HISTORICAL WEATHER AND CLIMATE EXTREMES FOR NEW YORK

Judith Curry and Roger Caiazza
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Summary

This report is aimed at assessing the robustness of the NYISO strategy to use 5 recent years of historical weather data to assess the robustness of an all-renewables power generation system. A survey of publicly available reports (e.g. NOAA and SUNY-Albany) was used to assess:

- Annual winter and summer temperatures since 1900
- Annual numbers of very hot days, very hot nights and very cold nights since 1900
- Summary of temperature extremes for the state, Central Park and Syracuse (all time high and low temperatures, # of days/year exceeding 90^{o}F, and lengths of cold and hot streaks (days).
- Number of temperature records set for NYC per decade since 1900
- Years with clustered heat waves
- Statistics on duration of heat and cold waves for Albany since 1874

Substantial variability in seasonal temperatures and occurrence of temperature extremes is seen on interannual, decadal, and multidecadal time scales. The underlying warming trend since 1900 has a relatively small impact on the temperature extremes. The most recent 5 year period does not capture the most extreme temperature events that have been observed in the historical records.

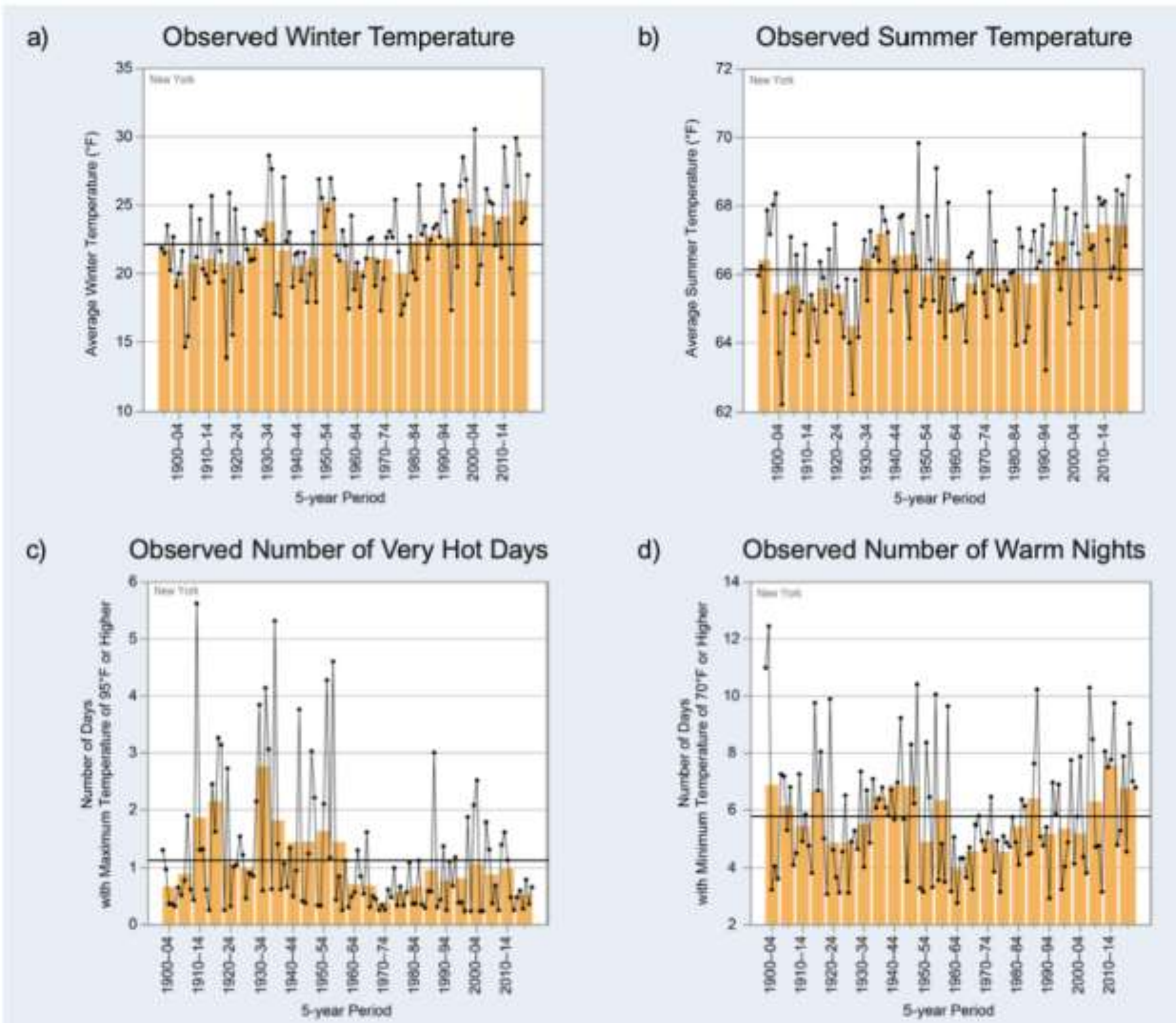
We recommend the following analyses to assess the vulnerability of a renewable power generation system to heat/cold extremes and wind/solar power droughts:

