

Road Weather Information Sites: Optimum Placement of Stations Across New Jersey

FINAL REPORT
July 2011

Submitted by

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In cooperation with

New Jersey
Department of Transportation
Bureau of Research
and
U.S. Department of Transportation
Federal Highway Administration

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1. Report No. FHWA-NJ-2011-006		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Roadway Weather Information Sites: Optimum Placement of Stations Across New Jersey				5. Report Date November 2004	
				6. Performing Organization Code	
7. Author(s) David A. Robinson, PhD, New Jersey State Climatologist				8. Performing Organization Report No.	
9. Performing Organization Name and Address Rutgers University Department of Geography 54 Joyce Kilmer Avenue Piscataway, NJ 08854				10. Work Unit No.	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address New Jersey Department of Transportation Federal Highway Administration P.O. Box 600 U.S. Department of Transportation Trenton, NJ 08625 Washington, D.C.				13. Type of Report and Period Covered Final	
				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract <p>The NJ Department of Transportation recognizes the need for a network of high-quality observations of atmospheric conditions along the State's roadways, including information on roadway conditions. Since the early 1990s, a network of approximately 30 stations, the Roadside Weather Information System (RWIS), has been installed across NJ (some stations have been decommissioned during this period while a similar number have been brought on line). However, since these stations were originally planned to be part of a 100-station network, the first 30 were not necessarily installed in the best locations to monitor the wide range of hazardous driving conditions that are often found across the State. While there are no plans to greatly increase the size of the current network, opportunities may exist to install some additional stations, perhaps by relocating some stations that currently sit close to others.</p> <p>As such, the Office of the New Jersey State Climatologist received funds from the NJ DOT to conduct a comprehensive study of the NJ RWIS network in order to assess the effectiveness of the present station distribution with respect to potential meteorological and climatological conditions across NJ. The study objectives included:</p> <ol style="list-style-type: none"> 1. Developing a database of quality controlled observations from the RWIS network that extends back two years and continues to grow throughout the project period. 2. Evaluating the current effectiveness of the distribution of RWIS stations in monitoring weather conditions throughout New Jersey's road network from a climatological perspective. 3. Recommending an optimal distribution of RWIS stations that best represents the variability of the weather and climate along New Jersey roadways. <p>We are pleased to report that, with the exception of the two-year pre-study database, all project objectives have been achieved. Furthermore, cooperation with NJDOT colleagues throughout this extended effort has resulted in dividends that greatly exceed original study goals. In particular, NJ RWIS observations are currently ingested every 15-20 minutes into the ONJSC's NJ Weather and Climate Network (NJWxNet), a growing integrative network of approximately 100 stations across the State. NJDOT-ONJSC cooperation has resulted in a funded effort that currently is supporting the development of a customized web-based delivery system of RWIS data to DOT decision makers.</p> <p>This report summarizes project activities over the past five years. This includes: 1) explanations of the NJWxNet database and dissemination system; 2) a cyber-atlas containing the most comprehensive collection of NJ climatological maps generated to date; 3) case studies that illustrate the rapidly changing weather conditions found across the State; and, 4) a series of maps showing recommended placements of new RWIS stations or relocations of current stations based on our meteorological and climatological evaluations.</p>					
17. Key Words Roadside weather stations, roadside weather observations			18. Distribution Statement No Restrictions		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No of Pages 71	22. Price

Executive Summary

The New Jersey Department of Transportation (NJDOT) has recognized the need for a network of high-quality observations of atmospheric conditions along the State's roadways, including information on roadway conditions. Since the early 1990s, a network of approximately 30 stations, the Roadside Weather Information System (RWIS), has been installed across NJ (some stations have been decommissioned during this period while a similar number have been brought on line). However, since these stations were originally planned to be part of a 100-station network, the first 30 were not necessarily installed in the best locations to monitor the wide range of hazardous driving conditions that are often found across the state. While there are no plans to greatly increase the size of the current network, opportunities may exist to install some additional stations, perhaps in part relocating some stations that currently sit close to others.

As such, the Office of the New Jersey State Climatologist received funds from the NJ DOT to conduct a comprehensive study of the NJ RWIS network in order to assess the effectiveness of the present station distribution with respect to potential meteorological and climatological conditions across NJ. As stated in the original proposal, study objectives included:

- Developing a database of quality controlled observations from the RWIS network that extends back two years and continues to grow throughout the project period.
- Evaluating the current effectiveness of the distribution of RWIS stations in monitoring weather conditions throughout New Jersey's road network from a climatological perspective.
- Recommending an optimal distribution of RWIS stations that best represents the variability of the weather and climate along New Jersey roadways.

We are pleased to report that, with the exception of the two-year pre-study database, all project objectives have been achieved. Furthermore, cooperation with NJDOT colleagues throughout this extended effort has resulted in dividends that greatly exceed original study goals. In particular, NJ RWIS observations are currently ingested every 15-20 minutes into the ONJSC's NJ Weather and Climate Network (NjWxNet), a growing integrative network of approximately 100 stations across the State. Furthermore, NJDOT-ONJSC cooperation has resulted in a funded effort that currently is supporting the development of a customized web-based delivery system of RWIS data to DOT decision makers.

This report summarizes project activities over the past five years. This includes: 1) explanations of the NjWxNet database and dissemination system; 2) a cyber-atlas containing the most comprehensive collection of NJ climatological maps generated to date; 3) case studies that illustrate the rapidly changing weather conditions found across the State; and, 4) a series of maps showing recommended placements of new RWIS stations or relocations of current stations based on our meteorological and climatological evaluations.

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OVERVIEW

A portion of the mission of The Office of the New Jersey State Climatologist (ONJSC) at Rutgers University is to gather, monitor and archive weather and climate data across the State. This is not limited to the observations made at airports or in the backyards of observers, but also holds for weather-critical locations, including New Jersey roadways. The NJ Department of Transportation has recognized the need for a network of high-quality observations of atmospheric conditions along the State's roadways, including information on roadway conditions. Since the early 1990s, a network of approximately 30 stations, the Roadside Weather Information System (RWIS), has been installed across NJ (some stations have been decommissioned during this period while a similar number have been brought on line). However, since these stations were originally planned to be part of a 100-station network, the first 30 were not necessarily installed in the best locations to monitor the wide range of hazardous driving conditions that are often found across New Jersey. While there are no plans to greatly increase the size of the current network, opportunities may exist to install some additional stations, perhaps in part relocating some stations that currently sit close to others.

As such, the ONJSC received funds from the NJ DOT to conduct a comprehensive study of the NJ RWIS network in order to assess the effectiveness of the present station distribution with respect to potential meteorological and climatological conditions across NJ. As stated in the original proposal, study objectives included:

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This report summarizes project activities over the past five years. This includes: 1) explanations of the NjWxNet database and dissemination system; 2) a cyber-atlas containing the most comprehensive collection of NJ climatological maps generated to date; 3) case studies that illustrate the rapidly changing weather conditions found across the State; and 4) a series of maps showing recommended placements of new RWIS stations or relocations of current stations based on our meteorological and climatological evaluations.

The ONJSC is fortunate to have the staff and resources to be uniquely qualified to conduct this study. We have an archive of official and unofficial climate observations dating back to the turn of the century, the technical expertise in data management, information display, and geographic information systems, and have a dedicated team of students and staff with detailed knowledge of the weather and climate of New Jersey.

We are grateful to numerous individuals within the NJDOT for their cooperation over the past five years. We look forward to continued interactions as we all strive to make transportation within New Jersey safer and more efficient.

NJWXNET

The New Jersey Weather and Climate Network (NJWxNet) is a comprehensive information resource for weather forecasting and weather-related decision making in New Jersey. It is a unique network of networks, including data gathered from over 40 stations operated by the ONJSC, along with more than 60 stations maintained by the NJ Department of Transportation, the NJ Turnpike, the National Weather Service, the U.S. Geological Survey, Stevens Institute of Technology, and others (figure 1). The combination of all of these stations makes the NJWxNet the most spatially dense weather network in the Nation, and likely the World.

The ONJSC processes the raw data from each network into a common format and populates a database within minutes of observations being obtained. Data and derived products are quickly made available for display in colorful maps, graphs and tables via the NJWxNet web site (<http://climate.rutgers.edu/njwxnet>) (figure 2) or other means (e.g., emailed reports). Maps display the latest observations of temperature, precipitation, wind speed and dew point (figure 3). Tables display information in a variety of formats. This includes single hourly observations from all stations, daily summary data from all stations, daily hourly observations from a single station, and daily summary data by month for a single station (tables 1-3). Tabular data can be sorted by any one of the columns, for instance, permitting a quick glance at all RWIS stations on a list of hourly observations. The latest hourly observations may also be displayed for a single station, in addition to meteographs showing the last 24 hours of temperature, humidity, barometric pressure, and wind in graphical format (figure 4).

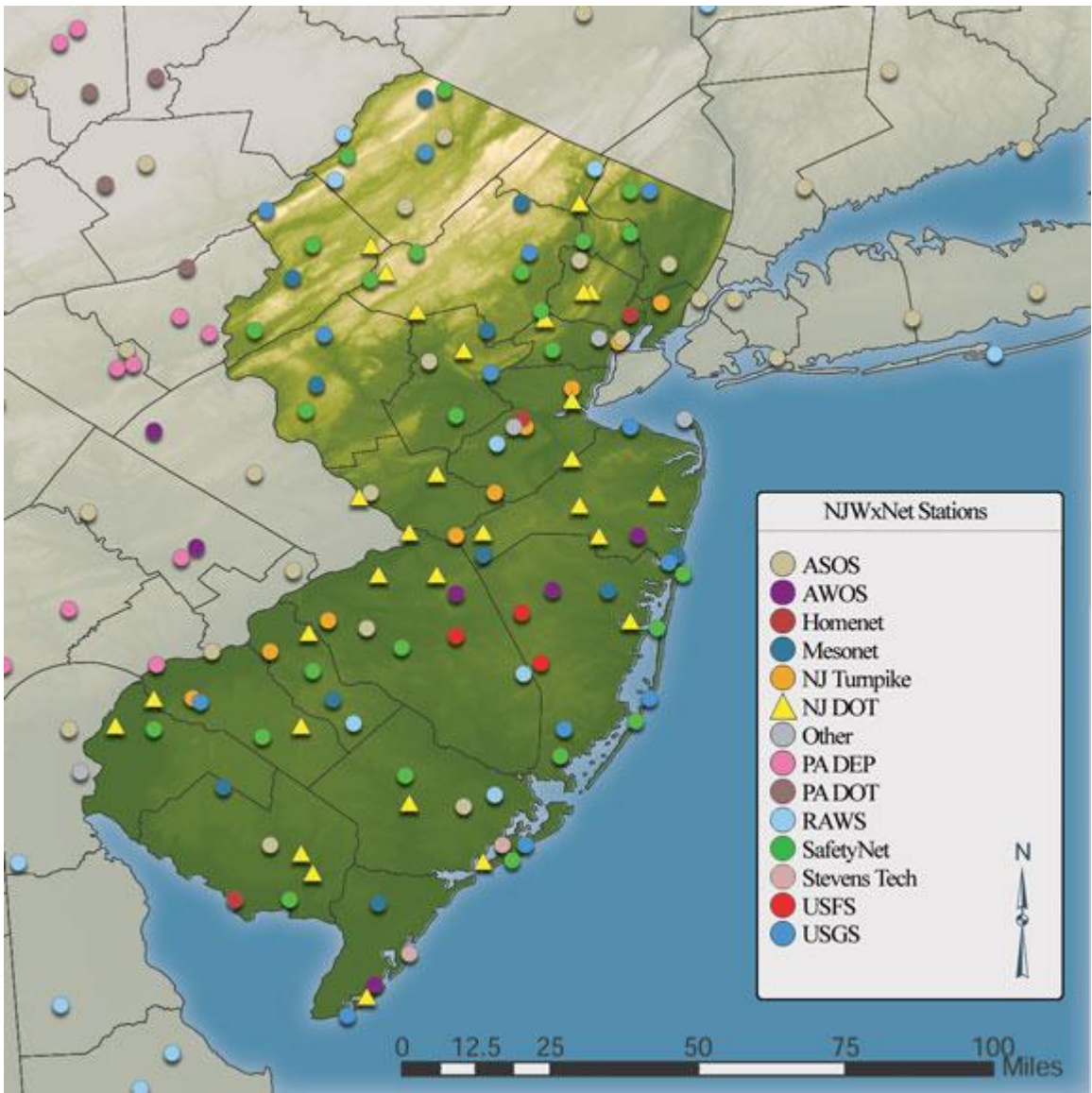




Figure 1. Locations of NJ Weather and Climate Network observing stations

SEARCH





Weather and Climate Network

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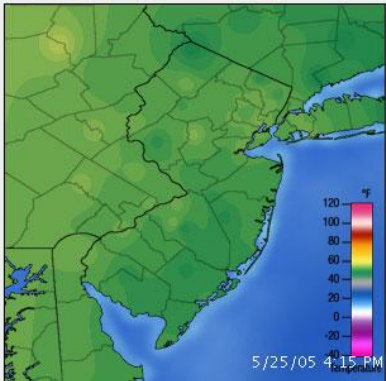
Latest Conditions

NJ Hot Spots

City, State	Temp
Somerville, NJ	55
Summit, NJ	54
Harrison, NJ	54
Stewartsville, NJ	54
Secaucus, NJ	53

NJ Cool Spots

City, State	Temp
High Point, NJ	46
Atlantic City (U), NJ	48
Wantage, NJ	48
Fort Dix, NJ	49
Mullica Twp., NJ	49



5/25/05 4:15 PM

[click on image to enlarge](#)

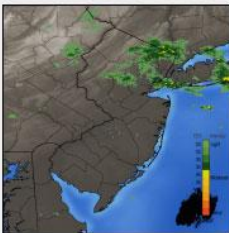
myCurrent Conditions

Sea Girt, NJ

52°


Humidity: 76%
 Pressure: 29.74
 Wind Speed: 17 from the NNE
[Choose a new location](#)

Latest Doppler Radar




[click on image to enlarge](#)

Latest IR Satellite



[click on image to enlarge](#)

NJ Climate News



A. Duvall

New Jersey has experienced severe storms this spring and summer, including this one from 24 May 2004 that affected the New Brunswick area.

Welcome to the NJ Weather and Climate Network (NJWxNet)

Welcome to the NJWxNet, your "one-stop shopping resource for New Jersey weather and climate information". This web site provides hourly, real-time observations from dozens of weather stations in colorful maps and tables for New Jersey.

Larger versions of the maps are available by clicking on "Weather Maps" in the menu, or by clicking the current hourly temperature map or the current radar map on this page. Tables of current and archived NJWxNet observations are located under "Weather Data" in the menu. Enter your zipcode or city and state under "Current Conditions" in the upper right corner of this page to display information from the station nearest to you.

The NJWxNet can help you every day to monitor what is going on outside throughout New Jersey. Use the NJWxNet to help choose between short sleeves and long sleeves and to keep track of heat waves, freezes, flooding rain and high winds. Bookmark this page so you can stay informed of what is happening in your local area.

Figure 2. Lead page of the NJWxNet web site (<http://climate.rutgers.edu/njwxnet>).

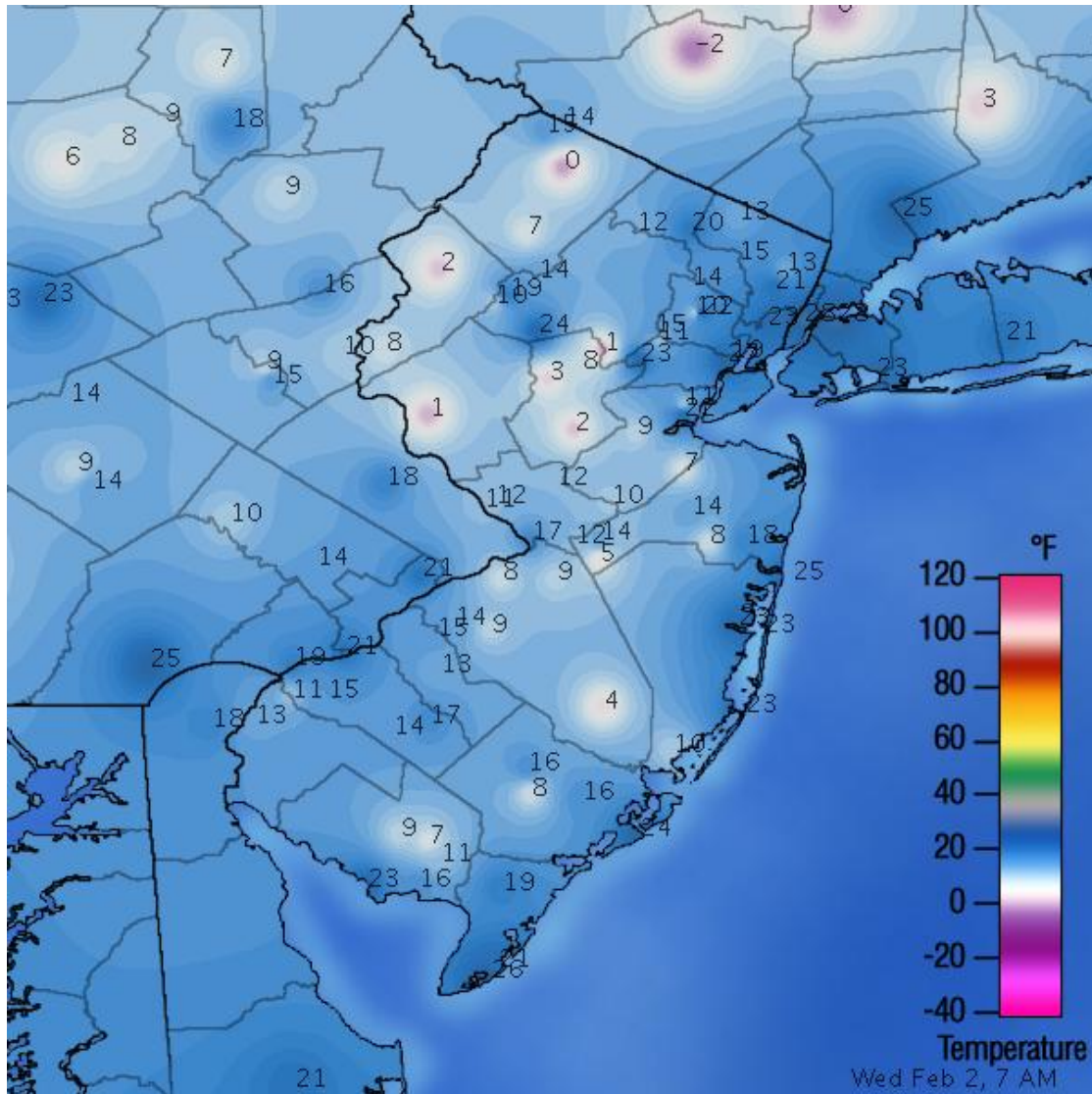


Figure 3. Example of an NJWxNet hourly temperature map; 7 AM February 2, 2005. Note the temperature inversions (valleys colder than higher elevations), and the relative warmth of coastal and urban areas.

Table 1. New Jersey Weather and Climate Network hourly observations at noon on September 29, 2005.

Observations are sorted by reporting network. Time of observation varies depending on when a station was accessed relative to the top of the hour. Temp: air temperature 5-6 ft above the ground; DewPt: dewpoint temperature; RH: relative humidity; BP: barometric pressure; Precip: precipitation; Wind: average wind speed either averaged over the past hour or for several minutes immediately prior to the observation; Max Wind: maximum wind speed either over the past hour or during a five-minute interval immediately prior to the observation; Wind Dir: direction of the Wind (wind blowing from the noted direction) over the observation interval.

City	State	Date/Time	Source	Temp	DewPt	RH	BP	Precip	Wind	Max	Wind
				°F	°F	%	in.	in.	mph	Wind	Dir
										mph	
Upper Freehold	NJ	2005-9-29 11-44	NJDOT	72	57	59			3	18	SSW
Maurice River 2	NJ	2005-9-29 11-44	NJDOT	74	60	62			7	16	SSW
Maurice River 1	NJ	2005-9-29 11-43	NJDOT	75	58	57			3	12	ESE
Mount Olive	NJ	2005-9-29 11-43	NJDOT	60	56	86			6	15	WNW
West Orange 1	NJ	2005-9-29 11-43	NJDOT	68	60	76			4	16	SW
Carneys Point	NJ	2005-9-29 11-43	NJDOT	71	68	89			4	17	WSW
West Windsor	NJ	2005-9-29 11-42	NJDOT	72	56	59			9	26	SSE
Eatontown 2 sfc	NJ	2005-9-29 11-42	NJDOT	77		42			14	25	SW
Logan	NJ	2005-9-29 11-42	NJDOT			90			6	15	SSW
Williamstown	NJ	2005-9-29 11-41	NJDOT	70	62	76			10	24	S
Allamuchy	NJ	2005-9-29 11-41	NJDOT	63		82			5	22	W
Hamilton 2	NJ	2005-9-29 11-41	NJDOT	75	55	50			10	22	S
Cherry Hill	NJ	2005-9-29 11-41	NJDOT	73	60	66			8	16	SSW
Woodbridge 2 sfc	NJ	2005-9-29 11-41	NJDOT								
Dover	NJ	2005-9-29 11-40	NJDOT	75	64	67					
Atlantic City	NJ	2005-9-29 11-40	NJDOT	73	73	99			19	28	SW
Woodbridge	NJ	2005-9-29 11-40	NJDOT	74	58	59			8	25	SSW
Springfield	NJ	2005-9-29 11-39	NJDOT	73		48			4	16	SW
Hamilton 1	NJ	2005-9-29 11-39	NJDOT	74	61	64			11	27	WSW
Old Bridge	NJ	2005-9-29 11-38	NJDOT	74	55	52			6	16	S
Freehold	NJ	2005-9-29 11-37	NJDOT	75	53	46			6	25	SW
West Orange 2	NJ	2005-9-29 11-36	NJDOT	70	61	74			7	14	SW
Howell	NJ	2005-9-29 11-36	NJDOT	76	53	45				19	SW
Ewing 2 sfc	NJ	2005-9-29 11-35	NJDOT						4	16	SSW
Berkeley Heights	NJ	2005-9-29 11-35	NJDOT	69	60	73			2	12	SW
Ewing	NJ	2005-9-29 11-35	NJDOT	69	60	73			4	16	SSW
Bernards	NJ	2005-9-29 11-26	NJDOT	71	57	62			10	16	SW
Wildwood	NJ	2005-9-29 11-26	NJDOT	75		65			22	32	W
Wanaque	NJ	2005-9-29 11-25	NJDOT	68	62	81			6	20	SW
Summit	NJ	2005-9-29 11-25	NJDOT	71	61	70			11	21	SW
Mansfield	NJ	2005-9-29 11-25	NJDOT		55	51			9	21	W

