D01 FIU Site Characterization Supporting Data

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C	09/23/2011	ECO-00279	Update to new document number's/template throughout document.

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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 visit to the 3 NEON sites in Domain 01. This document presents all the supporting data for FIU site characterization at D01.

1.2 Scope

FIU site characterization data and analysis results presented in this document are for the three D01 tower locations: Harvard Forest site (Advanced), Bartlett Experimental Forest site (Relocatable 1), and Plum Island Suburban Relocatable site (Relocatable 2). Issues and concerns for each site that need further review are also addressed in this document according to our best knowledge.
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 Design Science Requirements
AD[02]	NEON.DOC.011000 _ FIU Technical and Operation Requirements
AD[03]	
AD[04]	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
RD[03]	
RD[04]	

2.3 Acronyms

2.4 Verb Convention

"Shall" is used whenever a specification expresses a provision that is binding. The verbs "should" and "may" express non-mandatory provisions. "Will" is used to express a declaration of purpose on the part of the design activity.

3 HARVARD FOREST (ADVANCED TOWER SITE)

3.1 Site description

NEON Harvard Forest candidate advanced tower site is located at Harvard Forest, Petersham, Massachusetts (42.53690 N, -72.17266 W; elevation 340 m above sea level). The terrain was moderately hilly, 30 m relief, gentle slopes, ~95 % forested, with the nearest paved roads > 1 km away and small town > 10 km away (Wofsy *et al.* 1993). Soils are largely acidic sandy loams that developed in glacial tills overlying gneiss and schist bedrock. Variability in relief, depth to bedrock, and the local presence of a hardpan (restrictive sub-soil horizon) create a highly variable pattern of soil drainage. The average annual temperature is 8.5 ^{0}C, the frost-free period averages five months, and annual precipitation is well-distributed, averaging 105 cm, with 150 cm of snow (Rasche 1953). Harvard Forest is one of the oldest forest research sites in the United States, and has been intensively studied since its acquisition by Harvard University in 1907 (Motzkin *et al*. 1999).

There is an existing tower site and a measurement platform next to NEON Advanced Tower site. The existing tower is located at 42.537755 N latitude, 72.171478 W longitude and 340 m (ASL) elevation; the walkup platform is ~130m away (42.536875 N, 72.172602 W). Atmospheric measurements are taken from a 30 m tower (Rohn 25G), which extends 6 m above the forest canopy and from a walk-up platform. Ecological measurements are conducted in plots stretching out in the tower footprint (information source: http://atmos.seas.harvard.edu/lab/hf/hfsite.html). The Harvard Forest tower is on land owned by Harvard University. The site is designated as an LTER site. The forest has been impacted by hurricanes in 1938, 1944, 1954, 1960, and 1991. Climate measurements have been made at Harvard Forest since 1964 (Information source: http://public.ornl.gov/ameriflux/Site_Info/siteInfo.cfm?KEYID=us.harvard_forest.01).

The NEON tower is approximately 18 m east of the walkup platform; however, Bill Munger said that the walkup platform tower will be removed.

3.2 Ecosystem

Harvard Forest is a regenerating temperate forest. The vegetation is typical of the Transition Hardwoods-White Pine-Hemlock region (Westveld et al. 1956). Dominant species include red oak (*Quercus rubra*), red maple (*Acer rubrum*), black birch (*Betula lenta*), white pine (*Pinus strobus*), and hemlock (T*suga canadensis*), white oak (*Quercus alba*), black oak (*Quercus velutina*), Shagbark hickory (*Carya ovata*). The mixed deciduous forest is ~80-year-old. Mean canopy height is ~ 23 m, and structure shows a surface roughness length ~ 0.5-0.6 m and zero plane displacement ~ 19 m (http://public.ornl.gov/ameriflux/Site_Info/siteInfo.cfm?KEYID=us.harvard_forest.01). Canopy area density was estimated to be ~ 4.6 in summer and ~ 1.4 m^2 m^{-2} in winter season (Sierra *et. al*, 2009).

Vegetation and land cover information at surrounding region are presented below:

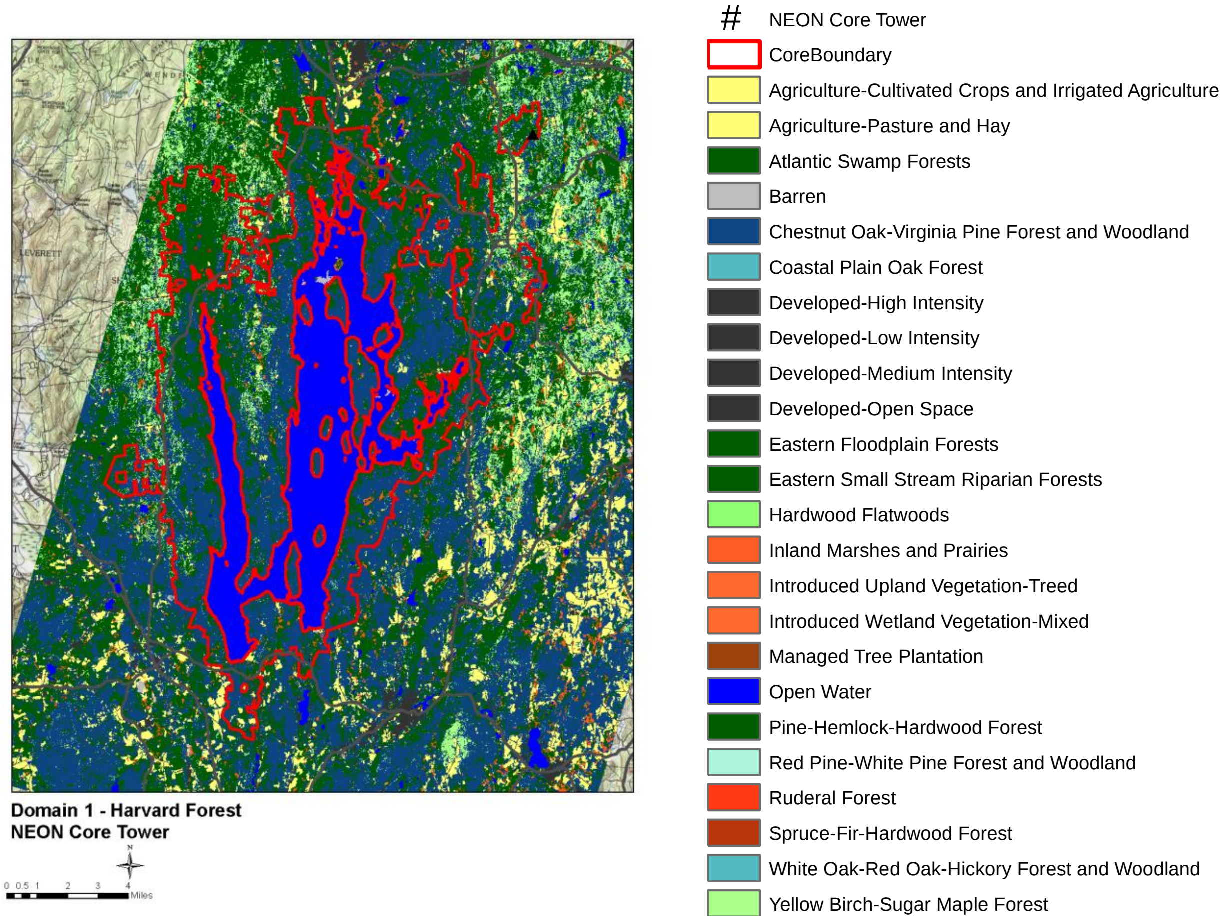


Figure 1. Vegetative cover map of Harvard Forest and surrounding areas (information is from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm).

Table 1. Percent Land cover type at Harvard Forest (information is from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Land cover type	Area (km^2)	Percentage (%)
Atlantic Swamp Forests	5869.20	0.59
Chestnut Oak-Virginia Pine Forest and Woodland	79680.50	7.97
Inland Marshes and Prairies	1476.34	0.15
Pine-Hemlock-Hardwood Forest	155849.14	15.60
Red Pine-White Pine Forest and Woodland	11009.66	1.10
Yellow Birch-Sugar Maple Forest	745245.17	74.59
Total	999130.02	100.00

The representative ecosystem that NEON design is focused around for this core site is eastern deciduous/mixed secondary forest.

Canopy height is ~26 m around tower site with lowest branches at ground level. Oak and other tree species form upper understory with height ~ 16 m. Seedlings and sapling of maple, hemlock and other species forms the lower understory with mean height ~ 5 m. Grasses, forbes and new seedlings form the understory at ground level with height ~ 1 m.

Table 2. Ecosystem and site attributes for Harvard Forest Advanced tower site.

Ecosystem attributes	Measure and units
Mean canopy height	26 m
Surface roughness[a]	0.8 m
Zero place displacement height[a]	22.5 m
Structural elements	Closed canopy, understory present, uniform
Time zone	Eastern time
Magnetic declination	14° 38' W changing by 0° 3' E/year

Note, [a] From model output.

3.3 Soils

3.3.1 Soil description

Soil data and soil maps (Figures 1, 2) below for Harvard Forest Advanced tower site were collected from 1 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.

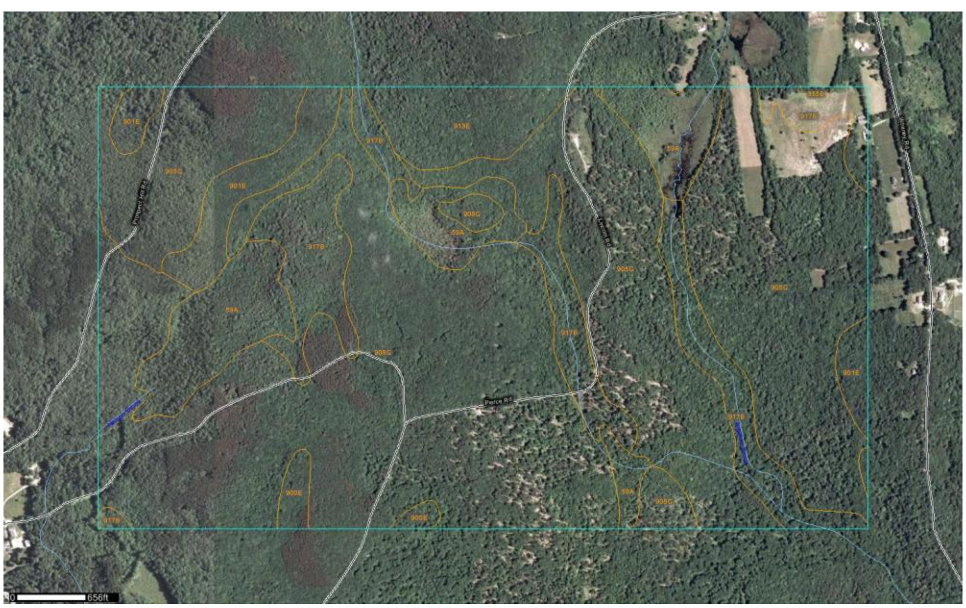


Figure 2. 1 km^2 soil map for Harvard forest NEON advanced tower site, center at tower location.

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 3. Soil Series and percentage of soil series within 1 km^2 centered on the tower.
Area Object Interest (AOI) is the mapping unit from NRCS.

Worcester County, Massachusetts, Northwestern Part (MA614)			
Map Unit Symbol	**Soil types**	**Acres in AOI**	**% AOI**
59A	Bucksport and Wonsqueak mucks, 0 to 3 percent slopes	75.1	*8.0%
253C	Hinckley loamy sand, 8 to 15 percent slopes	7.3	0.8%
253E	Hinckley loamy sand, 25 to 35 percent slopes	6.1	0.6%
254B	Merrimac fine sandy loam, 3 to 8 percent slopes	5.6	0.6%
355B	Marlow fine sandy loam, 3 to 8 percent slopes	3.9	0.4%
900E	Becket-Monadnock association, 15 to 45 percent slopes, extremely stony	13.3	1.4%
901E	Berkshire-Marlow association, 15 to 45 percent slopes, extremely stony	35.2	*3.7%
905C	Peru-Marlow association, 3 to 15 percent slopes, extremely stony	272.9	28.9%
908C	Becket-Skerry association, 3 to 15 percent slopes, extremely stony	335.8	*35.6%
913E	Lyman-Tunbridge-Berkshire association, 15 to 45 percent slopes, very rocky	64.5	6.8%
917B	Pillsbury-Peacham association, 0 to 8 percent slopes, extremely stony	101.1	*10.7%
924C	Tunbridge-Lyman-Berkshire association, 3 to 15 percent slopes, extremely stony	22.9	2.4%
Totals for Area of Interest		943.7	100.0%

Note, asterix indicates dominate soil type in airshed

Worcester County, Massachusetts, Northwestern Part 908C—Becket-Skerry association, 3 to 15 percent slopes, extremely stony Map Unit Setting *Mean annual precipitation:* 39 to 55 inches *Mean annual air temperature:* 39 to 45 degrees F *Frost-free period:* 120 to 240 days **Map Unit Composition** *Becket and similar soils:* 40 percent *Skerry and similar soils:* 30 percent *Minor components:* 30 percent **Description of Becket Setting** *Landform:* Hills *Landform position (two-dimensional):* Shoulder *Landform position (three-dimensional):* Nose slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable coarse-loamy eolian deposits over dense sandy lodgment till **Properties and qualities** *Slope:* 8 to 15 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 18 to 35 inches to dense material *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.60 in/hr) *Depth to water table:* About 24 to 42 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 2.9 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s

Typical profile *0 to 4 inches:* Fine sandy loam *4 to 13 inches:* Fine sandy loam *13 to 18 inches:* Sandy loam *18 to 25 inches:* Gravelly sandy loam *25 to 65 inches:* Gravelly fine sandy loam **Description of Skerry Setting** *Landform:* Hills *Landform position (two-dimensional):* Backslope *Landform position (three-dimensional):* Nose slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over dense sandy lodgment till derived from igneous and metamorphic rock **Properties and qualities** *Slope:* 8 to 15 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 15 to 35 inches to dense material *Drainage class:* Moderately well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.60 in/hr) *Depth to water table:* About 18 to 30 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 2.8 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 2 inches:* Fine sandy loam *2 to 7 inches:* Fine sandy loam *7 to 15 inches:* Gravelly fine sandy loam *15 to 22 inches:* Gravelly sandy loam *22 to 30 inches:* Gravelly loamy sand *30 to 65 inches:* Gravelly sand **Minor Components Berkshire** *Percent of map unit:* 10 percent **Marlow** *Percent of map unit:* 10 percent **Monadnock** *Percent of map unit:* 5 percent **Peru** *Percent of map unit:* 2 percent **Pillsbury** *Percent of map unit:* 2 percent *Landform:* Depressions **Peacham** *Percent of map unit:* 1 percent *Landform:* Depressions

Worcester County, Massachusetts, Northwestern Part 905C—Peru-Marlow association, 3 to 15 percent slopes, extremely stony Map Unit Setting *Mean annual precipitation:* 39 to 55 inches *Mean annual air temperature:* 39 to 45 degrees F *Frost-free period:* 120 to 240 days **Map Unit Composition** *Peru and similar soils:* 50 percent *Marlow and similar soils:* 20 percent *Minor components:* 30 percent **Description of Peru Setting** *Landform:* Hills *Landform position (two-dimensional):* Backslope *Landform position (three-dimensional):* Side slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable coarse-loamy eolian deposits over dense coarse-loamy lodgment till **Properties and qualities** *Slope:* 3 to 15 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 12 to 35 inches to dense material *Drainage class:* Moderately well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.60 in/hr) *Depth to water table:* About 18 to 30 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 3.2 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 3 inches:* Fine sandy loam *3 to 24 inches:* Fine sandy loam *24 to 65 inches:* Fine sandy loam **Description of Marlow Setting** *Landform:* Hills *Landform position (two-dimensional):* Shoulder *Landform position (three-dimensional):* Nose slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over dense coarseloamy lodgment till derived from mica schist **Properties and qualities** *Slope:* 3 to 15 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 24 to 28 inches to dense material *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.60 in/hr) *Depth to water table:* About 24 to 42 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 3.7 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 2 inches:* Highly decomposed plant material *2 to 5 inches:* Fine sandy loam *5 to 26 inches:* Fine sandy loam *26 to 65 inches:* Fine sandy loam **Minor Components Monadnock** *Percent of map unit:* 12 percent **Skerry** *Percent of map unit:* 12 percent **Pillsbury** *Percent of map unit:* 6 percent *Landform:* Depressions

Worcester County, Massachusetts, Northwestern Part 917B—Pillsbury-Peacham association, 0 to 8 percent slopes, extremely stony Map Unit Setting *Elevation:* 500 to 2,000 feet *Mean annual precipitation:* 39 to 55 inches *Mean annual air temperature:* 39 to 45 degrees F *Frost-free period:* 120 to

240 days **Map Unit Composition** *Pillsbury and similar soils:* 45 percent *Peacham and similar soils:* 35 percent *Minor components:* 20 percent **Description of Pillsbury Setting** *Landform:* Depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Rise *Down-slope shape:* Linear *Across-slope shape:* Concave *Parent material:* Friable coarse-loamy eolian deposits over dense coarse-loamy lodgment till derived from granite and gneiss **Properties and qualities** *Slope:* 0 to 8 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 15 to 35 inches to dense material *Drainage class:* Poorly drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.20 in/hr) *Depth to water table:* About 0 to 18 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 3.0 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 4 inches:* Gravelly fine sandy loam *4 to 24 inches:* Gravelly fine sandy loam *24 to 65 inches:* Gravelly fine sandy loam **Description of Peacham Setting** *Landform:* Depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Linear *Across-slope shape:* Concave *Parent material:* Highly-decomposed herbaceous organic material over dense coarse-loamy lodgment till derived from granite and gneiss **Properties and qualities** *Slope:* 0 to 8 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 6 to 18 inches to dense material *Drainage class:* Very poorly drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately high (0.00 to 0.20 in/hr) *Depth to water table:* About 0 inches *Frequency of flooding:* None *Frequency of ponding:* Frequent *Available water capacity:* Low (about 4.3 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 11 inches:* Highly decomposed plant material *11 to 14 inches:* Fine sandy loam *14 to 65 inches:* Gravelly fine sandy loam **Minor Components Peru** *Percent of map unit:* 10 percent **Chocorua** *Percent of map unit:* 5 percent *Landform:* Bogs **Wonsqueak** *Percent of map unit:* 4 percent *Landform:* Bogs **Lyman** *Percent of map unit:* 1 percent

Worcester County, Massachusetts, Northwestern Part 59A—Bucksport and Wonsqueak mucks, 0 to 3 percent slopes Map Unit Setting *Elevation:* 10 to 2,100 feet *Mean annual precipitation:* 39 to 55 inches *Mean annual air temperature:* 39 to 45 degrees F *Frost-free period:* 120 to 240 days **Map Unit Composition** *Bucksport and similar soils:* 45 percent *Wonsqueak and similar soils:* 35 percent *Minor components:* 20 percent **Description of Bucksport Setting** *Landform:* Bogs *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Concave *Across-slope shape:* Concave *Parent material:* Highly-decomposed herbaceous organic material **Properties and qualities** *Slope:* 0 to 3 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 high to high (0.20 to 6.00 in/hr) *Depth to water table:* About 0 to 6 inches *Frequency of flooding:* None *Frequency of ponding:* Frequent *Available water capacity:* Very high (about 20.9 inches) **Interpretive groups** *Land capability (nonirrigated):* 7w **Typical profile** *0 to 18 inches:* Muck *18 to 52 inches:* Muck *52 to 65 inches:* Muck **Description of Wonsqueak Setting** *Landform:* Bogs *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Concave *Across-slope shape:* Concave *Parent material:* Highly-decomposed herbaceous organic material over friable loamy basal till **Properties and qualities** *Slope:* 0 to 3 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 high to high (0.20 to 2.00 in/hr) *Depth to water table:* About 0 to 6 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very high (about 13.4 inches) **Interpretive groups** *Land capability (nonirrigated):* 7w **Typical profile** *0 to 15 inches:* Muck *15 to 36 inches:* Muck *36 to 65 inches:* Gravelly fine sandy loam **Minor Components Peacham** *Percent of map unit:* 5 percent *Landform:*

Depressions **Scarboro** *Percent of map unit:* 5 percent *Landform:* Terraces **Whitman** *Percent of map unit:* 5 percent *Landform:* Depressions **Searsport** *Percent of map unit:* 4 percent *Landform:* Bogs **Unnamed - other soils** *Percent of map unit:* 1 percent.

Worcester County, Massachusetts, Northwestern Part 900E—Becket-Monadnock association, 15 to 45 percent slopes, extremely stony Map Unit Setting *Mean annual precipitation:* 39 to 55 inches *Mean annual air temperature:* 39 to 45 degrees F *Frost-free period:* 120 to 240 days **Map Unit Composition** *Becket and similar soils:* 40 percent *Monadnock and similar soils:* 30 percent *Minor components:* 30 percent **Description of Becket Setting** *Landform:* Hills *Landform position (two-dimensional):* Shoulder *Landform position (three-dimensional):* Nose slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable coarse-loamy eolian deposits over dense sandy lodgment till **Properties and qualities** *Slope:* 25 to 45 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 18 to 35 inches to dense material *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.60 in/hr) *Depth to water table:* About 24 to 42 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 2.4 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 4 inches:* Fine sandy loam *4 to 13 inches:* Fine sandy loam *13 to 18 inches:* Sandy loam *18 to 25 inches:* Gravelly sandy loam *25 to 65 inches:* Gravelly fine sandy loam **Description of Monadnock Setting** *Landform:* Hills *Landform position (two-dimensional):* Shoulder *Landform position (three-dimensional):* Nose slope Map Unit Description: Becket-Monadnock association, 15 to 45 percent slopes, extremely stony–Worcester County, Massachusetts, Northwestern Part *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over firm sandy basal till derived from granite and gneiss **Properties and qualities** *Slope:* 25 to 45 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 15 to 30 inches to strongly contrasting textural stratification *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None
Available water capacity: Very low (about 2.8 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 4 inches:* Fine sandy loam *4 to 5 inches:* Sandy loam *5 to 20 inches:* Fine sandy loam *20 to 25 inches:* Loamy sand *25 to 65 inches:* Gravelly loamy sand **Minor Components Berkshire** *Percent of map unit:* 10 percent **Marlow** *Percent of map unit:* 10 percent **Peru** *Percent of map unit:* 4 percent **Skerry** *Percent of map unit:* 3 percent **Pillsbury** *Percent of map unit:* 2 percent *Landform:* Depressions **Peacham** *Percent of map unit:* 1 percent *Landform:* Depressions

Worcester County, Massachusetts, Northwestern Part 913E—Lyman-Tunbridge-Berkshire association, 15 to 45 percent slopes, very rocky Map Unit Setting *Elevation:* 10 to 3,500 feet *Mean annual precipitation:* 39 to 55 inches *Mean annual air temperature:* 39 to 45 degrees F *Frost-free period:* 120 to 240 days **Map Unit Composition** *Lyman and similar soils:* 35 percent *Tunbridge and similar soils:* 25 percent *Berkshire and similar soils:* 15 percent *Minor components:* 25 percent **Description of Lyman Setting** *Landform:* Ledges *Landform position (two-dimensional):* Summit *Landform position (three-dimensional):* Crest *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Shallow, friable loamy basal till derived from schist over schist **Properties and qualities** *Slope:* 15 to 45 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 14 to 22 inches to lithic bedrock *Drainage class:* Somewhat excessively drained *Capacity of the most limiting layer to transmit water (Ksat):* Low to high (0.01 to 6.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 3.1

inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 2 inches:* Highly decomposed plant material *2 to 5 inches:* Fine sandy loam *5 to 16 inches:* Fine sandy loam *16 to 18 inches:* Unweathered bedrock **Description of Tunbridge Setting** *Landform:* Ledges *Landform position (two-dimensional):* Summit *Landform position (three-dimensional):* Crest *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Moderately deep, friable coarse-loamy basal till derived from schist over schist **Properties and qualities** *Slope:* 15 to 45 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 24 to 27 inches to lithic bedrock *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to low (0.00 to 0.01 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 4.1 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 1 inches:* Highly decomposed plant material *1 to 3 inches:* Fine sandy loam *3 to 25 inches:* Gravelly sandy loam *25 to 26 inches:* Unweathered bedrock **Description of Berkshire Setting** *Landform:* Hills *Landform position (two-dimensional):* Backslope *Landform position (three-dimensional):* Side slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over firm coarseloamy basal till **Properties and qualities** *Slope:* 15 to 45 percent *Surface area covered with cobbles, stones or boulders:* 9.0 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 (0.20 to 6.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very high (about 13.5 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 1 inches:* Highly decomposed plant material *1 to 3 inches:* Fine sandy loam *3 to 27 inches:* Gravelly fine sandy loam *27 to 65 inches:* Gravelly sandy loam, gravelly sandy loam **Minor Components Becket** *Percent of map unit:* 6 percent **Marlow** *Percent of map unit:* 5 percent **Monadnock** *Percent of map unit:* 5 percent **Peru** *Percent of map unit:* 4 percent **Skerry** *Percent of map unit:* 3 percent **Peacham** *Percent of map unit:* 1 percent *Landform:* Depressions **Pillsbury** *Percent of map unit:* 1 percent *Landform:* Depressions.

Worcester County, Massachusetts, Northwestern Part 355B—Marlow fine sandy loam, 3 to 8 percent slopes Map Unit Setting *Mean annual precipitation:* 39 to 55 inches *Mean annual air temperature:* 39 to 45 degrees F *Frost-free period:* 120 to 240 days **Map Unit Composition** *Marlow and similar soils:* 85 percent *Minor components:* 15 percent **Description of Marlow Setting** *Landform:* Hills *Landform position (two-dimensional):* Backslope *Landform position (three-dimensional):* Nose slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable coarse-loamy eolian deposits over dense coarse-loamy lodgment till derived from mica schist **Properties and qualities** *Slope:* 3 to 8 percent *Depth to restrictive feature:* 20 to 39 inches to dense material *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.60 in/hr) *Depth to water table:* About 24 to 42 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 3.9 inches) **Interpretive groups** *Land capability (nonirrigated):* 2e **Typical profile** *0 to 2 inches:* Highly decomposed plant material *2 to 5 inches:* Fine sandy loam *5 to 26 inches:* Fine sandy loam *26 to 65 inches:* Fine sandy loam **Minor Components Peru** *Percent of map unit:* 5 percent **Becket** *Percent of map unit:* 3 percent **Monadnock** *Percent of map unit:* 3 percent **Berkshire** *Percent of map unit:* 2 percent **Pillsbury** *Percent of map unit:* 2 percent *Landform:* Depressions
Worcester County, Massachusetts, Northwestern Part 924C—Tunbridge-Lyman-Berkshire association, 3 to 15 percent slopes, extremely stony Map Unit Setting *Elevation:* 10 to 3,500 feet *Mean annual precipitation:* 39 to 55 inches *Mean annual air temperature:* 39 to 45 degrees F *Frost-free period:* 120 to 240 days **Map Unit Composition** *Tunbridge and similar soils:* 30 percent *Lyman and similar soils:* 25 percent *Berkshire and similar soils:* 15 percent *Minor components:* 30 percent **Description of Tunbridge**

Setting *Landform:* Ledges *Landform position (two-dimensional):* Summit *Landform position (three-dimensional):* Crest *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Moderately-deep, friable coarse-loamy basal till derived from schist over schist **Properties and qualities** *Slope:* 8 to 15 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 24 to 27 inches to lithic bedrock *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Low to high (0.01 to 6.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 4.1 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 1 inches:* Highly decomposed plant material *1 to 3 inches:* Fine sandy loam *3 to 25 inches:* Gravelly sandy loam *25 to 26 inches:* Unweathered bedrock **Description of Lyman Setting** *Landform:* Ledges *Landform position (two-dimensional):* Summit *Landform position (three-dimensional):* Crest *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Shallow, friable loamy basal till derived from schist over schist **Properties and qualities** *Slope:* 8 to 15 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 14 to 22 inches to lithic bedrock *Drainage class:* Somewhat excessively drained *Capacity of the most limiting layer to transmit water (Ksat):* Low to high (0.01 to 6.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 3.1 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 2 inches:* Highly decomposed plant material *2 to 5 inches:* Fine sandy loam *5 to 16 inches:* Fine sandy loam *16 to 18 inches:* Unweathered bedrock **Description of Berkshire Setting** *Landform:* Hills *Landform position (two-dimensional):* Backslope *Landform position (three-dimensional):* Side slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over firm coarseloamy basal till **Properties and qualities** *Slope:* 8 to 15 percent *Surface area covered with cobbles, stones or boulders:* 9.0 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 (0.20 to 6.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Moderate (about 8.8 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 1 inches:* Highly decomposed plant material *1 to 3 inches:* Fine sandy loam *3 to 8 inches:* Fine sandy loam *8 to 21 inches:* Gravelly fine sandy loam *21 to 65 inches:* Gravelly sandy loam **Minor Components Becket** *Percent of map unit:* 10 percent **Marlow** *Percent of map unit:* 5 percent **Monadnock** *Percent of map unit:* 5 percent **Peru** *Percent of map unit:* 5 percent **Skerry** *Percent of map unit:* 4 percent **Pillsbury** *Percent of map unit:* 1 percent *Landform:* Depressions.

3.3.2 Soil semi-variogram description

The goal of this site characterization of soil using semi-variograms is to determine the minimum distance between the soil plots in the soil array that can be considered spatially independent. The collected field data of soil properties will be used for semi-variograms, which is a geostatistical technique to detect spatial autocorrelation between mapped samples of a quantitative variable (*e.g.*, soil property data in our case). In a variogram, the averaged squared difference in the residual value of a variable between all pairs of points is computed across distance intervals (lag classes). The output is presented graphically as a plot of the average semi-variance versus distance class (Figure 3). The semi-variance will converge on total variance at distances for which values are no longer spatially auto-correlated (this is referred to as the range, Figure 3).

Three parameters estimated from the variogram describe spatial autocorrelation in the data (Figure 3), the range, the sill (the sill is the asymptotic value of semi-variance at the range), and the nugget variance (which describes sampling error or variation at distances below those separating the closest pairs of samples). The range, sill and nugget variance were estimated from theoretical models that were fitted to the empirical variograms using non-linear least squares methods. The range distance (*i.e.*, the distance beyond which samples are spatially independent) was estimated from the empirical variogram by fitting spherical theoretical models. This is the distance we will use to determine the spatial separation of soil plots in soil array.

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

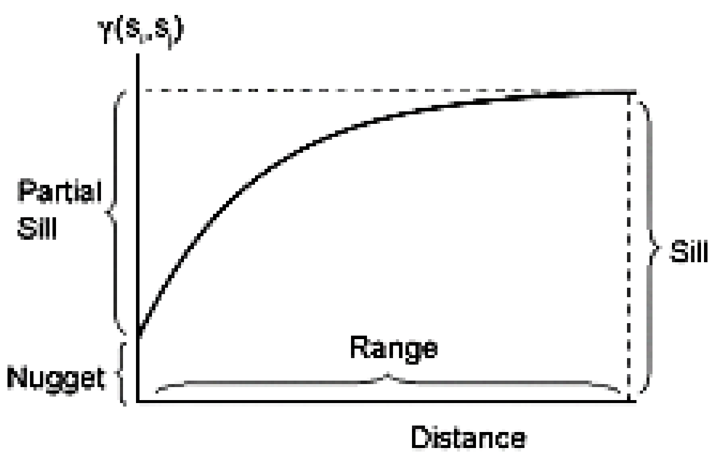


Figure 3. Example semivariogram, depicting range, sill, and nugget.

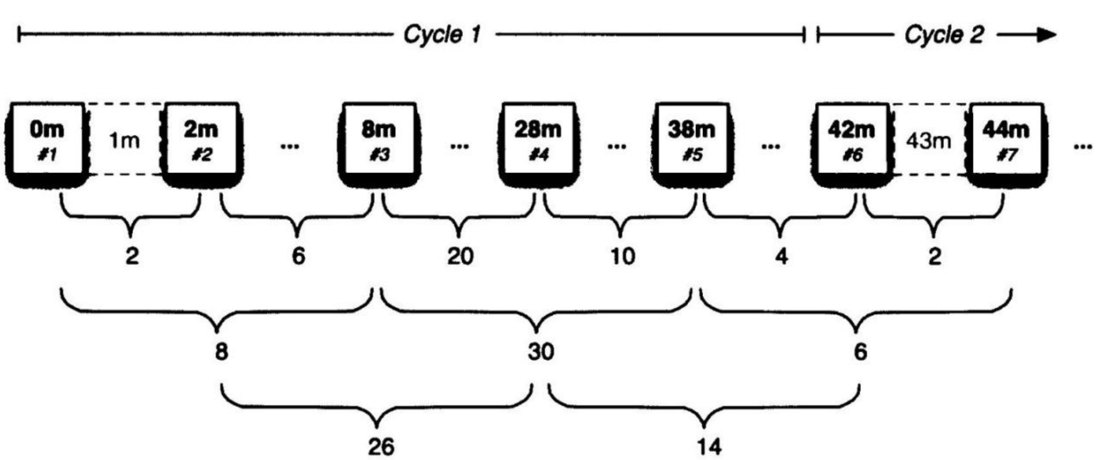


Figure 4. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 8 July 2010 at the Harvard Forest 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 (210 m, 84 m, and 84 m) located in the expected airshed at Harvard Forest. 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).

In addition to the FIU site characterization of soil temperature and moisture content, soil property data from a previous field survey by Dr Motzkin and others in 1992 from 269 soil sample plots (Figure 4) will be used to evaluate the spatial variation of surface soil at Harvard Forest Advanced tower site. These data from each of these plots include soil texture (clay, silt, and sand), cation exchange capacity (CEC), organic matter (OM), bulk density, pH, soil total carbon (C), total nitrogen (N), ratio of C:N, etc. Here, we analyzed semi-variograms for each of these textural and physical properties among the 269 plots.

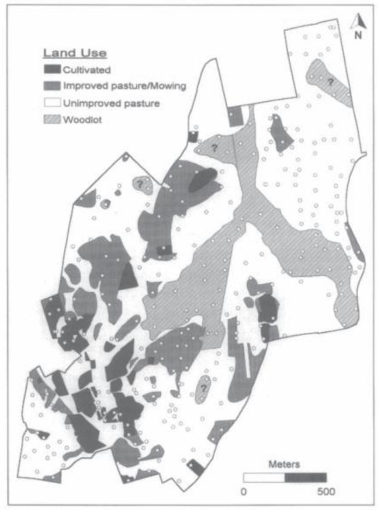


Figure 5. Historical land use map for the Prospect Hill Tract of Harvard Forest. Open circles indicate 269 sample plots (Motzkin *et al.* 1999)

3.3.3 Results and interpretation

3.3.3.1 Soil Temperature

Soil temperature data are the actual measurements during FIU site characterization. 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 6). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 6, left graphs) and directional semivariograms do not show anisotropy (Figure 7, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 7, right graph). The model indicates a distance of effective independence of 73 m for soil temperature.

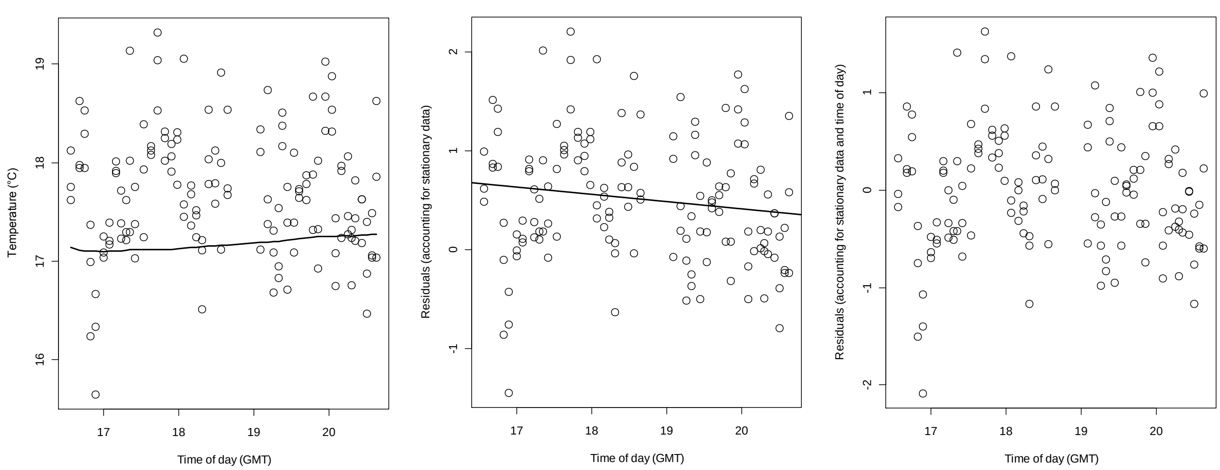


Figure 6. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear

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.

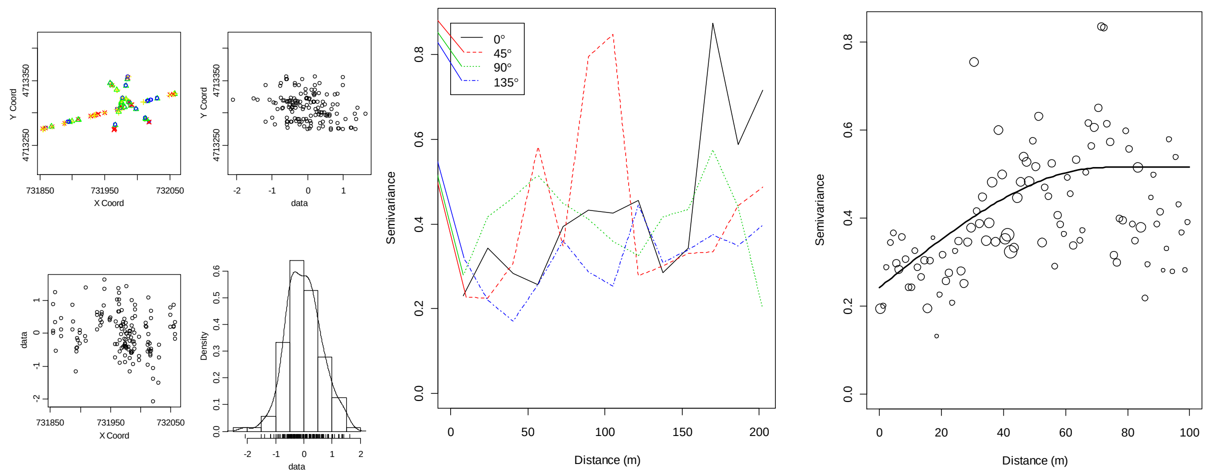


Figure 7. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

3.3.3.2 Soil water content

Soil water content data are the actual measurements during FIU site characterization. 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 8). Exploratory data analysis plots show that moisture content was consistently low at the western side of the sampling area (Figure 8, left graph) and directional semivariograms do not show anisotropy (Figure 9, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 9, right graph). The model indicates a distance of effective independence of 25 m for soil water content.

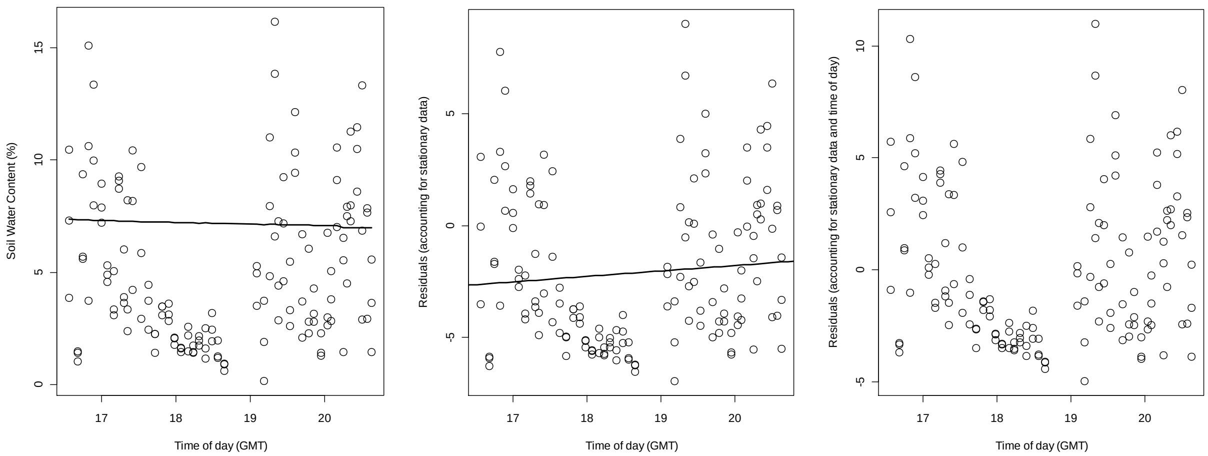


Figure 8. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting 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.

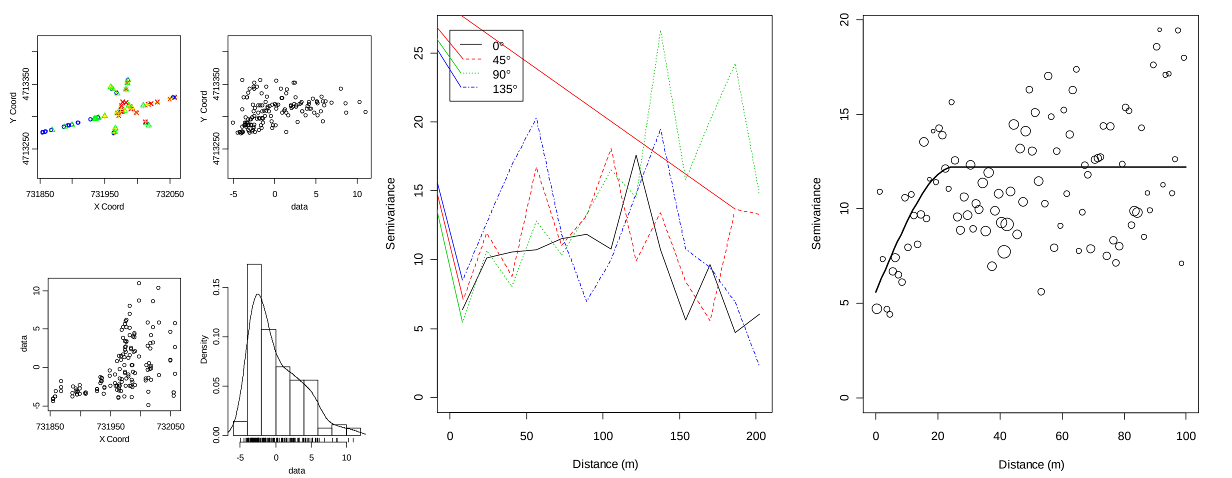


Figure 9. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

3.3.3.3 Other soil properties

Results in this session are analysis outputs based on the existing soil plots data (Motzkin *et al.* 1999). A spherical, exponential or Gaussian covariance model was fit using Cressie weights and a maximum distance of 319 m (Figures 5-34). The estimated distance of effective independence ranges from 50 meters to 880 m depending on the variables examined. Average distance is ~ 122 meters from these analysis. The results from Dr Nsalambi Nkongolo's analysis also vary from 12 m to over 1000 m (Appendix A) with average > 100 m. These distances determined by both analyses are too large to be practical in layout soil array. Because of soil sampling plot was 22.5 m X 22.5 m (Motzkin *et al.* 1999), the maximum resolution we can get is ~ 45 m, which is too spatially coarse for NEON's purpose.

From the pre-existing sampling plots (studies from Drs. Motzkin and Nkongolo), the plots were analyzed according to soil texture and soil properties, and semi-variogram analyses were preformed accordingly for clay, silt and sand dominated-plots, Figures 6-8, 9-11, and 12-14, respectively, and for CEC, OM, bulk density, pH, soil carbon, soil nitrogen, and C:N ratios in Figures 15-17, 18-20, 21-23, 24-26, 27-29, 30-32, and 33-35, respectively.

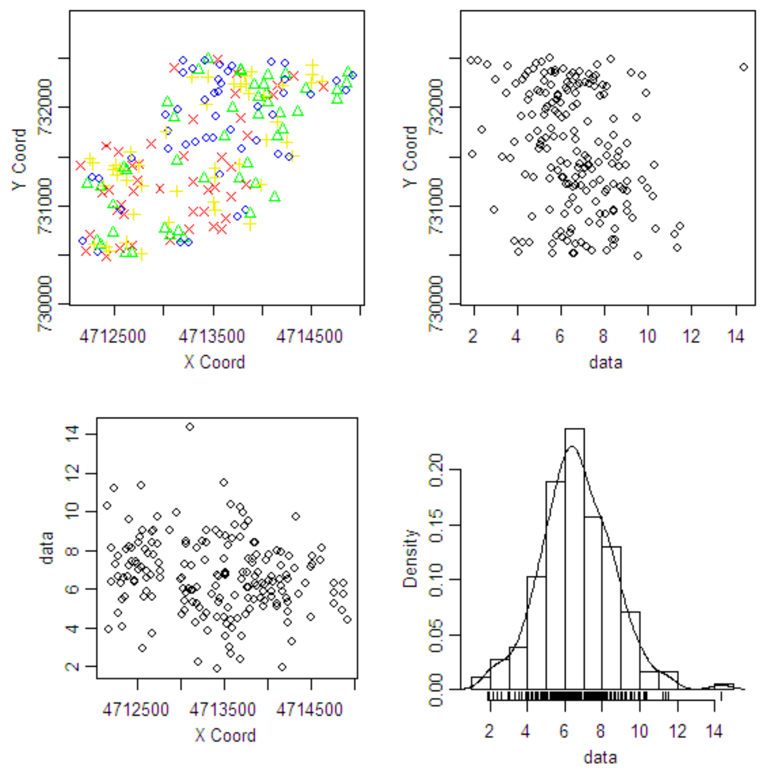


Figure 10. Exploratory data analysis for clay in the soil plots at the Harvard Forest Advanced Tower site.

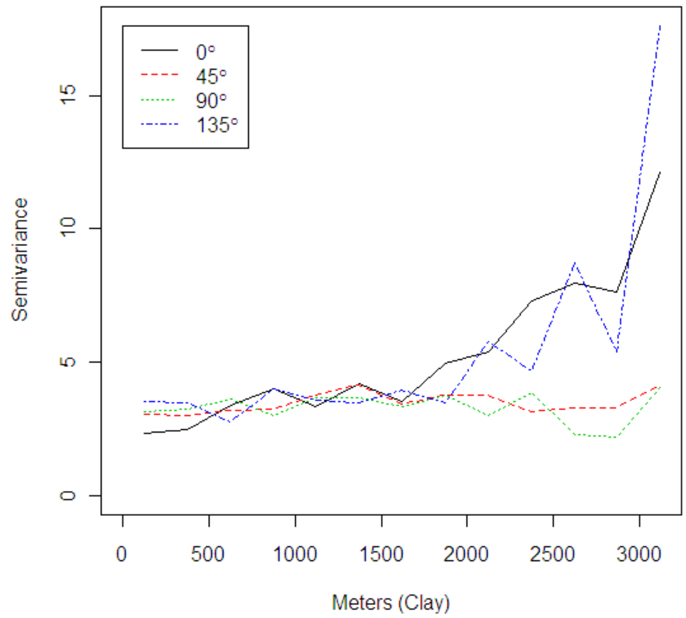


Figure 11. Directional variograms for clay in the soil plots at the Harvard Forest Advanced Tower site.

