12A.6 2015 Phased Array Radar Innovative Sensing Experiment

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1. INTRODUCTION

The overarching objective of the Phased Array Radar Innovative Sensing Experiment (PARISE) is to understand what effects higher-temporal resolution volumetric radar data may have on National Weather Service (NWS) forecasters' warning decision processes (e.g., Heinselman et al. 2012; Heinselman et al. 2015; Bowden et al. 2015; Bowden and Heinselman 2016). This understanding informs efforts to replace the current WSR-88D network with a network of phased array radars (e.g., Zrnić et al. 2007). The 2015 PARISE extends the work of previous experiments by:

1) Investigating whether the benefits of higher-temporal resolution radar data found in previous studies are evident with an increased sample size of participants and number of cases worked,

2) Obtaining a deeper understanding of forecasters' cognitive processes as they interact with different temporal resolutions of radar data, and

3) Understanding how temporal resolution impacts forecasters' cognitive workload and if and when data overload exists.

Components of 2015 PARISE aimed at achieving these three goals include the Traditional Experiment, described herein, and the Eye Tracking Experiment described in a companion paper by Bowden et al. (2016). Given the preliminary nature of this analysis, we focus on performance results from tornado cases only.

2. METHODOLOGY

2.1 Experimental Design

Thirty NWS forecasters from 25 Weather Forecast Offices within the Great Plains participated in the 2015 PARISE during six weeks of August and September 2015 at the Hazardous Weather Testbed in Norman, OK.

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All participants individually worked nine potentially severe weather events in simulated real time (Table 1). For each case, forecasters were randomly assigned phased array radar (PAR) data with one of the following approximate volumetric update times: one, two, or four min. These update times are referred to hereafter as full, half, and quarter-speed, respectively. The use of three different update times allows us to determine whether findings from previous experiments are repeated with a larger sample size, and to assess impacts of update time on situational awareness.

Participants were asked to work each case as if in normal operations. Prior to each event, a pre-briefing of the environmental setting was viewed. The radar data were displayed and cases completed using AWIPS-2. Following each case, participants viewed a replay of their interaction with the display and were asked to retrospectively recall everything they saw, thought, and did (e.g., Hoffman 2005; Heinselman et al. 2015). To explore how cognitive workload changes during the warning decision process, forecasters provided self-assessed instantaneous workload ratings (not shown) during each five-min interval of the retrospective recall.

3. PERFORMANCE RESULTS

The nine cases worked by forecasters were chosen to not only increase sample size compared to previous experiments (9 vs 2–4 cases), but also to assess forecasters' ability to distinguish between severe weather threats. Hence, this experiment included three tornado cases (Fig. 1), three hail and/or wind cases, and three null cases (Table 1). Of the three null cases, two had no severe weather reports, and one was a non-tornadic supercell with several severe hail reports (1 in or larger). A basic question, then, is how well forecasters distinguished the tornado threat while working these cases. As shown in Table 2, 70% (105 of 149) of tornado warnings were issued during tornado cases and only 9% (13 of 149) were issued during null cases; all of the latter warnings occurred during the non-tornadic supercell case. The remaining 21% of tornado warnings were issued during two of the three severe cases. These results indicate strong ability of participating forecasters to distinguish tornado threat for the cases worked. Two other findings of note are 1) only one tornado warning (of

13 total) was issued by a participant using full-speed data while working the non-tornadic supercell case and 2) more tornado warnings were issued by participants using half- and full-speed data while working tornado cases. The second finding raised the question as to whether the higher number of tornado warnings issued by those using faster updates resulted in higher false alarm ratios (FAR).

3.1 Verification Scores for Tornado Cases

Probability of detection (POD) and FAR scores were computed for each participant and tornado case (Fig. 2). Comparison of score distributions between the three tornado cases reveals that Eta was the most challenging of the three cases, as most PODs were zero and most FARs were 0.5 or higher (Fig. 2a). While the other two tornado cases contained tornadic supercell storms, Eta contained a tornadic squall line that produced a short-lived EF1-rated tornado along its leading edge (Fig. 1). Of the three perfect POD scores, one resulted from the use of half-speed data, and two resulted from the use of full-speed data. Future analysis of the retrospective recall data will provide contextual insight of participants' warning decision processes, including why only P11, P15, and P22 issued verified tornado warnings.

