D15 FIU SITE CHARACTERIZATION SUPPORTING DATA

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See configuration management system for approval history.

Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	12/10/2010	NEON.FIU.000255.CRE_D15 FIU Site Characterization Reports	INITIAL RELEASE
B	09/23/2011	ECO-00279	Update to new document number's/template throughout document.
C	01/28/2015	ECO-02592	Salt Lake City Urban site replaces Murray site in D15 FIU Site Characterization Report. Murray site was deemed not viable and an alternative location has been identified (Salt Lake City Urban).

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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 15. This document presents all the supporting data for FIU site characterization at D15.

1.2 Scope

FIU site characterization data and analysis results presented in this document are for the three D15 tower locations: Onaqui-Ault (Advanced), Salt Lake City Relocatable site (Relocatable 1), and Red Butte Canyon Relocatable site (Relocatable 2). Issues and concerns for each site that need further review are also addressed in this document according to our best knowledge.

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

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

AD[01]	NEON.DOC.011008 _ FIU Tower Design Science Requirements
AD[02]	NEON.DOC.011000 _ FIU Technical and Operation Requirements
AD[03]	
AD[04]	NEON.DOC.011029 _ FIU Precipitation Collector Site Design Requirements

2.2 Reference Documents

RD[01]	NEON.DOC.000008 NEON Acronym List
RD[02]	NEON.DOC.000243 NEON Glossary of Terms
RD[03]	
RD[04]	

2.3 Acronyms

2.4 Verb Convention

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

3 ONAQUI-AULT (ADVANCED TOWER SITE)

3.1 Site description

NEON Onaqui-Ault candidate advanced tower site (40.17620563, -112.4557424) is located 100 km southwest of Salt Lake City, UT (Figure 1). The Onaqui site is under the ownership predominantly of the USDI Bureau of Land Management (BLM) with some inclusion of State of Utah land. The site has open access to the public; although access is through a small amount of private land, gates are not locked and by law access is required. The major access constraint at the moment is that the current dirt roads are impassable by vehicles during wet and winter snow conditions. In the long term ATV access to the sites will work out best because the dirt roads can be challenging during the winter when snow covered and frequent 4-WD vehicle access during wet periods can cause excessive road damage.

The Onaqui site offers extensive sagebrush steppe transitioning into juniper woodland. Ecological research at this specific location or immediately nearby includes the Joint Fire Science Project focusing on sagebrush restoration following cheatgrass invasion and woodland expansion; historical USFS contrasting grazing and re-vegetation treatment studies; USU carbon, water and nutrient cycle studies as well as eddy covariance measurements; and Utah studies on the dynamics of rodents and hantavirus.

Climate: The Intermountain Region, located between the Sierra Nevada and Cascade ranges to the West and the Rocky Mountains to the east, is among the driest regions of the USA. In winter, western North American climate is dominated by a westerly flow of cool, moist air from the northern Pacific. However, the Sierras and Cascades cast a rain shadow across the Intermountain Region, leading to low precipitation in the basins. In summer, monsoonal flow from the subtropical eastern Pacific becomes more important, but most of the Intermountain Region is currently beyond the monsoon's typical northern limits although this moisture extends into the region during ENSO events. As a result, the climate of the Intermountain Region is arid to semiarid, with cool, moist winters and hot, dry summers. A gradient of precipitation seasonality occurs within the region. To the extreme north and west, virtually all precipitation occurs in fall through spring, with very dry summers. In the southern and eastern extremes, equal amounts of precipitation may fall in winter and summer. Even in these locations, however, most of the effective precipitation for plant growth is received in winter, since summer rains rapidly evaporate due to high temperatures. The Onaqui site provides a clear example of the regional climate (Figure 2). Mean annual precipitation is only 274 mm, and while it is distributed equitably throughout the year, soil moisture is recharged during the winter and spring when temperatures are low. Because the site is influenced by both Pacific winter storms and summer monsoon flow, this site will be sensitive to changes in either of these climate signals (Source for above Info: James Ehleringer, RFI for D15).

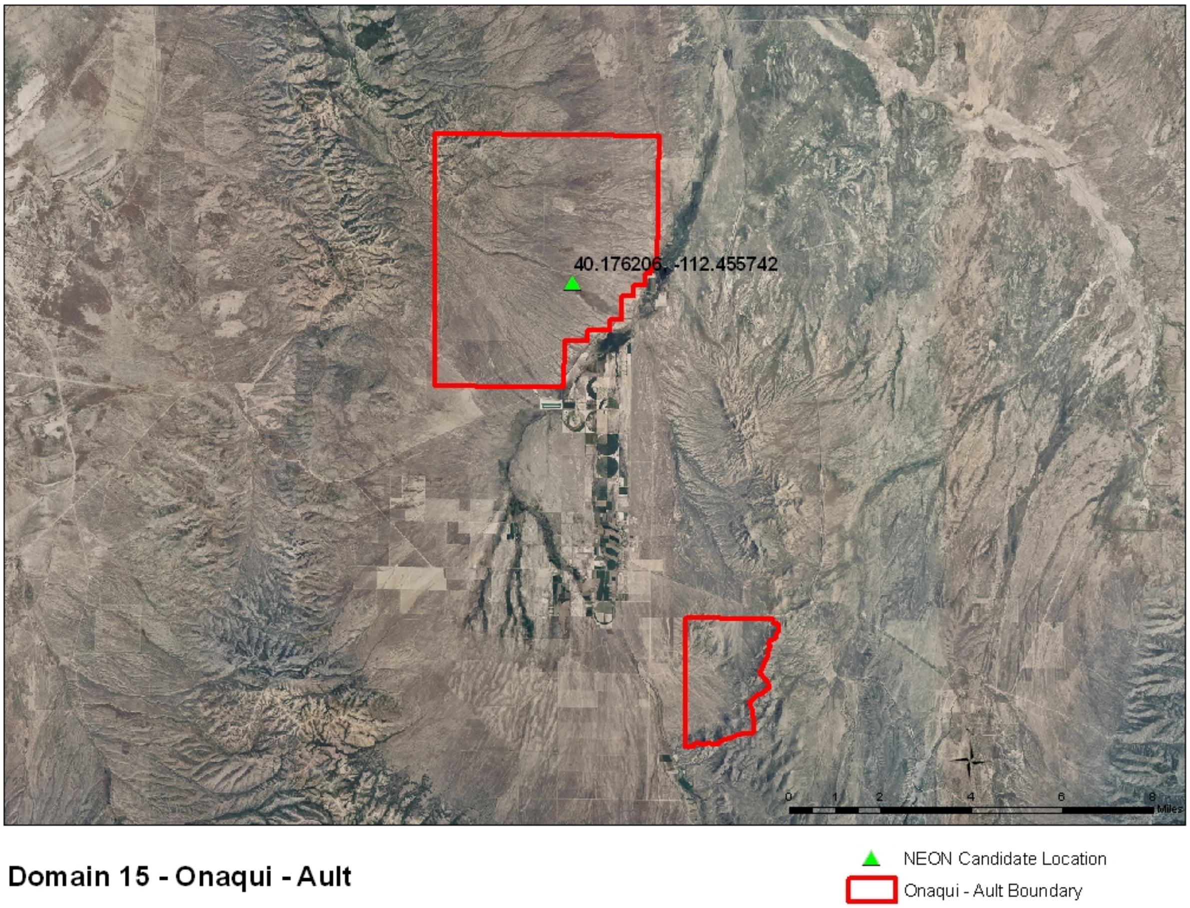


Figure 1. NEON candidate site tower location and boundary map

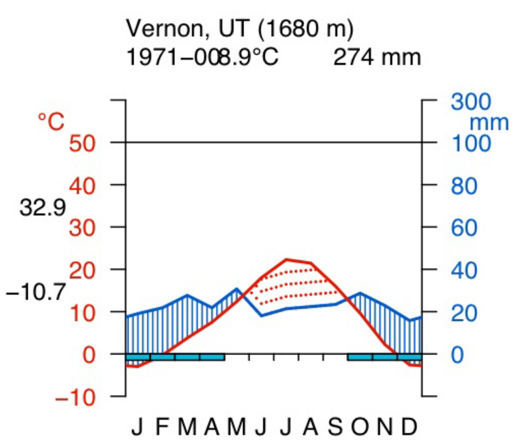


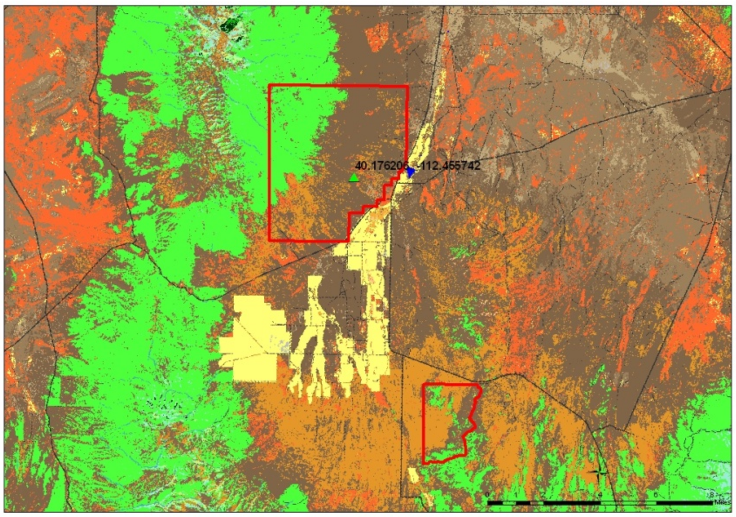
Figure 2. Climate diagram for Vernon, UT, approximately 8 km from the proposed Onaqui-Benmore site (1953-2005). Monthly average temperature data are shown in red; monthly average precipitation is shown in blue. Data are from the National Climate Data Center. Precipitation values differ from values for the Onaqui-Benmore site calculated using PRISM.

3.2 Ecosystem

Vegetation: Big sagebrush (*Artemisia tridentata* subspecies) is the defining feature of Intermountain Region lower elevation vegetation. The two most widespread vegetation types in the region are "Sagebrush steppe" and "Great Basin sagebrush" (Küchler, 1970). In sagebrush steppe, which occurs in basins in the northern half of the region, and at higher elevations in the southern half, sagebrush is co-dominant with perennial bunchgrasses, primarily *Pseudoroegneria spicata*. In Great Basin sagebrush, which occurs in drier and hotter basins, sagebrush is the dominant overstory species, and the understory is composed of a small-statured perennial grass, *Poa secunda*, and a variety of forbs. A variety of shrub-dominated communities occur at lower elevations in saline soils, and tree species, especially juniper and pinyon pine, are found at higher elevations. Each of these vegetation types occurs within the Onaqui-Benmore area. The site lies on a gently sloping alluvial fan and provides a gradient from salt desert at the bottom up through healthy Wyoming big sagebrush-grassland and into Juniper woodland. Vast areas of the Intermountain Region have been invaded by exotic plant species, especially annual species. Onaqui-Benmore is no exception. The following exotic plants are locally common at the proposed wildland site: Cheatgrass (*Bromus tectorum*), tall tumblemustard (*Sisymbrium altissimum*), pinnate tansymustard (*Descurainia sophia*), clasping pepperweed (*Lepidium perfoliatum*), Canada thistle (*Cirsium arvense*), prickly lettuce (*Lactuca serriola*), curveseed butterwort (*Ceratocephala testiculata*).

Disturbance regimes: Three types of disturbance play important roles in Intermountain ecosystems: livestock grazing, fire, and land-use change or urbanization (Source for above Info: James Ehleringer, RFI for D15).

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



Domain 15 - Onaqui - Ault

Figure 3. Vegetative cover map of Onaqui-Ault and surrounding areas

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

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

Veg Type	Area	Percent
Agriculture-Pasture and Hay	0.025295	0.04094694
Artemisia tridentata ssp. vaseyana Shrubland Alliance	0.0081	0.01311211
Barren	0.0009	0.0014569
Columbia Plateau Steppe and Grassland	0.0018	0.0029138
Developed-Low Intensity	0.159542	0.25826292
Developed-Medium Intensity	0.0036	0.00582761
Developed-Open Space	0.04003	0.06479967
Great Basin Pinyon-Juniper Woodland	16.07624	26.0238887
Great Basin Xeric Mixed Sagebrush Shrubland	0.420387	0.68051371
Inter-Mountain Basins Big Sagebrush Shrubland	33.37602	54.0284035
Inter-Mountain Basins Big Sagebrush Steppe	8.18083	13.2429577
Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland	0.032912	0.05327797
Inter-Mountain Basins Greasewood Flat	0.368108	0.59588631
Inter-Mountain Basins Juniper Savanna	1.147701	1.85787494
Inter-Mountain Basins Mixed Salt Desert Scrub	0.141884	0.22967809
Inter-Mountain Basins Montane Riparian Systems	0.003649	0.00590624
Inter-Mountain Basins Montane Sagebrush Steppe	0.001476	0.00238988
Inter-Mountain Basins Semi-Desert Grassland	0.004176	0.00676059
Inter-Mountain Basins Semi-Desert Shrub-Steppe	0.067595	0.10942183
Introduced Upland Vegetation-Annual and Biennial Forbland	0.365831	0.59219891
Introduced Upland Vegetation-Annual Grassland	1.263394	2.04515686
Introduced Upland Vegetation-Perennial Grassland and Forbland	0.045982	0.07443549
Mojave Mid-Elevation Mixed Desert Scrub	0.0054	0.00874141
Quercus gambelii Shrubland Alliance	0.0009	0.0014569
Rocky Mountain Lower Montane-Foothill Shrubland	0.002515	0.00407115
Rocky Mountain Montane Riparian Systems	0.027645	0.04475117
Southern Rocky Mountain Montane-Subalpine Grassland	0.003032	0.00490876
Total Area sq km	**61.77494**	100

The representative ecosystem that NEON design is focused on for this core site is open sage shrubland. It is evergreen shrubland. Ground coverage is ~60%. Canopy height is ~1.2 m around tower site with lowest branches at ground level. Grass understory with height ~ 0.3 m. Canopy area density is estimated to be 0.6 throughout the whole year.

Table 2. Ecosystem and site attributes for Onaqui-Ault Advanced tower site.

Ecosystem attributes	Measure and units

Mean canopy height	1.2 m
Surface roughness[a]	0.2 m
Zero place displacement height[a]	0.8 m
Structural elements	open canopy, uniform
Time zone	Mountain time zone
Magnetic declination	12° 20' E changing by 0° 7' W y-1

Note, [a] From field observation.

3.3 Soils

3.3.1 Soil description

Soil data and soil maps (Figures 4) below for Onaqui-Ault Advanced tower site were collected from 2.2 km^2 NRCS soil maps(http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm), which centered at the tower location, to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

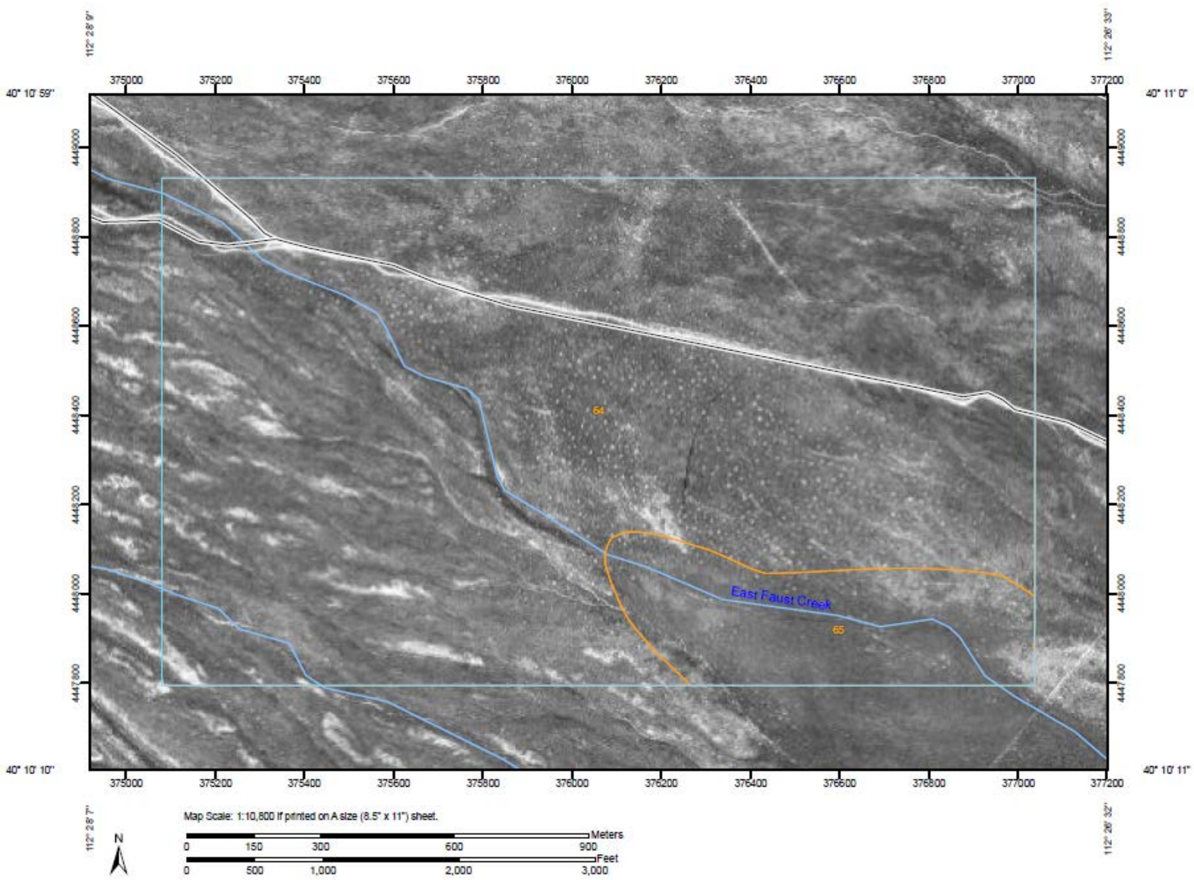


Figure 4. 2.2 km^2 soil map for Onaqui-Ault NEON advanced tower site, center at tower location.

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

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

Table 3. Soil Series and percentage of soil series within 2.2 km^2 centered on the tower.
Area Object Interest (AOI) is the mapping unit from NRCS.

Tooele Area, Utah - Tooele County and Parts of Box Elder, Davis and Juab Counties (UT611)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
64	Taylorsflat loam, 1 to 5 percent slopes	489.4	89.0%
65	Taylorsflat loam, saline, 0 to 3 percent slopes	60.3	11.0%
Totals for Area of Interest		**549.7**	**100.0%**

Tooele Area, Utah - Tooele County and Parts of Box Elder, Davis and Juab Counties-64—Taylorsflat loam, 1 to 5 percent slopes: Map Unit Setting Elevation: 5,000 to 6,000 feet Mean annual precipitation: 10 to 12 inches Mean annual air temperature: 45 to 52 degrees F Frost-free period: 110 to 140 days **Map Unit Composition** Taylorsflat and similar soils: 90 percent Minor components: 10 percent **Description of Taylorsflat Setting** Landform: Fan remnants, lake terraces Landform position (three-dimensional): Tread Down-slope shape: Concave, linear Across-slope shape: Convex, linear Parent material: Mixed alluvium and/or mixed lacustrine deposits **Properties and qualities** Slope: 1 to 5 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.57 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 40 percent Maximum salinity: Nonsaline to moderately saline (2.0 to 16.0 mmhos/cm) Sodium adsorption ratio, maximum: 30.0 Available water capacity: Moderate (about 8.1 inches) **Interpretive groups** Land capability classification (irrigated): 3s Land capability (nonirrigated): 6s Ecological site: Semidesert Loam (Wyoming Big Sagebrush) (R028AY220UT) **Typical profile** 0 to 4 inches: Loam 4 to 9 inches: Loam 9 to 60 inches: Loam **Minor Components: Hiko peak** Percent of map unit: 4 percent **Birdow** Percent of map unit: 3 percent **Spager** Percent of map unit: 3 percent

Tooele Area, Utah - Tooele County and Parts of Box Elder, Davis and Juab Counties-65—Taylorsflat loam, saline, 0 to 3 percent slopes: Map Unit Setting: Elevation: 4,300 to 5,300 feet Mean annual precipitation: 10 to 12 inches Mean annual air temperature: 45 to 52 degrees F Frost-free period: 110 to

140 days **Map Unit Composition:** Taylorsflat, saline, and similar soils: 90 percent Minor components: 10 percent **Description of Taylorsflat, Saline: Setting** Landform: Fan remnants, lake terraces Landform position (three-dimensional): Tread Down-slope shape: Concave, linear Across-slope shape: Convex, linear Parent material: Mixed alluvium and/or mixed lacustrine deposits **Properties and qualities:** Slope: 0 to 3 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.57 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 40 percent Maximum salinity: Very slightly saline to moderately saline (4.0 to 16.0 mmhos/cm) Sodium adsorption ratio, maximum: 30.0 Available water capacity: Moderate (about 8.0 inches) **Interpretive groups:** Land capability classification (irrigated): 4s Land capability (nonirrigated): 6s Ecological site: Semidesert Alkali Loam (Black Greasewood) (R028AY202UT) **Typical profile:** 0 to 3 inches: Loam 3 to 9 inches: Loam 9 to 60 inches: Loam **Minor Components: Taylorsflat** Percent of map unit: 4 percent Landform: Fan remnants, lake terraces Landform position (three-dimensional): Tread Down-slope shape: Concave, linear Across-slope shape: Convex, linear Ecological site: Semidesert Loam (Wyoming Big Sagebrush) (R028AY220UT) **Hiko peak** Percent of map unit: 3 percent Landform: Ridges Landform position (two-dimensional): Summit Landform position (three-dimensional): Crest, interfluves Down-slope shape: Convex Across-slope shape: Convex Ecological site: Semidesert Gravelly Loam (Wyoming Big Sagebrush) North (R028AY215UT) **Spager** Percent of map unit: 3 percent Landform: Fan remnants Down-slope shape: Concave Across-slope shape: Convex Ecological site: Semidesert Shallow Hardpan (8-10 Ppt) (R028AY231UT)

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.

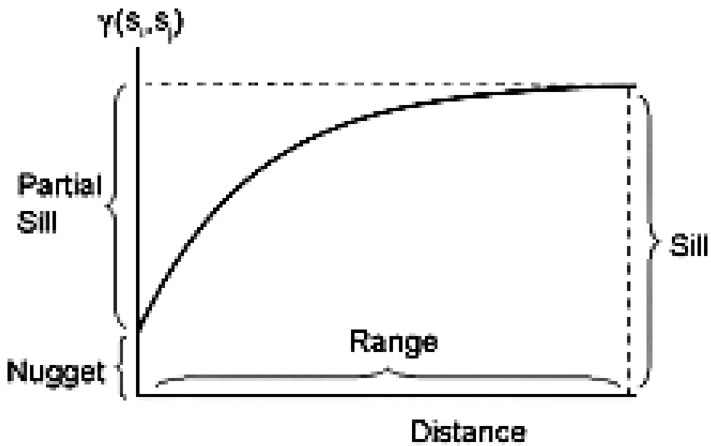


Figure 5. Example semivariogram, depicting range, sill, and nugget.

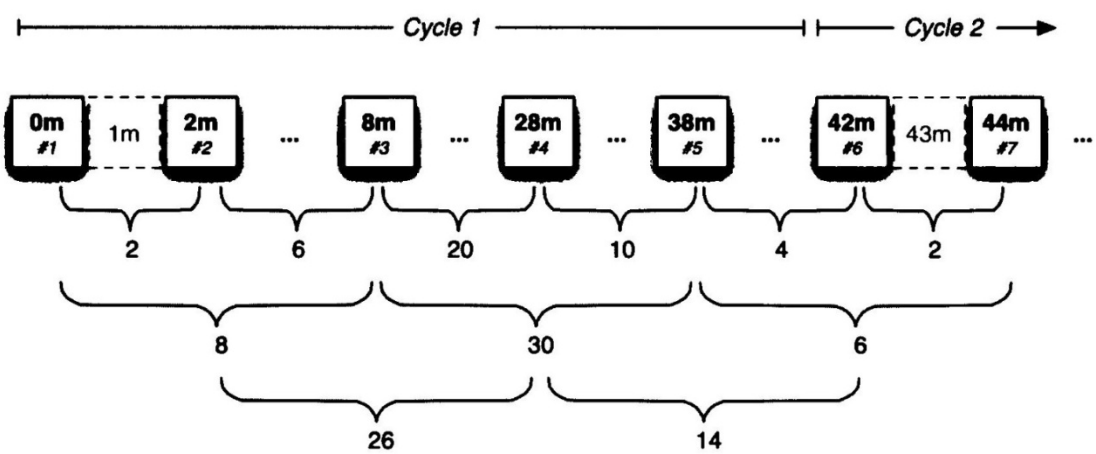


Figure 6. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 18 May 2010 at the Onaqui-Ault 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 (168 m, 84 m, and 84 m) located in the expected airshed at Onaqui-Ault. 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 graphs) 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 14 m for soil temperature.

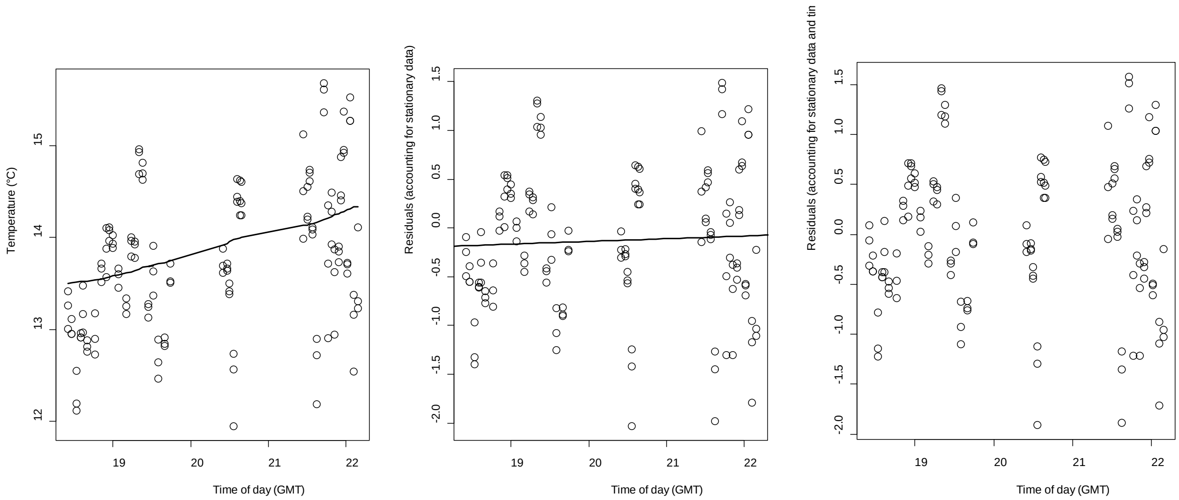


Figure 7. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting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

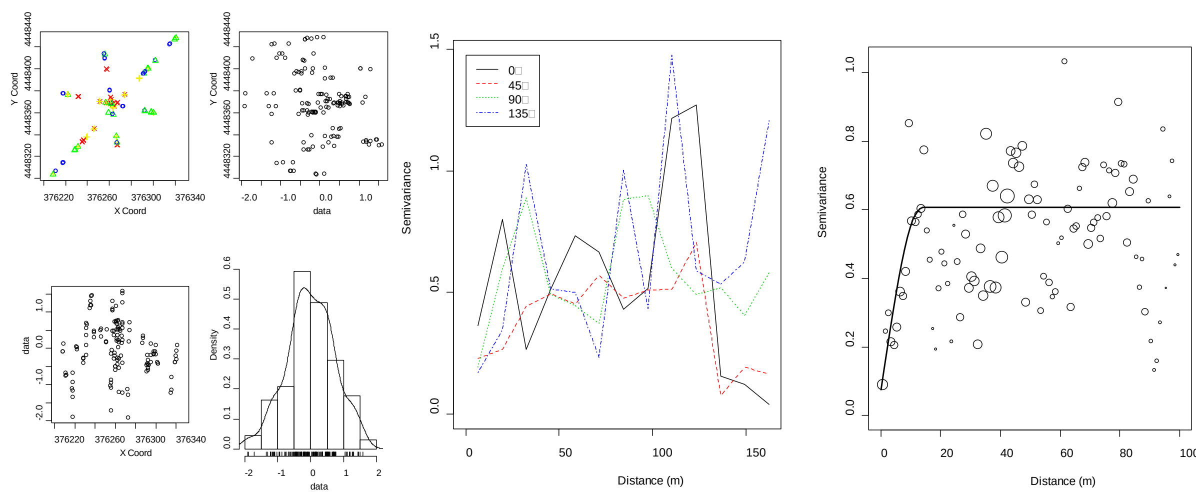


Figure 8. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

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 130 m for soil water content.

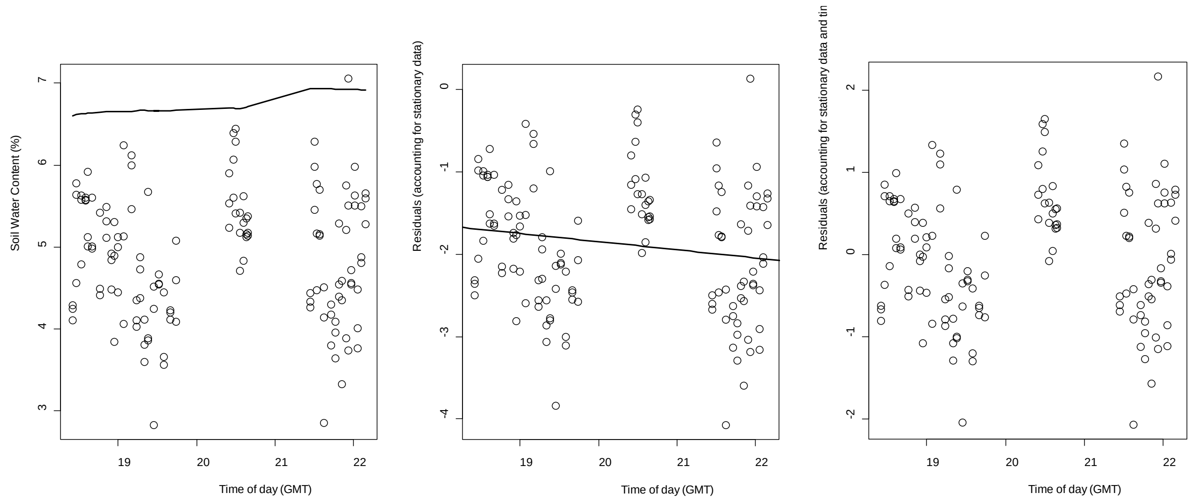


Figure 9. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting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

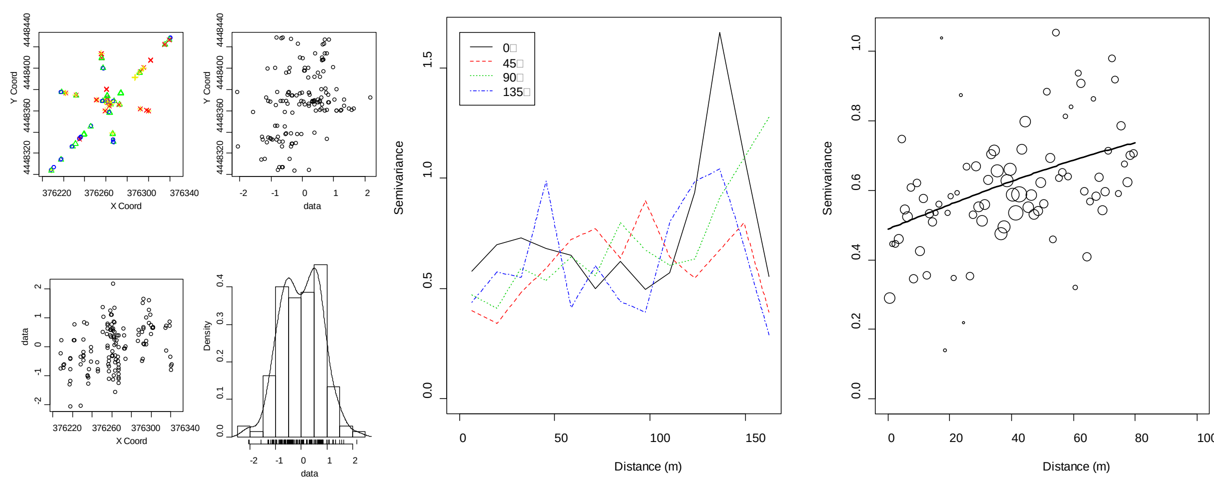


Figure 10. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

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 14 m for soil temperature and 130 m for soil moisture. Based on these results and the site design guidelines the soil plots at Onaqui-Ault 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 210° from the soil plot nearest the tower (i.e., first soil plot). The location of the first soil plot will be approximately 40.17743°, -112.45253°. 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 40.17828, -112.45367 (primary location); or 40.17792, -112.45134 (alternate location 1 if primary location is unsuitable); 40.17871, -112.45614 (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: Taylorsflat loam, saline, 0 to 3 percent slopes. The taxonomy of this soil is shown below:
Order: Aridisols
Suborder: Calcids
Great group: Haplocalcids
Subgroup: Xeric Haplocalcids
Family: Fine-loamy, mixed, superactive, mesic Xeric Haplocalcids
Series: Taylorsflat loam, saline, 0 to 3 percent slopes

Table 4. Summary of soil array and soil pit information at Onaqui-Ault. 0° represents true north and accounts for declination.

Soil plot dimensions	5 m x 5 m
Soil array pattern	B
Distance between soil plots: x	40 m
Distance from tower to closest soil plot: y	19 m
Latitude and longitude of 1st soil plot OR direction from tower	40.17743°, -112.45253°
Direction of soil array	210°
Latitude and longitude of FIU soil pit 1	40.17828, -112.45367 (primary location)
Latitude and longitude of FIU soil pit 2	40.17792, -112.45134 (alternate 1)
Latitude and longitude of FIU soil pit 3	40.17871, -112.45614 (alternate 2)
Dominant soil type	Taylorsflat loam, saline, 0 to 3 percent slopes
Expected soil depth	>2 m
Depth to water table	>2 m

Expected depth of soil horizons	Expected measurement depths*
0-0.08 m (loam)	0.04 m
0.08-0.23 m (loam)	0.16 m
0.23-1.52 m (loam)	0.88 m
1.52-2 m	1.76 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.

