Improved Transition of Instruments and Database Management

An Assessment of the Blue Hill Observatory in Milton, Massachusetts

Interactive Qualifying Project

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ABSTRACT

The Blue Hill Observatory and Science Center, founded in 1885, has held the longest active climate record to date. This observatory has maintained the same weather measuring instruments for many years and these instruments require a consistent system of transition. The first goal of this project was to develop a system for the transition of instruments in order for previously recorded data to be consistent to the future data collected. The data storage at the observatory has been either hand-written or electronic data forms. For the second goal of our project, we developed a prototype database that will consolidate all of the weather data recorded into one consistent form.

EXECUTIVE SUMMARY

The Blue Hill Observatory, located in Milton, Massachusetts, is a surface weather observatory where the observers make weather observations such as temperature, atmospheric pressure, sky cover, and minutes of sunshine. It was founded in 1885 by Abbot Lawrence Rotch and has kept the longest continuous record of weather observations since then. The observatory is one of the few manually operated weather stations still in service in the United States.

The weather data collected at the observatory is very unique because of the homogeneous data they collect. Homogeneous data is collected by maintaining the methods of data collection during the whole duration of time the data has been collected. This means that the data has been collected in the same location and the instruments used are the same type of instrument. It is important to note that the same instrument does not have to be used; as long as the same type of instrument is used the homogeneous data is still being collected.

Currently, many of the instruments used at the observatory are starting to deteriorate and the maintenance costs are become more frequent and expensive. The first goal of this project was to provide the Blue Hill Observatory with a procedure to transition from the current weather instrument to a new or replacement instrument.

To complete this goal, we first narrowed down the over thirty instruments used at the observatory to four. We did this in order to have an in depth analysis of four instruments instead of a brief overview of all thirty instruments. The four instruments were the 420 C Three-Cup Anemometer, Bendix Aerovane, Contact Anemometer, and Ombroscope. We then interviewed the chief observer, instrument technician, and other key figures to find out information about the current state of each instruments. We also created a grading scale for the instruments in order for the observatory to continually assess the current state of the instrument. We graded the instruments based on their duration of use, maintenance frequency, part availability, current mechanical condition and the urgency of replacement. The results of the grading scale were what we expected to be with the ombroscope receiving the lowest score of the four instruments and the 420 C Three-Cup Anemometer receiving the highest score.

Using the grading scale and the information we gained through research, we were able to develop a procedure for the transition of the instruments. The following are the steps we

recommend the Blue Hill Observatory to take when transitioning the current instrument to a new or replacement instrument:

1. Perform a Cost Analysis on Instrument for Transition
2. Identify Replacement Instrument
3. Determine Appropriate Method of Transition
4. Analyze and Investigate Discrepancies
5. Phase Out Transitioned Instrument

We also made recommendations on the instruments that the Blue Hill Observatory should transition to.

Since the Blue Hill Observatory has been collecting data over 127 years there are many different methods of data storage. These methods range from bound books with hand written observations to computer generated electronic forms. For the second goal of this project, we developed a prototype database, which will consolidate all of the past and current data collected into one uniform database.

In order to complete this goal we researched different management programs and data entry methods. We decided to use MySQL for our database because it is user friendly and fits the needs of the long-term data storage for the observatory. Once we were able to set up the database, we had an intern at the observatory test the database by entering data. We made modifications to the database based on the intern's suggestions. We then set up the database in the Blue Hill Observatory server in order for the observers to have access to the database. Due to time constraints and our limited knowledge in the area, we were not able to complete all of the aspects of the database which we want to. We made a list of all of the aspects that we would have wanted to complete and made recommendations on how they could be completed.

Once all of the weather data is entered into the database, it will enable easy access to historical homogeneous data collected at the Blue Hill Observatory. Many other observatories, such as the Mount Washington Observatory in New Hampshire, are not as keen as the Blue Hill Observatory to collect homogeneous data. As soon as an instrument with higher technological capabilities is available, the Mount Washington Observatory switches the instrument with no transition period. As a result, the data they collect is not homogeneous. This makes the data collected at the Blue Hill Observatory very unique. This data is very valuable to climatologists because the observatory ensures that the replacement instrument measures the weather data in a similar manner as the previous instrument. As a result, the climatologists are able to analyze the weather data and not be concerned if the change in instrument affected the data, but in fact know that the climate is changing. With the recommendations we made for this project, the Blue Hill Observatory will be able make seamless transitions of instruments and will have the framework for their weather data database, which will benefit the observatory in their collection of homogeneous data.

ACKNOWLEDGEMENTS

We would like thank our sponsor at the Blue Hill Observatory, Don McCasland, for providing our group with this project and the opportunity to work with the Blue Hill Observatory. He was instrumental with arranging meetings with appropriate parties to learn the necessary information needed for our project. He helped us on the direction of our project, and whenever we had questions on any aspect of the project, he provided helpful feedback that got us back on track.

We would also like to thank Dave Doe, the instrument technician at the Blue Hill Observatory, for his continued feedback on the grading scale. He provided us with the manuals for the specific instruments we decided to focus on, and gave suggestions for transition instruments.

The cooperative manager of the National Weather Service, Kim Buttrick, provided us with the information on the NWS relationship with the Blue Hill Observatory, as well as the instruments as well. With her help, we were able to create a more fundamentally sound transition system and grading report based on her feedback about the maintenance procedures performed by the National Weather Service technicians at the Blue Hill Observatory.

The staff members of both the Blue Hill and Mount Washington Observatories also deserve thanks for their continued aid in helping us understand the current processes used with their instruments and data storage methods.

We would also like to thank our project advisors, Professors Angel Rivera and Susan Vernon-Gerstenfeld. They have spent much of their time and energy making sure that we could succeed in this project, from correcting our seemingly endless writing mistakes to suggesting better presentation methods. They have been the steady positive force willing us to achieve our project’s potential, while also encouraging us to enjoy this experience and the privilege that it is.

Lastly, we would like to thank our ID 2050 professor, Ingrid Shockey, for educating us on the IQP process in its entirety and teaching us the proper procedures that it entails. She detailed the process in an easy to understand format, taught us how to go about our information gathering and report writing, and especially provided helpful aid in preparing our presentation skills, all so that we could achieve a successful project.

All of these people were instrumental in the completion of our project, and we would like to give them all one final thank you for all of the time, energy, and effort that they put in to help us achieve our goals. Thank you.

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CHAPTER ONE: INTRODUCTION

Since weather forecasts are based on current data and patterns, it is crucial that the data being collected by weather observatories are accurate and precise. Accuracy refers to how close a measured value is to the actual value, and precision refers to how close each of the measured values are to one another ("International vocabulary of," 2008). With the advancement of technology, weather instruments have been increasing in both accuracy and precision. Advancements in instrumentation and new technologies have added new factors for weather observatories to consider which were not there before when the observers relied solely on their own observations to record the weather. Since these instruments increase the validity of the weather observation, observatories want each instrument to function at their maximum capability.

The Blue Hill Observatory located in Milton, Massachusetts has been conducting weather research and collecting weather data since 1885, when the observatory was founded. It has been long renowned as a leader in its study of the weather, having kept the longest active climate record to date ("A brief history," 2010). The Blue Hill Observatory prides itself on its climate record because it strives to prolong the length of time an instrument is used to ensure that the data being collected is not affected by a change in instrument.

As a result, the Blue Hill Observatory provides a unique perspective on their climate data because of their homogeneous data collection methods. Homogenous data means that the data has the same controls and variables. For many of the weather observations, the observatory has been using the same instrument, location, and techniques to collect the weather data. As a result, the data collected by the Blue Hill Observatory is very valuable to scientists when they study the climate and its changing characteristics. The scientists will not have to question whether the change in instruments caused the variation in the data collected but rather be assured that the climate is changing. However, due to the long duration of use of the instruments, the current states of several of these instruments at the Blue Hill Observatory deteriorating and the maintenance costs are becoming more frequent and expensive.

The first goal of this project was to develop a procedure for seamless system of the transition of the current instrument to a new or replacement instruments in order to maintain the collection of homogeneous weather data. We accomplished this goal by assessing the instruments at the Blue Hill Observatory based on their current condition. We then created a grading scale for the observatory to be able to continually assess the current state of the instrument. We then made recommendations concerning the necessary steps that the observatory should take when transitioning the instruments.

Similar to the technological advancement of instruments, the methods of data storage have also evolved. For example, the first method of data storage used at the observatory was a collection of hand-written pages; now, the observatory uses a computer generated form to store the data they collect. These advancements in technology have caused the observatory to have many different forms of data storage, and they would like to consolidate their weather data into one uniform method of data storage.

For the second goal of our project we developed a prototype database, which will eventually store all 127 years of weather data collected. We were able to complete this goal by assessing all the different forms of data storage used currently and in the past. By comparing the different forms used, we were able to create our own data entry method to enter the historical weather data into the MySQL database. By having an intern at the observatory test the database, we were able to make the necessary changes to ease the process of entering the 127 years of weather data.

With the detailed steps of instrument transition, the Blue Hill Observatory will be able to continue the collection of homogenous data. The improved database management will allow the observatory to supply the research scientists with the data in a more organized and efficient manner. We intend that the recommendation we make for the observatory on the future aspirations of the database and replacement instruments will aid the collection of homogeneous data.

CHAPTER TWO: LITERATURE REVIEW

In the following chapter, we discuss the background research on the instruments we assessed and the prototype database we implemented at the Blue Hill Observatory. We also present two case studies, which gave us insight into the methods other observatories have used to deal with the problems that can arise when transitioning instruments. The data entry experiment we present gave us insight in which data entry method is the most accurate and time effective.

HISTORY OF THE BLUE HILL OBSERVATORY

The Blue Hill Observatory was founded in 1885 by Abbott Lawrence Rotch, who had always been interested in making observations of the weather. Rotch chose the top of the Great Blue Hill in Milton, Massachusetts on the Blue Hills Reservation for his observatory because he wanted a new perspective on weather observations. Since the top of the Great Blue Hill is the highest point within ten miles of the Atlantic Ocean, Rotch was able to study the weather in a continuously uninterrupted manner, which had not previously been done ("Blue Hill Meteorological," 2001).

Many of the instruments used to collect the weather data in the first few years of operation were made by the observers themselves in the basement of the observatory. An invention still being used today is the addition of the wind break around the standard weighing rain gauge, which restricted the wind and allowed more accurate measurements of rainfall. The observers were then able to maintain and make the necessary improvements to their instruments because of their firsthand knowledge of the instruments (Doe, David. 2012). These instruments have been used to record the data in a similar manner as when these instruments were first used in 1885.

The data collected at the observatory is very valuable to the National Weather Service for climate study because of their homogeneous data. The observatory strives to use the instruments for as long as possible in order to maintain consistent data collection. For example, a Contact Anemometer has been in use at the observatory since the year the observatory was founded in 1885. Unfortunately, due to advancements in technology, many observatories around the world have transitioned away from using instruments such as the Contact Anemometer to using automated weather systems. The Blue Hill Observatory is one of the few observatories left in the world which still collects manual observations for the National Weather Service.

NATIONAL WEATHER SERVICE

The National Weather Service (NWS) is one of six agencies that make up the National Oceanic and Atmospheric Administration (NOAA). The NWS provides weather forecast to give citizens an opportunity to adequately prepare for these pending conditions ("National Weather Service," 2012). The Blue Hill Observatory houses instruments owned by the National Weather Service such as the hydrothermometer and the all-weather precipitation gauge. The NWS pays a portion of observers' salary at the Blue Hill Observatory to record the measurements taken by the manual instruments, as well as to maintain and manage them.

The Blue Hill Observatory is one of the few remaining manually operated surface weather observatories that collect weather data for the National Weather Service. The weather records and observations taken manually by observers at the observatory are provided to the NWS for their own records. In return, the NWS has provided the observatory with some instruments, such as the 420 C series instruments, to collect specific weather data. A component of their partnership is the NWS provides maintenance and repair for the instruments and supplies the necessary replacement parts. However, over time as some of the instruments age, it has become impractical for the NWS to continue to service and maintain those instruments, so they discontinued their support for the instruments. For that reason, a system of transition needs to be in place to assure a seamless transition of the instruments if the NWS were to stop maintaining these instruments.

DIFFERENCE BETWEEN A SURFACE WEATHER OBSERVER AND A COOPERATIVE OBSERVER

The Blue Hill Observatory is a cooperative observatory as well as surface weather observatory for the National Weather Service. The National Weather Service Cooperative Observer network is made up of citizen weather observers who are members of the general public who collect weather observations in farms, urban and suburban areas, mountaintops, and other areas. A Surface Weather Observatory is an observatory where weather data measured by trained certified observers and is used for daily forecasts for their designated area (National Weather Service, 2010).

The NWS requires all of the surface weather observers to get certified as an observer. The individual must go through an extensive training period before making certified weather observations. The National Weather Service requires this training period to ensure that the observations are taken in a consistent manner. The observations measured at these stations include but are not limited to cloud height, visibility, wind speed and direction and temperature. Since weather observations are very subjective, the observer must also go through another training process once they have been placed at an observatory to learn how the observatory records certain observations such as visibility (National Weather Service, 2010).

The NWS supplies each cooperative observer with the training and equipment it needs to record the temperature, rainfall, and snow accumulation every day (Doesken & Reges, 2010). The NWS has set standards for these Cooperative Observers to have the data recorded in the most consistent method as possible; however, the data collected by the citizen scientists are not archived or certified by the National Weather Service. They fear the citizen scientist might not be as adamant to collect accurate and precise weather observations because they are unpaid volunteers as opposed to surface weather observers who are formal employees and passionate about the weather and climatic research. As a result, the National Weather Service consistently monitors the cooperative observers and ensures that they are supplied with the most accurate and precise weather instruments available (Buttrick, Kim. 2012).

WEATHER INSTRUMENTS

The first goal of this project is to provide the Blue Hill Observatory with a transition process from current weather instruments to new or replacement instruments. The instruments we focused on are the 420 C Three-Cup Anemometer, Contact Anemomter, Bendix Aerovane, and the ombroscope. We discuss why we chose these four instruments in Chapter Five: Discussion.

420 C Three-Cup Anemometer

Among the oldest set of wind instruments in use at the observatory is the 420 C Series, which consists of a wind vane and a three-cup anemometer; however, we will only be focusing on the three-cup anemometer. This standard three conical cup anemometer instrument measures the daily peak gust wind speed. As wind passes through the instrument, the three conical cups rotate which causes the magneto housed in the bottle of the instrument to generate an electrical current. The electric current then causes the needle of the wind speed recorder to move to the proper wind speed reading on the chart of the recorder. The next day, the observer uses the continuous wind speed line created by the recorder to find the peak gust wind speed for the previous day.

Figure 1: 420 C Three-Cup Anemometer

Contact Anemometer

The Contact Anemometer, also known as the Friez Dial Type Anemometer, is used at the Blue Hill Observatory to measure the fastest mile of wind that passed during that day. When the contact anemometer performs a single rotation due to the wind, a gear is caused to move up one notch. Once the gear moves 640 notches, a switch sends a signal to a chart recorder which makes a tick mark on a rotating chart. The observer is able to determine the fastest mile by comparing the amount of space between each tick mark on the chart.

Figure 2: Contact Anemometer

Bendix Aerovane

The Bendix Aerovane, also known as the propeller anemometer or the windmill, is used to determine the wind speed and direction over a period of time. The version of this instrument at the Blue Hill Observatory is a mechanical system that records its data based on the number of impeller rotations through a series of signals sent through circuits down to a chart recording device ("Windmill anemometers," 2012).

Figure 3: Bendix Aerovane

Ombroscope

The ombroscope is used at the observatory to determine when precipitated started and ended. The slanted cover of the ombroscope causes the precipitation to run off through the small hole on the cover (Strangeways, 2006). A water mark is made on the water sensitive time chart, which is run by a clock mechanism, indicating the time the precipitation started. The next day, the observer uses the time chart to determine the time precipitation started and end. The ombroscope is the only instrument at the Blue Hill Observatory that provides this unique ability of measuring the exact length of precipitation.

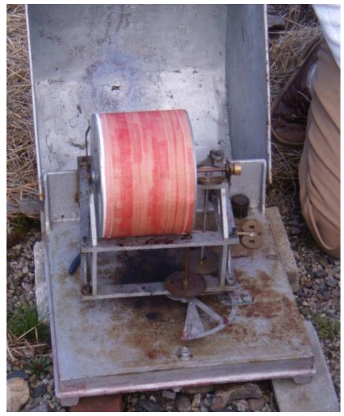


Figure 4: Ombroscope

HOMOGENEOUS DATA

The Blue Hill Observatory conducts its operations differently from other surface weather observatories by maintaining a homogeneous data collection process. Homogeneous data is data that is being measured in the same manner over an extended period of time. While the instruments do not need to be the same, the information must be measured in a manner that is consistent, such as from the same location and with the instrument being in the same degree of calibration. The Blue Hill Observatory is concerned that if they replace the instruments that have been measuring this data over its 127 years of service, that they will lose this homogeneous data. The purpose of the transition process we recommend is to provide a procedure for the replacement of the current instruments while still maintaining the observatory's homogeneous data collection.

B16, F6, AND WXD FORMS

Currently, the observatory collects and stores its weather data in different National Weather Service issued forms. One of the forms they use is the B16 form, which stores the surface weather observations for each day from midnight to midnight. This form records the temperature, wind speed and direction, sunshine, sky cover, and precipitation over one day. The second form that the Blue Hill Observatory uses is the F6 form, which is the monthly summary of the weather conditions at the site. The F6 form records the maximum and minimum temperature for each day of the month, which allows scientists to calculate the average temperature and the departure from normal temperature. The third form used by the observatory is the WXD Form, which consolidates the yearly data collected at the observatory. This form records some of the same information as the F6 such as the average temperature, as well as other weather information such as the different types of temperature readings (“Observer Handbook”, 2011). Examples of these forms are located in the Appendix A.