Based on tornado warning verification scores, Iota was a moderately challenging case and Zeta a relatively easy one (Fig. 2b, c). The two cases differ in that Iota presented a cluster of supercell storms with one EF0-rated tornado report, whereas Zeta presented an isolated supercell that produced two EF1-rated tornadoes and one EF2-rated tornado (Fig. 1; Table 1). Iota's POD scores ranged from 0.34 to 0.85. The highest number of POD scores 0.65 or greater resulted from the use of full-speed data (N=8), whereas the lowest number of such scores resulted from the use of quarter-speed data (N=1; Fig. 2b). Hence the use of half and especially full-speed data resulted in a distribution of superior POD scores. In contrast, the distributions of FAR scores were quite similar regardless of the update speed used. Although most FAR scores ranged from 0.25 to 0.75, a few participants in each update speed group issued no unverified warnings (Fig. 2b). Of these participants, only those using half- or full-speed data also achieved POD scores at the high end of the distribution (at or above 0.65).

The range of POD and FAR scores was most narrow for Zeta. Specifically, PODs spanned from 0.75 to 1.0 for all three update speeds, and most were at or near 1.0 (Fig. 2c). FARs spanned from 0.0 to 0.4, and most were zero regardless of update speed used.

In each tornado case, the relative similarity in distributions of FAR scores indicates little-to-no impact of radar update time on the number of unverified warnings. Hence, the higher number of warnings issued by participants using half or full-speed data (Table2) did not result in a higher number of false alarms. The most evident impact of radar data update speed occurred within the Iota case, where POD scores were highest for participants using full-speed data.

3.2 Tornado Warning Lead Times

Mean (along path) tornado warning lead times were computed for verified tornado warnings issued by each forecaster (e.g., Heinselman 2015). Additionally, median tornado warning lead time for all tornado events combined was computed for the three update speeds used (Fig. 3). The highest overall median tornado warning lead time, 14.5 min, resulted from the use of full-speed data. Interestingly, the overall median tornado warning lead times resulting from the use of quarter speed data was slightly longer than the median resulting from the use of half-speed data: 11.5 vs 10 min, respectively.

To understand the distributions leading to the combined median tornado warning lead times, we computed the median tornado warning lead times resulting from the use of full-, half-, and quarter-speed updates for each tornado event (Fig. 3). Given the poor verification scores for Eta, unsurprising is a zero median tornado lead time for all update speeds. This value contributes toward the relatively low overall median tornado lead times. For Iota, the median tornado warning lead times from highest to lowest resulted from the use of full-speed (14.5 min), half-speed (13.0 min), and quarter-speed (11.5 min) data, respectively. For the first tornado event during Zeta, the order of median tornado warning lead times were similar to the ordering of combined warning lead times: full-speed group (14.5 min), quarter-speed group (11.0 min), and half-speed group (9.0 min). Median lead times for full- and quarter-speed groups increased to 17.0 and 18.5 min, respectively, for the second tornado, while the median tornado lead time for the half-speed group increased slightly from 9.0 to 10.0 min. By the time the third tornado occurred, median tornado warning lead times decreased for full- and quarter-speed groups to 15.9 and 13.6 min, respectively, while the median tornado lead time for the half-speed group increased to 18.2 min.

4. NEXT STEPS

The results of this research are preliminary. We have explored group differences in performance measures for the three tornado cases. Our preliminary results indicate that verification measures and tornado lead times for the three cases examined differ based on case type, i.e., tornadic squall line vs tornadic supercell. Additionally, the preliminary results support previous findings of longer median tornado warning lead times when using 1-min vs 4-min volume updates. Future work will present verification and warning lead times for severe events. Additionally, the retrospective recall data collected will be analyzed to understand differences in forecaster cognitive behavior that drove the verification and warning lead time distributions. This contextual analysis will be enhanced by co-analyses of cognitive workload ratings collected for every 5-min period during the retrospective recall portion of the experiment.

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Table 1. Three case types a) Null, b) Wind and/or Hail, and c) Tornadic. Listed are case names, duration, and associated storm report magnitudes (inches, kts, EF-scale) and times (UTC; from Storm Data 2010, 2011, 2012, 2013).

a) Null Cases				
Case Name	**Duration (UTC)**	**Hail inches: UTC**	**Wind kts: UTC**	**Tornado EF#: UTC**
Epsilon	2059–2139 5 June 2012	None	None	None
Alpha	0724–0756 14 May 2010	None	None	None
*Theta	1957–2033 30 May 2013	1.75: 2013 1.00: 2015 1.00: 2030	None	None

*Theta is a nontornadic hail-producing supercell and therefore is a null with respect to tornado occurrence.