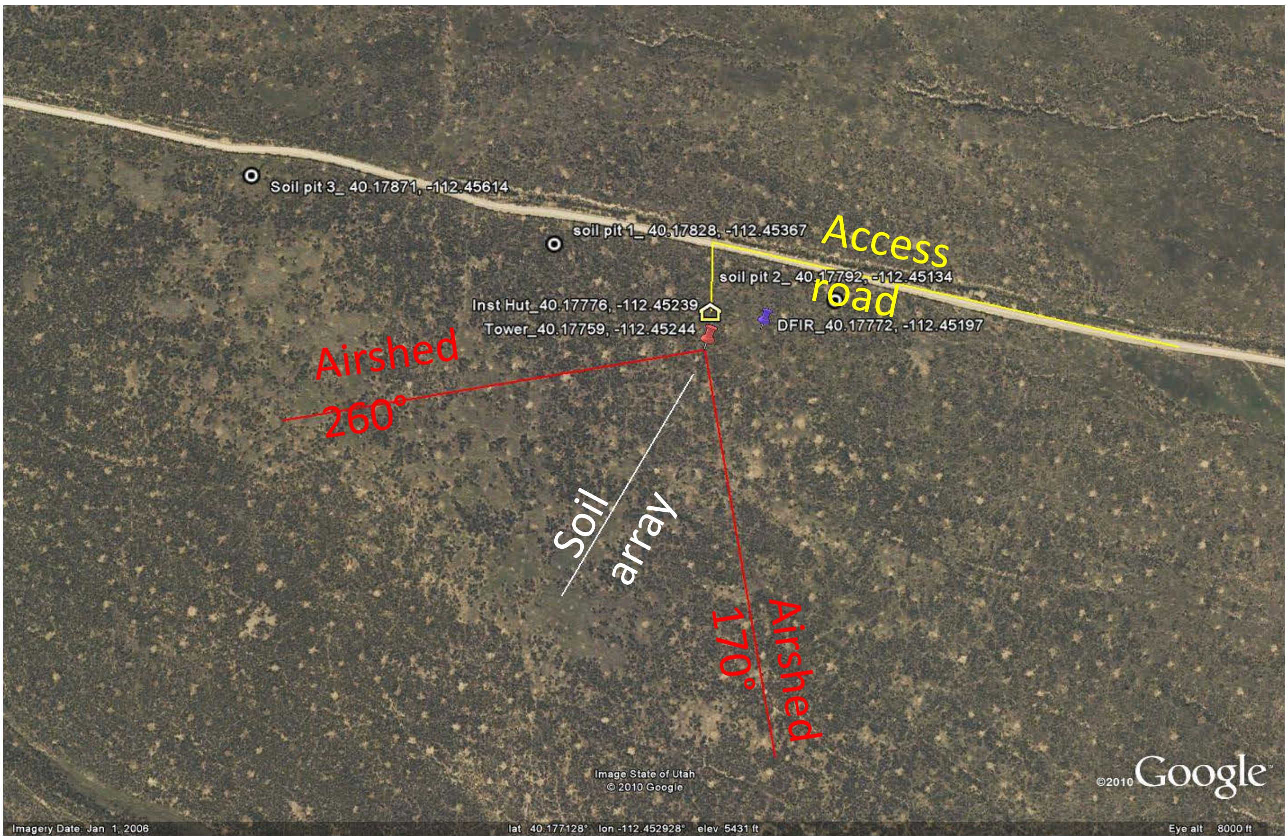


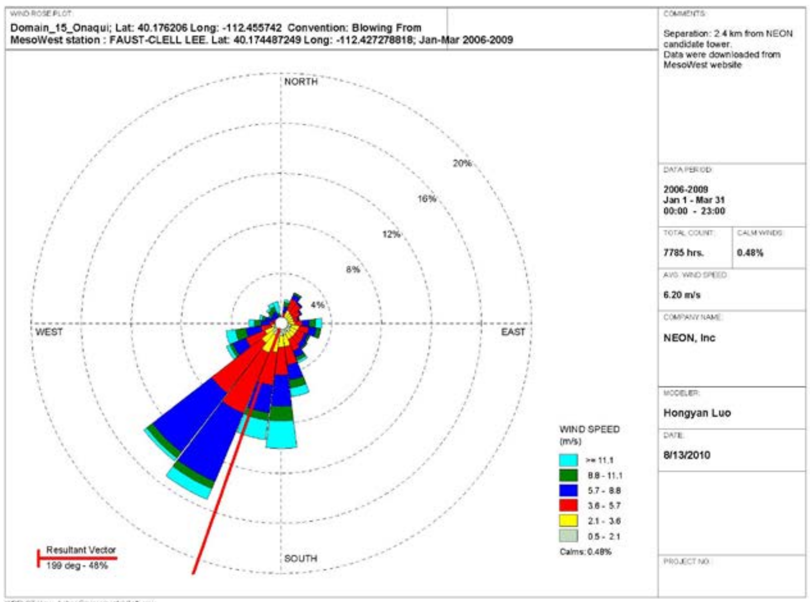
Figure 11. Site layout at Onaqui-Ault Advance site showing soil array and location of the FIU soil pits.

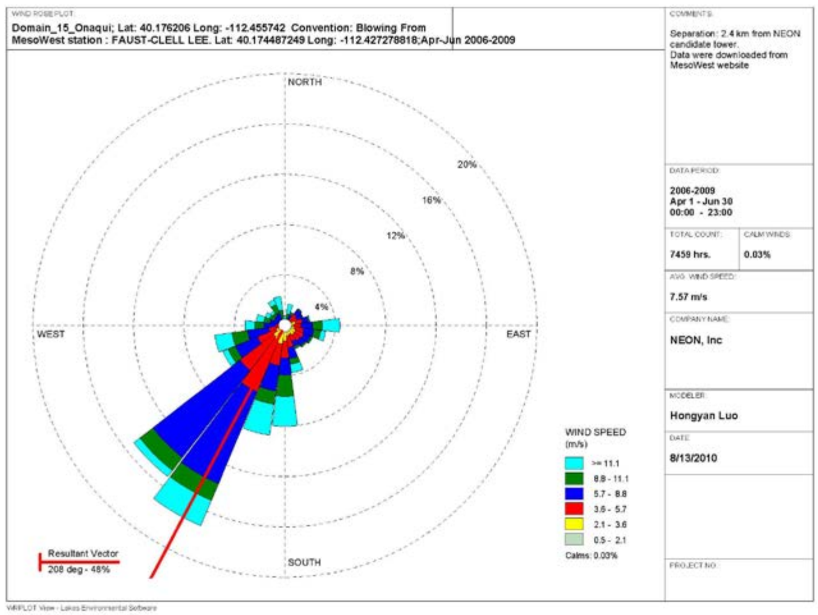
3.4 Airshed

3.4.1 Seasonal windroses

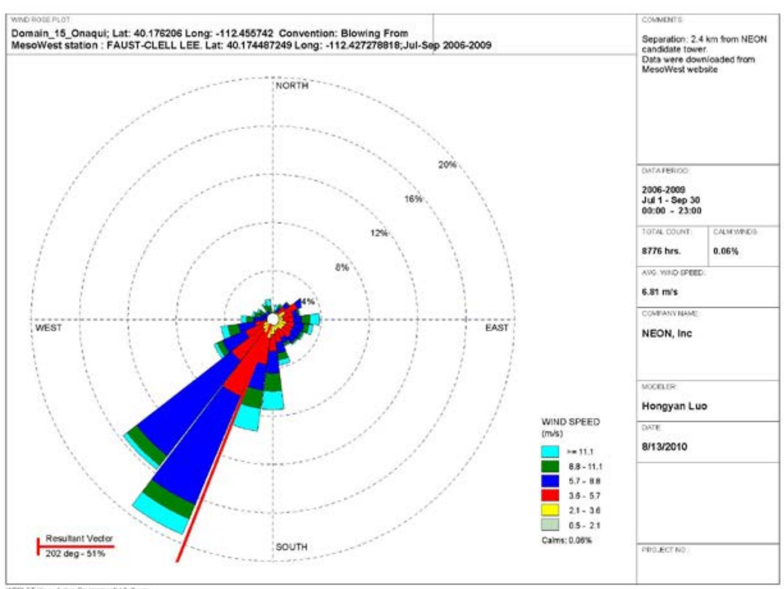
Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries, Figure 12. The weather data used to generate the following wind roses are from MesoWest station FAUST-CLELL LEE (40.174487249, -112.427278818), which is ~2.4 km from NEON tower site. The orientation of the wind rose follows that of a compass (assume declination applied). When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 24 cardinal directions.

3.4.2 Results (graphs for wind roses)





WIND ROSE PLOT:
Domain_15_Onaqui; Lat: 40.176206 Long: -112.455742 Convention: Blowing From
MesoWest station : FAUST-CLELL LEE. Lat: 40.174487249 Long: -112.427278818;Apr-Jun 2006-2009
COMMENTS:
Separation: 2.4 km from NEON candidate tower.
Data were downloaded from MesoWest website
NORTH
WEST
EAST
SOUTH
20%
16%
12%
8%
4%
DATA PERIOD:
2006-2009
Apr 1 - Jun 30
00:00 - 23:00
TOTAL COUNT:
7459 hrs.
CALM WINDS:
0.03%
AVG. WIND SPEED:
7.57 m/s
COMPANY NAME:
NEON, Inc
MODELER:
Hongyan Luo
DATE:
8/13/2010
PROJECT NO.:
WIND SPEED (m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 0.03%
Resultant Vector
208 deg - 48%
WRPLOT View - Lakes Environmental Software



WIND ROSE PLOT:
Domain_15_Onaqui; Lat: 40.176206 Long: -112.455742 Convention: Blowing From
MesoWest station : FAUST-CLELL LEE. Lat: 40.174487249 Long: -112.427278818;Jul-Sep 2006-2009
COMMENTS:
Separation: 2.4 km from NEON candidate tower.
Data were downloaded from MesoWest website
NORTH
WEST
EAST
SOUTH
20%
16%
12%
8%
4%
DATA PERIOD:
2006-2009
Jul 1 - Sep 30
00:00 - 23:00
TOTAL COUNT:
8776 hrs.
CALM WINDS:
0.06%
AVG. WIND SPEED:
6.81 m/s
COMPANY NAME:
NEON, Inc
MODELER:
Hongyan Luo
DATE:
8/13/2010
PROJECT NO.:
WIND SPEED (m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 0.06%
Resultant Vector
202 deg - 51%
WRPLOT View - Lakes Environmental Software

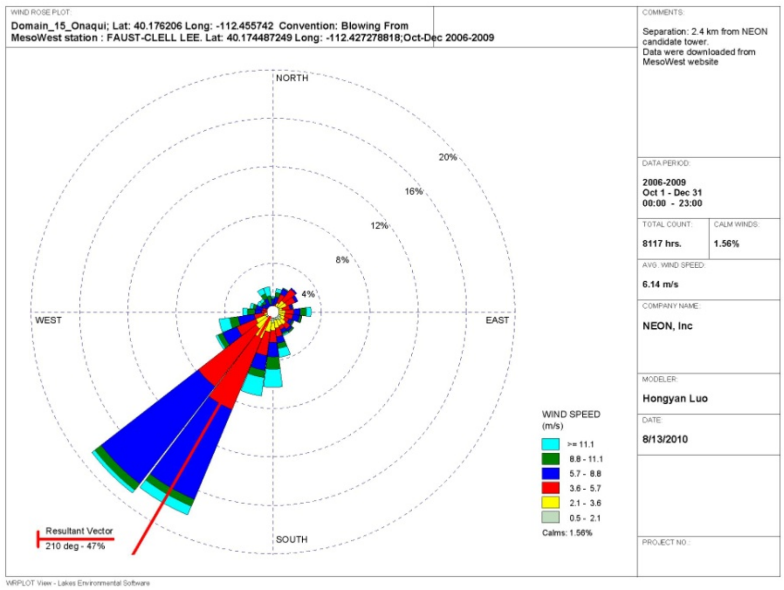


Figure 12. Windroses from MesoWest FAUST-CLELL LEE station.
Data used here are hourly data from 2006 to 2009. Data used here are hourly data from 2006 to 2009. Data was collected and obtained from the MesoWest FAUST-CLELL LEE station, which is ~2.4 km from NEON tower site. It is assumed that the wind data was corrected for declination. Panels are (from top to bottom), Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

3.4.3 Resultant vectors

Table 5. The resultant wind vectors from Onaqui-Ault site using hourly data from 2006 to 2009.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	199°	48
April to June	208°	48
July to September	202°	51
October to December	210°	47
Annual	204.75°	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.

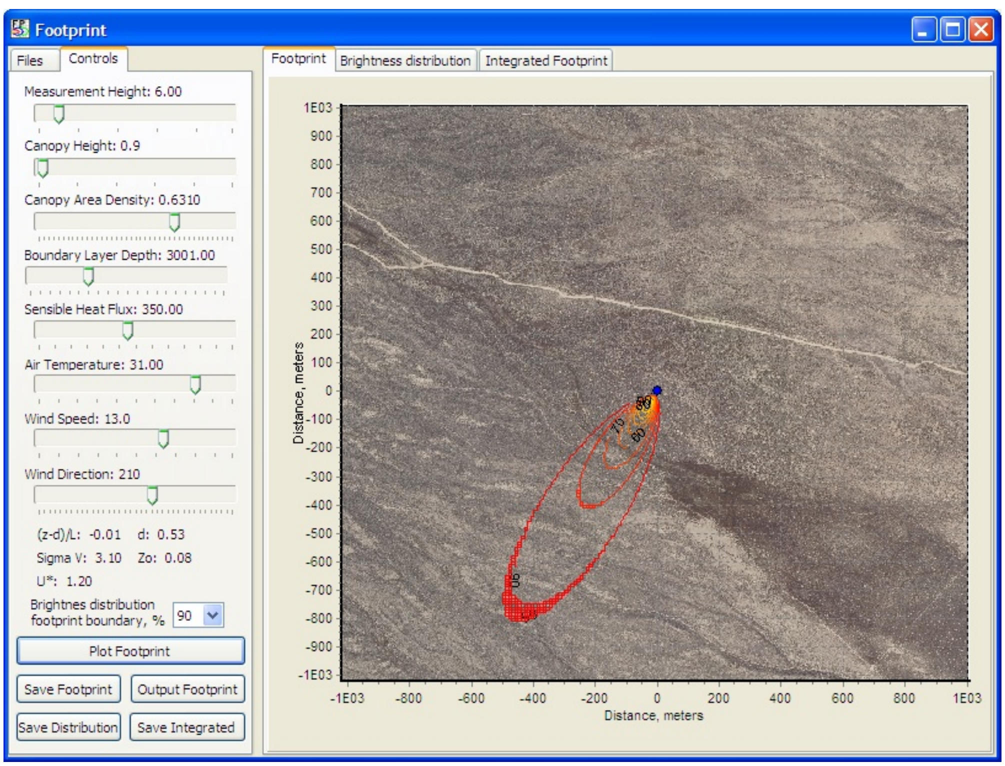
Table 6. Expected environmental controls to parameterize the source area model, and associated results from Onaqui-Ault advanced site.

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	6	6	6	6	6	6	m
Canopy Height	0.9	0.9	0.9	0.9	0.9	0.9	m
Canopy area density	0.63	0.63	0.63	0.63	0.63	0.63	m
Boundary layer depth	3000	3000	1500	1500	1500	750	m
Expected sensible heat flux	350	350	-50	50	50	-51	W m^{-2}
Air Temperature	31	31	21	5	5	0	°C
Max. windspeed	13	8	4.6	13	7.6	4.2	m s^{-1}
Resultant wind vector	210	210	210	210	210	210	degrees

Results							
(z-d)/L	-0.01	-0.04	0.04	0	-0.01	0.07	m
d	0.53	0.53	0.53	0.53	0.53	0.53	m
Sigma v	3.1	2.4	1.8	2.6	1.6	1.8	$m^2 s^{-2}$
Z0	0.08	0.08	0.08	0.08	0.08	0.08	m
u*	1.2	0.78	0.41	1.2	0.72	0.37	$m s^{-1}$
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	700	550	800	700	700	900	m
Distance of 80% cumulative flux	300	300	450	350	350	450	m
Distance of 70% cumulative flux	250	250	300	250	250	300	m
Peak contribution	45	45	45	45	45	45	m

Note: the model output in this table and the footprint graphs below are based on the original candidate tower site at 40.17620563, -112.4557424. The actual ecosystem structure and similar to estimate and the final tower location (40.17759, -112.45244) is only ~300 m apart. Footprint analysis is not redone based on the new tower site.

3.4.5 Results (source area graphs)



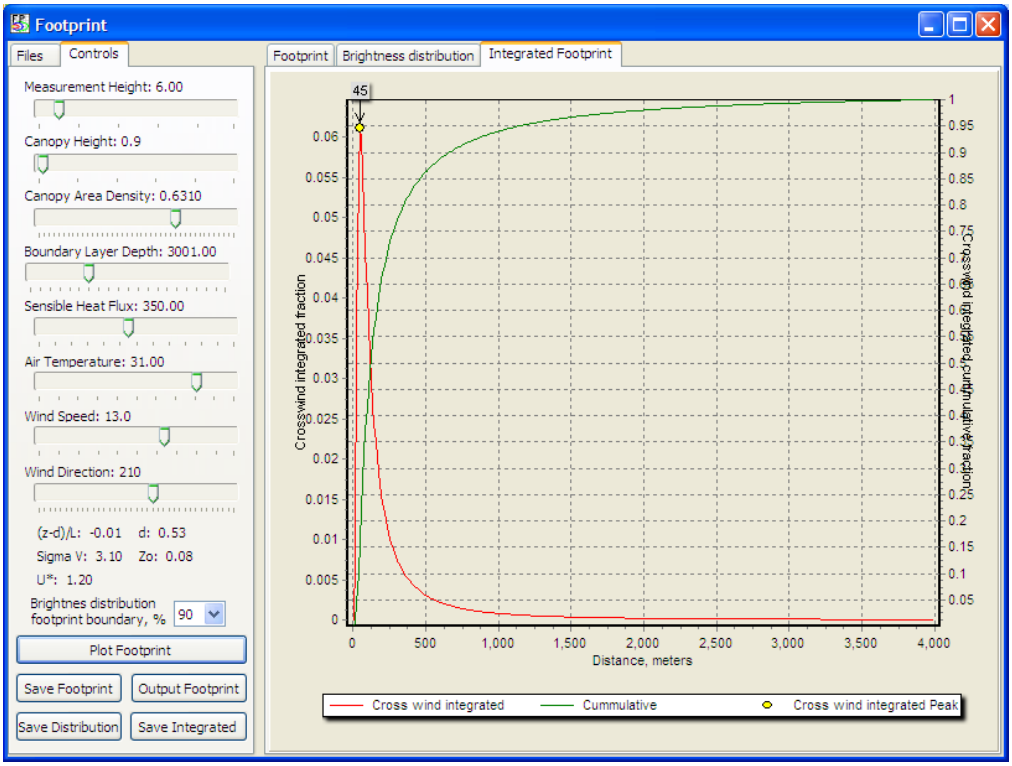
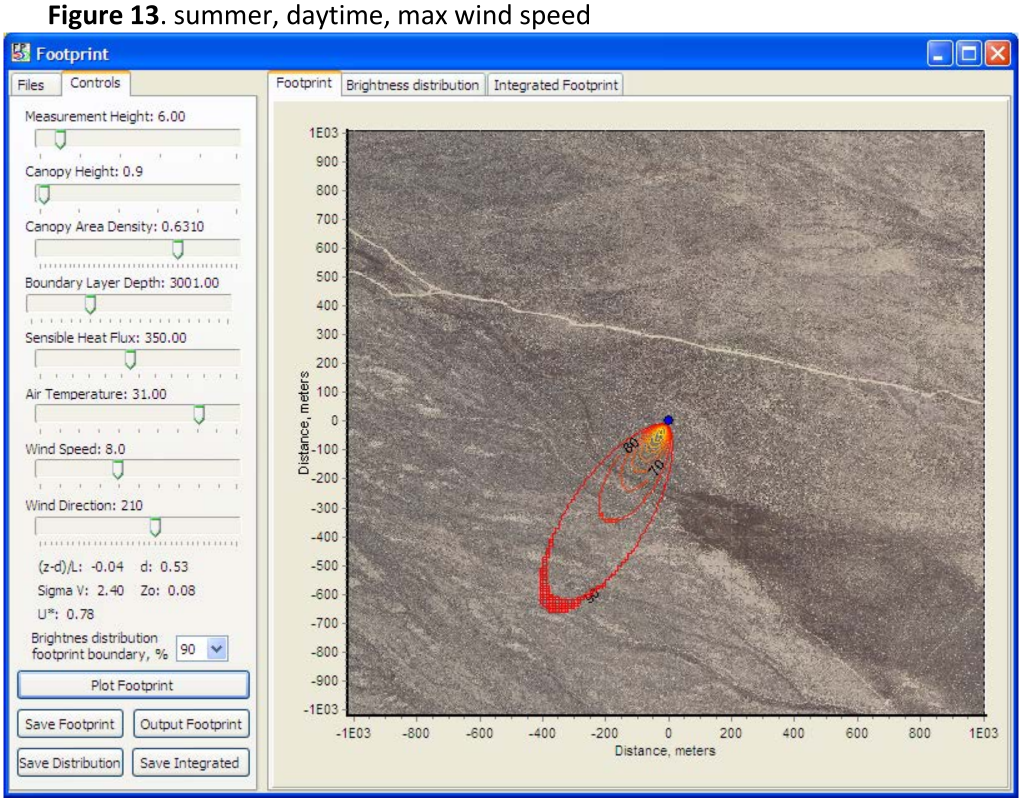


Figure 13. summer, daytime, max wind speed



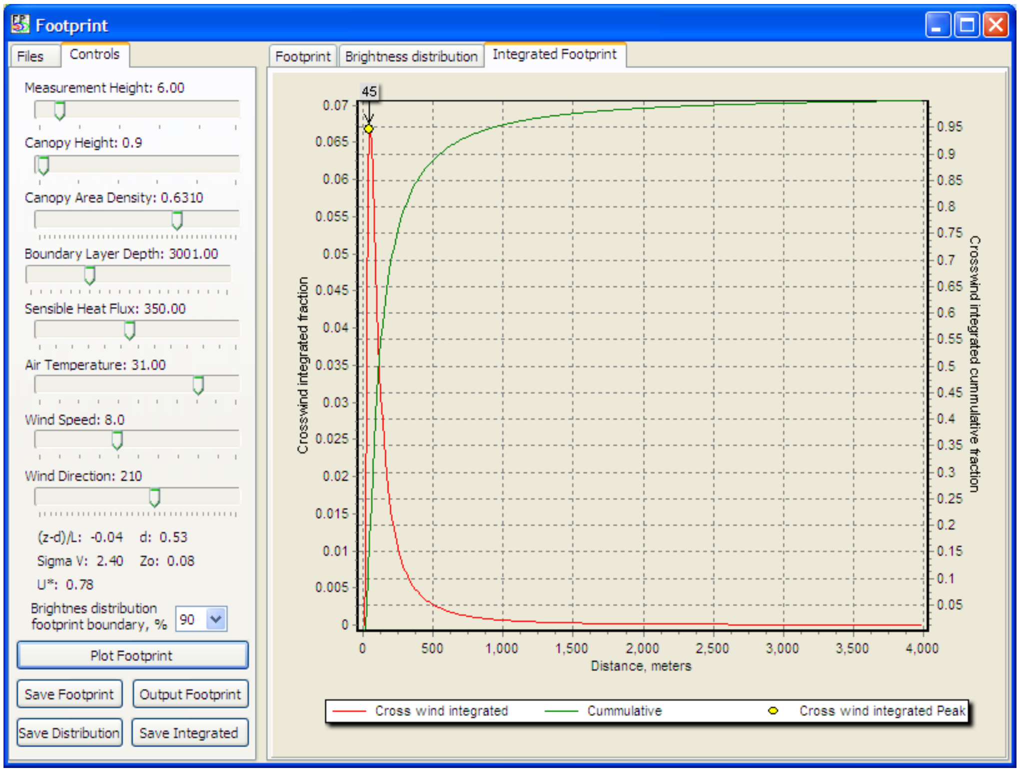
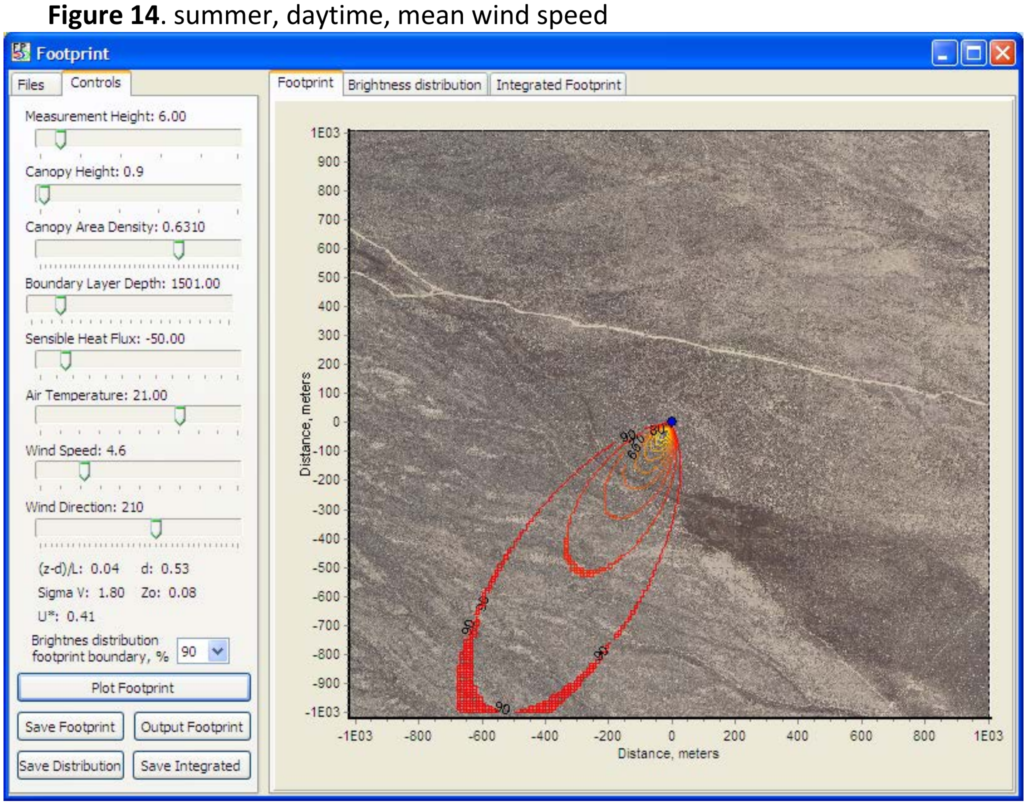


Figure 14. summer, daytime, mean wind speed



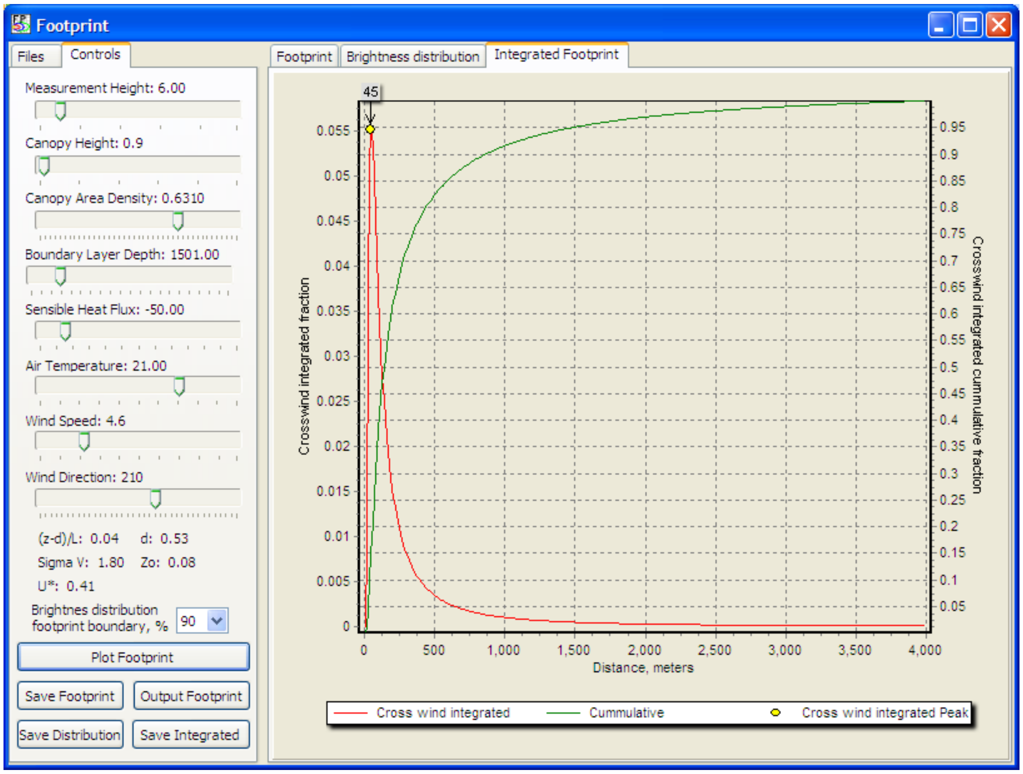
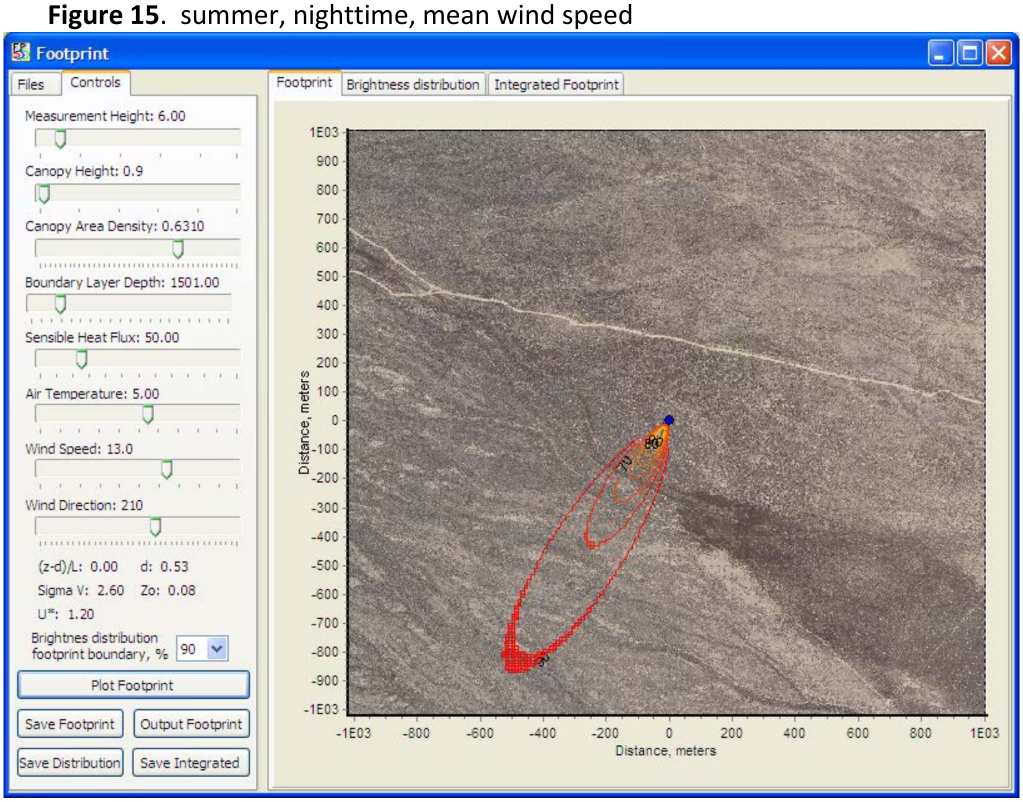


Figure 15. summer, nighttime, mean wind speed



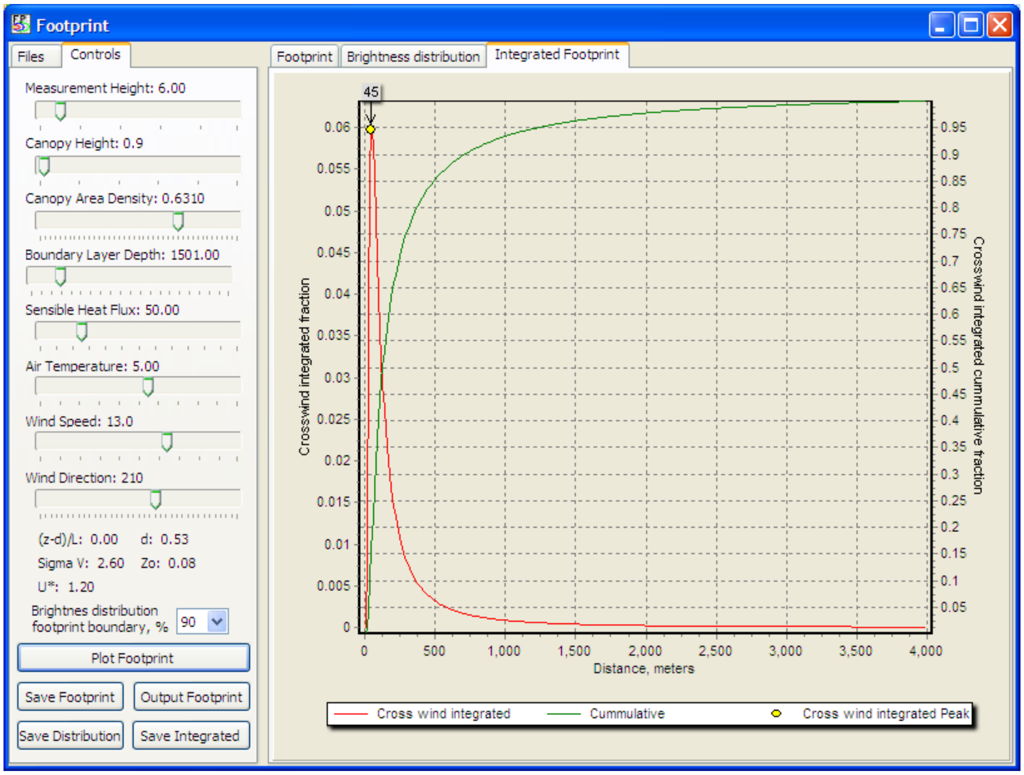
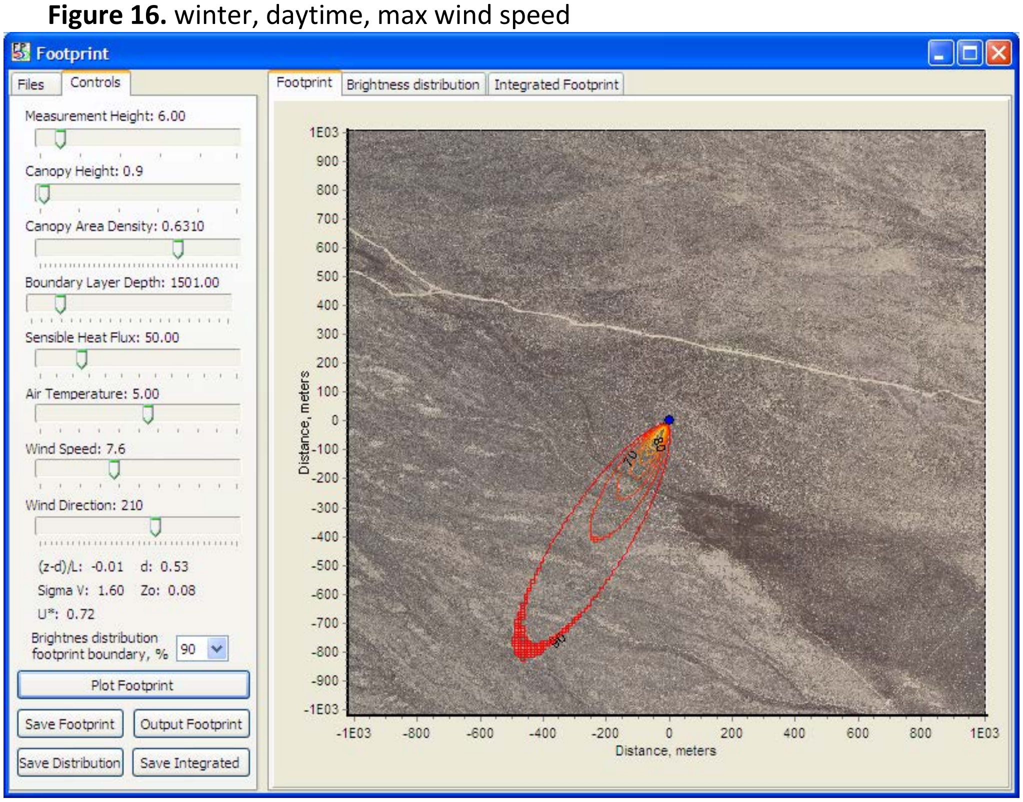


