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3 **The Value of Dual-Polarization Radar in Diagnosing the Complex**
4 **Microphysical Evolution of an Intense Snowband**
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ABSTRACT

The northeast U.S. extratropical cyclone of 8–9 February 2013 produced blizzard conditions and over 0.6–0.9 m (2–3 feet) of snow from Long Island through eastern New England. A surprising aspect of this blizzard was the development and rapid weakening of a snowband to the northwest of the cyclone center with radar reflectivity factor exceeding 55 dBZ. Because the radar reflectivity within snowbands in winter storms rarely exceeds 40 dBZ, this event warranted further investigation. The high radar reflectivity was due to mixed-phase microphysics in the snowband, characterized by high differential reflectivity ($Z_{DR} > 2$ dB) and low correlation coefficient ($CC < 0.9$), as measured by the operational dual-polarization radar in Upton, NY (KOKX). Consistent with these radar observations, heavy snow and ice pellets (both sleet and graupel) were observed. Later as the reflectivity decreased to less than 40 dBZ, surface observations indicated a transition to primarily high-intensity dry snow, consistent with lower-tropospheric cold advection. Therefore, the rapid decrease of the 50+ dBZ reflectivity resulted from the transition from higher-density, mixed-phase precipitation to lower-density, dry-snow crystals and aggregates. This case study indicates the value that dual-polarization radar can have in an operational forecast environment for determining the variability of frozen precipitation (e.g., ice pellets, dry snow aggregates) on relatively small spatial scales.

The northeast U.S. extratropical cyclone of 8–9 February 2013 resulted in a blizzard that produced over 0.9 m (3 feet) of snow in central Connecticut and over 0.6 m (2 feet) across portions of Long Island (Fig. 1). Hurricane-force winds battered the coast from Massachusetts to Maine. On Long Island, a rapid transition from rain to snow, with subsequent extreme snowfall rates of 7.5–10 cm h⁻¹ (3–4 in h⁻¹), occurred during the evening rush hour, stranding hundreds of cars on major highways. After the storm, a federal state of emergency was declared for Connecticut, and a federal disaster declaration was made for Connecticut and Long Island.

The heaviest snow fell within an intense band detected by the operational NWS radar network (Fig. 2). Although such bands are relatively common in the comma head of northeast U.S. cyclones (e.g., Nicosia and Grumm 1999; Novak et al. 2004, 2006, 2008, 2009, 2010), the radar reflectivity factor at horizontal polarization Z_H (referred to as simply *reflectivity* in the remaining text) in the band during the 8–9 February 2013 storm exceeded 55 dBZ, with isolated pockets nearing 60 dBZ. This reflectivity was substantially higher than the 30–40 dBZ found in snowbands in many other northeast U.S. cyclones (e.g., Figs. 3, 8, and 13 in Nicosia and Grumm 1999; Fig. 3 in Clark et al. 2002; Fig. 2 in Novak et al. 2004; Figs. 1 and 9 in Jurewicz and Evans 2004; Figs. 18–19 in Novak et al. 2006; Fig. 4 in Novak et al. 2008; Fig. 2c in Novak et al. 2009; Fig. 2a in Novak et al. 2010; Figs. 3 and 11 in Stark et al. 2013). In fact, a minimum reflectivity threshold of 40 dBZ has been used for convection in the severe storms community (Clark et al. 2012), which also speaks to the intensity of the observed 55-dBZ band. Furthermore, within an hour, the reflectivity values of the band rapidly decreased to

about 30 dBZ. Our interest in this case revolves around the reasons for this high reflectivity and its rapid decrease.

