D10 FIU Site Characterization
Supporting Data

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	10/01/2009	NEON.FIU.00131.CRE	INITIAL RELEASE
B	09/30/2010	NEON.FIU.000246.CRE	Updates see CRE
C	09/23/2011	ECO-00279	Update to new document numbers/template throughout document.
D	05/15/52013	ECO-00556	Add wordings for tower placement, distance of sensors from ecosystem edge, and exclusion zone for each site.

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1 DESCRIPTION

1.1 Purpose

Data collected, analyzed and described here as used to inform the site design activities for NEON project Teams, EHS (permitting), FCC, ENG and FSU. This document presents all the supporting data for FIU site characterization.

1.2 Scope

This document presents the FIU site characterization data are for the three D10 shortgrass steppe tower locations, CPER Pawnee site (Core), North Sterling site (Relocatable 1), and RMNP CastNet site (Relocatable 2).

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]		

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 CENTRAL PLAINS EXPERIMENTAL RANGE (PAWNEE GRASSLANDS), ADVANCED TOWER

3.1 Site description

The Central Plains Experimental Range (CPER) is located at the western edge of the Pawnee National Grasslands in Colorado, and administered by the USDA-Agricultural Research Service. The CPER is 19 km northeast of Nunn, Colorado. The CPER includes 6300 hectares of undulating rangeland at an elevation of 1500-1700 m (Hanson et al., 1996). The NEON tower location and measurement area are at this open field and relatively flat grassland.

Average annual precipitation averages 212 mm and ranges between 101 and 508 mm. Approximately 80% of the precipitation occurs between April and September (Hanson et al., 1996). The region is composed of shale and interbedded sandstones from the Laramie formation with extensive alluvial and eolian reworking of soils (Kelly et al., 1993). Currently, grazing by domestic livestock is the primary land use of native grassland, which occupies about 60% of the land area of the shortgrass steppe.

3.1.1 Ecosystem

The biotic communities of the shortgrass steppe ecosystem are particularly well-adapted for drought, with vegetative species such as blue grama (*Bouteloua gracilis*) and prickly-pear cactus (*Opuntia polyacantha*), large herbivores such as cattle (and previously, bison), and burrowing animals such as the black-tailed prairie dog (*Cynomys ludovicianus*) playing dominant roles in ecosystem function and maintenance.

The main natural plant communities are shortgrass steppe, floodplain shrubland, and salt meadow. The ecosystem is dominated by short grasses (64%), succulents (21%) and dwarf shrubs (8%). Blue grama predominates and contributes 60 to 80% percent of plant cover, biomass, and net primary productivity. Long-lived C4 grasses such as blue grama dominate under the characteristically dry conditions of the shortgrass steppe by efficiently accessing available water. Other important plants include buffalo grass (*Buchloe dactyloides*), prickly pear cactus, rabbitbrush (*Chrysothamnus nauseosa*) and saltbush (*Atriplex canescens*). The shortgrass steppe stores most biomass and resources belowground, so that aboveground disturbances do not drastically alter the vegetative community (information source: http://sgs.cnr.colostate.edu/about_location.aspx). Mean canopy height is ~0.4 m. The surface roughness and zero place displacement height are estimated to be ~0.06 m (0.15 canopy height, Arya, 1988, p. 150) and ~0.26 m (0.7 canopy height, Arya 1988 page 151), respectively.

Pronghorn (*Antilocapra americana*) are among the most common wildlife species seen on shortgrass steppe. Black-tailed prairie dogs (*Cynomys ludovicianus*), through their clipping and burrowing activities, are also conspicuous, and create habitat for a number of other invertebrate and vertebrate animals, including horned larks (*Eremophila alpestris*), mountain plovers (*Charadrius montanus*), and burrowing owls (*Athene cunicularia*). Other species of special conservation interest or concern include the swift fox (*Vulpes velox*) and the lark bunting (*Calamospiza melanocorys*), the state bird of Colorado (information source: http://sgs.cnr.colostate.edu/about_location.aspx).

3.2 Soils

Soil data and soil maps (Figure 1 and 2) below for CPRE Pawnee site were collected from 1 km^2 and 50 m^2 NRCS soil maps, which centered at the tower location, to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

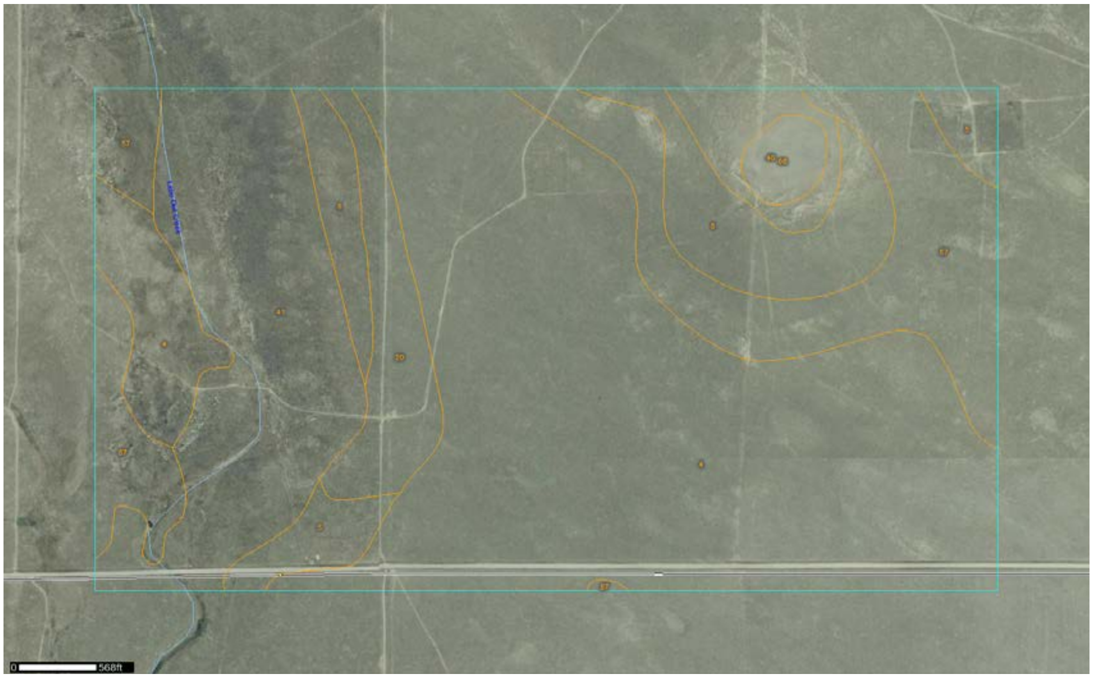


Figure 1. 1 km2 soil map for CPRE Pawnee site, center at tower location.

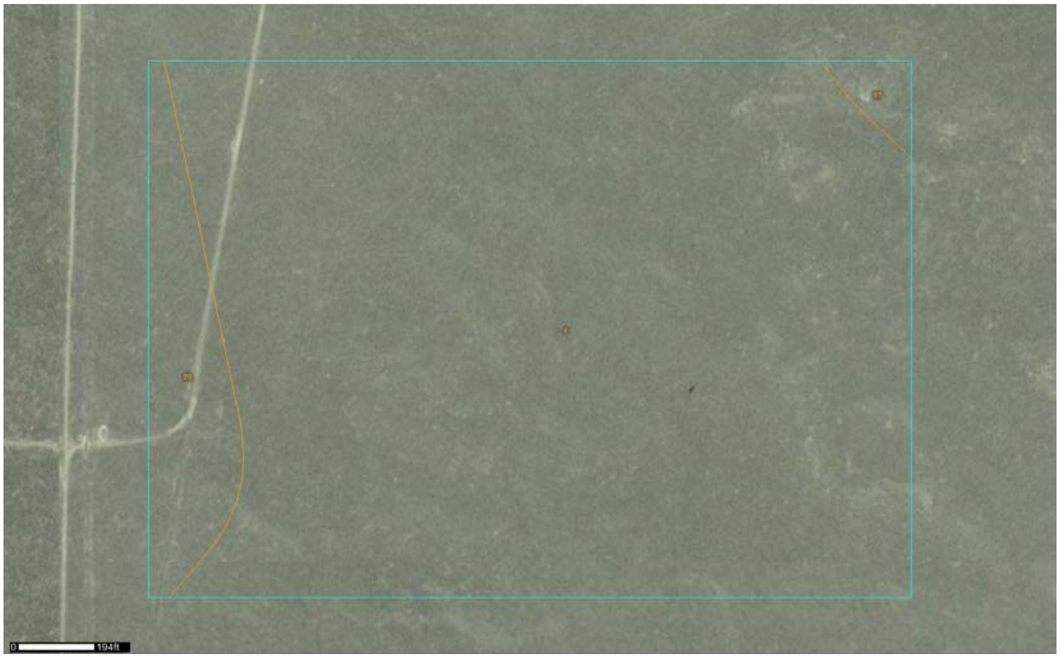


Figure 2. 50 m2 soil map for CPRE Pawnee site, center at tower location.

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

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

Table 1. Soil series and percentage of soil series within 1 km^2 centered on the tower.

Soil type	%
Weld County, Colorado, Northern Part 5—Ascalon fine sandy loam	48.0
Weld County, Colorado, Northern Part 41—Nunn clay loam	16.6
Weld County, Colorado, Northern Part 20—Cascajo gravelly sandy loam	4.8
Weld County, Colorado, Northern Part 40—Nunn loam	2.4
Weld County, Colorado, Northern Part 86—Playas	1.3
Weld County, Colorado, Northern Part 57—Renohill-Shingle complex	16.3

Weld County, Colorado, Northern Part 5—Ascalon fine sandy loam, 6 to 9 percent slopes Map Unit Setting Elevation: 4,500 to 6,500 feet Mean annual precipitation: 13 to 17 inches Mean annual air temperature: 46 to 57 degrees F Frost-free period: 130 to 160 days Map Unit Composition Ascalon and similar soils: 85 percent Minor components: 15 percent Map Unit Description: Ascalon fine sandy loam, 6 to 9 percent slopes–Weld County, Colorado, Northern Part CPER_1km Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009. Description of Ascalon Setting Landform: Plains Down-slope shape: Linear Across-slope shape: Linear Parent material: Calcareous loamy alluvium Properties and qualities Slope: 6 to 9 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 10 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Moderate (about 6.8 inches) Interpretive groups Land capability classification (irrigated): 4e Land capability (non-irrigated): 4e Ecological site: Loamy Plains (R067BY002CO) Typical profile 0 to 6 inches: Fine sandy loam 6 to 21 inches: Sandy clay loam 21 to 60 inches: Sandy loam Minor Components Altvan Percent of map unit: 7 percent Peetz Percent of map unit: 4 percent Cascajo Percent of map unit: 3 percent Aquic haplustolls Percent of map unit: 1 percent Landform: Swales

Weld County, Colorado, Northern Part 41—Nunn clay loam, 0 to 6 percent slopes Map Unit Setting Elevation: 4,500 to 6,700 feet Mean annual precipitation: 12 to 18 inches Mean annual air temperature: 46 to 54 degrees F Frost-free period: 115 to 180 days Map Unit Composition Nunn and similar soils: 85 percent Minor components: 15 percent Map Unit Description: Nunn clay loam, 0 to 6 percent slopes–Weld County, Colorado, Northern Part CPER_1km Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009 Page 2 of 3Description of Nunn Setting Landform: Stream terraces, plains Down-slope shape: Linear Across-slope shape: Linear Parent material: Calcareous loamy alluvium Properties and qualities Slope: 0 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): Moderately low to moderately high (0.06 to 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: High (about 9.2 inches) Interpretive groups Land capability classification (irrigated): 3e Land capability (non-irrigated): 4e Ecological site: Loamy Plains (R067BY002CO) Typical profile 0 to 8 inches: Clay loam 8 to 22 inches: Clay loam 22 to 60 inches: Clay loam Minor Components Avar Percent of map unit: 8 percent Manzanola Percent of map unit: 7 percent

Weld County, Colorado, Northern Part 20—Cascajo gravelly sandy loam, 5 to 20 percent slopes Map Unit Setting Elevation: 4,000 to 5,000 feet Mean annual precipitation: 11 to 13 inches Mean annual air temperature: 52 to 54 degrees F Frost-free period: 120 to 160 days Map Unit Composition Cascajo and similar soils: 85 percent Minor components: 15 percent Map Unit Description: Cascajo gravelly sandy loam, 5 to 20 percent slopes– Weld County, Colorado, Northern Part CPER_1km Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009. Description of Cascajo Setting Landform: Breaks, ridges Down-slope shape: Linear Across-slope shape: Linear Parent material: Calcareous gravelly alluvium Properties and qualities Slope: 5 to 20 percent Depth to restrictive feature: More than 80 inches Drainage class: 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 Calcium carbonate, maximum content: 25 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Low (about 3.9 inches) Interpretive groups Land capability (non-irrigated): 7s Ecological site: Gravel Breaks (R067BY063CO) Typical profile 0 to 3 inches: Gravelly sandy loam 3 to 24 inches: Very gravelly loamy sand 24 to 60 inches: Very gravelly sand Minor Components Stoneham Percent of map unit: 14 percent Otero Percent of map unit: 1 percent

Weld County, Colorado, Northern Part 40—Nunn loam, 0 to 6 percent slopes Map Unit Setting Elevation: 4,500 to 6,700 feet Mean annual precipitation: 12 to 18 inches Mean annual air temperature: 46 to 54 degrees F Frost-free period: 115 to 180 days Map Unit Composition Nunn and similar soils: 85 percent Minor components: 15 percent Map Unit Description: Nunn loam, 0 to 6 percent slopes–Weld County, Colorado, Northern Part CPER_1km Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009. Description of Nunn Setting Landform: Stream terraces, plains Down-slope shape: Linear Across-slope shape: Linear Parent material: Calcareous loamy alluvium Properties and qualities Slope: 0 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): Moderately low to moderately high (0.06 to 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Moderate (about 9.0 inches) Interpretive groups Land capability (non-irrigated): 4c Ecological site: Loamy Plains (R067BY002CO) Typical profile 0 to 7 inches: Loam 7 to 23 inches: Clay loam 23 to 60 inches: Clay loam 60 to 64 inches: Sandy clay loam Minor Components Manzanola Percent of map unit: 8 percent Avar Percent of map unit: 7 percent

Weld County, Colorado, Northern Part 86—Playas Map Unit Composition Playas: 100 percent Description of Playas Setting Landform: Playas Landform position (three-dimensional): Talf Down-slope shape: Linear Across-slope shape: Linear Parent material: Alluvium

Weld County, Colorado, Northern Part 57—Renohill-Shingle complex, 3 to 9 percent slopes Map Unit Setting Elevation: 3,600 to 6,200 feet Mean annual precipitation: 10 to 16 inches Mean annual air temperature: 46 to 48 degrees F Frost-free period: 100 to 160 days Map Unit Composition Renohill and similar soils: 50 percent Shingle and similar soils: 35 percent Minor components: 15 percent Map Unit Description: Renohill-Shingle complex, 3 to 9 percent slopes–Weld County, Colorado, Northern Part CPER_1km Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009. Description of Renohill Setting Landform: Breaks, ridges, plains Down-slope shape: Linear Across-slope shape: Linear Parent material: Calcareous, clayey loamy residuum weathered from shale Properties and qualities Slope: 3 to 9 percent Depth to restrictive feature: 20 to 40 inches to paralithic bedrock Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Low (about 5.0 inches) Interpretive groups Land capability (non-irrigated): 4e Ecological site: Loamy Plains (R067BY002CO) Typical profile 0 to 4 inches: Fine sandy loam 4 to 13 inches: Clay 13 to 29 inches: Clay loam 29 to 33 inches: Unweathered bedrock Description of Shingle Setting Landform: Breaks, plains, ridges Down-slope shape: Linear Across-slope shape: Linear Parent material: Calcareous loamy residuum weathered from shale Properties and qualities Slope: 3 to 9 percent Depth to restrictive feature: 10 to 20 inches to paralithic bedrock Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Very low (about 2.1 inches) Interpretive groups Land capability classification (irrigated): 6s Map Unit Description: Renohill-Shingle complex, 3 to 9 percent slopes–Weld County, Colorado, Northern Part CPER_1km Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009. Land capability (non-irrigated): 6s Ecological site: Shaly Plains (R067BY045CO) Typical profile 0 to 4 inches: Clay loam 4 to 11 inches: Clay loam 11 to 15 inches: Unweathered bedrock Minor Components Midway Percent of map unit: 8 percent Tassel Percent of map unit: 7 percent

Data Source Information Soil Survey Area: Weld County, Colorado, Northern Part Survey Area Data: Version 8, Apr 30, 2009 Map Unit Description: Renohill-Shingle complex, 3 to 9 percent slopes–Weld County, Colorado, Northern Part CPER_1km Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009

3.2.1 Soil semi-variogram description

The goal of this site characterization of soil using semi-variograms is to determine the minimum distance between the soil plots in the soil array that can be considered spatially independent. The spatial variation of surface soil will be estimated using field sampling data of soil temperature and soil water content (SWC) in the tower airshed at Central Plains Experimental Range (CPER) Pawnee site.

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

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

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

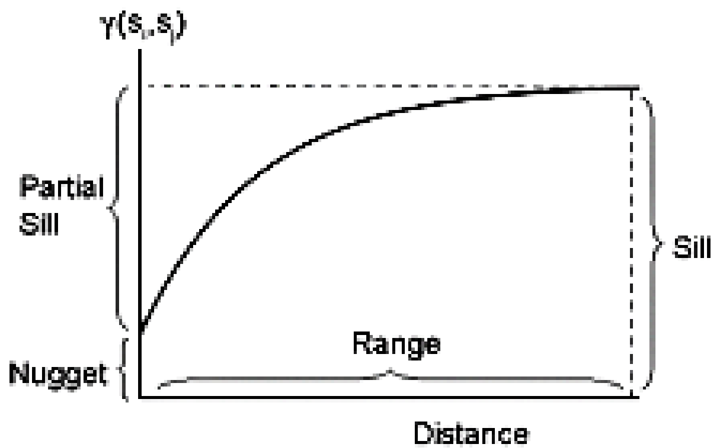


Figure 3. Example semivariogram, depicting range, sill, and nugget.

3.2.2 Soil Semi-Variogram Method, Experimental design, data analysis

Field measurements of soil temperature and soil water content (SWC) were taken on August 13 and August 14, 2009 at the at Central Plains Experimental Range (CPER) Pawnee site following the spatially cyclic sampling design by Bond-Lamberty et al. (2006, Figure 4). This design uses repeated pattern of samples to provide information about all distance with minimum of redundancy.

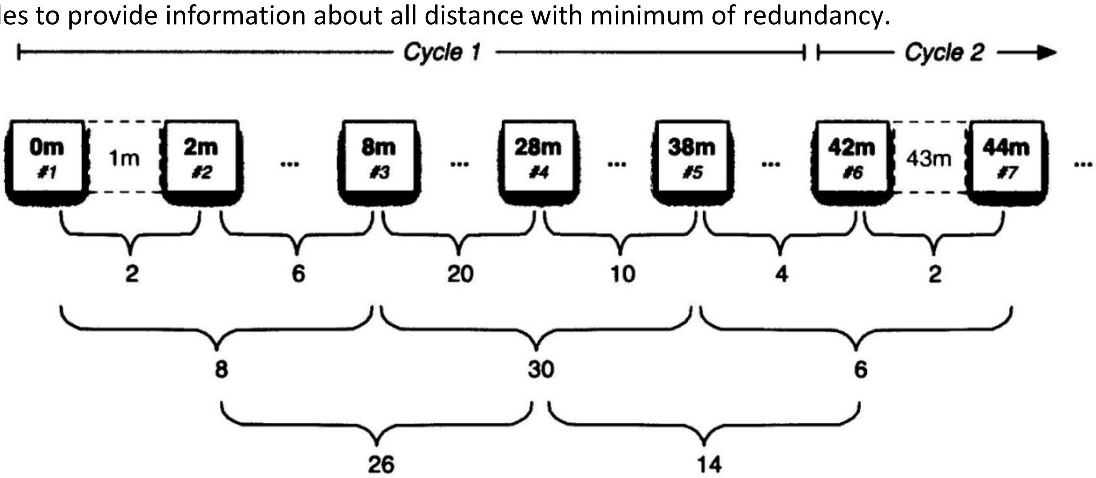


Figure 4. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

One 210-meter and two 84-meter transects were established at CPER Pawnee grasslands site. All transect were centered at the same location (Latitude: N40.81722, Longitude: W104.74924). First transect was 210 meters and ran toward the direction of 340^o (compass magnetic degrees, same below) from the pre-designed tower location (Latitude: N40.81636, Longitude: W104.74901). Sampling points for this transect were 26. Second transect was 84 meters and ran NE-SW direction (40^o-220^o) with 11 sampling points. Third transect was 84 meters and ran SE-NW direction (100^o– 280^o) with 11 sampling points. A Garmin GPS device was used to record the sampling location. All transects were set in the expected airshed (dominant wind directions, Figure 5, Figure 6). Rough airshed area was determined by the wind roses that were established based on the historic wind direction and wind speed data. The determination of accurate airshed area by models will be described in the "Airshed" session below.

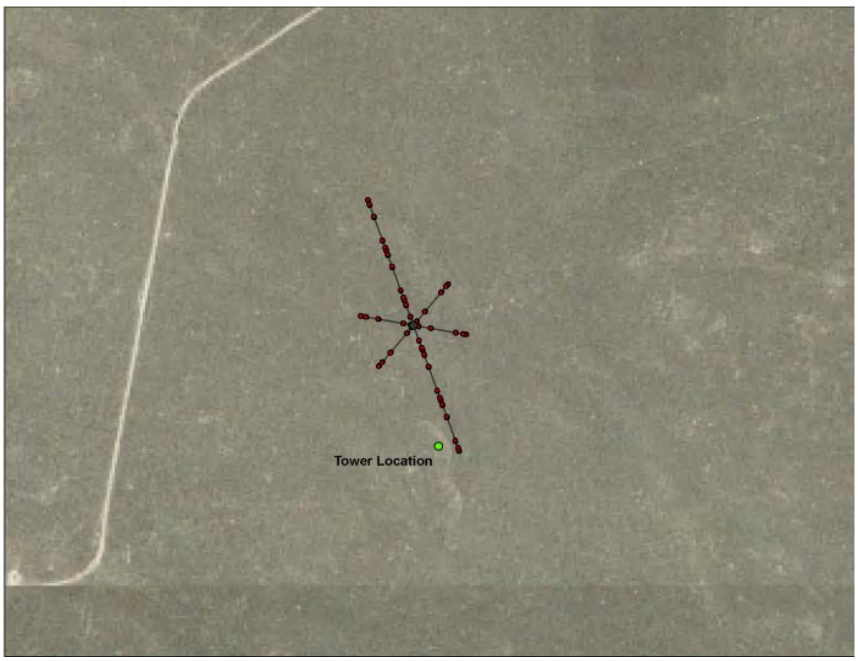


Figure 5. Established transects at Pawnee Grassland site

These transects were used for field measurements of soil temperature and soil water content for site characterization of soil. Tower location presented was the pre-designed tower location.

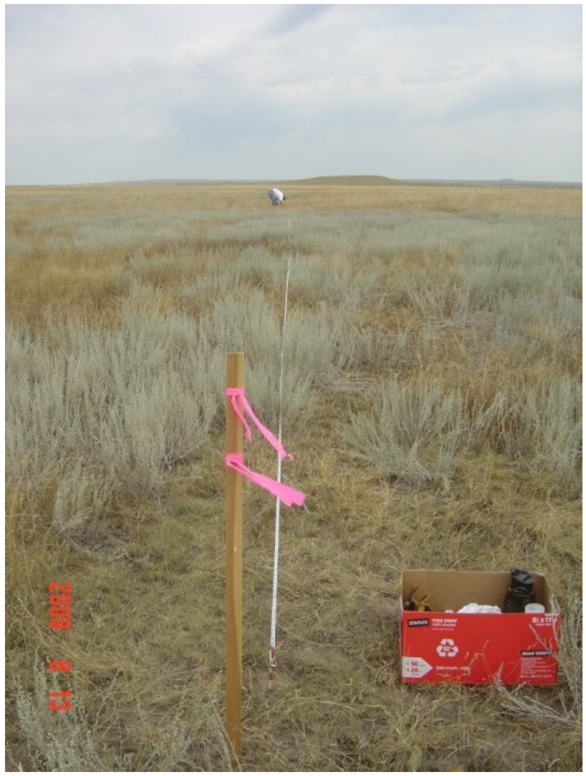


Figure 6. Established transects at CPRE Pawnee advance tower site.

3 replicates (30 cm apart from one another, Figure 7) were measured at each sampling point at fixed-depth (0-20 cm) using platinum resistance temperature sensors (RTD 810, Omega Engineering Inc., Stamford CT) for soil temperature and time domain diaelectric sensors (CS616, Campbell Scientific Inc., Logan UT) for SWC at each sampling points. Data collected were used for geospatial analyses of variograms in the R statistical computing language with the geoR package to test for spatial autocorrelation (Goovaerts, 1997; Trangmar et al., 1985; Webster, 1989) and to determine the distance for soil plots in the soil array.

For all data sets for temperature and SWC, there is evidence for the existence of spatial trends that can be modeled as a function of time. This is a consequence of the fluctuating solar radiation throughout the day. Trends were estimated and removed with a simple two parameter linear regression model and p-values for the model significance are provided in the respective text below in results session. For the most part, this approach was sufficient with respect to satisfying the assumption of stationarity. Hence, variogram models were constructed on the residuals from these regressions of the response variable on time. The range distance (*i.e.,* the distance beyond which samples are spatially independent) was estimated from the empirical variogram by fitting spherical theoretical models to both soil temperature and SWC data.

Figure 7. Three replicates of soil temperature and SWC

Measurements at each sampling point were at fixed-depth (0-20 cm). These 3 replicates are 30 cm apart from one another along the established transects at the CPRE Pawnee advance tower site.

3.2.3 Results and interpretation

Temperature

The temperature data display a strong pattern as a function of time. A linear regression ($p < 0.001$) of temperature on time was fit and used to extract this trend (Figure 8). Exploratory data analysis plots show that there is no distinct patterning of the residuals (Figure 9). Directional variograms of the residuals do not show any indication of anisotropy (Figure 10). It is worth noting here that the sampling design allowed for a better characterization of the directional variograms relative to the sampling design at Sterling. A spherical covariance model was fit using Cressie weights and a maximum distance of 125 meters (Figure 11). The estimated distance of effective independence was 88 meters. This information will be used to refine the design applied to the subsequent sites. If the maximum distance between samples in the final sampling design is less than the distance of effective independence, then increased sampling density may be required to achieve a nominal sample size in the presence of correlated data.

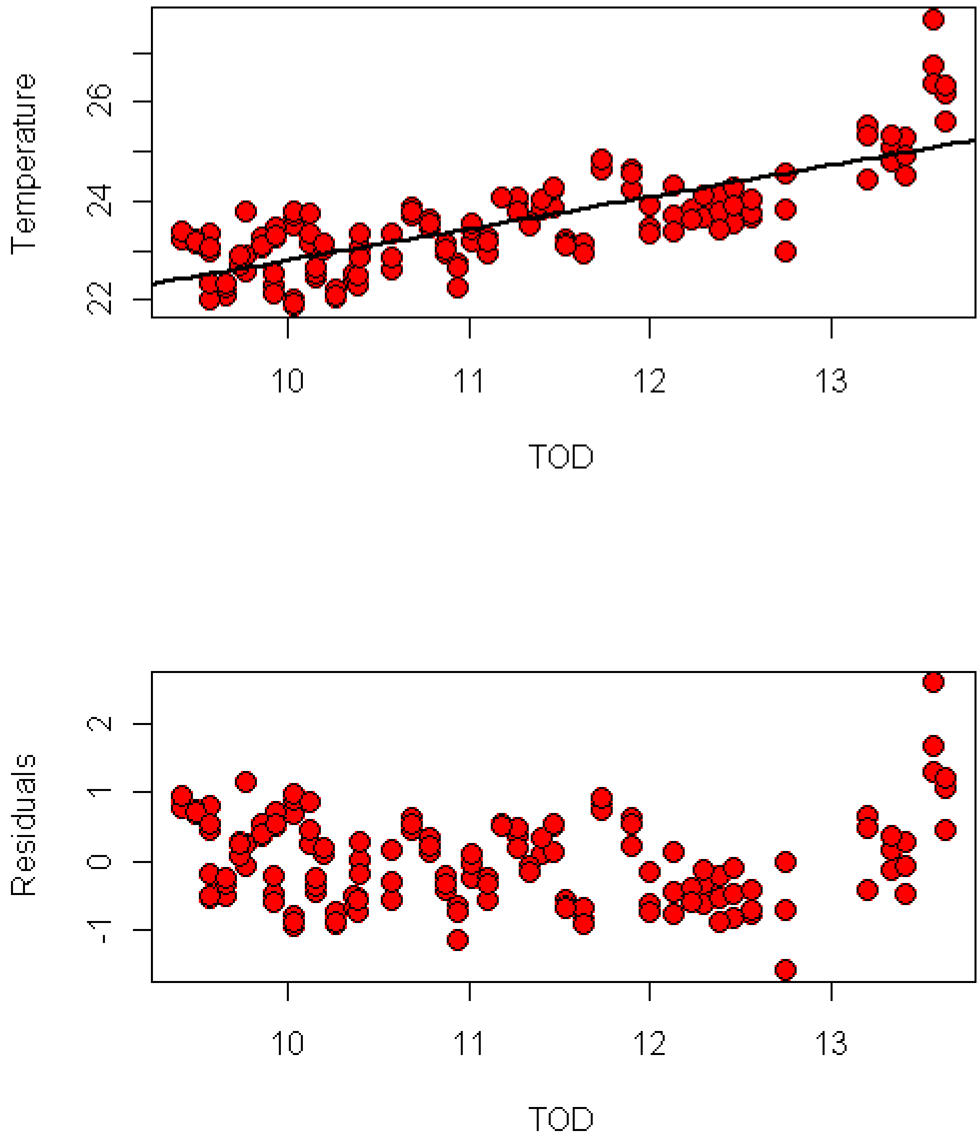


Figure 8. Time trend with linear regression fit and residuals for temperature at the CPRE Pawnee advance tower site.

