
Florida Coastal Monitoring Program (FCMP): Curation of hurricane wind data for DesignSafe-CI

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ABSTRACT

There is an increasing demand to access and use the Florida Coastal Monitoring Program (FCMP) ground level hurricane wind data from many researchers investigating hurricane meteorology, structural performance in extreme winds, building code developers, and others. DesignSafe-CI is the ideal location to curate and disseminate these data to users, as well as track users and uses. The datasets were collected over a period of 18 years using a variety of methods and instrumentation. A set of FCMP data curation and dissemination tools are developed and will be used to publish quality controlled FCMP data on DesignSafe-CI. This paper describes the development of Hurricane Wind Data (HWD), a data user interface, to view and identify datasets for further analysis.

1. Introduction

As the lead institution of the Florida Coastal Monitoring Program (FCMP), the University of Florida collected near-surface wind and rain data from Atlantic hurricanes and studied their effects on coastal infrastructure since 1999 [1], [2]. There is an increasing demand for the data from many researchers investigating hurricane meteorology, structural performance in extreme winds, building code developers, and others [1], [2]. To date, the data requests have been serviced on a case by case basis by the faculty of the Department of Civil and Coastal Engineering at the University of Florida. However, the data have been disseminated using a variety of inefficient methods over the last 18 years. DesignSafe-CI is a cyber-infrastructure component of the Natural Hazard Engineering Research Infrastructure (NHERI) funded by the National Science Foundation (NSF) [3]. Because of its public access and NHERI community users, this is the ideal location on which to curate and disseminate these data to users, as well as track users and uses. The data need to be processed to a common framework and visualization, containing analysis and selection tools to provide easy dissemination. The purpose of this paper is to discuss the development of Hurricane Wind Data (HWD), a graphical user interface (GUI) designed with a set of FCMP data curation and dissemination tools, used to publish quality controlled FCMP data on DesignSafe-CI.

2. Methodology

2.1 Near-surface wind characteristics data collection

The dataset collected through the Florida Coastal Monitoring Program (FCMP) is comprised of near surface wind characteristics data from 1999-2008 Atlantic hurricanes. There are 72

measurements in 21 named storms [4], [5]. The objectives of the FCMP are to measure ground level wind velocity and evaluate the effectiveness of structural retrofits [2]. The data was collected using a set of four portable towers to measure time histories of three-dimensional wind velocities at 5- and 10-meter elevations, barometric pressure, temperature, rate of rainfall, and relative humidity [1], [2]. The data are recorded as voltages and converted to engineering units [2]. The tower platforms are instrumented with two RM Young anemometer systems: a wind monitor (Model Number 05103V) and a custom array of three Gill propellers (Model Number 27106R) [2], [4]. The four-blade polypropylene helicoid propellers have dynamic characteristics that include a 2.7-m, 63% recovery distance constant and a damped natural wavelength of 7.4m [2],[4]. The wind monitor is rated for a 100m/s gust survival and has a 50% recovery vane delay distance of 1.3m [2], [4].

2.2 Design of Graphical User Interface (GUI) Layout

MATLAB User Interface (UI) is a graphical display that allows users to perform interactive tasks without the perception of detailed coding process to execute the tasks. The MATLAB UI can perform complex computation, read and write data files, communicate with other UIs, and display data as tables or plots. A GUI is referred to a UIs created using GUIDE, a drag-and-drop environment for laying out user interfaces (UIs). When a layout is set up, a fig-file (.fig) and a code file (.m), containing MATLAB functions that control UI, were created. The fig-file and the

