NWS Operations Proving Ground
Final Report

Tiny Threats-in-Motion (TIM)

An OPG in-residence evaluation of the Tiny TIM software for convective operations

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1. Executive Summary

In mid September, 2022, the OPG conducted our second in-residence evaluation since the start of the COVID pandemic. Participants representing each CONUS region evaluated the new Tiny Threats in Motion (TIM) on the OPG baseline AWIPS system. Overall, the OPG and the participants were very impressed with the status, capabilities, and efficiencies provided by Tiny TIM.

As is common with any test of new software on a baselined system, we identified a few software defects that require solutions prior to Tiny TIM becoming operational. Participants also provided a few suggestions related to the user experience, but they overwhelmingly favored the Hazard Services and Tiny TIM based experience over the current convective warning production process (WarnGen).

Interestingly, but maybe not surprisingly, the greatest concerns raised during the test involved policy and dissemination challenges over the warning forecaster experience or software "bugs". In particular, the participants discussed the relevance of expirations times once warning polygons can be extended in time.

Regardless of the challenges, it is clear to the OPG that Hazard Services and Tiny TIM offer incredible innovations that will have a profoundly positive effect on the future warning paradigm. In particular, there are two findings Tiny TIM offers an incredible opportunity to improve service equity by providing equitable lead times during severe convection. Also, Tiny TIM offers the potential to reduce "false alarm area" by allowing warning meteorologists to draw polygons more precisely around the threat area and then adjusting with time as the threat evolves.

The following report highlights the incredible work by GSL/NSSL in developing Tiny TIM and our collaborative effort to evaluate the software in the OPG.

2. Background (Spirit and Intent)

The OPG began coordinating with the National Weather Service Headquarters (NWSHQ), scientists from the Forecasting a Continuum of Environmental Threats (FACETs) program, and Hazardous Weather Testbed (HWT) in 2021 on a proposed evaluation of Threats-In-Motion (TIM) at the OPG. TIM is a warning dissemination approach that would enable the NWS to upgrade severe thunderstorm and tornado warnings from the current static polygon system, to one where there are continuously-updating polygons that move with storms in time and space. Thus, TIM represents a shifting of the current NWS convective warning paradigm toward a continuous flow of information within the FACETs framework.

In order to accomplish the goals set forth by the FACETs program and TIM, which are more long-term, a necessary step is to test the ability for forecasters to take current warnings and move them in both time and space. This short-term solution is referred to as Tiny TIM, and was developed within the Hazard Services-Convective (HS-C) workflow to allow for current convective polygon-based warnings to be extended in area and time. While this software was previously tested within the Hazardous Weather Testbed (HWT) on cloud versions of AWIPS, it had yet to be tested on a baseline AWIPS system like that in a Weather Forecast Office (WFO). As a result of the most recent 2022 Tiny TIM HWT experiment, several improvements had been made to the software, but needed to be further evaluated. Therefore, it was proposed to the OPG to evaluate Tiny TIM on our baseline AWIPS system and gain feedback from forecasters in the process.

The primary goal of the evaluation was to test the software with a broad range of forecasters to assess functionality, identify any impacts on forecaster workload, identify any inconsistencies (such as across county warning areas (CWAs), products, services, or other warning issuance), identify any dissemination challenges, examine ideal timing updates, and suggest improvements and new functionality. The following were objectives proposed by the FACETs program/HWT to support the primary goal:

Objective 1: Technology: Evaluate HS-Tiny TIM components and performance so that the software can be improved before operational implementation.

Objective 2: Human Factors: Measure forecaster workload using HS-Tiny TIM, including ease of use and graphical design.

Objective 3: Methodology: Assess how forecasters adopt their legacy warning methodology into the HS-Tiny TIM environment as they screen, rank, analyze, and decide to create, issue, modify, and manage continuous, feature-following objects.

Objective 4: Conceptology: Collect and analyze data on forecasters' thoughts on the paradigm change from "static" warnings to continuously-updating warnings.

3. Software Considerations and Design

Operational warnings are issued with a Valid Time Event Code (VTEC), which enables weather providers and vendors to automate and tailor the product stream delivered to their clients. Within the VTEC are two fields germane to this new functionality. First is the Event Tracking Number (ETN), which is a unique ID that is attached to each warning type (Severe Thunderstorm Warning or Tornado Warning). Presently, a warning cannot be extended in time or area for the same ETN. Each subsequent warning issued on a hazard has a different ETN assigned to it. Once the warning has expired or is canceled, the ETN is not reused.

In order to permit a single storm to maintain the same ETN throughout its lifecycle, Tiny TIM allows for the extension of area and time during warning updates by exploiting these existing product-extension VTEC action codes. These codes are used for other products, but are presently not used for severe thunderstorm or tornado warnings:

- VTEC = EXA: An extension of the area (can enlarge area) of the warning polygon
- VTEC = EXT: An extension of the expiration time of the warning polygon
- VTEC = EXB: An extension of BOTH the area (can enlarge area) and the expiration time of the warning polygon

With TIM, these product-extension VTEC action codes are meant to be used when a hazard is expected to last beyond the duration of a typical severe thunderstorm or tornado warning (e.g., 30- or 45-minutes), such as long-tracked supercells that occur during violent tornado outbreaks. For short-lived hazards, or for long-lived hazards nearing the end of their lifecycle, the traditional use of the warning continuance (VTEC = CON[1]) is used instead until the warning has expired or is canceled early. The Tiny TIM software includes "warning extension shortcuts" which allow forecasters to automatically extend the polygon area and time prior to issuance. The software also includes an optional capability to track hazards using a 2D footprint, which can more-precisely describe the 2D hazard than either the point or line tracking tools which are presently available.