In addition, the snow-to-liquid ratio varied rapidly during the storm. For example, a storm-total snowfall of 78.5 cm (30.9 in) with a liquid equivalent of 6.5 cm (2.5 in) fell at the National Weather Service (NWS) Weather Forecast Office (WFO) in Upton, NY (Fig. 3), which translated to a 12:1 snow-liquid ratio (e.g., Roebber et al. 2003; Ware et al. 2006), above normal for coastal New York (Baxter et al. 2005). Other places on Long Island experienced ratios as low as 4:1 at times. To compare the precipitation type to the observed thermodynamic profile was not possible because the 0000 UTC 9 February sounding at the WFO was incomplete, being launched into high winds and heavy snow.

Fortunately, this intense snowband was observed by the National Weather Service Weather Surveillance Radar-1988 Doppler radar (WSR-88D) at Brookhaven National Laboratory, Upton, NY, (KOKX) on Long Island, which had been upgraded with dual-polarization capabilities in January 2012. Dual-polarization radar signatures can be used to diagnose hydrometeor types (e.g., Ryzhkov and Zrnić 1998; Ryzhkov et al. 2005; Kennedy and Rutledge 2010; Kumjian 2013a,b) and offer a valuable opportunity to investigate the evolution of the intense snowband and its radar reflectivity. Although other papers have documented snowbands using dual-polarization radar (e.g., Trapp et al. 2001; Andrić et al. 2013), none have identified such high reflectivity factor in winter storms.

KOKX was ideally situated to observe the lowest 1 km AGL over Long Island and southern Connecticut, which is where both the most intense precipitation and a

diverse array of microphysical processes were occurring. Table 1 provides a summary of typical dual-polarization values for cold-season precipitation types and microphysical processes that were observed in this case. Moreover, detailed in-situ microphysics measurements were collected nearby at Stony Brook University on the north shore of Long Island using a stereomicroscope in a cold shed. Using these same sorts of microphysical observations at Stony Brook University, Stark et al. (2013) showed the microphysical evolution of a snowband, which transitioned from mainly moderately-rimed dendrites on the eastern (warm) side of a frontal zone to unrimed dendrites and plates on the western (cold) side. Media and mPING (meteorological Phenomena Identification Near Ground; Elmore et al. 2014) precipitation-type reports were available, as well. Thus, hydrometeor types diagnosed via dual-polarization radar can be compared to the variety of in-situ surface measurements.

The purpose of this paper is to use a combination of dual-polarization radar, detailed in-situ microphysical observations, and public precipitation-type observations to determine what caused the snowband's extreme radar reflectivity and rapid weakening while still maintaining intense snowfall ($4\text{--}8\text{ cm h}^{-1}$). Further, this article illustrates the value of dual-polarization radar in determining snowfall intensity and the type of frozen precipitation in an operational forecast environment.

OVERVIEW. The blizzard resulted from a rapidly deepening cyclone traveling northeastward along the East Coast of the United States (deepening 13 hPa in the 12 h starting at 1200 UTC 8 February 2013), as a much weaker cyclone traveled eastward across the Great Lakes region (Figs. 4a,b) in a classic Miller (1946) Type B cyclone

evolution (e.g., Kocin and Uccellini 2004). The coastal cyclone underwent an evolution consistent with the Shapiro–Keyser cyclone model (Shapiro and Keyser 1990), developing a strong bent-back front (Figs. 4b,c). Winds along the coastline were particularly strong within the cold conveyor belt (Carlson 1980; Schultz 2001), with an observed gust to 34 m s^{-1} at Boston Logan International Airport. The near-surface temperature was near or below freezing and decreasing due to diabatic cooling and cold advection over much of the northeast United States, ensuring that most precipitation would be frozen.

Heavy precipitation to the northwest of the surface cyclone at 0000 UTC 9 February occurred in a band of the type described by Novak et al. (2004) (Fig. 2). The ascending branch of the secondary circulation associated with Petterssen (1936) frontogenesis (Fig. 5), as described by Eliassen (1962) and Keyser et al. (1988), was aligned with the band. The 700-hPa frontogenesis at 0000 UTC exceeded $3 \text{ K (100 km}^3 \text{ h)}^{-1}$ along a band extending from Cape Cod to eastern Long Island (Fig. 5). The air above the frontal zone was characterized by regions of weak symmetric stability and conditional instability, ensuring robust ascent (not shown).

