Critique, Comments, and Weather:
a review of the Rand and HMMH sound studies

Prolog (and submission notes)

To: Andrew Biemer, Administrator Site Evaluation Committee
From: Eric (Ric) Werme
Date: 2023 May 1
Ref: Docket No. 2021-02, Investigation of Complaints Regarding Antrim Wind Energy Facility

Please add this document to the docket. It is relevant to the Public Meeting to be held on May 15th.

Introduction

This document is my response to the 2022 sound compliance study conducted in June 2022. It extends Dr. Fred Ward's comments on the weather conditions on the study dates and also on the non-compliance periods described by Rand Acoustics in a May 14, 2021 submission. These analyses are the last five pages of this document. My focus is on whether there was a nighttime temperature inversion. Equally important is the effect of wind shear – the change of wind speed with altitude. I go into more detail below.

Overall, neither Rand nor HMMH describe the weather conditions well. This is more than a bit disturbing, as the subcommittee has mandated that studies be done in conditions similar to when complaints were made. On the other hand, I have not come across a log of complaints, but I suspect they also do a poor job of describing conditions. While most people have little more than a thermometer for quantitative information, their wind information is typically more qualitative. Of course, the information is for a single point at ground level.

I live some 20 miles from the Antrim Wind Energy, and do have continuous, typical weather data from a weather station at my home in Sutton Mills. One can infer from how it changes over time to quite a bit about the atmosphere and cloud cover. My analyses are largely based on conditions at home, weather maps from soon after the observations, and information gleaned from the reports. I'm fairly pleased with the results and I think they will stand up to scrutiny from professional meteorologists. I hope the SEC will take them seriously.

Refraction we can see

We are familiar with refraction in liquids like water and solids like glass or diamonds. Cut diamonds and glass prisms are optimized to show off the difference in refraction with different colors of light. That's not our concern, we are simply interested in how sound bends as it passes through the atmosphere. The refraction we see with water allows us to see the boundary of water at a pond, in a glass, etc.

These have pronounced effects at the boundary, they don't really show up internally. In gases we see the effect of light bending through a length of the medium, e.g. the watery mirage from an asphalt road in hot summer sun or the distortion of the sun or full moon near the horizon. Sound does very similar things, except we can't perceive the effects directly.

Sound refraction due to temperature gradients

Normally air temperature decreases with height – during a clear day the peak of Mount Washington is some 30 F° cooler than in the Merrimack River valley near sea level. The speed of sound varies with temperature, the molecules in warm air move faster than in cold air, and their velocity is what propagates sound waves. As sound moves horizontally, it bends in the direction of the colder air. i.e. it refracts upward and away from the surface.

During clear nights, the air gets colder. Actually, the Earth's surface cools by radiating heat and that cools the air next to the surface. The cold, denser air flows downhill, ultimately pooling in valleys. If there isn't much wind, it undercuts air above the surface an we have an inversion – warm air floating above chilled air. Now sound moving horizontally is refracted downward and begins to propagate in a ring instead of a sphere. Instead of weakening with the square of the distance (the “inverse square law”), sound weakens with just distance and carries much further than during the day.

This is the effect Fred Ward pointed out, and its why I focus on temperature inversions in my analyses.

Sound refraction due to wind shear

Wind shear is a change in wind velocity with distance, for us it's with height, vertical wind shear. The change in the speed of sound doesn't change quickly with temperature. However, it's speed is relative the air that it's in – the speed of sound is about 760 miles per hour. Wind speed tends to increase with height – friction from trees buildings, etc slow wind down near the surface, and temperature inversions get involved too. When wind turbines have enough wind to run, any sound they generate is going faster downwind than upwind. Sound going downwind can go faster than sound near the surface – and that results in refraction toward the ground! Sound going upwind is slower than sound at ground level, so it refracts upward.

The net result of this is that wind turbine sound complaints will almost always be from places downwind of the turbines.

Refraction drawings

Here are a couple images from a blog post titled The Effect of Wind and Temperature Gradients on Sound Waves. I hoped to find a more sciency presentation I saw in the past that is very good, but this will do okay.

