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Developing a framework for automatically identifying tornado characteristics in forests

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SUMMARY:
There are currently gaps in the tornado hazard assessment in North America due to the inability to properly observe and assess tornado damage. This is in part due to tornadoes occurring in more remote areas, where less damage indicators are present. In these areas, trees may assist with assessing the wind speeds. There are currently several methods that have been used for examining forest damage due to tornadoes in North America, such as the Box method and Lombardo method. These methods require larger amounts of manual processing and as such may more often be used as a case study analysis. This study examines the tornado characteristics that are necessary to perform these methods. The nuances of these tornado characteristics and their uses in these approaches will be examined. Identification of these characteristics such as determining the fallen trees and which trees to use to estimate parameters such as tornado path and width will be discussed. Performing this analysis manually, there are many decisions that are made that impact the final tornado characteristics. These decisions determine the tornado characteristics that must be accounted for when creating an automated approach and the impact of such decisions analyzed.

Keywords: Trees, Automation, Tornado

1. INTRODUCTION

Windstorms such as tornadoes have been an area of great interest as they may cause catastrophic amounts of damage and potential for loss of life. This impact is heightened as population densities continue to rise. As a result, a good understanding of the tornado hazard present at any location is necessary. In more remote areas, the data required to properly map this tornado hazard is lacking due to the inability to properly observe these events. In North America, there are believed to be gaps in the tornado data, with many regions being more sparsely populated (Cheng et al., 2013) and as a result the estimation of tornado occurrence may be incorrect (Ektin et al., 2001). In these less populated areas, there are less man-made structures, damage indicators which are more thoroughly understood and examined such as in the EF-scale (McDonald et al., 2006).

In these more sparsely populated regions trees may be useful to properly assess tornado damage. In North America, there are large areas primarily covered in forests. There are some concerns with using forests as an indicator, such as missing trees as part of a more extensive track (Zenoble and Peterson, 2017) and accurately predicting tree strengths (Shikhov and Chernokulsky, 2018). However, as remote sensing has improved, imagery of these tracks can be gathered and analyzed. Despite these advances in examining tree damage, the analysis of forest damage has been performed in an ad hoc manner and still requires developing more standardized procedures. Even with these standardized procedures, the analysis performed may still be quite lengthy.

2. CURRENT METHODLOGIES

For this analysis, two accepted approaches for tornado analysis of forests were considered. These approaches were the Box method (Sills et al., 2020) and the Lombardo method (Lombardo et al., 2015). These two approaches were considered in part due to their different ways of assessing tornado damage. The Box method analyses the area of trees down and determines its wind speeds based on the percentage of trees down. The Lombardo method fits a vortex to the observed tree damage. Examining these approaches and how the analysis is performed, there are common characteristics that must be extracted. Both methods may follow the same approach in determining the initial tornado characteristics as shown in Figure 1. These characteristics are necessary to accurately estimate the tornado wind speeds, although used differently in both approaches.

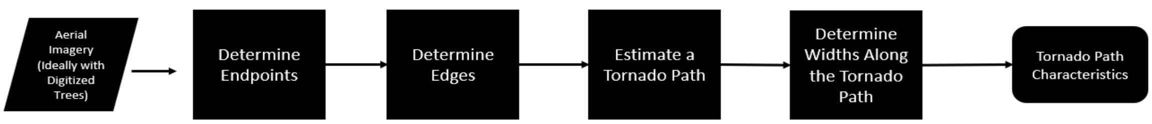

Figure 1. Inputs required for forest tornado analysis.

For the determination of the tornado characteristics, aerial imagery is required. For automation, ideally the fallen trees should be automatically identified along the tornado path. From these fallen trees the endpoints of the tornado path need to be determined. The next characteristic needed is determining the tornado path edges. These edges are used to estimate a tornado path, encompassing all the fallen tree damage. From the estimated tornado path, the maximum width along the tornado path can be determined. This maximum width should be perpendicular to the tornado path. These characteristics affect how these methods are performed and may affect the rating, such as the size of the boxes in the Box method or the amount of treefall to fit in the vortex for the Lombardo method.

3. METHODOLOGY

To better understand these approaches, a manual examination of a tornado tracks was performed. This process, shown in Figure 1, was performed on tornado tracks, and observations were made on how the tornado characteristics were determined. Figure 2 shows aerial imagery of a tornado track for the Lac Flocon, Quebec (Canada) 2020. Due to the lack of an automated process to determine the fallen trees along the tornado track, the fallen trees were identified manually along the tornado track and are shown outlined in orange. Treefall was identified, without regards to if they may or may not be tornadic in nature, similar to how an automated treefall detection software may handle the image. From the fallen trees, the edges of the tornado path lines were determined.