MICROPHYSICAL EVOLUTION OF THE BAND. We focus on three periods of precipitation over Long Island: 1) snow and sleet (2000–2300 UTC 8 February), 2) snow and sleet characterized by heavy riming and hydrometeor diversity (2300 UTC 8 February to 0200 UTC 9 February), and 3) less-dense snow coinciding with decreasing radar reflectivity Z_H (0200–0400 UTC 9 February).

1. *Intense snowfall and sleet: 2000–2300 UTC 8 February*

Based upon in-situ observations during this period, heavy snow fell across most of the northern half of Long Island (Table 2; Fig. 6). On the south shore of Long Island, a mix of heavy sleet, snow, and even rain at times was common, with several inches of sleet accumulation (personal communication with an NWS employee). When analyzed in tandem, the fields of differential reflectivity (Z_{DR}) and correlation coefficient (CC) from the dual-polarization radar exhibit two areas of mixed-phase hydrometeors (Fig. 6).

The first area (labeled “1” in Fig. 6) indicated melting snow aloft as it was falling through a warm layer. The increases in Z and Z_{DR} in this area were typical of a melting layer with water-coated ice, and the decrease in CC was a result of the diversity of hydrometeors and presence of non-Rayleigh scattering due to large, melting-snow aggregates (e.g., Zrníc et al. 1993; Ryzhkov and Zrníc 1998; Trömel et al. 2013; Kumjian 2013a,b).

The second area (labeled “2” along a line of $Z_H > 45$ dBZ, $Z_{DR} > 2$ dB, and $CC < 0.85$) was likely indicating mixed-phase precipitation below the melting layer (at about 600 m AGL). Indeed, this feature was similar to the re-freezing signature documented by Kumjian et al. (2013) and was likely an indication of rain re-freezing into sleet just above the surface. Similar to area 1, the substantial decrease in CC was due to a diversity of hydrometeors in a mix of liquid and ice, as well as further non-Rayleigh scattering. The highest reflectivity ($Z_H > 50$ dBZ) was located just north of the highest Z_{DR} . In this area, Z_{DR} was lower, but still elevated (around 0.5–1 dB) and CC was less than 0.95, indicative of a mixture of ice and some liquid. Therefore, dual-polarization data show that the

highest reflectivity at this time was not a result of pure snow, but a potential mixture of sleet, rain, and snow.

Traditionally, with a single-polarization radar and knowledge of the temperature profile, a forecaster would likely assume the enhanced reflectivity was a bright-band signature from melting hydrometeors, but would be unsure of the precipitation type at the surface. For example, the enhanced reflectivity may simply have been rain or a rain–snow mix, lessening expected snow totals. However, forecasters familiar with dual-polarization radar signatures were able to identify extreme snowfall rates and areas of heavy sleet with confidence. This information was valuable to key users in emergency management and broadcast media, based upon feedback provided to the NWS office.

2. Heavy riming and extreme hydrometeor diversity: 2300 UTC 8 February to 0200 UTC 9 February

Surface observations after 2300 UTC indicated mixed precipitation falling as far north as southern Connecticut (Fig. 7), and in-situ observations from Stony Brook University showed that snow-to-liquid ratios fell from 13:1 around 2200 UTC to only 4:1 around 0000 UTC, when heavily-rimed snow and ice pellets were observed (Table 2; Fig. 8a). Additionally, Connecticut media (R. Hanrahan 2013, personal communication) described some of the precipitation around 0030–0200 UTC as “large sleet” resembling pea-sized hail (Fig. 7).

