D18 FIU Site Characterization
Supporting Data

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1 DESCRIPTION

1.1 Purpose

Data collected, analyzed and described here are used to inform the site design activities for NEON project Teams: EHS (permitting), FCC, ENG and FSU. This report was made based on actual site visits to the 2 NEON sites in Domain 18. This document presents all the supporting data for FIU site characterization at Toolik Lake Advance site and Barrow Environmental Observatory (BEO) Relocatable site. The original candidate relocatable site was at 2nd pump station. It doesn't meet FIU and FSU requirements. Therefore, the relocatable site was moved to BEO based on the collective decision of FIU, FSU, FCC, EHS, and Project.

1.2 Scope

FIU site characterization data and analysis results presented in this document are for two D18 tower locations: Toolik Lake Advance site and Barrow Environmental Observatory (BEO) Relocatable site. Issues and concerns for each site that need further review are also addressed in this document according to our best knowledge.

Disclaimer, accuracy of our latitude and longitude points are subject to the tolerances of our GPS measurement system i.e., ~ ±3 m.

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

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

2.2 Reference Documents

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

2.3 Acronyms

2.4 Verb Convention

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

3 TOOLIK LAKE ADVANCED TOWER SITE

3.1 Site description

NEON candidate tower location at this site is located near Toolik Lake Field Station (Figure 1), University of Fairbanks.

The Institute of Arctic Biology Toolik Field Station (TFS) is a world-renowned Arctic climate change research station located in the northern foothills of the Brooks Range in Alaska at 68° 38' N, 149° 36' W, elevation 720 m. Toolik-based researchers have access to 87,000 acres designated by the Bureau of Land Management as a Research Natural Area. Toolik Field Station has been a major location for scientific research in the Arctic since 1975 (info source http://toolik.alaska.edu/).

Info below is from http://www.scannet.nu/content/blogcategory/52/160/ :

Climate: Mean temperature in January: -24.0 °C; Mean temperature in July: +11.5 °C; Mean annual precipitation: 318 mm.

Biodiversity: The area around Toolik Field Station includes a range of tundra ecosystems typical of the three nearby physiographic provinces: the Brooks Range, the arctic foothills, and the coastal plain. These tundra ecosystems include acidic and non-acidic tussock tundras, heath tundra, riparian shrub tundra, and wet sedge tundra, among others.

Human Dimension: There are no villages near the station; the closest habitations are an industrial pump station for the trans-Alaska oil pipeline and a State of Alaska maintenance station for the Dalton Highway. During winter, subsistence hunting is practiced sporadically near the station by residents of Anaktuvuk Pass, approximately 70 miles to the west. Tourism and sport hunting and fishing occur in summer and fall. Winter seismic exploration for natural gas has occurred nearby in recent years. Year-round scientific research is the dominant human activity in the vicinity of the station.

Species Performance: Data on plant and animal phenology and growth under a variety of experimental treatments have been collected in the vicinity of the station.

General Research: TFS has been the focus of long-term, intensive and process-based ecological research since 1975. Research at TFS has produced some of the longest continuous records of a wide range of environmental variables in the North American Arctic. Intensive research at TFS into the mechanisms underlying plant and animal adaptations to the environment and the controls over ecosystem processing of carbon and nutrients has been critical in developing an understanding of how and why arctic ecosystems will change in an altered environment. The Arctic LTER and several independently funded but closely linked projects investigate the effects of environmental change on arctic ecology and ecosystem structure and the function of arctic tundra, streams, and lakes. Research into vegetation response to environmental change has been extensive. Other research has focused on animal adaptations to life in arctic environments and how these adaptations might affect organisms' response to an altered environment. TFS hosts research on the deposition and cycling of environmental contaminants, including mercury and persistent organic pollutants. TFS is a base for long-term hydrologic research, and more recently has been used as an observation site for research on the thermospheric wind dynamics in the ionosphere. TFS and the arctic LTER maintain a long-term climate monitoring program, and TFS recently initiated year-round monitoring of a variety of other baseline environmental variables, including atmospheric deposition, snow cover, plant phenology, and the phenology of bird and mammal occurrence.

Existing Data Bases: A bibliography of publications arising from research at the station, climate records, and baseline environmental observations are available. Much of the data collected by research associated with the Arctic LTER and Toolik-based Arctic Observatory Network carbon, water, and energy flux project is also available on the web.

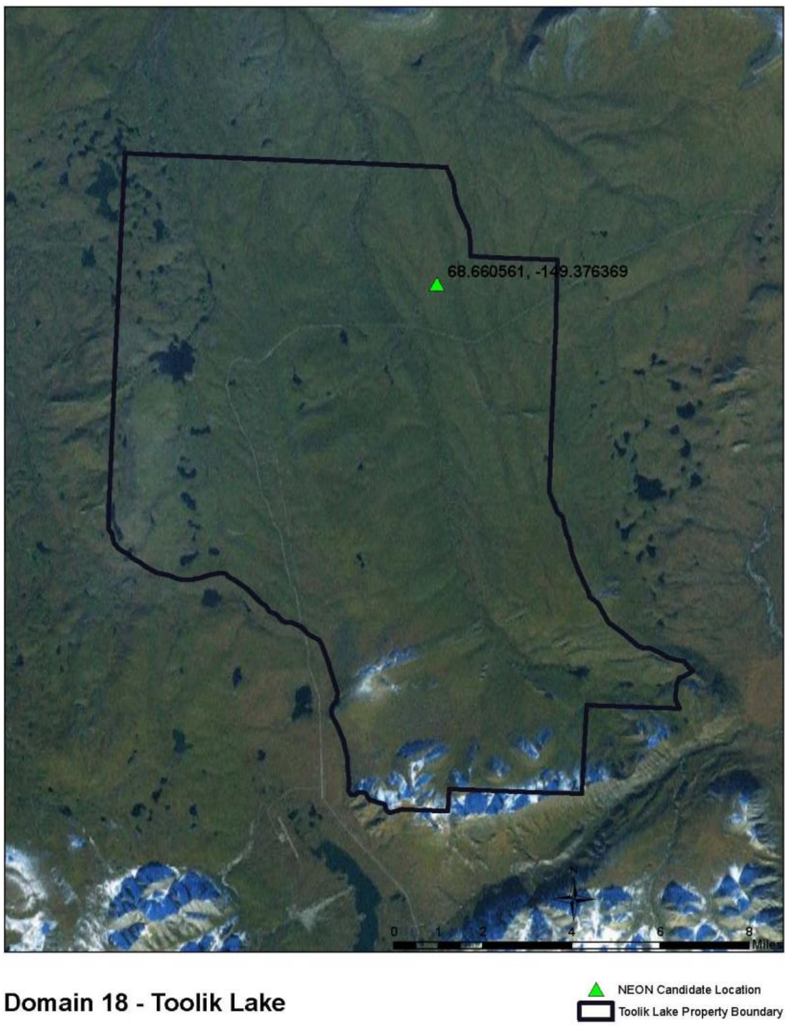


Figure 1. Boundary map for Toolik Lake and candidate tower location.

3.2 Ecosystem

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

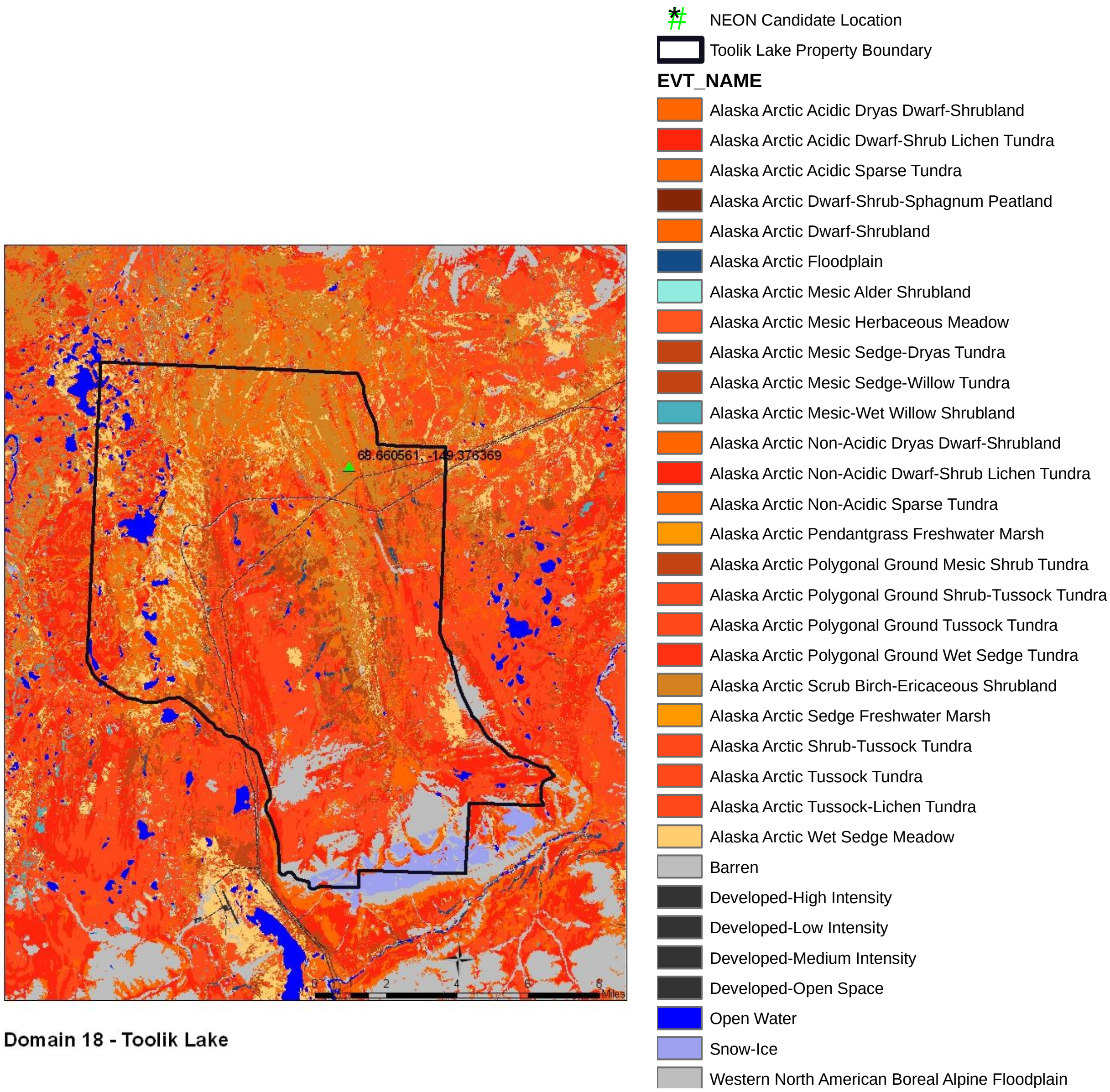


Figure 2. Vegetative cover map of Toolik Lake and surrounding areas (information is from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm).

Table 1. Percent Land cover type at Toolik Lake Advance tower site and surrounding areas (information is from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Vegetation Type	Area(km^2)	Percentage
Open Water	5.70896724	1.82231659
Snow-Ice	5.046080265	1.61072142
Developed-Low Intensity	1.821611873	0.58146306
Barren	21.2942531	6.79717874
Western North American Boreal Alpine Floodplain	0.217997926	0.06958548

Alaska Arctic Mesic Alder Shrubland	0.04238097	0.01352811
Alaska Arctic Mesic-Wet Willow Shrubland	0.993139808	0.31701271
Alaska Arctic Scrub Birch-Ericaceous Shrubland	43.30345577	13.8225712
Alaska Arctic Mesic Sedge-Willow Tundra	23.79904174	7.59671352
Alaska Arctic Mesic Sedge-Dryas Tundra	0.085490555	0.0272888
Alaska Arctic Acidic Sparse Tundra	0.351139252	0.11208453
Alaska Arctic Non-Acidic Sparse Tundra	0.09090753	0.02901791
Alaska Arctic Acidic Dryas Dwarf-Shrubland	2.567349264	0.81950429
Alaska Arctic Dwarf-Shrubland	49.47802262	15.7935083
Alaska Arctic Acidic Dwarf-Shrub Lichen Tundra	40.2376166	12.8439476
Alaska Arctic Shrub-Tussock Tundra	84.43366948	26.951438
Alaska Arctic Tussock Tundra	1.048149344	0.33457189
Alaska Arctic Tussock-Lichen Tundra	1.936642	0.61818096
Alaska Arctic Wet Sedge Meadow	28.86953981	9.21522916
Alaska Arctic Mesic Herbaceous Meadow	0.190439423	0.06078874
Alaska Arctic Dwarf-Shrub-Sphagnum Peatland	0.0036	0.00114913
Alaska Arctic Sedge Freshwater Marsh	0.021852686	0.00697543
Alaska Arctic Polygonal Ground Wet Sedge Tundra	0.063663101	0.02032142
Alaska Arctic Floodplain	1.675748052	0.53490296
Total Area Sq Km	313.2807584	100

The ecosystem inside the tower airshed and around tower is dominated by dry acidic tundra (Figure 3) and mixed with moist acidic tundra. Shrub tundra is observed on the lower hill slope on the west to tower. Plants include tussock tundra grass, salmon berry, dwarf birch, etc. Distance between tussock and inter-tussock is ~30 cm (max), and ~15 cm (mean). Mean canopy height is ~30 cm. During the site visit, plants were in active growing season and blooming on June 19, 2010. Moss layer is very thick (can be >20 cm). Sometimes our CS616 and RTD sensors (~20 cm) could not go through the moss layer to reach mineral soil layer. Future designs should take this fact into account. Organic soil is dark, rich and thick. Mineral soil is rocky.

Figure 3. Dry acidic tussock tundra is the dominant vegetation type at Toolik Lake site

Table 2. Ecosystem and site attributes for Toolik Lake tower site.

Ecosystem attributes	Measure and units
Mean canopy height	0.30 m
Surface roughness[a]	0.04 m
Zero place displacement height[a]	0.24 m
Structural elements	Tussock tundra grassland, homogenous
Time zone	Alaska Standard Time
Magnetic declination	21° 24' E changing by 0° 25' W/year

Note, [a] From field observation.

3.3 Soils

3.3.1 Soil description

No soil data or soil maps are available for this site from NRCS (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm).

3.3.2 Soil semi-variogram description

The goal of this aspect of the site characterization is to determine the minimum distance between the soil plots in the soil array such that data farther apart can be considered spatially independent. The collected field data will be used to produce semivariograms, which is a geostatistical technique to characterize spatial autocorrelation between mapped samples of a quantitative variable (*e.g.*, soil property data in our case). In an empirical semivariogram, the average of the squared differences of a response variable is computed for all pairs of points within specified distance intervals (lag classes). The output is presented graphically as a plot of the average semi-variance versus distance class (Figure 4). For the theoretical variogram models considered here, the semivariance will converge on the total variance at distances for which values are no longer spatially auto-correlated (this is referred to as the range, Figure 4).

For the theoretical variograms considered here, three parameters estimated from the data are used to fit a semivariogram model to the empirical semivariogram. This model is then assumed to quantitatively represent the correlation as a function of distance (Figure 4), the range, the sill (the sill is the asymptotic value of semi-variance at the range), and the nugget (which describes sampling error or variation at distances below those separating the closest pairs of samples). The range, sill and nugget are estimated from theoretical models that are fitted to the empirical variograms using non-linear least squares methods.

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

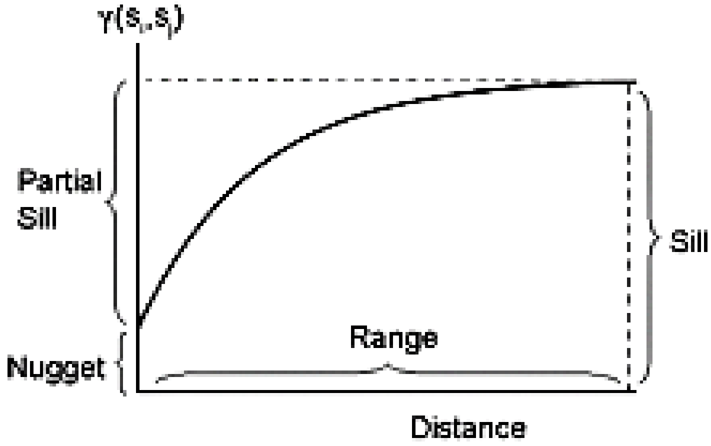


Figure 4. Example semivariogram, depicting range, sill, and nugget.

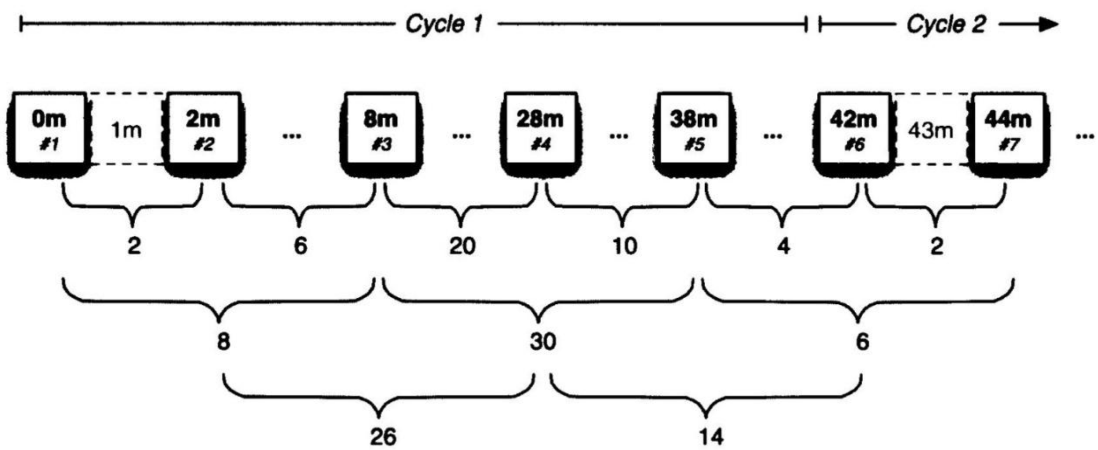


Figure 5. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 19 June 2010 at the Toolik Lake site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 5). Soil temperature and moisture measurements were collected along three transects (210 m, 84 m, and 84 m) located in the expected airshed at Toolik Lake. Details of how the airshed was determined are provided below. Soil temperature was measured with platinum resistance temperature sensors (RTD 810, Omega Engineering Inc., Stamford CT) and soil moisture was measured with time domain diaelectric sensors (CS616, Campbell Scientific Inc., Logan UT).

As well as measuring soil temperature and moisture at each sample point in Figure 5, measurements were also taken 30 cm in front and behind the sampling point along the axis of the transect. For example, at the 2 m sampling point, soil temperature and moisture was measured at 1.7 m, 2 m, and 2.3 m; this data is referred to as mobile data, since the measurements were taken at many different locations. In addition, soil temperature and moisture were continuously recorded at a single fixed location (stationary data) throughout the sampling time to correct for changes in temperature and moisture throughout the day.

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

3.3.3 Results and interpretation

3.3.3.1 Soil Temperature

Soil temperature data residuals, after accounting for changes in temperature in the stationary data and any remaining time of day trend, were used for the semivariogram analysis (Figure 6). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 7, left graph) and directional semivariograms do not show anisotropy (Figure 7, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 7, right graph). The model indicates a distance of effective independence of 3 m for soil temperature.