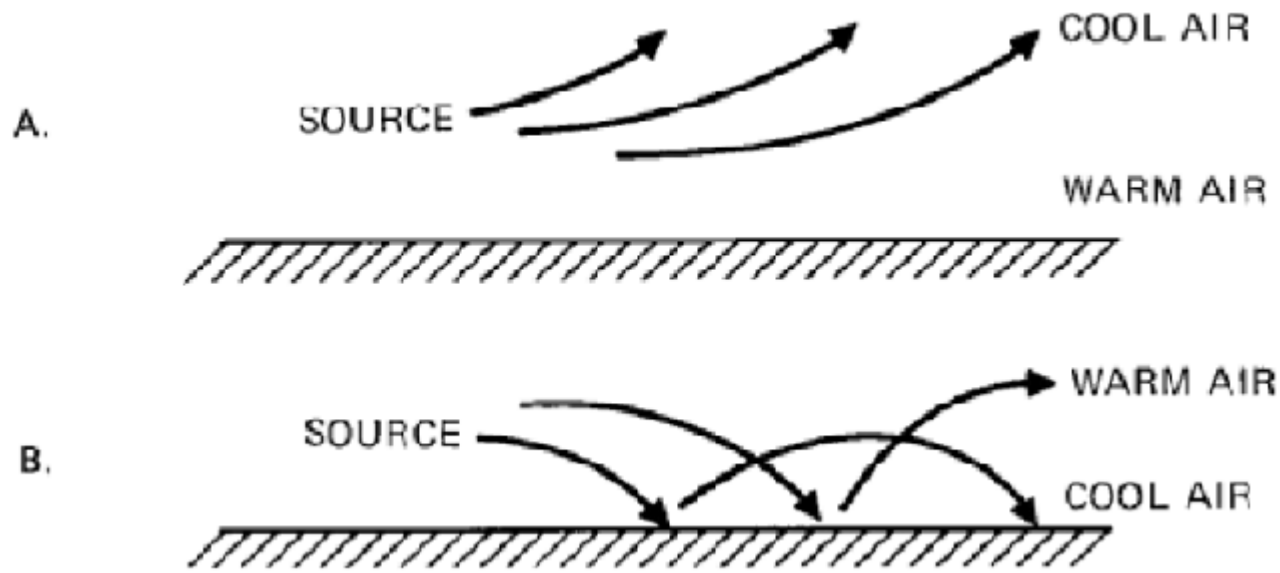


Illustration 1: Refraction due to temperature gradient

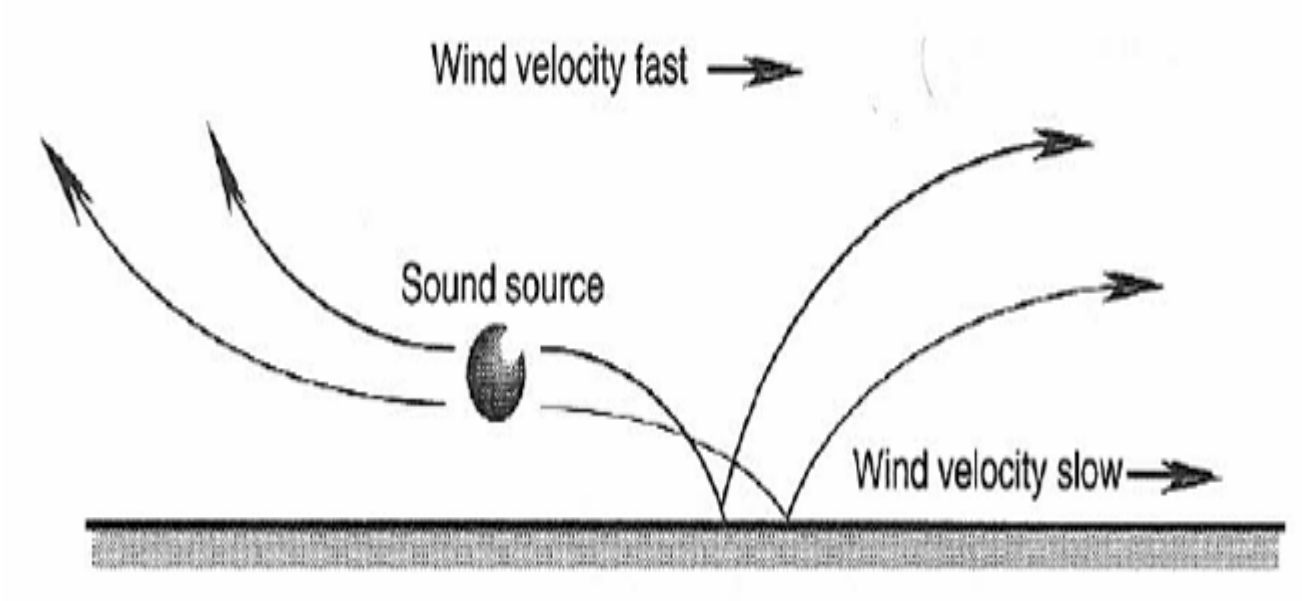


Illustration 2: Refraction due to wind shear

My Analyses

This is a good point to skip ahead and review my analyses. Then return below for my conclusions.

Conclusions

I don't know what HMMH was contracted to do, and some issues make no sense. For example, HMMH wanted to do long term recording, some of neighbors wanted long term recording, yet the report says “access to private property was not available.” The investigations were supposed to be

done during weather conditions similar to when the complaints were filed, but I haven't found the complaints to analyze. One of the study sites was a NHDOT maintenance facility. It was chosen because they could leave instruments there unattended for long sessions. However, sessions in the afternoon and evening were dominated by traffic noise from Rt 9, and the site was upwind of the turbines anyway. I assume that no noise complaints have been filed by NHDOT.

All three recording sessions were on Thursday and Friday, the last one “was chosen for forecast low wind conditions in the study area” after having problems with wind noise on microphones on the second visit. None of the visits were on days conducive to strong temperature inversion development.

The Rand Acoustics survey was done from a single site, the source of several complaints, at least according to the report and filings by the owner and neighbors. Long term monitoring led to at least a couple examples of significant noise exceedance, though possibly not by the long sampling period specified by the SEC for the HMMH study. (This is an extremely contentious point and the long sampling period greatly favors Antrim Wind Energy. It ignores how people hear sound, especially brief sounds like hammer impacts or wind turbine blade passes. It is discussed in other filings an hearings, it's not entirely clear to me how, when, or why it was adopted.) The cases highlighted in the report are examined below, and both occurred late at night when there was likely a strong inversion.

