Finnish wind data management and usage for Gauss modeling with SoundPlan-7.2 software

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Bachelor's thesis
May 2015
Environmental Engineering

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ABSTRACT

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Until now at Tampere University of Applied Sciences, training sessions with SoundPlan7.2 air pollution mode, did take place by using hypothetical or German meteorological data, provided by tutorials. This possibility allowed the users to learn about the general functions of the software system, but not getting any kind of realistic results, when modelling a scenario where Finnish weather conditions should be taken in to account.

The aim of the present work is to find Finnish available meteorological data and adapting them to the technical requirements of SoundPlan 7.2, in order to operate on the Gauss modelling calculation basis, getting results adjusting as much as possible to reality.

Three main questions had to be answered in this sense: what data are needed to operate such system, what sources to use for getting such data, and finally, how to apply them to operate effectively with SoundPlan 7.2.

CONTENDS

1 OBJECTIVES

The main objective of the present thesis is to contribute to the development of the usage of SoundPlan 7.2 Software at Tampere University of Applied Sciences.

For such purpose this thesis will aim to find ways to operate with SoundPlan 7.2 utilizing Finnish meteorological data for air pollution modeling, together with the option of Gauss calculation mode.

Fulfilling this objective involves three kinds of tasks or sub objectives: firstly the data needed to operate the system have to be determined, secondly reliable sources have to be found regarding Finnish wind data, and finally such data should be input, after possible adaptations, to work with the referred software.

The determination of the data needed will take place through the exploration of the different options offered by the system in comparison with the general principles of Gauss modeling.

Reliable and user friendly sources for meteorological data will have be proposed, and information provided for the interpretation and usage of such data.

2 INTRODUCTION

2.1 Meteorological related concepts

The wind´s speed and direction, together with solar radiation, atmospheric stability and precipitations, are considered the elements most involved in the distribution of air pollutants in the atmosphere. (David H.F.Liu; Béla G. Lipták, 2000, ss. 41-61)

The temperature usually decreases with height, and the different layers of the atmosphere are classified according to thermal criteria as shown in FIGURE 1. Problems related to climate and pollution will take place in the troposphere. (Ibid.)

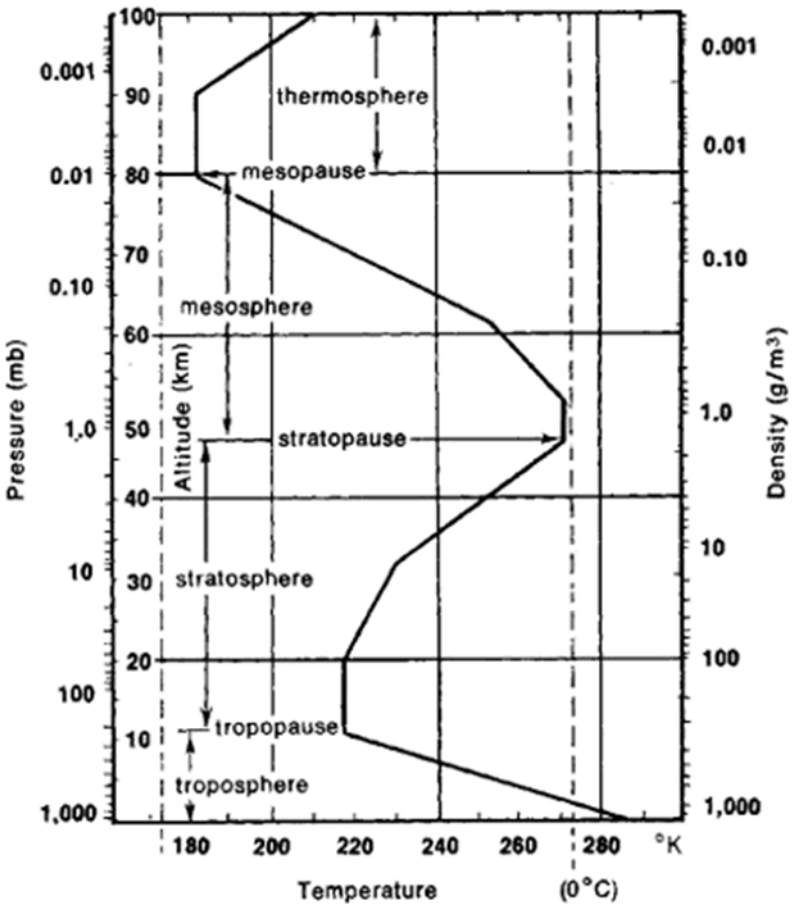


FIGURE 1. Atmospheric thermal structure from the ground level up to 100Km.

In the troposphere, atmospheric processes are governed by air masses getting turbulently mixed, unlike what happens above it. In the stratosphere however, an increase in temperature takes place with increasing height, caused by ozone concentration, as solar radiation is absorbed. (Ibid.)

2.2 Scales of air motion, wind roses and turbulences

Wind may be defined as air in motion. What scales of air motion are concerned, at scales of thousands of kilometres, the macro scale, this movement is originated in unequal distributions of atmospheric pressure and temperature, as well as under the influence of the earth's rotation. Wind normally proceeds from high to low pressure, deflected by the Coriolis Effect. (Ibid)

In areas of less than 10 kilometres, at the mesoscale and micro-scale, wind will be significantly influenced in its speed and direction of flow, by the nature of local topography. The overall effect of these flows is given by variations established hourly, daily or on seasonal basis; and the frequency of the different wind directions taking place, will be considered as an indication of those areas to which air pollutants are being transported with such frequency. (David H.F.Liu; Béla G. Lipták, 2000, pp. 41-61)

The speed and wind direction are important factors when considering the concentration and location of aerial pollution. The concentration of air pollutants will be inversely proportional to the wind speed, which determines the time that contaminants will move from its origin to the affected area.

Because air pollutants travel with the wind, they follow the same direction. The distribution of the different directions taken by the wind for a defined period, can be shown in a wind-rose, which may be presented graphically (FIGURE 2.), as well in form of data tables. (Ibid)

For visualization and subjective interpretation, a graphical wind rose may be more appropriate, showing wind frequencies from different possible directions, aligned to the corresponding azimuth (Vallero, 2008, ss. 650-654)

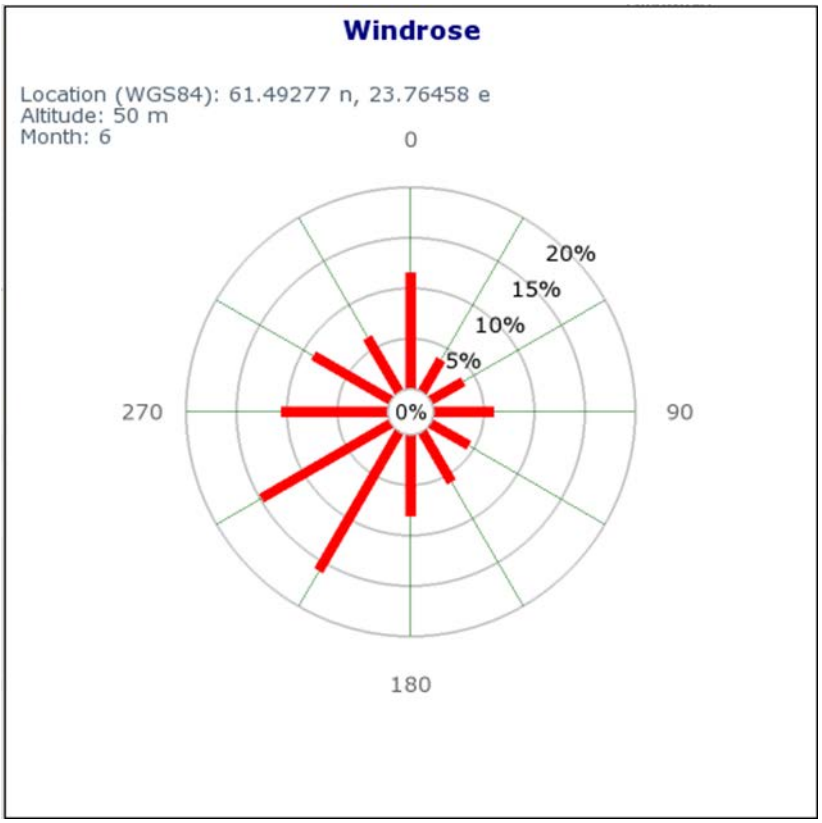


FIGURE 2. Predictive Wind rose.

In FIGURE 2. a wind rose shows a forecast for the month of June, provided by Finnish Wind Atlas services, based on statistical data, for direction and frequency of winds in the city of Tampere, distributed in twelve directions.

Turbulence in wind causes sudden variation of wind velocity and direction; such phenomenon is inducted in two ways: in the case of thermal turbulences, by the heating of the current from bellow, and in case of the so called mechanical turbulences, by disturbances or eddies, due to the characteristics of rough or irregular terrain. (David H.F.Liu; Béla G. Lipták, 2000, ss. 41-61)

An eddy refers to a portion of air, describing random and fluctuating motion. (P. Kudesia, V., and Kudesia, Ritu, 2008, s. 61)

2.3 Stability and Inversions

2.3.1 Stability

Dispersion of pollutants in our atmosphere is also affected by lapse rates, stability and inversions. In the stratosphere, as mentioned above, the temperature changes with altitude, the greater the height, the lower the temperature, this is termed adiabatic conditions; and we refer to the rate of changing temperatures with altitude, as ambient elapse rate. (David H.F.Liu; Béla G. Lipták, 2000, ss. 41-61)

This phenomenon is normally explained through the concept of “air parcel”, as an imaginary entity of air, being made up of a number of air molecules (but not vapour), with an imaginary boundary around them (Bhattacharya, 2010).

Placing such a parcel of air in the atmosphere, its temperature will be subject to its own variation of temperatures, independently from the prevailing temperature of the atmosphere, and this rate is called adiabatic elapse rate.

Humidity also affects the adiabatic elapse rate, so we distinguish between dry adiabatic elapse, as dry air cools at 9,80 ^{o}C per Km ; and a wet adiabatic elapse rate, which happens at 60 ^{o}C/km, due to the fact that condensation of water releases latent heat. But as a rising air parcel will never be completely saturated or totally dry, so the elapse rate will be somewhere between those limits. (David H.F.Liu; Béla G. Lipták, 2000, ss. 41-61)

Such concepts and terms allow us, in turn, to understand the concept of atmospheric stability, since we can distinguish between stable and unstable atmosphere, situations which will be given by the relationship between adiabatic and ambient lapse rates.

The tendency of a parcel of air at a temperature greater than the mass of air surrounding it, is to rise. In adiabatic conditions, as this parcel of air rises through the troposphere, gradually cooled, it will descend; under these conditions it is considered that the atmosphere is stable. (Bhattacharya, 2010)

If it occurs on the contrary, and the air parcel ascends although its temperature is lower than that of the surrounding air mass; or if it would descend despite having a higher temperature, the atmosphere would be unstable. (Ibid)

This should be also explained in terms of acceleration or deceleration, considering if buoyancy forces are acting in the direction of the air parcel´s motion or against it (FIGURE 3.) Should the vertical motion of the parcel be accelerated by the environment, the atmosphere is in an unstable condition; but if this motion is decelerated by environmental forces, then it is stable. (Guyot, 1996, s. 237)

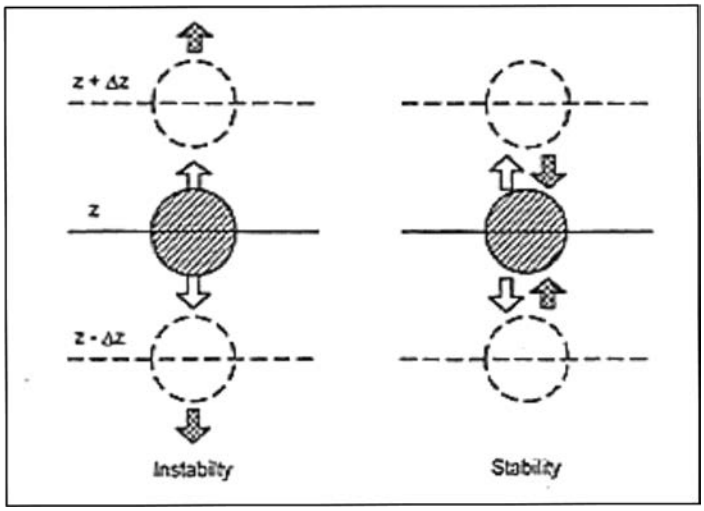


FIGURE 3. Stability and instability represented schematically. (Guyot, 1996)

FIGURE 3. Shows how the parcel of air is displaced by ±Δz; the direction of motion after displacement is shown by the shaded arrows.

So the relationship between the adiabatic and ambient lapse rates sets the principles of atmospheric stability leading to different kinds of situations in this sense. Should the ambient lapse exceed the adiabatic lapse rate, we will be in a very unstable atmospheric situation called super adiabatic. If the other way round, the ambient lapse rate should be lower, the situation is termed sub adiabatic, and would be stable.

A third possibility consists on the so called isothermal atmosphere, which is a stable situation where the ambient lapse rate is zero. (David H.F.Liu; Béla G. Lipták, 2000, ss. 41-61)

2.3.1.1 Inversion

If instead of decreasing with altitude, the temperature would increase, the lapse is said to be inverted or negative. This state is called inversion and takes place when colder air is wrapped up with warmer air. Such situation is extremely stable and sub adiabatic, as vertical motion of air is almost non-existent. (Ibid)

Three kinds of inversion may take place in the atmosphere: radiational, subsidence and frontal.

