D13 FIU Site Characterization
Supporting Data

PREPARED BY	ORGANIZATION	DATE
E. Ayres/H. Luo/M.Gebremedhin/H. Loescher/ N. Durden	FIU	11/08/2014

APPROVALS (Name)	ORGANIZATION	APPROVAL DATE
Hanne Buur	PSE	01/16/2015
David Tazik	SCI	12/12/2014

RELEASED BY (Name)	ORGANIZATION	RELEASE DATE
Judy Salazar	CM	01/20/2015

See Configuration Management System for approval history.

Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	1/28/2011	ECO-00066	INITIAL RELEASE
B	09/26/2011	ECO-00279	Update to new document number's/template throughout document.
C	10/29/2012	ECO-00681	Change the Fraser relocatable site to Winter Park relocatable site; include exclusion zone for each site.
D	01/20/2015	ECO-02469	Change the Winter Park relocatable site to a new Fraser relocatable site.

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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 13. This document presents all the supporting data for FIU site characterization at D13.

1.2 Scope

FIU site characterization data and analysis results presented in this document are for the three D12 tower locations: Niwot Ridge site (Advanced), Moab site (Relocatable 1), and Winter Park site (Relocatable 2). Issues and concerns for each site that need further review are also addressed in this document according to our best knowledge.

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

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

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

2.2 Reference Documents

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

2.3 Verb Convention

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

3 NIWOT RIDGE (ADVANCED TOWER SITE)

3.1 Site description

The Niwot Ridge site is located ~27 km west of Boulder, CO, and ~6 km east of the Continental Divide at an elevation of ~3500 m. The site is home to the Niwot Ridge Long Term Ecological Research (LTER) project (http://culter.colorado.edu/NWT/index.html). The original tower location was 40.05420658, -105.5821737; however, the tower was microsited during the site characterization and subsequent meetings with Niwot LTER personnel to best meet the NEON science requirements (new location: 40.05425, -105.58237; ~17 m west of the original location). The site is accessible to the public. The site is heavily used by researchers and many research plots are located near the NEON tower site.

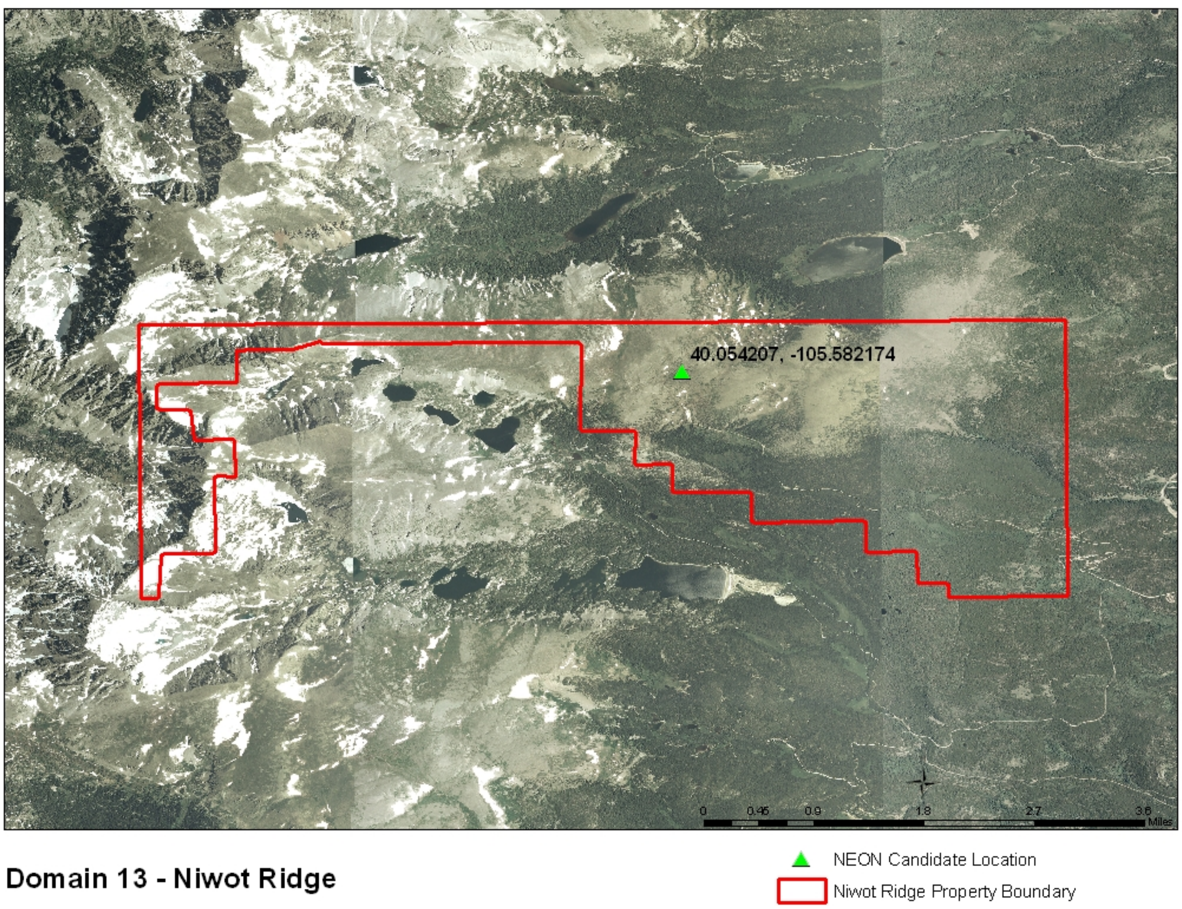
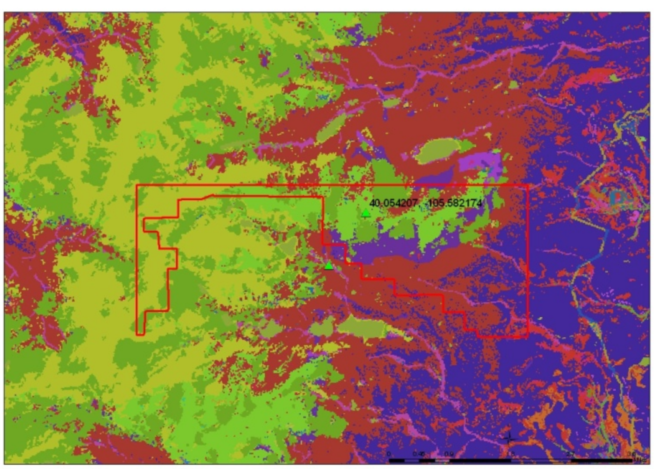


Figure 1. NEON candidate site tower location and boundary map. Coordinates represent the initial (old) tower site prior to micrositing.

3.2 Ecosystem

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



Domain 13 - Niwot Ridge

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

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

Vegetation Type	**Area**	**Percentage**
Open Water	0.002	0.013
Snow-Ice	2.600	15.609
Barren	2.144	12.870
Rocky Mountain Aspen Forest and Woodland	0.022	0.133
Rocky Mountain Lodgepole Pine Forest	2.317	13.905
Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	0.001	0.005
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4.585	27.525
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	1.718	10.313
Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland	0.014	0.085
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	0.286	1.715
Rocky Mountain Alpine Dwarf-Shrubland	0.197	1.180
Rocky Mountain Lower Montane-Foothill Shrubland	0.076	0.454
Rocky Mountain Alpine Fell-Field	0.001	0.004
Rocky Mountain Alpine Turf	2.496	14.983
Rocky Mountain Subalpine-Montane Mesic Meadow	0.019	0.114
Southern Rocky Mountain Montane-Subalpine Grassland	0.001	0.005
Rocky Mountain Subalpine/Upper Montane Riparian Systems	0.148	0.890
Artemisia tridentata ssp. vaseyana Shrubland Alliance	0.033	0.195
Total Area Sq Km	16.659	100.000

The terrain at the Niwot Ridge site is extremely complex mountainous terrain, which will complicate interpretation of tower flux data. However, existing PI driven eddy covariance research is being made at both the AmeriFlux site and at a nearby ridge line, and substantial gains in understanding complex flows have been made. This site meets the other tower requirements for incident climate and chemical climate, micrometeorology, and soil scale measurements. The tundra in the vicinity of the tower consists of a mixture of dry and wet tundra. Tree islands (primarily Engelmann spruce and subalpine fir) are common at the tower site.

According to http://culter.colorado.edu/NWT/site_info/climate/climate.html; "Niwot Ridge is characterized by low temperatures throughout the year, increased solar radiation (and consequently higher levels of ultraviolet radiation), higher wind velocities, and an abbreviated growing season. Annual mean temperature at 3743 m is -3.7 degrees Celsius. The January mean temperature is -13.2 °C and the July mean is 8.2 °C. Mean annual precipitation is about 930 mm…" High wind speeds occur at this site.

According to http://culter.colorado.edu/NWT/site_info/site_info.html: "Vegetation at the experimental sites on Niwot Ridge is classified as dry, moist and wet meadow communities and the dominant plant species are the gramminoid *Kobresia myosuroides*, the forb *Acomostylis rossii*, and the gramminoid *Deschamsia caespitosa* in protected microsites. Soils are Cryochrepts and are approximately 2.0 m in depth over granitic parent material."

Additional site and ecosystem information can be found at http://culter.colorado.edu/NWT/index.html

Based on our field observation, the vegetation around and within the tower airshed consists of a mixture of dry and wet tundra. Mean canopy height ranges 0.2 to 0.7 m with taller grasses, annuals and short perennials in the wetter spots. Tree islands are dotted on tundra with size commonly < 20 m × 20 m. There are two common types of tree islands here: spruce tree islands with height 3-4 m and dwarf-shrub islands (species is unclear) with height 0.3-1 m.

Figure 3. The Ecosystem at Niwot Ridge site is an Alpine tundra ecosystem.

Table 2. Ecosystem and site attributes for Niwot Ridge Advanced tower site.

Ecosystem attributes	Measure and units
Mean canopy height	0.6 m
Surface roughness[a]	0.1 m
Zero place displacement height[a]	0.3 m
Structural elements	Alpine tundra ecosystem, consists of a mixture of dry and wet tundra
Time zone	Mountain time zone
Magnetic declination	9° 22' E changing by 0° 7' W/year

Note, [a] From field observation.

3.3 Soils

3.3.1 Soil description

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

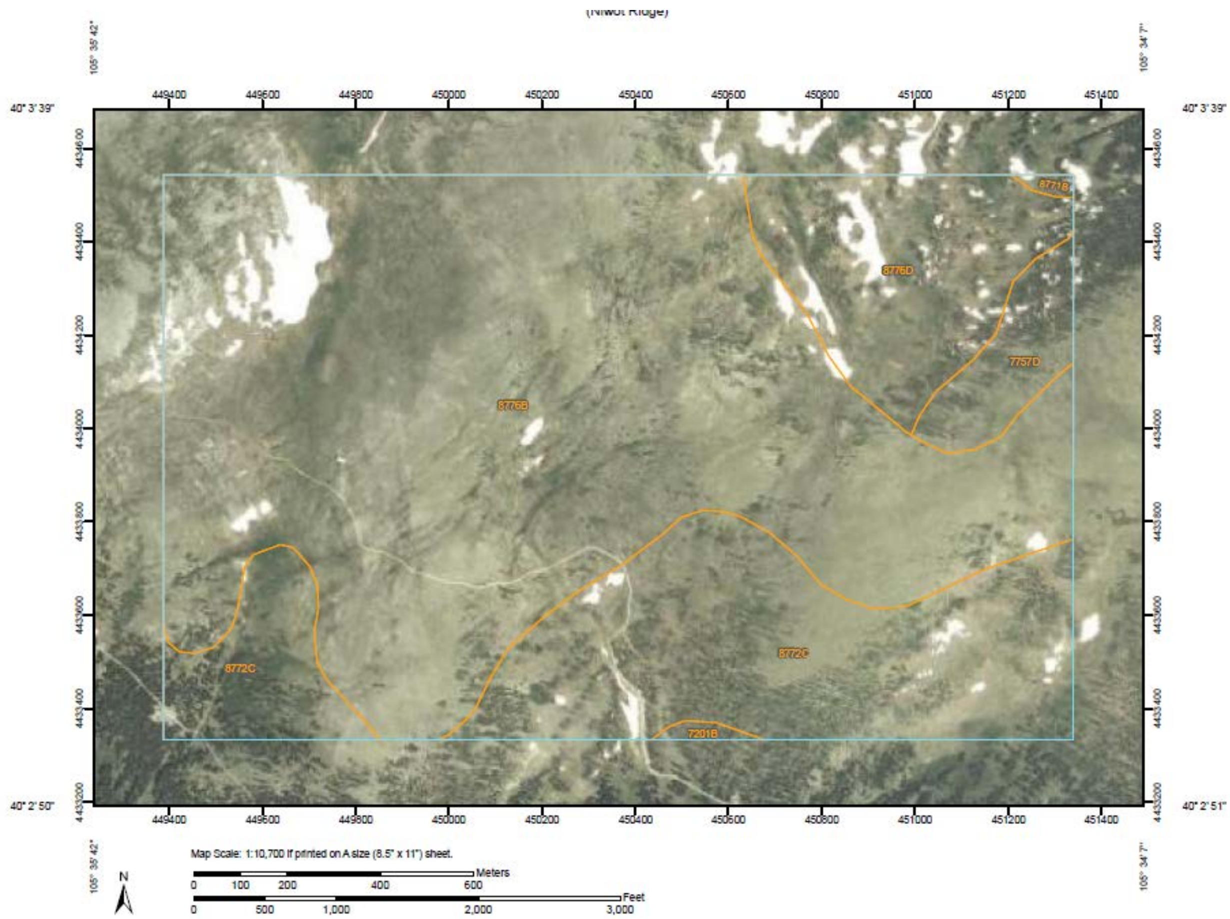


Figure 4. Soil map of the Niwot Ridge Relocatable site and surrounding areas.

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

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

Table 3. Soil series and percentage of soil series within 2.4 km^2 at the Niwot Ridge site

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties (CO645)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
7201B	Leighcan family, till substratum, 5 to 40 percent slopes	1.5	0.3%
7757D	Leighcan-Catamount families, moist-Rock outcrop complex, 40 to 150 percent slopes	18.2	3.1%
8771B	Leighcan family-Cryaquolls-Moran family complex, 5 to 40 percent slopes	1.1	0.2%
8772C	Moran family-Lithic Cryorthents-Leighcan family complex, 40 to 75 percent slopes	138.1	23.6%
8776B	Moran family-Lithic Cryorthents-Rubble land complex, 5 to 40 percent slopes	366.8	62.8%
8776D	Moran family-Lithic Cryorthents-Rubble land complex, 40 to 150 percent slopes	58.5	10.0%
Totals for Area of Interest		**584.4**	**100.0%**

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7201B—Leighcan family, till substratum, 5 to 40 percent slopes Map Unit Setting Elevation: 9,000 to 10,500 feet Mean annual precipitation: 20 to 40 inches Mean annual air temperature: 36 to 39 degrees F Frost-free period: 30 to 50 days **Map Unit Composition** Leighcan family, till substratum, extremely bouldery, and similar soils: 85 percent **Description of Leighcan Family, Till Substratum, Extremely Bouldery Setting** Landform: Mountain slopes, moraines Parent material: Residuum and/or till derived from igneous and metamorphic rock Properties and qualities Slope: 5 to 40 percent Depth to restrictive feature: More than 80 inches Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Very low (about 2.7 inches) **Interpretive groups** Other vegetative classification: Subalpine fir - Engelmann spruce/ myrtle whortleberry (ABLA-PIEN/VAMY2) (C0320), Subalpine fir - Engelmann spruce/grouse whortleberry (ABLA-PIEN/VASC) (C0321) **Typical profile** 0 to 2 inches: Cobbly silt loam 2 to 9 inches: Very cobbly silt loam 9 to 28 inches: Very cobbly sandy loam 28 to 45 inches: Extremely stony loamy sand 45 to 60 inches: Extremely stony loamy sand

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 8771B—Leighcan family-Cryaquolls-Moran family complex, 5 to 40 percent slopes Map Unit Setting Elevation: 10,500 to 11,500 feet Mean annual precipitation: 30 to 50 inches Mean annual air temperature: 34 to 37 degrees F Frost-free period: 10 to 30 days **Map Unit Composition** Leighcan family and similar soils: 35 percent Cryaquolls and similar soils: 25 percent Moran family and similar soils: 20 percent **Description of Leighcan Family Setting** Landform: Mountain slopes, moraines Parent material: Residuum and/or slope alluvium derived from igneous and metamorphic rock **Properties and qualities** Slope: 5 to 40 percent Depth to restrictive feature: More than 80 inches Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Very low (about 2.7 inches) **Interpretive groups** Other vegetative classification: Engelmann spruce/alpine clover (PIEN/TRDA2) (C0413) **Typical profile** 0 to 2 inches: Cobbly silt loam 2 to 9 inches: Very cobbly silt loam 9 to 28 inches: Very cobbly sandy loam

28 to 45 inches: Extremely stony loamy sand 45 to 60 inches: Extremely stony loamy sand **Description of Cryaquolls Setting** Landform: Flood plains, fens Parent material: Gravelly alluvium and/or glaciofluvial deposits derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 5 to 40 percent Depth to restrictive feature: More than 80 inches Drainage class: Poorly drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: Occasional Frequency of ponding: None Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: High (about 11.1 inches) **Interpretive groups** Other vegetative classification: Parry's clover/tufted hairgrass (TRPA5/DECA18) (F0608), Timber oatgrass/varileaf cinquefoil (DAIN/PODI2) (G1301) **Typical profile** 0 to 4 inches: Moderately decomposed plant material 4 to 16 inches: Silt loam 16 to 24 inches: Silt loam 24 to 30 inches: Silt loam 30 to 40 inches: Sandy loam 40 to 64 inches: Silt loam **Description of Moran Family Setting** Landform: Moraines, mountain slopes Parent material: Glaciofluvial deposits and/or residuum derived from igneous and metamorphic rock **Properties and qualities** Slope: 5 to 40 percent Depth to restrictive feature: 40 to 59 inches to paralithic bedrock Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Low (about 3.1 inches) **Interpretive groups** Other vegetative classification: Diamondlead willow/water sedge (SAPL2/CAAQ) (S1496) **Typical profile** 0 to 8 inches: Very stony fine sandy loam 8 to 13 inches: Very stony fine sandy loam 13 to 27 inches: Very cobbly sandy loam 27 to 42 inches: Very stony sandy loam 42 to 60 inches: Weathered bedrock

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7757D—Leighcan-Catamount families, moist-Rock outcrop complex, 40 to 150 percent slopes Map Unit Setting Elevation: 9,500 to 11,000 feet Mean annual precipitation: 20 to 40 inches Mean annual air temperature: 36 to 39 degrees F Frost-free period: 30 to 50 days **Map Unit Composition** Leighcan family, moist, and similar soils: 50 percent Catamount family, moist, and similar soils: 25 percent Rock outcrop: 15 percent **Description of Leighcan Family, Moist Setting** Landform: Mountain slopes Parent material: Residuum and/or slope alluvium derived from igneous and metamorphic rock **Properties and qualities** Slope: 40 to 75 percent Depth to restrictive feature: More than 80 inches Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Very low (about 2.7 inches) **Interpretive groups** Other vegetative classification: Subalpine fir - Engelmann spruce/ moss (ABLA-PIEN/MOSS) (C0311), Subalpine fir - Engelmann spruce/grouse whortleberry (ABLA-PIEN/VASC) (C0321) **Typical profile** 0 to 2 inches: Cobbly silt loam 2 to 9 inches: Very cobbly silt loam 9 to 28 inches: Very cobbly sandy loam 28 to 45 inches: Extremely stony loamy sand 45 to 60 inches: Extremely stony loamy sand **Description of Catamount Family, Moist Setting** Landform: Mountain slopes Parent material: Residuum weathered from igneous and metamorphic rock **Properties and qualities** Slope: 40 to 75 percent Depth to restrictive feature: 10 to 20 inches to paralithic bedrock; 20 to 40 inches to lithic bedrock Drainage class: Excessively drained Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.01 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Very low (about 0.9 inches) **Interpretive groups** Other vegetative classification: Subalpine fir - Engelmann spruce/ myrtle whortleberry (ABLA-PIEN/VAMY2) (C0320), Subalpine fir - Engelmann spruce/grouse whortleberry (ABLA-PIEN/VASC) (C0321) **Typical profile** 0 to 1 inches: Slightly decomposed plant material 1 to 2 inches: Gravelly loam 2 to 5 inches: Very gravelly sandy loam 5 to 11 inches: Extremely cobbly sandy loam 11 to 15 inches: Extremely cobbly sandy loam 15 to 26 inches: Weathered bedrock 26 to 30 inches: Unweathered bedrock **Description of Rock Outcrop Setting** Landform: Mountain slopes Landform position (two-dimensional): Backslope, summit Landform position (three-dimensional): Mountainflank **Properties and qualities** Slope: 60 to 150 percent Depth to restrictive feature: 0 inches to lithic bedrock Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr) **Typical profile** 0 to 60 inches: Unweathered bedrock

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 8772C—Moran family-Lithic Cryorthents-Leighcan family complex, 40 to 75 percent slopes Map Unit Setting Elevation: 10,500 to 11,200 feet Mean annual precipitation: 30 to 50 inches Mean annual air temperature: 34 to 37 degrees F Frost-free period: 10 to 30 days **Map Unit Composition** Moran family and similar soils: 40 percent Lithic cryorthents and similar soils: 30 percent Leighcan family and similar soils: 20 percent **Description of Moran Family Setting** Landform: Moraines, mountain slopes Parent material: Glaciofluvial deposits and/or residuum derived from igneous and metamorphic rock **Properties and qualities** Slope: 40 to 75 percent Depth to restrictive feature: 40 to 59 inches to paralithic bedrock Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Low (about 3.1 inches) **Interpretive groups** Other vegetative classification: Ross' avens/rock sedge (GEROT/ CASA10) (F0208x), Tufted hairgrass/Ross' avens (DECA18/ GEROT) (G1503) **Typical profile** 0 to 8 inches: Very stony fine sandy loam 8 to 13 inches: Very stony fine sandy loam 13 to 27 inches: Very cobbly sandy loam 27 to 42 inches: Very stony sandy loam 42 to 60 inches: Weathered bedrock **Description of Lithic Cryorthents Setting** Landform: Mountain slopes Parent material: Glaciofluvial deposits and/or residuum derived from igneous and metamorphic rock **Properties and qualities** Slope: 40 to 75 percent Depth to restrictive feature: 10 to 20 inches to lithic bedrock Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.01 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Very low (about 1.1 inches) **Interpretive groups** Other vegetative classification: Pennsylvania sedge/moss campion (CAPE6/SIAC) (G1299) **Typical profile** 0 to 1 inches: Slightly decomposed plant material 1 to 4 inches: Very cobbly sandy loam 4 to 11 inches: Very cobbly sandy loam 11 to 17 inches: Extremely cobbly sandy loam 17 to 21 inches: Unweathered bedrock **Description of Leighcan Family Setting** Landform: Mountain slopes, moraines Parent material: Residuum and/or slope alluvium derived from igneous and metamorphic rock **Properties and qualities** Slope: 40 to 75 percent Depth to restrictive feature: More than 80 inches Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Very low (about 2.7 inches) **Interpretive groups** Other vegetative classification: Engelmann spruce/alpine clover (PIEN/TRDA2) (C0413) **Typical profile** 0 to 2 inches: Cobbly silt loam 2 to 9 inches: Very cobbly silt loam 9 to 28 inches: Very cobbly sandy loam 28 to 45 inches: Extremely stony loamy sand 45 to 60 inches: Extremely stony loamy sand

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 8776B—Moran family-Lithic Cryorthents-Rubble land complex, 5 to 40 percent slopes Map Unit Setting Elevation: 10,700 to 12,000 feet Mean annual precipitation: 30 to 50 inches Mean annual air temperature: 34 to 37 degrees F Frost-free period: 10 to 30 days **Map Unit**

Composition Moran family and similar soils: 60 percent Lithic cryorthents and similar soils: 20 percent Rubble land: 15 percent **Description of Moran Family Setting** Landform: Moraines, mountain slopes Parent material: Glaciofluvial deposits and/or residuum derived from igneous and metamorphic rock **Properties and qualities** Slope: 5 to 40 percent Depth to restrictive feature: 40 to 59 inches to paralithic bedrock Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Low (about 3.1 inches) **Interpretive groups** Other vegetative classification: Ross' avens/rock sedge (GEROT/ CASA10) (F0208x), Bellardi kobresia/Ross' avens-curly sedge (KOMY/GEROT-CARU3) (G2401x), Tufted hairgrass/Ross' avens (DECA18/GEROT) (G1503) **Typical profile** 0 to 8 inches: Very stony fine sandy loam 8 to 13 inches: Very stony fine sandy loam 13 to 27 inches: Very cobbly sandy loam 27 to 42 inches: Very stony sandy loam 42 to 60 inches: Weathered bedrock **Description of Lithic Cryorthents Setting** Landform: Mountain slopes, cirques Parent material: Glaciofluvial deposits and/or residuum derived from igneous and metamorphic rock **Properties and qualities** Slope: 5 to 40 percent Depth to restrictive feature: 10 to 20 inches to lithic bedrock Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.01 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Very low (about 1.1 inches) **Interpretive groups** Other vegetative classification: Pennsylvania sedge/moss campion (CAPE6/SIAC) (G1299) **Typical profile** 0 to 1 inches: Slightly decomposed plant material 1 to 4 inches: Very cobbly sandy loam 4 to 11 inches: Very cobbly sandy loam 11 to 17 inches: Extremely cobbly sandy loam 17 to 21 inches: Unweathered bedrock **Description of Rubble Land Setting** Landform: Fans, mountainsides Landform position (two-dimensional): Backslope, footslope Landform position (three-dimensional): Side slope Parent material: Colluvium and/or residuum derived from igneous, metamorphic and sedimentary rock **Typical profile** 0 to 60 inches: Stones

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 8776D—Moran family-Lithic Cryorthents-Rubble land complex, 40 to 150 percent slopes Map Unit Setting Elevation: 10,700 to 12,000 feet Mean annual precipitation: 30 to 50 inches Mean annual air temperature: 34 to 37 degrees F Frost-free period: 10 to 30 days **Map Unit Composition** Moran family and similar soils: 45 percent Lithic cryorthents and similar soils: 30 percent Rubble land: 20 percent **Description of Moran Family Setting** Landform: Moraines, mountain slopes Parent material: Glaciofluvial deposits and/or residuum derived from igneous and metamorphic rock **Properties and qualities** Slope: 40 to 75 percent Depth to restrictive feature: 40 to 59 inches to paralithic bedrock Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water capacity: Low (about 3.1 inches) **Interpretive groups** Other vegetative classification: Bellardi kobresia/Ross' avens-curly sedge (KOMY/GEROT-CARU3) (G2401x), Tufted hairgrass/ Ross' avens (DECA18/GEROT) (G1503), Ross' avens/rock sedge (GEROT/CASA10) (F0208x) **Typical profile** 0 to 8 inches: Very stony fine sandy loam 8 to 13 inches: Very stony fine sandy loam 13 to 27 inches: Very cobbly sandy loam 27 to 42 inches: Very stony sandy loam 42 to 60 inches: Weathered bedrock **Description of Lithic Cryorthents Setting** Landform: Mountain slopes Parent material: Glaciofluvial deposits and/or residuum derived from igneous and metamorphic rock **Properties and qualities** Slope: 40 to 75 percent Depth to restrictive feature: 10 to 20 inches to lithic bedrock Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.01 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Very low (about 1.1 inches) **Interpretive groups** Other vegetative classification: Pennsylvania sedge/moss campion (CAPE6/SIAC) (G1299) **Typical profile** 0 to 1 inches: Slightly decomposed plant material 1 to 4 inches: Very cobbly sandy loam 4 to 11 inches: Very cobbly sandy loam 11 to 17 inches: Extremely cobbly sandy loam 17 to 21 inches: Unweathered bedrock **Description of Rubble Land Setting** Landform: Fans, mountainsides Landform position (two-dimensional): Backslope, footslope Landform position (three-dimensional): Side slope Parent material: Colluvium and/or residuum derived from igneous, metamorphic and sedimentary rock **Typical profile** 0 to 60 inches: Stones

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.

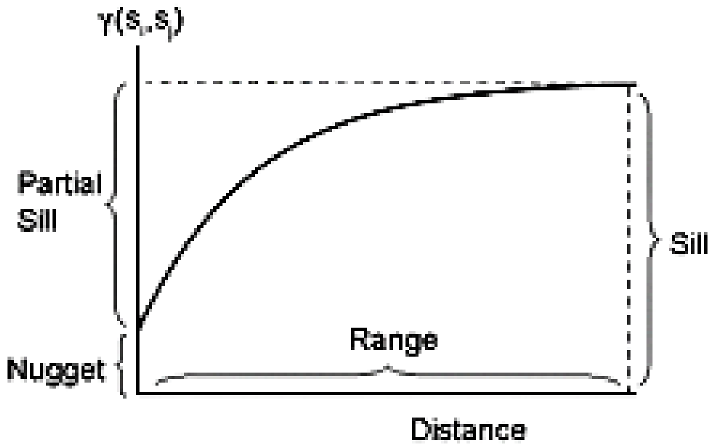


Figure 5. Example semivariogram, depicting range, sill, and nugget.

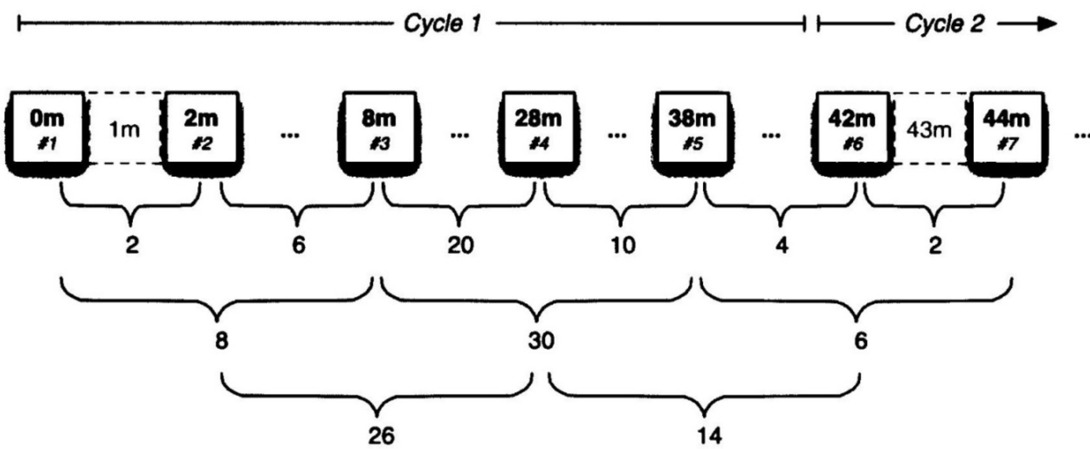


Figure 6. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 30 July 2010 at the Niwot Ridge 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 Niwot Ridge. 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 little distinct patterning of the residuals (Figure 8, left graph) and directional semivariograms do not show anisotropy (Figure 8, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 8, right graph). The model indicates a distance of effective independence of 5 m for soil temperature.

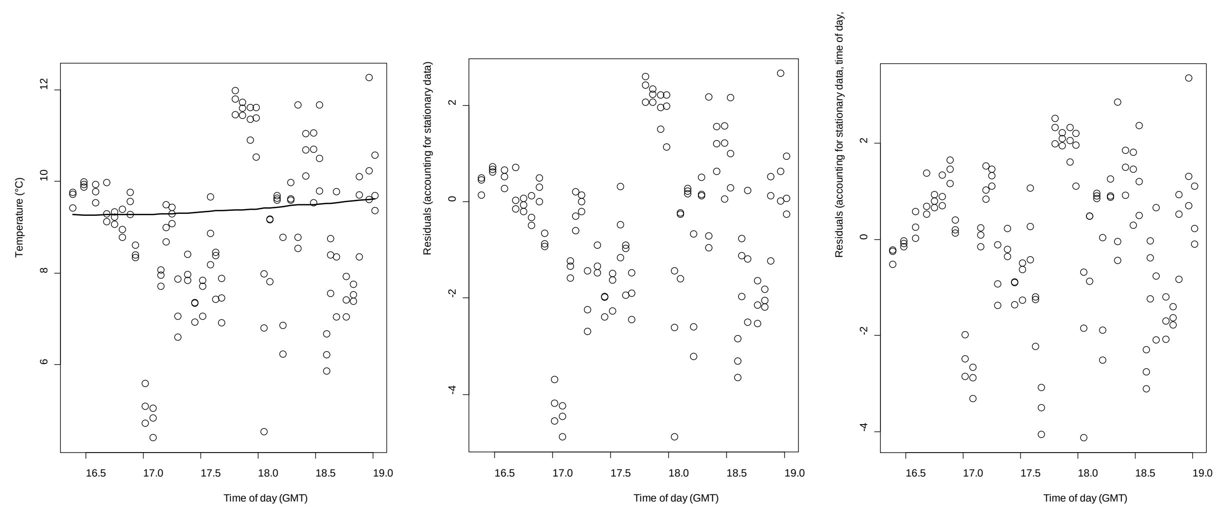


Figure 7. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting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

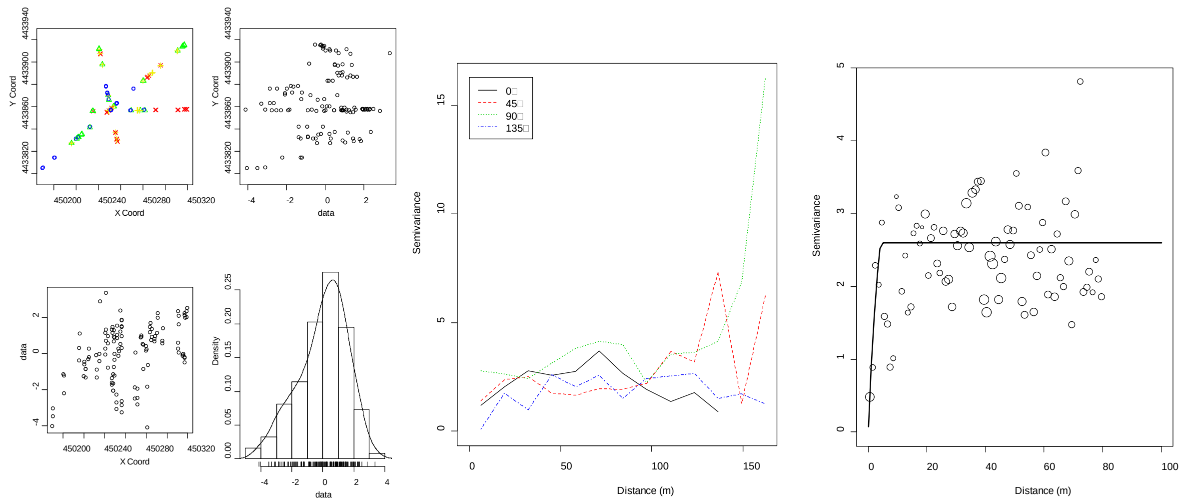


Figure 8. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

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 little 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 27 m for soil water content.