DATABASES

The Blue Hill Observatory seeks to combine the data previously collected with the current data to store all of their weather observations in one uniform database. Currently, the observatory uses computerized formats of the B16 and F6 forms. However, these formats are not able to provide the observers with querying capabilities or allow them to analyze the historical data from 1885. In this section, we will give descriptions of the databases, which we used in order to create a prototype database. A database is an electronic storage system for different types of data, such as text files and video. A database is part of a database system that enables multiple users to add, change, and maintain the database. The database system also has programs which allow the users to extract data in an efficient manner, make queries for specific data, and create reports of the data (Singh, 2011).

MySQL

For this project, we used MySQL, a popular database with query and storage capabilities (DuBois, 2005). Some advantages of MySQL are that it is secure, customizable, and compatible on many different operating systems or internet browsers (Valade, 2009). The compatibility of MySQL, meet the needs of the database for the observatory because it is easy to use or to customize for long-term data storage.

PHPMyAdmin

For this project, we used a database management program called PHPMyAdmin, which is a web interface to administer the MySQL database. PHPMyAdmin has features that vary from the management of the users of the database to modifying the data currently in the database (Delisle, 2012). For this project, PHPMyAdmin is used to manage the organization and users of the database.

DATA ENTRY FORMS

In order for the user to enter and view data in tables, front-end data entry forms needed to be creased for the database. To create these data entry forms, we used three different computer languages: HTML, JavaScript, and PHP. In the following paragraphs, we will describe what the language is and for what aspect it was used in the data entry forms.

HTML

HyperText Markup Language or HTML is a computer language that formats text into pages that can viewed on the internet. A main feature of HTML is hypertext, which means that the user can create a link to any other web page on the internet on the webpage they create. As a result, the information from the web page can be accessed from many different places. However, sometimes the HTML code will not be viewed exactly the same on every computer due to the different types of computers, internet browsers, and monitor sizes (Castro, 2007). This language is used for the design of the data entry form, such as the tables and the entry form on the page. The HTML code does not include any of the aspects of the form that check and submit the data into the MySQL database.

JavaScript

JavaScript is used as a programming language for the internet. All modern web sites use JavaScript, and it is compatible on most modern web browsers. This language is used to specify the web page acts with the information, and not the content or design of the page. JavaScript can be used to create functions for the page to implement after the user has entered data into the page (Flanagan, 2011). For example, if the user enters three numbers into a webpage, and then submit the data to be averaged, then JavaScript would perform the averaging. HTML would then display the result from the JavaScript function. For this data entry form, JavaScript is used to determine if the default date has been changed, and it is used to determine if there are any discrepancies between the two data entry tables.

PHP

Personal Home Page (PHP) is the language that submits the data into the appropriate place in the MySQL database when the data is entered into the entry forms. PHP is a scripting language that is mostly used with a web server to create HTML information. This means that even though PHP can be used to create webpages, most of the time it used to create a HTML page. This language can be combined with database tools, such as MySQL, to create and modify content in the database (MacIntyre, 2010). This language is used to take the data entered in with the web entry form and enter the data into the correct table in the MySQL database.

CASE STUDIES FOR OBSERVATORY INSTRUMENT TRANSITIONS

We evaluated two different scenarios to understand the pitfalls that occurred to other observatories while transitioning instruments. Each scenario provides an interesting account of different aspects of meteorological observations, thus providing us with several techniques to analyze and determine if appropriate for our situation. We will use these techniques to make recommendations in order for the Blue Hill Observatory to have seamless transitions of instruments.

A Comparison of Meteorological Observations from the South Pole Station

The Amundsen-Scott South Pole station, located in the southernmost place of the world, was established in November 1956. It is the only Antarctic Program station of the United States in Antarctica that houses scientists year round. Due to the extreme weather at the South Pole, the station had to take several extra steps to ensure the instruments collect data accurately. For example, the barometer, which measures atmospheric pressure, had to be kept in a heated shelter, known as an instrument suite, because it could not operate correctly past -40°C. In 2004, a new instrument suite had to be constructed because the previously used one became buried under the snow. To ensure that the data collected at the instrument suites were not affected by the new instruments and location, the scientists collected data observations at both sites from February 2004 through January 2005 (Keller, Baker, Lazzara & Gallagher, 2009).

The simultaneous collection of temperature data throughout a twelve month period allowed scientists to determine if the data were affected by the change in site and instrument.

After analysis of the mean daily differences for each month, the scientists determined that the differences were within the accuracy of the instruments except during the months of November, December, and January. The scientists concluded that the greater differences were due to increasing operational activities such as airplanes and snowplowing at the new site (Keller, Baker, Lazzara & Gallagher, 2009). Unfortunately, the new instrument and location did affect the pressure observations. The change in location resulted in lower pressure measurements because pressure measurements are dependent on the elevation of the measuring instrument. At the old station, the pressure was measured at an elevation of 2828 meters, which was nine meters lower than the elevation at the new location. Fortunately, the scientists were easily able to recalculate the pressure measurements to the elevation of the new station at 2836 meters (Keller, Baker, Lazzara & Gallagher, 2009).

This case study demonstrated that the data collected does not have to be affected by a change in instruments. It also showed how the station justified why the data was affected when there was a change in instrument and site. We can apply this case study when transitioning wind instruments such as the possible transition of the Bendix Aerovane to the RM Young Aerovane.

Changes in Instruments and Sites Affecting Historical Weather Records

The Urbana Station, established in 1888 by the University of Illinois, is known for being one of the best weather stations in the United States (Changnon and Kenkel, 2005). The leading scientists of the College of Agriculture supervise the weather station and train the observers how to use the instruments. As of 2005, the instruments were of the best quality, many of them having been designed and constructed by the scientists themselves. Observations were taken at the same place and time each day to ensure that the data is consistent. Over the one hundred years of observations, the station went through numerous advancements in technology, changes in the environment around them and site relocations, and had to adapt to all of these changes (Changnon and Kenkel, 2005).

When advancements in technology were made, managers of stations have to decide whether or not the new technology is worth implementing. Many stations go through the process of implementing the new technology because the advancements usually lead to more accurate and precise recordings. In 1948, the Urbana Station switched the instrument by which they measured the amount of precipitation from a tipping bucket to a weighing bucket style. After analyzing months of data, the station discovered that the weighing bucket style measured 15 – 35 percent more rain than the tipping bucket during the hourly readings. They speculated that this variation was because the tipping bucket was significantly slower when producing the values than the weighing-bucket. The station noted this increase in the accuracy of sampling rainfall amount and took it into account when analyzing long term data (Changnon and Kenkel, 2005).

When the Urbana Station had to be moved 2.2 km southwest of the site at Morrow Plots to a new location in 1984, the station took overlapping measurements to ensure the data being collected was not affected by the site change. Measurements such as temperature and wind speed were taken at the new and previous sites for three years to see the effect the site change had on the measurements. After analyzing the data, the station concluded that the site change resulted in an annual mean temperature decrease of 0.8°C. As a result of this change, the station constructed an adjusted curve that allows the difference in the actual and adjusted measurements to be seen. The following graph displays the actual measured value and the adjusted annual mean temperatures during 1889 through 2004.

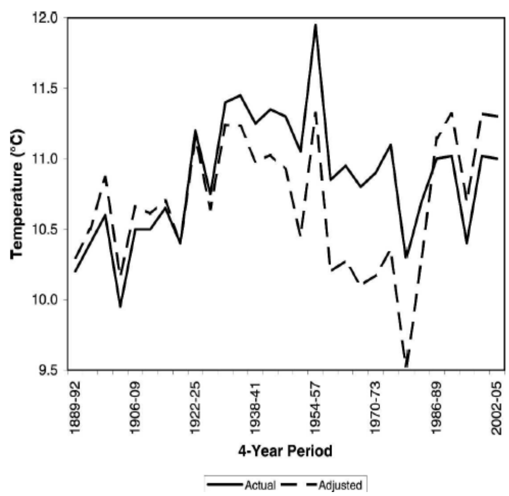


Figure 5: Measured and adjusted annual mean temperatures (1889 - 2004) (Changnon and Kenkel, 2005, p. 828)

The station decided that this decrease in temperature from the 1984 site change was insignificant because it would eliminate the urban heat island effect that resulted from the growing population of the adjacent town. Although the data was affected by the change in site location, the station was able to analyze the situation, make a conclusion about the cause, and find a solution for discrepancy in the data (Changnon and Kenkel, 2005).

This case study applies to our project because it illustrates the utility of using overlapping measures in the transition from the current instrument to a new or replaced one. Although this case study is slightly outdated, we will use the methods that they used as a reference to the more current methods of overlapping measurements to overcome the problems in the data collection when transitioning instruments.

THE IMPACT OF DATA ENTRY METHODS ON DATA ACCURACY

When entering in data into the computer, there are several different methods to decrease the number of errors that can occur. The three methods of data entry are:

1. Single entry - the user enters the data only once and goes onto the next data point
2. Single entry with visual checking - the user enters the data once and compares the data entered with the raw data
3. Double entry - the computer checks for mismatches from the data, which is entered twice

These methods vary in the time it takes to enter the same data set and the average number of errors that occur (Barchard & Pace 2011).

In order to determine which data entry method is the most accurate, 195 students were divided into three groups to test all the different entry methods. The first group entered the data once, but had been told that the accuracy was more important than speed. The second group entered the data and then checked the data visually by comparing their typed entries to the paper version. The third group entered the data in twice and used tools in Microsoft Excel to correct their errors (Barchard & Pace 2011).

The perfect accuracy, average time and number of errors that occurred for each method are as follows:

Table 1: Average Time and Number of Errors for Data Entry Method

Type of Entry	Perfect Accuracy	Average Number of Errors	Entries	Average Time
Double Entry	77.4%	0.34 errors	1260 entries	49.73 minutes
Single Entry with Visual Checking	17.1%	10.39 errors	1260 entries	37.43 minutes
Single Entry	5.5%	12.03 errors	1260 entries	30.03 minutes

The results from this study showed that double entry was the most accurate form of data entry. Even though double entry was the most accurate of the three methods, it also took the longest duration of time (Barchard & Pace 2011).

This experiment tested three methods of data entry, and determined which data entry method was the most accurate. By having the users enter in the same data, but with different methods allowed the study to show which method was the most accurate. Since there are over a hundred years of data that will be entered into the database at the observatory, we decided to make the type of entry for the prototype database a double entry in order to minimize the errors in the weather data.

CHAPTER THREE: METHODOLOGY

The first goal of this project was to develop a transition procedure for the Blue Hill Observatory to use when an instrument needs to be transitioned. This chapter outlines the steps we took in order to make the recommendations on the best instrument transition procedure. The second goal of this project was to develop a prototype database that consolidates the past and current weather data collected into one uniform database. This chapter outline the objectives we completed in order to develop the prototype database.

GOAL 1: TRANSITION OF INSTRUMENTS

The first goal of our project was to develop a seamless procedure for the transition of a current instrument to a new or replacement instrument at the Blue Hill Observatory. We were able to complete this goal by completing the following objectives:

1. Identify and research the current instruments currently in service at the Blue Hill Observatory
2. Construct a grading scale
3. Grade each of the instruments based on their current condition
4. Create and recommend a transition procedure for the instruments

Identify and Research Instruments Currently Used at the Blue Hill Observatory

The first objective was to identify and research the instruments used at the observatory. In order to complete this objective, we created a list of the instruments used at the observatory, interviewed the instrument technician, and researched information about the instruments.

Created a List of the Instruments used at the Observatory. We created a list of the instruments used at the Blue Hill Observatory and we wrote a description of the function, location, and history of each of the instruments. This list of seventeen weather instruments was compiled through discussions with observers and the instrument technician at the observatory. After the completion of the list of the instruments that are currently in service, we decided to focus on a few instruments in order to give an in depth analysis of the instruments instead of briefly analyzing all of the instruments. We go into more detail on why we chose these instruments in Chapter Five: Discussion. We choose the following are four instruments we focus on:

1. F420 C Anemometer
2. Contact Anemometer
3. Bendix Aerovane
4. Ombroscope

Interviewed the Observatory Technician. To obtain more information about each instrument, we interviewed David Doe, who is responsible for the maintenance of the instruments not supported by the NWS at the Blue Hill Observatory. He has been maintaining the instruments at the observatory since 1999, and is the most knowledgeable on the technical aspects of the instruments. He was able to provide us with the technical information of those instruments and the manuals detailing the maintenance instruction of those instruments. He also provided us with his continued commentary on how we should approach the construction of our transition systems.

Researched Information about each Instrument. By reading the manuals that David Doe provided us, we were able to obtain a better understanding of how each of the instruments work. The manuals provided us with diagrams, suggested maintenance procedures, assembly and disassembly instructions, and troubleshooting instructions. We used all of these aspects as references when constructing and assessing the grading scale.

Constructed the Grading Scale

In order to complete the third objective, we constructed a grading scale in order for the observatory to continually assess the current state of the instruments. We used the information from the research on the instruments and interviewed the observatory staff to determining the categories of the grading scale.

Interview Sheet for the Blue Hill Observatory Staff. Throughout the process of gathering information for the instruments at the Blue Hill Observatory, we encountered differing opinions among the observatory's staff. The differing in opinions were primarily on which instruments are more important to the observatory's data records and which are in most need of transitioning and replacement. We created an interview sheet for the observatory staff to fill out with questions that asked the observatory staff how they would rank the instruments that we were focusing on. This interview sheet is shown in Appendix B.

Aspects of the Grading Scale. When we constructed the grading scale, we designated a defined point system based on the importance of each parameter in comparison to one another. We then made a list of variables, which we considered important aspects of the current condition of the instrument. The following is the list and an explanation of the categories we used:

1. Duration of Use
2. Maintenance Frequency
3. Urgency of Replacement
4. Current Mechanical Condition
5. Part Availability

The following figure is the grading scale we constructed.

Table 2: Example Grading Scale

Beginning Point Total	**100**
Duration of Use (check one deduction)	
81-100+ yrs (-5 pts)	
61-80 yrs (-4 pts)	
41-60 yrs (-3 pts)	
21-40 yrs (-2 pts)	
1-20 yrs (-1 pt)	
New (-0 pts)	
Part Availability (rate each range, add total deductions)	
Operational Capacity of Manufacturer (-10 – 0 pts)	
Production capacity of instrument model (-10 – 0 pts)	
Availability of similar models on the market (-5 – 0 pts)	
Current Mechanical Condition (rate each range, add total deductions)	

Condition of wiring /sensors /mechanisms (-15 – 0 pts)	
Condition of mechanical structure (-10 – 0 pts)	
In-field Maintenance Frequency not per design (check one deduction)	
Monthly? (-20 pts)	
Quarterly? (-12 pts)	
Semi-annually? (-8 pts)	
Annually? (-4 pts)	
Has required no, or less often, maintenance (-0 pts)	
Urgency of Replacement	
(Deduct if applicable)	
Is a data recording instrument, not data reference (-5 pts)	
(rate each range, add deductions)	
Accuracy in data readings (-10 – 0 pts)	
Disruption in data integrity (-10 – 0 pts)	
Total Deductions	
Grade (final point total)	

Duration of Use. The first factor which we graded the instruments on is the duration of use. Many of the instruments at the observatory have been used for several decades, almost as long as the observatory has been in service. Unfortunately, these instruments deteriorate over time due to weather conditions, aging of instrument parts, and wear due to its continuous use. For this factor, we rated each instrument based on the length of time that it has been used at the observatory. The longer the instrument has been used the greater the reduction the instrument will receive. For example, the Bendix Aerovane, which has been in use at the observatory since the 1960s, would receive a lower point value than the Davis system, which was installed in 2004 at the observatory.

Unplanned Maintenance Frequency. The second factor that the instruments were graded on was the maintenance frequency. This factor is broken down into increments of time for when the instrument has needed unscheduled in-field maintenance. An example of an instrument that has a scheduled maintenance plan is the Contact Anemometer, which needs to be lubricated every three months. It is in the observatory's best interest to have instruments which do not require frequent maintenance because the maintenance costs the observatory time and money. As the instrument requires more maintenance than the annual maintenance check the number of deductions will increase for this category.

Current Mechanical Condition. We also graded the instruments based on their current mechanical condition by splitting this category into two subcategories. The first subcategory was the condition of the instrument's mechanical structure, such as the wiring, mechanisms and sensors. For example, the motor in Bendix Aerovane frequently malfunctions; as a result, this instrument will have a high number of deductions in this category. The second subcategory was the effects that the physical damage to the structure of the instrument has on the data reading capabilities. The lower point value the instrument receives in this subcategory, the higher priority for the observatory to consider a replacement. These two subcategories are general enough so that the scale can apply to any weather instrument while still including the necessary grading details of the instrument. Both of the subcategories are set in ranges, as the condition of the instrument can vary or worsen over time.

Part Availability. The fourth factor we graded the instruments on is the availability of their replacement parts. Since many of the instruments were manufactured during the early 1900's, the manufacturers are no longer supplying replacement parts for the instrument. As a result, the observatory has to rely on the few replacement parts that they currently have when a replacement part is needed. The weight of this factor was divided among three subcategories: the operational capacity of the manufacturer of the instrument, the production level of the instrument's specific model design, and the availability of similar models of the instrument on the market. If the replacement parts are readily available, the instrument received fewer deductions for this subcategory as opposed to an instrument whose replacement parts are no longer being manufactured which more points had to be deducted.

Urgency of Replacement. Finally, we rated each instrument on the urgency that the observatory has on replacing them. Since the Blue Hill Observatory prides itself in collecting homogeneous data, it wants to maintain the same instruments to ensure that the data collected by the instrument is as consistent as possible. As a result, the observatory may be less willing to transition away from an instrument that has been used to collect data for a long period of time in order to maintain the homogeneous data. Also, many of the weather instruments that are currently used at the observatory are of the few remaining instruments still in service across the United States and the world; therefore, the observatory wants to maintain the use of these instruments. The ombroscope is an example of an instrument that is one of the few of its type still in service. Important factors such as whether or not the instrument is used for their daily weather observations or just as a reference check to ensure the other instruments are functioning correctly, the accuracy in its data readings and how the accuracy has affected data integrity determined the points deducted for each instrument.

Graded each Instrument Based on their Current Condition

The third objective for this goal was to grade each instrument. With the research on each individual instrument and the help of David Doe, the instrument technician, we were able to assess and grade the current condition of each of the four instruments. We discuss the results of the grading scale in Chapter Four: Findings and Results.