Middlesex	NJ	2005-9-29 11-30	USGS	71					0			
Atlantic City (U)	NJ	2005-9-29 11-30	USGS	74								N
Pellettown	NJ	2005-9-29 11-0	USGS	67								
Swedesboro	NJ	2005-9-29 11-0	USGS	72								
Up. Saddle River	NJ	2005-9-29 11-0	USGS	72								
Stafford Forge	NJ	2005-9-29 11-0	USGS	75								
Fort Dix II	NJ	2005-9-29 12-0	USFS	75		57				2	10	SSW
Fort Dix I	NJ	2005-9-29 12-0	USFS	75		59		0		8		WSW
Cedar Bridge	NJ	2005-9-29 11-30	USFS	76		54		0		13		SSW
Silas Little	NJ	2005-9-29 11-30	USFS	75		71		0		10		SW
Avalon	NJ	2005-9-29 11-10	Stevens	73						3	9	SSW
Atlantic City (S)	NJ	2005-9-29 11-10	Stevens	74						4	12	S
Chatham	NJ	2005-9-29 11-51	SafetyNet	69	66	91					10	SE
Point Pleasant	NJ	2005-9-29 11-51	SafetyNet	73	72	95		0		13	24	SSE
West Creek	NJ	2005-9-29 11-51	SafetyNet	74	66	74	29.85	0		8	23	SE
Harvey Cedars	NJ	2005-9-29 11-51	SafetyNet	73	72	99	29.88	0		17	31	SE
Charlotteburg	NJ	2005-9-29 11-51	SafetyNet	65			29.8	0				S
Hackettstown	NJ	2005-9-29 11-51	SafetyNet	60	60	98	29.84	0.05			6	ESE
Mullica Twp.	NJ	2005-9-29 11-51	SafetyNet	73	67	82		0		8	20	SSW
Seaside Heights	NJ	2005-9-29 11-50	SafetyNet	73	70	92		0		18	29	SSE
Hawthorne	NJ	2005-9-29 11-50	SafetyNet	72	67	84	29.76	0		7	10	ESE
Walpack	NJ	2005-9-29 11-50	SafetyNet	61	61	100	29.82	0			7	S
Wantage	NJ	2005-9-29 11-50	SafetyNet	58	56	96	29.81	0.15		5	13	SW
Atlantic C. Marina	NJ	2005-9-29 11-50	SafetyNet	71	70	95	29.88	0		20	30	S
Lindenwold	NJ	2005-9-29 11-50	SafetyNet	71	68	91	29.86	0		13	18	SSE
Stewartsville	NJ	2005-9-29 11-50	SafetyNet	59		100	29.92	0.05		9	12	SSW
Bivalve	NJ	2005-9-29 11-50	SafetyNet	73	66	80	29.85	0		13	23	SW
Kingwood	NJ	2005-9-29 11-50	SafetyNet	59			29.88					SSW
Ramsey	NJ	2005-9-29 11-50	SafetyNet	69	65	87	29.78	0				NNE
Hope	NJ	2005-9-29 11-50	SafetyNet	60	59	95	29.82	0.15		6	6	SSE
Netcong	NJ	2005-9-29 11-50	SafetyNet	60		100		0.07			14	SE
Wayne	NJ	2005-9-29 11-50	SafetyNet	69	67	94					6	S
Hillsborough	NJ	2005-9-29 11-50	SafetyNet	70	66	87	29.83	0		7	11	SSE
Clayton	NJ	2005-9-29 11-50	SafetyNet	69	68	96	29.88	0.01			8	ESE
Red Lion	NJ	2005-9-29 11-50	SafetyNet	72	65	79	29.86	0				SE
East Brunswick	NJ	2005-9-29 11-0	Rutgers	72		69	29.71			2		SSW
Forsythe	NJ	2005-9-29 11-25	RAWS	78		72				13	25	
Secaucus	NJ	2005-9-29 11-55	Turnpike	73	61	66	29.75					N
Elizabeth	NJ	2005-9-29 11-53	Turnpike	74	60	61	29.67					S
East Windsor	NJ	2005-9-29 11-50	Turnpike	74	60	60	29.55					SW
Woodbridge	NJ	2005-9-29 11-47	Turnpike	74	58	57	29.56					SSW
Runnemede	NJ	2005-9-29 11-47	Turnpike		62	67	29.65					SSW
Chesterfield Twp.	NJ	2005-9-29 11-45	Turnpike			65	29.72					WSW
Mount Laurel	NJ	2005-9-29 11-38	Turnpike	73	62	69	29.79					SW
Woolwich Twp.	NJ	2005-9-29 11-37	Turnpike	73	62	69	29.63					SSW
Cream Ridge	NJ	2005-9-29 12-0	Mesonet	71	60	68	29.82	0		18	30	SW
Basking Ridge	NJ	2005-9-29 12-0	Mesonet	68	60	75	29.84	0		17	19	W
High Point	NJ	2005-9-29 12-0	Mesonet	55	52	90	29.87	0.19		6	17	W

Woodbine	NJ	2005-9-29 12-0	Mesonet	75	62	63	29.88	0	8	25	WSW
Oswego Lake	NJ	2005-9-29 12-0	Mesonet	74	61	62	29.9	0	15	26	W
Charlotteburg II	NJ	2005-9-29 12-0	Mesonet	64	62	92	29.72	0.01	2	9	WNW
Sea Girt	NJ	2005-9-29 12-0	Mesonet	74	64	71	29.84	0	14	35	SSW
Pittstown	NJ	2005-9-29 12-0	Mesonet	57	53	88	29.83	0.07	11	29	W
Harrison	NJ	2005-9-2911-50	Homenet	74	66	76	29.79	0	11	32	WSW
New Brunswick	NJ	2005-9-2911-50	Homenet	72				0			
McGuire AFB	NJ	2005-9-2911-42	AWOS	75	64				28	29	SW
Wildwood (A)	NJ	2005-9-2911-35	AWOS	75		65			16		
Farmingdale	NJ	2005-9-2911-35	AWOS	75		54			18	35	
Teterboro	NJ	2005-9-2911-51	ASOS	72	63		29.77	0.01	30	23	SW
Newark	NJ	2005-9-2911-51	ASOS	73	61		29.78	0	45	31	SW
Sussex	NJ	2005-9-2911-39	ASOS	64	63				30	33	SSW
Trenton	NJ	2005-9-29 11-0	ASOS	72	61				32	23	WSW

Table 2. Observations from the Berkeley Heights RWIS station on September 29, 2005, as found on the NJWxNet web site. See table 1 for column information.

City	State	Date/Time	Temp	DewPt	RH	Wind	Max	Wind
			°F	°F	%	mph	Wind	Dir
							mph	
Berkeley Heights	NJ	2005-9-29 0-5	62	59	89	0	1	SE
Berkeley Heights	NJ	2005-9-29 0-25	62	59	89	0	1	SSE
Berkeley Heights	NJ	2005-9-29 0-35	62	59	89	0	0	E
Berkeley Heights	NJ	2005-9-29 1-5	62	59	90	0	3	SE
Berkeley Heights	NJ	2005-9-29 1-25	61	58	90	0	2	S
Berkeley Heights	NJ	2005-9-29 1-35	61	59	91	0	1	S
Berkeley Heights	NJ	2005-9-29 2-5	61	58	91	0	1	E
Berkeley Heights	NJ	2005-9-29 2-25	61	58	92	0	1	SSE
Berkeley Heights	NJ	2005-9-29 2-35	60	57	92	0	2	ESE
Berkeley Heights	NJ	2005-9-29 3-5	61	59	92	4	7	SE
Berkeley Heights	NJ	2005-9-29 3-25	62	59	92	4	9	SSE
Berkeley Heights	NJ	2005-9-29 3-35	62	59	92	4	8	SSE
Berkeley Heights	NJ	2005-9-29 4-5	62	59	92	2	4	S
Berkeley Heights	NJ	2005-9-29 4-25	62	59	92	1	4	S
Berkeley Heights	NJ	2005-9-29 4-35	62	59	92	2	5	SSE
Berkeley Heights	NJ	2005-9-29 5-5	61	59	92	1	3	SSE
Berkeley Heights	NJ	2005-9-29 5-25	61	59	92	1	5	SE
Berkeley Heights	NJ	2005-9-29 5-35	62	59	92	2	6	SE
Berkeley Heights	NJ	2005-9-29 6-5	62	59	90	3	9	SSE
Berkeley Heights	NJ	2005-9-29 6-25	62	59	89	2	10	SE
Berkeley Heights	NJ	2005-9-29 6-35	62	59	89	1	7	S
Berkeley Heights	NJ	2005-9-29 7-5	62	59	89	2	9	SE
Berkeley Heights	NJ	2005-9-29 7-25	63	59	89	3	7	SSE

Berkeley Heights	NJ	2005-9-29 7-35	63	60	89	3	12	SSE
Berkeley Heights	NJ	2005-9-29 8-5	64	61	89	4	9	SSE
Berkeley Heights	NJ	2005-9-29 8-25	65	62	89	5	11	S
Berkeley Heights	NJ	2005-9-29 8-35	67	63	89	7	15	SE
Berkeley Heights	NJ	2005-9-29 9-5	69	63	81	9	17	S
Berkeley Heights	NJ	2005-9-29 9-25	70	62	76	9	22	S
Berkeley Heights	NJ	2005-9-29 9-35	70	62	74	9	22	SSE
Berkeley Heights	NJ	2005-9-29 10-5	70	58	66	9	21	SSE
Berkeley Heights	NJ	2005-9-29 10-25	71	58	64	7	21	S
Berkeley Heights	NJ	2005-9-29 10-35	71	57	62	11	22	SW
Berkeley Heights	NJ	2005-9-29 11-5	71	56	60	4	21	SW
Berkeley Heights	NJ	2005-9-29 11-25	69	59	71	7	13	SSW
Berkeley Heights	NJ	2005-9-29 11-35	69	60	73	2	12	SW
Berkeley Heights	NJ	2005-9-29 12-5	67	60	79	2	27	SW
Berkeley Heights	NJ	2005-9-29 12-25	61	58	89	11	22	W
Berkeley Heights	NJ	2005-9-29 12-35	61	58	91	10	20	W
Berkeley Heights	NJ	2005-9-29 13-5	58	56	92	9	20	WNW
Berkeley Heights	NJ	2005-9-29 13-25	58	56	92	6	22	WNW
Berkeley Heights	NJ	2005-9-29 13-35	58	55	92	4	17	NW
Berkeley Heights	NJ	2005-9-29 14-5	58	56	92	5	14	WNW
Berkeley Heights	NJ	2005-9-29 14-25	60	58	92	4	9	WNW
Berkeley Heights	NJ	2005-9-29 14-35	62	59	92	2	11	SW
Berkeley Heights	NJ	2005-9-29 15-5	64	56	74	9	14	W
Berkeley Heights	NJ	2005-9-29 15-25	66	54	66	5	15	W
Berkeley Heights	NJ	2005-9-29 15-35	67	50	55	8	17	WNW
Berkeley Heights	NJ	2005-9-29 16-5	68	37	32	7	22	W
Berkeley Heights	NJ	2005-9-29 16-25	68	34	28	4	18	W
Berkeley Heights	NJ	2005-9-29 16-35	68	33	27	6	17	W
Berkeley Heights	NJ	2005-9-29 17-5	67	33	28	2	12	NNE
Berkeley Heights	NJ	2005-9-29 17-35	67	36	32	1	7	E
Berkeley Heights	NJ	2005-9-29 18-5	64	37	37	2	9	NE
Berkeley Heights	NJ	2005-9-29 18-25	62	35	36	3	11	W
Berkeley Heights	NJ	2005-9-29 18-35	62	34	35	1	11	ESE
Berkeley Heights	NJ	2005-9-29 19-5	60	34	38	1	6	NE
Berkeley Heights	NJ	2005-9-29 19-25	59	33	37	2	9	N
Berkeley Heights	NJ	2005-9-29 19-35	59	32	36	1	9	NNE
Berkeley Heights	NJ	2005-9-29 20-5	58	28	32	1	7	WNW
Berkeley Heights	NJ	2005-9-29 20-25	56	29	35	1	5	NNE
Berkeley Heights	NJ	2005-9-29 20-35	56	29	35	0	5	NNE
Berkeley Heights	NJ	2005-9-29 21-5	55	29	38	1	4	N
Berkeley Heights	NJ	2005-9-29 21-25	55	29	37	1	6	ESE
Berkeley Heights	NJ	2005-9-29 21-35	54	29	39	1	6	N
Berkeley Heights	NJ	2005-9-29 22-5	52	30	43	1	4	NE
Berkeley Heights	NJ	2005-9-29 22-25	51	31	46	0	3	N
Berkeley Heights	NJ	2005-9-29 22-35	51	32	47	1	4	N
Berkeley Heights	NJ	2005-9-29 23-5	50	33	52	0	4	NNE

Berkeley Heights	NJ	2005-9-29 23-25	49	34	55	1	3	NNE
Berkeley Heights	NJ	2005-9-29 23-35	49	35	57	0	3	ENE

Table 3. Daily observations from the Hillsborough NJSafetyNet station for September 2005, as found on the NJWxNet web site.

Max Temp: highest temperature occurring at any time during the day (not just at the time of the hourly readings; this applies for all other variables); Min Temp: lowest temperature of the day; Precip: total daily precipitation; Max (Min) RH: maximum and minimum relative humidity of the day; BP Max (Min): maximum minimum barometric pressure of the day; Max Wind: maximum wind gust of the day.

City	State	Date/Time	Max Temp °F	Min Temp °F	Precip in.	Max RH %	Min RH %	BP Max in.	BP Min in.	Max Wind mph
Hillsborough	NJ	2005-9-1 0-0	86	63	0	100	40	29.96	29.7	24
Hillsborough	NJ	2005-9-2 0-0	91	57	0	100	34	30	29.88	24
Hillsborough	NJ	2005-9-3 0-0	82	57	0	96	38	30.09	29.96	20
Hillsborough	NJ	2005-9-4 0-0	85	55	0	100	37	30.3	30.09	19
Hillsborough	NJ	2005-9-5 0-0	85	58	0	100	33	30.44	30.29	12
Hillsborough	NJ	2005-9-6 0-0	85	54	0	100	39	30.48	30.38	12
Hillsborough	NJ	2005-9-7 0-0	86	50	0	100	34	30.4	30.21	12
Hillsborough	NJ	2005-9-8 0-0	90	51	0	100	26	30.21	30	16
Hillsborough	NJ	2005-9-9 0-0	86	57	0	100	33	30.16	30.03	14
Hillsborough	NJ	2005-9-10 0-0	86	51	0	100	24	30.27	30.16	16
Hillsborough	NJ	2005-9-11 0-0	85	50	0	100	33	30.38	30.24	12
Hillsborough	NJ	2005-9-12 0-0	93	56	0	100	27	30.26	30.03	18
Hillsborough	NJ	2005-9-13 0-0	95	58	0	100	32	30.08	29.98	15
Hillsborough	NJ	2005-9-14 0-0	86	59	0.79	100	64	30.09	30.01	12
Hillsborough	NJ	2005-9-15 0-0	85	71	0.20	100	75	30.11	30.03	13
Hillsborough	NJ	2005-9-16 0-0	85	72	0	100	69	30.11	29.96	15
Hillsborough	NJ	2005-9-17 0-0	87	69	0	100	61	30	29.89	16
Hillsborough	NJ	2005-9-18 0-0	85	60	0	100	42	30.13	29.99	18
Hillsborough	NJ	2005-9-19 0-0	89	57	0	100	41	30.25	30.13	13
Hillsborough	NJ	2005-9-20 0-0	85	64	0	100	59	30.18	30	20
Hillsborough	NJ	2005-9-21 0-0	87	58	0	100	35	30.18	30.05	15
Hillsborough	NJ	2005-9-22 0-0	87	53	0	100	30	30.16	29.97	19
Hillsborough	NJ	2005-9-23 0-0	87	62	0.02	100	47	30.19	29.96	16
Hillsborough	NJ	2005-9-24 0-0	74	51	0	100	45	30.37	30.19	13
Hillsborough	NJ	2005-9-25 0-0	77	51	0	100	63	30.35	30.15	14
Hillsborough	NJ	2005-9-26 0-0	81	62	0.26	100	67	30.15	29.7	23
Hillsborough	NJ	2005-9-27 0-0	76	50	0	100	37	30.14	29.7	25
Hillsborough	NJ	2005-9-28 0-0	76	44	0	100	48	30.24	30.09	12
Hillsborough	NJ	2005-9-29 0-0	74	50	0.16	100	48	30.11	29.8	30
Hillsborough	NJ	2005-9-30 0-0	69	39	0	100	39	30.26	30.11	13
Hillsborough	NJ	2005-10-1 0-0	76	39	0	100	40	30.38	30.25	11

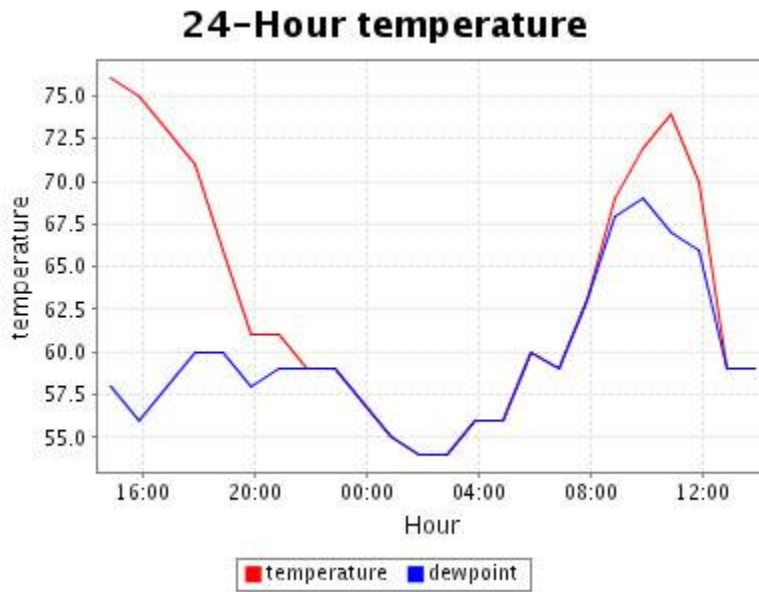


Figure 4. Meteograph depicting hourly temperatures and dewpoints at the Hillsborough, NJ, SafetyNet station between 3 PM September 28, 2005 and 2 PM September 29. Note the cold front passage close to noon on the 29th.

Quality control of ingested data is accomplished through an automated screening for extreme, unrealistic values and via a manual method that permits individual suspect variables to be eliminated from dissemination. All ingested data are stored; no observations are discarded.

Funds continue to be sought to complete full development of all network components. Along with this is a critical need to obtain support for NJWxNet operations and maintenance.

RWIS STATION METADATA

An important component of any observing station is metadata concerning that site, metadata being data about the data. Such information is being gathered for all NJWxNet stations. The first major effort in this direction was made when each RWIS station was visited. Station coordinates were recorded using global positioning system equipment and the location was photo-documented. This information may be found at <http://climate.rutgers.edu/njrwis/sites.html>. In addition to a series of photographs providing a general view of a station, pictures were taken in the four major cardinal directions away from a station and a fisheye (180 degree) picture was taken looking upwards very close to the station. The photographs help provide an understanding of observations. For instance, should the station be very close to pavement, a higher daytime temperature might be expected on a sunny day compared to an observation made in a nearby field. For the most part, we are pleased to report that the locations of RWIS stations are acceptable, permitting them to be used in NJWxNet overviews of current statewide conditions. The microclimate surrounding a station is particularly important to understanding observations (especially temperature) and to determine if readings can be combined with and compared to data gathered at other stations. Rarely does a RWIS station sit right by the warmth of a road. The majority of stations are somewhat distant from foliage that might obscure a large portion of the sky above a station and cast shadows on a station, thus creating

lower temperatures than nearby stations (and not adhering to World Meteorological Organization (WMO) siting standards). It needs mentioning that some stations have closed (e.g., those with Vaisala instrumentation) during the course of this project (station visits were conducted early in the project). Others began operating but have not been visited and photographed and we understand that as many as five stations have been installed but are not yet operating. Also, we have not found precipitation sensor data to be useful, and recommend that at some point in the future, rain gages be installed at all RWIS locations.

CLIMATOLOGICAL EVALUATION OF RWIS STATION DISTRIBUTION

Background

As mentioned in the Overview, the distribution of RWIS stations across New Jersey is not sufficient to adequately monitor the wide range of weather conditions that impact road travel. While this was understood prior to the commencement of this project, the purpose of this project was to identify where the most important meteorological “gaps” in coverage are situated. An evaluation of climatological conditions across the State was needed to assess the coverage and provide guidance for future station installations. This required a network of stations with well-distributed spatial coverage and approximately 30 years of observation (30 years being the WMO standard for climatological means). Fortunately, the National Weather Service’s Cooperative Observing Station (COOP) Network fulfills these two requirements. Daily observations from 46 of these sites in New Jersey are available for the 1971-2000 interval (a WMO standard interval for climate normals) (figure 5, table 4). Trained volunteers use standard NWS-supplied instrumentation to measure precipitation, snowfall, and maximum and minimum temperatures on a daily basis at these COOP sites. All data are sent to the National Climatic Data Center in Asheville, North Carolina, where observations are digitized, quality controlled, archived, and made available to interested parties.

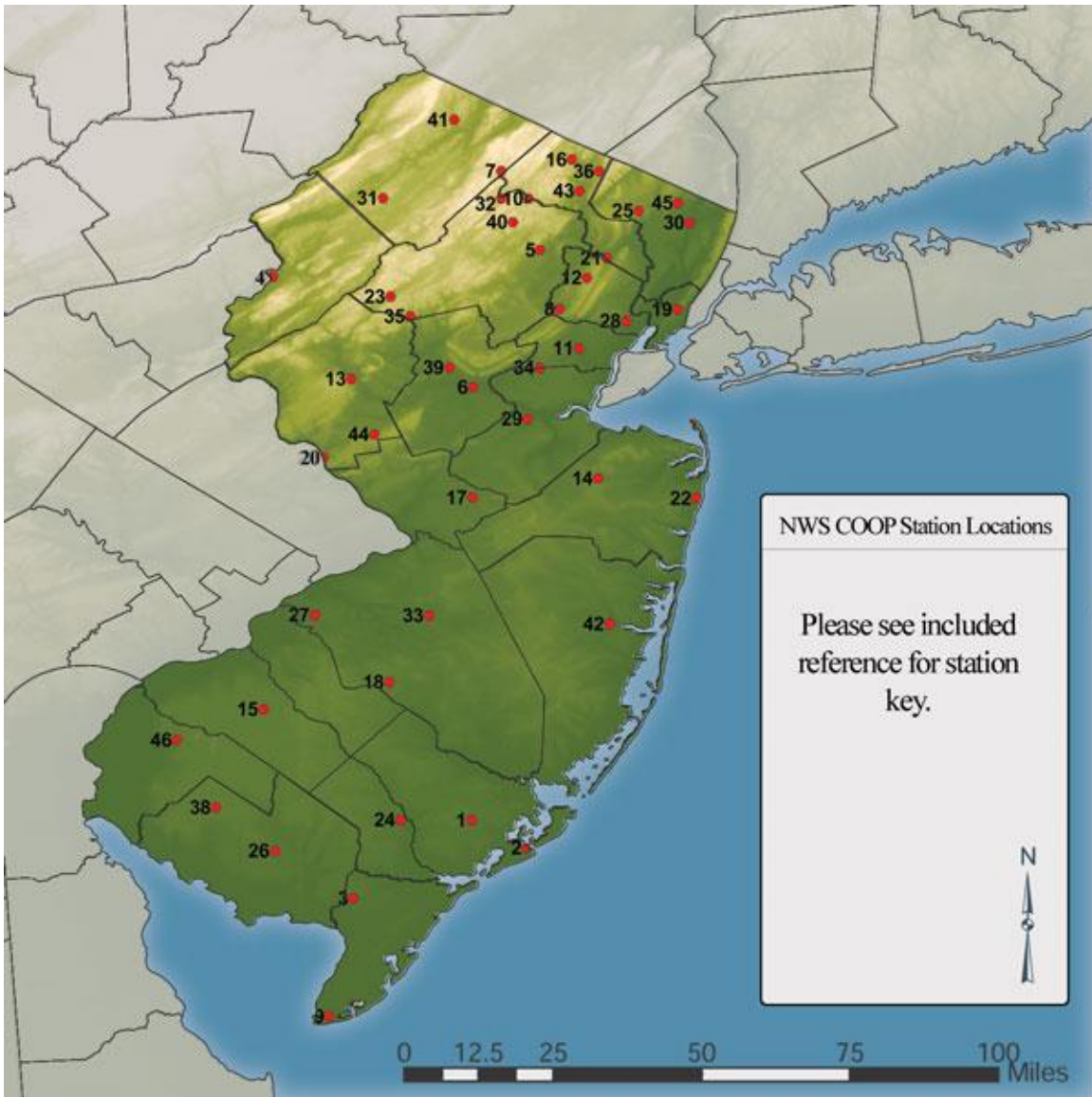


Figure 5. Locations of COOP stations used in climatological evaluations. Numbers on the map correspond to stations listed in table 4.

