Analyzing the April 1, 2023 Mid-Atlantic Severe Weather Outbreak: A Meteorological Case Study and Performance Overview of National Weather Service Weather Forecast Office Philadelphia/Mount Holly

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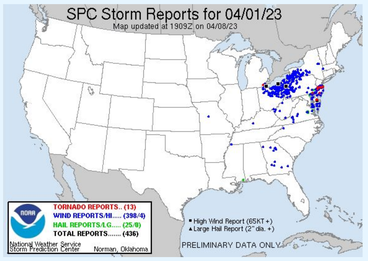
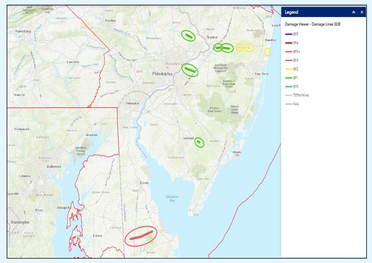
Overview/Tracks

On April 1, 2023 a significant severe weather outbreak occurred across the Mid-Atlantic region, causing extensive wind and tornado damage. The Philadelphia/Mount Holly (PHI) County Warning Area (CWA) saw a total of nine tornadoes which resulted in fatalities and widespread damage across multiple states. For context, the PHI CWA typically experiences around six to eight tornadoes per year.

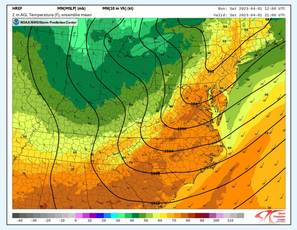
Of the nine tornadoes, seven occurred in New Jersey. One tornado occurred in Pennsylvania and one occurred in Delaware. The tornadoes in New Jersey and Pennsylvania were all rated EF-1 and EF-2. The lone tornado in Delaware was an EF-3 with estimated peak winds of 140 mph.

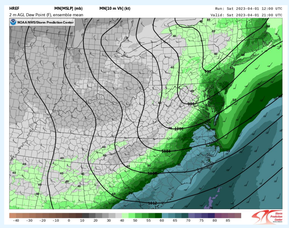


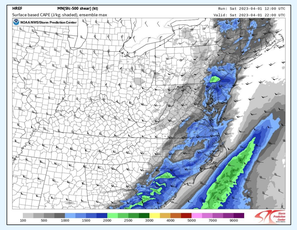


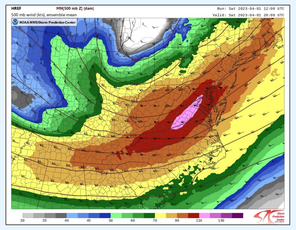
Synoptic Setup/Environmental Conditions

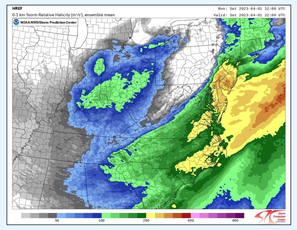
A very favorable synoptic/mesoscale environment for severe weather manifested across the PHI CWA on the afternoon of April 1. Severe weather parameters came together to form the right conditions for a tornado outbreak. A strong mid-level trough approached from the west with a 100-110+ knot 500 mb jet streak located upstream. At the surface, a cold front approached from the west and acted as the primary forcing mechanism. Ahead of the cold front, surface temperatures climbed into the 60s and 70s while surface dew points surged into the 50s to near 60°F. This allowed CAPE values to reach 1000-1500 J/kg. Strong low-level shear was present with 0-3 km bulk shear values approaching 50 knots. Significant veering of low-level winds led to favorably curved 0-1 km and 0-3 km hodographs with storm-relative helicity values of 200-300 m^2/s^2 and 300-400+ m^2/s^2 respectively. This potent environment led to high values of the Significant Tornado Parameter (STP) of 2-4+.

