UNIVERSITÄT BAYREUTH

Abt. Mikrometeorologie

Characterisation of a complex measuring site for flux measurements

CARBOEUROFLUX Workpackage No. 7

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Arbeitsergebnisse

Nr. 20

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1 Introduction

Since October 2000, work has been carried out on CARBOEUROFLUX Work Package No. 7 'Quality check and databasing' at the Department of Micrometeorology, University of Bayreuth. The document presented provides an overview of this project, describing in detail the design of the concept, the activities undertaken, and, in general, the results obtained. Before dealing with these three objectives, a short introduction provides basic information about the project's objectives and products, schedule and participants.

1.1 Objectives and products of the project

The main objective of this study is to develop a tool for the evaluation of complex flux measurement sites which combines existing quality assessment tools for flux measurements with footprint modelling. In this way it is possible to define the spatial context of the fluxes measured, and to include both topographical and land use features of the surrounding terrain and micrometeorological flux data in the analysis. This approach allows us to determine the flux data quality for different wind sectors and meteorological conditions, and thus to identify the most suitable situations for the collection of high-quality data sets.

For each of the participating stations, the overall performance of the flux measurements will be characterised in a final report. The main part of the analysis will be illustrated by 3-dimensional graphs as shown later on in part 5 of the text, indicating the computed flux property for discrete grid cells in the area surrounding the tower. These graphs are produced for

- the flux contribution to the total flux.
- the quality assessment of the fluxes of momentum, sensible heat, latent heat and CO_2.
- the vertical wind speed, with respect to the topography of the area.
- the percentage of the land use type of interest (see below).

In addition to this central part of the quality assessment program, the following features are investigated:

- local wind statistics in comparison with data from a nearby reference station.
- frequency distribution of land use classes.
- frequency distribution of the quality flags (see below) of the fluxes investigated.

On the CD provided to each participating team, there will also be the actual version of the software used for the source weight synthesis of the quality assessment data set. This software, in combination with the individual input data for the specific flux measurement site, can be used to produce individual quality assessments by defining limits for a set of important input parameters. This process will be described in more detail below.

1.2 Schedule of the project

October 2000	The basic concept of the quality assessment program was distributed in a first announcement to all research teams participating in the EUROFLUX-cluster. All groups interested in the analysis were asked to return a short questionnaire providing basic information about the sites.
February 2001	A detailed data request was distributed to all research teams who responded to our first announcement. The document described the kind of information as well as the format required for the analysis.
September 2001	The first data sets were provided from the cooperating EUROFLUX groups.
December 2001	The deadline for the delivery of the necessary information was postponed until the annual meeting of the EUROFLUX community in Budapest.
January 2002	With the first complete data sets available, test runs were initiated to implement the existing quality check features into a routine application which is capable of treating this amount of information.
March 2002	2^{nd} CARBOEURO-Meeting in Budapest. The first results of the approach were presented in a poster. In addition, more details of the quality assessment tools were discussed in a session on quality check and databasing. The final number of participants is reached.
October 2002	Processing of the data was completed.
November 2002	Presentation and discussion of the results in the context of a workshop in Thurnau near Bayreuth on the quality control of eddy-covariance measurements.
2003	Publication of the results. Modification and improvement of the existing tools using data sets from selected sites.

1.3 Participating research teams

Station Name	Country	Code	Responsible Investigator	Co-worker
Vielsalm	Belgium	BE1	Marc Aubinet	Bernard Heinesch
Brasschaat	Belgium	BE2	Arnaud Carrara	Arnaud Carrara
Bílý Kříž	Czech Republic	CZ1	Michal V. Marek	Katka Havránková
Hyytiälä	Finland	FI1	Timo Vesala	Yllar Rannik Tiina Markkanen
Sodankylä	Finland	FI2	Tuomas Laurila	Mika Aurela
Kaamanen	Finland	FI3	Tuomas Laurila	Mika Aurela
Hesse	France	FR1	André Granier	
Le Bray	France	FR2	Paul Berbigier	
Puechabon	France	FR4	Serge Rambal	Jean-Marc Ourcival
Hainich	Germany	GE1	Nina Buchmann	Alexander Knohl
Tharandt	Germany	GE2	Christian Bernhofer	Thomas Grünwald
Waldstein	Germany	GE3	Thomas Foken	Corinna Rebmann
Yatir Forest	Israel	IS1	Dan Yakir	Eyal Rotenberg
Renon	Italy	IT4	Riccardo Valentini Leonardo Montagnani Stefano Minerbi Luigi Minach	
Nonantola	Italy	IT5	Francesco Miglietta	Marianna Nardino
Lavarone	Italy	IT-ext	Alessandro Cescatti	Barbara Marcolla
Loobos	The Netherlands	NL1	Eddy Moors	Jan Elbers
Griffin	United Kingdom	UK1	John Moncrieff Paul Jarvis	Robert Clement

2 Data requirements

The input data set needed to run the model described can be divided into three major components:

- Meteorological input data
- Wind statistics
- Terrain information

Concerning detailed information on these data sets, e.g. the format of the terrain matrices or averaging intervals, please refer to the detailed data request document sent to each team in February 2001. This text is also provided on the result CD prepared for each participating research group.

2.1 Meteorological input data set

The dataset provided for the quality assessment should cover at least two months (preferably 3 months), and should be chosen from those months with the highest values of the fluxes in the course of the year. It is important that all wind direction sectors are included, if possible, under different stability conditions. The standard meteorological parameters, which were taken from the EUROFLUX data base, are listed in Table 1.