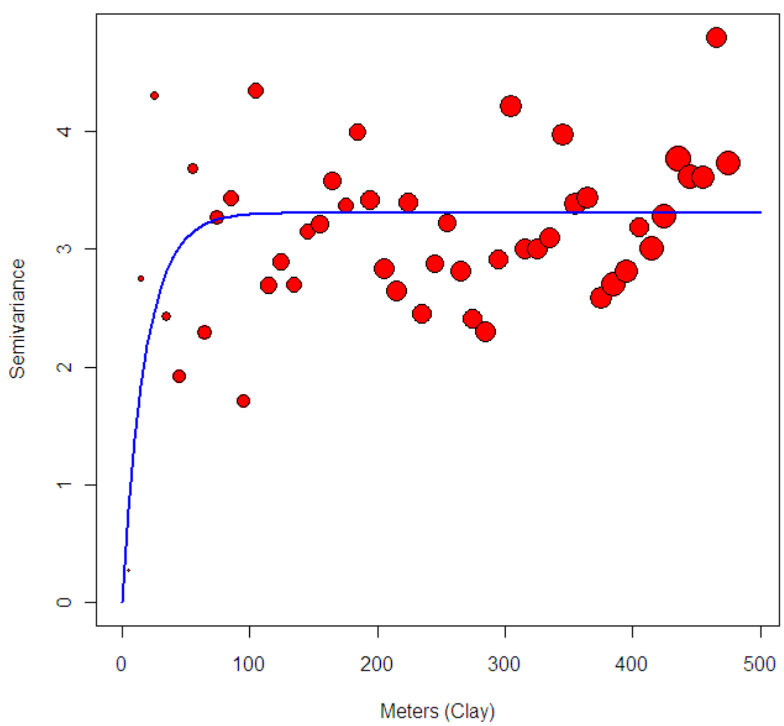


Figure 12. Empirical variogram and model fit for clay in the soil plots at the Harvard Forest Advanced Tower site.

variofit: model parameters estimated by WLS (weighted least squares):
covariance model is: exponential
parameter estimates: tausq sigmasq phi 0.0000 3.3058 18.4302
Practical Range with cor = 0.05 for asymptotic range: 55.212
variofit: minimised weighted sum of squares = 89.6533

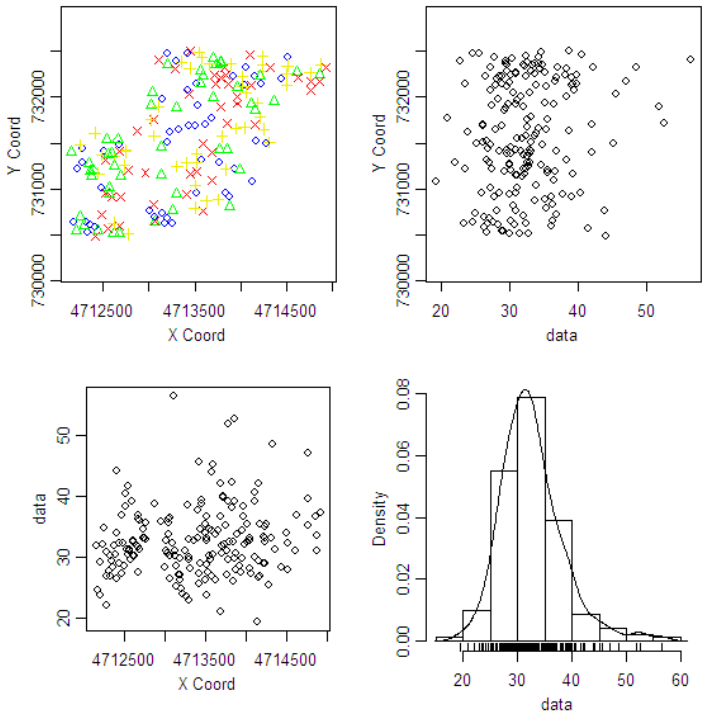


Figure 13. Exploratory data analysis for silt in the soil plots at the Harvard Forest Advanced Tower site.

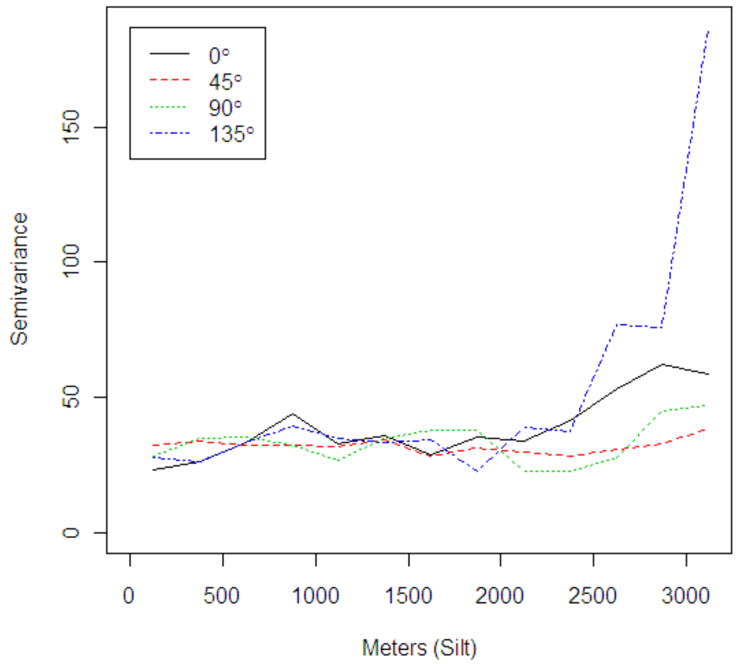


Figure 14. Directional variograms for silt in the soil plots at the Harvard Forest Advanced Tower site

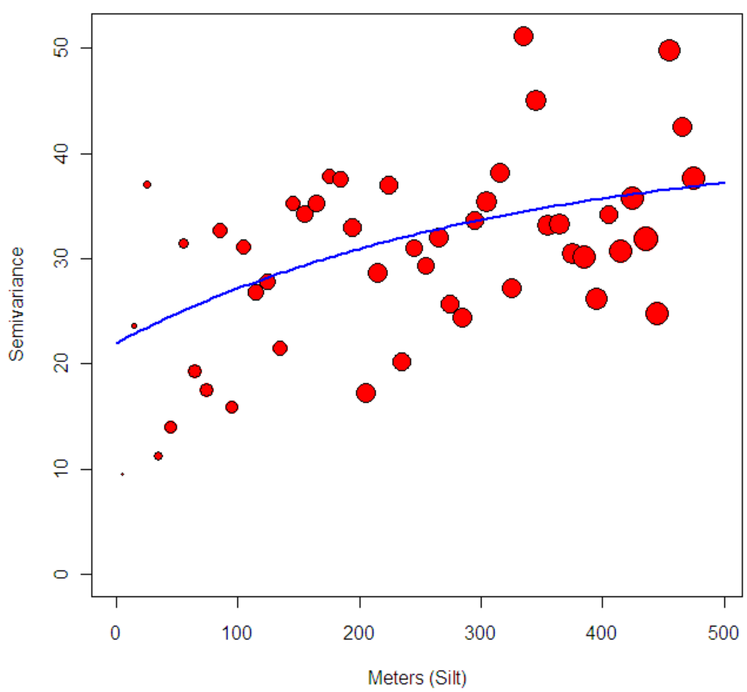


Figure 15. Empirical variogram and model fit for silt in the soil plots at the Harvard Forest Advanced Tower site

variofit: model parameters estimated by WLS (weighted least squares):
covariance model is: exponential
parameter estimates: tausq sigmasq phi 22.0037 19.2072 319.7355
Practical Range with cor=0.05 for asymptotic range: 957.842
variofit: minimised weighted sum of squares = 135.1071

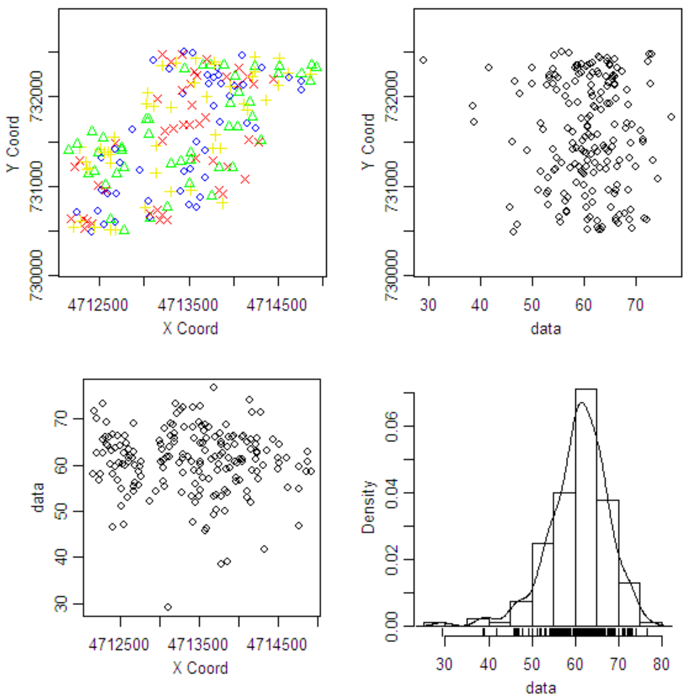


Figure 16. Exploratory data analysis for sand in the soil plots at the Harvard Forest Advanced Tower site.

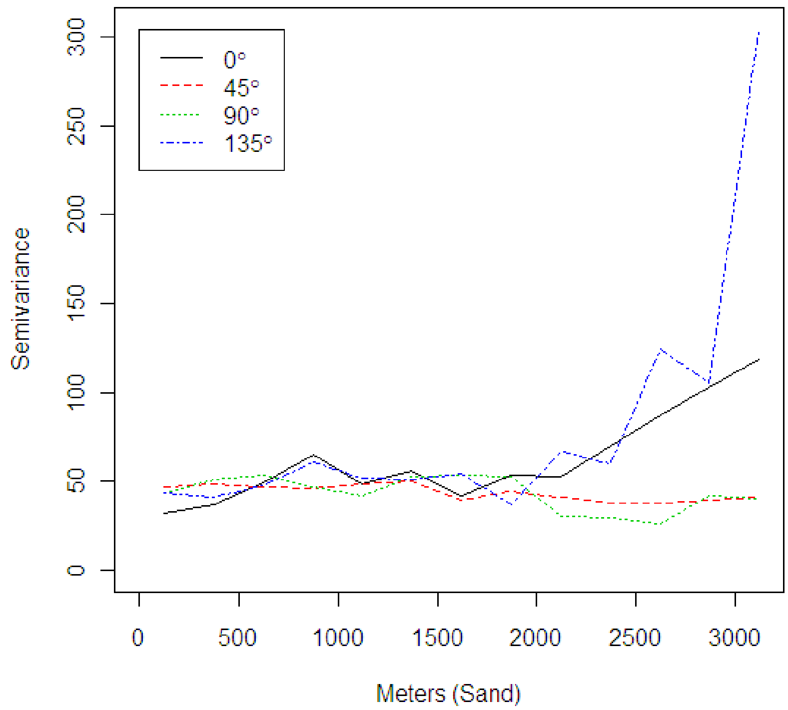


Figure 17. Directional variograms for sand in the soil plots at the Harvard Forest Advanced Tower site

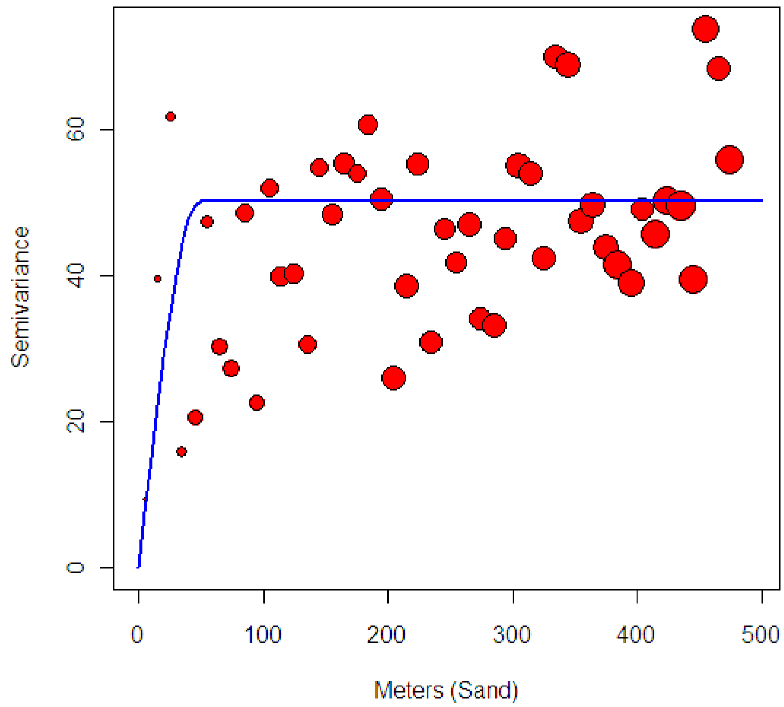


Figure 18. Empirical variogram and model fit for sand in the soil plots at the Harvard Forest Advanced Tower site.

variofit: model parameters estimated by WLS (weighted least squares):
covariance model is: spherical
parameter estimates: tausq sigmasq phi 0.0000 50.1457 49.5050
Practical Range with cor=0.05 for asymptotic range: 49.50501
variofit: minimised weighted sum of squares = 163.3746

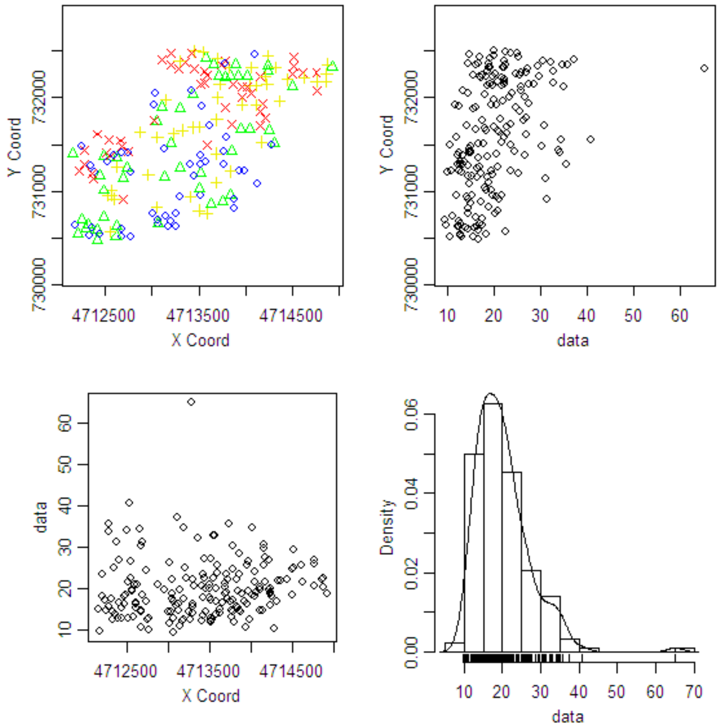


Figure 19. Exploratory data analysis for CEC in the soil plots at the Harvard Forest Advanced Tower site.

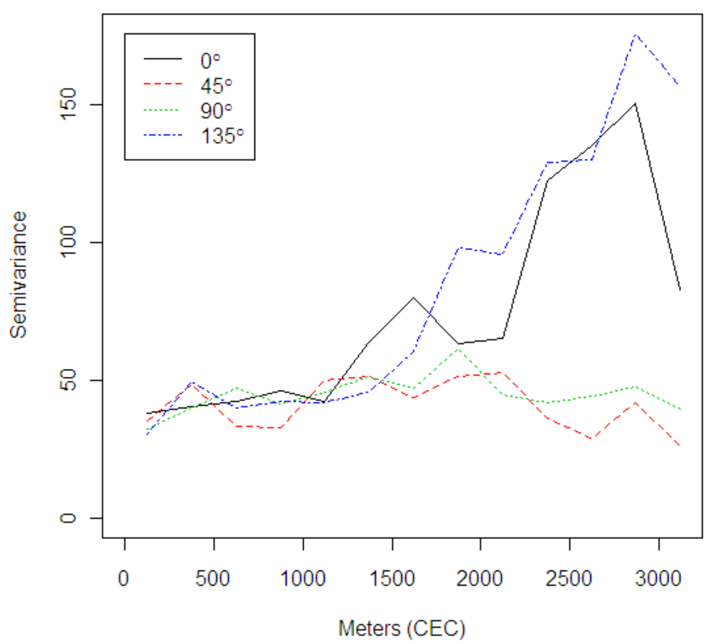


Figure 20. Directional variograms for CEC in the soil plots at the Harvard Forest Advanced Tower site

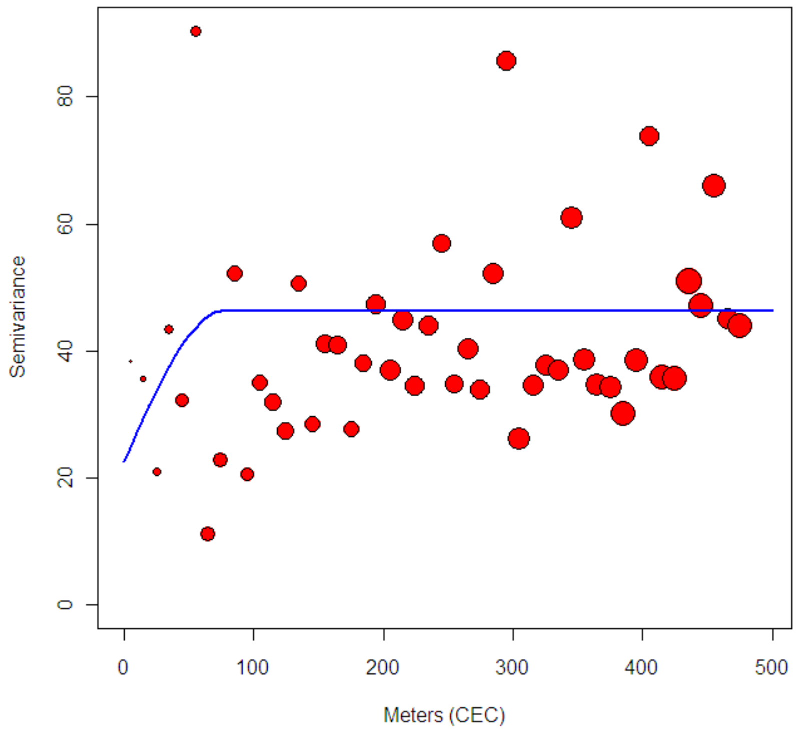


Figure 21. Empirical variogram and model fit for CEC in the soil plots at the Harvard Forest Advanced Tower site

variofit: model parameters estimated by WLS (weighted least squares):
covariance model is: spherical
parameter estimates: tausq sigmasq phi 22.4887 23.8709 77.8139
Practical Range with cor=0.05 for asymptotic range: 77.81386
variofit: minimised weighted sum of squares = 258.6139

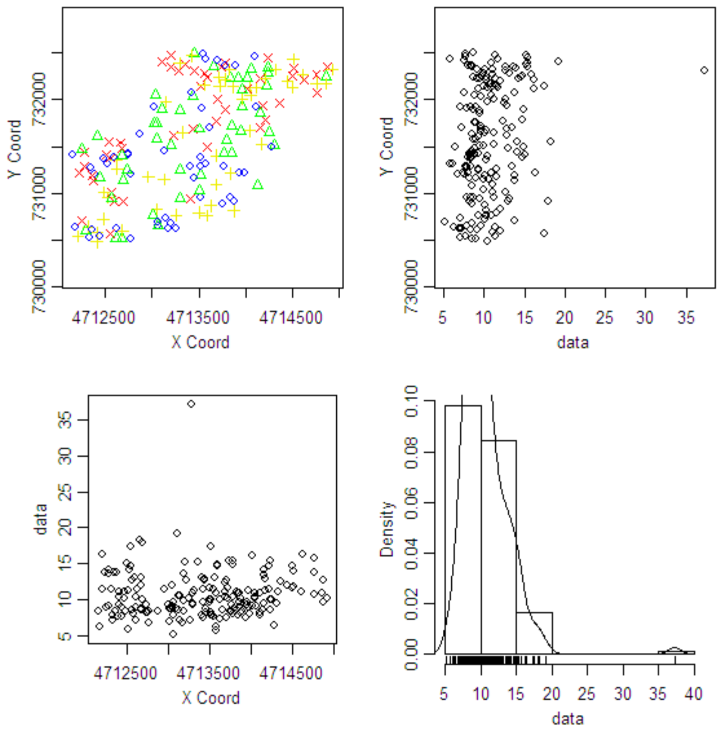


Figure 22. Exploratory data analysis for OM in the soil plots at the Harvard Forest Advanced Tower site.

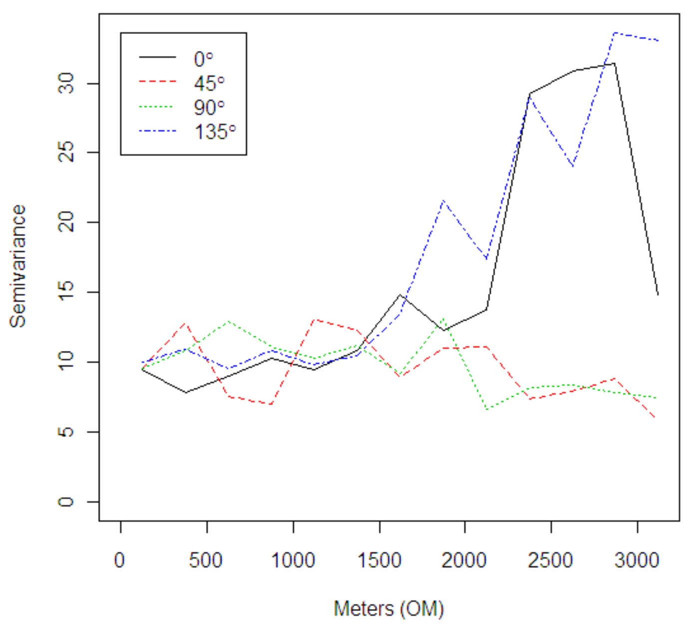


Figure 23. Directional variograms for OM in the soil plots at the Harvard Forest Advanced Tower site

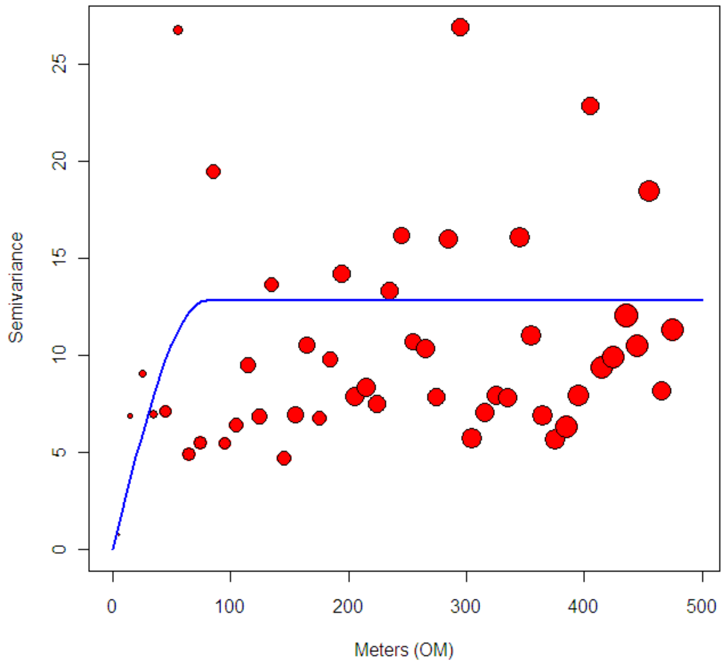


Figure 24. Empirical variogram and model fit for OM in the soil plots at the Harvard Forest Advanced Tower site.

variofit: model parameters estimated by WLS (weighted least squares):
covariance model is: spherical
parameter estimates: tausq sigmasq phi 0.0000 12.8025 79.0395
Practical Range with cor=0.05 for asymptotic range: 79.03951
variofit: minimised weighted sum of squares = 482.8416

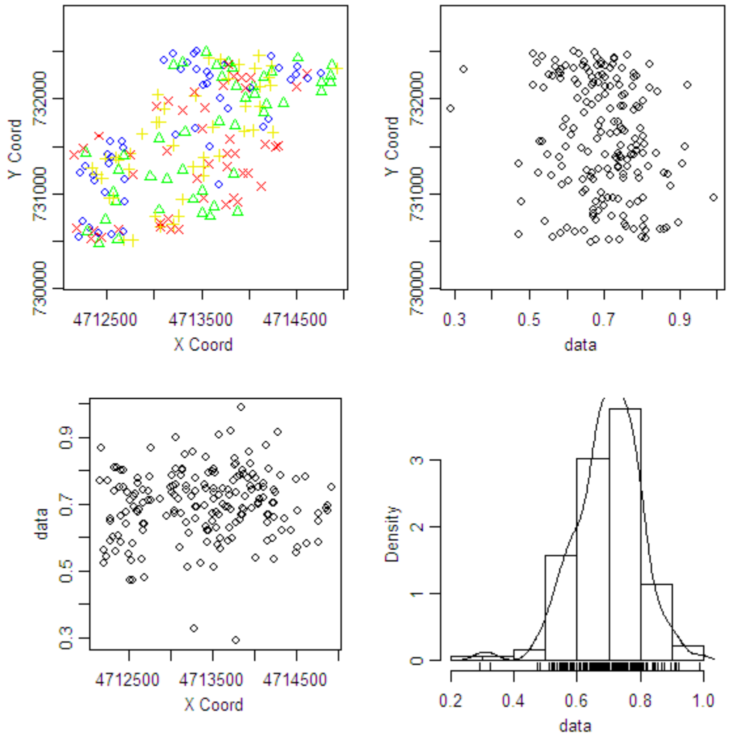


Figure 25. Exploratory data analysis for bulk density in the soil plots at the Harvard Forest Advanced Tower site.

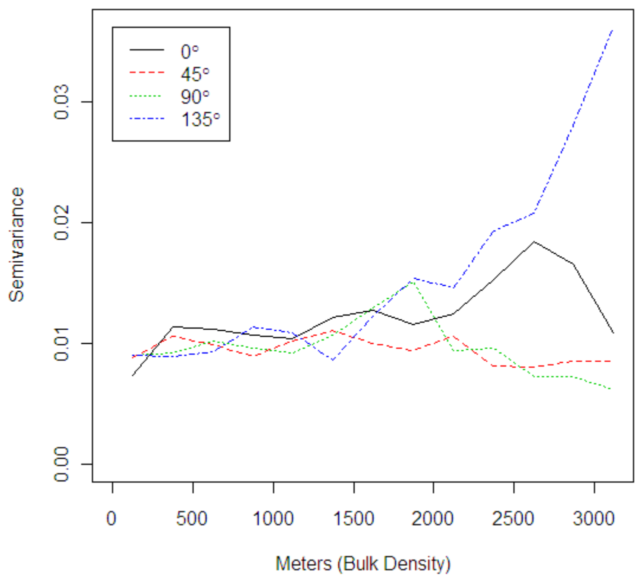


Figure 26. Directional variograms for bulk density in the soil plots at the Harvard Forest Advanced Tower site.

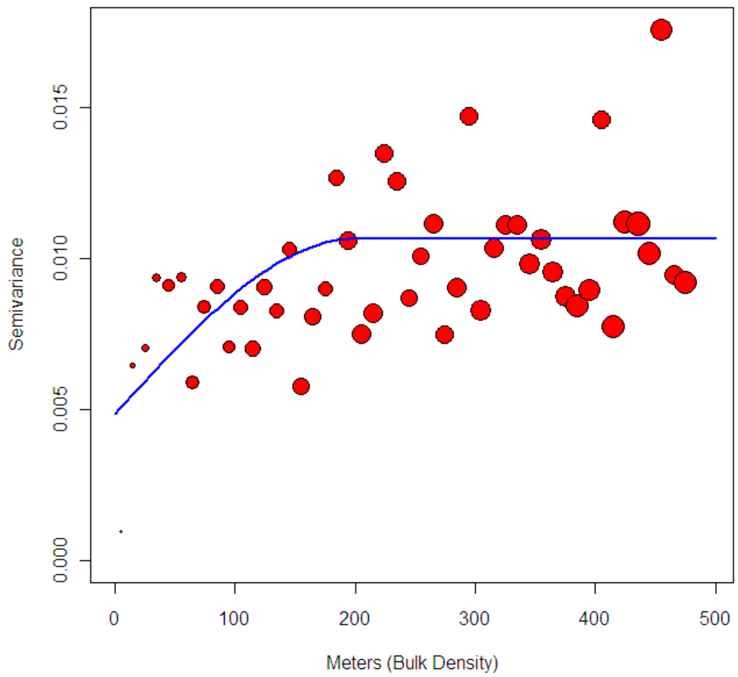


Figure 27. Empirical variogram and model fit for bulk density in the soil plots at the Harvard Forest Advanced Tower site

variofit: model parameters estimated by WLS (weighted least squares):
covariance model is: spherical
parameter estimates: tausq sigmasq phi 0.0049 0.0058 200.0042
Practical Range with cor=0.05 for asymptotic range: 200.0042
variofit: minimised weighted sum of squares = 133.1447

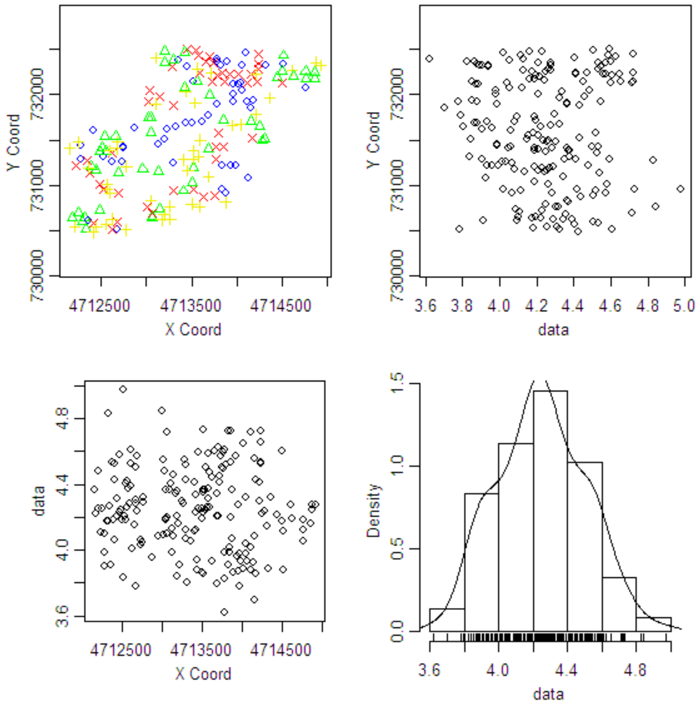


Figure 28. Exploratory data analysis for pH in the soil plots at the Harvard Forest Advanced Tower site.

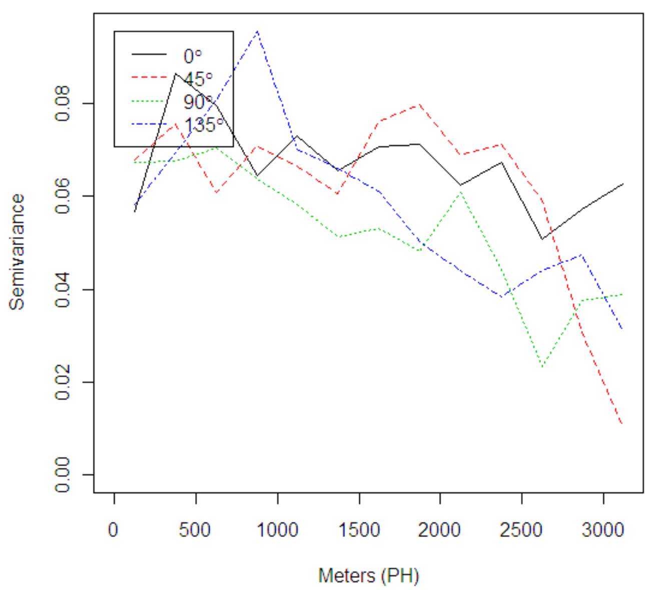


Figure 29. Directional variograms for pH in the soil plots at the Harvard Forest Advanced Tower site.

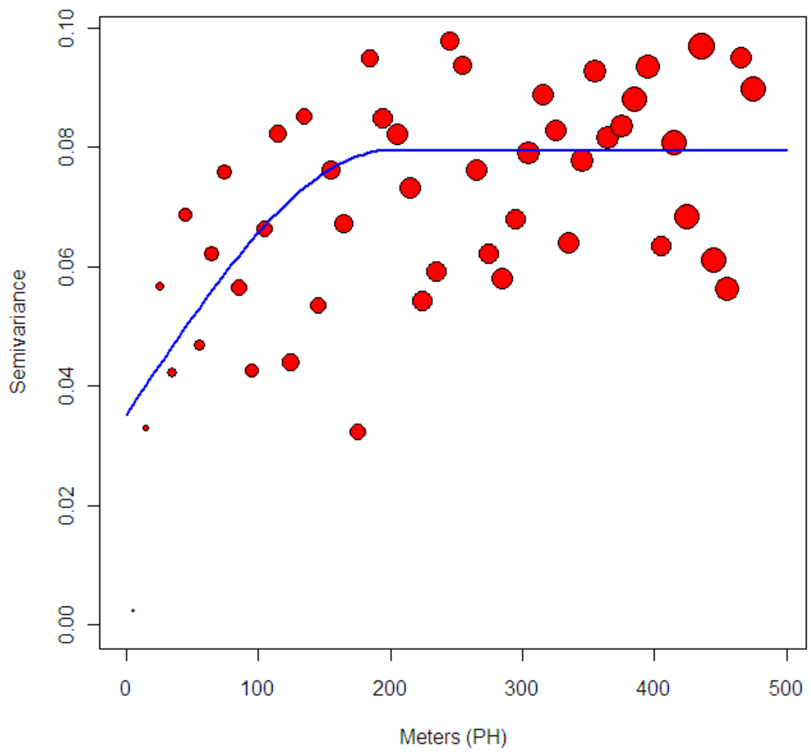


Figure 30. Empirical variogram and model fit for pH in the soil plots at the Harvard Forest Advanced Tower site.

variofit: model parameters estimated by WLS (weighted least squares):

covariance model is: spherical

parameter estimates: tausq sigmasq phi 0.0351 0.0444 200.0000

Practical Range with cor=0.05 for asymptotic range: 200

variofit: minimised weighted sum of squares = 101.5237

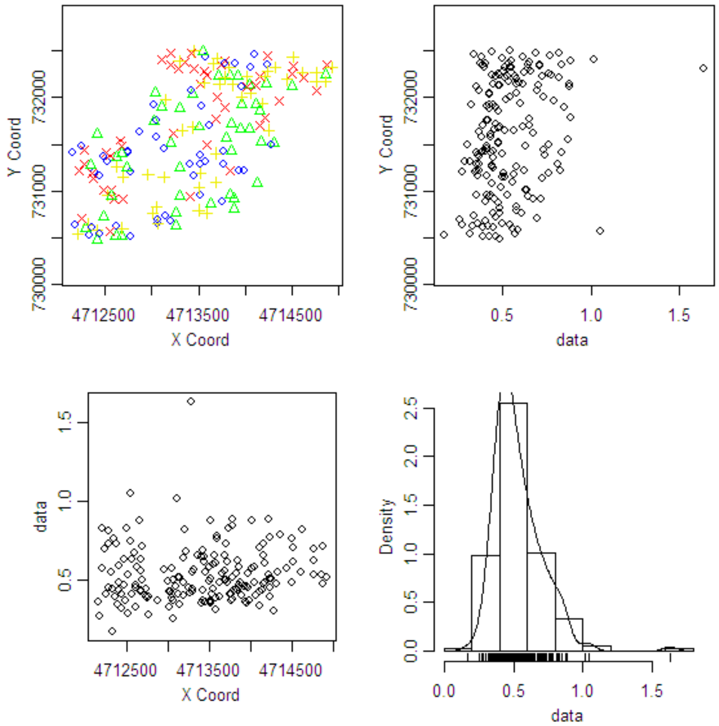


Figure 31. Exploratory data analysis for soil carbon in the soil plots at the Harvard Forest Advanced Tower site.

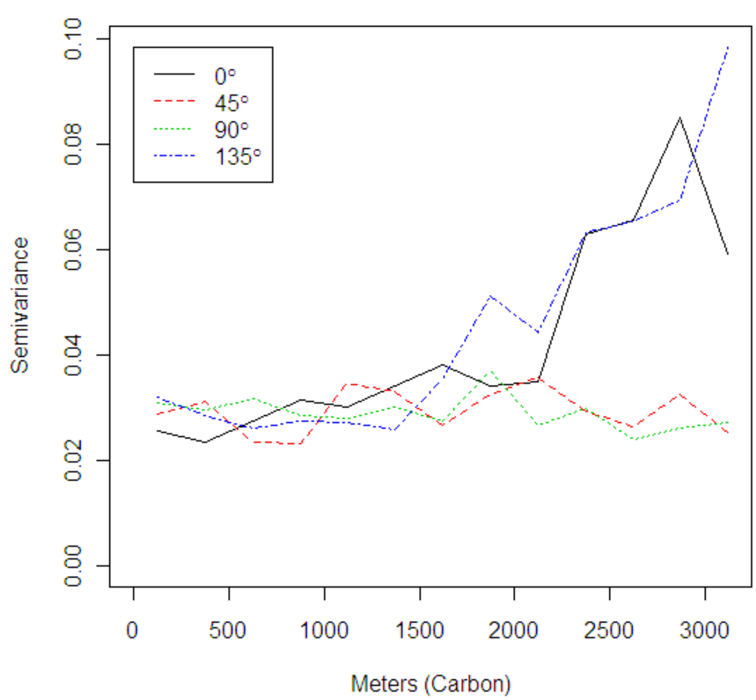


Figure 32. Directional variograms for clay in the soil plots at the Harvard Forest Advanced Tower site.

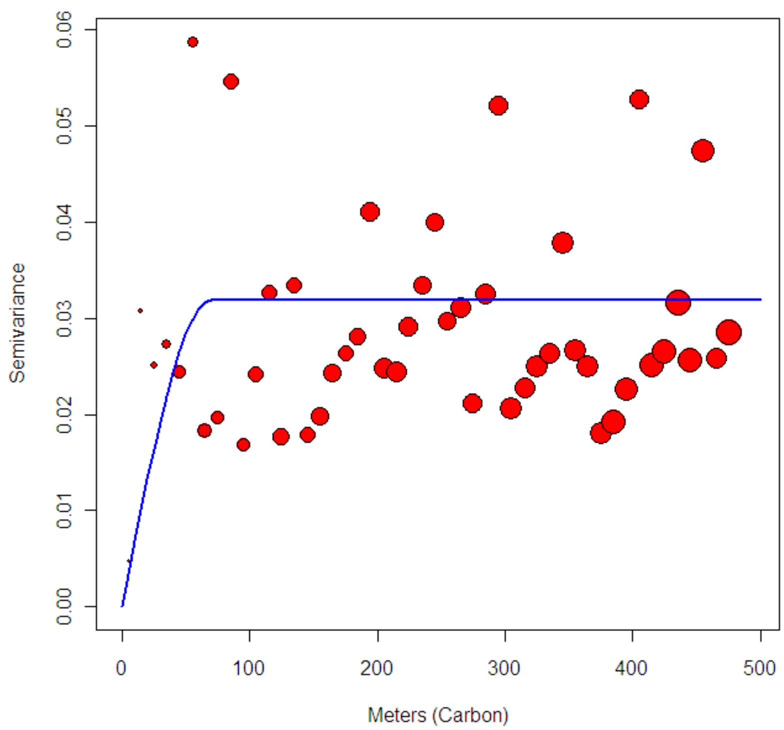


Figure 33. Empirical variogram and model fit for soil carbon in the soil plots at the Harvard Forest Advanced Tower site.

variofit: model parameters estimated by WLS (weighted least squares):

covariance model is: spherical

parameter estimates: tausq sigmasq phi 0.0000 0.0319 70.0045

Practical Range with cor=0.05 for asymptotic range: 70.00449

variofit: minimised weighted sum of squares = 252.6491

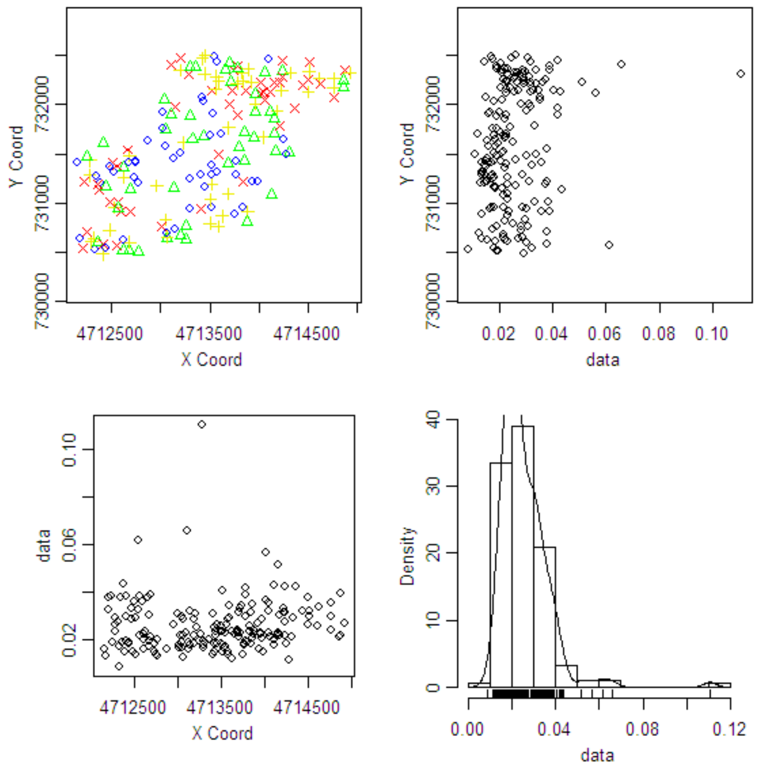


Figure 34. Exploratory data analysis plots for soil nitrogen in the soil plots at the Harvard Forest Advanced Tower site.

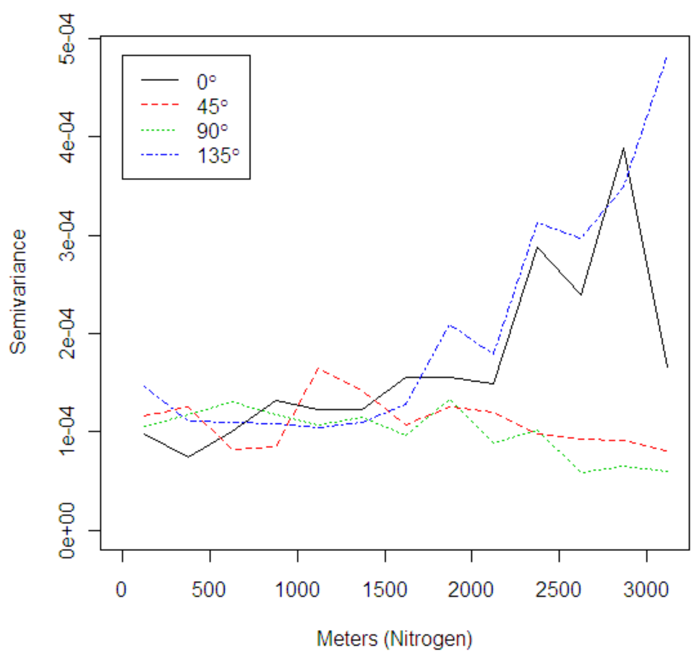


Figure 35. Directional variograms for soil nitrogen in the soil plots at the Harvard Forest Advanced Tower site.

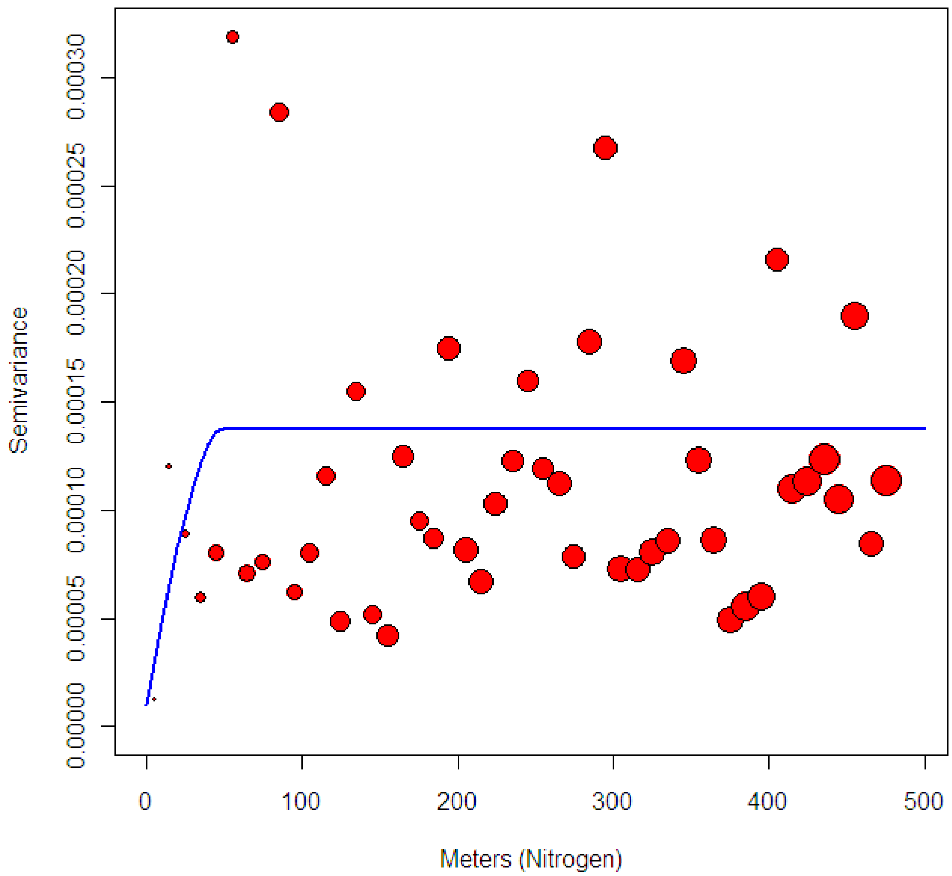


Figure 36. Empirical variogram and model fit for soil nitrogen in the soil plots at the Harvard Forest Advanced Tower site.
variofit: model parameters estimated by WLS (weighted least squares):
covariance model is: spherical
parameter estimates: tausq sigmasq phi 0e+00 1e-04 5e+01
Practical Range with cor=0.05 for asymptotic range: 50
variofit: minimised weighted sum of squares = 514.8996

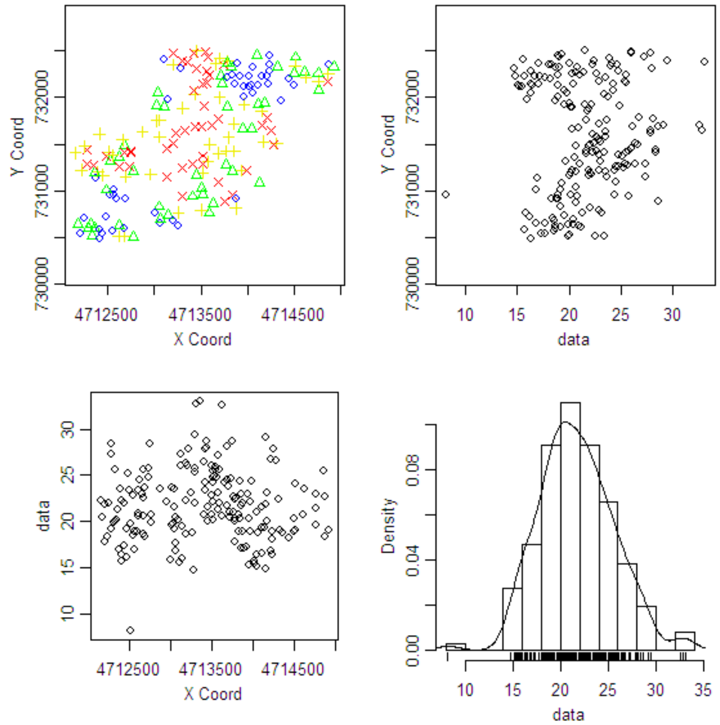


Figure 37. Exploratory data analysis plots for ration of C:N in the soil plots at the Harvard Forest Advanced Tower site.