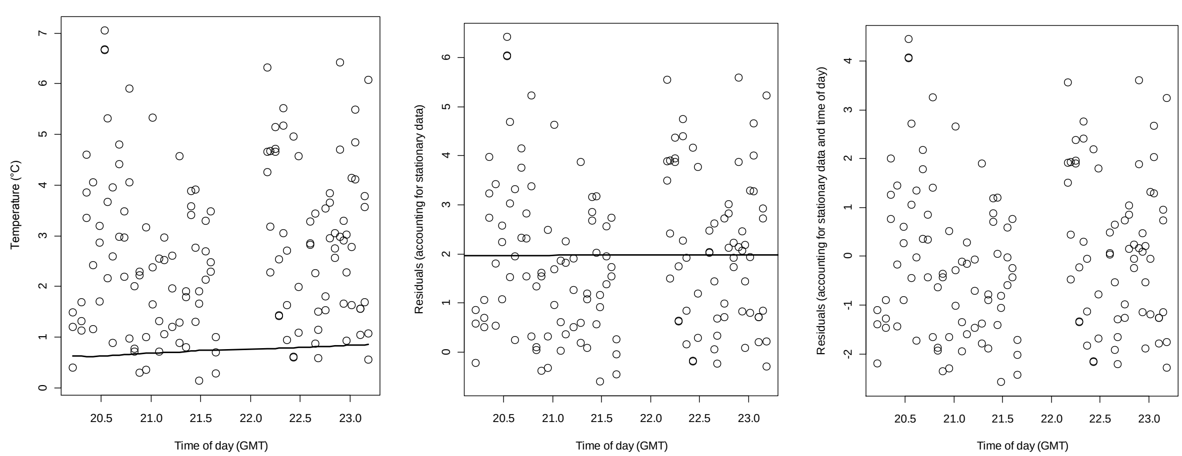


Figure 6. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting for changes temperature in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

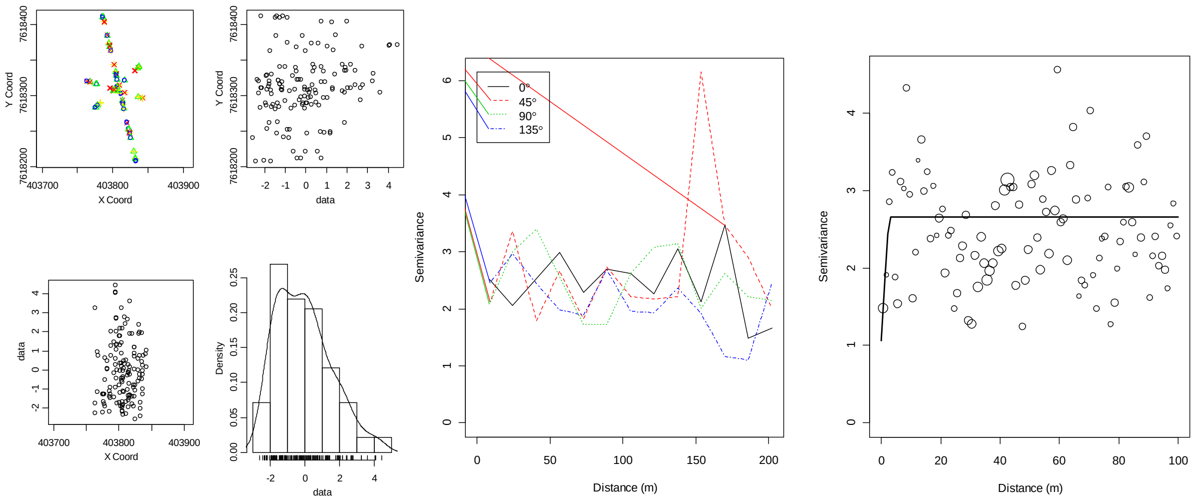


Figure 7. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

3.3.3.2 Soil water content

Soil water content data residuals, after accounting for changes in water content in the stationary data and any remaining time of day trend, were used for the semivariogram analysis (Figure 8). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 9, left graph) and directional semivariograms do not show anisotropy (Figure 9, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 9, right graph). The model indicates a distance of effective independence of 5 m for soil water content.

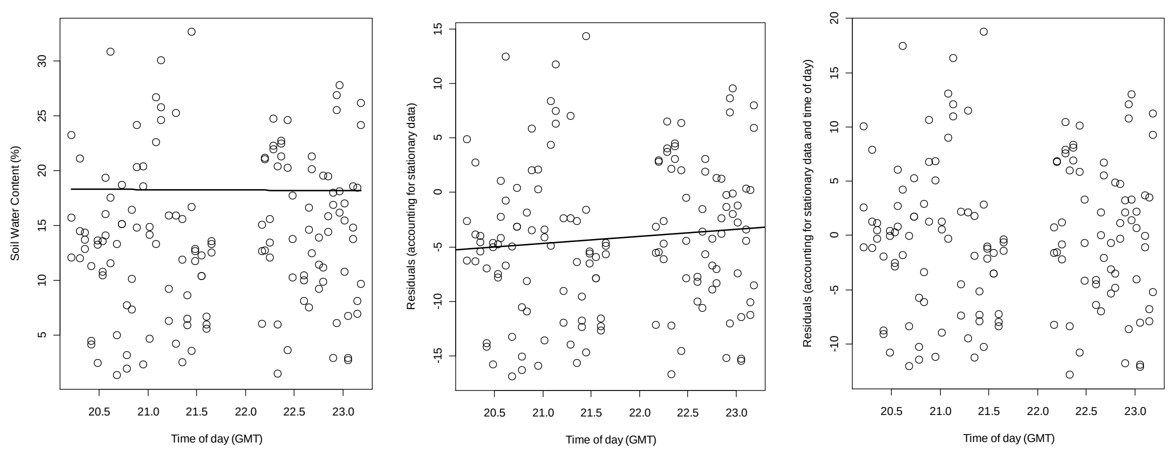


Figure 8. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting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

changes water content in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

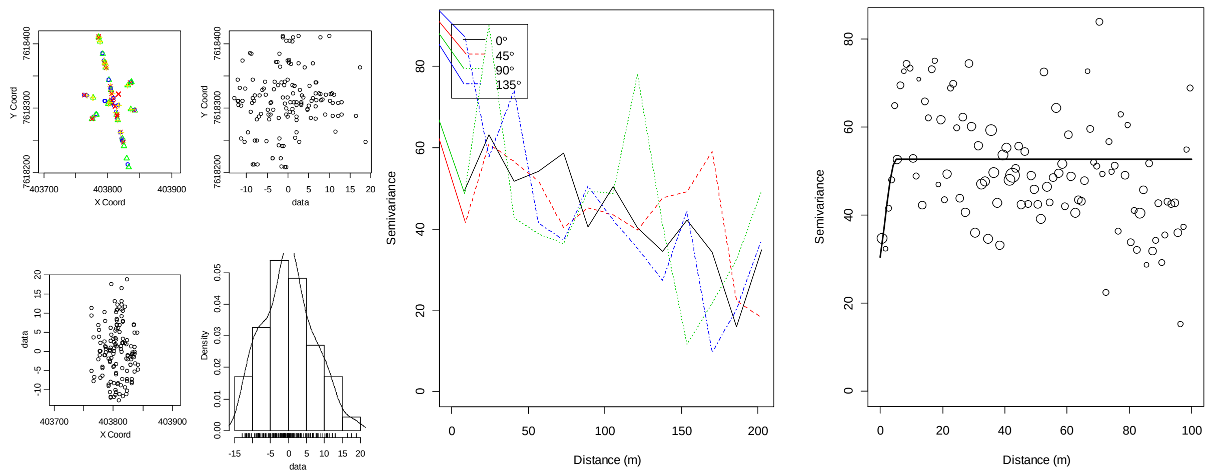


Figure 9. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

3.3.3.3 Soil array layout and soil pit location

The minimum distance allowable between soil plots is 25 m to ensure a degree of spatial independence in non-measured soil parameters (i.e., other than temperature and water content) and the maximum distance allowable between soil plots is 40 m due to cost constraints. The estimated distance of effective independence was 3 m for soil temperature and 5 m for soil moisture. Based on these results and the site design guidelines the soil plots at Toolik Lake shall be placed 25 m apart. The soil array shall follow the linear soil array design (Soil Array Pattern B) with the soil plots being 5 m x 5 m. The direction of the soil array shall be 165° from the soil plot nearest the tower. The location of the first soil plot will be approximately 68.660956, -149.370375. The exact location of each soil plot will be chosen by an FIU team member during site construction to avoid placing a soil plot at an unrepresentative location (e.g., rock outcrop, drainage channel, large tree, etc). The FIU soil pit for characterizing soil horizon depths, collecting soil for site-specific sensor calibration, and collecting soil for the FIU soil archive will be located at 68.655479°, -149.366187° (primary location); or 68.655274°, -149.367284° (alternate location 1 if primary location is unsuitable); or 68.655591°, -149.365120° (alternate location 2 if primary location is unsuitable). Soil pit locations should not show obvious signs of disturbance from pipeline or access road. A summary of the soil information is shown in Table 3 and site layout can be seen in Figure 10.

Dominant soil series at the site: Not available from NRCS. The taxonomy of this soil is shown below:
Order: Not available (likely Gelisols)
Suborder: Not available
Great group: Not available
Subgroup: Not available

Family: Not available
Series: Not available

Table 3. Summary of soil array and soil pit information at Toolik Lake. 0° represents true north and accounts for declination.

Soil plot dimensions	5 m x 5 m
Soil array pattern	B
Distance between soil plots: x	25 m
Distance from tower to closest soil plot: y	16 m
Latitude and longitude of 1st soil plot OR direction from tower	68.660956, -149.370375
Direction of soil array	165°
Latitude and longitude of FIU soil pit 1	68.655479°, -149.366187° (primary location)†
Latitude and longitude of FIU soil pit 2	68.655274°, -149.367284° (alternate 1)†
Latitude and longitude of FIU soil pit 3	68.655591°, -149.365120° (alternate 2)†
Dominant soil type	Not available from NRCS
Expected soil depth	Unknown (likely >2 m)
Depth to water table	Unknown

Expected depth of soil horizons	**Expected measurement depths***
Unknown	0.1 m
	0.35 m
	1.0 m
	3.0 m

*Currently, there are no data on the expected soil depth of soil horizons from NRCS. However, we fully expect to be measuring (at least) 4 different horizons, i.e., the top and bottom of the active layer, at 3 m and other TBD layers. The 3 m depth is below the biologically active layer, but provides a link between the active layer dynamics and the temperature regime of the deep permafrost, V. Romanofsky, pers. Comm.. Actual soil measurement depths will be determined based on measured soil horizon depths at the NEON FIU soil pit and may differ substantially from those shown here. At the NEON Alaska sites soil temperature and moisture sensors will be inserted up to 3 m deep in order to measure long-term permafrost dynamics.
†Soil pit locations should not show obvious signs of disturbance from pipeline or access road.

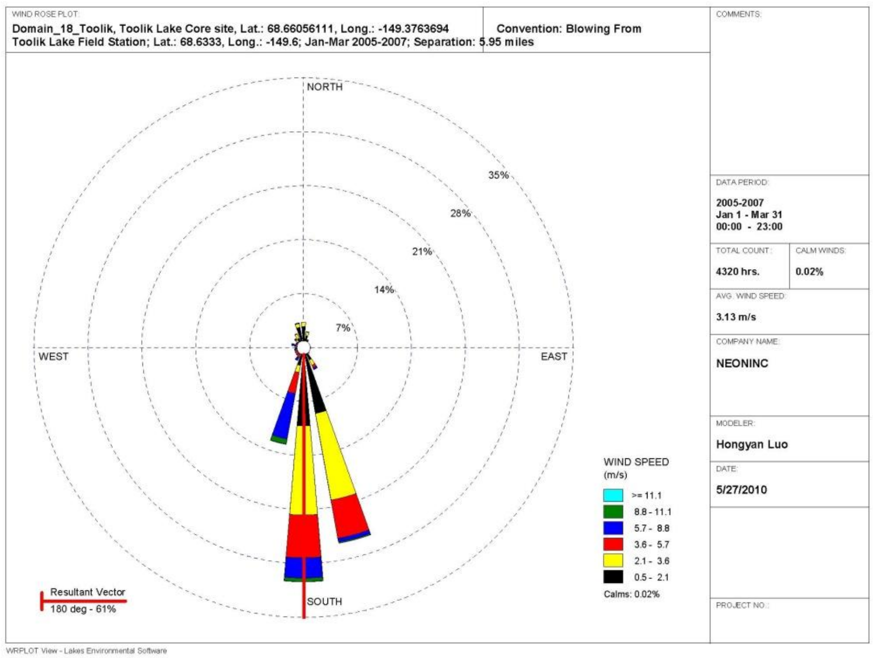
Figure 10. Site layout at Toolik Lake showing soil array and location of the FIU soil pit.

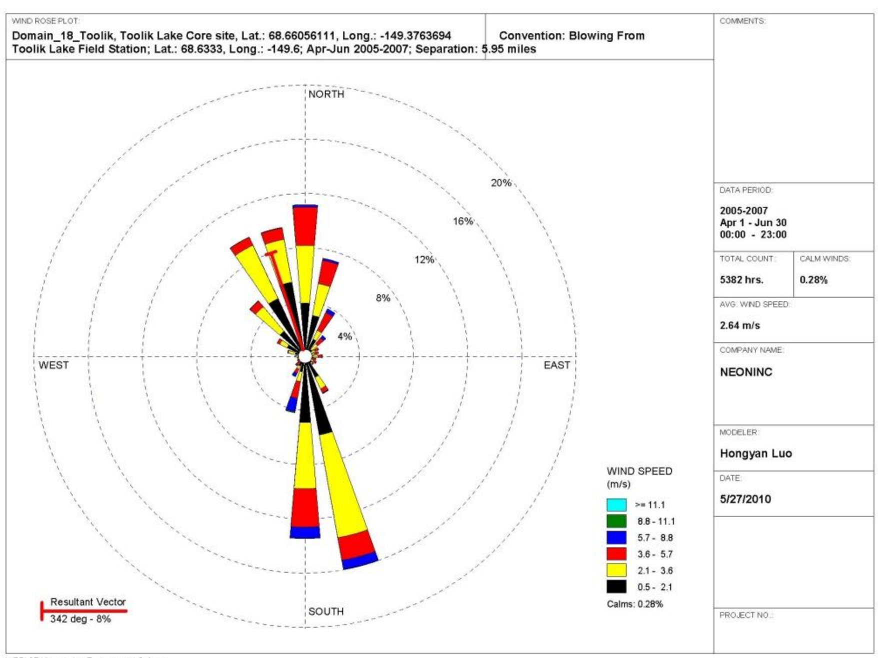
3.4 Airshed

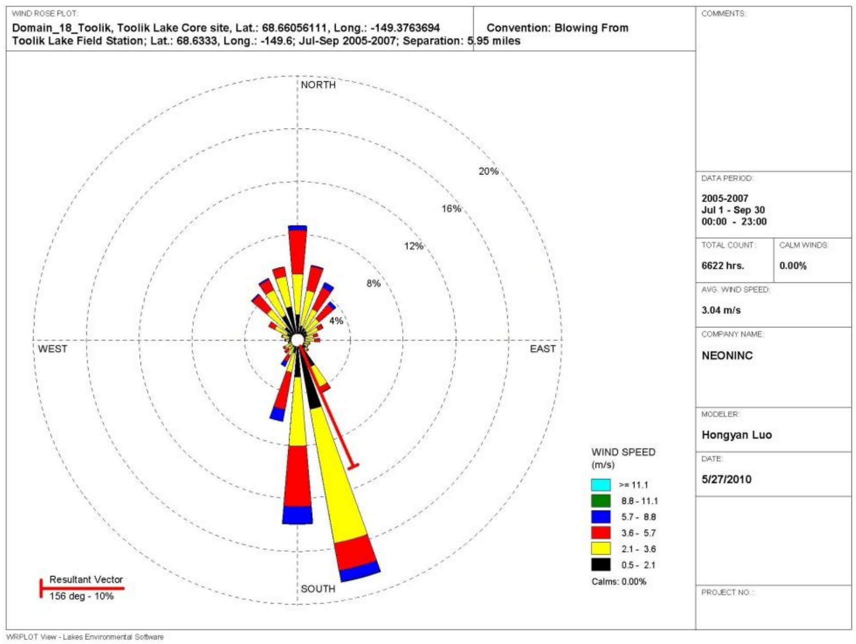
3.4.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries, Figure 11. The weather data used to generate the following wind roses are from Toolik Lake Field Station at 68.6333°, -149.6°, which is ~ 6 miles from NEON tower site. The orientation of the wind rose follows that of a compass (assume declination applied). When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 24 cardinal directions.

3.4.2 Results (graphs for wind roses)







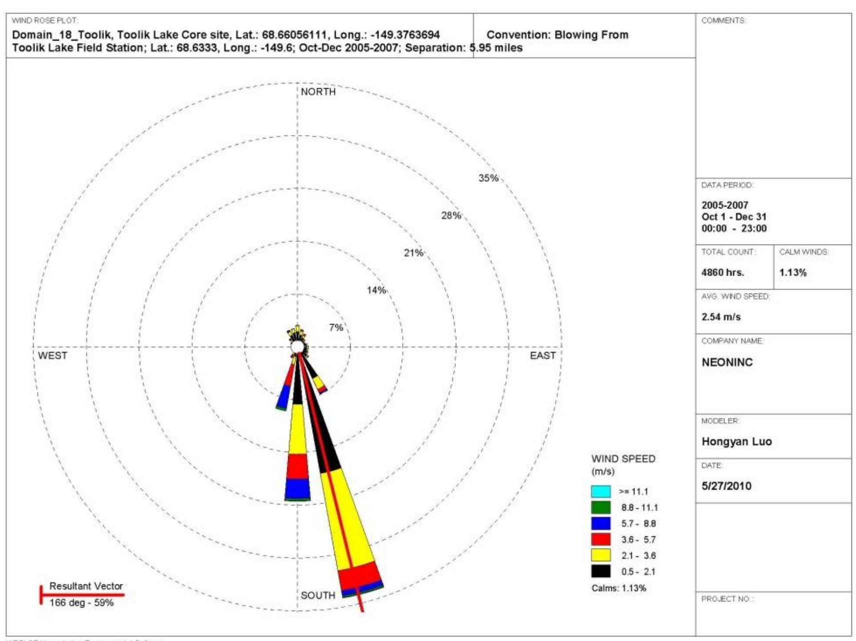


Figure 11. Windroses from the Toolik Lake Advance tower site.

Data used here are hourly data from 2005 to 2007. Data was collected and obtained are from Toolik Lake Field Station at 68.6333°, -149.6°. It is assumed that the wind data was corrected for declination. Panels are (from top to bottom), Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

3.4.3 Resultant vectors

Table 4. The resultant wind vectors from Toolik Lake Core site using hourly data from 2008 to 2009.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	180°	61
April to June	342°	8
July to September	156°	10
October to December	166°	59
Annual	166°	na.

3.4.4 Expected environmental controls on source area

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

As a general rule, shorter and less structurally complex ecosystems have good vertical mixing during all atmospheric stabilities. Taller and more structurally complex ecosystems have well mixed upper canopies during the daytime, and can be decoupled below the canopy under neutral and stable conditions (e.g., Harvard Forest, Bartlett Experimental Forest, and Burlington Conservation Area, though not applicable here in the tundra). The type of turbulence (mechanical verse convective) and the physical attributes of the ecosystem control the degree of mixing, and the length and size of the source area.

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

Table 5. Expected environmental controls to parameterize the source area model, and associated results from Toolik Lake advanced site.

