Supplementary Material for "Understanding Evacuation Behavioral Patterns Using Anonymized Device Data and High Resolution Parcel Level Data: Application to Hurricanes Irma and Matthew"

LBS Data Processing Steps

Raw Data Summaries

Before developing algorithms to process the raw data, the raw data was analyzed to better understand how the data depict population movements during a hurricane. To do this, we simply broke the state down into uniform geographical units and summarized the number of unique devices that appear in each of those units by day leading up to and after Hurricane Irma's landfall. Instead of looking at device counts for each geographical unit, we compared the device count to the average device count during the steady state period. Figure 1 shows these results, with red shades corresponding to areas with lower number of devices relative to steady state and blue shades corresponding to areas with higher number of devices relative to steady state.

The first panel of the figure was taken from 9/4/17, six days prior to landfall, and shows the typical steady-state conditions. The colorations in this panel represent normal day-to-day variations in device counts by day. The second panel (9/6/17) shows very little difference in the patterns from the first, other than we start to observe devices leaving the Florida Keys (islands off the southern coast of the state). In the third panel (two days prior to landfall, 9/8/17), the device counts in the Keys are even more pronounced, areas on the southern Gulf Coast of the state start to see lower device totals, and the interior and northern areas of the state start seeing higher device totals (especially along the major interstates). The fourth panel represents the day of landfall (9/10/17), with very pronounced changes in device totals. The Gulf coast zones have many fewer devices appearing relative to steady state while the interior and northern areas of the state have many more devices. This is consistent with evacuation behavior expected during the hurricane. The final two panels illustrate the re-normalization period two and four days after landfall.

Geospatial Indexing

In order to reduce computational complexity, coordinates for each observation were tagged to a hexagon (or hex-bin) using the H3 Python library. Such geospatial indexing is essential for aggregating and querying data at scale and choice of index is important. Polygons that discriminate particular areas can be very complex to handle (e.g., Census geographies or traffic analysis zone systems). The more complex the polygons the more calculations required to perform the indexing, which can result in lost efficiency. An efficient geospatial indexing system helps to overcome these hurdles. The H3 scheme was chosen for its efficiency at scale.

The H3 algorithm partitions the Earth's surface into a network of hexagons. The library allows the analyst to select from a variety of resolutions. Each hexagon is unique and is identifiable as such. Individual hexagons are addressed through a unique 64-bit identifier, an ideal key for a database table, or an in-memory dictionary. These identifiers are consistent across resolution levels, so the hex-bins can be mixed and matched as desired. For this analysis, the chosen resolution was such that individual hex-bins had edge length of 0.1 miles and total area of about 26 acres. It was determined that this resolution was ideal because it was small enough to capture device location without noise due to GPS or other errors but also not too small to overwhelm computing resources. Figure 2 shows a sample of the hex bins for the Tallahassee region with Census Block groups overlaid.

FIGURE 1 Relative Device Counts by Day for Hurricane Irma

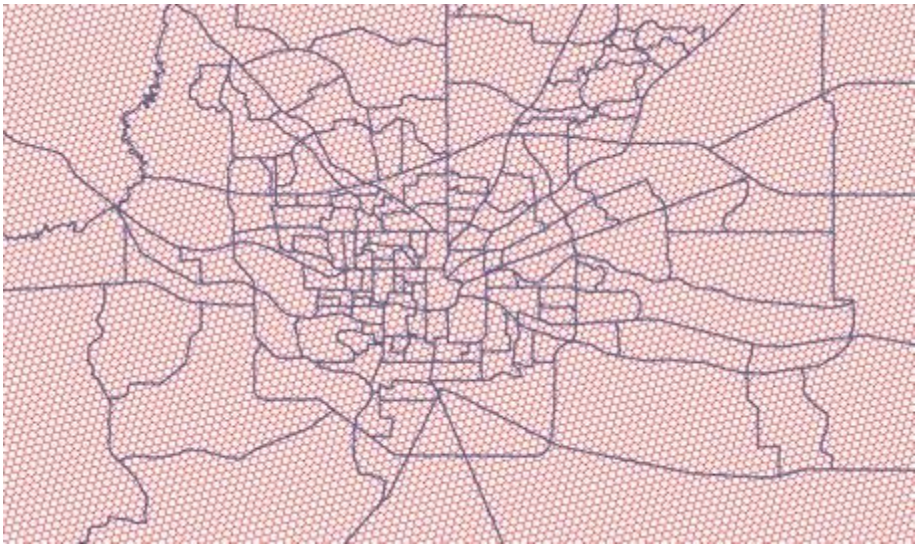

FIGURE 2 Hex-Bin Resolution vs. Census Block Groups in Tallahassee, FL (Source: Florida SRESP 2021)

References:

Florida SRESP: Central Florida Regional Planning Council (2021) Regional Behavioral Analysis. https://portal.floridadisaster.org/preparedness/RES/Studies/Shared Documents/Supporting Documents/Region-Specific Folders/2021_SRESP_BehavioralStudy_Statewide.pdf. Accessed 4 Apr 2023