D16 FIU Site Characterization
Supporting Data

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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 16. This document presents all the supporting data for FIU site characterization at D16.

1.2 Scope

FIU site characterization data and analysis results presented in this document are for the three D16 tower locations: Wind River Experimental Forest (Advanced), Thayer (Relocatable 1) and Abby Road 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 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 WIND RIVER EXPERIMENTAL FOREST (ADVANCED TOWER SITE)

3.1 Site description

NEON tower site at Wind River located at 45.820488, -121.951912 (45° 49' 13.7562", -121° 57' 6.8826").

The site is located in the Wind River valley of the southern Washington Cascade Range, approximately 75 km east of Portland, Oregon, near Carson, Washington. The Wind River old-growth forest, in the southern Cascade Range of Washington State, is a cool (average annual temperature, 8.7"C), moist (average annual precipitation, 2223 mm), 500-year-old Douglas-fir-westem hemlock forest of moderate to low productivity at 371 m elevation on a less than 10% slope. There is a seasonal snowpack (November- March), and rain-on-snow and freezing-rain events are common in winter. Local geology is characterized by volcanic rocks and deposits of Micocene/Oligocene Micocene-Oligocene (mixed) Micocene and Quaternary age, as well as intrusive rocks of Miocene age. Soils are medial, mesic, Entic Vitrands that are deep (2-3 m), well drained, loams and silt loams, generally stone free, and derived from volcanic tephra. The vegetation is transitional, between the Western Hemlock Zone and the Pacific Silver Fir Zone, and the understory is dominated by vine maple, salal, and Oregon grape. Stand structural parameters have been measured on a 4-ha plot. There are eight species of conifers, with a stand density of 427 trees ha^{-1} and basal area of 82.9 m2 ha^{-1}. Dominant conifers include Douglas-fir (3 5 trees ha^{-1}), western hemlock (224 trees ha^{-1}), Pacific Pacific yew (86 trees ha^{-1}), western red cedar (30 trees ha^{-1}), and Pacific silver fir (47 trees ha^{-1}). The average height of Douglas-fir is 52.0 m (tallest tree, 64.6 m), whereas western hemlock averages 19.0 m (tallest tree, 55.7 m). The regional disturbance regime is dominated by high-severity to moderate severity fire, from which this forest is thought to have originated. There is no evidence that fire has occurred in the forest after establishment. Primary agents of stand disturbance, which act at the individual to small groups of trees scale, are wind, snow loads, and drought, in combination and interacting with root-rot and butt-rot fungi, heart-rot fungi, dwarf mistletoe, and bark beetles. The forest composition is slowly shifting from dominance by Douglas-fir, a shade-intolerant species, to western hemlock, western red cedar, Pacific yew, and Pacific silver fir, all shade-tolerant species. The Wind River old-growth forest fits the regional definition of Douglas-fir "old growth" on western hemlock sites (info source: from “*Ecological Setting of the Wind River Old-growth Forest” by* Shaw *et al. (2004)* at http://www.fs.fed.us/pnw/pubs/journals/pnw_2004_shaw001.pdf).

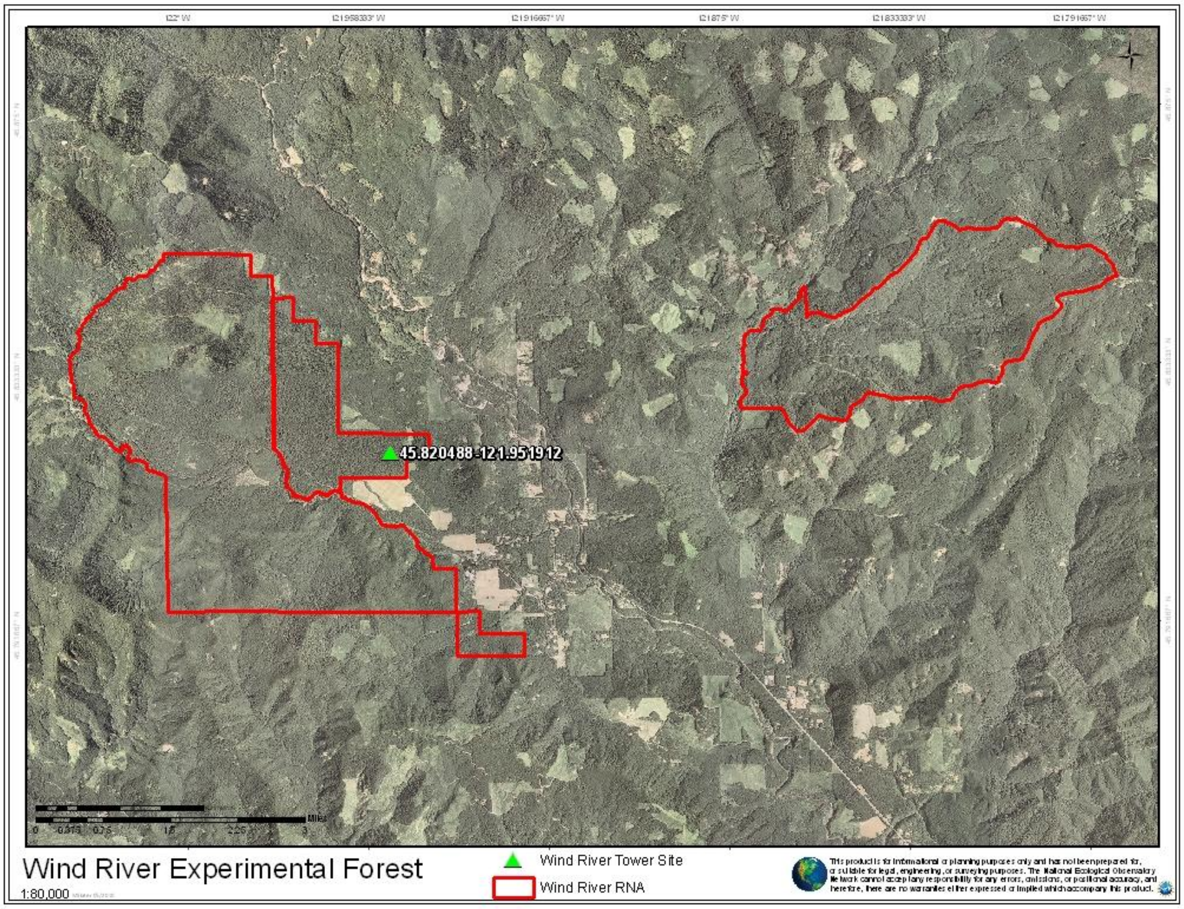


Figure 1. NEON candidate site tower location and boundary map.

3.2 Ecosystem

The following forest and understory information is from "*Ecological Setting of the Wind River Old-growth Forest" by* D. C. Shaw *et al. (2004;* http://www.fs.fed.us/pnw/pubs/journals/pnw_2004_shaw001.pdf):

Forest characterization: The wind River old-growth forest has eight coniferous species, including Douglas-fir, western hemlock, western red cedar (Thuja plicata), Pacific yew (Taxus brevijolia), Pacific silver fir, noble fir (Abies procera), grand fir (Abies grandis), western white pine (Pinus monticola), and two small stature angiosperms, cascara (Rharnnus purshiana) and Pacific dogwood (Cornus nuttallii). Red alder (Alnus rubra) occurs in some canopy gaps along the ephemeral stream. Here, the 1999 basal area of conifers is 82.9 m2 ha^{-1}, falling in the midrange (50-129 m^2 ha^{-1}) of 450- to 500-year-old stands reported by Franklin and Waring (1980) in the Pacific Northwest. Average density of all trees is 427 stems ha^{-1}. The majority of trees are western hemlock (224.0 trees ha^{-1}); however, Douglas-fir is the dominant species with respect to basal area (35.4 m^2 ha^{-1}), followed by western hemlock (26.9 m^2 ha^{-1}) and western red cedar (16.5 m^2 ha^{-1}). Average height of Douglas-fir is 52.0 m, with the tallest tree being

64.6 m, much less than the maximum heights of Douglas-fir, which often reach 70-80 m in more favorable sites (Franklin and Waring 1980). Western hemlock height averages 19.0 m, with the tallest tree being 55.4 m. This is in the range of maximum attainable heights (50-65 m) reported by Franklin and Waring (1980). The vertical structure of the forest is described in detail by Parker and colleagues (2004). The height and diameter distribution of Douglas-fir indicate a classic shade-intolerant cohort of trees that are not being replaced by reproduction. Western hemlock, western red cedar, Pacific yew, and Pacific silver fir are shade tolerant and reproducing well.

Understory vegetation: A total of seven plant associations were keyed from the 64 subplots using a report by Topik and colleagues (1986). These include, from wet-site to dry-site indicators, Western Hemlock1 Lady Fern (*Athyrium Jlk-femina*) (two subplots), Western Hemlock/Foamflower (*Tiarella frqoliata*) (four subplots), Western HemlockJAlaska Huckleberry (*Vaccinium a1askaense*)-salal (two subplots), Western HemlocklVanilla Leaf (2 3 subplots), Western Hemlock/Oregon Grape (two subplots), Western Hemlock/Oregon Grape-Salal (20 subplots), and Western HemlocklSalal (1 1 subplots). This diversity of habitat types at the subplot level reflects the diversity of microhabitat across the site. The wetter north and northeast portions of the plot keyed to wetter plant associations characterized by lady fern, foamflower, and vanilla leaf. The uphill portion of the plot is characterized by salal and Oregon grape.

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

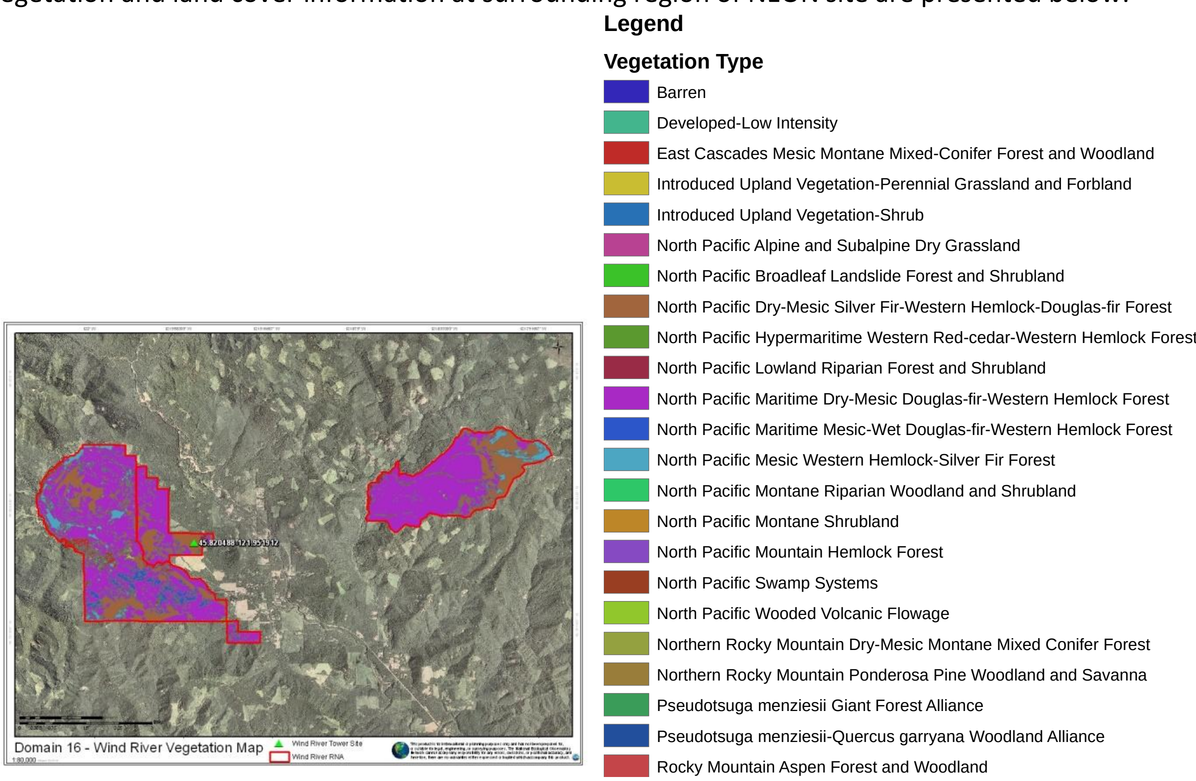


Figure 2. Vegetative cover map of Wind River tower site and surrounding areas (information is from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm).

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

Veg_Type	Area_km2	Percentage
Barren	0.006	0.015
Developed-Low Intensity	0.019	0.046
East Cascades Mesic Montane Mixed-Conifer Forest and Woodland	0.626	1.536
Introduced Upland Vegetation-Perennial Grassland and Forbland	0.075	0.183
Introduced Upland Vegetation-Shrub	0.001	0.001
North Pacific Alpine and Subalpine Dry Grassland	0.001	0.002
North Pacific Broadleaf Landslide Forest and Shrubland	0.126	0.310
North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest	7.902	19.384
North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest	0.157	0.385
North Pacific Lowland Riparian Forest and Shrubland	0.620	1.522
North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest	26.084	63.982
North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	1.777	4.360
North Pacific Mesic Western Hemlock-Silver Fir Forest	2.202	5.401
North Pacific Montane Riparian Woodland and Shrubland	0.140	0.343
North Pacific Montane Shrubland	0.007	0.018
North Pacific Mountain Hemlock Forest	0.001	0.002
North Pacific Swamp Systems	0.720	1.765
North Pacific Wooded Volcanic Flowage	0.004	0.009
Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	0.109	0.266
Northern Rocky Mountain Ponderosa Pine Woodland and Savanna	0.000	0.001
Pseudotsuga menziesii Giant Forest Alliance	0.017	0.043
Pseudotsuga menziesii-Quercus garryana Woodland Alliance	0.020	0.050
Rocky Mountain Aspen Forest and Woodland	0.153	0.376
Area_Total	**40.767**	**100**

According to the FIU field survey, the dominated tree species around tower location and in the airshed are Douglas fir, hemlock and yew. Average tree height is ~50 m. Lowest branch is between 9-15 m. These large trees are spaced 10-20 m apart. Tree trunks are covered by mosses, which indicates high humidity environment year round. Maples and some other small trees forms understory with height ~ 8 m. Understory is fairly open, except for the clearings that were created by the tree fallen. Vegetation on forest floor is ~ 0.3 m tall.

Figure 3. Ecosystem at the Wind River site.

Table 2. Ecosystem and site attributes for Wind River Advanced tower site.

Ecosystem attributes	Measure and units
Mean canopy height	50 m
Surface roughness[a]	6 m
Zero place displacement height[a]	38 m
Structural elements	Tall old-growth conifer forest
Time zone	Pacific time zone
Magnetic declination	16° 14' E changing by 0° 9' W/year

Note, [a] From field observation.

3.3 Soils

3.3.1 Soil description

NRCS soil map and data were not available for the Wind River site, but did cover some of the surrounding area. According to Shaw et al. (2004) the soil surrounding the canopy crane at Wind River belongs to the Stabler series.

Soil data and soil maps below for the Wind River site were collected from 10.5 km^2 NRCS soil maps (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

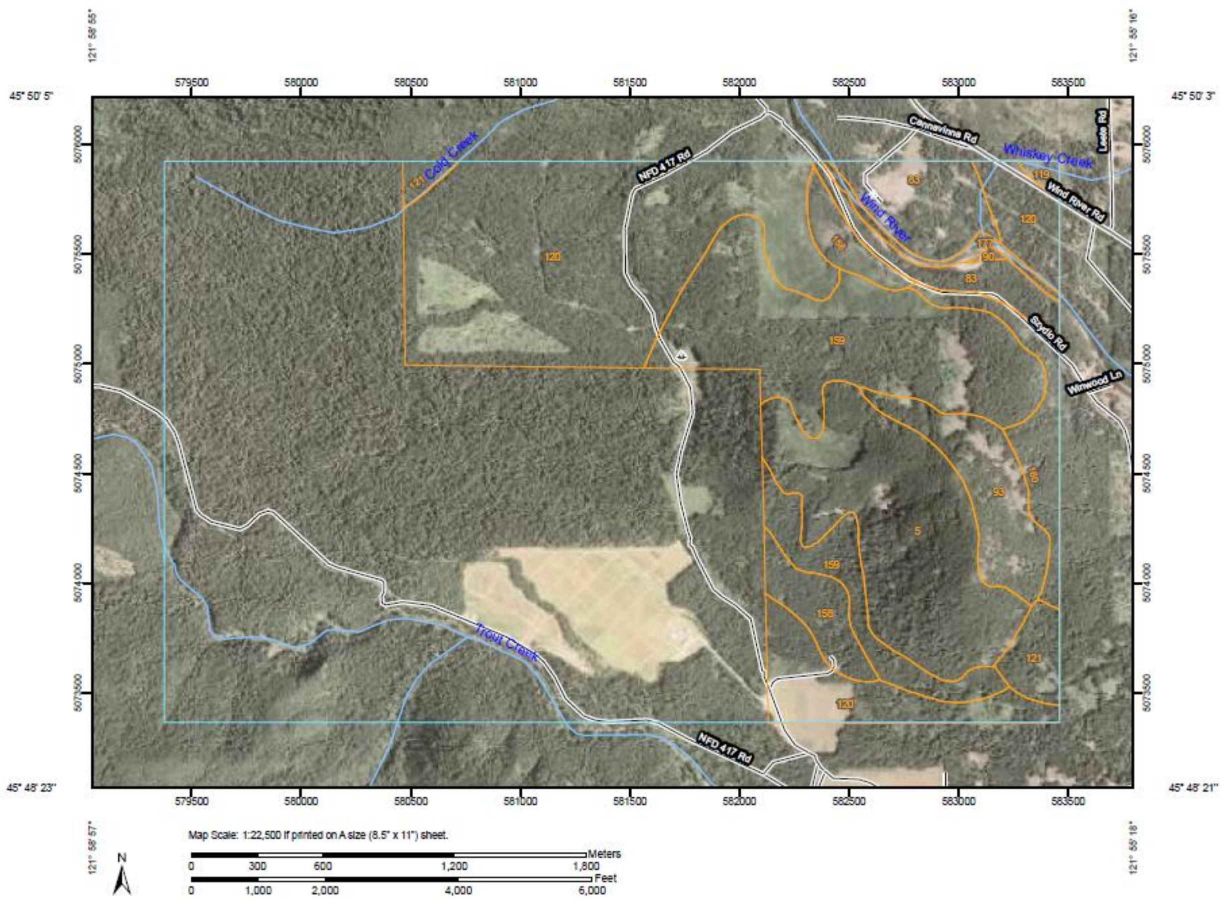


Figure 4. Soil map of the Wind River site and surrounding areas.

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 3. Soil series and percentage of soil series within 10.5 km^2 at the Wind River site

Gifford Pinchot National Forest Area, Washington (WA760)			
No soil data available for this soil survey area.			
Totals for Area of Interest		**2,586.6**	**100.0%**

Skamania County Area, Washington (WA659)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
5	Aschoff-Rock outcrop complex, 30 to 65 percent slopes	202.6	7.8%
83	Pillery fine sandy loam	93.2	3.6%
90	Riverwash	1.6	0.1%
93	Rock outcrop-Xerorthents complex, 50 to 90 percent slopes	69.2	2.7%
119	Stabbart clay loam	4.6	0.2%
120	Stabler loam, 0 to 8 percent slopes	447.9	17.3%
121	Stabler loam, 8 to 30 percent slopes	30.7	1.2%
158	Washougal gravelly loam, 2 to 8 percent slopes	56.1	2.2%
159	Washougal gravelly loam, 8 to 30 percent slopes	270.1	10.4%
160	Washougal gravelly loam, 30 to 50 percent slopes	46.5	1.8%
177	Water	12.6	0.5%
Subtotals for Soil Survey Area		**1,235.2**	**47.8%**
Totals for Area of Interest		**2,586.6**	**100.0%**

Skamania County Area, Washington 5—Aschoff-Rock outcrop complex, 30 to 65 percent slopes Map Unit Setting Elevation: 400 to 2,100 feet Mean annual precipitation: 60 to 115 inches Mean annual air temperature: 45 to 54 degrees F Frost-free period: 125 days **Map Unit Composition** Aschoff and similar soils: 55 percent Rock outcrop: 35 percent **Description of Aschoff Setting** Landform: Mountain slopes **Properties and qualities** Slope: 30 to 65 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Low (about 5.7 inches) **Interpretive groups** Land capability (nonirrigated): 7e **Typical profile** 0 to 12 inches: Very gravelly loam 12 to 47 inches: Very gravelly loam 47 to 60 inches: Very gravelly loam **Description of Rock Outcrop Properties and qualities** Slope: 30 to 65 percent Depth to restrictive feature: 0 inches to lithic bedrock **Interpretive groups** Land capability (nonirrigated): 8s

Skamania County Area, Washington 83—Pillery fine sandy loam Map Unit Setting Mean annual precipitation: 100 inches Mean annual air temperature: 46 degrees F Frost-free period: 110 to 130 days **Map Unit Composition** Pillery and similar soils: 100 percent **Description of Pillery Setting** Landform: Terraces, flood plains **Properties and qualities** Slope: 0 to 3 percent Depth to restrictive feature: 40 to 60 inches to strongly contrasting textural stratification Drainage class: Moderately well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: About 36 to 48 inches Frequency of flooding: Occasional Frequency of ponding: None Available water capacity: Moderate (about 6.2 inches) **Interpretive groups** Land capability (nonirrigated): 3w **Typical profile** 0 to 9 inches: Fine sandy loam 9 to 20 inches: Stratified fine sandy loam to silt loam 20 to 45 inches: Stratified loamy fine sand to fine sandy loam 45 to 60 inches: Very gravelly loamy sand

Skamania County Area, Washington 90—Riverwash Map Unit Composition Riverwash: 100 percent **Description of Riverwash Setting** Landform: Drainageways **Properties and qualities** Slope: 0 to 5 percent Depth to water table: About 0 to 24 inches Frequency of flooding: Frequent **Interpretive groups** Land capability (nonirrigated): 8 **Typical profile** 0 to 60 inches: Error

Skamania County Area, Washington 93—Rock outcrop-Xerorthents complex, 50 to 90 percent slopes Map Unit Setting Mean annual precipitation: 50 inches Mean annual air temperature: 54 degrees F Frost-free period: 140 days **Map Unit Composition** Rock outcrop: 65 percent Xerorthents and similar soils: 25 percent **Description of Rock Outcrop Properties and qualities** Slope: 50 to 90 percent Depth to restrictive feature: 0 inches to lithic bedrock **Interpretive groups** Land capability (nonirrigated): 8s **Description of Xerorthents Setting** Landform: Escarpments **Properties and qualities** Slope: 50 to 90 percent Depth to restrictive feature: 10 to 60 inches to lithic bedrock Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Low (about 3.3 inches) **Interpretive groups** Land capability (nonirrigated): 7e **Typical profile** 0 to 6 inches: Gravelly loam 6 to 31 inches: Very gravelly loam 31 to 35 inches: Unweathered bedrock

Skamania County Area, Washington 119—Stabbart clay loam Map Unit Setting Mean annual precipitation: 95 inches Mean annual air temperature: 46 degrees F Frost-free period: 125 days **Map Unit Composition** Stabbart and similar soils: 100 percent **Description of Stabbart Setting** Landform: Fans **Properties and qualities** Slope: 0 to 3 percent Depth to restrictive feature: More than 80 inches Drainage class: Somewhat poorly drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr) Depth to water table: About 6 to 12 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 11.7 inches) **Interpretive groups** Land capability (nonirrigated): 6w **Typical profile** 0 to 13 inches: Clay loam 13 to 37 inches: Clay loam 37 to 60 inches: Clay loam

Skamania County Area, Washington 120—Stabler loam, 0 to 8 percent slopes Map Unit Setting Elevation: 600 to 1,600 feet Mean annual precipitation: 80 inches Mean annual air temperature: 45 degrees F Frost-free period: 125 days **Map Unit Composition** Stabler and similar soils: 100 percent **Description of Stabler Setting** Landform: Terraces **Properties and qualities** Slope: 0 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 9.6 inches) **Interpretive groups** Land capability (nonirrigated): 2e **Typical profile** 0 to 9 inches: Loam 9 to 37 inches: Loam 37 to 60 inches: Sandy loam

Skamania County Area, Washington 121—Stabler loam, 8 to 30 percent slopes Map Unit Setting Elevation: 600 to 1,600 feet Mean annual precipitation: 80 inches Mean annual air temperature: 45

degrees F Frost-free period: 125 days **Map Unit Composition** Stabler and similar soils: 100 percent **Description of Stabler Setting** Landform: Terraces, mountain slopes **Properties and qualities** Slope: 8 to 30 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 9.6 inches) **Interpretive groups** Land capability (nonirrigated): 4e **Typical profile** 0 to 9 inches: Loam 9 to 37 inches: Loam 37 to 60 inches: Sandy loam

Skamania County Area, Washington 158—Washougal gravelly loam, 2 to 8 percent slopes Map Unit Setting Mean annual precipitation: 60 to 90 inches Mean annual air temperature: 48 degrees F Frost-free period: 165 days **Map Unit Composition** Washougal and similar soils: 100 percent **Description of Washougal Setting** Landform: Terraces **Properties and qualities** Slope: 2 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Low (about 5.1 inches) **Interpretive groups** Land capability (nonirrigated): 3s **Typical profile** 0 to 11 inches: Gravelly loam 11 to 44 inches: Very gravelly loam 44 to 60 inches: Very gravelly coarse sandy loam

Skamania County Area, Washington 159—Washougal gravelly loam, 8 to 30 percent slopes Map Unit Setting Mean annual precipitation: 60 to 90 inches Mean annual air temperature: 48 degrees F Frost-free period: 165 days **Map Unit Composition** Washougal and similar soils: 100 percent **Description of Washougal Setting** Landform: Terraces, escarpments **Properties and qualities** Slope: 8 to 30 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Low (about 5.1 inches) **Interpretive groups** Land capability (nonirrigated): 4e **Typical profile** 0 to 11 inches: Gravelly loam 11 to 44 inches: Very gravelly loam 44 to 60 inches: Very gravelly coarse sandy loam

Skamania County Area, Washington 160—Washougal gravelly loam, 30 to 50 percent slopes Map Unit Setting Mean annual precipitation: 60 to 90 inches Mean annual air temperature: 48 degrees F Frost-free period: 165 days **Map Unit Composition** Washougal and similar soils: 100 percent **Description of Washougal Setting** Landform: Escarpments **Properties and qualities** Slope: 30 to 50 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Low (about 5.1 inches) **Interpretive groups** Land capability (nonirrigated): 7e **Typical profile** 0 to 11 inches: Gravelly loam 11 to 44 inches: Very gravelly loam 44 to 60 inches: Very gravelly coarse sandy loam

Skamania County Area, Washington 177—Water Map Unit Composition Water: 100 percent

3.3.2 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 5). 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 5).

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 5), 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.

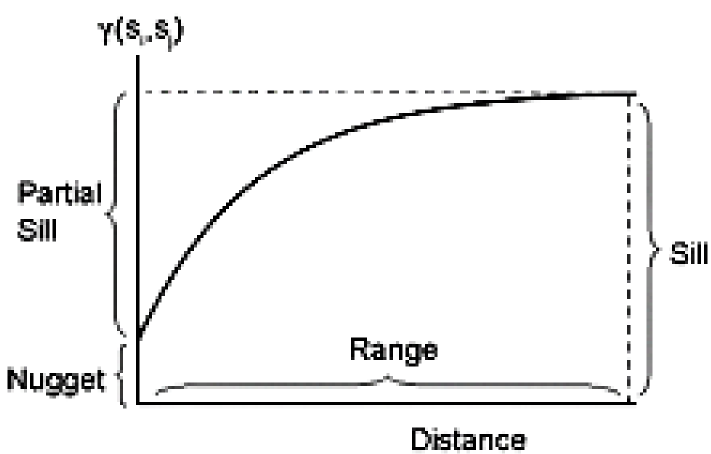


Figure 5. Example semivariogram, depicting range, sill, and nugget.

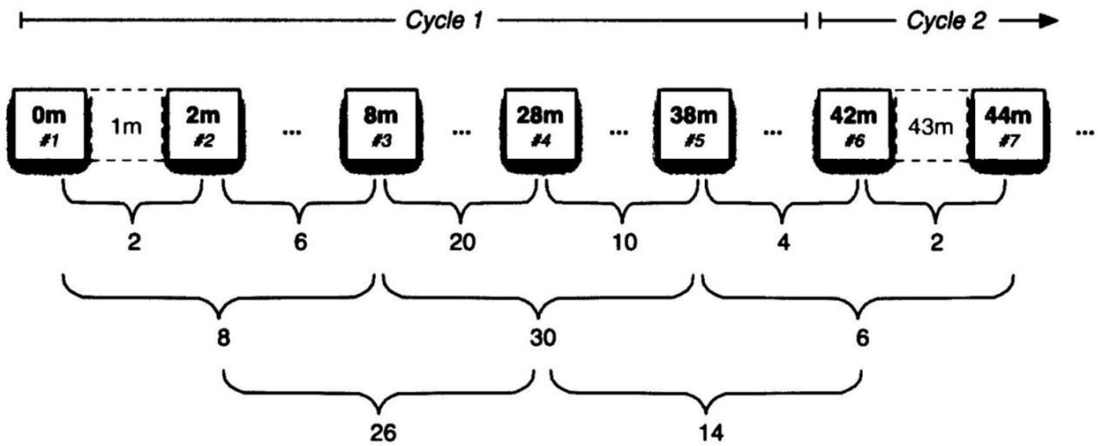


Figure 6. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 8 June 2010 at the Wind River site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 6). Soil temperature and moisture measurements were collected along three transects (210 m, 84 m, and 84 m) located in the expected airshed at Wind River. 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 6, measurements were also taken 30 cm in front and behind the sampling point along the axis of the transect. For example, at the 2 m sampling point, soil temperature and moisture was measured at 1.7 m, 2 m, and 2.3 m; this data is referred to as mobile data, since the measurements were taken at many different locations. In addition, soil temperature and moisture were continuously recorded at a single fixed location (stationary data) throughout the sampling time to correct for changes in temperature and moisture throughout the day.

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

3.3.3 Results and interpretation

3.3.3.1 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 7). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 8, left graph) and directional semivariograms do not show anisotropy (Figure 8, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 8, right graph). The model indicates a distance of effective independence of 4 m for soil temperature.

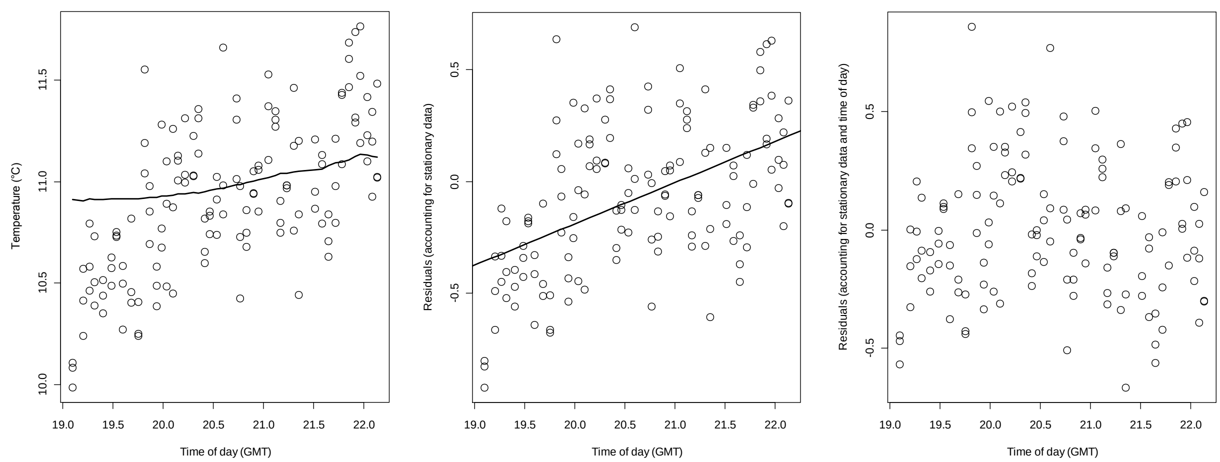


Figure 7. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting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

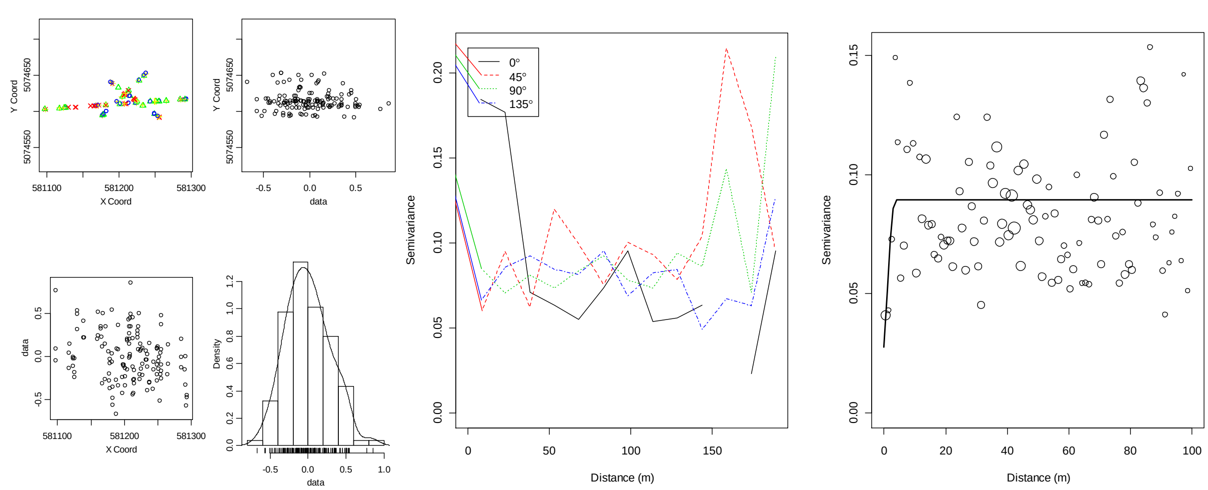


Figure 8. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

3.3.3.2 Soil water content

Soil water content data 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 9). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 10, left graph) and directional semivariograms do not show anisotropy (Figure 10, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 10, right graph). The model indicates a distance of effective independence of 3 m for soil water content.

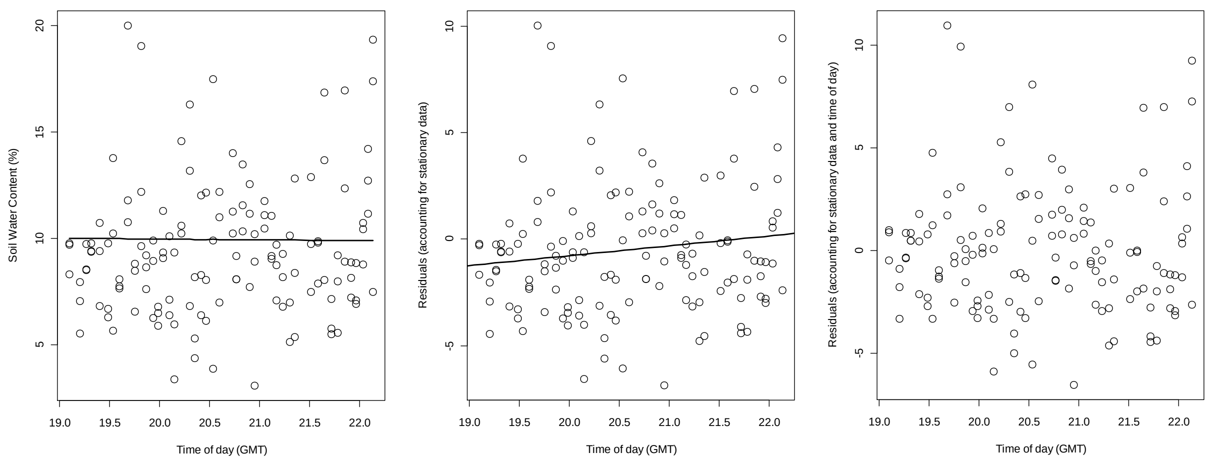


Figure 9. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting 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.

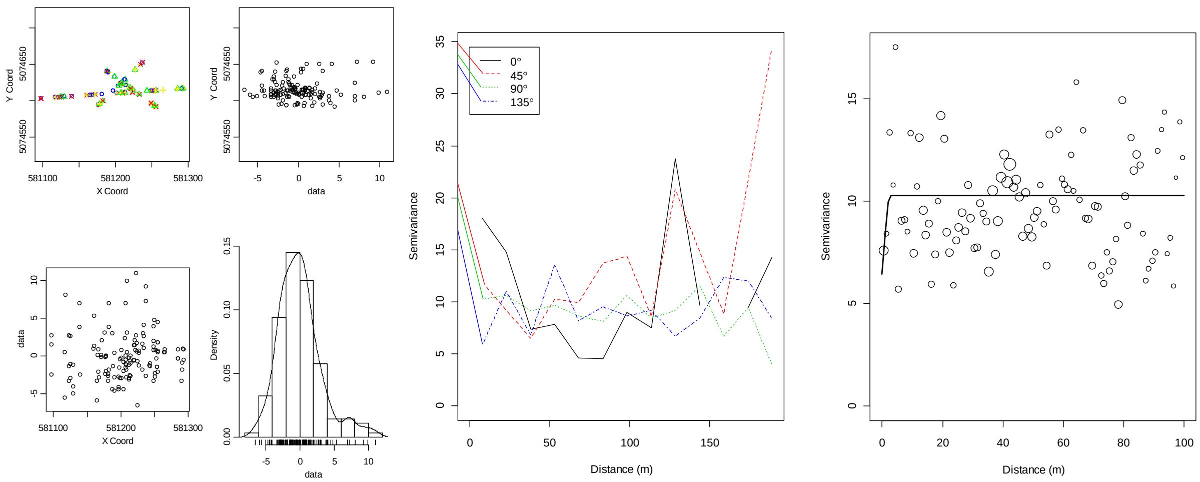


Figure 10. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

3.3.3.3 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 4 m for soil temperature and 3 m for soil moisture. Based on these results and the site design guidelines the soil plots at Wind River shall be placed 25 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 300° from the soil plot nearest the tower (i.e., first soil plot). The location of the first soil plot will be approximately 45.82033, -121.95348. 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 45.816306°, -121.950639° (primary location); or 45.816304°, -121.950191° (alternate location 1 if primary location is unsuitable); or 45.816283°, -121.949229° (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 11.

Dominant soil series at the site: Stabler. The taxonomy of this soil is shown below:
Order: Andisols
Suborder: Udands
Great group: Hapludands
Subgroup: Vitric Hapludands
Family: Medial, amorphic, mesic Vitric Hapludands
Series: Stabler

Table 4. Summary of soil array and soil pit information at Wind River. 0° represents true north and accounts for declination.