Parameters	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	
Approximate season	summer			winter			Units
	Day (max WS)	Day (mean WS)	Night	Day (max WS)	Day (mean WS)	night	qualitative
Atmospheric stability	Convective	convective	Stable	Convective	convective	Stable	qualitative
Measurement height	6	6	6	6	6	6	m
Canopy Height	0.45	0.45	0.45	0.45	0.45	0.45	m
Canopy area density	1.3	1.3	1.3	1.1	1.1	1.1	m
Boundary layer depth	800	800	800	400	400	400	m
Expected sensible heat flux	150	150	80	-75	-75	-75	$W\ m^{-2}$
Air Temperature	4	4	2	-20	-20	-20	°C
Max. windspeed	8.6	5.0	1.6	11	5.0	2.0	$m\ s^{-1}$
Resultant wind vector	170	170	360	181	181	181	degrees
Results							
(z-d)/L	-0.03	-0.14	-1.2	0.01	0.12	3.00	m
d	0.34	0.34	0.34	0.33	0.33	0.33	m
Sigma v	1.60	1.2	0.81	1.80	1.80	1.60	$m^2\ s^{-2}$
Z0	0.03	0.03	0.03	0.04	0.04	0.04	m
u*	0.69	0.42	0.17	0.87	0.36	0.04	$m\ s^{-1}$
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	750	500	200	900	1200	3250	m
Distance of 80% cumulative flux	400	300	150	500	700	2800	m
Distance of 70% cumulative flux	300	250	100	300	550	2300	m
Peak contribution	65	55	25	65	65	905	m

3.4.5 Results (source area graphs)

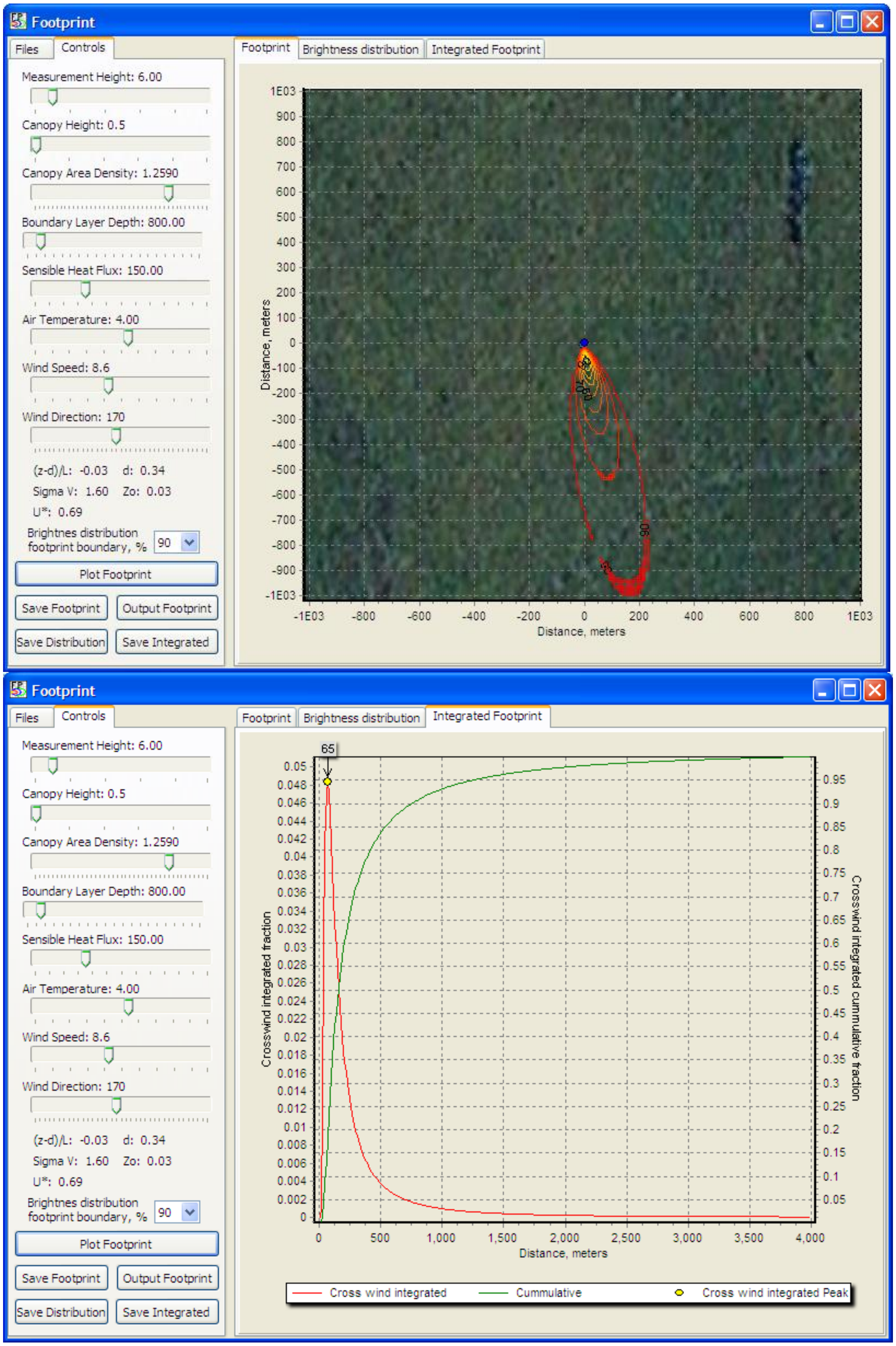


Figure 12. Toolik Lake Forest summer daytime (convective) footprint output with max wind speed.

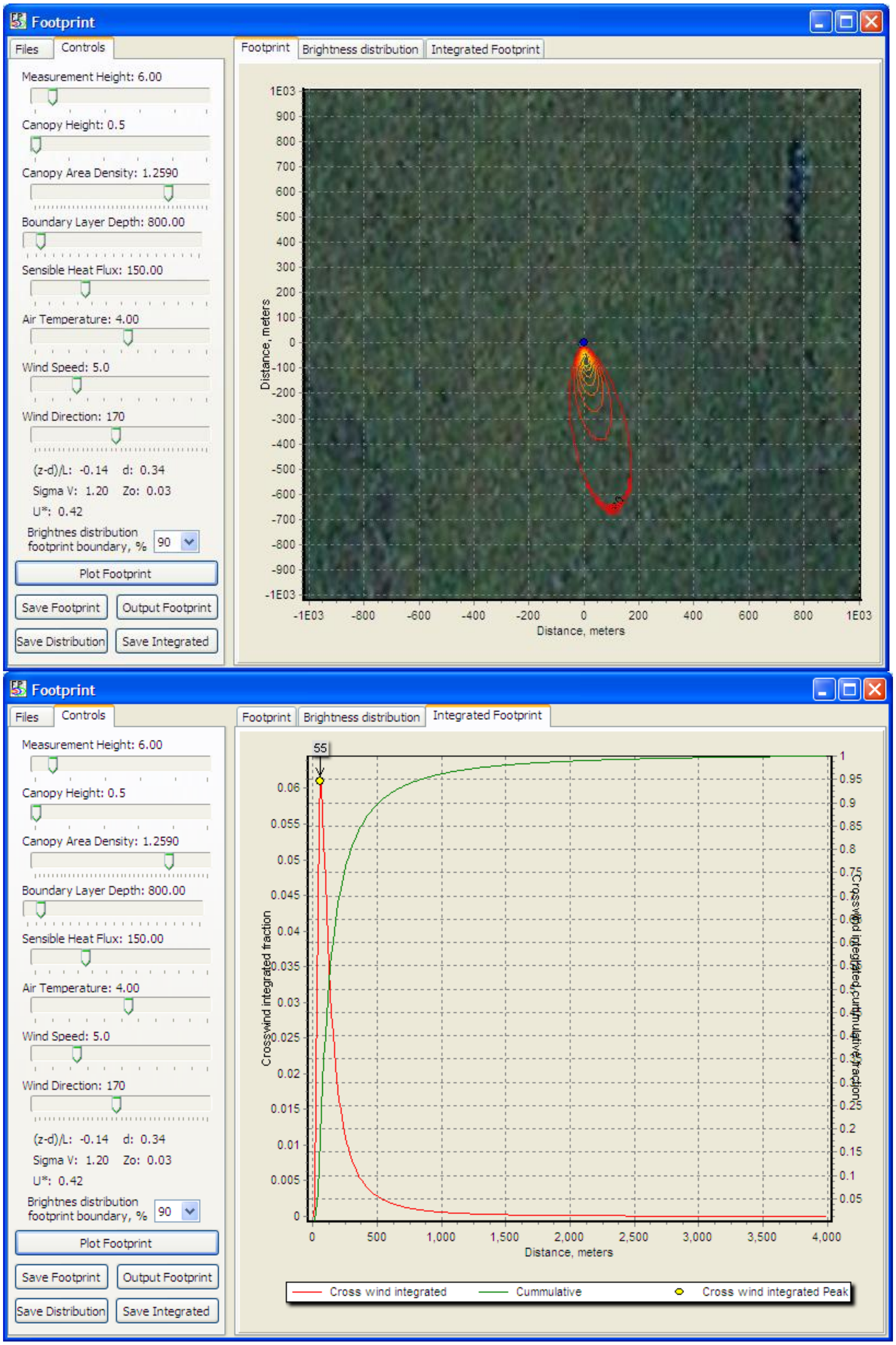


Figure 13. Toolik Lake summer daytime (convective) footprint output with mean wind speed.

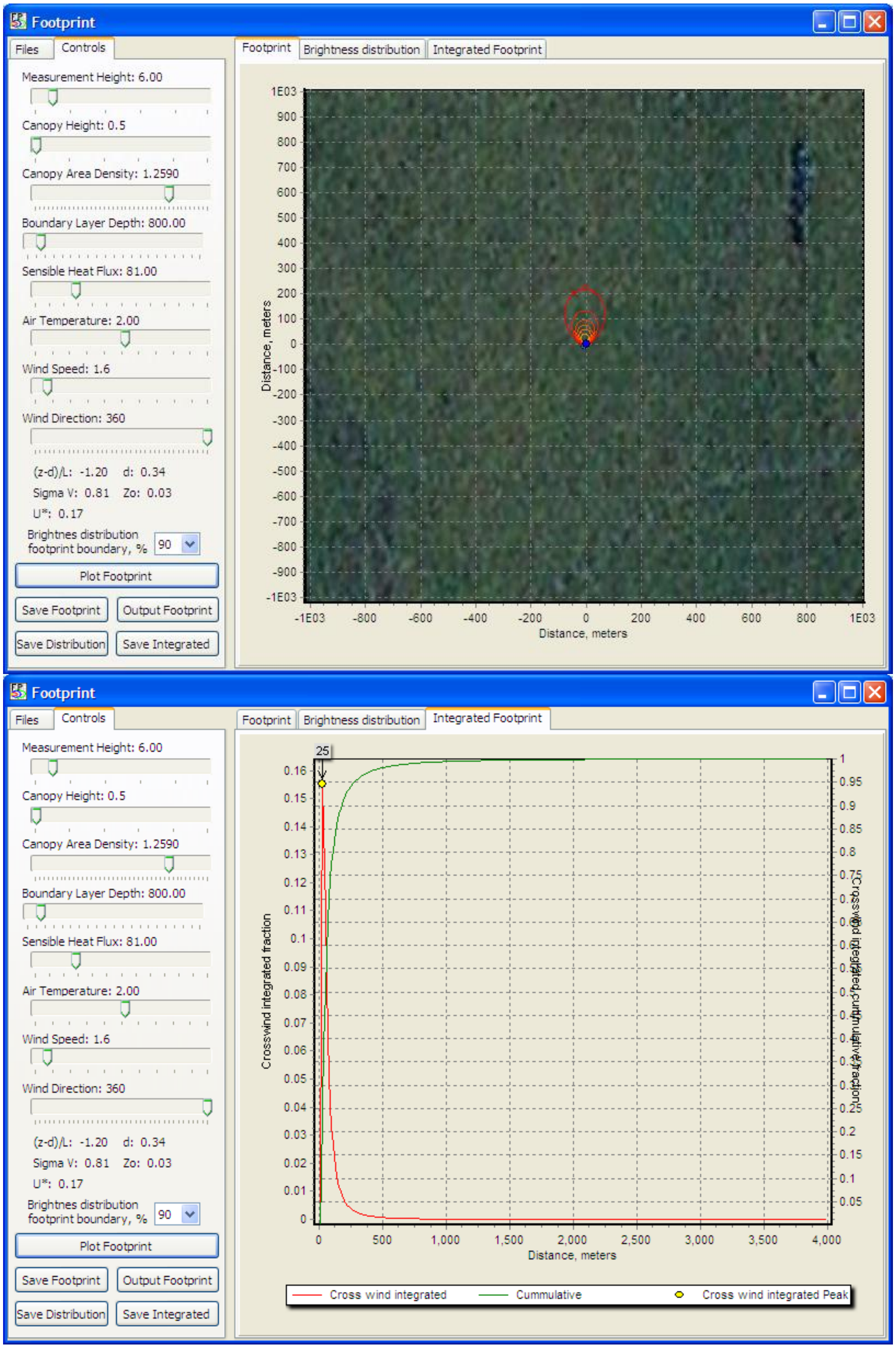


Figure 14. Toolik Lake summer nighttime (stable) footprint output with mean wind speed.

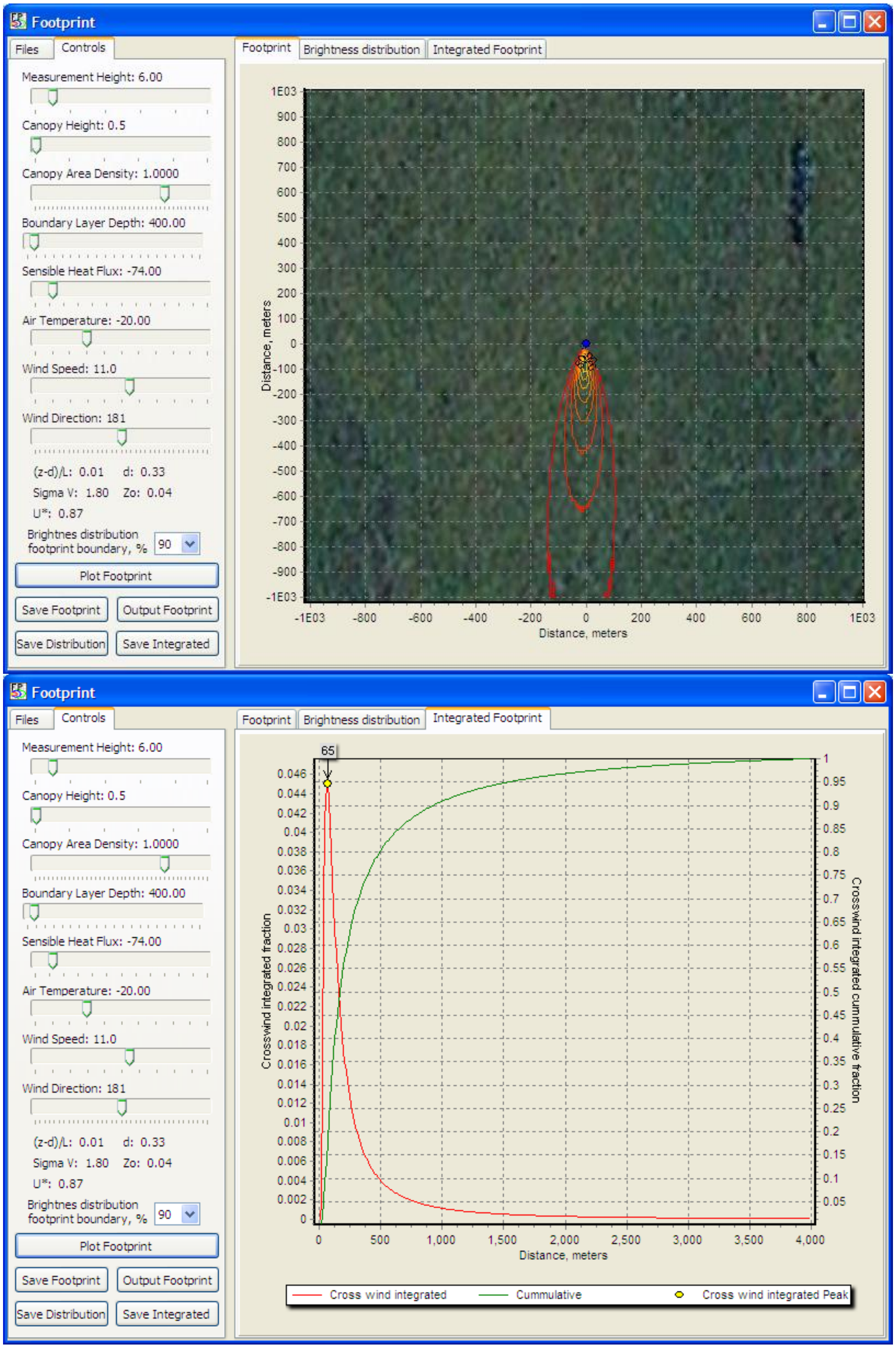


Figure 15. Toolik Lake winter daytime (convective) footprint output with max wind speed.

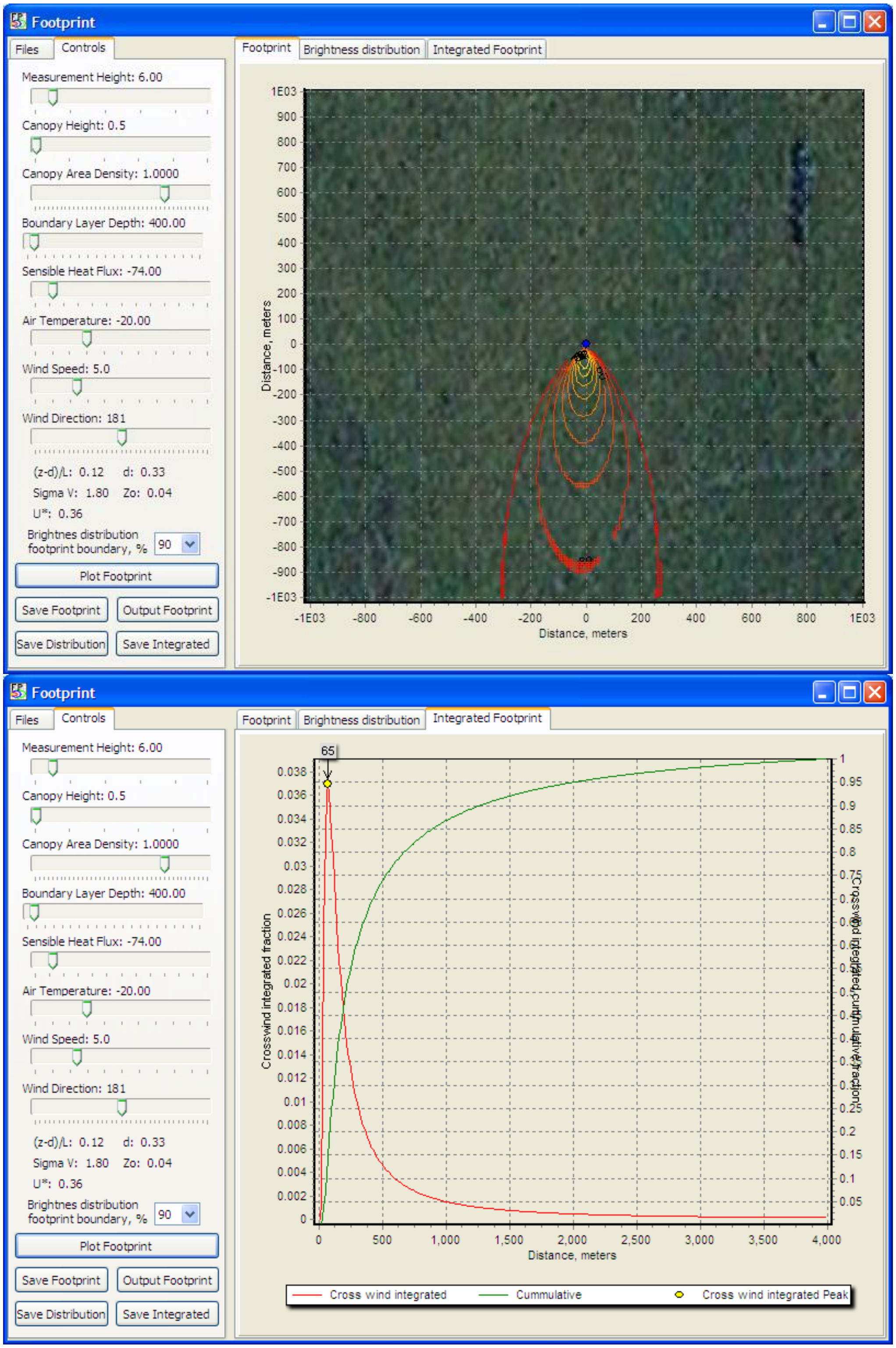


Figure 16. Toolik Lake winter daytime (convective) footprint output with mean wind speed.