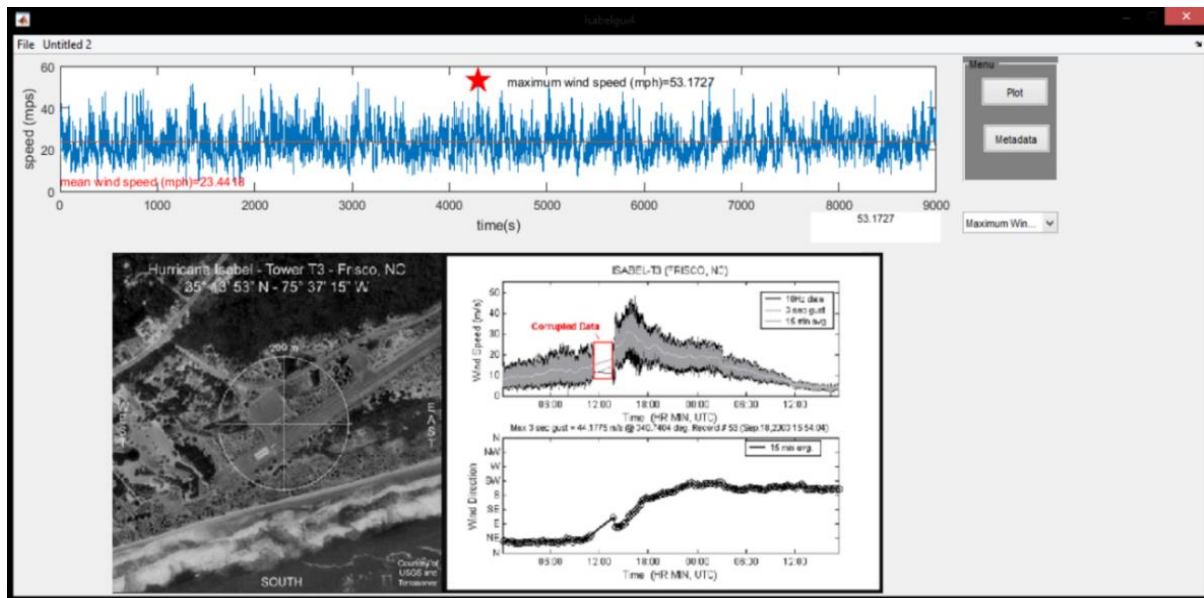


Figure 1: An example of GUI layout created for plotting a 2.5-hour wind speed data collected at 10 Hz during Hurricane Isabel in 2003. This layout contains a *Plot* button that generates a plot of time vs speed, a *Metadata* button to display GPS coordinates, an aerial image and map, and a pop-up menu that can identify important parameters such as maximum wind speed, mean wind speed, and turbulence intensity on the plot of time vs wind speed.

code file correspond to the tasks of laying out and programming the UI respectively. In this project, a common framework of the FCMP datasets were developed using UIs to enhance user interaction with the data and display metadata to provide clear guidance to users. Comprehensive GUI layouts were built containing sets of components including menus, toolbars, push buttons,

radio buttons, list boxes, etc. to give users the ability to navigate, filter, and analyze particular sets of data for their research.

Figure 1 shows an example of a simple layout in the GUI created for 2.5 hours of wind speed data collected at 10 Hz during Hurricane Isabel in 2003. The layout in this example consists of two user push buttons, *Plot* and *Metadata*, and a pop-up menu for maximum wind speed, mean wind speed, and turbulence intensity. The layout also contains two windows which display a graph or an image. The *Plot* button is used to plot a graph of time vs wind speed in the first window. The *Metadata* button creates a second window that includes GPS coordinates, aerial image and a map of the tower T3 used to collect this data. The maximum wind speed, mean wind speed, and turbulence intensity are also identified on the graph by choosing the options from the pop-up menu.

2.3 DesignSafe-Ci

DesignSafe-Ci is a cyber-infrastructure component of NHERI that provides computational tools to manage, analyze, and understand data for the Natural Hazard Engineering Research Infrastructure (NHERI) community [3]. DesignSafe-CI is an ideal environment to curate and disseminate the FCMP data as well as track user and uses. NHERI researchers who need the FCMP data for their projects can simply sign up for a DesignSafe-CI account and access the data by using the Hurricane Wind Data (HWD) GUI. Then, the users can either view or store the data into their personal DesignSafe-CI workspace. Figure 2 shows the flow chart of how the FCMP data will be processed and put into a standard framework HWD GUI that could help identify and analyze FCMP datasets.