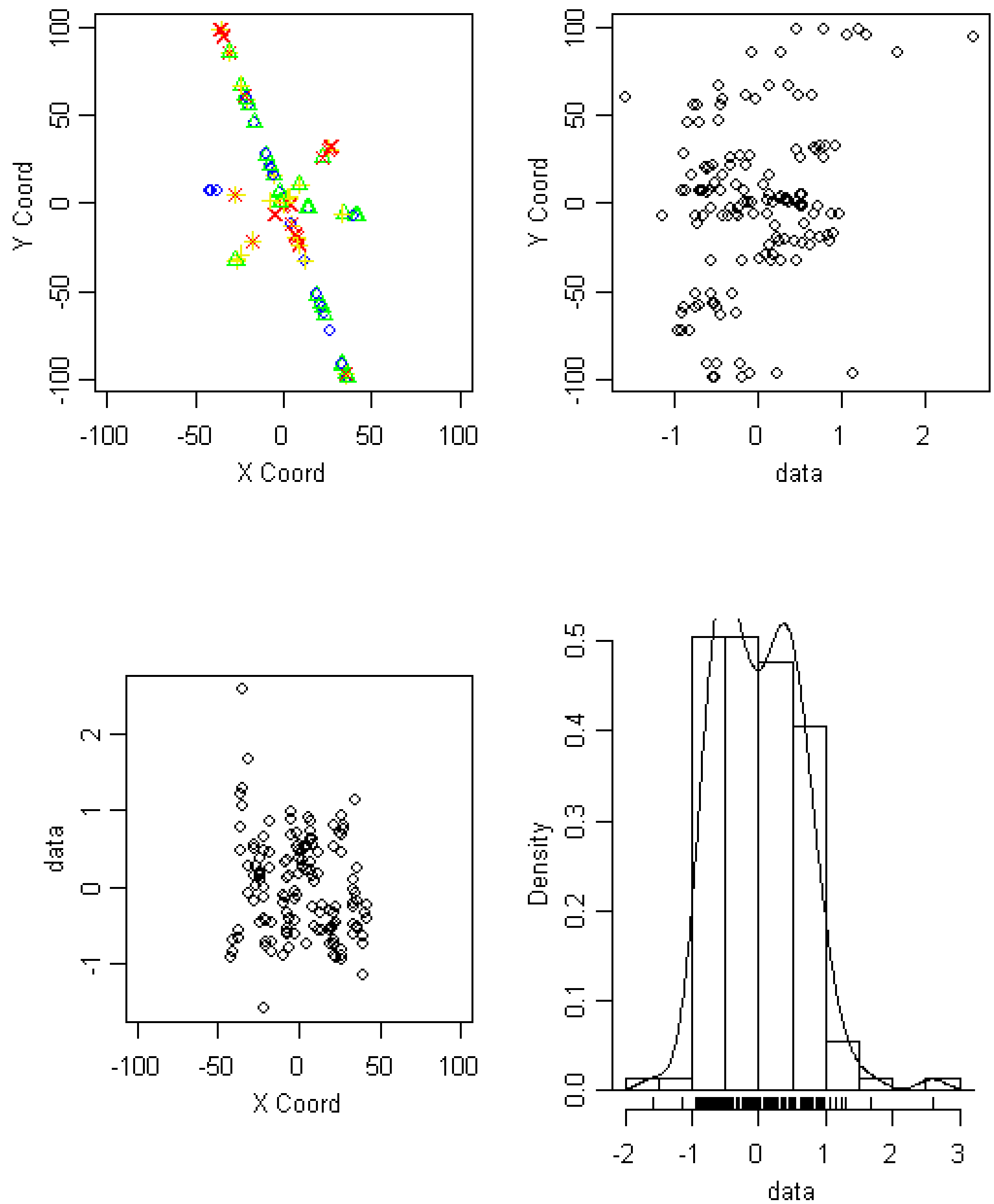


Figure 9. Exploratory data analysis plots for residuals from regression of temperature on time at the CPRE Pawnee advance tower site.

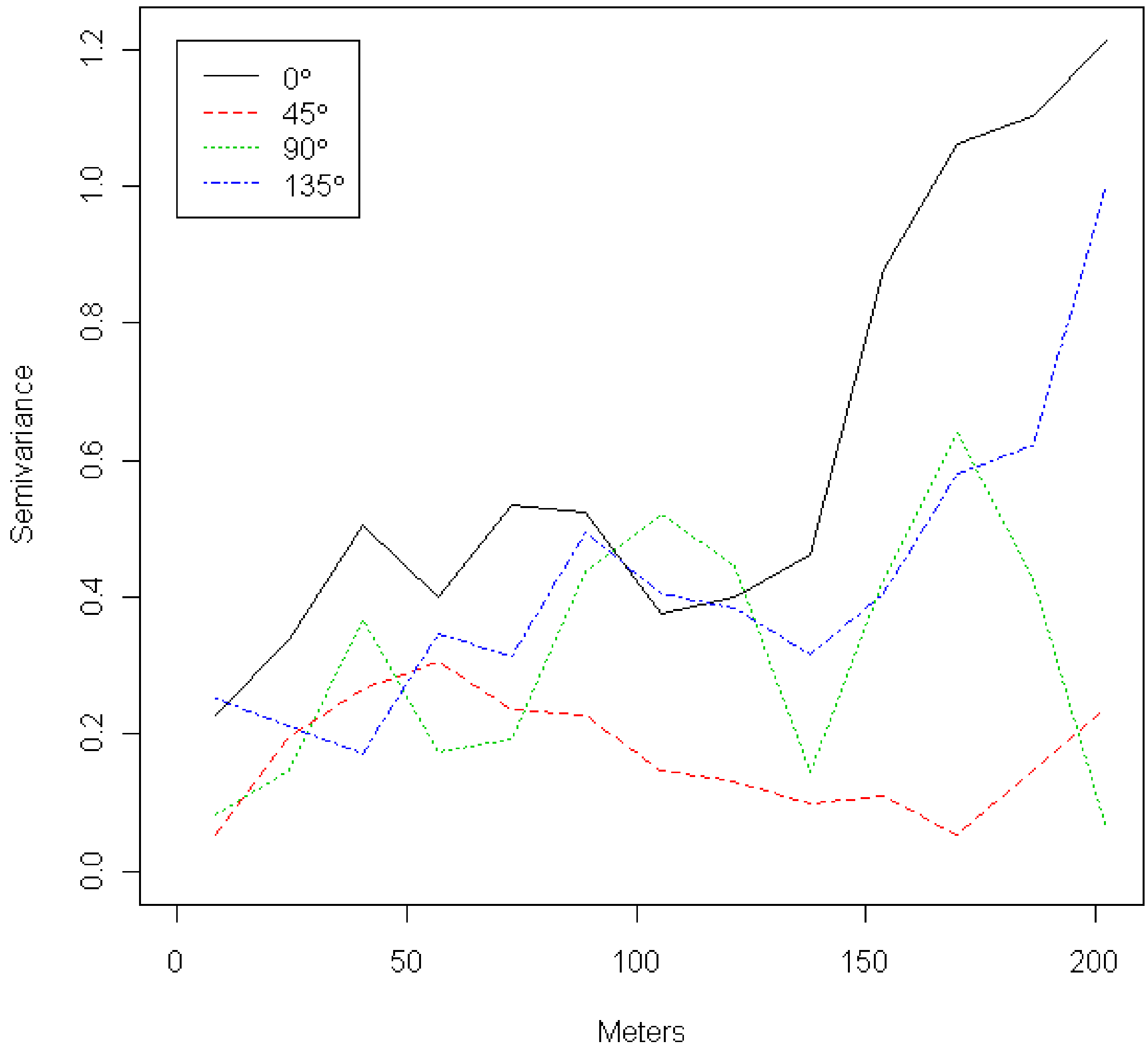


Figure 10. Directional variograms for residuals from regression of temperature on time at the CPRE Pawnee advance tower site.

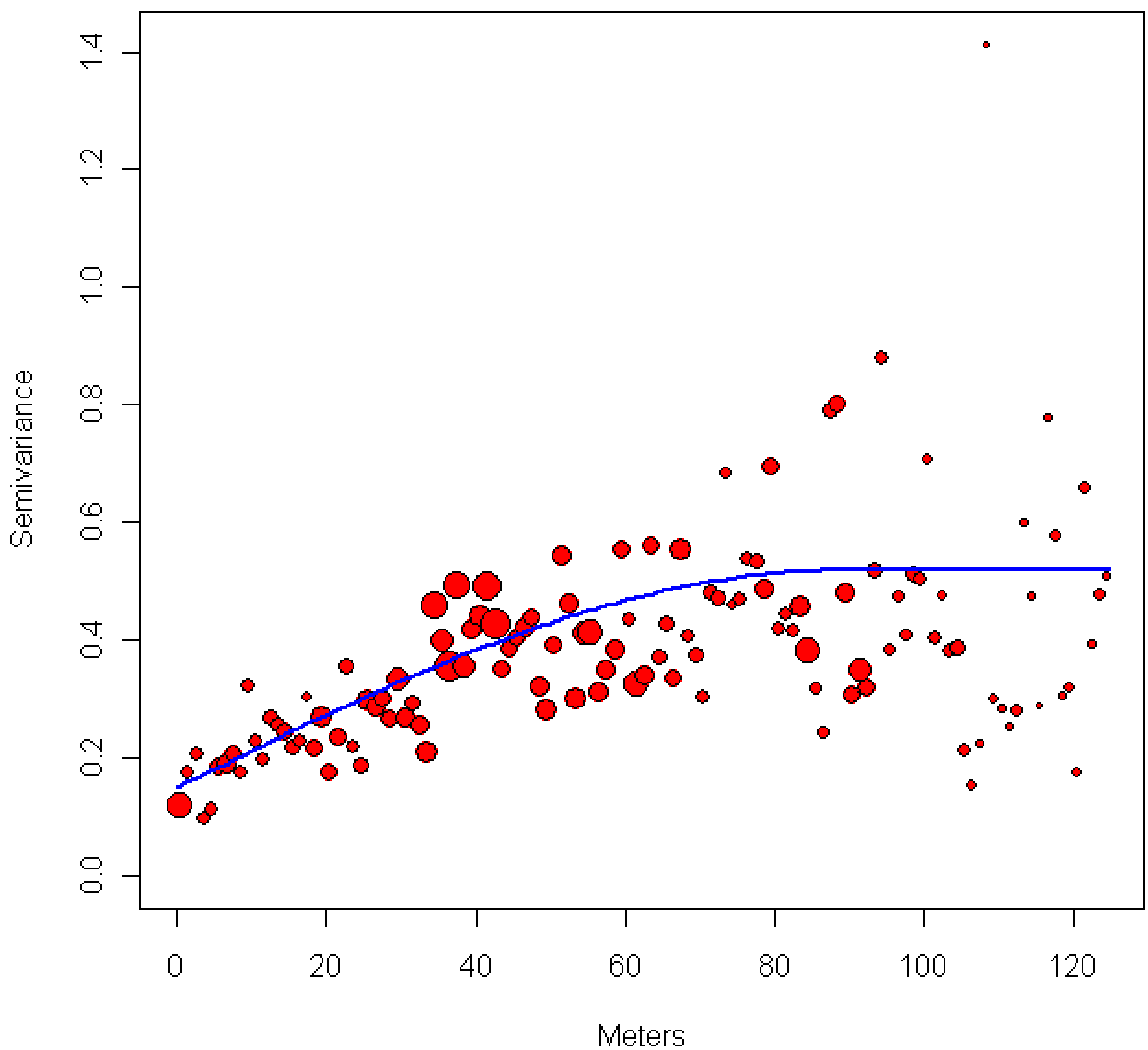


Figure 11. Empirical variogram and model fit for the residuals of the regression of temperature on time at the CPRE Pawnee advance tower site.

Soil Water Content

The soil water content (SWC) data display a decreasing pattern as a function of time. A linear regression ($p < 0.001$) of temperature on time was fit and used to extract this trend (Figure 12). Exploratory data analysis plots show that there is an increase in the spread of the residuals with respect to the center of the y-axis (upper right corner Figure 13). Directional variograms of the residuals do not show any indication of anisotropy (Figure 14). A spherical covariance model was fit using Cressie weights (Figure 15) and the estimated distance of effective independence was 35 meters. This information is used to refine the design applied to the subsequent sites.

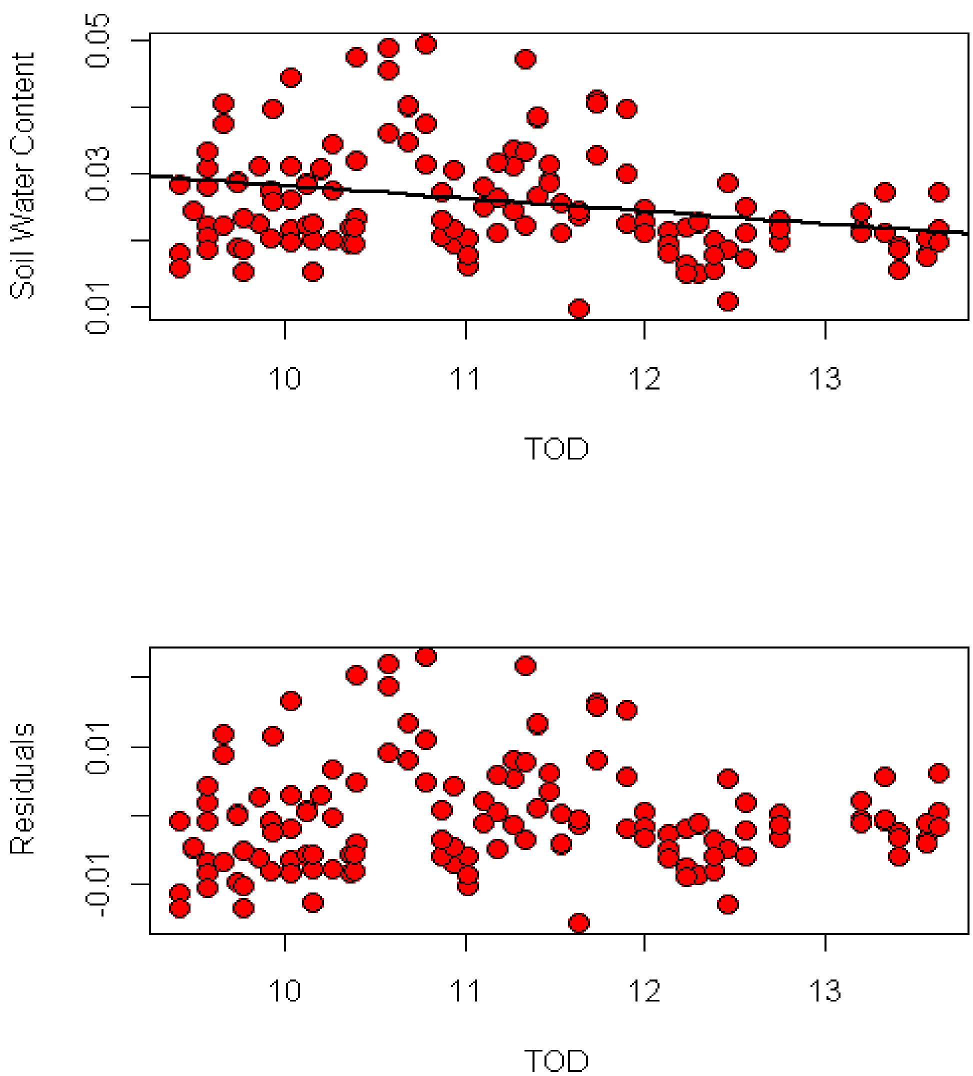


Figure 12. Time trend with linear regression fit and residuals for soil water content at the CPRE Pawnee advance tower site.

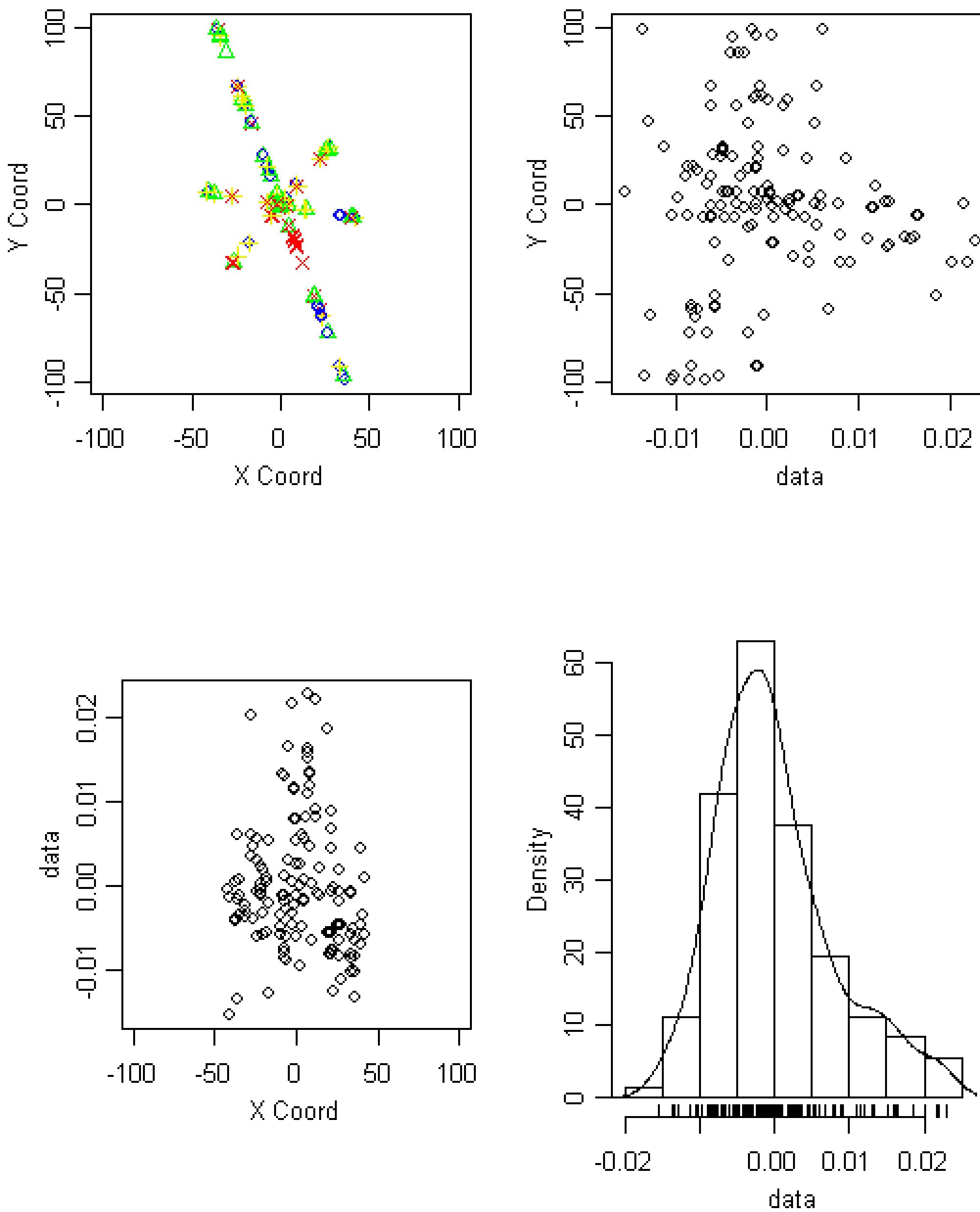


Figure 13. Exploratory data analysis plots for residuals from regression of soil water content on time at the CPRE Pawnee advance tower site.

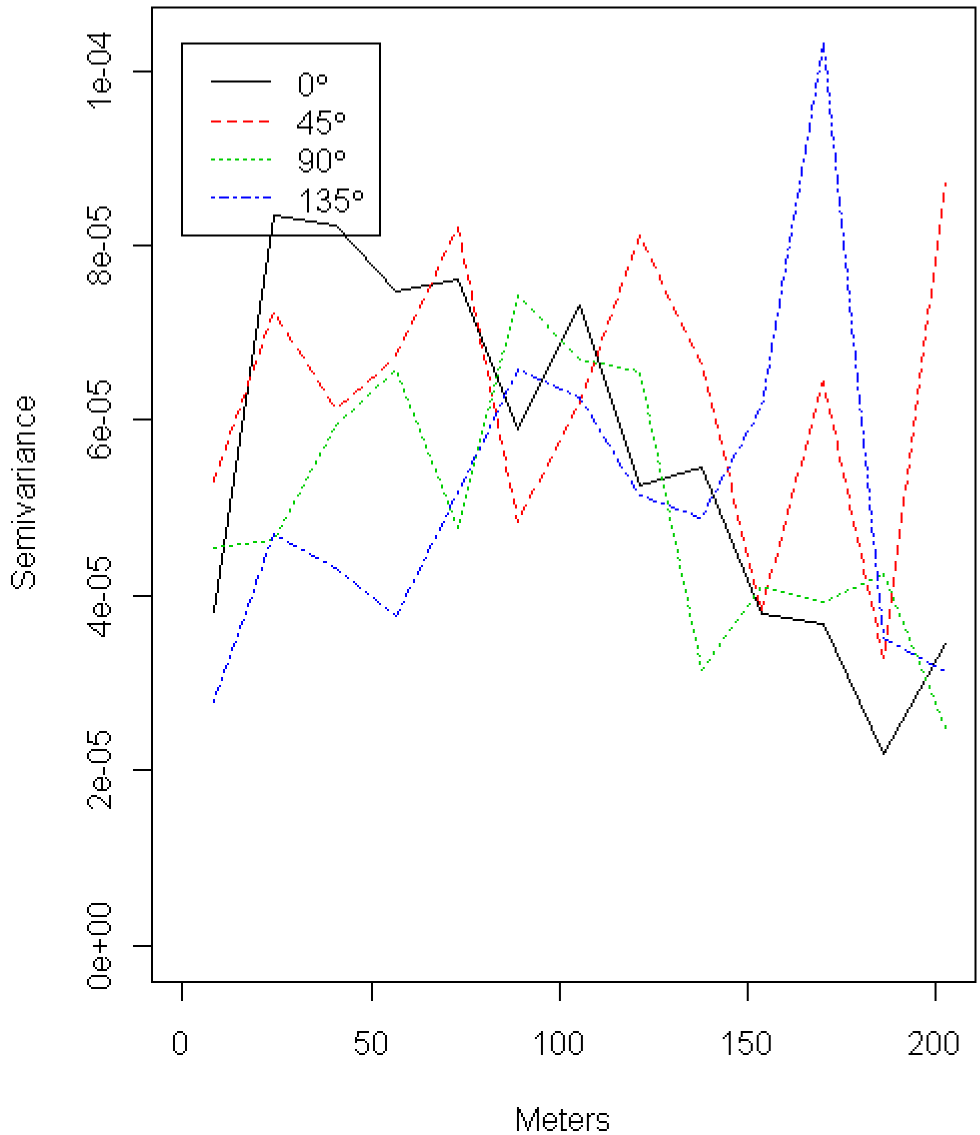


Figure 14. Directional variograms for residuals from regression of soil water content on time at the CPRE Pawnee advance tower site.

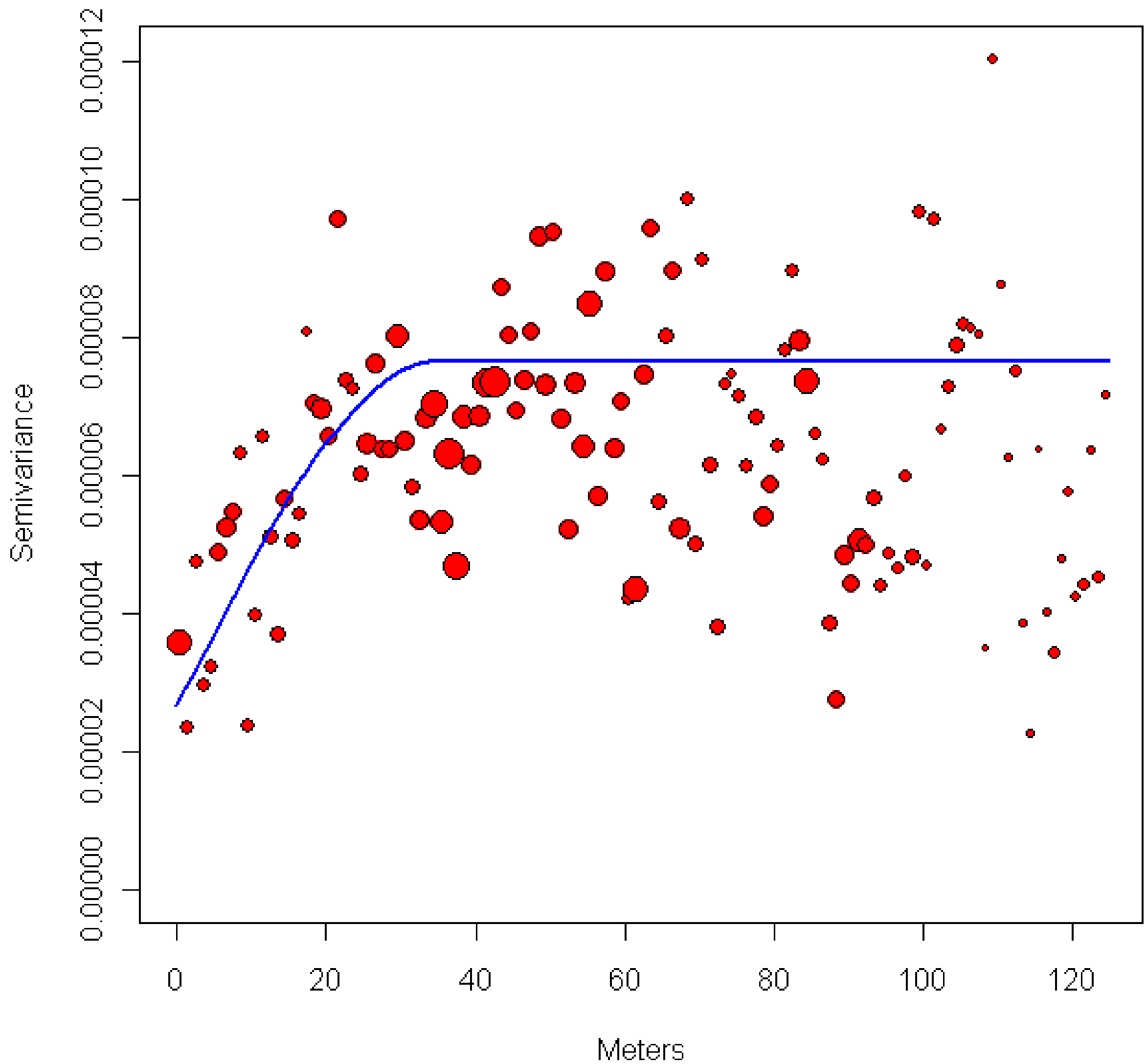


Figure 15. Empirical variogram and model fit for the residuals of the regression of soil water content on time at the CPRE Pawnee advance tower site.

3.2.4 Summary

The estimated distance of effective independence was 88 meters based on geospatial analysis of temperature data alone, which is impossible to separate soil plots so far apart due to the practical economic reasons. The estimated distance of effective independence was found to be 35 meters with a well-defined sill based on the geospatial analysis on SWC. This is confirmed by a previous study (Hanson at el., 1996) on spatial analysis of other soil properties (bulk density, percentage sand, percentage clay, percentage CaCo3 and percentage organic matter, etc.) at the same location of Pawnee grassland. The majority of the range results for above soil property variables are <35 meters in this study. Therefore, we are confident that the soil plots 35 meters apart from one another will be adequate to avoid the autocorrelation.

3.3 Airshed

3.3.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries (Figure 16 – 19). The orientation of the wind rose follows that of a compass. When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. Color bands depict the range of wind speeds. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 16 cardinal directions.

Data used here are hourly data from 1986 to 2007. Data was collected and obtained from the datasets of Short Grass Steppes Long Term Ecological Research (SGS-LTER) site, and compiled by B. McNoldy. Data were collected by a propeller anemometer mounted at 2.2 m inside the Agricultural Research Service (ARS) experimental area surrounded by flat topography. It is assumed that the wind data was corrected for declination.

3.3.2 Resultant vectors

Table 2. The resultant wind vectors from CPER Pawnee site using hourly data from 1999 to 2009.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
December to February	340°	12.7
March to May	337°	11.2
June to August	20°	7.4
September to November	335°	10.7
Annual mean	348°	na.

Table 3. The percent duration of winds among cardinal directions, 3 frequency bins on each side of the cardinal direction.

Data are from CPER Pawnee Site using hourly data from 1999 to 2009. Blue text and underline indicates the dominant, winds occurring for the cardinal direction >40% of the time.

Quarterly (seasonal) timeperiod	Cardinal direction			
	North	East	South	West
December to February	56.6	12.7	2.4	28.3
March to May	42.4	20.6	16.7	20.4
June to August	33.9	25.4	23.9	16.9
September to November	48.8	16.6	11.6	23.2

3.3.3 Acceptance criteria (overview)

Micrometeorological theory and the eddy covariance technique were established over uniform vegetative canopies with short roughness lengths on flat terrain and large fetch. The objective is to place a tower in such a way to optimize the amount of time where all the flows (winds) and microclimate with minimal disturbance and secondary filtering. Flow through the tower must be discounted and screened against data quality criteria. Flows that pass through a tower often have to be screened and filtered out of a long-term dataset. Part of the task here is to position the tower to optimize the amount of time wind flows from the desired landscape. Here at Pawnee, the tower was moved toward the south and east within the property boundary – to optimize the temporal coverage of desired flows, and to minimize the influence of the neighboring (undesirable) land use types. Additional concerns and acceptance criteria can be found in the FIU Tower Science requirements (AD[01]).

The tower should be sited to maximize the time with winds blowing from the desired land cover type, and with the longest upwind fetch attainable. If the surroundings are not of a uniform cover type, there needs to be some analysis of prevailing winds to demonstrate that the desired sectors are sampled uniformly through time. Consider the extreme example of a site with two different forest types and a consistent daily wind cycle that blew from one forest type and in the day and the other at night. Daily integrated NEE in this situation would be un-interpretable. This extreme condition is unlikely, but many sites could have more subtle wind direction biases that need to be examined and considered in data interpretation. All systems are subject to horizontal flux divergence, advective motions, wake effects and drainage of air sheds (AD[01]). Footprint analyses to determine the source area under different stabilities, wind speeds and direction among seasons provide valuable guidance for appropriate tower placement, documentation of site characteristics, and definition of data acceptance criteria (Foken & Leclerc, 2004; Horst & Weil, 1992; Horst & Weil, 1994a; Horst & Weil, 1994b; Horst, 2001; Kormann & Meixner, 2001; Schmid & Lloyd, 1999; Schmid, 1994; Schuepp et al., 1990). The criteria for tower placement should not only be concerned with the summer, productive periods, but also the seasonal transitional periods (spring and fall), and winter months when respiration process often dominate.

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

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

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

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

Winds at CPER Pawnee site are dominant from the north quadrant (Table 2), and annual resultant wind vector is from 348°. However, winds do come from the other quadrants during the summer months, due to the convective scales and storm fronts (Figure 18). Convective fronts develop daytime winds along the front range and generally pass over the site, travelling from the west to the east. But as they pass over they re-direct the winds to other vectors, from the east, south etc. (Figure 18).

The desired measurements are from lightly grazed, natural and minimally managed shortgrass prairie, with the dominant soil association being Ascalon fine silt loam with 0-6° slope (48% spatially dominant). The available west-to-east length of this ecosystem is ~800 m. Immediately to the east is another managed block of shortgrass prairie, but is managed as over grazed. These eastern winds would have to be inspected for data quality, and would be potentially biased by the differences in management and the subsequent changes in microclimate and biochemical cycling (flux rates). Hence, flows from the east are least desirable. Because flows through the tower have to be examined and potentially removed from the dataset, placing the leeward side of the tower closest to the east, optimizes flows over the source area from the west. To maximize the fetch (source area) from the NW from the winter, spring and fall seasons, the tower location should be placed in the SE area of the parcel. Because winds from the south occur during the summer and the results from the footprint analyses (Figures 20 - 23) indicate 80% of the cumulative flux is derived over ~ 200-300 m under summer convective conditions, the tower placement should be ~ 300 m north of the southern boundary. Instrument hut shall be placed in the leeward side of the tower and not influence the flows around the tower, hence, the distance of ~ 5 x the hut height towards the east of the tower is required (AD[02]).