By 0042 UTC, region 1 shrank and region 2 expanded (Fig. 7) in conjunction with the cooling in the lower troposphere (cf. Figs. 4a,b). Region 2 extended southwest to northeast across Long Island and into southern Connecticut, having rotated with the

snowband as the cyclone moved east (Fig. 4). The combination of heavy snow, raindrops, ice pellets approaching the size of hail, and graupel provided the necessary hydrometeor diversity to reduce CC less than 0.85 over such a large area. Additionally, a large number of liquid-coated ice hydrometeors would support the continued Z_H and Z_{DR} enhancements. The irregular-shaped, but smooth, structure of the ice pellets in Fig. 8a suggests a wet-growth process followed by aggregation and freezing of wet sleet or graupel. Therefore, polarimetric and in-situ evidence indicate a mixed-phase region similar to those observed in the updrafts of warm-season convection (Balakrishnan and Zrnić 1990; Ryzhkov et al. 2005; Kumjian and Ryzhkov 2008). Although the mixed-phase updraft signature is a common occurrence in warm-season convection, to our knowledge, such a feature has not been described in a winter storm.

3. Less-dense snow aggregates: 0200–0400 UTC 9 February

After 0200 UTC, the reflectivity values rapidly decreased to around 25–40 dBZ (Fig. 9) across the domain. Surface reports (e.g., automated surface observation stations, mPING) indicated a transition to entirely snow during this time (Fig. 9), consistent with continued cooling (Fig. 4c). Even with this information, a forecaster using only reflectivity data may have interpreted a rapid decrease of reflectivity as a weakening of the precipitation intensity. However, surface data demonstrated that snowfall intensity remained steady or even increased across many areas. The polarimetric variables helped reconcile these conflicting observations.

Between 0200 and 0400 UTC, Z_{DR} values generally fell below 1 dB across the entire area (Fig. 9), indicating a reduction of liquid water and a change to dry snow as the

dominant precipitation type, consistent with cold advection in the lowest 200 hPa as the cyclone moved northeastward (Fig. 4c). Additionally, areas of lower CC rapidly increased to 0.98–0.99, signaling the loss of extreme hydrometeor diversity and the dominance of dry-snow aggregates. Indeed, previous research and observations have shown that dry-snow aggregates tend to have Z_{DR} values near 0–0.5 dB and CC values of 1 (e.g., Ryzhkov and Zrnić 1998; Andrić et al. 2013; Table 1), similar to the observed values in Fig. 9. Observations at Stony Brook University supported the transition to dry snow, as indicated by a decrease in riming, more stellar types (Fig. 8b), an increase in snow-to-liquid ratio to over 10:1 by 0300 UTC, and a persistence of heavy snowfall rates (Table 2).

Thus the rapid decrease in reflectivity was due to a transition from higher-density precipitation (heavily-rimed snow, sleet, graupel, very small hail, rain and melting hydrometeors) to lower-density snow aggregates. In turn, the lower density of these aggregates resulted in less energy returned to the radar, which decreased reflectivity. Such a transition in hydrometeor types would be difficult for a forecaster to determine without the aid of dual-polarization radar data. This crucial data source enabled forecasters to maintain situational awareness of intense snowfall and relay these near-term updates to emergency managers. Additionally, this case exhibits the value of such information for aviation, in which accurate precipitation-type and resultant visibility forecasts are critical for the mitigation of delays and cancellations.

CONCLUSION. The northeast U.S. blizzard of 8–9 February 2013 brought heavy precipitation with varied and rapidly changing hydrometeor types, resulting in a challenging near-term forecast of snowfall accumulation and precipitation type. The relatively dense, wet hydrometeors and their extreme diversity led to radar reflectivity values exceeding 55 dBZ. In fact, a signature of a mixed-phase region was observed, similar to that observed in the updraft of warm-season convection. Later, a transition to colder, less-dense snow aggregates reduced reflectivity values, even though high snowfall rates were maintained.

