Data Mining Effects of 50 Years of Climate Change at Hawk Mountain Sanctuary

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Acknowledgements

- Dr. Laurie Goodrich, Sarkis Acopian Director of Conservation Science.
  - First contact and observation data for 2017-2018 in fall 2019.
  - Students and I became familiar with these data in preliminary projects in CSC458 Predictive Analytics I that fall.
  - Dr. Goodrich helped to set goals for the larger, KU grant-funded analysis project in 2022-2023, supplying 88 years of data.
- Bryan McNally and Tyler Blankenbiller did additional work in spring 2020 for CSC558 Predictive Analytics II using more data.
- Eric Burgos is completing his MS thesis correlating annual weather patterns to TOTAL raptor counts.
- Alex Rainer & Nathan Zolna are analyzing additional raptor species this fall. Emma Smith and R-E Miller will port and enhance Faith Evans' raptor observation animation in winter & spring 2023.

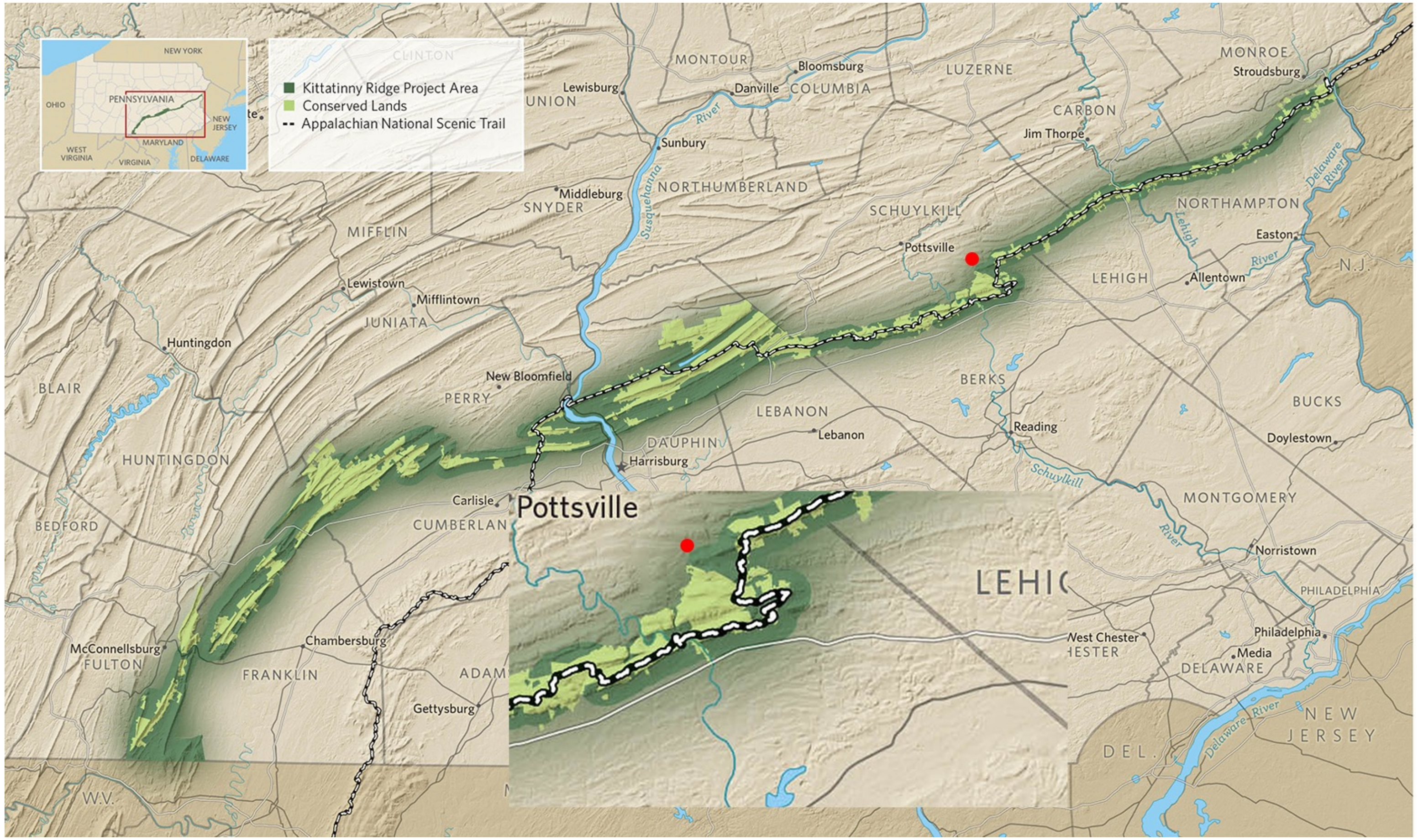
Hawk Mountain Sanctuary
in northeast Berks County, PA

- Annual autumn raptor migration observations and data recording since 1934.
    - One observation record per day until fall 1967, more thereafter.
    - One observation per hour from Aug. 15 through Dec 15. now.
- One large dataset in Jan. 2020, two more in Jan. 2022.
- Merged with weather NOAA data from Allentown Airport to compensate for missing weather data in early years.
- https://www.hawkmountain.org/

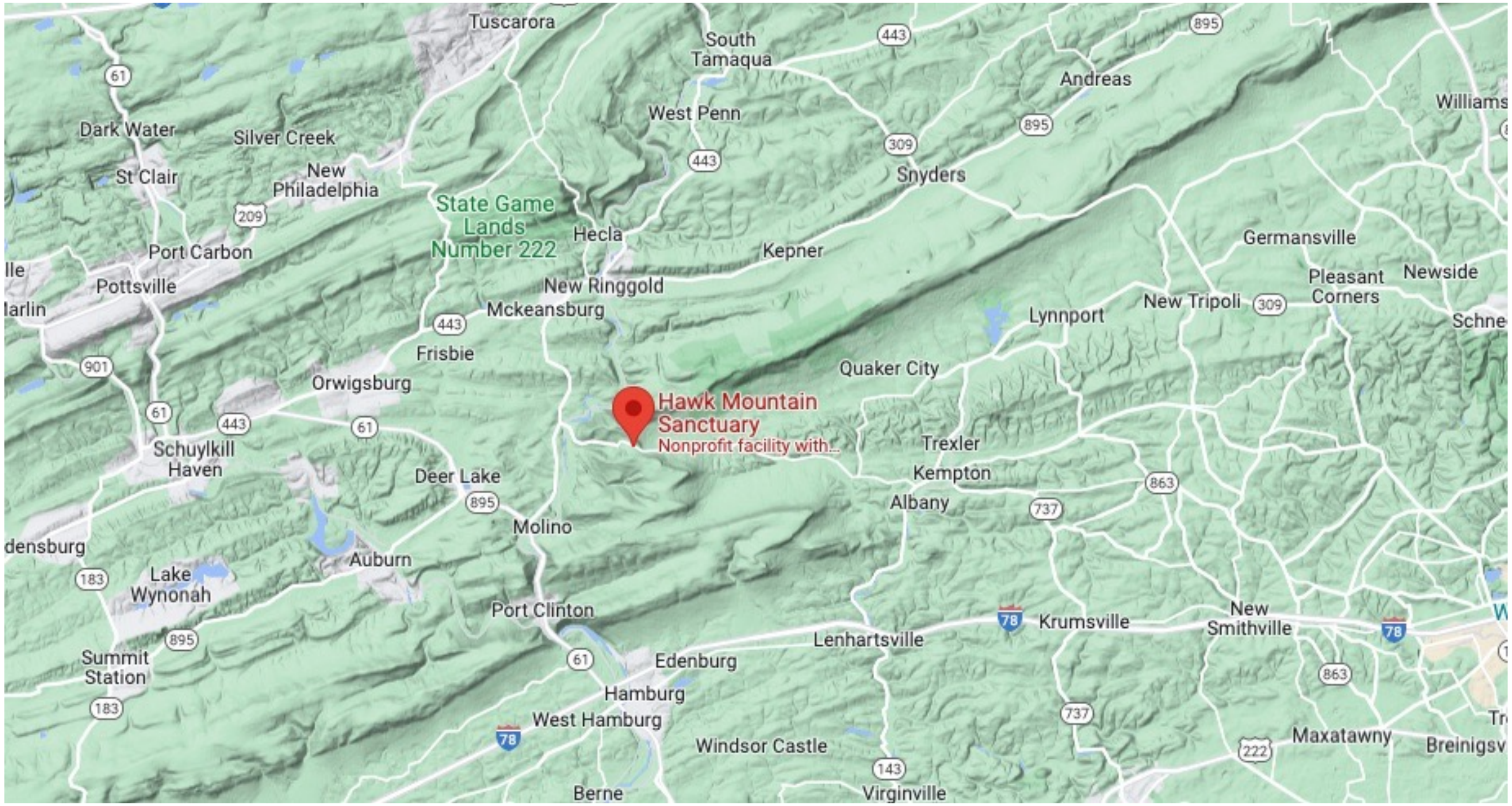
September 21, 2019 meeting Dr. Goodrich

September 21, 2019 North Lookout

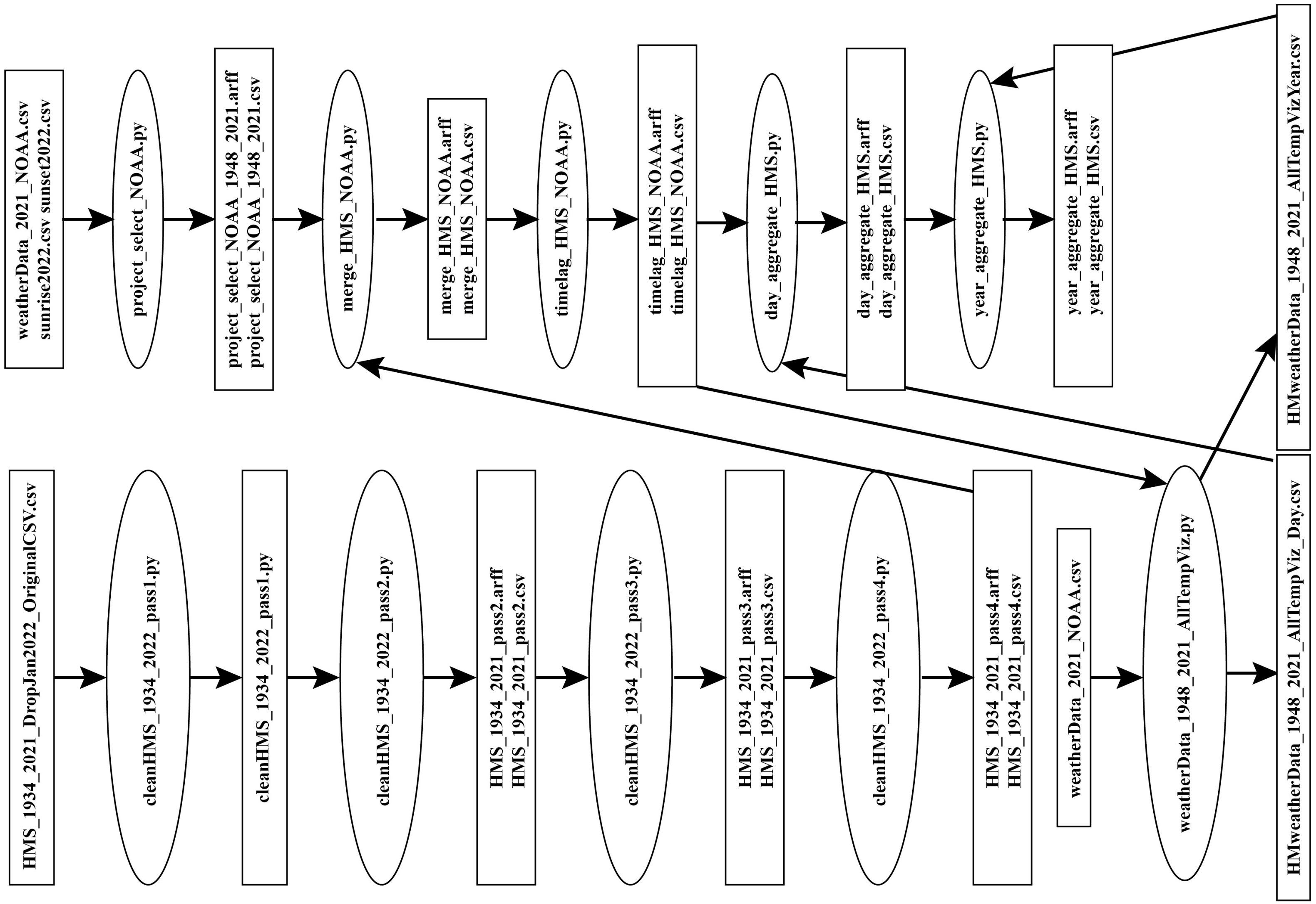
Kittatinny Ridge northeast to Hudson River



Kittatinny Ridge at Hawk Mountain



Data Cleaning, Ellipse = Script, Box = Store



Raw CSV Data from January 2022

Date	Start	Duration	BW	Temp	Wind Spd	Wind Dir	Visibility	Cloud Cover	Humidity	BARO	Flight DIR	Flight HT
30-Sep-34	0:00	180	2	0				0	0	0		
7-Oct-34	7:00	240	1	0				0	0	0		
8-Oct-34	8:00	540	0	0				0	0	0		
11-Oct-34	11:00	540	0	0				0	0	0		
16-Sep-10	16:00	60	11	18	2: 6-11 km/h (4-7 mph)	WNW	77	0	0	0	SW	2: Unaided eye
16-Sep-10	17:00	50	2	18	1: 1-5 km/h (1-3 mph)	NW	77	0	0	0	SW	2: Unaided eye
17-Sep-10	5:00	25	0	15	2: 6-11 km/h (4-7 mph)	NW	1	100	0	0		
17-Sep-10	6:00	60	0	16	3: 12-19 km/h (8-12 mph)	NW	12	100	0	0	SW	1: Eye level to 30m
17-Sep-10	7:00	60	5	16	3: 12-19 km/h (8-12 mph)	NW	9	100	0	0	SW	1: Eye level to 30m
17-Sep-10	8:00	60	120	16	3: 12-19 km/h (8-12 mph)	NW	12	80	0	0	SW	2: Unaided eye
17-Sep-10	9:00	60	101	16	4: 20-28 km/h (13-18 mph)	NW	40	50	0	0	SW	2: Unaided eye
17-Sep-10	10:00	60	143	17	3: 12-19 km/h (8-12 mph)	NW	40	40	0	0	SW	2: Unaided eye

Data Problems Resolved in Python Scripts

- Some years all temperatures recorded as 0 instead of missing.
  - Scan across day for variations, Unknown if all zeroes.
- Some temperatures would boil or freeze observers.
  - Any outside 3 standard deviations from mean Unknown.
- Some 0 temperatures recorded between 2 non-cold that day.
  - Take the mean of the 2 closest neighbors that day.
- NNW coded as NWN, WNN, and similar character transposes.
  - Python itertools.permutations to find canonical form.
- Strip leading and trailing text (e.g., units) from numbers.