Table 4. National Weather Service Cooperative Observing stations employed in project climatological evaluations. Note that some stations only report precipitation (PCP:P), others report both P and temperature (TMP:T), and fewer report snowfall (SNO:S). Station numbers correspond to their location, as shown in figure 5.

STATION	Elevation (ft)	TMP	PCP	SNO
1. Atlantic City Airport	60	T	P	S
2. Atlantic City Marina	10	T	P	
3. Belleplain St. Forest	30	T	P	S
4. Belvidere Bridge	263	T	P	
5. Boonton	280	T	P	S
6. Bound Brook	50		P	
7. Canistear Res.	1100		P	S
8. Canoe Brook	180	T	P	S
9. Cape May	20	T	P	S
10. Charlottesville Res.	760	T	P	S
11. Cranford	75	T	P	S
12. Essex Fells	350	T	P	
13. Flemington	260	T	P	S
14. Freehold	194	T	P	
15. Glassboro	100	T		
16. Greenwood Lake	470		P	S
17. Hightstown	100	T	P	S
18. Indian Mills	100	T	P	S
19. Jersey City	135	T	P	
20. Lambertville	68	T	P	S
21. Little Falls	150	T	P	
22. Long Branch	30	T	P	S
23. Long Valley	550	T	P	S
24. Mays Landing	20		P	S
25. Midland Park	210		P	S
26. Millville Airport	70	T	P	S
27. Moorestown	45	T	P	
28. Newark Int. Airport	7	T	P	S
29. New Brunswick	86	T	P	S
30. New Milford	12		P	
31. Newton	605	T	P	S
32. Oak Ridge Res.	880		P	S
33. Pemberton	60	T	P	S
34. Plainfield	90	T	P	S
35. Pottersville	365		P	S
36. Ringwood	305		P	
37. Sandy Hook	10	T	P	
38. Seabrook Farms	90	T	P	
39. Somerville	134	T	P	S
40. Split Rock Pond	800		P	
41. Sussex	450	T	P	S
42. Toms River	100	T	P	
43. Wanaque Dam	245	T	P	
44. Wertsville	220	T	P	
45. Woodcliff Lake	103		P	
46. Woodstown	98	T	P	S

Temperature, precipitation (rain and melted snowfall), and snowfall data for the 30-year interval were extracted from a database assembled within the ONJSC. Throughout this report, all values are in inches and degrees Fahrenheit, the public standard within the United States. No more than five years of data could be missing from the 1971-2000 interval for a station to be used in the study. A variety of climatological values were calculated for each station using the baseline data. Examples include mean monthly temperatures and precipitation, number of days annually with the daily maximum temperature equaling or exceeding 90 degrees, number of days with precipitation exceeding one inch, and number of days with snowfall greater than an inch. See table 5 for a list of all the climatological values generated for this project.

Mapping

Station climatological values were used to construct statewide maps. Together, the 46 maps produced represent the most complete atlas of NJ climatology produced to date. Maps were generated using ArcGIS software. Point values were used to create interpolated, color-filled maps. Inverse Distance Weighted (IDW) interpolation was employed in the process. IDW interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. It weights the points closer to the prediction location greater than those farther away. The interpolation did not take into account local and regional variations in topography found particularly in the northern portion of the State. Note from the station elevations listed in table 3 that there is an absence of reports from the highest elevations in the State. Proximity to the Atlantic Ocean was only considered in so much as several stations sit rather close to the coast. These shortcomings will be considered when discussing optimal station placement.

Maps depict temperature, precipitation, and snowfall monthly or seasonal totals, means, thresholds, and standard deviations. Color depictions vary from variable

Table 5. Climatological values generated for this project.

Variable	Generated for month or variable listed
Average monthly precipitation	January, February, March, April, July, October, December
Standard deviation from statewide average monthly precipitation	January, February, March, April, July, October, December
Average annual number of days with precipitation equaling or exceeding:	0.01", 0.10", 1.00", 2.00"
Standard deviation from statewide average annual number of days per year with precipitation equaling or exceeding:	0.01", 0.10", 1.00", 2.00"
Winter seasonal snowfall (October-May)	1997-1998, 1995-1996
Average annual number of days with snowfall equaling or exceeding:	0.5", 1.0", 4.0"
Standard deviation from statewide average annual number of days with snowfall equaling or exceeding:	0.5", 1.0", 4.0"
Average monthly minimum temperature	January, February, March, December
Standard deviation from statewide average monthly minimum temperature	January, February, March, December
Average annual number of days with minimum temperatures equal to or less than:	32°F, 20°F, 0°F
Standard deviation from statewide average annual number of days with minimum temperatures equal to or less than:	32°F, 20°F, 0°F
Average annual number of days with maximum temperatures equal to or greater than:	90°F, 100°F
Standard deviation from statewide average annual number of days with maximum temperatures equal to or greater than:	90°F, 100°F

to variable, with colors selected to best illustrate similarities and differences noted across New Jersey. The locations of operational RWIS stations are shown on each map, but not the location of Cooperative Weather Stations that were employed in generating the maps. This approach was taken so as to best depict RWIS coverage in comparison with the spatial variability of the various climatological measures. Special mention must be made of the standard deviation maps. Station standard deviations were calculated with respect to the multi-station statewide mean for a particular variable and map. This contributes to a more thorough evaluation of regional patterns of a particular variable within a month, more consistent interseasonal single variable comparisons, and in some regards, simpler comparisons between the distributions of different variables. For instance, with respect to precipitation, the inter-regional and month-to-month differences in measured precipitation are not substantial in most cases, thus demonstrating the utility of the standard deviation approach in enhancing differences.

Evaluation

An exhaustive evaluation of each of the project maps would be filled with redundancies and too much detail to prove of use in this investigation. Rather, a representative subset of maps will be displayed and discussed, with all maps posted on the project website (<http://climate.rutgers.edu/stateclim/njdot>). These evaluative efforts concentrated on the winter season, however other seasons were not ignored, as weather hazards associated with the maintenance, operation, and safety of New Jersey's roadways occur in all seasons.

Precipitation

Due to New Jersey's middle latitude coastal location, precipitation is relatively abundant and consistent, at least in a 30-year climatological sense, throughout the year. February is the driest month throughout most of the State, with totals at most locations within a half-inch of 3.00". July and August vie for the wettest

month of the year (do not be fooled by the lack of standing water on land during these months, as this is a result of evaporation exceeding precipitation during the summer). Summer monthly totals generally range from 4.00" to 5.00", except approximately an inch lower in southern coastal counties.

Most every month of the year exhibits a similar pattern of precipitation distribution across New Jersey. A maximum is found in the north central Highlands, with a minimum along the southern coast. The cool season months show a secondary maximum along the northern coast, and in late winter and early spring over inland southern areas. Summer precipitation is most abundant in inland portions of the State, particularly in the west central counties.

The primary precipitation pattern is a result of a broad maritime influence in the southern coastal areas that inhibits warm season rainfall associated with thunderstorms. In the cool season, this area of the State is at times farther from a storm track through the Ohio Valley and Great Lakes, and south of nor'easters that may not attain their greatest strength until off the New England coast. Northern areas of the State are closer to winter storms. Highlands maximums are also a function of elevation-induced enhancement. As moist air comes in from the west or off the ocean, it is lifted, condensation increases, and more precipitation falls. Conversely, a flow from the southeast crosses over the Highlands and then sinks once past them to the northwest. This results in a minor rain shadow or diminution of precipitation in the northwest valleys. Winter precipitation patterns are evident in January precipitation and standard deviation maps (figures 6-7).

July maps (figures 8-9) best depict the warm season pattern, where inland lower elevation precipitation is enhanced by a dominance of convective, showery type precipitation over these warmest areas of the State. Cooler conditions in the Highlands and northwest valleys result in less convection than farther south

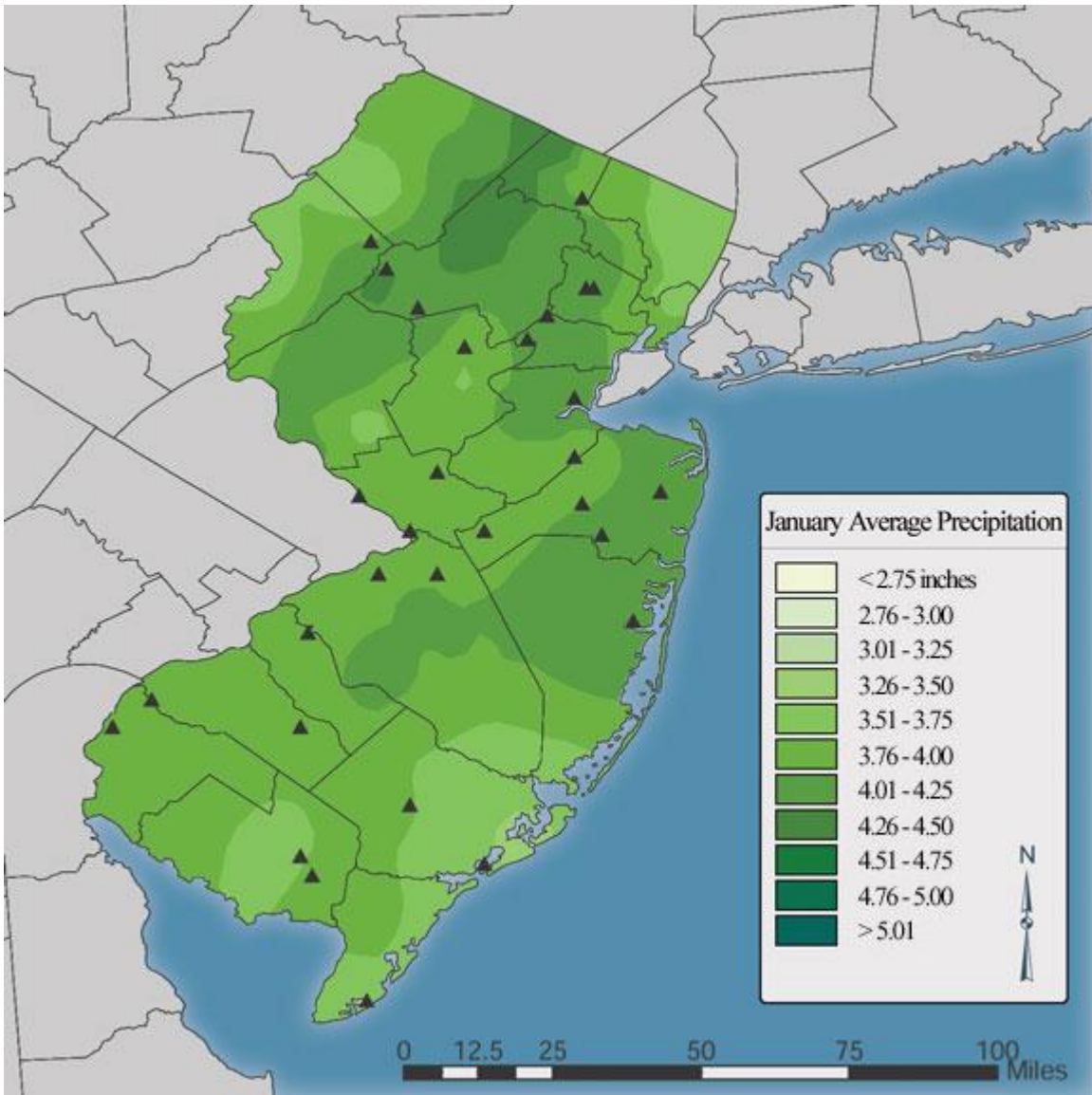


Figure 6. Average January precipitation based on observations from precipitation stations listed in table 4 for the period 1971-2000.

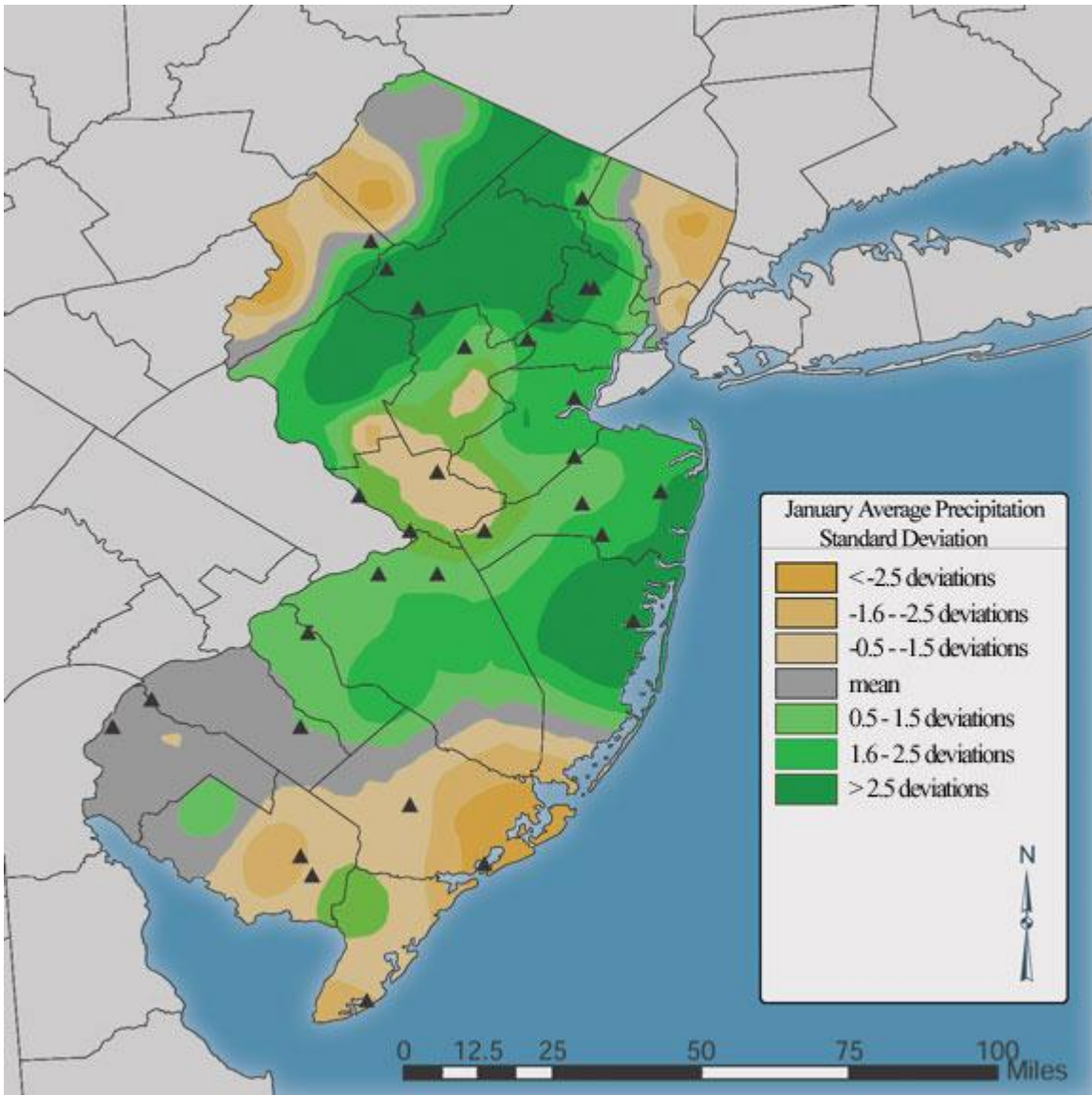


Figure 7. Standard deviations from the statewide average of January precipitation based on observations from precipitation stations listed in table 4 for the period 1971-2000.

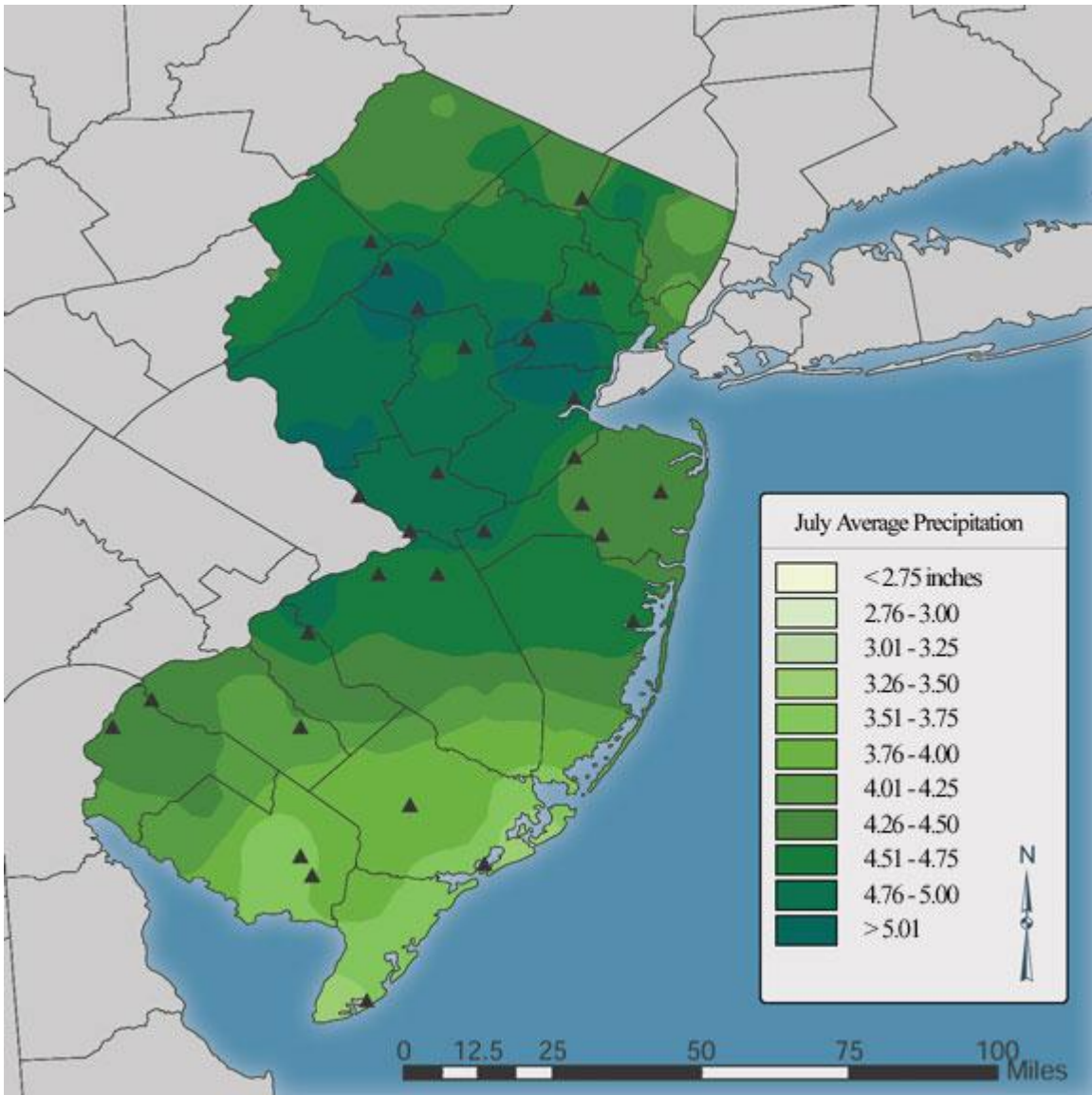


Figure 8. Average July precipitation based on observations from precipitation stations listed in table 4 for the period 1971-2000.

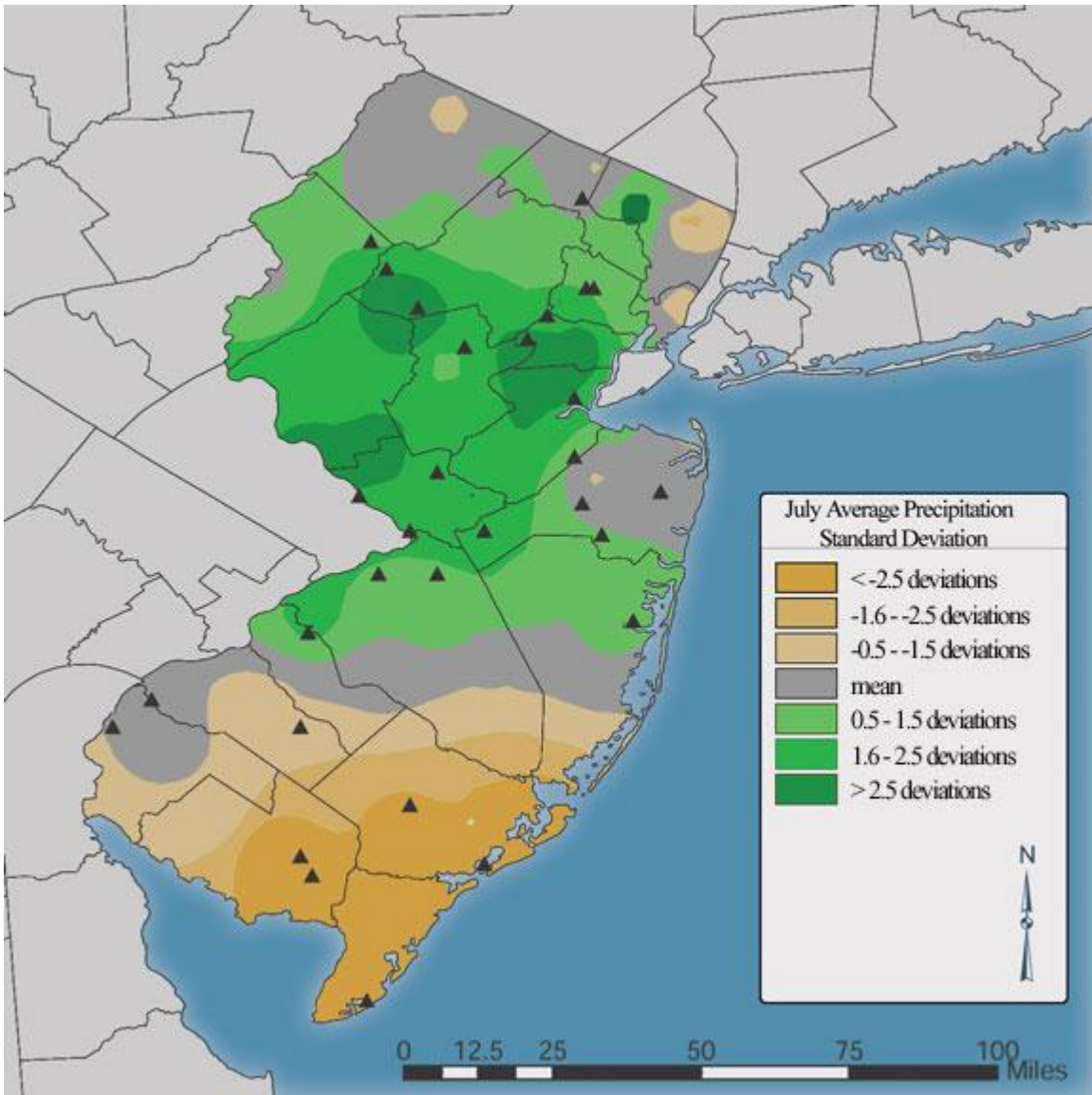


Figure 9. Standard deviations from the statewide average of July precipitation based on observations from precipitation stations listed in table 4 for the period 1971-2000.

in the more atmospherically unstable Piedmont and Inner Coastal Plain. The nearby cooler, more stable ocean and Delaware Bay inhibit convection in coastal areas, particularly the southern coast, thus the primary producer of warm season precipitation is diminished.