3.3.4 Results (graphs for wind roses)

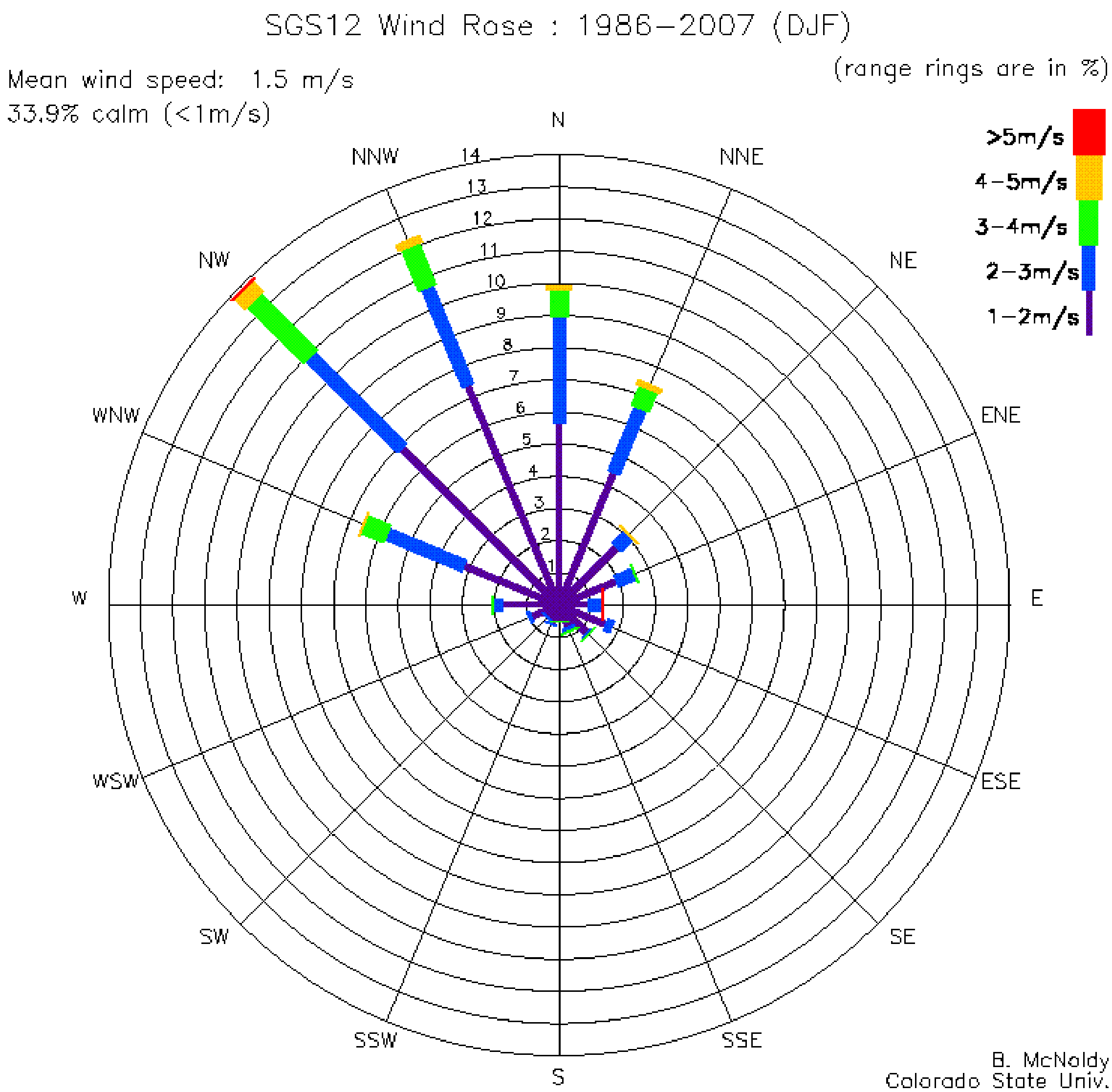


Figure 16. Wind roses of December - February for CPRE Pawnee site in 1986-2007

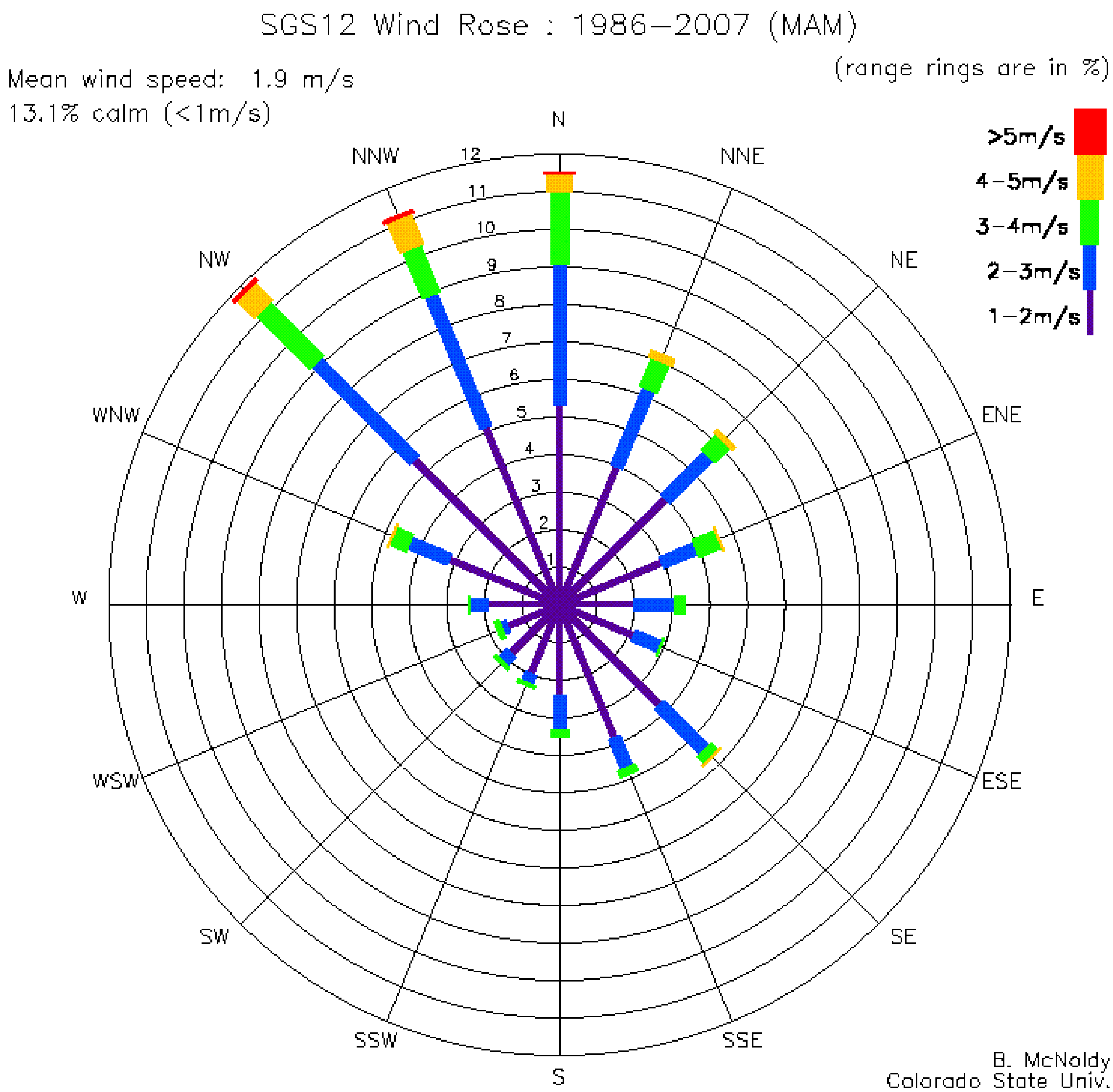


Figure 17. Wind roses of March - May for CPRE Pawnee site in 1986-2007

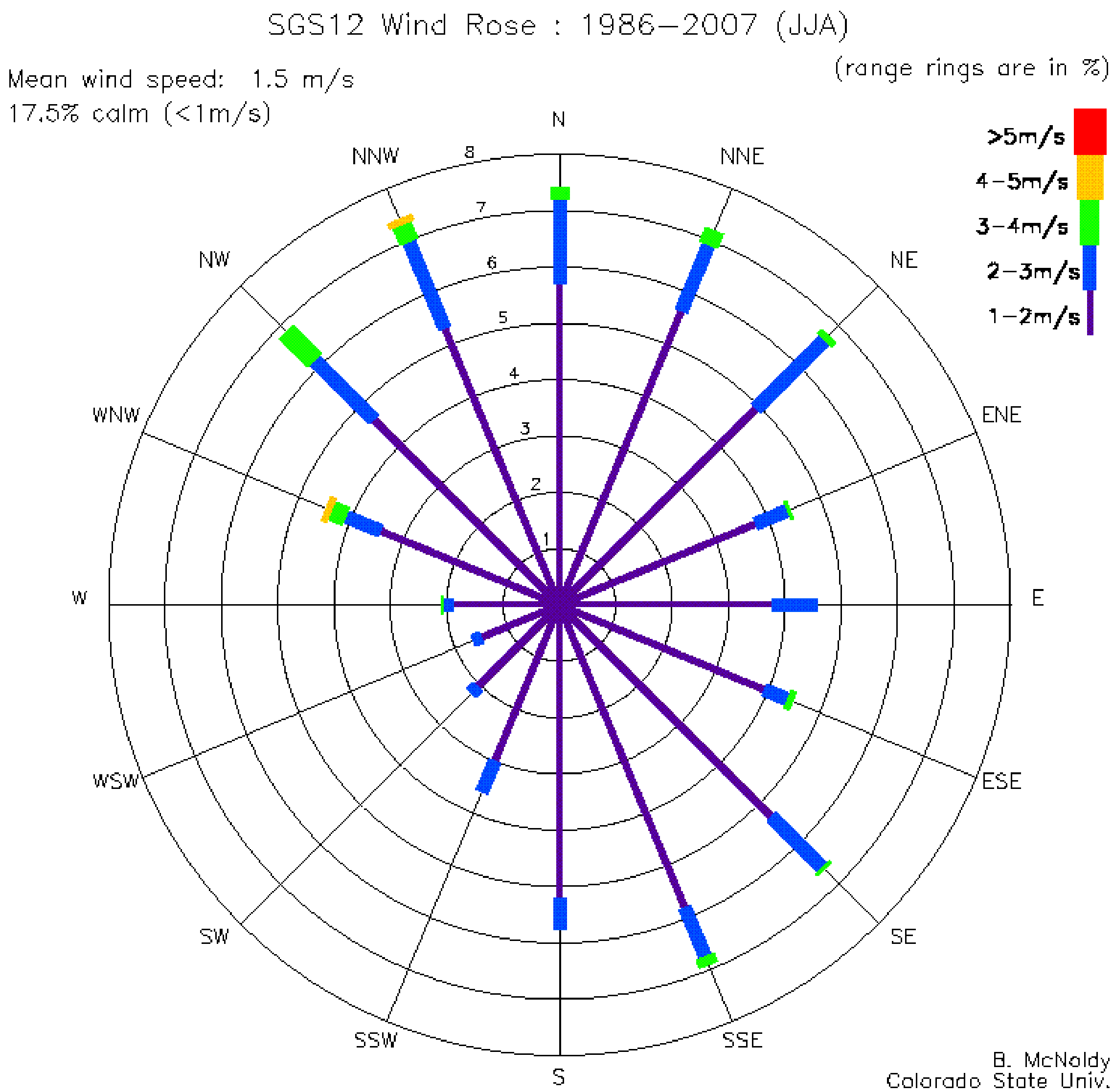


Figure 18. Wind roses of June - August for CPRE Pawnee site in 1986-2007

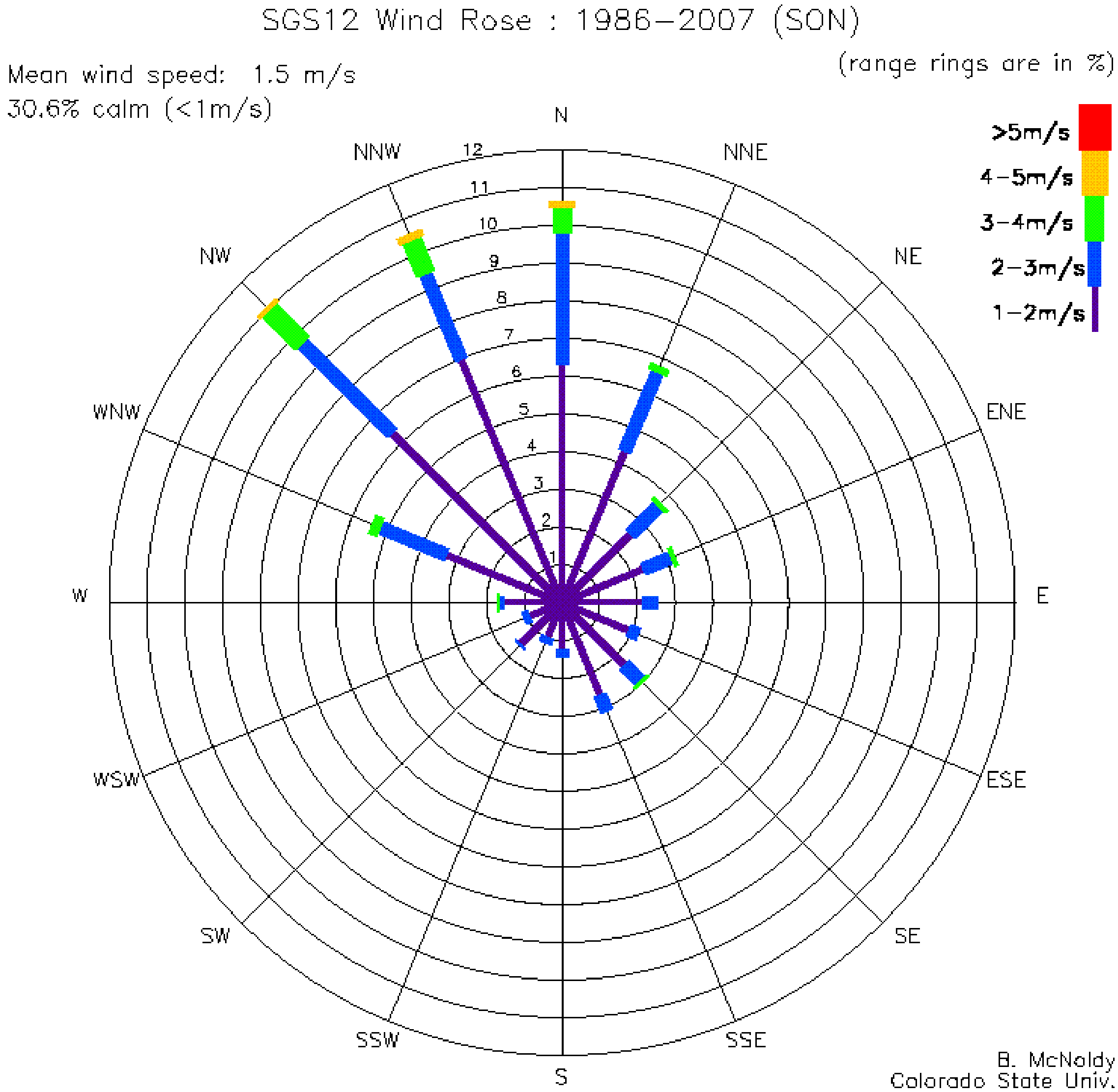


Figure 19. Wind roses of September - November for CPRE Pawnee site in 1986-2007

3.3.5 Expected environmental controls on source area

Two types of models were 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 & Weil, 1994). For strongly stable conditions, and Lagrangian solution was used (Kormann & Meixner, 2001). Here, the source area models where bounded by the expected conditions depicting the extreme conditions. Convective conditions typically have strong vertical mixing between the ecosystem and atmosphere (surface layer). Stable conditions typically winds have longer wave forms, that integrate measurements over 1000's m. Convective turbulence is often characterized by short mixing scales (scalar) and moderate daytime windspeeds, *e.g.,* 1-4 m s^{-2}. Higher windspeeds, 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 (Pawnee and North Sterling) 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 controls the degree of mixing, and the length and size of the source area.

Winds used for these model results are founded on the wind roses (Figure 16-19). Run 1 represents the expected conditions for near-neutral atmospheres, run 2 for stable atmospheres, and runs 3 and 4 for convective conditions. The primary difference between runs 3 and 4 is the maximum and average expected winds used, respectively. The annual resultant wind vector is placed as a centerline in the site map included in the graphics. The crosswind component: the width of the footprint was also estimated using the length of the 80% cumulative flux to calculate the angle from centerline, Appendix A. Figure A1.

Table 4. Expected environmental controls to parameterize the source area model, and associated results from CPER Pawnee advanced site.

parameters	Run 1	Run 2	Run 3	Run 4	units
Atmospheric stability	Near neutral	stable	convective	convective	qualitative
Max. windspeed	5.0	1.9	4.0	*1.5	m s-1
Expected sensible heat flux	10.0	0	120	50	W m-2
Resultant vector	315	315	315	315	degrees
Measurement height	8	8	8	8	m
Roughness length	0.05	0.05	0.05	0.05	m
Zero plane displacement	0.0	0.0	0.0	0.0	m
Air temperature	17.0	14.0	22.0	17.0	°C
Approximate season	Spring/fall	summer	summer	summer	qualitative
Results					
Distance source area begins	0	0	0	0	m
Distance of peak contribution	51.0	10.5	5.7	0.5	m
Distance of 20% cumulative flux	20	5	10	10	m
Distance of 40% cumulative flux	40	30	--	--	m
Distance of 60% cumulative flux	100	70	--	--	m
Distance of 80% cumulative flux	180	250	400	200	m
Distance of 100% cumulative flux	~1400	na.	600	400	m
Peak contribution	50.9	10.5	5.3	25.1	m
angle from centerline	18	29	27	27	degrees

3.3.6 Results (source area graphs)

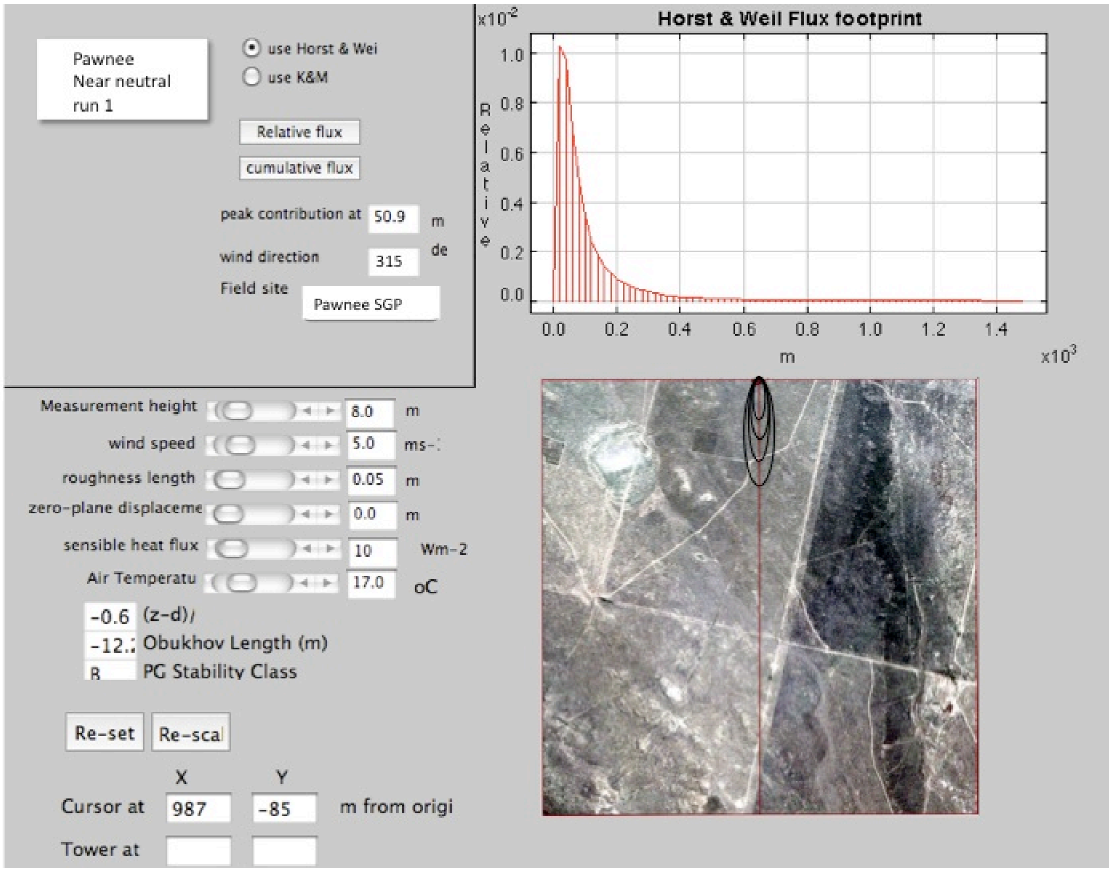


Figure 20.Tower flux footprint output for CPRE Pawnee site under near neutral conditions using an inverted plume dispersion model by Horst & Well.

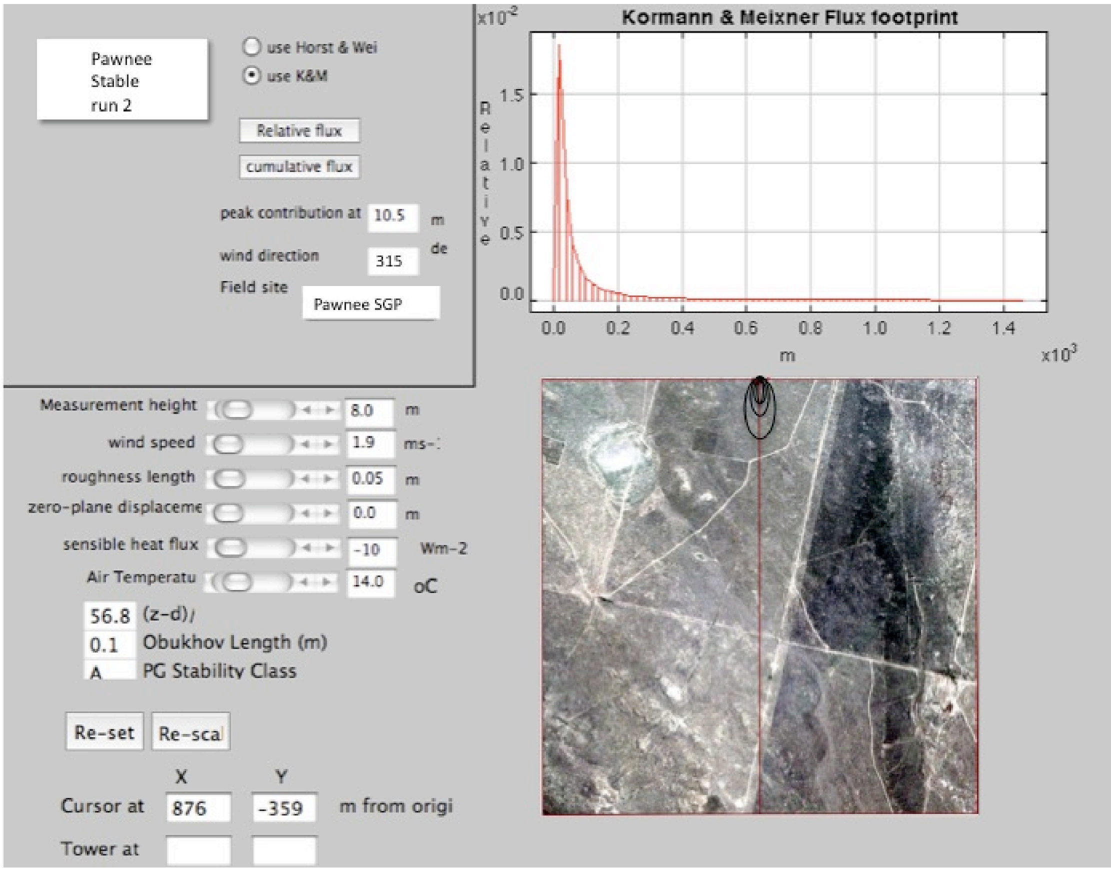


Figure 21.Tower flux footprint output for CPRE Pawnee site under stable conditions using an inverted plume dispersion model by Horst & Well.

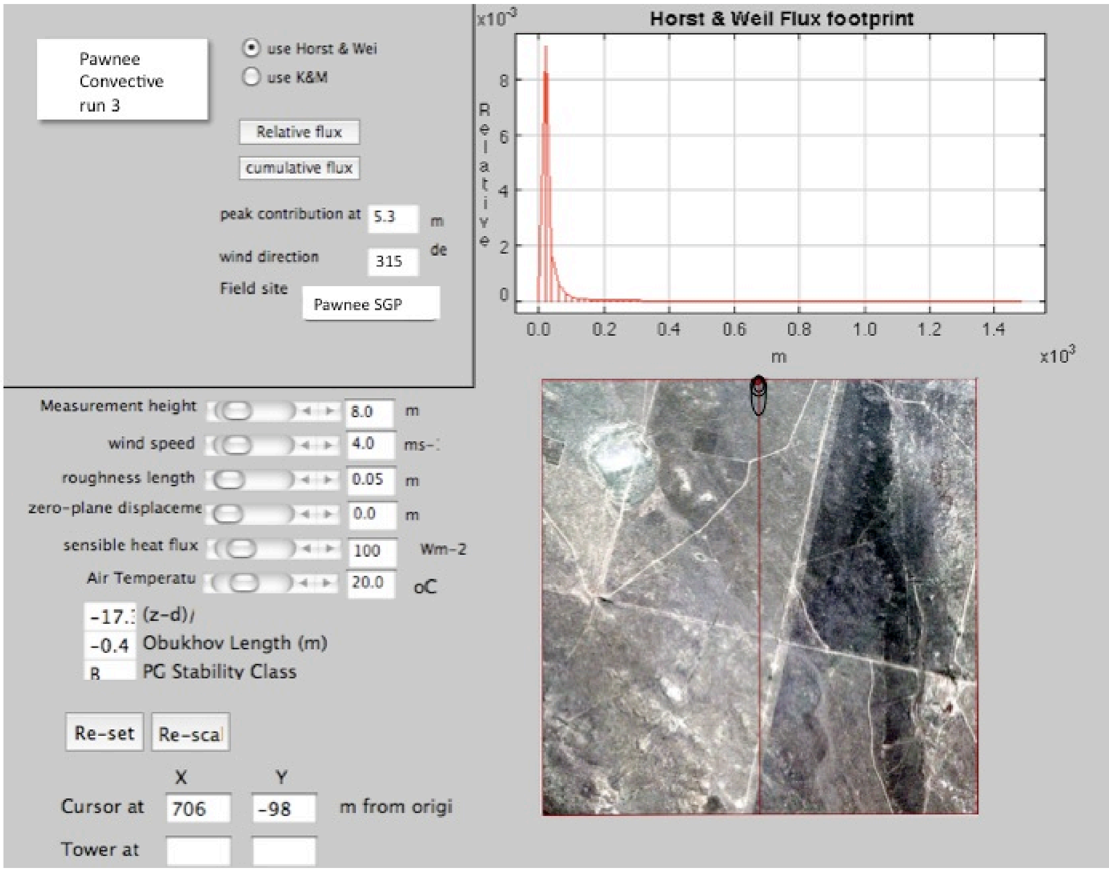


Figure 22.Tower flux footprint output for CPRE Pawnee site under convective conditions at mean expected wind speed using an inverted plume dispersion model by Horst & Well.

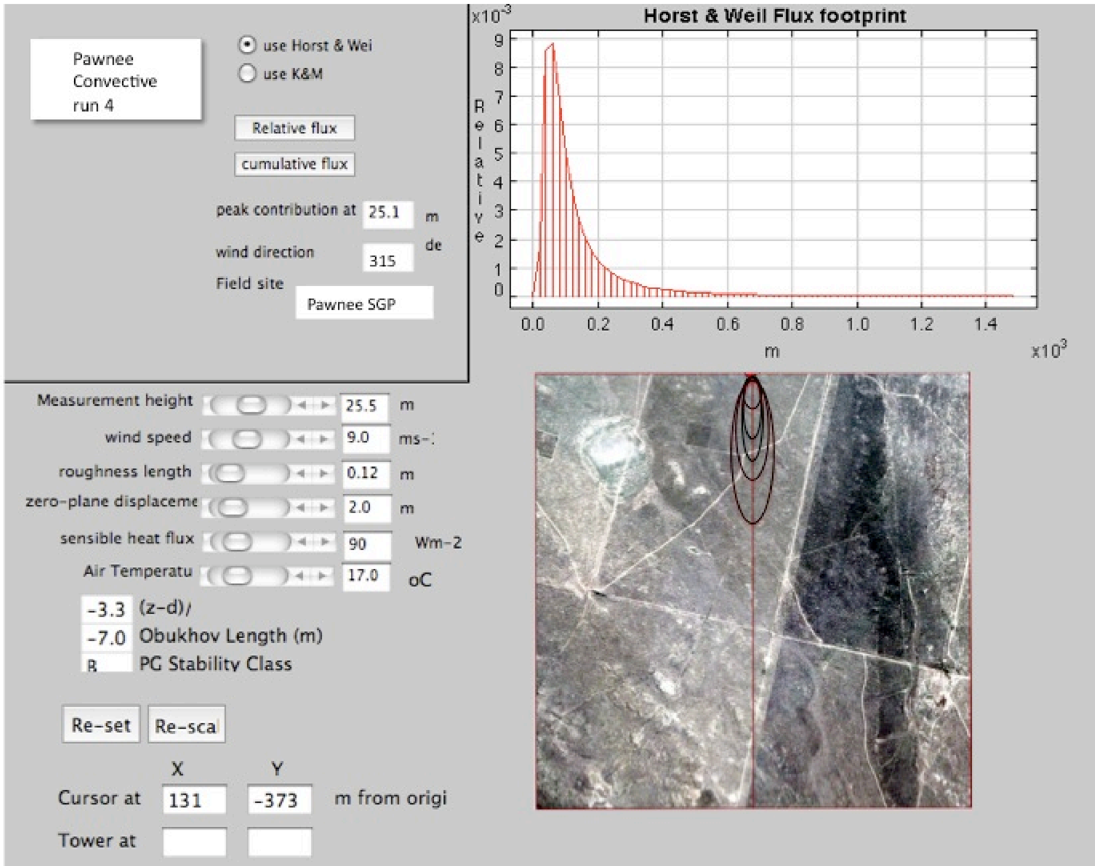


Figure 23.Tower flux footprint output for CPER Pawnee site under convective conditions at maximum expected wind speed using an inverted plume dispersion model by Horst & Well.

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.

3.3.7 Constraints on the FSU ecosystem plot locations

Winds are dominant from the north quadrant (Table 2), and annual resultant wind vector is from 348°. However, winds do come from the other quadrants during the summer months, due to the convective scales and storm fronts. The ecosystem productivity plots should be placed within i) the overall, annual extent of the footprint, ii) within the bounds of the permitted property, iii) span the dominant and co-dominant soil types, and iv) estimate the productivity from the ecosystem if interest. Given these constraint and the location of the tower, the shape of the overall, annual source is a large fan (where the apex is the tower location). The northern vector is 325° + 27° = 353° (constrained by the resultant angle and footprint angle). The length of the northern vector is 400 m. The southern vector is 135° constrained by windrose and property boundary. The length of the southern vector is ~ 300 m.

3.4 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. 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 163 to 15 degrees at this site (major).

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 600 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 400 m at this site.

4 NORTH STERLING, RELOCATEABLE TOWER 1

4.1 Site description

The North Sterling relocatable tower site (Latitude: N 40^{o}27'53.05", Longitude: W 103^{o}01'46.49") is located near Sterling, CO at a elevation ~1350 m and is about 500 m on the south-west of the junction of the County Road 59 and County Road 6. It is at the edge of a non-tilled experimental field that is used for the long-term sustainable Dryland Agroecosystems Project (DAP), which was initiated in 1985 at three sites in eastern Colorado (Sterling, Stratton, and Walsh) to evaluate the effects of cropping intensity on production, water use efficiency, and selected soil chemical and physical properties (Peterson et al., 1993). Summers are hot and low humid, winters are typically around freezing point, but can drop lower temperature. Occasional hail storms and thunderstorms are expected during the growing seasons. Seasonal high wind and tornados shall be considered in the tower design.

History: The site was established in 1985 and was chosen because of the three representative soils present in the catena. Prior to establishment of the no-till cropping systems the site had been under conventional tillage since it was taken from native sod in about 1910. Conventional tillage from 1910 to 1985 ranged from moldboard plowing in the early years to sweep tillage in the later years. The primary crop was winter wheat grown in a wheat-fallow rotation. Proso millet also had been grown occasionally in a few years prior to 1985.

Cropping systems under no-till management were initiated in 1985. These systems included: winter wheat (Triticum aestivum L.)-fallow (WF); winter wheat-maize (Zea mays L.)-fallow (WMF); winter wheat-maize-proso millet (Panicum miliaceum L.)-fallow (WMPF); continuous cropping (CC) (crops grown over the years included maize, sorghum, winter wheat, forage millet, and sunflower); and perennial grass (G). The systems represent a gradient of cropping intensity (crops divided by years in the rotation), Thus WF has an intensity factor of 0.50. Intensity factors for WMF, WMPF, and CC are 0.67, 0.75, and 1.0, respectively. The Native grass treatment does not have an intensity factor since it is a perennial system. Grass stands were established in the spring of 1986 and contain a mixture of perennial species including both warm and cool season grasses.