Wind & Flight Direction Need Better Representation

- NNW, etc. text does not work with time-series aggregation.
- Compass degrees are non-linear, crossing at 360 degrees.
- Solution is to tally into directional counters.
- `@attribute wndW numeric`
- `@attribute wndWNW numeric`
- `@attribute wndNW numeric`
- `@attribute wndNNW numeric`
- `@attribute wndUNK numeric` ETC.
- Daily & yearly counting works well with counter-based modeling.

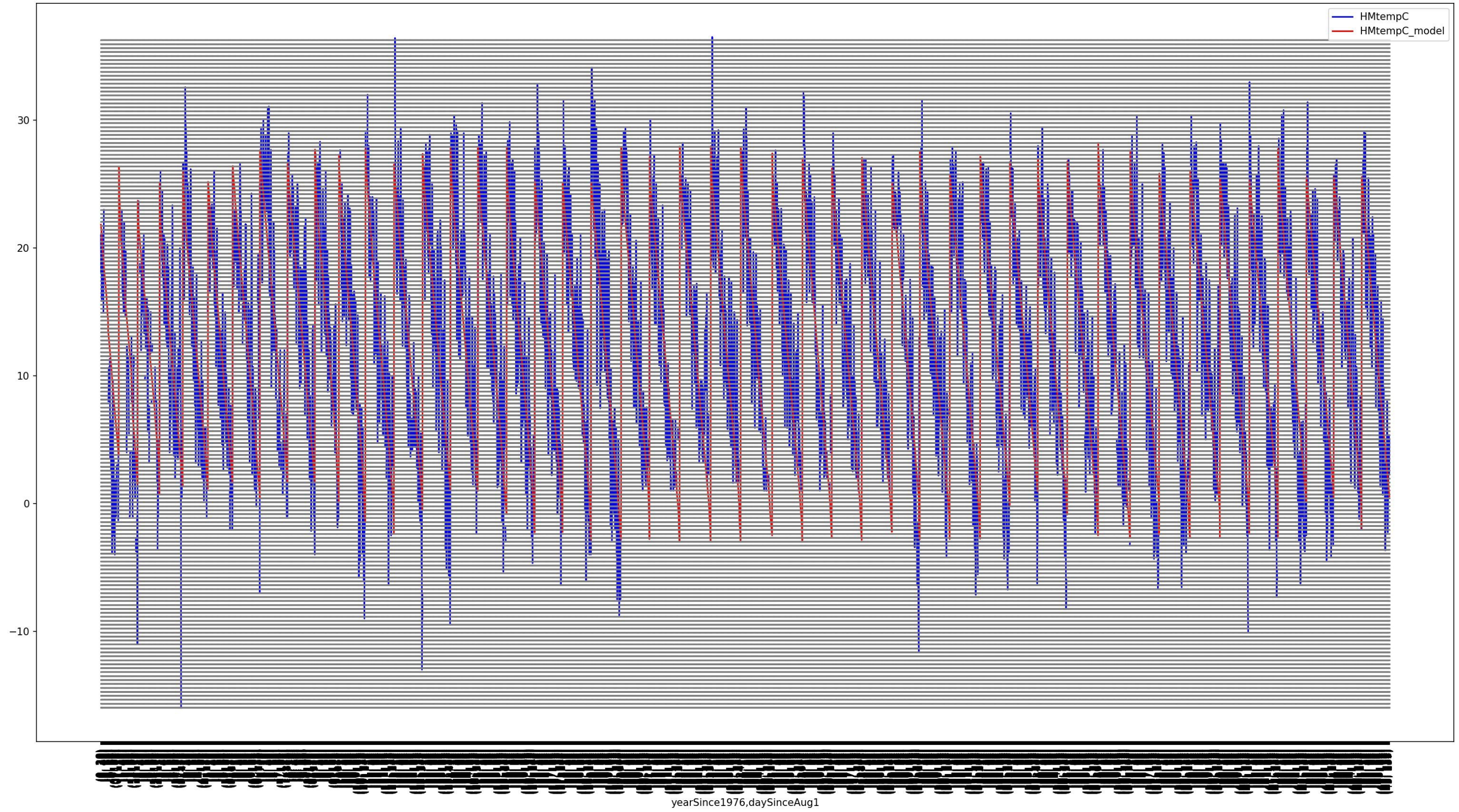
Aggregated Daily & Yearly HM and NOAA data

- ['yearday', COPY],
- ['daySinceAug1', __DERIVE_DAY_SINCE_AUG1__],
- ['hour', DROP],
- ['duration', TALLY],
- ['SkyCode', MEAN],
- ['HMtempC', MEAN],
- ['WindSpd', MEAN],# SOME day_aggregates
- ['WindDegrees', MODE],
- ['wndN', TALLY],
- ['wndNNE', TALLY],

Analysis Stage 1: Day and Year to Climate

- Yearly Aggregates are mostly for finding statistical trends.
  - Only 46 instances for 1976-2021 that have most climate data.
- Daily Aggregates are good for digging into details.
  - 5639 instances; finding raptor appearance dates is hit-or-miss.
- 230 Monthly aggregate instances for CSC458 & 523 this fall.
- Automated full cross-product of daily & yearly data X all climate attributes and 1 raptor type generated a **LOT** of analysis data. Mining analysis data led to some results.
- Used suggestions from Dr. Goodrich prune Stage 2 work.

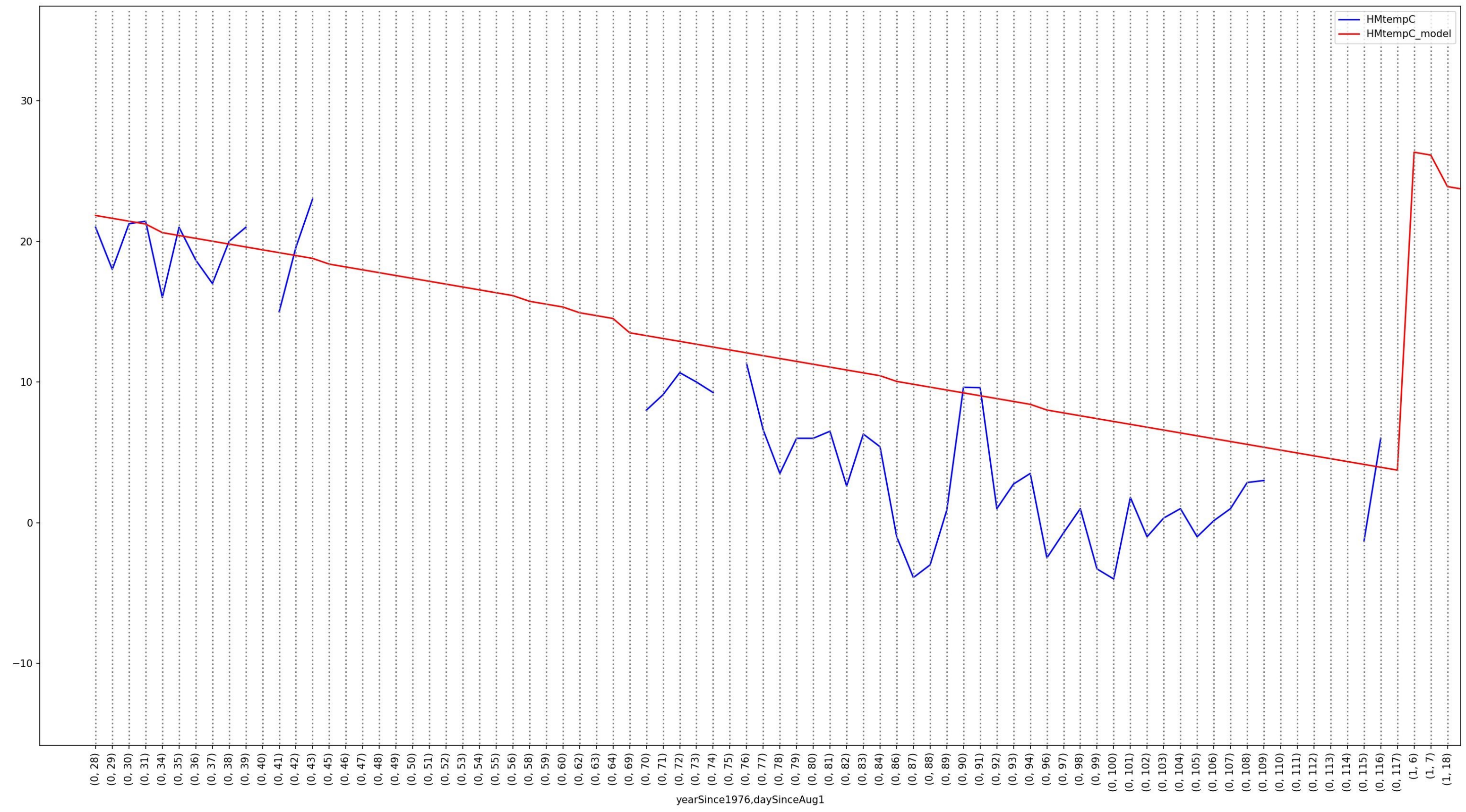
HMtempC_model = 0.0198 * yearSince1976 + -0.2034 * daySinceAug1 + 27.5346 ([Weka]())



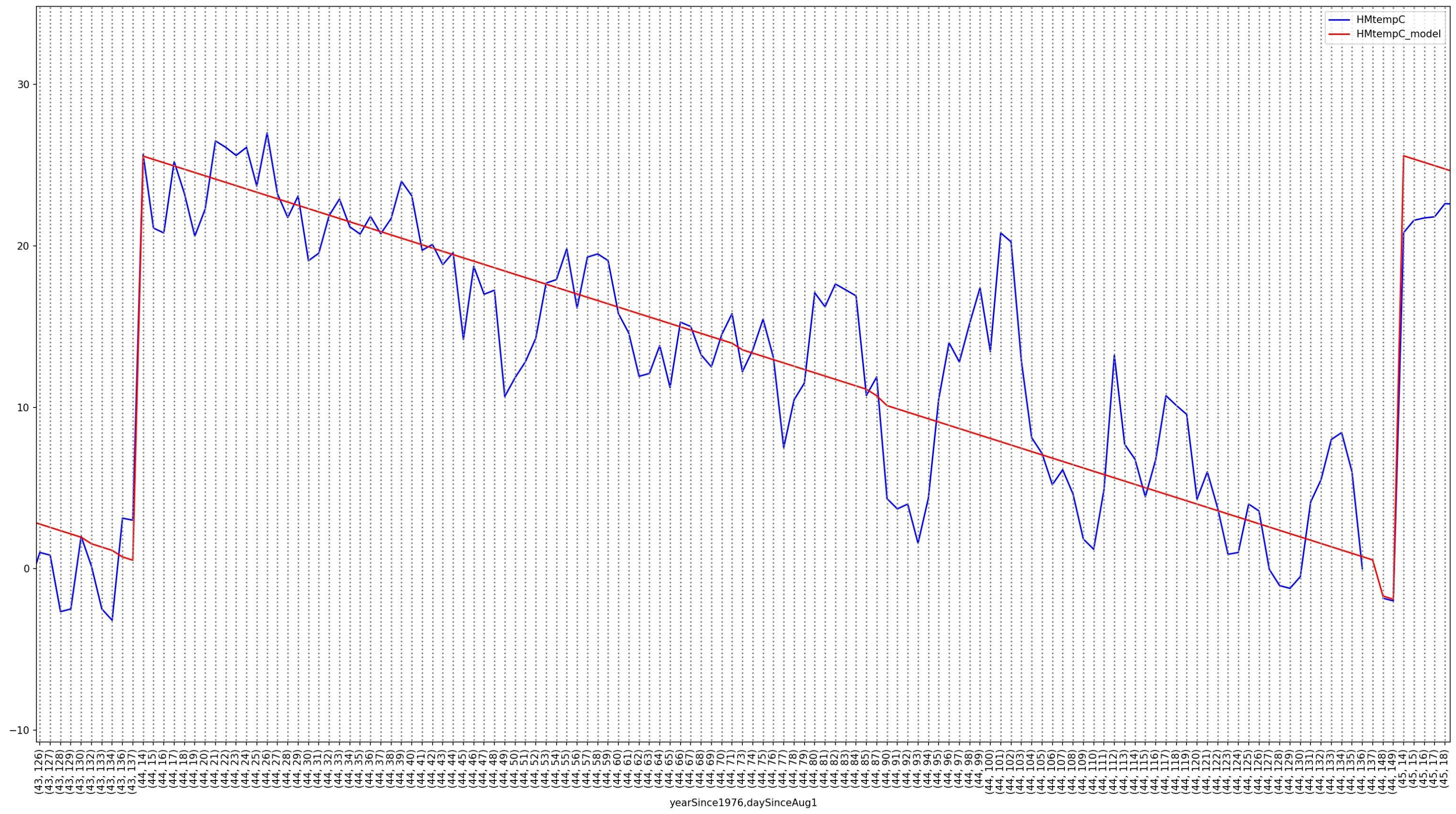
HMtempC_model = 0.0198 * yearSince1976 + -0.2034 * daySinceAug1 + 27.5346

- Linear Regression Model
- HMtempC =
- 0.0198 * yearSince1976 +
- -0.2033 * daySinceAug1 +
- 27.5322
- Correlation coefficient 0.8639
- Mean absolute error 3.3556
- Root mean squared error 4.2343
- Error measures are in domain units (degrees C in this model), with RMSE emphasizing outliers. Multipliers are in *approximate* domain units.