- Assembly of relevant historical data sets and gridded analyses
- Assess the frequency, return time and clustering of heat and cold wave events of different durations.
- Prepare stress test cases for the NYISO MARS model, to evaluate system performance under extreme conditions, beyond the 5-year period that was tested.
- Evaluate the spatial correlations of wind energy production between NY, PJM, IESO, NEISO, Quebec and relevant offshore regions.

DECADAL CLIMATE VARIABILITY AND CHANGE

Surface temperatures in NY have risen almost 2.5°C since 1900. However, this slow increase does not dominate climate extremes in the state over the past century. There is large interannual, decadal and multi-decadal variability associated with natural processes that influence climate variability.

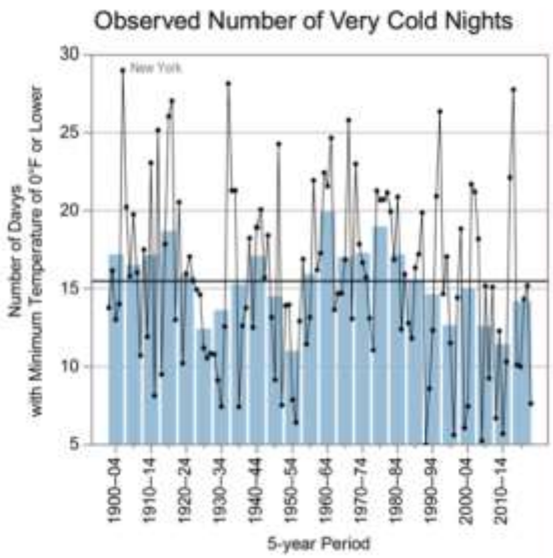
During the 1930's and 1950's, there were individual years and decades with temperatures comparable to the most recent decade. The number of very hot days ≥95°F was substantially greater in the first half of the 20th century, with a comparable number of very hot nights.

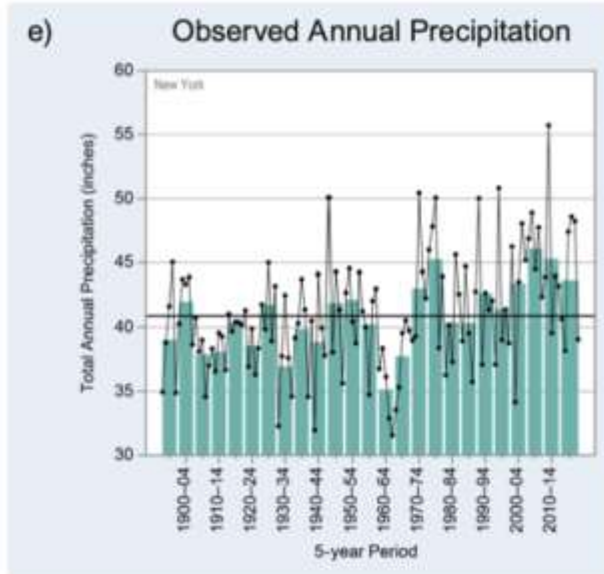


From NOAA: https://statesummaries.ncics.org/chapter/ny/

There is a trend of decreasing numbers of very cold nights since the high number ~1960, with below average numbers since the 1990's. However, comparable low numbers of very cold nights were observed in the 1920s, 1940s and early 1950s.

The most striking feature of the historical precipitation record is the severe drought during the 1960s.





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New York Historical Temperature Extremes

State

All time high: Troy	108°F	7/22 1926
All time low: Old Forge	-52°F	2/18 1979

Syracuse 1922-2023 (retrieved 3/10/23)*

All time high:	102°F	7/9 1936
All time low:	-26°F	2/18 1979
#days/yr ≥90°F:	28 days	1955
High temp streak ≤32°F:	32 days	1/30 – 3/2 2015
High temp streak ≥90°F:	8 days	8/24 – 9/4 1953
High temp streak ≥100°F:	3 days	7/8 – 7/10 1936