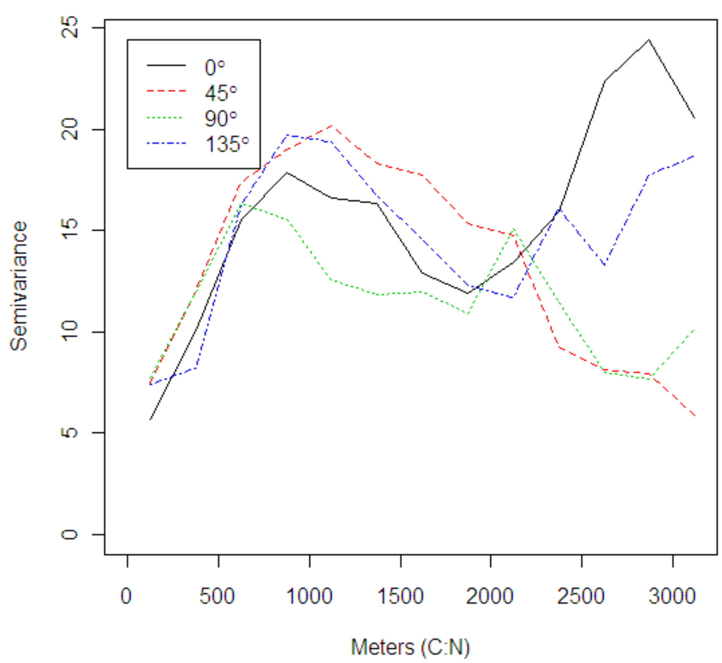


Figure 38. Directional variograms for C:N ratio in the soil plots at the Harvard Forest Advanced Tower site.

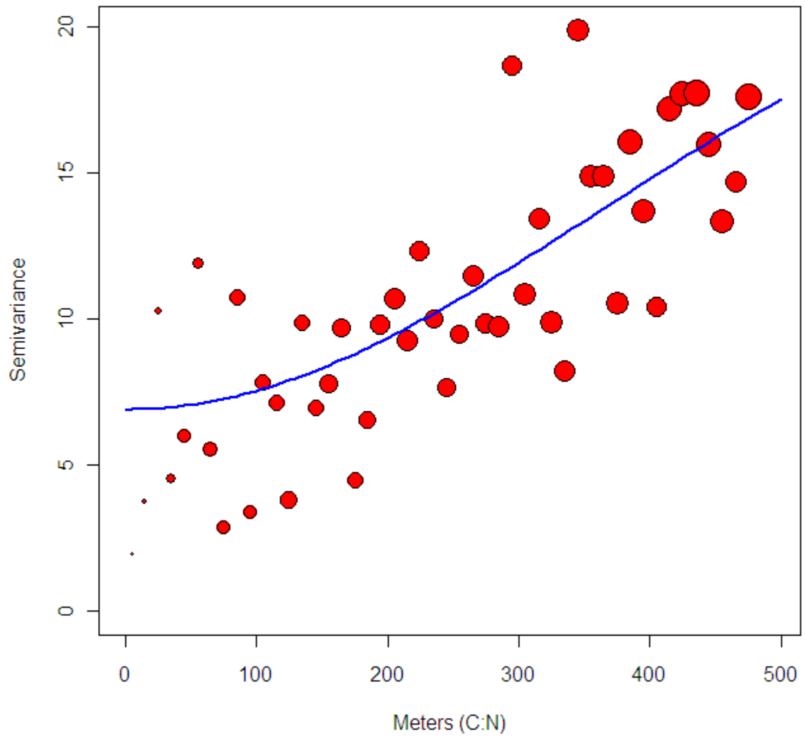


Figure 39. Empirical variogram and model fit for C:N ratio in the soil plots at the Harvard Forest Advanced Tower site.
variofit: model parameters estimated by WLS (weighted least squares):
covariance model is: gaussian
parameter estimates: tausq sigmasq phi 6.8985 17.1439 508.9077
Practical Range with cor=0.05 for asymptotic range: 880.8268
variofit: minimised weighted sum of squares = 155.1789

3.3.3.4 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, based on the FIU soil temperature and moisture content measurements, was 73 m for soil temperature and 25 m for soil moisture. Based on these results and the site design guidelines the soil plots at Harvard Forest 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 310° from the soil plot nearest the tower (i.e., first soil plot). The location of the first soil plot will be approximately 42.537093, -72.172956. 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 42.535626, -72.175605 (primary location); or 42.535152, -72.175615 (alternate location 1 if primary location is unsuitable); or 42.53783, -72.17230 (alternate location 2 if primary location is unsuitable). A summary of the soil information is shown in Table 4 and site layout can be seen in Figure 40.

Dominant soil series at the site: Becket-Skerry association, 3 to 15 percent slopes, extremely stony. The taxonomy of this soil is shown below:
Order: Spodosols
Suborder: Orthods
Great group: Haplorthods
Subgroup: Oxyaquic Haplorthods-Aquic Haplorthods
Family: Coarse-loamy, isotic, frigid Oxyaquic Haplorthods-Coarse-loamy, isotic, frigid Aquic Haplorthods
Series: Becket-Skerry association, 3 to 15 percent slopes, extremely stony

Table 4. Summary of soil array and soil pit information at Harvard Forest. 0° represents true north and accounts for declination.
All the expected soil depths are used for soil temperature and soil water content measurements. [a] is noted for soil CO2 measurement depths.

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	29 m
Latitude and longitude of 1st soil plot OR direction from tower	42.537093, -72.172956
Direction of soil array	310°
Latitude and longitude of FIU soil pit 1	42.535626, -72.175605 (primary location)
Latitude and longitude of FIU soil pit 2	42.535152, -72.175615 (alternate 1)
Latitude and longitude of FIU soil pit 3	42.53783, -72.17230 (alternate 2)
Dominant soil type	Becket-Skerry association, 3 to 15 percent slopes, extremely stony
Expected soil depth	0.45- 0.89 m
Depth to water table	0.61-1.07 m

Expected depth of soil horizons	Expected measurement depths
[a] 0-0.10 m (Fine sandy loam)	0.05 m
0.10-0.33 m (Fine sandy loam)	0.27 m
[a] 0.33-0.46 m (Sandy loam)	0.40 m
0.46-0.64 m (Gravelly sandy loam)	0.55 m
[a] 0.64-1.65 m (Gravelly fine sandy loam)	1.15 m

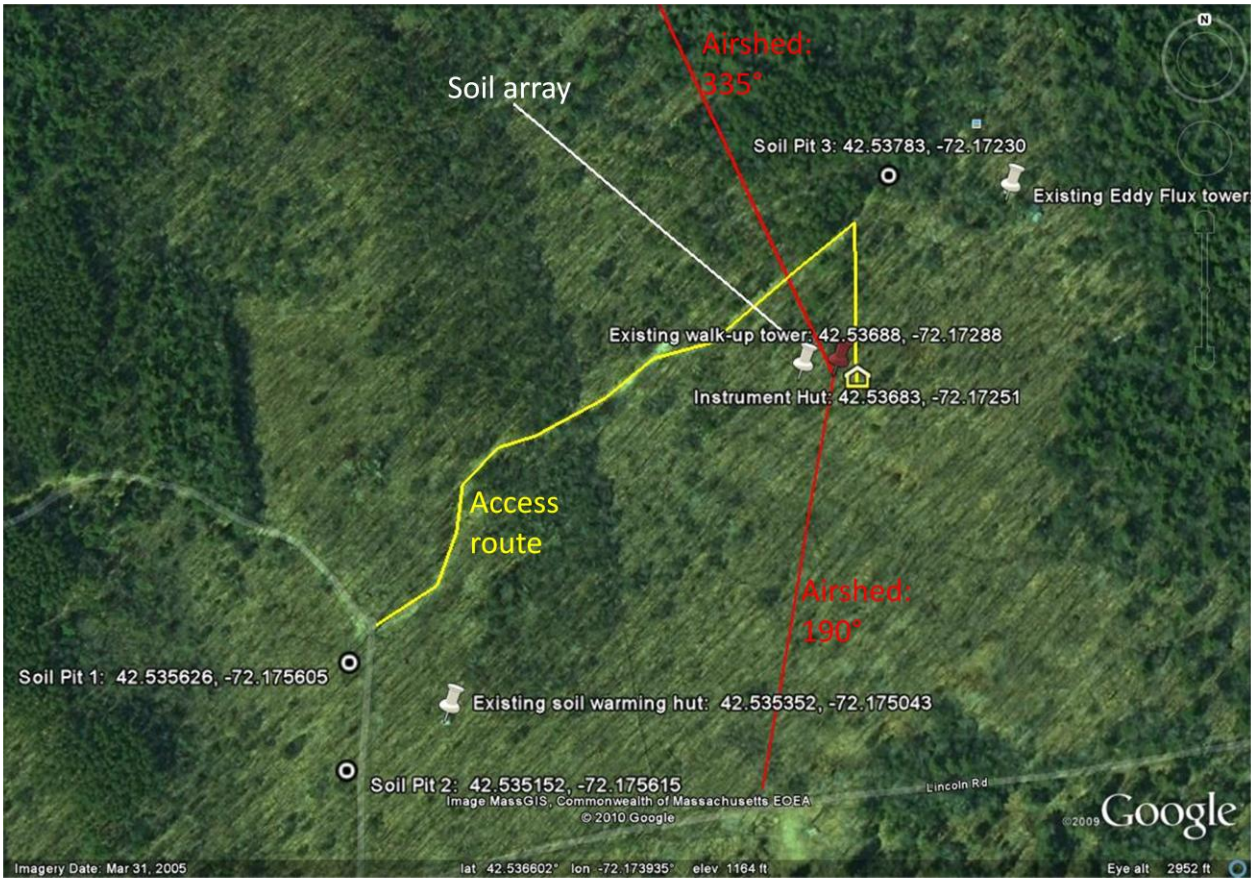


Figure 40. Site layout at Harvard Forest showing soil array and location of the FIU soil pits.

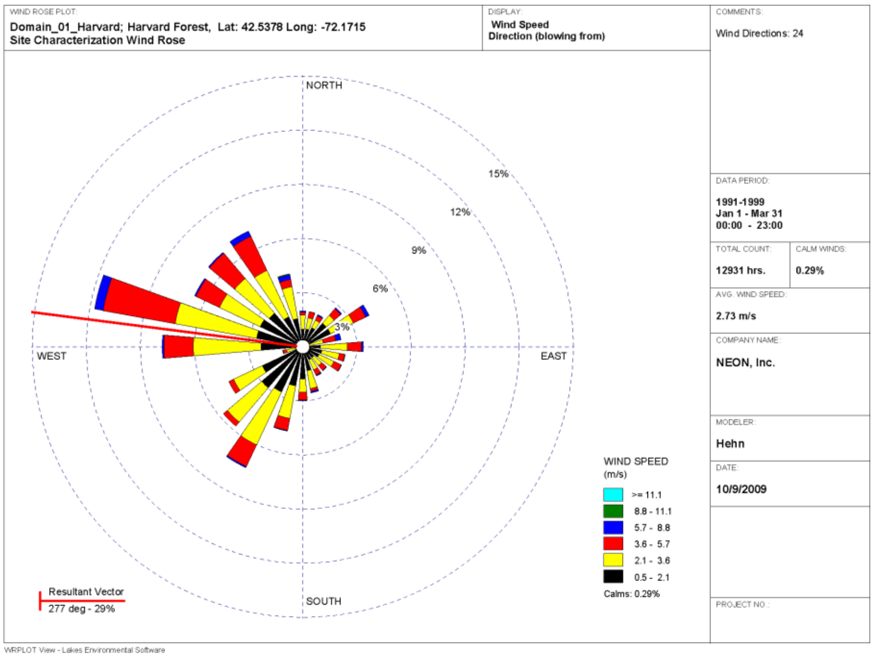
i) Tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 190° to 335° (clockwise from 190°) are the airshed area that would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access road to instrument hut.

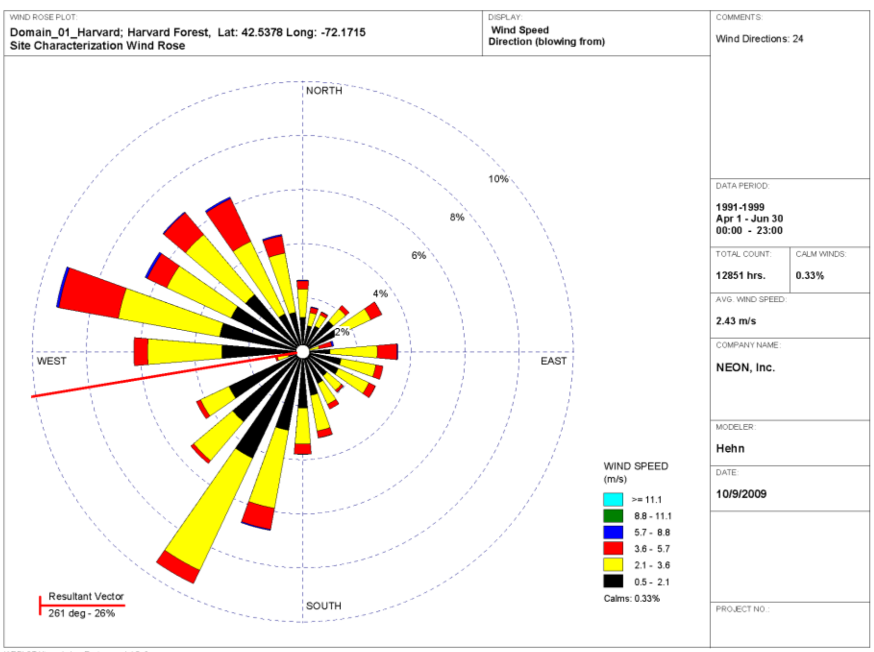
3.4 Airshed

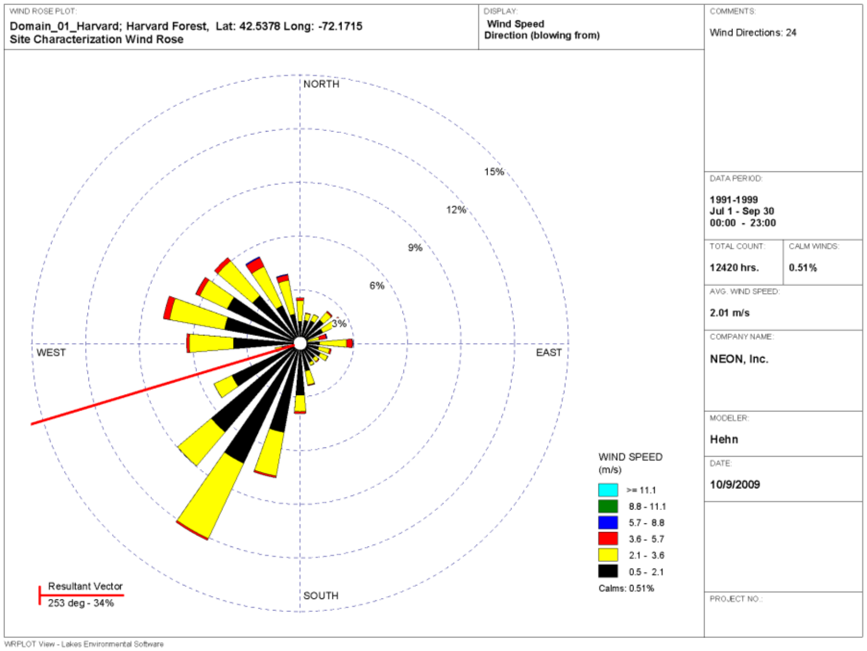
3.4.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries, Figure 41. The weather data used to generate the following wind roses are from Harvard Forest LTER site existing flux tower, which is ~200 m from NEON tower 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. 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.

3.4.2 Results (graphs for wind roses)







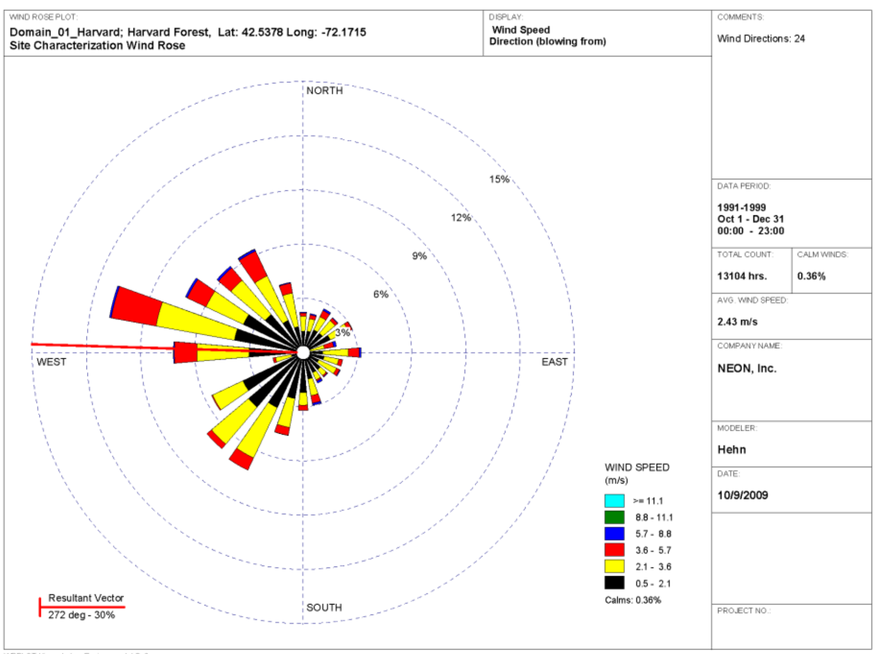


Figure 41. Windroses from the Harvard Forest LTER site.

Data used here are hourly data from 1991 to 1999. Data used here are hourly data from 1991 to 1999. Data was collected and obtained from the Harvard Forest LTER site. It is assumed that the wind data was corrected for declination. Panels are (from top to bottom), Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

3.4.3 Resultant vectors

Table 5. The resultant wind vectors from Harvard Forest using hourly data from 1991 to 1999.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	277°	29
April to June	261°	26
July to September	253°	34
October to December	272°	30
Annual	265.8°	na.

Table 6. The percent duration of winds among cardinal directions, Harvard Forest
3 frequency bins on each side of the cardinal direction. Data are from Harvard Forest using hourly data from 1991 to 1999. Blue text and underline indicates the dominant, winds occurring for the cardinal direction >40% of the time. Appears as though there is a systematic bias in the data from WWSW

Quarterly (seasonal) timeperiod	Cardinal direction			
	North	East	South	West
January to March	23.6	15.6	22.6	38.3
April to June	22.0	15.7	28.6	33.9
July to September	20.1	10.5	32.3	36.9
October to December	23.2	15.6	26.8	34.6

3.4.4 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, we used a web-based footprint model 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 7. Expected environmental controls to parameterize the source area model, and associated results from Harvard Forest advanced 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	33	33	33	33	33	33	m
Canopy Height	23	23	23	23	23	23	m
Canopy area density	4.6	4.6	4.6	1.4	1.4	1.4	m
Boundary layer depth	2000	2000	2000	2000	2000	2000	m
Expected sensible heat flux	350	350	30	50	50	-10	$W\ m^{-2}$
Air Temperature	23	23	14	3	3	-7	°C
Max. windspeed	5.7	3.4	1.4	8.8	3.7	1.7	$m\ s^{-1}$
Resultant wind vector	253	253	253	277	277	277	degrees
				Results			
(z-d)/L	-0.07	-0.24	-0.27	0.00	-0.04	0.18	m
d	19	19	19	16.00	16.00	16.00	m
Sigma v	2.4	2.00	0.87	3.00	1.60	1.80	$m^2\ s^{-2}$
Z0	0.81	0.81	0.81	1.60	1.60	1.60	m
u*	0.89	0.61	0.26	1.50	0.67	0.22	$m\ s^{-1}$
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	615.4	443.1	393.8	713.8	640.0	731.4	m
Distance of 80% cumulative flux	393.8	270.8	246.2	467.7	426.7	582.9	m
Distance of 70% cumulative flux	295.4	184.6	172.3	344.6	296.3	434.3	m
Distance of 60% cumulative flux	221.5	147.7	123.1	246.2	237.0	331.4	m

Distance of 50% cumulative flux	172.3	110.8	98.5	209.2	177.8	251.4	m
Distance of 40% cumulative flux	147.7	86.2	73.8	160.0	142.2	194.3	m
Distance of 30% cumulative flux	98.5	49.2	49.2	123.1	118.5	160.0	m
Distance of 20% cumulative flux	---	---	---	86.2	---	125.7	m
Distance of 10% cumulative flux	---	---	---	---	---	80.0	m
Peak contribution	60	60	20	200	200	250	m

3.4.5 Results (source area graphs)

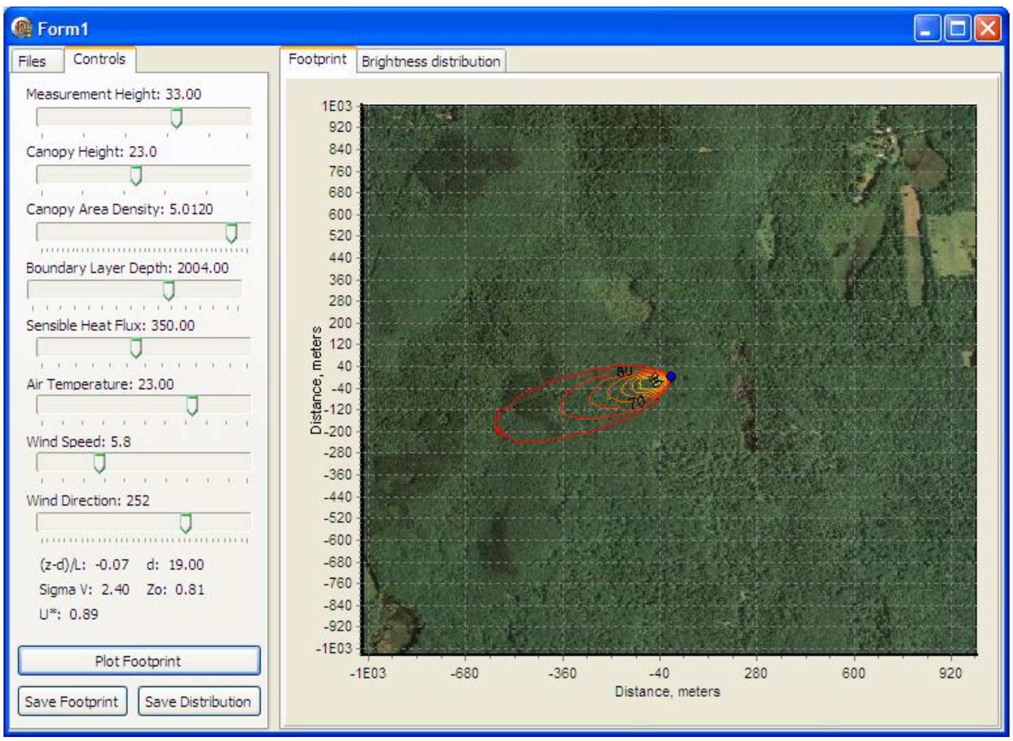


Figure 42. Harvard Forest summer daytime (convective) footprint output with max wind speed.

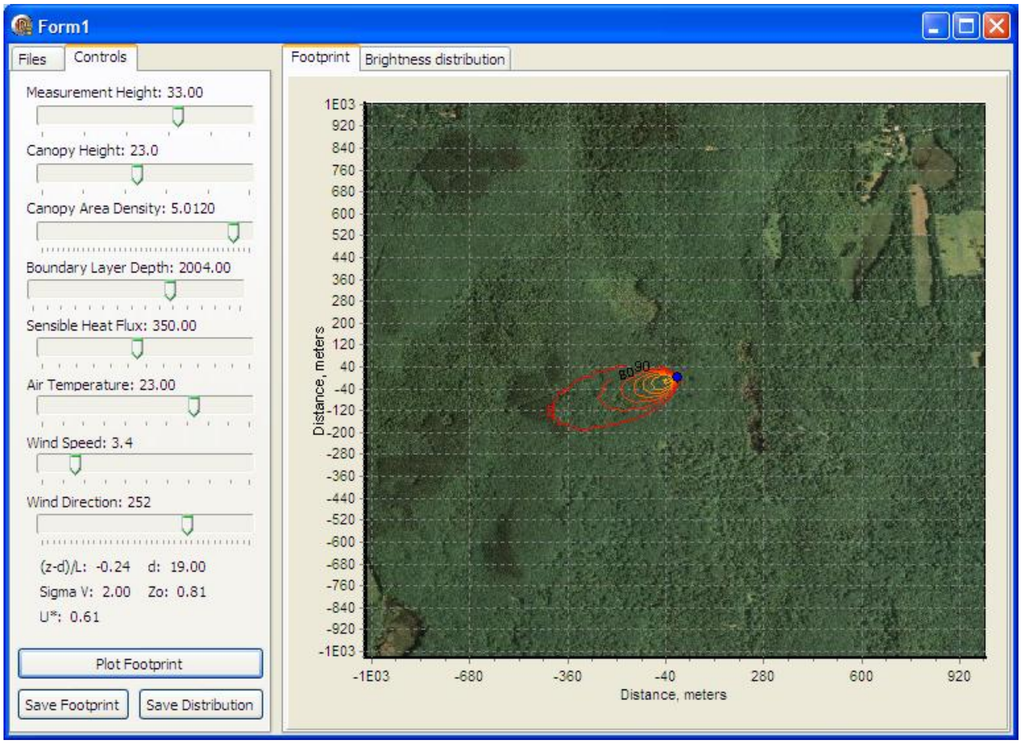


Figure 43. Harvard Forest summer daytime (convective) footprint output with mean wind speed.

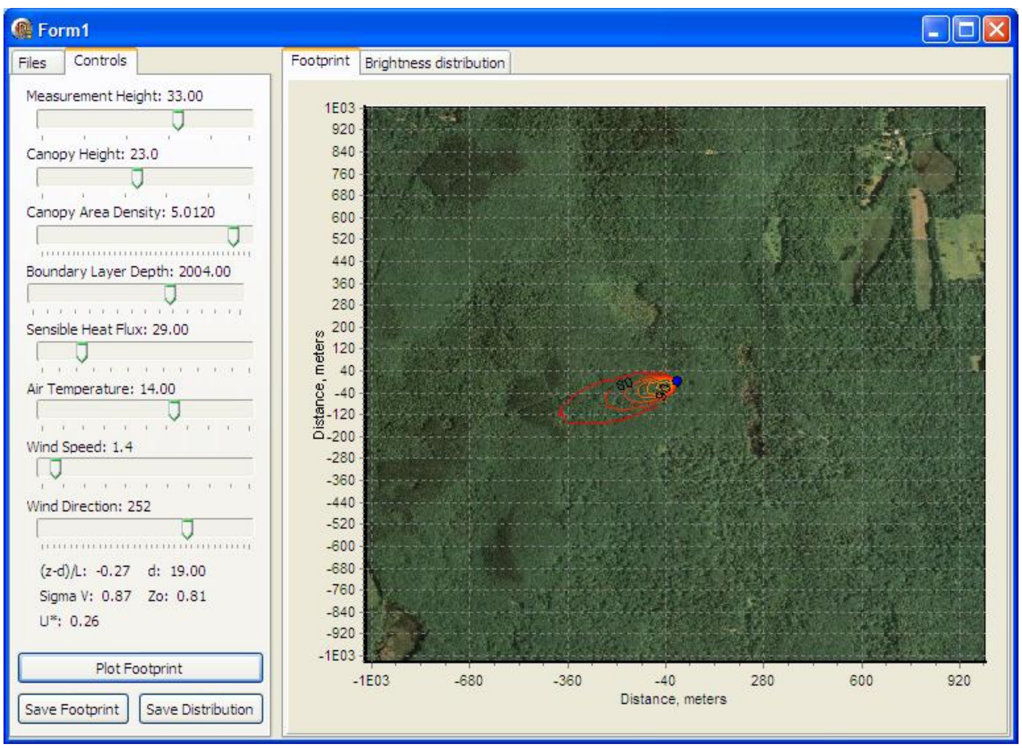


Figure 44. Harvard Forest summer nighttime (stable) footprint output with mean wind speed.

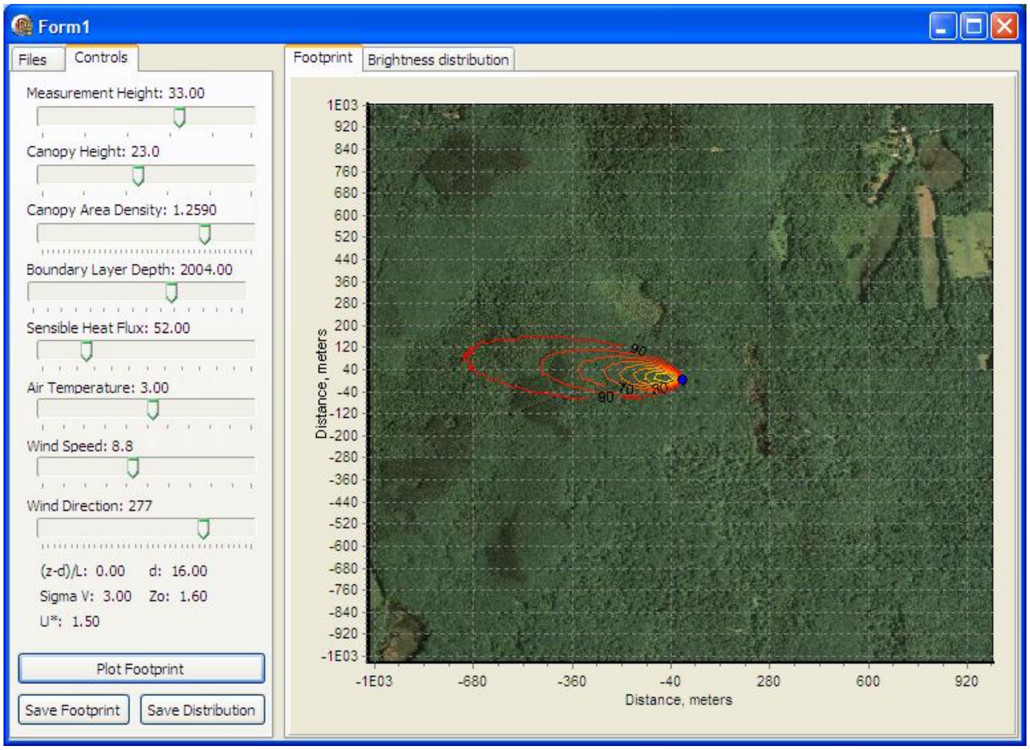


Figure 44. Harvard Forest winter daytime (convective) footprint output with max wind speed.

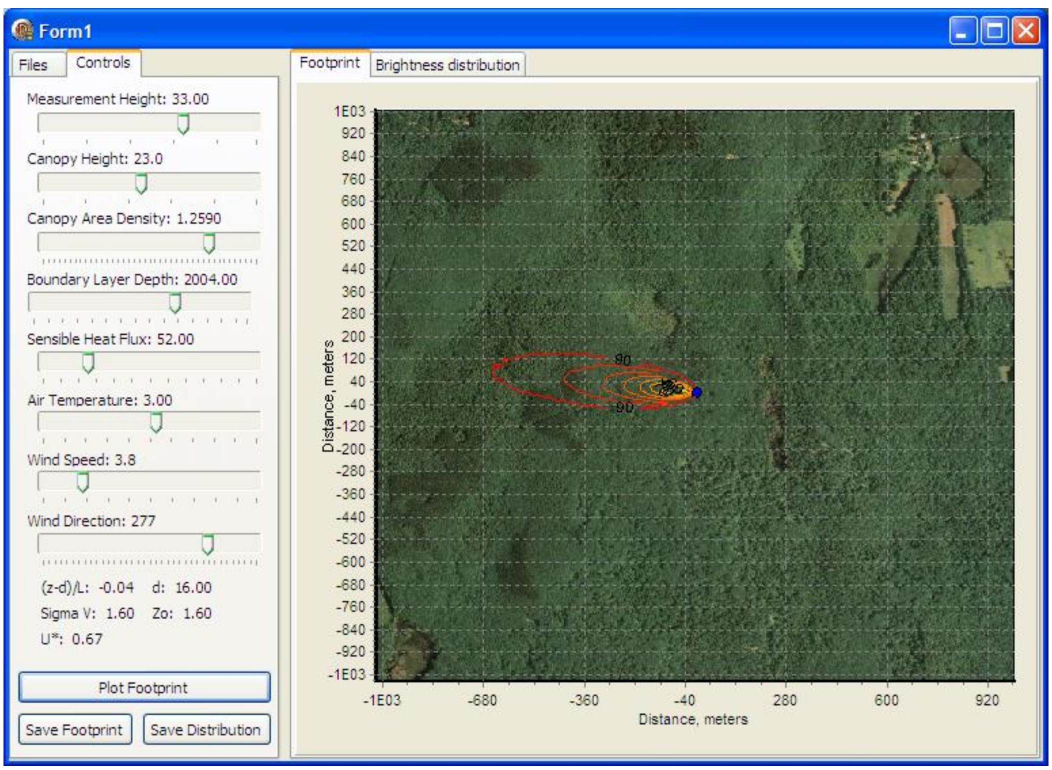


Figure 45. Harvard Forest winter daytime (convective) footprint output with mean wind speed.

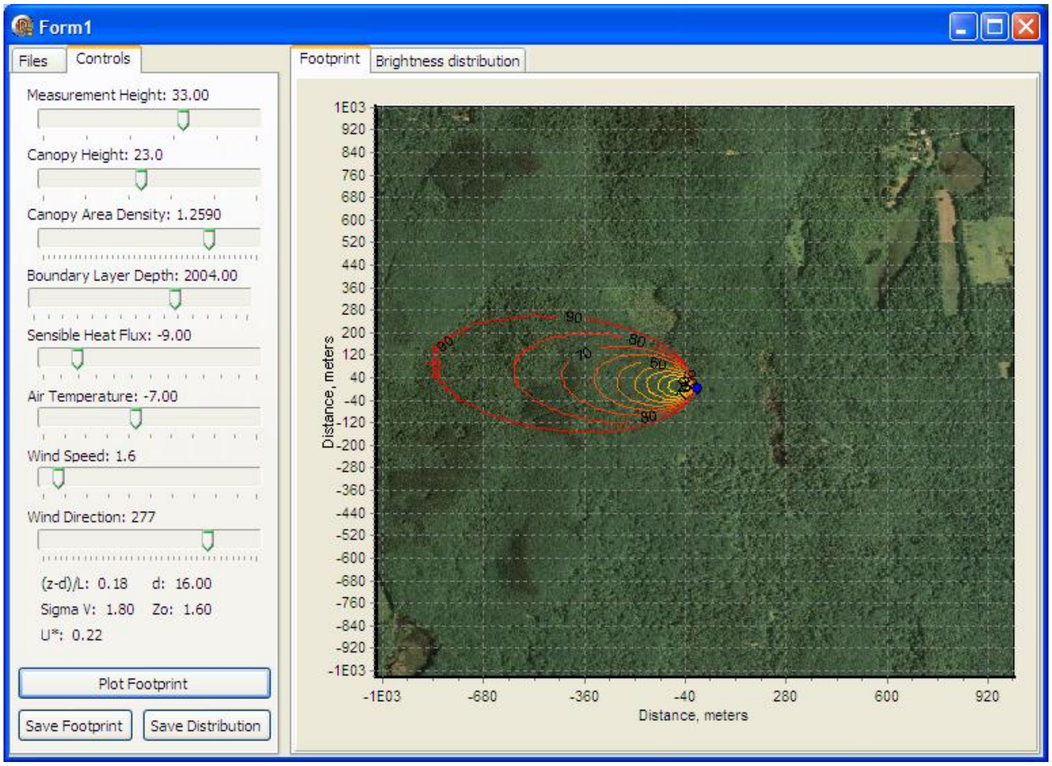


Figure 46. Harvard Forest winter nighttime (stable) footprint output with mean wind speed.

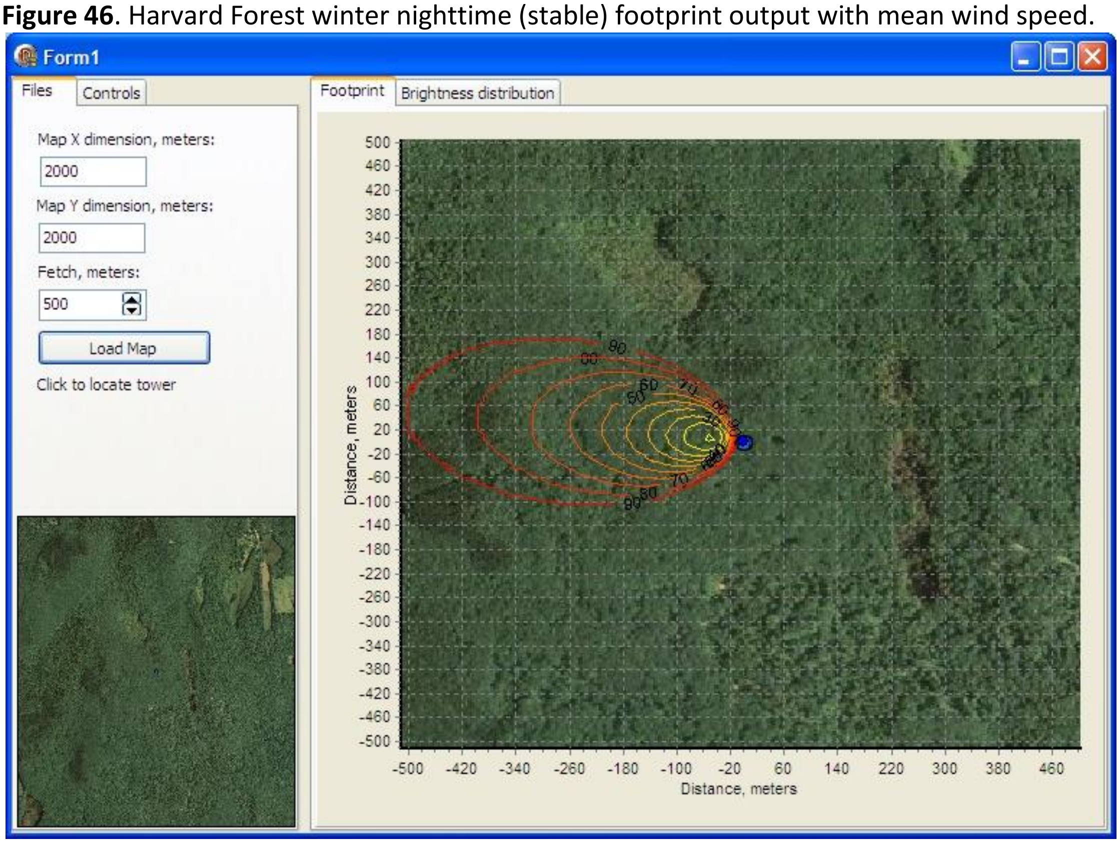


Figure 47. Harvard Forest winter nighttime (stable) footprint output with max wind speed. Fetch 500 m.

3.4.6 Acceptance criteria

Micrometeorological theory and the eddy covariance technique were established over uniform vegetative canopies with short roughness lengths on flat terrain and large fetch. The objective is to place a tower in such a way to optimize the amount of time where all the flows (winds) and microclimate with minimal disturbance and secondary filtering. Flow through the tower must be discounted and screened against data quality criteria (FIU V+V doc). Flows that pass through a tower often have to be screened and filtered out of a long-term dataset. If positioning a tower can be positioned on the landscape towards an undesirable land use type or influence on the leeward side of the tower—if it is well known the data will have low quality. Additional concerns and acceptance criteria can be found in the FIU Tower Science requirements, AD 01.

The tower should be sited to maximize the time with winds blowing from the desired land cover type, and with the longest upwind fetch attainable. If the surroundings are not of a uniform cover type, there needs to be some analysis of prevailing winds to demonstrate that the desired sectors are sampled uniformly through time. Consider the extreme example of a site with two different forest types and a consistent daily wind cycle that blew from one forest type and in the day and the other at night. Daily integrated net ecosystem exchange (NEE) in this situation would be un-interpretable. This extreme condition is unlikely, but many sites could have more subtle wind direction biases that need to be examined and considered in data interpretation. All systems are subject to horizontal flux divergence, advective motions, wake effects and drainage of air sheds (FIU Tower Science Requirements). Footprint analyses to determine the source area under different stabilities, wind speeds and direction among seasons provide valuable guidance for appropriate tower placement, documentation of site characteristics, and definition of data acceptance criteria (Foken and Leclerc 2004, Horst and Weil 1992, Horst and Weil 1994a, Horst and Weil 1994b, Horst, 2001, Kormann and Meixner 2001, Schmid and Lloyd 1999, Schmid 1994, Schuepp *et al*. 1990). The criteria for tower placement should not only be concerned with the summer, productive periods, but also the seasonal transitional periods (spring and fall), and winter months when respiration process often dominate.

Micro-topography requires visual inspection. Long wave forms and standing waves are common place over short stature ecosystems small < 10 m topographic relief and high (mechanical turbulent) winds occur (tundra, grasslands, alpine ecosystems). Preliminary data collection may be useful to determine if micro-topographic features affect the local microclimate and flow regimes.

The tower needs to be high enough to place the sensors well above the surrounding canopy, but not so high that the footprint during stable night-time conditions extends beyond the boundary of the ecosystem type of interest.

Other constraints are placed on our ability to locate and position a tower besides available footprint and flow regimes. At some locations, there is a large sensitivity towards viewing the tower above the canopy from houses, scenic over views, or within an urban area. This public concern is particularly prevalent in State and National Parks. A second constraint is the amount of land available for construction. Lastly, there are often nearby land uses or ecosystem types that can contribute undesirable information (fluxes, meteorology) to the tower based measurements. For example, different grazing patterns in a nearby field, large wetlands in the center of the desired footprint, roads that cause line sources of dust or hydrocarbons, or clearcuts that generate conflicting non-local circulations (Loescher *et al*. 2004). All these issues have to be balanced to achieve the scientific requirements.

Windroses were constructed on a seasonal basis where, *i*) the first estimation is the maximum and average seasonal windspeeds, *ii*) the season fractional wind directions, and *iii*) is the resultant wind direction.

Winds are dominant from the NNW to the SSW for all windrose periods (Figure 41), and supported by the quadrate analyses (Tables 6-5) with an annual resultant wind vector of 265.8°. Because winds from the east are infrequent and low velocities, the tower should be on the east side of the wind measurement booms. Because the winds are evenly distributed in frequency from the N, W and S (Table 4), to maximize the data coverage, the boom should be facing toward the West, 270°, close to the annual resultant vector. Because i) there is ample room within the property boundary, ii) the dominant soil type extends towards the west of the tower location, and iii) it is possible to place the soil array within the airshed, the soil array should extend also toward 310° vector.

The desired measurements are from eastern deciduous mixed forest with the dominant soil association being Becket-Skerry, 3 to 15° slopes, extremely stony (36 % spatially dominant), Table 5. Based on maps provided by Harvard Forest, there does not seem to be any limit on the source area based on property boundaries. Because flows through the tower have to be examined and potentially removed from the dataset, placing the leeward side of the tower closest to the east optimizes flows over the source area from the west. To maximize the fetch (source area) from the SW in all seasons, the tower location should be placed in the E area of this forest. Because winds from the NW to SW occur during all seasons and the results from the footprint analyses (Figures 42-47) indicate 80 % of the cumulative flux is within 700 m under the most extreme conditions (winter, stable atmosphere, high winds), and as small as 60 m in summer (strongly convective, unstable atmospheres).

3.4.7 Site design and tower attributes

Based on the information above, site design and layout are described below. According to wind roses, the prevailing wind direction blows from northwest to south west (190° to 335°, clockwise from 190°) throughout the year. Tower should be placed to a location to best catch the signals from the airshed of the ecosystem in interest, which is eastern deciduous mixed (maple-oak-pine-spruce-hemolck) forest. The tower site is 42.5369, -72.17266. The NEON tower is approximately 18 m east of the walkup platform; however, Bill Munger said that the walkup platform tower will be removed.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the west 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. An **instrument hut** should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind and should be positioned to have the longer side parallel to frequent wind direction to minimize the wind effects on instrument huts and to minimize the disturbances of wind regime by instrument hut, and in this case, instrument hut should be positioned on the southeast side of tower and have the longer side parallel to E-W direction. Because this is a closed canopy ecosystem, the distance between the tower and the instrument hut can be reduced to ~ 15 m. Therefore, we require the placement of instrument hut at 42.53683, -72.17251.