When forecasters issued warnings, they had a few options when using Tiny TIM/HS-C. They could issue a warning initialized off of a single point storm track, a linear storm track, motionless hazard, or the aforementioned 2D footprint tool. They then could modify the polygon size, shape,

[1] In the Tiny TIM software, if the forecaster has the "CON" option checked, then current operational WarnGen policies are in effect and extensions in duration/area are not allowed.

or duration and update the storm track. With regard to the storm track and polygon modifications, they also had a few options to choose from:

- Compute: If you want to replace the current polygon with the default as defined by the Point, Line, or Footprint tool. User action required to take effect; the polygon will not automatically update.
- Computing: Same as above, except that the polygon will automatically update with each radar frame update, motion vector change, or duration change.
- Advect: If you want to change the default polygon and use a manually-edited polygon. User action required to take effect; the polygon will not automatically update.
- Advecting: Same as above, except that the polygon will automatically update with each radar frame update, motion vector change, or duration change.

Essentially, the "*-ing*" terms are for automatic tracking that will update with each radar frame update, motion vector change, or duration change. Terms without the "*-ing*" are for manual tracking (like current WarnGen operations). The difference between the *Advect* and *Comput*e groups, however, have to do with the user preference on default polygon shape (*Compute*) and manually modified shape (*Advect*). It should be noted that new warnings created will default to computing, until it is changed/modified. If the forecaster selects *Compute* or *Computing* and then manually changes the polygon shape, it will automatically switch to *Advect*. They could also extend the warnings in time and/or choose to update certain sides of the polygon, where the forecaster could simply update the front, rear, or both, depending on if the storm has advanced quickly or slowly and they need to remove areas from the warning or add new areas accordingly. The uses for these are summarized below:

- *Update front*: After issuing a warning, the forecaster realizes that their polygon doesn't extend enough downstream but is still valid upstream due to backbuilding convection
    - Use case: Backbuilding convection combined with forward propagating cells
- *Update rear*: After issuing a warning, the forecaster notices that the storm has moved downstream a bit and there are areas that can be cleared from the warning
    - Use case: Standard warning update (like in WarnGen)
- *Update both*: After issuing a warning, the forecaster notices that the storm is displaced and some areas need to be removed *and* added to the warning
    - Use case: Long track storms

4. Experimental Design

The evaluation took place over four days (13–16 September 2022), with the first three days being dedicated to meteorological analysis using HS-C and the last day being dedicated to an in-depth debrief. We had a total of five forecasters from across diverse WFOs, representing at least one WFO from each CONUS region, join us for the in-residence evaluation (Fig. 1). Four of the forecasters were warning operators issuing Tiny TIM warnings using HS-C. We had the fifth forecaster serving as a mesoanalyst for all scenarios, supporting the warning operations of the other four forecasters. The mesoanalyst was the same forecaster throughout the entire duration of the evaluation and was chosen by the OPG as a subject matter expert.

Fig. 1. Photograph of participants and some of the evaluation staff during the evaluation

In total, the participants used Tiny TIM and HS-C approximately 4 hr daily (two 2-hr cases each day), with a 30–45 min recap of thoughts and perceptions at the end of each case led by the HWT/FACETs staff. The four forecasters were all assigned to be the same WFO for each case. There were a total of five displaced real-time scenarios that the forecasters analyzed (Table 1). During each scenario, forecasters were instructed to warn on severe hazardous convection with Severe Thunderstorm Warnings (SV.Ws) and Tornado Warnings (TO.Ws) and update them in space and time as the storms evolve or move. An example of these warnings from one of the scenarios presented to the forecasters is shown in Figure 2. However, because all four forecasters were assigned to the same WFO and these scenarios were initially chosen to accommodate approximately two forecasters, there was some unrealistic sectorization of warnings and some “warn-on showers” situations[2]. Therefore, we advise caution when analyzing discussions regarding the forecaster workload *during* the evaluation.

Table 1. Information on scenarios for each date of the evaluation

Date	Session	Scenario	Case runtime	WFO
13 September	PM	1	2 hr	SJT
14 September	AM	2	2 hr	BMX
14 September	PM	3	2 hr 15 min	DMX
15 September	AM	4	2 hr	ILN
15 September	PM	5	2 hr 15 min	EWX

The participants had a total of four monitors (two standard AWIPS monitors, one text workstation, one windows monitor) on the OPG baseline AWIPS infrastructure, with the local AWIPS server[3] pointed to the ‘test’ Network Control Facility (NCF), hereafter called TNCF. All warnings were issued on the baseline AWIPS. On the Windows monitor, forecasters had access to the OPG Cloud AWIPS instances to display and analyze non-radar meteorological data including: Multi-Radar/Multi-Sensor System (MRMS), Geostationary Operational Environmental Satellite (GOES) imagery and RGBs (including Global Lightning Mapper data), model data (Rapid Refresh; RAP), and probabilistic data (ProbSevere–v2). The mesoanalyst would primarily use these data in the Cloud AWIPS to keep forecasters aware of the evolving environment. These data could not be displayed in the hardened AWIPS workstations due to limitations of replaying archive data in a displaced real-time format.

The forecasters also had access to a dedicated Slack workspace and channel for the evaluation, where “injects” via reports, video clips, or mesoscale discussions would be simulated and managed by a bot developed by Pat Hyland (HWT staff)(Fig. 2). These injects were audibly noted

[2] Due to technical limitations, the OPG was unable to simulate multiple WFOs or using both WarnGen and Hazard Services at the same time which would have helped differentiate workload impacts.
[3] Note that OPG has all forecasters pointed to the same server, similar to standard operations, and not to individualized servers like in other testbeds.

by virtual staff member, Alyssa Bates, who joined us from home each day. While the integration of Slack was not a direct objective of the evaluation, it was an additive feature that greatly enhanced the "realism" of the evaluation.