Dual-polarization radar data—especially when analyzed in conjunction with temperature profile data and in-situ observations of microphysical types—improved upon single-polarization reflectivity data by adding information about the phase, density, and shape of the sampled hydrometeors. Such information facilitated a more detailed and accurate assessment of precipitation type and snowfall intensity in an operational setting, improving near-term forecasting capabilities, as confirmed by the NWS WFO New York forecasters on shift during the storm. As a result, this case serves as an excellent example of the additional information dual-polarization data provide to operational forecasters, enabling them to track and diagnose complex precipitation transition zones and areas of heavy snow with more confidence.

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precipitation-type reports critical to this work. The authors also acknowledge Jami Boettcher and Clark Payne (NWS Warning Decision Training Branch), as well as David Stark and Jeffrey Tongue (NWS WFO New York, NY), for useful discussion regarding the storm evolution. We thank Matthew Kumjian (Pennsylvania State University) for numerous talks regarding polarimetry. Brian Miretzky and an anonymous reviewer at the NWS Eastern Region provided informal reviews, and Steve Nesbitt and two anonymous reviewers provided formal reviews, all of which improved earlier drafts of this manuscript. Partial funding for Schultz was provided by the UK Natural Environment Research Council to the Diabatic Influences on Mesoscale Structures in Extratropical Storms (DIAMET) project at the University of Manchester (grant NE/I005234/1). Partial funding for Colle, Ganetis, and Sienkiewicz was provided from the National Science Foundation (AGS-1347499) and NOAA-CSTAR (NA10NWS4680003).

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TABLE AND FIGURE CAPTIONS

Table 1. A summary of typical dual-polarization values for some cool-season precipitation types and microphysical processes (adapted from Ryzhkov and Zrníc 1998, Andrić et al. 2013, Kumjian 2013a,b, and Kumjian et al. 2013). The terms “increasing/decreasing” in the table refer to the direction toward the ground.

Table 2. A summary of microphysical observations taken between 2115 UTC 8 February and 0345 UTC 9 February 2013 at Stony Brook University (yellow stars in Fig. 6, 7, and 9).

Figure 1: Map of snow accumulation (in) from 8–9 February 2013. (Courtesy of Brandon Vincent, Meteorologist at NWS Weather Forecast Office Raleigh, NC.)

Figure 2. A regional mosaic of radar reflectivity at 0000 UTC 9 February 2013. The dashed box indicates the region of interest for the dual-polarization data (Fig. 5). The arrow marks the location of the maximum reflectivity value of 57.5 dBZ at 0000 UTC.

Figure 3. The NWS WFO New York and KOKX in Upton, NY, on 9 February 2013, following the blizzard. Storm-total snowfall and liquid equivalent of 78.5 cm (30.9 in) and 12.4 cm (4.89 in), respectively, were measured here. The liquid equivalent included an early 5.9 cm (2.4 in) of rain. Note the cars buried in snow in the parking lot.

Figure 4. North American Model initial conditions of sea-level pressure (hPa, solid black lines), 950-hPa temperature ($^{\circ}\text{C}$, red lines with 0°C thick), and 950-hPa wind speed (m s^{-1} , colored according to scale): (a) 1200 UTC 8 February 2013, (b) 0000 UTC 9 February 2013, and (c) 1200 UTC 9 February 2013.

Figure 5. North American Model initial conditions at 0000 UTC 9 February 2013 of 700-hPa geopotential height (black lines every 6 dam), 700-hPa potential temperature (red lines every 2 K), 700-hPa Petterssen (1936) frontogenesis [$\text{K (100 km 3 h)}^{-1}$, colored according to scale], and 600-hPa moist equivalent potential vorticity (negative regions with purple hatching).

Figure 6. KOKX 0.5° Plan Position Indicators (PPIs) of reflectivity (Z_H ; top), differential reflectivity (Z_{DR} ; middle), and correlation coefficient (CC; bottom) at 2129 UTC. (top). mPING and media reports from 2115–2145 UTC. The speckled areas of reduced CC in southern Connecticut and around KOKX are a result of ground clutter. The black dot indicates the location of KOKX, and the star represents the location of the Stony Brook University surface observations. The dashed and dotted outlines indicate the two areas 1 and 2 of mixed-phase precipitation that are a focus for analysis.