Canopy height is ~26 m around tower site with lowest branches at ground level. Oak and otherstree species form upper understory with height ~ 16 m. Seedlings and sapling of maple, hemlock and other species forms the lower understory with mean height ~ 5 m. Grass and new seedling form the understory at ground level with height ~ 1m. We require 6 **measurement layers** on the tower with top measurement height at 36 m, and rest layers are 29 m, 23m, 16 m, 5 m and 0.8 m, respectively, to best characterize the fluxes on the tower top and environmental conditions in profile. This differs from what was budgeted (7 layers).

DFIR (Double Fenced International Reference) will be used for bulk precipitation collection. We had difficulty to find adequate open area to meet USCRN class 1 and class 2 criteria for DFIR within 500 m radius from tower. The best and closest open area we can find is on the south west side of tower and ~1.4 km away from tower, which is next to existing Harvard Forest weather station. Coordinates are 42.53308, -72.18986. Power is available at site. **Wet deposition collector** will collocate at the top of the tower. See AD 04 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. **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 this case, level 6 being the upper most level at this tower site.

Table 7. Site design and tower attributes for Harvard Forest Advanced site.

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

Attribute	lat	long	degree	meters	notes
Airshed area			190° to 335°		Clockwise from 190°
Tower location	42.53690	-72.17266	--	--	new site
Instrument hut	42.53683	-72.17251			
Instrument hut orientation vector	--	--	90° - 270°		
Instrument hut distance z	--	--	--	15	
Anemometer/Temperature boom orientation	--	--	270°	--	
DFIR	42.53308,	-72.18986			
Height of the measurement levels					
Level 1				0.3	m.a.g.l.
Level 2				5.0	m.a.g.l.
Level 3				16.0	m.a.g.l.

Level 4	23.0	m.a.g.l.
Level 5	29.0	m.a.g.l.
Level 6	38.0	m.a.g.l.
Tower Height	38.0	m.a.g.l.

See AD 03 for technical requirement to determine the boom height for the bottom most measurement level.

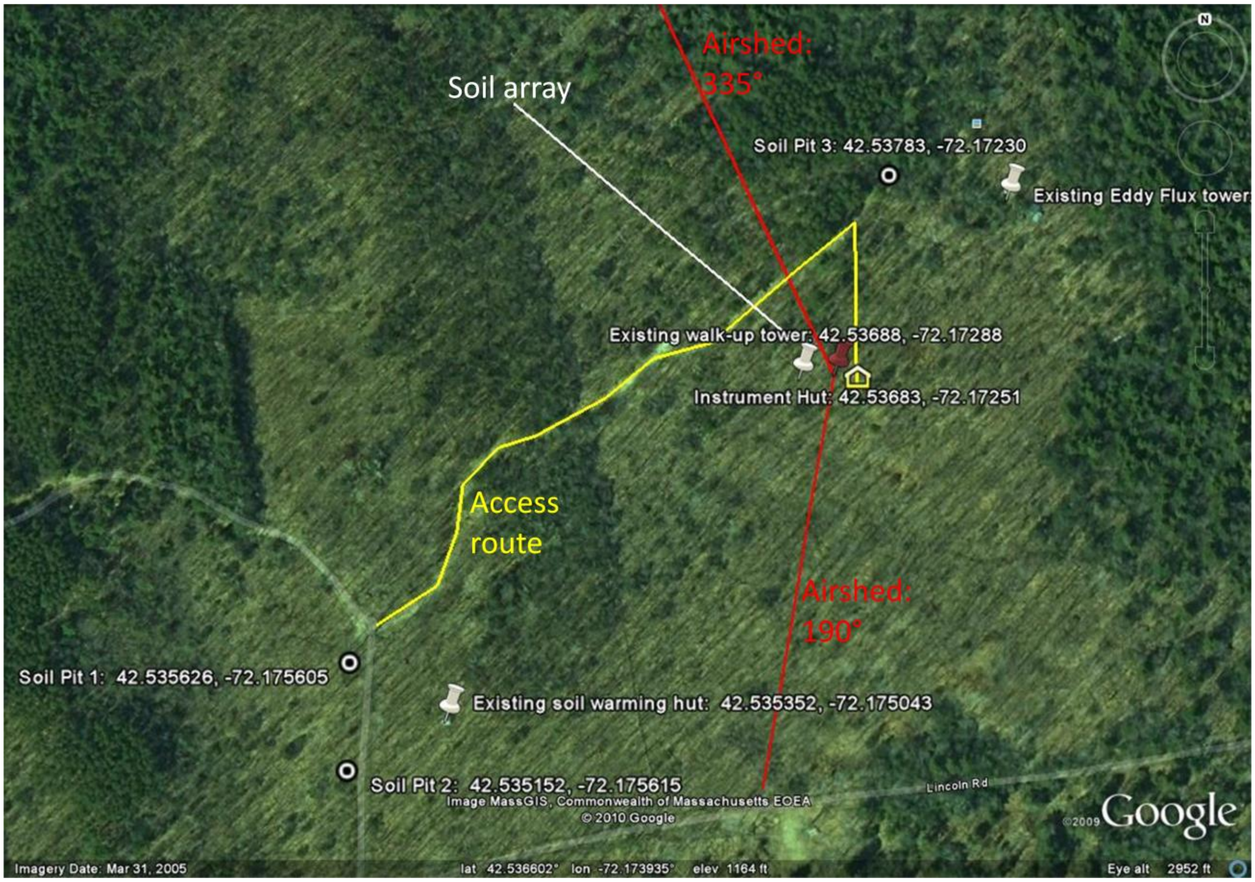


Figure 48. Site layout for Harvard Forest Advanced tower site.

Figure 48 above shows the proposed tower location, instrument hut location, airshed area and access road.

i) Tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 190° to 335° (clockwise from 190°) are the airshed area that would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access road to instrument hut.

Figure 49. DFIR location at Harvard Forest Advanced tower site.
Purple pin indicates the DFIR location, which is close to Harvard Forest buildings, it is~ 1.4 km away from tower location.

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 Harvard Forest 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 the soil array, except where it crosses the forest road.
- No boardwalk from the soil array boardwalk 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:

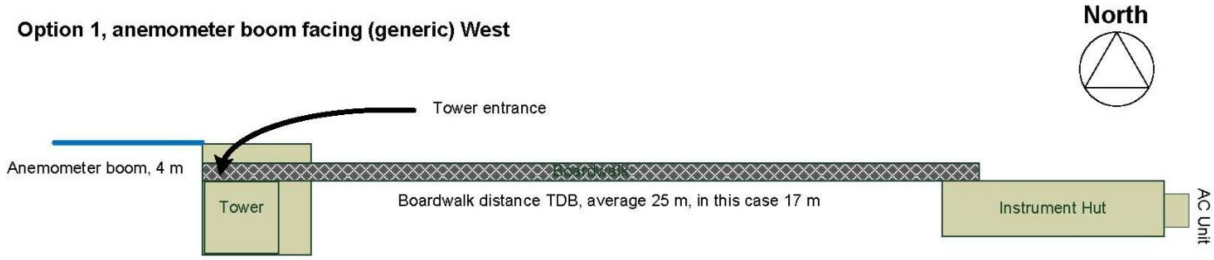


Figure 50 Generic diagram to demonstration the relationship between tower and instrument hut when boom facing west and instrument hut on the east towards the tower.

This is just a generic diagram. The actual layout of boardwalk (or path if no boardwalk required) and instrument hut position will be the joint responsibility of FCC and FIU. At Harvard Forest Advanced site, the boom angle will be 270 degrees, instrument hut will be on the southeast towards the tower, the distance between instrument hut and tower is ~15 m. The instrument hut vector will be E-W (90º-270º, longwise).

3.4.8 Information for ecosystem productivity plots

The tower at Harvard Forest Advanced site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (Northern hardwood forest). Major airshed area at this site are from 190° to 335° (clockwise from 190º), and 90% signals for flux measurements are in a distance of 700 m from tower, and 80% within 500 m. We suggest FSU Ecosystem Productivity plots be placed within the boundaries of 190° to 335° (clockwise from 190º) from tower.

3.5 Issues and attentions

The DFIR site we picked is in an existing open area, which is the closest clearing to our tower location that we could find (1370 m away from tower). This open area is currently use by Harvard Forest as a weather station, but it does not currently include a DFIR.

4 BARTLETT EXPERIMENTAL FOREST, RELOCATEABLE TOWER 1

4.1 Site description

NEON candidate Relocatable site (44.06388°, -71.28731°) is located inside the Bartlett Experimental Forest. The Bartlett Experimental Forest (BEF) is a field laboratory for research on the ecology and management of northern hardwoods and associated ecosystems. Research on the Bartlett includes:
1. extensive investigations on structure and dynamics of forests at several levels, and developing management alternatives to reflect an array of values and benefits sought by users of forest lands,
2. a better understanding of ecological relationships between wildlife habitats and forest management at various levels in order to integrate wildlife habitat maintenance and improvement with other forest management goals, and
3. preservation of undisturbed areas in the Northeast to study natural succession and anthropogenic impacts.
The Bartlett Experimental Forest is within the Saco Ranger District of the White Mountain National Forest in New Hampshire. It is managed by RWU-4155 of the Northern Research Station. Research activities began at the Bartlett Experimental Forest when it was established in 1931 and is 2,600 acres in size but will likely double in area with the forest plan revision that is being written. The Bartlett Experimental Forest extends from the village of Bartlett in the Saco River valley at 680 ft to about 3,000 ft at its upper reaches. Aspects across the forest are primarily north and east. This particular site was chosen because it represented conditions (soils, elevation, climate, tree species composition) typical of many forested areas throughout upper New England and northern New York.

The White Mountain National Forest, including the BEF, was purchased under the Weeks Act of 1911. In the late 19th century, the area was selectively logged for high value species, first eastern white pine and red spruce and later sugar maple and yellow birch. Logging railroads were laid and hardwood stands were clearcut for locomotive fuel. The lower third of the BEF was logged and some portions cleared for pasture. Upper portions were progressively less impacted with increasing elevation. Although fires are relatively rare, the 1938 hurricane did widespread damage. High grading resulted in more American beech, so when the beech scale-Nectria complex, or beech bark disease, arrived in the 1940s it caused substantial damage and continues to influence stand dynamics. An ice storm in 1998 was the most recent widespread natural disturbance, impacting mostly higher elevation stands. Occasional wind storms are common disturbances, but of relatively small scale.

The climate in the Bartlett area, where elevation ranges from 680 feet (210 m) to 3,000 feet (915 m) at the summit of the Upper Haystack, includes warm summers and cold winters. During the summer, daytime temperatures sometimes run into the low 90's° F (30's°C); winters are rigorous with temperatures often reaching -30° F (-35°C). Individual snowstorms often deposit more than 2 feet (60 cm) of new snow, and snow accumulates to depths of 5 to 6 feet (150 to 180 cm). Average annual precipitation at Bartlett is 50 inches (127 cm), distributed throughout the year. Severe winters limit most field work at the Experimental Forest to the period between May through November, although some wildlife studies (raptors and fur-bearers) continue.

The original coordinates (44.06464, -71.28808) are the site of an existing tower. The NEON tower site (44.06388^o, -71.28731^o) is approximately 100 m SE of the existing tower. This site was chosen to allow space for the soil array without having to cross the nearby road and to reduce the impact of the road (which was recently widened) on the flux measurements.

4.2 Ecosystem

There are areas of old-growth northern hardwoods with beech, yellow birch, sugar maple, and eastern hemlock (*Tsuga canadensis*) being the dominant species. Even-aged stands of red maple (*Acer rubra*), paper birch (*Betula papyrifera*), and aspen (*Populus temuloides, P. occidentalis*) occupy sites that were once cleared. Red spruce (*Picea rubens*) stands cover the highest slopes. Eastern white pine (*Pinus strobus*) is confined to the lowest elevations.

The native woody plants of the Bartlett Experimental Forest total 65 species in 43 genera and 21 plant families. Five families contain 36 species, more than half the total. The largest families are *Rosaceae* with 6 genera and 11 species; *Pinaceae* and *Caprifoliaceae*, each with 5 genera and 6 species; *Betulaceae* with 4 genera and 7 species; and *Ericaceae* with 4 genera and 6 species. Thirteen families are represented by a single genus of woody plants, and 8 of these families by a single species. The largest genera of woody plants are *Acer, Betula*, and *Rubus*, with 4 species each, and *Salix* and *Prunus*, with 3 each. Only 4 varieties have been distinguished. Two herbaceous species of woody genera are found here but not included in the total. They are *Aralia racemosa* (spikenard) and *Cornus canadensis* (bunchberry).

Three introduced species add 2 genera and 1 family (*Berberidaceae*) to the totals. These are; *Pinus sylvestris* (Scotch pine), *Malus pumila* (apple), and *Berberis thunbergii* (Japanese barberry). All are rare on the Forest. The first two are planted trees; the last was probably introduced by seed brought in by birds.

Nearly all of the Bartlett Experimental Forest is now covered by high forest. The primary forest cover type is the sugar maple-beech-yellow birch type. The upper elevations support stands of spruce and fir. Softwoods such as hemlock, balsam fir, and spruce are commonly mixed with hardwoods,

especially on cool steep slopes or on the poorly drained soils at lower elevations. Although white pine occurs mostly in stands at lower elevations, scattered specimens can be found over a large part of the Forest. Because of its northeasterly aspect, the Forest does not contain any extensive stands of oak. However, oak types are fairly common nearby on southerly and westerly slopes.
Because this upland area has no permanent rivers or lakes and no peat bogs, woody plants of those wet sites are lacking. Also, this mountainous area in the White Mountains has a relatively colder climate than nearby areas along the Atlantic coast. Thus some southern species are absent here even though they extend farther north near sea level. Also, the mountains on the Experimental Forest are not high enough for a timberline, so the dwarf shrubs of the subalpine and alpine zones are absent.

Several species apparently are the northernmost or hardiest representatives of their genus or family in northeastern North America or in the northern hardwood or eastern deciduous forests. For example, there is only 1 native species each of *Quercus, Ulmus, Cretaegus*, and *Tilia*. Certain tree genera of the eastern United States are absent, not ranging so far north, at least in the these mountains. These include *Carya, Castanea, Celtis, Morus, Liriodendron, Magnolia, Sassafras, Liquidambar, Platanus, Robinia, Aesculus*, and *Nyssa*. No range extensions or unusual records were found on the Bartlett Experimental Forest.

Canopy area density was estimated to be ~ 4.6 in summer and ~ 1.4 $m^2\ m^{-2}$ in winter season (Sierra *et. al*, 2009). More vegetation and land cover information are presented below:

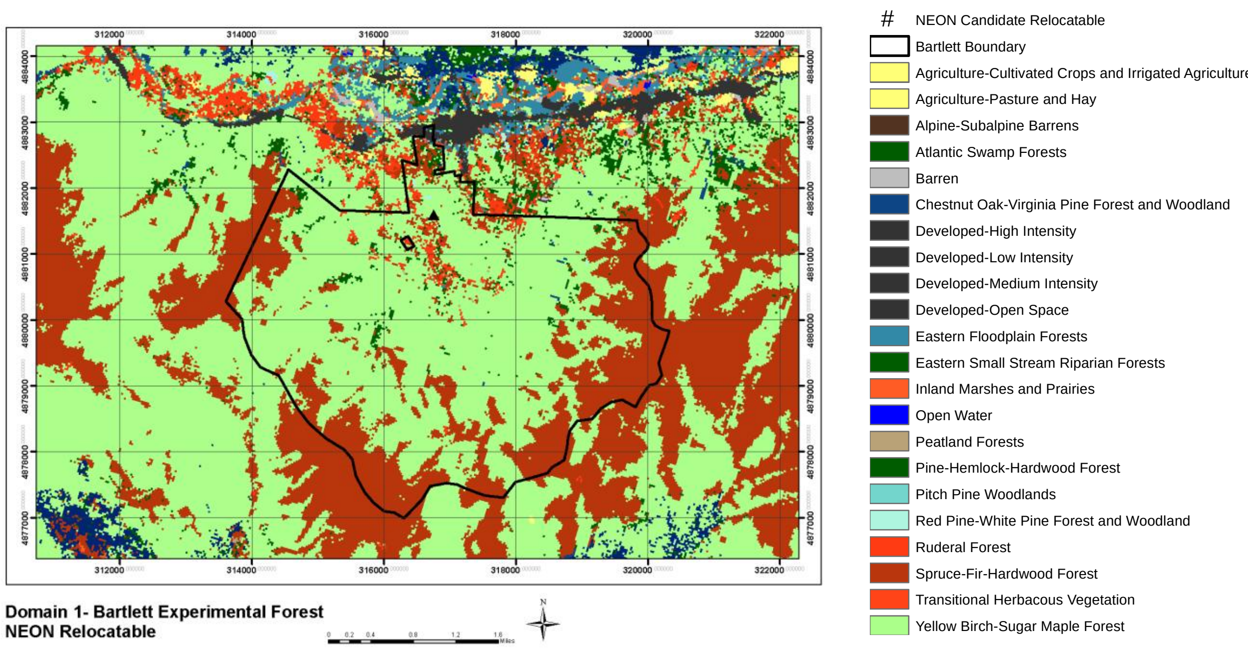


Figure 51. Vegetative cover map of Bartlett Experimental Forest and surrounding areas (information is from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Table 8. Land cover information at Bartlett Experimental Forest site (information is from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm).

Land cover types	Area (km^2)	Percentage

Atlantic Swamp Forests	77103.94	7.71
Inland Marshes and Prairies	11965.40	1.20
Peatland Forests	2700.00	0.27
Pine-Hemlock-Hardwood Forest	52051.39	5.21
Red Pine-White Pine Forest and Woodland	9065.56	0.91
Ruderal Forest	72866.65	7.29
Spruce-Fir-Hardwood Forest	29002.96	2.90
Yellow Birch-Sugar Maple Forest	745218.09	74.52
Total	999973.98	100.00

The representative ecosystem that NEON design is focused around for this relocatable site is eastern deciduous/mixed secondary forest typically found in Northeastern US but below the boreal ecotone.

Canopy height is ~23 m around tower site with lowest branches at ground level. Maple and beech form upper understory, which varies from 14 to 16 m in height. Seedlings and sapling of maple, hemlock and beech forms the lower understory with mean height ~ 4 m. Grass and other short vegetation form the understory at ground level with height ~ 0.2 m.

Table 9. Ecosystem and site attributes for the Bartlett Experiment Forest Relocatable site.

Ecosystem attributes	Measure and units
Mean canopy height	23 m
Surface roughness[a]	1.5 m
Zero place displacement height[a]	19.5 m
Structural elements	Closed-canopy, uniform, homogeneous
Time zone	Eastern time
Magnetic declination	15° 35' W changing by 0° 4' E year^{-1}

Note, [a] From field survey.

4.3 Soils

4.3.1 Description of soils

Soil data and soil maps (Figures 45) below for Harvard Forest Advanced tower site were collected from 1 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.

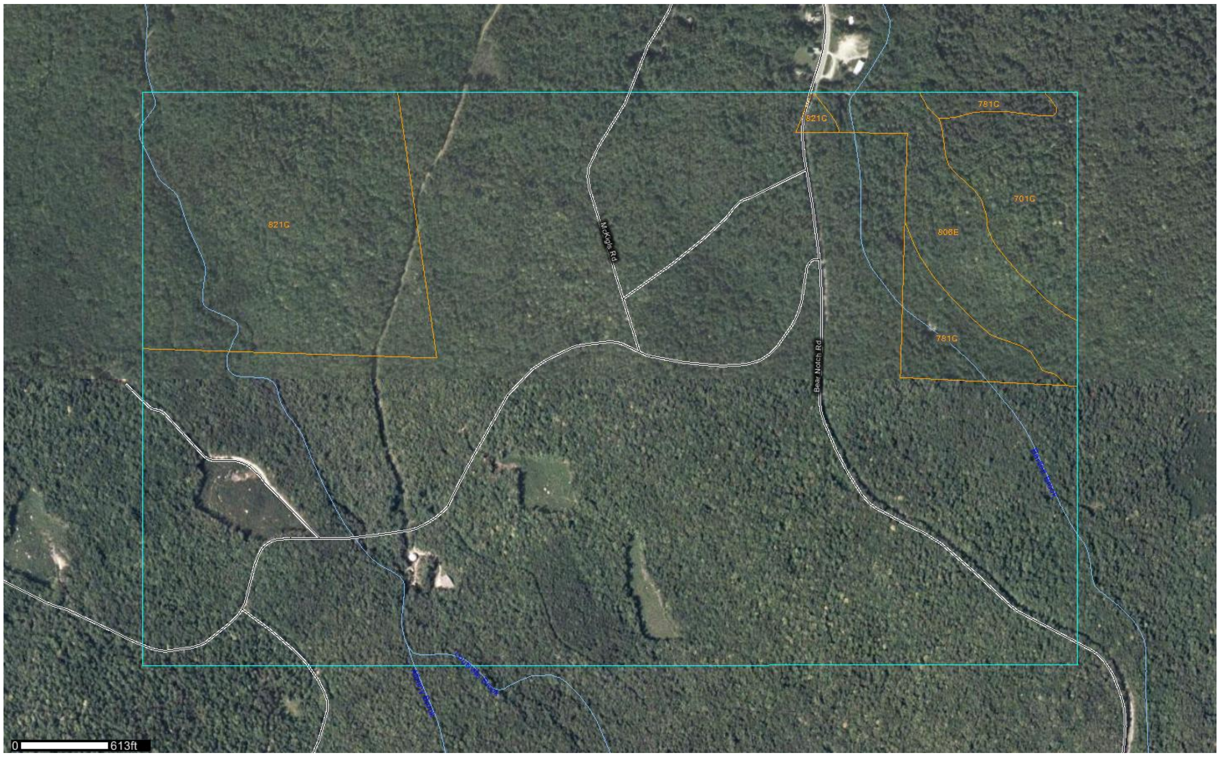


Figure 52. 1 km^2 soil map for Bartlett Experimental Forest relocatable site, center at tower location, north is top of map.

Soil Map Units 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. The 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, the soils are natural phenomena, and 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 soils 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 10. Soil series and percentage of soil series within 1 km^2 centered on the tower, Bartlett Experimental Forest.

Carroll County Area, New Hampshire (NH603)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
701C	Becket-Skerry fine sandy loams association, sloping, very stony	21.6	3.6%
780E	Lyman-Berkshire fine sandy loams association, steep, very rocky	0.0	0.0%
781C	Peru fine sandy loam association, sloping, very stony	14.5	2.4%
806E	Canaan-Redstone gravelly fine sandy loams association, steep, very rocky	24.0	4.0%
821C	Marlow-Peru fine sandy loams association, sloping, very stony	81.5	13.5%
Subtotals for Soil Survey Area		141.5	23.5%
Totals for Area of Interest		602.3	100.0%

Carroll County Area, New Hampshire701C—Becket-Skerry fine sandy loams association, sloping, very stony Map Unit Setting *Elevation:* 390 to 3,800 feet *Mean annual precipitation:* 39 to 50 inches *Mean annual air temperature:* 37 to 46 degrees *Frost-free period:* 90 to 160 days **Map Unit Composition** *Becket and similar soils:* 50 percent *Skerry and similar soils:* 30 percent **Description of Becket Setting** *Landform:* Hillslopes *Parent material:* Basal melt-out till derived from granite and gneiss and/or basal melt-out till derived from schist **Properties and qualities** *Slope:* 3 to 15 percent *Surface area covered with cobbles, stones or boulders:* 1.6 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 to moderately high (0.06 to 0.60 in/hr) *Depth to water table:* About 24 to 42 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 4.5 inches) **Interpretive groups** *Land capability (non-irrigated):* 6s **Typical profile** *0 to 18 inches:* Fine sandy loam *18 to 24 inches:* Gravelly fine sandy loam *24 to 42 inches:* Gravelly loamy sand **Description of Skerry Properties and qualities** *Slope:* 0 to 15 percent *Surface area covered with cobbles, stones or boulders:* 1.6 percent *Depth to restrictive feature:* More than 80 inches *Drainage class:* Moderately well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.60 in/hr) *Depth to water table:* About 12 to 30 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 4.6 inches) **Interpretive groups** *Land capability (non-irrigated):* 6s **Typical profile** *0 to 19 inches:* Fine sandy loam*19 to 23 inches:* Gravelly fine sandy loam*23 to 45 inches:* Gravelly loamy sand

Carroll County Area, New Hampshire806E—Canaan-Redstone gravelly fine sandy loams association, steep, very rocky Map Unit Setting *Elevation:* 390 to 3,800 feet *Mean annual precipitation:* 39 to 50 inches *Mean annual air temperature:* 37 to 46 degrees *Frost-free period:* 90 to 160 days **Map Unit Composition** *Canaan and similar soils:* 50 percent *Redstone and similar soils:* 30 percent **Description of Canaan Setting** *Landform:* Hillslopes *Parent material:* Till **Properties and qualities** *Slope:* 15 to 35 percent *Surface area covered with cobbles, stones or boulders:* 1.6 percent *Depth to restrictive feature:* 10 to 20 inches to lithic bedrock *Drainage class:* Somewhat excessively drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to low (0.00 to 0.01 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 1.6 inches) **Interpretive groups** *Land capability (non-irrigated):* 7s **Typical profile** *0 to 17 inches:* Very gravelly fine sandy loam*17 to 21 inches:* Unweathered bedrock **Description of Redstone**

Setting*Landform:* Hillslopes *Parent material:* Till **Properties and qualities** *Slope:* 15 to 35 percent *Surface area covered with cobbles, stones or boulders:* 1.6 percent *Depth to restrictive feature:* More than 80 inches *Drainage class:* Somewhat excessively drained *Capacity of the most limiting layer to transmit water (Ksat):* High (2.00to 6.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 3.1 inches) **Interpretive groups** *Land capability (non-irrigated):* 6s **Typical profile** *0 to 5 inches:* Fine sandy loam*5 to 17 inches:* Gravelly fine sandy loam*17 to 60 inches:* Very gravelly sand.

Carroll County Area, New Hampshire821C—Marlow-Peru fine sandy loams association, sloping, very stony Map Unit Setting *Elevation:* 390 to 3,800 feet *Mean annual precipitation:* 39 to 50 inches *Mean annual air temperature:* 37 to 46 degrees *Frost-free period:* 90 to 160 days **Map Unit Composition** *Marlow and similar soils:* 50 percent *Peru and similar soils:* 30 percent **Description of Marlow Setting** *Landform:* Hillslopes *Parent material:* Basal lodgement till derived from granite and gneiss and/or basal lodgement till derived from schist **Properties and qualities** *Slope:* 0 to 15 percent *Surface area covered with cobbles, stones or boulders:* 1.6 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 to moderately high (0.06 to 0.60 in/hr) *Depth to water table:* About 24 to 42 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 4.8 inches) **Interpretive groups** *Land capability (non-irrigated):* 6s **Typical profile** *0 to 6 inches:* Fine sandy loam *6 to 20 inches:* Gravelly fine sandy loam *20 to 42 inches:* Fine sandy loam **Description of Peru Setting** *Landform:* Hillslopes *Parent material:* Till **Properties and qualities** *Slope:* 0 to 15 percent *Surface area covered with cobbles, stones or boulders:* 1.6 percent*Depth to restrictive feature:* More than 80 inches *Drainage class:* Moderately well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.60 in/hr) *Depth to water table:* About 12 to 30 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Moderate (about 6.7 inches) **Interpretive groups** *Land capability (non-irrigated):* 6s **Typical profile** *0 to 18 inches:* Fine sandy loam *18 to 24 inches:* Gravelly sandy loam *24 to 50 inches:* Gravelly fine sandy loam

Carroll County Area, New Hampshire781C—Peru fine sandy loam association, sloping, very stony Map Unit Setting *Elevation:* 390 to 3,800 feet *Mean annual precipitation:* 39 to 50 inches *Mean annual air temperature:* 37 to 46 degrees *Frost-free period:* 90 to 160 days **Map Unit Composition** *Peru and similar soils:* 70 percent **Description of Peru Setting** *Landform:* Hillslopes *Parent material:* Till **Properties and qualities** *Slope:* 0 to 15 percent *Surface area covered with cobbles, stones or boulders:* 1.6 percent *Depth to restrictive feature:* More than 80 inches *Drainage class:* Moderately well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.60 in/hr)*Depth to water table:* About 12 to 30 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Moderate (about 6.7 inches) **Interpretive groups** *Land capability (non-irrigated):* 6s **Typical profile** *0 to 18 inches:* Fine sandy loam *18 to 24 inches:* Gravelly sandy loam*24 to 50 inches:* Gravelly fine sandy loam.

4.3.2 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 53). 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 53).

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 52), 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.

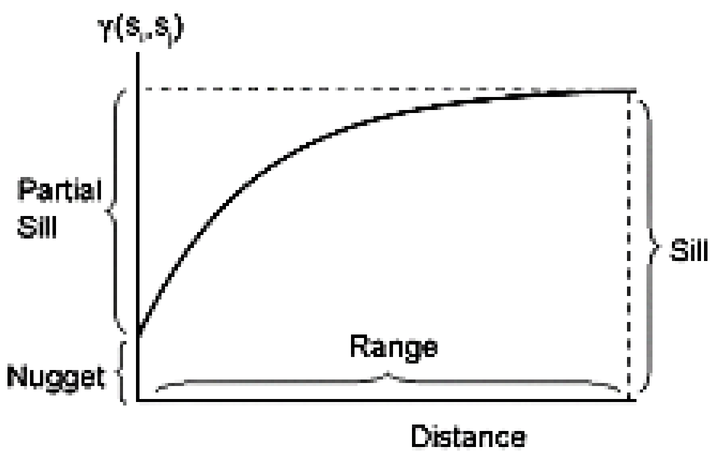


Figure 53. Example semivariogram, depicting range, sill, and nugget.

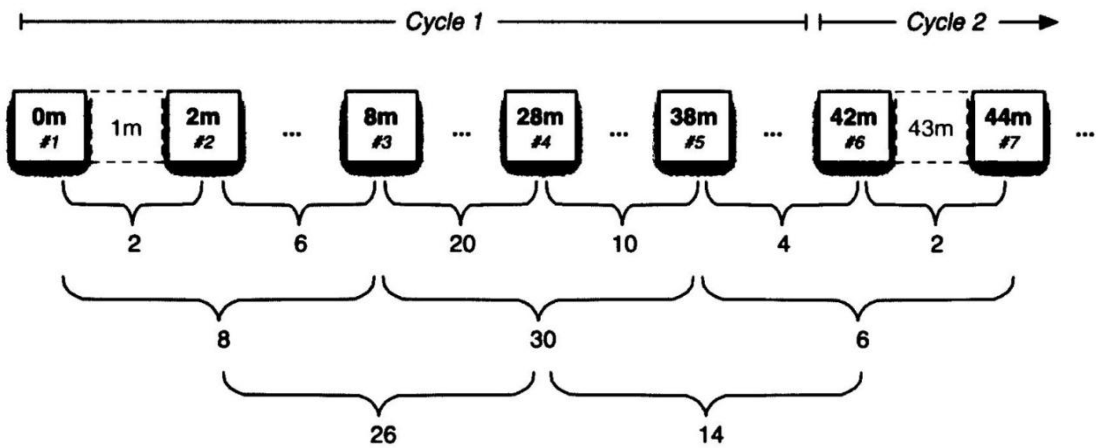


Figure 54. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 6 July 2010 at the Bartlett Experimental Forest site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 54). Soil temperature and moisture measurements were collected along three transects (168 m, 84 m, and 84 m) located in the expected airshed at Bartlett. 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 54, 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).

4.3.3 Results and interpretation

4.3.3.1 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 55). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 55, left graphs) and directional semivariograms do not show anisotropy (Figure 56, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 56, right graph). The model indicates a distance of effective independence of 40 m for soil temperature.

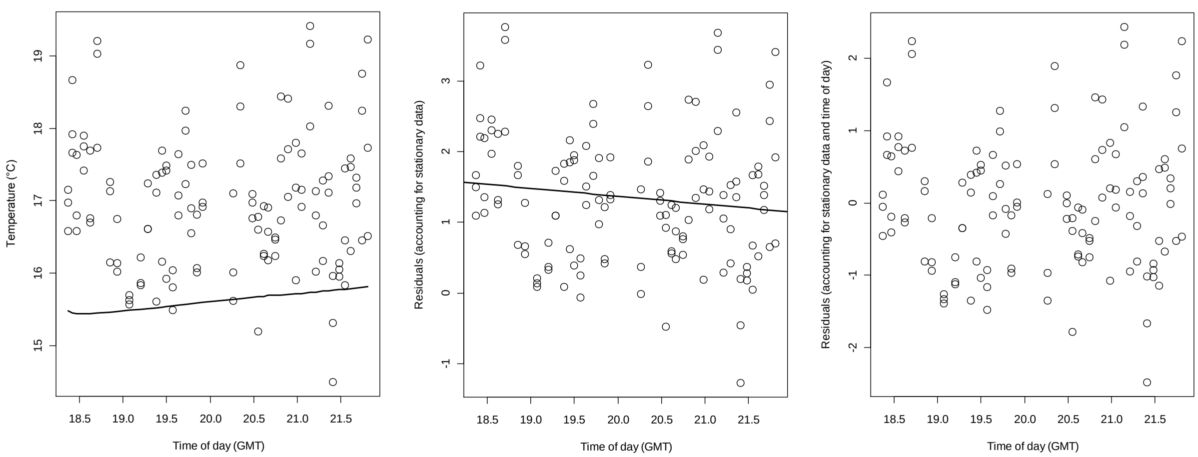


Figure 55. Bartlett semi variograms, left graph: mobile (circles) and stationary (line) soil temperature data.
Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature 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.

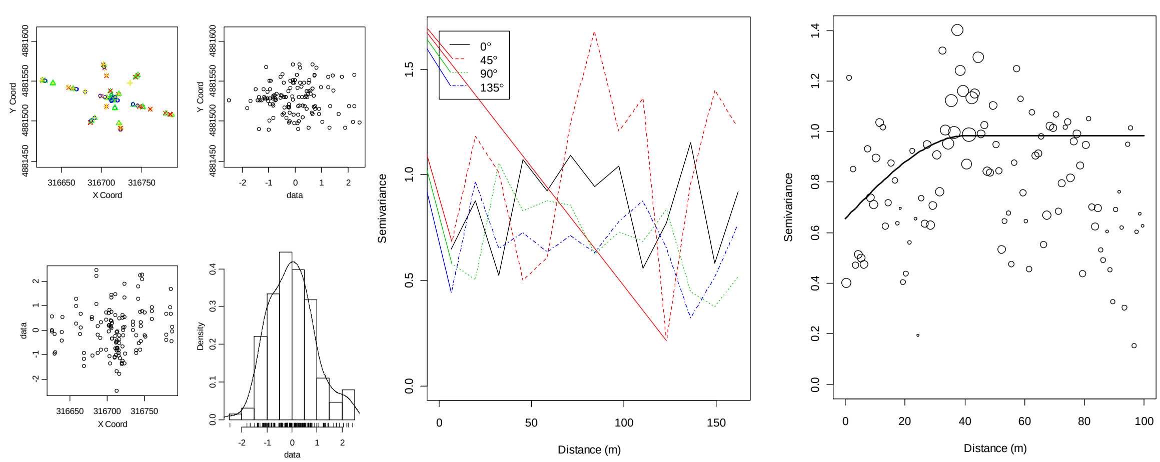


Figure 56. Bartlett semi variograms, left graphs: exploratory data analysis plots for residuals of temperature.
Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

4.3.3.2 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 57). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 57, left graph) and directional semivariograms do not show anisotropy (Figure 58, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 58, right graph). The model indicates a distance of effective independence of 68 m for soil water content.

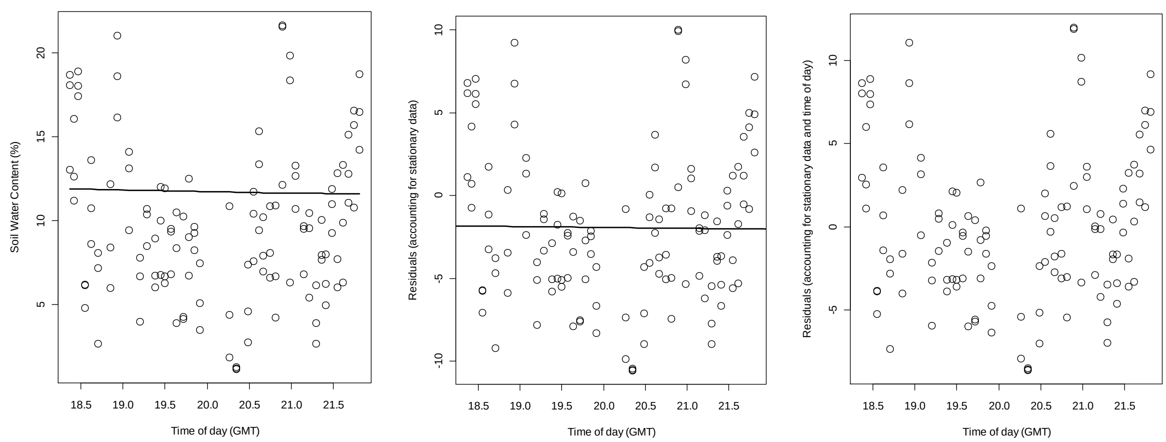


Figure 57. Bartlett semi variograms, left graph: mobile (circles) and stationary (line) soil water content data.
Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water 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.

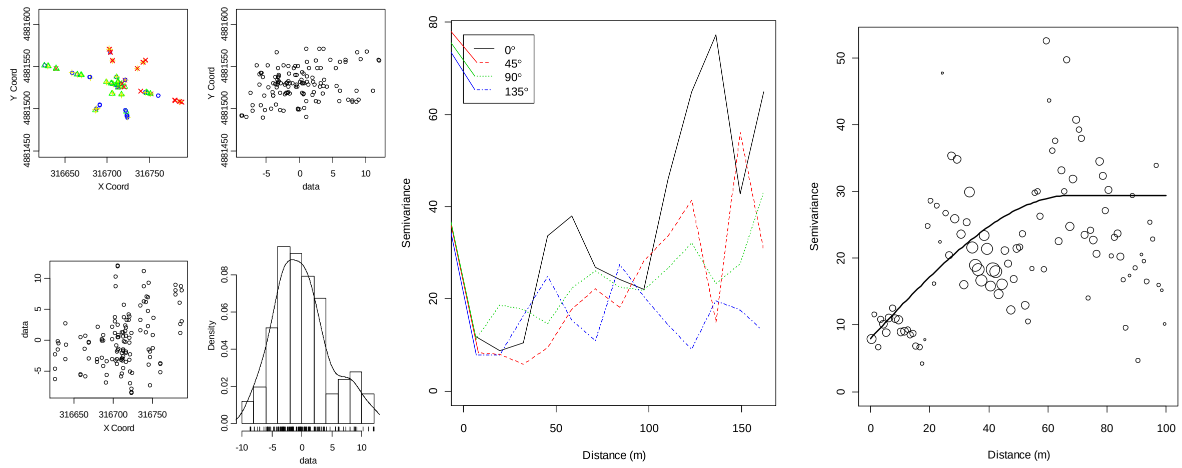


Figure 58. Bartlett semi variograms, left graphs: exploratory data analysis plots for residuals of soil water content.
Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

4.3.3.3 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 40 m for soil temperature and 68 m for soil moisture. Based on these results and the site design guidelines the soil plots at Bartlett 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 290° from the soil plot nearest the tower (i.e., first soil plot). The location of the first soil plot will be approximately 44.06388°, -71.28750°. 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 44.06512°, -71.28813° (primary location); or 44.06501°, -71.28750° (alternate location 1 if primary location is unsuitable); or 44.06487°, -71.28684° (alternate location 2 if primary location is unsuitable). A summary of the soil information is shown in Table 11and site layout can be seen in Figure 59.

Dominant soil series at the site: Not available from NRCS (a nearby dominant soil, used here as a proxy, is: Marlow-Peru fine sandy loams association, sloping, very stony). The taxonomy of this soil is shown below:
Order: Spodosols*
Suborder: Orthods*
Great group: Haplorthods*
Subgroup: Oxyaquic Haplorthods - Aquic Haplorthods*

Family: Coarse-loamy, isotic, frigid Oxyaquic Haplorthods - Coarse-loamy, isotic, frigid Aquic Haplorthods*
Series: Marlow-Peru fine sandy loams association, sloping, very stony*

*The NRCS soil survey did not cover the tower and soil array site, therefore, this soil type is used here as a proxy.

Table 11. Summary of soil array and soil pit information at Bartlett. 0° represents true north and accounts for declination.
Soil depths will be determined during the soil pit excavation.

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	15 m
Latitude and longitude of 1st soil plot OR direction from tower	44.06388°, -71.28750°
Direction of soil array	290°
Latitude and longitude of FIU soil pit 1	44.06512°, -71.28813° (primary location)
Latitude and longitude of FIU soil pit 2	44.06501°, -71.28750° (alternate 1)
Latitude and longitude of FIU soil pit 3	44.06487°, -71.28684° (alternate 2)
Dominant soil type	Marlow-Peru fine sandy loams association, sloping, very stony*
Expected soil depth	>2 m*
Depth to water table	0.30-1.07 m*

Expected depth of soil horizons	**Expected measurement depths**
0-0.15 m (Fine sandy loam)*	0.07 m*
0.15-0.51 m (Gravelly fine sandy loam)*	0.33 m*
0.51-1.07 m (Fine sandy loam)*	0.79 m*

*The NRCS soil survey did not cover the tower and soil array site. Therefore, this soil type, which is found nearby, is used here as a proxy.

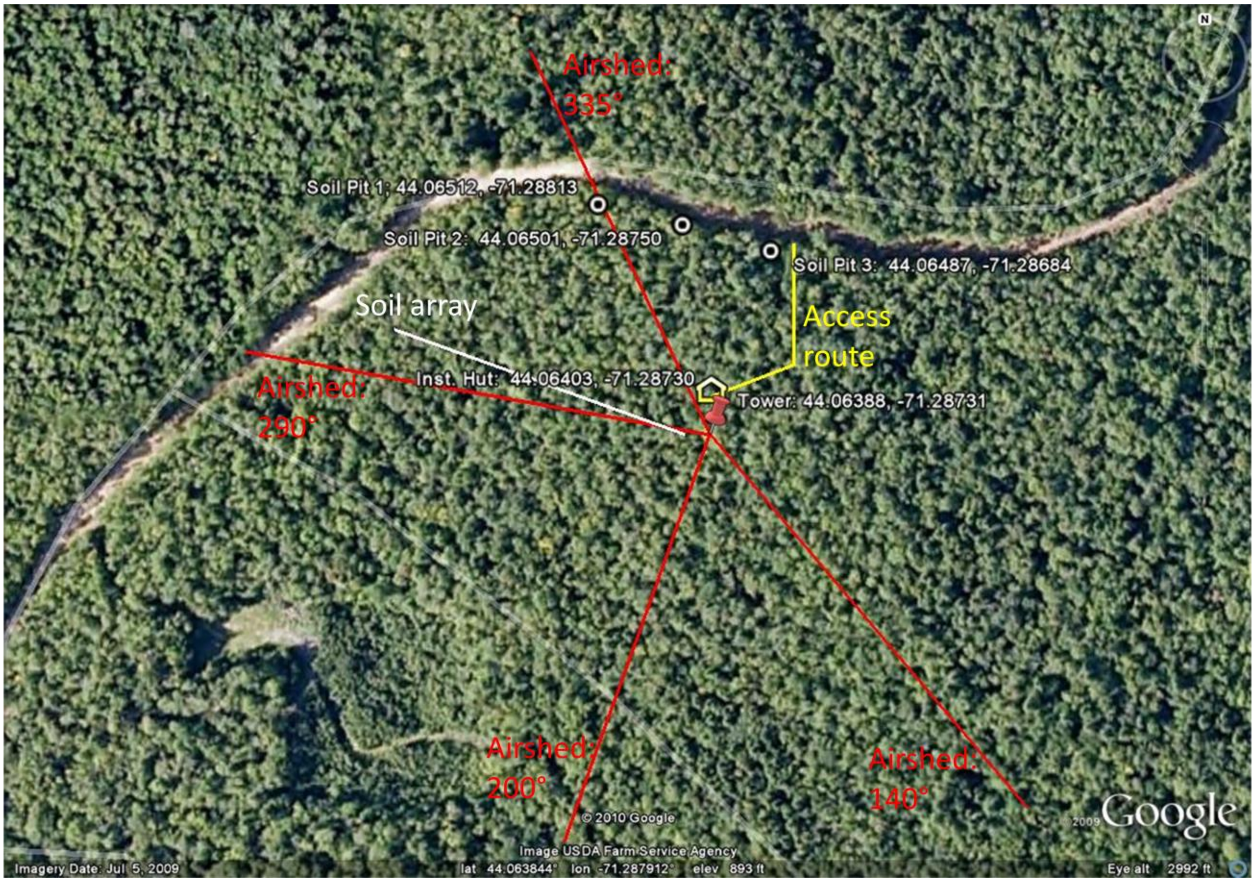


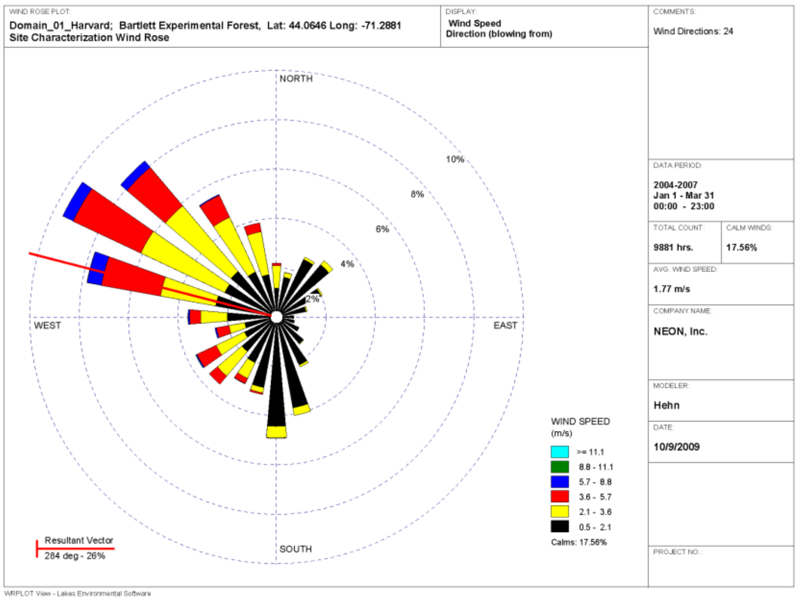
Figure 59. Site layout at Bartlett showing soil array and location of the FIU soil pits.