The amount of precipitation falling within a month or season and the characteristics of its regional distribution are critical in the decision process regarding the distribution of roadside weather monitoring. So too is the frequency of precipitation events. This includes not only how often it precipitates, but also how often events of different magnitudes occur. Therefore four map pairs were generated based on station observations of just how many days each year precipitation may be expected that exceeds 0.01", 0.10", 1.00" and 2.00" (number of days and standard deviations). Roughly one third of the annual daily measurable (at least 0.01") events are less than 0.10", which clearly minimizes runoff, ponding or flooding. However if that precipitation is in frozen form, should it fall as liquid on frozen surfaces (bridges being especially prone to this), or should it fall following a lengthy absence of any precipitation (thus oil may have accumulated on roadways and enhance slippery conditions when roads are wet), even this minimal amount may cause traffic hazards. More than a tenth of an inch, unless falling very slowly over the course of an entire day, will lead to some puddling and runoff. Roadways are not prone to flooding until an inch has fallen. Unless the rainfall is of a short, intense nature, significant flooding will not occur from the presence of poor roadway drainage or overwash from adjacent flooded streams and rivers until more than two inches falls in a day. With these larger values, we are mainly speaking of rainfall, as snowfall events having liquid water contents of such large magnitudes are relatively scarce in New Jersey, and obviously pose problems other than flooding (at least until they melt and/or block storm drains).

Measurable precipitation falls on all areas of New Jersey approximately 100 to 130 days each year (figure 10). As the daily precipitation amounts increase, the number of days with such events decreases, as do ranges between lowest and highest counts across the State. Generally, a tenth of an inch or more falls on 70 to 90 days, at least an inch on approximately 10-15 days, and two or more inches on 1 to 4 days (figures 11-13). As best seen on the standard deviation maps, there is generally a two-region pattern of precipitation days for each of the four thresholds, that being a north maximum and south minimum (figure 14).

However within each of these regions there are some interesting inter-threshold differences. In the north, days with measurable precipitation are greatest in the northwest, while the Highlands have the most one inch or larger events. Inland southern counties have fewer precipitation days than in the coastal south, however have more days of inch or greater precipitation than their coastal neighbors. The northern pattern may be explained by the proximity of the northwestern corner to the often-lingering cloudiness and showery precipitation of the inland higher elevations of Pennsylvania and New York. The Highlands enhancement is a result of the wettest airflows being lifted by the hills as moisture streams in from the ocean. In the south, coastal areas experience lingering clouds and showers more often than inland, but are spared from as many soaking convective summer rains than inland reaches.

Snowfall

New Jersey's middle latitude location results in snow falling in all portions of the State each winter. There have been several unusual winters in the past century when measurable snow (≥ 0.1 ") has failed to fall or been almost absent over southern portions of the State, but these are rare exceptions. On average, seasonal snowfall totals 10"-20" in the southern third of the State, 20-30" in the central third and 30-40" in the lower elevations of the northern third. The higher northern locations receive 40-60". These averages are not particularly meaningful, as interannual variations may be on the order of feet.

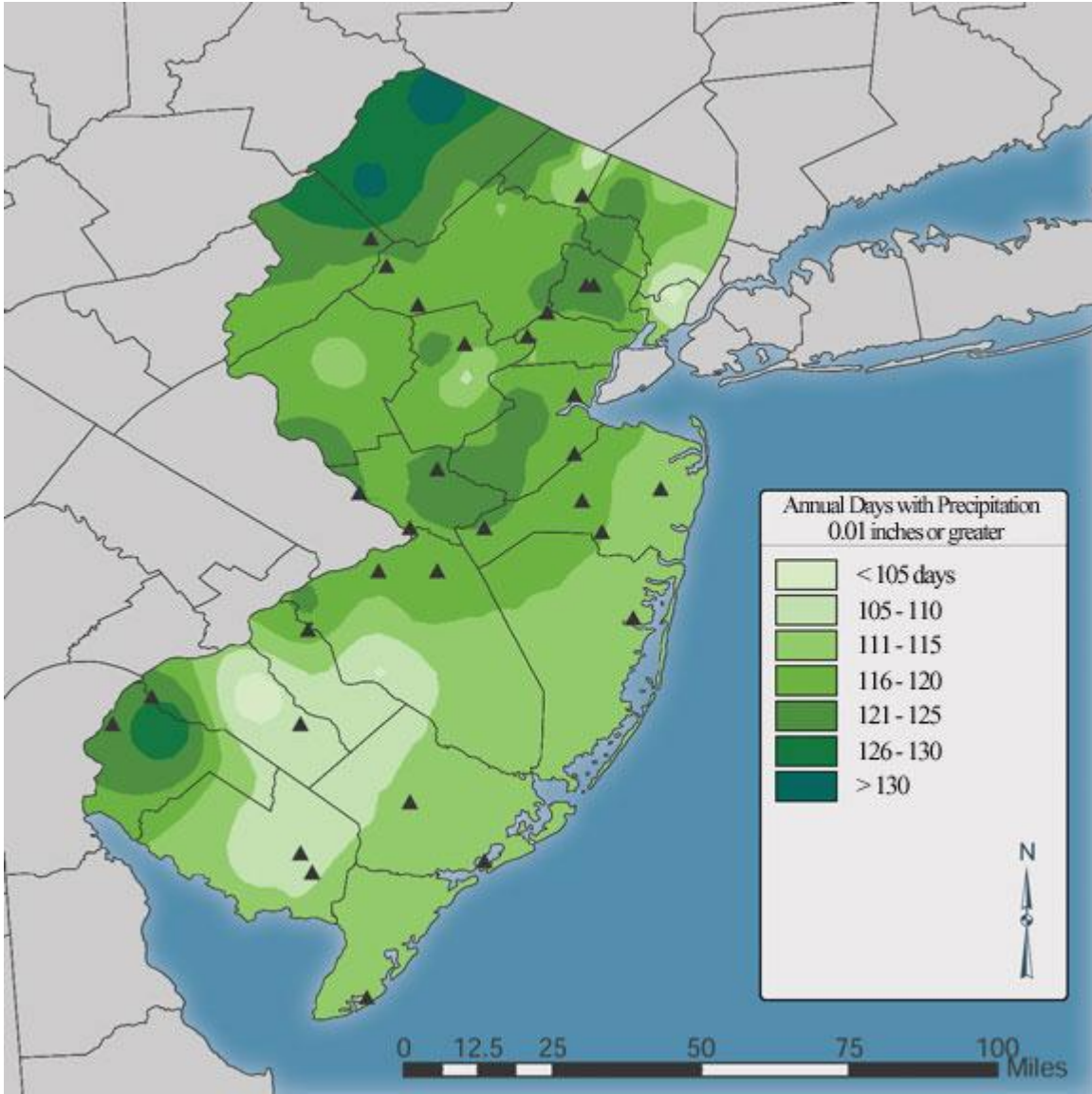


Figure 10. Average annual number of days with precipitation ≥ 0.01 " based on observations from precipitation stations listed in table 4 for the period 1971-2000.

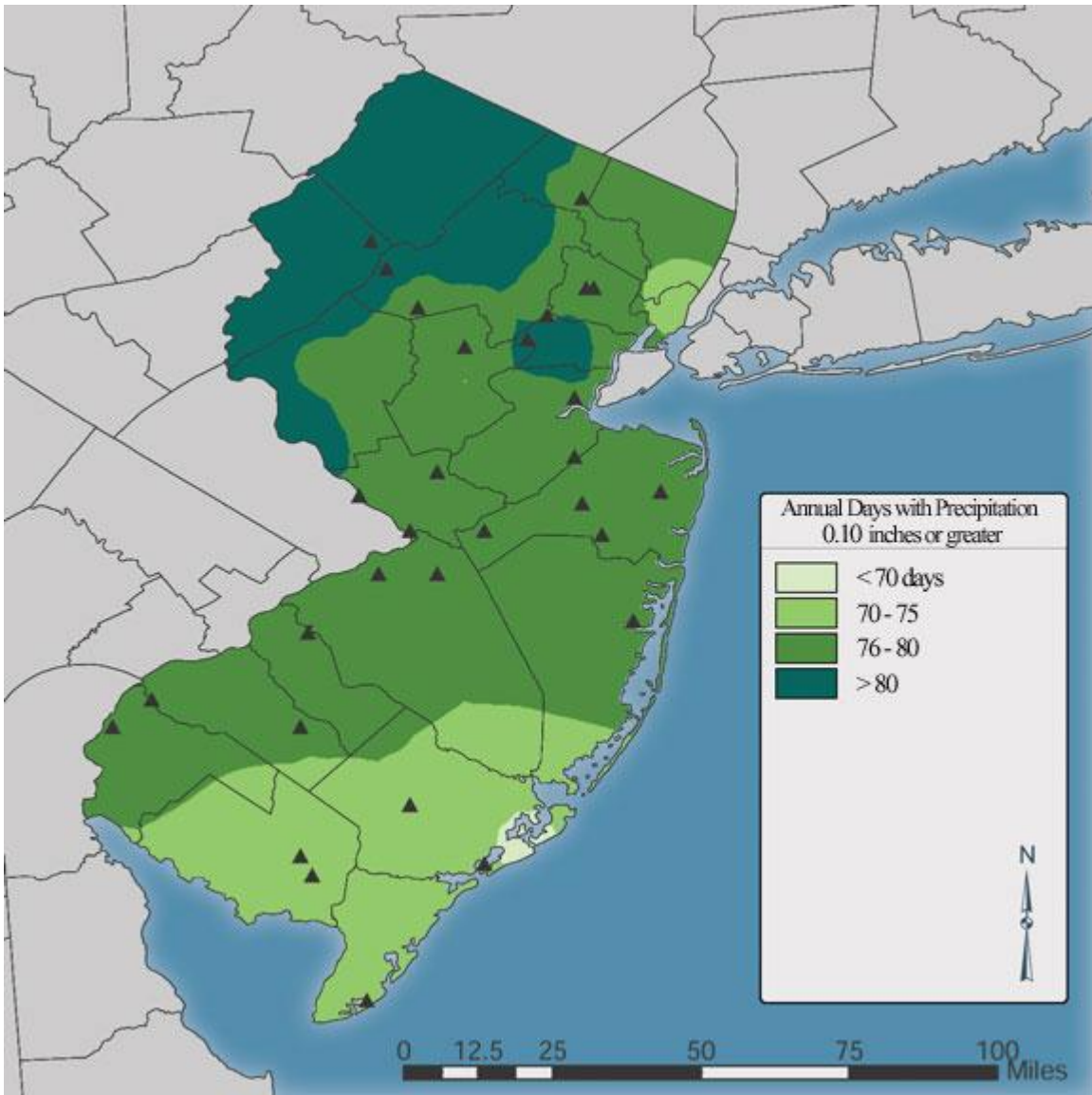


Figure 11. Average annual number of days with precipitation $\geq 0.10''$ based on observations from precipitation stations listed in table 4 for the period 1971-2000.

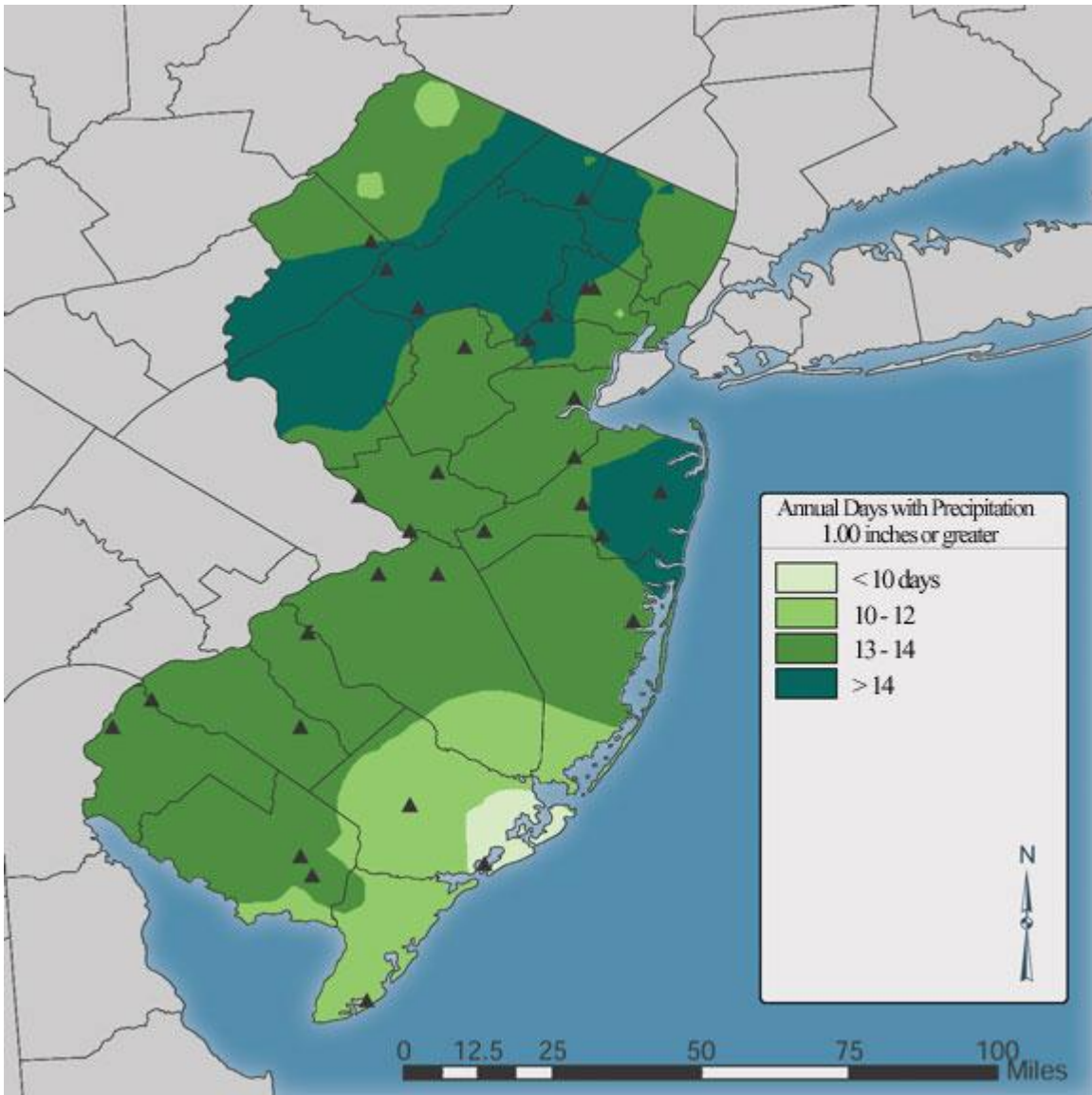


Figure 12. Average annual number of days with precipitation ≥ 1.00 " based on observations from precipitation stations listed in table 4 for the period 1971-2000.

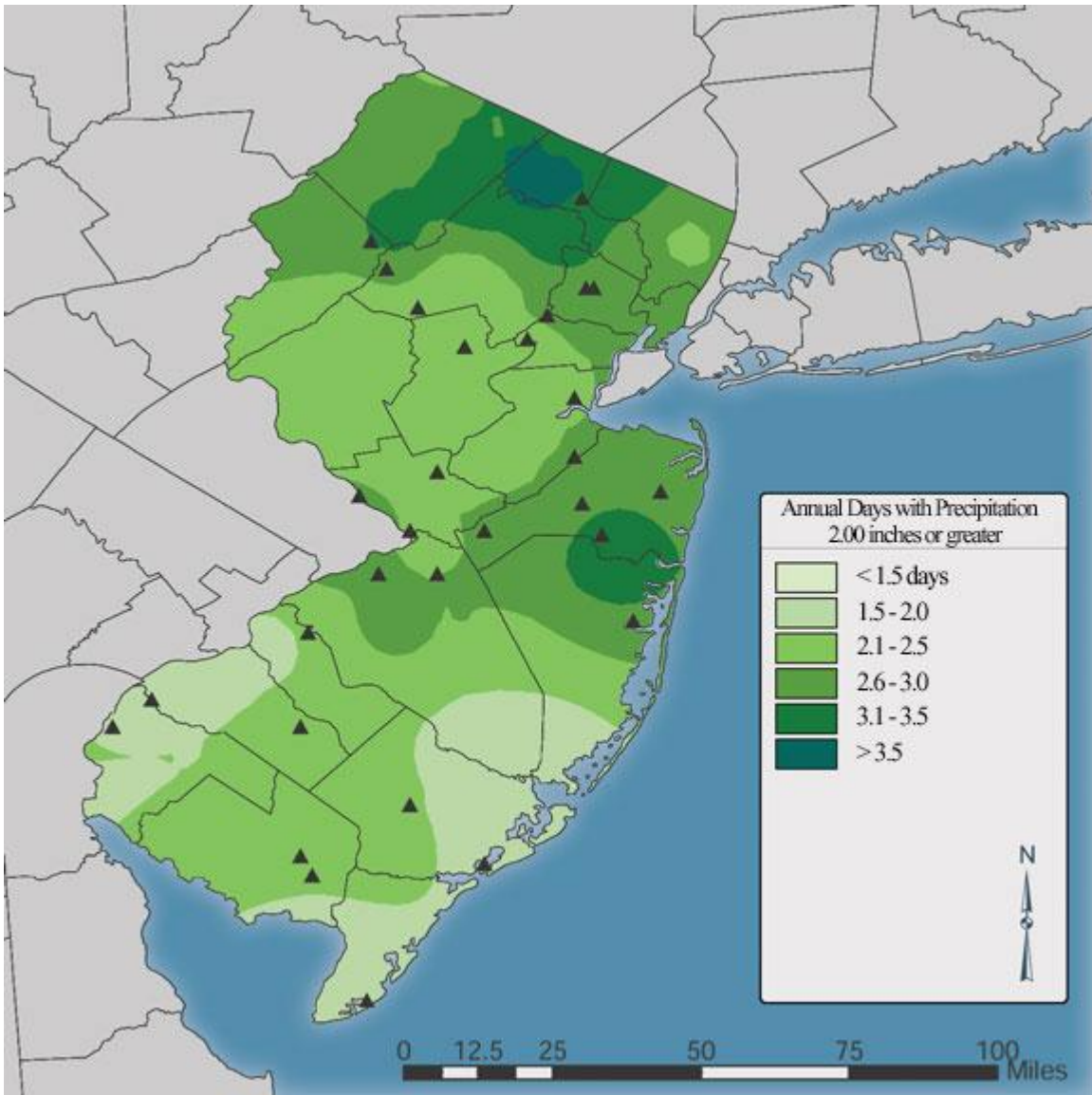


Figure 13. Average annual number of days with precipitation ≥ 2.00 " based on observations from precipitation stations listed in table 4 for the period 1971-2000.

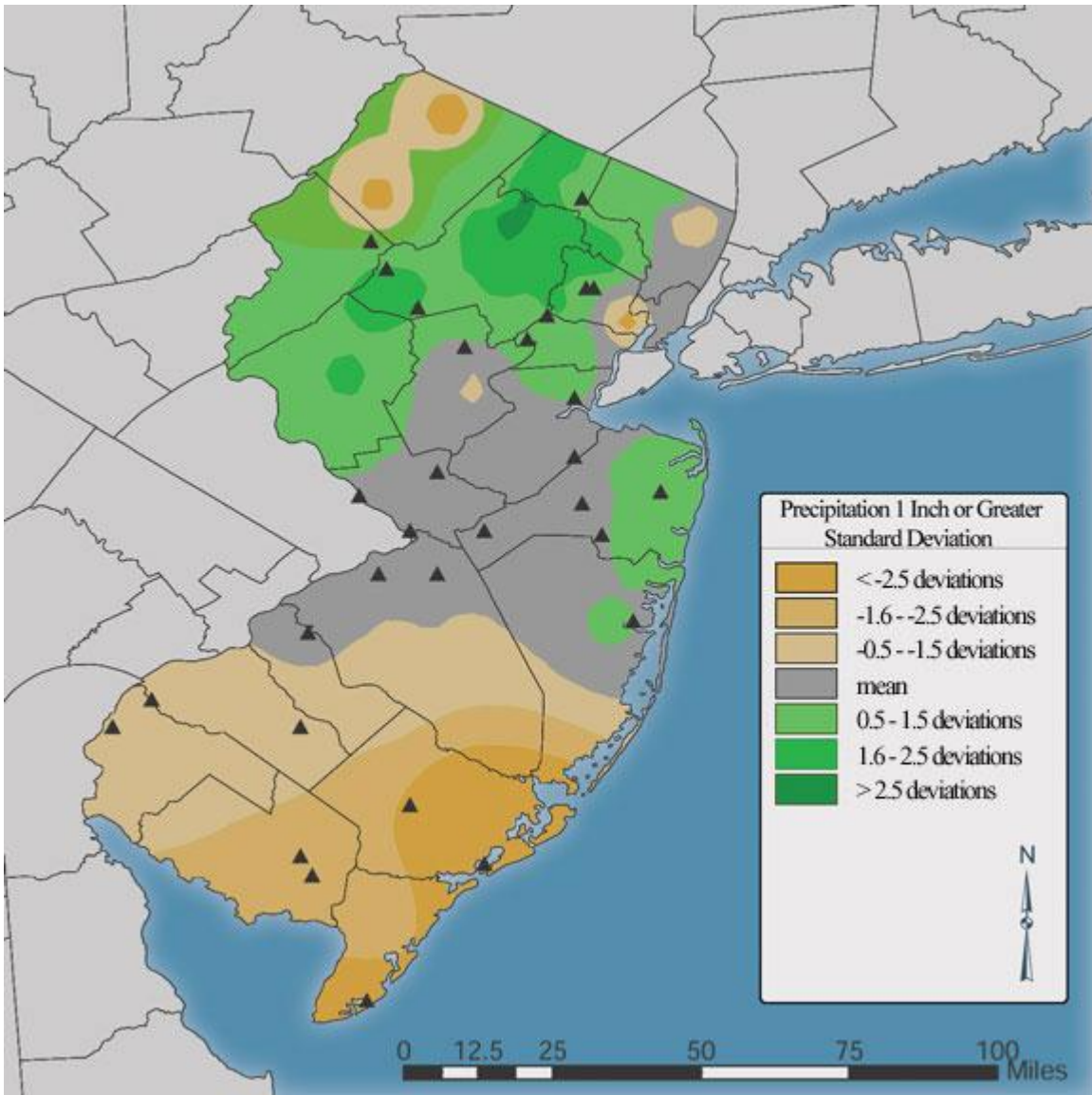


Figure 14. Standard deviations from the statewide average annual number of days with precipitation ≥ 1.00 " based on observations from precipitation stations listed in table 4 for the period 1971-2000.

Two winters within the past decade exemplify the variability. Statewide, the winter of 1997/98 was one of the least snowy on record (1972-73 had the least snow) (figure 15). Less than 5" fell in most of southern and central NJ, with only the northwest corner of the State having close to half of their annual average. Conversely, the winter of 1995/96 was the snowiest on record in NJ (figure 16). As much as 110" fell at High Point, with record breaking amounts, as much as 20" over former records, in northeast and central NJ. Less snow fell to the south, however totals still were commonly twice or more the annual average.