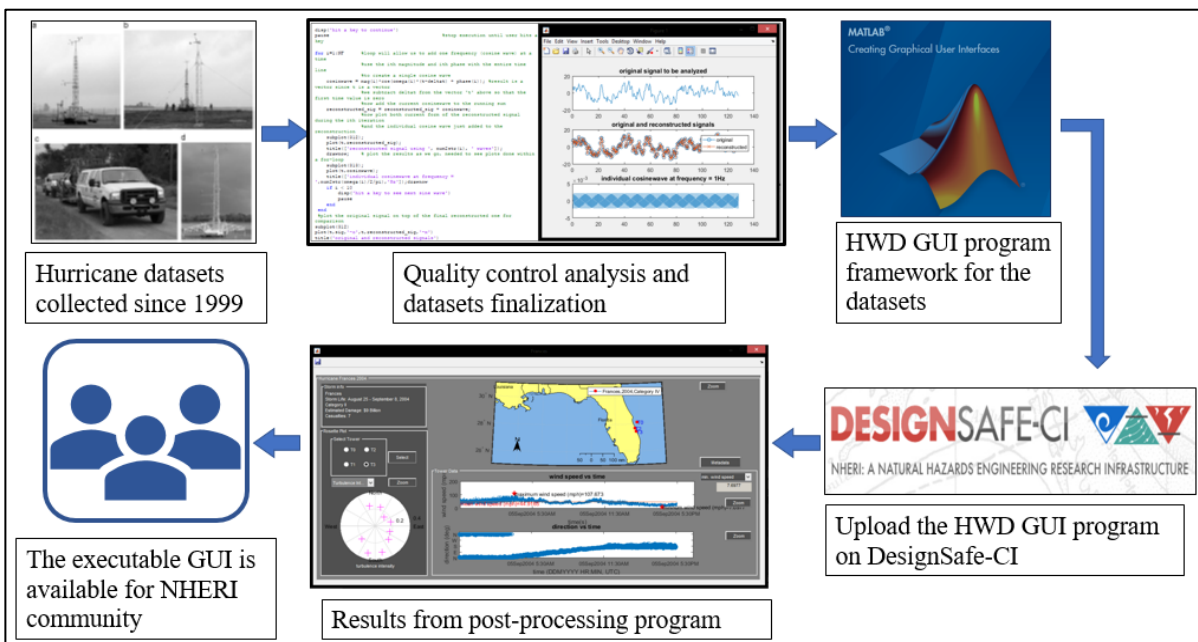


Figure 2: A flow chart showing how FCMP datasets are posted on DesignSafe-CI and shared with NHERI community

3. Features

3.1 Layer I: HWD GUI overview

The first layer of the HWD provides an overview of all tower datasets that are available for viewing (multiple storms and multiple towers per storm). Upon opening the UI, the user will see an HWD GUI overview window that displays a deployment map of the southeast US and icons that show where individual towers collected data (Fig. 3). These icons are color coded by storm, and all towers that took data in the same storm have the same color. A legend relates the color icons to storm name, storm year, and Saffir-Simpson Hurricane Intensity Scale (SS-scale) [6] classification. The *Zoom* button activates a pop-out version of the deployment map with image

