

An introduction to *WindTrax*

By Brian Crenna

This article is intended to introduce you to the main features and application of *WindTrax*, a graphical simulation environment for predicting turbulent transport of trace gases over short range. More information will be added as time permits.

A brief overview

WindTrax simulates the transport of trace gases in the atmospheric surface layer. It allows you to calculate both unknown emission rates from sources emitting these gases and their unknown concentrations anywhere in the vicinity of the sources. It assumes that the surface around the source(s) and sensor(s) is flat and free of obstructions, and that the longest distance between them is within about one kilometer. In practice, we've found that the presence of obstacles doesn't affect the results too much, provided care is taken with the positioning of the sensors. As the fetch between sources and sensors increases beyond one kilometer, the validity of model results becomes more uncertain because the surface layer flow model used in the program becomes extended beyond its usual range.

WindTrax uses numerical models called *Lagrangian stochastic* models to simulate the transport of trace gases from sources that emit them. The term "Lagrangian" means that the models release individual particles and follow them along their unique paths through the air, rather than performing calculations at fixed locations in space. "Stochastic" implies that the models mimic the random, turbulent motion of the atmosphere by introducing random numbers into the calculations determining the motion of each particle. As these particles travel through the air, they move through different regions of interest: they might pass close to a concentration sensor, increasing the concentration measured there; or they might touch down on the surface and pick up tracer from an emitting source, later carrying it further downwind.

Because the models are statistical, there is an inherent error associated with the predictions in WindTrax; it reports unknown source strengths and concentrations as a mean with a standard error. You will find that increasing the number of particles emitted will reduce the uncertainty in the predicted values. The drawback of having the program release more particles is that it takes longer to complete the simulation.

The surface layer wind model used in WindTrax requires that at least four parameters are known: the surface roughness length z_0 , which is related to the height of the plants, soil, or other elements covering the ground; the friction velocity u_* , which is determined by the vertical transport of horizontal momentum near the surface; a measure of atmospheric stability called the *Monin-Obukhov length*, L ; and the mean horizontal wind direction θ . These parameters can be specified in a variety of ways: they can be

entered directly, if you have calculated them ahead of time from your measurements; calculated by WindTrax from wind speed, sonic anemometer, or wind speed and temperature profiles measurements that you provide to it; or estimated from general conditions at the time and location of the observations. If you have observations of the wind statistics σ_u , σ_v , and/or σ_w , you can also provide these directly; otherwise, the program will estimate them using u^* , z_0 , and L from standard empirical relationships published in the literature. In practice, we have found that using actual measured values of the statistics improves the accuracy of the results over using the empirical formulae.

All observational data used in WindTrax is assumed to represent an average over a reasonable period. Common averaging periods are 15 to 30 minutes in length. Shorter averaging periods are less likely to be representative of the mean atmospheric state; longer periods might be affected by changes in the surface layer as the diurnal cycle evolves, especially during times of rapid transition (e.g. near sunrise and sunset).

To estimate unknown source emission rates, the program also requires that one or more concentration measurements be placed correctly around the source(s). The particle models relate the emission rate of each source to the concentrations measured by each sensor. WindTrax uses these relationships to calculate unknown values of emission rate, concentration, or both. For example, a single known concentration can be used to estimate the unknown emission rate from a source; that emission rate can then be used to predict the unknown concentration field over a wide area.

In general, the mathematics underlying the simulations implies that there must be at least as many *known* concentration measurements as there are *unknown* emission rates. WindTrax solves the following system of equations for unknown quantities:

$$a_{11} Q_1 + a_{12} Q_2 + \dots + a_{1n} Q_n + C_{BG} = C_1$$

$$a_{m1} Q_1 + a_{m2} Q_2 + \dots + a_{mn} Q_n + C_{BG} = C_m$$

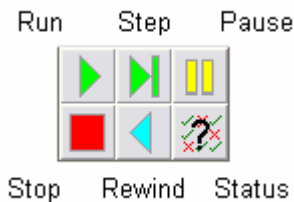
where C_{BG} is the background concentration and the coefficients a_{ij} relating emission rates Q_j to measured concentrations C_i are obtained from the particle models. If the background concentration of the gases of interest is also unknown, then an additional concentration measurement, preferably upwind of all sources, must be provided. If the number of known concentrations C_i is greater than the number of unknown sources Q_j (plus one, in the case that background concentration C_{BG} is also unknown), the solution will be the best fit in the least squares sense.

The placement of sensors relative to sources can have a major effect on the quality of the predictions generated by the models. If no concentrations are measured downwind of a source, then no estimate of its emission rate can be provided. This may seem obvious, but the variability of wind direction might cause some simulations to fail while others will succeed. When multiple unknown sources are present, the calculations are subject to large sensitivity to sensor placement and measurement error; ideally, each sensor would see only one source at a time to reduce this sensitivity. Where flow

obstacles such as buildings or fences are present, measurements are often better made further downwind of the source, well away from the obstacles; at least fifteen obstacle heights downwind is a useful rule of thumb.