Despite measuring snow in feet over the course of many a winter, days with snowfall of ≥ 0.5 " are not too numerous (figure 17). On average, they range from about four days in coastal counties to more than a dozen in northwest New Jersey. It bears repeating that observing stations used in this study sit at low elevations in the northwest, with hilltops in the region receiving more snow throughout the season. Days with ≥ 1.0 " of snowfall range from less than four in the far south to about a dozen (figure 18). The number of days with more significant snowfall, those with totals ≥ 4.0 ", are less common (figure 19). These plowable events number from one to three over most of the State. It is not that unusual for a season to pass without a single such event in the south and along the coast. Conversely, it is rare for the northwest to go a year without such a snowfall. It is also possible that a snowfall event may bridge two days, resulting in a greater frequency of larger episodes than the daily analysis suggests. Six inch, 10" or even greater events occur from time to time in all regions of the State, however their frequencies do not lend themselves toward meaningful mapping.

Temperature

The following climatological discussion of temperatures is divided into winter and summer seasons. Temperatures in each season play a role in road safety and maintenance, however winter cold is more of a concern. This report

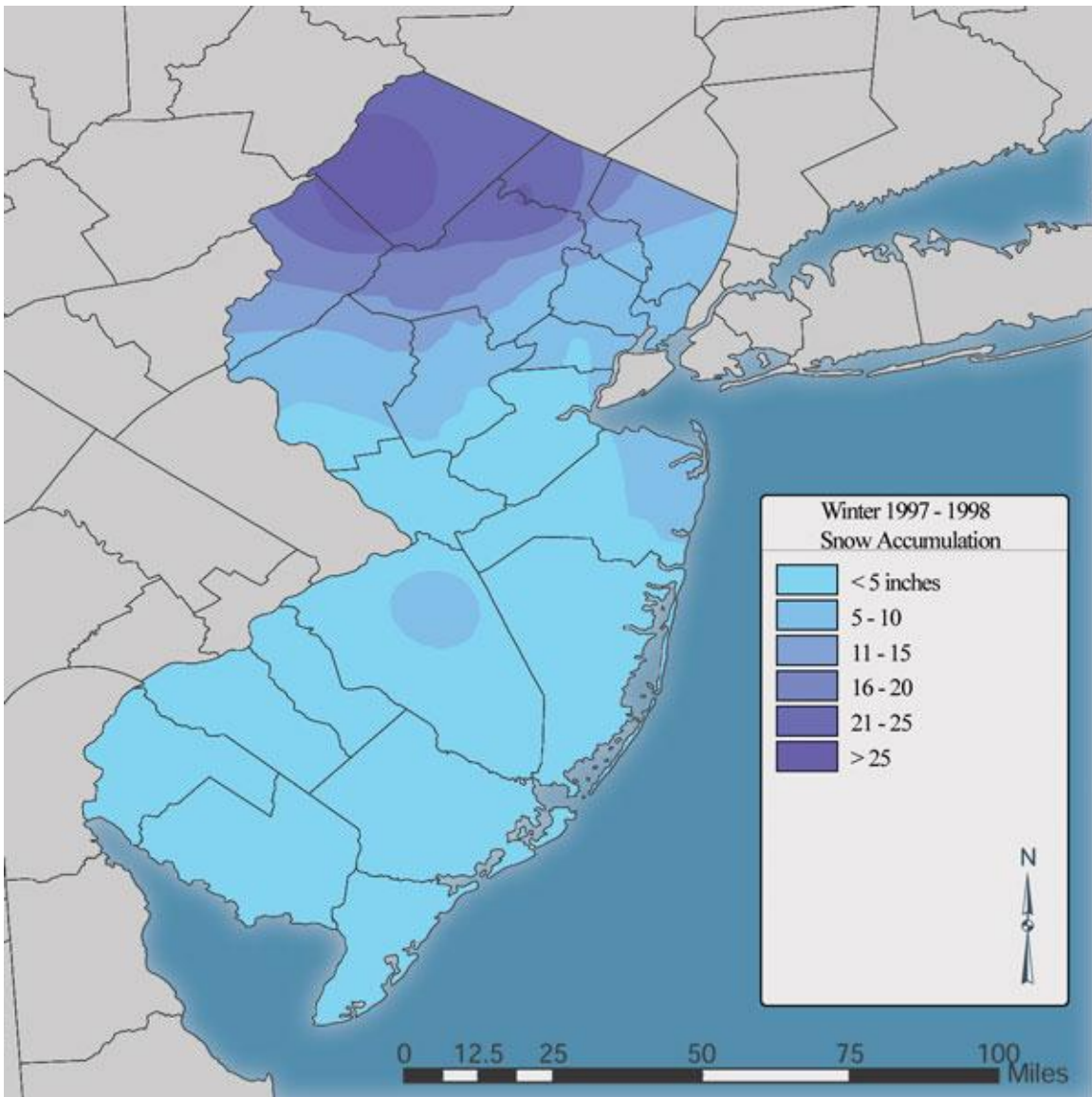


Figure 15. Snowfall during the 1997-1998 season. Based on 15 COOP stations with complete snow observations during this season.

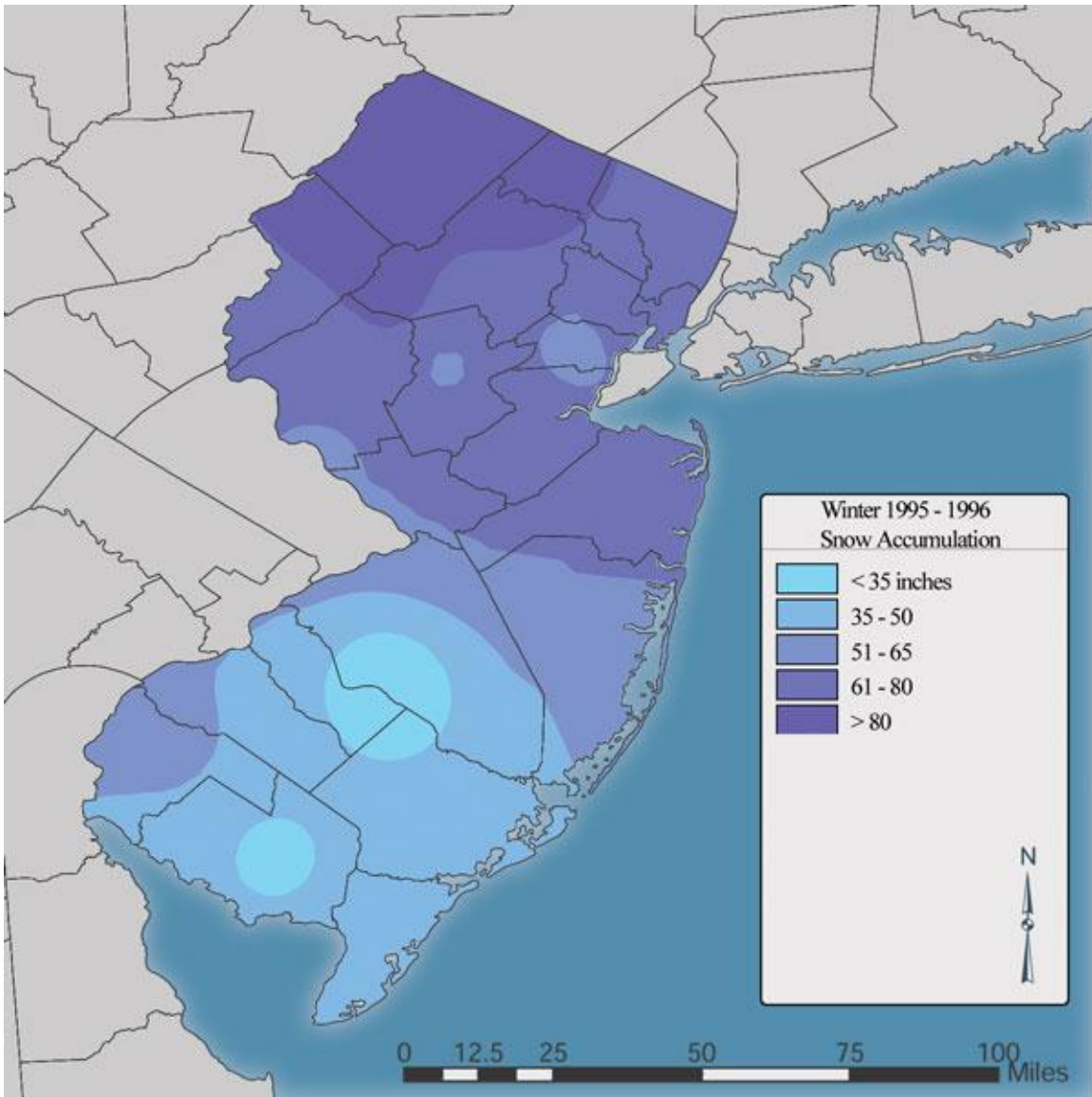


Figure 16. Snowfall during the 1995-1996 season. Based on 15 COOP stations with complete snow observations during this season.

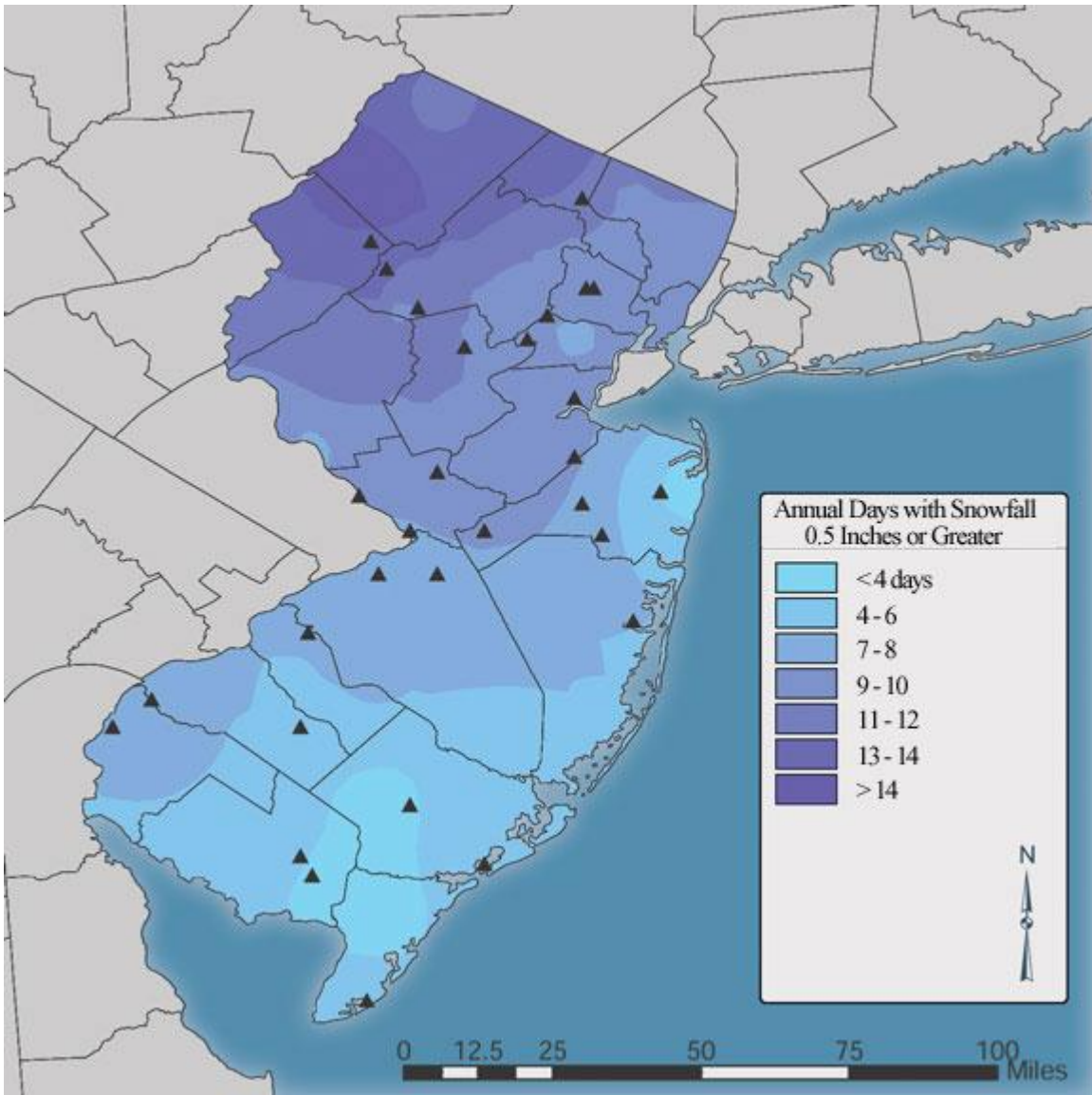


Figure 17. Average annual number of days with snowfall ≥ 0.5 " based on observations from snow stations listed in table 4 for the period 1971-2000.

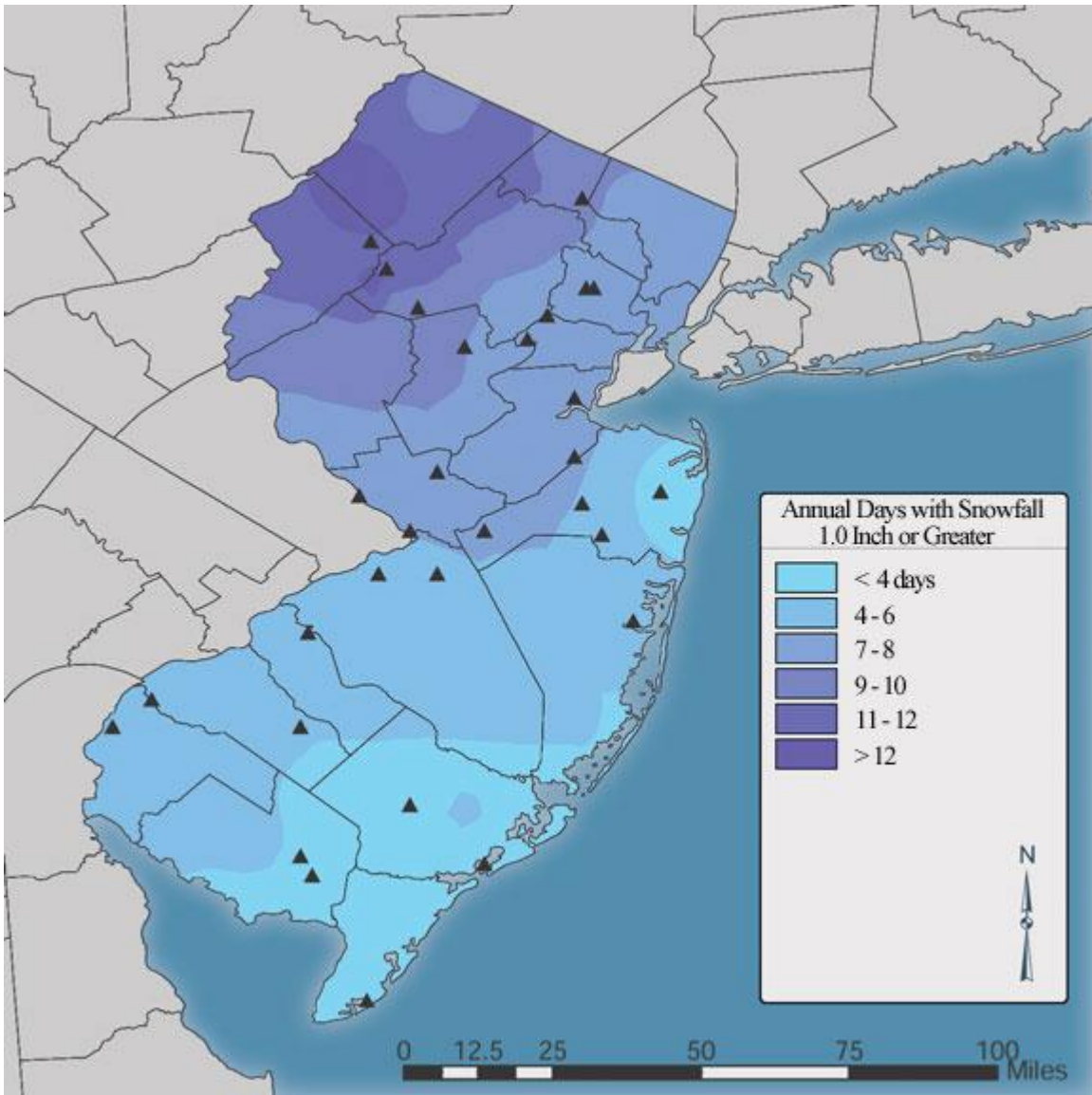


Figure 18. Average annual number of days with snowfall ≥ 1.0 " based on observations from snow stations listed in table 4 for the period 1971-2000.

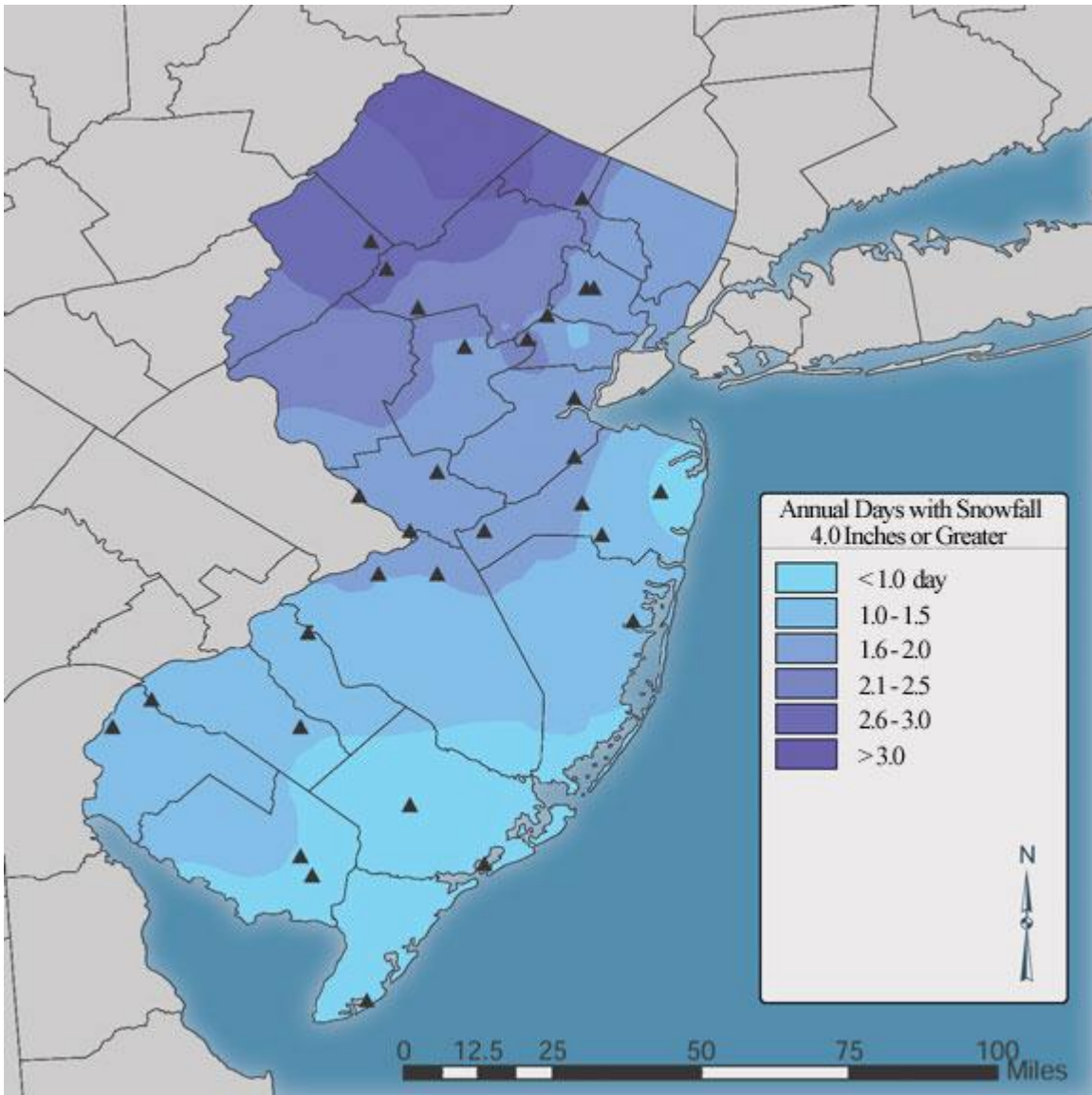


Figure 19. Average annual number of days with snowfall ≥ 4.0 " based on observations from snow stations listed in table 4 for the period 1971-2000.

concentrated on winter minimum temperatures, including monthly average minimums and minimum thresholds. Minimums during the three core winter months of December, January and February average below freezing over the entire State, with the exception of some southern coastal locations in December (e.g., figure 20). Minimums generally average in the 20°F during these months, with the exception of the northwest, where January and February averages dip into the teens. March minimums run in the upper 20°F to low 30°F in the northern half of the State and the low to mid 30°F in the south. The spatial distribution of minimums in all months is extremely consistent. The standard deviation maps identify an urban heat island bias near Newark (e.g., figure 21). The Pinelands of south Jersey are somewhat colder than the adjacent coast and southwest farmlands.

Temperatures fall below freezing on as many as 150 days each year in the coldest portions of northwest NJ, while less than half that number occur along the southern coast (figure 22). The average lies between 90 and 110 days over two thirds of the State. The large majority of these “freeze days” will see the afternoon maximum temperature rise above freezing. These frequent freeze-thaw cycles, along with rather plentiful winter precipitation, create an ideal environment for pothole development throughout the State.

Temperatures well below freezing have impacts of their own on transportation in New Jersey. Lows of $\leq 20^{\circ}\text{F}$ occur on more than 60 days in the northwest, while only a third of that number are found in southern coastal locations (figure 23). A common number for the majority of New Jersey is 20-30 days. Subzero lows on average occur only a day or two each year over most of the State (figure 24). Exceptions are the northwest, where as many or slightly more than six days on average exhibit such cold. Several consecutive years or more may go by without portions of the south or urban areas falling below zero.