Soil plot dimensions	5 m x 5 m
Soil array pattern	B
Distance between soil plots: x	25 m
Distance from tower to closest soil plot: y	123 m§
Latitude and longitude of 1st soil plot OR direction from tower	45.82033, -121.95348
Direction of soil array	300°
Latitude and longitude of FIU soil pit 1	45.816306°, -121.950639° (primary location)
Latitude and longitude of FIU soil pit 2	45.816304°, -121.950191° (alternate 1)
Latitude and longitude of FIU soil pit 3	45.816283°, -121.949229° (alternate 2)
Dominant soil type	Stabler
Expected soil depth	>2 m
Depth to water table	>2 m

Expected depth of soil horizons	**Expected measurement depths***
0-0.23 m (Loam)	0.12 m†
0.23-0.94 m (Loam)	0.59 m†
0.94-1.52 m (Sandy loam)	1.23 m†
2 m	2.00 m

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

†Expected soil CO_2 sensor depth (actual depths will be determined based on the FIU soil pit)

§The land owner requested that the soil plots be located outside the reach of the crane boom arm. First soil plot location is near the end of an existing boardwalk from the crane.

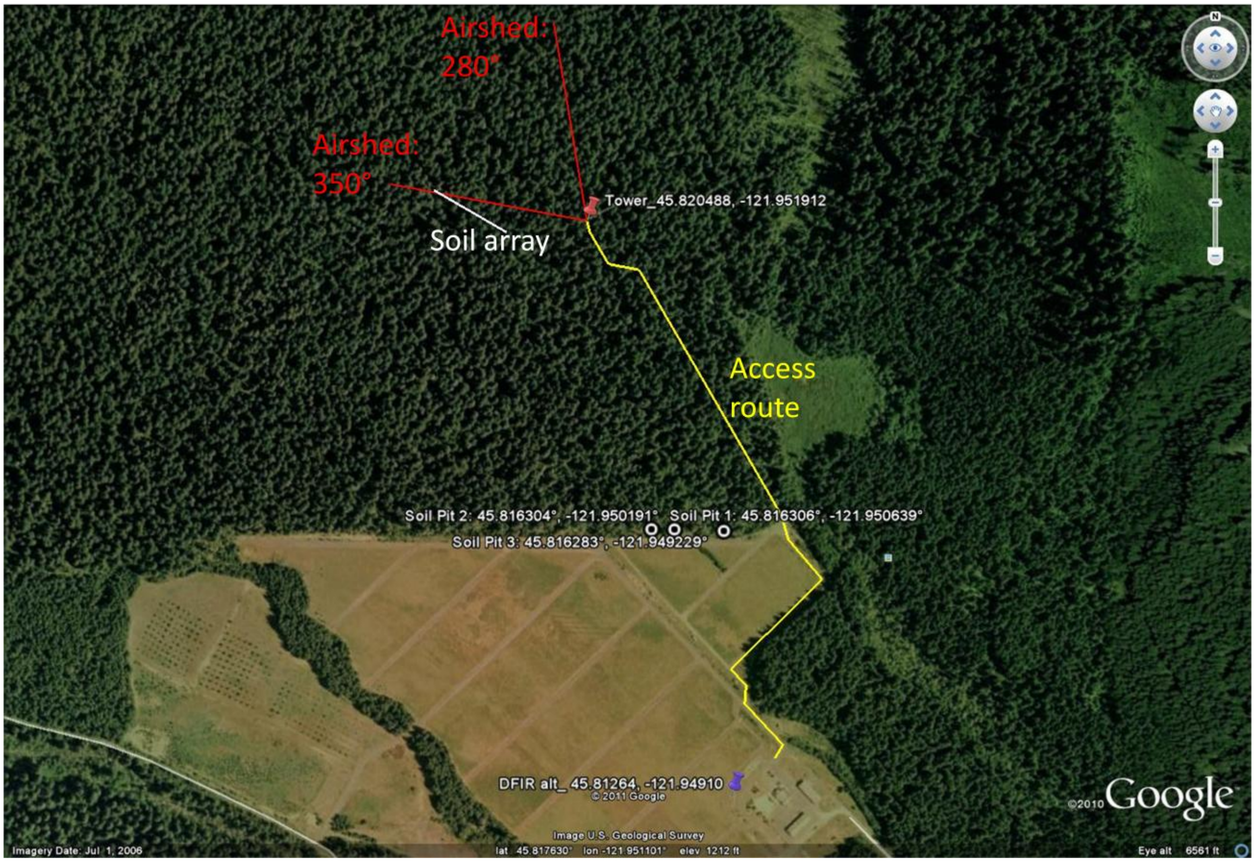


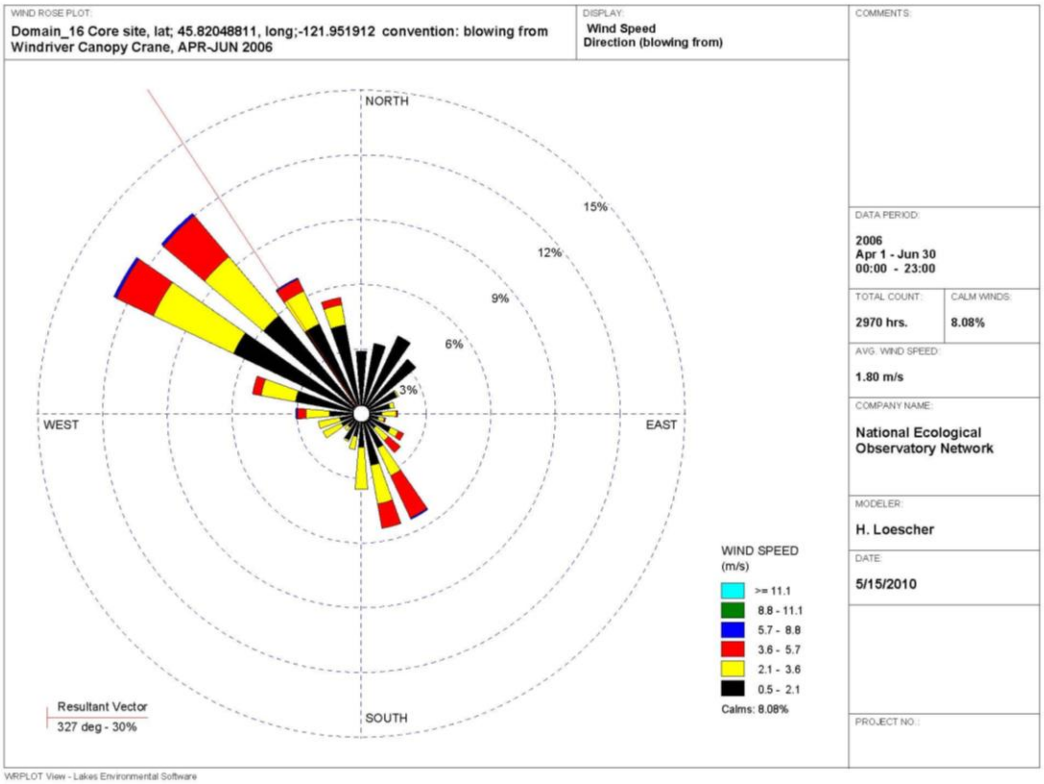
Figure 11. Site layout at Wind River showing soil array and location of the FIU soil pit.

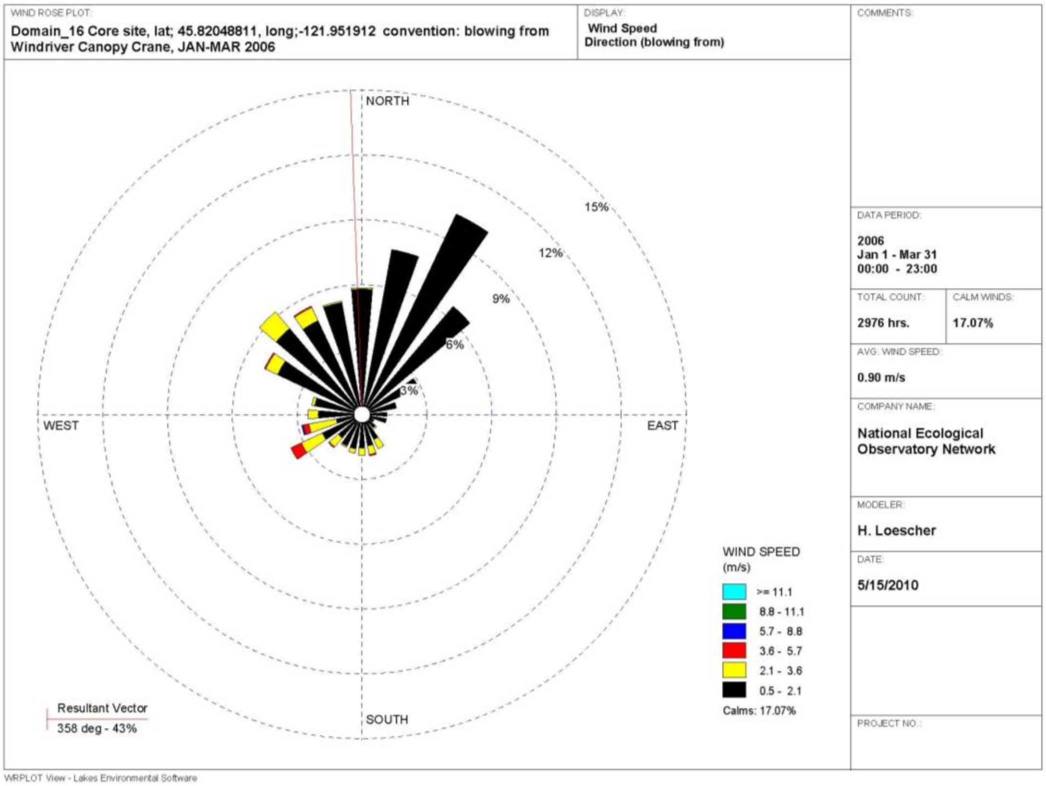
3.4 Airshed

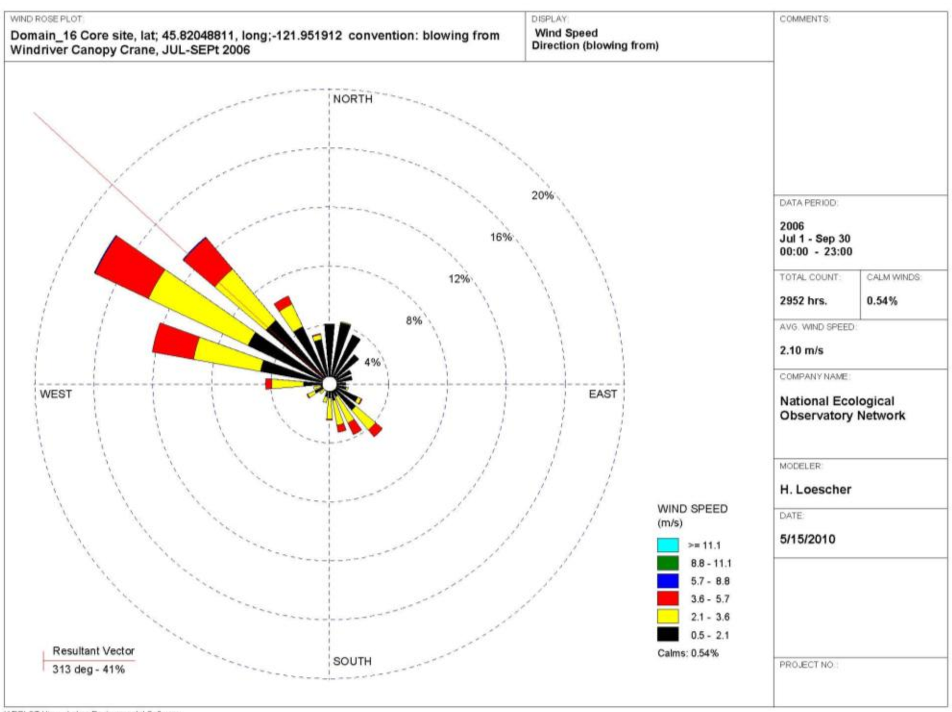
3.4.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries. The data used to make the wind roses below are 2006 data collected at Win River Crane, which is on site. The orientation of the windrose 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 in this case.

3.4.2 Results (graphs for wind roses)




WIND ROSE PLOT:
Domain_16 Core site, lat; 45.82048811, long;-121.951912 convention: blowing from
Windriver Canopy Crane, JAN-MAR 2006
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
DATA PERIOD:
2006
Jan 1 - Mar 31
00:00 - 23:00
TOTAL COUNT:
2976 hrs.
CALM WINDS:
17.07%
AVG. WIND SPEED:
0.90 m/s
COMPANY NAME:
National Ecological Observatory Network
MODELER:
H. Loescher
DATE:
5/15/2010
PROJECT NO.:
NORTH
SOUTH
EAST
WEST
3%
6%
9%
12%
15%
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: 17.07%
Resultant Vector
358 deg - 43%
WRPLOT View - Lakes Environmental Software


WIND ROSE PLOT:
Domain_16 Core site, lat; 45.82048811, long;-121.951912 convention: blowing from
Windriver Canopy Crane, JUL-SEPt 2006
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
DATA PERIOD:
2006
Jul 1 - Sep 30
00:00 - 23:00
TOTAL COUNT:
2952 hrs.
CALM WINDS:
0.54%
AVG. WIND SPEED:
2.10 m/s
COMPANY NAME:
National Ecological Observatory Network
MODELER:
H. Loescher
DATE:
5/15/2010
PROJECT NO.:
NORTH
SOUTH
EAST
WEST
4%
8%
12%
16%
20%
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: 0.54%
Resultant Vector
313 deg - 41%
WRPLOT View - Lakes Environmental Software

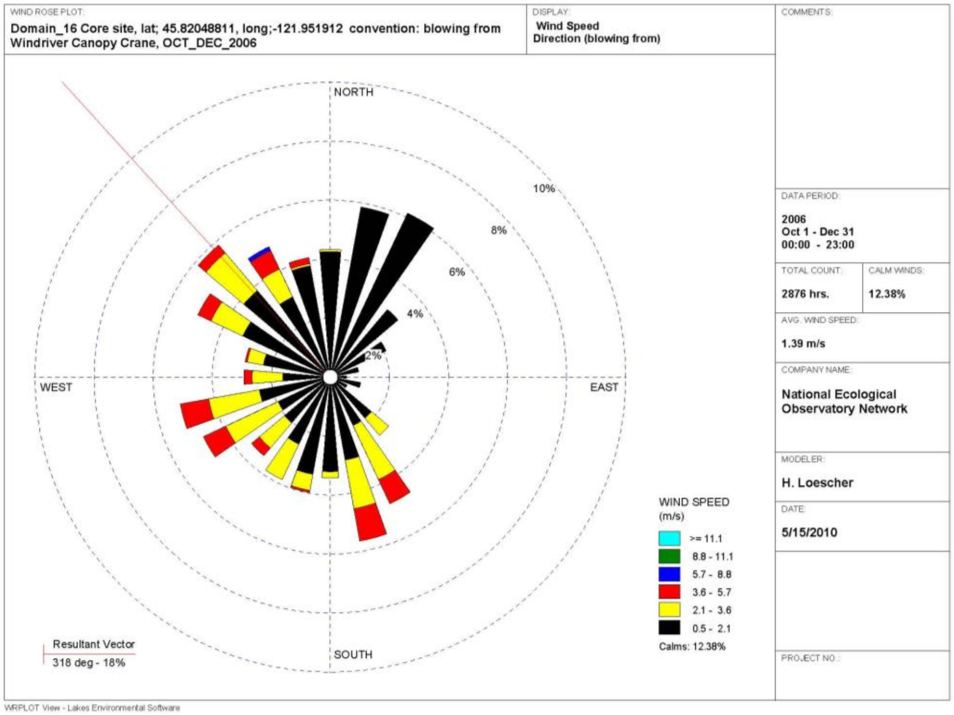


Figure 12. Windroses for Wind River Advanced tower site
The data used to make these wind roses are 2006 data from Wind River crane. It is assumed that the wind data was corrected for declination. Panels are (from top to bottom) January to December.

3.4.3 Resultant vectors

Table 5. The resultant wind vectors from Wind River using hourly data in 2006.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	358°	43
April to June	327°	30
July to September	313°	41
October to December	318°	18
Annual mean	329°	na.

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. 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.

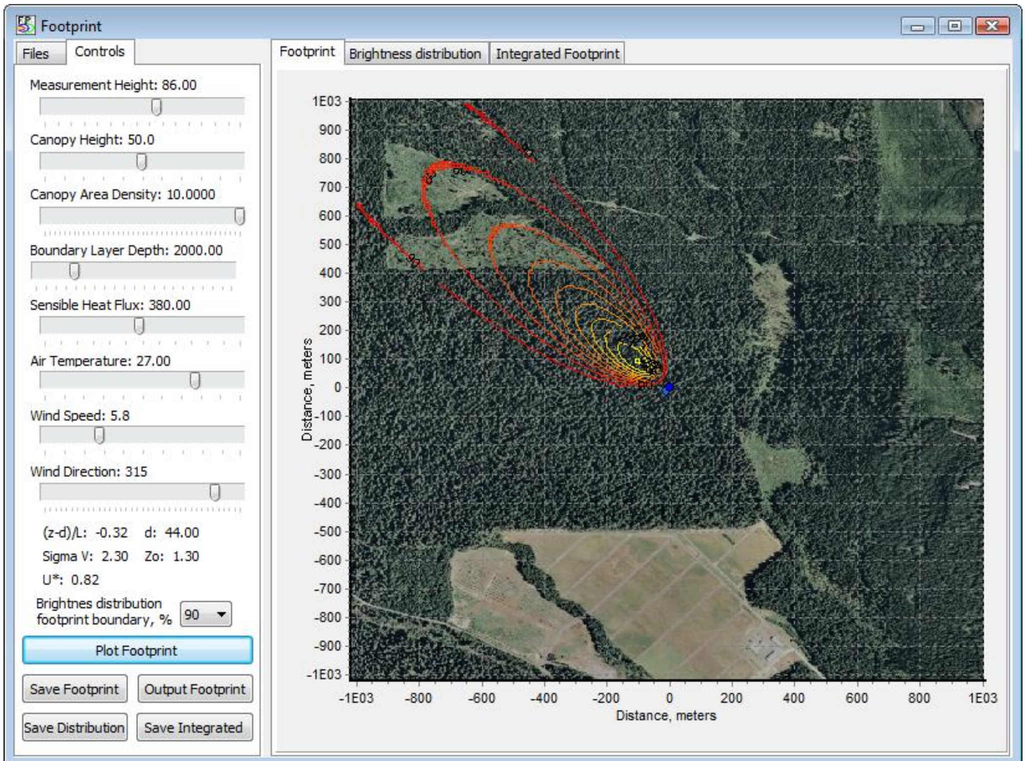
Here, we used a web-based footprint model to determine the footprint area under various conditions (model info: http://www.geos.ed.ac.uk/abs/research/micromet/EdiTools/). Winds used to run the model and generate following model results are extracted from the wind roses. Vegetation information, temperature 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 6. Expected environmental controls to parameterize the source area model, and associated results for Wind River advanced 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	86	86	86	86	86	86	m
Canopy Height	50	50	50	50	50	50	m
Canopy area density	10	10	10	8	8	8	m
Boundary layer depth	2000	2000	850	850	850	850	m
Expected sensible heat flux	380	380	-1	75	75	-1	W m^{-2}
Air Temperature	27	27	18	9	9	-10	°C
Max. windspeed	5.8	2.2	1.1	6.8	2	1.5	m s^{-1}
Resultant wind vector	315	315	315	360	360	360	degrees
Results							
(z-d)/L	-0.32	-1.5	1.3	-0.06	-0.64	0.13	m
d	44	44	44	44	44	44	m
Sigma v	2.3	1.9	1.6	1.8	1.00	1.7	m^2 s^{-2}
Z0	1.3	1.3	1.3	1.4	1.4	1.4	m

u*	0.82	0.48	0.07	0.85	0.39	0.16	m s^{-1}
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	1250	450	3250	2000	750	2500	m
Distance of 80% cumulative flux	800	300	2700	1750	450	1750	m
Distance of 70% cumulative flux	600	200	2250	950	300	1300	m
Peak contribution	185	65	865	255	95	305	m

3.5 Results (source area graphs)



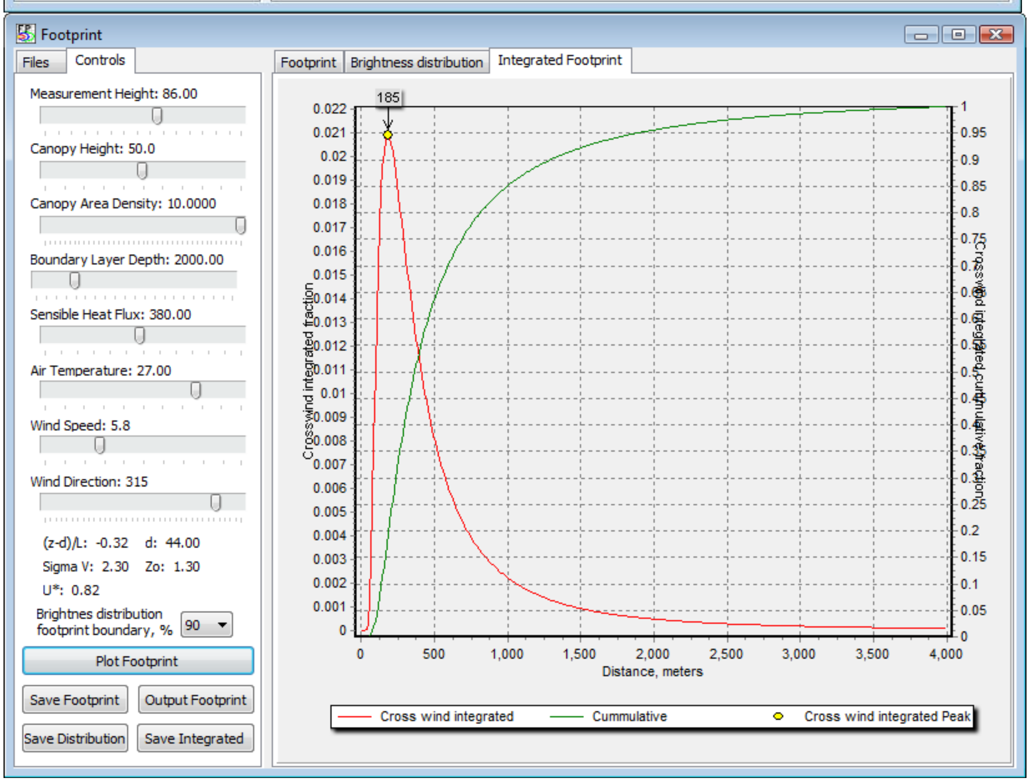


Figure 13. summer, daytime, max wind speed

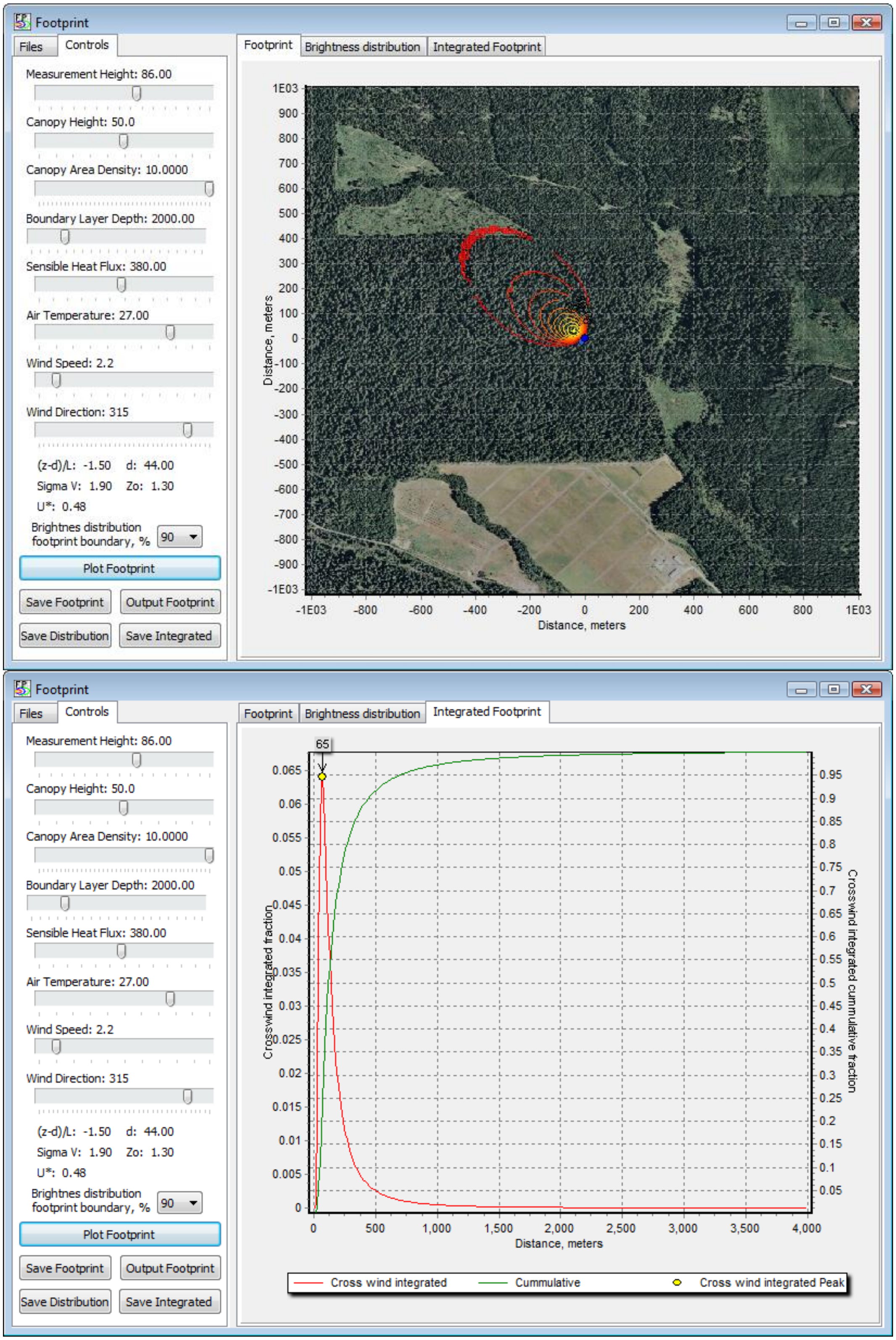


Figure 14. summer, daytime, mean wind speed

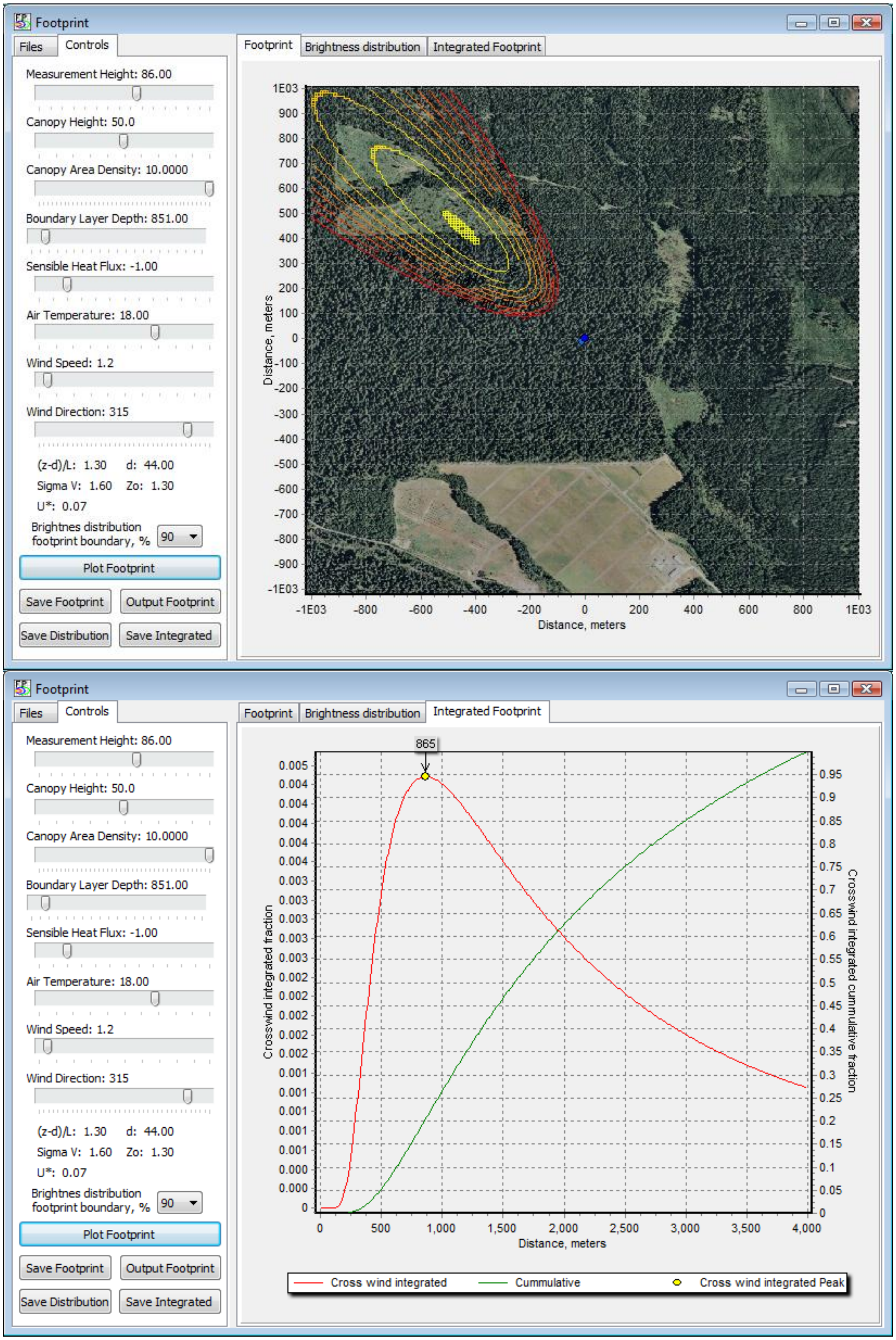


Figure 15. summer, nighttime, mean wind speed

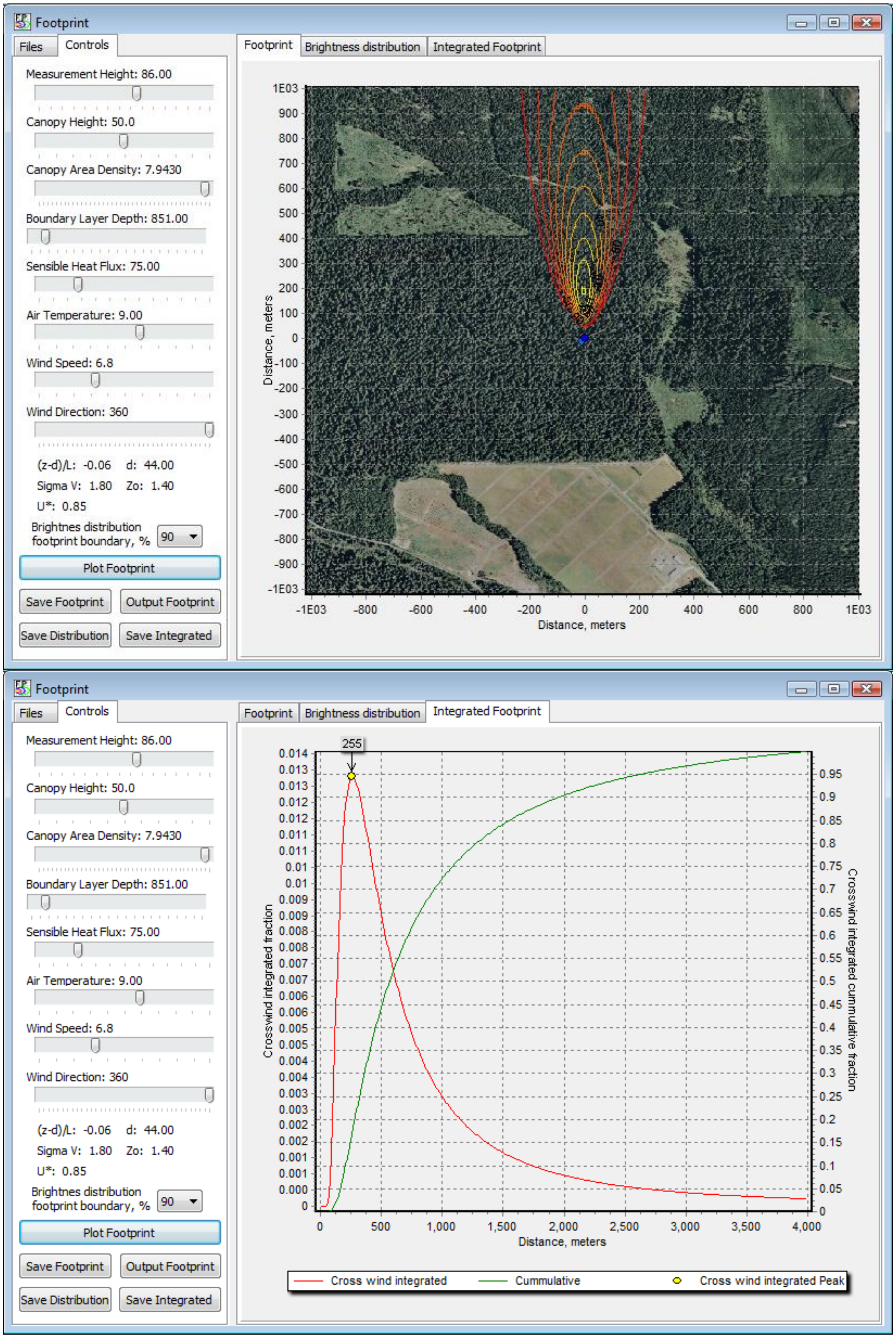


Figure 16. winter, daytime, max wind speed

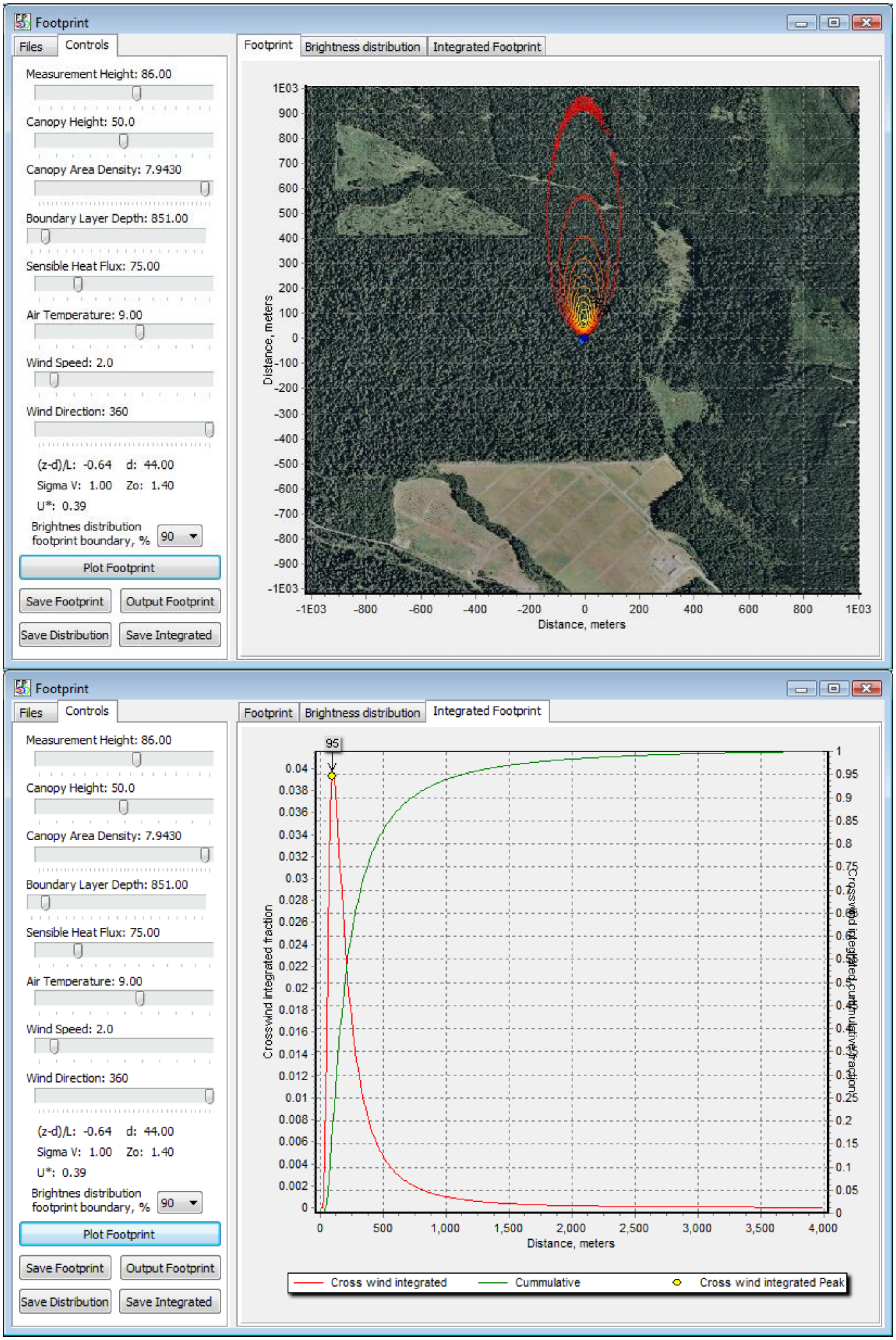
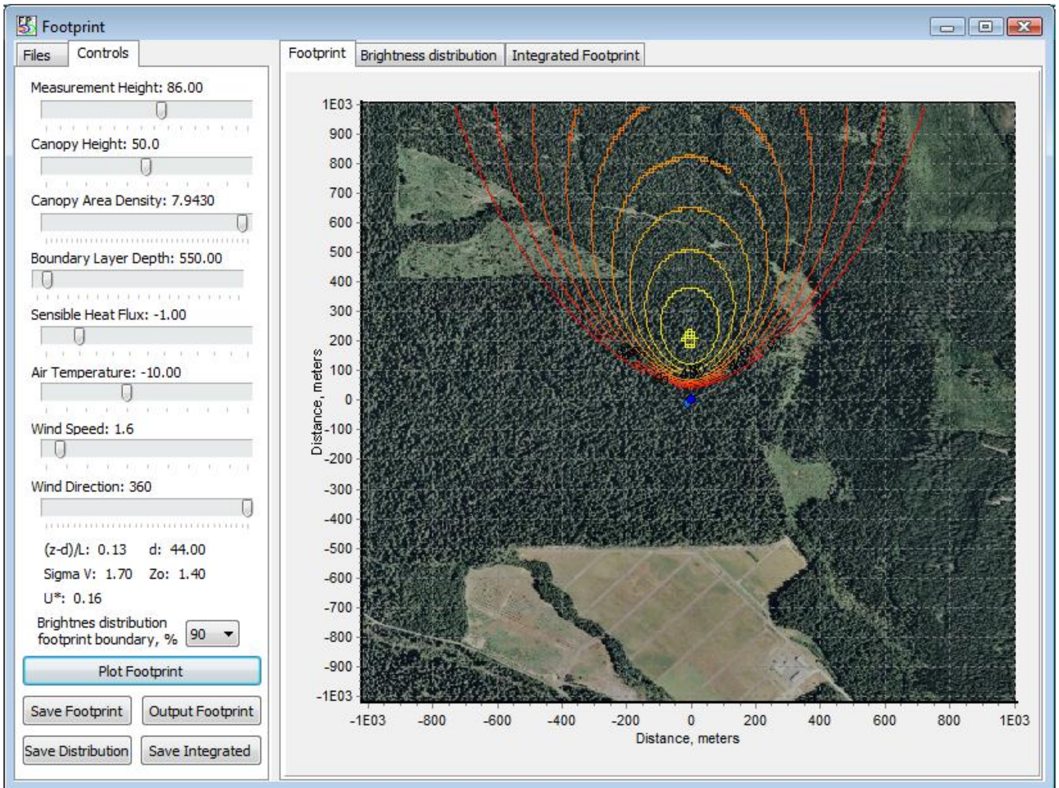


Figure 17. Winter daytime, mean wind speed



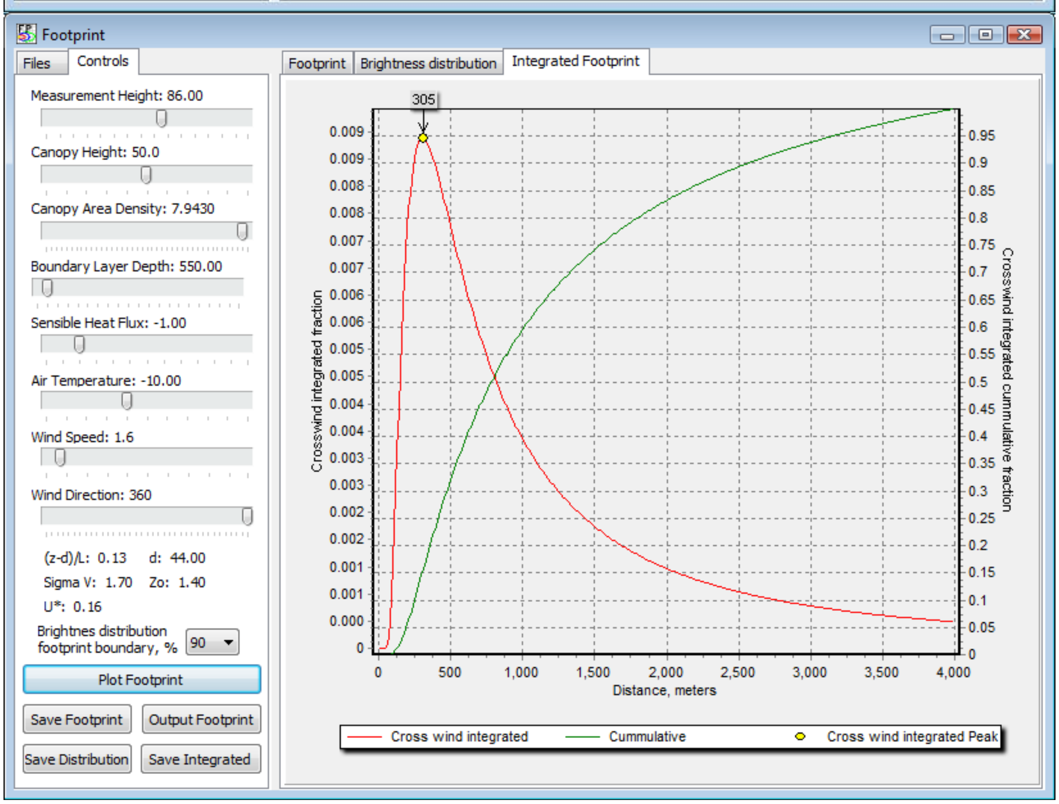


Figure 18. winter, nighttime, mean wind speed

3.5.1 Site design and tower attributes

The location of the tower at this site is 45.820488, -121.951912, which is exactly the existing tower site at Wind River. No new NEON tower structure will be constructed at this site.

