214 CONDITIONAL INTENSITY FORECAST VERIFICATION USING SIGNIFICANT SEVERE LOCAL STORM REPORTS

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1. INTRODUCTION

The Storm Prediction Center (SPC) issues day one and day two convective outlooks of severe thunderstorm hazards across the United States. Currently, day one and day two outlooks express probabilistic forecasts for tornado, severe wind, and severe hail threats. The probabilistic forecasts are an estimate of a severe hazard event occurring within twenty-five miles of a point. Each probabilistic forecast also communicates severe hazard intensity via single-hatched regions. A single-hatch region signifies a ten percent (or greater) probability of a significant severe hazard occurring within twenty-five miles of a point. Current significant severe hazard thresholds are a tornado rated at least EF2 on the enhanced Fujita scale, hail at least 5 cm (2 in) in diameter, and/or thunderstorm winds of at least 33.5 m/s (75 mph).

This current SPC forecasting framework, allows for some discrimination between high and low impact events, but it is limited by a single probability line for significant severe threats. Verification of past SPC probabilistic forecasts reveal that the expected intensity of severe hazard reports increase as the probabilistic coverage increases. Therefore, while current probabilistic coverage forecasts implicitly convey intensity information, the intensity forecast component could be better communicated. Prior research at SPC showed that SPC significant severe forecast areas, currently defined as 10% probability of significant severe, were not verifying uniformly as defined.

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However, analysis of the historical SPC forecast probabilities revealed multiple storm report intensity distributions. The prior work highlighted at least two intensity distributions that could be defined by applying simple rules to the existing outlooks. The two intensity distributions were referred to as single and double-hatched categories. This resulted in the development of the conditional intensity forecast framework.

Beginning in November 2021, SPC forecasters began issuing experimental conditional intensity hazard forecasts. Conditional intensity forecasts allow for greater forecaster flexibility during the forecast process. Within this framework, the single-hatch forecast category is no longer restricted to the unconditional 10% probability of significant severe reports, as it is conditional upon the severe weather hazard occurring. Additionally, a new double-hatch forecast category is available for forecasters. The conditional intensity framework allows for single and double-hatch forecast categories to be drawn within any underlying hazard probability. Flexibility in the placement of single and double-hatched regions allows the forecaster to better communicate the distribution of hazard intensities for a severe weather event. Single and double-hatched regions, in the conditional intensity framework, aim to highlight storm environments where significant severe hazards are possible given severe storm development. An example of a conditional intensity tornado forecast is shown below (Fig. 1).

This study looks to evaluate the experimental SPC conditional intensity hazard forecasts to determine if the forecasting framework can spatially distinguish between the varying hazard intensities across severe weather events.

2. DATA AND METHODS

2.1 SPC CONDITIONAL INTENSITY FORECASTS

In November 2021, SPC began an internal conditional intensity forecast experiment. On duty SPC forecasters issued daily experimental conditional intensity forecasts for each severe hazard type (tornado, thunderstorm wind, and hail). Conditional intensity forecasts were issued at 1200 UTC, 1300 UTC, 1630 UTC, and 2000

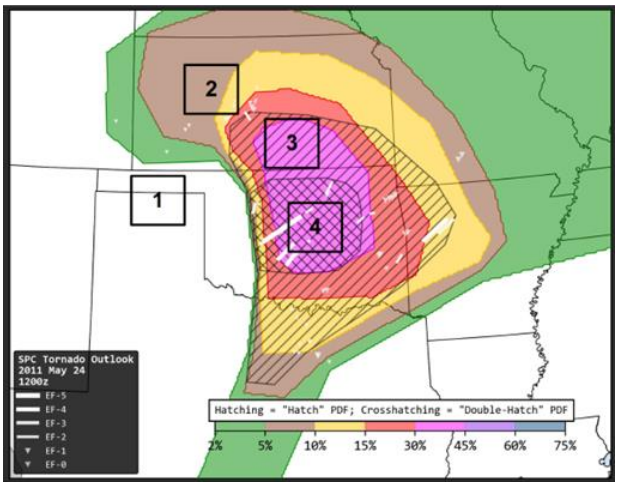

Fig. 1. Example conditional intensity tornado outlook with overlayed tornado tracks (white). Numbers represents each intensity bin 1) "no-severe", 2) "no-hatch", 3) "single-hatched", 4) "double-hatched".

UTC. Each conditional intensity forecast was valid between the issuance time and 1200 UTC the following day. All SPC forecasters were provided guidance regarding the conditional intensity framework prior to issuing the experimental forecasts. Conditional intensity forecasts are completed using NMAP and each forecast is saved internally for future analysis. The verification statistics in this study used conditional intensity forecasts issued during the analysis period, 1 November 2021 - 31 May 2022.