Made Recommendations on Instrument Transition

We made recommendations on the procedure we advise the Blue Hill Observatory to transition from the current instrument to a new or replacement instrument while continuing to collect homogeneous data. We also made recommendations on possible replacement instruments which we discuss in Chapter Four: Findings and Results.

GOAL 2: DATABASE DEVELOPMENT AND MANAGEMENT

The second goal was to develop a prototype database that consolidates all of the weather data collected into one uniform database. We were able to accomplish this goal by completing the following objectives:

1. Assessed the current and past data storage methods used at the Blue Hill Observatory
2. Created a Front End Data Entry method
3. Made recommendations on the next steps necessary to complete the database

Assess the Current and Past Data Storage Methods Used at the Blue Hill Observatory

The initial step in the creation of our prototype database was to assess the current and past data storage methods at the Blue Hill Observatory. Through discussion with Robert Skilling, the chief observer at the observatory, we were made aware of all of the weather data forms used at the observatory. We compared all of the different forms used from when they began recording weather observations in 1885 to the current forms used.

Made a Detailed List of all of the Weather Observations. Using the different weather data forms, we made a list of all of the weather observations in the B16, F6, and WXD forms. They included but were not limited to temperature, relative humidity, wind speed and direction, and precipitation. Based on these lists, we compared the similar weather observations on each form, which we used to plan the organization of the MySQL database.

Constructed a Front End Data Entry Method

In order to construct the front end data entry method we determined the categories necessary in the database and researched and tested different versions of Front End Data Entry methods.

Determined the Categories of Information to be Stored in the Database. We interviewed the chief observer and two other daily observers at the Blue Hill Observatory to gain insight on what they felt the database should consist of to maximize the benefit to the observatory. We also felt it was necessary to survey potential benefactors, such as stakeholders, users, and potential users of the database to get a perspective on their opinions about past weather data inquires. The population sample of the survey was members of the general public who signed up through email to receive daily weather data or who inquired about weather data from the observatory in the past. A total of 100 people were sent the survey through email.

Researched Different Versions of Front End Data Entry Methods for MySQL. After discussion with the benefactors of this database, we chose to create our own form of data entry using a combination of HTML, JavaScript, and PHP. This decision was made after several failed attempts of other front end data entry methods such as MySQL Workbench, PHPMyAdmin, and

Database Master. We decided to choose this combination because it is relatively easy for an inexperienced individual to understand.

Tested Different Versions of the Front End Data Entry Methods for MySQL. While the prototype of the database was developed, we tested the usability of the form with an intern at the observatory. After evaluating and considering the intern's feedback, we made modifications to the data entry form. After we made the suggested modifications, we had the intern enter the data in again and compared the results.

Made Recommendation on the Necessary Steps to Complete the Database

Once the prototype database was constructed we made recommendations for the Blue Hill Observatory to complete the database. The first step to complete this objective was to create documentation for the database and the data entry forms. We completed this step by creating procedures on how to add data into the database, how to move the data to another computer, and how the database is organized. Finally, we wanted to give recommendations on how the observatory can continue the development of the database.

CHAPTER FOUR: FINDINGS AND RESULTS

The first goal of this project was to develop a transition procedure the Blue Hill Observatory can use when transitioning instruments. In this chapter, we discuss the findings of our research on the four instruments currently used at the observatory and the findings that we used to determine the best procedure for instrument transition. We also discuss the results of our instrument grading scale and give a description of the prototype database.

FINDINGS FOR WEATHER INSTRUMENTS

Through discussions with key staff members at the Blue Hill Observatory such as the chief observer and the instrument technician we were able to assess the current condition of the four instruments**.**

420 C Three-cup Anemometer

The 420 C Three-cup Anemometer was installed at the Blue Hill Observatory by the National Weather Service in the late 1970’s and it has been used since then for the daily weather observations to measure the daily peak gusts. Recently, the NWS stopped providing maintenance for this instrument because of the lack of available replacement parts. A component of the instrument that is no longer manufactured is the bottles. Each bottle has a three year life expectancy and the observatory currently has a few of the replacement bottles left, which they will be able to rely on in the near future. However, the observatory will have to transition away from this instrument when they use up all of the available parts.

An aspect that needs to be considered when transitioning this instrument is the pen drag of the chart recorder. The Wind Gust Chart Recorder keeps a continuous chart recording of the instantaneous wind gust. When transitioning to a replacement instrument the pen drag will have to be taken into account to ensure the continuation of the collection of homogeneous data.

Contact Anemometer

The Contact Anemometer is used for the daily weather observations to measure the daily mean wind speed and the fastest mile. This instrument has been the most reliable instrument for the observatory throughout its use. The National Weather Service also installed this instrument at the observatory in 1960 but has stopped providing support for its maintenance because, similar to the 420 C series, the replacement parts are not readily available. As a result, the maintenance of the instrument became too difficult and costly for the NWS so they decided to stop servicing the instrument.

Currently, the observatory has a plan in place in which Dave Doe, the instrument technician, lubricates this instrument every three months. This lubrication has become an issue recently because the Texaco Regal “B” oil is no longer being produced. The observatory is currently trying a different type of oil but has found that this oil evaporates quicker than the oil previously used. As a result, the observatory will re-lubricate this instrument after two months instead of after three months. Despite this issue, the observatory is pleased with the current maintenance plan in use.

Bendix Aerovane

The Bendix Aerovane measures wind speed and direction and has been in use at the Blue Hill Observatory since the 1940’s. This instrument is in very poor condition and constantly needs maintenance. It frequently needs to be reoriented to true north after power failures and had has a defective motor on the right side which frequently needs to be reset by hand by an observer. Similar to the other instruments at the Blue Hill Observatory, many of the replacement parts for this instrument are no longer being manufactured so the observatory has to rely on the spare replacement parts that it has currently. The observatory uses the data collected; therefore, the observatory needs to find a viable replacement as soon as possible.

Ombroscope

The ombroscope was installed at the Blue Hill Observatory in 1904 and is used as a precipitation detector that records when precipitation is falling. The main concern with this instrument is the clock suddenly stops or is 15 to 30 minutes late. It is becoming very difficult and expensive for the observatory to find a clocksmith who knows how to fix the clock used in the ombroscope. Another constant problem that the observatory has to tend to is that snow often clogs the hole which restricts the precipitation from falling in. The instrument technician at the observatory has tried several ways to melt the snow; one method was placing a light bulb that will heat the cover of the ombroscope and melt the snow. The most effective method was placing a heated wire on the cover that will cause the snow to melt and not cause the hole to be clogged. Since this instrument has become very unreliable, it is currently only used as a reference check to ensure that the other precipitation instruments are functioning correctly.

GRADING REPORT

The following are the results of the initial grading report. As mentioned in the methodology we used our findings on the instruments to complete this form along with assistance from Dave Doe, the instrument technician at the Blue Hill Observatory.

Ombroscope

Table 3: Grading of Ombroscope

Beginning Point Total	**100**
Duration of Use (check one deduction)	**-5**
81-100+ yrs (-5 pts)	x
61-80 yrs (-4 pts)	
41-60 yrs (-3 pts)	
21-40 yrs (-2 pts)	
1-20 yrs (-1 pt)	
New (-0 pts)	
Part Availability (rate each range, add total deductions)	**-20**
Operational Capacity of Manufacturer (-10 – 0 pts)	-10
Production capacity of instrument model (-10 – 0 pts)	-10
Availability of similar models on the market (-5 – 0 pts)	-0
Current Mechanical Condition (rate each range, add total deductions)	**-12**
Condition of wiring /sensors /mechanisms (-15 – 0 pts)	-7
Condition of mechanical structure (-10 – 0 pts)	-5
In-field Maintenance Frequency not per design (check one deduction)	**-8**
Monthly? (-20 pts)	

Quarterly? (-12 pts)	
Semi-annually? (-8 pts)	x
Annually? (-4 pts)	
Has required no, or less often, maintenance (-0 pts)	
Urgency of Replacement	**-9**
(Check if applicable)	
Is a data recording instrument, not data reference (-5 pts)	
(rate each range, add deductions)	
Accuracy in data readings (-10 – 0 pts)	-5
Disruption in data integrity (-10 – 0 pts)	-4
Total Deductions	**-54**
Grade (final point total)	**46**

420 C Three-Cup Anemometer

Table 4: Grading of 420 C Three-Cup Anemometer

Beginning Point Total	**100**
Duration of Use (check one deduction)	**-2**
81-100+ yrs (-5 pts)	
61-80 yrs (-4 pts)	
41-60 yrs (-3 pts)	
21-40 yrs (-2 pts)	x
1-20 yrs (-1 pt)	
New (-0 pts)	
Part Availability (rate each range, add total deductions)	**-10**
Operational Capacity of Manufacturer (-10 – 0 pts)	0
Production capacity of instrument model (-10 – 0 pts)	-10
Availability of similar models on the market (-5 – 0 pts)	0
Current Mechanical Condition (rate each range, add total deductions)	**-2**

Condition of wiring /sensors /mechanisms (-15 – 0 pts)	-2
Condition of mechanical structure (-10 – 0 pts)	0
In-field Maintenance Frequency not per design (check one deduction)	**0**
Monthly? (-20 pts)	
Quarterly? (-12 pts)	
Semi-annually? (-8 pts)	
Annually? (-4 pts)	
Has required no, or less often, maintenance (-0 pts)	x
Urgency of Replacement	**-5**
(Check if applicable)	
Is a data recording instrument, not data reference (-5 pts)	x
(rate each range, add deductions)	
Accuracy in data readings (-10 – 0 pts)	0
Disruption in data integrity (-10 – 0 pts)	0
Total Deductions	**-19**
Grade (final point total)	**78**

Contact Anemometer

Table 5: Grading of Contact Anemometer

Beginning Point Total	**100**
Duration of Use (check one deduction)	**-3**
81-100+ yrs (-5 pts)	
61-80 yrs (-4 pts)	
41-60 yrs (-3 pts)	x
21-40 yrs (-2 pts)	
1-20 yrs (-1 pt)	
New (-0 pts)	
Part Availability (rate each range, add total deductions)	**0**

Operational Capacity of Manufacturer (-10 – 0 pts)	0
Production capacity of instrument model (-10 – 0 pts)	0
Availability of similar models on the market (-5 – 0 pts)	0
Current Mechanical Condition (rate each range, add total deductions)	**-12**
Condition of wiring /sensors /mechanisms (-15 – 0 pts)	-7
Condition of mechanical structure (-10 – 0 pts)	-5
In-field Maintenance Frequency not per design (check one deduction)	**0**
Monthly? (-20 pts)	
Quarterly? (-12 pts)	
Semi-annually? (-8 pts)	
Annually? (-4 pts)	
Has required no, or less often, maintenance (-0 pts)	x
Urgency of Replacement	**-5**
(Check if applicable)	
Is a data recording instrument, not data reference (-5 pts)	x
(rate each range, add deductions)	
Accuracy in data readings (-10 – 0 pts)	0
Disruption in data integrity (-10 – 0 pts)	0
Total Deductions	**-20**
Grade (final point total)	**80**

Bendix Aerovane

Table 6: Grading of Bendix Aerovane

Beginning Point Total	**100**
Duration of Use (check one deduction)	**-4**
81-100+ yrs (-5 pts)	
61-80 yrs (-4 pts)	x

41-60 yrs (-3 pts)	
21-40 yrs (-2 pts)	
1-20 yrs (-1 pt)	
New (-0 pts)	
Part Availability (rate each range, add total deductions)	**0**
Operational Capacity of Manufacturer (-10 – 0 pts)	0
Production capacity of instrument model (-10 – 0 pts)	0
Availability of similar models on the market (-5 – 0 pts)	0
Current Mechanical Condition (rate each range, add total deductions)	**-20**
Condition of wiring /sensors /mechanisms (-15 – 0 pts)	-15
Condition of mechanical structure (-10 – 0 pts)	-5
In-field Maintenance Frequency not per design (check one deduction)	**-8**
Monthly? (-20 pts)	
Quarterly? (-12 pts)	
Semi-annually? (-8 pts)	x
Annually? (-4 pts)	
Has required no, or less often, maintenance (-0 pts)	
Urgency of Replacement	**-18**
(Check if applicable)	
Is a data recording instrument, not data reference (-5 pts)	x
(rate each range, add deductions)	
Accuracy in data readings (-10 – 0 pts)	-8
Disruption in data integrity (-10 – 0 pts)	-5
Total Deductions	**-50**
Grade (final point total)	**50**

Summary of Grading Report

The results shown in this report demonstrate the summation of our findings on the condition of each instrument we researched. The ombroscope received the lowest grade due to its large deductions in part availability and mechanical condition. It is one of the only instruments of its kind; as a result, there are no mechanism replacement parts available to the observatory. Its mechanical condition also received large deductions due to its aged clock mechanism.

Both the Contact Anemometer and the 420 C Three - Cup Anemometer received the best grades on the report. The 420 C Three - Cup Anemometer received almost half of its deductions from the part availability section, as the bottles for its structure are no longer produced and the observatory has only a few more bottles remaining in storage. The Contact Anemometer received most of its deductions in the mechanical condition section, as the wiring and mechanisms, and its whole bodily structure are not in great condition.

The Bendix Aerovane received the lowest grade of instruments, which are used for the daily weather observations, demonstrating its need for a replacement instrument. This instrument had a great total of mechanical condition deductions, but also had the highest number of deductions in the urgency of replacement section. Not only is used for their daily weather observations, but there were substantial deductions on how accurately its weather observations are and how the inaccuracy has created further problems in the accuracy of its past readings.

This grading scale brings attention to the condition of the instrument with all of the important factors considered. It is an easy grading system that can be done in a short amount of time each month, and provides a great benefit to them by providing a monthly update on each of the instruments, as well as continued communication between the staff members who look through or use this report. This report shows that staff members have differing opinions on the categories that are most important, the results from each section, as well as the overall balanced score of all the categories. As a result, the observatory can choose to update the grading scale based on their opinion and what they deem as necessary changes.

FINDINGS FOR INSTRUMENT TRANSITION PROCEDURE

The steps we recommend the observatory to take when transitioning an instrument are:

1. Perform a cost analysis on the instrument which needs a replacement

2. Identify replacement instrument
3. Determine appropriate method of transition
4. Analyze and investigate discrepancies
5. Phase out transitioned instrument

An in depth analysis of these steps is in Chapter Six: Conclusions and Recommendation; in this section, we discuss the findings which lead us to determine these steps.

Cost Analysis

The first step of our recommended procedure is to perform a cost analysis on the instrument which needs a replacement instrument. When deciding to maintain the instruments currently used, the Blue Hill Observatory has to determine if the costs of maintaining the instrument exceeds the cost of installing a new instrument. The following chart shows the estimated average annual costs for the typical service for the instruments at the observatory require:

Table 7: Yearly Maintenance Cost for Instruments

Average Yearly Maintenance Cost for Bendix Aerovane	**$ 90.00**
Cleaning, adjusting pen drive motor, reorientation of wave on roof or pen motor in chart recorder (3 Hours)	$ 90.00
Average Yearly Maintenance Cost for 420 C Anemometer *	**$ 20.00**
Replacement of Bottles (2 Hours)	$ 20.00
Average Yearly Maintenance Cost for Ombroscope	**$ 60.00**
Checking Leveling, Balance and Lubricate as needed (30 Minutes)	$ 15.00
Mechanical Arm Repair (30 Minutes)	$ 15.00
Installation and Removal of heater wires (30 Minutes Spring and Fall)	$ 30.00
Average Yearly Maintenance Cost for Contact Anemometer	**$ 30.00**
Inspection and lubrication (15 minutes four times a year)	$ 30.00
Total Average Yearly Maintenance Cost of Specified Instruments	***$ 200.00***

* The 420 C Anemometer requires maintenance every three years therefore the yearly average is $20.00

All of these numbers are based on the wage of the instrument technician at the Blue Hill Observatory, which is $30 per hour. These figures consist of all of the scheduled maintenance repairs that the instruments require. Some years, this number may be higher or lower depending on unexpected maintenance repairs the instrument may require. The following chart, displays the cost of the instruments we recommend as replacement instruments:

Table 8: Possible Replacement Instruments and Costs for Each

Replacement Instrument for Bendix Aerovane	
RM Young Aerovane	$ 0.00 *
Replacement Instrument for 420 C Anemometer	
Vaisala Wind Set WA 15	$ 550.00
Replacement Instrument for Ombroscope	
RG – 11 Rain Sensor / Gauge	$ 59.00
Replacement Instrument for Contact Anemometer	
Vaisala WMT52	$ 1,112.00

* Already in use at the Blue Hill Observatory

We have an in depth analysis on why we choose these instruments as replacement instruments and on whether or not the observatory should transition to these instruments in our Conclusion and Recommendation chapter.

Comparing Current and Possible Replacement Instruments

The second step of our recommended transition procedure is to identify a replacement instrument. When transitioning an instrument, the observatory needs to compare the current instrument used with the possible replacement instrument in order to verify that the instruments record the weather data in a similar manner. The following are factors that the observatory should focus on:

1. How the instruments function during all four seasons
2. The instruments responsiveness
3. How the instruments averages its measurements
4. Resolution of the instruments

Functionality for All Four Seasons. The first factor of comparison between the two instruments is to determine how the instruments function during extreme weather conditions. This factor is especially important for the Blue Hill Observatory because of the vast differences among each of the four seasons. For example, the replacement instrument for the Contact Anemometer has to have the capability to measure 186 miles per hour because it is the highest measured wind speed recorded at the Blue Hill Observatory. If the replacement instrument does not have the same measuring capabilities as the current instrument, it is not a suitable replacement for the instrument.

Responsiveness. The second factor the observatory should compare between the replacement instrument and the instrument currently used is the responsiveness of the instrument, which is how quickly the instrument reacts to the changing conditions. An example of this difference in response times is the difference between a mercury barometer and an electronic barometer. The reading of the electronic barometer changes instantly when the atmospheric pressure changes. However, the reading of the mercury barometer has a longer lag time because the mercury has to rise to the proper level. The observatory must compare the lag time between the two instruments in order to ensure that their hourly data is not affected by the responsiveness of the instrument.

