Estimating Enhanced Fujita Scale Levels Based on Forest Damage Severity

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INTRODUCTION

- Enhanced Fujita (EF) scale estimates of tornado wind speeds remain challenging in rural areas with few traditional damage indicators.
- In some cases, such as the 27 April 2011 tornadoes that passed through mostly inaccessible terrain in the Great Smoky Mountains National Park (TN) and the Chattahoochee National Forest (GA), traditional ground-based tornado damage surveys are nearly impossible.
  - Great Smoky Mountains National Park (Eastern Tennessee)
    - NWS rated EF4
    - 18-mile track
  - Chattahoochee National Forest (Northeastern Georgia)
    - NWS rated EF3
    - 38-mile track
- The present work describes a novel method to infer EF-scale categories from forest damage using levels of tree damage and a coupled wind and tree resistance model.

AERIAL PHOTOGRAPHS

- Entire length of both tornado tracks
- Width: 5000 feet (~1500 meters)
- High-resolution: 8 inches per pixel

- Recorded fall direction of over 130,000 downed trees
- Over 448,000 standing and fallen trees tagged with geographic coordinates

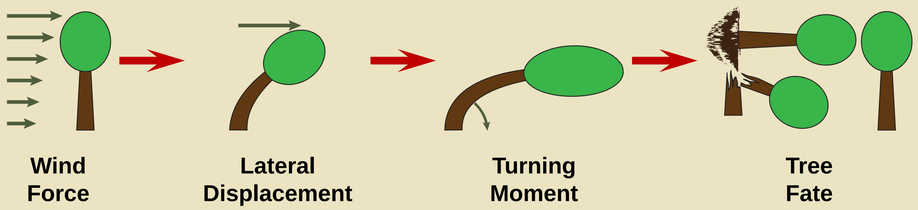
GROUND SURVEYS

- Ground surveys that sampled more than 2000 individual trees provide details on the composition of tree species and tree diameters within each tornado track.
- The Ideal Tree Distribution model[1] augments the observed tree characteristics to describe the shape of each tree (i.e., height, crown depth, and crown radius).

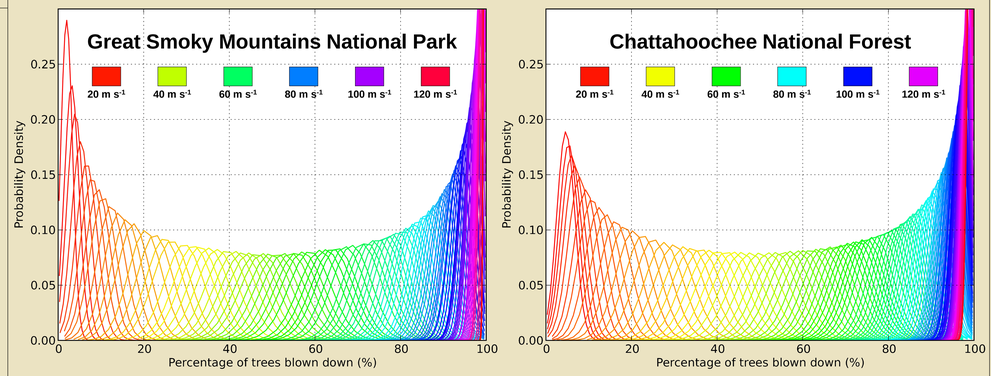
[1]Purves, D. W., J. W. Lichstein, and S. W. Pacala, 2007: Crown plasticity and competition for canopy space: A new spatially implicit model parameterized for 250 North American tree species. *PLoS ONE*, 2(9), e870, doi:10.1371/journal.pone.0000870.

RESAMPLING PROCESS

- For each tornado track, a statistical resampling procedure begins by randomly drawing, with replacement, a small sample of 100 trees from the database of observed trees.
- A coupled wind and tree resistance model determines the percentage of trees in that sample that fall for a given wind speed increment ranging from light breezes to extreme wind speeds.