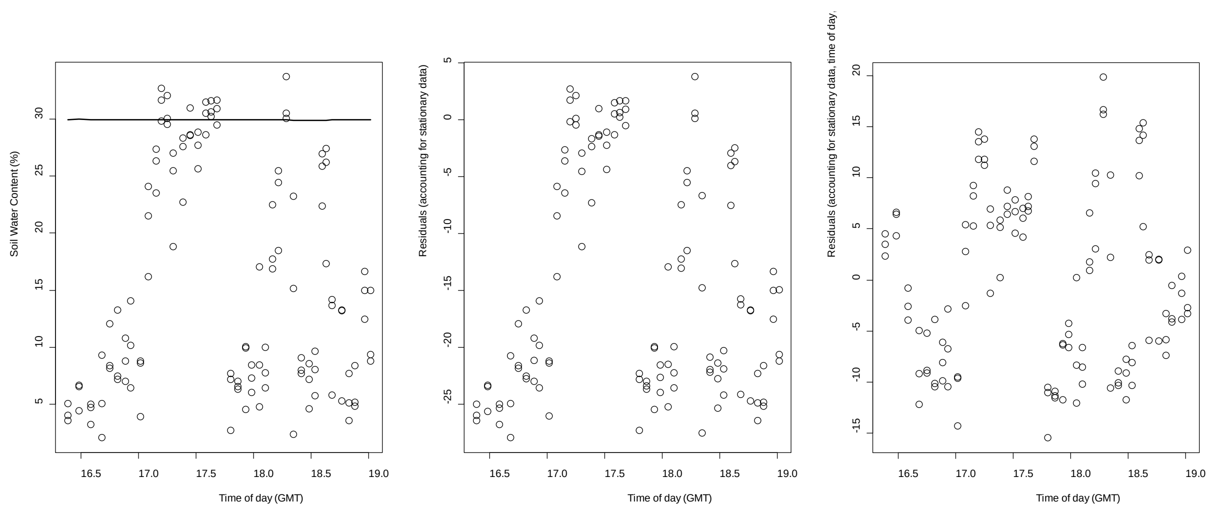


Figure 9. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting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

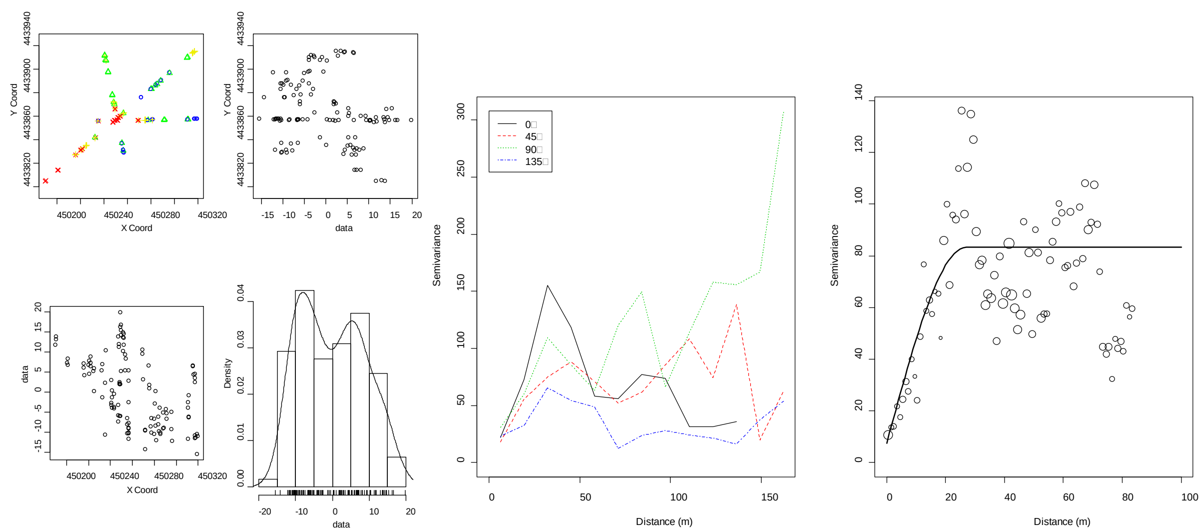


Figure 10. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

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 5 m for soil temperature and 27 m for soil moisture. Based on these results and the site design guidelines the soil plots at Niwot Ridge would normally be placed 27 m apart; however, prior to the availability of the semivariogram analyses presented above 25 m was chosen as the distance between plots and this distance was approved by the local Niwot Ridge personnel. Spacing the soil plots 25 m apart versus 27 m apart is not expected to negatively affect the science as the difference is so small and likely within the level of uncertainty associated with the semivariogram analyses. 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 120° from the soil plot nearest the tower (i.e., first soil plot). The location of the first soil plot will be approximately 40.054200°, -105.582550°. 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 40.052199°, -105.583685° (primary location); or 40.052377°, -105.583263° (alternate location 1 if primary location is unsuitable); or 40.052554°, -105.582817° (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: Moran family-Lithic Cryorthents-Rubble land complex, 5 to 40 percent slopes. The taxonomy of this soil is shown below:
Order: Inceptisols
Suborder: Cryepts
Great group: Humicryepts
Subgroup: Typic Humicryepts
Family: Loamy-skeletal, mixed, superactive Typic Humicryepts
Series: Moran family-Lithic Cryorthents-Rubble land complex, 5 to 40 percent slopes

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

Soil plot dimensions	5 m x 5 m
Soil array pattern	B
Distance between soil plots: x	25 m
Distance from tower to closest soil plot: y	16 m
Latitude and longitude of 1st soil plot OR direction from tower	40.054200°, -105.582550°
Direction of soil array	120°
Latitude and longitude of FIU soil pit 1	40.052199°, -105.583685° (primary location)
Latitude and longitude of FIU soil pit 2	40.052377°, -105.583263° (alternate 1)
Latitude and longitude of FIU soil pit 3	40.052554°, -105.582817° (alternate 2)
Dominant soil type	Moran family-Lithic Cryorthents-Rubble land complex, 5 to 40 percent slopes
Expected soil depth	0.25-1.50 m
Depth to water table	>2 m

Expected depth of soil horizons	Expected measurement depths*§
0-0.20 m (Very stony fine sandy loam)	0.10 m†
0.20-0.33 m (Very stony fine sandy loam)	0.27 m†
0.33-0.69 m (Very cobbly sandy loam)	0.51 m†
0.69-1.07 m (Very stony sandy loam)	0.88 m
1.07-1.52 (Weathered bedrock)	2.59 m
1.52 m	1.52 m

*Actual soil measurement depths will be determined based on measured soil horizon depths at the NEON FIU soil pit and may differ substantially from those shown here.
†Expected depth of soil CO_2 sensors
§Soil sensors will be placed up to 3 m deep at this site if soil depth allows

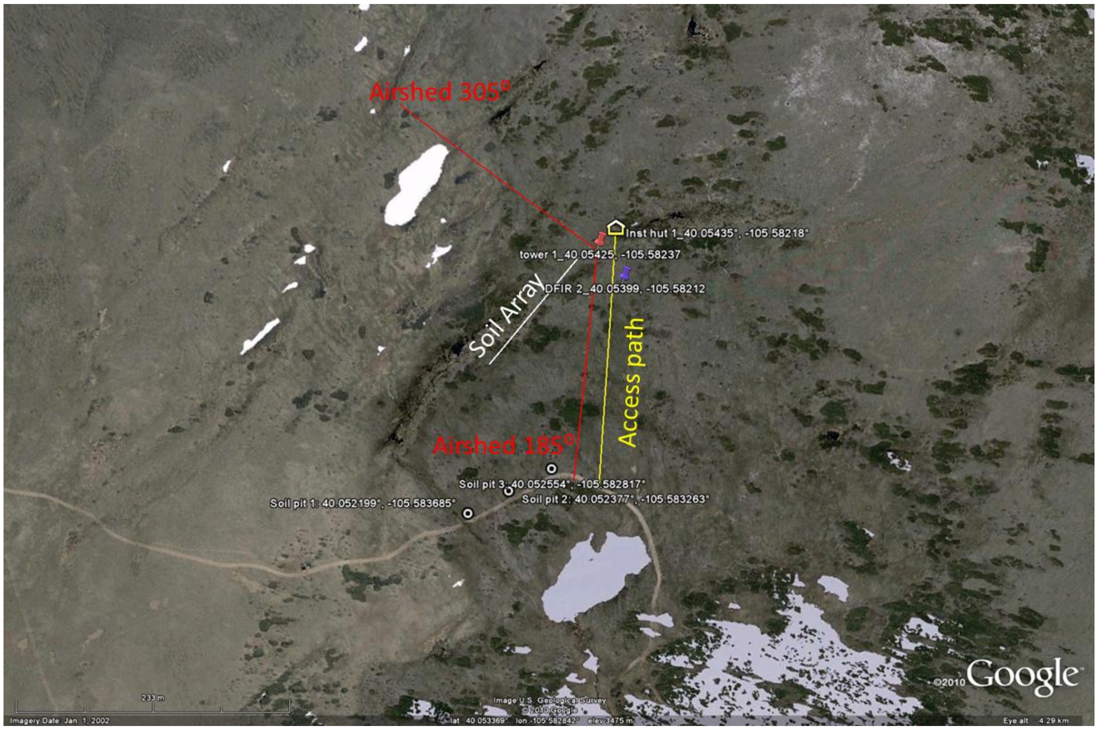


Figure 11. Site layout at Niwot Ridge showing soil array and location of the FIU soil pits.

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. The weather data and wind roses presented below are from Niwot Ridge LTER Tundra site. Coordinates for the weather station is not clear, but should be < 1 mile from NEON tower location. The orientation of the windrose follows that of a compass (assume declination applied). When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 24 cardinal directions in this case.

3.4.2 Results (graphs for wind roses)

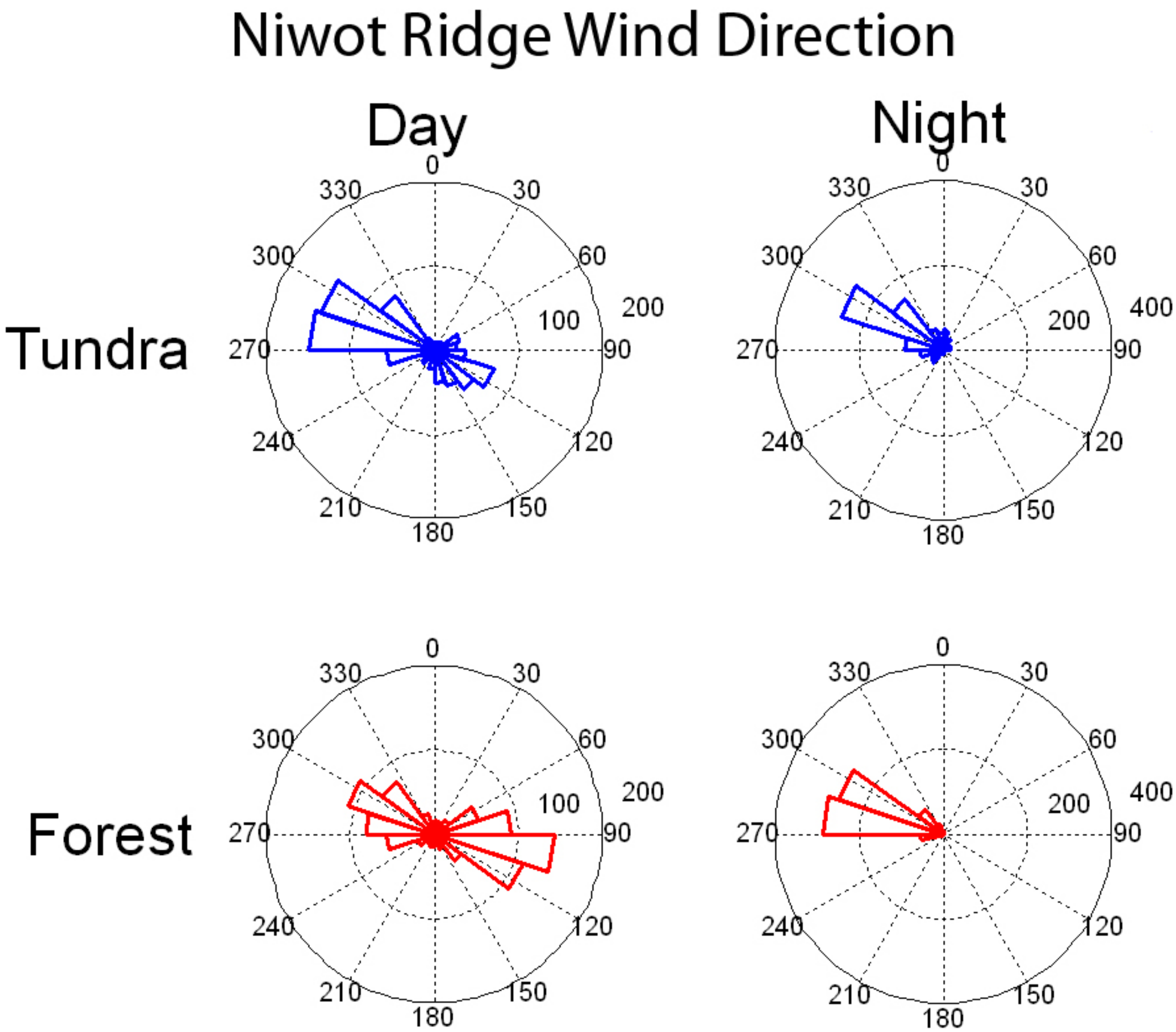


Figure 12. Windroses for Niwot Ridge Advanced tower site

Wind roses were provided by Niwot Ridge LTER. No detailed info about the weather station, data, or protocols were available. We assume the Tundra wind pattern would be closer to the wind pattern observed at the NEON tower location (Alpine tundra location).

3.4.3 Resultant vectors

Not available.

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 5. Expected environmental controls to parameterize the source area model, and associated results from Niwot Ridge 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	0.6	0.6	0.6	0.6	0.6	0.6	m
Canopy area density	2	2	2	1.5	1.5	1.5	m
Boundary layer depth	700	700	300	300	300	300	m
Expected sensible heat flux	320	320	-20	-50	-50	-75	W m^{-2}
Air Temperature	21	21	18	-15	-15	-25	°C
Max. windspeed	17.8	13.6	11.6	17.8	13.6	11.6	m s^{-1}

Resultant wind vector	285	285	295	285	285	295	degrees
Results							
(z-d)/L	-0.01	-0.02	0	0	0	0.01	m
d	0.45	0.45	0.45	0.43	0.43	0.43	m
Sigma v	3	2.4	1.8	1.8	1.80	1.8	$m^2 s^{-2}$
Z0	0.03	0.03	0.03	0.04	0.04	0.04	m
u*	1.4	1.1	0.9	1.4	1.10	0.92	$m s^{-1}$
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	800	800	800	850	850	800	m
Distance of 80% cumulative flux	450	450	490	490	500	495	m
Distance of 70% cumulative flux	300	300	300	400	350	300	m
Peak contribution	65	65	65	55	55	55	m

‡: Wind direction info was extract from existing WR for Niwot Ridge Tundra site. Summer wind speed data were obtained from Niwot Ridge LTER Saddle location. No winter data available, assume windspeed is same as summer. This is also applied to the source area graphs below.

3.4.5 Results (source area graphs)

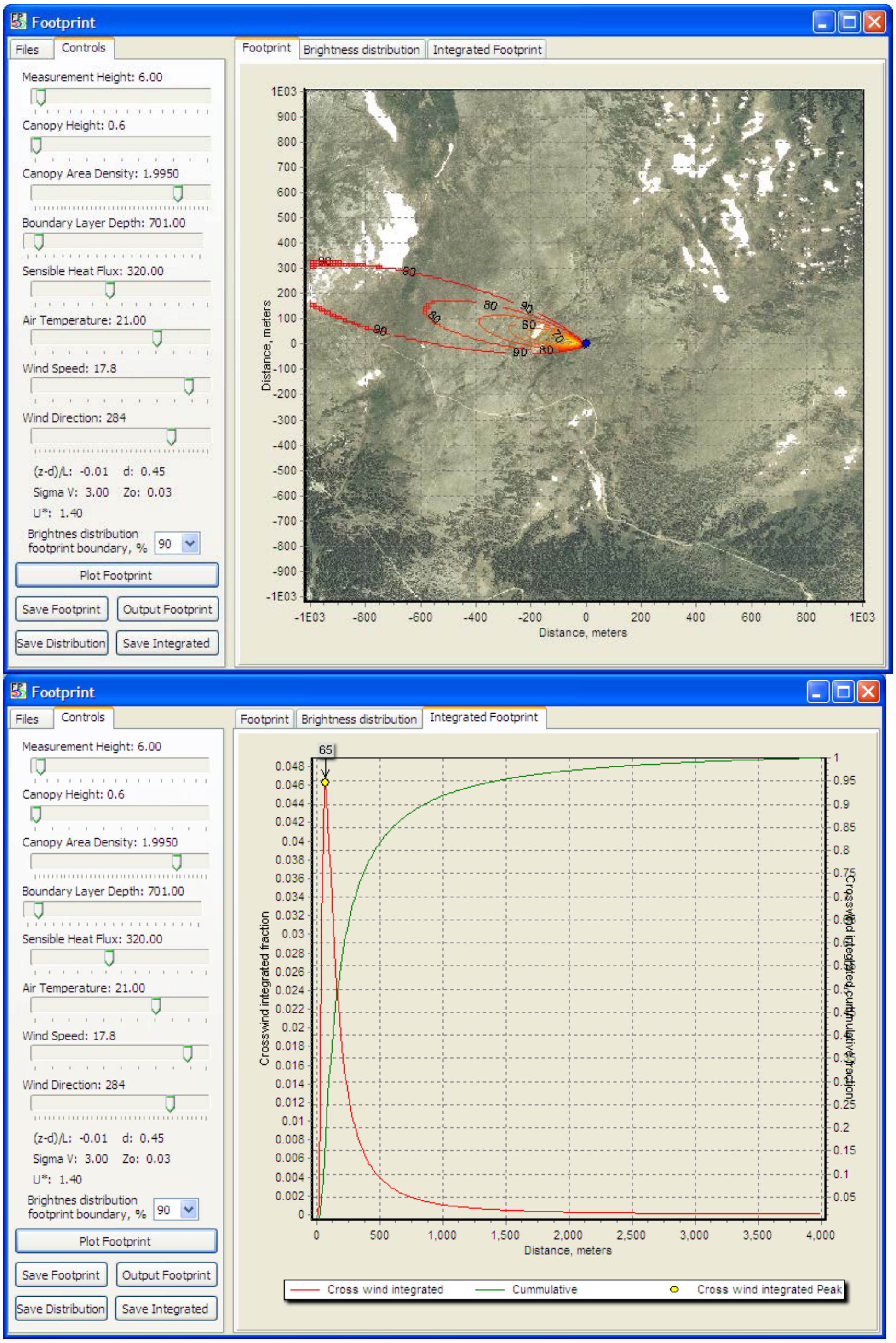


Figure 13. summer, daytime, max wind speed

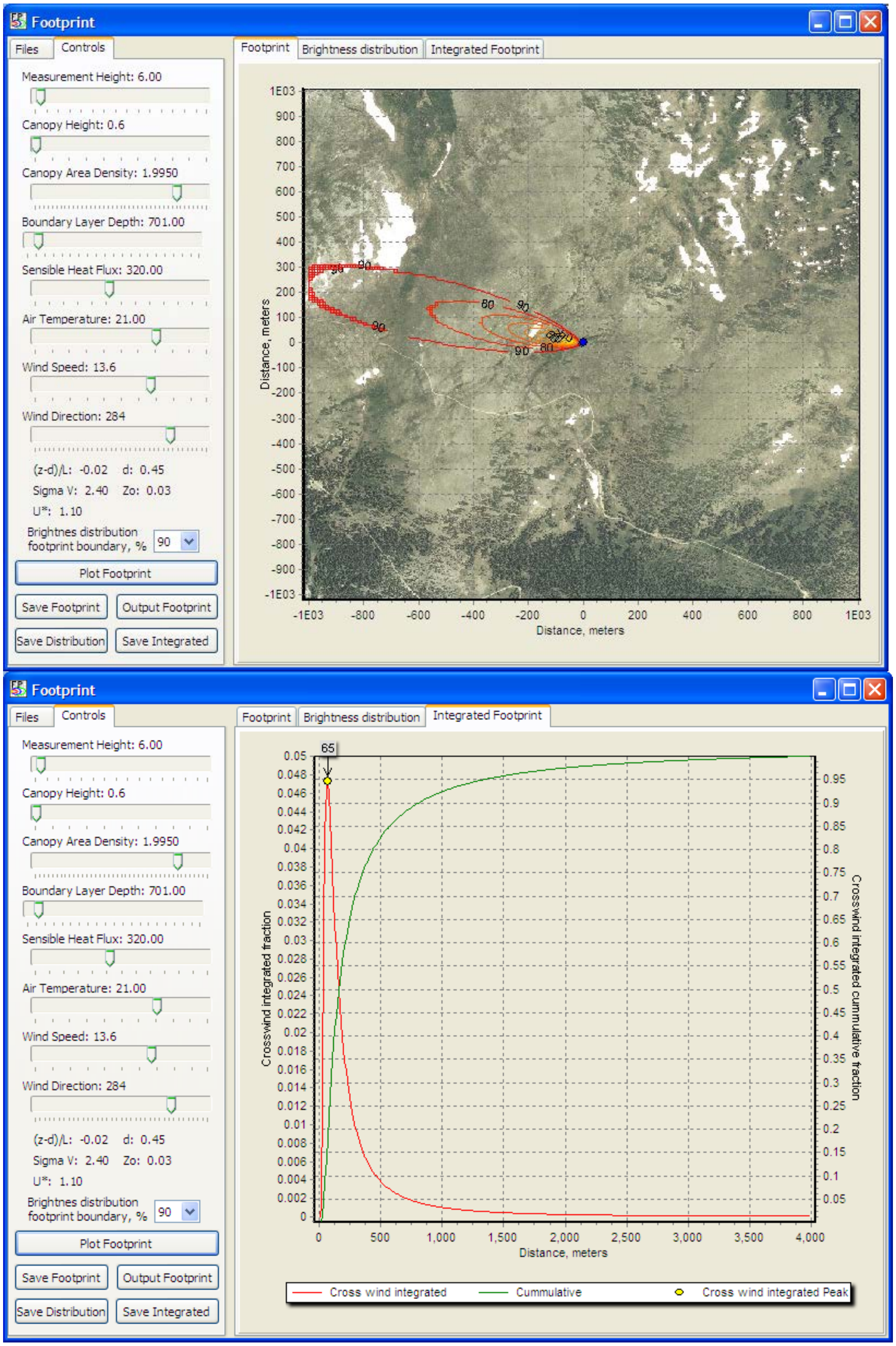


Figure 14. summer, daytime, mean wind speed

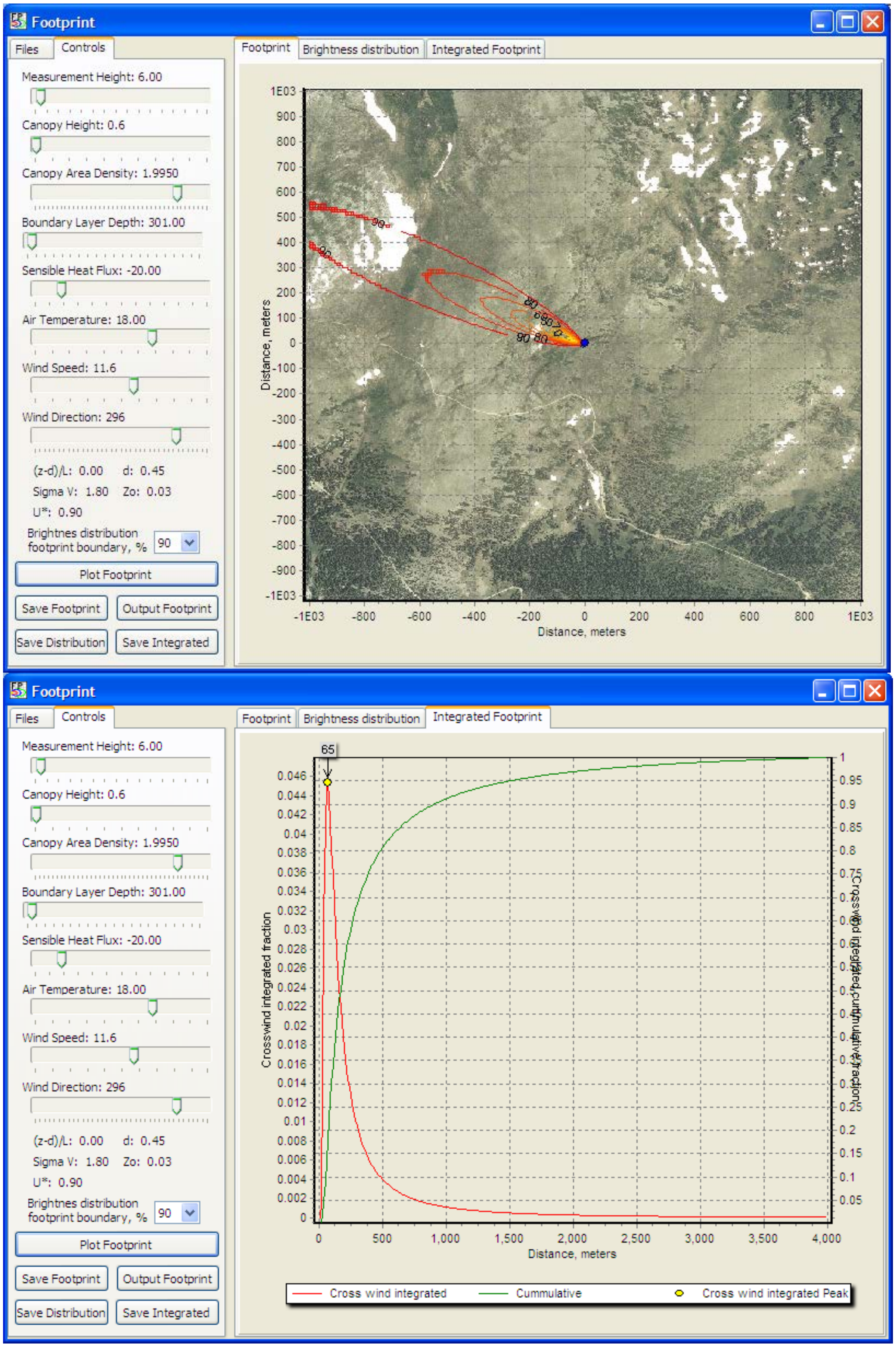


Figure 15. summer, nighttime, mean wind speed

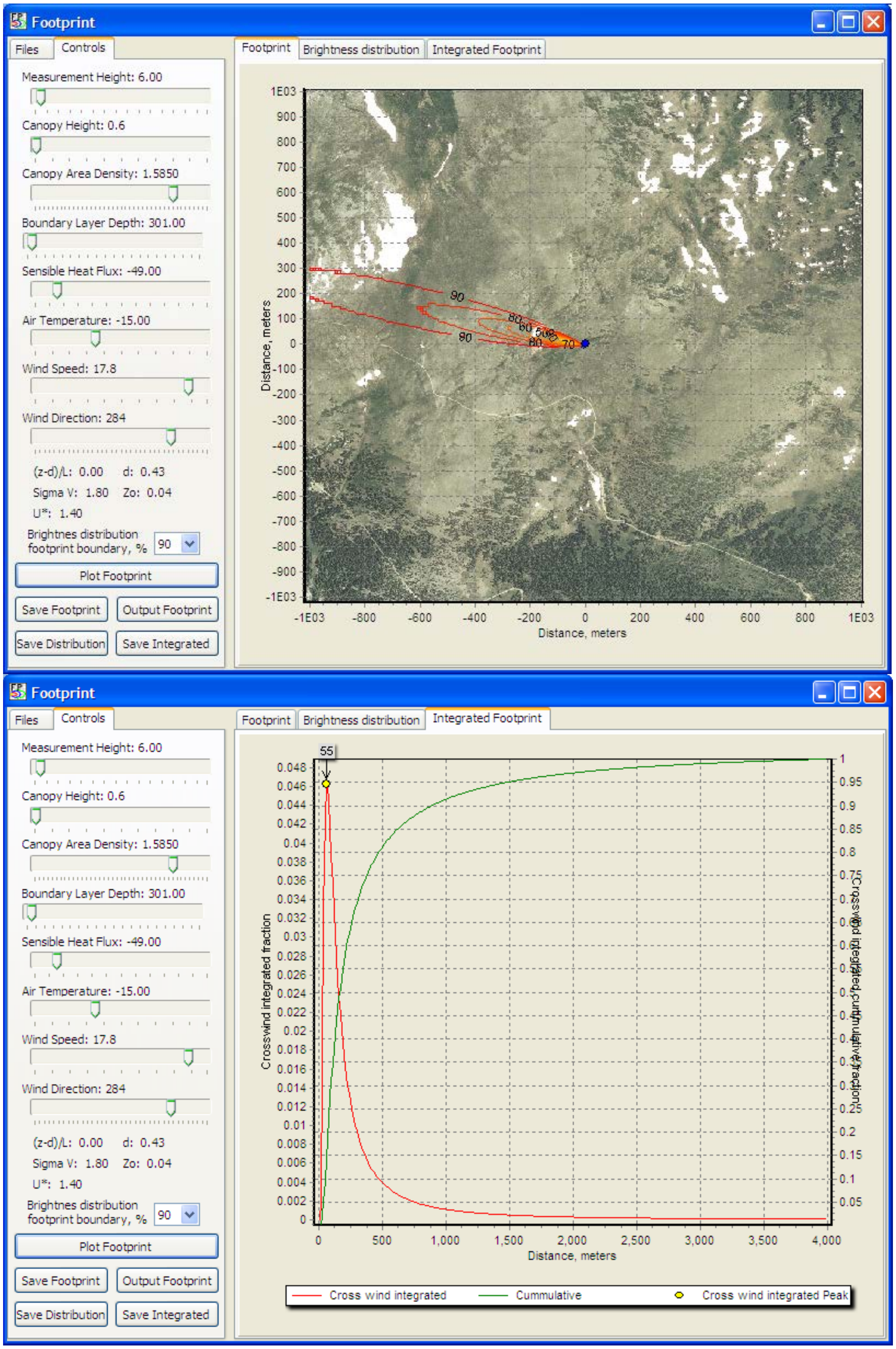


Figure 16. Run 4 winter, daytime, max WS

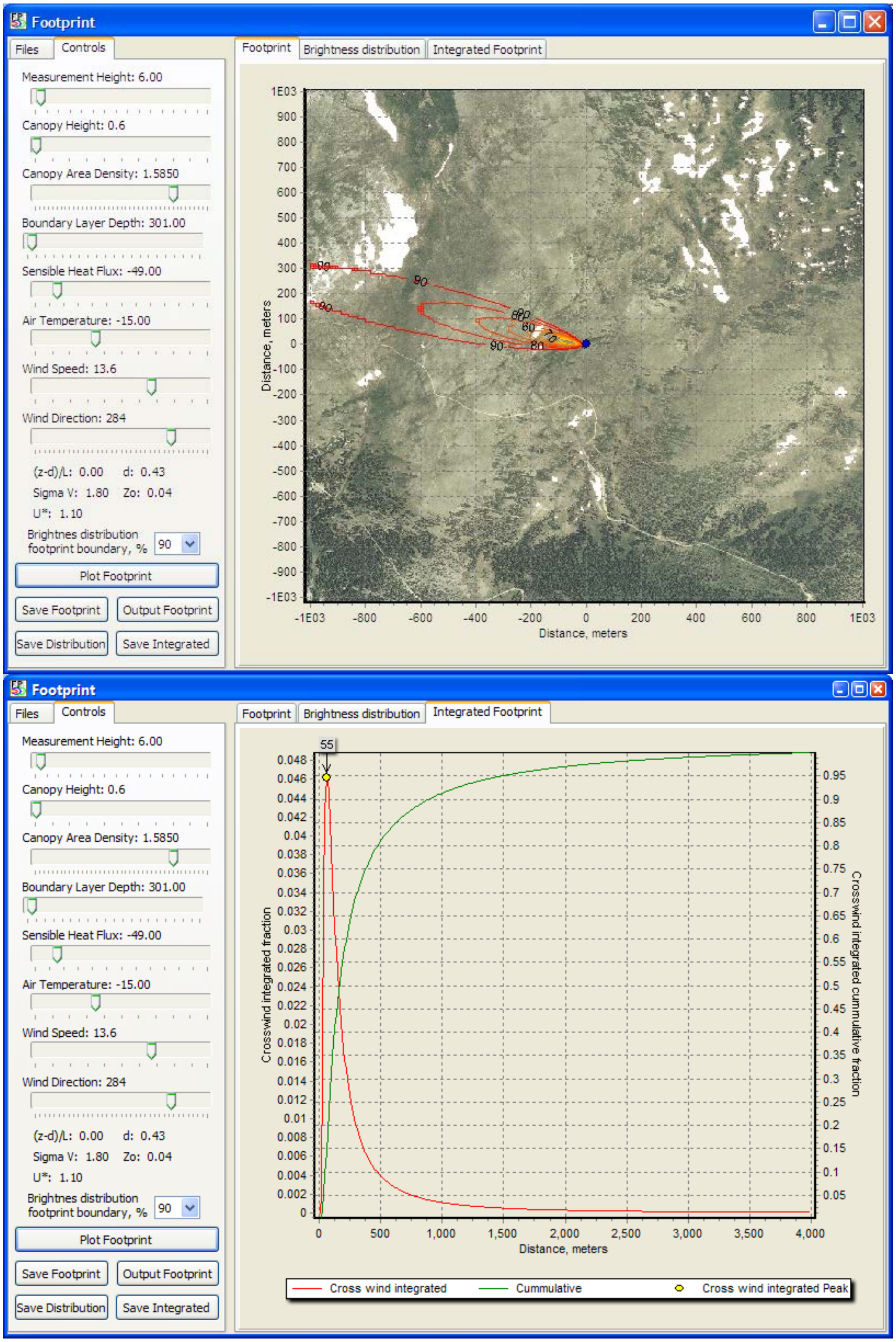


Figure 17. Winter daytime, mean wind speed

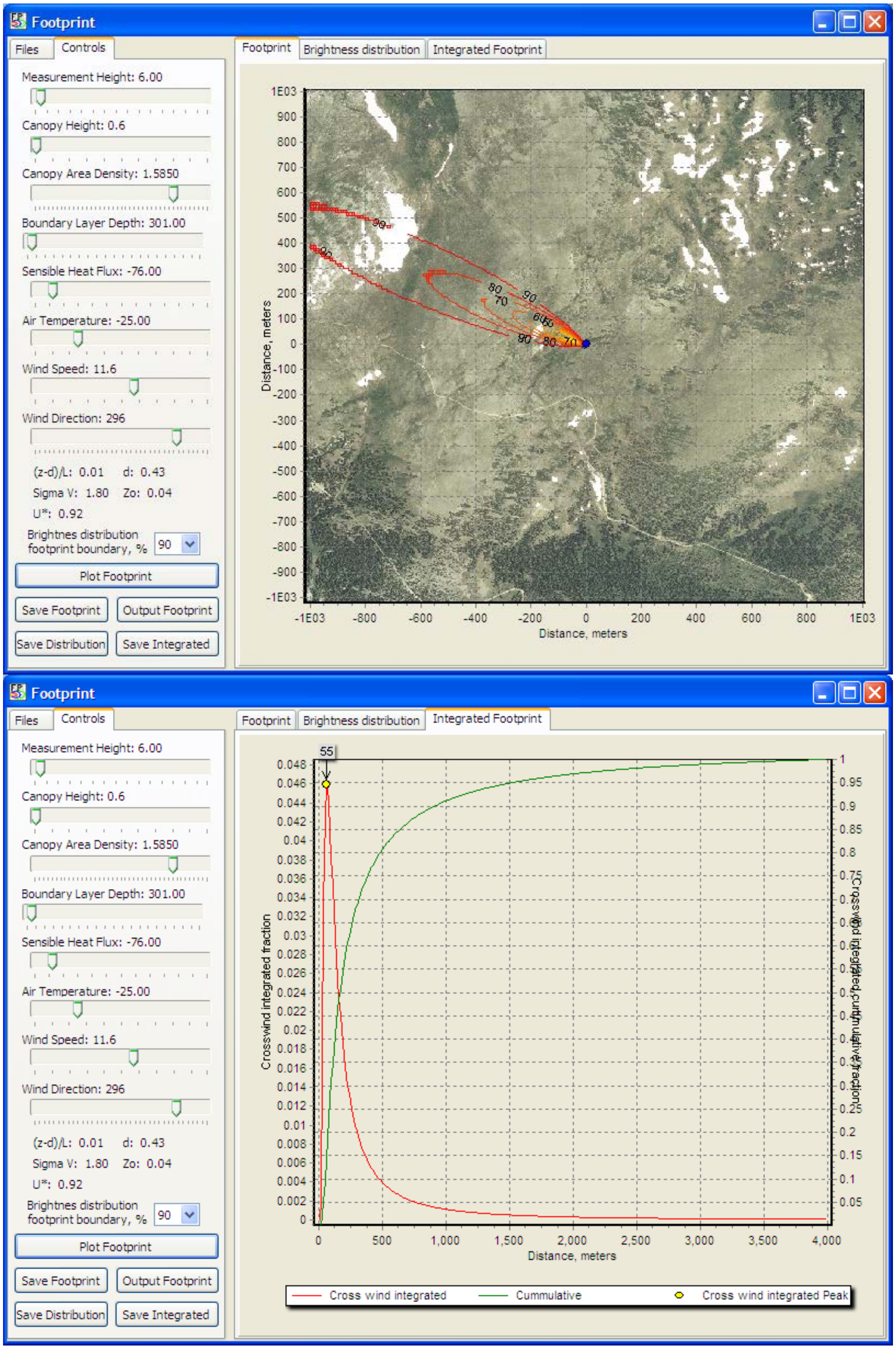


Figure 18. winter, nighttime, mean wind speed

3.5 Site design and tower attributes

According to wind roses, the prevailing wind direction blows from 255° to 325° (clockwise from 255°, major airshed). However, these windroses were made from the data at other (similar) weather station, which has different micro-terrain with our tower site. Based on the micro-terrain at the tower location, we expect to see the prevailing wind from west, also see wind from along the ridge from southwest and see nighttime drainage from northwest. Therefore, based on our best knowledge, the **major tower airshed** is from 185° to 305° (clockwise from 185°). Tower should be placed to a location to best capture the signals from the airshed over the ecosystem in interest, i.e., alpine tundra in this case. The candidate tower site was at 40.05420658°, -105.5821737°. After site visit, we microsited the tower location for ~17 m to 40.05425°, -105.58237° to avoid the snow drift effects from nearby tree islands. The new **tower location** is at 40.05425°, -105.58237°.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the SW will be best to capture signals from all wind directions. **Radiation boom arms** should always be facing south to avoid any shadowing effects from the tower structure. An **instrument hut** should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind and should be positioned to have the longer side parallel to frequent wind direction to minimize the wind effects on instrument huts and to minimize the disturbances of wind regime by instrument hut, and in this case, instrument hut should be positioned on the NE side of tower and have the longer side parallel to SW-NE direction. The location of instrument hut is at 40.05435°, -105.58218°.