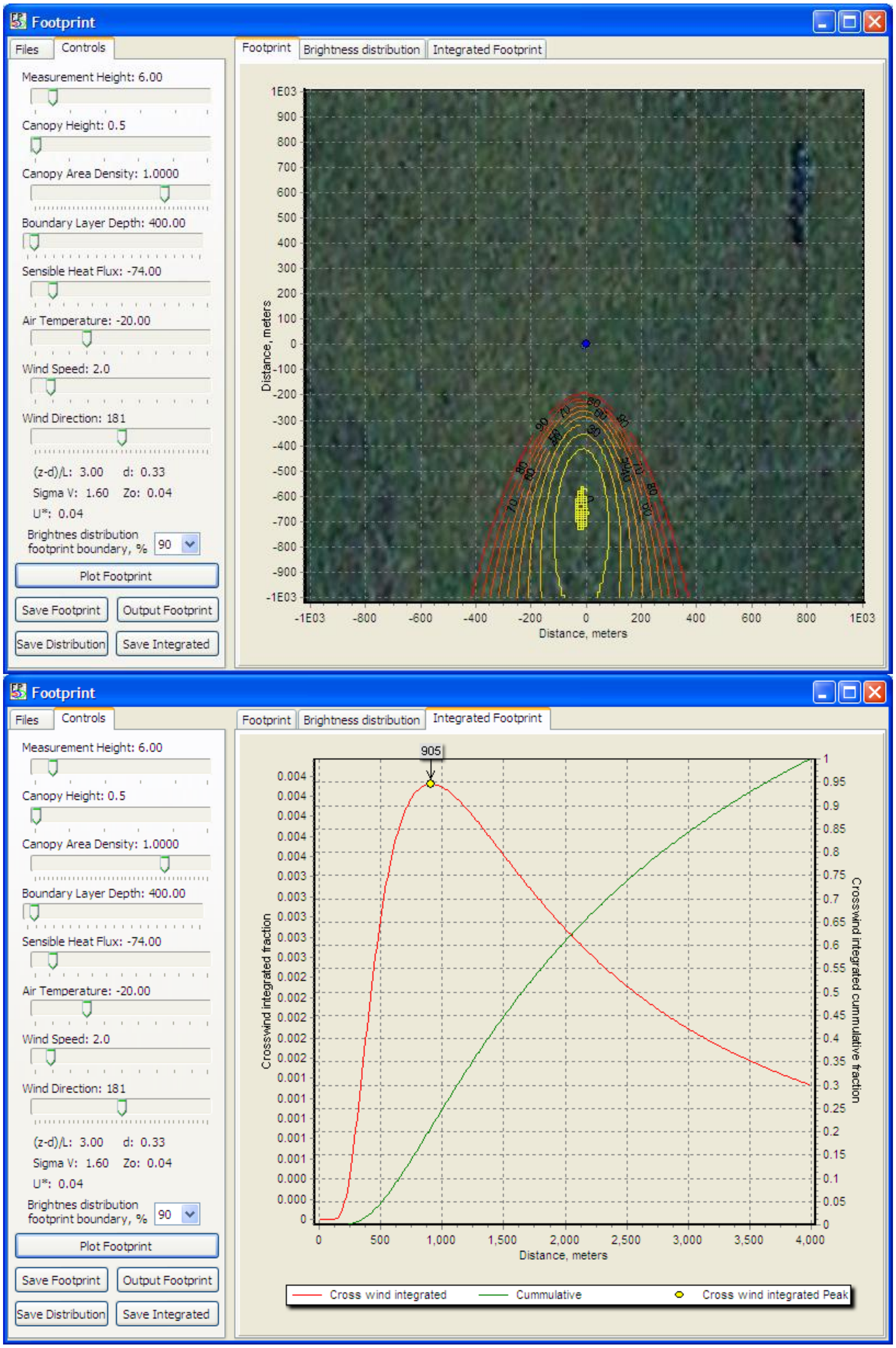


Figure 17. Toolik Lake winter nighttime (stable) footprint output with mean wind speed.

3.4.6 Site design and tower attributes

According to wind roses, the prevailing wind direction comes from 150º to 195º (major airshed, clockwise from 150º) and from 315º to 45º (secondary airshed, clockwise from 315º) throughout the year. But because the met station at Toolik Lake Field Station is at a lower elevation than the NEON tower location (which is at a ridge line) and at different topography, we expect the prevailing wind direction at NEON site will be slightly different. According to our experience and knowledge, we expect the prevailing wind direction will be along the mountain range, which runs 345° - 165°. Therefore, we expect the major airshed will be 135° to 195° (major airshed, clockwise from 135º), and the secondary airshed will be 300° to 30° (secondary airshed, clockwise from 300º). Tower should be placed to a location to best catch the signals from the airshed of the ecosystem in interest, which is tussock tundra here. Original candidate tower location is at 68.66056111°, -149.3763694°, which is at a slightly lower elevation than ridge and on a west-facing slope. It may be affected by some cold air drainage. During FIU site characterization at field, we microsited tower location for ~ 250 m toward ridge at 68.66109, -149.37047 to solve this problem. It is relatively flat and homogenous at the tower site and airshed areas.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the east will be best to capture signals from all major wind directions. **Radiation boom arms** should always be facing south similar to the setup at other NEON sites, even though it cannot totally avoid shadowing effects from the tower structure during summer season due to the sun circling the sky 24 hours a day for months. An **instrument hut** should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind and should be positioned to have the longer side parallel to frequent wind direction to minimize the wind effects on instrument huts and to minimize the disturbances of wind regime by instrument hut, and in this case, instrument hut should be positioned on the southeast side of tower and have the longer side parallel to SE-NW direction. Because this is tundra grassland, short statue ecosystem, the distance between the tower and the instrument hut is ~ 18 m. Therefore, we require the placement of instrument hut at 68.66103, -149.37088.

The ecosystem inside the tower airshed and around tower is dominant by dry acidic tundra and mixed with moist acidic tundra. Mean canopy height is ~30 cm. Moss layer on the floor is very thick (can be >20 cm). We require 4 **measurement layers** on the tower with top measurement height at 6 m, and rest layers are 3.5 m, 1.0 m, and 0.25 m, respectively, to best characterize the fluxes on the tower top and environmental conditions in profile.

DFIR (Double Fenced International Reference) will be used for bulk precipitation collection. Coordinates are 68.66098°, -149.37194°, which is ~60 m on WSW to tower and outside the major and secondary airshed. **Wet deposition collector** will collocate at the top of the tower. See AD 04 for further information and requirements for bulk precipitation collection and wet deposition collection.

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

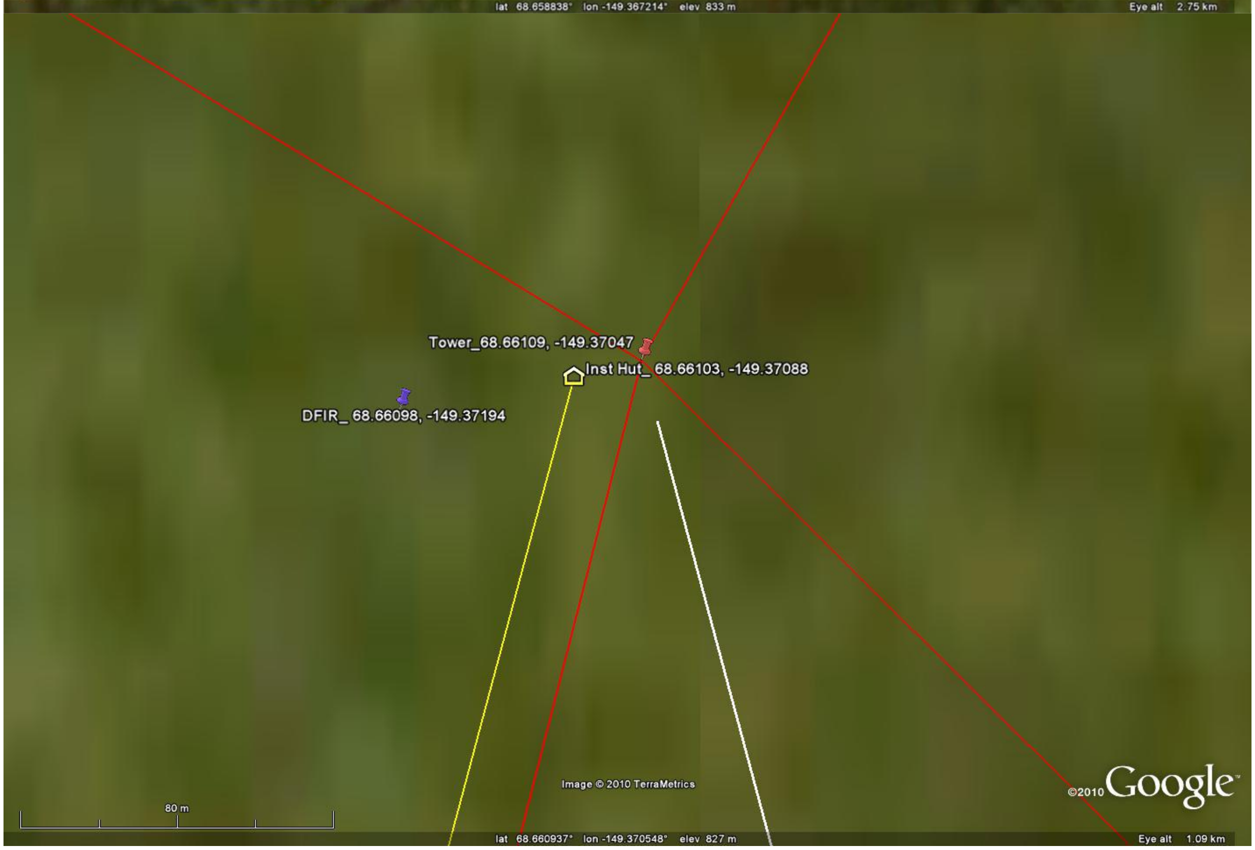
Table 6. Site design and tower attributes for Toolik Lake Advanced site.

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

Attribute	lat	long	degree	meters	notes
Airshed area			135° to 195° (major airshed 300° to 30° (secondary)		Clockwise from first angle
Tower location	68.66109°,	-149.37047°	--	--	new site
Instrument hut	68.66103°,	-149.37088°			
Instrument hut orientation vector	--	--	165° - 345°		
Instrument hut distance z	--	--	--	19	
Anemometer/Temperature boom orientation	--	--	90°	--	
DFIR	68.66098°,	-149.37194°			
Height of the measurement levels					
Level 1				0.25	m.a.g.l.
Level 2				1.0	m.a.g.l.
Level 3				3.5	m.a.g.l.
Level 4				6.0	m.a.g.l.
Tower Height				6.0	m.a.g.l.

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

Airshed 30°
Airshed 300°
Tower_68.66109, -149.37047
Inst Hut_ 68.66103, -149.37088
DFIR_ 68.66098, -149.37194
Soil array
Access road
Airshed 135°
Airshed 195°
Soil Pit 1: 68.655479°, -149.366187°
Soil Pit 3: 68.655591°, -149.365120°
Soil Pit 2: 68.655274°, -149.367284°
Image © 2010 TerraMetrics
© 2010 Google
582 m
©2010 Google
lat 68.658838° lon -149.367214° elev 833 m
Eye alt 2.75 km



Tower_68.66109, -149.37047
Inst Hut_ 68.66103, -149.37088
DFIR_ 68.66098, -149.37194
Image © 2010 TerraMetrics
80 m
©2010 Google
lat 68.660937° lon -149.370548° elev 827 m
Eye alt 1.09 km

Figure 18. Site layout for Toolik Lake Advance tower site.
Top panel shows general site layout for this site. Lower panel shows the detailed locations of tower, instrument hut and DFIR.
i) Tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors from 135° to 195° (major airshed, clockwise from 135°) and from 300° to 30° (secondary airshed, clockwise from 300°) are the airshed areas that would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access road to instrument hut. iv) Purple pin is the DFIR location.

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

- Boardwalk from access dirt road to instrument hut. This boardwalk should be wide enough to accommodate a snow machine or ATV (for winter safety)
- Boardwalk to soil array
- Boardwalk from soil array boardwalk to individual soil plots
- Boardwalk from the instrument hut to the tower to intersect on north face of the tower
- Boardwalk from instrument hut to DFIR site

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

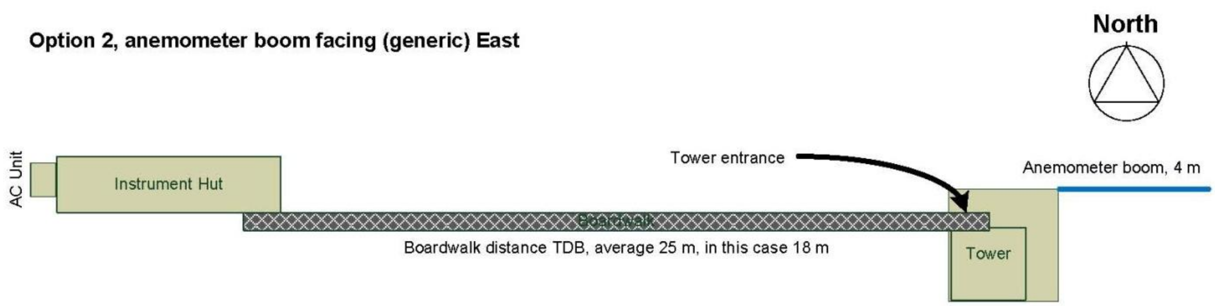


Figure 19. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing east and instrument hut on the west towards the tower.

This is a generic diagram. The actual layout of boardwalk (or path if no boardwalk required) and instrument hut position will be the joint responsibility of FCC and FIU. At this site, the boom angle will be 90°, instrument hut will be on the west towards the tower, the distance between instrument hut and tower is ~18 m. The instrument hut vector will be SSE-NNW (165° - 345°, longwise).

3.4.7 Information for ecosystem productivity plots

The tower at this site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (tussock tundra). Tower airshed areas are from 135º to 195º (major airshed, clockwise from 135º) and from 300º to 30º (secondary airshed, clockwise from 300º), and 90% signals for flux measurements are in a distance < 750 m from tower during summer and 1200 m during the winter, and 80% within 400 m during the summer and 700 m during the winter. We suggest FSU Ecosystem Productivity plots be placed within the boundaries of 135º to 195º (major airshed, clockwise from 135º) and 300º to 30º (secondary airshed, clockwise from 300º) from tower.

3.5 Issues and attentions

Oil pipeline is ~ 10 m tall on the south to tower location, ~ 500 m away. The distnce is >> 5 X of the pipeline height. Wake effect from pipeline to flux measurements is not a big concern. Given the tower location at 68.66109°,-149.37047°, we have ~ 500 m good fetch area before pipeline, which is adequate for most of the time during the year. We do not know if there will be any leak/emission of CO_2 from pipeline. But given this long distance away, it should not be a big concern for our CO_2 measurements.
Tower site locates on old geological form, which spreads large area and is representative for tussock tundra at Alaska.
Closest power source is at Toolik Lake Field Station, which is ~ 6 miles from NEON tower location. Generator may have to be deployed as power source.
It is very easy to get lost on tundra, especially when there is snow cover on the ground and 24 hours a day in dark for months during winter season and in foggy summer days. We suggest a flashing light on tower and/or instrument hut that can be turned on remotely prior to technician's field trip for tower maintenance to provide direction guidance. For the same reason, we suggest field technican should be supplied with a flashing light as safety gear, so that it can be set on the roadside to guide him/her back to his/her car after the maintenace work is done.
Tundra is a very delicate ecosystem. Boardwalk is required over tundra for all traffic between NEON facilities.
Construction is suggested in winter while ground is frozen, which will make it easier to transport materials, and has less damage on tundra heavy machines are used at field.
Grizzly bear was observed near this site. Field safety training about cold, bear, and self protection should be given to field crews prior to their field trip.
Specialized thick wires are needed for instruments to prevent from snapping and breaking in the in the cold winter.

4 BARROW ENVIRONMENTAL OBSERVATORY (BEO), RELOCATEABLE TOWER 1

4.1 Site description

NEON candidate Relocatable site in D18 was at 2nd Pump Station to study polygonal tundra ecosystem. But the this site doesn't meet FIU and FSU science requirements, therefore, this relocatable site is relocated to Barrow Environmental Observatory (BEO) at 71.28241, -156.61936, which has the same ecosystem type of polygonal tundra. No property boundary map is available at this moment. Biocomplexity project is ~ 700 m on the east to NEON tower location. An existing BEO tower locates at 71.28098, -156.61241, which is about 300 m on the SE to NEON tower location.

The info below about BEO is from http://www.scannet.nu/content/view/136/166/ .

Location: The Barrow Environmental Observatory (BEO), a 7,466-acre (3021 hectare) research reserve, is located at the northern most location on the Alaskan Arctic Coastal Plain near the City of Barrow. The BEO is bounded by native owned lands, U.S. Federal lands dedicated to research (e.g., NOAA, USGS) and Elson Lagoon, which is joined to the Beaufort Sea. Latitude: 71.2963 N, Longitude: -156. 5891 W. Elevation: 0 to approximately 8 meters above sea level. It is given to the Barrow Arctic Science Consortium to manage research activities for the North Slope Borough (Tribal governance).

Climate (1973-2008): Mean temperature in January: -26 ºC. Mean temperature in July: +4.4 ºC. Mean annual precipitation: 171 mm

Human Dimension: Barrow is the economic, transportation and administrative center for the government of the 230,509 square kilometer North Slope Borough. Located on the Chukchi Sea coast, Barrow is the northernmost community in the US. Traditionally, the community is known as Ukpeaġvik, "place where snowy owls are hunted." Barrow is the largest Iñupiat town in Alaska. Access is by plane from Anchorage, Fairbanks or Deadhorse with tourism providing a major summer activity. Oil and gas exploration and development to the east, south and offshore from Barrow provide revenue to the local community. Local subsistence hunting is common and focuses on marine mammals, fish, waterfowl and caribou.

General Research: The majority of research is carried out by visiting projects funded by several agencies (NSF, NASA, NOAA, U.S. Fish and Wildlife Service) and privately sponsored organizations. Most terrestrial research is conducted on the BEO and adjacent areas. Research and observational projects include active layer processes, permafrost temperatures, coastal erosion, snow cover dynamics, hydrology, plant phenology, trace gas fluxes, soil respiration, vegetation spectral reflectance, bird and small mammal census. Project activities are reported in the Annual BEO Report and are available on the BASC website . The Barrow Arctic Science Consortium and its staff, provides logistic support for many of these projects. The NSB Department of Wildlife Management is resident in Barrow and conducts research and harvest inventories of marine and large terrestrial mammals. In addition to the National Weather Service station, two federal agencies maintain year-round, long-term atmospheric observatories; NOAA Environmental Systems Research Laboratory (ESRL - formerly CMDL) and the DOE Atmospheric Radiation Monitoring (ARM) program.

Three major types of research utilize the BEO Scientific Research District:

Process and experimentation

Population biology and biodiversity studies

Environmental monitoring

Line power and a boardwalk system service the BEO-based biocomplexity, flooding and draining manipulative experiment. Several international observatory projects have permanent sites on the BEO. These include the TSP borehole and Active layer sites (CALM), ITEX and the Arctic Coastal Dynamics (ACD) key sites. Wireless communications are possible throughout the BEO.

Topography and hydrology (info source: http://www.arcticscience.org/pdf/beo-mp-sept02.pdf page 5 and 6): The main topographic feature of the BEO is the crescent shaped, old raised beach ridge that extends from the North Meadow Lake across the Navy-USGS-NOAA lands and re-enters the BEO extending to Central Marsh Slough. Beach ridge elevations range between 4.5 and 7.0 meters above sea level. Elevations along Elson Lagoon range from close to sea level to a maximum of 4.6 meters. Central Marsh Slough and Ikpik Slough, two small estuaries or sloughs, encroach upon the BEO as inland extensions of Elson Lagoon. Mayoeak Creek, a third estuary and small stream, forms the southeast boundary of the BEO. Two, long (2 km) shallow lakes are located in this southeastern section of the BEO (East and West Twin Lakes). Two smaller, shallow lakes are found at the northwestern section of the BEO (North and South Meadow Lakes; NML and SML). North Meadow Lake was the site of intensive research during the 1960s and 1970s and was serviced by a power line from NARL (Kelley and Weaver 1969). A third small lake is located in the southwest potion of the BEO and is named Cake Eater Lake (CEL) for present purposes. Numerous small shallow ponds are randomly distributed in former lake basins and low centered polygons. Other than the small streams at the headwaters of these estuaries, there are no well-defined drainage networks. Revegetated drained lake basins cover the landscape. Wet swampy areas interconnect many of these basins. During spring snowmelt these low wet areas carry the runoff waters to Elson Lagoon. The remaining snowmelt and majority of the summer precipitation remains on the tundra and in polygon ponds and subsequently evaporates or is absorbed into the thawing soil. The summer water balance of a small BEO basin draining into Central Marsh Creek was studied in the 1960s (Brown et al. 1968).

More info about BEO can be found http://www.arcticscience.org/researchBases.php and http://www.arcticscience.org/pdf/beo-mp-sept02.pdf .

4.2 Ecosystem

Ecosystem info below is from http://www.scannet.nu/content/view/136/166/ .

Biodiversity: The immediate Barrow region lies within the High Arctic Zone (Webber 1978), which has been more recently called the Bioclimatic Zone C (Walker 1995) and is dominated by sedge/grass moss wetland (CAVM vegetation unit #12). The landscape consists of polygonized tundra, vegetated drained lake basins, ponds and lakes. Vegetation types include aquatic, seasonally flooded, wet, moist, dry and occasionally bare ground. The Coastal Plain flora includes 124 vascular plant species, 177 mosses, and 49 hepatics (Brown 1980). Terrestrial fauna include 10 mammal species and 28 bird species. The Barrow area is of special interest because only a few kilometers inland from the Arctic Ocean, anthropogenic and maritime influences diminish, the summer climate ameliorates, land cover becomes more diverse and species diversity increases dramatically. The dramatic climatic and biotic gradients present multiple opportunities for gradient studies and comparison with other arctic research localities.

