COMPARISON OF ODOR DISPERSION AT SWINE FACILITIES AND WASTE PROCESSING CENTERS USING A EULERIAN-LAGRANGIAN MODEL
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ABSTRACT

The purpose of this report is to compare odor dispersion at swine facilities that use alternative waste technologies (as well as waste processing centers) with odor dispersion at two control farms that use conventional lagoon technology. The goal was to determine if these alternative technologies reduce or substantially eliminate the emission of odor that is detectable beyond the boundaries of the parcel or tract of land on which the facility is located. Odor dispersion from these alternative technologies was compared to odor dispersion from two control farms using conventional lagoon technology in order to determine if the alternative technologies were superior to conventional procedures in reducing odors downwind. Nineteen sites were evaluated: 1) Stokes farm (standard lagoon technology), 2) Moore farm (standard lagoon technology), along with seventeen alternative technologies including 3) Ambient Temperature Anaerobic Digester and Greenhouse for Swine Waste Treatment and Bioresource Recovery at Barham Farm, 4) Black Soldier Fly, 5) Aerobic Blanket System and Aerobic Digester at Carrolls Farm, 6) "BEST" (solids / liquids separation), Biomass Energy Sustainable Technology Site 1 (Corbett 1) (FAN® + TFS), 7) "BEST" (solids / liquids separation) Biomass Energy Sustainable Technology Site 2 (Corbett 4) (Filtramat™ + TFS), 8)"Ekokan" Biofiltration Technology, 9) BELT (Grinnells lab, NCSU campus), 10) Permeable Cover Anaerobic Digester with Aerobic Digester (and for August 2004, Evaporation System) at Harrells Farm, 11) Constructed Wetlands at Howard Farm, 12) Sequencing Batch Reactor and Equalization Tank at Hunt Farm, 13) Koger Gasifier, 14) BELT (LWRFL site), 15) "ORBIT" High Solids Anaerobic Digester, 16) ReCip Solids Separation – Reciprocating Wetland, 17) Super Soils Solids Separation / Nitrification-Denitrification / Soluble Phosphorus Removal / Solids Processing System, 18) Super Soils Composting Site, and 19) Mesophilic Digester and Aerobic Digester at Vestal Farm.

The trajectory and spatial distribution of odor and odorants downwind of each of the facilities (the alternative technologies and two controls) under two meteorological conditions (daytime and nighttime) were predicted using a Eulerian-Lagrangian model. The model was validated with experimental data. In general, the odor tended not to extend significantly for 200 meters or 400 meters downwind of any of the test sites during the daytime when the layer of air above the earth's surface is usually turbulent. However, odor was more likely to extend onto neighboring property in the evenings when deep surface cooling through long-wave radiation to space recreates a stable (nocturnal) boundary layer. The relative effectiveness of the different technologies differed somewhat by time of the day. The reason for the difference in rankings between day and night is a function of multiple factors including: a) the surface area that emits

odorants, b) the geometry of the facility (i.e. the distribution of odor sources), and c) the spatial distribution of the relative concentrations of odor intensity.

Modeling was performed using all odor sources at a facility. This model was strengthened during the course of the study with an increased number of testing sites and observations. For this reason, the downwind odor dispersion averages reported here are generally higher than those previously reported. For the farms with animals, the computations were performed with and without the swine houses to determine the contribution of the animals themselves along with the technology components. The swine housing itself plays a significant role in odor downwind, as do odor sources of moderate to moderately high intensity that have a large surface area. These computations also show that the geometric arrangement of the odor sources is an important factor in the dispersion of odor. The Engineering Subcommittee performance criteria recommendations report (Appendix D to the Phase 1 Report dated June 26, 2004) suggested that the operational definition of "substantial elimination" of odor emissions at the property boundary be those emissions that are equal to or less than the "weak" rating of "2" on the 0-8 odor intensity scale.

TECHNOLOGIES EVALUATED

Long distance dispersion of odors is a problem in some communities surrounding large-scale swine operations. The purpose of this research was to determine if alternative waste technologies reduce or substantially eliminate the emission of odor that is detectable beyond the boundaries of the parcel or tract of land on which the swine farm is located. Since all farms were of different sizes, and the property boundaries differed widely with respect to distance from odor sources, it was decided to model predicted odor dispersion at 200 and 400 meters from the closest odor sources in 4 directions (north, east, south and west). Odor dispersion from these alternative technologies was compared to odor dispersion from two control farms using conventional lagoon technology in order to determine if the alternative technologies were superior to conventional procedures in reducing odors downwind. Nineteen sites were evaluated: 1) Stokes farm (standard lagoon technology), 2) Moore farm (standard lagoon technology), along with seventeen alternative technologies including 3) Ambient Temperature Anaerobic Digester and Greenhouse for Swine Waste Treatment and Bioresource Recovery at Barham Farm, 4) Black Soldier Fly, 5) Aerobic Blanket System and Aerobic Digester at Carrolls Farm, 6) "BEST" (solids / liquids separation), Biomass Energy Sustainable Technology Site 1 (FAN® + TFS), 7) "BEST" (solids / liquids separation) Biomass Energy Sustainable Technology Site 2 (Filtramat™ + TFS), 8)"Ekokan" Biofiltration Technology, 9) BELT (Grinnells lab, NCSU campus), 10) Permeable Cover Anaerobic Digester with Aerobic Digester (and for August 2004, Evaporation System) at Harrells Farm, 11) Constructed Wetlands at Howard Farm, 12) Sequencing Batch Reactor and Equalization Tank at Hunt Farm, 13) Koger Gasifier, 14) BELT (LWRFL site), 15) "ORBIT" High Solids Anaerobic Digester, 16) ReCip Solids Separation – Reciprocating Wetland, 17) Super Soils Solids Separation / Nitrification-Denitrification / Soluble Phosphorus Removal / Solids Processing System, 18) Super Soils Composting Site, and 19) Mesophilic Digester and Aerobic Digester at Vestal Farm.

Odor Sources at Control farms

The control farms were the Stokes farm (Control Farm 1) near Scuffleton, North Carolina which had naturally ventilated houses and the Moore farm (Control Farm 2) near Kinston, North Carolina which had fan ventilated houses. Measurements at the Stokes farm included edge of houses downwind, between the houses, house effluent, house effluent pipe, lagoon, downwind of spray field, and at varying distances downwind from the farm. Measurements at the Moore farm included house exhaust fans, between the houses, house effluent, lagoon, downwind of spray field, and at varying distances downwind from the farm.

Land application at control (and alternative technology) farms was not included in the modeling due to the intermittent nature of the process.

Odor Sources at Sites with Alternative Technologies

Ambient Temperature Anaerobic Digester and Greenhouse for Swine Waste Treatment and Bioresource Recovery at Barham Farm

Odor source measurements at the Barham farm included house exhaust fans, between houses, digester effluent lagoon, digester effluent, house effluent, storage pond, biofilter 1 effluent, biofilter 2 effluent, greenhouse effluent, and at varying distances downwind of farm.

Black Soldier Fly

Odor source measurements at the Black Soldier Fly site included BSF solids, BSF basin, and in the BSF hut.

Aerobic Blanket System and Aerobic Digester at Carrolls Farm

Odor source measurements at the Carrolls farm included house exhaust fans, between houses, house effluent, primary (misting) lagoon, primary lagoon ABS, aerobic digester tanks (ABS mist), IESS lagoon, and at varying distances downwind of farm.

BEST (solids / liquids separation), Biomass Energy Sustainable Technology Site 1 (Corbett 1) (FAN® + TFS)

Odor source measurements at BEST/ Corbett 1 included edge of houses downwind side, between houses, house tunnel/pit fan, reception pit, solids separator, house effluent, separated liquids, separated solids, stabilization pond, TFS effluent, solids thickening effluent, feed tank, and at varying distances downwind of farm.

BEST (solids / liquids separation) Biomass Energy Sustainable Technology Site 2 (Corbett 4) (Filtramat™ + TFS)

Odor source measurements at BEST/ Corbett 4 included edge of houses downwind side, between houses, filtramat feed tank, solids separator, house effluent, separated liquids, separated solids, primary stabilization pond, secondary stabilization pond, TFS effluent, filtramat feed tank, post screen, solids thickening tank effluent, and at varying distances downwind of farm.

Ekokan Biofiltration Technology

Odor source measurements at Ekokan included house exhaust fans, between houses, house effluent, solids separator, separated liquids, separated solids, lagoon section 1 (treated water storage), lagoon section 2 (biosolids reservoir), lagoon section 3 (lagoon), equalization tank, biofilter A1 out, biofilter A2 out, biofilter B1 out, biofilter B2 out, biofilter A1 backwash, biofilter A2 backwash, biofilter B1 backwash, biofilter B2 backwash, and at varying distances downwind of farm.

BELT (Grinnells lab, NCSU campus)
Odor source measurements at Grinnells included exhaust fan, solids from belt system, urine from belt system, and at varying distances downwind of exhaust fan.

Permeable Cover Anaerobic Digester with Aerobic Digester (and for August 2004, Evaporation System) at Harrells Farm
Odor source measurements at the Harrells farm included edge of houses downwind side, house effluent, covered lagoon, storage basin, existing lagoons, aerobic basin, evaporation system, surface liquid of covered lagoon, and at varying distances downwind of exhaust fan.

Constructed Wetlands at Howard Farm
Odor source measurements at the Howard farm included house exhaust fans, between houses, solids separator, storage pond, house effluent, pre-settling basin, post-settling basin, settling basin, inner cell influent, inner cell effluent, outer cell influent, outer cell effluent, separated solids, downwind of spray field, at point source of land application of solids, and at varying distances downwind of farm.

Sequencing Batch Reactor and Equalization Tank at Hunt Farm
Odor source measurements at the Hunt farm included edge of houses downwind side, between houses, house effluent, primary lagoon, secondary lagoon, equalization tank, SBR tank, and at varying distances downwind of farm.

Koger Gasifier
Odor source measurements at the Koger gasifier included gasifier solids, gasifier ash, gasifier downwind side at various times during operation.

BELT (LWRFL site)
Odor source measurements at LWRFL included exhaust fan, solids from belt system, urine from belt system, and at varying distances downwind of exhaust fan.

ORBIT High Solids Anaerobic Digester
Odor source measurements at ORBIT included the feedstock, port 1 digester, port 2 digester, port 3 digester, port 4 digester, digester area, and at varying distances downwind of facility.

ReCip Solids Separation – Reciprocating Wetland
Odor source measurements at ReCip included edge of houses downwind side, between houses, house tunnel/pit fan, at ReCip cells, house effluent, lagoon 2 (storage pond), separated liquids, separated solids, day tank, and at varying distances downwind of farm.

Super Soils Solids Separation / Nitrification-Denitrification / Soluble Phosphorus Removal / Solids Processing System

Odor source measurements at Super Soils included edge of houses downwind side, between houses, house tunnel/pit fan, homogenization tank, house effluent, separated liquids, separated solids, homogenization tank, solids separator, lagoon, storage tank, denitrification tank #1, denitrification tank #2, nitrification tank, settling tank, and at varying distances downwind of farm.

Super Soils Composting Site
Odor source measurements at the Super Soils Composting Site included processed solids, stockpiled solids, fresh solids, shavings, compost pile, Compost-a-matic, cure piles, and cotton trash.

Mesophilic Digester and Aerobic Digester at Vestal Farm
Odor source measurements at the Vestal farm included edge of houses downwind side, between houses, settling tank, aerobic digester, clarifier liquid, clarifier solids, water re-use effluent, storage basin, house effluent, covered lagoon effluent, lift station reception pit, mesophilic digester sludge, and at varying distances downwind of farm.

MODEL USED TO EVALUATE DISPERSIONS FROM SWINE FACILITIES

The study design did not allow for direct and easy comparisons of the technologies (there were different size farms, the number and type of pigs varied, some sites were waste processing facilities and thus contained no animals, etc.), and this is the reason odor dispersion modeling was the most accurate way in which to evaluate the technologies and to make comparisons among them. There is no standard way to normalize odor source measurements for number/weights of pigs or to take into account the fact that at some sites only the liquid or solid portion of the waste stream was treated. Therefore, odor dispersion modeling was necessary in order to make fair and accurate comparisons.

The model used here (Schiffman et al., 2003a; Schiffman et al., 2003b; Schiffman et al., 2005) to predict the trajectory of odorous emissions from multiple sources on a swine operation (e.g. housing units, lagoons) has been used previously to predict the long-distance dispersion (Hsieh et al. 1997; Katul and Albertson, 1998; Nathan et al., 2002; Hsieh et al., 2003). This model allows us to utilize the spatial distribution of odor concentrations at multiple emission sources (in steady-state conditions) to predict the spatial distribution of odor (sensations) and odorants (compounds that induce odor sensations) downwind under a variety of meteorological conditions. For this report, dispersion of odor from each swine operation was simulated under two meterological conditions: 1) during daytime when the boundary layer is usually turbulent due to ground-level heating from solar short wave radiation, and 2) during the evening when deep surface cooling through long-wave radiation to space recreates a stable (nocturnal) boundary layer.

The model is based on stochastic differential equations for turbulent diffusion that utilize a Eulerian-Lagrangian approach (Katul and Albertson, 1998; Hsieh et al., 2003). The methodology was developed with support from the National Science Foundation (NSF-EAR and NSF-DMS), the Department of Energy through the National Institute for Global Environmental Change (NIGEC), and Terrestrial Carbon Processes (TCP) programs. This model has multiple advantages over standard Gaussian plume models in that it explicitly considers the velocity variances and covariances among its three components, integral time scale (a measure of eddy coherency), and complex boundary conditions (e.g. complex release points, surface boundary conditions). Other types of models were used by our dispersion experts before applying this model (e.g. puff model and other EPA dispersion models), and this model was found to best represent the data. Other models gave higher numbers for predicted downwind dispersion. The probable reason for this is that the standard Gaussian plume models do not do a sufficient job of taking into account factors such as complex release points, surface boundary conditions, eddy coherency and velocity variances.

Data used to predict the trajectory and spatial distribution of odor and odorants downwind from each facility using the model was collected in the following manner. The geographical area containing the odorant sources for each facility was partitioned into 10 meter^2 grids based on satellite photographs and architectural drawings. The relative odorant concentrations present at each grid point that corresponded to an odor source were determined from on site measurements using a trained odor panel. These data were supplemented and corroborated by samples collected in the field and evaluated in the laboratory by the trained panel. Great care was taken during the field measurements to avoid confounding odors from off-site as well as on-site sources which were not part of the system being analyzed. If the wind was unfavorable for measurement of a particular odor source at a given moment, the measurement of that source was taken at a later time when the wind had changed direction. In some cases where there was a system component which could not be isolated from confounding odor sources, due to wind factors and/or placement of odor sources to be measured, the odor intensity of the liquid or solid waste sample was used for the odor dispersion modeling. Panelists determined the intensity of the odor at each of the multiple odor sources on each farm using two methods: 1) 9 point rating scale (0 = none at all, 1 = very weak, 2 = weak, 3 = moderately weak, 4 = moderate, 5 = moderately strong, 6 = strong, 7 = very strong, 8 = maximal) and 2) using a portable olfactometer to determine the odor threshold.

In order to perform the dispersion modeling for odor, it is necessary to determine a mathematical relationship between odor perception and measurable concentration of odorants. The model utilizes hypothetical "odorous air parcels" to predict downwind odor intensity using an equation that was confirmed by experimental downwind odor measurements in the field during daytime measurements using a worst case scenario (without considering spraying). Odorous air parcels are used for modeling rather than sensations themselves because it is the physical odorants rather than sensations that are dispersed. For the examples illustrated in this report, we developed an equation to represent the relationship between perceived odor intensity determined in the field by a trained odor panel and "odorous air parcels" released by the mathematical model at each 10 meter^2 grid point that decay over distance:

$$y = 33.546\ e^{x}$$

where x is the odor intensity on a scale from 0 to 8 (given above) and y is the number of "particles" released. When odor is maximal (e.g. rated 8 on the scale above) at a specific 10 meter^2 grid point, the number of odorous air parcels released will be 100,000. When odor is rated moderate strong (e.g. rated 5), only 4,978 odorous air parcels will be released. When no odor is perceived at a specific 10 meter^2 grid point (e.g. rated 0), no odorous air parcels will be released from the 10 meter^2 grid point. After the dispersion modeling was performed and it was time to convert parcel numbers back into intensity, any number under 34 was considered to be "0" or no odor. This was to avoid difficulties in introducing negative numbers that arise due to logarithmic equations. The model predicts the decay over distance when odorous air parcels (related monotonically to human odor intensity ratings) are released from each of the 10 meter^2 grid points of an odorous facility. The model is then reconfirmed by experimental field measurements.

The downwind odor dispersion averages reported here are generally higher than those previously reported in the Phase 1 report. During the course of the investigation, the modeling was enhanced by additional data collected to better predict downwind odor dispersion. During the early stages of the experiment, as reported in Phase 1 of the Smithfield Agreement/Project OPEN research, the model usually predicted lower odor levels at 200 and 400 meters downwind than what was actually being perceived at those distances. Several improvements were made to the model which made it more reliably predictive of downwind dispersion of odor. First, it was decided that it was appropriate to calculate the average odor intensity of only the positive (e.g non-zero) odor intensities in each grid point at the 200 and 400 meter distances, instead of including the zero-intensity grid points at those distances in the average as was done earlier. The reason for this was that any odorous plumes that reach these distances are significant, and these plumes are not negated, nor made less significant by the presence of non-odorous grid points; in reality these odorous peaks are present and perceptible. Second, it was decided to increase the ratio of seed points (odorous parcels) released from a grid point to those included in the dispersion calculation, from 50:1 to 10:1. In other words, early in the process of modeling odor dispersion, for every 50 odorous parcels released from any grid point (based on the odor intensity of that grid point as described above and in previous reports) 1 was mathematically "dispersed", with the assumption that the other 49 (out of 50) odorous parcels would behave in the same manner as the one calculated. The newer modeling process has a higher resolution, with 1 odorous parcel's dispersion calculated for every 10 released from any grid point. Third, the earlier modeling utilized a linear method (instead of an exponential one) for determining the number of odorous parcels emitted from a given grid point, from which there is an uneven release of parcels within that grid point. For example, the earlier method for calculating the number of odorous parcels released from a grid point in which half of the 10 meter^2 area has an odor intensity of 2 and the other half's odor intensity is 6, would have been to calculate the odor intensity of the entire grid point as 4, and to determine the number of odorous parcels released from that grid point based on an odor intensity of 4. However, since the relationship between odor intensity and odorous air parcels is exponential and not linear, it is more accurate to take this into account when calculating the number of parcels released from a grid point which has different areas of varying odor intensity.

RESULTS

The dispersion plots derived from the odor dispersion modeling are shown in Figures 1 to 19 below; they illustrate the predicted odor intensity for each facility shown during the day and at night utilizing human odor intensity measurements. Human threshold data and hydrogen sulfide measurements provided similar dispersion plots as those for human intensity rating measurements. The plots utilize the logarithmic values of the number of odorous air parcels. That is, the number of odorous air parcels that reach any grid location downwind on dispersion were plotted because odor intensity is exponentially related to odorant concentration.

After modeling, the farms were then compared using the following procedure. First, the mean of the non-zero elements of the grid points at 200 meters from the source of odor closest to the downwind property line was determined for 4 directions (north, east, south, and west). For "North" (i.e. with a wind blowing to the north), the average was calculated at 200 meters from the northernmost odor source. In order to remove directional dependence in rankings, the average in each of the 4 directions was calculated. The farms were then compared with respect to mean odor intensity at 200 meters from the edge of the last odorous source in the direction of the wind for both day and night. The farms were also modeled with the houses removed and ranked using the same model. This procedure was repeated at 400 meters for both day and night. The results of the dispersion modeling are shown in Tables 2-6 below. Overall, the predicted odor dispersion was found to be greater at nighttime than during daytime at all farms which is consistent with field reports from individuals living nearby.

The reason for the difference in rankings between day and night is a function of multiple factors: a) the surface area that emits odorants; b) the geometry of the facility (i.e. the distribution of odor sources); and c) the spatial distribution of the relative concentrations of odor intensity. A farm with odor sources that align extensively in the direction of the wind will lead to higher odor intensities downwind at night than during the day because the most distant odor sources will reach further due to reduced mixing. Conversely, this same farm during the day will allow for greater odor dispersion within its own boundaries.

It is important to note that in some cases, the downwind odor intensities predicted by the model are higher for certain farms without houses than with houses. This is due to the fact that the location of the 200 and 400 meter sites for downwind predicted odor intensities as calculated were based on the location of the odor source closest to the direction of the dispersion (north, east, south or west), and sometimes when the houses are removed, a significant odor source then becomes closer to the 200 and 400 meter downwind location.

Odor dispersion modeling was performed with and without the houses for the facilities containing animals. These dispersions are shown below in Figures 1-19. Table 1 is a correlation matrix for field data, for all farms combined. Tables 2-6 give average downwind predicted odor intensities for all test sites, for night and day, for 200 meters and 400 meters downwind.

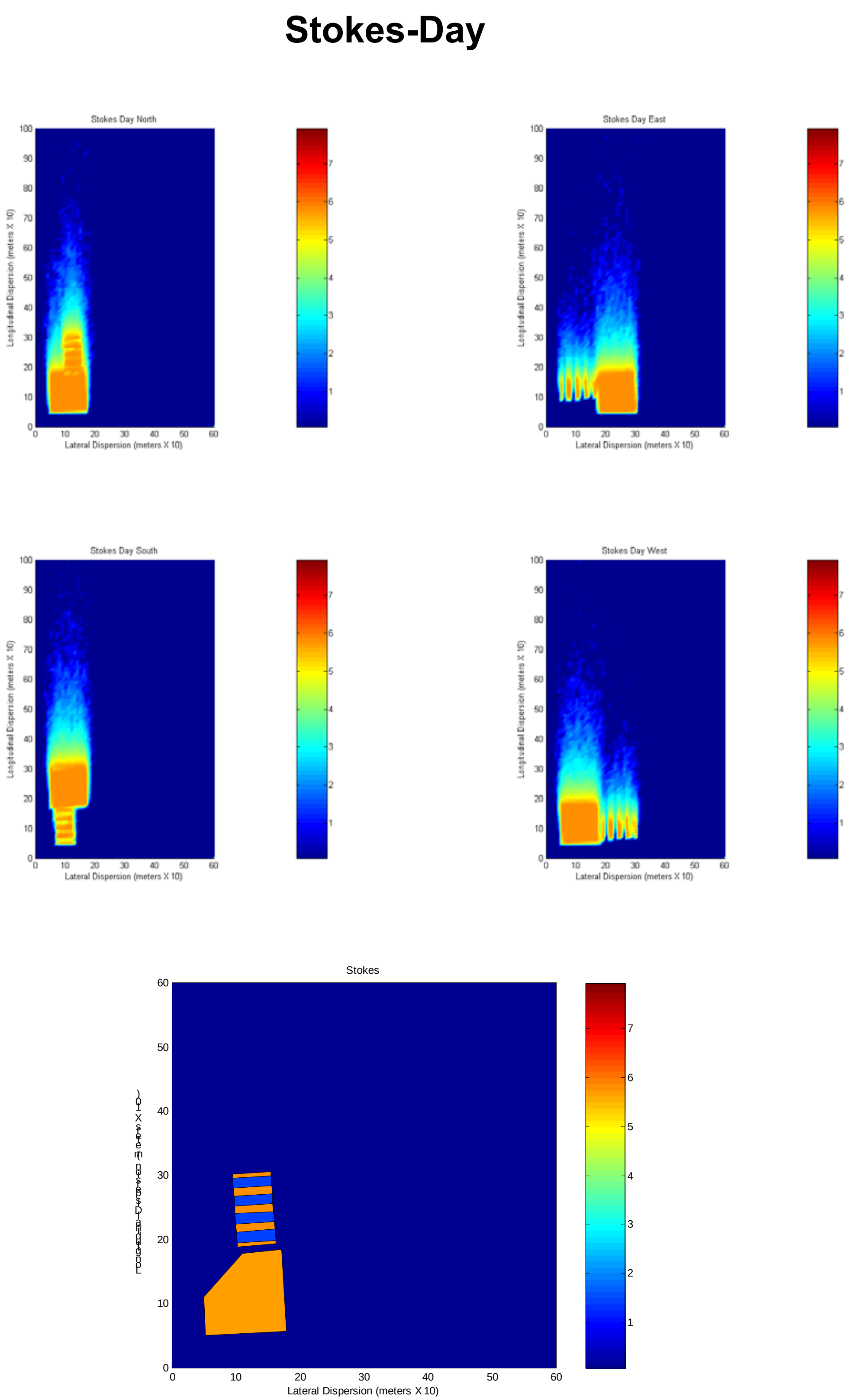

Figure 1a: Stokes farm: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Stokes-Night

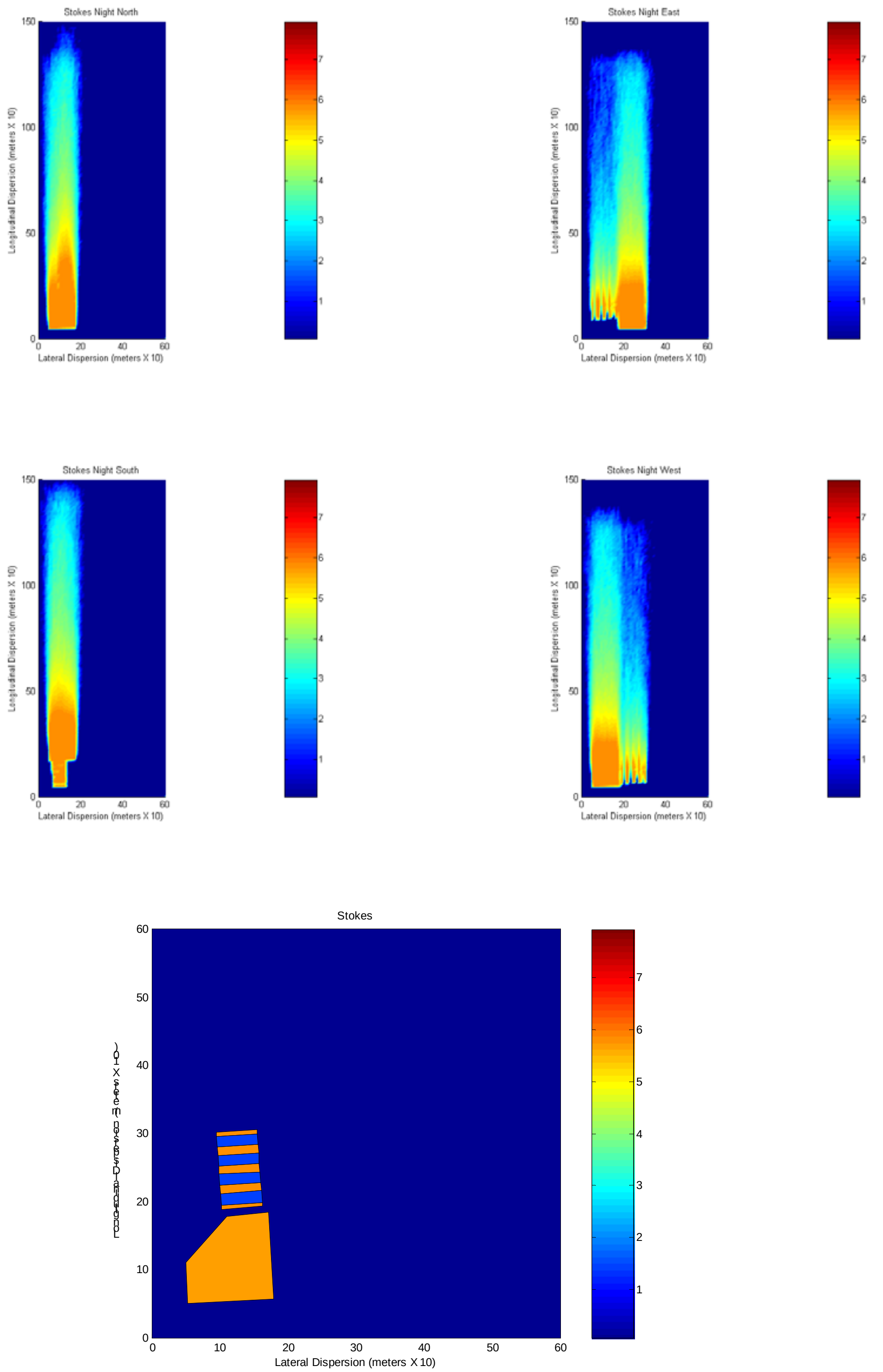

Figure 1b: Stokes farm: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

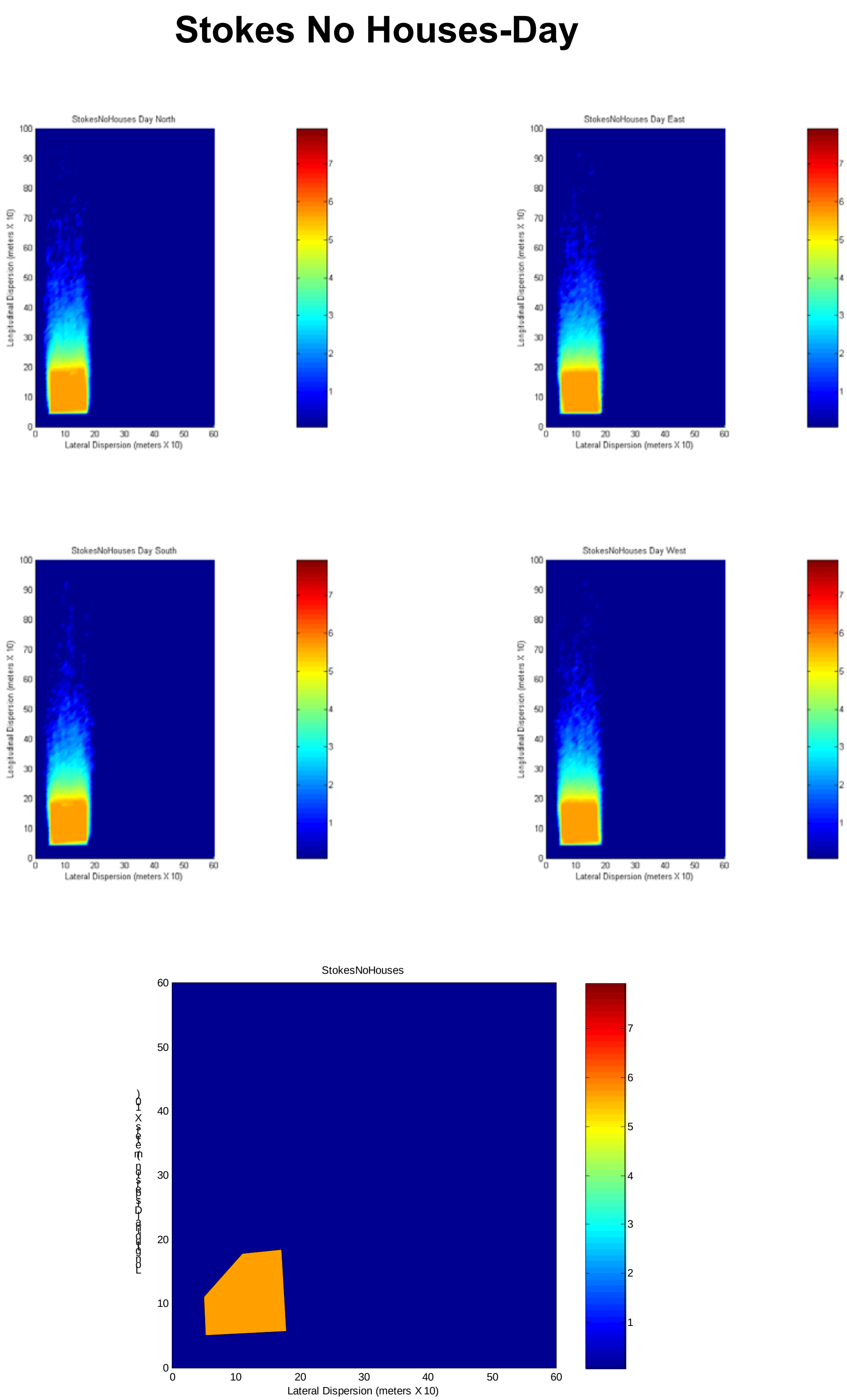

Figure 1c: Stokes farm without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Stokes No Houses-Night

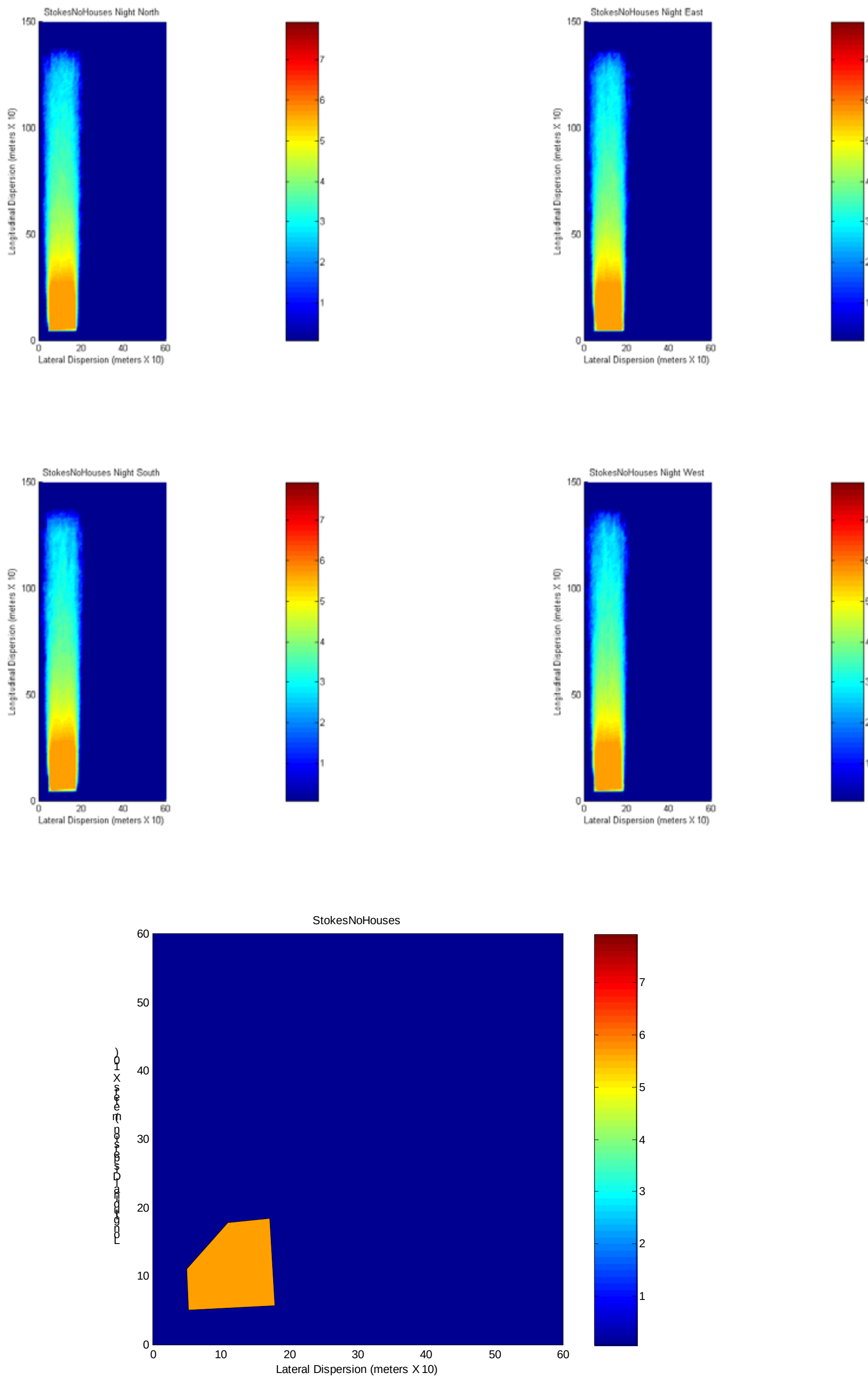

Figure 1d: Stokes farm without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Moore-Day

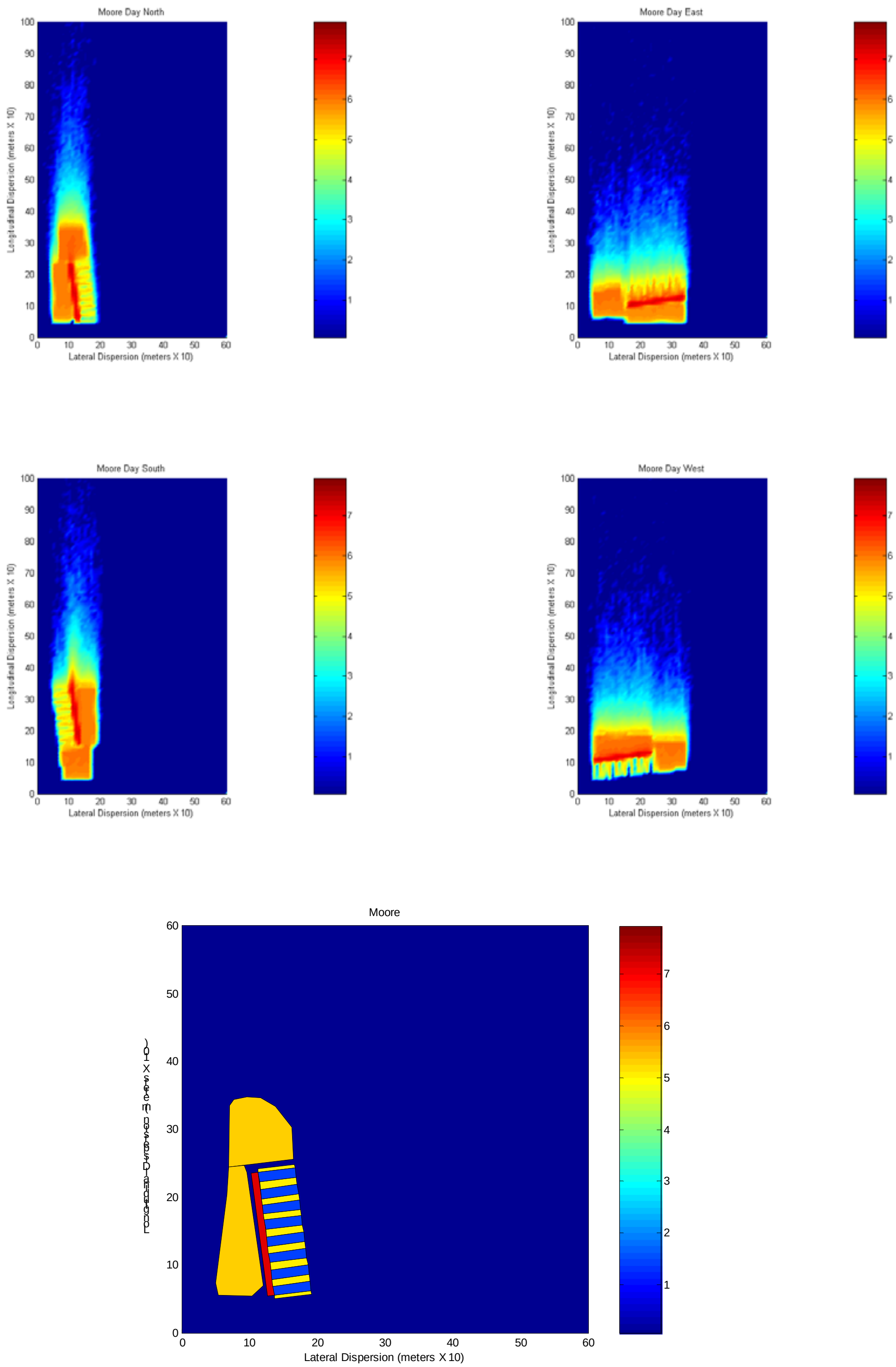

Figure 2a: Moore farm: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Moore-Night

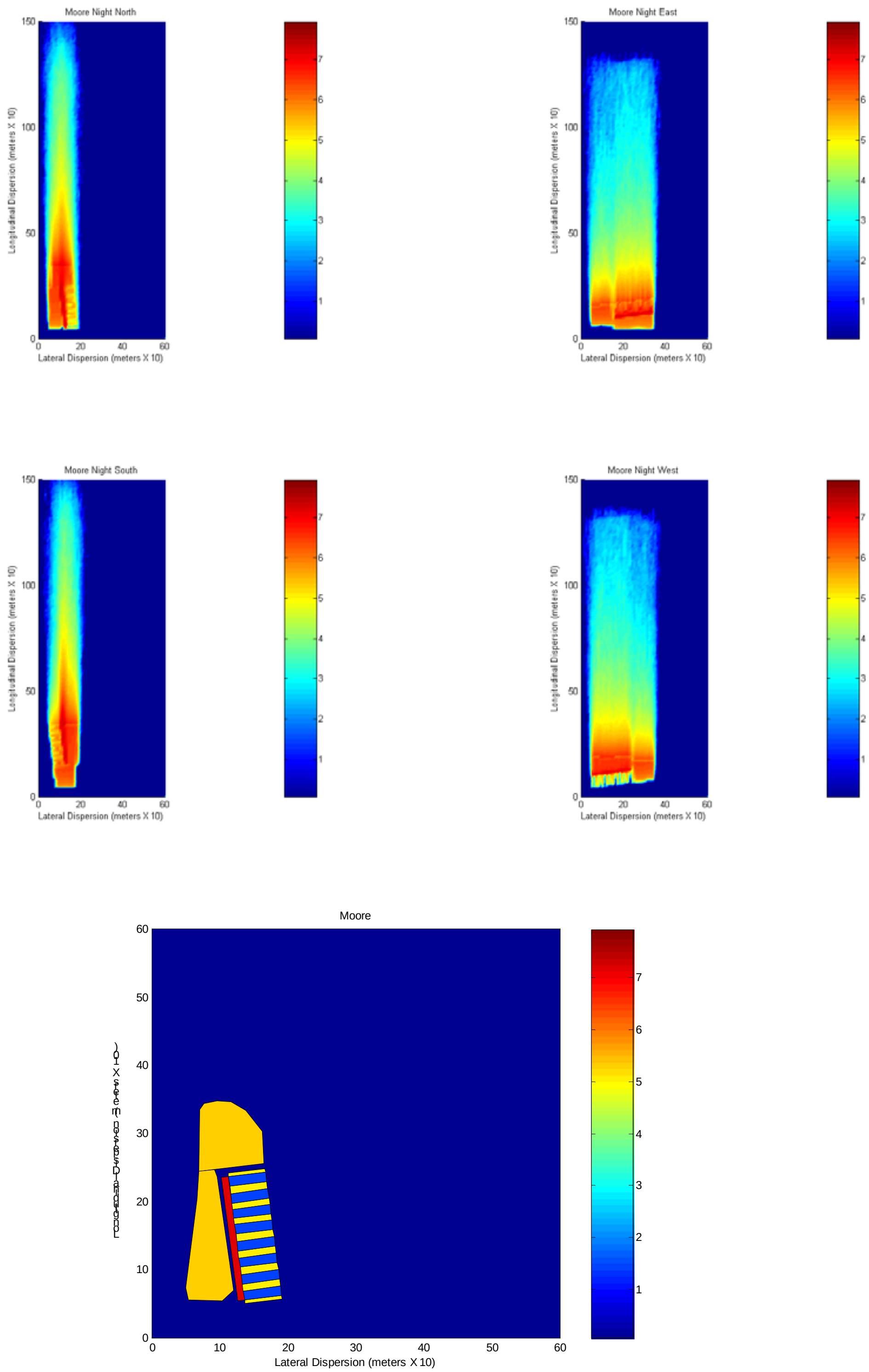

Figure 2b: Moore farm: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Moore No Houses-Day