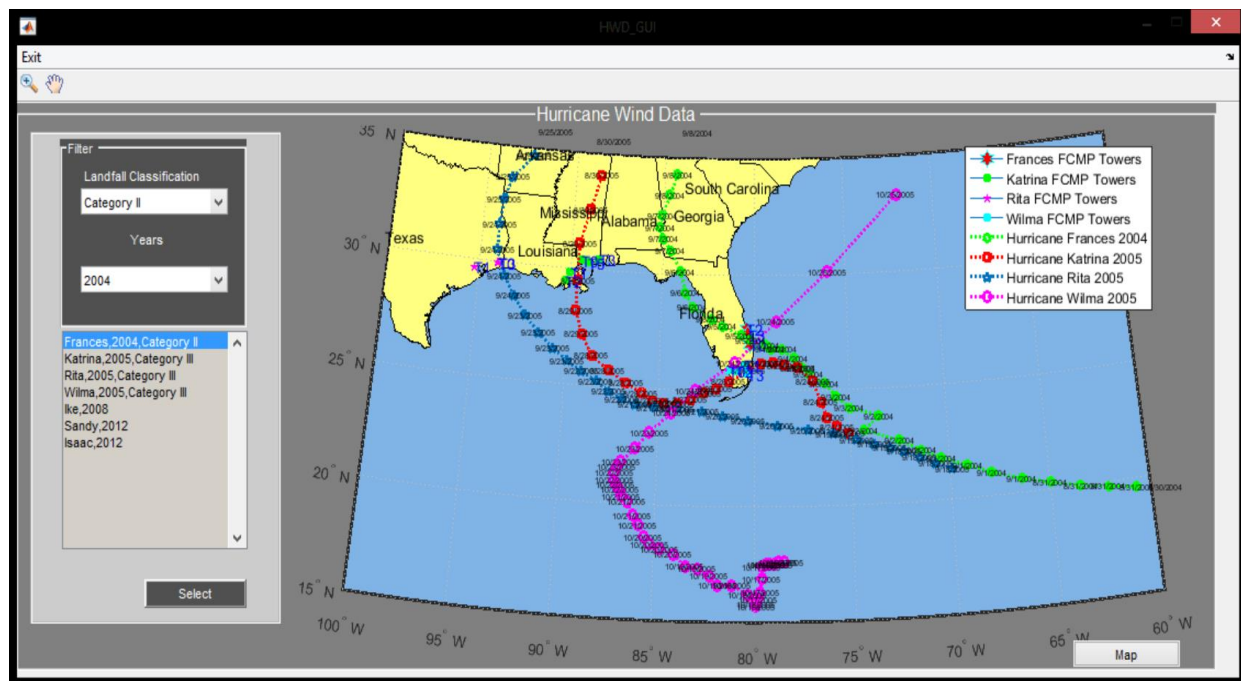


Figure 3: HWD GUI opening layout (Layer I). The layout contains two filtering popup menus classifying hurricane classification and years as well as a list box containing all hurricanes with classified names and year of occurrence. The layout also has a map showing FCMP tower deployment locations of all storms from 1998 to 2008.

manipulation tools. Furthermore, there is a *Filter* panel and a listbox on the left corner of the layout. The *Filter* panel helps users quickly narrow the search options and conveniently look at storm data by SS-scale or year. In addition, all storms are listed in a listbox located below the *Filter* panel to allow selection of any storm by activating the select push button below the listbox. After selecting the storm, the user is directed to a new popup HWD GUI window (Layer II) for that specific storm. Here, the user can access valuable information of the storm such as the portable tower wind data and metadata.

3.2 Layer II: Individual storm visualization

Upon selecting a particular storm for closer analysis, a second window appears (Fig. 4). The window provides a deployment map for that particular storm, where only the towers for that storm are displayed. Again, the user may launch a pop-out version of the map for closer inspection (Fig. 5). The *Storm info* panel gives the user general information about the storm such as the duration, the category, the estimated damage, and casualties. Located below the *Storm info* panel is the *Rosette Plot* panel; this panel contains a *Select Tower* button group allowing the user to select any tower and display the data on *Tower Data* section. After a tower is selected, all other operations are also activated for the data of that specific tower. For example, the *Select* button, upon activated, will generate two graphs, wind speed and direction plots vs time, on the two axes on the *Tower Data* panel as shown in figure 4. The *Zoom* buttons on the panel allow the user to generate separate popup figures of both graphs (Fig. 7 & 8) for a larger view of the data, zoom in and out, and store the figures to their personal DesignSafe-CI workspace as needed.