Radiation Inversions:

The radiational inversion takes place at low altitudes, inside the 50m to 200m range by rapid cooling of the ground by radiation (FIGURE 4). Inversion develops during the night, until the ground warms up again during the next day. Initially, only the air next to the ground will cool, but progressively it may reach altitudes of 150m or more. So pollution emitted during the cooling night hours, will be trapped under this inversion blanket. (Ibid)

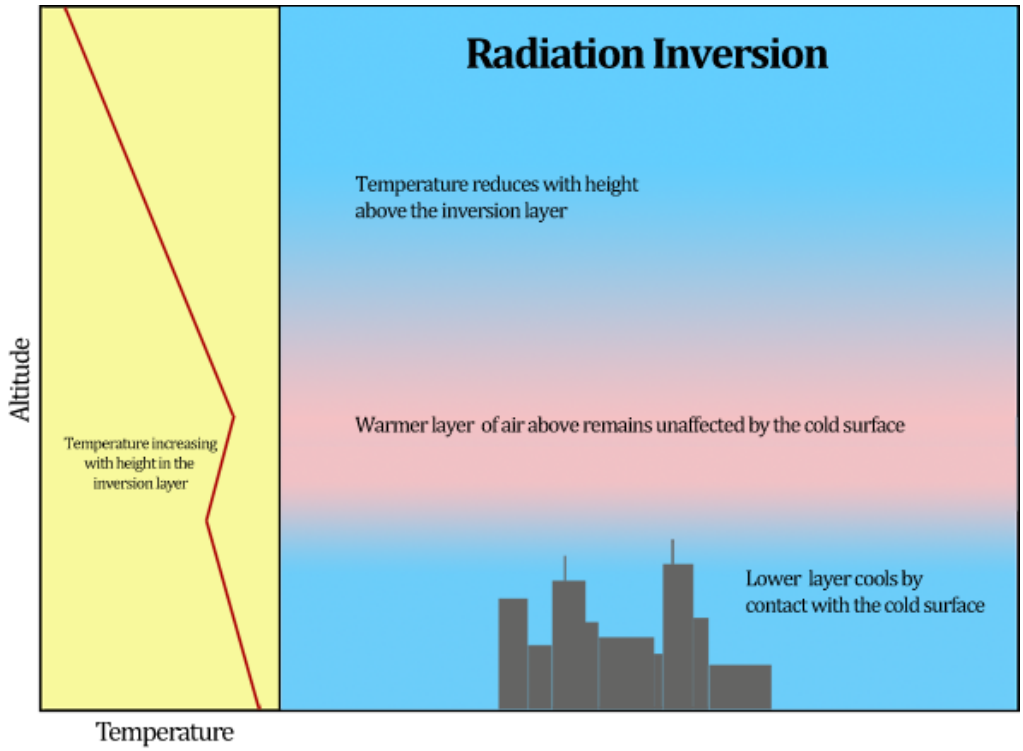


FIGURE 4. Schematic representation of radiation inversion (Fishler, 2013)

Subsidence inversions:

This type of inversion is due to the rise of hot air when it is replaced by a mass of cold air that descends on the surface. This can be caused by a stagnant high pressure or by a flow of cold air from the ocean into land surrounded by mountains. As affecting quite large areas for many days, subsidence inversion should be considered in air pollution control. (ibid)

A major factor in modification of air masses consists on its sinking or subsidence, taking place by stagnating high pressure systems; a large number of inversions are caused this way. The slow sinking air is heated by adiabatic compression, and this is how this kind of inversions is formed. (Maybeck, 1996)

Under these conditions the transport of pollutants will be reduced both, at the horizontal and the vertical level. Winds become light as the pressure gradient becomes weaker, diminishing the horizontal transport of pollutants; and as the subsiding layer is continuously descending, and it will act as a barrier inhibiting vertical dispersion (FIGURE 5.). (David H.F.Liu; Béla G. Lipták, 2000, ss. 41-61)

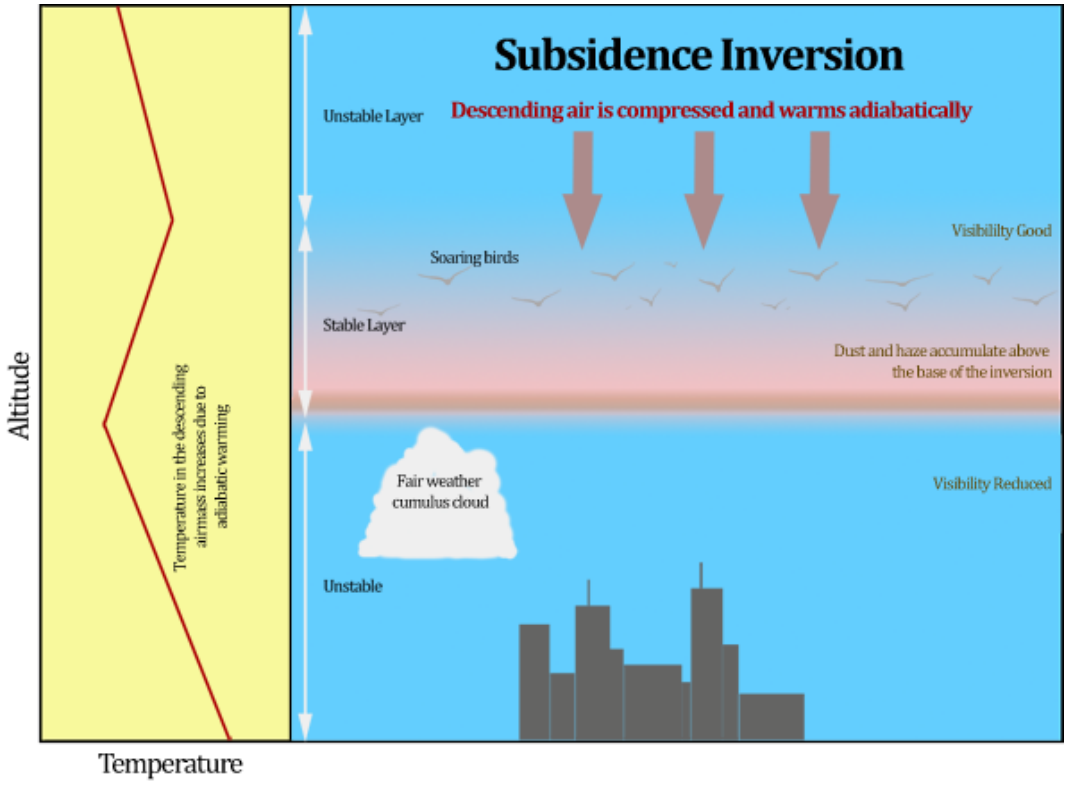


FIGURE 5. Schematic representation of subsidence inversions (Fishler, 2013)

In this kind of situation, in big cities or industrial areas, the stagnation of pollutants in the same area will increase its concentration, and if the situation is persisting for several days, it could be hazardous for the public health.

An added risk to this situations is the fog normally present in this kind of episodes, as fog converts SO_3 to H_2SO_4 , as well preventing the sun warming, to break the inversion, prolonging the situation of stagnation. (ibid)

Frontal Inversions:

Frontal Inversions are not as important what pollution control is concerned. They basically take place by the overrunning of a cold air mass by a warm one above (FIGURE 6). (Ibid)

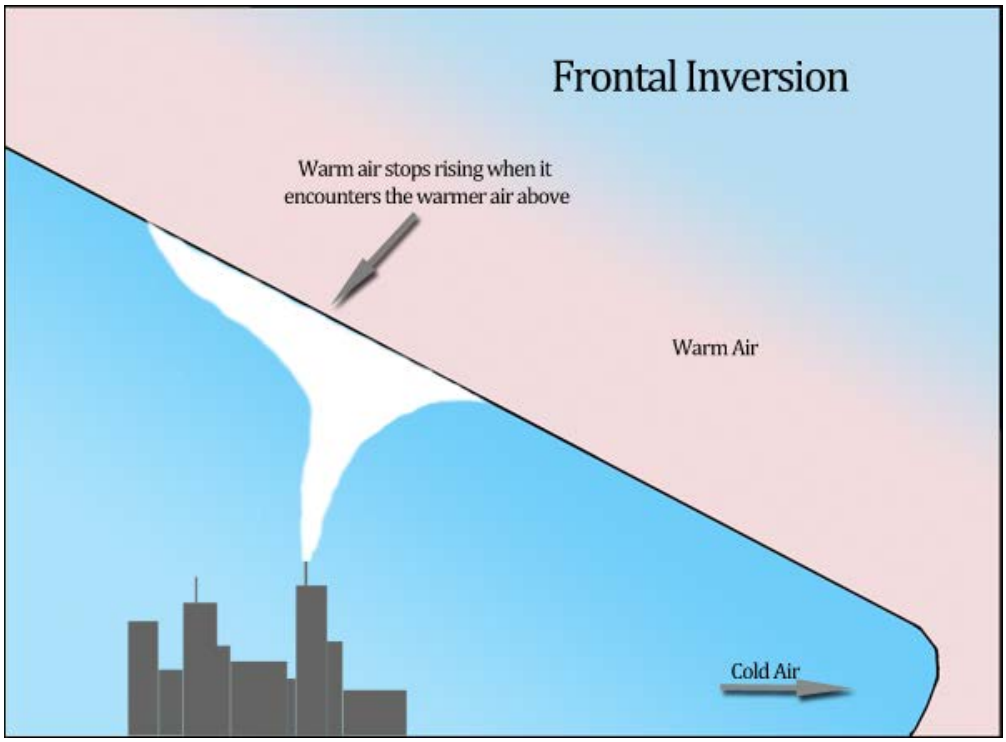


FIGURE 6. Schematic representation of frontal inversion. (Fishler, 2013)

2.3.2 Precipitation

Precipitation may contribute to the cleansing of pollutants on different ways; falling raindrops or snow may wash out large particles, smaller particles may accumulate when raindrops or snowflakes are formed in the clouds, and gaseous pollutants may get absorbed or diluted. (David H.F.Liu; Béla G. Lipták, 2000, ss. 41-61)

2.3.3 Topography

Natural and manmade elements have to be included when considering the topography of the terrain, which affect air flow generating small scale circulations, contributing in one way or another to the transportation of pollutants. (Ibid)

Land-see breeze

During the day, land heats quicker than the see, this will cause a lower pressure over the lands surface resulting in air flow from water to land. The breeze develops initially towards land, and as it extends in distance, air will tend to flow parallel to the coast line due to the Coriolis Effect.

After sun set , as the temperature of water remains relatively constant, and land temperature is cooling down faster, the breeze will take place from land to see.(Ibid.)

Mountain-valley winds

The walls of valleys, radiationally cooled, also cool down the air, producing a situation of atmospheric inversion. This may lead to critical accumulation of pollutants if those areas would be populated or if industrial activity taking place. (Ibid)

Urban heat island effects

Buildings and constructions enhance turbulences when airflow taking place over the city; but those constructions also act as a “radiation reservoir”, causing pressure differences between urban areas and the rural surroundings, thus inward circulation of air develops, contributing to the concentration of pollutants. (Ibid)

2.4 Atmospheric dispersion modelling

Random motions in a fluid, e.g. air turbulences, cause the spreading of the compounds suspended on it, this is called dispersion, thus the concentration of air pollutants reaching a certain area ,will be given by the dispersion. (Visscher, 2013, s. 4)

Air dispersion modelling will help us to evaluate possible problems created by air pollution sources, predicting the impact of the source on the quality of air, or determining the source if not known. (Ibid)

There is a wide range of air dispersion modeling methods, but in most cases the so called Gaussian Plume models and Gaussian puff models, are in practice, the most feasible ones. (Ibid)

2.4.1 The Gaussian Model

Watching the plume emitted by an air pollution source, it can be observed that the plume will rise and stabilize at a certain height, that it will fan out horizontally and vertically, and that it will adopt a randomly fluctuating shape. The random shape won't be considered by deterministic models, but the average concentration of pollutant over a certain time, normally one hour. These concepts are shown graphically in FIGURE 6.

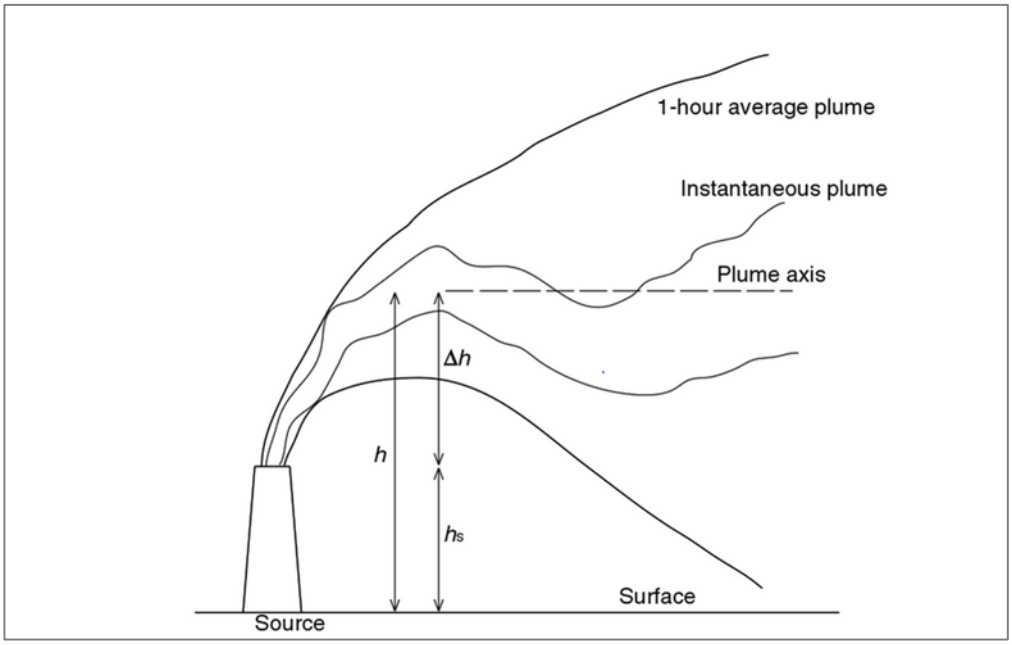


FIGURE 7. Concepts of air dispersion (Visscher, 2013)

In FIGURE 7. following definitions apply:

$h_s = source\ height\ (m)$
$\Delta_h = Plume\ rise\ (m)$
$h = effective\ source\ height\ (m)$

The Gaussian model is based on following theoretical principle: given a constant wind speed, direction, and turbulent diffusivity; and a source emitting a constant pollution stream, it is a proven fact, that the emitted plume will have a Gaussian concentration profile laterally and vertically, opening up fanwise as the distance to the source increases. (Ibid)

However this assumption should be tempered a bit, as it would not be accurate if taking an “instant snapshot” of the plume; but it is been proven by experience that the Gaussian tendency manifests, if considering the hourly average concentrations. It also has to be considered that wind speed is not independent of height. (Ibid)

In Gaussian plume dispersion modelling, there is a convention to define the coordinate axes as shown in FIGURE 8:

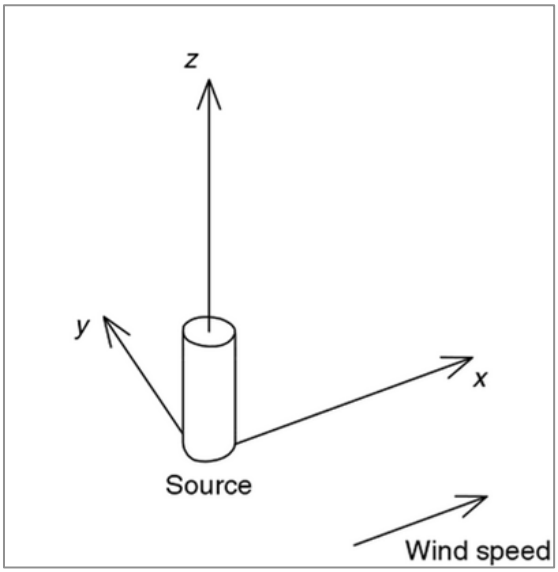


FIGURE 8. Coordinate system in simple Gaussian dispersion models. (Visscher, 2013)

In FIGURE 8 following terms apply:

$x =$ direction of the wind
$y =$ horizontal direction, perpendicularly to the wind
$y_0 =$ Located at the centre of the plume, considered to be positive when located on our left looking downwind
$z =$ vertical; On the surface $z = 0$; and positive above it

So the "basic golden rule" in Gaussian Plume modelling principle is that *time averaged* concentration of pollutant in the plume towards directions *y* and *z* will present the form of a Gaussian distribution; and the plume edge is 2, 15 standard deviations from the plume centre (FIGURE 9).