To run a WindTrax simulation, you will first draw a map showing the relative placement of the sources and sensors in your field experiment, using a set of tools similar to most simple drawing programs. By double-clicking with the cursor above any of the drawn objects, their properties can be set to values that match the actual field experiment.

Once the values are set, the simulation can be started by clicking the green Run button. WindTrax provides an estimate of how much time the simulation will require; a few minutes is typical, but it can be much longer depending on the parameters chosen for the objects on the map. When the simulation is completed, you can examine the properties of any object on the map by clicking on it with the cursor. To return to Edit mode and adjust the map, you will finally click on the blue Rewind button.



If you intend WindTrax to run a large set of simulations, you can connect an existing data file containing your measurements to set such values as wind speed, wind direction, atmospheric stability, and measured concentrations; then hook up an output data file to store the results you're interested in, such as unknown source emission rate. Each line of data in the input file represents one simulation and will usually generate one line of output data. During a simulation, all data on each line of the input file is read in and the values transferred to the connected objects; the models will then run and unknown quantities will be calculated; finally, the results will be written to any connected output files.

Model uncertainty

As mentioned earlier, due to the random nature of the model calculations performed by WindTrax, there is an uncertainty or *model error* associated with the predicted values of emission rate and concentration. WindTrax releases a set of particles for each sensor or point source present on the map. Each set will follow a distinct set of trajectories, and it is only in the average sense that unknown emission rates and/or concentrations can be determined. To assess model error, the program divides the set of particles into ten subgroups and calculates the unknown values for each subgroup. The model error is determined from the standard deviation of the mean values predicted by each subgroup.

Target size

One of the most important factors affecting model error is the size of the regions of interest through which the particles travel (i.e. sensors and sources.) As more particles travel through a given region, more samples of the region are taken and the model error is reduced. In practice, this means that the larger the target, the smaller is the error, and conversely. Because WindTrax allows you to set the size of the volume of interest for concentration sensors, it might seem reasonable to choose a large volume. Of course, the tradeoff is that the results represent an average over a larger volume, and will be further from the actual local values where the concentration changes rapidly with location.

Advantage of the backward model for area sources

WindTrax makes use of several tricks to improve efficiency and reduce the time required for completing an experiment within a given model error. To reduce the error associated with target size, WindTrax uses different models for area and point sources. Area sources offer a large target, whereas point sources and concentration sensors are very small targets by comparison. To take advantage of this large target size of area sources, WindTrax uses a surprising trick: it follows particles from a given sensor backward in time, in order to determine where it came from. We know that the particles were detected by the sensor, since they were initially located right at its position. Moving the particle backward through time, we can determine whether it touches down within an area source.

Touchdown catalogs

A second advantage of the backward model is that it generates sets of touchdown locations and stores them in data files called *touchdown catalogs*. These catalogs can be used instead of repeating a calculation for each sensor location or for each model run; using existing data is much faster than generating it anew. Prior to running the backward model, WindTrax scans through a list of all touchdown catalogs, looking for a file whose parameters match the present condition within the tolerance set by you. If you want the most accurate results, you can set the program to ignore existing files unless the parameters match exactly.

By default, WindTrax uses a set of standard catalogs, calculated for a range of release heights, surface roughness, wind parameters, and number of particles. These default catalogs are useful for quickly creating results because they are all pre-calculated. For generating final results, it is more accurate to select stricter tolerances, so that the parameters more closely match the input values.

WindTrax simulates line-average concentration sensors such as lasers by releasing particles at a fixed number of points along their length; the default value is thirty points, but this can be changed. Because touchdown catalogs are generated for a specific release height, it is most efficient to ensure that both ends of a line-average

sensor are at or near the same height. In this case, the same touchdown catalog can be used for each release point. If release height tolerance is set very low and the ends of a line-average sensor are at significantly different heights, they will require that up to thirty catalogs be created for each model run!

WindTrax generally stores the touchdown catalogs in the directory Catalogs. At the end of each session, you have the option of saving all catalogs generated during the session for later use, saving only some, or deleting them all. Because the program generates a large number of catalogs over time, a catalog manager has been included; it can be accessed by selecting Tools/TD Catalog Manager from the main menu. It will list all catalogs in the directory along with the parameters used to generate them. Using the manager, you can delete old catalogs and add new ones. If you have copied touchdown catalogs from a different directory into the Catalogs directory, WindTrax will not see them until you select File/Update List from the catalog manager's menu.

Particle number

In general, the more particles released by the models, the smaller the model uncertainty will be. Unfortunately, releasing more particles requires more time to complete the calculations. This tradeoff between accuracy and computation time is always present when working with WindTrax. By default, 50,000 particles are released at a time. The calculation time will depend on the speed of the computer, the distance the particles must travel between sources and sensors, and the condition of the atmosphere; a few minutes is typical but some calculations can take significantly longer.

Particle tracking distance

By default, WindTrax automatically tracks the model particles only as far as is required by the experimental design. You have the option of having the program either calculating only the minimum distance or setting a standard distance, to increase the usefulness of the touchdown catalogs for later simulations. For example, if you have two experiments with different sensor locations and the sensor is located closer to the source in the first experiment than in the second, WindTrax can reuse appropriate touchdown catalogs from the first experiment if the minimum tracking distance is set large enough. The default is to calculate all catalogs to at least 500m.