The dominant vegetation type around and within the tower airshed consists of a mixture of dry and wet tundra. Mean canopy height ranges 0.2 to 0.7 m with taller grasses, annuals and short perennials in the wetter spots. Tree islands are dotted on tundra with size commonly less than 20 m × 20 m. There are two common types of tree islands here: spruce tree islands with height 3-4 m and dwarf-shrub islands (species is unclear) with height 0.3-1 m. We require 4 **measurement layers** on the tower with top measurement height at 6 m, and remaining levels are 4 m, 1.0 m, and 0.2 m, respectively, to best characterize the fluxes on the tower top and environmental conditions in profile.

DFIR location is at 40.05399, -105.58212, which is ~35 m southeast toward tower. **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. The side of the tower with the anemometer boom is perpendicular to the boom direction. **Instrument hut orientation vector** is parallel to the long side of the instrument hut. **Instrument hut distance z** is the distance from the center of tower projection to the center of the instrument hut projection on the ground. The numbering of the **measurement levels** is that the lowest is level one, and each subsequent increase in height is numbered sequentially.

Table 6. Site design and tower attributes for Niwot Ridge Advanced site.

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

Attribute	lat	long	degree	meters	notes
Airshed area			185° to 305°		Clockwise from first angle
Tower location	40.05425,	-105.58237	--	--	new site
Instrument hut	40.05435°,	-105.58218°			
Instrument hut orientation vector	--	--	225° - 45°		
Instrument hut distance z	--	--	--	19	
Anemometer/Temperature boom orientation	--	--	225°	--	
DFIR	40.05399,	-105.58212			
Height of the measurement levels					
Level 1				0.2	m.a.g.l.
Level 2				1.0	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 below shows the proposed tower location, instrument hut location, DFIR, airshed area and access road.

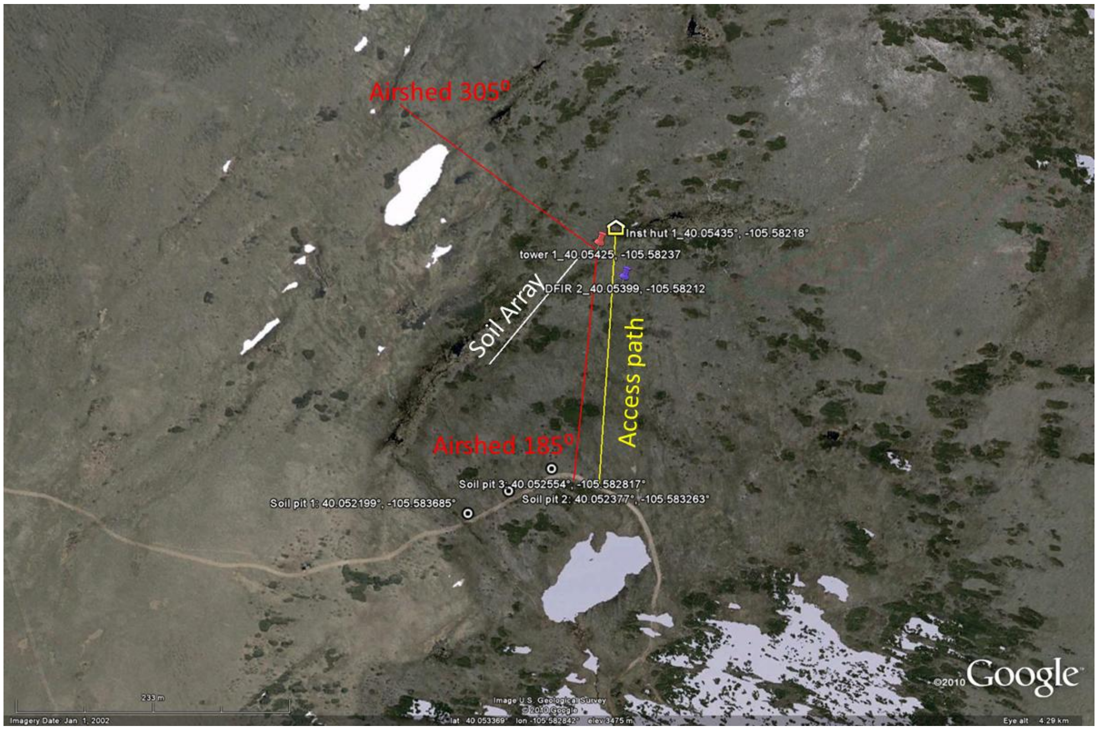


Figure 19. Site layout for Niwot Ridge Advanced tower site.

i) Tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 185° to 305° (clockwise from 185°, major airshed) are the airshed areas that would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access marked path to instrument hut along powerline (according to EHS). The actual layout of this path will be the joint responsibility of FCC and FIU. iv) Purple pin is DFIR location

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

- ***Raised boardwalks drift snow that can affect the long term ecology. However, damage to the access path and surrounding areas can also occur from marked paths and melting snowpack. Suggest material for a path/boardwalk be placed directly on the tundra, like that used at Barrow Alaska. This decision should be vetted among EHS, FCC, FIU and the host institutions.***
- Marked path from the road to instrument hut, pending landowner decision. Markers need to be tall enough to remain visible during winter.
- Marked path from the instrument hut to the tower to intersect on north face of the tower
- Marked path to the soil array
- No path from the soil array marked path to the individual soil plots
- Marked path needed to DFIR site

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

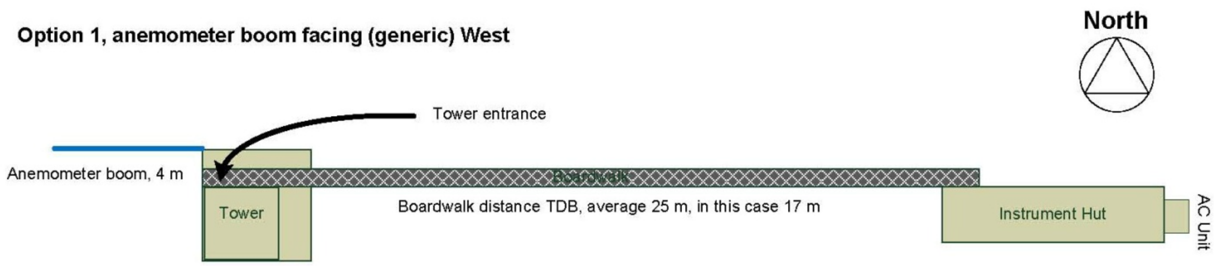


Figure 20. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing west and instrument hut on the east towards the tower.

This is just a generic diagram. The actual layout of boardwalk (or path if no boardwalk required) and instrument hut position will be the joint responsibility of FCC and FIU. At Niwot Ridge Advanced site, the boom angle will be 225°, instrument hut will be on the northeast towards the tower, the distance between instrument hut and tower is ~19 m. The instrument hut vector will be SW-NE (225°-45°, longwise).

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

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

DFIR location at this site has been chosen to meet USCRN class 1 or class 2 criteria. The DFIR location identified here and its (final) placement (e.g., during reviews, construction activities, FCC micrositing) will have to be evaluated against these conditions and requirements.

3.6 Information for ecosystem productivity plots

The tower at this site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (alpine tundra ecosystem). Based on our best knowledge, major airshed area at this site is from 185° to 305° (clockwise from 185°), and 80% of the information for flux measurements are within a distance of 500 m (90% within 850 m) from tower. We suggest FSU Ecosystem Productivity plots are placed within the major airshed boundaries of 185° to 305° (clockwise from 185°) from tower.

3.7 Exclusion Zone

To meet our Product Assurance metrics, our high quality Terrestrial Instrument System (TIS) measurements, and TIS requirements, no sampling, observations, or experiment shall be conducted within the tower exclusion zone without consulting and resolving any issues with TIS scientists as according to the 'NEON Research Collaboration Document' NEON.DOC.004312. The intent is to limit any activities that can either affect the wind flows (e.g., disturbance, buildings, structures, clear cutting, affect changes in structure), or the natural/expected process rates that would adversely affect NEON's data products. Because we cannot think of all such future activities, each will have to be evaluated on a case-by-case basis.

The exclusion zone is an area with these features:

a) The shape of the exclusion zone appears as a pie splice (plan view) with center point of the tower foundation (plan view) as its origin.
b) There may be more than one exclusion zone per tower, depending on the diurnal, seasonal and annual wind patterns.

c) The exclusion zone is a sub-area (i.e., inside) the total tower source area
d) Windrose analyses determine the wind vectors that bound the outside of the exclusion zone, which is clockwise from 185 to 305.

There are two criteria to determine the distance of the exclusion zone from the tower:

1) For all activities mentioned above, the distance from the tower is the maximum value of 90% cumulative flux of the source area at mean maximum wind speed under daytime convective (expected unstable) atmospheres, which is 850 at this site.
2) Some large disturbance activities also cannot occur in the nighttime tower footprint (because the nighttime tower footprint extends out much farther than the daytime source area). For all high impact activities, the distance from the tower is the maximum value of 80% cumulative flux of the source area at mean maximum wind speed under nighttime, thermally stratified, (expected) stable atmospheric conditions, which is 495 at this site.

3.8 Issues and attentions

The high elevation means that this site is often extremely cold and windy, especially during winter. Blizzards and blowing snow can reduce visibility to very short distance. Lightning is also a concern, particularly during the summer. Weather conditions can change rapidly at the site. A light on the tower could act as beacon to aid locating the tower under low visibility conditions, but it would have to be possible to turn off the light when it was not needed to minimize affects on tower based measurements.

Even though this is a short, potetnially self standing tower, we require guy wires here. Due to the high winds that can occur at the site guy wires are needed to increase the stability of the tower, instrument hut, and other equipment.

Many research plots (both active and inactive) are found in the area of the NEON site. The NEON design has been approved by site personnel, therefore, the locations are not expected to overlap with any research plots. However, caution should be used during construction and operation to avoid or minimize disturbance to research plots.

The tundra ecosystem is fragile and very susceptable to disturbance, therefore, maintaining strict access route is particularly important at this site. Site personnel suggested boardwalk would not be suitable since it would increase snow accumulation on the leeward side (see Boardwalk section of this report).

Gas tanks and other large equipment may need to be transported to the NEON site in winter using snowmobiles to avoid damaging the tundra. In other words, Field OPS will have to transport 1 years worth of tanks during the winter, rather than every 6 months.

There is concern from site personnel about the impact of contruction on the site. Strategies need to be developed to minimize distrubance. For example, it may be best to transport large items (e.g. instrument hut, tower, etc) to the site in winter when there is a layer of snow protecting the tundra.

4 MOAB, RELOCATEABLE TOWER 1

4.1 Site description

The Moab site is located ~25 miles south of Moab next to Road 191 (old, non-maintained, state highway). The original tower location was 38.16145, -109.65947 (corral pocket); however, this site was not practical for a NEON site because the distance to power was ~30 miles. A new site (38.24833, -106.38827) was selected with input from Jayne Belnap, which was closer to power and met the science goals for this site, including the ability to measure dust generation and deposition.

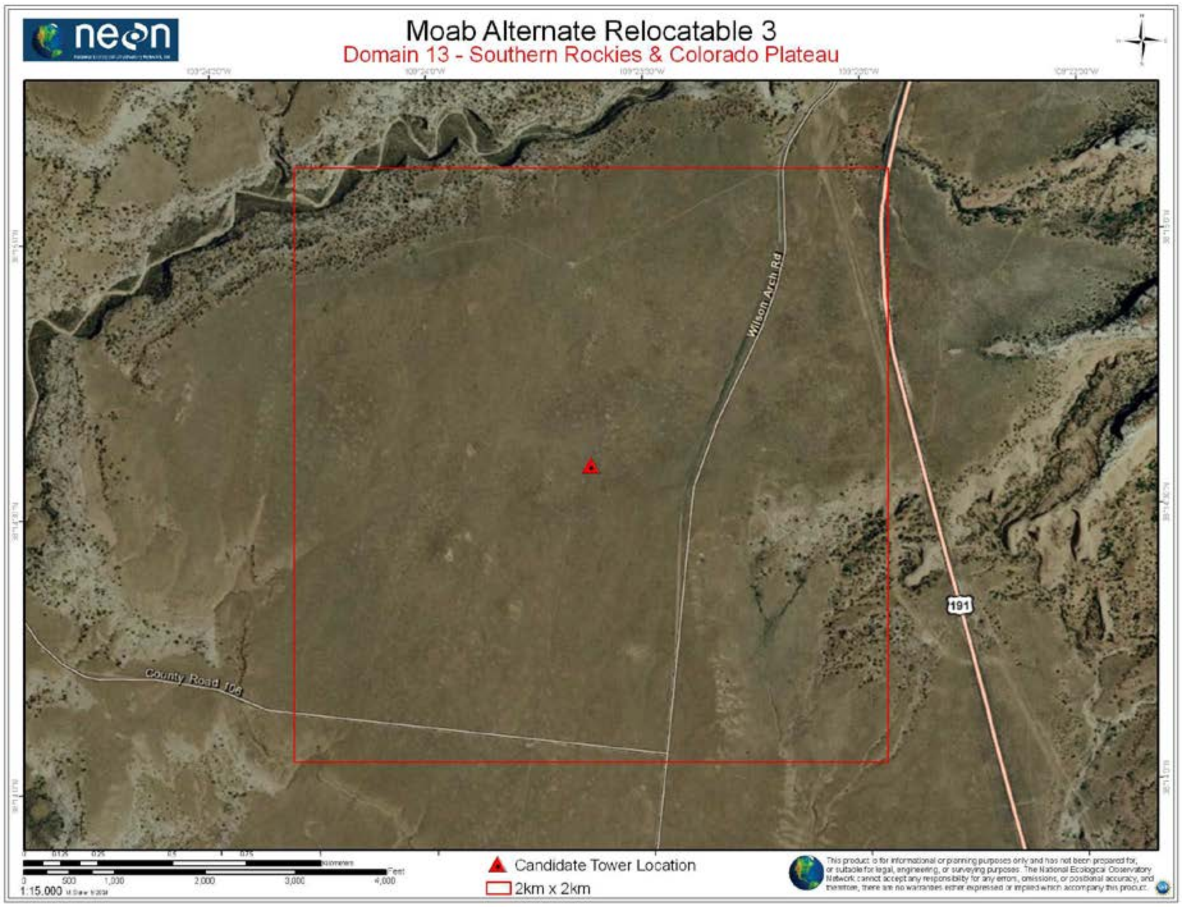


Figure 21. 2 km × 2 km map of the Moab site and candidate tower location.

4.2 Ecosystem

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

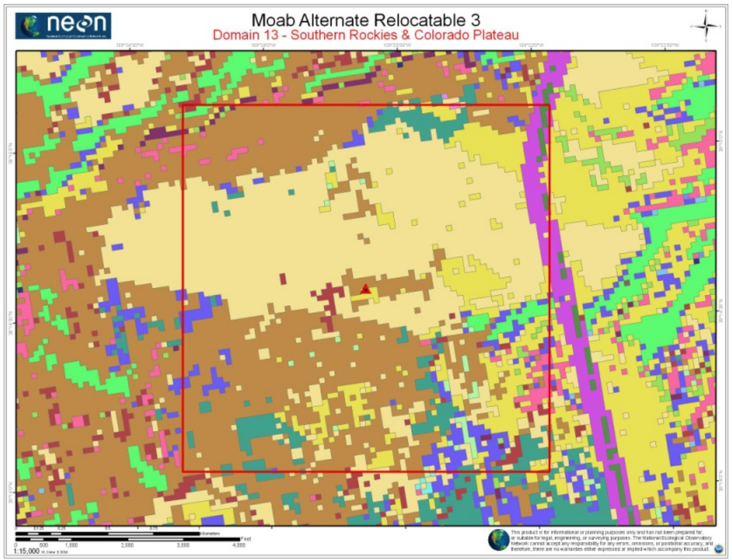


Figure 22. Vegetative cover map of the Moab relocatable site and surrounding areas (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm).

Table 7. Percent Land cover information at the Moab relocatable site (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Vegetation_Type	Area_KM2	Percentage
Barren	0.0398	0.996
Coleogyne ramosissima Shrubland Alliance	1.3566	33.916
Colorado Plateau Mixed Low Sagebrush Shrubland	0.0002	0.004
Colorado Plateau Pinyon-Juniper Woodland	0.0433	1.082
Developed-Low Intensity	0.0124	0.310
Developed-Open Space	0.0730	1.825
Inter-Mountain Basins Big Sagebrush Shrubland	0.4217	10.543
Inter-Mountain Basins Mat Saltbush Shrubland	0.0297	0.743
Inter-Mountain Basins Mixed Salt Desert Scrub	0.1544	3.861
Inter-Mountain Basins Semi-Desert Grassland	0.0472	1.179
Inter-Mountain Basins Semi-Desert Shrub-Steppe	0.0012	0.031
Introduced Riparian Vegetation	0.0082	0.204
Introduced Upland Vegetation-Annual Grassland	1.5986	39.965
Rocky Mountain Montane Riparian Systems	0.0122	0.306
Southern Colorado Plateau Sand Shrubland	0.2014	5.034
TOTAL	4.0000	100.000

The terrain at the tower site is flat with a very shallow slope towards the southwest. Vegetation is a mix of grasses (including *Boutilua* spp.) and forbs with a uniform distribution. Canopy height is ~ 20 cm. Bare ground accounts for ~30-60% of the surface. The site is lightly grazed. The site has a large fetch area to the east (predominant nighttime wind direction), south, and west, which is suitable to measure dust generation and deposition. Vegetation surface coverage and roughness are key factors affecting dust generation and deposition. The structure of this type of vegetation is representative of the dominant vegetation of the Colorado Plateau.

Figure 23. Ecosystem at the Moab relocatable site.

Table 8. Ecosystem and site attributes for Moab Relocatable site.

Ecosystem attributes	Measure and units
Mean canopy height	0.2 m
Surface roughness [a]	0.01 m
Zero place displacement height [a]	0.15 m
Structural elements	Grass and forbs, uniform
Time zone	Mountain time zone
Magnetic declination	10° 51' E changing by 0° 7' W/year

Note, [a] From field survey.

4.3 Soils

4.3.1 Description of soils

Soil data and soil maps below for the Moab tower site were collected from 12.0 km^2 NRCS soil maps (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

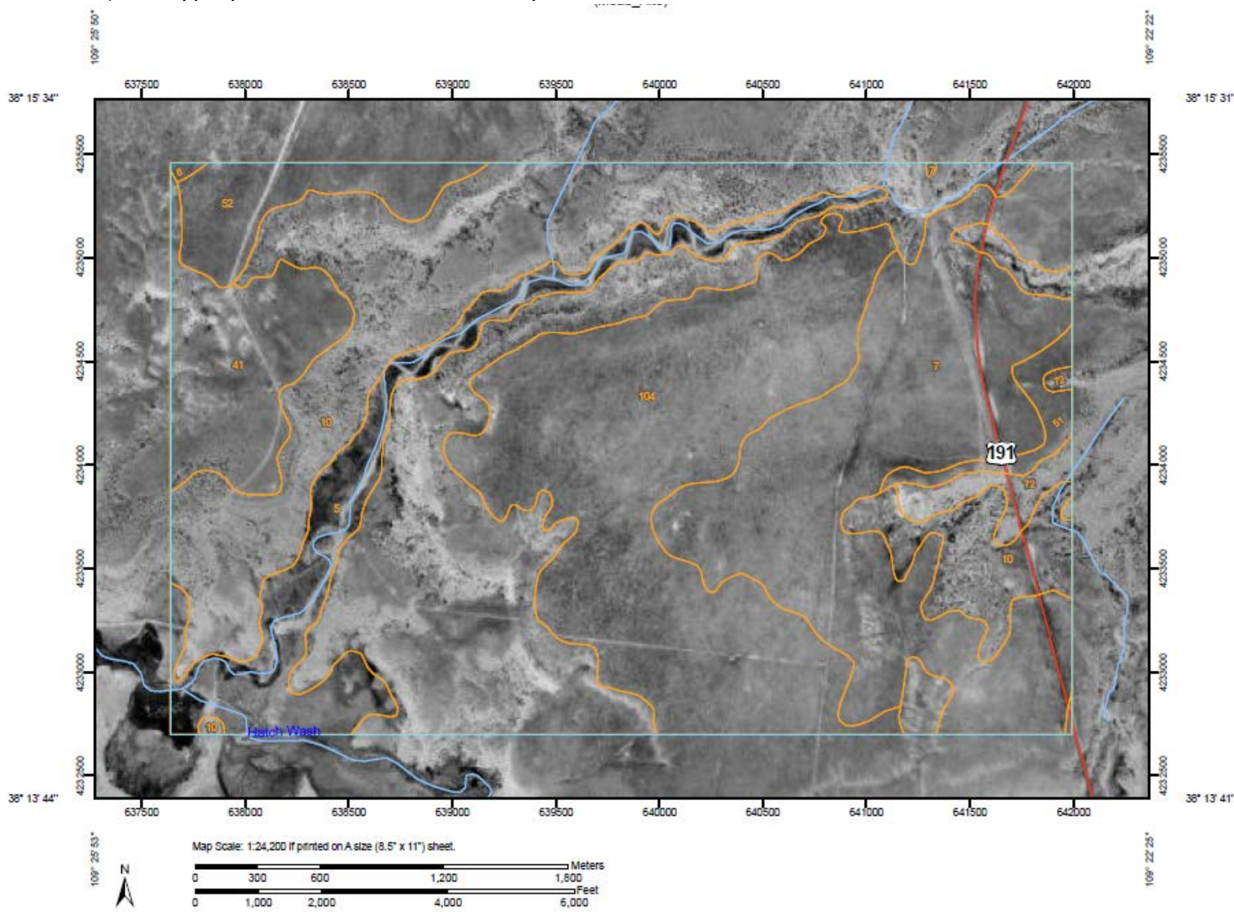


Figure 24. Soil map of the Moab site and surrounding areas.

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 9. Soil series and percentage of soil series within 12.0 km^2 at the Moab site

Canyonlands Area, Utah - Parts of Grand and San Juan Counties (UT633)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
5	Barnum silty clay loam, 0 to 3 percent slopes	235.9	7.9%
7	Begay fine sandy loam, 2 to 6 percent slopes	611.0	20.6%
8	Begay fine sandy loam, moist, 2 to 6 percent slopes	2.4	0.1%
10	Begay-Rock outcrop-Mido complex, 2 to 35 percent slopes	1,122.0	37.8%
41	Ignacio-Leanto fine sandy loams, 2 to 6 percent slopes	173.4	5.8%
51	Mido loamy fine sand, dry, 2 to 8 percent slopes	35.6	1.2%
52	Mivida fine sandy loam, 2 to 8 percent slopes	94.3	3.2%
72	Rock outcrop	40.5	1.4%
104	Windwhistle-Sazi very fine sandy loams, 1 to 3 percent slopes	652.9	22.0%
Totals for Area of Interest		**2,968.0**	**100.0%**

Canyonlands Area, Utah - Parts of Grand and San Juan Counties 5—Barnum silty clay loam, 0 to 3 percent slopes Map Unit Setting Elevation: 5,700 to 6,000 feet Mean annual precipitation: 10 to 12 inches Mean annual air temperature: 49 to 51 degrees F Frost-free period: 120 to 140 days **Map Unit Composition** Barnum and similar soils: 85 percent Minor components: 15 percent Description of Barnum Setting Landform: Valley flats Landform position (three-dimensional): Talf Down-slope shape: Concave Across-slope shape: Concave Parent material: Alluvium derived from sandstone **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 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: Occasional Frequency of ponding: None Calcium carbonate, maximum content: 20 percent Maximum salinity: Slightly saline to moderately saline (8.0 to 16.0 mmhos/cm) Sodium adsorption ratio, maximum: 30.0 Available water capacity: High (about 9.1 inches) **Interpretive groups** Land capability (nonirrigated): 7s Ecological site: Desert Loam (Shadscale) (R035XY109UT) **Typical profile** 0 to 3 inches: Silty clay loam 3 to 43 inches: Sandy clay loam 43 to 62 inches: Fine sand **Minor Components Very deep clayey soils** Percent of map unit: 5 percent **Barnum, surface mantle of loamy fine sand** Percent of map unit: 5 percent **Redbank** Percent of map unit: 5 percent

Canyonlands Area, Utah - Parts of Grand and San Juan Counties 7—Begay fine sandy loam, 2 to 6 percent slopes Map Unit Setting Elevation: 5,500 to 6,000 feet Mean annual precipitation: 9 to 12 inches Mean annual air temperature: 49 to 51 degrees F Frost-free period: 120 to 140 days **Map Unit Composition** Begay and similar soils: 75 percent Minor components: 25 percent **Description of Begay Setting** Landform: Cuestas, structural benches Down-slope shape: Linear Across-slope shape: Convex, linear Parent material: Eolian deposits derived from sandstone **Properties and qualities** Slope: 2 to 6 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 5 percent Gypsum, maximum content: 2 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Sodium adsorption ratio, maximum: 10.0 Available water capacity: Moderate (about 8.6 inches) **Interpretive groups** Land capability (nonirrigated): 6e Ecological site: Semidesert Sandy Loam (Fourwing Saltbush) (R035XY215UT) **Typical profile** 0 to 3 inches: Fine sandy loam 3 to 32 inches: Fine sandy loam 32 to 60 inches: Loamy fine sand **Minor Components Mido** Percent of map unit: 8 percent **Mivida** Percent of map unit: 5 percent **Ignacio** Percent of map unit: 5 percent **Windwhistle** Percent of map unit: 5 percent **Rock outcrop** Percent of map unit: 2 percent

Canyonlands Area, Utah - Parts of Grand and San Juan Counties 8—Begay fine sandy loam, moist, 2 to 6 percent slopes Map Unit Setting Elevation: 5,800 to 6,300 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 45 to 49 degrees F Frost-free period: 100 to 120 days **Map Unit Composition** Begay and similar soils: 75 percent Minor components: 25 percent **Description of Begay Setting** Landform: Cuestas, structural benches Down-slope shape: Linear Across-slope shape: Convex, linear Parent material: Eolian deposits derived from sandstone **Properties and qualities** Slope: 2 to 6 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 5 percent Gypsum, maximum content: 2 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Sodium adsorption ratio, maximum: 10.0 Available water capacity: Moderate (about 8.6 inches) **Interpretive groups** Land capability (nonirrigated): 6e Ecological site: Upland Loam (Basin Big Sagebrush) (R035XY306UT) **Typical profile** 0 to 3 inches: Fine sandy loam 3 to 32 inches: Fine sandy loam 32 to 60 inches: Loamy fine sand **Minor Components Mivida** Percent of map unit: 10 percent **Mido** Percent of map unit: 10 percent **Ignacio** Percent of map unit: 5 percent

Canyonlands Area, Utah - Parts of Grand and San Juan Counties 10—Begay-Rock outcrop-Mido complex, 2 to 35 percent slopes Map Unit Setting Elevation: 5,200 to 6,000 feet Mean annual precipitation: 9 to 12 inches Mean annual air temperature: 49 to 51 degrees F Frost-free period: 120 to 140 days **Map Unit Composition** Begay and similar soils: 35 percent Rock outcrop: 25 percent Mido and similar soils: 15 percent Minor components: 25 percent **Description of Begay Setting** Landform: Structural benches Down-slope shape: Linear Across-slope shape: Linear Parent material: Eolian deposits derived from sandstone **Properties and qualities** Slope: 2 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 5 percent Gypsum, maximum content: 2 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Sodium adsorption ratio, maximum: 10.0 Available water capacity: Moderate (about 8.6 inches) **Interpretive groups** Land capability (nonirrigated): 6e Ecological site: Semidesert Sandy Loam (Fourwing Saltbush) (R035XY215UT) **Typical profile** 0 to 3 inches: Fine sandy loam 3 to 32 inches: Fine sandy loam 32 to 60 inches: Loamy fine sand **Description of Rock Outcrop Setting** Landform: Cliffs, escarpments, ledges Down-slope shape: Linear Across-slope shape: Linear **Description of Mido Setting** Landform: Drainageways Down-slope shape: Linear Across-slope shape: Concave Parent material: Eolian deposits derived from sandstone **Properties and qualities** Slope: 8 to 35 percent Depth to restrictive feature: More than 80 inches Drainage class: Excessively drained Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Gypsum, maximum content: 1 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Sodium adsorption ratio, maximum: 5.0 Available water capacity: Low (about 4.7 inches) **Interpretive groups** Land capability classification (irrigated): 2s Land capability (nonirrigated): 7s Ecological site: Semidesert Sand (Fourwing Saltbush) (R035XY212UT) Other vegetative classification: Semidesert Sand (Four-Wing Saltbush) (035XY212UT_3) **Typical profile** 0 to 27 inches: Loamy fine sand 27 to 60 inches: Fine sand **Minor Components Windwhistle** Percent of map unit: 10 percent **Sazi** Percent of map unit: 5 percent **Redbank** Percent of map unit: 5 percent **Ignacio** Percent of map unit: 5 percent

Canyonlands Area, Utah - Parts of Grand and San Juan Counties 41—Ignacio-Leanto fine sandy loams, 2 to 6 percent slopes Map Unit Setting Elevation: 5,800 to 6,800 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 48 to 50 degrees F Frost-free period: 100 to 130 days **Map Unit Composition** Ignacio and similar soils: 40 percent Leanto and similar soils: 35 percent Minor components: 25 percent **Description of Ignacio Setting** Landform: Cuestas, structural benches Down-slope shape: Linear Across-slope shape: Convex, linear Parent material: Eolian deposits derived from sandstone **Properties and qualities** Slope: 2 to 6 percent Depth to restrictive feature: 20 to 40 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 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Low (about 3.8 inches) **Interpretive groups** Land capability (nonirrigated): 6s Ecological site: Upland Loam (Basin Big Sagebrush) (R035XY306UT) **Typical profile** 0 to 2 inches: Fine sandy loam 2 to 32 inches: Fine sandy loam 32 to 36 inches: Unweathered bedrock **Description of Leanto Setting** Landform: Cuestas, structural benches Down-slope shape: Linear Across-slope shape: Convex, linear Parent material: Eolian deposits derived from sandstone **Properties and qualities** Slope: 2 to 6 percent Depth to restrictive feature: 10 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 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Very low (about 1.8 inches) **Interpretive groups** Land capability (nonirrigated): 7s Ecological site: Upland Loam (Basin Big Sagebrush) (R035XY306UT) **Typical profile** 0 to 15 inches: Fine sandy loam 15 to 19 inches: Unweathered bedrock **Minor Components Begay** Percent of map unit: 10 percent **Mido** Percent of map unit: 6 percent **Rizno** Percent of map unit: 4 percent **Windwhistle** Percent of map unit: 3 percent **Rock outcrop** Percent of map unit: 2 percent

Canyonlands Area, Utah - Parts of Grand and San Juan Counties 51—Mido loamy fine sand, dry, 2 to 8 percent slopes Map Unit Setting Elevation: 5,500 to 6,000 feet Mean annual precipitation: 10 to 12 inches Mean annual air temperature: 49 to 51 degrees F Frost-free period: 120 to 140 days **Map Unit Composition** Mido and similar soils: 72 percent Minor components: 28 percent **Description of Mido Setting** Landform: Cuestas, structural benches Down-slope shape: Linear Across-slope shape: Convex Parent material: Eolian deposits derived from sandstone **Properties and qualities** Slope: 2 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Excessively drained Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Gypsum, maximum content: 1 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Sodium adsorption ratio, maximum: 5.0 Available water capacity: Low (about 4.7 inches) **Interpretive groups** Land capability (nonirrigated): 7s Ecological site: Semidesert Sand (Fourwing

Saltbush) (R035XY212UT) Other vegetative classification: Semidesert Sand (Four-Wing Saltbush) (035XY212UT_3) **Typical profile** 0 to 27 inches: Loamy fine sand 27 to 60 inches: Fine sand **Minor Components Begay** Percent of map unit: 15 percent **Ignacio** Percent of map unit: 5 percent **Rock outcrop** Percent of map unit: 5 percent **Arches** Percent of map unit: 3 percent

Canyonlands Area, Utah - Parts of Grand and San Juan Counties 52—Mivida fine sandy loam, 2 to 8 percent slopes Map Unit Setting Elevation: 5,000 to 5,400 feet Mean annual precipitation: 9 to 11 inches Mean annual air temperature: 51 to 53 degrees F Frost-free period: 140 to 150 days **Map Unit Composition** Mivida and similar soils: 90 percent Minor components: 10 percent **Description of Mivida Setting** Landform: Cuestas Down-slope shape: Linear Across-slope shape: Convex Parent material: Eolian deposits derived from sandstone **Properties and qualities** Slope: 2 to 8 percent Depth to restrictive feature: 40 to 60 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 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 40 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Low (about 5.4 inches) **Interpretive groups** Land capability (nonirrigated): 7e Ecological site: Semidesert Sandy Loam (Fourwing Saltbush) (R035XY215UT) **Typical profile** 0 to 4 inches: Fine sandy loam 4 to 15 inches: Fine sandy loam 15 to 43 inches: Fine sandy loam 43 to 47 inches: Unweathered bedrock **Minor Components Begay** Percent of map unit: 5 percent **Redbank** Percent of map unit: 5 percent

Canyonlands Area, Utah - Parts of Grand and San Juan Counties 72—Rock outcrop Map Unit Composition Rock outcrop: 100 percent **Description of Rock Outcrop Setting** Landform: Cliffs, escarpments Down-slope shape: Linear Across-slope shape: Linear

Canyonlands Area, Utah - Parts of Grand and San Juan Counties 104—Windwhistle-Sazi very fine sandy loams, 1 to 3 percent slopes Map Unit Setting Elevation: 5,600 to 6,000 feet Mean annual precipitation: 9 to 12 inches Mean annual air temperature: 49 to 51 degrees F Frost-free period: 120 to 140 days **Map Unit Composition** Windwhistle and similar soils: 40 percent Sazi and similar soils: 35 percent Minor components: 25 percent **Description of Windwhistle Setting** Landform: Cuestas, structural benches Down-slope shape: Linear Across-slope shape: Convex, linear Parent material: Eolian deposits derived from sandstone **Properties and qualities** Slope: 1 to 3 percent Depth to restrictive feature: 20 to 40 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 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 25 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Sodium adsorption ratio, maximum: 5.0 Available water capacity: Low (about 5.0 inches) **Interpretive groups** Land capability (nonirrigated): 7e Ecological site: Semidesert Sandy Loam (Fourwing Saltbush) (R035XY215UT) **Typical profile** 0 to 2 inches: Very fine sandy loam 2 to 25 inches: Very fine sandy loam 25 to 38 inches: Loamy very fine sand 38 to 42 inches: Unweathered bedrock **Description of Sazi Setting** Landform: Cuestas, structural benches Down-slope shape: Linear Across-slope shape: Convex, linear Parent material: Eolian deposits derived from sandstone **Properties and qualities** Slope: 1 to 3 percent Depth to restrictive feature: 20 to 40 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 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 25 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Low (about 4.3 inches) **Interpretive groups** Land capability (nonirrigated): 7e Ecological site: Semidesert

Sandy Loam (Fourwing Saltbush) (R035XY215UT) **Typical profile** 0 to 2 inches: Very fine sandy loam 2 to 17 inches: Very fine sandy loam 17 to 32 inches: Very fine sandy loam 32 to 36 inches: Unweathered bedrock **Minor Components Sazi** Percent of map unit: 10 percent **Begay** Percent of map unit: 10 percent **Ignacio** Percent of map unit: 3 percent **Strych** Percent of map unit: 2 percent

4.3.2 Soil semi-variogram description

The goal of this aspect of the site characterization is to determine the minimum distance between the soil plots in the soil array such that data farther apart can be considered spatially independent. The collected field data will be used to produce semivariograms, which is a geostatistical technique to characterize spatial autocorrelation between mapped samples of a quantitative variable (*e.g.*, soil property data in our case). In an empirical semivariogram, the average of the squared differences of a response variable is computed for all pairs of points within specified distance intervals (lag classes). The output is presented graphically as a plot of the average semi-variance versus distance class (Figure 25). For the theoretical variogram models considered here, the semivariance will converge on the total variance at distances for which values are no longer spatially auto-correlated (this is referred to as the range, Figure 25).