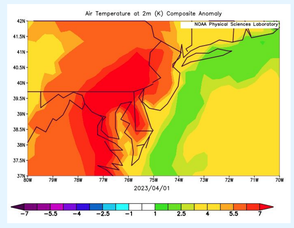


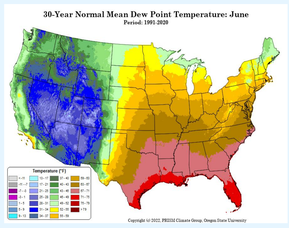


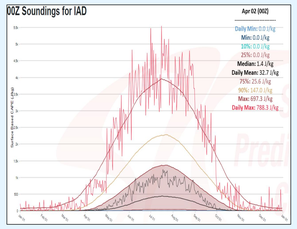


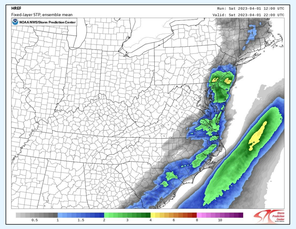


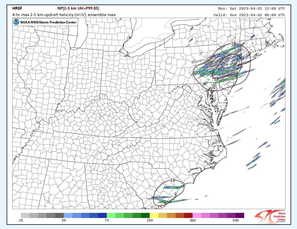






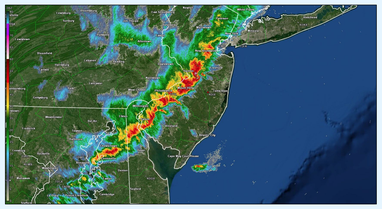


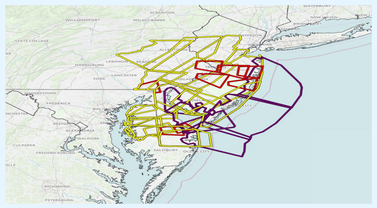




Radar Data/Warnings

A total of eight Tornado Warnings, 17 Severe Thunderstorm Warnings, and six Special Marine Warnings were issued during the event. PHI achieved a 92% Probability of Detection, 32% False Alarm Ratio, and an average lead time of 24.8 minutes for all warnings. Notably, tornado warnings were in effect for eight of the nine tornadoes, with just one tornado eluding detection due to the challenging linear storm mode.





KDIX KDOX TPHL

REF

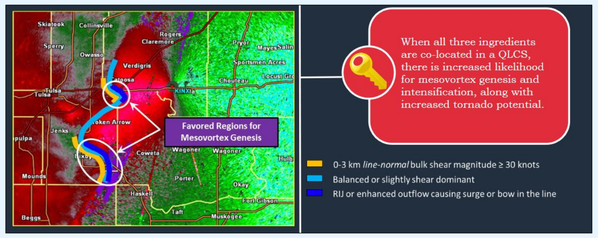
VEL

Forecasting Quasi-Linear Convective System (QLCS) Tornadogenesis: The Three-Ingredients Method (TIM)

Warning forecasters used experience, training, and the TIM during warning operations to recognize severe and tornado potential. This led to the issuance of timely, proactive warnings.

PHI achieved an average lead time of 7.8 minutes on all tornado warnings issued. This is greater than the national average lead time of 4.8 minutes according to Goodnight et al. (2022).

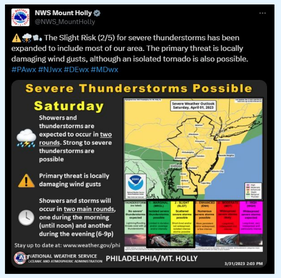
TIM

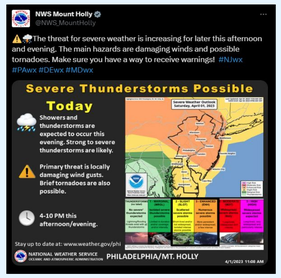


Goodnight, J. S., D. A. Chehak, and R. J. Trapp, 2022: Quantification of QLCS Tornadogenesis, Associated Characteristics, and Environments across a Large Sample. *Wea. Forecasting*, **37**, 2087–2105, https://doi.org/10.1175/WAF-D-22-0016.1.

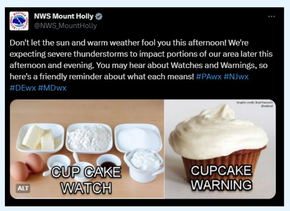
Reports/Messaging/Social Media

Forecast confidence increased the morning of April 1 when cloud coverage and showers exited the area early. This allowed ample time for diurnal heating and atmospheric destabilization. Forecasters recognized this and began to message the increasing threat to core partners and the public.





Before, during, and after the event, constant updates were provided on social media.



April 1, 2023 Tornado Outbreak — NATIONAL WEATHER SERVICE

Completed Damage Surveys	EF-rating	Est. Max Winds (mph)	Path Length (miles)	Max Path Width (yards)
Bridgeville-Ellendale, DE	EF-3	140	14.3	700
Jackson Township, NJ	EF-2	130	2.1	200
Jackson-Howell Township, NJ	EF-2	120	1.4	150
Sea Girt, NJ	EF-2	120	0.14	50
Allentown-Cream Ridge, NJ	EF-1	110	4.0	550
Wrightstown Township-Newtown, PA	EF-1	105	3.9	200
Cinnaminson-Delran-Moorestown, NJ	EF-1	100	6.0	600
Crosswicks, NJ	EF-1	100	2.8	300
Mays Landing, NJ	EF-1	100	0.9	110
Palmyra-Riverton, NJ	Straight-Line Wind	100	1.0	600