It appears neither study targeted particular weather conditions, but the 22 day recording session allowed recording in conditions of past complaints and two complaints logged during the session.

All in all, the Rand Acoustics study is far more informative and covers far more time at a known problem site. Of course, the HMMH report is far more valuable to Antrim Wind Energy and I am confident it will be presented as the better report to the SEC subcommittee.

References, with comments

This section is not as complete as I planned, I thought I had more time to finish this document.

https://www.nhsec.nh.gov/projects/2021-02/documents/2021-02_sound_study_hmmh_4-10-2023.pdf
This is the HMMH (Harris Miller Miller & Hanson Inc.) report, the subject of the upcoming hearing on may 15th.

https://www.nhsec.nh.gov/projects/2021-02/public_comments/2021-02_2021-05-14_sound_monitoring_report.pdf
This is the Rand Acoustics report from 2021 May 5. Apparently there is an earlier one that predates the formation of the study committee but I haven't gone looking for it.

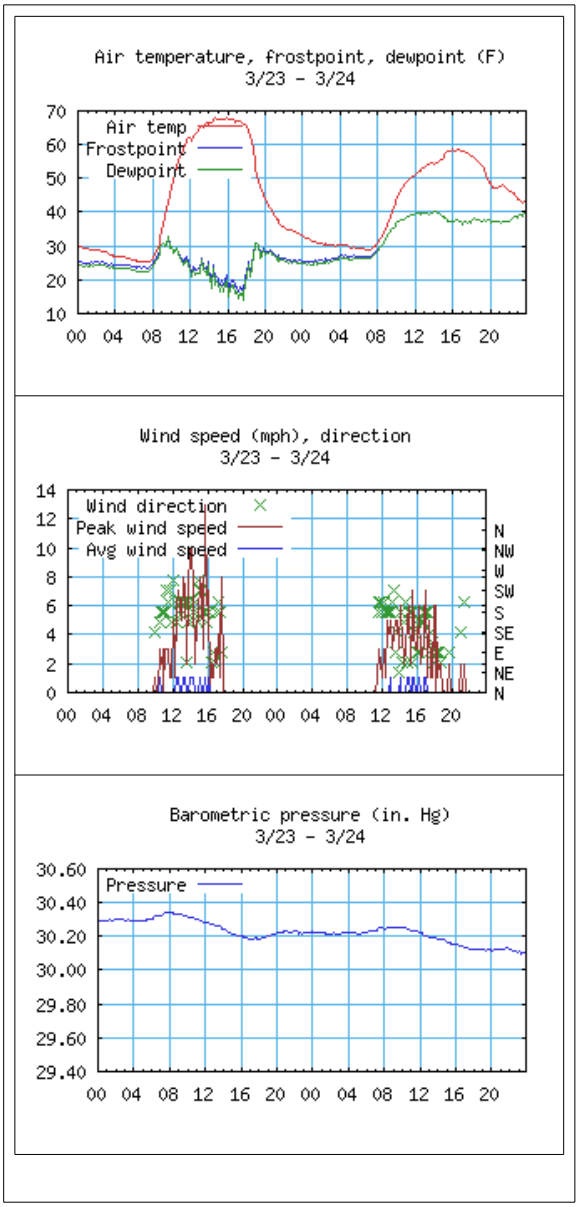
https://www.nhsec.nh.gov/projects/2021-02/documents/2021-02_comment_drward_4-27-2023.pdf
This is Fred Ward's response to the HMMR. It appears to be saved as a graphical image and cannot be directly used to copy and paste passages. (This document extends much of what Ward had to say.)

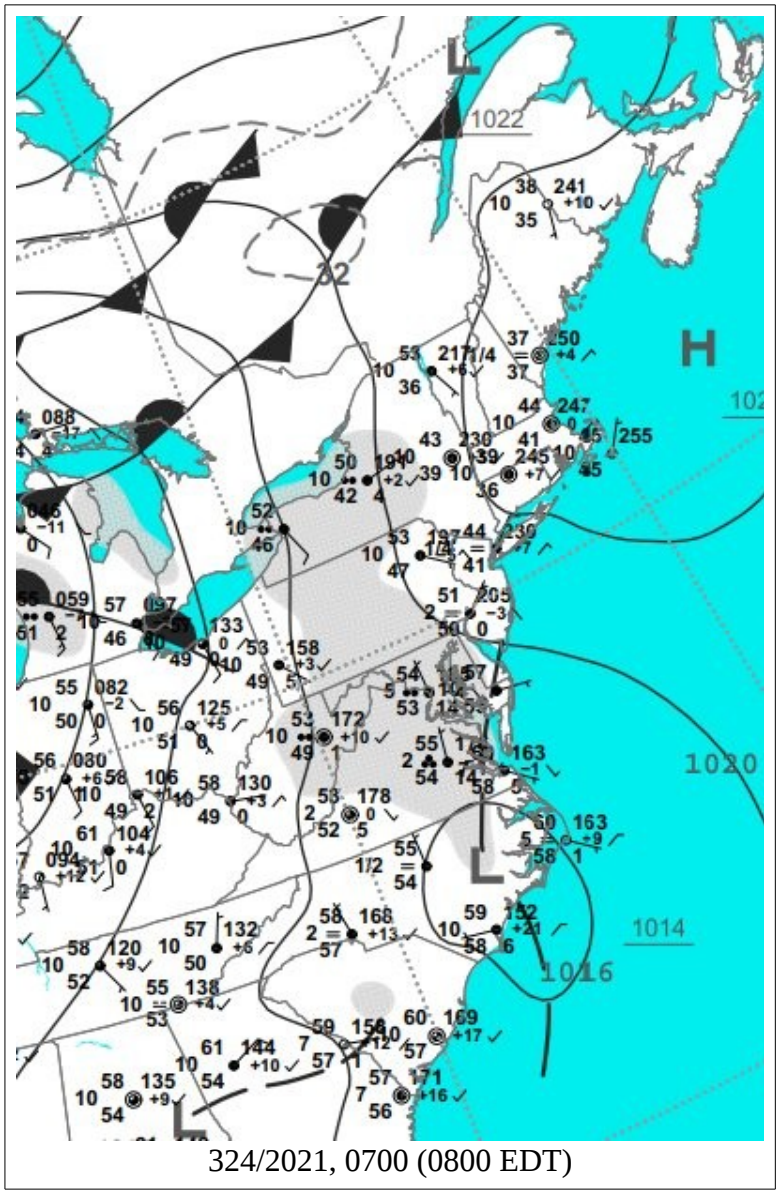
https://www.nhsec.nh.gov/projects/2021-02/documents/2021-02_public_comment_berwick_longgood.pdf
This was filed in September 2022 by Antrim Wind Energy neighbors Barbara Berwick and Janice

