D04 FIU SITE CHARACTERIZATION: SUPPORTING DATA

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See configuration management system for approval history.

The National Ecological Observatory Network is a project solely funded by the National Science Foundation and managed under cooperative agreement by NEON, Inc. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
1.0	5/3/2010		Initial draft
A	6/22/2010	NEON.FIU.000242.CRE	CCB approved initial release
B	10/13/2010	NEON.FUI.000262.CRE	Updates; see CRE
C	12/10/2010	NEON.FUI.000278.CRE	Updates; see CRE
D	09/23/2011	ECO-00279	Update to new document numbers &template
E	04/18/2013	ECO-01014	Change Guanica DFIR location; Add Ponce Mameyes Relocatable site characterization information

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1 DESCRIPTION

1.1 Purpose

Data collected, analyzed and described here are used to inform the site design activities for NEON project teams, EHS (permitting), FCC, ENG, and FSU. This report was made based on actual site visits to the three NEON sites in Domain 04. This document presents all the supporting data for FIU site characterization at Guanica Forest (Advanced), Lajas Experimental Station (Relocatable 1), and Ponce Mameyes (Relocatable 2).

1.2 Scope

FIU site characterization data presented in this document are for the three D04 tower locations: Guanica Forest (Advanced), Lajas Experimental Station (Relocatable 1), and Ponce Mameyes site (Relocatable 2). Data presented in this document are ready to be used by other PT teams.

Disclaimer: all latitude and longitude points are subject to the tolerances of our measurement system, i.e., GPS

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

AD[01]	NEON.DOC.011008	FIU Tower Science Requirements
AD[02]	NEON.DOC.011029	FIU Precipitation Collector Site Design Requirements

2.2 Reference Documents

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms

3 GUANICA (ADVANCED TOWER SITE)

3.1 Site Description

The forest is mature, but it has been disturbed periodically in the past. The indigenous Taíno people and Spanish colonizers used the forest as a wood source and had small settlements within its boundaries. Some farming, ranching, and cutting for firewood and charcoal did occur following European settlement. In 1919 the forest was designated a reserve by the US government. Forest cover is now a mosaic of mature native forest of >100 y old and secondary forests dominated by native and introduced species (Colon and Lugo 2006).

Rainfall at Guanica Forest site averages 860 mm yr^{-1}, distributed in two rainy seasons; one in the spring and the second in the late summer and fall corresponding with the hurricane season. Rainfall is highly variable both within and among seasons. Hurricanes are an important feature of the climate of the Atlantic Neotropical domain, and hit Puerto Rico about once every 9 years.

The soils of Guanica Forest are derived from limestone formed from marine deposits. The soils are extremely low in biologically available phosphorous (Lugo and Murphy 1986) and high in organic matter, which may in turn lead to nitrogen limitations as microbes take up nitrogen for decomposition. Meanwhile, increasing atmospheric transport of Sahara dust is adding dry deposition of P to the island; this may reduce phosphorous limitation.

The original tower location was placed at 17.97592830, -66.86355546. It was on the bottom of a large hill slope. Cold air drainage during nighttime along the hill slope will be a concern for accurate flux measurements. A new tower location at a relatively flat area was proposed at 17.96955, -66.86870, which is closer to the existing access road as well as electrical power, and is still under the same land owner. The ecosystem in interest is the same type, which is subtropical dry forest.

3.1.1 Ecosystem

The forest is a subtropical dry forest (Fig. 1). Canopy height averages 10 m at our tower site and mature forest is dense, with about 12,000 stems ha^{-1} (≥2.5 cm dbh). Tree species richness averages about 33 per 0.1 ha and there is a total of 169 tree species in Guanica Forest, with 50 species being relatively common (Murphy and Lugo 1986).

Forest has closed canopy. LAI reaches ~4 in peak growing season (September), and decreases to ~2 in February (Pers. Comm.., S. Van Bloem). Young seedlings are very dense and form understory, but no obvious stratums.

The ecosystem attributes to this site are summarized as following:

Table 1. Ecosystem and site attributes for the Guanica Forest Advanced site

Ecosystem attributes	Measure and units
Mean canopy height	10 m
Surface roughness[a]	1 m
Zero place displacement height[a]	7 m
Structural elements	Closed forest canopy, dense, uniform
Altitude[b]	15 [m] a.s.l.
Slope	3-10%
Aspect	SE
Time zone	Atlantic
Magnetic declination	12° 22' W changing by 0° 2' W/year
Frost-free period	365 days

[a] From field survey.

[b] From field survey and best estimate.

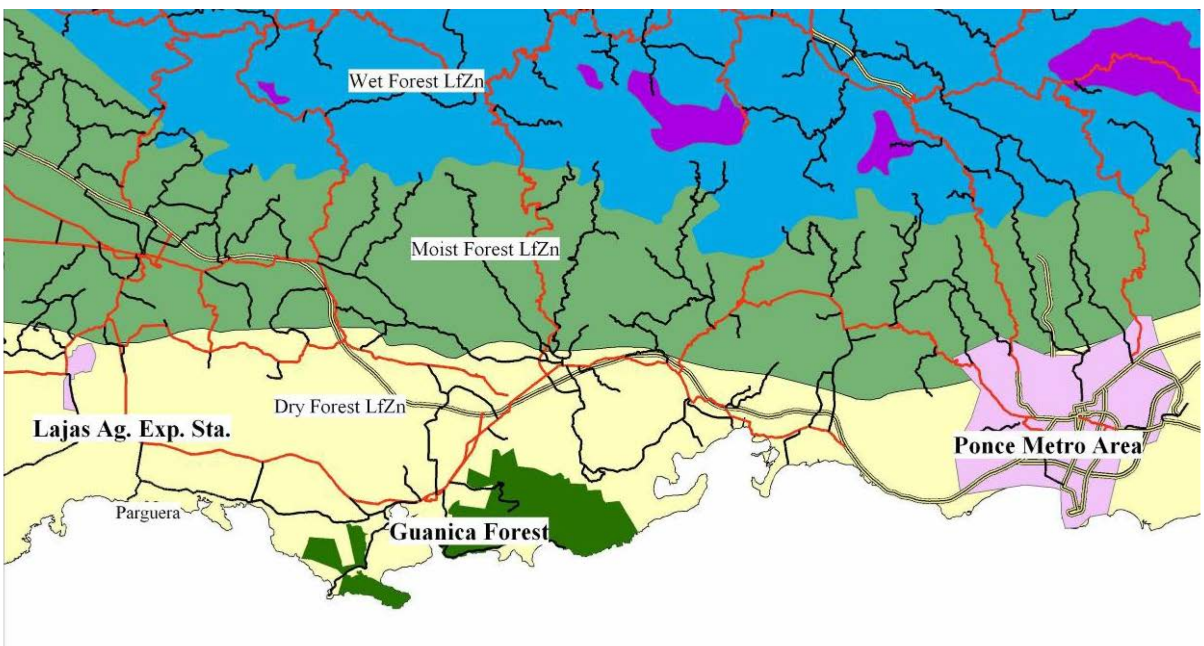


Figure 1. Ecozones in the area surrounding Guanica forest

3.2 Soils

3.2.1 Soil Description

Soil data and soil maps (Figure 2) below for Guanica advanced tower site were collected from 2.4 km^2 NRCS soil maps(http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm), which centered at the tower location, to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

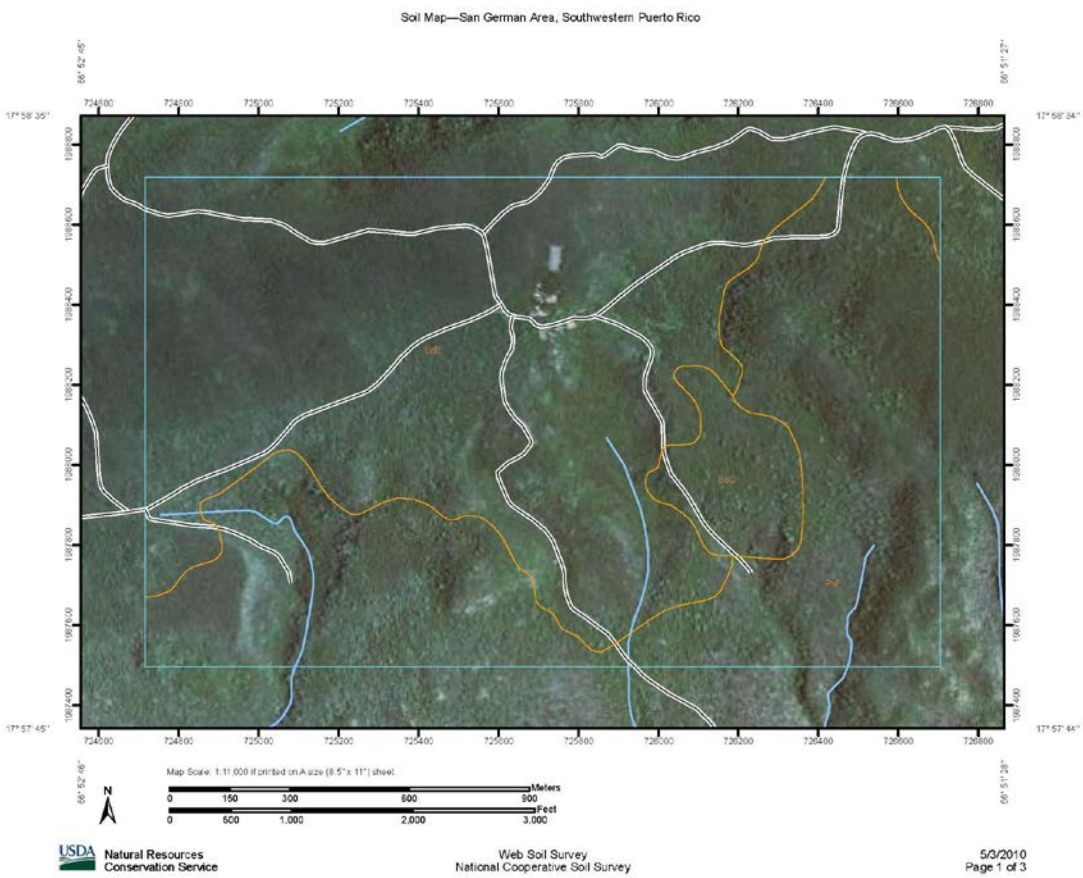


Figure 2. 2.4 km2 soil map for Guanica advanced tower site, center at tower location

Map Unit Description: The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit. A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes.

Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils. Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called non-contrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soil types or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas. An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a soil series. All the soils of a series have major horizons that are similar in composition, thickness, and arrangement. Soils of a given series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into soil phases. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series. Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups. A complex consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example. An association is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example. An undifferentiated group is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example. Some surveys include miscellaneous areas. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example. Additional information about the map units described in this report is available in other soil reports, which give properties of the soils and the limitations, capabilities, and potentials for many uses. Also, the narratives that accompany the soil reports define some of the properties included in the map unit descriptions.

Table 2. Soil Series and percentage of soil series within 2.4 km^2 centered on the tower.

San German Area, Southwestern Puerto Rico (PR787)			
Map Unit Symbol	**Soil types**	**Acres in AOI**	**% AOI**
LcE	La Covana-Limestone outcrop-Seboruco complex, 12 to 40 percent slopes	301.4	*56.4
PsF	Pitahaya-Limestone outcrop-Seboruco complex, 40 to 60 percent slopes	112.6	*20.5
SoC	Seboruco silty clay loam, 2 to 12 percent slopes	29.4	4.90%
Totals for Area of Interest		599.7	100.0%

* indicates dominant soil type(s) in airshed

San German Area, Southwestern Puerto Rico: LcE—La Covana-Limestone outcrop-Seboruco complex, 12 to 40 percent slopes. Map Unit Setting *Elevation:* 110 to 750 feet *Mean annual precipitation:* 16 to 50 inches *Mean annual air temperature:* 72 to 88 degrees F *Frost-free period:* 365 days Map Unit Composition *La covana and similar soils:* 60 percent *Limestone outcrop, aridic soil moisture regime:* 20 percent *Seboruco and similar soils:* 15 percent *Minor components:* 5 percent Description of La Covana Setting *Landform:* Hillslopes, ridges *Landform position (two-dimensional):* Backslope, shoulder, summit *Landform position (three-dimensional):* Crest, side slope, head slope *Down-slope shape:* Convex *Across-slope shape:* Linear *Parent material:* Residuum weathered from limestone Properties and qualities *Slope:* 12 to 40 percent *Depth to restrictive feature:* 6 to 20 inches to petrocalcic *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low (0.01 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Calcium carbonate, maximum content:* 95 percent *Maximum salinity:* Nonsaline (0.0 to 2.0 mmhos/cm) *Available water capacity:* Very low (about 1.5 inches) Interpretive groups *Land capability (nonirrigated):* 7s *Ecological site:* Calotropis procera-Pilosocereus royenii/Jacquinia arborea-Lantana involucrata/Aristida adscensionis-Chloris inflata (F271XZ026PR) Typical profile *0 to 5 inches:* Gravelly clay *5 to 19 inches:* Extremely gravelly clay *19 to 31 inches:* Cemented *31 to 80 inches:* Silt loam Description of Limestone Outcrop, Aridic Soil Moisture Regime Setting *Landform:* Hillslopes, ridges *Landform position (two-dimensional):* Backslope, shoulder, summit *Landform position (three-dimensional):* Side slope, head slope, crest *Down-slope shape:* Convex *Across-slope shape:* Linear Interpretive groups *Land capability (nonirrigated):* 8s Description of Seboruco Setting *Landform:* Hillslopes *Landform position (two-dimensional):* Summit, shoulder, backslope *Landform position (three-dimensional):* Head slope, crest, side slope *Down-slope shape:* Convex *Across-slope shape:* Linear *Parent material:* Shallow marine deposits derived from limestone Properties and qualities *Slope:* 12 to 40 percent *Depth to restrictive feature:* More than 80 inches *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low (0.01 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Calcium carbonate, maximum content:* 90 percent *Maximum salinity:* Nonsaline (0.0 to 2.0 mmhos/cm) *Sodium adsorption ratio, maximum:* 4.0 *Available water capacity:* Very low (about 2.5 inches) Interpretive groups *Land capability (nonirrigated):* 6e Typical profile *0 to 2 inches:* Silty clay loam *2 to 7 inches:* Silty clay loam *7 to 11 inches:* Very gravelly silty clay *11 to 19 inches:* Gravelly silt loam *19 to 26 inches:* Silt loam *26 to 31 inches:* Loam *31 to 31 inches:* Unweathered bedrock Minor Components Pitahaya *Percent of map unit:* 5 percent *Landform:* Hillslopes, ridges *Landform position (two-dimensional):* Backslope, summit, shoulder *Landform position (three-dimensional):* Side slope, crest, head slope *Down-slope shape:* Convex, linear *Across-slope shape:* Convex, linear

San German Area, Southwestern Puerto Rico: PsF—Pitahaya-Limestone outcrop-Seboruco complex, 40 to 60 percent slopes. Map Unit Setting *Elevation:* 80 to 750 feet *Mean annual precipitation:* 16 to 50 inches *Mean annual air temperature:* 72 to 88 degrees F *Frost-free period:* 365 days Map Unit Composition *Pitahaya and similar soils:* 60 percent *Limestone outcrop, aridic soil moisture regime:* 20 percent *Seboruco and similar soils:* 15 percent *Minor components:* 5 percent Description of Pitahaya Setting *Landform:* Hillslopes, ridges *Landform position (two-dimensional):* Summit, shoulder, backslope *Landform position (three-dimensional):* Crest, head slope, side slope *Down-slope shape:* Convex, linear *Across-slope shape:* Convex, linear *Parent material:* Residuum weathered from limestone Properties and qualities *Slope:* 40 to 60 percent *Depth to restrictive feature:* 5 to 20 inches to paralithic bedrock; 20 to 30 inches to lithic bedrock *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low (0.01 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Calcium carbonate, maximum content:* 70 percent *Maximum salinity:* Nonsaline (0.0 to 2.0 mmhos/cm) *Sodium adsorption ratio, maximum:* 2.0 *Available water capacity:* Very low (about 0.9 inches) Interpretive groups *Land capability (nonirrigated):* 7s Typical profile *0 to 2 inches:* Gravelly clay *2 to 11 inches:* Extremely gravelly clay *11 to 27 inches:* Weathered bedrock *27 to 80 inches:* Unweathered bedrock Description of Limestone Outcrop, Aridic Soil Moisture Regime Setting *Landform:* Hillslopes, ridges *Landform position (two-dimensional):* Shoulder, summit, backslope *Landform position (three-dimensional):* Side slope, head slope, crest *Down-slope shape:* Convex *Across-slope shape:* Linear Interpretive groups *Land capability (nonirrigated):* 8s Description of Seboruco Setting *Landform:* Hillslopes, mountain slopes *Landform position (two-dimensional):* Summit, shoulder, backslope *Landform position (three-dimensional):* Side slope, head slope, crest *Down-slope shape:* Convex *Across-slope shape:* Linear *Parent material:* Shallow marine deposits derived from limestone Properties and qualities *Slope:* 40 to 60 percent *Depth to restrictive feature:* More than 80 inches *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):*

Moderately low (0.01 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Calcium carbonate, maximum content:* 90 percent *Maximum salinity:* Nonsaline (0.0 to 2.0 mmhos/cm) *Sodium adsorption ratio, maximum:* 4.0 *Available water capacity:* Very low (about 2.5 inches) Interpretive groups *Land capability (nonirrigated):* 7e *Ecological site:* Calotropis procera-Pilosocereus royenii/Jacquinia arborea-Lantana involucrata/Aristida adscensionis-Chloris inflata (F271XZ026PR) Typical profile *0 to 2 inches:* Silty clay loam *2 to 7 inches:* Silty clay loam *7 to 11 inches:* Very gravelly silty clay *11 to 19 inches:* Gravelly silt loam *19 to 26 inches:* Silt loam *26 to 31 inches:* Loam *31 to 31 inches:* Unweathered bedrock Minor Components La covana *Percent of map unit:* 5 percent *Landform:* Hillslopes, ridges *Landform position (two-dimensional):* Summit, backslope, shoulder *Landform position (three-dimensional):* Head slope, crest, side slope *Down-slope shape:* Convex *Across-slope shape:* Linear

San German Area, Southwestern Puerto Rico: SoC—Seboruco silty clay loam, 2 to 12 percent slopes. Map Unit Setting *Elevation:* 80 to 250 feet *Mean annual precipitation:* 16 to 50 inches *Mean annual air temperature:* 72 to 88 degrees F *Frost-free period:* 365 days **Map Unit Composition** *Seboruco and similar soils:* 90 percent *Minor components:* 10 percent **Description of Seboruco Setting** *Landform:* Hillslopes, mountain slopes *Landform position (two-dimensional):* Summit, shoulder, backslope *Landform position (three-dimensional):* Head slope, side slope, crest, nose slope *Down-slope shape:* Convex *Across-slope shape:* Linear *Parent material:* Shallow marine deposits derived from limestone **Properties and qualities** *Slope:* 2 to 12 percent *Depth to restrictive feature:* More than 80 inches *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low (0.01 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Calcium carbonate, maximum content:* 90 percent *Maximum salinity:* Nonsaline (0.0 to 2.0 mmhos/cm) *Sodium adsorption ratio, maximum:* 4.0 *Available water capacity:* Very low (about 2.5 inches) **Interpretive groups** *Land capability (nonirrigated):* 4c **Typical profile** *0 to 2 inches:* Silty clay loam *2 to 7 inches:* Silty clay loam *7 to 11 inches:* Very gravelly silty clay *11 to 19 inches:* Gravelly silt loam *19 to 26 inches:* Silt loam *26 to 31 inches:* Loam *31 to 31 inches:* Unweathered bedrock **Minor Components Limestone outcrop** *Percent of map unit:* 5 percent *Landform:* Hillslopes, ridges *Landform position (three-dimensional):* Crest, side slope, nose slope, head slope **La covana** *Percent of map unit:* 5 percent *Landform:* Hillslopes, ridges *Landform position (two-dimensional):* Summit, backslope, shoulder *Landform position (three-dimensional):* Side slope, head slope, crest *Down-slope shape:* Convex *Across-slope shape:* Linear

3.2.2 Soil semi-variogram description

The goal of this aspect of the site characterization is to determine the minimum distance between the soil plots in the soil array such that data farther apart can be considered spatially independent. The collected field data will be used to produce semivariograms, which is a geostatistical technique to characterize spatial autocorrelation between mapped samples of a quantitative variable (*e.g.*, soil property data in our case). In an empirical semivariogram, the average of the squared differences of a response variable is computed for all pairs of points within specified distance intervals (lag classes). The output is presented graphically as a plot of the average semi-variance versus distance class (Figure 3).

For the theoretical variogram models considered here, the semivariance will converge on the total variance at distances for which values are no longer spatially auto-correlated (this is referred to as the range, Figure 3).

For the theoretical variograms considered here, three parameters estimated from the data are used to fit a semivariogram model to the empirical semivariogram. This model is then assumed to quantitatively represent the correlation as a function of distance (Figure 3), the range, the sill (the sill is the asymptotic value of semi-variance at the range), and the nugget (which describes sampling error or variation at distances below those separating the closest pairs of samples). The range, sill and nugget are estimated from theoretical models that are fitted to the empirical variograms using non-linear least squares methods.

The variogram analysis will be used, to determine the spatial scales at which we can consider soil measurements spatially independent. This characterization will directly inform the minimum distance between *i*) soil plots within each soil array, *ii*) the soil profile measurements, *iii*) EP plots, and *iv*) the microbial sampling locations. These data will directly inform NEON construction and site design activities.

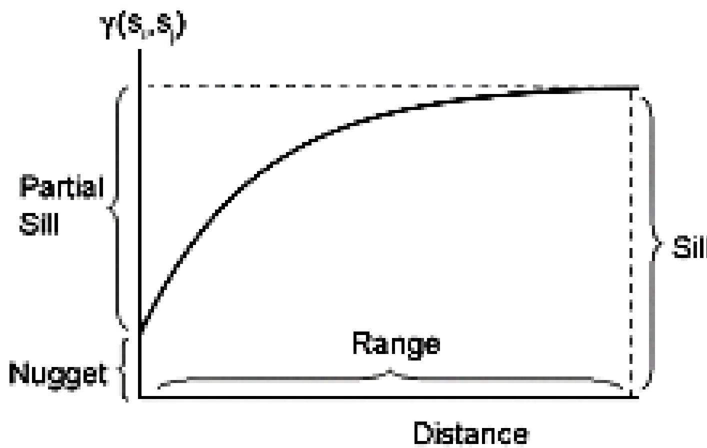


Figure 3. Example semivariogram depicting range, sill, and nugget

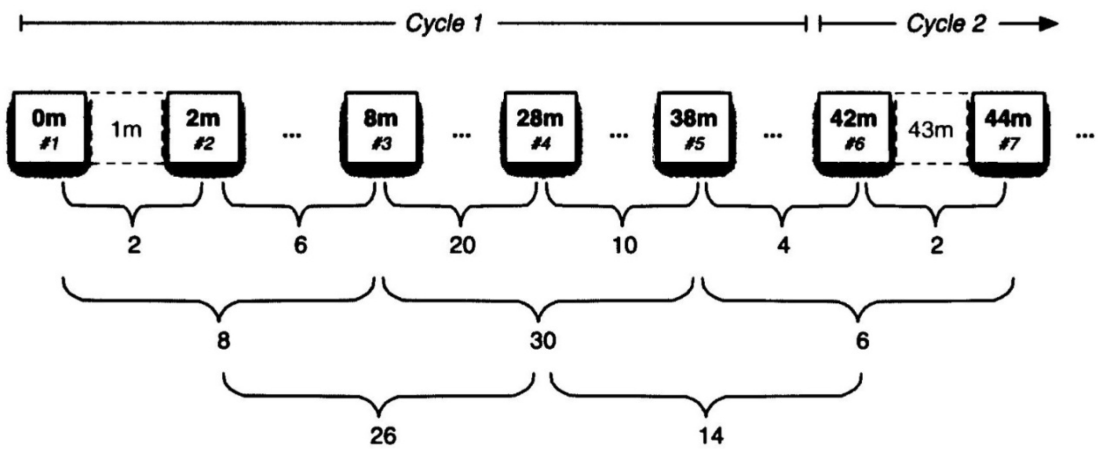


Figure 4. Spatially cyclic sampling design for the measurements of soil temperature and soil water content

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 18-19 March 2010 at the Guanica site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 4). Soil temperature and moisture measurements were collected along three transects (168 m, 84 m, and 84 m) located in the expected airshed at Guanica. Details of how the airshed was determined are provided below. Soil temperature was measured with platinum resistance temperature sensors (RTD 810, Omega Engineering Inc., Stamford CT) and soil moisture was measured with time domain diaelectric sensors (CS616, Campbell Scientific Inc., Logan UT).

As well as measuring soil temperature and moisture at each sample point in Figure 4, measurements were also taken 30 cm in front and behind the sampling point along the axis of the transect. For example, at the 2 m sampling point, soil temperature and moisture was measured at 1.7 m, 2 m, and 2.3 m; this data is referred to as mobile data, since the measurements were taken at many different locations. In addition, soil temperature and moisture were continuously recorded at a single fixed location (stationary data) throughout the sampling time to correct for changes in temperature and moisture throughout the day.

Data collected were used for geospatial analyses of variograms in the R statistical computing language with the geoR package to test for spatial autocorrelation (Trangmar *et al.* 1986; Webster & Oliver 1989; Goovaerts 1997; Riberiro & Diggle 2001) and estimate the distance necessary for independence among soil plots in the soil array. To correct for changes in temperature and moisture over the sampling period, the stationary data was subtracted from the mobile data. In many instances a time of day trend was still apparent in the data even after subtracting the stationary data from the mobile data. This time of day trend was corrected for by fitting a linear regression and using the residuals for the semivariogram analysis. Soil temperature and moisture data, R code, graphs, and R output can be found at: P:\FIU\FIU_Site_Characterization\DXX\YYYYYYY_Characterization\Soil Measurements\Soil Data Analysis (where XX = domain number and YYYYYYY = site name).

3.2.3 Results and interpretation

3.2.3.1 Soil Temperature

Soil temperature data residuals, after accounting for changes in temperature in the stationary data and any remaining time of day trend, were used for the semivariogram analysis (Figure 5). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 6, left graphs) and directional semivariograms do not show any indication of anisotropy (Figure 6, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 6, right graph). The model indicates a distance of effective independence of 89 m for soil temperature.

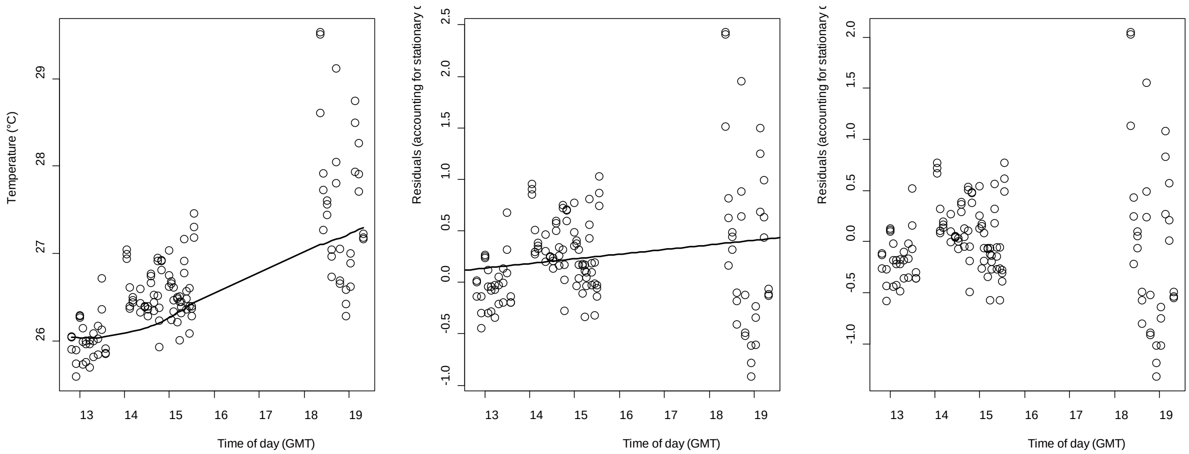


Figure 5. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting for changes temperature in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis

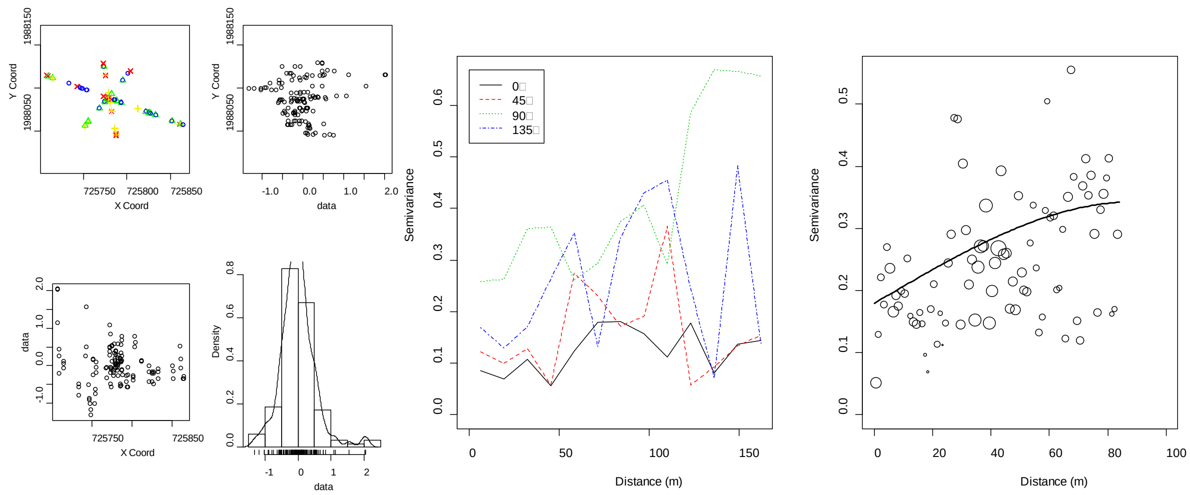


Figure 6. Left graph: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature

3.2.3.2 Soil water content

Soil water content data residuals, after accounting for changes in water content in the stationary data and any remaining time of day trend, were used for the semivariogram analysis (Figure 7). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 8, left graph) and directional semivariograms do not show any indication of anisotropy (Figure 8, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 8, right graph). The model indicates a distance of effective independence of 14 m for soil water content.

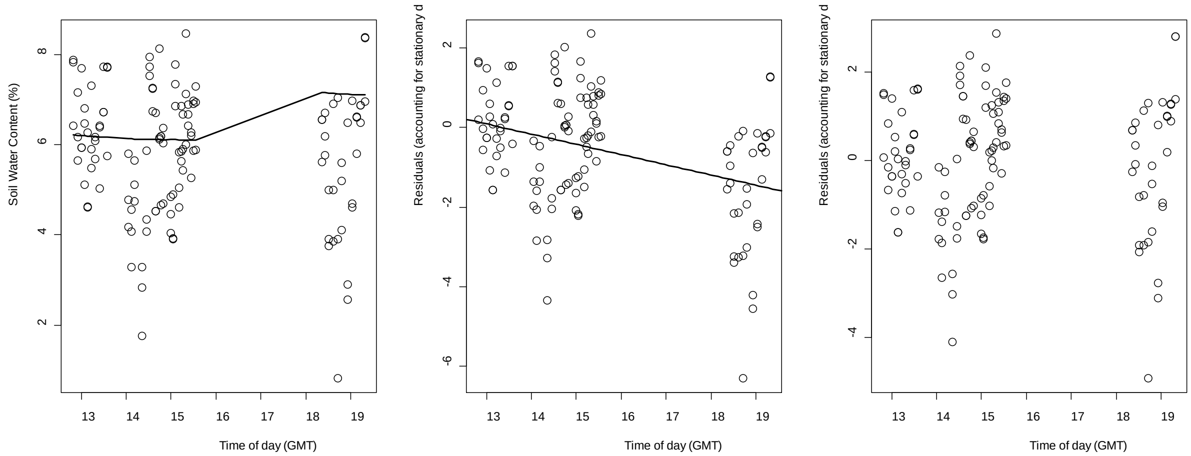


Figure 7. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting for changes water content in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis

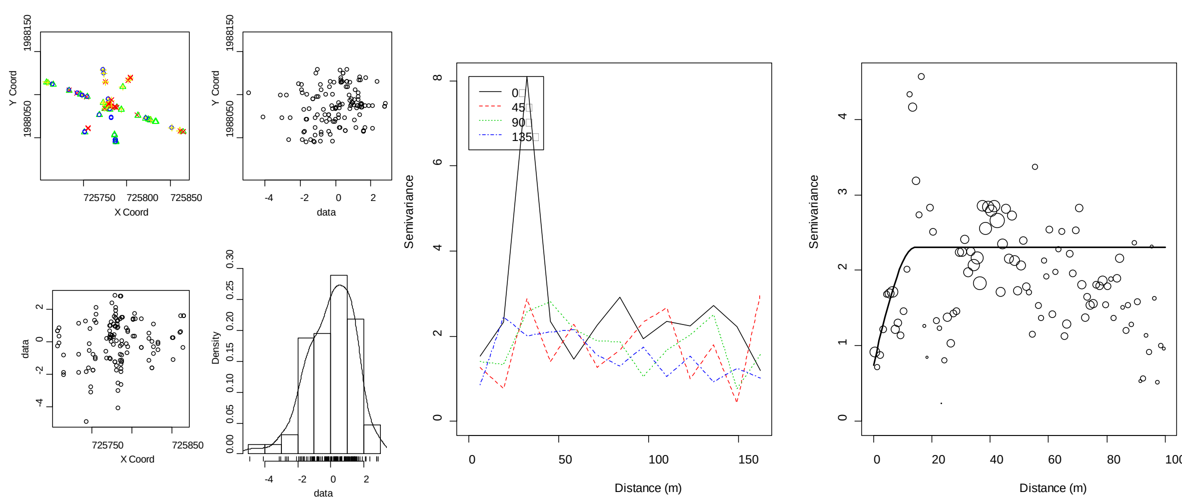


Figure 8. Left graph: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content

3.2.3.3 Soil array layout and soil pit location

The minimum distance allowable between soil plots is 25 m to ensure a degree of spatial independence in non-measured soil parameters (i.e., other than temperature and water content) and the maximum distance allowable between soil plots is 40 m due to cost constraints. The estimated distance of effective independence was 89 m for soil temperature and 14 m for soil moisture. Based on these results and the site design guidelines the soil plots at Guanica shall be placed 40 m apart. The soil array shall follow the linear soil array design (Soil Array Pattern B) with the soil plots being 5 m x 5 m. The direction of the soil array shall be 110° from the soil plot nearest the tower (i.e., first soil plot). The location of the first soil plot will be approximately 17.96957°, -66.86852°. The exact location of each soil plot will be chosen by an FIU team member during site construction to avoid placing a soil plot at an unrepresentative location (e.g., rock outcrop, drainage channel, large tree, etc). The FIU soil pit for characterizing soil horizon depths, collecting soil for site-specific sensor calibration, and collecting soil for the FIU soil archive will be located at 17.96997°, -66.86842°. A summary of the soil information is shown in Table 3 and site layout can be seen in Figure 9.