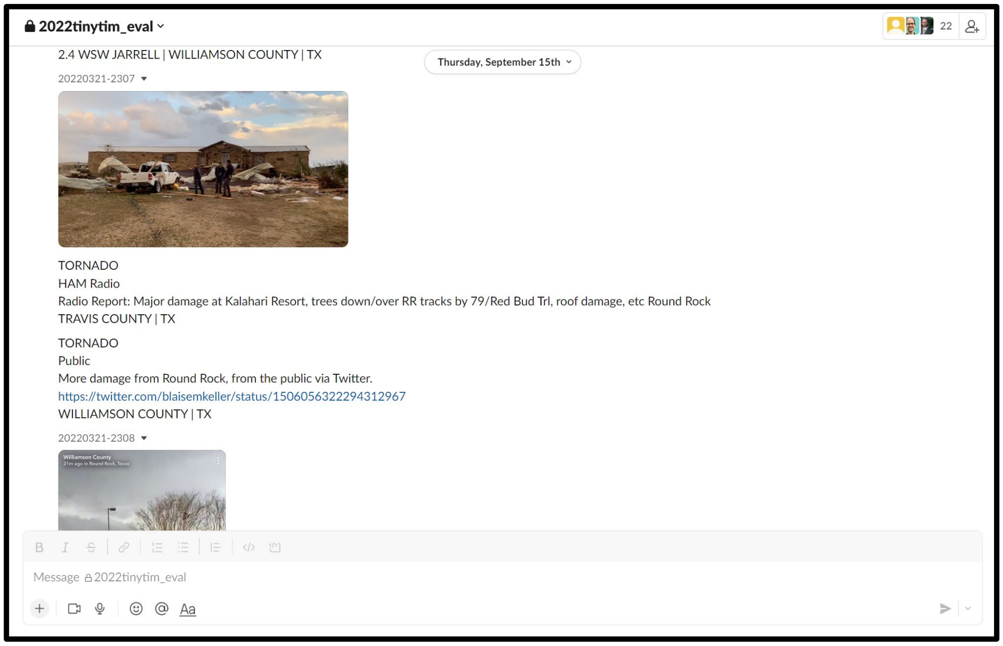

Fig. 2. Example of injects provided to the participants through the integration of Slack and automated timed bot.

The first scenario was conducted on the HWT dedicated Cloud instances to ensure that forecasters were on separate AWIPS servers, could not see each other's warnings, and become acclimated to the software without the added component of testing on a baseline system and any potential errors that may occur[4]. The participants followed a detailed job sheet, provided by HWT staff members for this first scenario and had the assistance of in-residence HWT (Greg Stumpf, Kevin Manross, Pat Hyland) and OPG (T. Connor Nelson) staff in walking through the job sheet (which can be assessed here: [SCENARIO 1 JOBSHEET-Tiny TIM OPG 2022]). Technical set up, troubleshooting, and AWIPS configuration was primarily handled by OPG staff (Matt Foster, Ryan Walsh) and AWIPS error documentation was handled by HWT staff (Greg Stumpf, Kevin Manross, with assistance from Jim Ramer pre-evaluation).

[4] The OPG conducted multiple (~3) dry runs of the software and scenarios where it was tested internally before participants arrived for the evaluation. The OPG found a few errors that were able to be addressed, or at least patched, before the evaluation.

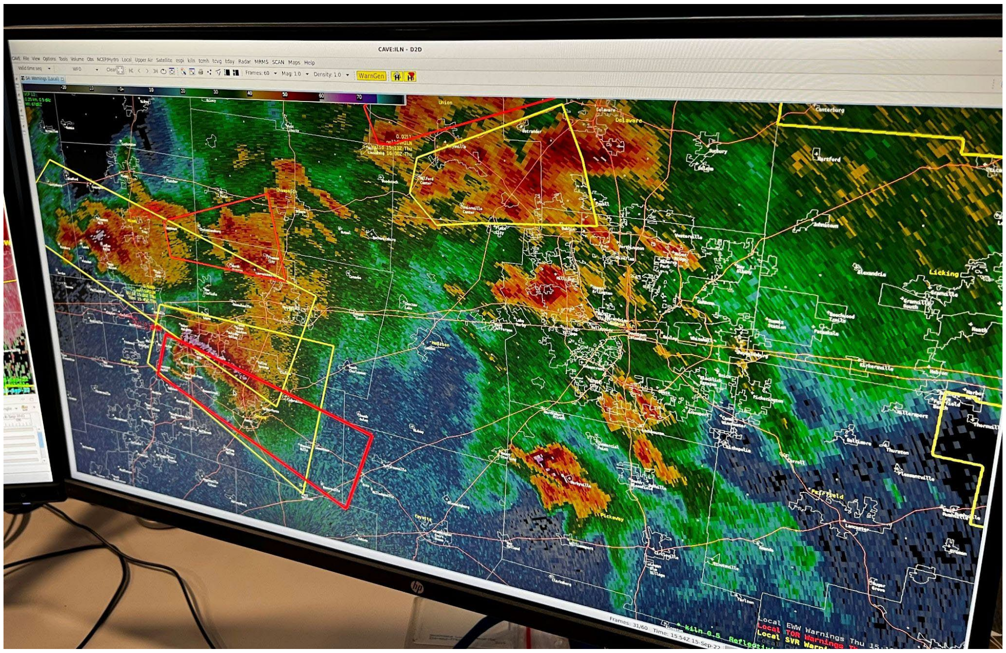

Fig. 3. Tiny TIM warning display from Scenario 4 of the evaluation. Tornado warnings are in red, severe warnings are in yellow, CWA borders are in yellow (bold), city names and county outlines are in white.

The participants also took multiple iterations of surveys throughout the evaluation period to gauge participant feedback. In total, the following methods were used by the HWT/FACETs staff to address their objectives:

- Pre-operations online survey
- Discussions during events with meteorologists and developers
- Post-event online surveys
- Post-event discussion
- End-of-week online survey
- End-of-week interview

While the OPG did not create these surveys or directly run the discussions/debriefs, we offered technical support for the surveys and helped to facilitate conversations and communication during the discussions.

5. Results

There were 6 findings from the evaluation that relate directly to participant experiences and 2 additional findings that relate to the potential provided by Tiny TIM.