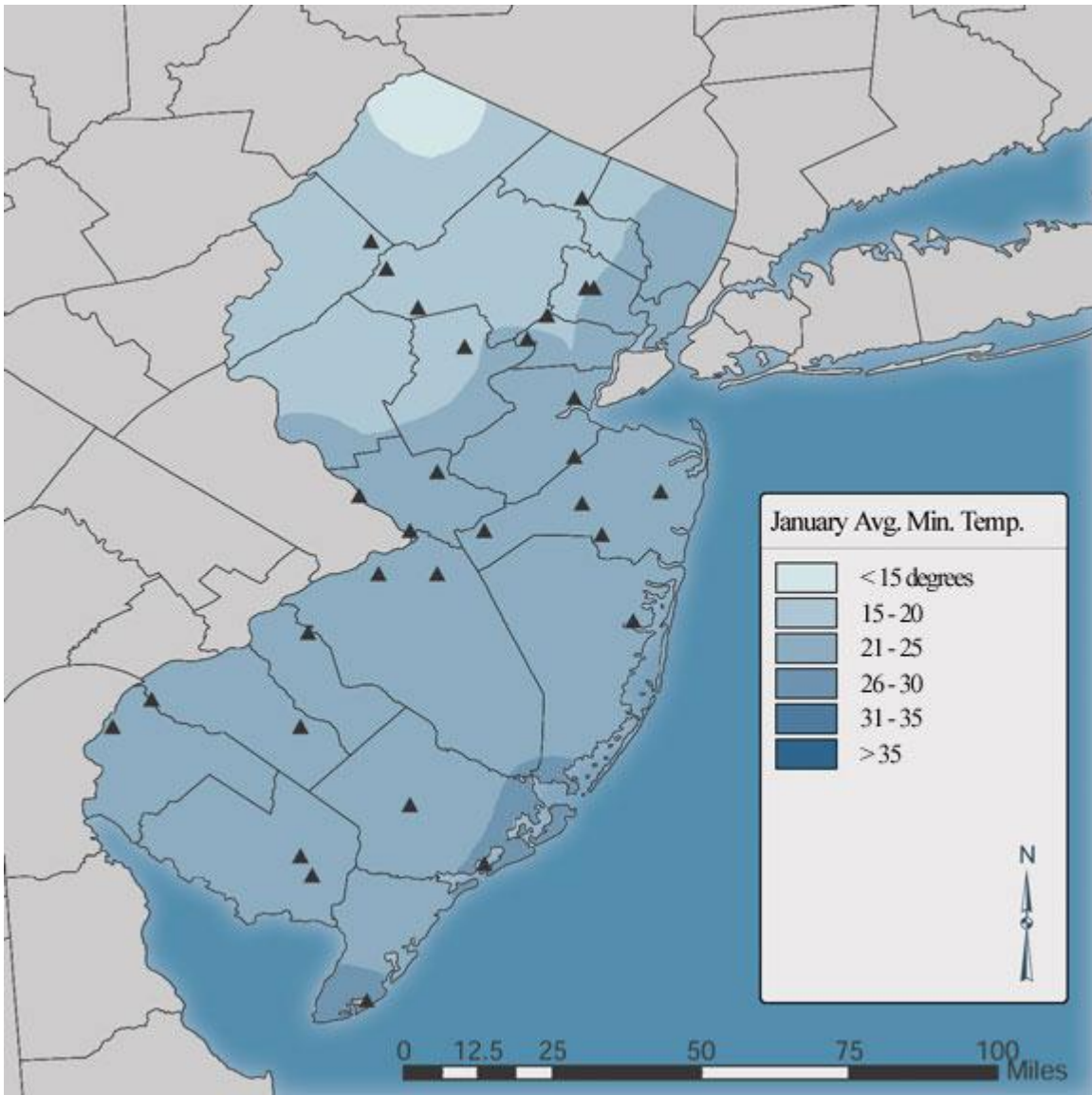


Figure 20. Average January minimum temperature based on observations from temperature stations listed in table 4 for the period 1971-2000.

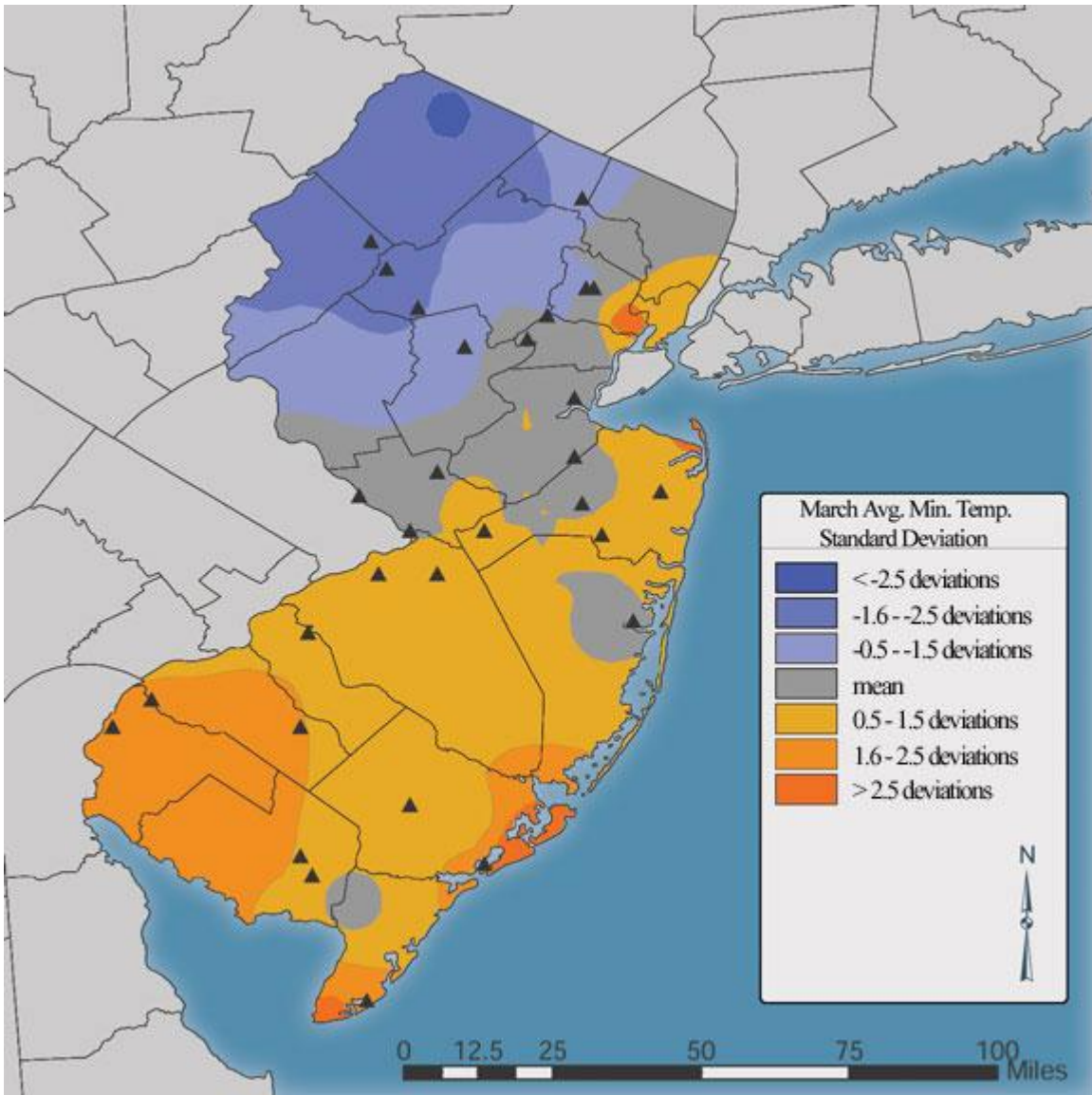


Figure 21. Standard deviations from the statewide average March minimum temperature from temperature stations listed in table 4 for the period 1971-2000.

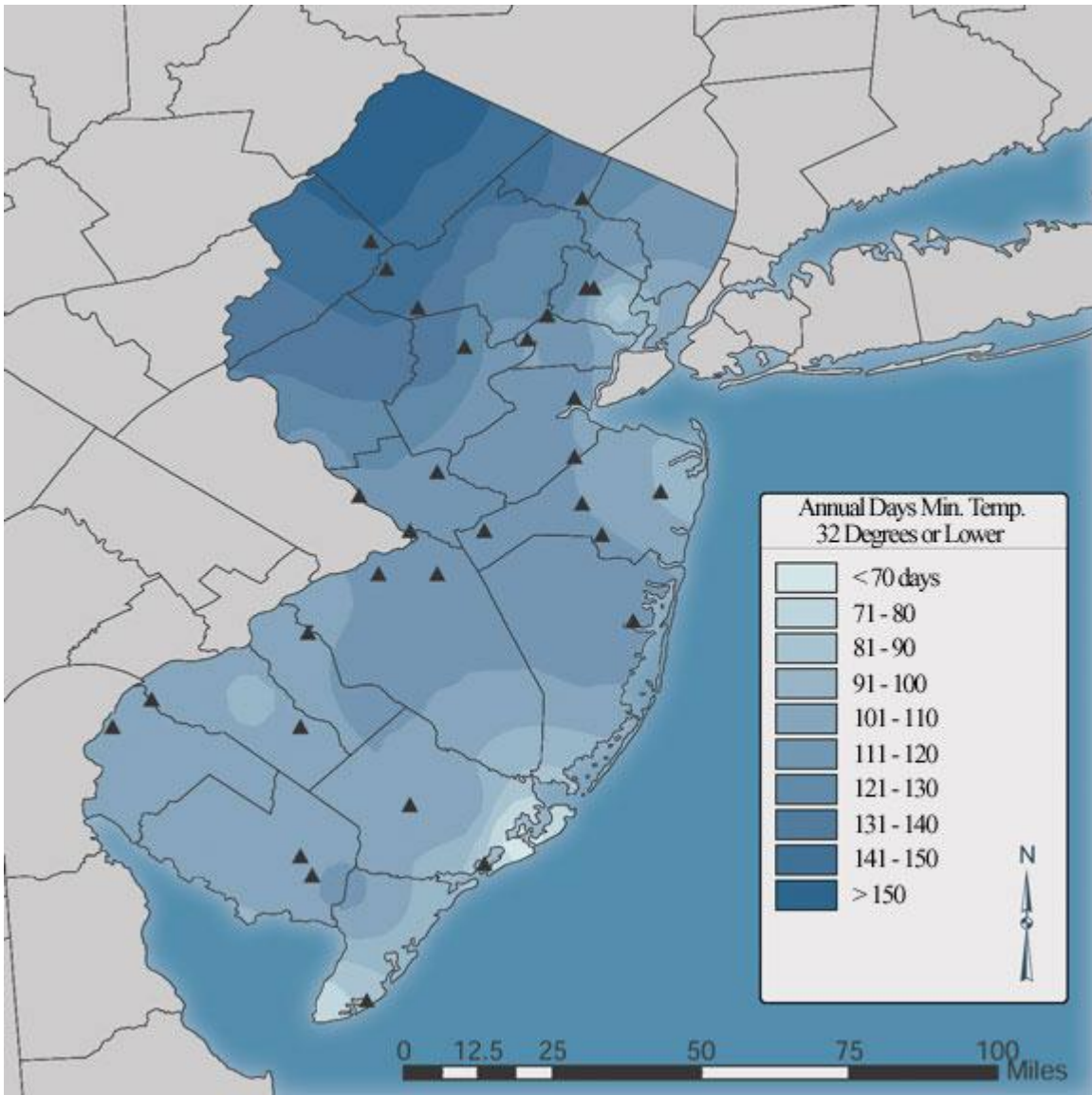


Figure 22. Average annual number of days with minimum temperatures $\leq 32^{\circ}\text{F}$ from temperature stations listed in table 4 for the period 1971-2000.

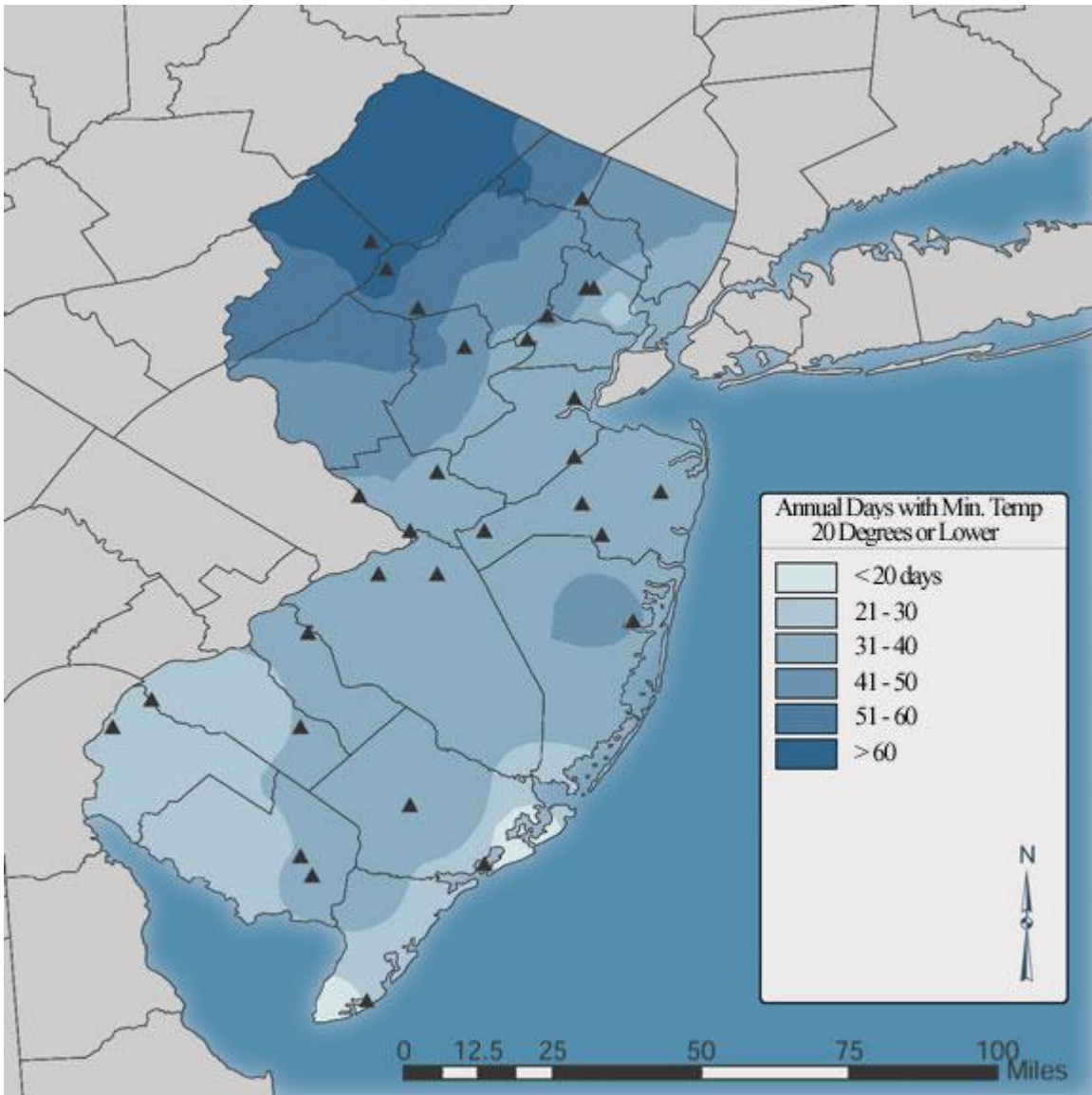


Figure 23. Average annual number of days with minimum temperatures $\leq 20^{\circ}\text{F}$ from temperature stations listed in table 4 for the period 1971-2000.

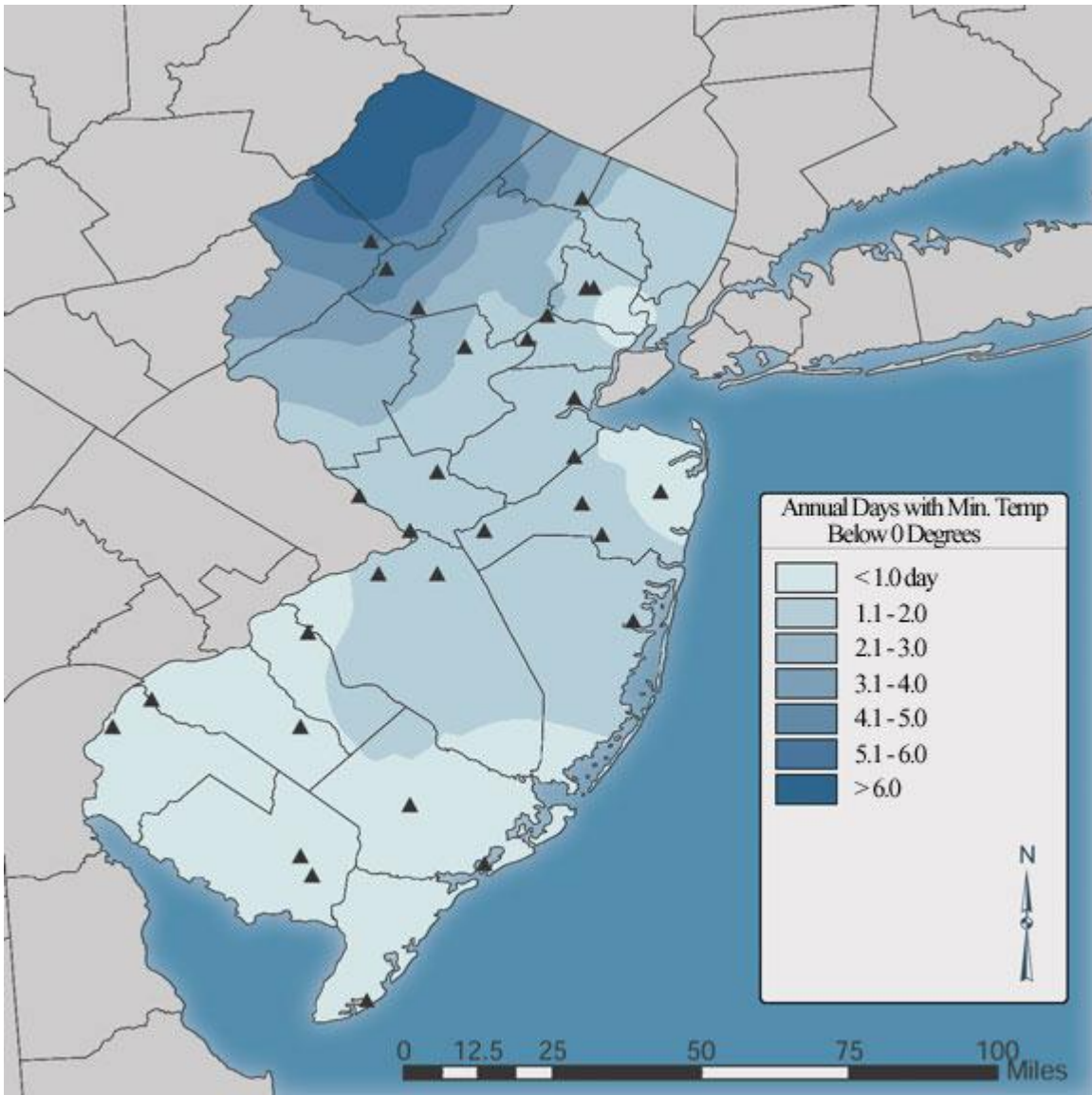


Figure 24. Average annual number of days with minimum temperatures < 0°F from temperature stations listed in table 4 for the period 1971-2000.

Excessive summer heat is often denoted through counts of days with maximum temperatures $\geq 90^{\circ}\text{F}$ and $\geq 100^{\circ}\text{F}$. Interior lowlands of the State have the largest number of such days, on average having 20-30 days of $\geq 90^{\circ}\text{F}$ maximums. Fewer than 10 such days occur each summer along the coast and at higher elevations. 100°F days are rare throughout NJ, averaging one day or less per year everywhere. The best chance of experiencing such a day lies in urban locations.

METEOROLOGICAL CASE STUDY EVALUATION OF RWIS STATION

It is rare for a day to elapse without seeing the benefit of the NJWxNet (including the valuable flow of data from the RWIS network) as it relates to some aspect of weather across all or a portion of New Jersey. This section will highlight one such critical winter day, followed by discussion of a recent early fall day.

December 14, 2003

This early winter day represents a microcosm of the varied weather conditions that can be observed across the State at a given time or at a given location within a day's time. Many similarities in relation to the previous climate discussion will be noted in the following paragraphs.

Precipitation fell throughout New Jersey on December 14th, 2003, totaling $\geq 1.50''$ in scattered locations, while the upper Delaware Valley and some coastal locations only received about $0.50''$. Snow fell from interior central NJ northward. Where snow fell, totals ranged from 1-2'' (Somerdale, Hightstown) to 5-7'' (Charlotteburg, Greenwood Lake, Boonton). A comparison of precipitation (defined as rain and melted snow) and snowfall totals for this event suggest that much of the area that experienced snowfall had either very wet snow at some point (snowfall to precipitation ratios less than 10:1), changed over to sleet for a time, or had a complete changeover to rain at some point during the day. Even High Point, where the temperature never exceeded 26°F , had $5.0''$ of snow, with

precipitation totaling 0.85" (6:1 ratio). Detailed reports from a number of stations verify the mixed nature of precipitation on the 14th.

A good idea of where and when a changeover from frozen to liquid precipitation occurred is seen in the temperature time series during this day. A changeover from snow to sleet usually occurs at temperatures below freezing (as measured several feet off the ground), thus can only be determined by visual observation or an automated visibility sensor. Figures 25 to 30 show the northward movement of the freezing line across the State on the 14th, with a subsequent southward descent overnight from the 14th into the 15th. Overnight conditions resulted in icy roadways, leading to travel difficulties on the morning of the 15th. Early on the 14th, prior to the commencement of precipitation, all but coastal areas were below freezing. By the time precipitation began to fall in the pre-dawn hours, temperatures were warm enough in the southernmost counties and up the coast so that only rain was falling in these locations. Further north, snow had commenced. Snow continued to fall into the mid-day hours in central NJ, while by noon, areas south of Route 195 were experiencing rain. By the evening rush hour, temperatures were above freezing from Mercer County northeast to Bergen County, and had risen to the low 50's°F in Cape May County. Meanwhile, it was 18°F at High Point and in the low 20's°F in northwest valleys where either snow or sleet continued to fall. The final northward thrust of milder air brought midnight temperatures close to the freezing point in the northwest and to near 40°F in the Route 1 corridor. Meanwhile, colder air was beginning to infiltrate the southwest, where temperatures had fallen into the mid 30's°F. By 6 AM on the 15th, temperatures were near the freezing point in the southern half of the State and in the mid 20's°F to 30°F in the north.

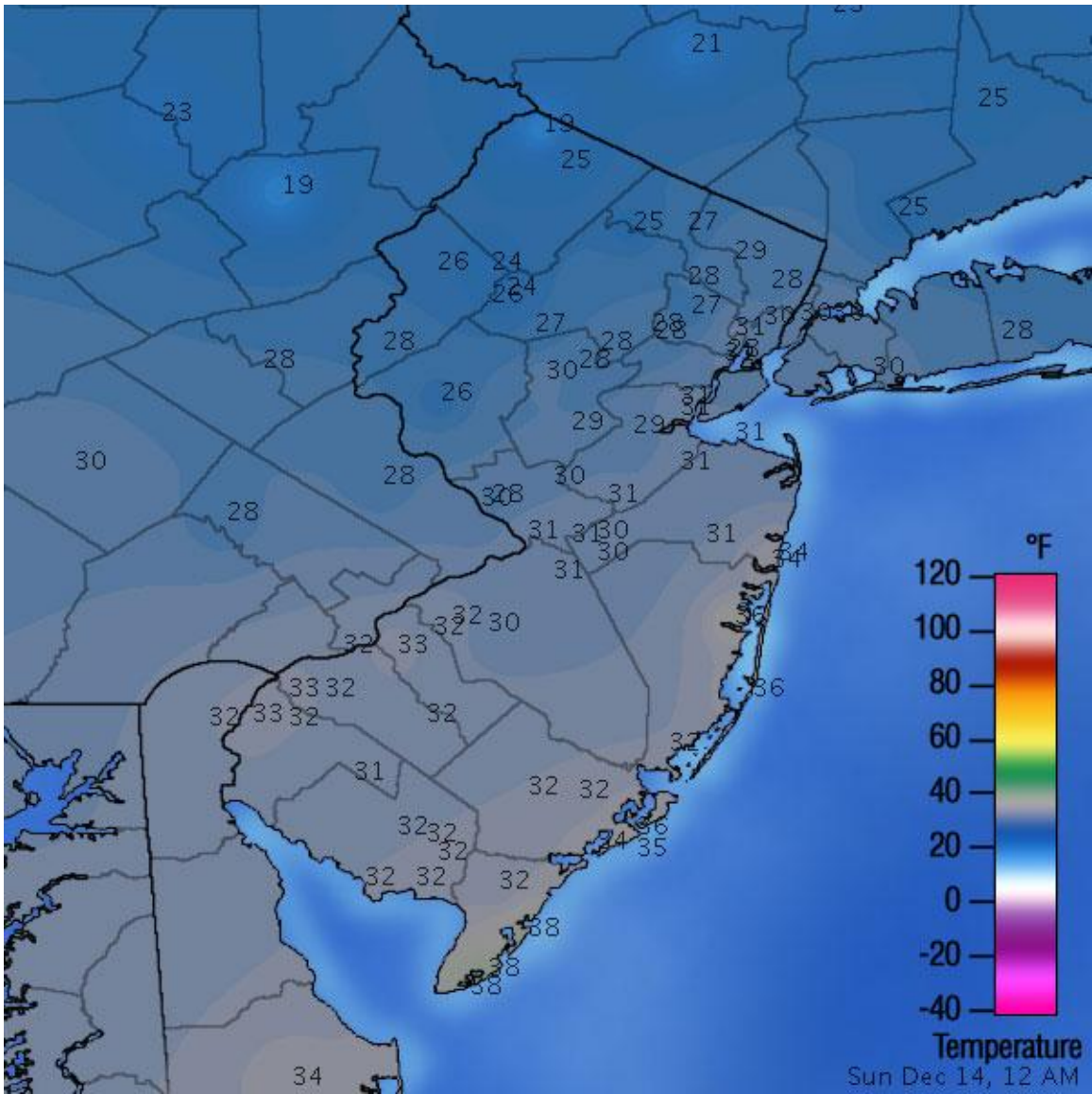


Figure 25. Temperatures at 12 AM on December 14, 2003.