HMtempC & HMtempC_model for 1976



HMtempC & HMtempC_model for 2020



Digging into HM Temp Trends this Semester

- daySinceAug1 <= 69.5 :
- | daySinceAug1 <= 44.5 : LM1 (1336/43.923%) **Aug 1 – Sep 14**
- | daySinceAug1 > 44.5 : LM2 (1091/46.866%) **Sep 15 – Oct 9**
- daySinceAug1 > 69.5 :
- | daySinceAug1 <= 101.5 : LM3 (1372/51.929%) **Oct 10 – Nov 10**
- | daySinceAug1 > 101.5 : LM4 (1419/55.291%) **Nov 11 – Dec 31**
- This is a Weka M5P model tree. The leaves are linear expressions.
- https://www.cs.waikato.ac.nz/ml/weka/

Digging deeper into HM Temp Trends this Fall

- LM num: 1 **Aug 1 – Sep 14**
- HMtempC = 0.0003 * yearSince1976 - 0.1335 * daySinceAug1 + 26.2001
- LM num: 2 **Sep 15 – Oct 9**
- HMtempC = 0.0003 * yearSince1976 - 0.212 * daySinceAug1 + 28.6385
- LM num: 3 **Oct 10 – Nov 10**
- HMtempC = 0.0405 * yearSince1976 - 0.191 * daySinceAug1 + 25.6877
- LM num: 4 **Nov 11 – Dec 31**
- HMtempC = 0.0003 * yearSince1976 - 0.1511 * daySinceAug1 + 21.7777

Digging deeper into HM Temp Trends this Fall

- M5P model tree with four leaf expressions on preceding slides.
- Correlation coefficient 0.8647
- Mean absolute error 3.3489
- Root mean squared error 4.2236

Pearson Correlation Coefficient Does Not Equal Equals!

- >>> from random import randint ; from scipy.stats import pearsonr
- >>> noise = [randint(-100,100) for i in range(0,1000)]
- >>> amplified = [value*100 for value in noise]
- >>> print(noise[0:2], amplified[0:2], len(noise), len(amplified))
- [-88, -81] [-8800, -8100] 1000 1000
- >>> pearsonr(noise,amplified)
- PearsonRResult(statistic=1.0, pvalue=0.0)

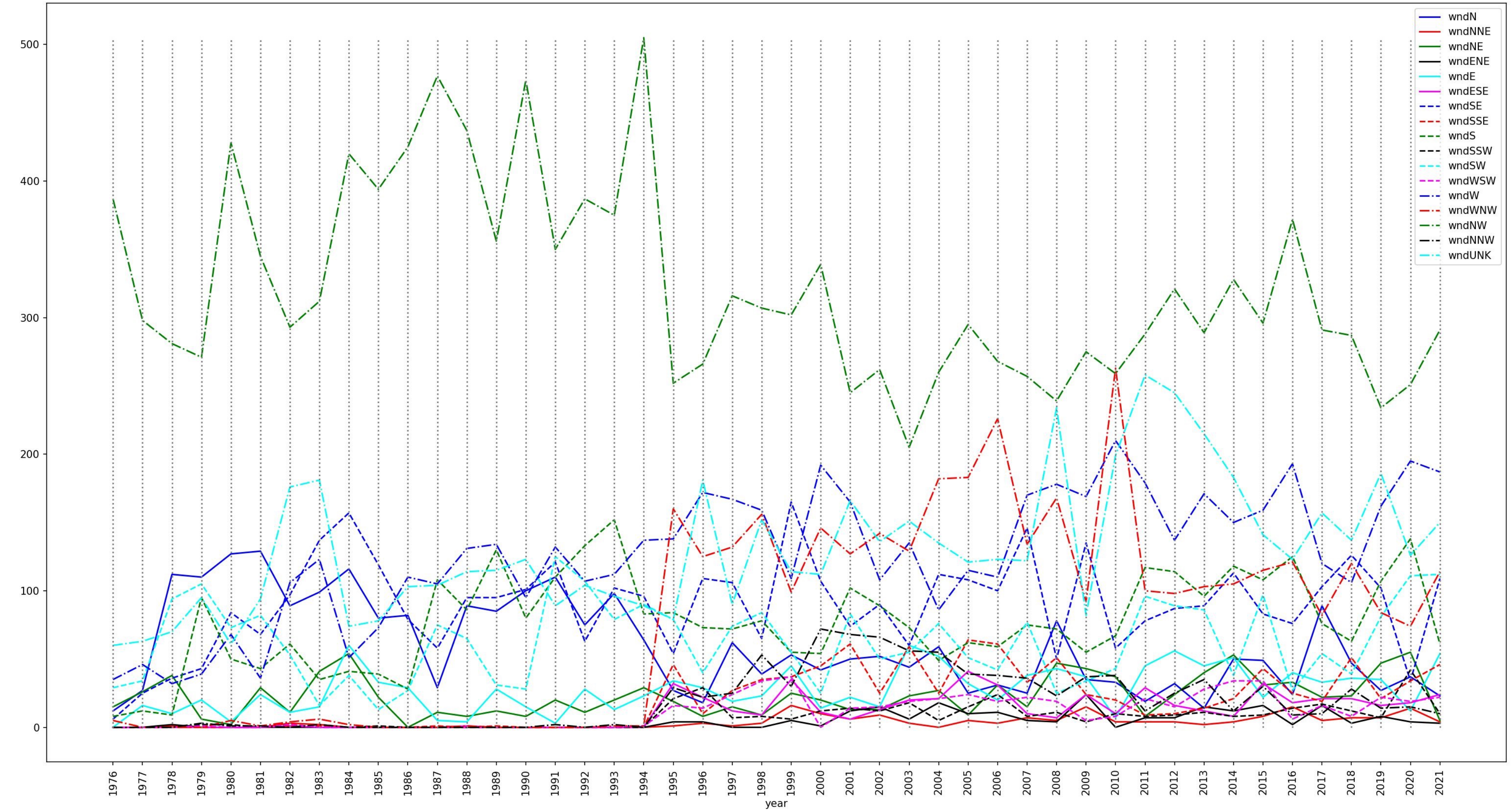
Band Temp Data by (Year,PeriodOf4), Take Mean Temp of Each Band, then Take Mean Year-to-Year Change for Each Band (45 years X 4 bands = 180 Changes)

- **Aug 1 – Sep 14 (Annual change of 0.053 degrees C for mean-per-year)**
  - HMtempC = 0.0003 * yearSince1976 - 0.1335 * daySinceAug1 + 26.2001
- **Sep 15 – Oct 9 (Annual change of 0.091 degrees C for mean-per-year)**
  - HMtempC = 0.0003 * yearSince1976 - 0.212 * daySinceAug1 + 28.6385
- **Oct 10 – Nov 10 (Annual change of 0.174 degrees C for mean-per-year)**
  - HMtempC = 0.0405 * yearSince1976 - 0.191 * daySinceAug1 + 25.6877
- **Nov 11 – Dec 31 (Annual change of 0.04 degrees C for mean-per-year)**
  - HMtempC = 0.0003 * yearSince1976 - 0.1511 * daySinceAug1 + 21.7777
- **.053x45 = 2.385° C : 4.29° F, .091x45 = 4.10° C : 7.4° F,**
- **.174x45 = 7.83° C : 14.1° F, .04x45 = 1.8° C : 3.2° F**

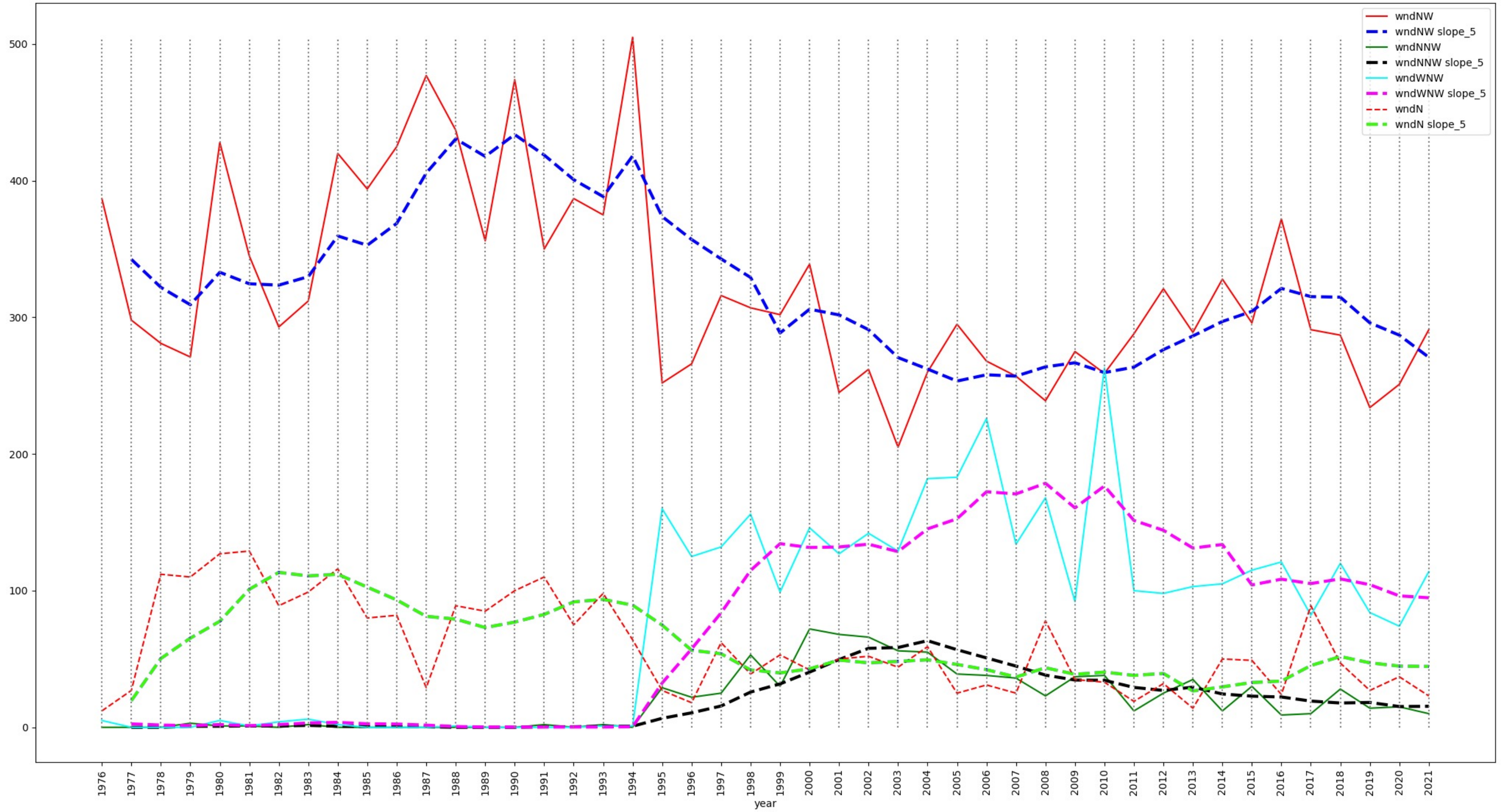
Allentown Airport Data -> Hawk Mountain

- Allentown NOAA data useful in its own right, but …
- Cities suffer from the Heat Island Effect
  - They are warmer overall.
  - They stay warm at night and into winter.
  - https://www.epa.gov/heatislands/learn-about-heat-islands
- Lehigh Valley maintained high pollution levels during COVID stay-at-home 2020-2021.

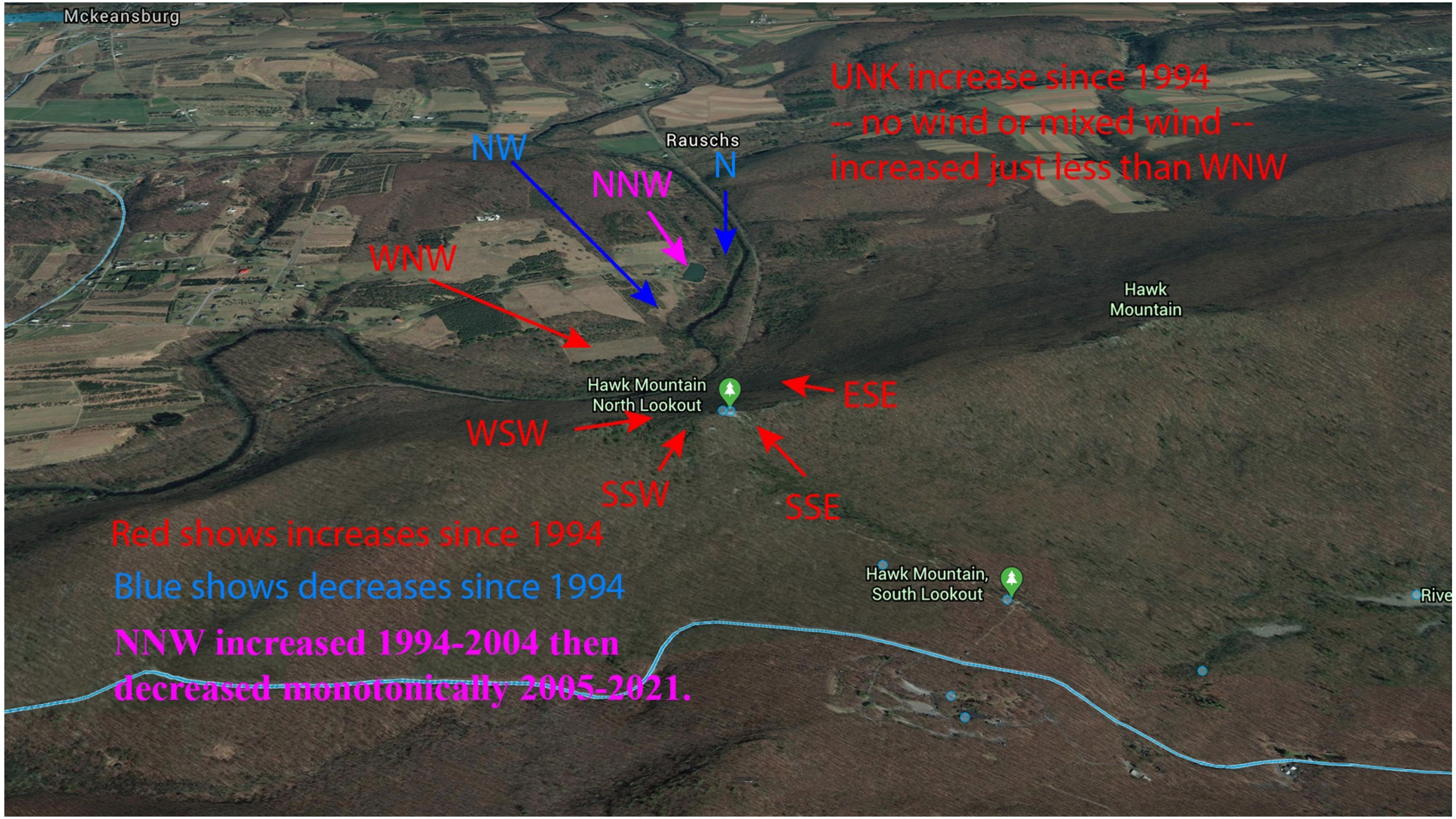
NW has Dissipated, NNW and WNW Wind Counts have Dissipated Wind UNKnown is Growing