Figure 16. winter, daytime, max wind speed



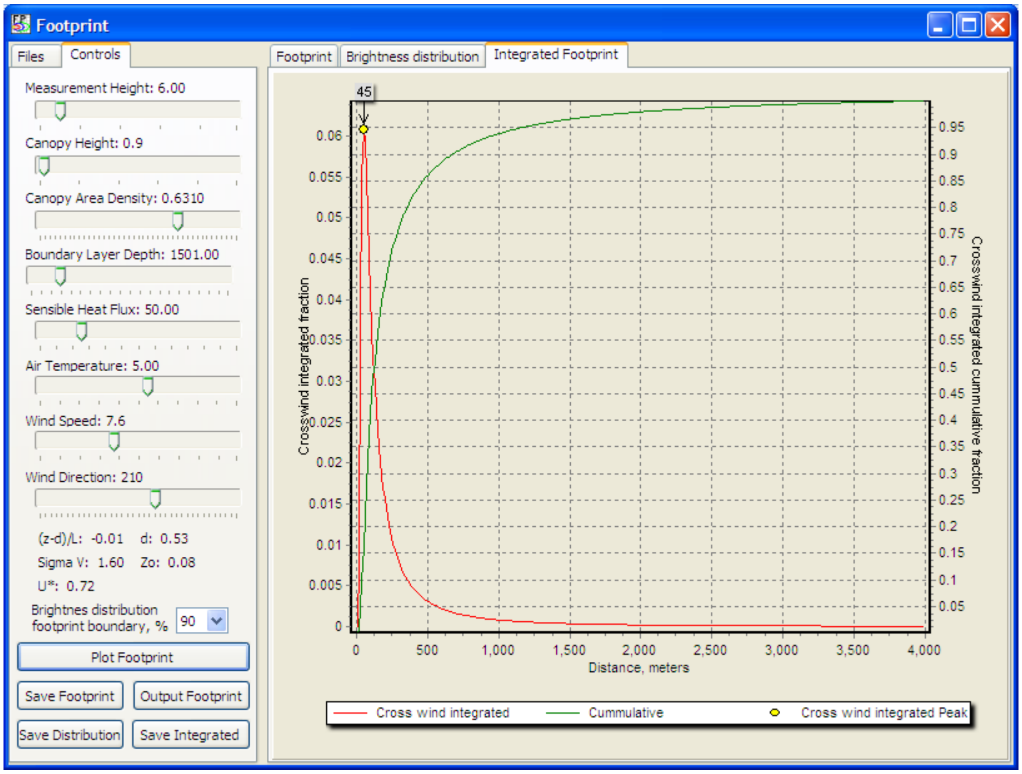
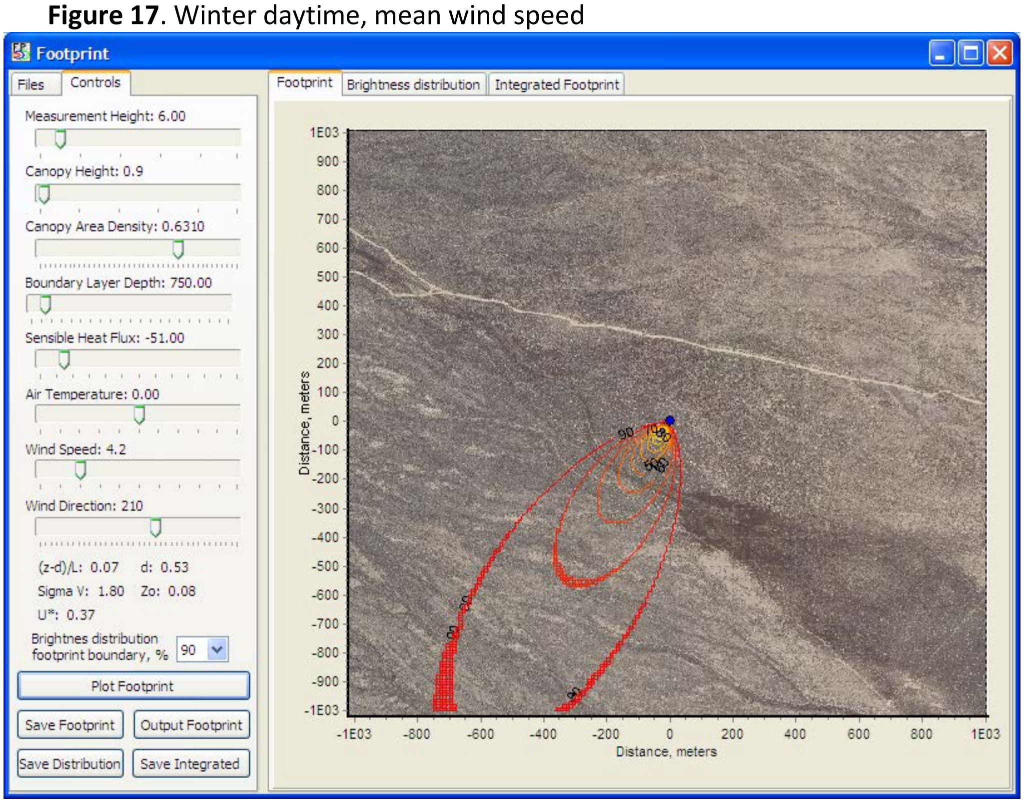


Figure 17. Winter daytime, mean wind speed



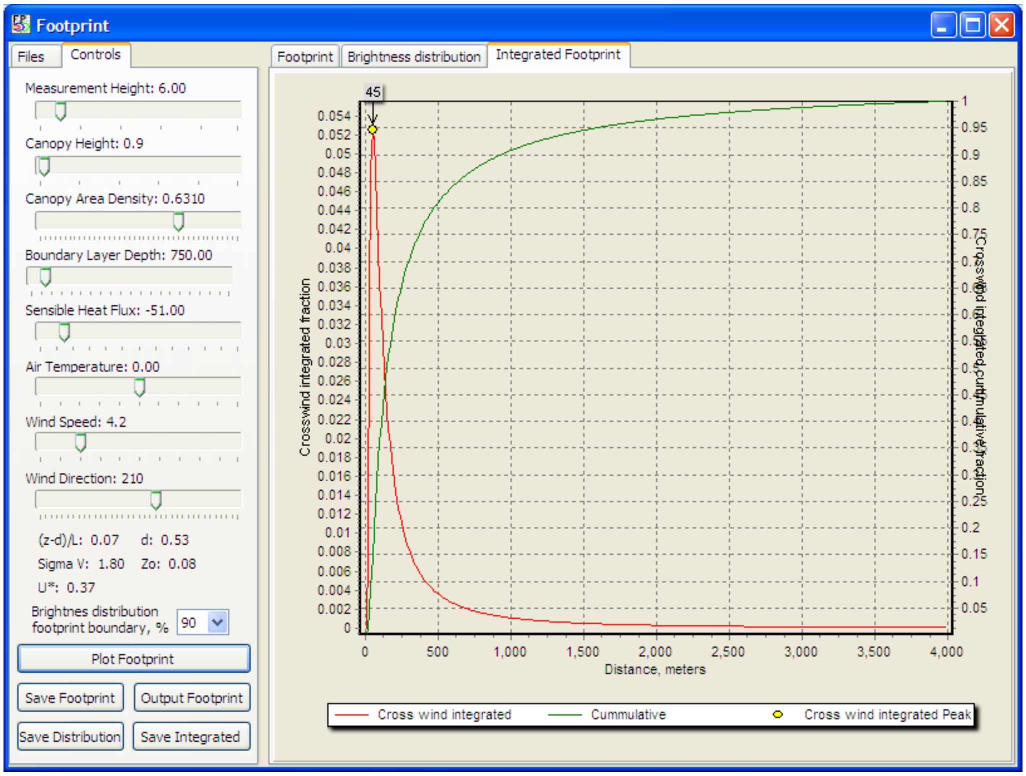


Figure 18. winter, nighttime, mean wind speed

3.4.6 Site design and tower attributes

According to wind roses, the prevailing wind direction blows from southwest (170^o to 260^o, clockwise from 170^o), which is consistent throughout the whole year. Tower should be placed to a location to best catch the signals from the airshed of the ecosystem in interest, which is open sage shrubland. The candidate tower site is 40.17620563, -112.4557424. After site visit, we moved tower location toward Northeast for ~300 m to maximize the fetch area on the Southwest direction of tower before the gully. The new tower location is at 40.17759, -112.45244.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the south will be best to capture signals from all r 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 north side of tower and have the longer side parallel to SW-NE direction. The location of instrument hut is at 40.17776, -112.45239.

Canopy height is ~1.2 m around tower site with lowest branches at ground level. We require 4 **measurement layers** on the tower with top measurement height at 6 m, and rest layers are 6 m, 4 m, 2 m, and 0.2 m, respectively, to best characterize the fluxes on the tower top and environmental conditions in profile. This differs from what was budgeted (5 layers).

DFIR (Double Fenced International Reference) will be at 40.17772, -112.45197, which is ~ 40 m away from tower. Closest power line intercept road at 40.17299, -112.42946. **Wet deposition collector** will collocate at the top of the tower. See AD 04 for further information and requirements for bulk precipitation collection and wet deposition collection.

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

Table 7. Site design and tower attributes for Onaqui-Ault 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			170° to 260°		Clockwise from 170°
Tower location	40.17759,	-112.45244	--	--	new site
Instrument hut	40.17776,	-112.45239			
Instrument hut orientation vector	--	--	210° - 30°		
Instrument hut distance z	--	--	--	20	
Anemometer/Temperature boom orientation	--	--	180°	--	
DFIR	40.17772,	-112.45197			
Height of the measurement levels					
Level 1				0.2	m.a.g.l.
Level 2				2.0	m.a.g.l.
Level 3				4.0	m.a.g.l.
Level 4				6.0	m.a.g.l.
Tower Height				6.0	m.a.g.l.

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

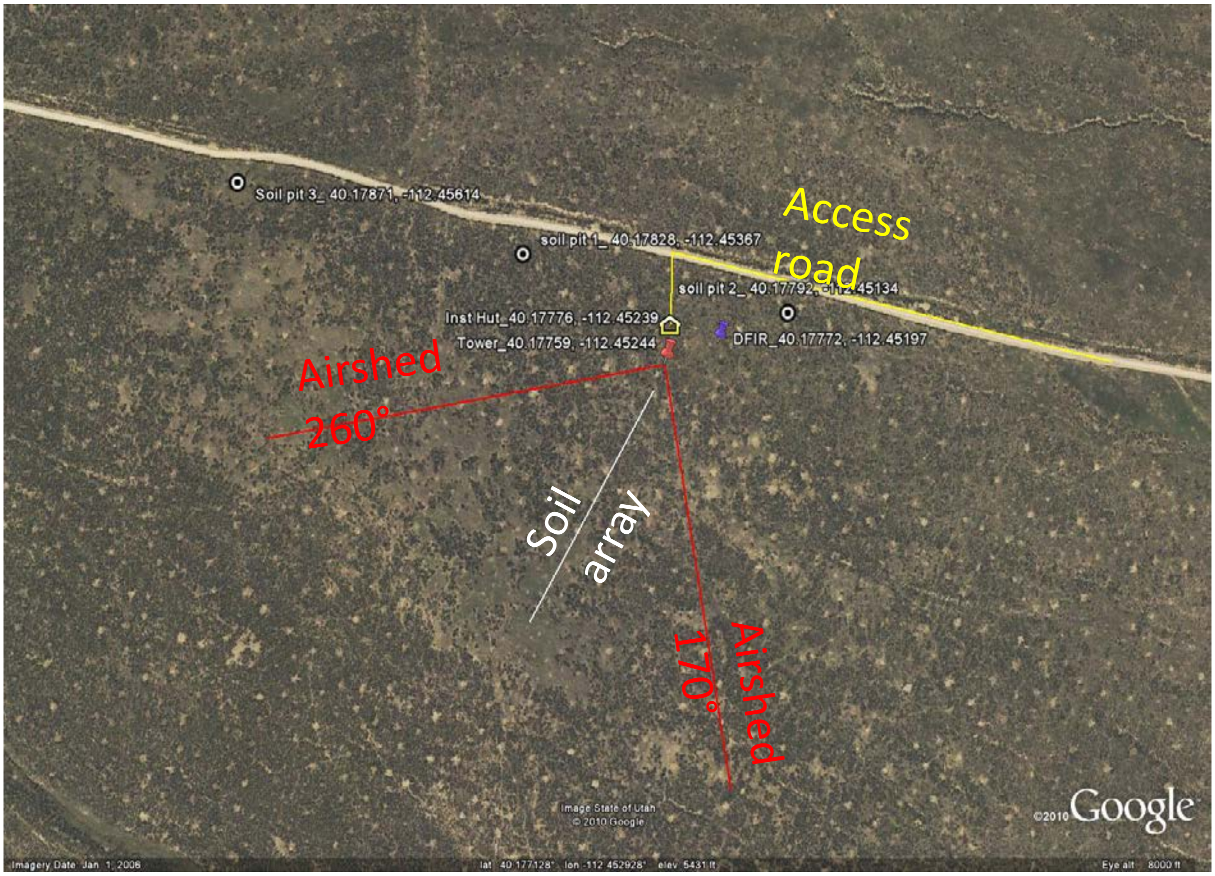


Figure 19. Site layout for Onaqui-Ault Advanced tower site.

Figure 19 above shows the proposed tower location, instrument hut location, DFIR, airshed area and access road.

i) Tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 170° to 260° (clockwise from 170°) are the airshed area that would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access road to instrument hut. iv) blue 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. Here, FIU assumes that all conduits will be either buried, or placed inside the boardwalk such that it does not extend beyond the 36" (0.914 m). wide footprint. The boardwalk to access the tower is not on any side that has a boom.

Specific Boardwalks at Onaqui-Ault Advance site:

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

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

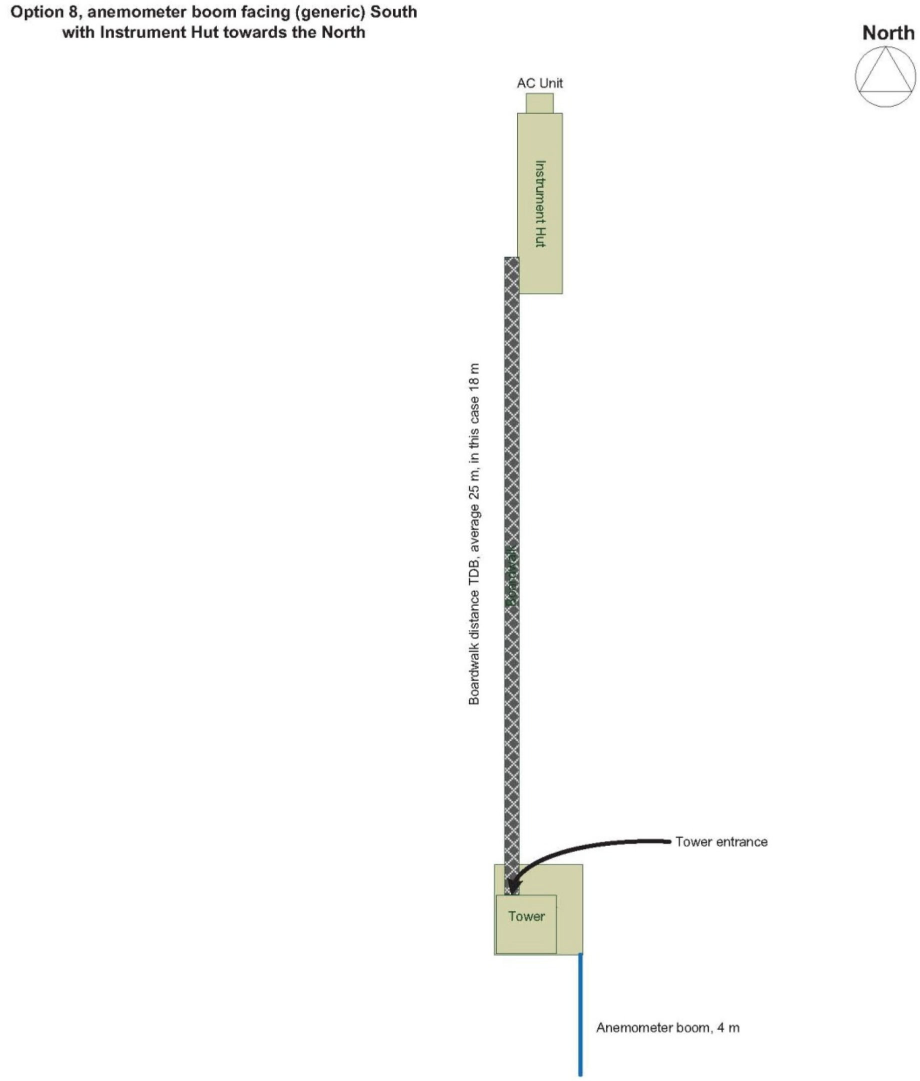


Figure 20 Generic diagram to demonstration the relationship between tower and instrument hut when boom facing south and instrument hut on the north towards the tower.

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 Onaqui-Ault Advanced site, the boom angle will be 180 degrees, instrument hut will be on the north towards the tower, the distance between instrument hut and tower is ~20 m. The instrument hut vector will be SW-NE (210º-30º, longwise).

3.4.7 Information for ecosystem productivity plots

The tower at Onaqui-Ault Advanced site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (sage shrubland). Major airshed area at this site are from 170° to 260° (clockwise from 170º), and 90% signals for flux measurements are in a distance of 700 m from tower, and 80% within 450 m. We suggest FSU Ecosystem Productivity plots be placed within the boundaries of 170° to 260° (clockwise from 170º) from tower.

3.5 Issues and attentions

Dirt road can be difficult to access after rain and during winter by vehicle. ATV may be the best way to access site during these conditions. This BLM site and adjunction private land is actively used for cattle grazing. Instrument protection will be a concern, just similar to any other grazed grassland.

4 SALT LAKE CITY (SLC) URBAN, RELOCATEABLE TOWER 1

4.1 Site description

This site is located in Central Salt Lake City. This site is a very small property. While permitting appeared to be straightforward and the science that can be done here (mainly FIU measurements) is adequate for NEON's needs, the narrow space allocations will make this location challenging for construction. The typical straight line soil array design pattern would not fit in this space, and should go with nonstandard design pattern. The tallest trees at this site were ~15.2 meters tall. There are anticipated power line conflicts with the western guy line and the northern guy line. The northern guy anchor is expected to extend out into the existing parking lot, which is not anticipated to be a challenge. It is also anticipated that an old "light pole" just south of the greenhouse will need to be removed to accommodate the position of the instrument hut. Additional "clean-up" and removal of old concrete beds will need to be conducted throughout the site.

The city officials were very much in favor of endorsing NEON's presence at this site. But because of the nature of this small property in the urban area, there is not much choice for FIU to layout the tower, instrument hut, soil plots and guy anchors. The following GPS coordinates (center point) of all large infrastructures reflect the best layout that we could configure at this site, and also favored by the city officials:

Name of the facility_	lat	long
Center of Tower	40.745890	-111.918070
Center of Soil Plot 1	40.745690	-111.918530
Center of Soil Plot 2	40.746076	-111.918541
Center of Soil Plot 3	40.746077	-111.918019
Center of Soil Plot 4	40.746081	-111.917400
Center of Soil Plot 5	40.745760	-111.917146
Center of Instrument Hut	40.745889	-111.917722
Guy Anchor Point 1	40.746171	-111.918128
Guy Anchor Point 2	40.745670	-111.918030
Guy Anchor Point 3	40.745926	-111.917740
Guy Anchor Point 4	40.745850	-111.918420

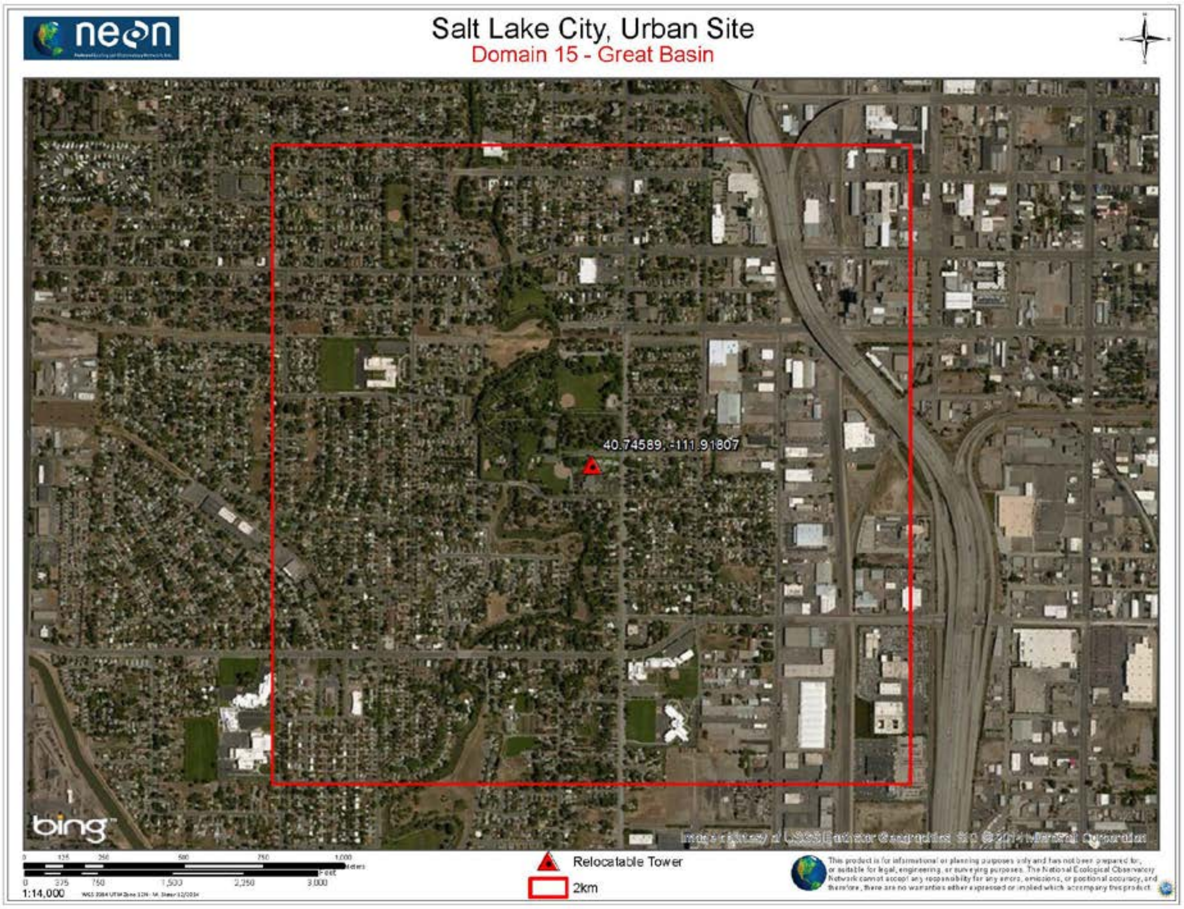


Figure 21. 2 km boundary of the SLC urban relocatable site and tower location.

4.2 Ecosystem

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

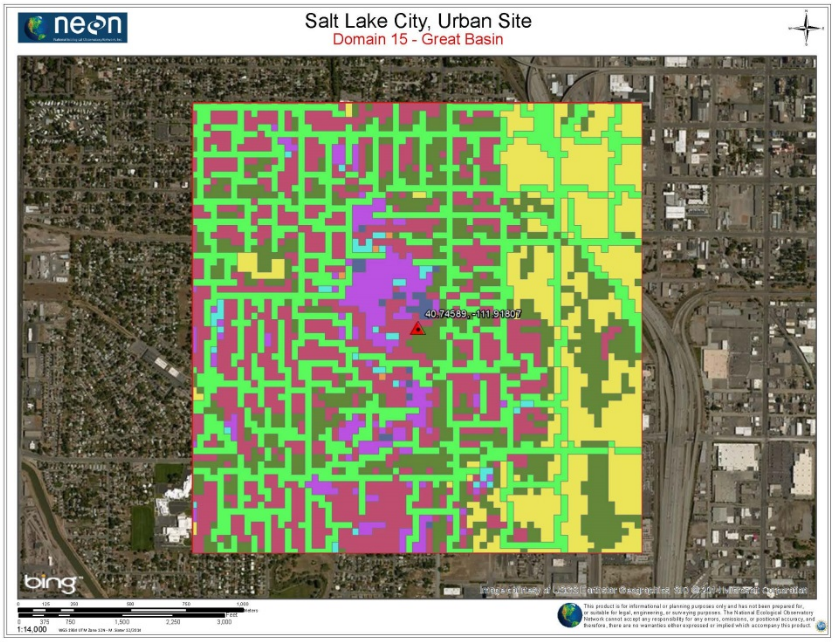


Figure 22. Vegetative cover map of SLC urban relocatable site and surrounding areas (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm).

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

VegType	**VegHeight**	**Area (KM2)**	**Percentage (%)**
Developed-Roads	Developed-Roads	1.32	33.09
Western Cool Temperate Urban Deciduous Forest	Developed-Upland Deciduous Forest	0.22	5.42
Western Cool Temperate Urban Evergreen Forest	Developed-Upland Evergreen Forest	0.00	0.09
Western Cool Temperate Urban Herbaceous	Developed-Upland Herbaceous	0.04	0.97
Western Cool Temperate Urban Mixed Forest	Developed-Upland Mixed Forest	0.02	0.56
Developed-High Intensity	Developed - High Intensity	0.65	16.31
Developed-Low Intensity	Developed - Low Intensity	1.04	25.88
Developed-Medium Intensity	Developed - Medium Intensity	0.71	17.68
TOTAL		**4**	**100**

The major airshed areas for this site are southeast (130° to 190°, clockwise from 130°) and northwest (280° to 10°, clockwise from 280°) of the tower. The ecosystem within the major airshed on the northwest is city parks (Jordan park, international Peace Garden, Poplar Grove Park, etc.) with lawn and trees, and the ecosystem within the major airshed on the southeast is residential buildings, paved roads and parking lots with trees along the streets and in the front and back yards of residential houses. Both are very typical urban ecosystems. Tree height is ~ 15 m, and building height is ~8 m.

Figure 23. Ecosystem (upper panel) and surrounding environment (lower panel) at SLC urban relocatable site.

Table 9. Ecosystem and site attributes for SLC urban relocatable site.

Ecosystem attributes	Measure and units
Mean canopy height	15 m
Surface roughness[a]	5 m
Zero place displacement height[a]	8 m
Structural elements	Parks with lawn and trees, residential buildings
Time zone	Mountain time zone
Magnetic declination	11.77° E ± 0.35° changing by 0.10° W per year

Note, [a] From estimates.

4.3 Soils

4.3.1 Description of soils

Soil data and soil maps (Figure 24) below for SLC urban tower site were collected from 8.31 km^2 NRCS soil maps (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm), which centered at the tower location, to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

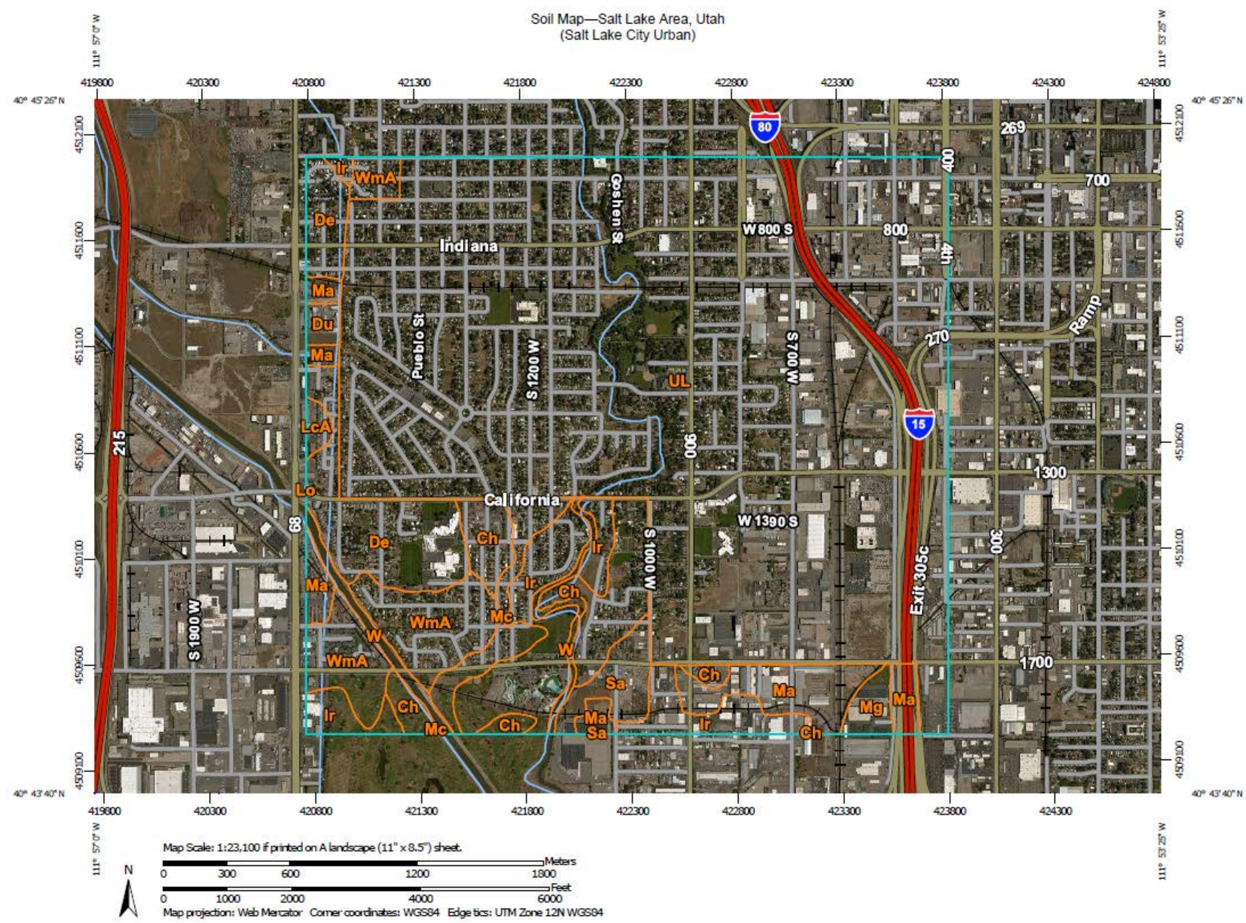


Figure 24. Soil map of the SLC urban Relocatable site and surrounding areas.

Soil Map Units Description: The map units delineated on the detailed soil maps in a soil survey represents the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called non-contrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas. An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. All the soils of a series have major horizons that are similar in composition, thickness, and arrangement. Soils of a given series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. T he name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, are an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Additional information about the map units described in this report is available in other soil reports, which give properties of the soils and the limitations, capabilities, and potentials for many uses. Also, the narratives that accompany the soil reports define some of the properties included in the map unit descriptions.