Calculating Averages. The third factor the observatory has to take into account is how the instrument calculates the average of the weather observation. Since there are many different ways of calculating an average, the observatory should check that the two instruments calculate the averages in a similar manner. The following are several different methods of calculating the average daily temperatures:

$$\text{Temperature}_{\text{average}} = \frac{Max+Min}{2} = \frac{each\ of\ the\ 24\ hour}{24} = \frac{4\ hours}{4}$$

All of the above methods calculate the daily average temperature, but they all will produce a different number for the average. As a result, the observatory has to ensure that the instruments average the weather data in a similar manner to verify that the weather data is not affected by the change in instrument.

Resolution. The fourth factor that the observatory has to take in to account when transitioning to a replacement instrument is the resolution of the two instruments. The resolution of an instrument is the accuracy of the data recorded. For example, if the rain gauge currently used recorded the amount of rain to the closest one hundredth of an inch, the replacement rain gauge should do so as well. The resolution of the instrument is important because the replacement instrument has to be, as already noted, as accurate as or more accurate than the instrument that is currently used.

Types of Instrument Transitions

The third step in our recommended procedure is to determine an appropriate method of transition. Depending on each instrument, the observatory has to choose which method of transition to use when transitioning to a new or replacement instrument. The two most common methods we researched were:

1. Simultaneous running of both instrument
2. Immediate of the instruments

The procedure for the simultaneous running of both instruments is that the observatory runs both the replacement instrument and the current instrument simultaneously side by side for at least a year in order to ensure that the weather data collection process and results are not affected by the change in instrument. Ideally the observatory should run the instruments simultaneously side by side for as long as possible; unfortunately this is not always able to happen with many of the instruments. The main reason is that the current instrument stops functioning before they collect the data for the whole year or the observatory does not have the space and resources to run both instruments for a year. It is recommended that the observatory compare the data from both instruments for at least a year so that the data collected can be compared in all four seasons (Briede, C.M. 2012).

This method allows the observers to analyze and compare the data collected by both instruments to see if there are any discrepancies between the two weather readings. Such a comparison allows the observers to find a viable justification for any discrepancies found. This is the best method to use if the observatory wants to ensure that they are recording homogeneous data because the comparison of the data verifies that the data being collected is not affected by the change in instruments. The simultaneous running of the instruments will also provide a margin of safety for any malfunctions that occur to the replacement instrument during its first year of use (Changnon and Kenkel, 2005).

The second method of transition is that the observatory simply replaces the current instrument with a new instrument. As soon as the observatory receives an instrument with higher technological capabilities, the observatory will replace the current instrument because the new instrument will be able to collect more accurate and precise data than the one currently used. A drawback to this method of transition is that the data collected will not be able to be used for climactic research because they did not verify that the instruments were collecting the data in a similar manner.

ACCESSING THE DATA ENTRY FORMS

When constructing the prototype data, we focused on the weather data observations in the B16 Form. We were able to create front end data entry forms, which is where the user enters the weather observation data. The forms we created were for Hourly Temperature, Hourly Precipitation, Hourly Sunshine Minutes, Hourly Wind Speed and Direction, Daily Sky Cover, Daily Lowest Visibility, and Daily Relative Humidity. Since each of the weather observations are measured differently, we had to make each form specifically for all the different weather observations. The screen shots of all of the forms are in Appendix C.

Procedure for Entering Data into Database

In the following section, we display the steps the users will have to complete in order to enter the weather data into the database.

1. Enter address into web browser

In order to access the database, the user has to be the Blue Hill Observatory server and will enter the following IP Address in the web browser: http://192.168.1.116/index.html .

2. Choose Weather Data Observation to Enter Data

The user then chooses the desired form in the screen, shown in the figure 6. For this demonstration we will be entering temperature data.

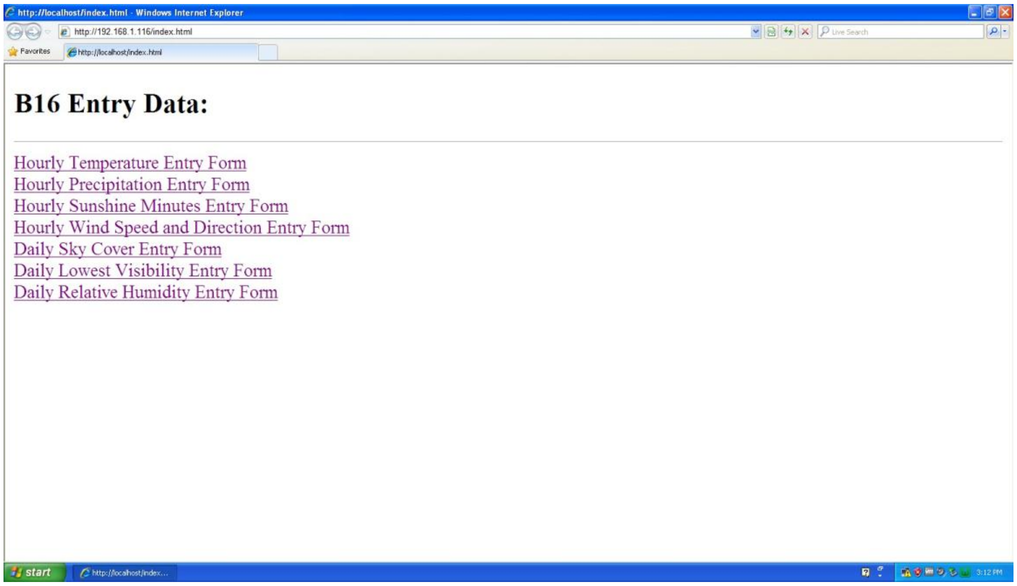


Figure 6: Index Page for Data Entry

3. Enter Weather Data

The user will first have to enter the date of the weather observations. Then, the user will enter the data into the Temperature (˚F) column, shown in figure 7.

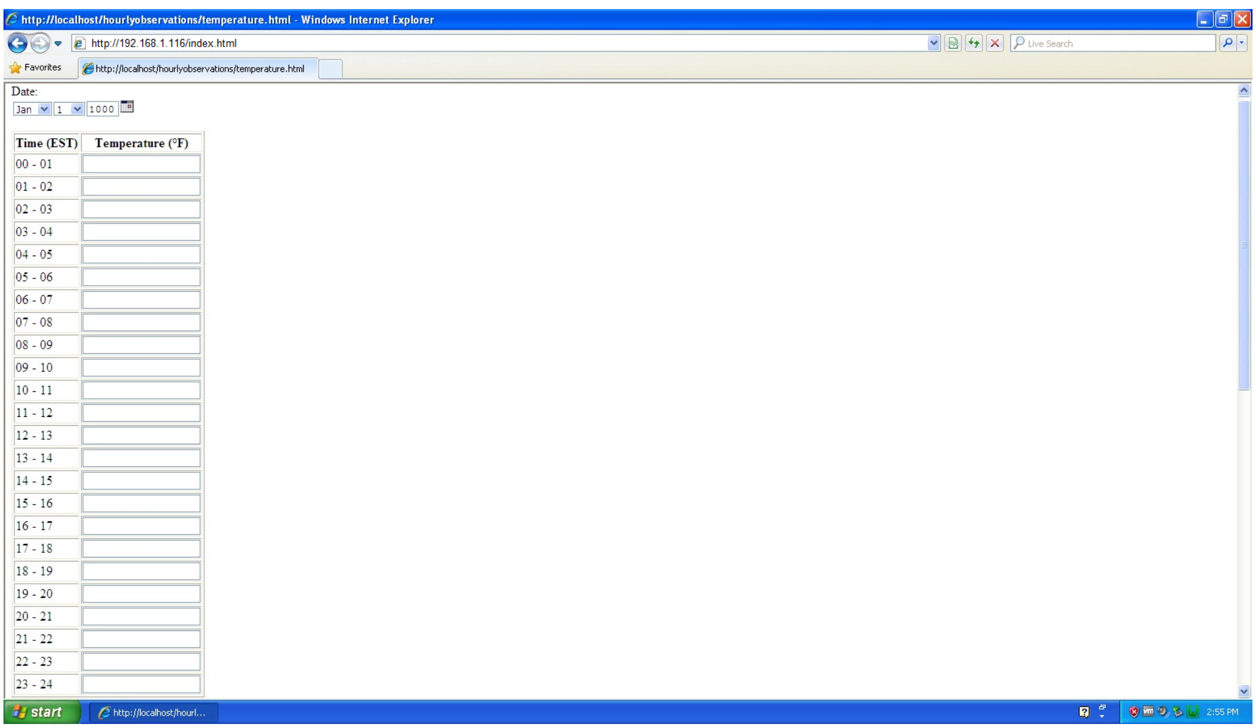


Figure 7: Data Entry Table for Temperature

The user will then reenter the data into the Retype Temperature (˚F) column, shown in figure 8; the discussion for why the user must reenter the data is in Chapter Five: Discussion.

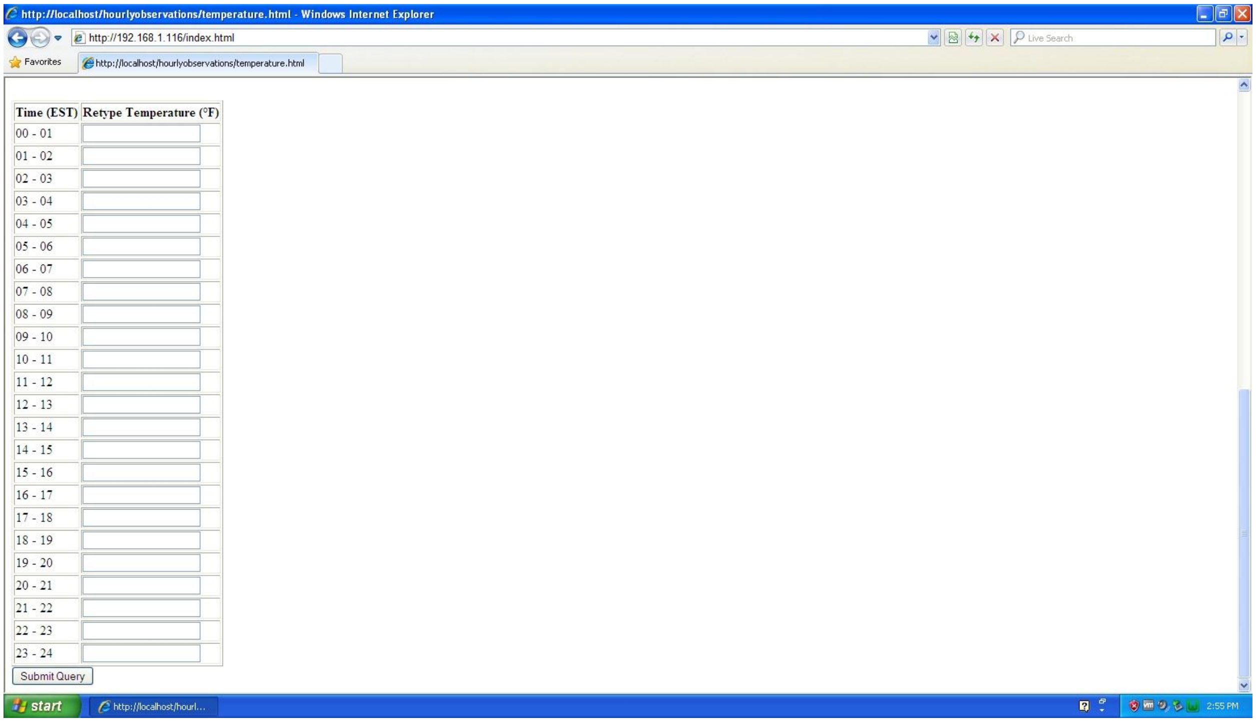


Figure 8: Re-entry Table for Temperature

Once all of the data has been entered, the user will click Submit Query. If the user does not change the default date and enter the correct data there will be an error message as displayed in Figure 9.

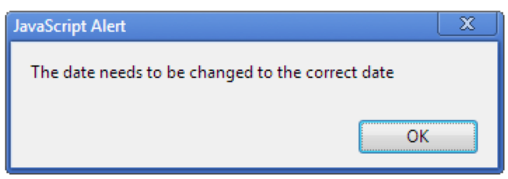


Figure 9: Error Message about Date

The user will have to change the data and click Submit Query again. If any of the rows between the two tables are not the same, the program will notify the user of any issues between the data entered. The pop up window, shown in Figure 10, will occur.

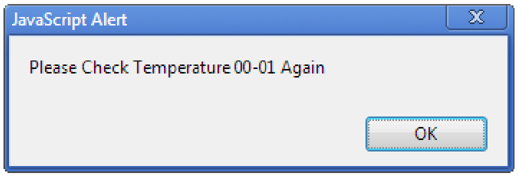


Figure 10: Error Message about Mismatched Data

The user will have to check each entry with the original weather data form to find the error. Once the error is found and fixed, the user will click Submit Query and the data will be entered into the database.

5. Check if data was entered into database

To check that the data was entered into the database, the user has to enter the following IP address into the web browser: http://192.168.1.116/PHPMyAdmin/. Figure 11 is a display of the database with the weather data entered into the database.

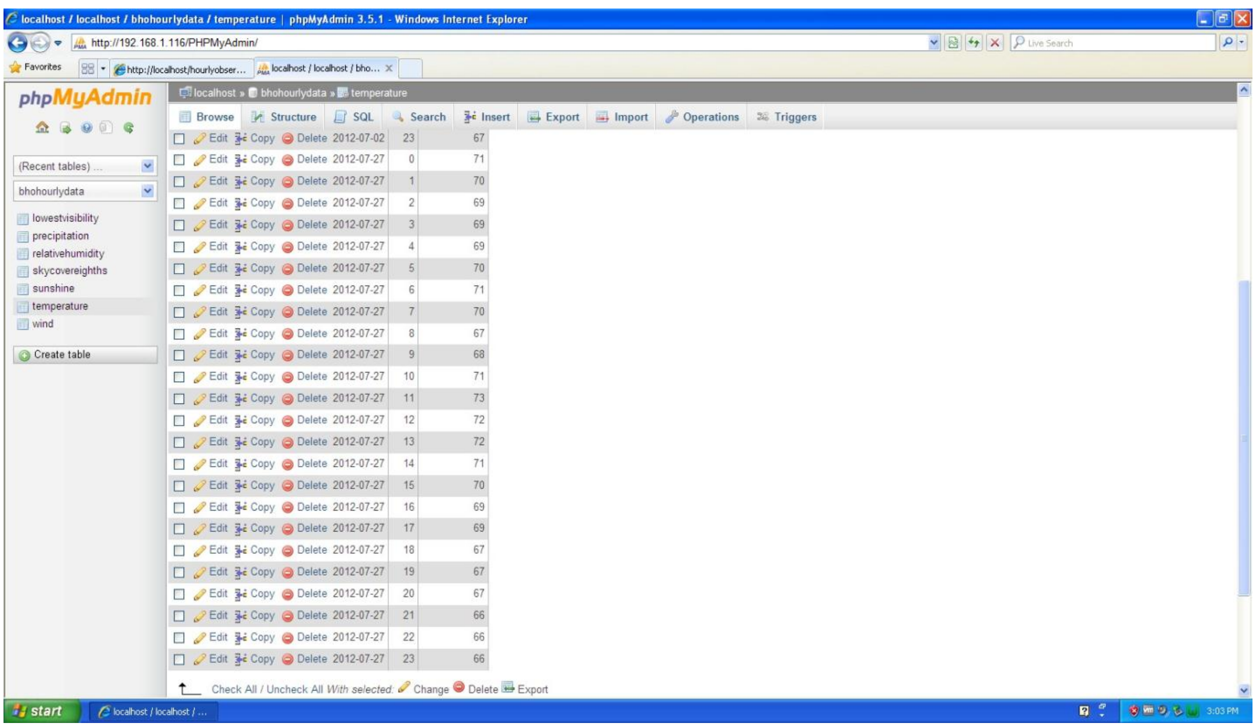


Figure 11: Data Entered in the Database

CHAPTER FIVE: DISCUSSION

This chapter discusses the results from the surveys and interview sheets we conducted during our project. We also discuss who should fill out the grading scale and why we chose these people to fill out the grading scale. In this chapter, we state why we chose the data entry method, explain certain aspects of the database, and state the results of the testing of the database. This chapter also discusses the benefit of manually operated weather observatories,

INTERVIEW SHEET RESULTS

From the responses that we received from the interview sheets, as we expected there were many varying opinions but also some topics that were generally agreed on. We discovered that there was not a linear relationship between the importance of an instrument and the need for transitioning an instrument. Some of the staff members thought that the most important instruments should be the last to be transitioned, while others thought that they should be the instruments transitioned and replaced most quickly, and there was no consensus on a single most important instrument. We also discovered that the instruments that we were focusing on were the instruments that were most in need of transition and replacement, providing an important validity to our study. The sheet was designed so that we could see varying opinions based on each staff member's responsibility with the observatory, but the results from the study showed that there was no consistency in that aspect. We did not have a large sample size, as we only sent the interview sheet to the staff of the Blue Hill Observatory and key figures we have been in contact with.

The purpose of this study was to help us determine how to construct and define our grading system, and while the results mostly varied, it taught us that our system must be flexible and adaptable. The observatory's staff has very different opinions on when which instruments should be transitioned and replaced, so our transition system had to be able to accommodate any future alterations that the staff might have to the system. These alterations might include a change to the weight system of the scale, re-defining of the grading parameters, as well as even detailing the scale to a particular instrument in order to be more specific with the grade. Based on these findings, we detailed our grading system with parameters that would be inclusive to the conditions of any weather instrument, yet with a simple enough structure so that it could include any alterations the observatory would wish to include.