NW, NNW , and WNW, N Wind Counts Falling

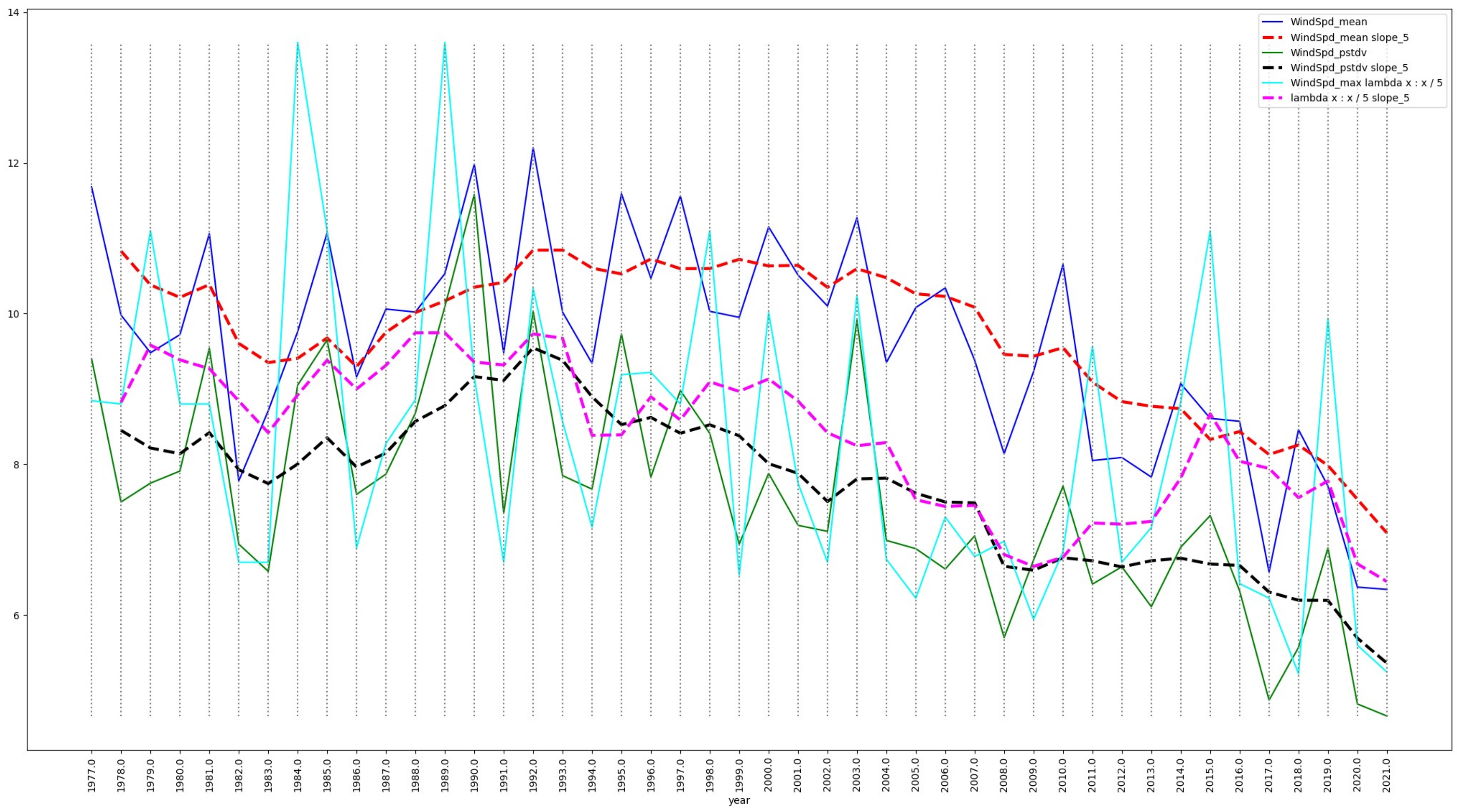


Wind Changes Outpace Temperature Changes



HM Wind Speed Declining Since 2002

Wind Speed Mean, PStdev, Max / 5

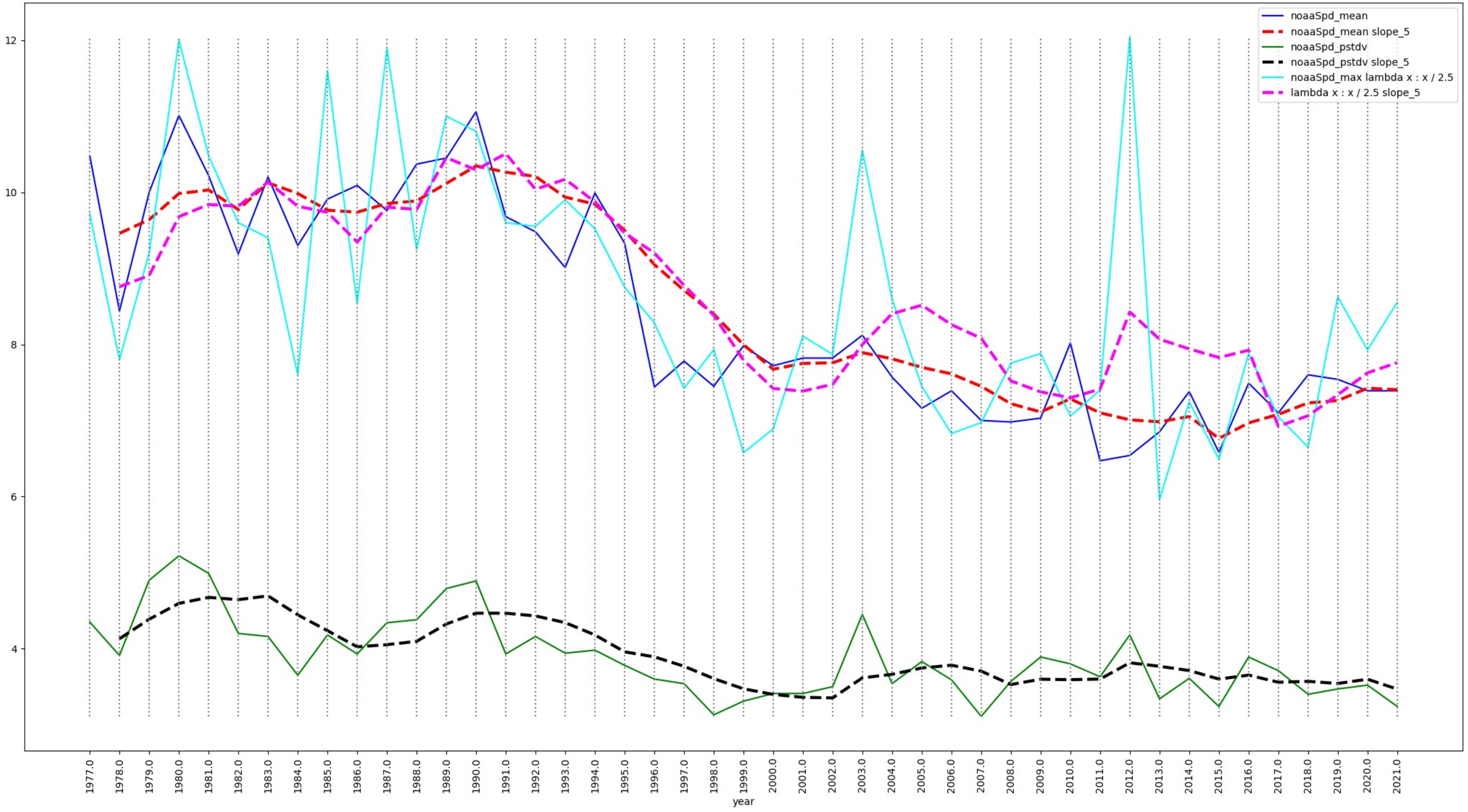


Dr. Goodrich Comments July 18, 2022

- I wonder if we should corroborate this drop off signal with data from National weather service? At least for recent decades?
- To me it is a real signal, as I feel as if wind speed changed this way. But I also know that in recent year, 2015 or after, some counters may be underestimating wind speed
- As they started using a wind gauge that is faulty in my opinion. I will address it this year and maybe have people record wind in two ways so we can assess how much off, it would be only off by maybe 5-10 mph
- Before 2010 or so we always use Beaufort wind scale, which is observer estimated based on tree movements. As rough as this sounds , I feel it does a better job of estimating winds than a hand held gauge that is subject o observer error and friction at ground level, tree blockage etc.

NOAA Allentown Wind Speed Trends

Wind Speed Mean, PStdev, Max / 2.5

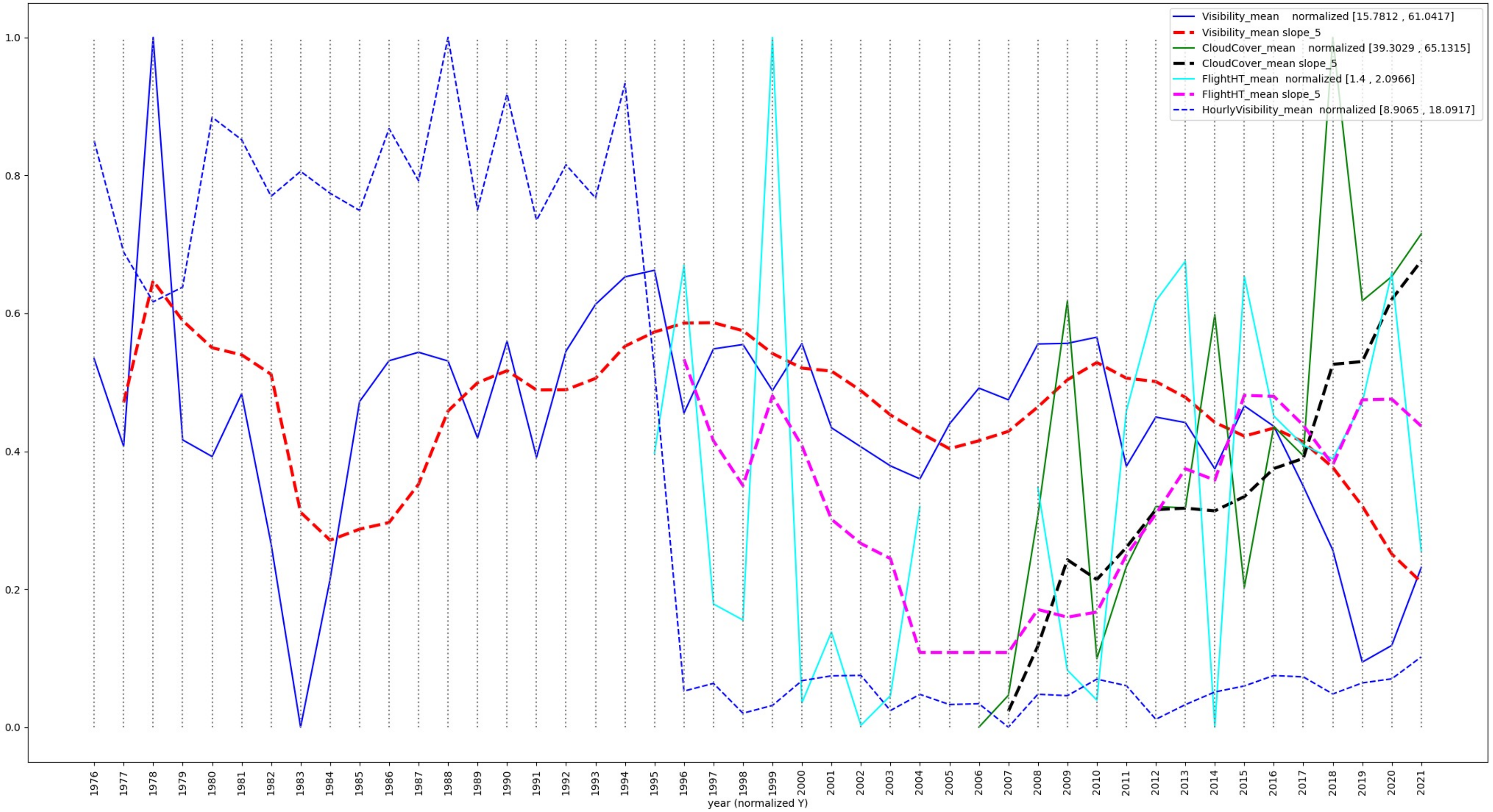


Global and Regional Stilling

- The planet is converging towards fewer distinct climates.
- https://e360.yale.edu/features/global-stilling-is-climate-change-slowing-the-worlds-wind
- “Why do we have wind at all on the planet?” asks Paul Williams, who studies wind as a professor of atmospheric science at the University of Reading in England. “It’s because of uneven temperatures — very cold at the poles and warm at the tropics. That temperature difference drives the winds, and that temperature difference is weakening. The Arctic is warming faster than the tropics.”
- Another recent study found that there will be regional and seasonal variability in winds in the United States as carbon dioxide levels increase: by 2100, wind speeds will decrease over most of the western U.S. and the East Coast, but the central U.S. will see an increase. Several other studies predict similar variability — both regional and seasonal — worldwide.

