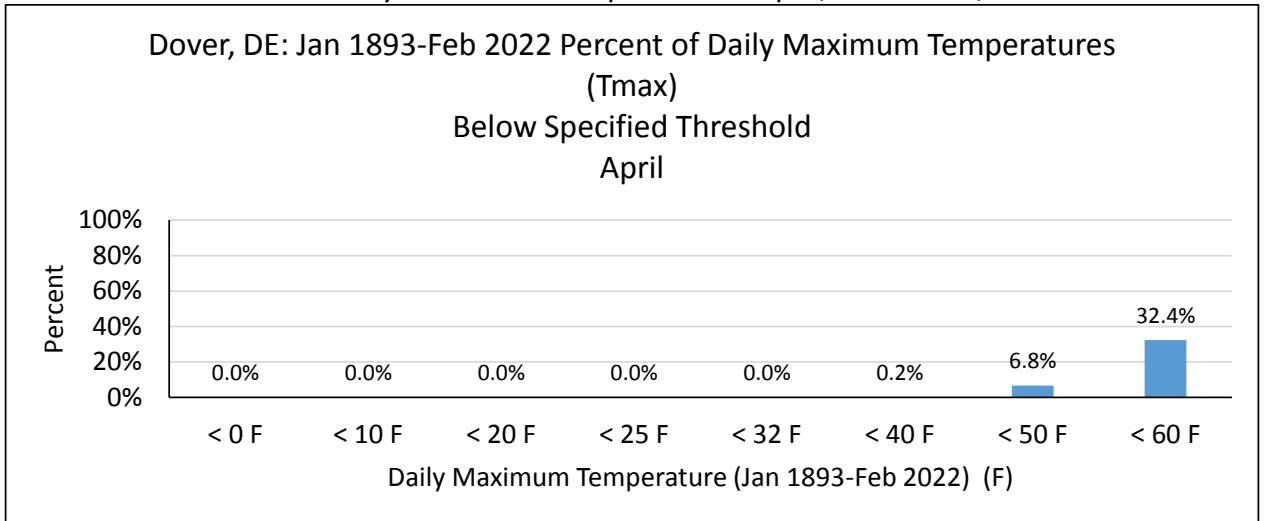
Thresholds for Daily Minimum Temperatures: April, November, December



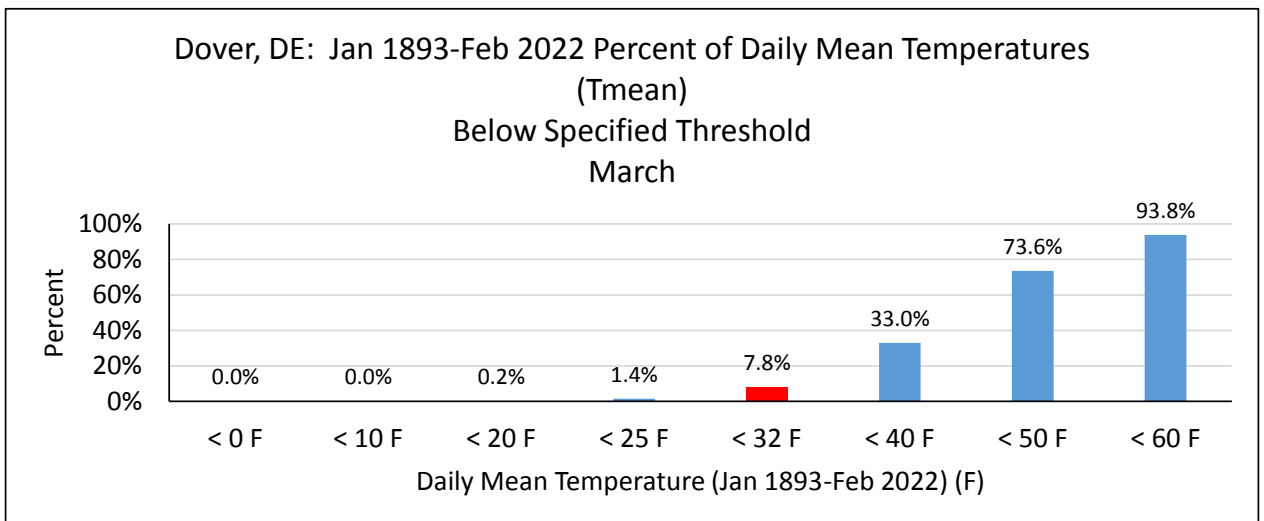
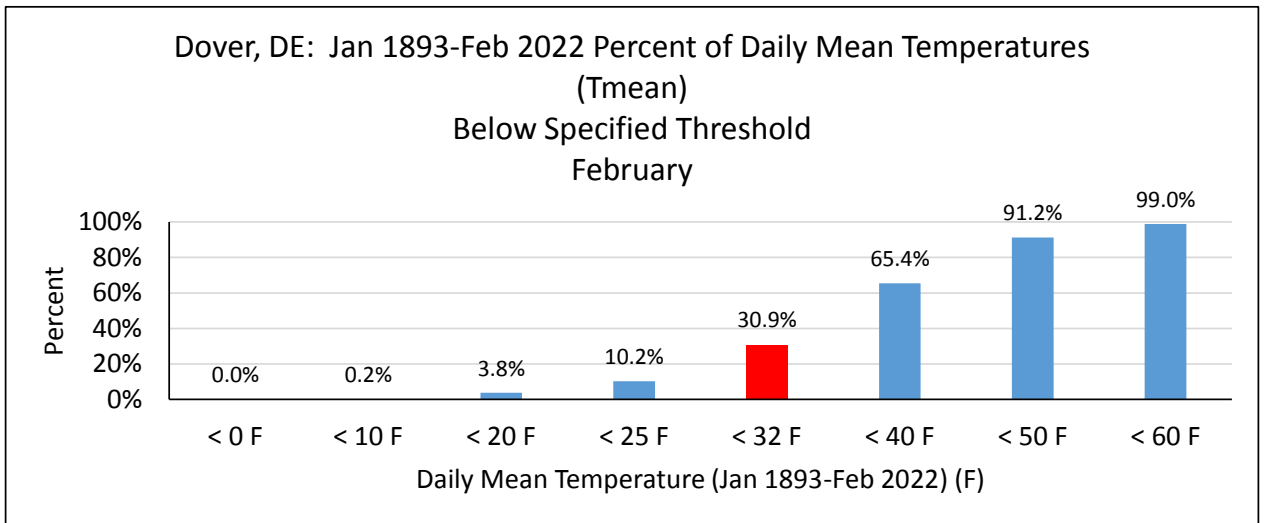
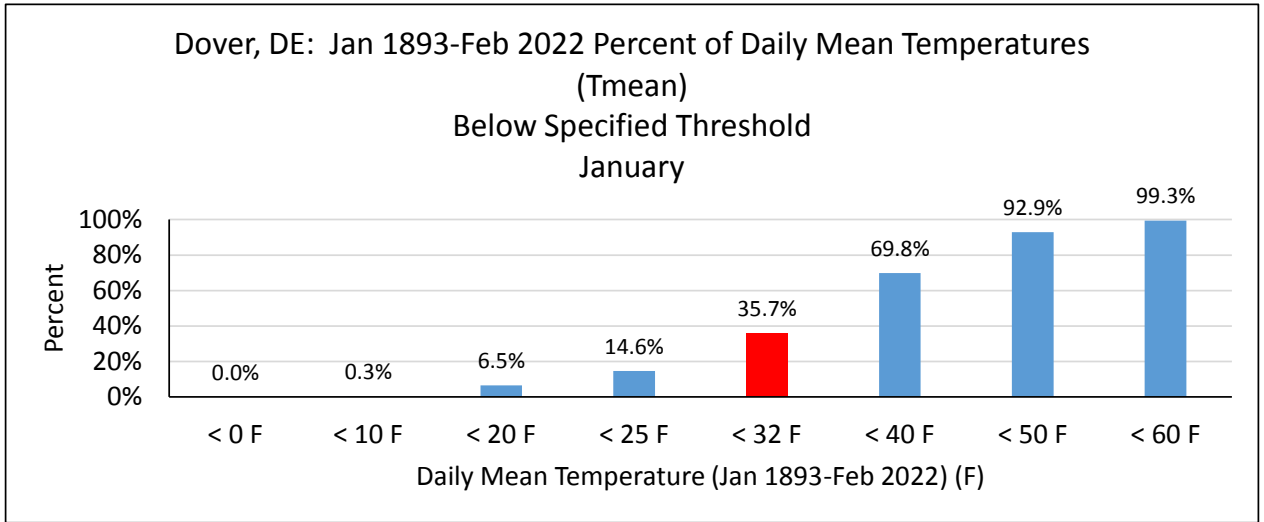
Thresholds for Daily Maximum Temperatures: January-March



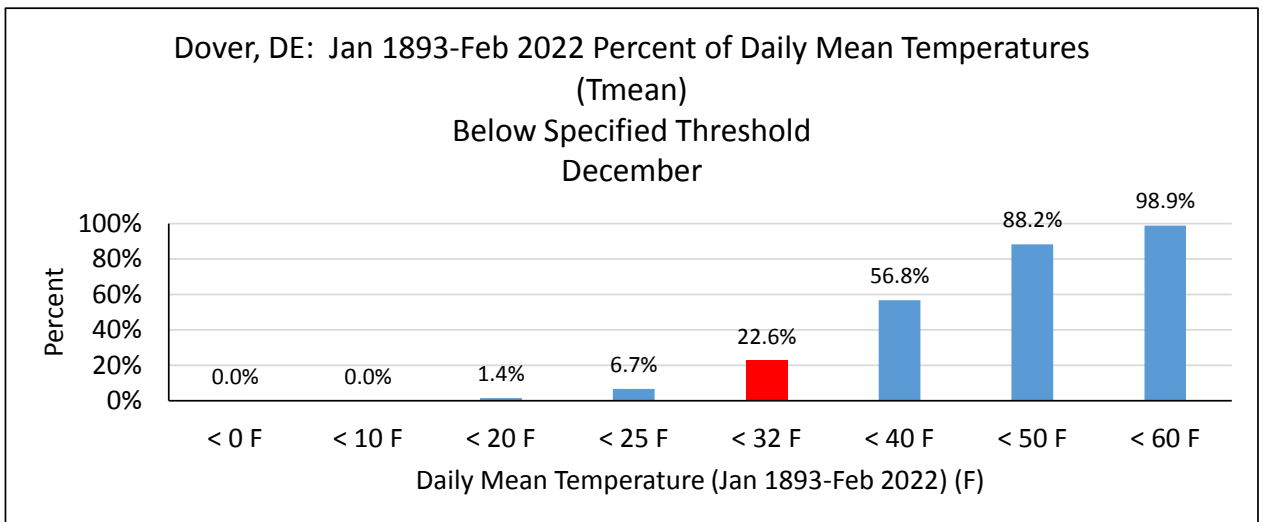
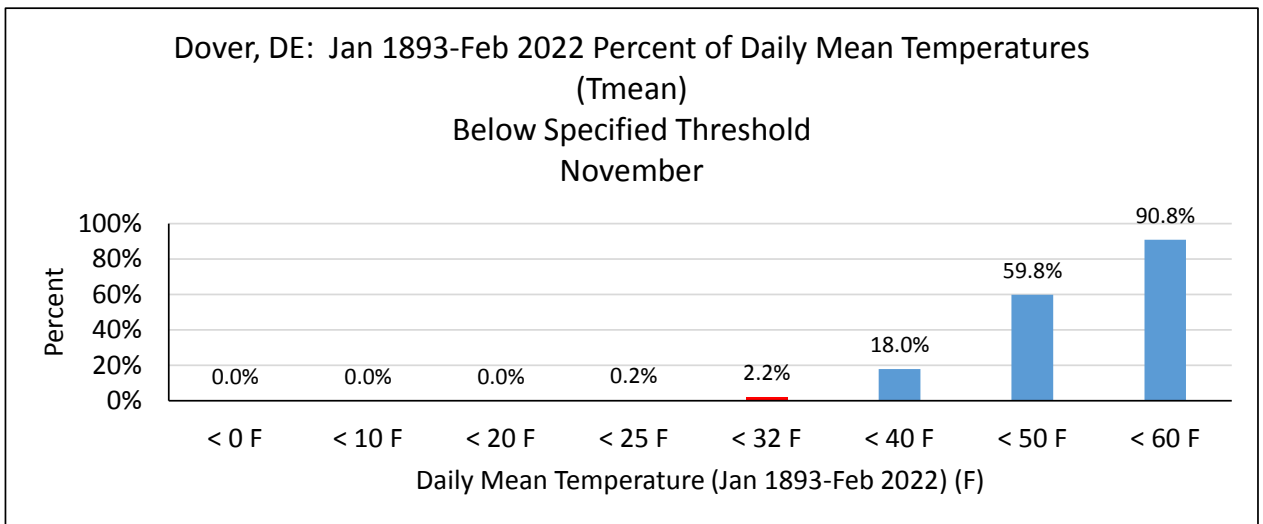
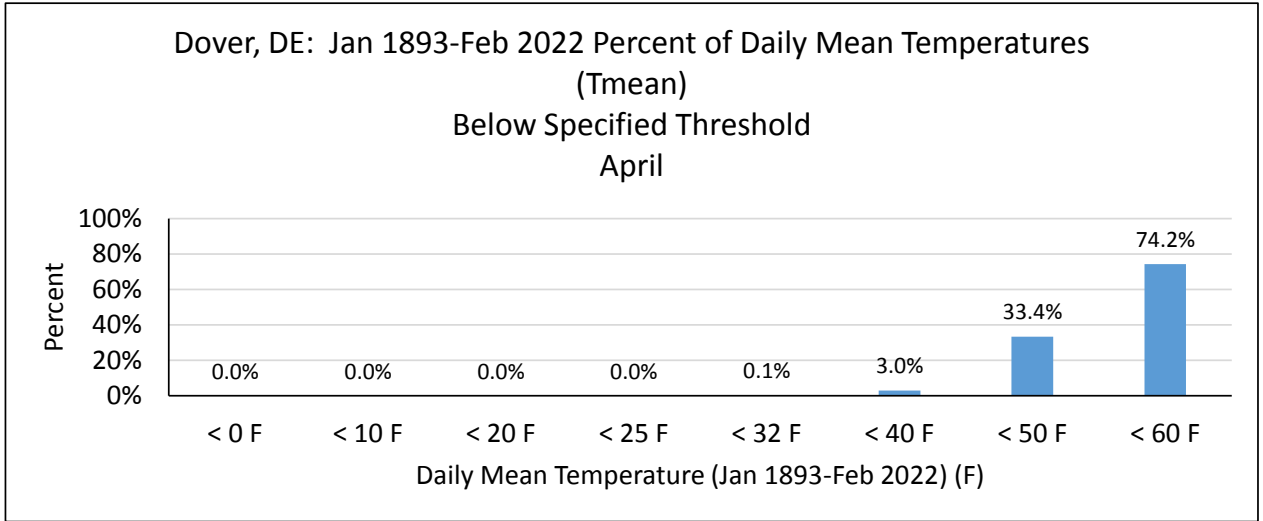
Thresholds for Daily Maximum Temperatures: April, November, December



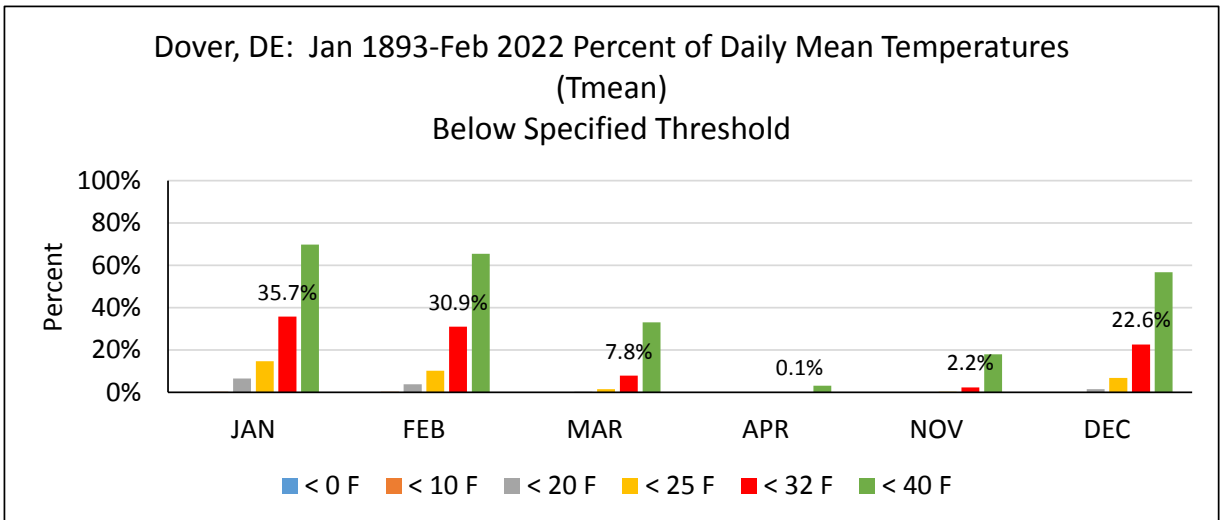
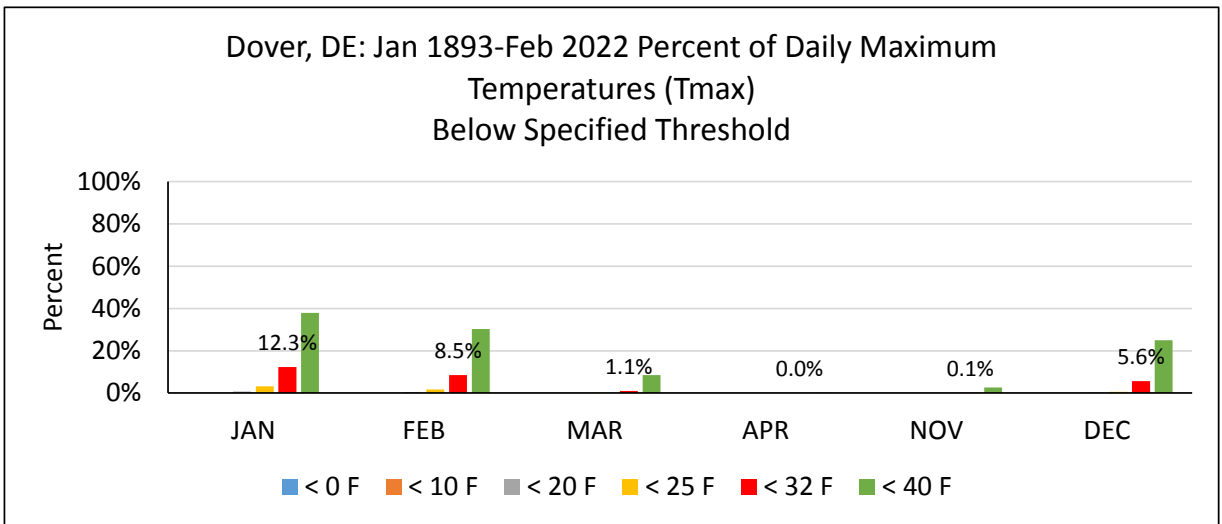
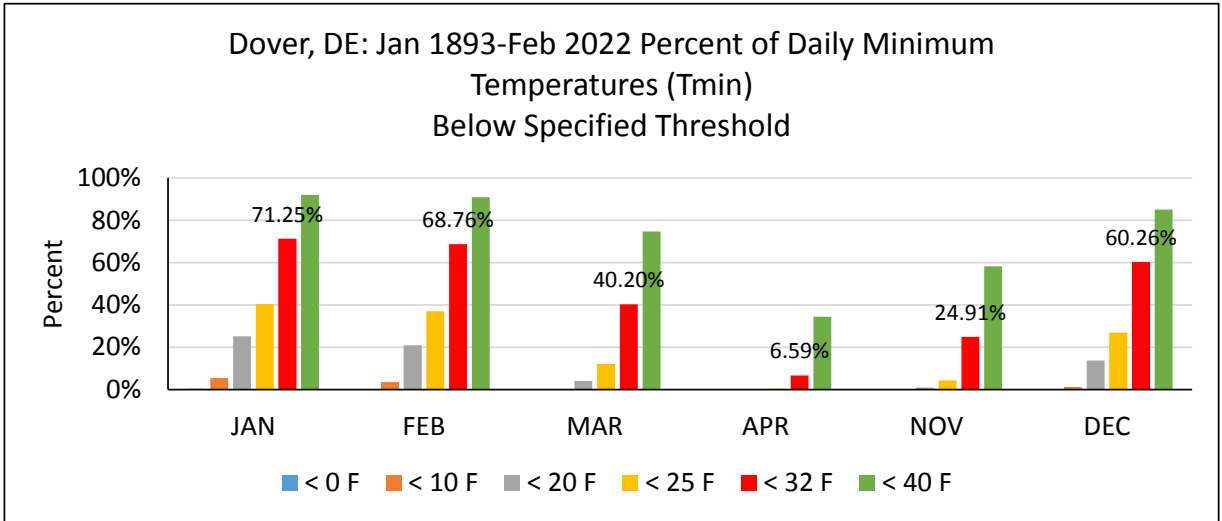
Thresholds for Daily Mean Temperatures: January-March



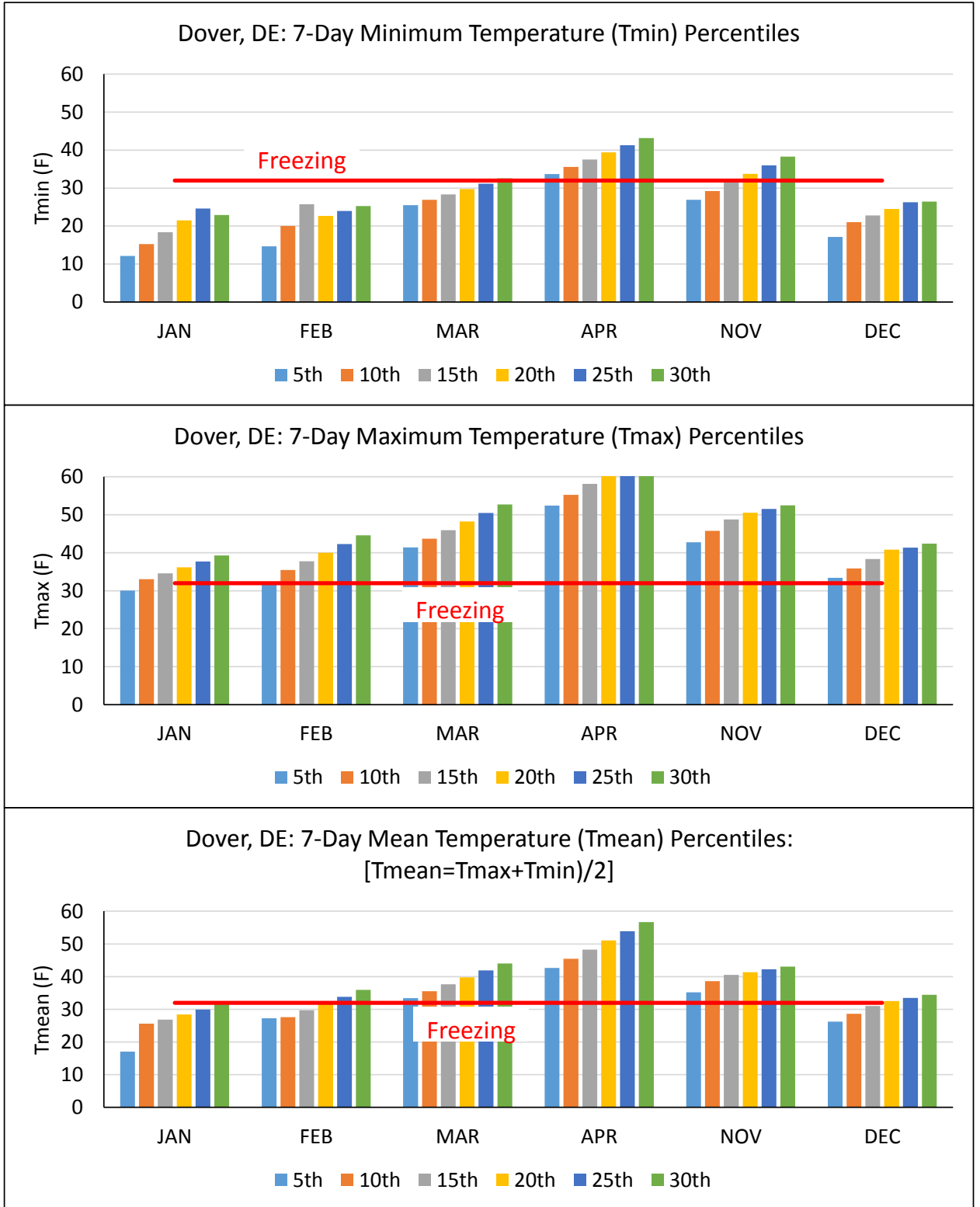
Thresholds for Daily Mean Temperatures: April, November, December



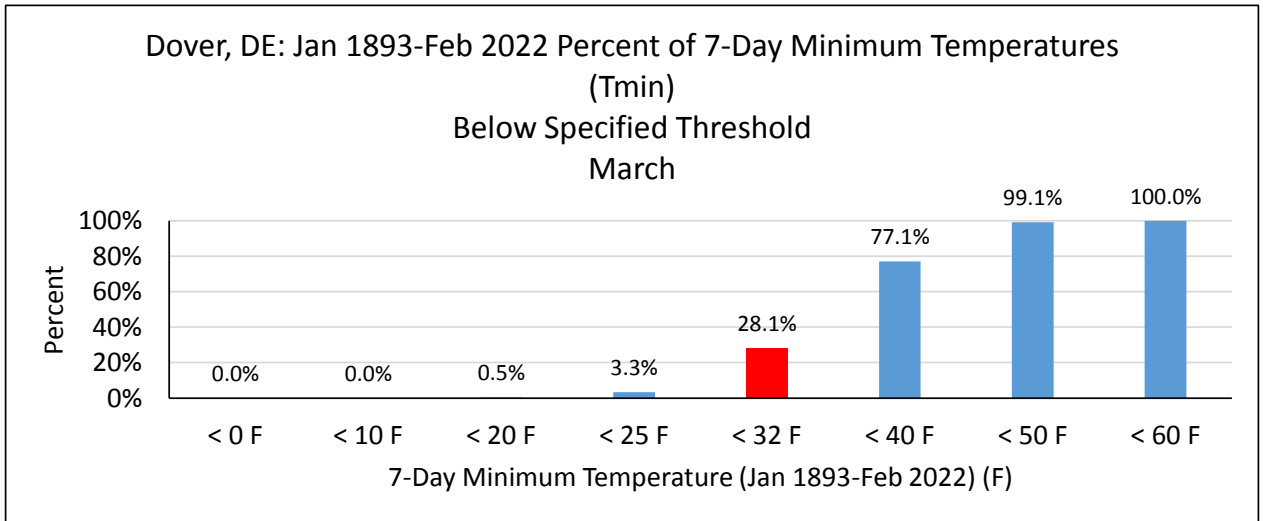
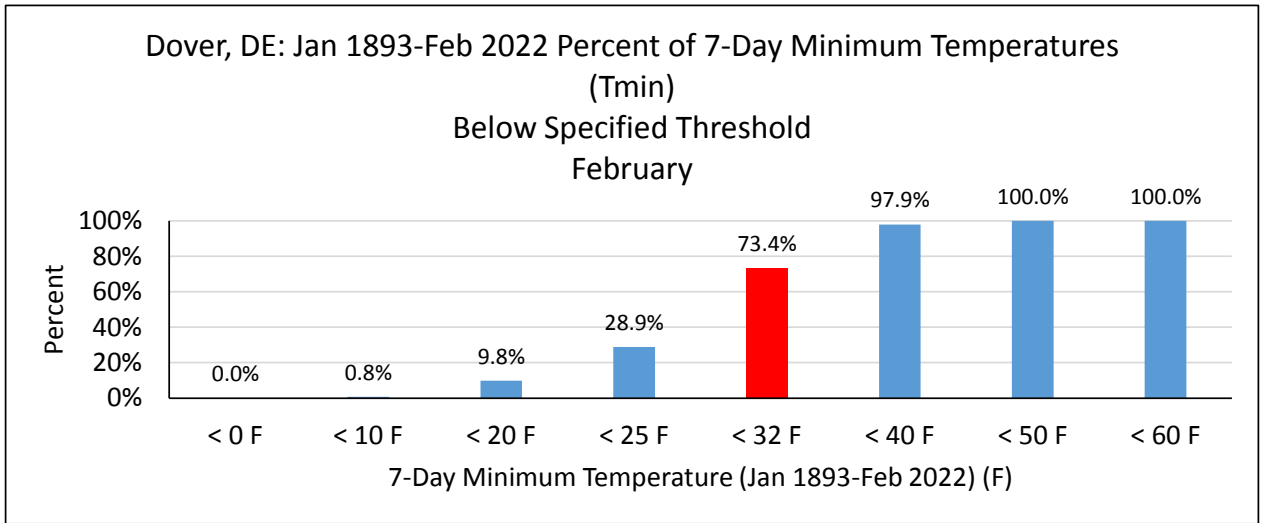
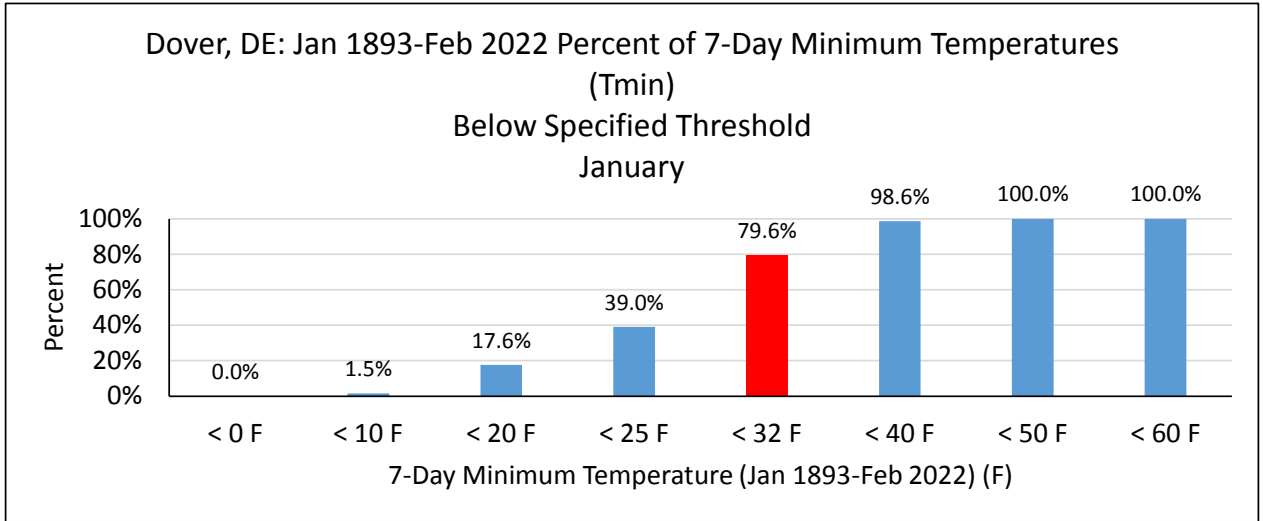
Summary of Daily Temperature Thresholds



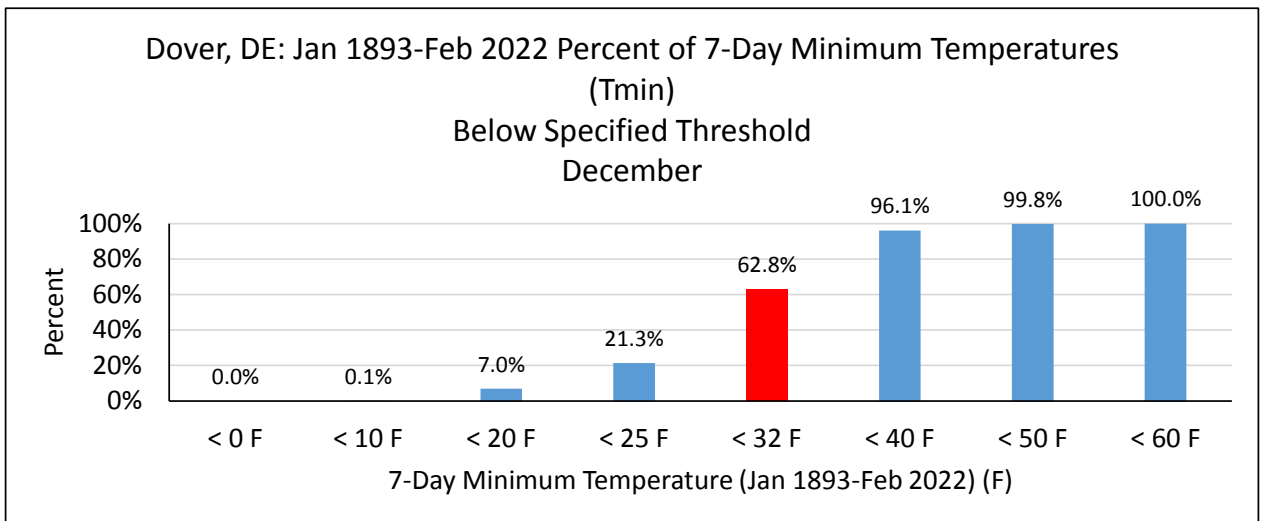
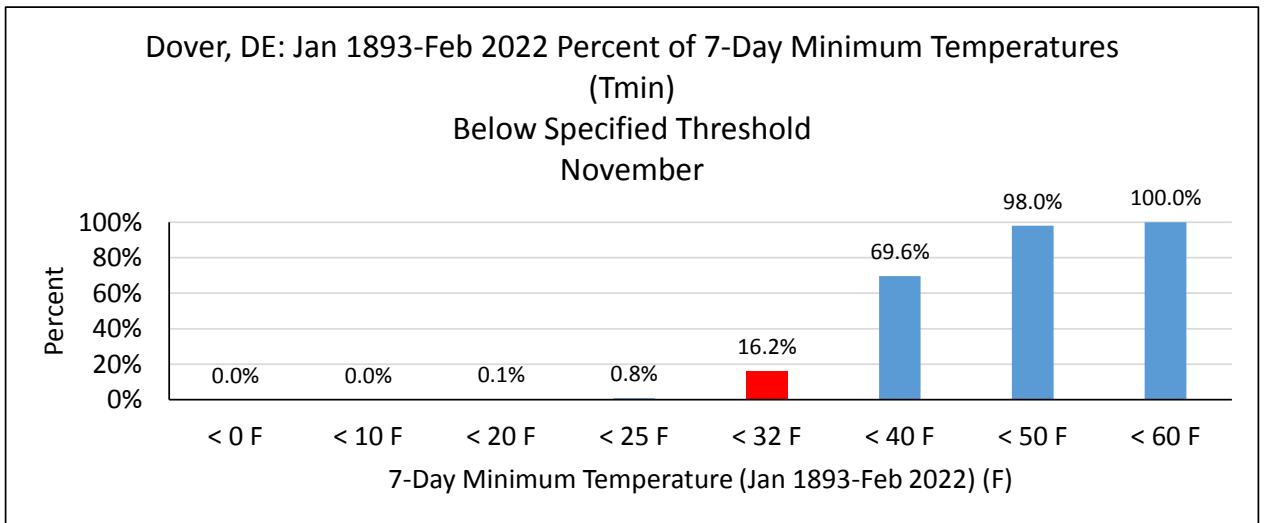
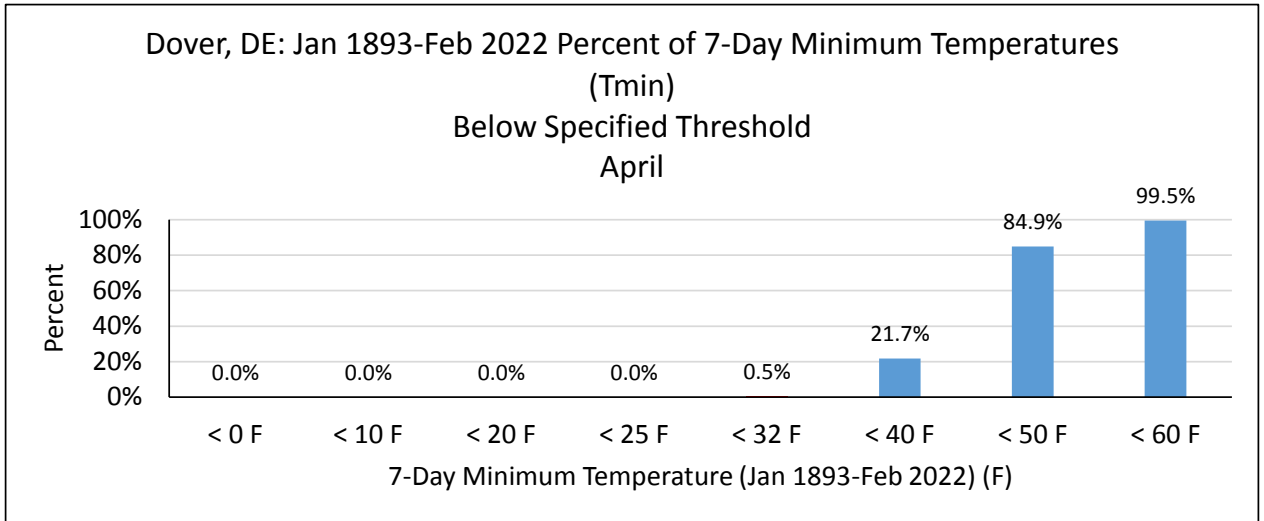
Percentiles of Weekly Average Temperatures