IDENTIFYING INSTRUMENTS FOR TRANSITION

In order to complete our first goal, we first needed to determine the instruments to focus our procedure on. We began by researching seventeen instruments out of the over thirty instruments of the Blue Hill Observatory, to have an adequate sample size and inclusive details of what to consider as part of the procedure. From that list of seventeen instruments, we decided to focus on four instruments that were a priority for transition: the Bendix Aerovane, the Contact Anemometer, the 420 C Three-Cup Anemometer, and the ombroscope. This narrowing of the list was decided by several factors, including the fact that some of the instruments are still being supported by the National Weather Service. This means that any maintenance work and physical handling of the instrument and its recording system would be done by technicians provided by the National Weather Service. Therefore, the observatory would not need a transition system for that instrument; however, there have been cases where the National Weather Service has discontinued their support of these instruments but the Blue Hill Observatory chose to maintain the instrument. In order to have a procedure in place for when this does happen, our procedure needed to flexible enough to incorporate possible adaptations in the future. We also decided that there is not a needed transition system for the instruments that are still currently being produced that are of the same model as the observatory could purchase any one of these models and be provided with an instrument that measures in the same manner as the previously serviced instrument.

SUBJECTIVITY OF GRADING SCALE

We acknowledge that there are some problems with subjectivity in the using of the instrument grading scale. Much of the grading ranges force the user to apply their personal perspective to the scale of their impressions on the instrument. However, as there is no other observatory that we could find that uses the same instruments as the Blue Hill Observatory, the staff members at the Blue Hill Observatory are the only people suitable enough to accurately assess each instrument. The dilemma is not who should fill out the grading scale, but rather trying to find a way to agree on each assessment of each instrument. Naturally, there would be slight differences in any assessment of any nature, but in this case, those differences would have to be small in order to ensure the accuracy of the statement.

We believe that in order for the grading assessment to be filled out in any case, some of the grades would be affected by lack of expertise and not lack of agreement on that focus. In order to fill out the grades appropriately, we would encourage a continued communication between the members of the staff to provide each other with updated information each individual may not know. For instance, there would be information the maintenance technician would know more thoroughly than an observer would about the mechanical condition of the instrument. In the process of communicating between each other, the observatory's staff would also be focusing on an agreement of each assessment as well. While the scale must remain subjective in itself, we believe that the observatory would inevitably provide a solution to that problem by communicating with each other to complete each assessment.

FILLING OUT THE GRADING SCALE

The purpose of the grading scale and report we constructed is to provide the Blue Hill Observatory with a system to check the current condition and priority level of a weather data recording instrument. However, since the scale was constructed to compile information about all of the most important aspects when considering a transition instrument, there are sections of the scale that one person may know more about than another, and vice versa, based on their area of expertise. For example, the current mechanical condition of the wiring and mechanisms may be graded more accurately by the maintenance technician who works on the instrument directly, rather than an observer whom may only notice these details to a lesser extent. Whereas for the urgency of replacement section, the observer would know more accurately how inaccurate the readings have been from an instrument than the technician, whom only works on the instrument directly and may know only passing details.

From one perspective, it might be preferable for the observatory to find a way for the observers to complete this grading scale. They would be paid and on the clock at that time, and have direct access to all of the instruments, so they would be able to determine the correct grade if they knew how to go about doing it. From another perspective, it would also make sense for the instrument technician to perform the grading scale. The technicians at the Blue Hill Observatory are contract technicians, and so the observatory would have to pay to bring that person to the observatory make the grading report. However, this technician would have greater understanding of the physical conditions of the instrument, they would be able to ask the observers on duty on the accuracy of the instruments in their readings, and would have more extensive knowledge of the manufacturer and replacement parts or instruments. For the Blue Hill Observatory, we feel that having both the observers and the instrument technician fill out the grading scale would be beneficial. This would help the observatory get an accurate description of the condition of each instrument. We also recommend the observatory to fill out the grading scale once a month in order to continually assess the current condition of each instrument.

PREVENTATIVE VS. IN-FIELD MAINTENANCE

An important aspect to consider in evaluating the instruments is the amount of maintenance each of the instruments have needed. There are mainly two types of maintenance done at the Blue Hill Observatory: preventative and in-field maintenance. Preventative maintenance is when the instrument is inspected without any cause, to determine if there are signs of future problems that the instrument may have. This type of maintenance, allows the observatory to foresee any future problems. In-field maintenance is when the instrument is in service but has acquired a problem and is not functioning properly. When this issue occurs, the observatory has to scramble to fix the problem or fear losing the weather data that the instrument records. It is a primary objective for the observatory to limit the in-field maintenance of any instrument and to have preventative maintenance performed when the instrument technician is already scheduled to be working at the observatory.

DATABASE SURVEY RESULTS

Through a survey, we were able to assess how users of the database would benefit from having access to data taken from 1885 to now. We sent the survey to over 100 people, but only received eight responses. The survey and formula for the rating average can be found in Appendix D and E respectively.

In order to determine how satisfied the individuals were about past data inquires; we asked questions about their past experience. We asked if the data that the Blue Hill Observatory provided meet your expectations; the following are the results:

Table 9: Results about Data Blue Hill Observatory Provided

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average
0	0	1	1	6	**4.63**

Since the majority of the individuals stated that they strongly agree that the data that the Blue Hill Observatory provided them met their expectations, we were able to determine that the current inquiry methods at the observatory are sufficient, but some individuals feel that they can improve on the data.

We also asked if the individuals felt that the observatory provided them with the data in a timely manner, the following are the results:

Table 10: Results about Time Taken to Receive Data

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average
0	0	1	3	4	**4.38**

Currently, if the time period of the data inquiry of the weather data is after 2000, the individual can simply ask the observatory for the data and they will provide them with an electronic version of the data. However, if the time period of the data inquiry is before 2000, the individual has to come into the observatory and look through the bounded books. This could be a reason why one individual chose neutral and three chose agree. This question shows how our project will benefit the observatory because the database will instantly provide the weather data to the individual when the inquiry is made.

USING MYSQL AS DATABASE

The database management system that we decided to use for our prototype database was MySQL. We chose MySQL because it is an Open Source project, which means that users can customize the program to their specific needs. We tested a few different programs to find a front end data entry method with query capabilities that was user friendly. Since there are over a hundred years of data that need to be entered into the database the data entry method has to be simple and easy to use. The different front end data entry methods we tried were MySQL Workbench, Database Master, and PHPMyAdmin.

The first program we tried was MySQL Workbench. This program had many different options for the management of a database and for the format of the database itself. We decided not to use this program because the data entry process was very tedious. When entering the data, the user would have to verify that the date was the same for each entry and change the hour for each data observation for each of the twenty-four hour temperature readings individually. Due to the complex nature of entering in data and lack of query capabilities, we choose to test other database management opinions.

The next program we tried, Database Master, had similar issues as MySQL Workbench. The user could not enter multiple data observations from the same day without having to enter in the data again each time. Similar to MySQL Workbench, there were no graphical query capabilities so the user would have to learn the programming language for querying the weather data in MySQL.

PHPMyAdmin was the closest program that we could find that accomplished some of the goals the observatory needed for the database because of the graphical querying capabilities. However, this program also required each hour to be entered separately for each of the data entry points but we decided to use this program as the database for the data.

The data entry method that we used for the database is a combination of HTML, JavaScript, and PHP. This method allowed for the flexibility to modify the entry form for the needs of the observatory. The form that we created allows the user to enter in the data into the each of the weather parameters. This allows the Blue Hill Observatory to modify and edit the entry form to fit the needs of the observatory.

ASPECTS OF DATABASE

When creating the database, we formatted the tables to look similar to the B16 form to ease the copying of data from the handwritten forms. However, since the format of the forms changed over the years it does not match for all of the forms used. We tried to make the forms as simple as possible to expedite the process of entering the 127 years of data.

When entering the data, we required that the user enter the data twice in order to decrease the number of human errors. The experiment which we discuss in Chapter 2: Literature Review explained how having the user enter the data point once and then reentering the data point in another column will minimize the number of human errors. We expect the user to check the raw data when reentering the data and not simply copy the data point that was initially entered. Although, it seems redundant and adds extra work for the user, when we had the intern enter the data this system caught a couple errors, which proved that this was necessary.

TESTING THE DATABASE

To test the functionality of the front end data entry method, we had a volunteer who was interning at the Blue Hill Observatory enter data. The intern was able to give us recommendations regarding how to make the data entry more efficient. The first suggestions the intern gave us was to place the column with the retype data entry underneath the initial data entry column because the set up was too confusing when the columns were side by side. Figure 12 shows the data entry columns side by side and side. Figure 13 shows the retype data entry column underneath the initial data entry column.

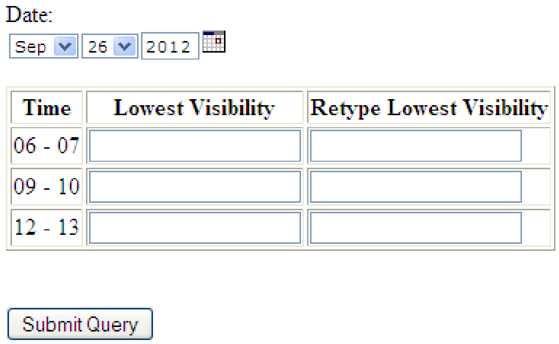


Figure 12: Data Entry Columns Side by Side

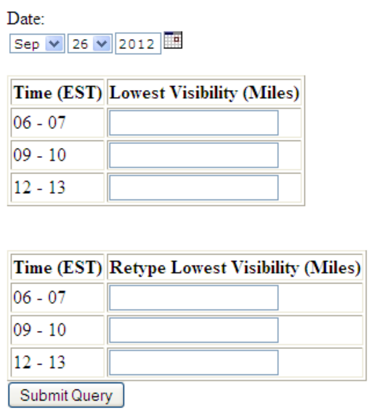


Figure 13: Initial Data Entry Column on top of Retype Data Entry Column

The intern also stated that the side by side columns defeats the purpose of the double entry method because the other column is so close that the user would simply copy the number from the first column instead of looking back at the raw data when entering the data for the retype column. Also, when the intern was entering the data, she frequently made errors which reliterated the need for the double entry because it caught many errors in the data entry.

CHARGING FOR ACCESS TO DATABASE

Currently, the observatory does not charge for the weather data available in their website, such as the Daily Discussion. They do charge the individual when a staff member needs to look up the data themselves and have to provide it by e-mail or mail. In our survey, only one person was charged for the data and the rest did not have to pay for it. With the completion of the database which we developed for the Blue Hill Observatory, they will have to decide whether or not they will charge users for access to the database.

In our survey we asked if the individuals would be willing to pay for the data collected at the Blue Hill Observatory; four of the individuals responded that they would not be willing to pay for the data and three responded that they would be willing to pay. The eighth response was a Commonwealth of Massachusetts agency so they are not able to comment on whether or not they would pay for access to the data. Since more individuals stated that they would not be willing to pay for the data, the Blue Hill Observatory needs to research if they will lose clientele if they start charging for their data.

BENEFITS OF MANUAL WEATHER STATIONS

When the National Weather Station was first established during the 1870's, there were about twenty-two military stations, which recorded weather observations. As time passed, these observation stations grew to as much as one in every county across the United States. Unfortunately, there are only a few manual observatories still in service across the United States. In the following section, we discuss the benefits of maintaining the manually operated weather stations and reasons on why many of them have ceased operation.

The main reason that the number of manually operated weather stations decreased significantly over the years is that they are very expensive to maintain. The operating costs of an observatory include but are not limited to observers' salaries and instrument maintenance repairs. Many of the observatories were forced to cease operations because costs were out weighing the benefit of the manual weather observations.

With the advancements in technology, the new weather instruments produced were automated and no longer needed an observer to record the weather data. These automated instruments were designed to make weather observations at specific times and the data collected would then be populated into the instrument database. These instruments eliminated the need for the observers which greatly decreased the operating costs. The only operating costs that the automated instruments require are the initial costs and maintenance costs.

Despite the cost of maintaining the manually operated stations and the advancements in instrument technology, there are many benefits of continuing the use of the manually operated stations. The main benefit for maintaining the operation of the manually operated stations is that many of the observatories have been collecting the weather data for over one hundred years. The Blue Hill Observatory has kept a continuous record of weather data since it was founded in 1885.

As mentioned previously in this project, this long record of homogeneous weather data is very beneficial to the study of the climate. Scientists are able to compare the data collected in 1885 and the current data to analyze the changing climate.

SOCIAL BENEFIT OF THE BLUE HILL OBSERVATORY

The Blue Hill Observatory is keen in collecting homogeneous data. The observatory ensures that the data being collected is homogeneous by using consistent collection methods throughout the whole data collection time period from 1885 to now. The consistent collection methods are that all the instruments use the same location and instrument design. It is important to note that the same instrument does not have to be used during the whole duration to collect homogenous data, just as long as the instrument is similar in design. An instrument that the observatory has had to change but still maintained the collection of homogeneous data is the Contact Anemometer. The instrument that is currently being used was installed in 1960 and it replaced an anemometer that had been in use since 1885. The Contact Anemometer was placed in the same location to continue the collection of homogeneous data. A case study of this instrument is summarized later in this section.

The data collected at the Blue Hill Observatory is therefore very unique because many other observatories do not ensure the collection of homogeneous data. Other observatories are more concerned with taking accurate and precise measurements and do not compare the data taken by the current and replacement instruments. For example, the Mount Washington Observatory in New Hampshire replaces an instrument when an instrument with higher technological capabilities is available. Since the Blue Hill Observatory verifies that the data being collected is not affected by the change in instrument, the data they collect is very valuable to climatologists. When the climatologists are analyzing the data collected at the Blue Hill Observatory, they can be assured that a change in the weather data is in fact due to climate change and not be concerned that a change in instrument caused the change in weather data.

The database, which we created, will allow the climatologist to have easy access to the homogeneous data collected at the Blue Hill Observatory. Currently, when an inquiry of the weather data was made, the individual would have to look through the bound books or talk to the observers themselves to find the data they are inquiring about. Once the database and data entry is complete, we intend that the observatory will be able to quickly search the database and find the information for the inquiry.

CASE STUDY: "WHY IS THE WIND SPEED DECREASING?"

A case study that proves how the homogeneous collection of data has helped justify that the climate at the Blue Hill Observatory is changing is "*Why is the Wind Speed Decreasing?"*. This case study explains how the wind speed at the observatory has decreased by more than ten percent in the last thirty years. The following is a graph shows the annual wind speed at the observatory from 1885 to 2008:

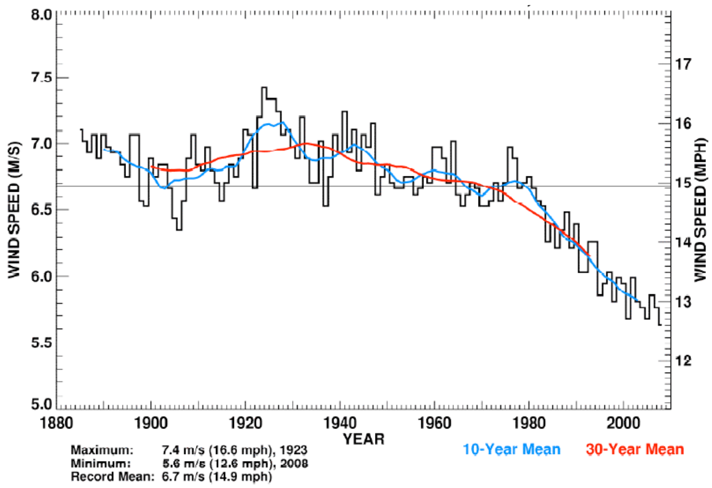


Figure 14: Annual Wind Speed at the Blue Hill Observatory

The case study explains how although the same instrument has not been in use over the one hundred years of data collection, the instruments used have been placed in the same location and height. The case study notes that there is an exception of the height of the instrument being raised ten feet in 1908. Since the wind speed weather data collection has been homogeneous over the time is has been collected, the observatory is able to say that the change in instruments did not affect the wind data collected. The observatory hypothesized that the decrease in wind speed was do due to the northward shift of the storm tracks which cross North America (Iacono 2009).

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

The first goal of this project was to develop a transition procedure for the Blue Hill Observatory. In this section, we recommend the steps that the observatory should take when transitioning instruments. We also compare and contrast the current instrument used and the instruments we recommend the observatory transition to. The last section concludes the second goal of our project and has recommendations on how the Blue Hill Observatory can continue to improve the database.

INSTRUMENT TRANSITION PROCEDURE

As mentioned in Chapter 4: Findings and Results, we recommend the Blue Hill Observatory to complete the following steps when transitioning from the current instrument used to a new or replacement instrument:

1. Perform Cost Analysis on Instrument for Transition
2. Identify Replacement Instrument
3. Determine Appropriate Method of Transition
4. Analyze and Investigate Discrepancies
5. Phase Out Transitioned Instrument

These steps were intended to be applied to the transition of any instrument at the observatory, but since we will identified the replacement instrument for the 420 C Three-Cup Anemometer, Contact Anemometer, Bendix Aerovane, and the ombroscope in the following section, the observatory does not have to complete step two when transitioning these instruments.

Perform Cost Analysis on Instrument for transition

The first step the observatory should take when transitioning away from the use of an instrument is to perform a cost analysis on the instrument that is in need of a transition. If the costs of maintaining the instrument are within an acceptable range for the observatory, then the recommended procedure for the observatory is to continue maintaining the instrument. Although they will continue using the instrument, we recommend they identify possible replacement candidates for the instrument for the observatory to be prepared with a replacement if the instrument were to fail in the near future. If the cost of maintaining the instrument exceeds the acceptable range for the observatory, the next step would be to designate the instrument for transition and determine an appropriate replacement instrument.

Identify Replacement Instrument

Once the current instrument is deemed ready for a transition, the next step is to locate a replacement instrument that is of or as close to the same design or model as possible. This is to lessen any extent of discrepancies in the data measuring process. Also, the replacement instrument must be within the range of specifications that the observatory desires. The specifications include measuring capabilities, energy consumption, degree of measurement accuracy, etc. The Blue Hill Observatory must be assured that any instrument they use to replace an existing instrument can be depended on to measure to their desired ability.

Determine Appropriate Method of Transition

There are two common methods of transition, as mentioned earlier, which are immediate replacement or a side-by-side period of analysis. If the instrument can be immediately replaced, it means that there is no need for an analysis period because either the instrument is no longer able to function or both the current and replacement instruments measure in a similar manner. If the replacement instrument cannot be installed for immediate use, or if the replacement instrument has calibration requirements, then it needs to be run alongside the current instrument for a period of at least one year, although preferably longer. While this is being done, the current instrument will still be used for recording weather data while the replacement instrument will be used as a reference tool.