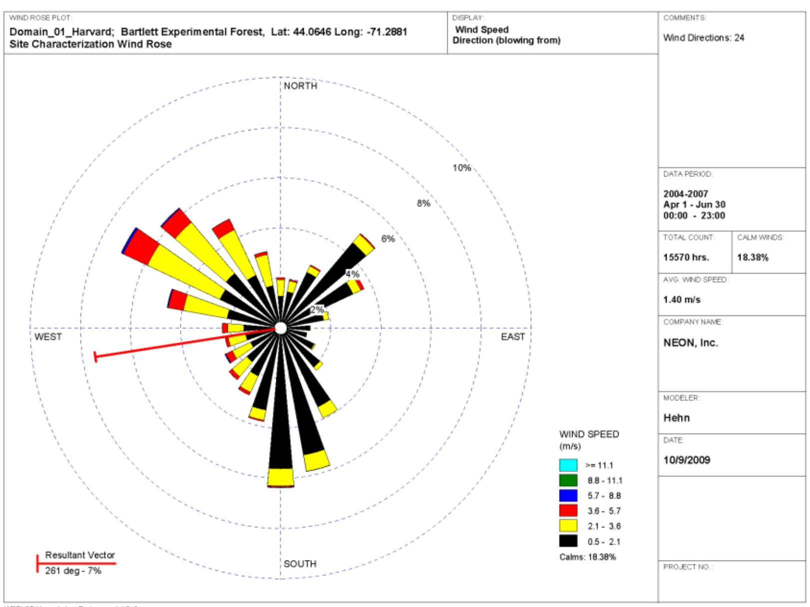
4.4 Airshed

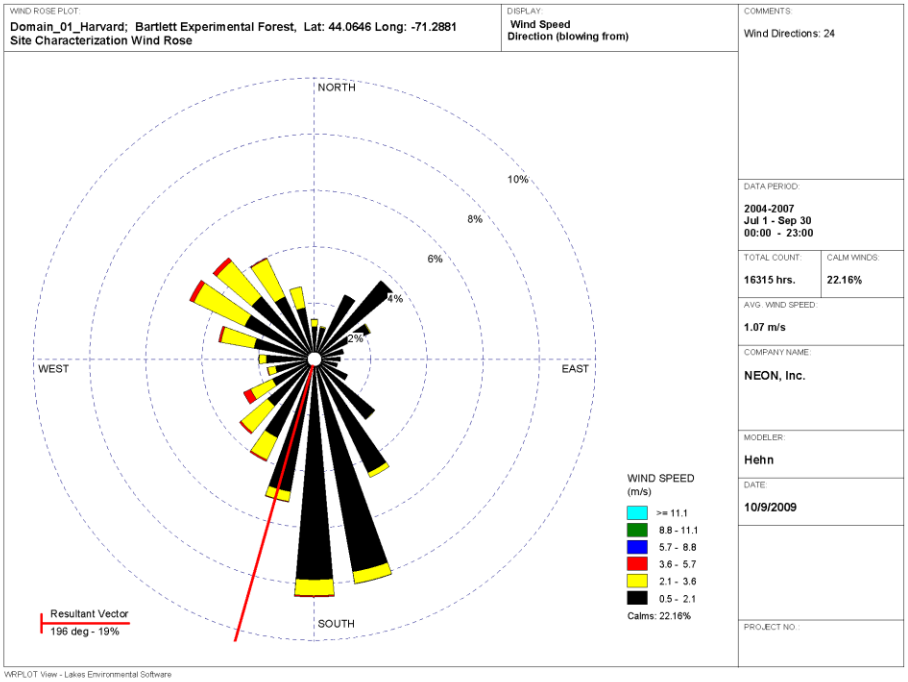
4.4.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries, Figure 59. The weather data used to generate the following wind roses are from Bartlett Experimental Forest AmeriFlux tower, which is ~100 m from NEON tower 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. 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.

4.4.2 Results (graphs for wind roses)







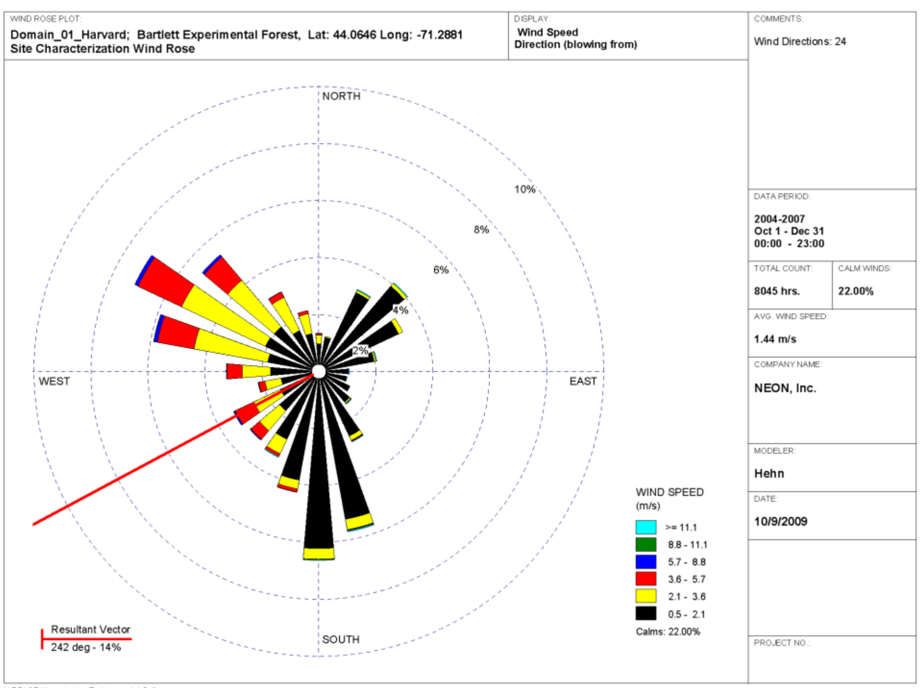


Figure 60. Windroses for Bartlett Experimental Forest.

Data used here are hourly data from 2004 to 2007. Data were level 2 data downloaded from AmeriFlux website ftp://cdiac.ornl.gov/pub/ameriflux/data/Level2/Sites_ByName/Bartlett_Experimental_Forest/with_gaps/ for Bartlett Experimental Forest. It is assumed that the wind data was corrected for declination. Panels (from Top to bottom), are from Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

4.4.3 Resultant vectors

Table 12. The resultant wind vectors from Bartlett Exp Forest using hourly data from 2004 to 2007.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	284°	26
April to June	261°	7
July to September	196°	19
October to December	242°	14
Annual mean	245.8°	na.

Table 13. The percent duration of winds among cardinal directions, Bartlett Exp. Forest. 3 frequency bins on each side of the cardinal direction were used for this calculation. Data are from Bartlett Exp. Forest using hourly data from 2004 to 2007. Blue text and underline indicates the dominant, winds occurring for the cardinal direction >40% of the time.

Quarterly (seasonal) timeperiod	Cardinal direction			
	North	East	South	West
January to March	27°	8.6°	25.5°	39°
April to June	25.7°	15.3°	31.3°	24.9°
July to September	32.1°	12.4°	40.2°	26.3°
October to December	22.5°	13.9°	30.2°	33.5°

4.4.4 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, we used a web-based footprint model 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 varify 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 14. Expected environmental controls to parameterize the source area model, and associated results from Bartlett Experimental Forest Relocatable tower site 1.

Parameters	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	
Approximate season	summer			winter			Units
	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	29	29	29	29	29	29	m
Canopy Height	19	19	19	19	19	19	m
Canopy area density	4.6	4.6	4.6	1.4	1.4	1.4	m
Boundary layer depth	2000	2000	2000	2000	2000	2000	m
Expected sensible heat flux	250	250	20	30	30	-20	W m^{-2}
Air Temperature	23	23	13	-1	-1	-11	°C
Max. windspeed	5.7	2.5	0.5	8.8	2.8	1.0	m s^{-1}
Resultant wind vector	172	172	172	300	300	300	degrees
			Results				
(z-d)/L	-0.06	-0.35	-0.55	0.00	-0.05	2.10	m
d	16	16	16	13	13	13	m
Sigma v	2.20	1.70	0.73	2.90	1.20	1.70	$m^2 s^{-2}$
Z0	0.67	0.67	0.67	1.30	1.30	1.30	m
u*	0.83	0.47	0.18	1.40	0.48	0.13	m s^{-1}
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	580.7	331.9	154.1	746.7	640.0	777.1	m
Distance of 80% cumulative flux	379.3	201.5	94.8	462.2	391.1	480.0	m

Distance of 70% cumulative flux	272.6	154.1	47.4	331.9	284.4	365.7	m
Distance of 60% cumulative flux	201.5	118.5	---	248.9	213.3	182.9	m
Distance of 50% cumulative flux	177.8	94.8	---	189.6	154.1	114.3	m
Distance of 40% cumulative flux	142.2	59.3	---	154.1	130.4	---	m
Distance of 30% cumulative flux	106.7		---	118.5	94.8	---	m
Distance of 20% cumulative flux	---	---	---	---	---	---	m
Distance of 10% cumulative flux	---	---	---	---	---	---	m
Peak contribution	70	10	20	160	32	540	m

4.4.5 Results (source area graphs)

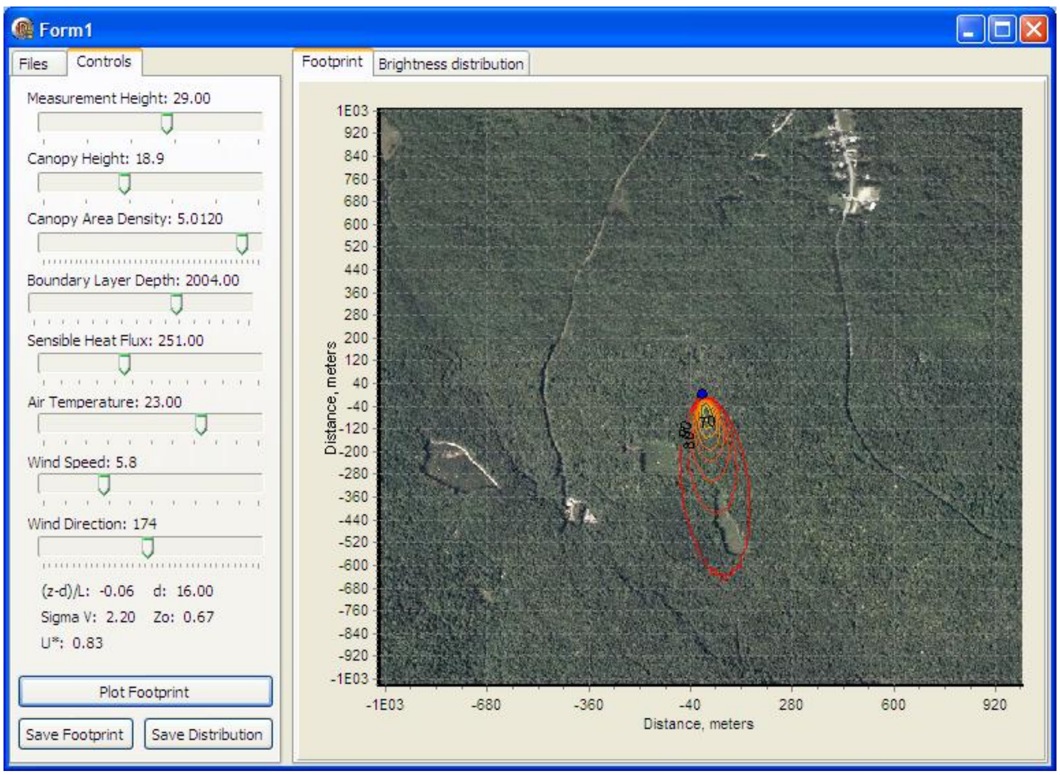


Figure 61. Bartlett Experimental Forest summer daytime (convective) footprint output with max wind speed.

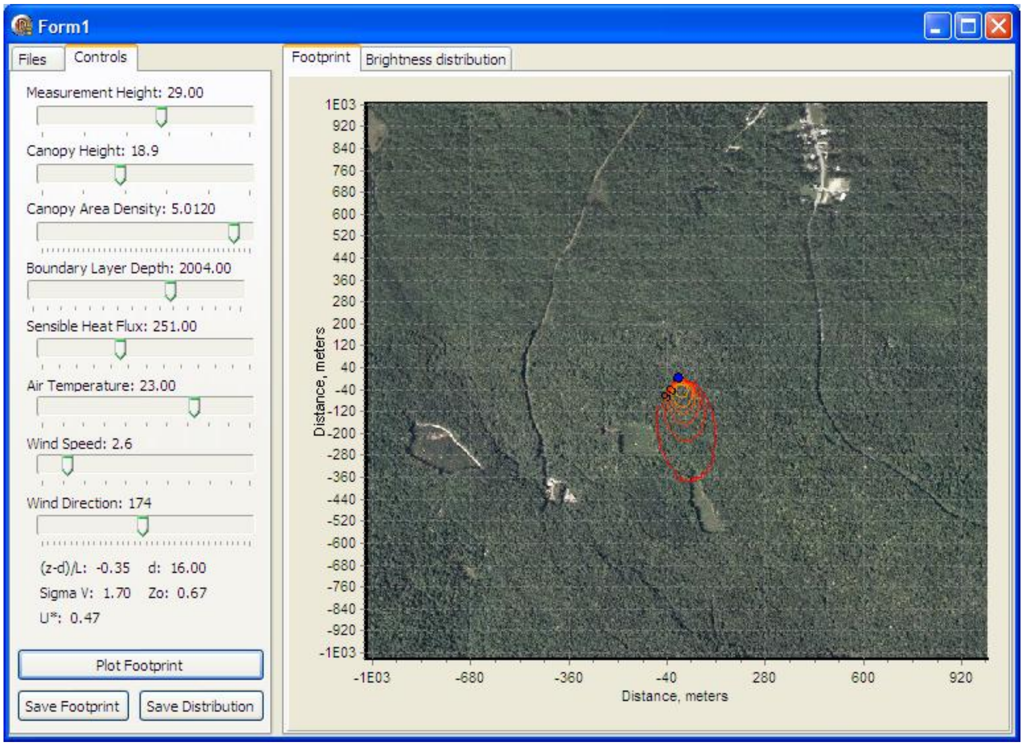


Figure 62. Bartlett Experimental Forest summer daytime (convective) footprint output with mean wind speed.

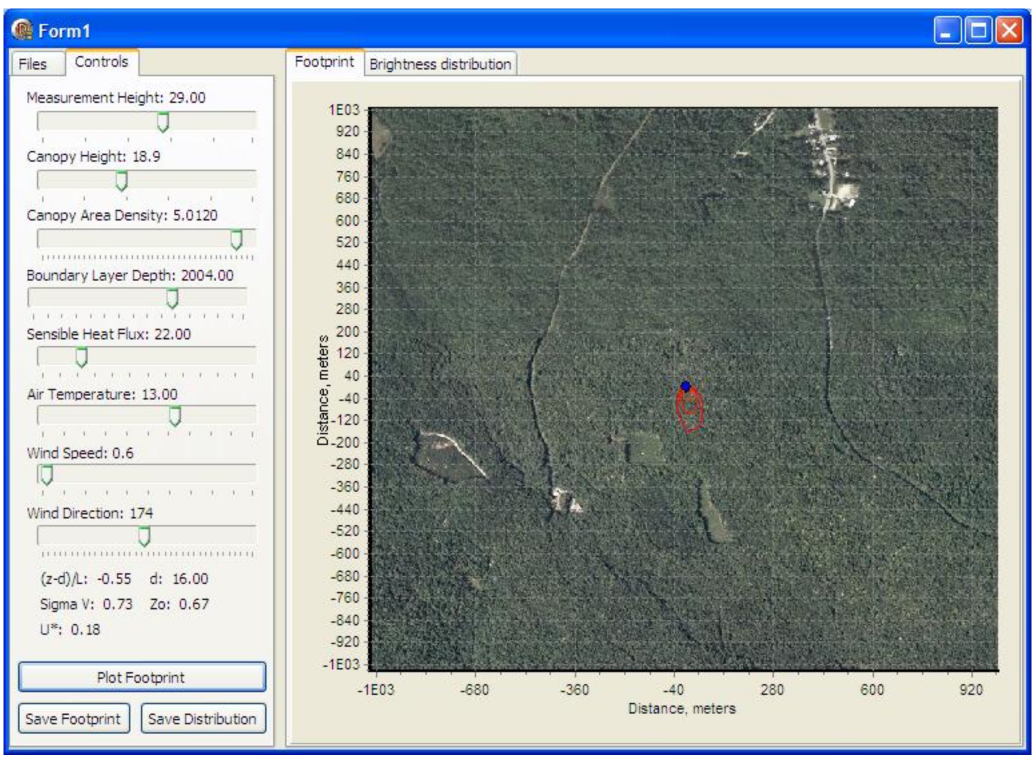


Figure 63. Bartlett Experimental Forest summer nighttime (stable) footprint output with mean wind speed.

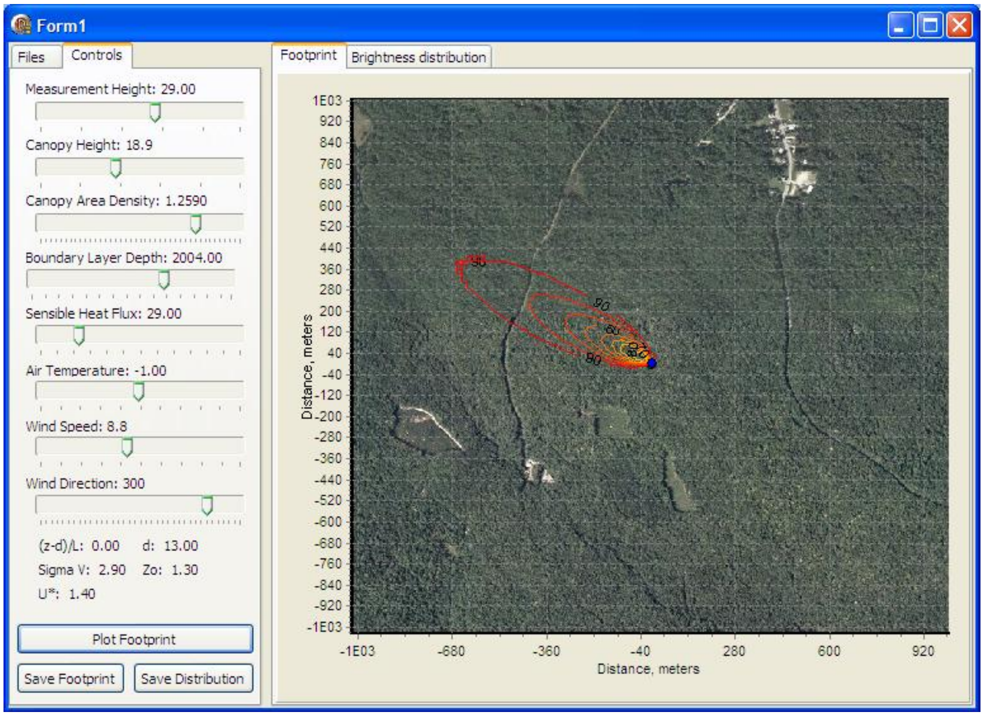


Figure 64. Bartlett Experimental Forest winter daytime (convective) footprint output with max wind speed.

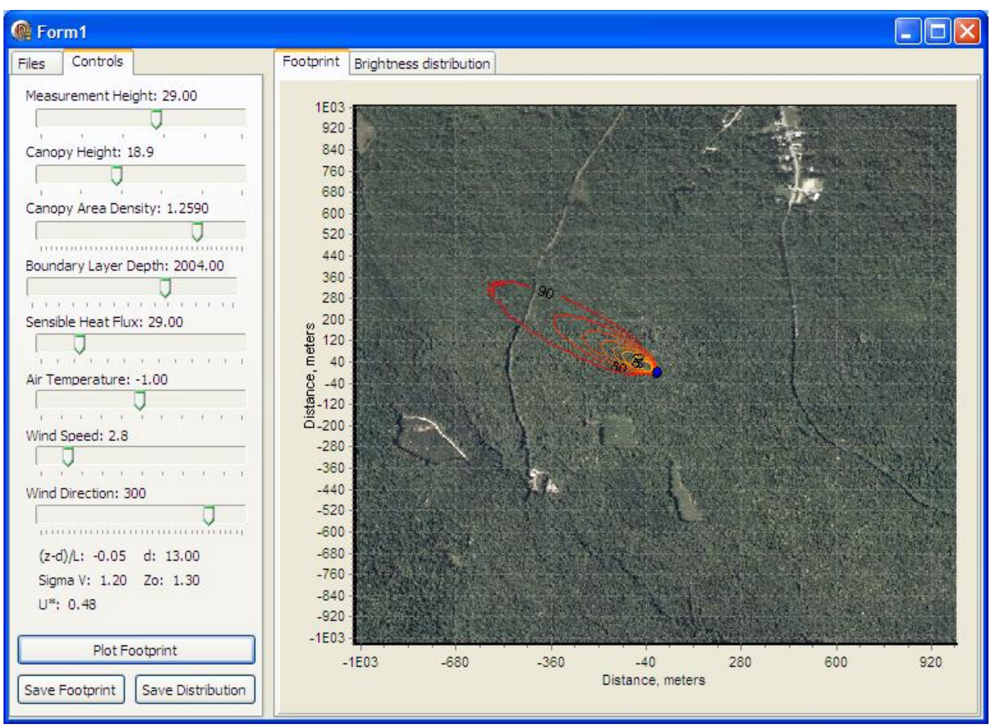


Figure 65. Bartlett Experimental Forest winter daytime (convective) footprint output with mean wind speed.

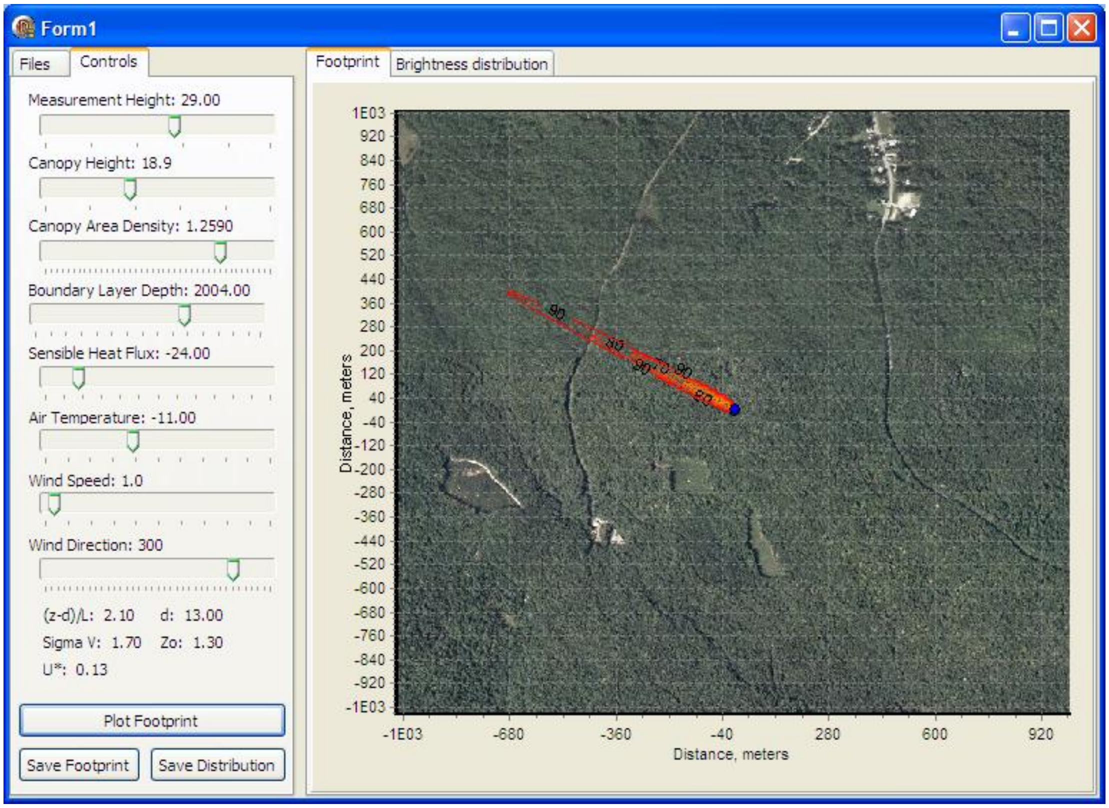


Figure 66. Bartlett Experimental Forest winter nighttime (stable) footprint output with mean wind speed.

4.4.6 Acceptance criteria

Micrometeorological theory and the eddy covariance technique were established over uniform vegetative canopies with short roughness lengths on flat terrain and large fetch. The objective is to place a tower in such a way to optimize the amount of time where all the flows (winds) and microclimate with minimal disturbance and secondary filtering. Flow through the tower must be discounted and screened against data quality criteria (FIU V+V doc). Flows that pass through a tower often have to be screened and filtered out of a long-term dataset. If positioning a tower can be positioned on the landscape towards an undesirable land use type or influence on the leeward side of the tower—if it is well known the data will have low quality. Additional concerns and acceptance criteria can be found in the FIU Tower Science requirements, AD 01.

The tower should be sited to maximize the time with winds blowing from the desired land cover type, and with the longest upwind fetch attainable. If the surroundings are not of a uniform cover type, there needs to be some analysis of prevailing winds to demonstrate that the desired sectors are sampled uniformly through time. Consider the extreme example of a site with two different forest types and a consistent daily wind cycle that blew from one forest type and in the day and the other at night. Daily-integrated net ecosystem exchange (NEE) in this situation would be un-interpretable. This extreme condition is unlikely, but many sites could have more subtle wind direction biases that need to be examined and considered in data interpretation. All systems are subject to horizontal flux divergence, advective motions, wake effects and drainage of air sheds (FIU Tower Science Requirements). Footprint analyses to determine the source area under different stabilities, wind speeds and direction among seasons provide valuable guidance for appropriate tower placement, documentation of site characteristics, and definition of data acceptance criteria (Foken and Leclerc 2004, Horst and Weil 1992, Horst and Weil 1994a, Horst and Weil 1994b, Horst, 2001, Kormann and Meixner 2001, Schmid and Lloyd 1999, Schmid 1994, Schuepp *et al*. 1990). The criteria for tower placement should not only be concerned with the summer, productive periods, but also the seasonal transitional periods (spring and fall), and winter months when respiration process often dominate.

Micro-topography requires visual inspection. Long wave forms and standing waves are common place over short stature ecosystems small < 10 m topographic relief and high (mechanical turbulent) winds occur (tundra, grasslands, alpine ecosystems). Preliminary data collection may be useful to determine if micro-topographic features affect the local microclimate and flow regimes.

The tower needs to be high enough to place the sensors well above the surrounding canopy, but not so high that the footprint during stable night-time conditions extends beyond the boundary of the ecosystem type of interest.

Other constraints are placed on our ability to locate and position a tower besides available footprint and flow regimes. At some locations, there is a large sensitivity towards viewing the tower above the canopy from houses, scenic over views, or within an urban area. This public concern is particularly prevalent in State and National Parks. A second constraint is the amount of land available for construction. Lastly, there are often nearby land uses or ecosystem types that can contribute undesirable information (fluxes, meteorology) to the tower based measurements. For example, different grazing patterns in a nearby field, large wetlands in the center of the desired footprint, roads that cause line sources of dust or hydrocarbons, or clearcuts that generate conflicting non-local circulations (Loescher *et al*. 2004). All these issues have to be balanced to achieve the scientific requirements.

Windroses were constructed on a seasonal basis where, *i*) the first estimation is the maximum and average seasonal windspeeds, *ii*) the season fractional wind directions, and *iii*) is the resultant wind direction.

Winds are dominant from the NW to the SE for all windrose periods at this site (Figure 60), and supported by the quadrate analyses (Tables 12-13) with an annual resultant wind vector of 245.8°. Because winds from the east are infrequent and low velocities, the tower should be on the east side of the wind measurement booms. Because the winds are evenly distributed in frequency from the N, W and S (Tables 12-13) and SSE during summer and fall, to maximize the data coverage, the boom should be facing toward west. However, winds do come from the other quadrants during the summer months, due to the convective scales and storm fronts. Because i) there is ample room within the property boundary, ii) the dominant soil type extends towards the west of the tower location, and iii) it is possible to place the soil array within the airshed.

Soil mapping units are not inclusive of all the areas on Bartlett Experimental Forest, we assume that the fraction of mapped soil associations are representative of the whole, making the dominant soil association being Marlow-Peru, fine sandy loams, 3 to 15° slopes, very stony (>14 % spatially dominant),

Table 10. Based on maps provided by Bartlett Experimental Forest, there does not seem to be any limit on the source area based on property boundaries. Because flows through the tower have to be examined and potentially removed from the dataset, placing the leeward side of the tower closest to the east optimizes flows over the source area from the west. To maximize the fetch (source area) from the W in all seasons, the tower location should be placed in the E area of this forest. Because winds from the NW to SW to SSE occur during all seasons and the results from the footprint analyses (Figures 61-66) indicate 80 % of the cumulative flux is within 500 m under the most extreme conditions (winter, stable atmosphere, high winds), and as small as 60 m in summer (strongly convective, unstable atmospheres). Because this is a closed canopy ecosystem, the distance between the base of the tower and the instrument hut can be reduced to 15 m.

4.4.7 Site design and tower attributes

Based on the information above, site design and layout are described below.
According to wind roses, the prevailing wind direction blows from northwest (280^o to 335^o, clockwise from 280^o) and from South (140^o to 200^o, clockwise from 140^o) throughout the year. Tower should be placed to a location to best catch the signals from the airshed of the ecosystem in interest, which is maple-beech forest. The original tower site was 44.06464^o, -71.28808^o. After FIU site characterization, we determine the exact **tower location** to be at 44.06388^o, -71.28731^o to avoid the potential interference of the dust and edge effects from the access road, and obtain longer fetch area of forest on the same side of the road. New location is southeast to the original candidate tower for ~100 m.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the west 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. An **instrument hut** should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind and should be positioned to have the longer side parallel to frequent wind direction to minimize the wind effects on instrument huts and to minimize the disturbances of wind regime by instrument hut, and in this case, instrument hut should be positioned on the southeast side of tower and have the longer side parallel to NW-SE direction. Because this is a closed canopy ecosystem, the distance between the tower and the instrument hut can be reduced to ~ 15 m. Therefore, we require the placement of instrument hut at 44.06403, -71.28730.

Canopy height is ~23 m around tower site with lowest branches at ground level. Maple and beech form upper understory, which varies from 14 to 16 m in height. Seedlings and sapling of maple, hemlock and beech forms the lower understory with mean height ~ 4 m. Grass and other short vegetation form the understory at ground level with height ~ 0.2 m. We require 6 **measurement layers** on the tower with top measurement height at 33 m, and rest layers are 26 m, 20 m, 16 m, 4 m and 0.1 m, respectively, to best characterize the fluxes on the tower top and environmental conditions in profile.

Secondary **precipitation collector** for bulk precipitation collection will be located the top of tower at this site. **Wet deposition collector** will collocate at the top of the tower. See AD 04 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. **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 this case, level 6 being the upper most level at this tower site.

Table 15. Site design and tower attributes for Bartlett Experimental Forest Relocatable site

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

Attribute	lat	long	degree	meters	notes
Airshed			280° to 335° (major) and 140° to 200°		Clockwise from first angle
Tower location	44.06388°,	-71.28731°	--	--	new site
Instrument hut	44.06403,	-71.28730			
Instrument hut orientation vector	--	--	130°-310°		
Instrument hut distance z	--	--	--	15	
Anemometer/Temperature boom orientation	--	--	270°	--	
Height of the measurement levels					
Level 1				0.1	m.a.g.l.
Level 2				4.0	m.a.g.l.
Level 3				16.0	m.a.g.l.
Level 4				20.0	m.a.g.l.
Level 5				26.0	m.a.g.l.
Level 6				35.0	m.a.g.l.
Tower Height				35.0	m.a.g.l.

See AD 03 for technical requirement to determine the boom height for the bottom most measurement level.

Figure 67 below shows the proposed tower location, instrument hut location, airshed area and access road.

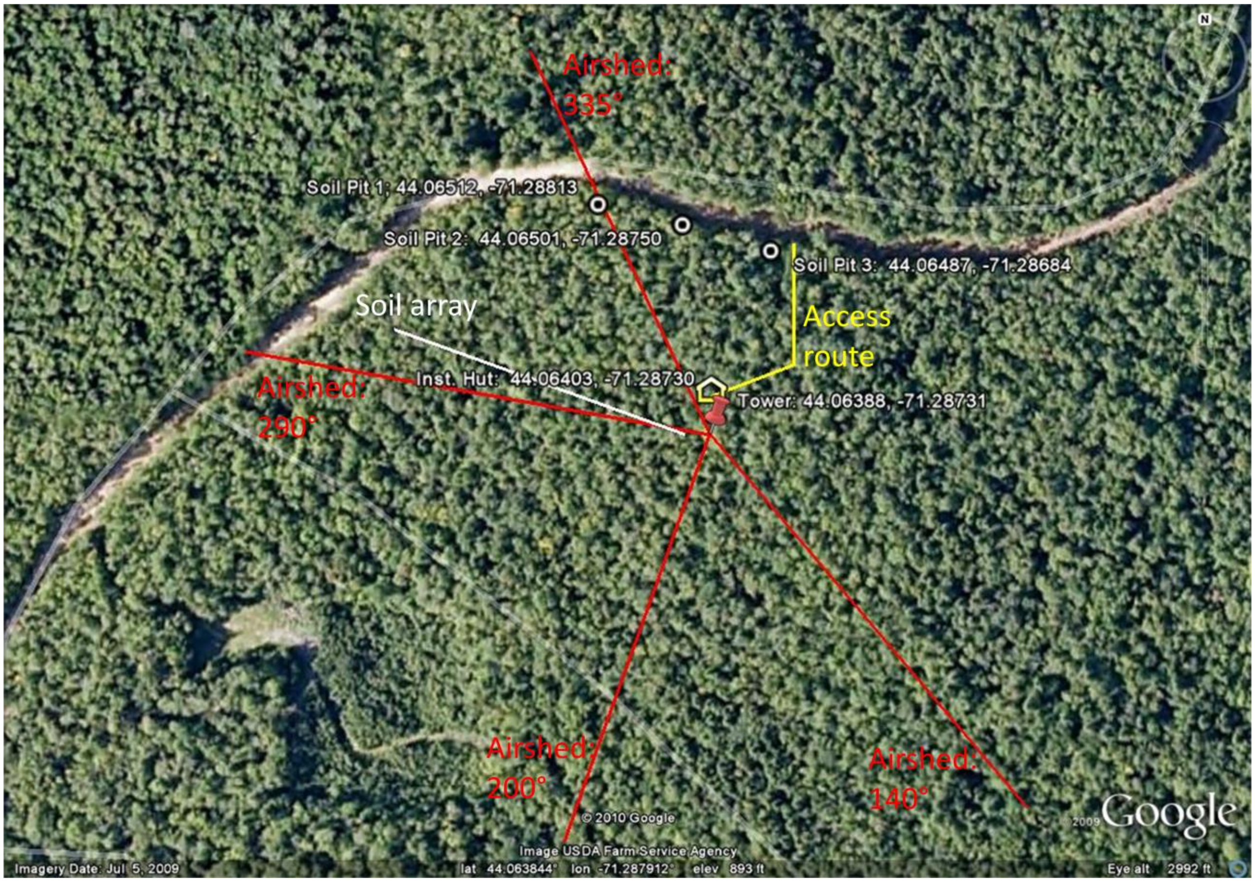


Figure 67. Site layout for Bartlett Experimental Forest Relocatable site.

i) new tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 280° to 335° (clockwise from 280°, major airshed) or from 140° to 200° (clockwise from 140°, secondary airshed) that would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access road to instrument hut. Correct tower location is in the table and FCC report.

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' 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.

Specific boardwalks at the Bartlett site

- Boardwalk is from the access dirt road to instrument hut and must avoid crossing the area used for measuring soil respiration by University of New Hampshire scientists, pending landowner decision
- Boardwalk from the instrument hut to the tower to intersect on north face of the tower
- Boardwalk to the soil array
- No boardwalk from the soil array boardwalk to the individual soil plots

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

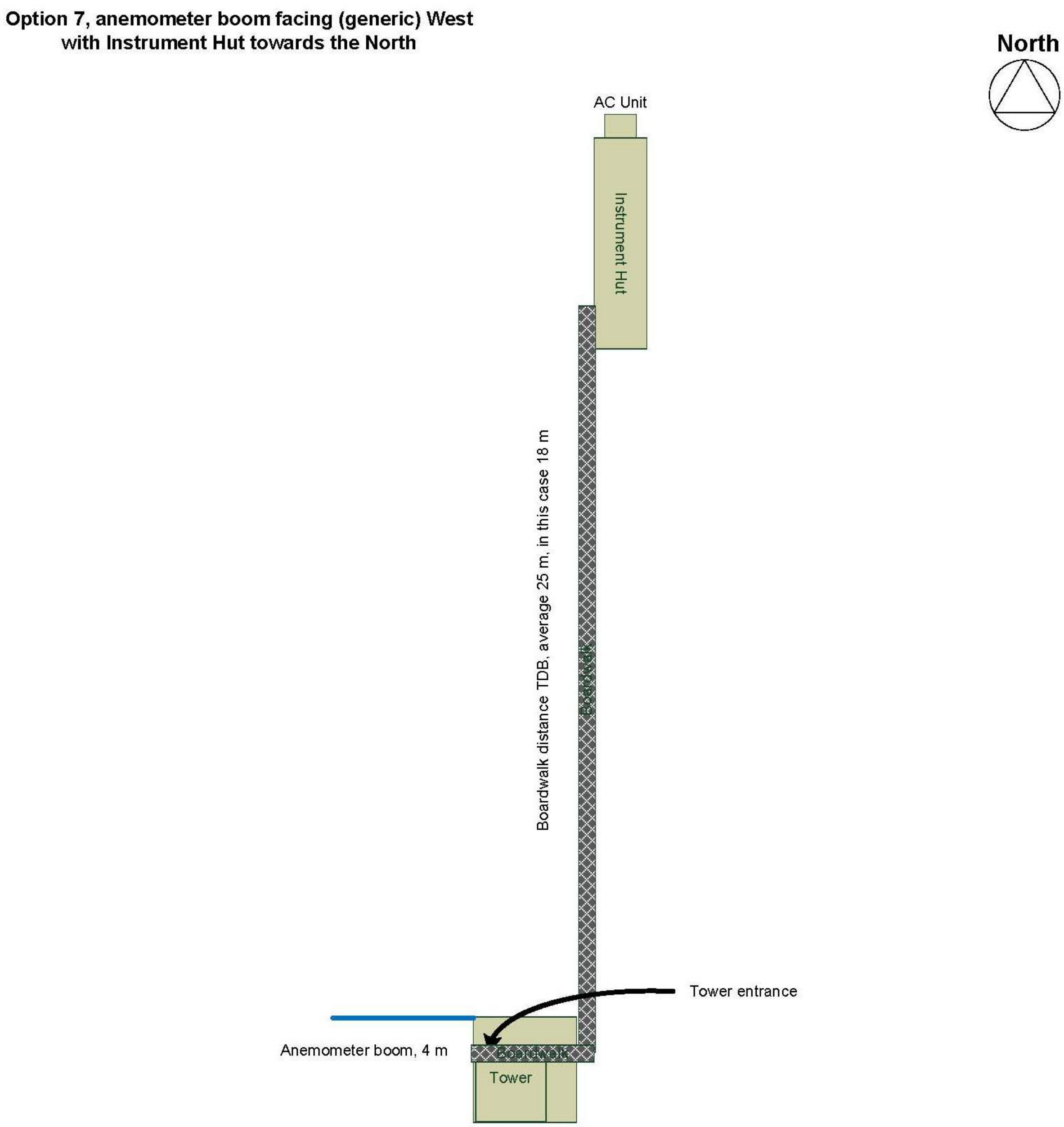


Figure 68. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing west and instrument hut on the north towards the tower.

This is just a generic diagram. The actual design of boardwalk (or path if no boardwalk required) and instrument hut position will be the responsibility of FCC and LAD following FIU's guidelines. At Bartlett Experimental Forest relocatable site, the boom angle will be 270 degrees, instrument hut will be on the north towards the tower, the distance between instrument hut and tower is ~15 m. The instrument hut vector will be SE-NW (130^{o}-310^{o}).

4.4.8 Information for ecosystem productivity plots

The tower at Bartlett Experimental Forest Relocatable site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (hardwood forest). Airshed at this site is from 280° to 335° (clockwise from 280°, major airshed) and from 140° to 200° (clockwise from 140°, secondary airshed), and 90% signals for flux measurements are within a distance of 800 m from tower, and 80% within 500 m. We suggest FSU Ecosystem Productivity plots be placed within the major airshed boundaries of 280° to 335° (clockwise from 250°) from tower.

4.5 Issues and attentions

Researchers from the University of New Hampshire use the area east of the existing tower (44.06388, -71.28731) to monitor soil respiration. NEON should avoid disturbing this area, i.e., the access route and power lines should go around this area.

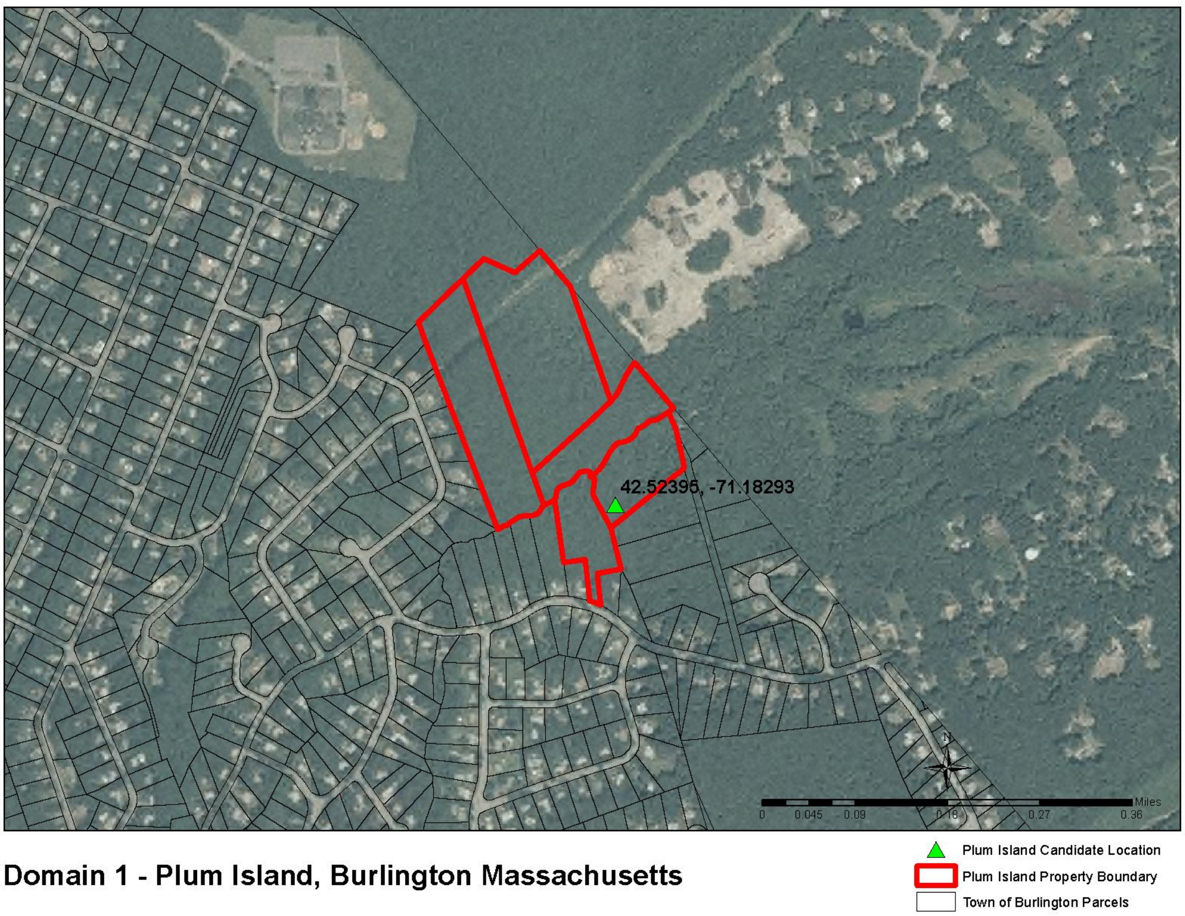
Some of the Forest Service representatives expressed concern about trenching power/communications lines in the soil and running them in conduit above the soil. However, they recognized that power and communications lines were needed at the NEON site. PT EHS will have to continue this conversation with the local site personnel.

5 PLUM ISLAND (BURLINGTON), RELOCATEABLE TOWER 2

5.1 Site description

The previous candidate relocatable tower site (42.51611111, -71.19166389) is located at the east corner of Rahanis park for public recreation, off Mill Street in Burlington, Massachusetts. Residential buildings densely surround this park. Human activities are very heavy at this area. It doesn't meet the science requirements for FIU and FSU teams, plus it also raises the concerns for the security of research facilities. An alternative site (42.52395, -71.18293) that FIU proposed is located within Sawmill brook conservation, Burlington, MA, which is next to the Aquatic/STREON site. Information provided below is based on this site.

Figure 68. Boarder of the Sawmill brook conservation area and tower location.



Note that the location boundaries are in red, but the area to the east of the conservation area is the Town of Wilmington MA open space and is also under a conservation easement.

5.2 Ecosystem

This conservation area is comprised of 27 acres of mostly dry woodland, wetlands and meadows. There are several trails through the property, with the main north/south trail blazed blue and the dead-ended side-trail blazed yellow. Sawmill Brook forms the southern border for most of the parcel. Birds and other wildlife give visitors an opportunity to enjoy nature. The property is accessible from a gate on Mill Street, from the gas line easement at Erin Lane, and from a trail starting behind the Fox Hill Elementary School. As a reference, please be aware of Burlington's historic Clapp's Mill Site. The Clapp's Mill Site consists of almost 4 acres directly adjacent to the Sawmill Brook Conservation Area, and contains the remnants of an historic dam and mill. A small parking area is located at the end of Sawmill Road off of Mill Street. (Information source: http://www.burlington.org/conservation/CON_areas.htm#SawmillCA).

Inside the park boundary, vegetation is mainly the Central Appalachian Dry Oak-Pine Forest, followed by Appalachian (Hemlock-) Northern Hardwood Forest. The trees in the forest are estimated be to 20 meters tall with canopy area density of 4.6 in summer and 1.4 in winter.