Other Regional Climate Trends

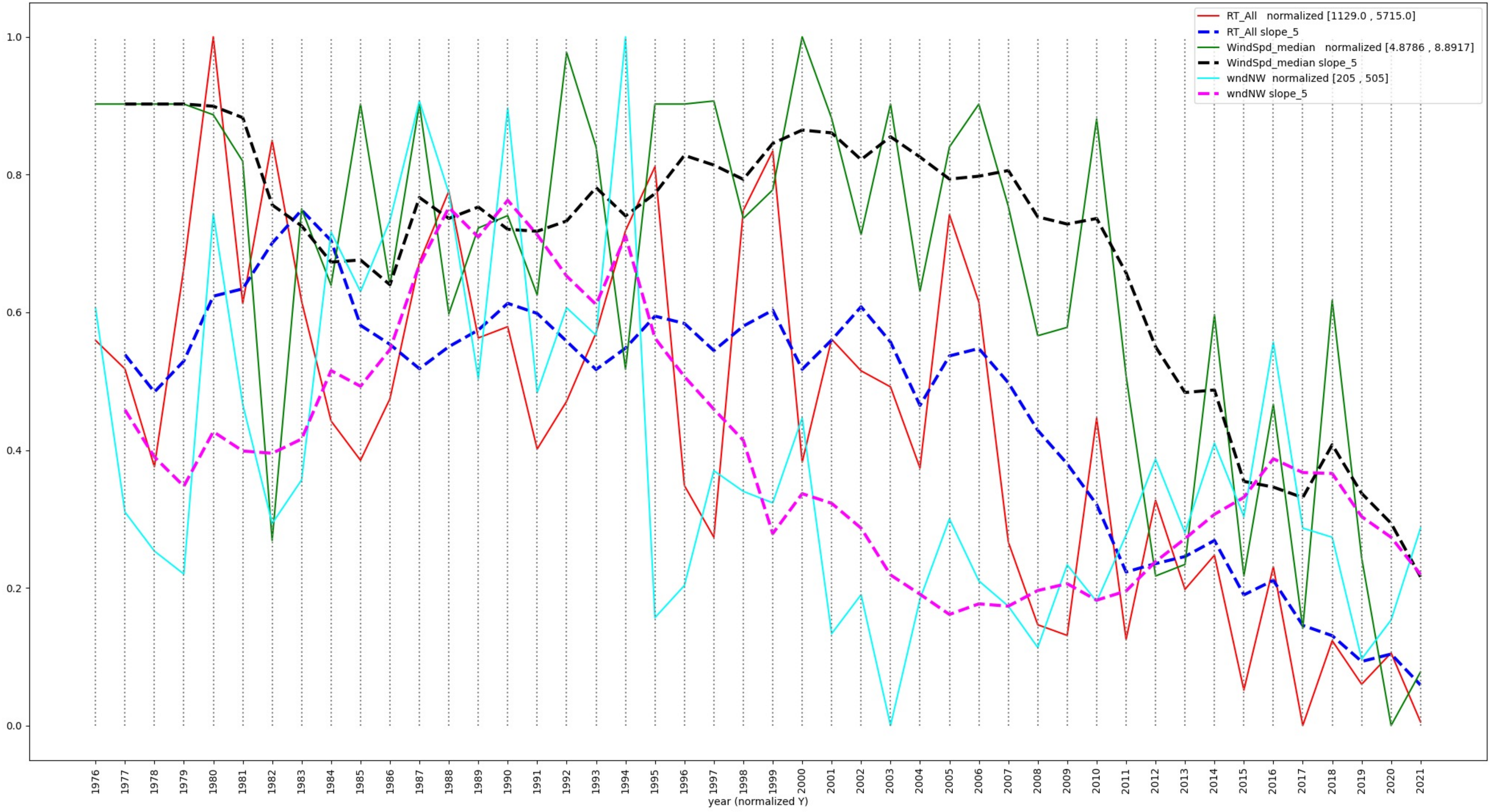
Visibility, Cloud Cover, Flight Height, NOAA Visibility



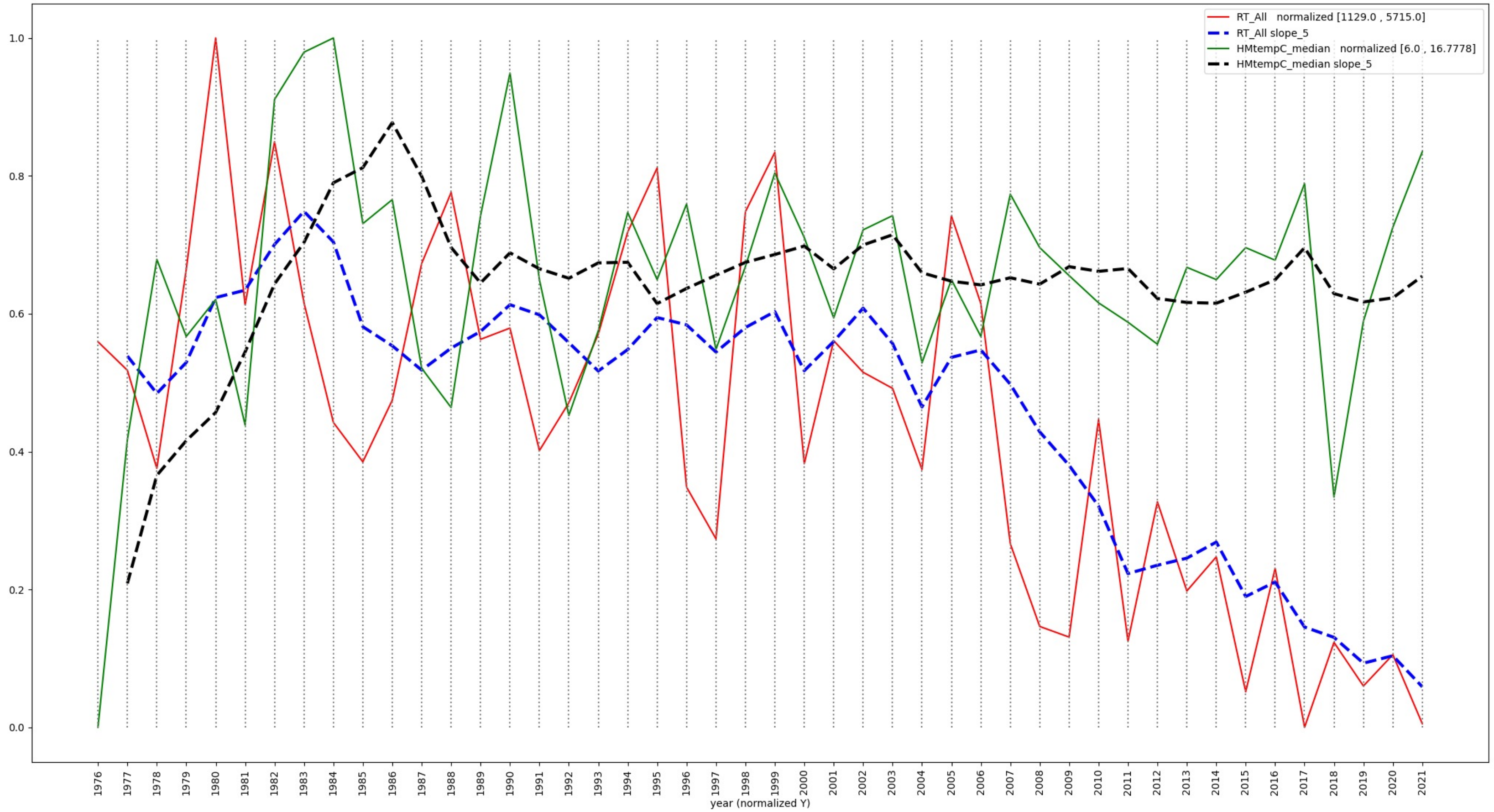
Analysis Stage 2: Climate to Raptor Counts

- Climate -> raptor analyses appear below with links here: Red-Tailed Hawk, Sharp-Shinned Hawk, American Kestrel, Bald Eagle, Golden Eagle, Broad-Winged Hawk, Total Raptors. Follow-up analyses by graduate students during the 2022-2023 academic year include Cooper's Hawk, Osprey, Northern Harrier, Northern Goshawk, and Rough-Legged Hawk.

Red-Tailed Hawks – Declining Slope (blue dashed) Matches **Wind Speed Median** (black), NW is Magenta (xrange [0.0, 1.0])



Red-Tailed Decline Does Not Track **Median Temperature C** as closely. (xrange [0.0, 1.0])



Increasing Cloud Cover Aliases the Year. Increasing TempC does as Well.

- **Simple linear regression** on CloudCover_median
  RT_All = -1453.92 * CloudCover_median + 2721.9,
- Predicting 3778.17 if attribute value is missing.
  Correlation coefficient 0.73
  Mean absolute error 632.78
  Root mean squared error 782.7286

Red Tails and LinearRegression

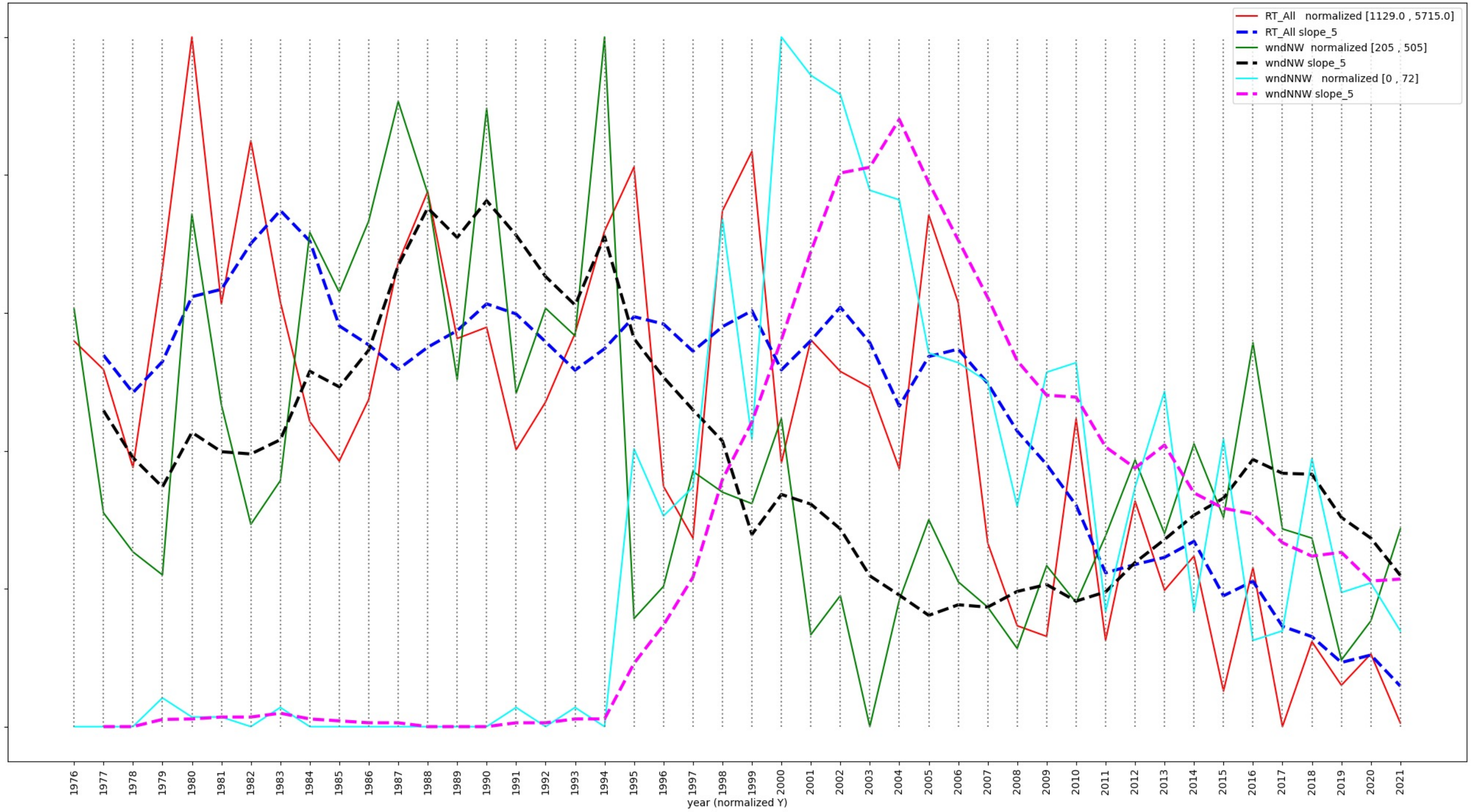
- **Linear Regression Model**
  RT_All =
  -3634.4268 * yearSince1976 +
  2270.8468 * wndWNW +
  1348.4813 * wndNW +
  3778.1611
  Correlation coefficient 0.6668
  Mean absolute error 710.4056
  Root mean squared error 869.1728
- See Figure 9 in this study.