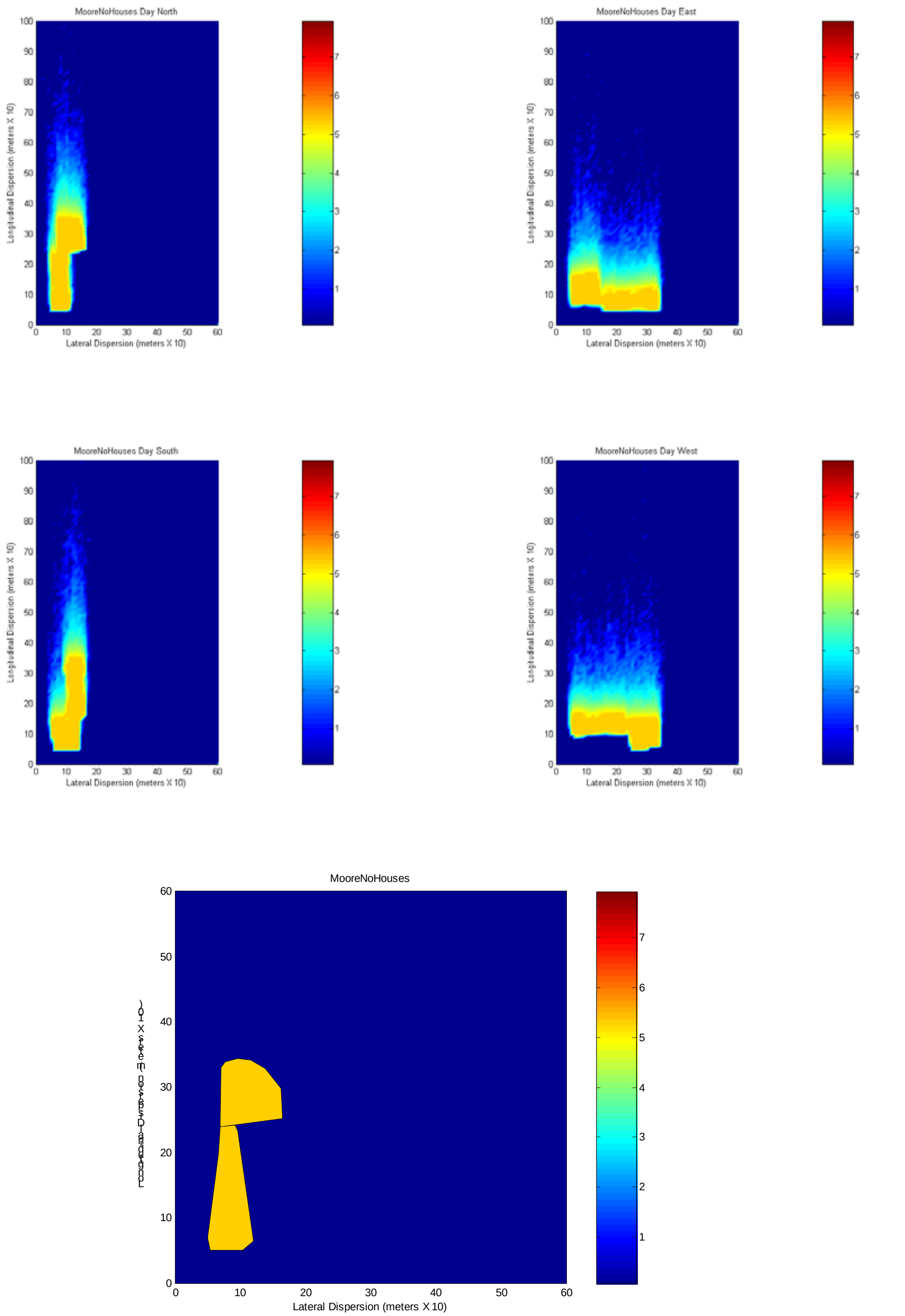

Figure 2c: Moore farm without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Moore No Houses-Night

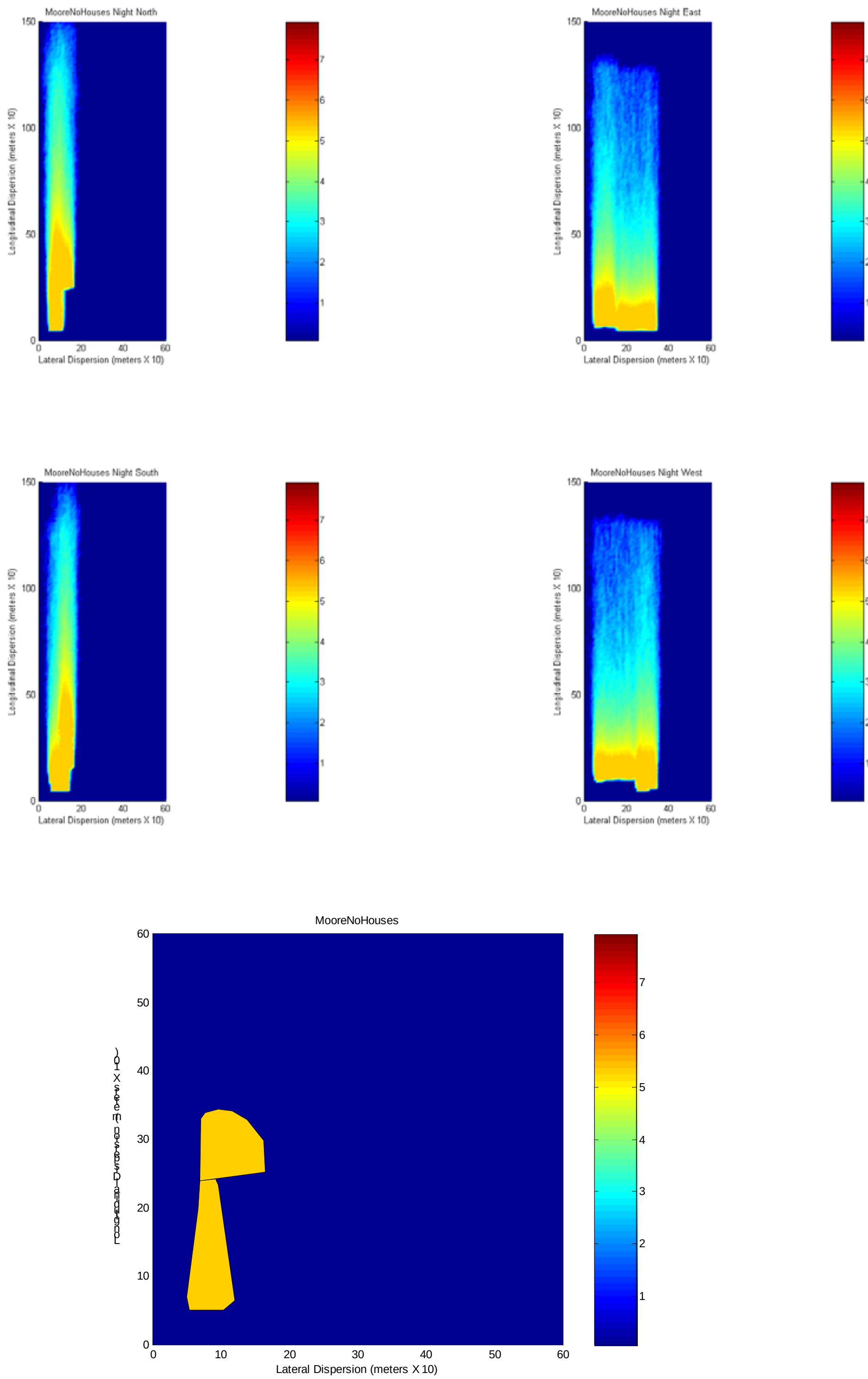

Figure 2d: Moore farm without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Barham-Day

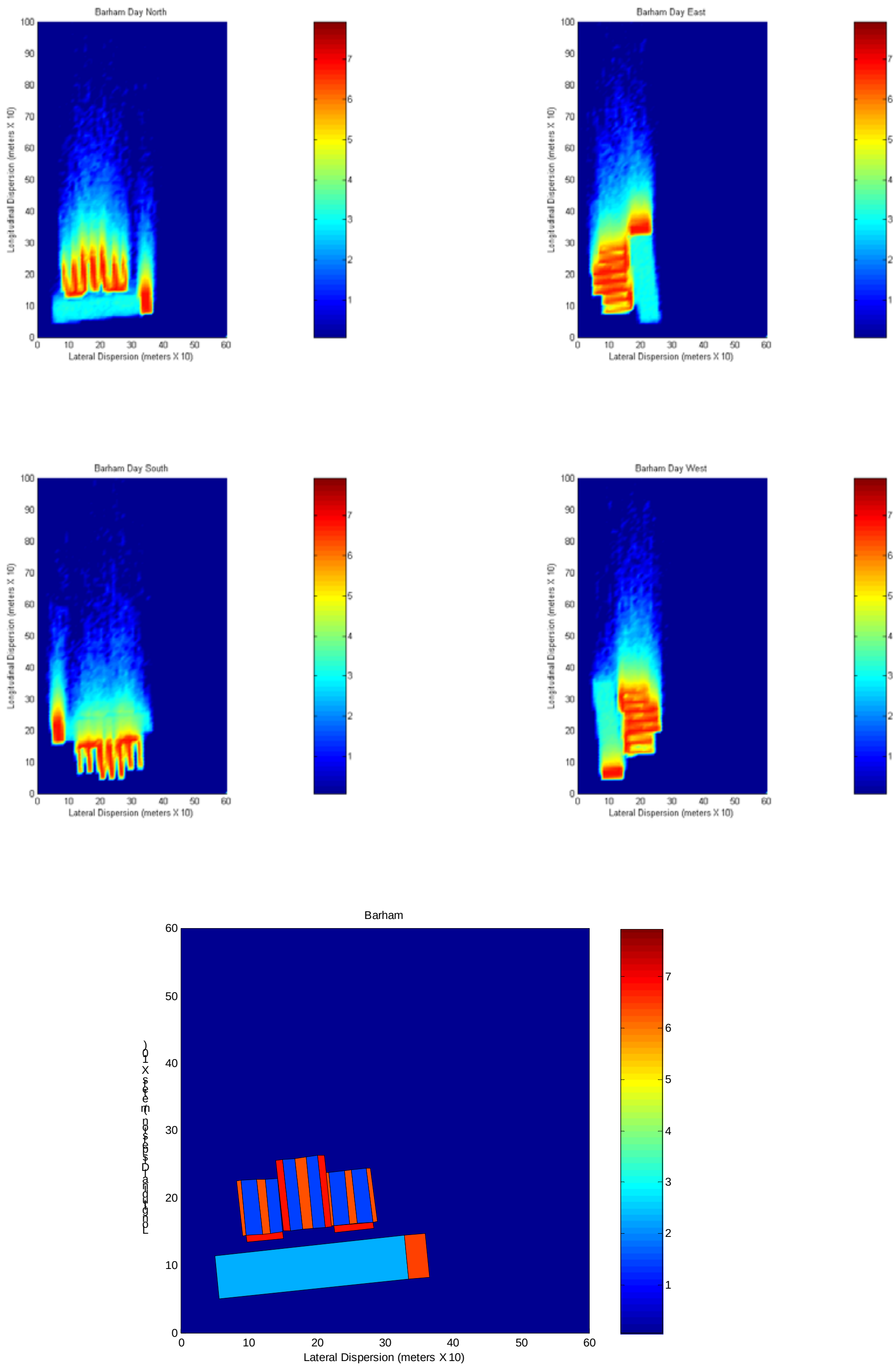

Figure 3a: Barham farm: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Barham-Night

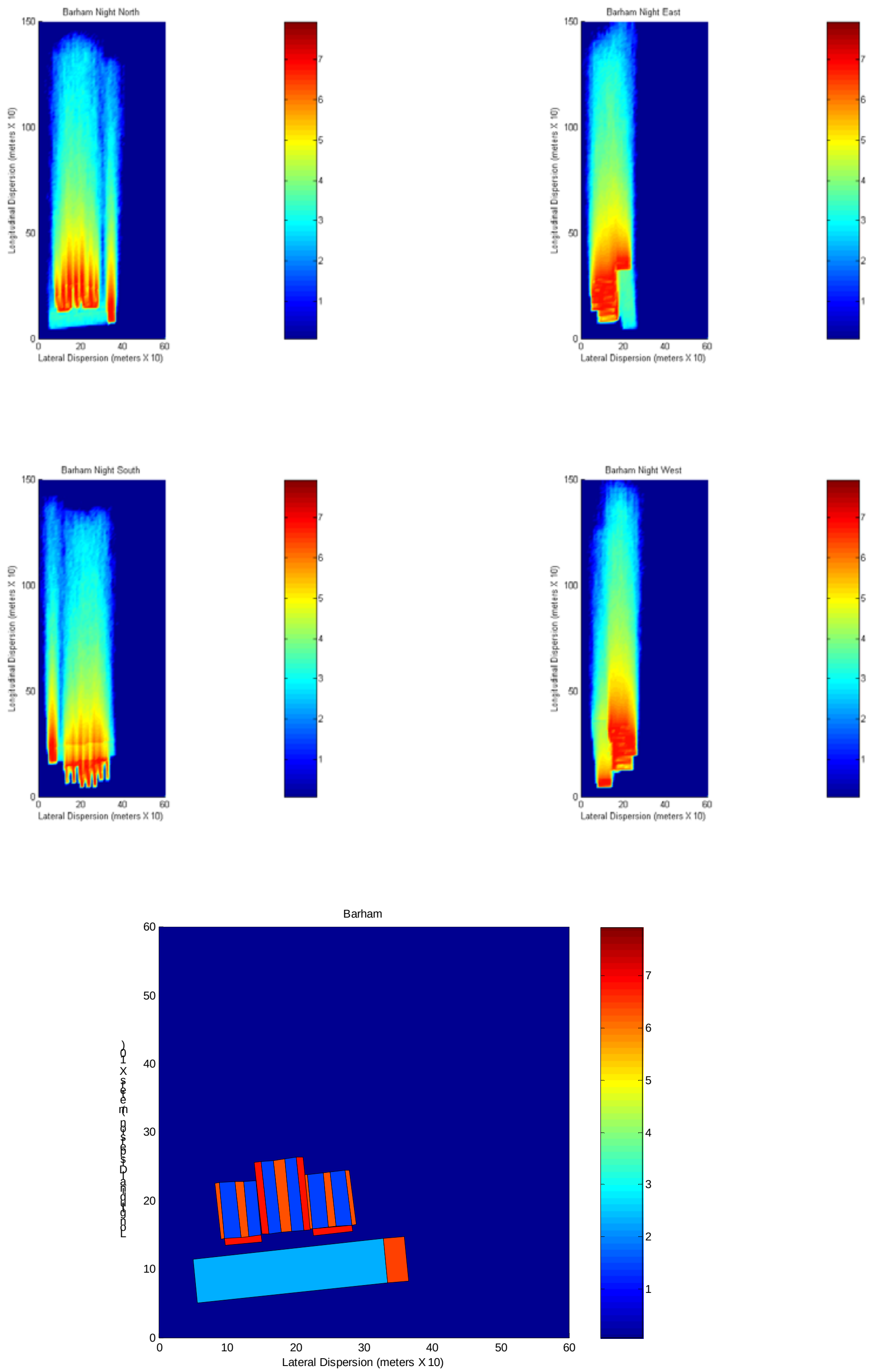

Figure 3b: Barham farm: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Barham No Houses-Day

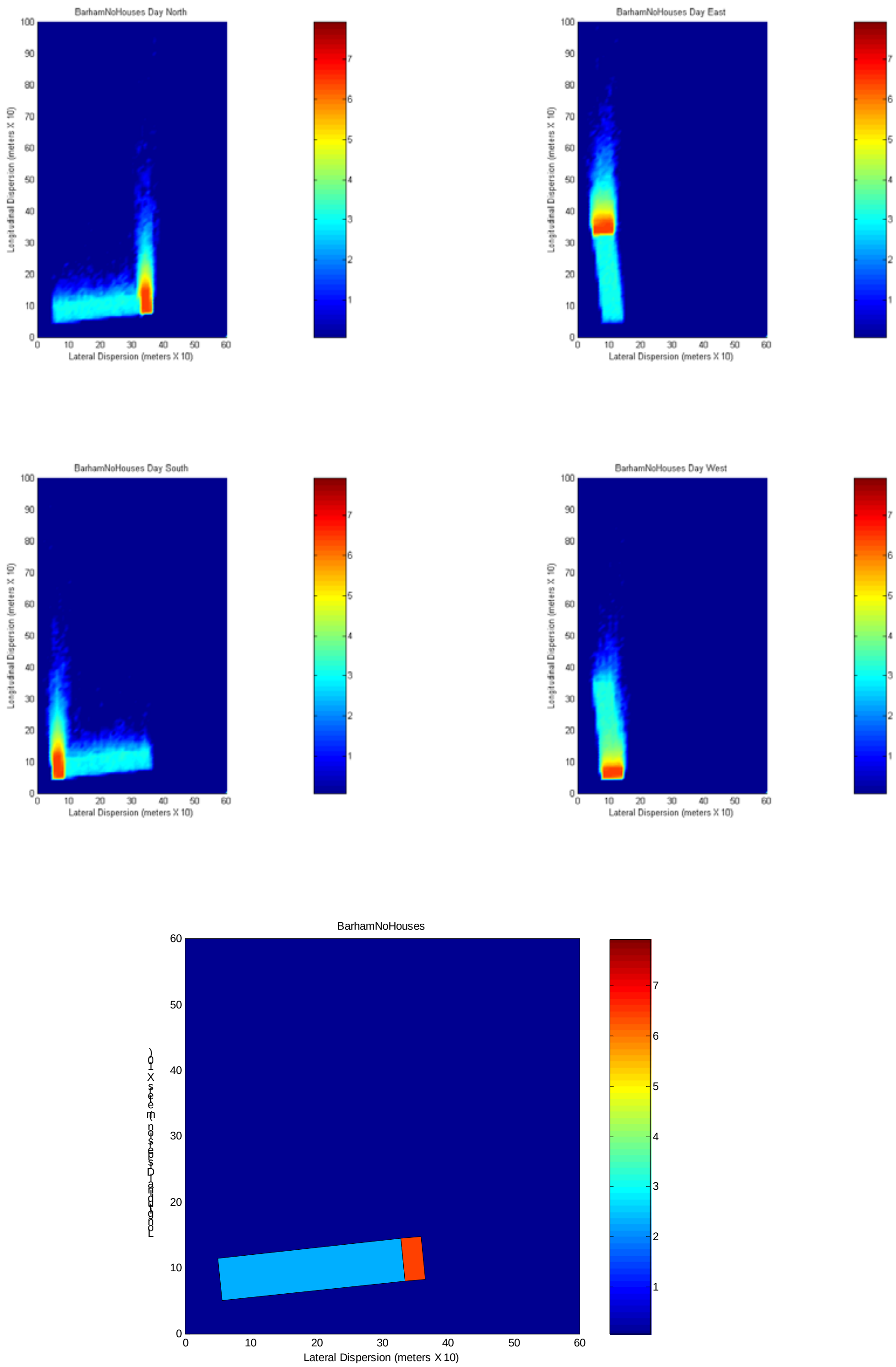

Figure 3c: Barham farm without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Barham No Houses-Night

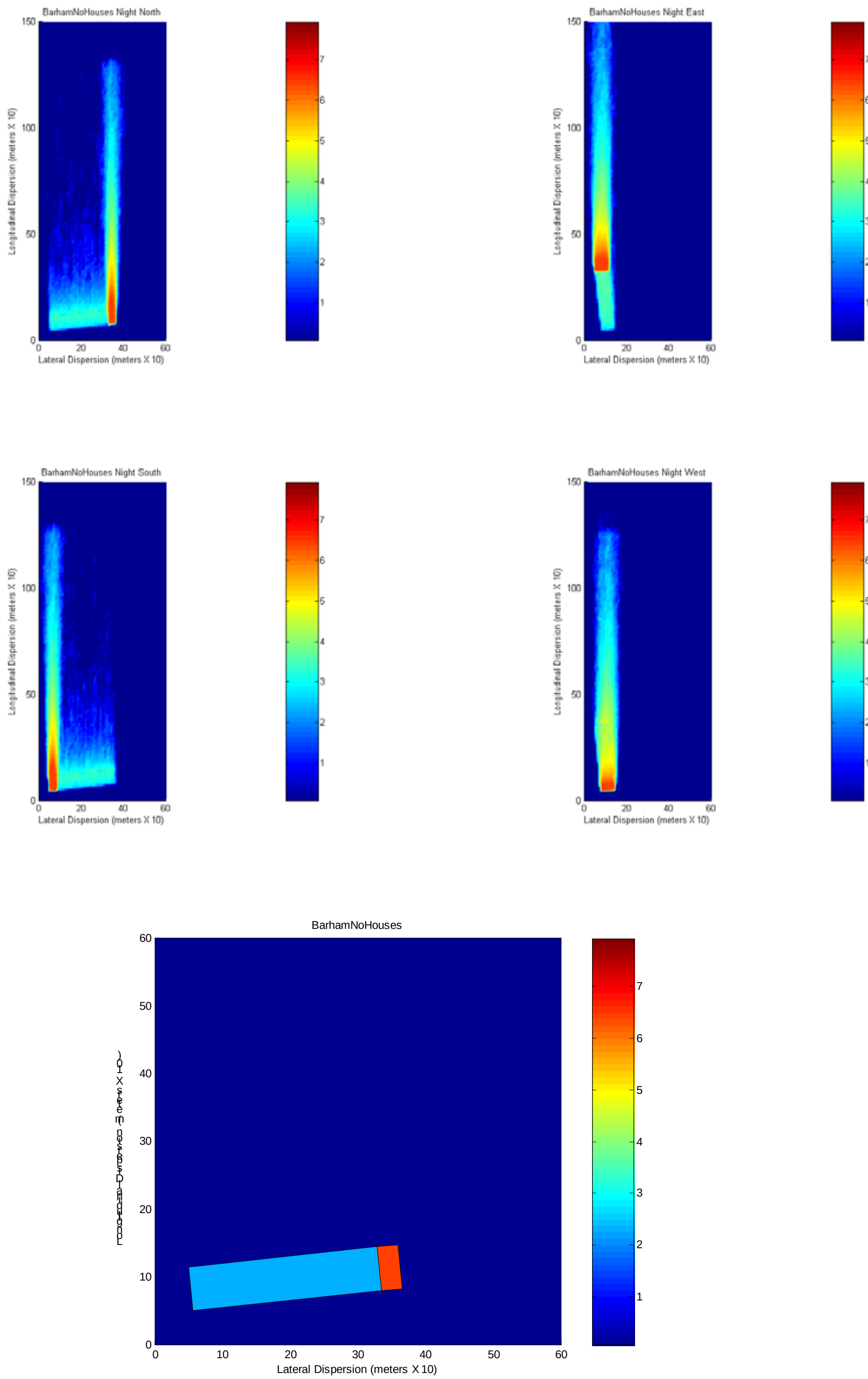

Figure 3d: Barham farm without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Black Soldier Fly-Day

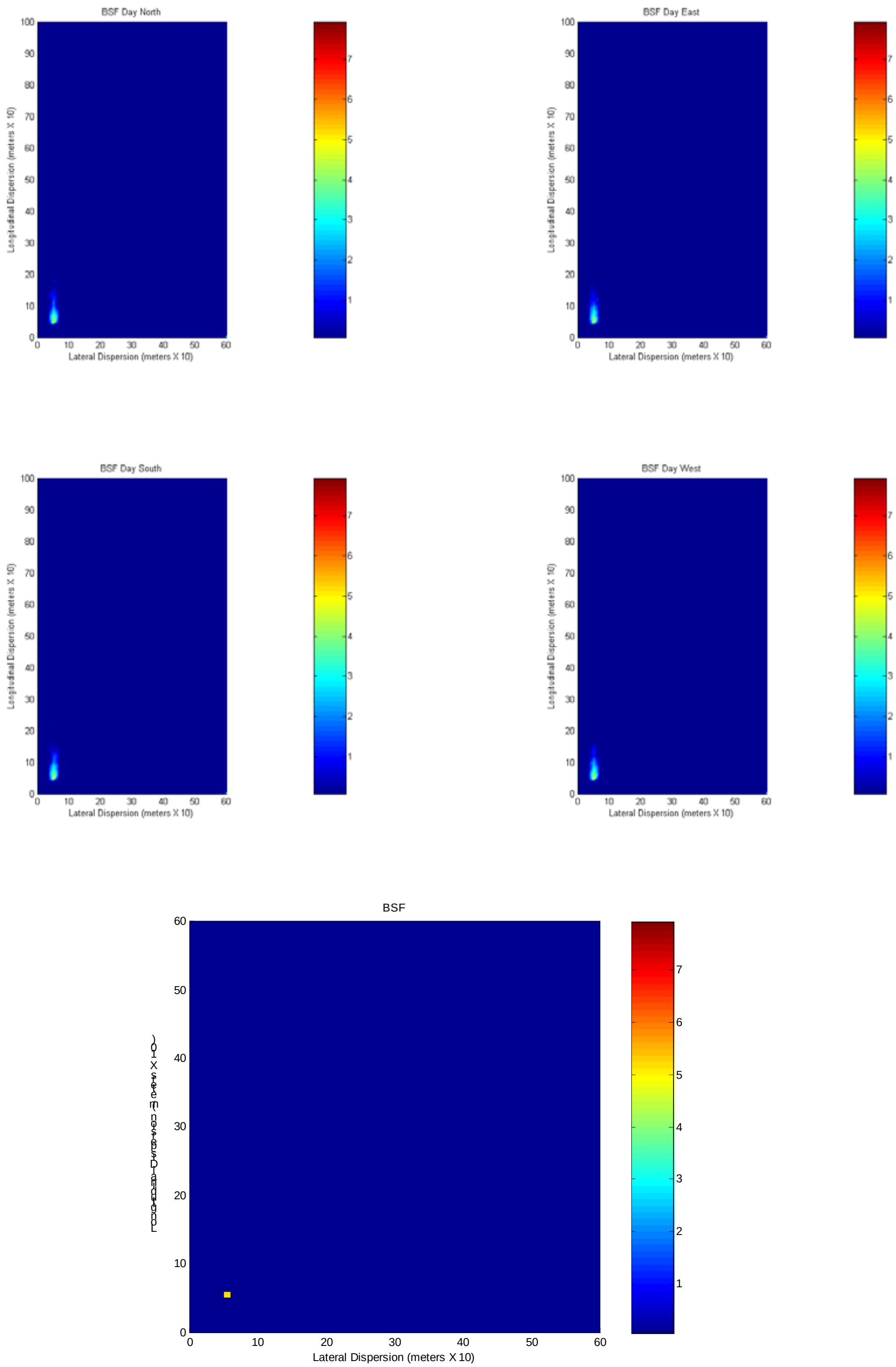

Figure 4a: Black Soldier Fly: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Black Soldier Fly-Night

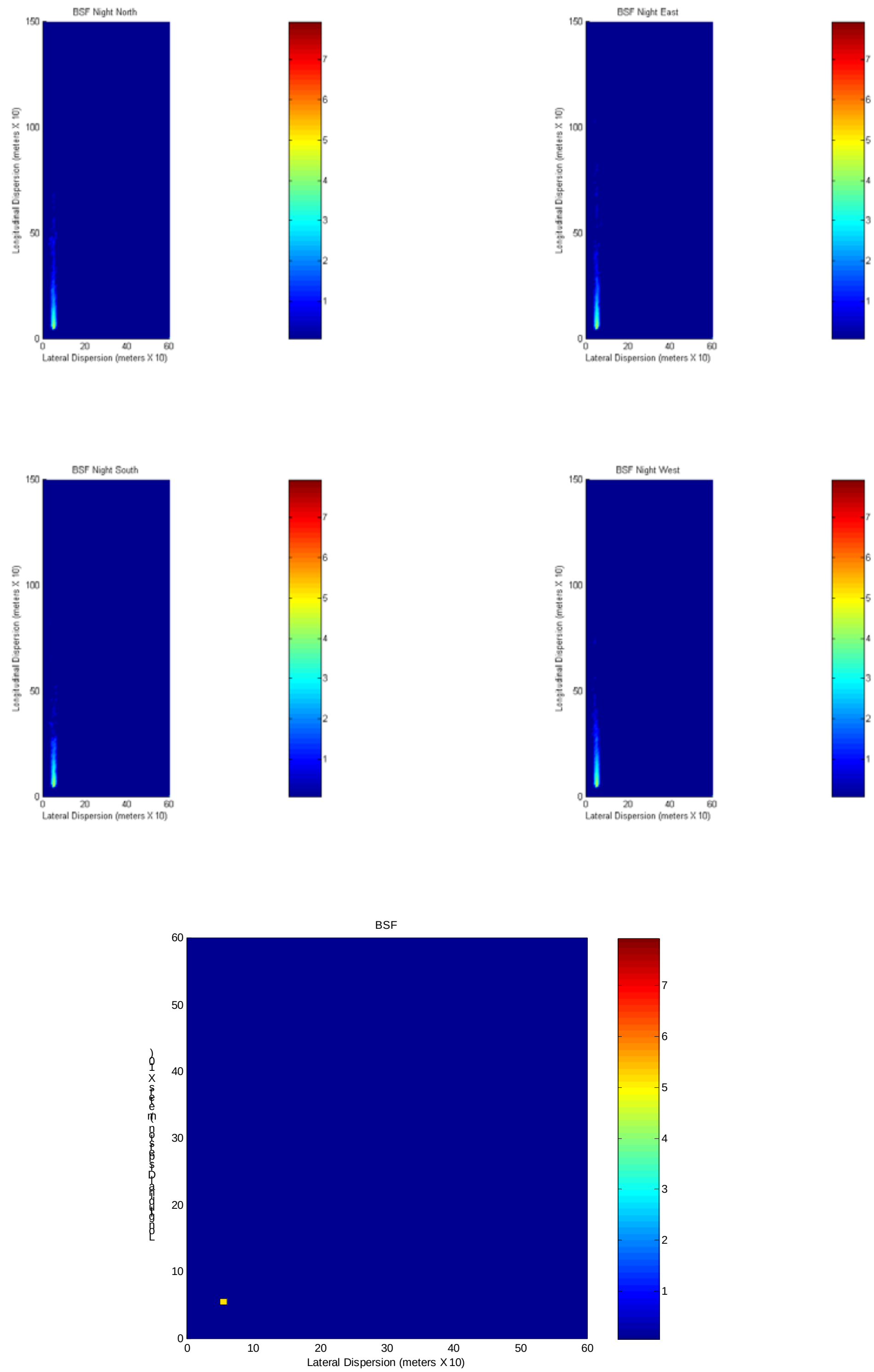

Figure 4b: Black Soldier Fly: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Carrolls Average-Day

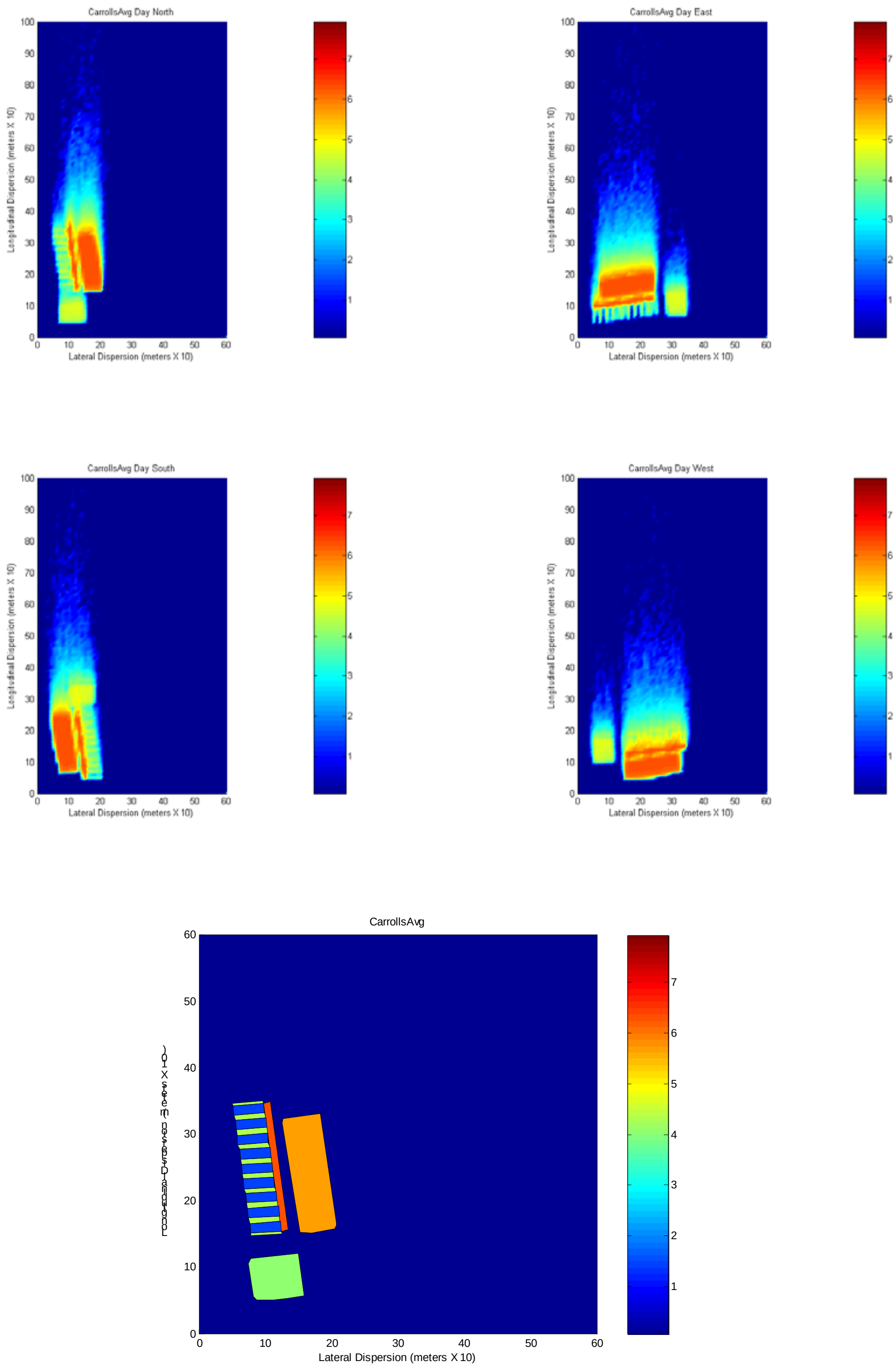

Figure 5a: Carrolls farm average: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Carrolls Average-Night

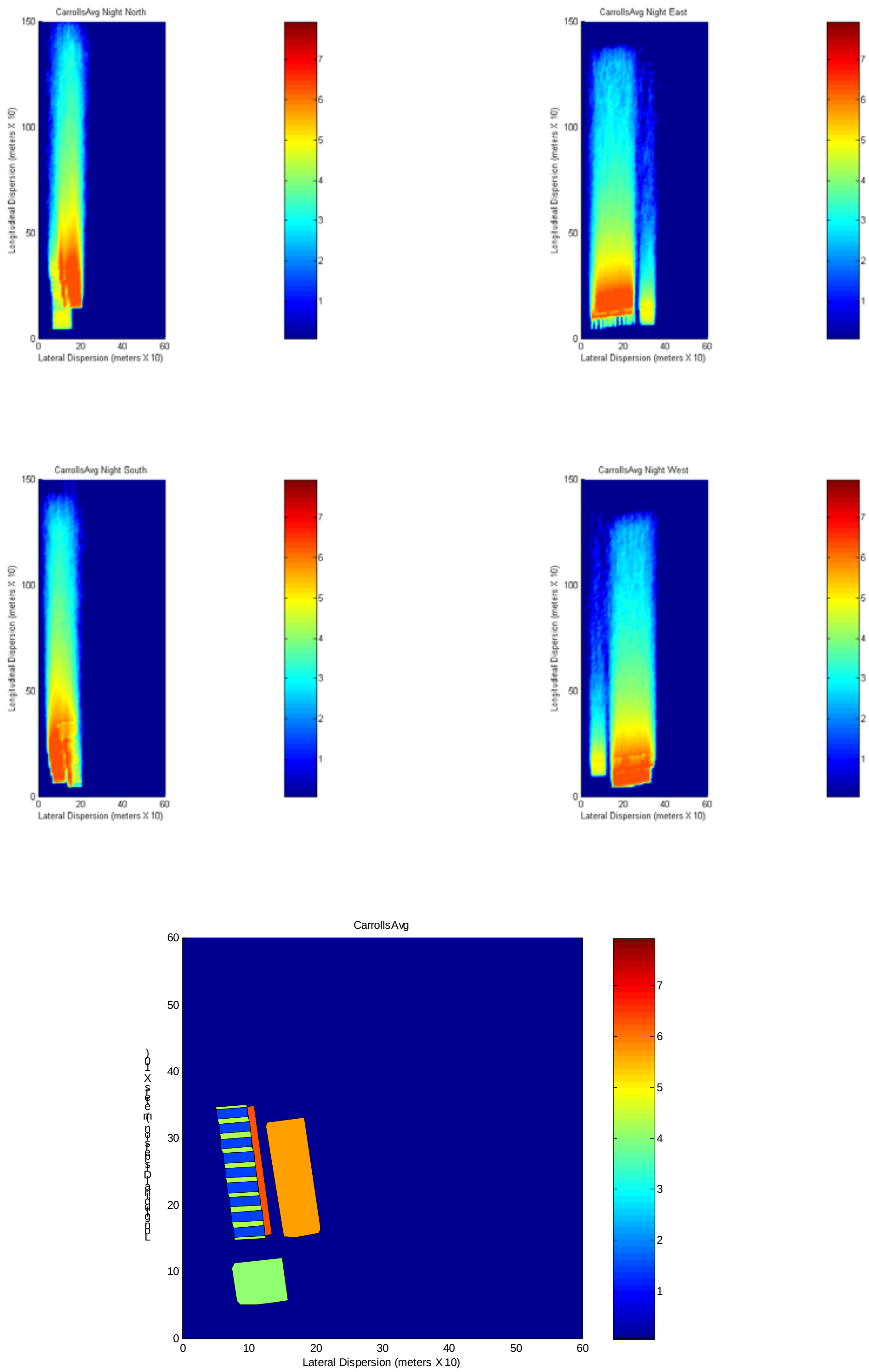

Figure 5b: Carrolls farm average: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Carrolls Average No Houses-Day

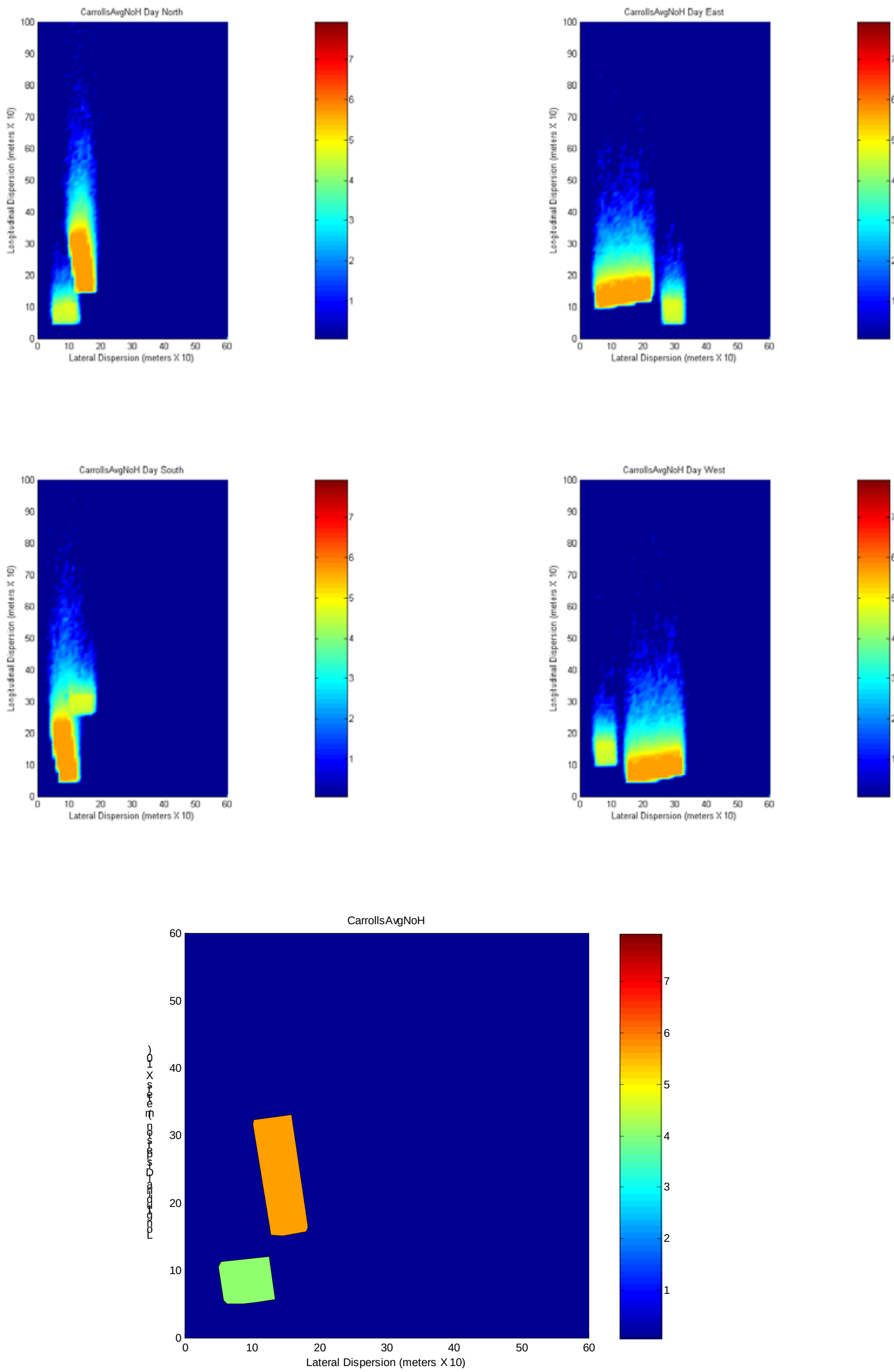

Figure 5c: Carrolls farm average without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Carrolls Average No Houses-Night

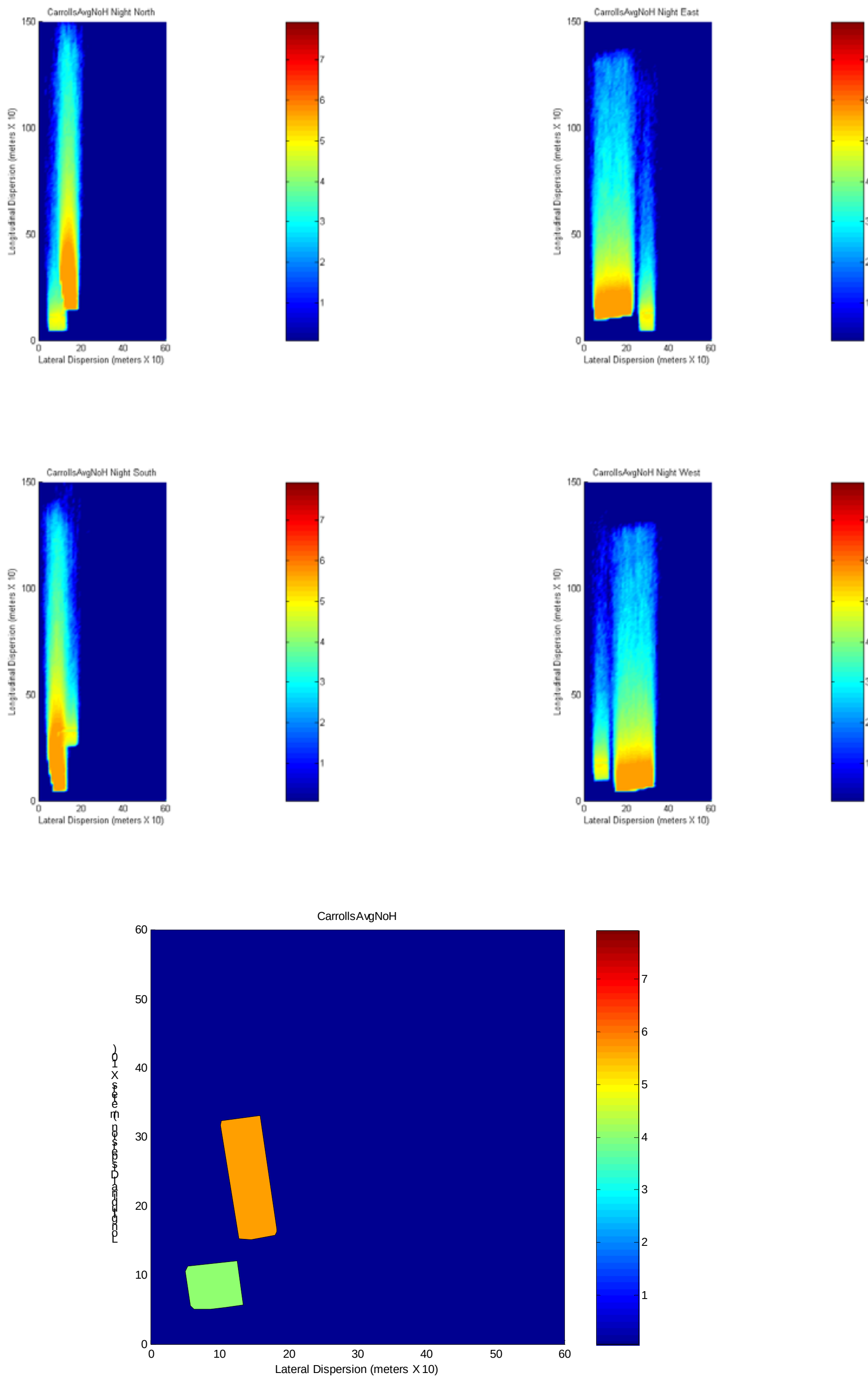

Figure 5d: Carrolls farm average without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Carrolls April 2004-Day