Longgood to make it very clear that they offered and wanted HMMH to do monitoring from their properties, or at least the Berwick property, where Rand Acoustics did their monitoring. They include SEC statements that the SEC wanted to do monitoring there. Neither they nor I understand how the discussion resulted in HMMH thinking that access was denied. This is a major factor contributing to the poor quality of the HMMH report.

Most concerning to me is this statement from Jonathan Evans : “Again, we are trying to avoid having anyone besides the homeowner[,] our expert[,] and myself in these conversations.” This presents a very unbalanced meeting – two professionals who have rejected the Rand Acoustics report and raises fears that they may want to pressure the homeowner into committing to support a study designed to refute Rand. Note that the Rand Report is online in the “Public Comments” section of the Docket yet criticism of it is posted in the Docket's home page!

Rand Report: 3/24/21 0000-0100





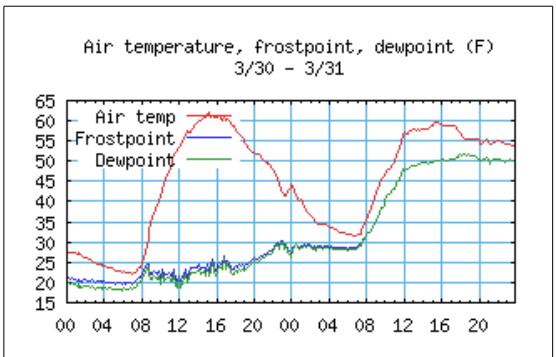
324/2021, 0700 (0800 EDT)

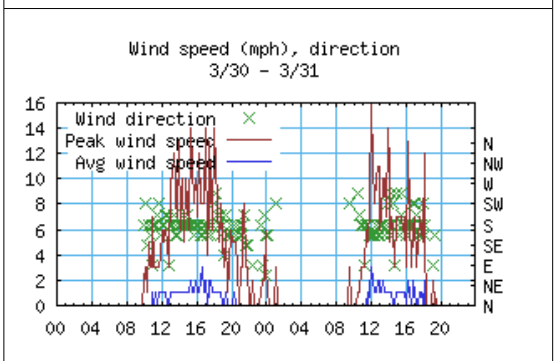
This is a near perfect example of a nighttime temperature inversion. The fast temperature rise in the morning of the 23rd shows the warmth of full sunlight destroying the previous inversion. As mixing occurs in the atmosphere, the rise slows and reaches an afternoon cap. The falling dew point shows the air mass is still dry despite the air flow from the south. As the sun's heating fades near sunset, convection and mixing slows. Radiational cooling quickly chills the surface air. As the inversion sets up, surface wind stops and the dew point rises as moisture evaporates from the ground. By midnight the inversion is firmly in place.

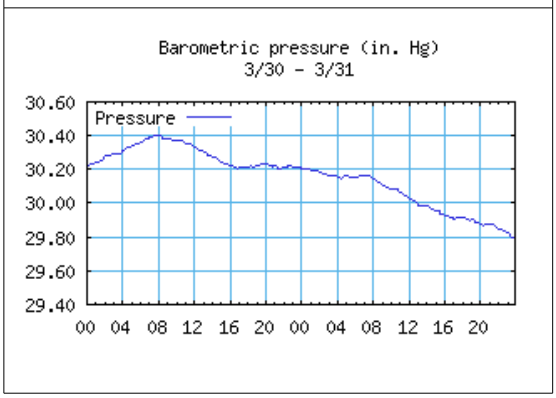
The slow temperature rise the next morning says the sky is cloud covered, but heating does break down the inversion and moister air shows a new air mass is moving in.