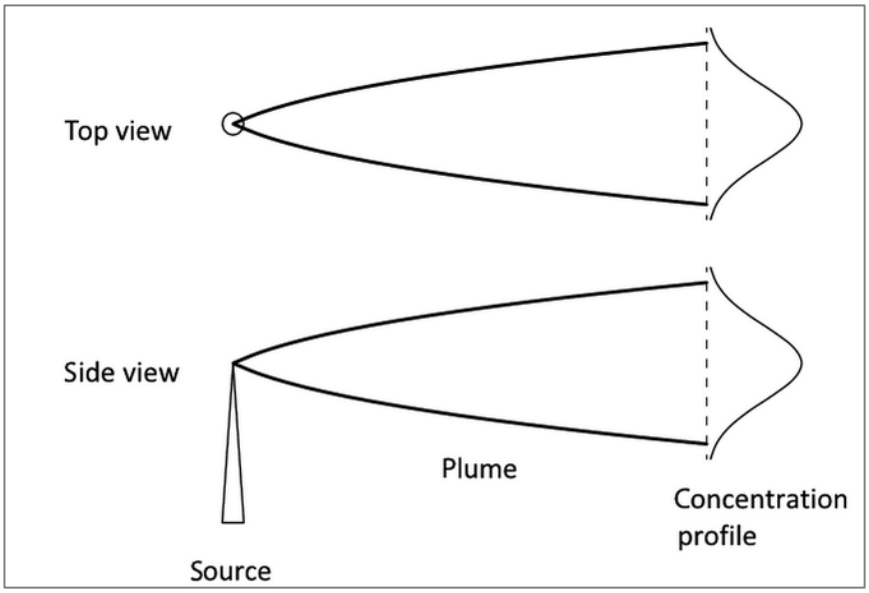


FIGURE 9. Projection of a Gaussian Plume, with concentration profiles. (Visscher, 2013)

The Gaussian model quantitatively*:*

In algebraic terms, pollutant concentrations following Gauss models may be considered in two ways: with boundaries and without.
In absence of boundaries, following equation can be applied (Visscher, 2013) :

$$c = \frac{Q}{2\pi u \sigma_y \sigma_z} exp\left(-\frac{1}{2}\frac{y^2}{\sigma_y^2}\right) exp\left[-\frac{1}{2}\frac{(z-h)^2}{\sigma_z^2}\right]$$

where:
$c =$ concentration at a given point $(g\ m^{-3})$
$Q =$ emission rate $(g\ s^{-1})$
$u =$ wind speed $m\ s^{-1}$
$\sigma_y =$ horizontal disperssion parameter (m)
$\sigma_x =$ vertical dispersion parameter(m)

But boundaries, as the ground or water´s surface, have to be considered in practice, as plumes behave as they would reflect on surfaces as shown on FIGURE 10.

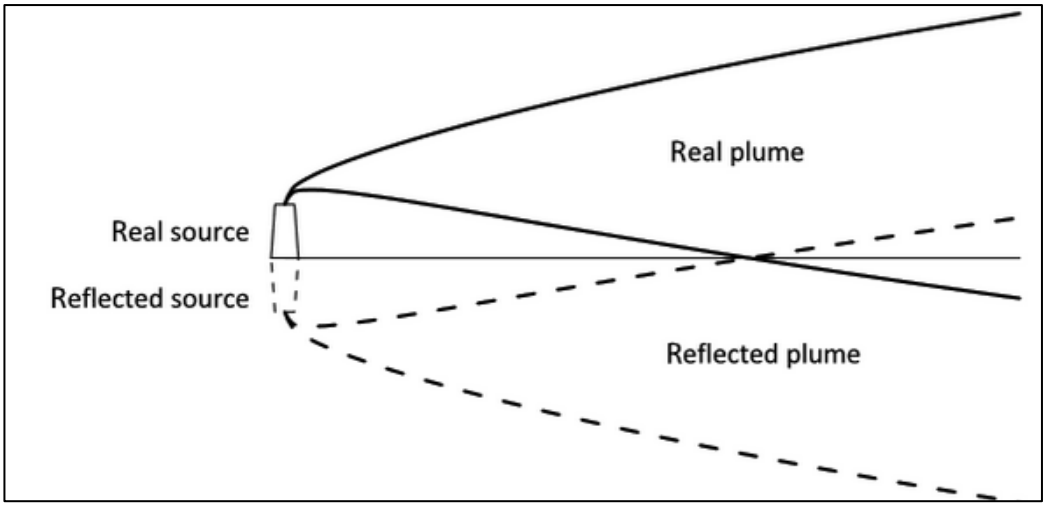


FIGURE 10. Plume reflection on the ground (Visscher, 2013 after Cooper C.D., Alley F.C., 2011)

In order to calculate the reflection effect, an imaginary source should be enclosed in the system, extending the equation as shown below in following equation (Visscher, 2013)

$$C = \frac{Q}{2\pi u \sigma_y \sigma_z} exp\left(-\frac{1}{2}\frac{y^2}{\sigma_z^2}\right)\left\{exp\left[-\frac{1}{2}\frac{(z-h)^2}{\sigma_z^2}\right] + \underbrace{exp\left[-\frac{1}{2}\frac{(z+h)^2}{\sigma_z^2}\right]}_{\text{reflection effect}}\right\}$$

Stability Classes and Dispersion Parameters

Some characteristics of the weather of the area should be taken into account to calculate the dispersion parameters σ_y and σ_z; and stability classes have to be considered for such purpose.

The most common scale used for such purpose contends the so called Pasquill-Gifford classes, classifying atmospheric stability into six classes, termed A through F as shown in TABLE 1. (Visscher, 2013, s.20)

TABLE 1: Pasquill-Gifford Stability Classes

Pasquill-Gifford Stability Classes	
A	Very unstable
B	Moderately unstable
C	Slightly unstable
D	Neutral
E	Slightly stable
F	Stable

Each of the Pasquill-Gifford Stability Classes follow solar radiation criteria which are shown in TABLE 2., and each one of them will have associated an estimated equation to calculate dispersion parameters, estimations which may vary according to the nature of topography , as shown in TABLE 3 for rural terrain and in TABLE 4. for an urban environment.

TABLE 2. Solar radiation and Pasquill-Gifford Stability Classes. (Visscher, 2013. after Turner and Schultze, 2007)

Day				**Night**	
Incoming solar radiation				Cloudiness	
$u(\frac{m}{s})$	Strong	Moderate	Slight	Cloudy$\geq 4/8$	Clear$\leq 3/8$
<2	A	A-B	B	E	F
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Considering *Strong* solar radiation the one in a clear summer day with sun positioned over 60° from horizon line, *Moderate* would be equivalent to a slightly cloudy summer day with sun positioned 35-60° . *Cloudy*$\geq 4/8$ would be the situation, for example, in a fall afternoon with the sun at 15-35° wile *clear*$\leq 3/8$ with partial cover of clouds. (Visscher, 2013. s 21)

TABLE3. Briggs (1973) Equations for dispersion with Pasquill-Gifford Stability Classes as a function of distance (x) ,estimated for rural environment. (Visscher, 2013.after Briggs 1973)

Stability class	$\sigma_y\ (m)$	$\sigma_z\ (m)$
A	$0{,}22x(1+0{,}0001x)^{-0{,}5}$	$0{,}2x$
B	$0{,}16x(1+0{,}0001x)^{-0{,}5}$	$0{,}12x$
C	$0{,}11x(1+0{,}0001x)^{-0{,}5}$	$0{,}08x(1+0{,}0002x)^{-0{,}5}$
D	$0{,}08x(1+0{,}0001x)^{-0{,}5}$	$0{,}06x(1+0{,}0015x)^{-0{,}5}$
E	$0{,}06x(1+0{,}0001x)^{-0{,}5}$	$0{,}03x(1+0{,}0003x)^{-1}$
F	$0{,}04x(1+0{,}0001x)^{-0{,}5}$	$0{,}016x(1+0{,}0003x)^{-1}$

TABLE 4. Briggs (1973) Equations for dispersion with Pasquill-Gifford Stability Classes as a function of distance *(x)*, estimated for urban environment. (Visscher, 2013.after Briggs 1973)

Stability class	$\sigma_y\ (m)$	$\sigma_z\ (m)$
A-B	$0{,}32x(1+0{,}0004x)^{-0{,}5}$	$0{,}24x(1+0{,}0001x)^{-0{,}5}$
C	$0{,}22x(1+0{,}0004x)^{-0{,}5}$	$0{,}2x$
D	$0{,}16x(1+0{,}0004x)^{-0{,}5}$	$0{,}14x(1+0{,}0003x)^{-0{,}5}$
E-F	$0{,}11x(1+0{,}0004x)^{-0{,}5}$	$0{,}081x(1+0{,}0015x)^{-0{,}5}$

3 RELATED DATA MANAGEMENT WITH SOUND PLAN 7.2

3.1 The raw data table

The management of the data-sets utilized in Sound Plan 7.2 takes place in the so called "Libraries", and general instructions about the different kinds of libraries, are contained in the Chapter 6 of the Sound Plan Air Manual.

The data sets used for calculation, have to be allocated in the "Project Libraries"; and what the management of wind data is concerned, the focus should be kept on the "Meteorological Station", more concretely on the "Raw Data" table.

Once the "Meteorological Station" is opened, it will be displayed as shown below and the option of "raw data" should be clicked, as shown in FIGURE 11.

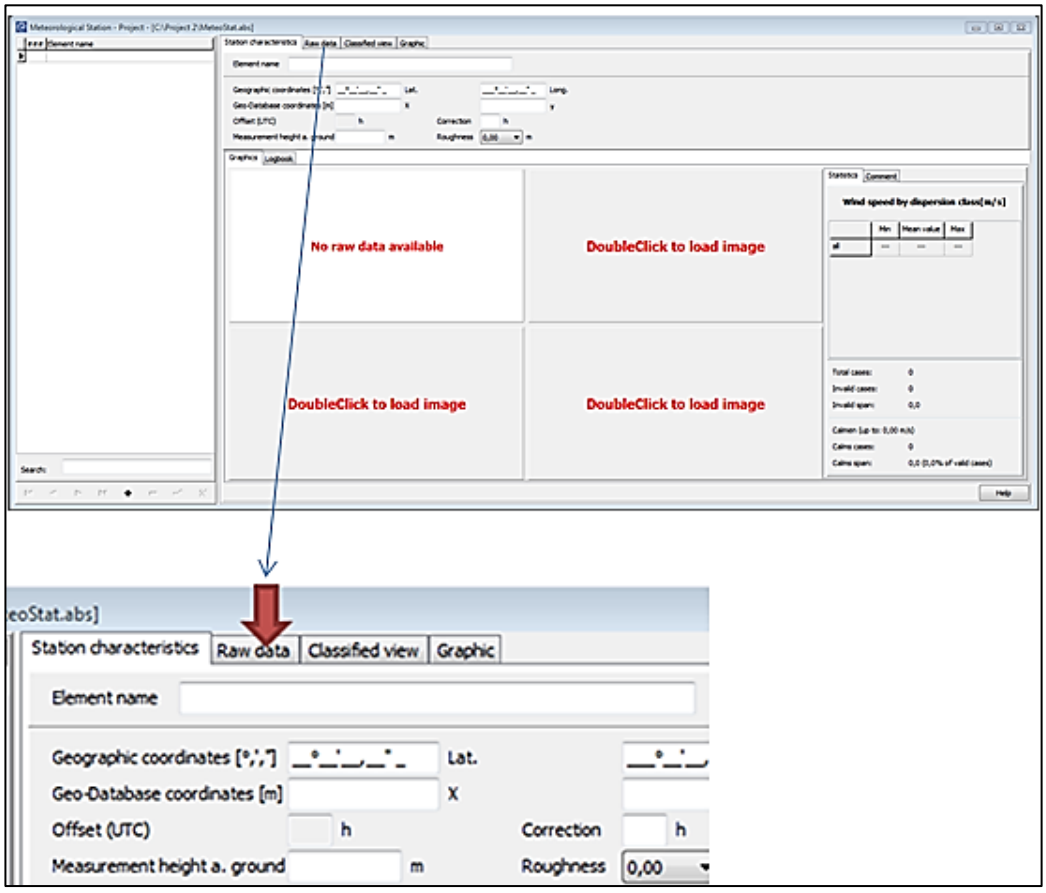


FIGURE 11.Clicking the "Raw data" option of Sound Plan 7.2 Meteorological Station

When doing so, a table will be displayed, see FIGURE 12. showing the different data required by the system for air pollution prognosis, and for different calculation systems.

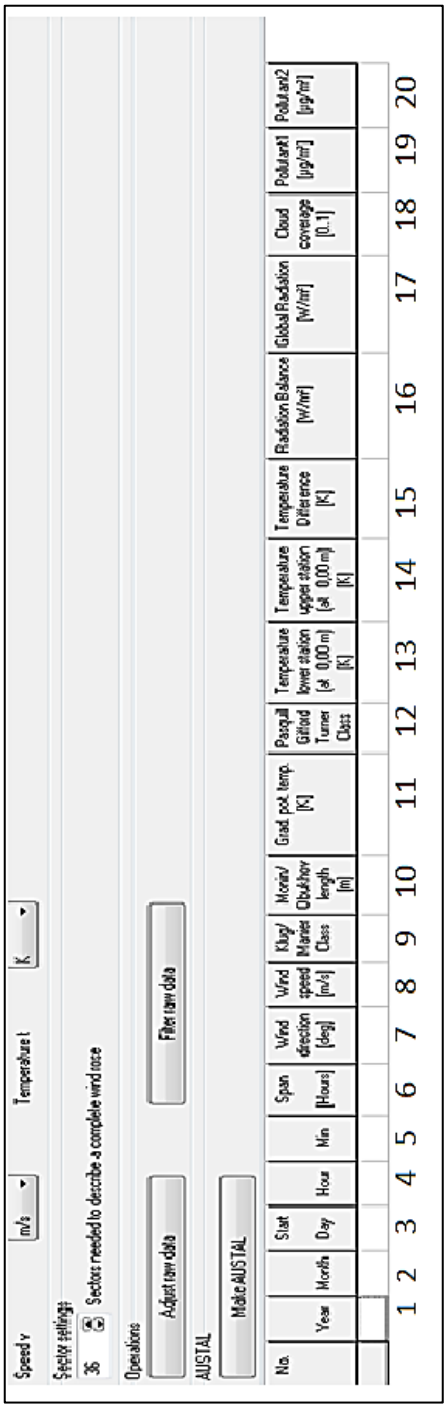


FIGURE 12. Header of raw data table displaying all the possible meteorological Data inputs (rotated image)

Besides the columns referring to the wind direction and wind speed, numbered in FIGURE 10. as 7 and 8 respectively, there are mainly two kinds of data in the table to be focused on: firstly the time related data , allocated in the columns numbered 1 to 6 , and secondly data related to atmospheric stability, numbered 9, 10,12,and 18 , corresponding to Klug/Manier Class, Monin/Obukhov length, Pasquill/Gifford and cloud coverage respectively.