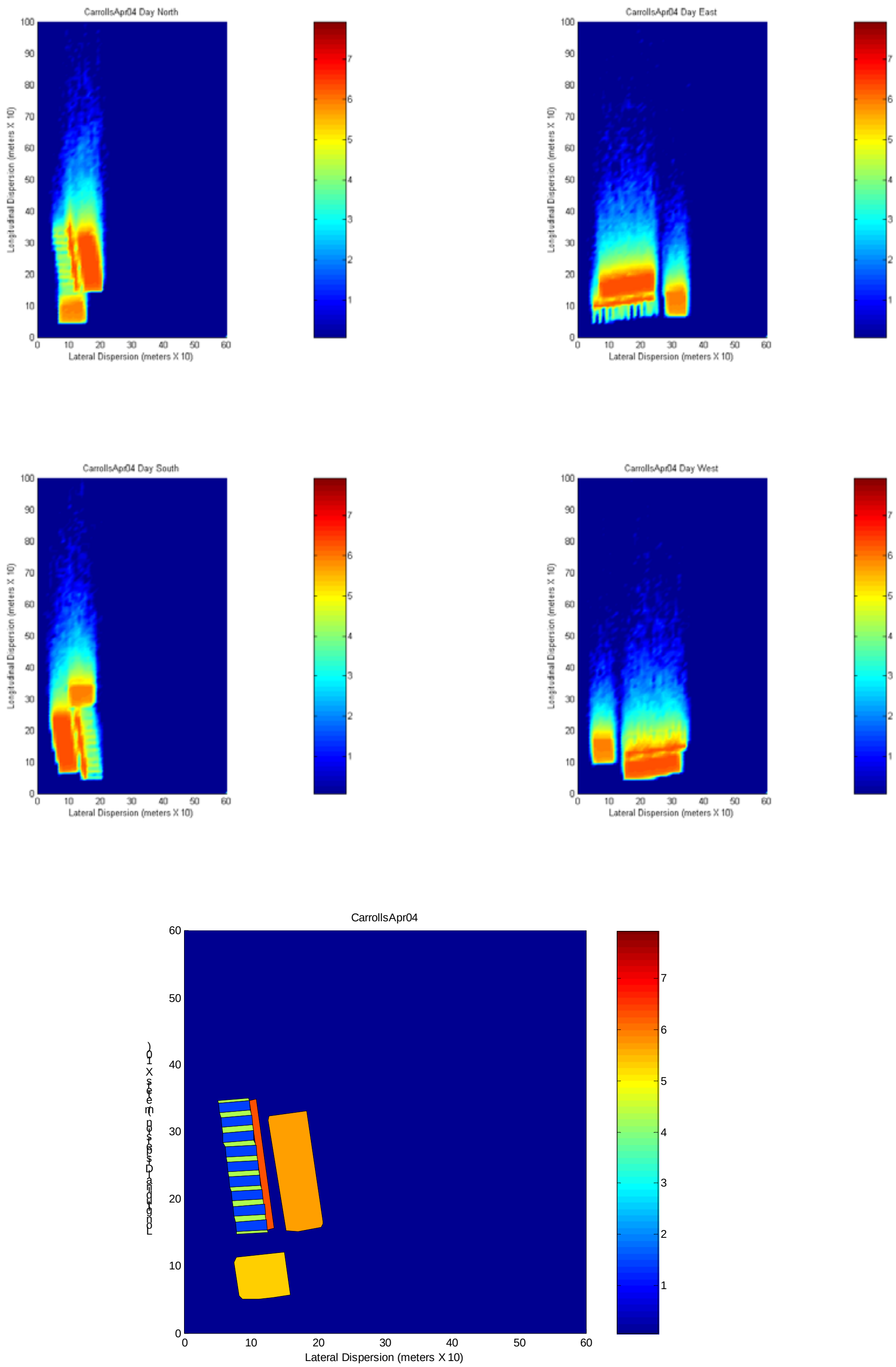

Figure 5e: Carrolls farm April 2004: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Carrolls April 2004-Night

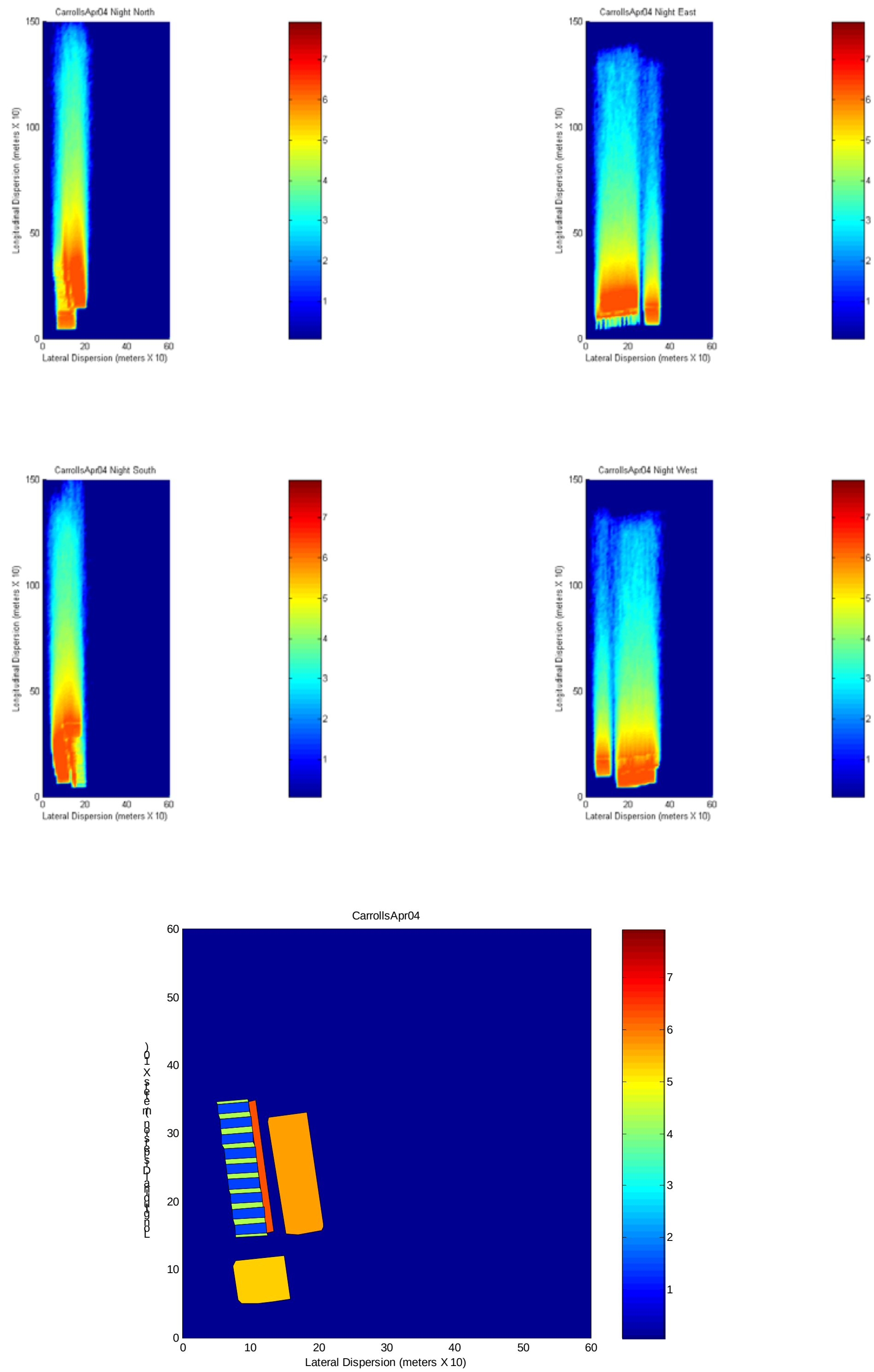

Figure 5f: Carrolls farm April 2004: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Carrolls April 2004 No Houses-Day

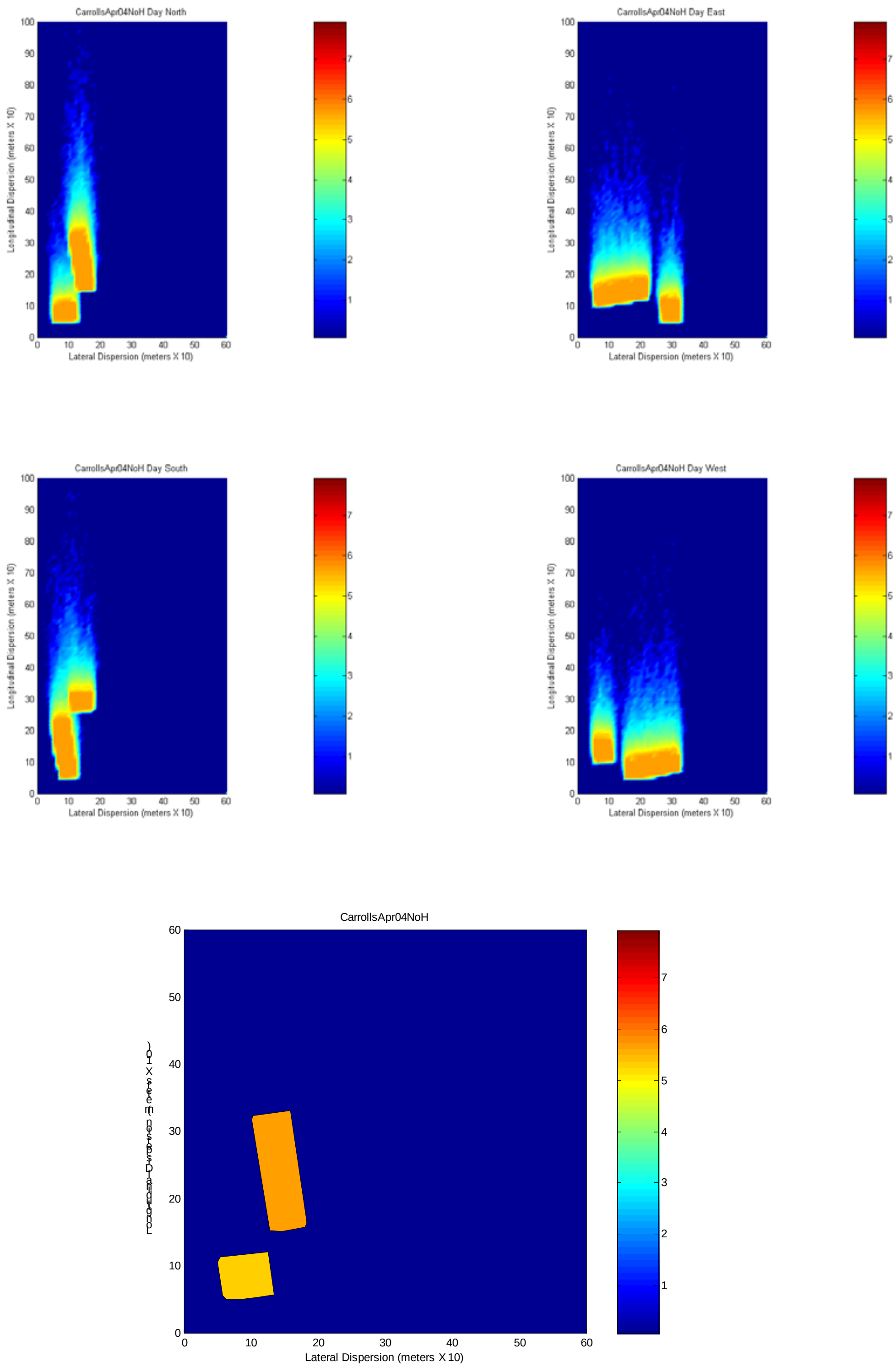

Figure 5g: Carrolls farm April 2004 without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Carrolls April 2004 No Houses-Night

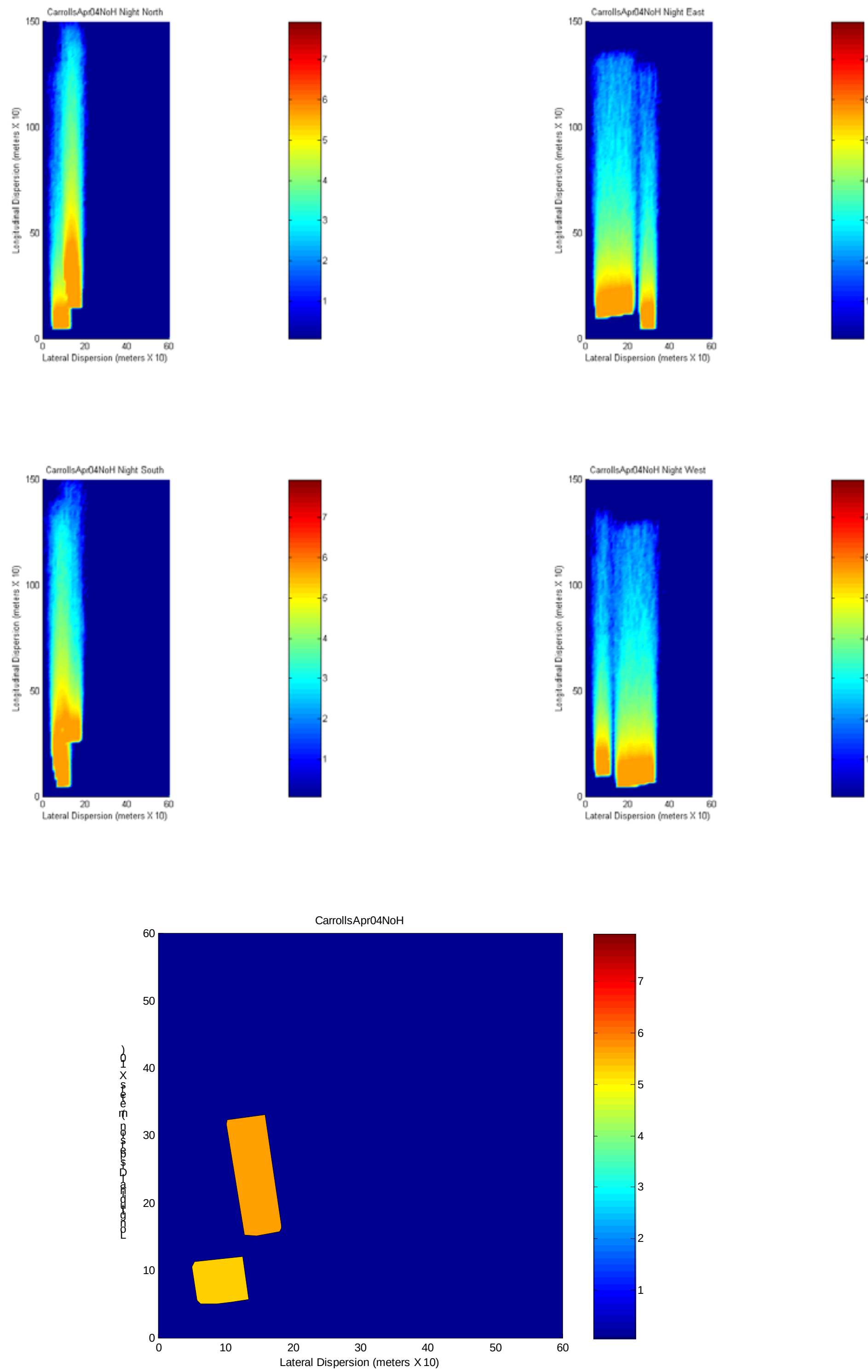

Figure 5h: Carrolls farm April 2004 without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Carrolls June 2004-Day

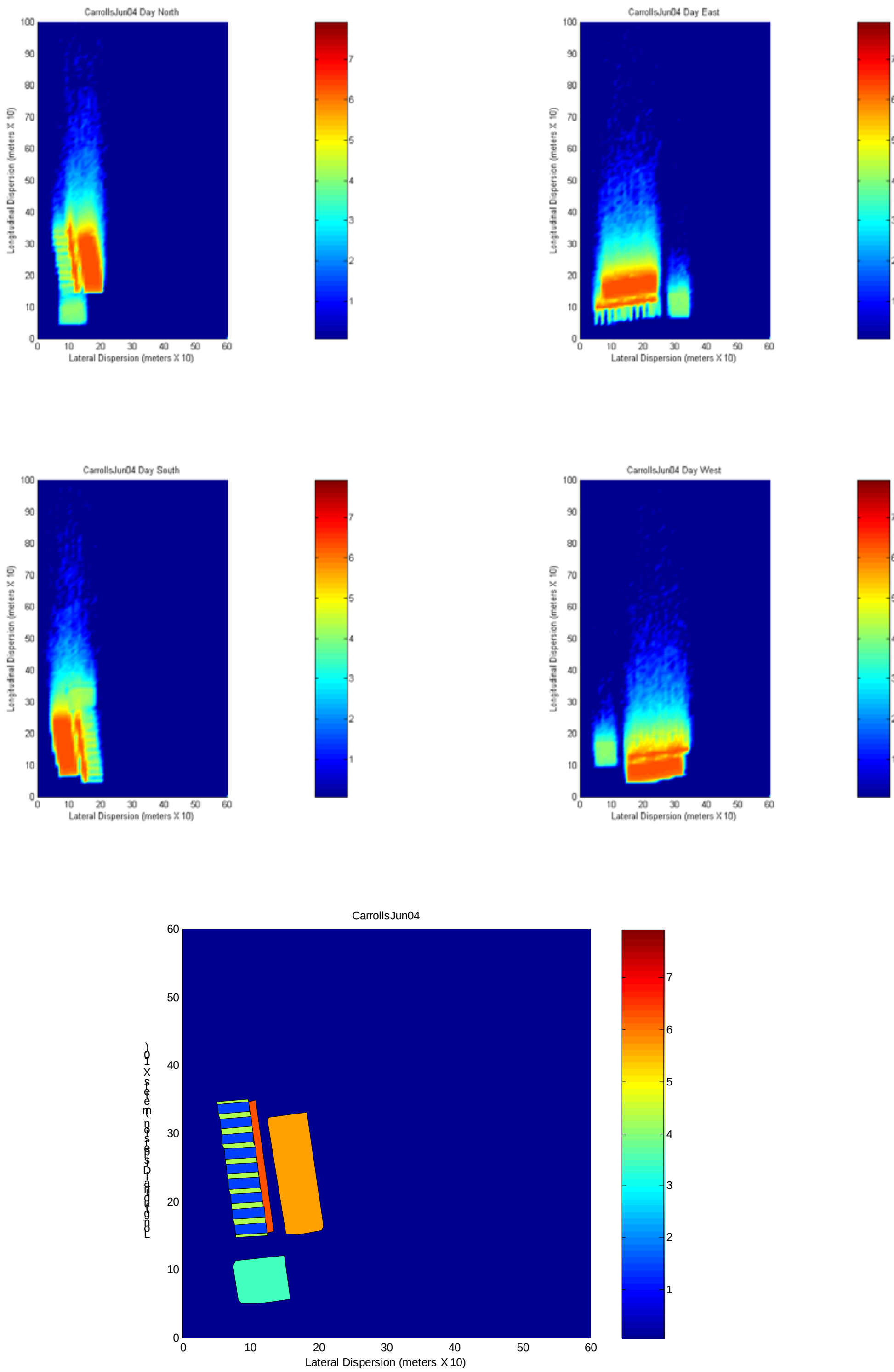

Figure 5i: Carrolls farm June 2004: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Carrolls June 2004-Night

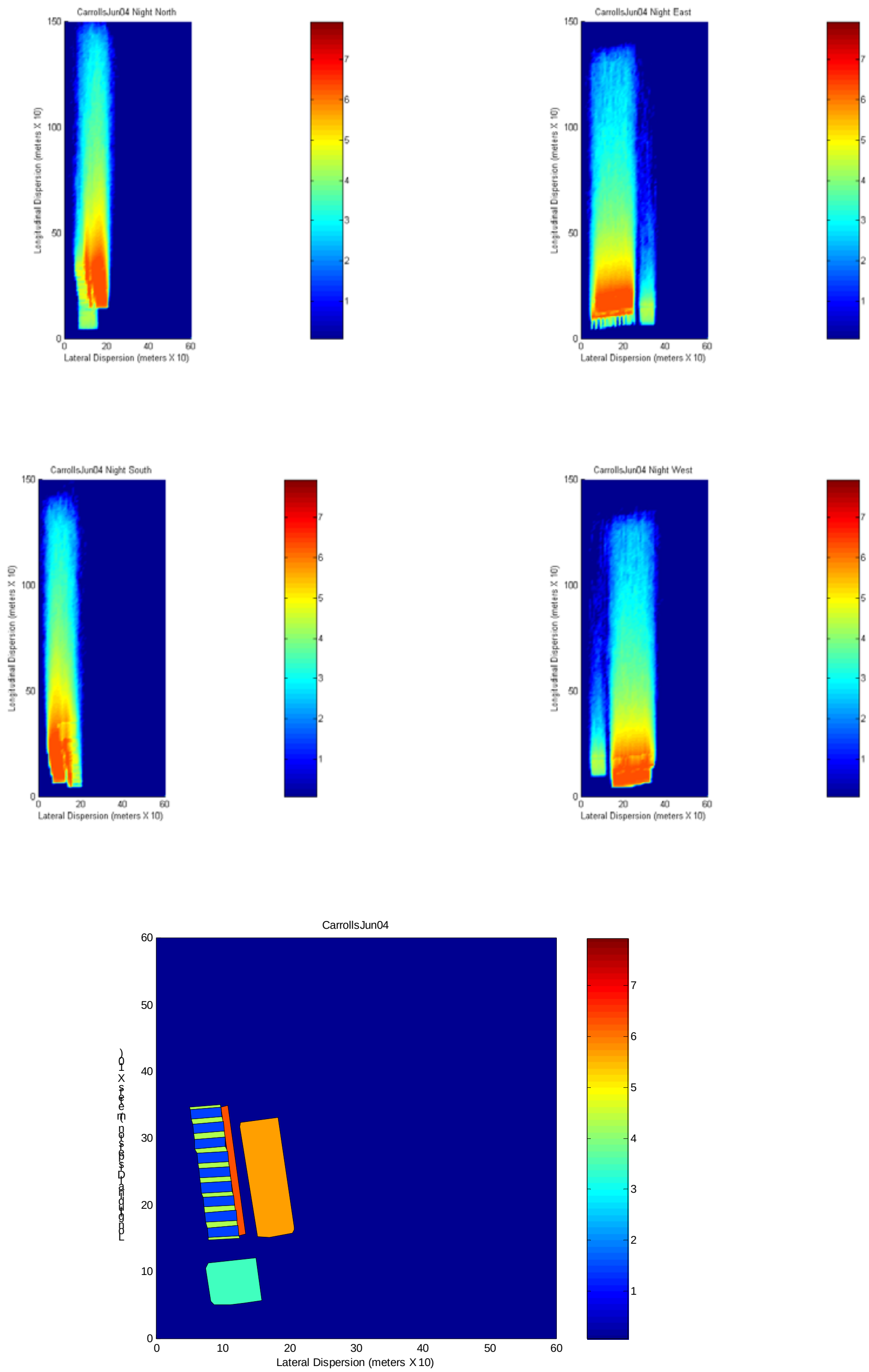

Figure 5j: Carrolls farm June 2004: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Carrolls June 2004 No Houses-Day

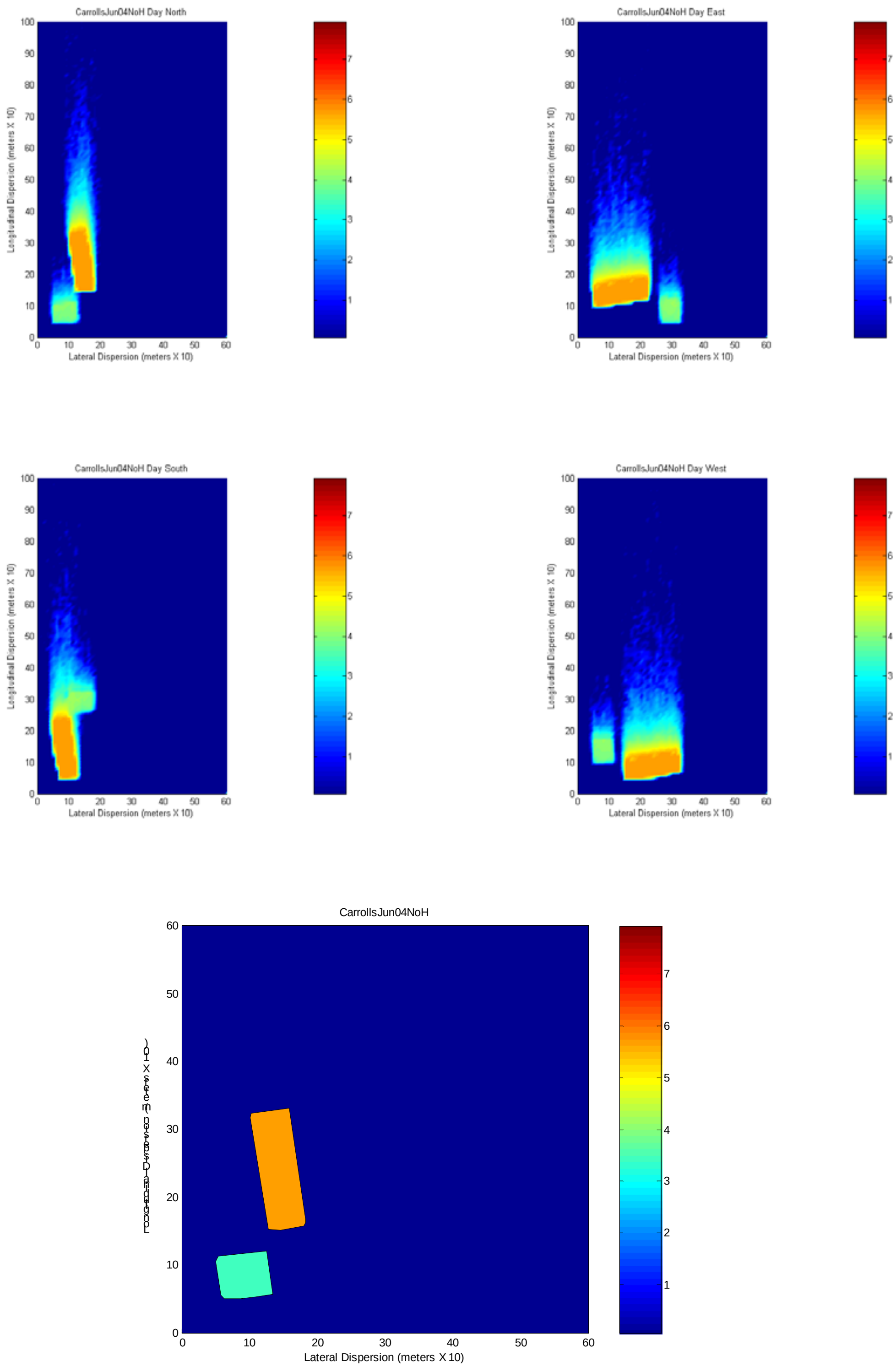

Figure 5k: Carrolls farm June 2004 without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Carrolls June 2004 No Houses-Night

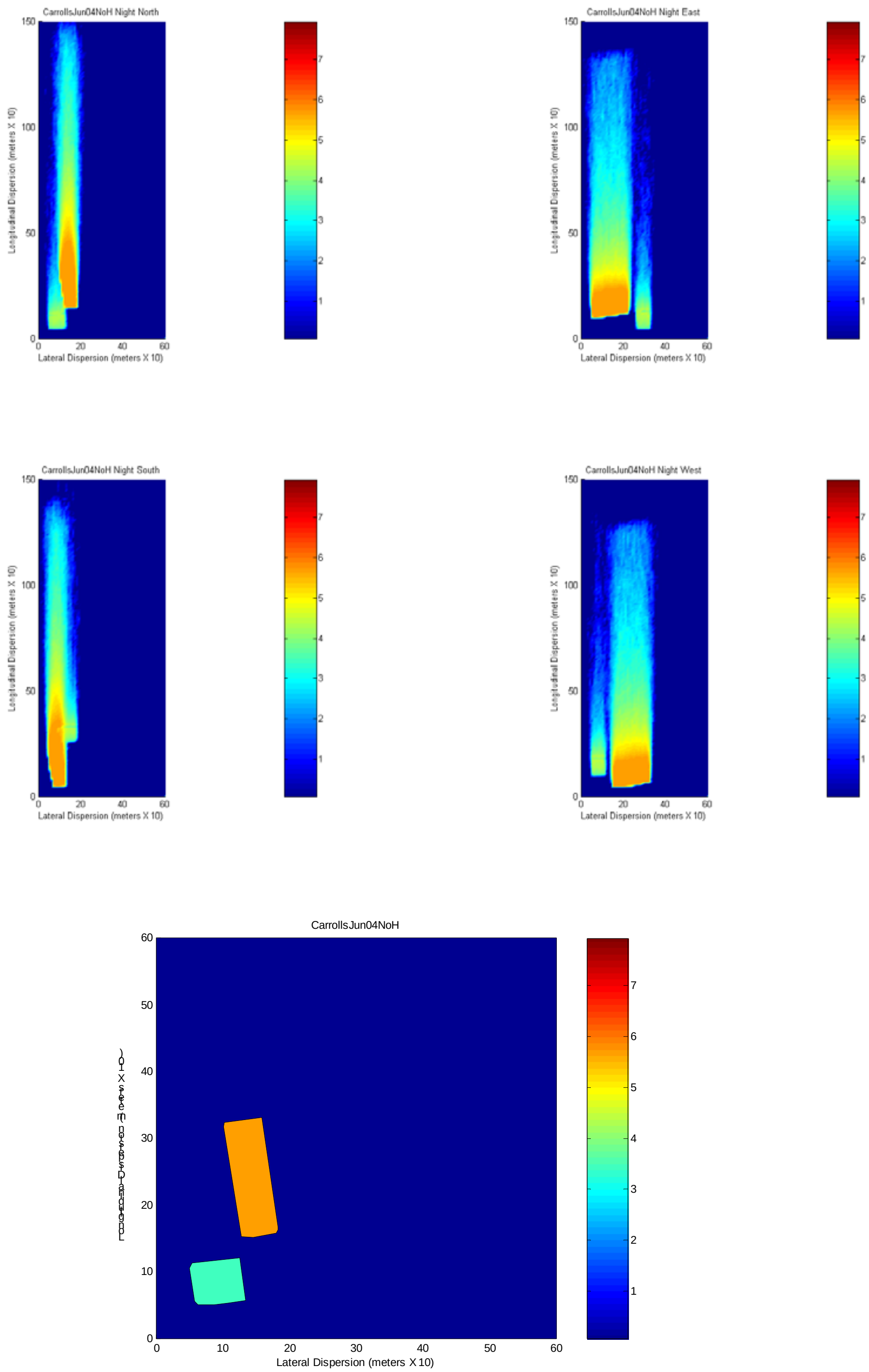

Figure 5l: Carrolls farm June 2004 without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Corbett 1-Day

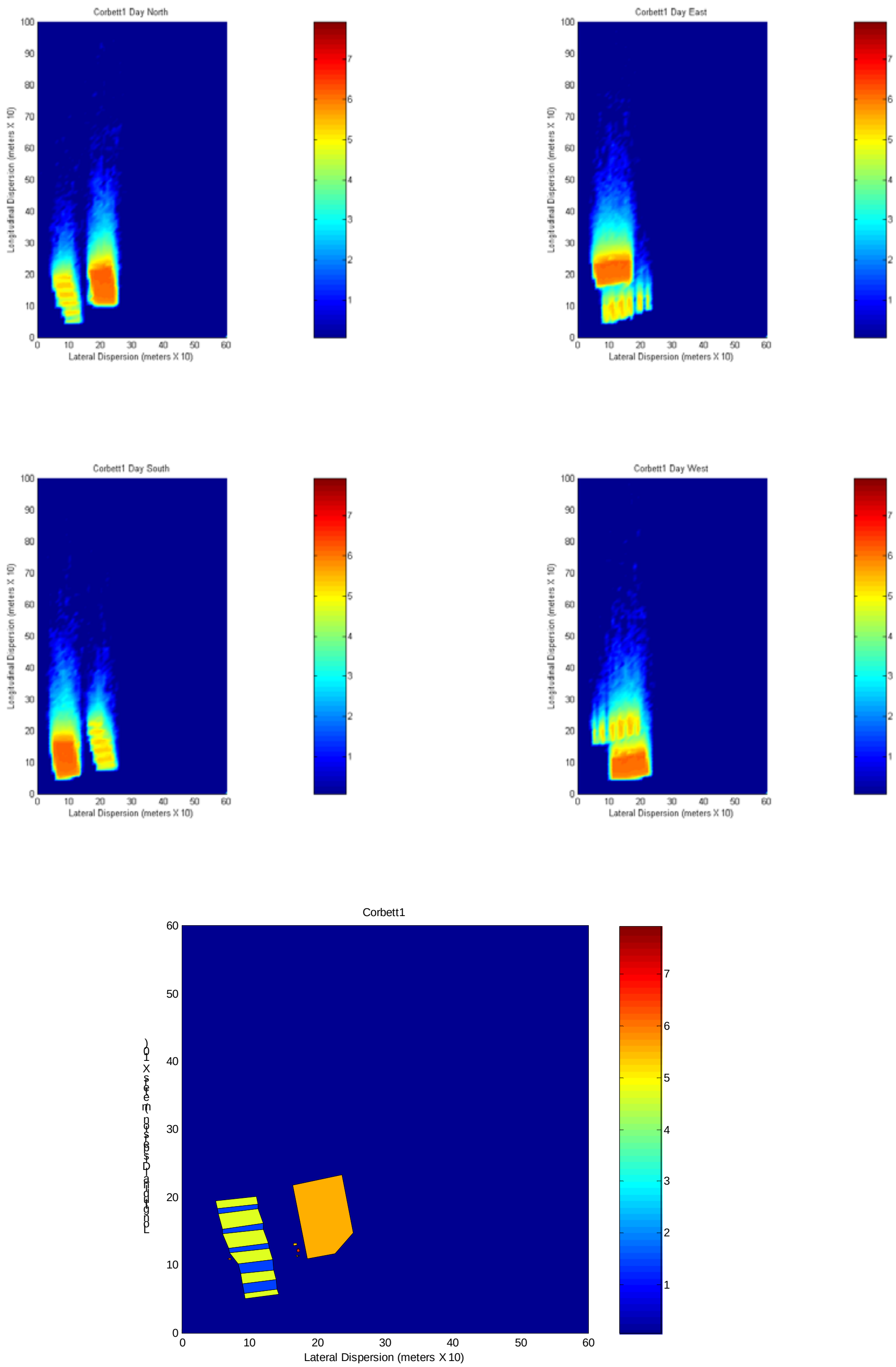

Figure 6a: Corbett 1 farm: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Corbett 1-Night

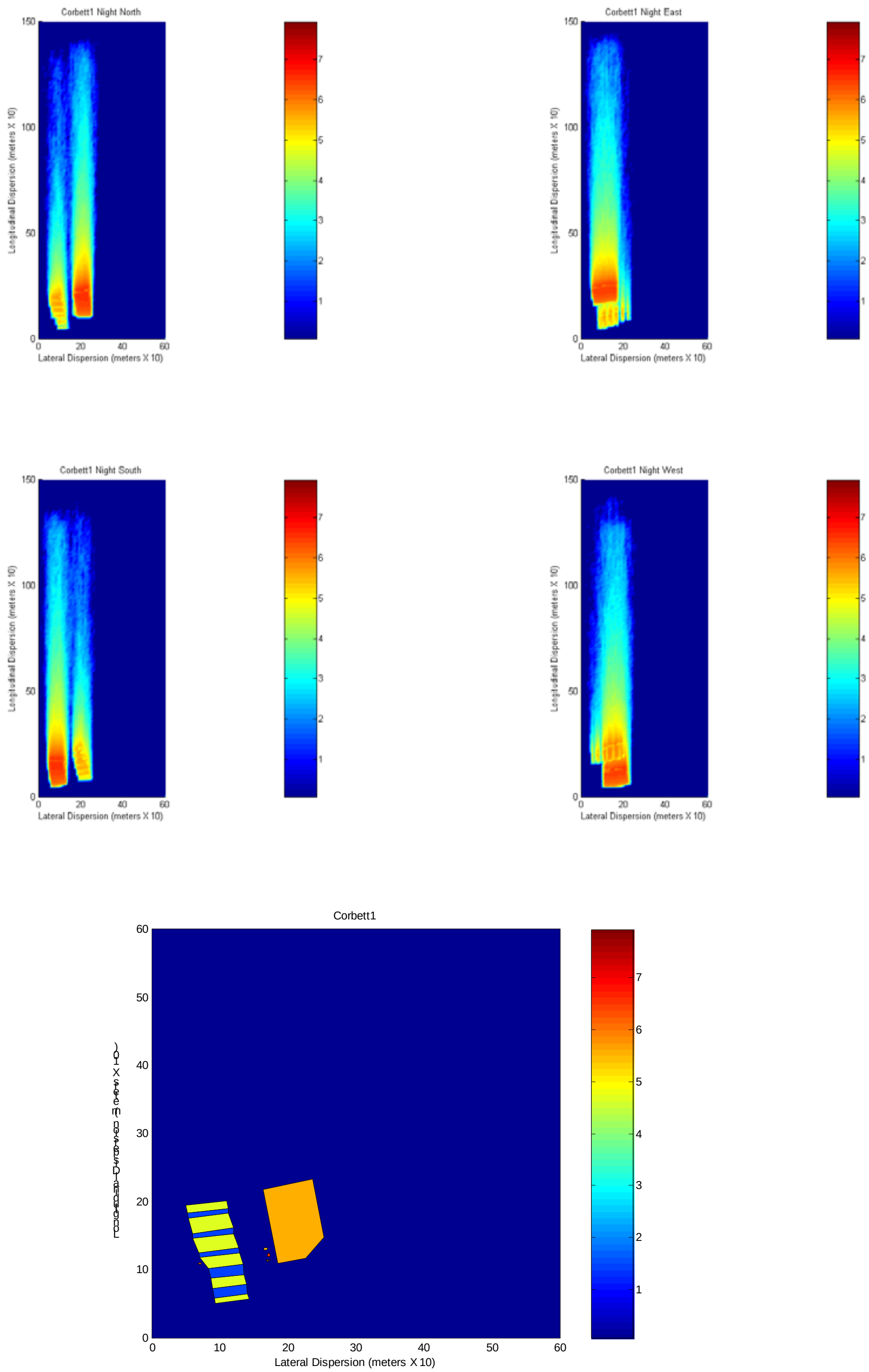

Figure 6b: Corbett 1 farm: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Corbett 1 No Houses-Day

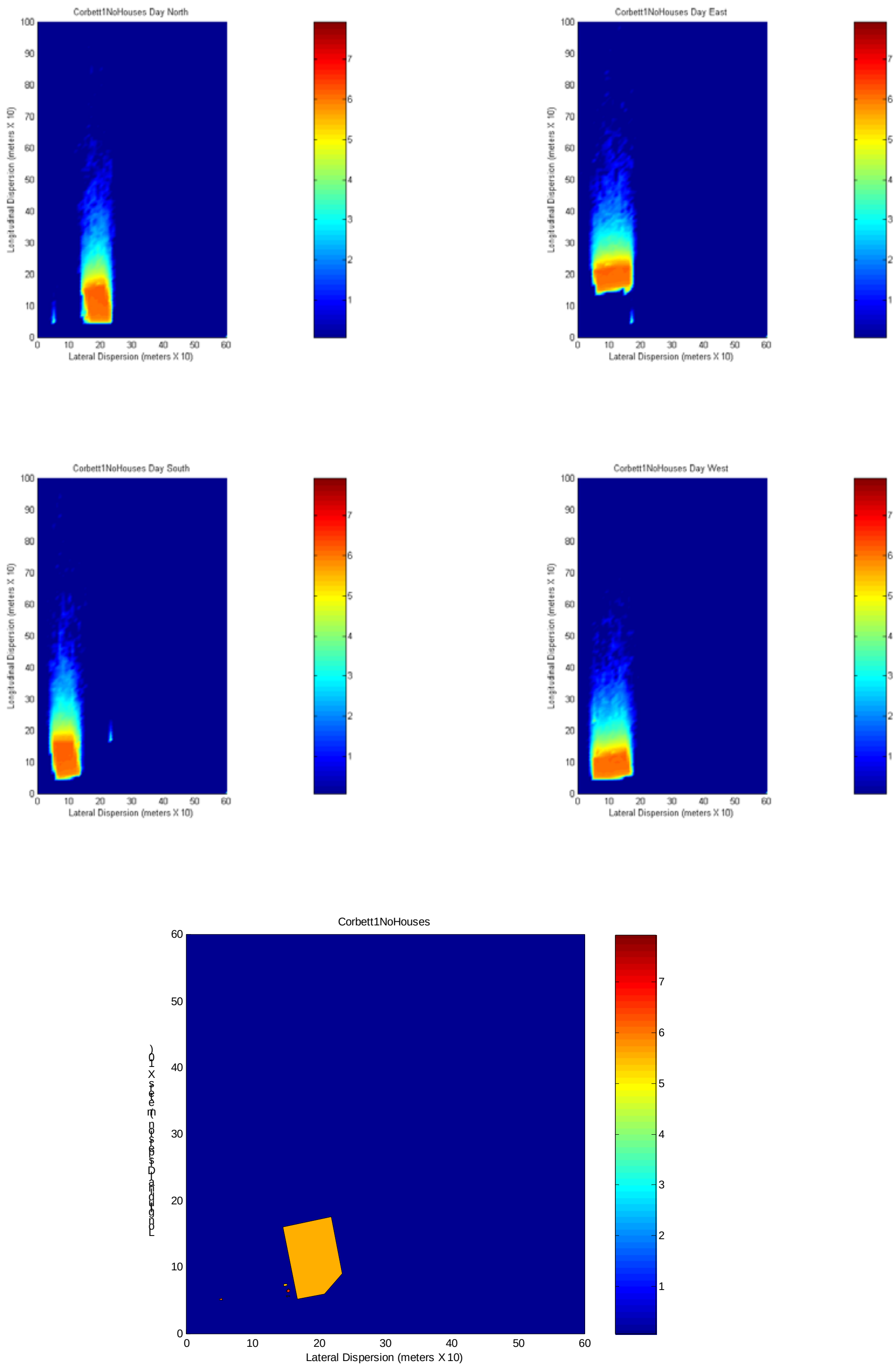

Figure 6c: Corbett 1 farm without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Corbett 1 No Houses-Night

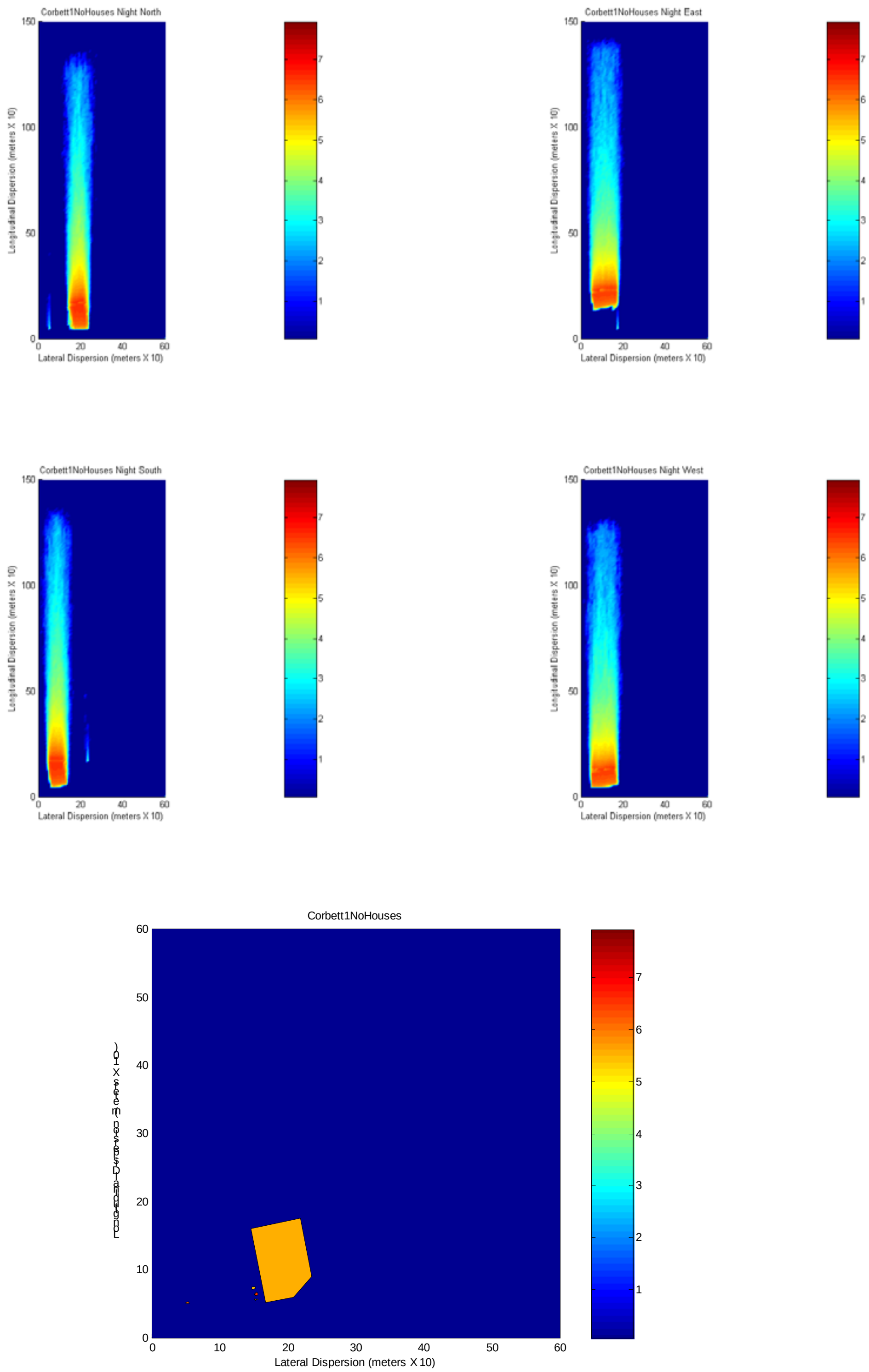

Figure 6d: Corbett 1 farm without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Corbett 4-Day