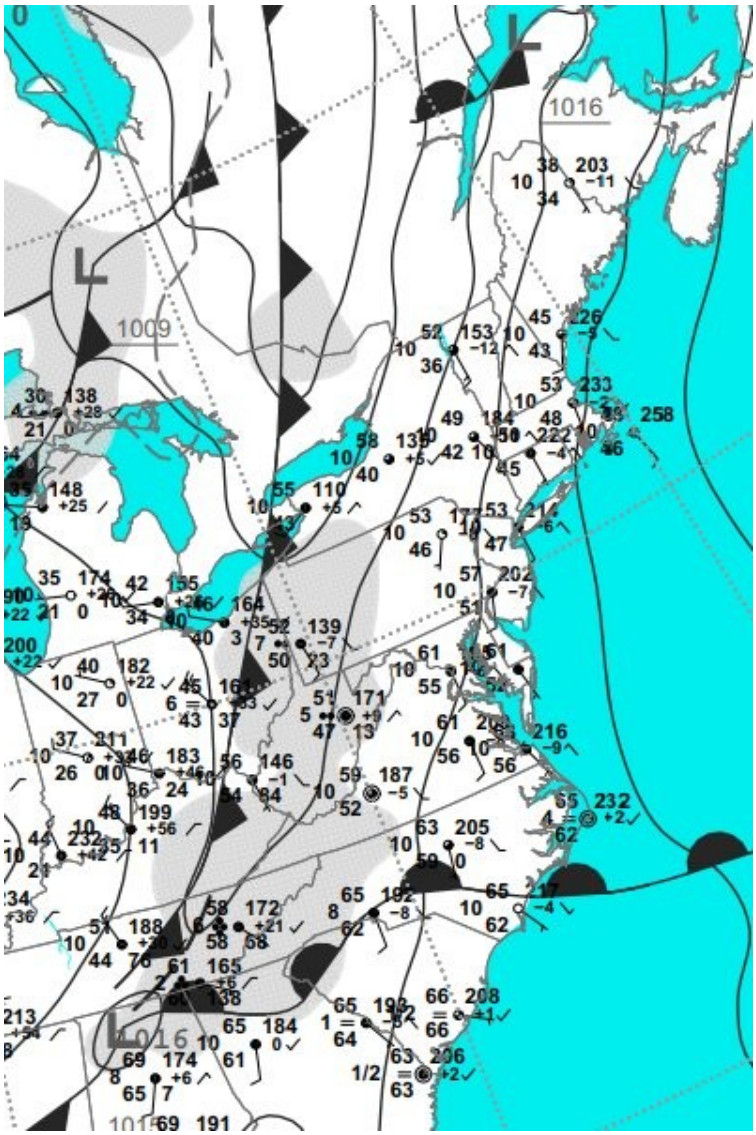
See weather maps at Daily Weather Maps March 22, 2021 - March 28, 2021.

Rand Report: 3/31/21 0300-0301









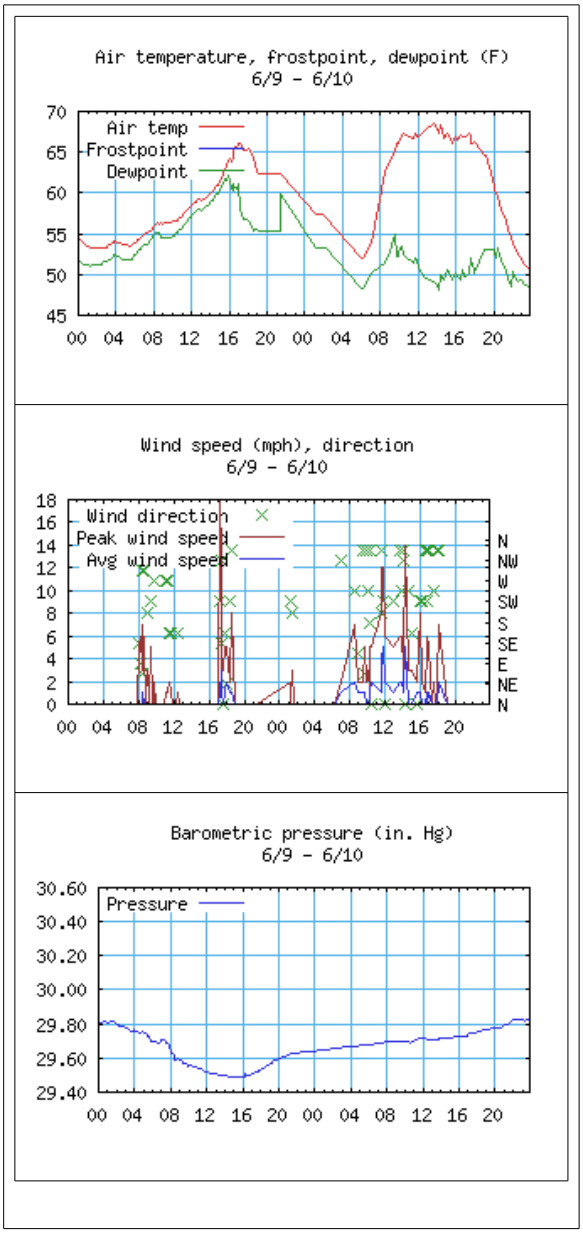
3/31/2021, 0700 EST (0800 EDT)