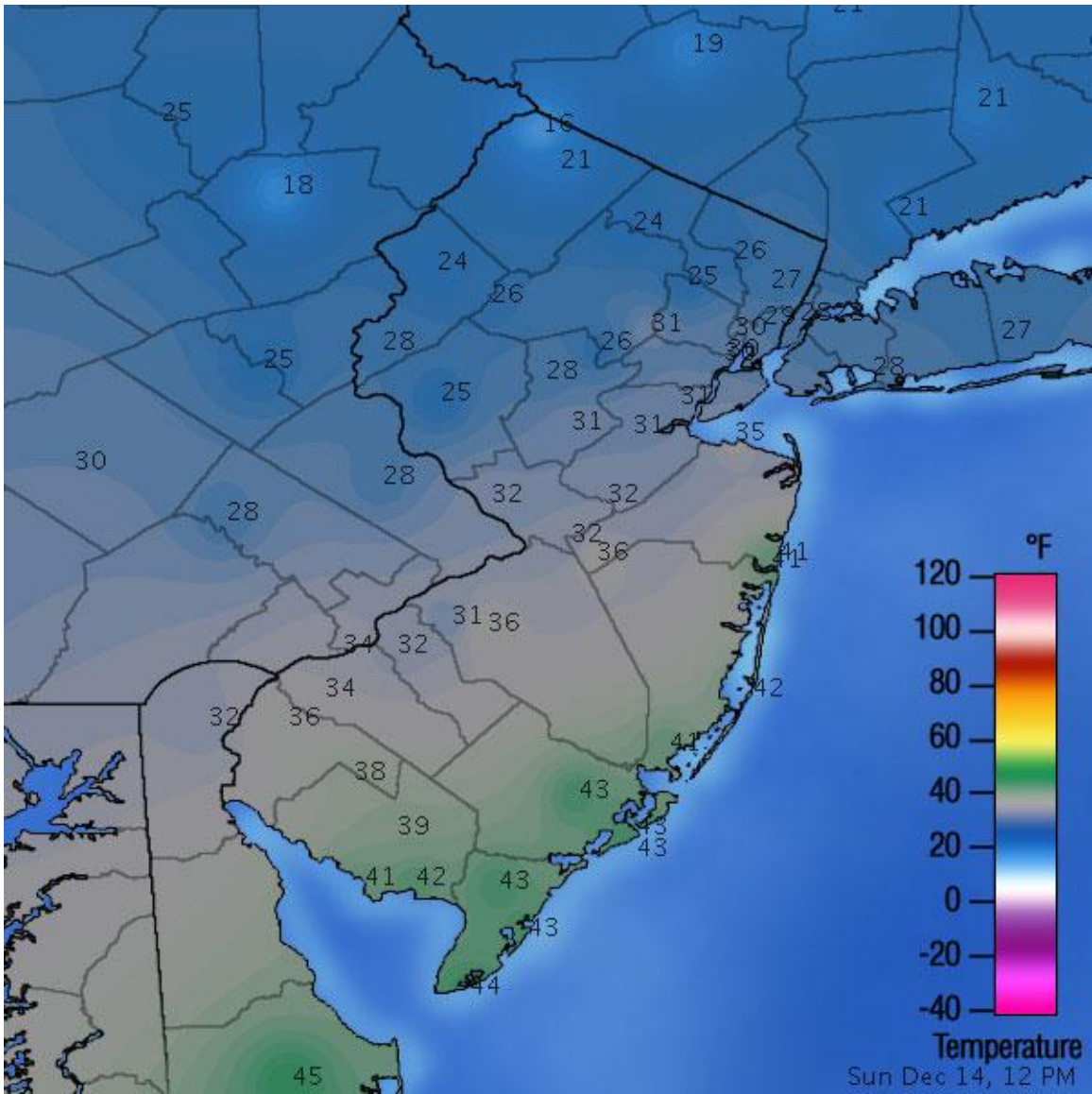


Figure 27. Temperatures at noon on December 14, 2003.

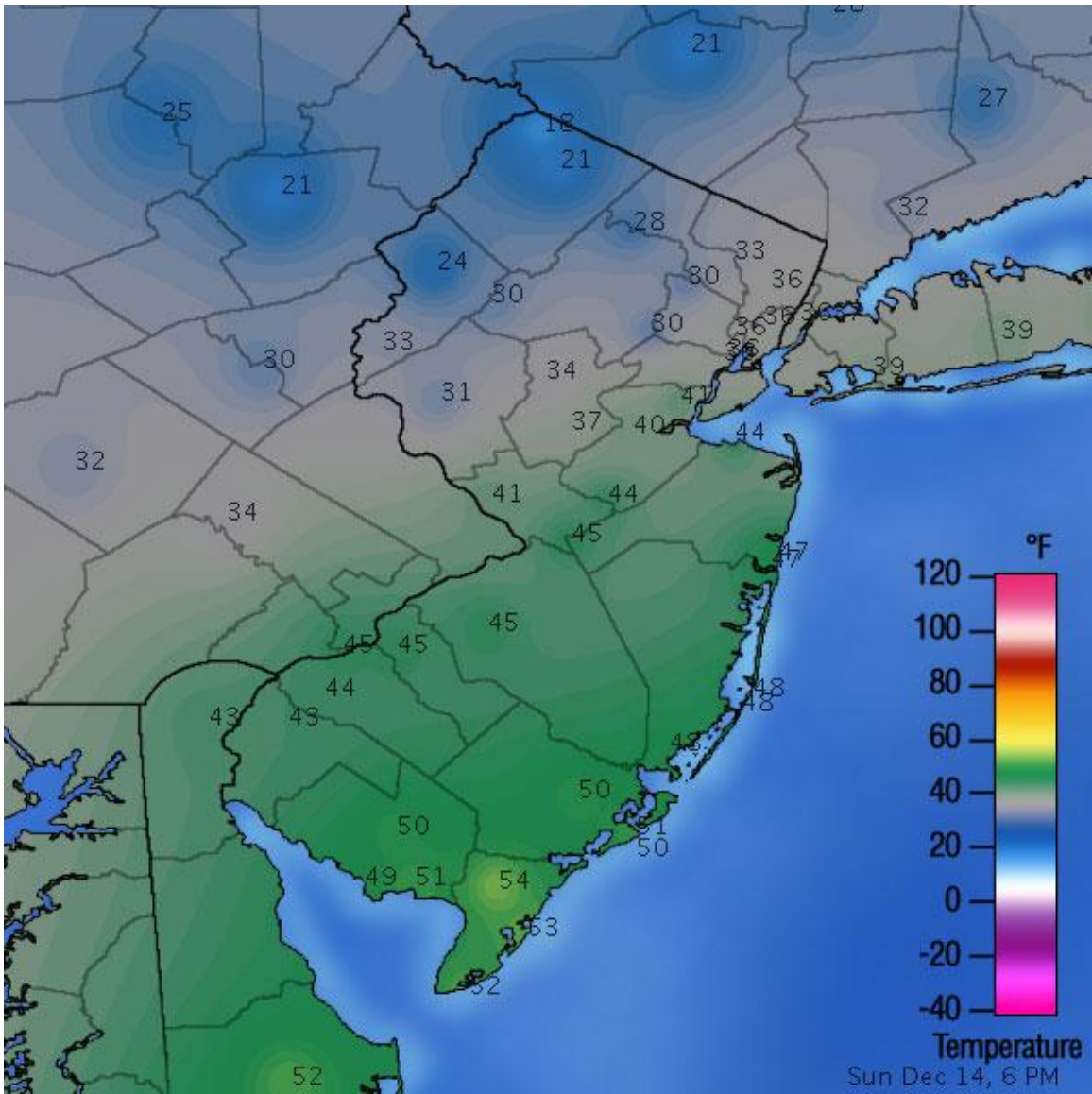


Figure 28. Temperatures at 6 PM on December 14, 2003.

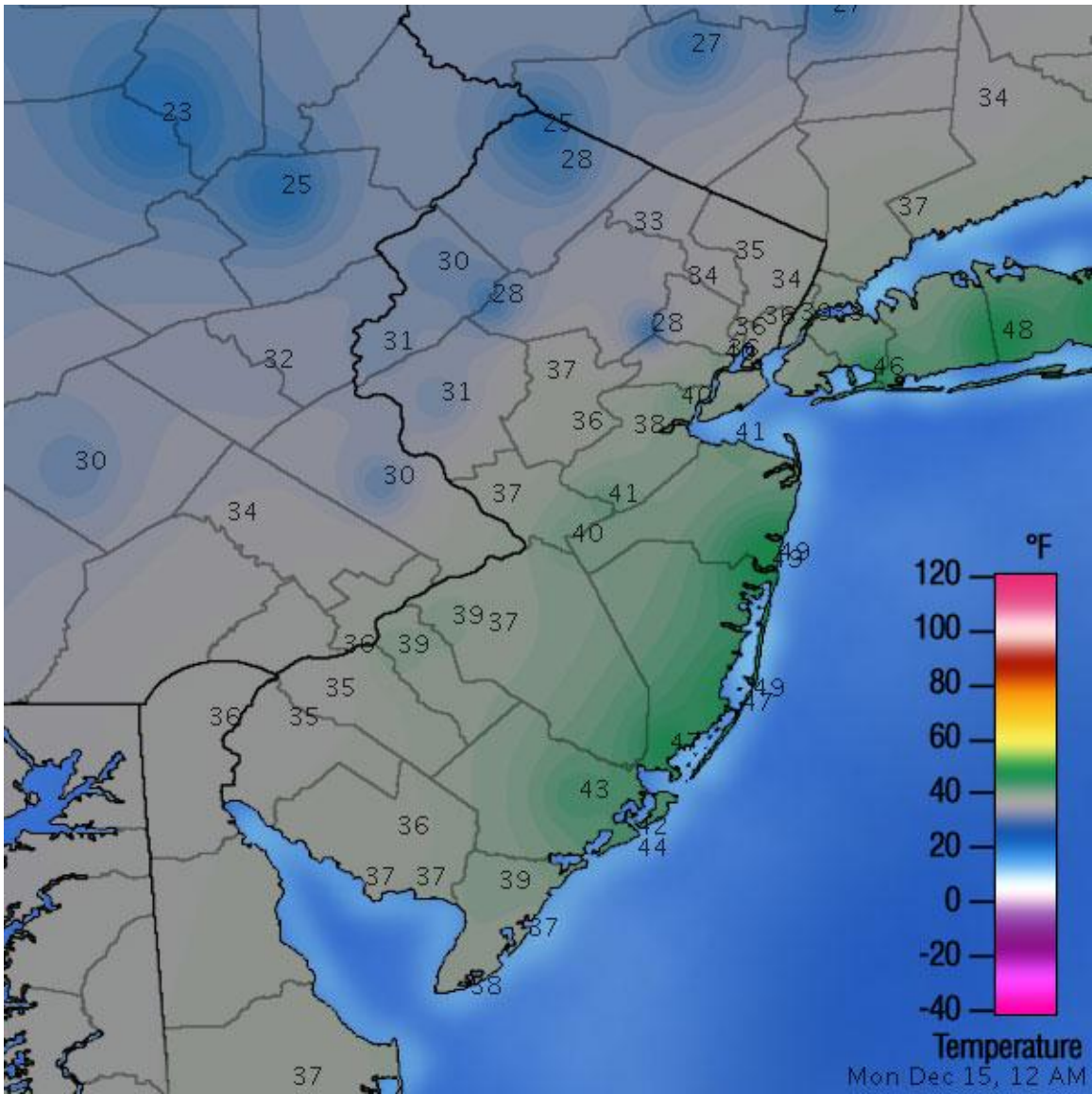


Figure 29. Temperatures at 12 AM on December 15, 2003.

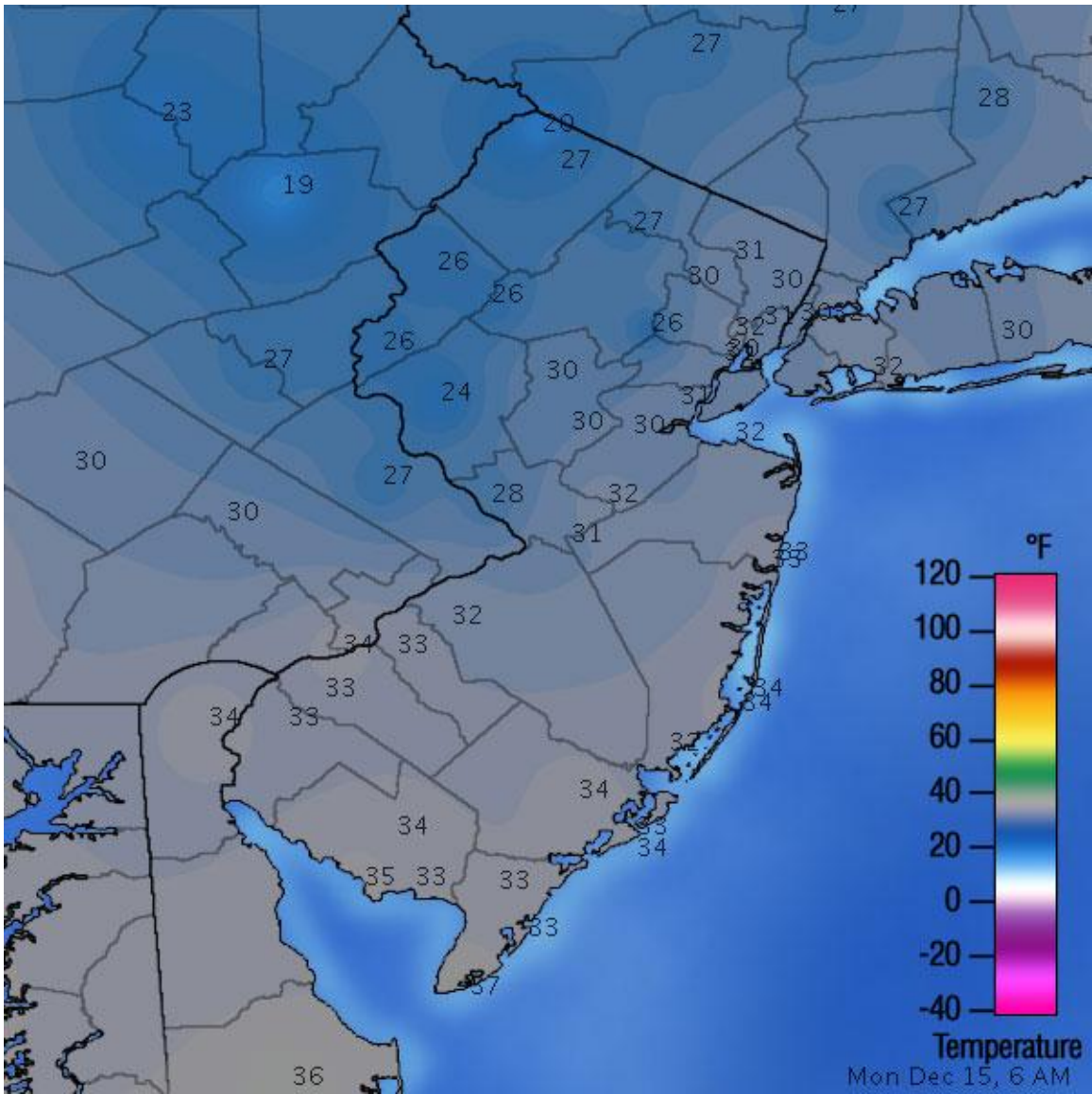


Figure 30. Temperatures at 6 AM on December 15, 2003.

September 29, 2005

While the weather on September 29, 2005 was not nearly as dramatic as noted in the previous example, there were some hazardous conditions (for instance, a tree fell on a car traveling on the Palisades Interstate Parkway during the evening rush hour). A cold front moved rapidly through New Jersey during the mid-day hours. This resulted in a decline in temperature of 10°F-15°F over a half hour's time. The progression of the front from west to east across NJ is seen in temperature maps for noon and 2 PM, and also in precipitation maps (figures 31-34). Figure 4 also shows the abrupt drop in temperature close to noon on a meteograph, a 24-hour time series of temperature and dewpoint at Hillsborough (Somerset County). As will be discussed below, winds were rather strong preceding, during and, in some areas, following frontal passage. Accompanying the front were quick bursts of rain, however totals were not impressive, at best amounting to several tenths of an inch. Throughout the day, moderately strong winds blew throughout the State. Winds gusted to 30-40 miles per hour in many areas. The wind map for noon shows the stronger gusts (figure 35). However it also shows a current difficulty with interpreting winds from the NJWxNet, as stations in different networks record average and peak wind gusts differently. At some, the peak hourly gust observed is the peak from any time during the past hour, at others it is the peak gust within a finite period (usually 5 minutes) close to the hourly observation time. At others, it has yet to be determined what approach has been taken. With time and additional financial support for the NJWxNet, these uncertainties will be resolved. More frequent polling of stations will also assist (RWIS data are available every 15-20 minutes, while resources are not available to access other networks more than once each hour or such data simply are not available).

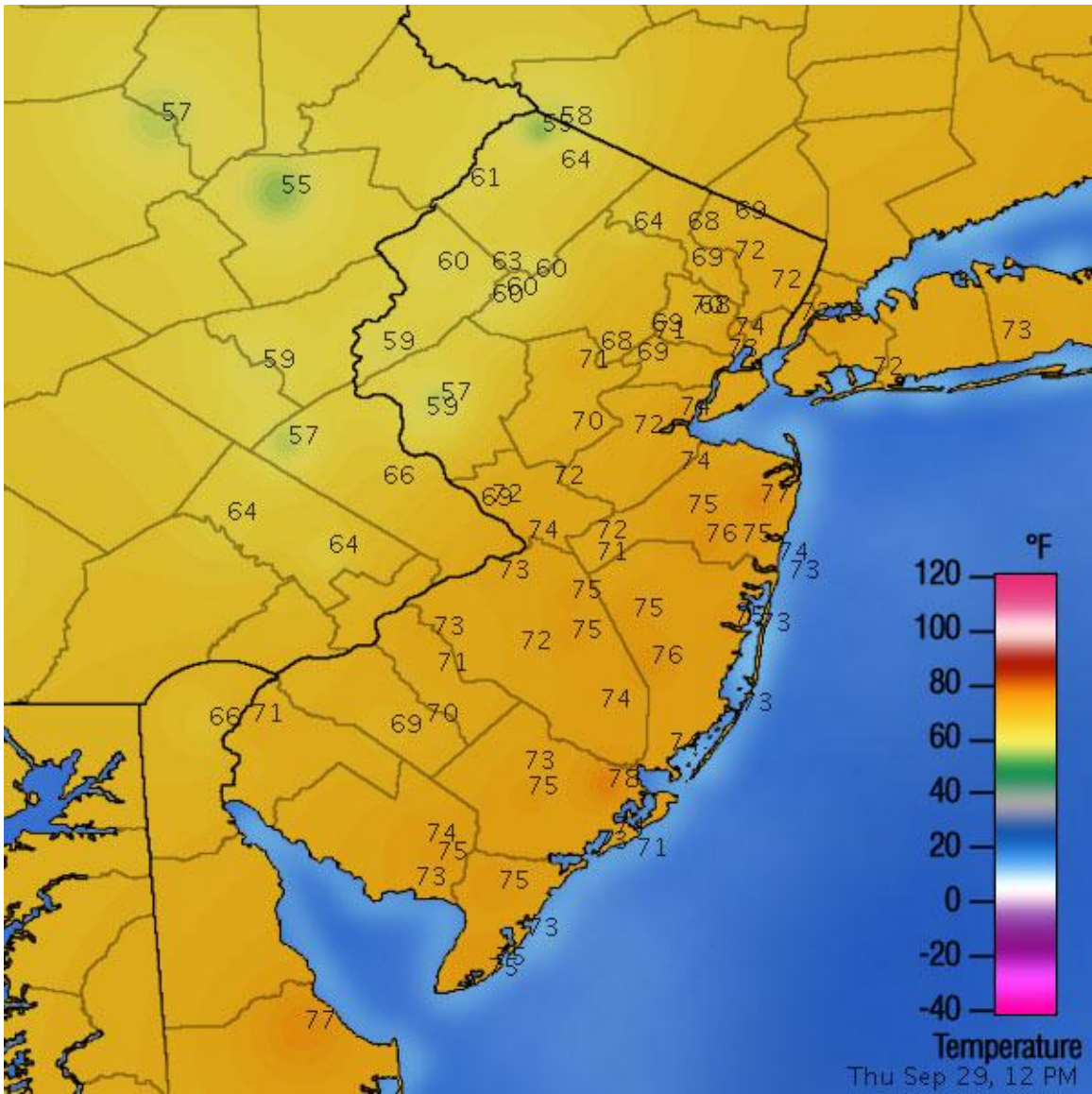


Figure 31. Temperatures at 12 PM on September 29, 2005.