3.2 Treatment of time related data

The first four columns serve the purpose to input the time parameters of the measurements while column 6, “span”, will contain the length of the intervals. See FIGURE 13.

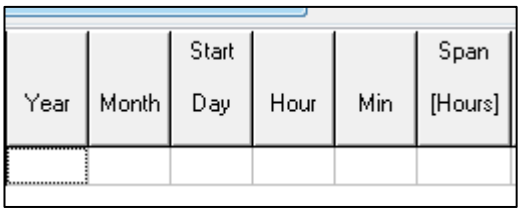


FIGURE 13.Time data columns on Raw Data Table.

The problem is, that most of open available wind statistics introduce time parameters in the form of a frequency, expressed in terms of a a percentage, or in number of hours, associated to every wind speed and wind direction considered.

For such reason the table should be adapted and some adjustments should be done at the Meteorological Station of the Project Library, utilizing the so called “Classified view”

By opening the Library, the system will ask for a name for the new element, after having named it, the “Classified View” button should be clicked at, see FIGURE 11.

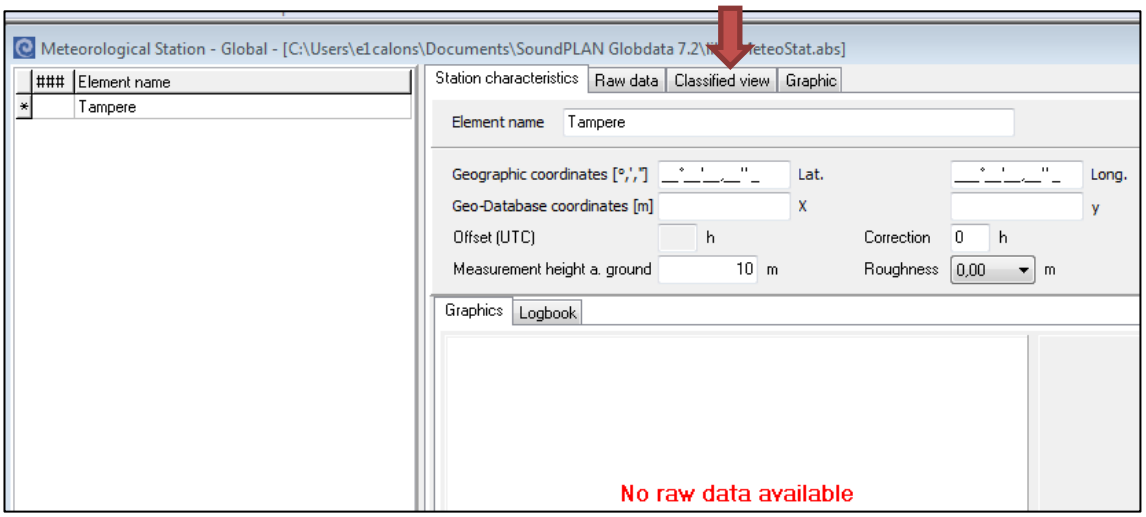


FIGURE 14.Activating the “Classified view”

The next step will consist on pressing the “create raw data “option as shown below in FIGURE 15. and answering “yes” to an emerging pop up window asking if “empty classes” should be omitted.

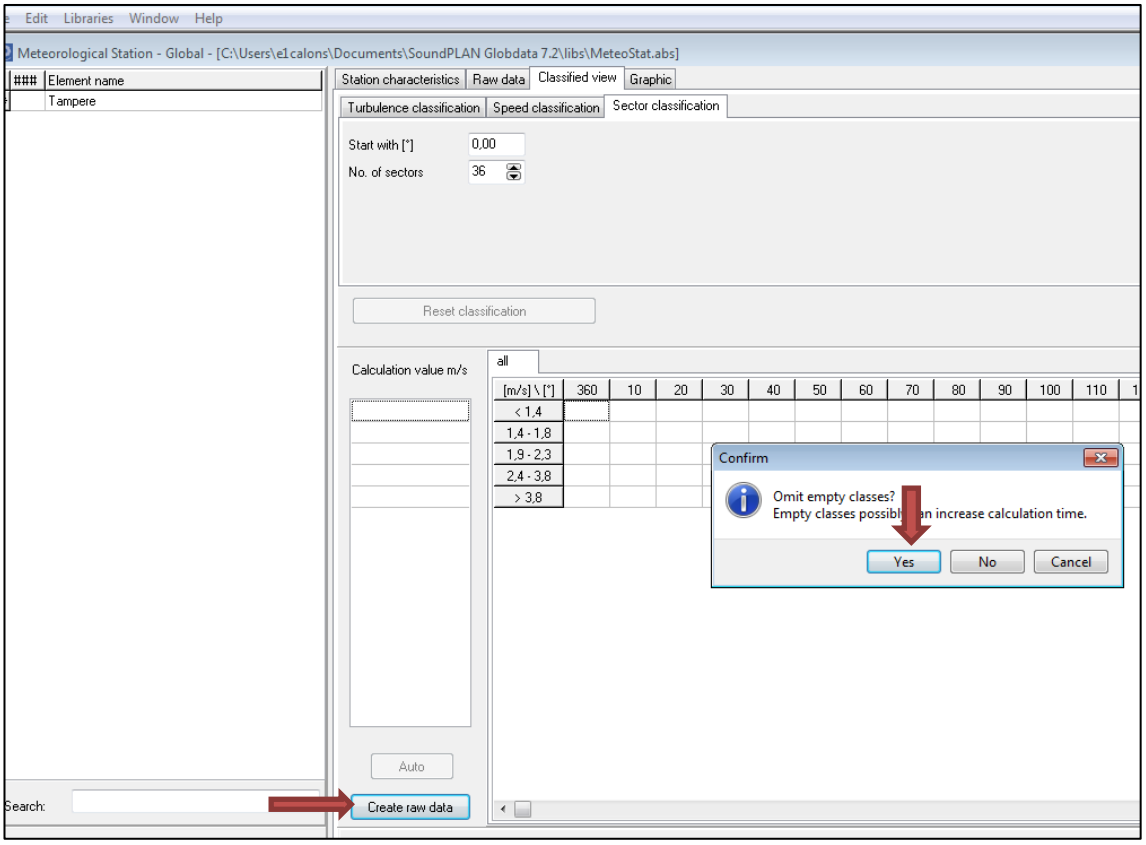


FIGURE 15.Activating the “Create raw data” option.

Further two pop-up windows will ask if the named element should be saved, and it is convenient to do so. The system will create a new element with the same name and the appendix: ”classified”, after it.

By doing so, the first five columns of the raw data table (FIGURE 12.); “year, month, day, hour and minute”, will be deactivated, habilitating the possibility to summarize the duration in the “span column”, using it to register frequencies instead of intervals, by adding the number of hours corresponding to each wind direction.

The data required to fill in the columns corresponding to “span” “wind speed” and “wind direction” can be obtained from “Finnish Wind Atlas”; the access and utility of this valuable source is explained in Chapter 3.

4 THE FINNISH “WIND ATLAS”.

4.1 General instructions for a valuable source

Predictive statistics about wind speed, direction and frequency, are facilitated, among others, by the Finnish wind Atlas, which is been conceived as an estimation tool for the production of wind energy. It contains monthly and annual data about wind speed, direction and frequency, displayed on interactive maps, which can be downloaded in Excel format.

Accessing Finnish Wind Atlas:

The Finnish Wind Atlas can be accessed under http://www.tuuliatlas.fi/en/ , which will initially open as shown in FIGURE 16.

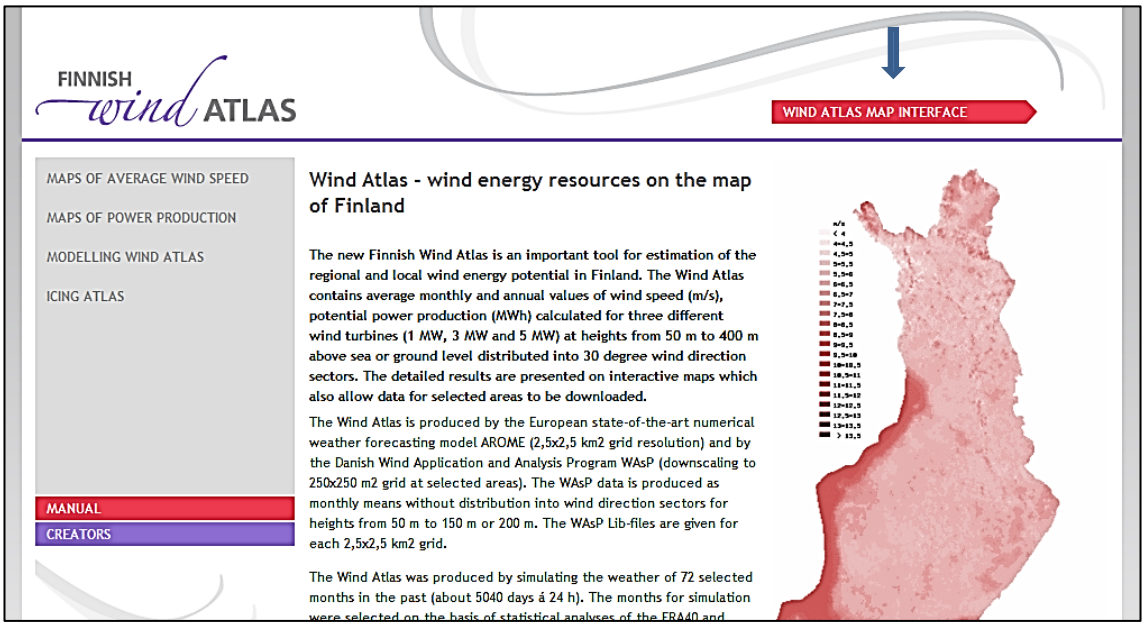


FIGURE 16. Finnish Wind Atlas page.

By clicking the option “Wind Atlas Map Interface” indicated with a red arrow on the right upper side, the interactive map option will be displayed as shown in FIGURE 17

FIGURE 17. Wind Atlas Map Interface

There is a menu located on the low right side (FIGURE 17.), and the first step will consist on choosing a between the 250m x 250m or 2.5km x 2.5km cells option.

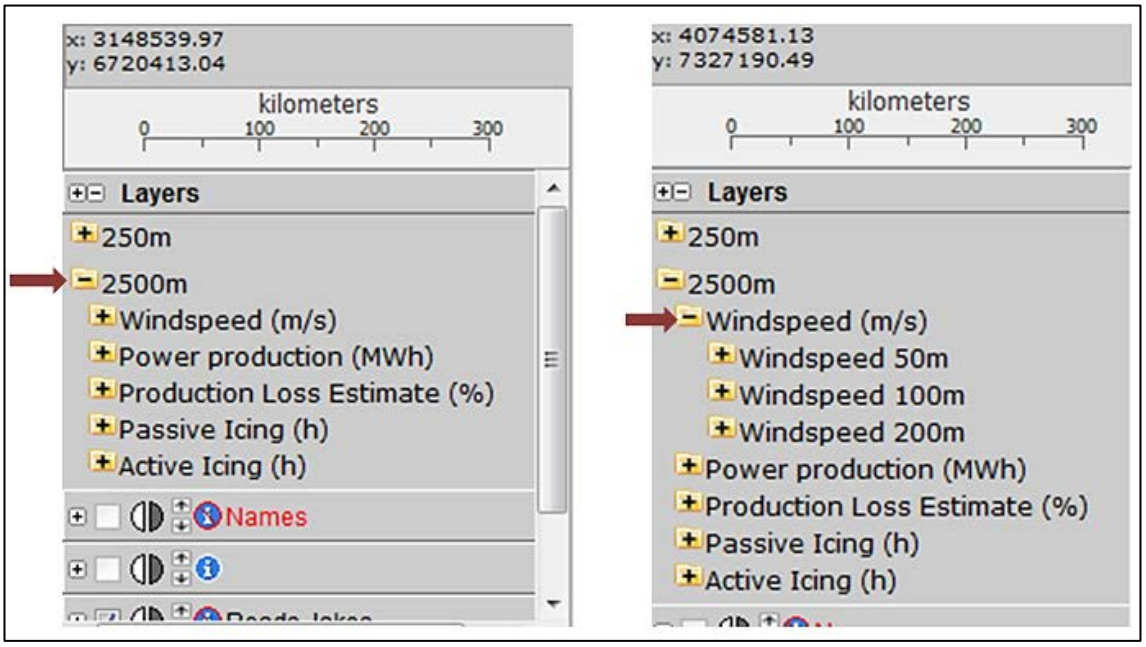


FIGURE 18. Options of menu located on the low right side

By clicking the chosen option, further options will be displayed as shown above in FIGURE 18, the next option to be utilized is “Wind speed (m/s)”, and it will display further three alternatives corresponding to 50m, 100m, and 200m of height.

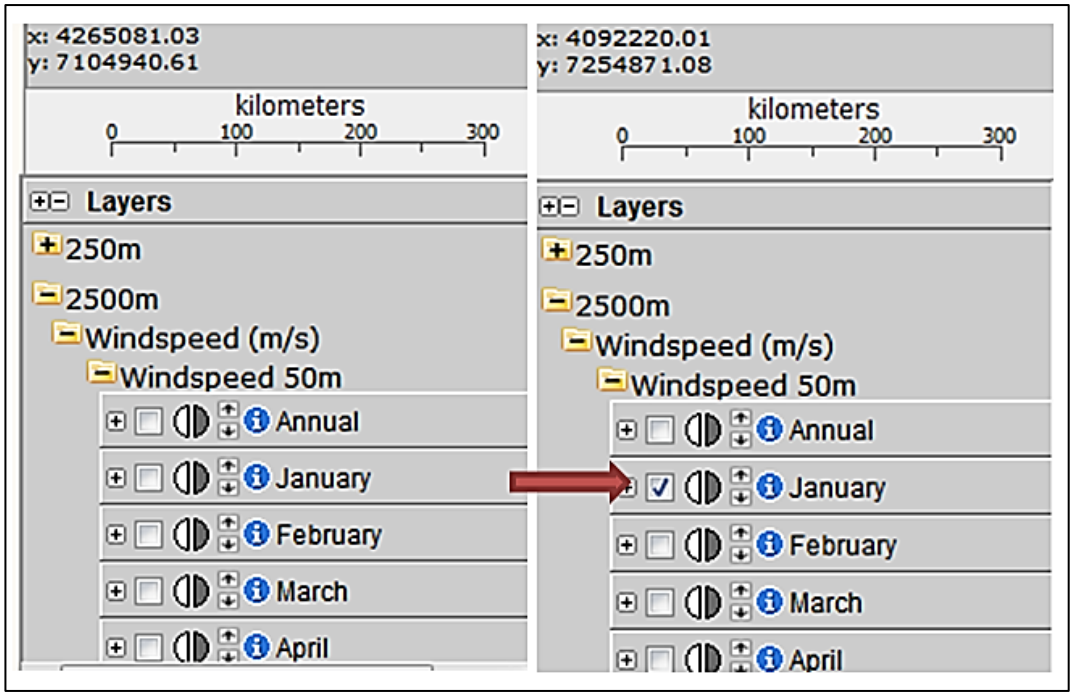


FIGURE 19. Options of menu located on the low right side

After having chosen the Windspeed at a certain height, options will be given to use annual or monthly data, see FIGURE 19.

