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Remote-sensing methods for assessing tornado and downburst damage in forests

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SUMMARY:
There are many regions of the world that are prone to tornadoes and downbursts but have vast areas of forest that lack the damage indicators necessary to easily assess these events. The Northern Tornadoes Project has developed a scalable box method for assessing this forest damage using the Canadian Enhanced Fujita scale that accounts for the proportion of trees down over a given area and is based on the size of the damaging wind event. To validate this method, tornadoes and downbursts of various sizes and intensities with forest and structural damage in the same vicinity are evaluated. This abstract discusses two tornadoes assessed using both approaches, showing through comparison that the assessment of the forest damage using the scalable box method is consistently in agreement with the assessment of the structural damage, whereas this is not the case when assessing the forest damage with a fixed box method. This type of comparison could similarly be applied to downbursts.

Keywords: tornado, downburst, forest

1. INTRODUCTION

Tornado numbers are historically underestimated in heavily forested regions, such as Canada, due to low population densities. The standard way of assessing damage from tornadoes and downbursts in North America is with the Enhanced Fujita (EF) scale developed by Texas Tech University (McDonald and Mehta, 2006). Damaging wind speeds are estimated using the EF scale by evaluating the damage done to a specified list of human-made and natural "damage indicators" (DIs). Each DI has a numbered list of sequential "degrees of damage" (DODs), and each DOD has an associated range of estimated wind speeds, which can then be translated to a rating from EF0 (weakest) to EF5 (strongest). The Canadian version of the EF scale has a few key differences from the American version (Sills et al., 2014). Notably, the Canadian scale evaluates tree damage by assigning DODs to forest damage based on the percentage of trees snapped or uprooted in an area.

The ability to assess the intensity of tornadoes and downbursts via forest damage is crucial in Canada as many of its severe wind events occur in regions that lack any other DIs. To fulfil this need, the Northern Tornadoes Project (NTP) developed the scalable box method (Sills et al., 2020). Although potentially more accurate methods for rating these tornadoes exist (e.g., Godfrey & Peterson, 2017; Karstens et al., 2013; and Lombardo et al., 2015), these methods are not yet tailored for operational use, require significant effort and data, and cannot easily be applied to downbursts.

2. METHODOLOGY

The scalable box method has been used to assess the intensity of tornadoes in heavily treed areas for several years. A full step-by-step description of this method can be found in Sills et al. (2020). In short, the scalable box method involves creating a contour around the damage along the tornado path in order to find the damage centreline, tornado centreline, and maximum path width. Then, a sampling box with sides that are 50% of the maximum path width is placed in the area of worst damage, ensuring that the tornado centreline runs through and parallel to that box. From this box, the percentage of trees snapped or uprooted, DOD, estimated maximum wind speed, and EF scale rating are sequentially determined. The 50% of maximum width size for the box was chosen based on past evaluation of various box dimensions for many tornadoes.

When assessing forest damage caused by downbursts, there are additional challenges not present in tornado assessments. Tornadoes typically have a relatively long and narrow path with a clear length, width, and centreline. Downbursts, however, exhibit a wide range of aspect ratios, have dimensions that are more difficult to define, and are often made up of smaller areas of damage (Fujita & Wakimoto, 1981). There is a need for a reliable method of assessing forest damage caused by downbursts that addresses these challenges. The authors of this work believe that the scalable box method used to assess tornadoes in Sills et al. (2020) could also be applied to downbursts with a few important adjustments as follows. First, a downburst envelope using a best-fit oval around the significant damage would be used to find the damage centreline and maximum path width. Second, the sampling box would be 20% of the maximum path width on all sides, instead of 50%. The reason that the sampling box is notably smaller relative to the maximum width when assessing downbursts versus tornadoes is because downbursts are typically wider than tornadoes, especially relative to their areas of worst damage. This means that using the same 50% of maximum width box for downbursts would result in larger boxes and greatly underestimating the intensity of the damage.

In order to validate the scalable box method, the objective of this study is to demonstrate that a damage box that scales with the size of the tornado or downburst allows a more accurate estimate of the tornado intensity than a box with a fixed size. To perform this comparison, tornadoes and downbursts of differing maximum widths will be assessed using both types of boxes. Because the failure wind speeds of common structures are generally better understood than the failure wind speed of trees, structural damage will be used as "truth" data, with the understanding that there is significant variability and uncertainty. Therefore, events will be chosen where forest and structural damage are located in the same vicinity. The discussion of this abstract will go through one example of this comparison, and the full presentation will involve a more thorough comparison.

3. DISCUSSION

The scalable box method analysis for two tornado tracks are compared for this discussion. The first tornado is an EF2 in Chatsworth, Ontario that occurred June 26, 2021; the second is an EF1 in Newbrook, Alberta that occurred on June 28, 2019. The worst forest and structural damage that resulted from each event are shown in Fig. 1. The Chatsworth tornado had a path length of 14.0 km and a maximum width of 660 m, resulting in a box size of 330 m (i.e., half the maximum width) per side. As seen in Fig. 1a, between 50% and 80% of the trees are uprooted or snapped within this box, leading to a DOD5 designation in the Canadian EF scale tree DI. Because these trees were healthy with adequate soil depth, the maximum wind speed in this location of worst damage, and therefore of the tornado as a whole, is the "expected" DOD5 value of 190 km/h. In support of this rating, there was also a farm property with significant structural damage just over 1 km west of the worst forest damage. At this property, a small barn and an addition to a house were destroyed by the tornado, shown in Fig. 1b. Given this structural damage, the tornado would have been rated as EF2 even without the extensive forest damage. The Newbrook tornado had a path length of 4.35 km and a maximum width of 210 m, resulting in a box size of 105 m per side. As seen in Fig. 1c, between 50% and 80% of trees are once again snapped or uprooted within this box. However, in this case, the tree species and shallow soil depth resulted in using the "lower bound" wind speed of DOD5, 145 km/h. In support of this rating, there was a farm property approximately 200 m west of the box. At this property, several garden sheds were rolled or carried a short distance by the tornado, as shown in Fig. 1d. This structural damage would have resulted in the tornado being rated as EF1 regardless of the forest damage, similar to the Chatsworth tornado.