Sensor collection volume (forward model)

The forward LS model runs whenever point sources are placed on the map; it releases particles from the sources and follows them forward in time as they are carried downwind. As they pass through a concentration sensor's volume, they contribute to the concentration measured there. No pre-calculations are possible, so the forward model is in general slower to complete its calculations than the backward model. The collection area is the same for all concentration sensors, and can be set by double-clicking on the forward model's icon near the upper-left of the map. You have the option of using either

fixed collection volumes or volumes that maintain a constant ratio between the collection width and its distance downwind of the source.

Handling model uncertainty

People using WindTrax often run a set of data at lower particle count to get a quick idea of the results, and at higher particle count to get final numbers. It's also common to set the backward model to use "standard" catalogs initially, and then tell it to run stricter tolerances or the exact values for the model parameters to generate final results.

WindTrax map objects






The basic objects that interact in WindTrax to perform a simulation are *models*, *sources*, *sensors*, *sensor platforms*, and *data objects*. Some of these objects are created automatically by WindTrax, while others you will place on the map yourself. A few objects such as text boxes have no role in simulations but are provided to improve the readability of the project map.

Models and special icons

Models are represented by square icons automatically placed in the upper left corner of the map. Double-clicking on these icons allows you to adjust different model parameters directly. Three models are presently available in WindTrax: the *atmospheric surface layer model*, which uses Monin-Obukhov similarity theory to calculate profiles of wind speed, temperature, and turbulence; the *backward LS model*, which calculates emission rate from area sources and creates data files called touchdown catalogs to speed up its performance; and the *forward LS model*, which calculates emission rates from point sources.

An object called the *LS Algebra Engine* performs the algebraic manipulations required to generate unknown emission rates and concentrations. It also monitors the general state of the sensor-source relationship, and will tell you whether or not the number of sensors is sufficient to allow predictions for the sources drawn on the map. At any time, you can look at WindTrax's interpretation of the sensors and sources by double-clicking on the LS Algebra Engine's icon. While the program is running, this object also reports the relative sensitivity of the algebraic system to measurement error and the goodness-of-fit between predictions and observations.

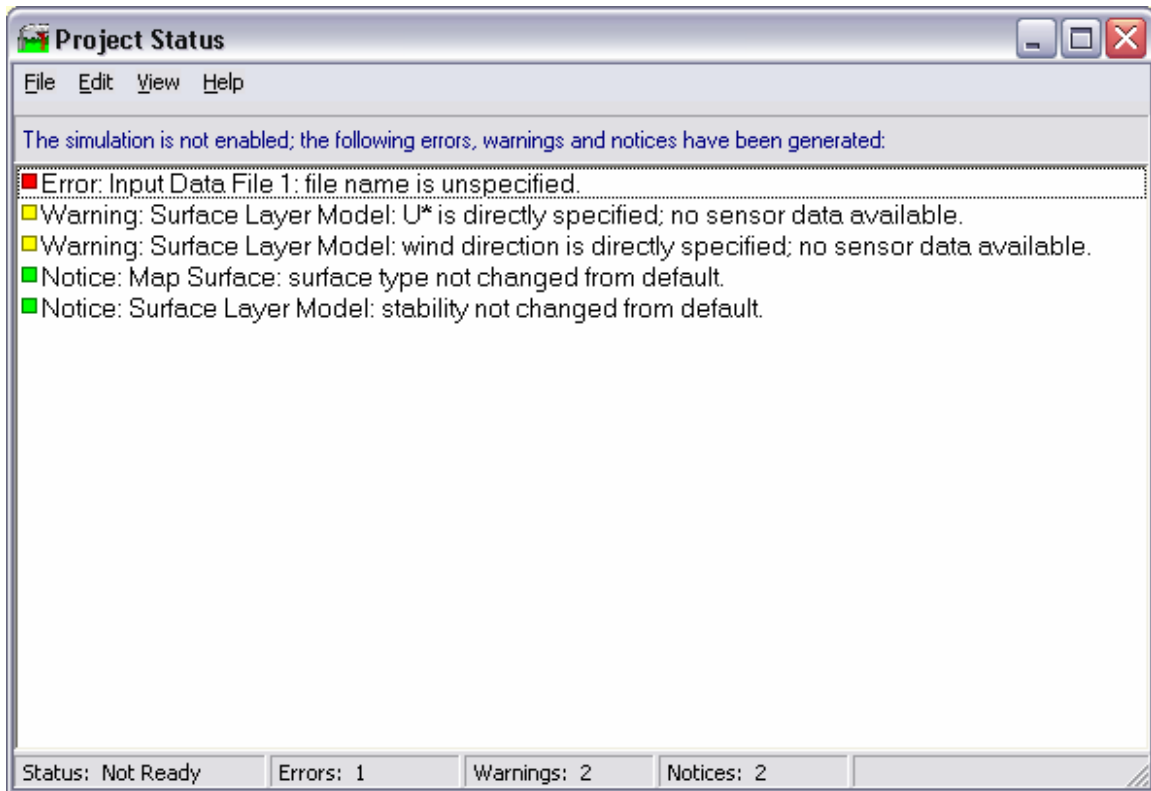
A special icon called the *Atmosphere* allows you to set certain global properties, such as the background concentration of any tracers present in the simulation.