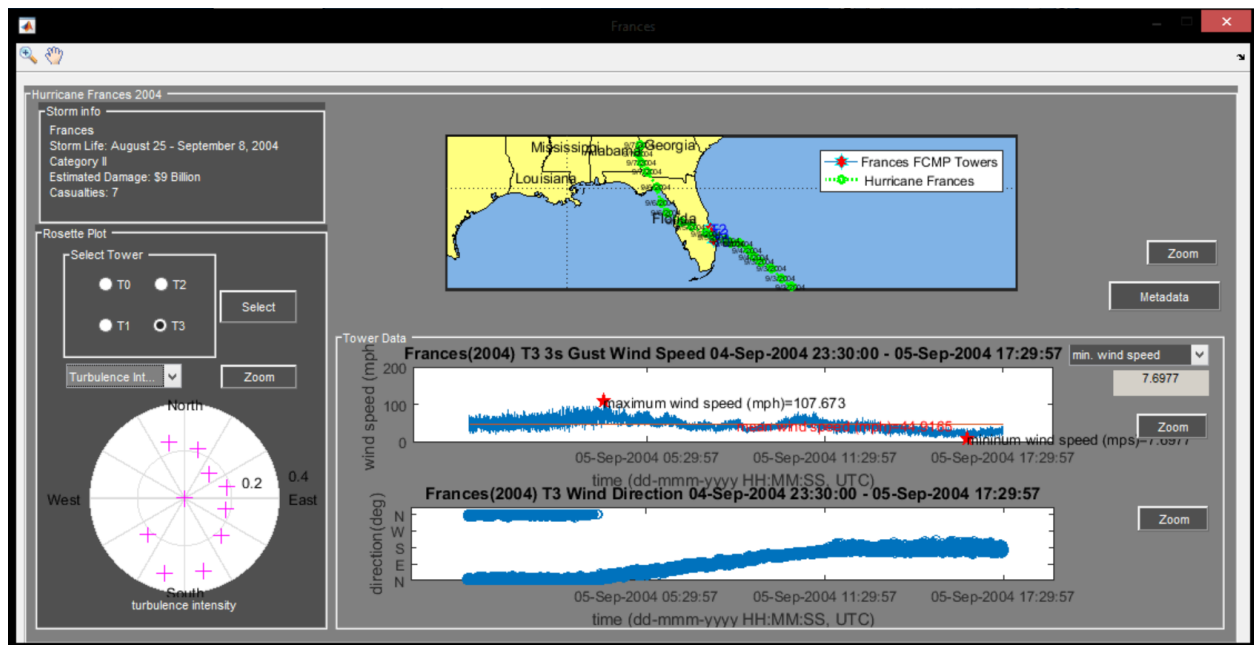


Figure 4: Hurricane Frances GUI layout. The storm info panel gives overall information about the storm. The layout also contains a tower deployment map of the storm, two axes for plotting the curated data, and a polar plot of direction versus important parameters: turbulence intensity, max. wind speed, and duration of the wind data.

While the interactive deployment map gives the user geographical locations of all towers, the *Metadata* button, upon activated, generates a popup figure of aerial images with GPS coordinate location of the selected tower (Fig. 9). The deployment map coupled with the aerial images will give the user a better understanding of the terrain condition where the tower was located to collect data during the hurricane; this is important to analyzing the observed turbulence intensity and the turbulence derived aerodynamic roughness associated with upwind terrain characteristics [1]. In the *Rosette Plot* panel, a rose plot also appears and provides statistical information (turbulence intensity, maximum wind speed, and duration) stratified by wind direction in 30 ° increments. For example, the maximum wind speed recorded in every 30 ° swath is displayed. The wind rose,

speed and direction plots can be selected and viewed in separate windows if desired (Fig. 6, 7, 8). Once the user selects a parameter on the listbox, the raw data collected from the tower will be loaded in the MATLAB code file, analyzed by our algorithm, and plotted. A polar plot of that parameter with respect to the wind direction is displayed (Fig. 4 & 6).