Table 10. Soil series and percentage of soil series within 8.31 km^2 at the SLC urban site

Salt Lake Area, Utah (UT612)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
Ch	Chipman silty clay loam, 0 to 1 percent slopes	87.0	4.2%
De	Deckerman fine sandy loam, 0 to 1 percent slopes	110.4	5.4%
Du	Dumps	7.9	0.4%
Ir	Lewiston loam, 0 to 1 percent slopes	132.5	6.5%
LcA	Lasil silt loam, 0 to 2 percent slopes	6.5	0.3%
Lo	Loamy borrow pits	0.0	0.0%
Ma	Made land	81.4	4.0%
Mc	Magna silty clay, 0 to 1 percent slopes	35.6	1.7%
Mg	Magna silty clay, peaty surface	13.5	0.7%
Sa	Saltair silty clay loam, 0 to 1 percent slopes	28.8	1.4%
UL	Urban land	1,422.0	69.3%
W	Water	24.2	1.2%
WmA	Welby silt loam, 0 to 1 percent slopes	103.3	5.0%
Totals for Area of Interest		**2,053.2**	**100.0%**

Salt Lake Area, Utah Ch—Chipman silty clay loam, 0 to 1 percent slopes Map Unit Setting *National map unit symbol:* j6h0 *Elevation:* 4,200 to 4,350 feet *Mean annual precipitation:* 14 to 18 inches *Mean annual air temperature:* 48 to 52 degrees F *Frost-free period:* 160 to 180 days *Farmland classification:* Prime farmland if irrigated and drained **Map Unit Composition** *Chipman and similar soils:* 85 percent *Minor components:* 15 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Chipman Setting** *Landform:* Flood plains *Landform position (three-dimensional):* Talf, dip *Down-slope shape:* Linear *Across-slope shape:* Concave *Parent material:* Alluvium **Typical profile** *A11 - 0 to 6 inches:* silty clay loam *A12 - 6 to 16 inches:* silty clay loam *C1ca - 16 to 36 inches:* silty clay loam *C2ca - 36 to 46 inches:* silty clay loam *C3ca - 46 to 51 inches:* silty clay loam *C4 - 51 to 59 inches:* silty clay **Properties and qualities** *Slope:* 0 to 1 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* Somewhat poorly drained *Runoff class:* Medium *Capacity of the most limiting* *layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.20 in/hr) *Depth to water table:* About 18 to 36 inches *Frequency of flooding:* Rare *Frequency of ponding:* None *Calcium carbonate, maximum in profile:* 60 percent *Salinity, maximum in profile:* Nonsaline to very slightly saline (0.0 to 4.0 mmhos/cm) *Sodium adsorption ratio, maximum in profile:* 13.0 *Available water storage in profile:* High (about 10.0 inches) **Interpretive groups** *Land capability classification (irrigated):* 2w *Land capability classification (nonirrigated):* 3w *Hydrologic Soil Group:* D *Ecological site:* Alkali bottom (alkali sacaton) (R028AY001UT) **Minor Components Magna** *Percent of map unit:* 3 percent *Landform:* Flood plains *Landform position (three-dimensional):* Talf, dip *Down-slope shape:* Linear *Across-slope shape:* Concave *Ecological site:* Wet saline meadow (saltgrass) (R028AY024UT) **Stony alluvial land** *Percent of map unit:* 2 percent **Ironton** *Percent of map unit:* 2 percent **Welby** *Percent of map unit:* 2 percent **Bramwell, hardpan variant** *Percent of map unit:* 2 percent **Chipman, saline-alkali, gravelly substratum** *Percent of map unit:* 2 percent **Magna, peaty surface** *Percent of map unit:* 2 percent *Landform:* Flood plains *Landform position (three-dimensional):* Talf, dip *Down-slope shape:* Linear *Across-slope shape:* Concave *Ecological site:* Wet saline meadow (saltgrass) (R028AY024UT)

Salt Lake Area, Utah De—Deckerman fine sandy loam, 0 to 1 percent slopes Map Unit Setting *National map unit symbol:* j6hb *Elevation:* 4,200 to 4,300 feet *Mean annual precipitation:* 14 to 18 inches *Mean annual air temperature:* 48 to 52 degrees F *Frost-free period:* 160 to 180 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Deckerman and similar soils:* 90 percent *Minor components:* 10 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Deckerman Setting** *Landform:* Flood plains, lake plains *Landform position (three-dimensional):* Talf, rise *Down-slope shape:* Linear *Across-slope shape:* Linear *Parent material:* Alluvium and/or lacustrine deposits **Typical profile** *A11&A12 - 0 to 6 inches:* fine sandy loam *C1 - 6 to 12 inches:* loam *C2ca - 12 to 20 inches:* loam *C3 - 20 to 35 inches:* sandy loam *C4 - 35 to 43 inches:* loam *IIC5 - 43 to 60 inches:* silty clay loam **Properties and qualities** *Slope:* 0 to 1 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* Somewhat poorly drained *Runoff class:* Low *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.20 in/hr) *Depth to water table:* About 24 to 42 inches *Frequency of flooding:* None *Frequency of ponding:* None *Calcium carbonate, maximum in profile:* 30 percent *Salinity, maximum in profile:* Slightly saline to moderately saline (8.0 to 16.0 mmhos/cm) *Sodium adsorption ratio, maximum in profile:* 60.0 *Available water storage in profile:* Moderate (about 6.5 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Land capability classification (nonirrigated):* 7w *Hydrologic Soil Group:* C *Ecological site:* Alkali bottom (alkali sacaton) (R028AY001UT) **Minor Components Lasil** *Percent of map unit:* 5 percent *Ecological site:* Alkali bottom (alkali sacaton) (R028AY001UT) **Saltair** *Percent of map unit:* 5 percent *Landform:* Lake terraces *Landform position (three-dimensional):* Tread *Down-slope shape:* Linear *Across-slope shape:* Linear *Ecological site:* Desert salty silt (iodinebush) (R028AY132UT)

Salt Lake Area, Utah Du—Dumps Map Unit Setting *National map unit symbol:* j6hg *Elevation:* 4,200 to 9,000 feet *Farmland classification:* Not prime farmland **Map Unit Composition** *Dumps:* 100 percent *Estimates are based on observations, descriptions, and transects of the mapunit.*

Salt Lake Area, Utah Ir—Lewiston loam, 0 to 1 percent slopes Map Unit Setting *National map unit symbol:* j6j9 *Elevation:* 4,210 to 4,450 feet *Mean annual precipitation:* 14 to 18 inches *Mean annual air temperature:* 48 to 52 degrees F *Frost-free period:* 160 to 180 days *Farmland classification:* Prime farmland if irrigated and drained **Map Unit Composition** *Lewiston and similar soils:* 85 percent *Minor components:* 15 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Lewiston Setting** *Landform:* Flood plains *Landform position (three-dimensional):* Talf, dip *Down-slope shape:* Linear *Across-slope shape:* Concave *Parent material:* Alluvium **Typical profile** *Ap - 0 to 7 inches:* loam *A1&AC - 7 to 20 inches:* very fine sandy loam *C1ca - 20 to 26 inches:* silt loam *A1b - 26 to 31 inches:* very fine sandy loam *IIC2 - 31 to 38 inches:* silt loam *IIIC3-5 - 38 to 68 inches:* loamy sand **Properties and qualities** *Slope:* 0 to 1 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* Somewhat poorly drained *Runoff class:* Low *Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr) *Depth to water table:* About 20 to 40 inches *Frequency of flooding:* Rare *Frequency of ponding:* None *Calcium carbonate, maximum in profile:* 30 percent *Salinity, maximum in profile:* Nonsaline to very slightly saline (0.0 to 4.0 mmhos/cm) *Sodium adsorption ratio, maximum in profile:* 13.0 *Available water storage in profile:* Moderate (about 7.8 inches) **Interpretive groups** *Land capability classification (irrigated):* 2w *Land capability classification (nonirrigated):* 7w *Hydrologic Soil Group:* C *Ecological site:* Semiwet fresh meadow (R028AY012UT) **Minor Components Kidman** *Percent of map unit:* 5 percent **Magna** *Percent of map unit:* 5 percent *Landform:* Flood plains *Landform position (three-dimensional):* Dip, talf *Down-slope shape:* Linear *Across-slope shape:* Concave *Ecological site:* Wet saline meadow (saltgrass) (R028AY024UT) **Chipman** *Percent of map unit:* 5 percent

Salt Lake Area, Utah LcA—Lasil silt loam, 0 to 2 percent slopes Map Unit Setting *National map unit symbol:* j6jx *Elevation:* 4,200 to 4,300 feet *Mean annual precipitation:* 14 to 18 inches *Mean annual air temperature:* 48 to 52 degrees F *Frost-free period:* 160 to 180 days *Farmland classification:* Farmland of statewide importance **Map Unit Composition** *Lasil and similar soils:* 85 percent *Minor components:* 15 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Lasil Setting** *Landform:* Lake plains *Landform position (three-dimensional):* Talf, rise *Down-slope shape:* Linear *Across-slope shape:* Linear *Parent material:* Lacustrine deposits **Typical profile** *H1 - 0 to 5 inches:* silt loam *H2 - 5 to 9 inches:* silt loam *H3 - 9 to 14 inches:* clay loam *H4 - 14 to 29 inches:* silt loam *H5 - 29 to 48 inches:* silt loam *H6 - 48 to 78 inches:* fine sand **Properties and qualities** *Slope:* 0 to 2 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* Somewhat poorly drained *Runoff class:* Medium *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.20 in/hr) *Depth to water table:* About 30 to 48 inches *Frequency of flooding:* None *Frequency of ponding:* None *Calcium carbonate, maximum in profile:* 40 percent *Salinity, maximum in profile:* Moderately saline to strongly saline (16.0 to 32.0 mmhos/cm) *Sodium adsorption ratio, maximum in profile:* 60.0 *Available water storage in profile:* Low (about 3.4 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Land capability classification (nonirrigated):* 7w *Hydrologic Soil Group:* D *Ecological site:* Alkali bottom (alkali sacaton) (R028AY001UT) **Minor Components Terminal** *Percent of map unit:* 5 percent **Deckerman** *Percent of map unit:* 5 percent **Jordan** *Percent of map unit:* 3 percent *Ecological site:* Alkali flat (black greasewood) (R028AY004UT) **Saltair** *Percent of map unit:* 2 percent *Landform:* Lake terraces *Landform position (three-dimensional):* Tread *Down-slope shape:* Linear *Across-slope shape:* Linear *Ecological site:* Desert salty silt (iodinebush) (R028AY132UT)

Salt Lake Area, Utah Lo—Loamy borrow pits Map Unit Setting *National map unit symbol:* j6k1 *Elevation:* 4,200 to 4,800 feet *Farmland classification:* Not prime farmland **Map Unit Composition**

Loamy borrow pits: 100 percent *Estimates are based on observations, descriptions, and transects of the mapunit.*

Salt Lake Area, Utah Ma—Made land Map Unit Composition *Made land:* 100 percent *Estimates are based on observations, descriptions, and transects of the mapunit.*

Salt Lake Area, Utah Mc—Magna silty clay, 0 to 1 percent slopes Map Unit Setting *National map unit symbol:* j6k3 *Elevation:* 4,200 to 4,350 feet *Mean annual precipitation:* 14 to 18 inches *Mean annual air temperature:* 48 to 52 degrees F *Frost-free period:* 160 to 180 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Magna and similar soils:* 85 percent *Minor components:* 15 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Magna Setting** *Landform:* Flood plains *Landform position (three-dimensional):* Talf, dip *Down-slope shape:* Linear *Across-slope shape:* Concave *Parent material:* Alluvium **Typical profile** *A11 - 0 to 2 inches:* silty clay *A12 - 2 to 12 inches:* silty clay *C1cag - 12 to 28 inches:* silty clay *A1b - 28 to 38 inches:* silty clay loam *C2b - 38 to 70 inches:* silty clay loam **Properties and qualities** *Slope:* 0 to 1 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* Poorly drained *Runoff class:* Very high *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.20 in/hr) *Depth to water table:* About 0 to 24 inches *Frequency of flooding:* Occasional *Frequency of ponding:* None *Calcium carbonate, maximum in profile:* 40 percent *Salinity, maximum in profile:* Nonsaline to slightly saline (2.0 to 8.0 mmhos/cm) *Sodium adsorption ratio, maximum in profile:* 13.0 *Available water storage in profile:* High (about 10.2 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Land capability classification (nonirrigated):* 5w *Hydrologic Soil Group:* C/D *Ecological site:* Wet saline meadow (saltgrass) (R028AY024UT) **Minor Components Magna, peaty surface** *Percent of map unit:* 5 percent *Landform:* Flood plains *Landform position (three-dimensional):* Talf, dip *Down-slope shape:* Linear *Across-slope shape:* Concave *Ecological site:* Wet saline meadow (saltgrass) (R028AY024UT) **Ironton** *Percent of map unit:* 5 percent **Chipman** *Percent of map unit:* 5 percent

Salt Lake Area, Utah Mg—Magna silty clay, peaty surface Map Unit Setting *National map unit symbol:* j6k4 *Elevation:* 4,200 to 4,350 feet *Mean annual precipitation:* 14 to 18 inches *Mean annual air temperature:* 48 to 52 degrees F *Frost-free period:* 160 to 180 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Magna, peaty surface, and similar soils:* 95 percent *Minor components:* 5 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Magna, Peaty Surface Setting** *Landform:* Flood plains *Landform position (three-dimensional):* Talf, dip *Down-slope shape:* Linear *Across-slope shape:* Concave *Parent material:* Alluvium **Typical profile** *Oi - 0 to 8 inches:* peat *A12 - 8 to 12 inches:* silty clay *C1cag - 12 to 28 inches:* silty clay *A1b - 28 to 38 inches:* silty clay loam *C2b - 38 to 70 inches:* silty clay loam **Properties and qualities** *Slope:* 0 to 1 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* Poorly drained *Runoff class:* Very high *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.20 in/hr) *Depth to water table:* About 0 to 24 inches *Frequency of flooding:* Occasional *Frequency of ponding:* None *Calcium carbonate, maximum in profile:* 40 percent *Salinity, maximum in profile:* Nonsaline to slightly saline (2.0 to 8.0 mmhos/cm) *Sodium adsorption ratio, maximum in profile:* 13.0 *Available water storage in profile:* High (about 11.2 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Land capability classification (nonirrigated):* 5w *Hydrologic Soil Group:* C/D *Ecological site:* Wet saline meadow (saltgrass) (R028AY024UT) **Minor Components Magna,**

peaty surface > 12 inches *Percent of map unit:* 5 percent *Landform:* Flood plains *Landform position (three-dimensional):* Talf, dip *Down-slope shape:* Linear *Across-slope shape:* Concave *Ecological site:* Wet saline meadow (saltgrass) (R028AY024UT)

Salt Lake Area, Utah Sa—Saltair silty clay loam, 0 to 1 percent slopes Map Unit Setting *National map unit symbol:* j6kn *Elevation:* 4,200 to 4,250 feet *Mean annual precipitation:* 14 to 18 inches *Mean annual air temperature:* 48 to 52 degrees F *Frost-free period:* 160 to 180 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Saltair and similar soils:* 95 percent *Minor components:* 5 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Saltair Setting** *Landform:* Lake terraces *Landform position (three-dimensional):* Tread *Down-slope shape:* Linear *Across-slope shape:* Linear *Parent material:* Lacustrine deposits **Typical profile** *H1 - 0 to 1 inches:* silty clay loam *H2 - 1 to 4 inches:* silty clay loam *H3 - 4 to 8 inches:* silty clay loam *H4 - 8 to 12 inches:* silty clay loam *H5 - 12 to 40 inches:* silty clay loam *H6 - 40 to 57 inches:* fine sandy loam **Properties and qualities** *Slope:* 0 to 1 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* Poorly drained *Runoff class:* Very high *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.20 in/hr) *Depth to water table:* About 0 to 12 inches *Frequency of flooding:* Occasional *Frequency of ponding:* None *Calcium carbonate, maximum in profile:* 30 percent *Gypsum, maximum in profile:* 2 percent *Salinity, maximum in profile:* Strongly saline (100.0 to 250.0 mmhos/ cm) *Sodium adsorption ratio, maximum in profile:* 1,000.0 *Available water storage in profile:* Very low (about 2.5 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Land capability classification (nonirrigated):* 8s *Hydrologic Soil Group:* C/D *Ecological site:* Desert salty silt (iodinebush) (R028AY132UT) **Minor Components Jordan** *Percent of map unit:* 5 percent *Ecological site:* Alkali flat (black greasewood) (R028AY004UT)

Salt Lake Area, Utah UL—Urban land Map Unit Setting *National map unit symbol:* j6lf *Elevation:* 4,200 to 9,000 feet *Farmland classification:* Not prime farmland **Map Unit Composition** *Urban land:* 100 percent *Estimates are based on observations, descriptions, and transects of the mapunit.*

Salt Lake Area, Utah W—Water Map Unit Composition *Water:* 100 percent *Estimates are based on observations, descriptions, and transects of the mapunit.*

Salt Lake Area, Utah WmA—Welby silt loam, 0 to 1 percent slopes Map Unit Setting *National map unit symbol:* j6lc *Elevation:* 4,200 to 4,400 feet *Mean annual precipitation:* 14 to 16 inches *Mean annual air temperature:* 49 to 51 degrees F *Frost-free period:* 130 to 150 days *Farmland classification:* Prime farmland if irrigated **Map Unit Composition** *Welby and similar soils:* 85 percent *Minor components:* 15 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Welby Setting** *Landform:* Lake terraces *Landform position (three-dimensional):* Tread *Down-slope shape:* Linear *Across-slope shape:* Linear *Parent material:* Lacustrine deposits **Typical profile** *Ap - 0 to 8 inches:* silt loam *A3 - 8 to 16 inches:* silt loam *B2 - 16 to 25 inches:* silt loam *C1ca - 25 to 33 inches:* loam *C2ca - 33 to 44 inches:* silt loam *C3 - 44 to 60 inches:* silty clay loam **Properties and qualities** *Slope:* 0 to 1 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* Well drained *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.20 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Calcium carbonate, maximum in profile:* 25 percent *Salinity, maximum in profile:* Very slightly saline to slightly saline (4.0 to 8.0 mmhos/cm) *Sodium adsorption ratio, maximum in profile:* 13.0 *Available water storage in profile:* High (about 9.6 inches) **Interpretive groups** *Land capability classification (irrigated):* 2c *Land capability classification (nonirrigated):* 3c *Hydrologic Soil Group:* C *Ecological site:* Upland loam (bonneville big sagebrush) north (R028AY310UT) *Other vegetative classification:* Upland Loam (Mountain Big Sagebrush) (028AY310UT) **Minor Components Deckerman** *Percent of map unit:* 3 percent **Kidman** *Percent of map unit:* 3 percent **Parleys** *Percent of map unit:* 3 percent **Taylorsville** *Percent of map unit:* 3 percent **Hillfield** *Percent of map unit:* 3 percent

4.3.1.1 Soil array layout and soil pit location

Due to the very small size of the SLC urban Relocatable site there was insufficient room for any of the typical NEON Soil Array layouts. As a result, locations for the soil plots were identified during the NEON site visit. The spacing between soil plots was at least 40 m apart edge to edge, since this corresponds to the maximum spacing between soil plots in NEON site designs. Because the locations of the soil plots were selected during the site visit, there was no need to do the soil semivariogram analysis that is usually performed at NEON sites. The soil plots at SLC urban shall be placed at least 40 m apart. The soil array shall follow a non-standard soil array design with the soil plots being 5 m x 5 m. The location of the each soil plot is shown in the table below. The exact location of each soil plot may be micrososited 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 40.745804°, -111.918311° (primary location); or 40.745722°, -111.918196° (alternate location 1 if primary location is unsuitable); or 40.745732°, -111.917354° (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 25.

Dominant soil series at the site: Urban land. The taxonomy of this soil is shown below:
Order: Unknown: Urban land
Suborder: Unknown: Urban land
Great group: Unknown: Urban land
Subgroup: Unknown: Urban land
Family: Unknown: Urban land
Series: Unknown: Urban land

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

Soil plot dimensions	5 m x 5 m
Soil array pattern	NA
Distance between soil plots: x	≥40 m
Distance from tower to closest soil plot: y	19 m
Latitude and longitude of 1st soil plot	40.745690, -111.918530
Latitude and longitude of 2nd soil plot	40.746076, -111.918541
Latitude and longitude of 3rd soil plot	40.746077, -111.918019
Latitude and longitude of 4th soil plot	40.746081, -111.917400

Latitude and longitude of 5th soil plot	40.745760, -111.917146
Latitude and longitude of FIU soil pit 1	40.745804°, -111.918311° (primary location)
Latitude and longitude of FIU soil pit 2	40.745722°, -111.918196° (alternate 1)
Latitude and longitude of FIU soil pit 3	40.745732°, -111.917354° (alternate 2)
Dominant soil type	Urban land
Expected soil depth	Unknown
Depth to water table	Unknown

Expected depth of soil horizons	**Expected measurement depths***
Unknown	Unknown

*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.

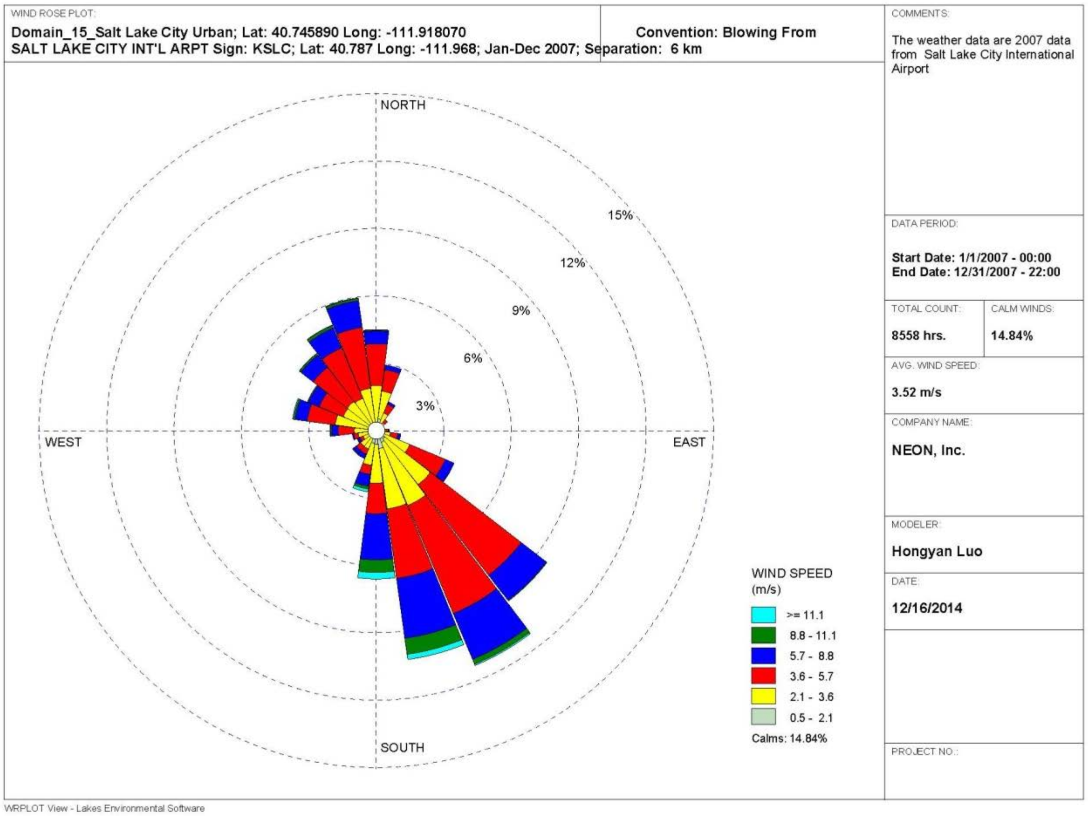
Figure 25. Site layout at SLC urban showing soil array and location of the FIU soil pit.

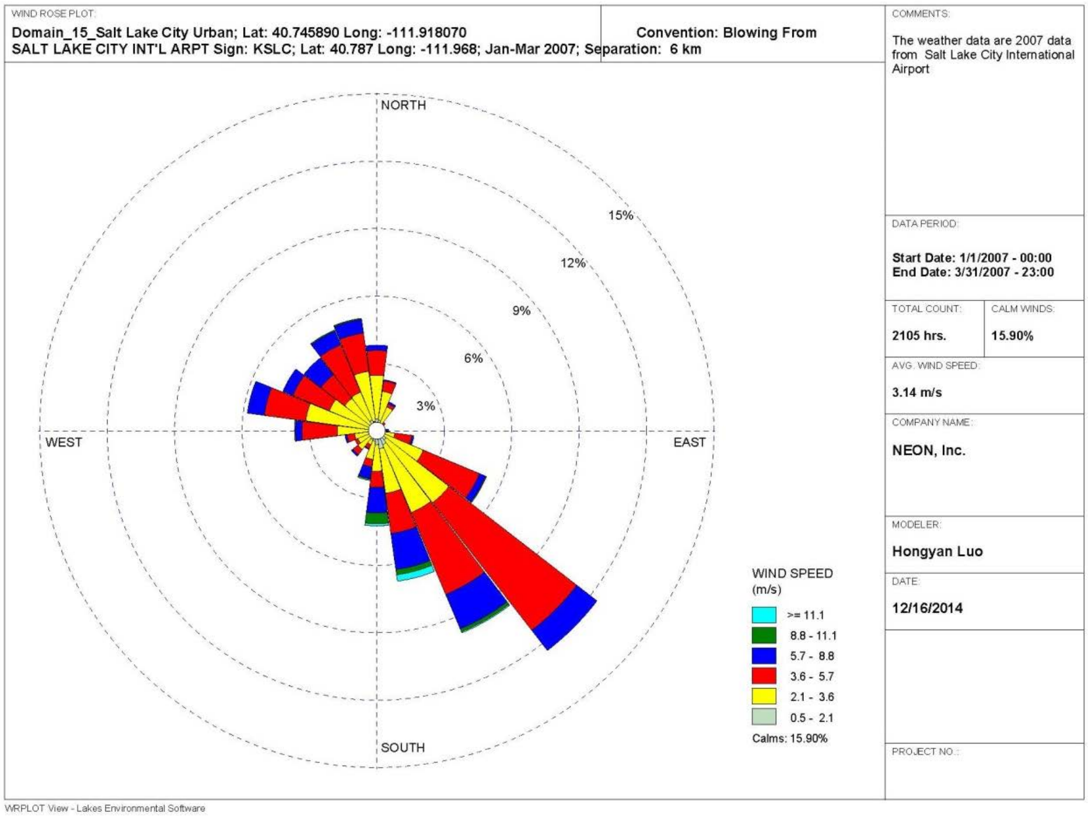
4.4 Airshed

4.4.1 Seasonal windroses

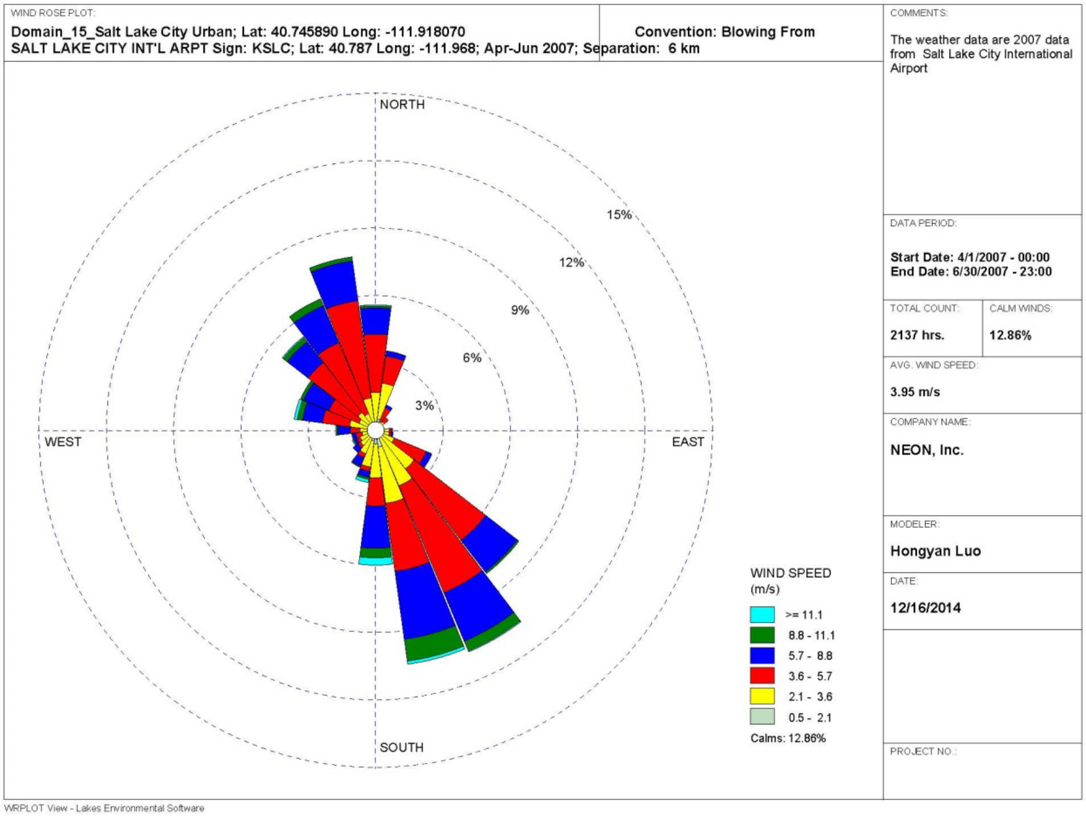
Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries. Data used to generate windroses were 2007 data set from Salt Lake City International airport, which is about 6 km away on the northwest direction of the tower. The orientation 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)

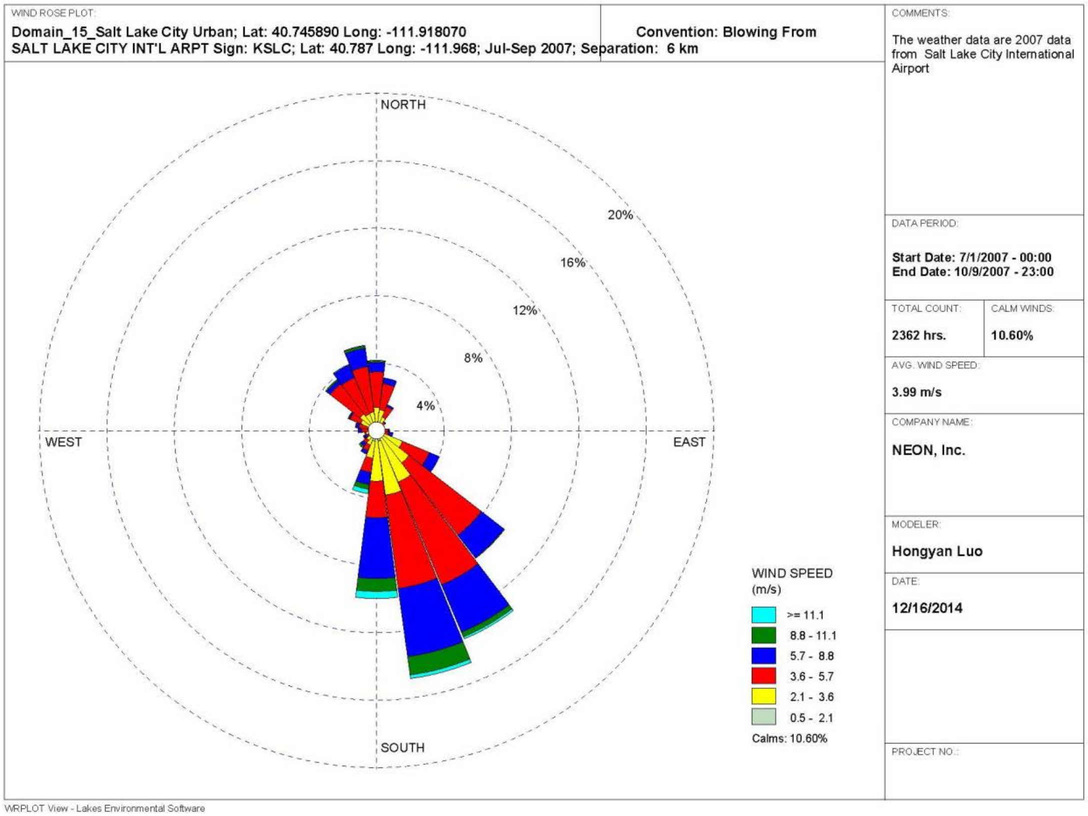

WIND ROSE PLOT:
Domain_15_Salt Lake City Urban; Lat: 40.745890 Long: -111.918070
SALT LAKE CITY INT'L ARPT Sign: KSLC; Lat: 40.787 Long: -111.968; Jan-Dec 2007; Separation: 6 km
Convention: Blowing From
NORTH
WEST
EAST
SOUTH
3%
6%
9%
12%
15%
WIND SPEED (m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 14.84%
COMMENTS:
The weather data are 2007 data from Salt Lake City International Airport
DATA PERIOD:
Start Date: 1/1/2007 - 00:00
End Date: 12/31/2007 - 22:00
TOTAL COUNT:
8558 hrs.
CALM WINDS:
14.84%
AVG. WIND SPEED:
3.52 m/s
COMPANY NAME:
NEON, Inc.
MODELER:
Hongyan Luo
DATE:
12/16/2014
PROJECT NO.:
WRPLOT View - Lakes Environmental Software



WIND ROSE PLOT:
Domain_15_Salt Lake City Urban; Lat: 40.745890 Long: -111.918070
SALT LAKE CITY INT'L ARPT Sign: KSLC; Lat: 40.787 Long: -111.968; Jan-Mar 2007; Separation: 6 km
Convention: Blowing From
NORTH
SOUTH
WEST
EAST
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: 15.90%
COMMENTS:
The weather data are 2007 data from Salt Lake City International Airport
DATA PERIOD:
Start Date: 1/1/2007 - 00:00
End Date: 3/31/2007 - 23:00
TOTAL COUNT:
2105 hrs.
CALM WINDS:
15.90%
AVG. WIND SPEED:
3.14 m/s
COMPANY NAME:
NEON, Inc.
MODELER:
Hongyan Luo
DATE:
12/16/2014
PROJECT NO.:
WRPLOT View - Lakes Environmental Software



WIND ROSE PLOT:
Domain_15_Salt Lake City Urban; Lat: 40.745890 Long: -111.918070
SALT LAKE CITY INT'L ARPT Sign: KSLC; Lat: 40.787 Long: -111.968; Apr-Jun 2007; Separation: 6 km
Convention: Blowing From
NORTH
SOUTH
WEST
EAST
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: 12.86%
COMMENTS:
The weather data are 2007 data from Salt Lake City International Airport
DATA PERIOD:
Start Date: 4/1/2007 - 00:00
End Date: 6/30/2007 - 23:00
TOTAL COUNT:
2137 hrs.
CALM WINDS:
12.86%
AVG. WIND SPEED:
3.95 m/s
COMPANY NAME:
NEON, Inc.
MODELER:
Hongyan Luo
DATE:
12/16/2014
PROJECT NO.:
WRPLOT View - Lakes Environmental Software


WIND ROSE PLOT:
Domain_15_Salt Lake City Urban; Lat: 40.745890 Long: -111.918070
SALT LAKE CITY INT'L ARPT Sign: KSLC; Lat: 40.787 Long: -111.968; Jul-Sep 2007; Separation: 6 km
Convention: Blowing From
NORTH
SOUTH
WEST
EAST
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: 10.60%
COMMENTS:
The weather data are 2007 data from Salt Lake City International Airport
DATA PERIOD:
Start Date: 7/1/2007 - 00:00
End Date: 10/9/2007 - 23:00
TOTAL COUNT:
2362 hrs.
CALM WINDS:
10.60%
AVG. WIND SPEED:
3.99 m/s
COMPANY NAME:
NEON, Inc.
MODELER:
Hongyan Luo
DATE:
12/16/2014
PROJECT NO.:
WRPLOT View - Lakes Environmental Software

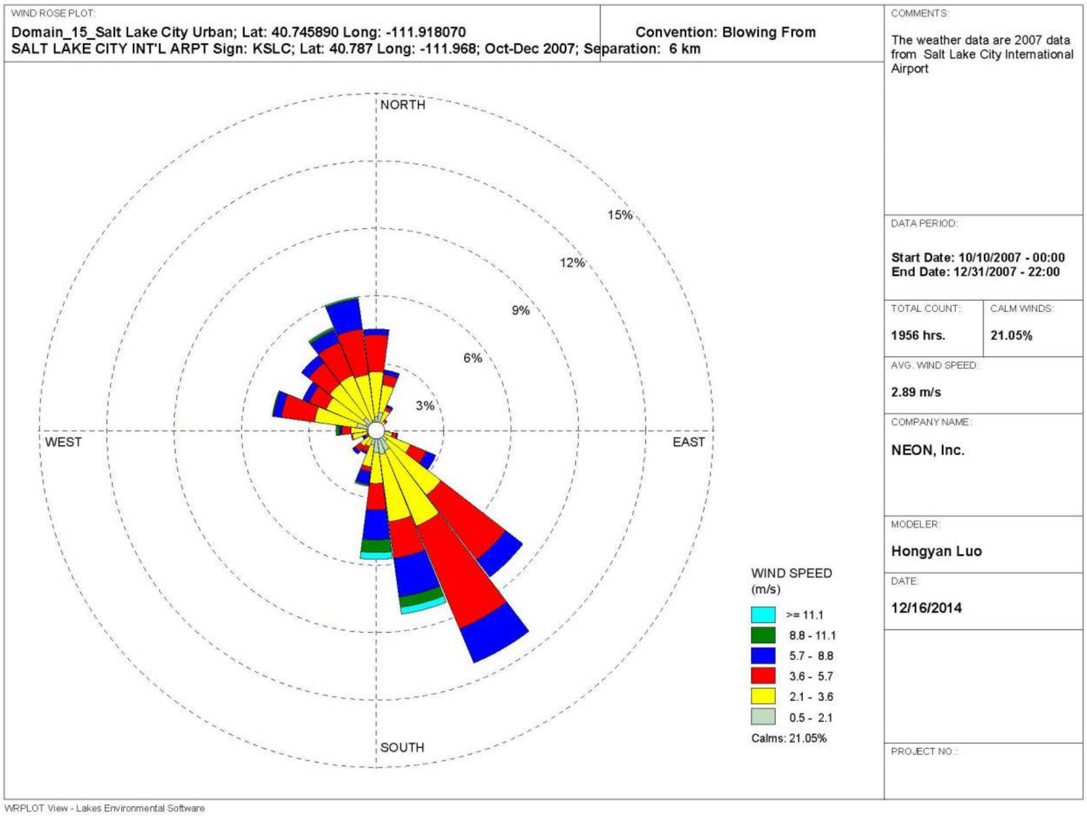


Figure 26. Windroses for SLC urban Relocatable tower site
Wind roses based on the data from Salt Lake City international airport. Panels (from top to bottom) are from annual, Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

4.4.3 Expected environmental controls on source area

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

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

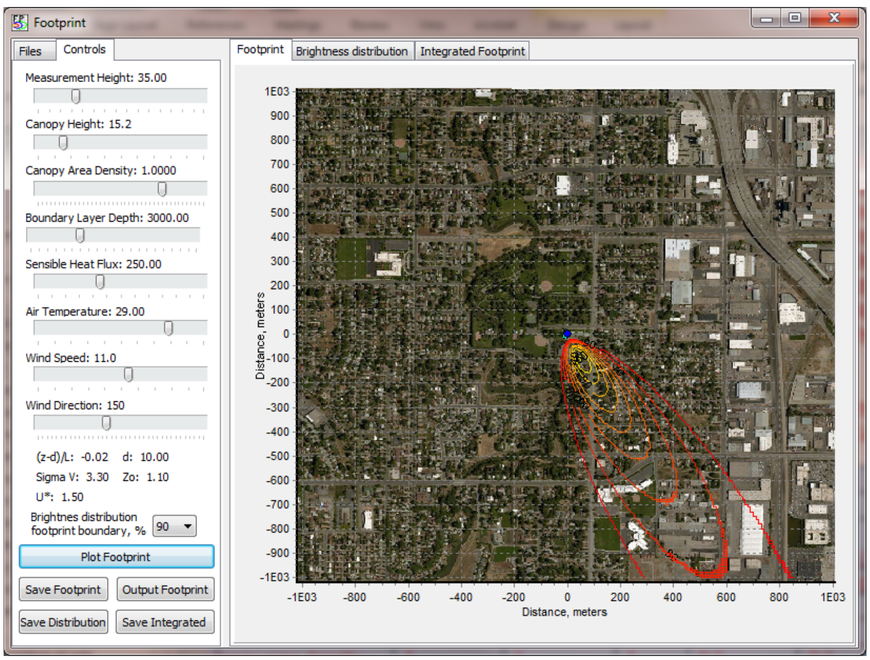
Here, we use a web-based footprint model to determine the footprint area under various conditions (model info: http://www.geos.ed.ac.uk/abs/research/micromet/EdiTools/). Winds used to run the model and generate following model results are extracted from the wind roses. Vegetation information, temperature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

Table 12. Expected environmental controls to parameterize the source area model based on the wind roses for Salt Lake City International airport, and associated results from Salt Lake City urban Relocatable tower site.