Special icons		
Object icon	Object name	Actions
	Surface layer model	Calculates wind, temperature, and turbulent statistics profiles; controls input sources for u^* , z_o , L , and θ .
	Backward LS model	Calculates particle trajectories for area sources
	Forward LS model	Calculates particle trajectories for point sources
	LS algebra engine	Computes unknown emission rates and concentrations; monitors algebraic system state
	Atmosphere	Allows access to global variables such as background concentration and screen temperature

Project status object

A hidden object called the *project status* monitors the state of all objects in the simulation, and determines whether or not the simulation can run. There are three conditions reported by the project status: *errors*, *warnings*, and *notices*. *Notices* are usually minor and are unlikely to affect the results of the simulation; for example, a notice is reported if the map surface roughness has not been changed from the default value. *Warnings* should be examined, since they imply conditions that will affect the results, but do not prevent the simulation from being completed; for example, if no pressure measurements are provided, WindTrax will warn you that pressure is being estimated from the elevation specified for the experiment site. In general, no simulation can run while any object has an *error* condition. Many errors are possible; for example, if the name of an input or output file is not specified; if all measured wind speeds are zero; or if there are not enough concentration measurements for the number of unknown sources on the map.

If the Run button is grey, you can find out where the error exists by clicking on the project status (?) button nearby to open the Project Status form. Errors are listed with a red square in front, while warnings and notices are listed following yellow and green squares, respectively. Often, you can open the property editor of the offending object by double-clicking on the error messages listed in the form.



Source objects

There are two types of gas source in WindTrax: *area sources*, which represent ground-level features covering a relatively large area, such as fields, animal pens, and ponds; and *point sources*, which are quite localized and might represent stacks, building vents, or individual animals.

Area sources are represented by solid colours and can be created using drawing tools or specified by a set of polygon vertices in a data file. Each colour represents a source that is assumed to have the same emission rate. A given source can be composed of any number of individual shapes, and does not have to be contiguous. A maximum of eight distinct area sources, each assumed to have a uniform emission rate, can be present on the map at one time.



Point sources are represented by small icons and are fairly limited in scope compared to most other dispersion models; no accommodation for jetting or stack downwash is allowed in WindTrax. However, point sources can be grouped together so that, for example, a set of barn vents can be simulated as a single source; otherwise, the algebra underlying the simulation would require that there be at least as many known concentration measurements as vents on the barn.

Sensors and sensor platforms


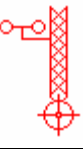
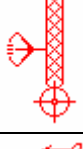


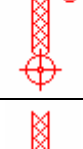
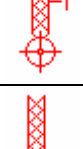


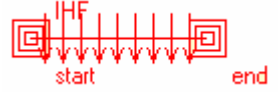
Sensors are used both to provide measured data as boundary conditions to the WindTrax models and to request unknown measurements from the models. The categories of sensor now available are:




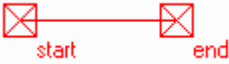

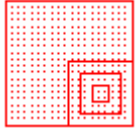
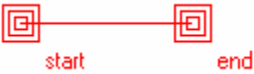
- Wind sensors, including the *cup anemometer*, which measures wind speed; the *wind vane*, which measures wind direction; the *standard anemometer*, which measures both; the *sonic anemometer*, which calculates u^* , z_o , and L from the data provided by a real sonic anemometer; and the *wind statistics sensor*, which allows you to provide your own estimates of the statistics σ_u , σ_v , and σ_w , all given as a ratio to u^* .
- Concentration sensors, including *point* and *line concentration sensors*, which are used to provide measurements of concentration to the models and/or report unknown concentrations.
- *Temperature* and *pressure sensors*, which are required if concentration is measured in units of ppm or ppb. If a pressure measurement is necessary but no measurement is provided, WindTrax will estimate surface pressure using the hypsometric equation; if temperature is required but unavailable, WindTrax will use a global variable called “screen temperature”. Of course, both cases will reduce the accuracy of the results.
- The *integrated horizontal flux sensor*, which estimates the mean mass flux through a given vertical plane.

All WindTrax sensors are placed on *sensor platforms*, which determine the position and number of locations at which measurements occur. Given measurements will almost always be provided by sensors attached to point platforms, which include the *instrument tower* and the *truck*. The tower’s location is fixed, whereas the truck platform can be moved around to different locations by setting its coordinates from a data file during multiple simulation runs. The only exception to the placement of given measurements on point platforms is the *line concentration sensor*, which measures average concentration along a line and represents a laser or open-path UV sensor.

WindTrax can also generate *transect plots*, *vertical profiles*, and vertical and horizontal *contour plots* of unknown quantities such as concentration. To do this, place one of these sensor platforms on the map and then attach sensors to them by selecting the appropriate sensor tool and clicking on the platforms’ icons. These plots are useful in gaining an overview of the measurement fields near the experiment site. As mentioned, a single concentration measurement can be used to predict the entire concentration field downwind of a source.