More vegetation and land cover information are presented below:

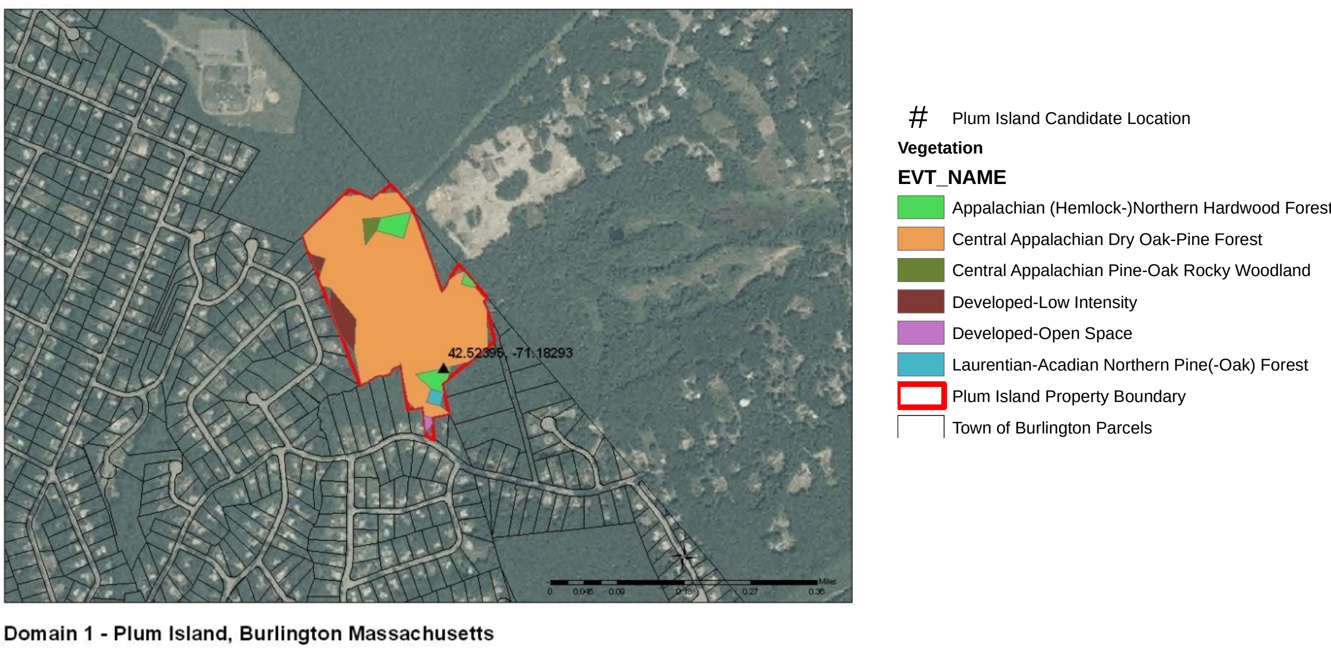


Figure 69. Vegetative cover map of Plum Island (Burlington) relocatable site and surrounding areas (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Table 16. Percent Land cover information at Plum Island (Burlington) relocatable site (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Land cover types	Area (km^2)	Percentage (%)
Appalachian (Hemlock-)Northern Hardwood Forest	0.006018593	5.201503026
Central Appalachian Pine-Oak Rocky Woodland	0.001349805	1.166554141
Developed-Low Intensity	0.005063295	4.375897073
Laurentian-Acadian Northern Pine(-Oak) Forest	0.0009	0.777815143
Central Appalachian Dry Oak-Pine Forest	0.101800685	87.98012675

Developed-Open Space	0.00057635	0.498103864
Total	0.115708727	100

The representative ecosystem that NEON design is focused around for this relocatable site is a natural area that is embedded in a typical Northeast urban environment.

Canopy height is ~24 m around tower site with lowest branches at ground level. Maple and oak form upper understory, which is ~ 14 m in height. Pine and some deciduous trees form second understory layers, which is ~ 8 m in mean canopy height. Recruitments of maple, oak, pine and beech forms the lower understory with mean height ~ 4 m. Grass and other short vegetation form the lowest understory at ground level with height ~ 0.4 m.

Table 17. Ecosystem and site attributes for the Plum Island Suburban Relocatable site.

Ecosystem attributes	Measure and units
Mean canopy height[a]	24 m
Surface roughness[a]	1.5 m
Zero place displacement height[a]	20.5 m
Structural elements	Closed forest, relatively homogeneous, understory presents
Time zone	Eastern time
Magnetic declination	15° 7' W changing by 0° 3' E year^{-1}

Note, [a] From field survey.

5.3 Soils

5.3.1 Description of soils

Soil data and soil maps (Figures 55) below for Harvard Forest Advanced tower site were collected from 1 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 70. Soil map of the Plum Island Subauban Relocatable site and surrounding areas.

Soil Map Units Description: The map units delineated on the detailed soil maps in a soil survey represents 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, the soils are natural phenomena, and 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 soils 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. T he 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, are 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 18. Soil series and percentage of soil series within 1 km^2 centered on the Plum Island tower

Middlesex County, Massachusetts (MA017)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
6A	Scarboro mucky fine sandy loam, 0 to 3 percent slopes	2.2	0.4%
51A	Swansea muck, 0 to 1 percent slopes	6.3	1.1%
52A	Freetown muck, 0 to 1 percent slopes	19.8	3.5%
71B	Ridgebury fine sandy loam, 3 to 8 percent slopes, extremely stony	4.0	0.7%
73B	Whitman fine sandy loam, 0 to 5 percent slopes, extremely stony	22.9	4.1%
103B	Charlton-Hollis-Rock outcrop complex, 3 to 8 percent slopes	48.7	8.6%
103C	Charlton-Hollis-Rock outcrop complex, 8 to 15 percent slopes	24.3	4.3%
103D	Charlton-Hollis-Rock outcrop complex, 15 to 25 percent slopes	36.4	6.4%
104C	Hollis-Rock outcrop-Charlton complex, 3 to 15 percent slopes	8.4	1.5%
104D	Hollis-Rock outcrop-Charlton complex, 15 to 25 percent slopes	12.6	2.2%
105E	Rock outcrop-Hollis complex, 3 to 35 percent slopes	17.4	3.1%
253B	Hinckley loamy sand, 3 to 8 percent slopes	14.6	2.6%
255B	Windsor loamy sand, 3 to 8 percent slopes	2.8	0.5%
256A	Deerfield loamy sand, 0 to 3 percent slopes	4.9	0.9%
260B	Sudbury fine sandy loam, 3 to 8 percent slopes	3.0	0.5%
302B	Montauk fine sandy loam, 3 to 8 percent slopes, extremely stony	43.2	7.6%
302C	Montauk fine sandy loam, 8 to 15 percent slopes, extremely stony	12.9	2.3%
302D	Montauk fine sandy loam, 15 to 25 percent slopes, extremely stony	12.3	2.2%
307B	Paxton fine sandy loam, 3 to 8 percent slopes, extremely stony	9.2	1.6%
311B	Woodbridge fine sandy loam, 3 to 8 percent slopes, very stony	4.3	0.8%
317B	Scituate fine sandy loam, 3 to 8 percent slopes, extremely stony	92.8	16.4%
317C	Scituate fine sandy loam, 8 to 15 percent slopes, extremely stony	3.2	0.6%
320B	Birchwood fine sandy loam, 3 to 8 percent slopes	7.1	1.3%
622C	Paxton-Urban land complex, 3 to 15 percent slopes	49.9	8.8%
623C	Woodbridge-Urban land complex, 3 to 15 percent slopes	78.8	13.9%

Middlesex County, Massachusetts (MA017)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
631C	Charlton-Urban land-Hollis complex, 3 to 15 percent slopes, rocky	7.0	1.2%
655	Udorthents, wet substratum	12.9	2.3%
656	Udorthents-Urban land complex	3.0	0.5%
Totals for Area of Interest		**565.0**	**100.0%**

103D—Charlton-Hollis-Rock outcrop complex, 15 to 25 percent slopes Map Unit Setting *Elevation:* 0 to 1,000 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 110 to 240 days **Map Unit Composition** *Charlton and similar soils:* 50 percent *Hollis and similar soils:* 25 percent *Rock outcrop:* 15 percent *Minor components:* 10 percent **Description of Charlton Setting** *Landform:* Ground moraines, drumlins *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over friable loamy basal till derived from granite and gneiss **Properties and qualities** *Slope:* 15 to 25 percent *Surface area covered with cobbles, stones or boulders:* 9.0 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 (0.60 to 6.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Moderate (about 7.3 inches) **Interpretive groups** *Land capability (nonirrigated):* 6s **Typical profile** *0 to 5 inches:* Fine sandy loam *5 to 22 inches:* Sandy loam *22 to 65 inches:* Gravelly sandy loam **Description of Hollis Setting** *Landform:* Hills, ridges *Landform position (two-dimensional):* Shoulder, summit *Landform position (three-dimensional):* Crest *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable, shallow loamy basal till over granite and gneiss **Properties and qualities** *Slope:* 15 to 25 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 8 to 20 inches to lithic bedrock *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 2.0 inches) **Interpretive groups** *Land capability (nonirrigated):* 6s **Typical profile** *0 to 2 inches:* Fine sandy loam *2 to 14 inches:* Fine sandy loam *14 to 18 inches:* Unweathered bedrock **Description of Rock Outcrop Setting** *Landform:* Ledges *Landform position (two-dimensional):* Summit *Landform position (three-dimensional):* Head slope *Down-slope shape:* Concave *Across-slope shape:* Concave *Parent material:* Granite and gneiss **Properties and qualities** *Slope:* 15 to 25 percent *Depth to restrictive feature:* 0 inches to lithic bedrock **Interpretive groups** *Land capability (nonirrigated):* 8s **Minor Components Canton** *Percent of map unit:* 2 percent *Landform:* Hills *Landform position (two-dimensional):* Summit, shoulder *Landform position (three-dimensional):* Head slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Narragansett** *Percent of map unit:* 2 percent *Landform:* Ridges, hills *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Linear *Across-slope shape:* Convex **Woodbridge** *Percent of map unit:* 2 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Summit, shoulder, toeslope *Landform position (three-dimensional):* Head slope, base slope, nose slope *Down-slope shape:* Linear *Across-slope shape:* Concave **Montauk** *Percent of map unit:* 2 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Summit, shoulder *Landform position (three-dimensional):* Nose slope, head slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Unnamed** *Percent of map unit:* 2 percent

103B—Charlton-Hollis-Rock outcrop complex, 3 to 8 percent slopes Map Unit Setting *Elevation:* 0 to 1,000 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 110 to 240 days **Map Unit Composition** *Charlton and similar soils:* 50 percent *Hollis and similar soils:* 25 percent *Rock outcrop:* 15 percent *Minor components:* 10 percent **Description of Charlton Setting** *Landform:* Drumlins, ground moraines *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over friable loamy basal till derived from granite and gneiss **Properties and qualities** *Slope:* 3 to 8 percent *Surface area covered with cobbles, stones or boulders:* 9.0 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 (0.60 to 6.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Moderate (about 7.3 inches) **Interpretive groups** *Land capability (nonirrigated):* 6s **Typical profile** *0 to 5 inches:* Fine sandy loam *5 to 22 inches:* Sandy loam *22 to 65 inches:* Gravelly sandy loam **Description of Hollis Setting** *Landform:* Ridges, hills *Landform position (two-dimensional):* Shoulder, summit *Landform position (three-dimensional):* Crest *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable, shallow loamy basal till over granite and gneiss **Properties and qualities** *Slope:* 3 to 8 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 8 to 20 inches to lithic bedrock *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 2.0 inches) **Interpretive groups** *Land capability (nonirrigated):* 6s **Typical profile** *0 to 2 inches:* Fine sandy loam *2 to 14 inches:* Fine sandy loam *14 to 18 inches:* Unweathered bedrock **Description of Rock Outcrop Setting** *Landform:* Ledges *Landform position (two-dimensional):* Summit *Landform position (three-dimensional):* Head slope *Down-slope shape:* Concave *Across-slope shape:* Concave *Parent material:* Granite and gneiss **Properties and qualities** *Slope:* 3 to 8 percent *Depth to restrictive feature:* 0 inches to lithic bedrock **Interpretive groups** *Land capability (nonirrigated):* 8s **Minor Components Canton** *Percent of map unit:* 2 percent *Landform:* Hills *Landform position (two-dimensional):* Summit, shoulder *Landform position (three-dimensional):* Head slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Narragansett** *Percent of map unit:* 2 percent *Landform:* Ridges, hills *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Linear *Across-slope shape:* Convex **Woodbridge** *Percent of map unit:* 2 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Shoulder, toeslope, summit *Landform position (three-dimensional):* Head slope, base slope, nose slope *Down-slope shape:* Linear *Across-slope shape:* Concave **Scituate** *Percent of map unit:* 2 percent *Landform:* Hillslopes, depressions *Landform position (two-dimensional):* Toeslope, summit *Landform position (three-dimensional):* Base slope, head slope *Down-slope shape:* Linear *Across-slope shape:* Concave **Unnamed** *Percent of map unit:* 1 percent **Montauk** *Percent of map unit:* 1 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Shoulder, summit *Landform position (three-dimensional):* Nose slope, head slope *Down-slope shape:* Convex *Across-slope shape:* Convex

103C—Charlton-Hollis-Rock outcrop complex, 8 to 15 percent slopes Map Unit Setting *Elevation:* 0 to 1,000 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 110 to 240 days **Map Unit Composition** *Charlton and similar soils:* 50 percent *Hollis and similar soils:* 25 percent *Rock outcrop:* 15 percent *Minor components:* 10 percent **Description of Charlton Setting** *Landform:* Drumlins, ground moraines *Landform position (two-dimensional):* Footslope

Landform position (three-dimensional): Base slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over friable loamy basal till derived from granite and gneiss **Properties and qualities** *Slope:* 8 to 15 percent *Surface area covered with cobbles, stones or boulders:* 9.0 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 (0.60 to 6.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Moderate (about 7.3 inches) **Interpretive groups** *Land capability (nonirrigated):* 6s **Typical profile** *0 to 5 inches:* Fine sandy loam *5 to 22 inches:* Sandy loam *22 to 65 inches:* Gravelly sandy loam **Description of Hollis Setting** *Landform:* Ridges, hills *Landform position (two-dimensional):* Shoulder, summit *Landform position (three-dimensional):* Crest *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable, shallow loamy basal till over granite and gneiss **Properties and qualities** *Slope:* 8 to 15 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 8 to 20 inches to lithic bedrock *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 2.0 inches) **Interpretive groups** *Land capability (nonirrigated):* 6s **Typical profile** *0 to 2 inches:* Fine sandy loam *2 to 14 inches:* Fine sandy loam *14 to 18 inches:* Unweathered bedrock **Description of Rock Outcrop Setting** *Landform:* Ledges *Landform position (two-dimensional):* Summit *Landform position (three-dimensional):* Head slope *Down-slope shape:* Concave *Across-slope shape:* Concave *Parent material:* Granite and gneiss **Properties and qualities** *Slope:* 8 to 15 percent *Depth to restrictive feature:* 0 inches to lithic bedrock **Interpretive groups** *Land capability (nonirrigated):* 8s **Minor Components Canton** *Percent of map unit:* 2 percent *Landform:* Hills *Landform position (two-dimensional):* Summit, shoulder *Landform position (three-dimensional):* Head slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Narragansett** *Percent of map unit:* 2 percent *Landform:* Ridges, hills *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Linear *Across-slope shape:* Convex **Scituate** *Percent of map unit:* 2 percent *Landform:* Hillslopes, depressions *Landform position (two-dimensional):* Toeslope, summit *Landform position (three-dimensional):* Base slope, head slope *Down-slope shape:* Linear *Across-slope shape:* Concave **Woodbridge** *Percent of map unit:* 2 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Summit, shoulder, toeslope *Landform position (three-dimensional):* Nose slope, head slope, base slope *Down-slope shape:* Linear *Across-slope shape:* Concave **Montauk** *Percent of map unit:* 1 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Shoulder, summit *Landform position (three-dimensional):* Nose slope, head slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Unnamed** *Percent of map unit:* 1 percent

631C—Charlton-Urban land-Hollis complex, 3 to 15 percent slopes, rocky Map Unit Setting *Elevation:* 0 to 1,000 feet *Mean annual precipitation:* 32 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 110 to 240 days **Map Unit Composition** *Urban land:* 40 percent *Charlton and similar soils:* 40 percent *Hollis and similar soils:* 10 percent *Minor components:* 10 percent **Description of Charlton Setting** *Landform:* Drumlins, ground moraines *Landform position (two-dimensional):* Backslope *Landform position (three-dimensional):* Side slope *Down-slope shape:* Linear *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over friable loamy basal till derived from granite and gneiss **Properties and qualities** *Slope:* 3 to 15 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 (0.60 to 6.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Moderate (about 7.3

inches) **Interpretive groups** *Land capability (nonirrigated):* 3e **Typical profile** *0 to 5 inches:* Fine sandy loam *5 to 22 inches:* Sandy loam *22 to 65 inches:* Gravelly sandy loam **Description of Urban Land Setting** *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Linear *Across-slope shape:* Linear *Parent material:* Excavated and filled land **Description of Hollis Setting** *Landform:* Ridges, hillslopes *Landform position (two-dimensional):* Backslope *Landform position (three-dimensional):* Side slope *Down-slope shape:* Linear *Across-slope shape:* Convex *Parent material:* Friable, shallow loamy basal till over granite and gneiss **Properties and qualities** *Slope:* 3 to 15 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 8 to 20 inches to lithic bedrock *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 2.0 inches) **Interpretive groups** *Land capability (nonirrigated):* 6s **Typical profile** *0 to 2 inches:* Fine sandy loam *2 to 14 inches:* Fine sandy loam *14 to 18 inches:* Unweathered bedrock **Minor Components Canton** *Percent of map unit:* 4 percent *Landform:* Hills *Landform position (two-dimensional):* Toeslope, backslope *Landform position (three-dimensional):* Base slope, side slope *Down-slope shape:* Linear *Across-slope shape:* Convex **Udorthents, loamy** *Percent of map unit:* 2 percent **Rock outcrop** *Percent of map unit:* 2 percent *Landform:* Ledges *Landform position (two-dimensional):* Summit *Landform position (three-dimensional):* Head slope *Down-slope shape:* Concave *Across-slope shape:* Concave **Scituate** *Percent of map unit:* 1 percent *Landform:* Depressions, hillslopes *Landform position (two-dimensional):* Toeslope, summit *Landform position (three-dimensional):* Base slope, head slope *Down-slope shape:* Linear *Across-slope shape:* Concave **Montauk** *Percent of map unit:* 1 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Shoulder, summit *Landform position (three-dimensional):* Nose slope, head slope *Down-slope shape:* Convex *Across-slope shape:* Convex

52A—Freetown muck, 0 to 1 percent slopes Map Unit Setting *Elevation:* 0 to 2,100 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 145 to 240 days **Map Unit Composition** *Freetown and similar soils:* 85 percent *Minor components:* 15 percent **Description of Freetown Setting** *Landform:* Bogs, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Concave *Across-slope shape:* Concave *Parent material:* Highly decomposed herbaceous organic material **Properties and qualities** *Slope:* 0 to 1 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 high to high (0.60 to 6.00 in/hr) *Depth to water table:* About 0 to 6 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very high (about 23.9 inches) **Interpretive groups** *Land capability (nonirrigated):* 7w **Typical profile** *0 to 9 inches:* Muck *9 to 65 inches:* Muck **Minor Components Swansea** *Percent of map unit:* 5 percent *Landform:* Bogs, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Concave *Across-slope shape:* Concave **Freetown, ponded** *Percent of map unit:* 5 percent *Landform:* Bogs, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Concave *Across-slope shape:* Concave **Scarboro** *Percent of map unit:* 5 percent *Landform:* Terraces *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Tread *Down-slope shape:* Linear *Across-slope shape:* Linear

253B—Hinckley loamy sand, 3 to 8 percent slopes Map Unit Setting *Elevation:* 0 to 2,100 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 145 to 240 days **Map Unit Composition** *Hinckley and similar soils:* 80 percent *Minor components:* 20

percent **Description of Hinckley Setting** *Landform:* Plains, terraces *Landform position (two-dimensional):* Summit *Landform position (three-dimensional):* Tread, rise *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Loose sandy and gravelly glaciofluvial deposits derived from granite and gneiss **Properties and qualities** *Slope:* 3 to 8 percent *Depth to restrictive feature:* More than 80 inches *Drainage class:* Excessively drained *Capacity of the most limiting layer to transmit water (Ksat):* High to very high (6.00 to 20.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 3.1 inches) **Interpretive groups** *Land capability (nonirrigated):* 3s **Typical profile** *0 to 7 inches:* Loamy sand *7 to 17 inches:* Very gravelly loamy sand *17 to 65 inches:* Stratified extremely gravelly coarse sand to extremely gravelly sand **Minor Components Merrimac** *Percent of map unit:* 7 percent *Landform:* Plains, terraces *Landform position (two-dimensional):* Shoulder *Landform position (three-dimensional):* Tread, rise *Down-slope shape:* Convex *Across-slope shape:* Convex **Windsor** *Percent of map unit:* 5 percent *Landform:* Terraces, flats, deltas *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Tread, rise *Down-slope shape:* Convex *Across-slope shape:* Convex **Carver** *Percent of map unit:* 3 percent *Landform:* Plains, deltas, terraces *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Tread, rise *Down-slope shape:* Convex *Across-slope shape:* Convex **Quonset** *Percent of map unit:* 2 percent *Landform:* Eskers, kames, terraces *Landform position (two-dimensional):* Shoulder *Landform position (three-dimensional):* Nose slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Sudbury** *Percent of map unit:* 2 percent *Landform:* Terraces, plains *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Tread, dip *Down-slope shape:* Linear *Across-slope shape:* Concave **Deerfield** *Percent of map unit:* 1 percent *Landform:* Deltas, stream terraces, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Tread, dip *Down-slope shape:* Concave *Across-slope shape:* Concave

104D—Hollis-Rock outcrop-Charlton complex, 15 to 25 percent slopes Map Unit Setting *Elevation:* 0 to 1,000 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 110 to 240 days **Map Unit Composition** *Rock outcrop:* 30 percent *Hollis and similar soils:* 30 percent *Charlton and similar soils:* 25 percent *Minor components:* 15 percent **Description of Hollis Setting** *Landform:* Ridges, hills *Landform position (two-dimensional):* Footslope, backslope *Landform position (three-dimensional):* Crest, head slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable, shallow loamy basal till over granite and gneiss **Properties and qualities** *Slope:* 15 to 25 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 8 to 20 inches to lithic bedrock *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 2.0 inches) **Interpretive groups** *Land capability (nonirrigated):* 6s **Typical profile** *0 to 2 inches:* Fine sandy loam *2 to 14 inches:* Fine sandy loam *14 to 18 inches:* Unweathered bedrock **Description of Rock Outcrop Setting** *Parent material:* Granite and gneiss **Properties and qualities** *Slope:* 15 to 25 percent *Depth to restrictive feature:* 0 inches to lithic bedrock **Interpretive groups** *Land capability (nonirrigated):* 8s **Description of Charlton Setting** *Landform:* Hills *Landform position (two-dimensional):* Shoulder, summit *Landform position (three-dimensional):* Side slope, base slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over friable loamy basal till derived from granite and gneiss **Properties and qualities** *Slope:* 15 to 25 percent *Surface area covered with cobbles, stones or boulders:* 9.0 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 (0.60 to 6.00 in/hr) *Depth to water table:* More than 80 inches

Frequency of flooding: None *Frequency of ponding:* None *Available water capacity:* Moderate (about 7.3 inches) **Interpretive groups** *Land capability (nonirrigated):* 6s **Typical profile** *0 to 5 inches:* Fine sandy loam *5 to 22 inches:* Sandy loam *22 to 65 inches:* Gravelly sandy loam **Minor Components Canton** *Percent of map unit:* 10 percent *Landform:* Hills *Landform position (two-dimensional):* Shoulder, summit *Landform position (three-dimensional):* Head slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Montauk** *Percent of map unit:* 3 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Shoulder, summit *Landform position (three-dimensional):* Nose slope, head slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Unnamed** *Percent of map unit:* 2 percent

104C—Hollis-Rock outcrop-Charlton complex, 3 to 15 percent slopes Map Unit Setting *Elevation:* 0 to 1,000 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 110 to 240 days **Map Unit Composition** *Rock outcrop:* 30 percent *Hollis and similar soils:* 30 percent *Charlton and similar soils:* 25 percent *Minor components:* 15 percent **Description of Hollis Setting** *Landform:* Hills, ridges *Landform position (two-dimensional):* Toeslope, backslope *Landform position (three-dimensional):* Crest, head slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable, shallow loamy basal till over granite and gneiss **Properties and qualities** *Slope:* 3 to 15 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 8 to 20 inches to lithic bedrock *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 2.0 inches) **Interpretive groups** *Land capability (nonirrigated):* 6s **Typical profile** *0 to 2 inches:* Fine sandy loam *2 to 14 inches:* Fine sandy loam *14 to 18 inches:* Unweathered bedrock **Description of Rock Outcrop Setting** *Landform:* Ledges *Landform position (two-dimensional):* Summit *Landform position (three-dimensional):* Head slope *Down-slope shape:* Concave *Across-slope shape:* Concave *Parent material:* Granite and gneiss **Properties and qualities** *Slope:* 3 to 15 percent *Depth to restrictive feature:* 0 inches to lithic bedrock **Interpretive groups** *Land capability (nonirrigated):* 8s **Description of Charlton Setting** *Landform:* Swales, hills *Landform position (two-dimensional):* Summit, shoulder *Landform position (three-dimensional):* Side slope, base slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over friable loamy basal till derived from granite and gneiss **Properties and qualities** *Slope:* 3 to 15 percent *Surface area covered with cobbles, stones or boulders:* 9.0 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 (0.60 to 6.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Moderate (about 7.3 inches) **Interpretive groups** *Land capability (nonirrigated):* 6s **Typical profile** *0 to 5 inches:* Fine sandy loam *5 to 22 inches:* Sandy loam *22 to 65 inches:* Gravelly sandy loam **Minor Components Canton** *Percent of map unit:* 10 percent *Landform:* Hills *Landform position (two-dimensional):* Shoulder, summit *Landform position (three-dimensional):* Head slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Scituate** *Percent of map unit:* 3 percent *Landform:* Hillslopes, depressions *Landform position (two-dimensional):* Summit, toeslope *Landform position (three-dimensional):* Base slope, head slope *Down-slope shape:* Linear *Across-slope shape:* Concave **Montauk** *Percent of map unit:* 1 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Summit, shoulder *Landform position (three-dimensional):* Nose slope, head slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Unnamed** *Percent of map unit:* 1 percent

302D—Montauk fine sandy loam, 15 to 25 percent slopes, extremely stony Map Unit Setting *Elevation:* 0 to 400 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees

F *Frost-free period:* 145 to 240 days **Map Unit Composition** *Montauk and similar soils:* 85 percent *Minor components:* 15 percent **Description of Montauk Setting** *Landform:* Hillslopes *Landform position (two-dimensional):* Backslope, footslope *Landform position (three-dimensional):* Base slope, side slope *Down-slope shape:* Linear *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over dense sandy lodgment till derived from granite **Properties and qualities** *Slope:* 15 to 25 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 20 to 37 inches to dense material *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.60 in/hr) *Depth to water table:* About 18 to 24 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 3.6 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 7 inches:* Fine sandy loam *7 to 20 inches:* Gravelly sandy loam *20 to 29 inches:* Sandy loam *29 to 65 inches:* Gravelly loamy sand **Minor Components Paxton** *Percent of map unit:* 10 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Backslope, summit *Landform position (three-dimensional):* Side slope, head slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Charlton** *Percent of map unit:* 5 percent *Landform:* Drumlins, ground moraines *Landform position (two-dimensional):* Backslope, toeslope *Landform position (three-dimensional):* Base slope, side slope *Down-slope shape:* Convex *Across-slope shape:* Convex

302B—Montauk fine sandy loam, 3 to 8 percent slopes, extremely stony Map Unit Setting *Elevation:* 0 to 400 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 145 to 240 days **Map Unit Composition** *Montauk and similar soils:* 85 percent *Minor components:* 15 percent **Description of Montauk Setting** *Landform:* Hillslopes *Landform position (two-dimensional):* Shoulder, summit *Landform position (three-dimensional):* Head slope, nose slope *Down-slope shape:* Convex *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over dense sandy lodgment till derived from granite **Properties and qualities** *Slope:* 3 to 8 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 20 to 37 inches to dense material *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.60 in/hr) *Depth to water table:* About 18 to 24 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 3.6 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 7 inches:* Fine sandy loam *7 to 20 inches:* Gravelly sandy loam *20 to 29 inches:* Sandy loam *29 to 65 inches:* Gravelly loamy sand **Minor Components Scituate** *Percent of map unit:* 10 percent *Landform:* Depressions, hillslopes *Landform position (two-dimensional):* Summit, toeslope *Landform position (three-dimensional):* Base slope, head slope *Down-slope shape:* Linear *Across-slope shape:* Concave **Paxton** *Percent of map unit:* 5 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Summit, backslope *Landform position (three-dimensional):* Head slope, side slope *Down-slope shape:* Convex *Across-slope shape:* Convex

302C—Montauk fine sandy loam, 8 to 15 percent slopes, extremely stony Map Unit Setting *Elevation:* 0 to 400 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 145 to 240 days **Map Unit Composition** *Montauk and similar soils:* 85 percent *Minor components:* 15 percent **Description of Montauk Setting** *Landform:* Hillslopes *Landform position (two-dimensional):* Backslope *Landform position (three-dimensional):* Side slope *Down-slope shape:* Linear *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over dense sandy lodgment till derived from granite **Properties and qualities** *Slope:* 8 to 15 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 20 to 37 inches to dense material

Drainage class: Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.60 in/hr) *Depth to water table:* About 18 to 24 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 3.6 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 7 inches:* Fine sandy loam *7 to 20 inches:* Gravelly sandy loam *20 to 29 inches:* Sandy loam *29 to 65 inches:* Gravelly loamy sand **Minor Components Paxton** *Percent of map unit:* 13 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Backslope, summit *Landform position (three-dimensional):* Side slope, head slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Woodbridge** *Percent of map unit:* 2 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Toeslope, shoulder, summit *Landform position (three-dimensional):* Head slope, nose slope, base slope *Down-slope shape:* Linear *Across-slope shape:* Concave

622C—Paxton-Urban land complex, 3 to 15 percent slopes Map Unit Setting *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 145 to 240 days **Map Unit Composition** *Urban land:* 40 percent *Paxton and similar soils:* 40 percent *Minor components:* 20 percent **Description of Paxton Setting** *Landform:* Hillslopes *Landform position (two-dimensional):* Footslope, backslope *Landform position (three-dimensional):* Base slope, side slope *Down-slope shape:* Linear *Across-slope shape:* Convex *Parent material:* Friable loamy eolian deposits over dense loamy lodgment till derived from granite and gneiss **Properties and qualities** *Slope:* 3 to 15 percent *Depth to restrictive feature:* 20 to 39 inches to dense material *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Low to moderately high (0.01 to 0.20 in/hr) *Depth to water table:* About 18 to 21 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 3.0 inches) **Interpretive groups** *Land capability (nonirrigated):* 3e **Typical profile** *0 to 7 inches:* Fine sandy loam *7 to 13 inches:* Fine sandy loam *13 to 22 inches:* Sandy loam *22 to 26 inches:* Sandy loam *26 to 65 inches:* Fine sandy loam **Description of Urban Land Setting** *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Linear *Across-slope shape:* Linear *Parent material:* Excavated and filled land **Minor Components Charlton** *Percent of map unit:* 10 percent *Landform:* Drumlins, ground moraines *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Montauk** *Percent of map unit:* 5 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Summit, shoulder *Landform position (three-dimensional):* Nose slope, head slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Woodbridge** *Percent of map unit:* 5 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Shoulder, toeslope *Landform position (three-dimensional):* Nose slope, base slope *Down-slope shape:* Concave *Across-slope shape:* Concave

71B—Ridgebury fine sandy loam, 3 to 8 percent slopes, extremely stony Map Unit Setting *Elevation:* 0 to 2,100 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 145 to 240 days **Map Unit Composition** *Ridgebury and similar soils:* 85 percent *Minor components:* 15 percent **Description of Ridgebury Setting** *Landform:* Depressions, drainageways *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Concave *Across-slope shape:* Concave *Parent material:* Friable loamy eolian deposits over dense loamy lodgment till derived from granite and gneiss **Properties and qualities** *Slope:* 3 to 8 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 10 to 30 inches to dense material *Drainage class:* Poorly drained *Capacity of the most limiting layer to transmit water (Ksat):* Low to moderately high (0.01 to 0.20 in/hr) *Depth to water table:* About 6 to 12 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 1.3 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 7 inches:* Fine sandy loam *7 to 10 inches:* Fine sandy loam *10 to 65 inches:* Sandy loam **Minor Components Scituate** *Percent of map unit:* 5 percent *Landform:* Hillslopes, depressions *Landform position (two-dimensional):* Toeslope, summit *Landform position (three-dimensional):* Head slope, base slope *Down-slope shape:* Linear *Across-slope shape:* Concave **Whitman** *Percent of map unit:* 5 percent *Landform:* Depressions, drainageways *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Concave *Across-slope shape:* Concave **Woodbridge** *Percent of map unit:* 5 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Summit, shoulder, toeslope *Landform position (three-dimensional):* Nose slope, head slope, base slope *Down-slope shape:* Linear *Across-slope shape:* Concave

105E—Rock outcrop-Hollis complex, 3 to 35 percent slopes Map Unit Setting *Elevation:* 0 to 2,100 feet *Mean annual precipitation:* 32 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 110 to 240 days **Map Unit Composition** *Rock outcrop:* 50 percent *Hollis and similar soils:* 45 percent *Minor components:* 5 percent **Description of Rock Outcrop Setting** *Landform:* Ledges *Landform position (two-dimensional):* Summit *Landform position (three-dimensional):* Head slope *Down-slope shape:* Concave *Across-slope shape:* Concave *Parent material:* Granite and gneiss **Properties and qualities** *Slope:* 5 to 20 percent *Depth to restrictive feature:* 0 inches to lithic bedrock **Interpretive groups** *Land capability (nonirrigated):* 8s **Description of Hollis Setting** *Landform:* Hills, ridges *Landform position (two-dimensional):* Backslope *Landform position (three-dimensional):* Side slope *Down-slope shape:* Linear *Across-slope shape:* Convex *Parent material:* Friable, shallow loamy basal till over granite and gneiss **Properties and qualities** *Slope:* 3 to 35 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 8 to 20 inches to lithic bedrock *Drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.14 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 2.0 inches) **Interpretive groups** *Land capability (nonirrigated):* 6s **Typical profile** *0 to 2 inches:* Fine sandy loam *2 to 14 inches:* Fine sandy loam *14 to 18 inches:* Unweathered bedrock **Minor Components Whitman** *Percent of map unit:* 3 percent *Landform:* Depressions, drainageways *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Concave *Across-slope shape:* Concave **Swansea** *Percent of map unit:* 1 percent *Landform:* Bogs, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Concave *Across-slope shape:* Concave **Unnamed** *Percent of map unit:* 1 percent

6A—Scarboro mucky fine sandy loam, 0 to 3 percent slopes Map Unit Setting *Elevation:* 0 to 2,100 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 °F *Frost-free period:* 145 to 240 days **Map Unit Composition** *Scarboro and similar soils:* 90 percent *Minor components:* 10 percent **Description of Scarboro Setting** *Landform:* Terraces *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Tread *Down-slope shape:* Linear *Across-slope shape:* Linear *Parent material:* Sandy glaciofluvial deposits **Properties and qualities** *Slope:* 0 to 1 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 high to high (0.60 to 6.00 in hr^{-1}) *Depth to water table:* About 0 to 6 inches *Frequency of flooding:* None *Frequency of ponding:* Frequent *Available water capacity:* Moderate (about 6.9 inches) **Interpretive groups** *Land capability (nonirrigated):* 5w **Typical profile** *0 to 3 inches:* Moderately decomposed plant material *3 to 11 inches:* Mucky fine sandy loam *11 to 21 inches:* Sand *21 to 29 inches:* Gravelly coarse sand, very gravelly coarse sand *29 to 65 inches:*

Gravelly coarse sand **Minor Components Wareham** *Percent of map unit:* 4 percent *Landform:* Terraces, depressions, deltas *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Tread, dip *Down-slope shape:* Concave *Across-slope shape:* Concave **Birdsall** *Percent of map unit:* 2 percent *Landform:* Depressions, flats *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Linear *Across-slope shape:* Concave **Raypol** *Percent of map unit:* 2 percent *Landform:* Terraces, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Tread, dip *Down-slope shape:* Concave *Across-slope shape:* Concave **Swansea** *Percent of map unit:* 2 percent *Landform:* Bogs, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Concave *Across-slope shape:* Concave

317B—Scituate fine sandy loam, 3 to 8 percent slopes, extremely stony Map Unit Setting *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 145 to 240 days **Map Unit Composition** *Scituate and similar soils:* 85 percent *Minor components:* 15 percent **Description of Scituate Setting** *Landform:* Hillslopes, depressions *Landform position (two-dimensional):* Toeslope, summit *Landform position (three-dimensional):* Head slope, base slope *Down-slope shape:* Linear *Across-slope shape:* Concave *Parent material:* Friable loamy eolian deposits over dense sandy lodgment till derived from granite and gneiss **Properties and qualities** *Slope:* 3 to 8 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 18 to 33 inches to dense material *Drainage class:* Moderately well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.20 in/hr) *Depth to water table:* About 18 to 24 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Low (about 3.1 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 8 inches:* Fine sandy loam *8 to 20 inches:* Sandy loam *20 to 27 inches:* Loamy fine sand *27 to 65 inches:* Gravelly loamy sand **Minor Components Woodbridge** *Percent of map unit:* 5 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Summit, shoulder, toeslope *Landform position (three-dimensional):* Base slope, nose slope, head slope *Down-slope shape:* Linear *Across-slope shape:* Concave **Montauk** *Percent of map unit:* 5 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Shoulder, summit *Landform position (three-dimensional):* Nose slope, head slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Ridgebury** *Percent of map unit:* 5 percent *Landform:* Depressions, drainageways *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Concave *Across-slope shape:* Concave

51A—Swansea muck, 0 to 1 percent slopes Map Unit Setting *Elevation:* 0 to 2,100 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 145 to 240 days **Map Unit Composition** *Swansea and similar soils:* 85 percent *Minor components:* 15 percent **Description of Swansea Setting** *Landform:* Bogs, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Concave *Across-slope shape:* Concave *Parent material:* Highly decomposed herbaceous organic material over loose sandy and gravelly glaciofluvial deposits **Properties and qualities** *Slope:* 0 to 1 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 high to high (0.60 to 6.00 in/hr) *Depth to water table:* About 0 to 6 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* High (about 11.0 inches) **Interpretive groups** *Land capability (nonirrigated):* 7w **Typical profile** *0 to 8 inches:* Muck *8 to 23 inches:* Muck *23 to 37 inches:* Loamy fine sand *37 to 65 inches:* Gravelly sand **Minor Components Saco** *Percent of map unit:* 5 percent *Landform:* Alluvial flats, terraces *Landform position (two-dimensional):* Toeslope

Landform position (three-dimensional): Tread, dip *Down-slope shape:* Linear *Across-slope shape:* Concave **Freetown** *Percent of map unit:* 5 percent *Landform:* Bogs, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Concave *Across-slope shape:* Concave **Scarboro** *Percent of map unit:* 3 percent *Landform:* Terraces *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Tread *Down-slope shape:* Linear *Across-slope shape:* Linear **Birdsall** *Percent of map unit:* 2 percent *Landform:* Depressions, flats *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Linear *Across-slope shape:* Concave

655—Udorthents, wet substratum Map Unit Setting *Elevation:* 0 to 3,000 feet *Mean annual precipitation:* 32 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 110 to 240 days **Map Unit Composition** *Udorthents, wet substratum, and similar soils:* 85 percent *Minor components:* 15 percent **Description of Udorthents, Wet Substratum Setting** *Parent material:* Loamy alluvium and/or sandy glaciofluvial deposits and/or loamy glaciolacustrine deposits and/or loamy marine deposits and/or loamy basal till and/or loamy lodgment till **Properties and qualities** *Slope:* 0 to 8 percent *Depth to restrictive feature:* More than 80 inches *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None **Minor Components Urban land** *Percent of map unit:* 8 percent *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Linear *Across-slope shape:* Linear **Freetown** *Percent of map unit:* 4 percent *Landform:* Bogs, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Concave *Across-slope shape:* Concave **Swansea** *Percent of map unit:* 3 percent *Landform:* Bogs, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Concave *Across-slope shape:* Concave

73B—Whitman fine sandy loam, 0 to 5 percent slopes, extremely stony Map Unit Setting *Elevation:* 0 to 2,100 feet *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 145 to 240 days **Map Unit Composition** *Whitman and similar soils:* 80 percent *Minor components:* 20 percent **Description of Whitman Setting** *Landform:* Depressions, drainageways *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Concave *Across-slope shape:* Concave *Parent material:* Friable loamy eolian deposits over dense loamy lodgment till derived from granite and gneiss **Properties and qualities** *Slope:* 0 to 5 percent *Surface area covered with cobbles, stones or boulders:* 9.0 percent *Depth to restrictive feature:* 12 to 20 inches to dense material *Drainage class:* Very poorly drained *Capacity of the most limiting layer to transmit water (Ksat):* Low to moderately high (0.01 to 0.20 in/hr) *Depth to water table:* About 0 to 6 inches *Frequency of flooding:* None *Frequency of ponding:* Frequent *Available water capacity:* Very low (about 2.9 inches) **Interpretive groups** *Land capability (nonirrigated):* 7s **Typical profile** *0 to 10 inches:* Fine sandy loam *10 to 18 inches:* Sandy loam *18 to 65 inches:* Gravelly sandy loam **Minor Components Ridgebury** *Percent of map unit:* 10 percent *Landform:* Depressions, drainageways *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Concave *Across-slope shape:* Concave **Woodbridge** *Percent of map unit:* 7 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Shoulder, toeslope, summit *Landform position (three-dimensional):* Base slope, nose slope, head slope *Down-slope shape:* Linear *Across-slope shape:* Concave **Birdsall** *Percent of map unit:* 3 percent *Landform:* Depressions, flats *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Linear *Across-slope shape:* Concave

623C—Woodbridge-Urban land complex, 3 to 15 percent slopes Map Unit Setting *Mean annual precipitation:* 45 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 145 to 240 days **Map Unit Composition** *Urban land:* 40 percent *Woodbridge and similar soils:* 40 percent *Minor components:* 20 percent **Description of Woodbridge Setting** *Landform:* Hillslopes *Landform position (two-dimensional):* Backslope, footslope *Landform position (three-dimensional):* Side slope, base slope *Down-slope shape:* Linear *Across-slope shape:* Concave *Parent material:* Friable loamy eolian deposits over dense loamy lodgment till derived from granite and gneiss **Properties and qualities** *Slope:* 3 to 15 percent *Depth to restrictive feature:* 18 to 39 inches to dense material *Drainage class:* Moderately well drained *Capacity of the most limiting layer to transmit water (Ksat):* Low to moderately high (0.01 to 0.20 in/hr) *Depth to water table:* About 18 to 21 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water capacity:* Very low (about 2.9 inches) **Interpretive groups** *Land capability (nonirrigated):* 3e **Typical profile** *0 to 2 inches:* Moderately decomposed plant material *2 to 4 inches:* Fine sandy loam *4 to 30 inches:* Fine sandy loam *30 to 65 inches:* Fine sandy loam **Description of Urban Land Setting** *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Linear *Across-slope shape:* Linear *Parent material:* Excavated and filled land **Minor Components Paxton** *Percent of map unit:* 10 percent *Landform:* Hillslopes *Landform position (two-dimensional):* Backslope, summit *Landform position (three-dimensional):* Head slope, side slope *Down-slope shape:* Convex *Across-slope shape:* Convex **Scituate** *Percent of map unit:* 7 percent *Landform:* Depressions, hillslopes *Landform position (two-dimensional):* Toeslope, summit *Landform position (three-dimensional):* Base slope, head slope *Down-slope shape:* Linear *Across-slope shape:* Concave **Ridgebury** *Percent of map unit:* 3 percent *Landform:* Depressions, drainageways *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Concave *Across-slope shape:* Concave

655—Udorthents, wet substratum Map Unit Setting *Elevation:* 0 to 3,000 feet *Mean annual precipitation:* 32 to 54 inches *Mean annual air temperature:* 43 to 54 degrees F *Frost-free period:* 110 to 240 days **Map Unit Composition** *Udorthents, wet substratum, and similar soils:* 85 percent *Minor components:* 15 percent **Description of Udorthents, Wet Substratum Setting** *Parent material:* Loamy alluvium and/or sandy glaciofluvial deposits and/or loamy glaciolacustrine deposits and/or loamy marine deposits and/or loamy basal till and/or loamy lodgment till **Properties and qualities** *Slope: 0* to 8 percent *Depth to restrictive feature:* More than 80 inches *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None **Minor Components Urban land** *Percent of map unit:* 8 percent *Landform position (two-dimensional):* Footslope *Landform position (three-dimensional):* Base slope *Down-slope shape:* Linear *Across-slope shape:* Linear **Freetown** *Percent of map unit:* 4 percent *Landform:* Bogs, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Concave *Across-slope shape:* Concave **Swansea** *Percent of map unit:* 3 percent *Landform:* Bogs, depressions *Landform position (two-dimensional):* Toeslope *Landform position (three-dimensional):* Dip *Down-slope shape:* Concave *Across-slope shape:* Concave

5.3.2 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 71). 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 71).

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 71), 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.

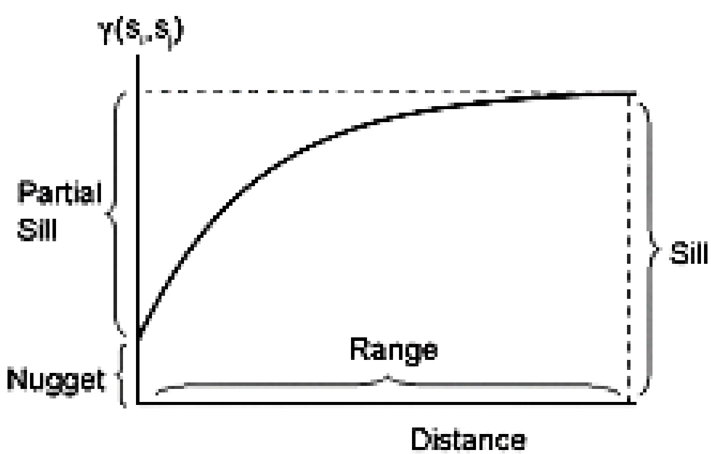


Figure 71. Example semivariogram, depicting range, sill, and nugget.