Before continuing, it is recomendable to click “once” at the zoom option located on the uper left side of the screen as shown in FIGURE 20.

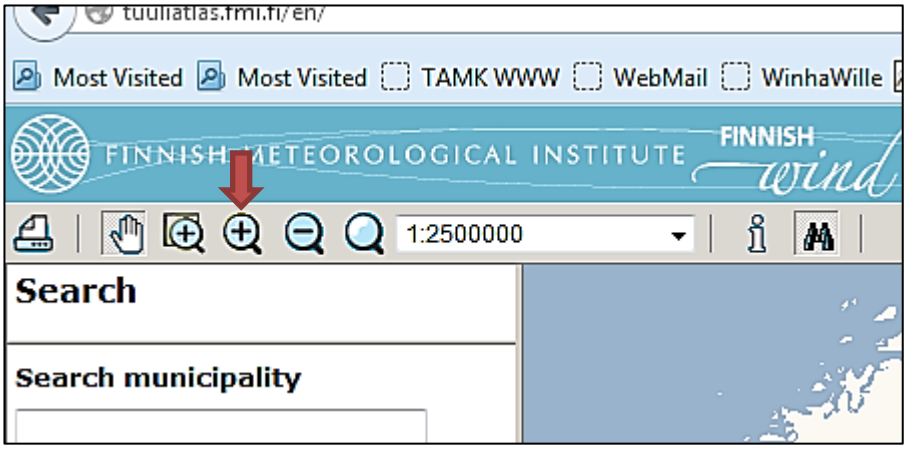


FIGURE 20: Recommended “click” on the zoom option

Clicking once on the zoom option , indicated with a red arrow on FIGURE 20 will make it possible to use further options on the menu, as shown in FIGURE 21.

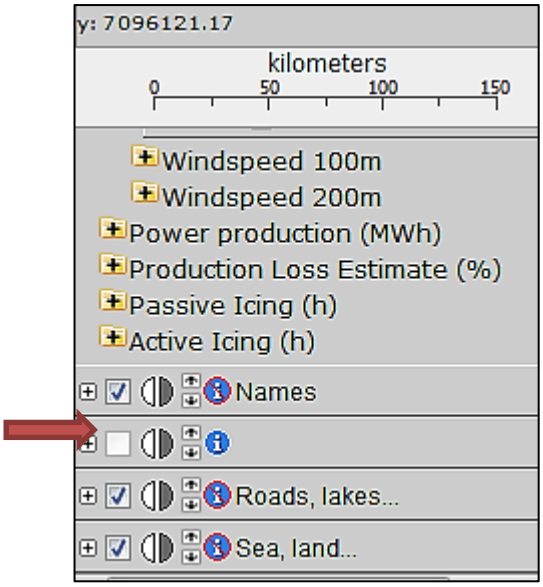


FIGURE 21: Further options on the menu

By clicking the options “Names”, “Roads- Lakes”, and “Sea-Land” , those elements will appear graphically displayed on the map, serving orientation purposes, as shown in FIGURE 22.

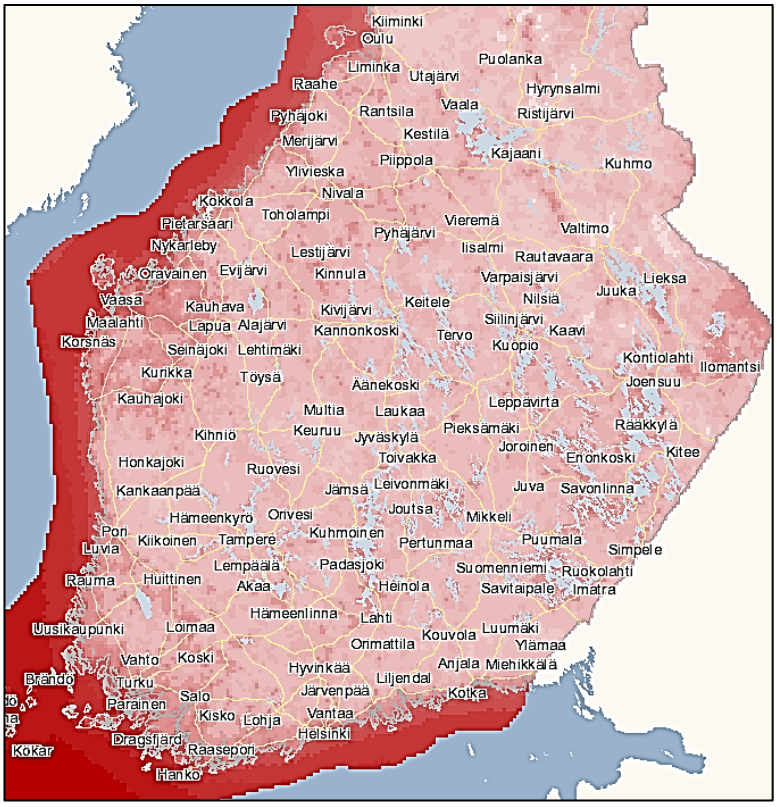


FIGURE 22. Graphically display of options on the map.

Going back to the upper left menu options of the screen shown in Figure 15, on the option “Search Municipality”, a certain area will be located and zoomed on the map.

By clicking the option on the upper part of the screen, and taking the cursor back to the map, any allocation inside the map can be chosen, the coordinates shown, and a results table opened (FIGURE 23.)

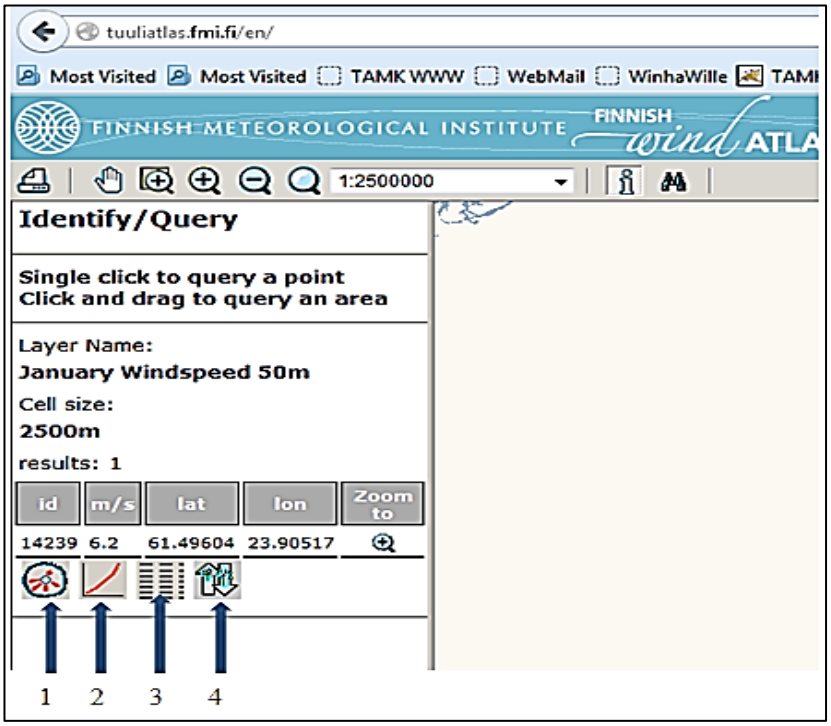


FIGURE 23. Results table

Different ways to visualize wind related data, corresponding to the chosen spot in the map, can be displayed by using the options indicated with blue arrows in FIGURE 18. Option 1 will show a wind rose like the one shown in FIGURE 2.

Option 2 will display a “Wind Speed Profile” in form of a graph, but the option which is going to be used as a data source in the present work, is Option 3.

By clicking the Option 3, an excel table will be displayed with wind data regarding the chosen area and period (FIGURE 23)

A1 | Data from selected area at period: January

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Data from	Grid size 2500 m																					
Wgs lat	Wgs lon	Altitude (i	Sector	Frequenc	Frequenc	V (m/s)	Weibull al	Weibull al	Weibull S	Weibull Si	Weibull N	Weibull N	Weibull U	Weibull U	T (Â°C)	Turbulenc	Turbulenc	Turbulenc	Turbulenc	Gust facto	Gust facto	Gust facto
61.49604	23.90517	50	1	5.34	2.52	5.9	6.6	2.5	4.6	2.6	8.3	4.4			-7.3	0.13				1.09	1.51	
61.49604	23.90517	50	2	2.22	1.51	3.9	4.4	2.3	3.6	2.8	5.9	3.1			-9.4					1.03	1.47	
61.49604	23.90517	50	3	2.92	2.42	3.9	4.4	1.8	3.6	2.2					-8	0.14				1.04	1.5	
61.49604	23.90517	50	4	3.43	2.82	4.3	4.8	2.5	4.3	2.7	7	4.3			-7.8	0.12				1.04	1.44	
61.49604	23.90517	50	5	4.23	2.32	5.2	5.9	2.1	4.5	2.3	7.9	3			-5.1	0.13				1.06	1.45	
61.49604	23.90517	50	6	8.97	4.44	6.1	6.9	2.7	5.1	2.6	8.4	4.6			-4.1	0.13	0.15			1.06	1.45	
61.49604	23.90517	50	7	8.77	4.23	6.5	7.2	3.4	5.2	4.2	8.6	7.9			-1.6	0.13				1.07	1.47	
61.49604	23.90517	50	8	13.41	6.86	6.8	7.6	2.7	5.5	2.9	9.5	5			-1.8	0.12	0.13			1.07	1.46	
61.49604	23.90517	50	9	19.66	8.37	6.8	7.6	3.4	5.7	4.2	8.7	4.7			-1.4	0.11	0.12			1.03	1.44	
61.49604	23.90517	50	10	12.4	6.45	6.5	7.3	2.9	5.5	3.2	8.9	4.6			-2.3	0.1	0.11			1.01	1.38	
61.49604	23.90517	50	11	9.88	5.54	6.1	6.9	2.2	5.2	2.5	9	3.3			-5.2	0.11	0.12			1.03	1.41	
61.49604	23.90517	50	12	8.77	5.34	6	6.8	2.2	5.1	2.6	9.3	3.6			-7.5	0.12	0.13			1.05	1.47	
61.49604	23.90517	50	Mean			6.2	7	2.6	5.1	2.8	8.8	4.3			-3.8	0.12	0.13	0.12		1.05	1.44	
61.49604	23.90517	50	Tot																			
61.49604	23.90517	75	1	5.85	3.13	6.2	7	2.4	5.3	2.2	9	4.7			-7.8	0.11				1.12	1.42	
61.49604	23.90517	75	2	1.92	1.11	4.6	5.2	2.6	4.5	3					-8.9	0.1				1.02	1.35	
61.49604	23.90517	75	3	2.62	2.02	4.5	5.1	1.8	4.3	1.9					-8.3	0.11				1.08	1.36	
61.49604	23.90517	75	4	3.53	3.02	4.8	5.5	2.5	5.5	2.3					-7.6	0.1				1.09	1.29	
61.49604	23.90517	75	5	3.73	2.22	5.9	6.7	2	5.5	2.5	9.3	2.8			-5.4	0.11	0.13			1.17	1.3	
61.49604	23.90517	75	6	8.47	6.05	6.9	7.7	2.9	6.7	3	9.8	4.2			-4.2	0.11	0.13			1.15	1.35	
61.49604	23.90517	75	7	9.27	6.65	7.2	8	3.3	7.3	3.3	9.7	4.9			-1.6	0.11	0.13			1.2	1.37	
61.49604	23.90517	75	8	13.61	8.97	7.5	8.4	2.8	7.2	3	10.5	4			-2.2	0.1	0.12			1.17	1.38	
61.49604	23.90517	75	9	19.56	10.89	7.5	8.4	3.4	7.3	3.6	9.5	4.1			-1.7	0.09	0.11			1.16	1.34	
61.49604	23.90517	75	10	12.5	7.46	7.1	8	3	7.3	3.1	9.3	3.7			-2.5	0.08	0.1			1.12	1.27	
61.49604	23.90517	75	11	10.18	5.75	6.6	7.5	2.3	6.5	2.6	9.6	3.1	3.1	2.5	-5.2	0.09	0.1			1.12	1.27	
61.49604	23.90517	75	12	8.77	5.24	6.7	7.5	2.3	6.2	2.7	10.2	3.6			-7.6	0.1	0.11			1.15	1.34	
61.49604	23.90517	75	Mean			6.8	7.7	2.6	6.7	2.8	9.6	3.7	3.7	2.8	-4	0.1	0.11	0.11		1.15	1.33	
61.49604	23.90517	75	Tot																			
61.49604	23.90517	100	1	6.05	3.63	6.9	7.7	2.7	6.3	2.7	9.6	4.3			-8	0.09	0.11			1.1	1.33	
61.49604	23.90517	100	2	1.82	1.11	5.1	5.7	2.7	5.5	2.6					-9.9	0.07				1.03	1.26	
61.49604	23.90517	100	3	2.62	2.32	5	5.7	1.9	5.6	1.8					-8.5	0.08				1.07		
61.49604	23.90517	100	4	3.63	3.33	5.1	5.7	2.1	5.7	2					-7.8	0.07				1.04		
61.49604	23.90517	100	5	4.03	3.63	6.4	7.2	2	6.9	2.1					-5.7	0.09	0.11			1.11		

FIGURE 23. Excel table with wind Data

The relevant data in this table are: “sector”, “Frequency all data”, and “V m/s” ; located in columns D, E, and G , respectively.

On column “D”, the direction of the wind will be displayed in twelve sectors, with an equivalence of 30° per sector .Column “E” contains the frequency of the wind expressed in percentages; thus for an interpretation regarding the number of hours, attention should be paid to the options displayed in the menu (FIGURE 20), as considering the annual or the monthly options will obviously have different connotations.

4.2 Exporting data from Finnish Wind Atlas to the Raw Data Table

The data regarding “Sector”, “Frequency all data”, and “V m/s” ; located in columns D, E, and G (see FIGURE 23 and 24) should be exported to the Raw Data Table of Sound Plan 7.2 (see FIGURE 10).