Species Performance: A rich history of geologic, soils, floristic and faunal research exists for the Barrow area. Currently The U.S. Fish and Wildlife Service and several other organizations monitor shorebird, waterfowl and avian predator populations. Plant phenology and community dynamics has been monitored at the International Tundra Experiment (ITEX) site, and several programs monitor terrestrial and marine mammal populations. Experimental manipulations include the ITEX passive warming experiments (1994 – present), herbivory exclosures (1948 to present) and a large-scale, biocomplexity flooding and draining experiment (2005 to present).

Based on a supervised classification of the IKONOS satellite imagery mosaic of July 16 and August 16, 2000 coverage of the BEO area, the most dominant vegetation type in the BEO is wet graminoid tundra, composing 38% of the entire BEO and 44% of its land area (Table 7). The next most dominant land cover types are dry meadow, moist meadow dominated by *Carex* spp. and emergent aquatic vegetation dominated by *Carex* spp. These rankings remain the same in the entire image area (info source: http://www.arcticscience.org/pdf/beo-mp-sept02.pdf page 6).

Table 7: Vegetation Class distribution in the BEO and the entire classified area.

Land Cover	% Area in BEO	% Land in BEO	% Area in total	% Land in total
Dry Heath – Lichen-dominated	2.3	2.8	2.3	2.9
Dry Heath —*Salix* spp.-dominated	4.2	5.1	4.0	5.0
Dry Heath - Mixed	0.3	0.3	0.3	0.3
Dry Meadow	9.8	11.9	8.7	10.9
Moist Meadow - Forb-dominated	4.1	5.0	4.1	5.1
Moist MeadowÄ—*Carex* spp.-dominated	7.6	9.2	7.1	8.9
Moist Meadow - Mixed graminoid-dominated	4.3	5.2	4.7	5.9
Wet Graminoid	36.7	44.4	35.0	43.8
Emergent Aquatic – *Arctophila fulva*-dominated	2.2	2.6	2.2	2.7
Emergent Aquatic —*Carex* spp.-dominated	6.8	8.2	6.3	7.9
Emergent Aquatic - Mixed	0.1	0.1	0.1	0.1
Water	17.3	NA	20.1	NA
Urban / Gravel	1.2	1.4	1.8	2.2
Barren Ground	0.4	0.5	0.9	1.1
Cloud	2.7	3.2	2.4	3.0

BASC mentioned that detailed maps about soil, vegetation, remote sensing can be obtained by making requests to Dr Craig Tweetie (Michigan State University, tweedie@msu.edu, 1-517-355-1285). His detailed contact info can be found at http://www.cevl.msu.edu/ael/personnel/tweedie.html. Dr Tweetie and his lab are voluntarily to gather research info and make maps for Barrow region.

Based on field observation during FIU site characterization, the representative ecosystem around NEON site is polygonal tundra meadow (mixed with wet and dry meadow, dominated by sedge and moss). Polygon berms is ~ 20-30 cm high, and ~2-4 m wide, and are punctuated by saturated/low polygons (some with open water. Open water size is 8 m^2 – 250 m^2), or punctuated by drier/high polygons of the same size/area. LAI is ~1.4 m. Canopy height ~ 0.3 m in summer.

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

Ecosystem attributes	Measure and units
Mean canopy height	0.3 m
Surface roughness[a]	0.05 m
Zero place displacement height[a]	0.1 m
Structural elements	Polygonal tundra meadow, homogenous
Time zone	Alaska standard time
Magnetic declination	18° 41' E changing by 0° 24' W/year

Note,
[a] From field survey.

Figure 20. Polygonal tundra meadow is the dominant ecosystem at BEO Relocatable site

4.3 Soils

4.3.1 Description of soils

No soil data and soil maps are available from NRCS (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm).

4.3.2 Soil semi-variogram description

The goal of this aspect of the site characterization is to determine the minimum distance between the soil plots in the soil array such that data farther apart can be considered spatially independent. The collected field data will be used to produce semivariograms, which is a geostatistical technique to characterize spatial autocorrelation between mapped samples of a quantitative variable (*e.g.*, soil property data in our case). In an empirical semivariogram, the average of the squared differences of a response variable is computed for all pairs of points within specified distance intervals (lag classes). The output is presented graphically as a plot of the average semi-variance versus distance class (Figure 21). For the theoretical variogram models considered here, the semivariance will converge on the total variance at distances for which values are no longer spatially auto-correlated (this is referred to as the range, Figure 21).

For the theoretical variograms considered here, three parameters estimated from the data are used to fit a semivariogram model to the empirical semivariogram. This model is then assumed to quantitatively represent the correlation as a function of distance (Figure 21), the range, the sill (the sill is the asymptotic value of semi-variance at the range), and the nugget (which describes sampling error or variation at distances below those separating the closest pairs of samples). The range, sill and nugget are estimated from theoretical models that are fitted to the empirical variograms using non-linear least squares methods.

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

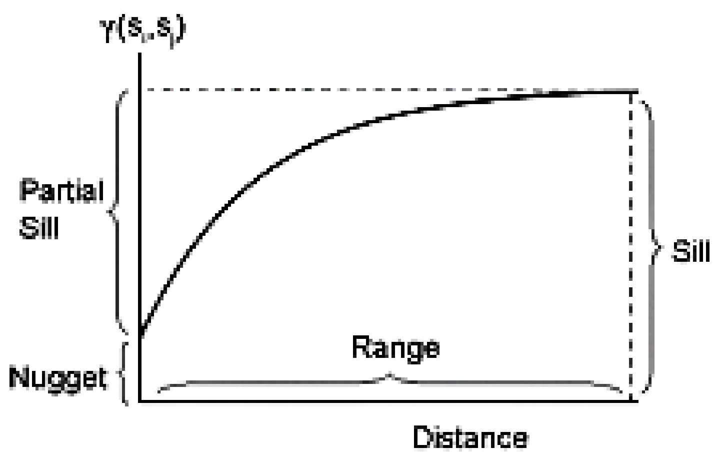


Figure 21. Example semivariogram, depicting range, sill, and nugget.

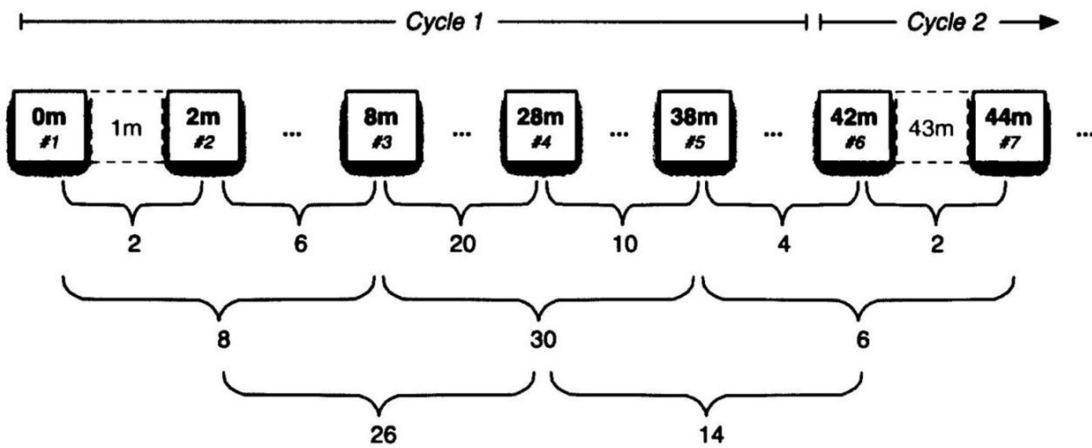


Figure 22. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 26 June 2010 at the Barrow site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 22). Soil temperature and moisture measurements were collected along three transects (210 m, 84 m, and 84 m) located in the expected airshed at Barrow. Details of how the airshed was determined are provided below. Soil temperature was measured with platinum resistance temperature sensors (RTD 810, Omega Engineering Inc., Stamford CT) and soil moisture was measured with time domain diaelectric sensors (CS616, Campbell Scientific Inc., Logan UT).

As well as measuring soil temperature and moisture at each sample point in Figure 22, measurements were also taken 30 cm in front and behind the sampling point along the axis of the transect. For example, at the 2 m sampling point, soil temperature and moisture was measured at 1.7 m, 2 m, and 2.3 m; this data is referred to as mobile data, since the measurements were taken at many different locations. In addition, soil temperature and moisture were continuously recorded at a single fixed location (stationary data) throughout the sampling time to correct for changes in temperature and moisture throughout the day.

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

4.3.3 Results and interpretation

4.3.3.1 Soil Temperature

Soil temperature data residuals, after accounting for changes in temperature in the stationary data, any remaining time of day trend, and trends relating to elevation, were used for the semivariogram analysis (Figure 23). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 24, left graph) and directional semivariograms do not show anisotropy (Figure 24, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 24, right graph). The model indicates a distance of effective independence of 14 m for soil temperature.

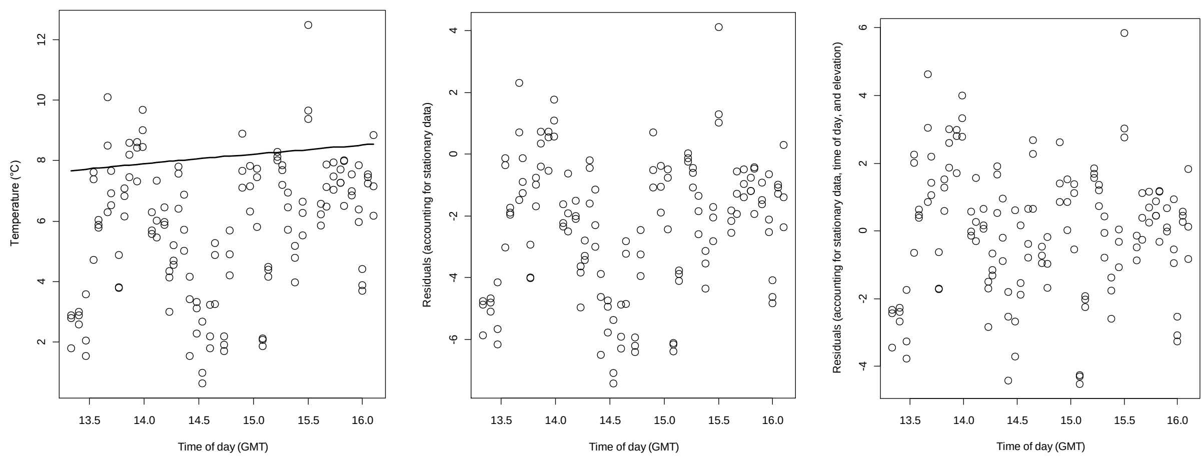


Figure 23. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting for changes temperature in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

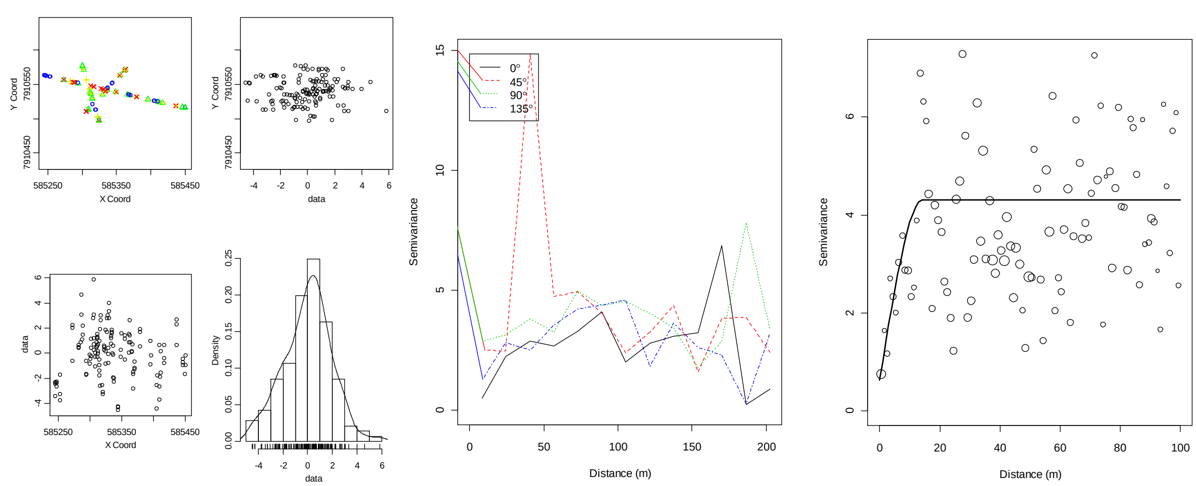


Figure 24. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

4.3.3.2 Soil water content

Soil water content data residuals, after accounting for changes in soil water content in the stationary data, any remaining time of day trend, and trends relating to elevation, were used for the semivariogram analysis (Figure 25). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 26, left graph) and directional semivariograms do not show anisotropy (Figure 26, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 26, right graph). The model indicates a distance of effective independence of >100 m for soil water content.

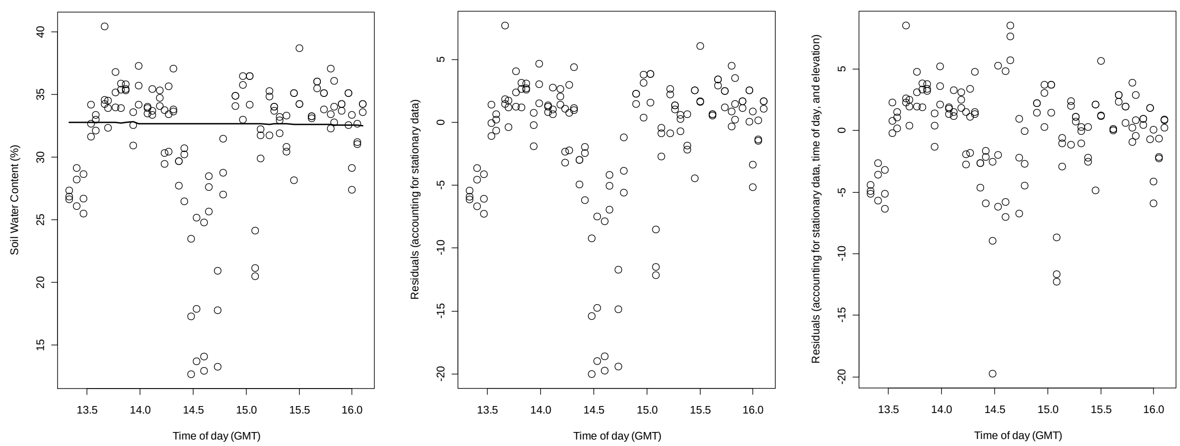


Figure 25. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting for changes water content in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

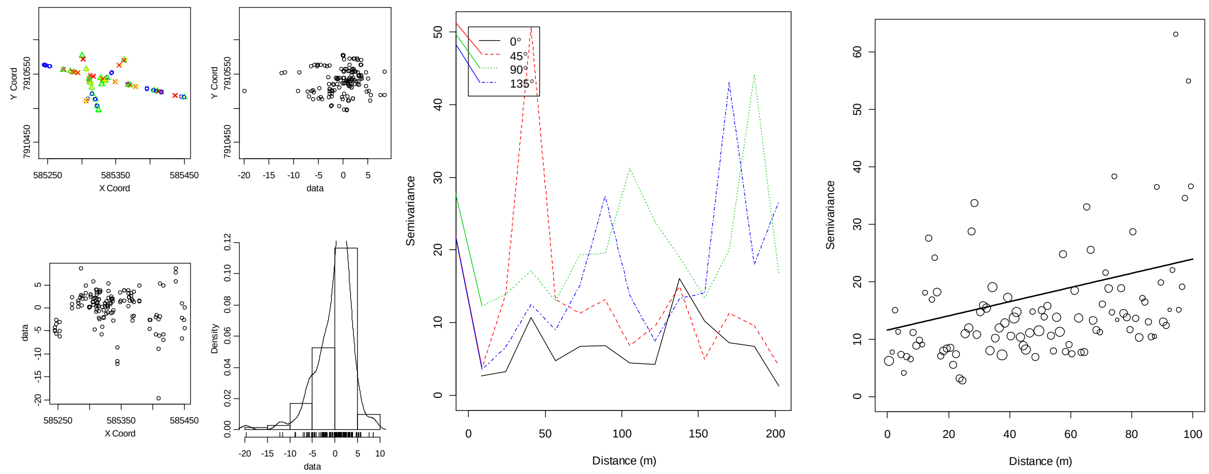


Figure 26. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

4.3.3.3 Soil array layout and soil pit location

The minimum distance allowable between soil plots is 25 m to ensure a degree of spatial independence in non-measured soil parameters (i.e., other than temperature and water content) and the maximum distance allowable between soil plots is 40 m due to cost constraints. The estimated distance of effective independence was 14 m for soil temperature and >100 m for soil moisture. Based on these results and the site design guidelines the soil plots at Barrow shall be placed 40 m apart. The soil array shall follow the linear soil array design (Soil Array Pattern B) with the soil plots being 5 m x 5 m. The direction of the soil array shall be 100° from the soil plot nearest the tower. The location of the first soil plot will be approximately 71.282373, -156.618911. The exact location of each soil plot will be chosen by an FIU team member during site construction to avoid placing a soil plot at an unrepresentative location (e.g., rock outcrop, drainage channel, large tree, etc). The FIU soil pit for characterizing soil horizon depths, collecting soil for site-specific sensor calibration, and collecting soil for the FIU soil archive will be located at 71.281369°, -156.651005° (primary location); or 71.281012°, -156.650352° (alternate location 1 if primary location is unsuitable); or 71.280562°, -156.649612° (alternate location 2 if primary location is unsuitable). A summary of the soil information is shown in Table 9 and site layout can be seen in Figure 27.

Dominant soil series at the site: Not available from NRCS. The taxonomy of this soil is shown below:
Order: Not available (likely Gelisols)
Suborder: Not available
Great group: Not available
Subgroup: Not available
Family: Not available
Series: Not available

Table 9. Summary of soil array and soil pit information at Barrow. 0° represents true north and accounts for declination.

Soil plot dimensions	5 m x 5 m
Soil array pattern	B
Distance between soil plots: x	40 m
Distance from tower to closest soil plot: y	17 m
Latitude and longitude of 1st soil plot OR direction from tower	71.282373, -156.618911
Direction of soil array	100°
Latitude and longitude of FIU soil pit 1	71.281369°, -156.651005° (primary location) †
Latitude and longitude of FIU soil pit 2	71.281012°, -156.650352° (alternate 1) †
Latitude and longitude of FIU soil pit 3	71.280562°, -156.649612° (alternate 2) †
Dominant soil type	Not available from NRCS
Expected soil depth	Not available from NRCS
Depth to water table	Not available from NRCS

Expected depth of soil horizons	Expected measurement depths*
Unknown	0.1 m
	0.35 m
	1.0 m
	3.0 m

*Currently, there are no data on the expected soil depth of soil horizons from NRCS. However, we fully expect to be measuring (at least) 4 different horizons, i.e., the top and bottom of the active layer, at 3 m and other TBD layers. The 3 m depth is below the biologically active layer, but provides a link between the active layer dynamics and the temperature regime of the deep permafrost, V. Romanofsky, pers. Comm.. Actual soil measurement depths will be determined based on measured soil horizon depths at the NEON FIU soil pit and may differ substantially from those shown here. At the NEON Alaska sites soil temperature and moisture sensors will be inserted up to 3 m deep in order to measure long-term permafrost dynamics.

†Soil pit locations should not show obvious signs of disturbance from pipeline or access road.