Dominant soil series at the site: La Covana-Limestone outcrop-Seboruco complex, 12 to 40 percent slopes. The taxonomy of this soil is shown below:

Order: Aridisols

Suborder: Calcids

Great group: Petrocalcids

Subgroup: Calcic Lithic Petrocalcids

Family: Fine-loamy, mixed, superactive, isohyperthermic Typic Calciargids

Series: La Covana-Limestone outcrop-Seboruco complex, 12 to 40 percent slopes

Table 3. Summary of soil array and soil pit information at Guanica. 0° represents true north and accounts for declination

Soil plot dimensions	5 m x 5 m
Soil array pattern	B
Distance between soil plots: x	40 m
Distance from tower to closest soil plot: y	19 m
Latitude and longitude of 1st soil plot OR direction from tower	17.96957°, -66.86852°
Direction of soil array	110°
Latitude and longitude of FIU soil pit	17.968963, -66.868795 (primary)
Latitude and longitude of FIU soil pit	17.970013, -66.866197 (alternate 1)
Latitude and longitude of FIU soil pit	17.968630, -66.865811 (alternate 2)
Dominant soil type	La Covana-Limestone outcrop-Seboruco complex, 12 to 40 percent slopes
Expected soil depth	>2 m
Depth to water table	>2 m
Expected depth of soil horizons	Expected measurement depths
0-0.13 m (gravelly clay)	0.07 m
0.13-0.48 m (extremely gravelly clay)	0.17 m
0.48-0.79 m (cemented)	0.31 m
0.79-2 m (silt loam)	1.40 m

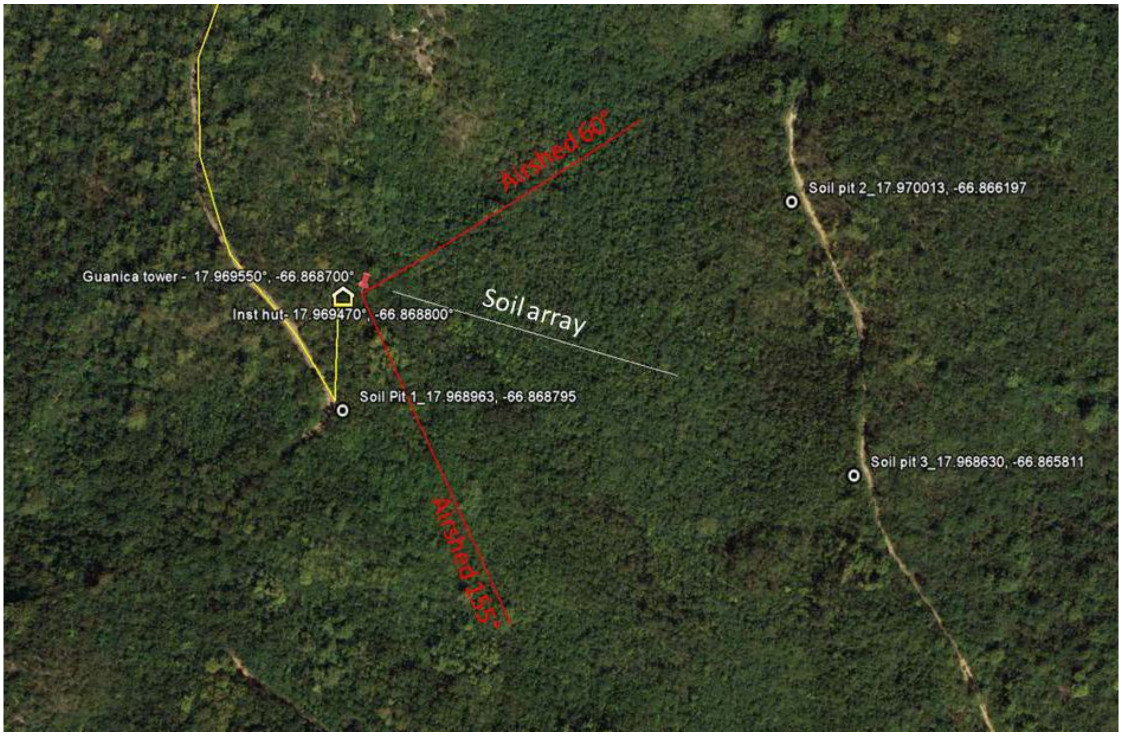


Figure 9. Site layout at Guanica to show soil array

3.3 Airshed

3.3.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries, Figures 10-13. The weather data used to generate the following wind roses are from Isla Maguesyes, Lajas, PR, which is ~11.8 miles southwest of NEON Guanica Forest Advanced site. The orientation of the wind rose follows that of a compass (assume declination applied). When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. Color bands depict the range of wind speeds. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 24 cardinal directions.

3.3.2 Results (graphs for wind roses)

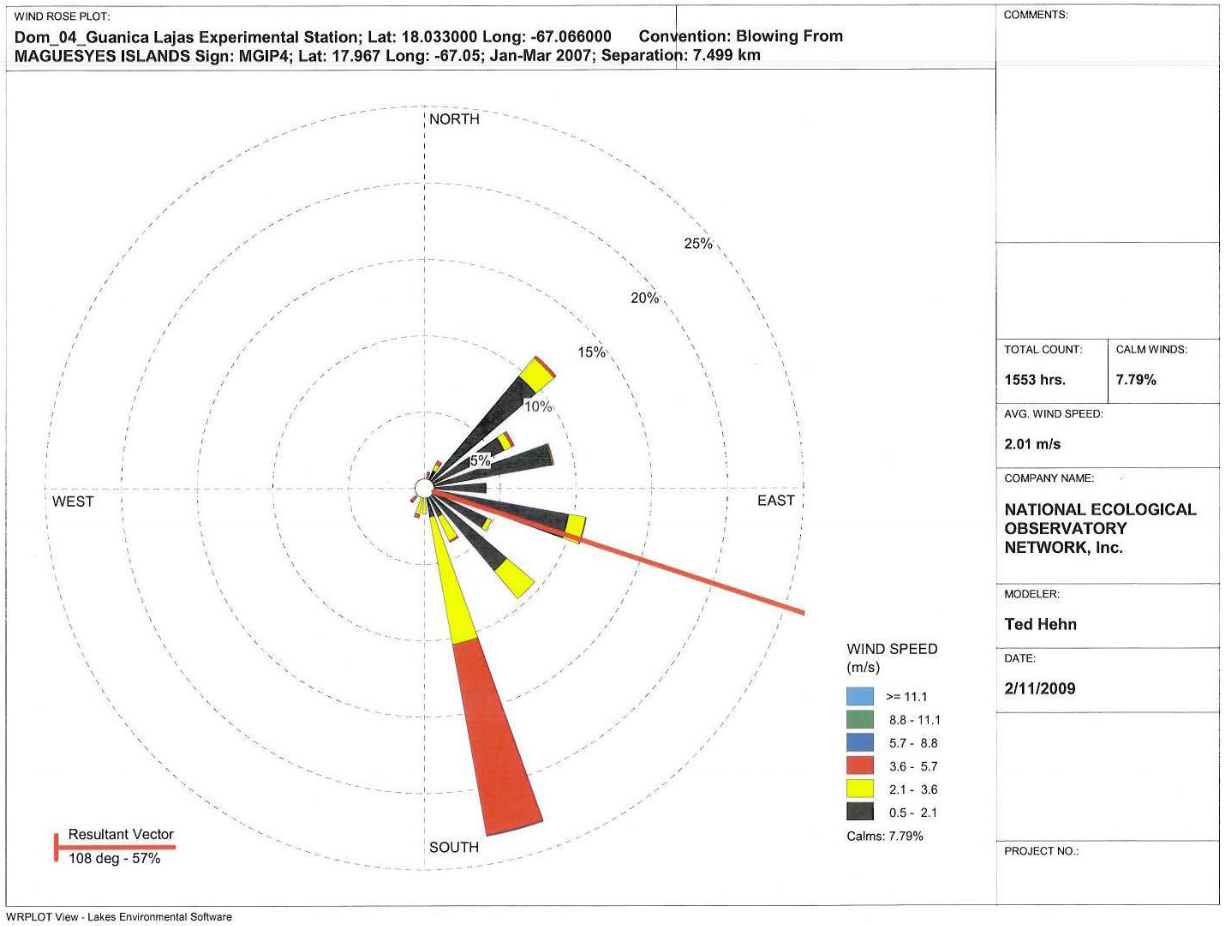


Figure 10. Windroses of January – March for D04 Guanica Forest Advanced site

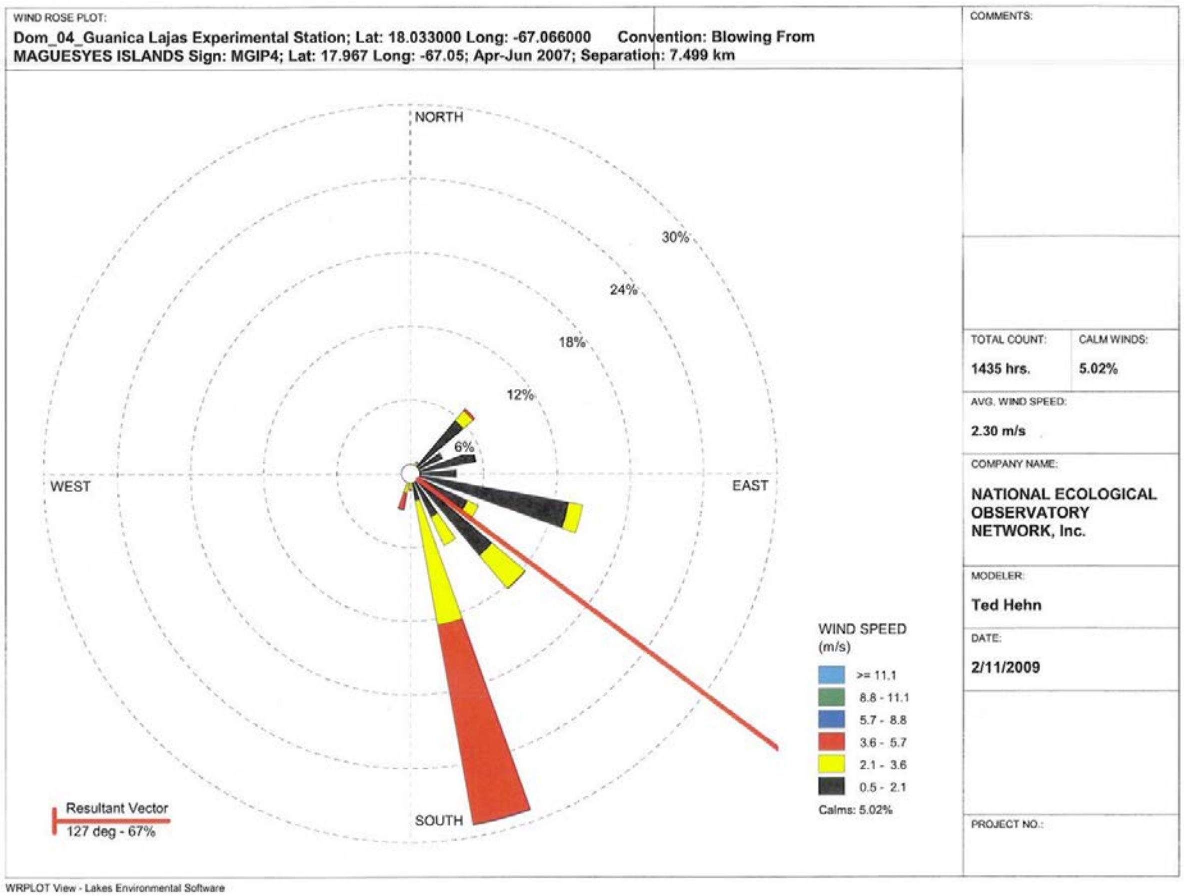


Figure 11. Windroses of April – June for D04 Guanica Forest Advanced site

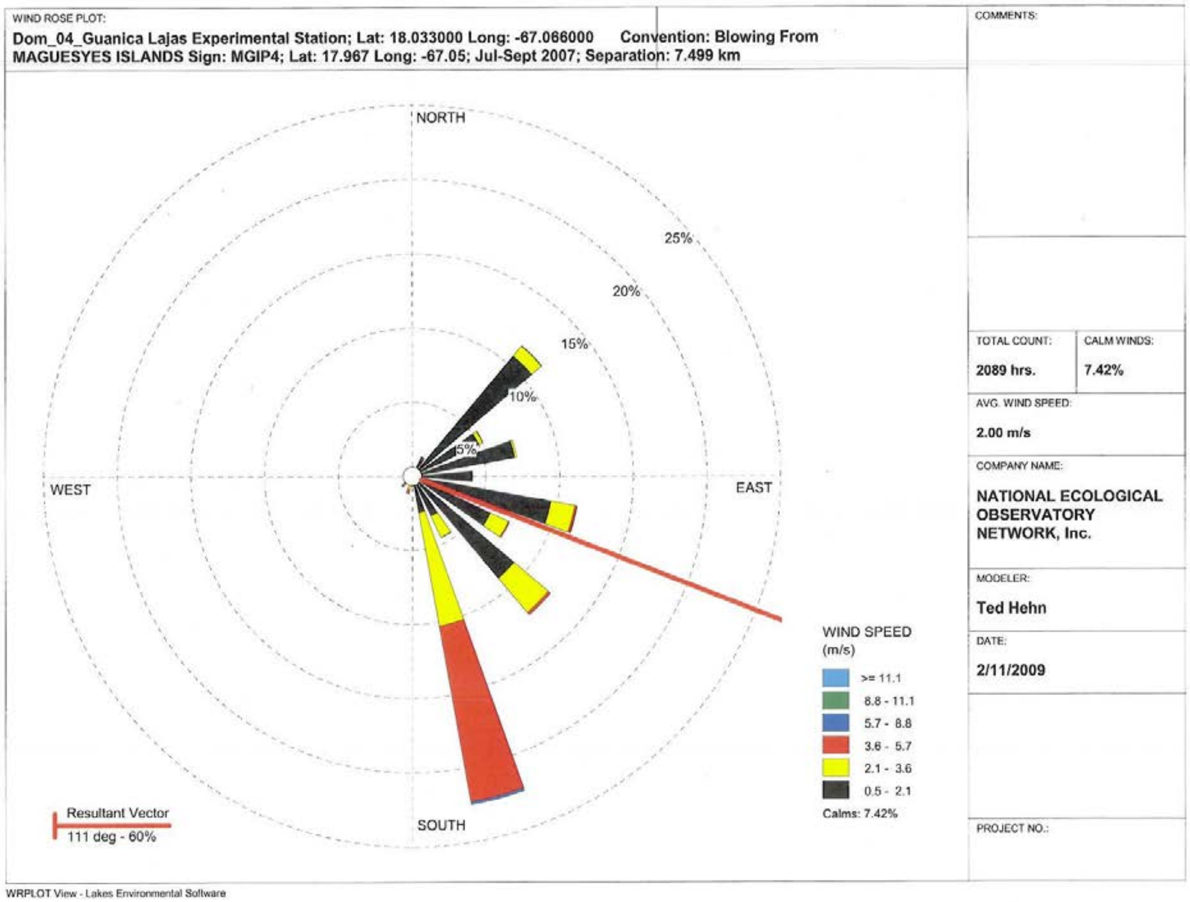


Figure 12. Windroses of July – September for D04 Guanica Forest Advanced site

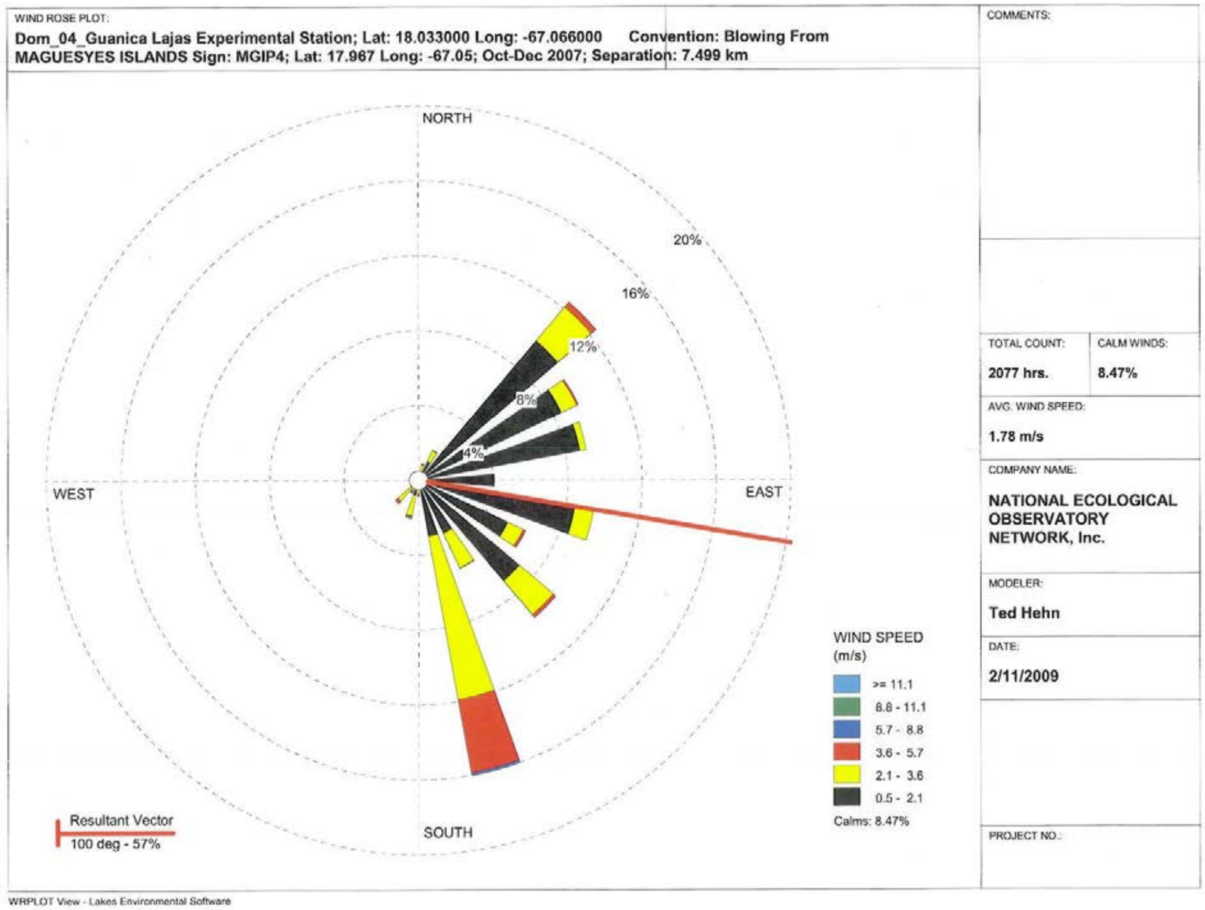


Figure 13. Windroses of October – December for D04 Guanica Forest Advanced site

3.3.3 Resultant vectors

Table 4. Resultant wind vectors for Guanica Forest Advanced site

Quarterly (seasonal) time period	Resultant vector	% duration
January to March	108°	57
April to June	127°	67
July to September	111°	60
October to December	100°	57
Annual mean	111.5°	na.

3.3.4 Expected environmental controls on source area

Two types of models were commonly used to determine the shape and extent of the source area under different and contrasting atmospheric stability classes. An inverted plume dispersion model with modeled cross wind solutions were used for convective conditions (Horst and Weil 1994). For strongly stable conditions, and Lagrangian solution was used (Kormann and Meixner 2001). The source area models where bounded by the expected conditions depict the extreme conditions. Convective conditions typically have strong vertical mixing between the ecosystem and atmosphere (surface layer). Stable conditions typically have long source area and associated waveforms. Convective turbulence is often characterized by short mixing scales (scalar) and moderate daytime wind speeds, *e.g.,* 1-4 m s^{-2}. Higher wind speeds, like those experienced over the Rockies, are often the product of mechanical turbulence with long waveforms. Because thermal stratification is very efficient in suppressing vertical mixing, stable conditions also have typically very long waveforms.

As a general rule, shorter and less structurally complex ecosystems have good vertical mixing during all atmospheric stabilities. Taller and more structurally complex ecosystems have well mixed upper canopies during the daytime, and can be decoupled below the canopy under neutral and stable conditions (e.g., Harvard Forest, Bartlett Experimental Forest, and Burlington Conservation Area). The type of turbulence (mechanical verse convective) and the physical attributes of the ecosystem control the degree of mixing, and the length and size of the source area.

Here, with support from Dr. R. Clement, we use a web-based footprint model that made by Micrometeorology Group at University of Edinburgh, UK to determine the footprint area under various conditions (model info: http://www.geos.ed.ac.uk/abs/research/micromet/EdiTools/). Winds used to run the model and generate following model results are extracted from the wind roses. Vegetation information, temperature and energy information were either from the RFI document, previous site visit report, available data files or best estimates from experienced expert. Measurement height was obtained from the Tower Height Info document provided by ENG group, then verify according to the real ecosystem structure after FIU site characterization at site. Runs 1-3 and 4-6 represents the expected conditions for summer and winter conditions, respectively, with maximum and mean wind speeds (daytime convective) and nighttime (stable atmospheres) conditions. The wind vector for each run was extracted from wind roses and is placed as a centerline in the site map included in the graphics. The width of the footprint was also estimated using the length between the isopleth of 80% cumulative flux and center line to calculate the angle from centerline. This information, along with distance of the cumulative flux isopleths and wind direction, will define the source area for the flux measurements on the top of the tower.

Table 5. Expected environmental controls to parameterize the source area model, and associated results from Guanica Forest Advanced tower site

Parameters	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	**Units**
Approximate season	summer			winter			
	Day (max WS)	Day (mean WS)	Night	Day (max WS)	Day (mean WS)	night	qualitative
Atmospheric stability	Convective	convective	Stable	Convective	convective	Stable	qualitative
Measurement height	22	22	22	22	22	22	m
Canopy Height	10	10	10	10	10	10	m
Canopy area density	4	4	4	3	3	3	m
Boundary layer depth	3000	3000	1500	1000	1000	700	m
Expected sensible heat flux	600	600	75	250	250	25	W m^{-2}
Air Temperature	33	33	24	24	24	20	°C
Max. windspeed	8.8	3.9	0.9	5.7	3.8	1.1	m s^{-1}
Resultant wind vector	155	155	60	155	155	60	degrees
Results							
(z-d)/L	-0.07	-0.44	-1.30	-0.10	-0.26	-0.65	m
d	8.2	8.20	8.20	8.00	8.00	8.00	m
Sigma v	3.00	2.50	0.96	1.80	1.50	0.59	m^2 s^{-2}
Z0	0.40	0.40	0.40	0.44	0.44	0.44	m
u*	1.10	0.59	0.21	0.73	0.53	0.18	m s^{-1}
Distance source area begins	20	0	0	40	30	0	m
Distance of 90% cumulative flux	800	400	200	800	550	390	m
Distance of 80% cumulative flux	500	250	150	480	380	230	m
Distance of 70% cumulative flux	390	200	125	380	280	180	m
Distance of 60% cumulative flux	320	160	100	300	230	150	m
Distance of 50% cumulative flux	260	130	75	220	190	120	m
Distance of 40% cumulative flux	200	125	55	180	150	90	m
Distance of 30% cumulative flux	150	100	40	150	110	60	m
Distance of 20% cumulative flux	100	65	25	100	80	30	m
Distance of 10% cumulative flux	60	30	10	60	50	10	m
Peak contribution	85	55	25	85	65	35	m
angle from centerline	36	49	62	30	33	28	degrees

3.3.5 Footprint model results (source area graphs)

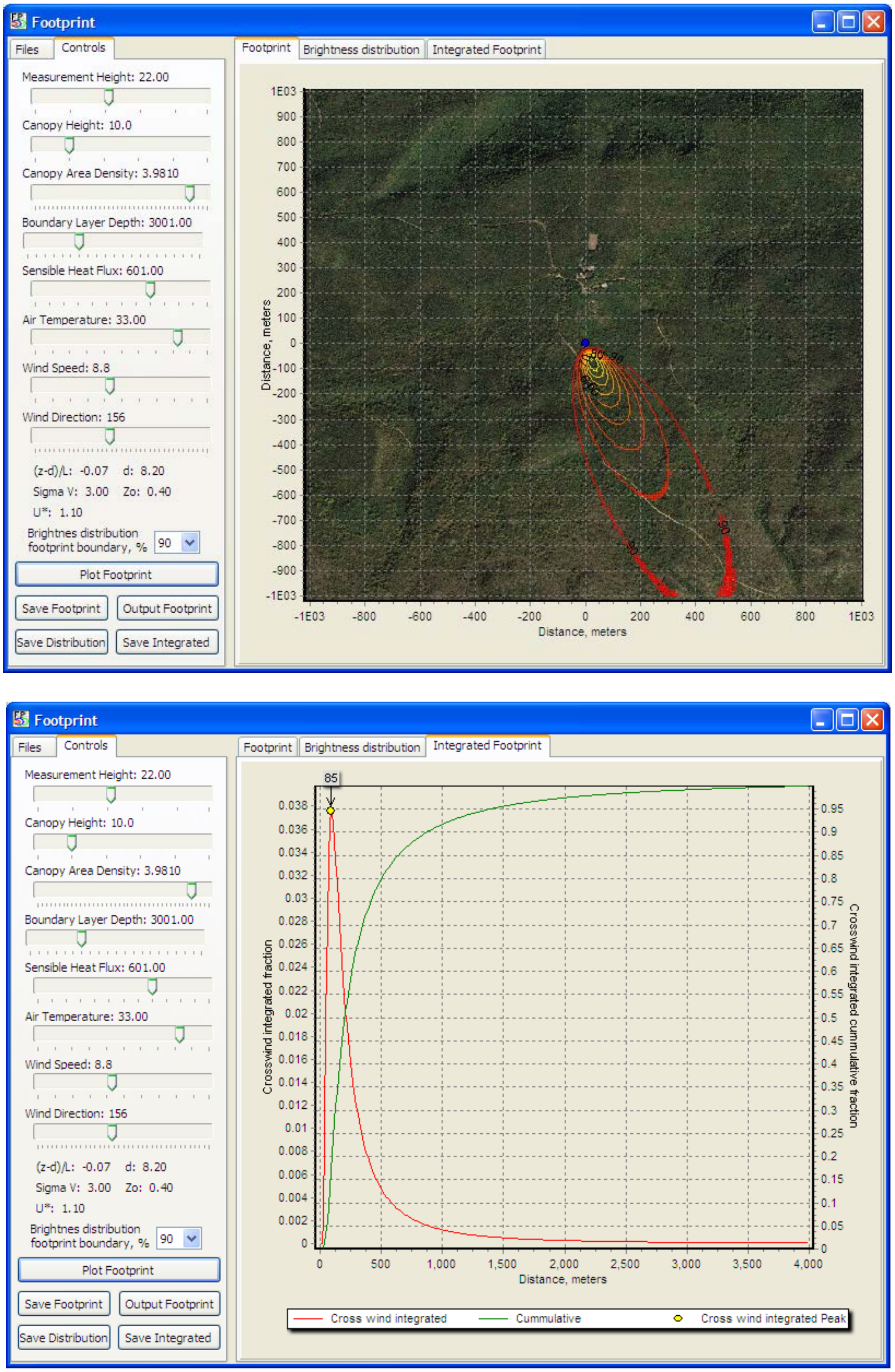
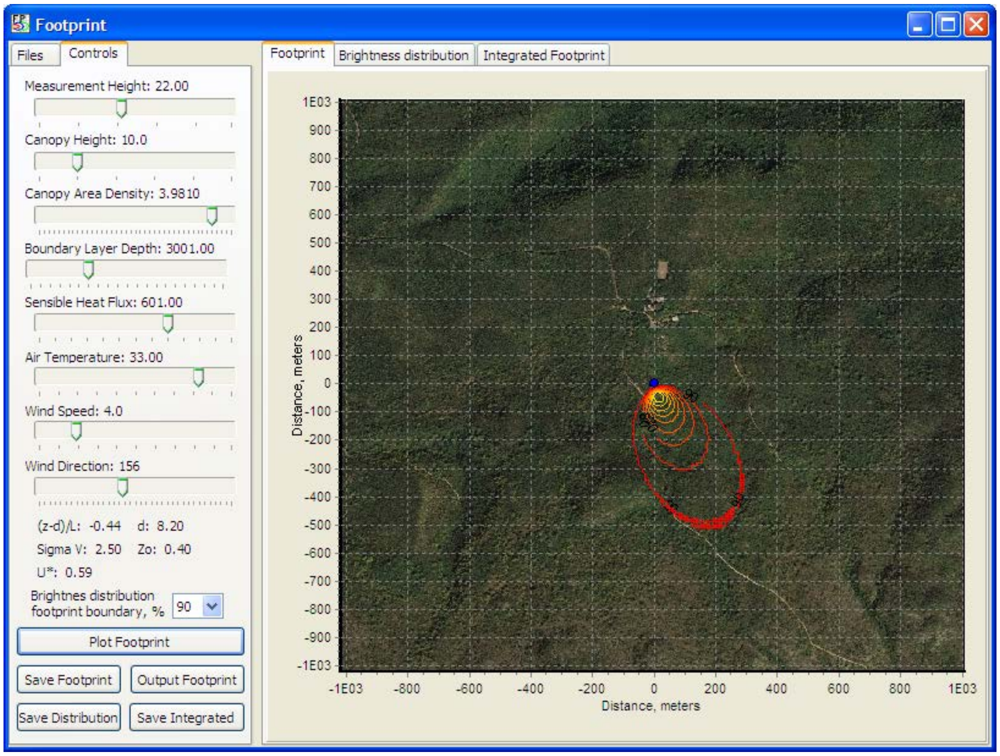


Figure 14. Run 1, summer, daytime, max WS



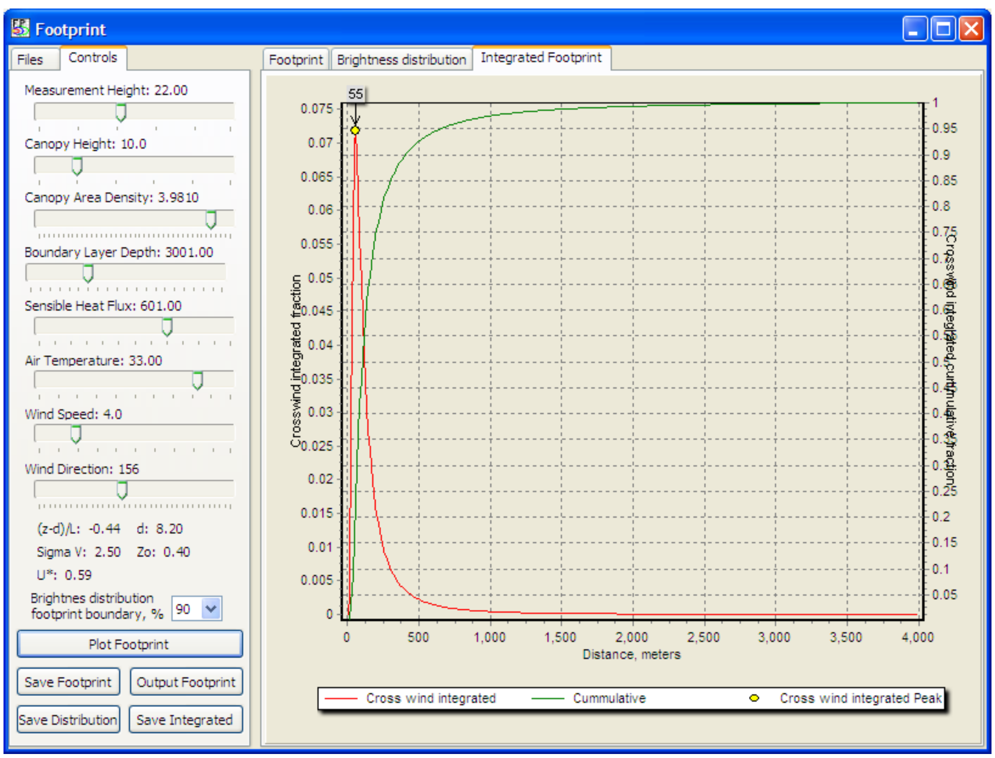
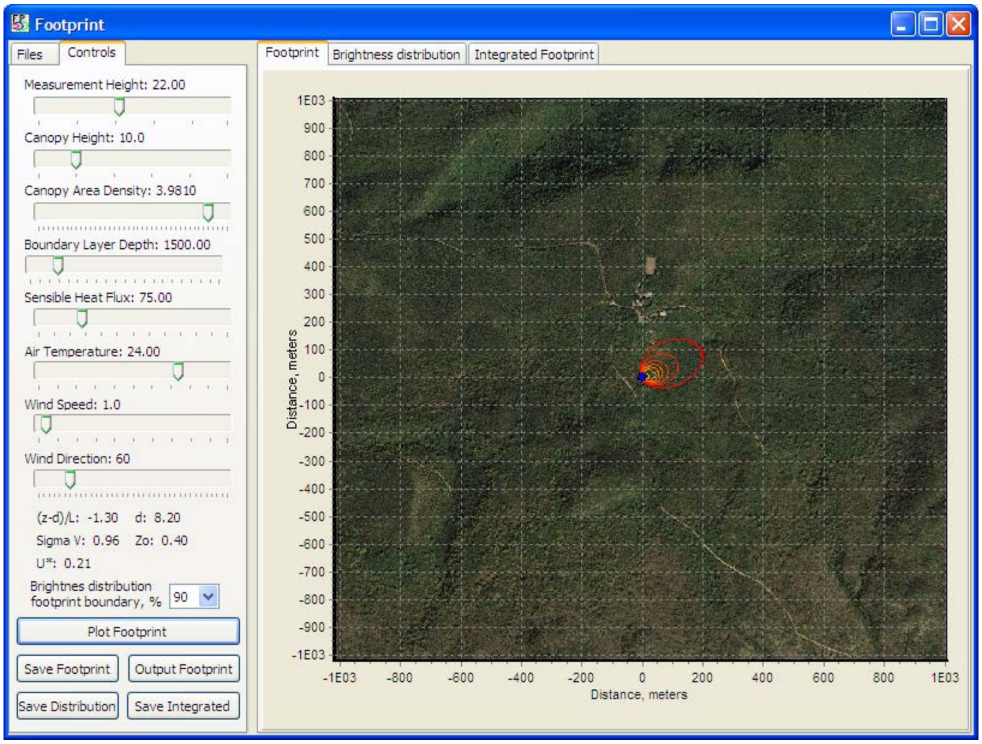


Figure 15. Run 3: summer, nighttime, mean WS



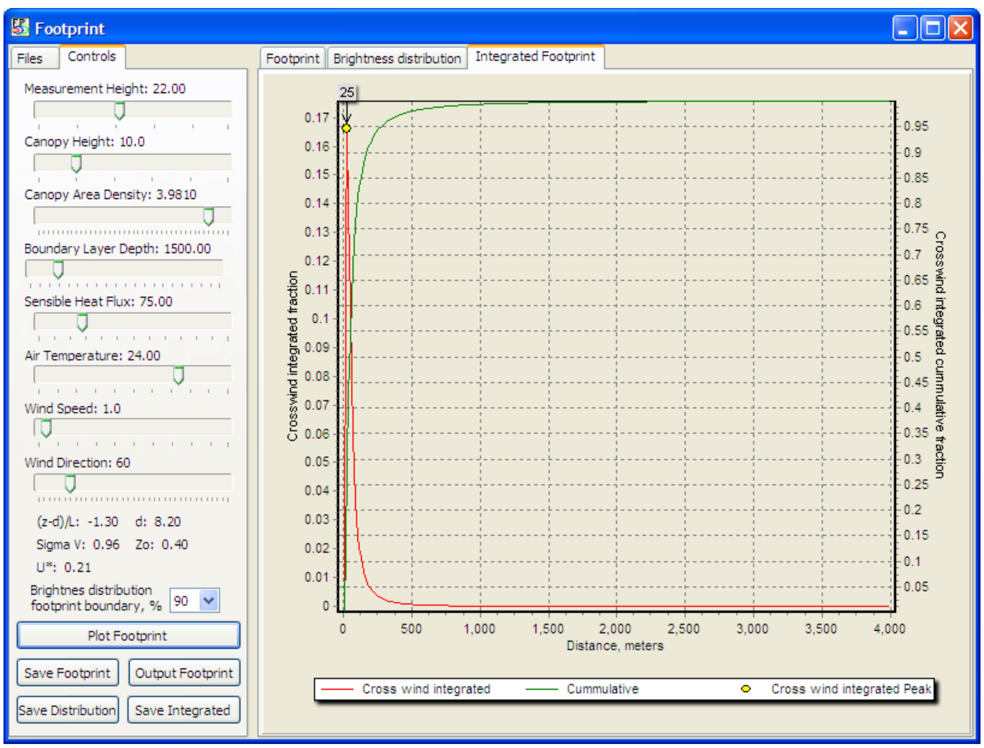
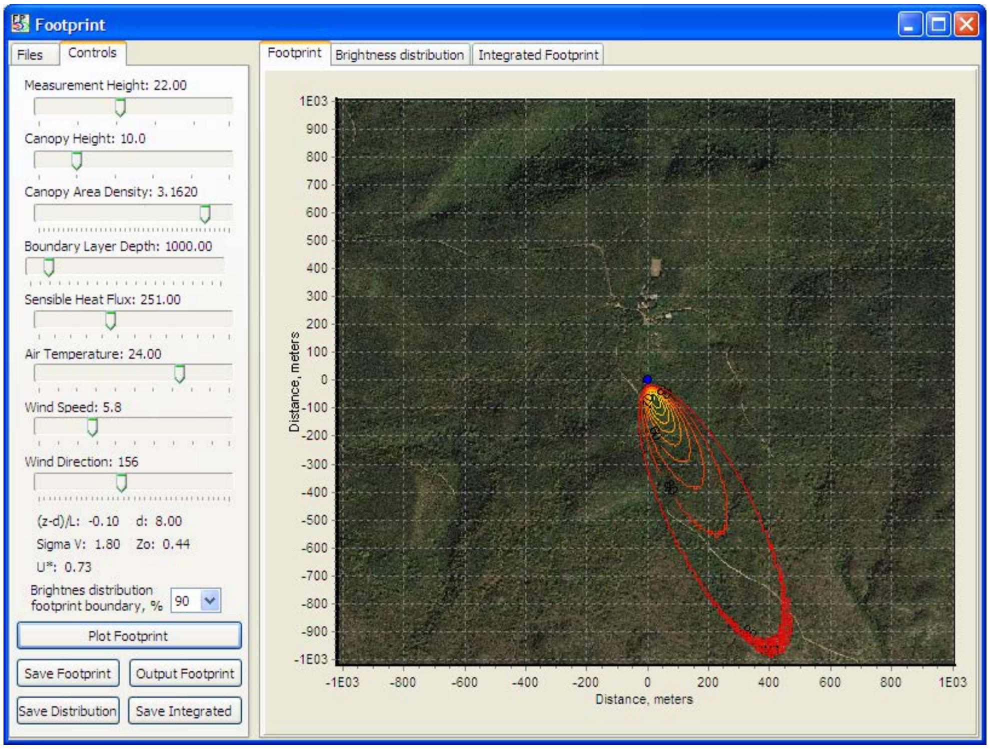