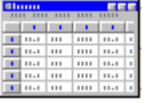
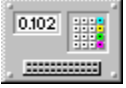
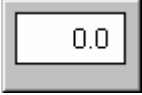

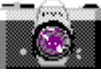

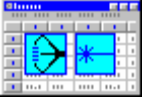

Sensor icons

Sensor icon (on tower)	Sensor name	Action
	Standard anemometer	Measures (given) or reports (unknown) mean wind speed and direction; most common method of indirectly supplying u^* to WindTrax
	Cup anemometer	Measures (given) or reports (unknown) mean wind speed; useful for specifying speeds in a profile
	Sonic anemometer	Measures (given) or reports (unknown) all wind statistics supplied by a 3D sonic anemometer
	Wind vane	Measures (given) or reports (unknown) mean wind direction
	Wind statistics	Measures (given) or reports (unknown) the wind statistics ratios σ_u / u^* , σ_v / u^* , and σ_w / u^*
	Point concentration	Measures (given) or reports (unknown) concentration of tracer gas at a single point (or multiple points, depending on the sensor platform it is attached to)
	Temperature	Measures (given) or reports (unknown) mean air temperature
	Pressure	Measures (given) or reports (unknown) mean air pressure
	Line concentration	Measures (given) or reports (unknown) line-averaged concentration; used for laser and open-path UV sensors
	Integrated horizontal flux	Reports mean integrated horizontal flux of gases

Sensor platform icons		
Platform icon	Platform name	Action
	Tower	Support point sensor measurements; sensors can be in either given or unknown modes; location is fixed
	Truck	As for Tower, but position can be moved using data connections.
	Line sensor	Line average concentration measurements; given or unknown mode
	Transect	Multipoint measurements, unknown mode only; used to predict transects of concentration or other variables
	Profile	Multipoint vertical measurements; unknown mode only
	Horizontal contour	Horizontal, two-dimensional plots of concentration, etc.; unknown mode only
	Vertical contour	Vertical, two-dimensional plots of concentration, etc.; unknown mode only

Data objects

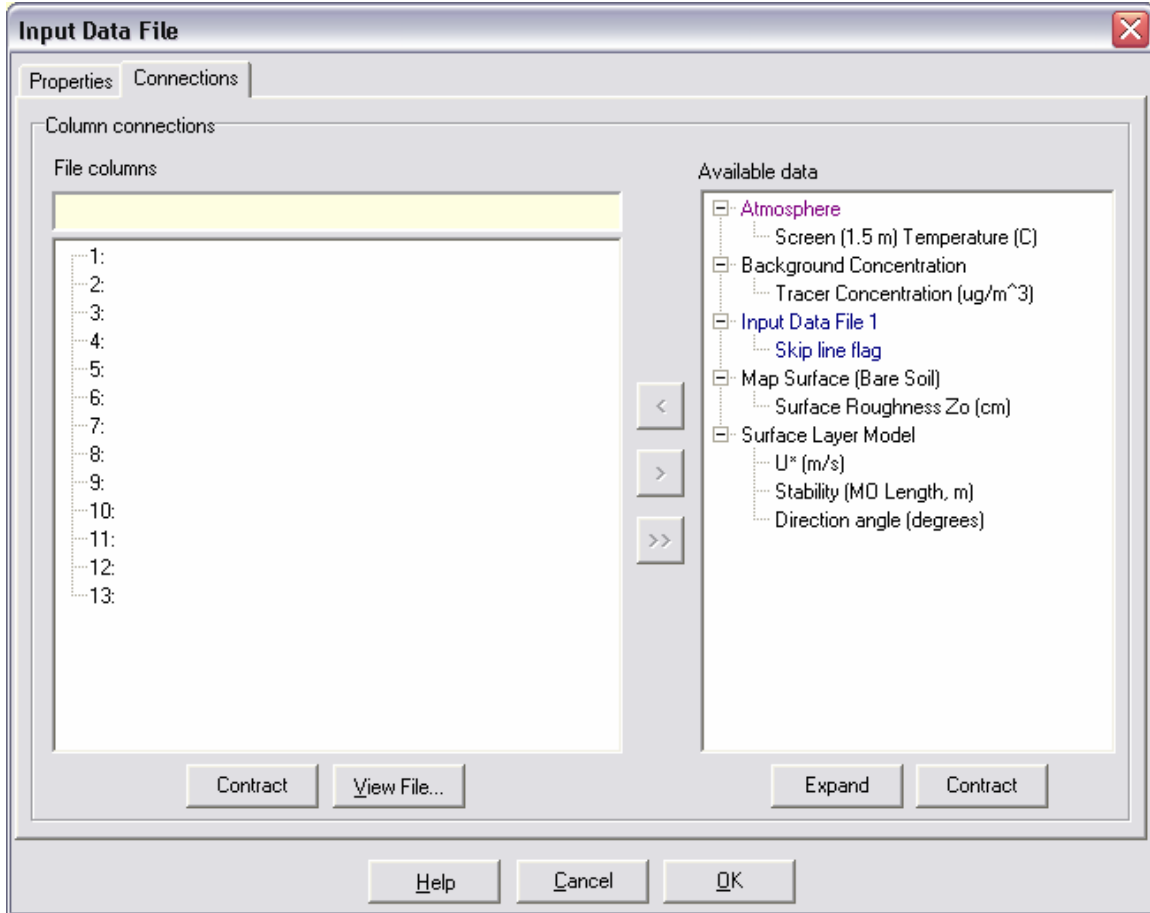
Data objects are used to interface WindTrax to data files or display results in an easy-to-read format. *Input data files* have icons that look like a spreadsheet, and are used to connect measured data to objects on the map. Each line of data will generate a separate model run. *Output data files* look like data loggers and store data from WindTrax objects. *Multimeters* provide a clearly visible display of one quantity at a time and simplify monitoring key values during a set of simulations. *Chart recorders* is similar to an output file but also creates a chart of each measured quantity. The *camera* stores screen images at each step, which can be useful in assessing the placement of particle touchdowns relative to the source, to determine how representative a given run was. *Signal generators* are useful for creating what-if scenarios; they allow you to specify any function and the set of domain points at which it is evaluated, and can be connected to any object's input data. The *real-time COM automation server* allows other programs to control WindTrax; it is being used by different groups to generate real-time estimates of emission rate. Finally, the *Cerex data file* is a specialized object that automates the connections between data files and map objects when Cerex line sensors are used.