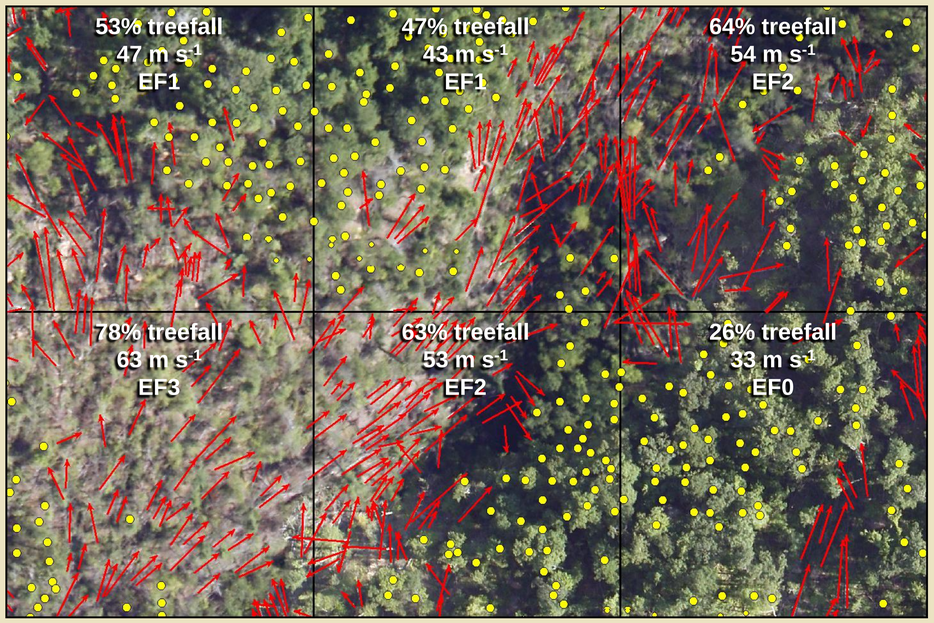


- By repeating this procedure 10,000 times, each wind speed increment corresponds with a Gaussian distribution of treefall percentages in the sampled plots.

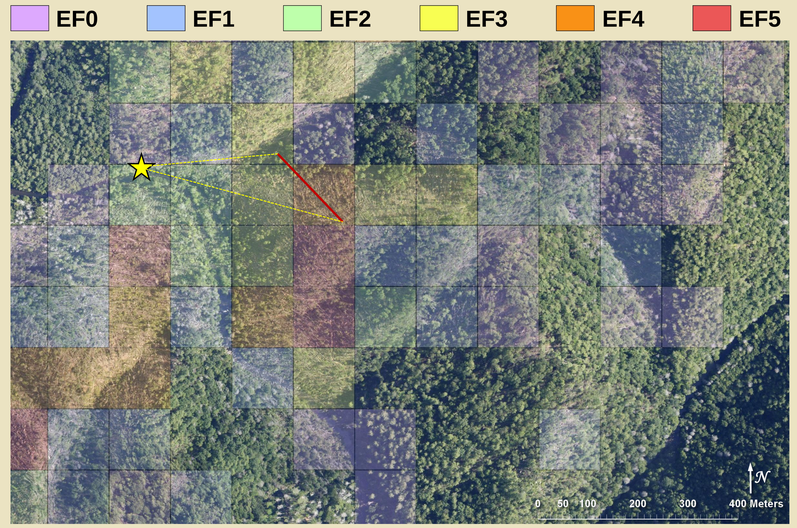


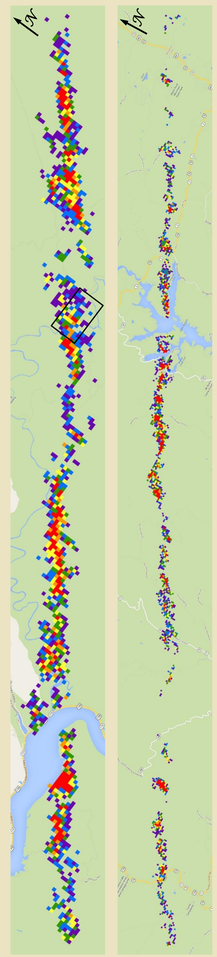
ASSIGN A DAMAGE RATING TO PLOTS ALONG THE TRACK

- The most probable wind speed that produced the damage in 100 m 100 m subplots is the wind speed corresponding with the Gaussian probability density function with its peak at the observed percentage of downed trees.



MAPS OF EF-SCALE DAMAGE





Top: EF-scale estimates near the intersection of the Hatcher Mountain Trail and the Little Bottoms Trail along Abrams Creek in the Great Smoky Mountains National Park (see inset on map at far left). The star indicates the location of the photographer and the red line corresponds with the field of view in the photo below.

Bottom: Photo, taken 15 months after the tornado, looking east showing a steep slope that the damage estimation technique labeled EF3 (lower left) and EF4 (right two-thirds). The tornado completely destroyed the forest canopy.

DISCUSSION

- This method uses tree damage severity to estimate tornado intensity in remote or inaccessible locations. The results are consistent with ground observations in both tornado tracks.
- The analysis requires a balanced spatial distribution of tagged trees in each subplot (i.e., approximately every n^{th} tree must be tagged).
- Confidence intervals can provide a range of possible wind speeds responsible for a given level of forest damage.

ACKNOWLEDGMENTS

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