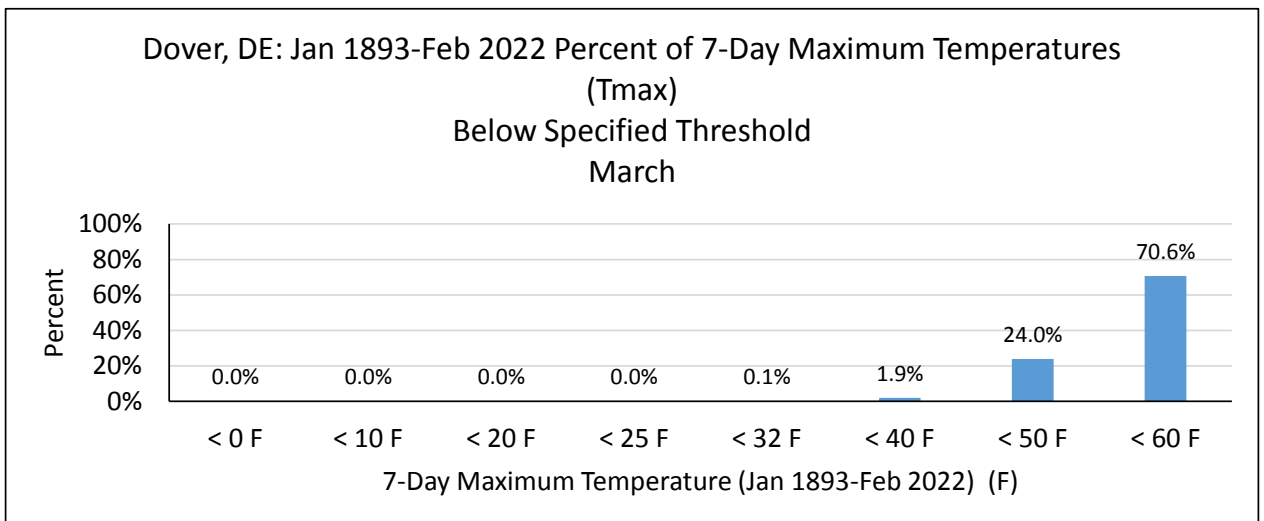
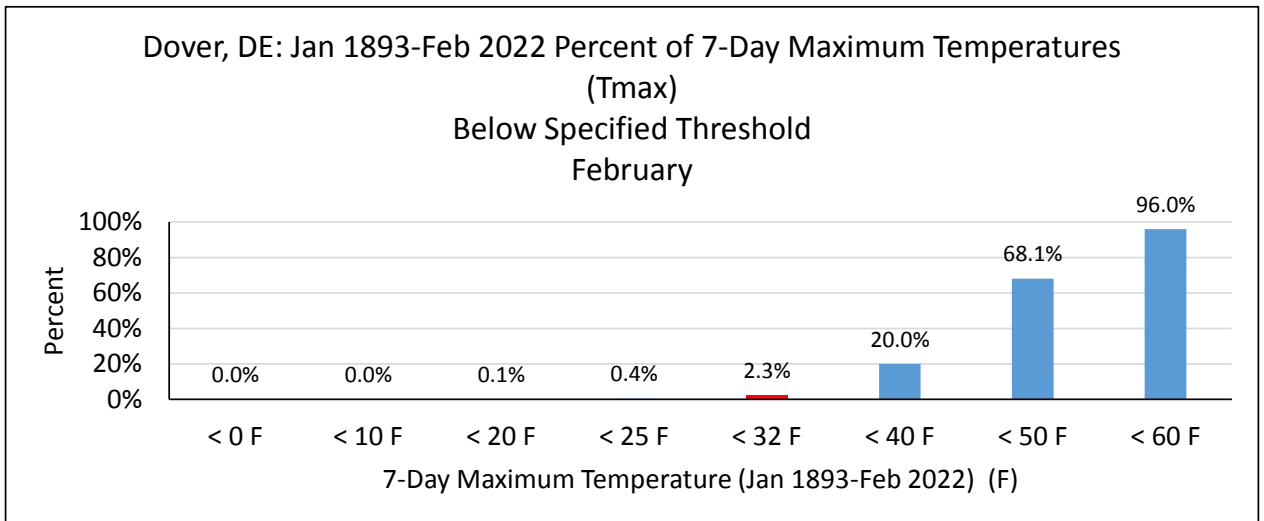
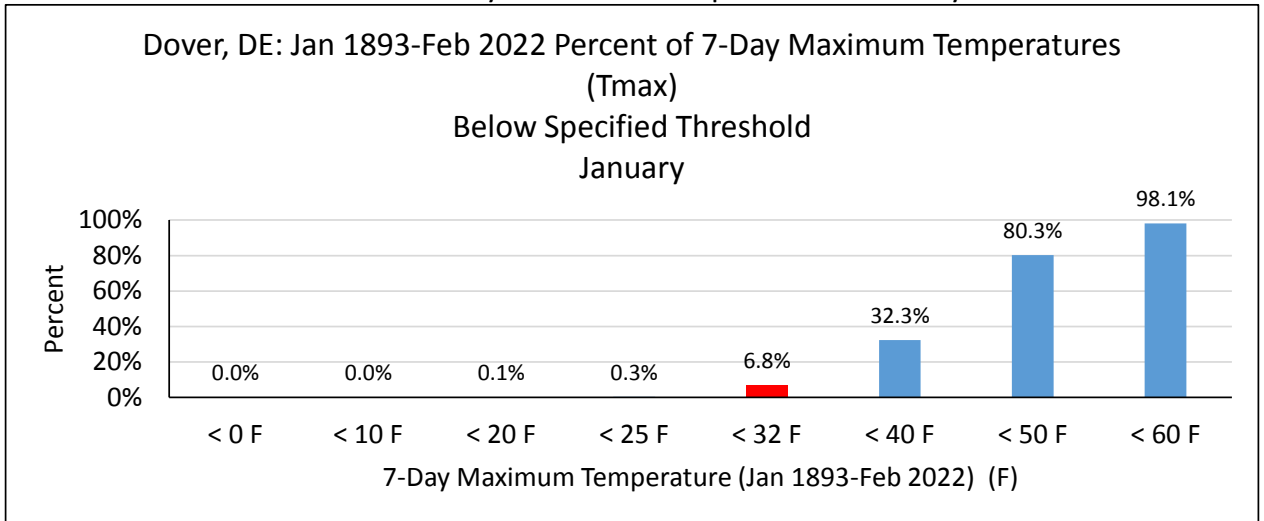
Thresholds for Weekly Minimum Temperatures: January-March



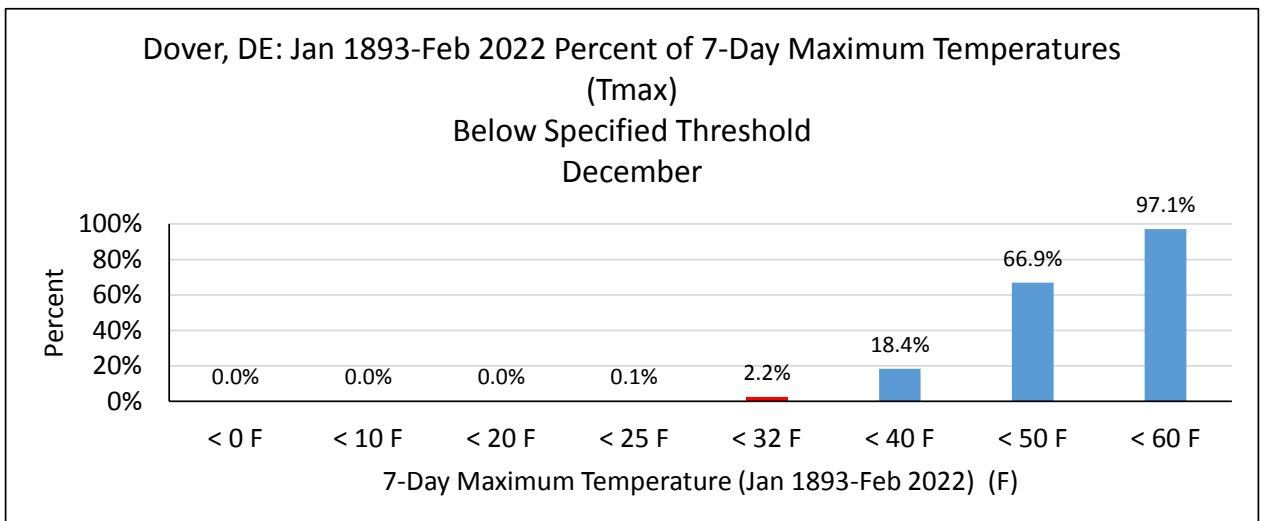
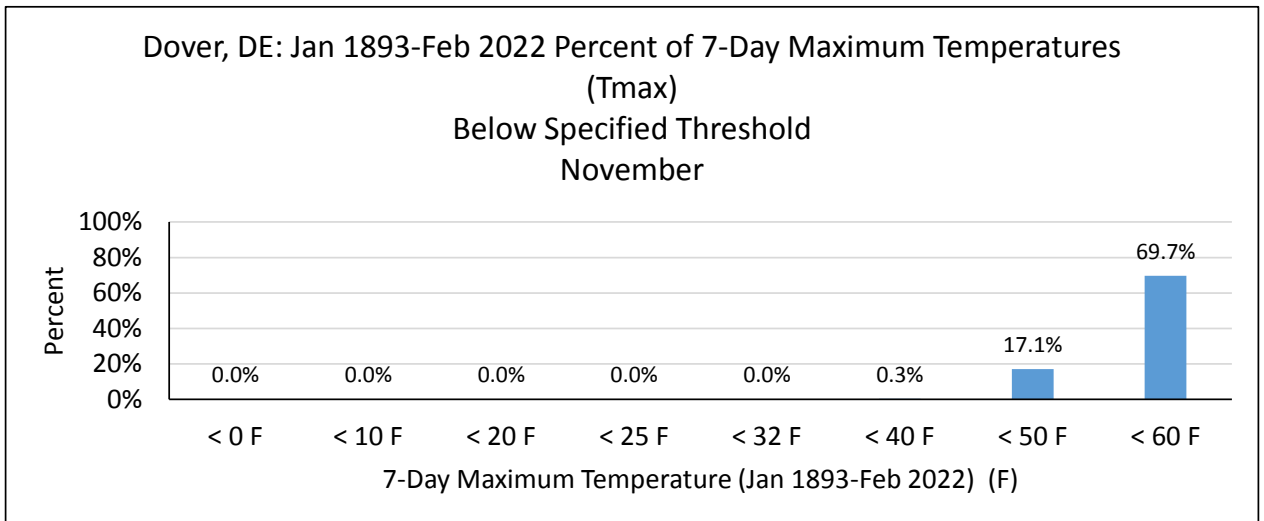
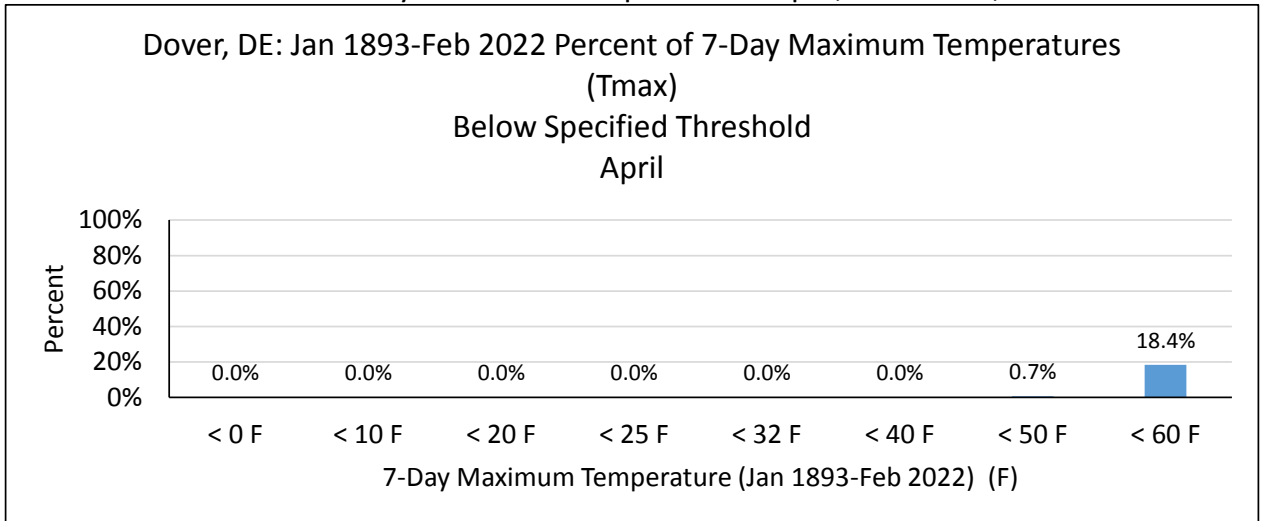
Thresholds for Weekly Minimum Temperatures: April, November, December



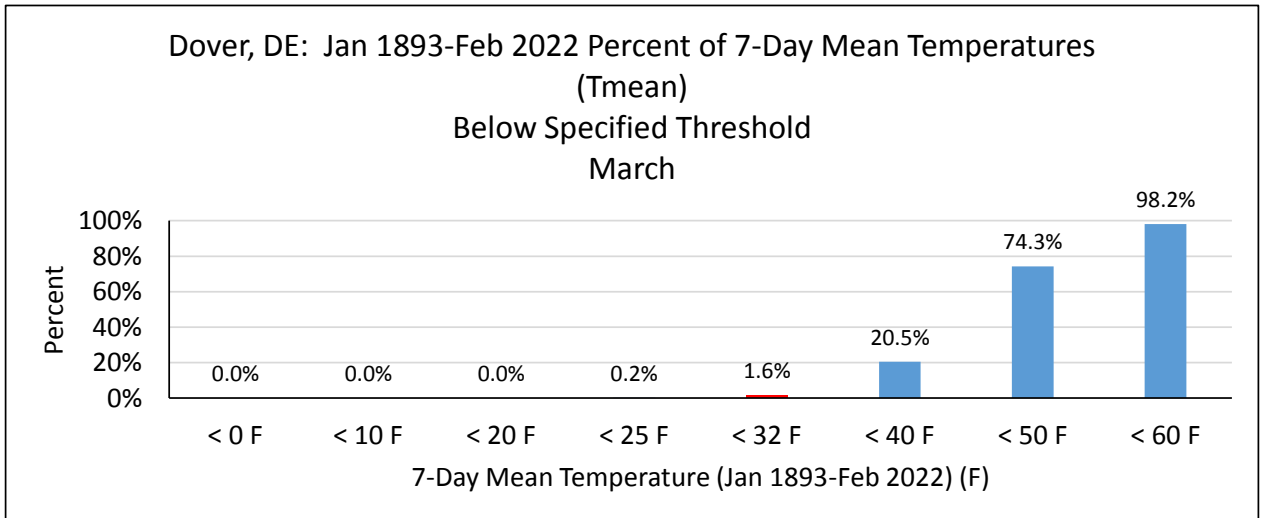
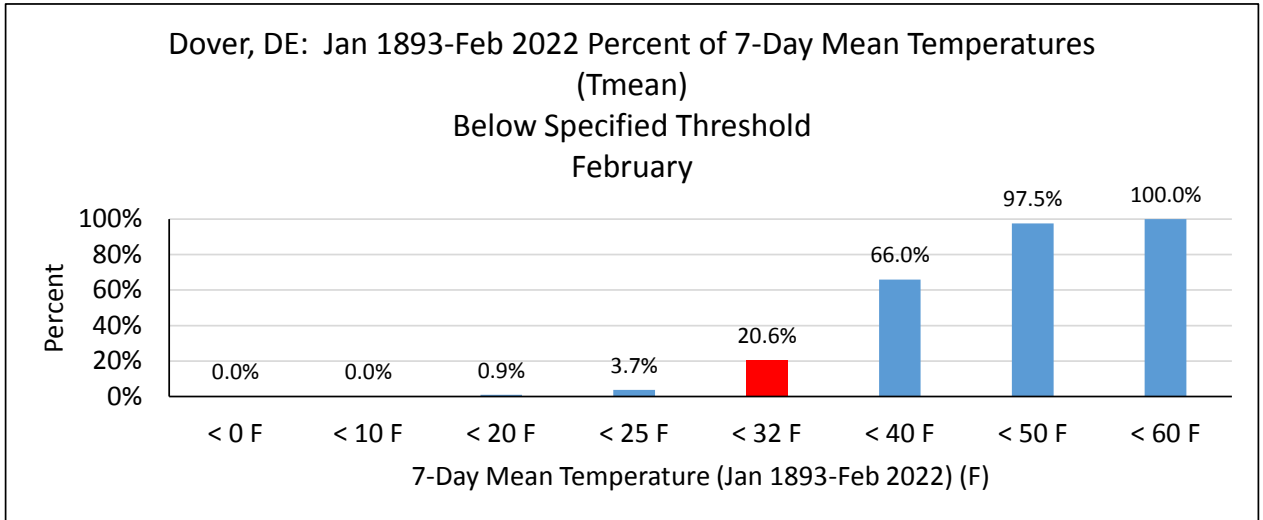
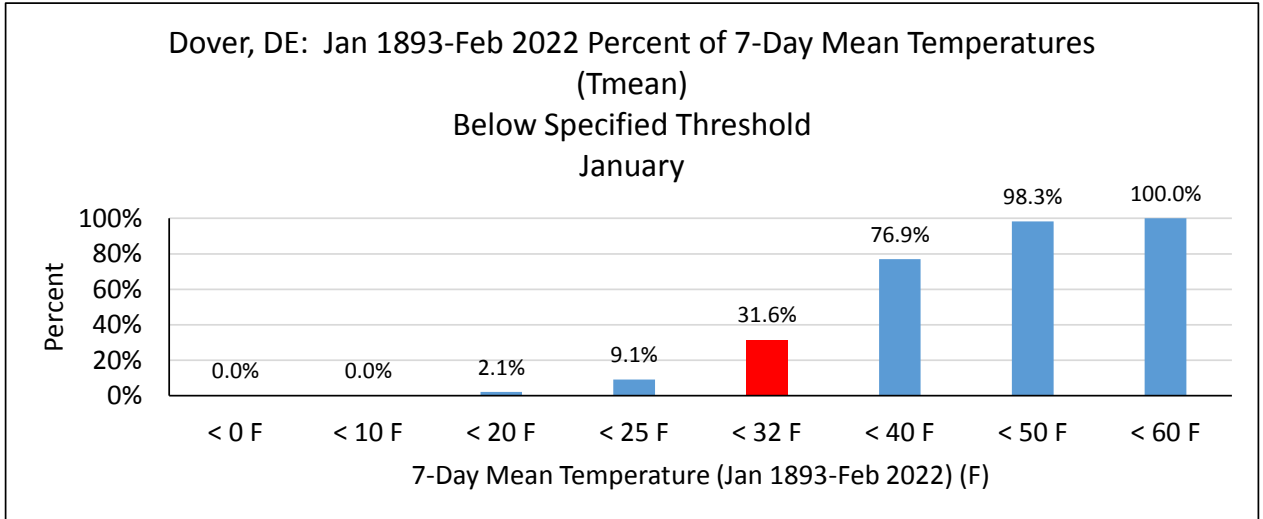
Thresholds for Weekly Maximum Temperatures: January-March



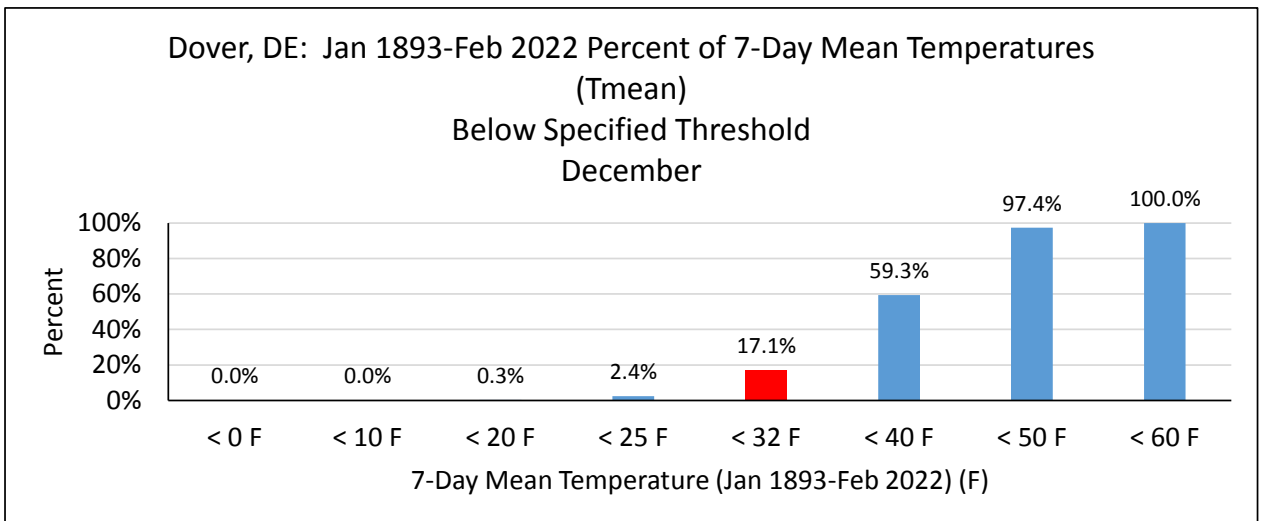
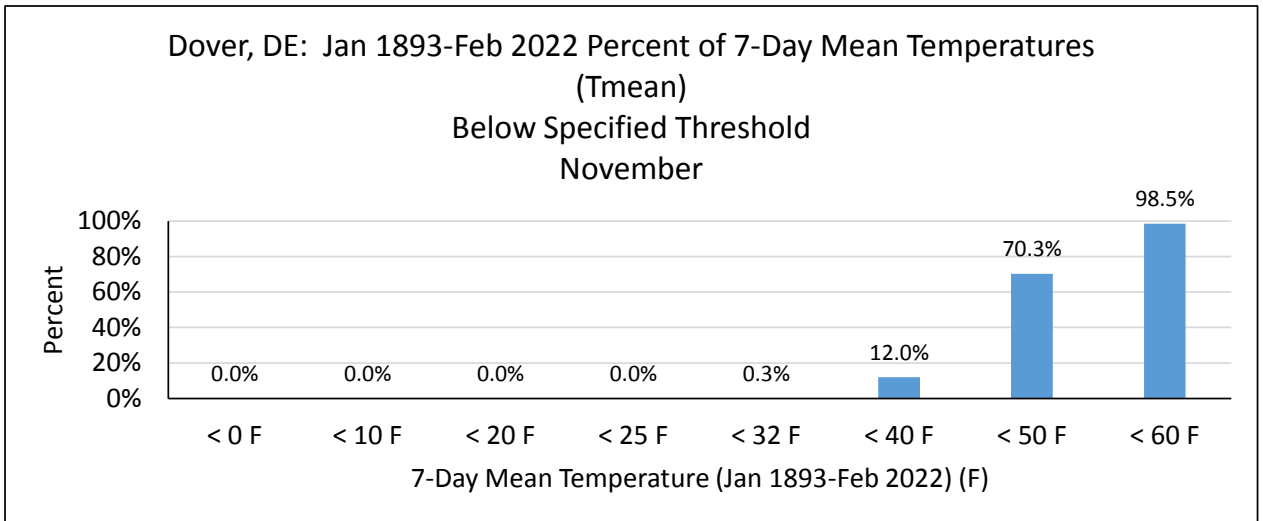
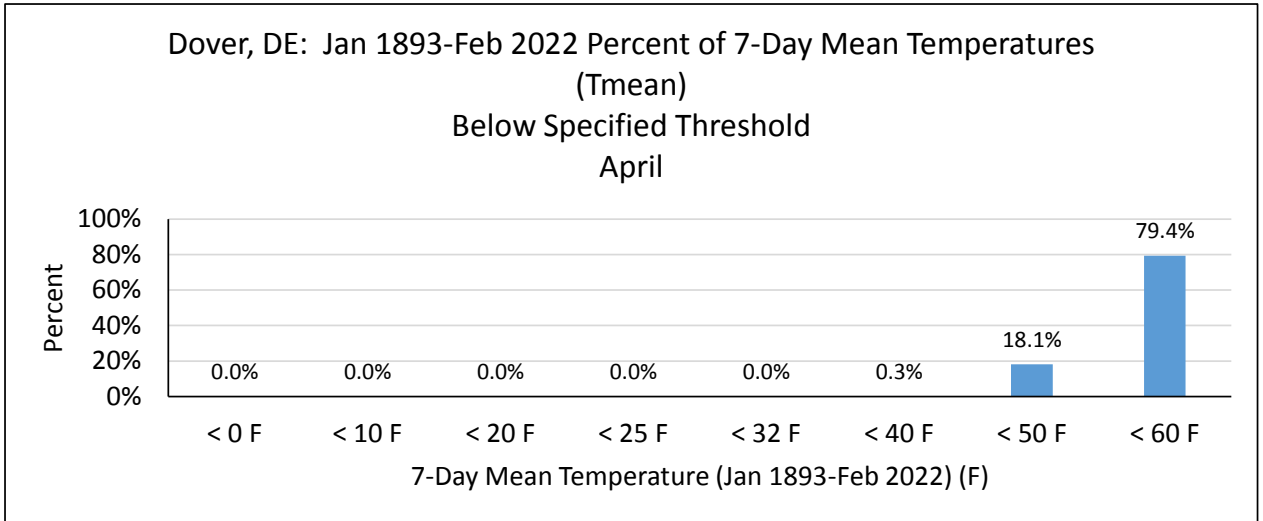
Thresholds for Weekly Maximum Temperatures: April, November, December



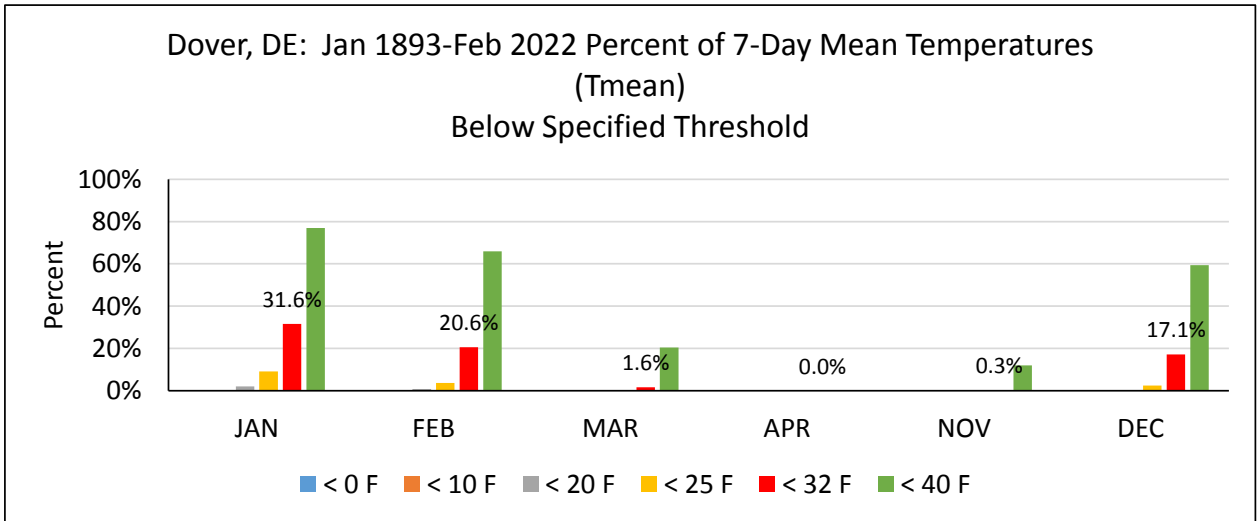
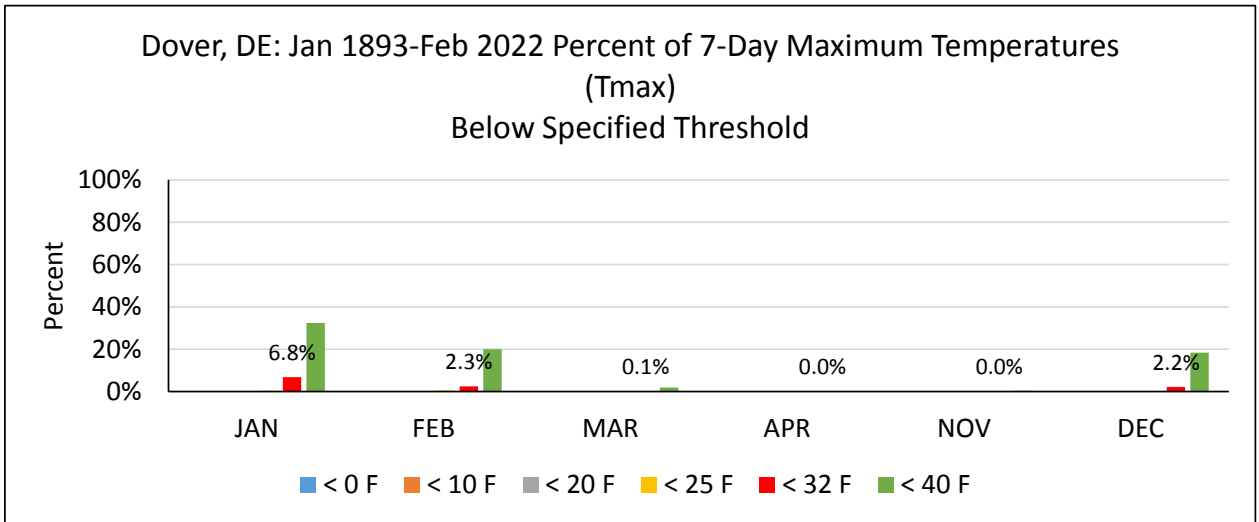
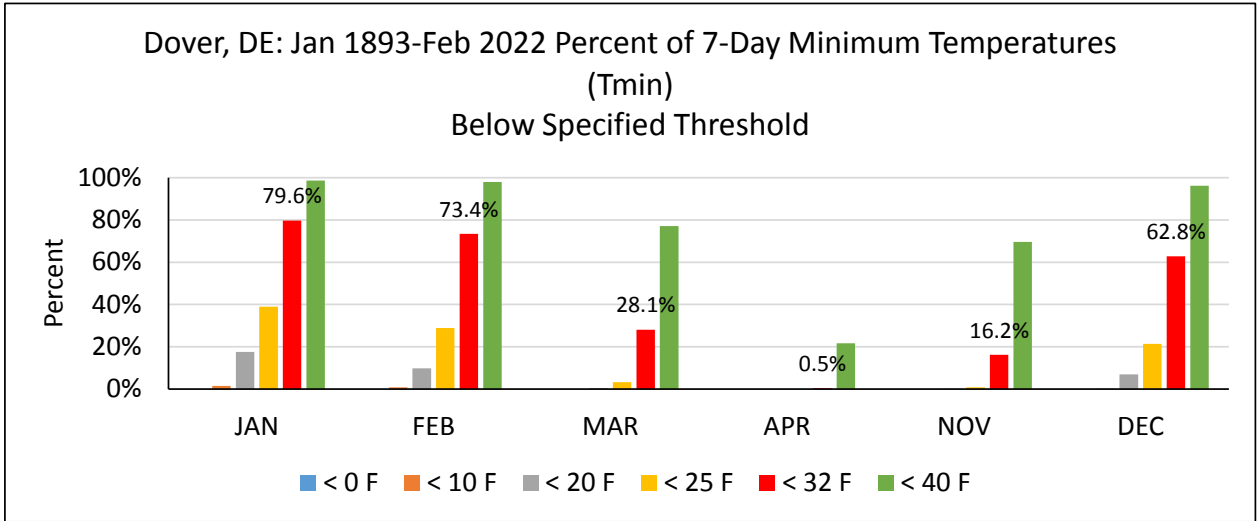
Thresholds for Weekly Mean Temperatures: January-March