According to the wind roses, wind can blow from any direction throughout the year. But wind blows most frequently from the airshed between 280^{o} and 350^{o} (clockwise from 280^{o}). Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the west will be best to capture signals from all 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. However, at this site, the existing instrument hut, which is within the tower pad, will be taken down and the NEON instrument hut will be placed within the pad at a location agreed with the land owner. This location will be used to place NEON instrument hut, which will be shared by Wind River and NEON. However, the timeline and procedures for this transition are currently to be determined. The instrument hut should be positioned to have the longer side parallel to SE-NW direction.

The dominated tree species around tower location and in the airshed are Douglas fir, hemlock and yew. Average tree height is ~50 m. Lowest branch is between 9-15 m. Bottom of the majority of the canopy is at ~ 35 m. Maples and some other small trees forms understory with height ~ 8 m. Vegetation on forest floor is ~ 0.3 m tall. We require 8 **measurement layers** on the tower with top measurement height at 86 m, and remaining levels are 60 m, 50 m, 42 m, 35 m, 20 m, 8m and 0.3 m, respectively, to best characterize the fluxes on the tower top and environmental conditions in profile.

DFIR location is at 45.81264, -121.94910, which is ~890 m southeast to tower. The rain gauge is located in the opening next to a parking lot. The distance between this location to the closest tree is ~135 m. Given the tree height around this opening is ~ 40 m, this distance is not far enough to meet USCRN class 1 siting criteria (>4 times the height of any obstacle taller in height) for DFIR, but meet the USCRN class 2 siting criteria (>2 times the height of any obstacle taller in height). **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. **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.

Table 7. Site design and tower attributes for Wind River 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			From 280° to 350°		Clockwise from first angle
Tower location	45.820488,	-121.951912	--	--	same site
Instrument hut					Use existing instrument hut location within the tower pad. Exact location within the pad requires landowner agreement.
Instrument hut orientation vector	--	--	135° - 315°		Pending landowner agreement
Instrument hut distance z	--	--	--	Unknown, didn't measure	
Anemometer/Temperature boom orientation	--	--	270°	--	
DFIR	45.81264,	-121.94910			
Height of the measurement levels					
Level 1				0.3	m.a.g.l.
Level 2				8.0	m.a.g.l.
Level 3				20.0	m.a.g.l.
Level 4				35.0	m.a.g.l.
Level 5				42.0	m.a.g.l.
Level 6				50.0	m.a.g.l.
Level 7				60.0	m.a.g.l.
Level 8				86.0	m.a.g.l.
Tower Height				86.0	m.a.g.l.

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

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

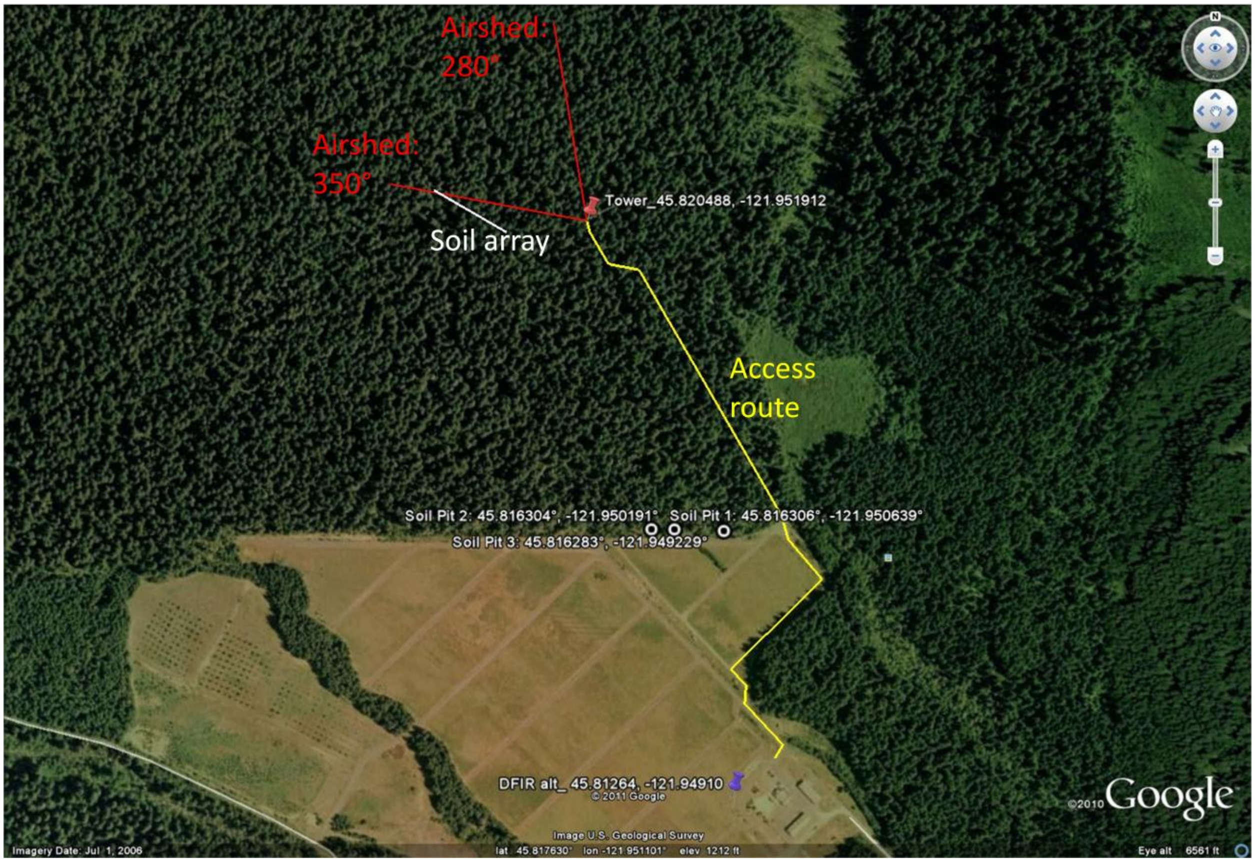


Figure 19. Site layout for Wind River Advanced tower site.
i) Tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 280° to 350° (major airshed, clockwise from 280°) would have quality wind data without causing flow distortions, respectively.iii) Yellow line is the suggested access road to instrument hut. iv) Purple pin is DFIR 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. 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). The boardwalk to access the tower is not on any side that has a boom.
Specific Boardwalks at Wind River Advance site:

- A forest road goes directly to the tower pad, which is also where the instrument hut will be located, so no new boardwalk/path is necessary.
- Boardwalk to the soil array. Note that a narrow boardwalk (~0.4 m wide) is already present from the tower site towards the first soil plot. This boardwalk ends ~30 m before the first soil plot. The existing boardwalk is not wide enough for an ATV or track-based Geoprobe-type machine.

- No boardwalk from the soil array boardwalk to the individual soil plots.
- No boardwalk or path needed to DFIR site.

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

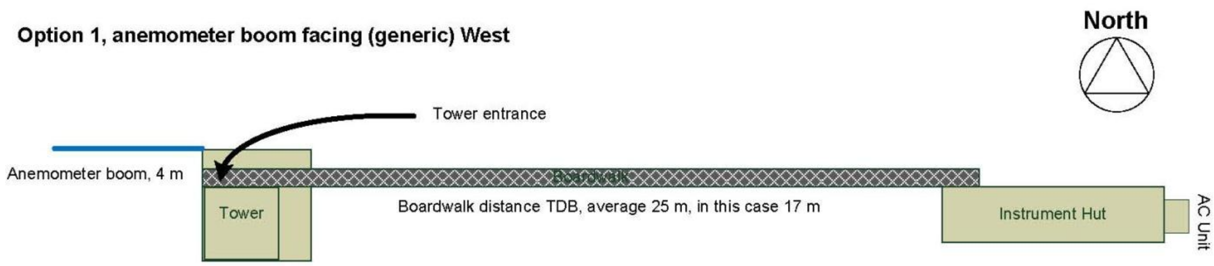


Figure 20. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing south and instrument hut on the east towards the tower.

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 Wind River Advanced site, the boom angle will be 270 degrees, instrument hut location is TBD, the distance between instrument hut and tower is unknown since the IH is TBD. The instrument hut vector will be SE-NW (135^{o}-315^{o}, longwise).

3.5.2 Information for ecosystem productivity plots

The tower at Wind River Advanced site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (Douglas fir – hemlock forest). Wind can blow from any direction during the year, but has higher frequency from 280° to 350° (clockwise from 280°). 90% signals for flux measurements are mainly from a distance < 1250 m from tower during daytime, and 80% within 800 m. But during nighttime, signals can be from > 2 km away from tower during nighttime. We suggest FSU Ecosystem Productivity plots are placed within the boundaries of 280^{o} to 350^{o} (clockwise from 350°) from tower.

3.6 Issues and attentions

The tower at this site is a canopy crane. At all the other NEON candidate sites at tower designed with input from NEON will be used. It is possible that the difference in tower structure could influence the tower-based measurements, but given the relatively long boom arms that will be used by NEON, this is not expected to significanly impact the science.

The landowners require that the instrument hut be placed within the existing tower pad (exact location is to be determined). The FIU design would typically place the instrument hut outside of the dominant airshed and at least 14 m from the tower (in a forest ecosystem), but due to the land owners request this will not occur at this site.

The land owners would not allow the soil plots to be placed within the radius of the loading jib, which extends 85 m from the tower. Therefore, the first soil plot is 123 m from the tower. It is important that the soil measurements can be related to the tower measurements, therefore, at most NEON sites the first soil plot will typically be about 15-30 m from the tower. However, the forest structure is similar at the soil array and tower and given the expected large footprint for the flux measurements this is not expected to significantly impact the science at this site.

The soil array is on the edge of the dominant airshed, rather than within the airshed, because there was an existing boardwalk to the soil array location. If the soil array was placed directly within the airshed an additional boardwalk would have been necessary from the tower to the soil array, which would have increased disturbance to the site. The vegetation and soil at the soil array is similar to that within the airshed, therefore, the location of the soil array on the fringes of the airshed is not expected to significantly imapct the science at this site.

4 THAYER, RELOCATEABLE TOWER 1

4.1 Site description

The Thayer site is managed by the Washington Department of Natural Resources (WDNR). The site is harvested for timber, and managed according to WDNR guidelines. The site was privately owned at the time of the last timber harvest, but was acquired by WDNR prior to re-planting.

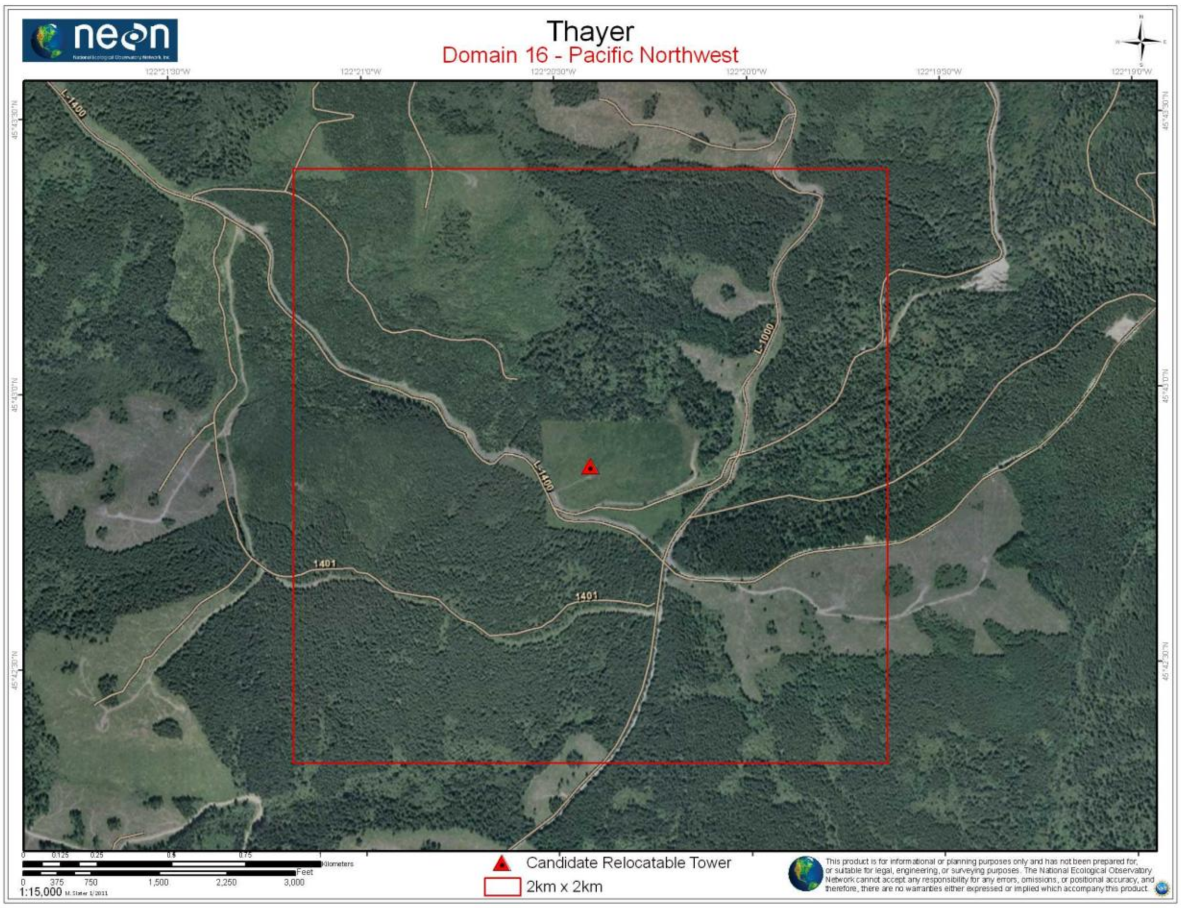


Figure 21. Thayer site and candidate tower location.

4.2 Ecosystem

Vegetation type and land cover information at this relocatable site are presented below:

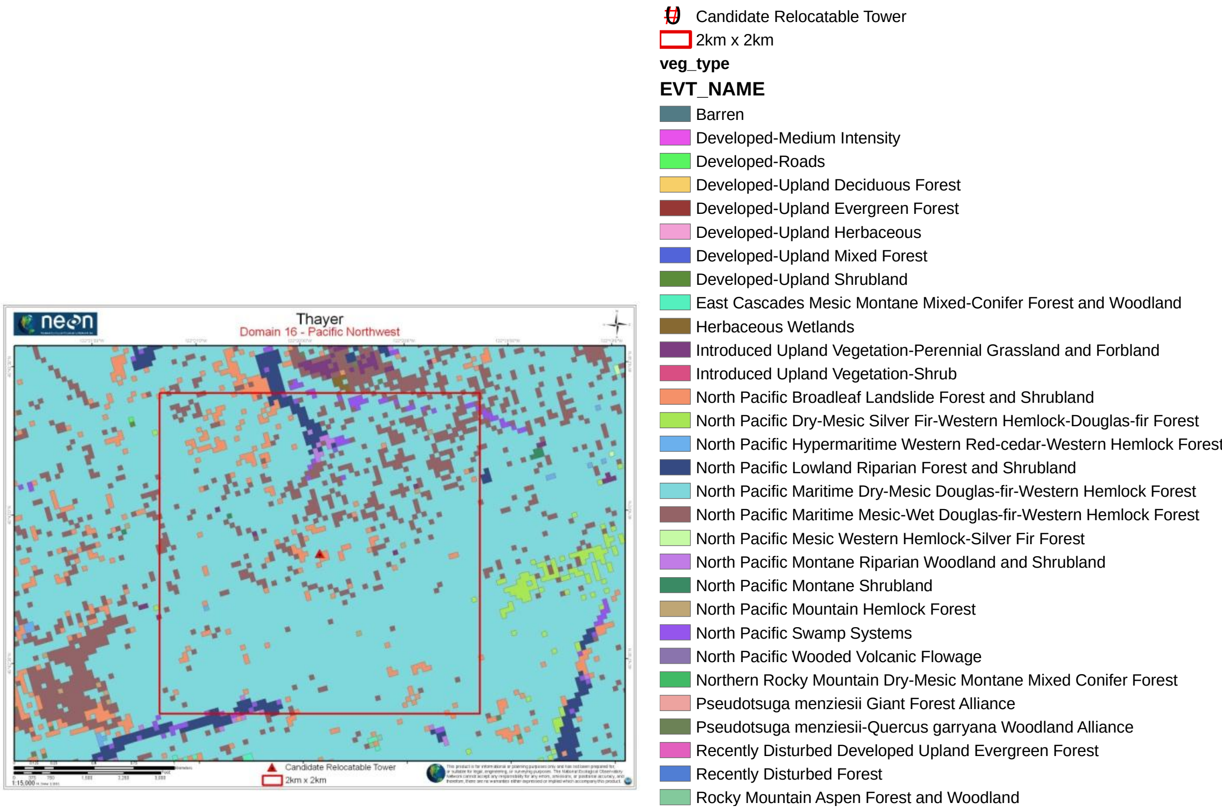


Figure 22. Vegetative cover map of the Thayer relocatable site and surrounding areas (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm).

Table 8. Percent Land cover information at the Thayer relocatable site (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Vegetation Type	Area_Km2	Percentage
Herbaceous Wetlands	0.00007	0.002
Introduced Upland Vegetation-Perennial Grassland and Forbland	0.00392	0.098
North Pacific Broadleaf Landslide Forest and Shrubland	0.13506	3.377
North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest	0.00090	0.022
North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest	0.00090	0.022
North Pacific Lowland Riparian Forest and Shrubland	0.05706	1.427
North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest	3.39078	84.771
North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	0.36205	9.051
North Pacific Montane Riparian Woodland and Shrubland	0.01154	0.288
North Pacific Montane Shrubland	0.00090	0.022
North Pacific Mountain Hemlock Forest	0.00360	0.090
North Pacific Swamp Systems	0.03316	0.829
TOTAL	3.999936	100

Tower location is inside a small forest management parcel (approximately 300 m × 500m), which is a typical size for management units in this region. WDNR management units must be less than 200 acres (0.8 km^2). Land ownership was private when the forest was last harvested, but was acquired by WDNR prior to re-planting. The surrounding forests are older (hence taller) and are largely managed by WDNR and trusts. One WDNR management policy states that adjacent forest management units cannot be harvested within 6 six years of each other to minimize the size of recently harvested land.

The ecosystem around tower and inside the major airshed is young Douglas fir forest, which was planted after logging 10-12 years ago. Fir is unevenly spaced. Canopy height is currently ~10-12 m and average ~11 m and the forest is approaching canopy closure. Trees grow actively at a rate of ~0.5 m per year. Assume the construction at this site will be in 2012 or 2013, which will give canopy height ~ 12 m (tree height will need to be reevaluated at the time of construction). The mean canopy height will be expected to reach ~ 18 m after 8 years of operation, which is approximately when the NEON relocatable tower will be decommissioned at this site. There is successional suite of tree species. Tree stem density is ~350 ha^{-1} to 800 ha^{-1}. Understory is very dense and the ground is not visible due to the thick ground cover. Shrub layer presents with height ~ 3 m. The understory at forest floor is ~ 0.3 m tall. There is a large amount of coarse woody debris from the previous harvest on the forest floor, which makes walking and access to the site extremely difficult.

Figure 23. Ecosystem and surrounding environment at the Thayer relocatable site.

Table 9. Ecosystem and site attributes for Thayer Relocatable site.

Ecosystem attributes	Measure and units
Mean canopy height at construction [a]	12.0 m
Surface roughness at construction [a]	1.5 m
Zero place displacement height at construction [a]	8.0 m
Mean canopy height at 8th year of operation [b]	18.0 m
Surface roughness at 8th year of operation [b]	2.0 m
Zero place displacement height at 8th year of operation [b]	14.0 m
Structural elements	Planted young trees, actively grow
Time zone	Pacific time zone
Magnetic declination	16° 18' E changing by 0° 9' W/year

Note, [a] From field survey and best estimates for the time at the construction, which will require top measurement level at 24 m above ground.

[b] Best estimates by the time that NEON tower is decommissioned at the end of the 8 years' services, which will require top measurement level at 30 m above ground, therefore, FCC should design and budget adequate tower height ahead and allow the increase of the top measurement level to 30 m.

4.3 Soils

4.3.1 Description of soils

Soil data and soil maps below for the Thayer tower site were collected from 4.5 km^2 NRCS soil maps (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

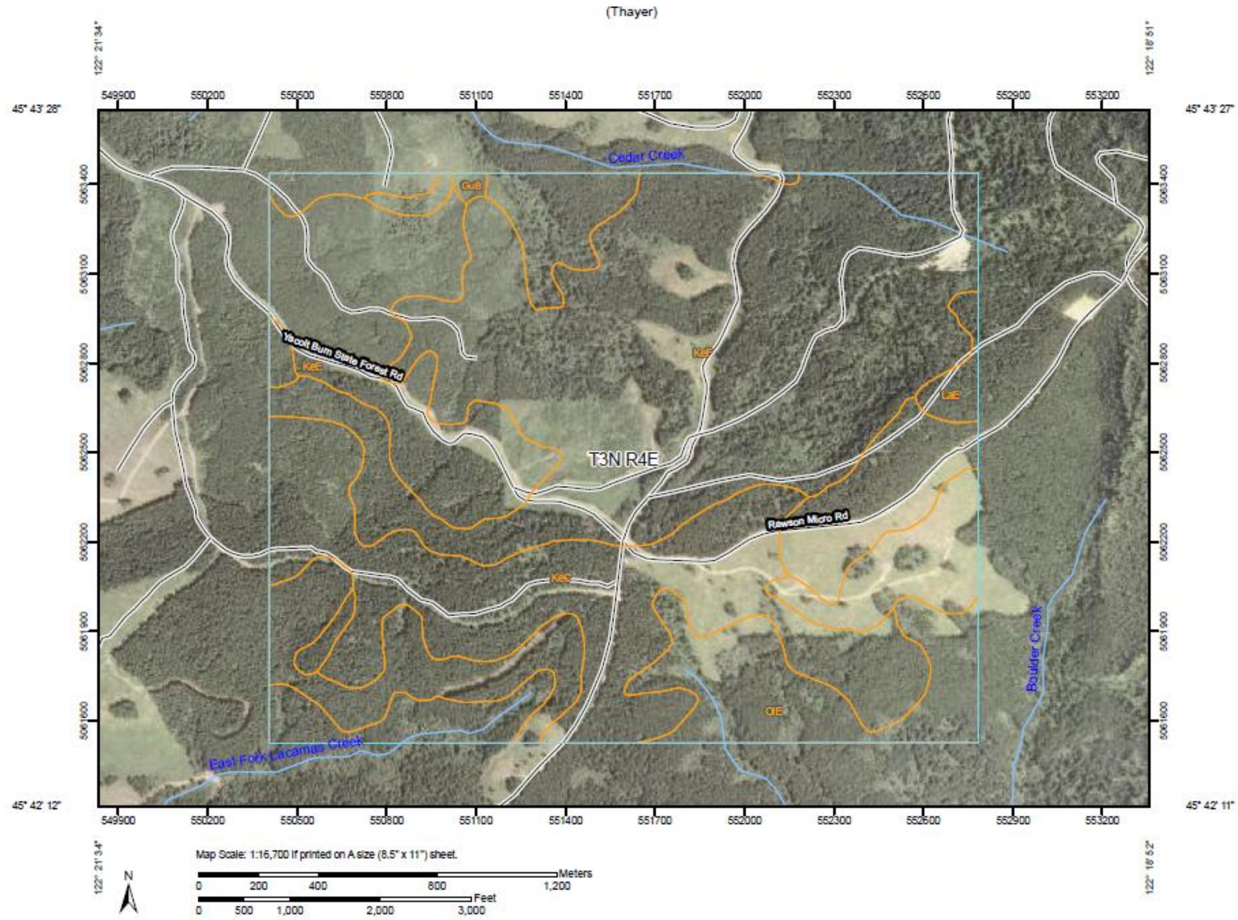


Figure 24. Soil map of the Thayer site and surrounding areas.

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 10. Soil series and percentage of soil series within 4.5 km^2 at the Thayer site

Clark County, Washington (WA011)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
GuB	Gumboot silt loam, 0 to 8 percent slopes	2.3	0.2%
KeC	Kinney silt loam, 3 to 15 percent slopes	234.2	20.8%
KeE	Kinney silt loam, 15 to 30 percent slopes	269.4	24.0%
KeF	Kinney silt loam, 30 to 50 percent slopes	496.2	44.2%
LaE	Larchmount cobbly silt loam, 15 to 30 percent slopes	10.9	1.0%
OlE	Olympic clay loam, 20 to 30 percent slopes	110.7	9.8%
Totals for Area of Interest		**1,123.6**	**100.0%**

Clark County, Washington GuB—Gumboot silt loam, 0 to 8 percent slopes Map Unit Setting Elevation: 1,000 to 2,000 feet Mean annual precipitation: 75 to 95 inches Mean annual air temperature: 50 to 54 degrees F Frost-free period: 180 to 220 days **Map Unit Composition** Gumboot and similar soils: 100 percent **Description of Gumboot Setting** Landform: Drainageways Parent material: Alluvium **Properties and qualities** Slope: 0 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Poorly drained Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 in/hr) Depth to water table: About 0 to 18 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 10.7 inches) **Interpretive groups** Land capability (nonirrigated): 6w **Typical profile** 0 to 12 inches: Silt loam 12 to 28 inches: Clay loam 28 to 50 inches: Silty clay 50 to 60 inches: Very gravelly silty clay

Clark County, Washington KeC—Kinney silt loam, 3 to 15 percent slopes Map Unit Setting Elevation: 600 to 2,300 feet Mean annual precipitation: 60 to 90 inches Mean annual air temperature: 45 to 50 degrees F Frost-free period: 120 to 190 days Map Unit Composition Kinney and similar soils: 100 percent **Description of Kinney Setting** Landform: Mountain slopes Parent material: Residuum weathered from igneous rock with a mantle of volcanic ash **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 (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 11.2 inches) **Interpretive groups** Land capability (nonirrigated): 3e **Typical profile** 0 to 7 inches: Silt loam 7 to 60 inches: Gravelly silty clay loam

Clark County, Washington KeE—Kinney silt loam, 15 to 30 percent slopes Map Unit Setting Elevation: 600 to 2,300 feet Mean annual precipitation: 60 to 90 inches Mean annual air temperature: 45 to 50 degrees F Frost-free period: 120 to 190 days **Map Unit Composition** Kinney and similar soils: 100 percent **Description of Kinney Setting** Landform: Mountain slopes Parent material: Residuum weathered from igneous rock with a mantle of volcanic ash **Properties and qualities** Slope: 15 to 30 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 11.2 inches) **Interpretive groups** Land capability (nonirrigated): 4e **Typical profile** 0 to 7 inches: Silt loam 7 to 60 inches: Gravelly silty clay loam

Clark County, Washington KeF—Kinney silt loam, 30 to 50 percent slopes Map Unit Setting Elevation: 600 to 2,300 feet Mean annual precipitation: 60 to 90 inches Mean annual air temperature: 45 to 50 degrees F Frost-free period: 120 to 190 days **Map Unit Composition** Kinney and similar soils: 100 percent **Description of Kinney Setting** Landform: Mountain slopes Parent material: Residuum weathered from igneous rock with a mantle of volcanic ash **Properties and qualities** Slope: 30 to 50 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 11.3 inches) **Interpretive groups** Land capability (nonirrigated): 7e **Typical profile** 0 to 5 inches: Silt loam 5 to 60 inches: Gravelly silty clay loam

Clark County, Washington LaE—Larchmount cobbly silt loam, 15 to 30 percent slopes Map Unit Setting Mean annual precipitation: 90 to 100 inches Mean annual air temperature: 43 degrees F **Map Unit Composition** Larchmount and similar soils: 100 percent **Description of Larchmount Setting** Landform: Mountain slopes Parent material: Volcanic ash and residuum and colluvium from igneous rock **Properties and qualities** Slope: 15 to 30 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Low (about 4.8 inches) **Interpretive groups** Land capability (nonirrigated): 4e **Typical profile** 0 to 23 inches: Cobbly silt loam 23 to 48 inches: Cobbly silt loam 48 to 60 inches: Cobbly clay loam

Clark County, Washington OlE—Olympic clay loam, 20 to 30 percent slopes Map Unit Setting Elevation: 200 to 2,000 feet Mean annual precipitation: 40 to 70 inches Mean annual air temperature: 50 to 54 degrees F Frost-free period: 150 to 200 days **Map Unit Composition** Olympic and similar soils: 100 percent Description of Olympic Setting Landform: Mountain slopes Parent material: Residuum and colluvium from igneous rock **Properties and qualities** Slope: 20 to 30 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 (0.20 to 0.57 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 10.2 inches) **Interpretive groups** Land capability (nonirrigated): 4e **Typical profile** 0 to 11 inches: Clay loam 11 to 42 inches: Clay loam 42 to 60 inches: Gravelly clay 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 25). 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 25).

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 25), 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.

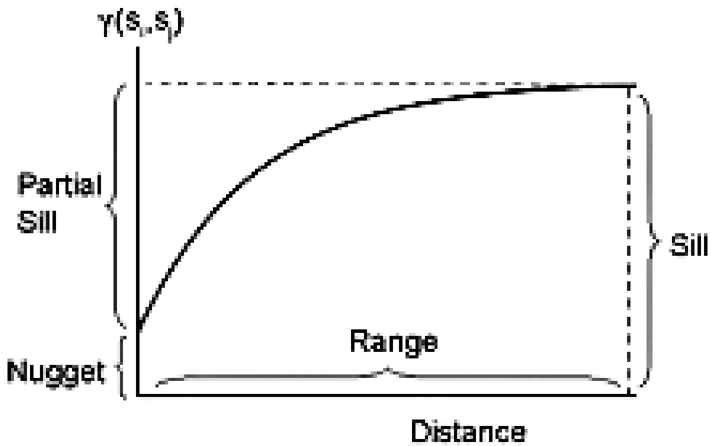


Figure 25. Example semivariogram, depicting range, sill, and nugget.

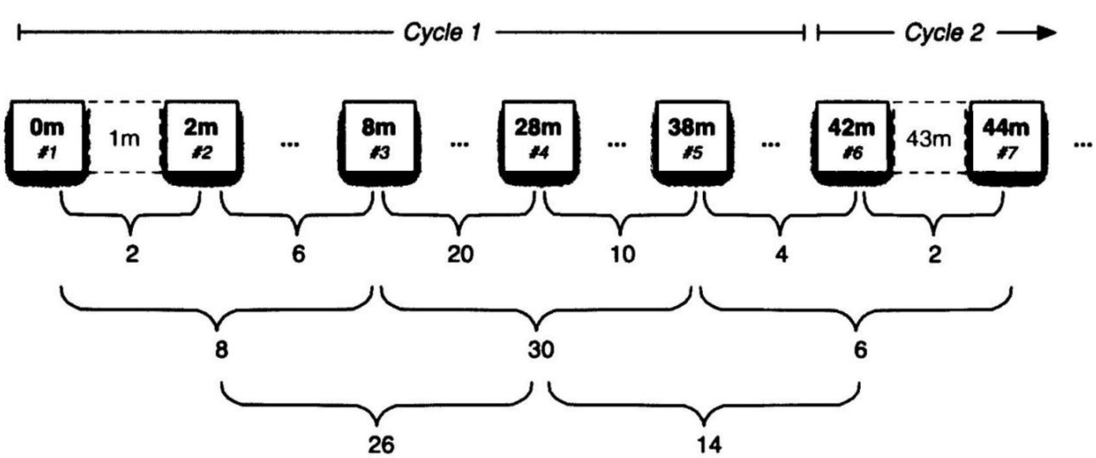


Figure 26. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 21 October 2010 at the Thayer site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 26). Soil temperature and moisture measurements were collected along three transects (100 m, 84 m, and 84 m) located in the expected airshed at Thayer. 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 26, 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 27). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 28, left graph) and directional semivariograms do not show anisotropy (Figure 28, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 28, right graph). The model indicates a distance of effective independence of 40 m for soil temperature.

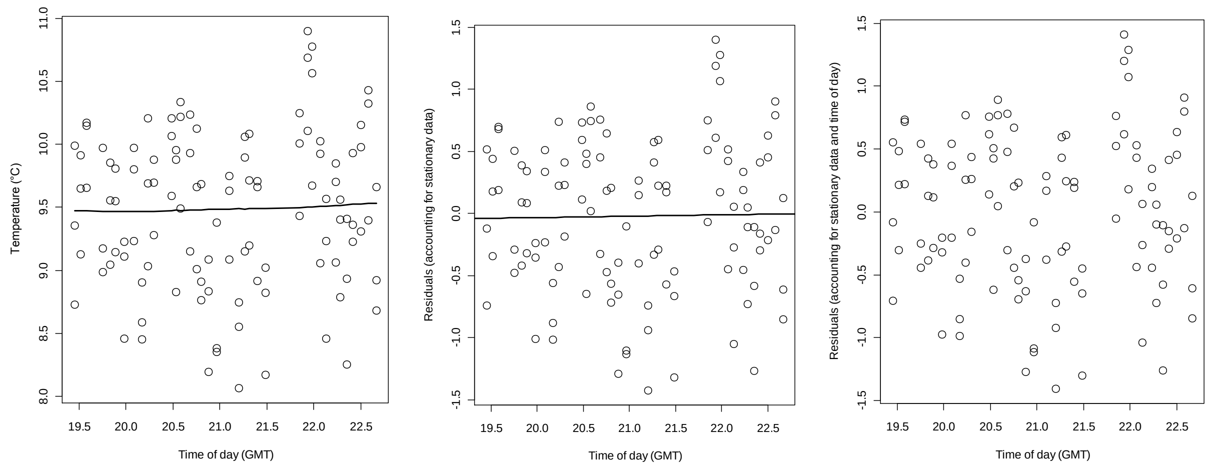


Figure 27. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting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

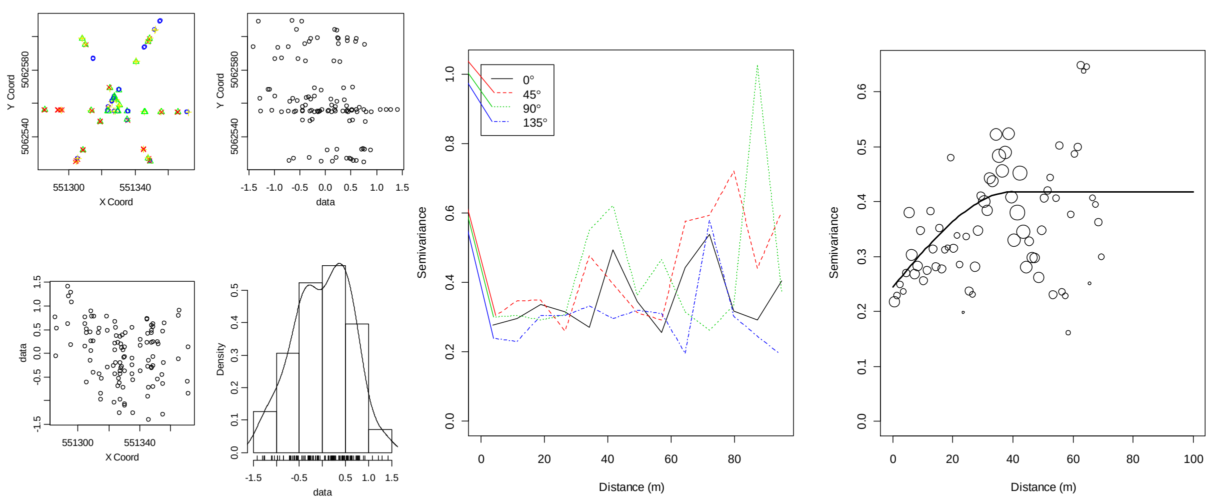


Figure 28. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

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 29). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 30, left graph) and directional semivariograms do not show anisotropy (Figure 30, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 30, right graph). The model indicates a distance of effective independence of >65 m for soil water content.