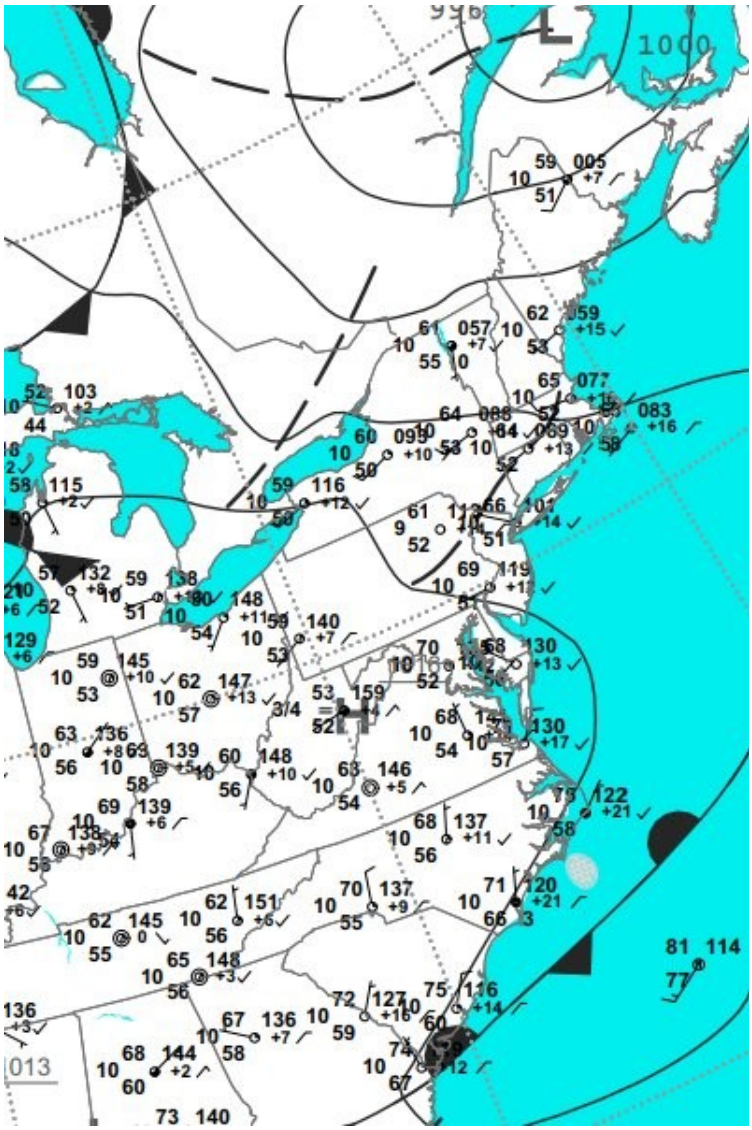
This shows another nighttime temperature inversion, but less pronounced than the 3/24 event. The morning temperature rise on the 30th shows the near-full sunlight destroying the previous inversion. I suspect the sky had a layer of cirrus clouds that reflected some sunlight. The rising dew point shows that a new air mass is working its way in. As the sun's heating fades near sunset, this time radiational cooling more slowly chills the surface air. The blip at midnight coincides with a little wind that briefly disrupts cooling. Eventually the inversion is strong and thick enough to prevent wind from reaching the surface.

Several things in the morning show that a dome of high pressure is moving away – the weaker temperature climb shows clouds are in place, the increase in dew point shows that moist air is moving in, the declining air pressure is showing that the high moves out and that low pressure is coming in. The slow temperature rise the next morning says the sky is cloud covered, but heating does break down the inversion and moister air shows a new air mass is moving in. Eventually, rain started on the evening of 4/1.

See weather maps at Daily Weather Maps March 29, 2021 - April 4, 2021.

HMMH – 6/9/2022





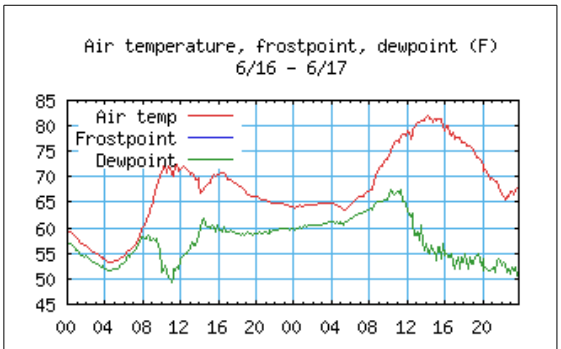
6/10/2022, 0700 EST (0800 EDT)

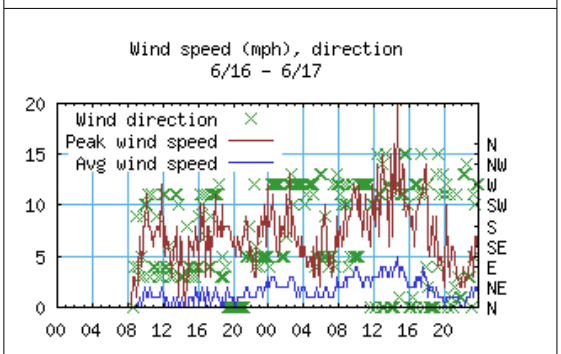
The jagged traces on the graphs are due to poor weather station reception at home while upgrading from an old and tired Davis VP to a VP2.