b) Wind and/or Hail Cases				
Case Name	**Duration (UTC)**	**Hail inches: UTC**	**Wind kts: UTC**	**Tornado EF#: UTC**
Beta	2120–2200 12 Aug 2011	None	61: 2200 (estimated)	None
Gamma	2330–2359 22 Oct 2011	1.25: 2329 1.50: 2358	None	None
Delta	2222–2301 4 May 2012	1.00: 2242 1.25: 2255	59: 2300 (measured)	None

c) Tornado Cases				
Case Name	**Duration (UTC)**	**Hail inches: UTC**	**Wind inches: UTC**	**Tornado EF#: UTC**
Eta	2130–2200 29 May 2013	None	None	EF1: 2200
Iota	2209–2301 30 May 2013	1.00: 2209 1.75: 2212 2.25: 2227	61: 2230 (estimated)	EF0: 2230
Zeta	2050–2154 19 May 2013	1.50: 2101 1.25: 2115 1.00: 2117 1.15: 2118 2.60: 2137	52: 2115 (estimated)	EF1: 2122–30 EF1: 2133–34 EF2: 2141–54

Table 2. Number of tornado warnings issued by update speed and case type.

Radar Update Speed	**Null Cases**	**Severe Cases**	**Tornado Cases**
Quarter Speed	6	8	29
Half Speed	6	12	38
Full Speed	1	11	38
Total Number (149)	13 (9%)	31 (21%)	105 (70%)