Figure 16. Run 3: summer, nighttime, mean WS



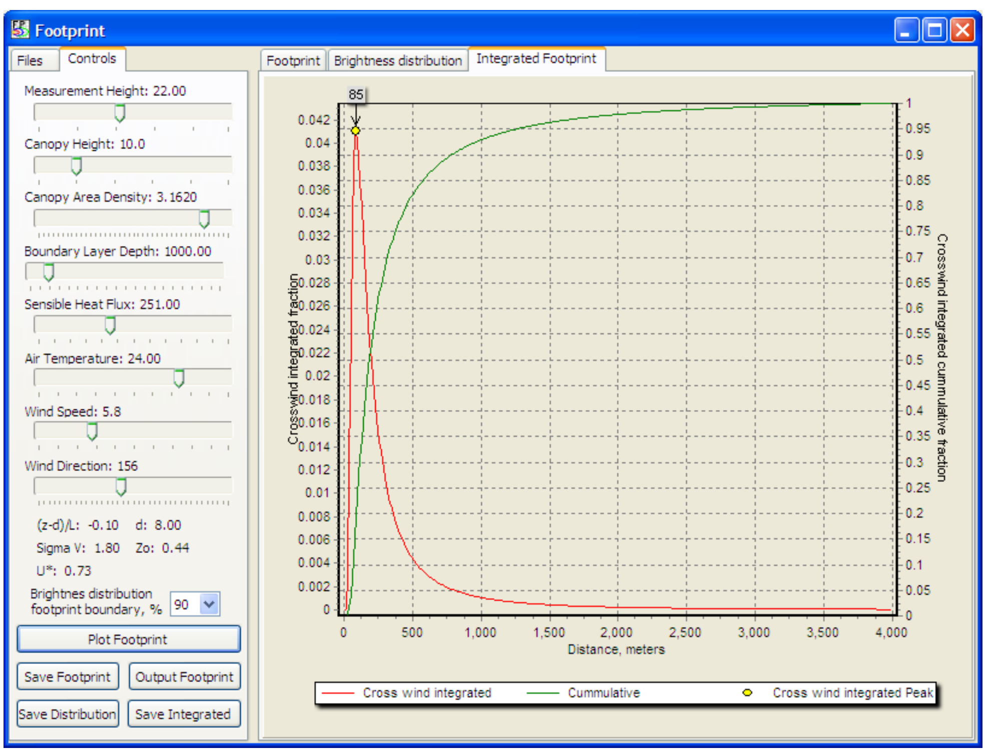


Figure 17. Run 4: winter, daytime, max WS

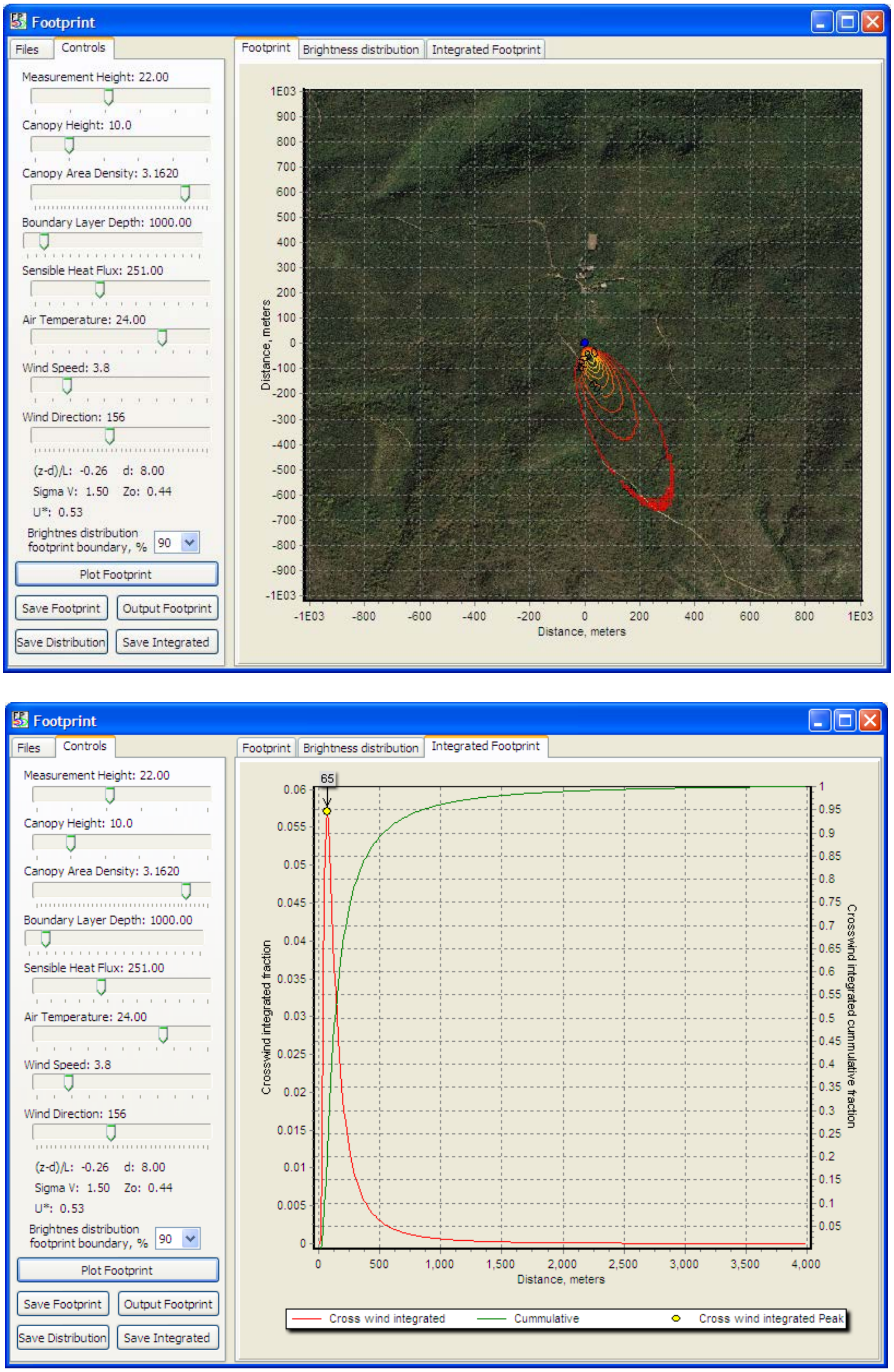
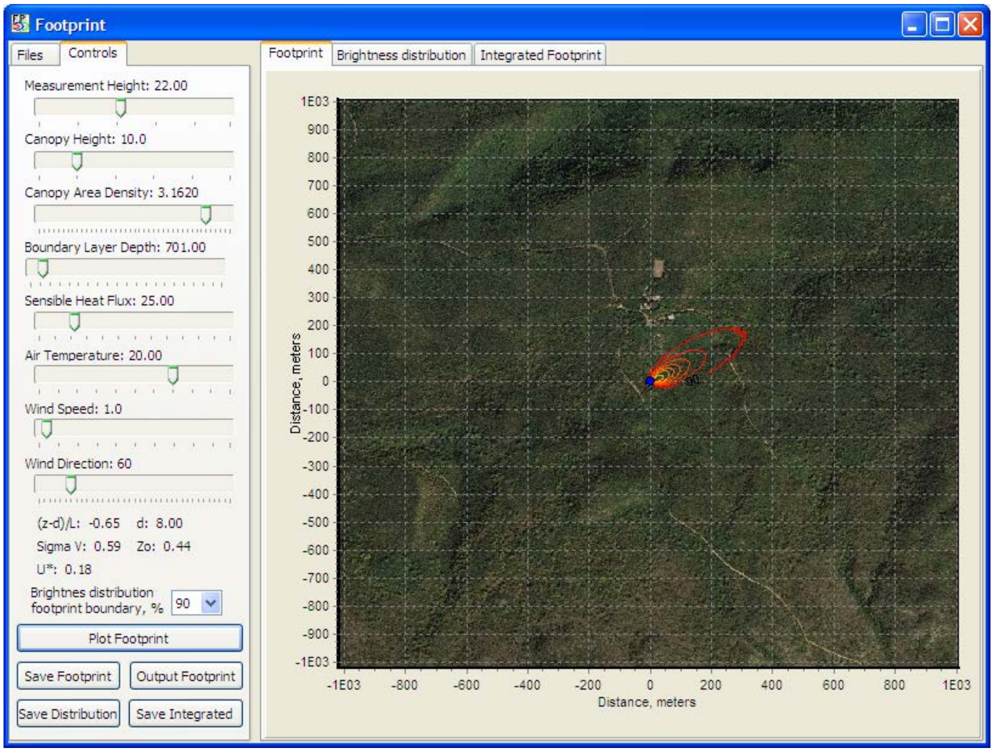


Figure 18. Run 5: winter, daytime, mean WS



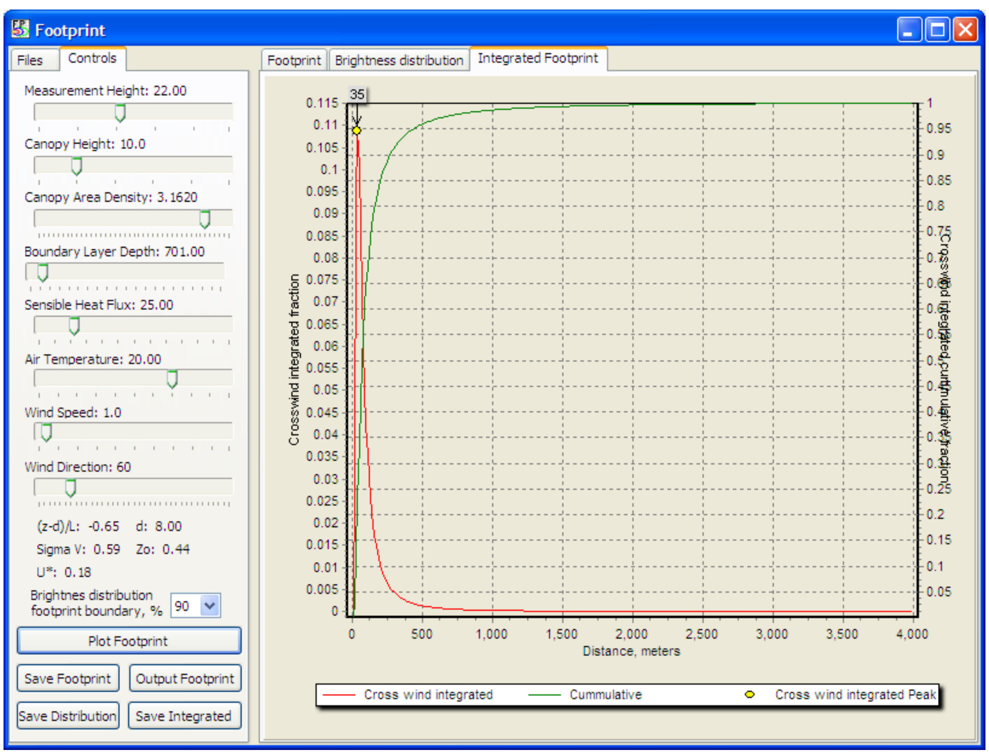


Figure 19. Run 6: winter, nighttime, mean WS

3.3.6 Tower location, instrument hut location, boardwalks, measurement layers on the tower and other sensor locations

Because the prevailing wind direction blows from east, north east and south east (60 degrees to 155 degrees), tower should be placed to a location to best catch the signals from the ecosystem in interest, which is subtropical dry forest at this site. An instrument hut should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind. Therefore, we require the placement of the tower at 17.96955, -66.86870, and instrument hut at 17.96947, -66.86880.

The site is dry tropical forest. Canopy height is ~ 10 m around tower site and in the airshed area. Mean height for the bottom branch is ~1 m. We suggest 5 measurement layers on the tower with top measurement height at 20 m, and rest layers are 12 m, 8 m, 4 m and 0.3 m, respectively.

Boardwalks. Ultimately, the decision to use a boardwalk will be, in part, based on owner's preferences. There are strong science requirements that minimize site disturbance to the surrounding area, which will be difficult to manage over a 30-y period. Traffic control is key to minimizing the site disturbance. Confining foot traffic to boardwalks minimizes site impact; this is particularly true in places where wear caused by foot traffic becomes noticeable and grows. For example, in places with snow part of the year, worn footpaths tend to have low places that collect water, or places where the snow pack becomes uneven causing personnel to walk farther and farther around the sides of the original path, causing the path to grow in width. This is a very common phenomenon. Here, FIU assumes that all conduits will be either buried, or placed inside the boardwalk such that it does not extend beyond the 36" (0.914 m). wide footprint. The boardwalk to access the tower is not on any side that has a boom.

Specific Boardwalks at this site:

- Boardwalk is from the access dirt road to instrument hut, pending landowner decision
- Boardwalk from the instrument hut to the tower to intersect on north face of the tower
- Boardwalk to soil array.
- No boardwalk from the soil array to the individual soil plots
- No boardwalk needed at DFIR site

The relative locations between tower, instrument hut and boardwalk can be found in the Figure below:

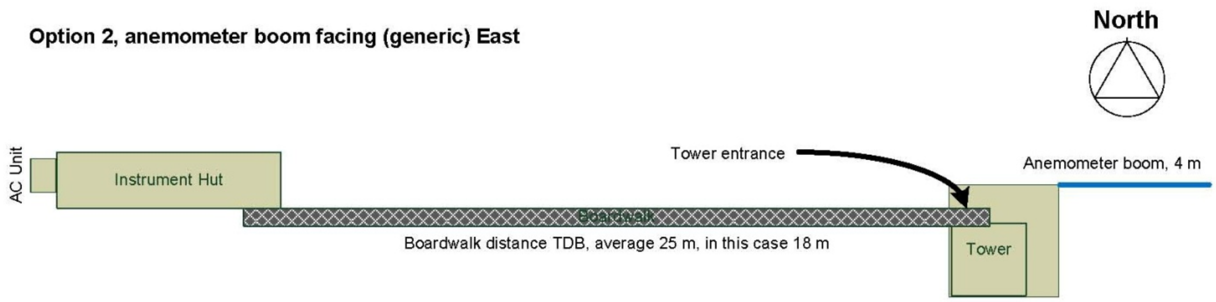


Figure 20. Orientation of tower, boardwalk and instrument hut for Guanica, Option 2 is required

The site layout is summarized in the table below. Assume the projected area of the tower is square. **Anemometer/temperature boom arm direction** is ***from*** the tower ***toward*** the prevailing wind direction or designated orientation. **Instrument hut orientation vector** is parallel to the long side of the instrument hut (short-side of instrument hut is perpendicular to the **Instrument hut orientation vector)**. **Instrument hut distance z** is the distance from the center of tower projection to the center of the instrument hut projection on the ground. The numbering of the **measurement levels** is that the lowest is level one, and each subsequent increase in height is numbered sequentially, in this case, level 5 being the upper most level at this tower site.

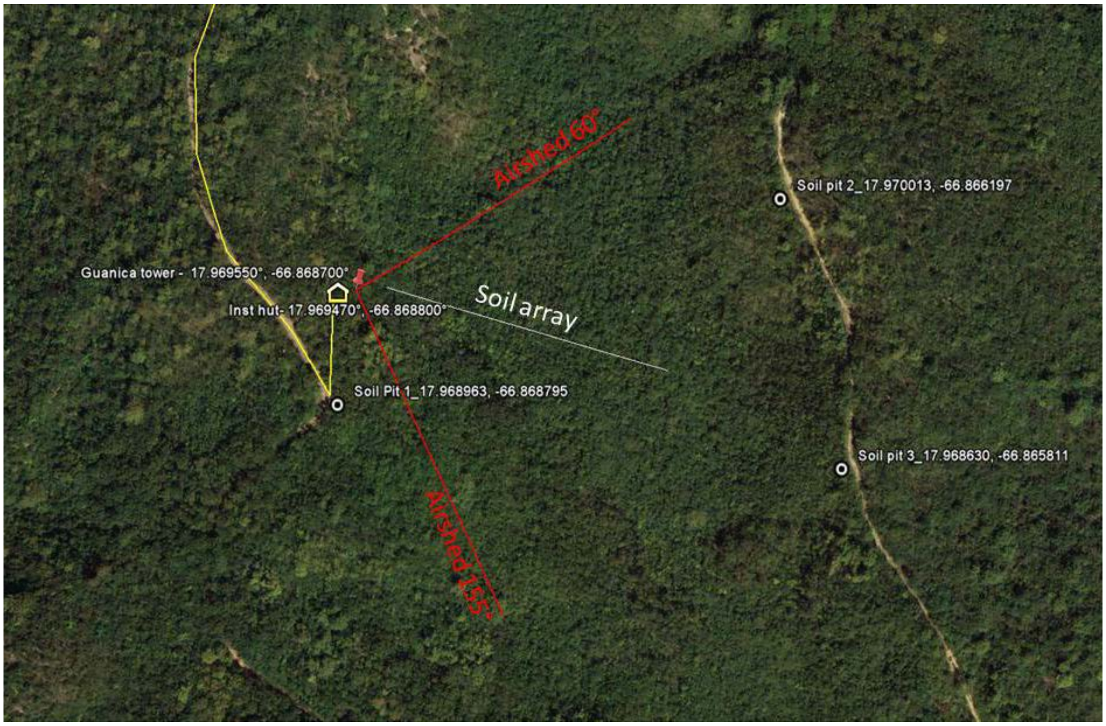
In the following table, 0° is true north with declination accounted for. Color of Instrument hut exterior shall be tan to best match the surrounding environment.

Table 6. Tower oriented design attributes for the Guanica Forest Advanced site

Attribute	Lat	Long	Degree	Meters	Notes
Airshed			60° to 155°		Clockwise from 60°
Tower location	17.96955	-66.86870	--	--	new site
Instrument hut	17.96947	-66.86880			
Instrument hut orientation vector	--	--	270° to 90°		
Instrument hut distance z	--	--	--	13	
Anemometer/Temperature boom orientation	--	--	90°	--	From tower point to this direction
DFIR	17.97515	-66.87946	--	--	
Height of the measurement levels					
Level 1				0.3	m.a.g.l.
Level 2				4.0	m.a.g.l.
Level 3				8.0	m.a.g.l.
Level 4				12.0	m.a.g.l.
Level 5				20.0	m.a.g.l.
Tower Height				20.0	m.a.g.l.

See AD[01] for technical requirement to determine the boom height for the bottom most measurement level.

Figure 15 below shows the proposed tower location, instrument hut location, airshed area and access road.



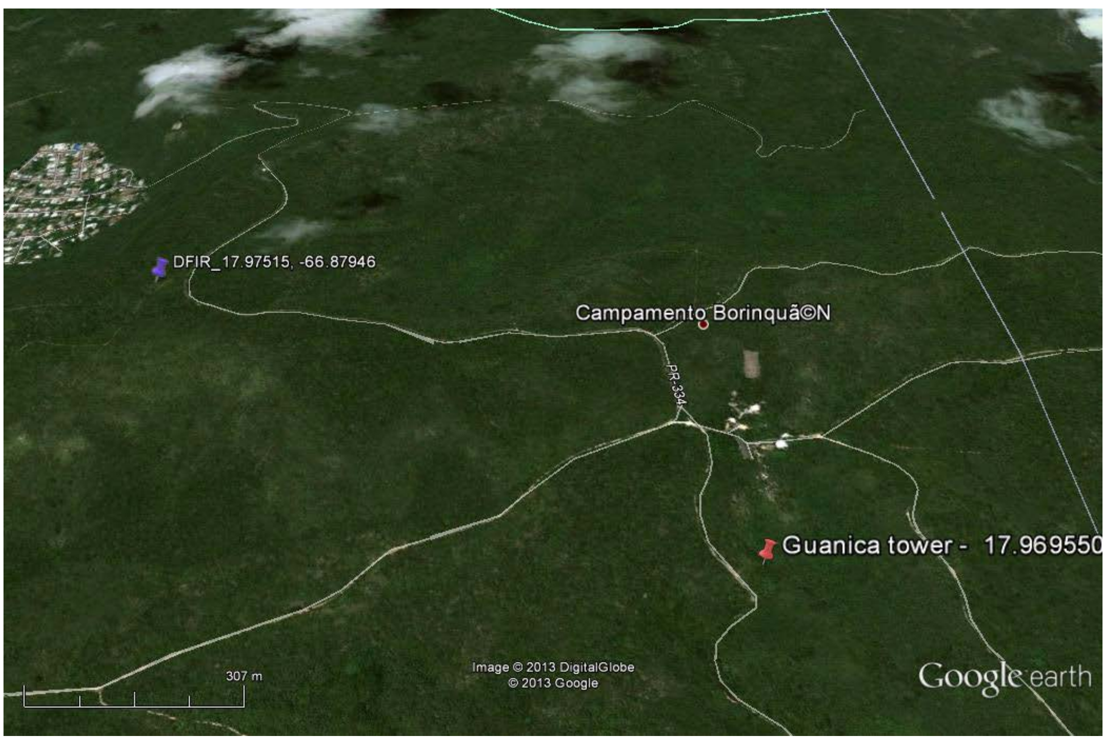


Figure 21. Two plan views of site layout at Guanica Advanced tower site

i) new tower location is presented, ii) red lines indicate the airshed boundaries. Vectors 60° and 155° are the North-eastern most and South-eastern most vectors (starting clockwise from 60°) that would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access road to instrument hut. iv) Blue pin indicates DFIR location for bulk precipitation collection.

Keep in mind that all **radiation sensors** above canopy need to be mounted on the south side of the tower to avoid shadow from tower structure and mounting parts.

DFIR (Double Fenced International Reference) for bulk precipitation collection was originally located at a water catchment on the north direction of tower about 400 meters away at Lat. 17.97314, Lon. -66.86831, and changed to 17.97515, -66.87946 in November 2011 per host request. This new location is about 1.3 km from tower location. **Wet deposition collector** will collocate at the top of the tower. See AD[02] for further information and requirements for bulk precipitation collection and wet deposition collection.

3.3.7 Information for ecosystem productivity plots

The tower at Guanica Advanced site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (subtropical dry forest). Wind vectors from the tower dictate the airshed is from 60 degrees to 155 degrees (clockwise from 60 degrees) in Figure14, and 90% signals for flux measurements are within a distance of 800 m from tower. The FSU Ecosystem Productivity plots are recommended within the airshed boundaries of the 60 degrees line, and the 155 degree line.

4 LAJAS (RELOCATABLE TOWER SITE 1)

4.1 Site Description

The Lajas Agricultural Experiment Station was created in 1946, comprises 232 ha and is about 30 m above sea level. Since 1999, the Lajas Valley has been declared an Agricultural Reserve in perpetuity. The site represents a tropical dry landscape totally dominated by agricultural activity. Rainfall averages 830 mm yr^{-1} and temperature about 25°C. Soils at the station are comprised of Vertisols.

A permanent first order stream runs through the station to the US Fish and Wildlife Refuge at Cartagena Lake (a GLEON site). The station comprises most of the stream's watershed area. Agricultural production at the station includes dairy, chickens, hogs, rice, annual vegetable crops, orchards of mangoes and citrus, and plantations of mahogany and leguminous forestry species.

The original tower location was placed at 18.03300000, -67.06600000. The airshed will mainly fall in the paddy rice field, which is small, patchy and not representative for this region. A new tower location we proposed is at 18.02125°,-67.07690°, which is controlled grazing land. It is still under the same land owner. The land use type is a typical type in this region, and fetch area is large and adequate for flux measurements. Power is very close to the proposed site (<300 m). Landowner is on lockstep with this change.

4.1.1 Ecosystem

The site is a controlled grazing grass field that is divided into grids by wire fences for experiments of different grazing frequency. Shrubs scatter in the field and were controlled under 4 m. Wind break trees (~10 -15 m in height) were planted along the field edge. But they are either on the leeside of proposed tower or are far away enough from tower, thus are not a concern for FIU measurements.

The species of the grasses are unclear. The height of the grassland is ~ 25 cm at the measuring period in March 2010, and expected to be taller during peak growing season (~0.4 m).

The ecosystem attributes to this site are summarized as following:

Table 7. Ecosystem and site attributes for the Lajas Relocatable site. The site is a confined grazed field

Ecosystem attributes	Measure and units
Mean canopy height	0.4 m
Surface roughness[a]	0.02 m
Zero place displacement height[a]	0.29 m
Structural elements	Short, uniform, homogeneous
Altitude[b]	15 [m] a.s.l.
Slope	0%
Aspect	±0
Time zone	Atlantic
Magnetic declination	12° 16' W changing by 0° 2' W/year
Frost-free period	365 days

[a] From footprint analysis below.

[b] http://www.lajaspr.com/engDescripcionGeographica.htm

4.2 Soils

4.2.1 Soil Description

Soil data and soil maps (Figure 15) below for Lajas relocatable tower site 1 were collected from 2.4 km^2 NRCS soil maps(http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm), which centered at the tower location, to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

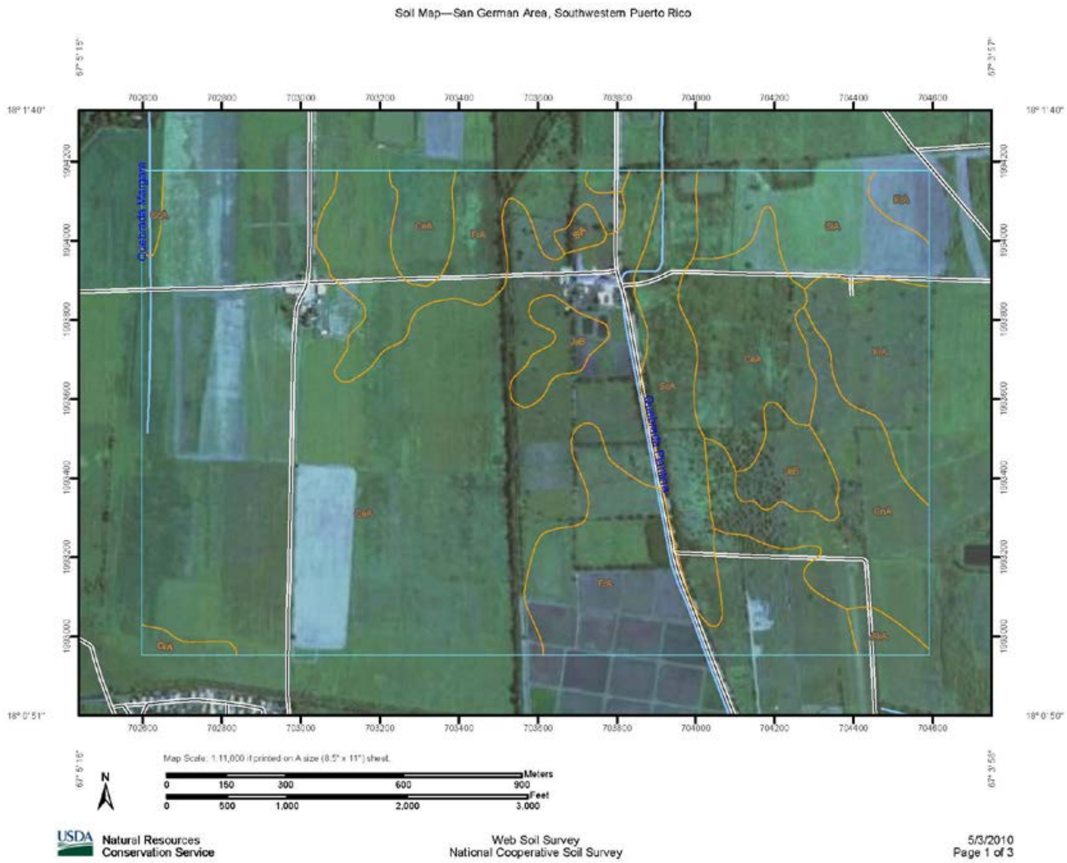


Figure 22. 2.4 km^2 soil map for Lajas relocatable site 1, center at tower location

Map Unit Description: The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit. A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils. Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called non-contrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soil types or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas. An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a soil series. All the soils of a series have major horizons that are similar in composition, thickness, and arrangement. Soils of a given series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into soil phases. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series. Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups. A complex consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example. An association is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example. An undifferentiated group is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example. Some surveys include miscellaneous areas. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example. Additional information about the map units described in this report is available in other soil reports, which give properties of the soils and the limitations, capabilities, and potentials for many uses. Also, the narratives that accompany the soil reports define some of the properties included in the map unit descriptions.

Table 8. Soil Series and percentage of soil series within 2.4 km^2 centered on the tower

San German Area, Southwestern Puerto Rico (PR787)			
Map Unit Symbol	**Soil types**	**Acres in AOI**	**% AOI**
AkA	Aguirre clay, occasionally ponded	4.1	0.70%
CeA	Cartagena clay, 0 to 2 percent slopes	333.7	*55.40%
FrA	Fraternidad clay, 0 to 2 percent slopes	132.6	*22.00%
GnA	Guanica clay, 0 to 1 percent slopes	41.8	6.90%
JaB	Jacana clay, 0 to 5 percent slopes	19.5	3.20%
OrA	Olivares muck, ponded	2.6	0.40%
ScA	San Anton clay loam, 0 to 2 percent slopes, occasionally flooded	35.2	5.90%
SiA	Santa Isabel clay, 0 to 2 percent slopes	32.9	5.50%
Totals for Area of Interest		602.4	100.00%

Note, asterisk indicates dominant soil type(s) in airshed

San German Area, Southwestern Puerto Rico: AkA—Aguirre clay, occasionally ponded. Map Unit Setting *Elevation:* 10 to 160 feet *Mean annual precipitation:* 25 to 66 inches *Mean annual air temperature:* 66 to 89 degrees F *Frost-free period:* 365 days **Map Unit Composition** *Aguirre and similar soils:* 95 percent *Minor components:* 5 percent **Description of Aguirre Setting** *Landform:* Basin floors, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Talf *Down-slope shape:* Linear *Across-slope shape:* Linear *Parent material:* Marine deposits derived from igneous and sedimentary rock **Properties and qualities** *Slope:* 0 to 1 percent *Depth to restrictive feature:* More than 80 inches *Drainage class:* Poorly drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.01 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* Occasional *Calcium carbonate, maximum content:* 15 percent *Available water capacity:* Very high (about 26.9 inches) **Interpretive groups** *Land capability classification (irrigated):* 4w *Land capability (nonirrigated):* 4w **Typical profile** *0 to 18 inches:* Clay *18 to 80 inches:* Clay **Minor Components Cartagena** *Percent of map unit:* 5 percent *Landform:* Fan skirts *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip, talf *Down-slope shape:* Linear, concave *Across-slope shape:* Linear

San German Area, Southwestern Puerto Rico: CeA—Cartagena clay, 0 to 2 percent slopes. Map Unit Setting *Elevation:* 10 to 160 feet *Mean annual precipitation:* 25 to 66 inches *Mean annual air* *temperature:* 66 to 89 degrees F *Frost-free period:* 365 days **Map Unit Composition** *Cartagena and similar soils:* 85 percent *Minor components:* 15 percent **Description of Cartagena Setting** *Landform:* Fan skirts *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip, talf *Down-slope shape:* Linear, concave *Across-slope shape:* Linear *Parent material:* Alluvium derived from igneous and sedimentary rock and/or marine deposits derived from igneous and sedimentary rock **Properties and qualities** *Slope:* 0 to 2 percent *Depth to restrictive feature:* More than 80 inches *Drainage class:* Somewhat poorly drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low (0.01 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Calcium carbonate, maximum content:* 25 percent *Maximum salinity:* Slightly saline to moderately saline (8.0 to 16.0 mmhos/cm) *Sodium adsorption ratio, maximum:* 20.0 *Available water capacity:* Moderate (about 7.6 inches) **Interpretive groups** *Land capability classification (irrigated):* 2s *Land capability (nonirrigated):* 3c **Typical profile** *0 to 7 inches:* Clay *7 to 15 inches:* Clay *15 to 46 inches:* Clay *46 to 60 inches:* Clay **Minor Components Aguirre** *Percent of map unit:* 15 percent *Landform:* Basin floors, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Talf *Down-slope shape:* Linear *Across-slope shape:* Linear

San German Area, Southwestern Puerto Rico: FrA—Fraternidad clay, 0 to 2 percent slopes. Map Unit Setting *Elevation:* 0 to 160 feet *Mean annual precipitation:* 25 to 66 inches *Mean annual air temperature:* 66 to 89 degrees F *Frost-free period:* 365 days **Map Unit Composition** *Fraternidad and similar soils:* 90 percent *Minor components:* 10 percent **Description of Fraternidad Setting** *Landform:* Fan skirts *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip, talf *Down-slope shape:* Linear, convex *Across-slope shape:* Linear, concave *Parent material:* Clayey alluvium derived from igneous, metamorphic and sedimentary rock **Properties and qualities** *Slope:* 0 to 2 percent *Depth to restrictive feature:* More than 80 inches *Drainage class:* Moderately well drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.01 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Calcium carbonate, maximum content:* 4 percent *Gypsum, maximum content:* 2 percent *Maximum salinity:* Nonsaline (0.0 to 2.0 mmhos/cm) *Sodium adsorption ratio, maximum:* 2.0 *Available water capacity:* Moderate (about 9.0 inches) **Interpretive groups** *Land capability (nonirrigated):* 2c **Typical profile** *0 to 13 inches:* Clay *13 to 17 inches:* Clay *17 to 65 inches:* Clay **Minor Components Cartagena** *Percent of map unit:* 5 percent *Landform:* Fan skirts *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip, talf *Down-slope shape:* Linear, concave *Across-slope shape:* Linear **Santa isabel** *Percent of map unit:* 5 percent *Landform:* Valleys, fan skirts *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Talf, dip *Down-slope shape:* Concave, linear *Across-slope shape:* Linear

San German Area, Southwestern Puerto Rico: GnA—Guanica clay, 0 to 1 percent slopes. Map Unit Setting *Elevation:* 0 to 160 feet *Mean annual precipitation:* 25 to 66 inches *Mean annual air temperature:* 66 to 89 degrees F *Frost-free period:* 365 days **Map Unit Composition** *Guanica and similar soils:* 80 percent *Minor components:* 20 percent **Description of Guanica Setting** *Landform:* Basin floors, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Talf, dip *Down-slope shape:* Concave, linear *Across-slope shape:* Linear *Parent material:* Clayey alluvium sediments derived from igneous, metamorphic and sedimentary rock **Properties and qualities** *Slope:* 0 to 1 percent *Depth to restrictive feature:* 50 to 65 inches to salic *Drainage class:* Somewhat poorly drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.01 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* Frequent *Calcium carbonate, maximum content:* 15 percent *Gypsum, maximum content:* 4 percent *Maximum salinity:* Slightly saline to moderately saline (8.0 to 16.0 mmhos/cm) *Sodium adsorption ratio, maximum:* 30.0 *Available water capacity:* Low (about 5.1 inches) **Interpretive groups** *Land capability (nonirrigated):* 3w **Typical profile** *0 to 4 inches:* Clay *4 to 12 inches:* Clay *12 to 52 inches:* Clay *52 to 79 inches:* Clay **Minor Components Aguirre** *Percent of map unit:* 10 percent *Landform:* Basin floors, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Talf *Down-slope shape:* Linear *Across-slope shape:* Linear **Fraternidad** *Percent of map unit:* 5 percent *Landform:* Fan skirts *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Talf, dip *Down-slope shape:* Convex, linear *Across-slope shape:* Concave, linear **Cartagena** *Percent of map unit:* 5 percent *Landform:* Fan skirts *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip, talf *Down-slope shape:* Linear, concave *Across-slope shape:* Linear

San German Area, Southwestern Puerto Rico: JaB—Jacana clay, 0 to 5 percent slopes. Map Unit Setting *Elevation:* 20 to 250 feet *Mean annual precipitation:* 14 to 66 inches *Mean annual air temperature:* 66 to 89 degrees F *Frost-free period:* 365 days **Map Unit Composition** *Jacana and similar soils:* 80 percent *Minor components:* 20 percent **Description of Jacana Setting** *Landform:* Hillslopes, alluvial fans *Landform position (two-dimensional):* Toeslope, summit, footslope, backslope, shoulder *Landform position (three-dimensional):* Base slope, side slope *Down-slope shape:* Convex, linear *Across-slope shape:* Linear, convex *Parent material:* Colluvium and residuum of mixed origin overlying basic volcanic rock **Properties and qualities** *Slope:* 2 to 5 percent *Depth to restrictive feature:* 24 to 39 inches to paralithic bedrock *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low (0.01 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Calcium carbonate, maximum content:* 1 percent *Maximum salinity:* Nonsaline (0.0 to 2.0 mmhos/cm) *Available water capacity:* Low (about 5.9 inches) **Interpretive groups** *Land capability classification (irrigated):* 2e *Land capability (nonirrigated):* 3c *Ecological site:* Calamovilfa longifolia/Lechea leggettii/Bolbitis pergamentacea (F271XZ011PR) **Typical profile** *0 to 20 inches:* Clay *20 to 30 inches:* Clay *30 to 33 inches:* Clay loam *33 to 33 inches:* Weathered bedrock **Minor Components Descalabrado** *Percent of map unit:* 10 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Summit, backslope, shoulder *Landform position (three-dimensional):* Base slope *Down-slope shape:* Concave, convex *Across-slope shape:* Concave, convex **Fraternidad** *Percent of map unit:* 10 percent *Landform:* Fan skirts *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip, talf *Down-slope shape:* Convex, linear *Across-slope shape:* Concave, linear

San German Area, Southwestern Puerto Rico: OrA—Olivares muck, ponded. Map Unit Setting *Elevation:* 0 to 160 feet *Mean annual precipitation:* 25 to 66 inches *Mean annual air temperature:* 66 to

89 degrees F *Frost-free period:* 365 days **Map Unit Composition** *Olivares and similar soils:* 95 percent *Minor components:* 5 percent **Description of Olivares Setting** *Landform:* Depressions, alluvial flats *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip, talf *Down-slope shape:* Concave *Across-slope shape:* Concave, linear *Parent material:* Loamy and clayey alluvium derived from igneous, metamorphic and sedimentary rock and/or loamy and clayey marine deposits derived from igneous, metamorphic and sedimentary rock **Properties and qualities** *Slope:* 0 to 2 percent *Depth to restrictive feature:* More than 80 inches *Drainage class:* Very poorly drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low (0.01 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* Frequent *Available water capacity:* Low (about 4.4 inches) **Interpretive groups** *Land capability (nonirrigated):* 7w **Typical profile** *0 to 2 inches:* Mucky peat *2 to 25 inches:* Silty clay *25 to 48 inches:* Silty clay *48 to 80 inches:* Silty clay **Minor Components Teresa, ponded** *Percent of map unit:* 3 percent *Landform:* Alluvial flats, valley floors *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Talf, dip *Down-slope shape:* Linear *Across-slope shape:* Linear **Cartagena** *Percent of map unit:* 2 percent *Landform:* Fan skirts *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip, talf, rise *Down-slope shape:* Linear, concave *Across-slope shape:* Linear

San German Area, Southwestern Puerto Rico: ScA—San Anton clay loam, 0 to 2 percent slopes, occasionally flooded. Map Unit Setting *Elevation:* 0 to 160 feet *Mean annual precipitation:* 14 to 54 inches *Mean annual air temperature:* 70 to 88 degrees F *Frost-free period:* 365 days Map Unit Composition *San anton and similar soils:* 95 percent *Minor components:* 5 percent Description of San Anton Setting *Landform:* Flood plains *Landform position (two-dimensional):* Footslope *Down-slope shape:* Linear *Across-slope shape:* Linear *Parent material:* Alluvium derived from igneous, metamorphic and sedimentary rock Properties and qualities *Slope:* 0 to 2 percent *Depth to restrictive feature:* More than 80 inches *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.57 to 1.98 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* Occasional *Frequency of ponding:* None *Calcium carbonate, maximum content:* 1 percent *Maximum salinity:* Nonsaline (0.0 to 2.0 mmhos/cm) *Sodium adsorption ratio, maximum:* 2.0 *Available water capacity:* High (about 9.5 inches) Interpretive groups *Land capability classification (irrigated):* 1 *Land capability (nonirrigated):* 2c Typical profile *0 to 8 inches:* Clay loam *8 to 13 inches:* Clay loam *13 to 24 inches:* Silty clay loam *24 to 31 inches:* Clay *31 to 41 inches:* Sandy clay loam *41 to 54 inches:* Loam *54 to 70 inches:* Sandy clay loam Minor Components Cortada *Percent of map unit:* 3 percent *Landform:* Flood plains *Landform position (two-dimensional):* Toeslope *Down-slope shape:* Linear *Across-slope shape:* Linear Vayas *Percent of map unit:* 2 percent *Landform:* Flood plains *Down-slope shape:* Linear *Across-slope shape:* Linear

San German Area, Southwestern Puerto Rico: SiA—Santa Isabel clay, 0 to 2 percent slopes. Map Unit Setting *Elevation:* 0 to 160 feet *Mean annual precipitation:* 25 to 66 inches *Mean annual air temperature:* 66 to 89 degrees F *Frost-free period:* 365 days **Map Unit Composition** *Santa isabel and similar soils:* 95 percent *Minor components:* 5 percent **Description of Santa Isabel Setting** *Landform:* Valleys, fan skirts *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):*

Dip, talf *Down-slope shape:* Concave, linear *Across-slope shape:* Linear *Parent material:* Clayey alluvium derived from volcanic and sedimentary rock **Properties and qualities** *Slope:* 0 to 2 percent *Depth to restrictive feature:* More than 80 inches *Drainage class:* Moderately well drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.01 in/hr) *Depth to water table:* About 60 to 72 inches *Frequency of flooding:* None *Frequency of ponding:* None *Calcium carbonate, maximum content:* 5 percent *Maximum salinity:* Nonsaline (0.0 to 2.0 mmhos/cm) *Sodium adsorption ratio, maximum:* 2.0 *Available water capacity:* Moderate (about 8.5 inches) **Interpretive groups** *Land capability (nonirrigated):* 2c **Typical profile** *0 to 10 inches:* Clay *10 to 63 inches:* Clay *63 to 69 inches:* Clay **Minor Components Fraternidad** *Percent of map unit:* 5 percent *Landform:* Fan skirts *Landform position (two-dimensional):* Toeslope *Down-slope shape:* Linear, convex *Across-slope shape:* Linear, concave

4.2.2 Soil semi-variogram description

The goal of this aspect of the site characterization is to determine the minimum distance between the soil plots in the soil array such that data farther apart can be considered spatially independent. The collected field data will be used to produce semivariograms, which is a geostatistical technique to characterize spatial autocorrelation between mapped samples of a quantitative variable (*e.g*., soil property data in our case). In an empirical semivariogram, the average of the squared differences of a response variable is computed for all pairs of points within specified distance intervals (lag classes). The output is presented graphically as a plot of the average semi-variance versus distance class (Figure 23). For the theoretical variogram models considered here, the semivariance will converge on the total variance at distances for which values are no longer spatially auto-correlated (this is referred to as the range, Figure 23).