The long-term average annual precipitation and temperature values are ~440 mm and ~9.5 ^{o}C for this site. Long-term cropping season open pan evaporation averages 1600 mm and the evapotranspiration (ET) is relatively low at this site (Table 5, Andales et al,. 2003). The crop rotations were wheat-corn-millet-fallow at this experimental site. Crops were planted using no-till planters and drills that only disturbed the soil in a narrow band to allow for a seed row. The candidate tower location is at the edge of this non-tilled experimental field (east) and a tilled private farmland (west), which is under conventional tillage crop-fallow management for at least 70 years (Ascough II et al., 2007). Because of the prevailing wind is from west direction, although the NEON tower location is inside the non-tilled experimental farmland, the major measurement areas (tower source area) will fall in the tilled private agricultural farmland.

The summit loam soil at Sterling is relatively shallow, with a partially cemented layer at about 90-cm depth that is slowly permeable to water but relatively impermeable to roots. The summit soil profile at this site had a root restriction at 90-cm depth (Andales et al., 2003). The soil physical and hydraulic properties are presented in Table 2 (Ascough II et al., 2007).

Table 5. General site information at the North Sterling relocatable tower site

Site Elevation (ft)	Mean Annual Temp. (°F)	Mean Annual Precipitation (1961-1990) (in)	Days Above 90°F (days)	Growing Season Open-Pan Evaporation (in)	Deficit Water[a] (in)	Relative Potential Evapotranspiration (PET)
4400 (1342 m)	49 (9.5 °C)	17 (432 mm)	42	63 (1600 mm)	-46 (-1169 mm)	Low
[a] Deficit water = precipitation - open-pan evaporation.						

(Andales et al*.,* 2003)

Table 6. Soil physical and hydraulic properties at the North Sterling relocatable site, CO

Soil horizon	Bulk density	Sand	Clay	OM†	Porosity‡	WC§ (33 kPa)‡	WC (1500 kPa)‡	Ksat‡¶
cm	g cm^{-3}	%			m^3 m^{-3}			cm h^{-1}
Sterling summit [Weld loam (fine, smectitic, mesic Aridic Paleustoll)]								
0–8	1.37	45.0	20.8	1.37	0.48	0.24	0.14	3.31
8–20	1.35	33.4	30.8	1.09	0.49	0.30	0.17	1.20
20–30	1.23	24.5	38.1	1.09	0.52	0.34	0.20	0.86
30–51	1.21	27.4	27.0	0.77	0.54	0.31	0.17	2.70
51–69	1.31	30.5	22.1	0.46	0.51	0.28	0.14	2.48
69–85	1.34	43.4	20.7	0.21	0.49	0.25	0.14	3.67
85–120	1.43	31.1	25.4	0.13	0.46	0.29	0.15	0.86

(Ascough II et al., 2007)

Note. †OM, organic matter, ‡Estimated in GPFARM, §WC, water content, 33 kPa is WC at field capacity, 1500 kPa is WC at wilting point, Ksat, saturated hydraulic conductivity.

4.1.1 Ecosystem

The crop rotations here are wheat-corn-millet-fallow at the non-tilled experiments site on the east of the tower. However, the crop rotations in the tilled private farmland are unknown, which is mainly driven by the market needs, price and agricultural policies. Therefore, canopy height can vary from 0 meter for fallow to 3-4 m for the mature corn stands. The roughness length also varies from 0.05 m to ~0.2 m, and zero plane displacement varies from 0 m to 2-3 m.

4.2 Soils

Soil data and soil maps (Figure 24 and 25) below for North Sterling Relocatable site were collected from 1 km^2 and 50 m^2 NRCS soil maps, which centered at the tower location, to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

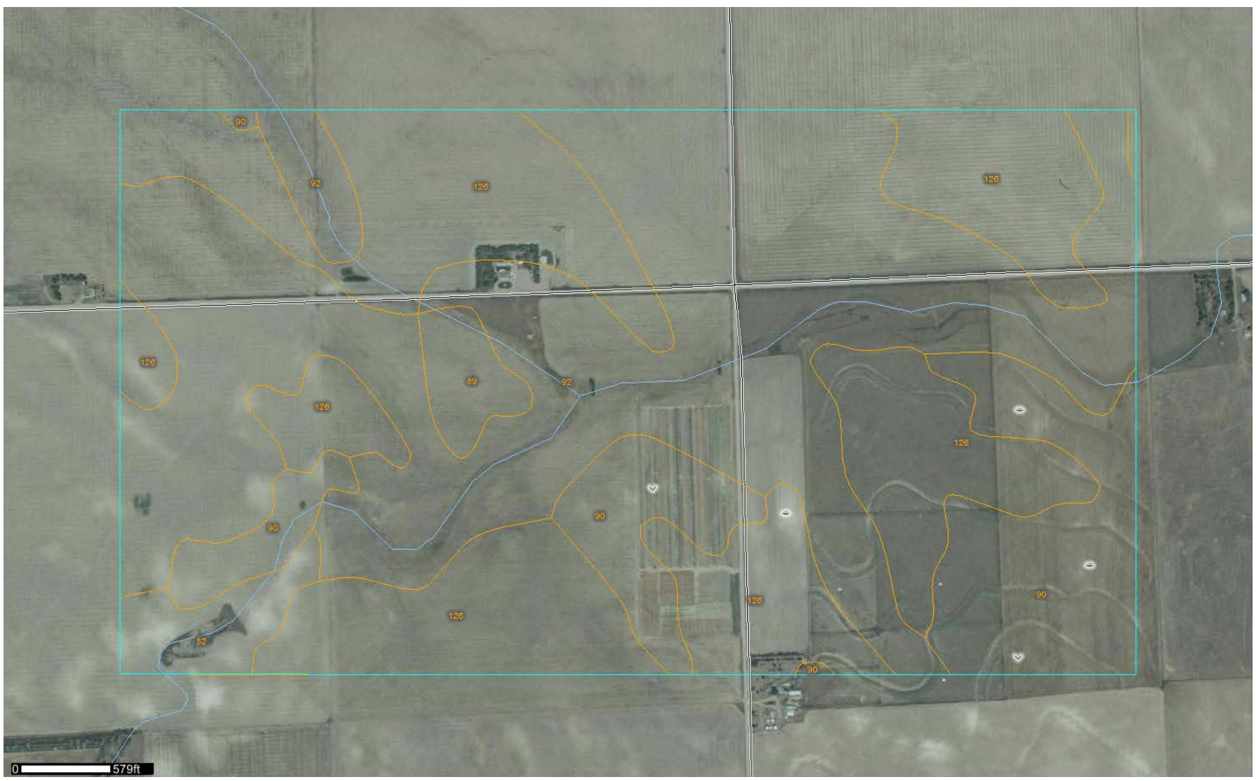


Figure 24. 1km2 soil map for North Sterling Relocatable site, center at tower location.

Figure 25. 1km2 soil map for North Sterling Relocatable site, center at tower location.

4.2.1 Description of soils

Map Unit Description. The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit. A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, 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. Map Unit Description: Weld loam, 1 to 3 percent slopes–Logan County, Colorado Sterling_1KM Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009

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

Logan County, Colorado 126—Weld loam, 1 to 3 percent slopes Map Unit Setting Elevation: 3,600 to 5,700 feet Mean annual precipitation: 13 to 17 inches Mean annual air temperature: 46 to 55 degrees F Frost-free period: 100 to 155 days Map Unit Composition Weld and similar soils: 80 percent Minor components: 20 percent Map Unit Description: Weld loam, 1 to 3 percent slopes–Logan County, Colorado Sterling_1KM Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009. Description of Weld Setting Landform: Cuestas Down-slope shape: Linear Across-slope shape: Linear Parent material: Calcareous loamy eolian deposits Properties and qualities Slope: 1 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: None Frequency of ponding: None Calcium carbonate, maximum content: 6 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: High (about 9.8 inches) Interpretive groups Land capability classification (irrigated): 2e Land capability (non-irrigated): 3e Ecological site: Loamy Plains (R067BY002CO) Typical profile 0 to 7 inches: Loam 7 to 18 inches: Silty clay loam 18 to 32 inches: Loam 32 to 60 inches: Sandy loam Minor Components Keith Percent of map unit: 13 percent Rago Percent of map unit: 7 percent

Logan County, Colorado 110—Wagonwheel-Stoneham complex, 2 to 5 percent slopes Map Unit Setting Elevation: 4,300 to 4,820 feet Mean annual precipitation: 15 to 17 inches Mean annual air temperature: 46 to 54 degrees F Frost-free period: 130 to 155 days Map Unit Composition Wagonwheel and similar soils: 45 percent Stoneham and similar soils: 30 percent Minor components: 25 percent Map Unit Description: Wagonwheel-Stoneham complex, 2 to 5 percent slopes– Logan County, Colorado Sterling_1KM Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009. Description of Wagonwheel Setting Landform: Plains Landform position (two-dimensional): Shoulder, backslope Landform position (three-dimensional): Side slope Down-slope shape: Linear Across-slope shape: Linear Parent material: Coarse-silty eolian deposits Properties and qualities Slope: 2 to 5 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 2.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Sodium adsorption ratio, maximum: 5.0 Available water capacity: High (about 10.0 inches) Interpretive groups Land capability classification (irrigated): 3 Land capability (non-irrigated): 4e Ecological site: Loamy Plains (R072XY001CO) Typical profile 0 to 7 inches: Loam 7 to 13 inches: Loam 13 to 18 inches: Loam 18 to 25 inches: Silt loam 25 to 41 inches: Silt loam 41 to 62 inches: Very fine sandy loam Description of Stoneham Setting Landform: Plains Landform position (two-dimensional): Backslope Down-slope shape: Linear Across-slope shape: Linear Parent material: Fine-loamy eolian deposits over fine-loamy alluvium Properties and qualities Slope: 2 to 5 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Map Unit Description: Wagonwheel-Stoneham complex, 2 to 5 percent slopes– Logan County, Colorado Sterling_1KM Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009. Calcium carbonate, maximum content: 15 percent Sodium adsorption ratio, maximum: 2.0 Available water capacity: High (about 9.1 inches) Interpretive groups Land capability classification (irrigated): 3e Land capability (non-irrigated): 4e Ecological site: Loamy Plains (R072XY001CO) Typical profile 0 to 4 inches: Loam 4 to 9 inches: Clay loam 9 to 13 inches: Clay loam 13 to 18 inches: Loam 18 to 34 inches: Loam 34 to 60 inches: Fine sandy loam Minor Components Colby Percent of map unit: 10 percent Landform: Plains Landform position (two-dimensional): Summit Landform position (three-dimensional): Side slope Other vegetative classification: LOAMY PLAINS (072XY001CO_1) Keith Percent of map unit: 6 percent Landform: Plains Landform position (two-dimensional): Backslope, footslope Other vegetative classification: LOAMY PLAINS (072XY001CO_1) Ulysses Percent of map unit: 5 percent Landform: Plains Other vegetative classification: LOAMY PLAINS (072XY001CO_1) Duroc Percent of map unit: 4 percent Landform: Plains Landform position (two-dimensional): Toeslope Landform position (three-dimensional): Side slope Other vegetative classification: LOAMY PLAINS (072XY001CO_1)

Logan County, Colorado 92—Rago loam Map Unit Setting Elevation: 3,600 to 4,100 feet Mean annual precipitation: 14 to 19 inches Mean annual air temperature: 46 to 48 degrees F Frost-free period: 120 to 150 days Map Unit Composition Rago and similar soils: 80 percent Minor components: 20 percent Map Unit Description: Rago loam–Logan County, Colorado Sterling_1KM Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009. Description of Rago Setting Landform: Drainageways, swales, flats Down-slope shape: Linear Across-slope shape: Linear Parent material: Calcareous loamy eolian deposits over calcareous loamy alluvium 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 0.60 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Available water capacity: High (about 9.7 inches) Interpretive groups Land capability classification (irrigated): 2e Land capability (non-irrigated): 2c Ecological site: Loamy Plains (R072XY001CO) Typical profile 0 to 8 inches: Loam 8 to 26 inches: Clay loam 26 to 49 inches: Loam 49 to 60 inches: Sandy loam Minor Components Keith Percent of map unit: 8 percent Satanta Percent of map unit: 6 percent Landform: Paleoterraces Richfield Percent of map unit: 6 percent

Logan County, Colorado 90—Platner loam, 3 to 5 percent slopes Map Unit Setting Elevation: 3,600 to 4,100 feet Mean annual precipitation: 14 to 19 inches Mean annual air temperature: 48 to 50 degrees F Frost-free period: 120 to 150 days Map Unit Composition Platner and similar soils: 80 percent Minor components: 20 percent Map Unit Description: Platner loam, 3 to 5 percent slopes–Logan County, Colorado Sterling_1KM Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009. Description of Platner Setting Landform: Ridges, hills Down-slope shape: Linear Across-slope shape: Linear Parent material: Calcareous alluvium and/or eolian deposits Properties and qualities Slope: 3 to 5 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.60 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 10 percent Available water capacity: Moderate (about 8.8 inches) Interpretive groups Land capability classification (irrigated): 3e Land capability (non-irrigated): 3e Ecological site: Loamy Plains (R072XY001CO) Typical profile 0 to 7 inches: Loam 7 to 18 inches: Clay loam 18 to 26 inches: Loam 26 to 34 inches: Fine sandy loam 34 to 60 inches: Gravelly sandy clay loam Minor Components Wages Percent of map unit: 10 percent Ascalon Percent of map unit: 5 percent Satanta Percent of map unit: 5 percent Landform: Paleoterraces

Logan County, Colorado 89—Platner loam, 1 to 3 percent slopes Map Unit Setting Elevation: 3,600 to 4,100 feet Mean annual precipitation: 13 to 19 inches Mean annual air temperature: 48 to 50 degrees F Frost-free period: 120 to 150 days Map Unit Composition Platner and similar soils: 85 percent Minor components: 15 percent Map Unit Description: Platner loam, 1 to 3 percent slopes–Logan County, Colorado Sterling_1KM Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009. Description of Platner Setting Landform: Cuestas Down-slope shape: Linear Across-slope shape: Linear Parent material: Alluvium and/or calcareous eolian deposits Properties and qualities Slope: 1 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 0.60 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 10 percent Available water capacity: Moderate (about 8.8 inches) Interpretive groups Land capability classification (irrigated): 2c Land capability (non-irrigated): 2c Ecological site: Loamy Plains (R072XY001CO) Typical profile 0 to 7 inches: Loam 7 to 18 inches: Clay loam 18 to 26 inches: Loam 26 to 34 inches: Fine sandy loam 34 to 60 inches: Gravelly sandy clay loam Minor Components Rago Percent of map unit: 6 percent Ascalon Percent of map unit: 5 percent Olney Percent of map unit: 4 percent

Logan County, Colorado 52—Kuma loam Map Unit Setting Elevation: 3,600 to 4,100 feet Mean annual precipitation: 15 to 19 inches Mean annual air temperature: 46 to 59 degrees F Frost-free period: 125 to 150 days Map Unit Composition Kuma and similar soils: 85 percent Minor components: 15 percent Map Unit Description: Kuma loam–Logan County, Colorado Sterling_1KM Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009 Page 2 of 3Description of Kuma Setting Landform: Depressions, swales, flats Down-slope shape: Linear Across-slope shape: Linear Parent material: Calcareous eolian deposits Properties and qualities Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 2.00 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 10 percent Gypsum, maximum content: 2 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: High (about 9.6 inches) Interpretive groups Land capability classification (irrigated): 2e Land capability (non-irrigated): 2c Ecological site: Loamy Plains (R067BY002CO) Typical profile 0 to 5 inches: Loam 5 to 28 inches: Loam 28 to 39 inches: Loam 39 to 60 inches: Very fine sandy loam Minor Components Richfield Percent of map unit: 5 percent Keith Percent of map unit: 5 percent Rago Percent of map unit: 5 percent

Data Source Information Soil Survey Area: Logan County, Colorado Survey Area Data: Version 7, Apr 29, 2009 Map Unit Description: Kuma loam–Logan County, Colorado Sterling_1KM Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009.

4.2.2 Soil Semi-variograms

The goal of this site characterization of soil using semi-variograms is to determine the minimum distance between the soil plots in the soil array that can be considered spatially independent. The spatial variation of surface soil will be estimated using field sampling data of soil temperature and soil water content (SWC) in the tower airshed at the North Sterling Relocatable site.

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

Three parameters estimated from the variogram describe spatial autocorrelation in the data (Figure 1): the range, the sill (the sill is the asymptotic value of semi-variance at the range), and the nugget variance (which describes sampling error or variation at distances below those separating the closest pairs of samples). The range, sill and nugget variance were estimated from theoretical models that were fitted to the empirical variograms using non-linear least squares methods. The range distance (i.e. the distance beyond which samples are spatially independent) was estimated from the empirical variogram by fitting spherical theoretical models. This is the distance we will use to determine the spatial separation of soil plots in soil array.

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

4.2.3 Soil Semi-Variogram Method, experimental design, data analysis

Measurements of soil temperature and soil water content (SWC) were taken on August 10, 2009 at the North Sterling Relocatable site following the spatially cyclic sampling design by Bond-Lamberty *et al.* (2006, Figure 4). This design uses repeated pattern of samples to provide information about all distance with minimum of redundancy.

Two 210-meter transects were established at North Sterling Relocatable tower site. Both started from a location (Latitude: N40.46198°Longitude: W103.02941°) that next to the tower location (Figure 26). All transects were set in the expected airshed (dominant wind directions, Figure 26). Rough airshed area was determined by the wind roses that were established based on the historic wind direction and wind speed data. The determination of accurate airshed area by models will be described in the "Airshed" section below.

First transect was 210 meters and ran toward the West direction of 270° (compass magnetic degrees, same below) from the potential tower location. Second transect was 210 meters and ran toward SW direction (220°). Each transects has 26 sampling points. A Garmin GPS device was used to record the sampling location. 3 replicates (30 cm apart from one another, Figure 27) were measured at each sampling point along established transects using platinum resistance temperature sensors (RTD810, Omega Engineering Inc.) for soil temperature and time domain diaelectric sensors (CS616, Campbell Scientific, Inc.) for SWC at each sampling points.

Soil temperature and SWC data collected were used for geospatial analyses of variograms in the R statistical computing language with the geoR package to test for spatial autocorrelation (Goovaerts, 1997; Trangmar et al., 1985; Webster, 1989) and to determine the distance for soil plots in the soil array.

For all data sets for temperature and SWC, there is evidence for the existence of spatial trends that can be modeled as a function of time. This is a consequence of the fluctuating solar radiation throughout the day. Trends were estimated and removed with a simple two parameter linear regression model and p-values for the model significance are provided in the respective text below in results session. For the most part, this approach was sufficient with respect to satisfying the assumption of stationarity. Hence, variogram models were constructed on the residuals from these regressions of the response variable on time. The range distance (i.e. the distance beyond which samples are spatially independent) was estimated from the empirical variogram by fitting spherical theoretical models to both soil temperature and SWC data.

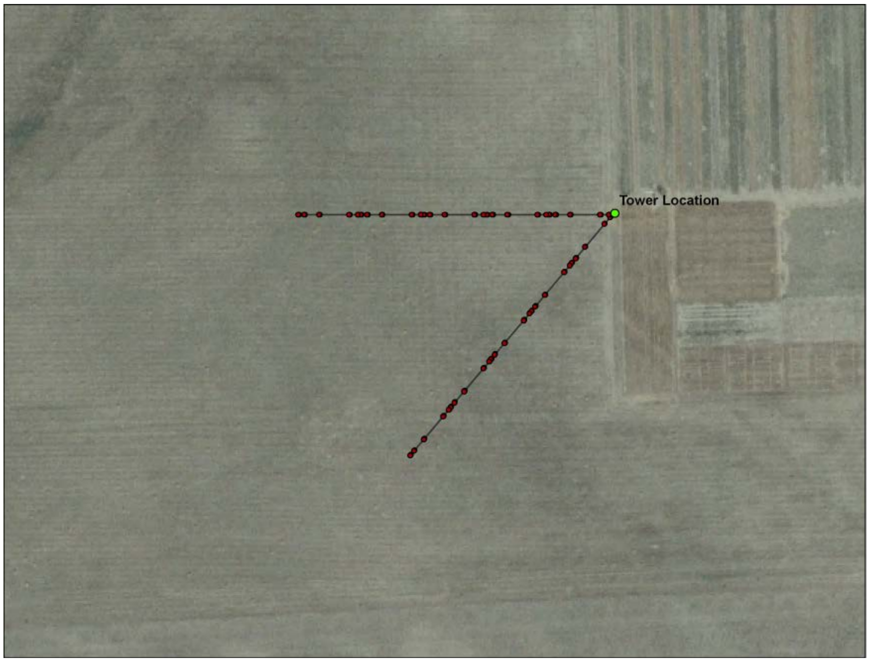


Figure 26. Established transects at the North Sterling Relocatable Site

Figure 27. Three replicates of soil temperature and SWC were measured at each sampling point at fixed-depth (0-20 cm).

These 3 replicates are 30 cm apart from one another along the established transects at the North Sterling Relocatable tower site.

Figure 28. FIU PT leader Dr H.W. Loescher is pointing to the resultant air shed of North Sterling relocatable site.

The device on his back includes a datalogger, 3 soil temperature sensors, and 3 soil water content sensors used for site characterization of soil.

4.2.4 Results and interpretation

Temperature

The temperature data display a strong pattern as a function of time. A linear regression ($p < 0.001$) of temperature on time was fit and used to extract this trend (Figure 29). Exploratory data analysis plots show that there is no distinct patterning of the residuals (Figure 30). Directional variograms of the residuals do not show any indication of anisotropy (Figure 31); however, there is an indication that the directional variograms may not be fully characterized as a consequence of the spatial layout of the sampling. A spherical covariance model was fit using Cressie weights (Figure 32) and the estimated distance of effective independence was 51 meters based on the temperature data. This information will be used to refine the design applied to the subsequent sites.

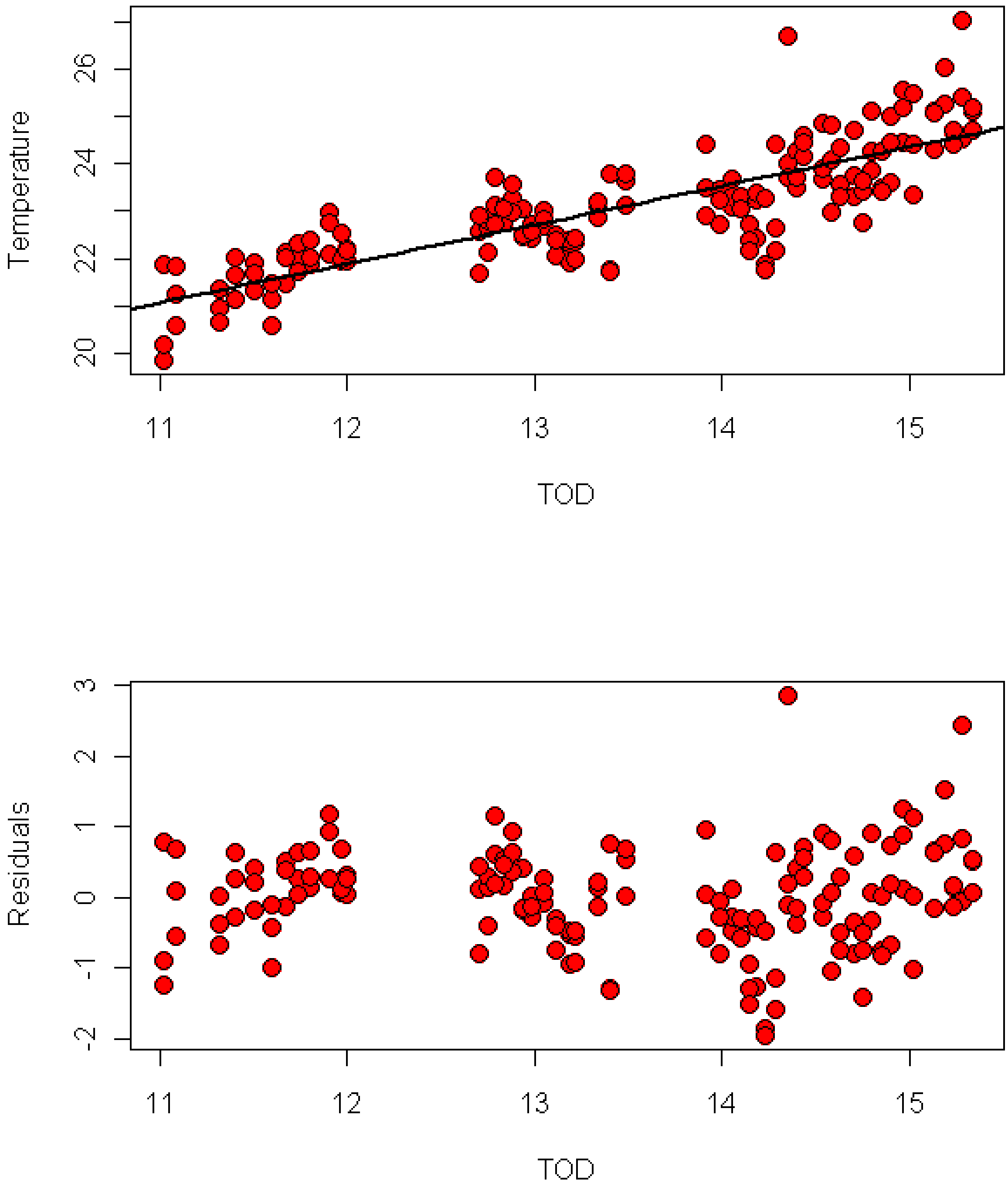


Figure 29. Time trend with linear regression fit and residuals for temperature at the North Sterling relocatable tower site.

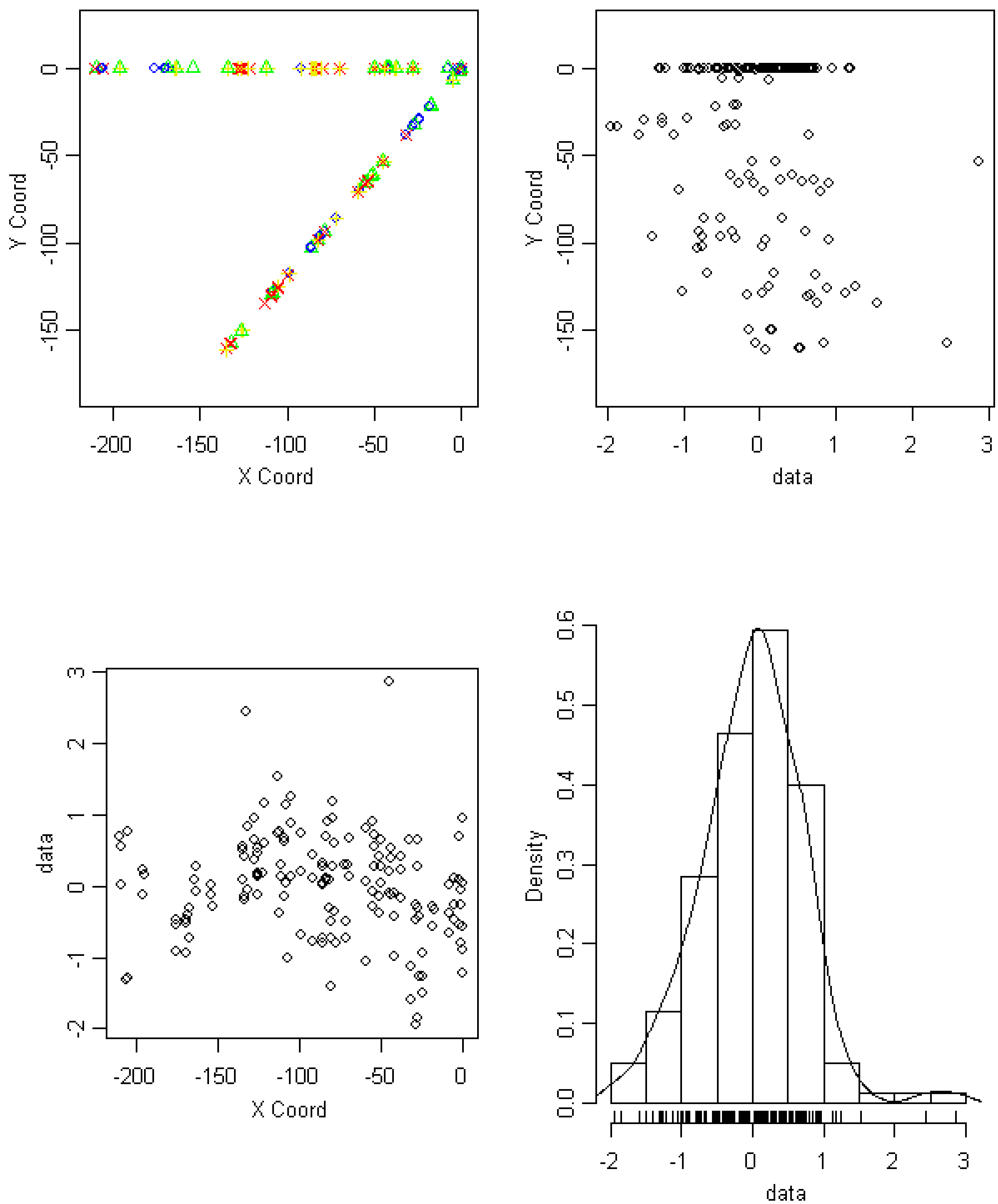


Figure 30. Exploratory data analysis plots for residuals from regression of temperature on time at the North Sterling relocatable tower site.

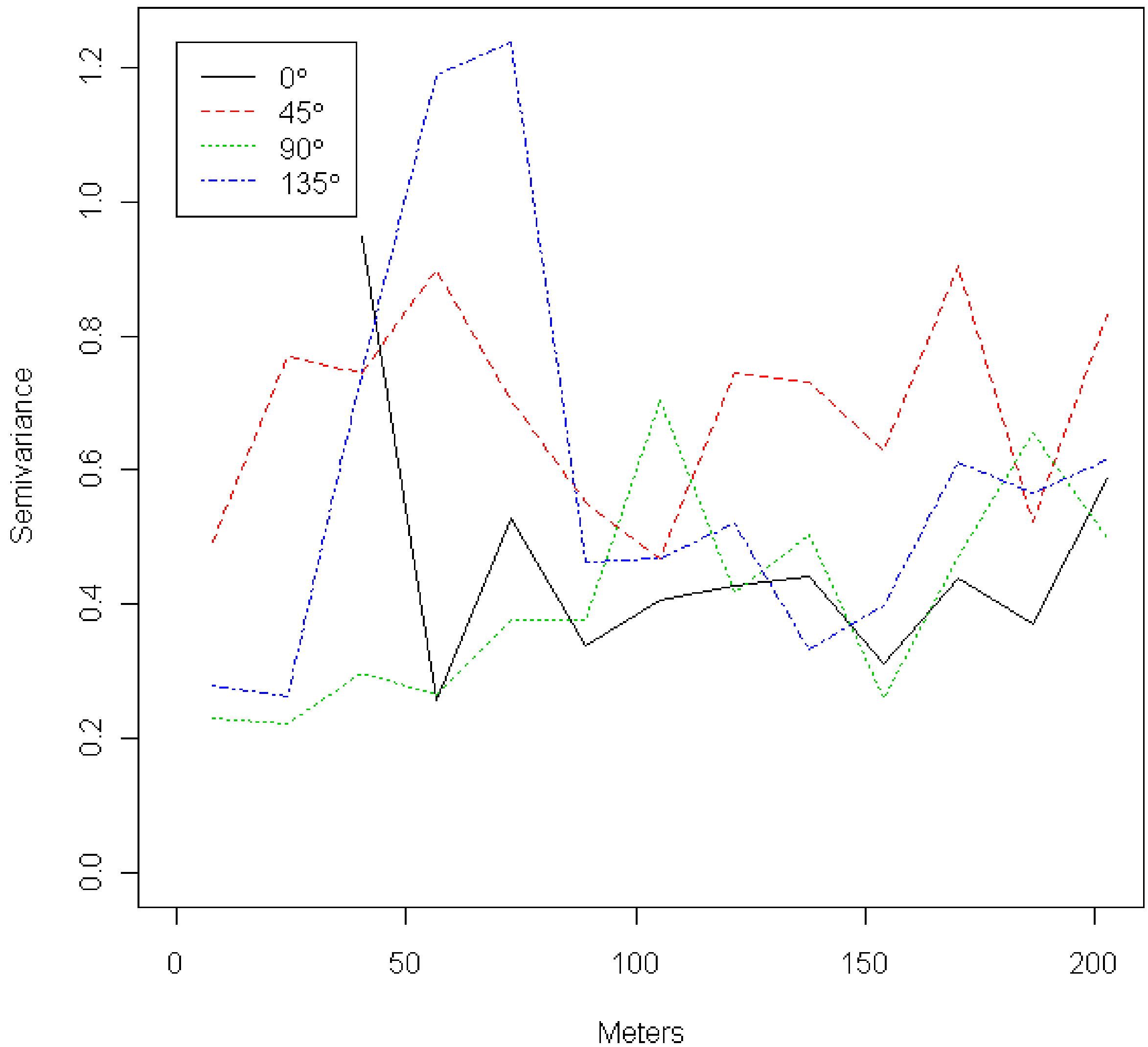


Figure 31. Directional variograms for residuals from regression of temperature on time at the North Sterling relocatable tower site.