Figure 5: Hurricane Frances deployment map. The map shows FCMP tower locations and color-coded storm path representing different stages of the storm.



Figure 6: Wind rose plots of turbulence intensity and maximum wind speed of hurricane Frances tower T3 data.

4. Discussion

With the aim of illustrating the main features of HWD GUI, we utilized 3s gust data collected by FCMP tower T3 during hurricane Frances in 2004. The data were collected over 18 hours from

04 Sep 2004 11:30PM (UTC) to 05 Sep 2004 5:30PM (UTC). Upon selection of the tower *T3* following by activation of the *Select* button in the *Select Tower* panel, the two graphs - wind speed vs time and direction vs time - were plotted on two axes in the *Tower Data* panel. The plots are then exported (Fig. 7 & 8) by activating the *Zoom* buttons on the panel. From the data shown in

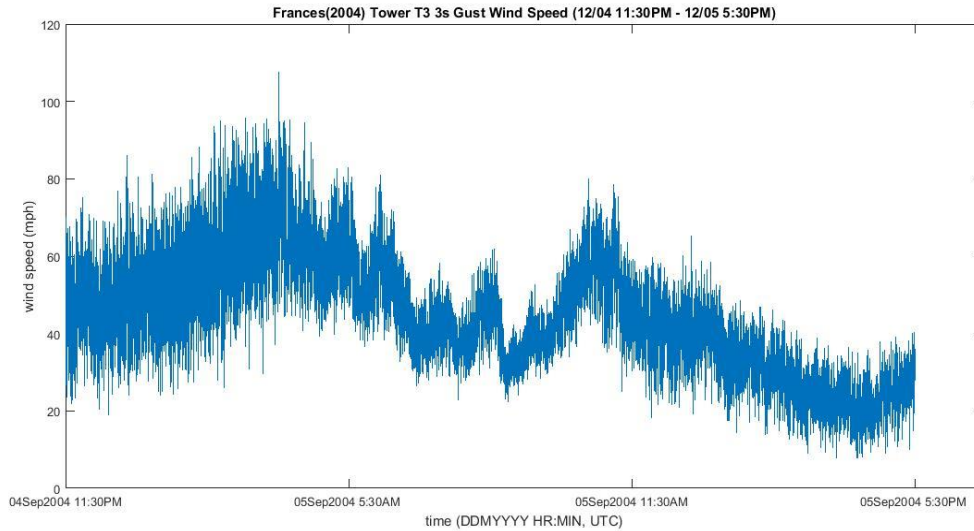


Figure 7: A plot of 3s gust wind speed data collected by tower T3 for 18 hours during hurricane Frances (UTC).