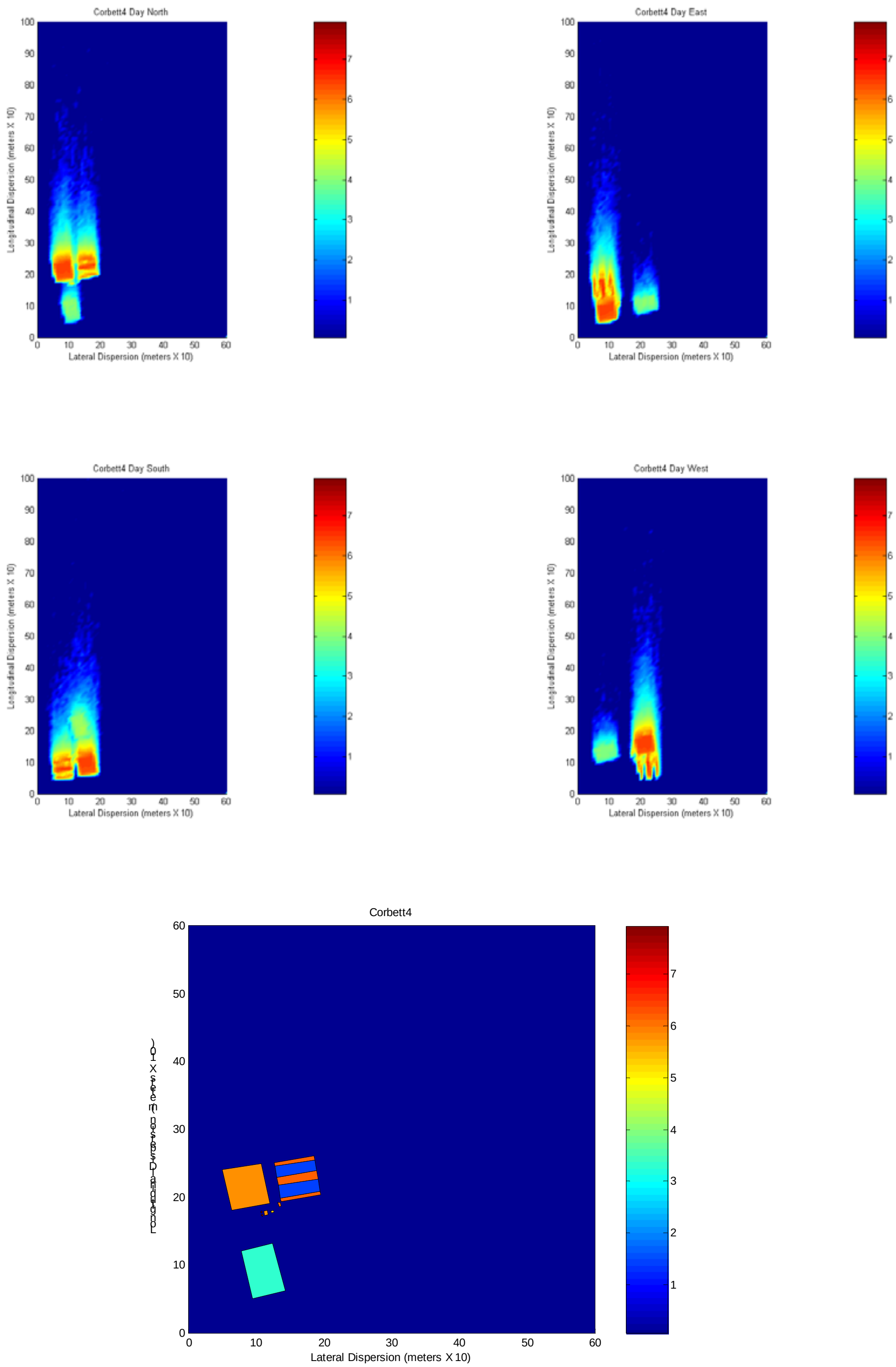

Figure 7a: Corbett 4 farm: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Corbett 4-Night

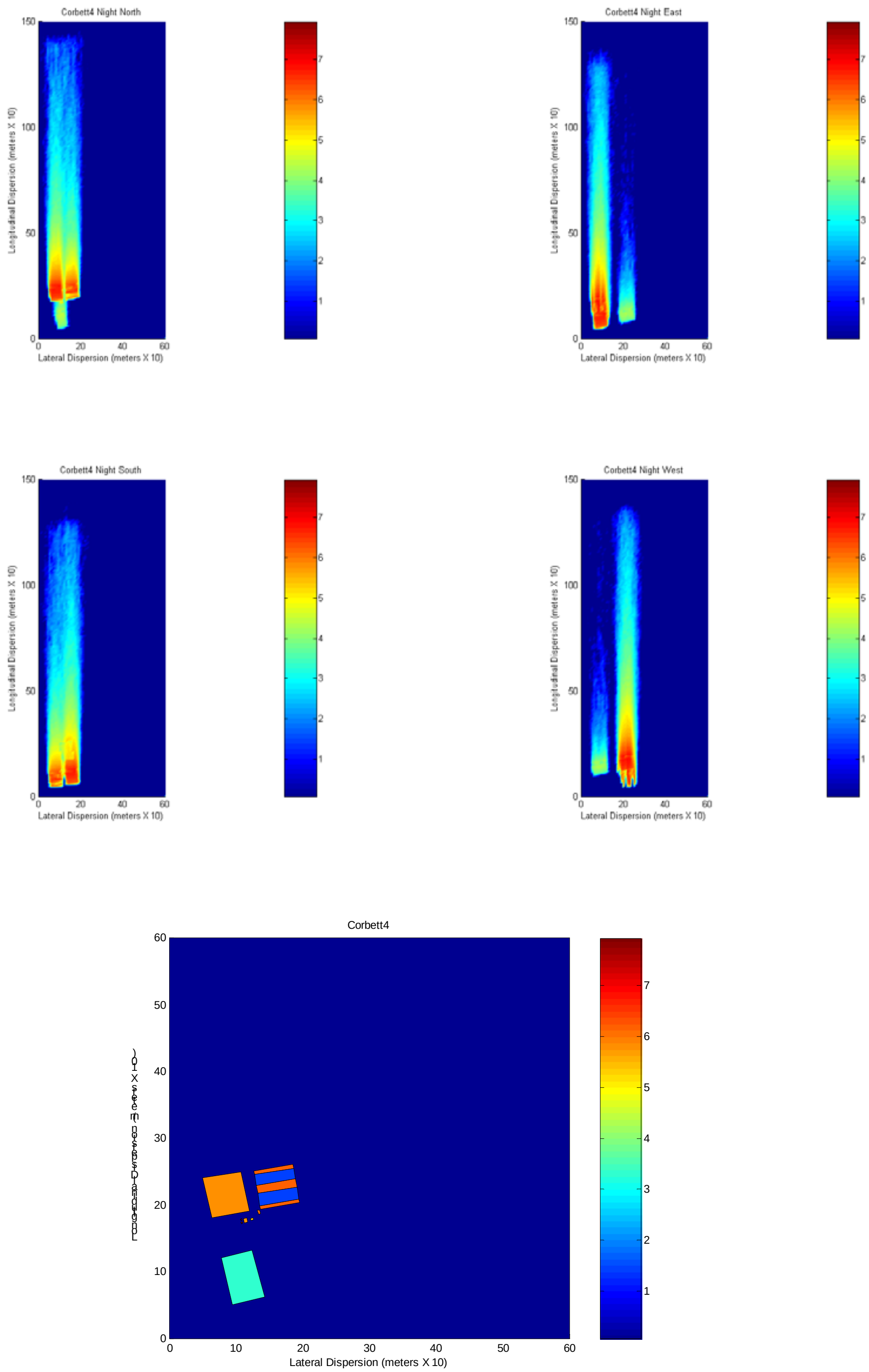

Figure 7b: Corbett 4 farm: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Corbett 4 No Houses-Day

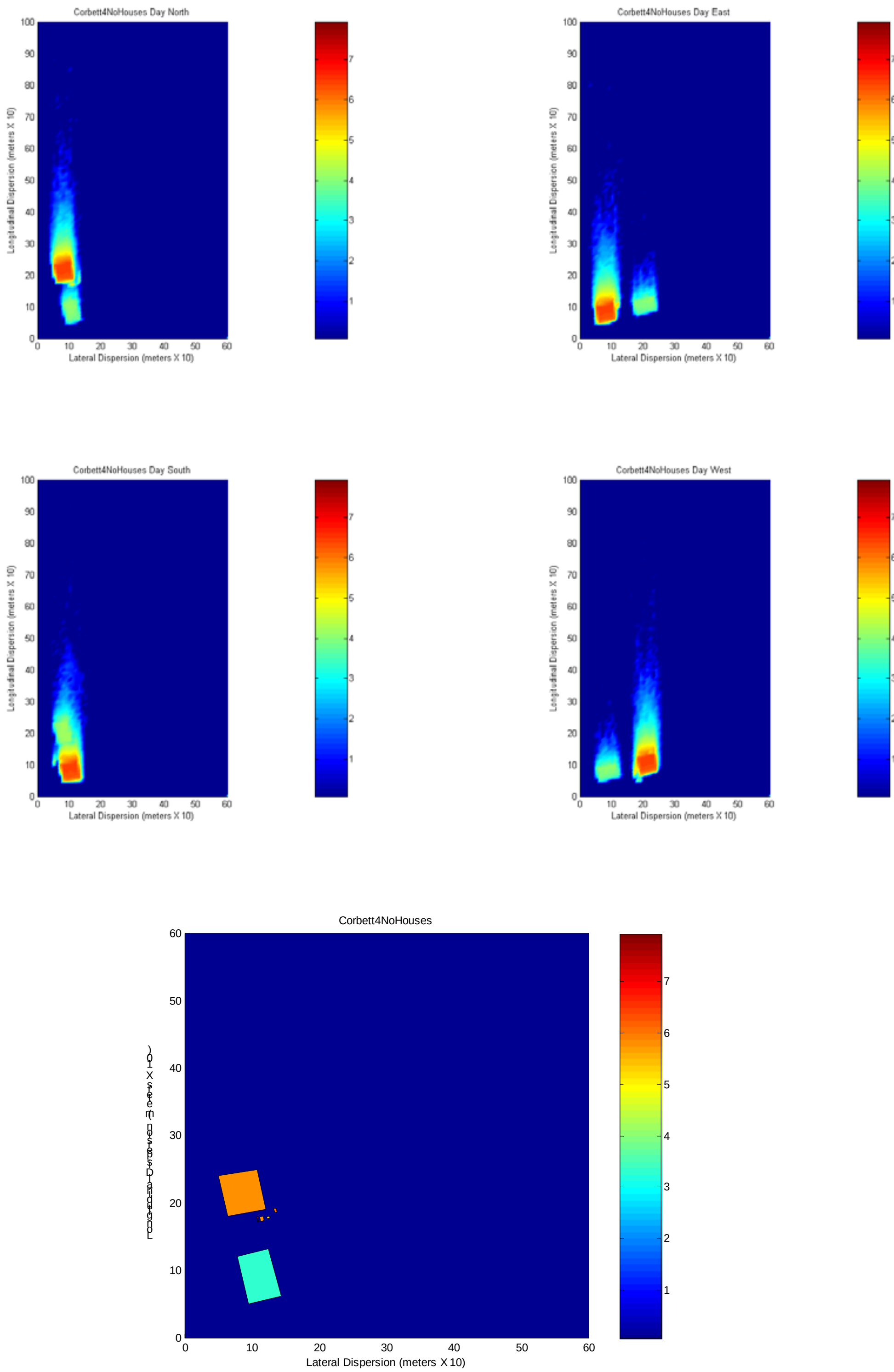

Figure 7c: Corbett 4 farm without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Corbett 4 No Houses-Night

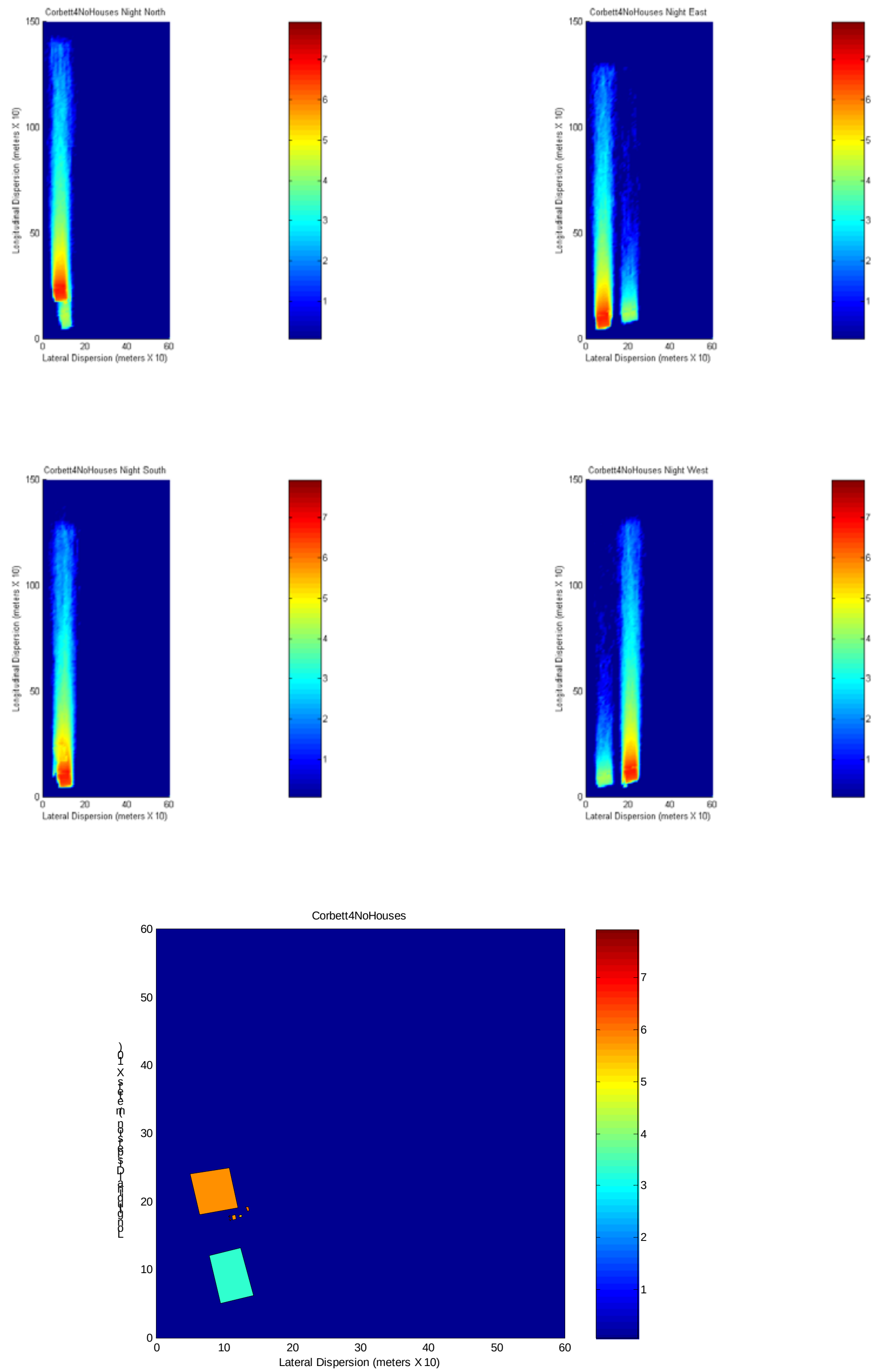

Figure 7d: Corbett 4 farm without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Ekokan-Day

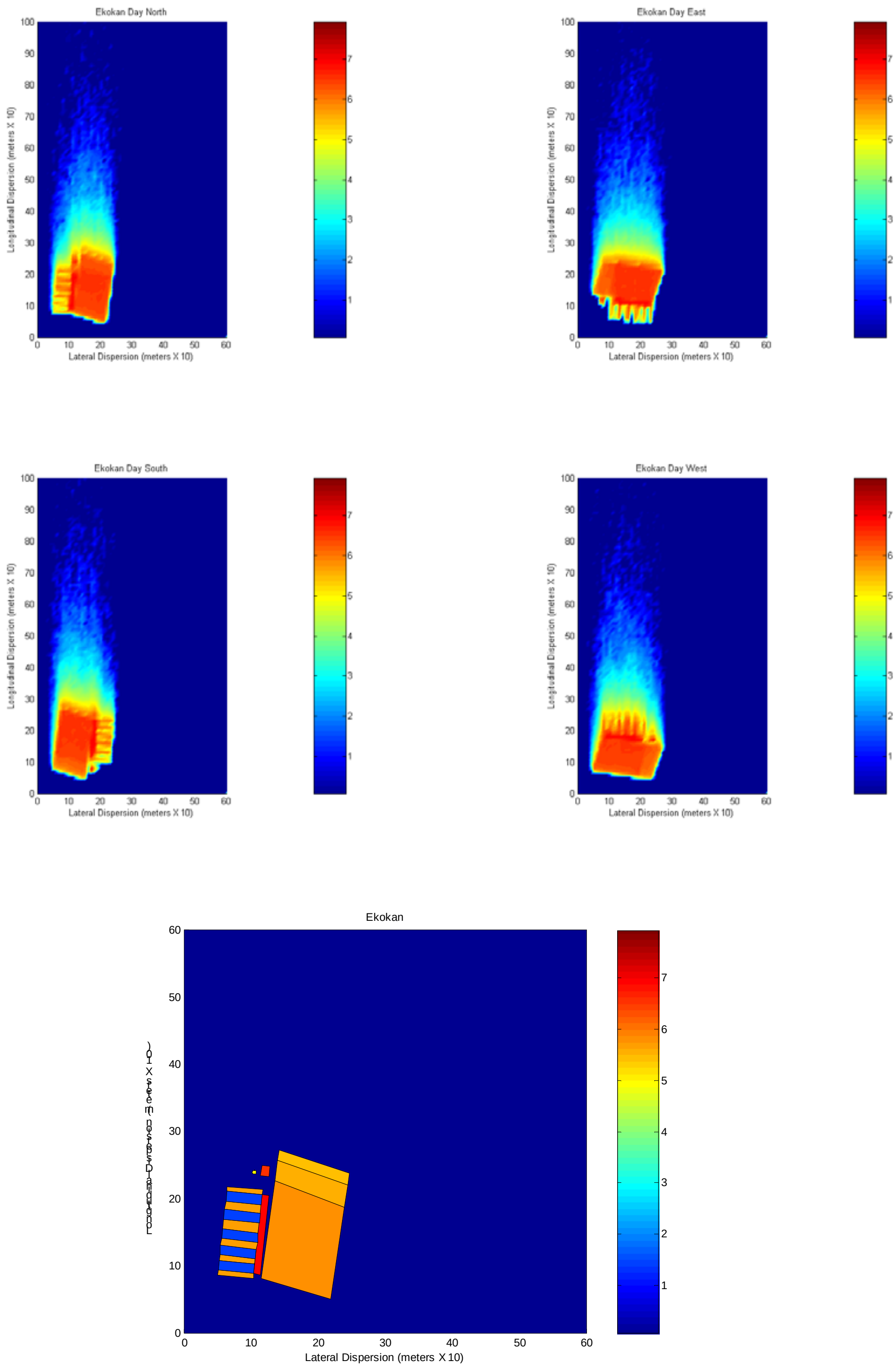

Figure 8a: Ekokan farm: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Ekokan-Night

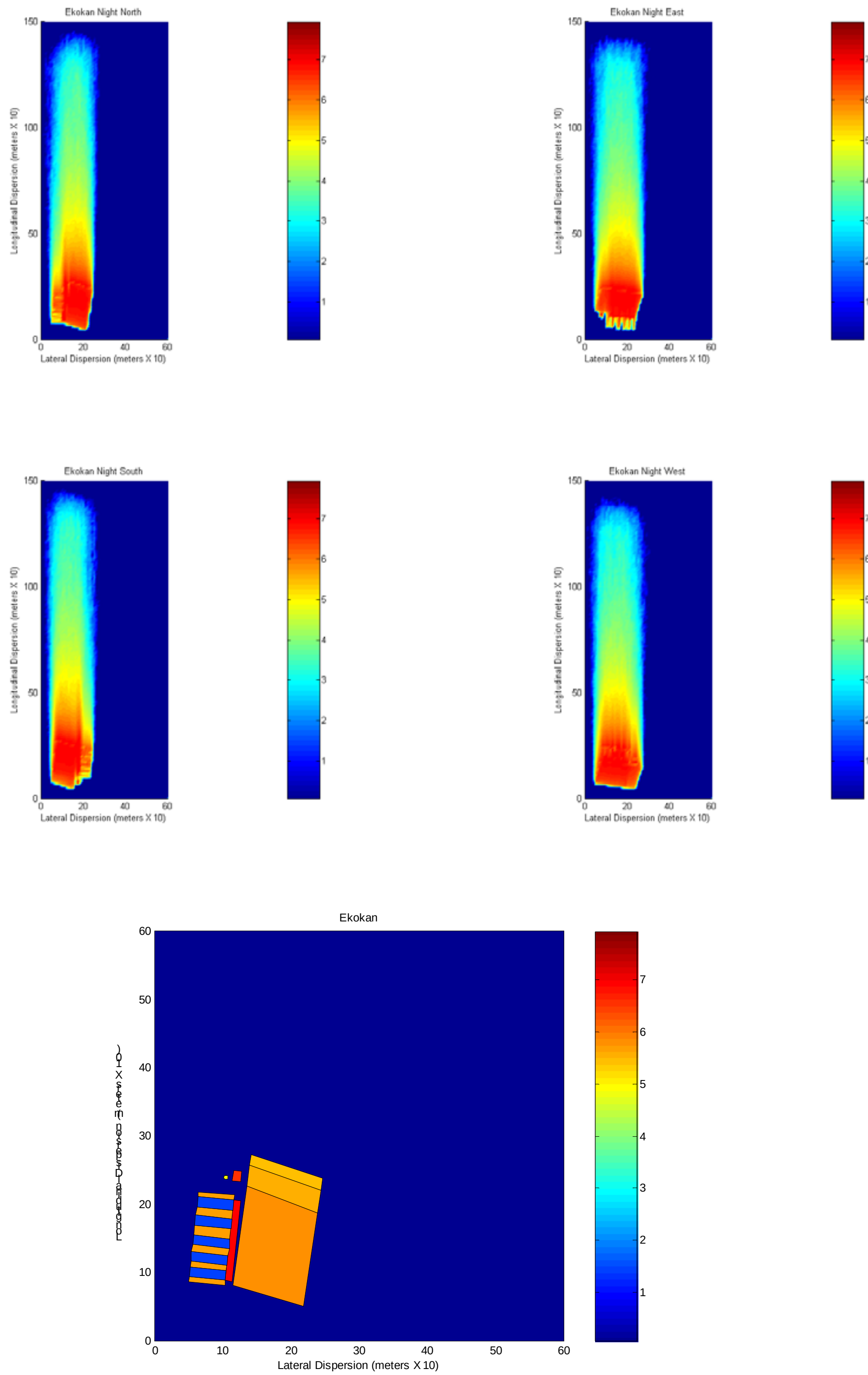

Figure 8b: Ekokan farm: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Ekokan No Houses-Day

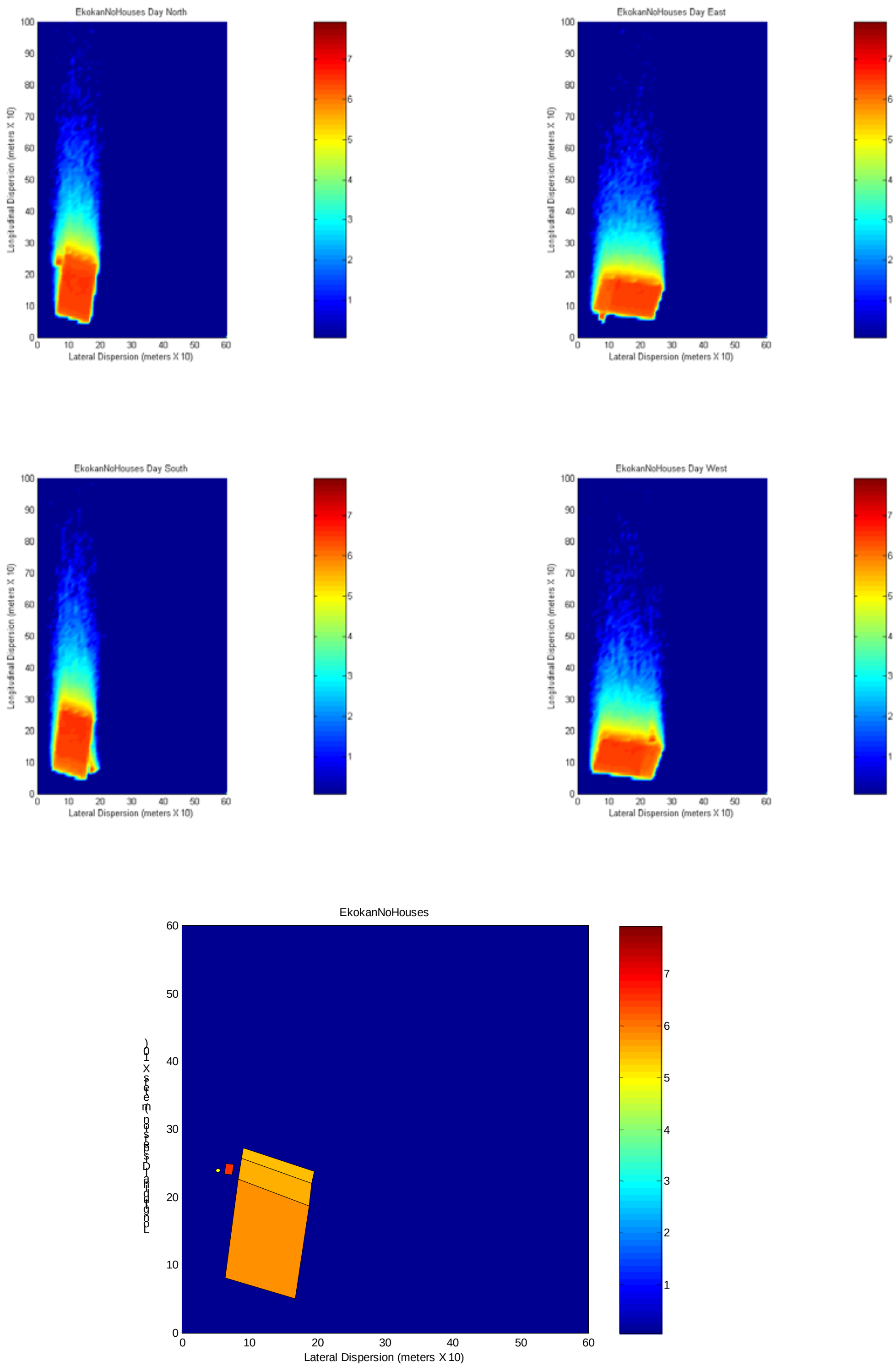

Figure 8c: Ekokan farm without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Ekokan No Houses-Night

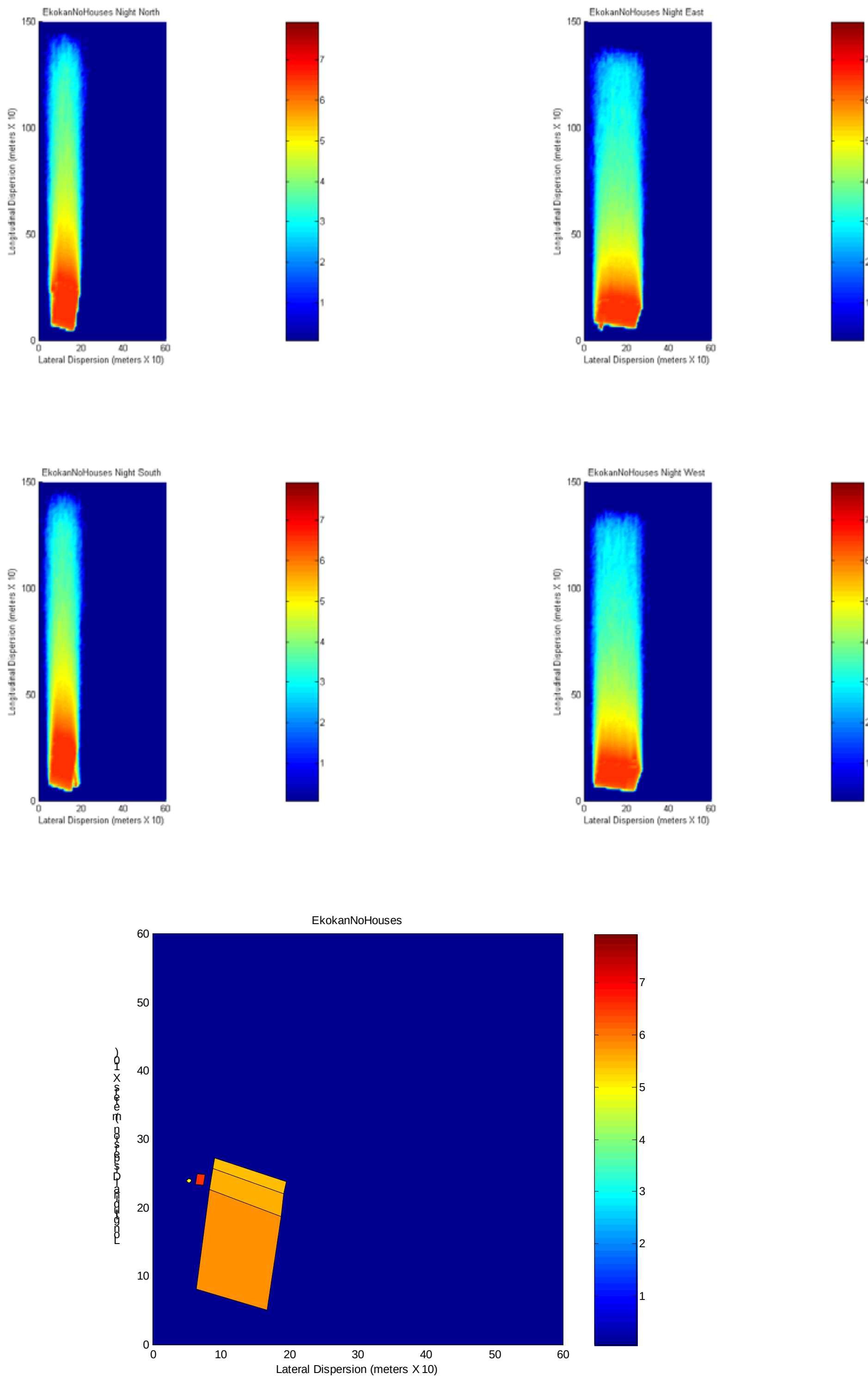

Figure 8d: Ekokan farm without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Grinnells-Day

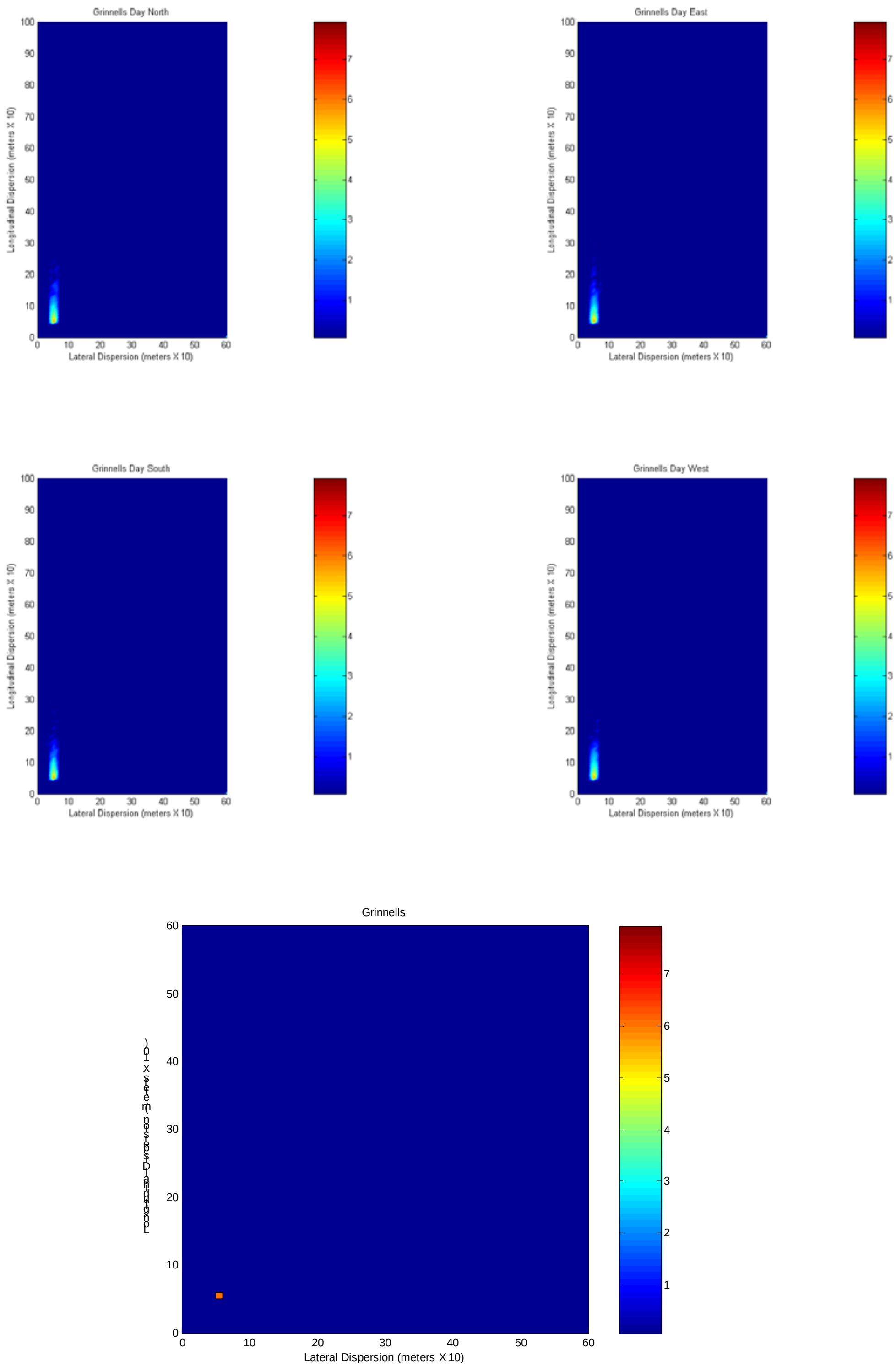

Figure 9a: Grinnells: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Grinnells-Night

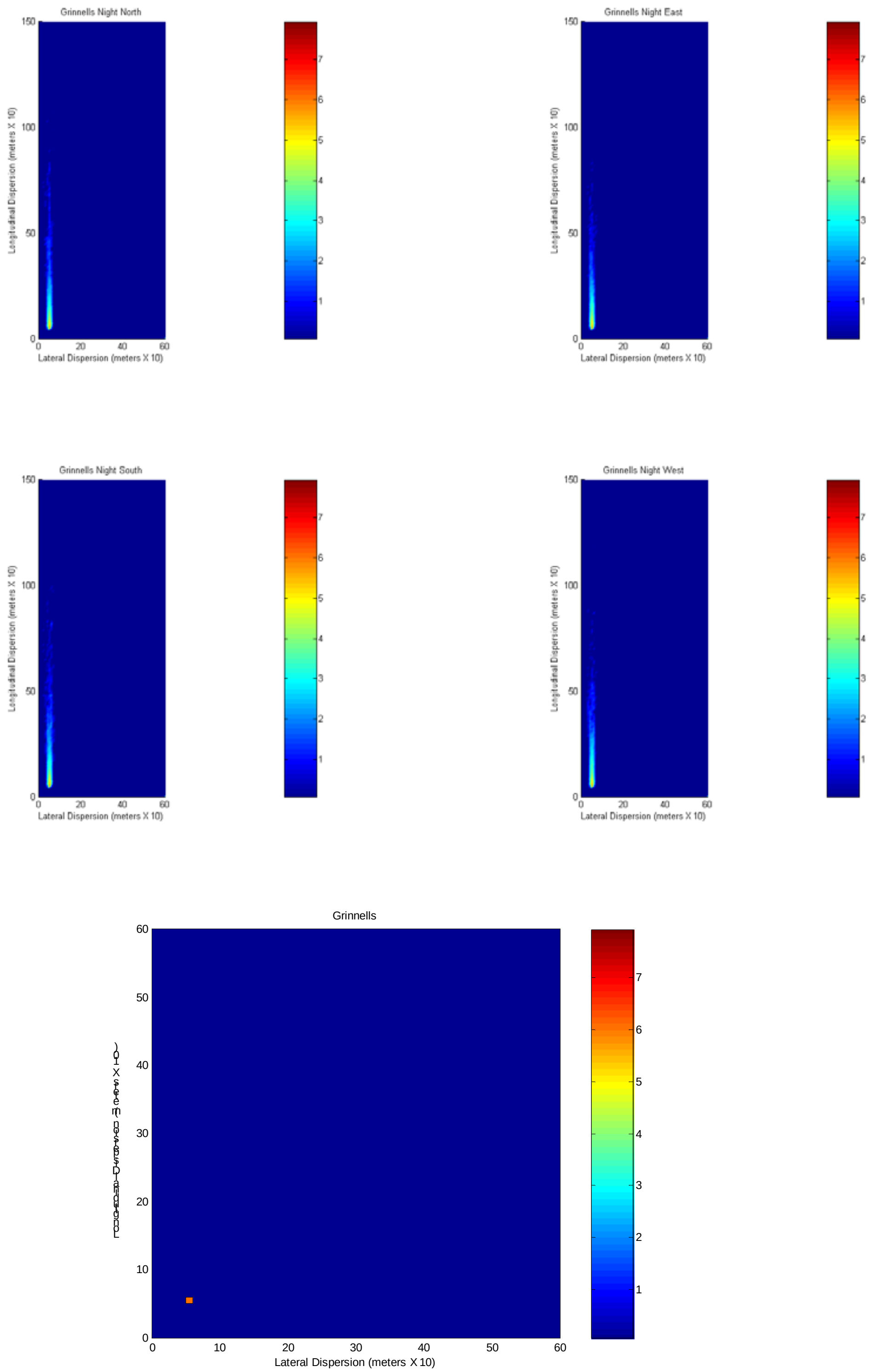

Figure 9b: Grinnells: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Harrells Average-Day

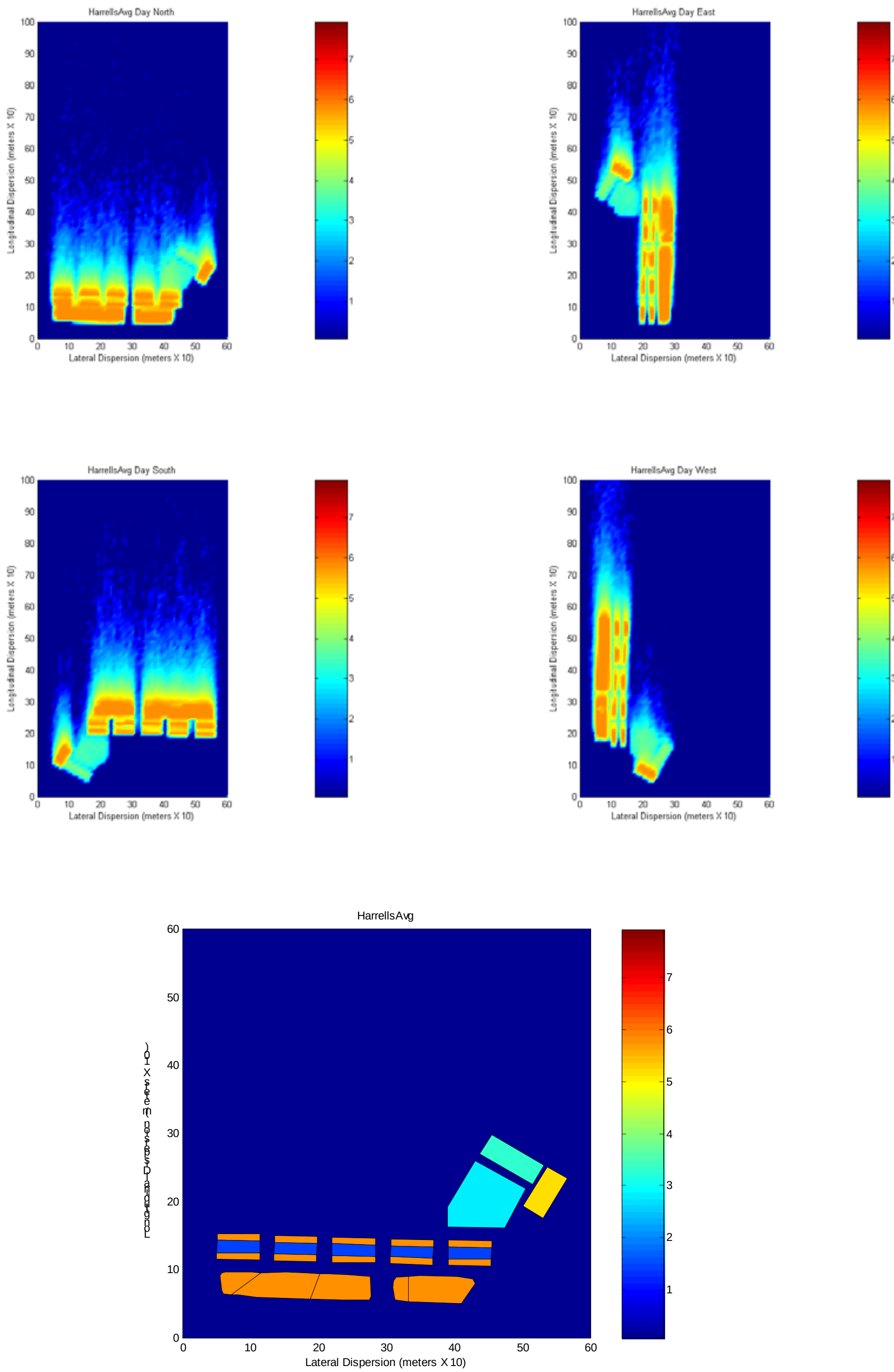

Figure 10a: Harrells farm average: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Harrells Average-Night

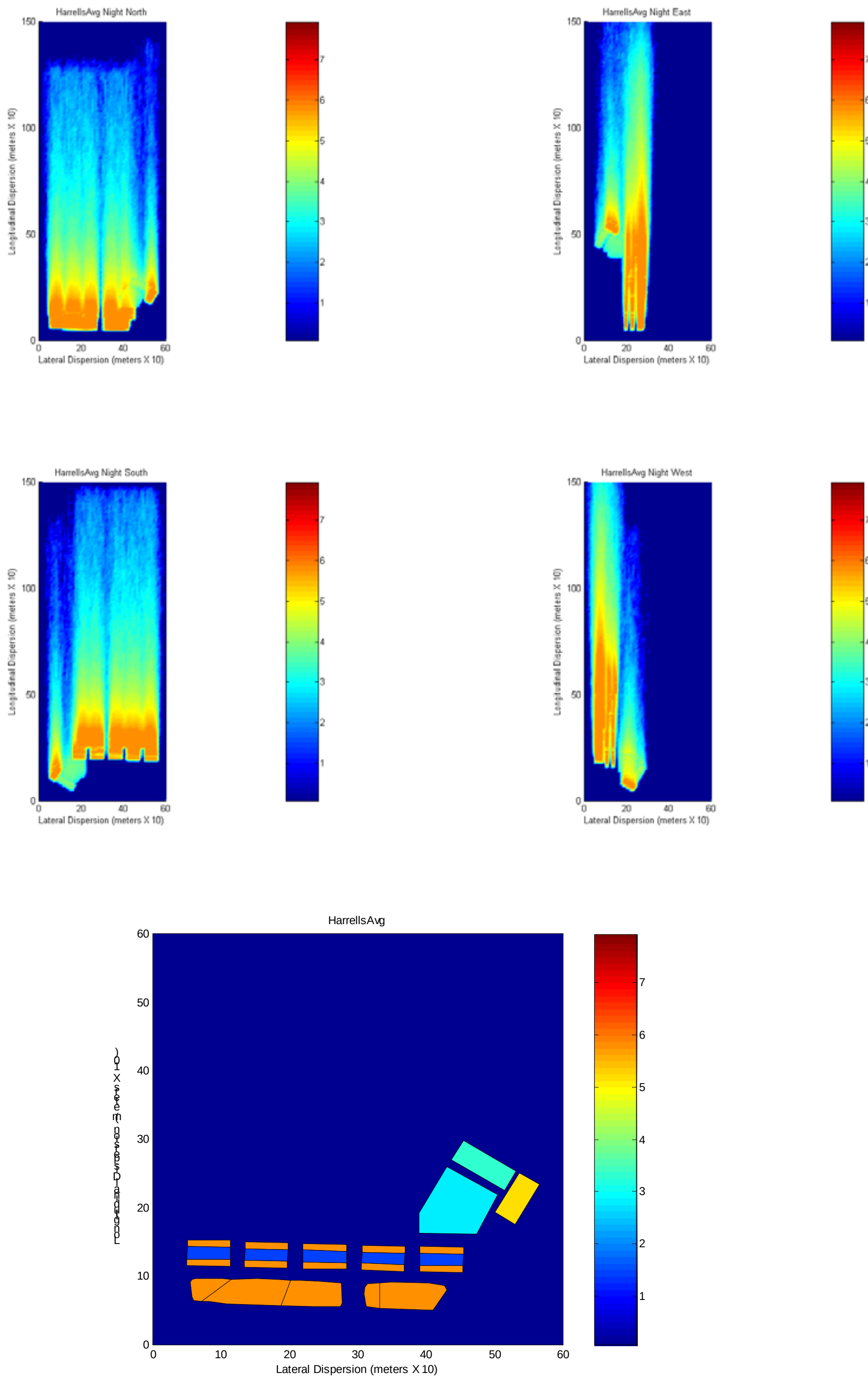

Figure 10b: Harrells farm average: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Harrells Average No Houses-Day