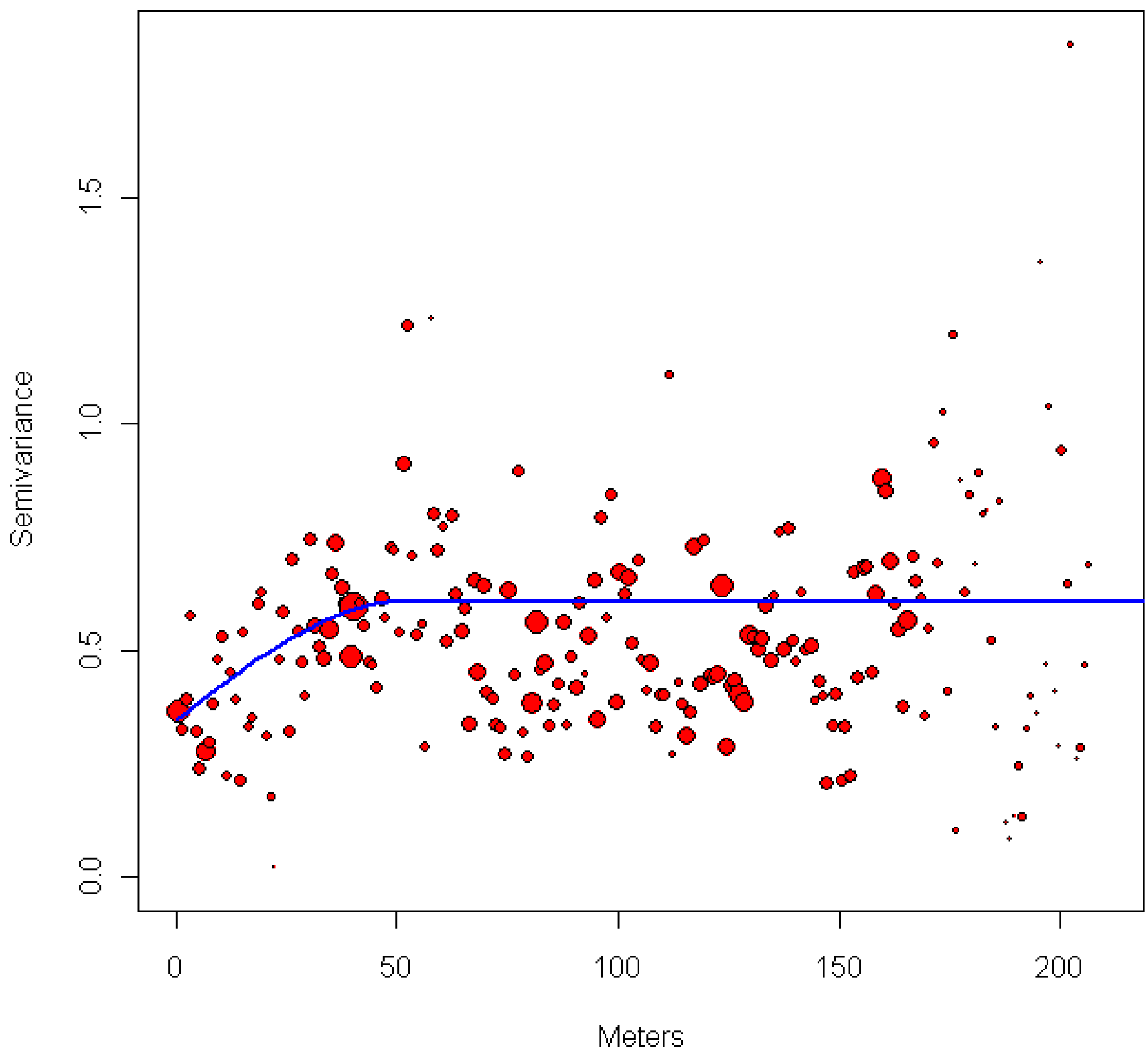
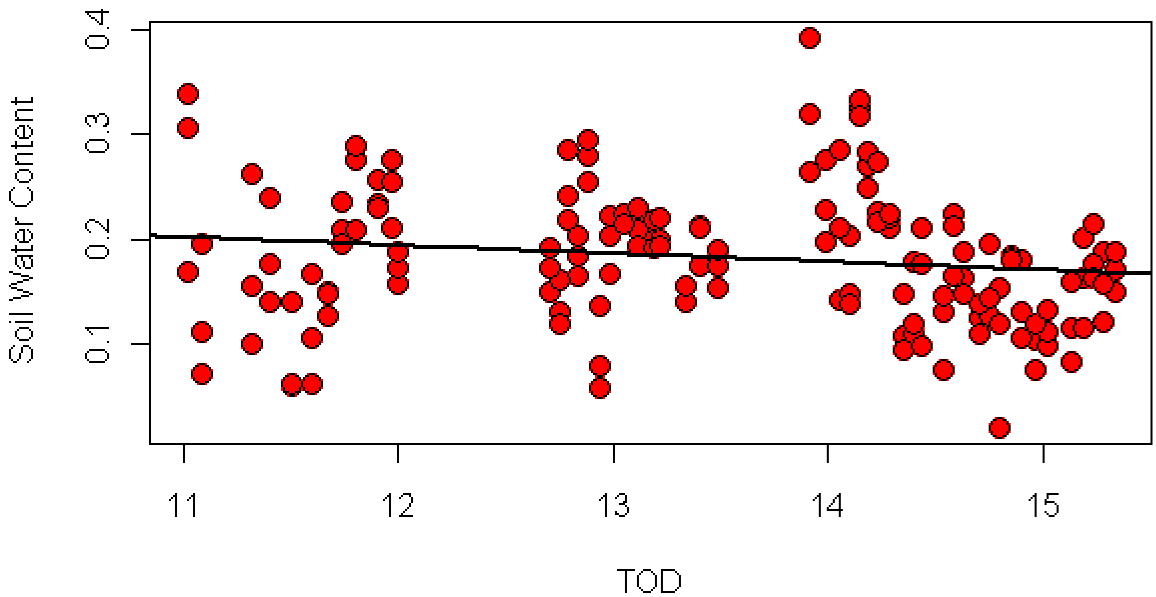


Figure 32. Empirical variogram and model fit for the residuals of the regression of temperature on time at the North Sterling relocatable tower site.

Soil Water Content

The soil water content (SWC) data display a weak pattern as a function of time. A linear regression (p = 0.05) of temperature on time was fit and used to extract this trend (Figure 33). Exploratory data analysis plots show that there is an increase in the spread of the residuals from left to right (lower left corner Figure 34). There are more samples collected in the right hand side of the plot, which would allow for more complete characterization of the underlying variability; however, these samples are also closer together which would tend to suggest more similar values in the presence of non-trivial spatial correlation. Directional variograms of the residuals do not show any indication of anisotropy (Figure 35); however, there is an indication that the directional variograms may not be fully characterized as a consequence of the spatial layout of the sampling. In addition, the directional variograms seem to suggest that the SWC data are relatively independent. A spherical covariance model was fit using Cressie weights (Figure 36) and the estimated distance of effective independence was 8 meters. This information will be used to refine the design applied to the subsequent sites.



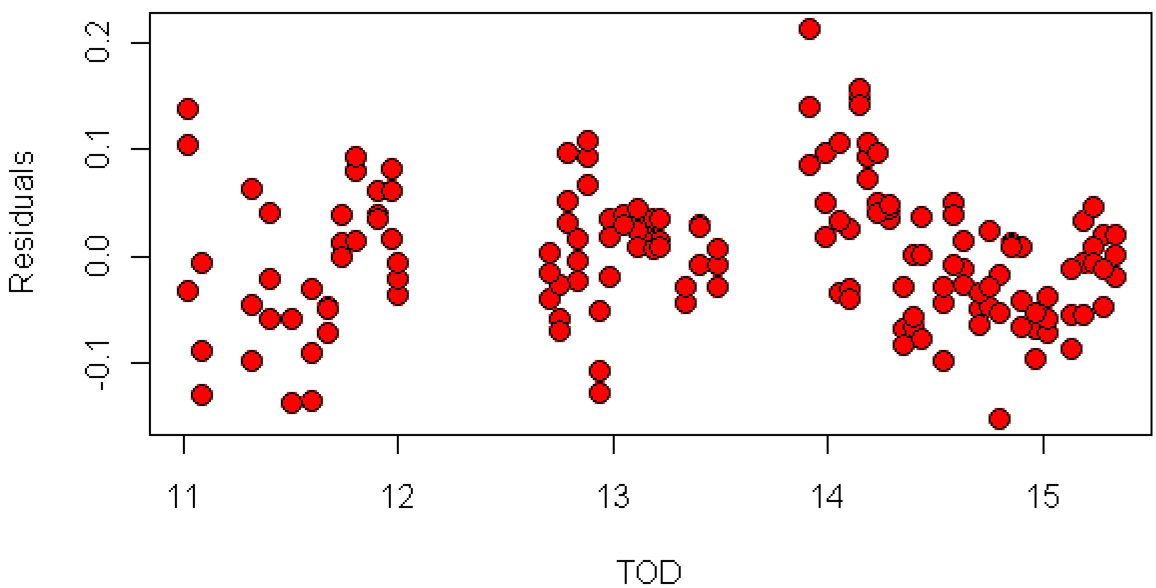


Figure 33. Time trend with linear regression fit and residuals for soil water content at the North Sterling relocatable tower site.

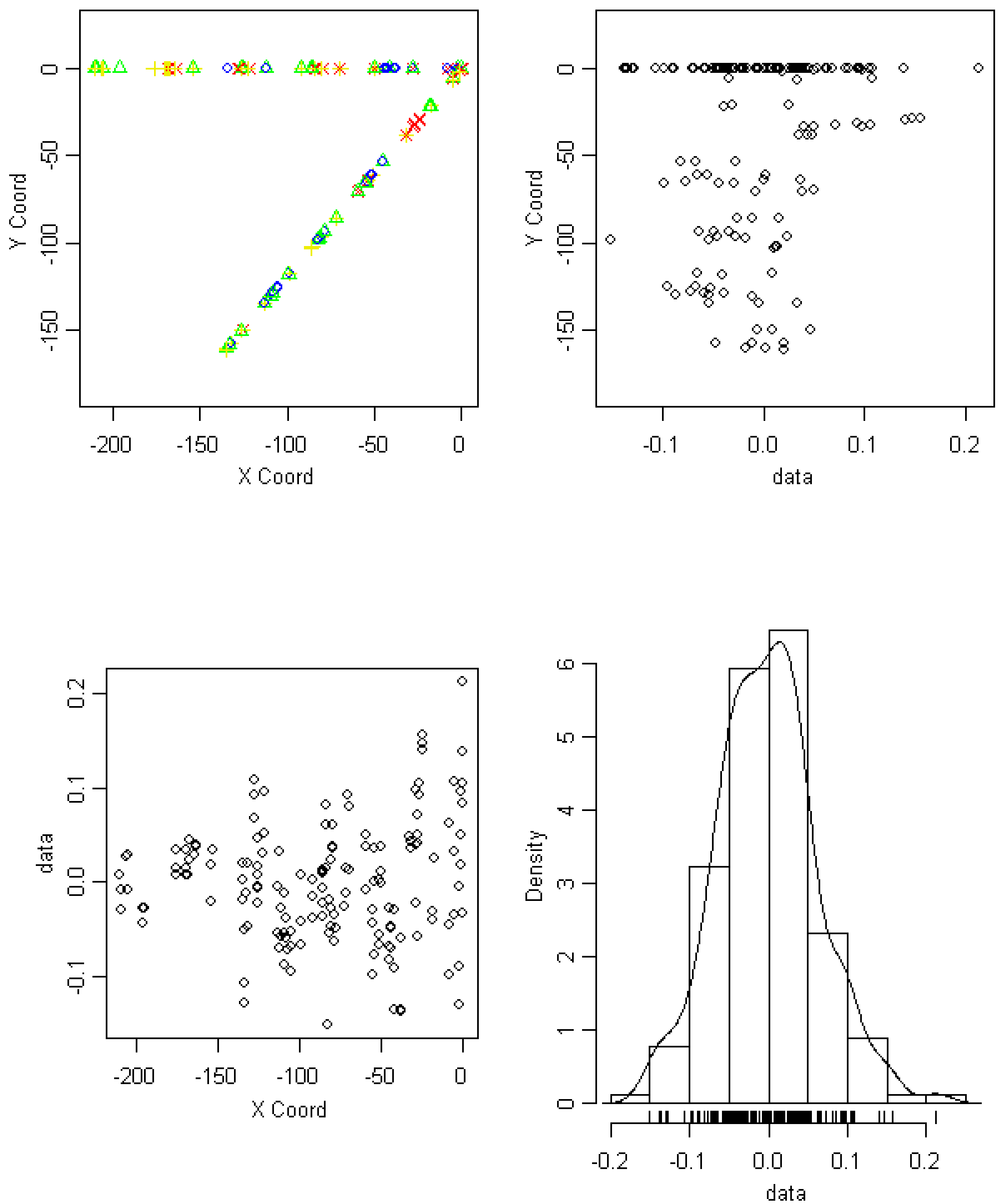


Figure 34. Exploratory data analysis plots for residuals from regression of soil water content on time at the North Sterling relocatable tower site.

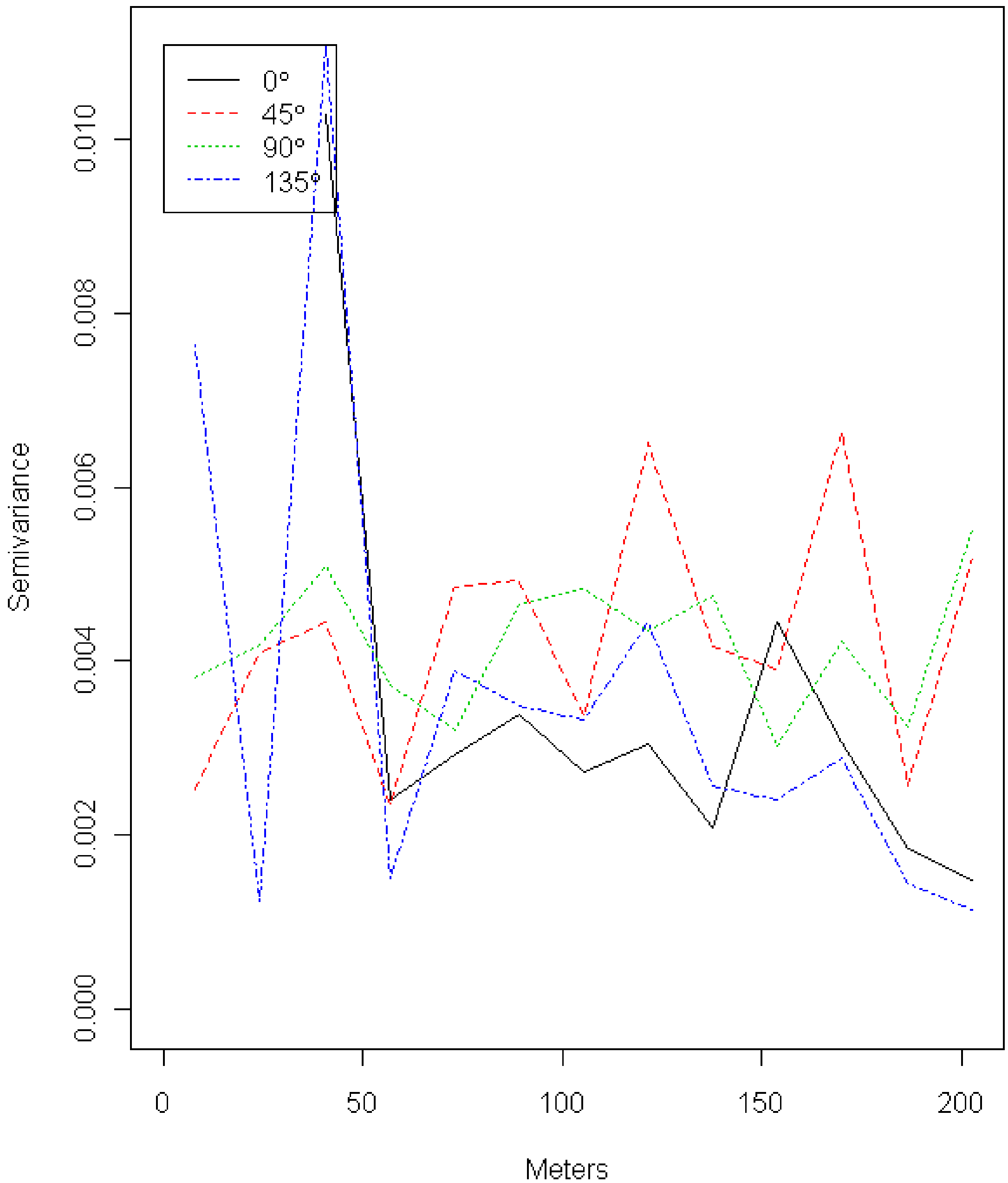


Figure 35. Directional variograms for residuals from regression of soil water content on time at the North Sterling relocatable tower site.

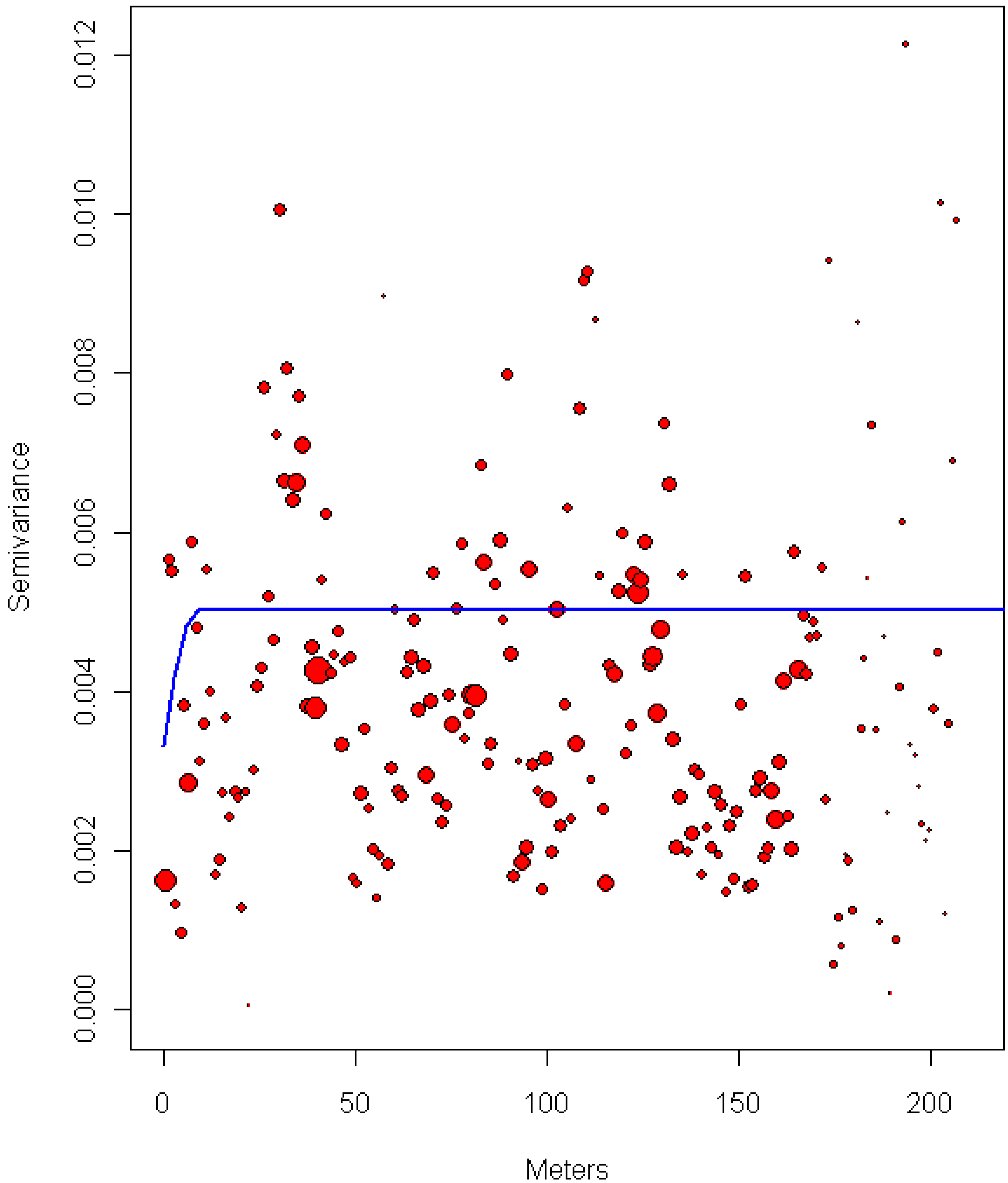


Figure 36. Empirical variogram and model fit for the residuals of the regression of soil water content on time at the North Sterling relocatable tower site.

4.2.5 Summary

The estimated distance of effective independence was found to be 8 meters on SWC and the SWC pattern show relatively independent on the distance. The estimated distance of effective independence was 50 meters based on geospatial analysis of temperature data alone, which is impossible to separate soil plots so far apart due to the practical economic reasons. If we choose the distance of 40 meters for soil plots separation, we are still have 80% confidence that our measurements in soil are independent based on the temperature variograms (assume the relationship is linear below the distance of 50 meters in Figure 32), and this is as far as the financial support allows. Therefore, the recommended distance between soil plots is 40 meters at North Sterling relocatable tower site to best avoid the autocorrelation as our financial support permits.

4.3 Airshed

4.3.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries. The orientation of the wind rose follows that of a compass. When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. Color bands depict the range of wind speeds. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 24 cardinal directions.

Data used here are hourly from 2006 to July 2009. Data was obtained from the Colorado Agricultural Meteorological Network (COAGMET) http://ccc.atmos.colostate.edu/~coagmet/rawdata_docs.php . Data were collected by a propeller anemometer mounted at 2.2 m inside the CSU experimental area surrounded by no-till corn. Hence, the anemometer was below canopy height when corn reached its full, seasonal height. These data were collected approximately 40 m north-east from the proposed tower site. It is assumed that the wind data was corrected for declination.

4.3.2 Resultant vectors

Table 7. The resultant wind vectors from North Sterling using hourly data from 2006 to 2009.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	24°	20
April to June	350°	18
July to September	341°	21
October to December	355°	14
Annual mean	357.5°	na.

Table 8. The percent duration of winds among cardinal directions, 3 frequency bins on each side of the cardinal direction.

Data are from North Sterling using hourly data from 2006 to 2009. . Blue text and underline indicates the dominant, winds occurring for the cardinal direction >40% of the time.

Quarterly (seasonal) timeperiod	**Cardinal direction**			
	North	East	South	West
January to March	30.7	24.0	22.5	22.3
April to June	36.5	16.8	21.7	20.4
July to September	41.8	10.6	24.6	19.6
October to December	30.0	22.6	23.6	23.8

4.3.3 Acceptance criteria

Winds are only dominant from the north quadrant (Table 8) during July-September, and annual resultant wind vector is from 358°. Winds come from the other quadrants during all other seasons. Convective fronts develop daytime winds along the front range and generally pass over the site, travelling from the west to the east, particularly during the spring and fall seasons. But as they pass over they re-direct the winds to other vectors, from the east, south etc. (Figure 37-40).

The desired measurements are from the surrounding agronomic field and contingent on annual economic decisions made by the land owner (shifting agriculture), with the co-dominant soil associations; Platner loam 3-5% slopes and Weld loam 1-3% slopes. Here, the parameters to estimate the tower footprint assume to be the most structurally complex agronomic decision--corn. The available west-to-east length of this ecosystem is ~800 m. Immediately to the east is a long term experimental field of no-till corn, managed by CSU. When wind comes from east, data would have to be inspected, which would be potentially biased by the differences between the CSU no-till corn and local management of the owners cropping. Regardless, the differences between these two cropping schemes will influence the microclimate and biochemical cycling (flux rates). Hence, flows from the east are least desirable. Because flows through the tower have to be examined and potentially removed from the dataset, placing the leeward side of the tower closest to the east (closest to the CSU plots), optimizes flows over the source area from the west. To maximize the fetch (source area) from the NW from the winter, spring and fall seasons, the tower location should be placed in the SE area of the parcel. Because winds from the south occur during the summer and the results from the footprint analyses (Figures 43, 44) indicate 80% of the cumulative flux is derived over ~ 200-300 m under summer convective conditions, the tower placement should be ~ 300 m north of the southern boundary. Instrument hut shall be placed in the leeward side of the tower and not influence the flows around the tower, hence, the distance of ~ 5 x the hut height towards the east of the tower is required (AD[02]).

4.3.4 Results (graphs for wind roses)

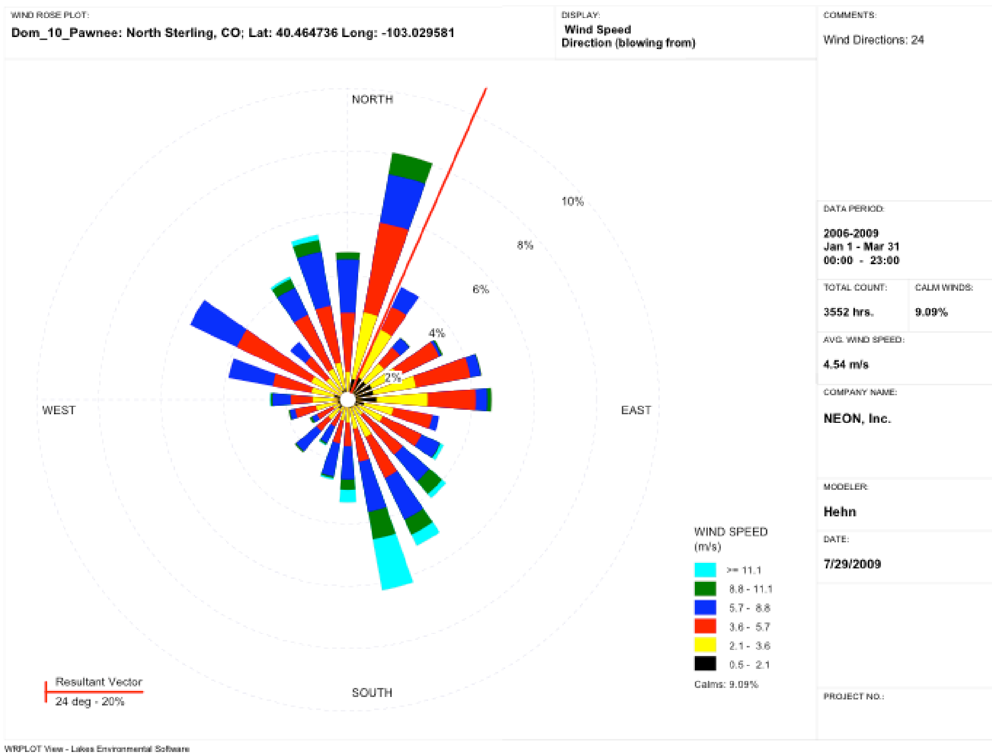


Figure 37. Wind roses of Jan - March for North Sterling Relocatable site in 2006-2009

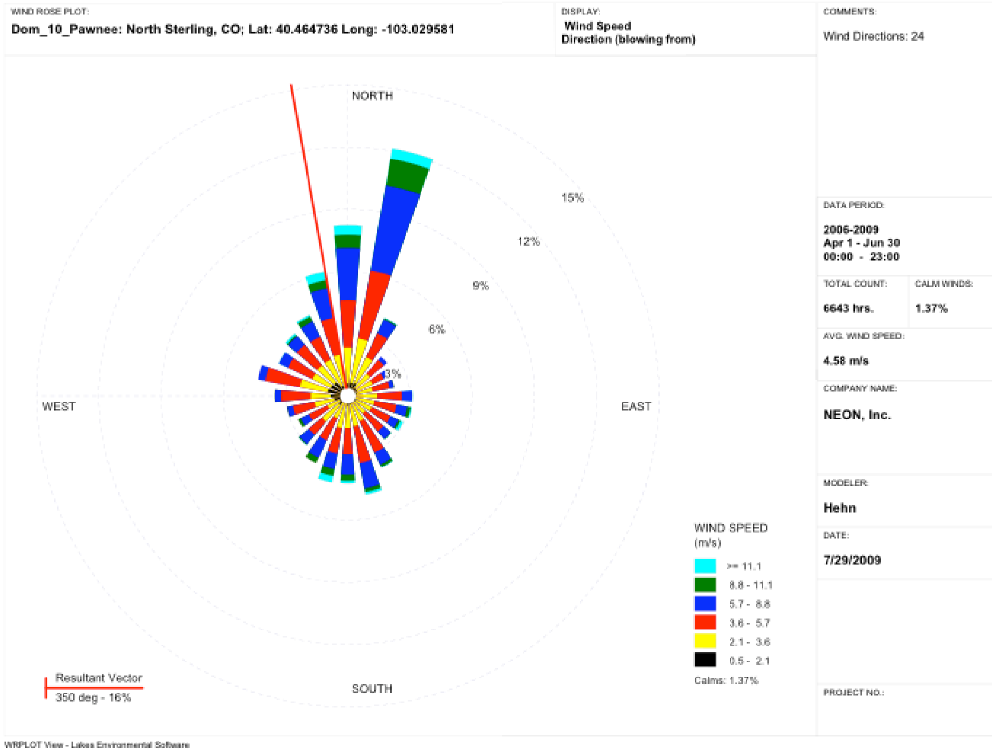


Figure 38. Wind roses of April - June for North Sterling Relocatable site in 2006-2009

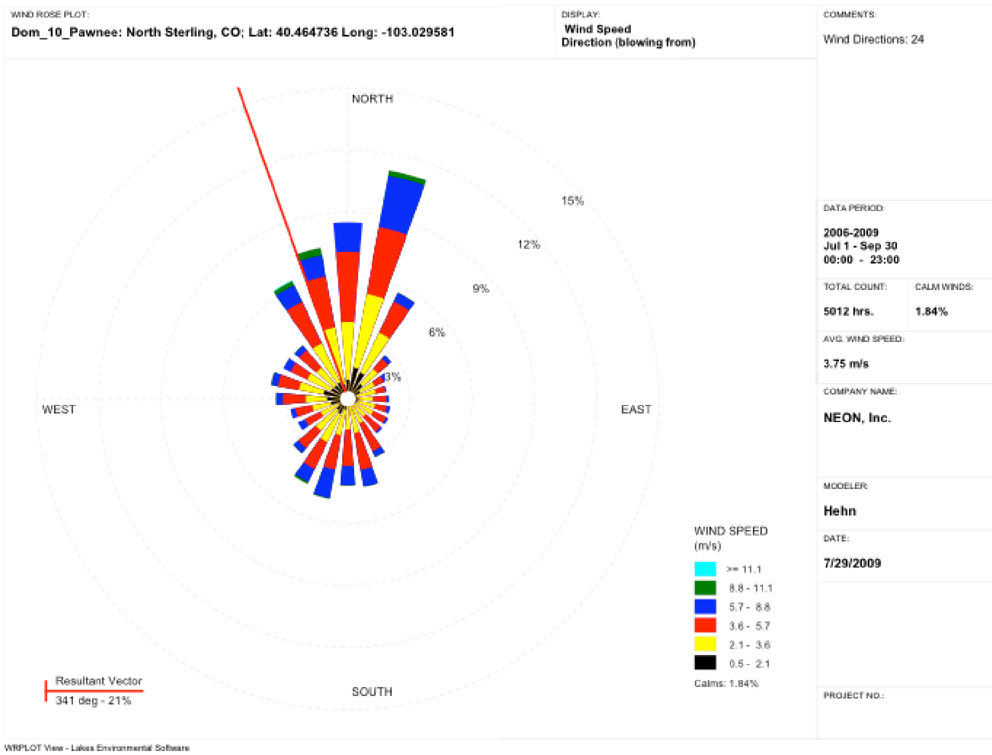


Figure 39. Wind roses of July - September for North Sterling Relocatable site in 2006-2009