For the theoretical variograms considered here, three parameters estimated from the data are used to fit a semivariogram model to the empirical semivariogram. This model is then assumed to quantitatively represent the correlation as a function of distance (Figure 25), the range, the sill (the sill is the asymptotic value of semi-variance at the range), and the nugget (which describes sampling error or variation at distances below those separating the closest pairs of samples). The range, sill and nugget are estimated from theoretical models that are fitted to the empirical variograms using non-linear least squares methods.

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

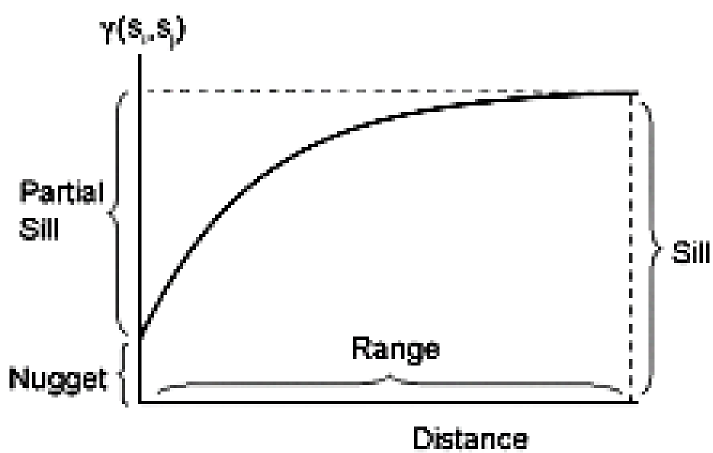


Figure 25. Example semivariogram, depicting range, sill, and nugget.

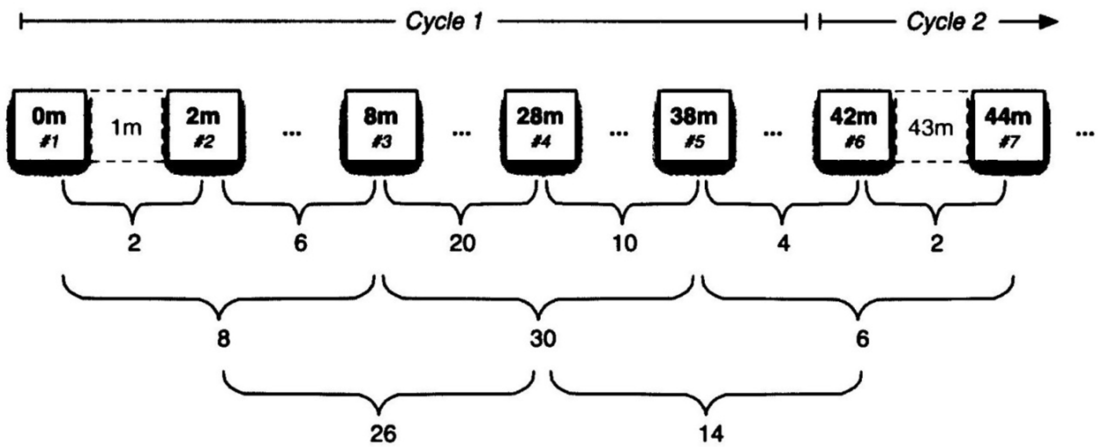


Figure 26. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 6 October 2010 at the Moab site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 26). Soil temperature and moisture measurements were collected along three transects (210 m, 84 m, and 84 m) located in the expected airshed at Moab. Details of how the airshed was determined are provided below. Soil temperature was measured with platinum resistance temperature sensors (RTD 810, Omega Engineering Inc., Stamford CT) and soil moisture was measured with time domain diaelectric sensors (CS616, Campbell Scientific Inc., Logan UT).

As well as measuring soil temperature and moisture at each sample point in Figure 26, measurements were also taken 30 cm in front and behind the sampling point along the axis of the transect. For example, at the 2 m sampling point, soil temperature and moisture was measured at 1.7 m, 2 m, and 2.3 m; this data is referred to as mobile data, since the measurements were taken at many different locations. In addition, soil temperature and moisture were continuously recorded at a single fixed location (stationary data) throughout the sampling time to correct for changes in temperature and moisture throughout the day.

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

4.3.3 Results and interpretation

4.3.3.1 Soil Temperature

Soil temperature data residuals, after accounting for changes in temperature in the stationary data and any remaining time of day trend, were used for the semivariogram analysis (Figure 27). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 28, left graph) and directional semivariograms do not show anisotropy (Figure 28, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 28, right graph). The model indicates a distance of effective independence of 16 m for soil temperature.

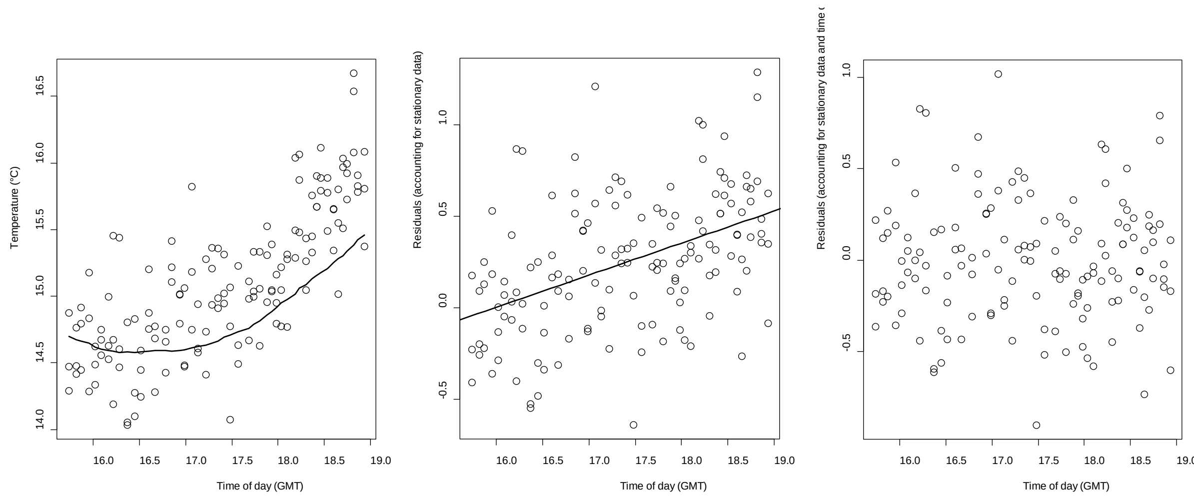


Figure 27. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting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

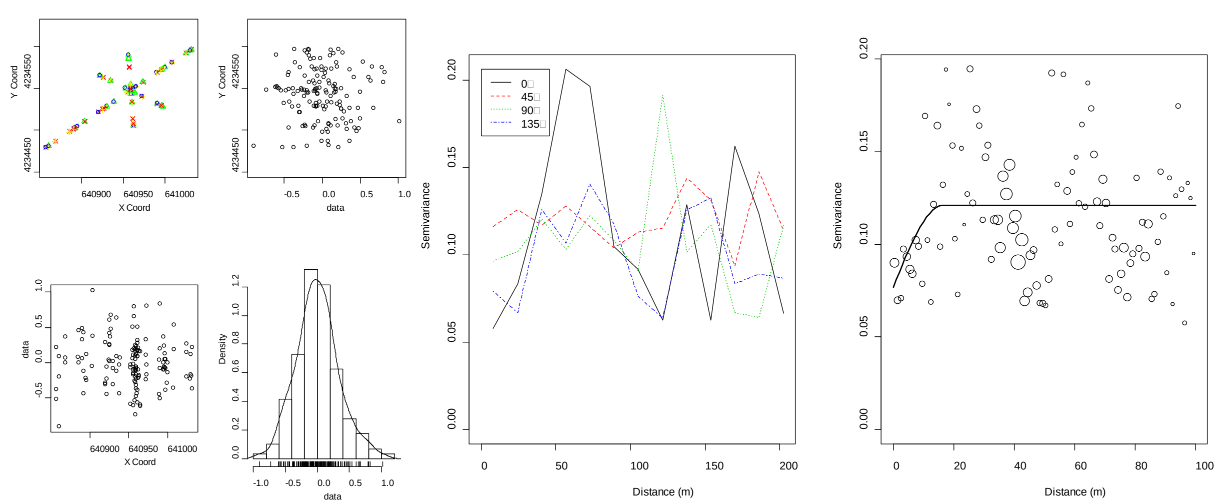


Figure 28. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

4.3.3.2 Soil water content

Soil water content data residuals, after accounting for changes in water content in the stationary data and any remaining time of day trend, were used for the semivariogram analysis (Figure 29). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 30, left graph) and directional semivariograms do not show anisotropy (Figure 30, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 30, right graph). The model indicates a distance of effective independence of 37 m for soil water content.

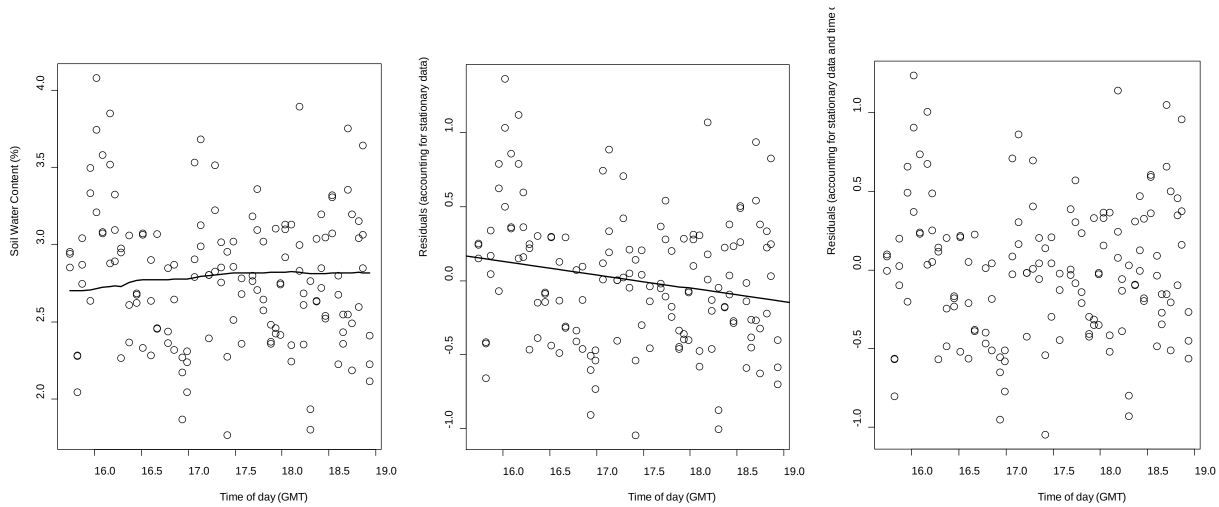


Figure 29. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting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

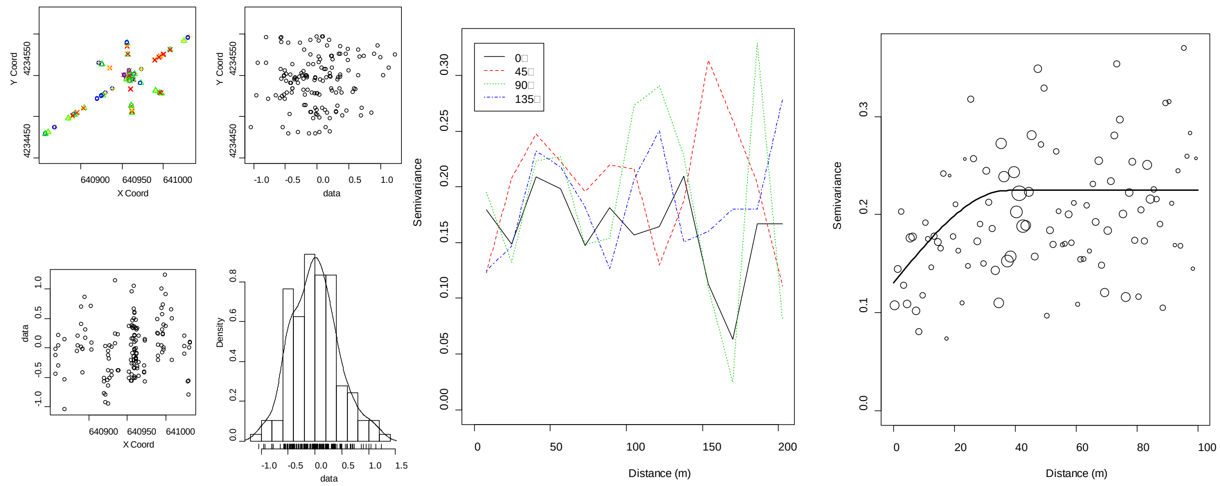


Figure 30. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

4.3.3.3 Soil array layout and soil pit location

The minimum distance allowable between soil plots is 25 m to ensure a degree of spatial independence in non-measured soil parameters (i.e., other than temperature and water content) and the maximum distance allowable between soil plots is 40 m due to cost constraints. The estimated distance of effective independence was 16 m for soil temperature and 37 m for soil moisture. Based on these results and the site design guidelines the soil plots at Moab shall be placed 37 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 250° from the soil plot nearest the tower (i.e., first soil plot). The location of the first soil plot will be approximately 38.24823, -109.38844. 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 38.251343°, -109.388814° (primary location); or 38.251157°, -109.389337° (alternate location 1 if primary location is unsuitable); or 38.250921°, -109.389868° (alternate location 2 if primary location is unsuitable). A summary of the soil information is shown in Table 10 and site layout can be seen in Figure 31.

Dominant soil series at the site: Windwhistle-Sazi very fine sandy loams, 1 to 3 percent slopes- Begay fine sandy loam, 2 to 6 percent slopes. The taxonomy of this soil is shown below:
Order: Aridisols
Suborder: Argids- Calcids- Cambids
Great group: Calciargids- Haplocalcids- Haplocambids
Subgroup: Ustic Calciargids- Ustic Haplocalcids- Ustic Haplocambids
Family: Coarse-loamy, mixed, superactive, mesic Ustic Calciargids- Coarse-loamy, mixed, superactive, mesic Ustic Haplocalcids- Coarse-loamy, mixed, superactive, mesic Ustic Haplocambids

Series: Windwhistle-Sazi very fine sandy loams, 1 to 3 percent slopes- Begay fine sandy loam, 2 to 6 percent slopes

Table 10. Summary of soil array and soil pit information at Moab. 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	37 m
Distance from tower to closest soil plot: y	19 m
Latitude and longitude of 1st soil plot OR direction from tower	38.24823, -109.38844
Direction of soil array	250°
Latitude and longitude of FIU soil pit 1	38.251343°, -109.388814° (primary location)
Latitude and longitude of FIU soil pit 2	38.251157°, -109.389337° (alternate 1)
Latitude and longitude of FIU soil pit 3	38.250921°, -109.389868° (alternate 2)
Dominant soil type	Windwhistle-Sazi very fine sandy loams, 1 to 3 percent slopes- Begay fine sandy loam, 2 to 6 percent slopes
Expected soil depth	0.50 to >2 m
Depth to water table	>2 m

Expected depth of soil horizons	**Expected measurement depths***
0-0.05 m (Very fine sandy loam)	0.03 m†
0.05-0.64 m (Very fine sandy loam)	0.35 m†
0.64-0.97 m (Loamy very fine sand)	0.81 m†
0.97-1.07 m (Unweathered bedrock)	1.02 m

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

†Expected depth of soil CO_2 sensors

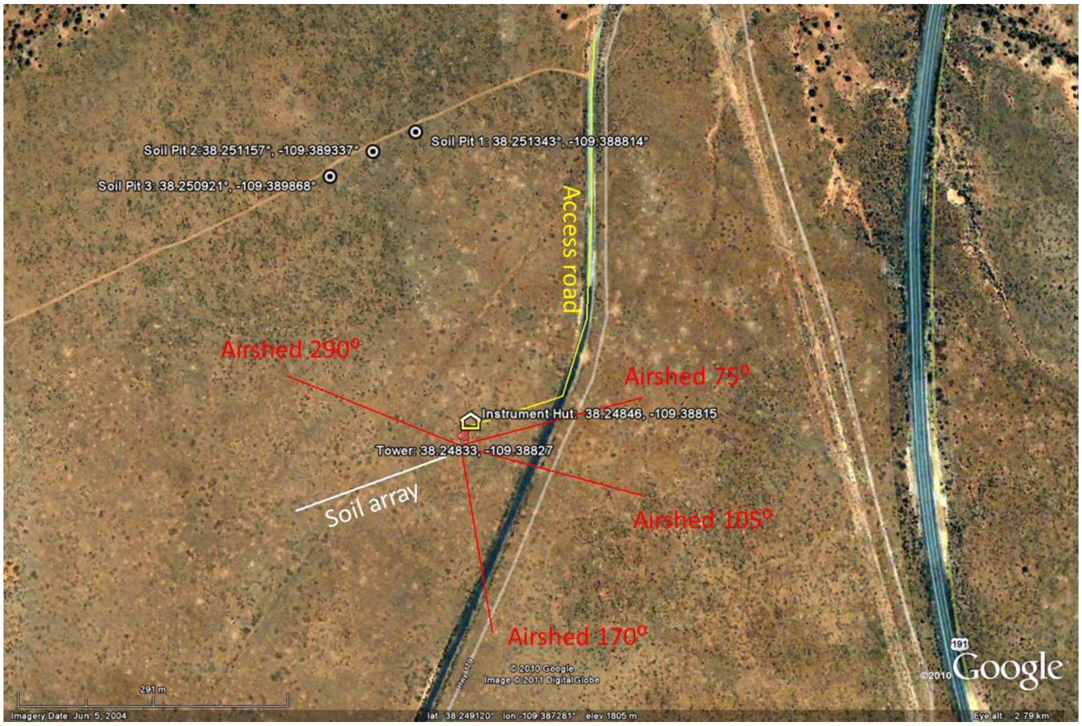


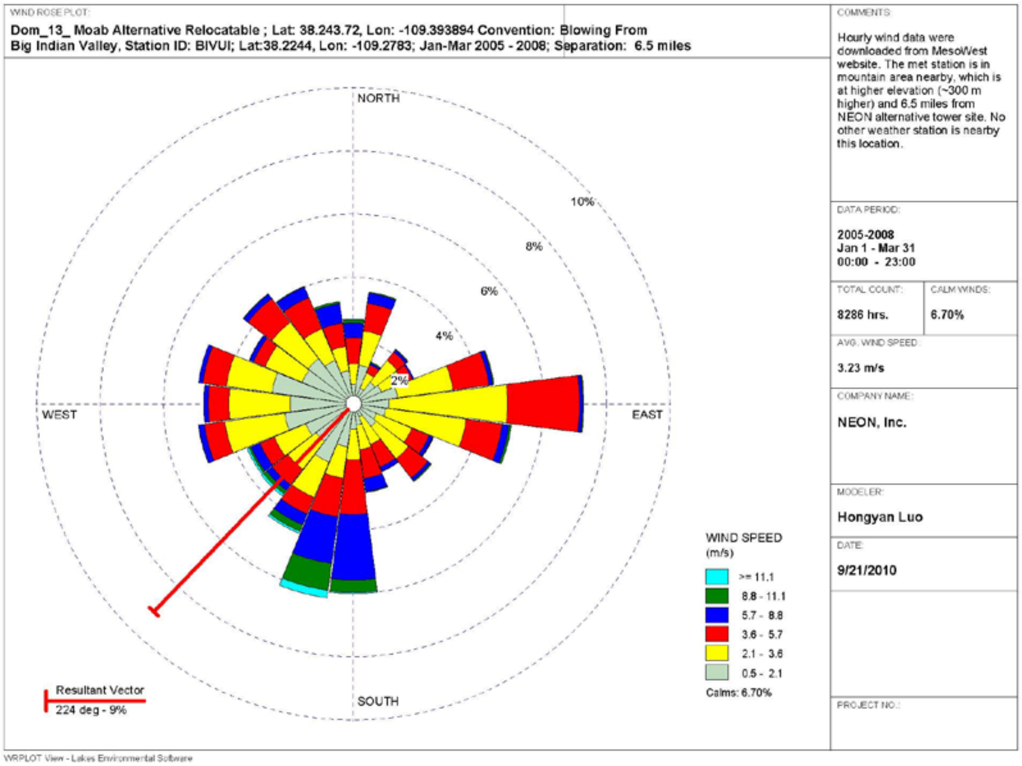
Figure 31. Site layout at Moab showing soil array and location of the FIU soil pits.

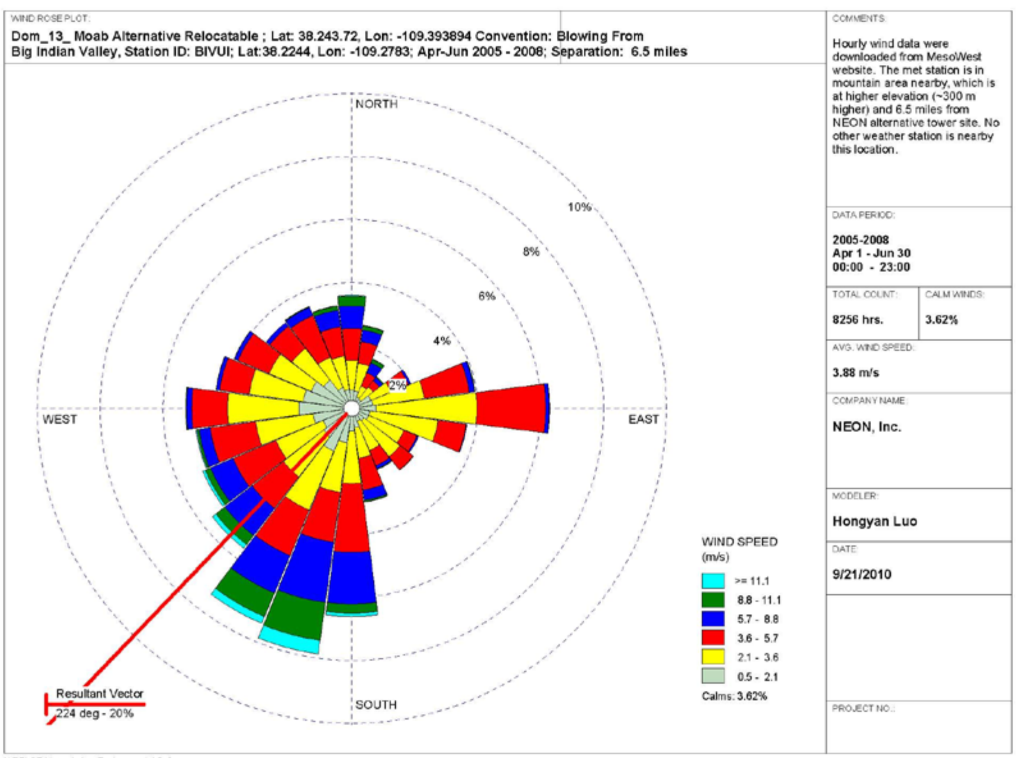
4.4 Airshed

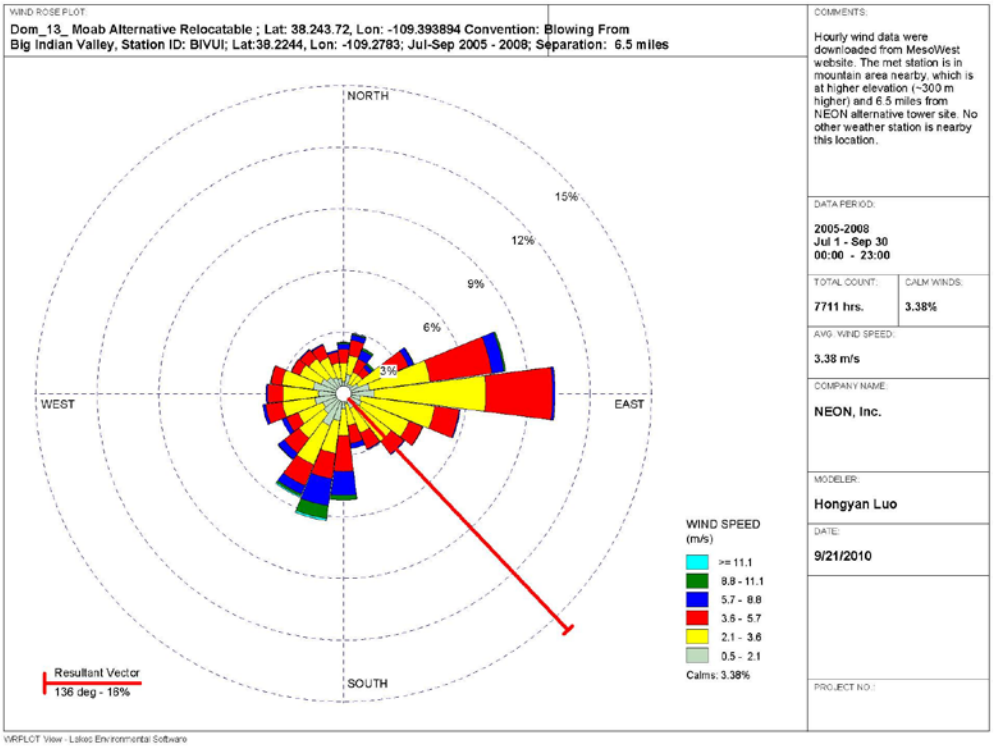
4.4.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries. The weather data used to generate the following wind roses are 2005-2008 data from MesoWest station at Big Indian (Station ID: BIVUI) at 38.2244, -109.2785, which is ~6.5 miles from tower site but at higher elevation (MesoWest website: http://mesowest.utah.edu/index.html). The orientation of the wind rose follows that of a compass (assume declination applied). When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 24 cardinal directions.

4.4.2 Results (graphs for wind roses)







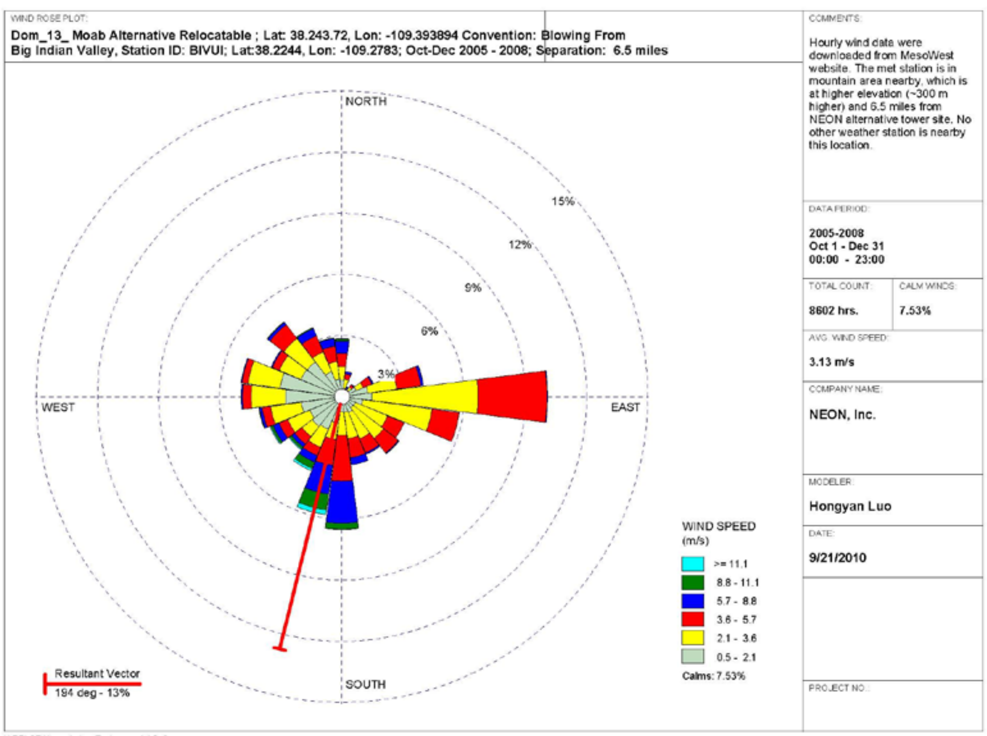


Figure 32. Windroses from Moab Relocatable site.

The weather data used to generate the following wind roses are 2005-2008 data from MesoWest station at Big Indian (Station ID: BIVUI) at 38.2244° -109.2785° (Lat Long), which is ~6.5 miles from tower site but at a higher elevation. It is assumed that the wind data was corrected for declination. Panels are (from top to bottom) Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

4.4.3 Resultant vectors

Table 11. The resultant wind vectors from Moab using hourly data in 2005-2008.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	224°	9
April to June	224°	20
July to September	136°	16
October to December	194°	13
Annual mean	194.5°	na.

4.4.4 Expected environmental controls on source area

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

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

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

Table 12. Expected environmental controls to parameterize the source area model and associated results from Moab 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	6	6	6	6	6	6	m
Canopy Height	0.3	0.3	0.3	0.3	0.3	0.3	m
Canopy area density	0.5	0.5	0.5	0.3	0.3	0.3	m
Boundary layer depth	3000	3000	1800	1800	1800	900	m
Expected sensible heat flux	700	700	175	320	320	-30	W m^{-2}
Air Temperature	35	35	29	22	22	14	°C
Max. windspeed	11.6	4.6	2.6	13	4.6	2.6	m s^{-1}
Resultant wind vector	195	195	90	195	195	90	degrees
Results							
(z-d)/L	-0.06	-0.63	-0.81	-0.02	-0.37	2.4	m
d	0.17	0.17	0.17	0.16	0.16	0.16	m
Sigma v	2.9	2.4	1.3	2.4	1.7	1.7	m^2 s^{-2}
Z0	0.03	0.03	0.03	0.02	0.02	0.02	m
u*	0.89	0.41	0.24	0.96	0.38	0.09	m s^{-1}
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	750	300	250	800	400	2600	m
Distance of 80% cumulative flux	450	200	200	480	250	1900	m
Distance of 70% cumulative flux	300	150	150	350	200	1400	m
Peak contribution	75	45	35	75	55	315	m

4.4.5 Results (source area graphs)

The tower location in the figures below are for a preliminary site location at 38.243072, -109.393894 used for micrositing and permitting. During the site characterization a new tower location was microsited at 38.24833, -109.38827, which is ~ 750 m northeast from the point in the graphs. Terrain is flat. We assume the footprint analysis presented here, is very similar to the new location a few hundred meters away, hence also apply to the new tower location.