Finding 1: Participants were thrilled with the Tiny TIM experience. Overall, participants were excited and enthusiastic about Tiny TIM and the demonstrated aspects of HS-C.

Not all of the participants have extensive experience with HS and indicated that there might be a slight learning curve, but the lack of experience was not inhibitive to the evaluation. The participants overwhelmingly felt that the software conceptually and technically was intuitive, especially after using the provided job sheet and walking through multiple scenarios. They also felt that the software behaved enough like the current operational WarnGen, but with added functionality that improves warning operations. In fact, one forecaster said: "*Tiny TIM and HS was pretty close to WarnGen in my office, with some added features. I think the bigger change is the mindset paradigm of moving warnings with the storm*". They further expressed desire to have such capabilities in their current operations and indicated that the TIM framework is a remarkable improvement for operations such that "*It's going to be hard to go back to the "old" way of warning (WarnGen), going back to operations after the evaluation*". Similar to the feedback from the 2022 HS-C in-residence evaluation at the OPG, the participants liked the ability to queue up multiple hazards at the same time (unlike WarnGen) and the freedom provided when they did not have to re-issue warnings, but rather modify them in space and time. However, while the participants praised the software and could see its potential in the operational workflow, there were some less than desirable aspects of the software, some noted technical bugs, and policy dogma that needs to be addressed. Despite these challenges, the participants felt that the advantages of Tiny TIM outweigh the disadvantages.

Finding 2: Participants felt the user experience (buttonology) was straightforward, intuitive, and easy to use.

Conceptually, the biggest concern of the participants was that they did not want to have to re-do entire processes multiple times if they accidentally clicked the wrong button; however, there is an 'undo' button in HS, which was also noted in the training job sheet. They liked that within the HS-C Console they could sort warnings in the console by name, hazard type, owner, etc. (Fig. 4). The sorting capabilities made it easy to find warnings and helped with situational awareness and sectorization. However, there were some noted issues when clicking on warnings, especially those owned by other forecasters. When forecasters would click on a warning, it would update to be owned by the last person who clicked on it. In one situation, a forecaster selected all of the warnings, locking out all other users. This issue appears to be caused by an automatic switch to “editing” when a forecaster clicks on a warning if the drawing state is *Computing* or *Advecting* and the radar frame updates, thereby redrawing the polygon. Ideally, the forecasters want to be able to just click on a warning and view it without locking others out from editing, but also easily change only the necessary information if needed. This feature may also present a challenge when considering hand-off of warnings in operations. It was suggested by the forecasters that a “Deselect” or a “Deselect all” button (similar to modern email services) be added. Further, there should be an extra “fail safe” or an extra step to take if you want to take over a warning and not just click on it. Warnings themselves were displayed well in AWIPS, but at times the 2D Footprint tracking tool and layering of warnings/modifications made it hard to move vertices of polygons and may end up under the footprint or previous warning.

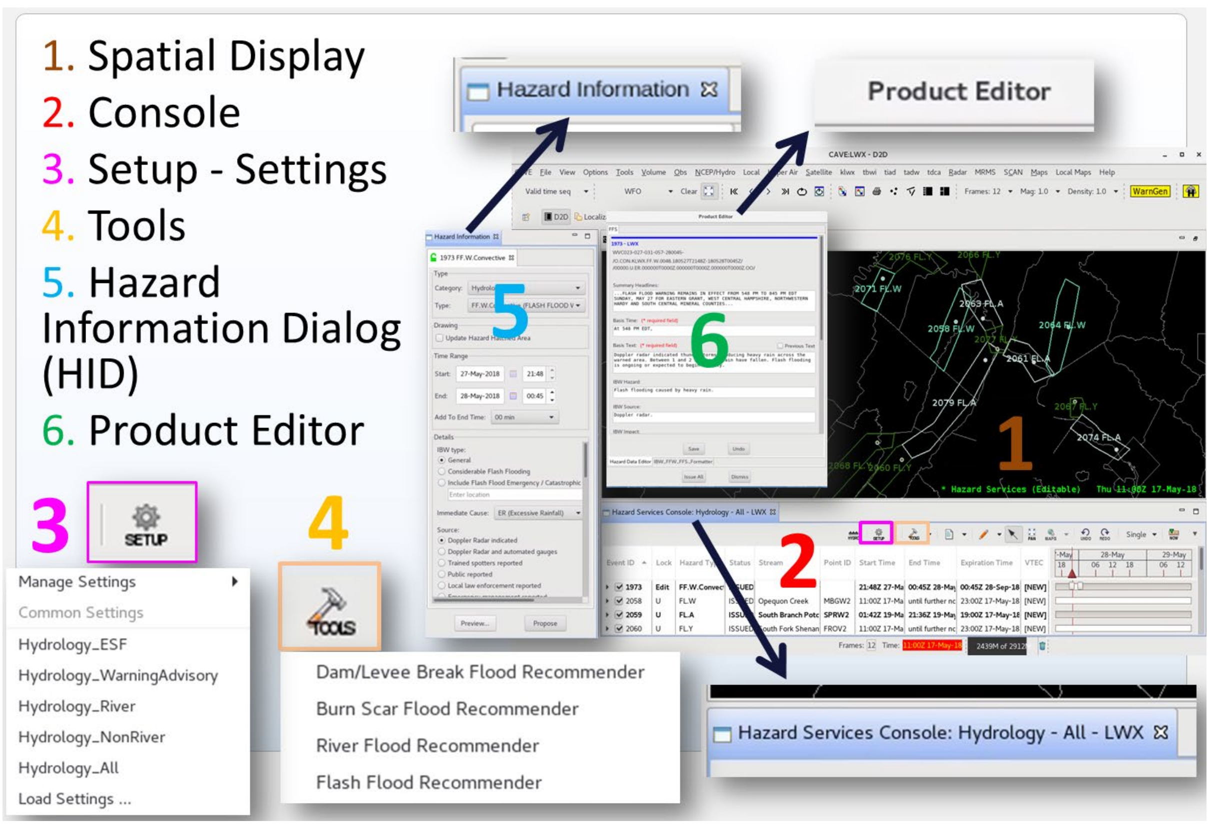

Fig. 4. Layout and components/names for HS, loaded on the ‘Hydro’ perspective (Figure adapted from https://vlab.noaa.gov/web/hazard-services/hs-ref).