D	E	F	G
Sector	Frequency all data (%)	Frequency Stab	V (m/s)
1	12.92	6.35	5
2	8.44	3.65	5.2
3	5.63	3.13	4.5
4	6.88	2.81	4.8
5	7.08	4.06	5.2
6	7.29	3.33	6.2
7	6.56	3.96	5.2
8	10.73	6.04	5.8
9	13.23	7.5	5.1
10	6.04	2.92	5.2
11	4.69	2.08	4.1
12	10.52	5	4.2
Mean	100.01		5.1

FIGURE 24. Sector, Frequency and Wind Velocity columns from Tuuli Atlas

In case of column D, wind speed, it can be done straight through the clipboard, for the entire column, but what “Frequency all data” and “sector” are concerned, some changes have to be done beforehand.

4.2.1 The “Frequency all data” column

Frequencies in Finnish Wind Atlas are expressed in the form of a percentage (see FIGURE 24) , but the “Span” column at the “Raw Data table” (see FIGURE 12), has to be filled in with the frequency expressed in number of hours.

One possibility would consist on inserting, in the same excel table, a new column in which the percentages are turned into the number of hours, and subsequently export it via clipboard to Sound Plan.

This data should better be managed on a monthly basis for reasons which will be explained further on.

4.2.2 The “Sector” Column

The wind direction in the Finnish Wind Atlas Excel table (FIGURE 23) is expressed in wind-rose sectors 1 to 12. It should be taken into to account that the “Raw Data table” (see FIGURE 10) requires the wind direction expressed in degrees, and if a wind rose (see FIGURE 2) is divided into 12 sectors, each sector is equivalent to 30°; thus in the raw data values 30° to 360° should be input.

5 ATMOSPHERIC STABILITY RELATED DATA

The Raw data table requires data regarding atmospheric stability for modelling; these data can be input on the columns depicted in FIGURE 12.

Klug/ Manier Class	Monin/ Obukhov length [m]	Grad. pot. temp. [K]	Pasquill Gifford Turner Class	Temperature lower station (at -999,00 m) [C]	Temperature upper station (at -999,00 m) [C]	Temperature Difference [C]	Radiation Balance [W/m²]	Global Radiation [W/m²]	Cloud coverage [0..1]	F

FIGURE 25. Atmospheric stability related data in the Raw Data Table.

Not all the depicted options have to be filled in, as most of them just serve the purpose of calculating the actual atmospheric stability class, which can be input directly, if such data would be available, in the Pasquil Gilford Turner column, according to the traditional scale, see TABLE 1. or in the "Klug/Manier Class" column, if data are available in such terms.

Klug/Manier Class is the German Scale System to designate meteorological stability classes according to the 1986 TA Luft Standards, it is used in Germany instead of the Pasquil Gilford Turner scale, see TABLE 5. (Foken & Nappo, 2008.pp 234-235).

	Klug/Manier	**Pasquill**
Very unstable	V	A
Unstable	IV	B
Neutral to light unstable	III/2	C
Neutral to light stable	III/I	D (neutral)
Stable	II	E (light stable)
Very Stable	I	F (Stable)

TABLE 5. Comparative table of the Klug/Manier and Pasquill atmospheric stability classes. (Foken & Nappo, 2008.)

According to the Finnish Metrological institute, stability classes are not included in commonly available meteorological time-location based statistics in Finland, for such reason, regarding the aim of the present work, the atmospheric stability required data will have to be calculated ,by using the calculation options offered by the Software , or be deduced by approximation of values given by literature.

In Sound Plan 7.2, Klug/Manier class can be deduced based on the Monin/Obukhof length, and also calculated based on wind speed, roughness length and cloud coverage. (Sound Plan, 2011.p.146), see FIGURE 12; but it is been found out in the present work, that this is not always possible.

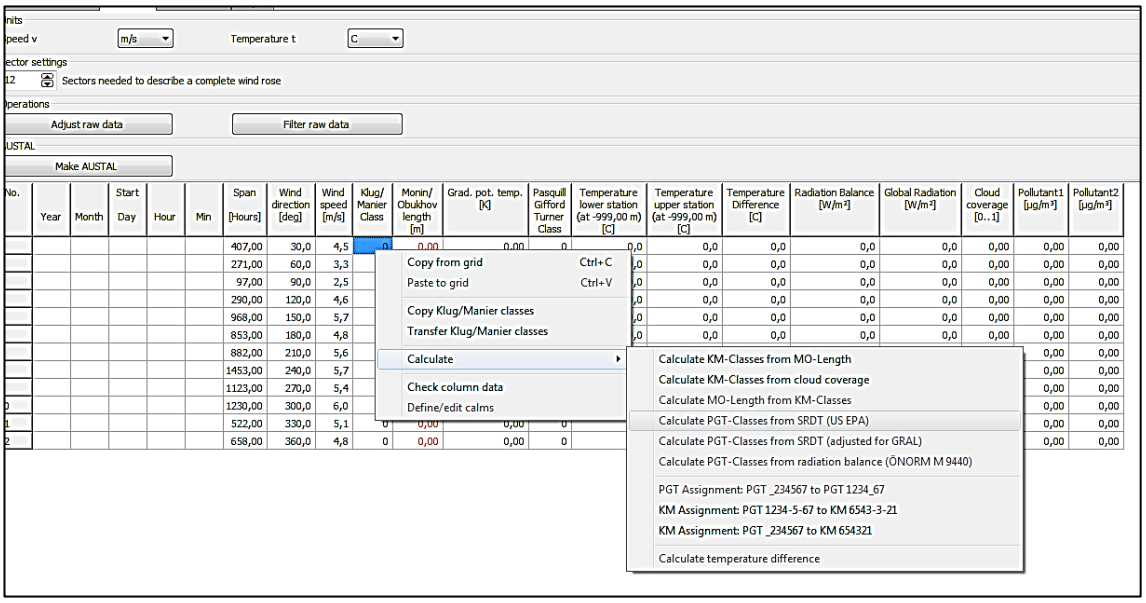


FIGURE 26. Atmospheric Stability calculation options on the raw data table.

In FIGURE 26 it is shown how by clicking on the Klug/Manier column, the option “calculate” will be displayed; and by clicking on “calculate” the options “Calculate KM from MO-Length” and “Calculate KM from cloud coverage” will be displayed.

5.1 Cloud coverage cannot be used with classified view

To “Calculate KM from cloud coverage”, such data have to be introduced in to the “cloud coverage” column and proceed as explained above and shown in FIGURE 12 .

Averaged cloud coverage data have been found available at the interface of the Atmospheric Science Data Centre of NASA[1], but by inserting such data in the Raw Data Table, and clicking on the option : “calculate from cloud coverage”; it comes out that calculating the Klug Manier Stability Classes is only possible by filling the Date Columns (FIGURE 11), thus using the “Classified view”, having replaced the Date Columns by frequencies, Klug Manier Stability Classes cannot be calculated based on Cloud Coverage (FIGURE 22).

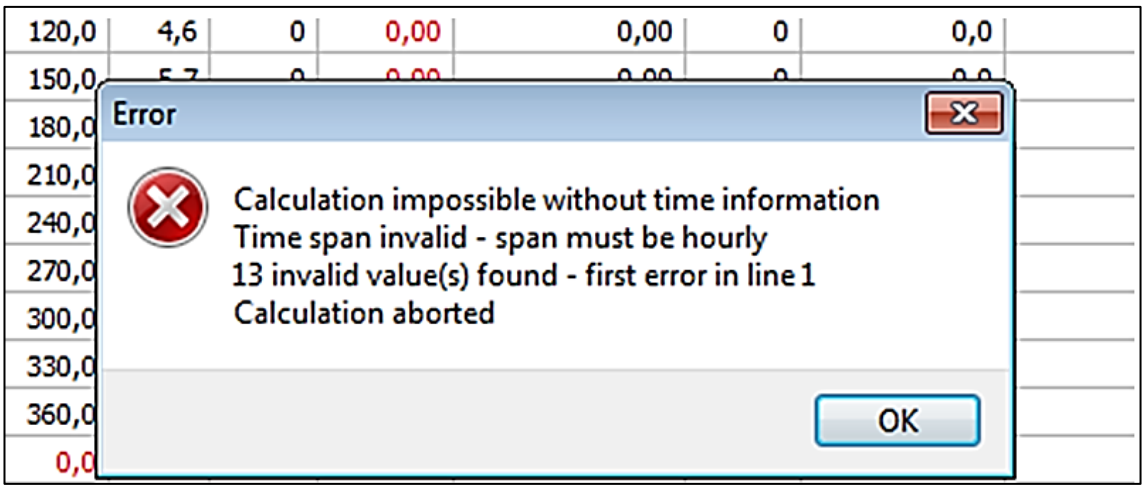


FIGURE 27. Atmospheric Stability cannot be calculated based on Cloud Coverage if classified view activated.

[1]https://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?email=skip%40larc.nasa.gov&step=1&lat=62&lon=25&submit=Submit

5.2 The Monin/Obukhov length and the roughness length

The Monin/Obukhov length (L) expresses the relationship between the mechanical force of the wind and the thermal force of buoyancy as possible dominant parameters in the production of turbulences. Over L, the kinetic energy of the wind will be dominant over the buoyancy, and the other way round will happen under it. (American-Meteorology-Society, 2012)

According to the Finnish Meteorological Institute, there are no available general data about Monin/Obukhov lengths in Finland, as they would require tower measurements.

But if such data would be available, Sound PLAN 7.2 would require the roughness length, see FIGURE 28.

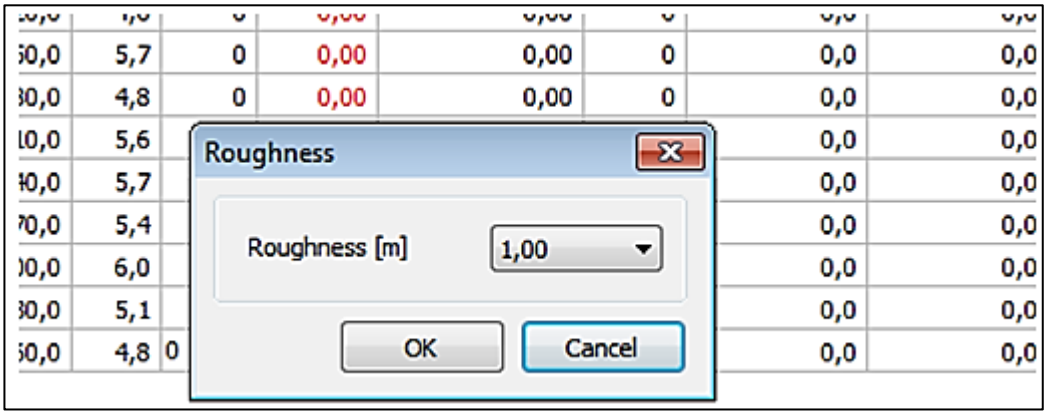


FIGURE 28. Sound PLAN 7.2 asking for the roughness length in order to calculate Klug/Manier Classes from Monin/Obukhof Length.

The calculation of the exact roughness length $z_0(m)$ would imply a very high degree of complexity, but there are approximate values commonly utilized for modelling purposes as shown in TABLE 6. (WMO, 2008-No. 8 p. I.5-12) which could be applied accordingly to the characteristics of local topography.

TABLE 6. Approximate roughness length $z_0(m)$ values commonly utilized (WMO, 2008-No. 8 p. I.5-12)

Terrain description	z_0 (m)
Open sea, Fetch at least 5 km	0.0002
Mud flats, snow; no vegetation, no obstacles	0.005
Open flat terrain; grass, few isolated obstacles	0.03
Low crops; occasional large obstacles, x/H > 20	0.10
High crops; scattered obstacles, 15 < x/H < 20	0.25
parkland, bushes; numerous obstacles, x/H ≈ 10	0.5
Regular large obstacle coverage (suburb, forest)	1.0
City centre with high- and low-rise buildings	≥ 2

So, if Monin/Obukhof length data are available, by inserting the convenient roughness length value, according to the nature of local topography, Sound Plan 7.2 will calculate the atmospheric stability classes on Klug/Manier Scale.

5.3 The solution: Atmospheric stability can be introduced as a constant value.

According to data obtained in measurement campaigns taking place in 17 locations in Finland, involving 265 months of mast data and 116 months of SODAR data between June 2009 and July 2013, it is been concluded, that E and D atmospheric stability classes are the most common ones in Finland, showing following frequencies: E = 67% and D=33% Pasquill/Gifford. (Sointu, I. 2014, p.p. 17 and 47).

As atmospheric stability remains almost constant in Finland all over the year and in a quite representative part of the territory, such value can be introduced as a constant in the raw data table of the meteorological station project library.

If considering the Pasquill/Gifford/Turner scale, light stable stability class (E) is taking place with a frequency of 67%, and neutral stability class (D) is taking place with a frequency of 33%; it can be concluded that with a frequency ≈100%, stability class III/I(neutral to light stable) Klug Manier is taking place in Finland; if considering the equivalences between scales (TABLE 5), thus such value may be introduced as a constant one in the raw data table.

The Sound Plan 7.2 input value for the III/I Klug Manier class is "3" (see TABLE 7), and this is the value to use , remaining constant, in the raw data table of the meteorological station , for air pollution modelling in Finland.

TABLE 7. Sound Plan input values for Klug/Manier stability classes. (SoundPlan.2011)

	Klug/Manier	**Sound Plan input value**
Very unstable	V	6
Unstable	IV	5
Neutral to light unstable	III/2	4
Neutral to light stable	III/I	3
Stable	II	2
Very Stable	I	1

6 A PRACTICAL EXAMPLE

6.1 Location

For a practical example the Naistenlahti Power Plant in Tampere (61.5098°N 23.7768°E) , which uses natural gas, peat, wood and fuel oil as fuels , will be considered.

The purpose of modelling the Naistenlahti area could be to know about the dispersion of pollutants and its concentrations in the nearby residential areas. (See FIGURE 29.)

FIGURE 29. Power plant of Naistenlahti in Tampere. (Free picture courtesy of Creative Commons)

In FIGURE 29. It can be observed that the power plant is closed to residential areas that could be affected by the pollutants transported by the plume of the chimney pointed at with the red arrow in the picture.

The modeling will take place in a two dimensional plane, using a bitmap as a reference as shown in FIGURE 30., where the location of the pollution source, pointed at with a red arrow, can be clearly observed.