In order to work with the integral turbulence characteristics (described later on), both the mean values as well as the standard deviation of particular variables are needed. These values have to be calculated for each 30-minute-interval from turbulent raw data. The datasets for which these parameters have to be calculated comprise:

- wind components u, v and w.
- air temperature T_a.
- CO_2- and H_2O-concentrations
- wind direction (calculated from u and v)

Table 1: Required data set from the EUROFLUX data base

variable ID number	variable name	measurement unit	variable description	measurement type	measurement frequency
0	date	none	site and date description ("019701131000")		
1	Fc	μmol m^{-2} s^{-1}	carbon dioxide	Eddy covariance	30 min
2	H	W m^{-2}	sensible heat	Eddy covariance	30 min
3	LE	W m-2	latent heat	Eddy covariance	30 min
4	E	mmol m-2 s-1	water vapour	Eddy covariance	30 min
5	TAU	Kg m-1 s-2	momentum	Eddy covariance	30 min
16	Rn	W m-2	net radiation	sensor	30 min
20	Ta	°C	air temperature	sensor	30 min
21	Pa	Kpa	pressure	sensor	30 min
26	Rh	%	relative humidity	sensor	30 min
27	WD	degrees	Wind direction	sensor	30 min
28	WS	m sec^{-1}	Wind horizontal speed	sensor	30 min

Some these parameters can also be calculated directly from turbulent raw data, if available. Turbulent raw data are also needed to enable a determination of stationarity for the different fluxes. Stationarity is one of the most useful features in the quality assessment of fluxes, so the assignment of flags for the different parameters is much more effective when turbulent raw data is available.

2.2 Wind statistics

In order to assess the general representativeness of the site (see below), or in other words the existence of sheltered or preferred wind sectors, the wind climatology of the specific site is compared to that of a reference station nearby. For this purpose, wind records of as long a period as possible, and a period of at least one year, have to be provided for both stations. Concerning the preparation of these statistics, please refer to the detailed data request document mentioned earlier.

2.3 Terrain information

The terrain information needed within this program has to be provided in the form of discrete matrices with regular grid spacing which cover the area surrounding the flux tower. Altogether, three different matrices are needed to perform our calculations. They contain information on roughness lengths, land use types, and elevation. Each grid element of the size L_R^2 is represented by a single value for each of those parameters.

3 Data quality assessment

The data quality assessment is separated into three parts: analysis of the wind statistics, assignment of quality flags for the flux measurements, and footprint evaluation. While the analysis of the wind statistics is a preliminary evaluation which provides information on the general representativeness of the site, the two other parts provide the input data set which is needed to run the main part of the analysis. This is the source weight synthesis procedure described in detail in part 4 of this text.

3.1 Analysis of the wind statistics

The evaluation of the wind statistics for each station is performed in order to reveal possible influences of the local topography on the wind field. By comparing the local wind statistics with data from a reference station nearby, disturbed wind directions can be identified in advance. If there are preferred or sheltered wind sectors, conditions which will most probably be caused by terrain effects such as slopes, hills, or the orientation of a valley, the statistics of the turbulent flow will also be affected. Thus, this analysis may help in interpreting deviations between modelled and measured integral turbulence characteristics or other quality check features. The statistic procedure and most of the data for the reference stations are taken from the European Wind Altas, TROEN & PETERSEN (1989).

The wind analysis consists of two parts as shown in Figure 1. On the right hand side, two bar charts show the relative frequency in percentages for each 30°-wind-sector of both the local

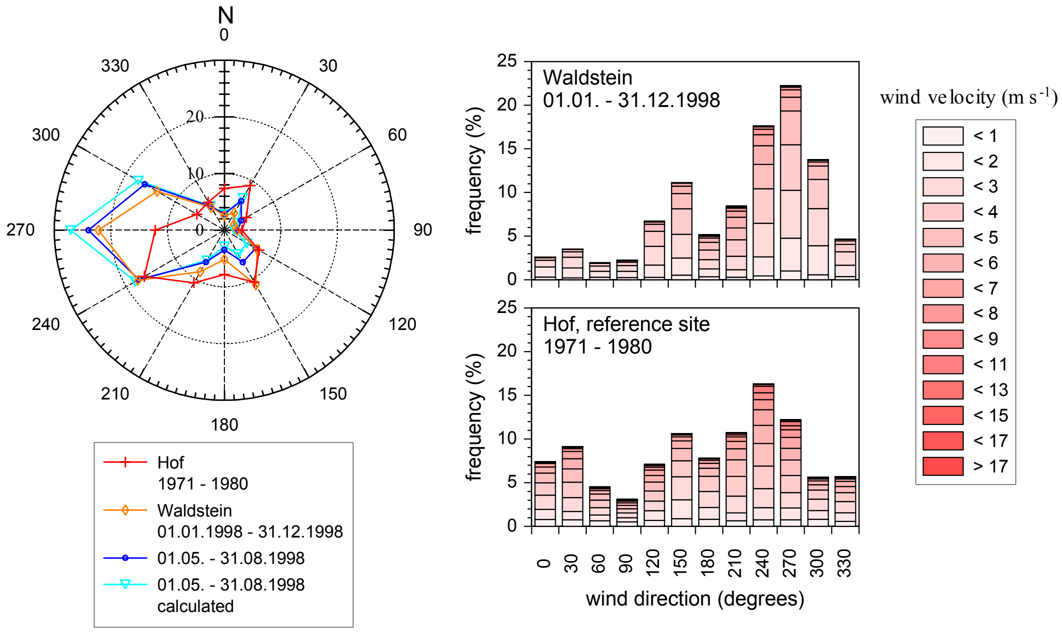

Figure 1: Exemplary wind statistic. Here, the results for the Weidenbrunnen/Waldstein tower with Hof as the reference station is displayed. Please refer to the text for detailed information. Figures are available in colour on the CD enclosed.

measurements and the reference station. Each bar is again separated into several boxes, indicating the contribution of the wind speed classes to the specific frequency. On the left hand side, the total frequency of each sector is displayed in a wind rose for several different cases. As these cases may differ from site to site, generally speaking, a detailed description is not, but will be provided for each site individually. Each graph contains the wind statistics for a measurement site and a reference station, using the same data as shown in the bar charts on the right. In addition, the wind roses from the data sets used for the quality check analysis are plotted. The number of those additional wind roses is different in most cases, dependent on the data set used. If there are too many additional graphs, this information may even be displayed in a graph of its own. The intention here is to take into account that for the observation period used for the quality check assessment, usually two or three months during the summer, the wind statistics may differ from those for the whole year. Furthermore, as some cases cannot be processed by the footprint model (see further below), even this selection may result in a different wind rose and is therefore also plotted (indicated in this example as 'calculated').