*https://www.extremeweatherwatch.com/cities/syracuse

NYC Central Park 1869-2023 (retrieved 3/10/23)*

All time high:	106°F	7/9 1936
All time low:	-15°F	2/9 1934
#days/yr ≥90°F	39 days	1991, 1993
High temp streak ≤32°F:	16 days	1/19 – 2/3 1961
High temp streak ≥90°F:	12 days	8/24 – 9/4 1953
High temp streak ≥100°F:	3 days	7/8 – 7/10 1993

*https://www.extremeweatherwatch.com/cities/new-york

Temperature records for NYC by decade

Daily low temp

Decade	Records Set
1860s	5
1870s	67
1880s	66
1890s	35
1900s	14
1910s	46
1920s	42
1930s	29
1940s	26
1950s	13
1960s	32
1970s	23
1980s	19
1990s	11
2000s	4
2010s	8
2020s	2

Daily high temp

Decade	Records Set
1870s	5
1880s	12
1890s	21
1900s	6
1910s	21
1920s	26
1930s	35
1940s	48
1950s	37
1960s	30
1970s	33
1980s	33
1990s	47
2000s	37
2010s	32
2020s	13

New York heat wave statistics - Roosevelt Island Historical Society
https://rihs.us/2022/07/22/friday-july-22-2022-hot-summers-are-not-unusual-just-see-the-story/

The 10 hottest days in New York City history, according to the National Weather Service:
1. July 9, 1936 — 106 degrees
2. July 22, 2011 — 104 degrees
(tied) July 21, 1977 — 104 degrees
(tied) Aug. 7, 1918 — 104 degrees
5. July 6, 2010 — 103 degrees
(tied) Aug. 9, 2010 — 103 degrees
(tied) July 3, 1966 — 103 degrees
(tied) Aug. 26, 1948 — 103 degrees
9. July 15, 1995 — 102 degrees
(tied) July 10, 1993 — 102 degrees

Since 1870, high temperatures of 100° or hotter have occurred in 31 years, about once every five years. The longest span without any 100-degree days was 16 years, between 1882-1897. More recently, there was a 10-year span between 1981-1990, and eight years between 2002-2009. In the ten-year years between 2010-12.

Records dating back to 1872 show that the most 90°days in a year has been 39 – and this happened twice – in 1991 and 1993. However, while 1991's occurred over a lengthy span of 23 weeks, 1993's were more concentrated, occurring over five fewer weeks. While 1991 experienced 90° temperatures during 24% of the summer season, 1993's corresponding figure was 31%. Yet, neither of these hot summers come close to 1999. Although that year had ten fewer 90°, they were concentrated in a sixty-day period. And 1988 wasn't far behind, with 33 90°days over 77 days (43% concentration).

Heat wave definition

In New York, a heat wave is defined by at least 3 consecutive days with high temperature exceeding 90^{o}F. Also used is a Heat Index (Apparent Temperature) factors in humidity.
Cold waves are defined as periods of 3 or more consecutive days with minimum temperatures of 0^{o}F degrees or less.

Heat wave duration since 1950 – Albany (through 8/9/22)
https://www.weather.gov/media/aly/Climate/heatwaves.pdf

10 days Aug 27-Sep 5, 1953

8 days July 31-August 7, 1955

7 days July 5-11, 1988; July 17-23, 1991

6 days 7/24-7/29 1963; 7/14-7/19, 1968; August 10-15, 1988; July 5-10, 1993; August 11-16, 2002; July 14-19, 2013; June 30-July 5, 2018; July 19-24, 2022; August 3-8, 2022

5 days July 1-5, 1955; July 14-18, 1955; July 19-23, 1978; July 9-13, 1987; July 21-25, 1987; July 5-9, 2011

Cold wave duration since 1950 – Albany (last entry 2021)
https://www.weather.gov/media/aly/Climate/coldwaves.pdf

15 days 1/20-2/3 1961

10 days 2/9-2/18, 1979

8 days 1/13-1/20, 1957; 1/7-1/14, 1968

7 days 1/18-1/24, 1970; 1/8-1/14, 1981; 12/27 2017-1/2, 2018

6 days 1/16-1/21, 1971; 12/17-12/22, 1980; 1/24-1/29, 1987; 1/4-1/9, 1996

5 days 12/30 1967- 1/3 1968; 12/31-2/4 1971; 1/27-31 1977; 2/13-2/17 1987; 12/21-12/25 1989

Cold waves – NYC Central Park

Number of Consecutive Days with Max Temperatures below 32° at Central Park
Period of record 1871 - present

Rank	Number of Days	Dates
1	16	1/19/1961 – 2/3/1961
2	15	1/23/1881 – 2/6/1881
3	***14***	***12/26/2017 – 1/8/2018***
4	13	1/10/1893 – 1/22/1893
5	12	1/27/1978 – 2/7/1978 1/23/1936 – 2/3/1936

RECOMMENDED ANALYSIS OF HISTORICAL DATA

Analyze historical weather data:

- Assess the frequency, return time and clustering of heat and cold wave events of different durations.
- Prepare stress test cases for the NYISO MARS model, to evaluate system performance under extreme conditions, beyond the 5-year period that was tested.
- Evaluate the spatial correlations of wind energy production between NY, PJM, IESO, NEISO, Quebec and relevant offshore regions.