Figure 7. KOKX 0.5° Plan Position Indicators (PPIs) of reflectivity (Z_H ; top), differential reflectivity (Z_{DR} ; middle), and correlation coefficient (CC; bottom) at 0042 UTC. (Top) mPING and media reports from 0030–0100 UTC. The speckled areas of reduced CC in southern Connecticut and around KOKX are a result of ground clutter. The black dot

indicates the location of KOKX, and the star represents the location of the Stony Brook University surface observations. The dashed and dotted outlines indicate the two areas 1 and 2 of mixed-phase precipitation that are a focus for analysis. The underlined “LS” indicates the location of the “large sleet” report.

Figure 8. A photo using a stereomicroscope at Stony Brook University (yellow stars on Figs. 6, 7, and 9) of (a) irregular sleet at 0043 UTC with inferred wet-growth and refreezing and a (b) lightly-rimed plate with dendrite extensions at 0415 UTC.

Figure 9. KOKX 0.5° Plan Position Indicators (PPIs) of reflectivity (Z_H ; top), differential reflectivity (Z_{DR} ; middle), and correlation coefficient (CC; bottom) at 0340 UTC. (Top) mPING and media reports from 0330–0430 UTC. The speckled areas of reduced CC in southern Connecticut and around KOKX are a result of ground clutter. The black dot indicates the location of KOKX, and the star represents the location of the Stony Brook University surface observations. The dashed and dotted outlines indicate the two areas 1 and 2 of mixed-phase precipitation that are a focus for analysis.

Table 1. A summary of typical dual-polarization values for some cool-season precipitation types and microphysical processes (adapted from Ryzhkov and Zrnić 1998, Andrić et al. 2013, Kumjian 2013a,b, and Kumjian et al. 2013). The terms “increasing/decreasing” in the table refer to the direction toward the ground.

Precip Type / Phase Change	Reflectivity at Horizontal Polarization (Z_H , dBZ)	Differential Reflectivity (Z_{DR} , dB)	Correlation Coefficient (CC)
Dry Snow Aggregates	5–35	0–0.5	> 0.97
Melting Snow	Increasing Z_H	Increasing Z_{DR} (typically > 1 dB)	Decreasing CC (typically 0.9–0.97)
Pure Rain	Variable Z_H	0–2 dB (for small to medium drops)	> 0.98
Re-freezing Process (Rain to Ice Pellets)	Decreasing Z_H (around 5–7 dBZ drop) within the re-freezing layer	Local maxima in Z_{DR}	Local minima in CC (can be < 0.9)

432 Table 2. A summary of microphysical observations taken between 2115 UTC 8 February
 433 and 0345 UTC 9 February 2013 at Stony Brook University (yellow stars in Fig. 6, 7, and
 434 9).

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Time (UTC)	Snow-to-Liquid Ratio	Snowfall Rate (cm h ⁻¹) [in h ⁻¹]	0.5° Elevation Angle Radar Reflectivity at Horizontal Polarization (dBZ)	Comments
2115–2245	13:1	4.0–8.5 [1.6–3.3]	35–45	Large aggregates (at times 2–4 cm in diameter); heavy snow
2330–0230	4:1–8:1	1.5–7.6 [0.6–3.0]	35–50 [2330–0200 UTC] 25–30 [0200–0230 UTC]	Substantial riming or “sleet” around 0030 UTC; small aggregates in heavy snow around 0230 UTC
0230–0345	8:1–10:1	6.5–6.7 [2.6]	25–35	Mixture of snow crystal types; heavy snow

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Figure 1: Map of snow accumulation (in) from 8–9 February 2013. (Courtesy of Brandon Vincent, Meteorologist at NWS Weather Forecast Office Raleigh, NC.)