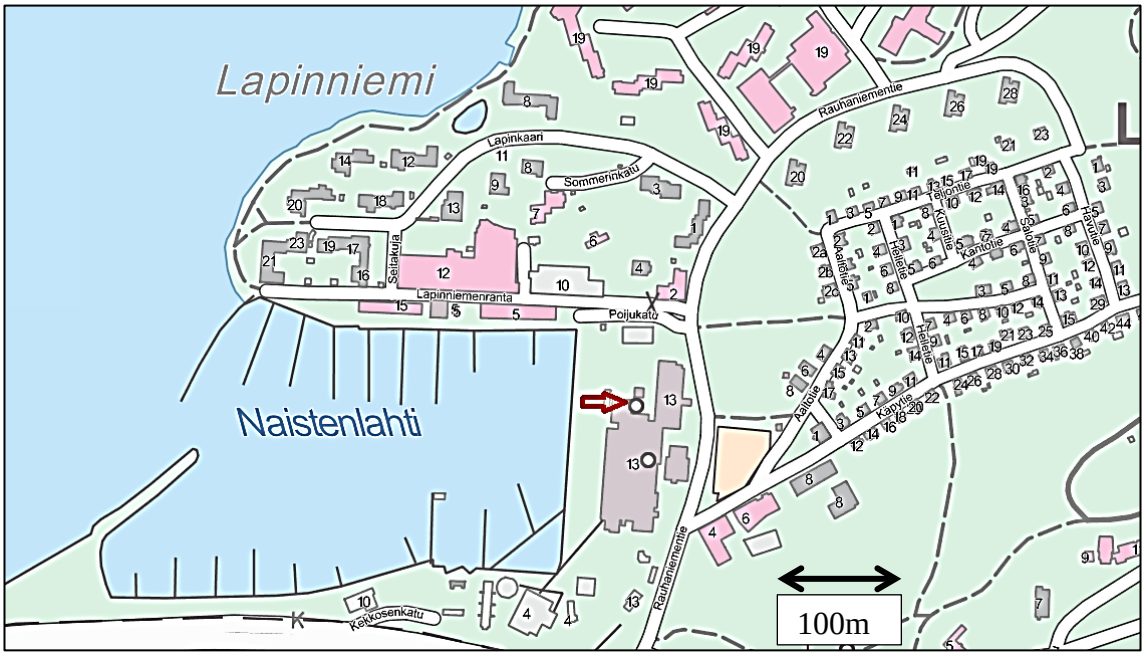


FIGURE 30. Location of the Naistenlahti power plant in two dimensional bitmap (map courtesy of www.paikkatietoikkuna.fi)

6.2 The required data

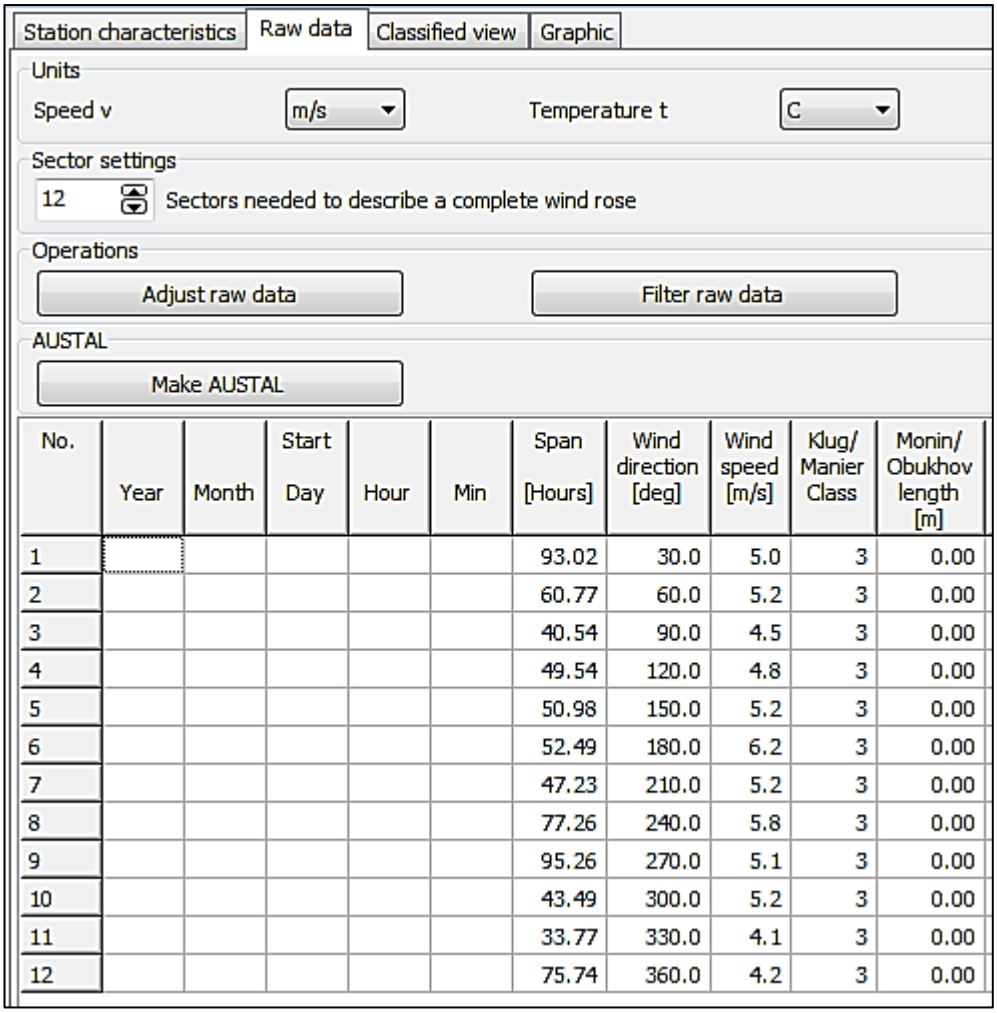
6.2.1 Meteorological data

Using the procedure mentioned in chapter 3 for the utilization of the Finnish Wind Atlas, data regarding wind direction, frequency and velocity, corresponding to the month of April 2015 have been obtained for the area to be modelled (TABLE 8.)

TABLE 8. Finnish Wind Atlas data for the month of April at Naistenlahti surroundings

Altitude (m)	Degrees	Sector	Number of hours	Frequency all data (%)	V (m/s)
100	30	1	93.024	12.92	5
100	60	2	60.768	8.44	5.2
100	90	3	40.536	5.63	4.5
100	120	4	49.536	6.88	4.8
100	150	5	50.976	7.08	5.2
100	180	6	52.488	7.29	6.2
100	210	7	47.232	6.56	5.2
100	240	8	77.256	10.73	5.8
100	270	9	95.256	13.23	5.1
100	300	10	43.488	6.04	5.2
100	330	11	33.768	4.69	4.1
100	360	12	75.744	10.52	4.2
50		Mean		100.01	5.1

In TABLE 8., in order to make export of data easier, the “Sector” column has been turned into degrees and the frequencies into number of hours. Such way they have been exported to the raw data table at the Meteorological Station Project Library , as shown in FIGURE 31.



No.	Year	Month	Start Day	Hour	Min	Span [Hours]	Wind direction [deg]	Wind speed [m/s]	Klug/ Manier Class	Monin/ Obukhov length [m]
1						93.02	30.0	5.0	3	0.00
2						60.77	60.0	5.2	3	0.00
3						40.54	90.0	4.5	3	0.00
4						49.54	120.0	4.8	3	0.00
5						50.98	150.0	5.2	3	0.00
6						52.49	180.0	6.2	3	0.00
7						47.23	210.0	5.2	3	0.00
8						77.26	240.0	5.8	3	0.00
9						95.26	270.0	5.1	3	0.00
10						43.49	300.0	5.2	3	0.00
11						33.77	330.0	4.1	3	0.00
12						75.74	360.0	4.2	3	0.00

FIGURE 31. Data of the raw data table imported from Finnish Wind Atlas

In FIFURE 31 it can also be observed, that the Klug Manier Class column has been filled with constant input value 3, corresponding to the “neutral to light stable” atmospheric stability class according to the LuftTA86 standards, as explained in chapter 4.3.

Such values will produce a wind rose as shown in FIGURE 32.

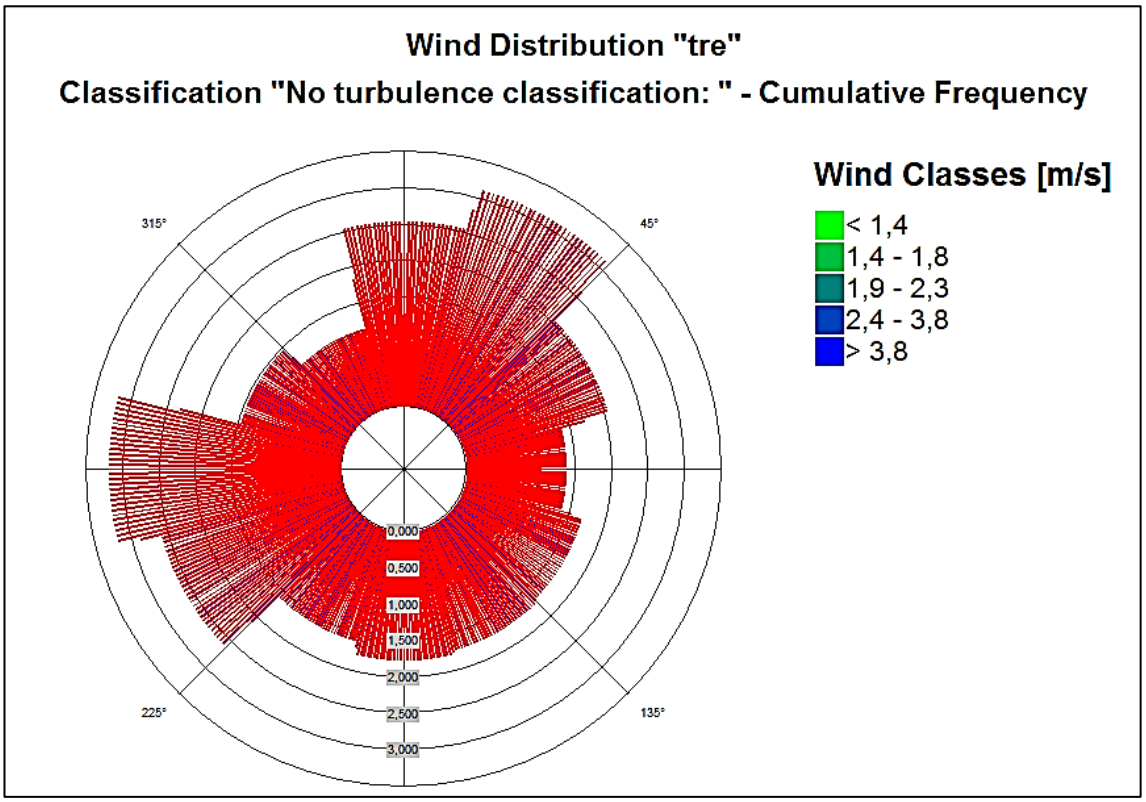


FIGURE 32. Wind rose for the values introduced in the row data table

6.2.2 Hypothetical emissions data

It is been estimated that the mass of exhausted pollutants of the Naistenlahti chimney is 50 tons per year, thus the value introduced as 173 kg per source and day , with a volume of emissions of 7000 m^3 per day, as shown in FIGURE 33. It is also be considered that the chimney will be 100 m high, and the concentration of the dispersed pollutants to be measured at 2 m from the ground level.

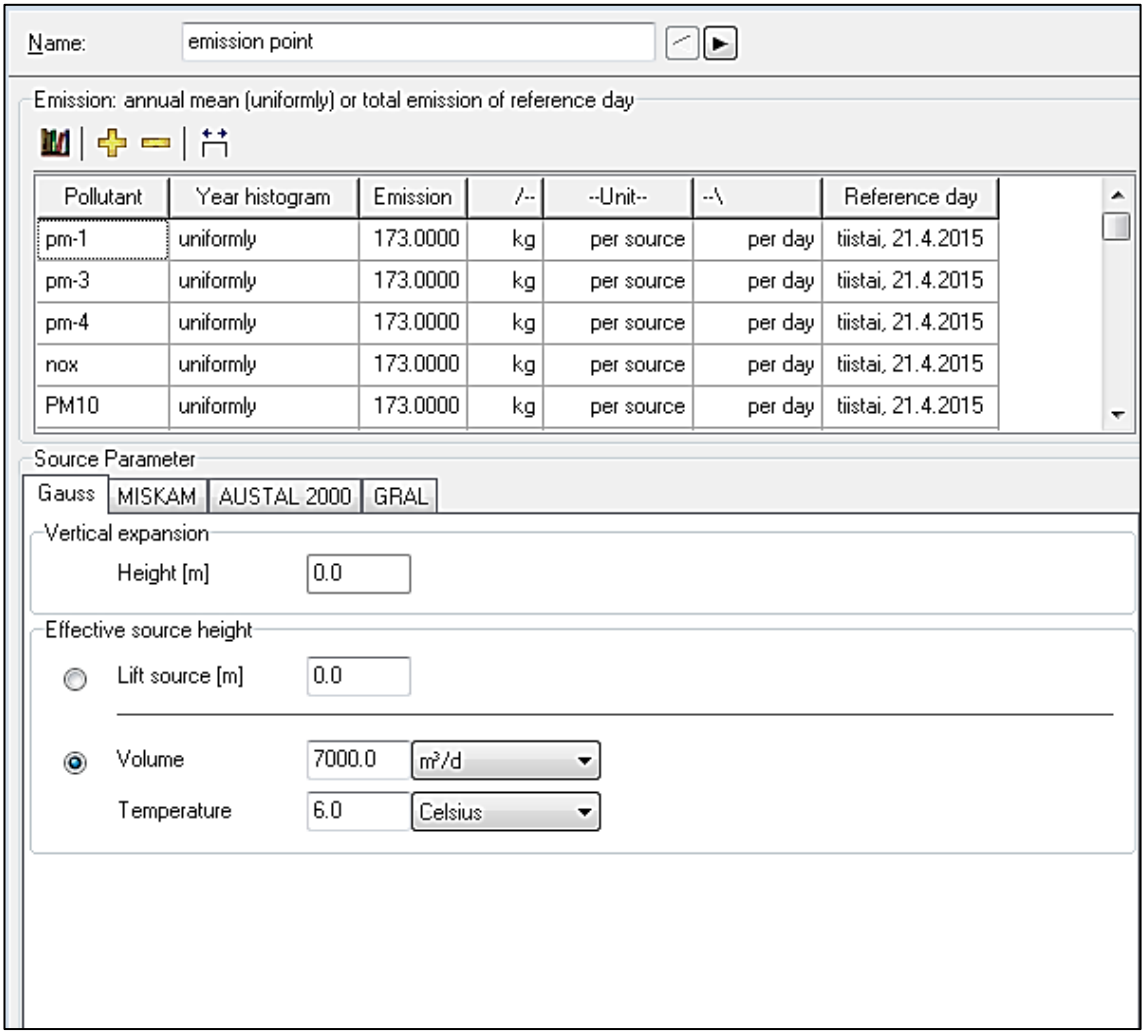


FIGURE 33. Emission data input in Sound Plan 2.7

6.3 The resulting model

The resulting model created, based on the meteorological and emission data input in the system, are as shown in FIGURES 34-36.