Thresholds for Weekly Mean Temperatures: April, November, December

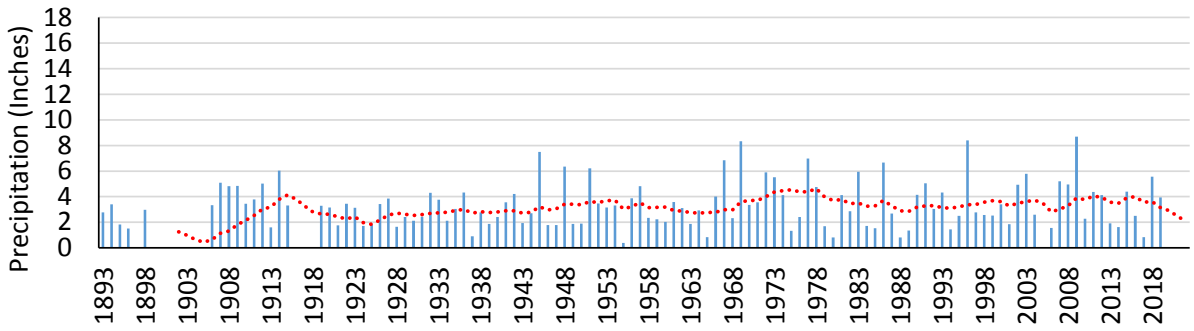


Summary of Weekly Temperature Thresholds

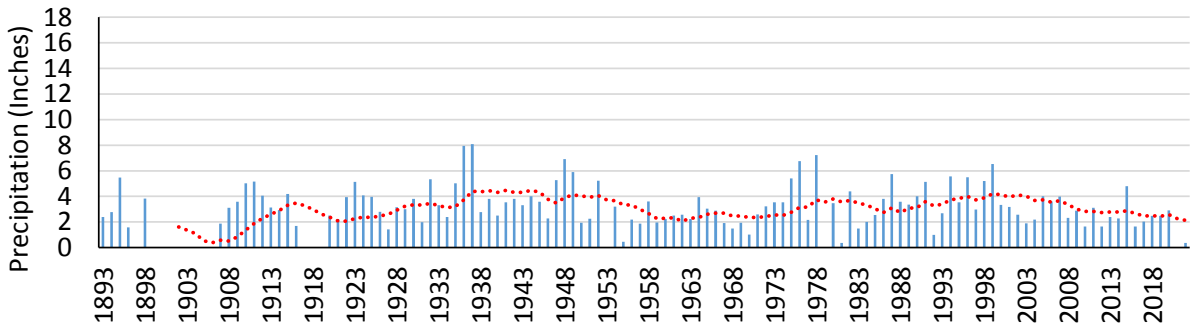


Time Series of Monthly Precipitation Totals: December-March

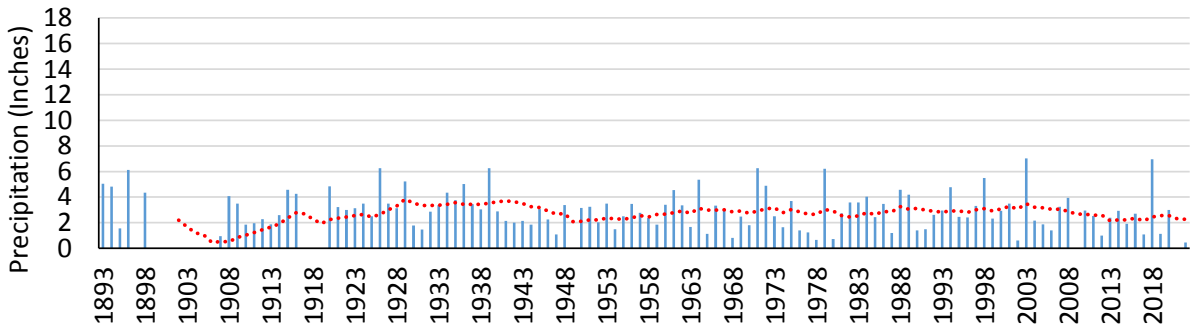
Dover, DE: December Monthly Precipitation



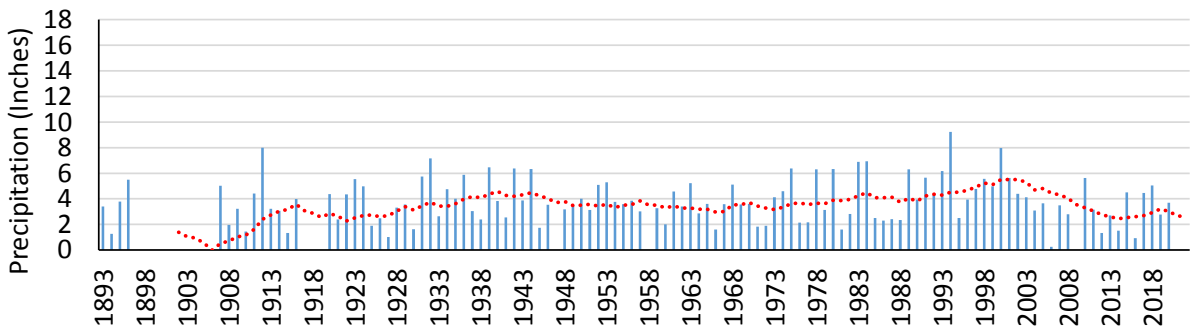
Dover, DE: January Monthly Precipitation



Dover, DE: February Monthly Precipitation

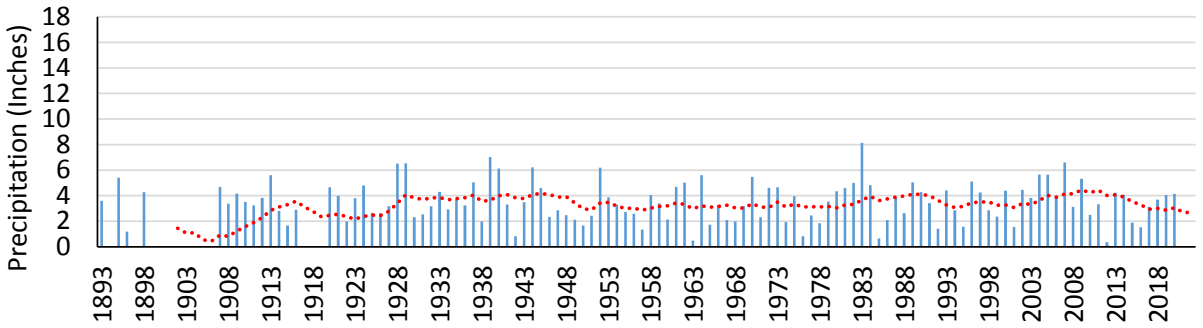


Dover, DE: March Monthly Precipitation

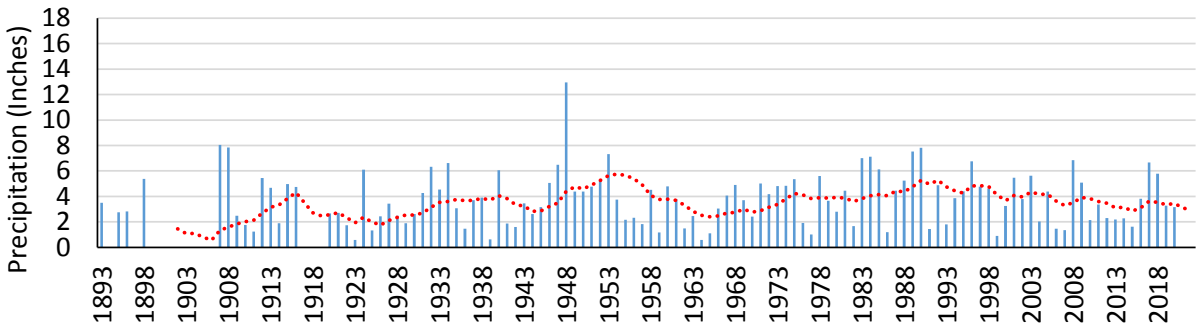


Time Series of Monthly Precipitation Totals: April-July

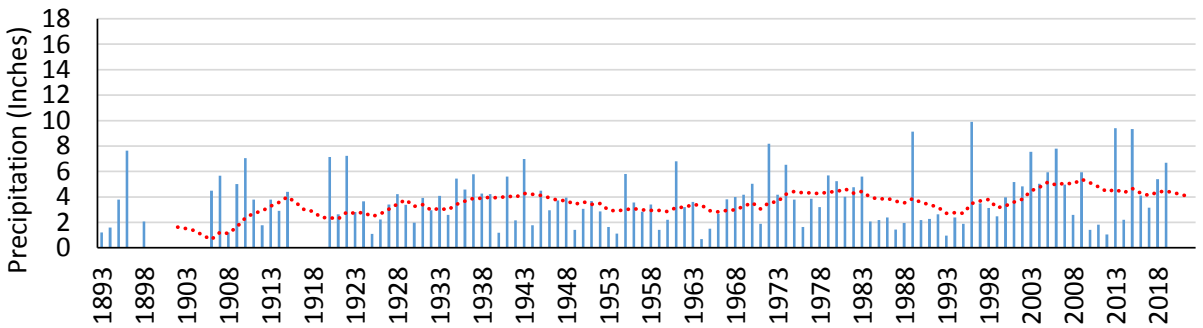
Dover, DE: April Monthly Precipitation



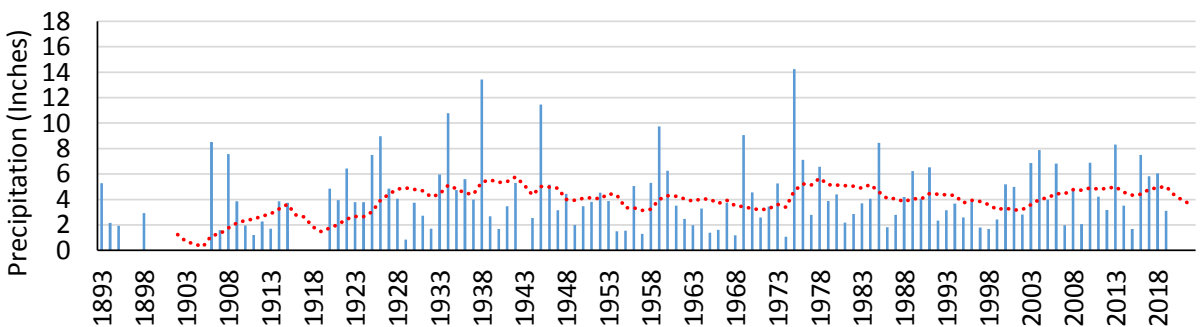
Dover, DE: May Monthly Precipitation



Dover, DE: June Monthly Precipitation

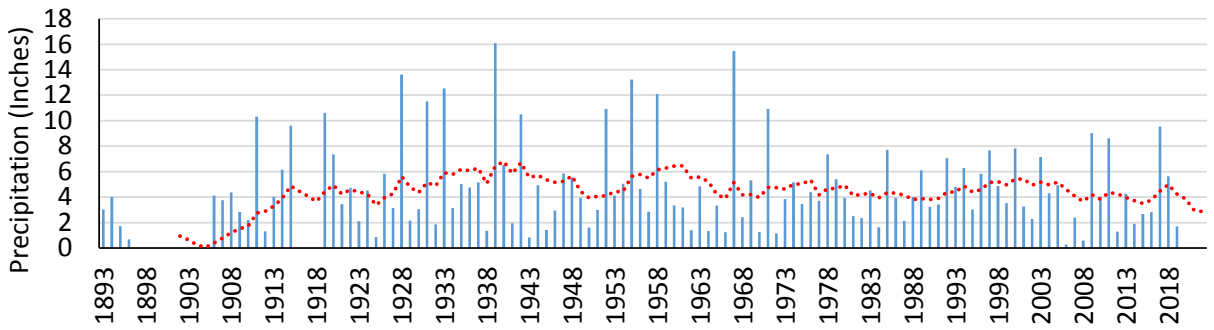


Dover, DE: July Monthly Precipitation

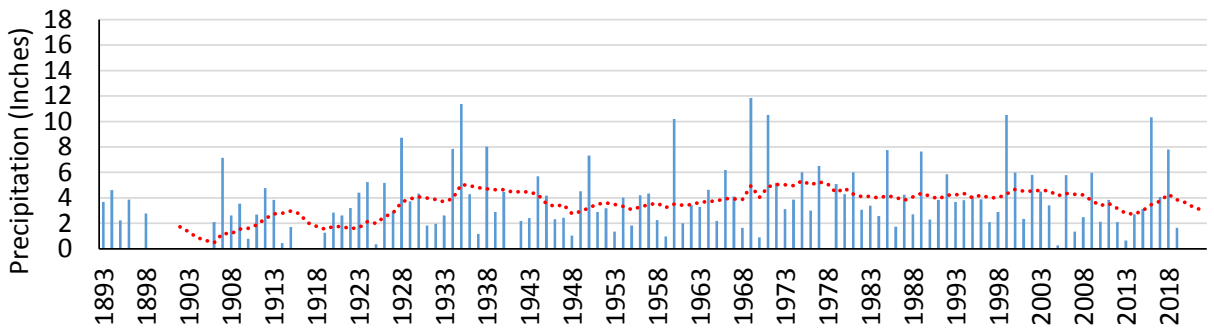


Time Series of Monthly Precipitation Totals: August-November

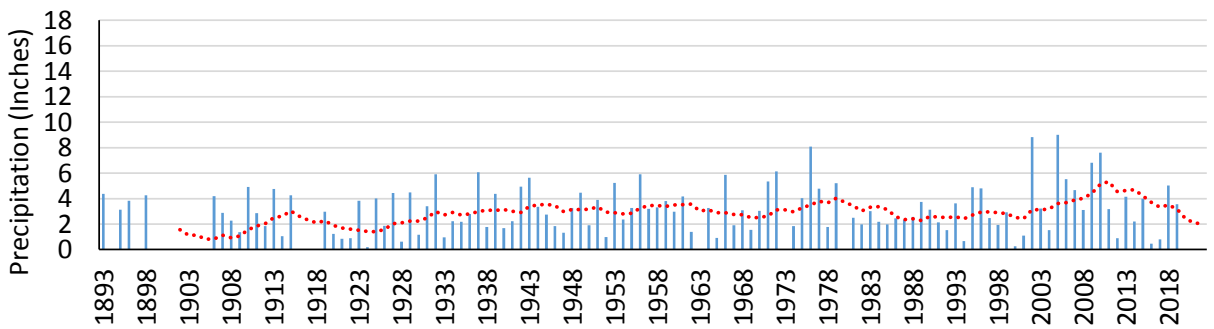
Dover, DE: August Monthly Precipitation



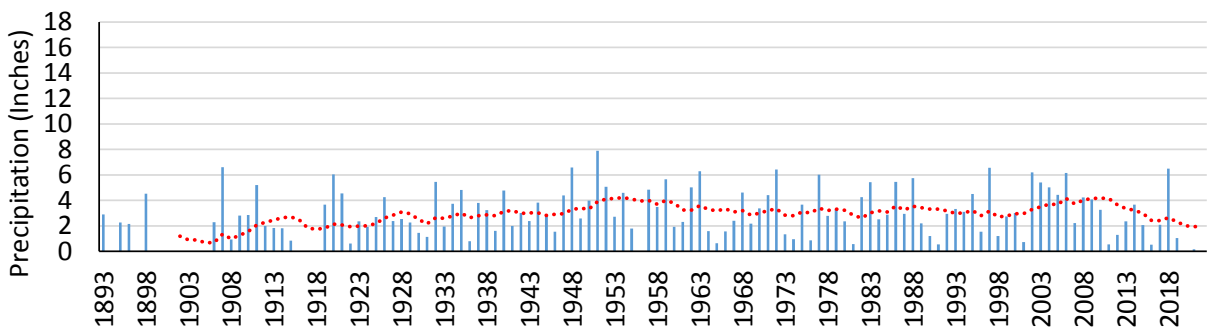
Dover, DE: September Monthly Precipitation



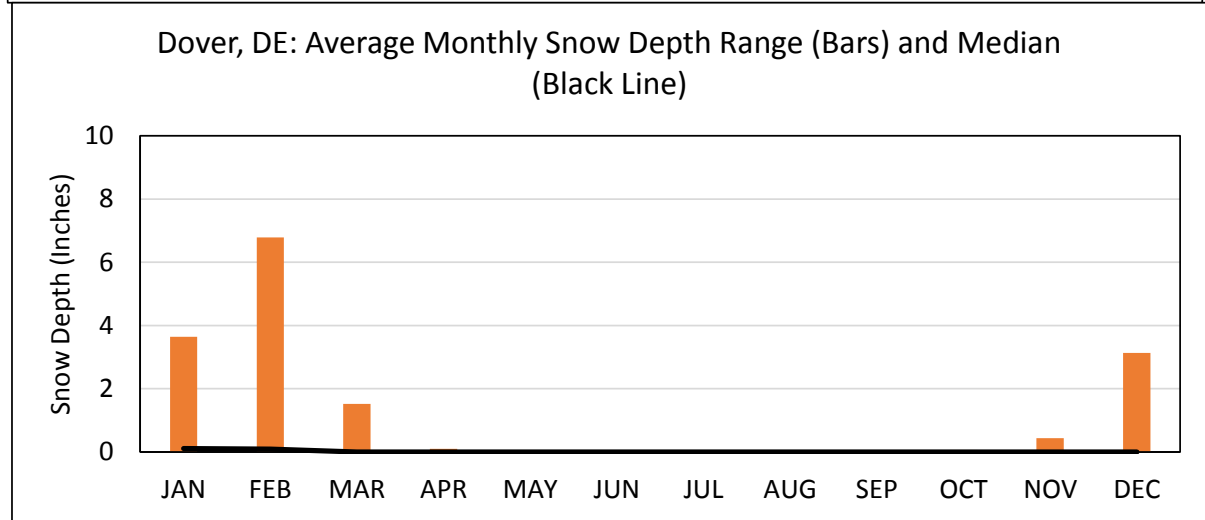
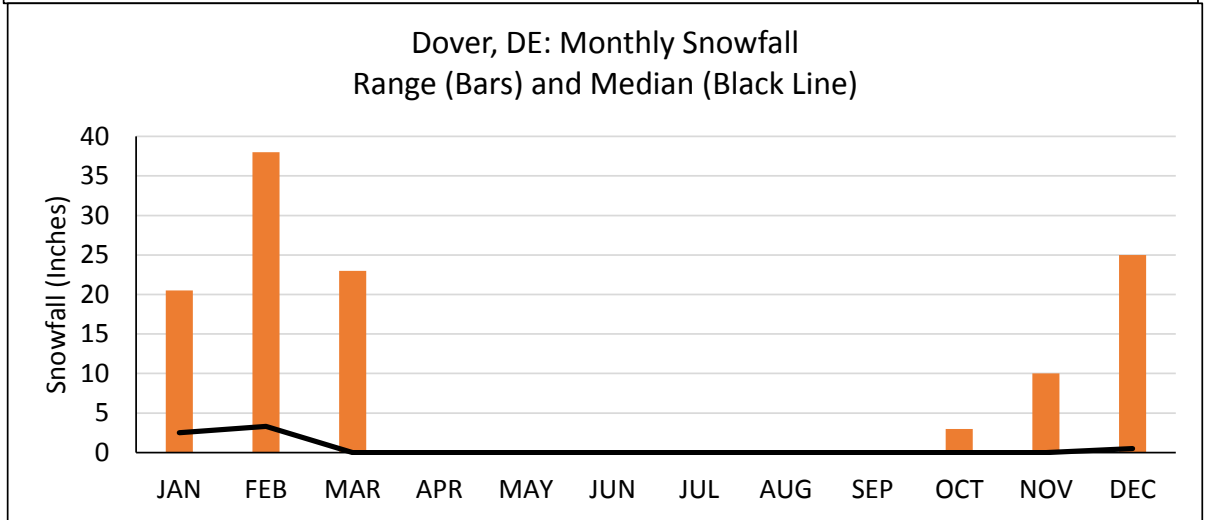
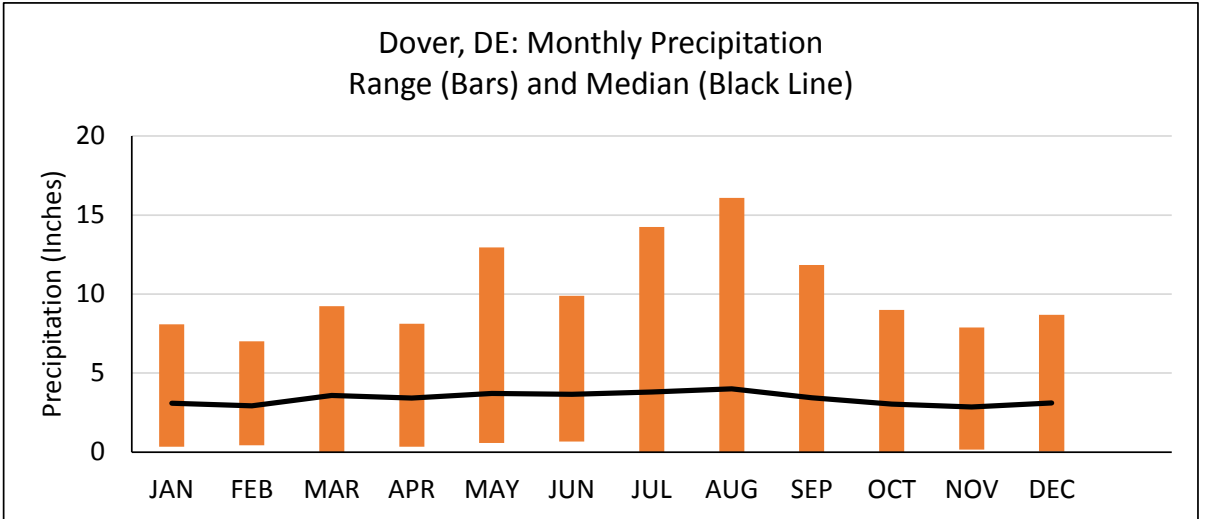
Dover, DE: October Monthly Precipitation



Dover, DE: November Monthly Precipitation

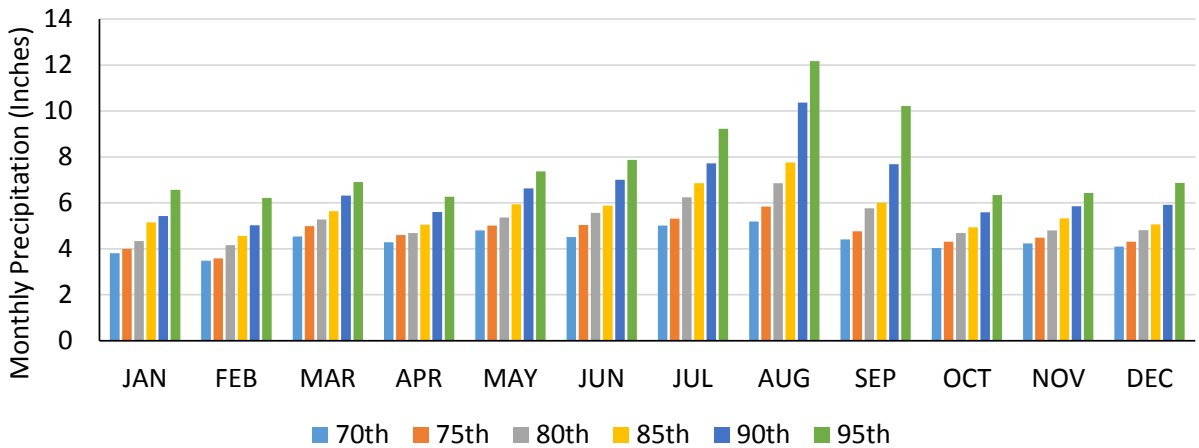


Monthly Ranges of Precipitation, Snowfall and Snow Depth

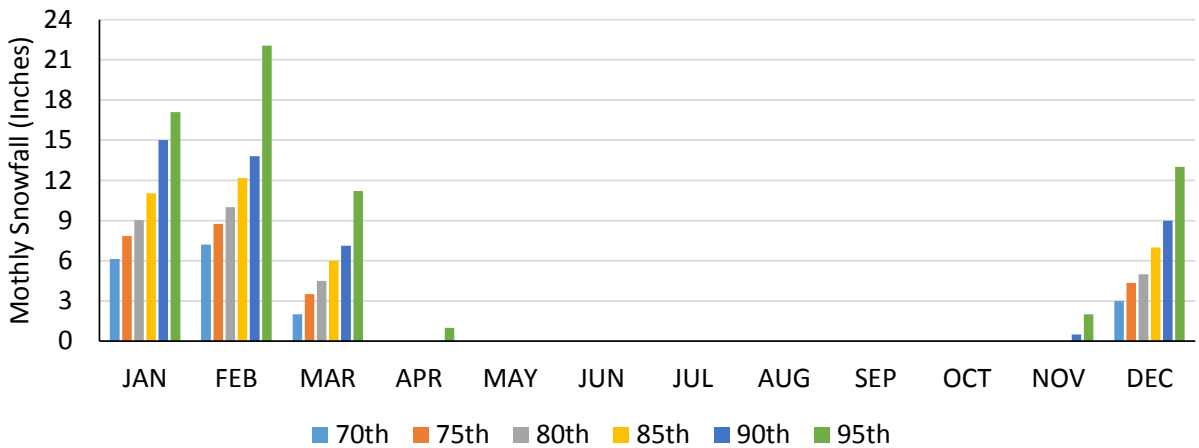


Percentiles of Monthly Precipitation, Snowfall and Snow Depth

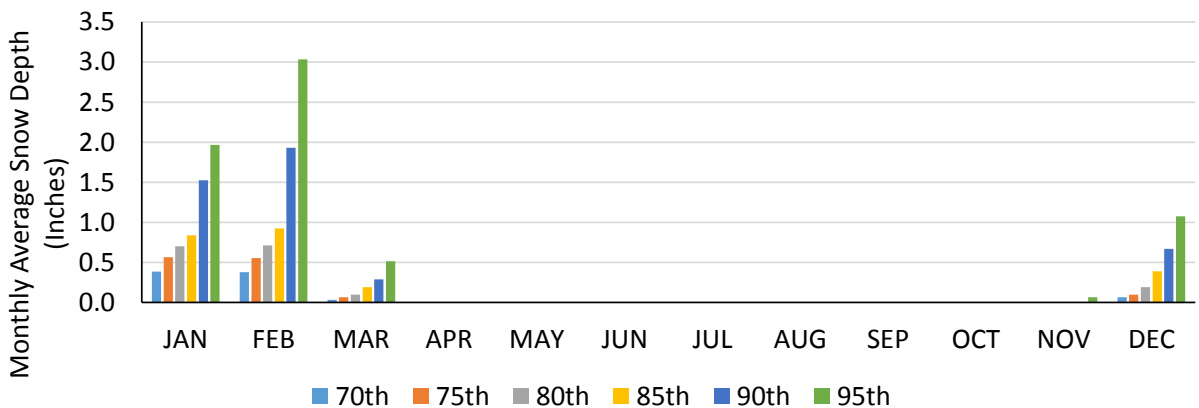
Dover, DE: Threshold for Specified Percentile of Rainfall Totals



Dover, DE: Threshold for Specified Percentile of Snowfall Totals

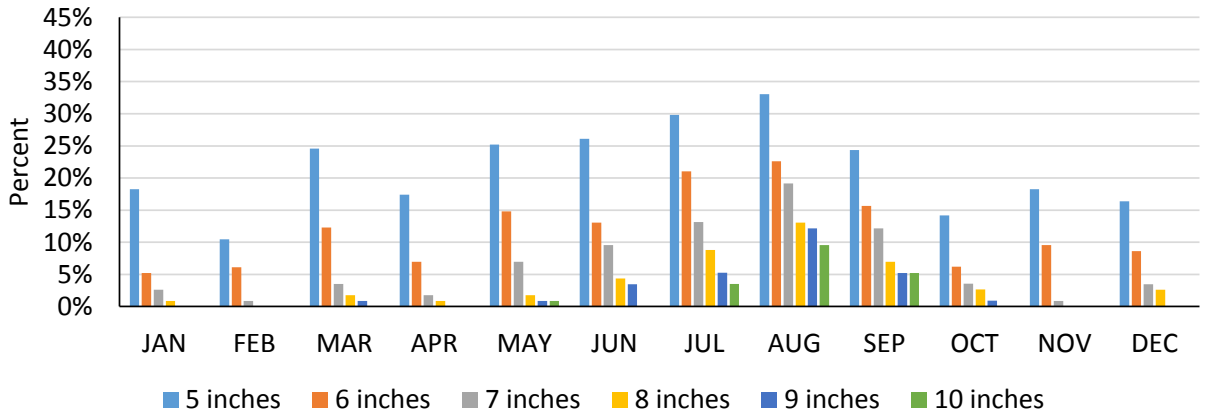


Dover, DE: Threshold for Specified Percentile of Monthly Average Snow Depth

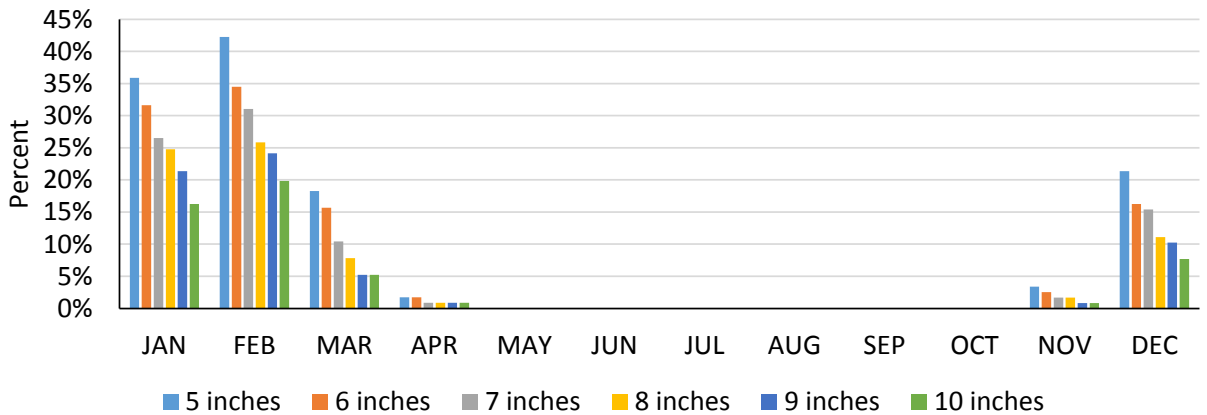


Thresholds for Monthly Precipitation, Snowfall and Snow Depth

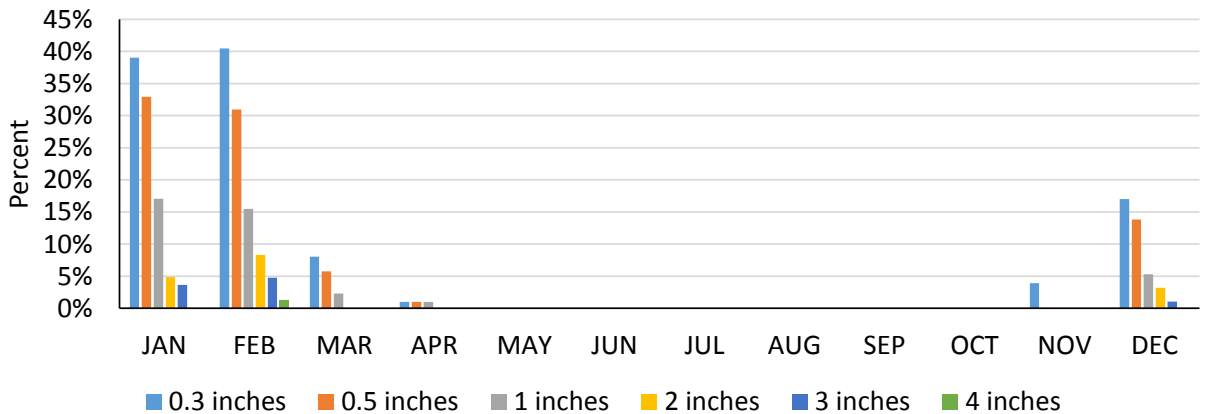
Dover, DE: Percent of Monthly Precipitation Totals Exceeding Specified Threshold



Dover, DE: Percent of Monthly Snowfall Totals Exceeding Specified Threshold

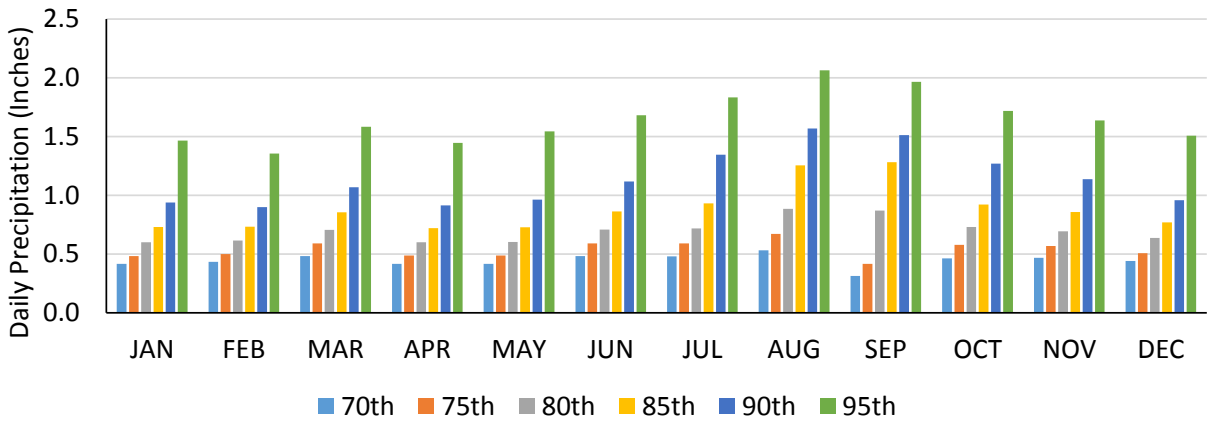


Dover, DE: Percent of Monthly Snowfall Totals Exceeding Specified Threshold

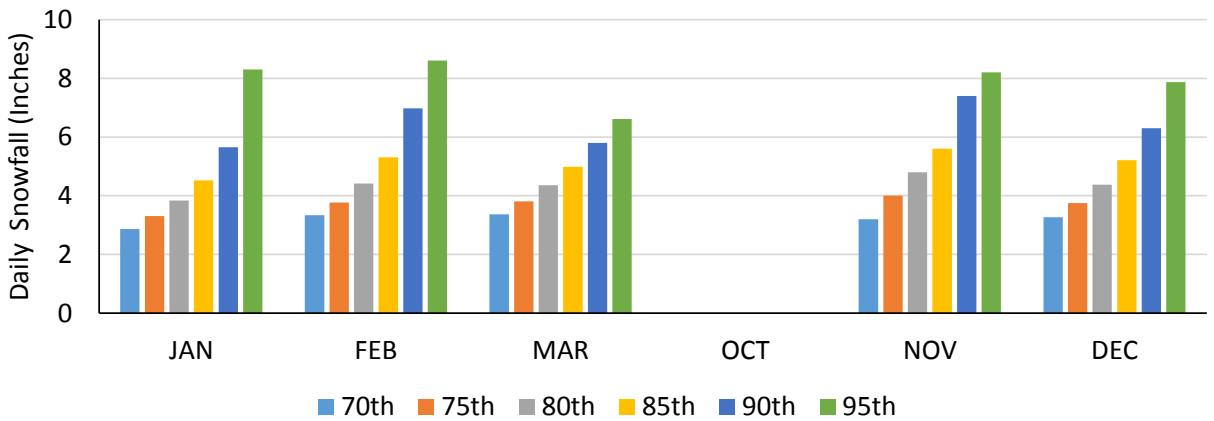


Percentiles of Daily Precipitation, Snowfall, and Snow Depth

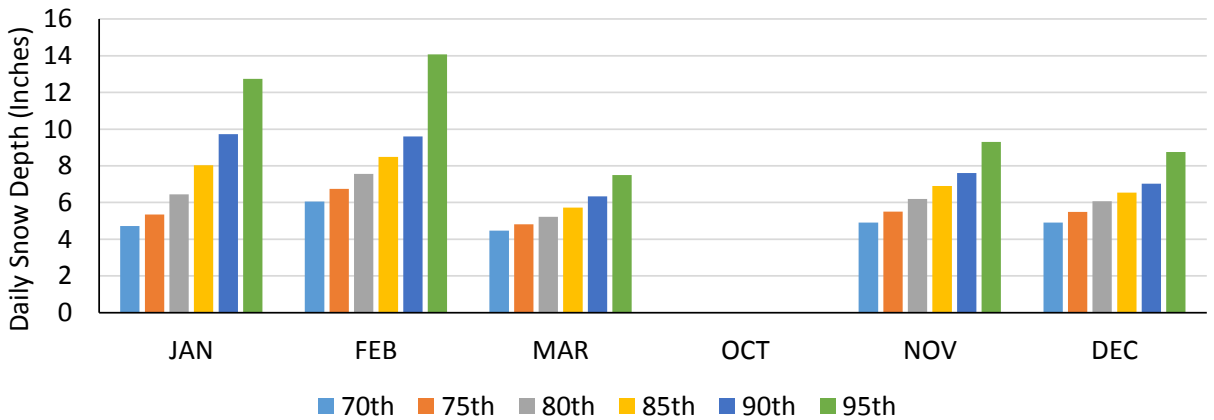
Dover, DE: Daily Precipitation Percentiles When It Does Rain