2.2 NCEI STORM DATA

National Centers for Environmental Information (NCEI) Storm Events Database (NCEI Storm Events Database 2022) was used in this study for the verification of conditional intensity forecasts over the analysis period. Specific event types, within the NCEI Storm Data, used for each severe hazard included "Tornado", "Thunderstorm Wind", and "Hail". SPC thresholds for severe and significant severe hazards were used to separate the storm data reports. Severe hazard thresholds used were, a tornado, hail at least 2.5 cm (1 in) in diameter, and/or thunderstorm winds of at least 26 m/s (58 mph). Significant severe hazard thresholds used were, tornadoes rated at least EF2 on the enhanced Fujita scale, hail at least 5 cm (2 in) in diameter, and/or thunderstorm winds of at least 33.5 m/s (75 mph).

2.3 CONDITIONAL INTENSITY FORECAST VERIFCATION

Verification of SPC-issued experimental conditional intensity forecasts were done using the ratio of significant severe weather reports to non-significant severe weather reports within each of the four conditional intensity forecast bins. The four conditional intensity forecast bins were designated by, 1) regions outside of forecasted probabilities (no severe), 2) regions within forecasted probabilities but outside single-hatched contours (no hatched), 3) regions within single-hatched contours but outside double-hatched contours (single-hatched), and 4) regions within double-hatched contours (double-hatched). NCEI storm reports were used to determine the significant to non-significant severe report ratio in each of the conditional intensity forecast bins, where this ratio is expected to increase from the first bin (no severe) through the fourth bin (double hatch). Given the conditional nature of these forecasts, it was determined best practice to evaluate the conditional intensity forecasts, and each intensity bin, over the total analysis period and not on a day-to-day basis.

3. RESULTS

3.1 TORNADO CONDITIONAL INTENSITY FORECAST VERIFICATION

SPC tornado conditional intensity forecasts successfully identified where tornadoes and significant severe tornadoes occurred over the analysis period. Approximately 80% of tornadoes and 90% of significant severe tornadoes occurred within tornado forecast probabilities (Fig. 2).

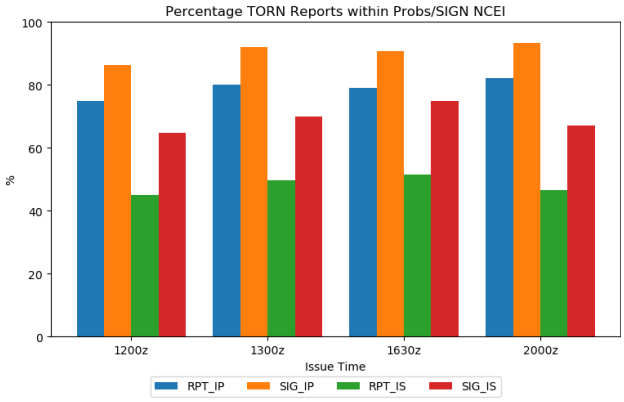

Fig. 2. Percent of significant and non-significant tornado reports that occurred within forecasted probability and single-hatched areas for each issuance time. Blue (reports in probabilities; RPT_IP), orange (SIG reports in probabilities; SIG_IP), green (reports in hatched; RPT_IS), red (SIG reports in hatched; SIG_IS).

The conditional intensity tornado forecasts also distinguished between non-significant and significant severe tornadoes. Within forecasted significant severe tornado regions (hatched or double-hatched) nearly 70% of all significant tornadoes occurred, while roughly 40% were non-significant tornadoes (Fig 2).

Verification of each conditional intensity bin reveals the ability of forecasts to distinguish between non-significant and significant tornadoes. Across each of the conditional intensity bins, the ratio of significant to non-significant tornado reports increase. Using the conditional intensity forecasting framework, this increasing ratio moving from a lower intensity to a higher intensity bin would be expected. Due to the low sample size (i.e., <=3 events) of forecasted double-hatch tornado regions, it is difficult to draw any conclusions from these results (Fig 3). However, as the sample size of conditional intensity forecasts expand, meaningful double-hatch bin statistics should emerge.

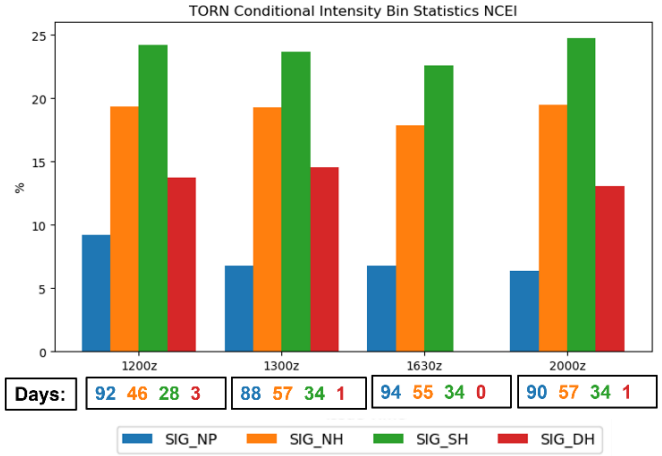

Fig. 3. Ratio of significant to non-significant severe tornado reports for each conditional intensity bin. Number of days each bin was forecasted are also shown. Blue (no severe; SIG_NP), orange (no-hatch; SIG_NH), green (single-hatch; SIG_SH), red (double-hatch; SIG_DH).