Analyze and Investigate Discrepancies

The purpose of running the current and replacement instrument side by side is to discover if there is any measuring discrepancies. If the replacement and current instrument are not measuring equally, then the observers would know that there is a problem with one of the instruments. The data comparisons allow the observers to find a viable justification for the discrepancies.

Phase Out Transitioned Instrument

Once the replacement instrument is measuring accurately, and the calibration adjustments have been noted, than the observers can be assured that it is ready to be used for data recording. The current instrument may still be left in service if the observatory wishes to maintain it for a longer period, which would allow for further analysis between the two instruments. One reason for doing this would be if the current instrument was still not too expensive to maintain, or was still providing a historical benefit. Once the replacement instrument's data was used for weather recording and the current instrument was taken out of service, the transition process would be complete.

POSSIBLE REPLACEMENT INSTRUMENTS

Ombroscope

The instrument we recommend the Blue Hill Observatory to replace the ombroscope with is the Hydreon Optical Rain Sensor – Model RG-11. This optical rain sensor can measure when a precipitation event is occurring and the amount of precipitation over a period of time. It is about the size of a tennis ball and is covered in a clear plastic dome. When the rain or precipitation hits the clear dome case, beams of infrared light activate as the sensor reads the information. This sensor includes many different weather data measuring modes including a tipping bucket emulation, a "it's raining" function with a skylight, condensation and frost sensing, wiper control, irrigation control, and drop control (Hydreon optical rain). This instrument could be used not only as a replacement instrument, but also as a reference tool for other precipitation instruments at the Blue Hill Observatory because of its extensive precipitation measuring capabilities.

While this instrument varies greatly in size with the ombroscope, we would recommend it as the replacement instrument for the ombroscope for several reasons. The first reason being that there is a great difference in the amount of maintenance required between these two instruments. While the ombroscope has been having issues with its clock mechanism and there are a scarce number of people who could be able to fix it, this rain sensor uses infrared beams and requires little to no maintenance. This would also mean that the issue of running out of the ombroscope chart recorders with the proper dye would be irrelevant as well. This sensor is a low cost alternative that is more reliable for its continued viability at the Blue Hill Observatory. We would recommend that the observatory consider this instrument for its ombroscope replacement.

420 C Three-Cup Anemometer

The instrument we recommend the observatory replace the 420 C Three-Cup Anemometer with is the WA 15 Wind Set. This instrument set is widely regarded as the standard in the wind sensor market. It has a successful history of meteorological use, it provides accurate wind speed measurements, and it has a low starting threshold for wind measurements. Also, its shaft has heating capabilities in order to prevent freezing precipitation in the bearings or wirings, in order for the instrument to withstand the colder climates if needed (WA15 wind set). While the Blue Hill Observatory may not require all of the accessories within the set, this anemometer is likely a candidate for the replacement instrument of the 420 C Three-Cup Anemometer.

There are many similarities in the designs of both the 420 C Three-Cup Anemometer and the Vaisala anemometers. They both include light-weight conical cups, which is beneficial as it provides linearity in the measuring capabilities of the instrument. This means that the instrument measures evenly and accurately for all wind speeds up to 75 m/s, which is the maximum wind speed that it will record (WA15 wind set). Also, being one of the most recent models for this instrument, there would be no issue with replacing parts on this instrument, which is the largest issue that the observatory faces with the 420 C Three-Cup anemometer. Based on the similarity in design, measuring capabilities, and the relatively low-cost of purchase, we recommend that this instrument be considered to replace the current anemometer in service at the Blue Hill Observatory.

Contact Anemometer

The WMT 52 Ultrasonic Wind Sensor is the ultrasonic wind sensor that we recommend as a possible replacement instrument for the Contact Anemometer at the Blue Hill Observatory. It has no moving parts and reads the wind speed as it passes by its sensors (Wmt52 ultrasonic wind). This instrument has a beginning threshold of almost zero, which means that the instrument almost instantly records wind data as it occurs, essentially providing some of the most accurate information possible. The sensors are in a triangular position, which provides great data availability and encompasses entire horizontal wind data. This instrument is also designed to not require periodic field maintenance or any type of repairs (Wmt52 ultrasonic wind).

Currently, there are other wind measurement instruments at the Blue Hill Observatory that could be used to measure the fastest mile of wind passage that has a similar design to the Contact Anemometer. However, if the observatory wishes for a replacement instrument, we would like to suggest this Ultrasonic Wind Sensor, even though its design is not similar to that of the Contact Anemometer. With limited power consumption, it is an instrument that the Blue Hill Observatory can implement into their data collection process if they so choose.

Bendix Aerovane

An instrument that is being considered as a possible transition instrument for the Bendix Aerovane is the RM Young Aerovane. This instrument is currently being used at the Blue Hill Observatory as part of the Davis System, which is a collection of electrically automated weather instruments that measure weather data and record to its own separate database. It measures the wind speed through the number of rotations of its impeller as the wind blows by, and then determines the wind's direction based on the shift in its positioning as the wind hits the rudder-like tail.

This instrument has been considered to be the best suited instrument to eventually replace the deteriorating Bendix Aerovane and is the instrument that we would recommend as the replacement. There are some differences in the size of the instruments, which might cause for some discrepancies in the data. However, as it has already been in service at the observatory, these discrepancies have already been noted and can be accounted for. The RM Young also already has its data stored and it would be simple and easy for the observers to retrieve the data for recording purposes. All of this included, we feel that it would be the best instrument to replace the Bendix Aerovane.

Belfort Model 120. If the Blue Hill Observatory is looking for a model that is as similar size to the Bendix Aerovane as possible, than another instrument to be considered for replacing the current instrument is the Belfort Model 120. This aerovane has a 3-bladed impeller where wind speed is calculated by its number of rotations, and a rear rudder section that pivots based on the wind's direction. It is connected by a shaft in the middle section and at the base of that shaft is a torque-synchro transmitter where the weather data is relayed to indicators. These indicators are positioned at a distance apart from the instrument and the amount of error in the readings as is allowable by the user (Model 120).

SUMMARY OF INSTRUMENT TRANSITION

We acknowledge that many of the recommended instruments are not of a similar design to the instruments they would be replacing, which is one of the criteria in our instrument transition procedure. For example, the ombroscope is very different to the Hydreon Optical Rain Sensor – Model RG-1, which was the closest instrument to the ombroscope we found. This example shows how automated instruments are limiting the production of manually operated instruments. As a result, the observatory has to decide whether or not to switch to the new automated technology.

We recommend the Blue Hill Observatory to continue the use of the manually operated instruments for as long as possible to maintain the collection of homogeneous data. Although it is expensive to maintain these instruments, they provide a historical perspective of how the weather instruments have evolved at the Blue Hill Observatory. However, we also recommend they integrate the automated instruments to incorporate the new technology.

FUTURE ASPIRATIONS FOR DATABASE

In the following section, we discuss the suggestions that we have for the future use for the database. These suggestions are aspects of the data entry forms and the database that we wanted to incorporate into the database but were not implemented due to time constraints and our limited expertise.

Date of Data Entry Forms

This aspect would mean that the first task that the user would do is to pick the date and then pick a data entry form, instead of picking the date for each data entry form. The user would then only have to enter the date once and not for every data entry form, which is what the user has to do currently. This would help streamline part of the process of entering in data, and could reduce the possibility of error when the date in entered into the form. To accomplish this, there needs to be a way to transfer the date selected on the first page through all of the other pages.

One way to accomplish this is to use the internet browser's history to remember the choice of the date throughout the pages. After the user is done with that specified date, then the memory can clear it so that the next date can be picked.

Modification Page for Data

A modification page for the data would allow the user to modify the data stored in the database in a web form. This form would be used instead of using PHPMyAdmin to modify the data in the database. The way that this part of the database could be accomplished would be to write a page that pulls the data in the database onto the page using PHP. The next step would be to allow the page to modify the data using an HTML form to submit the data back into the database with PHP. To accomplish this, there needs to be a form written, so that the user can select the weather variable and the date to see the data that is in the MySQL database. Then the next step would be to have the user be able to resubmit the data with different values. This might be accomplished with PHP and HTML combined on a page to search and retrieve the data from the database.

Automatically Populate Forms

Currently, the observers have to fill out the B16, F6, and WXD forms individually, which requires a lot of copying and pasting of weather data. We suggest that the observatory automatically populates all of the forms using a program that accesses the data in the database. The observer would click one button and the data from the database would be automatically entered into the B16. If the B16 were able to auto populate, the next step would be to populate the other forms used as well such as the F6, WXD and others. This process would reduce the issue of copying and pasting the data in between Excel documents, and could reduce the risk of copying or retyping a number incorrectly. This could be accomplished by having a program connect to Microsoft Office that accesses the MySQL Server and inserts the data into the correct places on the B16 Form. Another way to accomplish this could be to write a PHP code that puts the data into the correct places on the B16 Form. Another part to design could be to have the program automatically update the other forms when the B16 Form is updated. The program would look for the changes in between the different forms, and determine if the form needs to be updated.

Rest of Recorded Weather Observations for B16 Form

The weather observations that have forms entered into the database are Hourly Temperature, Hourly Precipitation, Hourly Wind Speed and Direction, Hourly Sunshine Minutes, Daily Sky Cover, Lowest Visibility, and Relative Humidity. The rest of the data on the B16 Form still needs a way to enter in the data and a table within the database to organize the data. To complete this aspect of the database, the first step would be to create the rest of the forms based off the data entry forms already created. After the forms are created, the next step would be to create a table in the database for the data.

Prevent Copy and Paste on Data Entry Forms

Currently, for our database the data entered into the initial entry column could be copy and pasted into the retype column, which defeats the purpose of the double entry of the data. This aspect of the data entry forms would not allow the user to copy and paste the data from the first entry table into the second entry table. A way that this part of the data entry form could be implemented would be to write code that prevents the user from copying and pasting on the page. This code would probably have to be written in JavaScript or some other web language.

Check Recorded Average with Computed Average on Form

This aspect of the database that the group would have liked to implement is that the average weather variable is calculated on the webpage and the user would compare the calculated value with what the value is on the form. This part of the data entry form would help the Blue Hill Observatory determine if the average calculated value from the hourly data is correct based on the calculations. The way that this aspect would be implemented in the forms is to have the calculated average shown at the bottom of the first table. For example, the temperature entry form would calculate the average temperature for the day, and then display that result at the end of the first entry table.

Check for Outliers in Data Entered

To check for outliers, the data entry forms need to have a modified check system. This means that the part of the data entry forms that checks to determine if the data in the two tables are the same would also have a check that determines if the entered data is within the normal weather information recorded at the Blue Hill Observatory. If there is an issue with the data entered into the form, such as the temperature is less than -20°F, which is the lowest temperature ever recorded at the observatory, then a popup window will show up asking the user if the data entered is correct. This system will check if the user accidently entering the wrong number; however, if the data entered is correct, then the user should have an option to be able to submit it into the database. A way that this could be implemented into the database is to add onto the checking already done during the checks of each table. A code would be written in a web language such as JavaScript. One part to consider is the system would be to allow the user to enter in the data after the popup window has confirmed that the data is typed in correctly and is not an accidental error.

Logbook of Maintenance on Instruments

A logbook of maintenance done on instruments in the database will allow the instrument technician to log all of the maintenance and repairs he completed. This log book will allow all of the staff at the observatory to be aware of all of the maintenance issues and when they were repaired. This would be accomplished by writing a form that the user can enter in the maintenance information for the specific instrument. This form should allow the user to pick the instrument and enter in the text from the log and store the maintenance in the database.

Monthly Instrument Grading Form

We would have liked to make a form for the observers to enter in the grading scale that we created for the instruments directly into the database. This form would allow the user to enter in the grading report and be able to store the information into the database. The way that this would be implemented into the database would be to create a form that allows the user to select the instrument that they would like to grade and depending on the aspect of the scale select or type in the grade that they would give the instrument.

DATABASE CONCLUSION

We implemented the database at the Blue Hill Observatory by installing the program onto one of the computers at the observatory. Now the observatory can access the database from any of the computers on their network. We also created documentation to support the database and our work on the database. We would like the Blue Hill Observatory to use this database into the future and to allow this to happen, the observatory needs to continue to update and add data into the database. One way to expand upon the database is to have the volunteers at the observatory begin to enter in the data from the forms that we have already created to begin to store their data in one place. If the observatory has volunteers that could help with the database, then the materials that we have provided should help the volunteers to understand what our group has done for the database.

Another possibility for the Blue Hill Observatory to expand on the database would be to create a new project for a Worcester Polytechnic Institute group. This group could be an Interactive Qualifying Project or a Master Qualifying Project, and they could take the suggestions made by our group to expand the database for the observatory. Having another WPI team work on the project would be beneficial if the group had a strong background in Computer Science and more time than our group had. They would be able to add more to the database and create other forms that would modify the database and to address some of the more extensive desires of the observatory, such as automatically populating the forms.

The database that we have created for the Blue Hill Observatory will provide a stepping stone for the observatory to develop the database to consolidate all of the historical weather data. Consolidating the historical data will help the observatory analyze the data collected over the 127 years in a much more efficient manner, as well as enabling the historical data to be much more easily accessible.

PROJECT SUMMARY

The purpose of our project was to develop a procedure for transitioning the current instruments to new or replacement instruments while maintaining homogeneous data collection, as well as developing a prototype database to consolidate all of the data forms produced. By providing the Blue Hill Observatory with this transition system, they will be able to continue to assess the condition of their instruments. With the grading scale, they will also be able to predict when certain issues will occur and when they should begin transitioning instruments based on their current status. This will ensure that their data remains homogeneous throughout the transition process. The prototype database provides the Blue Hill Observatory with the initial database that could eventually store all of their weather data and provide more readily available information for analysis. It is our hope that the Blue Hill Observatory will be able to use our work to improve their current processes and to make their weather data more accessible to those who are interested.

REFERENCES

Ackerman, S. A., & Martin, J. (February 6, 2012). What is the concept of heating degree-days? *Wisconsin State Journal*. Retrieved from http://au4sb9ax7m.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info:sid/summon.serialssolutions.com&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&rft.genre=article&rft.atitle=What+is+the+concept+of+heating+degree-days%3F&rft.jtitle=Wisconsin+State+Journal&rft.date=2012-02-06&rft.issn=0749-405X&rft.spage=A.2&rft.externalDBID=XWST&rft.externalDocID=2579604521

A brief history of the Blue Hill Meteorological Observatory. (2010). Retrieved from http://www.bluehill.org/history/history.html

Barchard, K. A., & Pace, L. A. (2011). Preventing human error: The impact of data entry methods on data accuracy and statistical results. *Computers in Human Behavior*, *27*(5), 1834-1839. doi: 10.1016/j.chb.2011.04.004

Blue Hill Observatory & Science Center. (2011) *Observer Handbook.* Blue Hill Observatory & Science Center. Sept. 16, 2012, http://www.bluehill.org/handbook/handbook.html

Briede, C.M. Personal Interview. 10 Sept 2012.

Buttrick, Kimberly. Personal Interview. 18 Sept. 2012.

Castro, E., & Safari Books Online. (2007). *HTML, XHTML & CSS: Visual quickstart guide*. Berkeley, CA: Peachpit Press.

Changnon, S. A., & Kunkel, K. K. (2005). Changes in instruments and sites affecting historical weather records: a case study. *Journal of Atmospheric and Oceanic Technology*, *23*(6), 825.

Davis, W. M. (1894). Elementary meteorology. Boston: Ginn & Company.

Delisle, M., & Safari Books Online. (2012). *Mastering phpMyAdmin 3. 4 for effective MySQL management.* Birmingham: Packt Publishing, Limited.

Doe, David. Personal Interview. 4 Sept. 2012.

Doesken, N., & Reges, H. (2010). The value of the citizen weather observer. *Weatherwise*, 66,6.

DuBois, P., & Safari Books Online. (2005). *MySQL*. Old Tappan: Sams.

Flanagan, D., & Safari Books Online. (2011). *JavaScript: The definitive guide*. Beijing: O'Reilly.

Hydreon optical rain sensor - model rg-11. (2012). Retrieved from http://www.rainsensors.com/

Iacono, M. J. (2009) Why is the Weed Speed Decreasing?. *Blue Hill Metoerological Observatory.*

International Bureau of Weights and Measures, Joint Committee for Guides in Metrology. (2008).*International vocabulary of metrology — basic and general concepts and associated terms*

Keller, L. M., Baker, K. A., Lazzara, M. A., & Gallagher, J. (2009). A comparison of meteorological observations from south pole station before and after installation of a new instrument suite. *Journal of Atmospheric and Oceanic Technology*, *26*(8), 1605-1613.

Lerner, E. K. L., & Lerner, B. W. (2008). Atmospheric Pressure. *The Gale Encyclopedia of Science*. Vol. 1. 4th ed. Retrieved from http://go.galegroup.com.ezproxy.wpi.edu/ps/i.do?action=interpret&id=GALE%7CCX2830100213&v=2.1&u=mlin_c_worpoly&it=r&p=GVRL&sw=w&authCount=1.

Lerner, E. K. L., & Lerner, B. W. (2008). Humidity. *The Gale Encyclopedia of Science/* Vol. 3, 4th ed. Retrieved from http://go.galegroup.com.ezproxy.wpi.edu/ps/retrieve.do?sgHitCountType=None&sort=RELEVANCE&inPS=true&prodId=GVRL&userGroupName=mlin_c_worpoly&tabID=T003&searchId=R1&resultListType=RESULT_LIST&contentSegment=&searchType=BasicSearchForm&currentPosition=1&contentSet=GALE%7CCX2830101185&&docId=GALE|CX2830101185&docType=GALE.

Model 120. (2012). Retrieved from http://www.belfortinstrument.com/products/model-120

National Weather Service. (2010). *National weather service instruction* 10 – 1304. http://www.nws.noaa.gov/directives/sym/pd01013004curr.pdf

Singh, S. K., & Safari Books Online. (2011). *Database systems: Concepts, design and applications, second edition* Pearson Education India.