Data object icons		
Data object icon	Object name	Actions
	Input data file	Connects existing data files to WindTrax projects, allowing multiple simulations
	Output data file (data logger)	Connects map object properties to output files for storage and later use
	Multimeter	Displays the present value of any map object property
	Chart recorder	Similar to an output data file, but also creates charts of the stored results
	Camera	Stores screen captures to a series of output image files, for use in assessing the validity of a given run
	Signal generator	Creates data to be connected to any map object using an arbitrary function evaluated over an arbitrary domain.
	Real-time COM server	Allows WindTrax to be controlled by external programs through the standard COM object interface.
	Cerex automated data file	Automates file connections and sensor selection for use with Cerex data files

Connecting data objects

All data objects are connected to WindTrax objects in a similar way. Double-clicking on the object's icon opens a property editor form. On each form are two lists, one showing the possible connections to all objects on the map, and the other showing the actual connections made to the data object. To make a connection, simply use the mouse to drag a property's label from the list of available data over to the list of file columns. The label will disappear from the available data and reappear in the file connection list, in the appropriate location. If you wish to connect more than one map object to a given column of the data file, hold down the Control button while dropping the property name on the list.

The image below shows the property editor for an input data file:

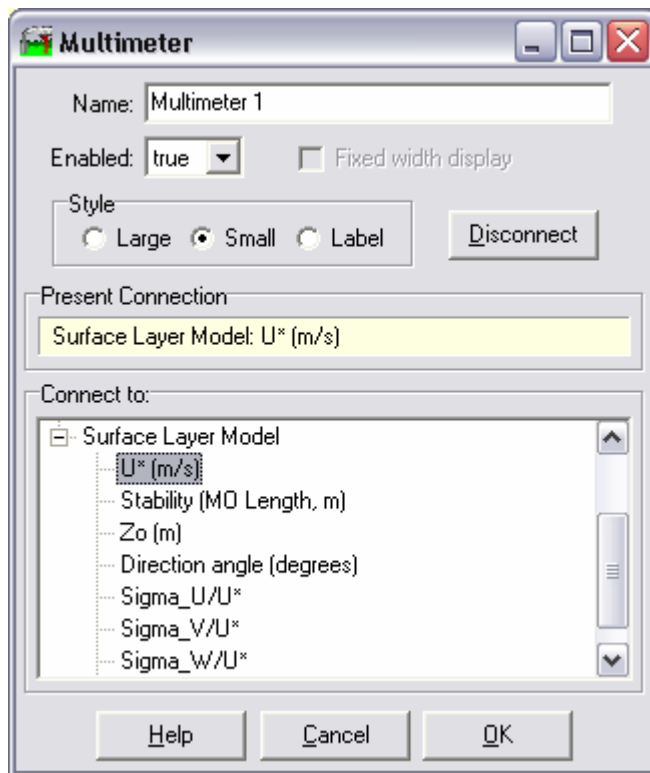


Each column in an input file represents a single object property. For example, one file column might be mean wind speed, a second wind direction, and a third the stability class; other columns would provide data on concentration measurements. When you specify the file name and the delimiter character (space, comma, tab, etc.) used to separate the columns of data on each line, WindTrax scans the file and determines the number of columns it contains. It then creates a column label, starting at 1, to allow you to place object property labels in the correct column. As you move the cursor over the column labels, a sample of the data (or the column header in the input file, if one was provided) is shown above the list to make selecting the correct column an easier task. To cancel a connection, drag the property name from the file column list back to the available data list.

It is important that you make sure the units of the data and the object property it is connected to are the same; in most cases, WindTrax cannot check for compatible measurement units. If you have connected a column to a property with incompatible data, an error will be generated at run time and the simulation step will be ignored. WindTrax also rejects lines of the file containing any invalid data.