For the theoretical variograms considered here, three parameters estimated from the data are used to fit a semivariogram model to the empirical semivariogram. This model is then assumed to quantitatively represent the correlation as a function of distance (Figure 23), the range, the sill (the sill is the asymptotic value of semi-variance at the range), and the nugget (which describes sampling error or variation at distances below those separating the closest pairs of samples). The range, sill and nugget are estimated from theoretical models that are fitted to the empirical variograms using non-linear least squares methods.

The variogram analysis will be used, to determine the spatial scales at which we can consider soil measurements spatially independent. This characterization will directly inform the minimum distance between *i*) soil plots within each soil array, *ii*) the soil profile measurements, *iii*) EP plots, and *iv*) the microbial sampling locations. These data will directly inform NEON construction and site design activities.

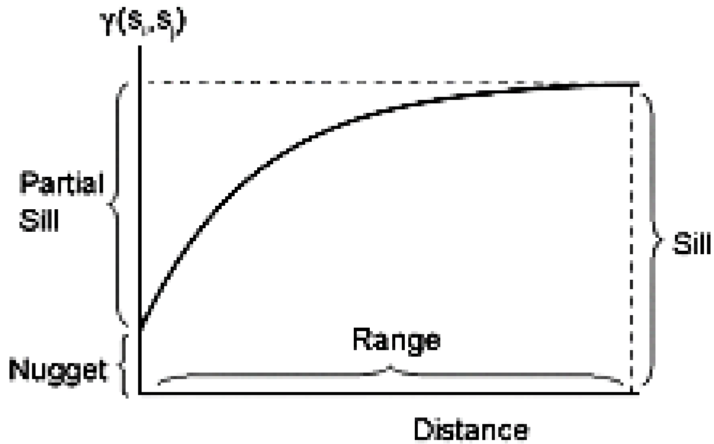


Figure 23. Example semivariogram, depicting range, sill, and nugget

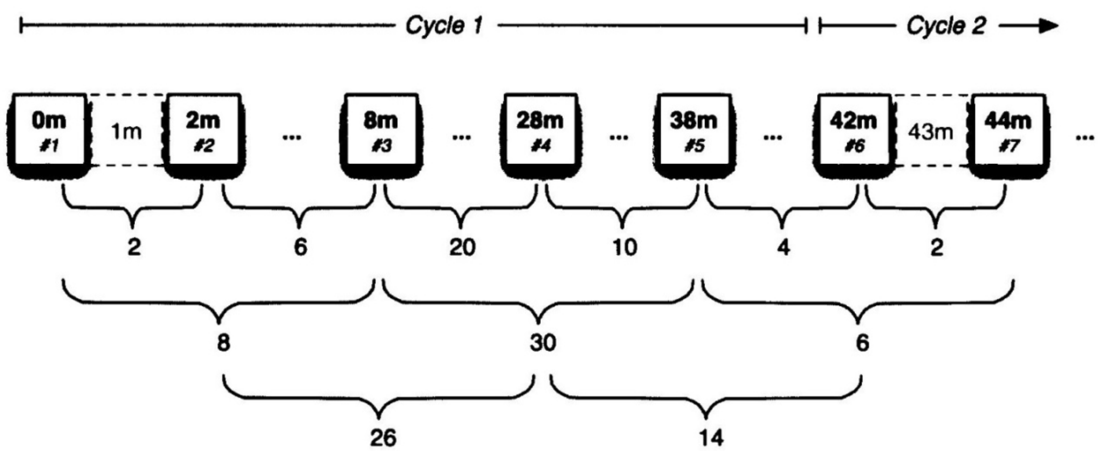


Figure 24. Spatially cyclic sampling design for the measurements of soil temperature and soil water content

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 17-18 March 2010 at the Lajas site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 24). Soil temperature and moisture measurements were collected along three transects (134 m, 84 m, and 84 m) located in the expected airshed at Lajas. Details of how the airshed was determined are provided below. Soil temperature was measured with platinum resistance temperature sensors (RTD 810, Omega Engineering Inc., Stamford CT) and soil moisture was measured with time domain diaelectric sensors (CS616, Campbell Scientific Inc., Logan UT).

As well as measuring soil temperature and moisture at each sample point in Figure 24, measurements were also taken 30 cm in front and behind the sampling point along the axis of the transect. For example, at the 2 m sampling point, soil temperature and moisture was measured at 1.7 m, 2 m, and 2.3 m; this data is referred to as mobile data, since the measurements were taken at many different locations. In addition, soil temperature and moisture were continuously recorded at a single fixed location (stationary data) throughout the sampling time to correct for changes in temperature and moisture throughout the day.

Data collected were used for geospatial analyses of variograms in the R statistical computing language with the geoR package to test for spatial autocorrelation (Trangmar *et al.* 1986; Webster & Oliver 1989; Goovaerts 1997; Riberiro & Diggle 2001) and estimate the distance necessary for independence among soil plots in the soil array. To correct for changes in temperature and moisture over the sampling period, the stationary data was subtracted from the mobile data. In many instances a time of day trend was still apparent in the data even after subtracting the stationary data from the mobile data. This time of day trend was corrected for by fitting a linear regression and using the residuals for the semivariogram analysis. Soil temperature and moisture data, R code, graphs, and R output can be found at: P:\FIU\FIU_Site_Characterization\DXX\YYYYYYY_Characterization\Soil Measurements\Soil Data Analysis (where XX = domain number and YYYYYYY = site name).

4.2.3 Results and interpretation

4.2.3.1 Soil Temperature

Soil temperature data residuals, after accounting for changes in temperature in the stationary data and any remaining time of day trend, were used for the semivariogram analysis (Figure 25). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 26, left graphs) and directional semivariograms do not show any indication of anisotropy (Figure 26, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 26, right graph). The model indicates a distance of effective independence of 12 m for soil temperature.

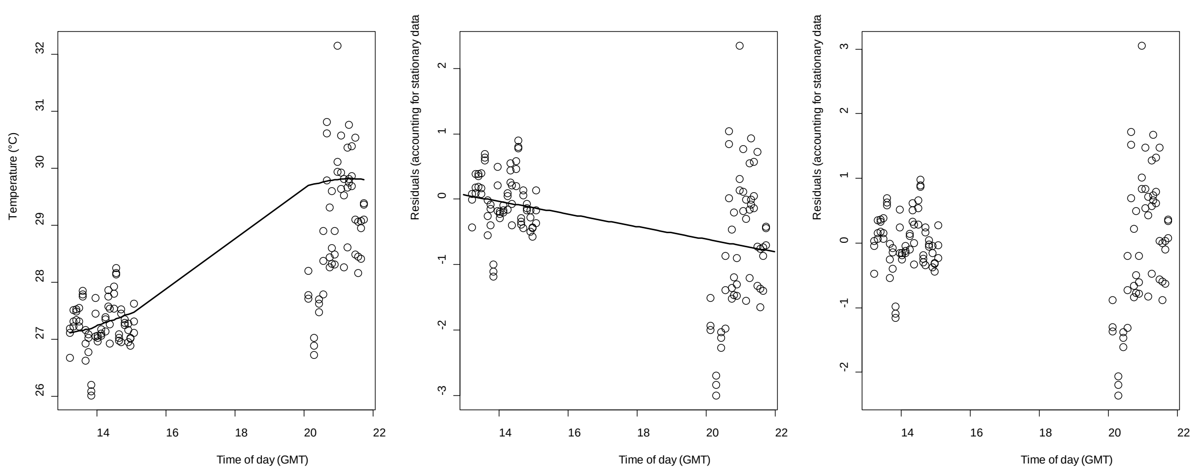


Figure 25. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting for changes temperature in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis

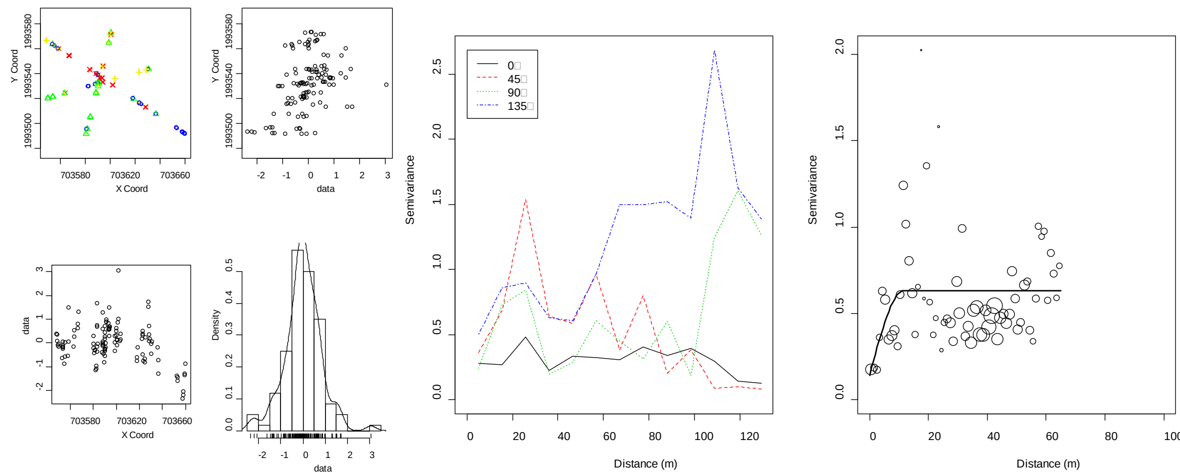


Figure 26. Left graph: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature

4.2.3.2 Soil water content

Soil water content data residuals, after accounting for changes in water content in the stationary data and any remaining time of day trend, were used for the semivariogram analysis (Figure 27). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 28, left graph) and directional semivariograms do not show any indication of anisotropy (Figure 28, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 28, right graph). The model indicates a distance of effective independence of 24 m for soil water content.

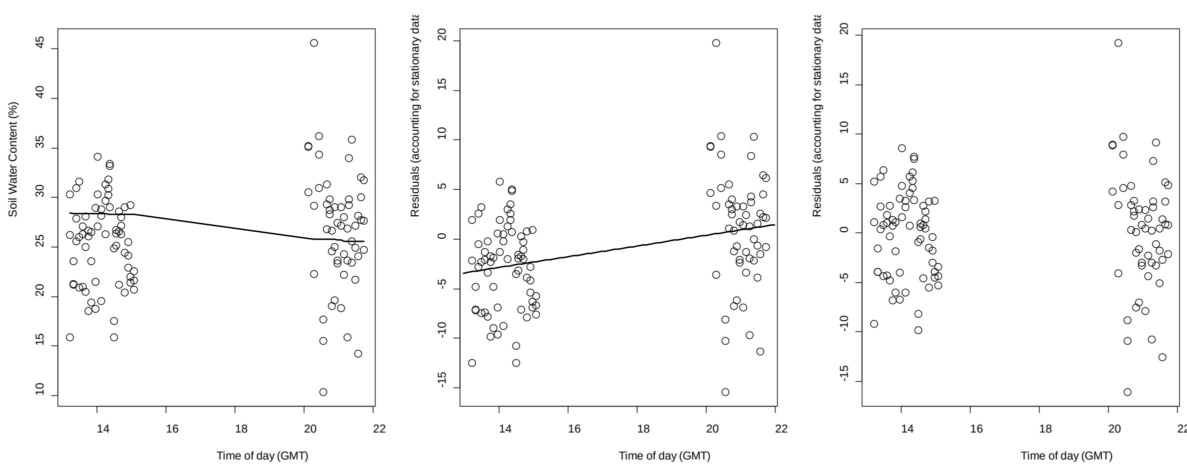


Figure 27. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting for changes water content in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis

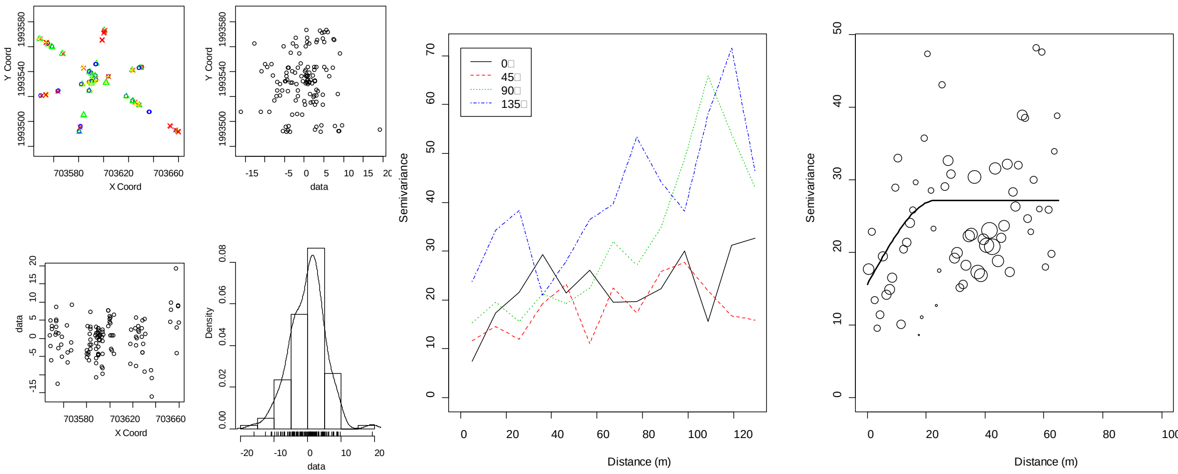


Figure 28. Left graph: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content

4.2.3.3 Soil array layout and soil pit location

The minimum distance allowable between soil plots is 25 m to ensure a degree of spatial independence in non-measured soil parameters (i.e., other than temperature and water content) and the maximum distance allowable between soil plots is 40 m due to cost constraints. The estimated distance of effective independence was 12 m for soil temperature and 24 m for soil moisture. Based on these results and the site design guidelines the soil plots at Lajas shall be placed 25 m apart. The soil array shall follow the most compact soil array design (Soil Array Pattern C) due to space constraints at the site with the soil plots being 5 m x 5 m (Figure 30). The direction of the soil array shall be 115° from the soil plot nearest the tower (i.e., first soil plot, Fig. 29-30). The location of the first soil plot will be approximately 18.02099°, -67.07670°W. The exact location of each soil plot will be chosen by an FIU team member during site construction to avoid placing a soil plot at an unrepresentative location (e.g., rock outcrop, drainage channel, large tree, etc). The FIU soil pit for characterizing soil horizon depths, collecting soil for site-specific sensor calibration, and collecting soil for the FIU soil archive will be located at approximately 18.02128°, - 67.07705°. A summary of the soil information is shown in Table 9 and site layout can be seen in Figure 30.

Dominant soil series at the site: Cartagena clay, 0 to 2 percent slopes. The taxonomy of this soil is shown below:

Order: Vertisols

Suborder: Usterts

Great group: Haplusterts

Subgroup: Sodic Haplusterts

Family: Fine, mixed, superactive, isohyperthermic Sodic Haplusterts

Series: Cartagena clay, 0 to 2 percent slopes

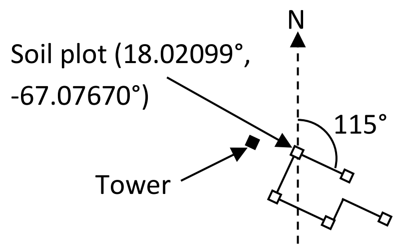


Figure 29. Schematic diagram of soil array layout in relation to tower. Soil plot positions are approximate

Table 9. Summary of soil array and soil pit information at Lajas. 0° represents true north and accounts for declination

Soil plot dimensions	5 m x 5 m
Soil array pattern	C
Distance between soil plots: x	25 m
Distance from tower to closest soil plot: y	21 m
Approximate latitude and longitude of 1st soil plot OR direction from tower	18.02099°, -67.07670°
Direction of soil array	115°
Latitude and longitude of FIU soil pit 1	18.021845°, -67.076083° (primary)
Latitude and longitude of FIU soil pit 2	18.021133°, -67.076068° (alternate)
Latitude and longitude of FIU soil pit 3	18.020211°, -67.076043° (alternate)
Dominant soil type	Cartagena clay, 0 to 2 percent slopes
Expected soil depth	>2 m
Depth to water table	>2 m

Expected depth of soil horizons	Expected measurement depths
0-0.18 m (clay)	0.09 m
0.18-0.38 (clay)	0.28 m
0.38-1.17 (clay)	1.55 m
1.17-1.52 (clay)	1.35 m

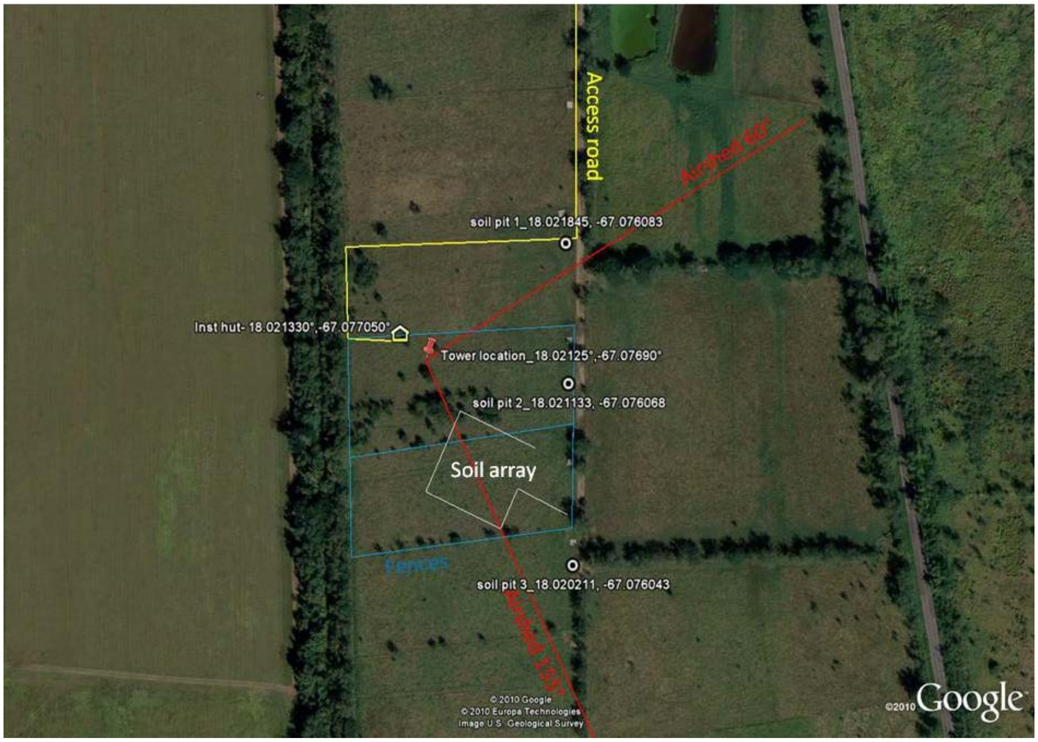


Figure 30. Site layout at Lajas showing soil array and location of the FIU soil pit

4.3 Airshed

4.3.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries, Figures 31-34. The weather data used to generate the following wind roses are from Isla Maguesyes, Lajas, PR, which is ~4.7 miles southeast of NEON Relocatable site at Lajas Experimental station. The orientation of the wind rose follows that of a compass (assume declination applied). When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. Color bands depict the range of wind speeds. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 24 cardinal directions.

4.3.2 Results (graphs for wind roses)

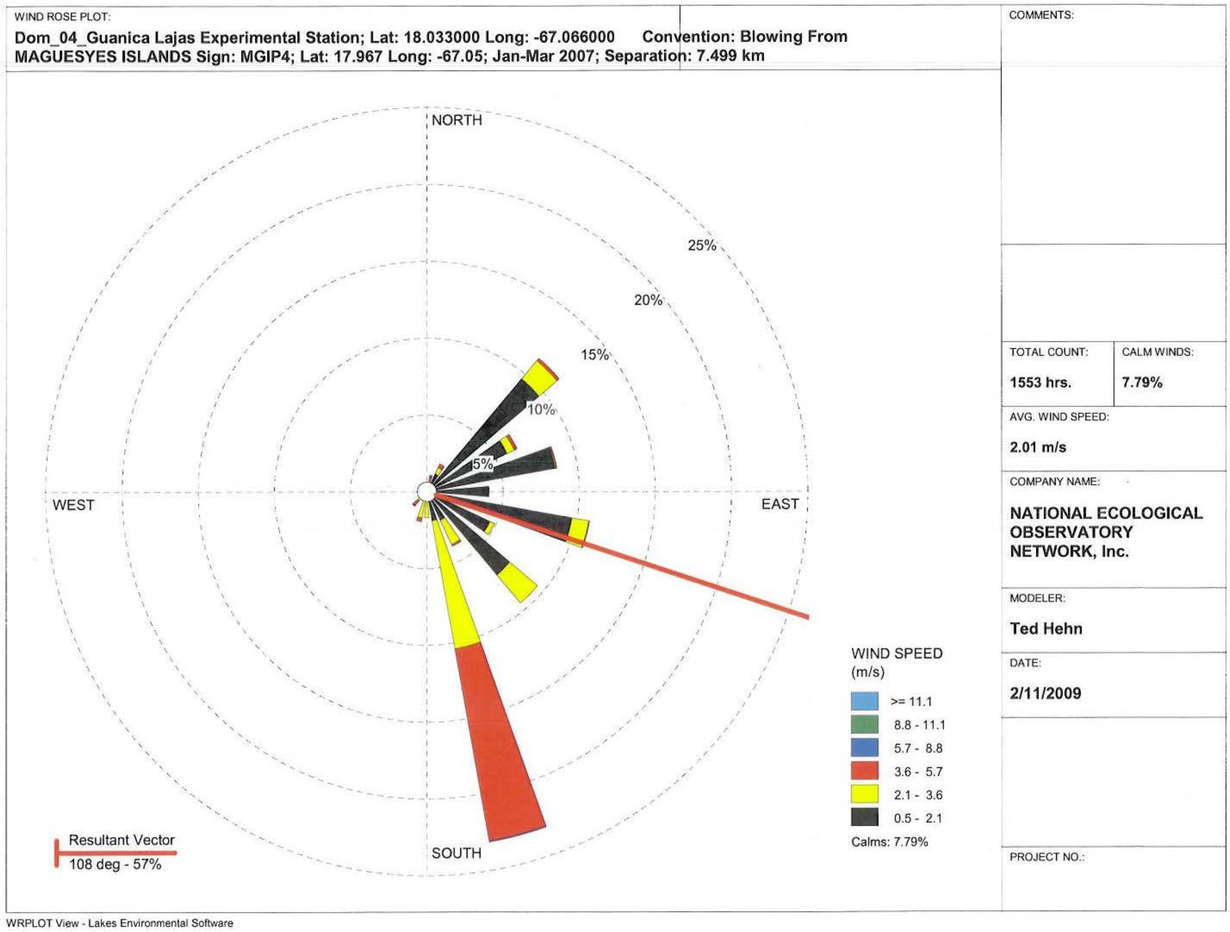


Figure 31. Windroses of January – March for D04 Lajas Experimental station Relocatable site

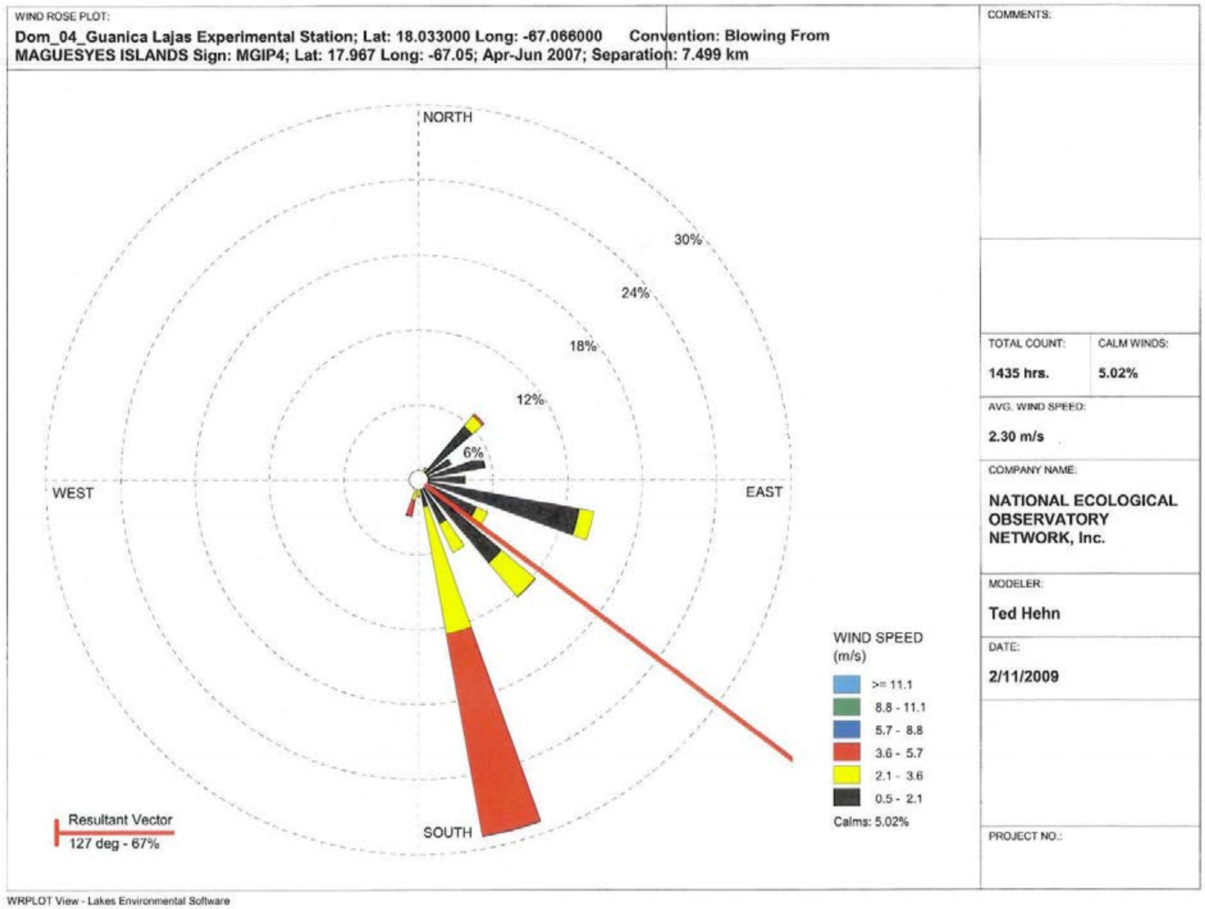


Figure 32. Windroses of April – June for D04 Lajas Experimental station Relocatable site

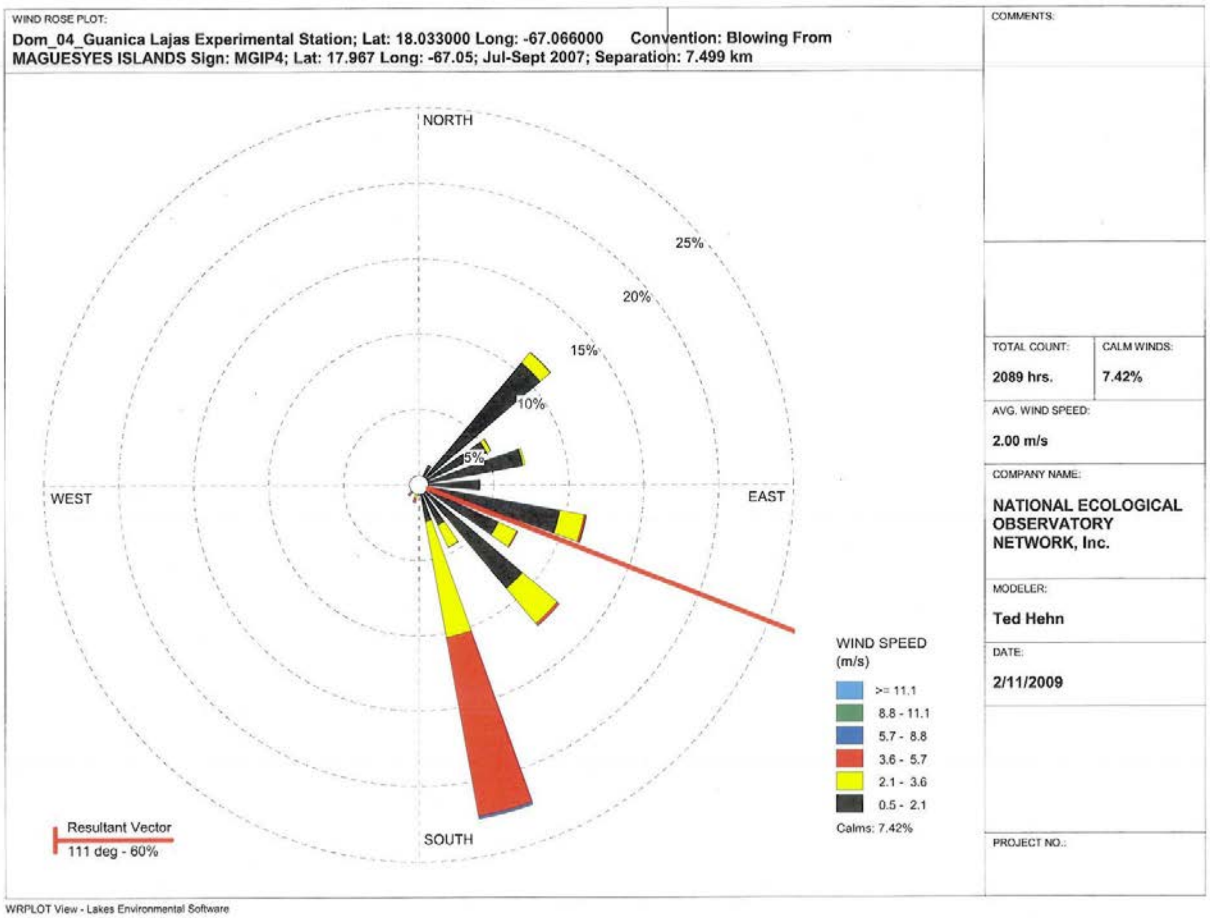


Figure 33. Windroses of July – September for D04 Lajas Experimental station Relocatable site

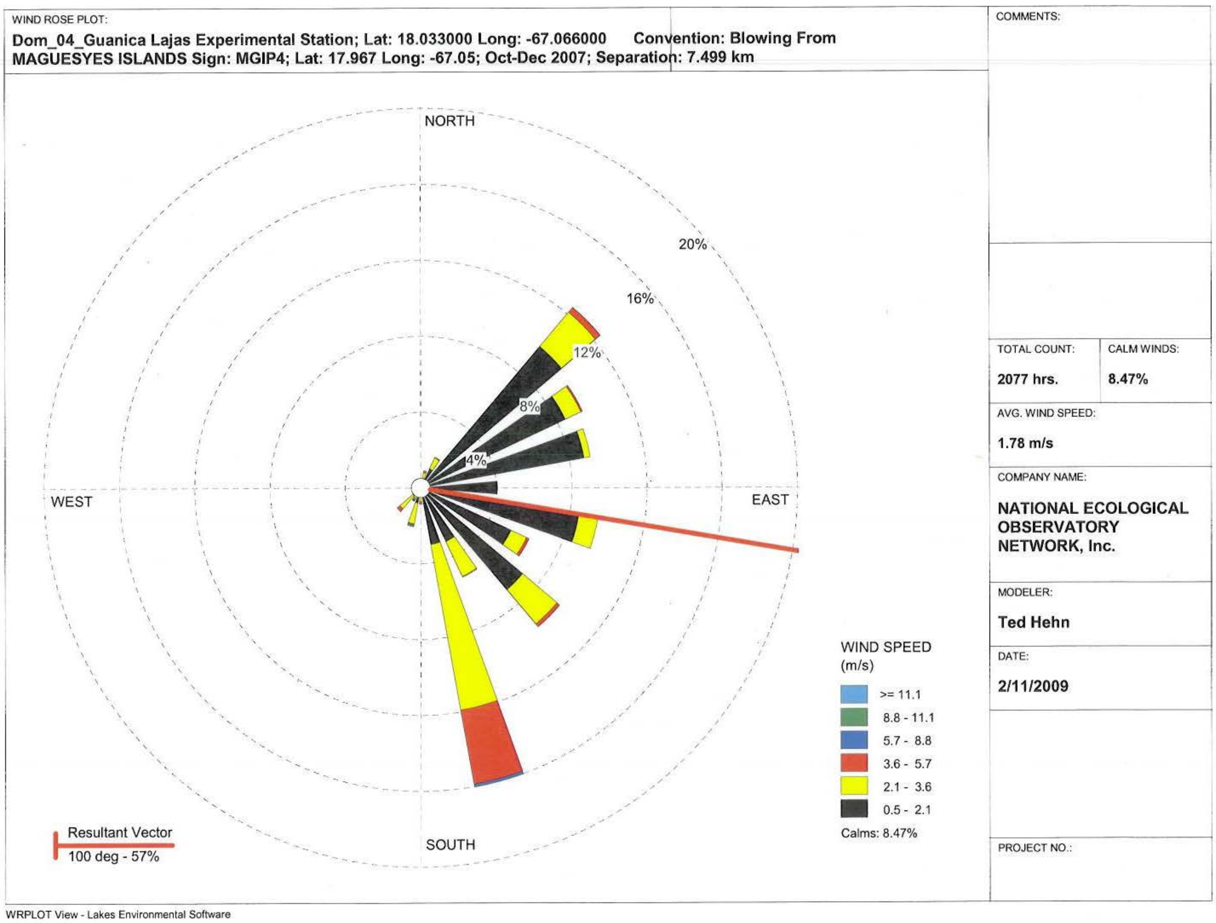


Figure 34. Windroses of October – December for D04 Lajas Experimental station Relocatable site

4.3.3 Resultant vectors

Table 10. Resultant wind vectors from Lajas Experimental Station

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	108°	57
April to June	127°	67
July to September	111°	60
October to December	100°	57
Annual mean	111.5°	na.