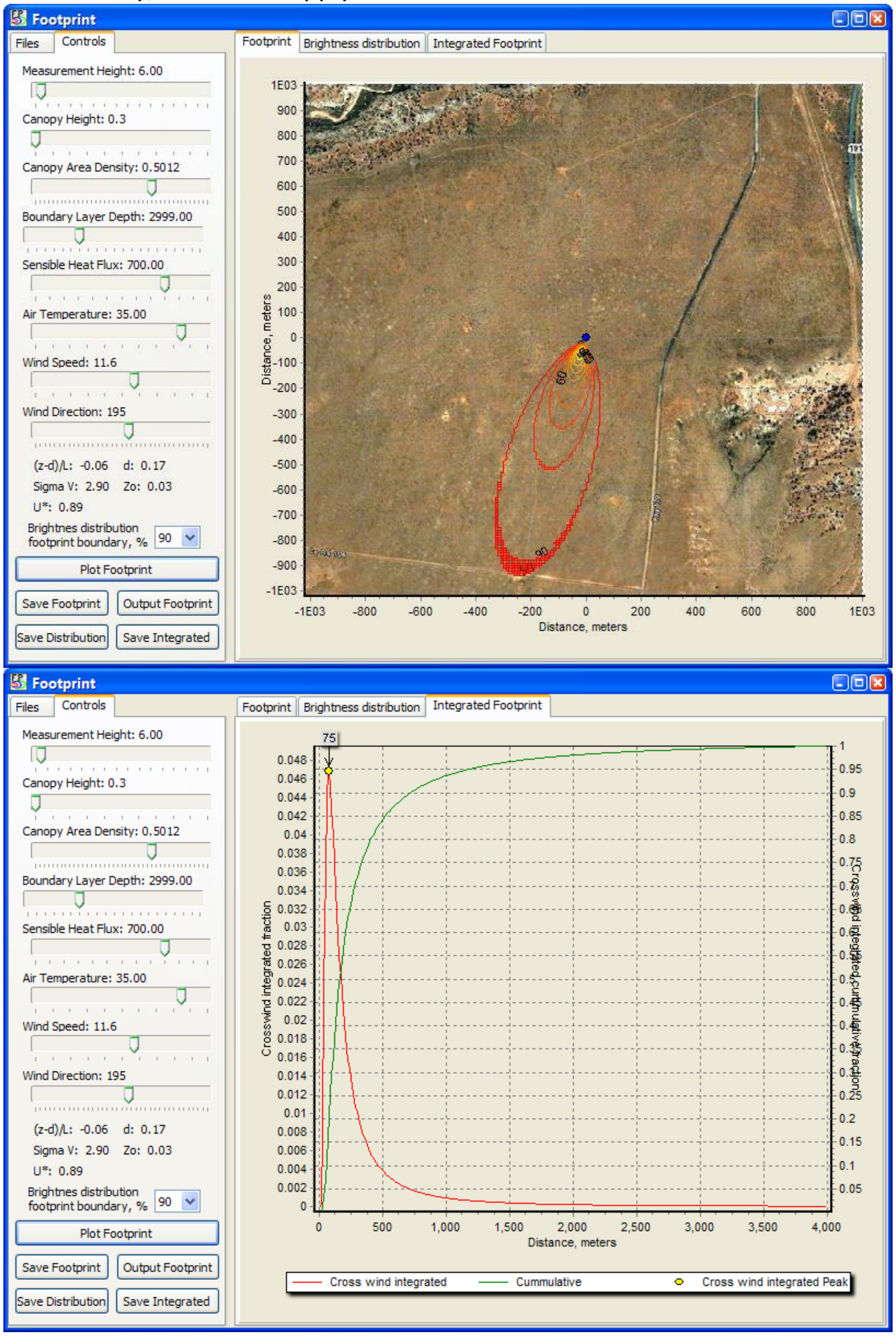


Figure 33. Moab Relocatable site summer daytime (convective) footprint output with max wind speed

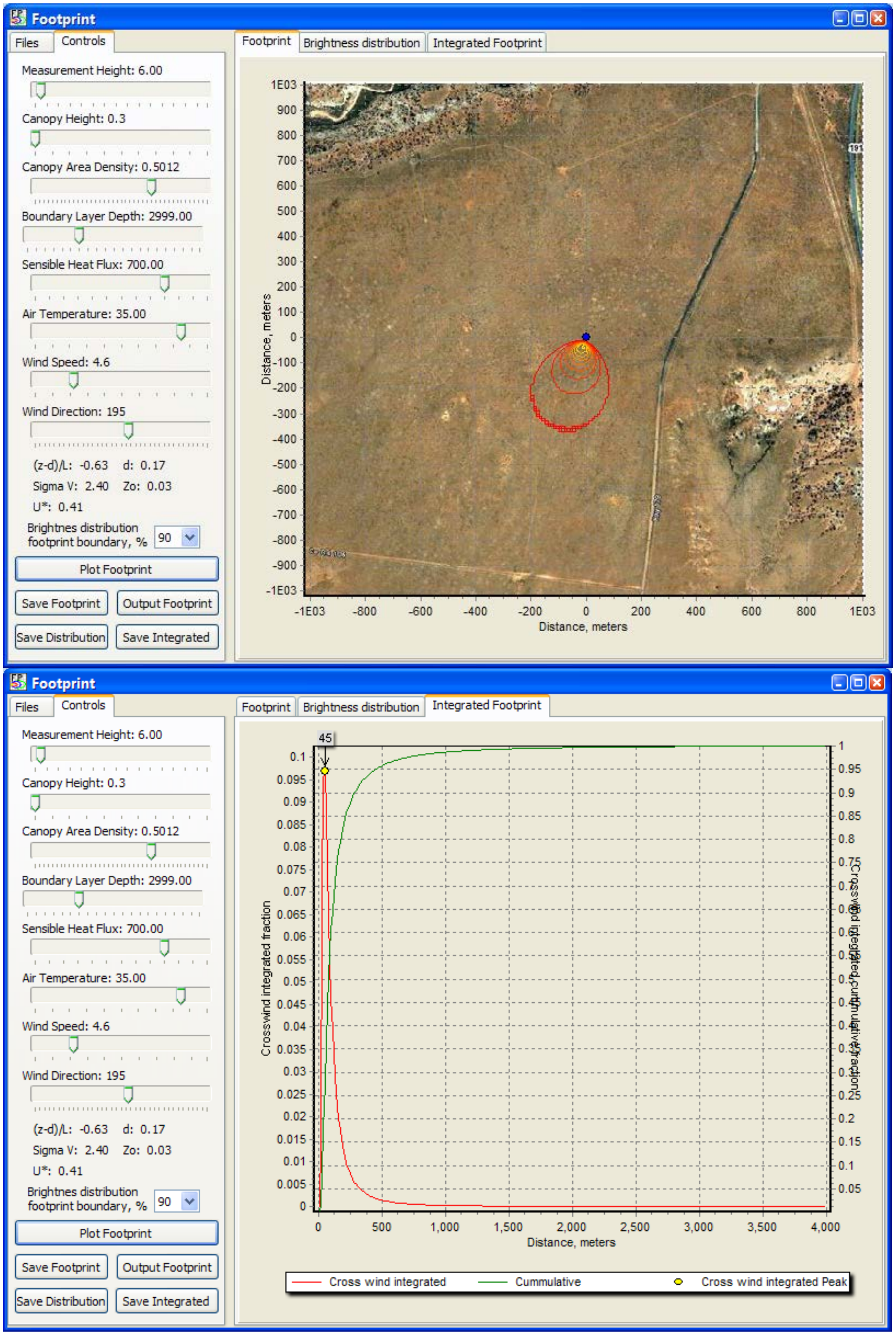


Figure 34. Moab Relocatable site summer daytime (convective) footprint output with mean wind speed

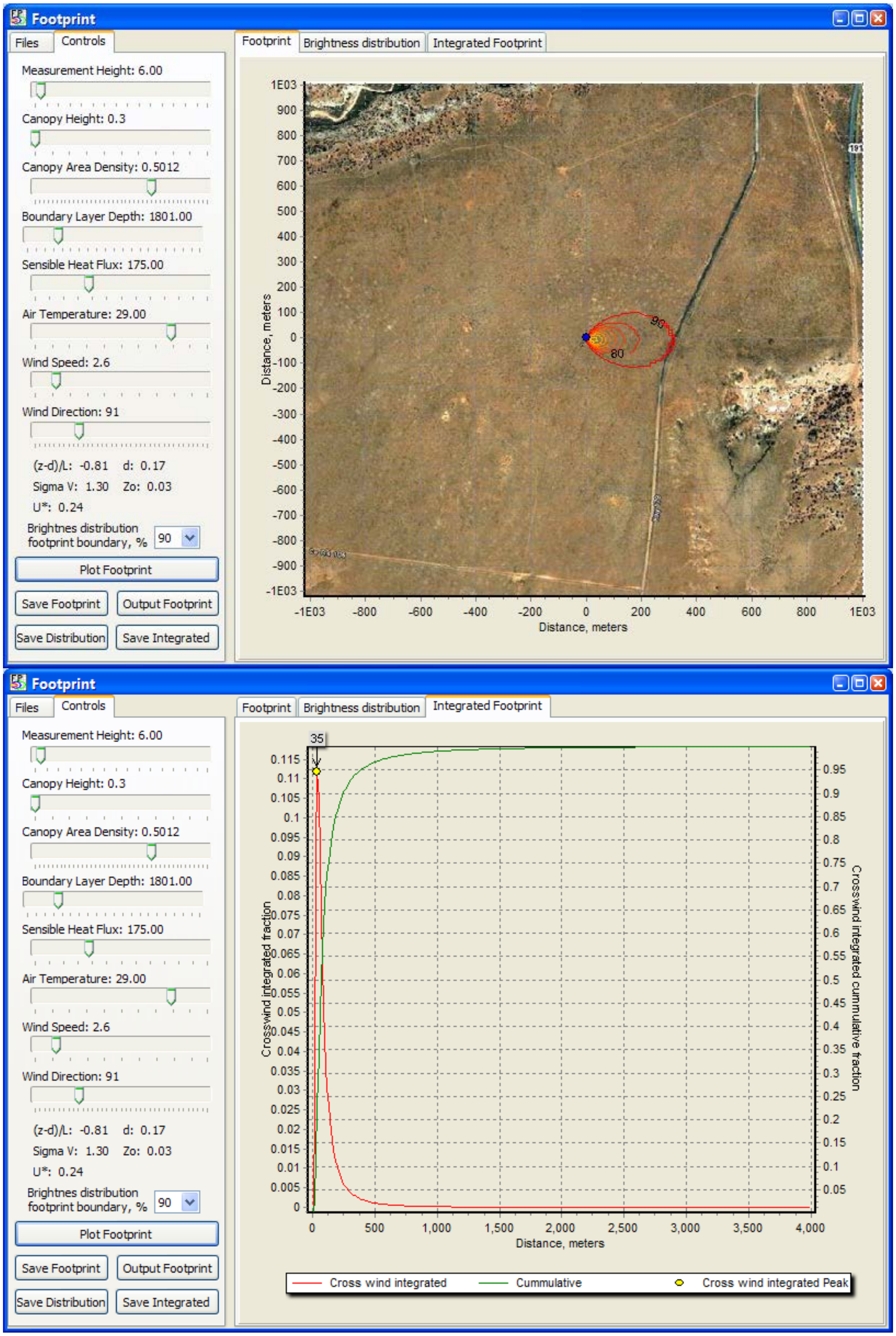


Figure 35. Moab Relocatable site summer nighttime (stable) footprint output with mean wind speed.

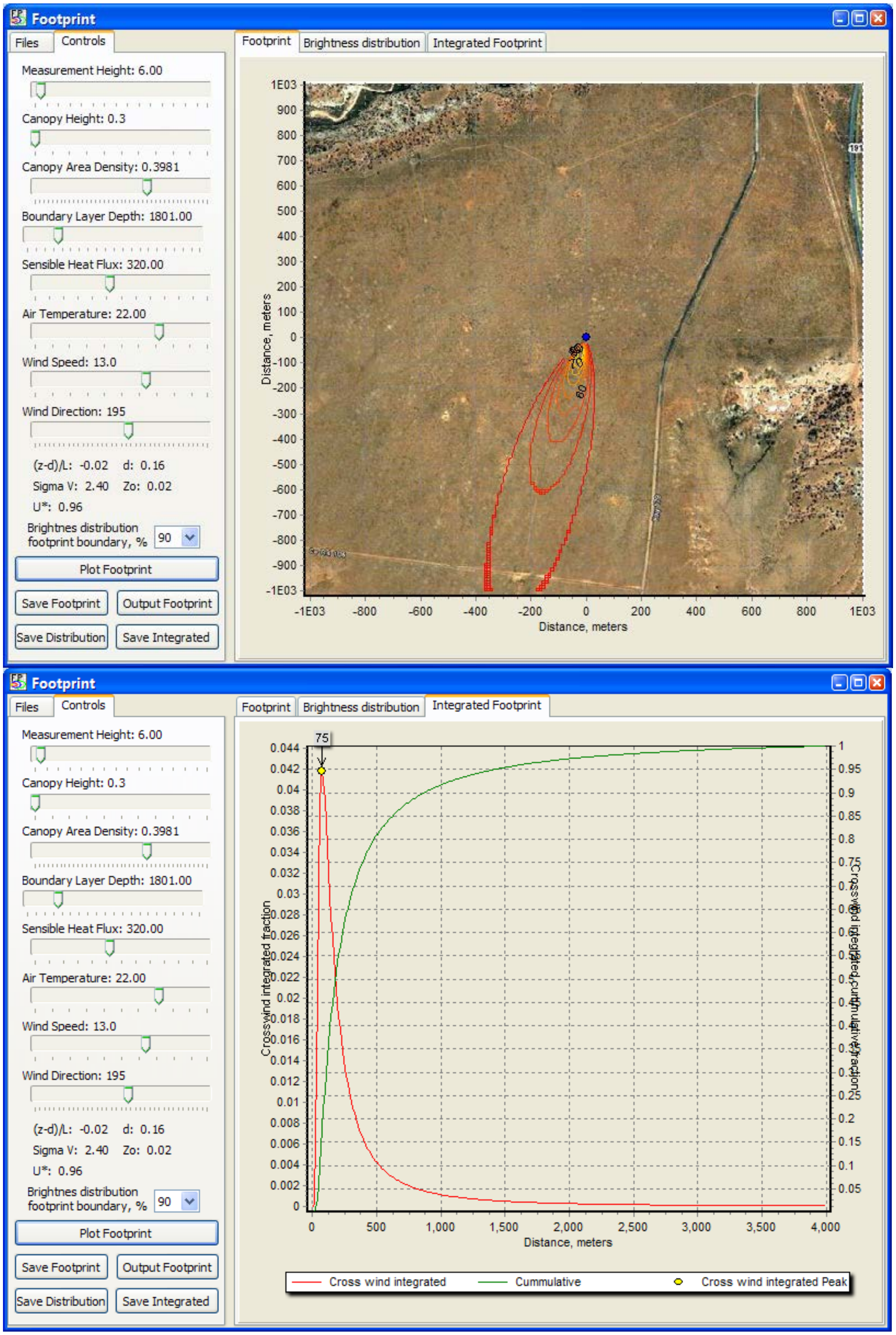


Figure 36. Moab Relocatable site winter daytime (convective) footprint output with max wind speed

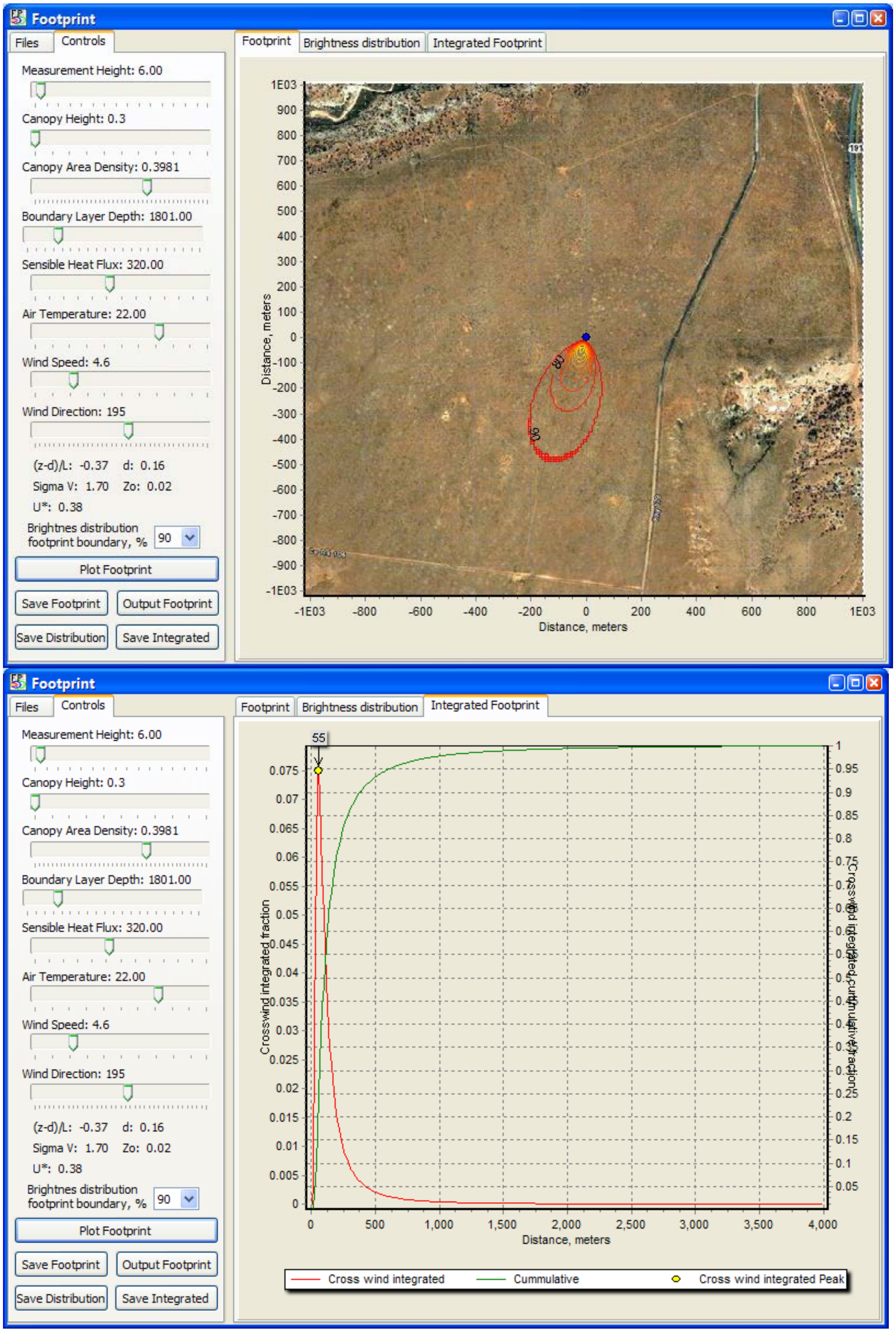


Figure 37. Moab Relocatable site winter daytime (convective) footprint output with mean wind speed.

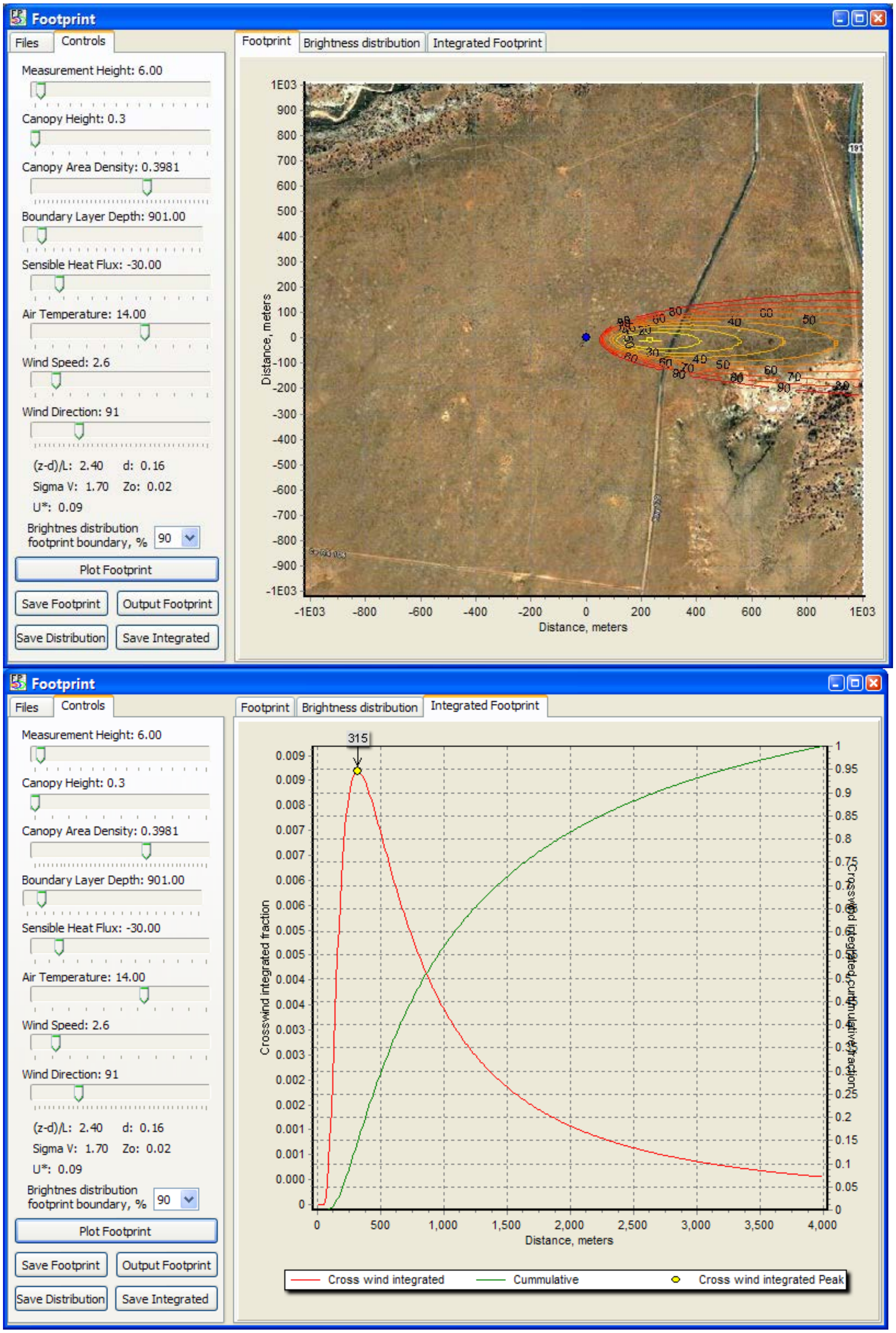


Figure 38. Moab Relocatable site winter nighttime (stable) footprint output with mean wind speed.

4.5 Site design and tower attributes

According to wind roses, wind can blow from any direction, but higher frequency wind blows from east (from 75° to 105°, clockwise from 75°, major airshed, especially at nighttime) and between 170° and 290° (clockwise from 170°, secondary airshed). This site is one of the NEON sites across Rocky Mountain to measure dust generation, transportation and deposition. According to local experience, dust generally comes from south and west direction. **Tower** should be placed to a location to best capture the signals from the ecosystem in interest. The original tower location (Corral Pocket) was at 38.16145, -109.65947, which is ~30 miles away from the closest power and is logistically difficult for NEON to construct and operate. Working with EHS, FCC and local contacts, FIU determined the new tower location to be at 38.24833, -106.38827.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the south will be best to capture signals from all major wind directions. **Radiation boom arms** should always be facing south to avoid any shadowing effects from the tower structure. An **instrument hut** should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind and should be positioned to have the longer side parallel to frequent wind direction to minimize the wind effects on instrument huts and to minimize the disturbances of wind regime by instrument hut, and in this case, instrument hut should be positioned on the northeast toward tower and have the longer side parallel to E-W direction. Therefore, we decide the placement of instrument hut at 38.24846, -109.38815.

The ecosystem around tower site and in the major tower airshed consists of a mix of grasses (including *Boutilua* spp.) and forbs with a uniform distribution. Canopy height is ~ 20 cm. Bare ground accounts for ~60% of the surface. We require 4 **measurement layers** on the tower with top measurement height at 6 m, and the remaining levels are 4 m, 2 m and 0.2 m, respectively, to best characterize the fluxes on the tower top and environmental conditions in profile.

Secondary **precipitation collector** for bulk precipitation collection will be located the top of tower at this site. W**et deposition collector** will be collocated 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. . The side of the tower with the anemometer boom is perpendicular to the boom direction. **Instrument hut orientation vector** is parallel to the long side of the instrument hut. **Instrument hut distance z** is the distance from the center of tower projection to the center of the instrument hut projection on the ground. The numbering of the **measurement levels** is that the lowest is level one, and each subsequent increase in height is numbered sequentially.

Table 13. Site design and tower attributes for Moab Relocatable site

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

Attribute	lat	long	degree	meters	notes
Airshed area			75° to 105° (major) and		Clockwise from first angle

			170° to 290° (secondary) airshed).		
Tower location	38.24833,	-109.38827	--	--	new site
Instrument hut	38.24846,	-109.38815			
Instrument hut orientation vector	--	--	90° - 270°		
Instrument hut distance z	--	--	--	18	
Anemometer/Temperature boom orientation	--	--	180°	--	
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 below shows the proposed tower location, instrument hut location, airshed area and access road.

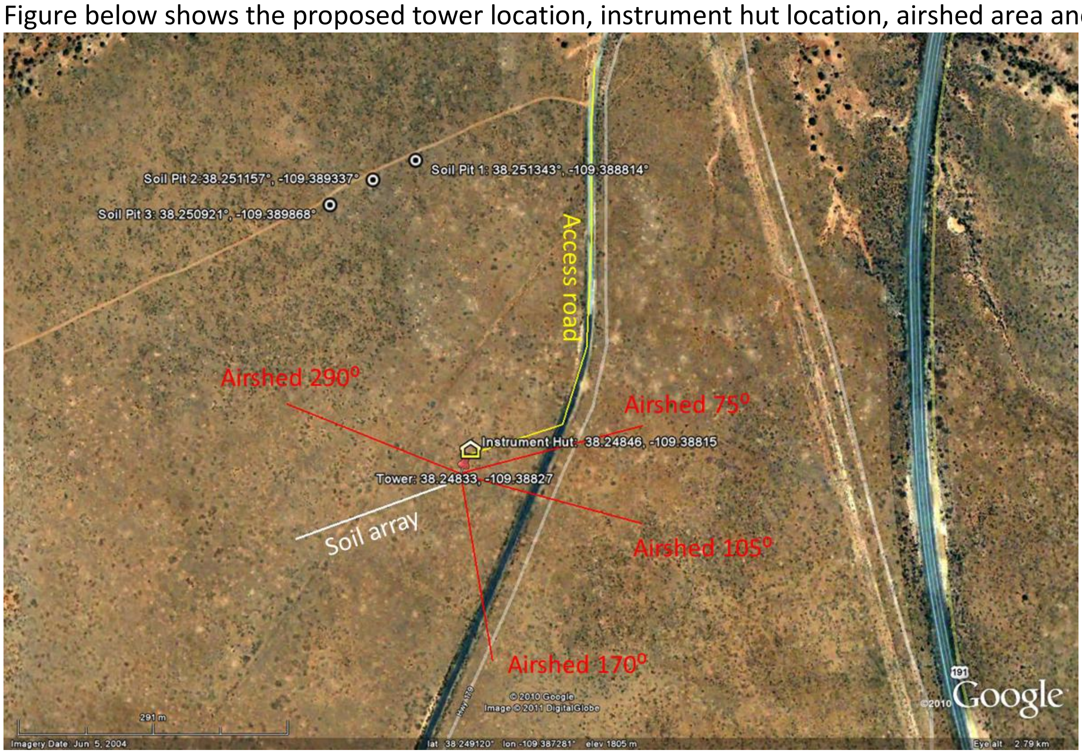


Figure 39. Site layout for Moab Relocatable site.

i) new tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 75° to 105° (clockwise from 75°, major airshed) and 170° to 290° (clockwise from 170°, secondary airshed) 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 Moab Relocatable site

- Boardwalk from the access road to instrument hut, pending landowner decision
- Boardwalk from the instrument hut to the tower to intersect on north face of the tower
- Boardwalk to the soil array
- Boardwalk to individual soil plots, this is because all the soil plots will be in the immediate airshed of the tower, and that the key Relocatable design is dust generation and collection.

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

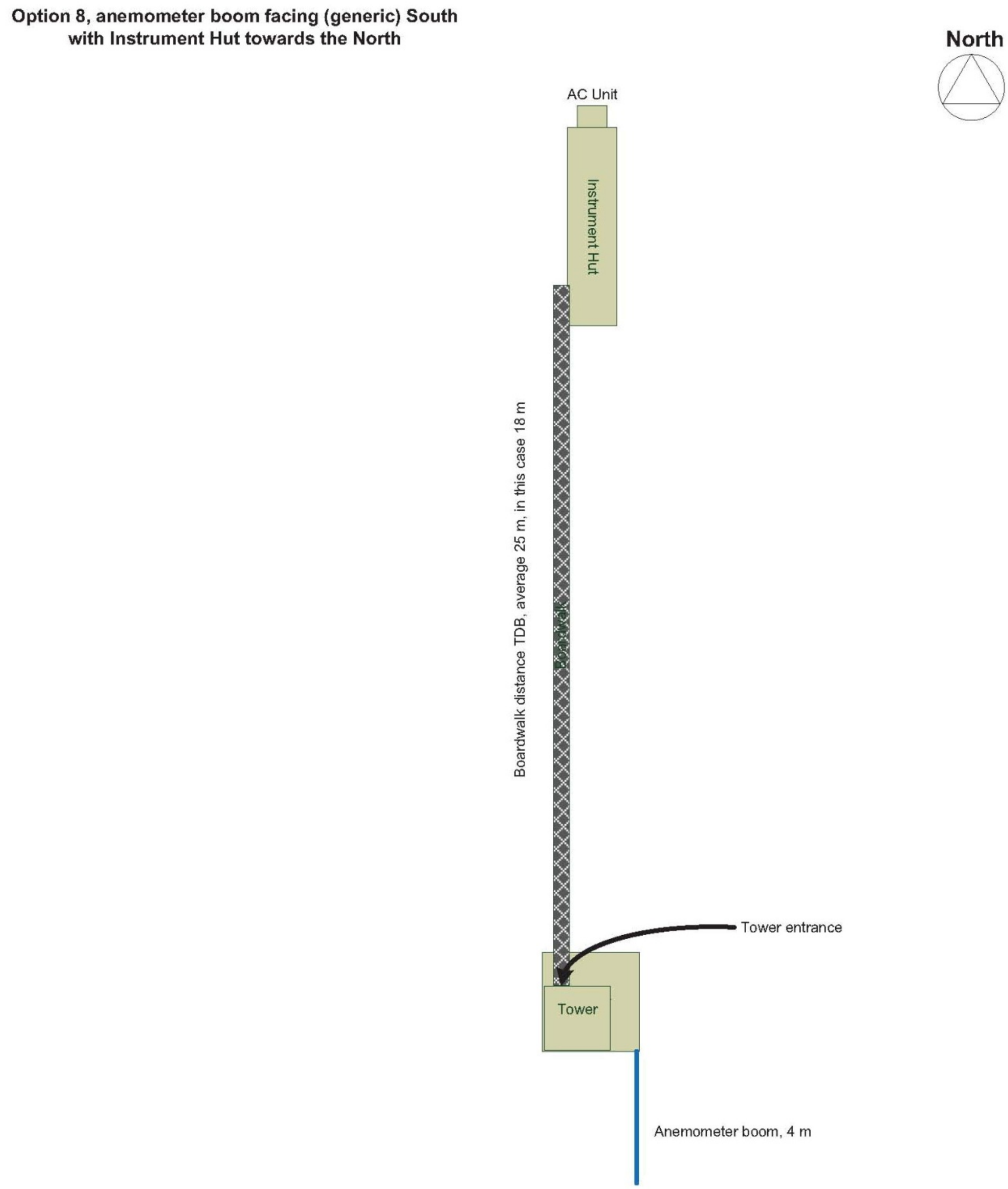


Figure 40. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing south and instrument hut on the north towards the tower.

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 Moab Relocatable site, the boom angle will be 180^o, instrument hut will be on the northeast towards the tower, the distance between instrument hut and tower is ~18 m. The instrument hut vector will be E-W (90^o-270^o, longwise).

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

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

4.6 Information for ecosystem productivity plots

The tower at Moab relocatable site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (grass and forbs). According to wind roses, wind can blow from any direction, but higher frequency winds can come from east (from 75° to 105°, clockwise from 75°, major airshed, especially at nighttime) and between 170° and 290° (clockwise from 170°, secondary airshed). This site is one of the NEON sites across D13 to measure dust generation, transportation and deposition. According to local people's experience, dust is generated from south and west direction. 80% signals for flux measurements during daytime are within a distance of ~400 m from tower (90% within ~700 m). We suggest FSU Ecosystem Productivity plots are placed within the boundaries of 75° to 105° (clockwise from 75°, major airshed, especially at nighttime) and 170° to 290° (clockwise from 170°, secondary airshed) from tower.

4.7 Exclusion Zone

To meet our Product Assurance metrics, our high quality Terrestrial Instrument System (TIS) measurements, and TIS requirements, no sampling, observations, or experiment shall be conducted within the tower exclusion zone without consulting and resolving any issues with TIS scientists as according to the 'NEON Research Collaboration Document' NEON.DOC.004312. The intent is to limit any activities that can either affect the wind flows (e.g., disturbance, buildings, structures, clear cutting, affect changes in structure), or the natural/expected process rates that would adversely affect NEON's data products. Because we cannot think of all such future activities, each will have to be evaluated on a case-by-case basis.

The exclusion zone is an area with these features:

a) The shape of the exclusion zone appears as a pie splice (plan view) with center point of the tower foundation (plan view) as its origin.
b) There may be more than one exclusion zone per tower, depending on the diurnal, seasonal and annual wind patterns.
c) The exclusion zone is a sub-area (i.e., inside) the total tower source area

d) Windrose analyses determine the wind vectors that bound the outside of the exclusion zone, which is clockwise from 75 degrees to 105 degrees at this site (major), and clockwise from 170 to 290 (secondary).

There are two criteria to determine the distance of the exclusion zone from the tower:

1) For all activities mentioned above, the distance from the tower is the maximum value of 90% cumulative flux of the source area at mean maximum wind speed under daytime convective (expected unstable) atmospheres, which is 800 m at this site.
2) Some large disturbance activities also cannot occur in the nighttime tower footprint (because the nighttime tower footprint extends out much farther than the daytime source area). For all high impact activities, the distance from the tower is the maximum value of 80% cumulative flux of the source area at mean maximum wind speed under nighttime, thermally stratified, (expected) stable atmospheric conditions, which is 1900 m at this site.

4.8 Issues and attentions

Dust generation and deposition is the important science theme at this site. The soil, especially the soil crust, is sensitive to disturbance, which results in increased dust generation. **Extra care** must be taken to minimize distrubance at this NEON site.

There was evidense of development of a residential subdivision about 2 km north of the NEON site, but this is not expected to significantly affect NEON data.

5 FRASER , RELOCATEABLE TOWER 2

5.1 Site description

Fraser Experimental Forest is a research station managed by the US Forest Service. According to http://www.fs.fed.us/rm/fraser/: “Fraser... was established in 1937 in the heart of the central Rocky Mountains. …the Rocky Mountain Research Station maintains this 36 square-mile outdoor research laboratory, which is located about 50 air miles from Denver. The location is an ideal and well-suited location to study timber, water, wildlife management, and their integration in the high elevation subalpine coniferous forests. The primary research focus for Fraser has been the effect of management practices on water yield and quality.” The site is west of the continental divide.

The tower location is proposed to be at 39.892670°, -105.891710°, which is very close to the Fraser Experimental Forest office and is at an elevation ~9500’.