Valade, Janet. (2009). *PHP & MySQL for dummies*. US: For Dummies.

Wa15 wind set for high performance wind measurement. (2012). Retrieved from http://www.vaisala.com

Wa25 wind set for arctic conditions. (2012). Retrieved from http://www.vaisala.com

Wmt52 ultrasonic wind sensor for accurate and stable measurement. (2012). Retrieved from http://www.vaisala.com

APPENDIX A: FORMS USED AT THE BLUE HILL OBSERVATORY

B16 FORM

Blue Hill Observatory P.O. Box 500 Milton, MA 02186 DATE: Friday, July 27, 2012

Time (EST	Temp (°F)	Precip (inches)	WIND Dir.	WIND Spd (mph	Sunshin (min)	Sky Cover (0-8)	Lwst VSBL (mls)	Prsnt WX	Rel. Hum.	Mnts VSBL	Notes
00-01	71		WSW	14					90		
01-02	70		W	12							
02-03	69		WSW	10							
03-04	69	T	WSW	10							RW-B33 CTD
04-05	69	0.01	W	9	0						RW-E17 B42 CTD LGT AND INTMT
05-06	70	T	W	4	0						RW-03 B31E58 LGT AND INTMT
06-07	71	T	SE	2	0	8	25	0	93		[1] OVS AS FEW LWR CUFRA/STFRA NW-E-SE
07-08	70	T	ESE	2	0					2@0	RW-B00E05
08-09	67		NE	7	0						
09-10	68		NE	9	0	8	25	0	89		[2] OVC AS FEW FAINT CUFRA DRFTG BLO SMT
10-11	71		NE	8	24					1@0	
11-12	73		NE	9	24						
12-13	72		NE	10	6	8	15	0	82		[3] OVC AS DMLY VSBL OVD DSNT FG ALQDS
13-14	72		NE	8	18					1@0	
14-15	71		NNE	8	0						
15-16	70	T	NE	7	0						L-B40 CTD
16-17	69	T	NNE	6	0						L-E10
17-18	69		NE	4	0						
18-19	67		E	4	0				92		
19-20	67		E	2	0						
20-21	67		E	3							
21-22	66		SE	3							
22-23	66		NE	2							
23-24	66		ENE	2							
Sum.		0.01		155	72					TIME:	
Aver.	69.17		Prevail.	6.5	Poss 877					0432E	SUNRISE
Misc.	69.75		NE		9%					1909E	SUNSET

Scheduled Observations

Time (EST	Station Pressure	Dry Bulb	Wet Bulb	Dewpoin	Relative Humidity	Temperature Max	Temperature Min	Precip	Snow-07E Fall	Snow-07E Depth	Vapor Pressure
0700	29.049	71.0	69.8	69	93%	82	69	0.01	0.0	0	24.2
1900	29.184	67		65	92%						21.1
0800		70.0	68.7	68	93%				Average ->		22.7
0900		67.2	65.5	65	92%						
1000		68.4	66.0	65	89%						
1300		71.5	67.8	66	82%						

Summary of Day (Midnight to Midnight)

Temperature 24HR Max	Temperature 24HR Min	24HR Precip Water Equiv.	24HR Snowfall	Snow Dpth 0700	Sunshine Total Min.	Sunshine % poss.	WIND Fast. Mile/Dir		WIND Time	WIND Peak Gust (KTS)
73	66	0.01	0.0	0	79	9%	16 *	WSW	0012E	18 WSW @ 0030E **

Friday, July 27, 2012

Average Temperature	70
Normal Temperature	72
Departure from Normal	-2
Heating Degree Days	0
Cooling Degree Days	5

Station Pressure Computations

Time (EST)	0700	1900	AVG
Attached Therm.	24.8		
Observed Barometer	988.0		
Total Correction	-4.3		
Station Pressure	983.7	988.3	986
Barograph Reading	#####	#####	
Barograph Correction	0.004	0.004	

Additional Notes:

[1] FEW HIER STFRA ALQDS LONE CUFRA BLO SMT ENE FEW AC UNDULATUS ALQDS DSNT F ALQDS DNSR SPTS WNW-NE HAZY VSBY HIER SE-W 30V40 VSBY LWR WNW-NE 12

[2] NE-SE DSNT FG ALQDS DSNR SPTS NW-NE VSBY HIER SSE-SW 40 VSBY LWR NW-NE 10 HAZY

[3] DNSR SPTS NW-NE HAZY/INCRSNG HZ

* ADDITIONAL FASTEST MILE: 16 MPH WSW AT 0004E

** ADDITIONAL PEAK GUST: 18 KTS WSW AT 0011E, 0013E

INITIALS: GT STATION NO. 19-0736-02

Figure 15: B16 Form

F6 FORM

WS FORM F-6	U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL WEATHER SERVICE	STATION	Blue Hill Observatory Milton, MA 02186
PRELIMINARY LOCAL CLIMATOLOGICAL DATA		MONTH	July
		YEAR	2012
LATITUDE	42° 13' N	LONGITUDE	71° 07' W
GROUND ELEVATION	629 FT.	STANDARD TIME	Eastern

DAY	TEMPERATURE °F MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	DEGREE DAYS (Base 65°) HEATING	COOLING	PRECIPITATION (in.) TOTAL	SNOWFALL, ICE PELLETS	SNOW, ICE PELLETS OR ICE ON GROUND AT 0700	WIND AVERAGE SPEED (mph)	FASTEST MILE SPEED (mph)	DIRECTION	SUNSHINE TOTAL (Min.)	PERCENT OF POSSIBLE	SKY COVER SUNRISE TO SUNSET (Tenths)	WEATHER OCCURANCES	PEAK GUST (mph)	DIRECTION OF PEAK GUST	AVG. STATION PRESSURE (mb)	AVG. STATION VAPOR PRESSURE (mb)
1	2	3	4	5	6A	6B	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	89	67	78	8	0	13	0.01	0	0	10.8	22	WSW	676	74		3	32	WSW	986	21.2
2	84	66	75	5	0	10	T	0	0	8.3	15	W	644	71			23	W	988	19.3
3	85	63	74	3	0	9	0	0	0	8.3	15	W	787	86			23	W	989	17.3
4	85	66	76	5	0	11	0.37	0	0	9.9	15	S	480	53		3	20	W	985	24.2
5	81	68	75	4	0	10	0	0	0	8.8	17	NW	729	80			23	NW	985	20.7
6	86	64	75	4	0	10	0	0	0	6.0	14	SSW	753	83			18	SSW	989	20.3
7	81	69	75	4	0	10	T	0	0	10.0	16	W	224	25			23	W	986	22.6
8	87	66	77	5	0	12	0	0	0	9.7	14	WNW	814	90			23	W	987	18.4
9	82	61	72	0	0	7	0	0	0	8.5	15	W	770	85			22	W	991	13.5
10	83	61	72	0	0	7	0	0	0	8.0	12	SSE	887	98			18	W	994	13.2
11	84	64	74	2	0	9	0	0	0	8.3	15	S	795	88			21	S	999	17.5
12	89	64	77	5	0	12	0	0	0	10.0	20	SSW	875	97			25	SSW	998	16.9
13	89	66	78	6	0	13	0	0	0	12.3	21	S	604	67			28	S	999	19.0
14	90	69	80	8	0	15	0	0	0	10.0	19	W	521	58			24	W	998	20.3
15	91	68	80	8	0	15	T	0	0	9.0	15	SW	539	60			18	SW	993	24.0
16	91	70	81	9	0	16	T	0	0	8.2	17	NW	771	86			23	NW	986	24.7
17	95	71	83	11	0	18	0	0	0	12.9	26	SW	831	93			33	SSW	985	22.3
18	91	69	80	8	0	15	1.45	0	0	9.0	31	ENE	322	36		1,3	40	NE	987	25.5
19	81	63	72	0	0	7	0	0	0	6.8	13	NNW	535	60			21	NNW	992	18.3
20	70	61	66	-6	0	1	0	0	0	7.3	12	ENE	62	7			18	E	995	16.7
21	77	58	68	-4	0	3	0	0	0	8.2	15	SSE	861	97			20	ENE	996	14.6
22	84	59	72	0	0	7	0	0	0	11.4	19	S	868	98			24	S	997	16.5
23	84	63	74	2	0	9	0.02	0	0	12.8	22	SSW	354	40			27	SSW	992	22.7
24	88	65	77	5	0	12	0.09	0	0	12.0	29	WNW	477	54		3	43	NW	980	22.7
25	82	59	71	-1	0	6	0	0	0	10.5	23	WNW	828	94			30	NW	986	14.0
26	82	67	75	3	0	10	T	0	0	10.1	17	S	105	12			23	WSW	982	22.8
27	73	66	70	-2	0	5	0.01	0	0	6.5	16	WSW	79	9			21	WSW	986	22.7
28	79	64	72	0	0	7	1.44	0	0	7.8	20	NE	402	46		1,3	25	NE	992	20.4
29	69	61	65	-7	0	0	T	0	0	8.0	13	NE	0	0		2	22	NE	993	19.7
30	82	59	71	-1	0	6	0	0	0	7.8	17	S	835	96			22	S	996	18.0
	76	62	69	-3	0	4	0.53	0	0	7.2	14	SE	104	12		2	20	E	993	20.1
SUM	2590	1999	2304	+81	0	289	3.92	0.0	0	284.4	-----	-----	####	-----		-----	-----	-----	-----	610.1
AVG	83.5	64.5	74.3	+2.6	0	+66	-0.1	0	0	9.2	FASTEST	DIR.	POSSIBLE	%		-----	-----	-----	-----	19.7
										MISC.	31	ENE	####	63		-----	43	NW	-----	-----

TEMPERATURE DATA			PRECIPITATON DATA			
AVERAGE MONTHLY	74.0		TOTAL FOR THE MONTH	3.92	IN.	
DEPARTURE FROM NORMAL	+2.1		DEPARTURE FROM NORMAL	-0.10	IN.	
HIGHEST	95	ON 17th	GRTST IN 24 HRS.	1.45	ON	18th
LOWEST	58	ON 21st	**SNOWFALL, ICE PELLETS**			
NUMBER OF DAYS WITH -			TOTAL FOR THE MONTH	0.0	IN.	
MAX 32° OR BELOW	0		GRTST IN 24 HRS.	0.0	ON	16TH
MAX 90° OR ABOVE	5		[illegible]	0	ON	26TH
MIN 32° OR BELOW	0		**PRESSURE DATA**			
MIN 0° OR BELOW	0		HIGHEST SEA-LEV	30.2	IN. ON	13th
HEATING DEGREE DAYS (Base 65°)			LOWEST SEA-LEV	29.5	IN. ON	24th
TOTAL THIS MONTH	0					
DEPARTURE FROM NORMAL	-3					
SEASONAL TOTAL	4984					
DEPARTURE FROM NORMAL	##					
COOLING DEGREE DAYS (Base 65°)						
TOTAL THIS MONTH	289					
DEPARTURE FROM NORMAL	+66					
SEASONAL TOTAL	439					
DEPARTURE FROM NORMAL	+87					

WEATHER	
NUMBER OF DAYS -	
CLEAR (Scale 0-3)	
PARTLY CLOUDY (Scale 4-7)	
CLOUDY (Scale 8-10)	
WITH 0.01 INCH OR MORE PRECIP.	8
WITH 0.10 INCH OR MORE PRECIP.	4
WITH 0.50 INCH OR MORE PRECIP.	3
WITH 1.00 INCH OR MORE PRECIP.	2

SYMBOLS USED IN COLUMN 16

1 - FOG REDUCING VISIBILITY TO 6 MILES OR LESS
2 - FOG REDUCING VISIBILITY TO 1/4 MILE OR LESS
3 - THUNDER
4 - ICE PELLETS
5 - HAIL
6 - GLAZE OR RIME
7 - BLOWING DUST OR BLOWING SAND REDUCING VISIBILITY TO 1/4 MILE OR LESS
8 - SMOKE OR HAZE
9 - BLOWING SNOW
X - TORNADO

MAXIMUM PRECIPITATON

AT (Minutes)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATON (inches)	0.23	0.3	0.43	0.5	0.7	0.72	0.9	0.94	1.02	1.17	1.39	1.47
ENDED: DATE	18	18	18	18	18	18	18	18	28	18	18	18
TIME	1428	1606	1438	1438	1626	1637	1656	1711	1948	1623	1653	1711

BAROMETRIC PRESSURE		
Hpc. 649 FT. MSL		
Avg Station Pressure:	####	ins.
Avg Sea Level Pressure	####	ins.

AVERAGE RELATIVE HUMIDITY			
1AM:	84%	1PM:	54%
7AM:	79%	7PM:	69%
Pk. Gust Aerovane	46 MPH NW 24TH		
PREV. WIND DIR.	S @	14%	
STATION INDEX NO:	19-0736-02		

CLIMAT	####	9905	0137	0233	####	01004	####	0000

Figure 16: F6 Form

WXD FORM

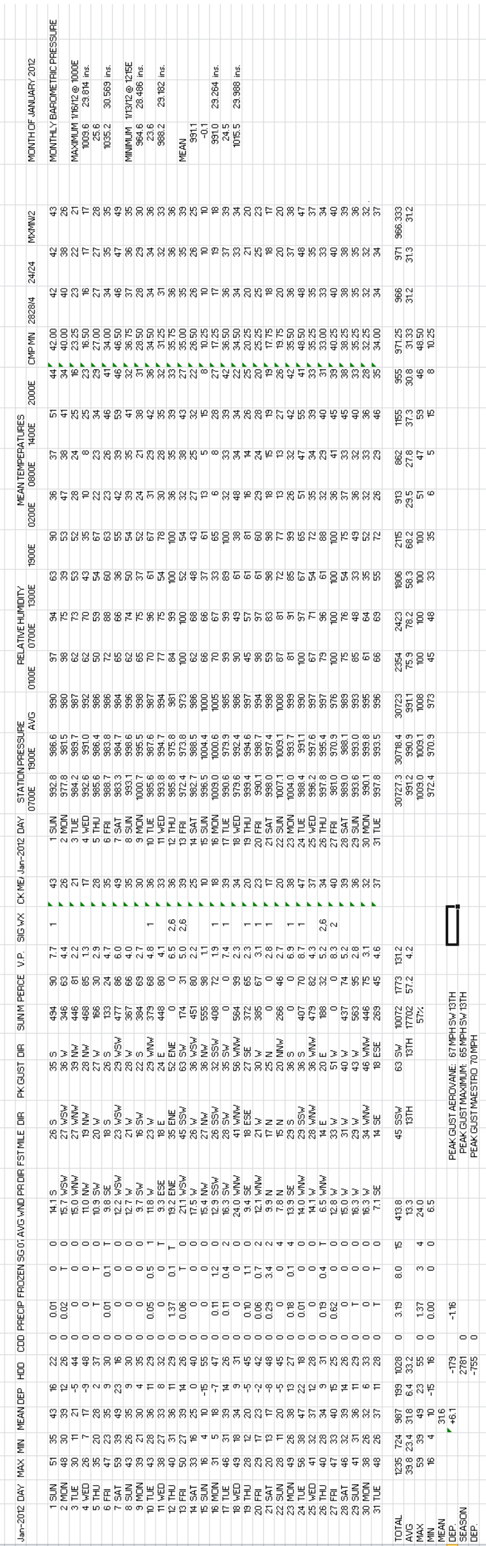


Figure 17: WXD Form

APPENDIX B: INTERVIEW SHEET

SAMPLE SURVEY TO BLUE HILL STAFF

1. What is your role at the Blue Hill Observatory?
    a. Manager
    b. Observer
    c. Maintenance Worker
    d. Tour Guide
    e. Other (please specify)

2. How would you rank these instruments on a scale from 1-5 (one being the most, 5 being the least) of how important they are to the observatory in general?
    a. Contact anemometer
    b. Ombroscope
    c. 420C Series (wind speed instrument)
    d. Bendix Aerovane
    e. Standard Gauge Weighing Rain Gauge

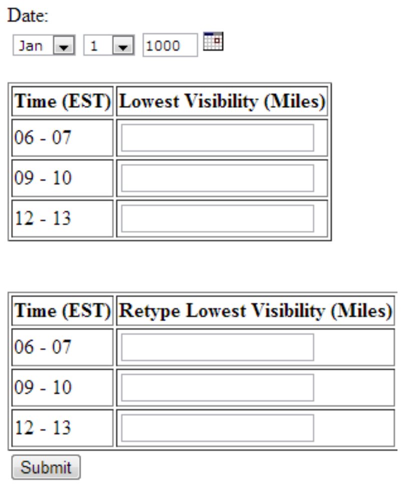
3. How would you rank these instruments on a scale from 1-5 (one being quickest, five being the longest to wait) of how quickly these instruments should be replaced at the observatory?
    a. Contact Anemometer
    b. Ombroscope
    c. 420C series (wind speed instrument)
    d. Bendix Aerovane
    e. Standard Gauge Weighing Rain Gauge

4. Is there a timeframe that you think each of the previously listed instruments should be transitioned/replaced in?

5. Are there any additional comments that you have, perhaps about certain difficulties you have personally had with any of the previously listed instruments?

6. In the terms of a Non-NWS supported instrument that is in certain need of transition or replacement, is there an instrument that we haven't mentioned that you feel should be considered?