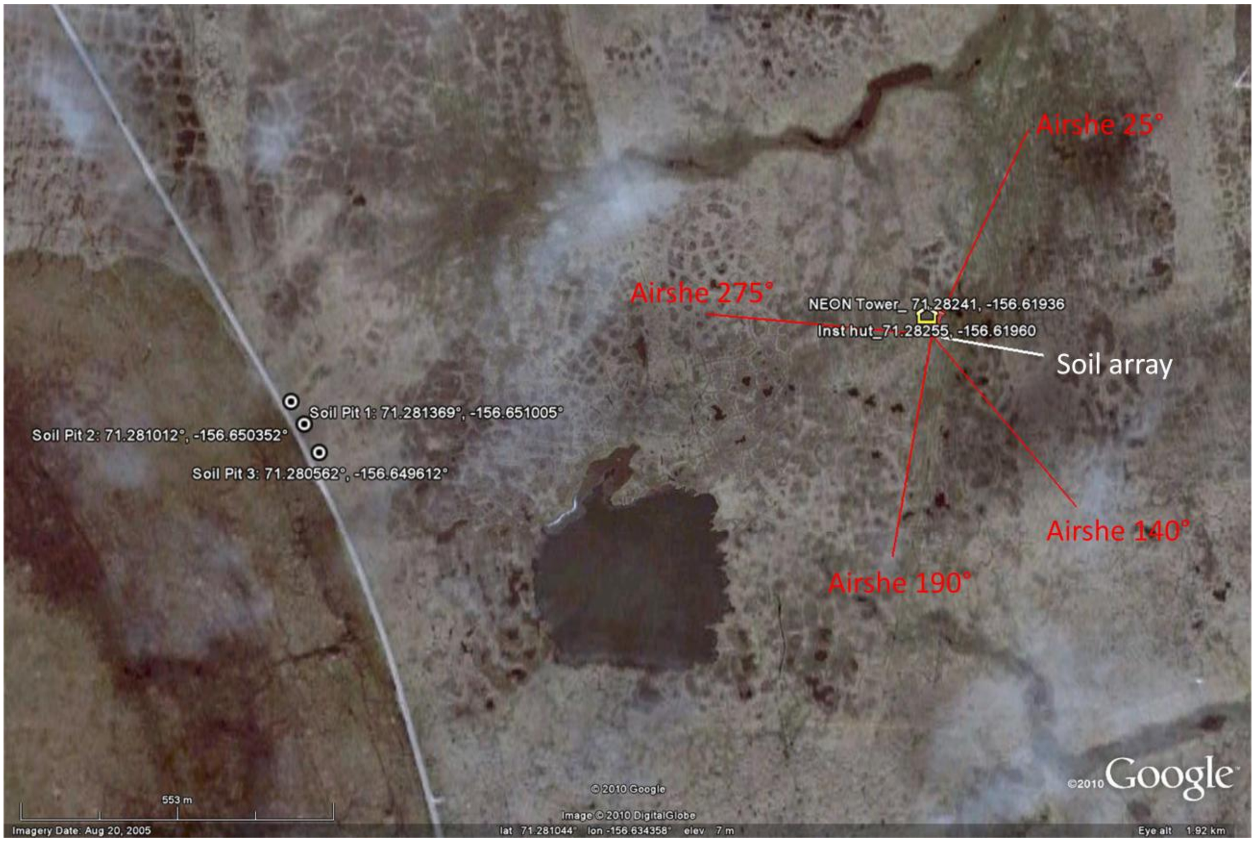


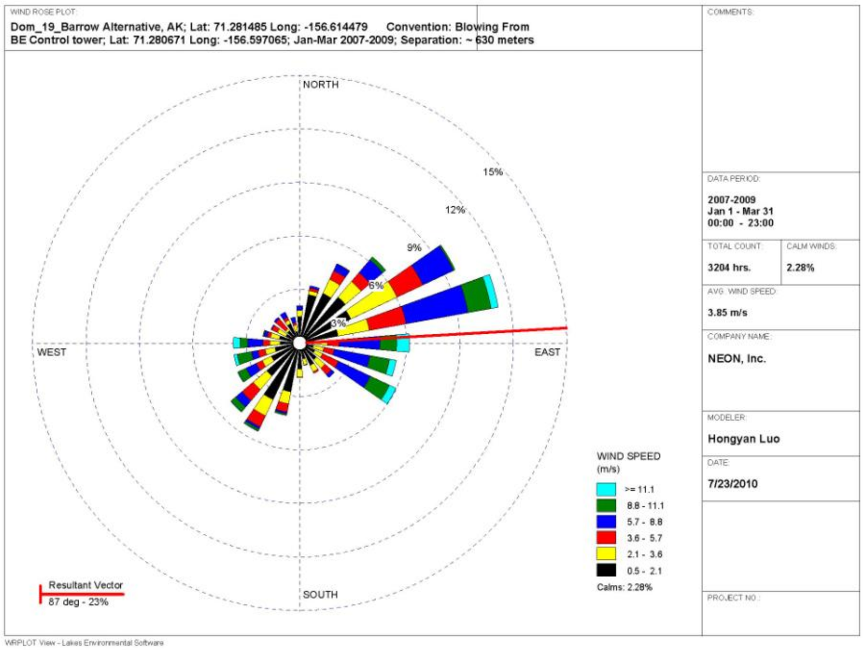
Figure 27. Site layout at Barrow showing soil array and location of the FIU soil pit.

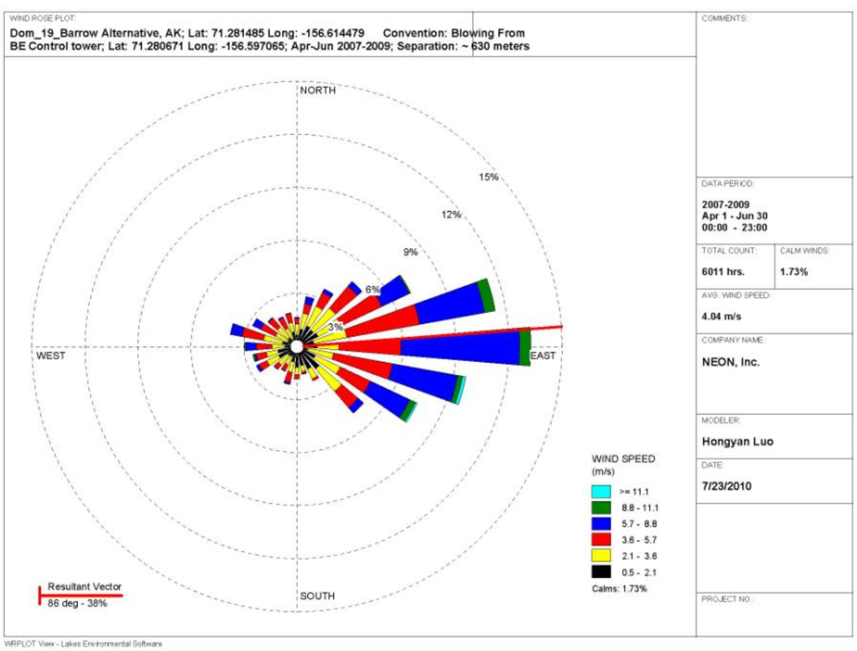
4.4 Airshed

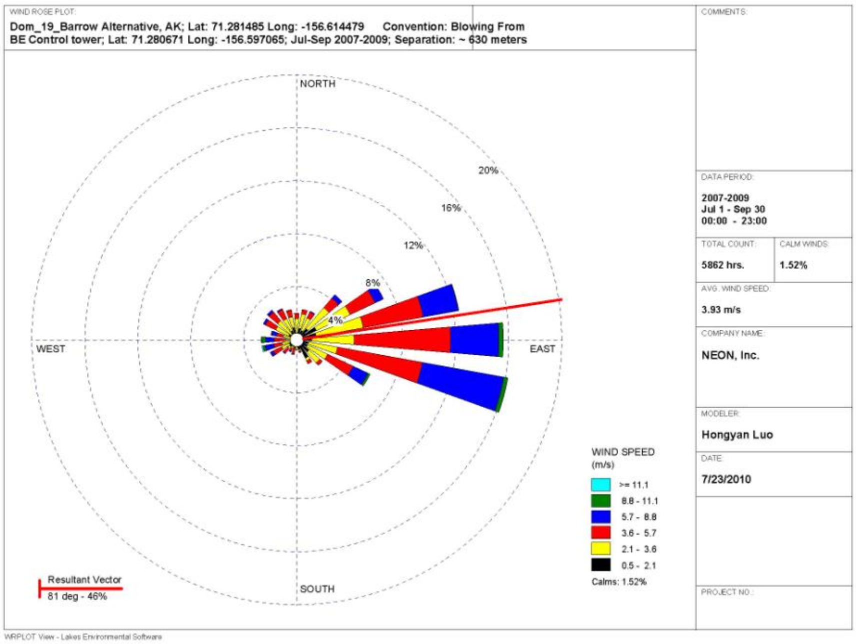
4.4.1 Seasonal windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given timeseries, Figure 32. The weather data used to generate the following wind roses are from existing Biocomplexity Control tower at 71.280671, -156.597065, which is ~ 600 m on the ESE to NEON tower site. The orientation of the wind rose follows that of a compass (assume declination applied). When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 24 cardinal directions.

4.4.2 Results (graphs for wind roses)







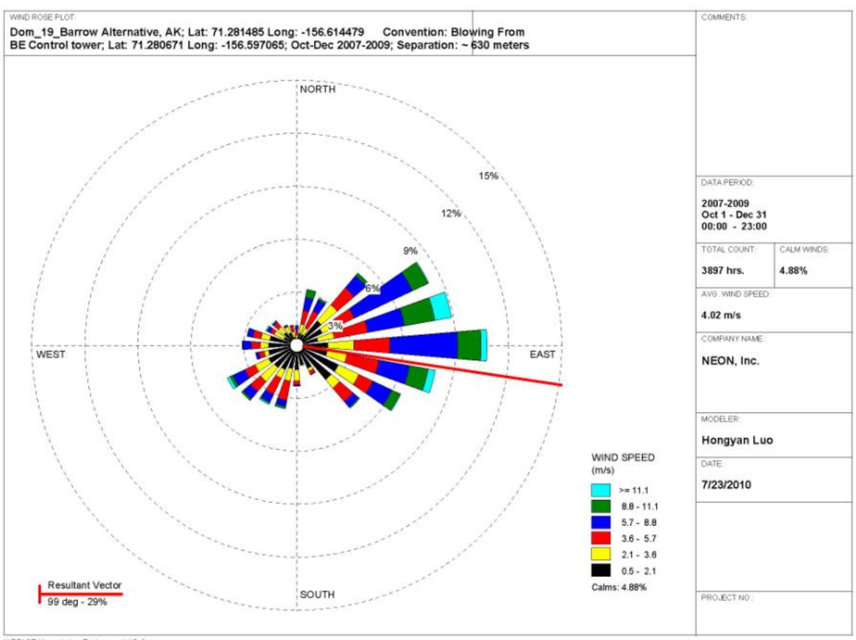


Figure 28. Windroses for BEO relocatable site.

Data used here are from 2007 to 2009 from existing Biocomplexity Control tower at 71.280671, -156.597065, which is ~ 650 m on the ESE to NEON tower site. Data were downloaded from Global

Change Research Group (GCRG) at San Diego State University (http://gcrg.sdsu.edu/). It is assumed that the wind data was corrected for declination. Panels (from Top to bottom), are from Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

4.4.3 Resultant vectors

Table 10. The resultant wind vectors from BEO relocatable site using hourly data from 2007 to 2009.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	87°	23
April to June	86°	38
July to September	81°	46
October to December	99°	29
Annual mean	88.25°	na.

4.4.4 Expected environmental controls on source area

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

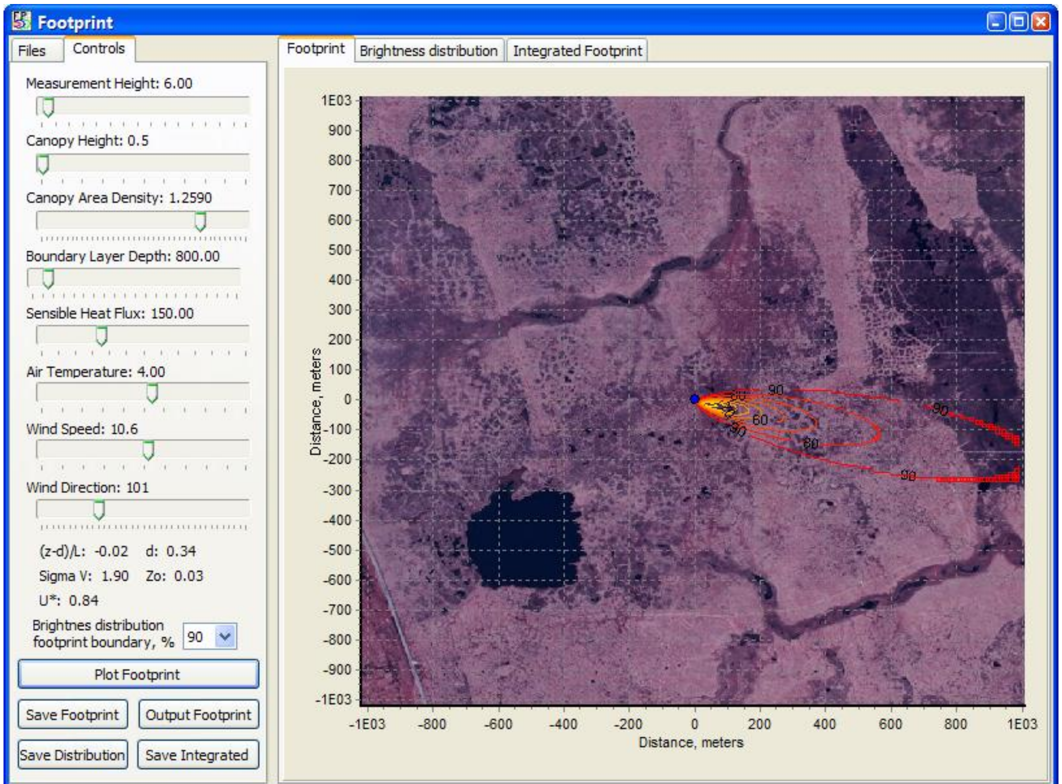
As a general rule, shorter and less structurally complex ecosystems have good vertical mixing during all atmospheric stabilities. Taller and more structurally complex ecosystems have well mixed upper canopies during the daytime, and can be decoupled below the canopy under neutral and stable conditions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

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

Table 11. Expected environmental controls to parameterize the source area model, and associated results from BEO Relocatable tower site.

Parameters	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	
Approximate season	summer			winter			Units
	Day (max WS)	Day (mean WS)	Night	Day (max WS)	Day (mean WS)	night	qualitative
Atmospheric stability	Convective	convective	Stable	Convective	convective	Stable	qualitative
Measurement height	6	6	6	6	6	6	m
Canopy Height	0.5	0.5	0.5	0.1	0.1	0.1	m
Canopy area density	1.259	1.259	1.259	0.8	0.8	0.8	m
Boundary layer depth	800	800	800	300	300	300	m
Expected sensible heat flux	150	150	150	-74	-74	-74	W m^{-2}
Air Temperature	4	4	4	-20	-20	-20	°C
Max. windspeed	10.6	4.6	2.4	13	5.4	2.6	m s^{-1}
Resultant wind vector	100	100	100	70	70	70	degrees
Results							
(z-d)/L	-0.02	-0.19	-0.77	0.01	0.28	3	m
d	0.34	0.34	0.34	0.06	0.06	0.06	m
Sigma v	1.9	1.2	1	1.8	1.7	1.6	m^2 s^{-2}
Z0	0.03	0.03	0.03	0.01	0.01	0.01	m
u*	0.84	0.38	0.24	0.78	0.27	0.05	m s^{-1}
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	800	450	250	1250	1900	3400	m
Distance of 80% cumulative flux	450	250	180	700	1150	2850	m
Distance of 70% cumulative flux	300	200	120	450	750	2500	m
Peak contribution	65	55	35	85	115	1075	m

4.4.5 Results (source area graphs)



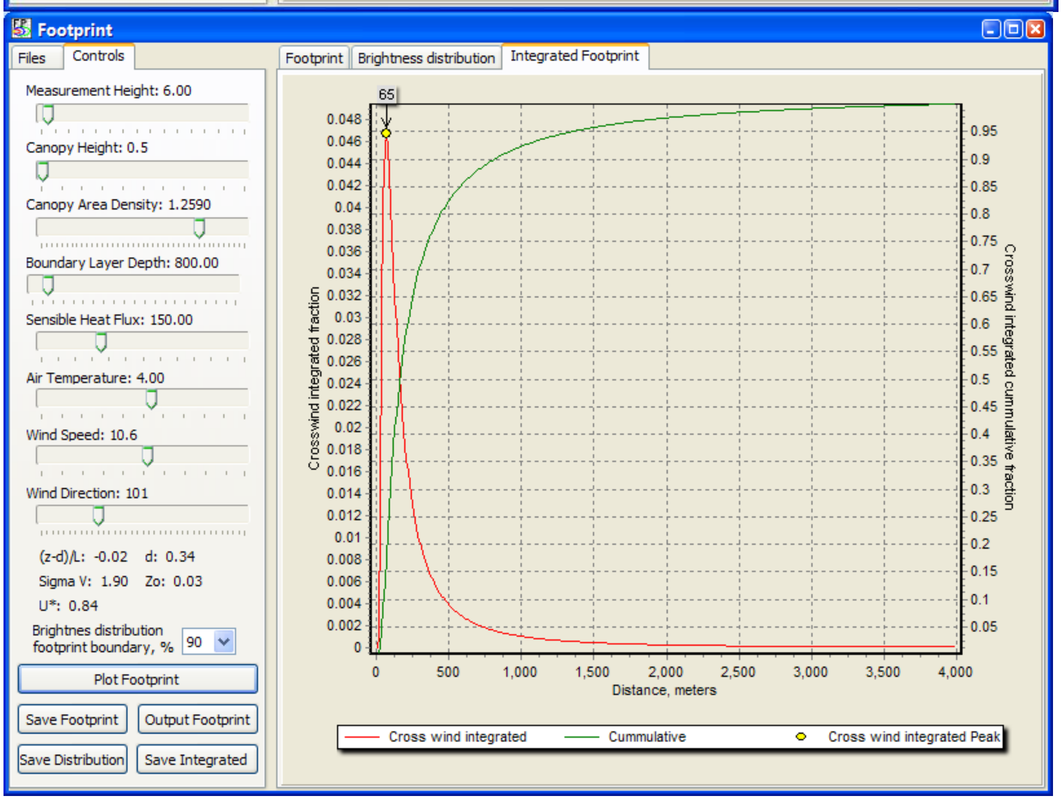


Figure 29. BEO summer daytime (convective) footprint output with max wind speed.

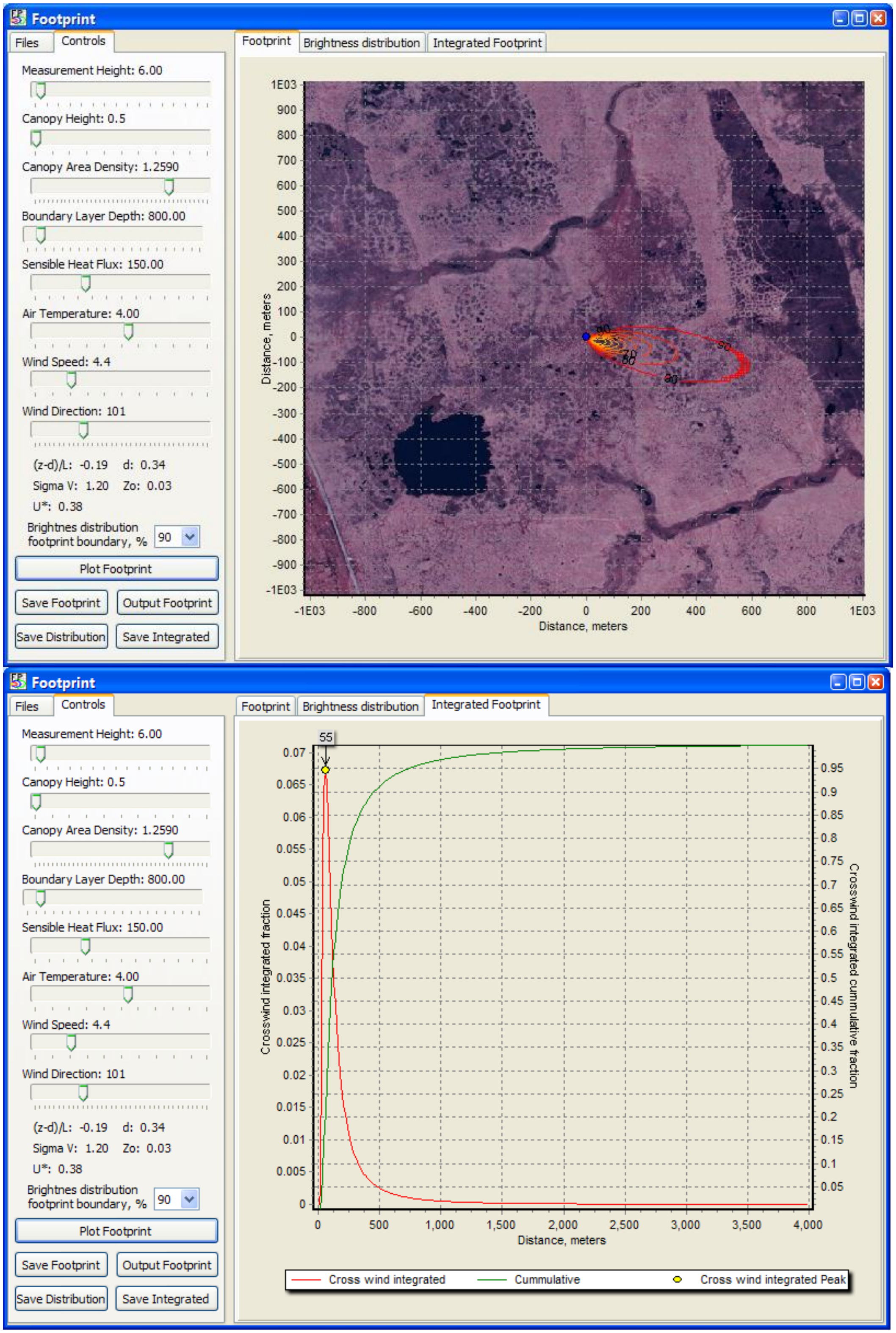


Figure 30. BEO summer daytime (convective) footprint output with mean wind speed.