Return Time Analysis for Temperature Extremes

Time series of temperature data for Central Park (since 1865) and Albany (since 1874):

- Return time for heat/cold waves of 5+, 7+ and 10+ days duration
- Seasonal cluster analysis of heat waves of 3+ and longer duration
- Decadal-scale cluster analysis

Stress Test Case Studies for the NYISO MARS model

Assemble relevant data sets:

- NY Mesonet: surface temperature, humidity, solar radiation. Since 2018.
- HRRR analyses: hourly 3 km resolution. surface temperature, humidity, solar radiation, 80 km winds. Since 2014.
- ERA5: hourly, 35 km resolution. surface temperature, humidity, solar radiation, 100 km winds. Since 1950.
- ERA5 land: hourly, 9 km resolution. surface temperature, humidity, solar radiation. Since 1979.
- Historical data on hydropower production from NYISO (how far back?)
- Locations of current/projected wind/solar farms

Select extreme periods:

- 5+ day heat/cold waves
- Seasons with large % of $\geq 90^oF$ or $\leq 32^oF$ days
- Periods with extended wind droughts 3+ days (metric to be defined)

Data quality assessment:

- Assess quality of HRRR and ERA5 Land solar radiation data against NY MesoNet
- Assess quality ERA5 100 m wind variability data against HRRR 80 m winds

Assemble case studies:

- Hourly, gridded time series for entire season
- Weather data: surface temperature, humidity, solar radiation; 80/100 m wind speeds,
- Geographic region: NY only, or include offshore, PJM, IESO, NEISO, Hydro Quebec.

Climatology of Wind and Solar Droughts

Analyze wind and solar data since 2014, using HRRR analyses:

- Monthly analysis of the climatological diurnal cycle of wind and solar power (gridded or regional): average, standard deviation, 95th percentile. Assess diurnal storage needs.
- Frequency of wind and solar droughts exceeding 5 days (metric to be defined). Assess weather related storage needs.
- Seasonal cycle of wind and solar power. Assess seasonal storage needs.

Assess interannual variability of winter and summer wind/solar power since 1950.

Wind power correlation analysis: daily, weekly, monthly, seasonal, annual

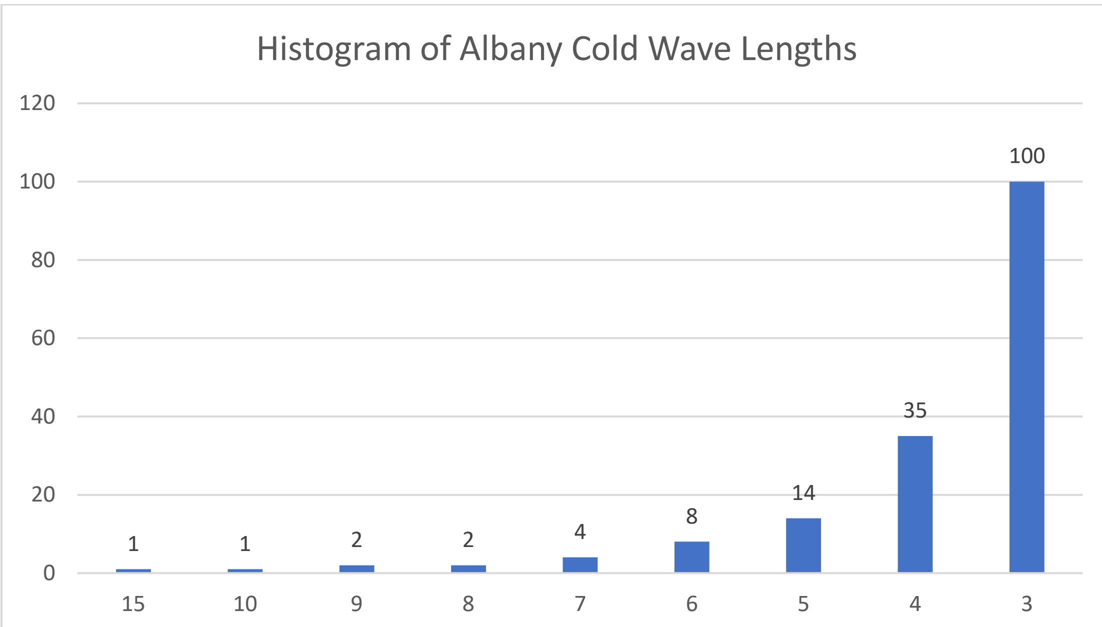
- Regions within NY state
- NY state correlations with offshore PJM, IESO, NEISO, Quebec