Parameters	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	
Approximate season	summer			winter			Units
	Day (max WS)	Day (mean WS)	Night	Day (max WS)	Day (mean WS)	night	qualitative
Atmospheric stability	Convective	convective	Stable	Convective	convective	Stable	qualitative
Measurement height	35	35	35	35	35	35	m
Canopy Height	15.2	15.2	15.2	15.2	15.2	15.2	m
Canopy area density	1.0	1.0	1.0	0.5	0.5	0.5	m
Boundary layer depth	3000	3000	1500	1500	1500	750	m
Expected sensible heat flux	250	250	-50	50	50	-50	W m^{-2}
Air Temperature	29	29	18	5	5	0	°C
Windspeed	11	3.8	4.2	11	3.2	3.2	m s^{-1}
Wind direction	150	150	345	135	135	315	degrees
Results							
(z-d)/L	-0.02	-0.29	0.17	0.00	-0.14	3.00	m
d	10.00	10.00	10.00	8.5	8.5	8.50	m
Sigma v	3.30	2.00	1.70	3.00	1.20	1.60	m^2 s^{-2}
Z0	1.10	1.10	1.10	1.30	1.30	1.30	m
u*	1.50	0.62	0.43	1.50	0.49	0.14	m s^{-1}

Distance source area begins	50	50	50	50	50	250	m
Distance of 90% cumulative flux	1500	700	2050	1550	1000	3350	m
Distance of 80% cumulative flux	800	450	1300	900	600	2800	m
Distance of 70% cumulative flux	600	300	900	650	450	2400	m
Peak contribution	135	85	165	135	115	1015	m

4.4.4 Results (source area graphs)



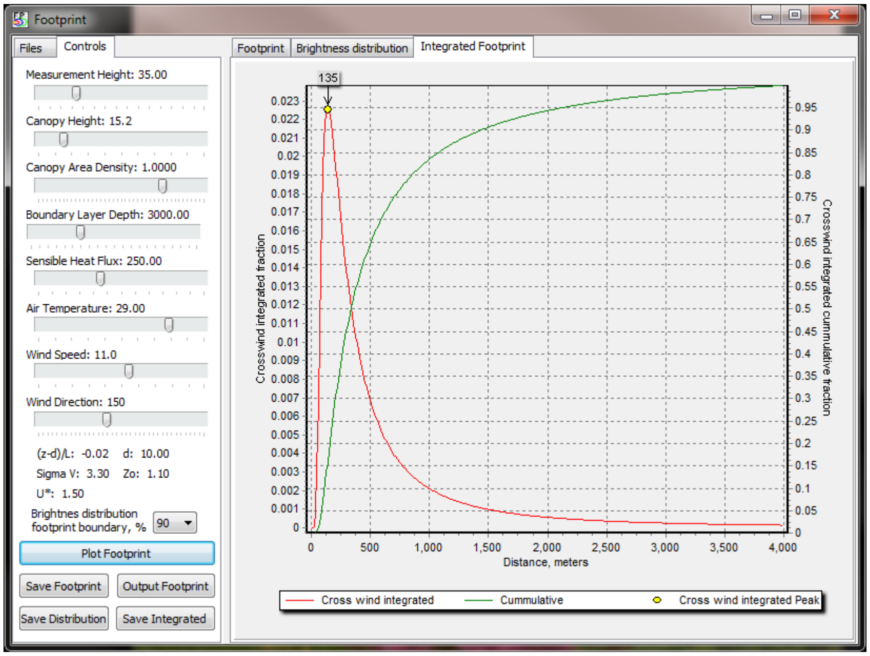
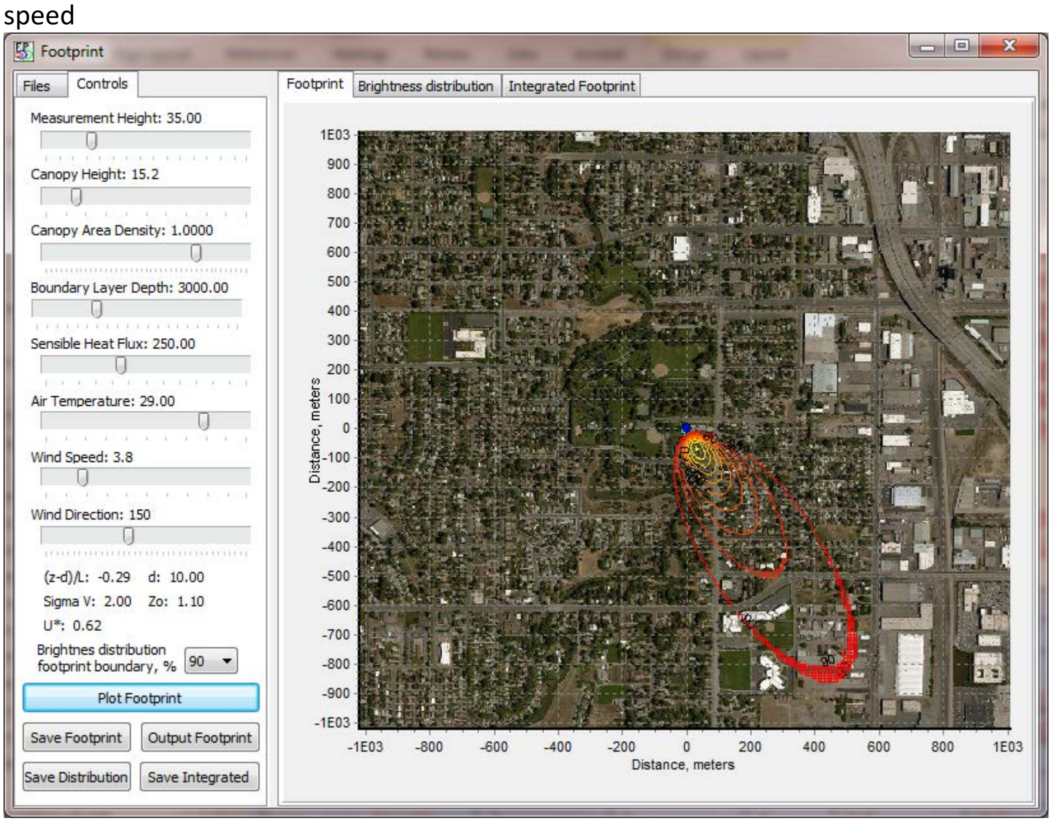


Figure 27. SLC urban Relocatable site summer daytime (convective) footprint output with max wind speed



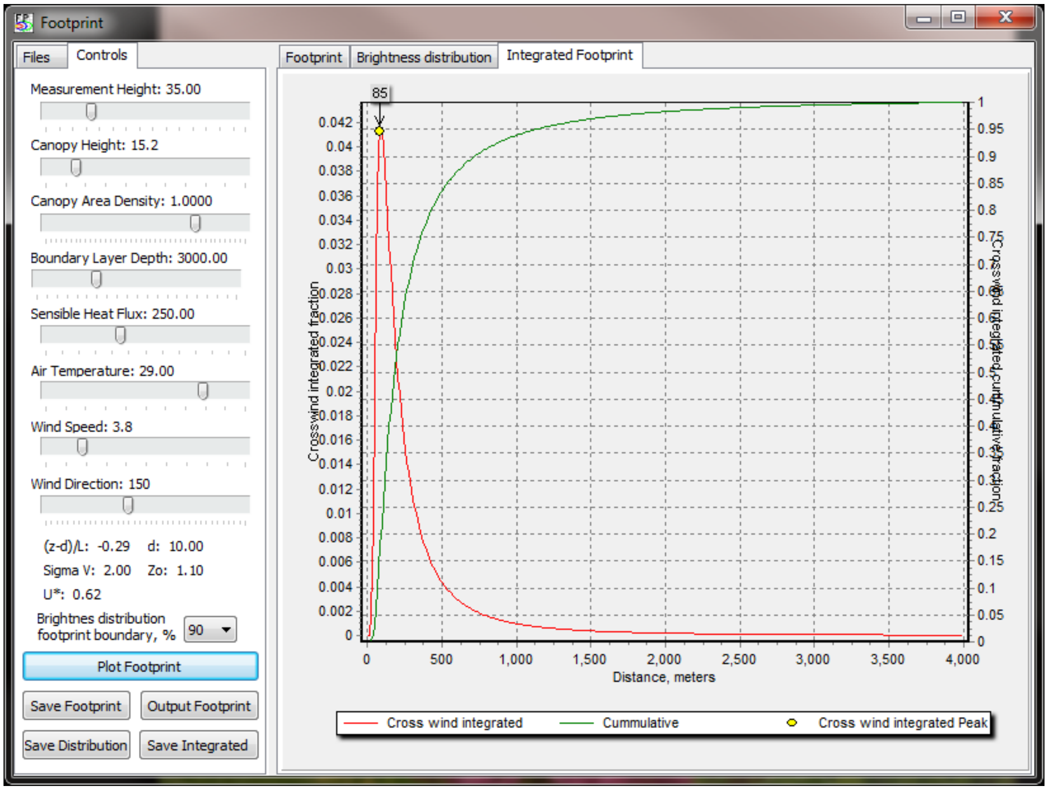
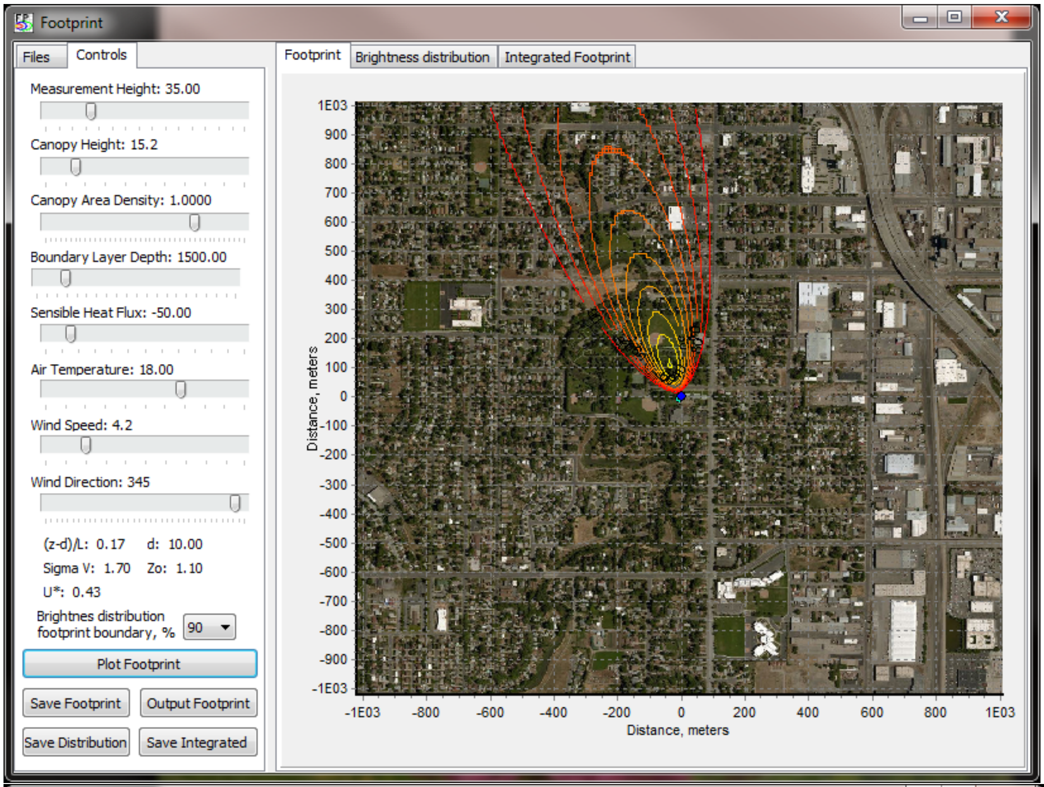
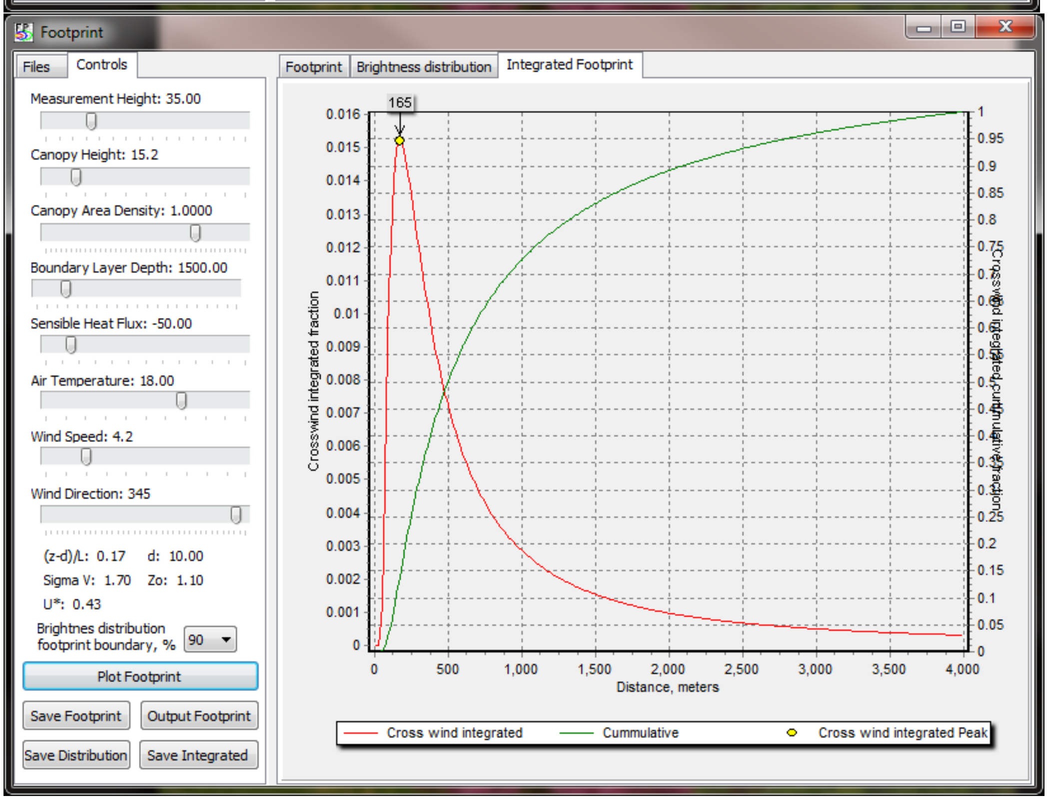


Figure 28. SLC urban Relocatable site summer daytime (convective) footprint output with mean wind speed

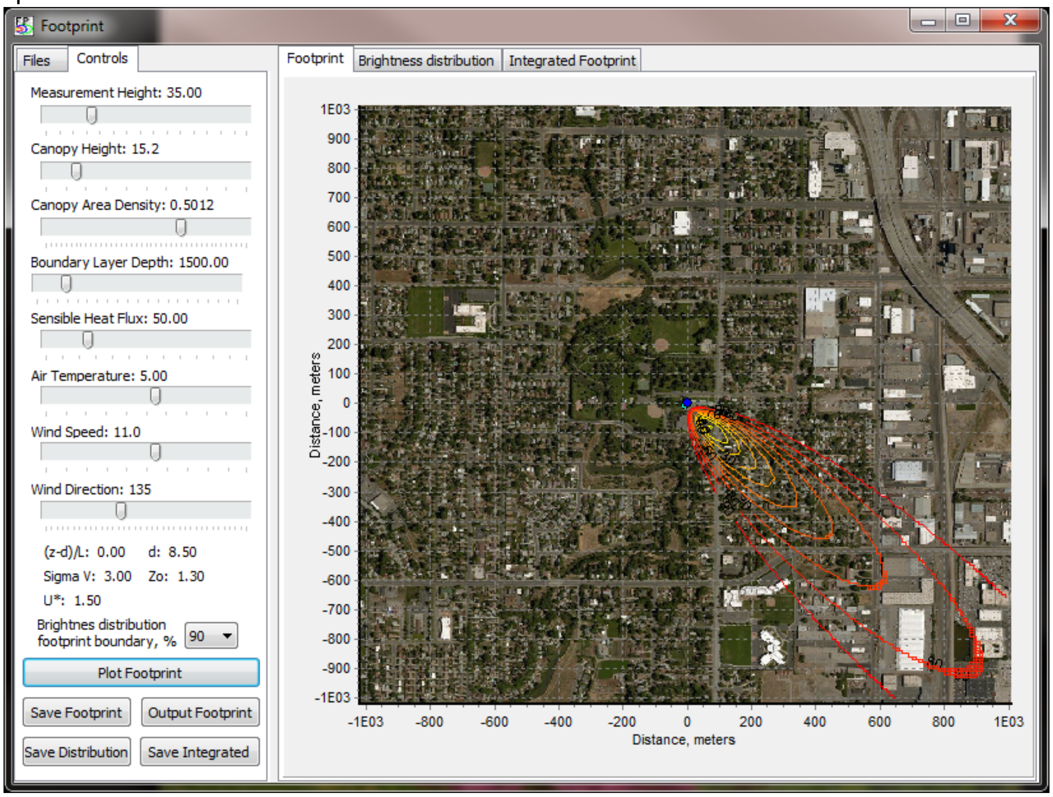


Footprint
Files
Controls
Footprint
Brightness distribution
Integrated Footprint
Measurement Height: 35.00
Canopy Height: 15.2
Canopy Area Density: 1.0000
Boundary Layer Depth: 1500.00
Sensible Heat Flux: -50.00
Air Temperature: 18.00
Wind Speed: 4.2
Wind Direction: 345
(z-d)/L: 0.17 d: 10.00
Sigma V: 1.70 Zo: 1.10
U*: 0.43
Brightnes distribution footprint boundary, % 90
Plot Footprint
Save Footprint
Output Footprint
Save Distribution
Save Integrated
Distance, meters
Distance, meters



Footprint
Files
Controls
Footprint
Brightness distribution
Integrated Footprint
Measurement Height: 35.00
Canopy Height: 15.2
Canopy Area Density: 1.0000
Boundary Layer Depth: 1500.00
Sensible Heat Flux: -50.00
Air Temperature: 18.00
Wind Speed: 4.2
Wind Direction: 345
(z-d)/L: 0.17 d: 10.00
Sigma V: 1.70 Zo: 1.10
U*: 0.43
Brightnes distribution footprint boundary, % 90
Plot Footprint
Save Footprint
Output Footprint
Save Distribution
Save Integrated
165
Crosswind integrated fraction
Distance, meters
Cross wind integrated
Cummulative
Cross wind integrated Peak

Figure 29. SLC urban Relocatable site summer nighttime (stable) footprint output with mean wind speed.



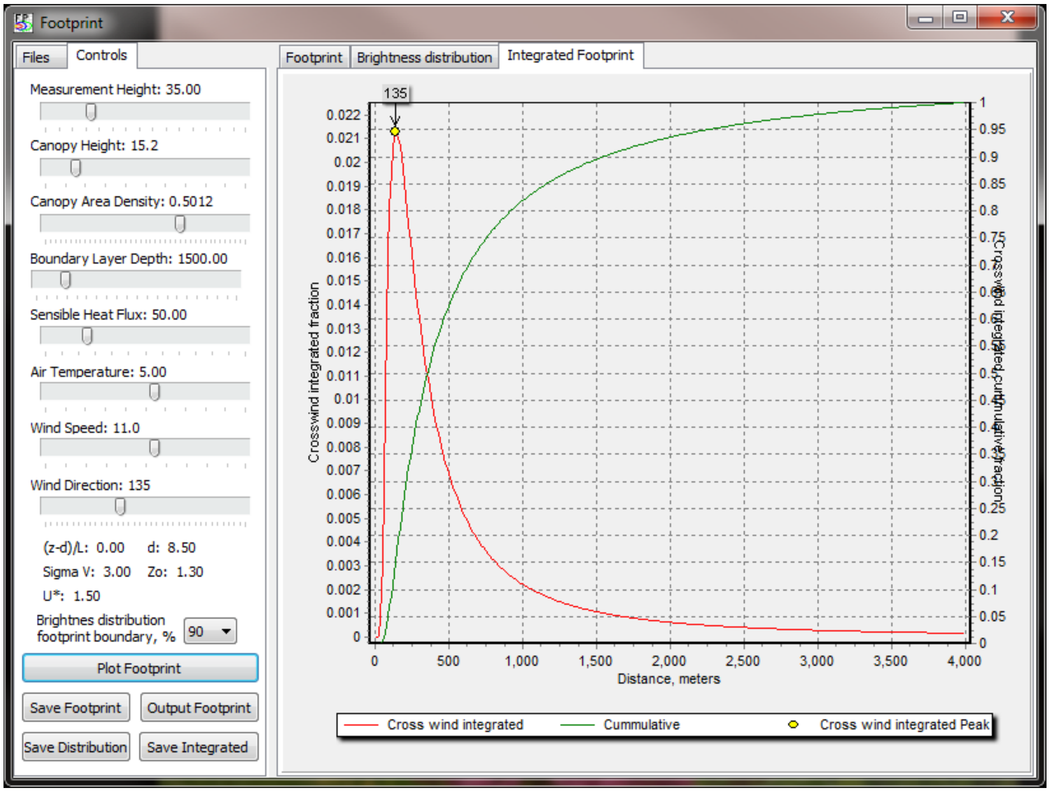
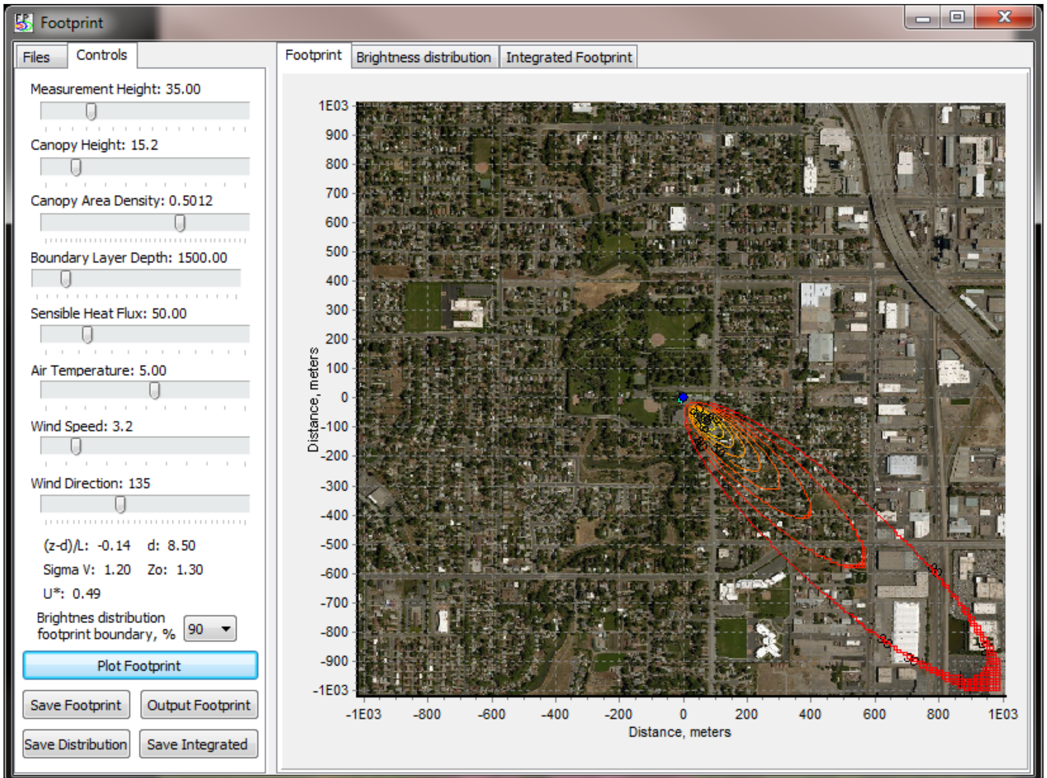
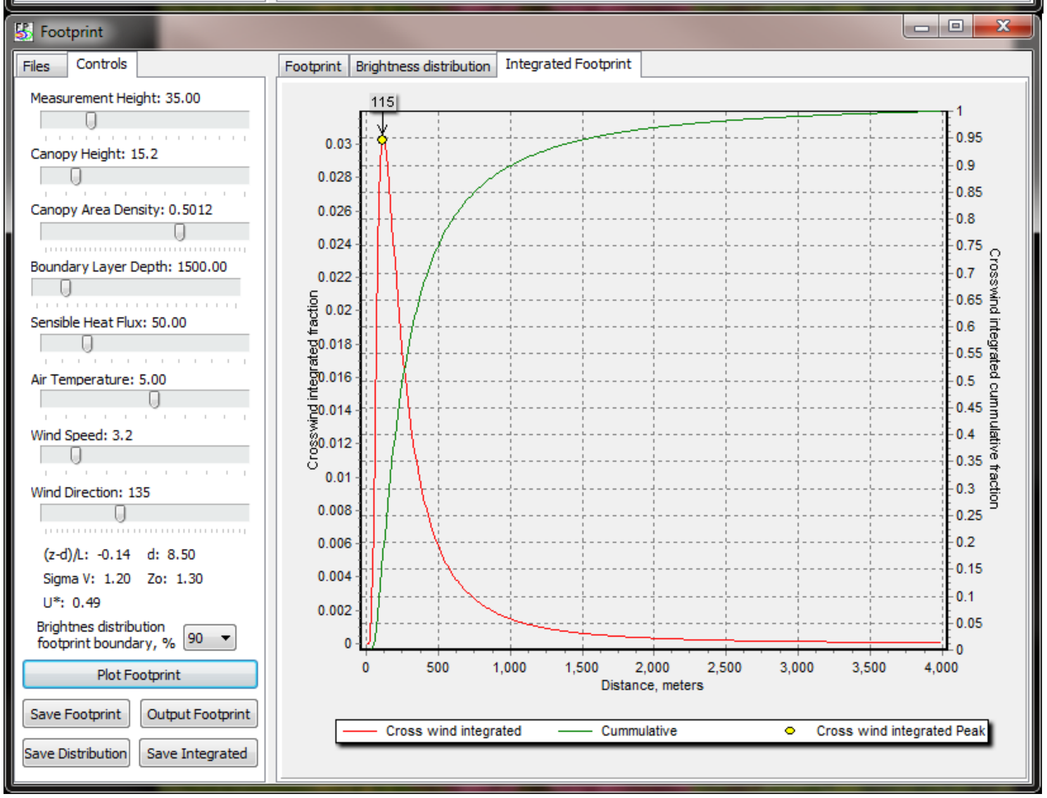


Figure 30. SLC urban Relocatable site winter daytime (convective) footprint output with max wind speed

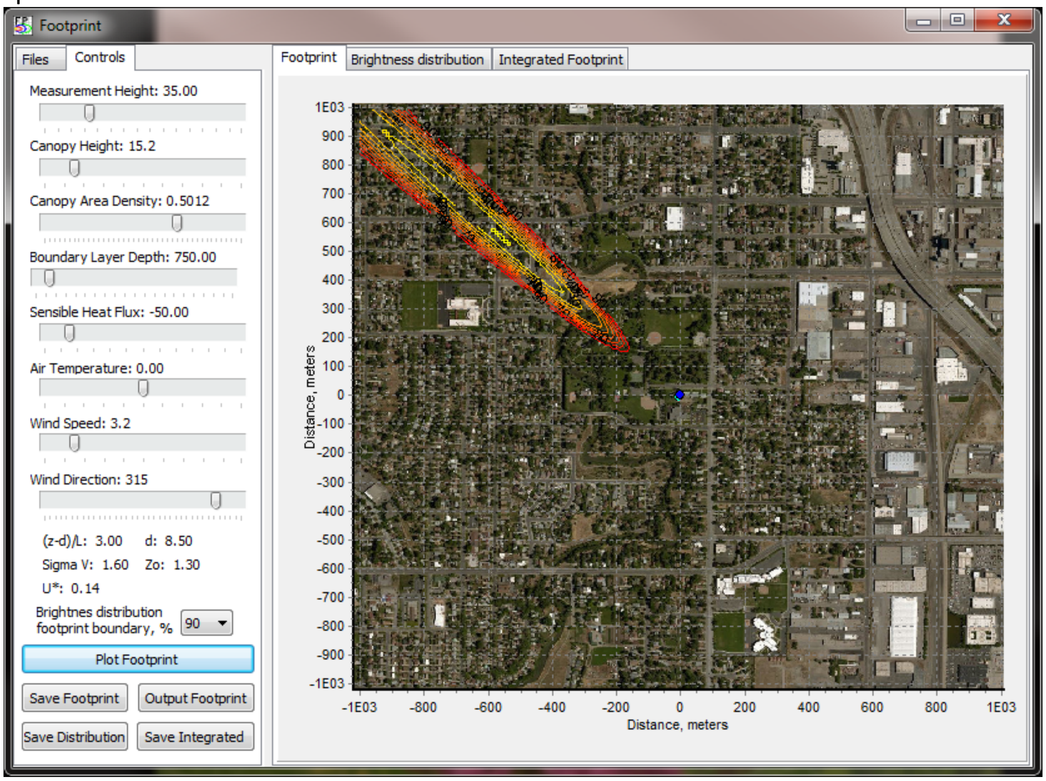


Footprint
Files
Controls
Measurement Height: 35.00
Canopy Height: 15.2
Canopy Area Density: 0.5012
Boundary Layer Depth: 1500.00
Sensible Heat Flux: 50.00
Air Temperature: 5.00
Wind Speed: 3.2
Wind Direction: 135
(z-d)/L: -0.14 d: 8.50
Sigma V: 1.20 Zo: 1.30
U*: 0.49
Brightnes distribution footprint boundary, % 90
Plot Footprint
Save Footprint
Output Footprint
Save Distribution
Save Integrated
Footprint
Brightness distribution
Integrated Footprint
Distance, meters
Distance, meters



Footprint
Files
Controls
Measurement Height: 35.00
Canopy Height: 15.2
Canopy Area Density: 0.5012
Boundary Layer Depth: 1500.00
Sensible Heat Flux: 50.00
Air Temperature: 5.00
Wind Speed: 3.2
Wind Direction: 135
(z-d)/L: -0.14 d: 8.50
Sigma V: 1.20 Zo: 1.30
U*: 0.49
Brightnes distribution footprint boundary, % 90
Plot Footprint
Save Footprint
Output Footprint
Save Distribution
Save Integrated
Footprint
Brightness distribution
Integrated Footprint
115
Crosswind integrated fraction
Crosswind integrated cummulative fraction
Distance, meters
Cross wind integrated
Cummulative
Cross wind integrated Peak

Figure 31. SLC urban Relocatable site winter daytime (convective) footprint output with mean wind speed.