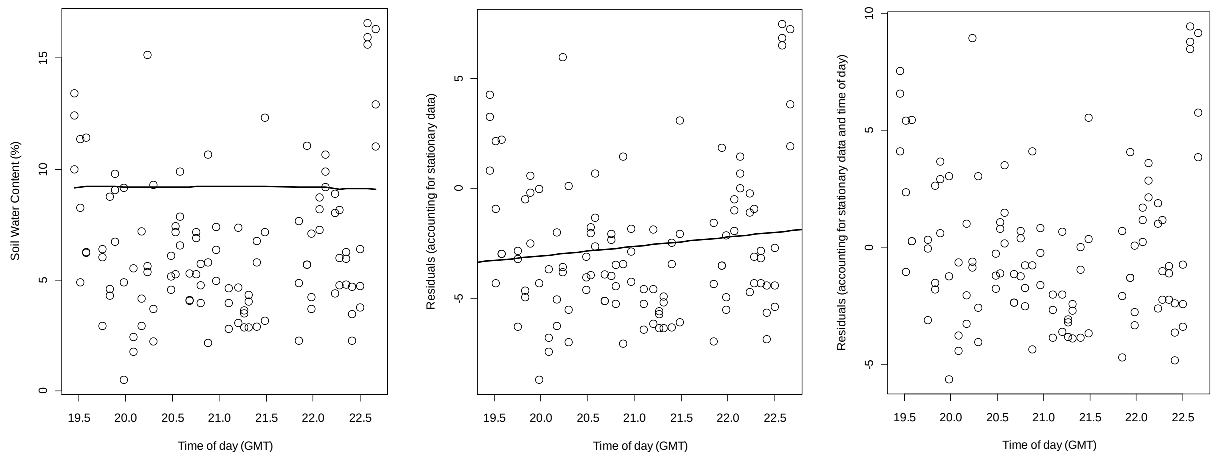


Figure 29. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting 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.

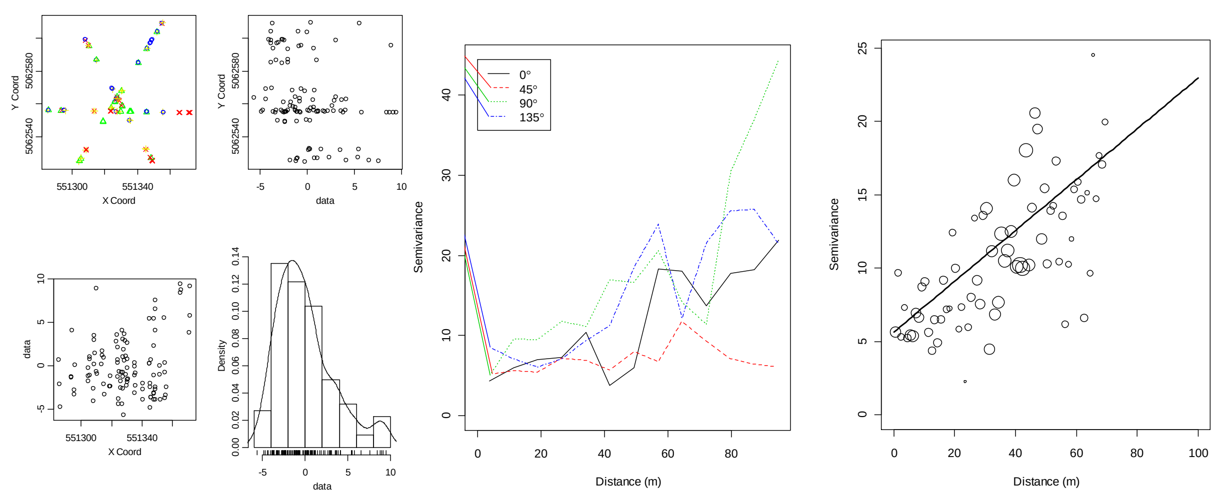


Figure 30. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

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 >65 m for soil moisture. Based on these results and the site design guidelines the soil plots at Thayer 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 133° from the soil plot nearest the tower (i.e., first soil plot). The location of the first soil plot will be approximately 45.714261, -122.340126. 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 45.713403°, -122.341609° (primary location); or 45.713161°, -122.341351° (alternate location 1 if primary location is unsuitable); or 45.713670°, -122.341863° (alternate location 2 if primary location is unsuitable). A summary of the soil information is shown in Table 11 and site layout can be seen in Figure 31.

Dominant soil series at the site: Kinney silt loam, 30 to 50 percent slopes. The taxonomy of this soil is shown below:
Order: Inceptisols
Suborder: Udepts
Great group: Dystrudepts
Subgroup: Andic Dystrudepts
Family: Fine-loamy, isotic, mesic Andic Dystrudepts
Series: Kinney silt loam, 30 to 50 percent slopes

Table 11. Summary of soil array and soil pit information at Thayer. 0° represents true north and accounts for declination.

Soil plot dimensions	5 m x 5 m
Soil array pattern	B
Distance between soil plots: x	40 m
Distance from tower to closest soil plot: y	16 m
Latitude and longitude of 1st soil plot OR direction from tower	45.714261, -122.340126
Direction of soil array	133°
Latitude and longitude of FIU soil pit 1	45.713403°, -122.341609° (primary location)
Latitude and longitude of FIU soil pit 2	45.713161°, -122.341351° (alternate 1)
Latitude and longitude of FIU soil pit 3	45.713670°, -122.341863° (alternate 2)
Dominant soil type	Kinney silt loam, 30 to 50 percent slopes
Expected soil depth	>2 m
Depth to water table	>2 m

Expected depth of soil horizons	**Expected measurement depths***
0-0.13 m (Silt loam)	0.07 m†

0.13-1.52 m (Gravelly silty clay)	0.83 m†
2 m	2 m†

*Actual soil measurement depths will be determined based on measured soil horizon depths at the NEON FIU soil pit and may differ substantially from those shown here.
†Expected soil CO_2 sensor depth (actual depths will be determined based on the FIU soil pit)

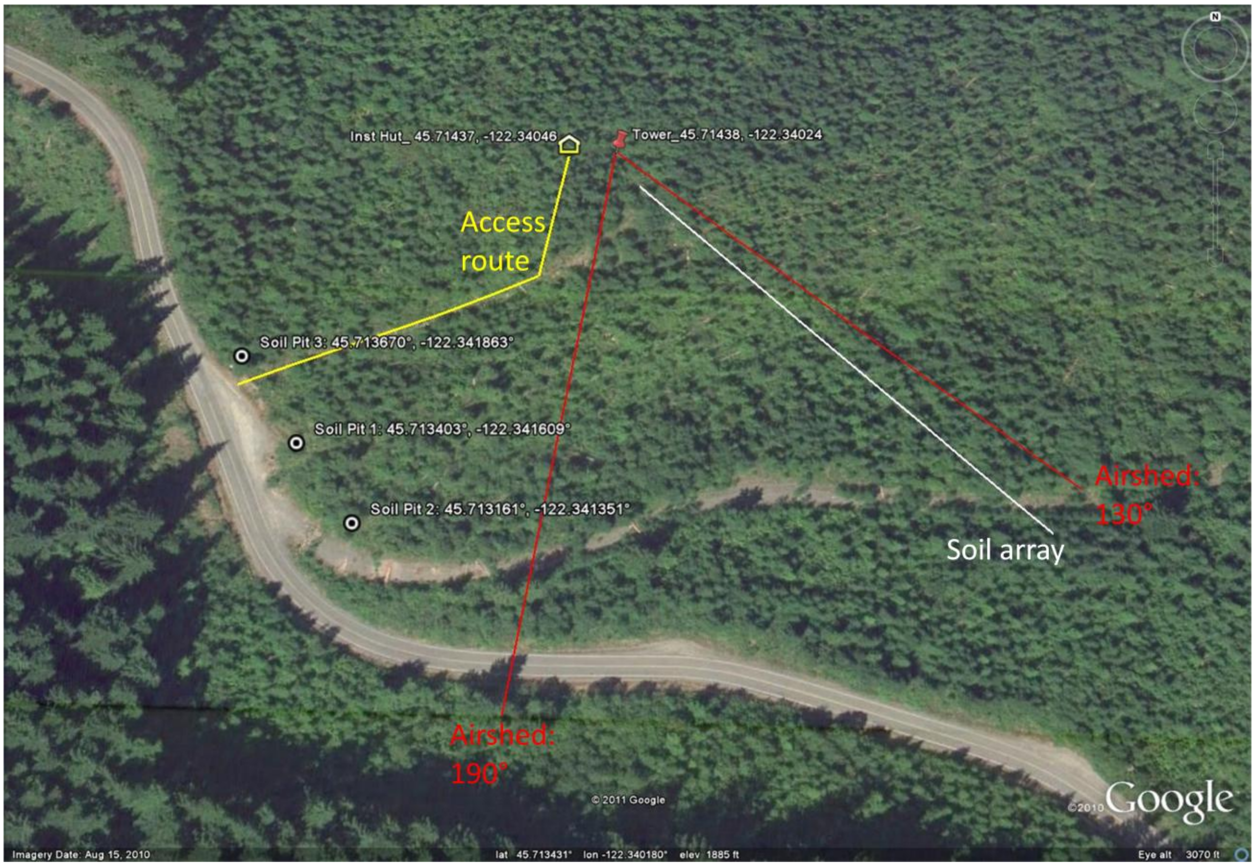


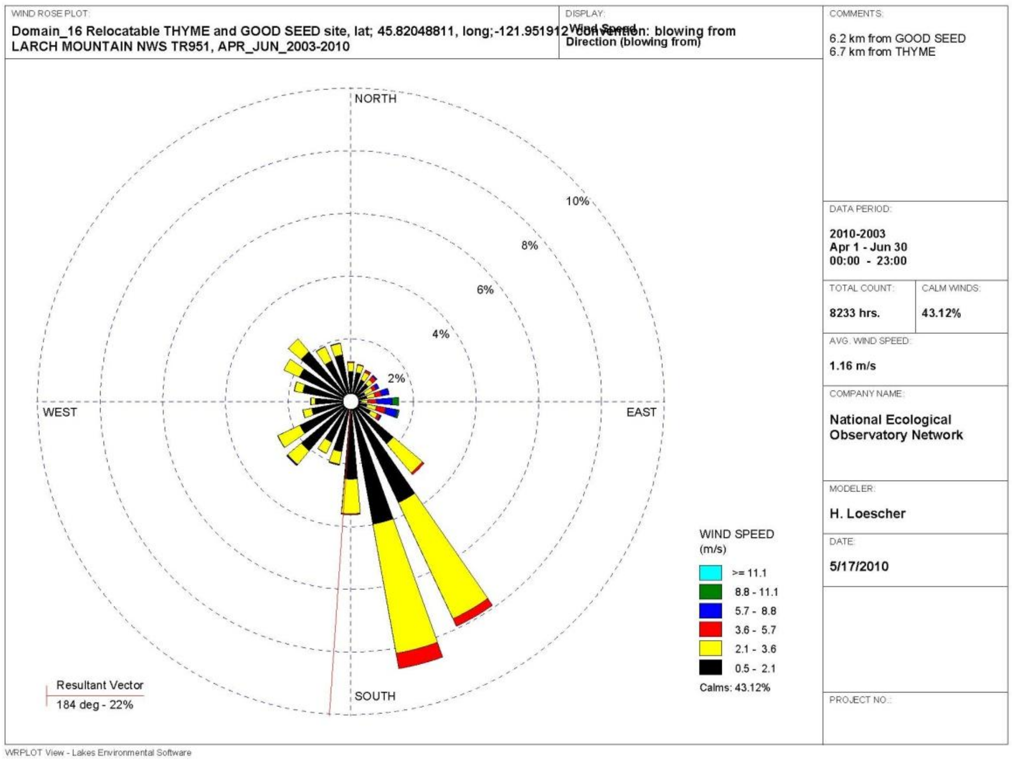
Figure 31. Site layout at Thayer showing soil array and location of the FIU soil pit.

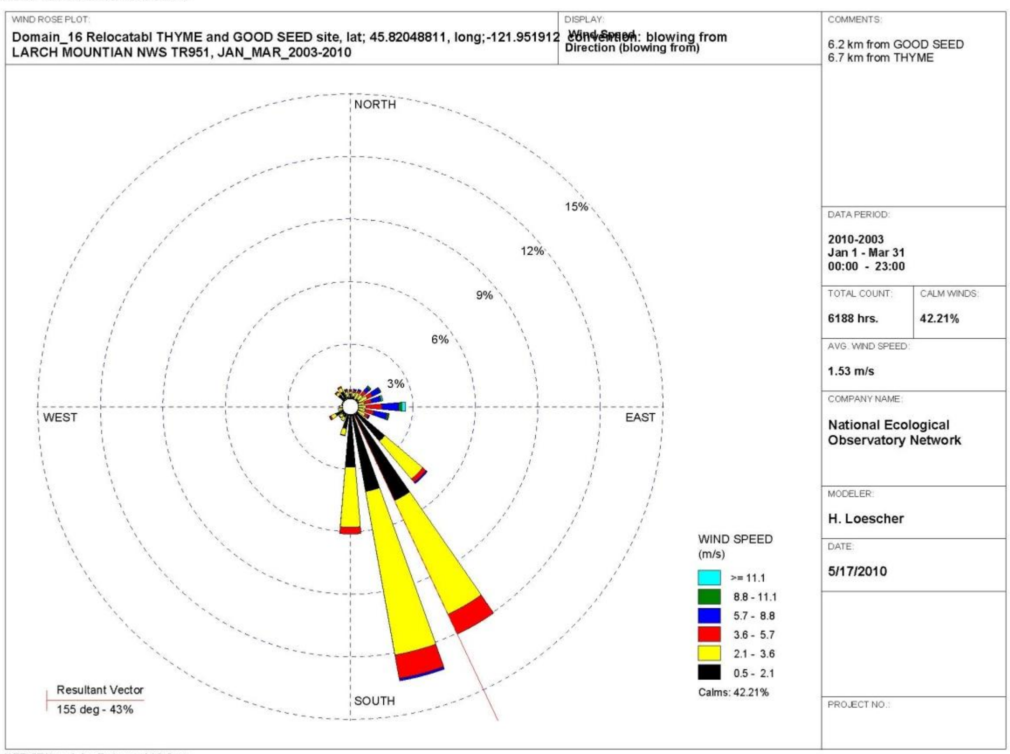
4.4 Airshed

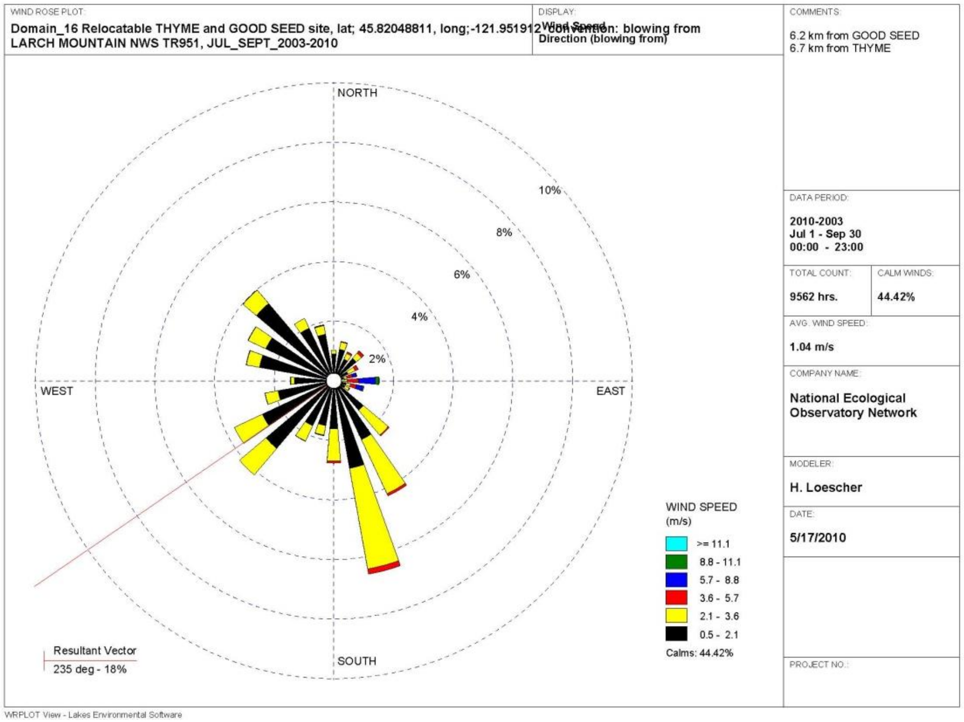
4.4.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries. The weather data used to generate the following wind roses are 2003 to 2010 data from MesoWest weather station at Larch Mountain (ID: TR951, Lat. 45.7231, Lon. -122.3453), which is ~1 km west to 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)







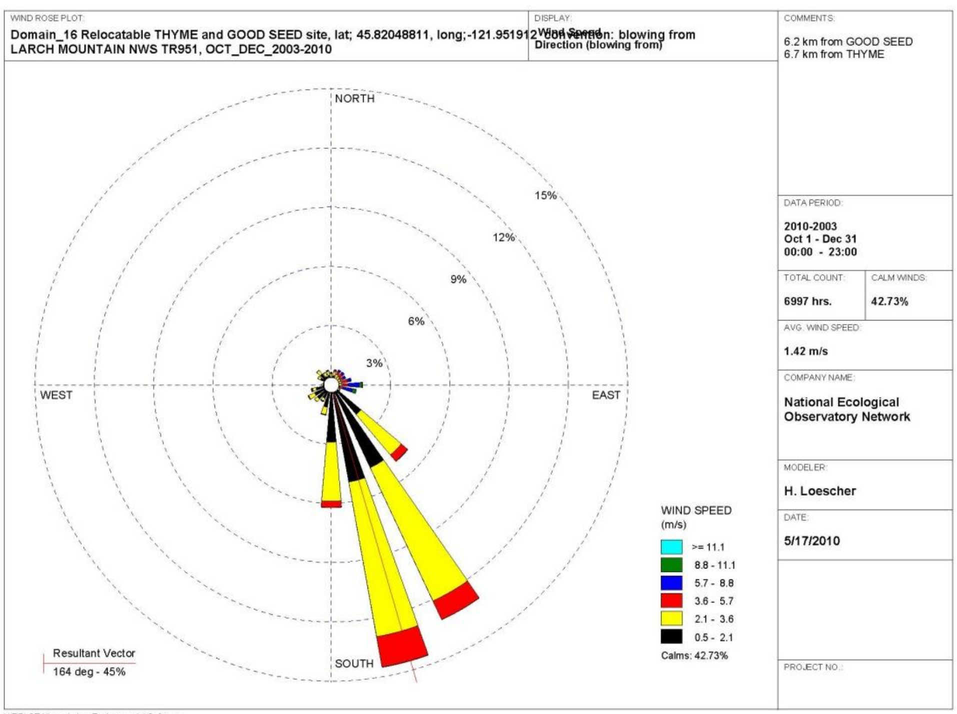


Figure 32. Windroses from Larch Mountain station for Thayer Relocatable site.
Data used here are 2003-2010 data from MesoWest station Larch Mountain (ID TR951) at 45.7231, -122.3453, which is ~1 km from tower site. It is assumed that the wind data was corrected for declination. Panels are (from top to bottom) Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

4.4.3 Resultant vectors

Table 12. The resultant wind vectors for Thayer Relocatable site using hourly data in 2003-2010.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	155°	43
April to June	184°	22
July to September	235°	18
October to December	164°	45
Annual mean	184.5	na.

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 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 represent 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.

Because the forest is actively growing at this site, the canopy height and required measurement height will change over time. We present two sets of footprint analysis outcome below for the time during construction (or at the beginning of operation) and for the time at the end of 8th year of operation, which is approximate the time to decommission NEON tower at this site.

Table 13. Expected environmental controls to parameterize the source area model and associated results from Thayer Relocatable tower site at the construction.

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	24	24	24	24	24	24	m
Canopy Height	12	12	12	12	12	12	m
Canopy area density	4	4	4	3	3	3	m
Boundary layer depth	1800	1800	900	800	800	600	m
Expected sensible heat flux	375	375	0	75	75	0	W m^{-2}
Air Temperature	27	27	18	9	9	-10	°C
Max. windspeed	5.8	2.2	1.2	5.8	1.6	1.6	m s^{-1}
Resultant wind vector	165	165	210	160	160	160	degrees
				Results			
(z-d)/L	-0.13	-0.68	0	-0.03	-0.53	0	m
d	9.8	9.8	9.8	9.6	9.6	9.6	m
Sigma v	2.2	1.8	0.28	1.6	0.91	0.38	m^2 s^{-2}
Z0	0.48	0.48	0.48	0.53	0.53	0.53	m
u*	0.76	0.44	0.14	0.73	0.29	0.19	m s^{-1}
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	700	250	1200	1000	300	1200	m
Distance of 80% cumulative flux	450	200	700	550	250	700	m
Distance of 70% cumulative flux	300	150	450	450	200	450	m
Peak contribution	75	35	85	85	35	85	m

Table 14. Expected environmental controls to parameterize the source area model and associated results from Thayer Relocatable tower site at the end of 8th year of operation.

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	30	30	30	30	30	30	m
Canopy Height	18	18	18	18	18	18	m
Canopy area density	5	5	5	4	4	4	m
Boundary layer depth	1800	1800	900	800	800	600	m
Expected sensible heat flux	375	375	0	75	75	0	W m^{-2}
Air Temperature	27	27	18	9	9	-10	°C
Max. windspeed	5.8	2.2	1.2	5.8	1.6	1.6	m s^{-1}
Resultant wind vector	165	165	210	160	160	160	degrees
Results							
(z-d)/L	-0.11	-0.53	0	-0.03	-0.44	0	m
d	15	15	15	15	15	15	m
Sigma v	2.3	1.8	0.3	1.7	0.94	0.41	m^2 s^{-2}
Z0	0.64	0.64	0.64	0.71	0.71	0.71	m
u*	0.82	0.49	0.15	0.78	0.31	0.21	m s^{-1}
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	750	250	1200	1000	350	1100	m
Distance of 80% cumulative flux	450	200	700	500	200	700	m
Distance of 70% cumulative flux	300	150	450	300	150	450	m
Peak contribution	75	25	85	85	35	85	m

4.4.5 Results (source area graphs)

By the time of construction:

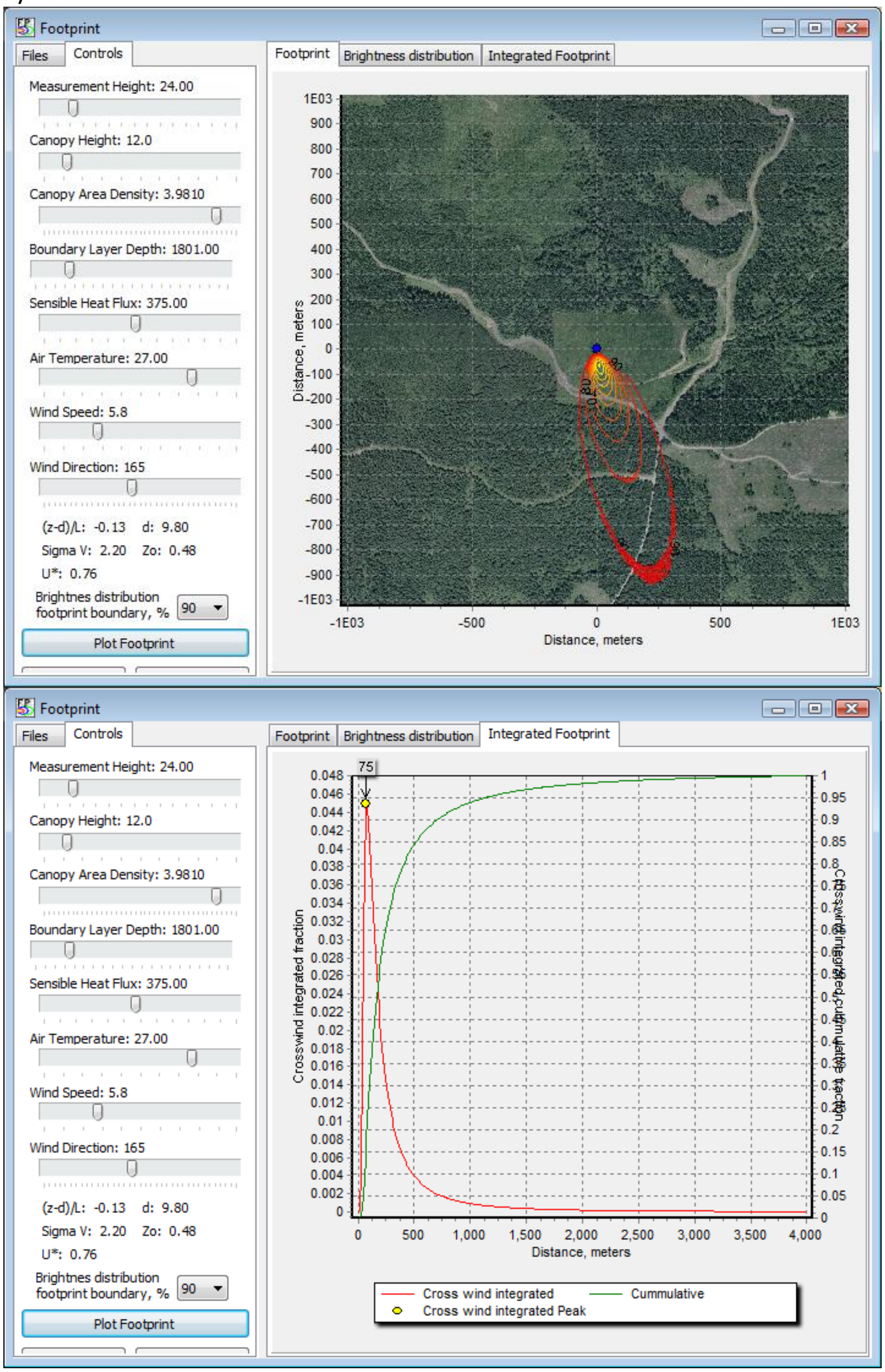


Figure 33. Thayer Relocatable site summer daytime (convective) footprint output with max wind speed at construction

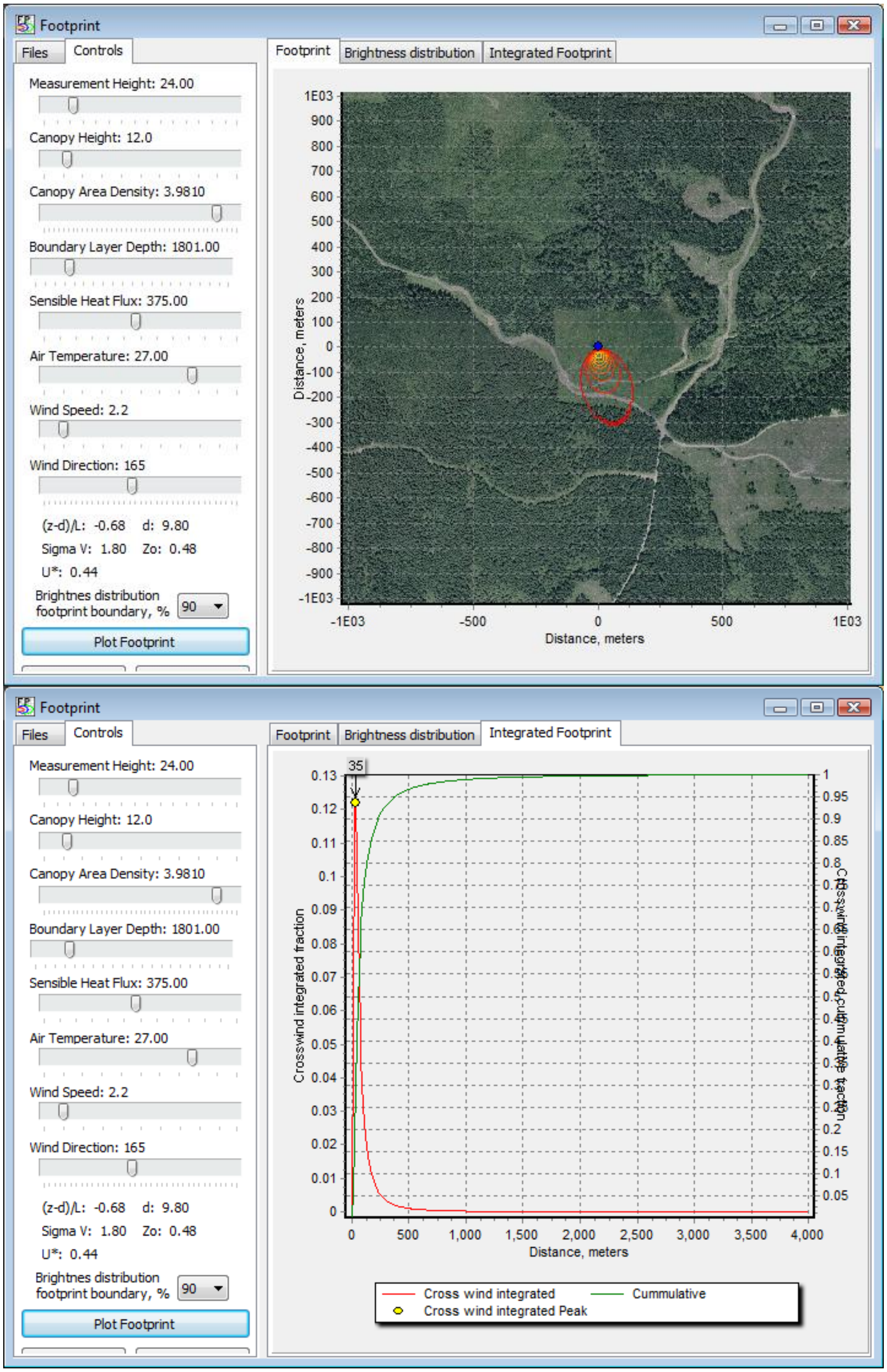


Figure 34. Thayer Relocatable site summer daytime (convective) footprint output with mean wind speed at construction

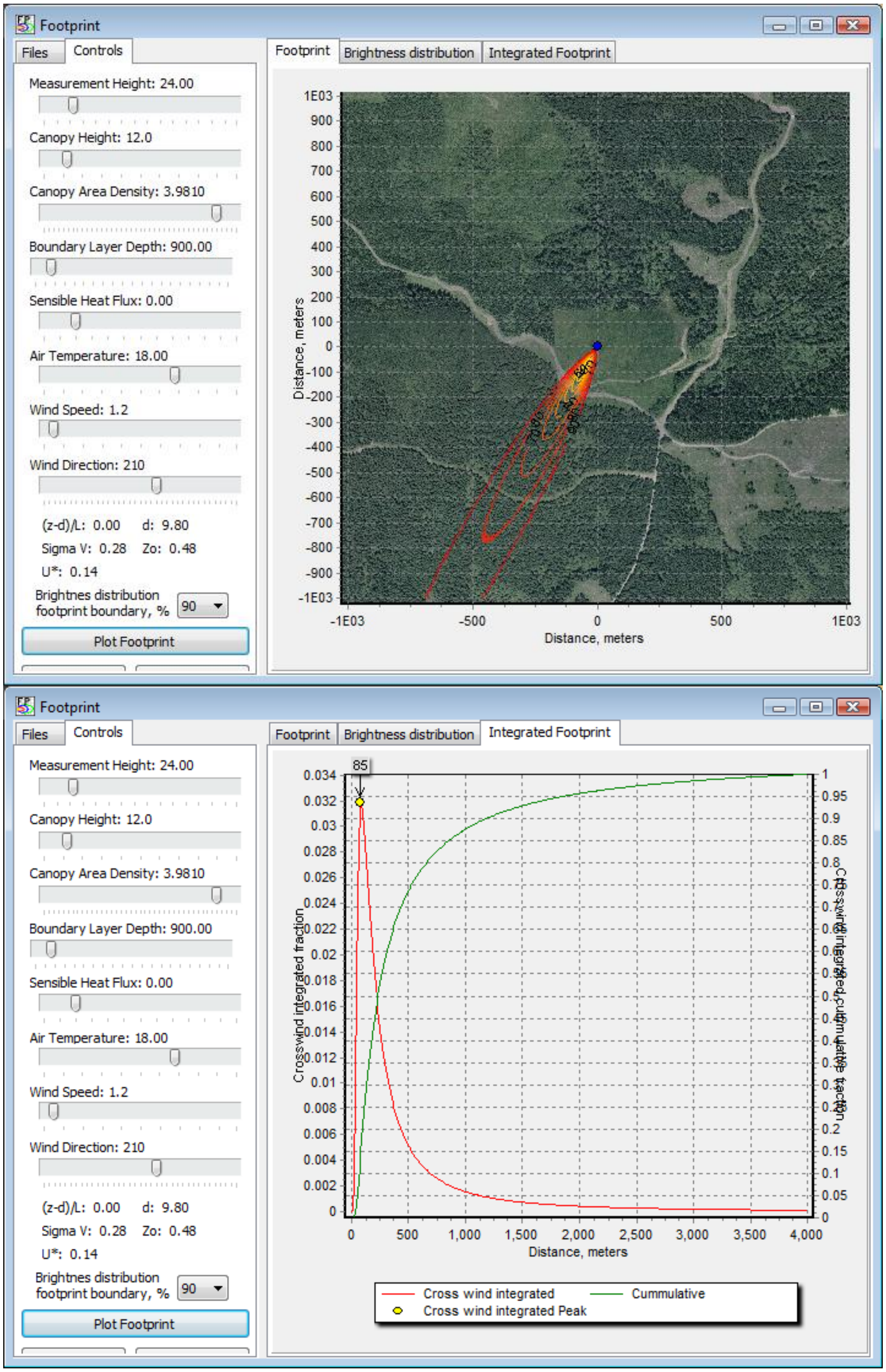


Figure 35. Thayer Relocatable site summer nighttime (stable) footprint output with mean wind speed at construction.

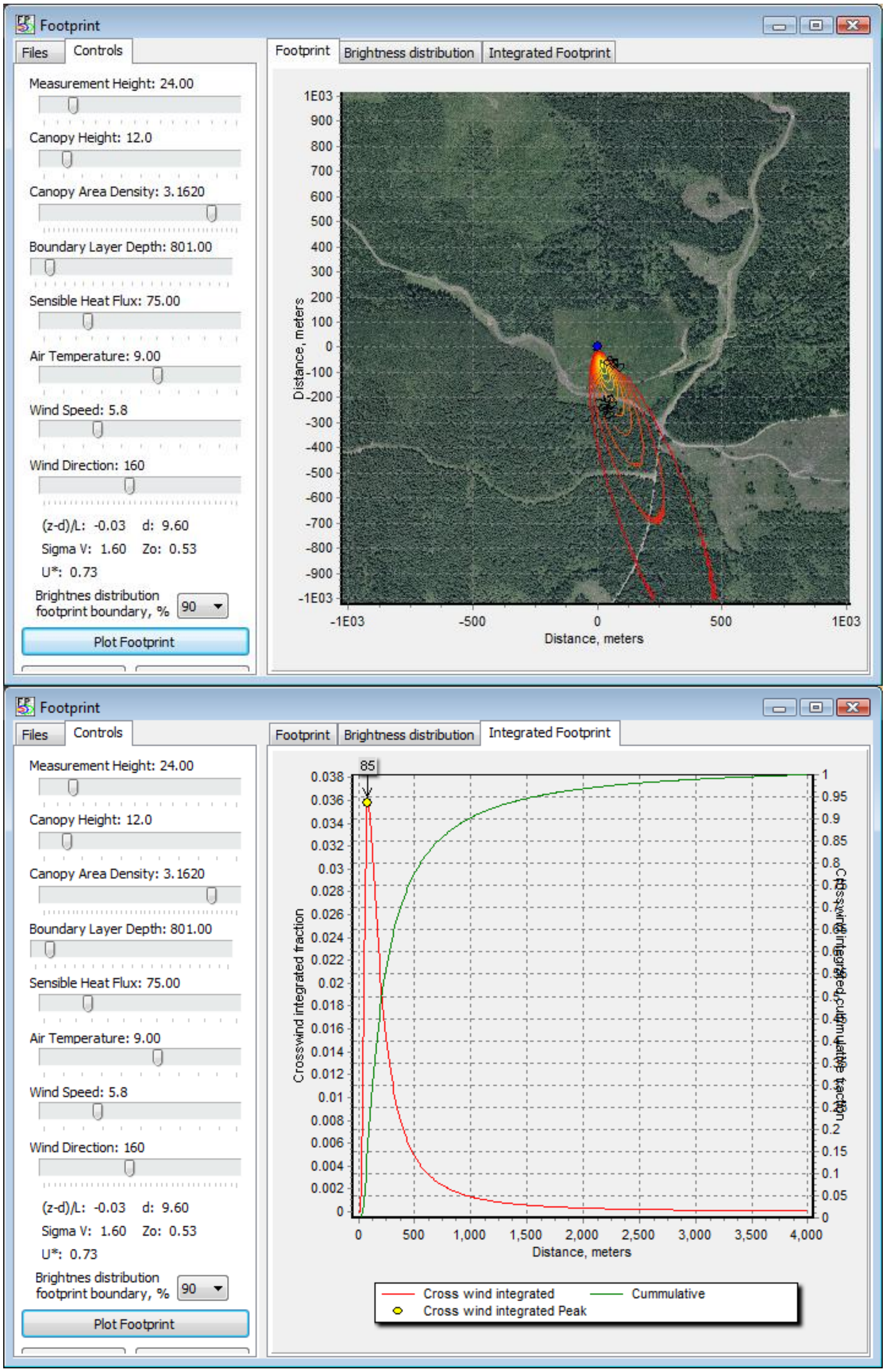


Figure 36. Thayer Relocatable site winter daytime (convective) footprint output with max wind speed at construction

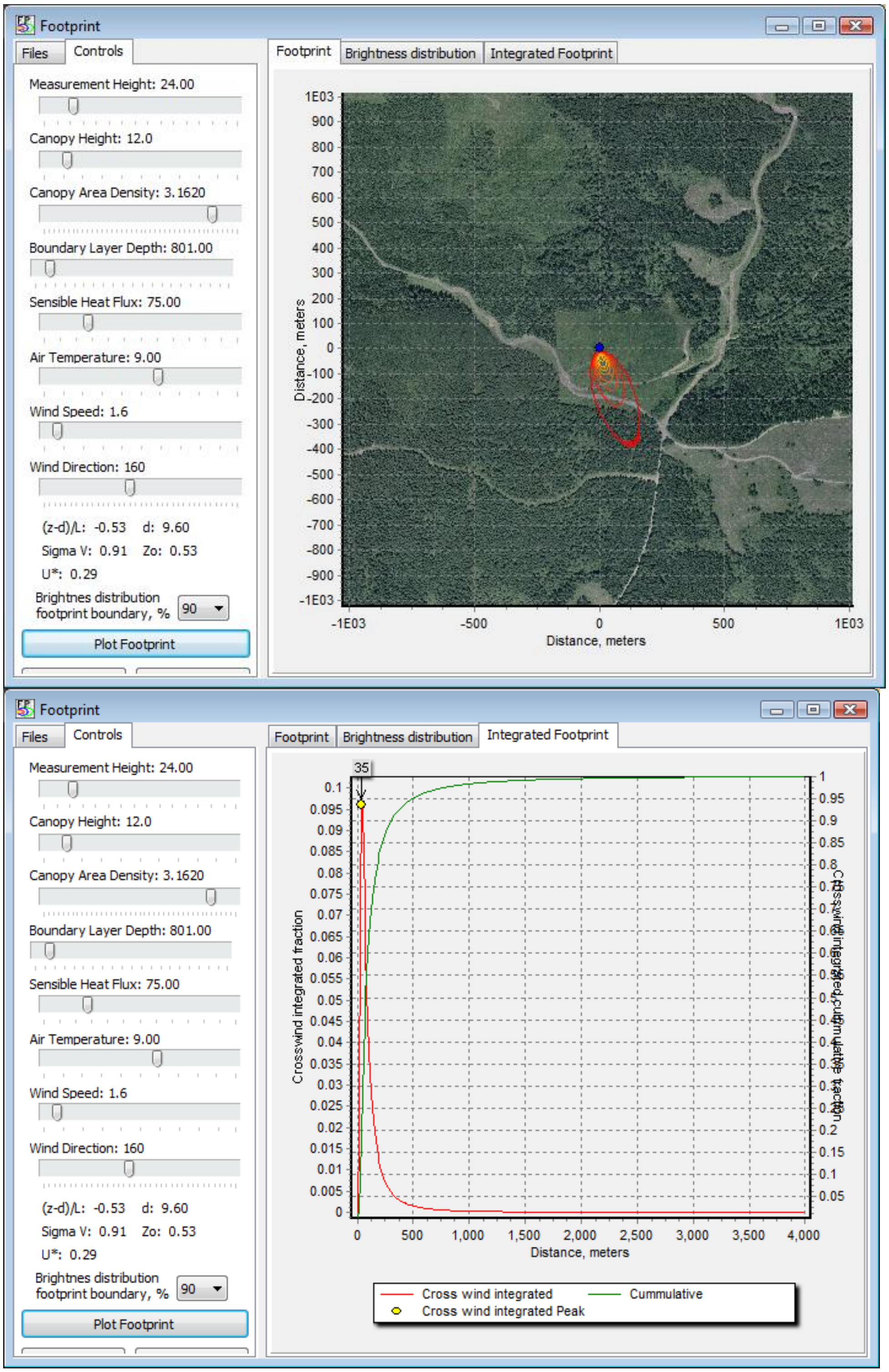


Figure 37. Thayer Relocatable site winter daytime (convective) footprint output with mean wind speed at construction.