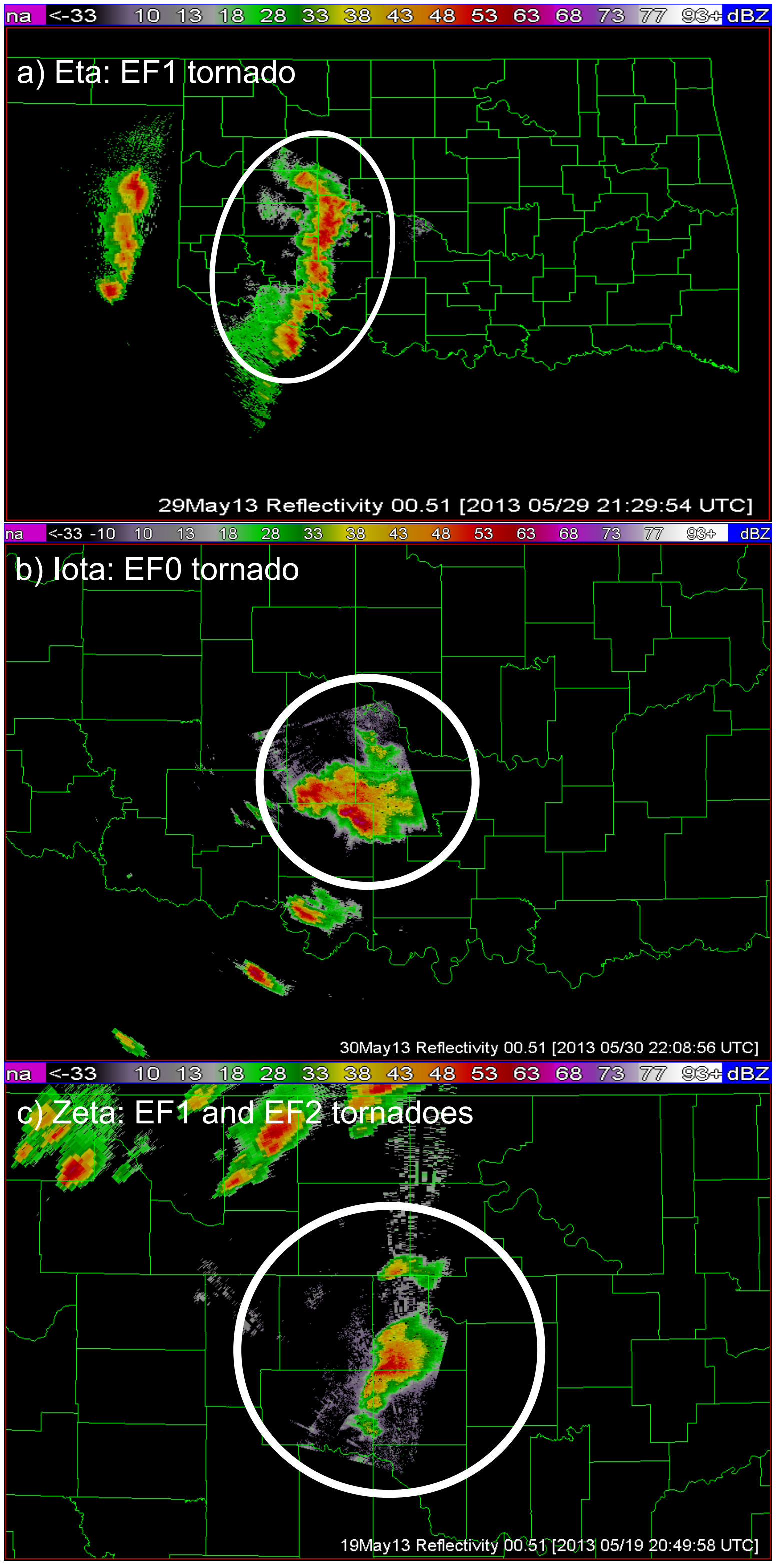

Figure 1. White circles enclose the tornado cases worked by forecasters, including: a) Eta, b) Iota, and c) Zeta. See Table 1 for details.

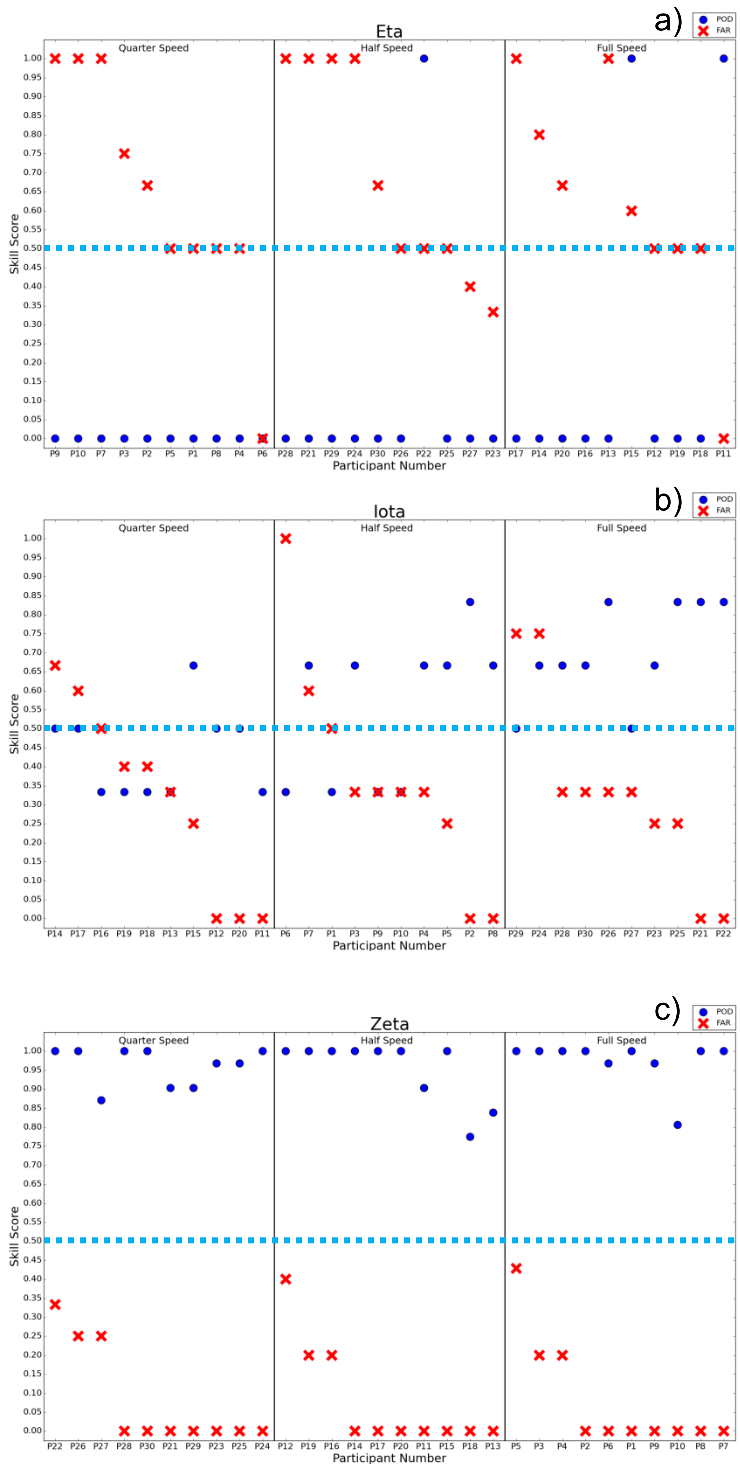

Figure 2. Distribution of each participant's POD and FAR scores, organized by radar update time, for tornado cases a) Eta, b) Iota, and c) Zeta. Blue circles denote POD, while red crosses denote FAR. Dashed blue line at 0.5 is plotted to aid comparison of verification measures.