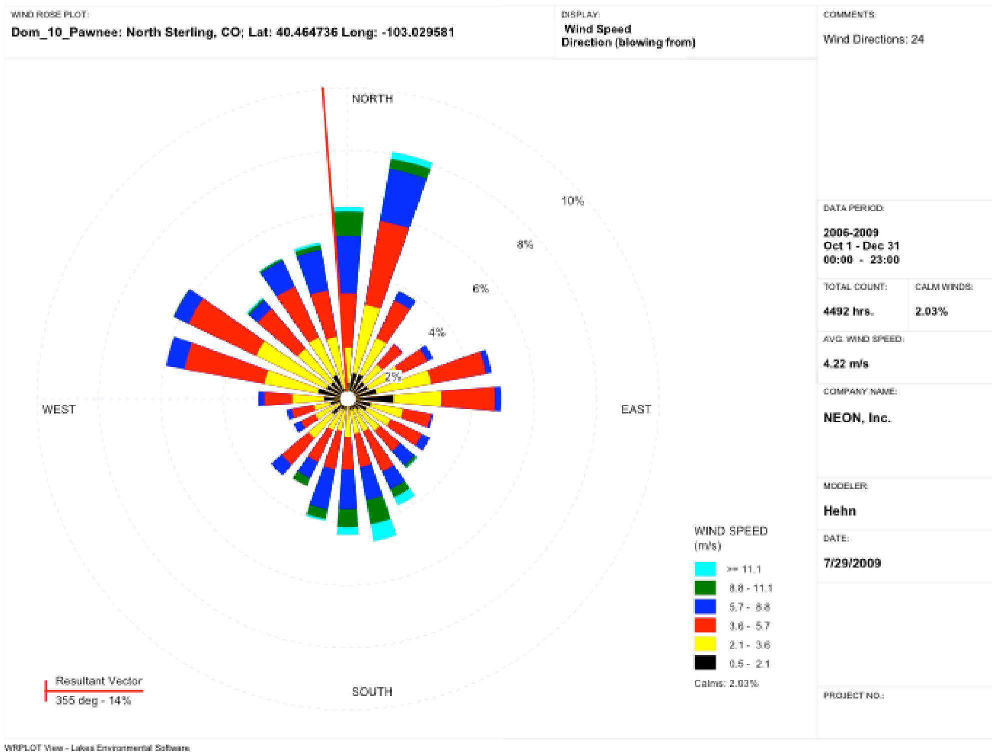


Figure 40. Wind roses of October - December for North Sterling Relocatable site in 2006-2009

4.3.5 Expected environmental controls on source area

Table 9. Expected environmental controls to parameterize the source area model, and associated results from the North Sterling relocatable site.

parameters	Run 1	Run 2	Run 3	Run 4	units
Atmospheric stability	Near neutral	stable	convective	convective	qualitative
Max. windspeed	11.0	8.8	11.0	*4.6	m s-1
Expected sensible heat flux	10.0	-10	120	70	W m-2
Resultant vector	225	225	225	225	degrees
Measurement height	8	8	8	8	m
Roughness length	0.2	0.2	0.2	0.2	m
Zero plane displacement	1.0	2.0	2.0	2.0	m
Air temperature	20.0	14.0	28.0	27.0	°C
Approximate season	Spring/fall	summer	summer	summer	qualitative
Results					
Distance source area begins	0	50	0	0	m
Distance of peak contribution	85	16	8	18.3	m
Distance of 20% cumulative flux	50	80	10	10	m
Distance of 40% cumulative flux	100	120	40	20	m
Distance of 60% cumulative flux	190	240	--	60	m
Distance of 80% cumulative flux	400	790	--	190	m
Distance of 100% cumulative flux	>1600	>1600	400	600	m
Peak contribution	84.3	84.3	7.8	18.3	m
Angle from centerline	37	34	27	18	degrees

4.3.6 Results (source area graphs)

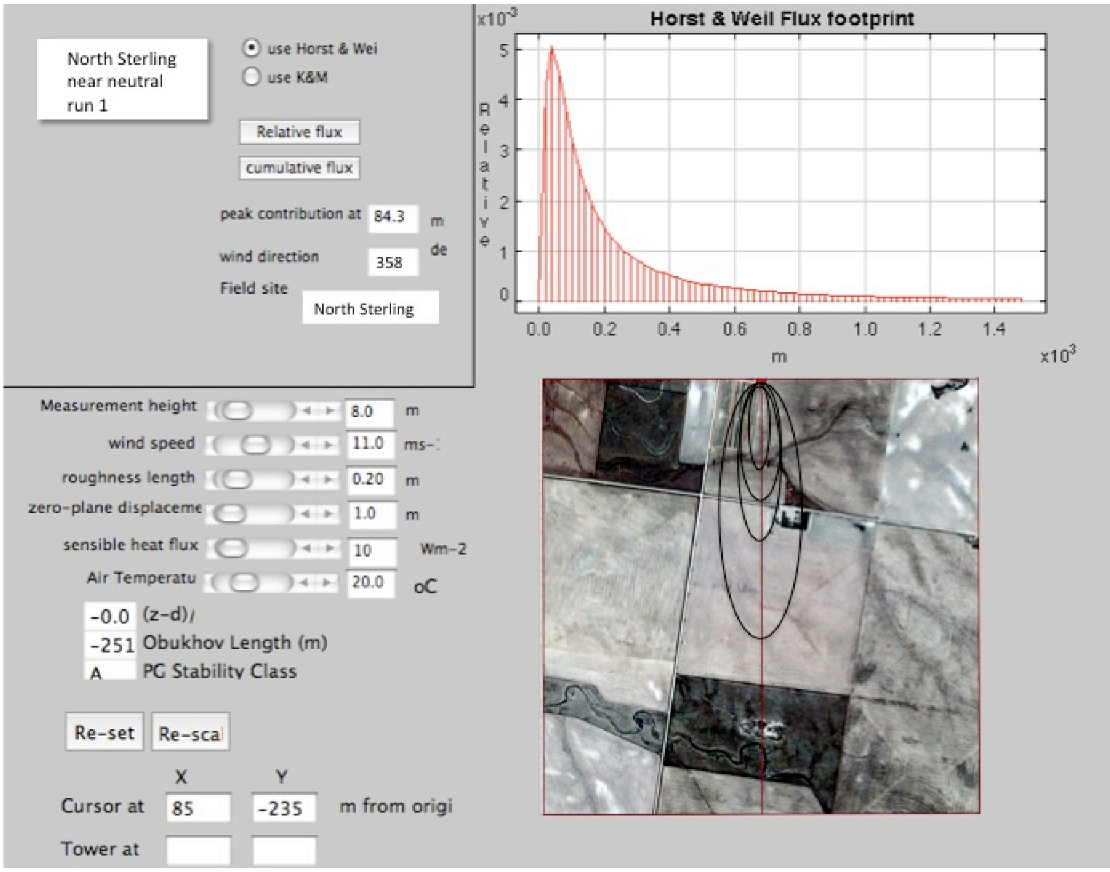


Figure 41. Tower flux footprint output for North Sterling Relocatable site under near neutral conditions using an inverted plume dispersion model by Horst & Well.

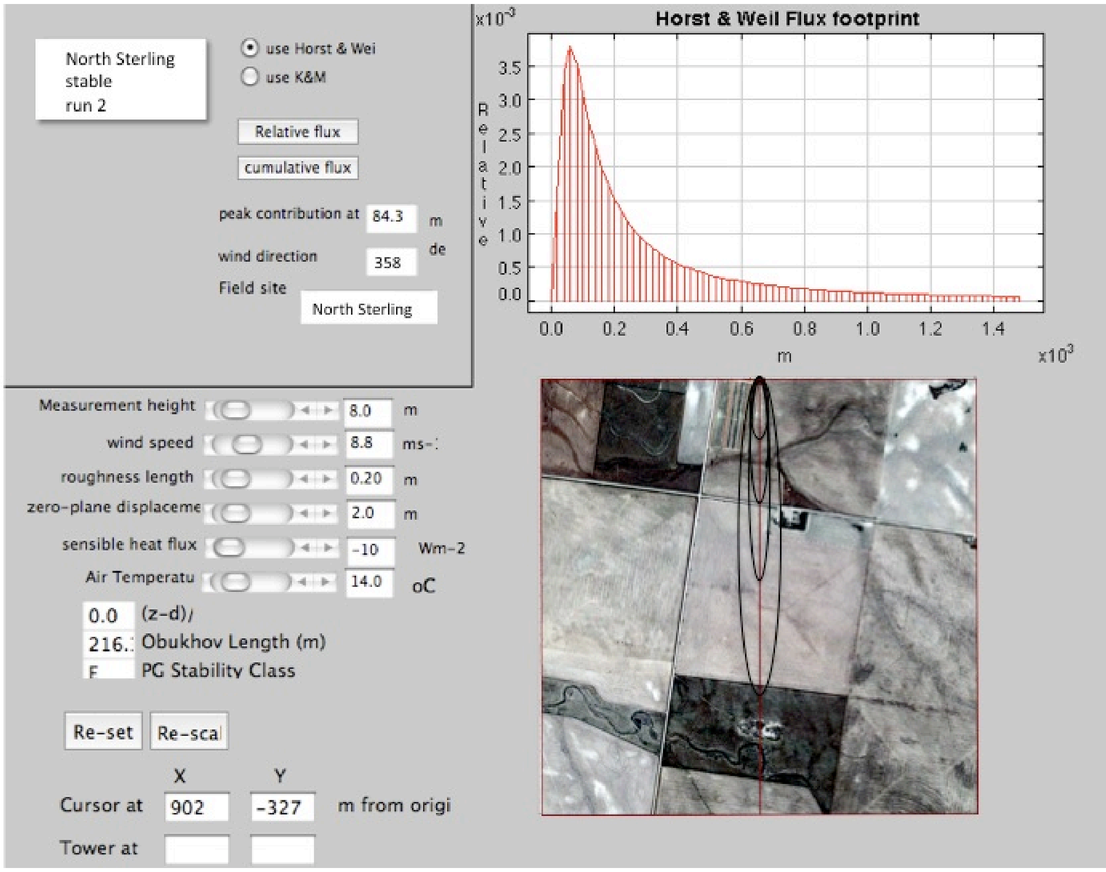


Figure 42. Tower flux footprint output for North Sterling Relocatable site under stable conditions using an inverted plume dispersion model by Horst & Well.

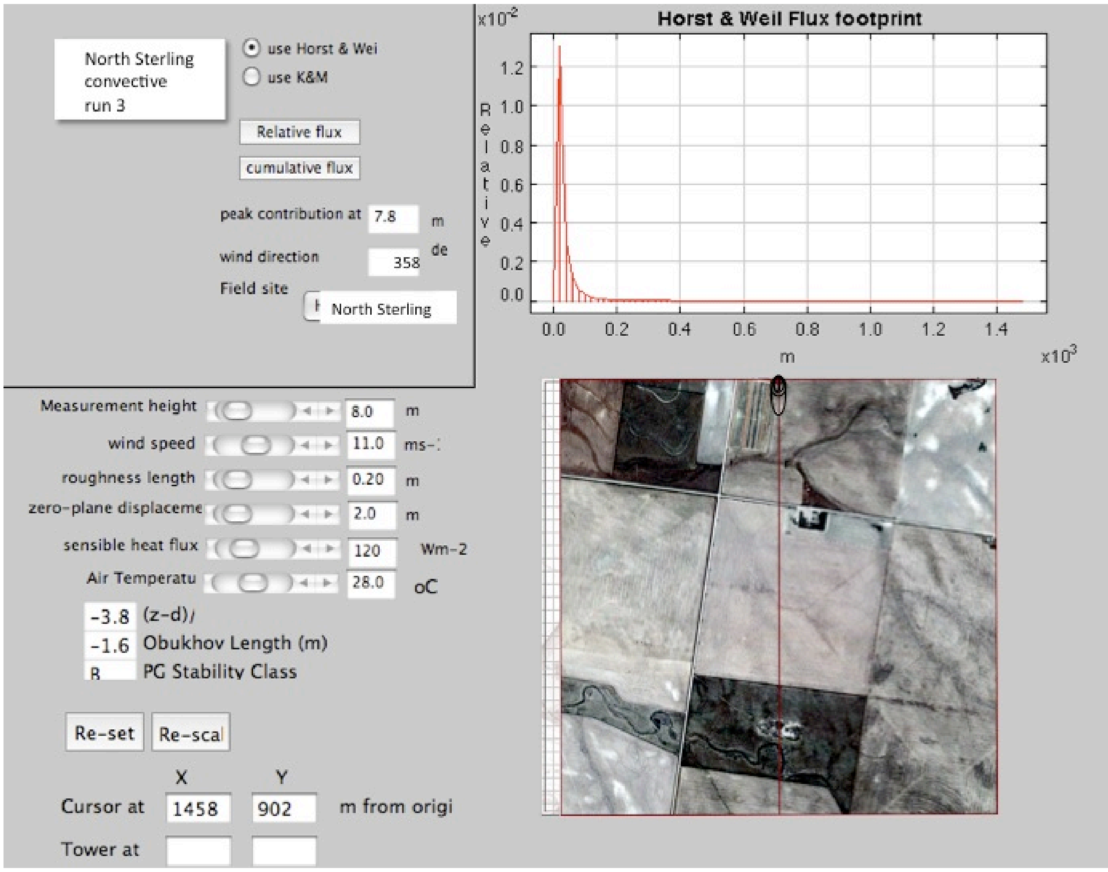


Figure 43. Tower flux footprint output for North Sterling Relocatable site under convective conditions at maximum expected wind speed using an inverted plume dispersion model by Horst & Well.

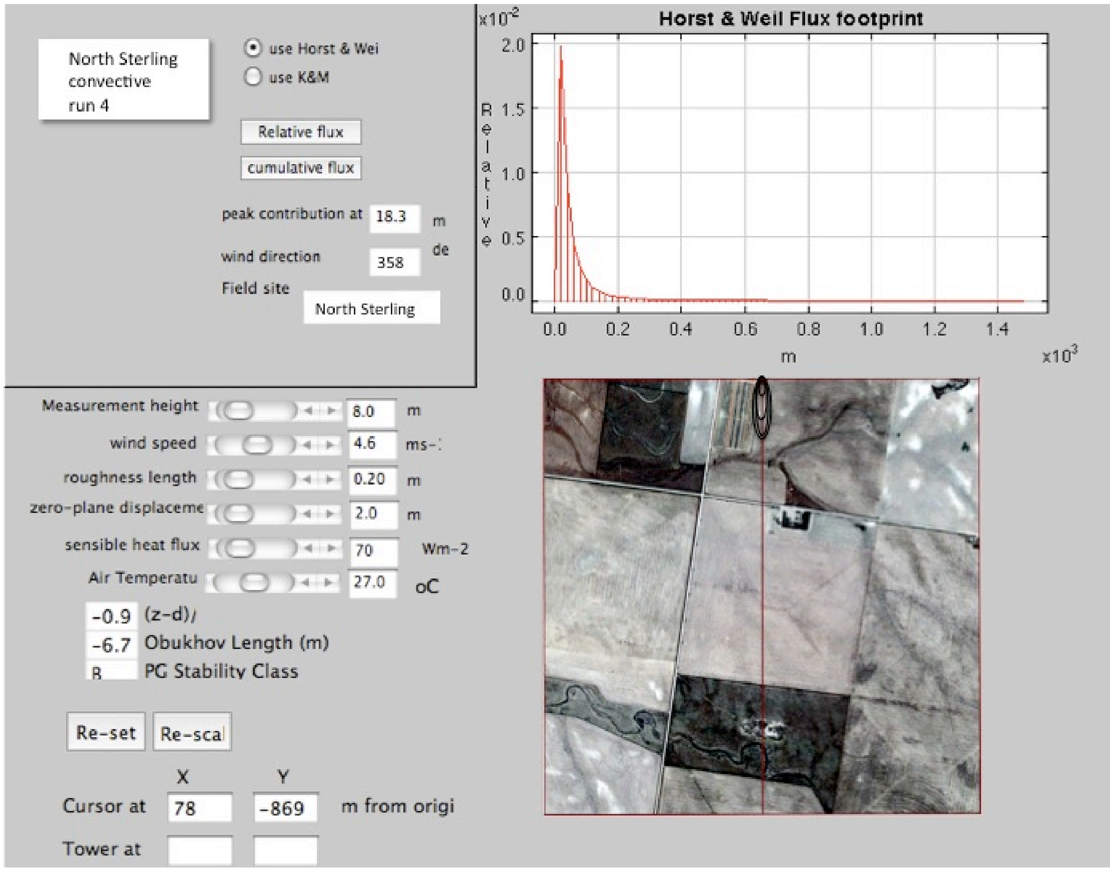


Figure 44. Tower flux footprint output for North Sterling Relocatable site under convective conditions at maximum expected wind speed using an inverted plume dispersion model by Horst & Well.

Because the ecosystem has a height of the mean plant canopy 0-4 m, the Tower has been sited to i) optimize the temporal coverage of flow-based measurements over the representative environment, ii) minimize flow distortions caused by local ecosystem structure or topography (orography), and iii) 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 (crop ecosystem), 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.

4.3.7 Constraints on the FSU ecosystem plot locations

Winds are only dominant from the north quadrant (Table 8) during July-September, and annual resultant wind vector is from 358°. Winds come from the other quadrants during all other seasons. Convective fronts develop daytime winds along the front range and generally pass over the site, travelling from the west to the east, particularly during the spring and fall seasons. But as they pass over they re-direct the winds to other vectors, from the east, south etc. (Figure 37-40).

The ecosystem productivity plots should be placed within i) the overall, annual extent of the footprint, ii) within the bounds of the permitted property, iii) span the dominant and co-dominant soil types, and iv) estimate the productivity from the ecosystem if interest.

Given these constraint and the location of the tower, the shape of the overall, annual source is a large fan (where the apex is the tower location). The northern vector is 358° + 27° = 25°. But the western boundary of the CSU plots constrain the northern vector. The length of the northern vector is 400 m. The southern vector is 135° constrained by windrose and property boundary. The length of the southern vector is ~ 300 m.

4.4 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. 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:

e) 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.
f) There may be more than one exclusion zone per tower, depending on the diurnal, seasonal and annual wind patterns.
g) The exclusion zone is a sub-area (i.e., inside) the total tower source area
h) Windrose analyses determine the wind vectors that bound the outside of the exclusion zone, which is clockwise from 135 to 25 degrees at this site (major).

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

3) 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 600 m at this site.
4) 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 790 m at this site.

5 CASTNET, RELOCATEABLE TOWER 2

5.1 Site description

The Rocky Mountain National Park Clean Air Status and Trends Network (RMNP CastNet) Relocatable tower site is located within the boundaries of RMNP at latitude N 40.27791° and longitude W 105.54584°. Current tower stake is at a relative flat clearing, which is surrounding by the heavily wooded mountain terrain, except some residential housing, clearing openings and some entertainment areas on the north-west direction. This direction is happen to be the prevailing direction, which means, if current tower location is used to set up tower, our measurements will be heavily impacted by human's daily activity instead of the natural mountain forest ecosystem that we are interested in. Plus, the recirculation at the edge of the forest would be another big concern for our turbulent measurements. Therefore, to solve this source area problem and the edge effect issue, tower location is suggested to be moved ~200 m toward south-west direction into a ponderosa pine wood stand at latitude N 40.27587° and longitude W 105.54629°.

The elevation for the tower site is at ~2750 m, on the western side of the Long's Peak (4346 m). The air drainage during the nights along the large and extended mountain slope could be a concern for the accurate turbulence measurements, as well as the CO_2 profile measurements on the forest ecosystem that we are interested in. The meteorological conditions in different seasons in 2006 are resented in Table 10, 11, and 12 (Barna et al*.,* 2009).

Table 10. Summary statistics for core site hourly meteorological data during April 2006.

720 Observations	Temperature (°C)	Relative Humidity	Precipitation (mm)	Wind Speed (m/sec)	Wind Direction (degrees)
Minimum	-9.68	6.12	0.00	0.04	1.91
Mean	3.75	42.69	0.04	2.56	235.98
Median	3.72	38.75	0.00	1.99	277.97
Maximum	15.89	96.00	4.20	13.68	358.58
Standard Deviation	5.88	23.09	0.23	1.99	98.52

Table 11. Summary statistics for core site hourly meteorological data during July 2006.

744 Observations	Temperature (°C)	Relative Humidity (%)	Precipitation (mm)	Wind Speed (m sec^{-1})	Wind Direction (degrees)
Minimum	6.25	10.35	0.00	0.09	0.52
Mean	15.41	54.38	0.16	1.53	241.33
Median	15.28	49.58	0.00	1.44	294.77
Maximum	25.80	97.00	7.50	3.81	359.98
Standard Deviation	4.53	23.34	0.61	0.72	104.56

Table 12. Summary statistics for core site hourly meteorological data during August 1-15, 2006.

392 Observations	Temperature (^oC)	Relative Humidity (%)	Precipitation (mm)	Wind Speed (m/sec)	Wind Direction (degrees)
Minimum	5.50	18.20	0.00	0.11	0.67
Mean	14.30	54.77	0.06	1.48	226.48
Median	14.42	53.82	0.00	1.32	275.11
Maximum	23.20	95.35	4.50	4.31	358.68
Standard Deviation	3.66	16.90	0.37	0.76	102.00

5.1.1 Ecosystem

Immediate to the suggested tower location, the vegetation are dominant by Ponderosa Pine forest (Figure 45), which typically distribute ~ 1680 m - 2850 m at RMNP. Mature trees large, with open rounded or flat-topped crown. Tree height can reach ~35 m, trunk massive, to ~1 m diameter. Bark is thick, reddish, with vanilla, or butterscotch scent. Needles are ~3 in to 7 in long, in bundles of 2 to 3. Female cones are large, woody, with a short spine on each scale. Trees scattered or in clumps, generally not crowded. Ponderosa pine forests are normally with diverse understory, dominated by shrubs and grasses (information source: http://www.nps.gov/romo/naturescience/trees.htm). However, the sources that contribute to the FIU measurements on the tower could include the signals from other ecosystem at higher altitude, *e.g.,* Douglas Fir, Lodgepole Pine, Rocky Mountain Juniper or Red Cedar, Quaking Aspen, etc. ((information source: http://www.nps.gov/romo/naturescience/trees.htm).

Figure 45. RMNP CastNet site is dominant by an open Ponderosa pine forest at the proposed new tower site.

Investigation at field indicates that the canopy height of the Ponderosa Pine forest ranged from ~20 m to ~27 m with a mean height of ~22 m near the suggested tower location. The roughness length ranges from ~1.5 m to ~2 m with a mean of ~1.8 m. The zero plane displacement height varies from ~ 16 m to ~23 m with a mean of ~20 m. Understory is dominant by shrubs and grasses shorter than 1 m. The average height for understory is ~ 20 cm.

5.2 Soils

Soil data and soil maps (Figure 46) below for RMNP CastNet Relocatable site were collected from 1 km^2 NRCS soil maps, which centered at the tower location, to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

Figure 46. 1km^2 soil map for RMNP CastNet Relocatable site, center at tower location.

5.2.1 Description of soils

Map Unit Description The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit. A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, 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. Map Unit Description: Catamount gravelly coarse sandy loam, 5 to 20 percent slopes–Rocky Mountain National Park, Colorado, Parts of Boulder, Grand, and Larimer Counties Castnet_1km Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009.

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

Rocky Mountain National Park, Colorado, Parts of Boulder, Grand, and Larimer Counties 4—Catamount gravelly coarse sandy loam, 5 to 20 percent slopes Map Unit Setting Elevation: 8,000 to 10,000 feet Mean annual precipitation: 18 to 24 inches Mean annual air temperature: 39 to 43 degrees F Frost-free period: 50 to 70 days Map Unit Composition Catamount and similar soils: 90 percent Map Unit Description: Catamount gravelly coarse sandy loam, 5 to 20 percent slopes–Rocky Mountain National Park, Colorado, Parts of Boulder, Grand, and Larimer Counties Castnet_1km Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009. Description of Catamount Setting Landform: Structural benches Landform position (two-dimensional): Summit, backslope, shoulder Landform position (three-dimensional): Mountainflank Down-slope shape: Linear Across-slope shape: Linear Parent material: Gravelly slope alluvium and/or residuum weathered from granite and/or schist and/or gneiss Properties and qualities Slope: 5 to 20 percent Surface area covered with cobbles, stones or boulders: 1.0 percent Depth to restrictive feature: 10 to 20 inches to paralithic bedrock Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately high (0.00 to 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Very low (about 1.0 inches) Interpretive groups Land capability (non-irrigated): 7s Other vegetative classification: Lodgepole pine/kinnikinnick (PICO/ ARUV) (C0901) Typical profile 0 to 1 inches: Slightly decomposed plant material 1 to 3 inches: Gravelly coarse sandy loam 3 to 10 inches: Very gravelly coarse sandy loam 10 to 14 inches: Very gravelly coarse sandy loam 14 to 24 inches: Weathered bedrock

Rocky Mountain National Park, Colorado, Parts of Boulder, Grand, and Larimer Counties 5—Catamount-Bullwark-Rock outcrop complex, 10 to 40 percent slopes Map Unit Setting Elevation: 8,000 to 9,900 feet Mean annual precipitation: 18 to 24 inches Mean annual air temperature: 37 to 42 degrees F Frost-free period: 50 to 70 days Map Unit Composition Catamount and similar soils: 45 percent Bullwark and similar soils: 30 percent Map Unit Description: Catamount-Bullwark-Rock outcrop complex, 10 to 40 percent slopes–Rocky Mountain National Park, Colorado, Parts of Boulder, Grand, and Larimer Counties Castnet_1km Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009. Rocky outcrop: 15 percent Description of Catamount Setting Landform: Structural benches Landform position (two-dimensional): Shoulder, backslope Landform position (three-dimensional): Mountainflank Down-slope shape: Convex Across-slope shape: Convex Parent material: Gravelly slope alluvium and/or residuum weathered from granite and/or schist and/or gneiss Properties and qualities Slope: 10 to 40 percent Depth to restrictive feature: 10 to 20 inches to paralithic bedrock Drainage class: Somewhat excessively drained Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately high (0.00 to 0.20 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Very low (about 1.0 inches) Interpretive groups Land capability (non-irrigated): 7s Other vegetative classification: Lodgepole pine/kinnikinnick (PICO/ ARUV) (C0901) Typical profile 0 to 1 inches: Slightly decomposed plant material 1 to 3 inches: Gravelly coarse sandy loam 3 to 10 inches: Very gravelly coarse sandy loam 10 to 14 inches: Very gravelly coarse sandy loam 14 to 24 inches: Weathered bedrock Description of Bullwark Setting Landform: Mountain slopes Landform position (two-dimensional): Footslope, backslope Landform position (three-dimensional): Mountainflank Down-slope shape: Linear Across-slope shape: Linear Parent material: Colluvium and/or residuum weathered from granite and/or gneiss and/or schist Properties and qualities Slope: 10 to 40 percent Surface area covered with cobbles, stones or boulders: 1.0 percent Depth to restrictive feature: 20 to 40 inches to paralithic bedrock; 30 to 50 inches to lithic bedrock Drainage class: Well drained Map Unit Description: Catamount-Bullwark-Rock outcrop complex, 10 to 40 percent slopes–Rocky Mountain National Park, Colorado, Parts of Boulder, Grand, and Larimer Counties Castnet_1km Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009 Page 3 of 4Capacity 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 Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Very low (about 1.9 inches) Interpretive groups Land capability (non-irrigated): 7e Other vegetative classification: Lodgepole pine/kinnikinnick (PICO/ ARUV) (C0901) Typical profile 0 to 2 inches: Slightly decomposed plant material 2 to 9 inches: Very gravelly coarse sandy loam 9 to 15 inches: Very gravelly sandy loam 15 to 23 inches: Very cobbly sandy loam 23 to 32 inches: Weathered bedrock 32 to 60 inches: Unweathered bedrock Description of Rock Outcrop Setting Landform: Mountain slopes Landform position (two-dimensional): Summit, shoulder Landform position (three-dimensional): Mountainflank Down-slope shape: Linear Across-slope shape: Linear Parent material: Granite and/or gneiss and/or schist Properties and qualities Slope: 10 to 40 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

Data Source Information Soil Survey Area: Rocky Mountain National Park, Colorado, Parts of Boulder, Grand, and Larimer Counties Survey Area Data: Version 6, Jan 30, 2008 Map Unit Description: Catamount-Bullwark-Rock outcrop complex, 10 to 40 percent slopes–Rocky Mountain National Park, Colorado, Parts of Boulder, Grand, and Larimer Counties Castnet_1km Natural Resources Conservation Service Web Soil Survey National Cooperative Soil Survey 7/22/2009.

5.2.2 Soil Semi-variograms

The goal of this site characterization of soil using semi-variograms is to determine the minimum distance between the soil plots in the soil array that can be considered spatially independent. The spatial variation of surface soil will be estimated using field sampling data of soil temperature and soil water content (SWC) in the tower airshed at Rocky Mountain National Park Clean Air Status and Trends Network (RMNP CastNet) Relocatable site.

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

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

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

5.2.3 Soil Semi-variogram Method, experimental design, data analysis

Measurements of soil temperature and soil water content (SWC) were taken on August 13 and August 14, 2009 at the RMNP CastNet Relocatable tower site following the spatially cyclic sampling design by Bond-Lamberty et al. (2006, Figure 4). This design uses repeated pattern of samples to provide information about all distance with minimum of redundancy.

Because the current tower location (Latitude: N40.27791°, Longitude: W105.54584°) doesn't meet FIU science requirement about tower fetch in representative ecosystem. An alternative tower location is suggested at (Latitude: N40.27587°, Longitude: W105.54629°). The soil temperature and SWC measurements were conducted next to the suggested new tower location (Figure 47). Four 84-meter transects were established at RMNP CastNet Relocatable tower site (Figure 47, Figure 48). They were centered at a same point (Latitude: N40.27598°, Longitude: W105.54581°). 11 sampling points were taken along each transect. A Garmin GPS device was used to record the sampling location. The direction (compass magnetic degrees) for these 4 transects are 335°-155°, 290°-110°, 245°-65°, and 200°-20°, respectively.

3 replicates (30 cm apart from one another, Figure 49) were measured at each sampling point at fixed-depth (0-20 cm) using platinum resistance temperature sensors (Omega RTD810) for soil temperature and time domain diaelectric sensors (CS616) for SWC at each sampling points. Data collected were used for geospatial analyses of variograms in the R statistical computing language with the geoR package to test for spatial autocorrelation (Goovaerts 1997, Trangmar et al. 1985, Webster 1989) and to determine the distance for soil plots in the soil array.