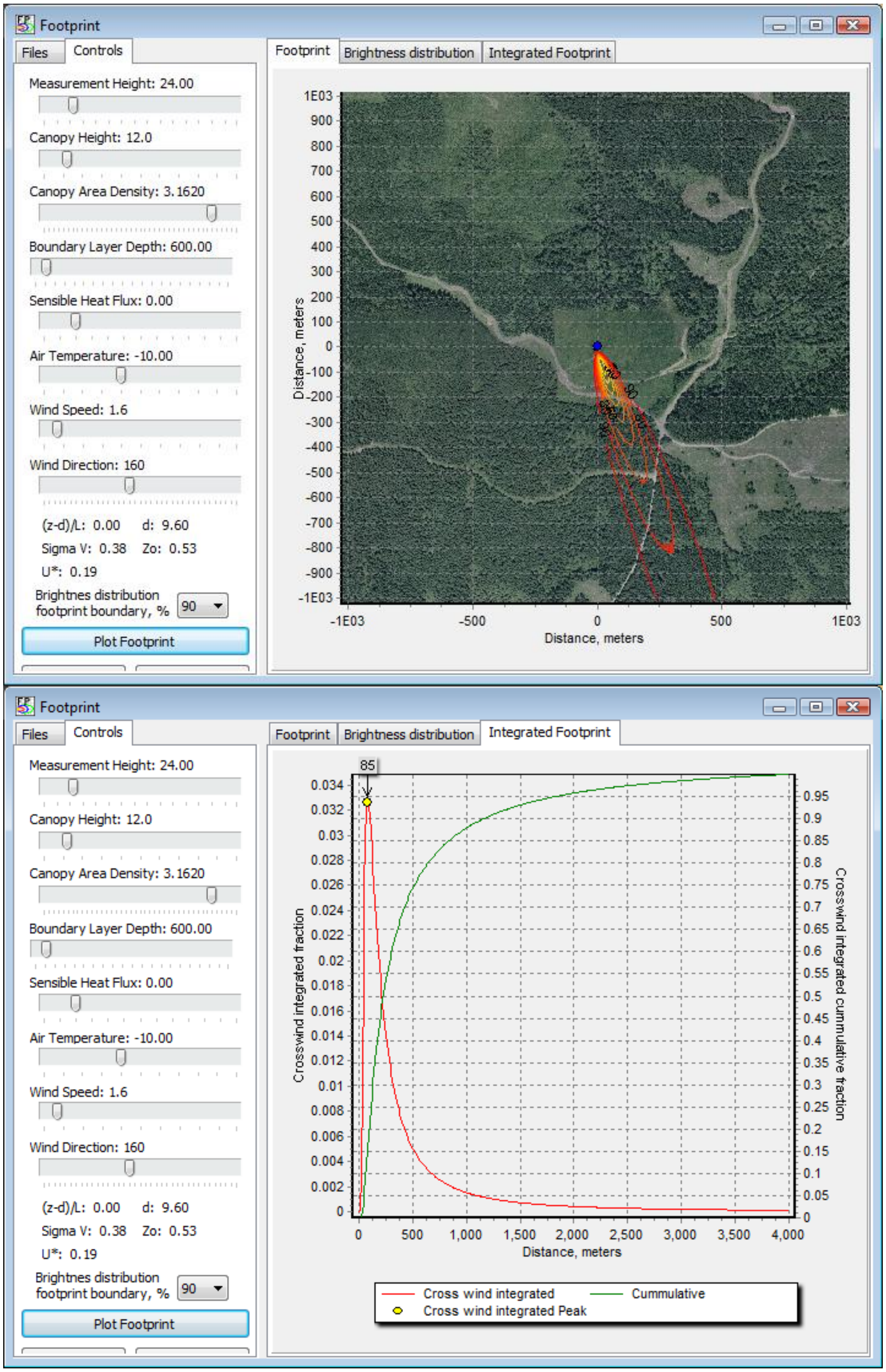


Figure 38. Thayer Relocatable site winter nighttime (stable) footprint output with mean wind speed at construction.

By the time NEON tower operates for 8 years:

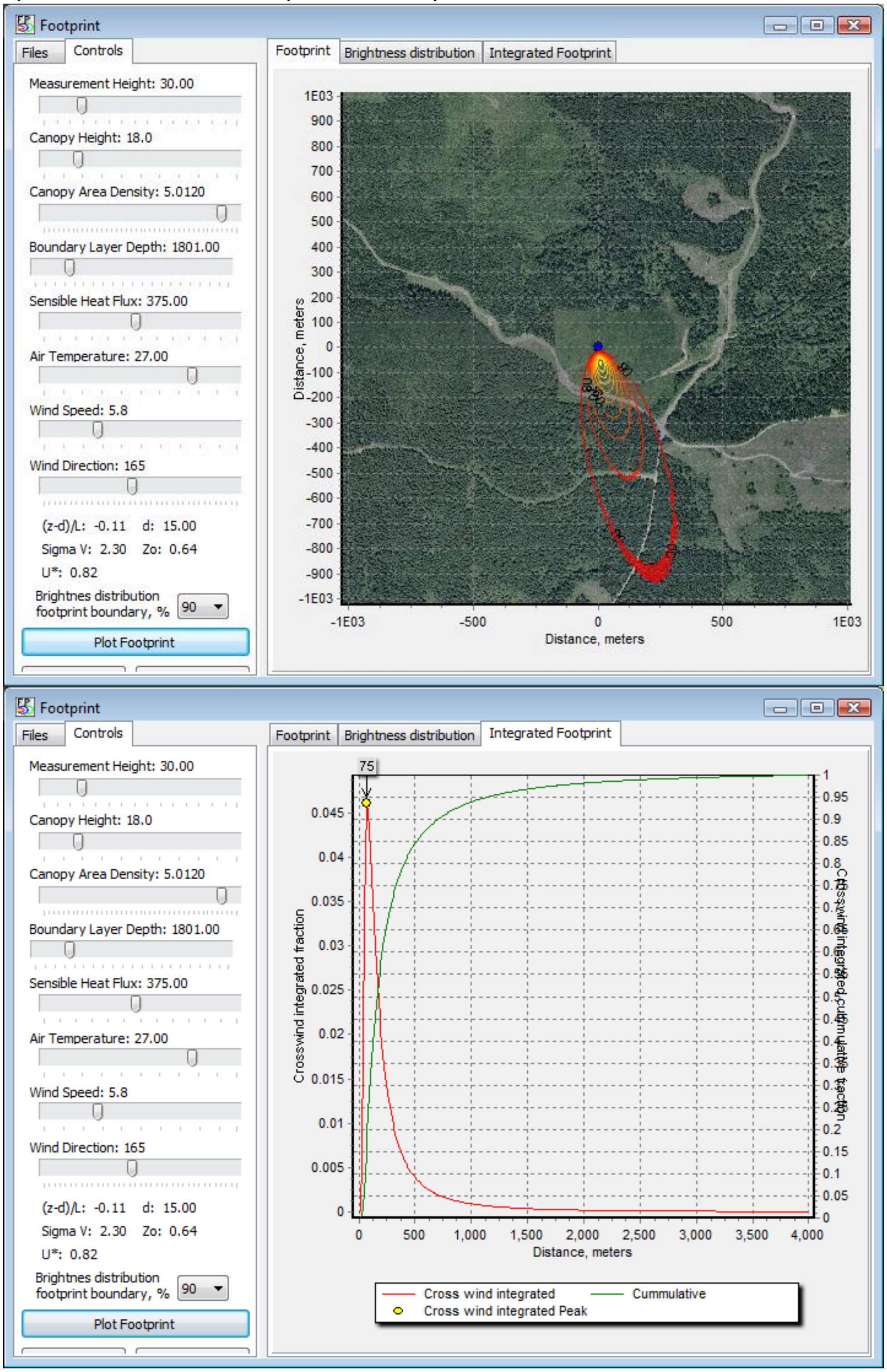


Figure 39. Thayer Relocatable site summer daytime (convective) footprint output with max wind speed at the end of operation

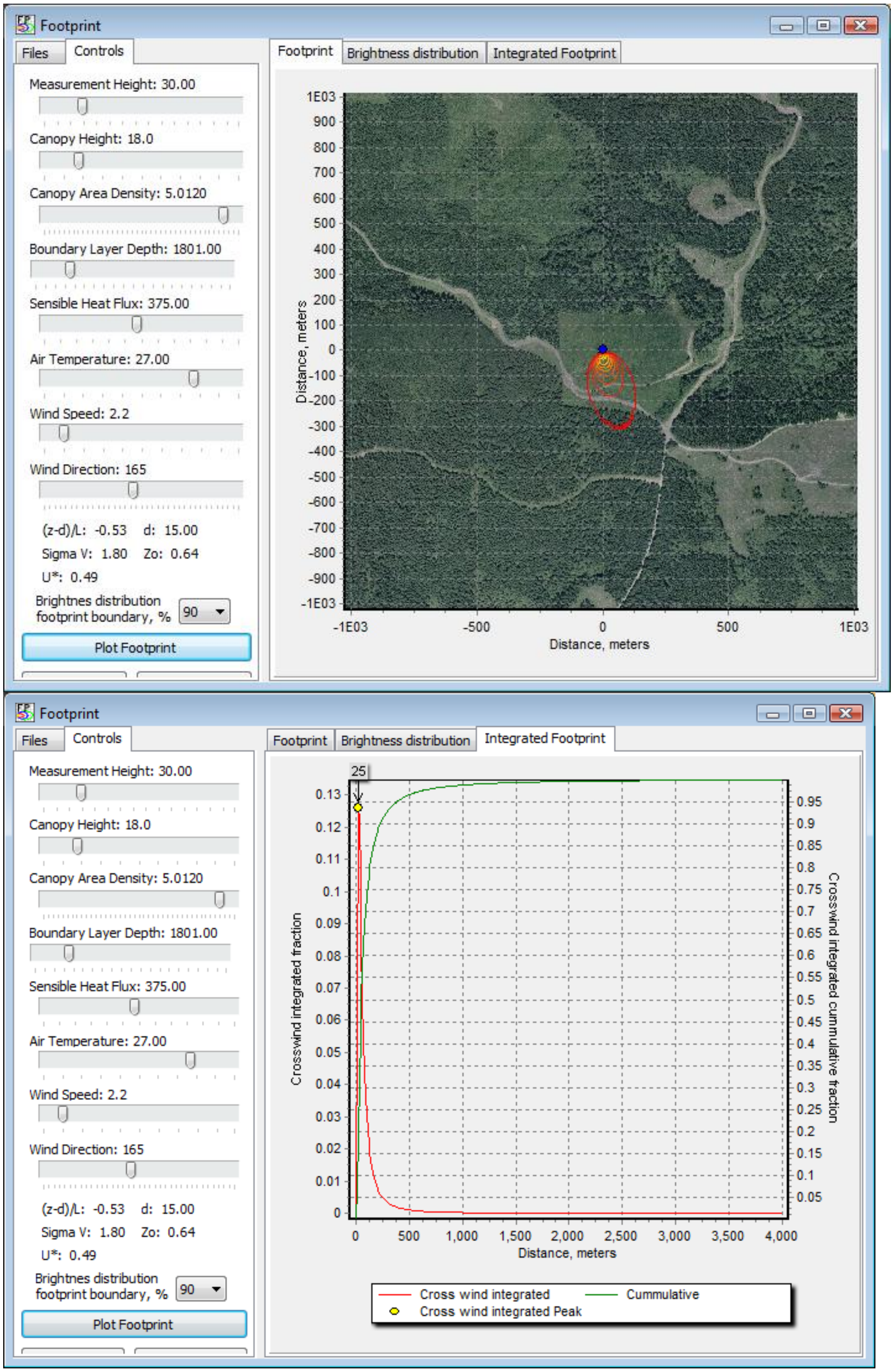


Figure 40. Thayer Relocatable site summer daytime (convective) footprint output with mean wind speed at the end of operation

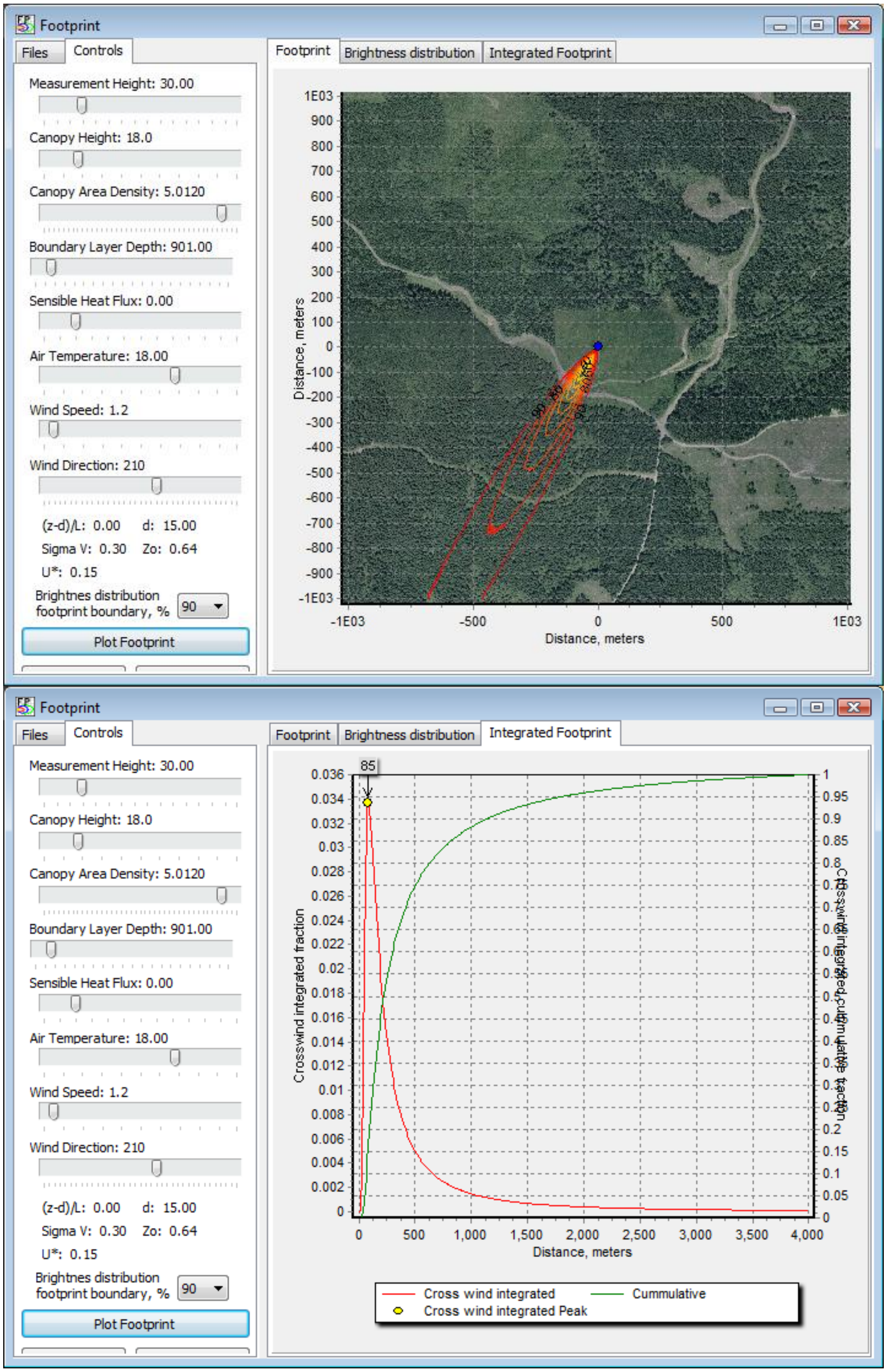


Figure 41. Thayer Relocatable site summer nighttime (stable) footprint output with mean wind speed at the end of operation.

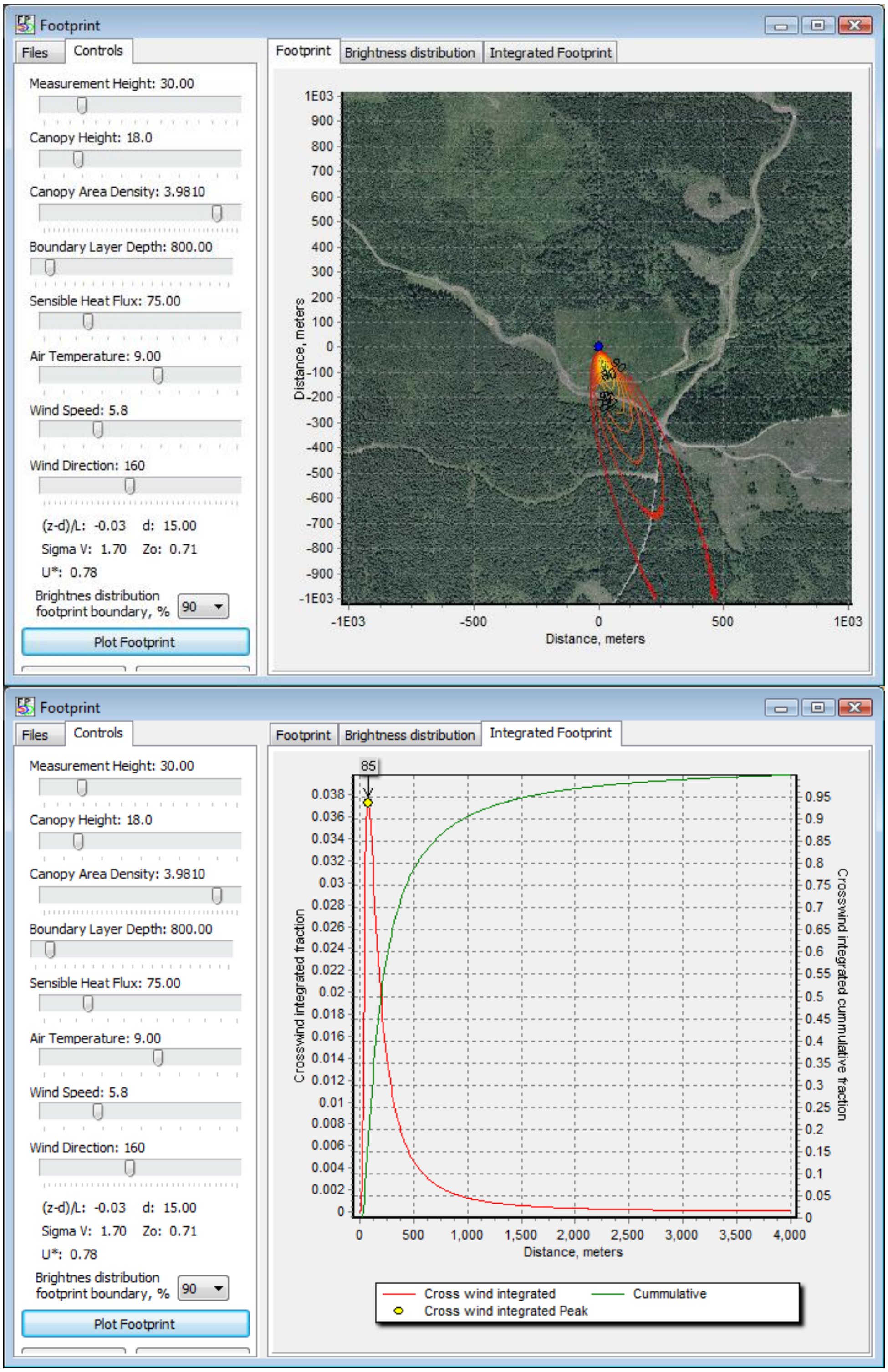


Figure 42. Thayer Relocatable site winter daytime (convective) footprint output with max wind speed at the end of operation

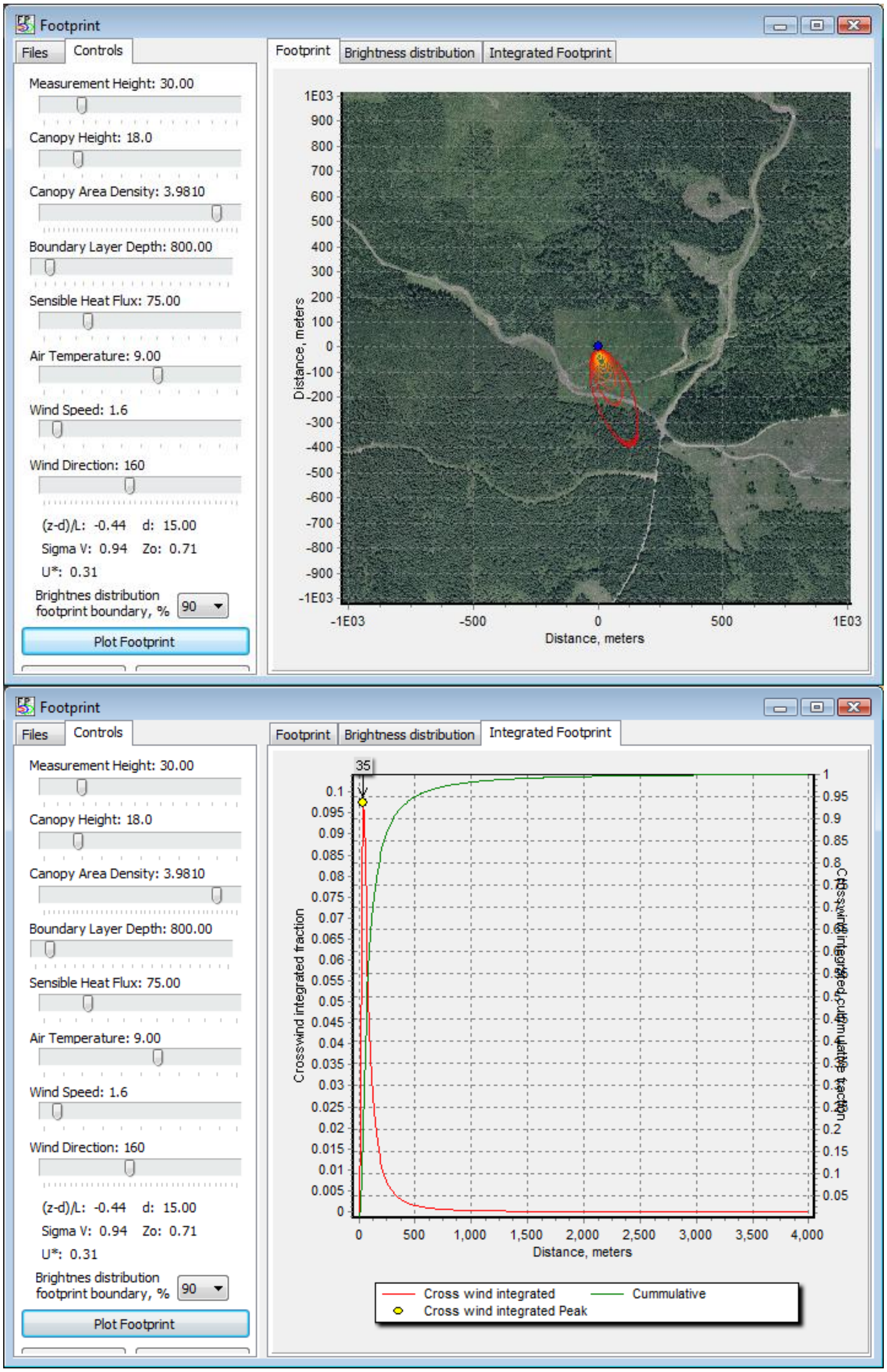


Figure 43. Thayer Relocatable site winter daytime (convective) footprint output with mean wind speed at the end of operation.

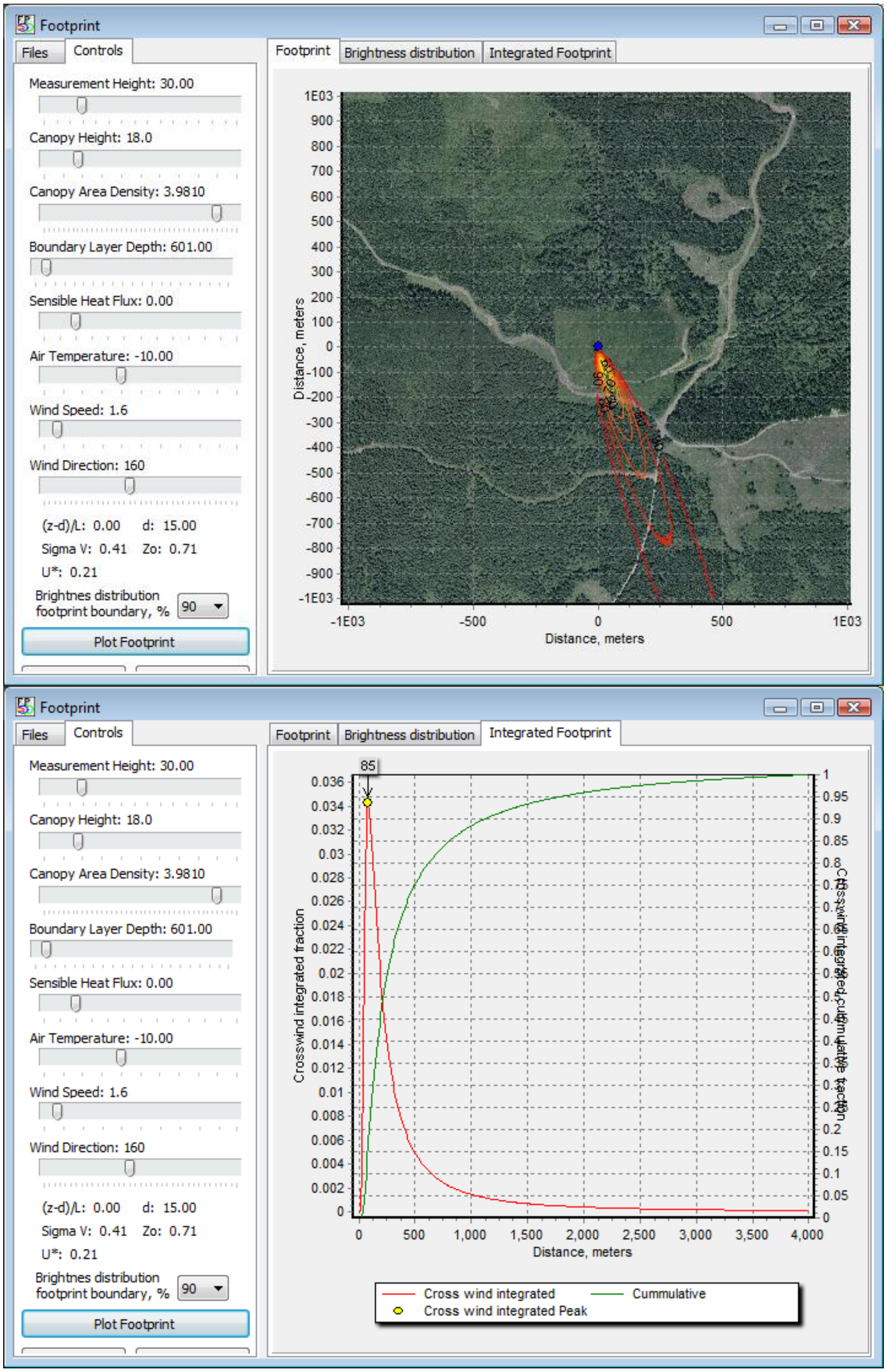


Figure 44. Thayer Relocatable site winter nighttime (stable) footprint output with mean wind speed at the end of operation.

4.4.6 Site design and tower attributes

According to wind roses, wind can blow from any direction between SE and NW, but prevailing wind blows from SSE direction (130^o to 190^o, clockwise from 130^o). **Tower** should be placed to a location to best catch the signals from the airshed of the ecosystem in interest, which is young Douglas fir forest at this site. We determined that the tower location is at 45.71438, -122.34024. However, due to the small size of this young Douglas fir parcel, fetch area of the tower at this site is likely to go beyond the boundary of this management parcel and extend into neighbor managements parcels (which are forest at different heights), particularly under daytime strong wind conditions and nighttime calm wind condition (see footprint analysis results above). Edge effects and uncertainties, therefore, cannot be avoided.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the south 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 west toward tower and have the longer side parallel to SE-NW direction. Therefore, we decide the placement of instrument hut at 45.71437, -122.34046.

The ecosystem around tower and inside the major airshed is young Douglas fir forest. Canopy height is currently ~10-12 m and average ~11 m. Trees grow actively (~0.5 m per year). Assume the construction at this site will be in 2012 or 2013, which will give canopy height ~ 12 m. The mean canopy height will be expected to reach ~ 18 m after 8 years of operation, which is approximately by the time NEON relocatable tower decommissioned at this site. Shrub layer presents with height ~ 3 m. The understory at forest floor is ~ 0.3 m tall. Tree height shall be reevaluated at the time of construction to ensure the tower height and boom heights are appropriate.

Because this is a young tree plantation, the tree height will change prior to construction, and during our operational period. This plant canopy is rapidly accruing height and will continue to grow for several decades. If the tower was to be built on site characterization date (10/20/10), the tower height would be 21 m.a.g.l. If we assume construction will occur 2 years from this date, i.e., late 2012, then the top measurement level shall be 24 m.a.g.l. During operations the tower height will also need to be increased according to the FIU Science Requirements, for example at the end of 8 years of operation (late 2020) the top measurement level will need to be 30 m.a.g.l. For the remainder of this site characterization, we assume the site will be constructed in 2012, and require a tower height of 24 m.a.g.l. ***If the schedule changes for whatever reason, this height will have to be re-calculated.*** Therefore, we require 5 **measurement layers** on the tower with top measurement height at 24 m, and the remaining levels are 15 m, 9 m, 3.0 m, and 0.3 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 **wet deposition collector** will be 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.

Table 15. Site design and tower attributes for Thayer Relocatable site

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

Attribute	lat	long	degree	meters	notes
Airshed area			130° to 190°		Clockwise from first angle
Tower location	45.71438,	-122.34024	--	--	new site
Instrument hut	45.71437,	-122.34046			
Instrument hut orientation vector	--	--	160° - 340°		
Instrument hut distance z	--	--	--	17	
Anemometer/Temperature boom orientation	--	--	180°	--	
Height of the measurement levels*					
Level 1				0.3	m.a.g.l.
Level 2				3.0	m.a.g.l.
Level 3				9.0	m.a.g.l.
Level 4				15.0	m.a.g.l.
Level 5				24.0	m.a.g.l.
Tower Height				24.0	m.a.g.l.

* These dimensions assume a late 2012 construction, see text above. Any change to this schedule the heights would have to be re-calculated.
See AD 03 for technical requirement to determine the boom height for the bottom most measurement level.

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

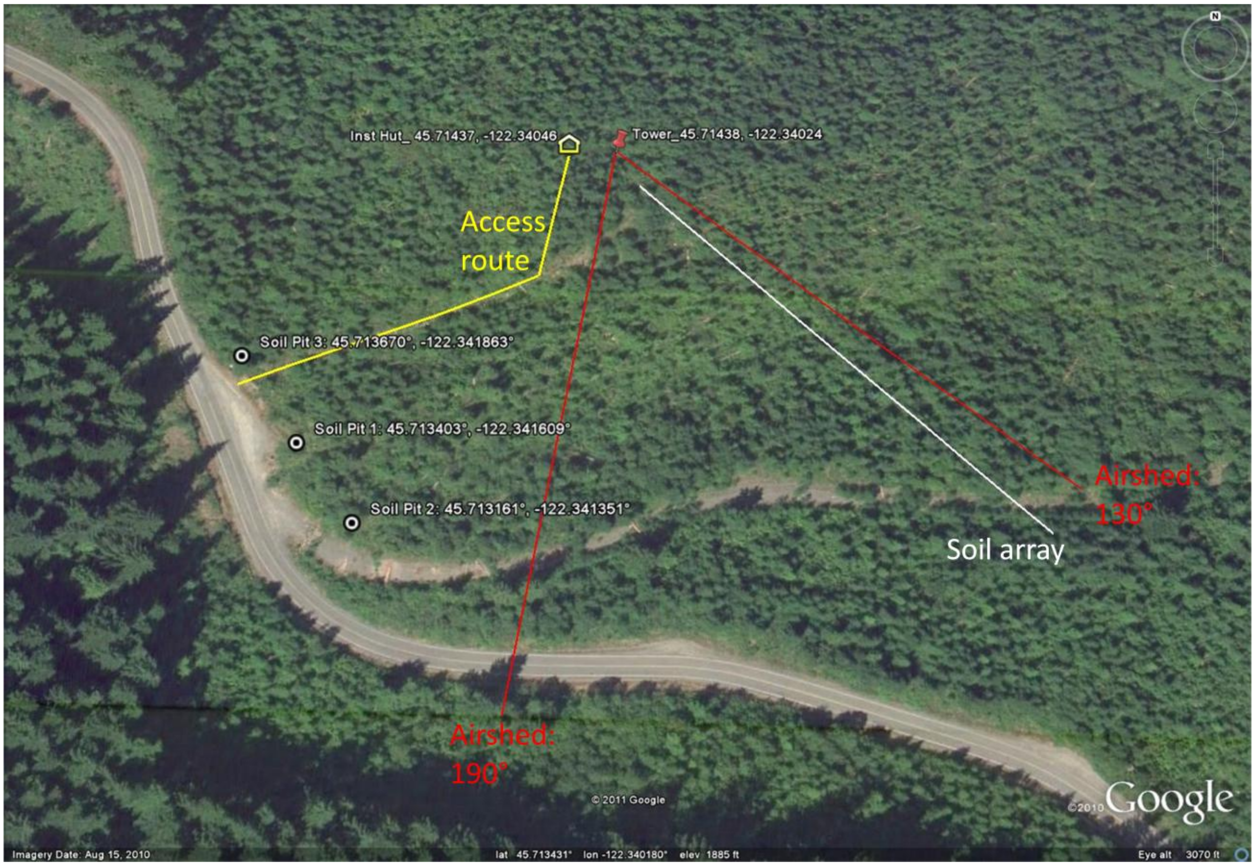


Figure 45. Site layout for Thayer Relocatable site.
i) tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 130° to 190° (clockwise from 130°) would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access 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 Thayer Relocatable site

- Boardwalk from the access point to the 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
- No boardwalk to individual soil plots

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

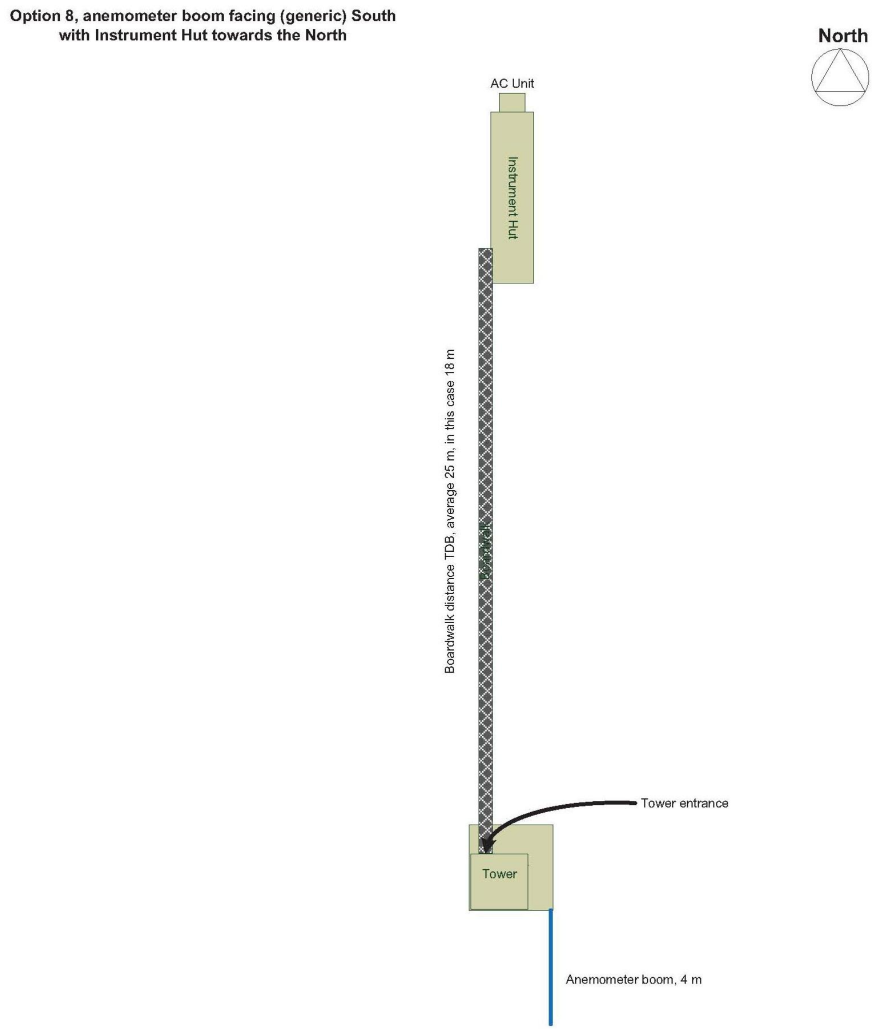


Figure 46. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing south and instrument hut on the north towards the tower.