3.2 Quality flag assignment for the flux measurements

The quality flag assignment used within this program is based on FOKEN & WICHURA (1996). Their evaluation of flux data quality is based specifically on tests for stationarity and integral turbulence characteristics (ITC). In addition, the vertical wind component and the standard deviation of the wind velocity are taken into account. Each of these features is rated with a flag from 1 (best) to 9 (worst), indicating their accordance with theoretical or modelled 'ideal' values. To compute the overall performance, all of the flags are combined to result in a single classification, again ranging from 1 to 9.

Table 2: Scheme for the assessment of the final quality flags for flux measurements within this study. The original flag values for stationarity and ITC are those proposed by FOKEN & WICHURA (1996), the final flags are modified from their approach.

final flag	stationarity	ITC
1 (best)	< 3	< 3
2	< 3	< 5
3	< 5	< 5
4	< 5	< 7
5 (worst)	> 4	> 6

This scheme has been modified in the context of this quality assessment program. On the one hand, wind direction fluctuations are neglected, while the vertical wind component is evaluated in a separate analysis. On the other hand, some classes of the remaining features, namely stationarity and ITC, are combined so that the differentiation is somewhat rougher, ranging only from 1 to 5 instead of 1 to 9. The scheme for the assessment of the final flags is presented in Table 2. This classification mode can be refined up to the degree of differentiation in the paper by FOKEN & WICHURA (1996), but in this context we decided to reduce the resolution for the sake of a concise visualisation.

Another modification to the basic concept as proposed by FOKEN & WICHURA (1996) concerns the modelled values of the integral turbulence characteristics. In this study, the updated functions by THOMAS & FOKEN (2002) have been used. For the following fluxes, the listed features have been investigated:

- Momentum flux: stationarity tests for $\overline{w'u'}$ and comparison of σ_w / u_* and σ_u / u_* with modelled values.
- Sensible heat flux: stationarity tests for $\overline{w'T'}$ and comparison of σ_w / u_* and σ_T / T_* with modelled values.
- Latent heat flux: stationarity tests for $\overline{w'q'}$ and comparison of σ_w / u_* with modelled values.
- CO_2 flux: stationarity tests for $\overline{w'CO_2'}$ and comparison of σ_w / u_* with modelled values.

For most of the participating stations, two graphs for each of the fluxes have been produced. They display the combined flux data quality assessments as will be described in detail in the following part of the text. One of them, showing the 'quality flags', was computed with both stationarity analysis and ITC comparison, while the other, titled 'stationarity fluxes', makes use of only the results from the stationarity evaluation of the specific flux. This distinction has principally been made because, for the fluxes of sensible and latent heat as well as for CO_2, the development of idealised models for the integral turbulence characteristics is still under development for complex terrain. Thus, the deviations between measured and modelled values for these scalars may be caused by insufficient parameterisations. Where the deviations between quality flags and stationarity flags were small, only one graph was produced.

As previously mentioned, the vertical wind speed w is analysed in a separate evaluation. Flags for this parameter are assigned again according to FOKEN & WICHURA (1996). As proposed by the authors, a threshold of 0.35 $m \cdot s^{-1}$ is chosen to differentiate between valid or rejected measurements, respectively. The accepted values correspond to a quality flag lower than 5.

3.3 Footprint analysis

The footprint routine used in the actual version of the quality assessment software is the FSAM-model proposed by SCHMID (1997). It is integrated into a software termed EXASITE, which has been developed and upgraded within the course of this project. The routine is illustrated in a flow chart in Figure 2.

The program makes use of the following meteorological input data set:

- Date and time of the measurement
- Friction velocity u_* [m/s]
- Air temperature T_a [°C]
- Sensible heat flux Q_H [W/m²]
- Wind direction ϕ [°]
- Obuchov length L [m] (optional)
- Standard deviation of the crosswind velocity σ_v [$m \cdot s^{-1}$] (optional)

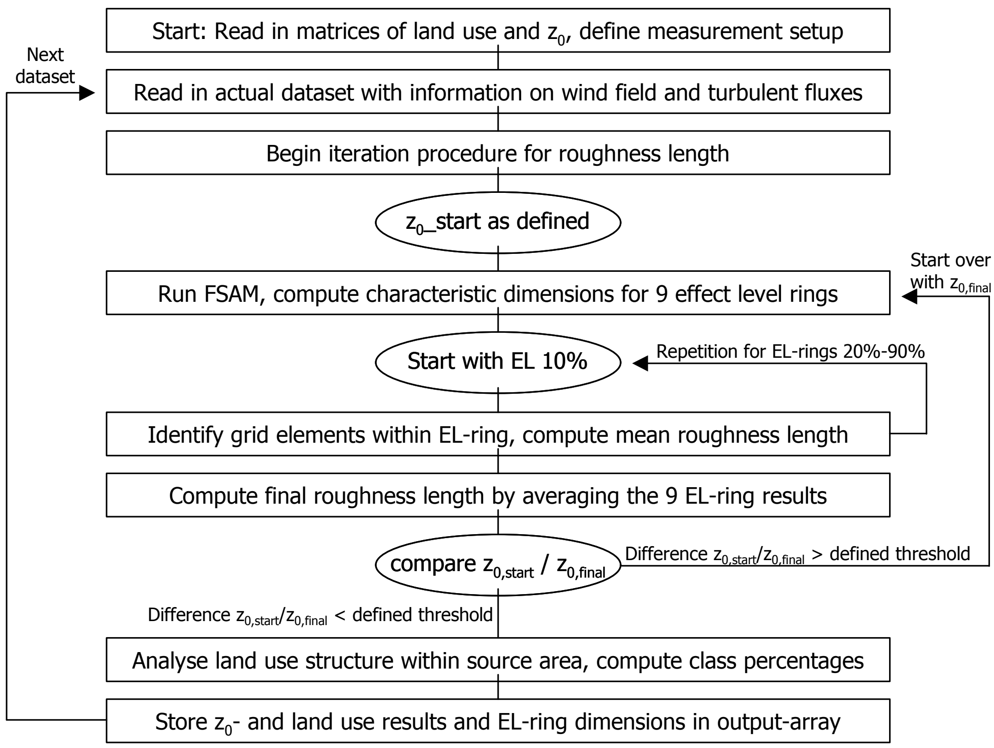

Figure 2: Flow chart of the program EXASITE. For more details please refer to the text.