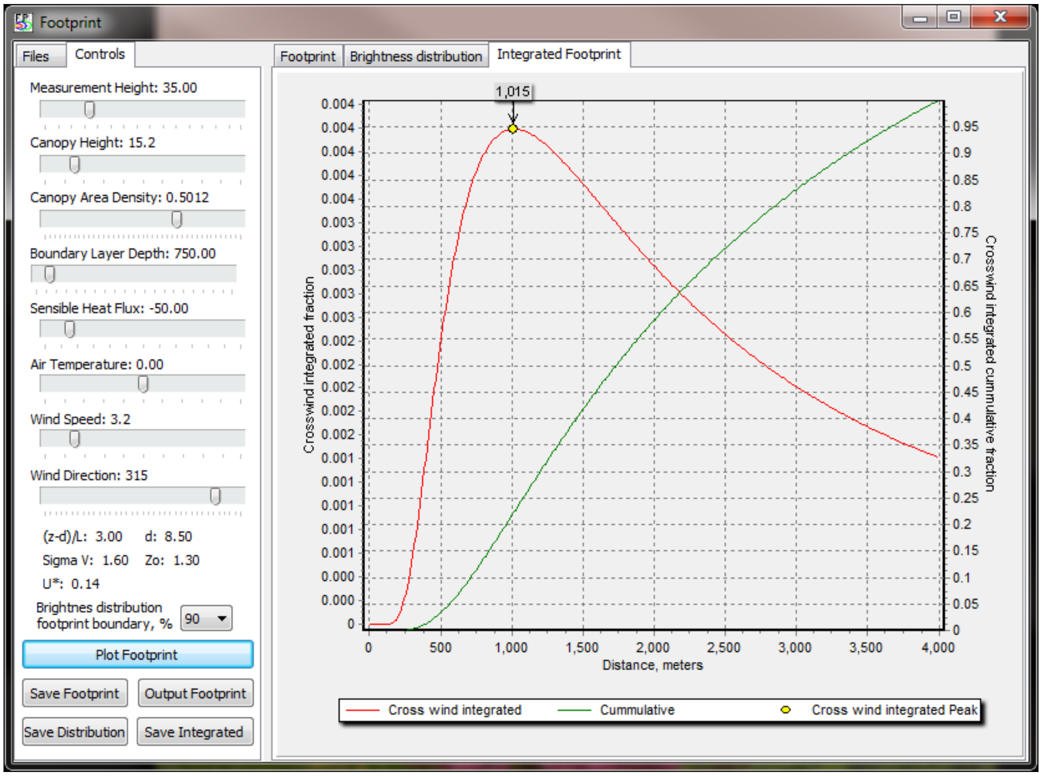


Figure 32. SLC urban Relocatable site winter nighttime (stable) footprint output with mean wind speed.

4.4.5 Site design and tower attributes

No location within this small property is ideal for flux measurements and climate measurements, which is typical for urban sites. Within inputs from city offers, we picked a tower location at the west corner that will give us some reasonable measurements. According to wind roses, the wind direction blows from NW and SE throughout the whole year. The prevailing wind airshed for the tower is from 130^o to 190^o (clockwise from 130^o) and from 280^o to 10^o (clockwise from 280^o). An **instrument hut** should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind, and in this case, we placed the instrument hut location to the east of tower outside the major airshed to minimize its impacts on the tower measurements.

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

The major airshed areas for this site are southeast (130° to 190°, clockwise from 130°) and northwest (280° to 10°, clockwise from 280°) of the tower. The ecosystem within the major airshed on the northwest is city parks (Jordan park, international Peace Garden, Poplar Grove Park, etc.) with lawn and trees, and the ecosystem within the major airshed on the southeast is residential buildings, paved roads and parking lots with trees along the streets and in the front and back yards of residential houses. Both are very typical urban ecosystems. Tree height is ~ 15 m, and building height is ~8 m. Constraint by the city regulation, the tower design cannot go beyond 35 m. Therefore, we require 6 **measurement layers** on the tower with top measurement height at 35 m (well-mixed layer), and rest layers are 20 m (roughness layer), 14 m (canopy top), 8 m (in canopy), 2 m (above ground, shrubs heights) and 0.3 m (ground surface), respectively, to best characterize the fluxes on the tower top and environmental conditions in profile.

Secondary **precipitation collector** for bulk precipitation collection will be located the top of tower at this site. **Wet deposition collector** will deployed at the top of tower at this site. See AD 04 for further information and requirements for bulk precipitation collection and wet deposition collection.

The site layout is summarized in the table below. Assume the projected area of the tower is square. **Anemometer/temperature boom arm direction** is ***from*** the tower ***toward*** the prevailing wind direction or designated orientation. **Instrument hut orientation vector** is parallel to the long side of the instrument hut. **Instrument hut distance z** is the distance from the center of tower projection to the center of the instrument hut projection on the ground. The numbering of the **measurement levels** is that the lowest is level one, and each subsequent increase in height is numbered sequentially, in this case, level 6 being the upper most level at this tower site.

Table 13. Site design and tower attributes for SLC Urban Relocatable site

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

Attribute	lat	long	degree	meters	notes
Airshed			130° to 190° and 280° to 10°		Clockwise from first angle
Tower location			40.745890	-111.918070	
Instrument hut			40.745889	-111.917722	
Instrument hut orientation vector	--	--	90°-270°		E-W
Instrument hut distance z	--	--	--	28	
Anemometer/Temperature boom orientation	--	--	215°	--	
Height of the measurement levels					
Level 1				0.3	m.a.g.l.
Level 2				2.0	m.a.g.l.
Level 3				8.0	m.a.g.l.
Level 4				14.0	m.a.g.l.
Level 5				20.0	m.a.g.l.
Level 6				35.0	m.a.g.l.
Tower Height				35.0	m.a.g.l.

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

Figure 40 below shows the proposed tower location, instrument hut location, airshed area and access road.

Figure 33. Site layout for SLC Urban Relocatable site.

i) new tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 130° to 190° (clockwise from 130°) and 280° to 10° (clockwise from 280°) 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 SLC Urban Relocatable site

- Boardwalk or improved path is NOT required to access instrument hut since it surrounded by parking area
- Boardwalk or improved path is NOT required from the instrument hut to the tower, but suggest marked path
- Soil array boardwalk or improved path is NOT required since all soil plots are next to existing walk way.
- No boardwalk or improved path to the individual soil plots

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

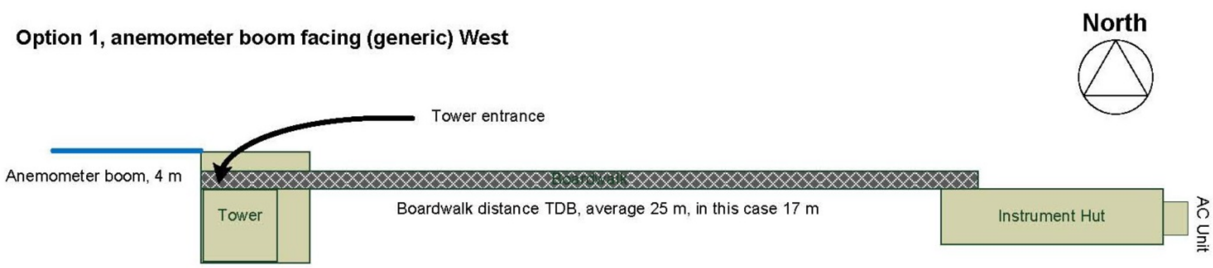


Figure 34. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing west and instrument hut on the east towards the tower.

This is just a generic diagram when boom facing west and instrument hut on the general east towards the tower. The actual design of boardwalk (or path if no boardwalk required) and instrument hut position will be the responsibility of FCC and LAD following FIU's guidelines. At SLC Urban Relocatable site, the boom angle will be 215 degrees, instrument hut will be on the east towards the tower, the distance between instrument hut and tower is ~28 m. The instrument hut vector will be E-W (90°-270°).

4.4.6 Information for ecosystem productivity plots

The tower at SLC Urban relocatable site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (urban ecosystem including grassland, trees and residential buildings). Major airshed area at this site are from 130° to 190° (clockwise from 130°) and from 280° to 10° (clockwise from 280°), and 90% signals for flux measurements are in a distance of 700 m to ~3 km from tower, and 80% daytime signals are within 900 m. Due to the nature of this small property, FIU plots are not able to fit in the airshed within this property. Separate locations for FSU plots in the city parks or residential green area should be explored.

4.5 Issues and attentions

In meeting with the city officials during our visit to SLC, they were very much in favor of endorsing NEON's presence at this site. Essentially, the site as laid-out, was approved. They had a number of suggestions related to minor details (e.g. keep soil plots ~8' in from the sidewalk, maintain the curbline and create a vertical "spar" to prevent the guy wire from blocking passageway along the sidewalk, etc.). Most, if not all, of these concerns can be addressed at the 60% site design review. The city would like to begin the permitting process right away so NEON can begin construction at this site as soon as feasibly possible.

There are anticipated power line conflicts with the western guy line and the northern guy line. The northern guy anchor is expected to extend out into the existing parking lot – this is not anticipated to be a challenge. It is also anticipated that an old "light pole" just south of the greenhouse will need to be removed to accommodate the position of the instrument hut. Additional "clean-up" and removal of old concrete beds will need to be conducted throughout the site.

5 RED BUTTE CANYON, RELOCATEABLE TOWER 2

5.1 Site description

The candidate relocatable tower site (40.781428, -111.804246) is located in Red Butte Canyon (RBC), Salt Lake City, Utah. Tower location is inside a small piece of forest. After FIU site characterization, we microsted tower location ~70 m toward NNE to the location of 40.78205, -111.80394 to avoid edge effects on all directions on the climate measurements.

The main objective is to monitor the influence of urban air masses into the range, and to monitor changes of snow accumulation and composition. Salt Lake City (SLC), UT, is located on SW of the proposed location, and synoptic and local circulations can bring urban airborne aerosols into the proposed site. Several groups from University of Utah have ongoing studies around this site. Ehleringer et al (1992) provide a good description of the site and the land use history. They wrote: "*In size, Red Butte Canyon is relatively small compared with other drainages in the region. The drainage basin covers an area of approximately 20.8 km2. The drainage arises on the East from a minor divide between City Creek and Emigration Canyons to the West… The diversity of slope and aspect combination of terrain contributes to a variety of biotic communities along an elevation gradient about 150m on the west end to more than 2510 m at the crest*". According to Ehleringer et al (1992), the main use of this canyon, just after the pioneer arrival was to provide water from the stream and sandstone quarried to be used for contruction in SLC. The major use of RBC water was by the US Army at Fort Douglas, which established at the mouth of the canyon in 1862. However, due to the mining of sandstone and human activity, RCB water was contaminated. In 1890 the government declared that the waters of Red Butte were sole property of the US Army. The present dam was constructed between 1928 and 1930, and the reservoir provided water for Fort Douglas until its closure in 1991. The RBC was also used for timber and cattle grazing (Info source: R Sakai, 2008, FIU site visit report).

Climate within Red Butte Canyon is characterized by hot, dry summers and long, cold winters. Most precipitation occurs in winter and spring, with the summer rains less predictable and dependent on the extent to which monsoonal systems penetrate into northern Utah. Mean annual precipitation ranges from about 500 mm (20 in) at the lower elevation to approximately 900 mm (35 in) at the higher elevations (info source: http://redbuttecanyon.net/climate.html).

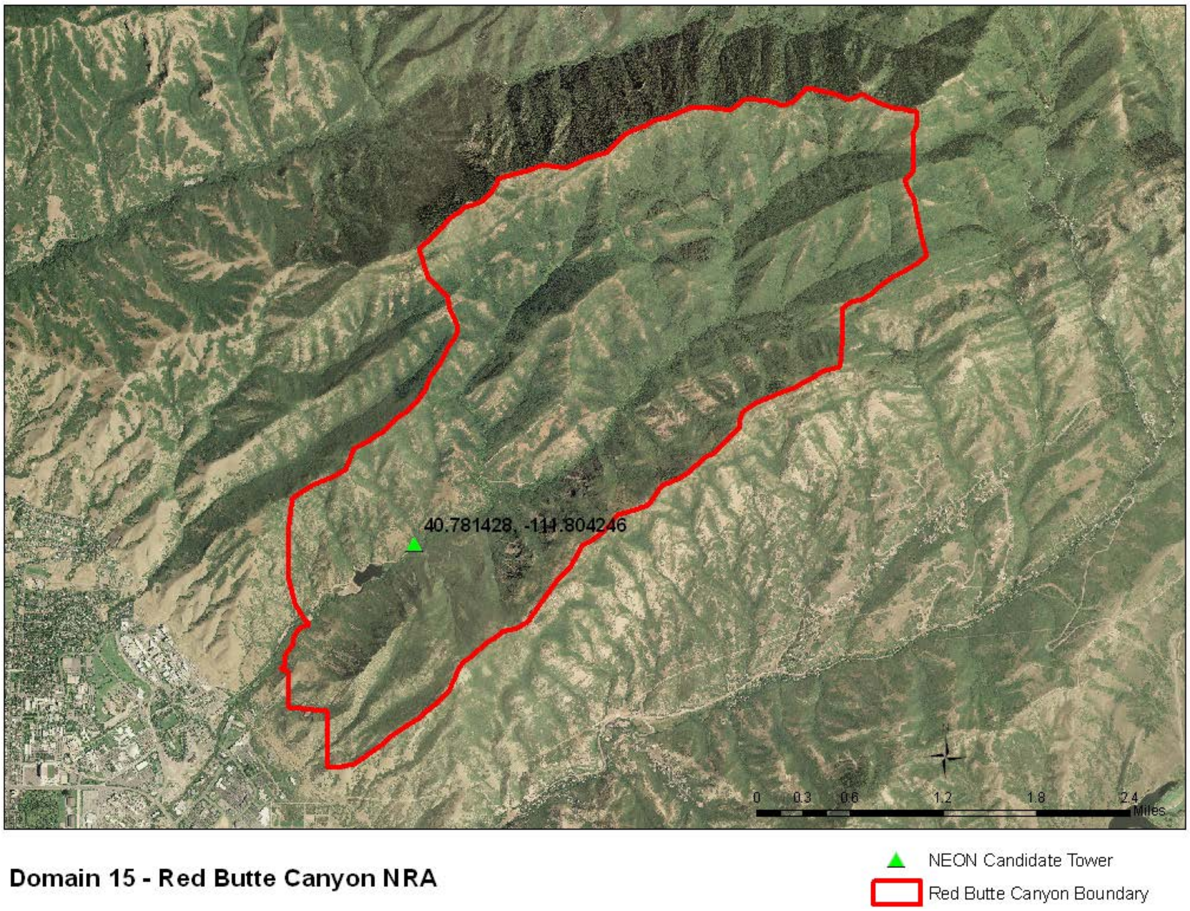


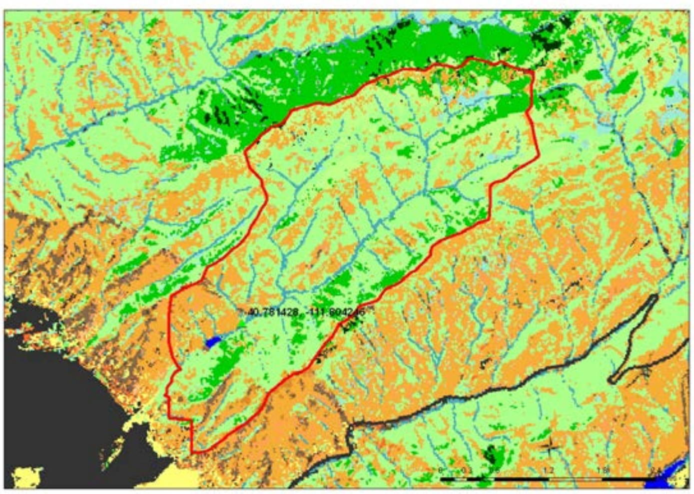
Figure 35. Property boundary of the Red Butte Canyon and tower location.

5.2 Ecosystem

There is a strong xeric to mesic elevation gradient, with lower portions of the canyon dominated by a spring-active grassland community and the upper portions of the canyon typically consisting of summer-active scrub oak, aspen, and coniferous forest communities. Composition within each of these communities is not constant, but instead species vary in their importance within a community type as orientation and elevation change. These elevation gradients represent a continuum of moisture availability, with high temperatures and low precipitation amounts at lower elevations making conditions more xeric, while slope orientations less southerly in exposure become progressively more mesic within an elevation band. Soil type and depth also play a major role in affecting plant distribution by providing variation in the water-holding capacity of the substrate. The distribution of the scrub-oak community to the highest elevations within the canyon is most likely related to soil conditions, since at high elevations scrub oak persists on south-, east-, and west-facing slopes that would normally be expected to be dominated by aspen if it were not for the very shallow, rocky soils that typify these elevations within Red Butte Canyon (info source: http://redbuttecanyon.net/ecology.html).

Gambel oak (*Quercus gambelii*) is the dominant type of vegetation throughout the altitudinal range of the canyon. It forms what appear to be randomly spaced clones throughout much of the area. In accordance with the moisture regimen, the clones may range from thickets 0.3 m (1 ft) or less in height in dry upland sites to stands of stately, well-spaced tress in lowland areas. Both walls of the canyon support often nearly impenetrable oak in association with bigtooth maple (*Acer grandidentatum*), the latter growing chiefly in drainage-ways. Few species thrive as understory with dense oak cover. The most common are *Galium aparine* (catchweed bedstraw) and *Mahonia repens* (Oregon grape). Others appearing seasonally under oak are *Erythronium grandiflorum* (dogtooth violet), *Claytonia lanceolata* (lanceleaf spring beauty), *Hydrophyllum capitatum* (ballhead waterleaf), and *H. occidentale* (western waterleaf). Among plants commonly fringing oak clones are listed to the right (Info source: http://redbuttecanyon.net/oakmaple.html).

More vegetation and land cover information are presented below:



Domain 15 - Red Butte Canyon NRA

Figure 36. Vegetative cover map of Red Butte Canyon relocatable site and surrounding areas (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Table 14. Percent Land cover information at Red Butte Canyon relocatable site (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Veg_Type	**Area**	**Percent**
Abies concolor Forest Alliance	0.728698	3.28729414
Agriculture-Pasture and Hay	0.022575	0.10184225
Artemisia tridentata ssp. vaseyana Shrubland Alliance	0.063975	0.28860266
Colorado Plateau Pinyon-Juniper Woodland	0.038984	0.17586342
Developed-Open Space	0.046185	0.20835081
Great Basin Xeric Mixed Sagebrush Shrubland	0.154936	0.69894703
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	0.275446	1.24259121
Inter-Mountain Basins Big Sagebrush Shrubland	0.01395	0.0629302
Inter-Mountain Basins Big Sagebrush Steppe	0.002053	0.00926012
Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland	0.306701	1.38358731
Inter-Mountain Basins Greasewood Flat	0.0009	0.00406007
Inter-Mountain Basins Montane Sagebrush Steppe	0.077426	0.34928346
Introduced Riparian Vegetation	0.012276	0.05538095
Introduced Upland Vegetation-Annual Grassland	0.0036	0.01624028
Open Water	0.027	0.12180213
Quercus gambelii Shrubland Alliance	2.202224	9.93464949
Rocky Mountain Alpine/Montane Sparsely Vegetated Systems	0.009901	0.0446651
Rocky Mountain Aspen Forest and Woodland	2.759384	12.448106
Rocky Mountain Bigtooth Maple Ravine Woodland	9.905339	44.684867
Rocky Mountain Gambel Oak-Mixed Montane Shrubland	2.18573	9.86024256
Rocky Mountain Lodgepole Pine Forest	0.063656	0.28716573
Rocky Mountain Lower Montane-Foothill Shrubland	0.025405	0.11460793
Rocky Mountain Montane Riparian Systems	1.270306	5.73059114
Rocky Mountain Subalpine-Montane Mesic Meadow	0.445748	2.01085448
Sonora-Mojave Semi-Desert Chaparral	0.021838	0.09851574
Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	0.054361	0.24523422
Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	1.447601	6.53040453
Southern Rocky Mountain Montane-Subalpine Grassland	0.0009	0.00406007
Total Area sq km	22.1671	100

The ecosystem is hardwood (oak dominated) forest where NEON tower is located. Canopy height is ~10 m around tower site with lowest branches at 2 m. Shrub and recruit seedling and saplings forms understory with height ~3 m. Grass and many other annuals form understory at ground level with canopy height ~ 0.4 m.

Table 15. Ecosystem and site attributes for Red Butte Canyon Relocatable site.

Ecosystem attributes	Measure and units
Mean canopy height[a]	10 m
Surface roughness[a]	0.7 m
Zero place displacement height[a]	7.5 m
Structural elements	Closed forest, understory presents
Time zone	Mountain time zone
Magnetic declination	12° 13' E changing by 0° 7' W $year^{-1}$

Note, [a] From model output.

5.3 Soils

5.3.1 Description of soils

Soil data and soil maps (Figure 44) below for Red Butte tower site were collected from 2.2 km^2 NRCS soil maps (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm), which centered at the tower location, to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

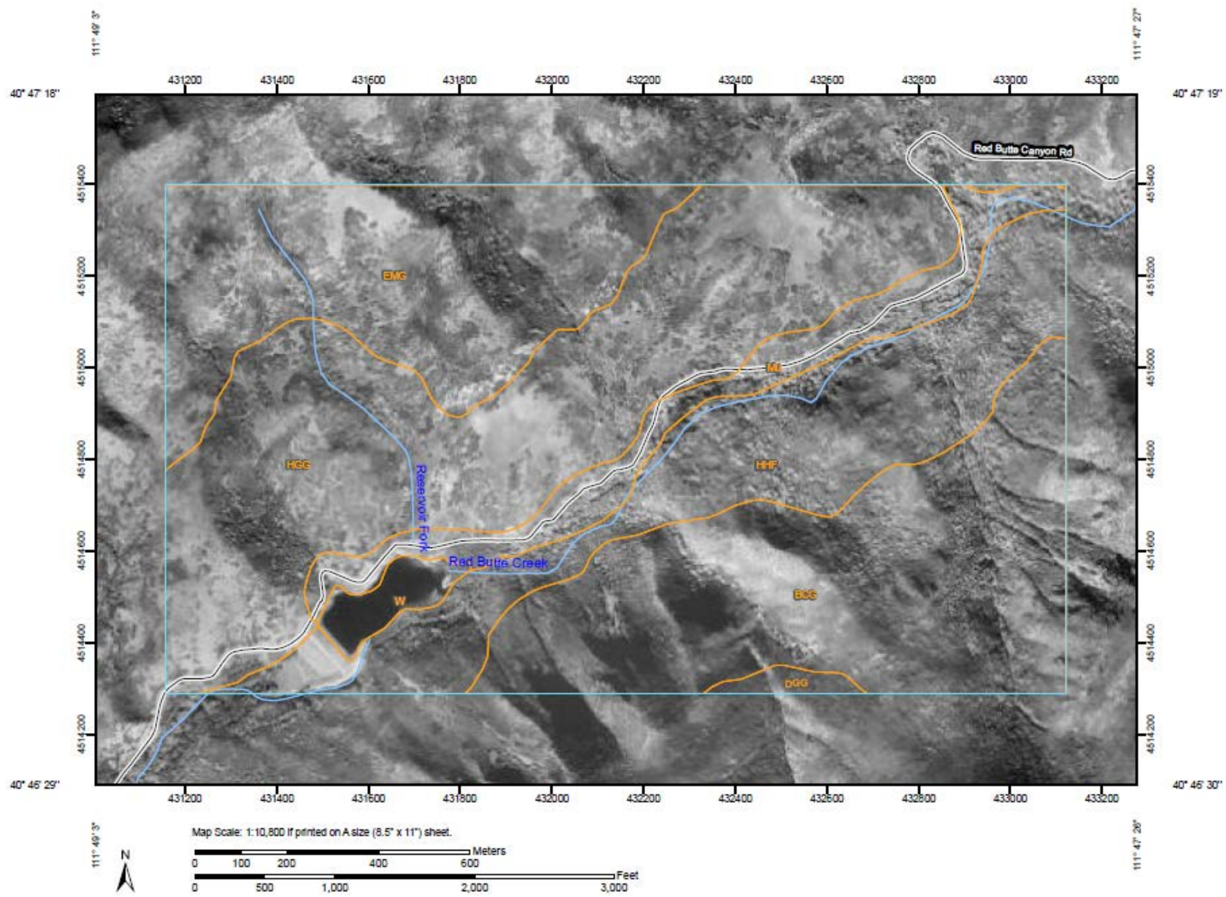


Figure 37. Soil map of the Red Butte Relocatable site and surrounding areas.

Soil Map Units Description: The map units delineated on the detailed soil maps in a soil survey represents the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called non-contrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas. An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. All the soils of a series have major horizons that are similar in composition, thickness, and arrangement. Soils of a given series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. T he name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, are an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Additional information about the map units described in this report is available in other soil reports, which give properties of the soils and the limitations, capabilities, and potentials for many uses. Also, the narratives that accompany the soil reports define some of the properties included in the map unit descriptions.

Table 16. Soil series and percentage of soil series within 2.2 km^2 centered on the Red Butte tower

Salt Lake Area, Utah (UT612)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
BCG	Brad very rocky loamy sand, 40 to 80 percent slopes	131.0	24.3%
DGG	Deer Creek-Picayune association, steep	3.5	0.7%
EMG	Emigration very cobbly loam, 40 to 70 percent slopes	100.3	18.6%
HGG	Harkers-Wallsburg association, steep	167.4	31.0%
HHF	Harkers soils, 6 to 40 percent slopes	91.6	17.0%
Mu	Mixed alluvial land	37.2	6.9%
W	Water	8.2	1.5%
Totals for Area of Interest		**539.3**	**100.0%**

Salt Lake Area, Utah- BCG—Brad very rocky loamy sand, 40 to 80 percent slopes: Map Unit Setting Elevation: 5,400 to 8,000 feet Mean annual precipitation: 20 to 25 inches Mean annual air temperature: 44 to 46 degrees F **Map Unit Composition** Brad and similar soils: 60 percent Rock outcrop: 25 percent **Description of Brad Setting** Landform: Mountain slopes Landform position (three-dimensional): Mountainflank Down-slope shape: Convex Across-slope shape: Convex Parent material: Residuum weathered from sandstone **Properties and qualities** Slope: 40 to 80 percent Depth to restrictive feature: 12 to 20 inches to lithic bedrock Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately high (0.00 to 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Very low (about 0.5 inches) **Interpretive groups** Land capability (nonirrigated): 7s Ecological site: Mountain Shallow Loam (Mountain Big Sagebrush) (R047XA446UT) **Typical profile** 0 to 8 inches: Very cobbly loamy sand 8 to 14 inches: Extremely cobbly loamy sand 14 to 24 inches: Unweathered bedrock Description of Rock Outcrop **Setting** Landform: Mountain slopes Landform position (three-dimensional): Mountainflank Down-slope shape: Convex Across-slope shape: Convex

Salt Lake Area, Utah-DGG—Deer Creek-Picayune association, steep: Map Unit Setting: Elevation: 5,400 to 7,000 feet Mean annual precipitation: 20 to 25 inches Mean annual air temperature: 44 to 46 degrees F Frost-free period: 80 to 100 days Map Unit Composition Deer creek and similar soils: 55 percent Picayune and similar soils: 35 percent **Description of Deer Creek Setting** Landform: Mountain slopes Landform position (three-dimensional): Mountainflank Down-slope shape: Convex Across-slope shape: Convex Parent material: Colluvium derived from limestone and/or residuum weathered from limestone **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 low to moderately high (0.06 to 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 40 percent Available water capacity: Moderate (about 8.0 inches) **Interpretive groups** Land capability (nonirrigated): 7e Ecological site: Mountain Loam (Oak) (R047XA432UT) **Typical profile** 0 to 11 inches: Loam 11 to 16 inches: Clay loam 16 to 25 inches: Gravelly clay 25 to 34 inches: Gravelly clay 34 to 45 inches: Very gravelly clay loam 45 to 60 inches: Very gravelly clay loam **Description of Picayune Setting** Landform: Mountain slopes Landform position (three-dimensional): Mountainflank Down-slope shape: Convex Across-slope shape: Convex Parent material: Colluvium derived from limestone and/or residuum weathered from limestone **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 0.60 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 50 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: High (about 9.3 inches) **Interpretive groups** Land capability (nonirrigated): 7e Ecological site: Mountain Loam (Shrub) (R047XA434UT) **Typical profile** 0 to 7 inches: Gravelly clay loam 7 to 13 inches: Gravelly clay loam 13 to 29 inches: Gravelly clay loam 29 to 60 inches: Clay loam

Salt Lake Area, Utah- -EMG—Emigration very cobbly loam, 40 to 70 percent slopes: Map Unit Setting: Elevation: 5,500 to 7,000 feet Mean annual precipitation: 18 to 25 inches Mean annual air temperature: 44 to 46 degrees F Frost-free period: 80 to 100 days **Map Unit Composition** Emigration and similar soils: 95 percent **Description of Emigration Setting** Landform: Mountain slopes Landform position (three-dimensional): Mountainflank Down-slope shape: Convex Across-slope shape: Convex Parent material: Residuum weathered from limestone and sandstone **Properties and qualities** Slope: 40 to 70 percent Depth to restrictive feature: 12 to 20 inches to lithic bedrock Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately high (0.00 to 0.60 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Very low (about 1.7 inches) **Interpretive groups** Land capability (nonirrigated): 7s Ecological site: Mountain Shallow Loam (Curlleaf Mountainmahogany) (R047XA440UT) **Typical profile** 0 to 4 inches: Very cobbly loam 4 to 14 inches: Very gravelly clay loam 14 to 18 inches: Extremely cobbly clay loam 18 to 28 inches: Unweathered bedrock

Salt Lake Area, Utah - HHF—Harkers soils, 6 to 40 percent slopes: Map Unit Setting; Elevation: 5,500 to 7,500 feet Mean annual precipitation: 20 to 25 inches Mean annual air temperature: 44 to 46 degrees F Frost-free period: 80 to 100 days **Map Unit Composition** Harkers and similar soils: 45 percent Harkers and similar soils: 45 percent **Description of Harkers Setting** Landform: Alluvial fans, mountain slopes Down-slope shape: Concave Across-slope shape: Convex Parent material: Colluvium derived from limestone, sandstone, and shale and/or residuum weathered from limestone, sandstone, and shale **Properties and qualities** Slope: 10 to 40 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Moderate (about 8.6 inches) **Interpretive groups** Land capability (nonirrigated): 6e Ecological site: Mountain Loam (Oak) (R047XA432UT) **Typical profile** 0 to 14 inches: Loam 14 to 19 inches: Gravelly clay loam 19 to 42 inches:

Gravelly clay 42 to 58 inches: Very gravelly clay 58 to 80 inches: Very gravelly clay loam **Description of Harkers Setting** Landform: Alluvial fans, mountain slopes Down-slope shape: Concave Across-slope shape: Convex Parent material: Colluvium derived from limestone, sandstone, and shale and/or residuum weathered from limestone, sandstone, and shale **Properties and qualities** Slope: 6 to 40 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Moderate (about 8.2 inches) **Interpretive groups** Land capability (nonirrigated): 6e Ecological site: Mountain Loam (Oak) (R047XA432UT) **Typical profile** 0 to 14 inches: Cobbly loam 14 to 19 inches: Gravelly clay loam 19 to 42 inches: Gravelly clay 42 to 58 inches: Very gravelly clay 58 to 80 inches: Very gravelly clay loam

Salt Lake Area, Utah - HGG—Harkers-Wallsburg association, steep: Map Unit Setting: Elevation: 5,500 to 7,500 feet Mean annual precipitation: 20 to 25 inches Mean annual air temperature: 44 to 46 degrees F Frost-free period: 80 to 120 days **Map Unit Composition** Harkers and similar soils: 55 percent Wallsburg and similar soils: 35 percent **Description of Harkers Setting** Landform: Fanhead trenches on alluvial fans Landform position (three-dimensional): Side slope Down-slope shape: Concave, linear Across-slope shape: Convex, concave Parent material: Colluvium derived from limestone, sandstone, and shale and/or residuum weathered from limestone, sandstone, and shale **Properties and qualities** Slope: 6 to 40 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Moderate (about 8.6 inches) **Interpretive groups** Land capability (nonirrigated): 6e Ecological site: Mountain Loam (Oak) (R047XA432UT) **Typical profile** 0 to 14 inches: Loam 14 to 19 inches: Gravelly clay loam 19 to 42 inches: Gravelly clay 42 to 58 inches: Very gravelly clay 58 to 80 inches: Very gravelly clay loam **Description of Wallsburg Setting** Landform: Breaks on alluvial fans Landform position (three-dimensional): Interfluve Down-slope shape: Concave, convex Across-slope shape: Convex, linear

Salt Lake Area, Utah - Mu—Mixed alluvial land: Map Unit Setting: Elevation: 4,200 to 4,350 feet Frost-free period: 130 to 150 days **Map Unit Composition** Mixed alluvial land and similar soils: 95 percent Minor components: 5 percent **Description of Mixed Alluvial Land Setting** Landform: Flood plains Landform position (three-dimensional): Talf, dip Down-slope shape: Linear Across-slope shape: Concave **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 low to moderately high (0.06 to 0.20 in/hr) Depth to water table: About 13 to 36 inches Frequency of flooding: Frequent Frequency of ponding: None Calcium carbonate, maximum content: 40 percent Maximum salinity: Slightly saline to strongly saline (8.0 to 32.0 mmhos/cm) Sodium adsorption ratio, maximum: 20.0 Available water capacity: Low (about 5.4 inches) **Interpretive groups** Land capability (nonirrigated): 6w Ecological site: Wet Fresh Streambank (R028AY022UT) **Typical profile** 0 to 6 inches: Loam 6 to 60 inches: Gravelly clay loam **Minor Components** Poorly drained soils Percent of map unit: 5 percent Landform: Flood plains Landform position (three-dimensional): Talf, dip Down-slope shape: Linear Across-slope shape: Concave Ecological site: Wet Saline Meadow (R028AY024UT)

Salt Lake Area, Utah - W—Water: Map Unit Composition: Water: 100 percent

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 45). 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 45).

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 45), 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.

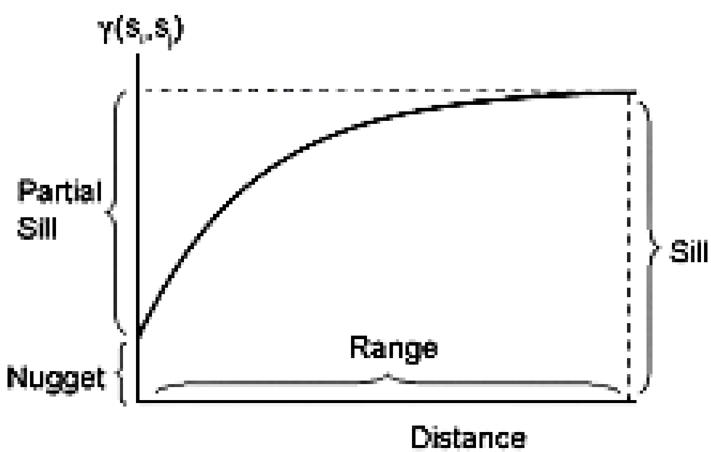


Figure 38. Example semivariogram, depicting range, sill, and nugget.