APPENDIX: WORST CASE EVENTS

Possible Worst Case – Cold event, Albany, NY

Possible Worst Case – Albany, NY

The analysis of cold wave durations for Albany for 1874 -2021 is a useful guide to the potential for extended periods of extreme cold weather. The analysis defined a cold wave as three or more consecutive days with minimum temperatures of zero degrees or less. Over the 148 winters analyzed, there were 167 cold waves of three days or more distributed as shown below.



Importantly, there was a 15-day period from January 20 until February 3, 1961 that will likely turn out to be the worst-case cold wave. The following table highlights that period. This was a period when high-pressure systems dominated the weather in the Northeast, as confirmed with a check of daily weather maps. The analysis of New York renewable resource availability should address this because it is likely that there were light winds in the high-pressure systems, there was significant snow depth that could impact solar resources on flat surfaces, and the cold temperatures would likely cause peak loads in a highly electrified energy system. Also note that temperatures were low in prior and subsequent periods that could impact energy storage availability further.

National Weather Service Albany, New York Daily Observations

Date	Maximum Temperature	Minimum Temperature	Average Temperature	Precipitation	Snowfall	SnowDepth
1/9/61	19	11	15	0	0	10
1/10/61	24	-1	11.5	0	0	10
1/11/61	39	3	21	0	0	10
1/12/61	36	9	22.5	0	0	8
1/13/61	37	3	20	0	0	8
1/14/61	45	30	37.5	0	0	6
1/15/61	30	17	23.5	T	T	6
1/16/61	31	19	25	0.02	0.3	6
1/17/61	40	11	25.5	0	0	6
1/18/61	40	11	25.5	T	T	6
1/19/61	11	1	6	T	0.1	6
1/20/61	5	0	2.5	0.43	5.2	9
1/21/61	15	-14	0.5	0	0	10
1/22/61	17	-17	0	T	T	10
1/23/61	15	-12	1.5	T	T	10
1/24/61	13	-8	2.5	0.04	0.5	10
1/25/61	12	-8	2	0	0	10
1/26/61	12	-1	5.5	0.1	1.7	10
1/27/61	16	-3	6.5	0.01	0.1	11
1/28/61	20	-2	9	0	0	11
1/29/61	25	-8	8.5	T	T	10
1/30/61	19	-6	6.5	0	0	9
1/31/61	23	-1	11	T	T	9
2/1/61	6	-7	-0.5	0	0	9
2/2/61	5	-18	-6.5	0	0	9
2/3/61	11	-10	0.5	0.02	0.2	9
2/4/61	25	10	17.5	0.79	10.1	14
2/5/61	23	-3	10	0	0	19
2/6/61	32	17	24.5	0	0	19
2/7/61	32	6	19	0	0	19

1960's drought
http://ocp.ldeo.columbia.edu/res/div/ocp/drought/catskills/Seager_etal_Catskills.pdf

It is concluded that past precipitation variability in the region, including the drought and pluvial, were caused by internal atmospheric variability. Such events are unpredictable and a drought like the 1960s one could return while the long-term wetting trend need not continue, conclusions that have implications for management of New York City's water resources.

However, a drought reconstruction based on four tree ring chronologies from the Shawangunk Mountains and another from Schunemunk Mountain, all just south of the Catskills, shows the 1960s drought to have been the most severe in the last few centuries although longer, but less extreme, droughts had occurred in prior centuries (Cook and Jacoby 1977). The 1960s drought is a severe interruption of a general wetting trend over the past half millennium (Pederson in prep.). Just as curious as the 1960s drought is the shift to a wetter climate in the region that began around the early 1970s and has continued to date. The causes of this are unknown.

In conclusion, the precipitation history in the Catskills Mountains region of the New York City watershed, including such dramatic events as the early to mid 1960s drought and the subsequent pluvial, have been caused by atmospheric variability. There is also no evidence that the wetting trend was caused by anthropogenic climate change. This means that, first, it cannot be assumed that the wet climate of recent decades will continue and that, instead, drier conditions more typical of the last century could return and, second, a severe drought like that of the 1960s could again happen at any time and with no warning and with no ability to predict either its onset or its continuation.