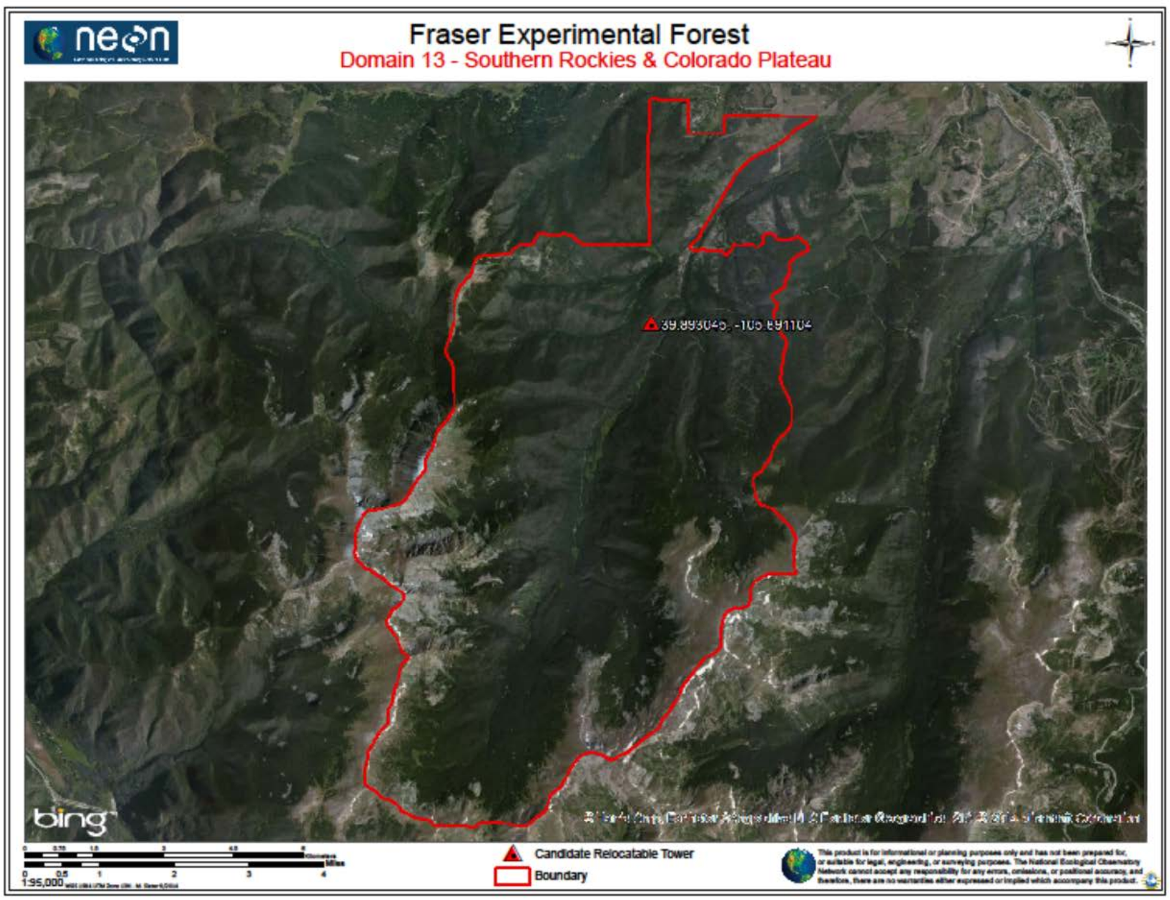


Figure 41. Fraser boundary map and candidate tower location.

5.2 Ecosystem

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

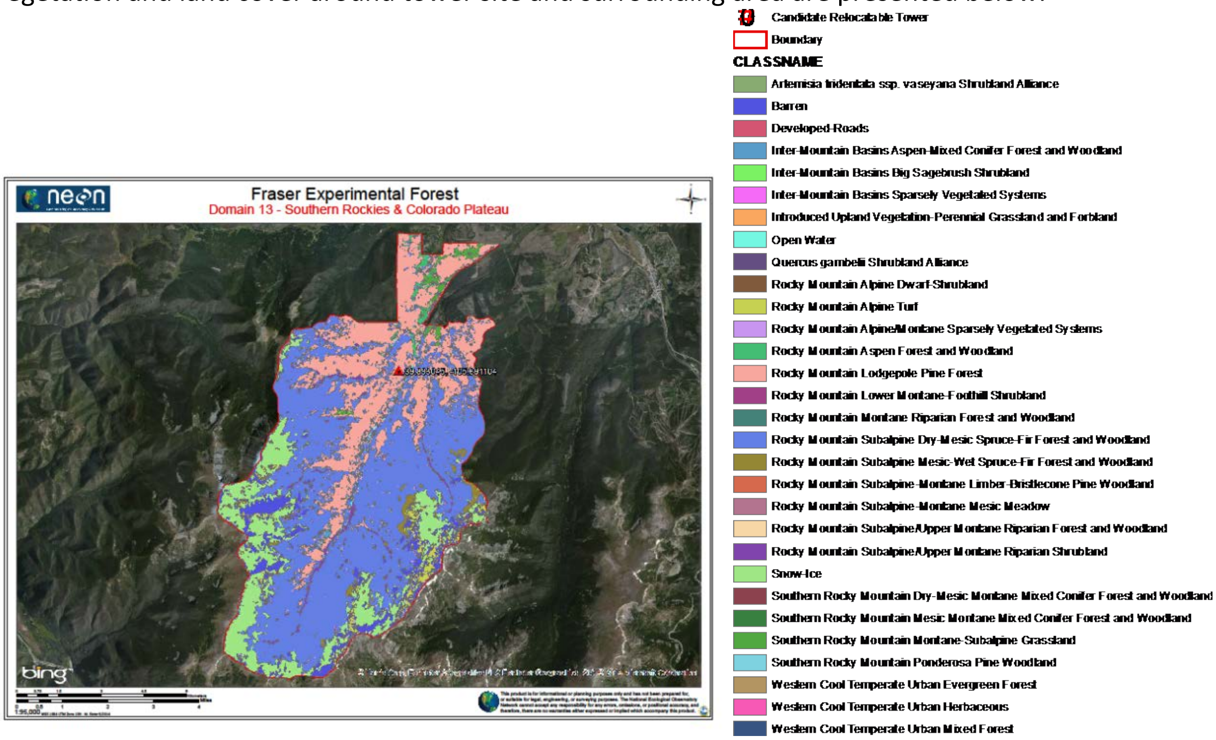


Figure 42. Vegetative cover map of the Fraser relocatable site and surrounding areas (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

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

Veg_Type	Veg_Height	Area_KM2	Percentage
Artemisia tridentata ssp. vaseyana Shrubland Alliance	Shrub Height 0 to 0.5 meters	0.11	0.12
Barren	Barren	5.29	5.81
Developed-Roads	Developed-Roads	0.03	0.03
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	Forest Height 0 to 5 meters	0.02	0.02
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	Forest Height 10 to 25 meters	0.49	0.53
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	Forest Height 5 to 10 meters	0.00	0.00
Inter-Mountain Basins Big Sagebrush Shrubland	Shrub Height 0 to 0.5 meters	0.04	0.04
Inter-Mountain Basins Sparsely Vegetated Systems	Sparse Vegetation Height	0.20	0.22

Introduced Upland Vegetation-Perennial Grassland and Forbland	Herb Height 0 to 0.5 meters	0.00	0.00
Open Water	Open Water	0.29	0.32
Quercus gambelii Shrubland Alliance	Shrub Height 0 to 0.5 meters	0.00	0.00
Rocky Mountain Alpine Dwarf-Shrubland	Shrub Height 0 to 0.5 meters	0.47	0.52
Rocky Mountain Alpine Turf	Herb Height 0 to 0.5 meters	1.68	1.84
Rocky Mountain Alpine/Montane Sparsely Vegetated Systems	Sparse Vegetation Height	0.68	0.74
Rocky Mountain Aspen Forest and Woodland	Forest Height 0 to 5 meters	0.00	0.00
Rocky Mountain Aspen Forest and Woodland	Forest Height 10 to 25 meters	0.71	0.78
Rocky Mountain Aspen Forest and Woodland	Forest Height 5 to 10 meters	0.01	0.01
Rocky Mountain Lodgepole Pine Forest	Forest Height 0 to 5 meters	0.04	0.04
Rocky Mountain Lodgepole Pine Forest	Forest Height 10 to 25 meters	20.74	22.78
Rocky Mountain Lodgepole Pine Forest	Forest Height 5 to 10 meters	0.05	0.05
Rocky Mountain Lower Montane-Foothill Shrubland	Shrub Height 0 to 0.5 meters	0.07	0.08
Rocky Mountain Montane Riparian Forest and Woodland	Forest Height 0 to 5 meters	0.00	0.00
Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland	Forest Height 10 to 25 meters	0.00	0.00
Rocky Mountain Subalpine-Montane Mesic Meadow	Herb Height 0 to 0.5 meters	0.13	0.14
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Forest Height 0 to 5 meters	1.09	1.20
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Forest Height 10 to 25 meters	42.81	47.01
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Forest Height 25 to 50 meters	0.00	0.00
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Forest Height 5 to 10 meters	0.10	0.11
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	Forest Height 0 to 5 meters	0.16	0.17
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	Forest Height 10 to 25 meters	1.13	1.24
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	Forest Height 5 to 10 meters	0.01	0.01

Rocky Mountain Subalpine/Upper Montane Riparian Forest and Woodland	Forest Height 5 to 10 meters	0.00	0.00
Rocky Mountain Subalpine/Upper Montane Riparian Shrubland	Shrub Height 0 to 0.5 meters	1.03	1.13
Rocky Mountain Subalpine/Upper Montane Riparian Shrubland	Shrub Height 0.5 to 1.0 meter	0.09	0.10
Rocky Mountain Subalpine/Upper Montane Riparian Shrubland	Shrub Height 1.0 to 3.0 meters	0.02	0.02
Snow-Ice	Snow/Ice	12.41	13.63
Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	Forest Height 10 to 25 meters	0.00	0.00
Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	Forest Height 10 to 25 meters	0.01	0.01
Southern Rocky Mountain Montane-Subalpine Grassland	Herb Height 0 to 0.5 meters	1.01	1.11
Southern Rocky Mountain Ponderosa Pine Woodland	Forest Height 0 to 5 meters	0.00	0.00
Southern Rocky Mountain Ponderosa Pine Woodland	Forest Height 10 to 25 meters	0.00	0.00
Southern Rocky Mountain Ponderosa Pine Woodland	Forest Height 5 to 10 meters	0.00	0.00
Western Cool Temperate Urban Evergreen Forest	Developed-Upland Evergreen Forest	0.08	0.09
Western Cool Temperate Urban Herbaceous	Developed-Upland Herbaceous	0.00	0.00
Western Cool Temperate Urban Mixed Forest	Developed-Upland Mixed Forest	0.06	0.07
TOTAL		**91.07**	**100.00**

Similar to Niwot ridge core site, the terrain at Fraser relocatable site is complex mountainous terrain. The forest in the vicinity of the tower is dominated by Engelmann spruce (*picea engelmannii)* and mixes with the Lodgepole pine forest, and has a mixed age structure with active recruitment. Many beetle killed trees standing in this forest ecosystem or falling on the forest floor. Tree height ranges from few centimeters on the ground to 22 m above ground without obvious strata. Average top canopy height is ~ 22 m around the proposed tower site with lowest branch level height is at ~2 m for mature spruce trees and ~10m for mature pine trees. We do not expect top canopy height will increase dramatically during the NEON operation at this site, e.g., ~10 y. The vegetation and shrubs at forest floor are ~ 0.20 m to 1 m in height.

Table 15. Ecosystem and site attributes for the Fraser Relocatable site.

Ecosystem attributes	Measure and units
Mean canopy height [a]	22 m
Surface roughness [a]	2 m
Zero place displacement height [a]	18 m
Structural elements	Spruce, pine and fir forest, semi-open canopy, mixed age and height
Time zone	Mountain time zone
Magnetic declination	8.96° E changing by 0.13° W per year

Note, [a] From field survey. Although the forest actively recruits, we do not expect mean canopy height for the top mature canopy change dramatically. Therefore, 22 m canopy height at site characterization is used here for tower height estimate.

Figure 43. Ecosystem at the Fraser Relocatable site

5.3 Soils

5.3.1 Description of soils

Soil data and soil maps below for the Fraser relocatable site were collected from

22.8 km^2 NRCS soil maps (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

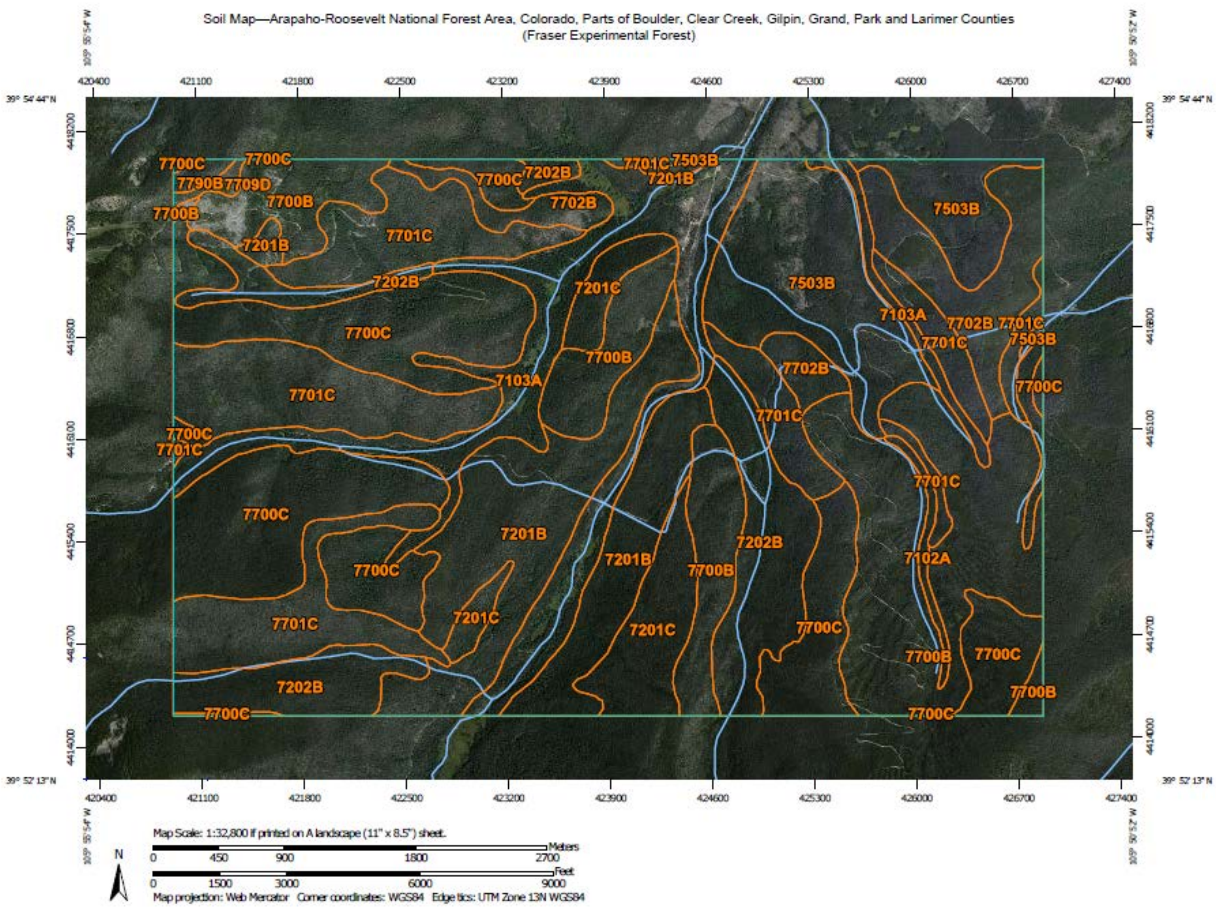


Figure 44. Soil map of the Fraser Relocatable site and surrounding areas

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

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

Table 16. Soil series and percentage of soil series within 22.8 km2 at the Fraser site

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties (CO645)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
7102A	Cryaquepts-Cryaquolls complex, 0 to 15 percent slopes	25.6	0.5%
7103A	Cryaquolls-Leighcan family, till substratum complex, 0 to 15 percent slopes	617.6	11.0%
7201B	Leighcan family, till substratum, 5 to 40 percent slopes	646.3	11.5%
7201C	Leighcan family, till substratum, 40 to 75 percent slopes	234.3	4.2%
7202B	Leighcan family, till substratum-Cryaquolls complex, 5 to 40 percent slopes	461.5	8.2%
7503B	Herd-Frisco families complex, sandstone substratum, 5 to 40 percent slopes	495.4	8.8%
7700B	Leighcan family, 5 to 40 percent slopes	965.4	17.2%
7700C	Leighcan family, 40 to 75 percent slopes	992.0	17.6%
7701C	Leighcan family, 40 to 75 percent slopes, south aspects	853.9	15.2%
7702B	Frisco-Catamount, moist families complex, 5 to 40 percent slopes	303.5	5.4%
7709D	Leighcan family-Rock outcrop complex, 40 to 150 percent slopes, south aspects	12.9	0.2%
7790B	Lithic Cryorthents, subalpine-Rubble land complex, 5 to 40 percent slopes	14.3	0.3%
Totals for Area of Interest		**5,622.8**	**100.0%**

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7701C—Leighcan family, 40 to 75 percent slopes, south aspects Map Unit Setting National map unit symbol: tlyp Elevation: 9,500 to 11,500 feet Mean annual precipitation: 20 to 40 inches Mean annual air temperature: 36 to 39 degrees F Frost-free period: 30 to 50 days Farmland classification: Not prime farmland **Map Unit Composition** Leighcan family, south aspects, and similar soils: 85 percent Estimates are based on observations, descriptions, and transects of the mapunit. **Description of Leighcan Family, South Aspects Setting** Landform: Mountain slopes Parent material: Residuum and/or slope alluvium derived from igneous and metamorphic rock **Typical profile** A - 0 to 2 inches: cobbly silt loam AE - 2 to 9 inches: very cobbly silt loam Bw - 9 to 28 inches: very cobbly sandy loam BCd - 28 to 45 inches: extremely stony loamy sand Cd - 45 to 60 inches: extremely stony loamy sand **Properties and qualities** Slope: 40 to 75 percent Depth to restrictive feature: 20 to 60 inches to densic material Natural drainage class: Somewhat excessively drained Runoff class: High Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Available water storage in profile: Very low (about 2.1 inches) **Interpretive groups** Land capability classification (irrigated): None specified Hydrologic Soil Group: C Other vegetative classification: Lodgepole pine/myrtle whortleberry (PICO/VAMY2) (C0909), Subalpine fir - Engelmann spruce/ myrtle whortleberry (ABLA-PIEN/VAMY2) (C0320)

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7709D—Leighcan family-Rock outcrop complex, 40 to 150 percent slopes, south aspects Map Unit Setting *National map unit symbol:* tlyr *Elevation:* 9,500 to 11,500 feet *Mean annual precipitation:* 20 to 40 inches *Mean annual air temperature:* 36 to 39 degrees F *Frost-free period:* 30 to 50 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Leighcan family, south aspects, and similar soils:* 50 percent *Rock outcrop:* 35 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Leighcan Family, South Aspects Setting** *Landform:* Mountain slopes *Parent material:* Residuum and/or slope alluvium derived from igneous and metamorphic rock **Typical profile** *A - 0 to 2 inches:* cobbly silt loam *AE - 2 to 9 inches:* very cobbly silt loam *Bw - 9 to 28 inches:* very cobbly sandy loam *BCd - 28 to 45 inches:* extremely stony loamy sand *Cd - 45 to 60 inches:* extremely stony loamy sand **Properties and qualities** *Slope:* 40 to 75 percent *Depth to restrictive feature:* 20 to 60 inches to densic material *Natural drainage class:* Somewhat excessively drained *Runoff class:* High *Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water storage in profile:* Very low (about 2.1 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* C *Other vegetative classification:* Subalpine fir/elk sedge (ABLA/ CAGE2) (C0201), Subalpine fir - Engelmann spruce/myrtle whortleberry (ABLA-PIEN/VAMY2) (C0320) **Description of Rock Outcrop Setting** *Landform:* Mountain slopes *Landform position (two-dimensional):* Backslope, summit *Landform position (three-dimensional):* Mountainflank **Typical profile** *R - 0 to 60 inches:* bedrock **Properties and qualities** *Slope:* 60 to 150 percent *Depth to restrictive feature:* 0 inches to lithic bedrock *Runoff class:* Very high *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.06 in/hr) **Interpretive groups** *Land capability classification (irrigated):* None specified *Land capability classification (nonirrigated):* 8

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7103A—Cryaquolls-Leighcan family, till substratum complex, 0 to 15 percent slopes Map Unit Setting *National map unit symbol:* tqlp *Elevation:* 9,000 to 11,000 feet *Mean annual precipitation:* 20 to 40 inches *Mean annual air temperature:* 36 to 39 degrees F *Frost-free period:* 30 to 50 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Cryaquolls and similar soils:* 50 percent *Leighcan family, till substratum, and similar soils:* 40 percent *Minor components:* 3 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Cryaquolls Setting** *Landform:* Drainageways, flood plains, depressions *Parent material:* Gravelly glaciofluvial deposits and/or gravelly till derived from igneous, metamorphic and sedimentary rock **Typical profile** *Oe - 0 to 4 inches:* moderately decomposed plant material *A1 - 4 to 16 inches:* silt loam *A2 - 16 to 24 inches:* silt loam *A3 - 24 to 30 inches:* silt loam *2Cg - 30 to 40 inches:* sandy loam *2Agb - 40 to 64 inches:* silt loam **Properties and qualities** *Slope:* 0 to 15 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* 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

0 inches *Frequency of flooding:* Occasional *Frequency of ponding:* Occasional *Available water storage in profile:* High (about 11.1 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* B/D *Other vegetative classification:* Geyer's willow-willow/reedgrass (SAGE2-SALIX/CALAM) (S1495), Diamondlead willow/water sedge (SAPL2/CAAQ) (S1496) **Description of Leighcan Family, Till Substratum Setting** *Landform:* Mountain slopes, outwash plains *Parent material:* Glacial till and/or alluvium derived from igneous and metamorphic rock **Typical profile** *A - 0 to 2 inches:* cobbly silt loam *AE - 2 to 9 inches:* very cobbly silt loam *Bw - 9 to 28 inches:* very cobbly sandy loam *BCd - 28 to 45 inches:* extremely stony loamy sand *Cd - 45 to 60 inches:* extremely stony loamy sand **Properties and qualities** *Slope:* 0 to 15 percent *Depth to restrictive feature:* 20 to 60 inches to densic material *Natural drainage class:* Somewhat excessively drained *Runoff class:* Medium *Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water storage in profile:* Very low (about 2.1 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* C *Other vegetative classification:* Subalpine fir - Engelmann spruce/ grouse whortleberry (ABLA-PIEN/VASC) (C0321), Subalpine fir - Engelmann spruce/myrtle whortleberry (ABLA-PIEN/VAMY2) (C0320) **Minor Components Cryohemists** *Percent of map unit:* 3 percent

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7102A—Cryaquepts-Cryaquolls complex, 0 to 15 percent slopes Map Unit Setting *National map unit symbol:* tqsc *Elevation:* 8,500 to 10,000 feet *Mean annual precipitation:* 20 to 40 inches *Mean annual air temperature:* 36 to 39 degrees F *Frost-free period:* 30 to 50 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Cryaquepts and similar soils:* 55 percent *Cryaquolls and similar soils:* 30 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Cryaquepts Setting** *Landform:* Drainageways, flood plains, depressions *Parent material:* Colluvium and/or slope alluvium derived from igneous and metamorphic rock **Typical profile** *Oi - 0 to 1 inches:* slightly decomposed plant material *Oe - 1 to 2 inches:* moderately decomposed plant material *A/E - 2 to 8 inches:* gravelly loam *E - 8 to 14 inches:* gravelly sandy loam *Bg - 14 to 20 inches:* very gravelly sandy loam *BCg - 20 to 31 inches:* very gravelly sandy loam *Cg - 31 to 50 inches:* very gravelly sandy loam *Cr - 50 to 62 inches:* bedrock **Properties and qualities** *Slope:* 0 to 15 percent *Depth to restrictive feature:* 40 to 60 inches to paralithic bedrock *Natural drainage class:* Poorly drained *Runoff class:* Medium *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.06 in/hr) *Depth to water table:* About 0 inches *Frequency of flooding:* Occasional *Frequency of ponding:* Occasional *Available water storage in profile:* Low (about 4.3 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* B/D *Other vegetative classification:* Subalpine fir - Engelmann spruce/ reedgrass (ABLA-PIEN/CALAM) (C0305), Subalpine fir - Engelmann spruce/arrowleaf groundsel (ABLA-PIEN/SETR) (C0316) **Description of Cryaquolls Setting** *Landform:* Drainageways, flood plains *Parent material:* Gravelly alluvium and/or gravelly glaciofluvial deposits derived from igneous, metamorphic and sedimentary rock **Typical profile** *Oe - 0 to 4 inches:* moderately decomposed plant material *A1 - 4 to 16 inches:* silt loam *A2 - 16 to 24 inches:* silt loam *A3 - 24 to 30 inches:* silt loam *2Cg - 30 to 40 inches:* sandy loam *2Agb - 40 to 64 inches:* silt loam **Properties and qualities** *Slope:* 0 to 15 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* 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 0 inches *Frequency of flooding:* Occasional *Frequency of ponding:* Occasional *Available water storage in profile:* High (about 11.1 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* B/D

Other vegetative classification: Diamondlead willow/mountain sedge (SAPL2/CASC13) (S1497), Diamondlead willow/water sedge (SAPL2/CAAQ) (S1496)

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7201C—Leighcan family, till substratum, 40 to 75 percent slopes Map Unit Setting *National map unit symbol:* tlyh *Elevation:* 9,000 to 11,000 feet *Mean annual precipitation:* 20 to 40 inches *Mean annual air temperature:* 36 to 39 degrees F *Frost-free period:* 30 to 50 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Leighcan family, till substratum, and similar soils:* 85 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Leighcan Family, Till Substratum Setting** *Landform:* Moraines, mountain slopes *Parent material:* Glacial till and/or alluvium derived from igneous and metamorphic rock **Typical profile** *A - 0 to 2 inches:* cobbly silt loam *AE - 2 to 9 inches:* very cobbly silt loam *Bw - 9 to 28 inches:* very cobbly sandy loam *BCd - 28 to 45 inches:* extremely stony loamy sand *Cd - 45 to 60 inches:* extremely stony loamy sand **Properties and qualities** *Slope:* 40 to 75 percent *Depth to restrictive feature:* 20 to 60 inches to densic material *Natural drainage class:* Somewhat excessively drained *Runoff class:* High *Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water storage in profile:* Very low (about 2.1 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* C *Other vegetative classification:* Subalpine fir - Engelmann spruce/ grouse whortleberry (ABLA-PIEN/VASC) (C0321), Subalpine fir - Engelmann spruce/myrtle whortleberry (ABLA-PIEN/VAMY2) (C0320)

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7503B—Herd-Frisco families complex, sandstone substratum, 5 to 40 percent slopes Map Unit Setting *National map unit symbol:* tlyl *Elevation:* 8,000 to 9,500 feet *Mean annual precipitation:* 20 to 40 inches *Mean annual air temperature:* 36 to 39 degrees F *Frost-free period:* 30 to 50 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Herd family, sandstone substratum, and similar soils:* 50 percent *Frisco family, sandstone substratum, and similar soils:* 40 percent *Minor components:* 10 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Herd Family, Sandstone Substratum Setting** *Landform:* Structural benches, mountain slopes *Parent material:* Residuum weathered from mudstone **Typical profile** *Oi - 0 to 1 inches:* slightly decomposed plant material *A/E - 1 to 5 inches:* loam *Bt1 - 5 to 19 inches:* gravelly clay loam *Bt2 - 19 to 31 inches:* clay loam *BC - 31 to 44 inches:* clay loam *2C - 44 to 61 inches:* extremely paragravelly clay loam **Properties and qualities** *Slope:* 5 to 40 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* Well drained *Runoff class:* 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:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water storage in profile:* Moderate (about 7.3 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* C *Other vegetative classification:* Lodgepole pine/myrtle whortleberry (PICO/VAMY2) (C0909), Subalpine fir - Engelmann spruce/ myrtle whortleberry (ABLA-PIEN/VAMY2) (C0320) **Description of Frisco Family, Sandstone Substratum Setting** *Landform:* Benches *Parent material:* Colluvium and/or residuum derived from sandstone **Typical profile** *Oi - 0 to 1 inches:* slightly decomposed plant material *Oe - 1 to 3 inches:* moderately decomposed plant material *A - 3 to 5 inches:* sandy loam *E - 5 to 13 inches:* gravelly sandy loam *Bt - 13 to 32 inches:* very cobbly sandy clay loam *BCt - 32 to 62 inches:* extremely cobbly sandy loam **Properties and qualities** *Slope:* 5 to 40 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* Well drained *Runoff class:* High

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water storage in profile:* Low (about 4.2 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* B *Other vegetative classification:* Subalpine fir - Engelmann spruce/ grouse whortleberry (ABLA-PIEN/VASC) (C0321), Subalpine fir - Engelmann spruce/myrtle whortleberry (ABLA-PIEN/VAMY2) (C0320) **Minor Components Cryaquolls** *Percent of map unit:* 10 percent

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7700B—Leighcan family, 5 to 40 percent slopes Map Unit Setting *National map unit symbol:* tlym *Elevation:* 9,000 to 11,200 feet *Mean annual precipitation:* 20 to 40 inches *Mean annual air temperature:* 36 to 39 degrees F *Frost-free period:* 30 to 50 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Leighcan family and similar soils:* 85 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Leighcan Family Setting** *Landform:* Mountain slopes *Parent material:* Residuum and/or slope alluvium derived from igneous and metamorphic rock **Typical profile** *A - 0 to 2 inches:* cobbly silt loam *AE - 2 to 9 inches:* very cobbly silt loam *Bw - 9 to 28 inches:* very cobbly sandy loam *BCd - 28 to 45 inches:* extremely stony loamy sand *Cd - 45 to 60 inches:* extremely stony loamy sand **Properties and qualities** *Slope:* 5 to 40 percent *Depth to restrictive feature:* 20 to 60 inches to densic material *Natural drainage class:* Somewhat excessively drained *Runoff class:* High *Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water storage in profile:* Very low (about 2.1 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* C *Other vegetative classification:* Subalpine fir - Engelmann spruce/ grouse whortleberry (ABLA-PIEN/VASC) (C0321), Subalpine fir - Engelmann spruce/moss (ABLA-PIEN/MOSS) (C0311), Subalpine fir - Engelmann spruce/myrtle whortleberry (ABLAPIEN/ VAMY2) (C0320)

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7700C—Leighcan family, 40 to 75 percent slopes Map Unit Setting *National map unit symbol:* tlyn *Elevation:* 9,500 to 11,500 feet *Mean annual precipitation:* 20 to 40 inches *Mean annual air temperature:* 36 to 39 degrees F *Frost-free period:* 30 to 50 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Leighcan family and similar soils:* 85 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Leighcan Family Setting** *Landform:* Mountain slopes *Down-slope shape:* Linear *Across-slope shape:* Linear *Parent material:* Residuum and/or slope alluvium derived from igneous and metamorphic rock **Typical profile** *A - 0 to 2 inches:* cobbly silt loam *AE - 2 to 9 inches:* very cobbly silt loam *Bw - 9 to 28 inches:* very cobbly sandy loam *BCd - 28 to 45 inches:* extremely stony loamy sand *Cd - 45 to 60 inches:* extremely stony loamy sand **Properties and qualities** *Slope:* 40 to 75 percent *Percent of area covered with surface fragments:* 16.0 percent *Depth to restrictive feature:* 20 to 60 inches to densic material *Natural drainage class:* Somewhat excessively drained *Runoff class:* High *Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water storage in profile:* Very low (about 2.1 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* C *Other vegetative classification:* Subalpine fir - Engelmann spruce/ grouse whortleberry (ABLA-PIEN/VASC) (C0321), Subalpine fir - Engelmann spruce/moss (ABLA-PIEN/MOSS) (C0311), Subalpine fir - Engelmann spruce/myrtle whortleberry (ABLAPIEN/ VAMY2) (C0320)

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7202B—Leighcan family, till substratum-Cryaquolls complex, 5 to 40 percent slopes Map Unit Setting *National map unit symbol:* tqln *Elevation:* 8,000 to 11,000 feet *Mean annual precipitation:* 20 to 40 inches *Mean annual air temperature:* 36 to 45 degrees F *Frost-free period:* 30 to 50 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Leighcan family, till substratum, and similar soils:* 60 percent *Cryaquolls and similar soils:* 25 percent *Minor components:* 5 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Leighcan Family, Till Substratum Setting** *Landform:* Moraines, mountain slopes *Parent material:* Glacial till and/or alluvium derived from igneous and metamorphic rock **Typical profile** *A - 0 to 2 inches:* cobbly silt loam *AE - 2 to 9 inches:* very cobbly silt loam *Bw - 9 to 28 inches:* very cobbly sandy loam *BCd - 28 to 45 inches:* extremely stony loamy sand *Cd - 45 to 60 inches:* extremely stony loamy sand **Properties and qualities** *Slope:* 5 to 40 percent *Depth to restrictive feature:* 20 to 60 inches to densic material *Natural drainage class:* Somewhat excessively drained *Runoff class:* High *Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water storage in profile:* Very low (about 2.1 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* C *Other vegetative classification:* Subalpine fir - Engelmann spruce/ grouse whortleberry (ABLA-PIEN/VASC) (C0321), Subalpine fir - Engelmann spruce/myrtle whortleberry (ABLA-PIEN/VAMY2) (C0320) **Description of Cryaquolls Setting** *Landform:* Drainageways, flood plains, depressions *Parent material:* Gravelly alluvium and/or gravelly glaciofluvial deposits derived from igneous, metamorphic and sedimentary rock **Typical profile** *Oe - 0 to 4 inches:* moderately decomposed plant material *A1 - 4 to 16 inches:* silt loam *A2 - 16 to 24 inches:* silt loam *A3 - 24 to 30 inches:* silt loam *2Cg - 30 to 40 inches:* sandy loam *2Agb - 40 to 64 inches:* silt loam **Properties and qualities** *Slope:* 5 to 40 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* Poorly drained *Runoff class:* Medium *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 0 inches *Frequency of flooding:* Occasional *Frequency of ponding:* Occasional *Available water storage in profile:* High (about 11.1 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* A/D *Other vegetative classification:* Diamondlead willow/mountain sedge (SAPL2/CASC13) (S1497), Diamondlead willow/water sedge (SAPL2/CAAQ) (S1496) **Minor Components Typic cryaquepts** *Percent of map unit:* 5 percent

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7702B—Frisco-Catamount, moist families complex, 5 to 40 percent slopes Map Unit Setting *National map unit symbol:* tlyq *Elevation:* 9,000 to 10,200 feet *Mean annual precipitation:* 20 to 40 inches *Mean annual air temperature:* 36 to 39 degrees F *Frost-free period:* 30 to 50 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Frisco family and similar soils:* 45 percent *Catamount family, moist, and similar soils:* 40 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Frisco Family Setting** *Landform:* Benches *Down-slope shape:* Linear *Across-slope shape:* Linear *Parent material:* Colluvium and/or residuum derived from sandstone **Typical profile** *Oi - 0 to 1 inches:* slightly decomposed plant material *Oe - 1 to 3 inches:* moderately decomposed plant material *A - 3 to 5 inches:* sandy loam *E - 5 to 13 inches:* gravelly sandy loam *Bt - 13 to 32 inches:* very cobbly sandy clay loam *BCt - 32 to 62 inches:* extremely cobbly sandy loam **Properties and qualities** *Slope:* 5 to 40 percent *Percent of area covered with surface fragments:* 0.0 percent *Depth to restrictive feature:* More than 80 inches *Natural drainage class:* Well drained *Runoff class:* Medium *Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water storage in profile:* Low (about 4.2 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* B *Other vegetative classification:* Subalpine fir - Engelmann spruce/ myrtle whortleberry (ABLA-PIEN/VAMY2) (C0320), Subalpine fir - Engelmann spruce/common juniper (ABLA-PIEN/JUCO6) (C0309) **Description of Catamount Family, Moist Setting** *Landform:* Mountain slopes *Down-slope shape:* Linear *Across-slope shape:* Linear *Parent material:* Residuum weathered from igneous and metamorphic rock **Typical profile** *Oi - 0 to 1 inches:* slightly decomposed plant material *A1 - 1 to 2 inches:* gravelly loam *A2 - 2 to 5 inches:* very gravelly sandy loam *Bw - 5 to 11 inches:* extremely gravelly sandy loam *C - 11 to 15 inches:* extremely gravelly sandy loam *Cr - 15 to 26 inches:* bedrock *R - 26 to 36 inches:* bedrock **Properties and qualities** *Slope:* 5 to 40 percent *Percent of area covered with surface fragments:* 0.0 percent *Depth to restrictive feature:* 10 to 20 inches to paralithic bedrock; 20 to 40 inches to lithic bedrock *Natural drainage class:* Excessively drained *Runoff class:* High *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.01 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water storage in profile:* Very low (about 0.9 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* D *Other vegetative classification:* Lodgepole pine/kinnikinnick (PICO/ ARUV) (C0901), Lodgepole pine/common juniper (PICO/ JUCO6) (C0905), Subalpine fir - Engelmann spruce/myrtle whortleberry (ABLA-PIEN/VAMY2) (C0320)

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7201B—Leighcan family, till substratum, 5 to 40 percent slopes Map Unit Setting *National map unit symbol:* tlyg *Elevation:* 9,000 to 10,500 feet *Mean annual precipitation:* 20 to 40 inches *Mean annual air temperature:* 36 to 39 degrees F *Frost-free period:* 30 to 50 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Leighcan family, till substratum, and similar soils:* 85 percent *Estimates are based on observations, descriptions, and transects of the mapunit.* **Description of Leighcan Family, Till Substratum Setting** *Landform:* Moraines, mountain slopes *Parent material:* Glacial till and/or alluvium derived from igneous and metamorphic rock **Typical profile** *A - 0 to 2 inches:* cobbly silt loam *AE - 2 to 9 inches:* very cobbly silt loam *Bw - 9 to 28 inches:* very cobbly sandy loam *BCd - 28 to 45 inches:* extremely stony loamy sand *Cd - 45 to 60 inches:* extremely stony loamy sand **Properties and qualities** *Slope:* 5 to 40 percent *Depth to restrictive feature:* 20 to 60 inches to densic material *Natural drainage class:* Somewhat excessively drained *Runoff class:* High *Capacity of the most limiting layer to transmit water (Ksat):* Moderately high to high (0.60 to 2.00 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water storage in profile:* Very low (about 2.1 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* C *Other vegetative classification:* Subalpine fir - Engelmann spruce/ grouse whortleberry (ABLA-PIEN/VASC) (C0321), Subalpine fir - Engelmann spruce/myrtle whortleberry (ABLA-PIEN/VAMY2) (C0320)

Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties 7790B—Lithic Cryorthents, subalpine-Rubble land complex, 5 to 40 percent slopes Map Unit Setting *National map unit symbol:* tlz1 *Elevation:* 9,000 to 11,500 feet *Mean annual precipitation:* 20 to 40 inches *Mean annual air temperature:* 36 to 39 degrees F *Frost-free period:* 30 to 50 days *Farmland classification:* Not prime farmland **Map Unit Composition** *Lithic cryorthents, subalpine, and similar soils:* 60 percent *Rubble land:* 25 percent *Estimates are based on observations,* *descriptions, and transects of the mapunit.* **Description of Lithic Cryorthents, Subalpine Setting** *Landform:* Mountain slopes *Down-slope shape:* Linear *Across-slope shape:* Convex *Parent material:* Glaciofluvial deposits and/or residuum derived from igneous and metamorphic rock **Typical profile** *Oi - 0 to 1 inches:* slightly decomposed plant material *A - 1 to 4 inches:* very gravelly sandy loam *AC - 4 to 11 inches:* very cobbly sandy loam *C - 11 to 17 inches:* extremely cobbly sandy loam *R - 17 to 27 inches:* bedrock **Properties and qualities** *Slope:* 5 to 40 percent *Depth to restrictive feature:* 10 to 20 inches to lithic bedrock *Natural drainage class:* Somewhat excessively drained *Runoff class:* Low *Capacity of the most limiting layer to transmit water (Ksat):* Very low to moderately low (0.00 to 0.01 in/hr) *Depth to water table:* More than 80 inches *Frequency of flooding:* None *Frequency of ponding:* None *Available water storage in profile:* Very low (about 1.1 inches) **Interpretive groups** *Land capability classification (irrigated):* None specified *Hydrologic Soil Group:* D *Other vegetative classification:* Engelmann spruce/alpine clover (PIEN/TRDA2) (C0413), Limber pine/alpine clover (PIFL2/ TRDA2) (C1006), Limber pine/common juniper (PIFL2/JUCO6) (C1005) **Description of Rubble Land Setting** *Landform:* Fans, mountainsides *Landform position (two-dimensional):* Backslope, footslope *Landform position (three-dimensional):* Side slope *Parent material:* Colluvium and/or residuum derived from igneous, metamorphic and sedimentary rock **Typical profile** - *0 to 60 inches:* boulders **Interpretive groups** *Land capability classification (irrigated):* None specified *Land capability classification (nonirrigated):* 8

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.

