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Estimating wind speeds for unique wind damage events by combining multiple damage survey data sets in the cloud

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SUMMARY:
Cloud computing infrastructure such as DesignSafe has enabled data re-use of a kind that has not previously been possible. Data that are published by various entities can be merged in the cloud with tools such as QGIS to facilitate wind speed estimates for unique damage events that were not part of the original data collection. For example, in this study, the December 2021 Kentucky tornadoes were studied using wind speed estimates from the US National Oceanic and Atmospheric Administration (NOAA) and drone imagery shared on DesignSafe. By merging these data sets in QGIS and searching the images for vehicles that had been moved in the storm, wind speed estimates were found for those vehicle movements by correlating the vehicle positions with the NOAA damage estimates. This approach combined with data published in DesignSafe represents a powerful source of data for those who wish to examine unique wind damage events and develop new damage indicators.

Keywords: tornado, field data, damage survey

1. BACKGROUND MOTIVATION

Although vehicles are very commonly shifted and thrown by tornadoes, the aerodynamic mechanisms behind this phenomenon are not well understood at present and the current Enhanced Fujita scale does not include vehicles. Some recent work has advanced the general understanding of vehicles in tornadoes using tornado simulator and wind tunnel tests (Haan et al., 2017) and using field observations (Paulikas et al., 2016). To develop and support a damage indicator for the Enhanced Fujita scale, more data on tornado-induced vehicle motion is always helpful.

Part of the vision of the cyberinfrastructure platform DesignSafe (www.designsafe-ci.org) was for it to be a place where data could be shared and re-used by multiple users. In the past, damage survey data consisted mainly of the photographs and observations of a small group of researchers and were typically shared with a report containing only a portion of the photos of the event. Cloud platforms have enabled both the storage of large quantities of such photos and the re-use of such photos in the cloud using applications built for such purposes. An example of such re-use would be to conduct work that is similar to Paulikas et al. (2016) but in the cloud. Paulikas et al. (2016) estimated the wind speeds required to move vehicles by recording the EF rating of damaged houses that were near the moved vehicles. The method demonstrated with this study is doing the same thing but using ground images and drone images of vehicles that were moved and

then comparing those to nearby EF ratings from NOAA's Damage Assessment Toolkit (NOAA, 2021).

2. INCORPORATION OF CLOUD DATA AND TOOLS

The mapping software QGIS can be run on the cloud in DesignSafe. Using QGIS as the foundation, various sources of data can be merged. In the case of the December 2021 tornadoes in Kentucky, damage assessment data was found from NOAA's Damage Assessment Toolkit (DAT). This database contains data from the US National Weather Service for all damaging wind storms. One can search the database for a particular date range and see the data available for a given location. Fig. 1 shows the DAT data for the December 2021 Kentucky tornadoes. Shapefiles for this event were downloaded from the DAT and then uploaded to DesignSafe to be displayed in QGIS.

Drone imagery from the Kentucky tornadoes from Pilkington et al. (2021) was then also displayed in QGIS along with the DAT data (see Fig. 2). This image shows the drone imagery overlaid with symbols for each damage assessment that was done by the National Weather Service as well as the track of the tornado.

The next step in the analysis then involves zooming in on the drone imagery to find events of interest. These could be particular types of structural damage, or they could be damage indicators that have not been studied in depth. In this study, vehicles that were moved by the tornado were sought. An example of the vehicle analysis is shown in the next section.