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 Thayer Relocatable site, the boom angle will be 180^{o}, instrument hut will be on the west towards the tower, the distance between instrument hut and tower is ~17 m. The instrument hut vector will be SE-NE (160^{o}-340^{o}, longwise).

4.4.7 Information for ecosystem productivity plots

The tower at Thayer relocatable site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (young Douglas fir forest). Prevailing wind blows from 130° to 190°, clockwise from 130°. Due to the actively growing ecosystem and adjustment of the height of top measurement level over time, tower fetch area will change accordingly. We expect that 90% signals for flux measurements during daytime are within a distance of 350 m from tower for mean wind speed conditions over the operation period of 8 years, and 80% within 250 m. But during nighttime stable calm wind conditions and daytime maximum wind speed, flux sensor on tower can detect signals beyond 1 km from tower. We suggest FSU Ecosystem Productivity plots are placed within the boundaries of 130° to 190° (major, clockwise from 130°) from tower.

4.5 Issues and attentions

Site is very small. Only ~70% flux signals during daytime are within the same management plot of young Doglas fir forest; ~ 30% daytime signal and some nighttime signals will be from the neighboring mature forest in the major airshed, which is south to southeast to tower. It will be challenging to intepret the measurement results. However, this cannot be easily avoided in this region, because landownership and forest management practices are based on small parcels in this region and Washington Department of Natural Resources guidelines do not allow adjacent forest units to be harvested within 6 years of each other.

The plant canopy is actively and rapidly accruing height. Design, construction and operations need to take this into account. During the site characterization visit mean canopy height was ~11 m. We assume the construction at this site will be in 2012 or 2013 and that the tree growth rate is ~0.5 m/yr, which will give canopy height ~ 12 m at construction. The mean canopy height is expected to reach ~ 18 m after 8 years of operation, which is approximately by the time NEON relocatable tower decommissioned at this site. For any change to this schedule the heights would have to be re-calculated. FCC should design and budget adequate tower height ahead and allow the increase of the top measurement level to 30 m. Tree height shall be reevaluated at the time of construction to ensure the tower height and boom heights are appropriate.

The landowner requests that the boardwalk goes around the trees at this site, rather than cut them down. The trees are relatively young (~10-12 years old) and may have stem diameters below the threshold diamieter usually recorded by a site surveyors for NEON's Facilities and Civel Construction (FCC) group. A special request to record smaller diameter stems may be necessary for the construction survey at this site.

5 ABBY ROAD, RELOCATEABLE TOWER 2

5.1 Site description

The Abby Road site is managed by the Washington Department of Natural Resources (WDNR). The site is harvested for timber, and managed according to WDNR guidelines. There is a campground nearby (1-2 km from the site).

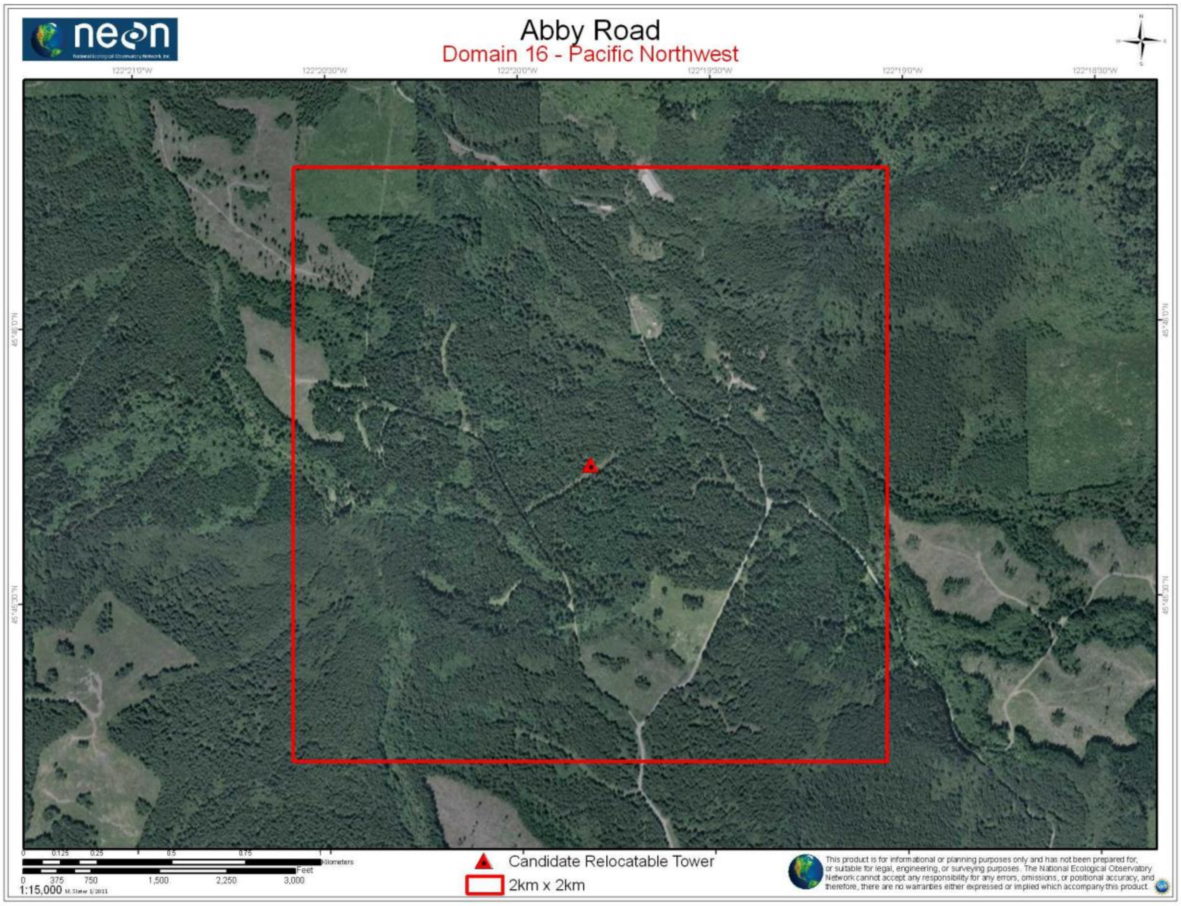


Figure 47. Abby Road site and original tower location.

5.2 Ecosystem

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

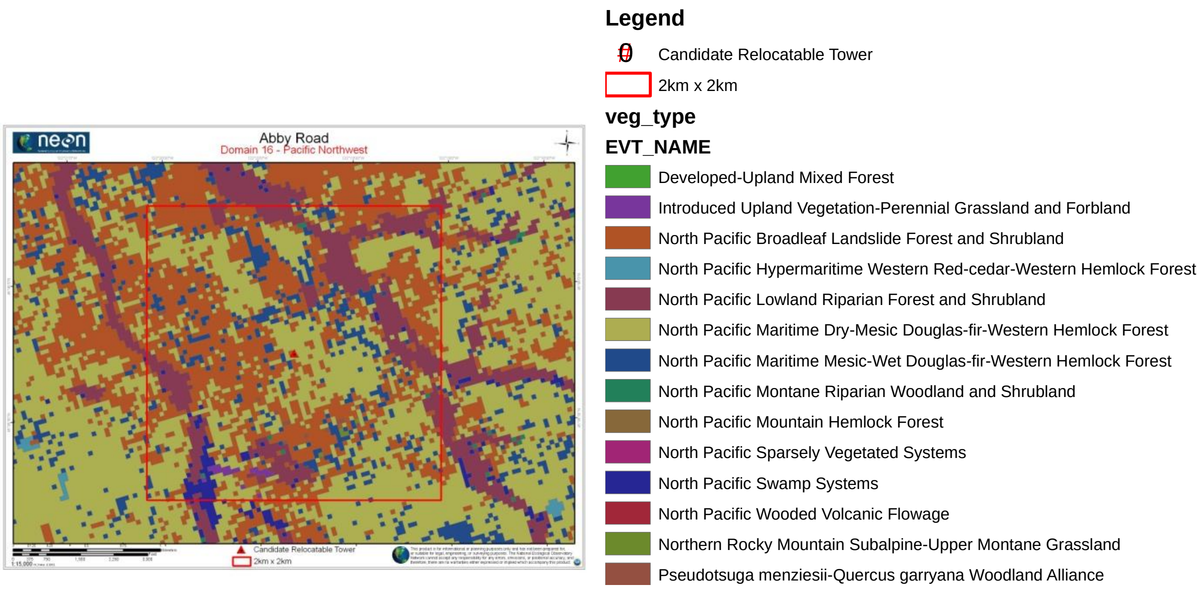


Figure 48. Vegetative cover map of the Abby Road relocatable site and surrounding areas (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

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

Vegetation_Type	Area_Km2	Percentage
Introduced Upland Vegetation-Perennial Grassland and Forbland	0.019	0.47
North Pacific Broadleaf Landslide Forest and Shrubland	1.498	37.46
North Pacific Lowland Riparian Forest and Shrubland	0.527	13.17
North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest	1.491	37.28
North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	0.372	9.29
North Pacific Montane Riparian Woodland and Shrubland	0.005	0.13
North Pacific Mountain Hemlock Forest	0.002	0.04
North Pacific Swamp Systems	0.065	1.62
Northern Rocky Mountain Subalpine-Upper Montane Grassland	0.004	0.11
Pseudotsuga menziesii-Quercus garryana Woodland Alliance	0.017	0.42
TOTAL	4.000	100

Tower location is inside a small forest management parcel (approximately 450 m × 500 m), which is a typical size for management units in this region. This parcel was recently logged and re-planted with Douglas fir (seedlings are 4-6 years old). Large mature forests ~34 m are at the edge of all sides this management parcel. In addition, there are patches of matures trees within the parcel; WDNR managements practices require of proportion of mature trees to be retained when a parcel of land is harvested. This will result in large edge effects and uncertainties for flux measurements over this young forest.

The ecosystem around tower and inside the major airshed is young Douglas fir forest, which is 4-6 years old. Canopy height is currently ~1 m. The trees are growing actively (~0.5 m per year). Assume the construction at this site will be in 2012 or 2013, which will give canopy height ~ 2 m. The mean canopy height will be expected to reach ~ 6 m after 8 years of operation, which is approximately by the time NEON relocatable tower decommissioned at this site. Slash pine trees are dotted in the site with height ~ 1.5 m. Stem density is ~350 ha^{-1} to 850 ha^{-1}. The understory at forest floor is thick and ~ 0.4 m tall, and dominated by ferns, grasses, thistle, etc. Management at this site is to leave it fallow 1-2 years after harvesting and then hand plant seedlings at stocking density. Canopy closure will likely occur in ~10-12 years. Pre-commercial thinning begins at 14-16 years. Rotation age is 40-50 years in this region. Fertilization and herbicide treatments were applied at planting and are re-applied as needed during stand development.

Table 17. Ecosystem and site attributes for the Abby Road Relocatable site.

Ecosystem attributes	Measure and units
Mean canopy height at construction [a]	2.0 m
Surface roughness at construction [a]	0.5 m
Zero place displacement height at construction [a]	1.4 m
Mean canopy height at 8th year of operation [b]	6.0 m
Surface roughness at 8th year of operation [b]	0.8 m
Zero place displacement height at 8th year of operation [b]	3.0 m
Structural elements	Replanted young trees, actively grow
Time zone	Pacific time zone
Magnetic declination	16° 18' E changing by 0° 9' W/year

Note, [a] From field survey and best estimates for the time at the construction, which will require top measurement level at 8 m above ground.

[b] Best estimates by the time that NEON tower is decommissioned at the end of the 8 years' services, which will require top measurement level at 15 m above ground, therefore, FCC should design and budget adequate tower height ahead and allow the increase of the top measurement level to 15 m.

Figure 49. Recently planted Douglas fir forest ecosystem at Abby Road Relocatable site.

5.3 Soils

5.3.1 Description of soils

Soil data and soil maps below for the Abby Road tower site were collected from 4.7 km^2 NRCS soil maps (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

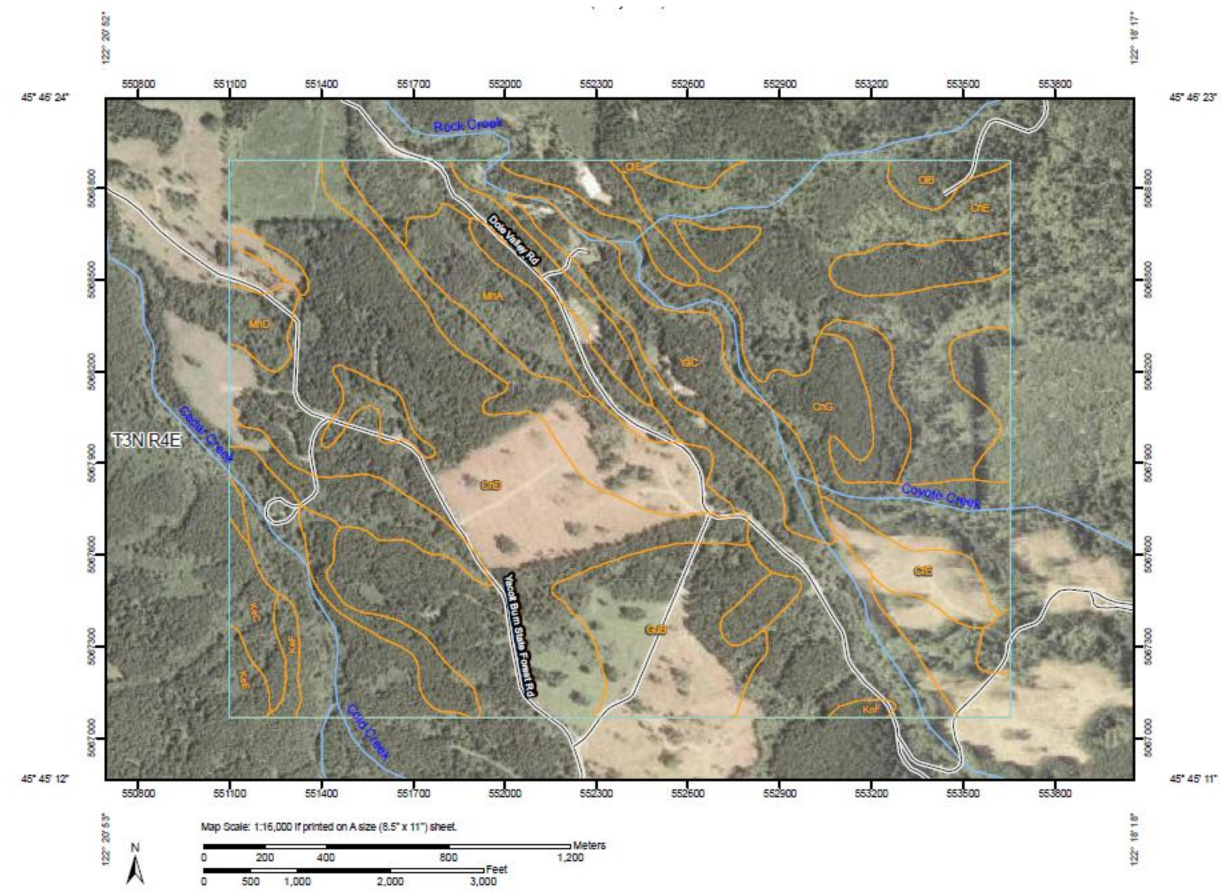


Figure 50. Soil map of the Abby Road Relocatable site and surrounding areas.

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. 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, 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 $4.7km^2$ at the Abby Road site

Clark County, Washington (WA011)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
CnD	Cinebar silt loam, 8 to 20 percent slopes	385.7	33.4%
CnE	Cinebar silt loam, 20 to 30 percent slopes	224.9	19.5%
CnG	Cinebar silt loam, 30 to 70 percent slopes	198.7	17.2%
CrE	Cinebar stony silt loam, 3 to 30 percent slopes	21.4	1.9%
GuB	Gumboot silt loam, 0 to 8 percent slopes	126.2	10.9%
KeC	Kinney silt loam, 3 to 15 percent slopes	14.6	1.3%
KeE	Kinney silt loam, 15 to 30 percent slopes	6.8	0.6%
KeF	Kinney silt loam, 30 to 50 percent slopes	7.6	0.7%
KnF	Kinney cobbly silt loam, 30 to 60 percent slopes	2.5	0.2%
MnA	Minniece silty clay loam, 0 to 3 percent slopes	31.5	2.7%
MnD	Minniece silty clay loam, 3 to 20 percent slopes	22.0	1.9%
OlB	Olympic clay loam, 3 to 8 percent slopes	9.5	0.8%
OlF	Olympic clay loam, 30 to 60 percent slopes	1.0	0.1%
YaC	Yacolt loam, 3 to 15 percent slopes	101.6	8.8%
Totals for Area of Interest		**1,153.9**	**100.0%**

Clark County, Washington CnD—Cinebar silt loam, 8 to 20 percent slopes Map Unit Setting Elevation: 50 to 2,000 feet Mean annual precipitation: 50 to 75 inches Mean annual air temperature: 48 to 52 degrees F Frost-free period: 160 to 250 days **Map Unit Composition** Cinebar and similar soils: 100 percent **Description of Cinebar Setting** Landform: Hillslopes, terraces Parent material: Volcanic ash **Properties and qualities** Slope: 8 to 20 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Very high (about 18.0 inches) **Interpretive groups** Land capability (nonirrigated): 3e **Typical profile** 0 to 13 inches: Silt loam 13 to 48 inches: Silt loam 48 to 60 inches: Loam

Clark County, Washington CnE—Cinebar silt loam, 20 to 30 percent slopes Map Unit Setting Elevation: 50 to 2,000 feet Mean annual precipitation: 50 to 75 inches Mean annual air temperature: 48 to 52 degrees F Frost-free period: 160 to 250 days **Map Unit Composition** Cinebar and similar soils: 100 percent **Description of Cinebar Setting** Landform: Hillslopes, terraces Parent material: Volcanic ash

Properties and qualities Slope: 20 to 30 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Very high (about 18.0 inches) **Interpretive groups** Land capability (nonirrigated): 4e **Typical profile** 0 to 13 inches: Silt loam 13 to 48 inches: Silt loam 48 to 60 inches: Loam

Clark County, Washington CnG—Cinebar silt loam, 30 to 70 percent slopes Map Unit Setting Elevation: 50 to 2,000 feet Mean annual precipitation: 50 to 75 inches Mean annual air temperature: 48 to 52 degrees F Frost-free period: 160 to 250 days **Map Unit Composition** Cinebar and similar soils: 100 percent **Description of Cinebar Setting** Landform: Hillslopes, terraces Parent material: Volcanic ash **Properties and qualities** Slope: 30 to 70 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Very high (about 18.0 inches) **Interpretive groups** Land capability (nonirrigated): 7e **Typical profile** 0 to 13 inches: Silt loam 13 to 48 inches: Silt loam 48 to 60 inches: Loam

Clark County, Washington CrE—Cinebar stony silt loam, 3 to 30 percent slopes Map Unit Setting Elevation: 50 to 2,000 feet Mean annual precipitation: 50 to 75 inches Mean annual air temperature: 48 to 50 degrees F Frost-free period: 150 to 240 days **Map Unit Composition** Cinebar and similar soils: 100 percent **Description of Cinebar Setting** Landform: Hillslopes, terraces Parent material: Volcanic ash **Properties and qualities** Slope: 3 to 30 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Very high (about 13.8 inches) **Interpretive groups** Land capability (nonirrigated): 6s **Typical profile** 0 to 13 inches: Stony silt loam 13 to 48 inches: Silt loam 48 to 60 inches: Loam

Clark County, Washington GuB—Gumboot silt loam, 0 to 8 percent slopes Map Unit Setting Elevation: 1,000 to 2,000 feet Mean annual precipitation: 75 to 95 inches Mean annual air temperature: 50 to 54 degrees F Frost-free period: 180 to 220 days **Map Unit Composition** Gumboot and similar soils: 100 percent **Description of Gumboot Setting** Landform: Drainageways Parent material: Alluvium **Properties and qualities** Slope: 0 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Poorly drained Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 in/hr) Depth to water table: About 0 to 18 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 10.7 inches) **Interpretive groups** Land capability (nonirrigated): 6w **Typical profile** 0 to 12 inches: Silt loam 12 to 28 inches: Clay loam 28 to 50 inches: Silty clay 50 to 60 inches: Very gravelly silty clay

Clark County, Washington KnF—Kinney cobbly silt loam, 30 to 60 percent slopes Map Unit Setting Elevation: 600 to 2,300 feet Mean annual precipitation: 60 to 90 inches Mean annual air temperature: 45 to 50 degrees F Frost-free period: 120 to 190 days **Map Unit Composition** Kinney and similar soils: 100 percent **Description of Kinney Setting** Landform: Mountain slopes Parent material: Residuum weathered from igneous rock with a mantle of volcanic ash **Properties and qualities** Slope: 30 to 60 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 11.3 inches) **Interpretive groups** Land capability (nonirrigated): 7e **Typical profile** 0 to 5 inches: Cobbly silt loam 5 to 60 inches: Gravelly silty clay loam

Clark County, Washington KeC—Kinney silt loam, 3 to 15 percent slopes Map Unit Setting Elevation: 600 to 2,300 feet Mean annual precipitation: 60 to 90 inches Mean annual air temperature: 45 to 50 degrees F Frost-free period: 120 to 190 days **Map Unit Composition** Kinney and similar soils: 100 percent **Description of Kinney Setting** Landform: Mountain slopes Parent material: Residuum weathered from igneous rock with a mantle of volcanic ash **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 (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 11.2 inches) **Interpretive groups** Land capability (nonirrigated): 3e **Typical profile** 0 to 7 inches: Silt loam 7 to 60 inches: Gravelly silty clay loam

Clark County, Washington KeE—Kinney silt loam, 15 to 30 percent slopes Map Unit Setting Elevation: 600 to 2,300 feet Mean annual precipitation: 60 to 90 inches Mean annual air temperature: 45 to 50 degrees F Frost-free period: 120 to 190 days **Map Unit Composition** Kinney and similar soils: 100 percent **Description of Kinney Setting** Landform: Mountain slopes Parent material: Residuum weathered from igneous rock with a mantle of volcanic ash **Properties and qualities** Slope: 15 to 30 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 11.2 inches) **Interpretive groups** Land capability (nonirrigated): 4e **Typical profile** 0 to 7 inches: Silt loam 7 to 60 inches: Gravelly silty clay loam

Clark County, Washington KeF—Kinney silt loam, 30 to 50 percent slopes Map Unit Setting Elevation: 600 to 2,300 feet Mean annual precipitation: 60 to 90 inches Mean annual air temperature: 45 to 50 degrees F Frost-free period: 120 to 190 days **Map Unit Composition** Kinney and similar soils: 100 percent **Description of Kinney Setting** Landform: Mountain slopes Parent material: Residuum weathered from igneous rock with a mantle of volcanic ash **Properties and qualities** Slope: 30 to 50 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 11.3 inches) **Interpretive groups** Land capability (nonirrigated): 7e **Typical profile** 0 to 5 inches: Silt loam 5 to 60 inches: Gravelly silty clay loam

Clark County, Washington MnA—Minniece silty clay loam, 0 to 3 percent slopes Map Unit Setting Elevation: 1,400 to 2,500 feet Mean annual precipitation: 8 to 12 inches Mean annual air temperature: 48 to 50 degrees F Frost-free period: 130 to 150 days **Map Unit Composition** Minniece and similar soils: 100 percent **Description of Minniece Setting** Landform: Drainageways Parent material: Colluvium and alluvium from igneous rock **Properties and qualities** Slope: 0 to 3 percent Depth to restrictive feature: More than 80 inches Drainage class: Poorly drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: About 0 to 24 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Moderate (about 8.8

inches) **Interpretive groups** Land capability (nonirrigated): 5w **Typical profile** 0 to 4 inches: Silty clay loam 4 to 17 inches: Silty clay 17 to 48 inches: Clay 48 to 52 inches: Unweathered bedrock

Clark County, Washington MnD—Minniece silty clay loam, 3 to 20 percent slopes Map Unit Setting Elevation: 1,400 to 2,500 feet Mean annual precipitation: 8 to 12 inches Mean annual air temperature: 48 to 50 degrees F Frost-free period: 130 to 150 days **Map Unit Composition** Minniece and similar soils: 100 percent **Description of Minniece Setting** Landform: Drainageways Parent material: Colluvium and alluvium from igneous rock **Properties and qualities** Slope: 3 to 20 percent Depth to restrictive feature: More than 80 inches Drainage class: Poorly drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: About 0 to 24 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Moderate (about 8.8 inches) **Interpretive groups** Land capability (nonirrigated): 6w **Typical profile** 0 to 4 inches: Silty clay loam 4 to 17 inches: Silty clay 17 to 48 inches: Clay 48 to 52 inches: Unweathered bedrock

Clark County, Washington OlB—Olympic clay loam, 3 to 8 percent slopes Map Unit Setting Elevation: 200 to 2,000 feet Mean annual precipitation: 40 to 70 inches Mean annual air temperature: 50 to 54 degrees F Frost-free period: 150 to 200 days **Map Unit Composition** Olympic and similar soils: 100 percent **Description of Olympic Setting** Landform: Mountain slopes Parent material: Residuum and colluvium from igneous rock **Properties and qualities** Slope: 3 to 8 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 (0.20 to 0.57 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 10.3 inches) **Interpretive groups** Land capability (nonirrigated): 2e **Typical profile** 0 to 15 inches: Clay loam 15 to 44 inches: Clay loam 44 to 60 inches: Gravelly clay loam

Clark County, Washington OlF—Olympic clay loam, 30 to 60 percent slopes Map Unit Setting Elevation: 200 to 2,000 feet Mean annual precipitation: 40 to 70 inches Mean annual air temperature: 50 to 54 degrees F Frost-free period: 150 to 200 days **Map Unit Composition** Olympic and similar soils: 100 percent **Description of Olympic Setting** Landform: Mountain slopes Parent material: Residuum and colluvium from igneous rock **Properties and qualities** Slope: 30 to 60 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: High (about 10.2 inches) **Interpretive groups** Land capability (nonirrigated): 7e **Typical profile** 0 to 10 inches: Clay loam 10 to 41 inches: Clay loam 41 to 60 inches: Gravelly clay loam

Clark County, Washington YaC—Yacolt loam, 3 to 15 percent slopes Map Unit Setting Elevation: 400 to 1,100 feet Mean annual precipitation: 75 to 95 inches Mean annual air temperature: 48 degrees F Frost-free period: 125 to 150 days **Map Unit Composition** Yacolt and similar soils: 100 percent **Description of Yacolt Setting** Landform: Terraces Parent material: Volcanic ash, alluvium and/or glacial drift **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 (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Moderate (about 7.8 inches) **Interpretive groups** Land capability (nonirrigated): 3e **Typical profile** 0 to 6 inches: Loam 6 to 23 inches: Loam 23 to 60 inches: Cobbly loam

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 51). 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 51).

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 51), 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.

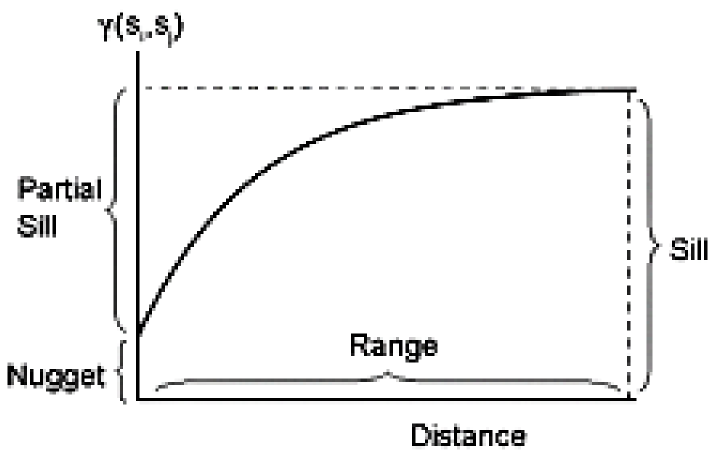


Figure 51. Example semivariogram, depicting range, sill, and nugget.

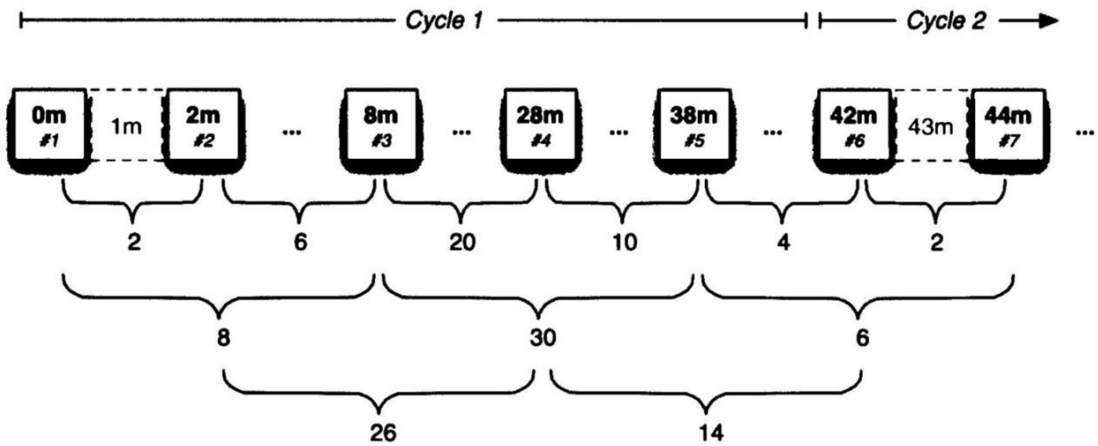


Figure 52. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 20 October 2010 at the Abby Road site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 52). Soil temperature and moisture measurements were collected along three transects (210 m, 84 m, and 84 m) located in the expected airshed at Abby Road. 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 52, 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 53). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 54, left graph) and directional semivariograms do not show anisotropy (Figure 54, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 54, right graph). The model indicates a distance of effective independence of 3 m for soil temperature.

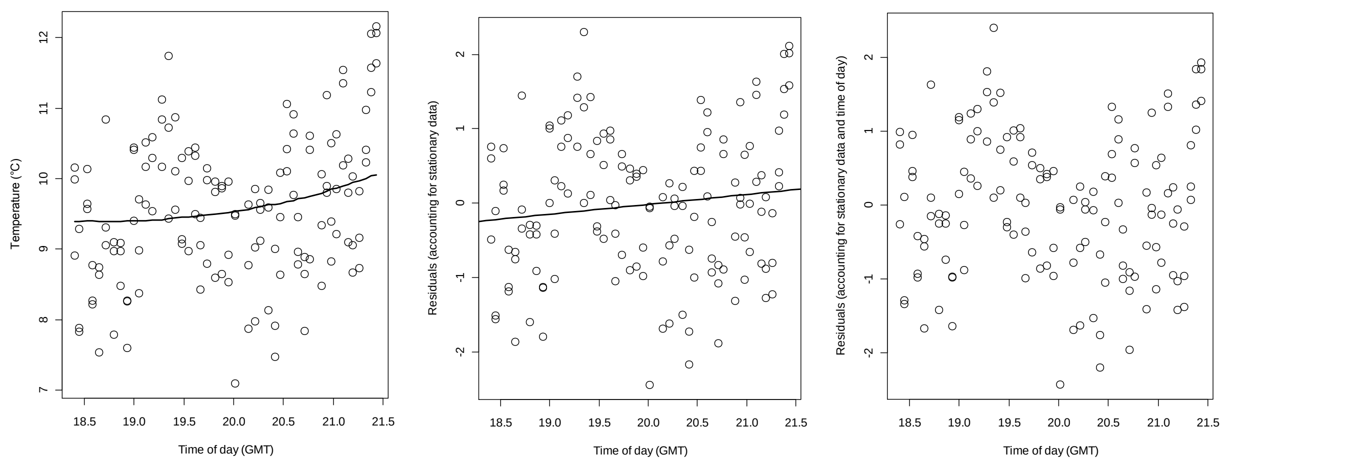


Figure 53. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting for changes temperature in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

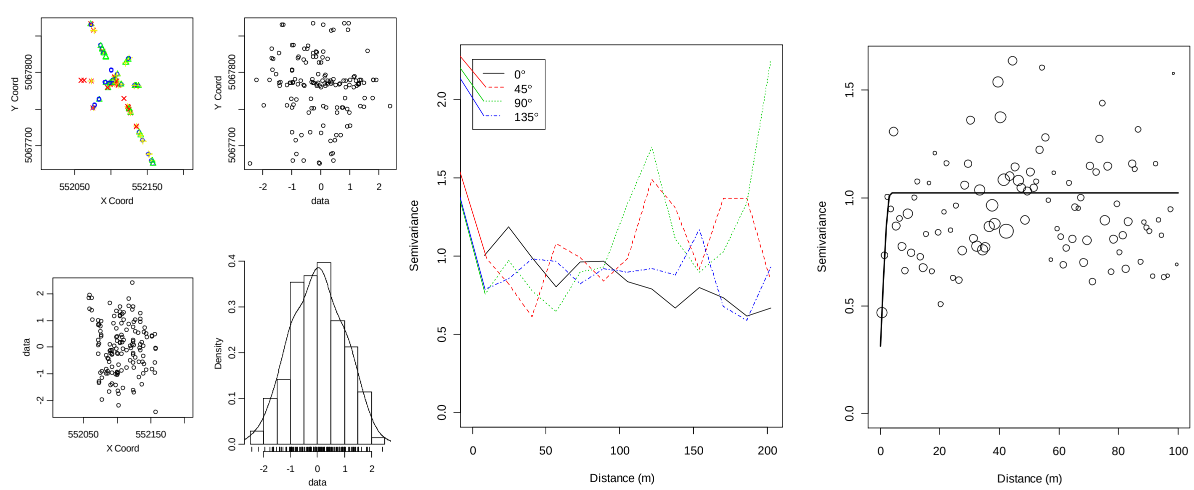


Figure 54. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

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 55). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 56, left graph) 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 21 m for soil water content.

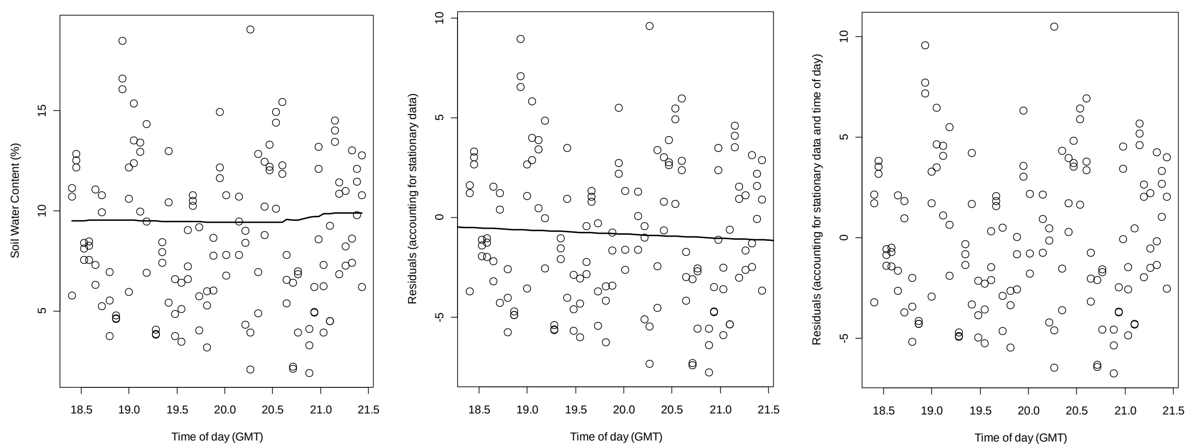


Figure 55. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting 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.

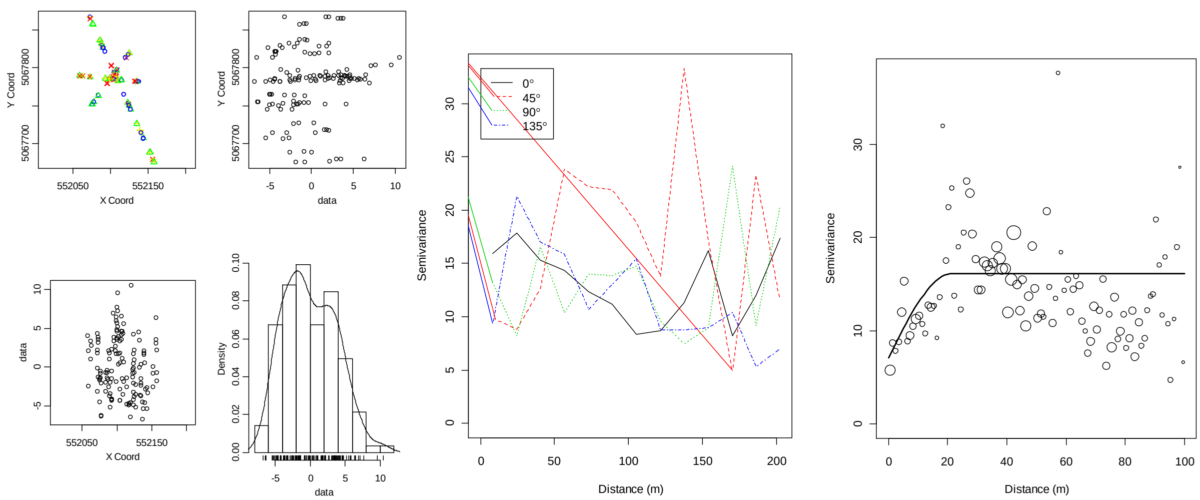


Figure 56. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

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 3 m for soil temperature and 21 m for soil moisture. Based on these results and the site design guidelines the soil plots at Abby Road shall be placed 25 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 140° from the soil plot nearest the tower (i.e., first soil plot). The location of the first soil plot will be approximately 45.76200, -122.33017. 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 45.762435°, -122.329415° (primary location); or 45.762429°, -122.329764° (alternate location 1 if primary location is unsuitable); or 45.761691°, -122.331113° (alternate location 2 if primary location is unsuitable). A summary of the soil information is shown in Table 19 and site layout can be seen in Figure 57.