In addition, required are terrain information about roughness length and land use structure as well as basic information about the measurement setup such as effective measurement height and latitude position of the tower.

EXASITE starts with an input routine which allows the user to define basic information about the measurement setup. Then the terrain information is read in from the input matrices. After the necessary meteorological input parameters, as defined above, are read in, the main iteration loop starts with a footprint calculation employing a user-defined start value for the roughness length z_0. The integrated SCHMID (1997) model produces characteristic dimensions defining the two-dimensional horizontal extension of each so-called effect-level ring. Using these dimensions, which sketch a discrete version of the source weight function, it is possible to assign a weighting factor to each of the cells of the roughness matrix. A schematic description of the result of this process is shown in Figure 3.

A new roughness length $z_{0,final}$ is calculated as the mean value of all the cells within the source area under consideration of the weighting factors. This result is compared with the start value of z_0, which in the first iteration step is the user defined parameter $z_{0,start}$. If the difference between the two values is larger than a fixed threshold, the iteration loop starts again with the improved value of $z_{0,final}$ as the input value for the FSAM routine. If start- and final-roughness lengths differ beneath this certain threshold, the iteration loop is terminated. For the final position of the source area, the standard deviation of the roughness length elements will also be calculated. This parameter may be used to assess the heterogeneity of roughness elements within the footprint.

In the next step, the land use structure within the computed source area will be analysed. The weighting factors of the last source weight function result are used to calculate the contribution of each type of land use (which can be up to 20, as defined by the user) to the total flux. The minimum requirement in the context of the CARBOEUROFLUX study was the differentiation between:

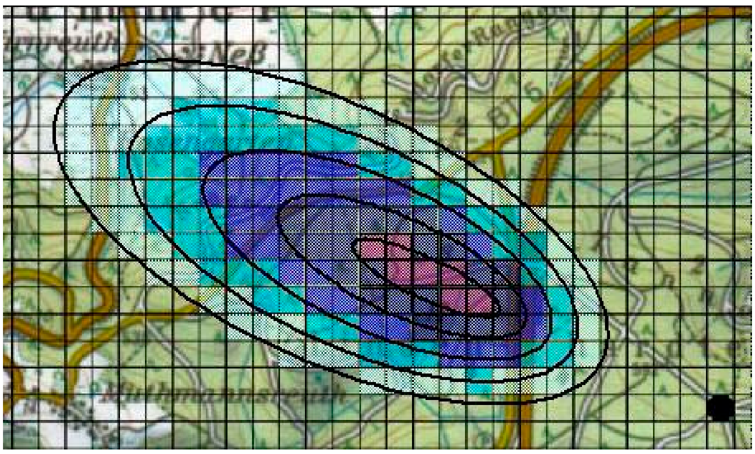

Figure 3: Schematic description of the assignment of weighting factors to different elements of the terrain matrix within EXASITE. The matrix cells within the source area are coloured. Darker colours indicate a higher value for the weighting factor, the black dot indicates the tower position. Figures are available in colour on the CD enclosed.

– Land use class 0: Area of interest
– Land use class 1: Settlement area
– Land use class 2: Other

Here, 'area of interest' indicates the land use type which was intended to be studied at the specific measurement site. For most of the stations within the EUROFLUX cluster, this will be forest.

Due to certain restrictions of the SCHMID (1997) model concerning the necessary input parameters, a portion of the input data set cannot be processed. Most of the time, these problems occur during stable stratification, when the computed source area grows to an extent that makes the numerical algorithms unstable. This effect leads to some selectivity in the input data set, because a considerable number of the night time situations cannot be included in the analysis. In addition, the selection of suitable input data differs from site to site because parameters of the general experimental setup, such as measurement height or mean roughness length, also influence this process. As a consequence, the input data set provided by the cooperating research groups is altered individually, which restricts the comparability of the different stations within this study. The numbers of processed and rejected data sets are analysed in a separate table of statistics which is also provided on the result CD.

To recapitulate, EXASITE produces a dataset with the following information:

– An individual roughness length for each half-hour-measurement.
– Specific contributions of each land use class to the total flux.
– Standard deviation of the land use percentages within the source area for each measurement.
– Characteristic dimensions of the different effect level boundaries of the source area for each measurement.

4 Source weight synthesis of quality assessment results

To produce the overall performance of the flux data quality for a specific site, the results of all the footprint calculations from EXASITE are combined with the data quality assessment that is described in part 3.2 of this text. This process is termed 'source weight synthesis' because the products of the procedure are two-dimensional matrices and graphs which form a combination of all the footprint analyses for the specific site. These matrices show, for example, the dominating data quality class for each of the grid cells of the matrix surrounding the tower, in combination with its contribution to the total flux. The software for this purpose, which was produced in the course of this quality assessment approach, is termed TERRAFEX. The data flow of the principal routines of this program is illustrated in Figure 4.