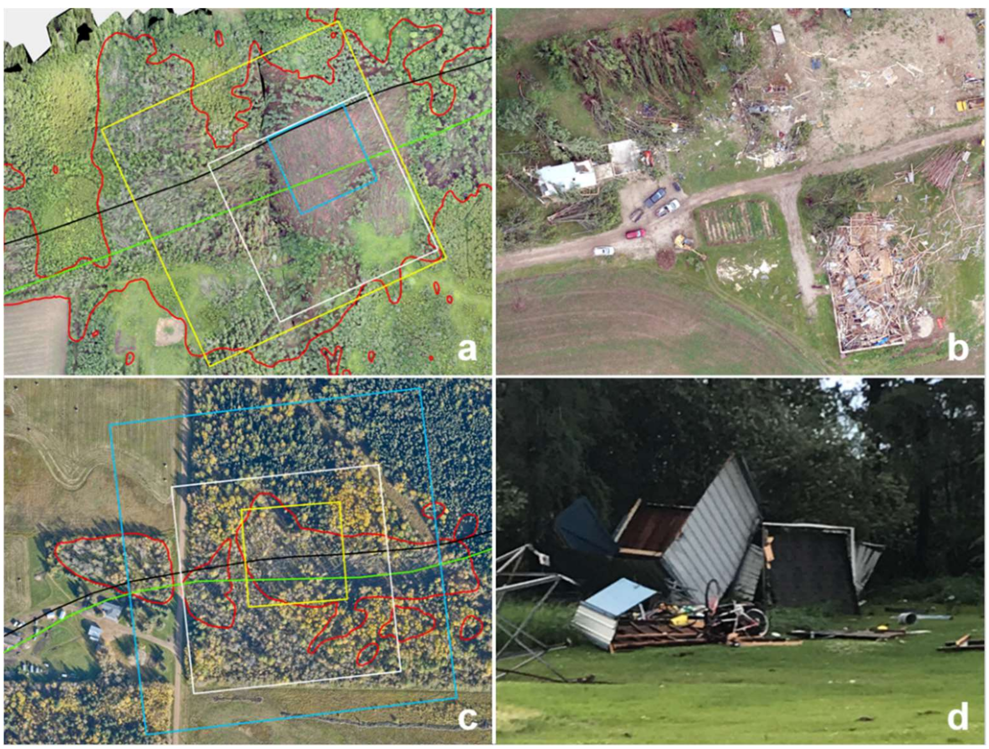

Figure 1. (a) A drone orthomosaic of the worst forest damage from the Chatsworth tornado showing the tree damage (red outline), damage centreline (green), tornado centreline (black), scaled 330 m box (yellow), fixed 105 m box (blue), and fixed 220 m box (white). (b) A drone photo of the worst structural damage from the Chatsworth tornado. (c) An aircraft orthomosaics of the worst forest damage from the Newbrook tornado showing the same features as Fig. 2a, including a scaled 105 m box (yellow), fixed 330 m box (blue), and fixed 220 m box (white). (d) A ground photo of the worst structural damage from the Newbrook tornado.

In both the Chatsworth and Newbrook tornadoes, using the scalable box method to rate the forest damage resulted in the same rating of the tornado as using the structural damage, keeping in mind that the failure wind speeds of these structures is generally well understood relative to tree damage. Part of the reason for this agreement is that the scalable box method accounts for the size of the tornado, which was notably different between these two cases. Several studies have used fixed box sizes to evaluate forest damage from tornadoes, but no fixed box size would work for both of these tornadoes. The 105 m box used to assess the Newbrook tornado is almost identical to the 100 m boxes used in some tornado studies of forest damage. If this fixed box size were used to evaluate the Chatsworth tornado (Fig. 1a), every tree in that box would be snapped or uprooted, resulting in a DOD6 classification with over 80% of trees snapped or uprooted, greatly overestimating the wind speed of the event. The 330 m box size applied to the worst forest damage of the Newbrook tornado would result in a DOD3 classification with less than 20% of trees being uprooted or snapped within this box (Fig. 1c), greatly underestimating the wind speed of the event. Finally, one might suggest using a fixed box size halfway between the two in this example, about 220 m. In the Chatsworth tornado, a 220 m fixed box would still have more than 80% of trees snapped or uprooted, resulting in estimated wind speeds of 235 km/h instead of 190 km/h. In the Newbrook tornado, a 220 m fixed box would have between 20% and 50% of trees snapped or uprooted, resulting in estimated maximum wind speeds of 105 km/h instead of 145 km/h.

The full paper will describe more than just the Chatsworth and Newbrook examples to better validate the scalable box method for tornadoes. Additionally, a comparison using the same method will be done for downbursts. This comparison will be performed using the scalable box method for downbursts described earlier. Given the greatly varying shapes and more challenging assessments of downbursts, this validation will not be as straightforward.

4. CONCLUSIONS

This work identifies the reasons that a scalable box method for forest damage caused by downbursts is needed, describes this method, and gives an example of how the scalable box method can be validated. A larger sample size is needed to demonstrate that a scalable box method is more accurate in rating forest damage from severe wind events than a fixed box method, and this will be provided in the full paper. A reliable method of assessing forest damage from both tornadoes and downbursts will aid in accurately documenting and analyzing the many damaging wind-events that occur in forested areas that lack structural damage indicators.

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