4.3.4 Expected environmental controls on source area

Two types of models were commonly used to determine the shape and extent of the source area under different and contrasting atmospheric stability classes. An inverted plume dispersion model with modeled cross wind solutions were used for convective conditions (Horst and Weil 1994). For strongly stable conditions, and Lagrangian solution was used (Kormann and Meixner 2001). The source area models where bounded by the expected conditions depict the extreme conditions. Convective conditions typically have strong vertical mixing between the ecosystem and atmosphere (surface layer). Stable conditions typically have long source area and associated waveforms. Convective turbulence is often characterized by short mixing scales (scalar) and moderate daytime wind speeds, *e.g.,* 1-4 m s^{-2}. Higher wind speeds, like those experienced over the Rockies, are often the product of mechanical turbulence with long waveforms. Because thermal stratification is very efficient in suppressing vertical mixing, stable conditions also have typically very long waveforms.

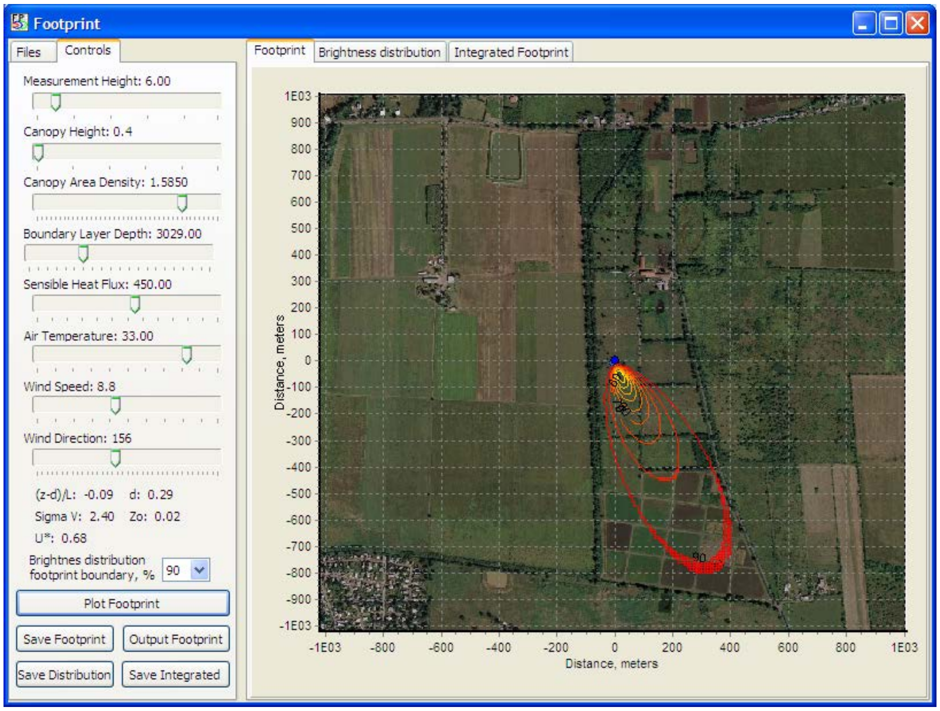
As a general rule, shorter and less structurally complex ecosystems have good vertical mixing during all atmospheric stabilities. Taller and more structurally complex ecosystems have well mixed upper canopies during the daytime, and can be decoupled below the canopy under neutral and stable conditions (e.g., Harvard Forest, Bartlett Experimental Forest, and Burlington Conservation Area). The type of turbulence (mechanical verse convective) and the physical attributes of the ecosystem control the degree of mixing, and the length and size of the source area.

Here, with support from Dr. R. Clement, we use a web-based footprint model that made by Micrometeorology Group at University of Edinburgh, UK to determine the footprint area under various conditions (model info: http://www.geos.ed.ac.uk/abs/research/micromet/EdiTools/). Winds used to run the model and generate following model results are extracted from the wind roses. Vegetation information, temperature and energy information were either from the RFI document, previous site visit report, available data files or best estimated from experienced expert. Measurement height was determined from the Tower Height Info document provided by ENG group, then verify according to the real ecosystem structure after FIU site characterization at site. Runs 1-3 and 4-6 represents the expected conditions for summer and winter conditions, respectively, with maximum and mean windspeeds (daytime convective) and nighttime (stable atmospheres) conditions. The wind vector for each run was estimated from wind roses and is placed as a centerline in the site map included in the graphics. The width of the footprint was also estimated using the length between the isopleth of 80% cumulative flux and center line to calculate the angle from centerline. This information, along with distance of the cumulative flux isopleths and wind direction, will define the source area for the flux measurements on the top of the tower.

Table 11. Expected environmental controls to parameterize the source area model, and associated results from Lajas Experimental Station Relocatable tower site

Parameters	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	**Units**
Approximate season	summer			winter			
	Day (max WS)	Day (mean WS)	Night	Day (max WS)	Day (mean WS)	night	qualitative
Atmospheric stability	Convective	convective	Stable	Convective	convective	Stable	qualitative
Measurement height	6	6	6	6	6	6	m
Canopy Height	0.4	0.4	0.4	0	0	0	m
Canopy area density	1.6	1.6	1.6	0	0	0	m
Boundary layer depth	3000	3000	1500	1000	1000	700	m
Expected sensible heat flux	450	450	75	250	250	25	$W\ m^{-2}$
Air Temperature	33	33	24	24	24	20	°C
Wind speed	8.8	3.9	0.9	5.7	3.8	1.1	$m\ s^{-1}$
Wind vector	155	155	60	155	155	60	degrees
Results							
(z-d)/L	-0.01	-0.11	-0.52	-1.40	-3.00	-3.00	m
d	2.40	2.40	2.40	0.00	0.00	0.00	m
Sigma v	2.90	2.20	0.93	1.20	1.20	0.51	$m^2\ s^{-2}$
Z0	0.13	0.13	0.13	0.00	0.00	0.00	m
u*	1.10	0.54	0.18	0.23	0.16	0.05	$m\ s^{-1}$
Roughness length							m
Distance source area begins	0	0	0	10	0	0	m
Distance of 90% cumulative flux	300	180	125	500	350	350	m
Distance of 80% cumulative flux	200	100	80	350	230	230	m
Distance of 70% cumulative flux	150	80	50	250	150	150	m
Distance of 60% cumulative flux	115	65	30	200	125	125	m
Distance of 50% cumulative flux	85	50	25	160	100	100	m
Distance of 40% cumulative flux	65	35	15	125	80	80	m
Distance of 30% cumulative flux	40	20	10	90	60	60	m
Distance of 20% cumulative flux	20	10	5	65	50	50	m
Distance of 10% cumulative flux	10	5	0	40	30	30	m
Peak contribution	25	25	15	85	55	55	m
angle from centerline	34	45	43	27	38	40	degrees

4.3.5 Footprint model results (source area graphs)



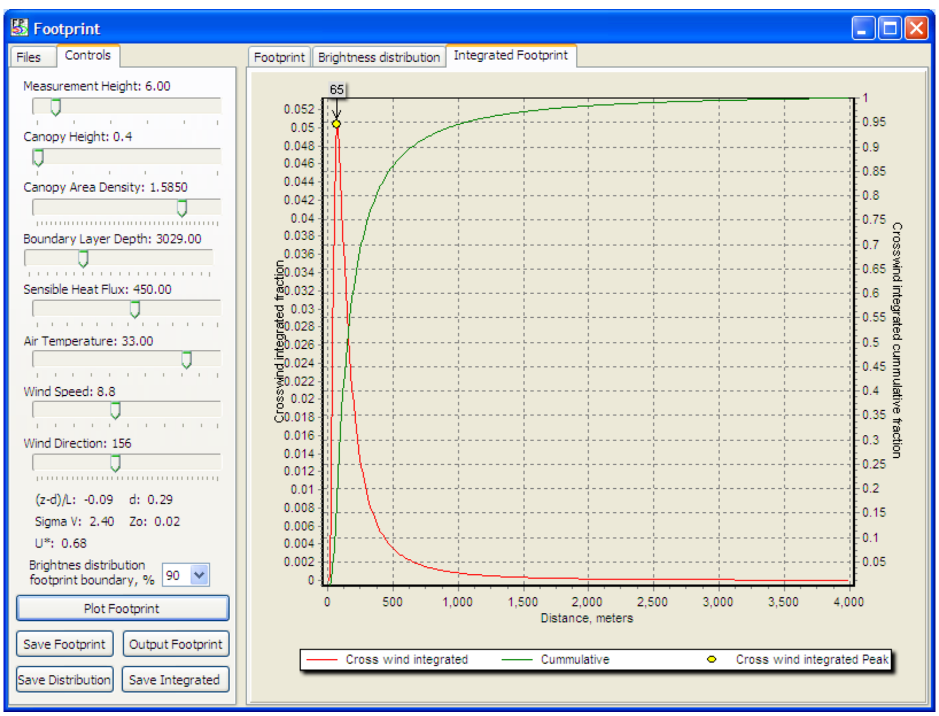
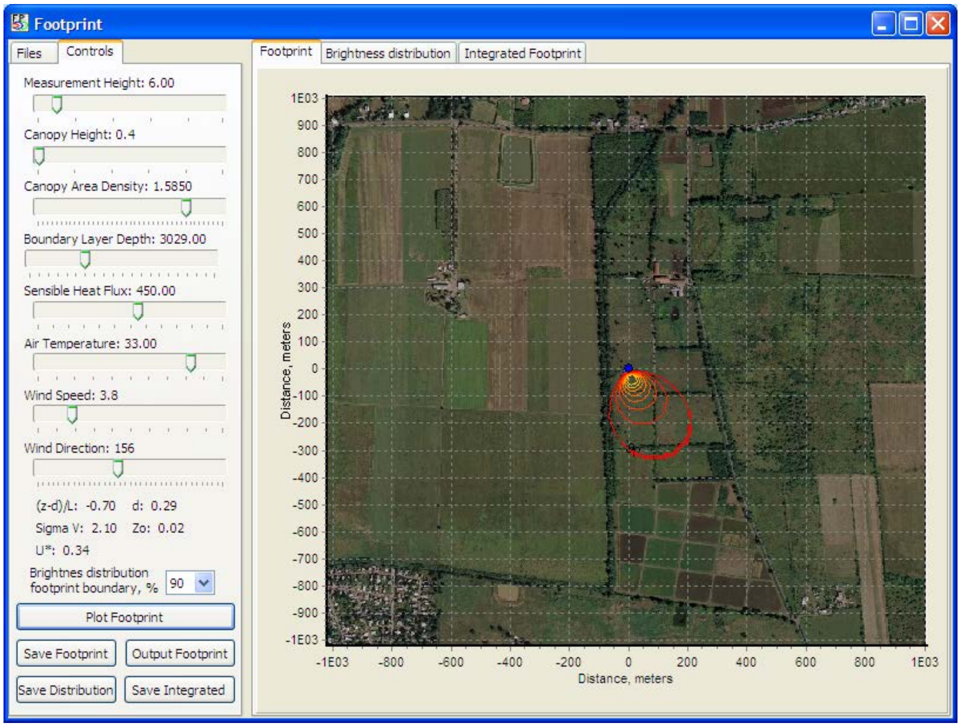


Figure 35. Lajas Experimental Station summer daytime (convective) footprint output with max wind speed



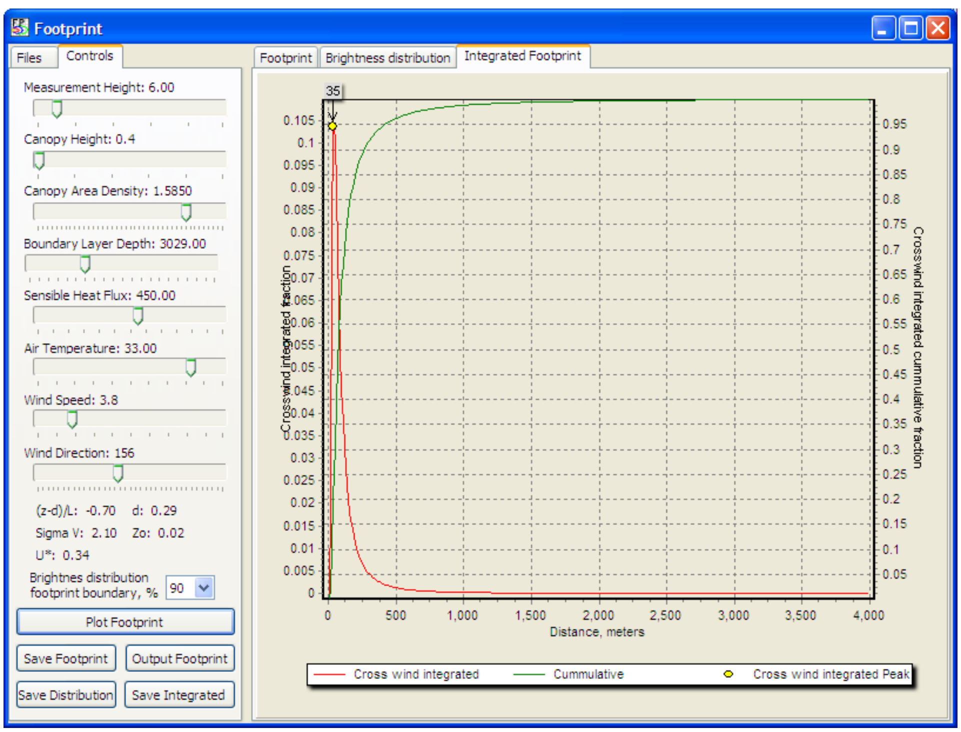
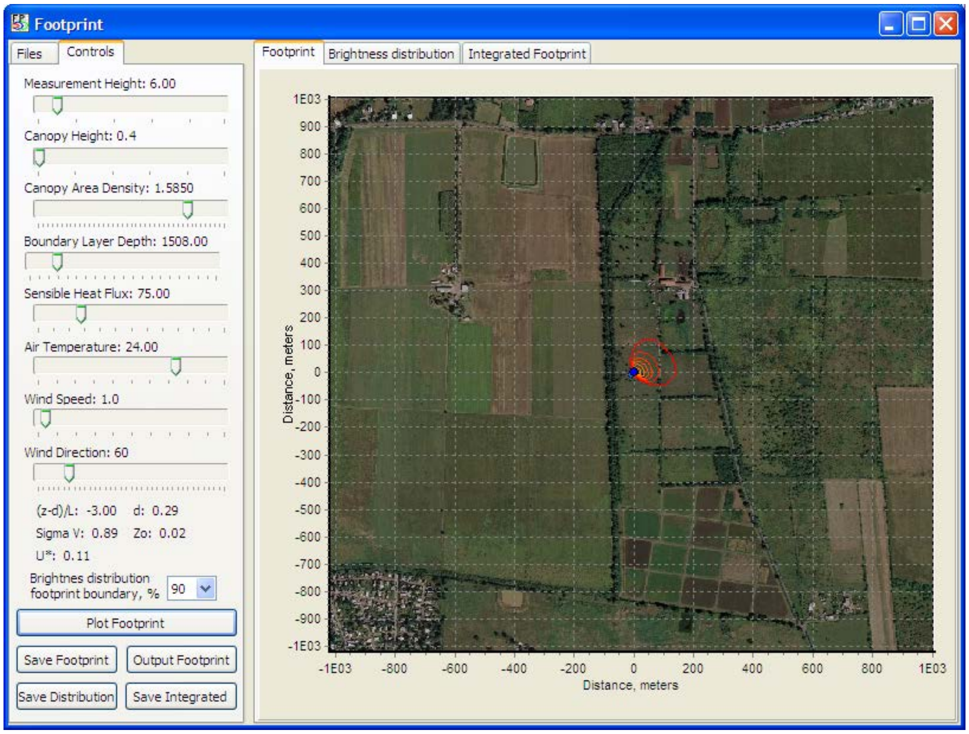


Figure 36. Lajas Experimental Station summer daytime (convective) footprint output with mean wind speed



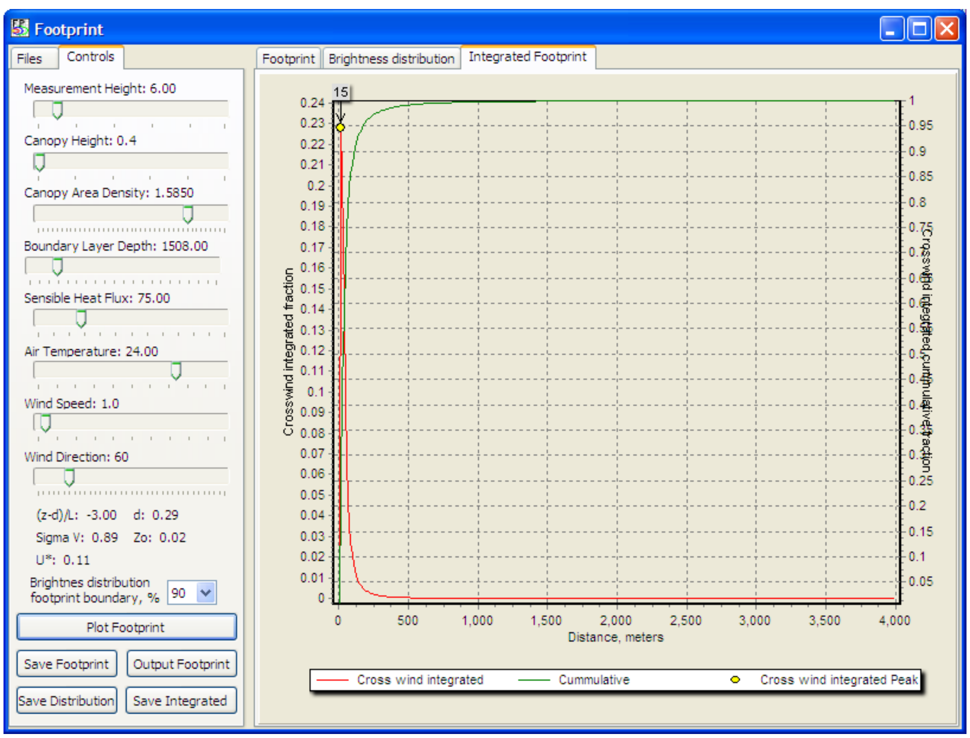
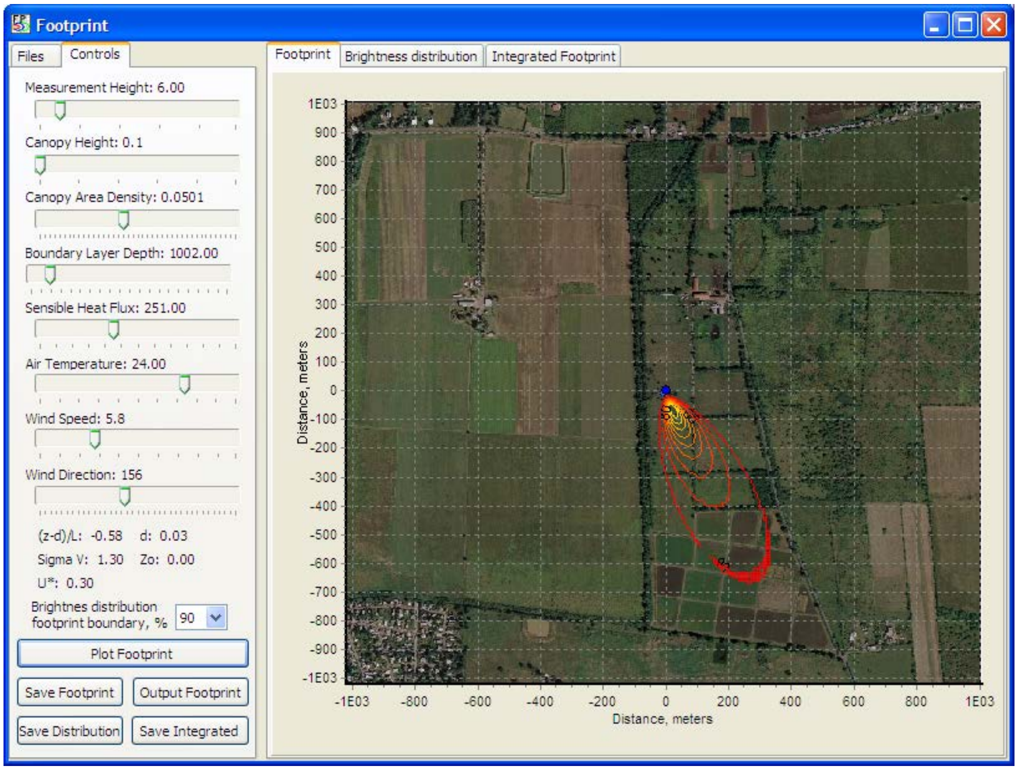


Figure 37. Lajas Experimental Station summer nighttime (stable) footprint output with mean wind speed



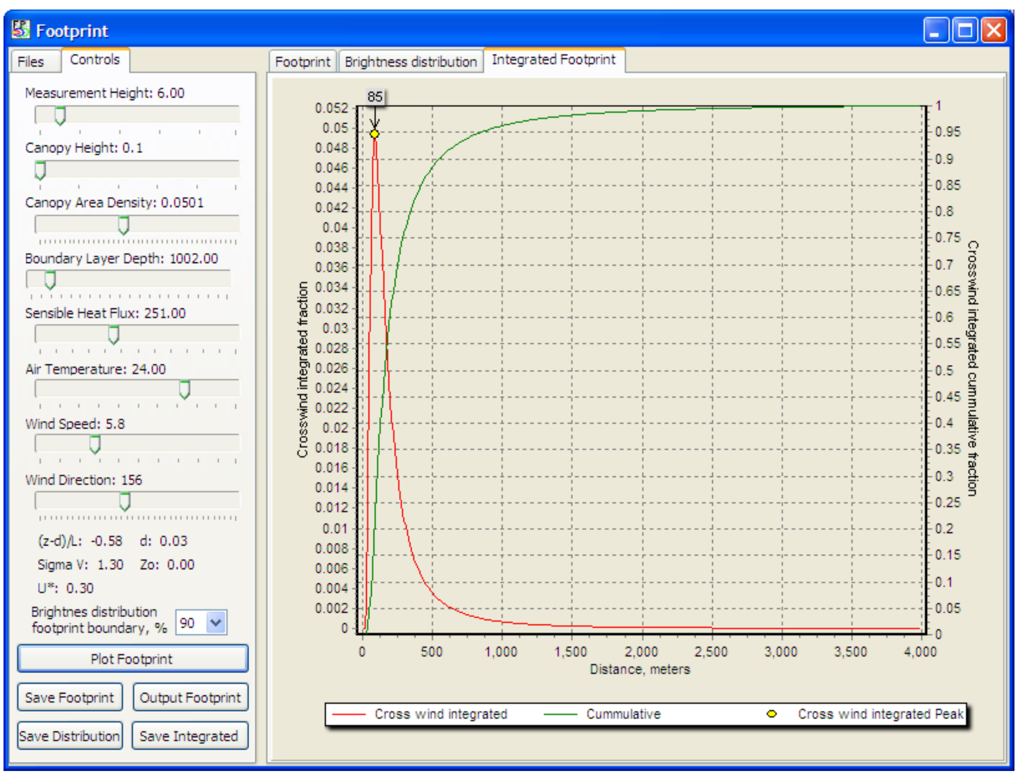
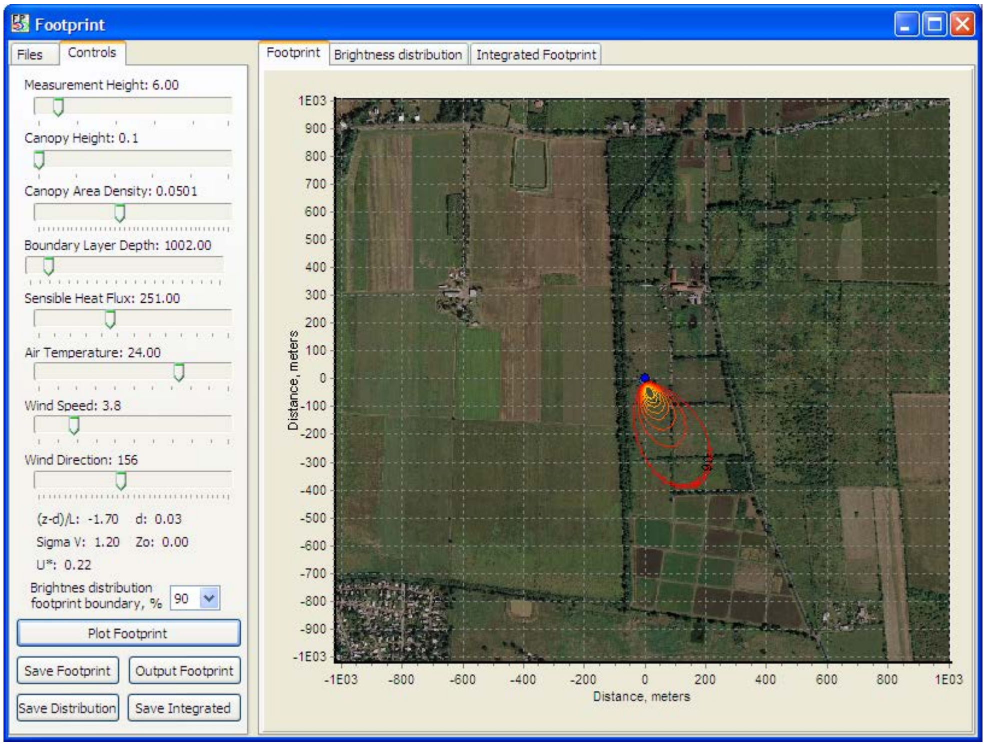


Figure 38. Lajas Experimental Station winter daytime (convective) footprint output with max wind speed



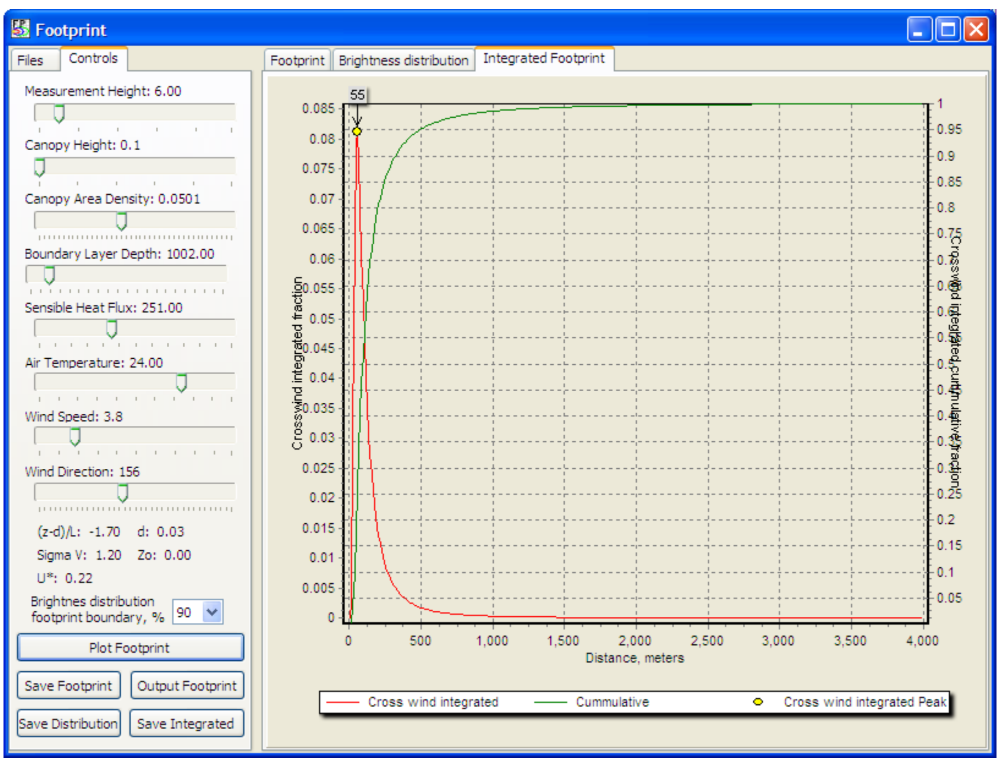
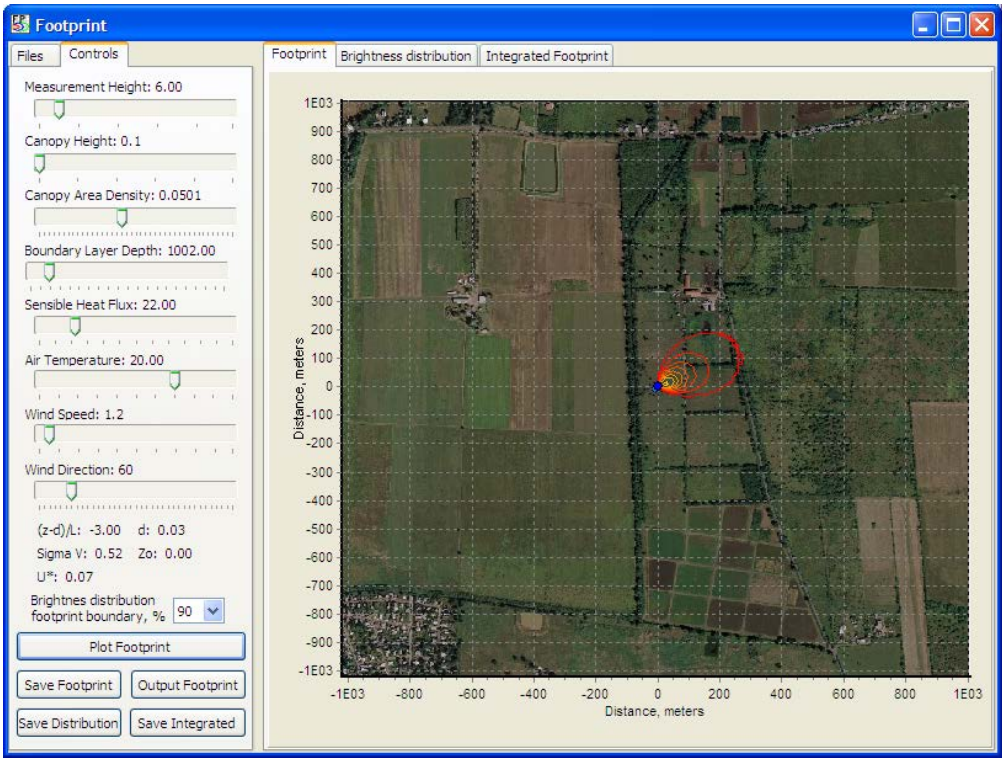


Figure 39. Lajas Experimental Station winter daytime (convective) footprint output with mean wind speed



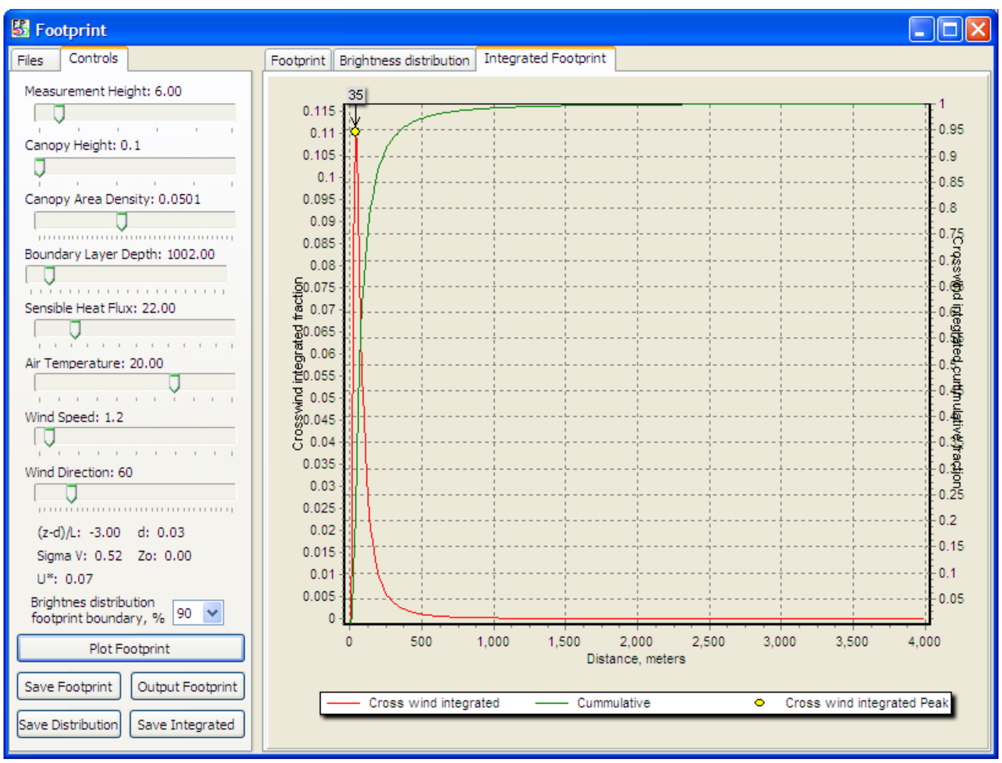


Figure 40. Lajas Experimental Station winter nighttime (stable) footprint output with mean wind speed

4.3.6 Tower location, instrument hut location, boardwalks, measurement layers on the tower and other sensor locations

Because the prevailing wind direction blows from east, north east and south east (30 degrees to 155 degrees), tower should be placed to a location to best catch the signals from the ecosystem in interest, which is controlled grazing field at this site. An instrument hut should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind. Therefore, we require the placement of the tower at 18.02102, -67.07690, and instrument hut at 18.02133, -67.07705.

The site is grazing grassland and vegetation is short. We require 4 measurement layers on the tower with top measurement height at 6 m, and rest layers are 4 m, 2 m and 0.15 m, respectively.

Keep in mind that all radiation sensors need to be mounted on the south side of the tower.

Boardwalks. Ultimately, the decision to use a boardwalk will be, in part, based on owner's preferences. There are strong science requirements that minimize site disturbance to the surrounding area, which will be difficult to manage over a 30-year period. Traffic control is key to minimizing the site disturbance. Confining foot traffic to boardwalks minimizes site impact; this is particularly true in places where wear caused by foot traffic becomes noticeable and grows. For example, in places with snow part of the year, worn footpaths tend to have low places that collect water, or places where the snow pack becomes uneven causing personnel to walk farther and farther around the sides of the original path, causing the path to grow in width. This is a very common phenomenon. Here, FIU assumes that all conduits will be either buried, or placed inside the boardwalk such that it does not extend beyond the 36" (0.914 m). wide footprint. The boardwalk to access the tower is not on any side that has a boom.

Specific Boardwalks at this site:

- Gravel walkway is from the access dirt road to instrument hut, down the fence line (towards the instrument hut), pending landowner decision, and ease to bring supplies to instrument hut
- Boardwalk from fence line west to instrument hut
- boardwalk from the instrument hut to the tower to intersect on north face of the tower
- No boardwalk to the soil array and the individual soil plots

The relative locations between tower, instrument hut and boardwalk can be found in Figure 35 below.