TERRAFEX produces as its main output data base with one line for each of the matrix cells (for most of the sites within the CARBOEUROPE-cluster, there are between 800 and 1200 cells) with about 230 columns. The columns contain summed up weighting factors as well as the numbers of measurements for each flux, quality feature, and stratification regime. This evaluation procedure will be explained in more detail later on. The quality features investigated are:

- Momentum flux
- Sensible heat flux
- Latent heat flux
- CO_2-flux
- Vertical wind speed
- Percentage of the land use type of interest within the source area

TERRAFEX starts with some input routines allowing the user to define site specific information and parameter limits which designate the dataset to be used for the analysis. A possible parameter limit might be that only data sets with quality flags for the sensible heat flux between 1 and 3 are used. Meteorological input parameters can also be restricted to a certain range, e.g. a friction velocity between 0.25 and 0.4 $m \cdot s^{-1}$ or a wind direction between 180 and 270 degrees. The limit restrictions and the sequence mode, displayed in the following flow chart, are not used within the context of the CARBOEUROPE quality assessment program because in this context all

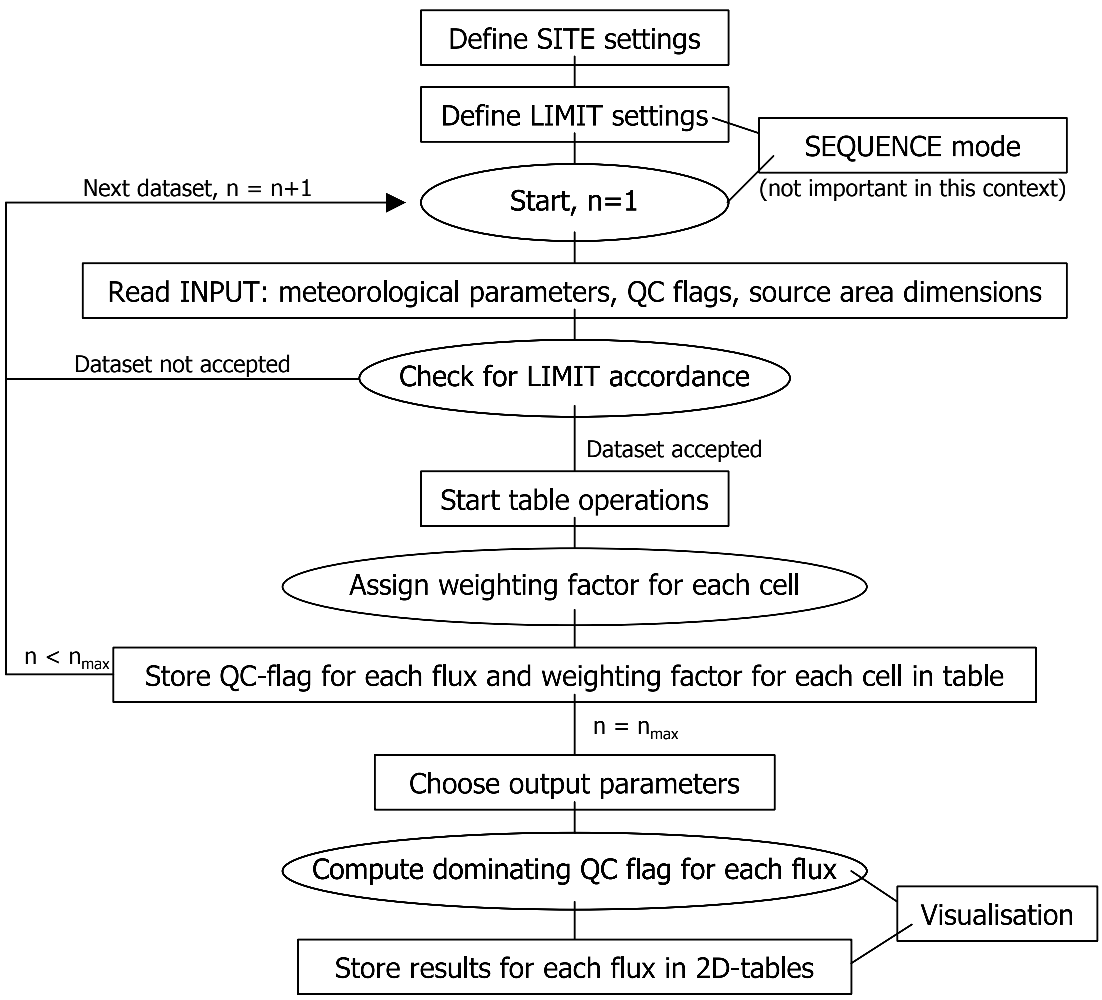

Figure 4: Flow chart of the program TERRAFEX. For more details please refer to the text.

the available data sets are used for the analysis. For more details concerning these features, please refer to the TERRAFEX program description.

Starting with the first data set (n=1), the input data is read in and checked for accordance with the user defined limits. If accepted, the data is further used for the so called table operations. This expression refers to the central results table which has already been mentioned above. To each cell of the matrix, a weighting factor will be assigned according to the characteristic dimensions of the source weight function read from the EXASITE results. These weighting factors are stored in the table, with the line chosen for the specific matrix cell number, and the column selected with respect to [1] stratification regime (e.g. neutral stratification), [3] quality check feature (e.g. momentum flux), and [3] quality check class (e.g. QC 2). If one of the matrix cells is within the source area of several data sets under the same conditions regarding stratification and QC class (which is the case for most parts of the matrix), the weighting factors of all data sets are summed up and the total number of cases is stored. For more details, please refer again to the TERRAFEX program description.

After processing all the data sets up to $n=n_{max}$, for each of the matrix cells and each of the quality check features under different stratification regimes, the central result table contains the distribution of summed up weighting factors for each quality class. Using this data, the overall performance for each distribution is determined by computing the median. After this, for a selection of output features as defined by the user, a two-dimensional array is produced containing the overall QC-result for the specific quality feature of each matrix cell. This array can also be visualised within the Program.

In conclusion, the products of TERRAFEX are as follows:

- For each of the quality check features listed above, the dominant quality check class for each cell, defined by the median of the QC-class distribution, will be produced as a two-dimensional array.
- The weighting factors of the complete data set will be summed up in order to calculate the contribution of each cell to the total flux.
- All results can be computed for different stratification regimes.
- Using the limit settings, the user can constrict the analysis to certain quality classes or a range of values for specific meteorological parameters, allowing a more detailed analysis under special conditions. The variation of these input parameters can also be performed automatically in a sequence mode with user defined upper and lower limits at specific increments.