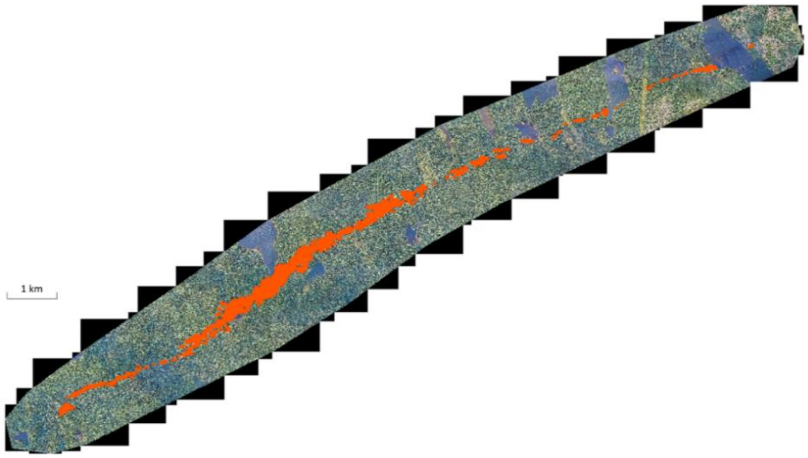

Figure 2. Tornado track with manually identified trees of Lac Flocon. Manually determined treefall is shown in orange throughout the track

4. OBSERVATIONS OF MANUAL IDENTIFICATION OF TORNADO CHARACTERISTICS

From the analysis of the tornado tracks, it can be observed that there are several decision points that need to be made when determining the tornado path characteristics. In areas with a higher intensity of treefall, it is clearer whether the damage patterns are tornadic or not. To determine the tornado path length, appropriately identifying the endpoints is necessary, these points may be more difficult to determine due to the less intense nature of the damage.

When examining the areas of treefall, there are issues as to how much of the treefall to consider as part of the track. The inclusion or exclusion of this treefall may affect the overall estimation of the length of the track or the width. Figure 3 shows an area of high intensity of damage towards the centre of the tornado track. In this figure, two approaches are considered to assess the tornado path. As can be seen on the image, away from the high intensity of damage, there are areas of more scattered treefall. The inclusion of the treefall towards the bottom of the image would increase the maximum width of the tornado. To properly assess what is part of the tornado path, the scattered damage towards the top of the image and the gap in treefall towards the bottom of the image must be handled. For an automated procedure, a set of criteria is necessary to have a consistent approach or at least indicate that these regions should be re-examined for a semi-automated procedure.

Another area that needs to be examined for automation is determining the tornado path line. Ideally, the convergence line can be used for the tornado path line, however the convergence line may not exist on portions of the track. The convergence line can be determined using the treefall directions. An automated approach would need to examine these treefall directions and determine where the fall directions start to converge. An automated approach would have to identify where the convergence line does not exist. In these cases, the damage centerline is used (a line that goes the midpoint between the edges of the tornado damage). As shown in Figure 3, what is included will affect the damage centerline. To assess the tornado path line, the convergence line along the tornado path will need to be made and then further criteria is needed for the damage centerline.

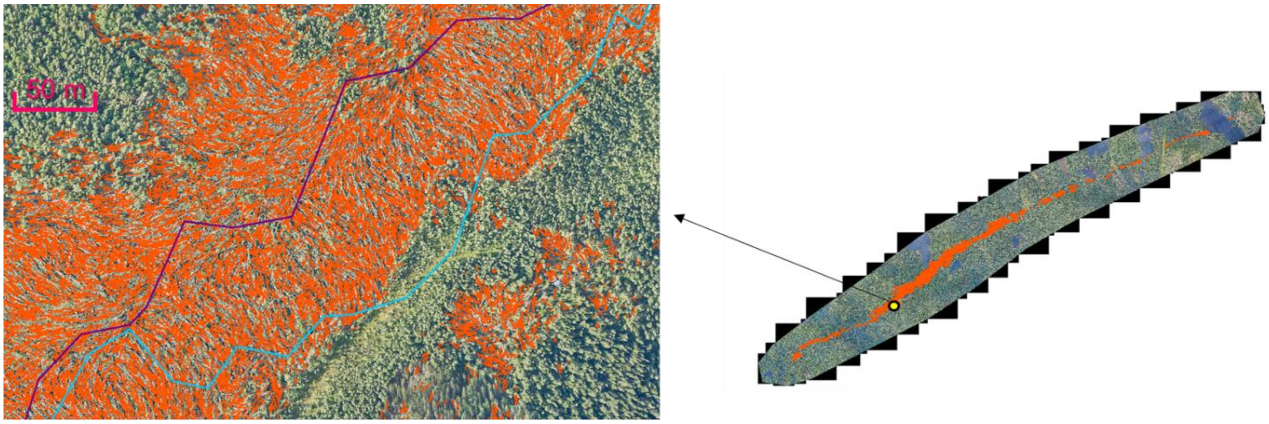

Figure 3. Portion of the tornado track of Lac Flocon. Identified treefall shown in orange. Two potential tornado paths are shown in the image. The purple line indicates the damage centerline not considering the gap in tornado damage or scattered damage while the teal line shows damage centerline considering all treefall found.

5. CONCLUSIONS

For determining the characteristics of a tornado path, decisions must be made to handle the tornado path edges and what treefall to include or not include. Further issues arise in determining the tornado path lines. The convergence lines of the tornado must be determined but criteria for a damage centerline must be created for the areas where a convergence line does not exist. An automated or semi-automated method must properly consider these aspects to program a computer-driven analysis of a tornado track. The full paper will present a complete detailed analysis of these methods.

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