Finding 3: Participants did express concern over the plethora of options in tracking and updating between: 1.) *Advect*, *Advecting*, *Compute*, *Computing*; and, 2.) *Update Front*, *Update Rear*, *Update Both*.

Participants were confused by the terminology between *Advect*, *Advecting*, *Compute*, and *Computing* and were unsure when to use each one. They suggested just having *Compute* and *Advect*, with an extra toggle to click on/off automated tracking to be able to more readily bounce back and forth between the two. This switch would also include a verbage change to be either automatic or manual tracking instead of "-*ing*". They would also prefer to have the default be automated tracking, where they could switch to manual tracking if they think the storm motion is incorrect. After the first scenario, the participants did not seem to have a problem between *Compute* vs. *Advect*, as *Advect* is simply a polygon that has been modified in shape but advected out in time rather than the standard *Compute* polygon. However, the participants did note that they do not see the use in reverting from *Advect* to the original shape when updating. Updating polygon sides with the *Update Front*, *Update Rear*, and *Update Both* options also presented a challenge to the participants. It was not clear to the participants when they should use these options and when to change them. They also expressed that while the default is *Update Rear* for new warnings in the current iteration of the software, the update options should not be available for new warnings, only for warning updates.

Finding 4: Participants felt Tiny TIM was more efficient than WarnGen.

With regard to storm motion, the ability to change storm track throughout an event is more efficient than in WarnGen as forecasters can correct their tracks (and thus warning orientation) on-the-fly without issuing a separate new warning. This updating capability was unanimously supported by the participants and is believed to be a time-saving feature as they would not have to expire/cancel and re-issue warnings continuously. However, constant updating or too frequent updating may be a large time demand; thus, there needs to be clear and concise best practices established to ensure that forecaster burnout does not occur and consistency for emergency managers and partners is achieved. A final issue with regard to updates is the so-called "windshield wiper" effect, where warnings considerably wobble with time due to small deviations in track, thereby being hard to verify and potentially cause issues in warning dissemination (discussed further below).

Finding 5: There are several options to select from when issuing an initial warning but it is unclear if this is a net positive or negative compared to WarnGen.

When initially issuing a warning, there are many options available for forecasters to use, including: line, fixed (like in WarnGen), point, footprint, footprint*, and line*. Overall, the participants liked these options and could envision use cases for each of them. In particular, participants liked using the 2D footprint, especially in complex scenarios like non-single cell clusters of storms or non-linear convection. However, the participants noted that they would like more of a "buffer" around the footprint (perhaps be automatically bigger on the backside). There was no particular preference between using the 2D footprint tool compared to the point (i.e., "drag me to storm" dot) tool, except for time and workload. The footprint tool took more time to use, but was perhaps more useful. The point tool was good for a "quick and dirty" assessment and output of a warning. There was also some confusion about the "*" methods (footprint* and line*) that allow for different advecting speeds. The participants felt that they were useful, but needed a lot of checks and could easily get out of control with small motions. The participants liked that warnings could be associated with independent storm motions and was identified as an advantage of Tiny TIM over WarnGen. As an example, this functionality makes it easier to issue warnings for linear convection, where the bow of the line may be progressing faster than the flanks. The participants suggested forecasters spend more time using the footprint* tool on the most impactful items and not for isolated events and noted that it may be too time consuming when working with ***many*** warnings to perfect the vertices. The participants also offered up the following changes to the tool and naming convention:

- It would be nice if the polygon was truly dynamic and could grow/shrink with time following the difference in motions
- Use the term "dynamic" and not "*", as the * doesn't mean anything intuitively
- Have the capability to use ProbSevere as the initial first guess on footprint geometry[5]
- The forecasters suggested using a "buffer" functionality, where forecasters could incrementally increase/decrease the size of the 2D footprint. This functionality is currently available in the HS-Probabilistic Hazard Information (PHI) prototype.

Finding 6: The software during the OPG evaluation was very stable, but a few "bugs" were encountered that require solutions prior to operationalization.

There were some notable errors and bugs that the forecasters encountered. Participants encountered quite a few AlertViz "red banner" errors, at least one of which were noted during the 2022 HS-C evaluation: Failure to put VTEC records. This error occurred particularly frequently for

[5] This capability is available in other iterations/versions of HS (HS-PHI).

one forecaster, but the error itself was not consistently reproducible from forecaster-to-forecaster or action-to-action. During dry-runs of the evaluation, OPG staff encountered an odd error that required a site-level patch for one scenario (Scenario #3) only. As far as we are aware, this patch resolved the immediate problem and no additional errors occurred associated with this patch. Similar to the 2022 HS-C evaluation, forecasters noted a 15–20 s lag for warning issuance when hitting “Issue all”. This lag varied depending on the size and complexity of the polygon, was longer when using the footprint, and was longer when many warnings were issued (in some cases in excess of 45 s). In a worst-case scenario, the lag for issuance was longer than the development of the warning. With four forecasters on one WFO, it did not appreciably affect operations, but if there were only two it would have decreased the ability to rapidly issue and update warnings in a Tiny TIM framework. We believe that this lag is related to an issue between the OPG AWIPS and the TNCF server. OPG is working with the AWIPS NCF to investigate the issue and cause. There were other circumstantial errors/bugs experienced by the forecasters, including:

- <u>Extensions in time</u>: Extensions in time maintains a 60-min threshold, leading to extensions in area every time it is executed. This extension gets compounded and produces a large error.
- <u>Accordion effect</u>: While it is intended to keep the front end of the warning if you speed up/slow down the storm tracking, it can lead to an inverted warning, especially if the forecaster drags the storm motion dot too far back.
- <u>Edges of CWA</u>: In one instance a forecaster used the line tool to update a warning near the edge of the CWA and it got split into two warnings, with one existing outside of the CWA.
- <u>Footprint*</u>: Forecasters noted some odd behavior in the motion tracking
- <u>Text changes</u>: There are times where a cluster of storms is not a line but is also not a point, so changes to text need to occur, stating: “Storms extended from….” instead of discussing the feature as a line.