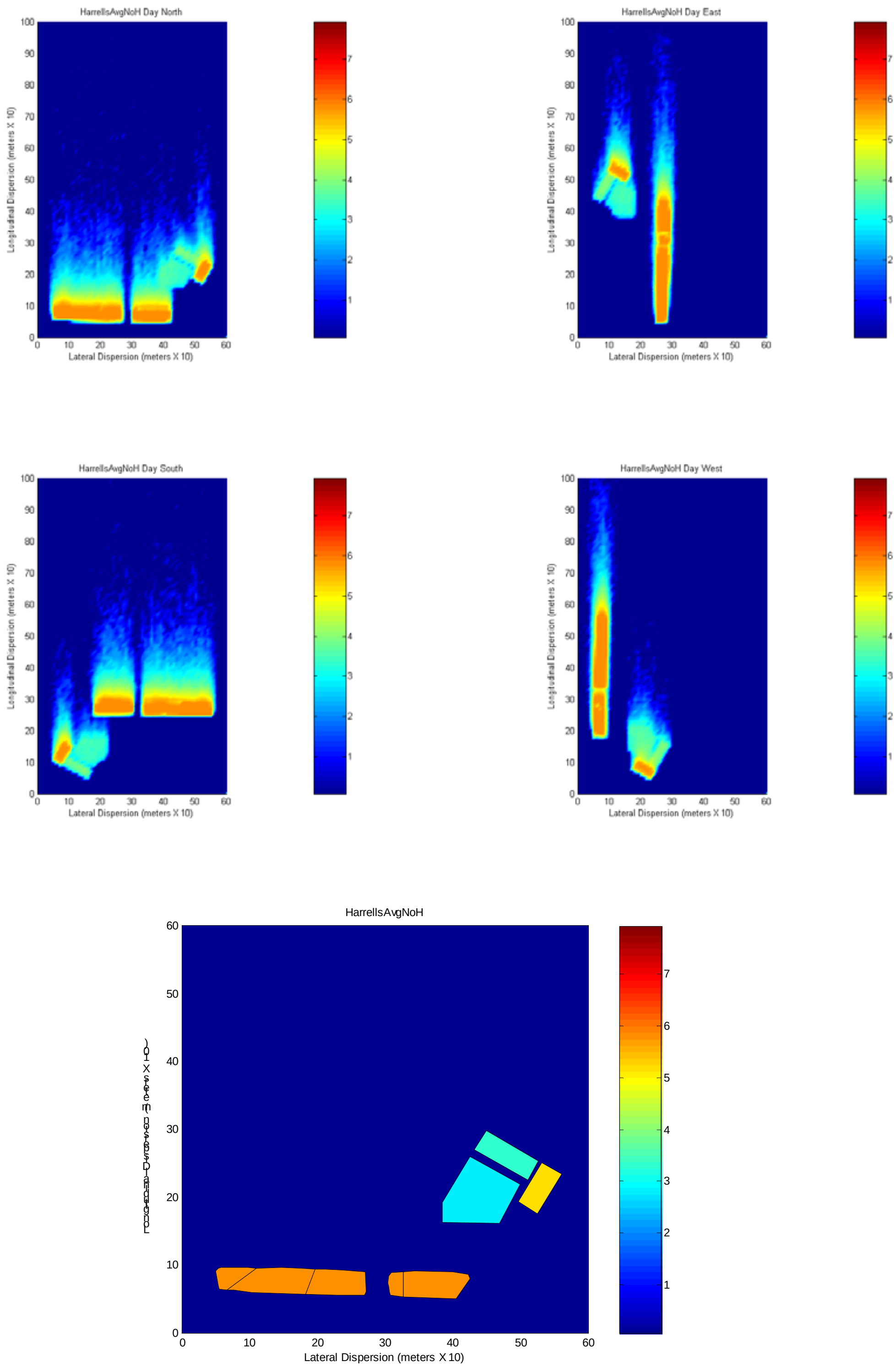

Figure 10c: Harrells farm average without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Harrells Average No Houses-Night

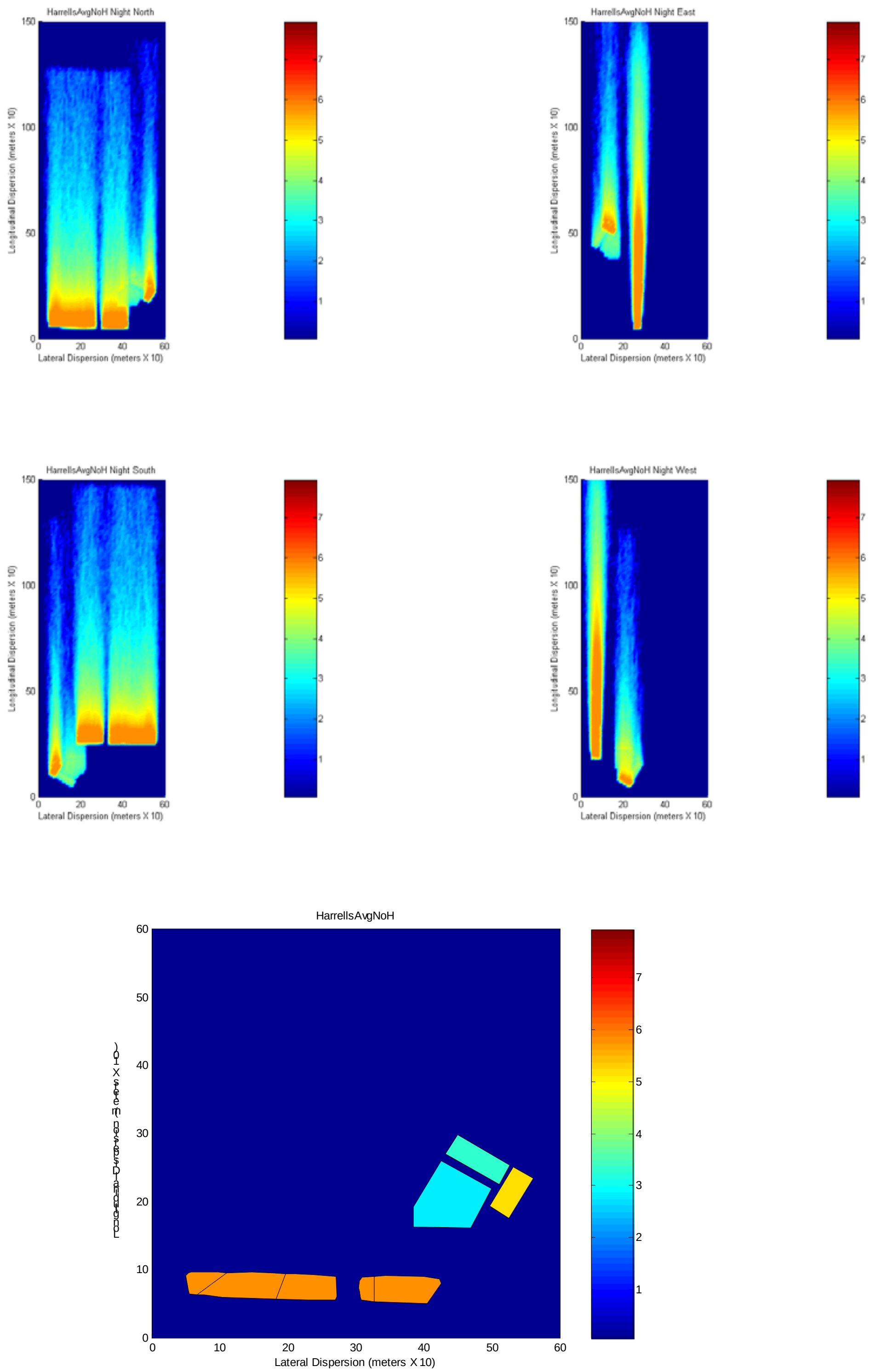

Figure 10d: Harrells farm average without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Harrells with Evaporation System-Day

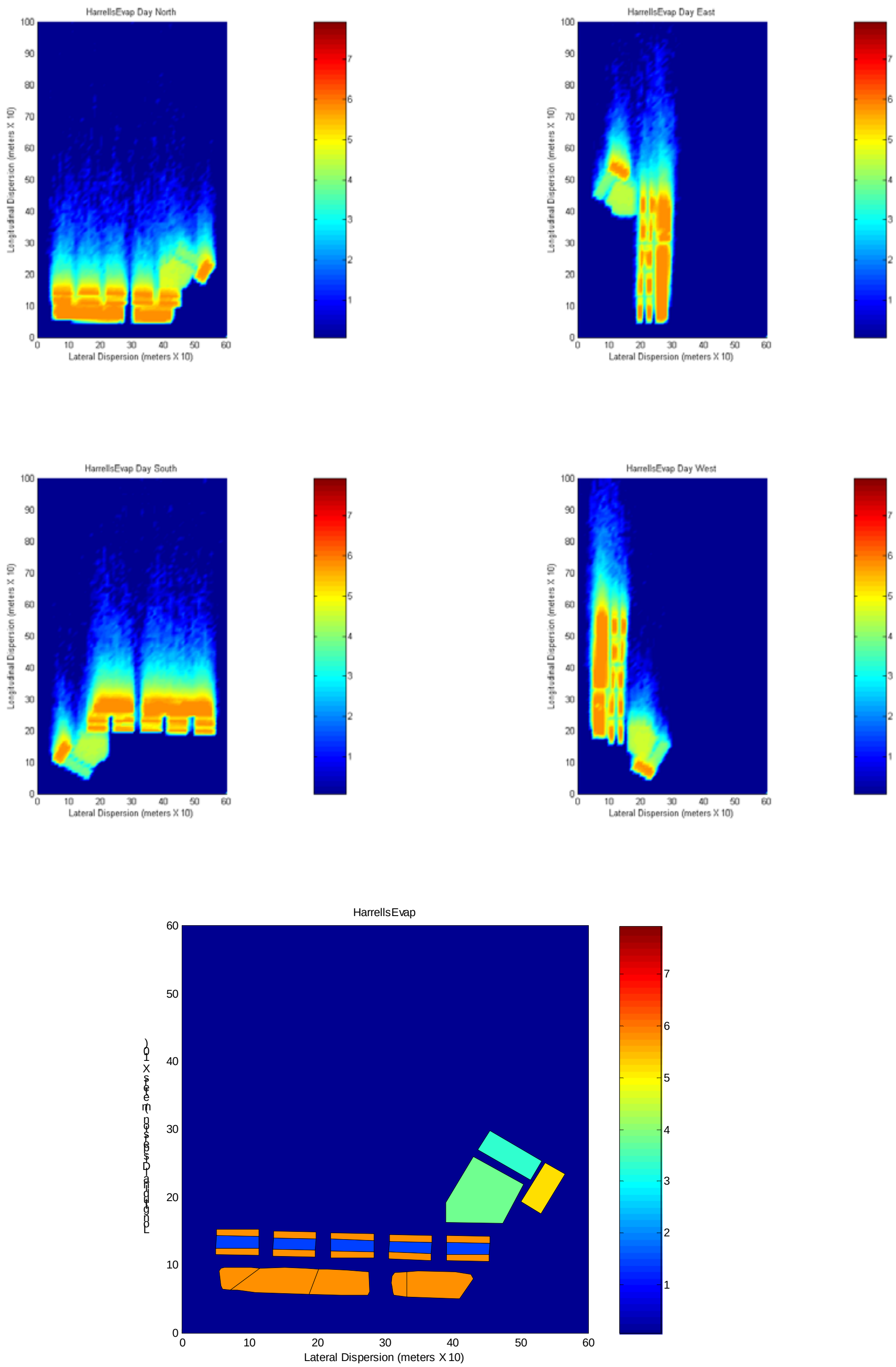

Figure 10e: Harrells farm with evaporation system: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Harrells with Evaporation System-Night

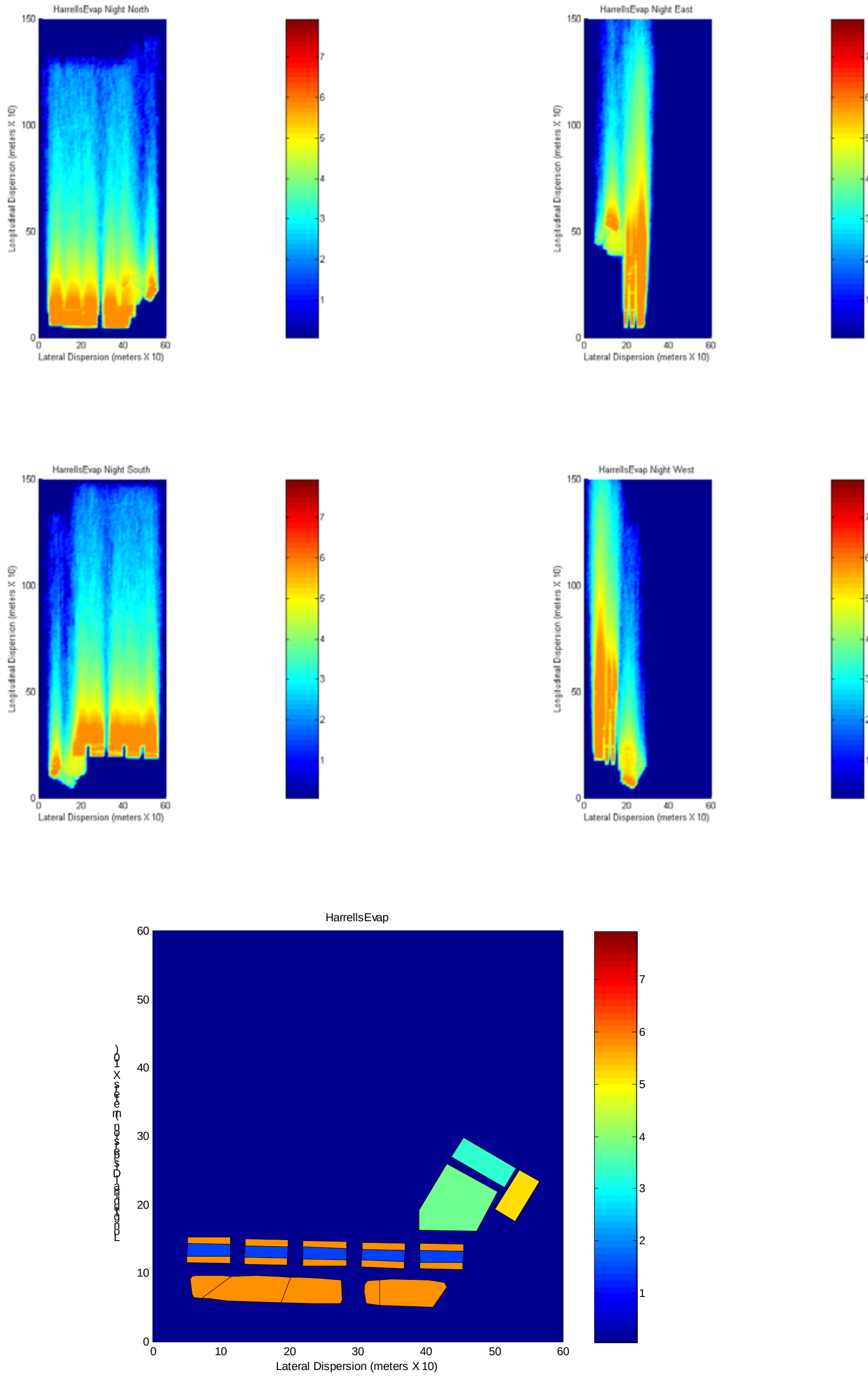

Figure 10f: Harrells farm with evaporation system: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Harrells with Evaporation System No Houses-Day

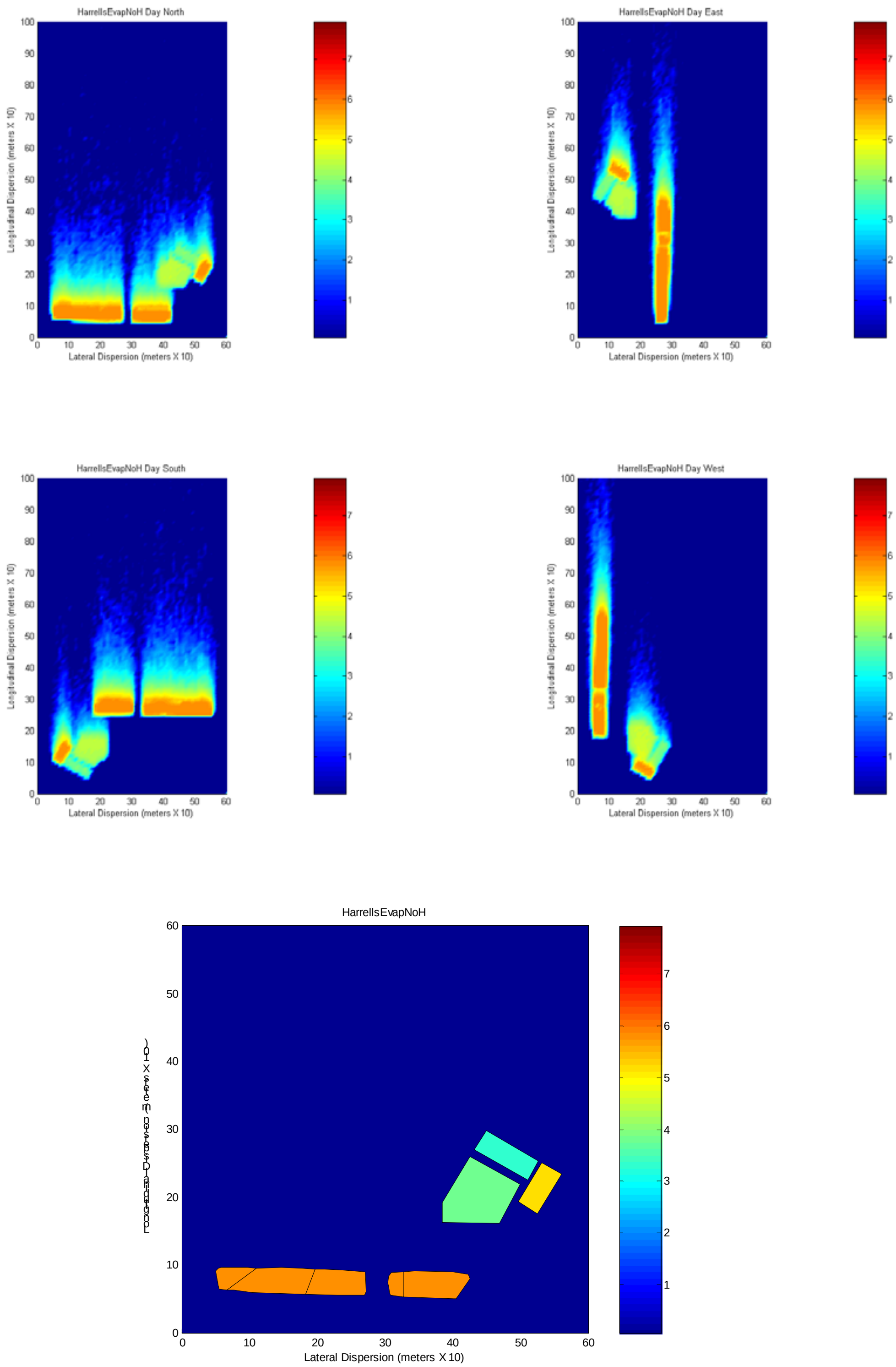

Figure 10g: Harrells farm with evaporation system without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Harrells with Evaporation System No Houses-Night

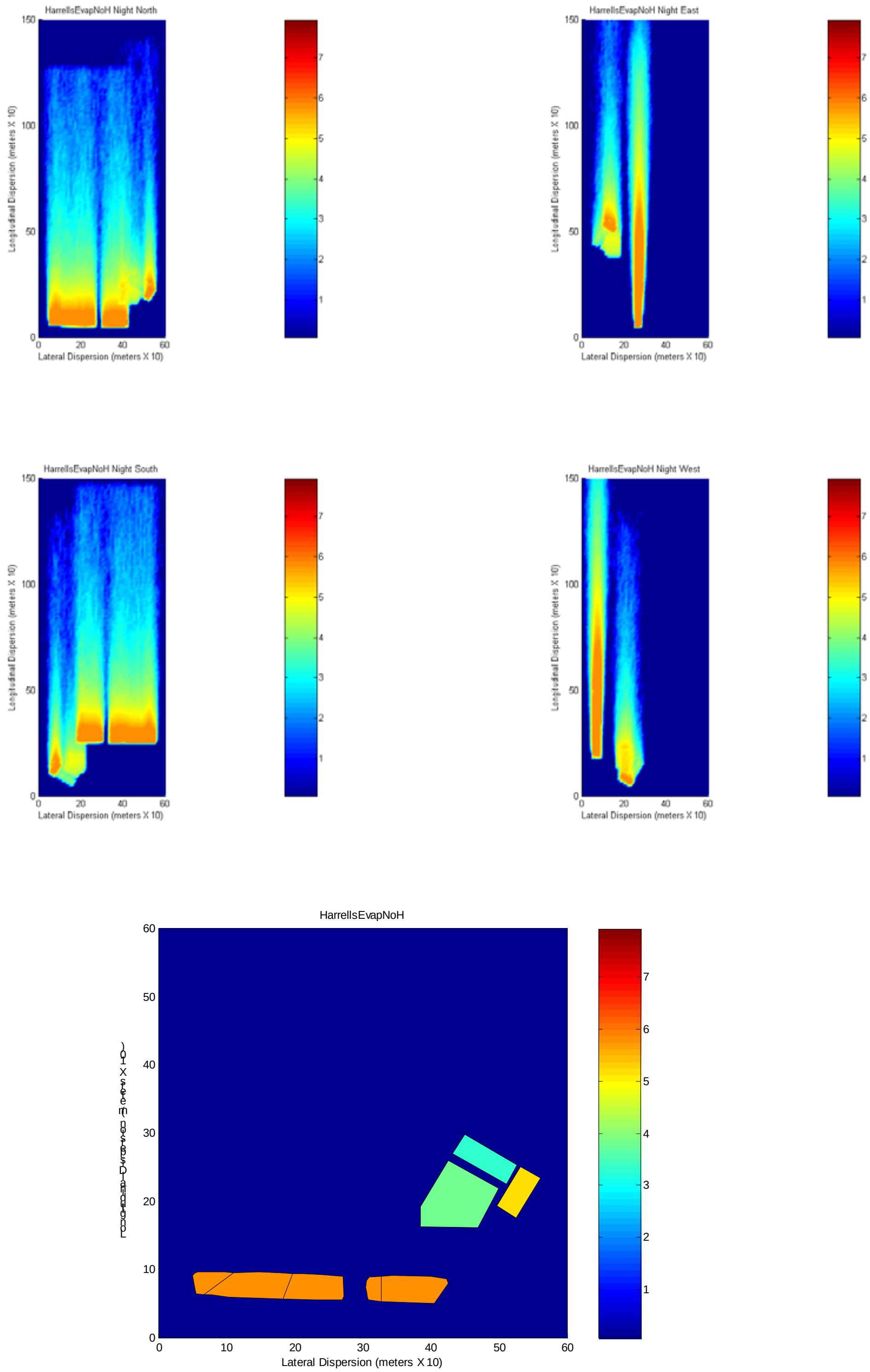

Figure 10h: Harrells farm with evaporation system without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Howard-Day

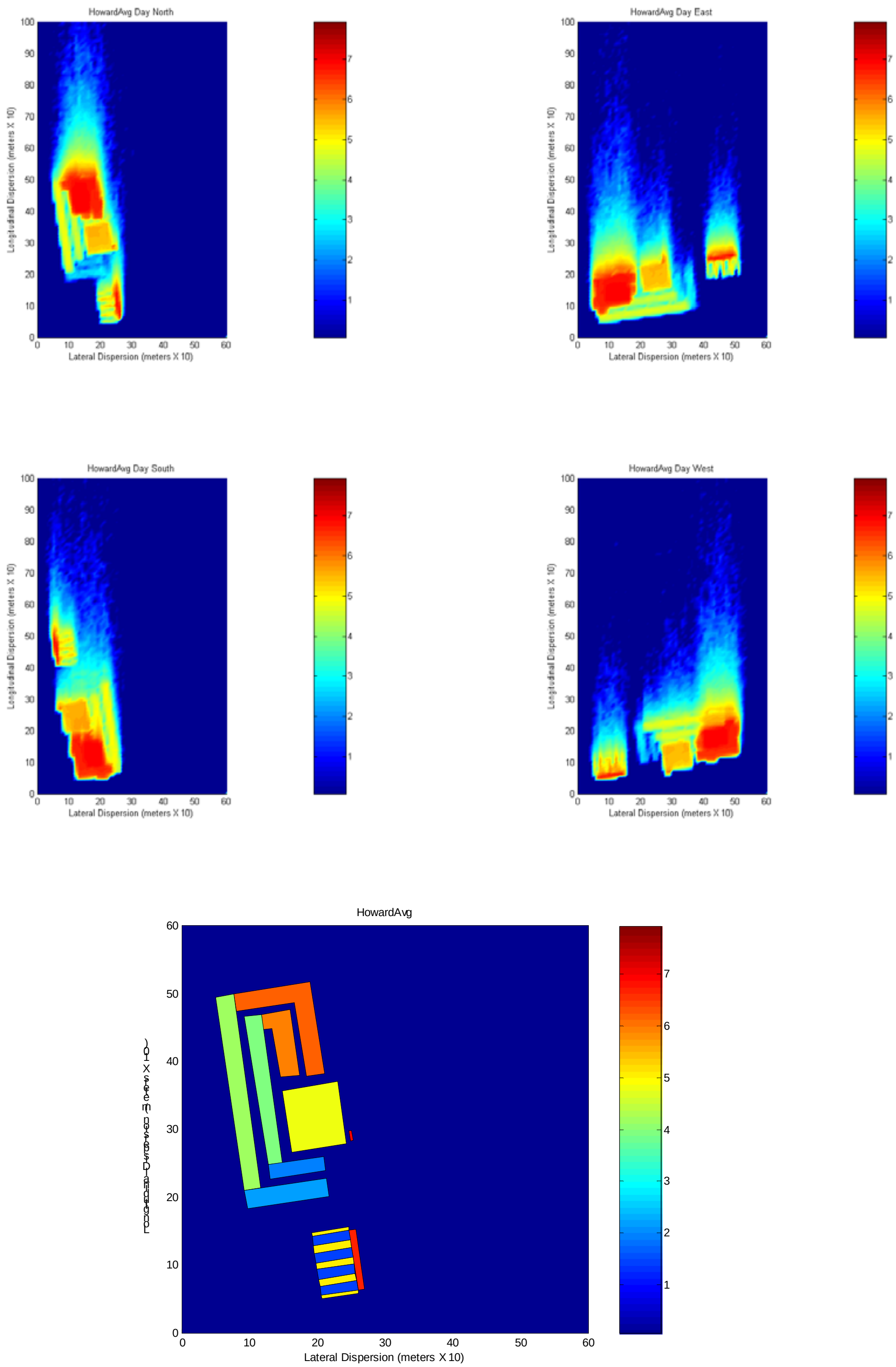

Figure 11a: Howard farm: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Howard-Night

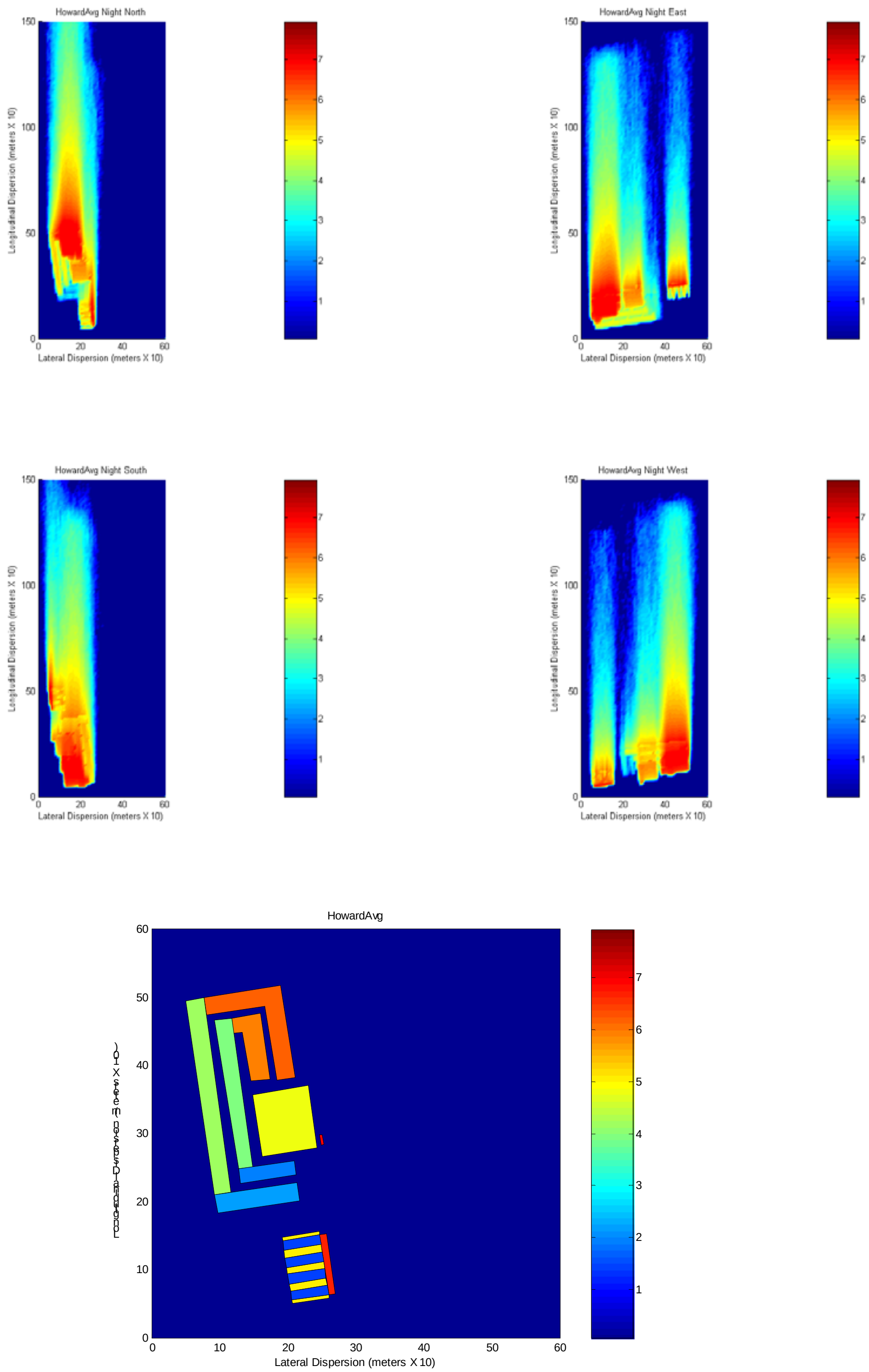

Figure 11b: Howard farm: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Howard No Houses-Day

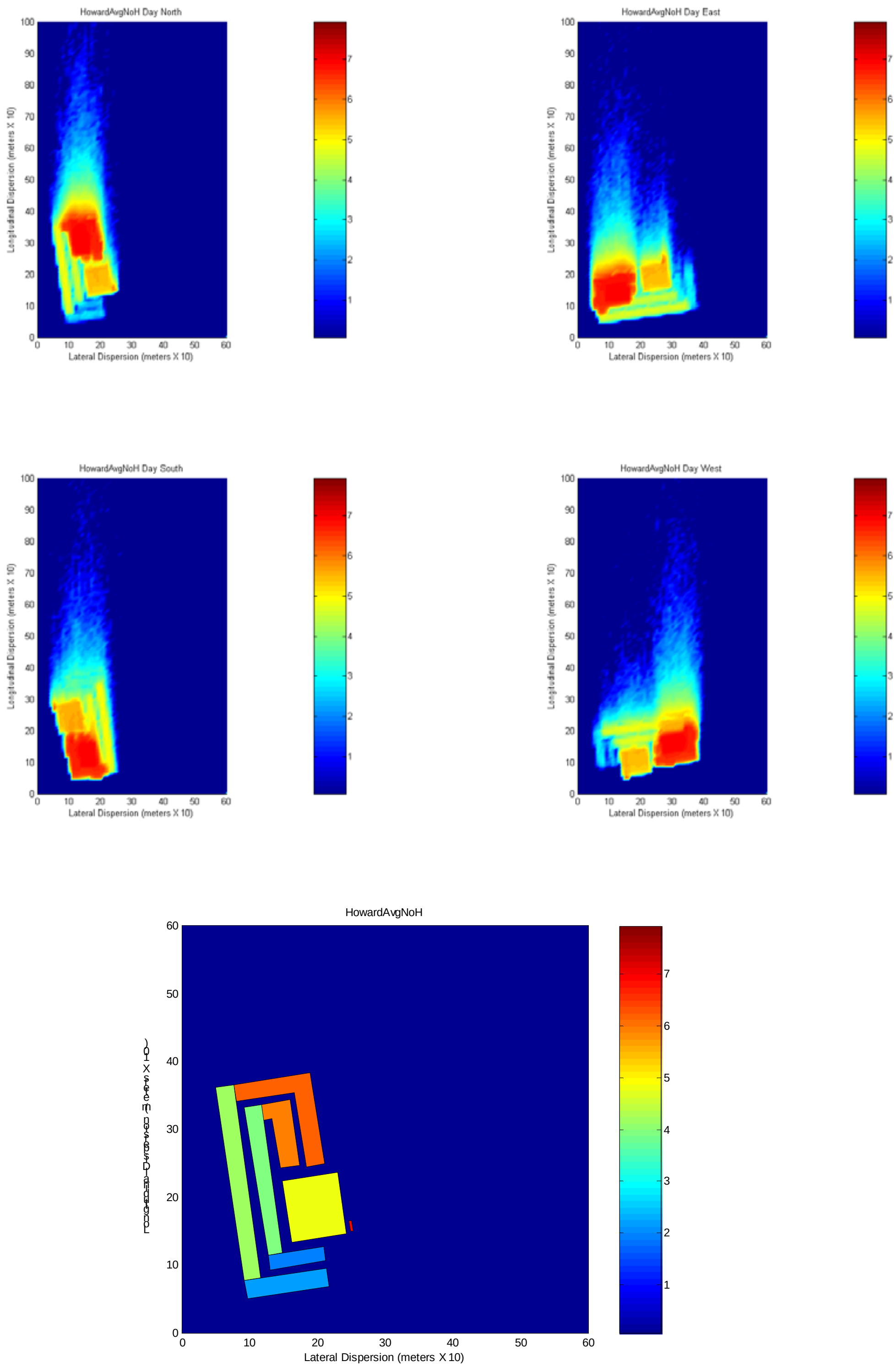

Figure 11c: Howard farm without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Howard No Houses-Night

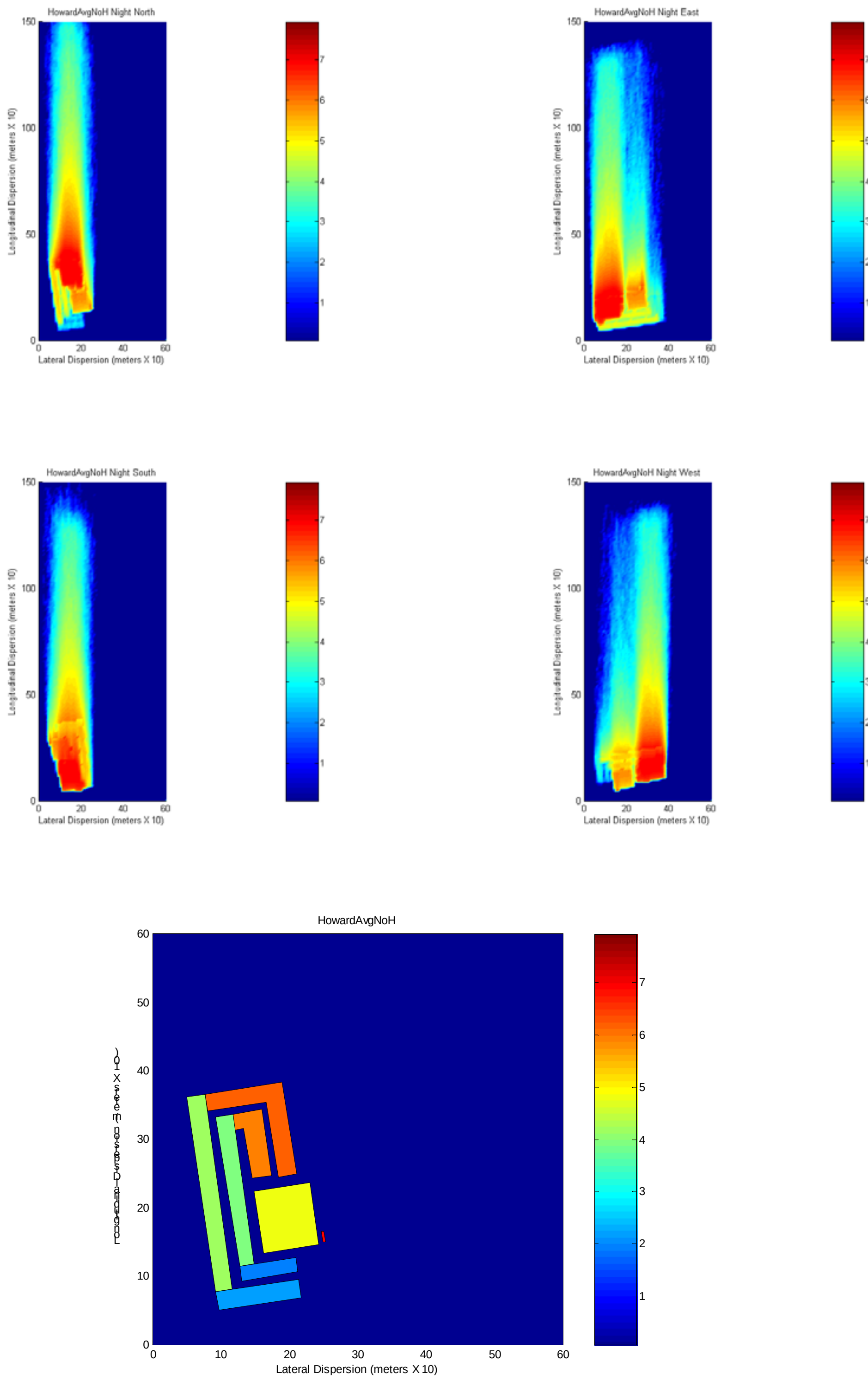

Figure 11d: Howard farm without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Hunt-Day

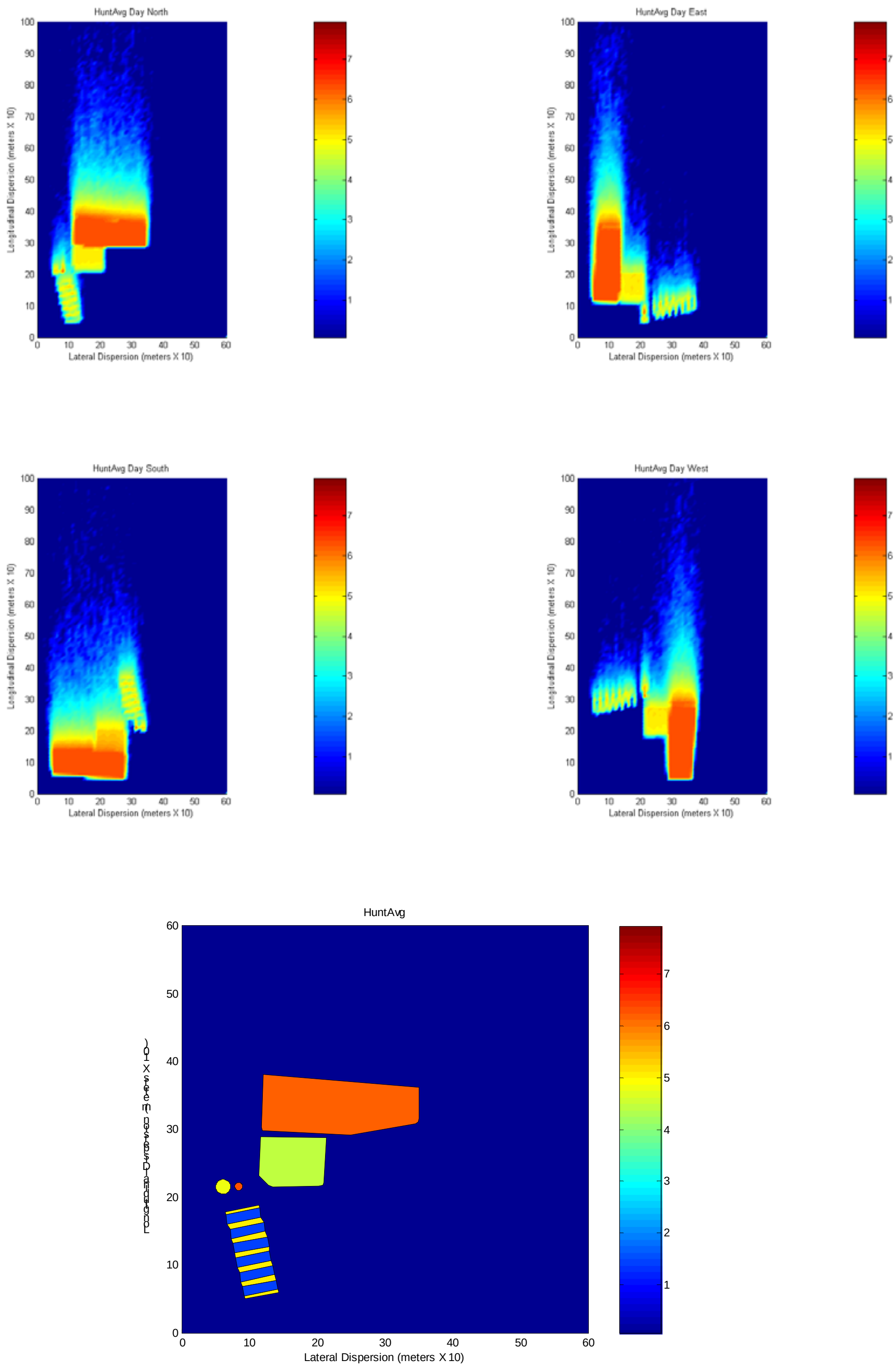

Figure 12a: Hunt farm: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Hunt-Night