3.2 HAIL CONDITIONAL INTENSITY FORECAST VERIFICATION

SPC hail conditional intensity forecasts successfully identified where severe hail and significant severe hail occurred over the analysis period. Forecasted conditional intensity hail probabilities captured 85% of severe hail reports and 90% of significant severe hail reports. Conditional intensity hail forecasts were also able to identify where significant severe hail occurred. The percentage of significant severe hail reports that occurred within a forecasted single or double-hatched region increased from 40% to 55% across the forecast issuance times. While only 20% to 30% of non-significant severe hail reports occurred within forecasted single or double-hatched regions over the analysis period (Fig 4).

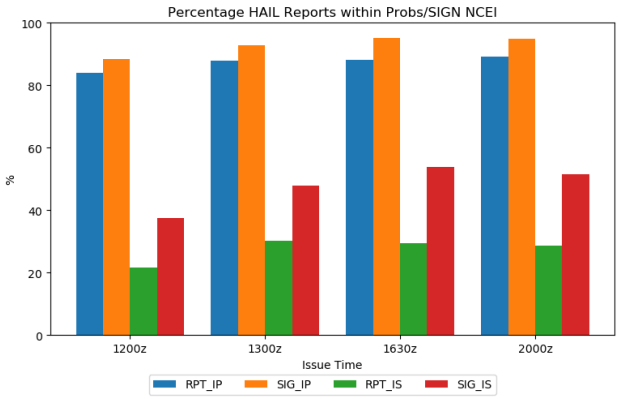

Fig. 4. Same as Fig. 2, except for hail reports.

The ratio of significant severe hail reports to non-significant severe hail reports across each conditional intensity bin further demonstrates that the conditional intensity hail forecasts did discriminate between significant and non-significant hail. Forecast bin ratios were found to increase, moving from a lower intensity to a higher intensity bin. Within the single-hatch conditional intensity bin, the ratio of significant to non-significant severe hail reports was nearly 20%. Again, due to the low sample size of forecasted double-hatch hail regions, it is difficult to draw any conclusions regarding the highest intensity bin.

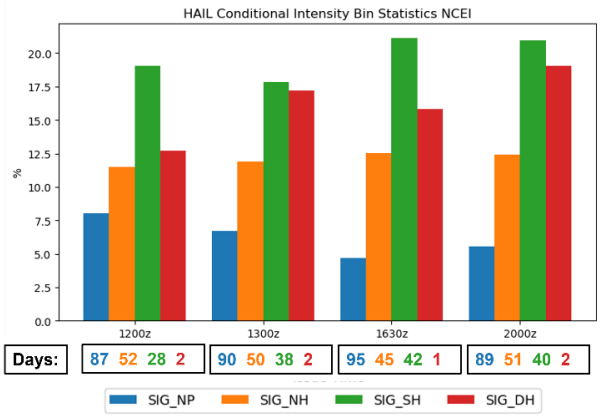

Fig. 5. Same as Fig. 3, except for hail reports.

However, the single and double-hatch bin ratios being higher than the no-hatch bin ratio displays forecast skill in identifying where larger hail occurred (Fig. 5).

3.3 WIND CONDITIONAL INTENSITY FORECAST VERIFICATION

SPC conditional intensity wind forecasts successfully identified where severe thunderstorm wind and significant severe thunderstorm wind occurred over the analysis period. Approximately 85% of severe wind and 90% of significant severe wind occurred within severe wind forecast probabilities (Fig. 6).

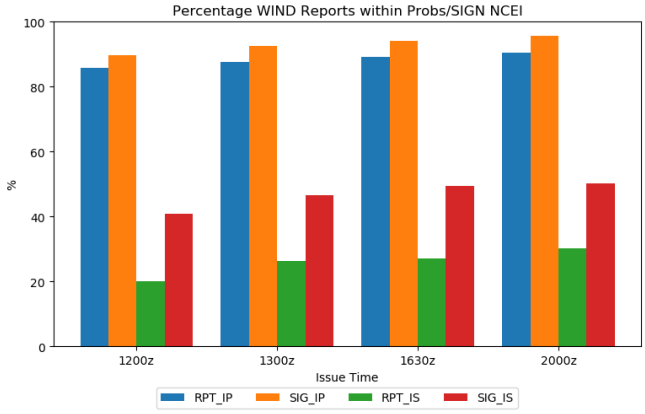

Fig. 6. Same as Fig. 2, except for wind reports.