Exemplary graphs of TERRAFEX results are shown in part 7 of the text.

5 Exemplary results for the Waldstein/Weidenbrunnen site

This part of the text refers to the file, 'GE3_present.pdf' which is stored on the CD enclosed. It was originally prepared for the QA/QC-Workshop in Thurnau, Nov. 15 – 17, 2002.

The methods used have been described in detail in the preceding parts of this document. The same procedure, shown here as an example for the Waldstein / Weidenbrunnen site, was applied on 17 sites participating in the CARBOEUROFLUX project, as listed in the table in part 1.3 of this text.

All the flux measurement sites which were investigated in the course of this project have been analysed in the same way. Differences between the investigations only arise from the different land use types and grid size of the investigated areas. Some groups could not provide the standard deviation of the crosswind component, σ_v. For these, σ_v was parameterised according to THOMAS & FOKEN (2002). A comparison of such modelled values of σ_v and measured values yields a mean slope of 1.02 (r^2=0.76) over all sites investigated. Some groups were able to provide raw data for the entire data set, so that σ_v could also be determined and quality tests could be performed according to FOKEN & WICHURA (1996).

A typical feature of the footprint analysis according to SCHMID (1997) is that cases under strongly stable conditions cannot be calculated. This results in a possible underestimation of stable stratification conditions (only about 20 % of all stable cases could be taken into account).

Annex A contains a list with general descriptions of the figures from the file, 'GE3_present.pdf'. These are discussed in the following parts of the text.

5.1 General Features

From the investigated period (May 1 – Aug 31, 1998), 5417 half-hour data sets were available for the footprint calculations. Quality checks could be carried out for the complete data set.

For 4155 (77 %) data sets, footprint calculations could be performed. Of these, 40 % are unstable cases, 43 % are neutral cases, and 17 % are stable cases.

From the frequency distribution of the friction velocity u_* (fig. 12, p. 17), it can be seen that stable cases and cases with low values of u_* are rare in the footprint analysis, as also mentioned above. These findings are consistent with the fact that fluxes with low turbulence conditions are usually rejected.

5.2 Wind statistics

The wind pattern for the Waldstein / Weidenbrunnen site has a wind regime similar to the reference site Hof (fig. 2, right graph, p. 2), but with a pronounced maximum of the wind direction to the west. Easterly winds are shifted to south-south-eastern directions, as a result of a canalisation by the valley in this direction. The data set reduced by the footprint model (see light blue line in the left graph) has an even more enhanced maximum in the west and fewer frequencies in south-eastern directions.

5.3 Land use classification

As a result of the relatively homogeneous landscape (see figs. 3a and 3b, pp. 3 and 4), in 86 % of all cases, the area of interest (AOI) contributes with more than 80 % to the measured fluxes; in 50 % of all cases, 100 % of the flux contribution originates from the area of interest (see figs.

4a and 5, pp. 5 and 6). The sectors with non-forest land use, found west of the tower, have a high flux contribution and contribute to the flux from western directions, with less than 80 % coming from the area of interest, even though these sectors are quite small. The sector from north to east primarily has flux contributions of 100 % from the area of interest, but low flux contribution.

5.4 Quality assessment

Momentum flux τ: All grid cells in the investigated area around the tower are flagged 1 (best), besides a sector more than about 1 km away from the tower to the east, which has a quite low flux contribution. This level of quality is caused by the integral turbulence characteristic (ITC) of the horizontal wind component u, as can be seen by comparing figures 6a and 6b (pp. 7 and 8). All in all, the data set has a high data quality for the momentum flux, with 91 % of all investigated cases flagged 1 and 2 (figs. 11a and 11b, pp. 15 and 16).

Sensible heat flux H: As for all sites, the quality of the sensible heat flux seems to be very low. This level of quality is caused by the integral turbulence characteristic of the temperature, as can be seen by comparing figures 6a, 7a and 7b (pp. 7, 9 and 10). With regard to both stationarity and integral turbulence characteristics, only the first 100 m nearest to the tower are of good quality (fig. 7a). The reason for this is that the parameterisations of the ITC(T) above high vegetation are not yet developed for neutral and stable stratification. Stationarity per se (fig. 7b, p. 10) shows a high data quality in all directions. Only 13 % of all cases are of quality 3 to 5 (fig. 11b, p. 16).

Latent heat flux λE: There are two sectors north and west of the tower which while of intermediate quality, still have high flux contribution. Most of the classification is related to instationarities (fig. 8a, p. 12, fig. 8b not shown because of redundancy), with 41 % of all data flagged 3 to 5 (figs. 11a and 11b, pp. 15 and 16). The uncertainty of these data can probably be related to the measurement system. Higher air humidities under weather conditions from western and northern wind directions cause problems with the measurement of water vapour fluxes using the closed path system used (LI6262).

Carbon dioxide flux F_{CO2}: All grid cells in the area investigated around the tower are flagged 1 (fig. 9a, p. 13), with only 11 % of all data are flagged 3 to 5 (figs. 11a and 11b).

5.5 Vertical wind w

As can be seen from Figures 10a and 10b (pp. 13 and 14) the vertical wind is negatively influenced by the topography south-east of the tower, which still has quite a high flux contribution. These grid cells contribute to an absolute w_{mean} of more than 0.35 ms^{-1} with a frequency of up to 18 %. This fact can be attributed to the slope in this south-east direction. For 109 (3 %) out of 4155 investigated data sets, the absolute value of the vertical wind component is above 0.35 ms^{-1}.

6 Conclusion

In conclusion, Figure 5 presents an overview of the input datasets needed within this program, the way these are fed into the software included with the process of flux data quality assessment, and the structure of data flow between the software components.