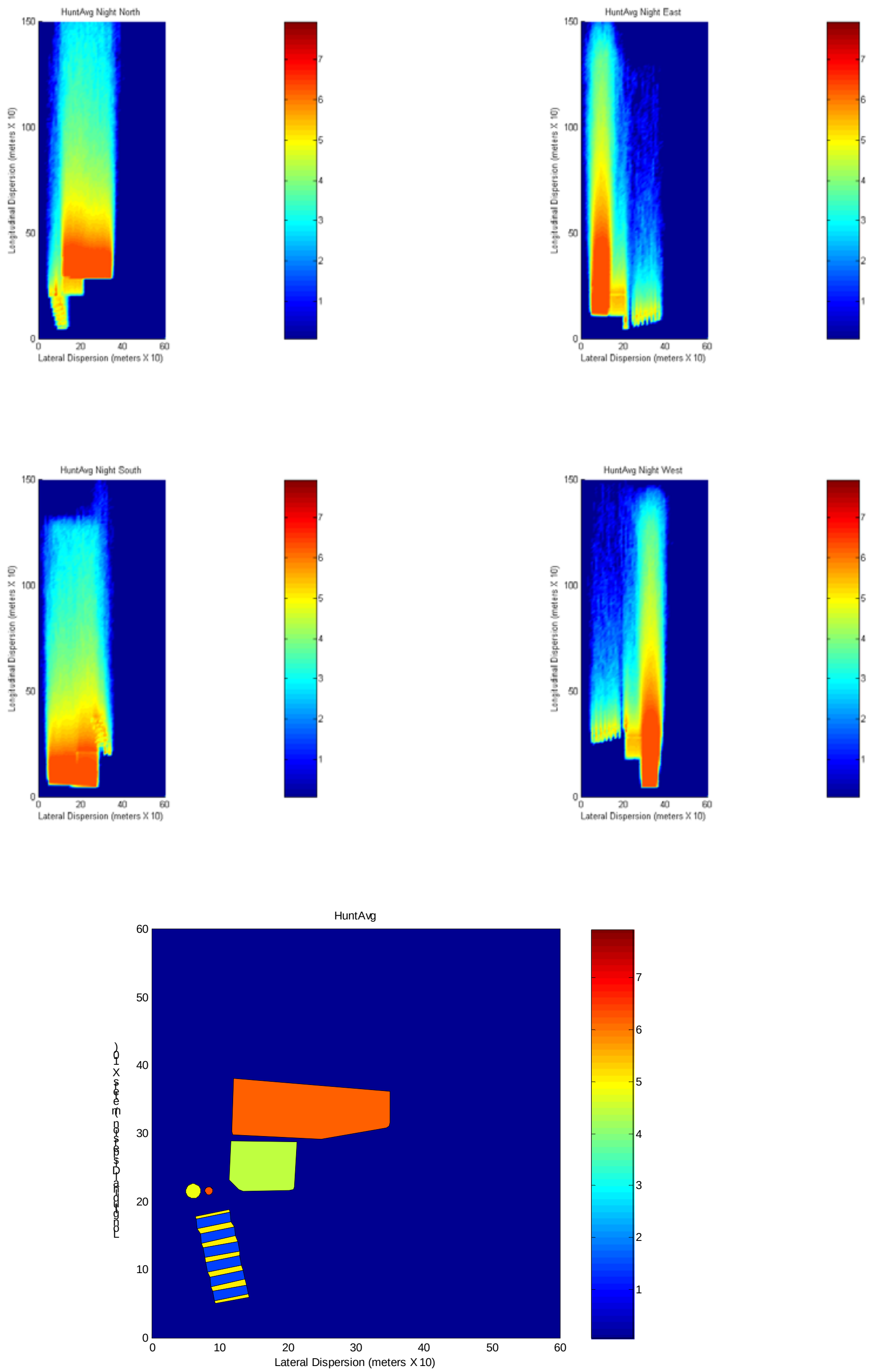

Figure 12b: Hunt farm: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Hunt No Houses-Day

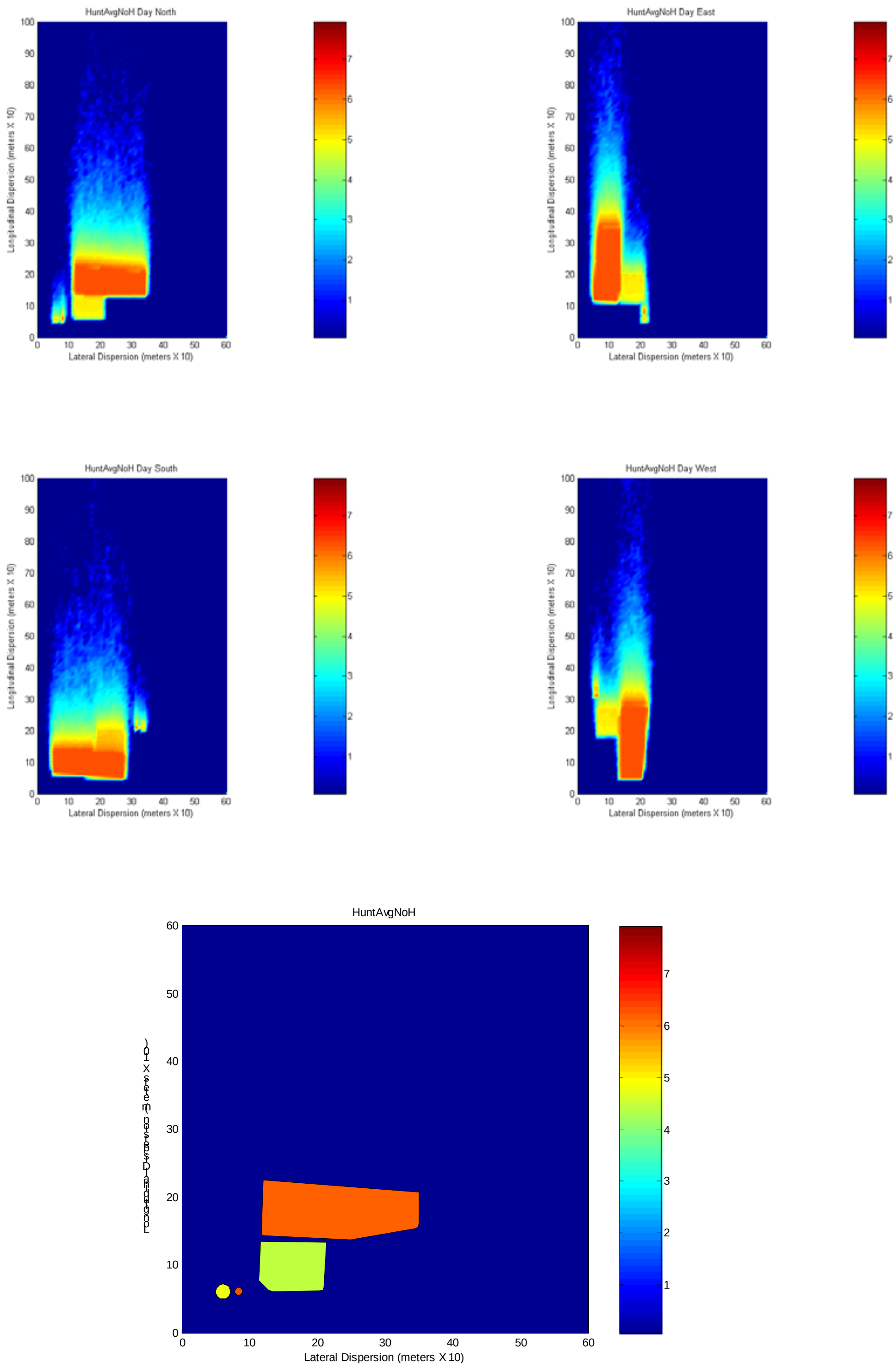

Figure 12c: Hunt farm without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Hunt No Houses-Night

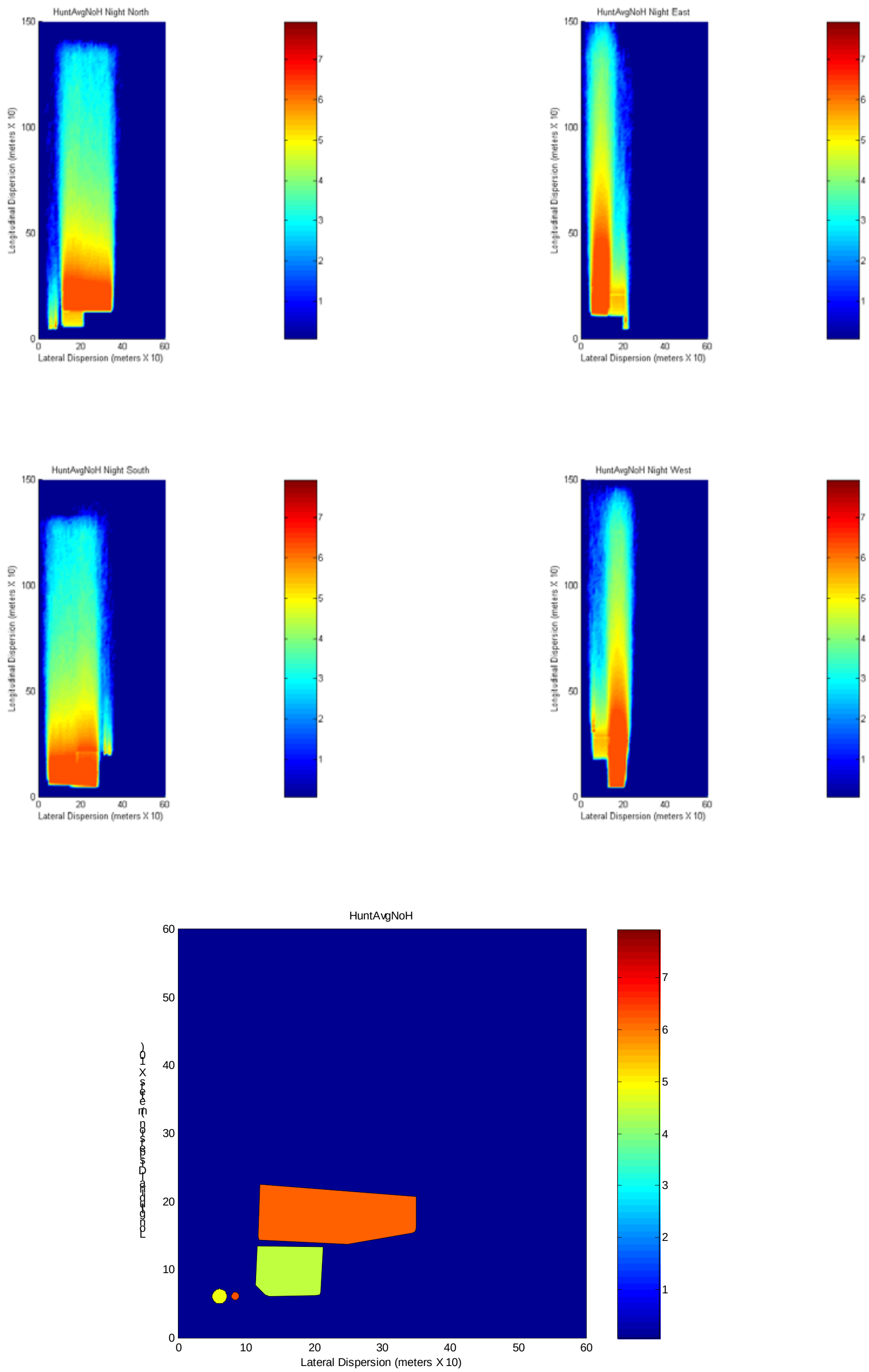

Figure 12d: Hunt farm without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Koger-Day

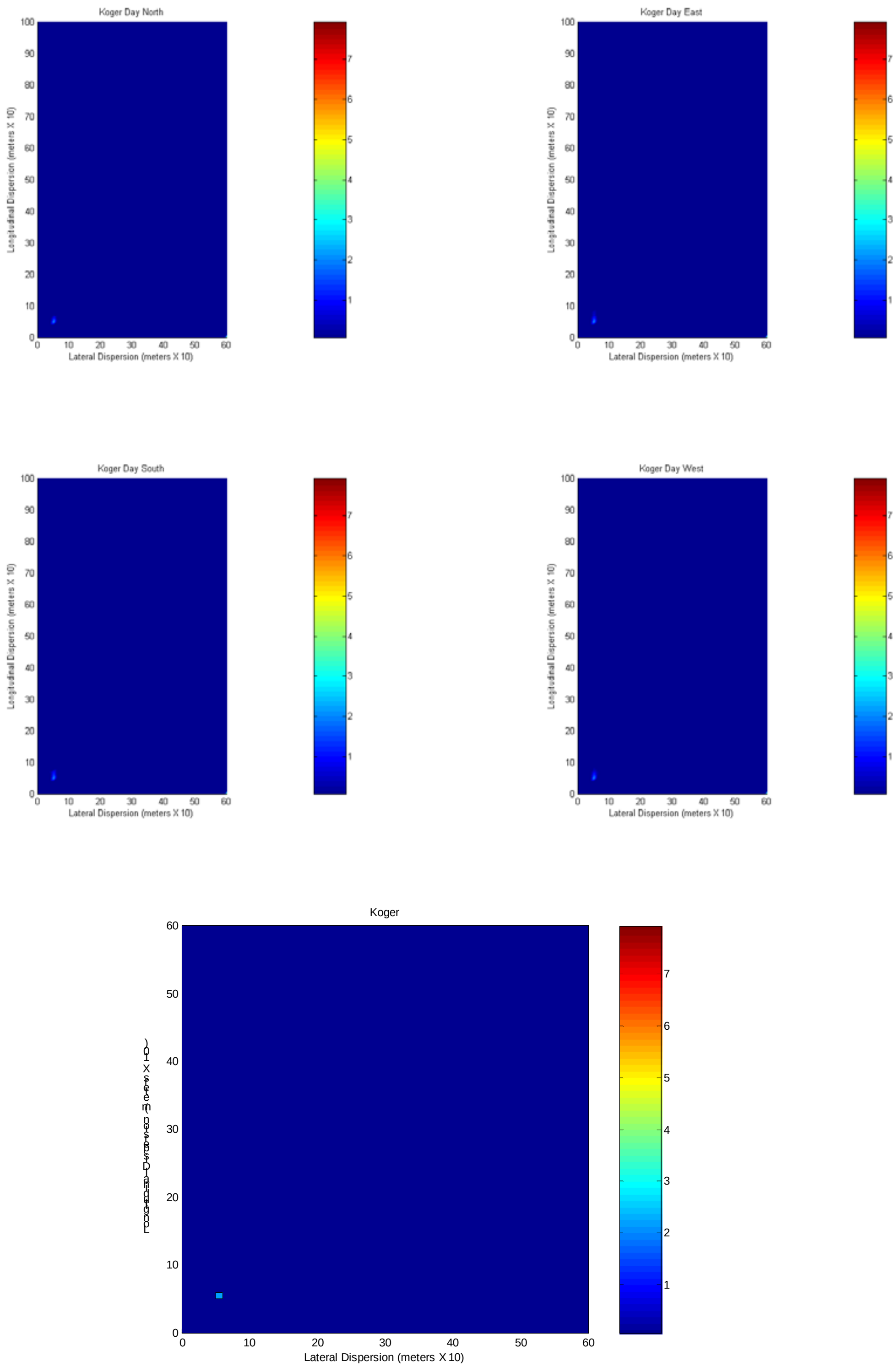

Figure 13a: Koger gasifier: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Koger-Night

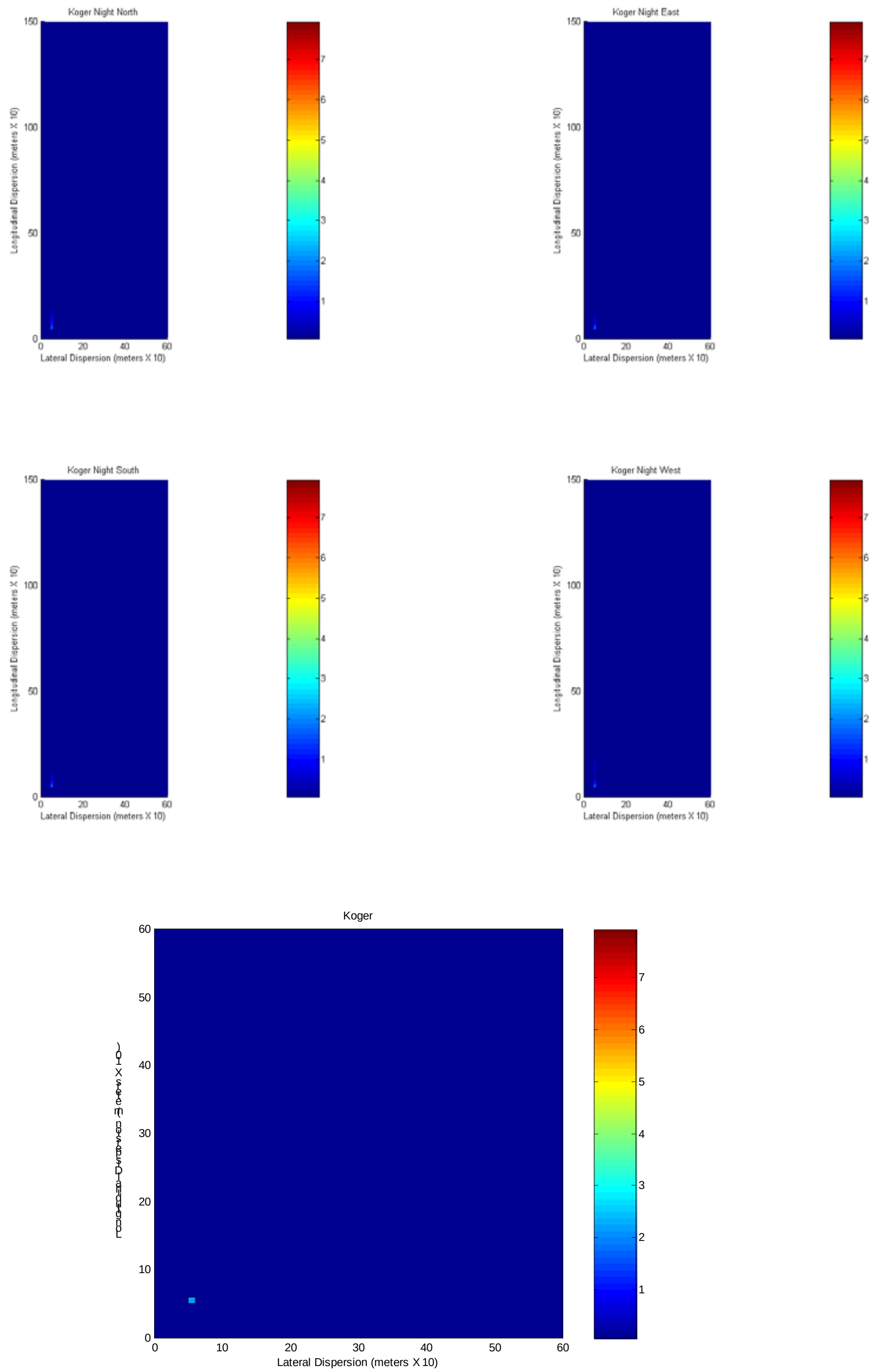

Figure 13b: Koger gasifier: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Lake Wheeler Rd. Belt System-Day

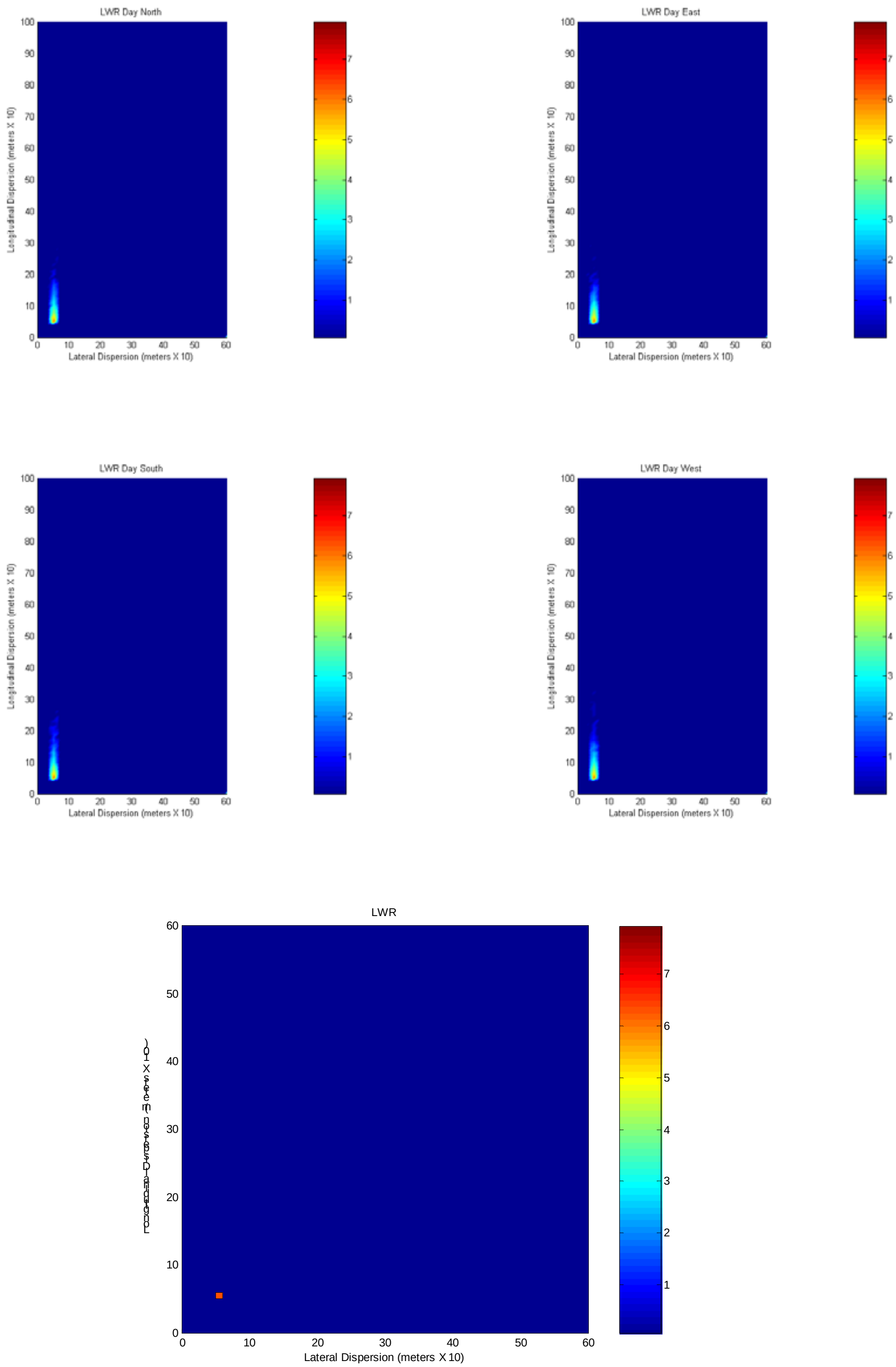

Figure 14a: Lake Wheeler Rd. belt system: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Lake Wheeler Rd. Belt System-Night

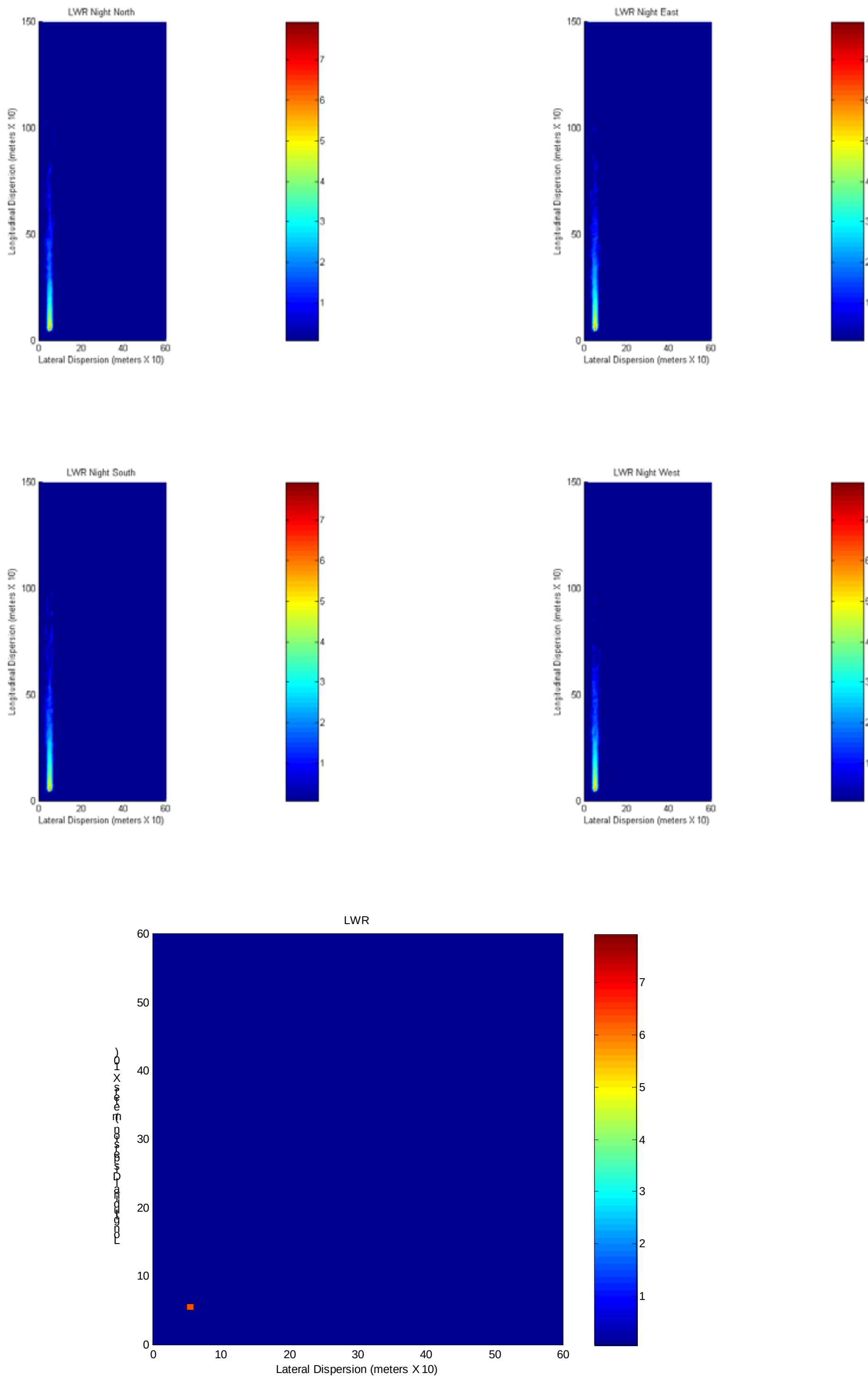

Figure 14b: Lake Wheeler Rd. belt system: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

ORBIT-Day

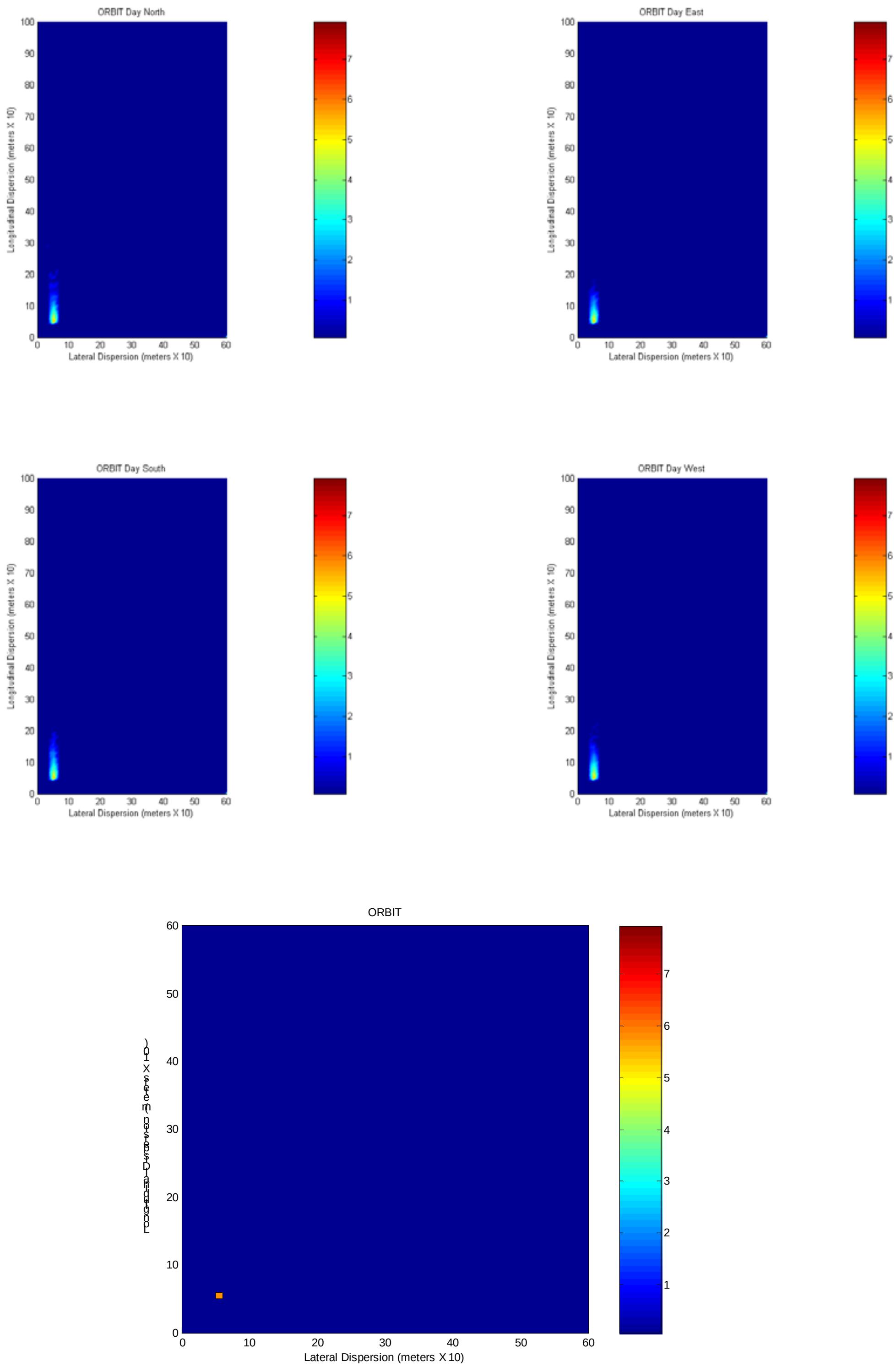

Figure 15a: ORBIT: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

ORBIT-Night

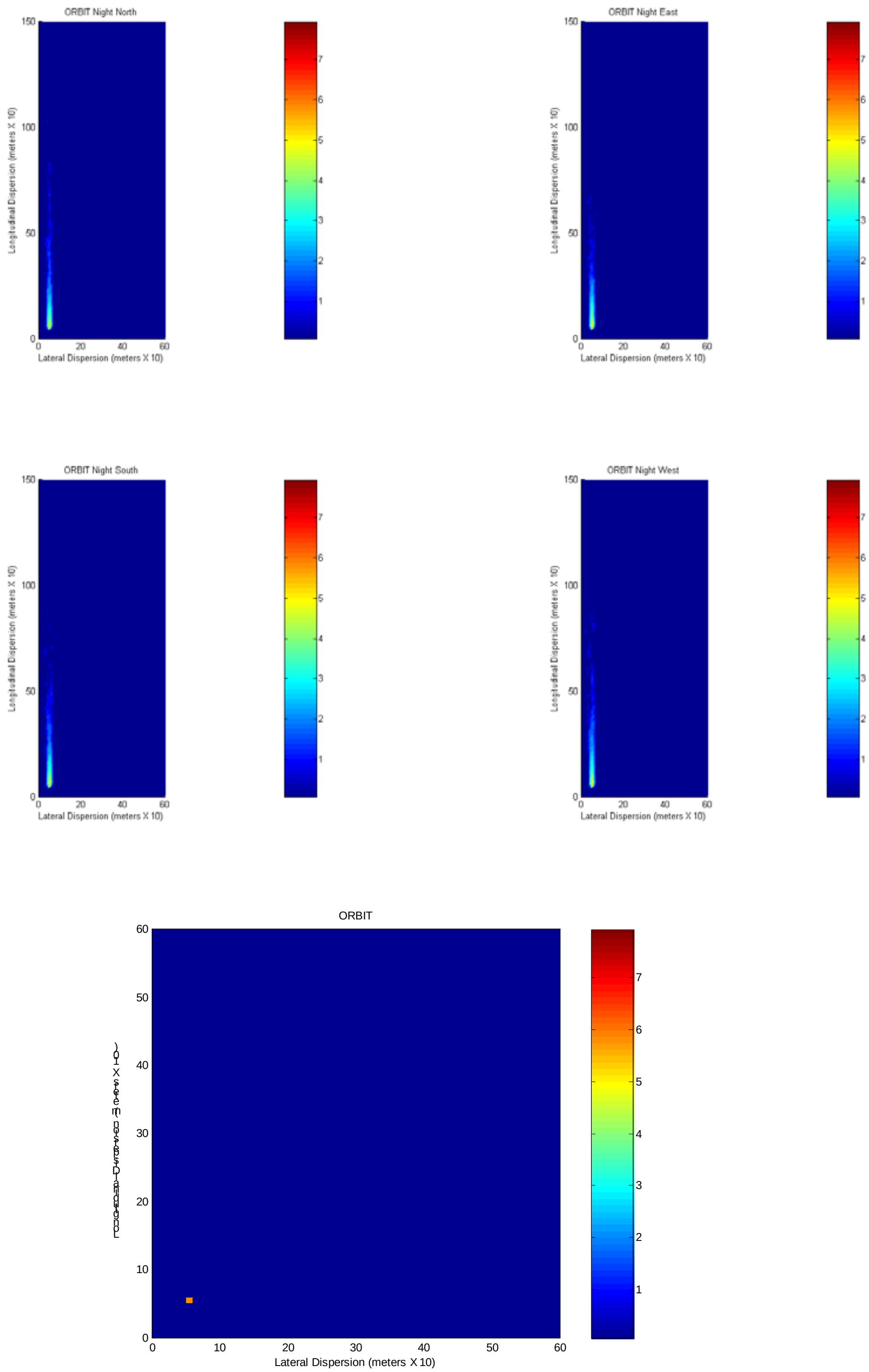

Figure 15b: ORBIT: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

ReCip-Day

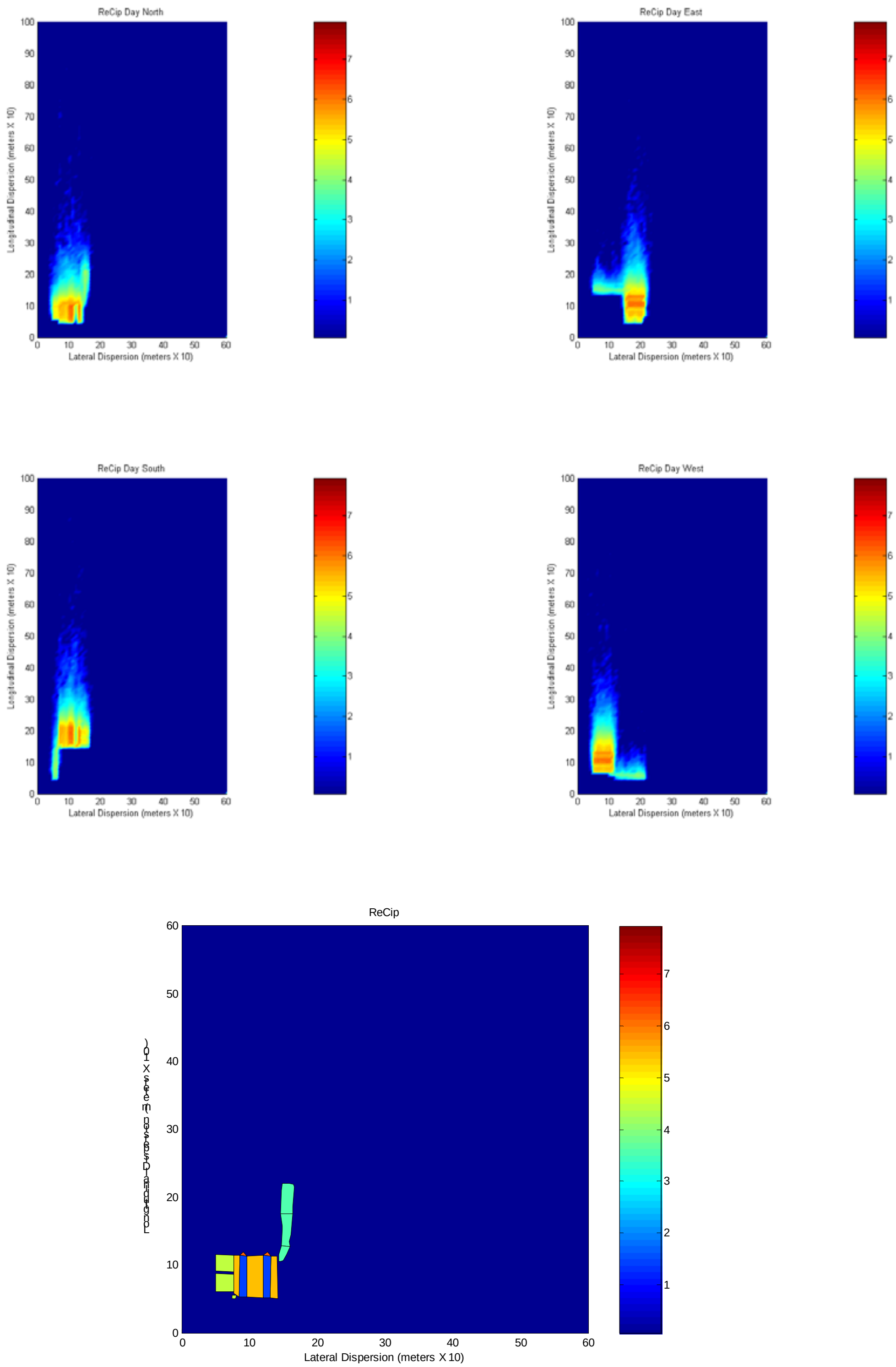

Figure 16a: ReCip farm: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

ReCip-Night

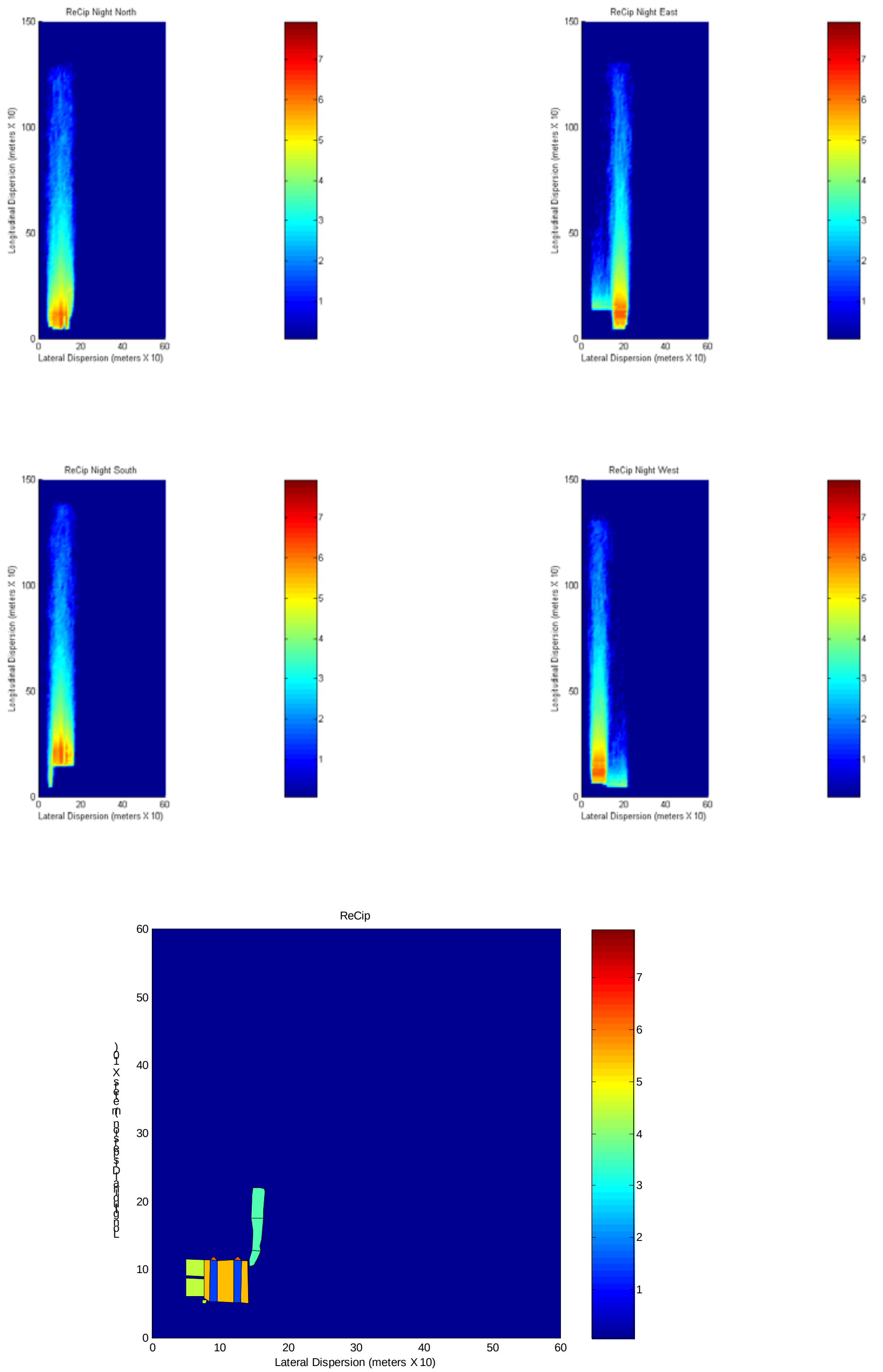

Figure 16b: ReCip farm: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

ReCip No Houses-Day

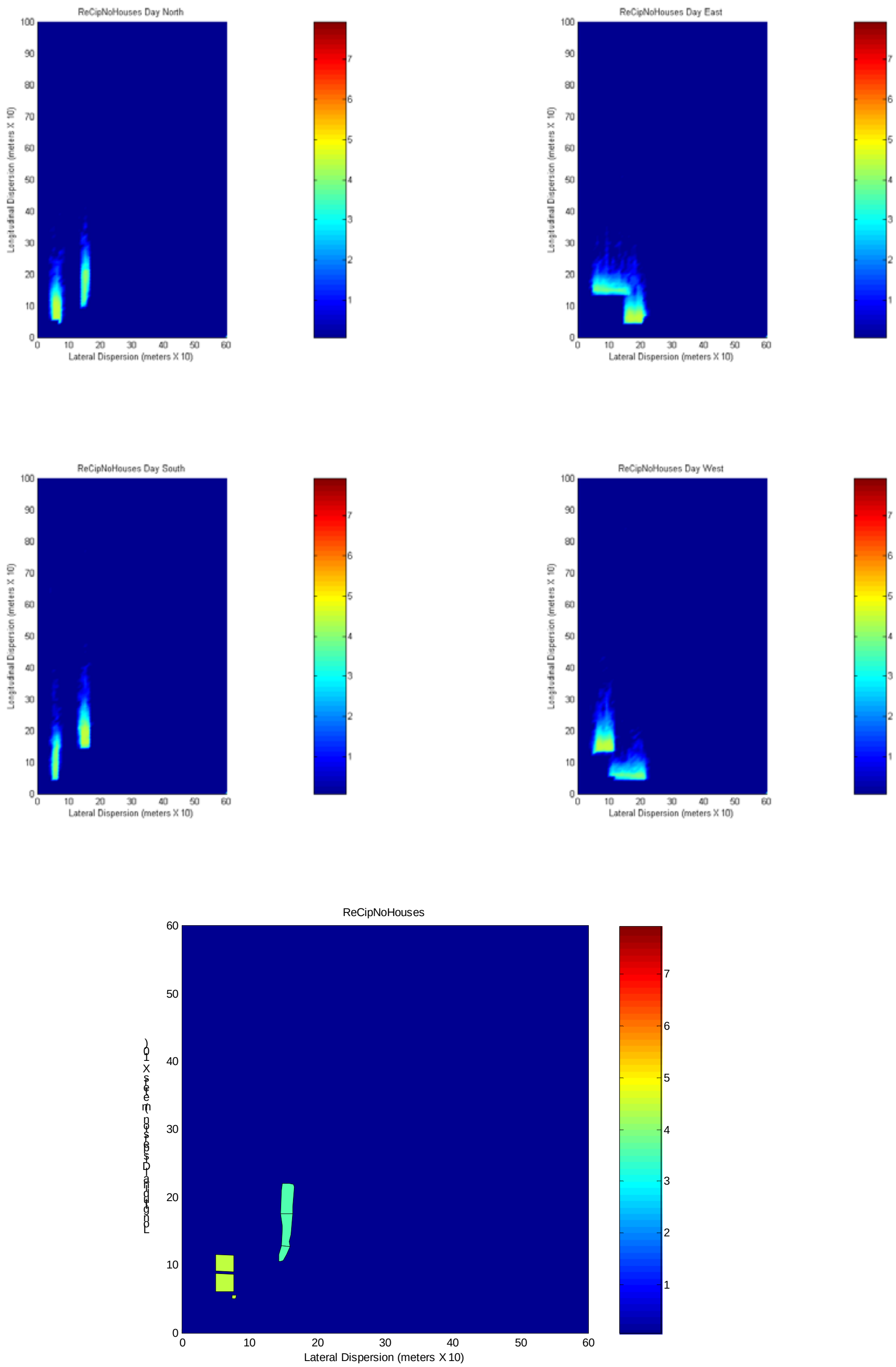

Figure 16c: ReCip farm without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