Figure 2. A regional mosaic of radar reflectivity at 0000 UTC 9 February 2013. The dashed box indicates the region of interest for the dual-polarization data (Fig. 5). The arrow marks the location of the maximum reflectivity value of 57.5 dBZ at 0000 UTC.

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446 Figure 3. The NWS WFO New York and KOKX in Upton, NY, on 9 February 2013,
447 following the blizzard. Storm-total snowfall and liquid equivalent of 78.5 cm (30.9 in)
448 and 12.4 cm (4.89 in), respectively, were measured here. The liquid equivalent included
449 an early 5.9 cm (2.4 in) of rain. Note the cars buried in snow in the parking lot.

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Sea-Level Pressure, 950-mb Temperature and Wind Speed

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452 Figure 4. North American Model initial conditions of sea-level pressure (hPa, solid black

453 lines), 950-hPa temperature (°C, red lines with 0°C thick), and 950-hPa wind speed (m s⁻¹

454 ¹, colored according to scale): (a) 1200 UTC 8 February 2013, (b) 0000 UTC 9 February

455 2013, and (c) 1200 UTC 9 February 2013.

**700-mb Geopotential Height, Potential Temperature, Frontogenesis
and 600-mb Negative Moist Equivalent Potential Vorticity**

457

458 Figure 5. North American Model initial conditions at 0000 UTC 9 February 2013 of 700-
 459 hPa geopotential height (black lines every 6 dam), 700-hPa potential temperature (red
 460 lines every 2 K), 700-hPa Petterssen (1936) frontogenesis $[\text{K (100 km 3 h)}^{-1}]$, colored
 461 according to scale], and 600-hPa moist equivalent potential vorticity (negative regions
 462 with purple hatching).

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Figure 6. KOKX 0.5° Plan Position Indicators (PPIs) of reflectivity (Z_H ; top), differential reflectivity (Z_{DR} ; middle), and correlation coefficient (CC; bottom) at 2129 UTC. (top). mPING and media reports from 2115–2145 UTC. The speckled areas of reduced CC in southern Connecticut and around KOKX are a result of ground clutter. The black dot indicates the location of KOKX, and the star represents the location of the Stony Brook University surface observations. The dashed and dotted outlines indicate the two areas 1 and 2 of mixed-phase precipitation that are a focus for analysis.

476

477 Figure 7. KOKX 0.5° Plan Position Indicators (PPIs) of reflectivity (Z_H ; top), differential
 478 reflectivity (Z_{DR} ; middle), and correlation coefficient (CC; bottom) at 0042 UTC. (Top)
 479 mPING and media reports from 0030–0100 UTC. The speckled areas of reduced CC in
 480 southern Connecticut and around KOKX are a result of ground clutter. The black dot indicates
 481 the location of KOKX, and the star represents the location of the Stony Brook University
 482 surface observations. The dashed and dotted outlines indicate the two areas 1 and 2 of mixed-
 483 phase precipitation that are a focus for analysis. The underlined “LS” indicates the location of
 484 the “large sleet” report.

Figure 8. A photo using a stereomicroscope at Stony Brook University (yellow stars on Figs. 6, 7, and 9) of (a) irregular sleet at 0043 UTC with inferred wet-growth and refreezing and a (b) lightly-rimmed plate with dendrite extensions at 0415 UTC.

Figure 9. KOKX 0.5° Plan Position Indicators (PPIs) of reflectivity (Z_H ; top), differential reflectivity (Z_{DR} ; middle), and correlation coefficient (CC; bottom) at 0340 UTC. (Top) mPING and media reports from 0330–0430 UTC. The speckled areas of reduced CC in southern Connecticut and around KOKX are a result of ground clutter. The black dot indicates the location of KOKX, and the star represents the location of the Stony Brook University surface observations. The dashed and dotted outlines indicate the two areas 1 and 2 of mixed-phase precipitation that are a focus for analysis.