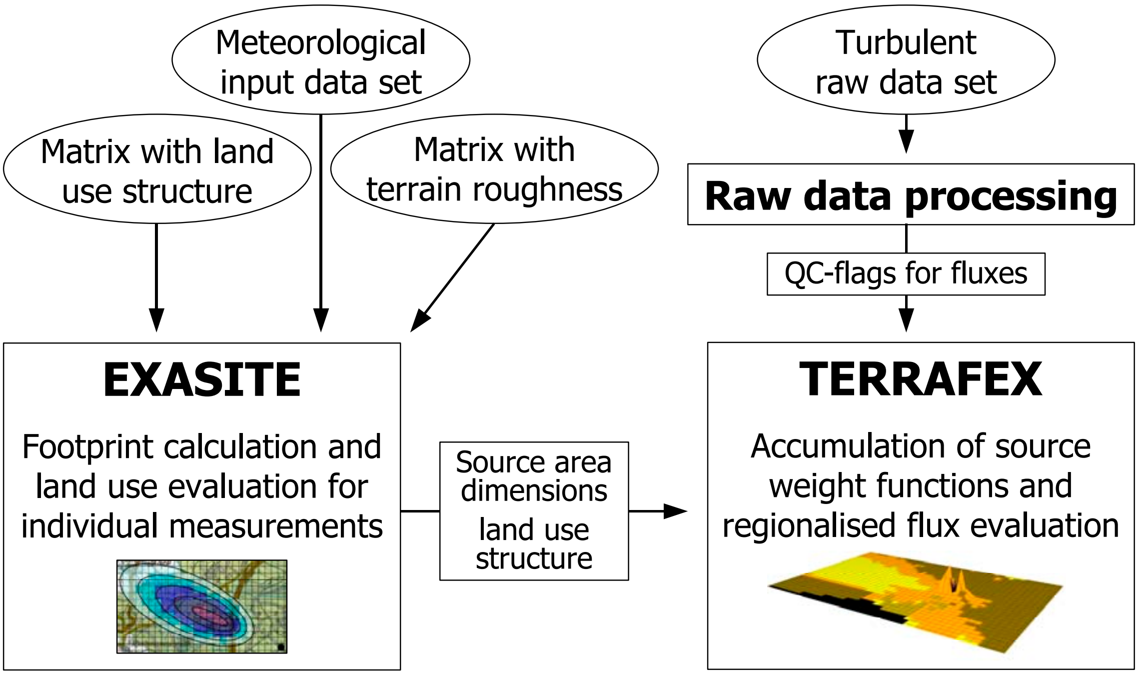

Figure 5: Overview of the main input data sets needed for the quality assessment and of the linkages among the major software tools used within this approach. Figures are available in colour on the CD enclosed.

Figures 6 and 7 show the exemplary results of the quality assessment program, computed with data from the Weidenbrunnen/Waldstein tower. These graphs are also included in the file 'GE3_present.pdf' as discussed in part 5 of the text. In these two graphs, the area surrounding the flux tower (indicated by a blue bar) is separated into discrete cells in accordance with the input matrices of roughness length and land use structure. The colours of the cells indicate the overall result of the data quality assessment. The examples show quality flags (stationarity and integral turbulence characteristics)for latent heat flux in Figure 6 and land use evaluation in Figure 7. The topography in both graphs indicates the relative contribution of each cell to the total flux, normalised with the maximum flux contribution (thus ranging from 0 to 1).

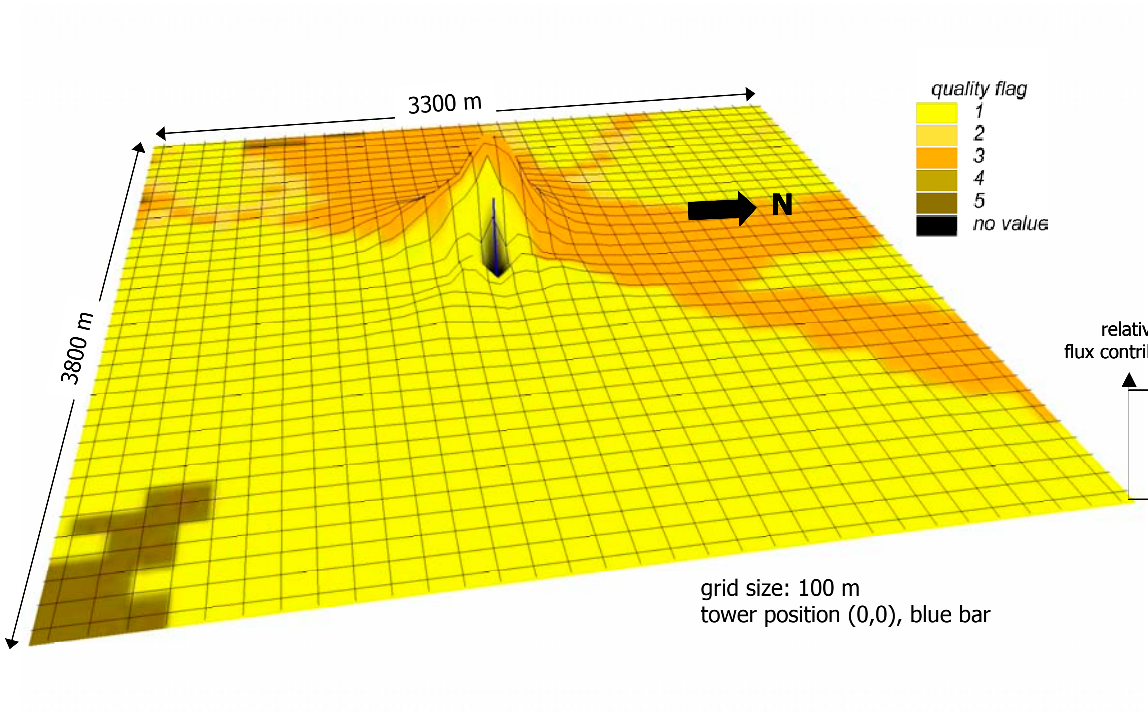

Figure 6: Quality flags for the latent heat flux λE with flux contribution. Results were obtained with data from the Weidenbrunnen/Waldstein site for the period 01.05. – 31.08.1998. Figures are available in colour on the CD enclosed.