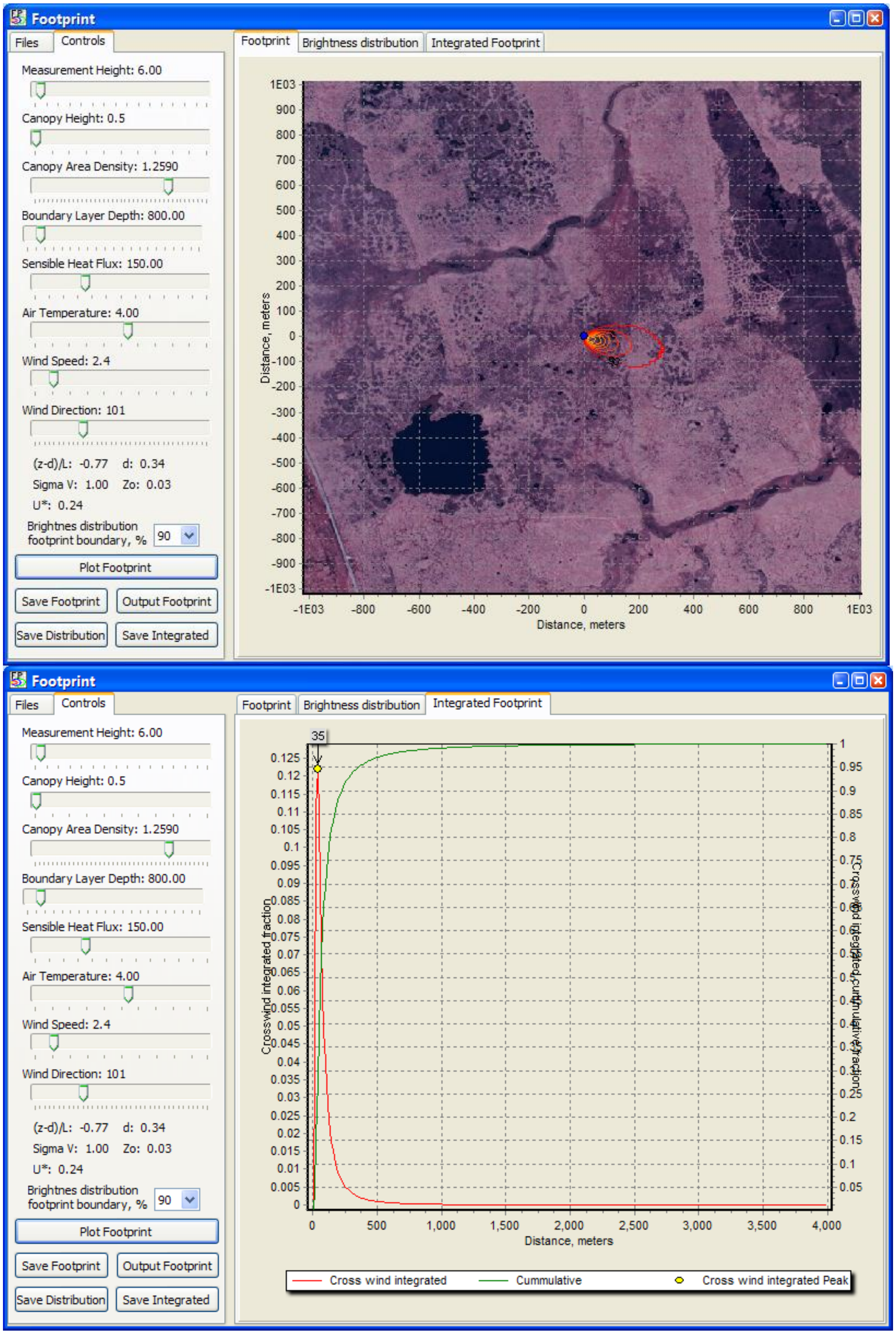


Figure 31. BEO summer nighttime (stable) footprint output with mean wind speed.

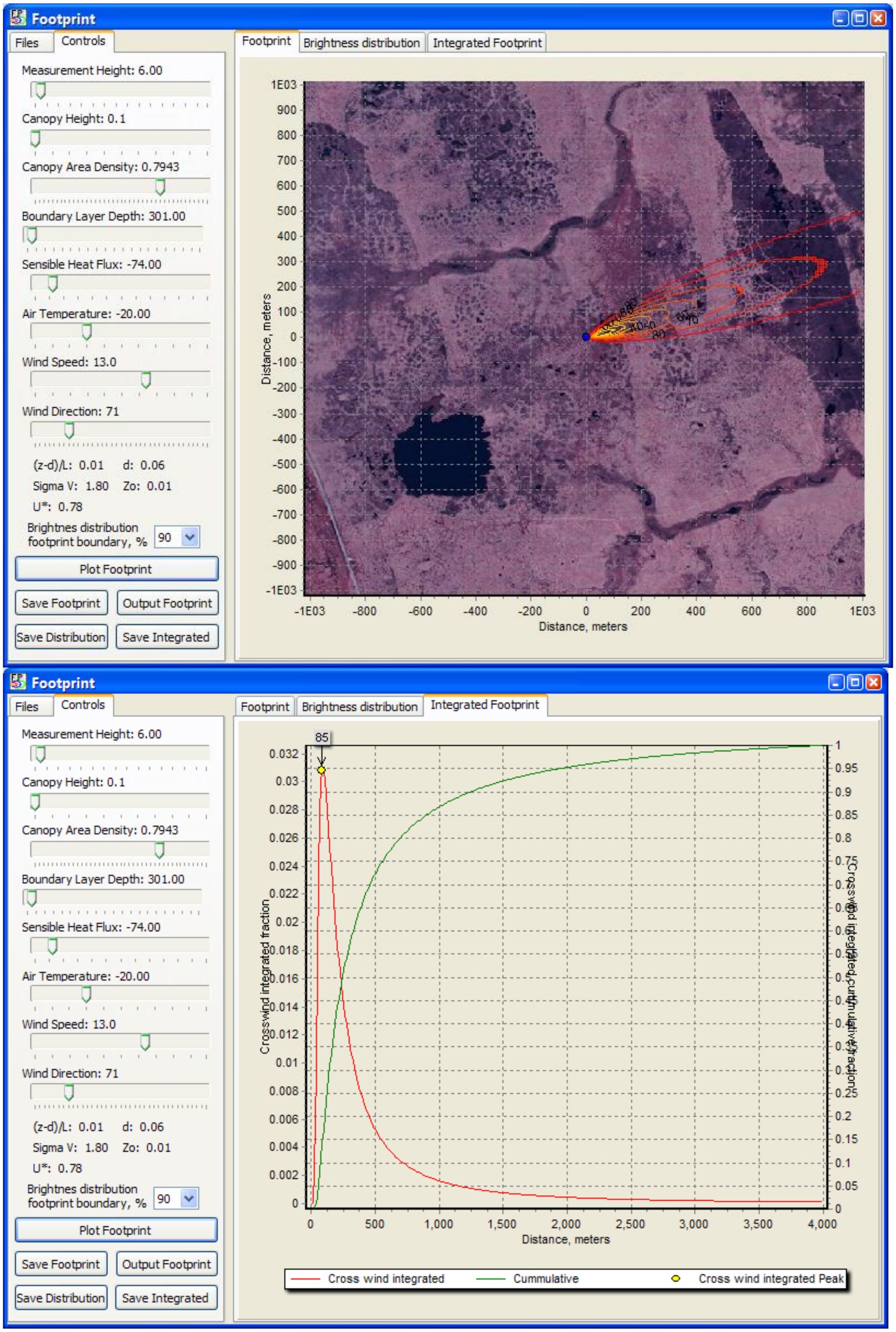


Figure 32. BEO winter daytime (convective) footprint output with max wind speed.

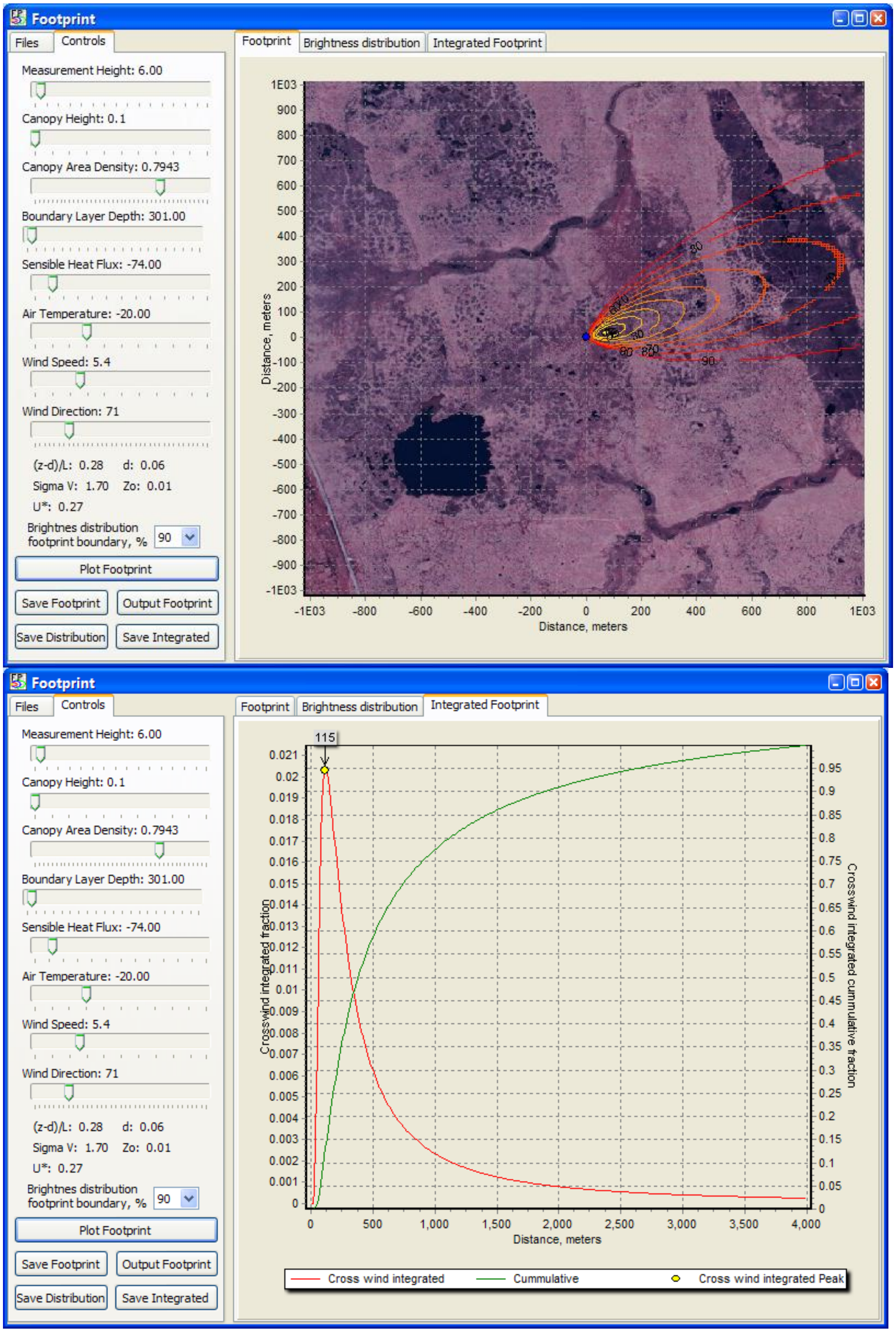
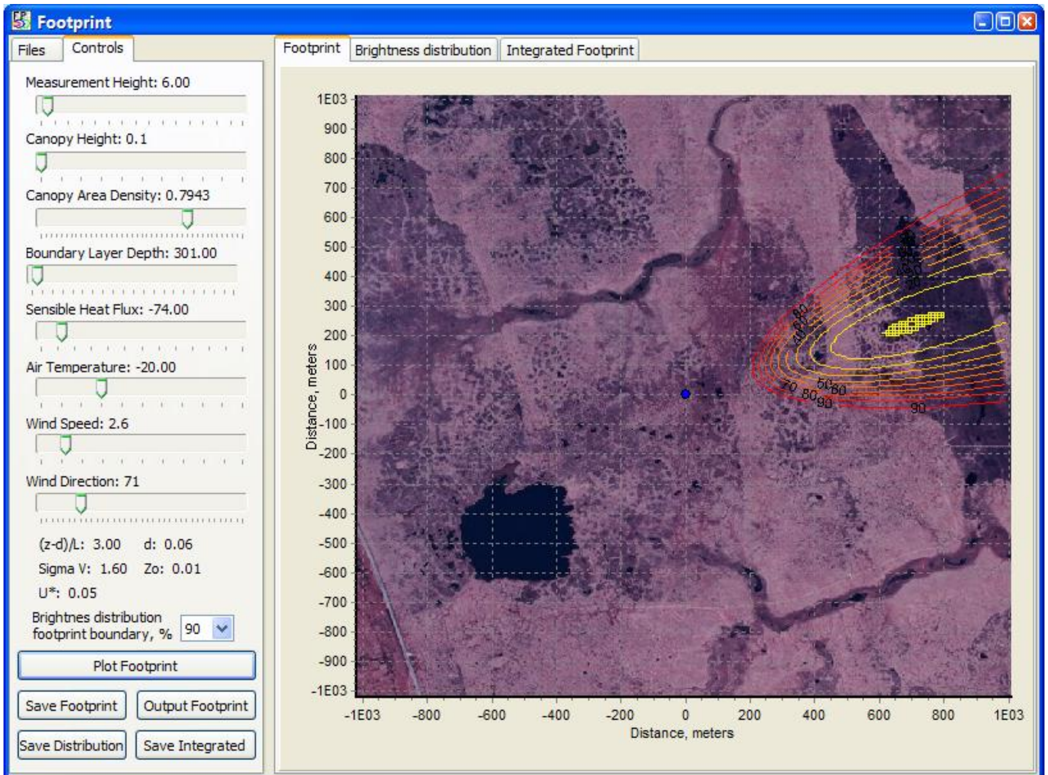


Figure 33. BEO winter daytime (convective) footprint output with mean wind speed.



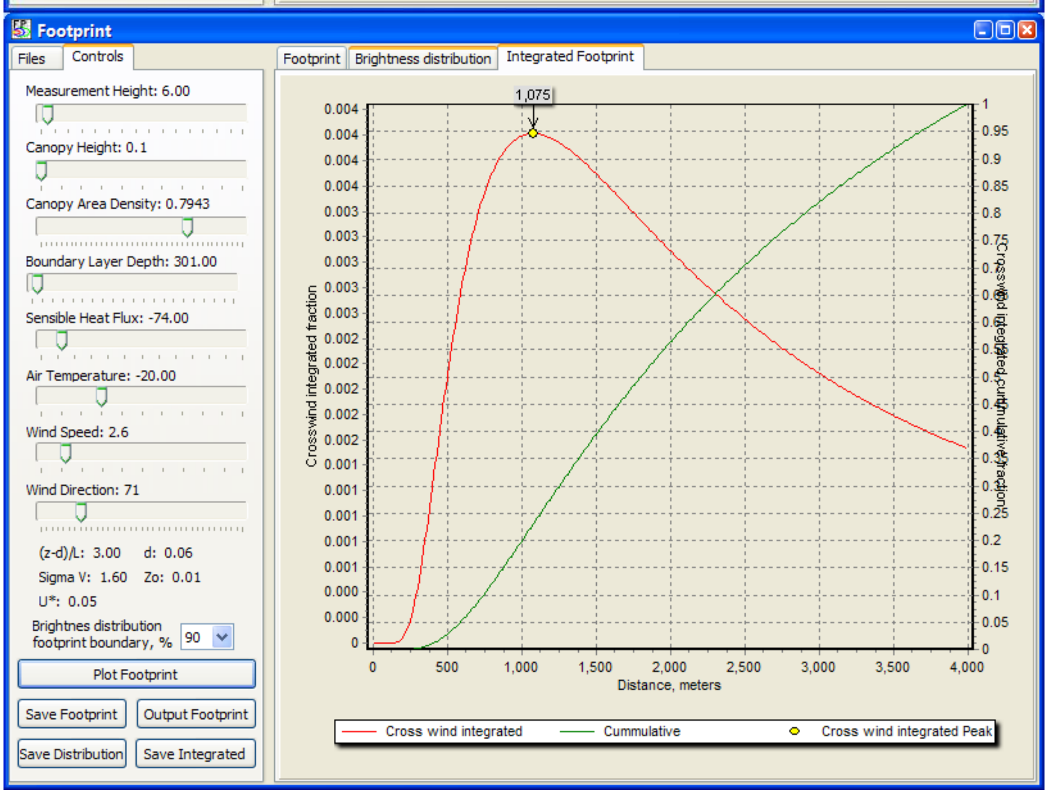


Figure 34. BEO winter nighttime (stable) footprint output with mean wind speed.

4.4.6 Site design and tower attributes

According to wind roses, the prevailing wind direction blows from 25° to 140° (major airshed, clockwise from 25°) and from 190° to 275° (clockwise from 190°) throughout the year, but has higher frequency from 40° to 125° (clockwise from 40°). Tower should be placed to a location to best catch the signals from the airshed of the ecosystem in interest, which is polygonal tundra meadow ecosystem. Tower location was determined to be 71.28241, -156.61936 during FIU site characterization.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the SSE will be best to capture signals from all major wind directions. **Radiation boom arms** should always be facing south similar to the setup at other NEON sites, even though it cannot totally avoid shadowing effects from the tower structure during summer season due to the sun circling the sky 24 hours a day for months. An **instrument hut** should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind and should be positioned to have the longer side parallel to frequent wind direction to minimize the wind effects on instrument huts and to minimize the disturbances of wind regime by instrument hut, and in this case, instrument hut should be positioned on the northwest side of tower and have the longer side parallel to E-W direction. Because this is a short grassland ecosystem and polygonal area, the distance between the tower and the instrument hut determined to be ~ 18 m at this site to avoid either tower location or instrument hut location fells on polygonal burms. Therefore, we require the placement of instrument hut at 71.28255°, -156.61960°.

At this site, the representative ecosystem around NEON site is polygonal tundra meadow (mixed with wet and dry meadow, dominated by sedge and moss). LAI is ~1.4 m. Canopy height is ~ 0.3 m in summer. We require 4 **measurement layers** on the tower with top measurement height at 6 m, and rest layers are 3.5 m, 1.0 m and 0.2 m, respectively, to best characterize the fluxes on the tower top and environmental conditions in profile.

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

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

Table 12. Site design and tower attributes for BEO site

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

Attribute	lat	long	degree	meters	notes

Airshed			25^o to 140^o (major) and 190^o to 275^o		Clockwise from first angle
Tower location	71.28241°,	-156.61936°	--	--	New site
Instrument hut	71.28255°,	-156.61960°			
Instrument hut orientation vector	--	--	90^o-270^o		
Instrument hut distance z	--	--	--	18	
Anemometer/Temperature boom orientation	--	--	165°	--	
Height of the measurement levels					
Level 1				0.2	m.a.g.l.
Level 2				1.0	m.a.g.l.
Level 3				3.5	m.a.g.l.
Level 4				6.0	m.a.g.l.
Tower Height				6.0	m.a.g.l.