APPENDIX C: SCREENSHOTS OF DATA ENTRY FORMS



Date:

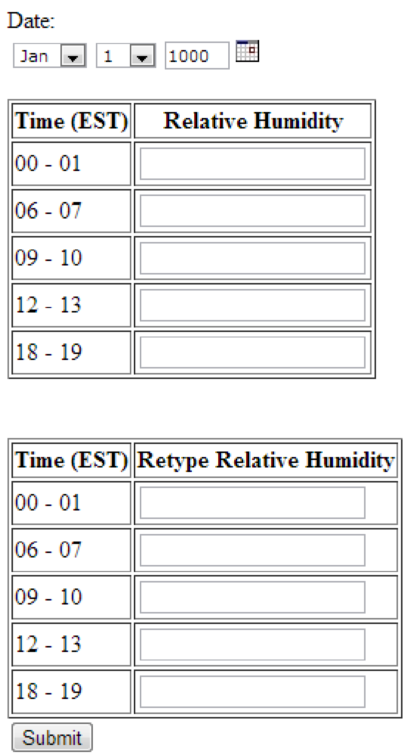
Jan 1 1000

Time (EST)	Lowest Visibility (Miles)
06 - 07	
09 - 10	
12 - 13	

Time (EST)	Retype Lowest Visibility (Miles)
06 - 07	
09 - 10	
12 - 13	

Submit

Figure 18: Screenshot of Lowest Visibility Tables



Date:

Jan 1 1000

Time (EST)	Relative Humidity
00 - 01	
06 - 07	
09 - 10	
12 - 13	
18 - 19	

Time (EST)	Retype Relative Humidity
00 - 01	
06 - 07	
09 - 10	
12 - 13	
18 - 19	

Submit

Figure 19: Screenshot of Relative Humidity

Date:

Jan 1 1000

Time (EST)	Sky Cover (0-8)
06 - 07	Not Recorded
09 - 10	Not Recorded
12 - 13	Not Recorded

Time (EST)	Retype Sky Cover (0-8)
06 - 07	Not Recorded
09 - 10	Not Recorded
12 - 13	Not Recorded

Submit

Date:

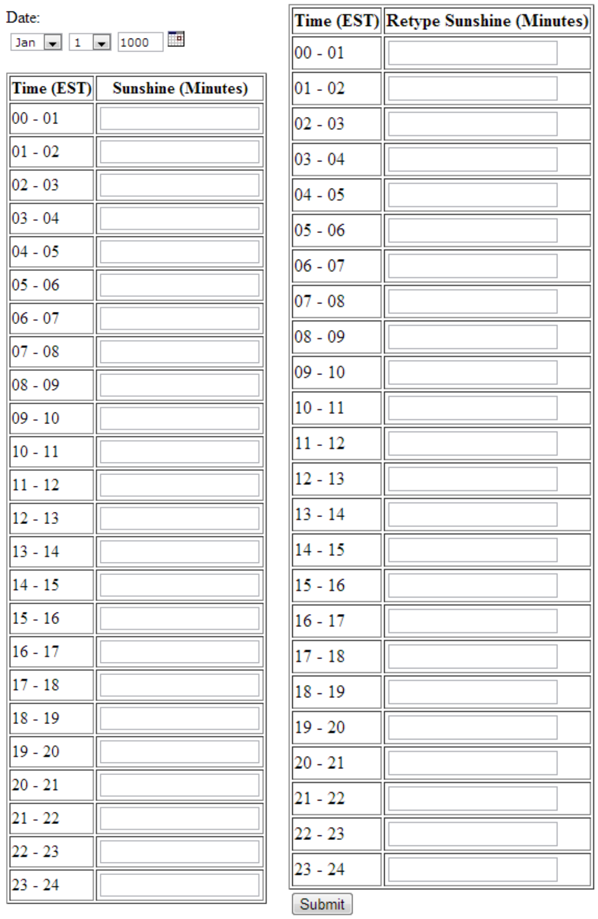
Jan 1 1000

Time (EST)	Precipitation (Inches)
00 - 01	
01 - 02	
02 - 03	
03 - 04	
04 - 05	
05 - 06	
06 - 07	
07 - 08	
08 - 09	
09 - 10	
10 - 11	
11 - 12	
12 - 13	
13 - 14	
14 - 15	
15 - 16	
16 - 17	
17 - 18	
18 - 19	
19 - 20	
20 - 21	
21 - 22	
22 - 23	
23 - 24	

Time (EST)	Retype Precipitation (Inches)
00 - 01	
01 - 02	
02 - 03	
03 - 04	
04 - 05	
05 - 06	
06 - 07	
07 - 08	
08 - 09	
09 - 10	
10 - 11	
11 - 12	
12 - 13	
13 - 14	
14 - 15	
15 - 16	
16 - 17	
17 - 18	
18 - 19	
19 - 20	
20 - 21	
21 - 22	
22 - 23	
23 - 24	

Submit

Figure 20: Screenshots of Precipitation Tables



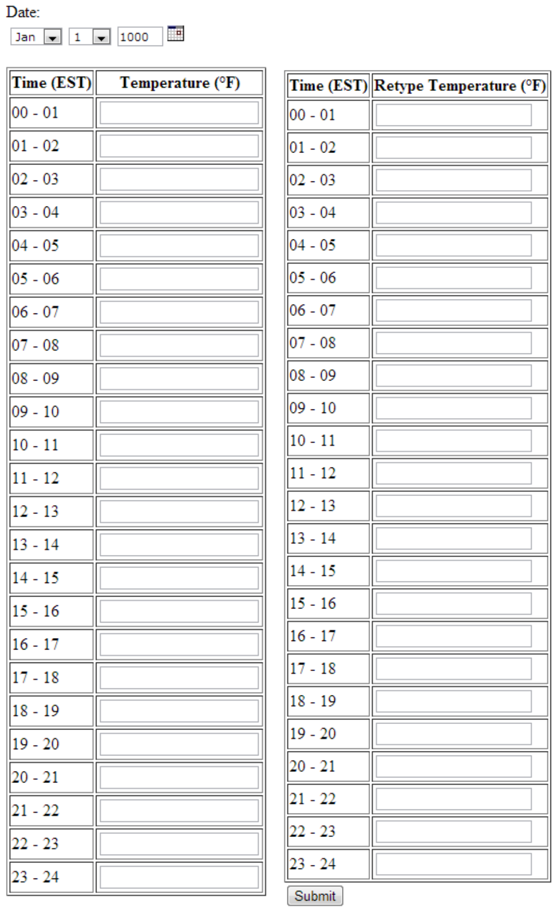
Date:
Jan 1 1000

Time (EST)	Sunshine (Minutes)
00 - 01	
01 - 02	
02 - 03	
03 - 04	
04 - 05	
05 - 06	
06 - 07	
07 - 08	
08 - 09	
09 - 10	
10 - 11	
11 - 12	
12 - 13	
13 - 14	
14 - 15	
15 - 16	
16 - 17	
17 - 18	
18 - 19	
19 - 20	
20 - 21	
21 - 22	
22 - 23	
23 - 24	

Time (EST)	Retype Sunshine (Minutes)
00 - 01	
01 - 02	
02 - 03	
03 - 04	
04 - 05	
05 - 06	
06 - 07	
07 - 08	
08 - 09	
09 - 10	
10 - 11	
11 - 12	
12 - 13	
13 - 14	
14 - 15	
15 - 16	
16 - 17	
17 - 18	
18 - 19	
19 - 20	
20 - 21	
21 - 22	
22 - 23	
23 - 24	

Submit

Figure 21: Screenshots of Sunshine Minutes


Date:
Jan 1 1000

Time (EST)	Temperature (°F)
00 - 01	
01 - 02	
02 - 03	
03 - 04	
04 - 05	
05 - 06	
06 - 07	
07 - 08	
08 - 09	
09 - 10	
10 - 11	
11 - 12	
12 - 13	
13 - 14	
14 - 15	
15 - 16	
16 - 17	
17 - 18	
18 - 19	
19 - 20	
20 - 21	
21 - 22	
22 - 23	
23 - 24	

Time (EST)	Retype Temperature (°F)
00 - 01	
01 - 02	
02 - 03	
03 - 04	
04 - 05	
05 - 06	
06 - 07	
07 - 08	
08 - 09	
09 - 10	
10 - 11	
11 - 12	
12 - 13	
13 - 14	
14 - 15	
15 - 16	
16 - 17	
17 - 18	
18 - 19	
19 - 20	
20 - 21	
21 - 22	
22 - 23	
23 - 24	

Submit

Figure 22: Screenshots of Temperature

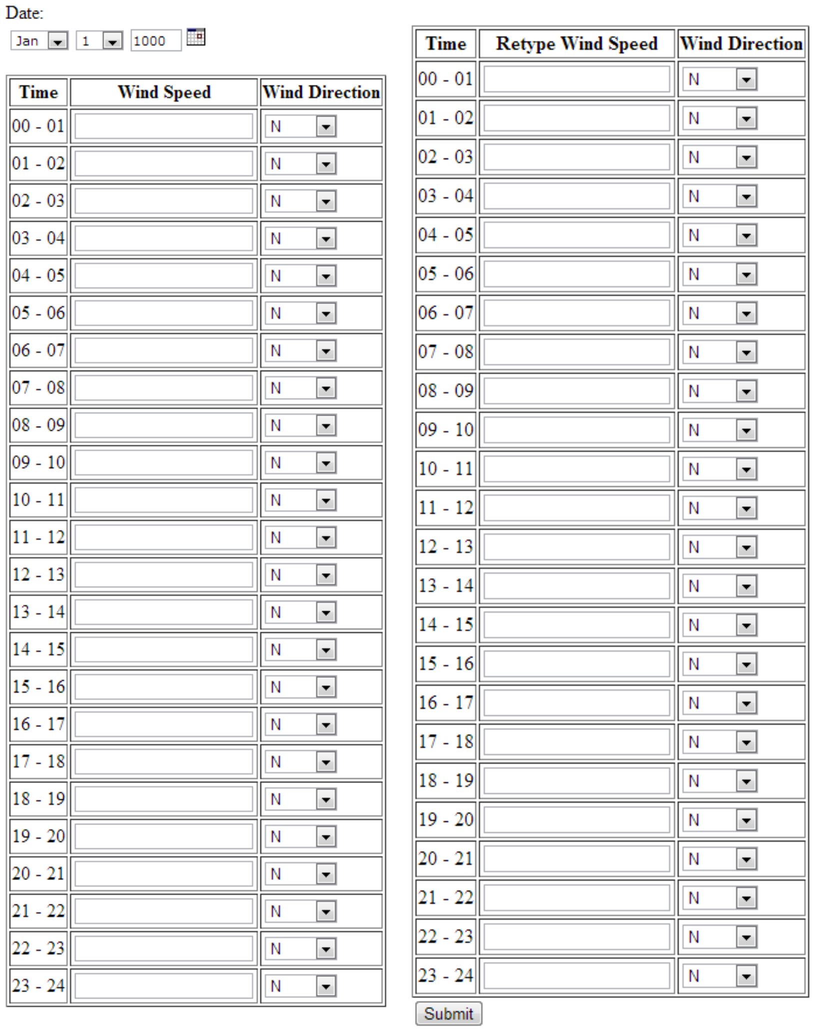


Figure 23: Screenshots of Wind Speed and Direction

APPENDIX D: DATABASE SURVEY

DATA SHARING AT THE BLUE HILL OBSERVATORY

Name:

Occupation:

Organization:

1. What type of weather data did you inquire of the Blue Hill Observatory?
    a. Wind
    b. Temperature
    c. Precipitation
    d. Sunshine
    e. Other (Please Specify)

2. What kind of format did the Blue Hill Observatory provide the data in?
    a. Paper
    b. Electronic
    c. Other (Please Specify)

3. Based on your answer for Question 2, would providing the data in an electronic copy be more beneficial?
    a. Yes
    b. No

4. Did the data that the Blue Hill Observatory provided meet your expectations?

    Strongly Disagree Disagree Neutral Agree Strongly Agree

5. Did the Blue Hill Observatory provide you with the data in a timely manner?

    Strongly Disagree Disagree Neutral Agree Strongly Agree

6. From the data that the Blue Hill Observatory provided, were you able to accomplish the goal that you needed the data for?
    a. Yes
    b. No

7. From the data that the Blue Hill Observatory provided, were you able to accomplish the goal that you needed the data for?
    a. Yes
    b. No
8. Based on your previous answer, would you be willing to pay for the homogeneous data collected at the Blue Hill Observatory?
    a. Yes
    b. No

9. I would be more inclined to become a member of the Blue Hill Observatory if one of the member benefits is free access to their data.
    a. Yes
    b. No

10. In your own opinion, how could the Blue Hill Observatory improve the way that they distributed their data?

APPENDIX E: RATING AVERAGE CALCULATION

The following are the calculations for the rating average from the survey results.

Did the data that the Blue Hill Observatory provide you meet your expectations?

Table 11: Data from Survey about Data that Blue Hill Observatory Provided

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average
0	0	1	1	6	**4.63**

$$\frac{(1*3)+(1*4)+(6*5)}{8} = 4.63$$

Did the Blue Hill Observatory provide the data in timely manner?

Table 12: Data from Survey about Amount of Time Data was provided

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average
0	0	1	3	4	**4.38**

$$\frac{(1*3)+(1*4)+(6*5)}{8} = 4.38$$

APPENDIX F: LIST OF RECORDED WEATHER INFORMATION

In the following appendix, we define all of the weather data on the forms used at the observatory and how the observers measure each observation.

TEMPERATURE

Temperature is a physical property of an object that measures the ability to pass heat to another object. It compares the warmth or coldness of this object to a standard value. The temperature is recorded by many different instruments at the Blue Hill Observatory such as the glass thermometer, ASOS, and the Davis System. The maximum temperature is the highest temperature observed for the day, and the minimum temperature is the lowest temperature observed for the day. The maximum and minimum temperatures are recorded by the Maximum and Minimum Thermometers.

PRECIPITATION

The amount of precipitation is measured by the depth to which a flat surface would be covered if no water were lost by evaporation or run-off. It is typically measured in inches or millimeters. The Blue Hill Observatory uses the Standard Eight-Inch Rain Gauge for their daily observations. They also use the ombroscope to measure the start and end time of precipitation events. The ASOS Standard Eight-Inch Rain Gauge, Davis System Tipping Bucket, and the Graphing Weighing Rain Gauge are also used to measure precipitation.

WIND SPEED AND DIRECTION

Wind speed measures how fast air in motion is moving. It is typically measured in miles per hour or in knots. Wind direction states in which direction the wind is blowing in. Wind direction is stated in clockwise degrees from north i.e. N, NNE, NE, ENE, E, etc. The Blue Hill Observatory uses the Bendix Aerovane to measures the wind speed and direction. The Aerovane Wind Recorder keeps a continuous chart recording of wind speed and direction. The Contact Anemometer also measures wind speed but in a mechanical process by sending a signal to a single register once it has rotated 640 notches which indicates that a mile of has passed through the anemometer. The Wind Vane from the 420 C series, Davis Pulsing Anemometer and the RM

Young Aerovane measure wind speed and direction but the Blue Hill observatory only uses them as an observation tool to compare to other instruments.

PEAK GUST

Peak Gust is the highest instantaneous wind speed in an hour. At the Blue Hill Observatory the Three Cup Anemometer from the 420 C Series measures the peak gusts. The Wind Gust Chart recorder keeps a continuous recording of instantaneous wind gusts.

SUNSHINE

The amount of sunshine is recorded by the Campbell- Stokes Sunshine Recorder at the Blue Hill Observatory. This sunshine recorder measures the duration of direct sunlight. The width and depth of the burn depends on how brightly the sun is shining. Possible Sunshine is the amount of sunshine possible from sunrise to sunset. Percentage of sunshine minutes is the percentage of the actual sunshine minutes over the total sunshine minutes possible.

DEW POINT

Dew Point is the temperature at which water vapor must be cooled to for it to turn into a liquid. The Blue Hill Observatory uses the Psychrometer as known as the Dry Bulb/Wet Bulb Thermometer to derive a calculated dew point.

VISIBILITY

Visibility is the maximum horizontal distance an observer can see based on fixed-distance markers. The following are some of the Blue Hill Observatories markers:

- Kite Shed: 1/16 mile, E
- NWS Weather Radio/State Police radio mast: 1/16, SW
- Ponkapoag Pond: 1 ½ miles (near shore), 2 miles (far shore), SSE
- Norwood airport: 3 ¼ miles, SW
- Dorchester gas tank: 7 1/8 miles, NNE
- Providence, RI: 31 miles, SSW
- Grand Monadnock, Jaffery, NH: 68 miles NW

PRESSURE

Pressure is the amount of force that the atmosphere exerts on Earth. Atmospheric pressure changes every day due to the weather systems in the atmosphere. Pressure decreases as elevation gets higher; and increases as elevation gets lower. At the Blue Hill Observatory Station Pressure is measured by the mercury barometers. The Four-Day Barograph used at the Blue Hill Observatory is a continuous recording of station pressure. The ASOS and the Davis system also calculate the pressure, but they are only used to check mercury barometers.

RELATIVE HUMIDITY

Relative humidity is a percent that states how much water vapor is in the air. It describes the phase state of air when the evaporation and condensation phases are in equilibrium. The hygrothermograph keeps a consistent reading of temperature and relative humidity. The Psychrometer is used to derive a calculated relative humidity. The ASOS and the Davis system also calculate the relative humidity, but they are only used to check the psychrometer.

VAPOR PRESSURE

Vapor pressure is the pressure that forms as a result of vapor forming from liquid. Vapor pressure is measured in millimeters of mercury. The Pyschrometer is used to derive a calculated measurement of vapor pressure. The ASOS and the Davis system also calculate the vapor pressure, but they are only used to check the psychrometer.

HEATING AND COOLING DEGREE-DAY

As the temperature outside drops below 65 degrees, the heat must be turned on in order for buildings to be maintained at an inside temperature of 70 degrees. The amount of heat that is required to keep the building at 70 degrees is proportional to the amount of accumulated days below 65 degrees. This heating degree-day index allows fuel distributors to predict the demand of fuel in the coming days. A Cooling Degree-Day is essentially the same as a heating degree-day except for it is used when the temperature is above 65 degrees.

SKYCOVER EIGHTHS

When observing the amount of clouds in the sky the observers describe the cloud cover in eights. Zero eighths being that there are no clouds in the sky and eight eighths is that the sky is completely covered by clouds.

MOUNTAIN VISIBILITY

When making the daily observations, observers use nearby mountains as landmarks to approximate the miles of visibility at that current time. The observers rank each mountain on a scale of 0 to 3, 3 being the clearest visibility. The following are the mountains used:

Name	Distance from Blue Hill	Visibility	Direction
Nobscot Hill	19 ¼ Miles	20 Miles	WNW
Mount Washcusett	44 Miles	45 Miles	WNW
Mount Monadnock	66 Miles	65 Miles	NW

Ranking from 0 to 3

1^0 = Faintly Visible

1^1 = visible but hazy

1^2 = clearly visible

1^3 = reserved for the clearest possible