Output data files have neither a specific order nor a specific number of columns for the output data, so no column numbers are provided on the data file connections list. Instead, you simply drag and drop object properties onto the list, and can rearrange them in whatever order you choose.

Because multimeters can be connected to only one object property at a time, the file list is replaced by a single edit box:



Connections are made by dragging and dropping available properties in the list to the "Present Connection" edit box above the list.

Map object output mode

Many objects in WindTrax can either provide data or request unknown data. For example, a concentration sensor can either specify the concentration actually measured at a given location or be used to request that an unknown concentration be calculated for its location. These two modes of operation are referred to as *output modes*; objects can be in either *given* out mode or *unknown* output mode. Most objects have only one property of interest that can be changed from given to unknown modes. A few objects, such as the wind statistics sensor, map surface, and atmosphere's background concentration, have more than one property whose output mode can be set individually.

Most objects have a default output mode when they are created, though this can be changed by selecting the mode when adding objects to the map by changing the value in the combo-box at the top of the main form.

It is up to you to specify which object data is given and which is unknown. A common mistake is to leave the output mode of the background concentration at given, even though a concentration sensor is placed upwind of the source. WindTrax will not identify that the upwind sensor is intended to measure background concentration and your results will not reflect the measurements correctly; it will accept background concentration as given and determine the best least square fit to the over-determined sensor-source system.

The output mode of sensors sometime depends on the type of platform to which they are attached. Sensors placed on profile, contour, and transect plots are automatically put in unknown mode, and this can't be changed. Sensors on towers and trucks can either provide or request data, as can the line concentration sensor.

Output mode can be changed while WindTrax is in edit mode by double-clicking on an object to show its property editor and setting the mode with the Output Mode radio button box on the Measurements tab sheet. Alternatively, pressing Control plus T will toggle the output mode of all selected objects on the map, provided they have any properties whose output mode can be changed

Determining the surface layer model parameters

The surface layer model used in WindTrax requires the seven parameters u^* , z_o , L , θ , σ_u/u^* , σ_v/u^* , and σ_w/u^* to completely specify the wind and temperature fields. As mentioned earlier, the last three parameters can be estimated using standard empirical relationships if they were not measured in your field program.

The new versions of the program allow you to set these parameters in a number of different ways. In Version 1.0, you had to specify surface roughness directly using the map surface; stability using a "stability sensor"; and wind speed and direction using a standard anemometer. WindTrax 2.0 can receive the data in several new ways; you can

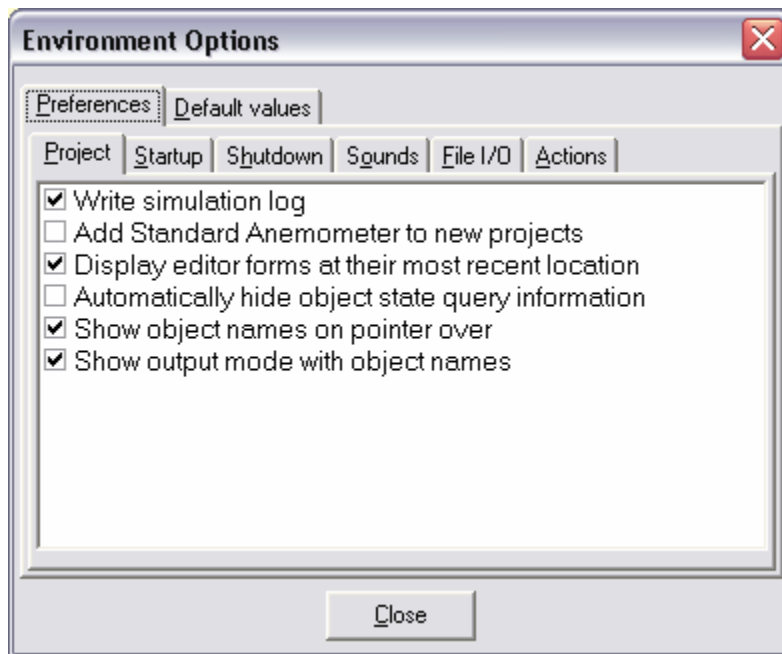
- provide data directly from a sonic anemometer, from which WindTrax will derive u^* , z_o , L , and wind direction;
- provide a profile of wind speeds and temperatures, which WindTrax will use to determine u^* , z_o , and L ;
- add a two-speed, two-temperature bulk Richardson number profile, which will be used to estimate u^* and L ;
- provide a single measured wind speed and direction, from which u^* will be derived, and specify z_o , and L directly (the default option available in earlier versions);
- specify all parameters including wind direction directly, without using any sensors

If more than one of the preceding surface layer model data sources is present on the map, WindTrax will select from among them in the order they appear in the above list. For example, if both a profile and a sonic anemometer are present, the profile will be ignored.

A valid profile for use in estimating the surface layer model parameters has at least four temperature measurements and/or four or more wind speed measurements. All sensors must be located on the same tower platform, and no two wind or temperature measurements can be located at the same level. WindTrax will fit the best wind and temperature profiles in the least squares sense through the measured data.