Finding 7: Tiny TIM offers an incredible opportunity to improve service equity by providing equitable lead times during severe convection.

While the OPG did not explicitly measure warning lead time values during the test, we could clearly see that the Threats in Motion polygons would warn downstream communities faster than traditional WarnGen polygons. In future evaluations, the OPG would be interested in running parallel tests to objectively measure the lead time improvement.

Finding 8: Tiny TIM offers the potential to reduce "False Alarm Area" by allowing warning meteorologists to draw polygons more precisely around the threat area and then adjusting with time as the threat evolves.

"False Alarm Area" is not an official statistic or metric captured by the NWS. For the purposes of this report, consider "False Alarm Area" to be the area inside a convective warning that experiences little to no convection. Using a Tiny TIM methodology would likely reduce the False Alarm Area by allowing warning meteorologists to draw polygons more precisely around the threat area and then adjusting the area with time as the threat evolves. This is especially true for the initial warning issuance because warning meteorologists need to account for uncertainty when drawing an initial warning polygon.

5.1 Warning policy and operations

In addition to testing the software capabilities, the participants discussed the benefits and challenges in implementing Tiny TIM into operations and concerns about warning policy. In an operational setting, the immediate concerns involve ensuring that warnings do not overlap, especially when offices sectorize operations and warnings are issued well out ahead of the storms. However, having a single ETN was incredibly easy with long-track tornado events and alleviates some of the issue of overlapping warnings (moving to storm-based hazard warnings). On the other hand, one of the concerns with having one single ETN is covering two separate events and knowing how to verify those events. Thus, there needs to be standardization on when to use one warning or two warnings, such as in the case of a storm that looks like it may split but has yet to completely form two unique updrafts. In a similar line of logic, a question was brought up, philosophically and ethically: "*what are the limitations on moving warnings around*?" Participants were concerned that, while not the goal, it could be possible to issue a warning on a storm that dies out and never produces severe conditions and move the warning to a different storm that will verify better. It turns out that there is a fail-safe built into HS-C to address this concern, where if a polygon is moved to a completely new location with no overlap with counties from the last location, it assigns a new ETN. In an ideal situation where Tiny TIM was used correctly, however, the forecasters believe that it will improve false alarm rate for hazardous conditions as they can correct warnings (size, shape, duration, verbage) more dynamically as the situation evolves. Research is also being conducted by the Tiny TIM staff members (lead by Greg Stumpf) that will explore novel methods for verifying warnings that move in space and time.

The second immediate concern with Tiny TIM is the workload on the forecasters and cultural shifts in warning mindsets. On the first day of the evaluation, the forecasters were given explicit guidance that the warning update should be the same as a Severe Weather Statement update rate currently used in operations (~15 min) and only update at a higher frequency if/when their workload allows or for special circumstances such as a violent long-track tornado in a metropolitan area. Such guidance must be adopted by all WFOs if the software is to be integrated into operations. Without this guidance or clearly defined best practices, forecasters may feel obligated to update warnings with every radar volume scan and become overwhelmed with small updates. This issue of rapid update can be exacerbated with the windshield wiper effect, where warnings may fluctuate due to small variations in storm motion that may be meteorologically relevant or be a 1–3 volume scan fluke or quick deviant motion. To account for this, participants also suggested having polygons automatically flare out more on the backend (like a wedge instead of a rectangle) and update the warnings at a consistent time interval relative to the speed of the event.

While the total workload during the evaluation using Tiny TIM was described as less than WarnGen, it took considerable mental energy to update warnings and move them in space and time[6]. Thus, "*while the implementation of Tiny TIM may not save mental capacity, it does save physical time in the creation of warnings.*" High quality mesoanalysis also helps the workload of the forecaster, albeit more indirectly for tornado warnings. The mesoanalysis was useful for warning awareness and changes in environmental conditions that may suppress or enhance convection as events evolved across the WFO. Because one of the FACETs goals is hazard-based messaging, forecasters were asked about issuing separate warnings for severe and tornado events. Forecasters suggested that it depended upon workload and how the event unfolds. With Tiny TIM, they believe that they can more easily split these two warning types, as they are not "doubling up" on polygons.

Another, and likely the most major, concern brought up by the forecasters relates to the nature of warning expiration times and dissemination challenges[7]. In the current paradigm, the expiration

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[6] The discussion of mental exhaustion was forecaster and case dependent. Not surprisingly, more warnings under the responsibility of one forecaster (like a widespread tornado event) require a lot of mental energy to update on a routine basis than one or two warnings.

[7] While forecasters did note that they were unsure how much policy change would occur between WarnGen and Tiny TIM, as Tiny TIM is an intermediate step towards a "taller" TIM, these concerns were discussed in terms of both the broader TIM framework and how warnings are communicated.

time is in reference to when a specific warning will end and it may, or may not, overlap with other existing or future warnings. With this paradigm shift to a TIM framework however, all participants felt that expiration times of warnings are both antiquated and confusing. For example, if we issue a single warning that follows the hazard in space-time, then the true “expiration time” of the single ETN warning may be when the storm itself is no longer considered severe or tornadic, which may be several hours into the future.