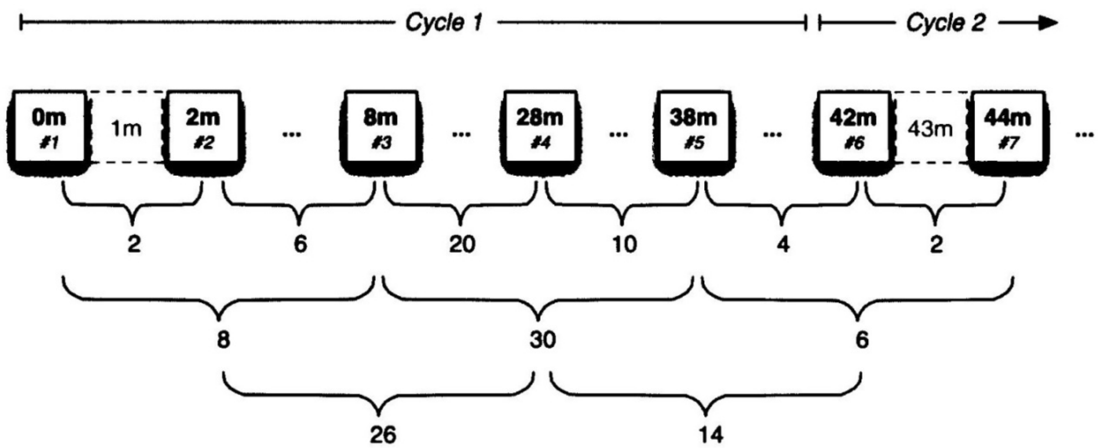


Figure 39. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 20 May 2010 at the Red Butte site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 39). Soil temperature and moisture measurements were collected along four transects (84 m, 84 m, 84 m, and 84 m) located in the expected airshed at Red Butte. 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 39, 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 40). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 41, left graphs) and directional semivariograms do not show anisotropy (Figure 41, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 41, right graph). The model indicates a distance of effective independence of 114 m for soil temperature.

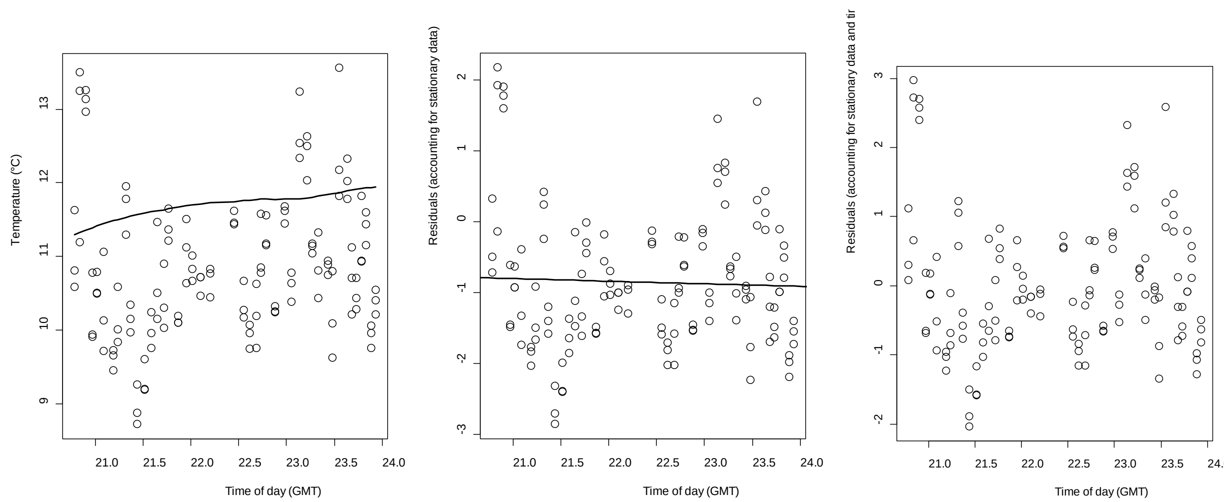


Figure 40. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting for changes temperature in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

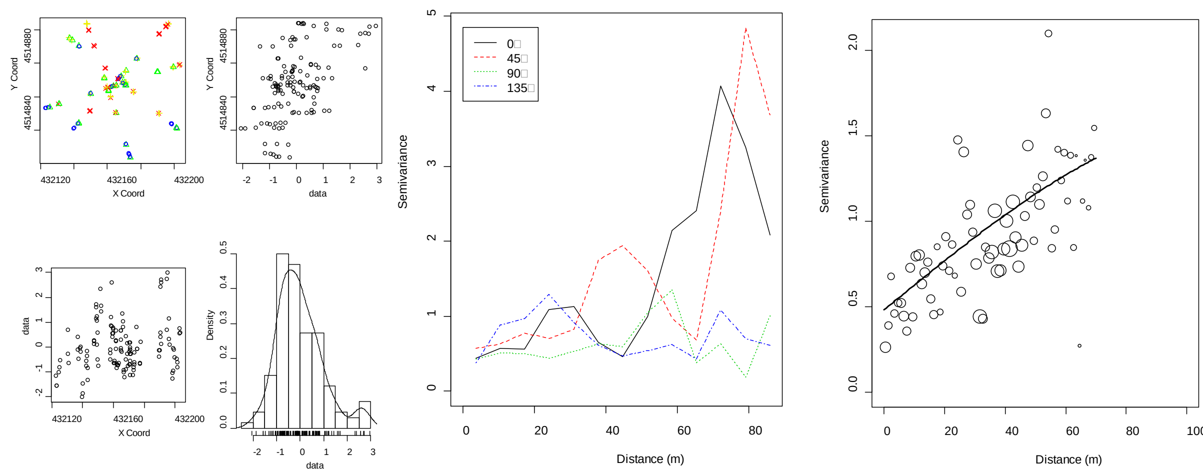


Figure 41. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

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 42). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 43, left graph) and directional semivariograms do not show anisotropy (Figure 43, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 43, right graph). The model indicates a distance of effective independence of 17 m for soil water content.

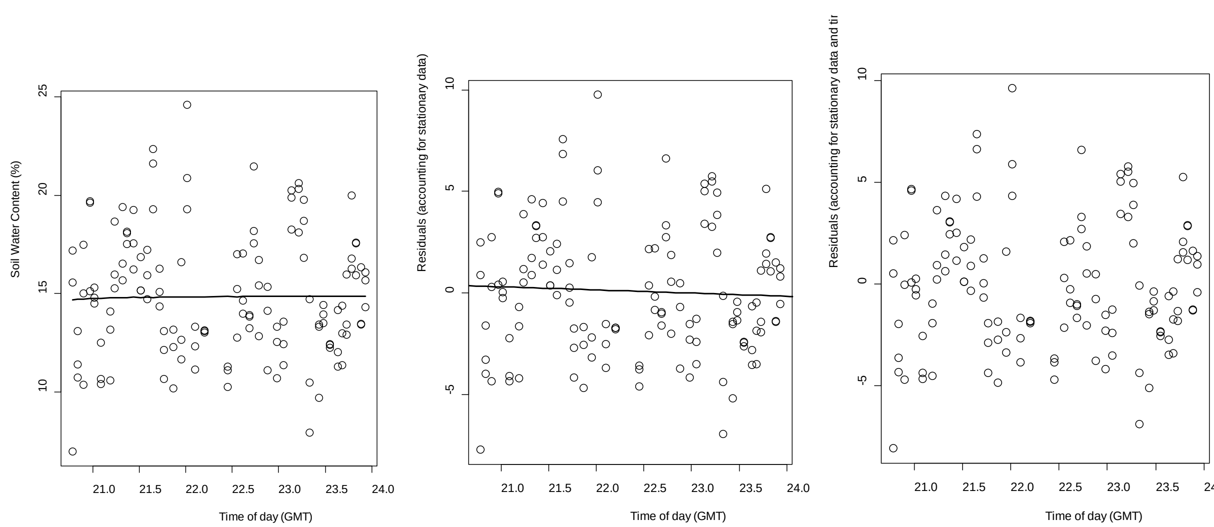


Figure 42. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting 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.

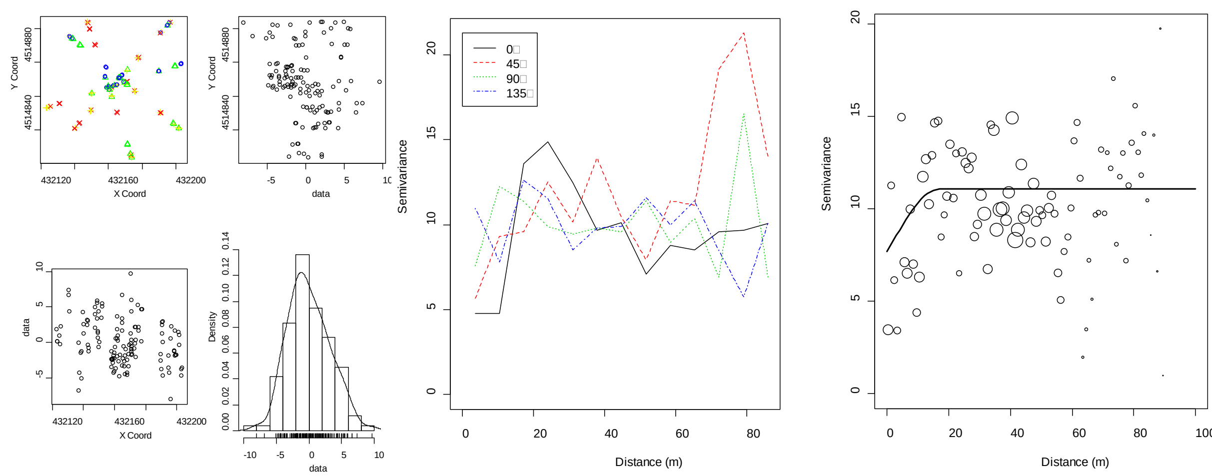


Figure 43. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

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 114 m for soil temperature and 17 m for soil moisture. Based on these results and the site design guidelines the soil plots at Red Butte shall be placed 40 m apart. The soil plots will be 5 m x 5 m. Due to the small area and width of the forested area at Red Butte none of the exiting soil array patterns could fit into this location. Therefore, a new site specific pattern was developed for Red Butte (see Table 11 for approximate latitude and longitude of each soil plot). 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 40.78170, -111.80366 (primary location); or 40.78264, -111.80326 (alternate location 1 if primary location is unsuitable); or 40.78133, -111.80410 (alternate location 2 if primary location is unsuitable). A summary of the soil information is shown in Table 18 and site layout can be seen in Figure 44.

Dominant soil series at the site: Harkers-Wallsburg association, steep. The taxonomy of this soil is shown below:
Order: Mollisols
Suborder: Xerolls
Great group: Palexerolls-Argixerolls
Subgroup: Typic Palexerolls-Lithic Argixerolls
Family: Fine, smectitic, frigid Typic Palexerolls-Clayey-skeletal, smectitic, frigid Lithic Argixerolls
Series: Harkers-Wallsburg association, steep

Table 17. Summary of soil array and soil pit information at Red Butte. 0° represents true north and accounts for declination.

Soil plot dimensions	5 m x 5 m
Soil array pattern	NA
Distance between soil plots: x	40 m
Distance from tower to closest soil plot: y	6 m
Latitude and longitude of 1st soil plot*	40.782070, -111.803872
Latitude and longitude of 2nd soil plot*	40.782541, -111.803842
Latitude and longitude of 3rd soil plot*	40.782281, -111.803355
Latitude and longitude of 4th soil plot*	40.782738, -111.803323
Latitude and longitude of 5th soil plot*	40.782916, -111.802774
Direction of soil array	NA
Latitude and longitude of FIU soil pit 1	40.78170, -111.80366 (primary location)
Latitude and longitude of FIU soil pit 2	40.78264, -111.80326 (alternate 1)
Latitude and longitude of FIU soil pit 3	40.78133, -111.80410 (alternate 2)
Dominant soil type	Harkers-Wallsburg association, steep
Expected soil depth	0.30 m to >2 m
Depth to water table	>2 m

Expected depth of soil horizons	**Expected measurement depths†**
0-0.36 m (Loam)	0.18 m
0.36-0.48 m (Gravelly clay loam)	0.42 m
0.48-1.07 (Gravelly clay)	0.78 m
1.07-1.47 m (Very gravelly clay)	1.27 m
1.47-2 m (Very gravelly clay loam)	1.74 m

*Due to the unusual shape of the soil array at Red Butte approximate coordinates are given for each soil plot.
†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.

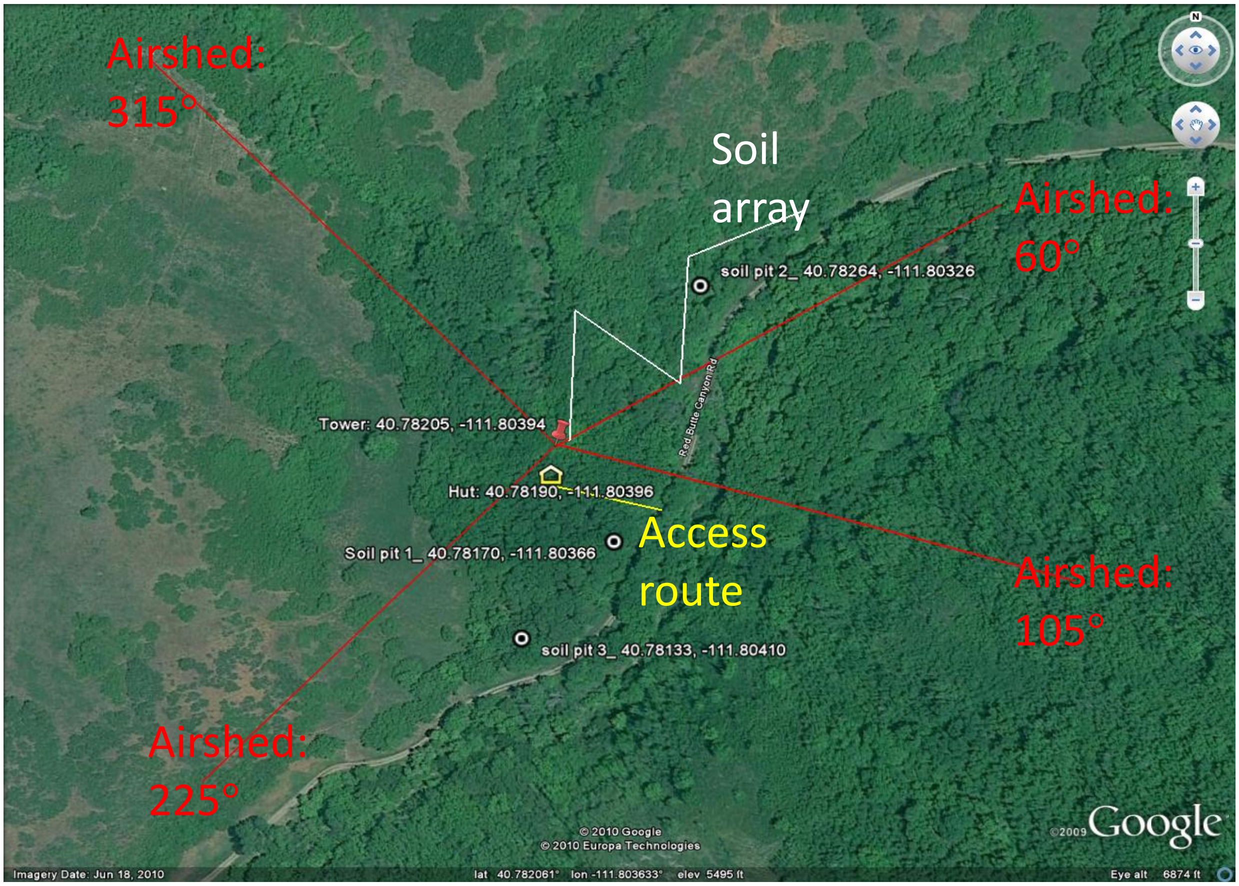


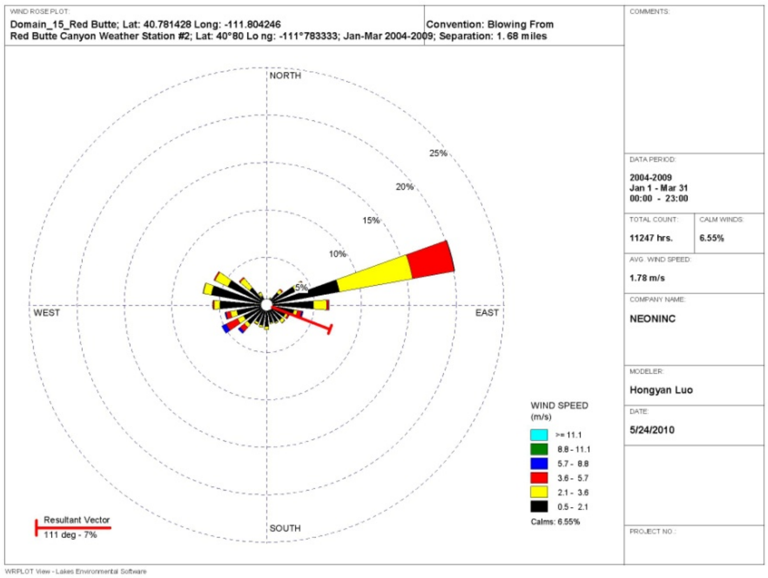
Figure 44. Site layout at Red Butte showing soil array and location of the FIU soil pit.

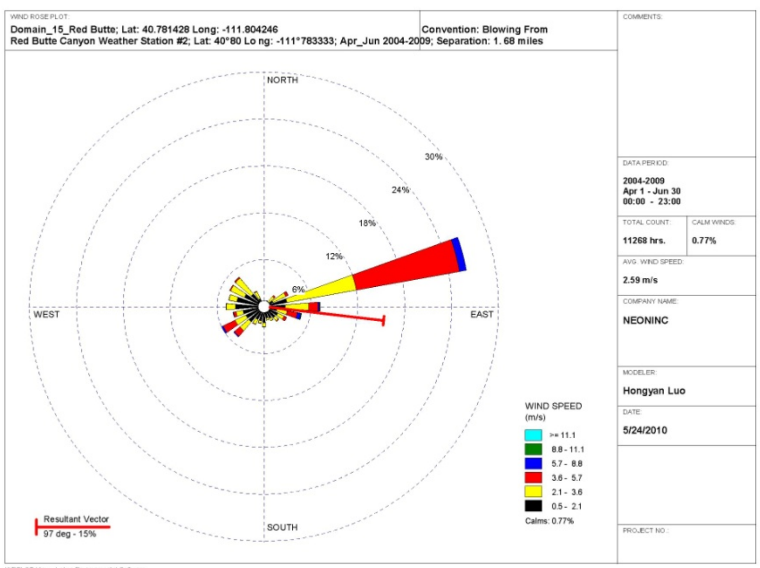
5.4 Airshed

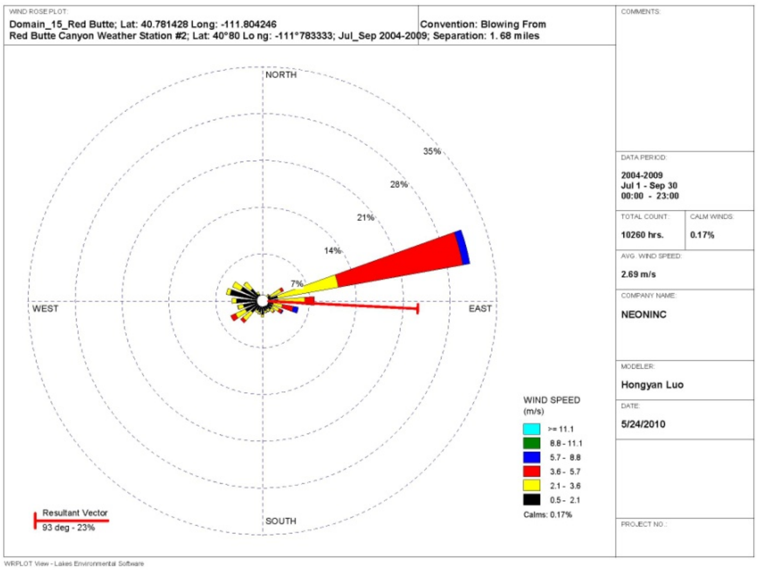
5.4.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries. Data used to generate windroses were 2004-2009 data set from Red Butte Canyon Weather station #2 (40° 48', -111° 47'), which is about 1.68 miles away on the northeast to NEON Red Butte Canyon candidate relocatable tower site (40.781428 ^{o}, -111.804246^{o}). Data file used for wind roses is RBWS_1_highres_090715.txt and was downloaded from http://ecophys.biology.utah.edu/public/Red_Butte_Canyon/Weather/. 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)







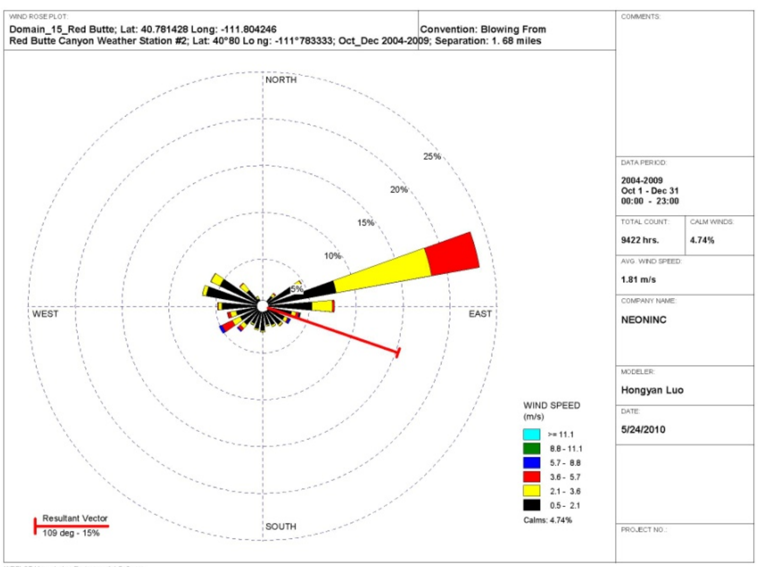


Figure 45. Windroses for Red Butte Canyon Relocatable tower site
Wind roses based on the data from Red Butte Canyon Weather station #2 (40° 48', -111° 47'). Panels (from top to bottom) are from Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

5.4.3 Resultant vectors

Table 18. The resultant wind vectors from Red Butte Canyon Weather station #2 using hourly data in 2004-2009.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	111°	7
April to June	97°	15
July to September	93°	23
October to December	109°	15
Annual mean	102.5°	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.

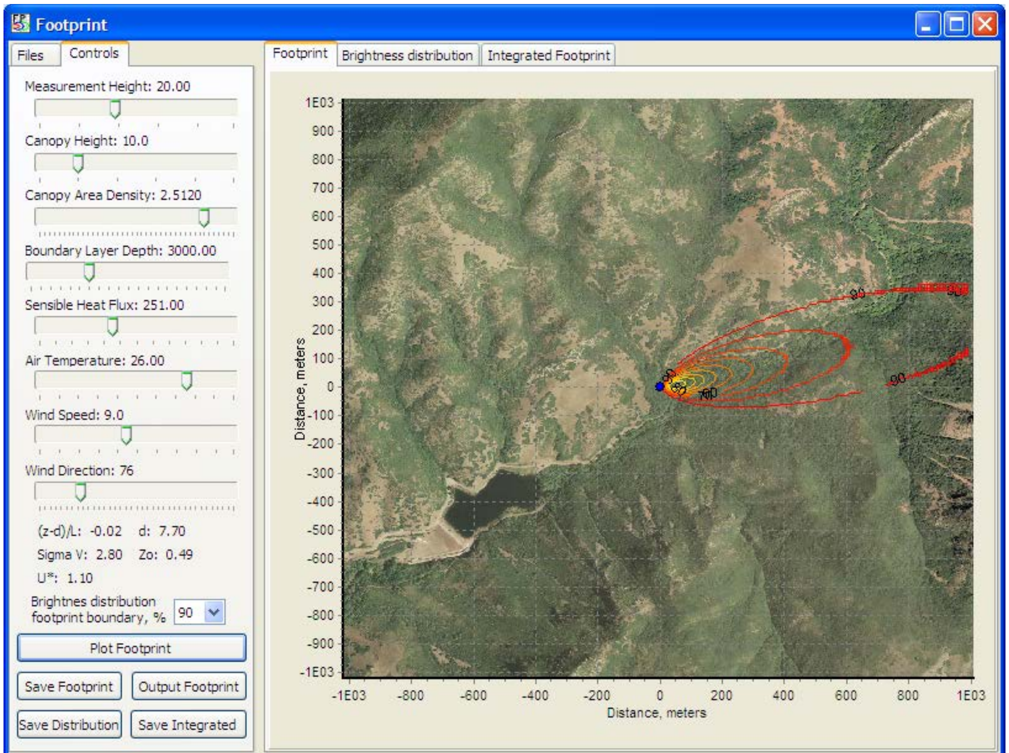
As a general rule, shorter and less structurally complex ecosystems have good vertical mixing during all atmospheric stabilities. Taller and more structurally complex ecosystems have well mixed upper canopies during the daytime, and can be decoupled below the canopy under neutral and stable conditions (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.

Table 19. Expected environmental controls to parameterize the source area model based on the wind roses for Red Butte Canyon Weather station #2 (40° 48', -111° 47'), and associated results from Red Butte Canyon Relocatable tower site.

Parameters	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	
Approximate season	summer			winter			Units
	Day (max WS)	Day (mean WS)	Night	Day (max WS)	Day (mean WS)	night	qualitative
Atmospheric stability	Convective	convective	Stable	Convective	convective	Stable	qualitative
Measurement height	20	20	20	20	20	20	m
Canopy Height	10	10	10	10	10	10	m
Canopy area density	2.512	2.512	2.512	1	1	1	m
Boundary layer depth	3000	3000	1500	1500	1500	750	m
Expected sensible heat flux	251	251	-9	50	50	-51	$W\ m^{-2}$
Air Temperature	26	26	24	8	8	6	°C
Max. windspeed	9	4	2	9.8	2	1.6	$m\ s^{-1}$
Resultant wind vector	76	76	255	76	76	255	degrees
Results							
(z-d)/L	-0.02	-0.18	0.14	0	-0.21	3	m
d	7.7	7.7	7.7	6.6	6.6	6.6	m
Sigma v	2.8	2	1.8	2.8	1	1.6	$m^2\ s^{-2}$
Z0	0.49	0.49	0.49	0.74	0.74	0.74	m
u*	1.1	0.58	0.21	1.4	0.34	0.04	$m\ s^{-1}$
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	800	500	950	950	400	3600	m
Distance of 80% cumulative flux	500	350	750	500	250	3200	m
Distance of 70% cumulative flux	400	250	500	300	200	2800	m
Peak contribution	75	55	85	65	45	1785	m

5.4.5 Results (source area graphs)



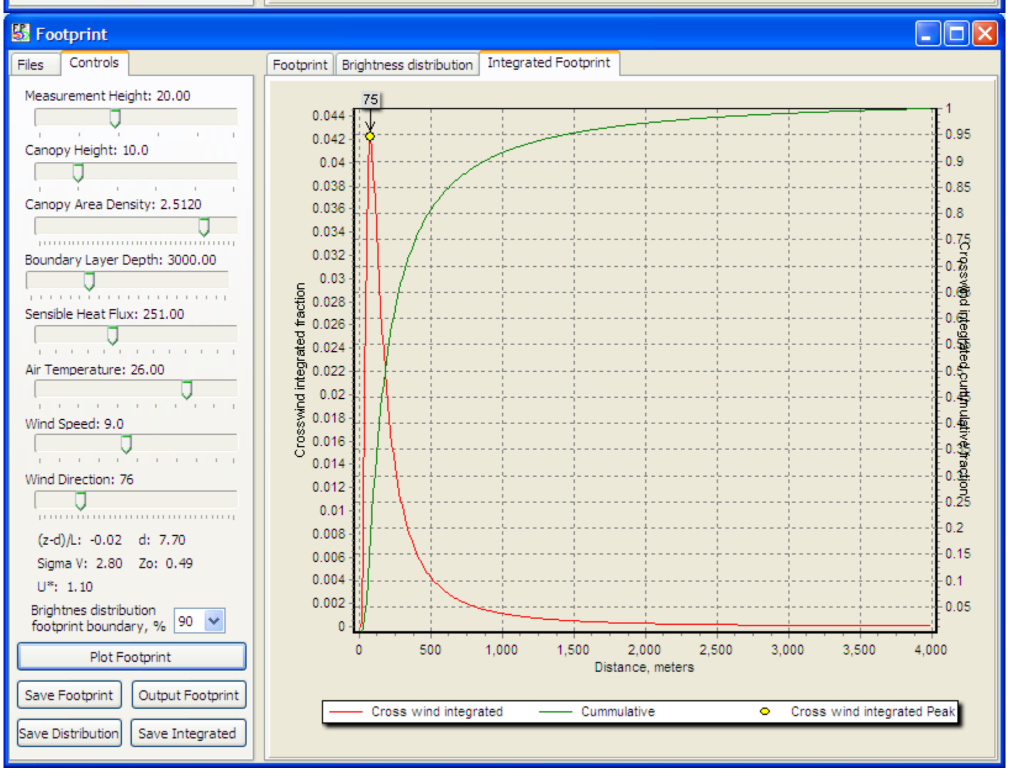
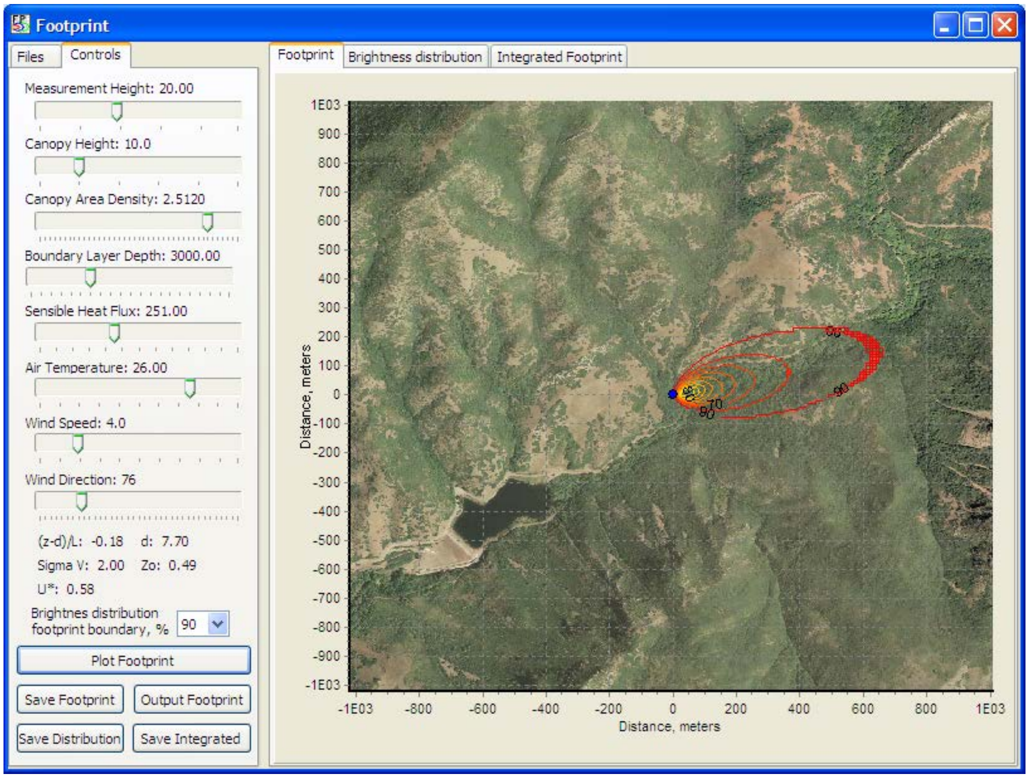


Figure 46. Red Butte Canyon Relocatable site summer daytime (convective) footprint output with max wind speed