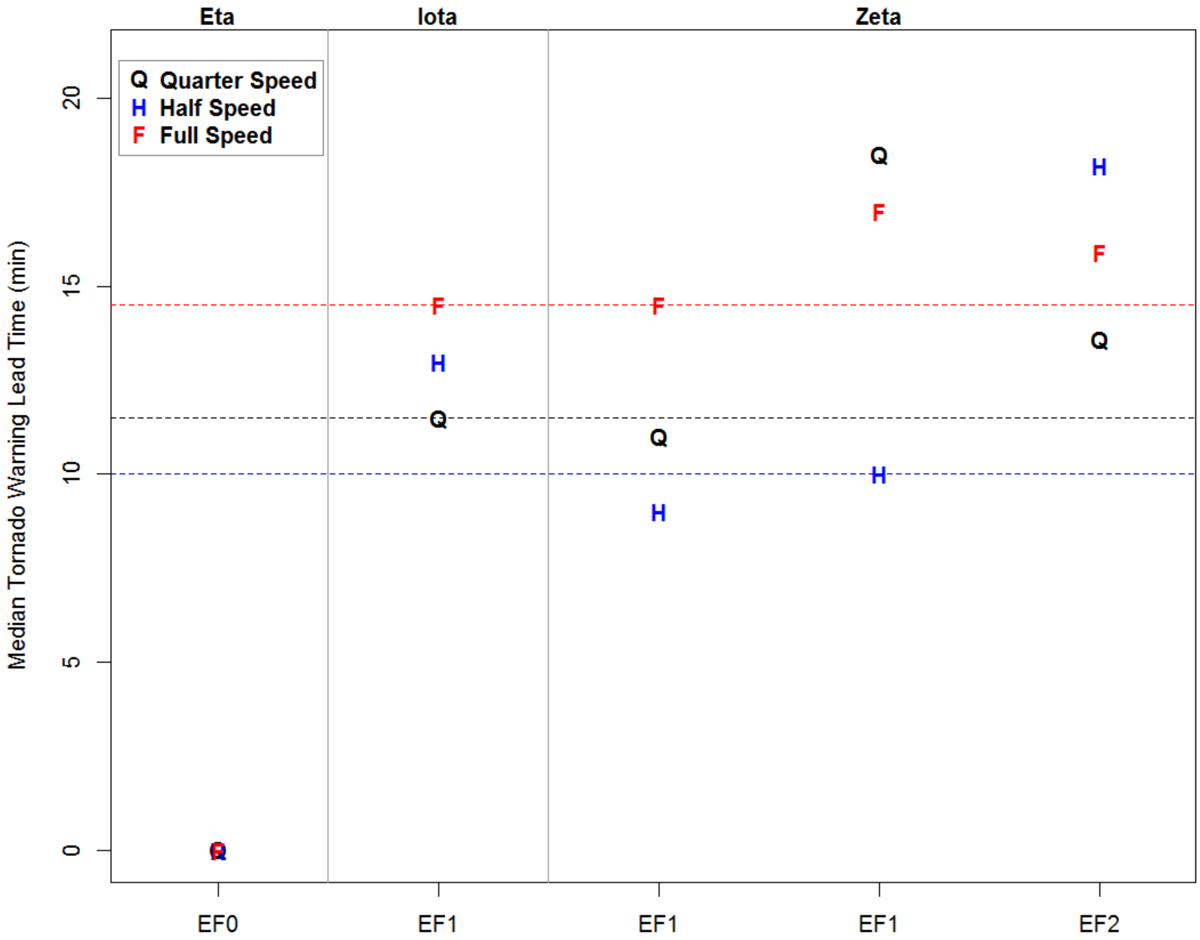

Figure 3. Distribution of median tornado warning lead times resulting from the use of full-speed (red F), half-speed (blue H), and quarter-speed (black Q) radar data for tornado events comprising each case. Dashed horizontal lines denote the combined median tornado warning lead time for full-speed (red dashed), half-speed (blue dashed), and quarter-speed (black dashed) radar updates.