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

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

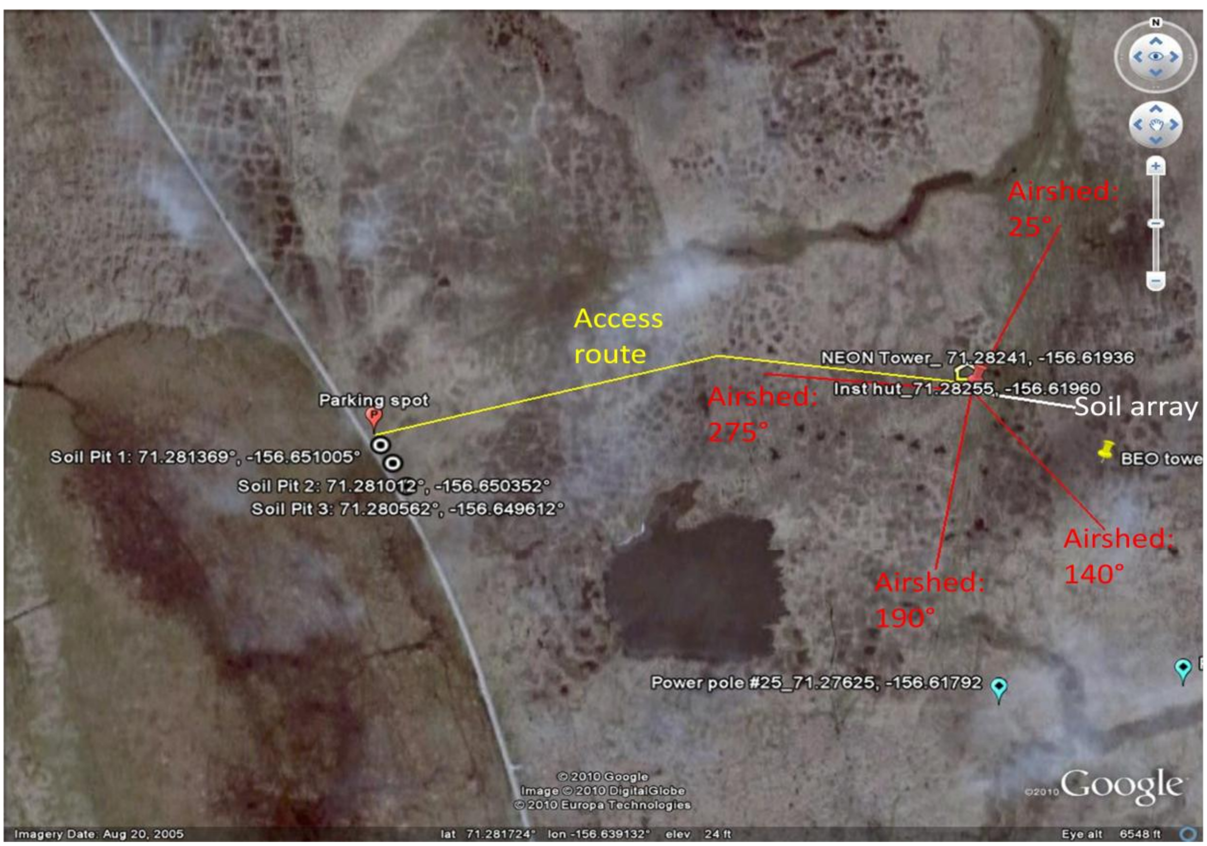


Figure 35. Site layout for BEO Relocatable site.

Top panel indicates the site layout with the preferred access boardwalk in yellow. Construction of new boardwalk and a parking spot on roadside are needed.

Middle panel shows the alternative boardwalk in blue if recommended boardwalk is not accepted for any reason.

Lower panel shows the detailed location of tower, instrument hut and alternative boardwalk. Boardwalk should keep 22.5 m away from the projection of the top boom arm on the ground to avoid the interference of boardwalk on the measurements of down facing radiation sensors.
i) tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors from 25^o to 140^o (major airshed, clockwise from 25^o) and from 190^o to 275^o (secondary, clockwise from 190^o) would have quality wind data without causing flow distortions, respectively.

Boardwalks. Ultimately, the decision to use a boardwalk will be, in part, based on owner's preferences. There are strong science requirements that minimize site disturbance to the surrounding area, which will be difficult to manage over a 30-y period. Traffic control is key to minimizing the site disturbance. Confining foot traffic to boardwalks minimizes site impact; this is particularly true in places where wear caused by foot traffic becomes noticeable and grows. For example, in places with snow part of the year, worn footpaths tend to have low places that collect water, or places where the snow pack becomes uneven causing personnel to walk farther and farther around the sides of the original path, causing the path to grow in width. This is a very common phenomenon. Here FIU assumes that all conduits will be either buried, or placed inside the boardwalk. Material is not known, but must be fire proof, and in some locations the site is seasonally flooded and inundated with water. Boardwalks may also provide a scratching structure for grazing animals that in turn, would wear and unduly impact the site. Site by site evaluations must be done.
Specific Boardwalks at this site (Tundra ecosystem is fragile. Boardwalk is required for traffic between NEON facilities over tundra):

- Boardwalk from access dirt road to instrument hut. Recommended boardwalk in the top panel of Fig. 35 is outside airshed and has minimal impacts on scientific measurements, but requires large amount of new boardwalk and a new parking spot at roadside. In case this recommended boardwalk is not accepted for any reason, alternative access boardwalk is proposed in the middle and lower panel of Fig 35. This boardwalk can use existing parking spot on roadside, and half of the boardwalk can be the existing boardwalk to Biocomplexity towers, and second half of the boardwalk will be built along the existing vehicle track. This alternative access boardwalk will reduce the disturbance on tundra, but will have some impacts on tower measurements since it crosses secondary tower airshed.
- Boardwalk from the instrument hut to the tower to intersect on north face of the tower
- Boardwalk to soil array.
- Boardwalk from soil array boardwalk to individual soil plots
- Boardwalk should be wide enough for snow machine and ATV traffic to the instrument hut only.

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

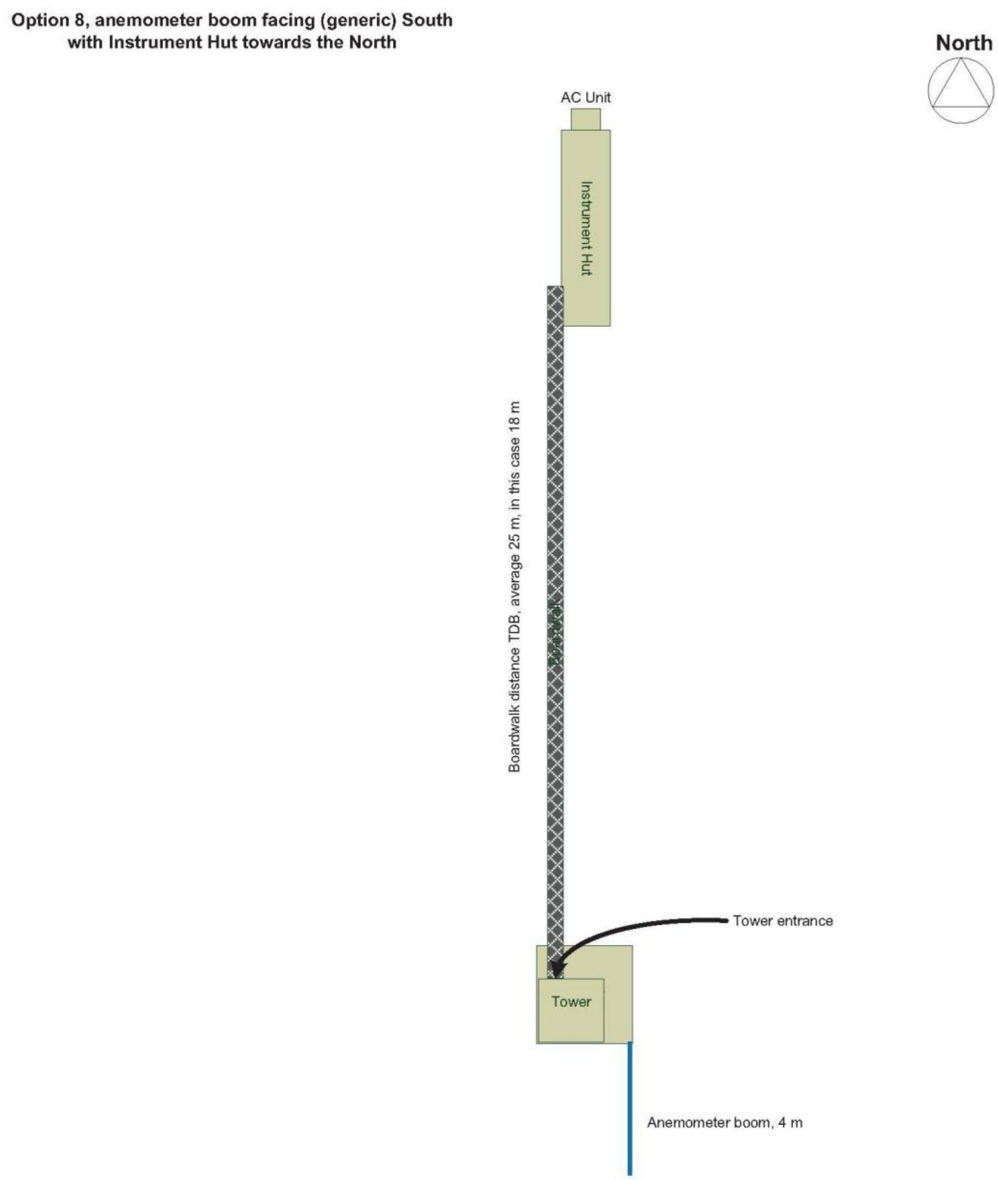


Figure 36. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing south and instrument hut on the north towards the tower.

This is just a generic diagram. The actual design of boardwalk (or path if no boardwalk required) and instrument hut position will be the joint responsibility of FCC and FIU. At this site, the boom angle will be 165 degrees. Instrument hut will be on the northwest towards the tower, and access tower on north. The distance between instrument hut and tower is ~18 m. The instrument hut vector will be E-W (90^{o}-270^{o}, longwise).

4.4.7 Information for ecosystem productivity plots

The tower at this site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (polygonal tundra). Airshed at this site is from 25^{o}

to 140° (major airshed, clockwise from 25°) and from 190° to 275° (clockwise from 190°), but has higher frequency from 40° to 125° (clockwise from 40°). 90% signals for flux measurements are within a distance of 800 m from tower during summer, but can be > 1250 m during winter, and 80% within 450 m during summer and > 700 m during winter. The pick contribution is from area > 300 m during winter. We suggest FSU Ecosystem Productivity plots to be placed within the major airshed boundaries of 40° to 125° (clockwise from 40°) from tower.

4.5 Issues and attentions

The NEON candidate tower location at 2nd Pump Station doesn't meet FIU and FSU requirements, and is logistically difficult, thus this relocatable site is relocated to Barrow Environmental Observatory (BEO) based on the collective decision of FIU, FSU, FCC, EHS, and Project. Transportation, local supports, lodging, foods and maintenance for FIU and FSU are easier at Barrow than 2nd pump station site. However, because Barrow is at coast area, more foggy days and less visibility may make it difficult for AOP to plan their flights.
It is very easy to get lost on tundra, especially when there is snow cover on the ground and 24 hours a day in dark for months during winter season and in foggy summer days. We suggest a flashing light on tower and/or instrument hut that can be turned on remotely prior to technician's field trip for tower maintenance to provide direction guidance. For the same reason, we suggest field technican should be supplied with a flashing light as safety gear, so that it can be set on the roadside to guide him/her back to his/her car after the maintenace work is done.
Arctic tundra is very fragile. Boardwalk is required from access dirt road to instrument hut, and between all NEON field facilities.
Specialized thick wires are needed for instruments to prevent from snapping in cold winter.
Local technicians (BASC, ARM, etc) are recommended to maintain NEON facilities and instruments after training with NEON, which can dramatically reduce trips and cost, and reduce instrument down time.
ARM does not allow tower climbing during winter due to safety concern of ice and snow on tower. We are not sure what is NEON's safety policy at Arctic, and how to minimize the instrument down time to meet NEON's design goal.
BEO is area that polar bears are frequently seen. Field safety training about cold, bear, rabid fox, and self protection should be given to field crews prior to their field trip.
Line power is ~670 m on the south to NEON BEO tower. Intermittent power outage occurs. UPS backup power is required.
Studies are very active at this area. Many are ecological studies, which may provide many helpful initial data for NEON project. Before construction, NEON should check other active studies in this area and minimize the physical conflicts with other existing or ongoing research projects, e.g., DOE ARM warming experiment at BEO.
Construction is suggested in winter while ground is frozen, which will make it easier to transport materials, and has less damage on tundra heavy machines are used at field. One barge arrive Barrow per year in August. NEON need plan ahead if mass construction materials need go on barge.

Communication fiber cables may be brought to Barrow in 2011. This may be a resource that NEON can use to transfer data back to HQ.
Archeological survey has to be done 1 year before construction.
Instrument hut may need to be elevated due to potential snow drifts. More discussion is needed with BASC regarding this requirement.
Freeze and thaw cycles can shift the location of the sensors in the soil. Need figure out a strategy to secure sensors in place for long-term measurements.

5 REFERENCES:

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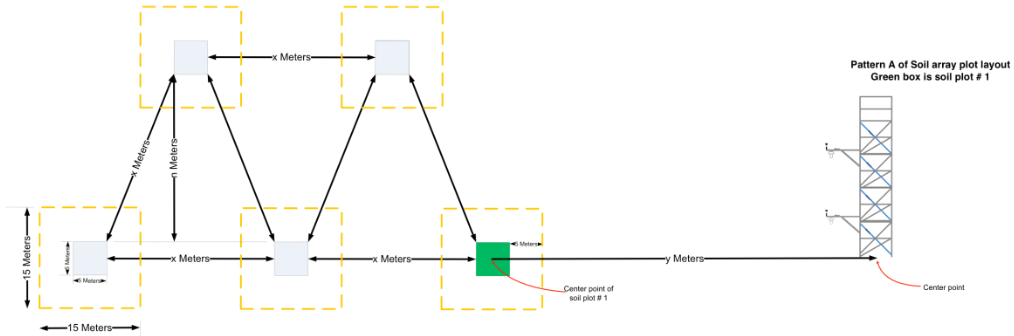
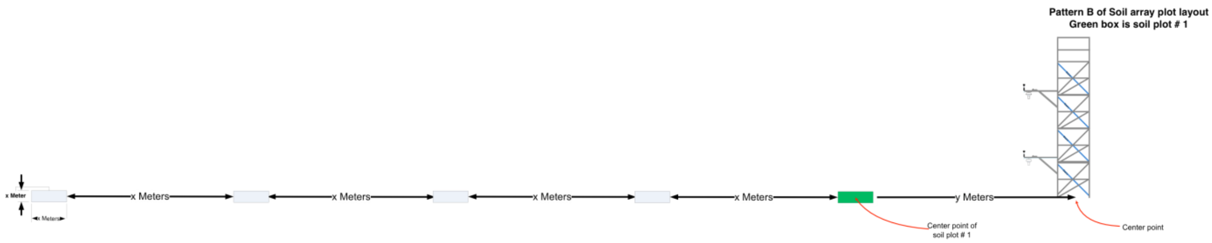
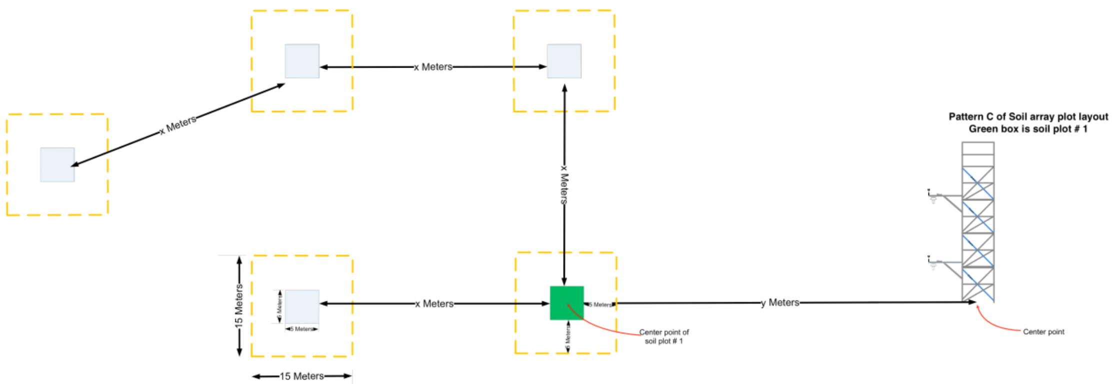
6 APPENDIX A. OPTIONAL SOIL ARRAY PATTERNS.







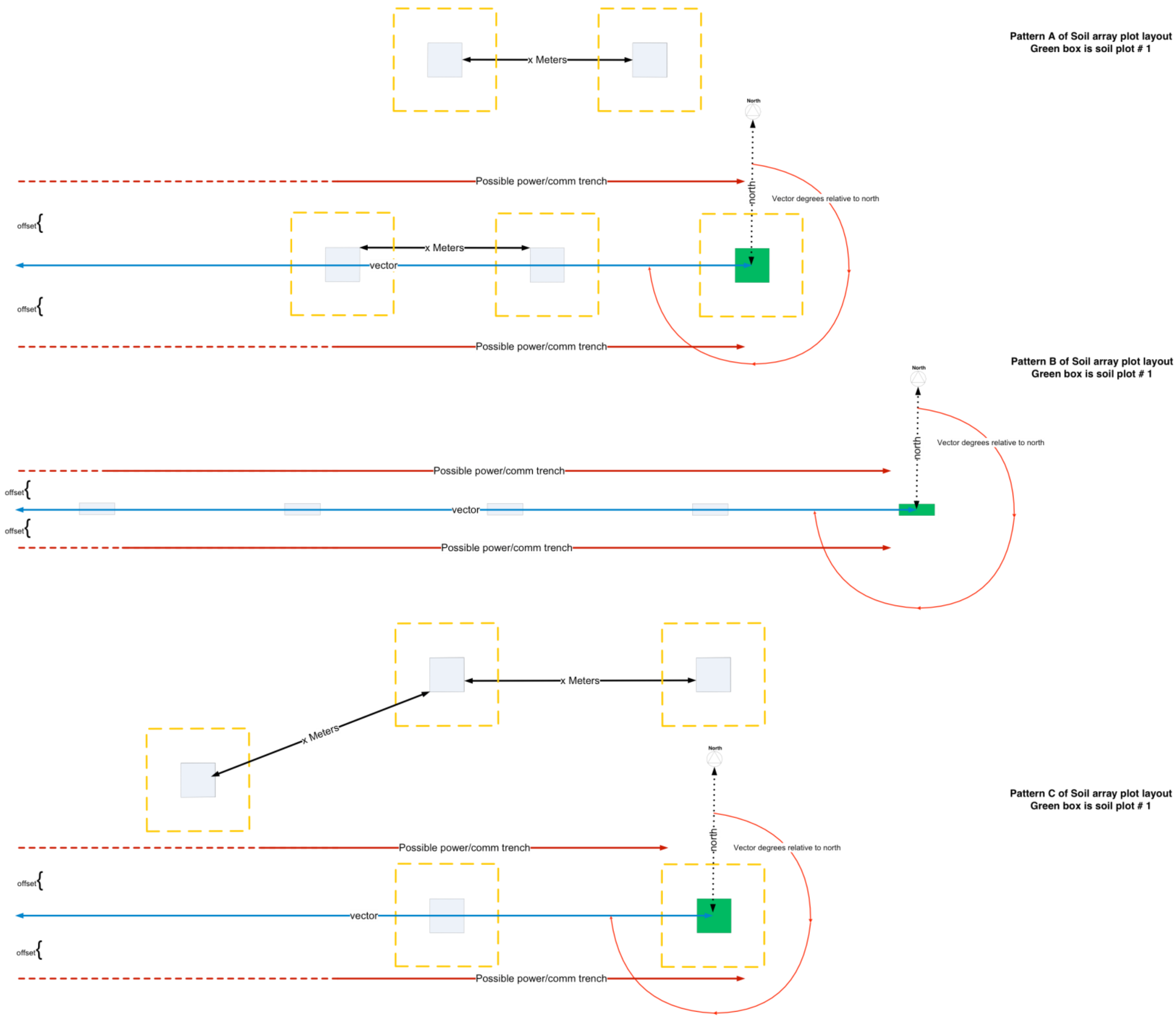


Figure A1. Conceptual diagram of Soil Array Patterns

Outlines the orientation for the soil array and instrument hut from the center point of the tower. The x, y, z distances are i) the distance between soil plots, ii) distance between the tower centerpoint and the closest edge of soil plot, and iii) the distance between the tower centerpoint and the closest edge of the instrument hut, respectively. The yellow outline around each soil plot is the 5 m perimeter keep out zone.