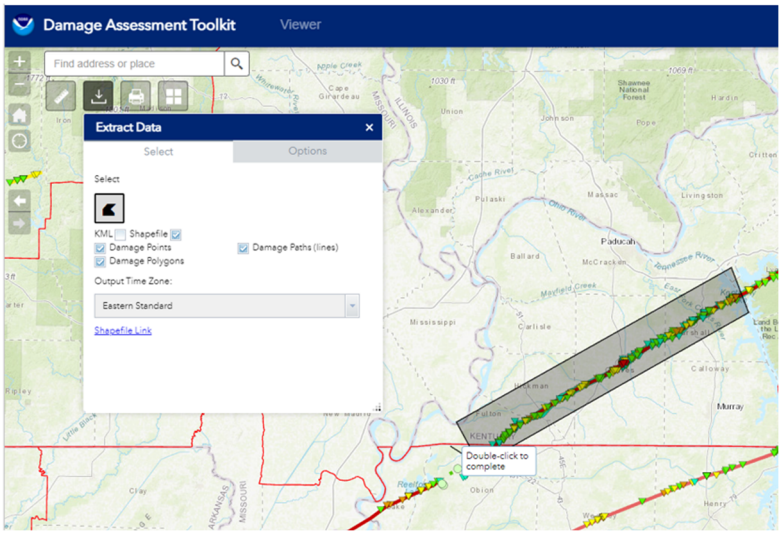

Figure 1. Screenshot of the Damage Assessment Toolkit (NOAA, 2022) for the Dec 10, 2021 Kentucky tornadoes.

Figure 2. Screenshot of QGIS (within DesignSafe) showing drone imagery from Mayfield, Kentucky (Pilkington et al., 2021) along with NOAA Damage Assessment Toolkit (DAT) data points (NOAA 2021). The yellow box has been added to indicate the view that is enlarged in Fig. 3.

3. EXAMPLE OF RESULTS

Although numerous vehicles were found in the drone imagery along the damage path, one example is illustrated here. The area of Fig. 2 highlighted with yellow is shown in two degrees of enlargement in Fig. 3. Several vehicles in a parking lot have been shifted around because of the tornado. The nearest DAT data points (shown on the left in Fig. 3) show EF3 level damage corresponding to 67 m/s (150 mph). This can be used as an estimate of the wind speed that moved the vehicles in the parking lot.

Moving along the damage path, many vehicles were found to have moved. Using this same method of geo-correlation of the damage indicators gave a large range of wind speeds required to move the vehicles. Anywhere from 45 m/s to 74 m/s was found near vehicles that had slid or flipped. While it is often difficult to determine the starting location of each vehicle – and thus exactly what movement occurred – the wide range of velocity estimates is consistent with the field data of Paulikas et al. (2016).

Figure 3. Left: Enlarged view of a portion of Fig. 2 showing drone imagery (Pilkington, et al., 2021) overlaid with NOAA DAT data points (NOAA 2021). The green dot denotes the location of vehicles that were moved by the tornado. Right: Enlarged view of the area circled in red in the photo on the left.

7. CONCLUSIONS

This study has demonstrated the re-use of data in the cloud to develop wind speed estimates for wind damage events. Vehicles that moved during the 2021 Kentucky tornadoes were located using drone imagery, and wind speed estimates were found by geo-correlating the vehicle locations with damage data that had been published in NOAA's Damage Assessment Toolkit. This type of work opens up a very large data resource for researchers seeking to study particular types of damage events.

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REFERENCES

Haan, Jr. F.L., Sarkar, P.P., Kopp, G.A., Stedman, D.A., 2017. Critical wind speeds for tornado-induced vehicle movements. Journal of Wind Engineering and Industrial Aerodynamics, 168, 1–8.

NOAA, Damage Assessment Toolkit, https://apps.dat.noaa.gov/StormDamage/DamageViewer/, Accessed: July, 2022.

Paulikas, M.J., Schmidlin, T.W., Marshall, T.P., 2016. The Stability of Passenger Vehicles at Tornado Wind Intensities of the (Enhanced) Fujita Scale. Weather, Climate, and Society, 8, 85–91.

Pilkington, S., Roueche, D., Gutierrez Soto, M., Alam, M., Napolitano, R., Kijewski-Correa, T., Prevatt, D., Kaushal, S.S., Nakayama, J., Saleem, M.R., Ibrahim, H., Lyda, A., Lester, H., Caballero Russi, D., Gurley, K., Robertson, I., Lombardo, F., 2021. StEER: 10 December 2021 Midwest Tornado Outbreak Joint Preliminary Virtual Reconnaissance Report and Early Access Reconnaissance Report, DOI: 10.17603/ds2-2b2k-ws96.