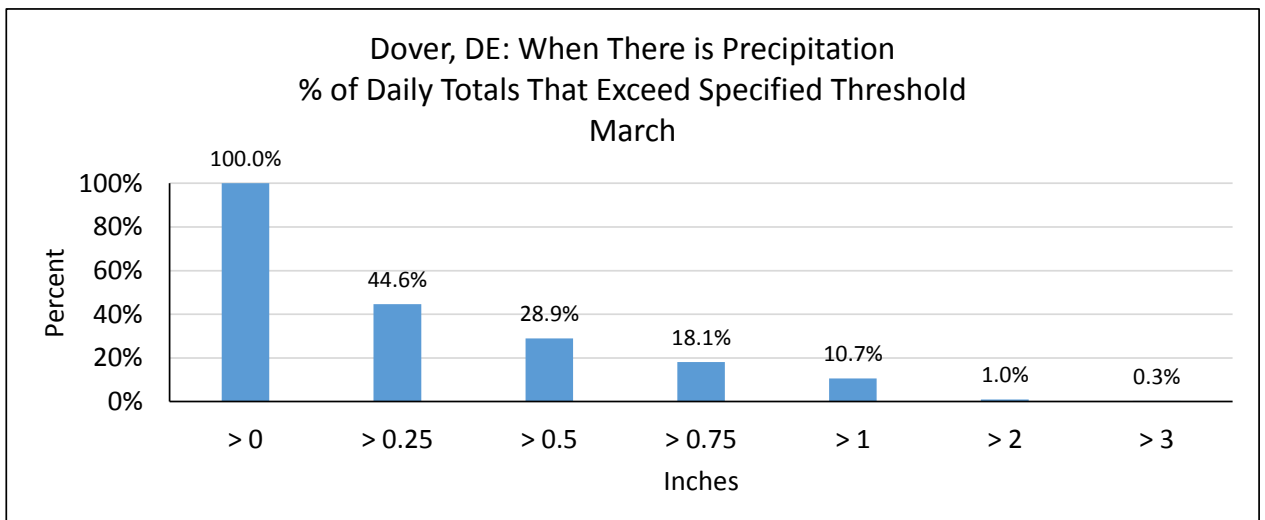
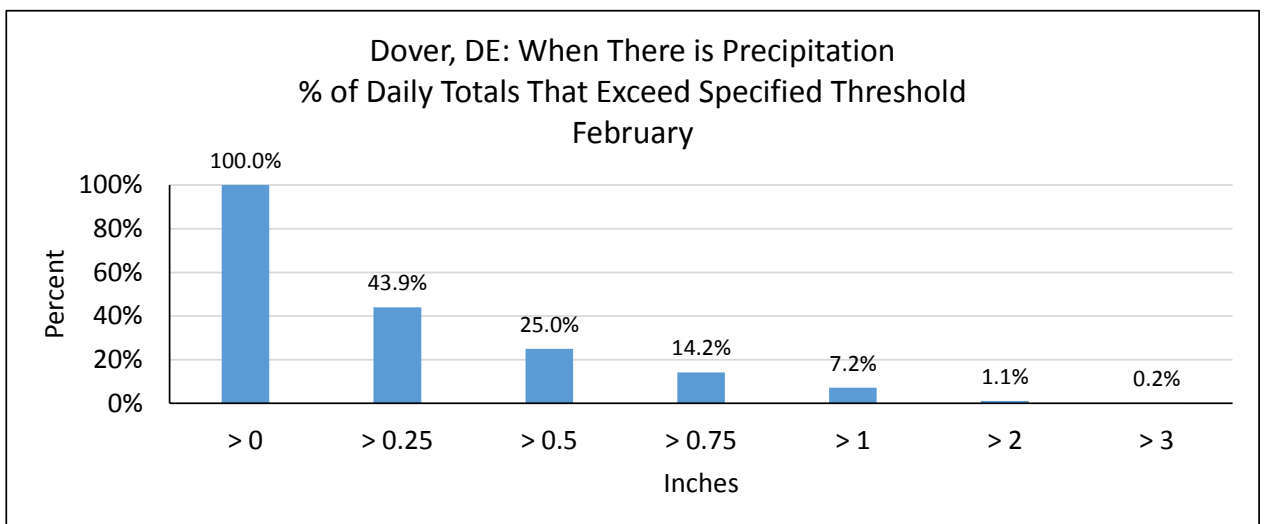
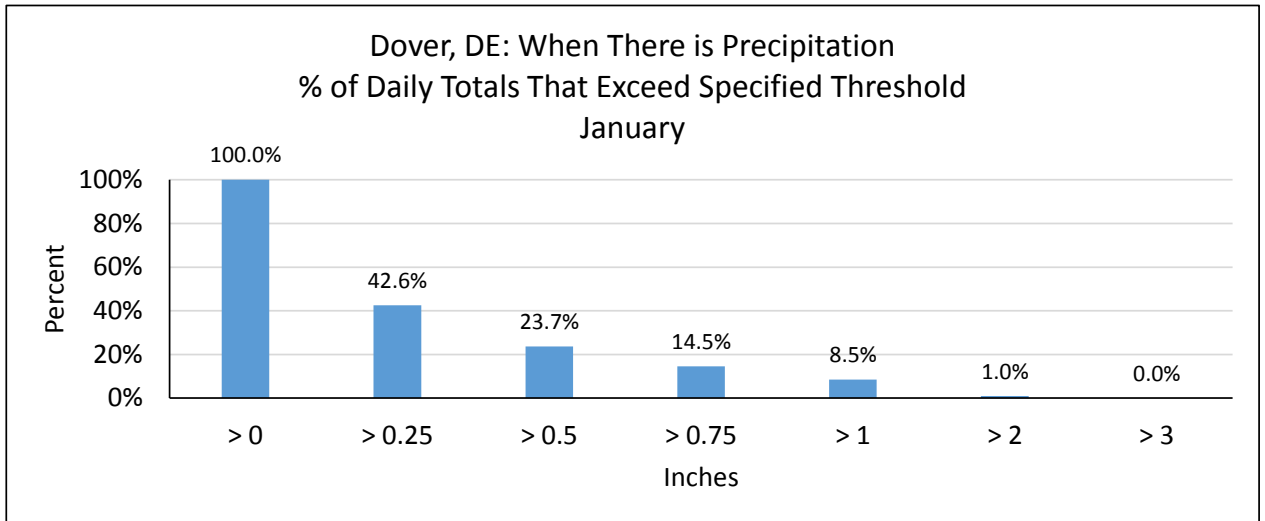
Dover, DE: Threshold for Specified Percentile of Snowfall Totals



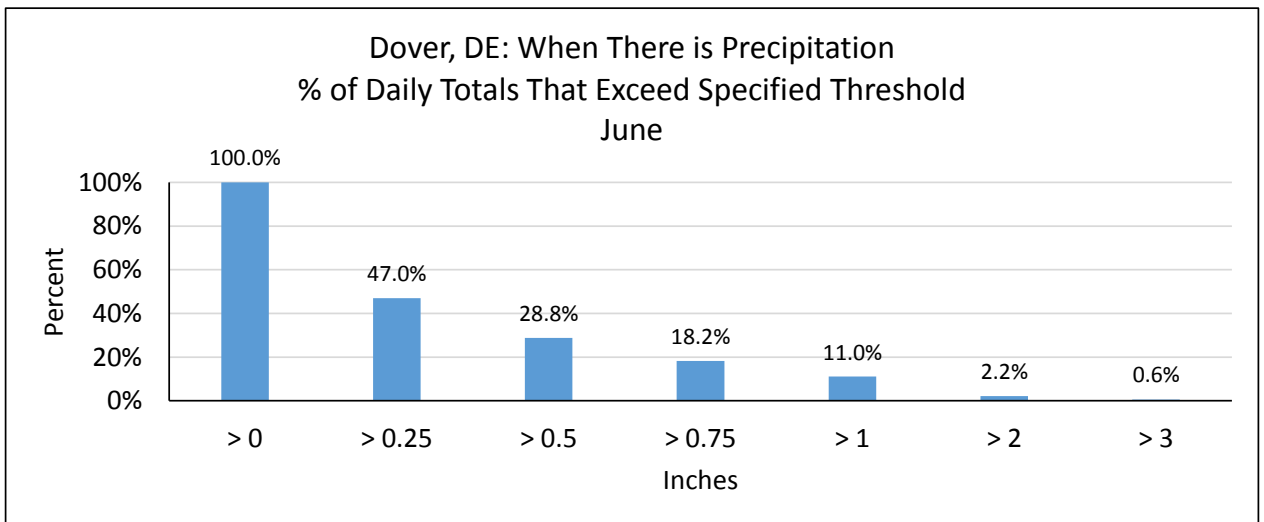
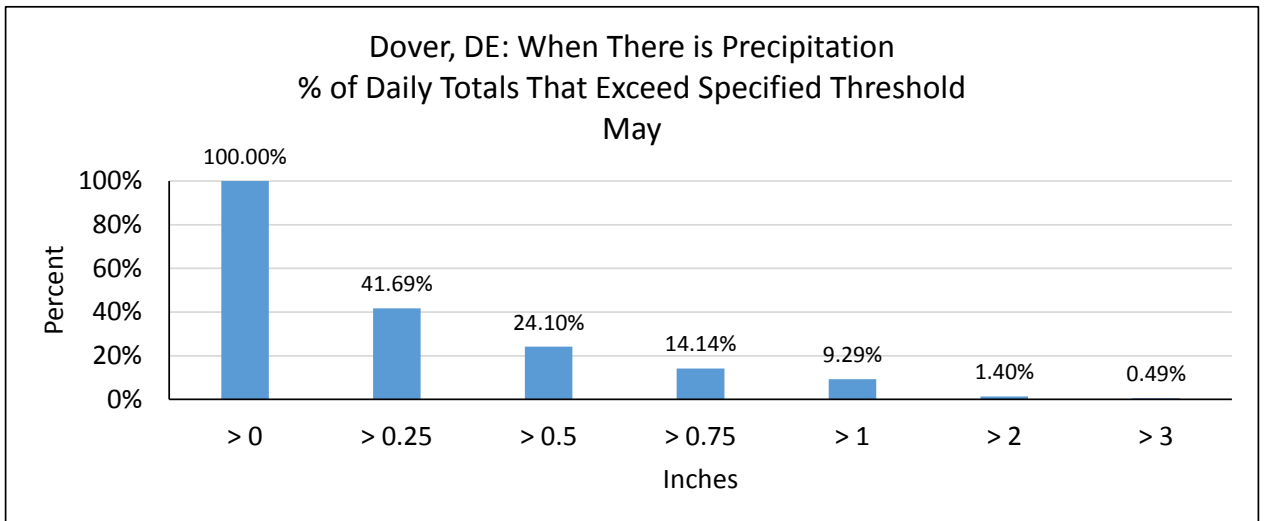
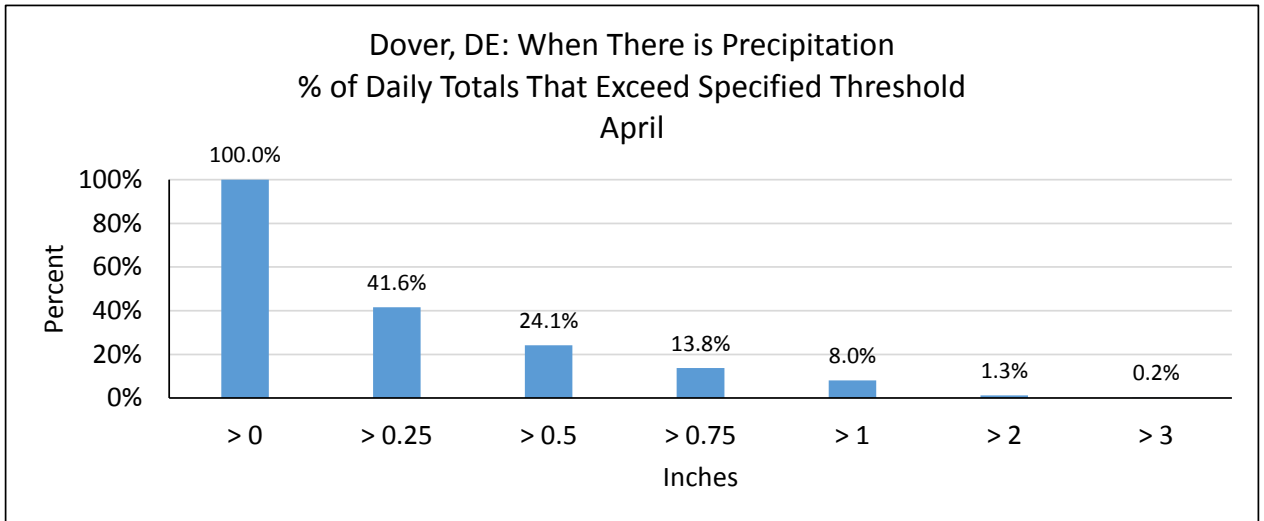
Dover, DE: Daily Snow Depth Percentiles When There is Snow Cover



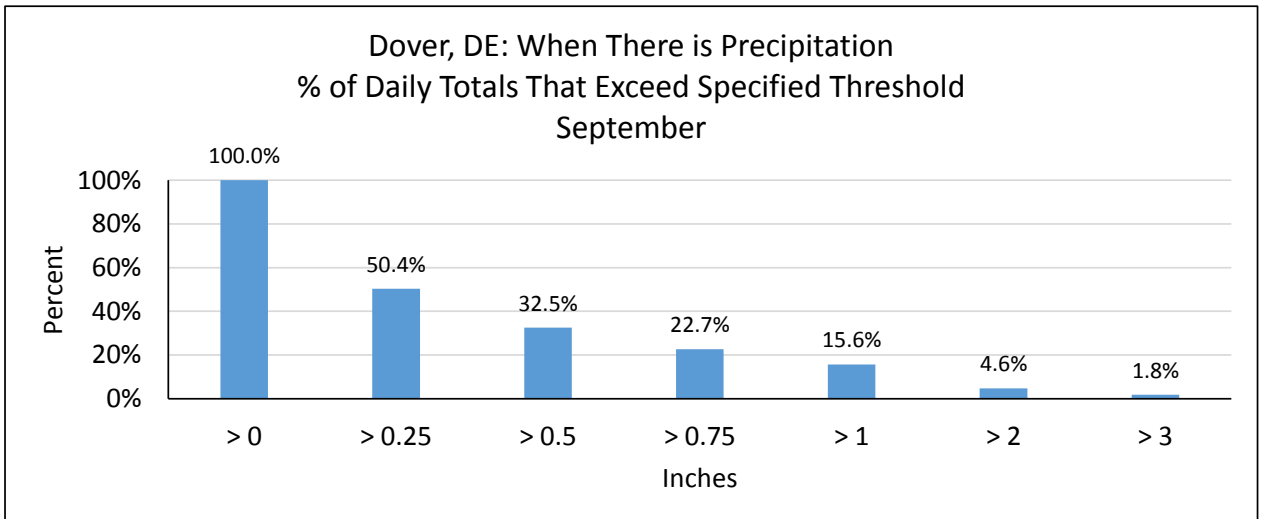
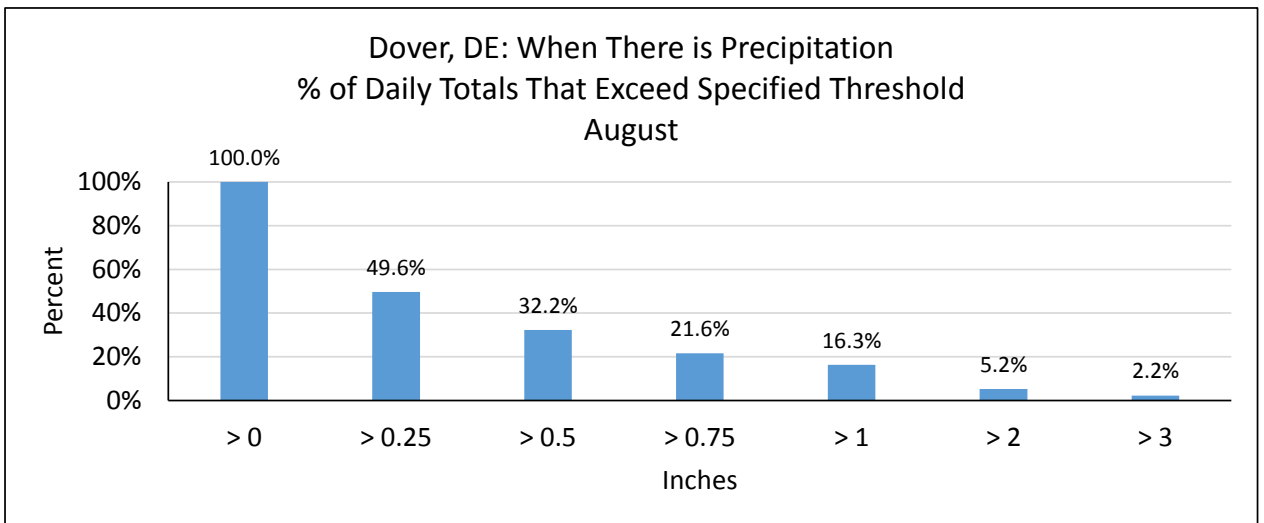
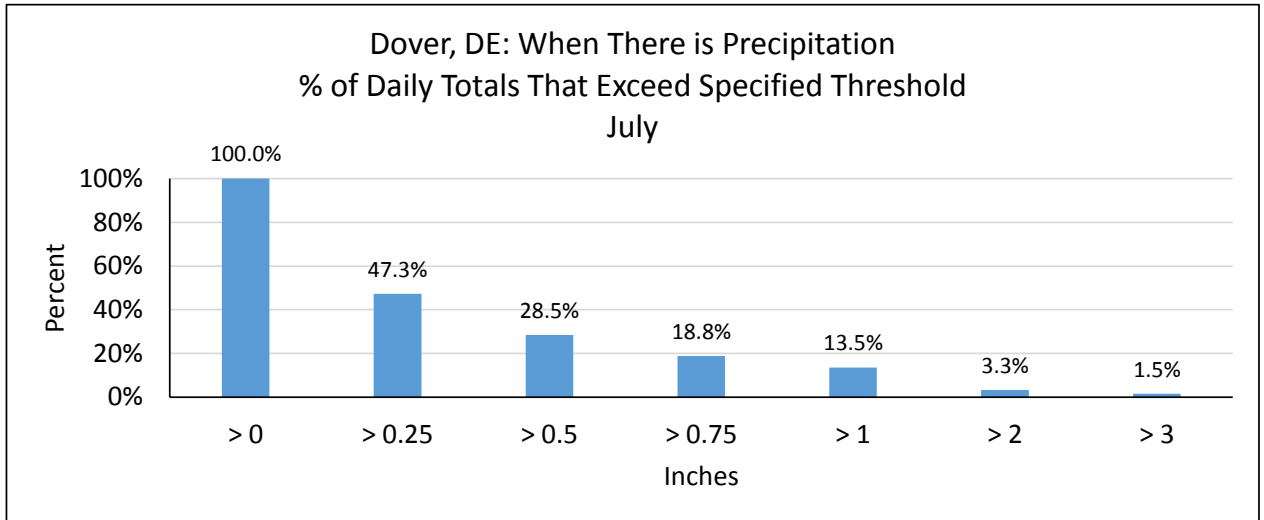
Thresholds of Daily Precipitation: January-March



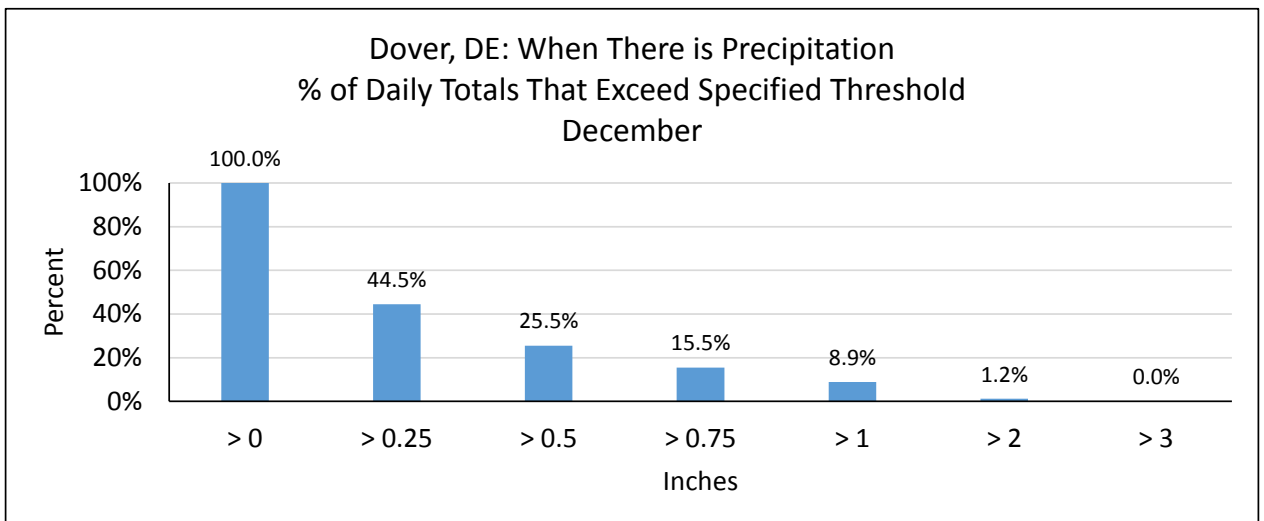
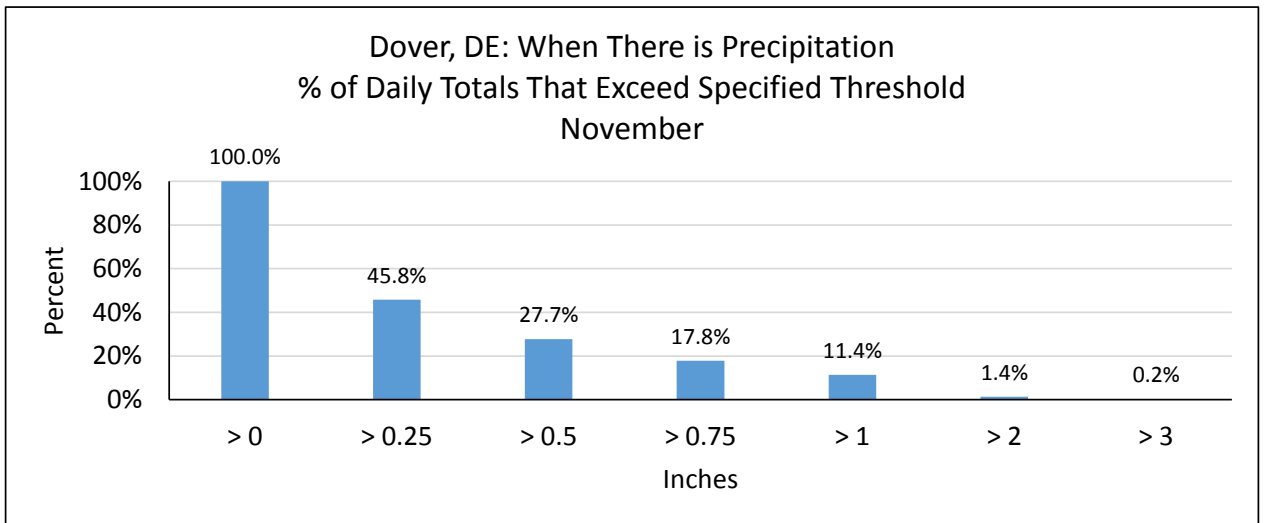
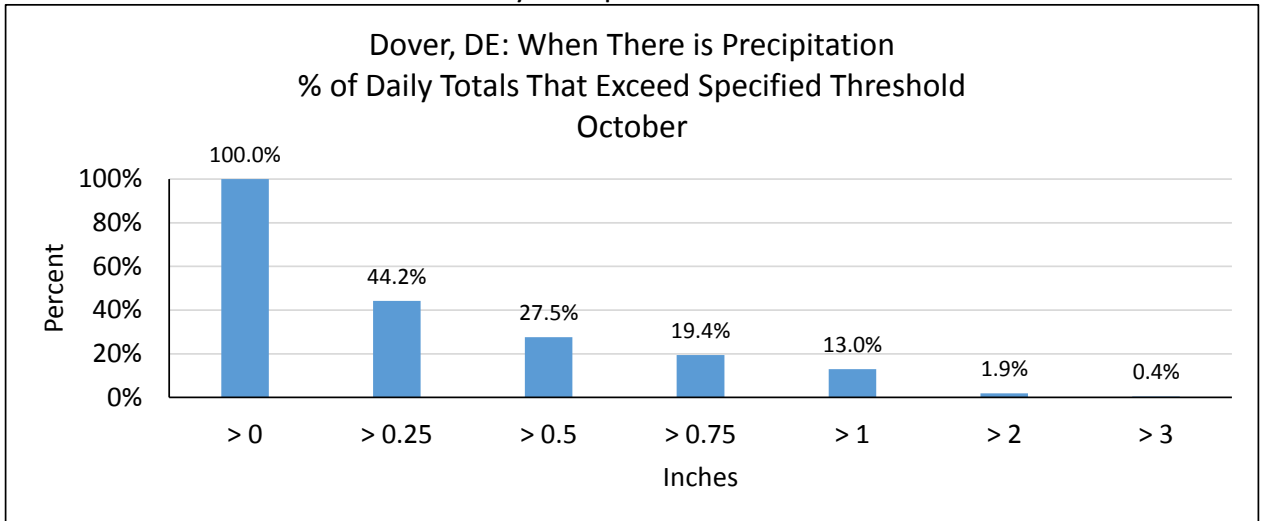
Thresholds of Daily Precipitation: April-June



Thresholds of Daily Precipitation: July-September

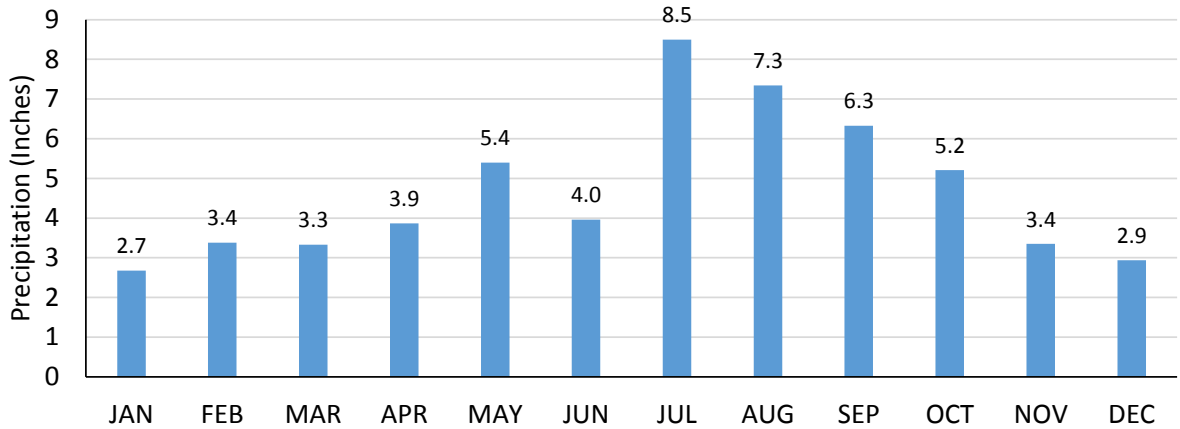


Thresholds of Daily Precipitation: October-December

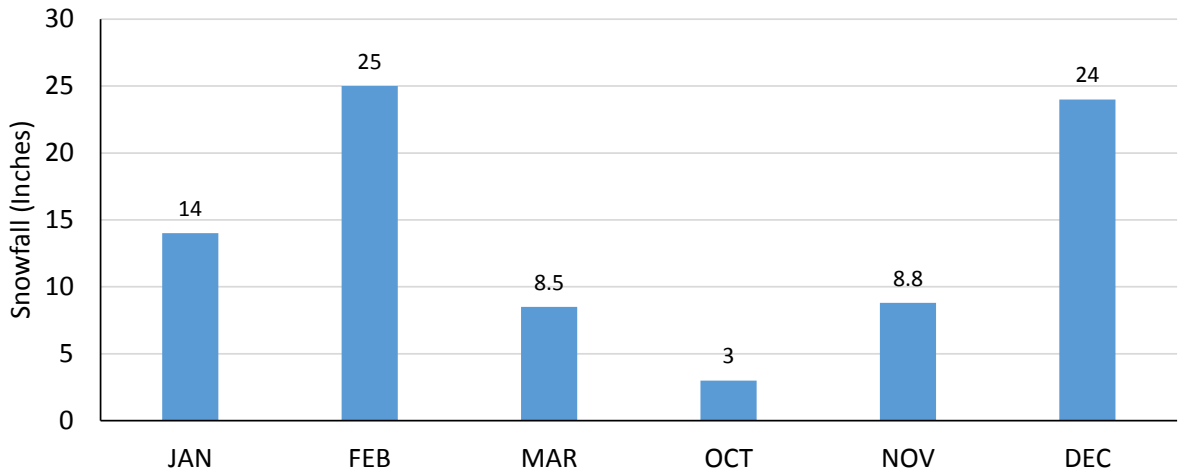


Highest Daily Precipitation Totals

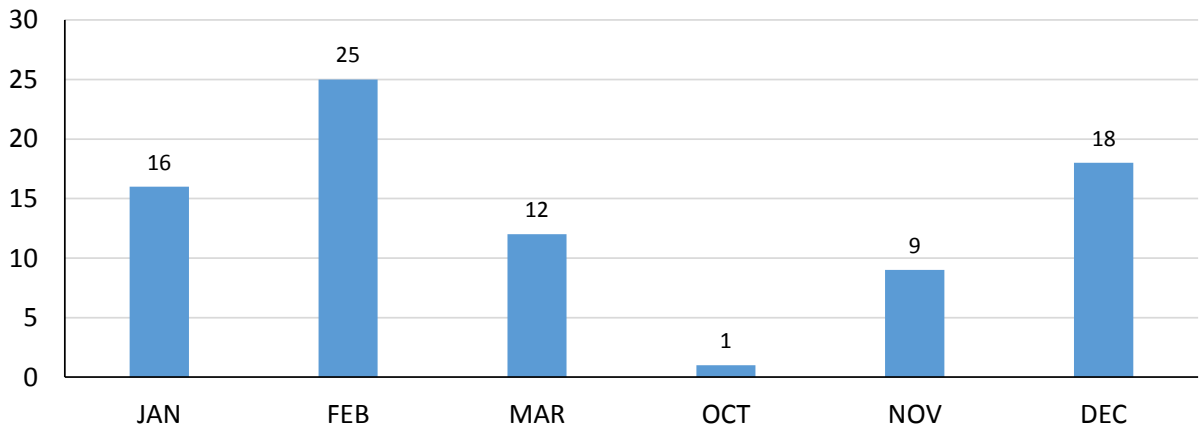
Highest Daily Precipitation Totals For Each Calendar Month



Highest Daily Snowfall Totals For Each Calendar Month

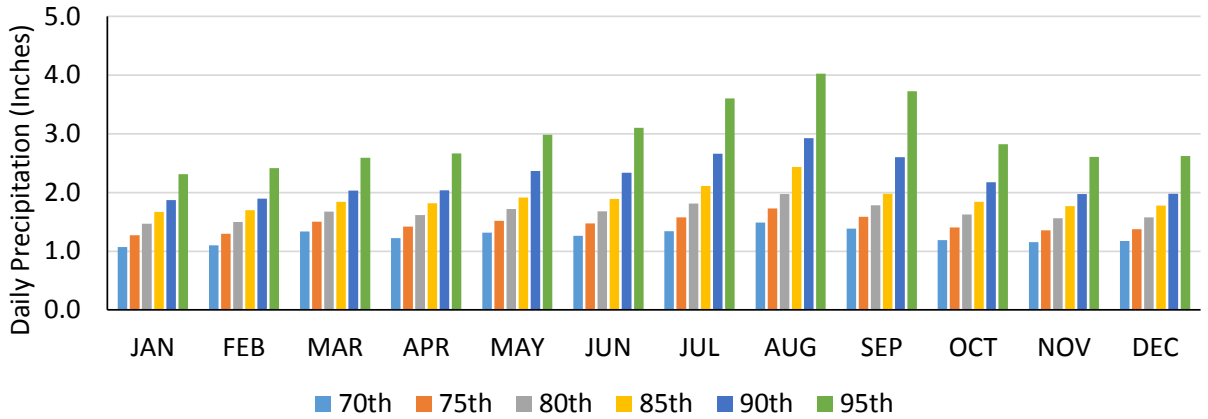


Record Daily Snow Depth For Each Calendar Month

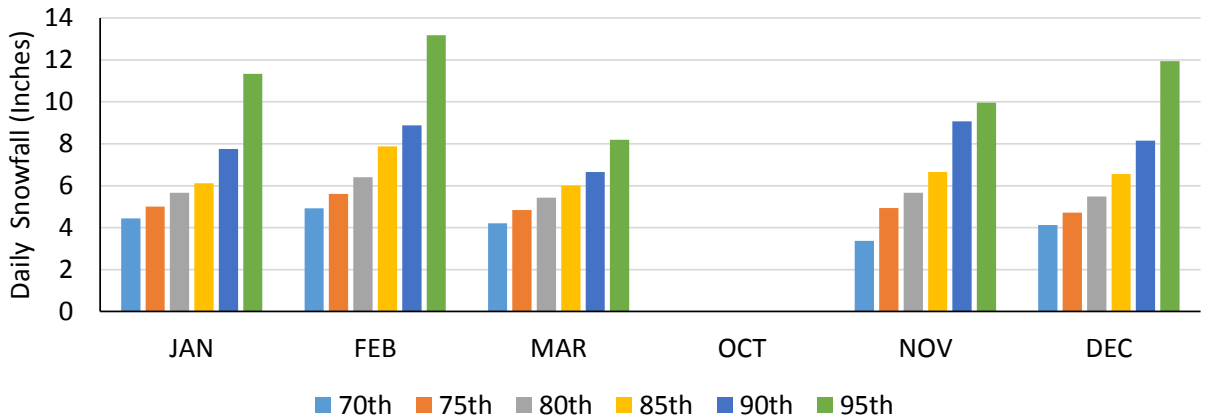


Percentiles of Weekly Precipitation, Snowfall, and Snow Depth

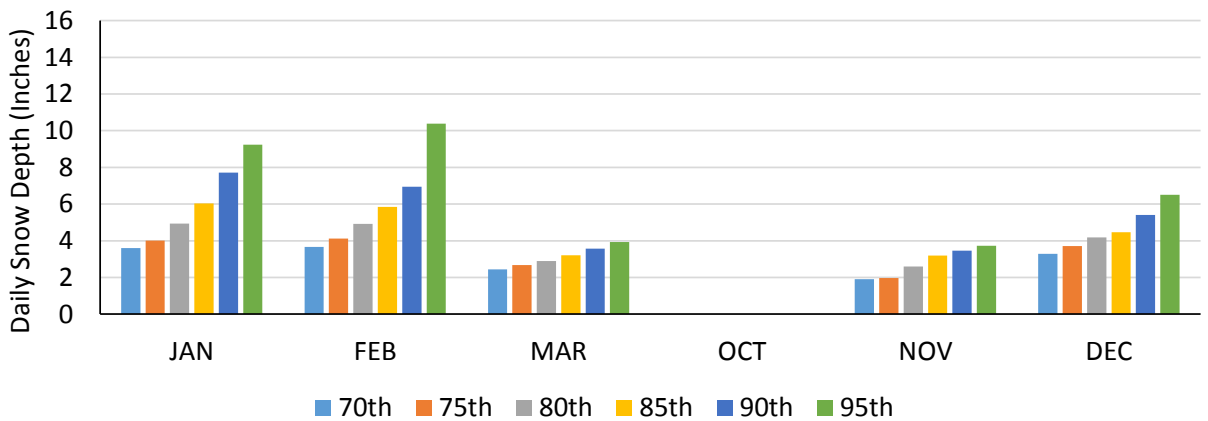
Dover, DE: 7-Day Precipitation Percentiles When It Does Rain