These differences also present issues in disseminating warning information and public perception if an expiration time changes for a specific location as the warning polygon moves (Fig. 5). This also is problematic for communication of warnings when using static images, such as Impact Based Decision Support Services (IDSS) graphics on social media, that may not be correct even minutes after issuance if the forecaster makes modifications. Thus, the participants suggested removing the expiration time in warnings, keeping the warning live until it is “all clear”, canceled, or moved. They also, however, believe that a more optimal workflow would be to use a time-of-arrival approach or “pathcast” of impacts at various locations within the warning. This suggestion would require a much larger change in culture and operational/warning policies.

Outside of the expiration time concerns, additional policy related concerns related to warning update speed were brought up by the forecasters. In some cases, the forecasters felt that they were updating too frequently. While the goal is to have 10–15 min updates, sans a catastrophic tornado, some forecasters choose to update more frequently; thereby, they set a precedent for the public and core partners on expectations for spatiotemporal warning updates.

Another example of public perception of updates harkens back to the windshield wiper effect noted by the participants. In an extreme example, small deviations in storm motion may severely impact populations of people who were in a warning initially, 5-minutes later are removed from the warning, and 10-minutes later added back in (Fig. 6). This extreme example highlights the importance of having clear and distinct guidelines on warning updates both temporally and spatially. In the more full scale “taller” TIM software, there is a feature called “cooldown” that helps mitigate this issue, where areas that are removed from a warning will actually remain warned for an additional 5 min in case they are placed back into the warning on the next radar scan update. This default buffer value can also be changed by the forecaster. However, forecasters also suggested allowing individual warnings to have their own individual cooldown rate.

A final point brought up by the forecasters is the dynamic capabilities of warnings until the storms reach the CWA line. The software allows for the extension in time and area, but the issue still remains that this only occurs up to the CWA line, at which they have to stop extending the warnings and have two warnings (one for each CWA) for the same storm.

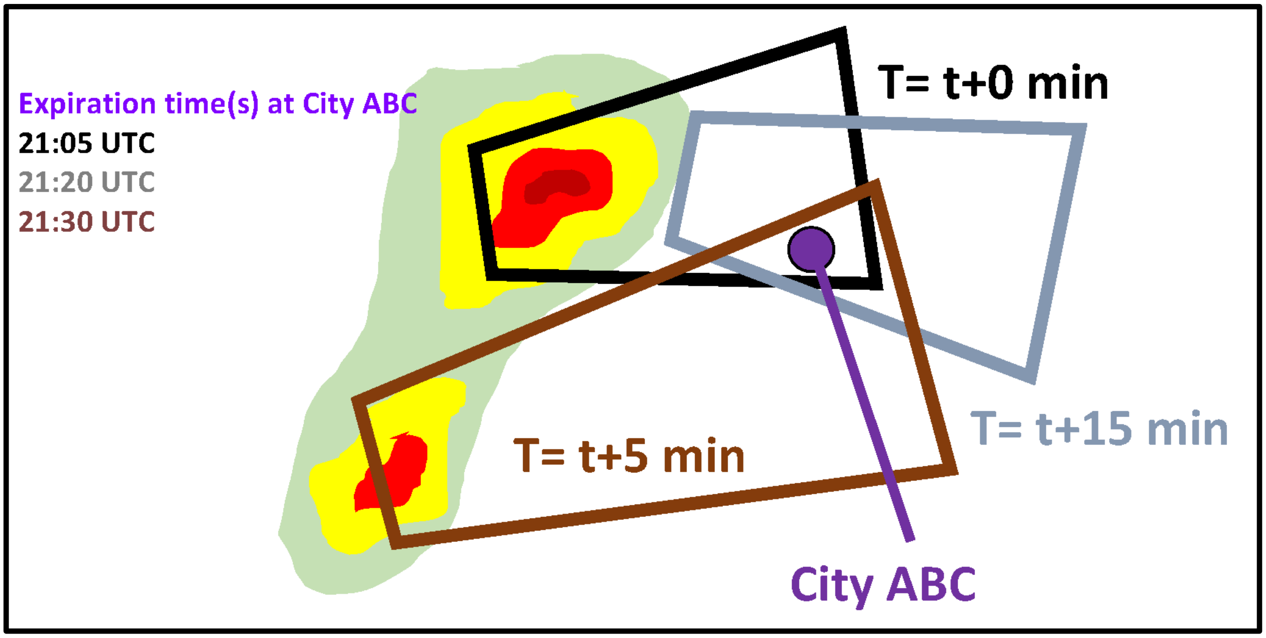

Fig. 5. Example of Tiny TIM warnings issued at different times (color coded) for a theoretical storm (dBZ colored on left). One warning is issued at T=t+0 min and a second warning is issued at T=t+5 min. The first warning is moved at T=t+15 min (gray). Thus, theoretical "City ABC" would experience three different warning expiration times (with two of those being for the same ETN warning) within 15 min.