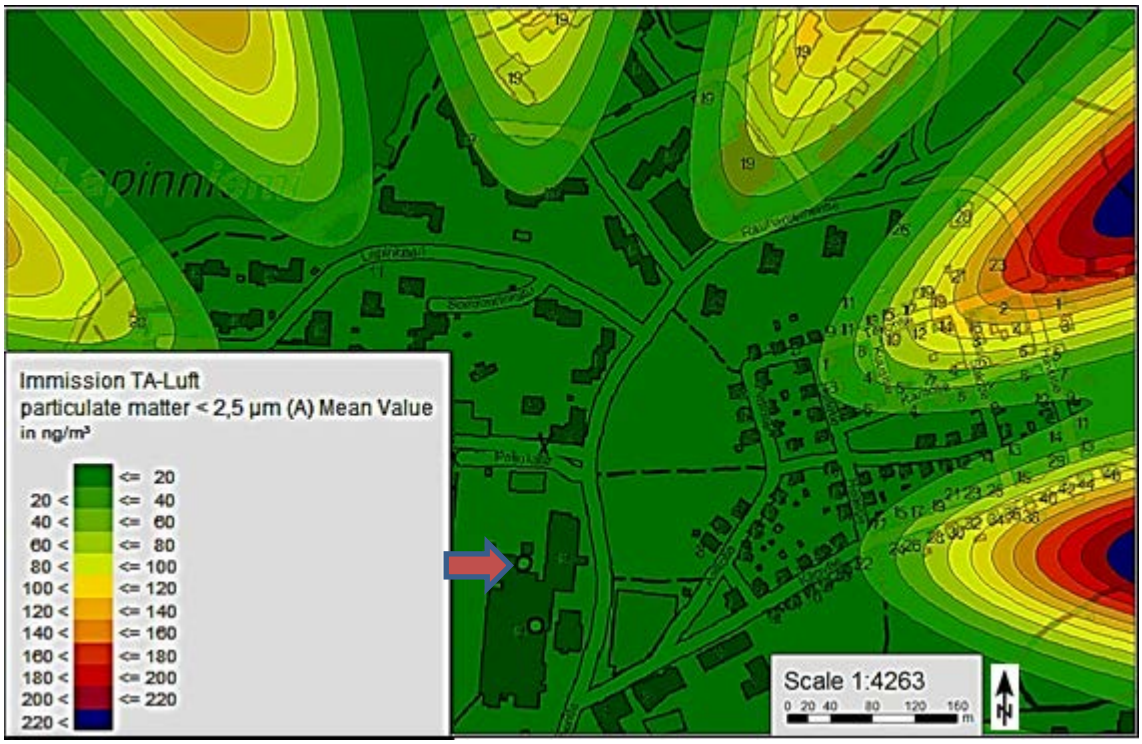


FIGURE 34. Resulting Sound Plan 7.2 model for Naistenlahti power plant emissions´ dispersion.

The display of different colours will correspond to the system´s calculation of concentration of pollutants in the depicted area. The image at FIGURE 34. suggests that, considering calculations in the area depicted, concentration of < 2, 5µm particulate matter will reach its highest level, of ≈200 ng/m^3, at the areas depicted in blue, located at approximately 400 m east from the source, indicated with a red arrow.

But to understand the true scope of the dispersion, a brighter area should be taken into consideration as shown in FIGURE 35, from which further conclusions can be drawn.

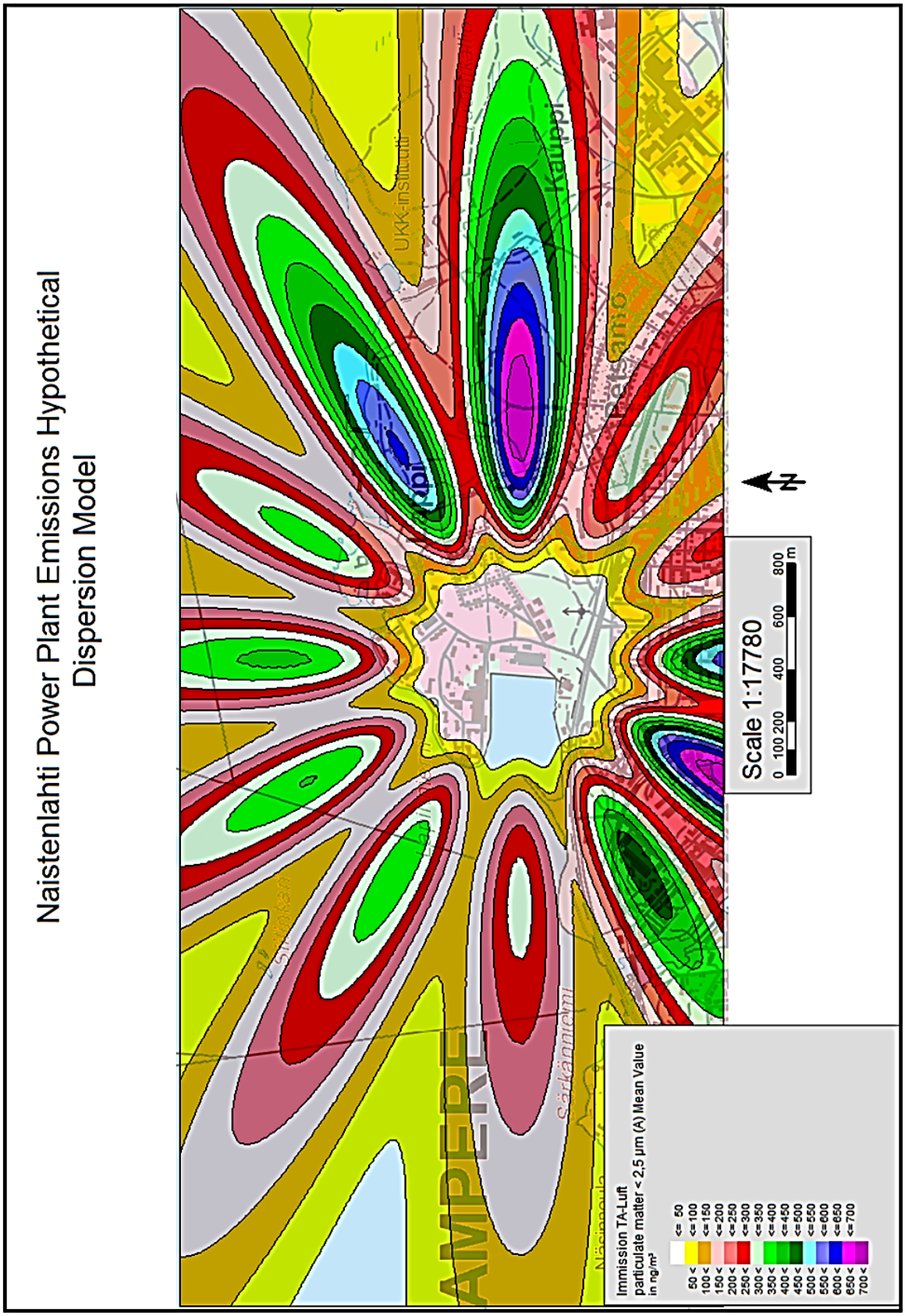


FIGURE 35. (Rotated) Emissions´ dispersion model with extended calculation area for Naistenlahti, estimations for the month of April.

In FIGURE 35 , for the purposes of visibility, the colours have been changed from the standard ones in FIGURE 34, for better appreciation of the base map and location of concentration of pollutants.

Based on the results depicted in FIGURE 35. we observe the highest concentrations of pollutants are ≈200 ng/m^3 at an approximate distance of 800 m East and Southwest from the south.

The plume dispersion for the twelve sectors of a wind rose are easy to identify in FIGUREs 30-31, as the ovoid coloured areas disposed in a circle surrounding the emission point.

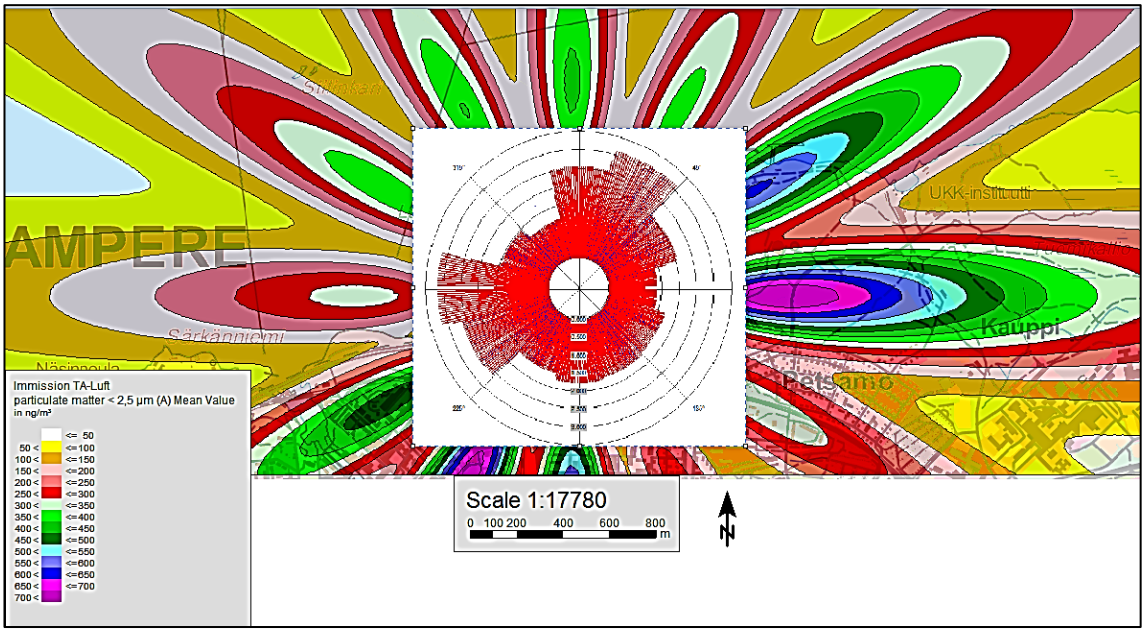


FIGURE 36. Naistenlahti emissions´ dispersion model with inserted wind rose.

Observing the wind rose inserted in FIGURE 31 it is easy to notice that different wind speeds and directions are correlated with different results.

In this particular case and for these meteorological conditions, the highest concentrations mentioned above are associated to the wind coming from sector 9 (270°), and given the frequency of such wind (see FIGURE 29.), we know that the depicted area was expected to be exposed to ≈200 ng/m3 concentration of pollutants for 95,26 hours during the month of April.

7 CONCLUSIONS

So we may conclude that the information obtained may contribute to a better use of SoundPlan 7.2 at TAMK for educational purposes, allowing the usage of relevant Finnish meteorological data as one more step for further developments , accomplishing the main objective of the present work.

In order to operate the Gauss model calculation option offered by SoundPlan 7.2, the software requires: data concerning time parameters, wind velocity, wind direction and atmospheric stability. This will allow the creation of a meteorological situation on which modelling and calculations will be based (see section 1.4.1)

The required data, with the exception of the atmospheric stability, can be obtained from The Finnish Wind Atlas in Excel format, and can be exported to the raw data table of meteorological station project library with some minor changes (see chapter 3)

The atmospheric stability is an extremely important piece of information which cannot be neglected if the aim is to get any kind of realistic results. SoundPlan 7.2 offers different options to calculate such data, which are neither needed nor applicable to the case as explained in Section 5; and based on information provided by literature, it can be said, that such value does not vary drastically in Finland, which, together with the fact that atmospheric stability is an approximation tolerant parameter, allows us to insert such value as a constant in the system, which using the German Klug/Manier class scale would correspond to III/I -Neutral to light stable and should be input as “3” in the Raw Data Table

The use of the classified view option of SoundPlan 7.2, associating wind sectors to frequencies, offers the advantage of final modelling results, where the time of exposure of delimited areas to the considered pollutants can be easily deduced, and facilitating valuable information to be considered in eco-toxicological studies.

8 REFERENCES

American-Meteorology-Society. (2012). Obukhov length. Meteorology Glossary. Retrieved March 25, 2015, from http://glossary.ametsoc.org/wiki/Obukhov_length

APTI. (n.d.). Monin-Obukhov Length. (A. P. Professionals, Ed.) Retrieved March 23, 2015, from https://www.shodor.org/os411/courses/411c/module06/unit01/page08.html

Bhattacharya, P. J. (2010, August 4). Lecture Series on Fundamentals of Environmental Pollution and Control by Prof. Jayanta Bhattacharya, Department of Mining Engineering, IIT Kharagpur. Retrieved February 2, 2015, from http://nptel.iitm.ac.in: https://www.youtube.com/watch?v=QoruG4ma210

Cooper C.D., Alley F.C. (2011). Air Pollution Control, 4th ed. Long Grove, IL: Waveland Press.

D.B, Turner; R.H, Schultze. (2007). Practical Guide to Atmospheric Dispersion Modelling. Dallas: Consultants, Inc. TX and Air and Waste Management Association, Pittsburgh.

David H.F.Liu; Béla G. Lipták. (2000). Air Pollution. Washington, D.C: Lewis publishers.

Encyclopaedia, S. (1970). The Great Soviet Encyclopaedia, 3rd Edition (1970-1979).

Foken, T., & Nappo, C. (2008). Micrometeorology. Bayreuth: Springer Science & Business Media.

Finnish Wind Atlas. Retrieved February 2, 2015, from http://www.tuuliatlas.fi/en/

Guyot, G. (1996). Physics of the Environment and Climate. Paris: Praxis Publishing (Chichester)/Dunod éditeur (Paris).

Langner, C. a. (2011). A comparison of Model performance between AERMOD and AUSTAL 2000. Kos: Air and Waste management Association DOI:13.3155/1047-

3289.61.640 14th Conference on Harmonization within Atmospheric Dispersion Modelling for Regulatory Purposes.

Maybeck, H. F. (1996, July 12). Subsidence Inversions. Recognition and Application in Lighter-than-air Flight. (P. S. College, Ed.) Plymouth, New Hampshire, UK. Retrieved 2 10, 2015, from http://www.maybeck.com/inversions/

P. Kudesia, V., and Kudesia, Ritu. (2008). Air Pollution. 61. IND: Pragati Prakashan: ProQuest ebrary. Retrieved February 5, 2015

Ritter, M. E. (2012, 5 6). The Physical Environment: an Introduction to Physical Geography. Retrieved 2 12, 2015, from http://www.earthonlinemedia.com/ebooks/tpe_3e/title_page.html

Roble, R. G. (2004). Atmospheric Structure/Encyclopaedia of Applied Physics; Volume 1/2 (Vol. 1/2). (G. L.Trigg, Ed.) WILEY-VCH Verlag GmbH&Co.KGaA.

Sointu, I. (2014). Wind profile assessment for wind power purposes; Analysis and comparison of mast and SODAR mesurements from 17 sites in Finland. Helsinki: University of Helsinki/Department of Physics.

Sound Plan. (2011). Manual SoundPLAN Air Quality (pre-excerpt 09/2011). Barunstein+Berndt GmbH.

Vallero, D. (2008). Fundamentals of Air Pollution (4th ed.). Burlington, San Diego, California, USA: ELSEVIER.

Visscher, A. D. (2013). Air Dispersion Modelling: Foundations and Applications. NJ, USA: John Wiley & Sons, 2013. ProQuest ebrary. Web. 16 February 2015.