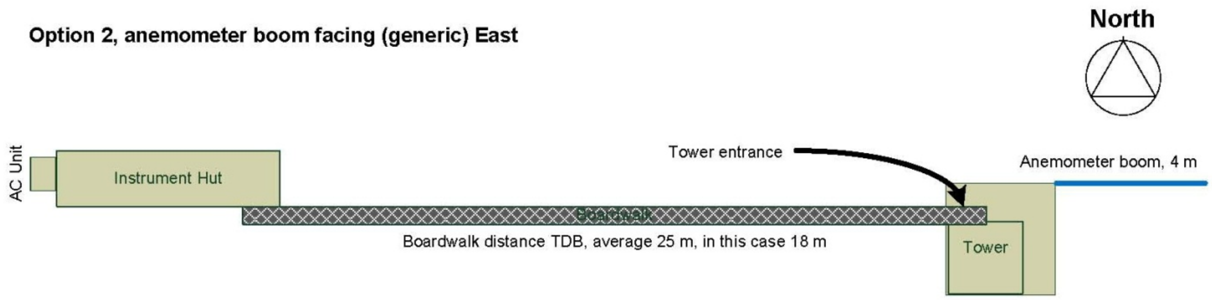


Figure 41. Orientation of tower, boardwalk and instrument hut for Lajas Relocatable site. Option 2 is required

The site layout is summarized in the table below. Assume the projected area of the tower is square. **Anemometer/temperature boom arm direction** is ***from*** the tower ***toward*** the prevailing wind direction or designated orientation. **Instrument hut orientation vector** is parallel to the long side of the instrument hut (short-side of instrument hut is perpendicular to the **Instrument hut orientation vector)**. **Instrument hut distance z** is the distance from the center of tower projection to the center of the instrument hut projection on the ground. The numbering of the **measurement levels** is that the lowest is level one, and each subsequent increase in height is numbered sequentially, in this case, level 4 being the upper most level at this tower site.

In the following table, 0° is true north with declination accounted for. Color of Instrument hut exterior shall be tan to best match the surrounding environment.

Table 12. Tower oriented design attributes for the Lajas Relocatable site

Attribute	lat	long	degree	meters	notes
Airshed			60° to 155°		Clockwise from 60°
Tower location	18.02125	-67.07690	--	--	new site
Instrument hut	18.02133	-67.07705			
Instrument hut orientation vector	--	--	270° to 90°		
Instrument hut distance z	--	--	--	19	
Anemometer/Temperature boom orientation	--	--	90°	--	
Height of the measurement levels					
Level 1				0.15	m.a.g.l.
Level 2				2.0	m.a.g.l.
Level 3				4.0	m.a.g.l.
Level 4				6.0	m.a.g.l.
Tower Height				6.0	m.a.g.l.

See AD[01] for technical requirement to determine the boom height for the bottom most measurement level.

Figure 42 below shows the proposed tower location, instrument hut location, airshed area and access road.

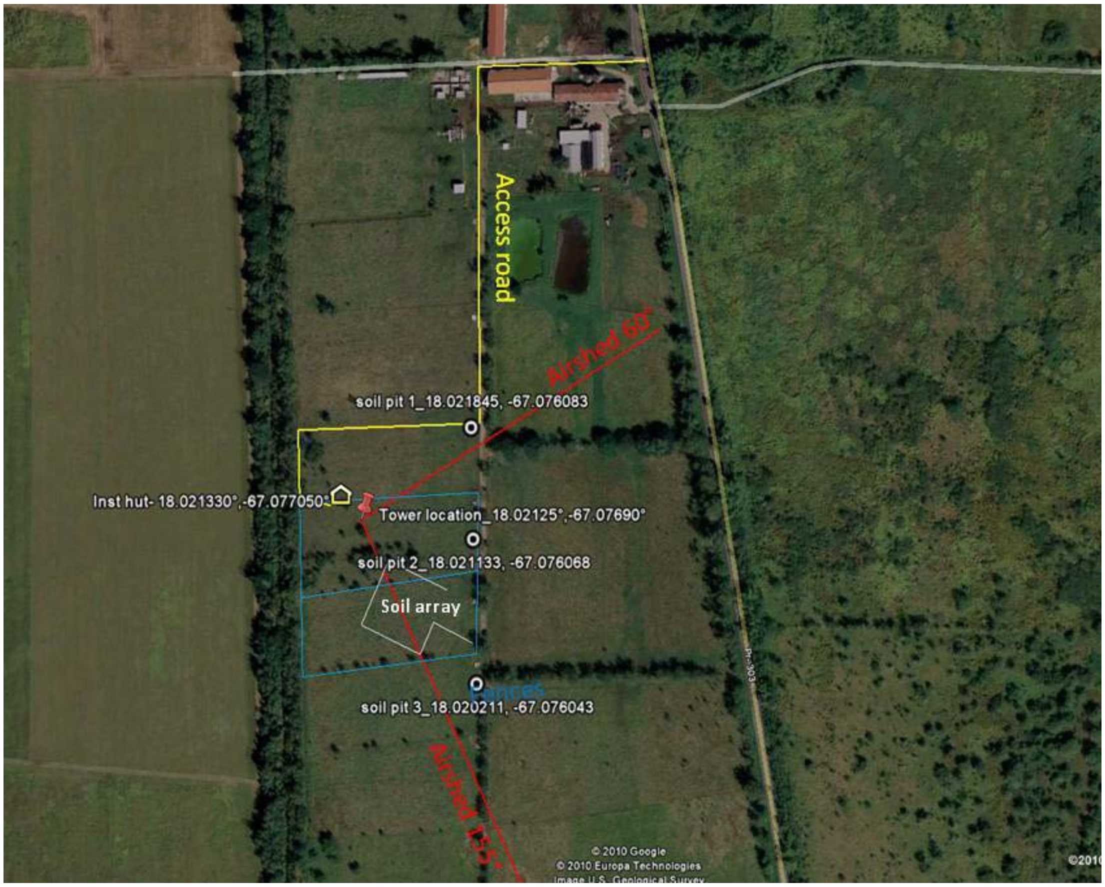


Figure 42. Plan view of the Site layout at Lajas Relocatable site

i) new tower location is presented, ii) red lines indicate the airshed boundaries. Vectors 60° and 155° are the North-eastern most and South-eastern most vectors (starting clockwise from 60°) that would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access road to instrument hut. iv) Blue lines are fences

Keep in mind that all **radiation sensors** above canopy need to be mounted on the south side of the tower to avoid shadow from tower structure and mounting parts.

Secondary **precipitation collector** for bulk precipitation collection will be located the top of tower at this site. No **wet deposition collector** will deployed at this site. See AD[02] for further information and requirements for bulk precipitation collection and wet deposition collection.

4.3.7 Information for ecosystem productivity plots

The tower at Lajas site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (grazing grassland). Wind vectors from the tower dictate the airshed is from 60 degrees to 155 degrees (clockwise from 60 degrees) in Figure 42, and 90% signals for flux measurements are within a distance of 500 m from tower, and 80% within 350 m. The road on the east most direction on the map is the boundary line. The FSU Ecosystem Productivity plots should be within the boundaries of the 60 degrees line, the 155 degree line and the road on east direction.

5 PONCE MAMEYES (RELOCATABLE TOWER SITE)

5.1 Site Description

The NEON relocatable site at Ponce, PR is designed to monitor urban environment. After several rounds of site selection, this site location is determined to be at Mameyes, a former landslide area, with help from the USDA-FS (Dr. S. Van Bloem as the key contact).

The landslide/mudslide occurred on October 7, 1985 during the tropical storm Isabel. A hilly region outside of the city collapsed under the oversaturated soil, burying much of the local community. It is hypothesized that the soils were already saturated by human waste, and the additional rains caused the landslide to occur. The landslide was responsible for at least 129 deaths (other reports says up to 500), and caused severe damage in the area. More than 100 homes were destroyed, and many others were later condemned due to soil instability. The mudslide (which by some estimates) was the worst landslide disaster in North American history. The only reclamation was at the bottom of the slope in the location of the memorial. Otherwise, the area was left as is, and a naturally regenerated secondary forest emerged through the rubble.

After the landslide and evacuation, most housing in this community collapsed or was destroyed, leaving large amounts of foundation and residential material on the ground surface or buried. 80 – 90% of the ground surface in this area is covered by housing debris. Plants naturally seeded and grew between the concrete gaps in the soil and on any rubble cavity. Plants rapidly formed a complete closed forest canopy, interweaving the roots from the plant canopy and the concrete rubble. The structure of this highly disturbed, secondary urban forest pairs closely with the natural forest found at Guanica.

Mameyes was an urban residential area that was abandoned after the landslide and has since reverted to a forest. From a scientific perspective, this is a unique site to study ecosystem recovery as well as the progress of invasive species after severe human and natural disturbance. It fits well with the planned NEON's design strategy for this domain, as well as contrasting well with other urban sites. Power is within ~200 m of the NEON candidate site, at the water treatment plant.

5.1.1 Ecosystem

Vegetation and land cover around tower site and surrounding area are presented below:

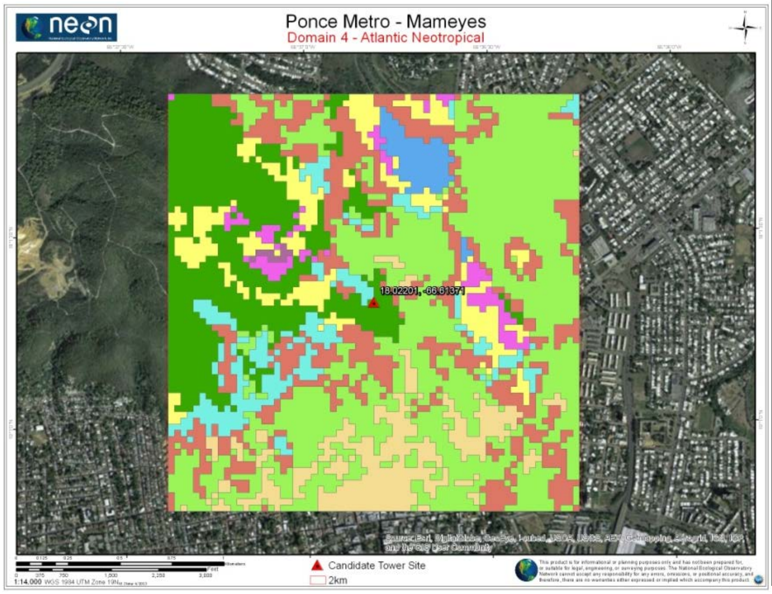


Figure 43. Vegetative cover map of the Ponce Mameyes relocatable site and surrounding areas

(From USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Table 13. Percent Land cover information at the Ponce Mameyes relocatable sit

Vegetation Type	Area (Km^2)	Percentage
Barren Land	0.01	0.23
Developed High Intensity	0.34	8.55
Developed Low Intensity	0.72	18.11
Developed Medium Intensity	1.48	37.18
Developed Open Space	0.25	6.22
Evergreen Forest	0.69	17.28
Grassland/Herbaceous	0.32	7.94
Open Water	0.08	2.13
Shrub/Scrub	0.09	2.37
TOTAL	3.98	100.00

(from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

The regenerated forest at Mameyes tower site is well-developed (see figure below). Currently, the overstory of this forest ecosystem is dominated by *Leucaena sp. Flanboyant (Delondx Resia) sp., African tulip tree (Spathodea Canpaulata), Mesquite (Presupes), Bacida Boswss, Caupas,* etc. The height of the overstory is ~ 21 m with its lower branches at ~ 14 m, and no obvious canopy strata. The younger seedlings form dense understory with height ranging from 1 to 5 m. Grasses, mother-in-law's tongue and other annuals cover the forest floor, with a height of ~ 1.5 m.

The ecosystem attributes to this site are summarized as following:

Table 14. Ecosystem and site attributes for the Mameyes Relocatable site

Ecosystem attributes	Measure and units
Mean canopy height	21 m
Surface roughness[a]	0.9 m
Zero place displacement height[a]	17 m
Structural elements	Well-developed overstory and understory, no obvious canopy strata
Time zone	Atlantic
Magnetic declination	12° 16' W changing by 0° 2' W/year
Frost-free period	365 days

[a] From footprint analysis below.

Figure 44. Forest ecosystem at the Ponce Mameyes Relocatable site

5.2 Soils

5.2.1 Soil Description

Soil data and soil maps below for Mameyes relocatable tower site 1 were collected from 1.6 km^2 NRCS soil maps (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

Figure 45. 1.6 km^2 soil map for Mameyas relocatable site 1

Map Unit Description: The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit. A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils. Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called non-contrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soil types or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas. An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a soil series. All the soils of a series have major horizons that are similar in composition, thickness, and arrangement. Soils of a given series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into soil phases. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series. Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups. A complex consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example. An association is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example. An undifferentiated group is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example. Some surveys include miscellaneous areas. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example. Additional information about the map units described in this report is available in other soil reports, which give properties of the soils and the limitations, capabilities, and potentials for many uses. Also, the narratives that accompany the soil reports define some of the properties included in the map unit descriptions.

Table 15. Soil Series and percentage of soil series within 1.6 km^2.

Ponce Area, Puerto Rico Southern Part (PR688)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
AgF	Aguilita gravelly clay loam, 20 to 60 percent slopes	216.7	54.5%
Jg	Jacaguas silty clay loam	6.6	1.7%
NOTCOM	Not complete	159.4	40.1%
Sa	San Anton clay loam	9.7	2.4%
YcC	Yauco silty clay loam, 5 to 12 percent slopes	5.5	1.4%
Totals for Area of Interest		**397.8**	**100.0%**

Ponce Area, Puerto Rico Southern Part - AgF—Aguilita gravelly clay loam, 20 to 60 percent slopes: Map Unit Setting Elevation: 150 to 820 feet Mean annual precipitation: 14 to 54 inches Mean annual air temperature: 70 to 88 degrees F Frost-free period: 365 days **Map Unit Composition** Aguilita and similar soils: 100 percent **Description of Aguilita Setting** Landform: Hillslopes Landform position (two-dimensional): Summit, shoulder, backslope Landform position (three-dimensional): Head slope, crest, side slope Down-slope shape: Linear, convex Across-slope shape: Convex, linear Parent material: Colluvium and residuum **Properties and qualities** Slope: 20 to 60 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 95 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Sodium adsorption ratio, maximum: 5.0 Available water capacity: Moderate (about 7.3 inches) **Interpretive groups** Land capability (nonirrigated): 7e **Typical profile** 0 to 13 inches: Gravelly clay loam 13 to 60 inches: Gravelly loam

Ponce Area, Puerto Rico Southern Part Jg—Jacaguas silty clay loam: Map Unit Setting Elevation: 20 to 200 feet Mean annual precipitation: 25 to 40 inches Mean annual air temperature: 79 to 81 degrees F Frost-free period: 365 days **Map Unit Composition** Jacaguas and similar soils: 95 percent Minor components: 5 percent **Description of Jacaguas Setting** Landform: Flood plains Landform position (two-dimensional): Footslope Landform position (three-dimensional): Tread Down-slope shape: Convex, linear Across-slope shape: Linear Parent material: Moderately fine textured stratified sediments **Properties and qualities** Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Excessively drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: Frequent Frequency of ponding: None Calcium carbonate, maximum content: 30 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Sodium adsorption ratio, maximum: 30.0 Available water capacity: Low (about 5.3 inches) **Interpretive groups** Land capability classification (irrigated): 3s Land capability (nonirrigated): 4c **Typical profile** 0 to 14 inches: Silty clay loam 14 to 60 inches: Very cobbly loam **Minor Components Machuelo** Percent of map unit: 5 percent Landform: Flood plains

Landform position (two-dimensional): Footslope Landform position (three-dimensional): Tread Down-slope shape: Linear Across-slope shape: Linear

Ponce Area, Puerto Rico Southern Part - NOTCOM—Not complete: Map Unit Composition Not complete: 100 percent

Ponce Area, Puerto Rico Southern Part - Sa—San Anton clay loam: Map Unit Setting Elevation: 0 to 160 feet Mean annual precipitation: 14 to 54 inches Mean annual air temperature: 70 to 88 degrees F Frost-free period: 365 days **Map Unit Composition** San anton and similar soils: 97 percent Minor components: 3 percent **Description of San Anton Setting** Landform: Flood plains Landform position (two-dimensional): Footslope Landform position (three-dimensional): Tread Down-slope shape: Linear Across-slope shape: Linear Parent material: Stratified alluvial deposits **Properties and qualities** Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: Occasional Frequency of ponding: None Calcium carbonate, maximum content: 5 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Sodium adsorption ratio, maximum: 2.0 Available water capacity: High (about 9.8 inches) **Interpretive groups** Land capability classification (irrigated): 1 Land capability (nonirrigated): 2c **Typical profile** 0 to 22 inches: Clay loam 22 to 27 inches: Loam 27 to 34 inches: Silty clay loam 34 to 52 inches: Silt loam 52 to 60 inches: Clay loam **Minor Components Vayas** Percent of map unit: 3 percent Landform: Flood plains Landform position (two-dimensional): Toeslope Landform position (three-dimensional): Talf Down-slope shape: Linear Across-slope shape: Linear

Ponce Area, Puerto Rico Southern Part YcC—Yauco silty clay loam, 5 to 12 percent slopes Map Unit Setting Elevation: 10 to 500 feet Mean annual precipitation: 20 to 40 inches Mean annual air temperature: 79 to 81 degrees F Frost-free period: 365 days **Map Unit Composition** Yauco and similar soils: 100 percent **Description of Yauco Setting** Landform: Hillslopes Landform position (two-dimensional): Backslope, footslope Landform position (three-dimensional): Base slope, side slope Down-slope shape: Concave Across-slope shape: Linear, convex Parent material: Calcareous sediments **Properties and qualities** Slope: 5 to 12 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 95 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Sodium adsorption ratio, maximum: 2.0 Available water capacity: Moderate (about 8.4 inches) **Interpretive groups** Land capability classification (irrigated): 3e Land capability (nonirrigated): 4c **Typical profile** 0 to 10 inches: Silty clay loam 10 to 20 inches: Silty clay loam 20 to 60 inches: Loam

5.2.2 Soil semi-variogram description

Due to the large amount of building material debris across the entire site it was not possible to insert the soil temperature and soil moisture sensors into the ground. As a result the semivariogram analysis that is performed at most NEON sites to determine the spacing between TIS soil plots could not be performed.

5.2.2.1 Soil array layout and soil pit location

The minimum distance allowable between soil plots is 25 m to ensure a degree of spatial independence and the maximum distance allowable between soil plots is 40 m due to cost constraints. Since the semivariogram analysis could not be performed to guide soil plot spacing at this site we conservatively choose the maximum allowable distance between soil plots at Mameyes based on the site design guidelines above (i.e., 40 m). The soil array shall follow a compact soil array design (Soil Array Pattern C) with the soil plots being 5 m x 5 m. The direction of the soil array shall be 175° from the soil plot nearest the tower (i.e., first soil plot, Fig. 40). The location of the first soil plot will be approximately 18.022167°, -66.613599°. The exact location of each soil plot may be micrbelieved to avoid placing a soil plot at an unrepresentative location (e.g., rock outcrop, drainage channel, large tree, etc). The FIU soil pit for characterizing soil horizon depths, collecting soil for site-specific sensor calibration, and collecting soil for the FIU soil archive will be located at 18.022505°, -66.614144° (primary location); or 18.022281°, -66.613965° (alternate location 1 if primary location is unsuitable); or 18.022630°, -66.614281° (alternate location 2 if primary location is unsuitable). A summary of the soil information is shown in Table 16 and site layout can be seen in Figure 41.

Dominant soil series at the site is not available as it is currently mapped as “Not complete” on the USDA NRCS Web Soil Survey.

Table 16. Summary of soil array and soil pit information at Memeyes. 0° represents true north and accounts for declination

Soil plot dimensions	5 m x 5 m
Soil array pattern	C
Distance between soil plots: x	40 m
Distance from tower to closest soil plot: y	21 m
Latitude and longitude of 1st soil plot OR direction from tower	18.022167°, -66.613599°
Direction of soil array	175°
Latitude and longitude of FIU soil pit 1	18.022505°, -66.614144° (primary location)
Latitude and longitude of FIU soil pit 2	18.022281°, -66.613965° (alternate 1)
Latitude and longitude of FIU soil pit 3	18.022630°, -66.614281° (alternate 2)
Dominant soil type	Not available
Expected soil depth	Not available (expected to be >2m)
Depth to water table	Not available

Expected depth of soil horizons	Expected measurement depths*
Not available†	Not available†

*Actual soil measurement depths will be determined based on measured soil horizon depths at the NEON FIU soil pit and may differ substantially from those shown here.

†The soil array area has not been fully mapped on the NRCS Web Soil Survey yet.

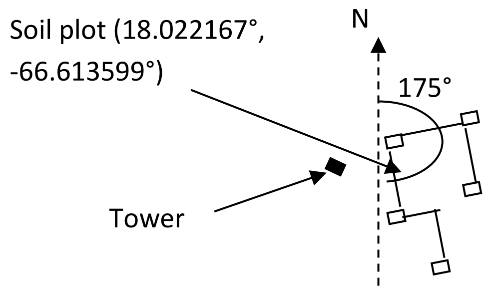


Figure 46. Schematic diagram of soil array layout in relation to tower. Soil plot positions are approximate

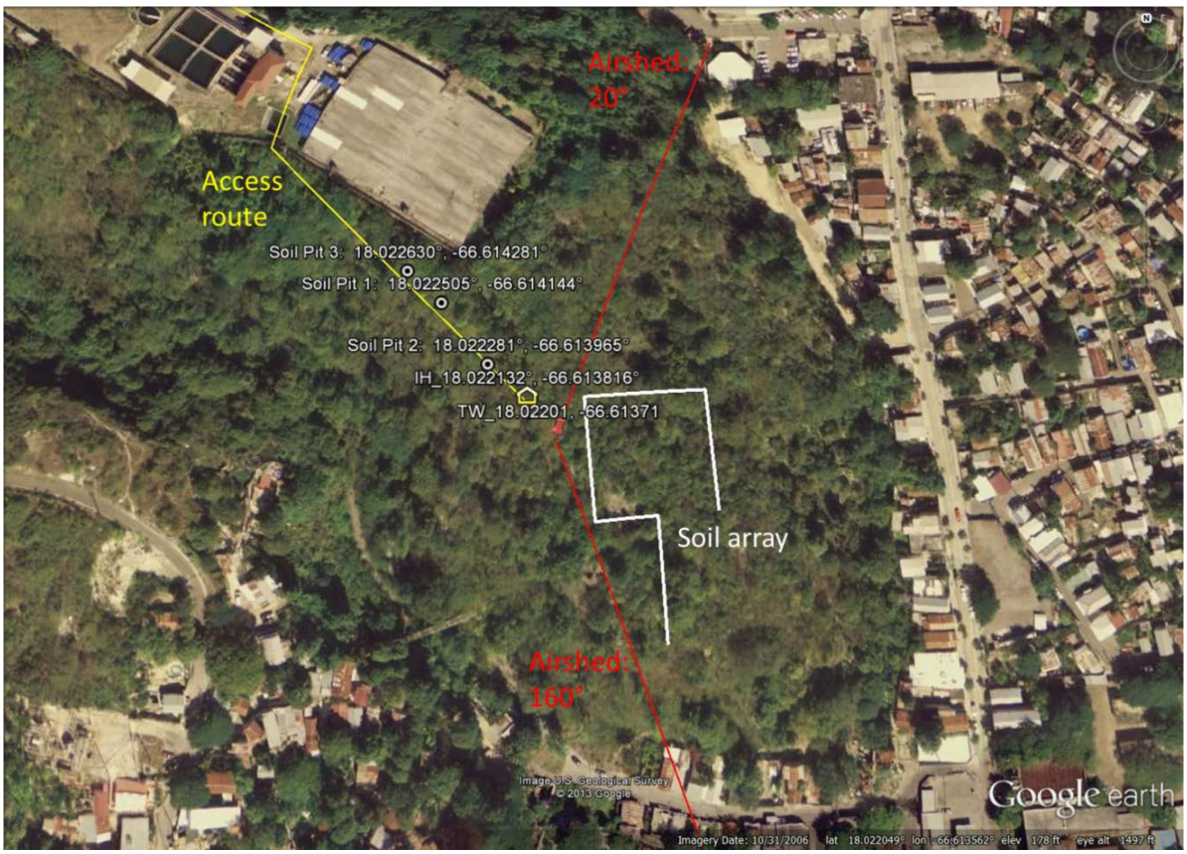


Figure 47. Site layout at Mameyes showing soil array and location of the FIU soil pit

5.3 Airshed

5.3.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries. The weather data used to generate the following wind roses are from Mercedita airport, PR, which is ~5 miles east of NEON Ponce Mameyes Relocatable site. The orientation of the wind rose follows that of a compass (assume declination applied). When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. Color bands depict the range of wind speeds. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 24 cardinal directions.

5.3.2 Results (graphs for wind roses)

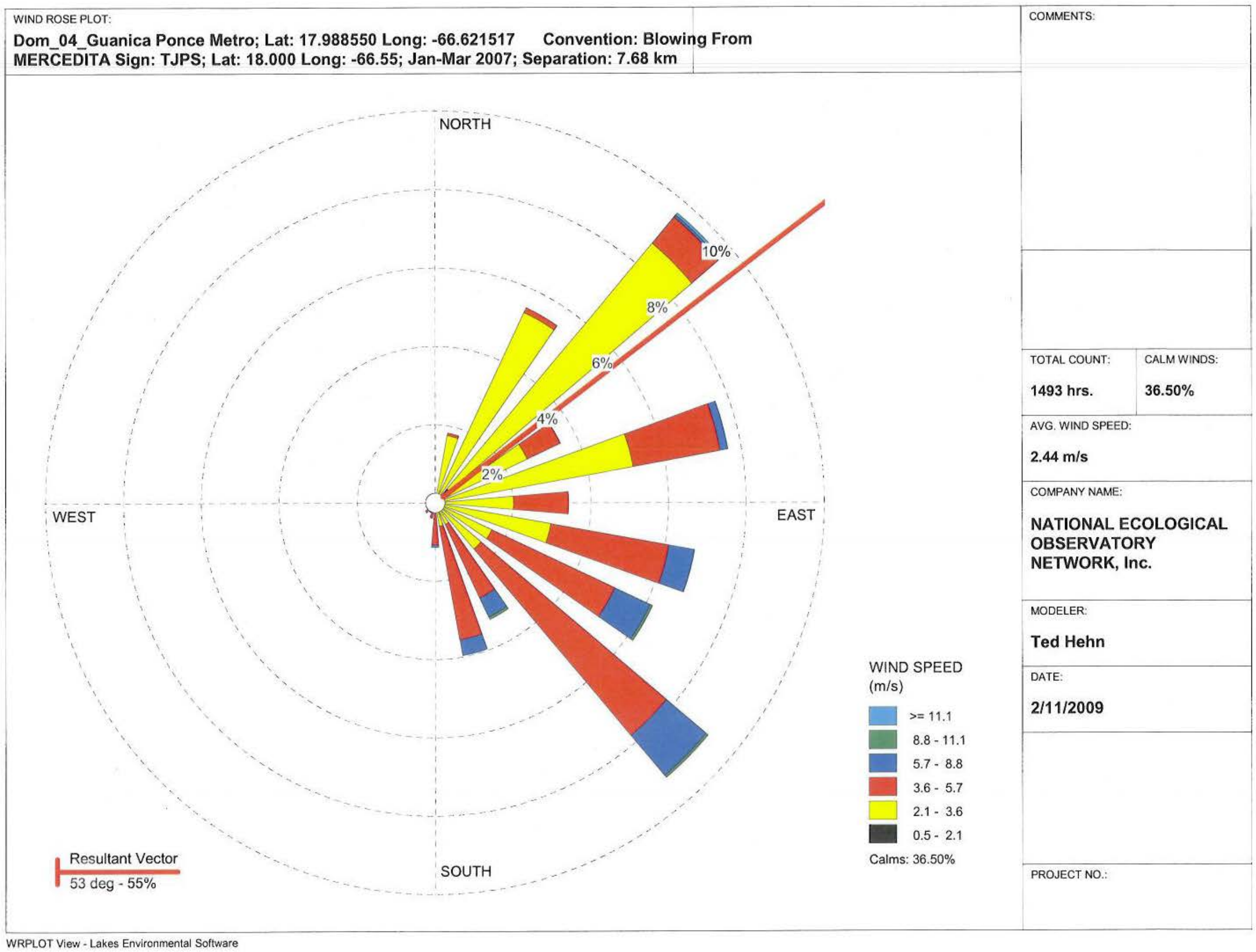


Figure 48. Windroses of January – March for D04 Ponce Mameyes Relocatable site

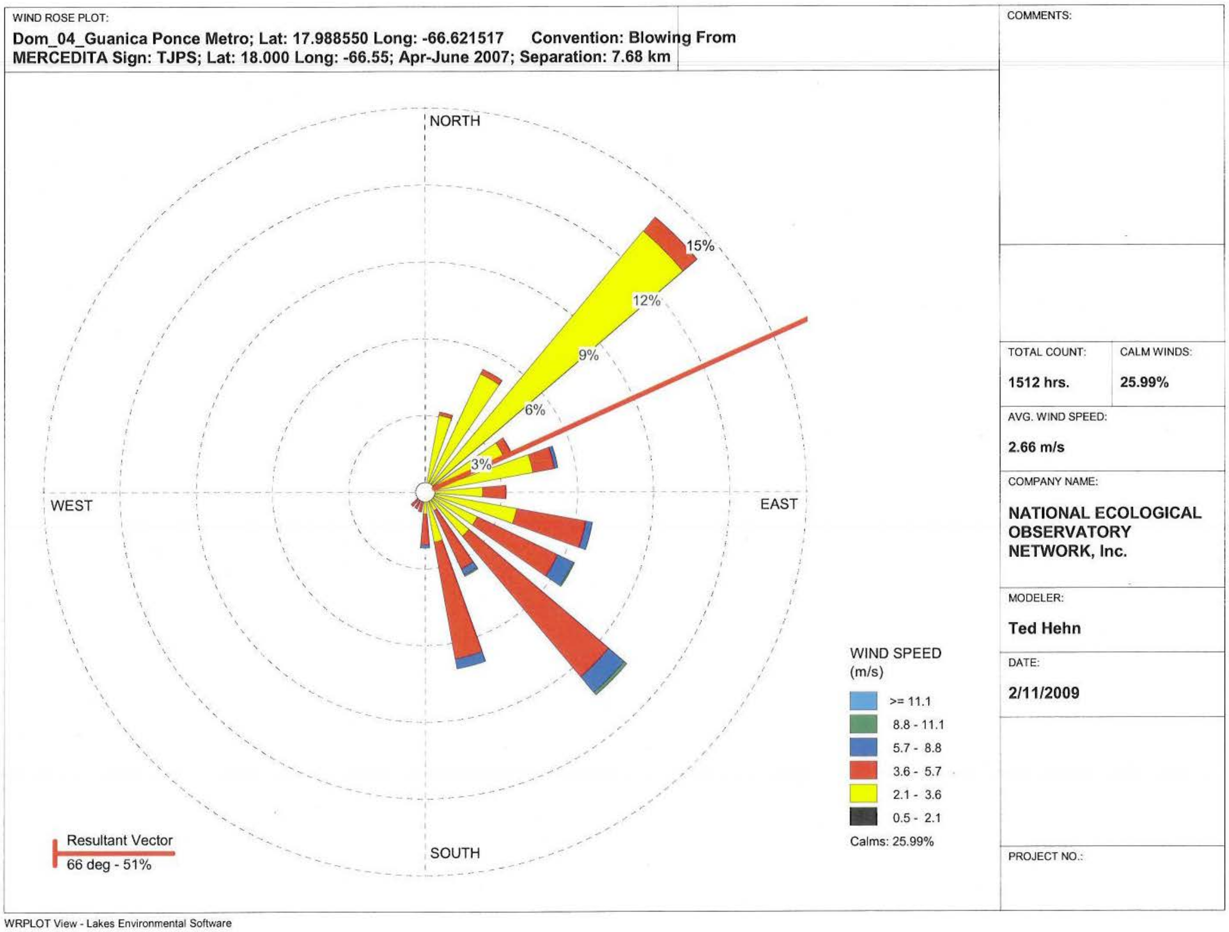


Figure 49. Windroses of April-June for D04 Ponce Mameyes Relocatable site

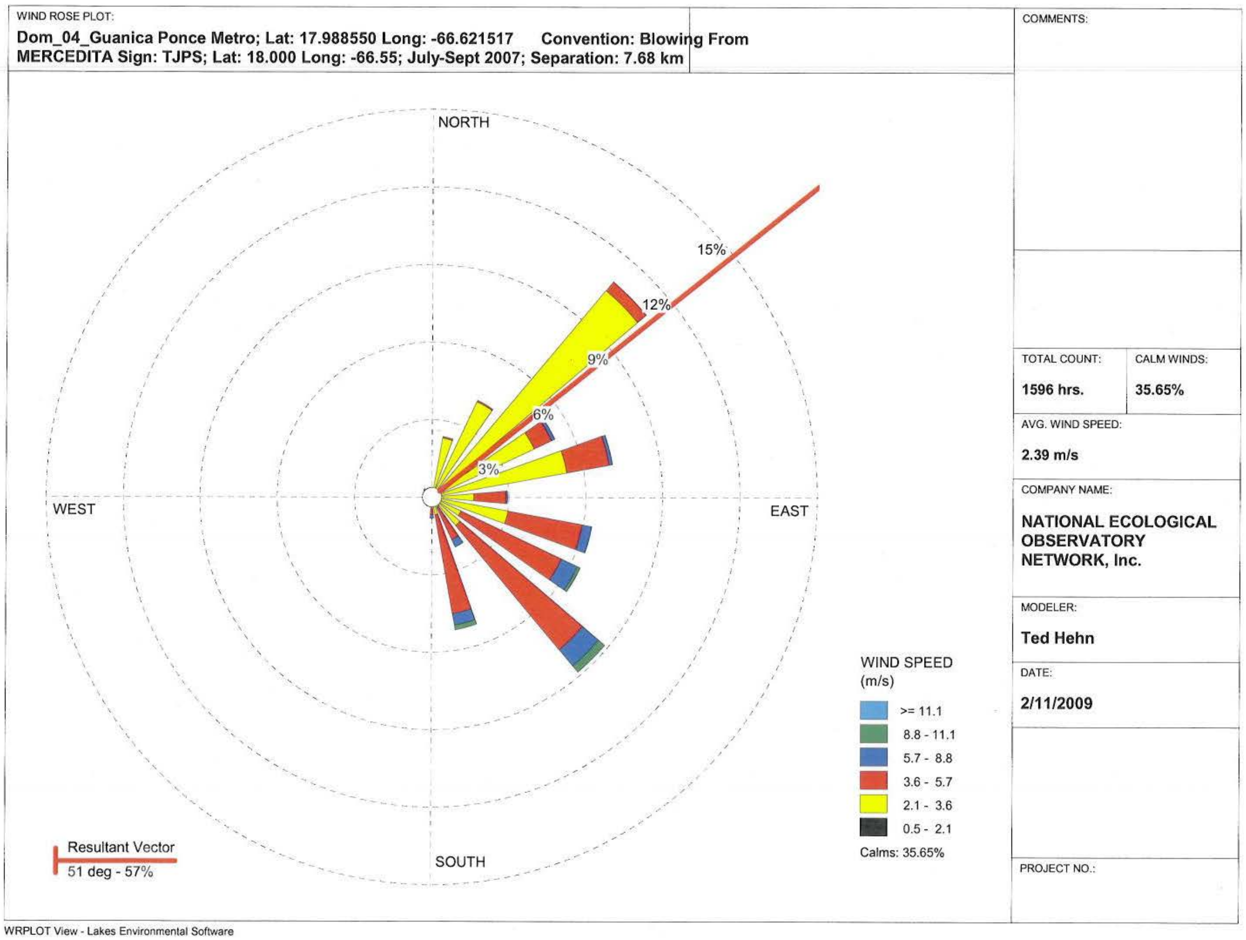


Figure 50. Windroses of July – September for D04 Ponce Mameyes Relocatable site

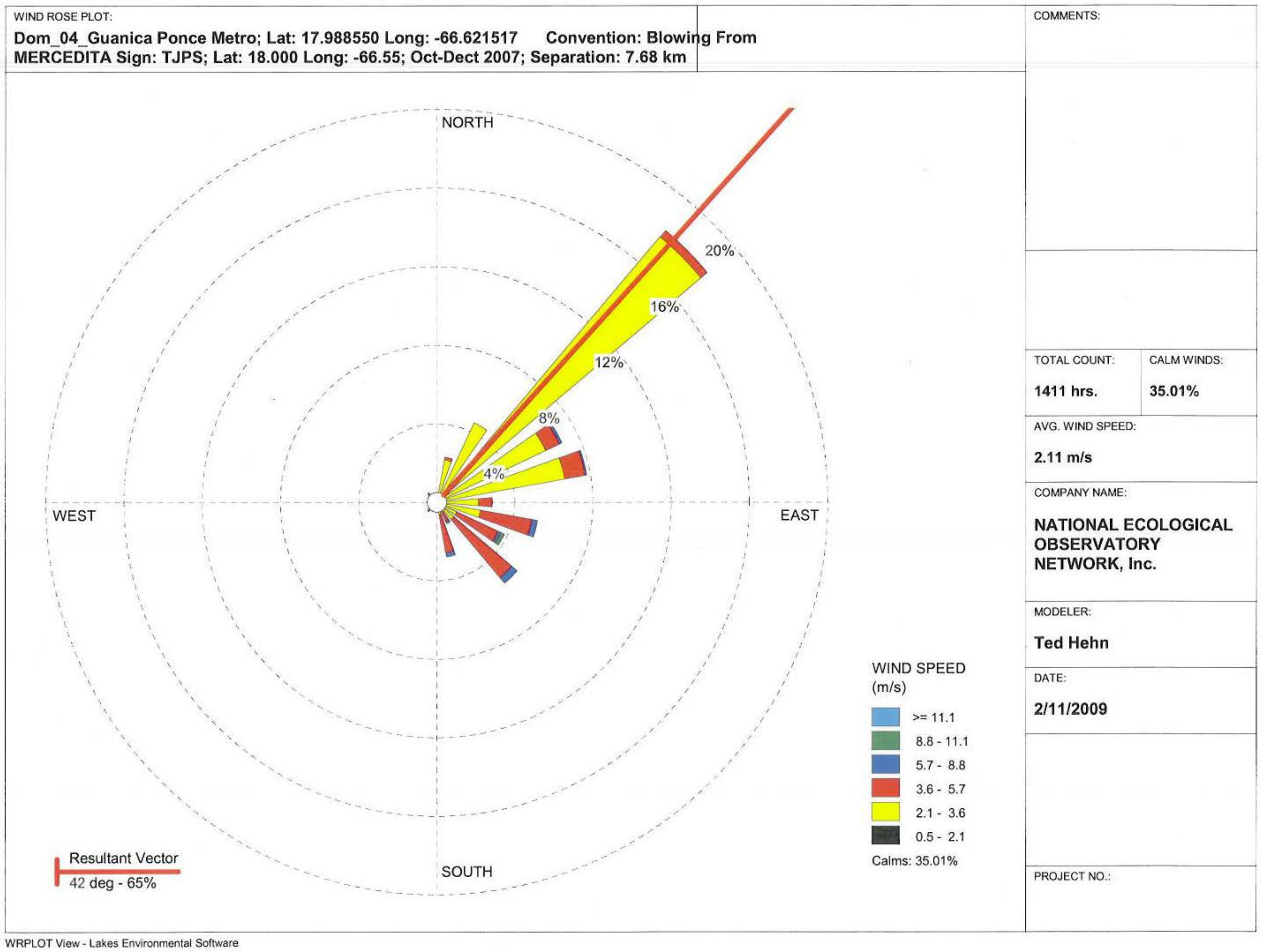


Figure 51. Windroses of October-December for D04 Ponce Mameyes Relocatable site

5.3.3 Expected environmental controls on source area

Two types of models were commonly used to determine the shape and extent of the source area under different and contrasting atmospheric stability classes. An inverted plume dispersion model with modeled cross wind solutions were used for convective conditions (Horst and Weil 1994). For strongly stable conditions, and Lagrangian solution was used (Kormann and Meixner 2001). The source area models where bounded by the expected conditions depict the extreme conditions. Convective conditions typically have strong vertical mixing between the ecosystem and atmosphere (surface layer). Stable conditions typically have long source area and associated waveforms. Convective turbulence is often characterized by short mixing scales (scalar) and moderate daytime wind speeds, *e.g.,* 1-4 m s^{-2}. Higher wind speeds, like those experienced over the Rockies, are often the product of mechanical turbulence with long waveforms. Because thermal stratification is very efficient in suppressing vertical mixing, stable conditions also have typically very long waveforms.