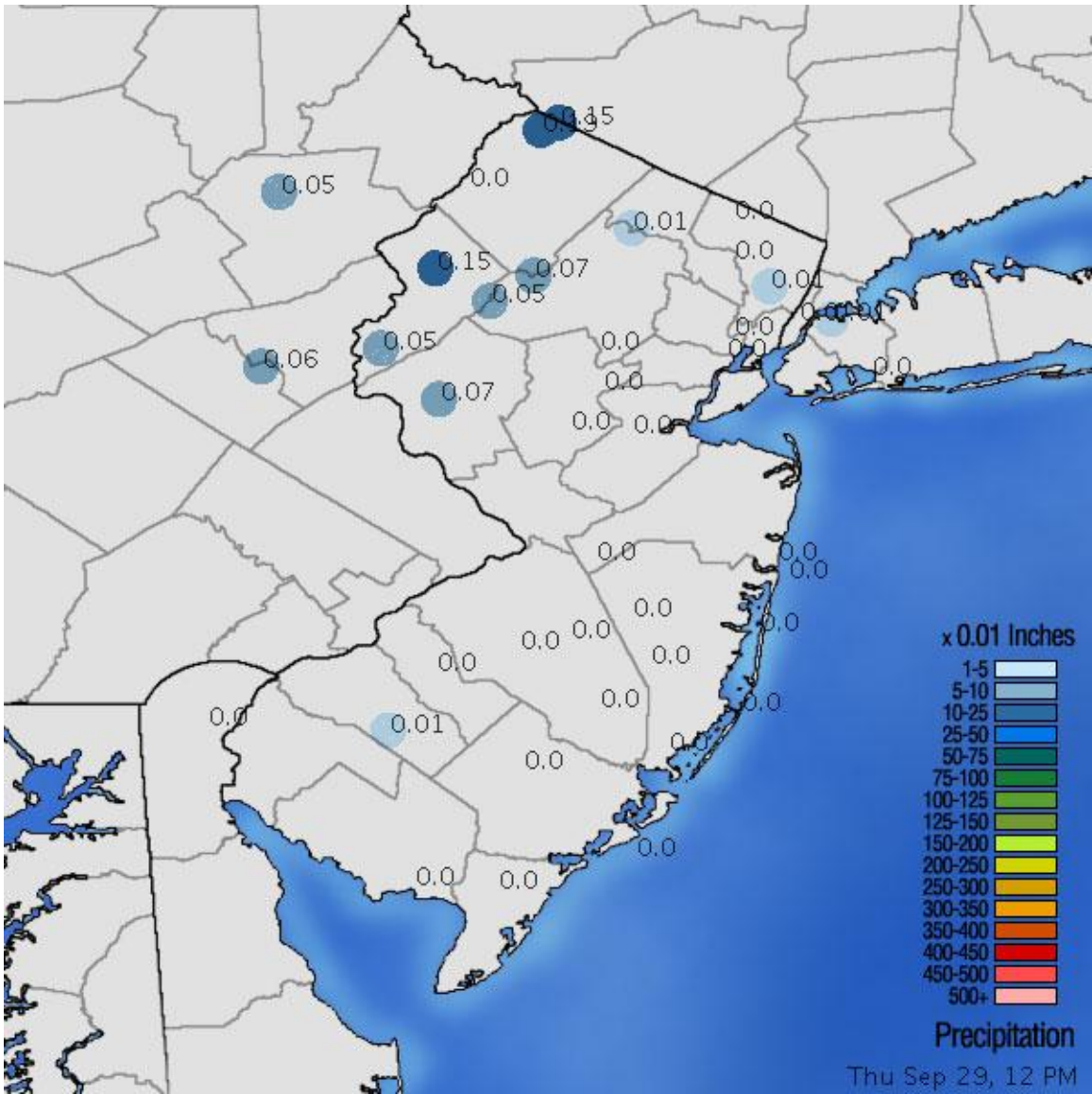


Figure 32. Precipitation between 11 AM and 12 PM on September 29, 2005.

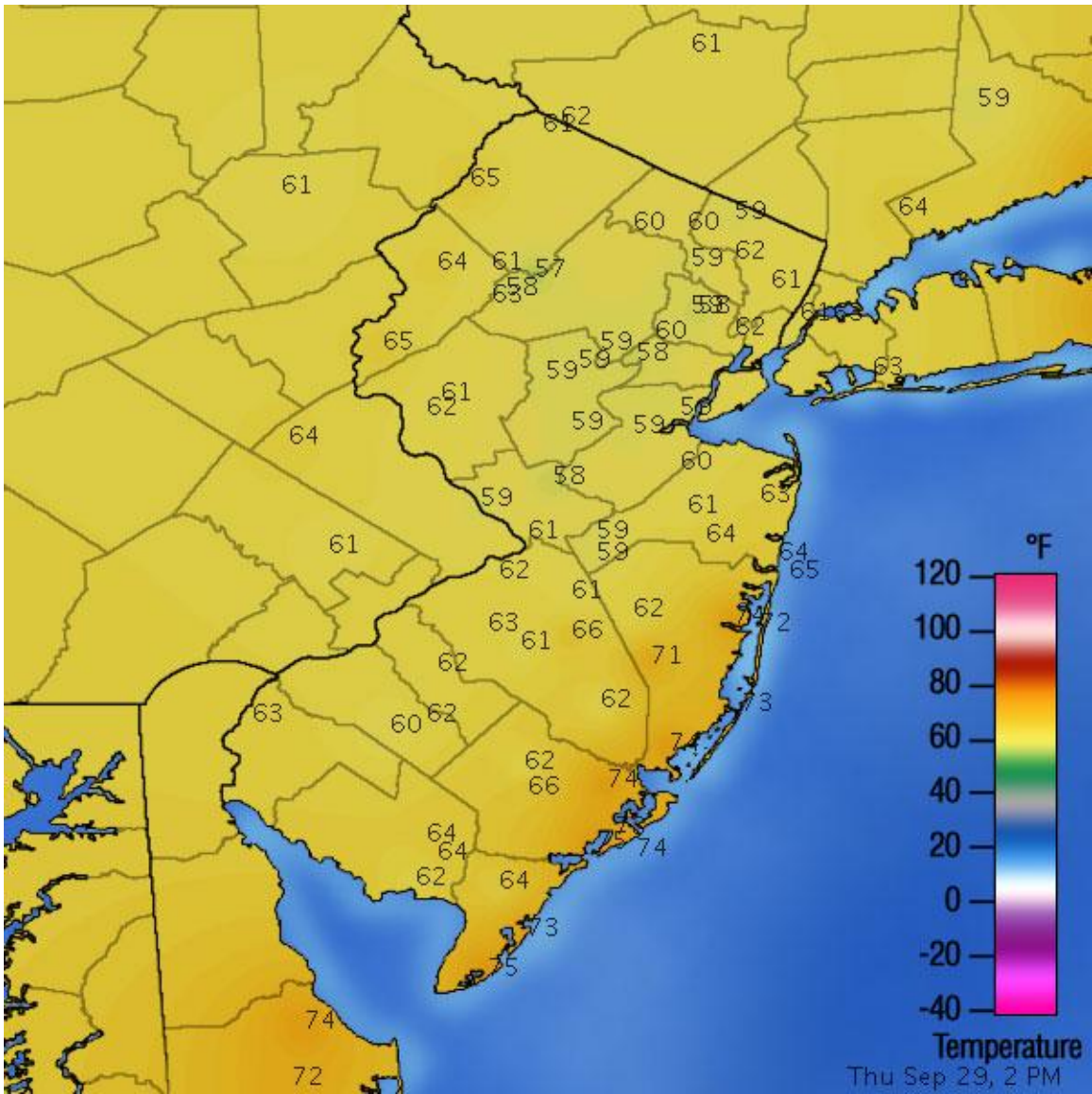


Figure 33. Temperatures at 2 PM on September 29, 2005.

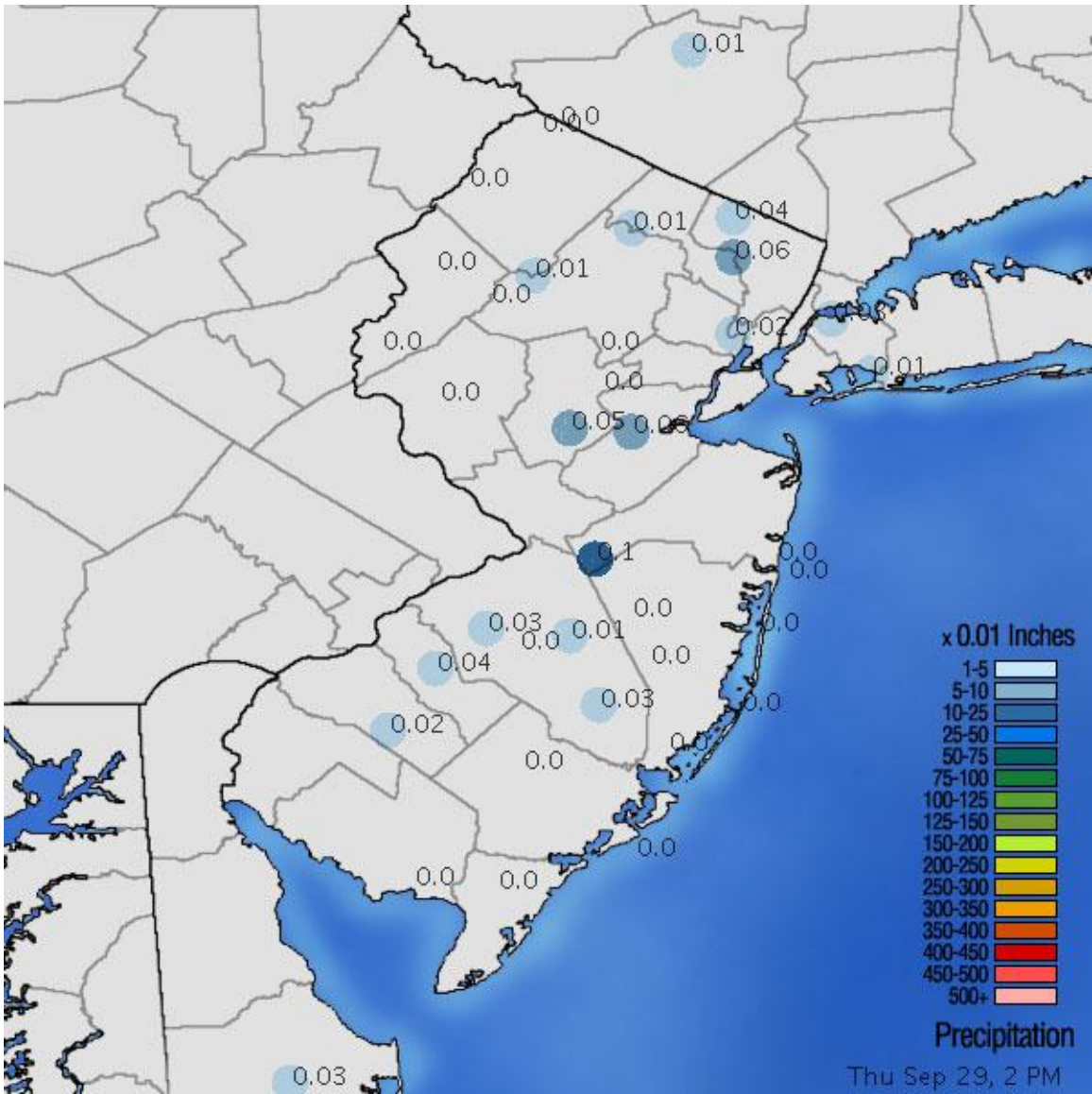


Figure 34. Precipitation between 1 PM and 2 PM on September 29, 2005.

OPTIMAL DISTRIBUTION OF RWIS STATIONS: RECOMMENDATIONS

The preceding examination of key climate elements across New Jersey and several case studies of weather events impacting the State provide useful evaluative information for determining where holes lie within the current NJDOT RWIS network. Certainly a denser statewide network of stations would provide more detailed local information to assist with decision making. While this can be provided using the current RWIS network in conjunction with at least 70 additional stations within the overarching NJ Weather and Climate Network, it is prudent to plan for a more equitable distribution of RWIS stations than is currently the case. RWIS stations lie within key transportation corridors and have the added benefit of recording roadway conditions. They also serve as an independent source of information to the NJDOT, should reports fail to be received from other networks.

The current distribution of RWIS stations is uneven across New Jersey (see station locations plotted on any of the climatology maps). This might suffice, should: 1) NJ weather be consistent spatially; 2) NJ weather be consistent temporally; 3) NJ have uniform topography, with all locations equidistant from the coast; 4) the population of the State only reside close to where stations are presently located; and, 5) the road network be sparse where stations are presently not located. However, none of these apply. Therefore, recommendations regarding RWIS station placement are made here. As requested, in one case locations for 15 new stations are suggested, maintaining all current stations. The second approach suggests relocating six stations that currently are somewhat duplicative with respect to another nearby RWIS station to key station-sparse areas, thus reducing the cost of establishing new stations and completing network build out. Decisions are based primarily on weather and climate considerations and the presence of State roadways. Secondary considerations include elevation, population density, road density, and the placement of stations close to key intersections.

Presently, stations are conspicuously absent in the northwest and northeast corners of the State. Conditions in Sussex County are often quite different, and in winter more severe, than elsewhere. Thus two stations are recommended, one somewhere on Rt. 23 (perhaps at a hillside or hill top location), the other along Rt. 206 (a valley location is suggested). In Warren County, the Delaware Valley is currently not monitored, thus stations are recommended near the western reaches of Rt. 80 and Rt. 78. Figures 36 and 37 depict the recommended locations for these stations with and without a sampling of roadways plotted. In the northeast, stations are recommended in Bergen County somewhere near the Rt. 287-Rt. 17 intersection and on Rt. 9W atop the Palisades. Another station is recommended near the Rt.17-Rt.3 intersection, perhaps where a former RWIS Vaisala station was located. These northeast stations lie in a heavily traveled area and their recommended distribution addresses elevation and urban weather influences.

These themes continue with recommended stations near the intersection of Rt. 78 and the Garden State Parkway, and near the Rt. 80-Rt. 287 intersection. A final north Jersey addition would be a station near the Rt. 202-Rt. 31 intersection in Hunterdon County.

Currently, RWIS coverage is most complete in central NJ, thus no additional stations are recommended here. Rather, attention moves to the south, where five new stations are proposed. This includes one within or near Camden, in the vicinity of Routes 76, 295 and 42. Another should be located in the Salem – western Cumberland county area. Within the Pinelands, a station is recommended to be installed somewhere near the Rt. 206/Rt.70 intersection or perhaps several miles east of there near the Rt. 70/Rt. 72 intersection. Closer to the coast, a station is recommended near the Rt. 70/Garden State Parkway intersection. Further south, a final station is suggested near the Atlantic County – Cape May County border, perhaps as far south as along Rt. 50 or further north in the vicinity of Routes 9, 52 and the Garden State Parkway.

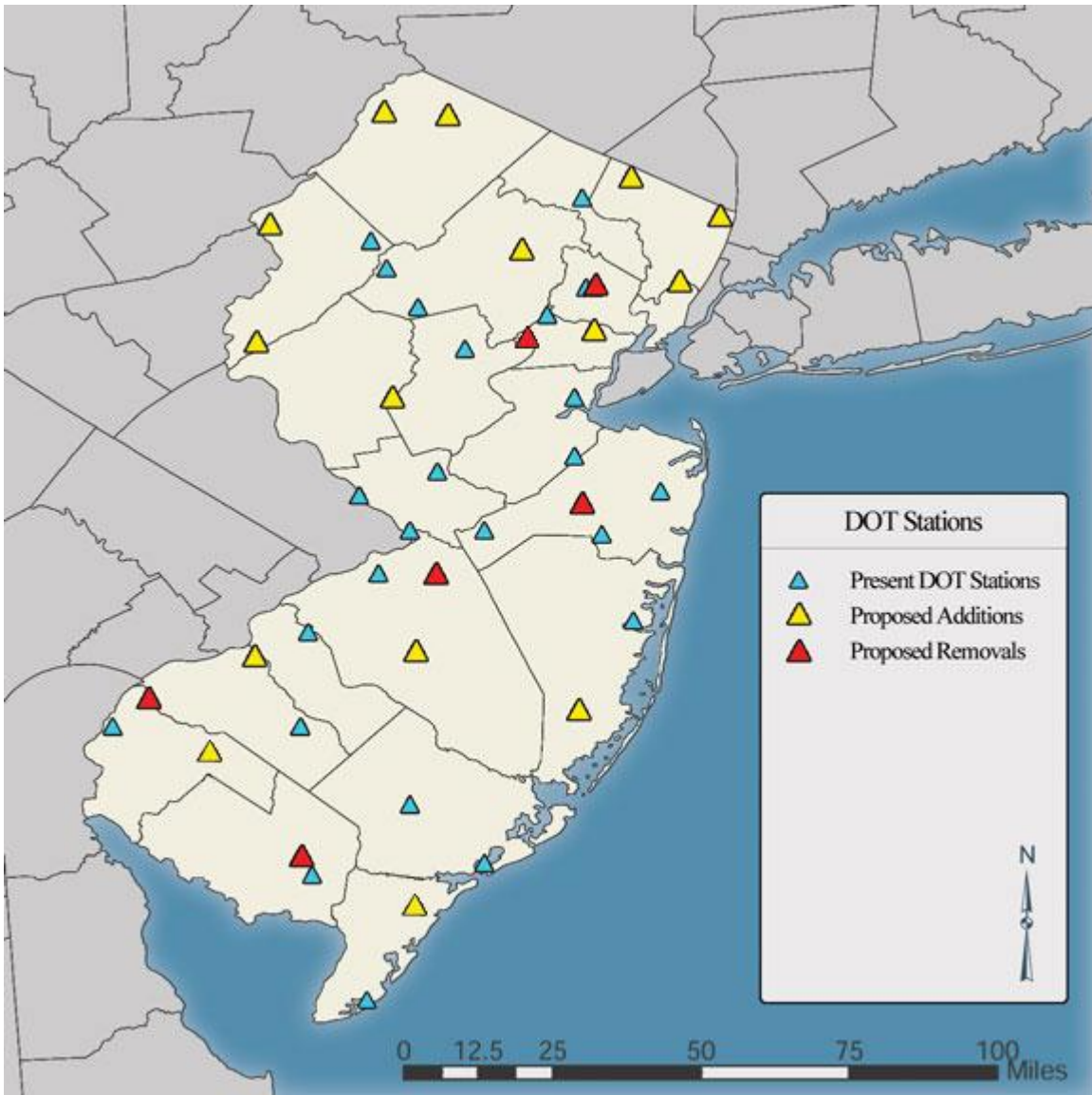


Figure 36. Recommended locations for additional RWIS stations, and suggestions for where stations might be removed (no roads).

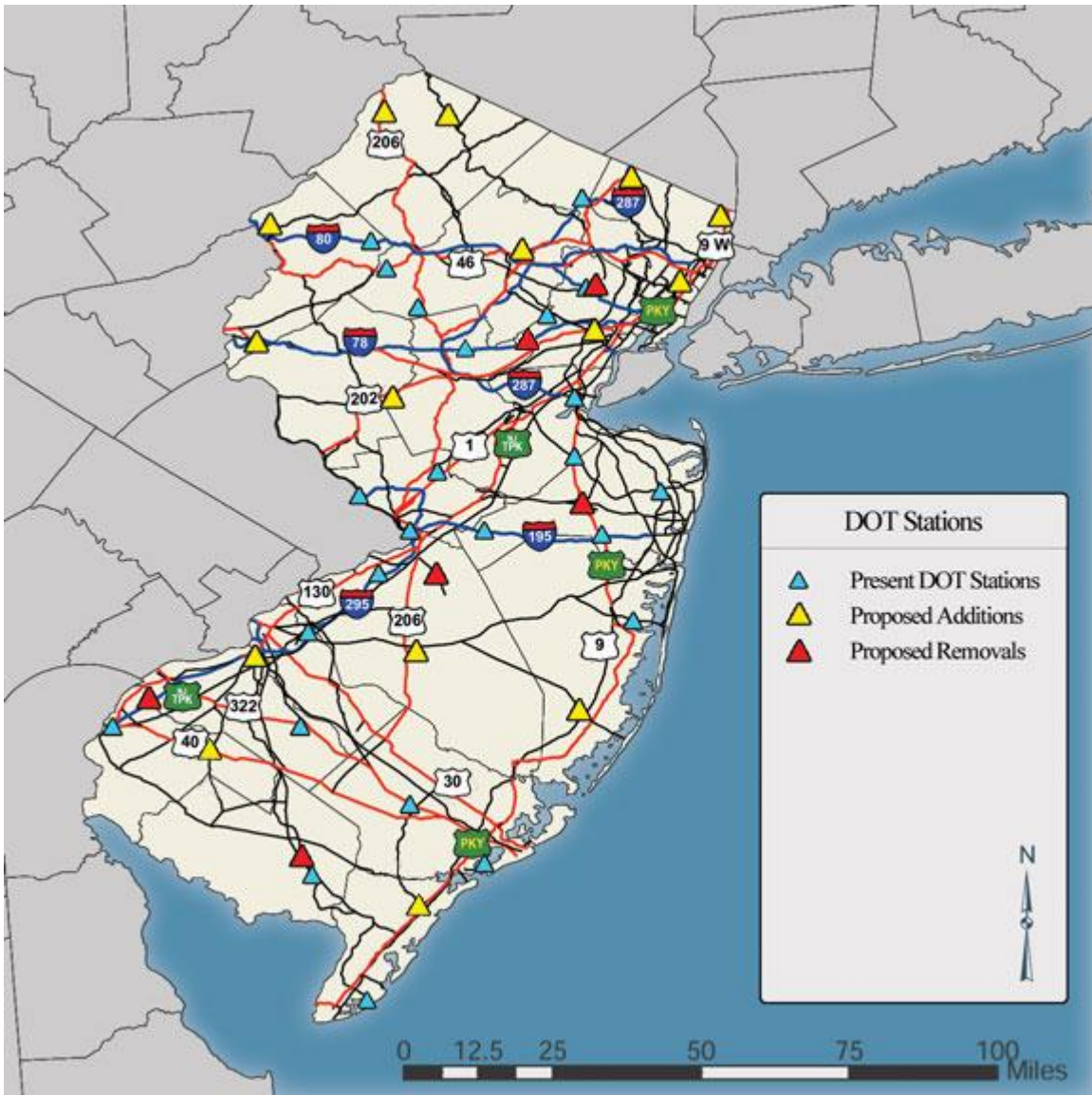


Figure 37. Recommended locations for additional RWIS stations, and suggestions for where stations might be removed (roads included).

If need be, there are as many as six current stations that might be relocated, as presently there are some station pairs in rather close proximity to one another. Suggested for potential relocation are one station within each of the following pairs: 1) West Orange stations 1 –2; 2) Hamilton stations 1 –2; 3) Maurice River stations 1 – 2; 4) Berkeley Heights – Summit; 5) Logan – Carneys Point; and 6) Howell – Freehold (figures 36-37). Certainly, arguments can be made to maintain both stations in each pair. For instance, the Berkeley Heights – Summit and West Orange pairs lie in hilly terrain and within heavily traveled regions.

CONCLUSIONS AND RECOMMENDATIONS

This project has produced dividends exceeding initial expectations. The population of an excellent database of RWIS data has begun these past few years, and the feed of data into the database has been quite consistent since late 2004. However, to see the NJDOT RWIS network transition from a sporadic, primarily winter season-only telephone-accessed network to one that is presently accessed via cellular means on a 365 days per year basis is gratifying.

The evaluation of the current effectiveness of RWIS station distribution has provided an opportunity to upgrade the ONJSC historic Cooperative station database, develop new statewide climatologies, and use such information in an applied manner. The project has also served as an impetus toward developing and evaluating case studies of specific weather events across New Jersey. These achievements will facilitate future applied endeavors of this kind. As for the task at hand, the climatologies and case studies have provided strong support for the need to expand the RWIS network into the northwestern and northeastern corners, and southern reaches of the State. They illustrate the variable nature of our weather, whether it is a plethora of conditions dispersed across the State or rapid changes at an individual location.

It is our understanding that some of the RWIS observational holes have begun to be filled through several road projects that have provided opportunities for the procurement and installation of RWIS stations. However, some of these stations (e.g., Rt. 18 and River Road in Piscataway) are not in areas with the greatest need for stations, nor has communication yet been established with many (if any) of these stations. Still, all stations will be welcome once they are brought on line.

While this project has been underway, considerable progress has been made in the development and operation of the New Jersey Weather and Climate Network. The RWIS is serving as a key network within the NJWxNet “network of networks”, and hopefully will continue to be a vital component for years to come. It is highly recommended that decisions regarding future placement of RWIS stations and the number deployed take into account the present and planned location of non-RWIS stations across New Jersey. Rather than add RWIS stations, it may be more cost-effective to support the operation and maintenance of non-RWIS stations and networks that are currently operating. Of course, any such evaluation must first take into account the need to monitor roadway conditions at key locations across the state, however expenses for atmospheric sensors could be minimized at many such sites. It is also recommended that RWIS stations be equipped with precipitation gages, ideally heated gages that permit real-time measurement of the liquid content of frozen precipitation. Sensors that provide evidence that precipitation is falling, yet do not directly measure the precipitation quantity, fail to provide a full understanding of weather conditions at a station. RWIS precipitation gages, in conjunction with the many other electronic precipitation gages reporting to the NJWxNet, would assist NJDOT staff, National Weather Service forecasters, and other public and private concerns to immediately grasp the significance of a developing event and permit the issuance of timely warnings.