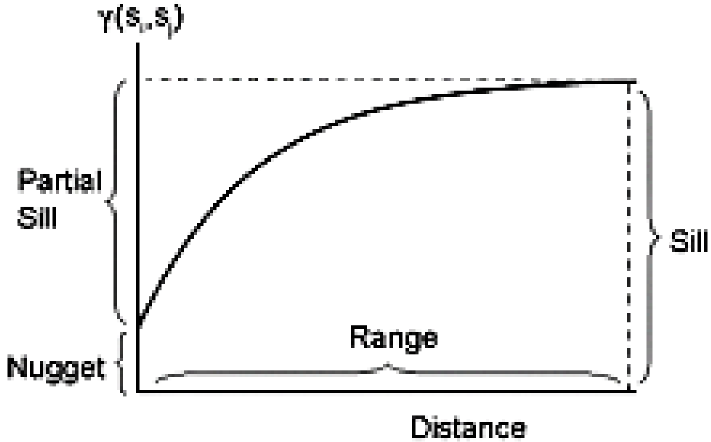


Figure 45. Example semivariogram, depicting range, sill, and nugget.

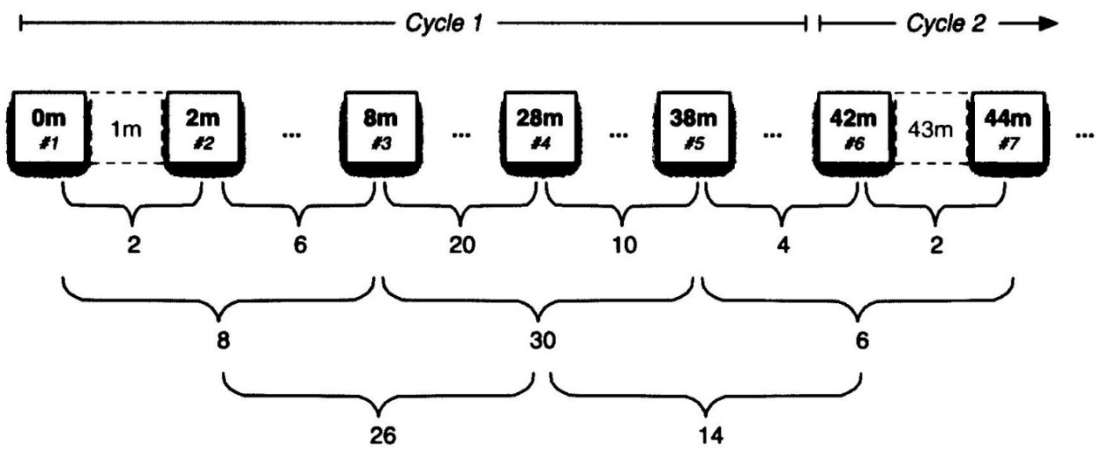


Figure 46. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 3 October 2014 at the Fraser site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 46). Soil temperature and moisture measurements were collected along three transects (210 m, 84 m, and 84 m) located in the expected airshed at Fraser. 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 46, 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 47). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 48, left graph) and directional semivariograms do not show anisotropy (Figure 48, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 48, right graph). The model indicates a distance of effective independence of 6 m for soil temperature.

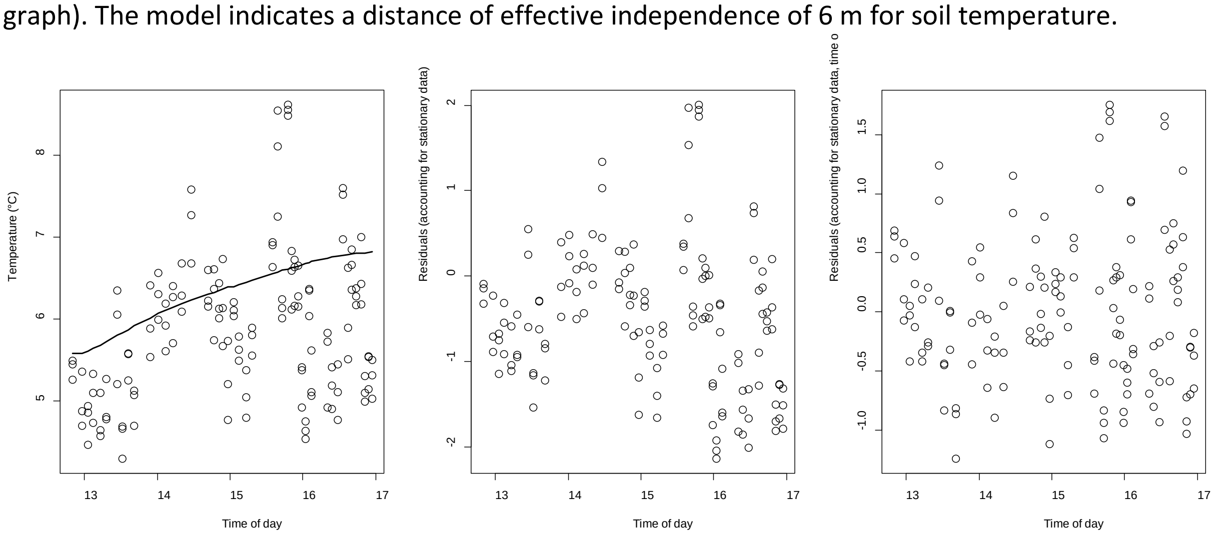


Figure 47. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting for changes temperature in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

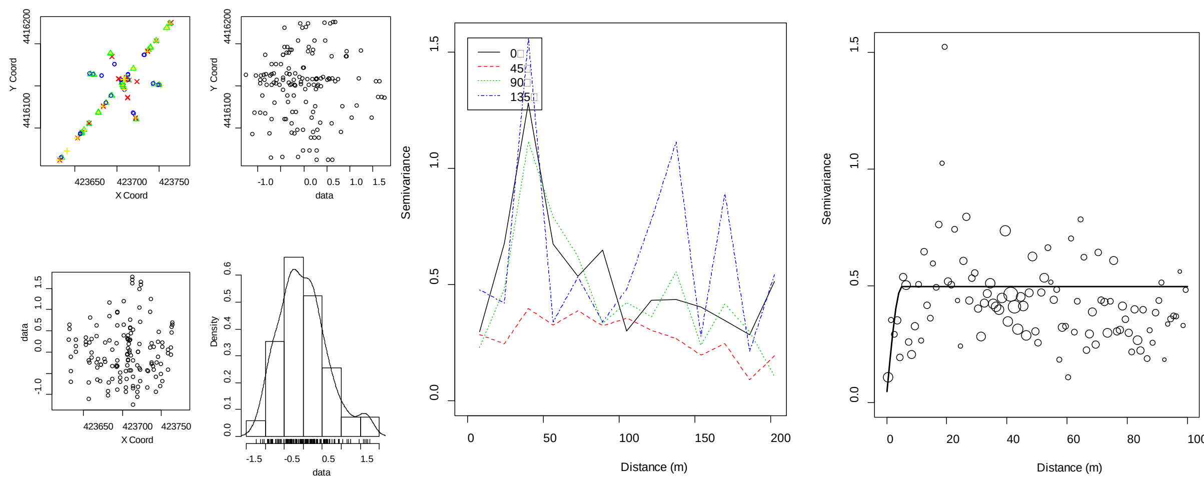


Figure 48. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

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 49). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 50, left graph) and directional semivariograms do not show anisotropy (Figure 50, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 50, right graph). The model indicates a distance of effective independence of 50 m for soil water content.

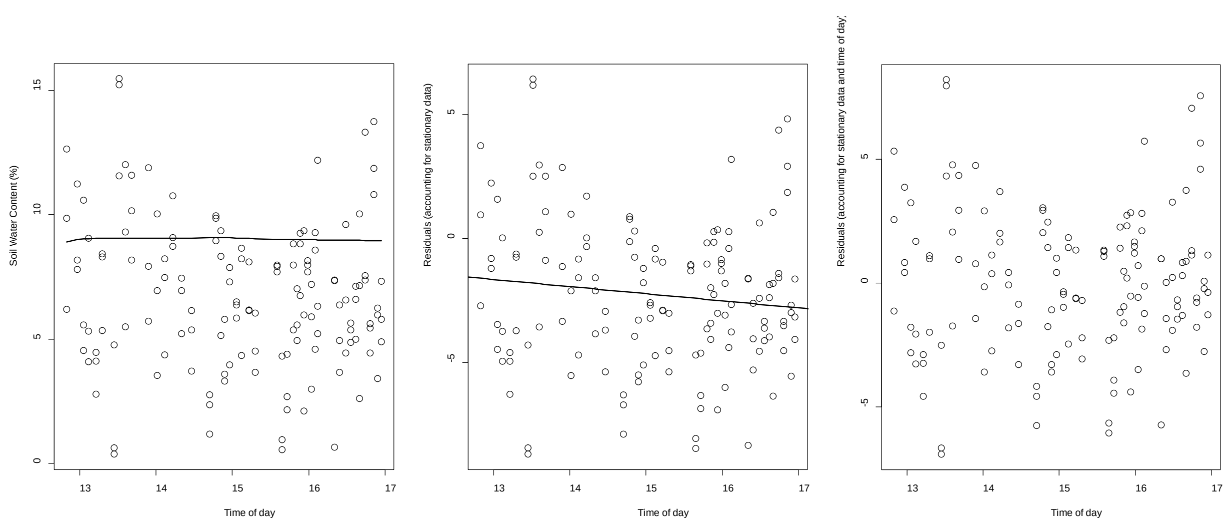


Figure 49. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting 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.

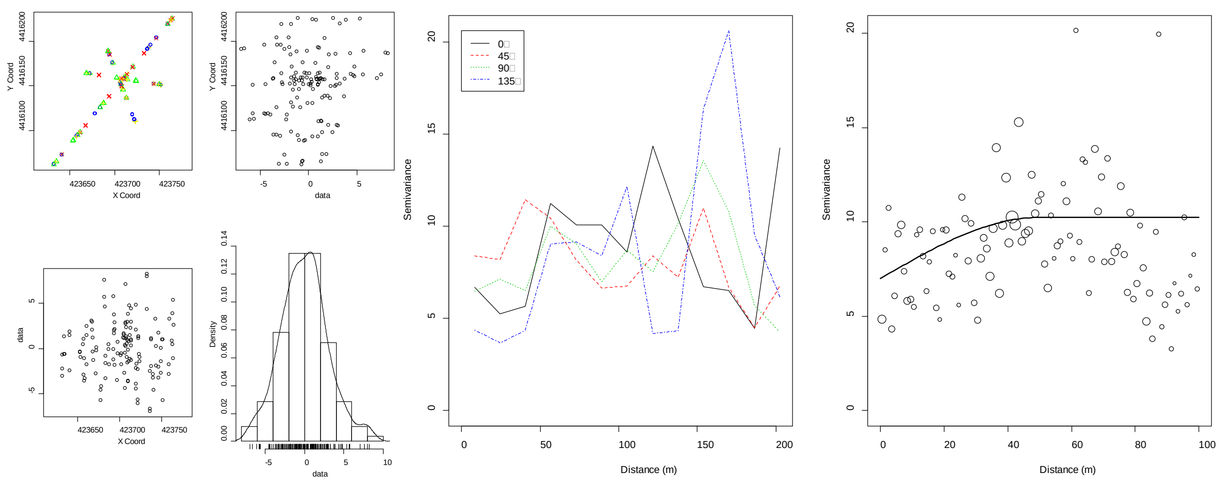


Figure 50. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

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 6 m for soil temperature and 50 m for soil moisture. Based on these results and the site design guidelines the soil plots at Fraser 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 39.89253°, -105.89188°. The exact location of each soil plot may be microsited 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 selected along the site access route during the FCC site design process to minimize disturbance to the site by accessing the soil pit. A summary of the soil information is shown in Table 17 and site layout can be seen in Figure 48.

Dominant soil series at the site: Leighcan family, till substratum, 5 to 40 percent slopes - Leighcan family, 5 to 40 percent slopes. The taxonomy of this soil is shown below:
Order: Inceptisols
Suborder: Cryepts
Great group: Dystrocryepts
Subgroup: Typic Dystrocryepts
Family: Loamy-skeletal, mixed, superactive Typic Dystrocryepts
Series: Leighcan family, till substratum, 5 to 40 percent slopes - Leighcan family, 5 to 40 percent slopes

Table 17. Summary of soil array and soil pit information at Fraser. 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	22 m
Latitude and longitude of 1st soil plot OR direction from tower	39.89253°, -105.89188°
Direction of soil array	210°
Latitude and longitude of FIU soil pit 1	TBD, will be picked along site access route during site design process
Latitude and longitude of FIU soil pit 2	TBD, will be picked along site access route during site design process
Latitude and longitude of FIU soil pit 3	TBD, will be picked along site access route during site design process
Dominant soil type	Leighcan family, till substratum, 5 to 40 percent slopes - Leighcan family, 5 to 40 percent slopes
Expected soil depth	0.51-1.52 m
Depth to water table	>2 m

Expected depth of soil horizons	**Expected measurement depths***
0-0.05 m (cobbly silt loam)	0.03 m
0.05-0.23 m (very cobbly silt loam)	0.14 m
0.23-0.71 (very cobbly sandy loam)	0.47 m
0.71-1.14 m (extremely stony loamy sand)	0.93 m
1.14-1.52 m (extremely stony loamy sand)	1.33 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.

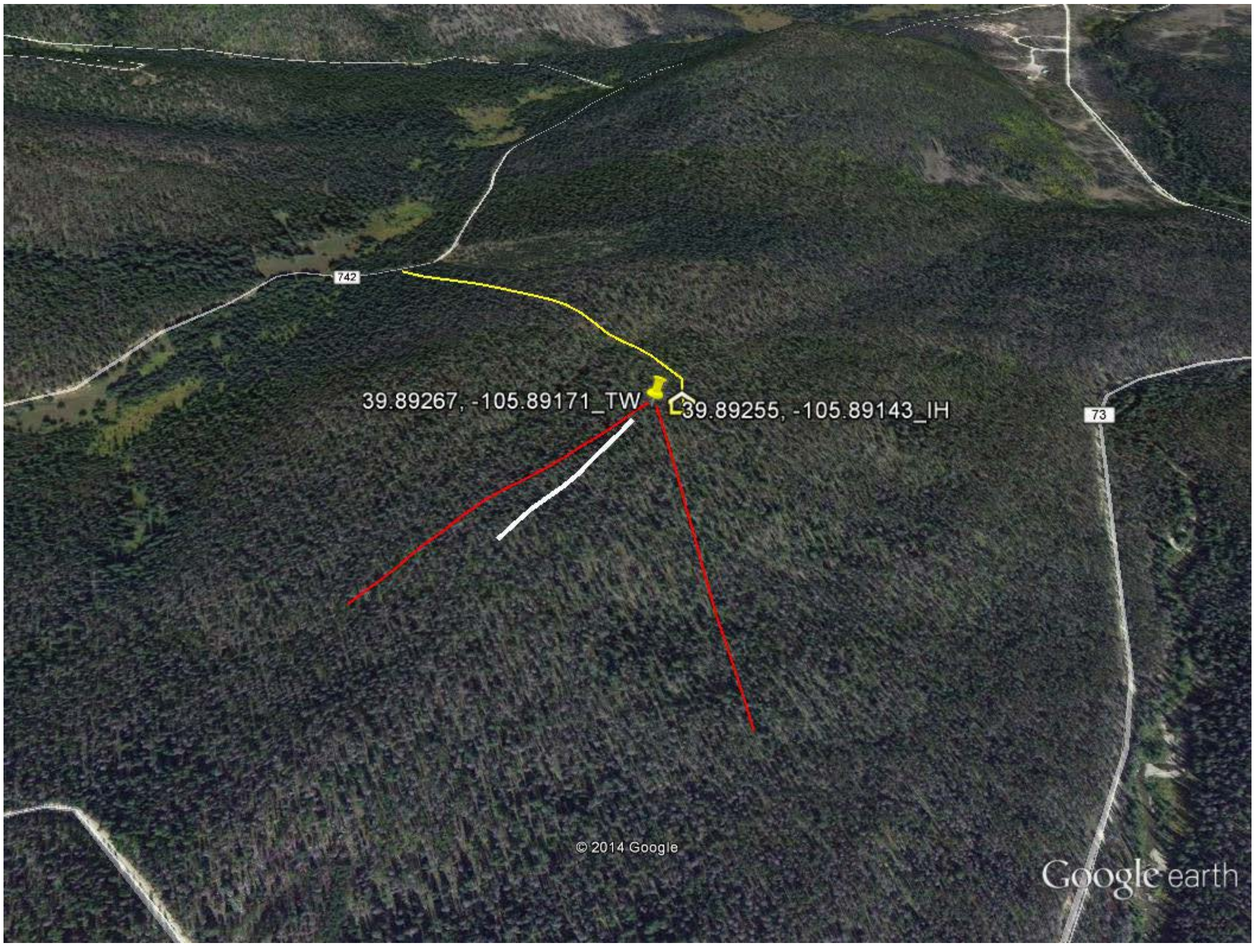


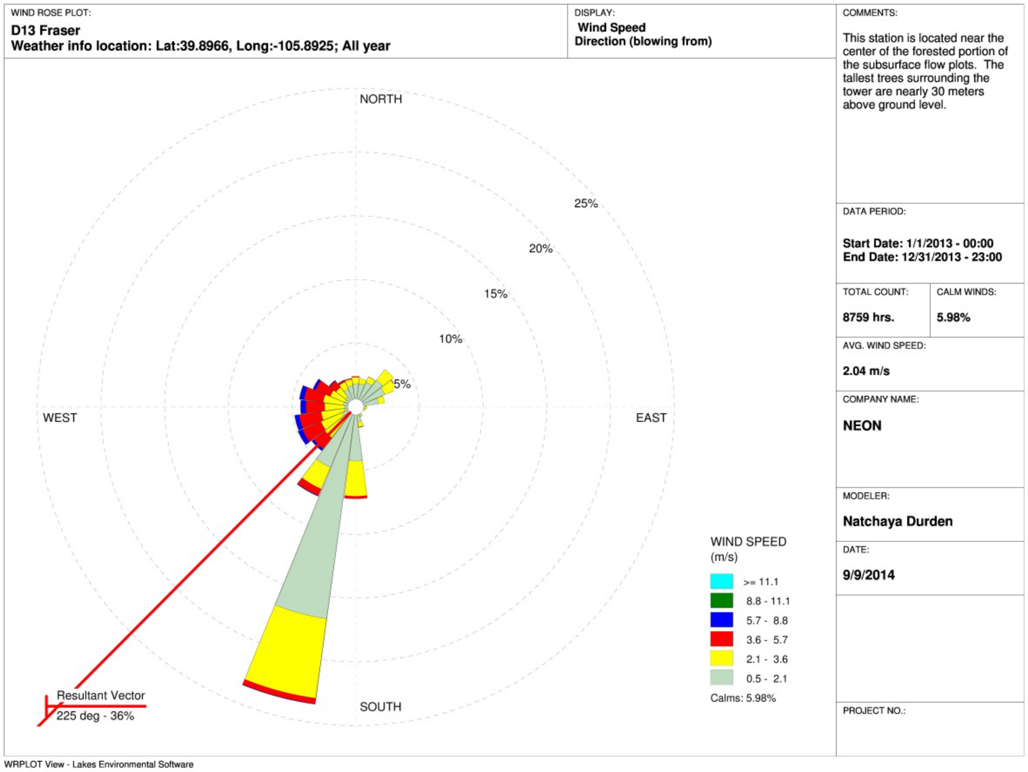
Figure 48. Site layout at Fraser showing soil array.

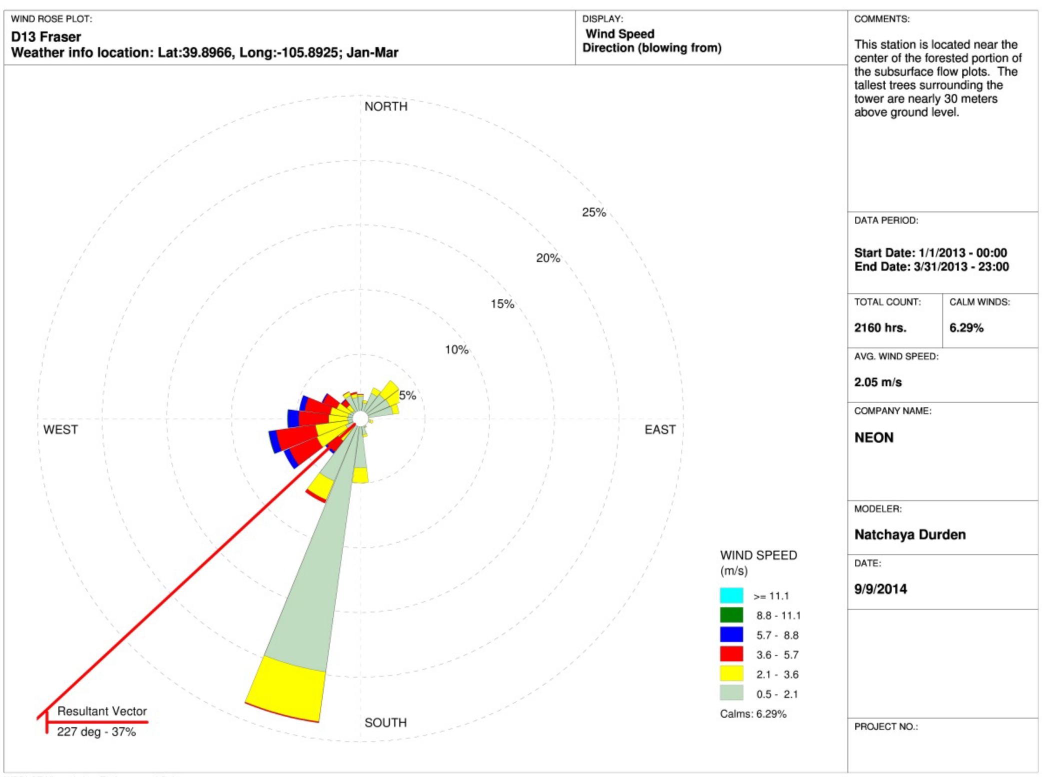
5.4 Airshed

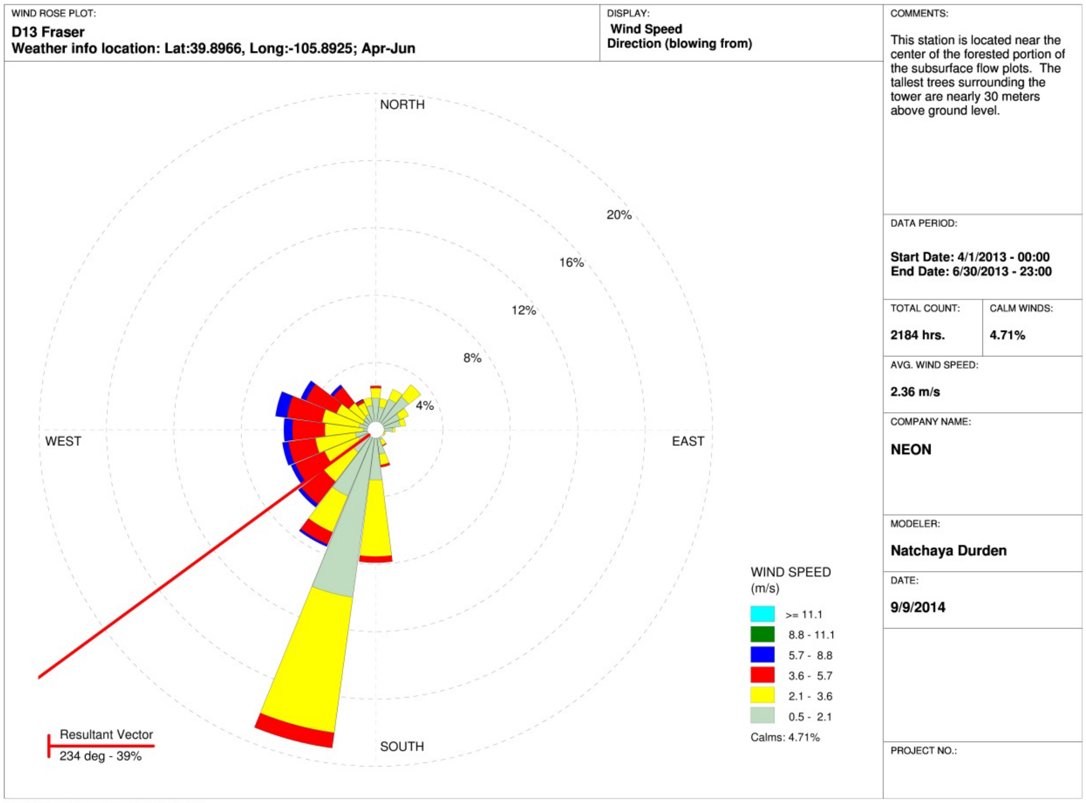
5.4.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries. The weather data used to generate the following wind roses are provided by Dr. Kelly Elder (personal communication) from his weather station at 39.8966, -105.8925. The met station (coordinates unclear) is at 2,820 m elevation and less than 500 m from the candidate tower site. This station is located near the center of the forested portion of the subsurface flow plots (an experimental plot). The tallest trees surrounding the met station tower are nearly 30 meters above ground level. Hourly data were used to plot these wind roses. 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.

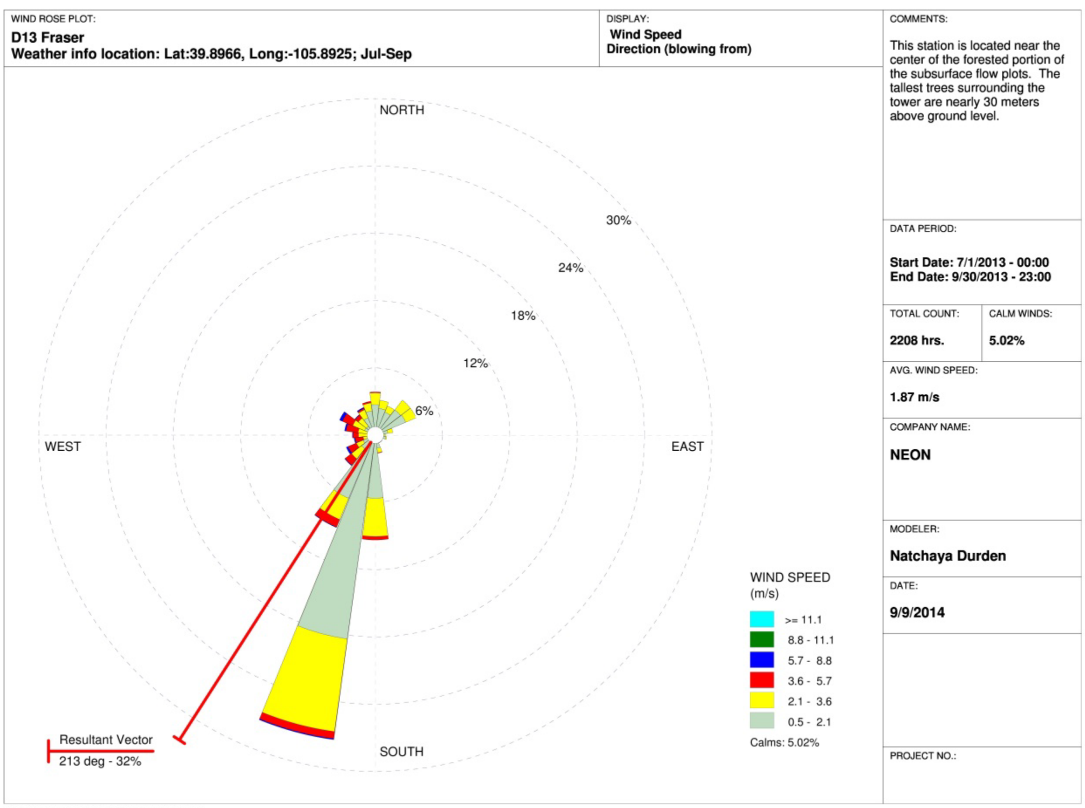
5.4.2 Results (graphs for wind roses)







WRPLOT View - Lakes Environmental Software



WRPLOT View - Lakes Environmental Software

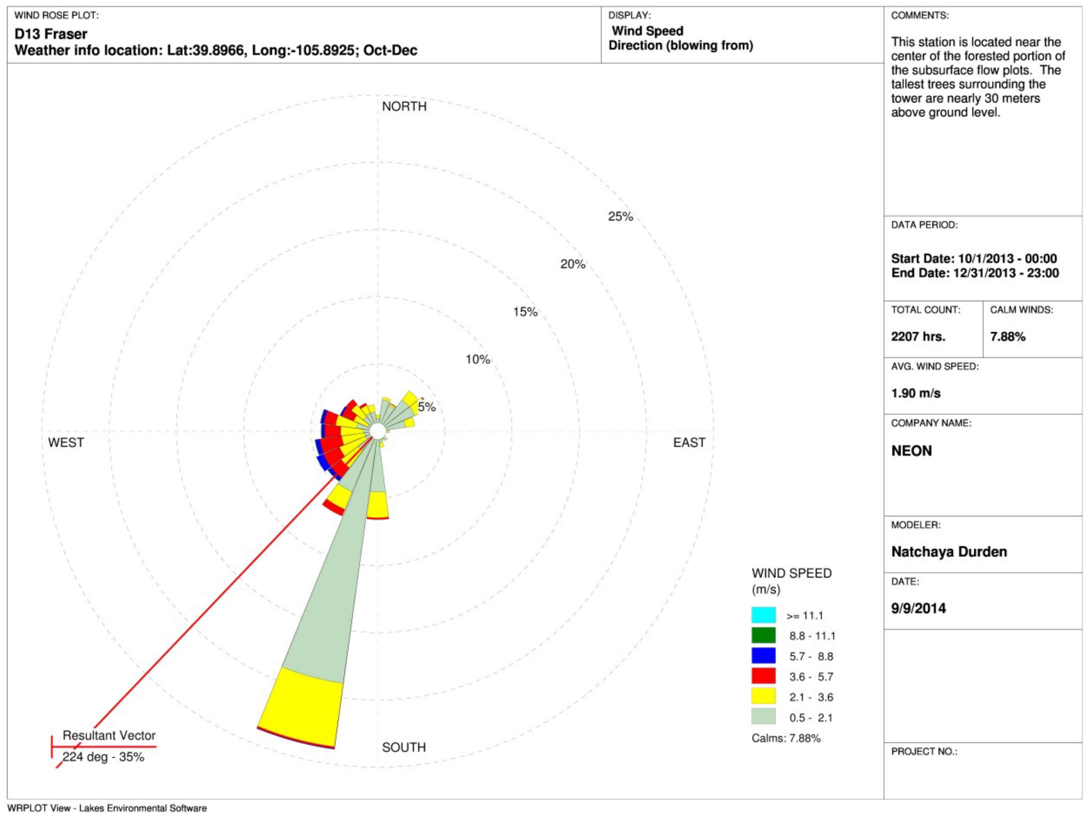


Figure 49. Windroses from Fraser relocatable site.