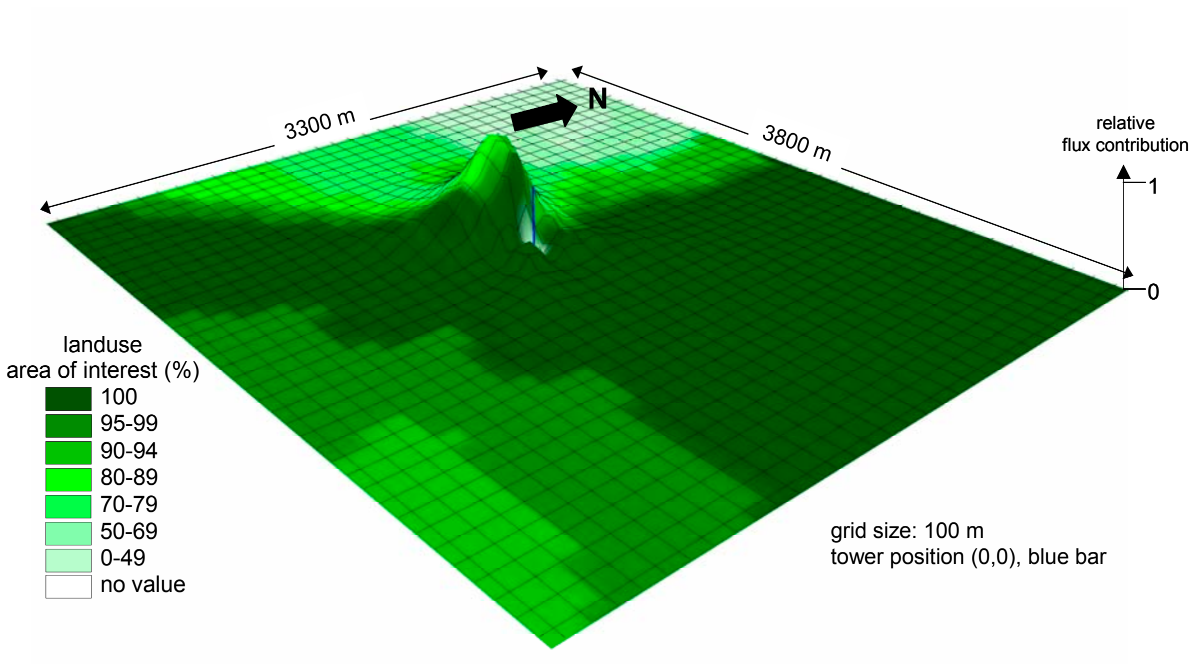

Figure 7: Quality flags for the land use evaluation with flux contribution. Results were obtained with data from the Weidenbrunnen/Waldstein site for the period 01.05. – 31.08.1998. Figures are available in colour on the CD enclosed.

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Annex A: List of figures in 'GE3_present.pdf'

	flux contribution
9a (p. 12)	Aerial representation of quality flags for carbon dioxide flux F_{CO2} with flux contribution
10a (p. 13)	Aerial representation of quality flags for vertical wind component w with flux contribution
10b (p. 14)	Aerial representation of quality flags for vertical wind component w with topography
11a (p. 15)	Bar diagrams with frequency distribution of quality flags (stationarity and integral turbulence characteristics) for the different fluxes
11b (p. 16)	Bar diagrams with frequency distribution of quality flags (only stationarity) for the different fluxes
12 (p. 17)	Bar diagrams with frequency distribution of friction velocity Left graph: for the complete data set provided, right graph: for the reduced data set

Annex B: Previous publications of `Universität Bayreuth, Abt. Mikrometeorologie, Arbeitsergebnisse´

Nr	Name	Titel	Datum
01	Foken	Der Bayreuther Turbulenzknecht	01/99
02	Foken	Methode zur Bestimmung der trockenen Deposition von Bor	02/99
03	Liu	Error analysis of the modified Bowen ratio method	02/99
04	Foken et al.	Nachtfrostgefährdung des ÖBG	03/99
05	Hierteis	Dokumentation des Expertimentes Dlouha Louka	03/99
06	Mangold	Dokumentation des Experiments am Standort Weidenbrunnen, Juli/August 1998	07/99
07	Heinz, Handorf, Foken	Strukturanalyse der atmosphärischen Turbulenz mittels Wavelet-Verfahren zur Bestimmung von Austauschprozessen über dem antarktischen Schelfeis	07/99
08	Foken	Comparison of the sonic anemometer Young	10/99

		Model 81000 during VOITEX-99	
09	Foken et al.	Lufthygienisch-Bioklimatische Kennzeichnung des oberen Egertales, Zwischenbericht 1999	11/99
10	Sodemann	Stationsdatenbank zum BStMLU-Projekt Lufthygienisch-Bioklimatische Kennzeichnung des oberen Egertales	03/00
11	Neuner	Dokumentation zur Erstellung der meteorologischen Eingabedateien für das Modell BEKLIMA	10/00
12	Foken et al.	Dokumentation des Experimentes VOITEX-99	12/00
13	Bruckmeier et al.	Documentation of the experiment EBEX-2000, July 20 to August 24, 2000	01/01
14	Foken et al.	Lufthygienisch-Bioklimatische Kennzeichnung des oberen Egertales	02/01
15	Göckede	Die Verwendung des footprint-Modells nach SCHMID (1997) zur stabilitätsabhängigen Bestimmung der Rauhigkeitslänge	03/01
16	Neuner	Berechnung der Evapotranspiration im ÖBG (Universität Bayreuth) mit dem SVAT-Modell BEKLIMA	05/01
17	Sodemann	Dokumentation der Software zur Bearbeitung der FINTUREX-Daten	08/02
18	Göckede et al.	Dokumentation des Experiments STINHO-1	08/02
19	Göckede et al.	Dokumentation des Experiments STINHO-2	12/02
20	Göckede et al.	Characterisation of a complex measuring site for flux measurements	12/02