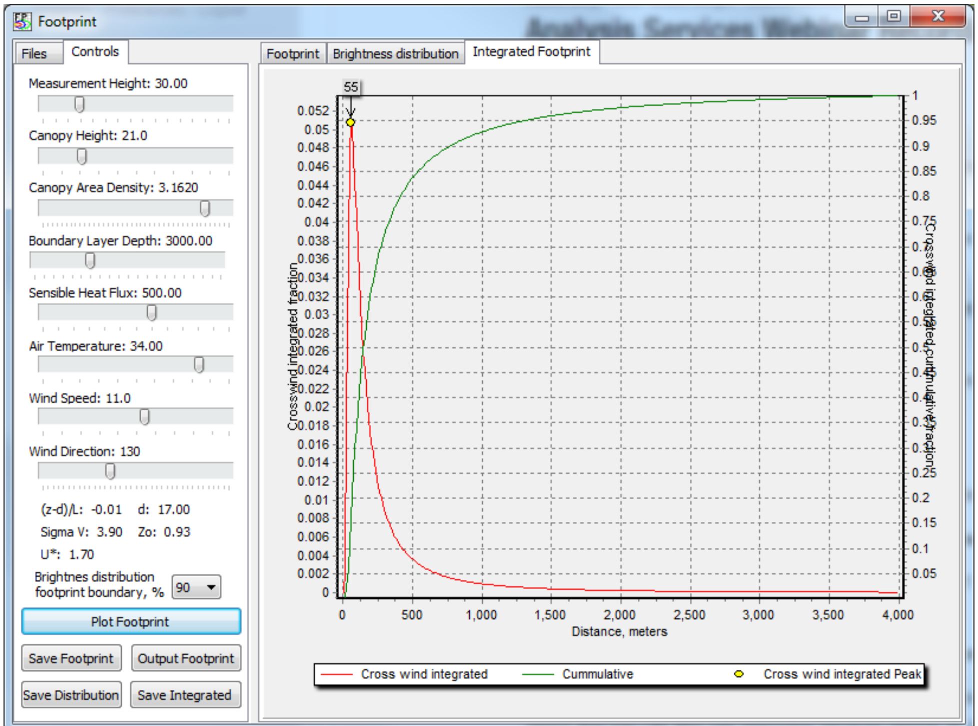
As a general rule, shorter and less structurally complex ecosystems have good vertical mixing during all atmospheric stabilities. Taller and more structurally complex ecosystems have well mixed upper canopies during the daytime, and can be decoupled below the canopy under neutral and stable conditions (e.g., Harvard Forest, Bartlett Experimental Forest, and Burlington Conservation Area). The type of turbulence (mechanical verses convective) and the physical attributes of the ecosystem control the degree of mixing, and the length and size of the source area.

Here, with support from Dr. R. Clement, we use a web-based footprint model that made by Micrometeorology Group at University of Edinburgh, UK to determine the footprint area under various conditions (model info: http://www.geos.ed.ac.uk/abs/research/micromet/EdiTools/). Winds used to run the model and generate following model results are extracted from the wind roses. Vegetation information, temperature and energy information were either from the RFI document, previous site visit report, available data files or best estimated from experienced expert. Measurement height was determined during FIU site characterization at site. Runs 1-3 and 4-6 represents the expected conditions for summer and winter conditions, respectively, with maximum and mean windspeeds (daytime convective) and nighttime (stable atmospheres) conditions. The wind vector for each run was estimated from wind roses and is placed as a centerline in the site map included in the graphics. The width of the footprint was also estimated using the length between the isopleth of 80% cumulative flux and center line to calculate the angle from centerline. This information, along with distance of the cumulative flux isopleths and wind direction, will define the source area for the flux measurements on the top of the tower.

Table 17. Expected environmental controls to parameterize the source area model, and associated results from Ponce Mameyes Relocatable tower site

Parameters	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	**Units**
Approximate season	summer			winter			
	Day (max WS)	Day (mean WS)	Night	Day (max WS)	Day (mean WS)	night	qualitative
Atmospheric stability	Convective	convective	Stable	Convective	convective	Stable	qualitative
Measurement height	30	30	30	30	30	30	m
Canopy Height	21	21	21	21	21	21	m
Canopy area density	3.5	3.5	3.5	3.2	3.2	3.2	m
Boundary layer depth	3000	3000	1500	1000	1000	700	m
Expected sensible heat flux	500	500	75	250	250	25	$W\ m^{-2}$
Air Temperature	33	33	24	24	24	20	°C
Horizontal windspeed	11	4.6	3.0	12	4.5	3.2	$m\ s^{-1}$
Resultant wind vector	130	130	50	135	135	45	degrees
Results							
(z-d)/L	-0.01	-0.14	-0.09	-0.01	-0.09	-0.03	m
d	17	17	17	17	17	17	m
Sigma v	3.9	2.6	1.3	3.8	1.8	1.10	m s
Z0	0.93	0.93	0.93	0.93	0.93	0.93	m
u*	1.7	0.80	0.5	1.8	0.74	0.5	$m\ s^{-1}$
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	750	450	500	800	500	700	m
Distance of 80% cumulative flux	400	250	300	450	300	400	m
Distance of 70% cumulative flux	300	200	250	300	240	280	m
Peak contribution	55	45	55	55	55	55	m

5.3.4 Footprint model results (source area graphs)



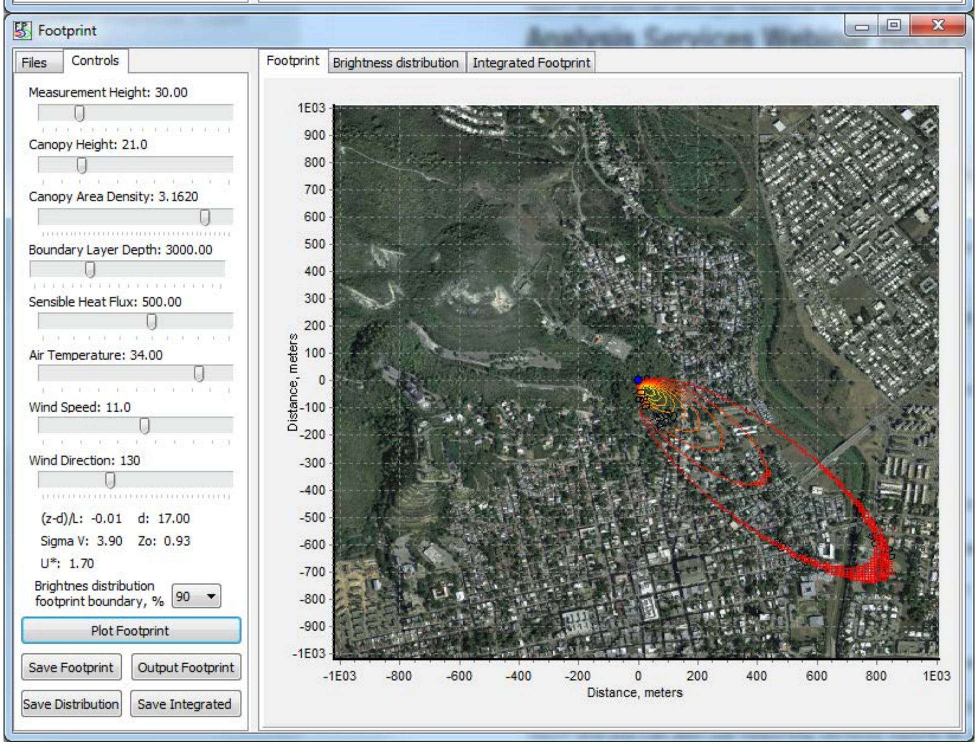


Figure 52. Ponce Mameyes summer daytime (convective) footprint output with max wind speed

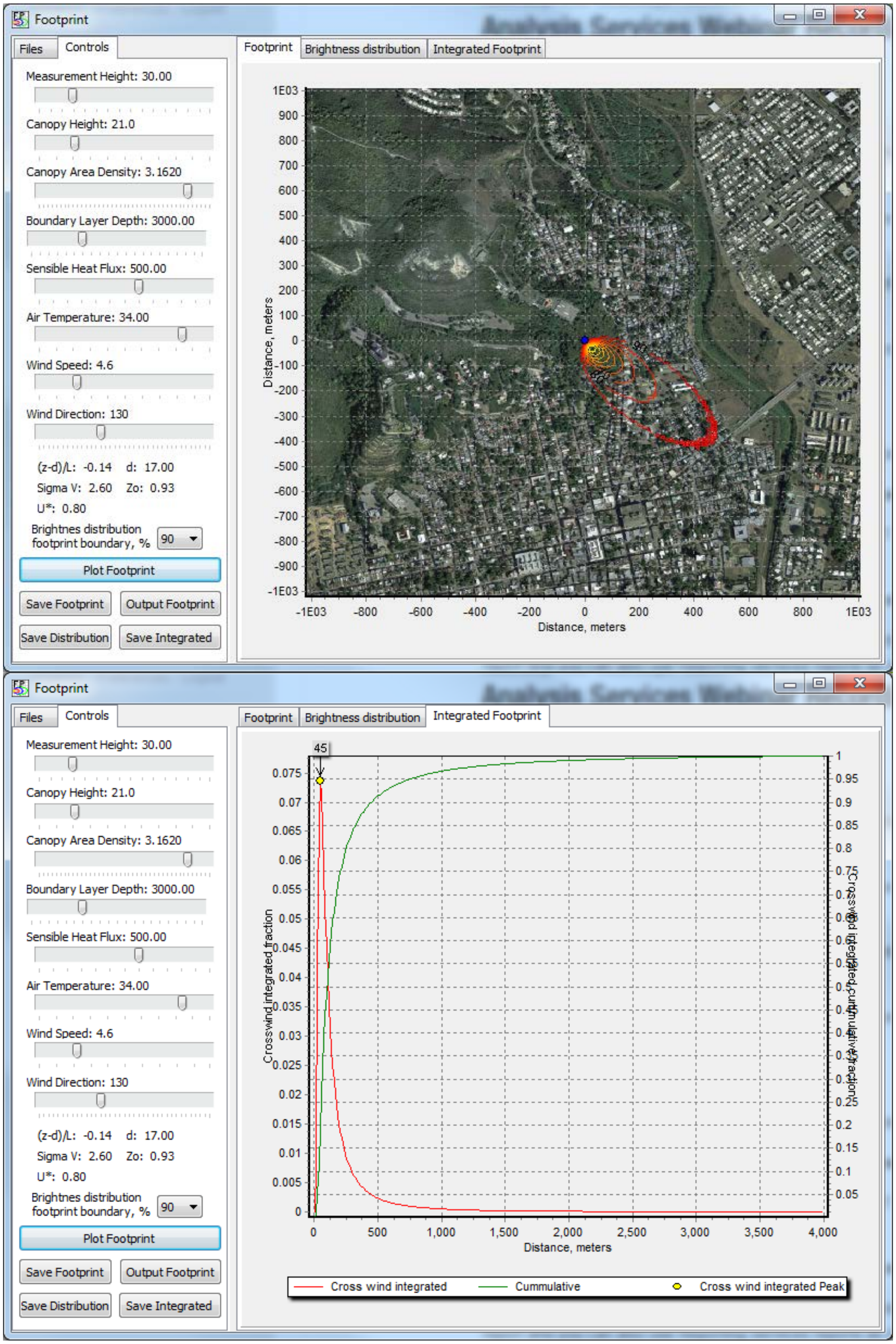


Figure 53. Ponce Mameyes summer daytime (convective) footprint output with mean wind speed

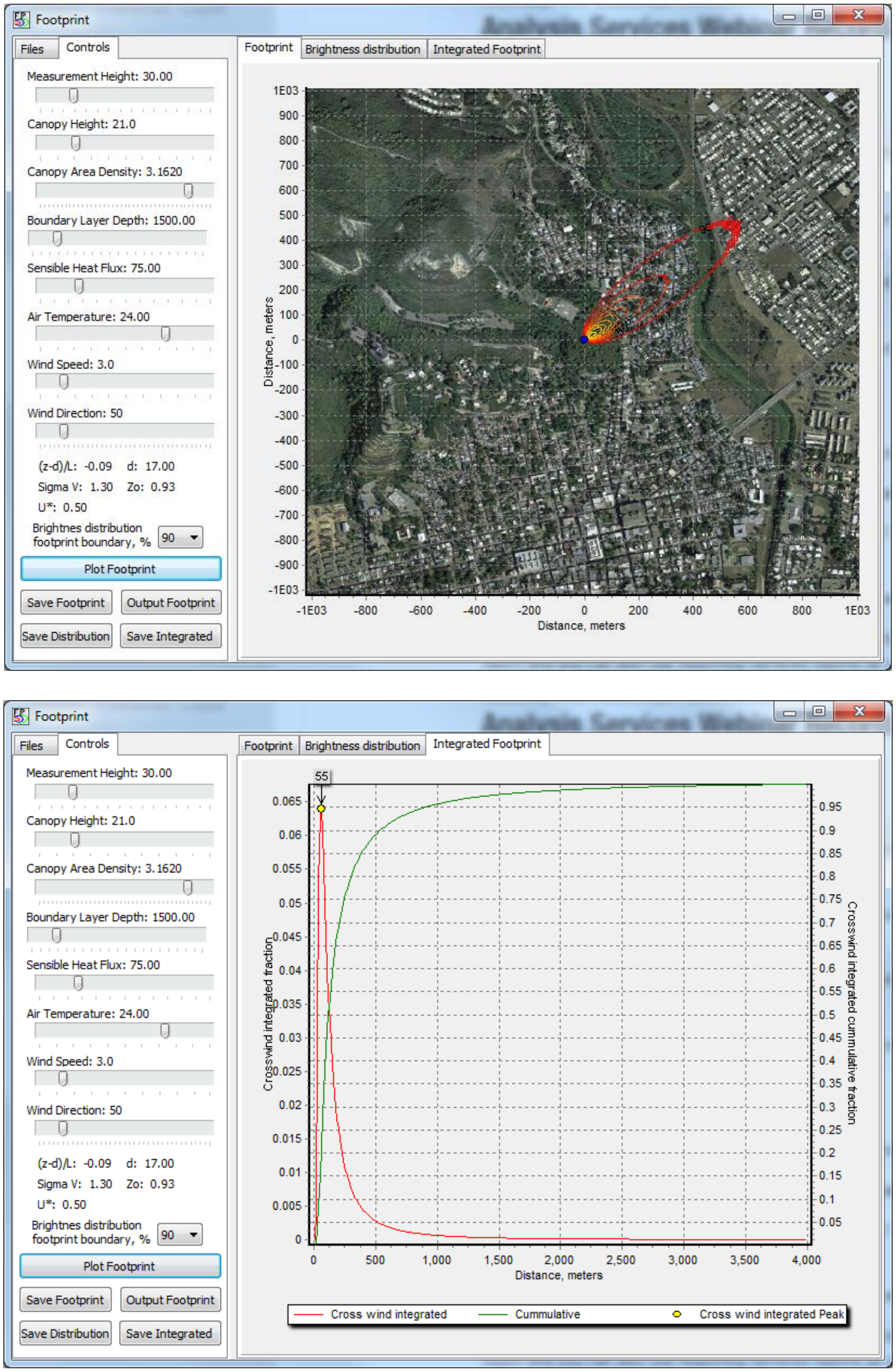
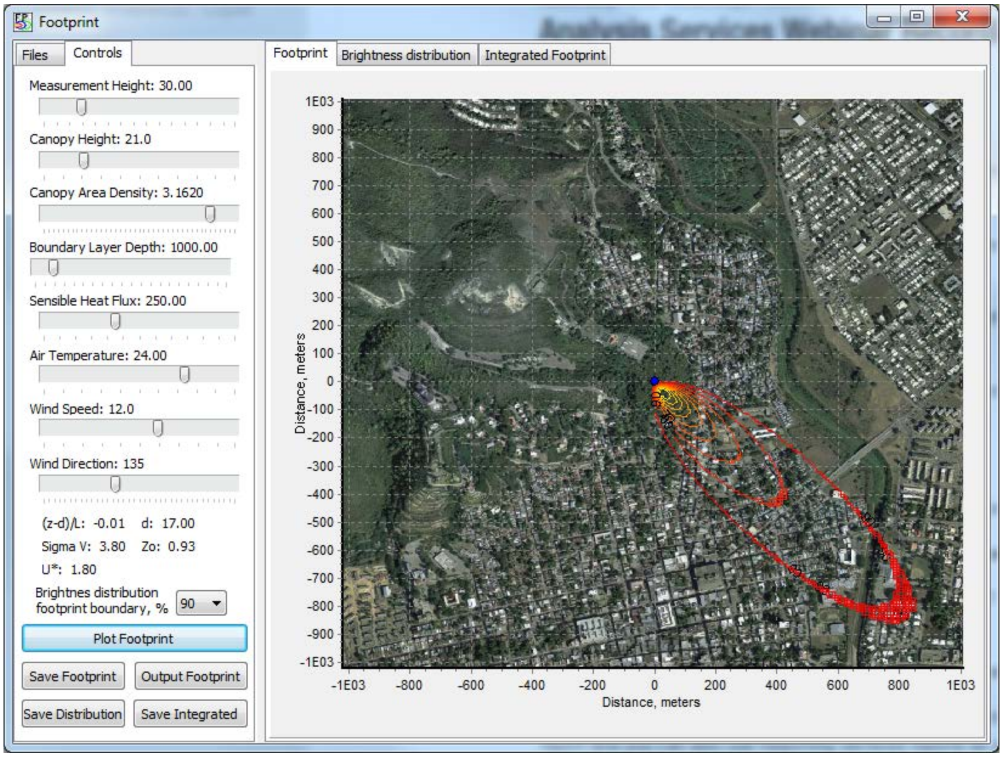


Figure 54. Ponce Mameyes summer nighttime (stable) footprint output with mean wind speed



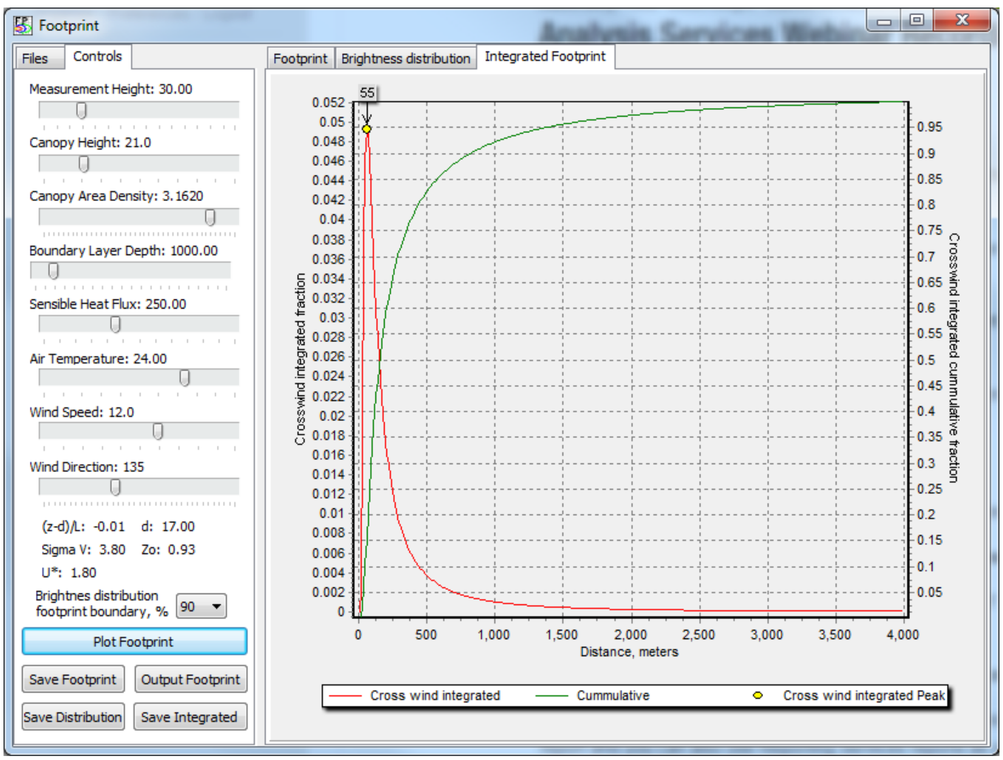
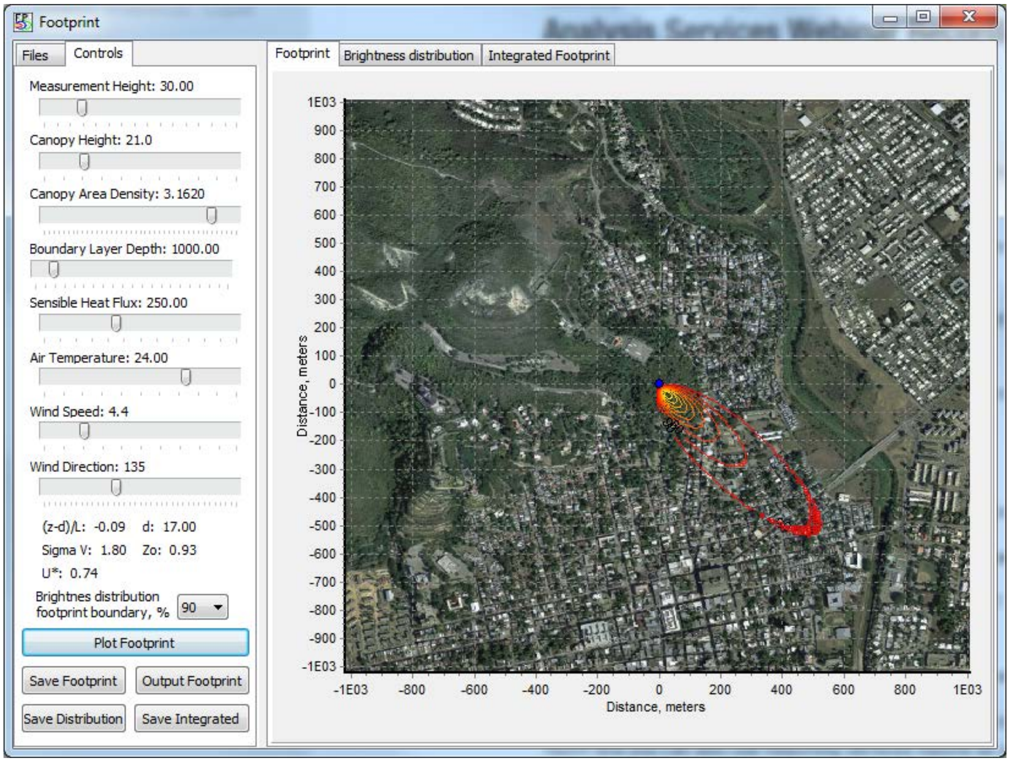


Figure 55. Ponce Mameyes winter daytime (convective) footprint output with max wind speed



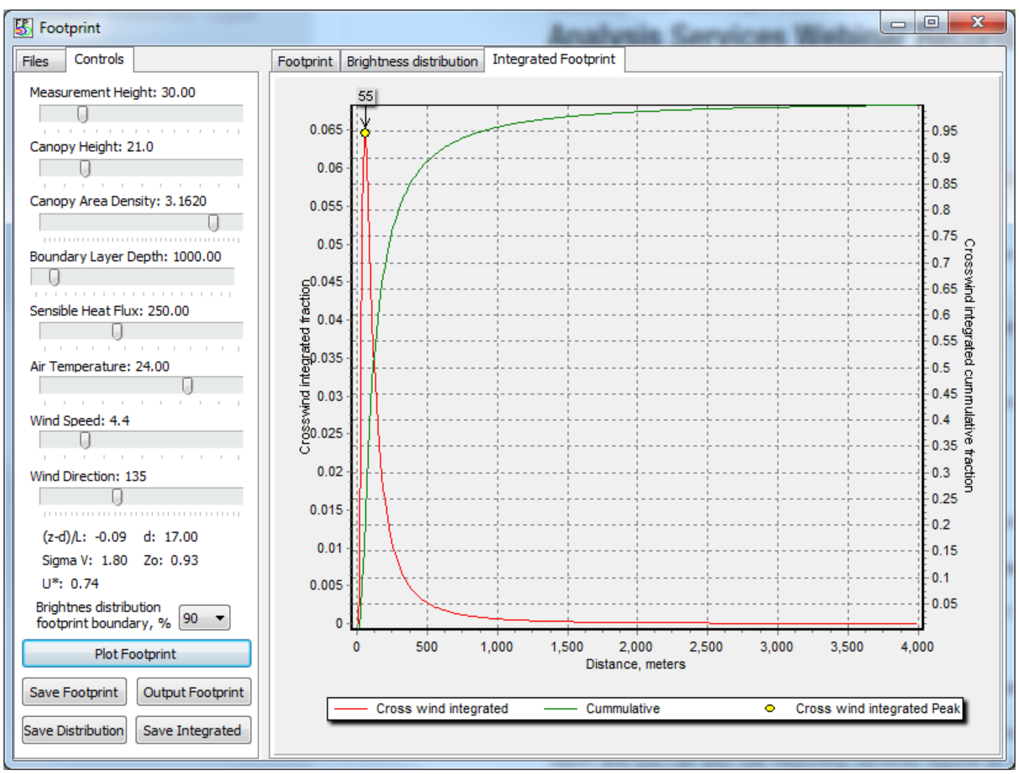
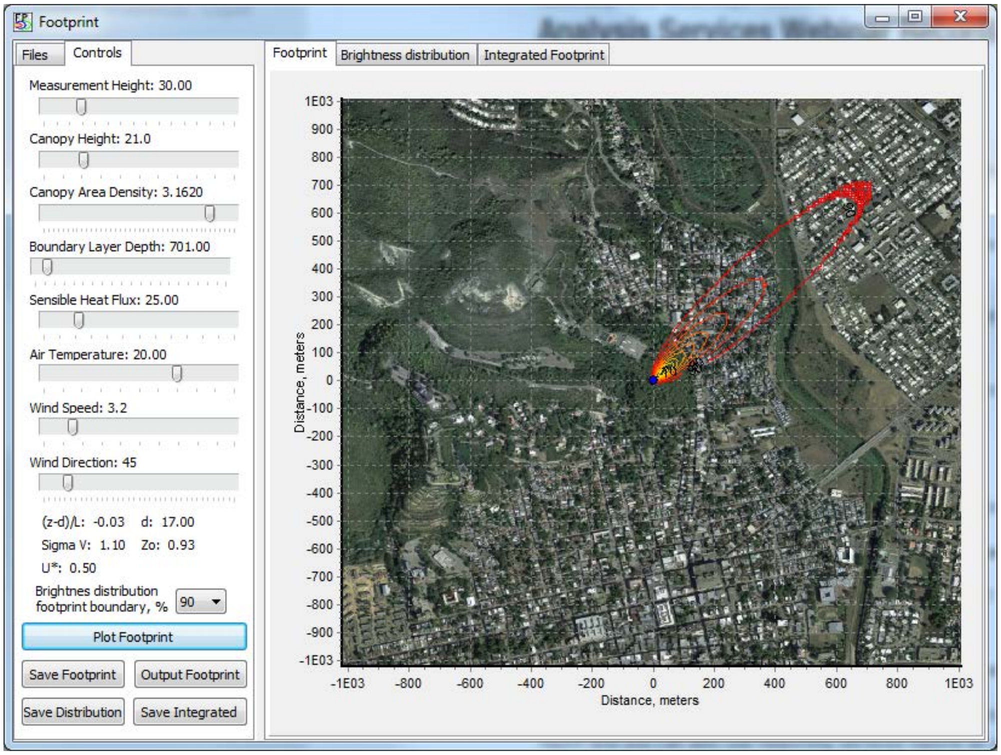


Figure 56. Ponce Mameyes winter daytime (convective) footprint output with max wind speed



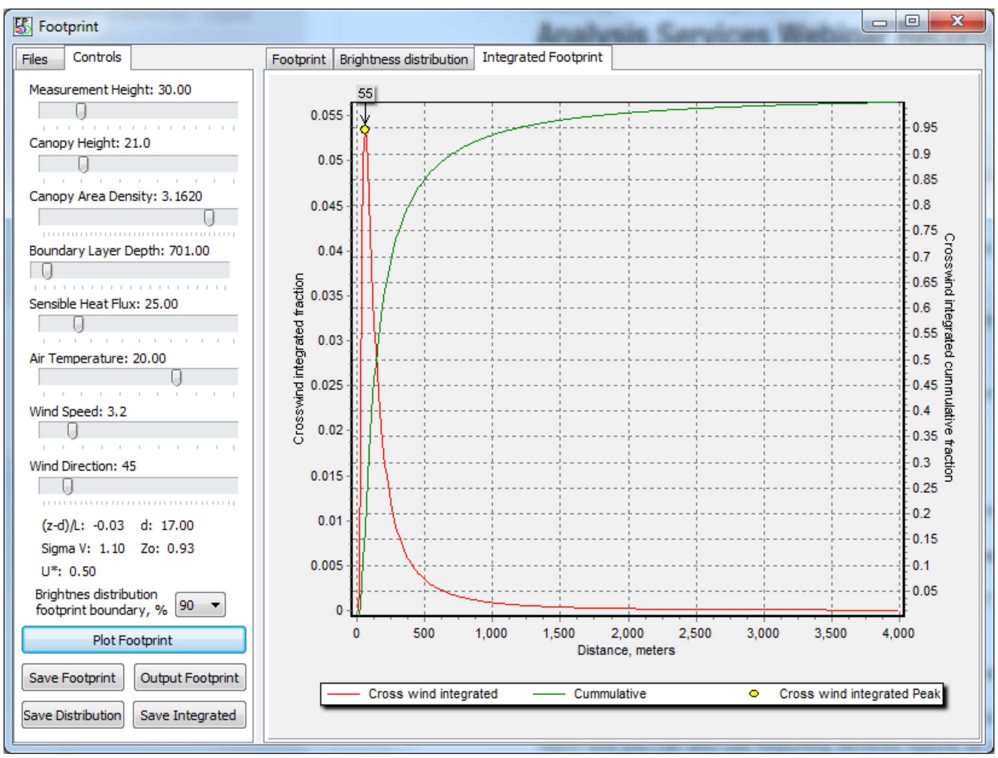


Figure 57. Ponce Mameyes winter nighttime (stable) footprint output with mean wind speed

5.3.5 Tower location, instrument hut location, boardwalks, measurement layers on the tower and other sensor locations

According to the wind roses, the prevailing wind direction during the daytime is from S, SE, NE, which are residential, urban areas. But accordingly to the local landscape, we expect that the prevailing nighttime winds will be mainly from cold drainage from the high slopes on the W. To best catch the ecosystem flux scales from all directions and minimize the impact of the water treatment plant, the tower location at this site will be at 18.02201, -66.61371 (80 m from closest forest edge), and instrument hut at 18.022132°, -66.613816°. The distance between the tower and the instrument hut is ~ 14 m.

Eddy covariance, sonic wind and air temperature **boom arms** orientation pointing to 90° will be best to capture signals from all major wind directions. **Radiation boom arms** should always be facing south to avoid any shadowing effects from the tower structure.

The regenerated forest at Mameyes tower site is well-developed (see figure below). Currently, the overstory of this forest ecosystem is dominated by *Leucaena sp. Flanboyant (Delondx Resia) sp., African tulip tree (Spathodea Canpaulata), Mesquite (Presupes), Bacida Boswss, Caupas,* etc. The height of the overstory is ~ 21 m with its lower branches at ~ 14 m, and no obvious canopy strata. The younger seedlings form dense understory with height ranging from 1 to 5 m. Grasses, mother-in-law's tongue and other annuals cover the forest floor, with a height of ~ 1.5 m. Therefore, we require 6 **measurement layers** on the tower with top measurement height at 30 m, and remaining levels are at 25 m, 21 m, 17 m, 3 m and 0.3 m, respectively, to best characterize the fluxes on the tower top and the microclimate scales.

Secondary **precipitation collector** for bulk precipitation collection will be located the top of tower at this site. No **Wet deposition collector** will be collocated at the tower top. See AD[02] for further information and requirements for bulk precipitation collection and wet deposition collection.

The site layout is summarized in the table below. Assume the projected area of the tower is square. **Anemometer/temperature boom arm direction** is ***from*** the tower ***toward*** the prevailing wind direction or designated orientation. The side of the tower with the anemometer boom is perpendicular to the boom direction. **Instrument hut orientation vector** is parallel to the long side of the instrument hut. **Instrument hut distance z** is the distance from the center of tower projection to the center of the instrument hut projection on the ground. The numbering of the **measurement levels** is that the lowest is level one, and each subsequent increase in height is numbered sequentially.

In the following table, 0° is true north with declination accounted for. Color of Instrument hut exterior shall be tan or best match the surrounding environment.

Table 18. Site design and tower attributes for Ponce Mameyes Relocatable site

Attribute	lat	long	degree	meters	notes
Airshed			20° to 160°		Clockwise from first angle.
Tower location	18.02201,	-66.61371	--	--	new site
Instrument hut	18.022132°	-66.613816			
Instrument hut orientation vector	--	--	270°-90°		
Instrument hut distance z	--	--	--	17.5	
Anemometer/Temperature boom orientation	--	--	90°	--	
Height of the measurement levels					
Level 1				0.3	m.a.g.l.
Level 2				3.0	m.a.g.l.
Level 3				17.0	m.a.g.l.
Level 4				21.0	m.a.g.l.
Level 5				25.0	m.a.g.l.
Level 6				30.0	m.ag.l.
Tower Height				30.0	m.a.g.l.

See AD[01] for technical requirement to determine the boom height for the bottom most measurement level.

Figure below shows the proposed tower location, instrument hut location, airshed area and access road.