Red Tails and M5P Model Tree

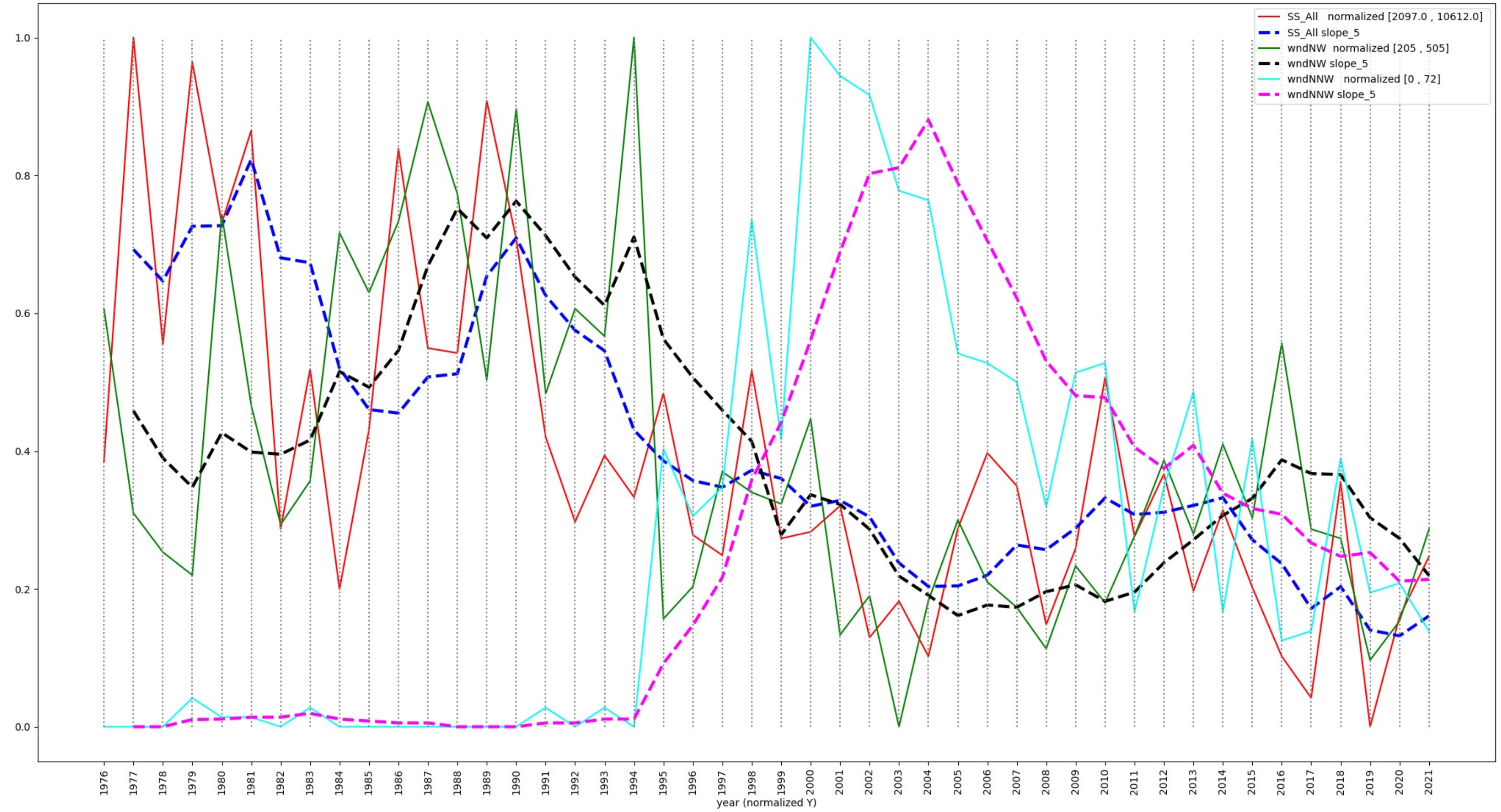
- **M5 pruned model tree:**
  yearSince1976 <= 0.678 : LM1 (31/68.389%)
  yearSince1976 > 0.678 : LM2 (15/36.876%)
  LM num: 1
  RT_All =
  -1211.0951 * yearSince1976
  + 518.7268 * wndWNW
  + 4032.3638
  LM num: 2
  RT_All =
  -1857.0125 * yearSince1976
  + 686.2995 * WindSpd_median
  + 795.381 * wndWNW
  + 2935.1756
  Number of Rules : 2
  Correlation coefficient 0.7106
  Mean absolute error 657.7596
  Root mean squared error 805.8803

  The normalized yearSince1976 value of 0.678 corresponds to the boundary between 2006 and 2007.
- See Figure 9 in this study.

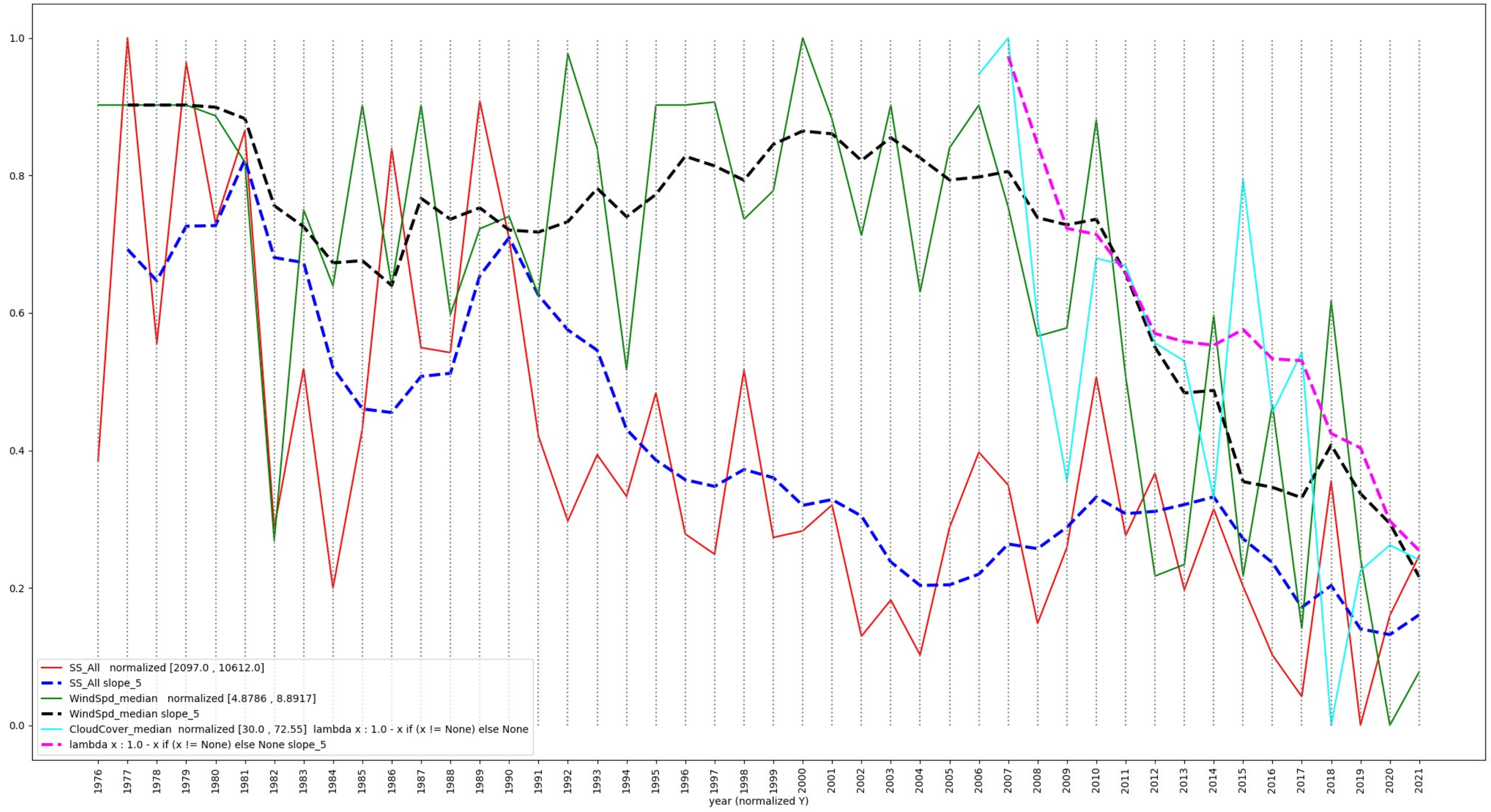
Trends in **wndNW** and wndNNW to Red Tails.
(xrange [0.0, 1.0])



Trends in **wndNW** and wndNNW to Sharp Shins.
(xrange [0.0, 1.0])



Sharp Shins, Wind Speed Median, Inverse Cloud Cover



Linear Models

- **Simple Linear Regression** on wndENE
  SS_All = -4223.09 * wndENE + 6239.8, Predicting 0 if attribute value is missing.
  Correlation coefficient 0.358
  Mean absolute error 1576.7458
  Root mean squared error 1989.6326

  <u>MODEL 25</u>
  Linear Regression Model
  SS_All =
  3924.1695 * WindSpd_median +
  -3321.1986 * wndNNW +
  3708.5498
  Correlation coefficient 0.5636
  Mean absolute error 1410.895
  Root mean squared error 1720.5199

M5P Model Tree

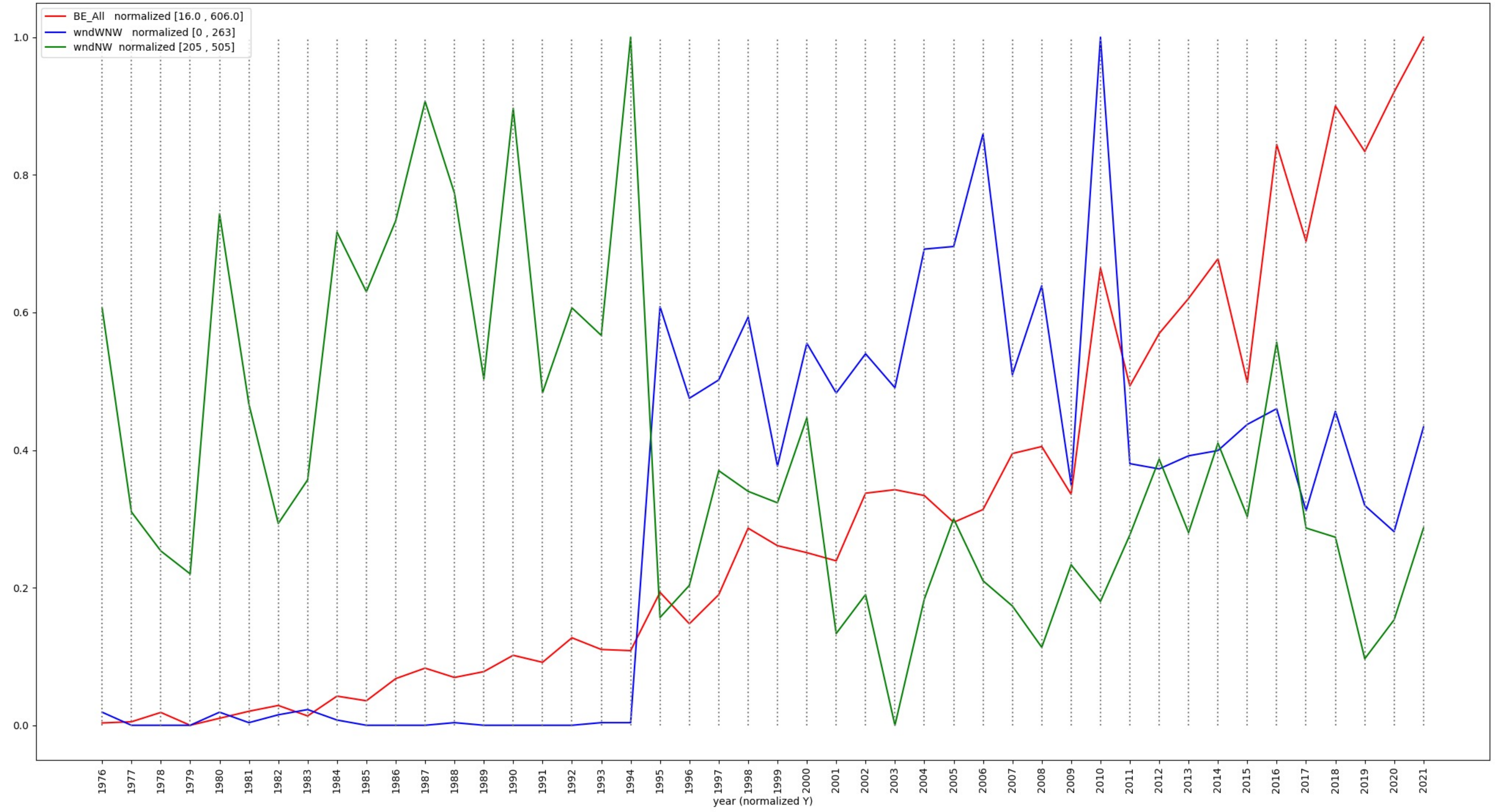
- **M5 pruned model tree**:
  (using smoothed linear models)
  LM1 (46/73.697%)
  LM num: 1
  SS_All =
  2819.8671 * WindSpd_median
  - 1769.7587 * wndENE
  - 2736.3734 * wndWNW
  + 4702.091
  Number of Rules : 1
  Correlation coefficient 0.5656
  Mean absolute error 1408.2835
  Root mean squared error 1717.2739

American Kestrels ☹

- AK_All and related AK attributes do not correlate closely to climate change factors that correlate reasonably well with RT_All and SS_All counts discussed above. Uncovering the causes for declines in AK numbers in North America is an active area of research for raptor biologists. The following quotation is from a November 2020 summary. [19]

  "Thankfully, some researchers are starting to break through the fog after analyzing prior data. The American Kestrel Partnership [20], a project of The Peregrine Fund [21], is one such group of scientists. Now, it believes the key to understanding the kestrel's decline lies in their wintering grounds or during migration."

American Bald Eagles and the DDT Ban ☺
WNW and NW counts. Note some peak/valley alignment.