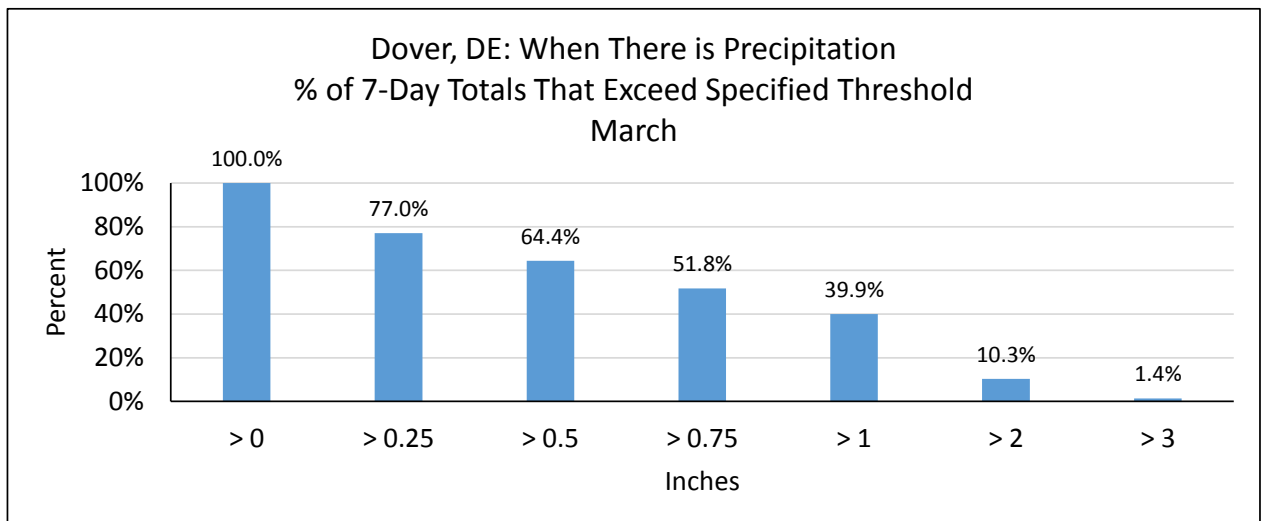
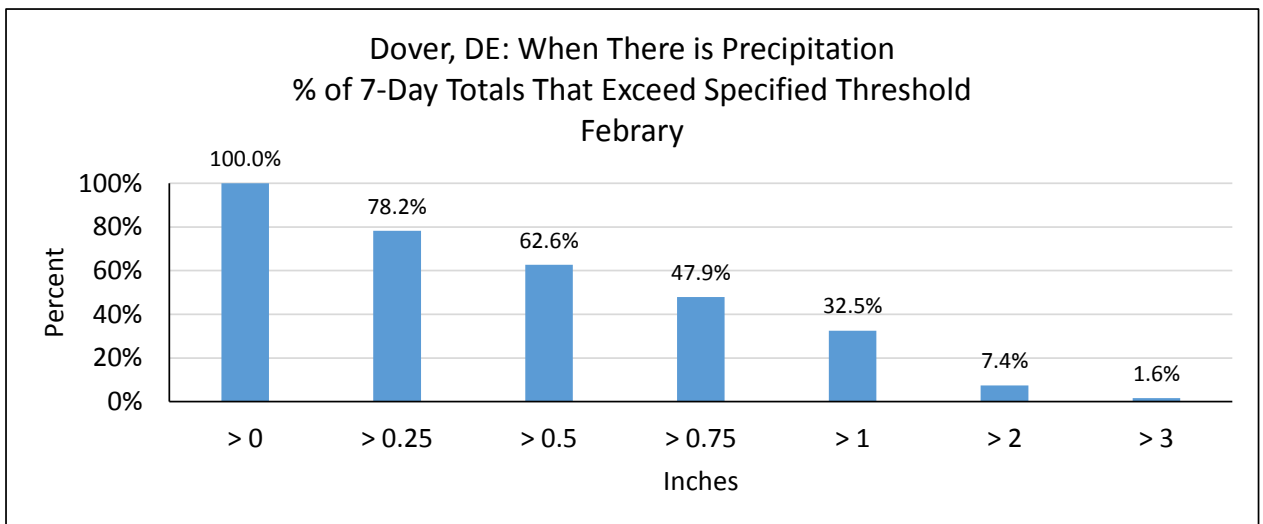
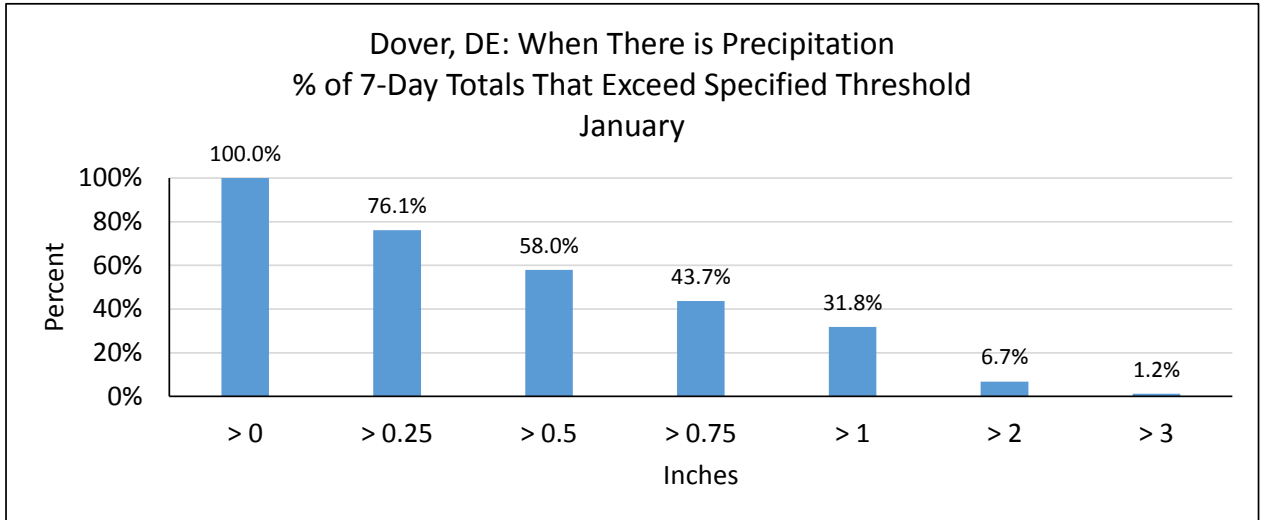
Dover, DE: 7-Day Snowfall Percentiles When It Does Snow



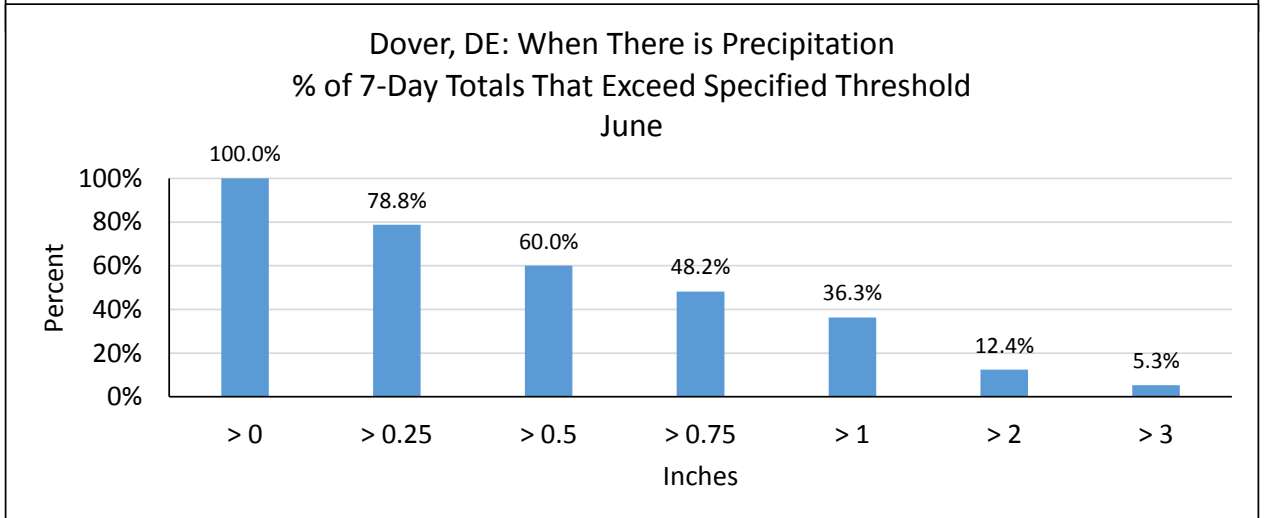
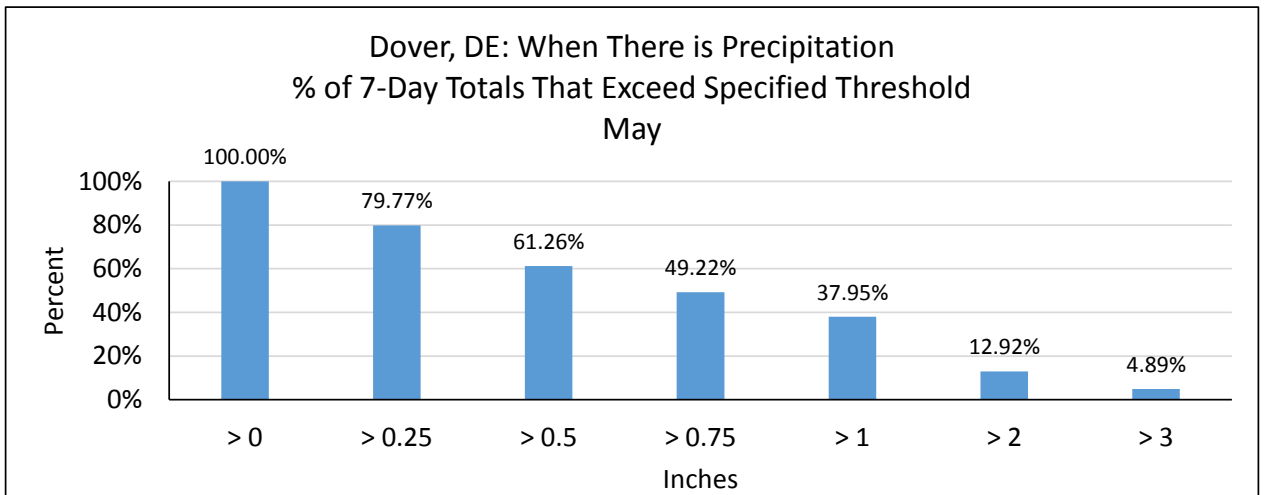
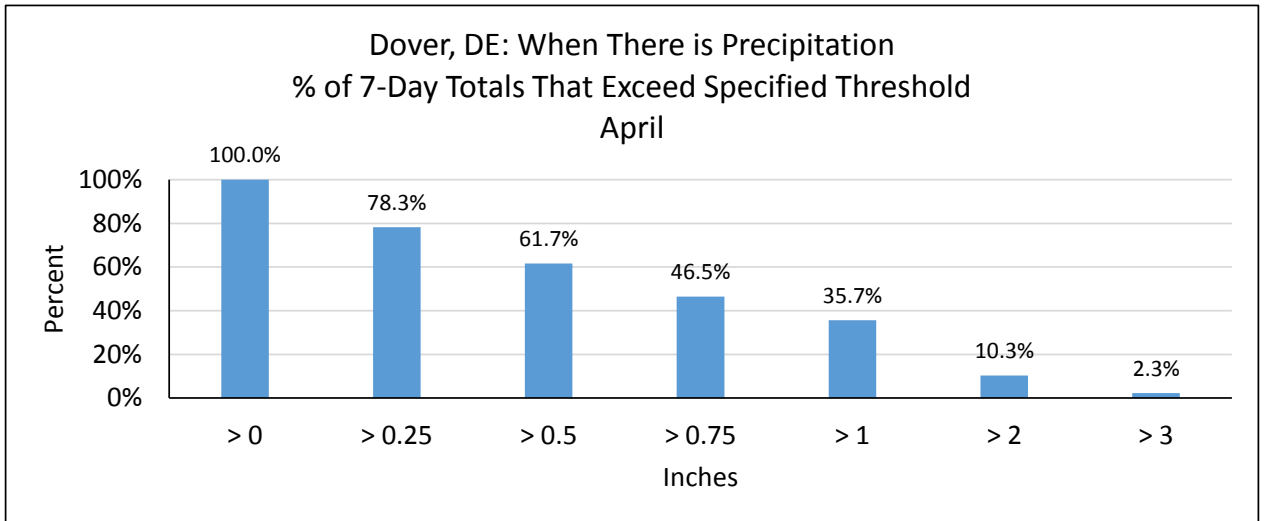
Dover, DE: 7-Day Snow Depth Percentiles When There is Snow Cover



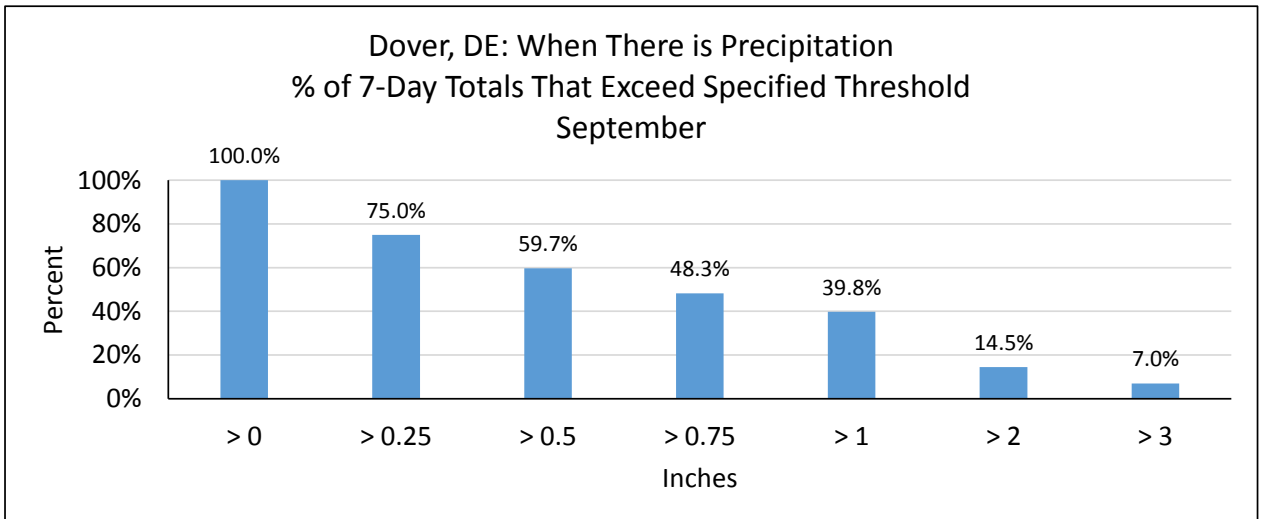
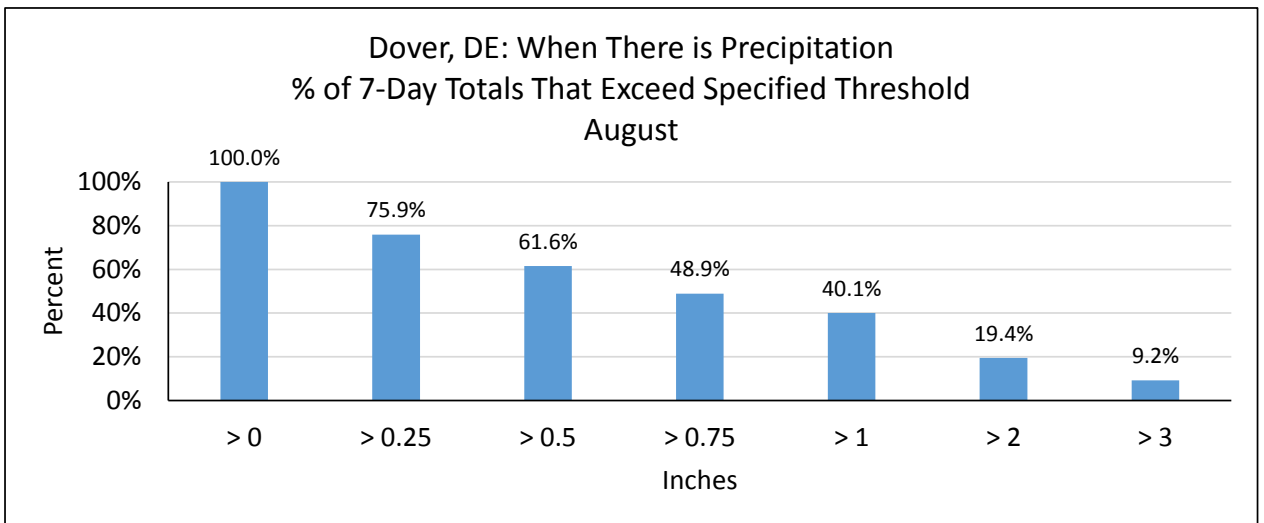
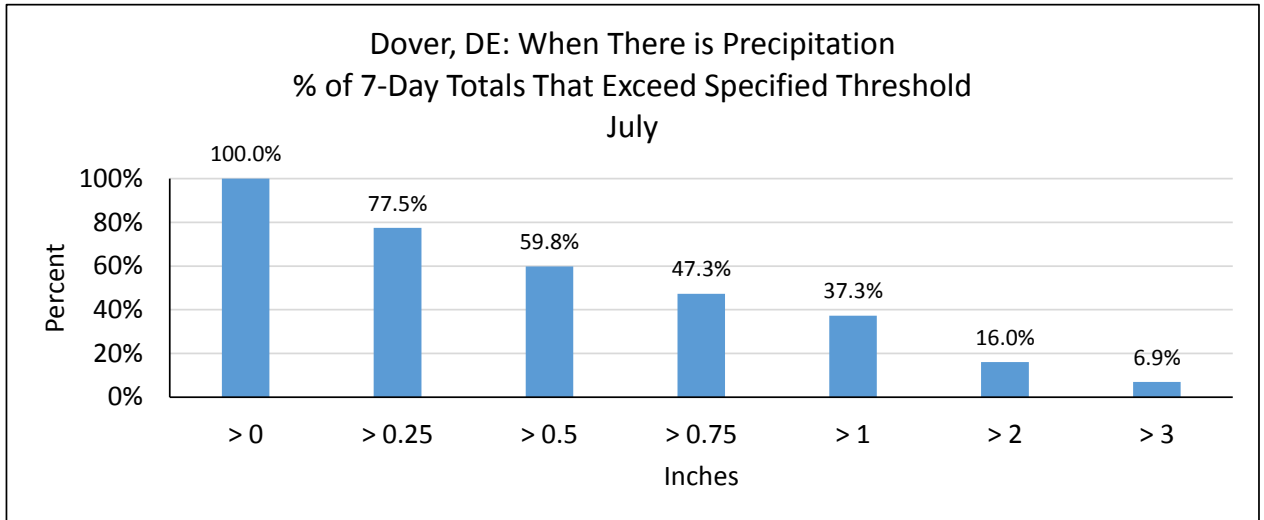
Thresholds of Weekly Precipitation: January-March



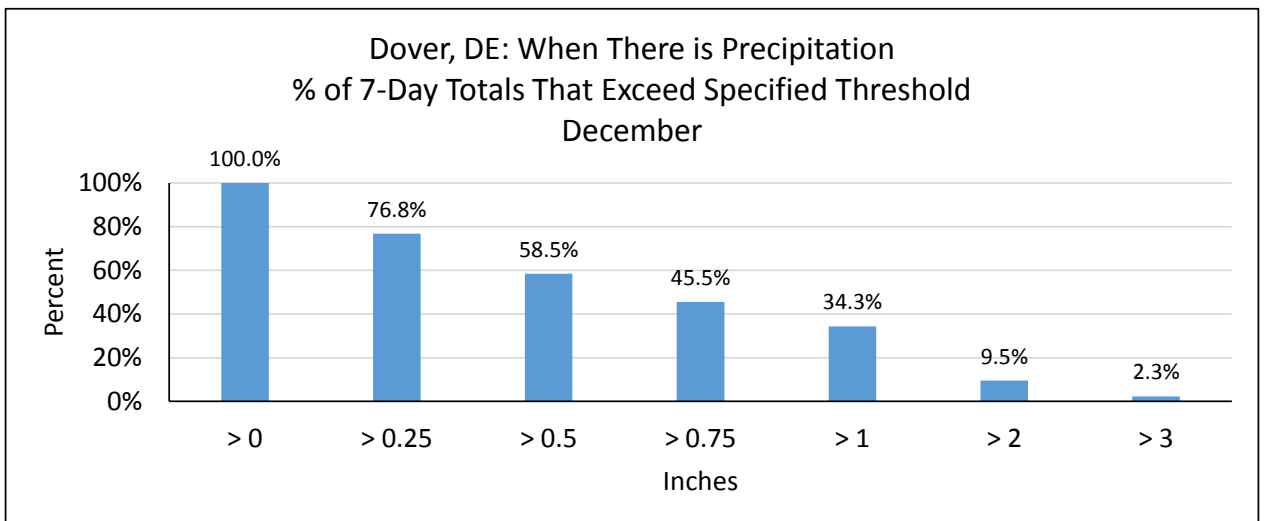
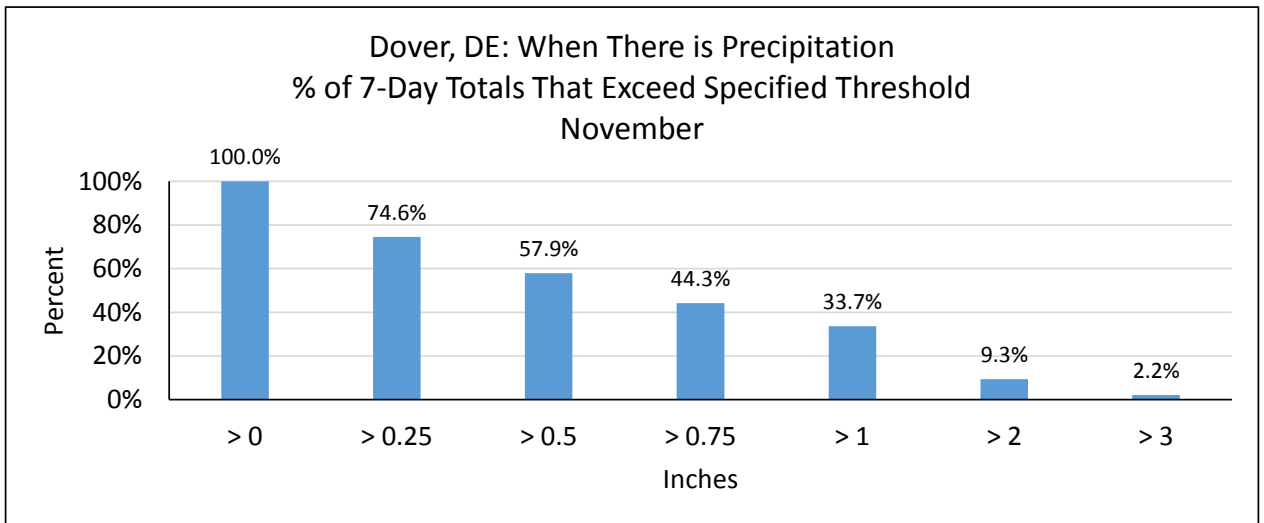
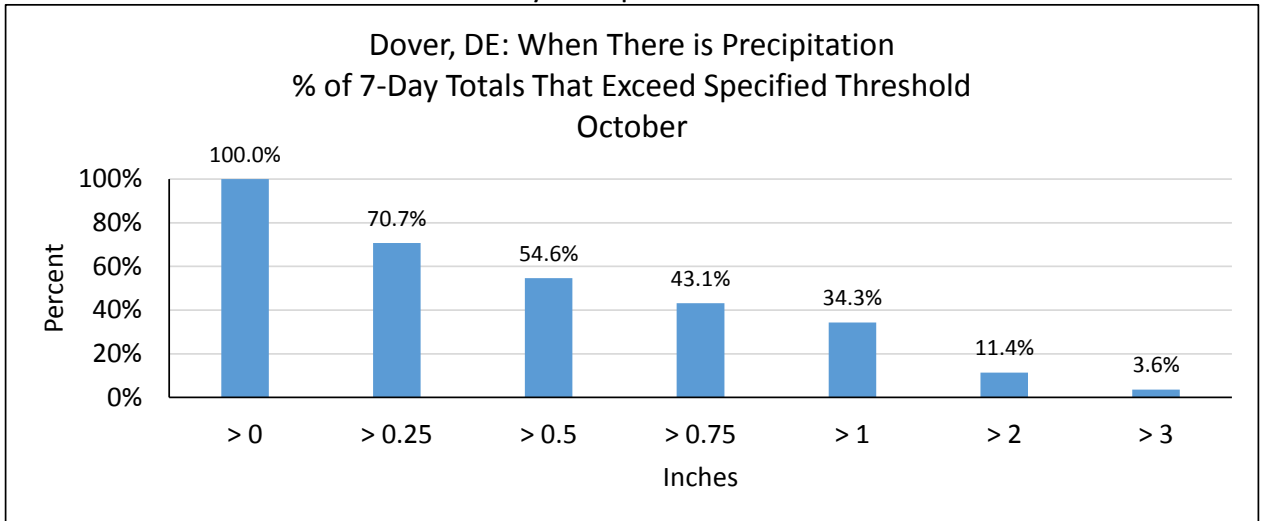
Thresholds of Weekly Precipitation: April-June



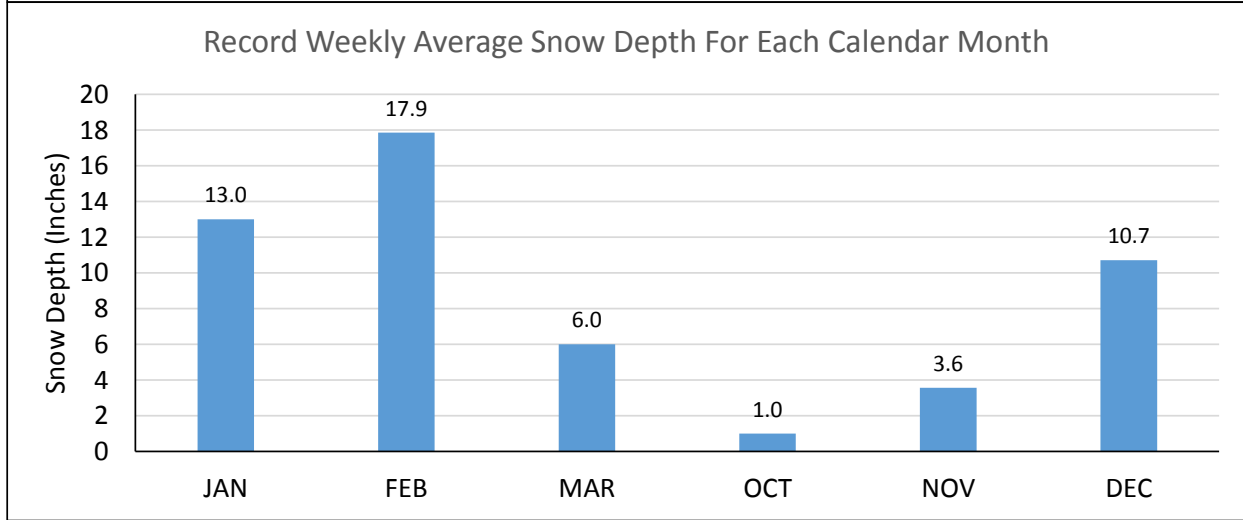
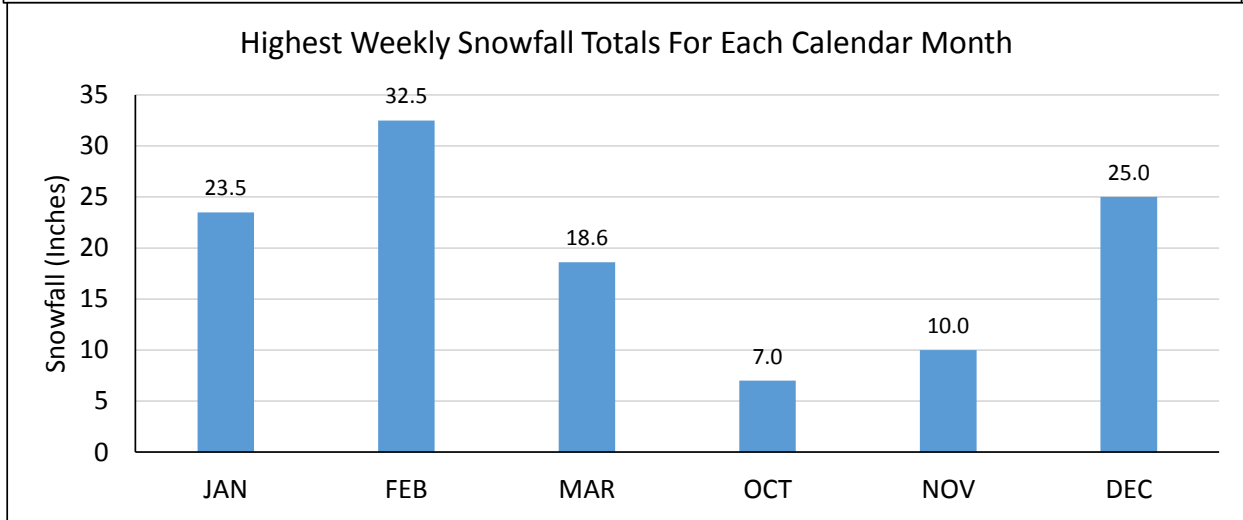
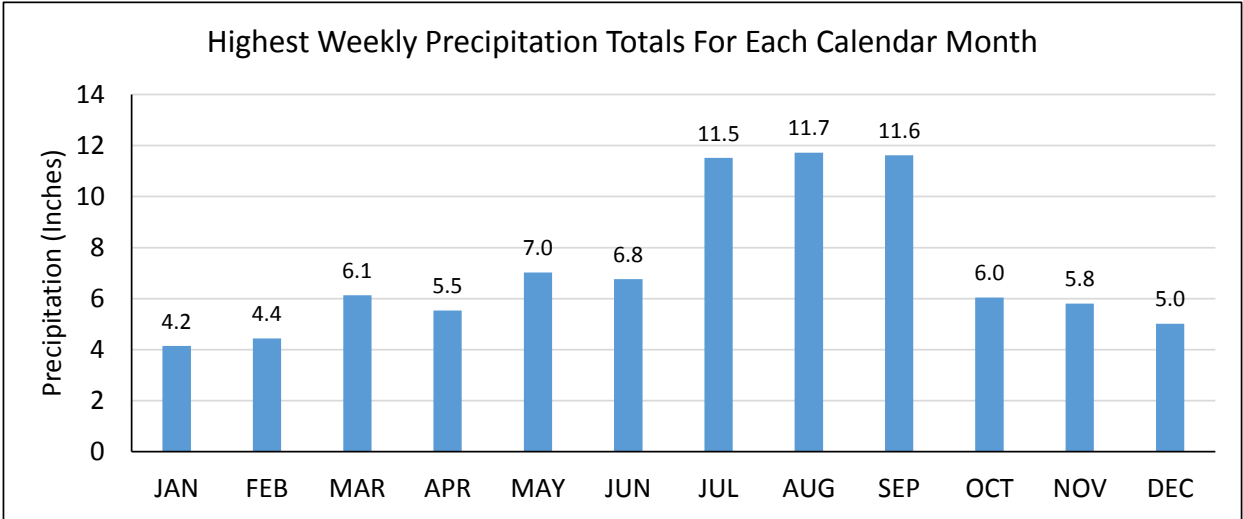
Thresholds of Weekly Precipitation: July-September



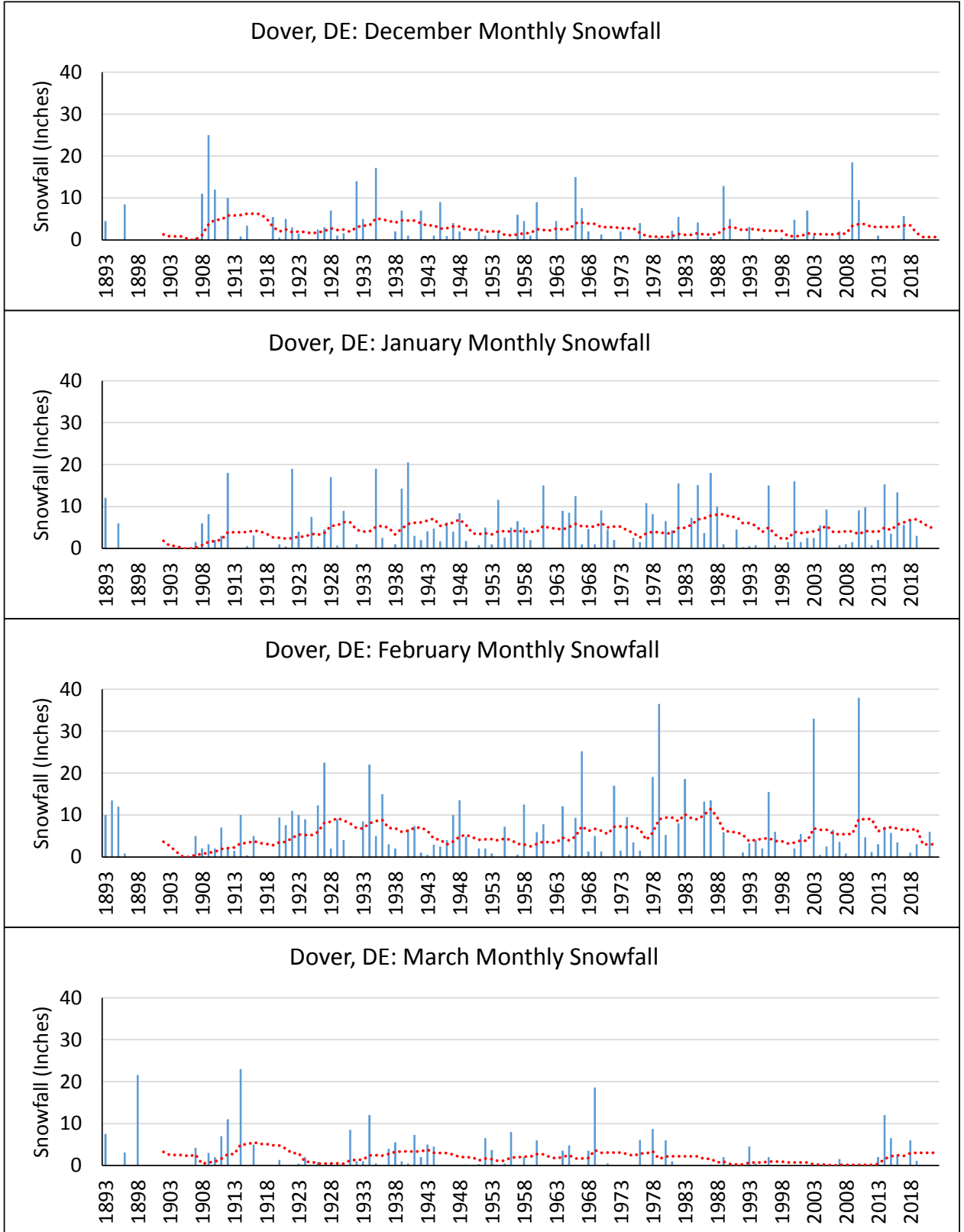
Thresholds of Weekly Precipitation: October-December