ReCip No Houses-Night

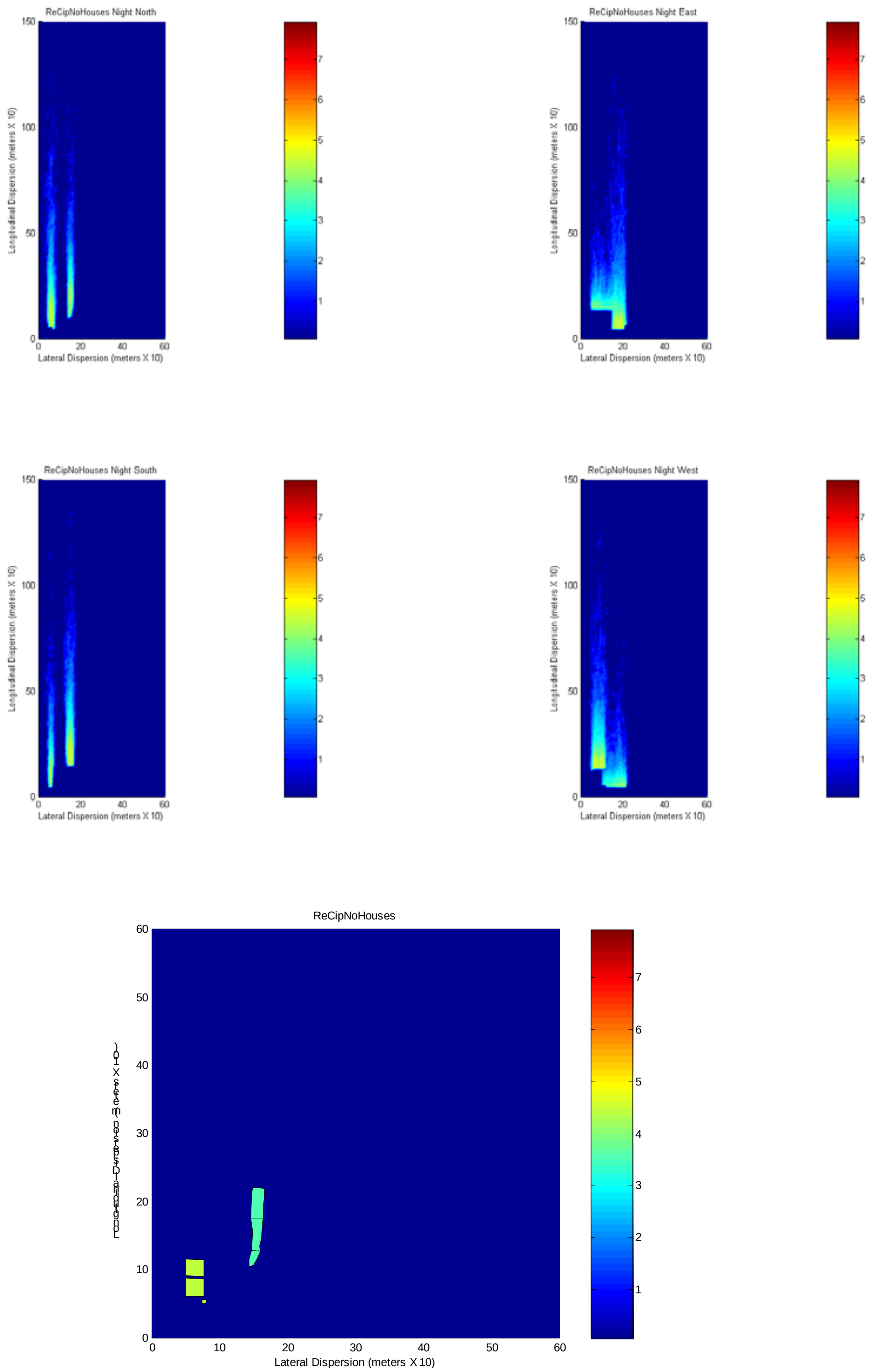

Figure 16d: ReCip farm without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Super Soils-Day

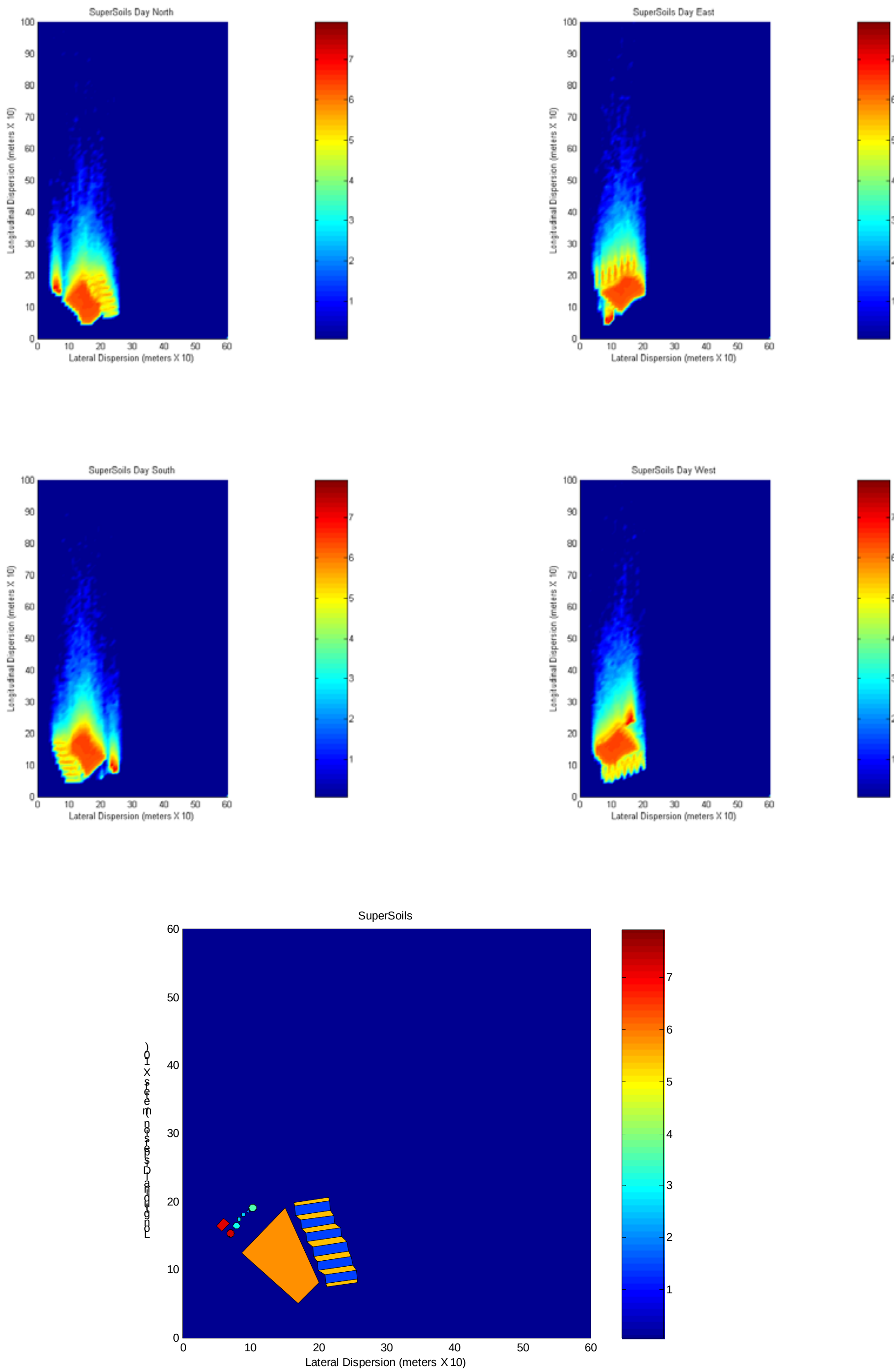

Figure 17a: Super Soils farm: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Super Soils-Night

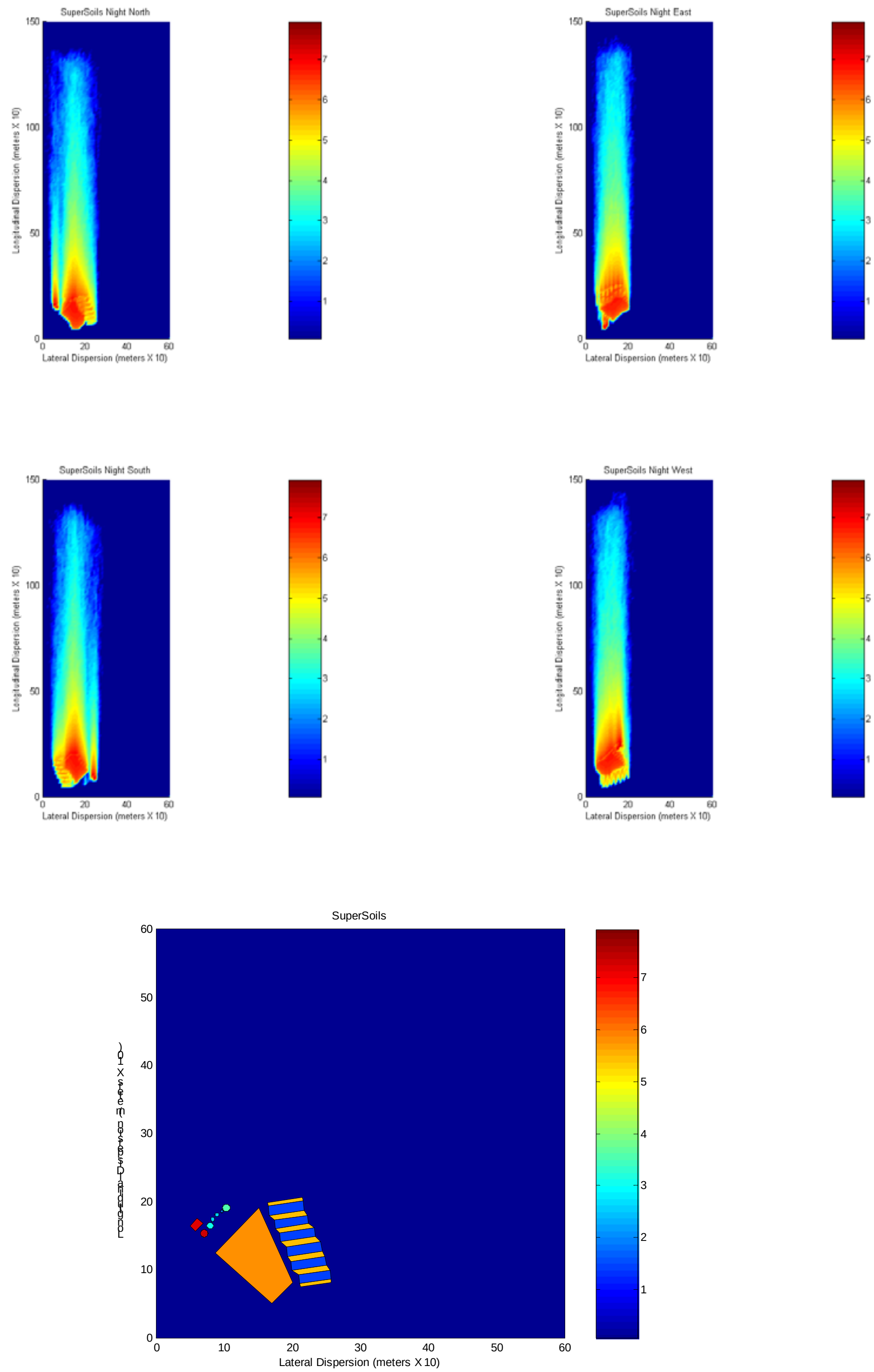

Figure 17b: Super Soils farm: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Super Soils Technology-Day

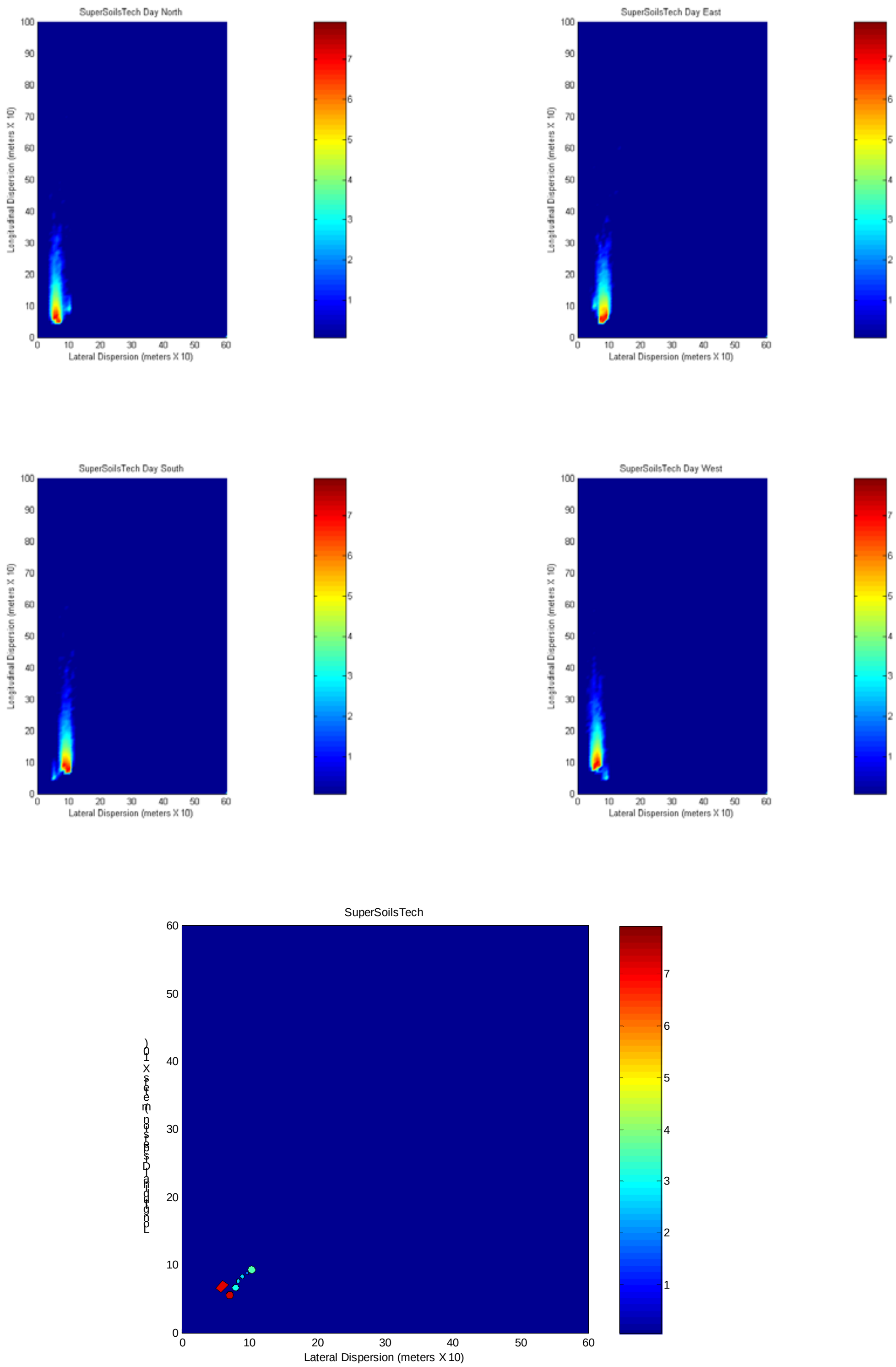

Figure 17c: Super Soils technology: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Super Soils Technology-Night

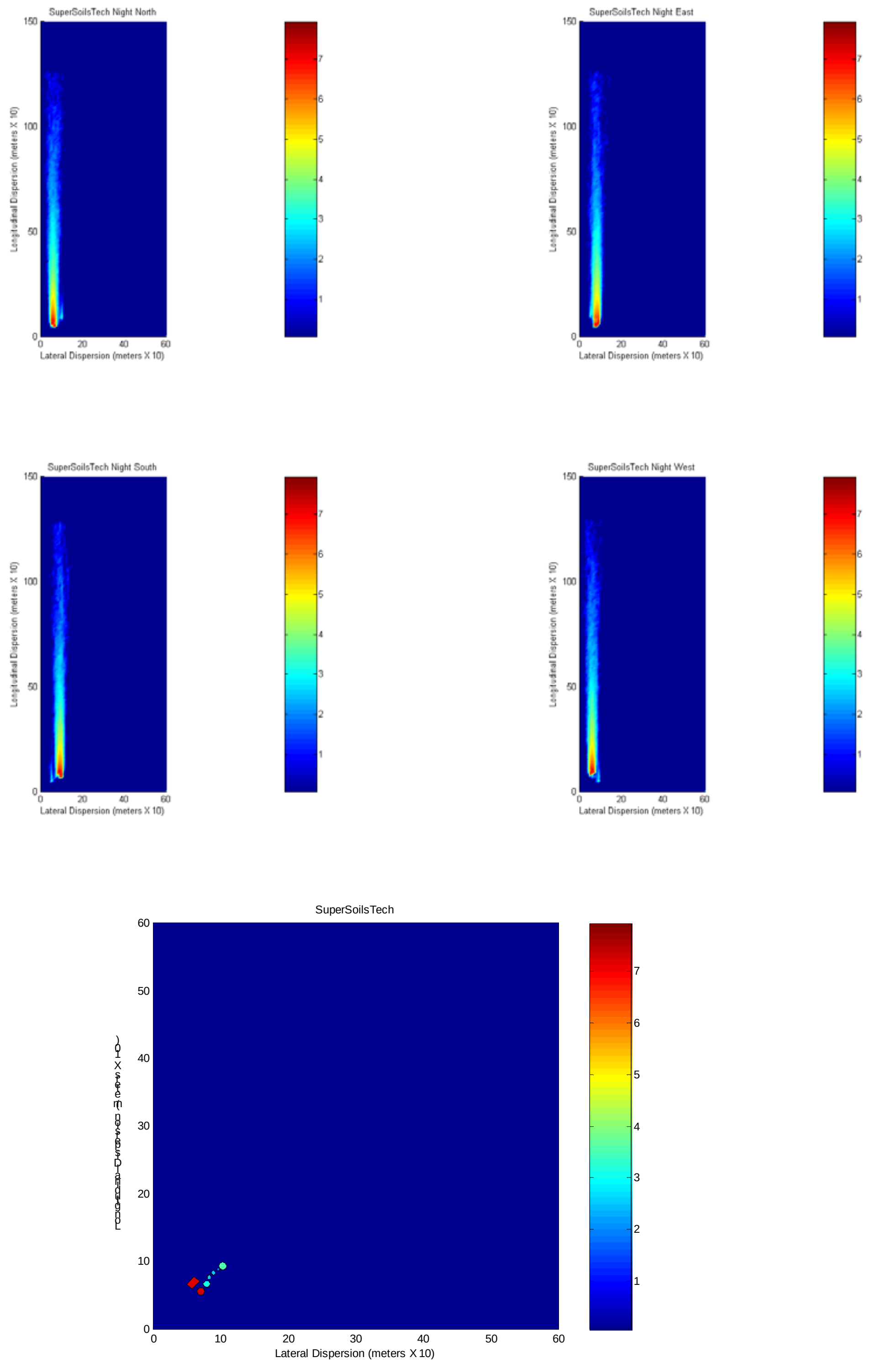

Figure 17d: Super Soils technology: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Super Soils Composting-Day

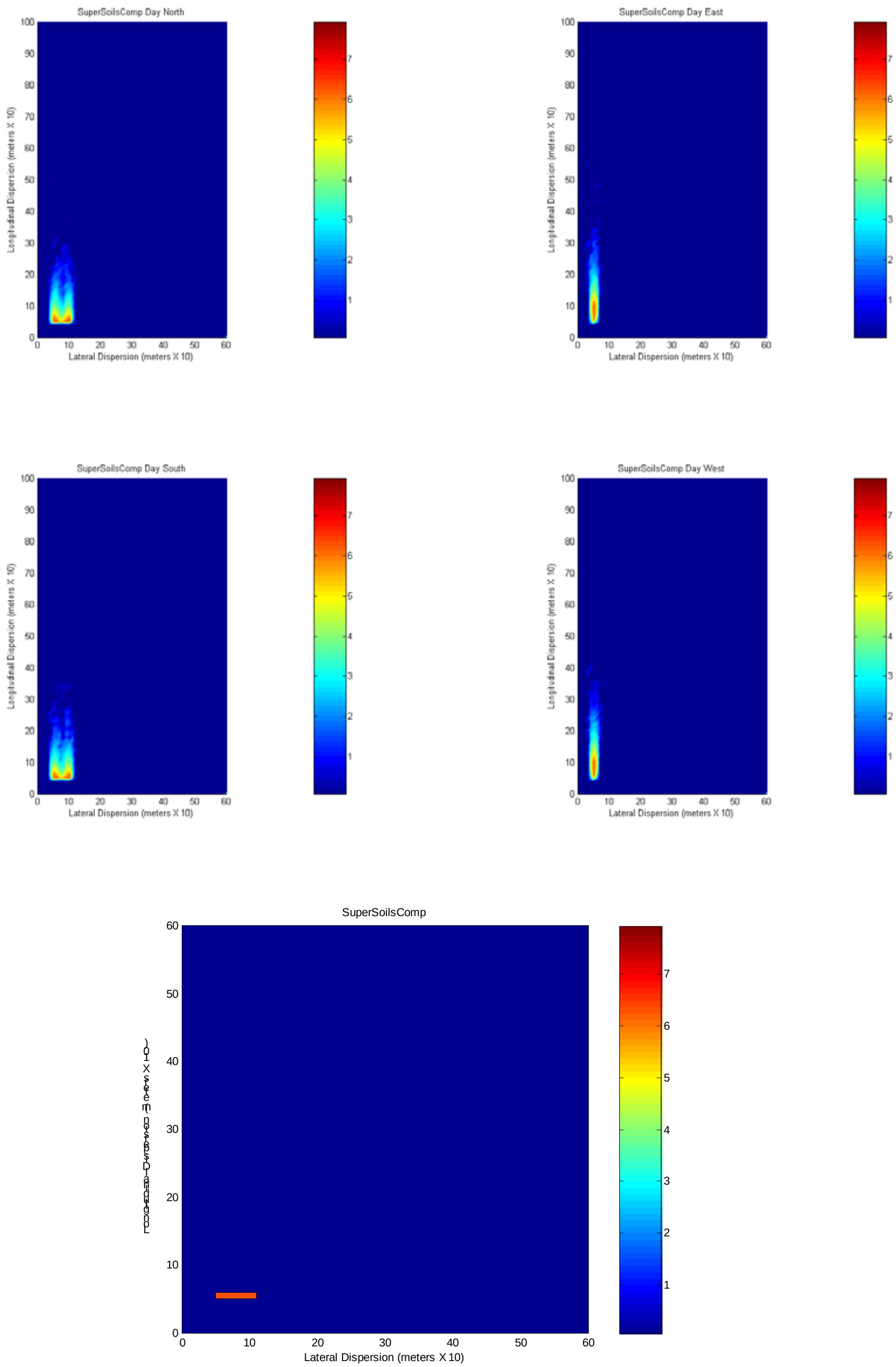

Figure 18a: Super Soils composting site: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Super Soils Composting-Night

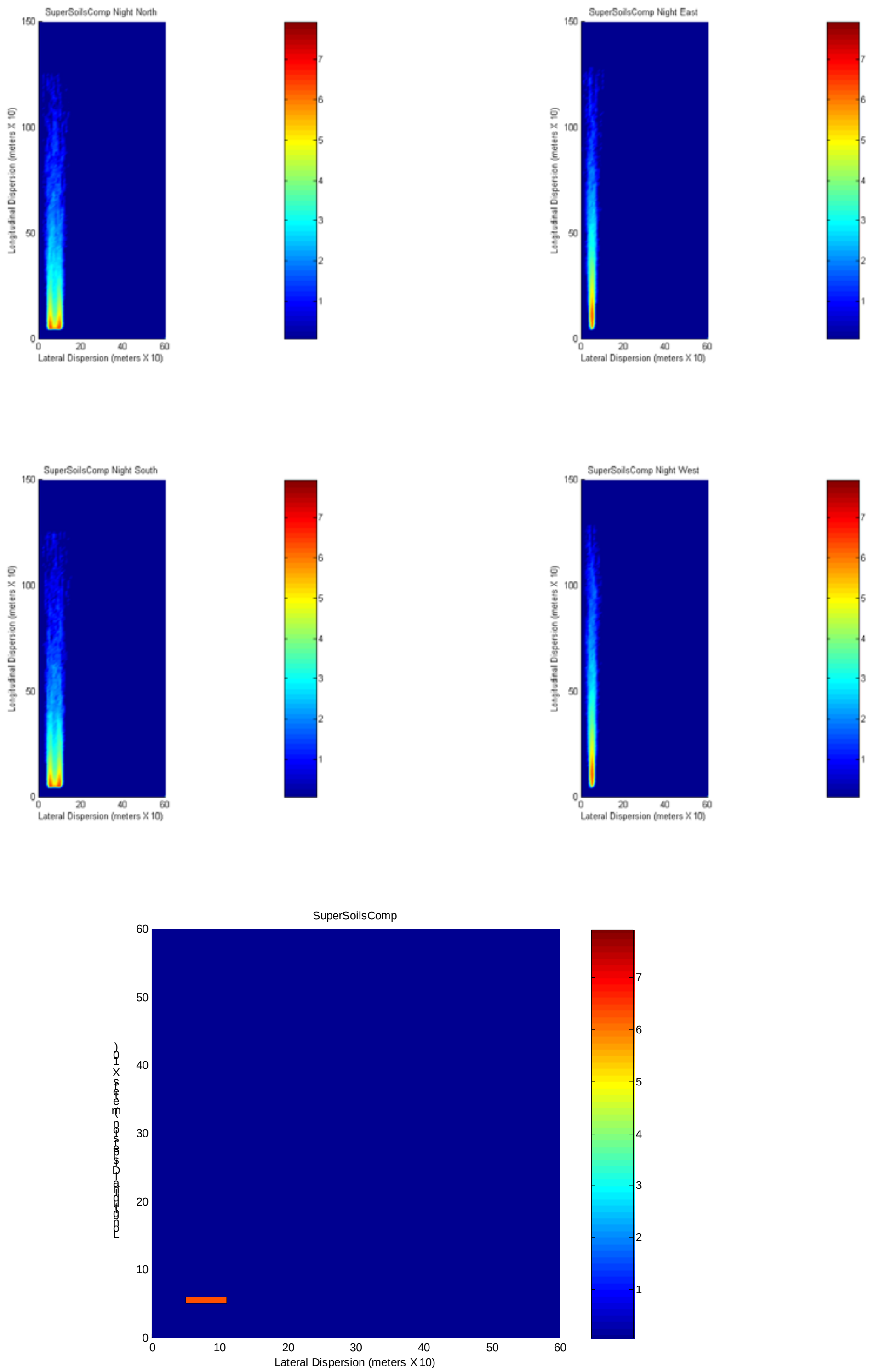

Figure 18b: Super Soils composting site: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Vestal Average-Day

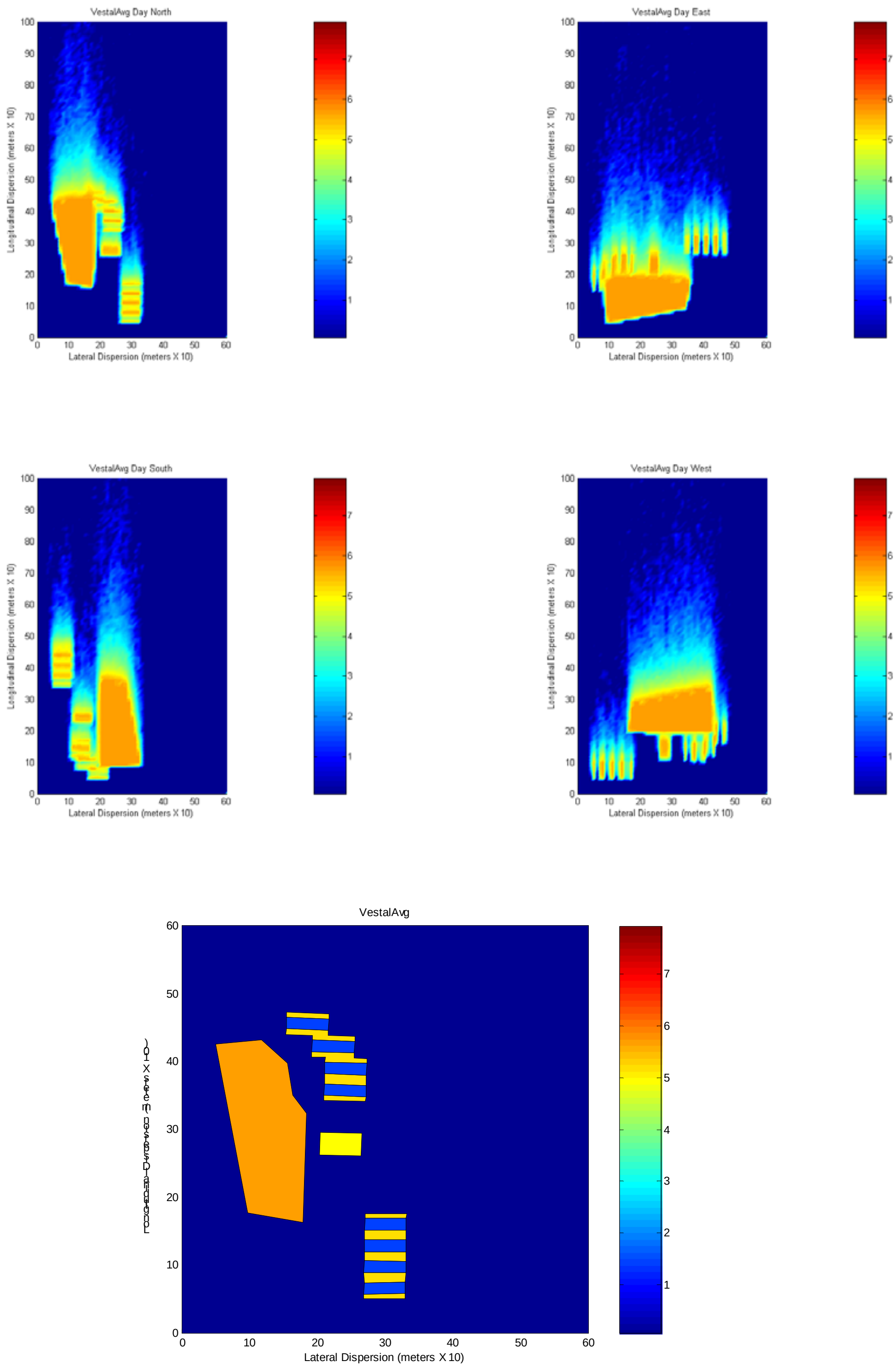

Figure 19a: Vestal farm average: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Vestal Average-Night

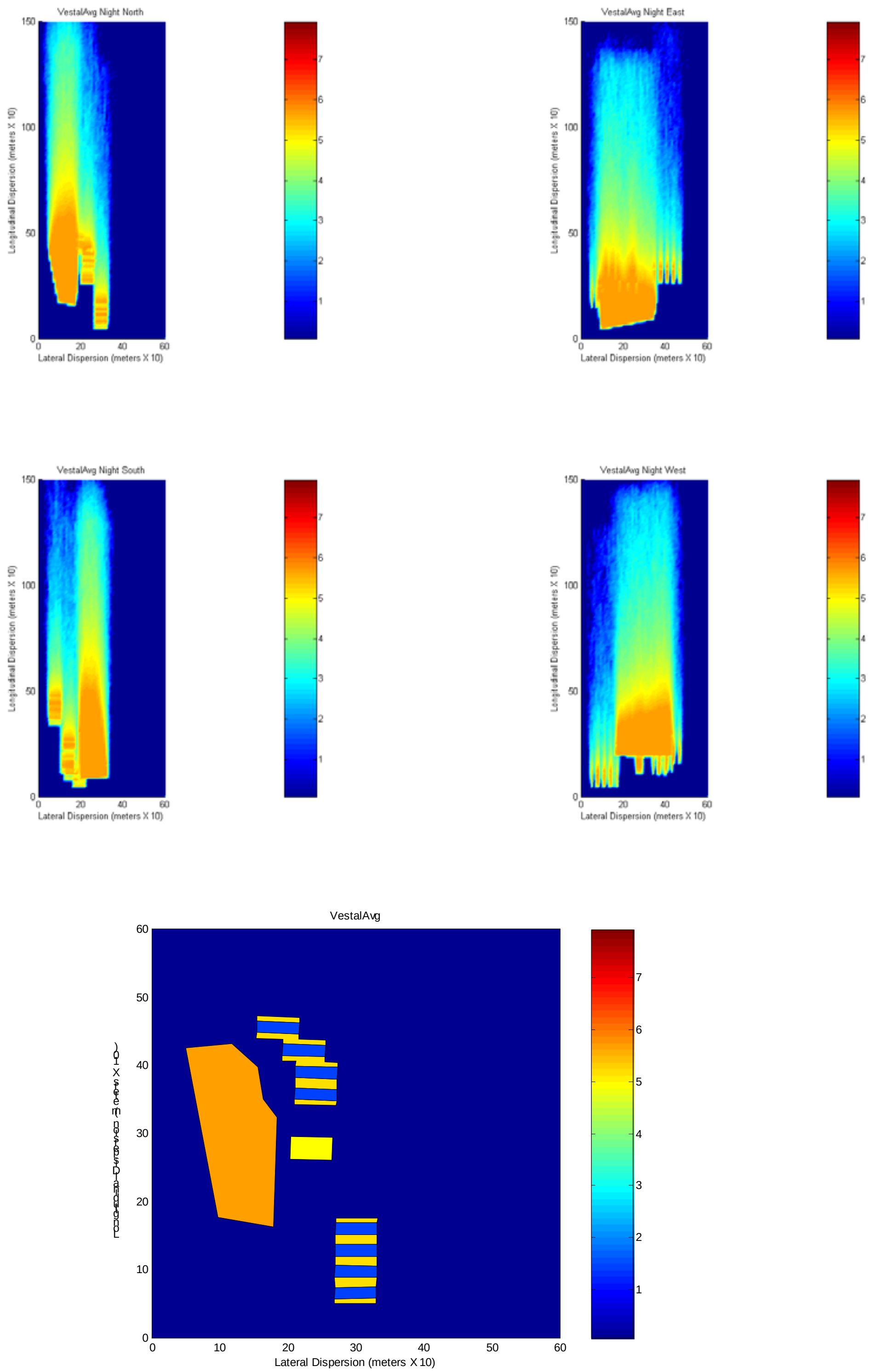

Figure 19b: Vestal farm average: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Vestal Average No Houses-Day

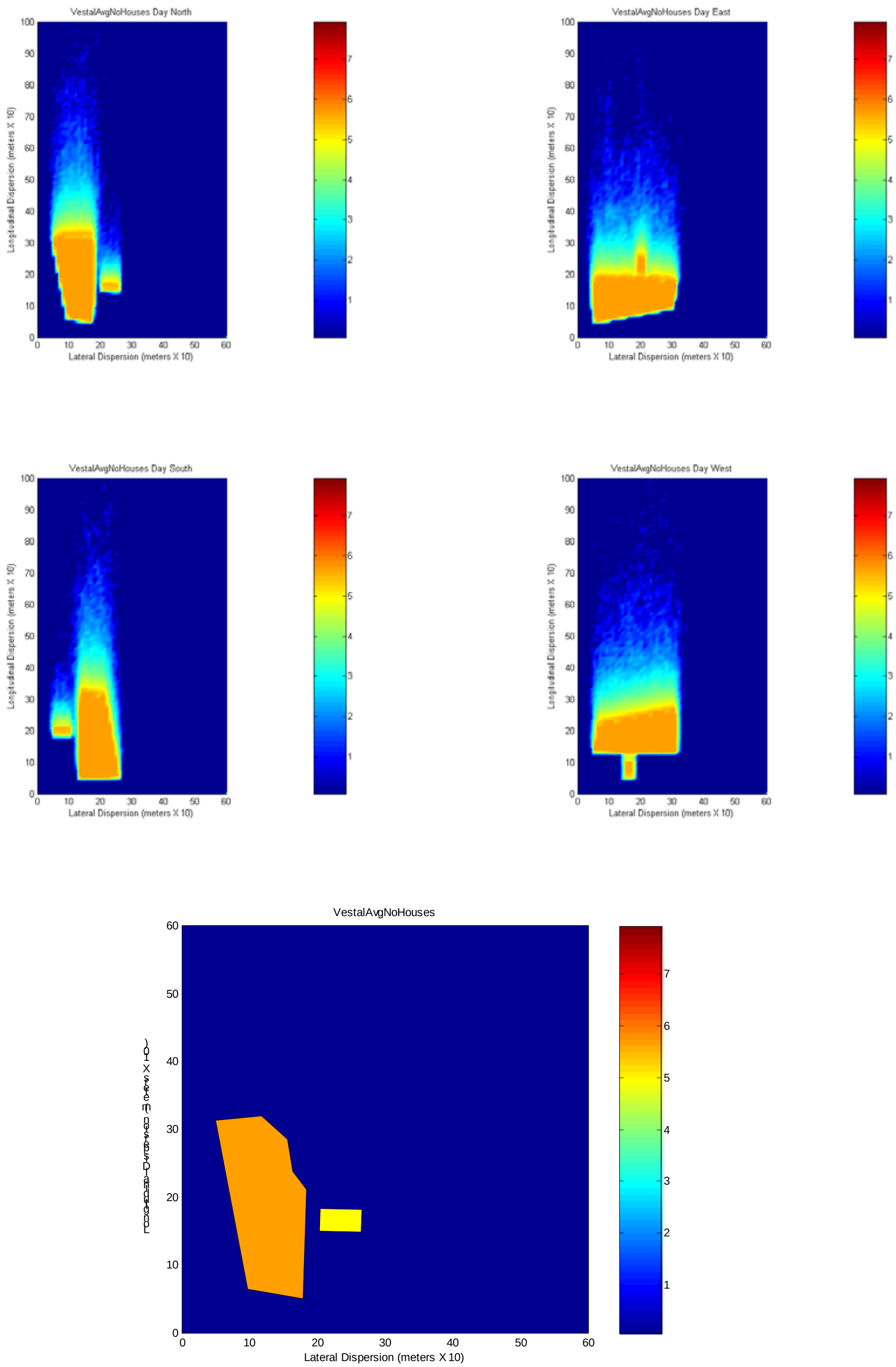

Figure 19c: Vestal farm average without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Vestal Average No Houses-Night

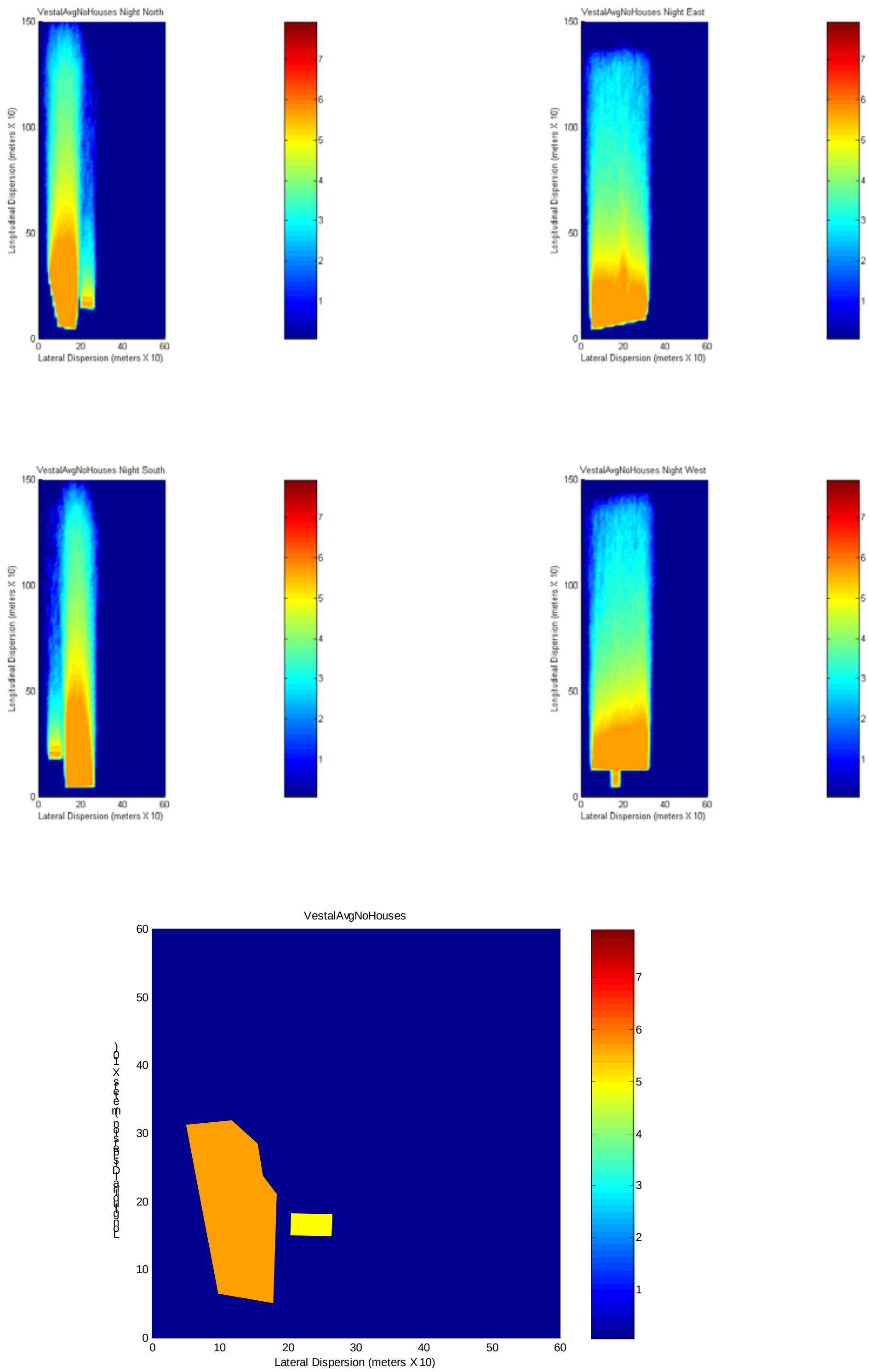

Figure 19d: Vestal farm average without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Vestal March 2004-Day

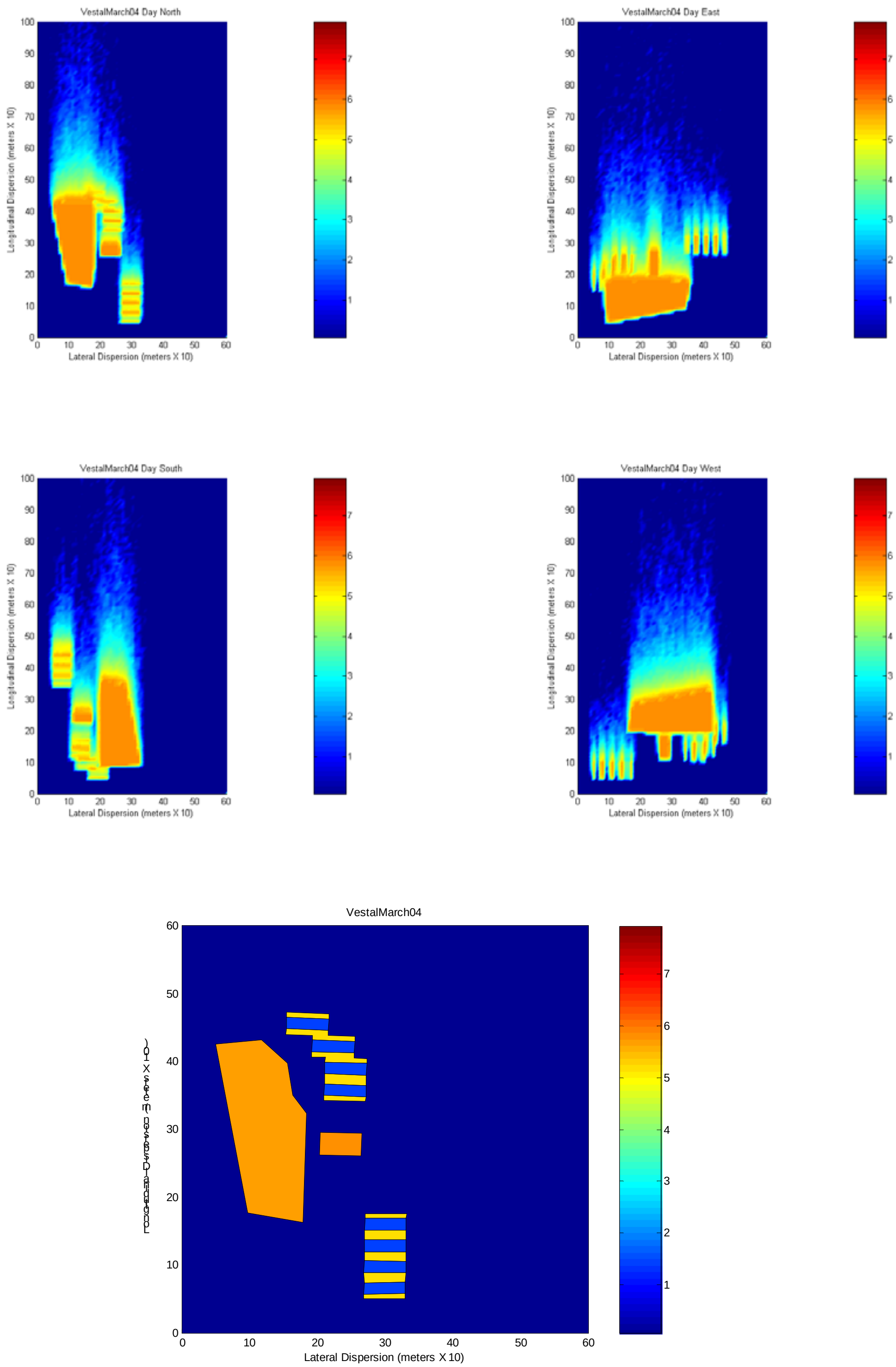

Figure 19e: Vestal farm March 2004: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Vestal March 2004-Night