Dominant soil series at the site: Cinebar silt loam, 8 to 20 percent slopes. The taxonomy of this soil is shown below:
Order: Andisols
Suborder: Xerands
Great group: Haploxerands
Subgroup: Humic Haploxerands
Family: Medial, mixed, mesic Humic Haploxerands
Series: Cinebar silt loam, 8 to 20 percent slopes

Table 19. Summary of soil array and soil pit information at Abby Road. 0° represents true north and accounts for declination.

Soil plot dimensions	5 m x 5 m
Soil array pattern	B
Distance between soil plots: x	25 m
Distance from tower to closest soil plot: y	49 m
Latitude and longitude of 1st soil plot OR direction from tower	45.76200, -122.33017
Direction of soil array	140°
Latitude and longitude of FIU soil pit 1	45.762435°, -122.329415° (primary location)
Latitude and longitude of FIU soil pit 2	45.762429°, -122.329764° (alternate 1)
Latitude and longitude of FIU soil pit 3	45.761691°, -122.331113° (alternate 2)
Dominant soil type	Cinebar silt loam, 8 to 20 percent slopes
Expected soil depth	>2 m
Depth to water table	>2 m

Expected depth of soil horizons	**Expected measurement depths***
0-0.33 m (Silt loam)	0.17 m†
0.33-1.22 m (Silt loam)	0.78 m†
1.22-1.52 m (Loam)	1.37 m†
2 m	2 m

*Actual soil measurement depths will be determined based on measured soil horizon depths at the NEON FIU soil pit and may differ substantially from those shown here.
†Expected soil CO_2 sensor depth (actual depths will be determined based on the FIU soil pit)

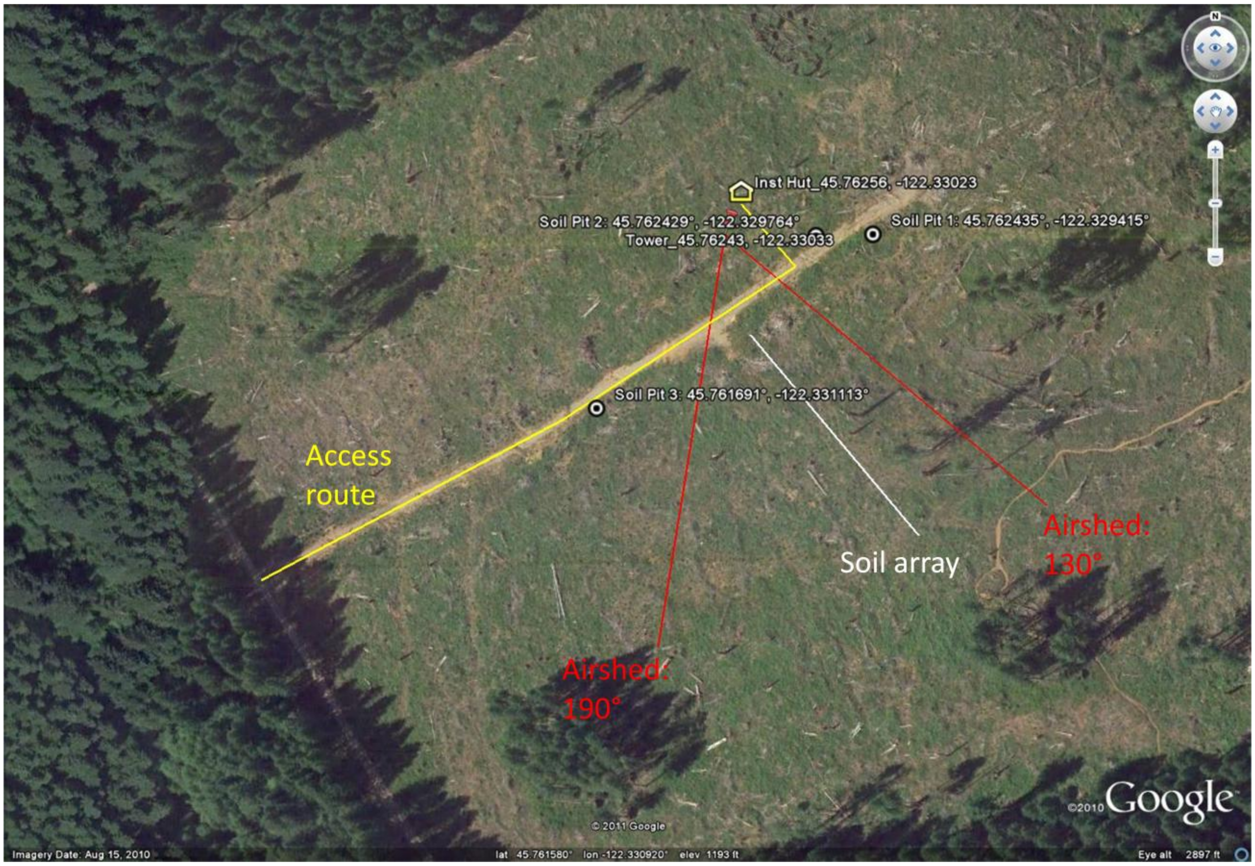


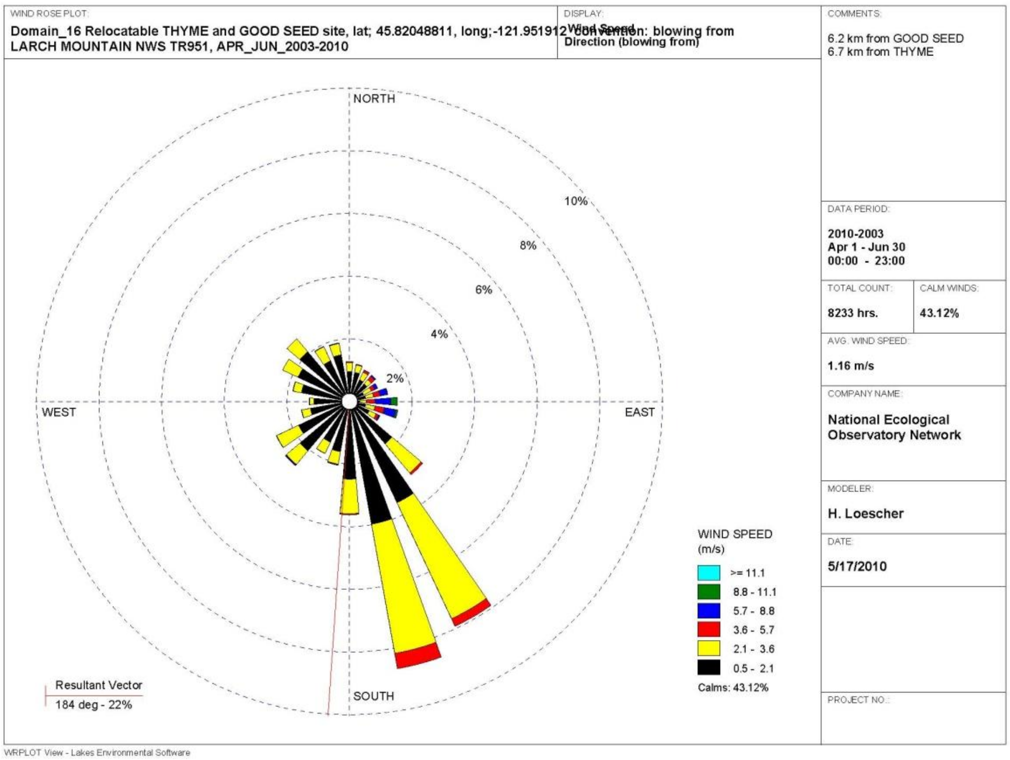
Figure 57. Site layout at Abby Road showing soil array and location of the FIU soil pit.

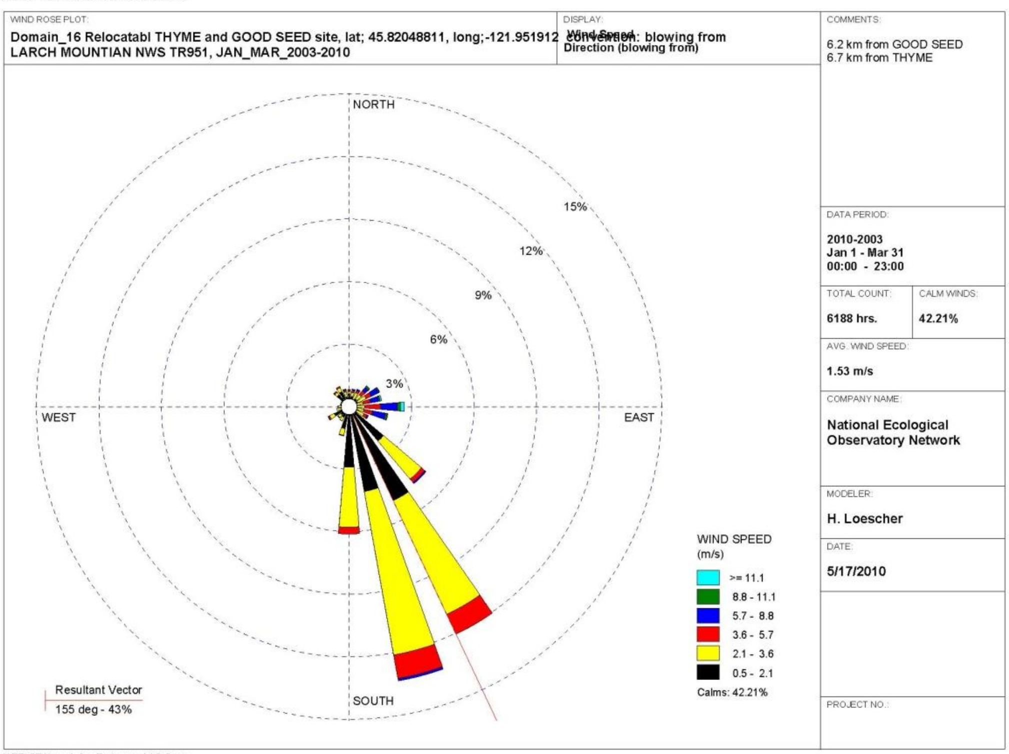
5.4 Airshed

5.4.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries. The weather data used to generate the following wind roses are 2003 to 2010 data from MesoWest weather station at Larch Mountain (ID: TR951, Lat. 45.7231, Lon. -122.3453), which is ~4.5 km SSW to tower location. 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)





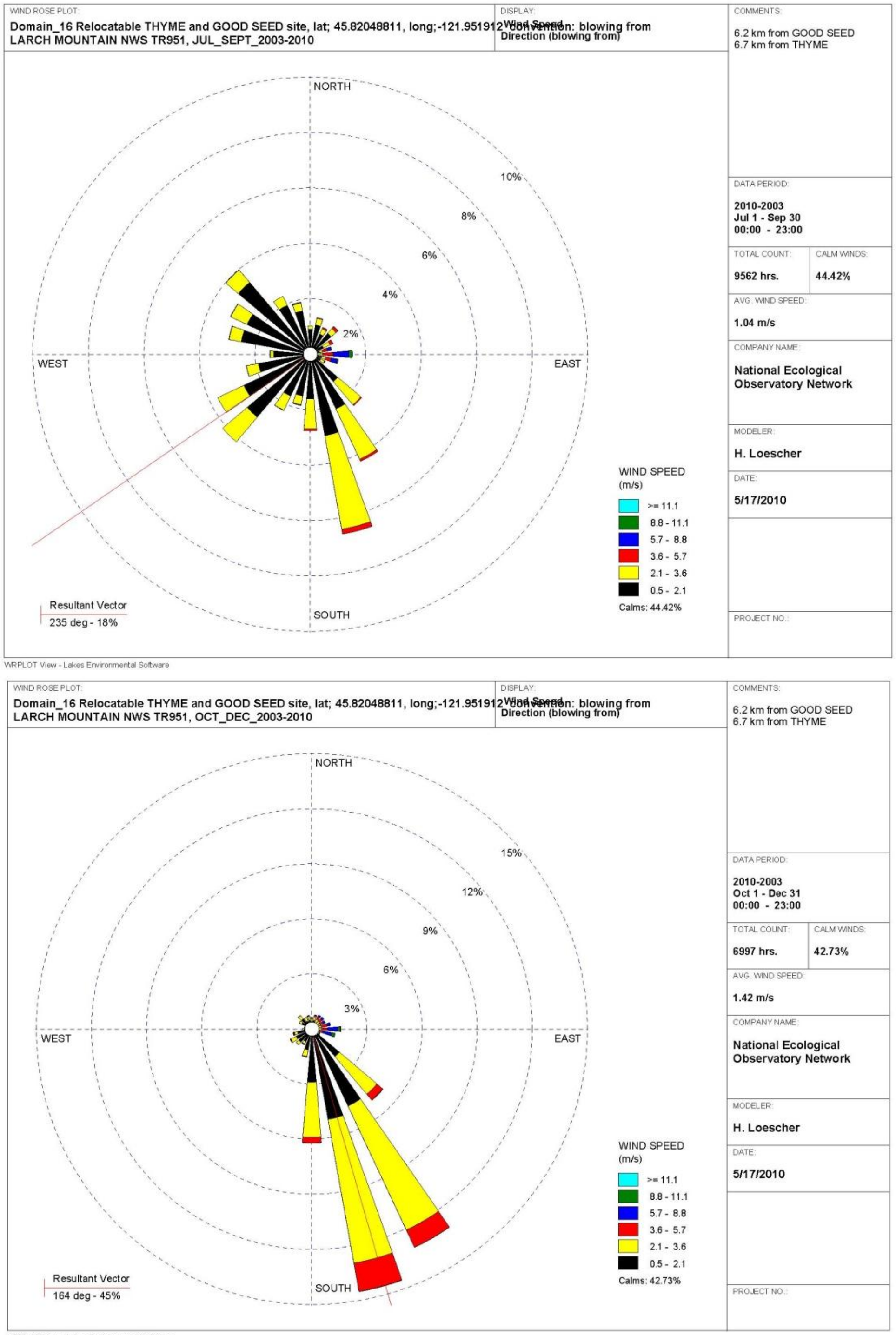


Figure 58. Windroses from Larch Mountain station for Thayer Relocatable site.
Data used here are 2003-2010 data from MesoWest station Larch Mountain (ID TR951) at 45.7231, -122.3453, which is ~4.5 km on the SSW to tower location. It is assumed that the wind data was corrected for declination. Panels are (from top to bottom) Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

5.4.3 Resultant vectors

Table 20. The resultant wind vectors for Thayer Relocatable site using hourly data in 2003-2010.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	155°	43
April to June	184°	22
July to September	235°	18
October to December	164°	45
Annual mean	184.5	na.

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 represent 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.

Because the forest is actively growing at this site, the canopy height and required measurement height will change over time. We present two sets of footprint analysis outcome below for the time during construction (or at the beginning of operation) and for the time at the end of 8th year of operation, which is approximate the time to decommission NEON tower at this site.

Table 21. Expected environmental controls to parameterize the source area model and associated results for Abby Road Relocatable tower site at construction.

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	7	7	7	7	7	7	m
Canopy Height	1.1	1.1	1.1	1.1	1.1	1.1	m
Canopy area density	2	2	2	1.5	1.5	1.5	m
Boundary layer depth	1800	1800	960	800	800	600	m
Expected sensible heat flux	400	400	6	75	75	0	W m^{-2}
Air Temperature	29	29	18	9	9	-10	°C
Max. windspeed	5.8	2.2	1.2	5.8	1.6	1.6	m s^{-1}
Resultant wind vector	165	165	210	160	160	160	degrees
			Results				
(z-d)/L	-0.16	-1.3	-0.26	-0.04	-0.86	0	m
d	0.82	0.82	0.82	0.82	0.82	0.82	m
Sigma v	1.9	1.7	0.4	1.2	0.8	0.27	m^2 s^{-2}
Z0	0.06	0.06	0.06	0.06	0.06	0.06	m
u*	0.55	0.27	0.12	0.52	0.18	0.14	m s^{-1}
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	450	200	450	700	200	850	m
Distance of 80% cumulative flux	250	150	250	400	150	480	m
Distance of 70% cumulative flux	200	100	200	300	100	300	m
Peak contribution	55	25	45	65	25	55	m

Table 22. Expected environmental controls to parameterize the source area model and associated results for Abby Road Relocatable tower site at the end of 8th year of operation.

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	14	14	14	14	14	14	m

Canopy Height	7	7	7	7	7	7	m
Canopy area density	3	3	3	2.5	2.5	2.5	m
Boundary layer depth	1800	1800	960	800	800	600	m
Expected sensible heat flux	400	400	6	75	75	0	$W\ m^{-2}$
Air Temperature	29	29	18	9	9	-10	°C
Max. windspeed	5.8	2.2	1.2	5.8	1.6	1.6	$m\ s^{-1}$
Resultant wind vector	165	165	210	160	160	160	degrees
Results							
(z-d)/L	-0.08	-0.55	-0.13	-0.02	-0.42	0	m
d	5.6	5.6	5.6	5.6	5.6	5.6	m
Sigma v	2.2	1.8	0.46	31.6	0.88	0.38	$m^2\ s^{-2}$
Z0	0.31	0.31	0.31	0.31	0.31	0.31	m
u*	0.76	0.4	0.16	0.72	0.26	0.19	$m\ s^{-1}$
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	500	200	450	700	250	750	m
Distance of 80% cumulative flux	300	150	250	400	200	450	m
Distance of 70% cumulative flux	250	100	150	250	150	250	m
Peak contribution	45	25	45	55	25	55	m

5.4.5 Results (source area graphs)

By the time of the construction:

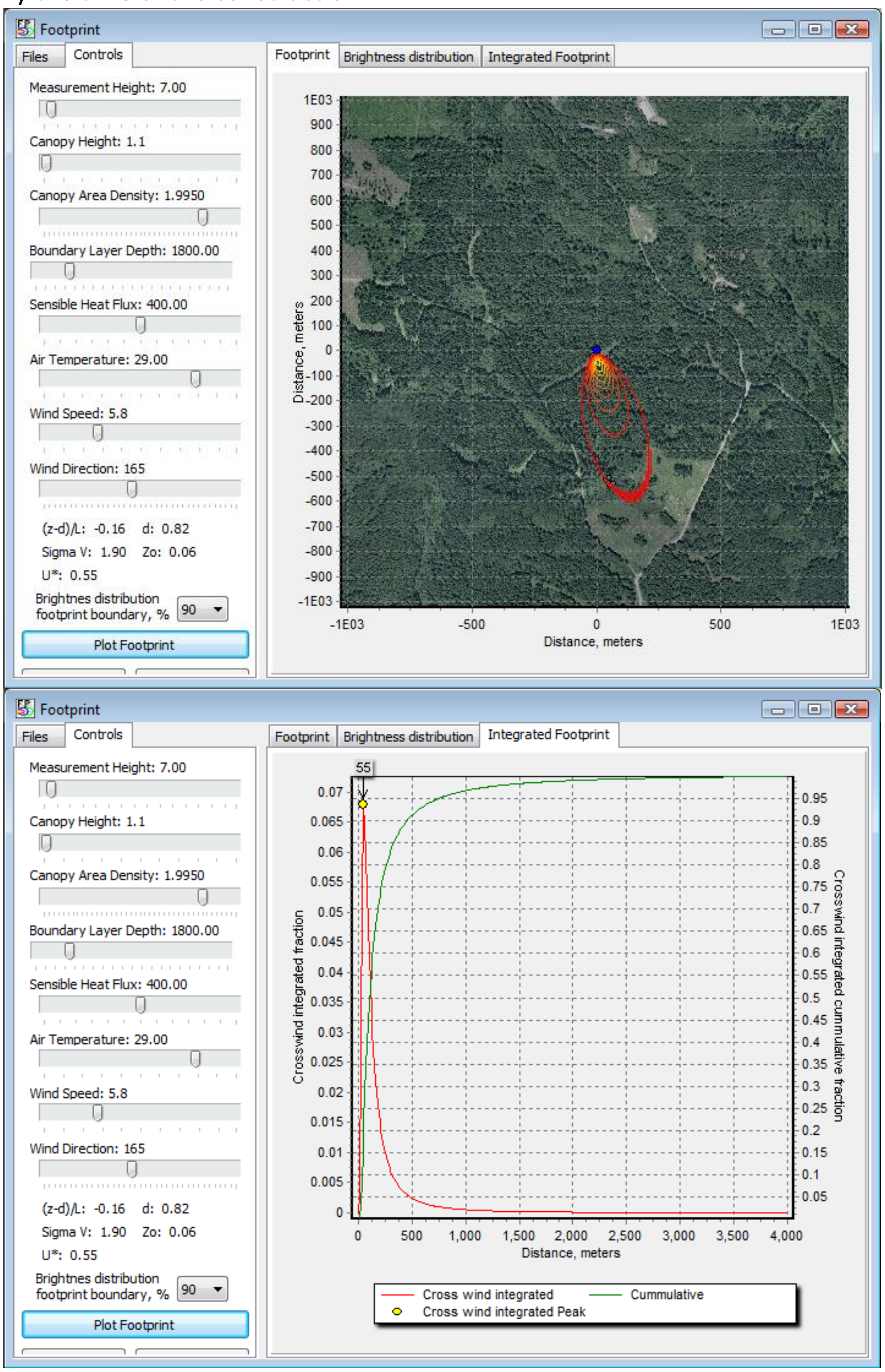


Figure 59. Abby Road Relocatable site summer daytime (convective) footprint output with max wind speed at construction.

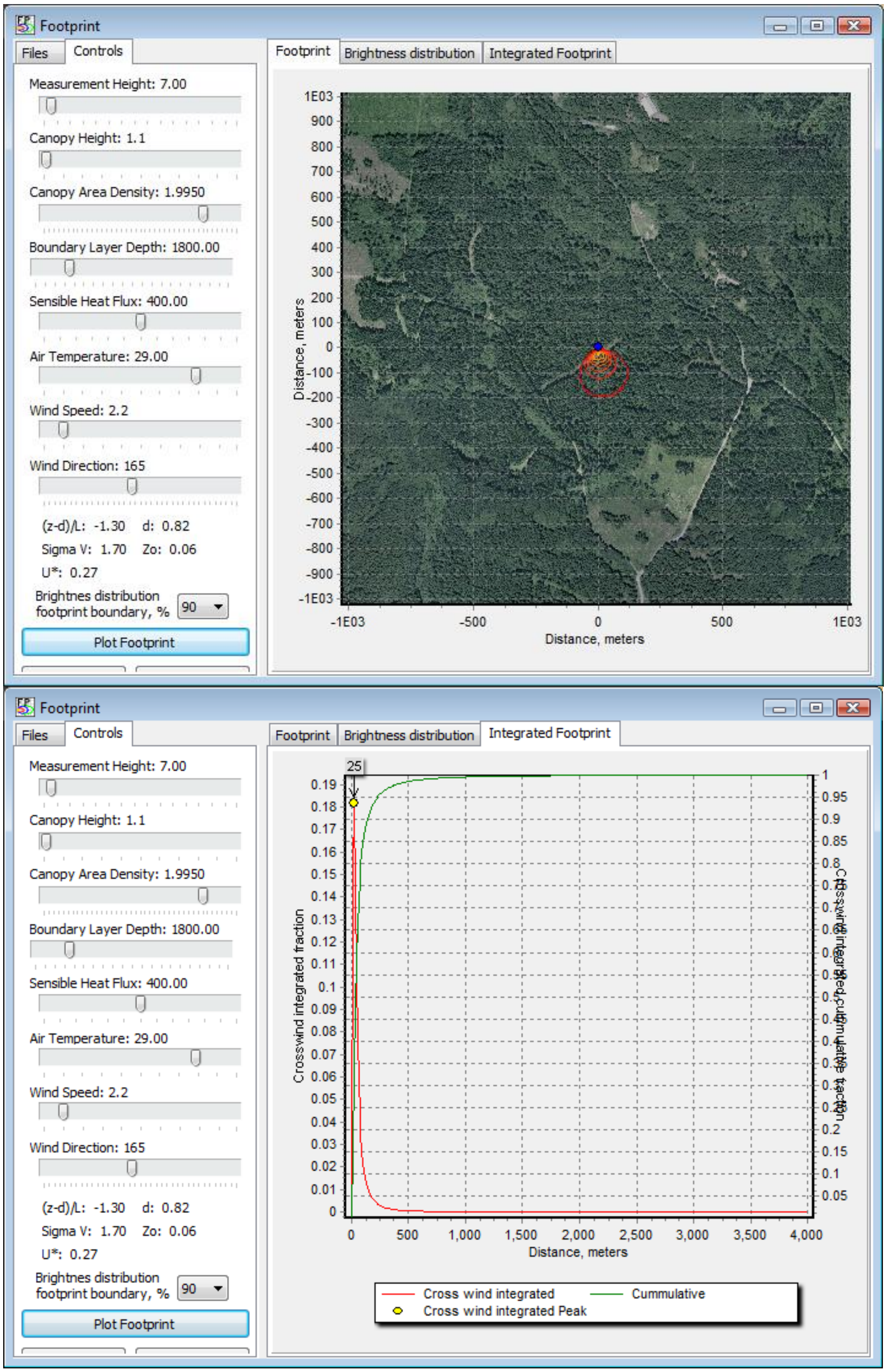


Figure 60. Abby Road Relocatable site summer daytime (convective) footprint output with mean wind speed at construction

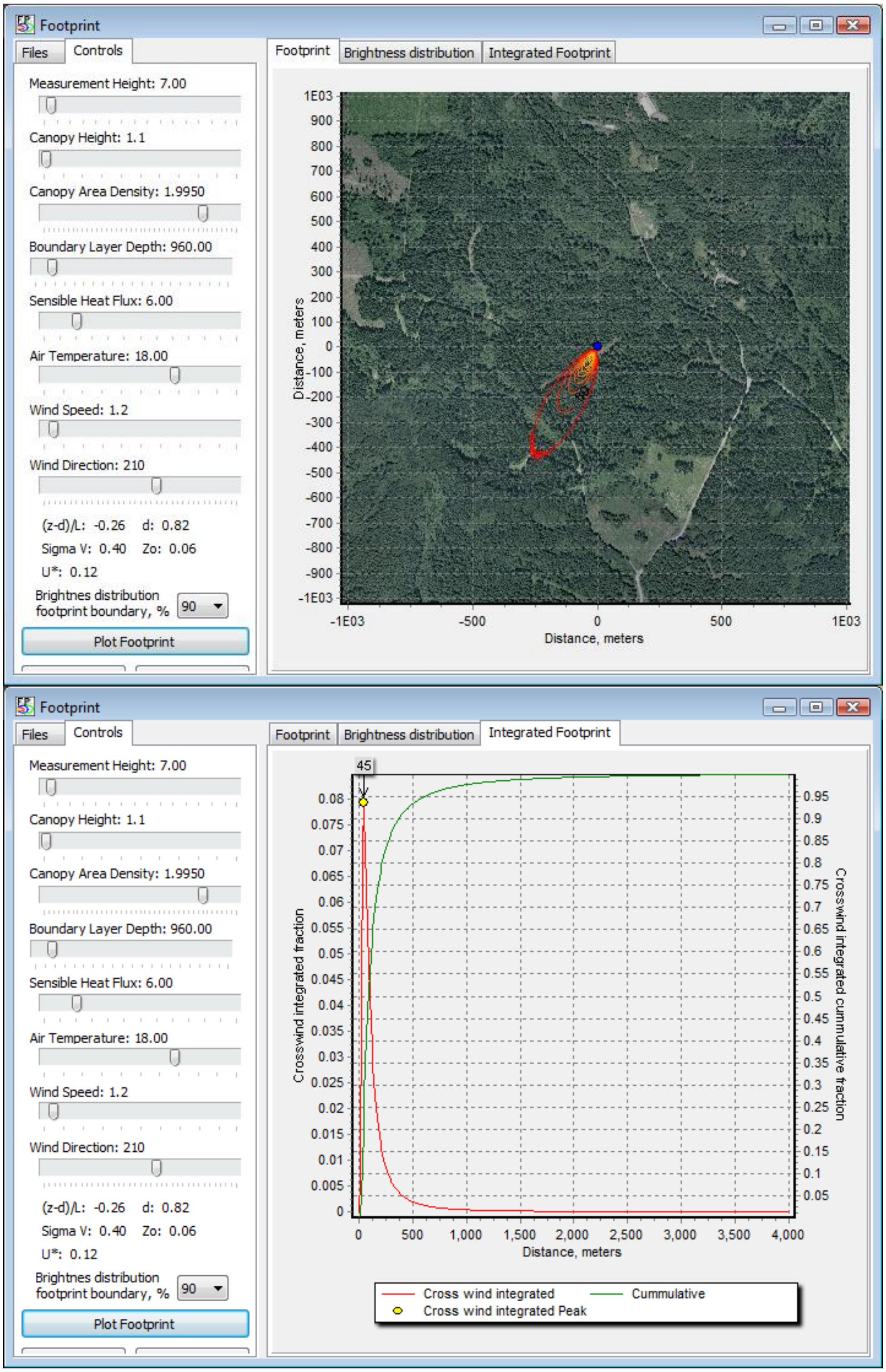


Figure 61. Abby Road Relocatable site summer nighttime (stable) footprint output with mean wind speed at construction

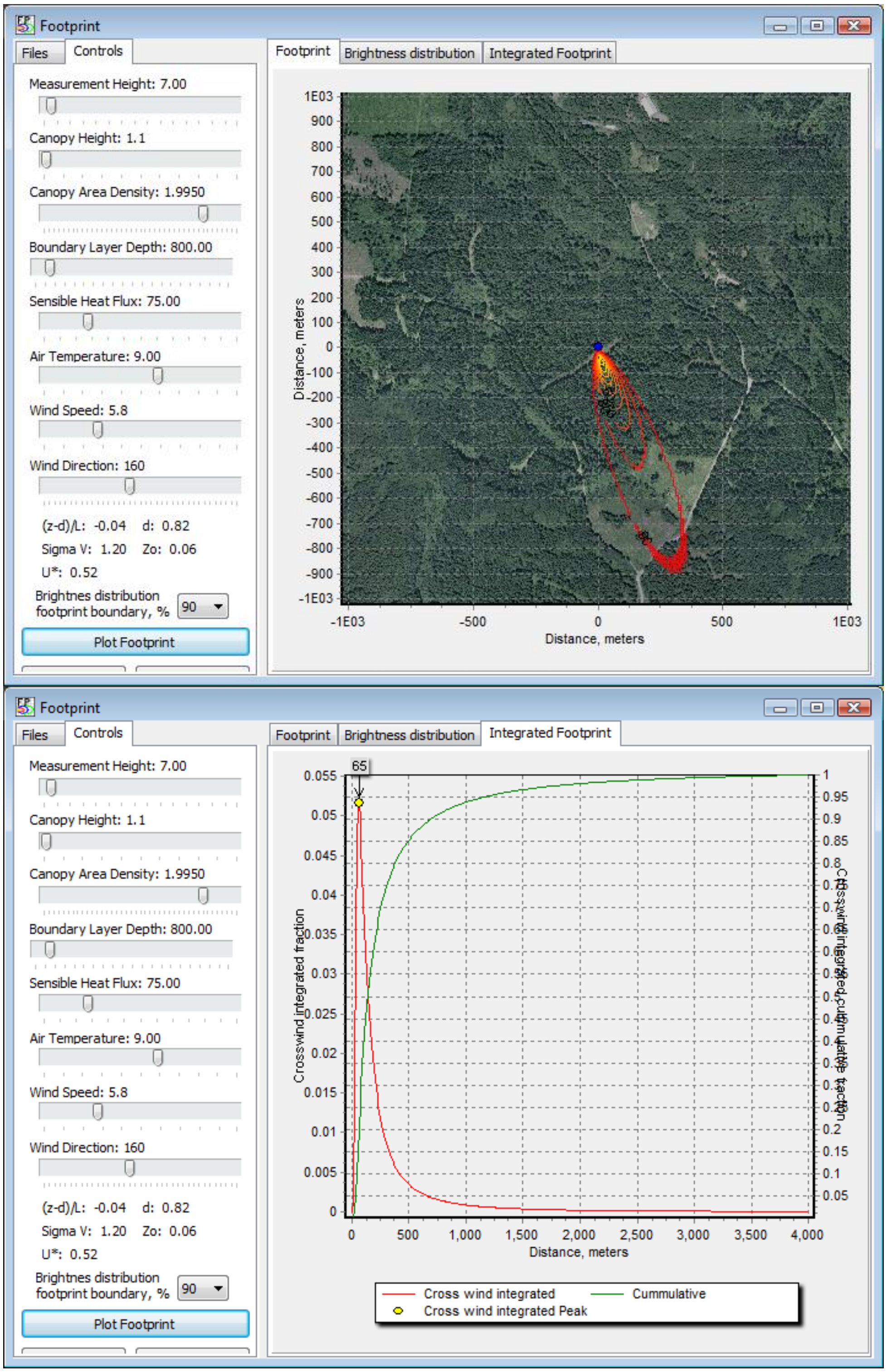


Figure 62. Abby Road Relocatable site winter daytime (convective) footprint output with max wind speed at construction

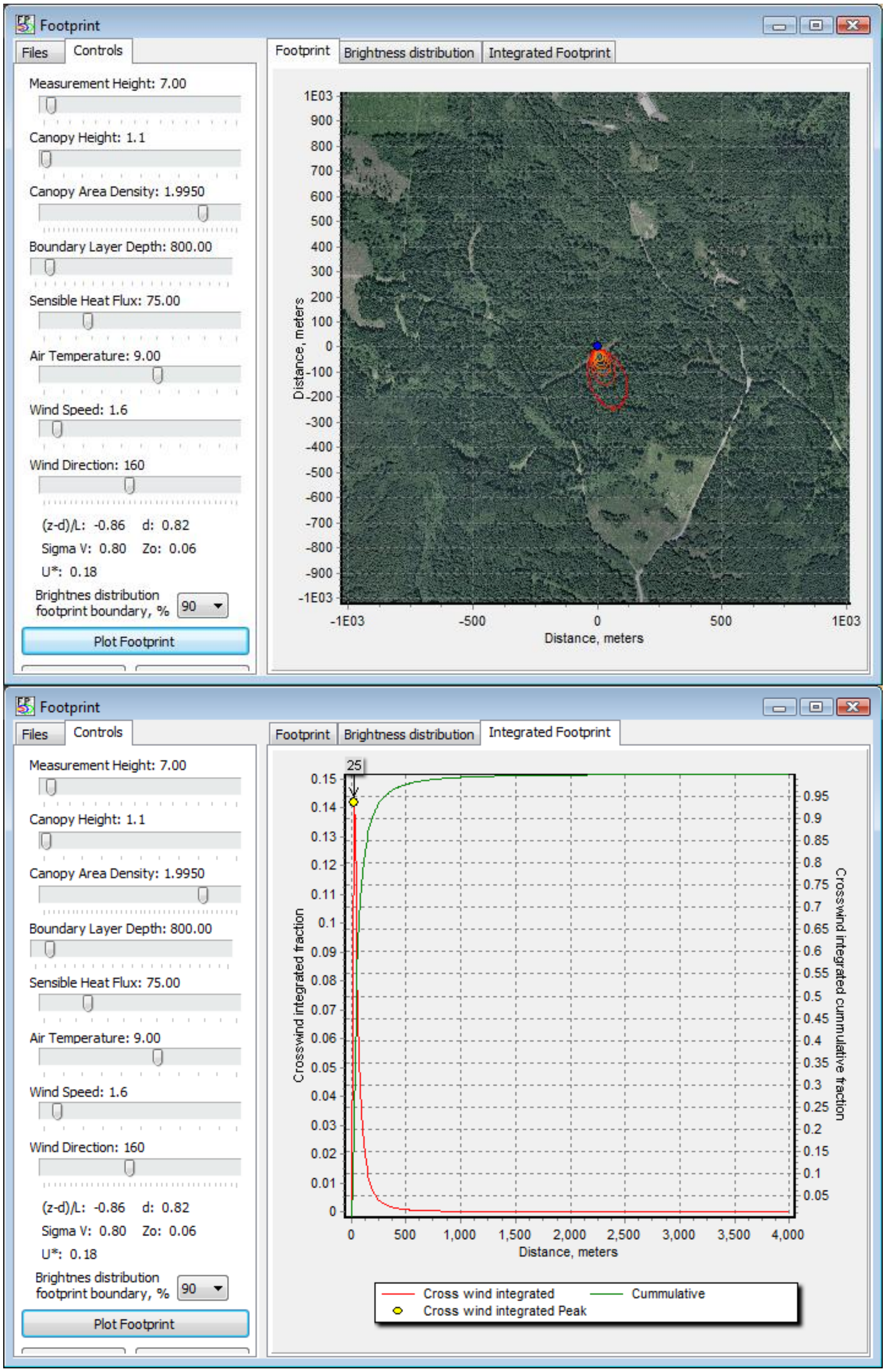


Figure 63. Abby Road Relocatable site winter daytime (convective) footprint output with mean wind speed at construction