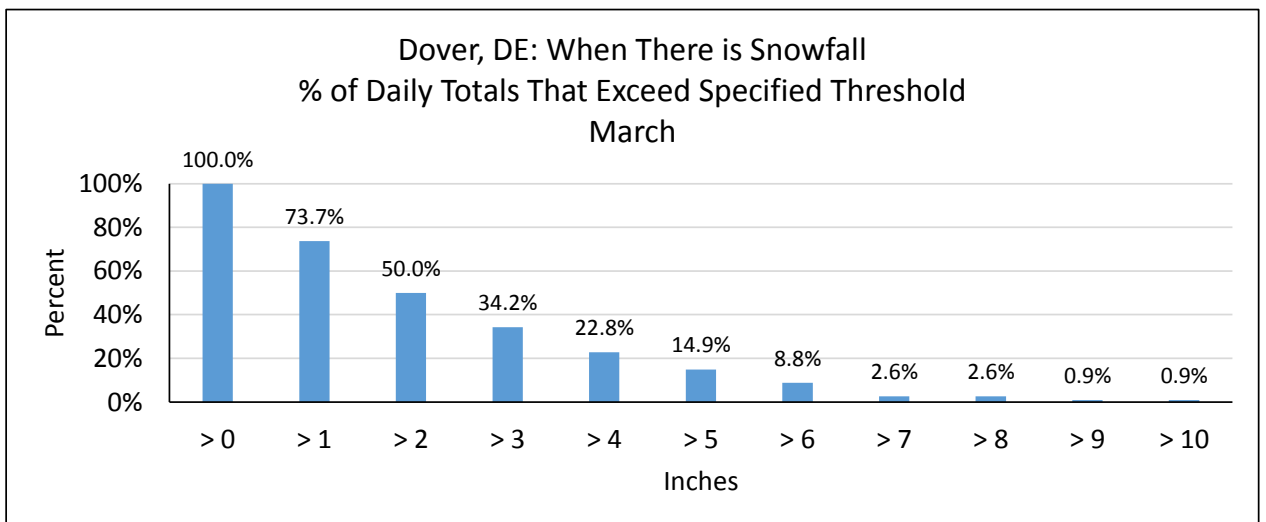
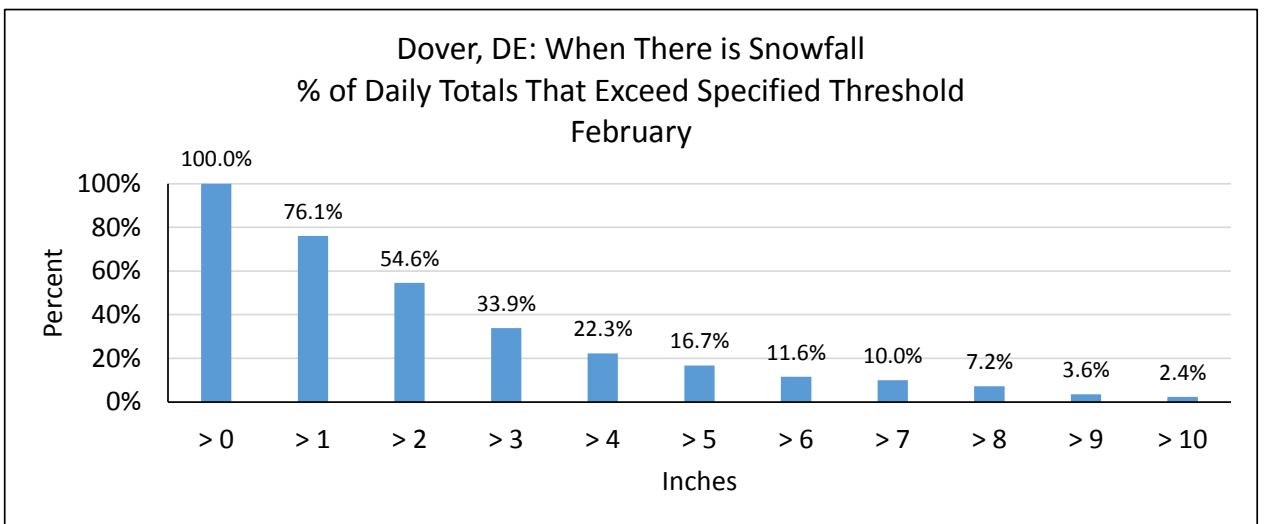
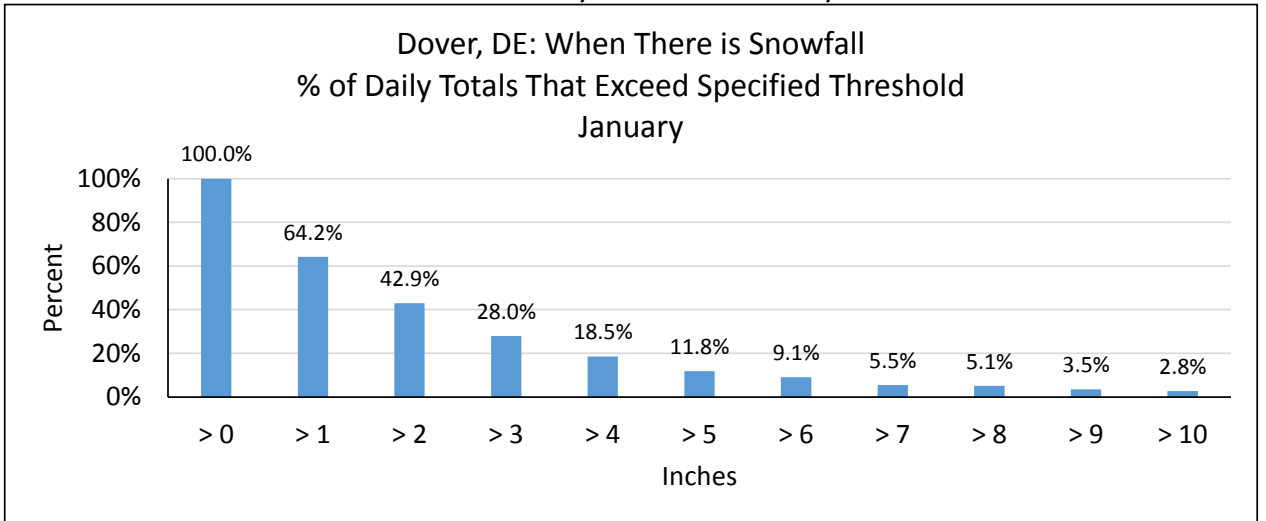
Highest Weekly Precipitation Totals



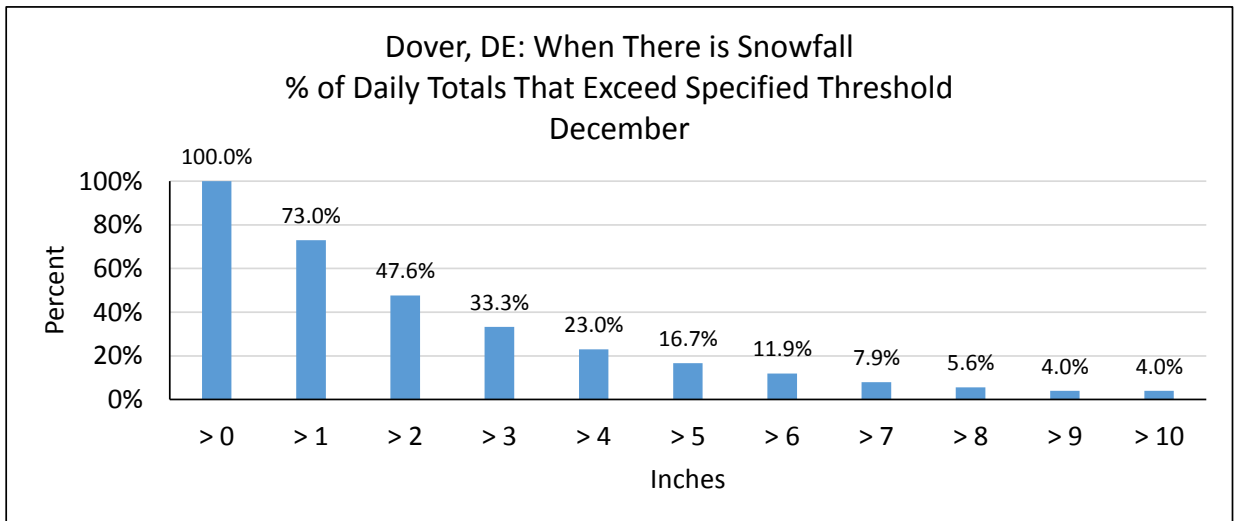
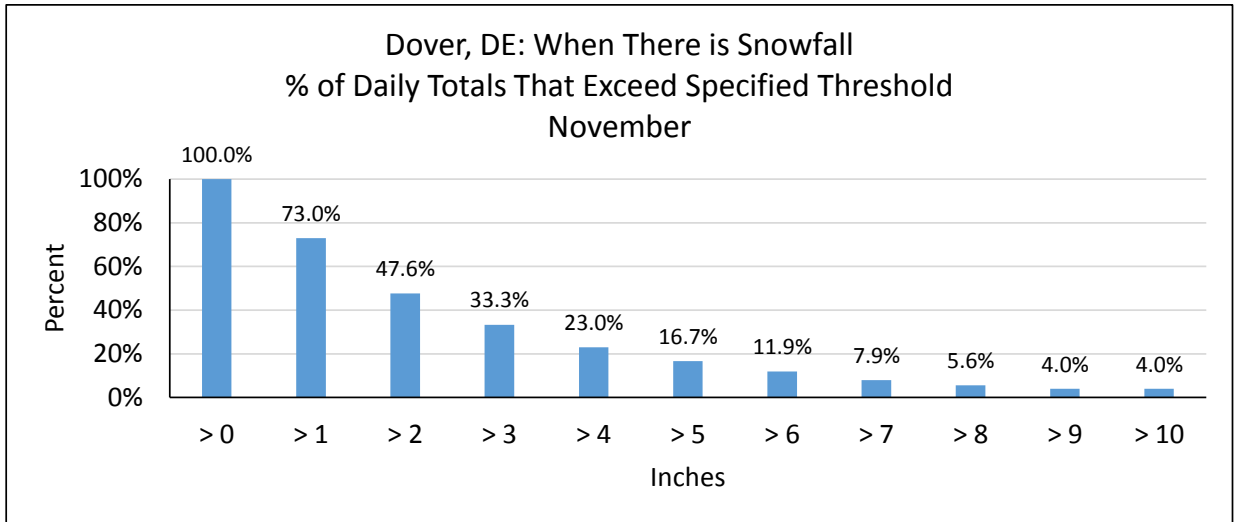
Time Series of Monthly Snowfall Totals: December-March



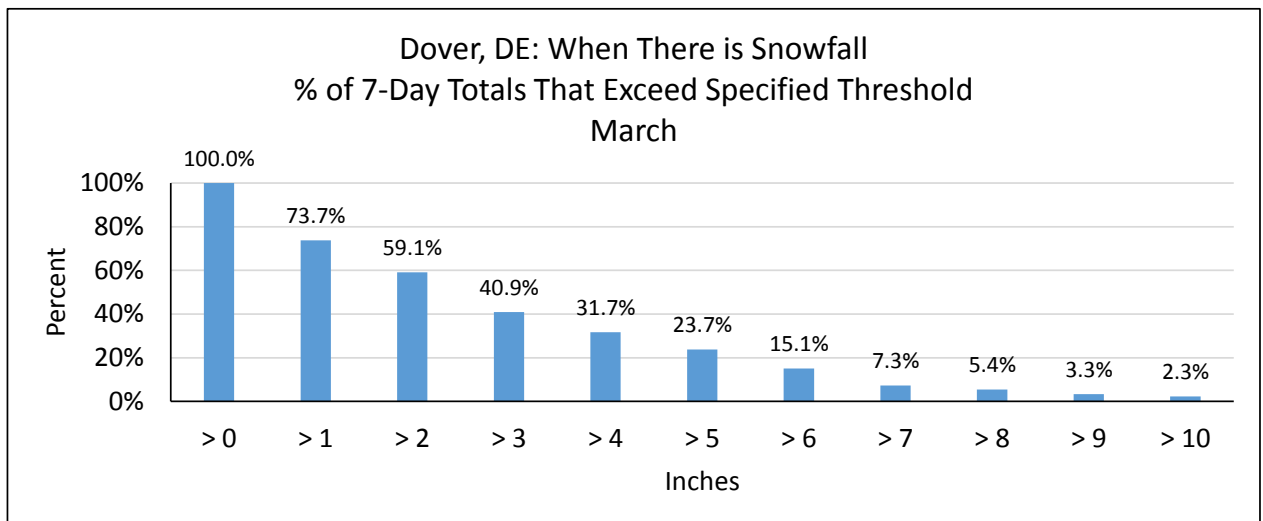
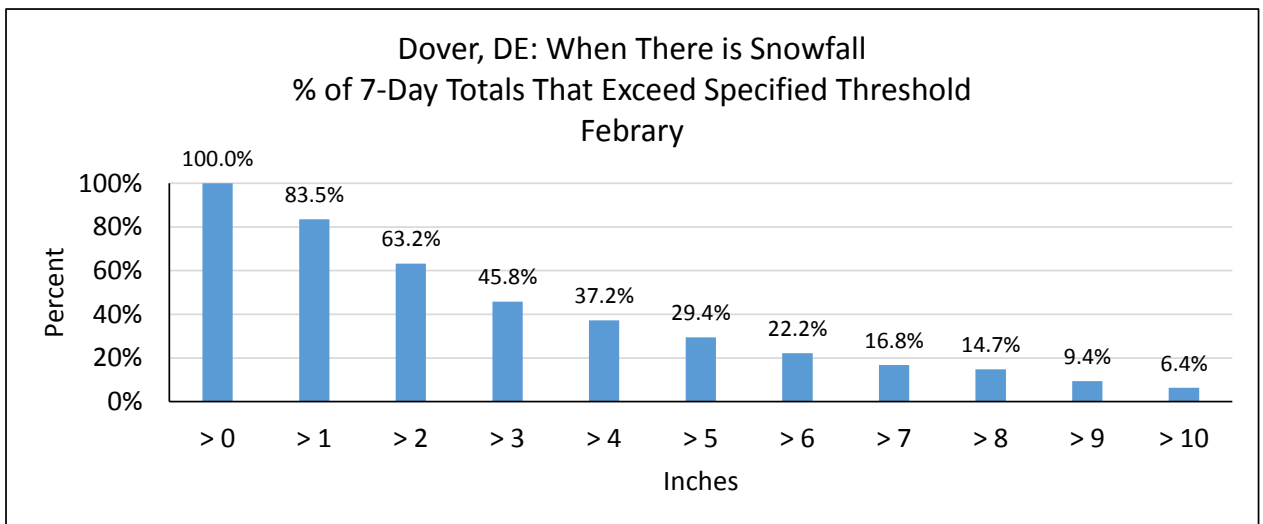
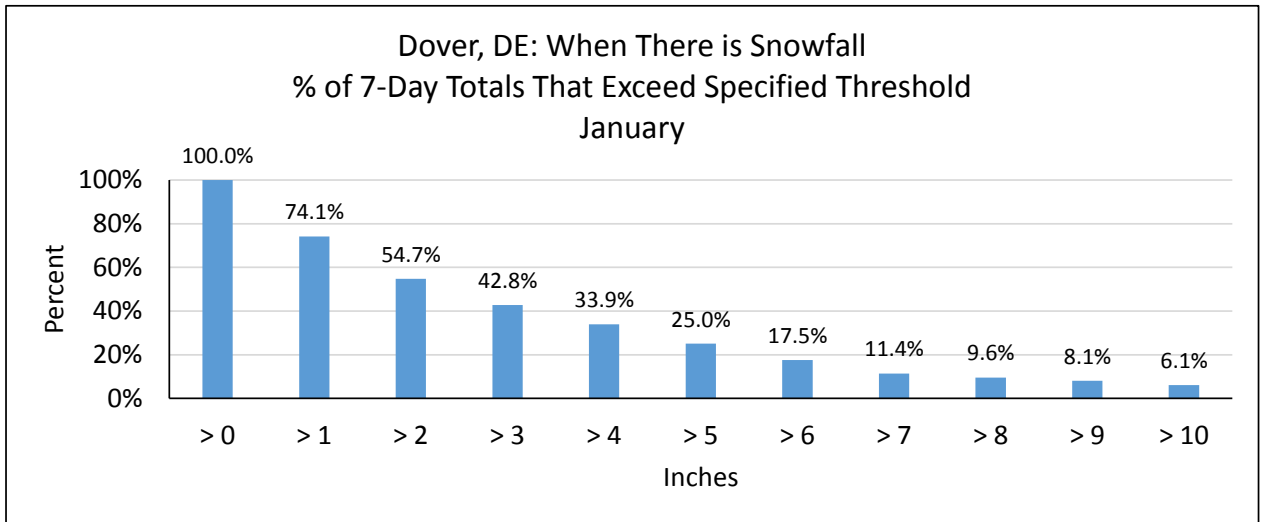
Thresholds of Daily Snowfall: January-March



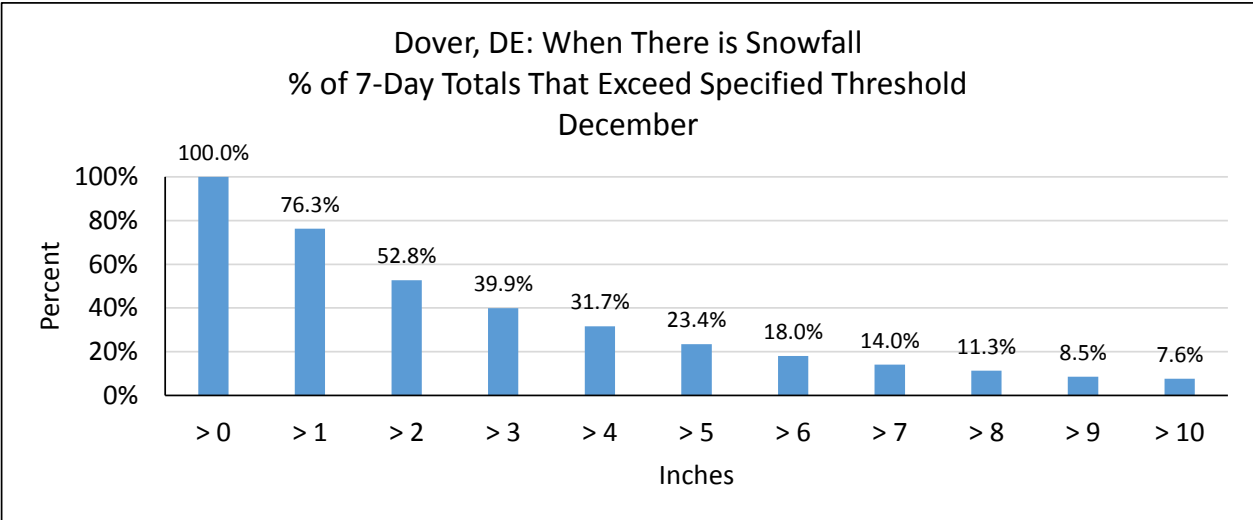
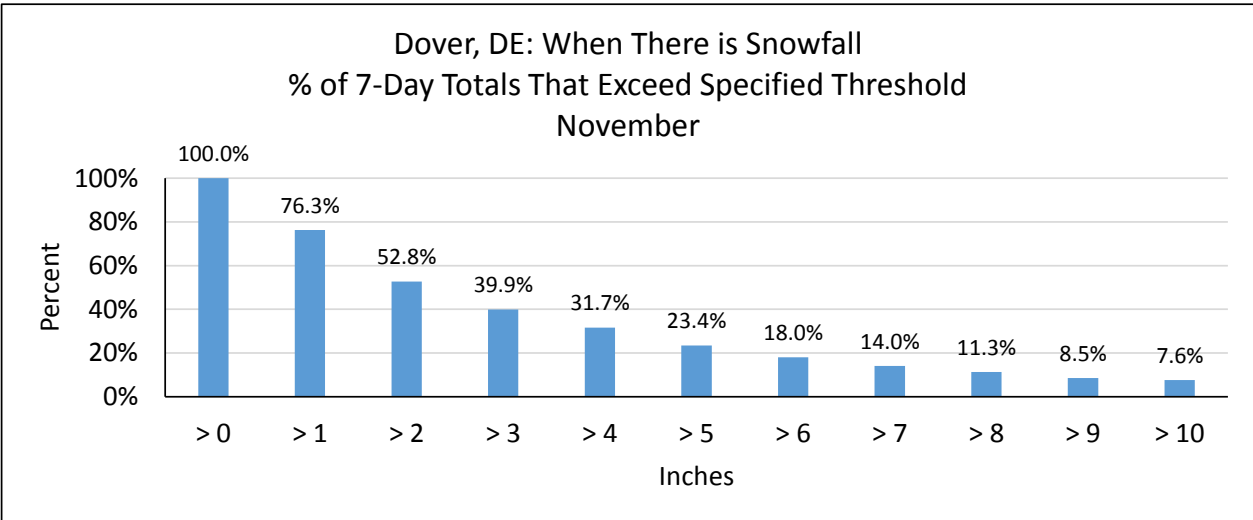
Thresholds of Daily Snowfall: November-December



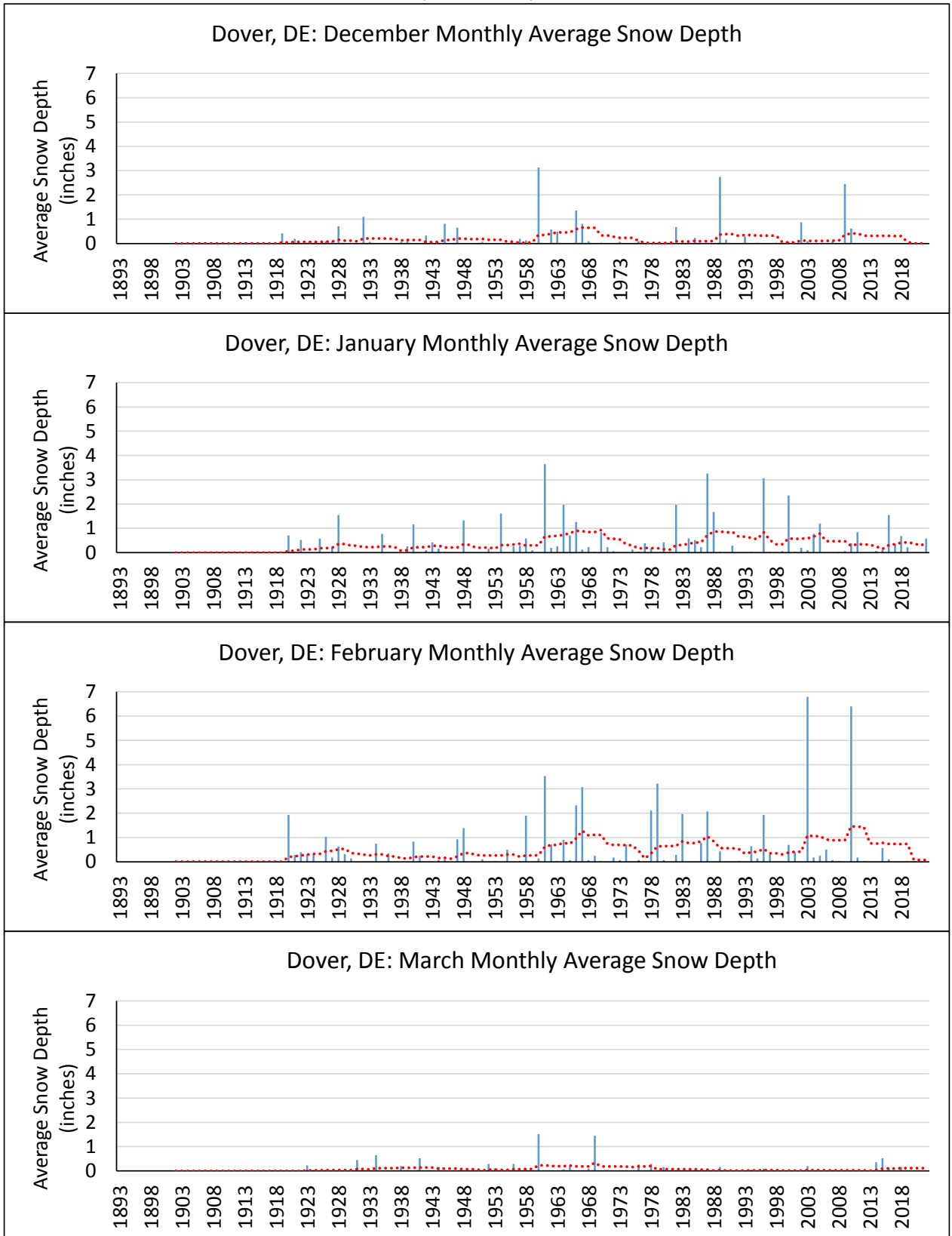
Thresholds of Weekly Snowfall: January-March



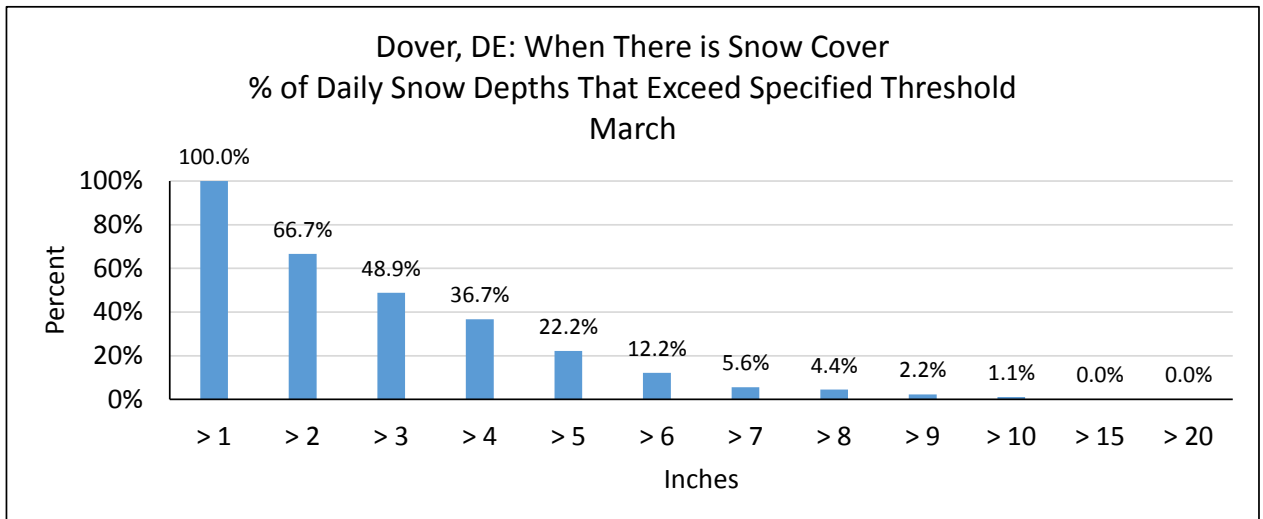
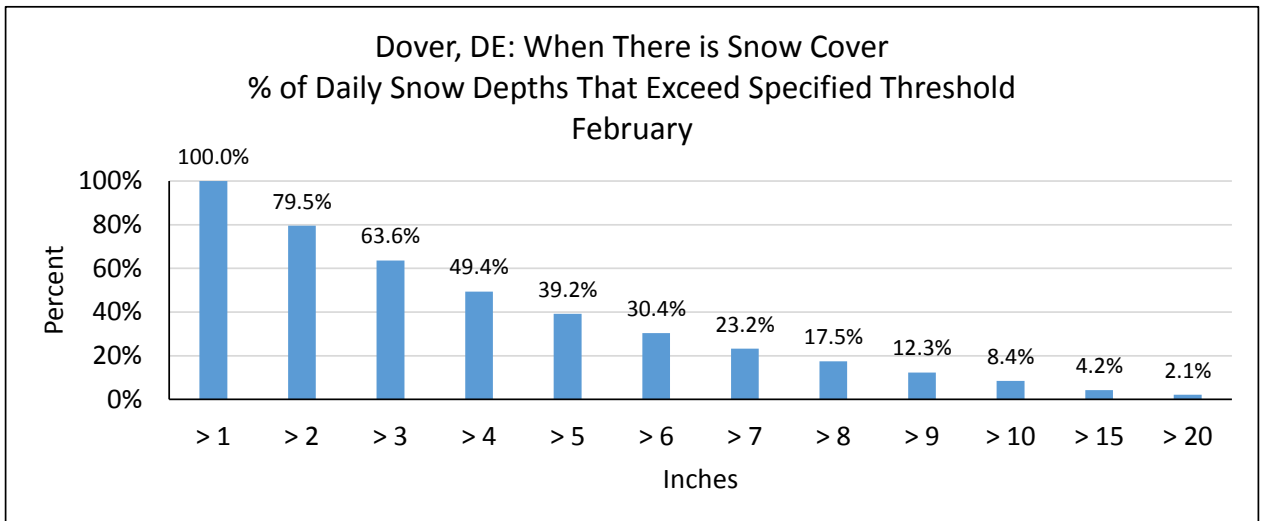
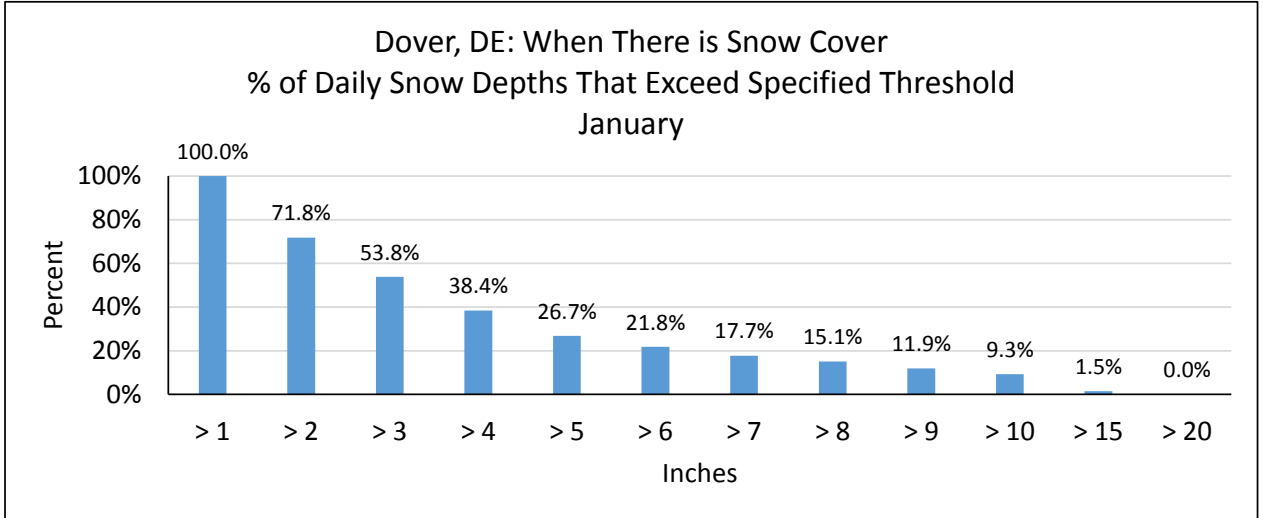
Thresholds of Weekly Snowfall: November-December