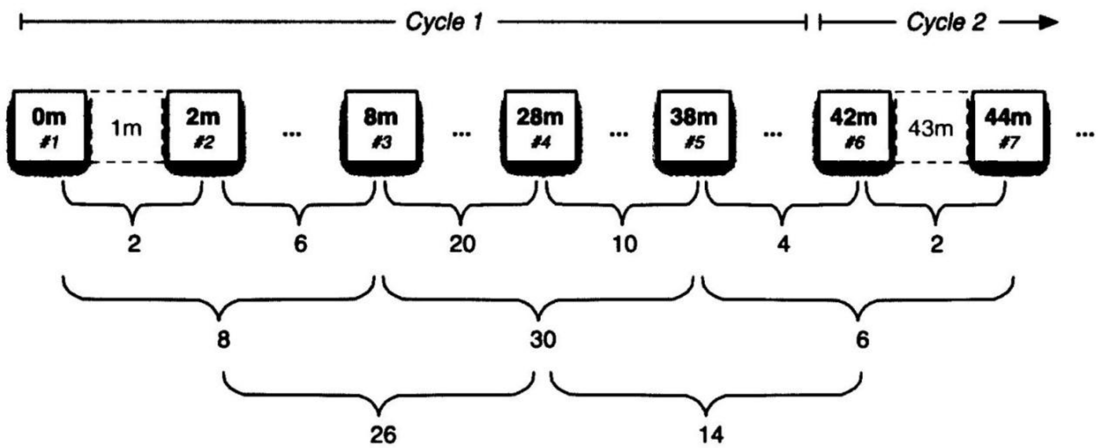


Figure 72. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 7 July 2010 at the Plum Island Subauban Relocatable site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 72). Soil temperature and moisture measurements were collected along three transects (134 m, 84 m, and 84 m) located in the expected airshed at Plum Island Subauban Relocatable site. 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 72, 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).

5.3.3 Results and interpretation

5.3.3.1 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 75). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 75, left graphs) and directional semivariograms do not show anisotropy (Figure 76, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 76, right graph). The model indicates a distance of effective independence of 9 m for soil temperature.

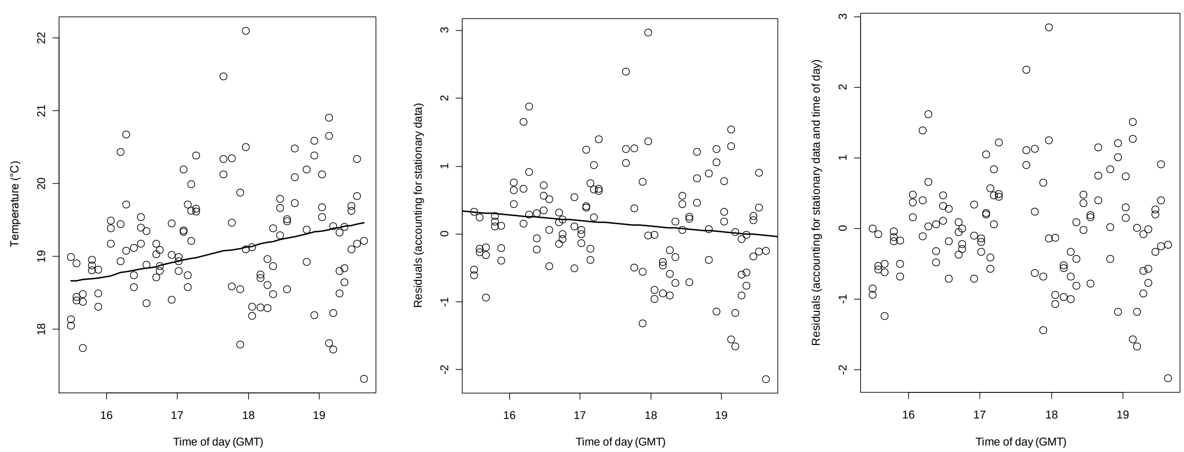


Figure 75. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting for changes temperature in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

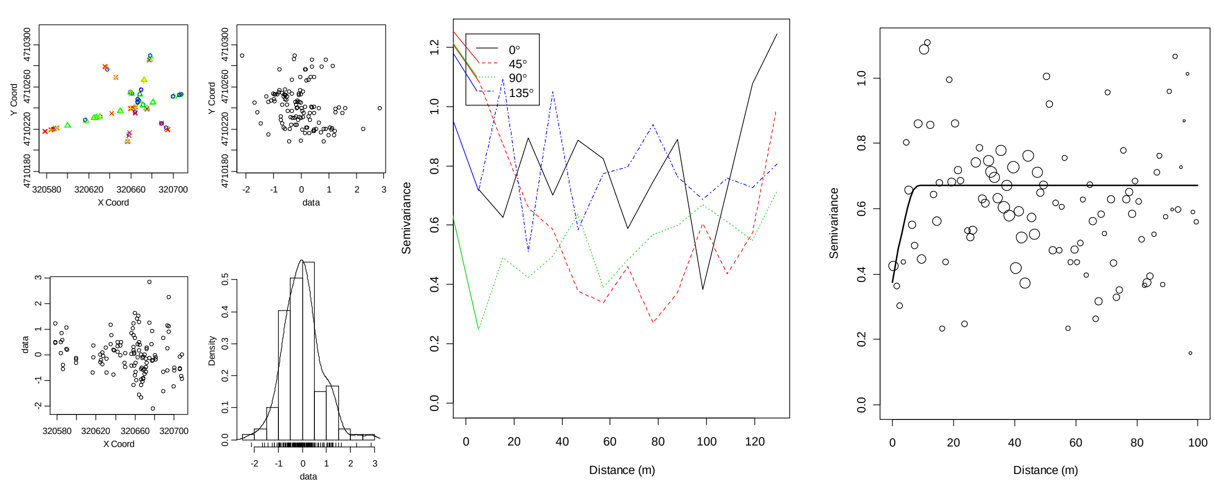


Figure 76. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

5.3.3.2 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 77). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 77, left graph) and directional semivariograms do not show anisotropy (Figure 78, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 78, right graph). The model indicates a distance of effective independence of 10 m for soil water content.

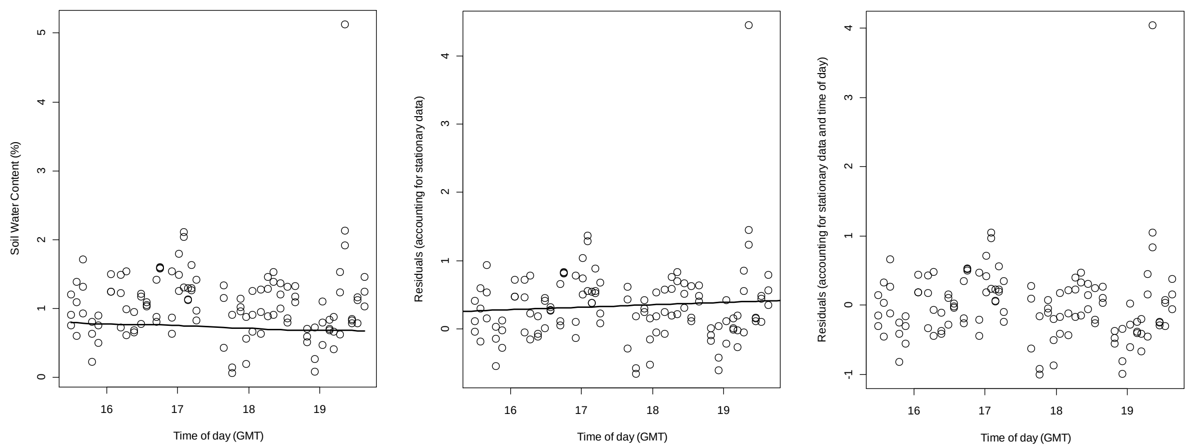


Figure 77. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting 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.

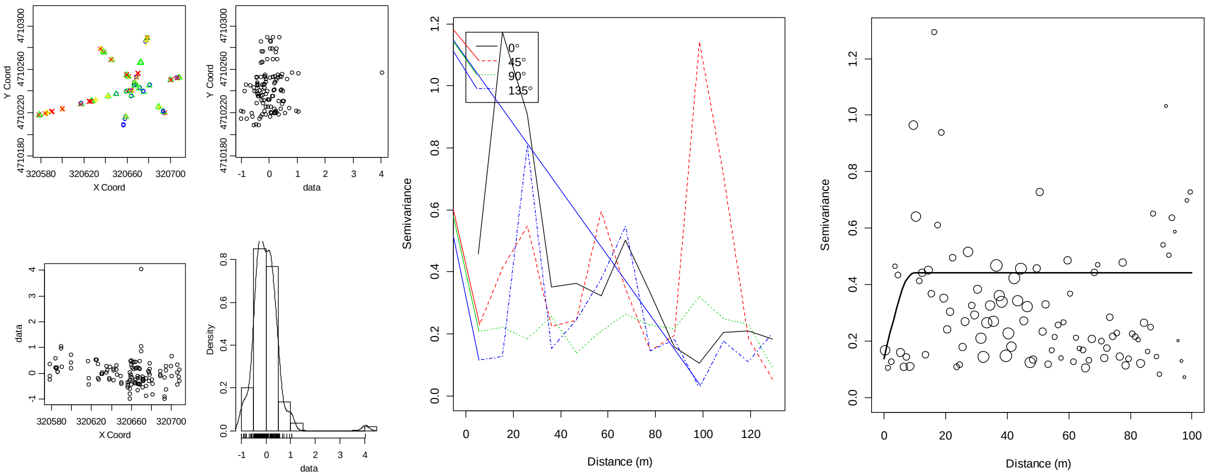


Figure 78. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

5.3.3.3 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 9 m for soil temperature and 10 m for soil moisture. Based on these results and the site design guidelines the soil plots at Plum Island Suburban Relocatable site 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 (Figures 79-80). The direction of the soil array shall be 234° from the soil plot nearest the tower (i.e., first soil plot, Figures 79-80). The location of the first soil plot will be approximately 42.52399°, -71.18307°. 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 42.52431°, -71.18233° (primary location); or 42.52446°, -71.18281° (alternate location 1 if primary location is unsuitable); or 42.52492°, -71.18217° (alternate location 2 if primary location is unsuitable). A summary of the soil information is shown in Table 18 and site layout can be seen in Figure 80.

Dominant soil series at the site: Scituate fine sandy loam, 3 to 8 percent slopes, extremely stony. The taxonomy of this soil is shown below:
Order: Inceptisols
Suborder: Udepts
Great group: Dystrudepts
Subgroup: Oxyaquic Dystrudepts
Family: Coarse-loamy, mixed, active, mesic Oxyaquic Dystrudepts
Series: Scituate fine sandy loam, 3 to 8 percent slopes, extremely stony

Table 19. Summary of soil array and soil pit information at Plum Island Suburban Relocatable site. 0° represents true north and accounts for declination.
All the expected soil depths are used for soil temperature and soil water content measurements. [a] is noted for soil CO_2 measurement depths.

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	16 m
Latitude and longitude of 1st soil plot OR direction from tower	42.52399°, -71.18307°
Direction of soil array	234°
Latitude and longitude of FIU soil pit 1	42.52431°, -71.18233° (primary location)
Latitude and longitude of FIU soil pit 2	42.52446°, -71.18281° (alternate 1)
Latitude and longitude of FIU soil pit 3	42.52492°, -71.18217° (alternate 2)
Dominant soil type	Scituate fine sandy loam, 3 to 8 percent slopes, extremely stony
Expected soil depth	0.46-0.84 m
Depth to water table	0.46-0.61 m

Expected depth of soil horizons	Expected measurement depths
[a] 0-0.20 m (Fine sandy loam)	0.10 m
[a] 0.20-0.51 m (Sandy loam)	0.36 m
0.51-0.69 m (Loamy fine sand)	0.60 m
[a] 0.69-1.65 m (Gravelly loamy sand)	1.17 m

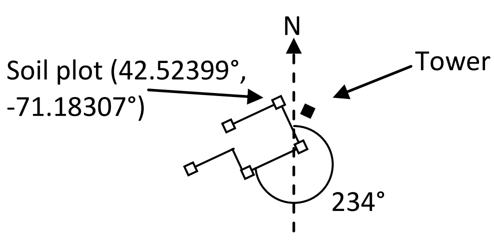


Figure 79. Schematic diagram of soil array layout in relation to tower. Soil plot positions are approximate.

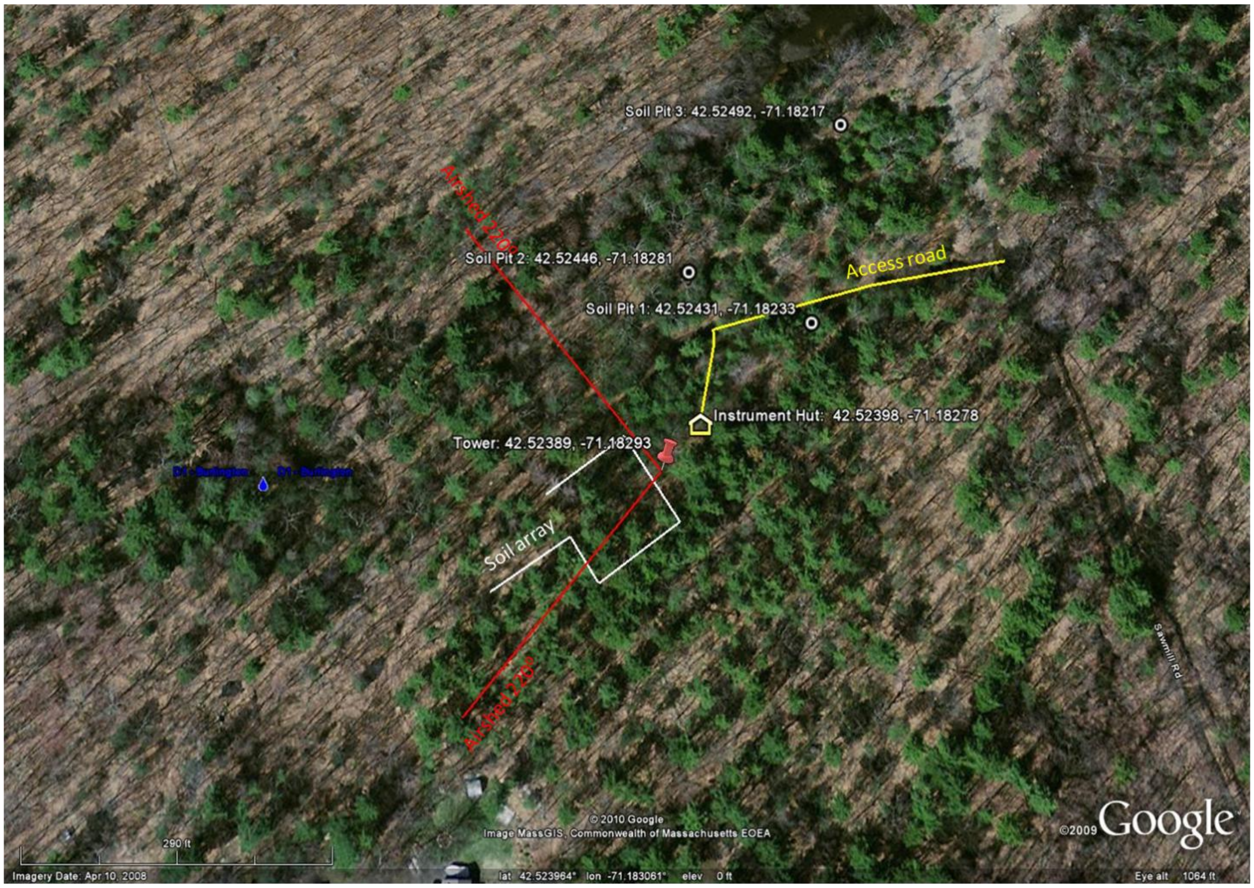


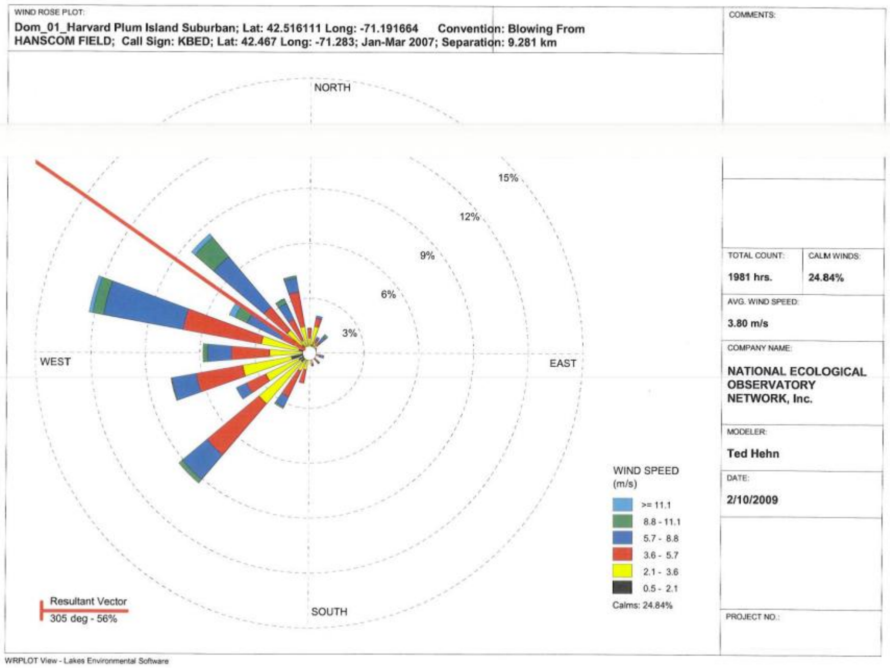
Figure 80. Site layout at Plum Island Suburban Relocatable site showing soil array and location of the FIU soil pits.

5.4 Airshed

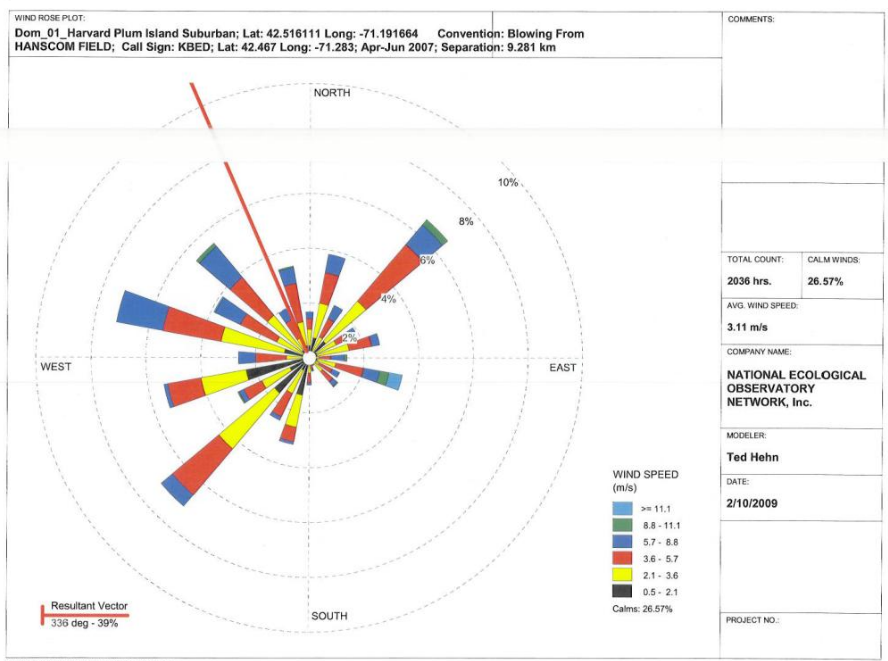
5.4.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries (Figures 56, 57). Data used to generate windroses were 2007 data set from Hanscom AFB airport (42.467^{o}, -71.283^{o}), which is about 10 miles away from NEON Plum Island relocatable tower site (42.52395^{o}, -71.18293^{o}). 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. 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.

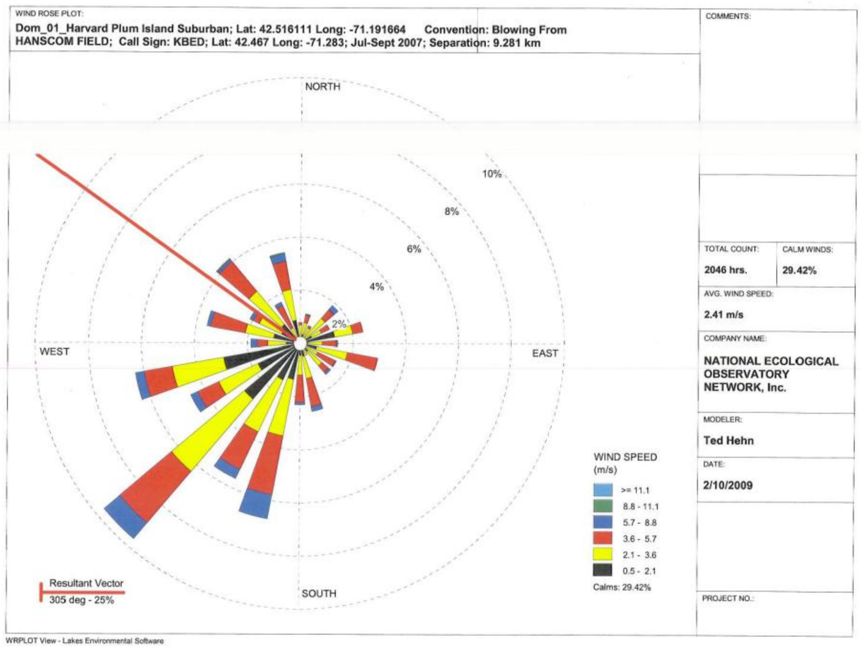
5.4.2 Results (graphs for wind roses)



WIND ROSE PLOT:
Dom_01_Harvard Plum Island Suburban; Lat: 42.516111 Long: -71.191664 Convention: Blowing From
HANSCOM FIELD; Call Sign: KBED; Lat: 42.467 Long: -71.283; Jan-Mar 2007; Separation: 9.281 km
COMMENTS:
NORTH
WEST
EAST
SOUTH
15%
12%
9%
6%
3%
TOTAL COUNT:
1981 hrs.
CALM WINDS:
24.84%
AVG. WIND SPEED:
3.80 m/s
COMPANY NAME:
NATIONAL ECOLOGICAL OBSERVATORY NETWORK, Inc.
MODELER:
Ted Hehn
DATE:
2/10/2009
PROJECT NO.:
WIND SPEED (m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 24.84%
Resultant Vector
305 deg - 56%
WRPLOT View - Lakes Environmental Software



WIND ROSE PLOT:
Dom_01_Harvard Plum Island Suburban; Lat: 42.516111 Long: -71.191664 Convention: Blowing From
HANSCOM FIELD; Call Sign: KBED; Lat: 42.467 Long: -71.283; Apr-Jun 2007; Separation: 9.281 km
COMMENTS:
NORTH
WEST
EAST
SOUTH
10%
8%
6%
4%
2%
TOTAL COUNT:
2036 hrs.
CALM WINDS:
26.57%
AVG. WIND SPEED:
3.11 m/s
COMPANY NAME:
NATIONAL ECOLOGICAL OBSERVATORY NETWORK, Inc.
MODELER:
Ted Hehn
DATE:
2/10/2009
PROJECT NO.:
WIND SPEED (m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 26.57%
Resultant Vector
336 deg - 39%
WRPLOT View - Lakes Environmental Software



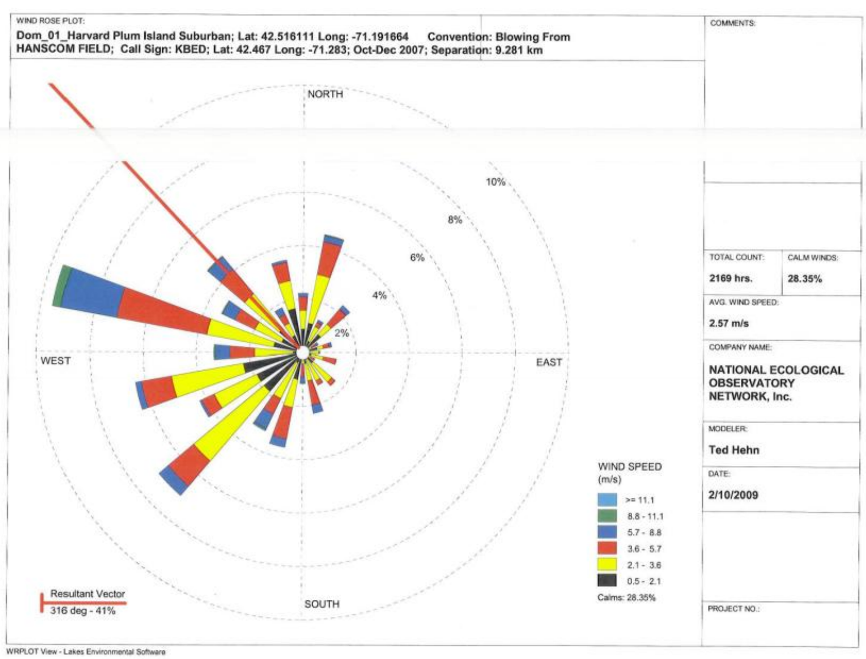


Figure 81. Windroses for Plum Island Relocatable tower site (Burlington MA)
Wind roses based on the data from Hanscom Field airport, Panels (from top to bottom) are from Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

5.4.3 Resultant vectors

Table 20. The resultant wind vectors from Hanscom Field airport using hourly data in 2007.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	305°	56
April to June	336°	34
July to September	305°	25
October to December	316°	41
Annual mean	315.5°	na.

Table 21. The percent duration of winds among cardinal directions, Plum Island Suburban Relocatable site.
3 frequency bins on each side of the cardinal direction were used for this calculation. Data are from Hanscom AFB using hourly data in 2007. Blue text and underline indicates the dominant, winds occurring for the cardinal direction >40% of the time.

Quarterly (seasonal) timeperiod	Cardinal direction			
	North	East	South	West
January to March	22.8°	2.1°	16.1°	59.1°
April to June	27.7°	21.2°	16.6°	33.4°
July to September	14.7°	13.3°	33.2°	38.9°
October to December	22.2°	5.4°	21.4°	40.1°

5.4.4 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, ,we use a web-based footprint model 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 22. Expected environmental controls to parameterize the source area model based on the wind roses for Hanscom AFB airport, and associated results from Plum Island (Burlington) Relocatable tower site.

Parameters	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	
Approximate season	summer			winter			Units
	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	40	40	40	40	40	40	m
Canopy Height	20	20	20	20	20	20	m
Canopy area density	3.6	3.6	3.6	1.4	1.4	1.4	m
Boundary layer depth	2000	2000	2000	2000	2000	2000	m
Expected sensible heat flux	420	420	80	70	70	-5	$W\ m^{-2}$
Air Temperature	24.5	24.5	14.5	5	5	-5	°C
Max. windspeed	8.8	3.4	1.4	8.8	4.8	2.8	$m\ s^{-1}$
Resultant wind vector	225	225	225	285	285	285	degrees
			Results				
(z-d)/L	-0.07	-0.50	-0.72	-0.01	-0.06	0.08	m
d	16	16	16	14	14	14	m
Sigma v	2.80	2.10	1.20	2.60	1.70	1.80	$m^2\ s^{-2}$
Z0	0.89	0.89	0.89	1.40	1.40	1.40	m
u*	1.10	0.60	0.31	1.20	0.70	0.32	$m\ s^{-1}$
Distance source area begins	20	0	0	20	20	30	m
Distance of 90% cumulative flux	983.7	545.2	260.7	900.7	935.4	1020.0	m
Distance of 80% cumulative flux	699.3	331.9	225.2	675.6	701.5	790.0	m
Distance of 70% cumulative flux	308.1	248.9	165.9	533.3	541.5	630.0	m
Distance of 60% cumulative flux	331.9	189.6	118.5	414.8	430.8	530.0	m
Distance of 50% cumulative flux	284.4	154.1	94.8	343.7	356.9	420.0	m

Distance of 40% cumulative flux	237.0	130.4	71.1	284.4	295.4	340.0	m
Distance of 30% cumulative flux	189.6	106.7	---	225.2	233.8	280.0	m
Distance of 20% cumulative flux	165.9	83.0	---	177.8	184.6	220.0	m
Distance of 10% cumulative flux	---	---	---	142.2	147.7	180.0	m
Peak contribution	70	10	20	131	131	337	m

5.4.5 Results (source area graphs)

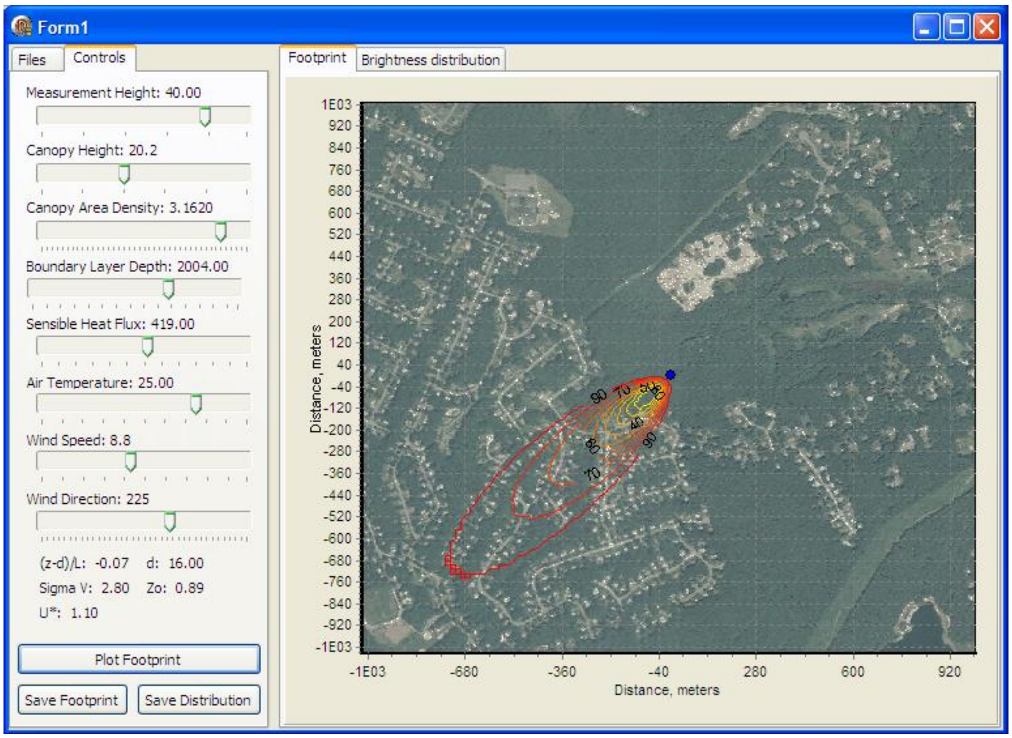


Figure 82. Plum Island Relocatable site summer daytime (convective) footprint output with max wind speed:

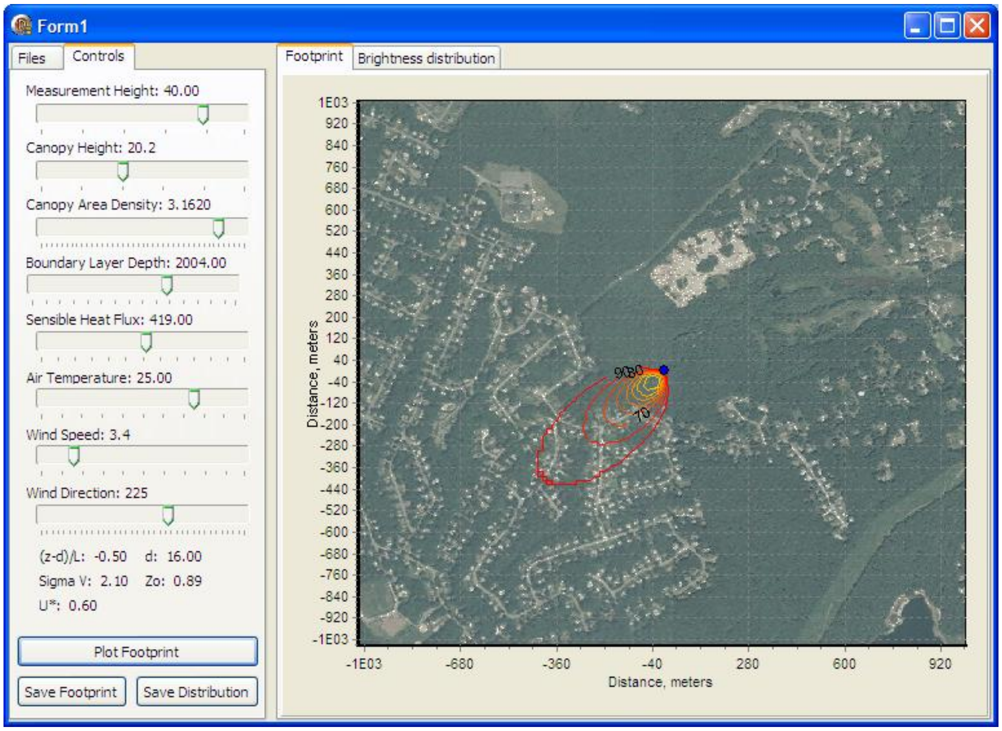


Figure 83. Plum Island Relocatable site summer daytime (convective) footprint output with mean wind speed:

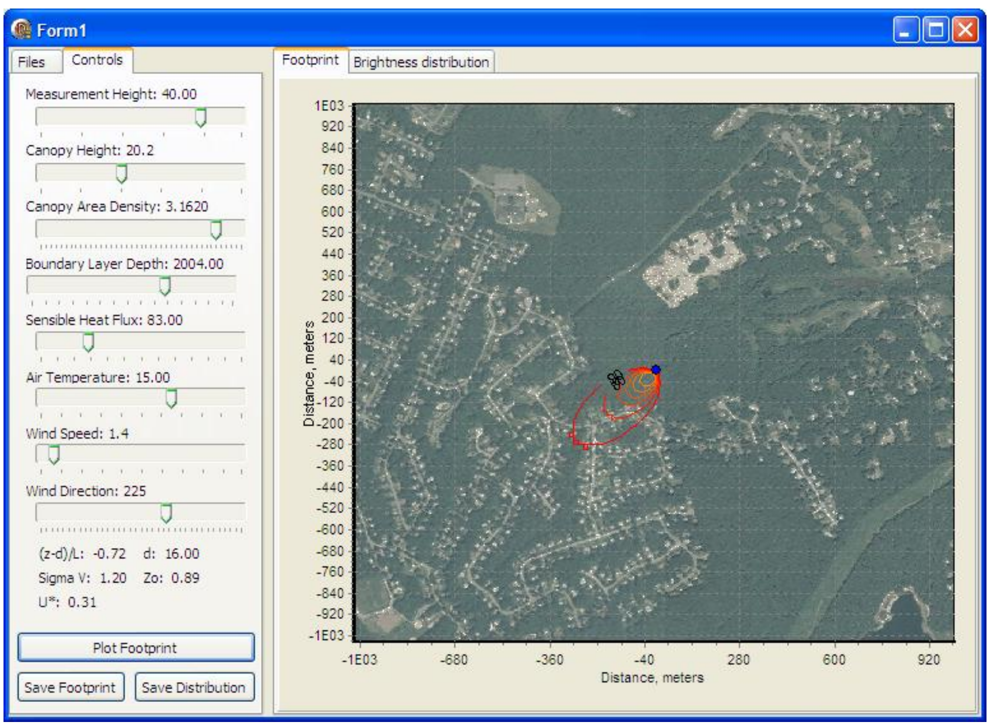


Figure 84. Plum Island Relocatable site summer nighttime (stable) footprint output with mean wind speed.

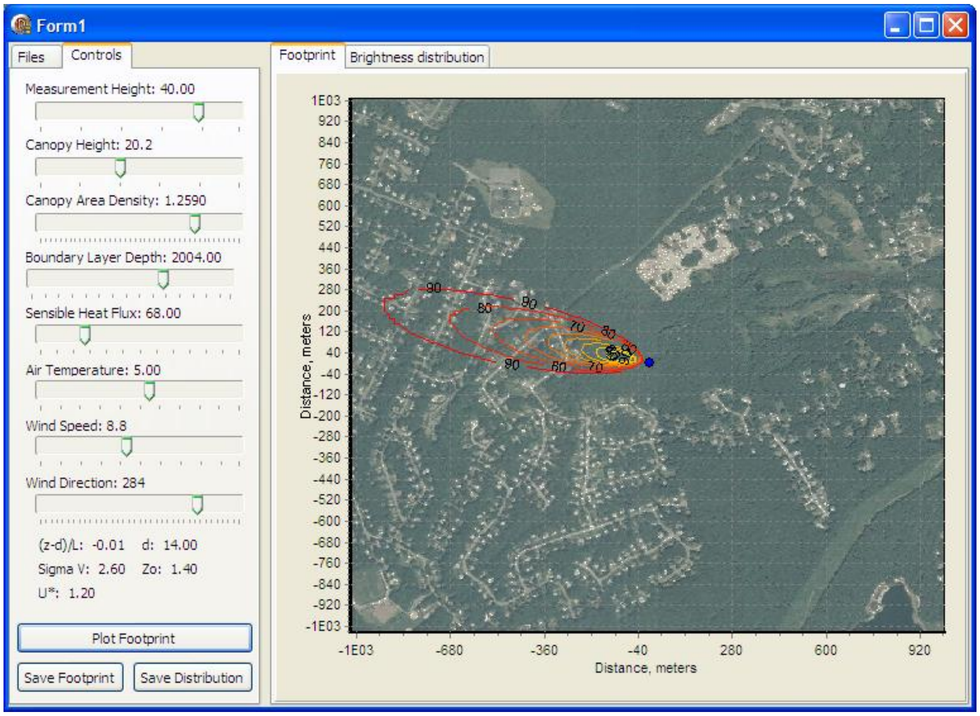


Figure 85. Plum Island Relocatable site winter daytime (convective) footprint output with max wind speed:

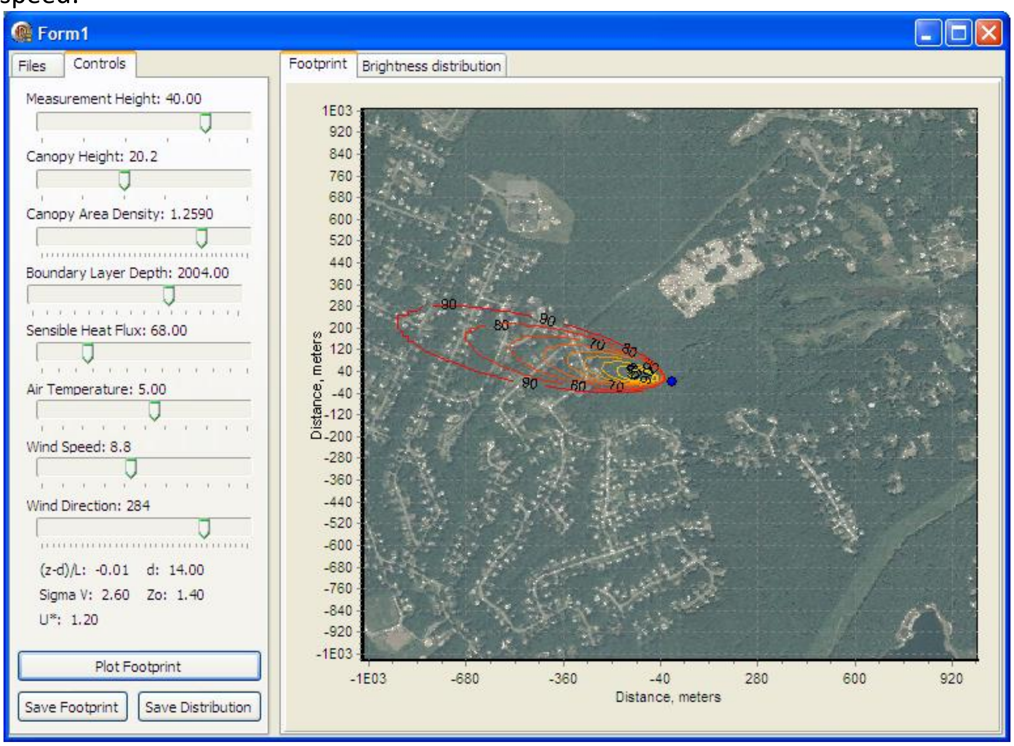


Figure 86. Plum Island Relocatable site winter daytime (convective) footprint output with mean wind speed.

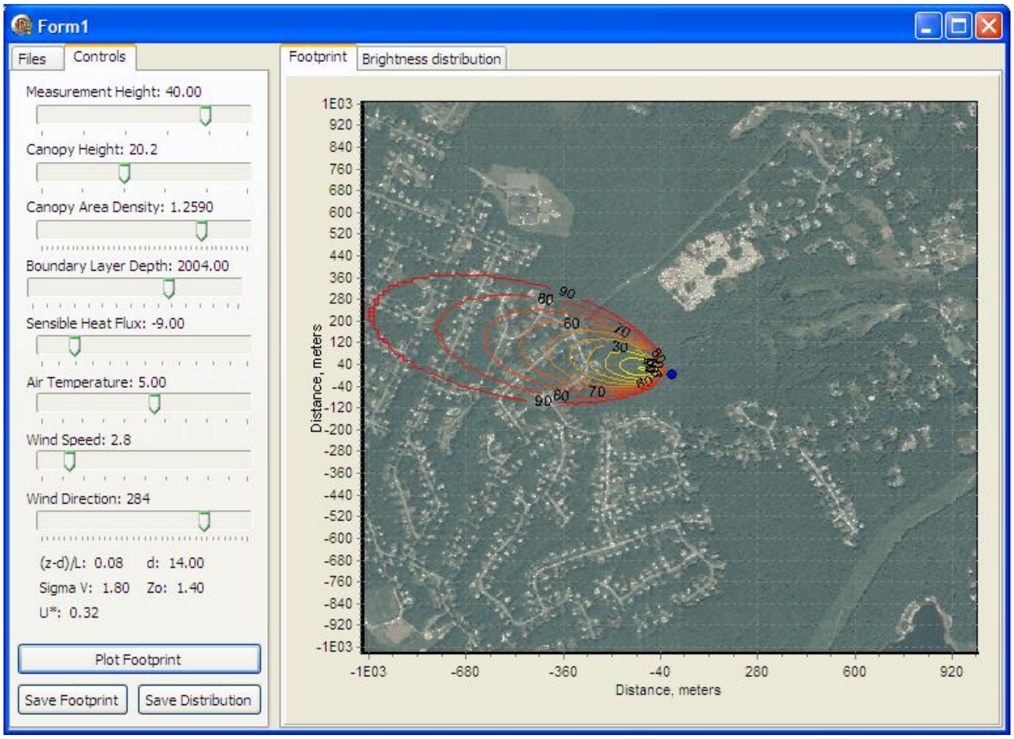


Figure 87. Plum Island Relocatable site winter nighttime (stable) footprint output with mean wind speed.

5.4.6 Acceptance criteria

Micrometeorological theory and the eddy covariance technique were established over uniform vegetative canopies with short roughness lengths on flat terrain and large fetch. The objective is to place a tower in such a way to optimize the amount of time where all the flows (winds) and microclimate with minimal disturbance and secondary filtering. Flow through the tower must be discounted and screened against data quality criteria (FIU V+V doc). Flows that pass through a tower often have to be screened and filtered out of a long-term dataset. If positioning a tower can be positioned on the landscape towards an undesirable land use type or influence on the leeward side of the tower—if it is well known the data will have low quality. Additional concerns and acceptance criteria can be found in the FIU Tower Science requirements, AD 01.

The tower should be sited to maximize the time with winds blowing from the desired land cover type, and with the longest upwind fetch attainable. If the surroundings are not of a uniform cover type, there needs to be some analysis of prevailing winds to demonstrate that the desired sectors are sampled uniformly through time. Consider the extreme example of a site with two different forest types and a consistent daily wind cycle that blew from one forest type and in the day and the other at night. Daily integrated net ecosystem exchange (NEE) in this situation would be un-interpretable. This extreme condition is unlikely, but many sites could have more subtle wind direction biases that need to be examined and considered in data interpretation. All systems are subject to horizontal flux divergence, advective motions, wake effects and drainage of air sheds (FIU Tower Science Requirements). Footprint analyses to determine the source area under different stabilities, wind speeds and direction among seasons provide valuable guidance for appropriate tower placement, documentation of site characteristics, and definition of data acceptance criteria (Foken and Leclerc 2004, Horst and Weil 1992, Horst and Weil 1994a, Horst and Weil 1994b, Horst, 2001, Kormann and Meixner 2001, Schmid and Lloyd 1999, Schmid 1994, Schuepp *et al*. 1990). The criteria for tower placement should not only be concerned with the summer, productive periods, but also the seasonal transitional periods (spring and fall), and winter months when respiration process often dominate.

Micro-topography requires visual inspection. Long wave forms and standing waves are common place over short stature ecosystems small < 10 m topographic relief and high (mechanical turbulent) winds occur (tundra, grasslands, alpine ecosystems). Preliminary data collection may be useful to determine if micro-topographic features affect the local microclimate and flow regimes.

The tower needs to be high enough to place the sensors well above the surrounding canopy, but not so high that the footprint during stable night-time conditions extends beyond the boundary of the ecosystem type of interest.

Other constraints are placed on our ability to locate and position a tower besides available footprint and flow regimes. At some locations, there is a large sensitivity towards viewing the tower above the canopy from houses, scenic over views, or within an urban area. This public concern is particularly prevalent in State and National Parks. A second constraint is the amount of land available for construction. Lastly, there are often nearby land uses or ecosystem types that can contribute undesirable information (fluxes, meteorology) to the tower based measurements. For example, different grazing patterns in a nearby field, large wetlands in the center of the desired footprint, roads that cause line sources of dust or hydrocarbons, or clearcuts that generate conflicting non-local circulations (Loescher *et al*. 2004). All these issues have to be balanced to achieve the scientific requirements.

Windroses were constructed on a seasonal basis where, *i*) the first estimation is the maximum and average seasonal windspeeds, *ii*) the season fractional wind directions, and *iii*) is the resultant wind direction.

Winds are dominant from the NW to the SW for all windrose periods (Figure 81), and supported by the quadrate analyses (Tables 20-21) with an annual resultant wind vector of 315°. There are three general circulation patterns that dominate the wind flows in this region, for much of the year the winds are dominated by the continental high with wind originating over north central US and south central Canada causing western and north-western winds, ii) during late spring and throughout the summer the Bermuda high originates winds occurring from the east, and iii) infrequent winter storm fronts originating from the NE over the northern Atlantic ocean. Because winds from the east and to the north east are less frequent and low velocities, the tower should be on the NE side of the wind measurement booms. Because the winds are evenly distributed in frequency from the N, W and S (Table 20) and SSE during summer and fall, to maximize the data coverage, the boom should be facing toward the West, 270°, close to the annual resultant vector. However, winds do come from the other quadrants during the summer months, due to the convective scales and storm fronts. Because i) there is ample room within the property boundary, ii) the dominant soil type extends towards the west of the tower location, and iii) it is possible to place the soil array within the airshed.