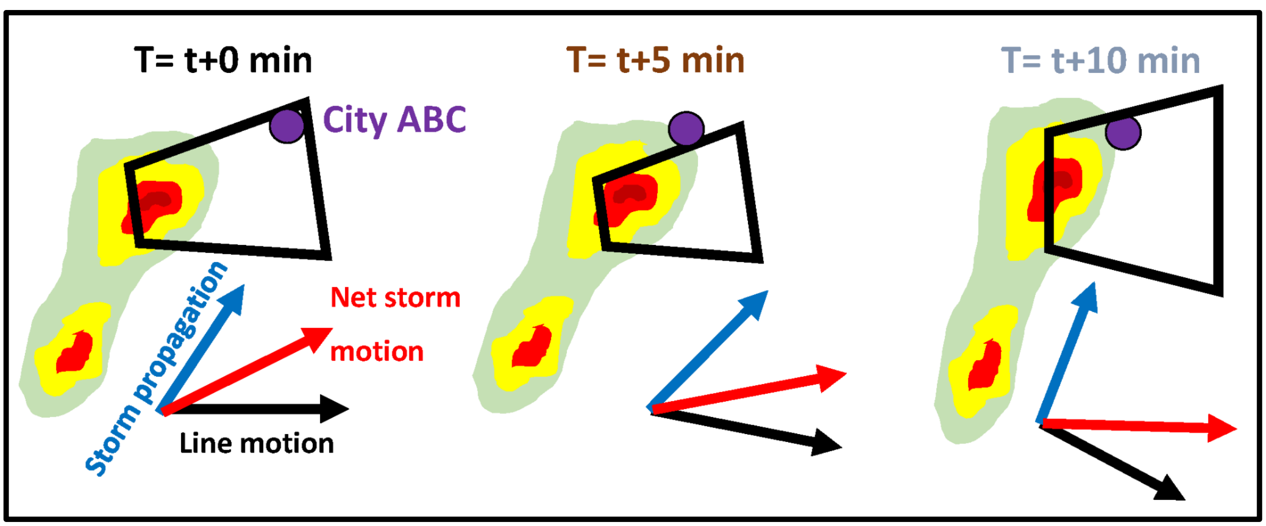

Fig. 6. Example of the "windshield wiper" effect with Tiny TIM warnings issued at different times (color coded) for a theoretical storm (dBZ colored). Theoretical "City ABC" (purple) would be within the warning at T=t+0 min, outside of the warning at T=t+5 min, and back inside of the warning at T=t+10 min.

6. Summary

To summarize, the participants unambiguously and unanimously agreed that the Tiny TIM software and HS-C was extremely powerful, useful, and would like to see it implemented into operations soon. They also unanimously believe that it should be used for *any* long track event, not just catastrophic events. They felt that the software would have vast forecaster support nationwide. When paired with mesoanalysis, they felt more situationally aware and felt that Tiny TIM would improve operational efficiency and physical workload. However, mental workload will depend on situational and forecaster-to-forecaster conditions, including: other tasks they are managing, the total number of warnings, the number of staff, the meteorological complexity of the event, and frequency of updates. They also felt that Tiny TIM will improve warning lead time, increase verification, and will be useful for both the media and emergency managers to see changes in the warnings over time. The "take-away" message from the evaluation is that the "*Advantages of Tiny TIM greatly outweigh the disadvantages. The disadvantages are conceptually disseminating the information and some technological errors.*" and that "*Tiny TIM has the ability to save lives, but we need to work on how to get it implemented*."

Outside of the Tiny TIM software, there were two major technological issues that occurred:

- Inconsistent "Failure to put VTEC record" errors
- Time-lag delay on warning issuance related to HS-C (likely an issue with communication with the TNCF server)

These issues, while problematic, did not severely interfere with the evaluation of Tiny TIM or the issuance of warnings. These issues were also both documented as part of the 2022 OPG HS-C evaluation and, thus, are not likely to be attributed to Tiny TIM. Thus, continued investigation should be taken to address these errors, determine their cause, analyze any potential impacts on operations, and assess these errors when the AWIPS server is not pointed to the TNCF.

The remaining issues noted by the participants can be grouped into two categories: 1.) Technological (both with Tiny TIM and HS-C); and, 2.) Policy. These issues are summarized below:

1. **Technological**

Tiny TIM

- Complexity of the options available with regard to tracking and updating (too many options available and too many drop-down menus)
    - Naming convention and structure of the Tiny TIM storm track tool
        - *Advect, Advecting, Compute, Computing*: perhaps change the terminology to "Manual" and "Automatic" tracking, with a check box
    - Utility and training on updating of warnings using the *Update Front, Update Rear, Update Both* protocols
- Desire changes related to the Footprint tool, where there is more of a buffer around the footprint
    - Suggested hitting a "buffer" button to increase size of the buffer Train footprint tool to look for dBZ threshold
    - Sometimes, forecasters might want to track a hook echo or other phenomena rather than the maximum reflectivity.
- Line* and Footprint* have some potential, but they need a few checks
    - Maybe use the term "dynamic" and not '*', as the naming is confusing
- Footprint tool and layering makes it hard to move vertices of polygon, may end up under footprint
- Storm track tool was pretty useful, but when forecasters drag the tracking dot to the storm, it centers on the middle of the polygon and not the line; so, it shifts the viewpoint
- There needs to be a quick way in the Hazard Information Dialog (HID; Fig. 4) to assess duration and time and not do mental math to get a new end time when moving a warning
- There needs to be some way (like a Modify button) to deal with polygon jumping and reverting changes when radar frame updates

HS-C

- Track hatching was not really too visible in the polygon; thus, forecasters would like them to be more visible. *Note*: This is being addressed as a result of the 2022 OPG HS-C evaluation, and a new decorations format is being developed.
- Add a "revert to last issued" in the HID and add a "Unselect" or "Deselect All" button
    - If you click on a warning you don't own, there should be a fail save of extra step to take it over and not just clicking on it
- Seeing the timeline on the HS-C console was great, but it would be great to be able to edit (extend/shorten) using the timeline, especially for long-fuse warnings

- Having the CWA listed as a default on the HS-C console would be good, especially with the handoff of warnings. Having the impact-based warning tag (considerable, catastrophic, etc.) would be nice to have as well.

Thus, the OPG recommends that **further testing and evaluation occur using Tiny TIM and HS-C on a baseline AWIPS, incorporating the above changes to the software**. We also recommend that the suggestions made by the forecasters, especially those pertaining to terminology and functionality be integrated into the next iterations of HS-C and Tiny TIM.

2. **Policy**

- Expiration time of warnings is not relevant and can lead to problems in the TIM paradigm
- There needs to be clear best practices on spatiotemporally updating warnings (update frequency, spatial constraints, etc.) like those outlined in the evaluation instructions and training
- Dissemination aspects to partners and the public can be problematic and require guidance and changes to the way in which information is shared

Thus, the OPG also *strongly* recommends that **additional discussions and consideration be taken to analyze how Tiny TIM can be successfully integrated into operations and the downstream dissemination impacts**. This analysis should include the opinions of emergency managers, forecasters, broadcasters, and social scientists.