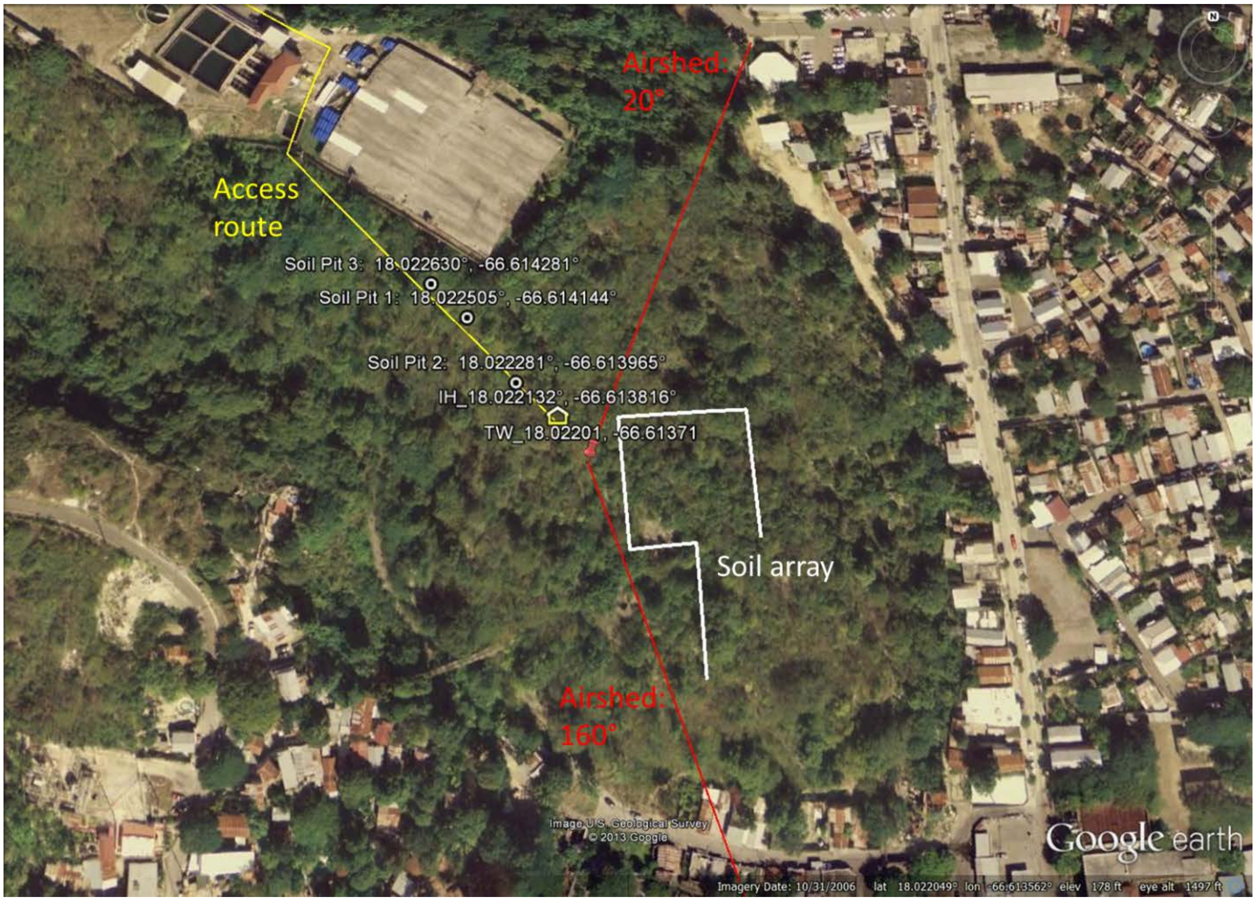


Figure 58. Site layout for Ponce Mameyes Relocatable site

i) tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors from 20^{o} to 160^{o} (clockwise from 20^{o}, major airshed) would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access way to instrument hut.

Boardwalks. Ultimately, the decision to use a boardwalk will be, in part, based on owner's preferences. There are strong science requirements that minimize site disturbance to the surrounding area, which will be difficult to manage over a 30-year period. Traffic control is key to minimizing the site disturbance. Confining foot traffic to boardwalks minimizes site impact; this is particularly true in places where wear caused by foot traffic becomes noticeable and grows. For example, in places with snow part of the year, worn footpaths tend to have low places that collect water, or places where the snow pack becomes uneven causing personnel to walk farther and farther around the sides of the original path, causing the path to grow in width. This is a very common phenomenon. FIU assumes that all conduits will be either buried, or placed inside the boardwalk such that it does not extend beyond the 36' wide footprint. While the final design is not yet known, there are some general criteria that can be outlined. We assume that the boardwalk width is 36" (0.914 m). Material is not known, but must be fire proof, and in some locations the site is seasonally flooded and inundated with water. Boardwalks may also provide a scratching structure for grazing animals that in turn, would wear and unduly impact the site. Site by site evaluations must be done.

Vegetation is dense at this site. To minimize the impacts on the tree roots, and to let field crew access site safely for route works, specific boardwalks at this site:

- Boardwalk from the access dirt road to instrument hut, pending landowner decision.
- Boardwalk from the instrument hut to the tower.
- Boardwalk to soil array Boardwalk from soil array boardwalk to individual soil plots.

The relative locations between tower, instrument hut and boardwalk can be found in the diagram below:

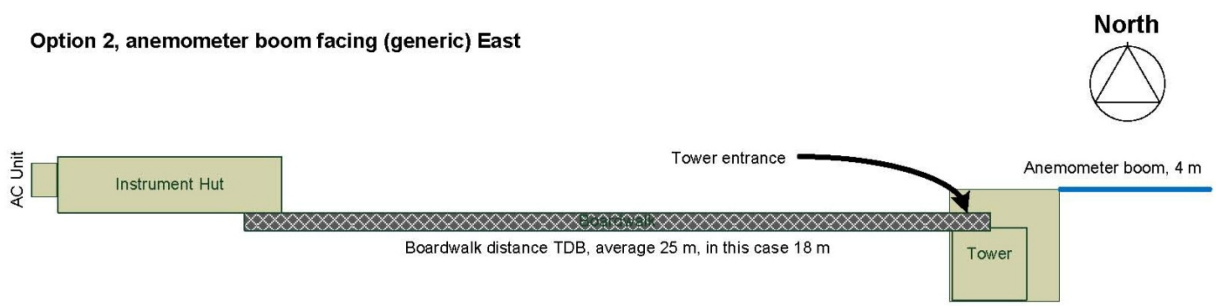


Figure 59. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing east and instrument hut on the west side of the tower

Because the ecosystems has a height of the mean plant canopy > 1.75 m and the tower has to pass through the plant canopy vertically, tower has been sited to i) allow the tower protrude through the canopy with minimal foliage removal during the tower establishment, ii) optimize the temporal coverage of flow-based measurements over the representative environment, iii) minimize flow distortions caused by local ecosystem structure or topography (orography), and iv) allow the sensors on the tower booms to measure the representative surrounding environment. The location identified here and its (final) placement (e.g., during reviews, construction activities, FCC micrositing) will have to be evaluated against these conditions and requirements.

To avoid edge effect on science measurements, tower, soil array, and sensor locations have been sited such that the meteorological sensors and soil sensors are ≥ 60 m away from the edge of the representative ecosystem in interest. However, due to the small size of the forest area, flux sensors are < 180 m from the edge of the forest ecosystem, and the footprint area extends into the urban residential area. The sensor locations identified here and its (final) placement (e.g., during reviews, construction activities, FCC micrositing) will have to be evaluated against these conditions and requirements.

5.3.6 Information for ecosystem productivity plots

The tower at Ponce Mameyes site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (regenerated forest under the impacts of urban environment). Wind vectors from the tower dictate the airshed is from 20 degrees to 160 degrees (clockwise from 20 degrees), and 90% signals for flux measurements are within a distance of 800 m from tower, and 80% within 500 m.

5.4 Issues and concerns

Based on our observations, we highlight the following issues and concerns at this site:

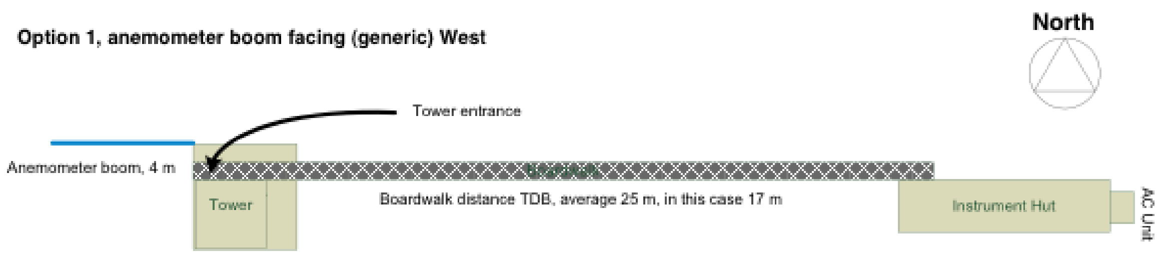
1. The regenerated forest area is small. The signals measured by some tower sensors are likely mixed with both forest ecosystem and surrounding urban environment.
2. 80-90% of the ground surface and soil were covered by the concrete and metal materials (See figure below). It will be a challenge for FCC to establish a tower foundation and an instrument hut foundation. Heavy machinery may be needed to excavate. But it is challenging to determine how to bring the heavy machinery to the site through the dense canopy without significantly impacting the site and vegetation.
3. 80-90% of the ground surface and soil were covered by concrete and metal material. After several hours of visual inspection, FIU can only identify two possible locations for soil plots. It will be a challenge to deploy the full FIU measurements here. A special design may be needed for this site.
4. A memorial park was built and dedicated to the victims of the landslide area. The proposed site is next to a memorial park but still in the landslide area. Hence, permitting may be challenging. The construction of a tower and disturbing the ground may become an issue to the families of the victims.
5. This small piece of land is surrounded by lower-income neighborhoods.
6. Safety concerns:
    a. This site is close to Ponce drinking water treatment plant, which is a gated and fenced property. If the NEON tower and instrument hut are fenced within the existing property and personnel can gain access through the water plant's gate, the tower and instrument hut will be well secured. Fencing around the water treatment plant can be extended to accommodate tower and instrument hut. This site does not appear to be used by the local communities, as evidenced by little of no walking paths throughout the area.
    b. The concrete and metal debris (see figure below) on the ground create an uneven surface filled with hidden holes that are often covered by leaves and plants, generating potential safety concerns for field crews. Dense forest and vines make it difficult to walk around.
    c. Due to the close proximity of houses to the site, human safety may be a concern in this area, but not any more or less than that found elsewhere in Ponce (pers comm. Vice

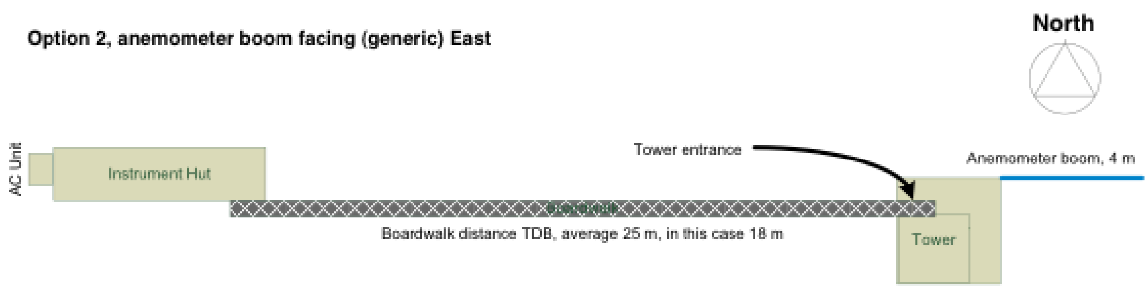
Mayor Arturo Valis). Field technicians should not have any concern at this site during daylight hours.

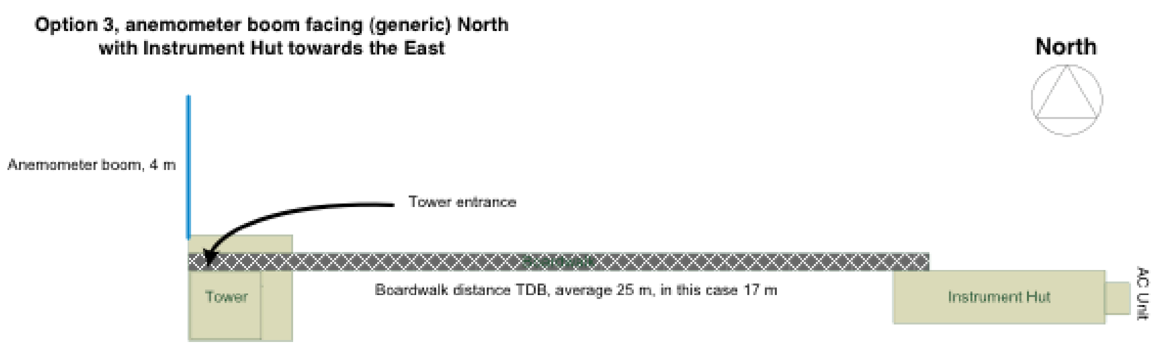
d. Tower and instrument hut locations will be less than 200 m from the neighborhood housing. Theft, vandalism and destruction of property are a common occurrence in this area, though this can be minimized through fencing and access through the water treatment plant.

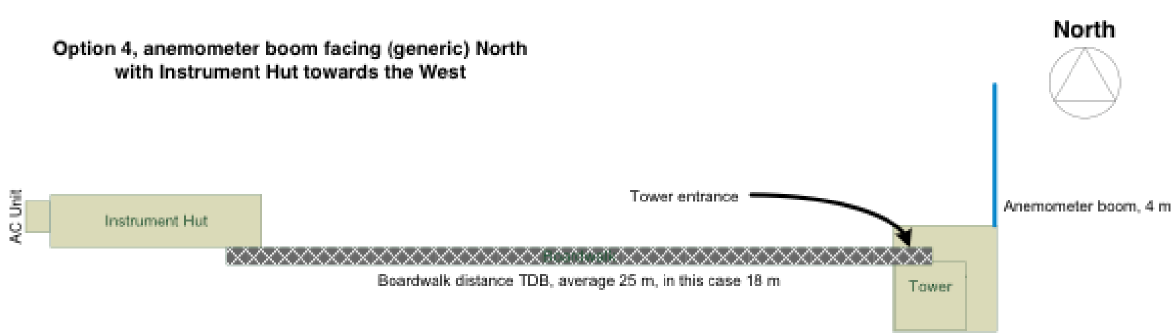
Figure 60. Typical view of the concrete and metal debris on the ground surface at Ponce Mameyes tower site.

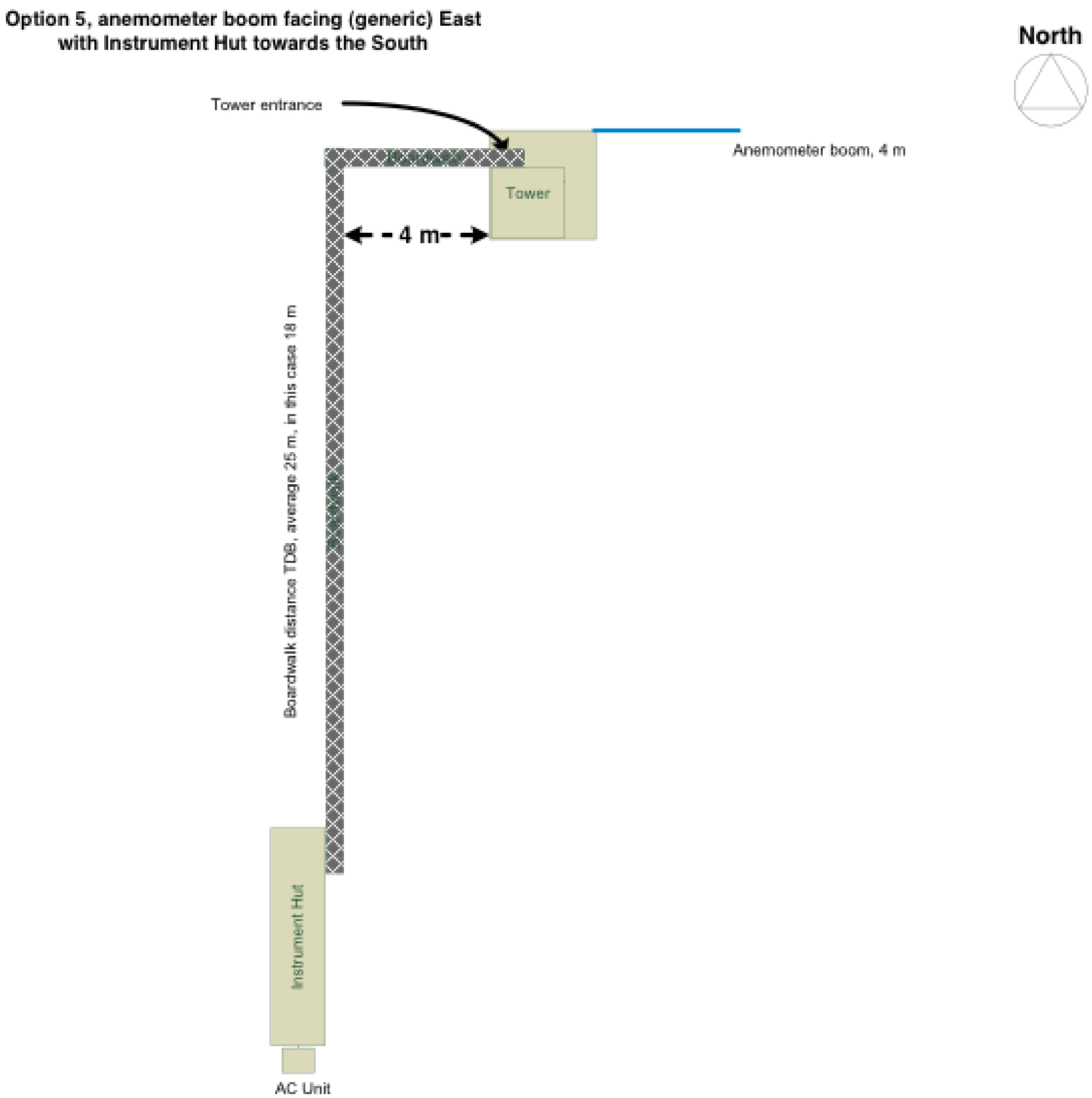
APPENDIX A: GENERIC SITE LAYOUTS AND SOIL ARRAY PATTERNS

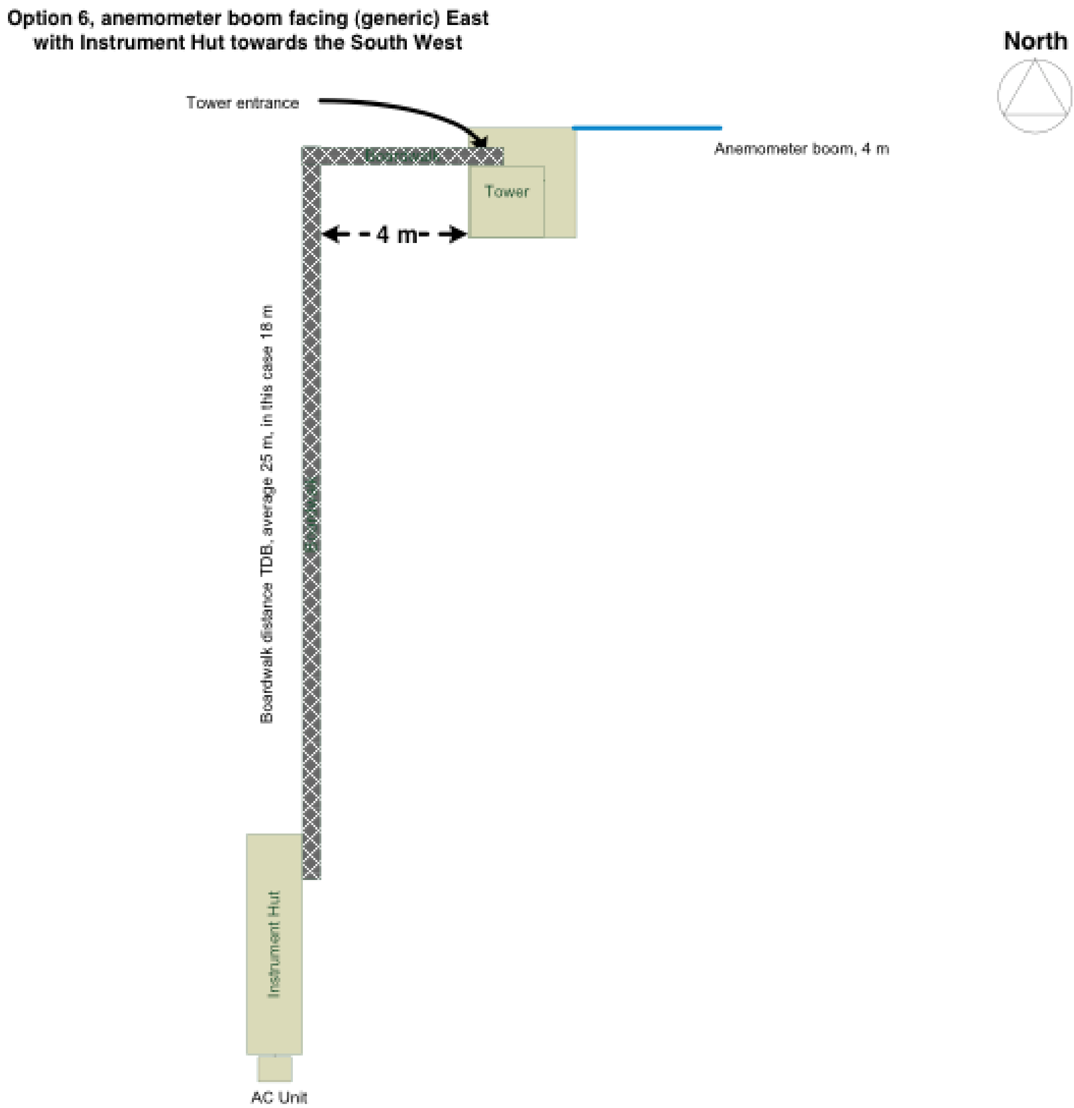




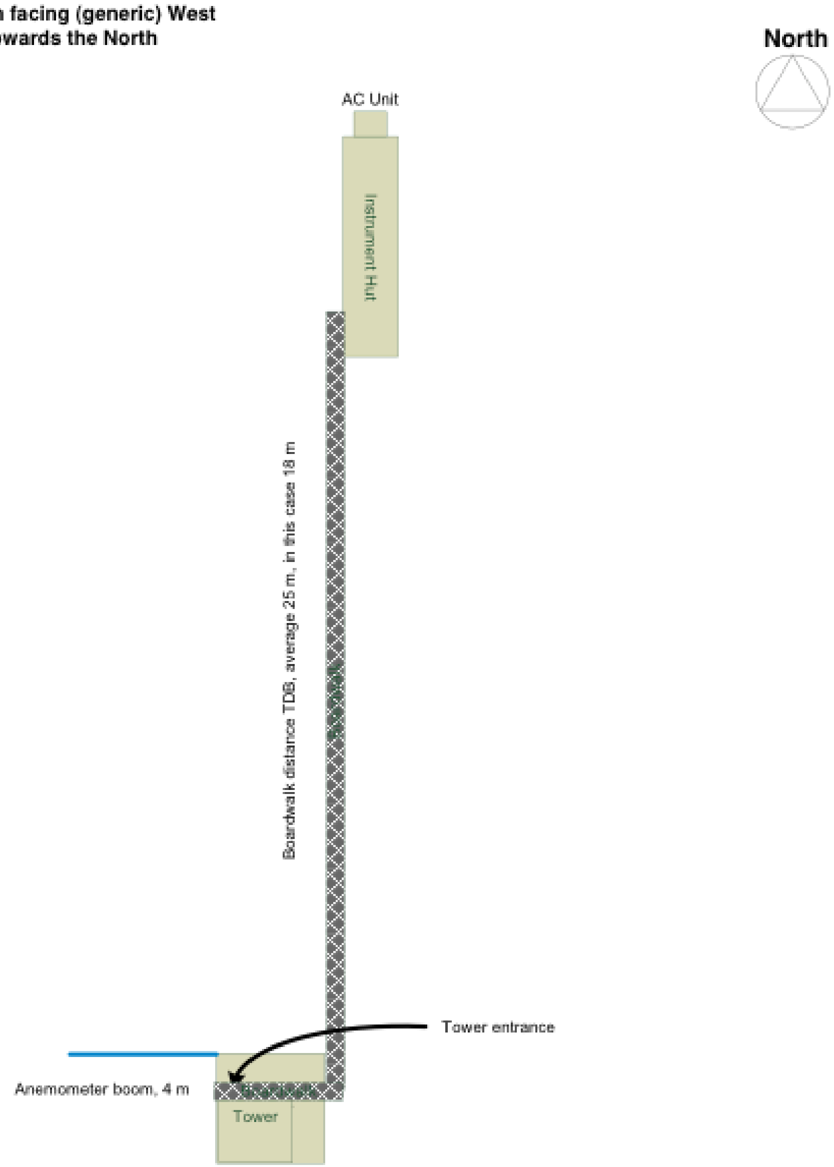





Option 5, anemometer boom facing (generic) East
with Instrument Hut towards the South
North
Tower entrance
Anemometer boom, 4 m
Tower
- 4 m-
Boardwalk distance TDB, average 25 m, in this case 18 m
Instrument Hut
AC Unit


Option 6, anemometer boom facing (generic) East
with Instrument Hut towards the South West
North
Tower entrance
Anemometer boom, 4 m
Tower
4 m
Boardwalk distance TDB, average 25 m, in this case 18 m
Instrument Hut
AC Unit

Option 7, anemometer boom facing (generic) West with Instrument Hut towards the North



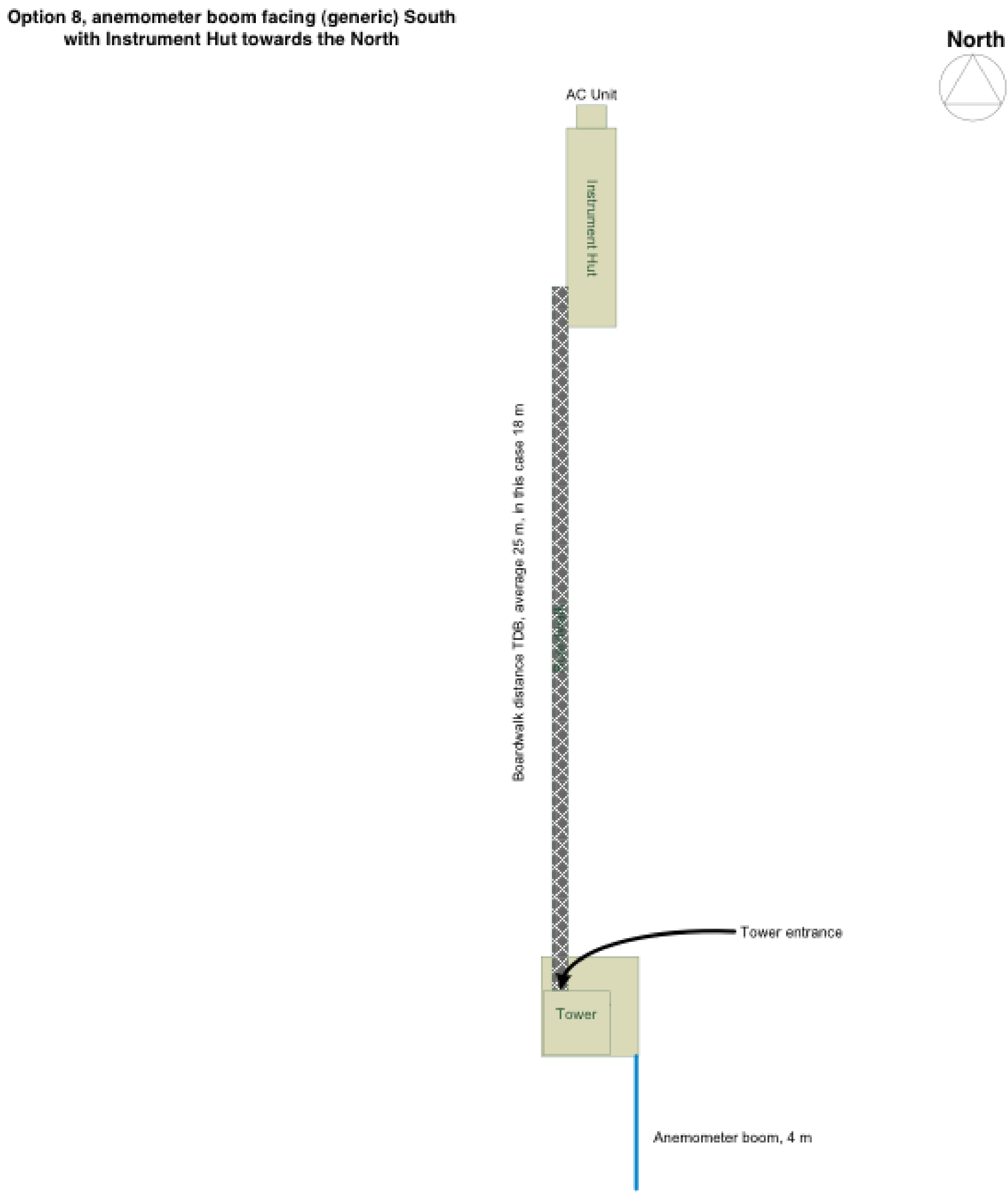
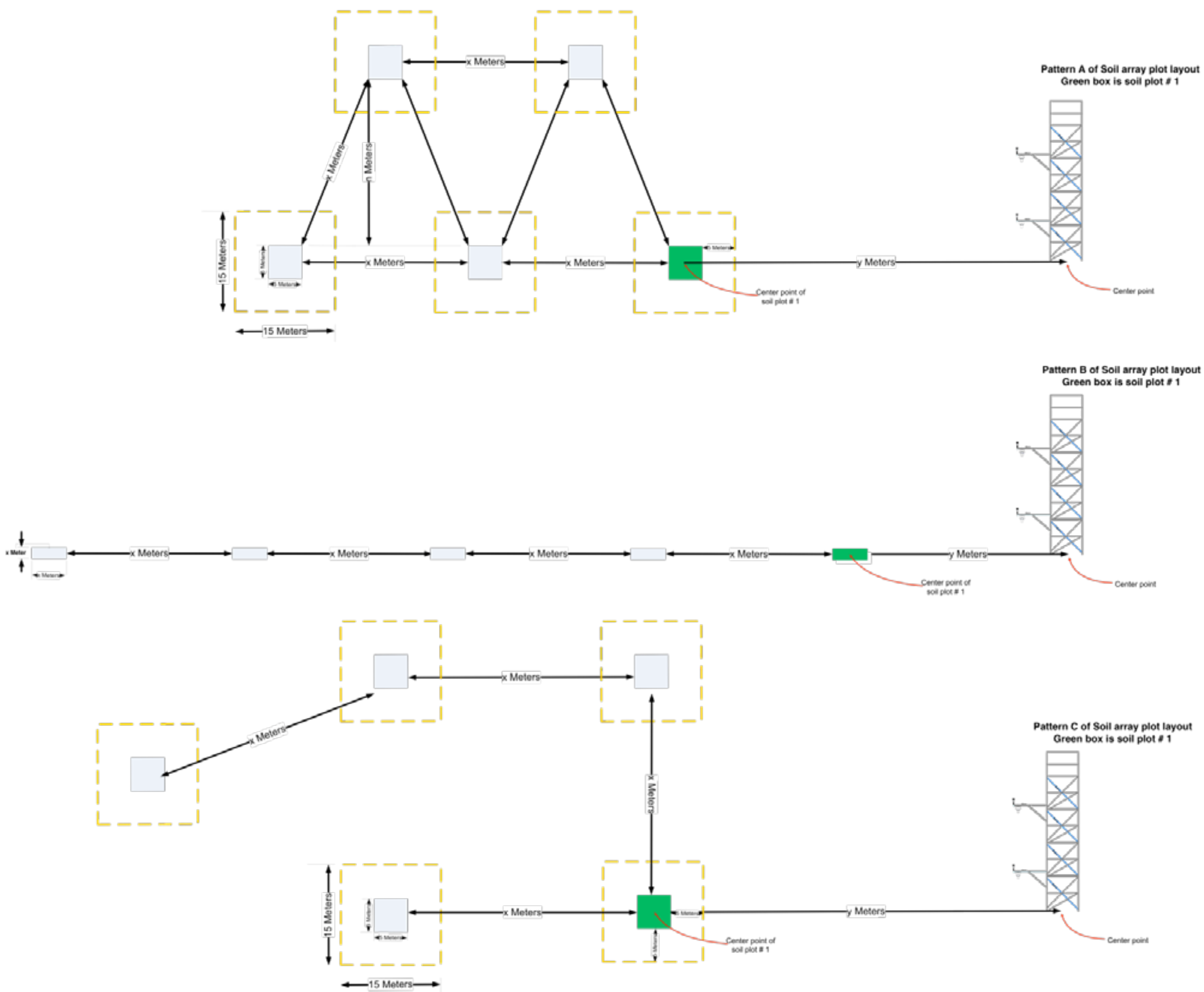


Figure 61. Generic patterns for the boardwalk configuration

These generic configurations are from the instrument hut to the tower based on 5 generic scenarios. The five options are based on anemometer boom orientation and the leeward side of the tower where the instrument hut is located. The tower entrance is always on the North side of the tower. Exact tower and instrument hut location and orientation will be specified at each location and presented in the site characterization document.



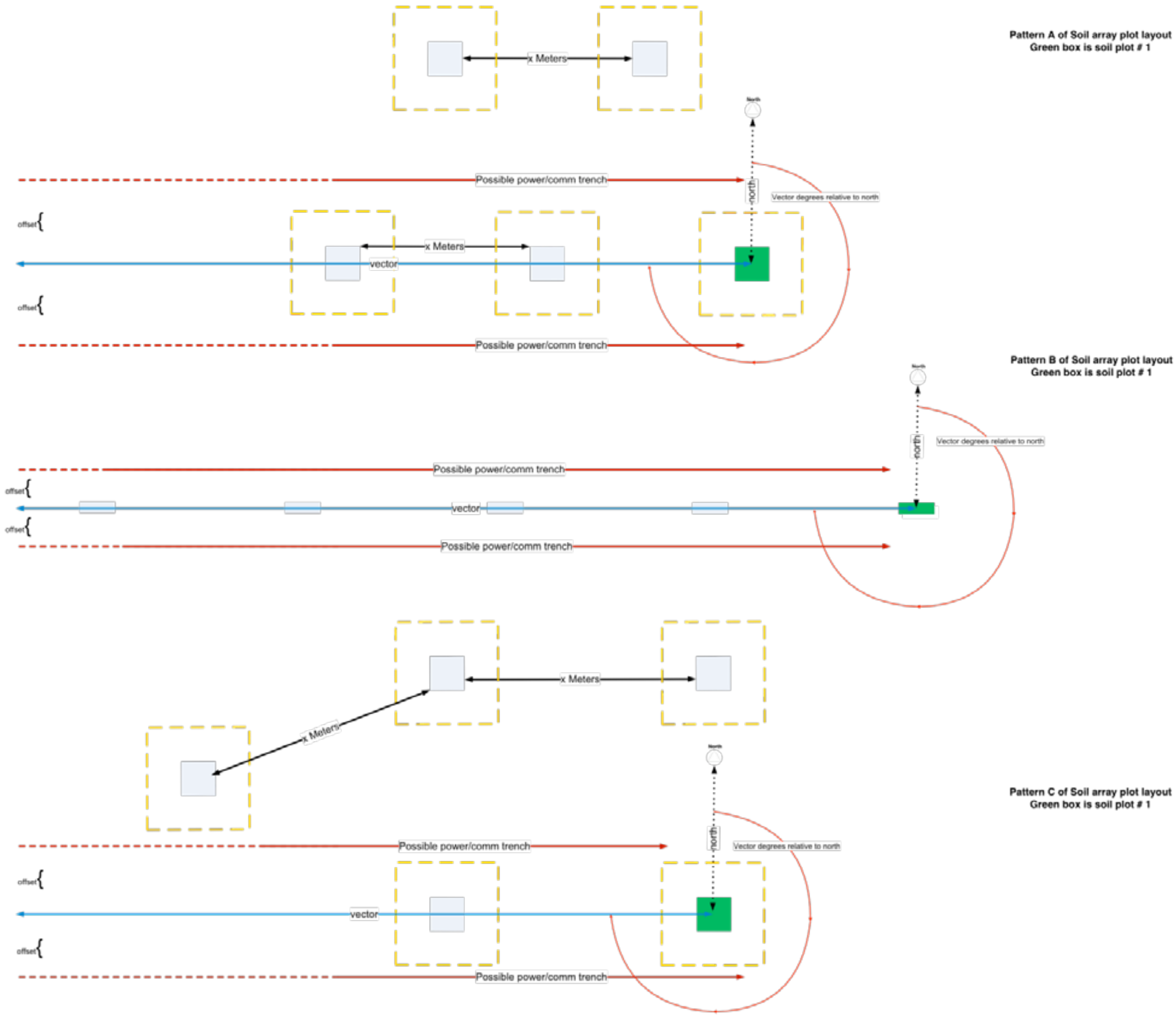


Figure 62. Conceptual diagram of Soil Array Patterns

Outlines the orientation for the soil array and instrument hut from the center point of the tower. The x, y, z distances are i) the distance between soil plots, ii) distance between the tower centerpoint and the closest edge of soil plot, and iii) the distance between the tower centerpoint and the closest edge of the instrument hut, respectively. The yellow outline around each soil plot is the 5 m perimeter keep out zone.

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