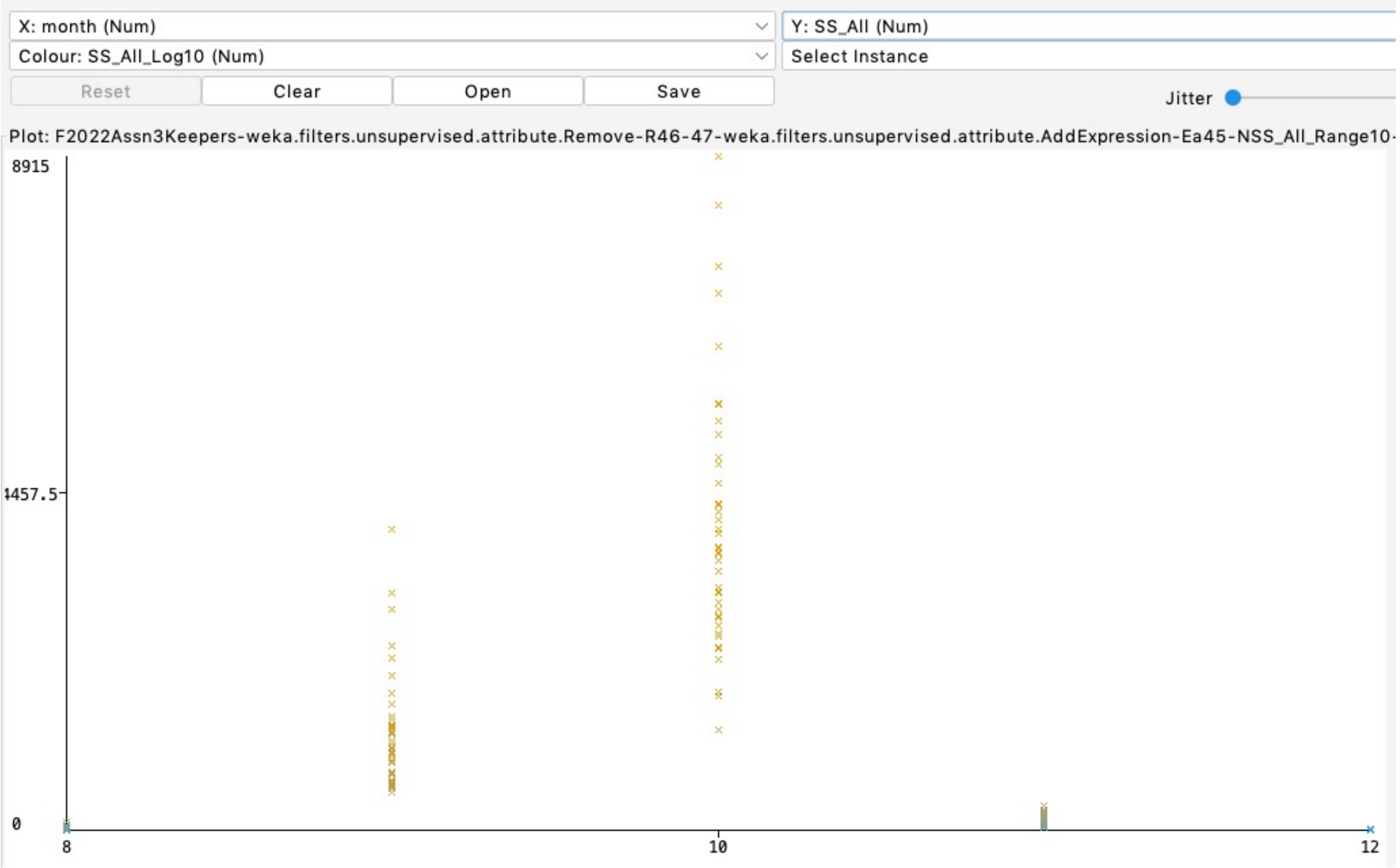


Monthly Sharp Shins Using $\log_{10}$ to compress their range in CSC458 and CSC523 Projects

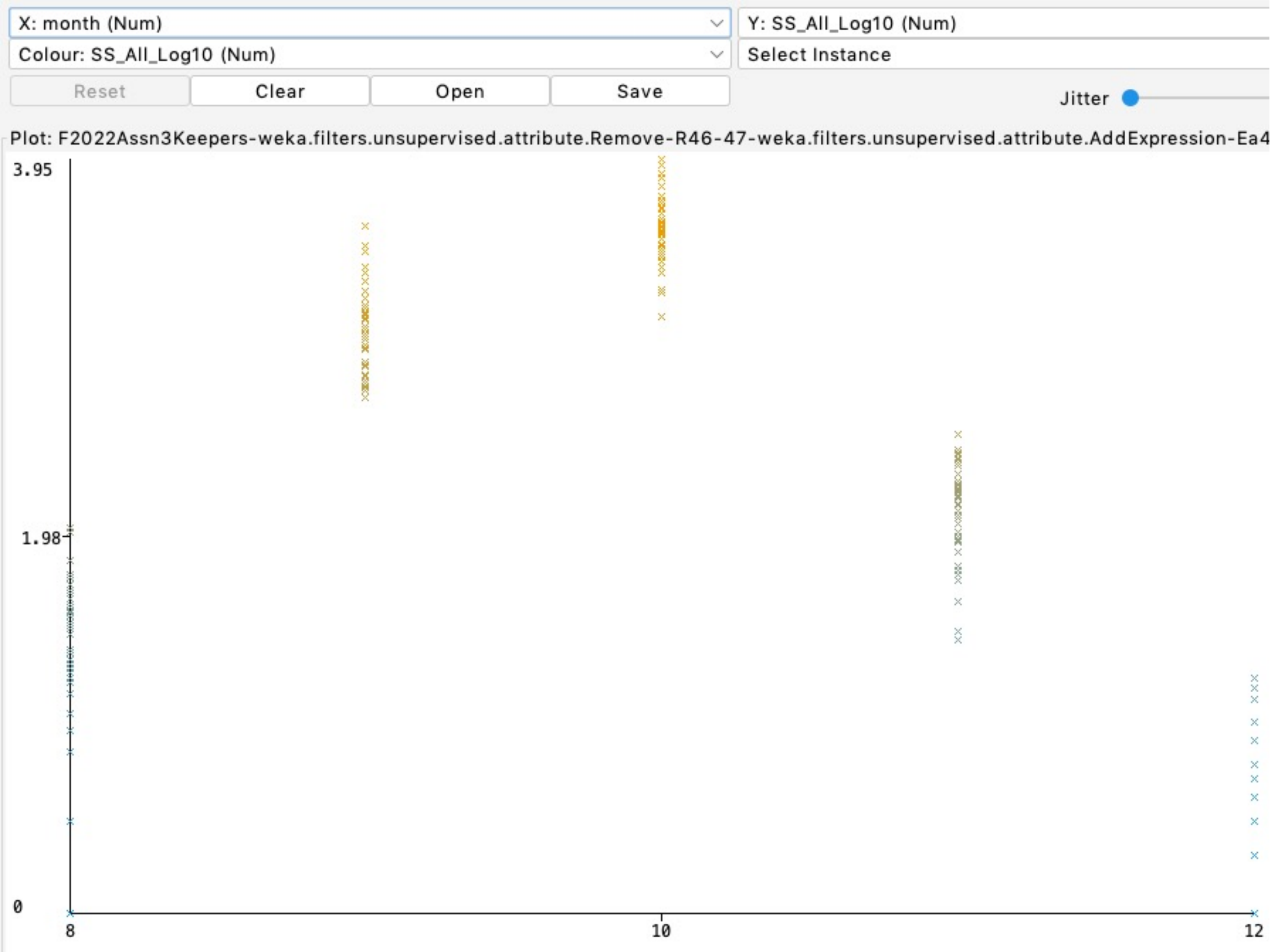
- DATA 6 **Log10Target** REGRESSOR TreeMAE4 TRAIN # 113 TEST # 113 CORR_COEF **0.957048** RMSQERROR 0.347317 MABSERROR 0.257563
- DATA 3 **NumericTarget** REGRESSOR TreeMAE4 TRAIN # 113 TEST # 113 CORR_COEF **0.829190** RMSQERROR 957.847162 MABSERROR 382.690265

- DATA 5 Log10Target REGRESSOR LinReg TRAIN # 113 TEST # 113 CORR_COEF **0.894922** RMSQERROR 0.547910 MABSERROR 0.446600
- DATA 2 NumericTarget REGRESSOR LinReg TRAIN # 113 TEST # 113 CORR_COEF **0.429892** RMSQERROR 1965.833469 MABSERROR 1602.905396

Uncompressed Sharp Shin Counts by Month



Compressed $\log_{10}$ Sharp Shin Counts by Month



Conclusions? More Work to be Done!

- Diminishing wind speeds and NW-NNW-N counts may be reducing the focusing effect of wind->ridge leading to North Lookout.
  - Wintering further north could be a factor for some species.
  - Ideally, we would have high-quality counts to the north and south.
- Graduate student analysis funded through spring 2023.
  - Follow-up analyses by graduate students during the 2022-2023 academic year include Cooper's Hawk, Osprey, Northern Harrier, Northern Goshawk, and Rough-Legged Hawk.
- Undergraduate web-based migration visualization through spring.
  - https://youtu.be/uR3bIhE9uL8
- CSC458 Analytics I and CSC523 Scripting for Data Science in fall and CSC558 Analytics in spring uncover new patterns, e.g., peaks and valleys in climate-raptor correlations, observation period discontinuities in temperature.
- My summary report due end of summer 2023. Probably some papers.

Following Added 12/31/2022

- The posted study discusses rising and falling slope correlations in normalized annual raptor totals and normalized climate aspects, mostly wind counts. Normalization maps [min, max] for each count or value to [0.0, 1/0], and fine slope varies in the range [-4,4] per Figure 1.
- https://acad.kutztown.edu/~parson/HawkMtnDaleParson2022/
- This was the basis for CSC458 Assignment 1 which I extended this week.
- https://faculty.kutztown.edu/parson/fall2022/CSC458Spring2022Assn1.html
- https://docs.scipy.org/doc/scipy-0.14.0/reference/generated/scipy.stats.spearmanr.html

Bald Eagle Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (0.684, 'BE_All_FineNum', 'WindSpd_median_FineNum'),
- (0.506, 'BE_All_FineNum', 'wndWNW_FineNum'),
- (0.388, 'BE_All_FineNum', 'wndNW_FineNum'),
- (0.367, 'BE_All_FineNum', 'wndW_FineNum'),
- (0.233, 'BE_All_FineNum', 'wndNE_FineNum'),
- (0.15, 'BE_All_FineNum', 'wndSSW_FineNum'),
- (0.084, 'BE_All_FineNum', 'wndS_FineNum'),
- (0.038, 'BE_All_FineNum', 'wndE_FineNum'),

Bald Eagle Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (-0.013, 'BE_All_FineNum', 'wndSSE_FineNum'),
- (-0.032, 'BE_All_FineNum', 'wndUNK_FineNum'),
- (-0.053, 'BE_All_FineNum', 'wndNNW_FineNum'),
- (-0.132, 'BE_All_FineNum', 'wndSE_FineNum'),
- (-0.241, 'BE_All_FineNum', 'HMtempC_median_FineNum'),
- (-0.275, 'BE_All_FineNum', 'wndN_FineNum'),
- (-0.477, 'BE_All_FineNum', 'wndWSW_FineNum'),
- (-0.487, 'BE_All_FineNum', 'wndESE_FineNum'),
- (-0.519, 'BE_All_FineNum', 'wndSW_FineNum'),
- (-0.657, 'BE_All_FineNum', 'wndENE_FineNum')

Rough Legged Hawk Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (0.608, 'RL_All_FineNum', 'wndE_FineNum'),
- (0.438, 'RL_All_FineNum', 'wndWSW_FineNum'),
- (0.31, 'RL_All_FineNum', 'wndSW_FineNum'),
- (0.281, 'RL_All_FineNum', 'wndN_FineNum'),
- (0.141, 'RL_All_FineNum', 'wndUNK_FineNum'),
- (0.104, 'RL_All_FineNum', 'wndS_FineNum'),
- (0.059, 'RL_All_FineNum', 'wndSE_FineNum'),
- (0.058, 'RL_All_FineNum', 'HMtempC_median_FineNum'),

Rough Legged Hawk Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (-0.016, 'RL_All_FineNum', 'wndW_FineNum'),
- (-0.024, 'RL_All_FineNum', 'wndNE_FineNum'),
- (-0.056, 'RL_All_FineNum', 'wndSSE_FineNum'),
- (-0.088, 'RL_All_FineNum', 'wndESE_FineNum'),
- (-0.101, 'RL_All_FineNum', 'wndNNE_FineNum'),
- (-0.147, 'RL_All_FineNum', 'wndENE_FineNum'),
- (-0.201, 'RL_All_FineNum', 'WindSpd_median_FineNum'),
- (-0.211, 'RL_All_FineNum', 'wndWNW_FineNum'),
- (-0.25, 'RL_All_FineNum', 'wndNNW_FineNum'),
- (-0.267, 'RL_All_FineNum', 'wndSSW_FineNum'),

Sharp Shinned Hawk Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (0.557, 'SS_All_FineNum', 'WindSpd_median_FineNum'),
- (0.338, 'SS_All_FineNum', 'wndSSE_FineNum'),
- (0.299, 'SS_All_FineNum', 'wndWNW_FineNum'),
- (0.277, 'SS_All_FineNum', 'wndNW_FineNum'),
- (0.177, 'SS_All_FineNum', 'wndNNW_FineNum'),
- (0.173, 'SS_All_FineNum', 'wndSSW_FineNum'),
- (0.158, 'SS_All_FineNum', 'wndSE_FineNum'),
- (0.067, 'SS_All_FineNum', 'wndNNE_FineNum'),

Sharp Shinned Hawk Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (-0.011, 'SS_All_FineNum', 'wndW_FineNum'),
- (-0.038, 'SS_All_FineNum', 'wndESE_FineNum'),
- (-0.06, 'SS_All_FineNum', 'wndN_FineNum'),
- (-0.071, 'SS_All_FineNum', 'wndNE_FineNum'),
- (-0.131, 'SS_All_FineNum', 'wndSW_FineNum'),
- (-0.16, 'SS_All_FineNum', 'wndS_FineNum'),
- (-0.269, 'SS_All_FineNum', 'wndE_FineNum'),
- (-0.282, 'SS_All_FineNum', 'wndUNK_FineNum'),
- (-0.284, 'SS_All_FineNum', 'HMtempC_median_FineNum'),
- (-0.341, 'SS_All_FineNum', 'wndWSW_FineNum'),
- (-0.361, 'SS_All_FineNum', 'wndENE_FineNum')]