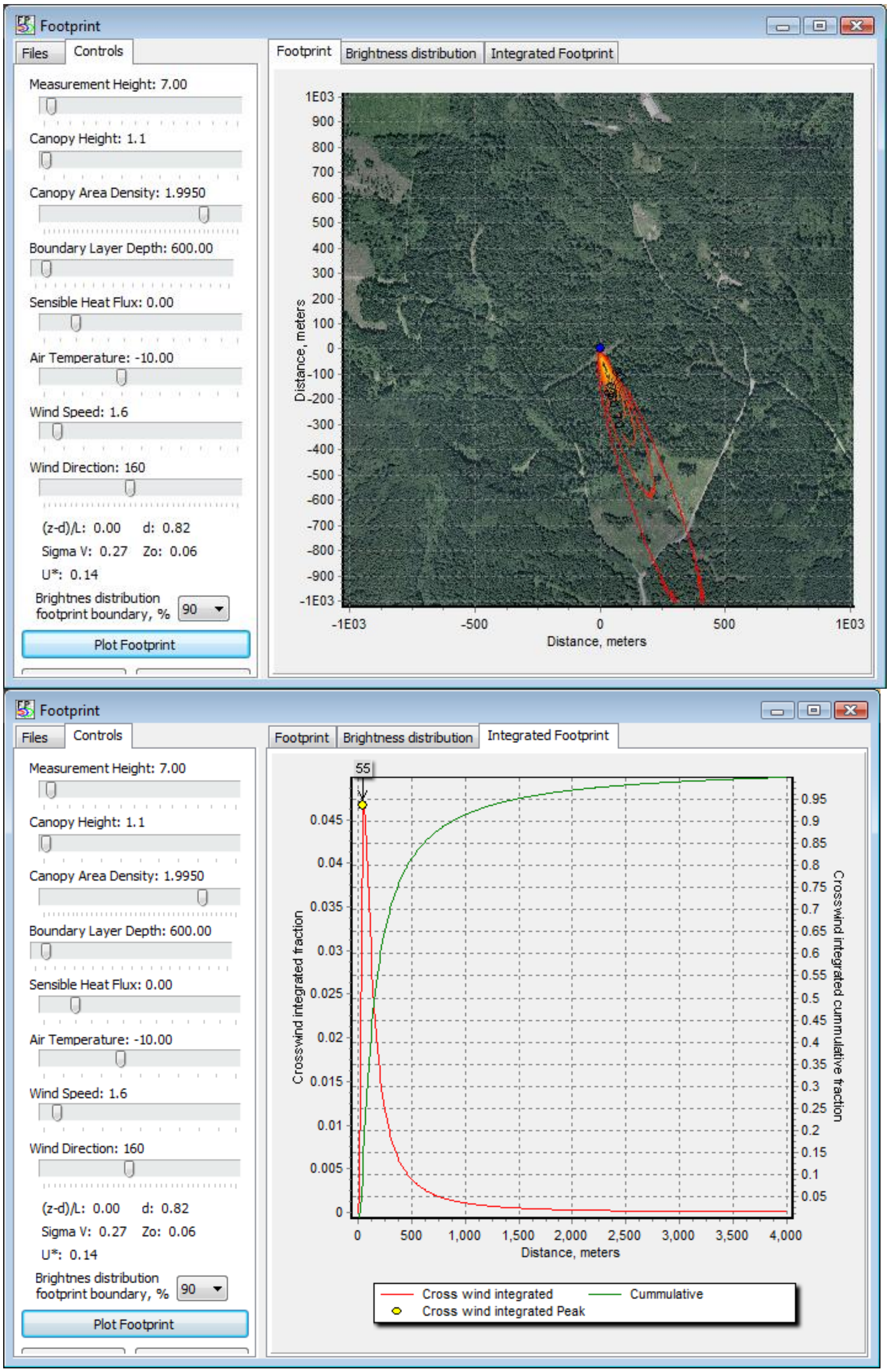


Figure 64. Abby Road Relocatable site winter nighttime (stable) footprint output with mean wind speed at construction

By the end of 8th year of operation:

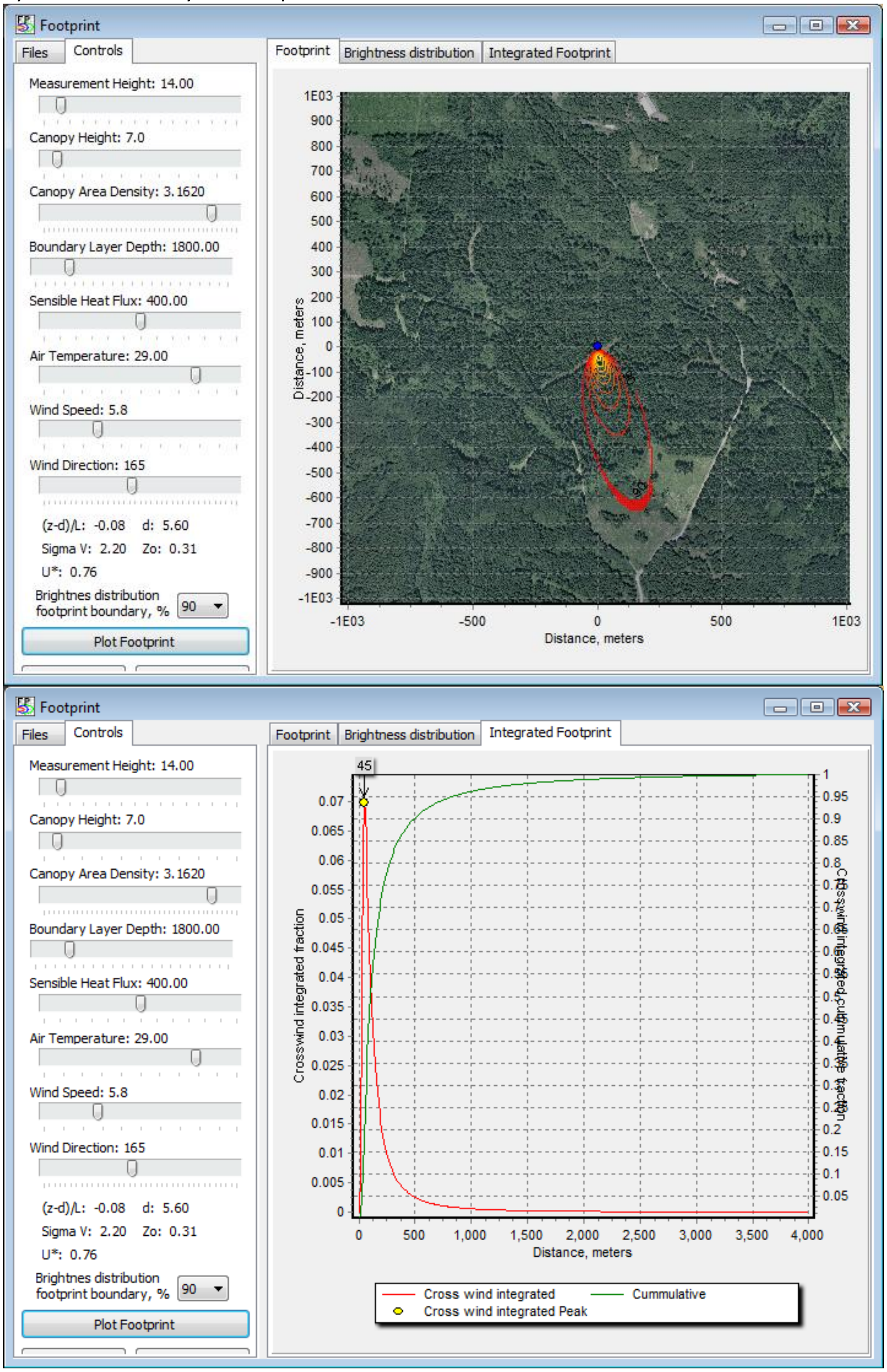


Figure 65. Abby Road Relocatable site summer daytime (convective) footprint output with max wind speed at the end of 8th year operation

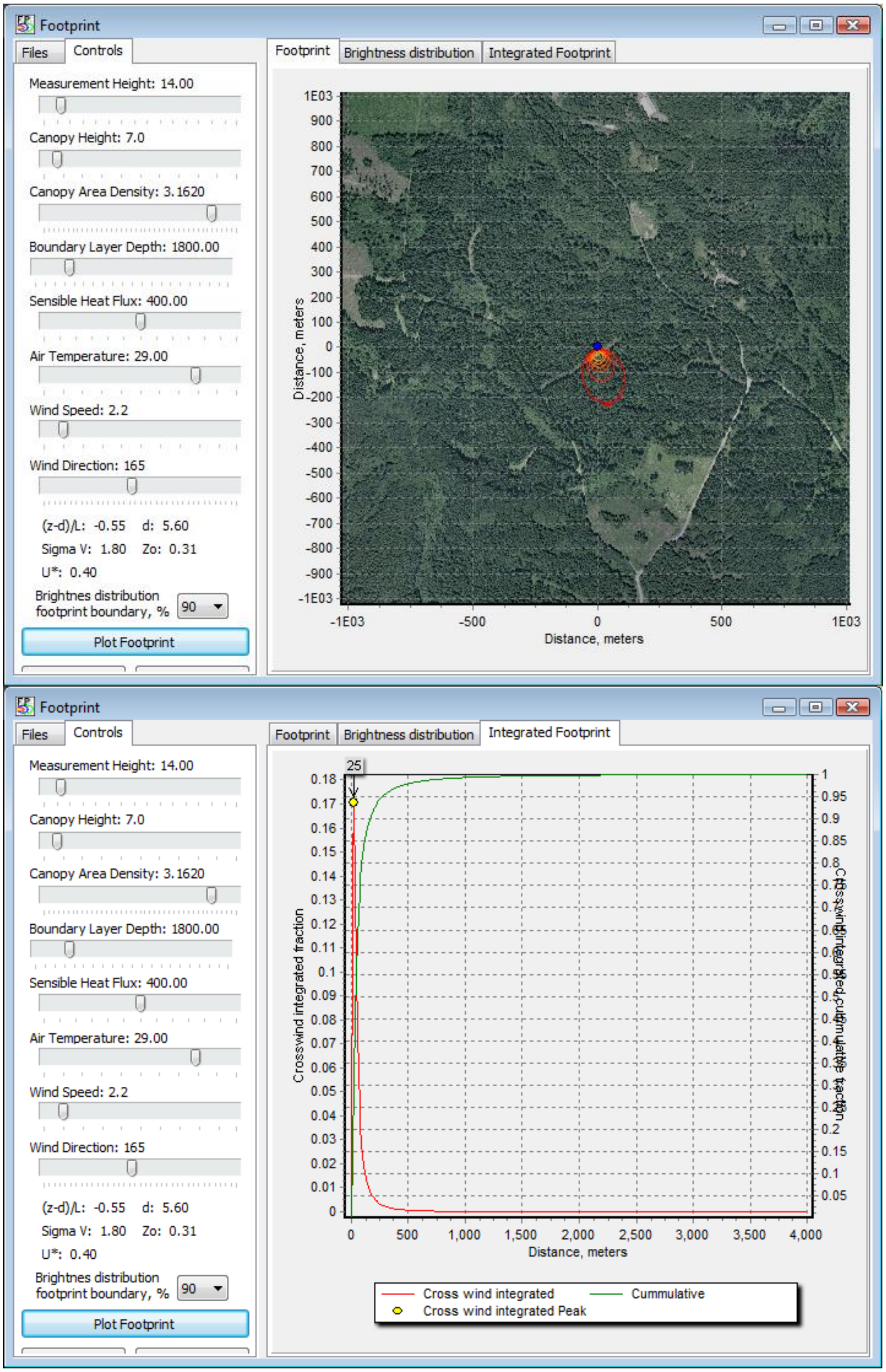


Figure 66. Abby Road Relocatable site summer daytime (convective) footprint output with mean wind speed at the end of 8th year operation

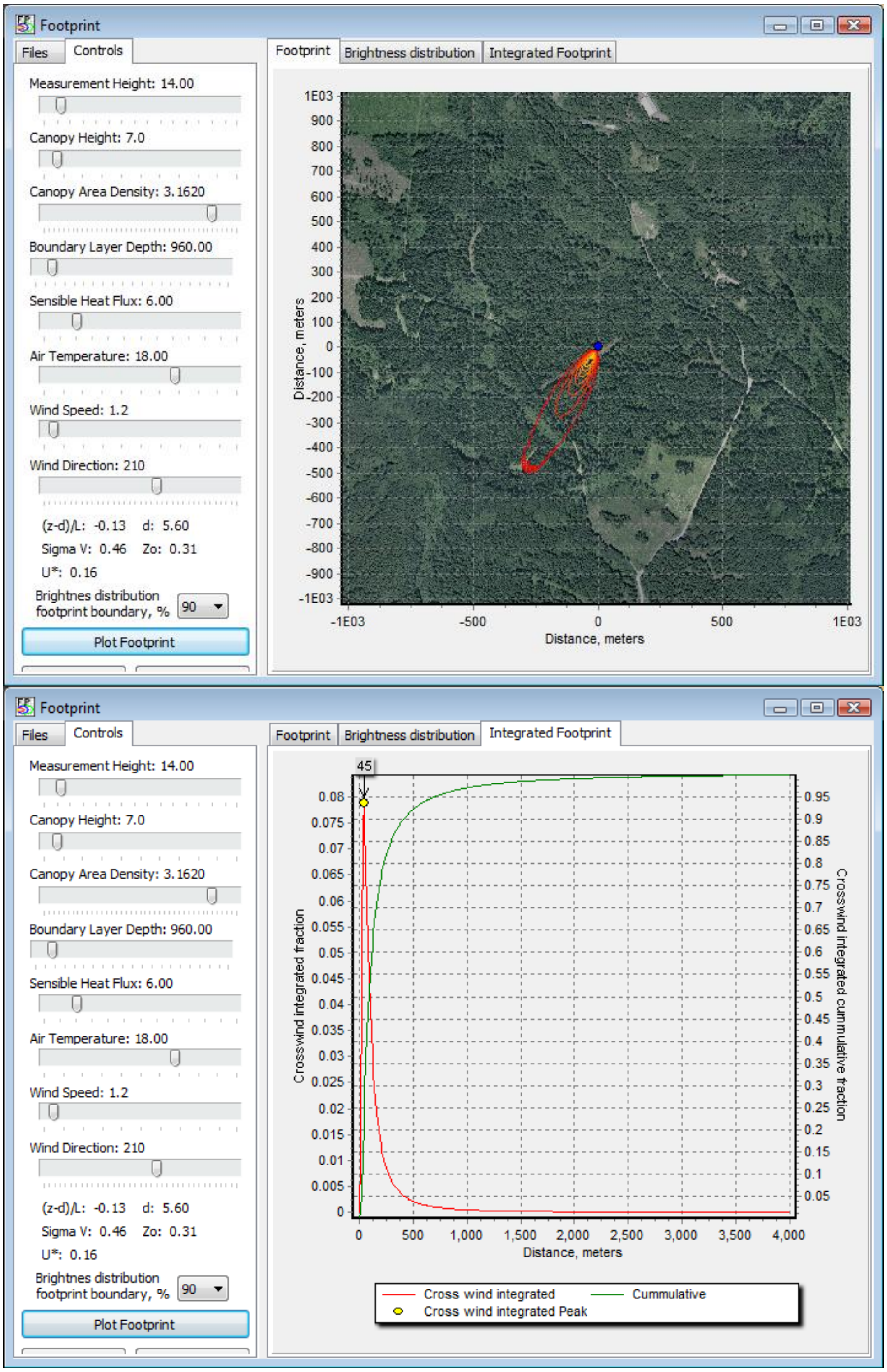


Figure 67. Abby Road Relocatable site summer nighttime (stable) footprint output with mean wind speed at the end of 8th year operation

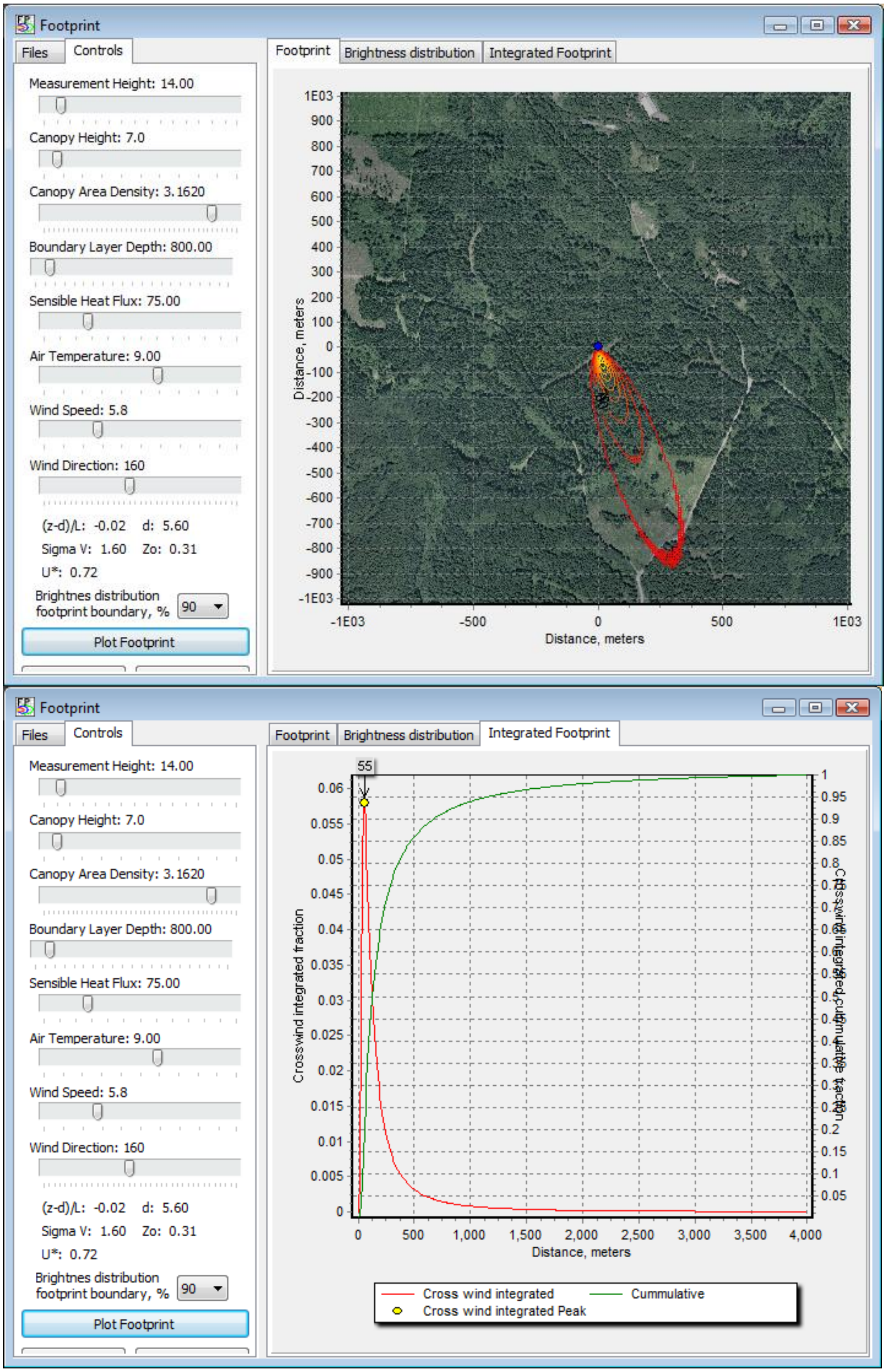


Figure 68. Abby Road Relocatable site winter daytime (convective) footprint output with max wind speed at the end of 8th year operation

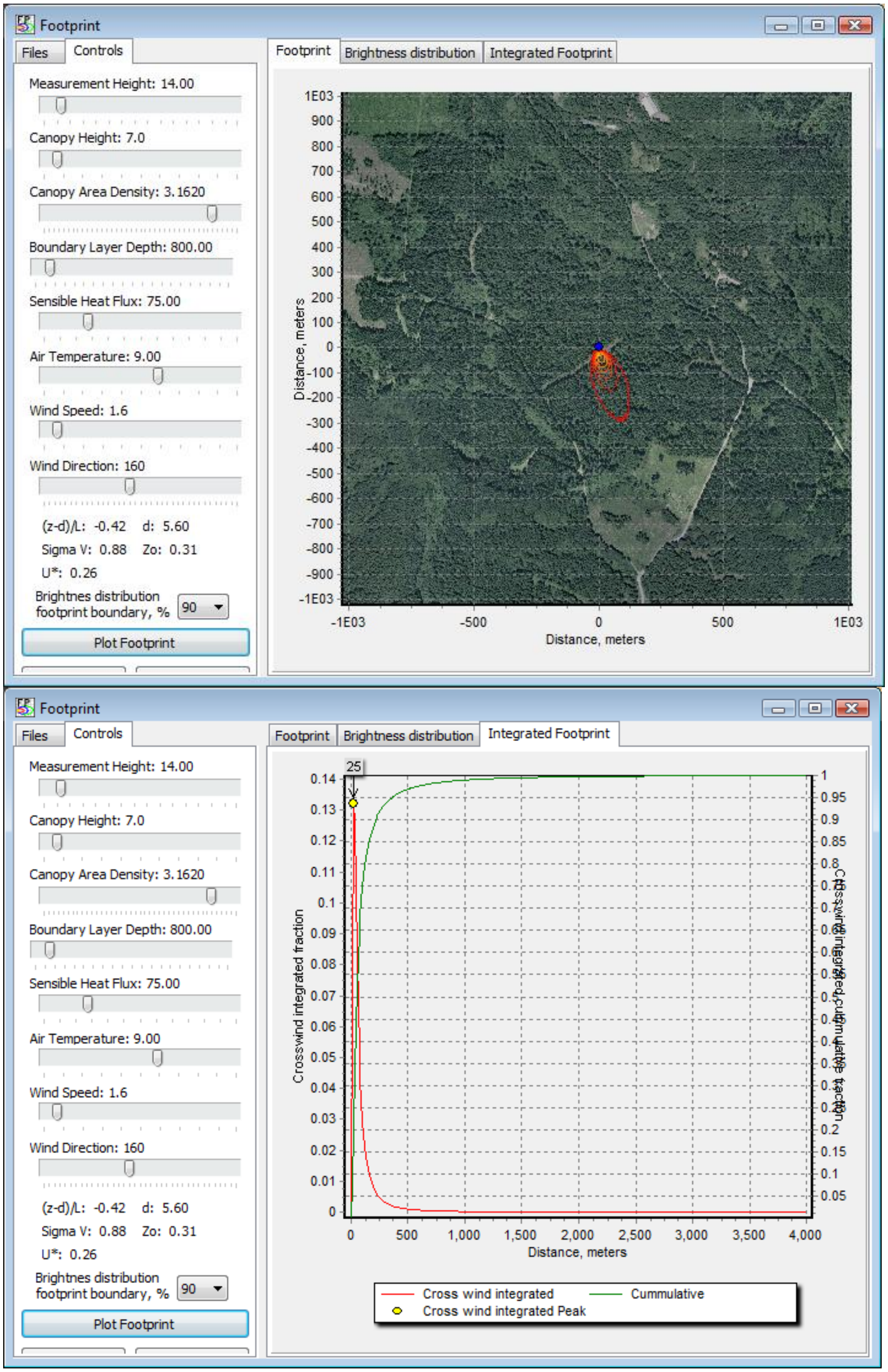


Figure 69. Abby Road Relocatable site winter daytime (convective) footprint output with mean wind speed at the end of 8th year operation

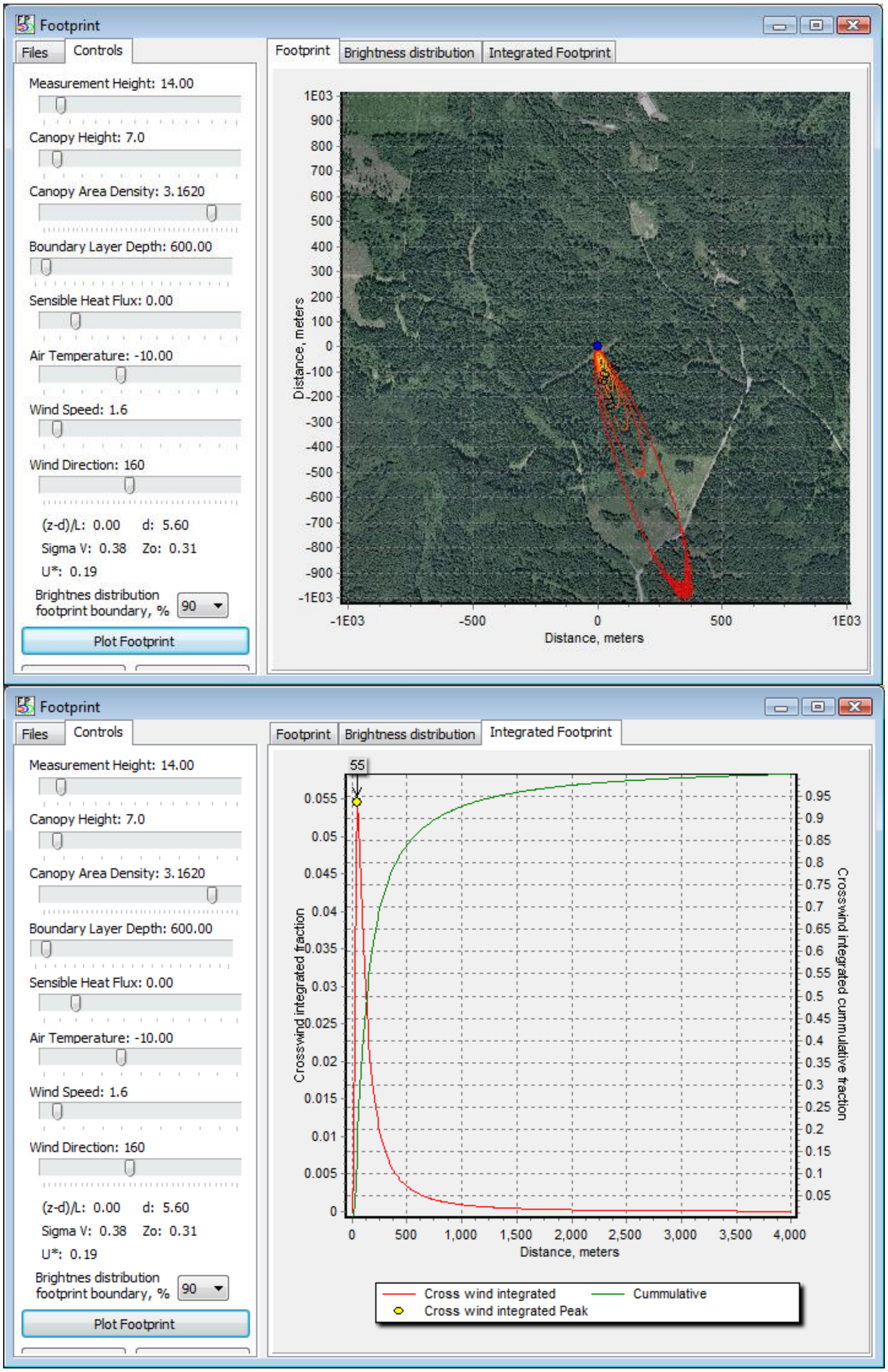


Figure 70. Abby Road Relocatable site winter nighttime (stable) footprint output with mean wind speed at the end of 8th year operation

5.4.6 Site design and tower attributes

According to wind roses, wind can blow from any direction between SE and NW, but prevailing wind blows from SSE direction (130^{o} to 190^{o}, clockwise from 130^{o}). **Tower** should be placed to a location to best catch the signals from the airshed of the ecosystem in interest, which is recent planted young Douglas fir forest at this site. We determined that the tower location is at 45.76243, -122.33033. However, due to the small size of this young Douglas fir parcel, fetch area of the tower at this site is likely to go beyond the boundary of this management parcel and extend into neighbor managements parcels (which are forest at different heights), particularly under daytime strong wind conditions and nighttime calm wind condition (see footprint analysis results above). The distance between tower and the closest point of the forest at edge is ~120 m. Therefore, edge effects and uncertainties for flux measurements cannot be avoided.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the south 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 west toward tower and have the longer side parallel to SE-NW direction. Therefore, we decide the placement of instrument hut at 45.76256, -122.33023.

The ecosystem around tower and inside the major airshed is young Douglas fir forest, which is 4-6 years old. Canopy height is currently ~1 m. Trees grow actively (~0.5 m per year). Assume the construction at this site will be in 2012 or 2013, which will give canopy height ~ 2 m. The mean canopy height will be expected to reach ~ 6 m after 8 years of operation, which is approximately by the time NEON relocatable tower decommissioned at this site. The understory at forest floor is thick and ~ 0.4 m tall, and dominated by ferns, grasses, thistle, etc.

Because this is a young tree plantation, the tree height will change prior to construction, and during our operational period. This plant canopy is rapidly accruing height and will continue to grow for several decades. If the tower was to be built on site characterization date (10/20/10), the tower height would be 6 m. If the tower is to build 2 years from this date, i.e., late 2012, the tower height would be 8 m.a.g.l. During operations the tower height will also need to be increased according to the FIU Science Requirements, for example at the end of 8 years of operation (late 2020) the top measurement level will need to be 15 m.a.g.l. For the remainder of this site characterization, we assume the site will be constructed in 2012, and require a tower height of 8 m.a.g.l. ***If the schedule changes for whatever reason, this height will have to be re-calculated.*** Therefore, we require 4 **measurement layers** on the tower with top measurement height at 8 m, and the remaining levels are 6 m, 3 m, and 0.3 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 **wet deposition collector** will be 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.

Table 23. Site design and tower attributes for Abby Road Relocatable site

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

Attribute	lat	long	degree	meters	notes
Airshed			130° to 190°		Clockwise from first angle
Tower location	45.76243,	-122.33033	--	--	
Instrument hut	45.76256,	-122.33023			
Instrument hut orientation vector	--	--	160°-340°		longwise
Instrument hut distance z	--	--	--	17	
Anemometer/Temperature boom orientation	--	--	180°	--	
Height of the measurement levels*					
Level 1				0.3	m.a.g.l.
Level 2				3.0	m.a.g.l.
Level 3				6.0	m.a.g.l.
Level 4				8.0	m.a.g.l.
Tower Height				8.0	m.a.g.l.

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

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

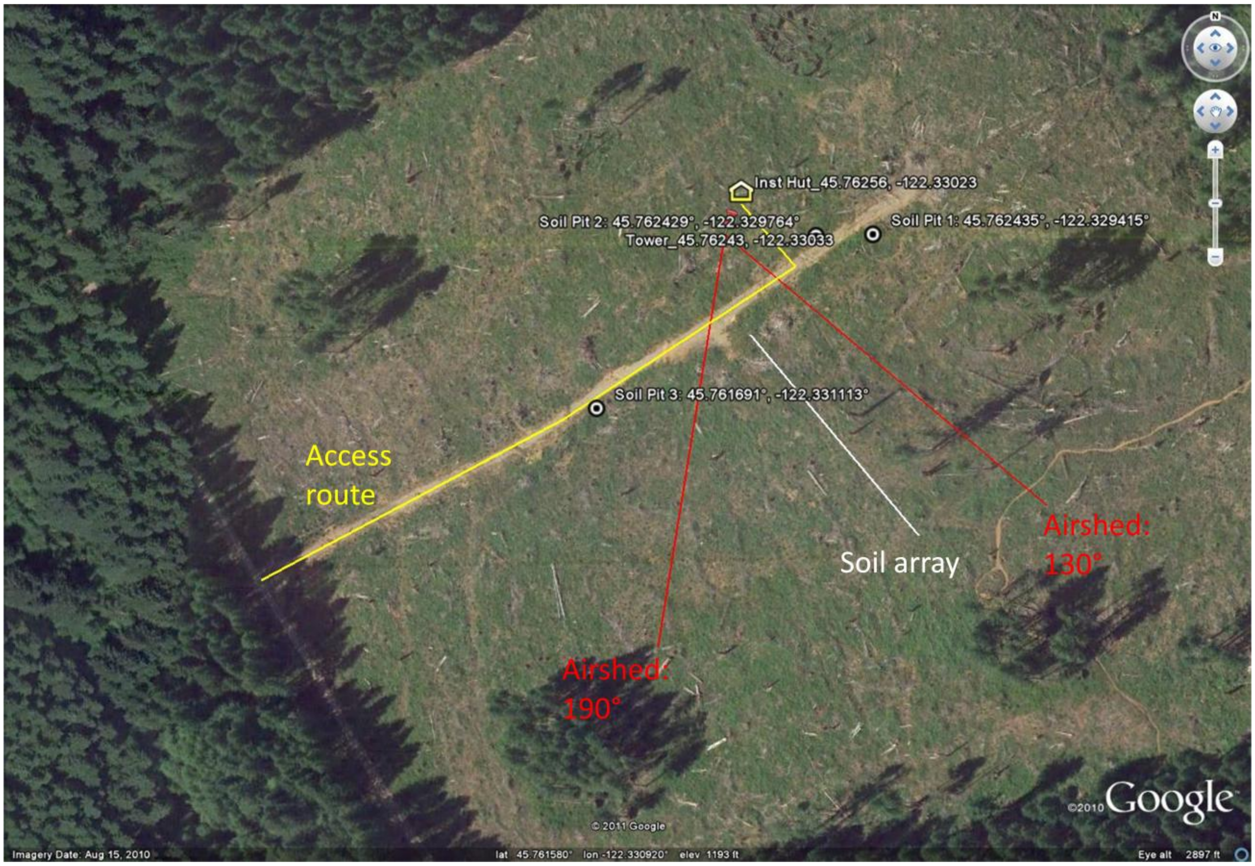


Figure 71. Site layout for Abby Road Relocatable site.
i) Tower location is presented (red pin), ii) Airshed boundary lines are not presented. Prevailing winds blow from 130^{o} to 190^{o} (clockwise from 130^{o}). iii) Yellow line is the suggested access road to instrument hut.

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. 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 this site:

- Boardwalk from logging access road to instrument hut (i.e. ~40 m in length), pending landowner decision.

- Boardwalk from the instrument hut to the tower to intersect on north face of the tower, pending landowner decision
- Boardwalk to soil array
- No boardwalk from soil array boardwalk to individual soil plots.

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

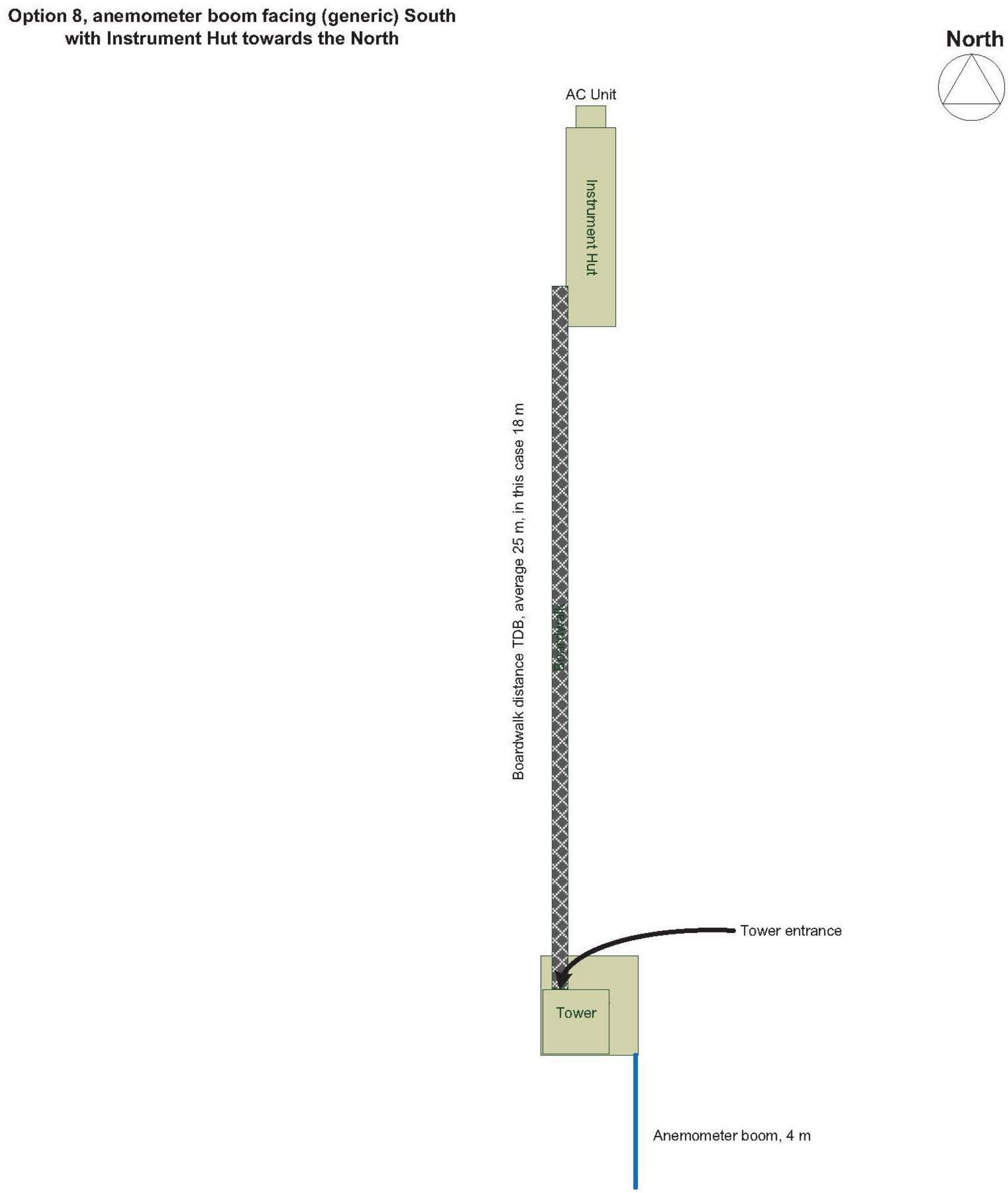


Figure 72. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing south and instrument hut on the north towards the tower.

This is just a generic diagram when boom facing south and instrument hut on the northern side of the tower. The actual design of boardwalk (or path if no boardwalk required) and instrument hut position will be joint responsibility of FCC and FIU. At Abby Road Relocatable site, the boom angle will be 180 degrees, instrument hut will be on the northeast towards the tower, the distance between instrument hut and tower is ~17 m. The instrument hut vector will be SW-NE (160°-340°, longwise).

5.4.7 Information for ecosystem productivity plots

The tower at Thayer relocatable site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (young Douglas fir forest). Prevailing wind blows from 130^{o} to 190^{o}, clockwise from 130^{o}. Due to the actively growing ecosystem and adjustment of the height of top measurement level over time, tower fetch area will change accordingly. We expect that 90% signals for flux measurements during daytime are within a distance of 700 m from tower for the operation period of 8 years, 80% within 400 m, and 70% within 300 m. Because of the small size of the management parcel (approximately 450 m × 500 m), and the distance between tower and the forest edge in the major airshed is only ~ 300 m, 30% of the flux signals will likely come from the taller forest (34 m) outside our measurement parcel. Uncertainty is large but cannot be avoided.We suggest FSU Ecosystem Productivity plots are placed within the boundaries of 130^{o} to 190^{o} (major, clockwise from 130°) from tower.

5.5 Issues and attentions

The forest parcel for the tower site is small. The fetch area for flux measurements will likely to extend into neighboring managements parcels with tall trees (34 m). Only ~70% flux signals are from the area within the same management plot of young Douglas fir forest. It will be challenging to intepret the measurement results. However, this cannot be easily avoided in this region, because landownership and forest management practices are for small parcels in this region.

The plant canopy is actively and rapidly accruing height. Design, construction and operations need to take this into account. During the site characterization visit mean canopy height was ~1 m. We assume the construction at this site will be in 2012 or 2013 and that the tree growth rate is ~0.5 m/yr, which will give canopy height ~ 2 m at construction. The mean canopy height is expected to reach ~ 6 m after 8 years of operation, which is approximately by the time NEON relocatable tower decommissioned at this site. For any change to this schedule the heights would have to be re-calculated. FCC should design and budget adequate tower height ahead and allow the increase of the top measurement level from 8 m to 15 m. Tree height shall be reevaluated at the time of construction to ensure the tower height and boom heights are appropriate.

The landowner requests that the boardwalk goes around the trees at this site, rather than cut them down. The trees are young (~4-6 years old) and may have stem diameters below the threshold diamieter usually recorded by a site surveyors for NEON's Facilities and Civel Construction (FCC) group. A special request to record smaller diameter stems may be necessary for the construction survey at this site.

There is a campground near the site (1-2 km away), but whether and how often people enter this site is unknown. Signs and fences may be required to minimize disturbance to NEON infracstructure and instruments.

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