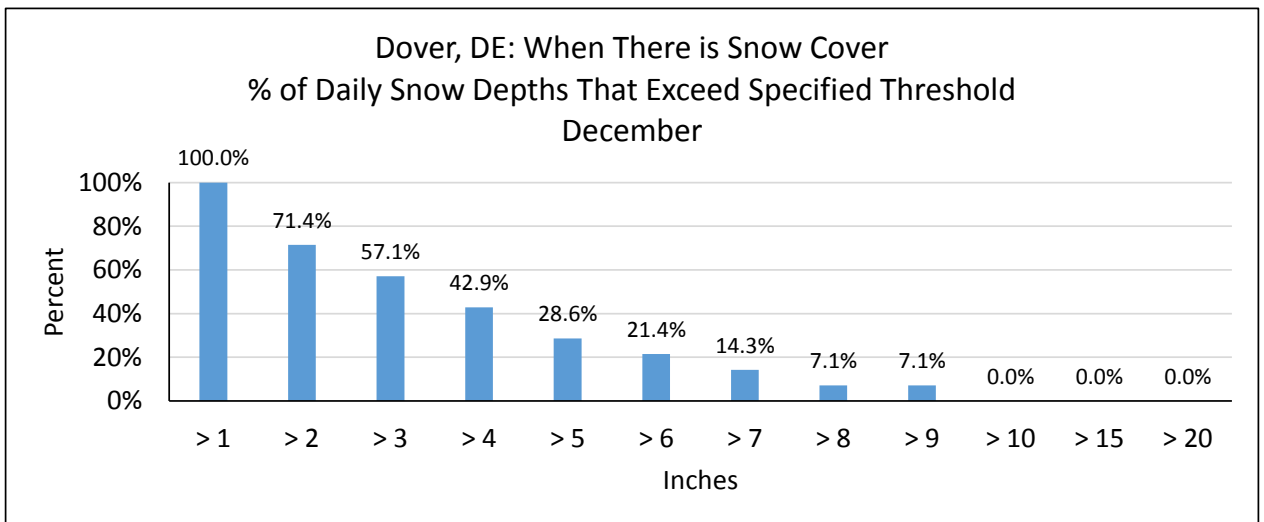
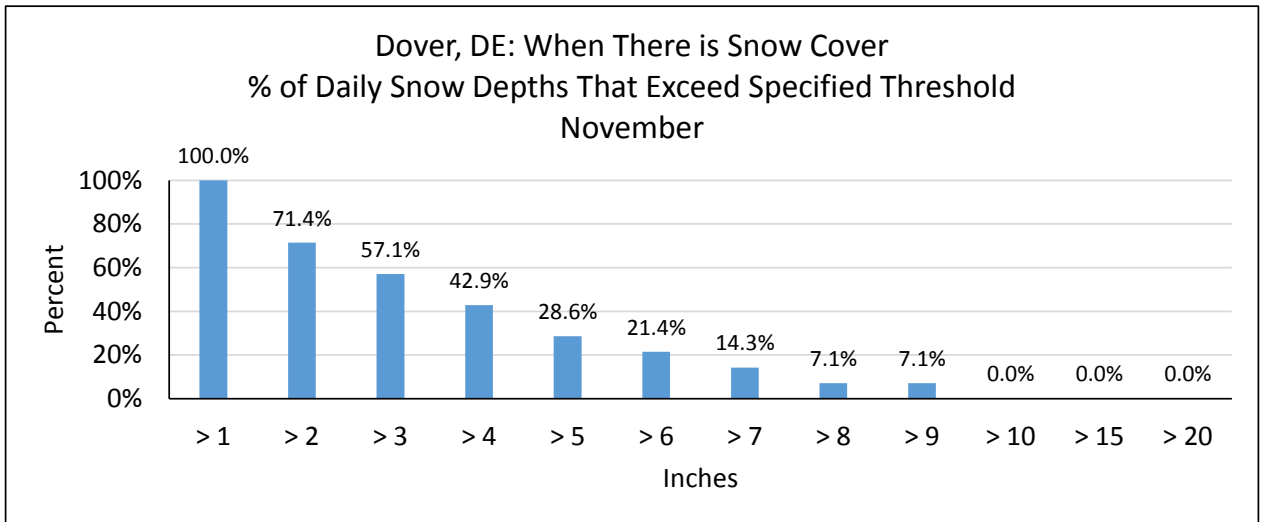
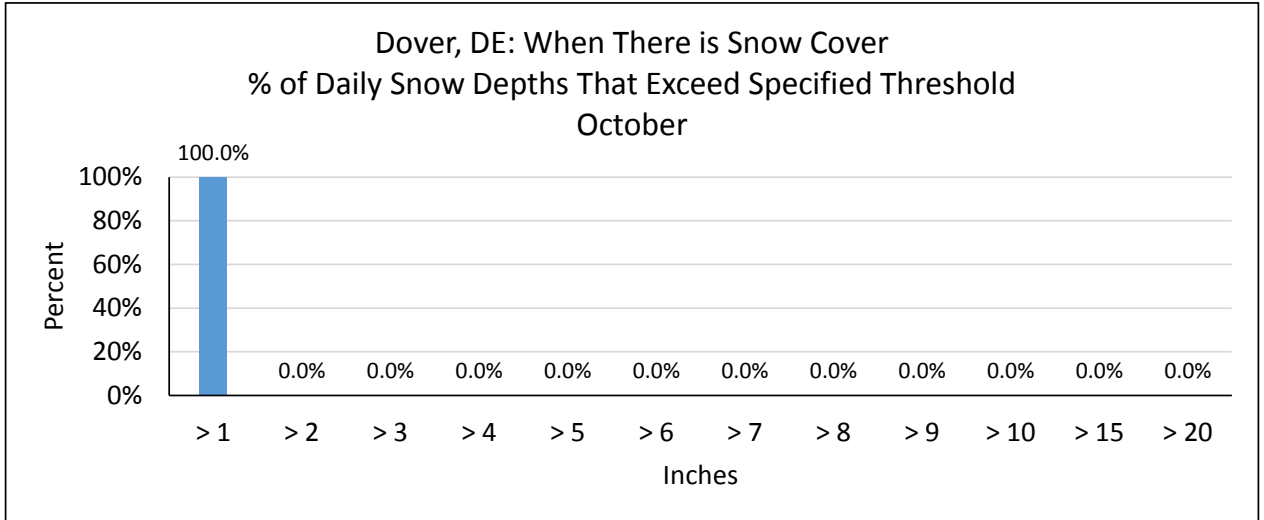
Time Series of Monthly Snow Depth: December-March



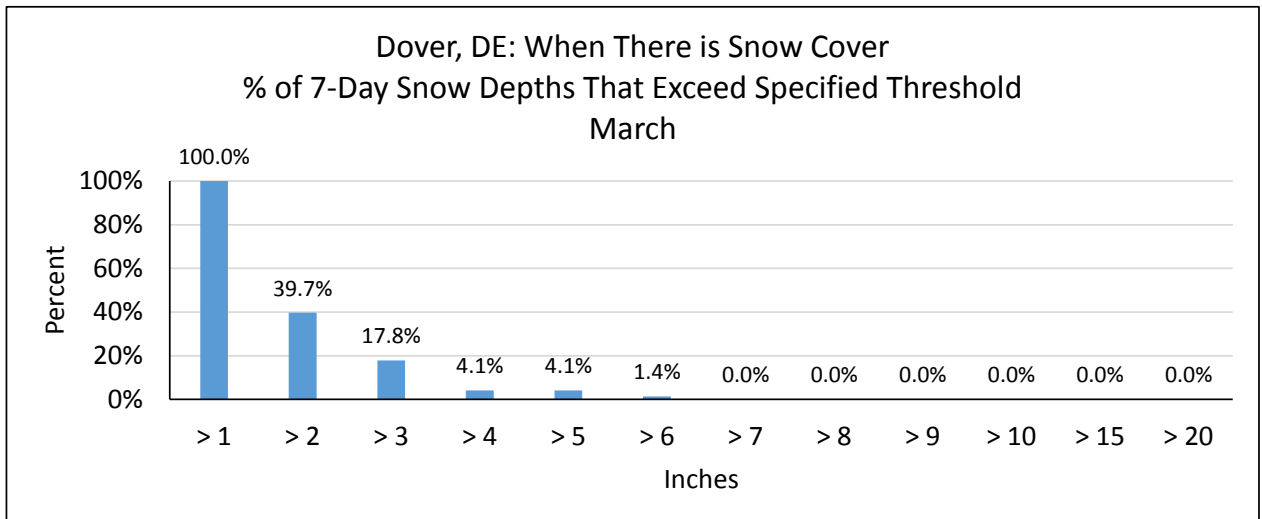
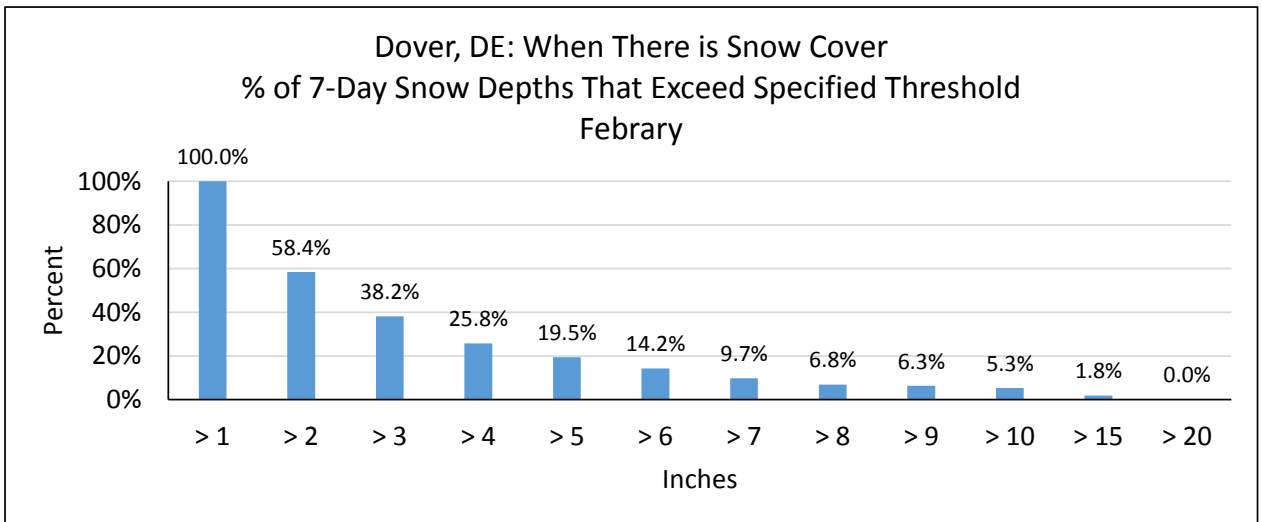
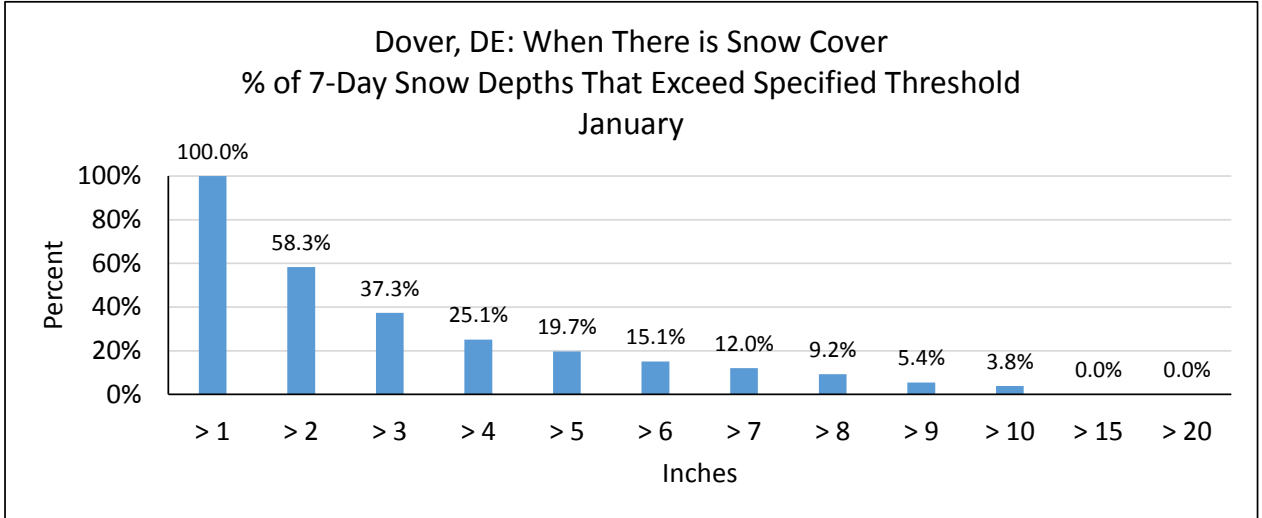
Thresholds of Daily Snow Depth: January-March



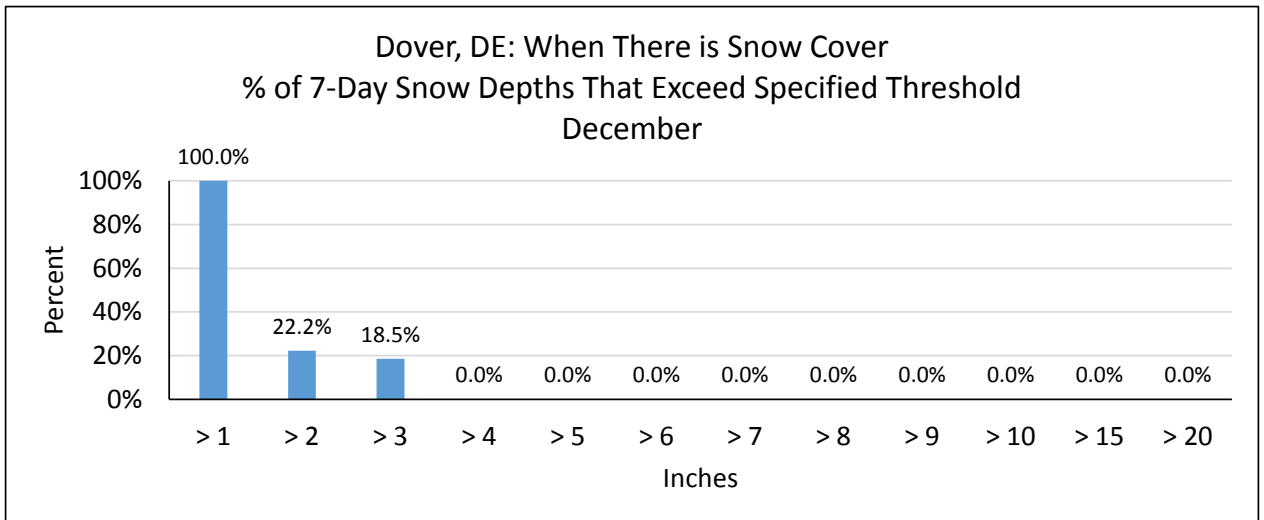
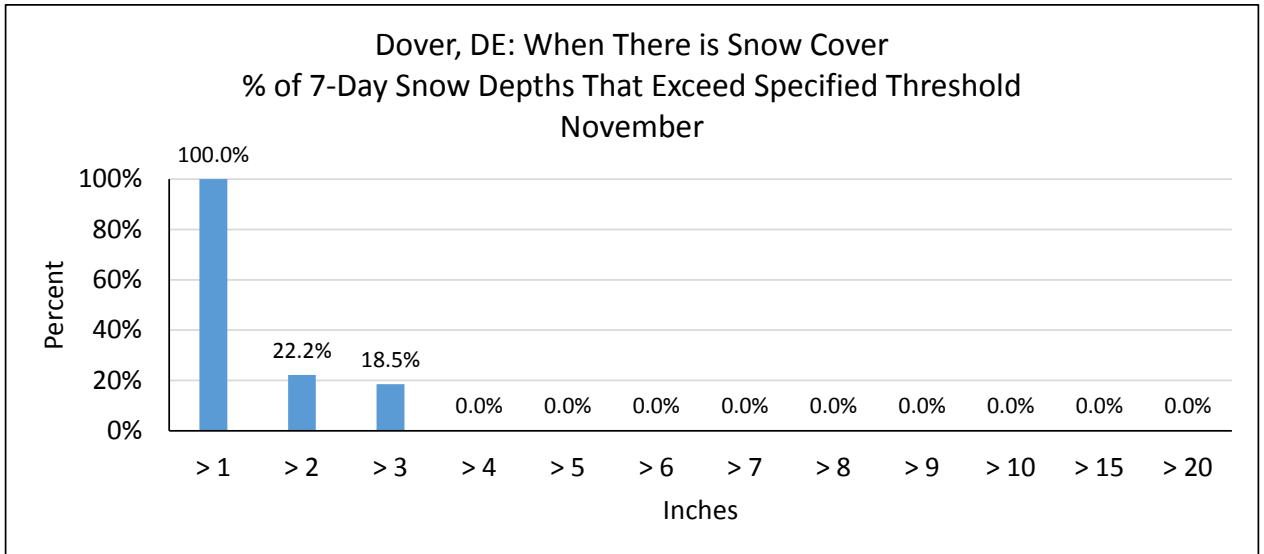
Thresholds of Daily Snow Depth: October-December



Thresholds of Weekly Snow Depth: January-March

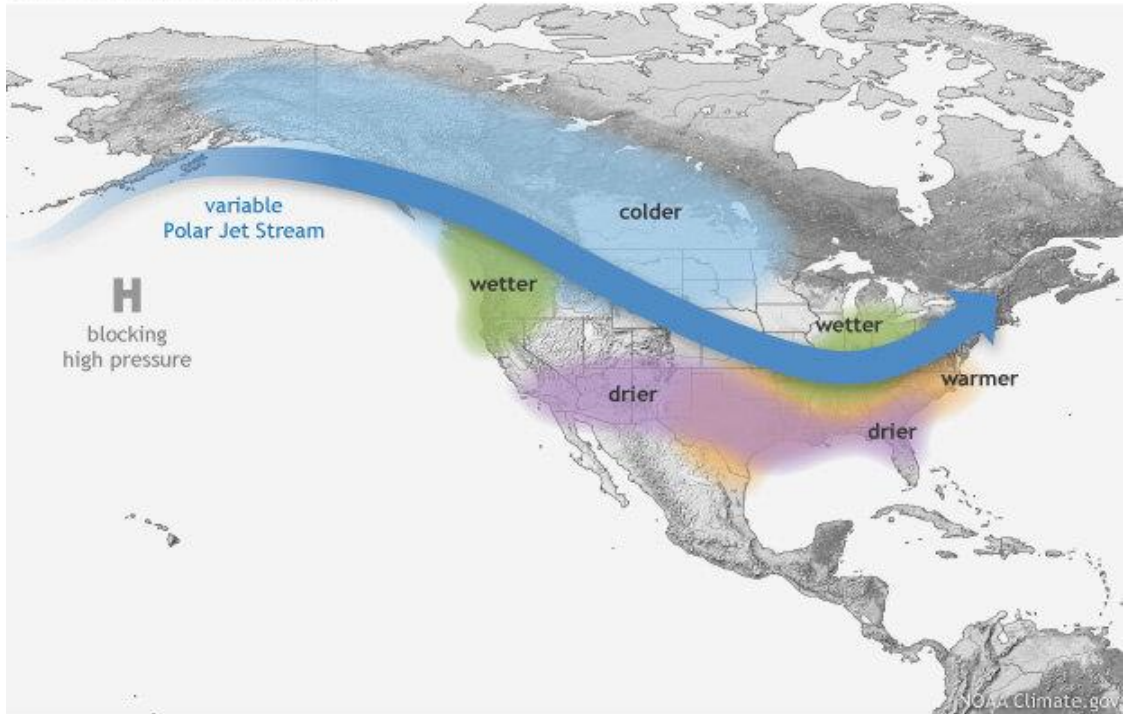


Thresholds of Weekly Snow Depth: November-December

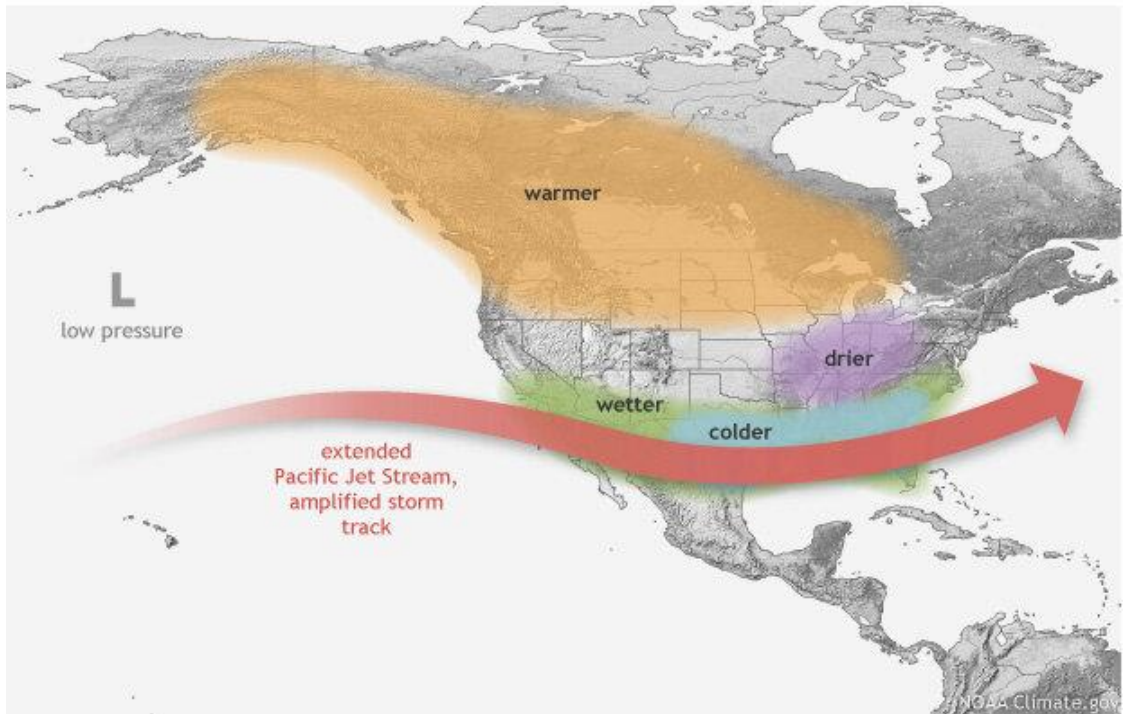


Wintertime La Niña and El Niño Patterns

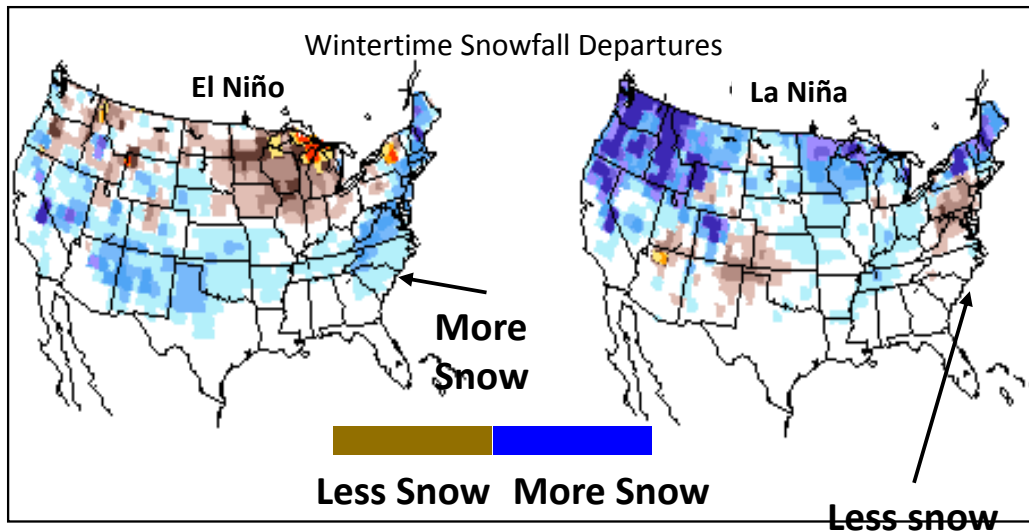
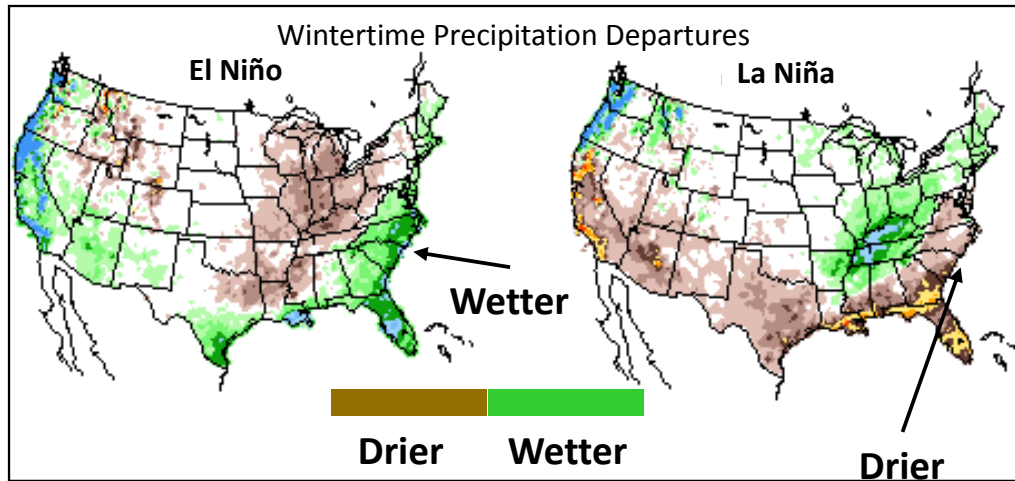
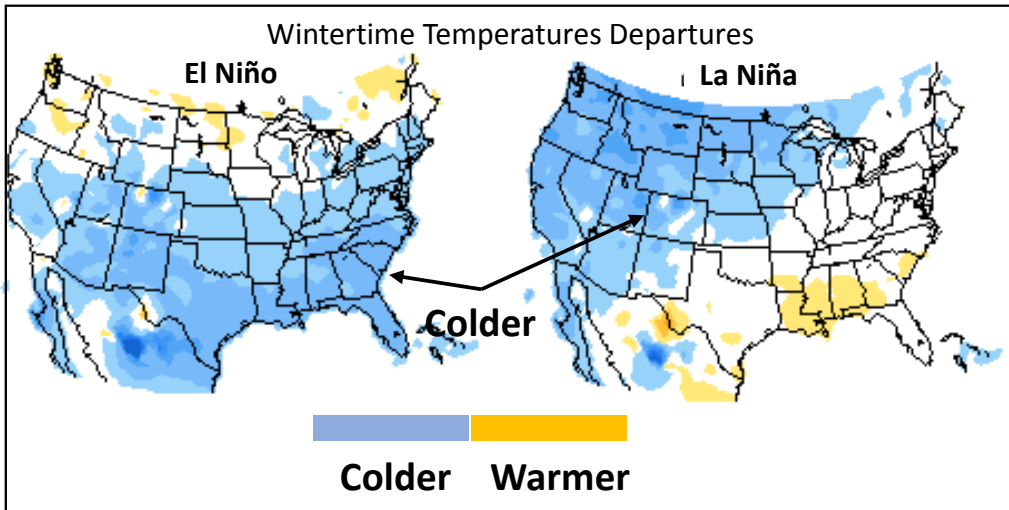
WINTER LA NIÑA PATTERN



WINTER EL NIÑO PATTERN



January-March Conditions During El Niño and La Niña

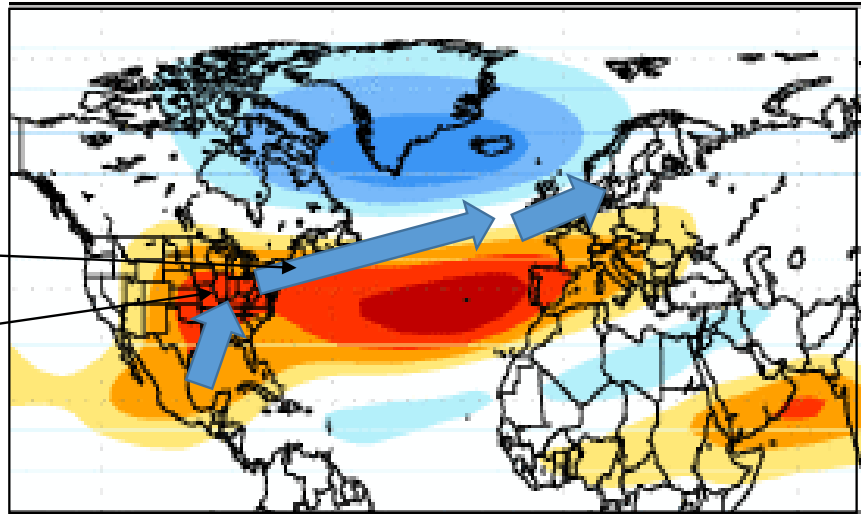


North Atlantic Oscillation: December-February

Comparing Positive and Negative Phase
Air Pressure and Jet Stream Winds: Departures from Normal

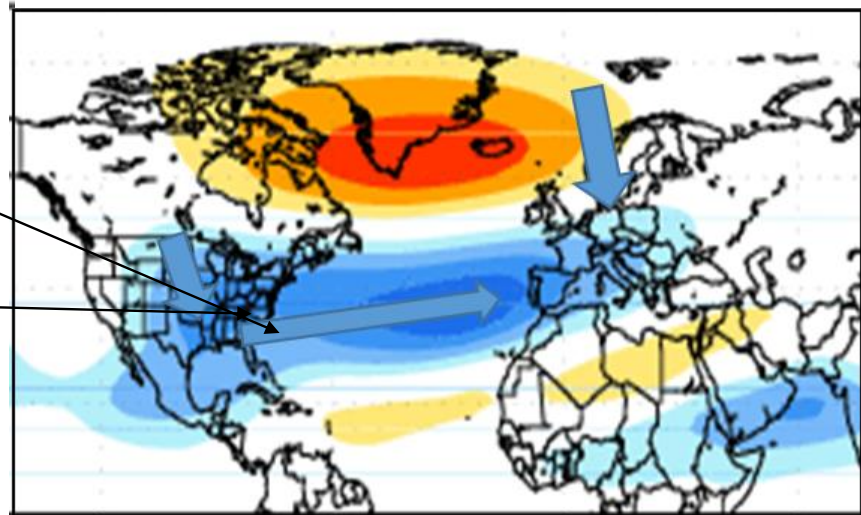
Positive Phase

- Jet Stream Winds Farther North
- Higher Air Pressure in eastern U.S.



Negative Phase

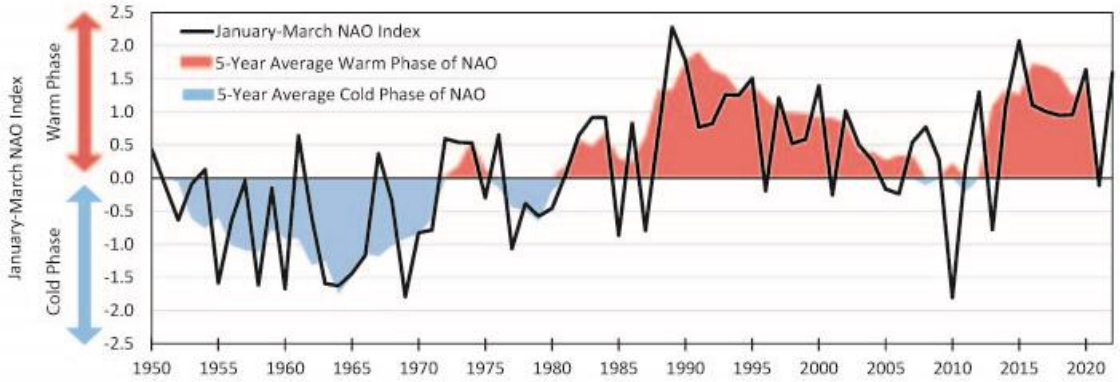
- Jet Stream Winds Farther South
- Lower Air Pressure in eastern U.S.



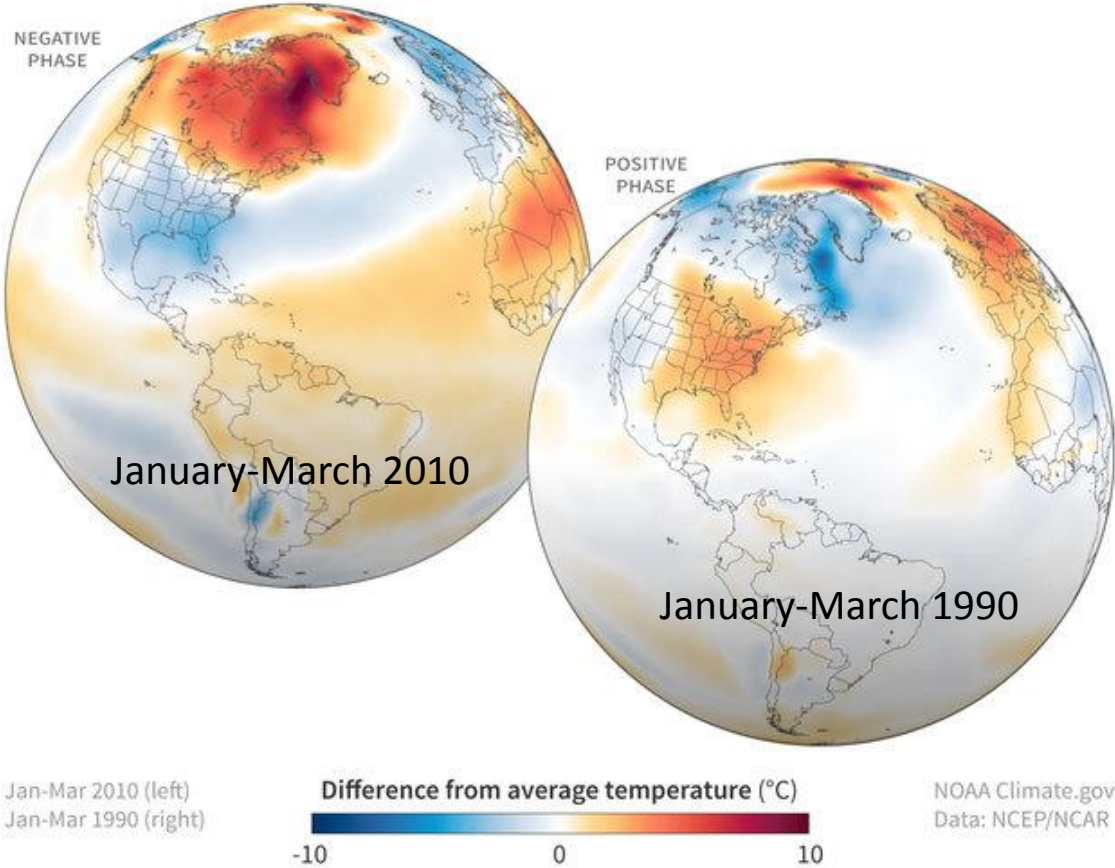
 Higher Pressure  Lower Pressure

 Jet Stream Winds

Monthly Time Series of the North Atlantic Oscillation (NAO)



NAO TEMPERATURE PATTERNS

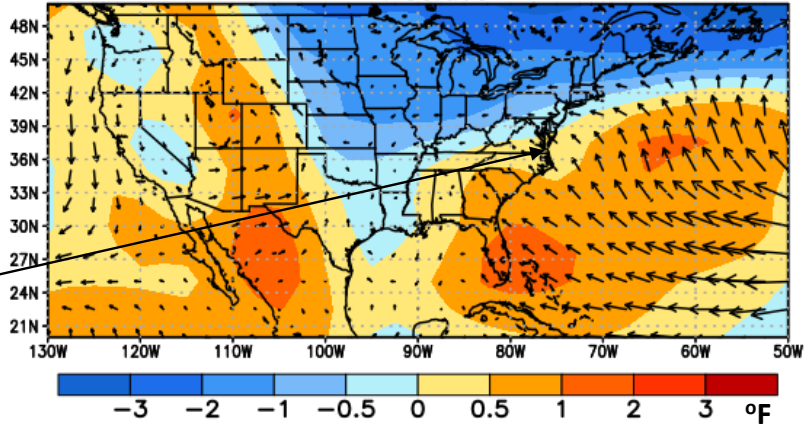


NAO Temperature and Wind Patterns During December-February

Comparing Positive and Negative Phase
 Surface Temperature (°F) and Wind (Arrows): Departures from Normal

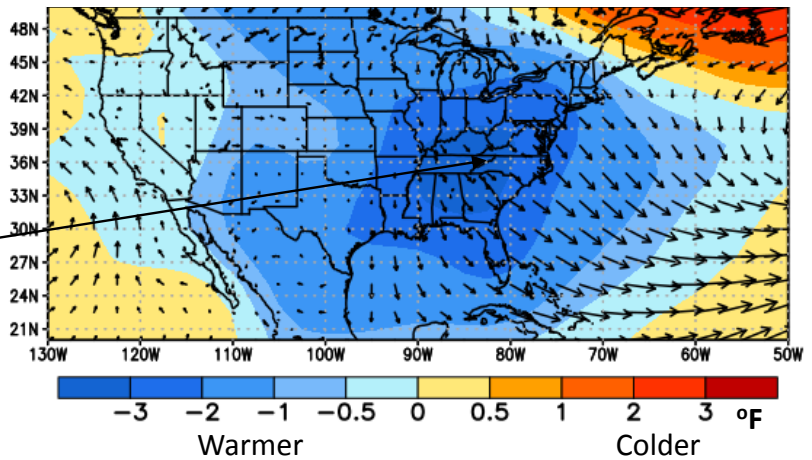
Positive Phase

- Warmer Winter in Southeastern U.S.
- More Southerly Winds Near Surface



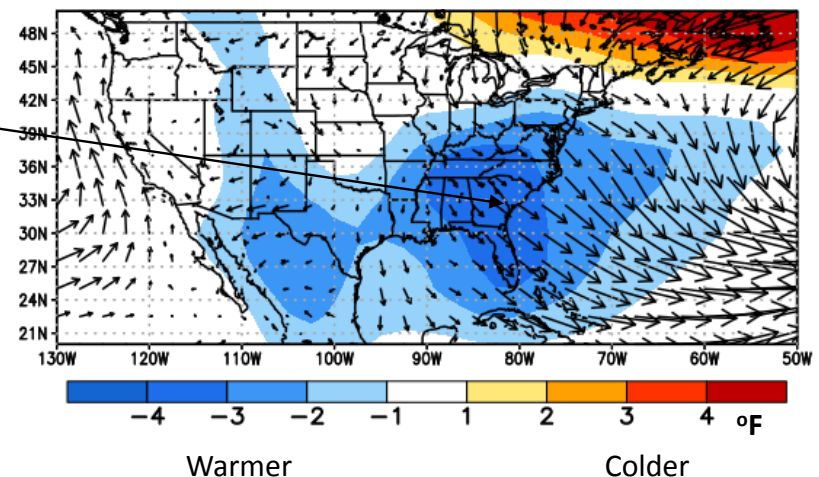
Negative Phase

- Colder Winter in Eastern U.S.
- More Northerly Winds Near Surface



Difference (Negative minus Positive Phase)

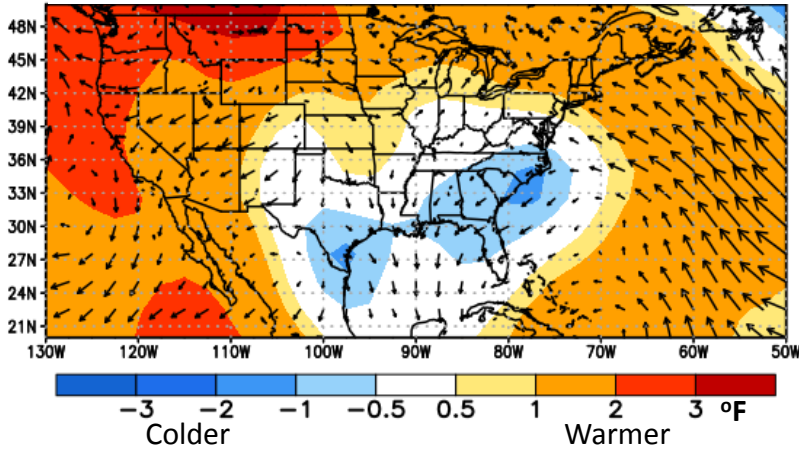
Wintertime Temperatures are 2-4 °F Colder in the Southeastern Quadrant of U.S. During Negative NAO Compared to Positive NAO



Combined El Niño and NAO Temperature and Wind Impacts

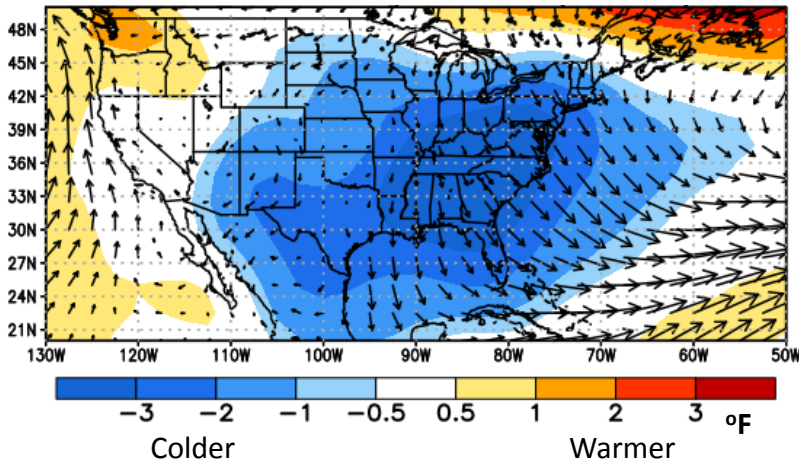
Surface Temperature (°F) and Winds (Arrows): Departures from Normal
December-February

El Niño and Positive NAO Phase



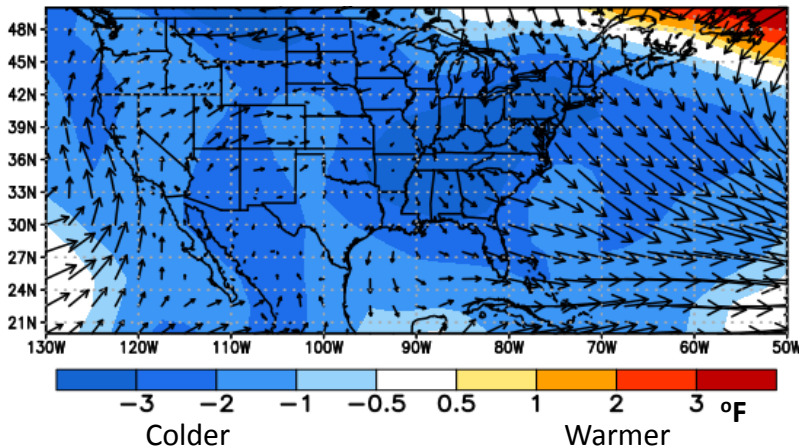
When El Niño occurs during a positive NAO phase, the northern U.S. experiences above-average temperatures and the southeastern U.S. experiences below-average temperatures.