Cooper’s Hawk Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (0.54, 'CH_All_FineNum', 'wndSSE_FineNum'),
- (0.506, 'CH_All_FineNum', 'WindSpd_median_FineNum'),
- (0.322, 'CH_All_FineNum', 'wndSSW_FineNum'),
- (0.186, 'CH_All_FineNum', 'wndNW_FineNum'),
- (0.14, 'CH_All_FineNum', 'wndWNW_FineNum'),
- (0.057, 'CH_All_FineNum', 'wndNNE_FineNum'),
- (0.044, 'CH_All_FineNum', 'wndESE_FineNum'),
- (0.011, 'CH_All_FineNum', 'wndS_FineNum'),
- (0.002, 'CH_All_FineNum', 'wndW_FineNum'),

Cooper’s Hawk Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (-0.072, 'CH_All_FineNum', 'wndSE_FineNum'),
- (-0.075, 'CH_All_FineNum', 'wndWSW_FineNum'),
- (-0.084, 'CH_All_FineNum', 'wndUNK_FineNum'),
- (-0.087, 'CH_All_FineNum', 'wndSW_FineNum'),
- (-0.098, 'CH_All_FineNum', 'wndNNW_FineNum'),
- (-0.105, 'CH_All_FineNum', 'wndN_FineNum'),
- (-0.194, 'CH_All_FineNum', 'wndNE_FineNum'),
- (-0.208, 'CH_All_FineNum', 'HMtempC_median_FineNum'),
- (-0.422, 'CH_All_FineNum', 'wndENE_FineNum')

Golden Eagle Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (0.506, 'GE_All_FineNum', 'WindSpd_median_FineNum'),
- (0.5, 'GE_All_FineNum', 'wndWNW_FineNum'),
- (0.474, 'GE_All_FineNum', 'wndSSE_FineNum'),
- (0.468, 'GE_All_FineNum', 'wndSSW_FineNum'),
- (0.203, 'GE_All_FineNum', 'wndNE_FineNum'),
- (0.107, 'GE_All_FineNum', 'wndUNK_FineNum'),
- (0.102, 'GE_All_FineNum', 'wndE_FineNum'),
- (0.021, 'GE_All_FineNum', 'wndW_FineNum'),
- (0.009, 'GE_All_FineNum', 'wndESE_FineNum'),

Golden Eagle Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (-0.006, 'GE_All_FineNum', 'wndNW_FineNum'),
- (-0.069, 'GE_All_FineNum', 'wndN_FineNum'),
- (-0.095, 'GE_All_FineNum', 'wndS_FineNum'),
- (-0.106, 'GE_All_FineNum', 'HMtempC_median_FineNum'),
- (-0.136, 'GE_All_FineNum', 'wndNNW_FineNum'),
- (-0.148, 'GE_All_FineNum', 'wndWSW_FineNum'),
- (-0.249, 'GE_All_FineNum', 'wndNNE_FineNum'),
- (-0.304, 'GE_All_FineNum', 'wndSE_FineNum'),
- (-0.384, 'GE_All_FineNum', 'wndSW_FineNum'),
- (-0.559, 'GE_All_FineNum', 'wndENE_FineNum')

Northern Harrier Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (0.415, 'NH_All_FineNum', 'wndSSE_FineNum'),
- (0.289, 'NH_All_FineNum', 'wndSW_FineNum'),
- (0.282, 'NH_All_FineNum', 'WindSpd_median_FineNum'),
- (0.265, 'NH_All_FineNum', 'wndS_FineNum'),
- (0.26, 'NH_All_FineNum', 'wndE_FineNum'),
- (0.22, 'NH_All_FineNum', 'wndWSW_FineNum'),
- (0.197, 'NH_All_FineNum', 'wndSSW_FineNum'),
- (0.063, 'NH_All_FineNum', 'wndNNE_FineNum'),
- (0.046, 'NH_All_FineNum', 'wndNE_FineNum'),
- (0.016, 'NH_All_FineNum', 'wndESE_FineNum'),
- (0.006, 'NH_All_FineNum', 'wndW_FineNum'),

Northern Harrier Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (-0.025, 'NH_All_FineNum', 'wndSE_FineNum'),
- (-0.114, 'NH_All_FineNum', 'wndWNW_FineNum'),
- (-0.133, 'NH_All_FineNum', 'wndN_FineNum'),
- (-0.137, 'NH_All_FineNum', 'wndNNW_FineNum'),
- (-0.184, 'NH_All_FineNum', 'wndUNK_FineNum'),
- (-0.188, 'NH_All_FineNum', 'HMtempC_median_FineNum'),
- (-0.216, 'NH_All_FineNum', 'wndENE_FineNum'),
- (-0.302, 'NH_All_FineNum', 'wndNW_FineNum')

Red-tailed Hawk Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (0.398, 'RT_All_FineNum', 'WindSpd_median_FineNum'),
- (0.284, 'RT_All_FineNum', 'wndSSW_FineNum'),
- (0.224, 'RT_All_FineNum', 'wndSSE_FineNum'),
- (0.171, 'RT_All_FineNum', 'wndNNE_FineNum'),
- (0.149, 'RT_All_FineNum', 'wndS_FineNum'),
- (0.144, 'RT_All_FineNum', 'wndWNW_FineNum'),
- (0.13, 'RT_All_FineNum', 'wndNW_FineNum'),
- (0.108, 'RT_All_FineNum', 'wndNE_FineNum'),
- (0.009, 'RT_All_FineNum', 'wndW_FineNum'),

Red-tailed Hawk Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (-0.045, 'RT_All_FineNum', 'wndE_FineNum'),
- (-0.051, 'RT_All_FineNum', 'wndESE_FineNum'),
- (-0.068, 'RT_All_FineNum', 'wndUNK_FineNum'),
- (-0.137, 'RT_All_FineNum', 'wndWSW_FineNum'),
- (-0.143, 'RT_All_FineNum', 'wndNNW_FineNum'),
- (-0.161, 'RT_All_FineNum', 'HMtempC_median_FineNum'),
- (-0.194, 'RT_All_FineNum', 'wndSE_FineNum'),
- (-0.229, 'RT_All_FineNum', 'wndN_FineNum'),
- (-0.236, 'RT_All_FineNum', 'wndSW_FineNum'),
- (-0.394, 'RT_All_FineNum', 'wndENE_FineNum')

Total Raptors Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (0.396, 'TOTAL_FineNum', 'wndNW_FineNum'),
- (0.357, 'TOTAL_FineNum', 'wndSE_FineNum'),
- (0.352, 'TOTAL_FineNum', 'WindSpd_median_FineNum'),
- (0.21, 'TOTAL_FineNum', 'wndESE_FineNum'),
- (0.169, 'TOTAL_FineNum', 'wndWNW_FineNum'),
- (0.125, 'TOTAL_FineNum', 'wndSSW_FineNum'),
- (0.087, 'TOTAL_FineNum', 'wndNNE_FineNum'),

Total Raptors Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (-0.021, 'TOTAL_FineNum', 'HMtempC_median_FineNum'),
- (-0.036, 'TOTAL_FineNum', 'wndUNK_FineNum'),
- (-0.074, 'TOTAL_FineNum', 'wndENE_FineNum'),
- (-0.113, 'TOTAL_FineNum', 'wndS_FineNum'),
- (-0.122, 'TOTAL_FineNum', 'wndE_FineNum'),
- (-0.201, 'TOTAL_FineNum', 'wndSSE_FineNum'),
- (-0.211, 'TOTAL_FineNum', 'wndNNW_FineNum'),
- (-0.26, 'TOTAL_FineNum', 'wndW_FineNum'),
- (-0.274, 'TOTAL_FineNum', 'wndWSW_FineNum'),
- (-0.278, 'TOTAL_FineNum', 'wndSW_FineNum'),
- (-0.326, 'TOTAL_FineNum', 'wndN_FineNum'),
- (-0.343, 'TOTAL_FineNum', 'wndNE_FineNum')]

American Kestrel Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (0.348, 'AK_All_FineNum', 'wndNNE_FineNum'),
- (0.346, 'AK_All_FineNum', 'wndSE_FineNum'),
- (0.332, 'AK_All_FineNum', 'wndNW_FineNum'),
- (0.287, 'AK_All_FineNum', 'WindSpd_median_FineNum'),
- (0.199, 'AK_All_FineNum', 'wndNNW_FineNum'),
- (0.047, 'AK_All_FineNum', 'wndSSE_FineNum'),
- (0.034, 'AK_All_FineNum', 'wndWNW_FineNum'),
- (0.013, 'AK_All_FineNum', 'wndSW_FineNum'),

American Kestrel Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (-0.04, 'AK_All_FineNum', 'wndW_FineNum'),
- (-0.066, 'AK_All_FineNum', 'wndSSW_FineNum'),
- (-0.082, 'AK_All_FineNum', 'wndS_FineNum'),
- (-0.087, 'AK_All_FineNum', 'wndESE_FineNum'),
- (-0.088, 'AK_All_FineNum', 'wndE_FineNum'),
- (-0.164, 'AK_All_FineNum', 'HMtempC_median_FineNum'),
- (-0.166, 'AK_All_FineNum', 'wndN_FineNum'),
- (-0.213, 'AK_All_FineNum', 'wndNE_FineNum'),
- (-0.296, 'AK_All_FineNum', 'wndUNK_FineNum'),
- (-0.313, 'AK_All_FineNum', 'wndENE_FineNum'),
- (-0.423, 'AK_All_FineNum', 'wndWSW_FineNum')

Northern Goshawk Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (0.345, 'NG_All_FineNum', 'wndE_FineNum'),
- (0.276, 'NG_All_FineNum', 'wndS_FineNum'),
- (0.272, 'NG_All_FineNum', 'wndW_FineNum'),
- (0.269, 'NG_All_FineNum', 'wndSSE_FineNum'),
- (0.229, 'NG_All_FineNum', 'WindSpd_median_FineNum'),
- (0.197, 'NG_All_FineNum', 'wndSW_FineNum'),
- (0.182, 'NG_All_FineNum', 'wndNNE_FineNum'),
- (0.12, 'NG_All_FineNum', 'wndUNK_FineNum'),
- (0.085, 'NG_All_FineNum', 'wndSSW_FineNum'),
- (0.025, 'NG_All_FineNum', 'wndNW_FineNum'),

Northern Goshawk Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (-0.002, 'NG_All_FineNum', 'wndWSW_FineNum'),
- (-0.099, 'NG_All_FineNum', 'wndSE_FineNum'),
- (-0.109, 'NG_All_FineNum', 'HMtempC_median_FineNum'),
- (-0.136, 'NG_All_FineNum', 'wndWNW_FineNum'),
- (-0.179, 'NG_All_FineNum', 'wndESE_FineNum'),
- (-0.183, 'NG_All_FineNum', 'wndN_FineNum'),
- (-0.193, 'NG_All_FineNum', 'wndNNW_FineNum'),
- (-0.205, 'NG_All_FineNum', 'wndNE_FineNum'),
- (-0.457, 'NG_All_FineNum', 'wndENE_FineNum')]

Broad Wing Hawk Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (0.279, 'BW_All_FineNum', 'wndSE_FineNum'),
- (0.228, 'BW_All_FineNum', 'wndESE_FineNum'),
- (0.184, 'BW_All_FineNum', 'wndNW_FineNum'),
- (0.164, 'BW_All_FineNum', 'wndENE_FineNum'),
- (0.099, 'BW_All_FineNum', 'HMtempC_median_FineNum'),
- (0.066, 'BW_All_FineNum', 'wndS_FineNum'),
- (0.064, 'BW_All_FineNum', 'WindSpd_median_FineNum'),
- (0.061, 'BW_All_FineNum', 'wndSSW_FineNum'),
- (0.06, 'BW_All_FineNum', 'wndWNW_FineNum'),
- (0.017, 'BW_All_FineNum', 'wndNNE_FineNum'),

Broad Wing Hawk Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (-0.055, 'BW_All_FineNum', 'wndUNK_FineNum'),
- (-0.07, 'BW_All_FineNum', 'wndE_FineNum'),
- (-0.075, 'BW_All_FineNum', 'wndWSW_FineNum'),
- (-0.143, 'BW_All_FineNum', 'wndSW_FineNum'),
- (-0.145, 'BW_All_FineNum', 'wndNNW_FineNum'),
- (-0.254, 'BW_All_FineNum', 'wndW_FineNum'),
- (-0.303, 'BW_All_FineNum', 'wndNE_FineNum'),
- (-0.335, 'BW_All_FineNum', 'wndSSE_FineNum'),
- (-0.363, 'BW_All_FineNum', 'wndN_FineNum')

Osprey Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (0.217, 'OS_All_FineNum', 'wndN_FineNum'),
- (0.214, 'OS_All_FineNum', 'wndWNW_FineNum'),
- (0.173, 'OS_All_FineNum', 'WindSpd_median_FineNum'),
- (0.165, 'OS_All_FineNum', 'wndNE_FineNum'),
- (0.161, 'OS_All_FineNum', 'wndS_FineNum'),
- (0.131, 'OS_All_FineNum', 'wndE_FineNum'),
- (0.095, 'OS_All_FineNum', 'wndSE_FineNum'),
- (0.064, 'OS_All_FineNum', 'wndNW_FineNum'),
- (0.016, 'OS_All_FineNum', 'wndSSW_FineNum'),
- (0.002, 'OS_All_FineNum', 'wndSW_FineNum'),

Osprey Peak / Valley Correlations for Normalized Slopes 2000 - 2021

- (-0.024, 'OS_All_FineNum', 'wndNNW_FineNum'),
- (-0.043, 'OS_All_FineNum', 'wndUNK_FineNum'),
- (-0.073, 'OS_All_FineNum', 'wndNNE_FineNum'),
- (-0.151, 'OS_All_FineNum', 'wndWSW_FineNum'),
- (-0.182, 'OS_All_FineNum', 'wndENE_FineNum'),
- (-0.216, 'OS_All_FineNum', 'HMtempC_median_FineNum'),
- (-0.223, 'OS_All_FineNum', 'wndSSE_FineNum'),
- (-0.237, 'OS_All_FineNum', 'wndW_FineNum'),
- (-0.344, 'OS_All_FineNum', 'wndESE_FineNum')