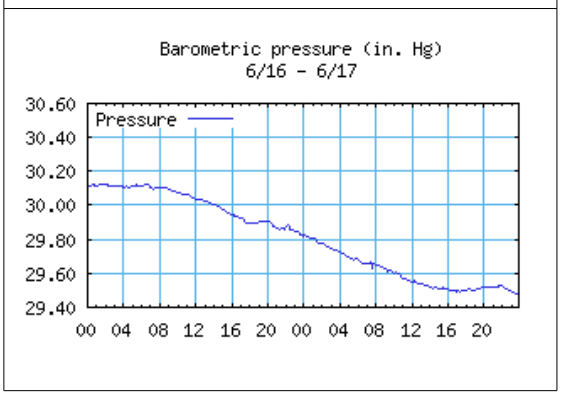
The barograph trace shows a frontal passage in the afternoon of the 9th before HMMH monitoring started. There had been rain in the morning, after the front the dew point fell but likely increased as the evening inversion formed. Cool and drier air would have come in after the front, and the inversion must have been rather weak given that the ground temperature fell only some 13 F°. The weather data does show some wind at 0200, another indicator of a weak inversion. Clouds likely moved out overnight and allowed the fast temperature climb after dawn.

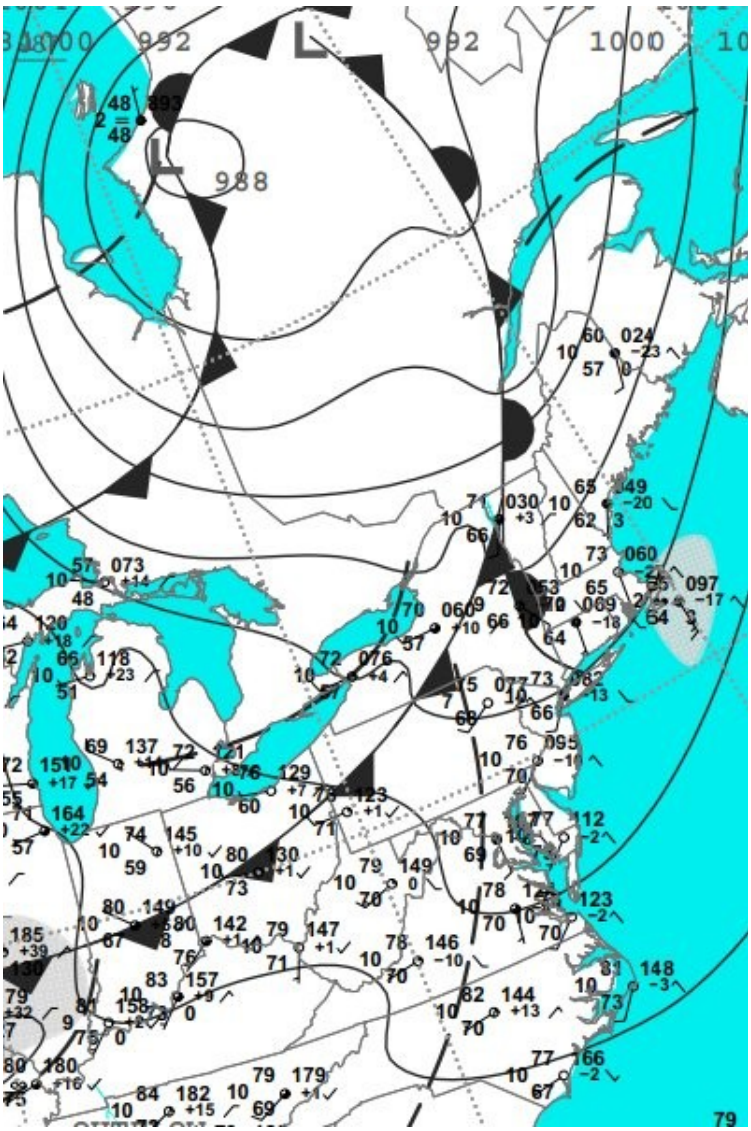
See weather maps at Daily Weather Maps June 6, 2022 - June 12, 2022.

HMMH – 6/16/2022









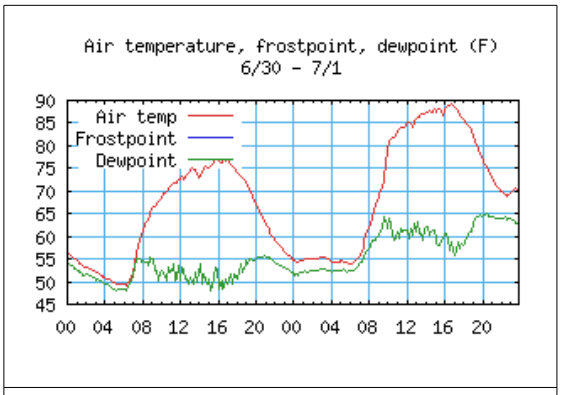
6/17/2022, 0700 EST (0800 EDT)

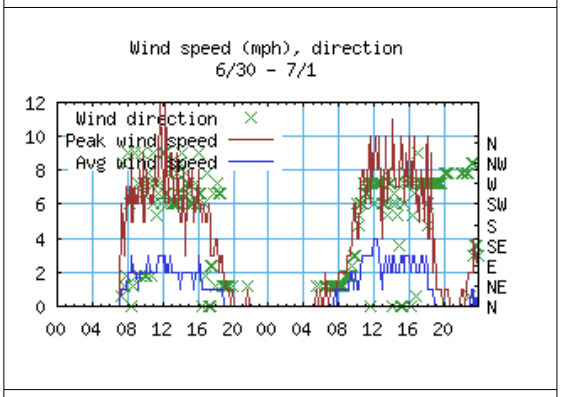
A long serial port cable allowed me to place the weather station console where it could reliably receive information from the outdoor sensors.