El Niño and Negative NAO Phase



When El Niño occurs during a negative NAO phase, the eastern half of the U.S. experiences below-average temperatures.

Difference in El Niño Signal between Negative and Positive NAO Phase (Negative minus Positive)

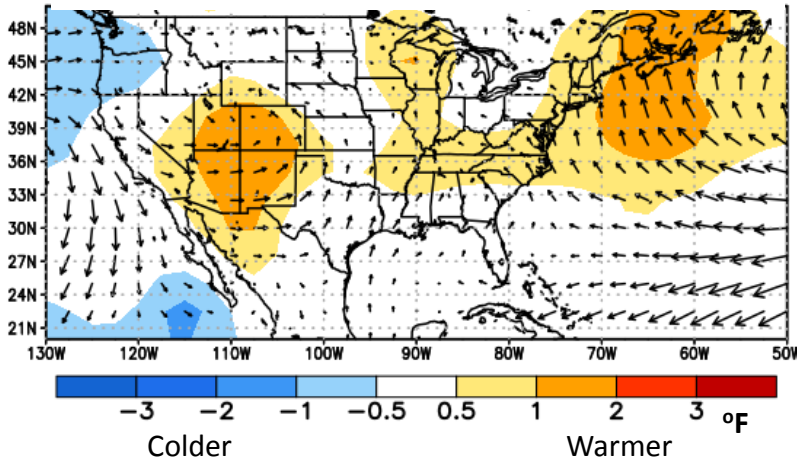


During El Niño, the negative NAO phase produces colder temperatures across the U.S. compared to the positive phase.

Combined La Niña and NAO Temperature and Wind Impacts

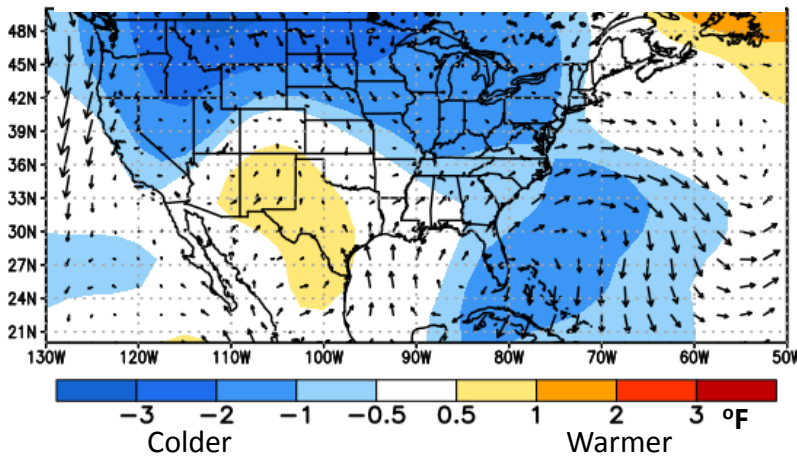
Surface Temperature (°F) and Winds (Arrows): Departures from Normal
December-February

La Niña and Positive NAO Phase



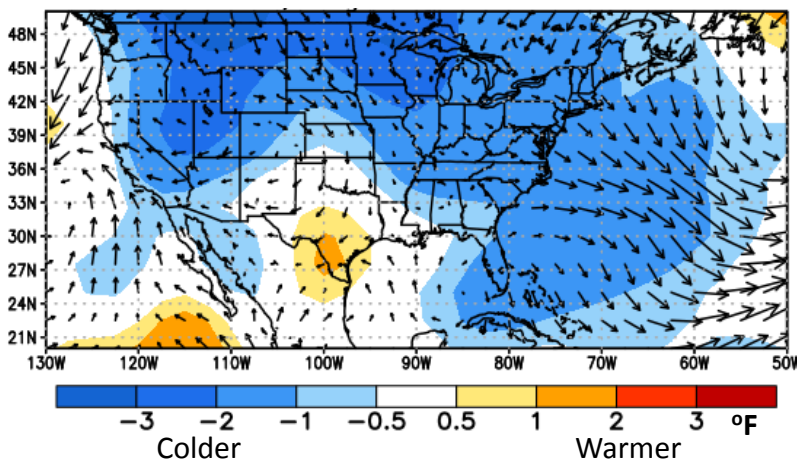
When La Niña occurs during a positive NAO phase, most of the U.S. experiences near-average temperatures.

La Niña and Negative NAO Phase



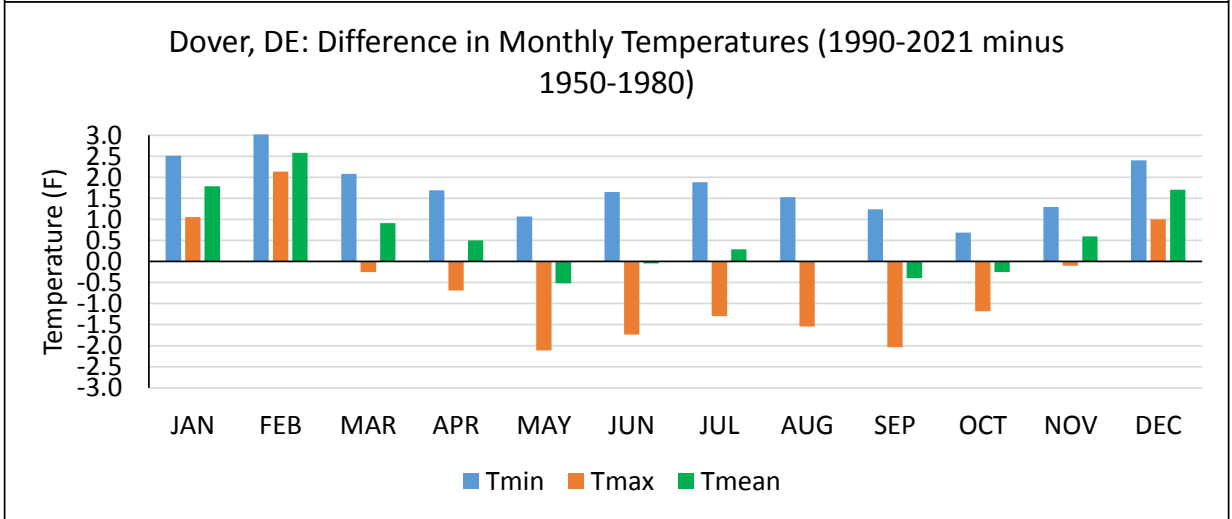
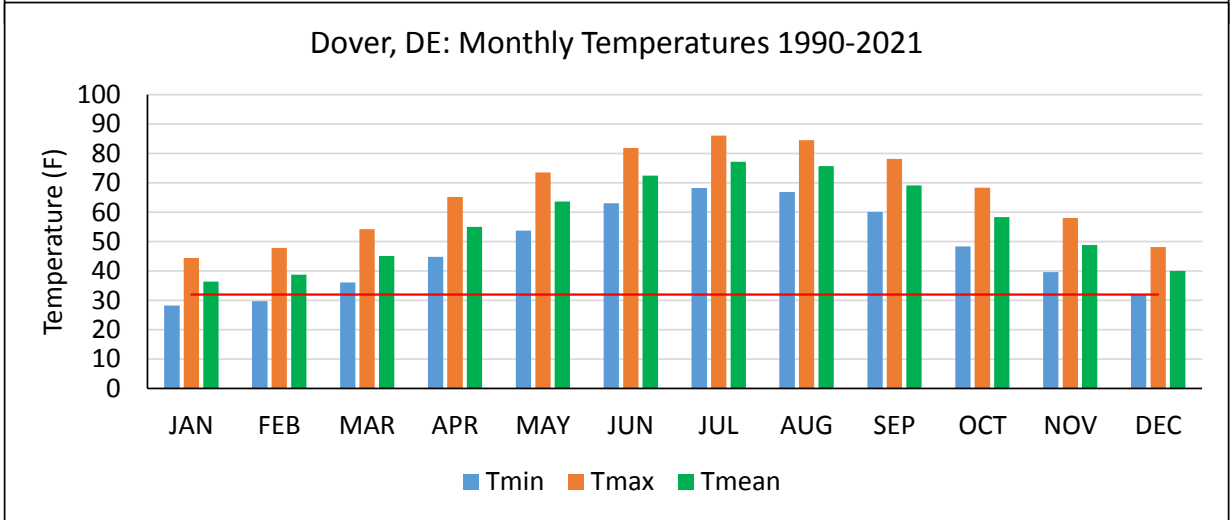
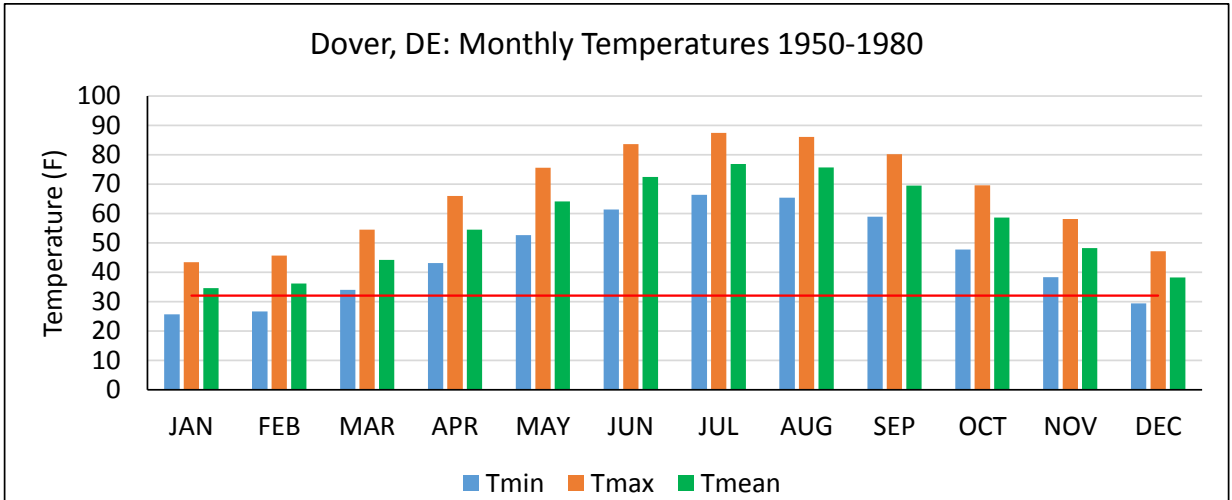
When La Niña occurs during a negative NAO phase, the northern and eastern U.S. experience below-average temperatures.

Difference in La Niña Signal between Negative and Positive NAO Phase (Negative minus Positive)

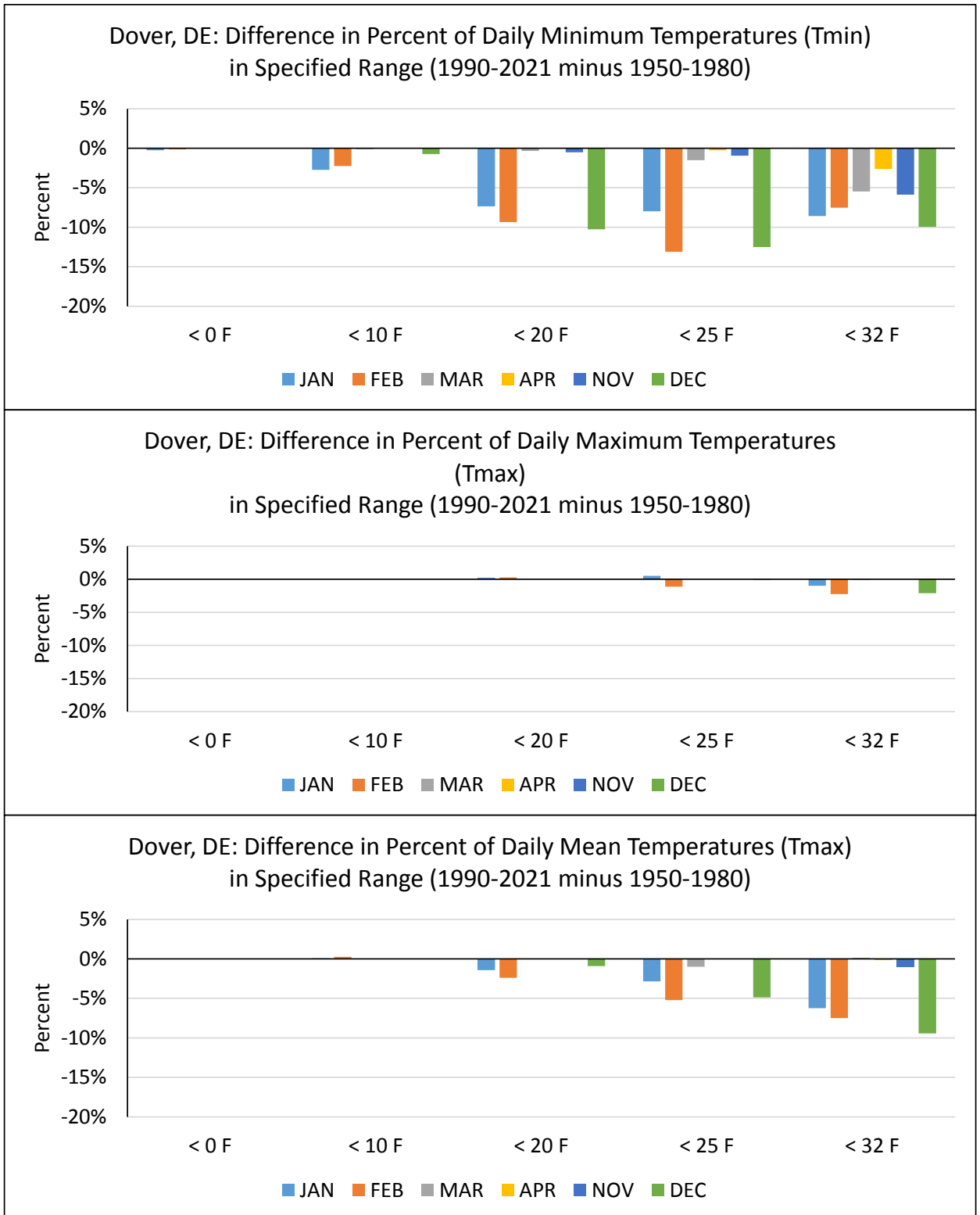


During La Niña, the negative NAO phase produces colder temperatures in the northern and eastern U.S. compared to the positive phase.

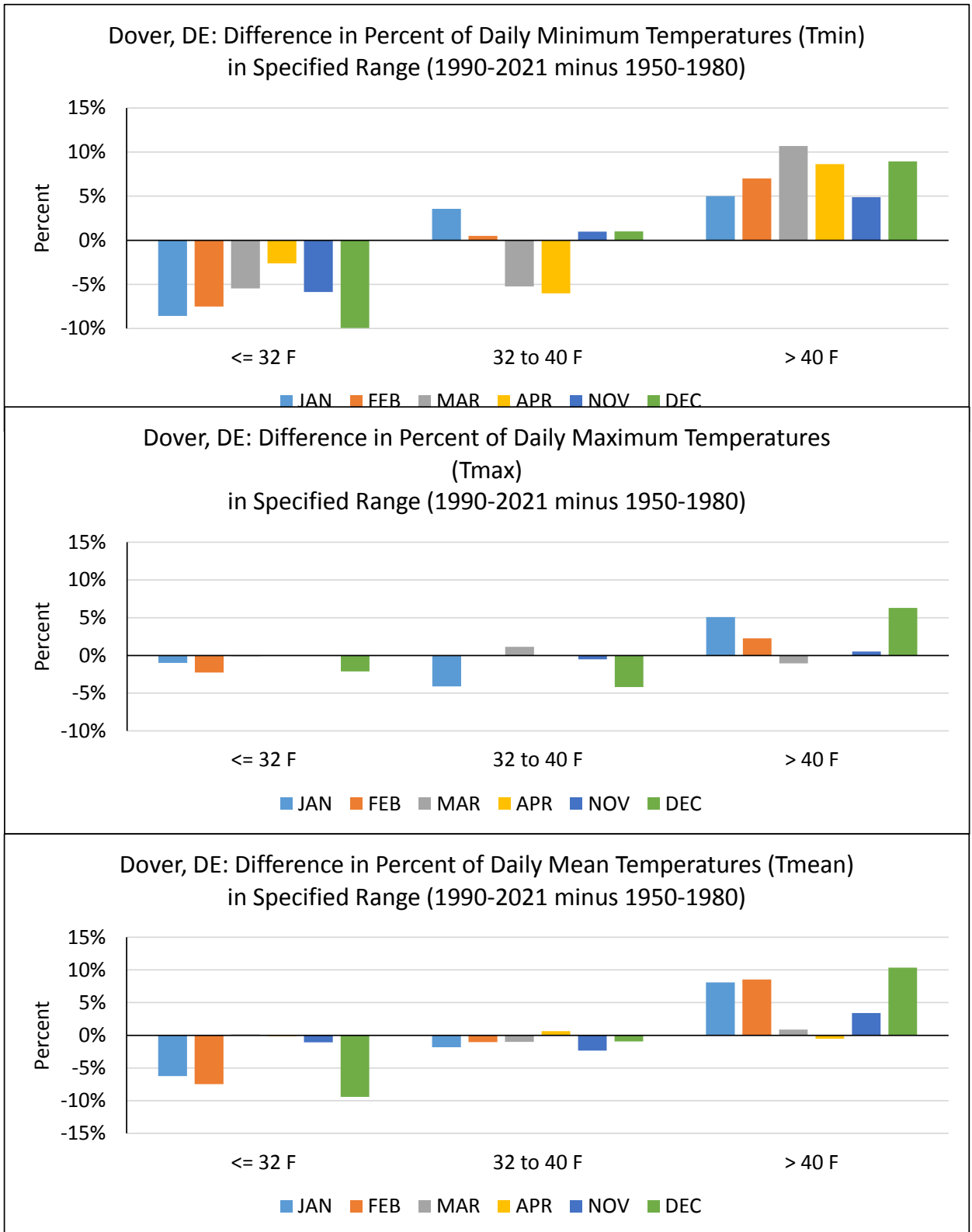
Contrasting Conditions During 1950-1980 and 1990-2021
 Thresholds of Monthly Temperatures



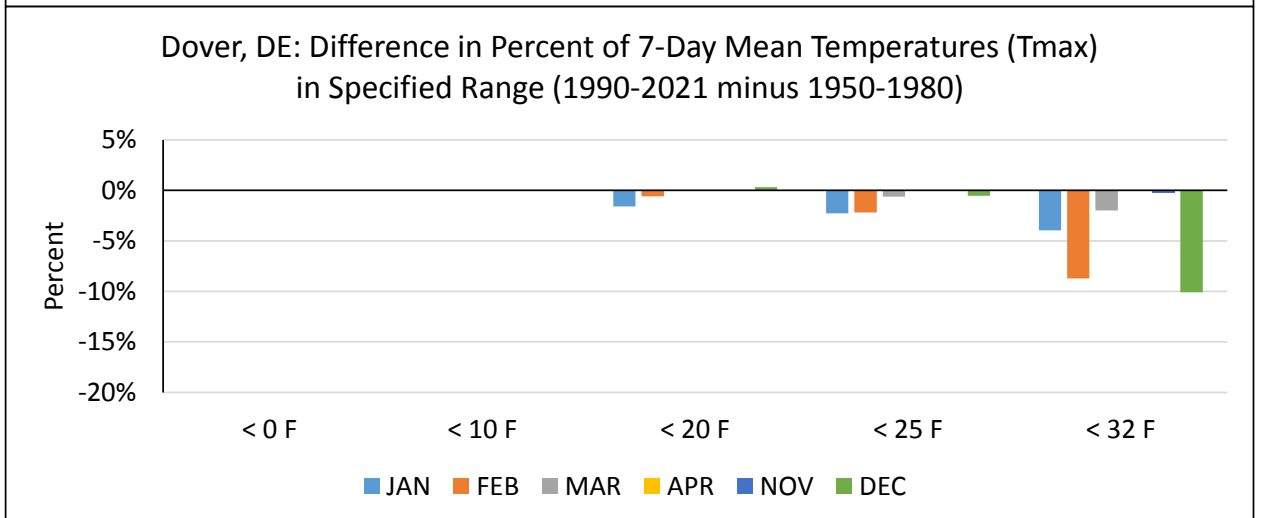
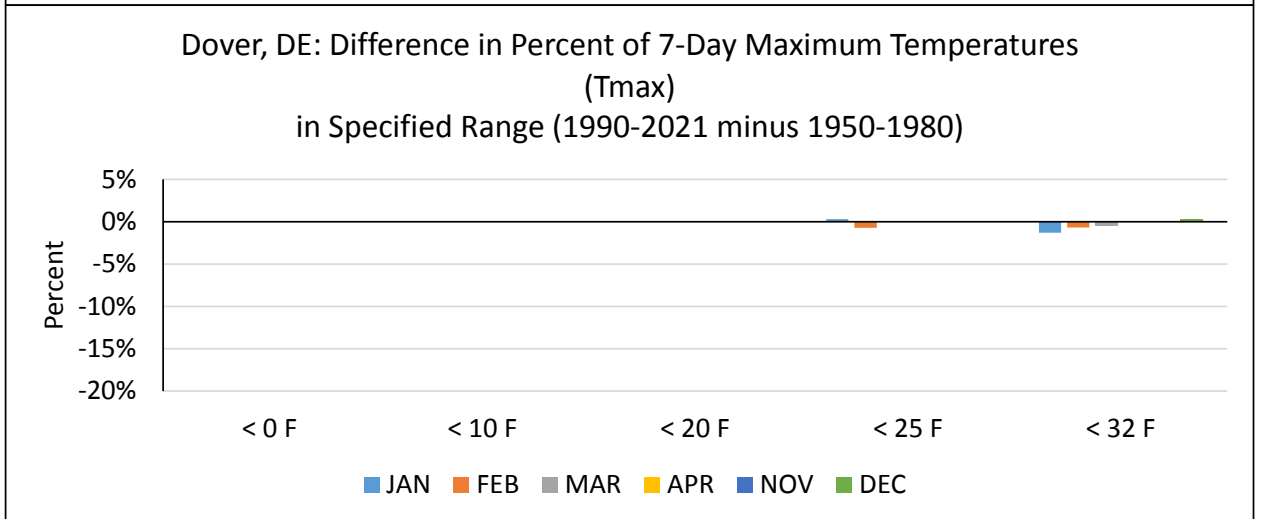
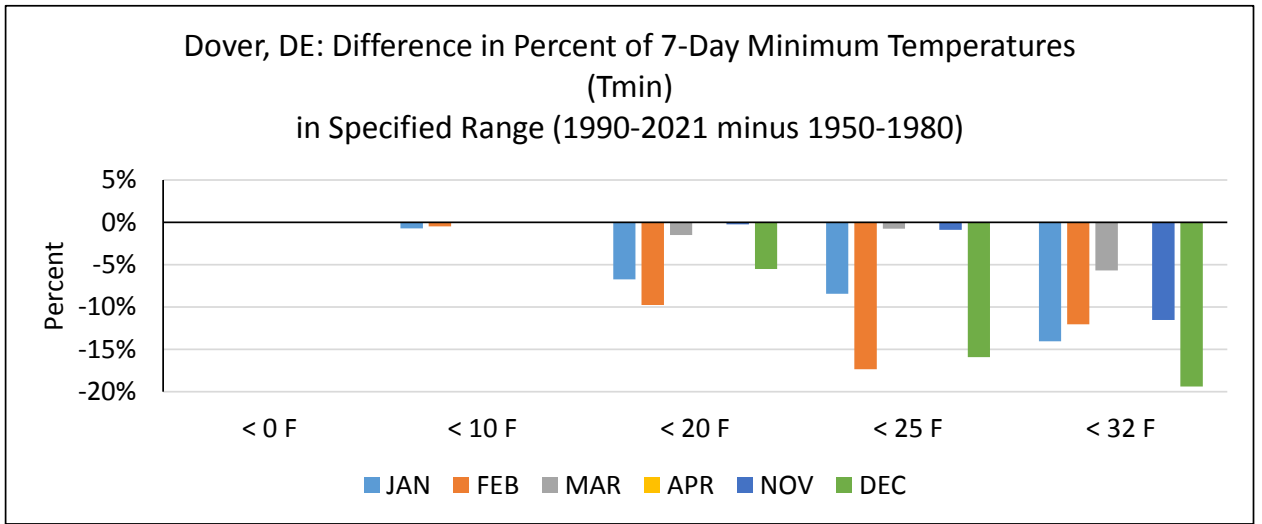
Contrasting Conditions During 1950-1980 and 1990-2021 Thresholds of Daily Freezing Temperatures



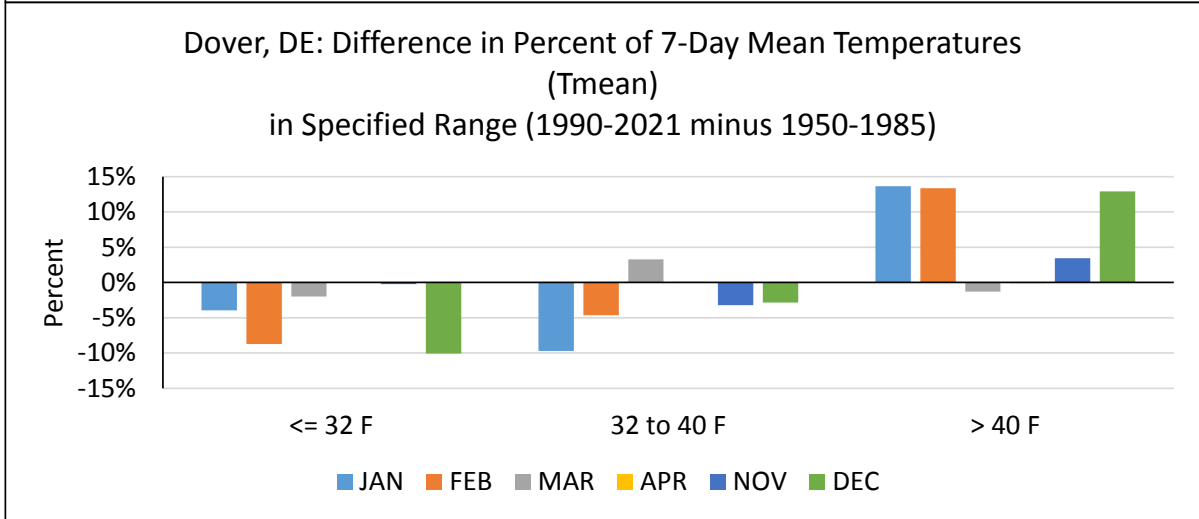
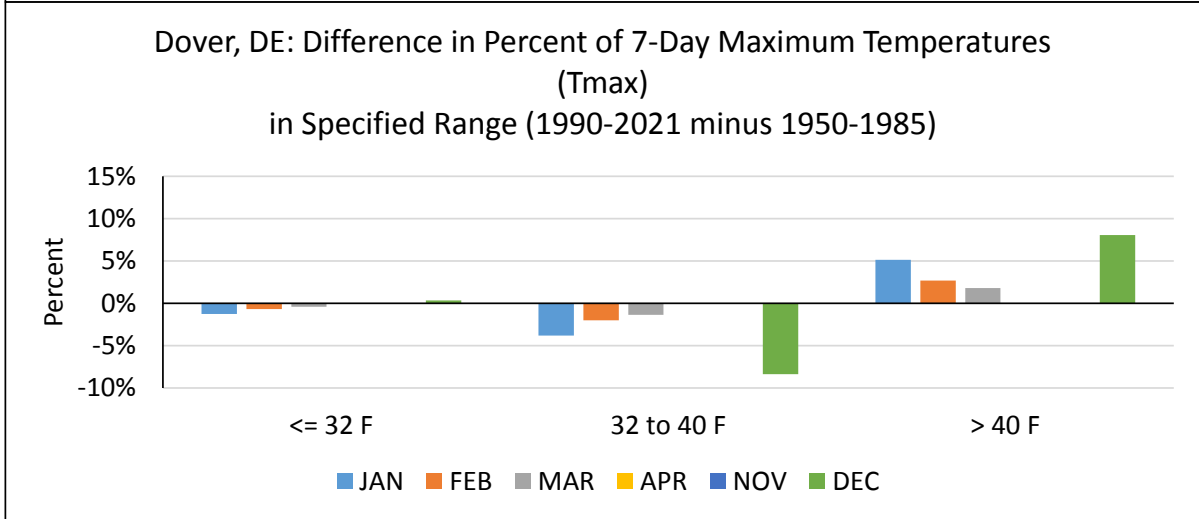
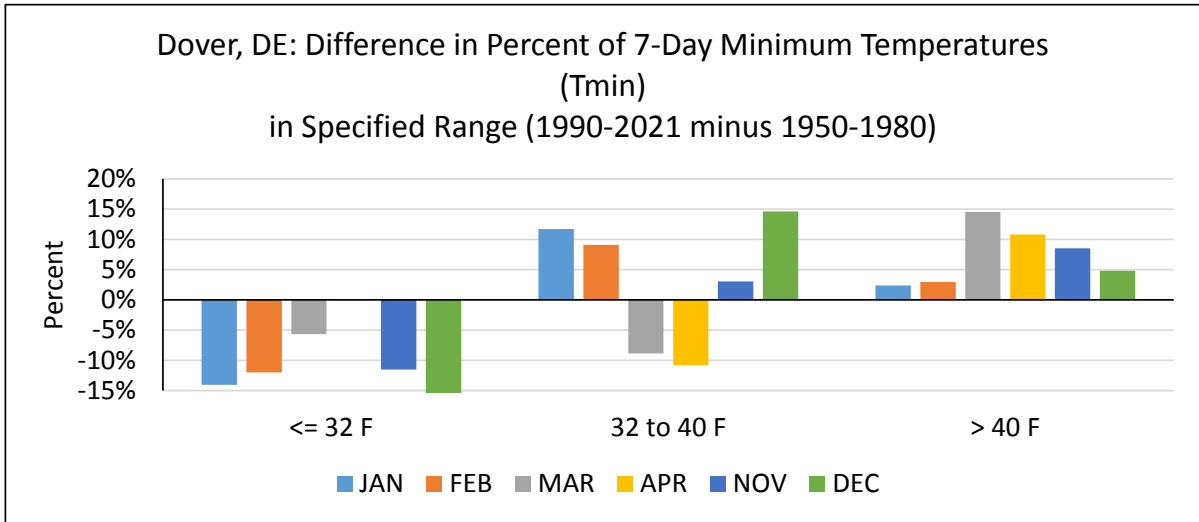
Contrasting Conditions During 1950-1980 and 1990-2021
 Thresholds of Daily Freezing/Non-Freezing Temperatures



Contrasting Conditions During 1950-1980 and 1990-2021
 Thresholds of Weekly Freezing Temperatures



Contrasting Conditions During 1950-1980 and 1990-2021
 Thresholds of Weekly Freezing/Non-Freezing Temperatures



Contrasting Conditions During 1950-1980 and 1990-2021
 Monthly Precipitation, Snowfall, Average Snow Depth