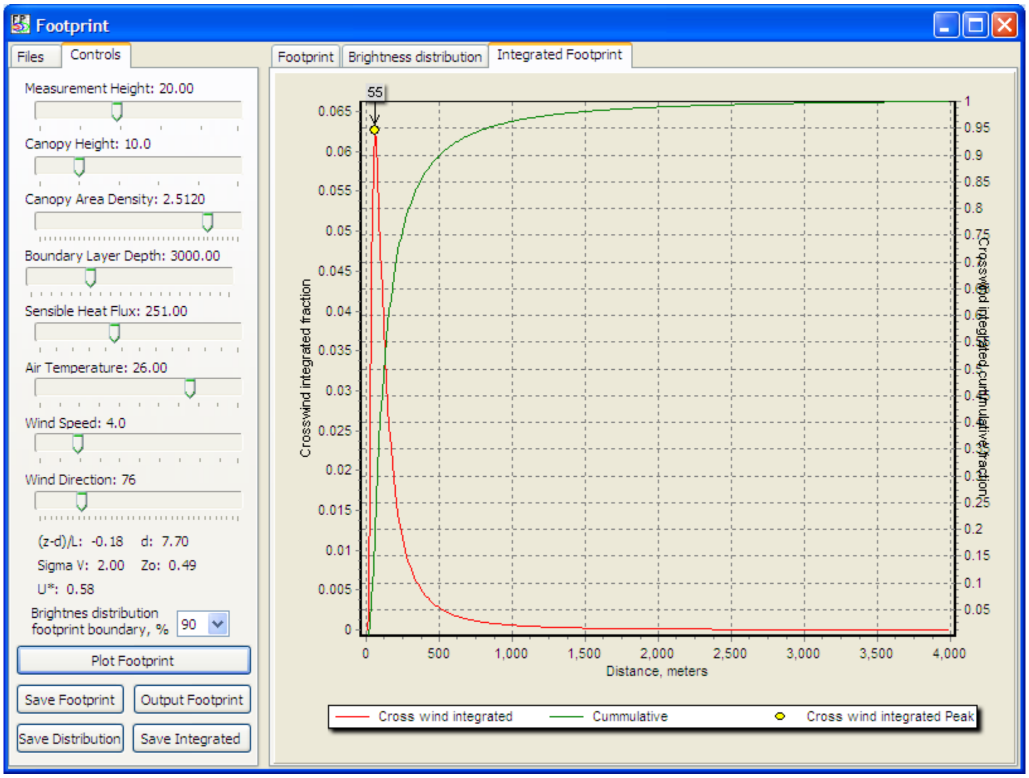
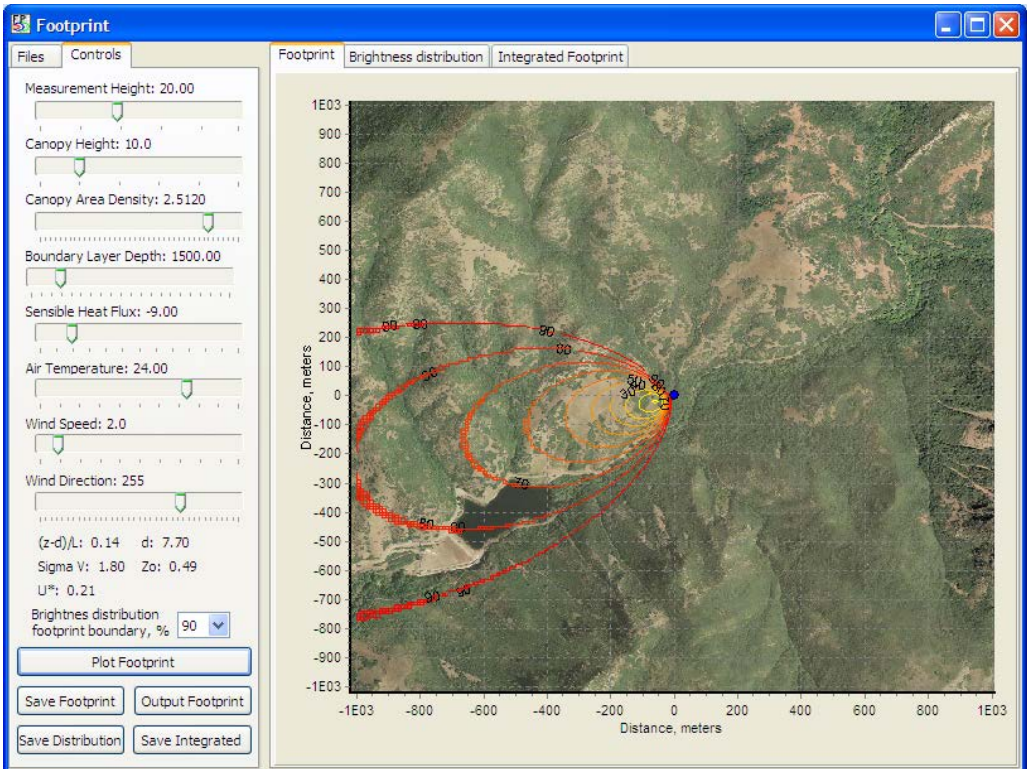
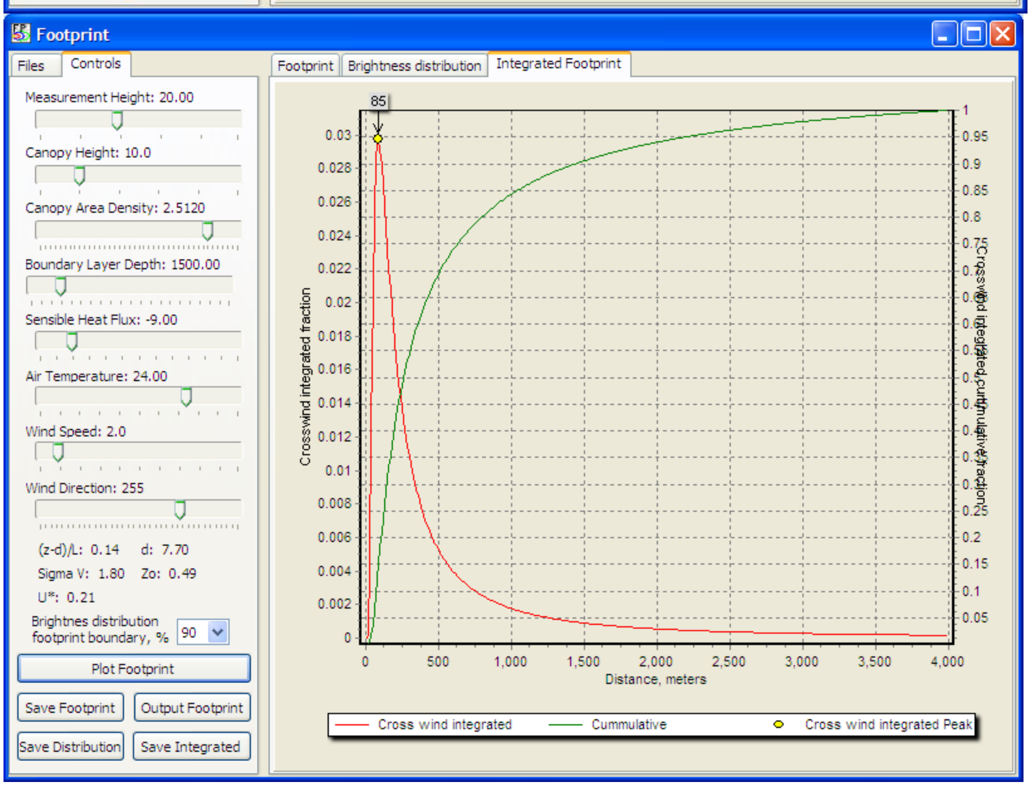


Figure 47. Red Butte Canyon Relocatable site summer daytime (convective) footprint output with mean wind speed

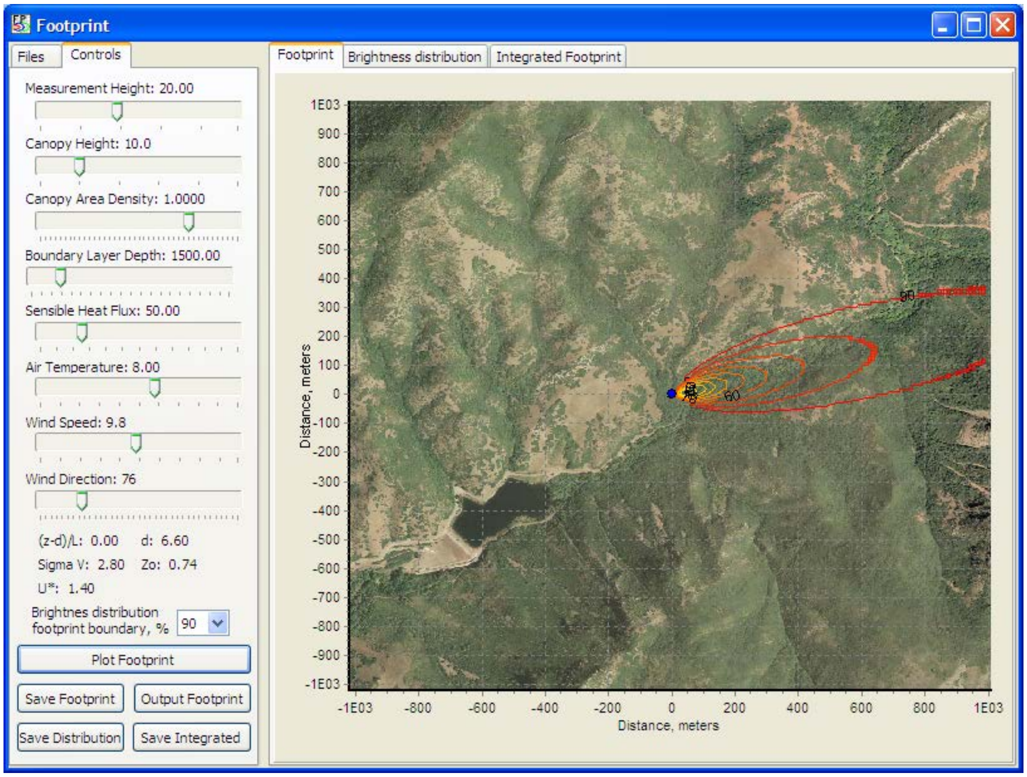


Footprint
Files
Controls
Measurement Height: 20.00
Canopy Height: 10.0
Canopy Area Density: 2.5120
Boundary Layer Depth: 1500.00
Sensible Heat Flux: -9.00
Air Temperature: 24.00
Wind Speed: 2.0
Wind Direction: 255
(z-d)/L: 0.14 d: 7.70
Sigma V: 1.80 Zo: 0.49
U*: 0.21
Brightnes distribution footprint boundary, % 90
Plot Footprint
Save Footprint
Output Footprint
Save Distribution
Save Integrated
Footprint
Brightness distribution
Integrated Footprint
Distance, meters
Distance, meters



Footprint
Files
Controls
Measurement Height: 20.00
Canopy Height: 10.0
Canopy Area Density: 2.5120
Boundary Layer Depth: 1500.00
Sensible Heat Flux: -9.00
Air Temperature: 24.00
Wind Speed: 2.0
Wind Direction: 255
(z-d)/L: 0.14 d: 7.70
Sigma V: 1.80 Zo: 0.49
U*: 0.21
Brightnes distribution footprint boundary, % 90
Plot Footprint
Save Footprint
Output Footprint
Save Distribution
Save Integrated
Footprint
Brightness distribution
Integrated Footprint
85
Crosswind integrated fraction
Crosswind integrated, cummulative fraction
Distance, meters
Cross wind integrated
Cummulative
Cross wind integrated Peak

Figure 48. Red Butte Canyon Relocatable site summer nighttime (stable) footprint output with mean wind speed.



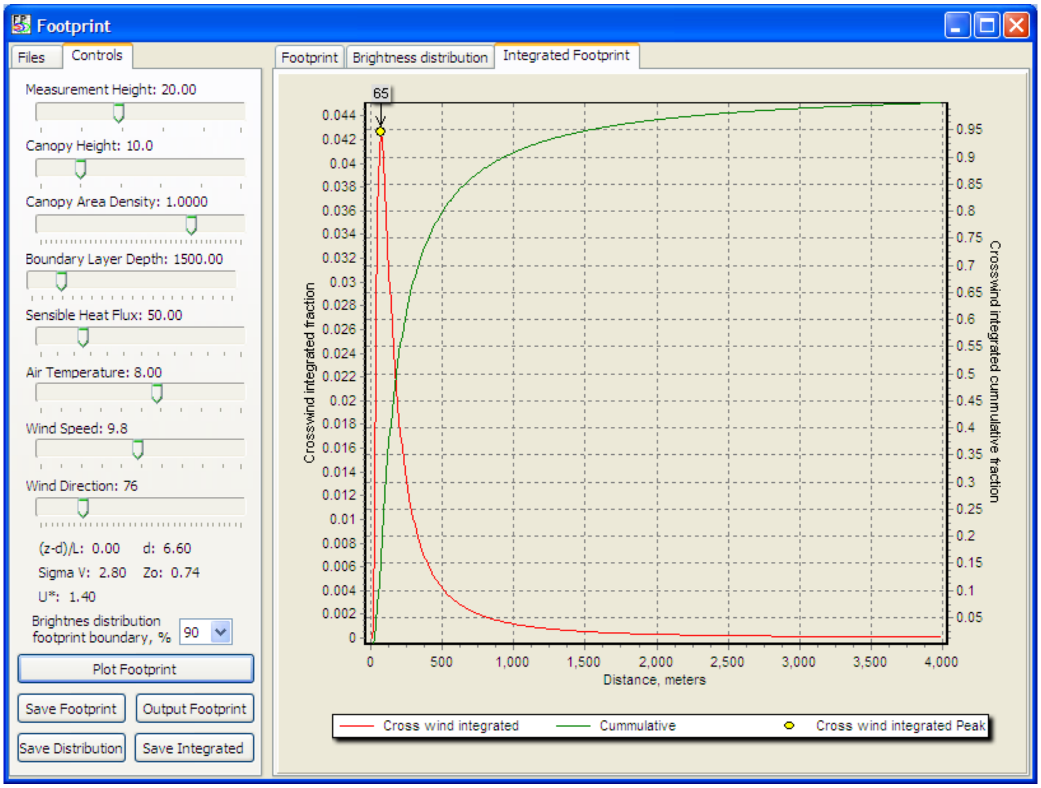
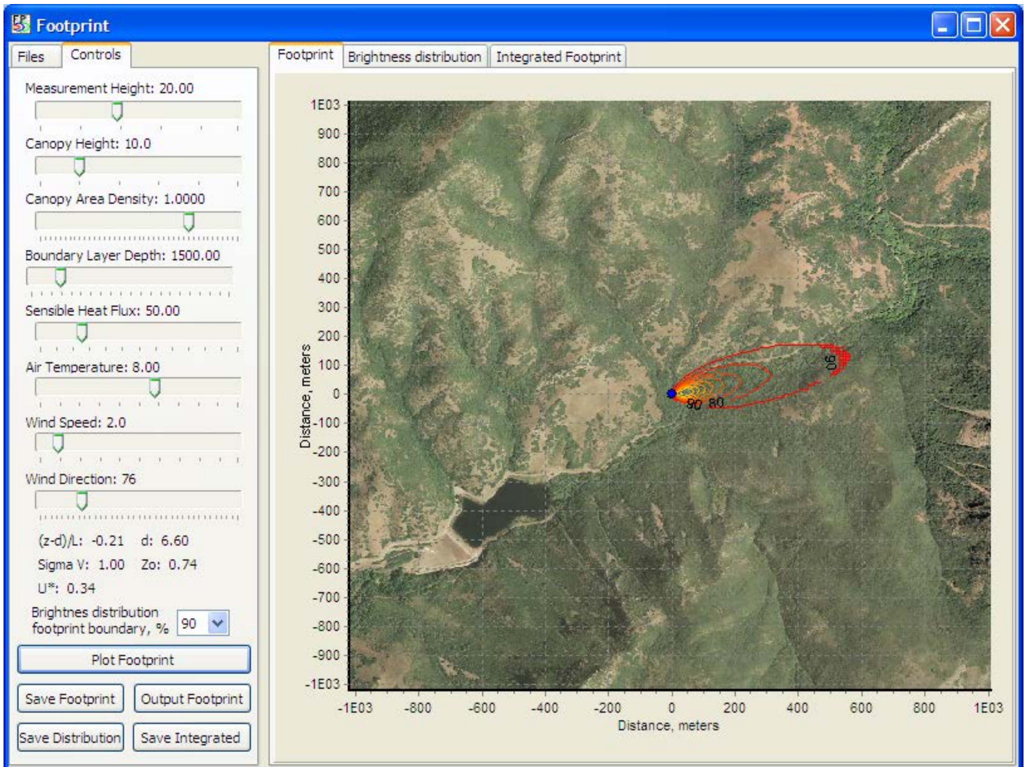
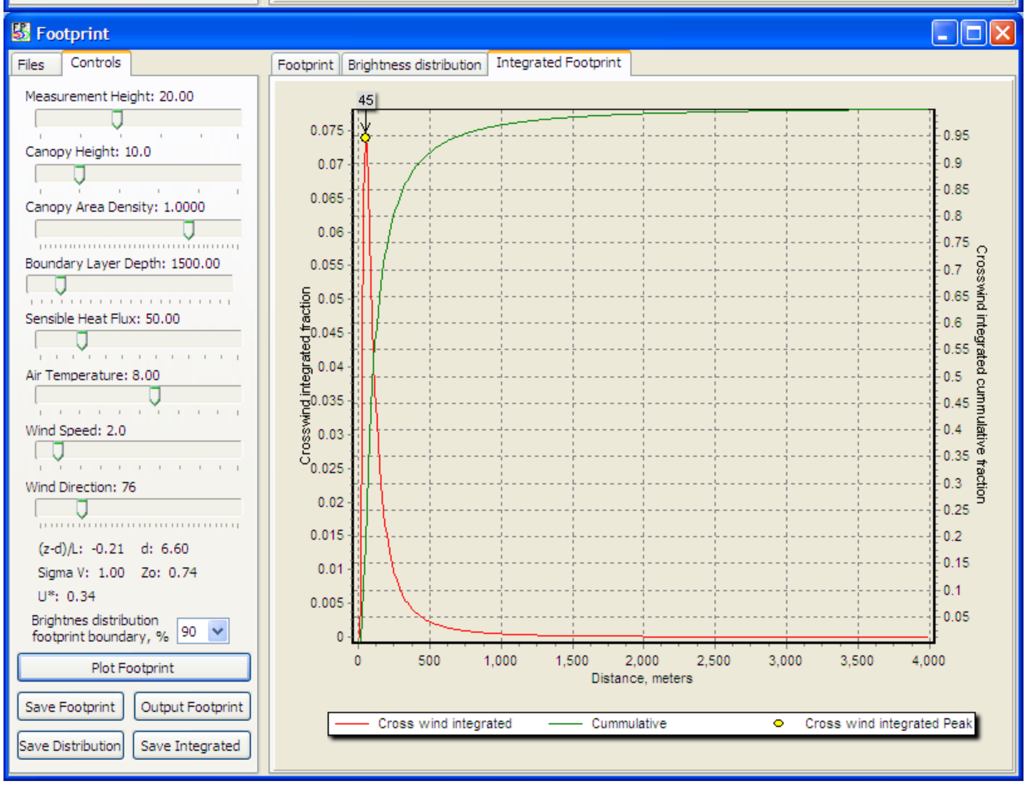


Figure 49. Red Butte Canyon Relocatable site winter daytime (convective) footprint output with max wind speed

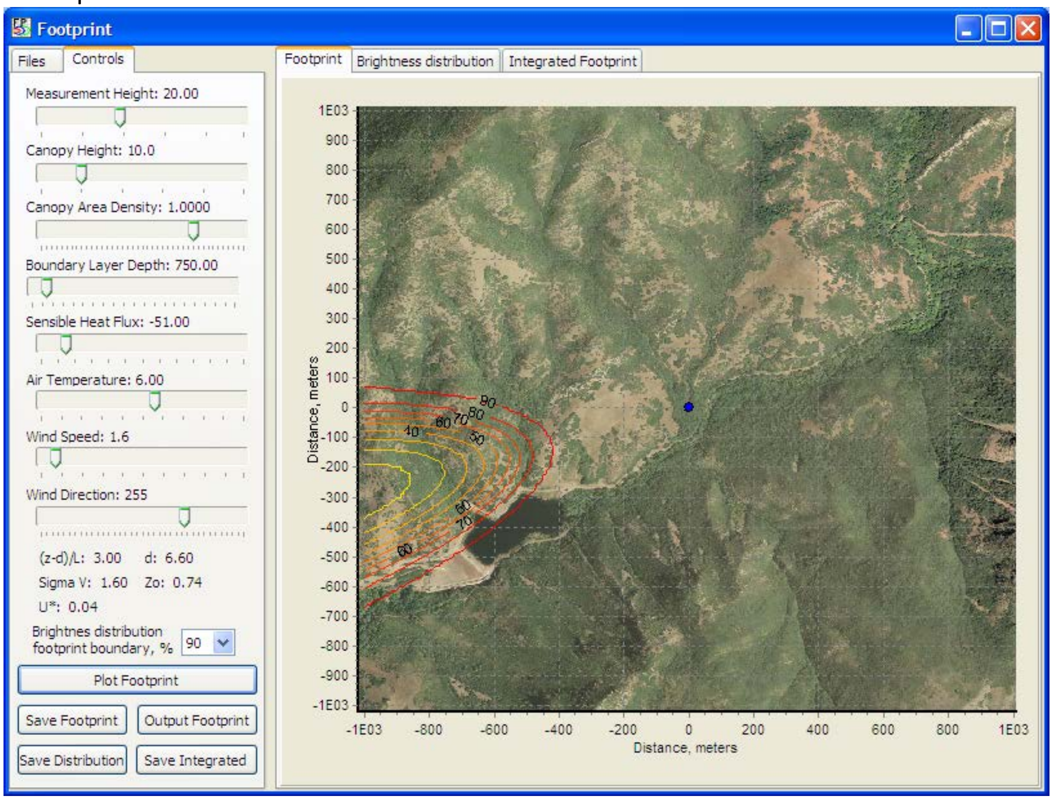


Footprint
Files
Controls
Measurement Height: 20.00
Canopy Height: 10.0
Canopy Area Density: 1.0000
Boundary Layer Depth: 1500.00
Sensible Heat Flux: 50.00
Air Temperature: 8.00
Wind Speed: 2.0
Wind Direction: 76
(z-d)/L: -0.21 d: 6.60
Sigma V: 1.00 Zo: 0.74
U*: 0.34
Brightnes distribution footprint boundary, % 90
Plot Footprint
Save Footprint
Output Footprint
Save Distribution
Save Integrated
Footprint
Brightness distribution
Integrated Footprint
Distance, meters
Distance, meters
90 80



Footprint
Files
Controls
Measurement Height: 20.00
Canopy Height: 10.0
Canopy Area Density: 1.0000
Boundary Layer Depth: 1500.00
Sensible Heat Flux: 50.00
Air Temperature: 8.00
Wind Speed: 2.0
Wind Direction: 76
(z-d)/L: -0.21 d: 6.60
Sigma V: 1.00 Zo: 0.74
U*: 0.34
Brightnes distribution footprint boundary, % 90
Plot Footprint
Save Footprint
Output Footprint
Save Distribution
Save Integrated
Footprint
Brightness distribution
Integrated Footprint
45
Crosswind integrated fraction
Crosswind integrated cummulative fraction
Distance, meters
Cross wind integrated
Cummulative
Cross wind integrated Peak

Figure 50. Red Butte Canyon Relocatable site winter daytime (convective) footprint output with mean wind speed.



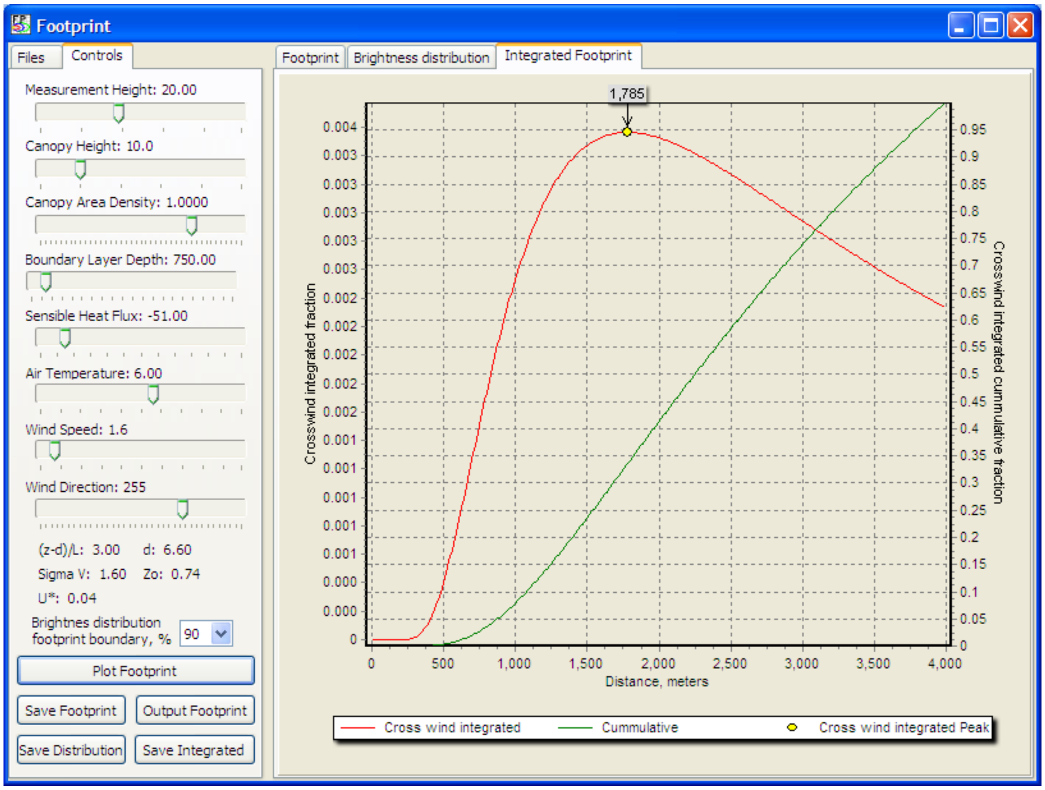


Figure 51. Red Butte Canyon Relocatable site winter nighttime (stable) footprint output with mean wind speed.

5.4.6 Site design and tower attributes

According to wind roses, the wind direction blows from E and ENE along the canyon throughout the whole year. The prevailing wind airshed for the tower is from 60° to 105° (clockwise from 60°), with highest frequency wind blowing from 75°. Secondary airshed is from 225° to 315° (clock wise from 225°). The tower should be placed to a location to best catch the signals from the airshed of the ecosystem in interest, which is deciduous oak forest. Tower location is inside a small piece of forest. After FIU site characterization, we microsted tower location ~70 m toward NNE to the location of 40.78205, -111.80394 to avoid edge effects on all directions on the climate measurements.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the north 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 southwest toward tower and have the longer side parallel to ENE-WSW direction. Because this is a closed canopy ecosystem, the distance between the tower and the instrument hut can be reduced to ~ 15 m. Therefore, we require the placement of instrument hut at 40.78190, -111.80396.

Canopy height is ~10 m around tower site with lowest branches at 2 m. Shrub and recruit seedling and saplings forms understory with height ~3 m. Grass and many other annuals form understory at ground level with canopy height ~ 0.4 m. We require 5 **measurement layers** on the tower with top measurement height at 18 m, and rest layers are 18 m, 12 m, 7 m, 2 m and 0.25 m, respectively, to best characterize the fluxes on the tower top and environmental conditions in profile.

Secondary **precipitation collector** for bulk precipitation collection will be located the top of tower at this site. No w**et deposition collector** will deployed at this site. See AD 04 for further information and requirements for bulk precipitation collection and wet deposition collection.

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

Table 20. Site design and tower attributes for Red Butte Canyon Relocatable site

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

Attribute	lat	long	degree	meters	notes
Airshed			60° to 105° (major) 225°to 315° (secondary)		Clockwise from first angle
Tower location	40.78205,	-111.80394	--	--	new site
Instrument hut	40.78190,	-111.80396			
Instrument hut orientation vector	--	--	75°-255°		ENE-WSW
Instrument hut distance z	--	--	--	15	
Anemometer/Temperature boom orientation	--	--	360°	--	
Height of the measurement levels					
Level 1				0.25	m.a.g.l.
Level 2				2.0	m.a.g.l.
Level 3				7.0	m.a.g.l.

Level 4	12.0	m.a.g.l.
Level 5	18.0	m.a.g.l.
Tower Height	18.0	m.a.g.l.

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

Figure 59 below shows the proposed tower location, instrument hut location, airshed area and access road.

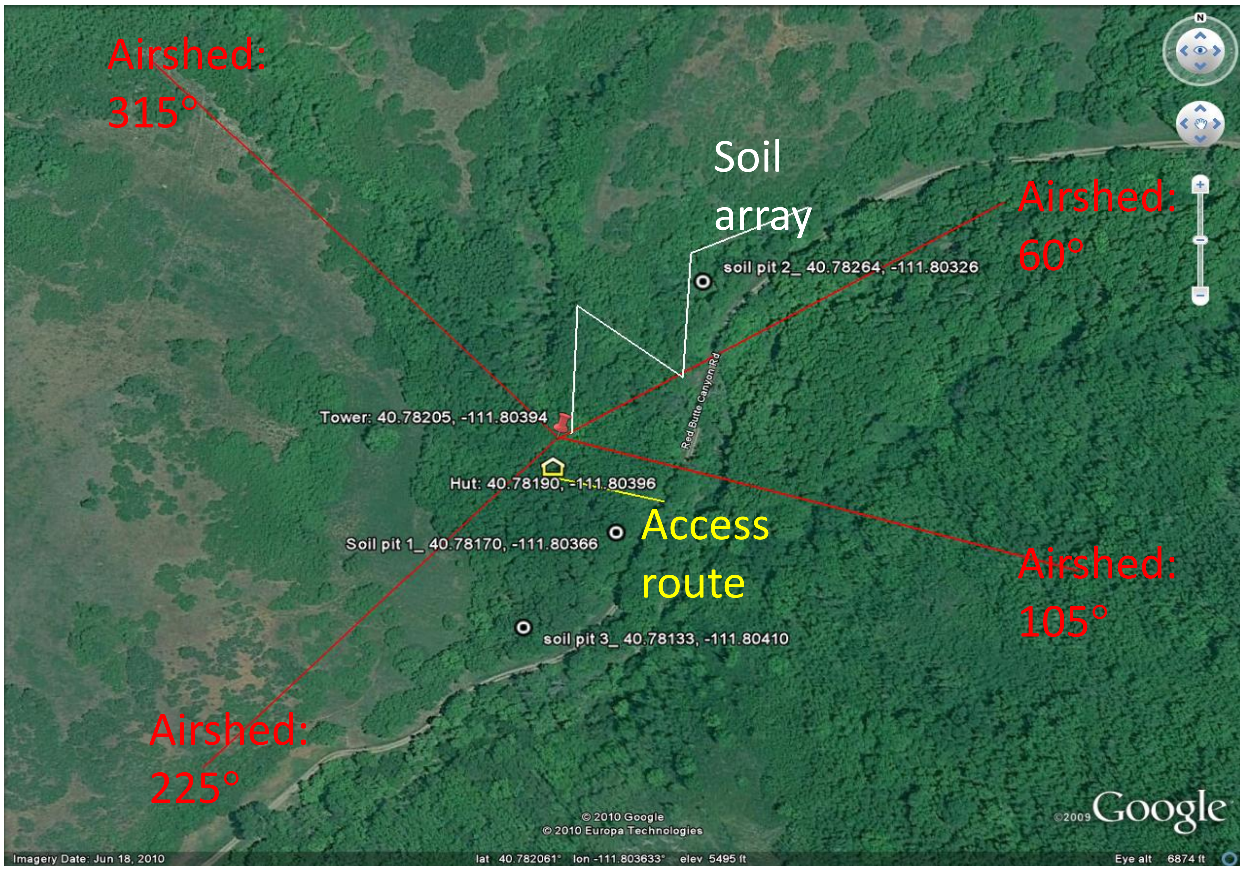


Figure 52. Site layout for Red Butte Canyon Relocatable site.

i) new tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 60^{o} to 105^{o} (major airshed, clockwise from 60^{o}) and 225^{o} to 315^{o} (secondary airshed, clockwise from 225^{o}) 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 Red Butte Canyon Relocatable site

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

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

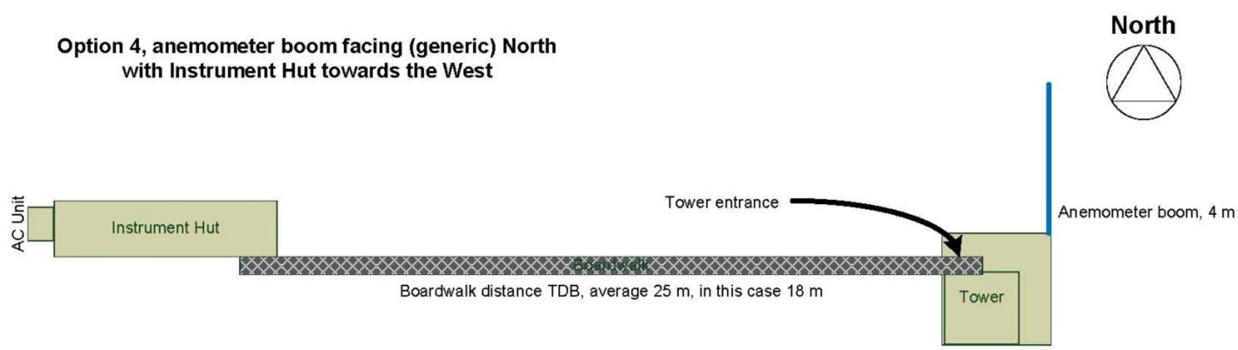


Figure 53. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing north and instrument hut on the west towards the tower.
This is just a generic diagram when boom facing north and instrument hut on the general east (includes southwest) towards the tower. The actual design of boardwalk (or path if no boardwalk required) and instrument hut position will be the responsibility of FCC and LAD following FIU's guidelines. At Red Butte Canyon Relocatable site, the boom angle will be 360 degrees, instrument hut will be on the southwest towards the tower, the distance between instrument hut and tower is ~15 m. The instrument hut vector will be ENE-WSW (75^o-255^o).

5.4.7 Information for ecosystem productivity plots

The tower has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (deciduous oak forest). Airshed at this site is from 60^o to 105^o (clockwise from 60^o), with highest frequency wind from 75^o throughout the whole year. Secondary airshed is from 225^o to 315^o (clockwise from 225^o). 90% signals for flux measurements are within a distance of 950 m from tower, and 80% within 750 m. Therefore, we suggest FSU Ecosystem Productivity plots are placed within the major tower airshed boundaries of 60° to 105° (clockwise from 60°).

5.5 Issues and attentions

The ecosystems are very patchy sourround this site with small pieces of forest stands, meadows, and shrublands. The forest for tower location is a small patch on the northwest side of Red Butte Canyon Road, and difficult to fit in soil array. Flux fetch area is beyond this small patch of forest stand and extends into the forest on the southeast side of Red Butte Canyon Road, which is similar forest type. The tower has been position to best characterize the flux signals over this forest on both sides of road. Red Butte Canyon Road is a small dirt road. We assume its effects on flux measurements are not important. Tower site is at a bottom of valley with large steep slopes on both sides of Red Butte Canyon Road, and in the middle of a large canyon that run NE to SW. Cold air drainage and horizontal advections induced by complex terrain are concerns at this site for flux measruements. It is not adequate to estimate absolute amount of gas exchange and turbulent flux using single point measurements, such as eddy covariance technique, but it is still valid and useful to interpret the long term trend, seasonal variation and inter-annual variation of ecological processes.

6 REFERENCES:

Bond-Lamberty B., Brown K.M., Goranson C. & Gower S.T. (2006). Spatial dynamics of soil moisture and temperature in a black spruce boreal chronosequence. *Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere*, 36, 2794-2802

Ehleringer et al (1992). Red Butte Canyon Research Natural Area: History, Flora, Geology, Climate, and Ecology. Great Basin Naturalist, 2,95-121.

Goovaerts P. (1997). *Geostatistics for Natural Resource Evaluation*. Oxford University Press, Oxford.

Horst, TW, Weil, JC, 1992. Footprint estimation for scalar flux measurements in the atmospheric surface layer. *Boundary Layer Meteorology* **59**, 279-296.

Horst, TW, Weil, JC, 1994a. How far is far enough?: The fetch requirements for micrometeorological measurement of surface fluxes. *J. Atmospheric Oceanic Technology*, **11**, 1019-1025.

Horst, TW, Weil, JC, 1994b. Corrigenda: How far is far enough?: The fetch requirements for micrometeorological measurement of surface fluxes. *J. Atmospheric Oceanic Technology*, **12**, 447.

Horst, TW, 2001. Comments on: Footprint analysis: a closed analytical solution based on height-dependent profiles of wind speed and eddy viscosity. *Boundary Layer Meteorology* **101**, 435-447.

Kormann R, Meixner, FX, 2001. An analytic footprint model for neutral stratification, *Bound.-Layer Meteorol.* **99.**

Riberiro J.R. & Diggle P.J. (2001). geoR: A package for geostastical analysis. R-NEWS, 1, ISSN 1609-3631

Trangmar B.B., Yost R.S. & Uehara G. (1986). Application of geostatistics to spatial studies of soil properties. *Advances in Agronomy*, 45-94

Webster R. & Oliver M.A. (1989). Optimal interpolation and isarthmic mapping of soil properties: VI Disjuctive kriging and mapping the conditional probability. *Journal of Soil Science*, 40, 497-512