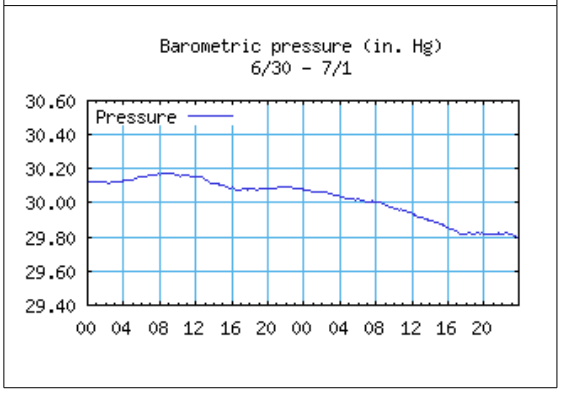
HMMH data from the afternoon and evening of the 16th had too much wind noise to be usable. Everything above says that the weather was a complicated mess. Overnight wind prevented anything like an inversion to form, wind coming from the southwest or the east suggests that a back door cold front had reached me. HMMH did get two samples that were usable after midnight, both were from sites south of the wind project and not very interesting.

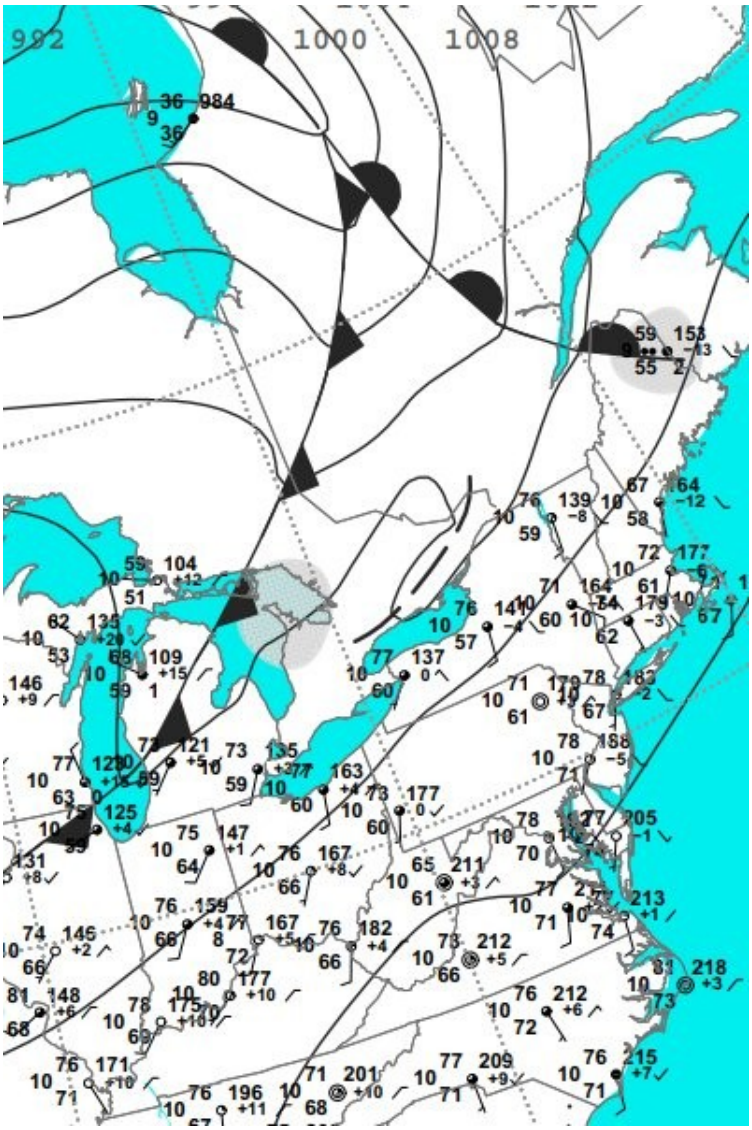
My remarkably low air pressure by the end of the 17th is from a very deep low pressure system near Hudson's Bay. These days were likely representative of no day from any of the noise complaints being investigated. See Daily Weather Maps June 13, 2022 - June 19, 2022.

HMMH – 6/30/2022









July 1, 2020 0700 EST (0800 EDT)

The 16th looks like it was a pretty nice day with comfortable temperatures and dry air. Overnight a warm front came through and daytime mixing brought down much warmer and humid air. In between the flat temperature from 0000 to 0600 says clouds and no good opportunity to develop a deep inversion. The wide spacing of isobars means light winds.

HMMH says the date was "chosen for forecast low wind conditions in the study area." They certainly got their wish in the afternoon and evening – wind speed at turbine nacelles was 3.5 and 3.3 m/sec and power generation per turbine was some 10% of full output. The wind picked up at night to respectable levels, but the direction at the nacelles averaged some 227° - southwest - and blew along the ridge instead of toward the monitoring sites.

In summary, it was a very good day to show compliance with with the noise standard.
See Daily Weather Maps June 27, 2022 - July 3, 2022.