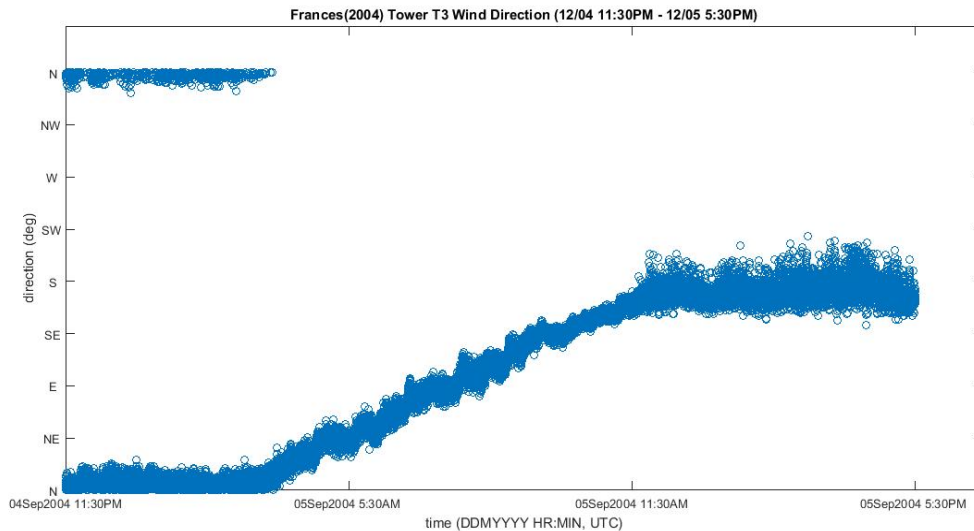


Figure 8: A plot of wind direction vs time collected by tower T3 for 18 hours during hurricane Frances (UTC).

the HWD GUI, a quick observation could be made on the time of the passage of the hurricane eye with two velocity peaks (Fig. 7) and the associated near 180° change in wind direction from North (N) to South (S) (Fig. 8); this also suggested that the tower was located very close to the eye of the storm. The same observations were made for other hurricane analyses presented in Masters, Tieleman, and Balderrama [1].



A



B



C



D

Figure 9: Aerial images of FCMP portable towers during hurricane Frances in 2004 [5]. The images are shown when the Metadata button is selected.

In addition, when the user selects hurricane Frances tower T3 on the *Select Tower* panel, the data file for T3 is also selected for all operations in the GUI. After the maximum wind speed and turbulence intensity are selected in the listbox in the *Rosette Plot* panel, the tower T3 wind data will be analyzed and segmented into twelve segments in the code file. For each segment, the maximum wind speed is taken and plotted against the corresponding wind direction in a polar plot (Fig. 6B). As shown in Figure 6B, the maximum wind speed was blowing from the closer to the North in the North East (NE) direction and there was almost no wind blowing from the North

West (NW) direction. The finding was consistent with the *Turbulence Intensity* polar plot (Fig. 6A) and *Wind Direction* plot (Fig. 8). According to the plot in Fig. 6A, there was a higher turbulence intensity from the North (N) and the South (S); this could have been caused by rougher terrain from the up-stream surface wind current. One could notice that the observation matches with the aerial image shown in Figure 9D. The East (E) side of the tower has an ocean open terrain condition, whereas the N and the S have rougher upwind terrain conditions due to residential buildings; this results in a higher turbulence intensity in both N and S compared to E since the observed turbulence intensities and the turbulence derived aerodynamic roughness are associated with upwind terrain characteristics [1].

The next major task is to coordinate with the DesignSafe-CI staff to accomplish two sequential tasks. The first is to develop a mechanism for users to identify the specific datasets they wish to tag and copy over (more likely link) to their own DesignSafe workspace for further analysis using their own code. This tagging method will be incorporated into the existing UI tool. The second task is then to migrate the completed beta version UI tool over to DesignSafe for testing.

To many researchers, the most challenging aspect of data sharing process is the metadata to understand what kind of data was collected and how it was collected. The introduction of the graphical tool, HWD GUI, will certainly accelerate research workflow for many researchers investigating hurricane meteorology, structural performance in extreme winds, building code developers, etc. HWD GUI provides a quick way to share the FCMP data to the NHERI community, enabling researchers to access and download the data for their research. Here, we established a standard template and location on DesignSafe-CI for future and current datasets from other researchers. Currently, this UI tool does not provide any detailed statistical analyses of tower data beyond visualization and simple benchmark values (e.g. max wind speed). The intent of this tool is to give the user the ability to identify which datasets would be useful to download for their own further analysis (length scales, gust factors, stationarity tests, probability modeling, spectral analyses, etc.) using their own preferred methods. Adding these analysis features to this UI tool is at this time considered to be unnecessary.

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