Changing the WindTrax environment

WindTrax allows you to change many of its default behaviours, such as the way it starts when first loaded and the manner in which it responds to the completion and cancellation of simulations. Select Tools/Environment from the main menu, to open the Environment editor form, shown here:



You can also set the priority given to WindTrax on the computer by selecting Tools/Task Priority... from the main menu. In general, WindTrax is a CPU hog and attempting to run other programs on the computer at the same time can be a frustrating experience. If you change its priority to Low, the program will allow you to perform other tasks, while still returning to feed at the CPU trough whenever possible.

Steps in creating and running a WindTrax project

Although the list of steps required to create and run a WindTrax simulation is surprisingly large, there are no real surprises and each step is intuitive. They do not have to be followed in any specific order, though some naturally follow after others. Because there is no Undo function in WindTrax, it is a good idea to save the project to a file both early and fairly often. (Undo is presently under development.) Here is a typical procedure:

- 1) Set the map scale and grid origin using the Grid tool button so that the experiment will fit within the map (for simplicity of use, it's often best to restrict it to the visible screen, though you can also adjust the size of the map.)
- 2) Adjust the map orientation if required by double-clicking on the North Indicator icon.
- 3) If you are measuring concentrations in ppm or ppb but do not know the surface pressure, set the elevation by double-clicking anywhere on the map surface where no icons are present. If you do not have temperature measurements, set the Screen Temperature to an appropriate value by double-clicking on the Atmosphere.
- 4) Depending on the way in which you will report the model parameters u^* , z_o , L , and θ , place wind sensors on the map as needed.
- 5) If you have an aerial image file of the experiment domain, add it to the background by clicking the Imported image button on the Miscellaneous tool bar and specifying the file name; then clicking on the map surface. Adjust its location by dragging it with the cursor.
- 6) Place all concentration sensors and draw any sources on the map as required. Make sure that all sensors are at the correct heights.
- 7) Set the output mode of sources and concentration sensors as required and select all gases being emitted and measured. Set all measurement units to match those of your real instruments.
- 8) If background concentrations are assumed to be known, adjust the background values by double-clicking on the Atmosphere icon and selecting the Measurements tab. If any background concentrations are unknown, set their output mode at the same form location. The output mode of each measured/emitted gas must be specified separately.
- 9) If you are using input data from a file, add an input file to the map, specify the file name, and connect the appropriate object data.
- 10) If you are not using file data, set values for surface roughness, wind data, stability; and other measurements (pressure, temperature, concentration).
- 11) If you wish to calculate plots, place sensor platforms and add the appropriate sensors to them.
- 12) If you are using an input data file, add an output file icon to the map and connect any properties of interest to it.
- 13) Adjust the LS model parameters and options by double-clicking on their icons.
- 14) If the Run button is gray, click the Status (?) button to determine the source of error.

- 15) If the Run button is enabled, click it to start the simulation. Once the simulation is completed, you can examine the value of any object property by clicking on it with the cursor. When ready to return to Edit mode, click the blue Rewind button.
- 16) If you are using input file data, you can step through the lines in the file one at a time by clicking the Step Run button instead of the Run button.
- 17) At any time, you can cancel a simulation by clicking the Stop button.
- 18) If the model uncertainty is too large, increase the number of particles released by the LS model(s) and rerun the simulation.
- 19) If the time predicted for completion of a given step is too large, reduce the number of particles released by the LS models, select Use minimum tracking distance, and/or set the backward model to use standard catalogs.

WindTrax project files and batch files

Once drawn, a map can be saved to a *project file* to be reopened at a later time. WindTrax project files end in either “.wxf” (Version 2.0) or “.wpx” (Version 1.0). WindTrax 2.0 and above can read project files from all earlier versions, but WindTrax 1.0 can read only .wpx files. If any new version of the program does not correctly read your project files from earlier versions, please send the file by email to Help@ThunderBeachScientific.com; WindTrax will be immediately debugged to ensure that it does load your project.

If you would like WindTrax to run a set of project files sequentially, create a text file and list the complete path name of each project file on a separate line. Then, click on the Batch Run button at the top left of the main form and specify the name of the text file you have created. WindTrax will load each project in the order listed and run the simulation for each. Of course, to save the results of these runs, your projects will have to include output data files.

A checklist when running simulations

Did you:

- Adjust the grid scale and map orientation correctly?
- Provide the correct u^* , z_o , L , and θ ?
- Set the output mode of background concentration correctly?
- Specify all gases for all sensors and sources?
- Set the height of all sensors correctly?
- Set all measurement units correctly?
- Provided a pressure and temperature if concentration is measured in ppm or ppb, or set the site elevation if no pressure is available?
- Ensure that the model error is sufficiently small for your experiment and adjust the particle number as required?
- Ensure that the predicted calculation time is shorter than the expected lifespan of the Sun?

Further information

The primary source of information on using WindTrax remains its on-line help files. These files cover both the theoretical and practical aspects of the program in greater detail. If you have any questions that are not covered by this article or the help files, please contact Thunder Beach Scientific at Help@ThunderBeachScientific.com and your questions will be answered as soon as possible after they are received.