The desired measurements are from a natural area within a mosaic of suburban environment typically found in NE urban settings. Soil mapping units are very inclusive of all the areas In Burlington

Conservation area, Burlington MA, Plum Island LTER, we assume that the fraction of mapped soil associations are representative of the whole, making the co-dominant soil associations being i) Scituate, fine sandy loams, 3 to 8° slopes, extremely stony (>17 % spatially dominant), and ii) Woodbridge-urban land complex, 3 to 15° slopes, Table 12. Based on maps provided by Clapp Historic Mill site (Burlington Conservation area), there seems to be boundary limits where the source area extends beyond the property boundaries. Because flows through the tower have to be examined and potentially removed from the dataset, placing the leeward side of the tower closest to the east optimizes flows over the source area from the west. To maximize the fetch (source area) from the NW and SW in all seasons, the tower location should be placed in the E area of this forest. Because winds from the NW to SW occur during all seasons and the results from the footprint analyses (Figures 82-87) indicate 80 % of the cumulative flux is within 700 m under the most extreme conditions (winter, stable atmosphere, high winds), and as small as 60 m in summer (strongly convective, unstable atmospheres). Because this is a closed canopy ecosystem, the distance between the tower and the instrument hut can be reduced to 15 m.

5.4.7 Site design and tower attributes

Based on the information above, site design and layout are described below.
According to wind roses, the wind direction blows from north, northwest, west and southwest depending on season. The prevailing wind airshed for the tower is from 190° to 20° (clockwise from 190°), but has higher frequency wind from 220° to 320° (clockwise from 220°) throughout the whole year. The tower should be placed to a location to best catch the signals from the airshed of the ecosystem in interest, which is deciduous urban forest (mix of oak, maple, pine and beech). FIU determined that the tower location is 42.52395, -71.18293.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the west 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. An **instrument hut** should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind and should be positioned to have the longer side parallel to frequent wind direction to minimize the wind effects on instrument huts and to minimize the disturbances of wind regime by instrument hut, and in this case, instrument hut should be positioned on the northeast toward tower and have the longer side parallel to W-E direction. Because this is a closed canopy ecosystem, the distance between the tower and the instrument hut can be reduced to ~ 15 m. Therefore, we require the placement of instrument hut at 42.52398, -71.18278.

Canopy height is ~24 m around tower site with lowest branches at ground level. Maple and oak form upper understory, which is ~ 14 m in height. Pine and some deciduous trees form second understory layers, which is ~ 8 m in mean canopy height. Recruitments of maple, oak, pine and beech forms the lower understory with mean height ~ 4 m. Grass and other short vegetation form the lowest understory at ground level with height ~ 0.4 m. We require 6 **measurement layers** on the tower with top measurement height at 34 m, and rest layers are 27 m, 21 m, 12 m, 4 m and 0.2 m, respectively, to best characterize the fluxes on the tower top and environmental conditions in profile.

Secondary **precipitation collector** for bulk precipitation collection will be located the top of tower at this site. No w**et deposition collector** will deployed at this site. See AD 04 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. **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 this case, level 6 being the upper most level at this tower site.

Table 22. Site design and tower attributes for Plum Island Suburban Relocatable site

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

Attribute	lat	long	degree	meters	notes
Airshed			220° to 320°		Clockwise from 220°
Tower location	42.52395,	-71.18293	--	--	new site
Instrument hut	42.52398,	-71.18278			
Instrument hut orientation vector	--	--	90°-270°		
Instrument hut distance z	--	--	--	15	
Anemometer/Temperature boom orientation	--	--	270°	--	
Height of the measurement levels					
Level 1				0.2	m.a.g.l.
Level 2				4.0	m.a.g.l.
Level 3				12.0	m.a.g.l.
Level 4				21.0	m.a.g.l.
Level 5				27.0	m.a.g.l.
Level 6				36.0	m.a.g.l.
Tower Height				36.0	m.a.g.l.

See AD 03 for technical requirement to determine the boom height for the bottom most measurement level.

Figure 88 below shows the proposed tower location, instrument hut location, airshed area and access road.

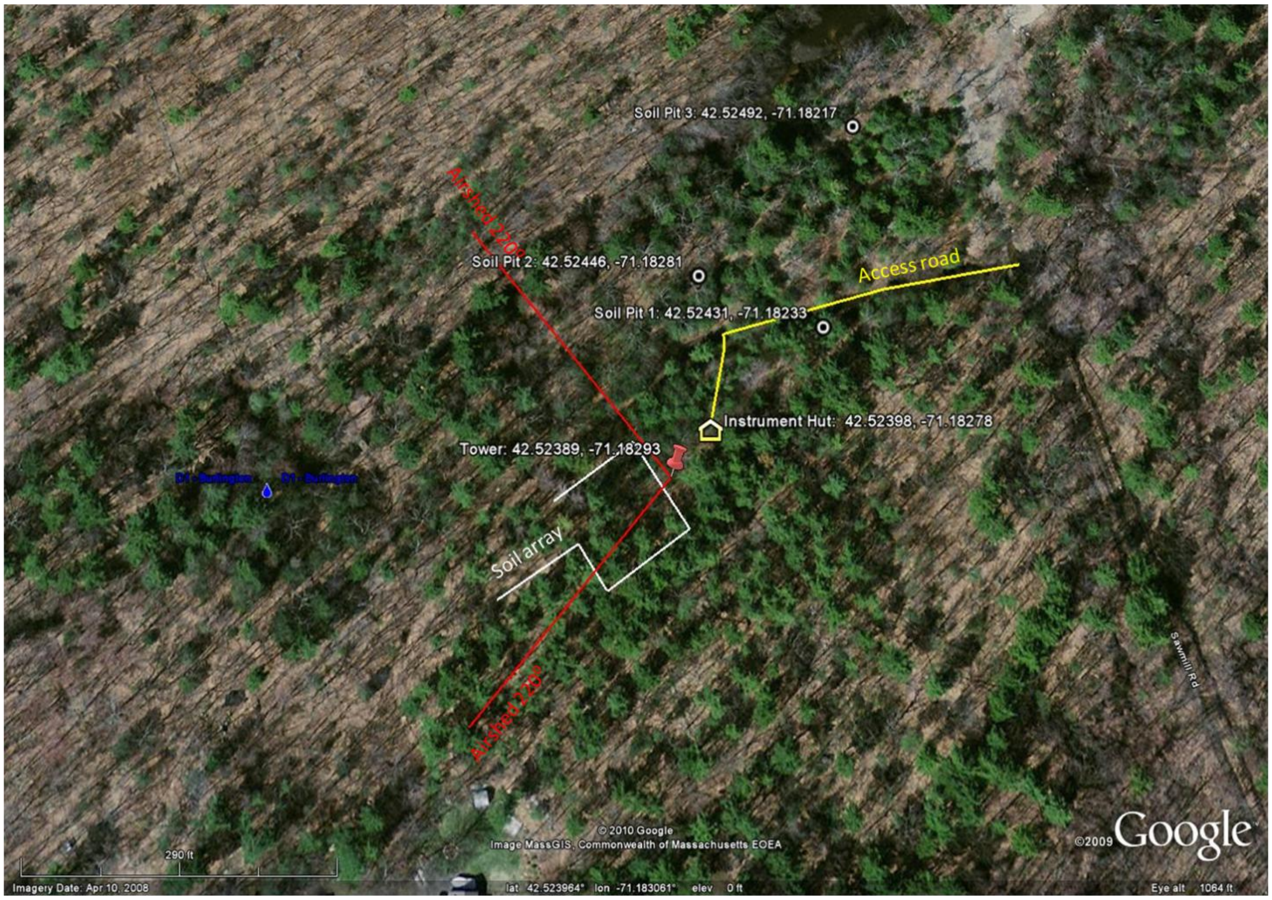


Figure 88. Site layout for Plum Island Suburban Relocatable site.

i) new tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 220° to 320° (clockwise from 220°) would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access road 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-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' 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.

Specific boardwalks at the Plum Island Suburban Relocatable site

- No boardwalk is from the access dirt road 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
- No boardwalk from the soil array boardwalk to the individual soil plots

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

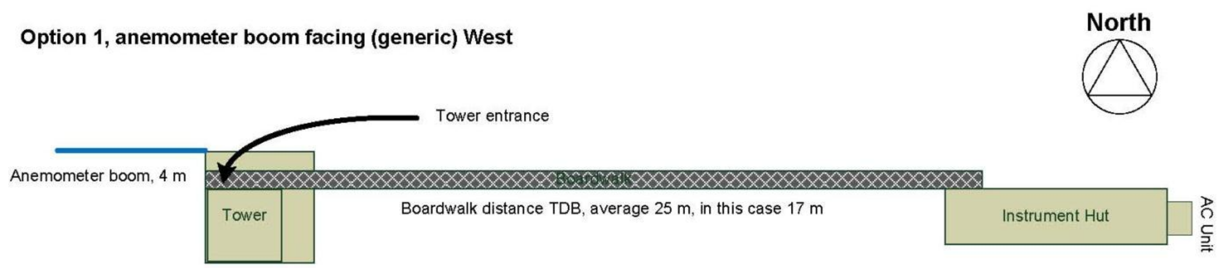


Figure 89. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing west and instrument hut on the east towards the tower.

This is just a generic diagram when boom facing west and instrument hut on the general east (includes northeast and east) towards the tower. The actual design of boardwalk (or path if no boardwalk required) and instrument hut position will be the responsibility of FCC and LAD following FIU's guidelines. At Plum Island Suburban Relocatable site, the boom angle will be 270 degrees, instrument hut will be on the northeast towards the tower, the distance between instrument hut and tower is ~15 m. The instrument hut vector will be E-W (90^o-270^o).

5.4.8 Information for ecosystem productivity plots

The tower at Plum Island Suburban Relocatable site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (hardwood deciduous urban forest). Airshed at this site is from 190^o to 20^o (clockwise from 190^o), but has higher frequency wind from 220^o to 320^o (clockwise from 220^o) throughout the whole year. 90% signals for flux measurements are within a distance of 1000 m from tower, and 80% within 800 m. Therefore, we suggest FSU Ecosystem Productivity plots are placed within the major tower airshed boundaries of 220^o to 320^o (clockwise from 220^o).

5.5 Issues and attentions

Wil Wollheim indicated that security would be an issue at the Plum Island Suburban Relocatable site, since it is an urban conservation area with residential areas within a few hundred meters of the tower site. Fencing around the tower will likely be necessary and possibly around the instrument hut. The currently location of the instrument hut is close to one of the major paths through the conservation area, the tower is approximately 20 m from the path.

The conservation area is small and the tower airshed will likely extend beyond the conservation area into the residential area and beyond.

6 REFERENCES:

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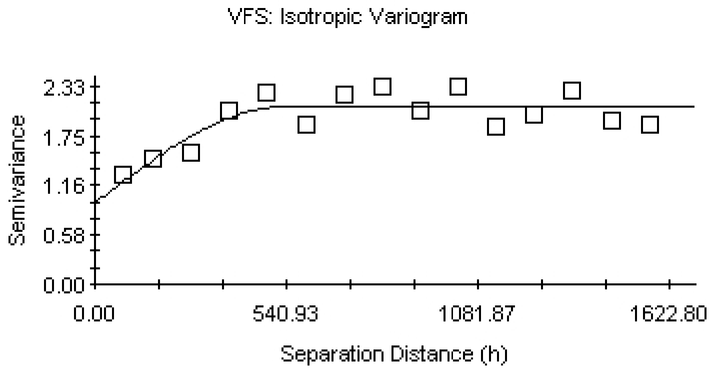
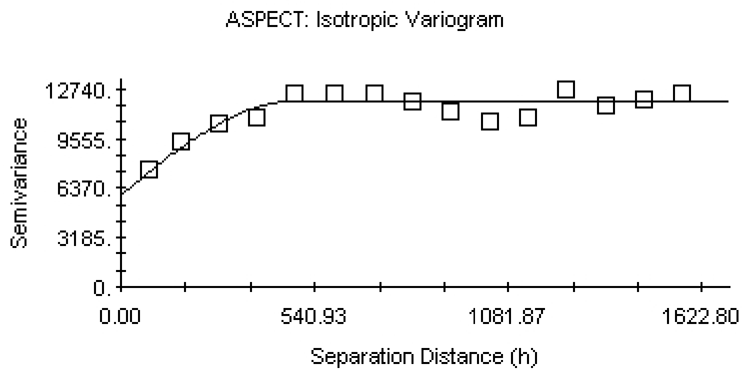
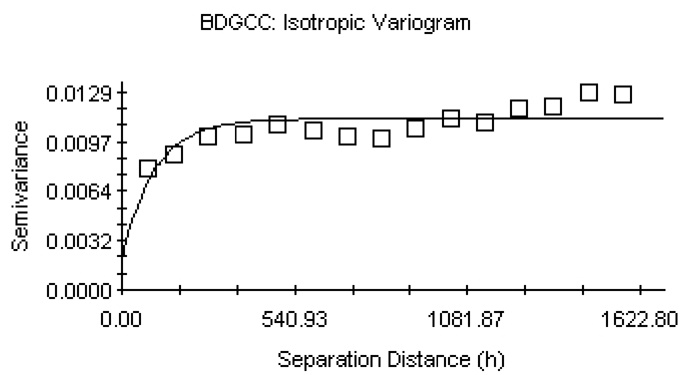
7 APPENDIX A. SEMI-VARIOGRAM RESULTS FROM DR NSALAMBI NKONGOLO.



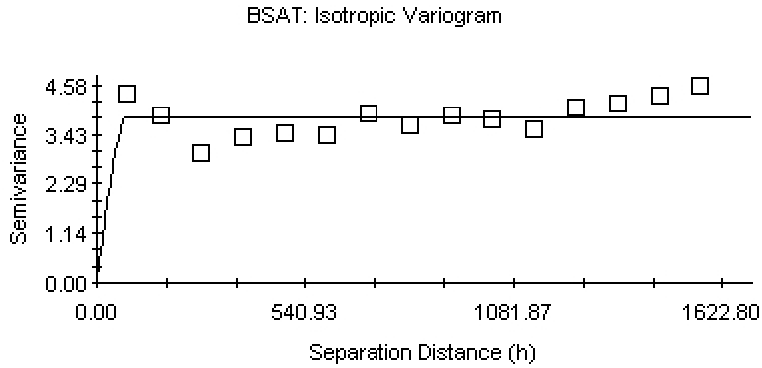
Spherical model (Co = 0.95900; Co + C = 2.09200; Ao = 537.00; r2 = 0.696; RSS = 0.440)



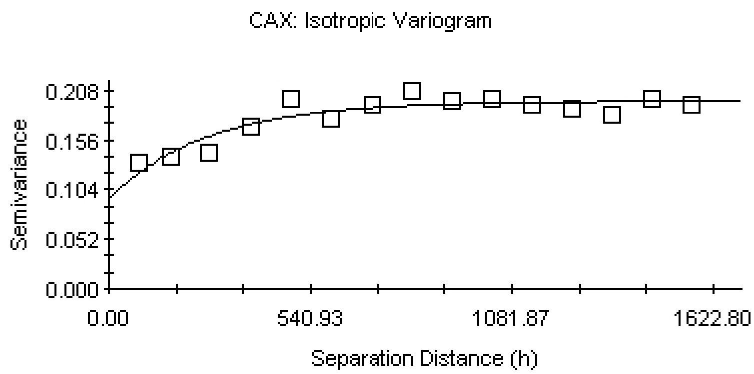
Spherical model (Co = 5970.00000; Co + C = 11950.00000; Ao = 480.00; r2 = 0.800; RSS = 5728355.)



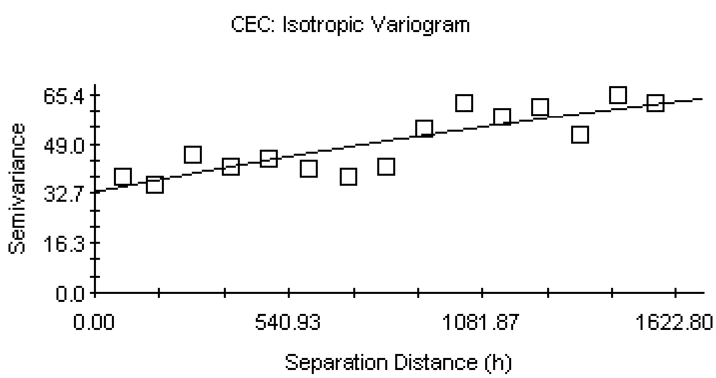
Exponential model (Co = 0.00198; Co + C = 0.01116; Ao = 102.00; r2 = 0.509; RSS = 1.302E-05)



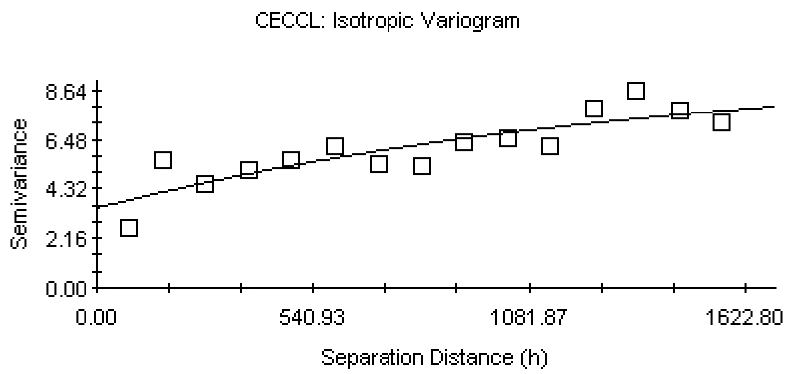
Spherical model (Co = 0.01000; Co + C = 3.83300; Ao = 79.00; r2 = 0.000; RSS = 2.61)



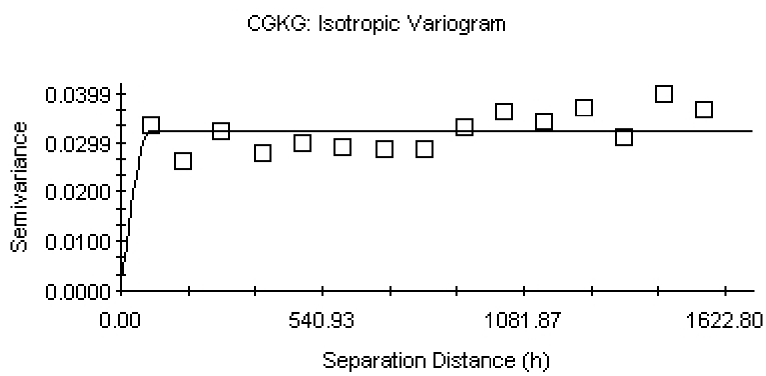
Exponential model (Co = 0.09500; Co + C = 0.19700; Ao = 265.00; r2 = 0.832; RSS = 1.406E-03)



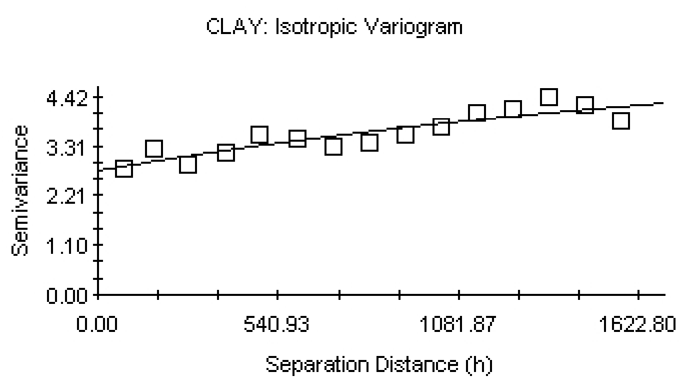
Exponential model (Co = 33.20000; Co + C = 107.40000; Ao = 3152.00; r2 = 0.727; RSS = 414.)



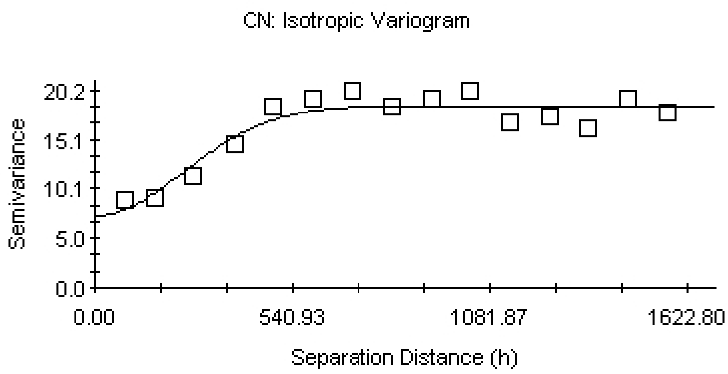
Exponential model (Co = 3.47000; Co + C = 9.82000; Ao = 1399.00; r2 = 0.739; RSS = 8.02)



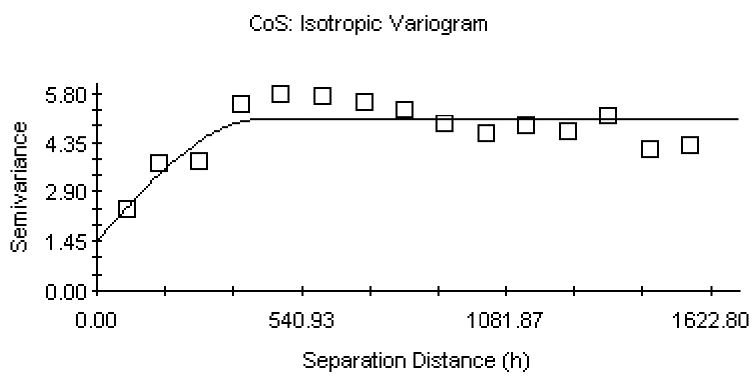
Spherical model (Co = 0.00097; Co + C = 0.03224; Ao = 79.00; r2 = 0.000; RSS = 2.269E-04)



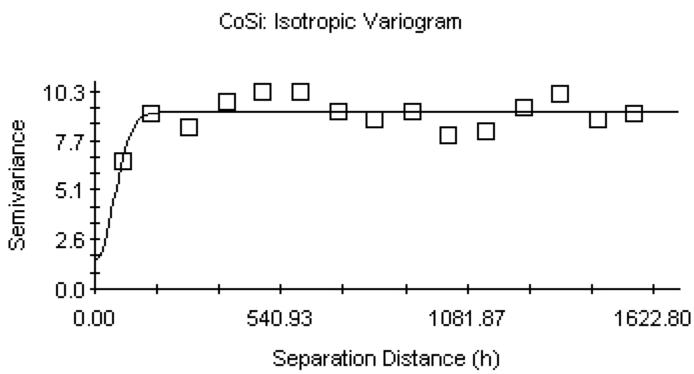
Exponential model (Co = 2.76700; Co + C = 5.53900; Ao = 2151.00; r2 = 0.802; RSS = 0.647)



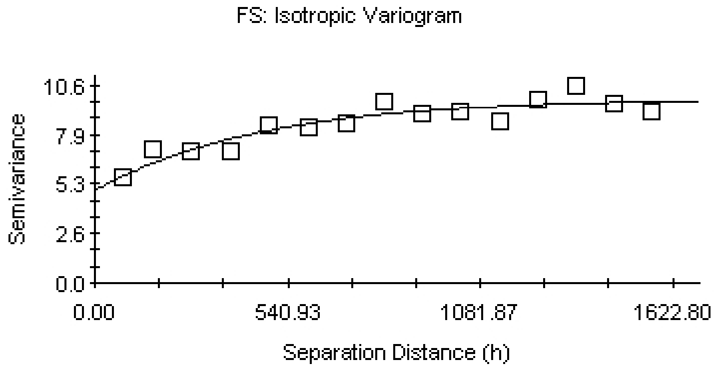
Gaussian model (Co = 7.34000; Co + C = 18.63000; Ao = 342.00; r2 = 0.881; RSS = 23.9)



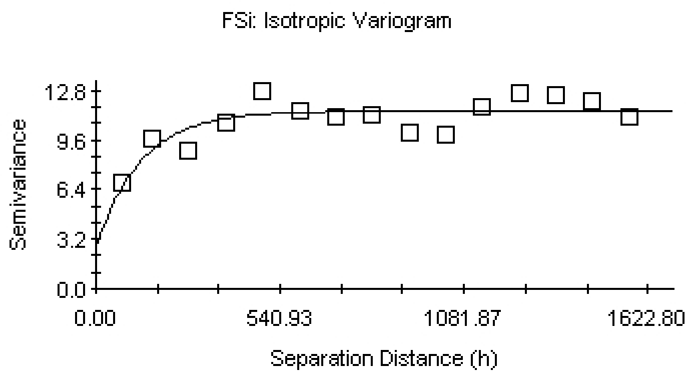
Spherical model (Co = 1.46000; Co + C = 5.02500; Ao = 430.00; r2 = 0.664; RSS = 3.92)



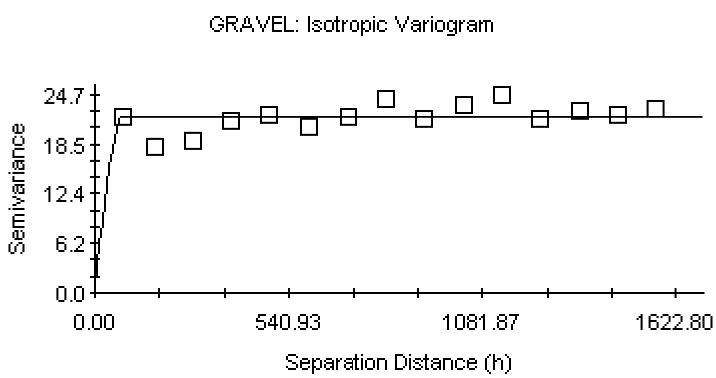
Gaussian model (Co = 1.46000; Co + C = 9.19000; Ao = 76.00; r2 = 0.479; RSS = 6.81)



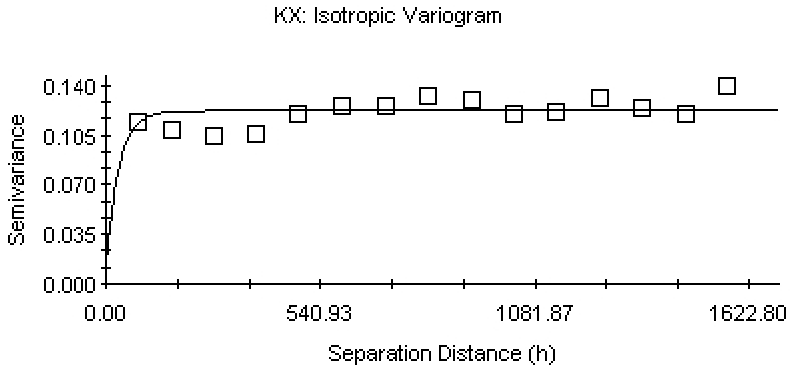
Exponential model (Co = 4.93000; Co + C = 9.87000; Ao = 464.00; r2 = 0.847; RSS = 3.70)



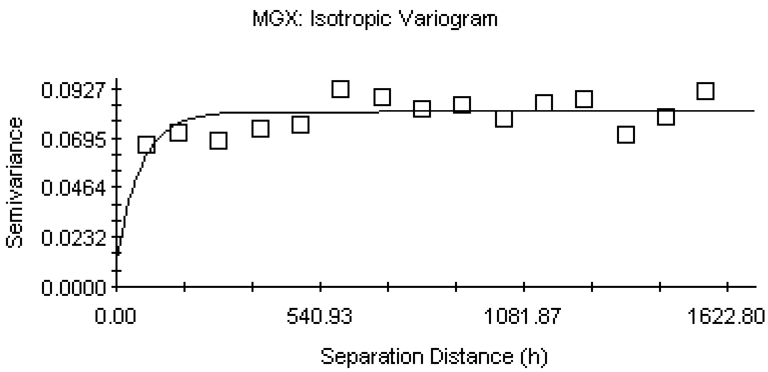
Exponential model (Co = 2.65000; Co + C = 11.53000; Ao = 132.00; r2 = 0.655; RSS = 12.5)



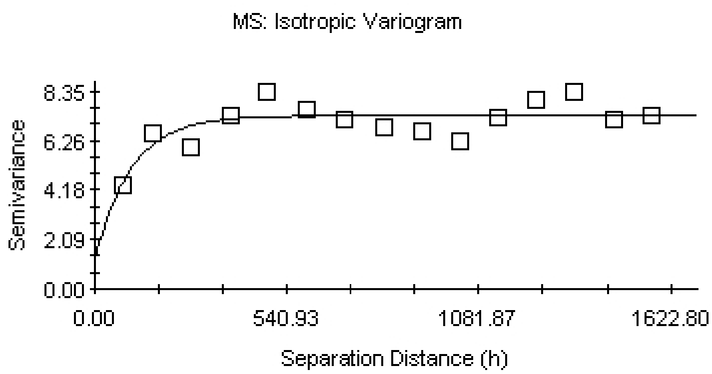
Spherical model (Co = 0.71000; Co + C = 21.94000; Ao = 79.00; r2 = 0.000; RSS = 41.4)



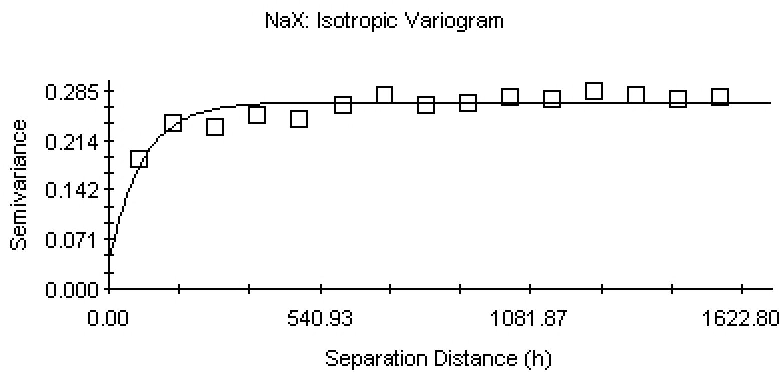
Exponential model (Co = 0.00950; Co + C = 0.12200; Ao = 32.00; r2 = 0.049; RSS = 1.315E-03)



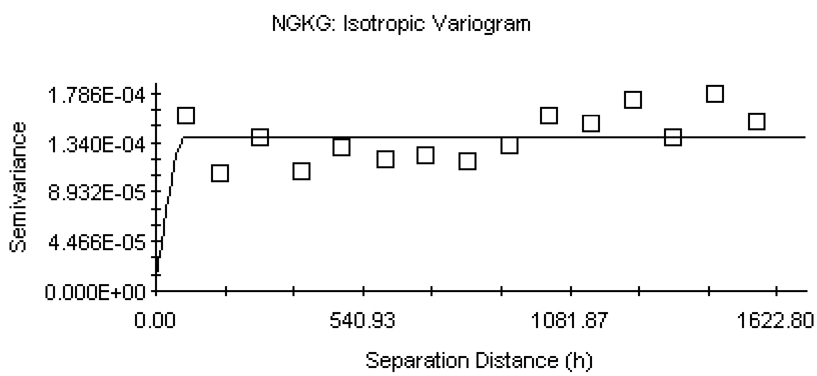
Exponential model (Co = 0.01040; Co + C = 0.08190; Ao = 64.00; r2 = 0.282; RSS = 7.537E-04)



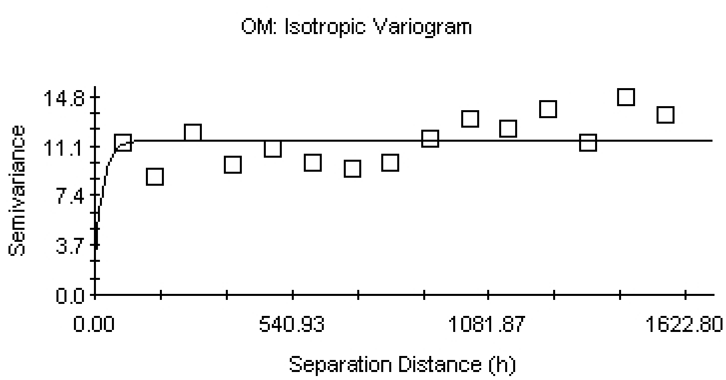
Exponential model (Co = 1.16000; Co + C = 7.31900; Ao = 101.00; r2 = 0.586; RSS = 5.72)



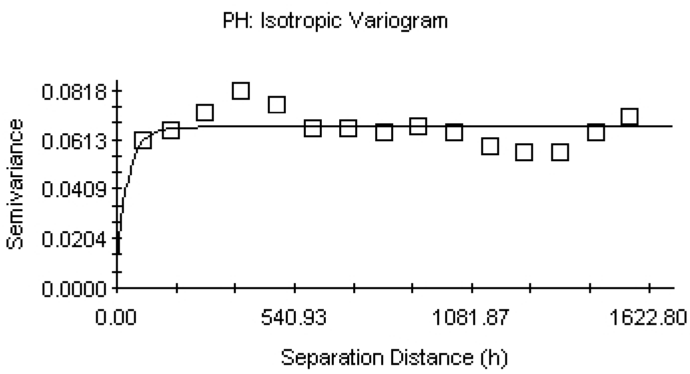
Exponential model (Co = 0.03780; Co + C = 0.26860; Ao = 86.00; r2 = 0.762; RSS = 2.240E-03)



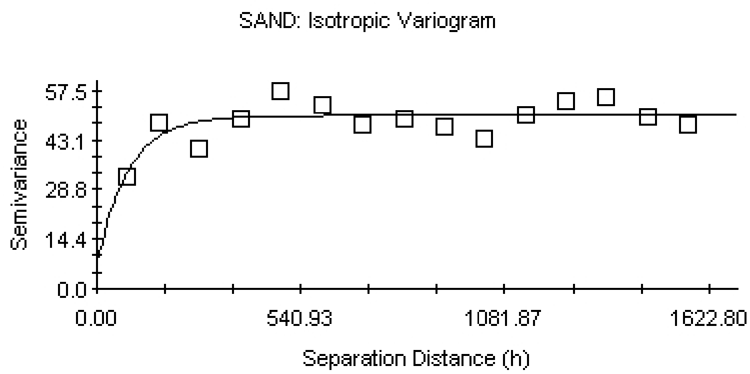
Spherical model (Co = 0.00001; Co + C = 0.00014; Ao = 79.00; r2 = 0.000; RSS = 7.181E-09)



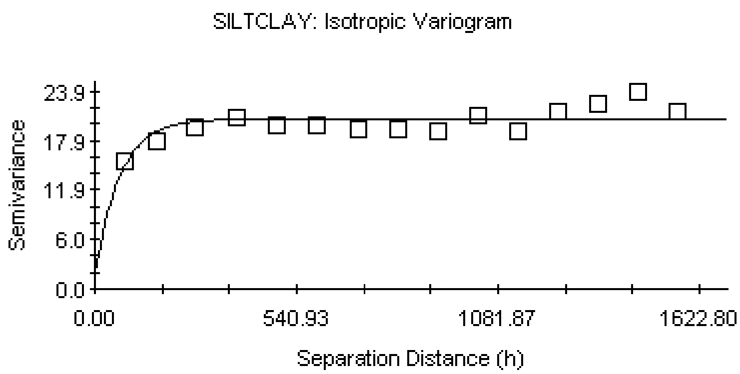
Exponential model (Co = 2.17000; Co + C = 11.53000; Ao = 24.00; r2 = 0.001; RSS = 44.8)



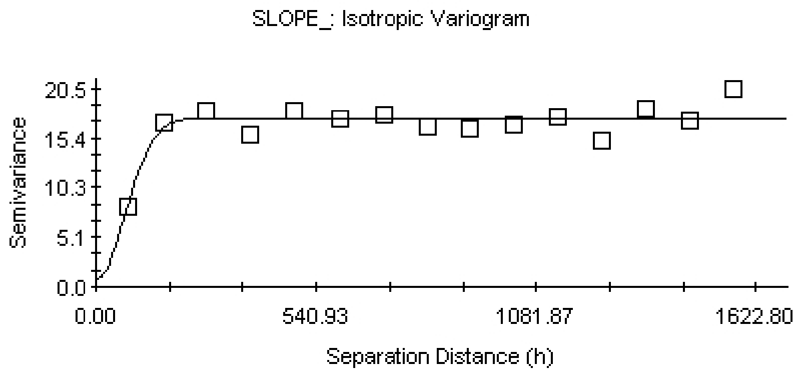
Exponential model (Co = 0.00910; Co + C = 0.06650; Ao = 35.00; r2 = 0.045; RSS = 6.607E-04)



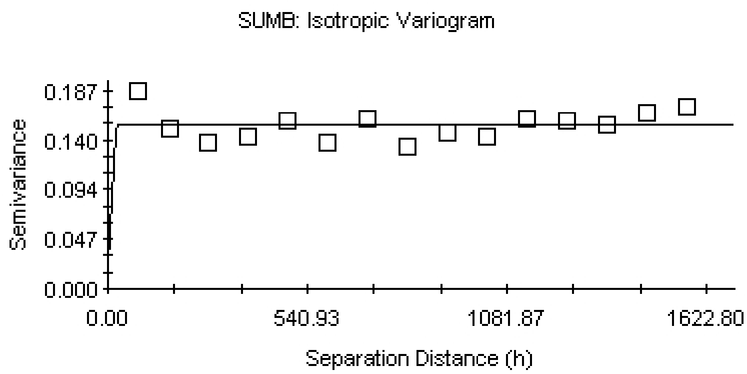
Exponential model (Co = 6.90000; Co + C = 50.26000; Ao = 84.00; r2 = 0.514; RSS = 267.)



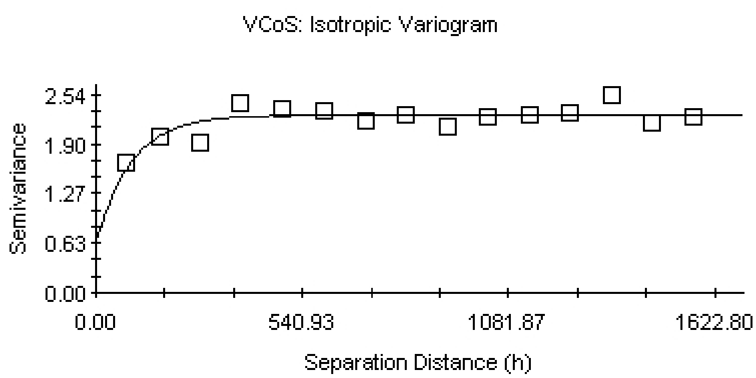
Exponential model (Co = 1.40000; Co + C = 20.52000; Ao = 66.00; r2 = 0.498; RSS = 27.7)



Gaussian model (Co = 0.74000; Co + C = 17.44000; Ao = 100.00; r2 = 0.776; RSS = 22.4)

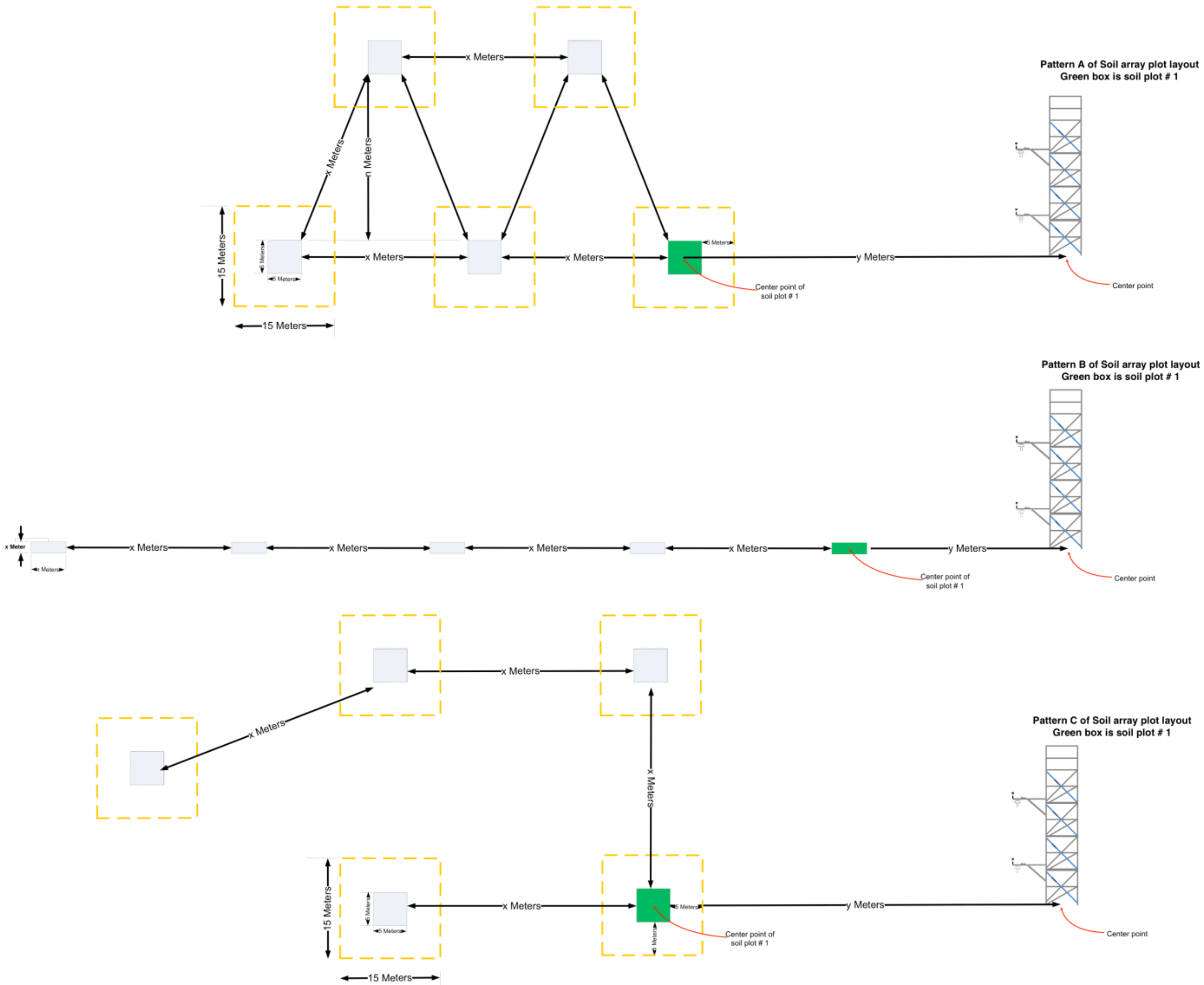


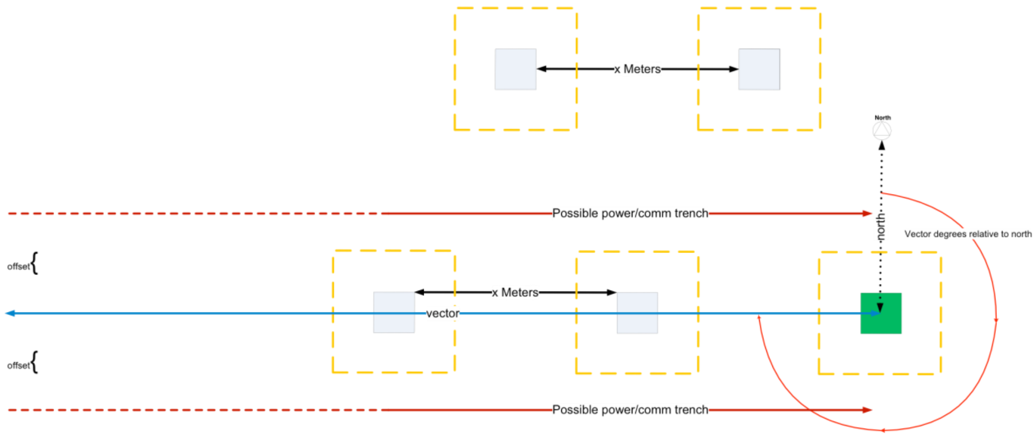
Gaussian model (Co = 0.01790; Co + C = 0.15480; Ao = 12.00; r2 = 0.000; RSS = 2.856E-03)



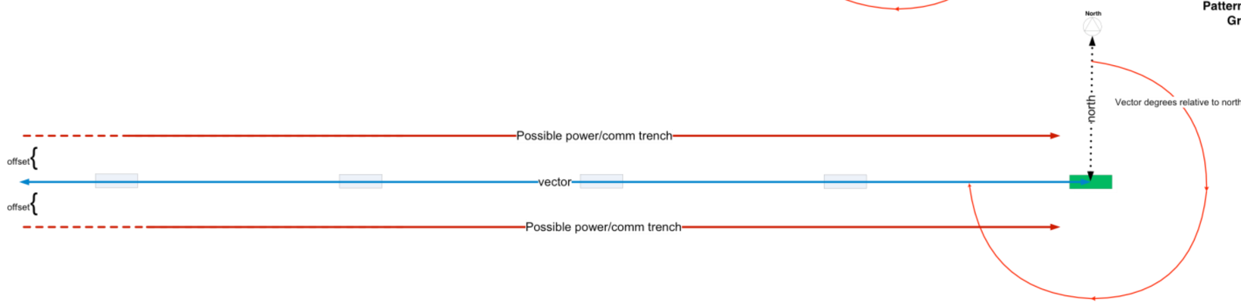
Exponential model (Co = 0.63100; Co + C = 2.28000; Ao = 93.00; r2 = 0.642; RSS = 0.240)

8 APPENDIX B. OPTIONAL SOIL ARRAY PATTERNS.

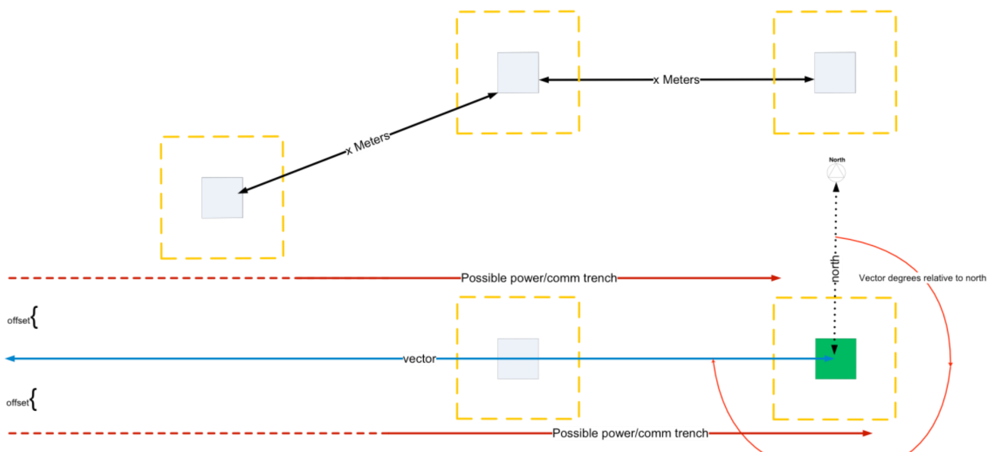




Pattern A of Soil array plot layout
Green box is soil plot # 1



Pattern B of Soil array plot layout
Green box is soil plot # 1



Pattern C of Soil array plot layout
Green box is soil plot # 1