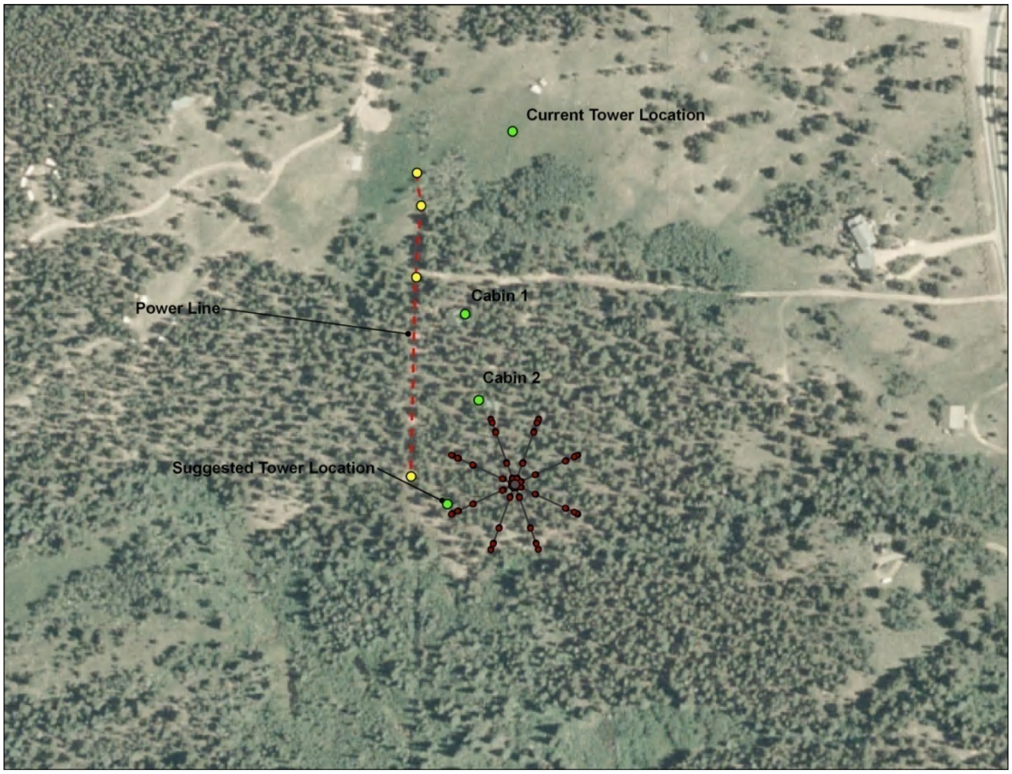


Figure 47. Established transects at RMNP CastNet Relocatable site.

These transects were used for field measurements of soil temperature and soil water content for site characterization of soil are presented. Current tower location, suggested tower location, partial of the power line, and two recent built cabins are also presented.

Figure 48. Established transects at RMNP CastNet Relocatable tower site.

Figure 49. Three replicates of soil temperature and SWC were measured at each sampling point at fixed-depth (0-20 cm).

For all data sets for temperature and SWC, there is evidence for the existence of spatial trends that can be modeled as a function of time. This is a consequence of the fluctuating solar radiation throughout the day. Trends were estimated and removed with a simple two parameter linear regression model and p-values for the model significance are provided in the respective text below in results session. For the most part, this approach was sufficient with respect to satisfying the assumption of stationarity. Hence, variogram models were constructed on the residuals from these regressions of the response variable on time. The range distance (i.e. the distance beyond which samples are spatially independent) was estimated from the empirical variogram by fitting spherical theoretical models to both soil temperature and SWC data.

5.2.4 Results and interpretation

Temperature

The temperature data display a strong pattern as a function of time. A linear regression ($p < 0.001$) of temperature on time was fit and used to extract this trend (Figure 50). Exploratory data analysis plots show that there is no distinct patterning of the residuals (Figure 51). Directional variograms of the residuals do not show any indication of anisotropy (Figure 52). A spherical covariance model was fit using Cressie weights and a maximum distance of 125 meters (Figure 53). The estimated distance of effective independence was 101 meters (Figure 53). This information will be used to refine the design applied to the subsequent sites. If the maximum distance between samples in the final sampling design is less than the distance of effective independence, then increased sampling density may be required to achieve a nominal sample size in the presence of correlated data.

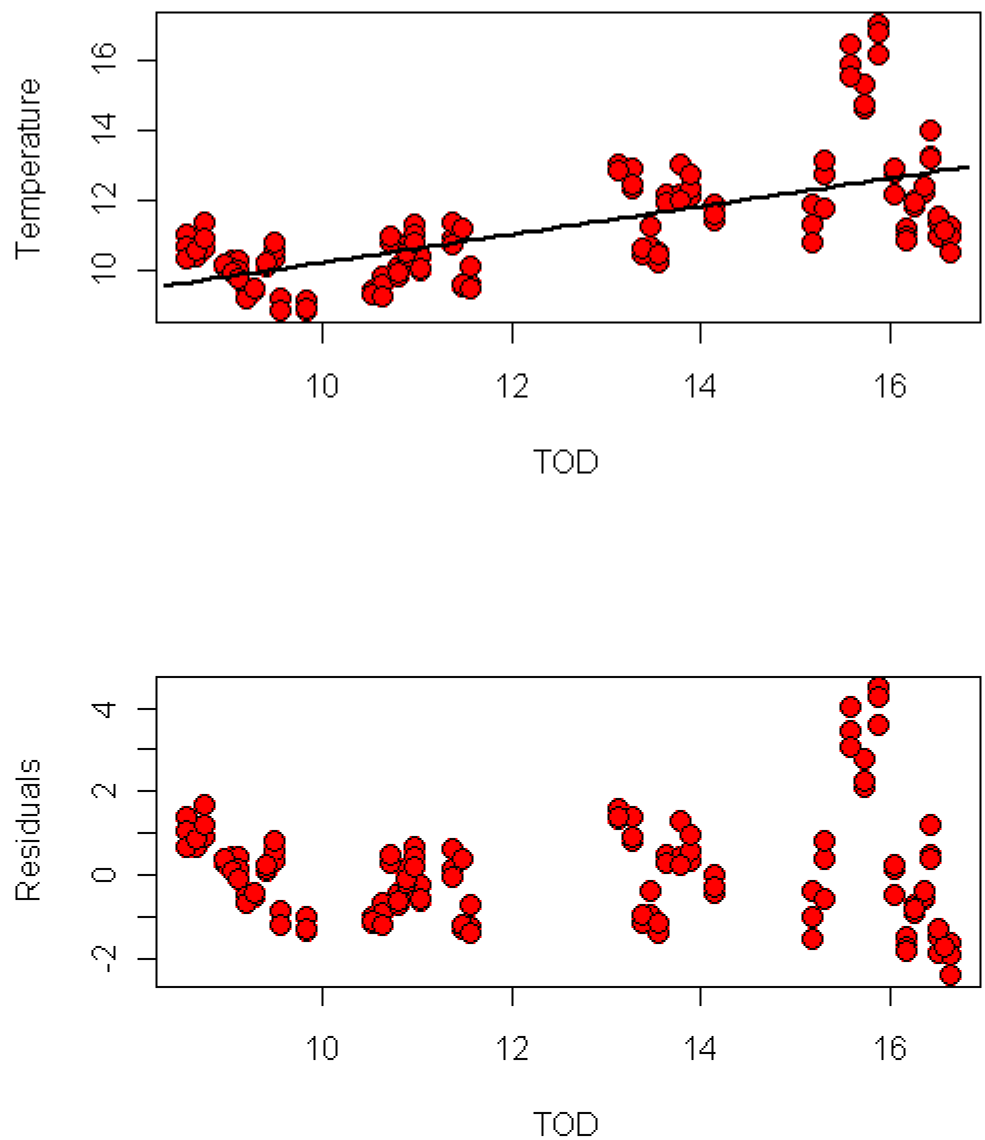


Figure 50. Time trend with linear regression fit and residuals for temperature at the RMNP CastNet relocatable site.

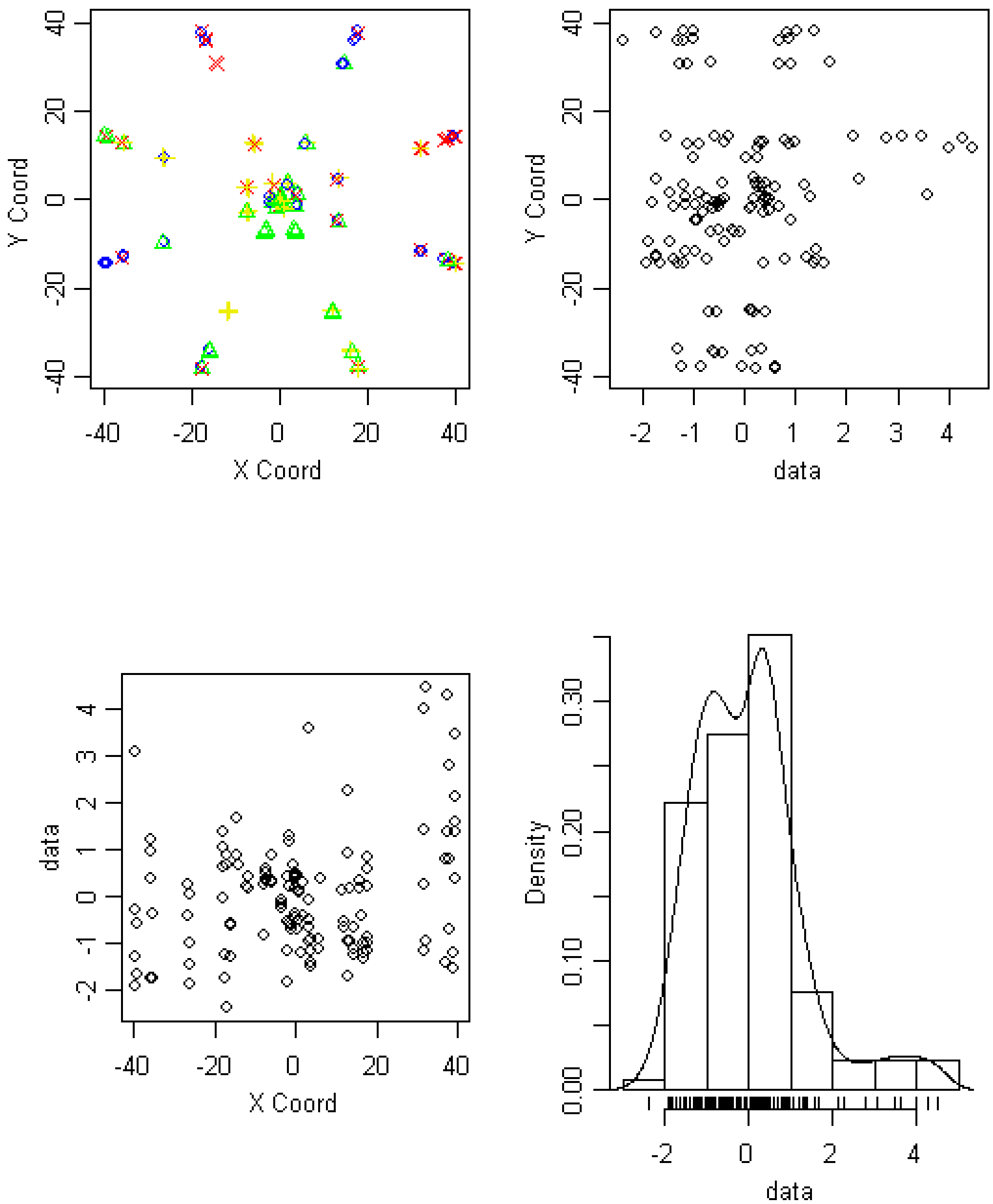


Figure 51. Exploratory data analysis plots for residuals from regression of temperature on time at the RMNP CastNet relocatable site.

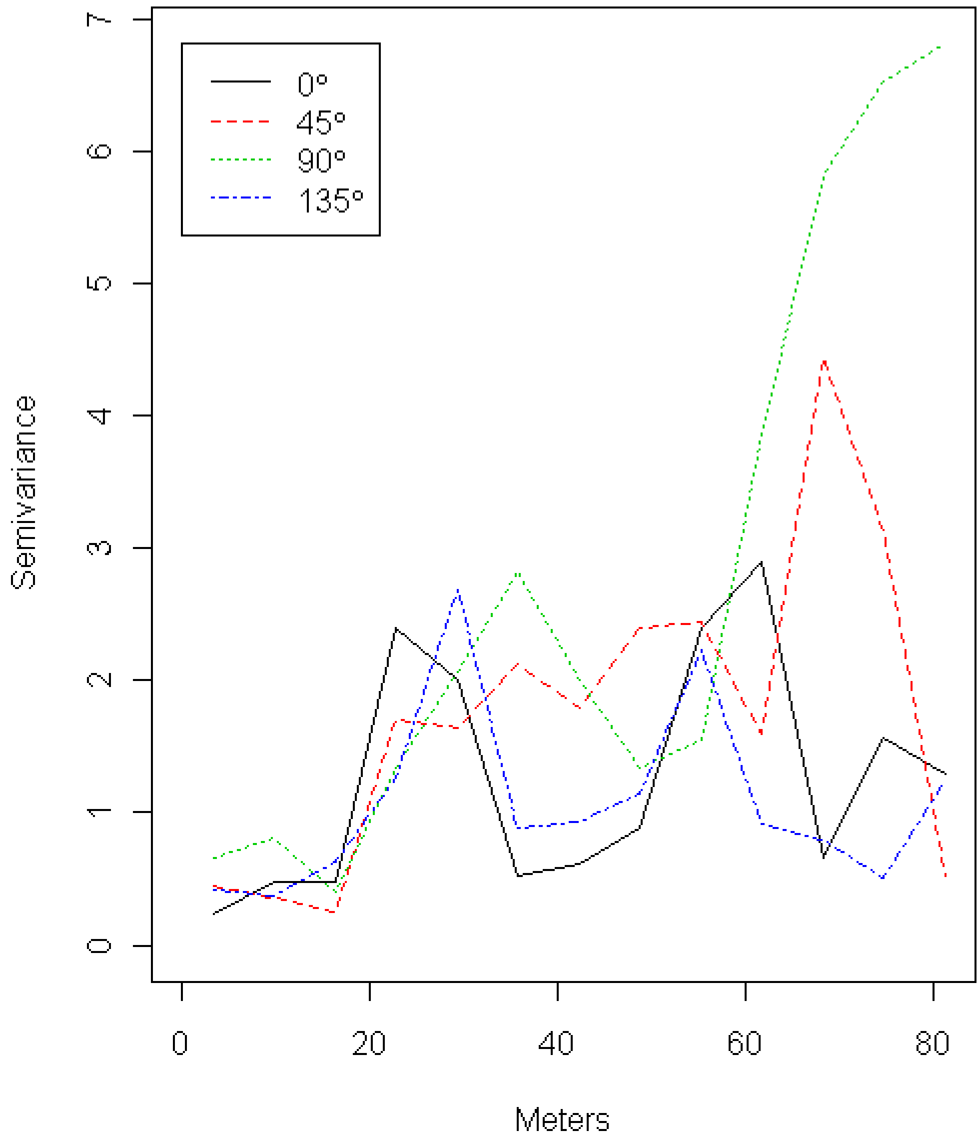


Figure 52. Directional variograms for residuals from regression of temperature on time at the RMNP CastNet relocatable site.

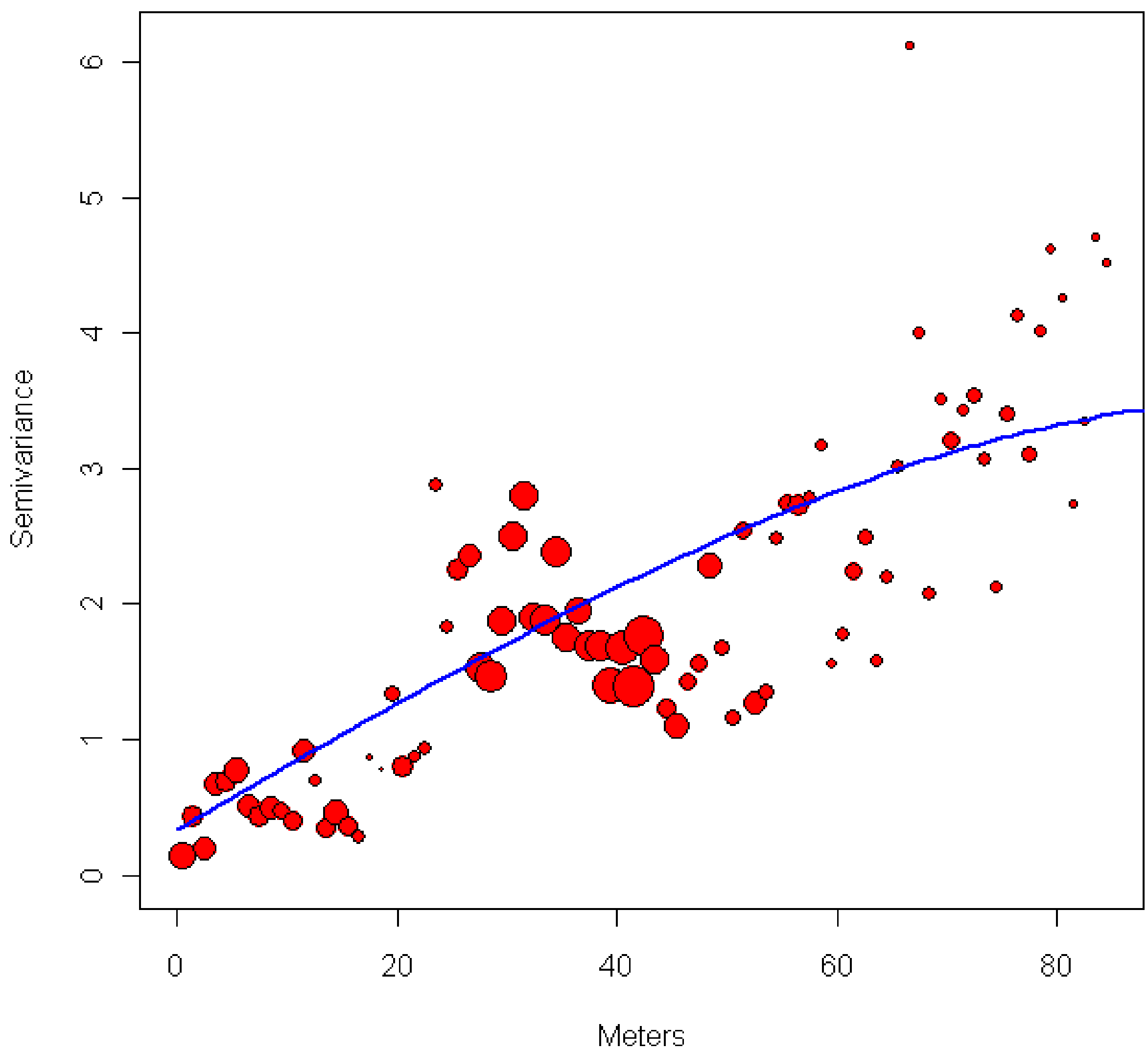


Figure 53. Empirical variogram and model fit for the residuals of the regression of temperature on time at the RMNP CastNet relocatable site.

Soil Water Content

The soil water content (SWC) data display a weakly increasing pattern as a function of time. A linear regression (p = 0.03) of temperature on time was fit and used to extract this trend (Figure 54). Exploratory data analysis plots show that there is a potentially decreasing trend from left to right across the horizontal extent of the data (lower left corner Figure 55). Directional variograms of the residuals do not show any indication of anisotropy (Figure 56). A spherical covariance model was fit using Cressie weights (Figure 57) and the estimated distance of effective independence was 35.0 meters. This information will be used to refine the design applied to the subsequent sites.

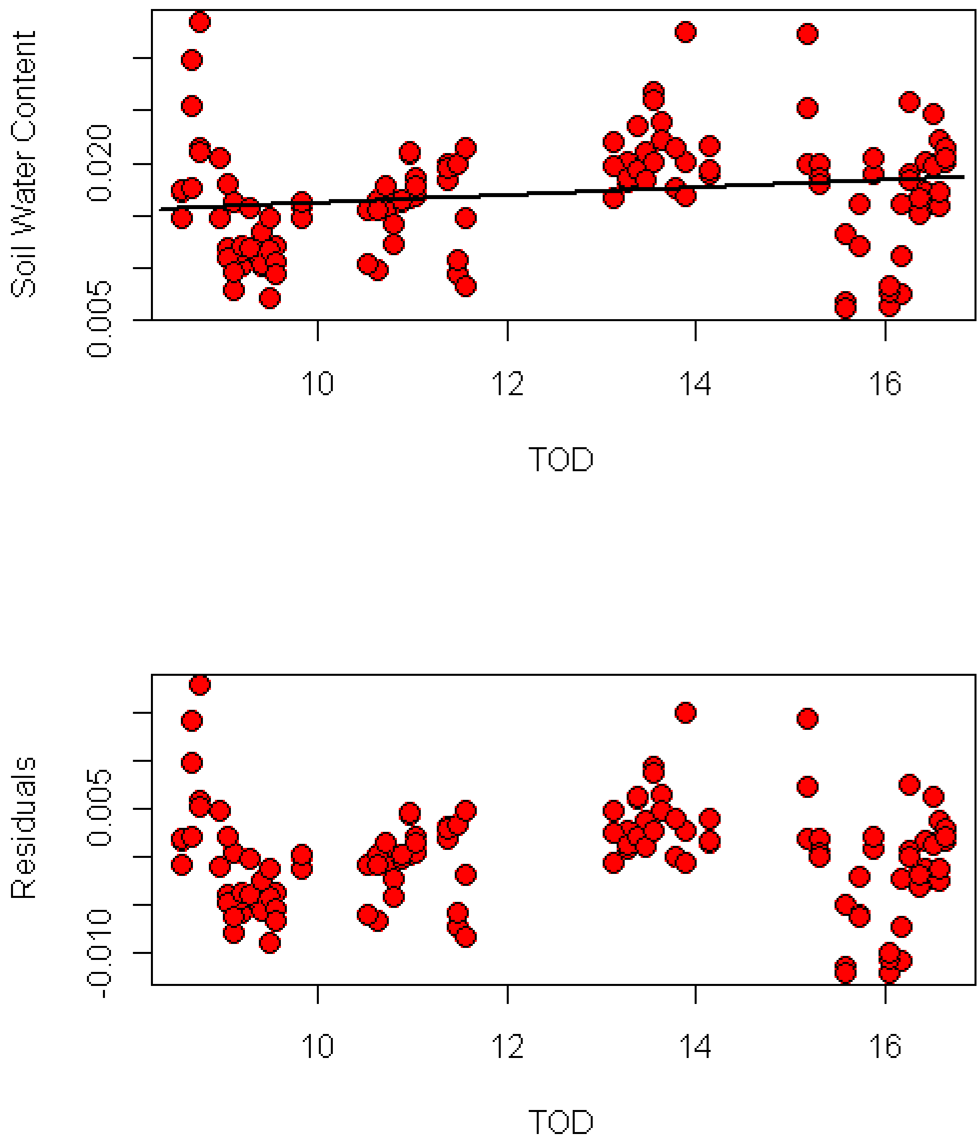


Figure 54. Time trend with linear regression fit and residuals for soil water content at the RMNP CastNet relocatable site.

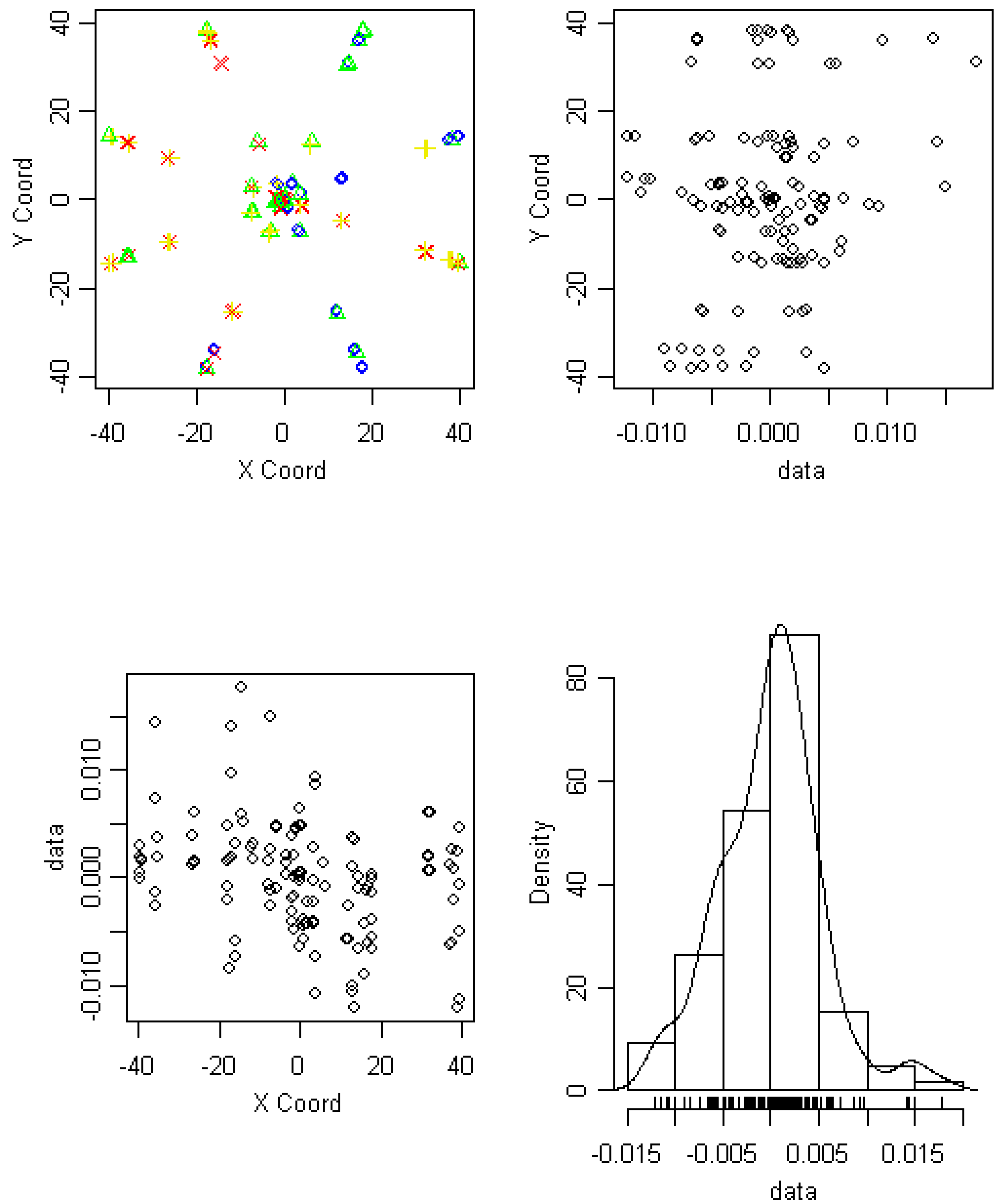


Figure 55. Exploratory data analysis plots for residuals from regression of soil water content on time at the RMNP CastNet relocatable site.

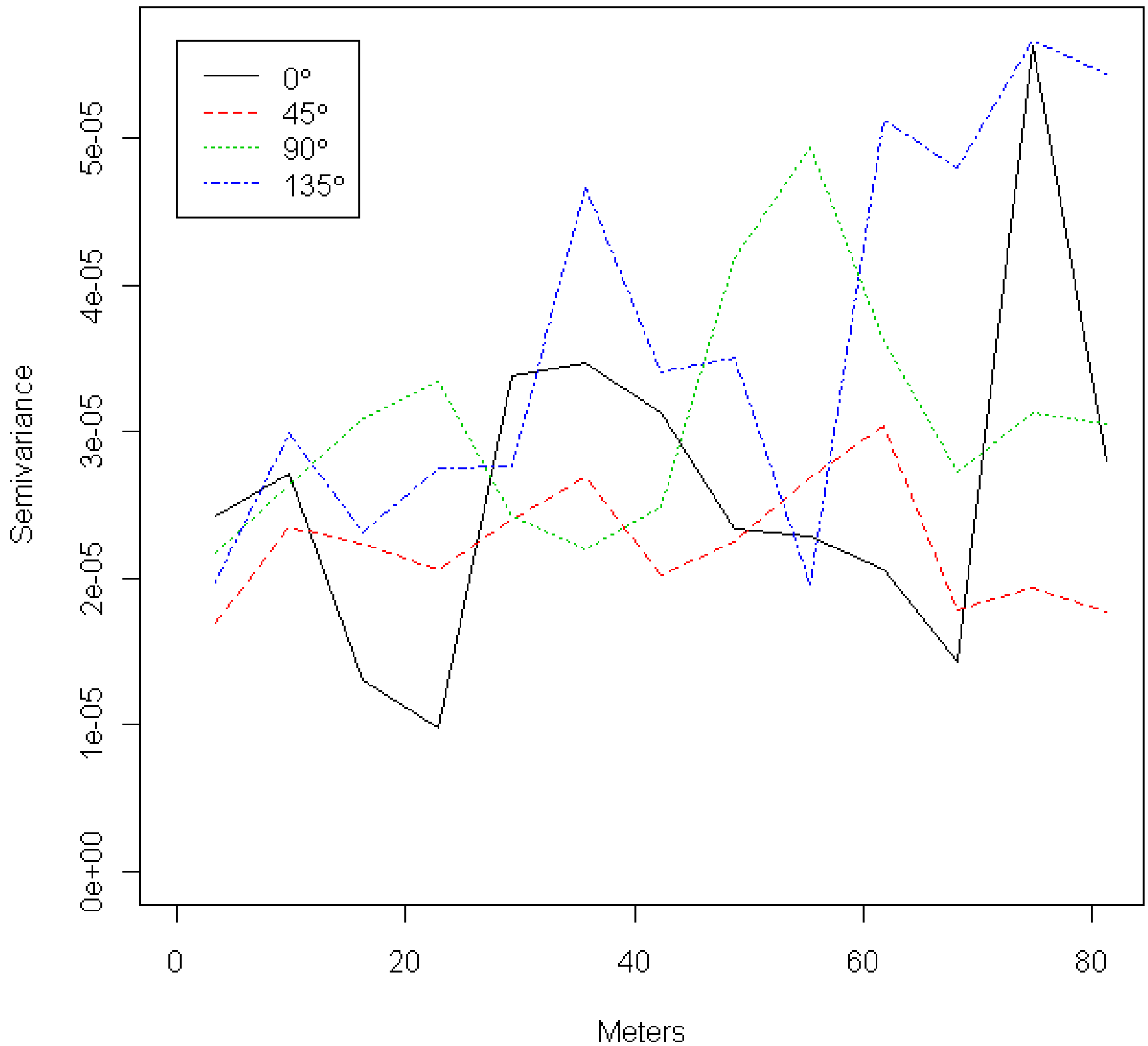


Figure 56. Directional variograms for residuals from regression of soil water content on time at the RMNP CastNet relocatable site.