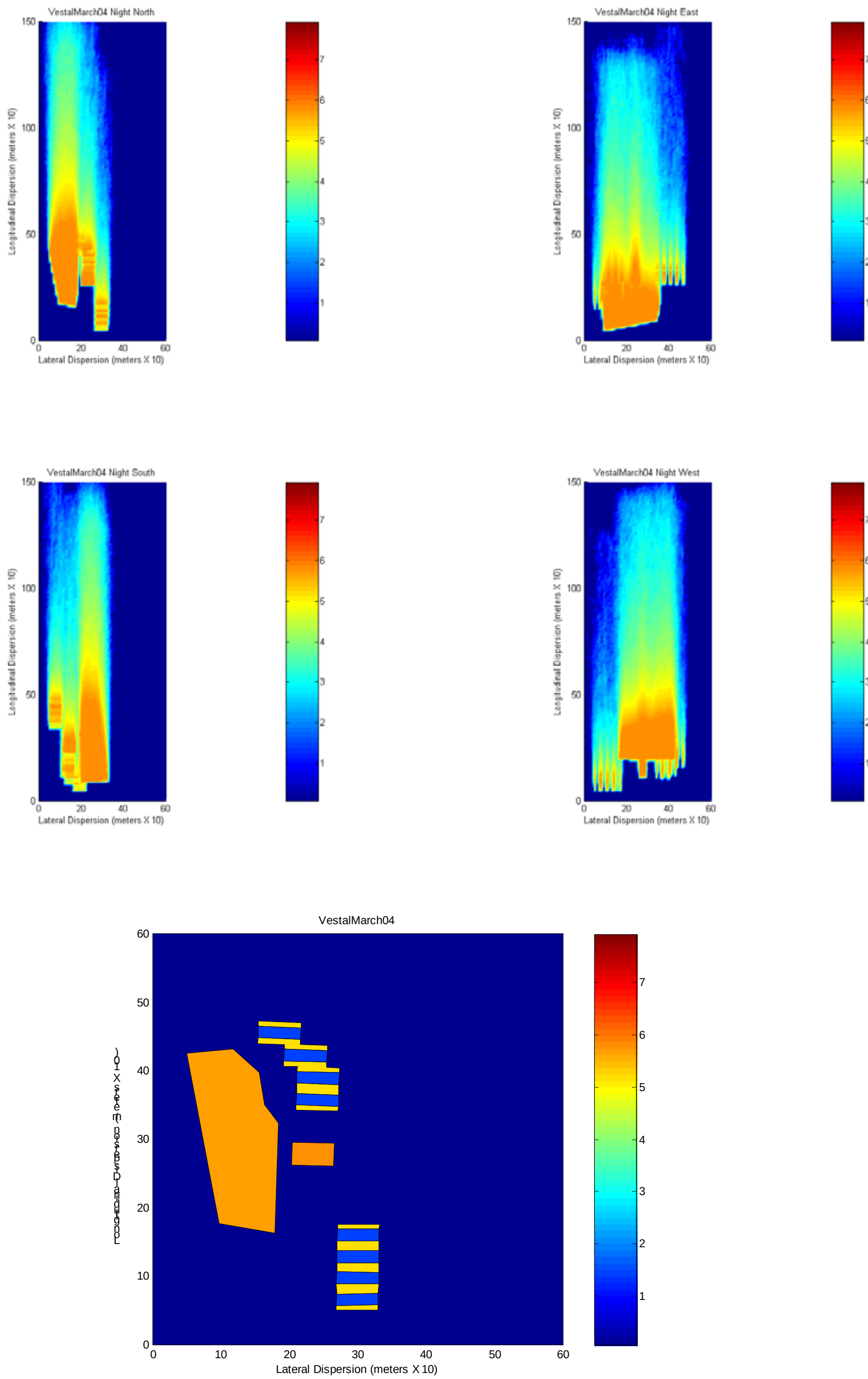

Figure 19f: Vestal farm March 2004: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Vestal March 2004 No Houses-Day

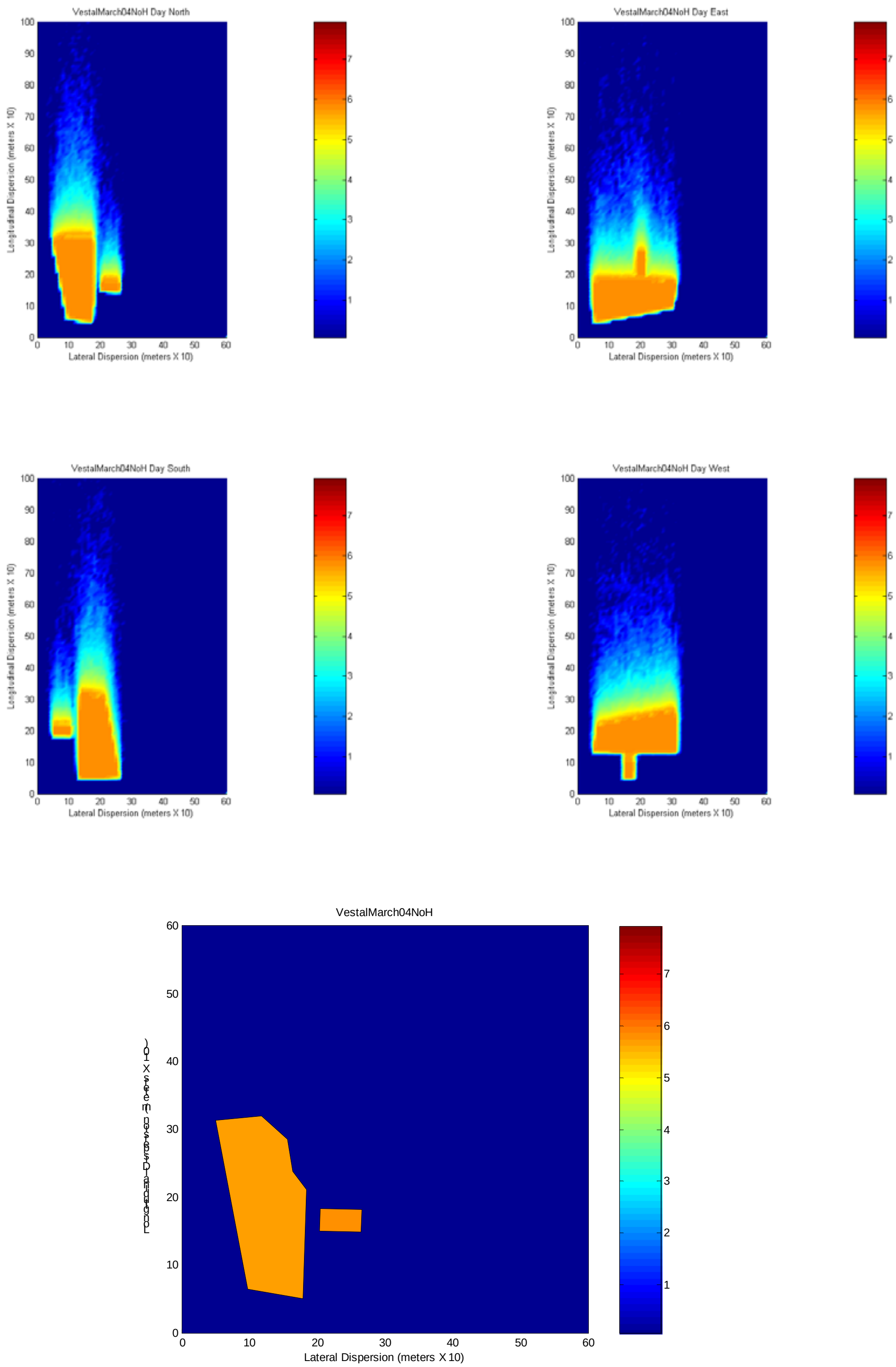

Figure 19g: Vestal farm March 2004 without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Vestal March 2004 No Houses-Night

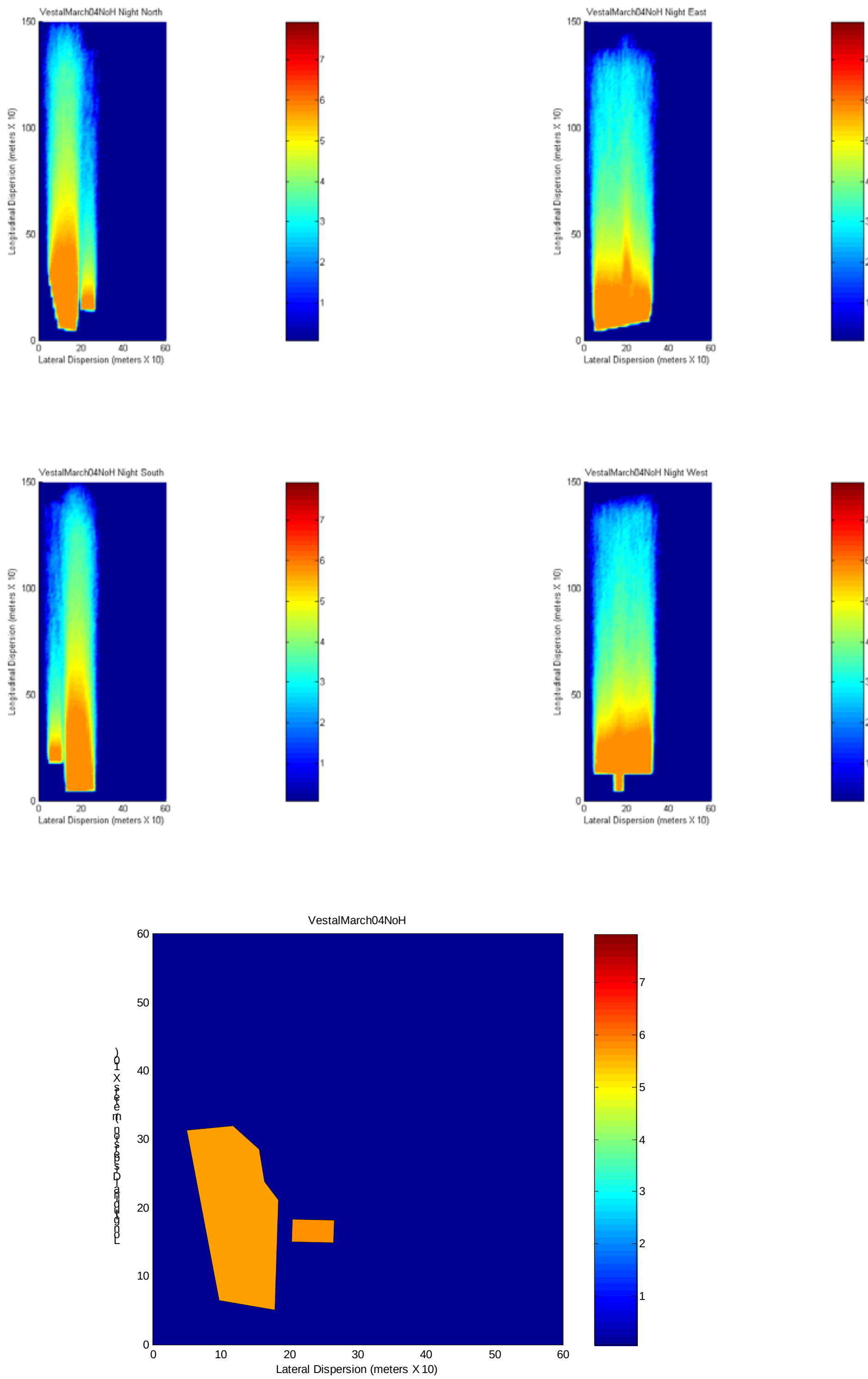

Figure 19h: Vestal farm March 2004 without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Vestal August 2004-Day

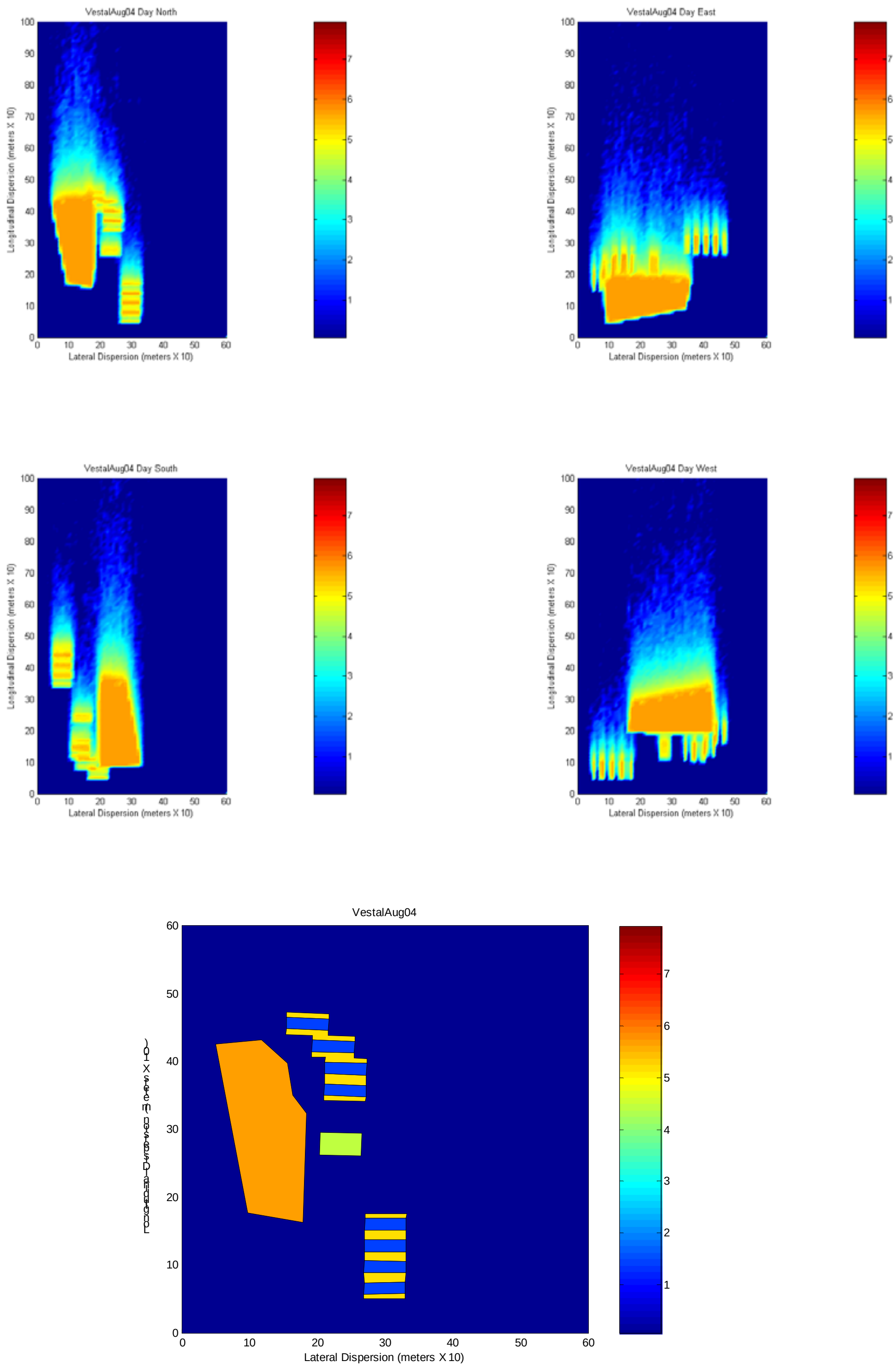

Figure 19i: Vestal farm August 2004: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Vestal August 2004-Night

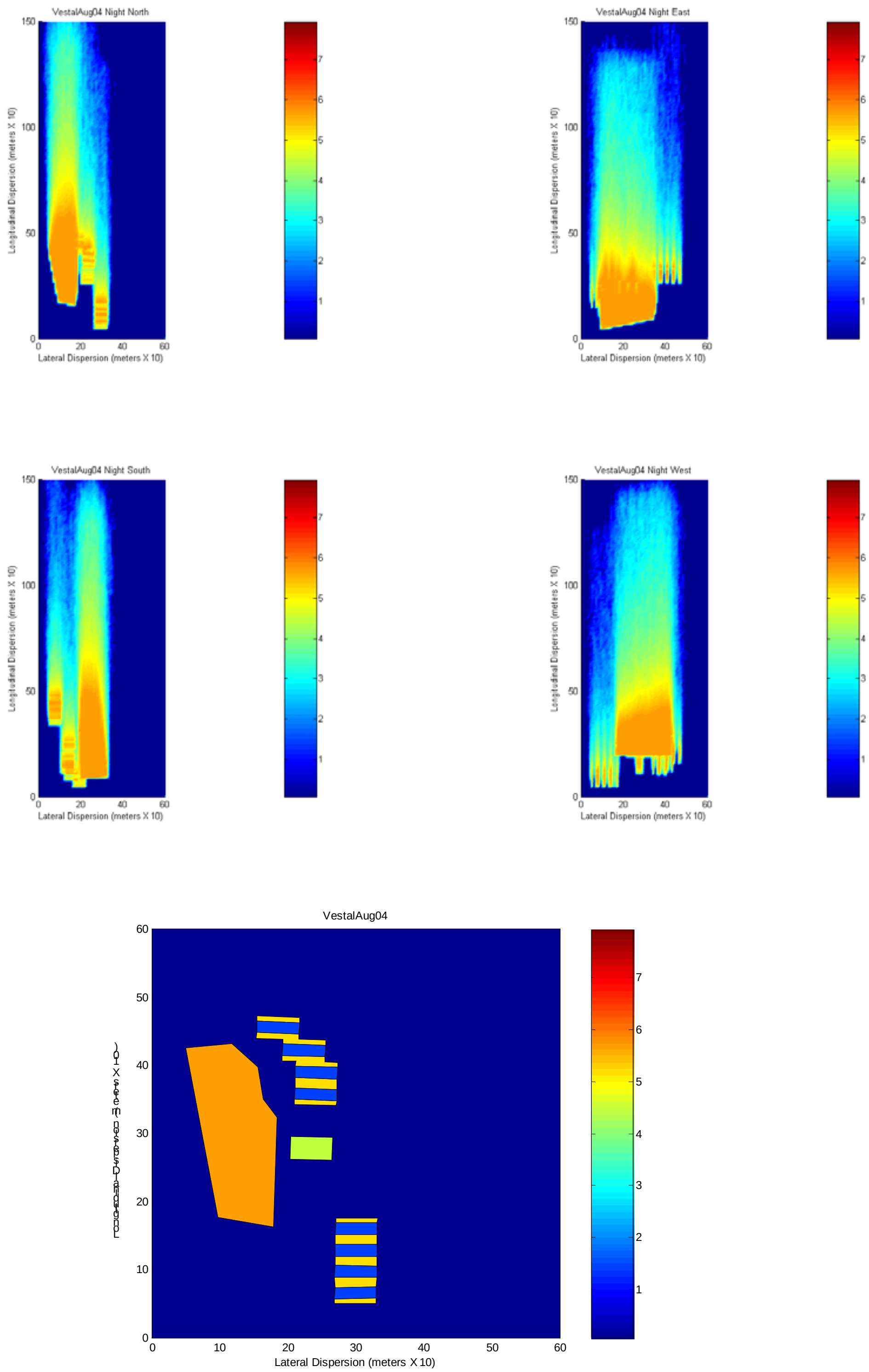

Figure 19j: Vestal farm August 2004: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Vestal August 2004 No Houses-Day

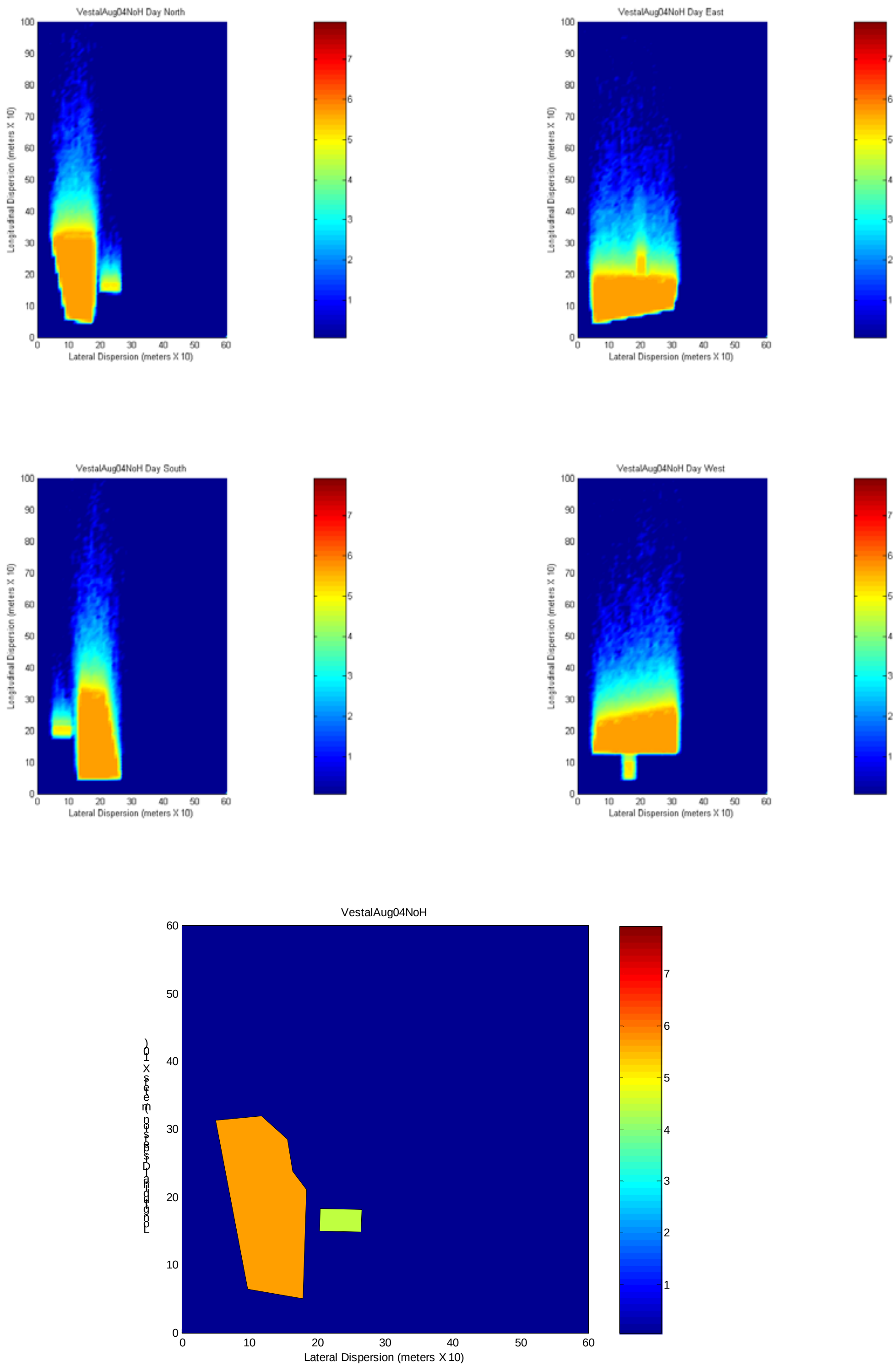

Figure 19k: Vestal farm August 2004 without houses: Daytime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Vestal August 2004 No Houses-Night

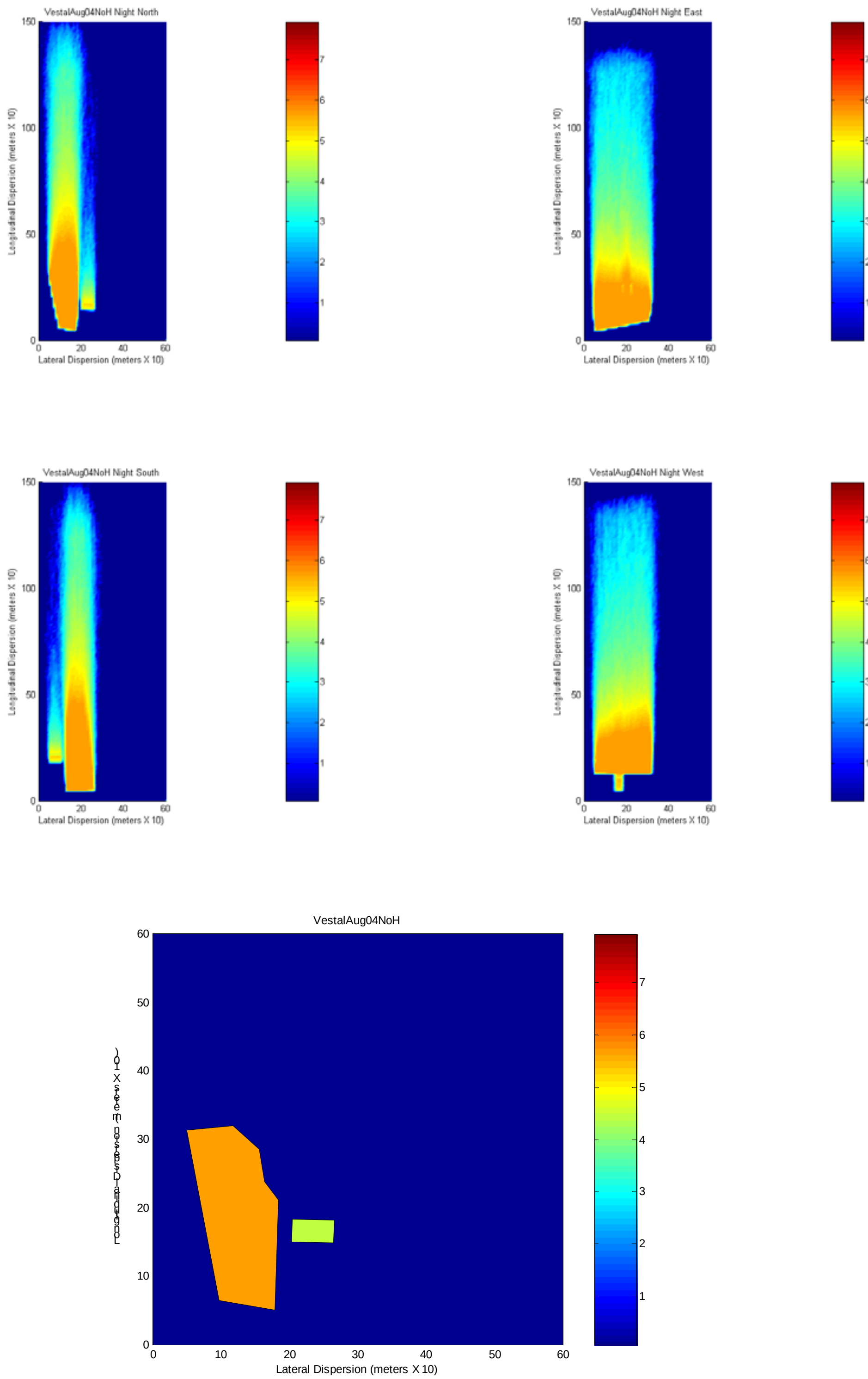

Figure 19l: Vestal farm August 2004 without houses: Nighttime odor dispersions. North, east, south and west dispersions are depicted; at bottom is map indicating odor sources.

Table 1: Correlation matrix for field data, data from all farms combined.

	maximum VOC 10.6eV ppbRAE	average VOC 10.6eV ppbRAE	maximum VOC 11.7eV ppbRAE	average VOC 11.7eV ppbRAE	maximum H_2S (Jerome)	average H_2S (Jerome)	maximum H_2S with amm. filt. (Jerome)	average H_2S with amm. filt. (Jerome)	odor intensity	odor threshold (D/T)	maximum dust (EPAM)	average dust (EPAM)	ammonia (Drager)
maximum VOC 10.6eV ppbRAE	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
average VOC 10.6eV ppbRAE	**0.7669**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
maximum VOC 11.7eV ppbRAE	**0.2235**	**0.2914**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
average VOC 11.7eV ppbRAE	**0.1910**	**0.2574**	**0.8318**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
maximum H_2S (Jerome)	**0.0286**	**0.0386**	**0.0032**	**0.0072**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
average H_2S (Jerome)	**0.0197**	**0.0348**	**0.0075**	**0.0251**	**0.9609**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
maximum H_2S with amm. filt. (Jerome)	**0.0194**	**0.0245**	**0.0025**	**0.0114**	**0.9156**	**0.9006**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
average H_2S with amm. filt. (Jerome)	**0.0098**	**0.0161**	**0.0060**	**0.0241**	**0.9713**	**0.9805**	**0.9360**	**x**	**x**	**x**	**x**	**x**	**x**
odor intensity	**0.0116**	**0.0004**	**0.0284**	**0.0219**	**0.3242**	**0.3408**	**0.2823**	**0.3021**	**x**	**x**	**x**	**x**	**x**
odor threshold (D/T)	**0.0062**	**0.0029**	**0.0490**	**0.0274**	**0.3046**	**0.3614**	**0.2499**	**0.3188**	**0.5974**	**x**	**x**	**x**	**x**
maximum dust (EPAM)	**0.0062**	**0.0119**	**0.0332**	**0.0120**	**0.0015**	**0.0050**	**0.0119**	**0.0135**	**0.0324**	**0.0264**	**x**	**x**	**x**
average dust (EPAM)	**0.0071**	**0.0053**	**0.0113**	**0.0396**	**0.0223**	**0.0189**	**0.0362**	**0.0288**	**0.0149**	**0.0202**	**0.6183**	**x**	**x**
ammonia (Drager)	**0.0294**	**0.0280**	**0.0478**	**0.0714**	**0.1326**	**0.1826**	**0.1116**	**0.1588**	**0.1218**	**0.1258**	**0.0302**	**0.0407**	**x**

Tables 2-6. Environmentally Superior Technology candidate projects demonstrated performance for odor reduction (Technology Determinations). Values shown are average odor intensity ratings at 200 and 400 meters determined by the model during the day and night where: 0=none at all; 1=very weak; 2=weak; 3=moderately weak; 4=moderate; 5=moderately strong; 6=strong; 7=very strong; and 8=maximal.

Table 2: Average odor intensities for night, 200 meters downwind, ranked from highest to lowest.

Test Site	Night 200m Average	Rank
EKOKAN	4.412	1
Stokes No Houses	4.231	2
Moore	4.167	3
EKOKAN No Houses	4.155	4
Vestal March 2004 No Houses	4.116	5
Stokes	4.027	6
Vestal Average No Houses	3.999	7
Hunt No Houses	3.989	8
Vestal August 2004 No Houses	3.955	9
Barham	3.851	10
Howard No Houses	3.798	11
Carrolls April 2004	3.793	12
Howard	3.709	13
Carrolls April 2004 No Houses	3.680	14
Vestal March 2004	3.640	15
Super Soils	3.637	16
Moore No Houses	3.610	17
Vestal Average	3.594	18
Carrolls June 2004	3.559	19
Carrolls Average	3.547	20
Vestal August 2004	3.546	21
Hunt	3.432	22
Corbett 1 No Houses	3.403	23
Harrells with Evaporation System	3.398	24
Carrolls Average No Houses	3.398	25
Harrells Average	3.355	26
Corbett 1	3.289	27
Carrolls June 2004 No Houses	3.179	28
Corbett 4	2.979	29
Harrells with Evaporation System No Houses	2.957	30
Harrells Average No Houses	2.915	31
Corbett 4 No Houses	2.839	32
Super Soils Composting	2.742	33
Super Soils Technology	2.618	34
ReCip	2.466	35
Barham No Houses	2.380	36
Grinnells	1.901	37
Lake Wheeler Rd. Belt System	1.728	38
ReCip No Houses	1.468	39
ORBIT	1.441	40
Black Soldier Fly	1.113	41
Koger gasifier	0.044	42

Table 3: Average odor intensities for night, 400 meters downwind, ranked from highest to lowest.

Test Site	Night 400m Average	Rank
EKOKAN	3.642	1
EKOKAN No Houses	3.417	2
Vestal March 2004 No Houses	3.403	3
Hunt No Houses	3.359	4
Moore	3.354	5
Vestal Average No Houses	3.346	6
Stokes No Houses	3.311	7
Barham	3.239	8
Vestal August 2004 No Houses	3.219	9
Stokes	3.166	10
Howard No Houses	3.109	11
Carrolls April 2004	3.077	12
Moore No Houses	3.070	13
Vestal Average	3.054	14
Howard	3.025	15
Vestal March 2004	3.014	16
Vestal August 2004	2.973	17
Carrolls April 2004 No Houses	2.971	18
Hunt	2.909	19
Carrolls Average	2.896	20
Harrells with Evaporation System	2.890	21
Super Soils	2.870	22
Harrells Average	2.859	23
Carrolls June 2004	2.830	24
Corbett 1 No Houses	2.829	25
Carrolls Average No Houses	2.692	26
Carrolls June 2004 No Houses	2.596	27
Corbett 1	2.555	28
Corbett 4	2.492	29
Harrells with Evaporation System No Houses	2.458	30
Harrells Average No Houses	2.325	31
Corbett 4 No Houses	2.102	32
ReCip	2.095	33
Barham No Houses	2.034	34
Super Soils Technology	1.984	35
Super Soils Composting	1.877	36
Lake Wheeler Rd. Belt System	1.141	37
ReCip No Houses	0.921	38
Grinnells	0.860	39
ORBIT	0.766	40
Black Soldier Fly	0.381	41
Koger gasifier	0.000	42

Table 4: Average odor intensities for day, 200 meters downwind, ranked from highest to lowest.

Test Site	Day 200m Average	Rank
EKOKAN	1.734	1
Hunt No Houses	1.733	2
Stokes No Houses	1.692	3
EKOKAN No Houses	1.572	4
Moore	1.511	5
Vestal Average No Houses	1.486	6
Vestal August 2004 No Houses	1.460	7
Vestal March 2004 No Houses	1.454	8
Howard No Houses	1.451	9
Hunt	1.388	10
Stokes	1.367	11
Howard	1.353	12
Carrolls June 2004	1.313	13
Barham	1.282	14
Carrolls April 2004 No Houses	1.251	15
Carrolls Average	1.248	16
Carrolls April 2004	1.242	17
Super Soils	1.204	18
Carrolls June 2004 No Houses	1.178	19
Corbett 1 No Houses	1.163	20
Moore No Houses	1.157	21
Vestal August 2004	1.132	22
Vestal March 2004	1.128	23
Vestal Average	1.088	24
Carrolls Average No Houses	1.085	25
Harrells with Evaporation System	1.052	26
Barham No Houses	1.041	27
Corbett 4	1.040	28
Harrells Average	1.028	29
Harrells Average No Houses	1.016	30
Corbett 1	1.012	31
Harrells with Evaporation System No Houses	1.004	32
Corbett 4 No Houses	0.971	33
ReCip	0.808	34
Super Soils Technology	0.756	35
Super Soils Composting	0.627	36
Lake Wheeler Rd. Belt System	0.072	37
Grinnells	0.044	38
Black Soldier Fly	0.000	39
Koger gasifier	0.000	40
ORBIT	0.000	41
ReCip No Houses	0.000	42

Table 5: Average odor intensities for day, 400 meters downwind, ranked from highest to lowest.

Test Site	Day 400m Average	Rank
Hunt No Houses	0.790	1
EKOKAN No Houses	0.706	2
Howard	0.702	3
Howard No Houses	0.667	4
EKOKAN	0.659	5
Hunt	0.645	6
Moore	0.641	7
Vestal March 2004 No Houses	0.578	8
Carrolls April 2004	0.566	9
Stokes	0.565	10
Vestal August 2004 No Houses	0.552	11
Carrolls June 2004	0.548	12
Vestal August 2004	0.529	13
Barham	0.509	14
Stokes No Houses	0.498	15
Vestal Average No Houses	0.488	16
Vestal March 2004	0.467	17
Moore No Houses	0.462	18
Carrolls April 2004 No Houses	0.460	19
Carrolls June 2004 No Houses	0.453	20
Harrells with Evaporation System	0.451	21
Harrells Average	0.446	22
Corbett 4	0.444	23
Vestal Average	0.435	24
Carrolls Average No Houses	0.424	25
Carrolls Average	0.413	26
Super Soils	0.406	27
Corbett 1 No Houses	0.399	28
Harrells with Evaporation System No Houses	0.374	29
Corbett 1	0.368	30
Corbett 4 No Houses	0.328	31
Harrells Average No Houses	0.327	32
Barham No Houses	0.323	33
ReCip	0.315	34
Super Soils Technology	0.088	35
Super Soils Composting	0.044	36
Black Soldier Fly	0.000	37
Grinnells	0.000	38
Koger gasifier	0.000	39
Lake Wheeler Rd. Belt System	0.000	40
ORBIT	0.000	41
ReCip No Houses	0.000	42

Table 6: Average odor intensities for night and day, 200 meters and 400 meters downwind.

Test Site	Time	Distance	Average
Stokes	Night	200m	4.0269
	Night	400m	3.166
	Day	200m	1.3667
	Day	400m	0.5647
Stokes No Houses	Night	200m	4.2309
	Night	400m	3.3114
	Day	200m	1.6917
	Day	400m	0.4983
Moore	Night	200m	4.1668
	Night	400m	3.3541
	Day	200m	1.5114
	Day	400m	0.6412
Moore No Houses	Night	200m	3.6101
	Night	400m	3.0705
	Day	200m	1.1574
	Day	400m	0.4623
Barham	Night	200m	3.8509
	Night	400m	3.2394
	Day	200m	1.2824
	Day	400m	0.5089
Barham No Houses	Night	200m	2.3801
	Night	400m	2.0339
	Day	200m	1.0412
	Day	400m	0.3226
Black Soldier Fly	Night	200m	1.1126
	Night	400m	0.3811
	Day	200m	0
	Day	400m	0
Carrolls Average	Night	200m	3.547
	Night	400m	2.8963
	Day	200m	1.248
	Day	400m	0.4135
Carrolls Average No Houses	Night	200m	3.3978
	Night	400m	2.6917
	Day	200m	1.0846
	Day	400m	0.4242
Carrolls April 2004	Night	200m	3.7928
	Night	400m	3.0773
	Day	200m	1.2418
	Day	400m	0.5658
Carrolls April 2004 No Houses	Night	200m	3.6797
	Night	400m	2.9715
	Day	200m	1.2512

	Day	400m	0.4603
Carrolls June 2004	Night	200m	3.559
	Night	400m	2.8299
	Day	200m	1.313
	Day	400m	0.5478
Carrolls June 2004 No Houses	Night	200m	3.1789
	Night	400m	2.5959
	Day	200m	1.1781
	Day	400m	0.4531
Corbett 1	Night	200m	3.2888
	Night	400m	2.5554
	Day	200m	1.0122
	Day	400m	0.3681
Corbett 1 No Houses	Night	200m	3.4029
	Night	400m	2.8285
	Day	200m	1.1632
	Day	400m	0.3991
Corbett 4	Night	200m	2.9793
	Night	400m	2.4917
	Day	200m	1.0403
	Day	400m	0.4439
Corbett 4 No Houses	Night	200m	2.8389
	Night	400m	2.1025
	Day	200m	0.9711
	Day	400m	0.328
EKOKAN	Night	200m	4.4121
	Night	400m	3.642
	Day	200m	1.734
	Day	400m	0.6593
EKOKAN No Houses	Night	200m	4.1549
	Night	400m	3.4168
	Day	200m	1.5721
	Day	400m	0.7056
Grinnells	Night	200m	1.9009
	Night	400m	0.8596
	Day	200m	0.044
	Day	400m	0
Harrells Average	Night	200m	3.355
	Night	400m	2.8592
	Day	200m	1.0283
	Day	400m	0.4459
Harrells Average No Houses	Night	200m	2.9152
	Night	400m	2.325
	Day	200m	1.0162
	Day	400m	0.3267

Harrells with Evaporation System	**Night**	**200m**	**3.3978**
	Night	**400m**	**2.8899**
	Day	**200m**	**1.0522**
	Day	**400m**	**0.451**
Harrells with Evaporation System No Houses	**Night**	**200m**	**2.9569**
	Night	**400m**	**2.4578**
	Day	**200m**	**1.0038**
	Day	**400m**	**0.3741**
Howard	**Night**	**200m**	**3.7088**
	Night	**400m**	**3.0254**
	Day	**200m**	**1.3526**
	Day	**400m**	**0.7023**
Howard No Houses	**Night**	**200m**	**3.7979**
	Night	**400m**	**3.109**
	Day	**200m**	**1.4513**
	Day	**400m**	**0.6672**
Hunt	**Night**	**200m**	**3.4316**
	Night	**400m**	**2.9086**
	Day	**200m**	**1.3882**
	Day	**400m**	**0.6451**
Hunt No Houses	**Night**	**200m**	**3.989**
	Night	**400m**	**3.3592**
	Day	**200m**	**1.7329**
	Day	**400m**	**0.7895**
Koger gasifier	**Night**	**200m**	**0.044**
	Night	**400m**	**0**
	Day	**200m**	**0**
	Day	**400m**	**0**
Lake Wheeler Rd. Belt System	**Night**	**200m**	**1.7275**
	Night	**400m**	**1.1409**
	Day	**200m**	**0.0719**
	Day	**400m**	**0**
ORBIT	**Night**	**200m**	**1.4408**
	Night	**400m**	**0.7655**
	Day	**200m**	**0**
	Day	**400m**	**0**
ReCip	**Night**	**200m**	**2.4657**
	Night	**400m**	**2.0948**
	Day	**200m**	**0.8077**
	Day	**400m**	**0.3154**
ReCip No Houses	**Night**	**200m**	**1.4676**
	Night	**400m**	**0.9211**
	Day	**200m**	**0**
	Day	**400m**	**0**
Super Soils	**Night**	**200m**	**3.6369**

	Night	**400m**	**2.8696**
	Day	**200m**	**1.2043**
	Day	**400m**	**0.4061**
Super Soils Technology	**Night**	**200m**	**2.6182**
	Night	**400m**	**1.9836**
	Day	**200m**	**0.756**
	Day	**400m**	**0.088**
Super Soils Composting	**Night**	**200m**	**2.7422**
	Night	**400m**	**1.8767**
	Day	**200m**	**0.6272**
	Day	**400m**	**0.044**
Vestal Average	**Night**	**200m**	**3.5944**
	Night	**400m**	**3.0543**
	Day	**200m**	**1.0881**
	Day	**400m**	**0.4351**
Vestal Average No Houses	**Night**	**200m**	**3.9994**
	Night	**400m**	**3.3456**
	Day	**200m**	**1.4858**
	Day	**400m**	**0.4877**
Vestal March 2004	**Night**	**200m**	**3.6403**
	Night	**400m**	**3.0137**
	Day	**200m**	**1.1277**
	Day	**400m**	**0.4668**
Vestal March 2004 No Houses	**Night**	**200m**	**4.1161**
	Night	**400m**	**3.4026**
	Day	**200m**	**1.4541**
	Day	**400m**	**0.5777**
Vestal August 2004	**Night**	**200m**	**3.5461**
	Night	**400m**	**2.9733**
	Day	**200m**	**1.1315**
	Day	**400m**	**0.5288**
Vestal August 2004 No Houses	**Night**	**200m**	**3.955**
	Night	**400m**	**3.2185**
	Day	**200m**	**1.4602**
	Day	**400m**	**0.5521**

CONCLUSION

Odor dispersion depends on a variety of factors including the surface area that emits odorants, the geometry of the facility (i.e. the distribution of odor sources), the spatial distribution of the relative concentrations of odor intensity, and the meteorological conditions. In order to determine if a specific waste technology reduces or substantially eliminates the emission of odor that is detectable beyond the boundaries of the parcel or tract of land on which the swine farm is located, each of these factors must be taken into account using a dispersion model.

Modeling was performed using all odor sources at a facility. This model was strengthened during the course of the study with an increased number of testing sites and observations. For this reason, the downwind odor dispersion averages reported here are generally higher than those previously reported. For the farms with animals, the computations were performed with and without the swine houses to determine the contribution of the animals themselves along with the technology components. The swine housing itself plays a significant role in odor downwind, as do odor sources of moderate to moderately high intensity that have a large surface area. These computations also show that the geometric arrangement of the odor sources is an important factor in the dispersion of odor. If there are extreme differences in the relative intensities of the odor sources on a farm, the most intense source(s) should not be located near the boundary of the farm in the predominant downwind direction. If there is no predominant wind direction, the most potent odor source should be located at the center, surrounded by weaker sources.

The Engineering Subcommittee performance criteria recommendations report (Appendix D to the Phase 1 Report dated June 26, 2004) suggested that the operational definition of "substantial elimination" of odor emissions at the property boundary be those emissions that are equal to or less than the "weak" rating of "2" on the 0-8 odor intensity scale.

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