Conditional intensity wind forecasts also distinguished between non-significant and significant severe wind reports. Within forecasted significant severe wind areas (hatched or double-hatched) nearly 45% of all significant wind reports occurred, while only 25% of non-significant wind reports occurred (Fig 6).

Verification of each conditional intensity forecast bin revealed notable forecast skill in distinguishing where significant and non-significant wind reports occurred. The forecast bin ratios drastically increased from about 15% to as high as 70% going from a lower intensity to a higher intensity conditional forecast bin. Forecast bin ratios also were shown to increase within each issuance period. While the sample size of double-hatch bins was limited, it was encouraging to see higher ratios for the double-hatch bin overall (Fig. 7). These double-hatch forecasts were issued on the most active days for significant severe wind reports (i.e., 15 December 2021 and 12 May 2022) during the period (and historically).

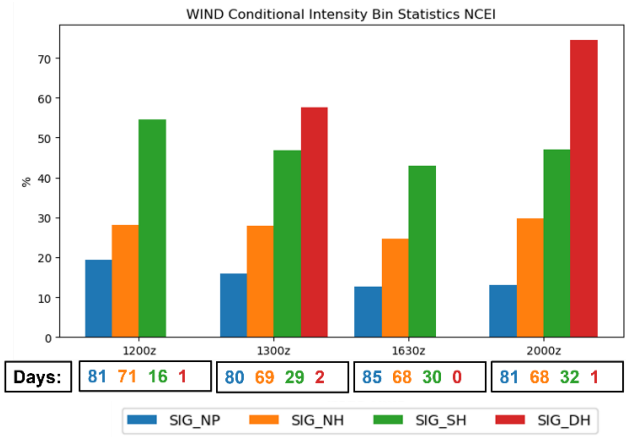

Fig. 7. Same as Fig. 3, except for wind reports.

4. DISCUSSION

The SPC experimental conditional intensity hazard forecasts issued between November 2021 and May 2022 appeared to show forecasting skill in distinguishing areas where significant and non-significant severe hazards occurred. Conditional intensity wind forecasts performed the best during the analysis period. The increase in the ratio of significant severe to non-significant severe reports (15% to 70%) going from a lower intensity to a higher intensity conditional forecast bin is ideal (Fig. 7). The wind forecasts may have performed the best because of two well forecasted derecho events during the analysis period. These two severe wind events produced many significant severe wind reports relative to the other days in the analysis period. Tornado and hail conditional forecasts also displayed the same bin ratio increase across each conditional intensity bin, showing skill in distinguishing where significant and non-significant severe hazards occurred.

Conditional intensity forecasts are best evaluated over a long (i.e., multiple years) forecast period. While the small sample size of forecasted double-hatch regions limit conclusions that can be drawn from this intensity bin, the three other intensity bins showed promising forecast skill. As the conditional intensity hazard forecasts continue to be issued internally at the SPC, a larger sample size of each forecast bin will be evaluated in future studies.

The conditional intensity forecast framework allows for greater forecaster flexibility during the forecast process. It allows forecasters to better communicate the spectrum of possible hazard intensities for a severe weather event (e.g., highly conditional significant severe threat – low probability of a very intense event). Conditional intensity forecasts essentially separate forecast probabilities from the single and double-hatch forecast options. Forecasters would have the option of forecasting single and double-hatch areas within any underlying forecast probability. For example, a classic Southern Plains dry-line event could result in several significant severe storm reports. However, such events are conditional on the development of thunderstorms. The conditional intensity framework allows for the communication of a possible significant severe event even when the probability of thunderstorm development is relatively low.

5. SUMMARY

Conditional intensity forecasts issued over the analysis period appeared to successfully distinguish where significant and non-significant severe hazards occurred. A goal of the conditional intensity framework is to highlight thunderstorm environments favorable of supporting any type of significant severe hazard. Specifically, the double-hatch intensity bin can be used to communicate the most extreme thunderstorm environments capable of having the greatest impacts to life and property. Conditional intensity forecasts could better communicate potential hazard intensities to local emergency managers, first responders, and the public.

The verification of the conditional intensity forecasts is essential for the advancement and calibration of the conditional intensity forecasting framework. Getting SPC forecaster feedback on the forecasting process and concerns when issuing experimental conditional intensity forecasts is also important. This study was an attempt at the verification of conditional intensity hazard forecasts. Additional verification methods and techniques will be necessary to further evaluate hazard based conditional intensity forecasts.

REFERENCES

NCEI Storm Events Database, 2022: Search results for all U.S. states and areas, event types: Hail, Tornado, Thunderstorm Wind. [Available from: https://www.ncdc.noaa.gov/stormevents/ftp.jsp, accessed 2022-10-1.]