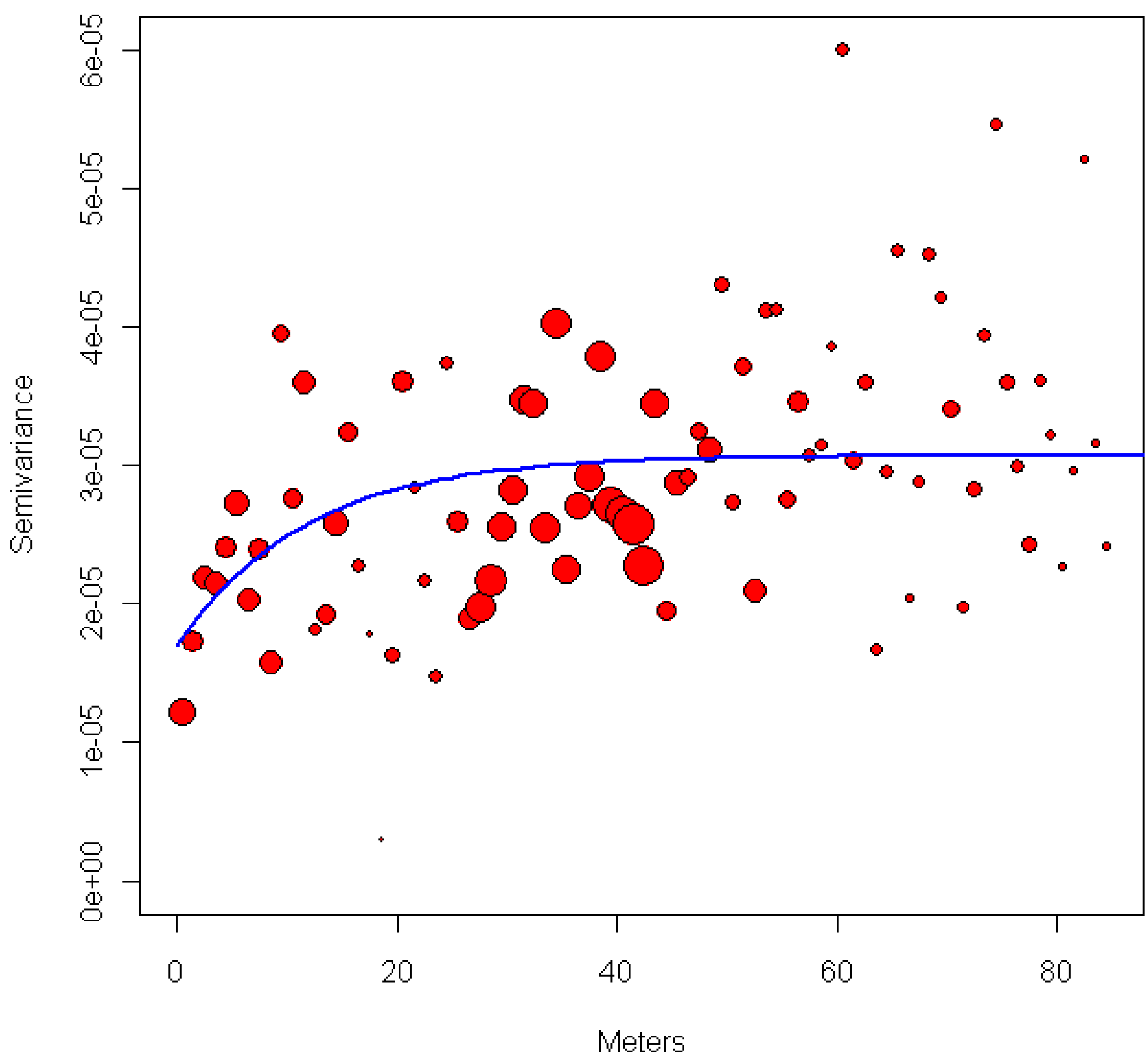


Figure 57. Empirical variogram and model fit for the residuals of the regression of soil water content on time at the RMNP CastNet relocatable site.

5.2.5 Summary

The estimated distance of effective independence was 101 meters based on geospatial analysis of temperature data alone, which is impossible to separate soil plots so far apart due to the economic reasons. The temperature results should be discounted due to the non-uniform radiation heating on ground surface in the canopy opening areas. The estimated distance of effective independence was found to be 35 meters with a well-defined sill based on the geospatial analysis on SWC. Therefore, the distance of 35 meters is recommended for the design of soil plots at the RMNP CastNet relocatable site.

5.3 Airshed

5.3.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries. The orientation of the wind rose follows that of a compass. When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. Color bands depict the range of wind speeds. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 24 cardinal directions.

Data used here are hourly data from 1999 to July 2009. Data was collected and obtained from the EPA CASTNET site, http://www.epa.gov/CASTNET/sites/rom406.html. Data were collected by a propeller anemometer mounted at 2.2 m inside the CASTNET experimental area in an open field surrounded by ponderosa pine (large edge effects). Hence, the anemometer was below canopy height and may be subject to large errors. These data were collected approximately 140 m from the proposed tower site. It is assumed that the wind data was corrected for declination.

5.3.2 Resultant vectors

Table 13. The resultant wind vectors from CASTNET using hourly data from 1999 to 2009.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	306°	49
April to June	293°	33
July to September	303°	36
October to December	311°	50
Annual mean	303.3°	na.

Table 14. The percent duration of winds among cardinal directions, 3 frequency bins on each side of the cardinal direction.

Data are from Castnet using hourly data from 1999 to 2009. Blue text and underline indicates the dominant, winds occurring for the cardinal direction >40% of the time.

Quarterly (seasonal) timeperiod	Cardinal direction			
	North	East	South	West
January to March	31.4	4.8	11.4	49.3
April to June	24.5	8.6	19.9	44.0
July to September	24.5	9.8	14.8	44.7
October to December	34.0	7.2	11.0	44.9

5.3.3 Acceptance criteria

Winds are dominant from the west quadrant across all seasons (Table 14), and annual resultant wind vector is from 303° (Table 13). However, the resultant vector is influenced by winds throughout the North and west over the continental divide. Daytime winds flow upslope contra to the predominant flows and often observed in mid-elevation sites throughout the front range. Overall, the winds are fairly constrained by direction, this is an advantage of this site.

The desired measurements are from natural ecosystems (in this case, Ponderosa Pine) mid-elevation of the western slope of the Rockies to assess dust and chemical transport. The source area of this site is complex with advective flows and large surface roughness from patchy ecosystem structure (forest, fields, rock outcrops, steep mountainous slopes, etc.). Co-located with this site is the CastNet atmospheric chemistry monitoring site in an open field. Tower placement should be avoided in the leeward side of an abrupt change in ecosystem structure (AD[01]). In other words, large wake effects and recirculation occur when wind flows over a tree canopy prior to flowing over a field (AD[01]). Hence, the tower placement should not be in the clearing field with the co-located CastNet monitoring.

The extent of the forest is patchy in this area. Residential areas (Salvation Army retreat, and ex-urban homes) are to the North and North-east of this parcel. To optimize measurement of the flows over the forest, i) the tower placement should be in align with the forest and the dominant wind flows, and ii) as far from the urban residences as possible. Placing the tower in the SW section of this parcel into the forest, not only achieves these criteria, but also allows for over-forest flows to occur upslope (from the daytime flows). Because wind velocities are often high, and summertime convective energy is lower than that found on the prairie, source areas are generally much larger than that found at the other D10 sites (section 5.3.6). Instrument hut shall be placed in the leeward side of the tower and not influence the flows around the tower, hence, the distance of ~ 5 x the hut height towards the east of the tower is required (AD[02]).

5.3.4 Results (graphs for wind roses)

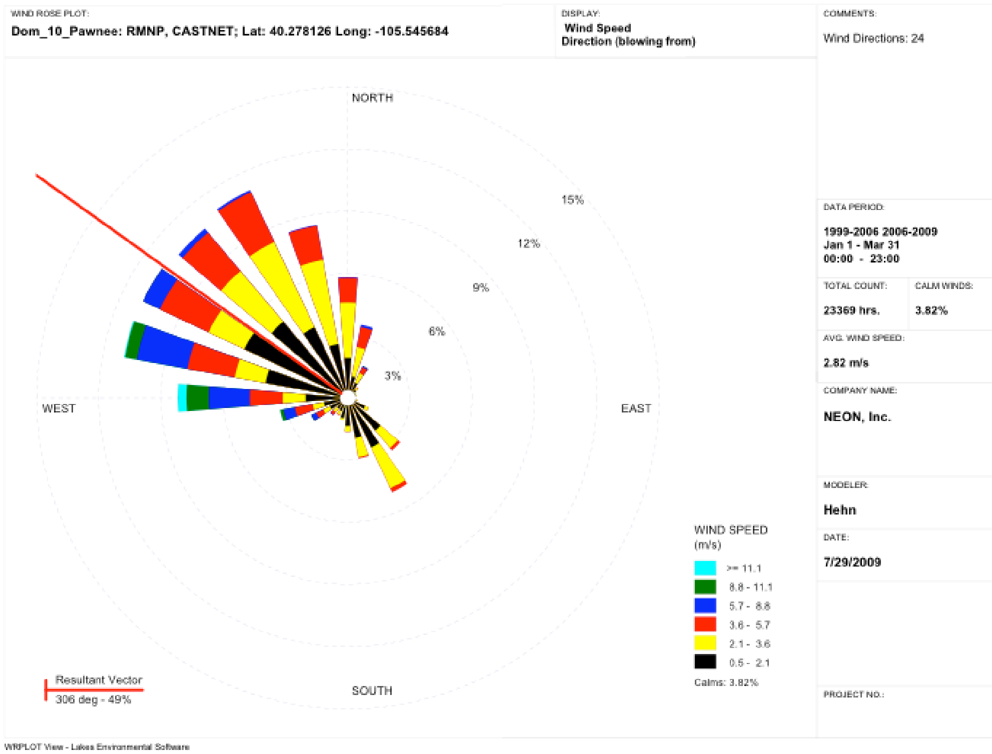


Figure 58. Wind roses of Jan - March for RMNP CastNet Relocatable site in 1999-2009

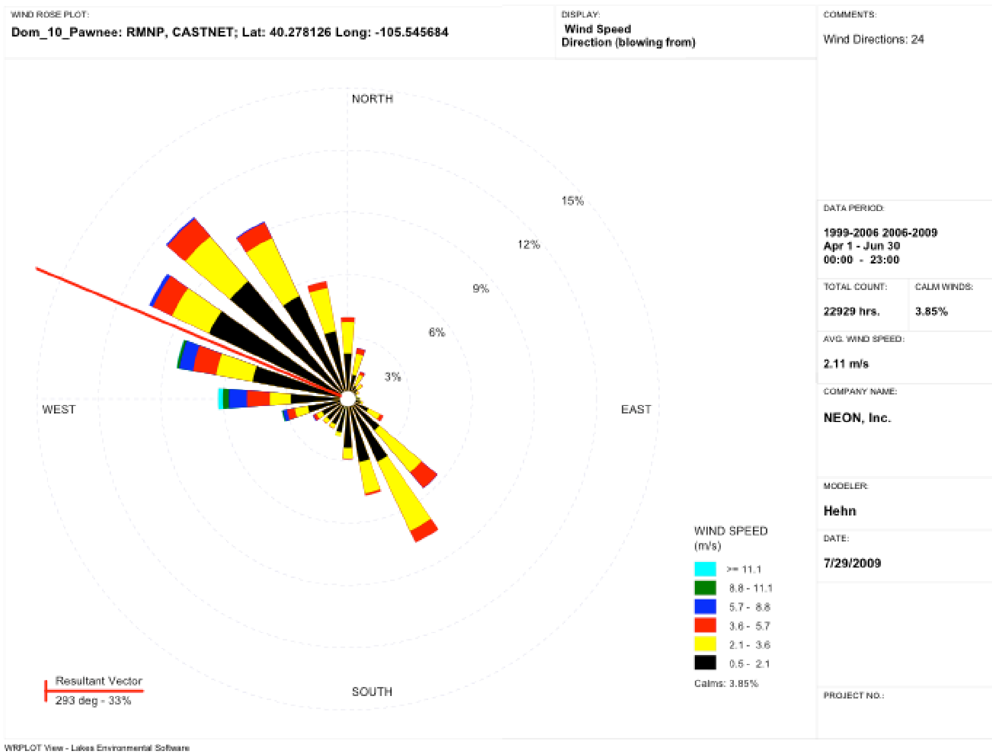


Figure 59. Wind roses of April - June for RMNP CastNet Relocatable site in 1999-2009

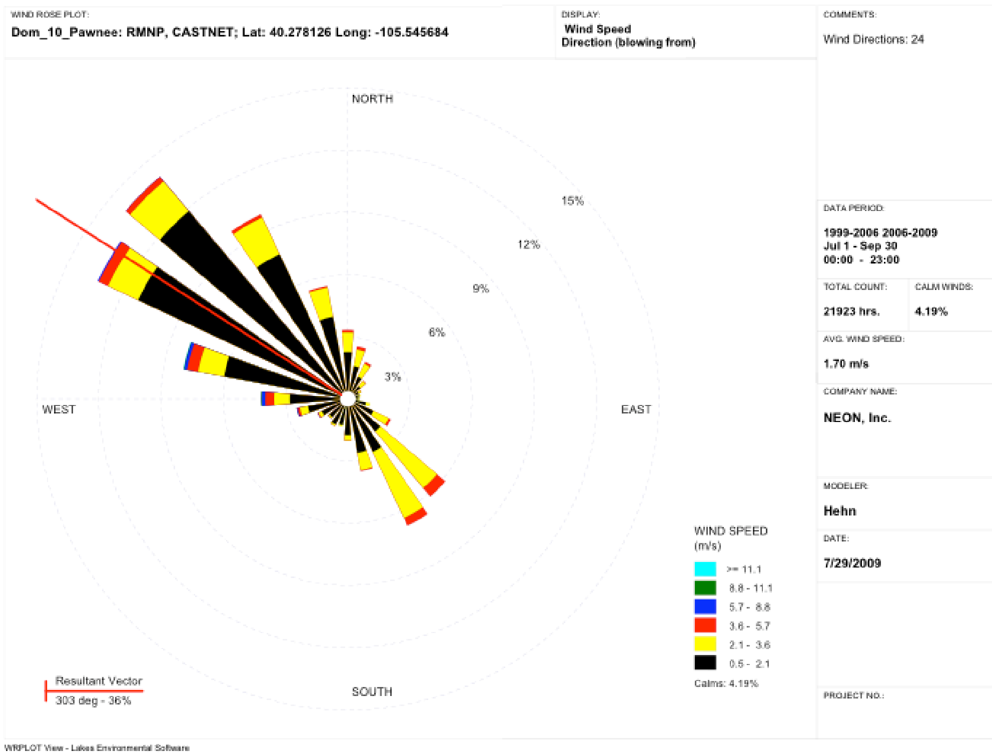


Figure 60. Wind roses of June - September for RMNP CastNet Relocatable site in 1999-2009

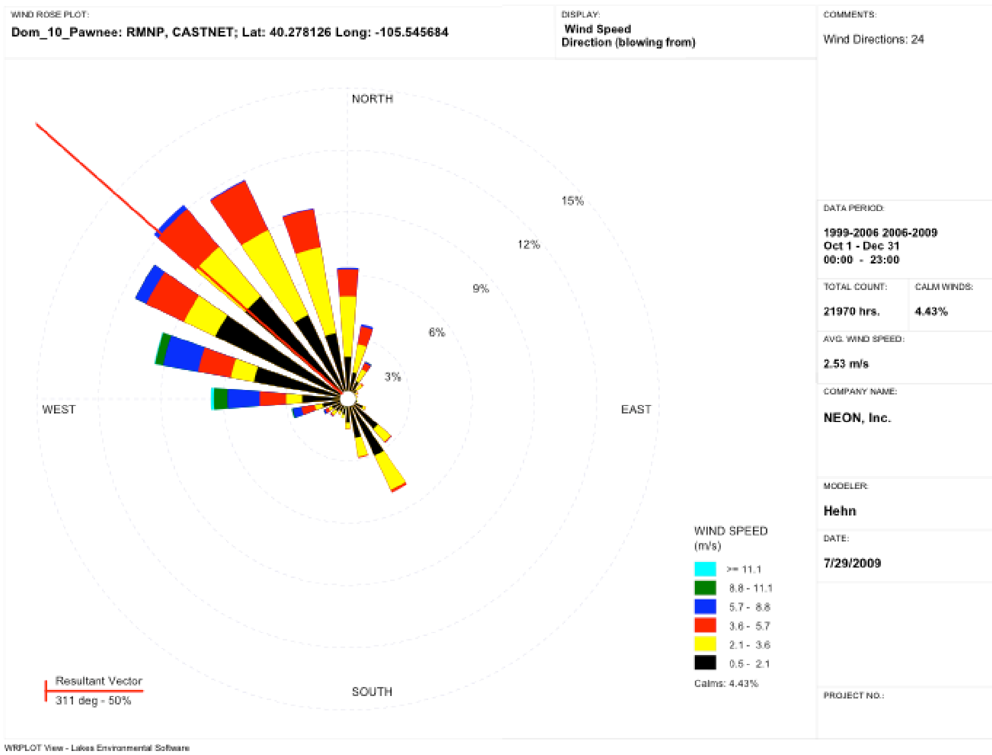


Figure 61. Wind roses of October - December for RMNP CastNet Relocatable site in 1999-2009

5.3.5 Expected environmental controls on source area

Table 15. Expected environmental controls to parameterize the source area model, and associated results from the CASTNET relocatable site.

parameters	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**units**
Atmospheric stability	Near neutral	stable	convective	convective	qualitative
Max. windspeed	8.8	2.8	5.7	*1.7	m s-1
Expected sensible heat flux	10.0	0	120	50	W m-2
Resultant vector	300	300	300	300	degrees
Measurement height	27	27	27	27	m
Roughness length	1.0	1.0	1.0	1.0	m
Zero plane displacement	14.0	16.0	16.0	16.0	m
Air temperature	20.0	14.0	22.0	17.0	°C
Approximate season	Spring/fall	summer	summer	summer	qualitative
Results					
Distance source area begins	0	50	0	0	m
Distance of peak contribution	137	187	7.6	27.4	m
Distance of 20% cumulative flux	100	200	10	10	m
Distance of 40% cumulative flux	220	380	20	60	m
Distance of 60% cumulative flux	410	620	90	70	m
Distance of 80% cumulative flux	1000	1500	>1400	110	m
Distance of 100% cumulative flux	>1600	na.	na.	600	m
Peak contribution	137.7	169.5	8.0	25.9	m
Angle from centerline	22	25	na.	29	degrees

5.3.6 Results (source area graphs)

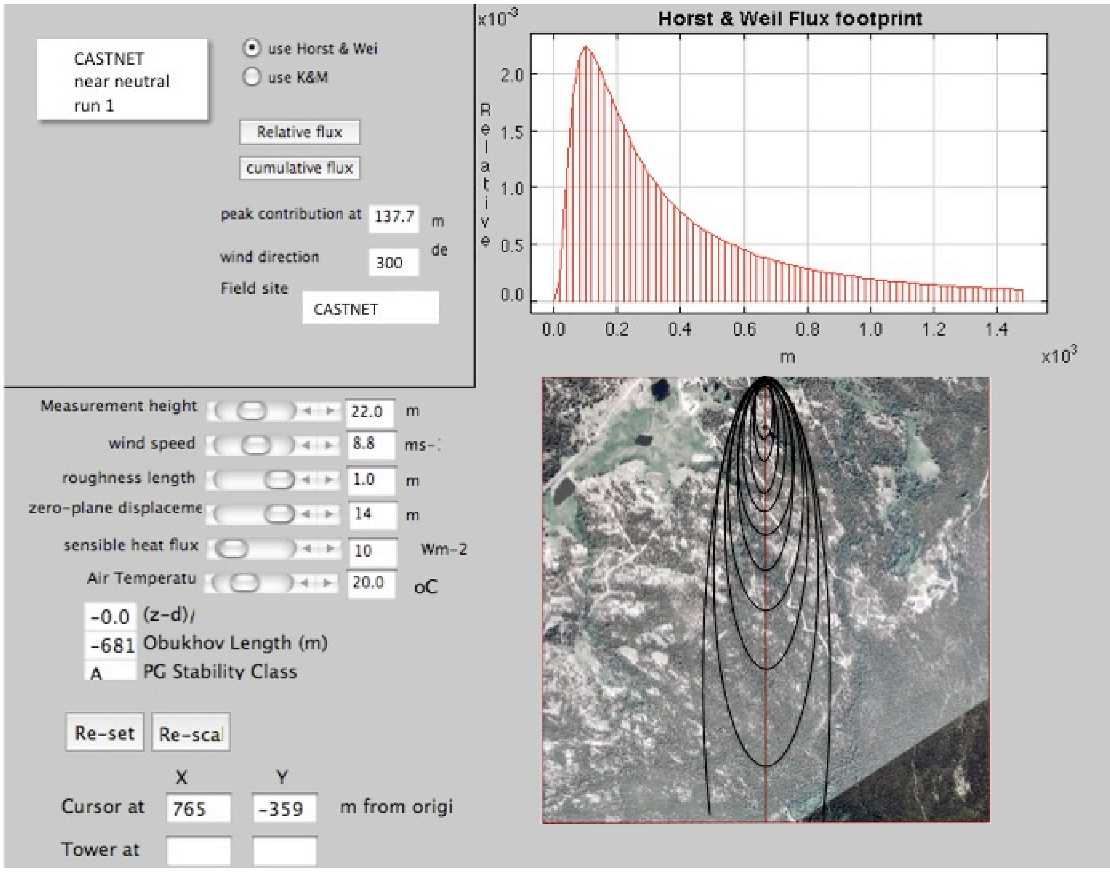


Figure 62. Tower flux footprint output for RMNP CastNet Relocatable site under near neutral conditions using an inverted plume dispersion model by Horst & Well.

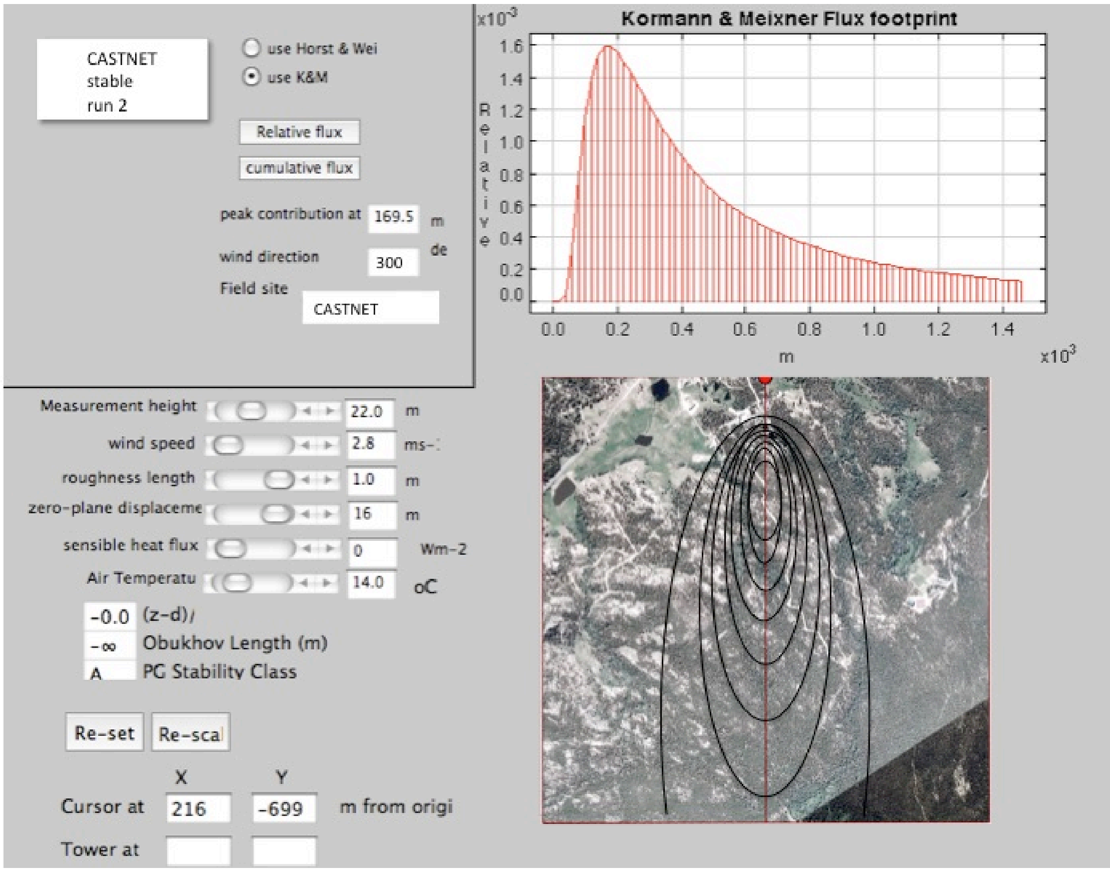


Figure 63. Tower flux footprint output for RMNP CastNet Relocatable site under stable conditions using K&M model.

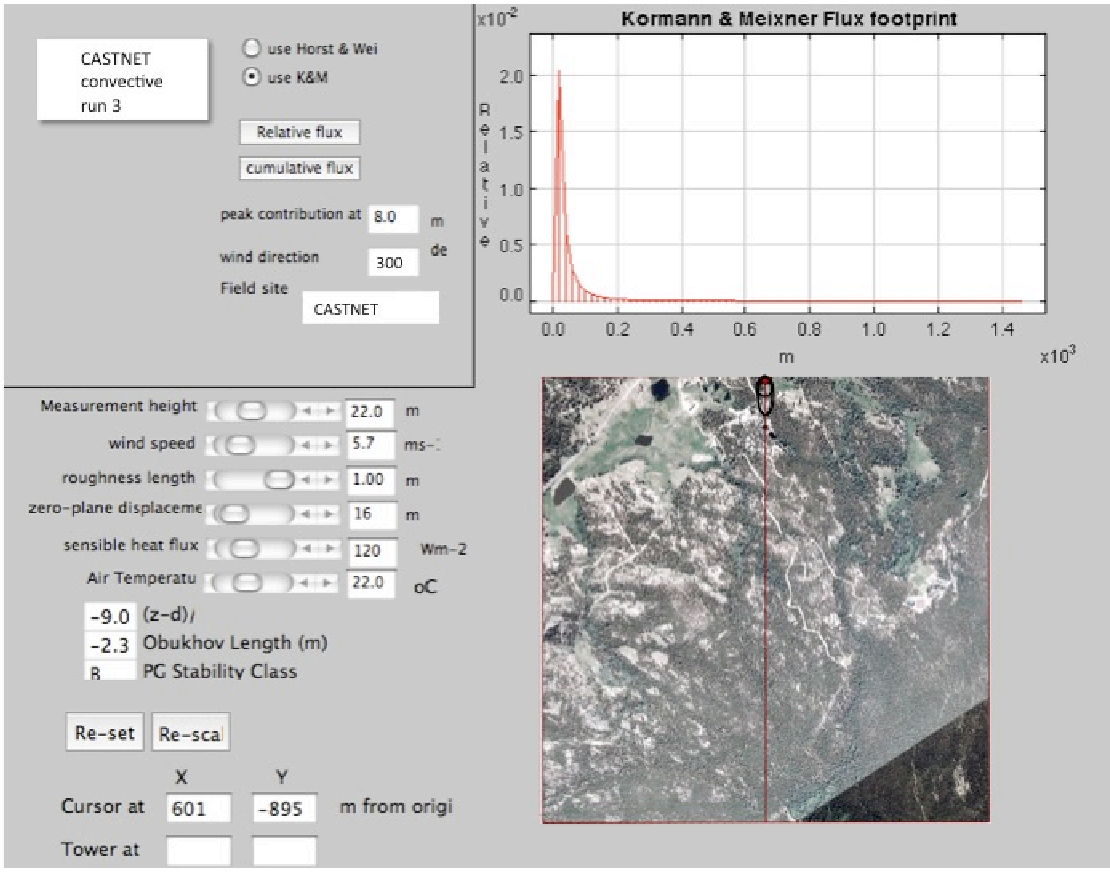


Figure 64. Tower flux footprint output for RMNP CastNet Relocatable site under convective conditions at maximum expected wind speed using K&M model.

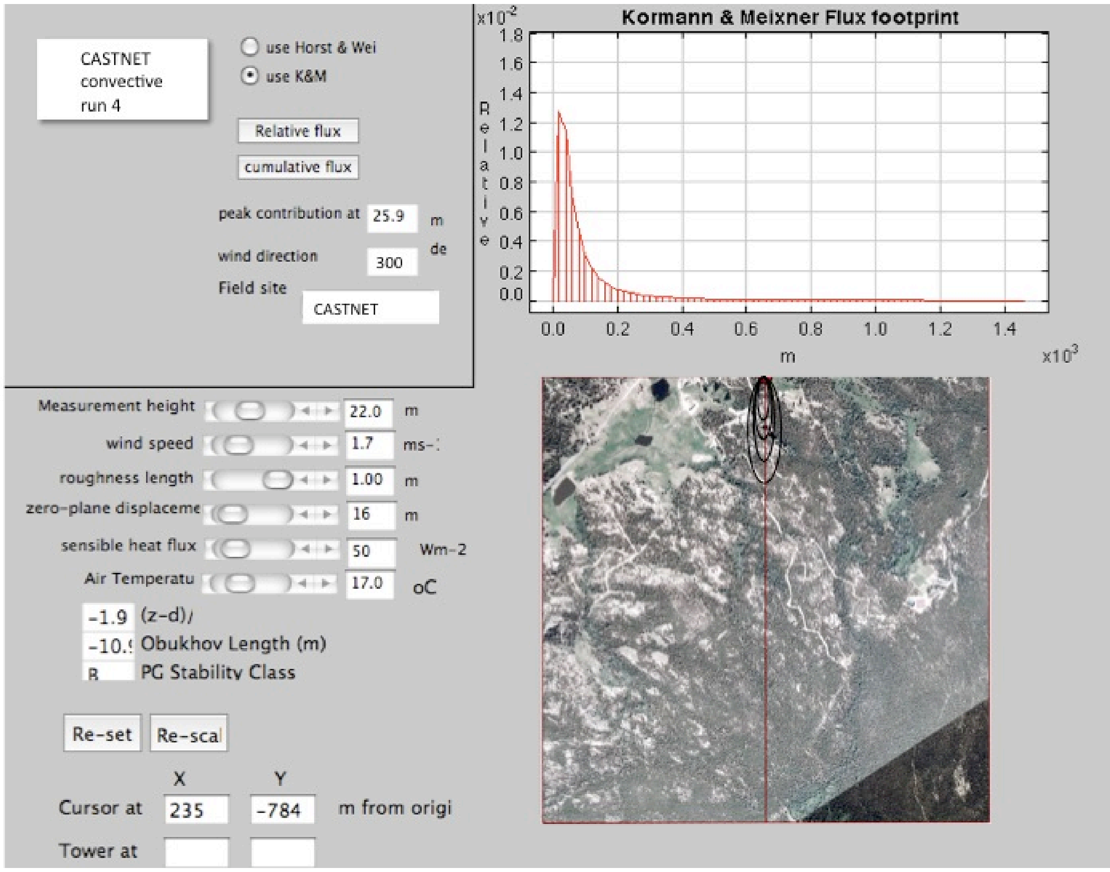


Figure 65. Tower flux footprint output for RMNP CastNet Relocatable site under convective conditions at mean expected wind speed using K&M model.

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 pass through the canopy with minimizing 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., 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.

5.3.6.1 Constraints on the FSU ecosystem plot locations

Winds are dominant from the west quadrant across all seasons (Table 14), and annual resultant wind vector is from 303° (Table 13). However, the resultant vector is influenced by winds throughout the North and west over the continental divide. Daytime winds flow upslope contra to the predominant flows and often observed in mid-elevation sites throughout the front range. Overall, the winds are fairly constrained by direction, this is an advantage of this site.

The ecosystem productivity plots should be placed within i) the overall, annual extent of the footprint, ii) within the bounds of the permitted property, iii) span the dominant and co-dominant soil types, and iv) estimate the productivity from the ecosystem if interest.

However, property boundary does not allow for the size of ecosystem productivity plots. The available property in the dominant wind direction is also limited. This site does not desirable for the installation of ecosystem productivity plots.

5.4 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. 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:

i) 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.
j) There may be more than one exclusion zone per tower, depending on the diurnal, seasonal and annual wind patterns.
k) The exclusion zone is a sub-area (i.e., inside) the total tower source area
l) Windrose analyses determine the wind vectors that bound the outside of the exclusion zone, which is clockwise from 263 to 341 degrees at this site (major).

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

5) 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 600 m at this site.
6) 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 1500 m at this site.

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7 APPENDIX A

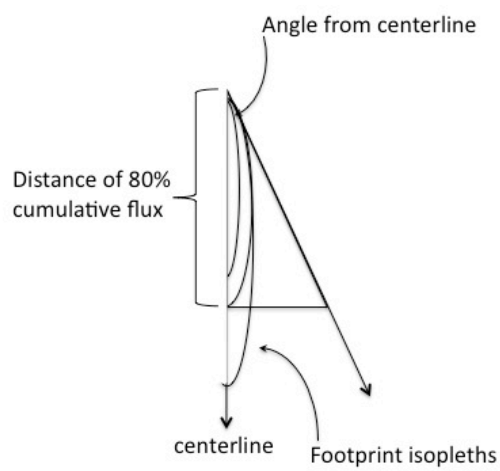

Figure A1. Footprint geometry, where the angle from centerline was calculated from the distance 80% the of cumulative flux is calculated.