Data used here are 2013 data from Fraser Experimental Forest weatehr station at flow plot. The met station (coordinates unclear) is ~2820 m elevation and less than 500 m from NEON candidate tower. It is assumed that the wind data was corrected for declination. Panels are (from top to bottom) annual, Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

5.4.3 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, Lagrangian solution was used (Kormann and Meixner 2001). The source area models were 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 18. Expected environmental controls to parameterize the source area model based on the wind roses for and associated results for Fraser 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	26	26	26	26	26	26	m
Canopy Height	14	14	14	14	14	14	m
Canopy area density	2.512	2.512	2.512	2.512	2.512	2.512	m
Boundary layer depth	700	700	300	300	300	300	m
Expected sensible heat flux	320	320	-20	-50	-50	-75	$W\ m^{-2}$
Air Temperature	21	21	18	-11	-11	-15	°C
Max. windspeed	7.0	2	1.6	9.2	2.4	1.6	$m\ s^{-1}$
Resultant wind vector	195	195	195	195	195	195	degrees
Results							
(z-d)/L	-0.06	-0.50	3	0.01	3	3	m
d	11	11	11	11	11	11	m
Sigma v	2.2	1.40	1.60	1.70	1.60	1.60	$m^2\ s^{-2}$
Z0	0.69	0.69	0.69	0.69	0.69	0.69	m
u*	0.97	0.48	0.04	1.20	0.05	0.04	$m\ s^{-1}$
Distance source area begins	0	0	520	0	520	520	m

Distance of 90% cumulative flux	820	220	3620	1130	3620	3620	m
Distance of 80% cumulative flux	480	120	3280	630	3280	3280	m
Distance of 70% cumulative flux	320	90	2960	420	2970	2960	m
Peak contribution	75	25	2055	85	2055	2055	m

5.4.4 Results (source area graphs)

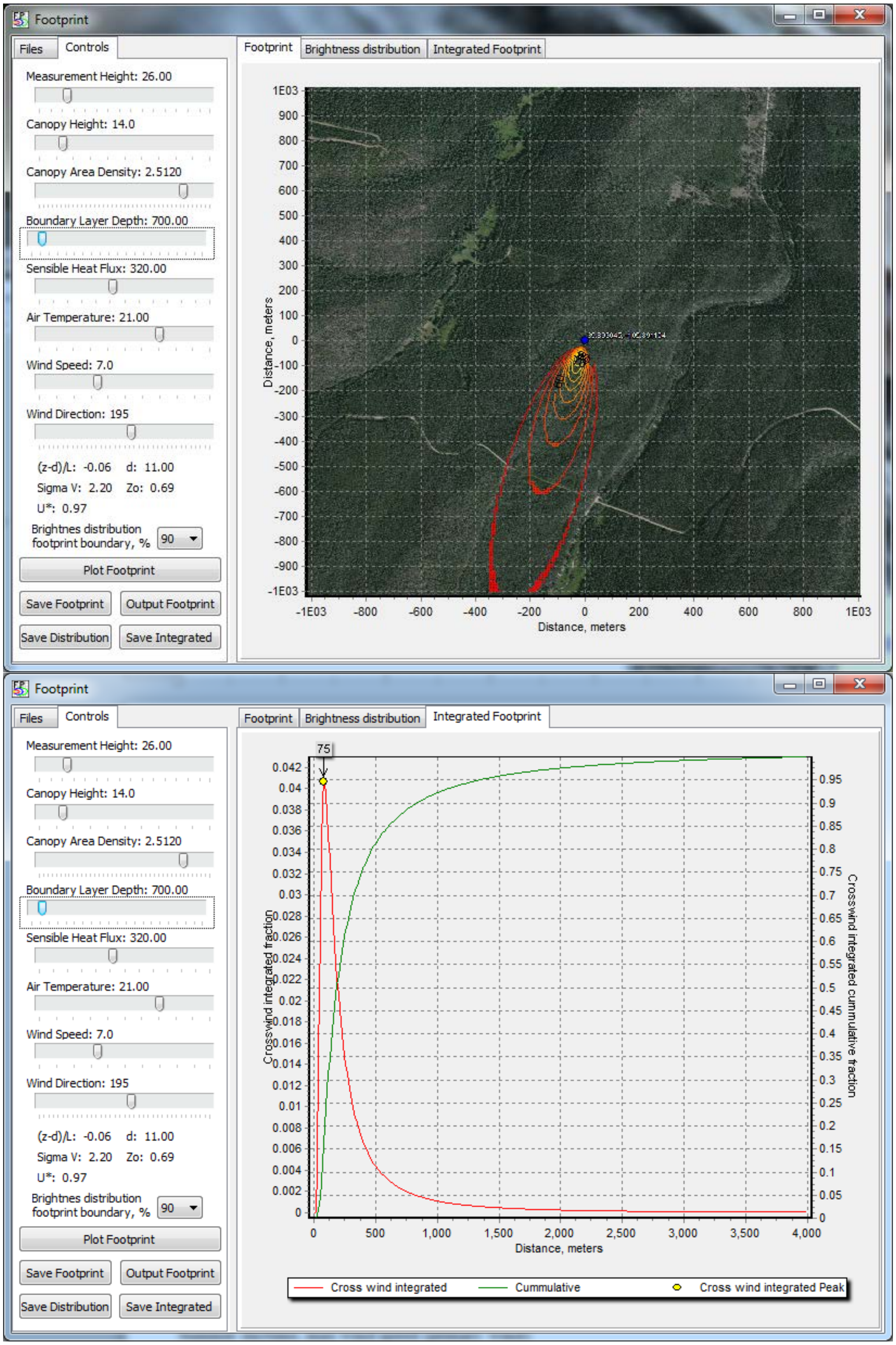


Figure 50. Fraser Summer daytime, max wind speed (primary wind)

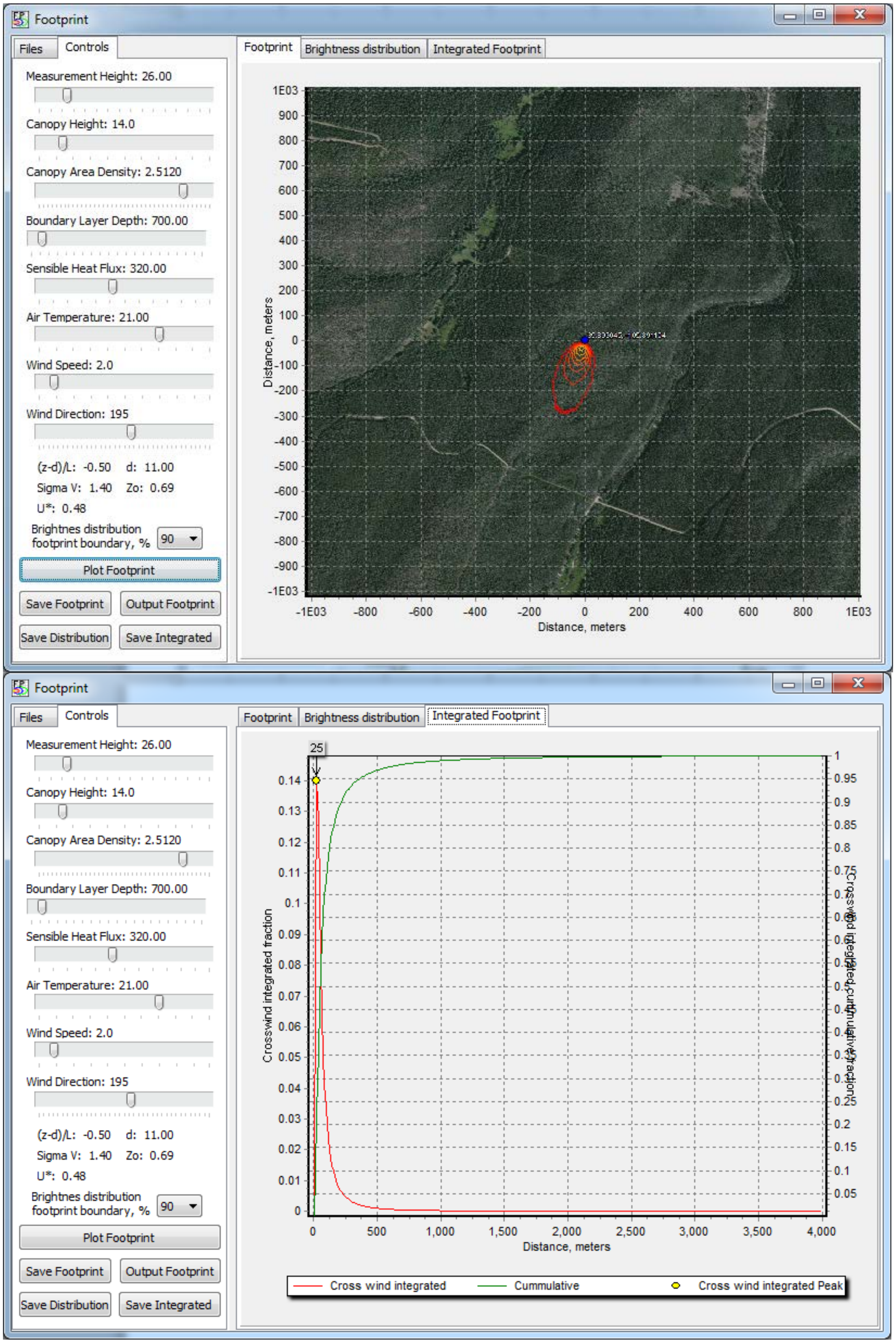


Figure 51. Fraser Summer, daytime, mean wind speed (primary wind roses)

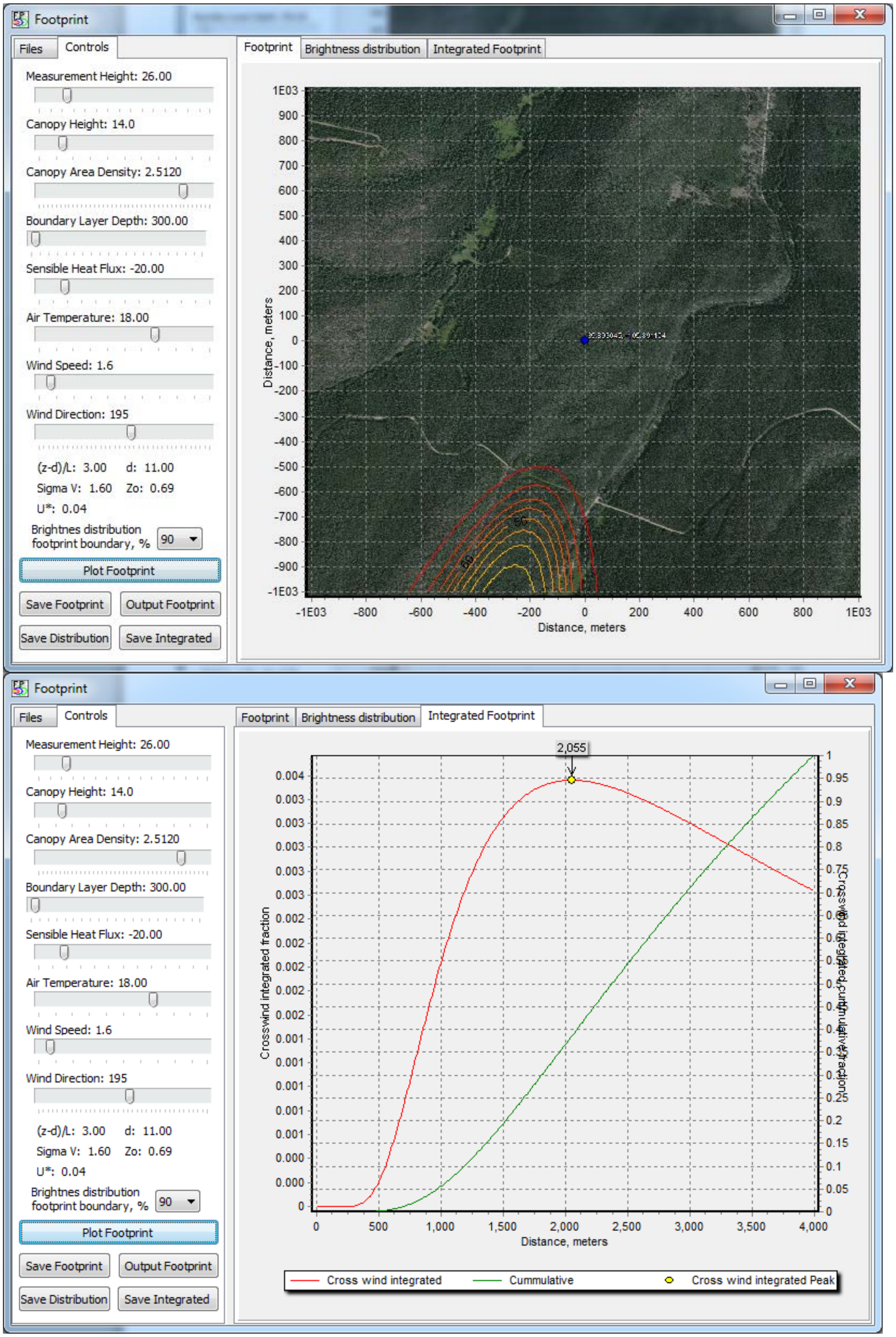


Figure 52. Fraser Summer, nighttime, mean wind speed

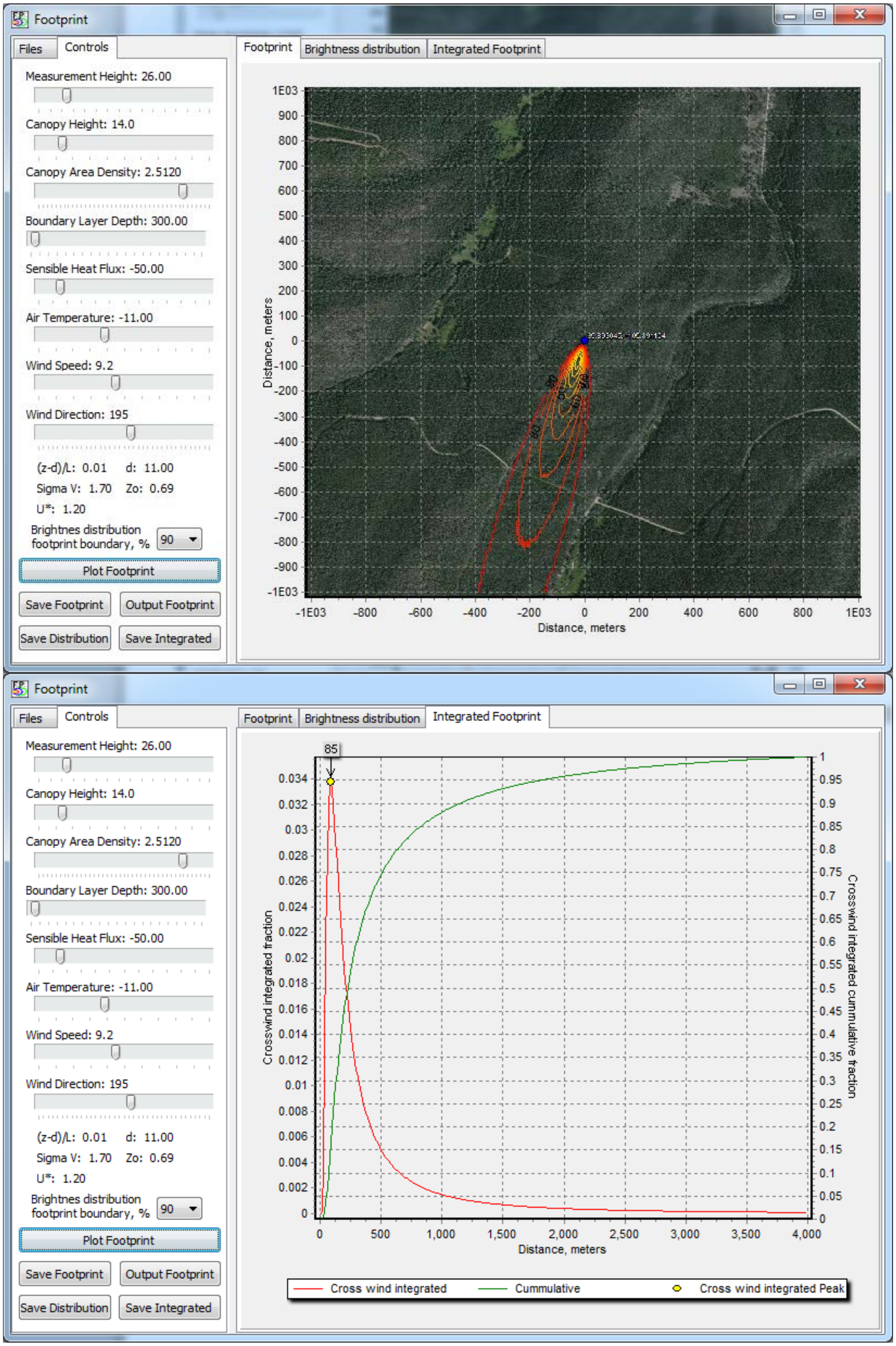


Figure 53. Fraser Winter, daytime, max wind speed

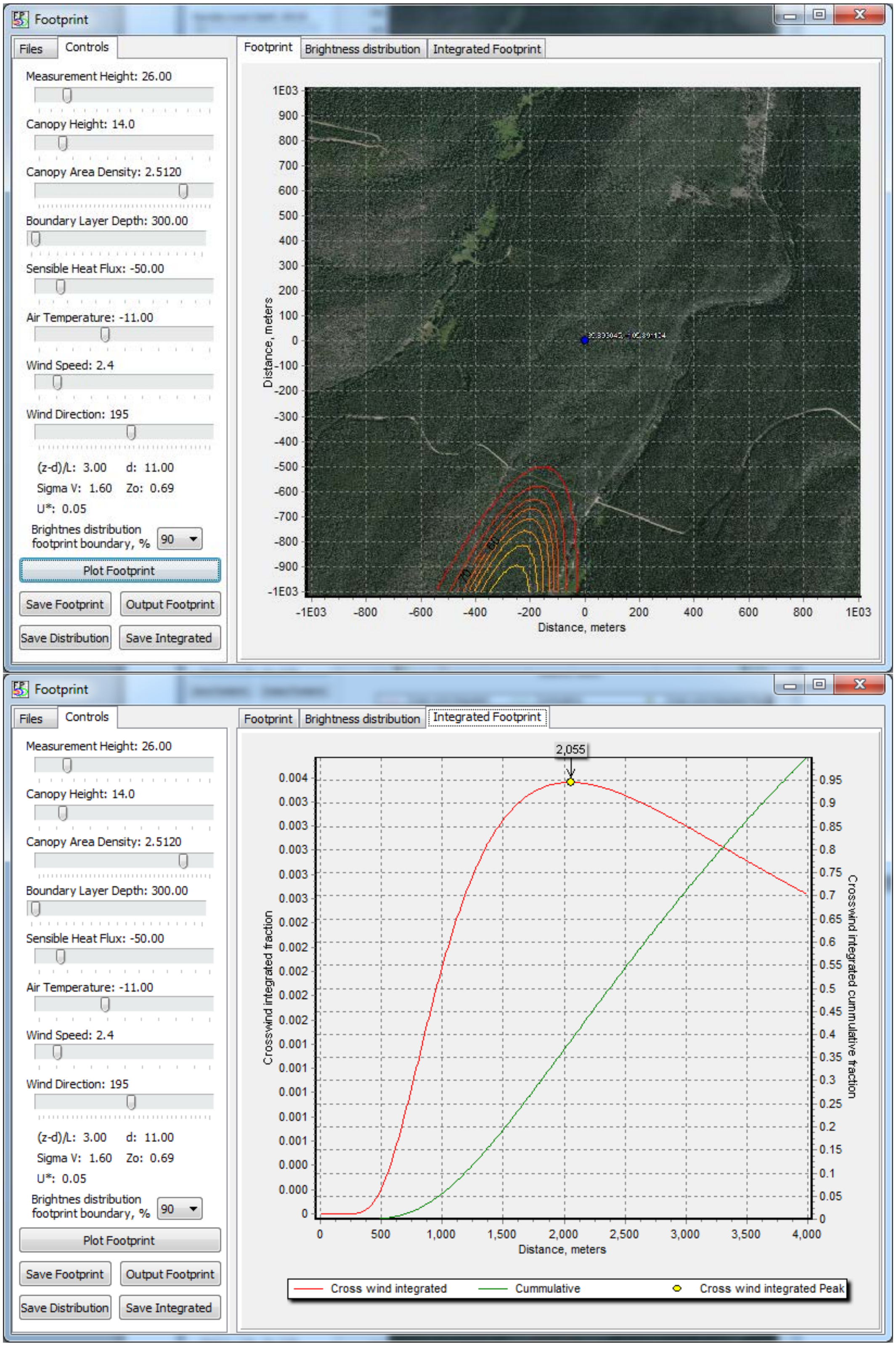


Figure 54. Fraser Winter, daytime, mean wind speed

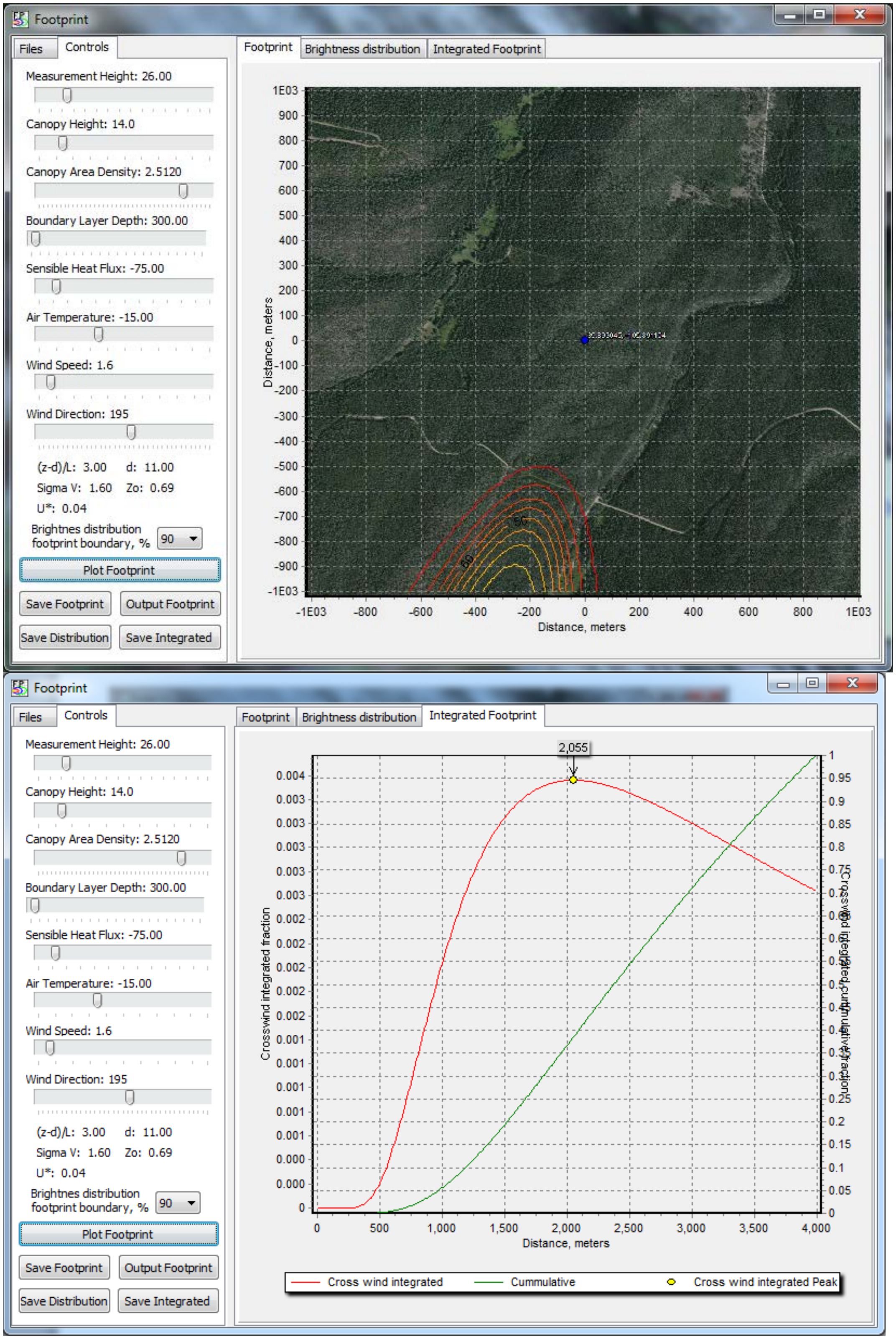


Figure 55. Fraser Winter, nighttime, mean wind

5.5 Site design and tower attributes

According to wind roses, prevailing wind blows from SSW (170^o to 220^o, clockwise from 170^o). There will be some winds blow from west and northeast, particularly in winter daytime season. The weather data used to generate these wind roses were from the met station at Fraser Experimental Forest flow plot, which is at a slightly lower elevation and less than 500 m from NEON candidate tower. We expect the wind patterns are slightly different at NEON site due to the complicated mountainous terrain, but would not significantly alter this analysis. **Tower** should be placed to a location to best capture the signals from the airshed of the ecosystem in interest. After FIU site characterization, we determined that tower location at 39.89267°, -105.89171° to best meet the NEON science requirements.

Eddy covariance, sonic wind and air temperature **boom arms** orientation pointing to 300^o will be best to capture signals from all major wind directions. **Radiation boom arms** should always be facing south to avoid any shadowing effects from the tower structure. An **instrument hut** should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind and should be positioned to have the longer side parallel to frequent wind direction to minimize the wind effects on instrument huts and to minimize the disturbances of wind regime by instrument hut, and in this case, instrument hut should be positioned on the southeast of tower and have the longer side parallel to SW-NE direction. Therefore, we decide the placement of instrument hut at 39.89255, -105.89143. The distance between the tower and the instrument hut is ~ 25 m. Both tower location and instrument hut location were selected at relatively open spots to minimize the tree cutting and minimize site disturbance.

The forest in the vicinity of the tower is dominated by Engelmann spruce (*picea engelmannii)* and mixes with the Lodgepole pine forest, and has a mixed age structure with active recruitment. Many beetle killed trees standing in this forest ecosystem or falling on the forest floor. Tree height ranges from few centimeters on the ground to 22 m above ground without obvious strata. Average top canopy height is ~ 22 m around the proposed tower site with lowest branch level height is at ~2 m for mature spruce trees and ~10m for mature pine trees. We do not expect top canopy height will increase dramatically during the NEON operation at this site, e.g., ~10 y. The vegetation and shrubs at forest floor are ~ 0.20 m to 1 m in height. Therefore, we require 6 **measurement layers** on the tower with top measurement height at 34 m (tower top at mixed surface layer), and remaining levels are at 25 m (above canopy in the roughness layer), 21 m (at the canopy top), 10 m (most young seedling layer transition into mature tree layer), 2 m (transition from ground level to tree canopy) and 0.3 m (ground level), respectively, to best characterize the fluxes on the tower top and the microclimate scales.

Secondary **precipitation collector** for bulk precipitation collection will be located the top of tower at this site. **Wet deposition collector** will be collocated at the tower top. 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. The side of the tower with the anemometer boom is perpendicular to the boom direction. **Instrument hut orientation vector** is parallel to the long side of the instrument hut.

Instrument hut distance z is the distance from the center of tower projection to the center of the instrument hut projection on the ground. The numbering of the **measurement levels** is that the lowest is level one, and each subsequent increase in height is numbered sequentially.

Table 19. Site design and tower attributes for Fraser Relocatable site
0° is true north with declination accounted for. Color of Instrument hut exterior shall be tan or best match the surrounding environment.

Attribute	lat	long	degree	meters	notes
Airshed			170° to 220°		Clockwise from first angle.
Tower location	39.89267	-105.89171	--	--	new site
Instrument hut	39.89255	-105.89143			
Instrument hut orientation vector	--	--	200°-20°		
Instrument hut distance z	--	--	--	25	
Anemometer/Temperature boom orientation	--	--	300°	--	
Height of the measurement levels					
Level 1				0.3	m.a.g.l.
Level 2				2.0	m.a.g.l.
Level 3				10.0	m.a.g.l.
Level 4				21.0	m.a.g.l.
Level 5				25.0	m.a.g.l.
Level 6				34.0	m.ag.l.
Tower Height				34.0	m.a.g.l.

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

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

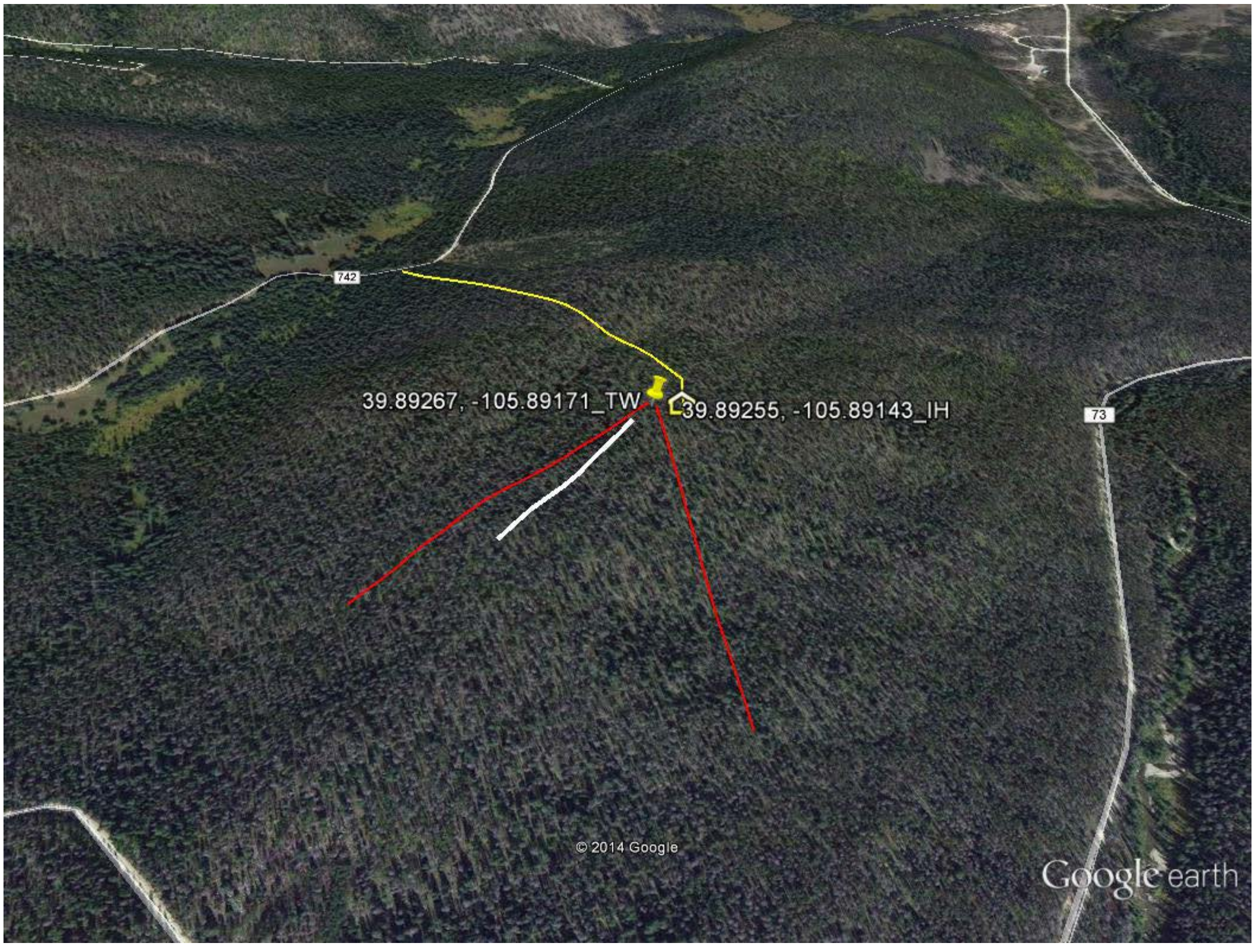


Figure 56. Site layout for Fraser Relocatable site.

i) tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors from 170^o to 220^o (clockwise from 170^o, major airshed) would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access way to instrument hut.

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

Specific boardwalks at this site:

- Boardwalk or on-grade boardwalk from the access dirt road to instrument hut, pending landowner decision.
- Boardwalk from the instrument hut to the tower pending landowner decision
- Boardwalk or on-grade boardwalk to soil array

No boardwalk from soil array boardwalk to individual soil plots.

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

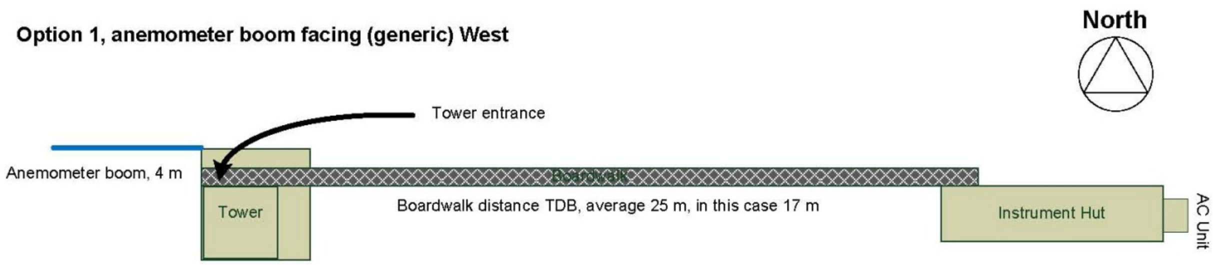


Figure 57. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing west and instrument hut on the east towards the tower.

This is just a generic diagram when boom facing west and instrument hut on the eastern side of the tower. The actual design of boardwalk (or path) and instrument hut position will be joint responsibility of FCC and FIU. At Fraser Relocatable site, the boom angle will be 300 degrees, instrument hut will be on the southeast side of the tower, the distance between instrument hut and tower is ~25 m. The instrument hut vector will be SW-NE (200°-20°, longwise).

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

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

5.6 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 (mixed spruce and fir and pine conifer forest). Prevailing winds blow from south (170° to 220°, clockwise from 170°). We expect that 80% for flux measurements are ~480 m during daytime and >3 km from tower during night time in summer seasons, and 90% signals are ~820 m from tower during daytime and >3 km during nighttime. However, during the winter seasons, 80% signals are within 630 m during daytime and over 3km for nighttime, while 90% signals are come from larger distance ~1km during daytime and > 3km during night time. We suggest FSU Ecosystem Productivity plots are placed within the boundaries of 170° to 220° (clockwise from 170°) from tower.

5.7 Issues and attentions

The road to the site is unpaved, as a result 4-wheel drive and high ground clearance is recommended to access the site.

Boardwalks can be used at the site, but it is not unusual to have very deep snow in forest clearings, so route markers will be needed for winter access.

Beetle killed trees are common in this region. Many already fell on the ground (access harzard) and many are still standing, but could fall or snap any time under windy conditions (safety harzard).

There are few beetle killed trees around tower location. They likely come down in next few years either by wind force or gravity. Consideration will be needed to protect tower, guy wires, booms and sensors.

One of the key science themes at this site supposes be a middle elevation (9000' to 1100') to capture the dust transport cross the Rocky Mountains. This tower location is at ~9,500', which is toward the low end of the range and similar to the low elevation site at CASTNET (~9,000'). From this science theme, this site is less ideal.

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